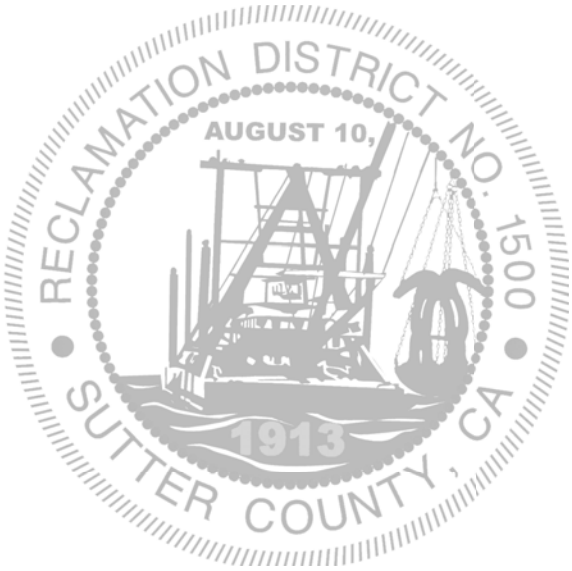
Reclamation District No. 1500 Groundwater Management Plan

In Association with Sutter Mutual Water Co.
and Pelger Mutual Water Co.
(Collectively the Sutter Basin Partners)



Final

February 2012

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Final

Reclamation District No. 1500 Groundwater Management Plan

In Association with Sutter Mutual Water Company and Pelger Mutual Water Company (Collectively the Sutter Basin Partners)

Prepared for

Reclamation District No. 1500
15094 Cranmore Rd.
PO Box 128
Robbins, CA 95676

Updated February 2012

CH2MHILL

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Acronyms and Abbreviations

°F	degrees Fahrenheit
Bay-Delta	San Francisco Bay/Sacramento-San Joaquin Estuary
bgs	below ground surface
CASGEM	California Statewide Groundwater Elevation Monitoring
cfs	cubic feet per second
CVP	Central Valley Project
District	Reclamation District No. 1500
DWR	California Department of Water Resources
DWR Sutter Subbasin	Sutter Subbasin number 5-21.62 of the Sacramento Valley Groundwater Basin, as defined by California Department of Water Resources (see Appendix E)
GMP	groundwater management plan
gpm	gallons per minute
GPS	global positioning system
M&I	municipal and industrial
mg/L	milligrams per liter
PMWC	Pelger Mutual Water Company
RD 1500	Reclamation District No. 1500
Reclamation	Bureau of Reclamation
SACFEM	Sacramento Valley Finite-Element Groundwater Model
SB 1938	Senate Bill 1938
SMWC	Sutter Mutual Water Company
Sutter Basin	The area generally bounded by the Tisdale Bypass, Sutter Bypass, and Sacramento River comprising the area of RD 1500 (see Figure 1-1)
Sutter Basin Partners	Sutter Basin Water Management Partners (RD 1500, SMWC, and PMWC)
SVWMA	Sacramento Valley Water Management Agreement
SVGB	Sacramento Valley Groundwater Basin

TDS	total dissolved solids
USGS	U.S. Geological Survey
Water Code	California Water Code
WQCP	water quality control plan

SECTION 1

Introduction

The Sutter Basin is located in the southern portion of Sacramento Valley in California (see Figure 1-1; figures are located at the end of their respective section) on the east side of the Sacramento River. Surface water is the primary irrigation water supply in Sutter Basin. Water use within Sutter Basin is influenced by water rights contracts, year type (that is, wet versus dry), cropping, and the condition of and access to existing infrastructure. To meet the needs of water users within Sutter Basin for shared agricultural and environmental interests, drainwater reuse and supplemental groundwater supply are utilized. Reclamation District No. 1500 (RD 1500 or District), Sutter Mutual Water Company (SMWC), and Pelger Mutual Water Company (PMWC) compose the Sutter Basin Water Management Partners (Sutter Basin Partners) (see Figure 1-2). The partnership was formed to collaboratively plan and manage the shared water resources of Sutter Basin when appropriate. This groundwater management plan (GMP) update describes Sutter Basin's water resources and how the Sutter Basin Partners intend to manage the groundwater resource as part of sustainable conjunctive water management. At this time, SMWC does not pump groundwater, and PMWC pumps limited quantities of groundwater to augment surface water supplies only. Private land owners outside the companies' boundaries use groundwater for irrigation to supplement surface water supplies.

This GMP update was funded by the California Department of Water Resources (DWR) through the Northern California Joint Exercise of Powers Proposition 50 Integrated Regional Water Management Implementation Grant. The local sponsor for this work is SMWC in cooperation with RD 1500, and fellow local water purveyor, PMWC.

1.1 Goal

This GMP supports effective and sustainable groundwater management, consistent with Sutter Basin Partner's mission, which includes delivering cost-effective, quality irrigation water for sustainable agricultural production and environmental benefit.

Section 4 presents the following groundwater management objectives and strategies for achieving these objectives:

- Maintain Sutter Basin long-term agricultural viability
- Promote resource sustainability
- Increase long-term water supply reliability
- Promote cooperative regional outreach and regulatory compatibility

1.2 Authority

In 1997, the Sutter Basin Partners announced their collective intention to work cooperatively to explore the potential for jointly managing groundwater as a viable water resource in Sutter Basin. In 2010, SMWC received grant funding from DWR through Proposition 50 to

work with RD 1500, Sutter Basin's groundwater planning and monitoring entity, and PMWC to update RD 1500's 1997 GMP (see Appendix A).

Adoption procedures for and substantive components of a GMP are outlined in Section 10750 et seq., of the California Water Code (Water Code), also known as Assembly Bill 3030. In 2002, Senate Bill 1938 (SB 1938) amended this section of the Water Code, making formalized and effective groundwater management a requirement for any agency seeking state funding.

Adoption of the SB-1938-compliant GMP adhered to the following required processes:

- Publish a Notice of Public Hearing
- Conduct a public hearing to discuss RD 1500's intention to develop a GMP
- Adopt a Resolution of Intent (see Appendix B)
- Prepare a GMP with interested parties
- Publish a second Notice of Public Hearing
- Conduct a second public hearing to discuss RD 1500's adoption of the GMP
- Given no majority opposition, pass a Resolution to Adopt the GMP (see Appendix B)

1.3 Components

DWR generally recommends the inclusion of 14 components to formulate an effective and comprehensive GMP. These components are described in DWR's Bulletin 118 – Update 2003 (DWR, 2003a) and in the DWR's brochure, *Water Facts, No. 10: Components of a Groundwater Management Plan* (DWR, 2003b). The Water Code and Chapter 3 of the DWR's Bulletin 118 – Update 2003 specifically classify GMP components into two categories: required and recommended. Table 1-1 summarizes DWR's criteria for an SB 1938-compliant GMP.

This GMP is a basin-specific plan that can be updated and modified as additional groundwater information becomes available and as conjunctive use management evolves. Table 1-1 summarizes the components included in this GMP update.

TABLE 1-1
Assembly Bill 3030 Groundwater Management Plan Components
Reclamation District No. 1500 and Sutter Basin Partners Groundwater Management Plan

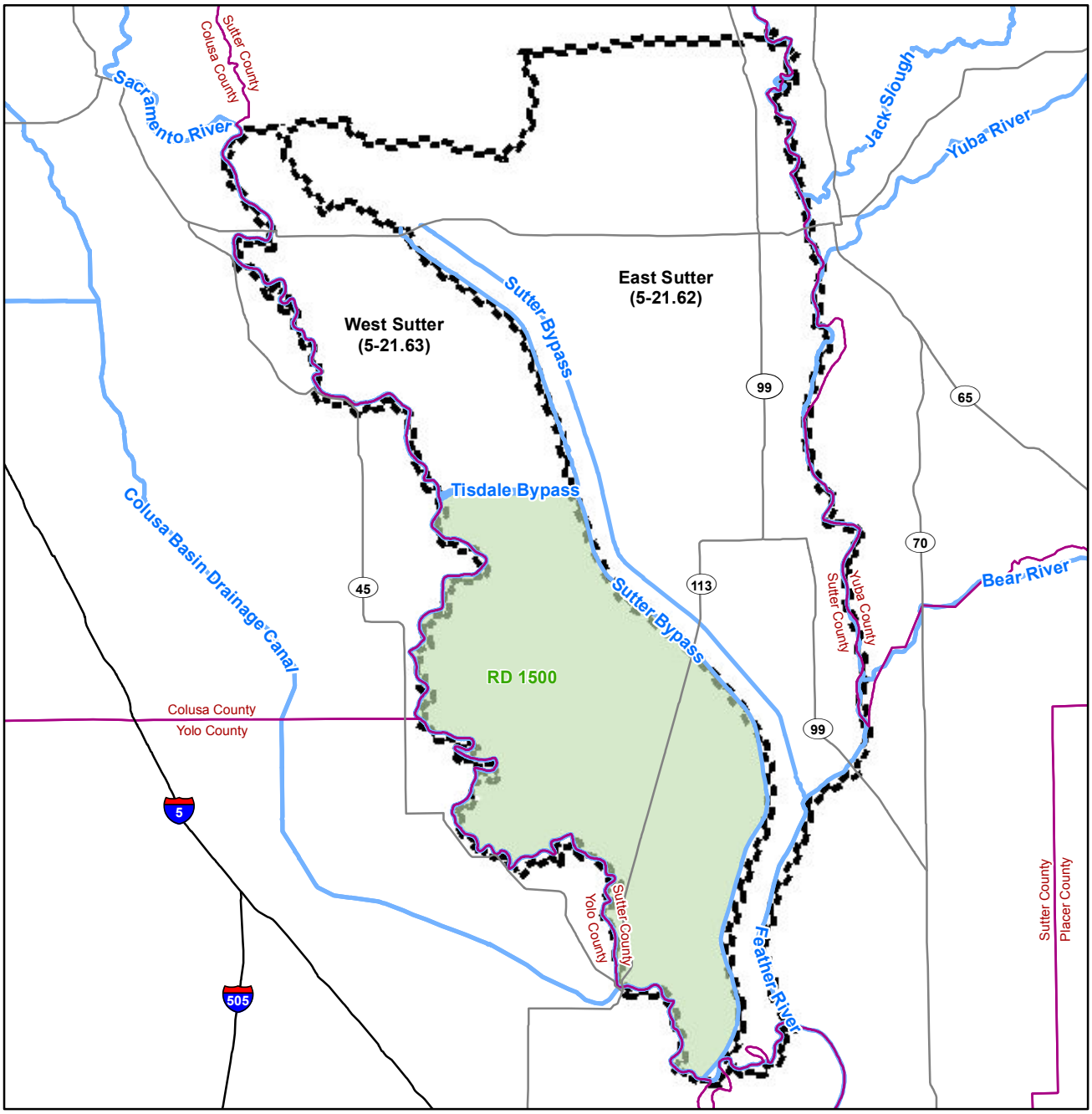
Water Code Section 10750 et seq., Required Components		
Requirement	**Sutter Basin Partners Action**	**Section**
Provide documentation that a written statement was provided to the public (Water Code section 10753.4(b)).	Notices were posted in advance of public hearings and a Resolution of Intent was passed at the first public hearing on March 29, 2011, after public comments. The Resolution of Intent is provided in Appendix B.	Table 1-1; Appendix B
Establish management objectives for the groundwater basin that are subject to the GMP (Water Code section 10753.7(a)(1)).	Establish foundational management objectives that can be built upon when or if a conjunctive water management program is developed by the Sutter Basin Partners.	Section 3

TABLE 1-1
Assembly Bill 3030 Groundwater Management Plan Components
Reclamation District No. 1500 and Sutter Basin Partners Groundwater Management Plan

Monitoring Plan: Include components relating to monitoring and managing groundwater levels, groundwater quality, inelastic land surface subsidence, and changes in surface flow and surface water quality that directly affect groundwater levels or quality, or are caused by groundwater pumping (Water Code section 10753.7(a)(1)).	Groundwater infrastructure is described in Sections 2 and 3. The monitoring plan compliant with RD 1500's California Statewide Groundwater Elevation Monitoring (CASGEM) participation is provided in Appendix C.	Sections 2 and 3; Appendix C
Include a plan by the managing entity to "involve other agencies that enable the local agency to work cooperatively with other public entities whose service area or boundary overlies the groundwater basin" (Water Code section 10753.7(a)(2)).	The very nature of water resources planning in Sutter Basin is cooperative through the Sutter Basin Partnership. Furthermore, the Sutter Basin Partners have developed an outreach program complete with quarterly newsletters, Web site, and landowner surveys (summarized in Appendix D). Representatives from the Sutter Basin Partnership entities attend Sutter County groundwater planning meetings.	Sections 1 and 3; Appendix D
Adopt monitoring protocols.	RD 1500 coordinates monitoring with DWR through CASGEM, using a network of privately owned groundwater wells.	Sections 2 and 3; Appendix C
Provide a map of the groundwater basin as defined by Bulletin 118 – Update 2003 (Water Code section 10753.7(a)(3)) (DWR, 2003a).	A map is provided in the GMP. Note that RD 1500's purview is only a limited portion of Sutter Basin as defined by Bulletin 118 – Update 2003 (DWR, 2003a).	Figure 1-1; Appendix E
Use appropriate geologic and hydrogeologic principles within the GMP. The Sutter Basin Partners worked with DWR, North Central Region in developing this GMP update.	The GMP was reviewed by professional geologists who are familiar with local geology and hydrogeology. Furthermore, generally agreed-upon regional principles for groundwater management were included.	Section 2
Water Code Section 10750 et seq., Voluntary Components		
Voluntary Components	**Sutter Basin Partners Action**	**GMP Section**
Administer a well abandonment and well destruction program.	Defer to Sutter County on this element.	
Mitigate conditions of overdraft.	The RD 1500 portion of Sutter Basin is not in overdraft. Groundwater use within Sutter Basin is minimal. RD 1500 will work with DWR to monitor groundwater elevations through the CASGEM program. If a formalized surface water/ groundwater conjunctive use program is developed by Sutter Basin purveyors, a mitigation plan would be developed accordingly.	

TABLE 1-1
Assembly Bill 3030 Groundwater Management Plan Components
Reclamation District No. 1500 and Sutter Basin Partners Groundwater Management Plan

Monitor groundwater levels and storage.	Refer to RD 1500's CASGEM Groundwater Elevation Monitoring Plan (Appendix C) and DWR monitoring activities and regional activities (Sacramento Valley Water Management Agreement [SVWMA]).	Appendix C
Facilitate conjunctive use operations.	To be developed under the operating plans for regional programs (for example, SVWMA) and individual water purveyor programs.	
Identify well-construction policies.	A preliminary design for future groundwater production wells is available at the District, and defers to DWR standards when appropriate.	Section 3
Develop relationships with state and federal regulatory agencies.	The Sutter Basin Partners are active participants in regional programs working in partnership with numerous state and federal regulatory agencies, including DWR, Sutter County, and Reclamation.	Sections 1 and 3
DWR Bulletin 118 – Update 2003 Recommended Components		
Recommended Components	**Sutter Basin Partners Action**	**GMP Section**
Describe area to be managed under the GMP.	The GMP describes and graphically illustrates the groundwater program area.	Section 2
Describe the local groundwater monitoring program.	The GMP describes the groundwater monitoring program, by way of the CASGEM Groundwater Elevation Monitoring Plan.	Appendix C
Describe integrated water management planning efforts.	RD 1500 participates in integrated management activities on a local basin level and a statewide level (described in the GMP).	Sections 1 and 3
Report on implementation of the GMP.	The GMP presents RD 1500's reporting method.	Section 3
Periodically re-evaluate the GMP by the managing entity.	The GMP presents RD 1500's intentions for periodic re-evaluations.	Section 3



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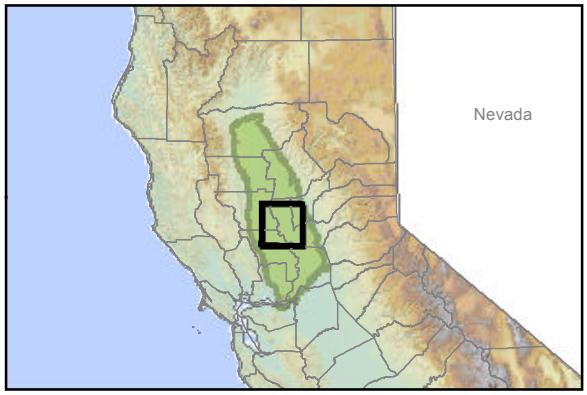

LEGEND

- DWR Sutter Subbasin (5-21)
- Reclamation District No. 1500
- Sacramento Valley Groundwater Basin

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FIGURE 1-1
Sutter Basin Location Map
RD 1500 and Sutter Basin Partners
Groundwater Management Plan
Sutter County, California

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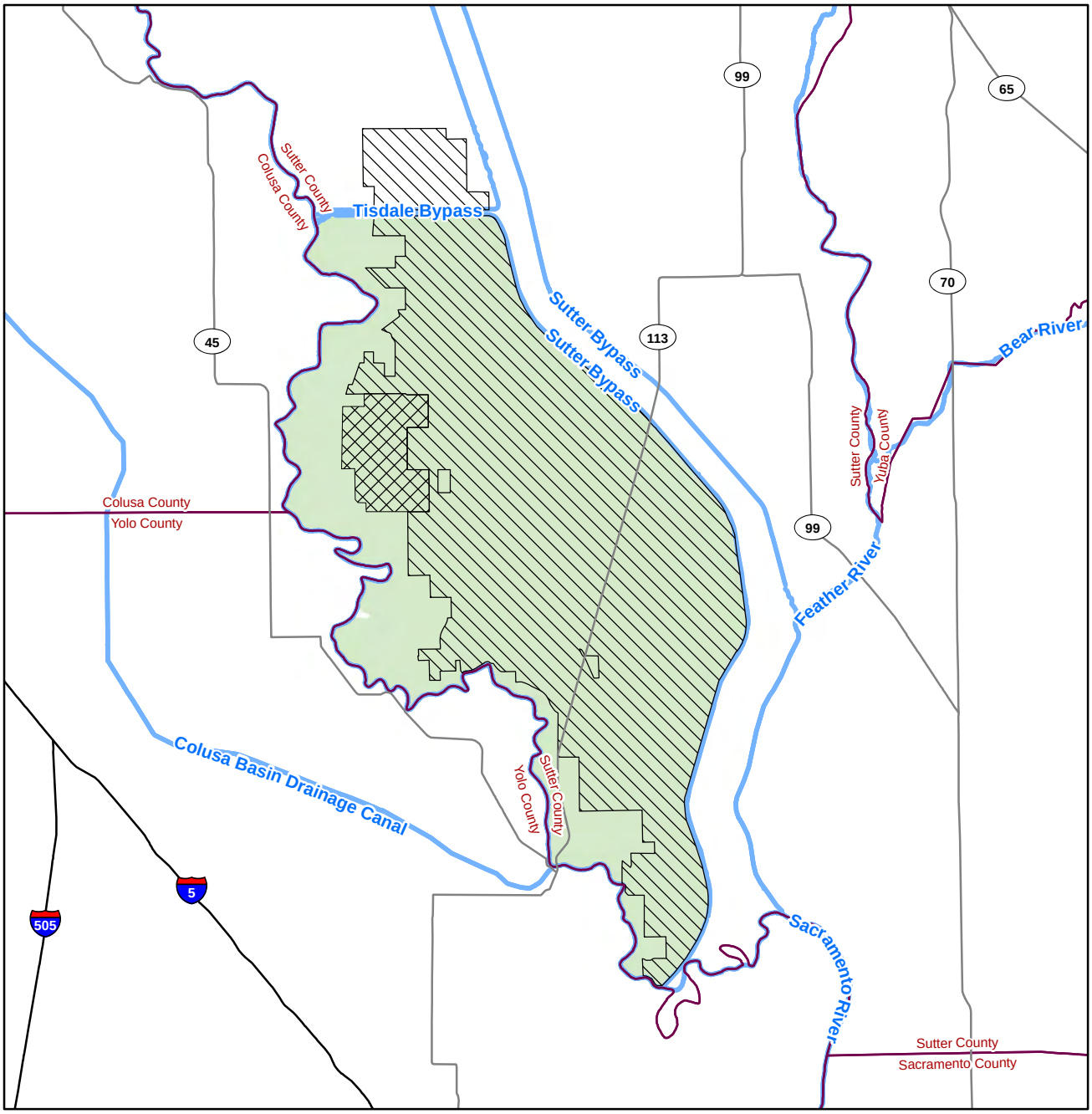

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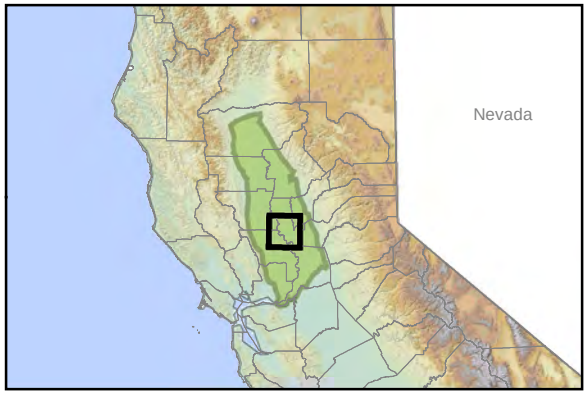

LEGEND

- Reclamation District No. 1500
- Pelger Mutual Water Company
- Sutter Mutual Water Company
- Sacramento Valley Groundwater Basin

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FIGURE 1-2
Sutter Basin Partners Location Map
RD 1500 and Sutter Basin Partners
Groundwater Management Plan
Sutter County, California

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SECTION 2

Sutter Basin

2.1 Background

RD 1500 was formed by a special act of the California State Legislature in 1913, to provide drainage and reclamation of lands within its boundaries. The District is in Sutter County, approximately 45 miles northwest of Sacramento, California. The District is confined by surface water features and engineered channels (Sacramento River, Tisdale Bypass, and Sutter Bypass). The RD 1500 service area encompasses nearly 68,000 acres. Levees were constructed to reduce flooding. Drainwater channels were constructed to convey drainwater so that crops could be grown, and the first pumping plant was completed in 1914, to convey drainwater out of Sutter Basin. The original pumping plant still stands today and operates during emergency flood control conditions.

SMWC is also located within Sutter Basin, approximately 45 miles northwest of Sacramento, California. SMWC was formed in 1919, encompasses approximately 50,000 acres, and serves 150 landowners. SMWC boundaries encompass the town of Robbins. SMWC operates four pumping plants at three locations: Tisdale Pumping Plant (960-cubic-foot-per-second [cfs] capacity), State Ranch Bend Pumping Plant (150 cfs), and Portuguese Bend Pumping Plant (106 cfs). SMWC also has nine surface water reuse pump sites and three portable booster pumps with a total combined capacity of approximately 290 cfs. SMWC does not provide water service for municipal and industrial (M&I) use.

PMWC is also located within Sutter Basin and uses surface water from the Sacramento River via one pumping facility, the Pelger Pump Station, located on the Sacramento River at River Mile 111.72. PMWC was formed in March 1965, and executed a water rights settlement contract with the United States in May 1965. PMWC is a long-term Sacramento River Settlement Contractor with Bureau of Reclamation (Reclamation). In 2005, PMWC renewed its long-term contract with Reclamation, which authorizes the continued annual delivery of 8,860 acre-feet until March 31, 2045. PMWC also relies on drainwater for a secondary source of water supply, with diversions from RD 1500 drains. Approximately three privately owned wells within PMWC boundaries are used to supplement surface water supplies to meet irrigation needs. PMWC does not provide water service for M&I use.

2.2 Planning Efforts and Work to Date

In 1997, the Sutter Basin Partners announced their collective commitment to work cooperatively to explore and potentially manage groundwater as a viable water resource in Sutter Basin. RD 1500's 1997 GMP was a first step toward managing Sutter Basin's groundwater resources in a cooperative and thoughtful way. A copy of RD 1500's 1997 GMP is provided in Appendix A.

2.2.1 Local and County Planning

RD 1500, SMWC, and PMWC developed the Sutter Basin Partnership to collaboratively plan for the wise management of the shared water resources of Sutter Basin. This partnership believes that cooperative and coordinated land and water management go hand in hand with being a good neighbor, along with helping to confirm the continued beneficial, efficient, and cost-effective management and use of local land and water resources now and into the future. This GMP update is a product of the collaborative process implemented by the Sutter Basin Partners.

PMWC is planning to augment surface water supplies by installing one new groundwater production well in 2012. The well would increase system reliability and flexibility, and offset reduction in Sacramento River diversions during drought and designated critical years. Additionally, RD 1500 is planning the installation of a new multi-completion groundwater monitoring well. The well is expected to be completed by spring 2012, and the data gathered will increase the understanding of aquifer characteristics. Both of these projects are made possible through a funding partnership with DWR (Proposition 50 Integrated Regional Water Management Plan implementation funding); the Reclamation Act of 1902 (32 Stat. 388), as amended and supplemented; and Public Law 108-361, Section 103(d)(5), Section 9504(a).

County Planning

Sutter County is currently developing a GMP. Sutter Basin Partner representatives attend the Sutter County groundwater management planning meetings, and anticipate participating in the development of the Sutter County GMP as appropriate.

2.2.2 Regional Planning

The Sutter Basin Partners have participated in regional planning efforts that reach beyond the Sutter Basin. Although water transfers provide some relief, additional flexibility in moving water among regional users could assist in meeting water demands. Improved coordination of water supplies at the regional level is needed to improve overall water management and to establish operational improvements. The Sutter Basin Partners actively participate in Regional Planning as appropriate to improve management while maintaining autonomy.

Sacramento River Basinwide Water Management Plan and Regional Water Management Plan

One of the initial steps in regional planning was taken in the mid-1990s, when the Sacramento River Settlement Contractors initiated discussions with Reclamation for Central Valley Project (CVP) contract renewals. The Sacramento River Settlement Contractors, in cooperation with Reclamation and DWR, prepared the *Sacramento River Basinwide Water Management Plan* (CH2M HILL et al., 2004a). Finalized in 2004, the *Sacramento River Basinwide Water Management Plan* identified potential water management improvements, including subbasin-level management actions, conjunctive water management projects, and water use efficiency projects. This planning process resulted in a high level of regional cooperation and was also the basis for the *Regional Water Management Plan* (CH2M HILL, 2007).

Sacramento Valley Water Management Agreement

In 1995, the State Water Resources Control Board adopted a water quality control plan (WQCP) for the San Francisco Bay/Sacramento-San Joaquin Estuary (Bay-Delta). In July 1998, the State Water Resources Control Board began water rights hearings to consider how to implement the 1995 WQCP, which is an administrative action to allocate responsibility for achieving the 1995 WQCP objectives to water rights holders affecting the beneficial uses of the Bay-Delta. Phase 8 of the hearings addressed the responsibility of water right holders in the Sacramento Valley to meet the 1995 WQCP requirements.

Phase 8 was expected to entail many years of litigation and judicial review. This extended process would have resulted in adverse impacts on the environment and undermined the progress of other statewide water management initiatives. As an alternative, more than 40 water suppliers in the Sacramento Valley, including SMWC and PMWC, negotiated and executed the SVWMA with Reclamation, DWR, U.S. Fish and Wildlife Service, California Department of Fish and Game, and the State Water Contractors. Signed in 2002, the SVWMA committed stakeholders to meeting water quality standards in the Sacramento-San Joaquin River Delta. It also outlined a cooperative regional approach to improve local, regional, and statewide water supply reliability and quality, while providing supplies to help meet water quality standards in the Sacramento-San Joaquin River Delta.

The SVWMA is the result of a collaborative grassroots effort to formulate a successful and viable alternative to traditional water management in a state with increasing constraints on its water resources. The SVWMA seeks to remedy the water resources challenges while maintaining consistency with state water resources goals and objectives.

Sacramento Valley Framework for Integrated Regional Water Management Plan

In December 2000, the Northern California Water Association and Sacramento Valley water leaders prepared a paper titled *An Integrated Water Supply Management and Water Development Program for the Sacramento Valley*. This paper described a framework for a possible partnership between Sacramento-region interests and federal and state agencies. The paper noted that "the goal of the program is…to achieve 100 percent of existing and future M&I and agricultural demand within Northern California" while ensuring sustainable groundwater supplies (Northern California Water Association, 2001). Associated with this effort, the Sacramento Valley Finite-Element Groundwater Model (SACFEM) (CH2M HILL, 2009), was developed to help facilitate the responsible use of the groundwater resource. A groundwater monitoring plan was also developed for the Sacramento Valley (Appendix C).

The following key items influencing the preparation of this GMP are included as appendices to this GMP update:

- Natural Resources Study for RD 1500 and SMWC – 1996 (Appendix F)
- RD 1500's GMP – 1997 (Appendix A)
- SVWMA – 2001 (Appendix G)
- Sacramento Valley Technical Memorandum #2, 2003 Technical Measurement and Monitoring Committee Summary Report (Appendix H)

- CASGEM Groundwater Elevation Monitoring Plan – 2011 (Appendix C)
- Location of SMWC groundwater monitoring well (scheduled for installation, winter 2012) (Figure 2-1)
- Landowner outreach program, including newsletter, survey, and Web site development (Appendix D)

2.3 Groundwater Management Cooperation

The Sutter Basin Partners have worked collaboratively and are committed to continue to examine the potential of the groundwater resource in DWR Sutter Subbasin covered by RD 1500's service boundaries (Figure 1-2) as a viable component to Sutter Basin's overall water resources supply and management.

2.3.1 Local

Entities within the Sutter Basin have a long history of working together to address local and regional resource constraints. Drainwater reuse is an excellent example of managing a resource in a solution-based way across local boundaries. Although RD 1500 is the drainage district, both major water purveyors in the area, SMWC and PMWC, work together to reuse the drainwater to help meet water supply demands. The Sutter Basin Partners are experienced in working together and working with local municipalities (for example, the town of Robbins).

SMWC and PMWC have participated with RD 1500 in groundwater resource discussions for almost 20 years. Resolutions to show support and active participation in the RD 1500 GMP update are provided in Appendix B. The Sutter Basin Partners are fully committed to continuing their local cooperative planning approach.

2.3.2 Regional (State and Federal)

Conjunctive water management opportunities are among the promising actions investigated by DWR in regional water management plans. SMWC and PMWC are both active members of regional water management activities and work with regional groups such as the Northern California Water Association and resource agencies such as the DWR and Reclamation. Both SMWC and PMWC are signatories to the 2001 SVWMA, in which both DWR and Reclamation are cooperating entities. As part of this agreement, a Technical Measurement and Monitoring Committee with a Groundwater Subcommittee was formed. The Groundwater Subcommittee was made up of California water professionals from DWR, Reclamation, the State Water Contractors, and consultants. Many of the principles developed as part of the subcommittee for responsible use of groundwater within the Sacramento Valley are used within this GMP update (see Appendix H).

The Sutter Basin Partners are also working closely with DWR during this GMP update. DWR representatives have been present at board meetings discussing this update and have been invited to review and comment on different phases of the update. The GMP update is also being coordinated with CASGEM implementation.

2.3.3 Stakeholder Participation and Public Outreach

The Sutter Basin Partners have made a conscious effort to increase stakeholder participation and public outreach as part of this GMP update. The following significant steps have been taken to increase information dissemination and develop a cohesive outreach program:

- **Landowner outreach letter –** In January 2011, RD 1500, on behalf of the Sutter Basin Partners, sent out a letter to each landowner providing an update on water-related activities in Sutter Basin, including (1) new communications capabilities, (2) recent water resources investigations and infrastructure improvements to help increase water supply reliability within Sutter Basin, and (3) potential for stakeholder participation (including participating in the GMP update process, providing local water use and system information via survey, and submitting local stories of water users for the quarterly newsletter).
- **Landowner survey –** RD 1500 received a higher than expected response to a landowner survey sent out in February 2011. A 30 percent response rate, much higher than expected from a mailed survey, was calculated. In this survey, landowners and water users provided limited information about their surface water and groundwater usage.
- **Web site –** In spring 2011, the Sutter Basin Partners established an interactive Web site where stakeholders and interested parties can obtain information regarding partnership activities specific to Sutter Basin Partners. The Web site still has portions under construction, but should be completed by summer 2012 (www.sutterbasinwater.com).

Copies of the landowner letter and the landowner survey are provided in Appendix D.

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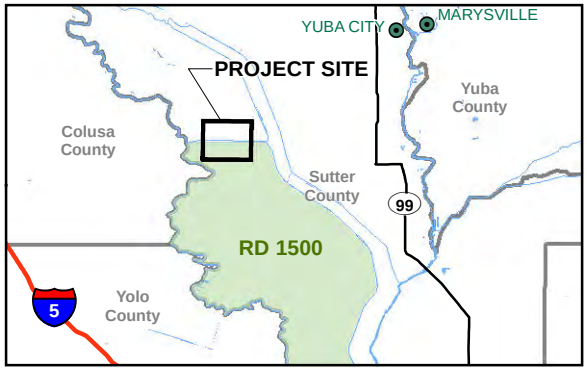
VICINITY MAP



Legend

ANTICIPATED DRILLING LOCATION FOR SMWC-MW01s,m,d

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FIGURE 2-1
Proposed Sutter Mutual Water Company Groundwater Monitoring Well Location Map
RD 1500 and Sutter Basin Partners
Groundwater Management Plan
Sutter County, California

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SECTION 3

Water Resources

3.1 Physical Setting

3.1.1 Geology

RD 1500 lies within the southwestern portion of the DWR Sutter Subbasin of the Sacramento Valley Groundwater Basin (SVGB). The SVGB is a north-northwestern trending, asymmetrical trough filled with as much as 10 miles of both marine and continental rocks and sediment (Page, 1986). On the eastern side, the SVGB overlies basement bedrock that rises relatively gently to form the Sierra Nevada; and on the western side, the underlying basement bedrock rises more steeply to form the Coast Ranges. Overlying the basement bedrock are marine sandstone, shale, and conglomerate, which generally contain brackish or saline water (DWR, 1978). Holocene- to Miocene-age, freshwater-bearing continental deposits overlie the marine deposits.

Holocene-age deposits in the RD 1500 area include stream channel, floodplain, and alluvial fan sediments. Floodplain sediments are deposited in low-energy environments; therefore, they typically exhibit low permeabilities. Alluvial fan and stream channel sediments are deposited in higher energy environments. Because they are coarser grained, these materials generally have high permeabilities. These recent sediments are underlain by older deposits of the Modesto, Riverbank, Turlock Lake, Laguna, Tehama, and Mehrten Formations (DWR, 1978; Helley and Harwood, 1985).

Pleistocene-age alluvial fan, terrace, and channel ridge sediments of the Modesto Formation are composed of materials deposited by streams draining the Sierra Nevada and Coast Ranges (Helley and Harwood, 1985). The formation consists of a heterogeneous assemblage of predominantly light colored gravely sand, silt, and clay (DWR, 1978; Helley and Harwood, 1985). The Modesto Formation was deposited by active streams, as the formation borders these waterways.

The Pleistocene-age Riverbank Formation consists of alluvial terraces and fans, which are older than the Modesto Formation, as distinguished by the geomorphic position and more mature soil profile (Helley and Harwood, 1985). Deposits include reddish gravel, sand, and silt.

The Turlock Lake Formation is composed of arkosic gravels, sands, and silts eroded from plutonic rocks of the Sierra Nevada Range along the eastern side of the SVGB (Helley and Harwood, 1985). These Pleistocene-age deposits have been deeply weathered and dissected, displaying as much as 100 feet of erosional relief. Alluvial fans and terraces of the Turlock Lake Formation are present topographically above those of the Riverbank and Modesto Formations.

The most prominent geological feature in the RD 1500 area is the Sutter Buttes, located north of the district. The Sutter Buttes are the remnants of an early Pliocene to Pleistocene-age volcano that was part of the Coast Range to the east (U.S. Geological Survey [USGS], 2011).

Deposits of the Sutter Buttes are divided into the following units (Helley and Harwood, 1985; USGS, 2011; Williams and Curtis, 1977):

- Central lake beds – a sequence of well-bedded volcanic sediments predominantly of lacustrine, although partially fluvatile, in origin located in the center of the buttes.
- Castellated core – the interior portion of the buttes, which consist of coalescing andesite domes.
- Moat – a low-lying ring of valleys that immediately surround the castellated core. The moat is underlain by late Cretaceous sedimentary rocks that were uplifted and tilted by the igneous intrusion. These deposits have eroded over time to form the low-lying moat valleys. Volcanic domes present within the moat are composed predominantly of rhyolite and dacite, although some andesitic domes are present.
- Rampart – the outer-most portion of the Sutter Buttes consisting of low-lying hills. Tuff breccia deposits of the rampart are primarily reworked volcanic sediments (fluvatile and lahar deposits), although lenses of airfall ejecta are present. The Sutter Buttes rampart may extend into the northern portion of RD 1500.

The Laguna Formation is composed predominantly of fine-grained, poorly sorted reddish to yellowish brown silt, clay, and sandy with local sand and gravel lenses (Page, 1986). The Pliocene-age sediments were deposited contemporaneously with the Tehama Formation (DWR, 1978). The unit is highly variable, ranging from predominantly silt with sandy lenses to sand with clay and silt lenses. The Laguna Formation was deposited as a westward thickening "wedge" on low-sloping alluvial fans by streams draining the Sierra Nevada. Thickness ranges from 300 feet along the Sierra Nevada foothills to as much as 1,000 feet near the Sacramento River (DWR, 1978). Deposits of the Laguna Formation exhibit low to moderate permeability due to the fine-grained character and cementation of the formation.

From its source area in the Coast Ranges, the Pliocence-age Tehama Formation dips eastward beneath the valley floor interfingering with the Laguna Formation at depth (DWR, 1978). The Tehama Formation consists of alluvial sediments (predominantly sand, silt, and clay) deposited by streams draining the Coast Ranges. Although the Tehama Formation is mostly fine grained, it contains sufficient sand and gravel zones in many areas to provide large quantities of groundwater to wells.

The Nomlaki Tuff Member of the Tuscan Formation is present at the base of both the Laguna and Tehama Formations in the SVGB (Helley and Harwood, 1985). The unit consists of white, light-gray, to reddish-tan dacitic pumice tuff and pumic lapilli tuff. The Nomlaki Tuff ranges from a massive ash flow to distinctly bedded pumiceous sediments.

The Miocene-Pliocene-age Mehrten Formation includes both hard-gray tuff breccias derived from eruptions in the Sierra Nevada and interbedded fluvatile volcanic silts, sands, and gravels (DWR, 1978; Page, 1986). These deposits dip southwestward and range in thickness from 200 to 1,000 feet. Tuff breccias and clays yield little water and function as confining

layers; whereas, the volcanic sands of the Mehrten Formation can yield large quantities to agricultural wells (DWR, 1978).

3.1.2 Hydrogeology

The freshwater aquifer system within the Sutter Basin portion of the SVGB is composed of Quaternary to Late Tertiary continental deposits that overlie the marine sediments. The cumulative thickness of water-bearing deposits within the Sutter Subbasin increases from a few hundred feet near the Sierra Nevada foothills on the east to over 2,000 feet along the western margin of the DWR Sutter Subbasin (DWR, 1978). The groundwater system in the DWR Sutter Subbasin can be thought of as a single unconfined to semiconfined (leaky) aquifer system with groundwater levels typically within approximately 10 feet of the land surface (DWR, 1992).

Historically, groundwater levels have generally remained stable, with no long-term trends. However, groundwater levels are influenced by climate, temporarily declining during droughts, and rising when normal or above-normal precipitation occurs. For example, some short-term declines were noticeable during the droughts of 1976 through 1977 and in 1987 through 1992. These declines were followed by recovery to pre-drought levels after one or more successive normal or above-normal precipitation events occurred.

According to regional groundwater elevation contour maps for spring 1997, groundwater movement within RD 1500 is generally to the southeast with a hydraulic gradient of approximately 2 feet per mile (DWR, 2003c). Groundwater elevation data have been collected within RD 1500 from more than 20 locations from 1929 through the present (DWR, 2011a). Continuous groundwater elevations are currently monitored in eight wells within RD 1500 with periods of record dating back to 2004 in several locations. Examination of data indicates that during years of normal precipitation, groundwater levels typically have an average seasonal fluctuation of approximately 4 feet, and during drought years, groundwater levels have been shown to fluctuate by greater than 10 feet (DWR, 2011a).

3.1.3 Hydrology

The water balance of the SVGB is dominated by a large annual influx of water falling as precipitation on the surrounding mountains and on the valley floor. A portion of this water is consumed through evapotranspiration (both by agricultural crops and by native vegetation), and the remainder occurs as runoff and groundwater recharge. The total average annual runoff to the Sacramento Valley Hydrologic Region, including the 850,000 acre-feet estimated for the Redding Groundwater Basin, is 22.4 million acre-feet (DWR, 2003a). Municipal, industrial, and agricultural water use in the hydrologic region totals approximately 8 million acre-feet, 2.5 million acre-feet of which comes from groundwater. A portion of this applied water, as well as the remaining 14.4 million acre-feet of runoff, is potentially available to recharge the SVGB and replenish groundwater storage that has been depressed as a result of groundwater pumping.

The main surface water features in the DWR Sutter Subbasin area of the SVGB include the Sacramento River, Feather River, Tisdale Bypass, and Sutter Bypass. The constructed Sutter Bypass acts as a flood control overflow for the Sacramento River. Surface water and

groundwater interact on a regional basis, so gains and losses to groundwater vary significantly, geographically and temporally.

3.1.4 Topography and Soils

The topography of the DWR Sutter Subbasin area of the SVGB is composed primarily of the gentle flatlands of the Sacramento Valley. The only prominent topographic feature near Sutter Basin is the Sutter Buttes at its northern boundary, a Pliocene volcanic plug that rises abruptly 2,000 feet above the surrounding valley floor (USGS, 2011). Primary soil associations found within Sutter Basin are as follows (U.S. Department of Agriculture, 2009):

- San Joaquin-Bruella-Kimball (CA411): Moderately deep and very deep, level to nearly level, well-drained sandy loam and loam on terraces.
- Oswald-Gridley-Subaco (CA463): Moderately deep, level to nearly level, poorly drained and moderately well-drained clay and clay loam in basins and on basin rims.
- Clear Lake-Capay-Stockton (CA410): Deep and very deep, level to nearly level, poorly drained and moderately well-drained clay and silty clay in basins and on basin rims.
- Columbia-Shanghai-Nueva (CA462): Very deep, level to nearly level, somewhat poorly drained silt loam, loam, and fine sandy loam on floodplains.

3.1.5 Climate

Generally, Sutter Basin experiences hot, dry summers and mild, rainy winters. Sutter County has an average July high temperature of 94 degrees Fahrenheit (°F) and an average January low of 36°F. On average, Sutter Basin receives 60 days of rain per year. Table 3-1 provides historical climate data for Sutter Basin.

TABLE 3-1
Historical Climate Data for Knights Landing, California
Reclamation District No. 1500 and Sutter Basin Partners Groundwater Management Plan

Month	Average Total Rainfall[a] (inches)	Average Temperature[b] (°F)	
		Maximum	Minimum
January	3.76	54.0	37.6
February	3.20	60.5	40.9
March	1.70	66.8	43.6
April	1.22	73.9	46.8
May	0.64	82.3	51.8
June	0.14	90.5	56.2
July	0.01	96.4	57.8
August	0.07	94.9	56.6
September	0.16	90.0	55.4
October	0.97	79.3	49.8
November	1.76	65.2	42.7
December	3.60	54.9	37.9
Average Annual Total	17.23		

[a]Rainfall data as recorded at Kirkville by RD 1500 staff, 2000-2010.

[b]Temperature data for Knights Landing, California, obtained from the March 1, 1906, to December 31, 2010, period of record (Western Regional Climate Center, 2011).

3.1.6 Economy

The Sutter Basin economy is predominantly composed of agriculture. Sutter Basin provides rich soils, proximity to water supply, and mild climate, which all promote the strong agricultural land uses in Sutter Basin. Other sectors of the local economy in Sutter Basin include construction, manufacturing, services, and education.

3.2 Surface Water

The Sutter Basin is primarily agricultural in nature. Surface water from the Sacramento River is the primary source of irrigation water, with groundwater providing a relatively limited source (less than 20 percent) of supplemental supply within the western portion of the Sutter Basin (CH2M HILL et al., 2004b). The two largest water purveyors within Sutter Basin are SMWC and PMWC. Independent water users, known as Rimlanders, are generally located in a contiguous swath of land between the Sacramento River and the western boundaries of SMWC and PMWC. RD 1500 is responsible for drainage in Sutter Basin and encompasses all of these water supply entities and all acreage in Sutter Basin (see Figure 1-2). Figure 3-1 shows the main drainage infrastructure in Sutter Basin, and Figure 3-2 shows show the main irrigation conveyance infrastructure in Sutter Basin. Although groundwater is not a primary water source for Sutter Basin, groundwater does contribute to flows into some of the drains, particularly in the connate water zone. Table 3-2 provides an overview of Sutter Basin water and drainwater entities.

TABLE 3-2
Overview of Sutter Basin Water and Drainwater Entities
Reclamation District No. 1500 and Sutter Basin Partners Groundwater Management Plan

Description	SMWC	PMWC	Rimlanders
Service Area (acres)	50,071[a]	3,000	15,000±
Average Total Surface Water Supply (acre-feet)[b]	227,000	12,000	Not available

[a]Gross acreage reported. Irrigated acreage ranged from 44,900 to 51,200, from 2001 through 2010; rice decomposition and winter water acreages are not included.

[b]From SMWC and PMWC water records, 2000 through 2010.

Tables 3-3 and 3-4 show SMWC and PMWC cropping patterns, respectively. Rice has been the predominant crop in Sutter Basin over the past several decades (Tables 3-3 and 3-4). Cropping patterns are subject to change, which can influence irrigation demands and drainwater quantity.

3.2.1 Sutter Mutual Water Company

SMWC is a Sacramento River Settlement Contractor with a base supply allotment of 169,500 acre-feet and a CVP water supply of 56,500 acre-feet. SMWC delivers water to approximately 50,000 acres via four pumping plants on the Sacramento River at three locations: Tisdale Pumping Plant (960-cfs capacity), State Ranch Bend Pumping Plant (150 cfs), and Portuguese Bend Pumping Plant (106 cfs). SMWC does not provide water service for M&I use. The average combined diversion rate during the peak irrigation season (May through August) is approximately 1,300 acre-feet per day. The Tisdale Pumping Plant discharges water to the Tisdale Canal with distribution to the West, East, and Central Canals

and their laterals. This is the largest service area, totaling 42,900 acres on both the west and east sides of the Main Drain. The State Ranch Bend Pumping Plant supplies water to the State Ranch Bend Main Canal and its laterals. This service area is approximately 5,700 acres.

TABLE 3-3
Sutter Mutual Water Company Typical Cropping Patterns
Reclamation District No. 1500 and Sutter Basin Partners Groundwater Management Plan

Crop Type	Average Acreage (percent)
Rice	51
Wheat/Barley	10
Tomatoes	9
Safflower	7
Sunflower	7
Beans	5
Corn	4
Alfalfa	2
Other	5
Total	**100**

Note:
SMWC crop acreage records from 2000 through 2010.

TABLE 3-4
Pelger Mutual Water Company Typical Cropping Patterns
Reclamation District No. 1500 and Sutter Basin Partners Groundwater Management Plan

Crop	Average Acreage (percent)
Rice	47
Wheat/Barley	11
Tomatoes	10
Safflower	9
Sunflower	5
Beans	1
Corn	4
Alfalfa	0
Other	13
Total	**100**

Note:
Derived from PMWC records for 2000 through 2010.

The Portuguese Bend Pumping Plant discharges water to the Portuguese Bend Main Canal and service area of 2,600 acres. On average, nearly 90 percent of irrigation diversions are during May through August. The greatest year-to-year variations in SMWC irrigation deliveries are in May and June.

The State Ranch Bend service area occasionally experiences irrigation delivery demands that exceed the irrigation delivery capacity. The system constraint is the State Ranch Bend Pumping Plant; it cannot pump all water required to meet peak irrigation demands when there is large rice acreage. According to SMWC staff, the State Ranch Bend conveyance

infrastructure has capacity for additional flow if additional flow could be provided to the system. Additional pumping capacity was added in 2010 to curtail a portion of the water shortages.

SMWC operates nine drainwater recycle pumps and three portable booster pumps in Sutter Basin, as shown on Figure 3-1. These recycle pumps convey drainwater directly into adjacent irrigation canals. The combined drainwater recycling capacity is roughly 290 cfs. Additionally, SMWC has used portable drainwater recycle pumps to relieve problem areas in the past. Currently, the approximated volume of reused drainwater is 15,000 to 56,000 acre-feet annually. Appendix A provides additional information about data collection.

3.2.2 Pelger Mutual Water Company

PMWC is a Sacramento River Settlement Contractor with a base supply allotment of 7,110 acre-feet and a CVP water supply of 1,750 acre-feet. PMWC delivers water to approximately 3,000 irrigated acres. The Pelger Pump Station on the Sacramento River discharges water to the PWMC water distribution system. Approximately three privately owned wells within PMWC boundaries are used to supplement surface water supplies to meet irrigation needs. Additionally, PMWC operates one portable and six permanent drainwater recycle pumps, as shown on Figure 3-1. These recycle pumps convey drainwater directly into adjacent irrigation canals.

By annual permit, PMWC is authorized to pump RD 1500 drainwater for recycle and reuse. Because of Sutter Basin's flat topography, drainwater control structures outside the PMWC service area affect drainwater levels at some of the PMWC recycle pumps. PMWC and RD 1500 communicate about the drainwater levels, particularly in drain laterals ML-15 and ML-17. PMWC supplies irrigation water into a drain to make up a portion of a drainwater pump capacity so that it can operate.

3.2.3 Rimlanders

Rimlanders pump their own irrigation water, primarily directly from the Sacramento River. They do not receive surface irrigation water from a water purveyor. Drainwater from Rimlanders' fields that enters the drainage channel network is managed by RD 1500 and is, therefore, available for reuse.

3.2.4 Sutter Basin Drainage System

Drainwater System

RD 1500 collects and manages drainwater within Sutter Basin. Drainwater outflow includes both drainwater resulting from agricultural practices during the irrigation season and precipitation runoff during the rainy season. Drainwater either flows by gravity or is pumped out of Sutter Basin at the Karnak Pumping Plant, depending on the water levels in the Sutter Basin Main Drain and the Sacramento River.

The Main Drain, which generally flows north to south, bisects Sutter Basin and collects the majority of the drainwater from lands encompassed by RD 1500. An elaborate network of both drain laterals and sublaterals conveys drainwater to the Main Drain from both the east and west. A few row-crop fields in Sutter Basin have tile drains to facilitate root zone

drainage, but overall, tile drains are not prevalent. When feasible, farmers use private pumps to reuse drainwater from the RD 1500 drain network. The existing reuse infrastructure has been expanded to provide greater drainwater reuse capability and flexibility.

Drainwater is checked-up in the drains during the irrigation season to provide backwater hydraulic gradients for the existing drainwater recycling pumps. Because a high water table can damage row and field crops, drainwater levels must be carefully maintained to prevent such a situation and protect Sutter Basin's crops. Checks are removed after the growing season to facilitate drainage and leaching of the root zone, and maximize surface runoff drainage capacity.

Drainwater Quality

Irrigation water quality and sustainable soil growing conditions are ongoing concerns for Sutter Basin farmers, especially relating to groundwater pumping and drainwater reuse. Previous studies have examined water quality in the Sutter Basin (see Appendices A, C, E, F, and G). As previously described, a connate water zone underlies Sutter Basin where saline water under artesian pressure rises to the ground surface along the Sutter Basin Fault. CH2M HILL delineated this zone by evaluating information provided in previous reports and from observations by SMWC and RD 1500 staff. Despite previous Sutter Basin water quality studies that span at least 40 years, a degree of uncertainty regarding water quality remains. The following water quality statements are generally accepted:

- Drainwater quality varies spatially but remains uncertain (see Appendix A).
- Drainwater tends to be higher in total dissolved solids (TDS) in the connate water zone and near the downstream end of Sutter Basin, east of the town of Robbins.
- Drainwater quality varies seasonally; TDS at the Karnak Pumping Plant can fluctuate at least three-fold throughout a year.
- Drainwater has been successfully reused for irrigation in Sutter Basin for decades.
- Where drainwater is reused, blending it with surface irrigation water is common.
- The SMWC irrigation delivery standard for TDS is 750 milligrams per liter.

3.3 Groundwater Resources

3.3.1 Storage

Groundwater storage is the volume of water that would drain by gravity from a given saturated thickness of the aquifer deposits underlying a designated geographic area. Useable groundwater storage potential in Sutter County has been estimated at approximately 5 million acre-feet (DWR, 2003d); it is estimated that 1.26 million acre-feet of this storage capacity underlies SMWC and PMWC (DWR, 2003c). Not all of this groundwater storage is available for groundwater use annually. Overuse of the groundwater resource could adversely affect groundwater quality, yields of nearby production wells, local streamflow, or the environment. Careful management and use of the groundwater resource are key elements of RD 1500's GMP.

Quantifying the relative contributions of recharge for a basin is challenging. Accurately quantifying the changes of the various recharge rates due to an extraction project is even more challenging. Only with a combination of monitoring over time, evaluating aquifer properties and water flow, and comparing modeling analyses with measured data can these relative effects be understood. Using sound technical judgment, and monitoring and measuring the effects of the project over time will help the Sutter Basin Partners develop and make reasonable operational decisions through time and in conjunction with local and regional groundwater management objectives. This monitoring and measurement will also provide the ability to understand the basic characteristics of the DWR Sutter Subbasin and to monitor changes in subbasin conditions to avoid affecting other groundwater users.

3.3.2 Use

Agriculture is the primary use of groundwater in the Sutter Basin. There are also urban and environmental groundwater uses. Groundwater levels in wells in the Sutter Basin are depressed seasonally, but fully recover over the winter months in all but the driest years. Further study is necessary to determine the effects of a prolonged, severe drought on regional groundwater levels.

Agricultural

As reported by DWR, annual agricultural groundwater use has been estimated at 171,400 acre-feet in the DWR Sutter Subbasin of the SVGB (DWR, 2003d). Groundwater use is expected to increase as competition for reliable surface water supplies increases.

Urban

Annual domestic groundwater use has been estimated at 3,900 acre-feet in the DWR Sutter Subbasin of the SVGB (DWR, 2003d). SMWC overlies the agricultural and residential town of Robbins, but does not provide water service for M&I use. M&I water demand near the SMWC service area is anticipated to increase only slightly over the next decade. All future M&I requirements are assumed to be met by groundwater supplies.

Environmental

In 1990, approximately 250 acres of riparian vegetation were estimated to be incidentally supplied by irrigation, including vegetation directly adjacent to delivery laterals or influenced by leakage from the delivery system. Such vegetation includes habitat used by the federally listed giant garter snake (*Thamnophis gigas*). Other endangered species within the service area include the western yellow-billed cuckoo (*Coccyzus americanus occidentalis)*, Swainson's hawk (*Buteo swainsoni*), bank swallow (*Riparia riparia)*, wood duck (*Aix sponsa)*, western pond turtle (*Emys marmorata*), California tiger salamander (*Ambystoma californiense*), California red-legged frog (*Rana draytonii)*, valley elderberry longhorn beetle (*Desmocerus californicus dimorphus)*, and California hibiscus. Agricultural development has favored other species, notably waterfowl and ring-necked pheasants. Drainage ditches support blue and channel catfish, carp, crayfish, and bullfrogs.

Approximately 10,000 acres of rice stubble have been flooded in the past, with associated winter habitat benefits to migratory waterfowl that use the area as part of the Pacific Flyway. SMWC has set a companywide limit at 10,000 to 12,000 rice-field flooded acres

because of winter flooding concerns. The flooding of rice fields in the spring and summer provides wetlands habitat during these periods for waterfowl and terrestrial species. Rice fields that are not flooded also provide habitat for waterfowl and upland birds as resting areas. No formally managed designated environmental or wetlands areas are within SMWC.

3.3.3 Production Wells

Average well yield values for agricultural and M&I wells were compiled by Olmsted and Davis (1961) from Pacific Gas and Electric Company pump test records for counties in the Sacramento Valley. Reported well yields for the RD 1500 area average 740 gallons per minute (gpm) (from 45 wells with an average depth of 303 feet). Information compiled by DWR from well completion reports suggests that agricultural and M&I wells yield 728 gpm on average in the DWR Sutter Subbasin of the SVGB (DWR, 2003d); however, groundwater production from wells within PMWC have yielded approximately 2,000 to 4,000 gpm during recent conjunctive water management programs (MBK Engineers, 2010). SMWC does not currently use groundwater production wells. Information contained in DWR records for wells in the DWR Sutter Subbasin of the SVGB includes the following (DWR, 2003d):

- Number of domestic wells: 496
- Range in domestic well depths: 35 to 320 feet below ground surface (bgs) (average domestic well depth: 121 feet bgs)
- Number of M&I wells: 205
- Range in M&I well depths: 60 to 672 feet bgs (average M&I well depth: 205 feet bgs)

Future groundwater production wells are anticipated to have the following characteristics:

- Drilling techniques: Mud-rotary or reverse circulation rotary drilling.
- Materials and procedures:
  - Blank well casing will likely range from nominal 18- to 24-inch-diameter steel of appropriate alloy to minimize significant corrosion over the desired lifespan of the well.
  - Screen materials will likely range from 18- to 24-inch-diameter steel of appropriate alloy to minimize significant corrosion over the desired lifespan of the well.
  - Gravel pack will extend a safe distance above the top of the well screen and be topped with a finer grained transition sand.
  - Gravel pack material will depend on lithology encountered during drilling, the geophysical log, and the selected well screen aperture size.
  - Cement/bentonite grout will be used above the transition sand to the land surface as the seal.
  - Wells will be developed using some combination of airlift, surge, swab, and pump techniques until turbidity is less than 10 nephelometric turbidity units and field

parameters are stabilized (for example, pH, electrical conductivity, and temperature).

- After a production well is installed and developed, a vertical turbine pump with an electrical motor ranging from 25 to 200 horsepower will be installed to extract the groundwater through welded steel pipe (and appurtenances like butterfly valves and flow meters) ranging in diameter from 8 to 16 inches.
- High-density polyethylene pipe will convey water from the welded steel pipe to the open-channel conveyance systems of the individual irrigation districts and water companies.
- Hydraulic testing will be performed at each production well to aid in evaluating well efficiency and local aquifer properties.

Inspection

A qualified inspection team will be tasked with quality assurance and control during well installation and development. The inspection team will likely consist of one to two resident inspectors during surface infrastructure installation, well installation, and well development. Inspectors will record observations in inspection diaries, which will be collected and archived for project records. A geologist will provide drilling oversight for installation of the wells, at the direction of the Sutter Basin Partners. The onsite geologist will verify that well installation materials meet specifications and that the drilling and well installation and development procedures are executed correctly. The onsite geologist will also document the cuttings in a soil boring log (Unified Soil Classification System soil type encountered with depth).

Installation

PMWC plans to install a groundwater production well in 2012 as part of the Integrated Regional Water Management Program. The high-production well will produce supplemental flows of up to 3,000 gpm during dry years to temporarily reduce surface water diversions from the Sacramento River.

3.3.4 Quality

Groundwater quality in the SVGB is generally excellent (DWR, 2003a). However, some portions of the DWR Sutter Subbasin have naturally occurring minerals, which present some concerns. According to groundwater quality sampling performed within RD 1500, TDS and electrical conductivity concentrations exceeding 500 milligrams per liter (mg/L) and 1,000 microSiemens per centimeter persist throughout the district. In general, these constituents decrease in concentration closer to the Sacramento River. Concentrations of boron exceed 0.5 mg/L throughout the district, which may create toxicity issues for sensitive plants. Arsenic concentrations are generally less than 0.01 mg/L within RD 1500; however, concentrations approaching 0.1 mg/L have been detected in the south central portion of the district. Measured concentrations of manganese generally exceed 0.15 mg/L throughout the district, which may pose a risk to crops, particularly if acidic soils are present.

The northwest trending Sutter Basin Fault creates groundwater quality issues related to high TDS concentrations within the DWR Sutter Subbasin (DWR, 2003c; Hull, 1984). The fault acts as a conduit for the upward movement of connate water from deeper marine sediments. It has been reported that saline intrusion has displaced up to 2,000 feet of fresh water in the continental deposits, forming a mound of saline water in the east-central portion of the DWR Sutter Subbasin. The total depth of fresh water in PMWC is approximately 1,200 feet bgs (Berkstresser, 1973). The fresh water is underlain by saline water. Uncertainty of groundwater quality remains a concern for the Sutter Basin Partners.

3.4 Groundwater Information Management

3.4.1 Groundwater Monitoring

As shown on Figure 3-3, groundwater levels in the Sutter Basin have been historically monitored through a cooperative effort by DWR and Sutter County in more than 25 wells within the RD 1500 jurisdictional boundary. Of these, 15 wells are actively monitored (locations with groundwater level data available for 2011 in the water data library). However, RD 1500 now participates in the CASGEM program. The following presents background information from the DWR CASGEM Web site (DWR, 2011b):

> *On November 4, 2009 the State Legislature amended the Water Code with SBx7-6, which mandates a statewide groundwater elevation monitoring program to track seasonal and long-term trends in groundwater elevations in California's groundwater basins. To achieve that goal, the amendment requires collaboration between local monitoring entities and Department of Water Resources (DWR) to collect groundwater elevation data. Collection and evaluation of such data on a statewide scale is an important fundamental step toward improving management of California's groundwater resources.*
>
> *In accordance with this amendment to the Water Code, DWR developed the California Statewide Groundwater Elevation Monitoring (CASGEM) program. The intent of the CASGEM program is to establish a permanent, locally-managed program of regular and systematic monitoring in all of California's alluvial groundwater basins. The CASGEM program will rely and build on the many, established local long-term groundwater monitoring and management programs. DWR's role is to coordinate the CASGEM program, to work cooperatively with local entities, and to maintain the collected elevation data in a readily and widely available public database. DWR will also continue its current network of groundwater monitoring as funding allows.*
>
> *The law anticipates that the monitoring of groundwater elevations required by the enacted legislation will be done by local entities.*

Sutter County has declined to participate with local agencies in the CASGEM program. Thus, RD 1500 has agreed to be the local entity of record for the corresponding service area within Sutter County and the Sutter Basin. RD 1500 is working with DWR to meet the requirements of the CASGEM program. Phase 1 has been completed. Phase 2 is expected to be completed in 2012, when DWR's online tool becomes fully functional. RD 1500 has a

CASGEM-compliant monitoring plan (provided in Appendix C). Monitoring will be conducted annually each spring and fall using the groundwater monitoring network.

Figure 3-4 presents the subset of these wells (five locations, including well clusters) that were selected for inclusion in the CASGEM program. These wells were chosen by DWR to monitor groundwater levels (and corresponding elevations) in the Sutter Basin. Groundwater elevation monitoring is conducted at frequencies ranging from biannually (once in the spring and again in the fall) to continuously at each of the active wells in RD 1500's network that are accessible for monitoring. Consistent with minimum CASGEM requirements, this monitoring is conducted to measure seasonal high and low groundwater elevations for the Sutter Basin. The Sutter Basin Partners intend to continue to seek opportunities jointly with DWR to extend the monitoring network as funding allows.

According to the availability of recent data, 9 wells are currently monitored for groundwater quality within the RD 1500 jurisdictional boundary. The town of Robbins collects groundwater quality samples at well cluster 12N02E23H001M through 12N02E23H004M. Samples are analyzed for general chemistry and dissolved metals. General chemistry data collected during 2011 are also available for wells 13N01E12J002M, 13N01E24G002M, 13N01E24G003M, 13N01E24G004M, and 13N02E17A001M.

SMWC plans to install at least one multi-completion groundwater monitoring well in 2012. Should funding permit, additional monitoring wells will likely be installed to assist in the overall monitoring program. New monitoring wells will likely be multi-completion and will generally follow the DWR design approach (as appropriate to the local geology and hydrogeology) presented on Figure 3-5.

3.4.2 Groundwater Modeling

Existing Groundwater Model

Potential impacts on groundwater and surface water resources that could result from future implementation of groundwater production programs would be assessed quantitatively through the use of the SACFEM model (CH2M HILL, 2009). SACFEM was developed using the MicroFEM (Hemker, 2011) modeling platform, which is a three-dimensional, transient, finite-element groundwater flow model that simulates single-density groundwater flow in layered systems. SACFEM was developed specifically to evaluate potential impacts on surface water and groundwater resources that could result from the implementation of conjunctive water management projects across the Sacramento Valley. Output from SACFEM provides estimates of impacts on surrounding groundwater levels and changes in streamflow resulting from project pumping. SACFEM is based on a high-resolution model grid that consists of over 120,000 surface nodes and seven model layers. The grid resolution is on the order of 100 meters in areas where projects are proposed, providing localized and regional forecasts of potential impacts on water resources.

SACFEM also contains a highly detailed surface water budgeting module that computes the distributions of agricultural pumping and the deep percolation of applied water and precipitation monthly over the water years[1] 1970 through 2003 calibration period. The

[1]A water year runs from October 1 of the previous calendar year through September 30. For example: water year 1970 includes October 1, 1969, through September 30, 1970.

surface water module incorporates land use information (primarily cropping patterns), water source information, and surface water rights data to estimate the time series of deep percolation and agricultural pumping on a node-by-node basis for each month in the model. SACFEM is calibrated to monthly water levels measured in monitoring wells across the Sacramento Valley during the water years 1970 through 2003 calibration period. Because this 34-year calibration period includes both severe drought periods (1976 through 1977 and 1987 through 1992) and extremely wet years (1983), projections of potential project-related impacts can be evaluated over a range of hydrologic conditions.

Groundwater Program Analysis

The potential incremental impacts on groundwater and surface water resources resulting from implementation of future groundwater production programs would be assessed using SACFEM, as described above. Impact analyses would account for baseline conditions, which are based on the 1970 through 2003 historical period. This period was selected to account for both extremely dry and wet conditions, as well as the availability of data to allow for calibrating the model. The potential impacts of operating future projects would be evaluated against the baseline condition.

Projected impacts would represent those predicted to occur solely as a direct result of implementing a proposed project. Such incremental impacts would be in addition to fluctuations resulting from climatic conditions; groundwater production from surrounding domestic, M&I, or agricultural supply wells; or implementation of other local groundwater production programs.

3.4.3 Land Subsidence

Historically, land subsidence in the Sutter Basin has not been a concern, especially because of minimal groundwater pumping for irrigation. The DWR Sutter Subbasin is not in a state of groundwater overdraft. Sutter Basin Partners defer to Sutter County and DWR for this monitoring effort, but if opportunities for funding arise, the Sutter Basin Partners will assist as appropriate to develop a monitoring network that may include extensometers.

Land subsidence is currently measured in the SVGB via global positioning system (GPS) monitoring networks and borehole extensometers. Three GPS monitoring networks exist in the Delta, Yolo County, and Glenn County. The networks were surveyed in the late-1990s and early 2000s, and require periodic resurveying to assess whether subsidence occurs. During 2008, DWR, in cooperation with 20 federal, state, and local agencies, established a network of approximately 340 GPS stations throughout the SVGB (DWR, 2009). The baseline survey for the Sacramento Height Modernization Project was conducted in 2008. Of the approximately 340 stations, 30 are located within Sutter County and 3 are located within the RD 1500 jurisdictional boundary. These stations will be periodically resurveyed to evaluate land surface elevation changes. DWR currently maintains the following 13 borehole extensometers in the SVGB: two in Yolo County, one in Sutter County, two in Colusa County, three in Glenn County, and five in Butte County.

3.5 Conjunctive Water Use

Annual operating plans for regional and local participation in groundwater programs will be developed as appropriate if extensive groundwater pumping is undertaken. Implementation of groundwater programs will be in compliance with all federal, state, and local regulations.

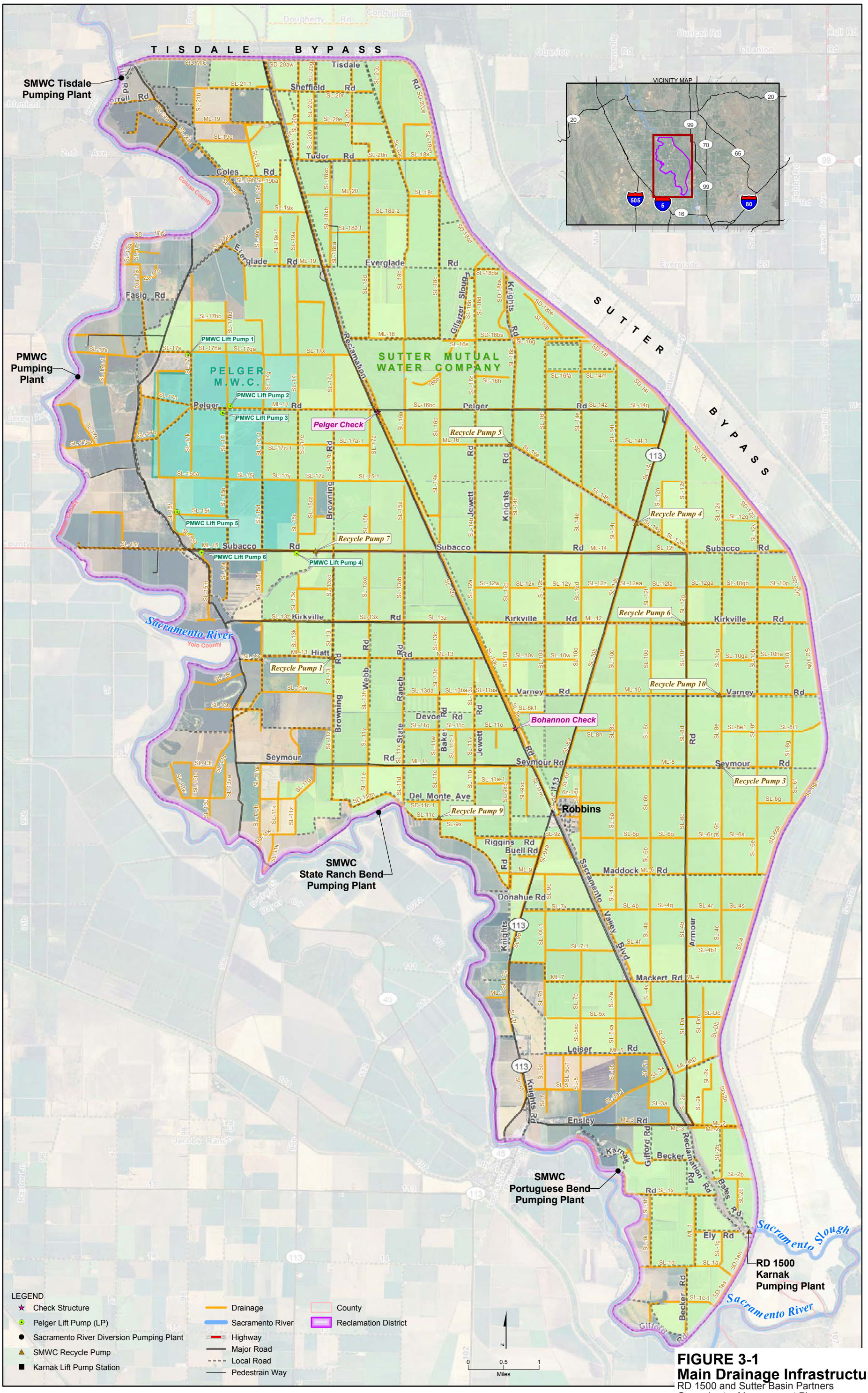

FIGURE 3-1
Main Drainage Infrastructure
RD 1500 and Sutter Basin Partners
Groundwater Management Plan
Sutter County, California

CH2MHILL®

WBG072511212716RDD_3-1

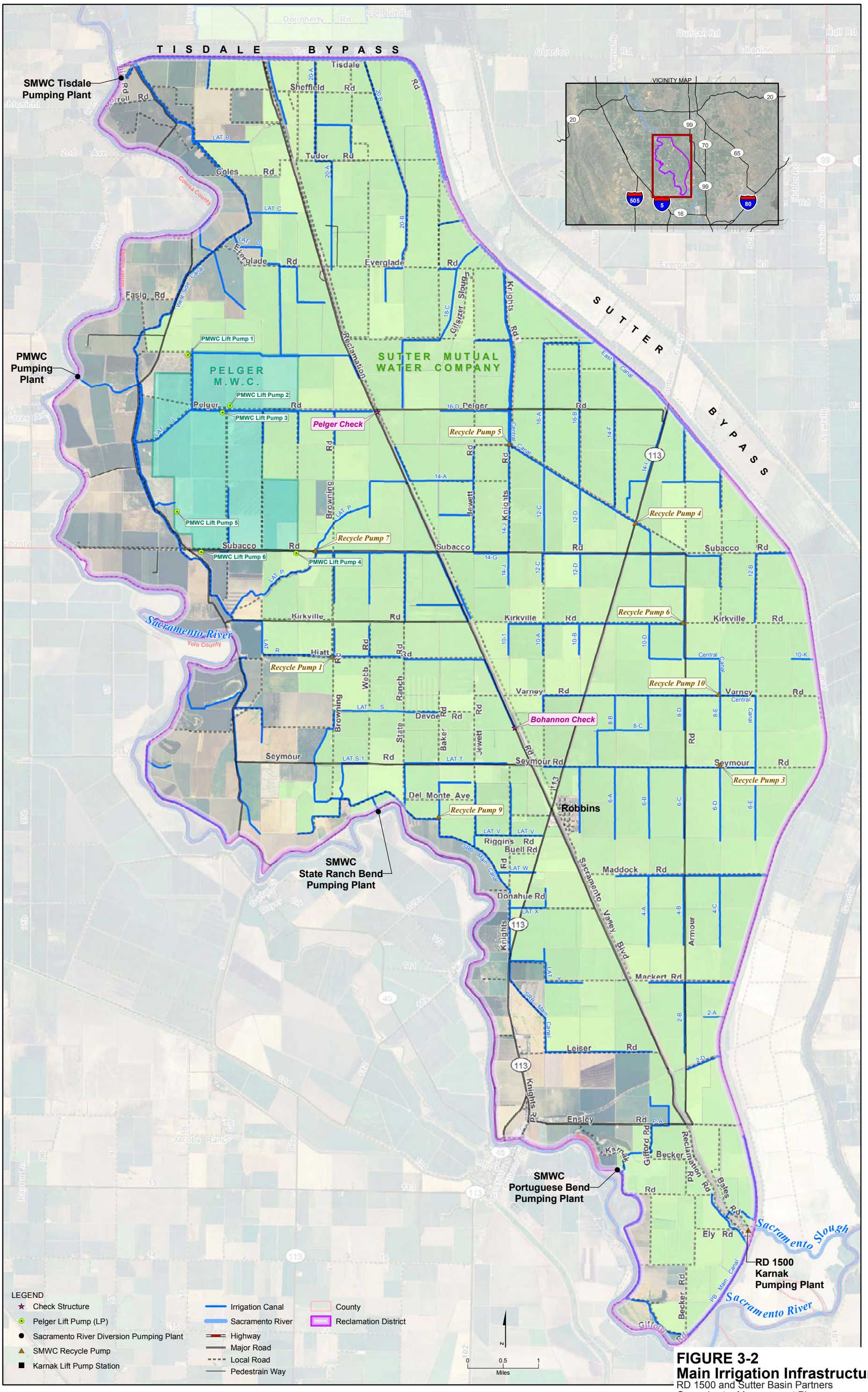

FIGURE 3-2
Main Irrigation Infrastructure
RD 1500 and Sutter Basin Partners
Groundwater Management Plan
Sutter County, California

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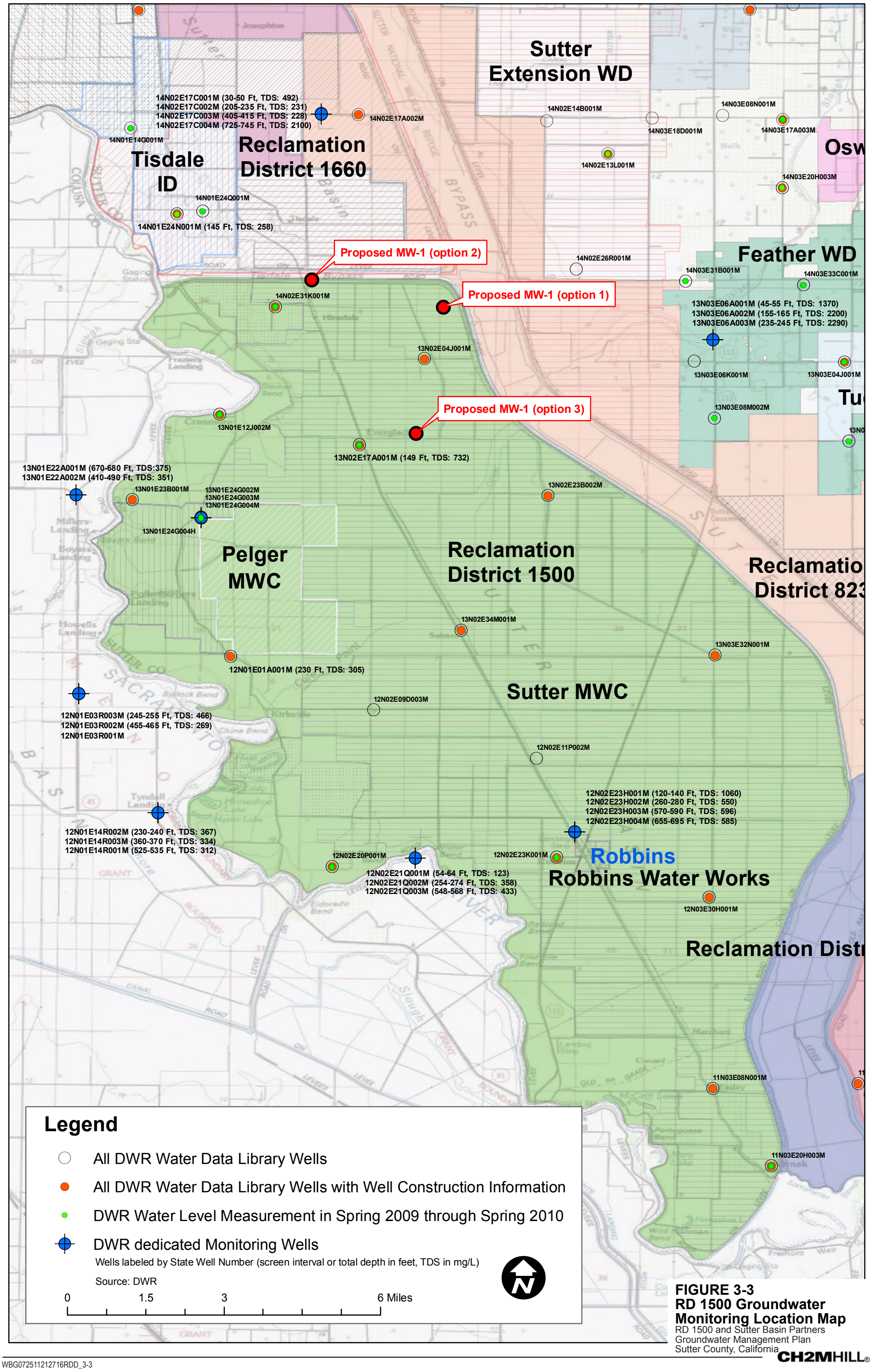


FIGURE 3-3
RD 1500 Groundwater Monitoring Location Map
RD 1500 and Sutter Basin Partners
Groundwater Management Plan
Sutter County, California

CH2MHILL®

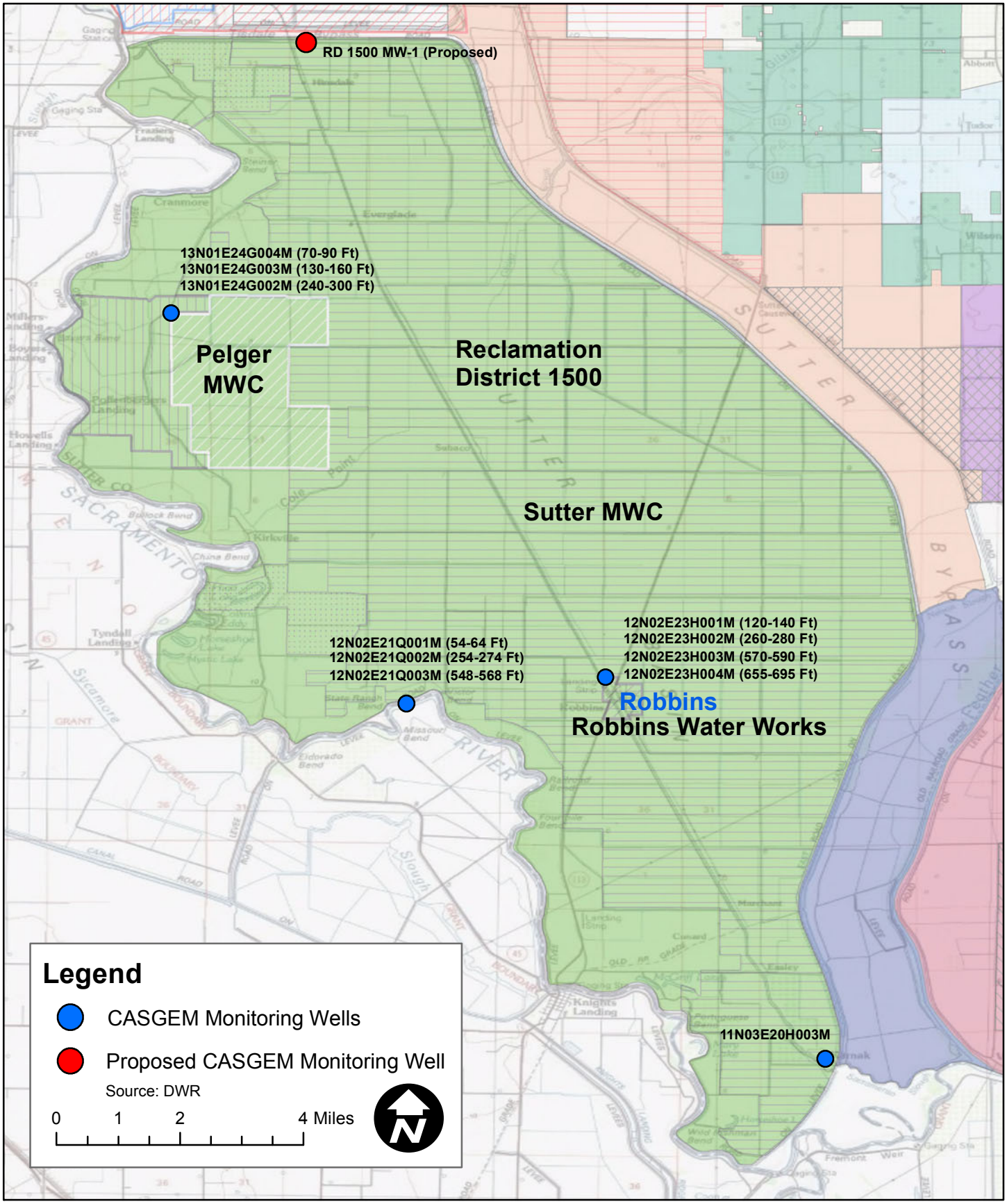
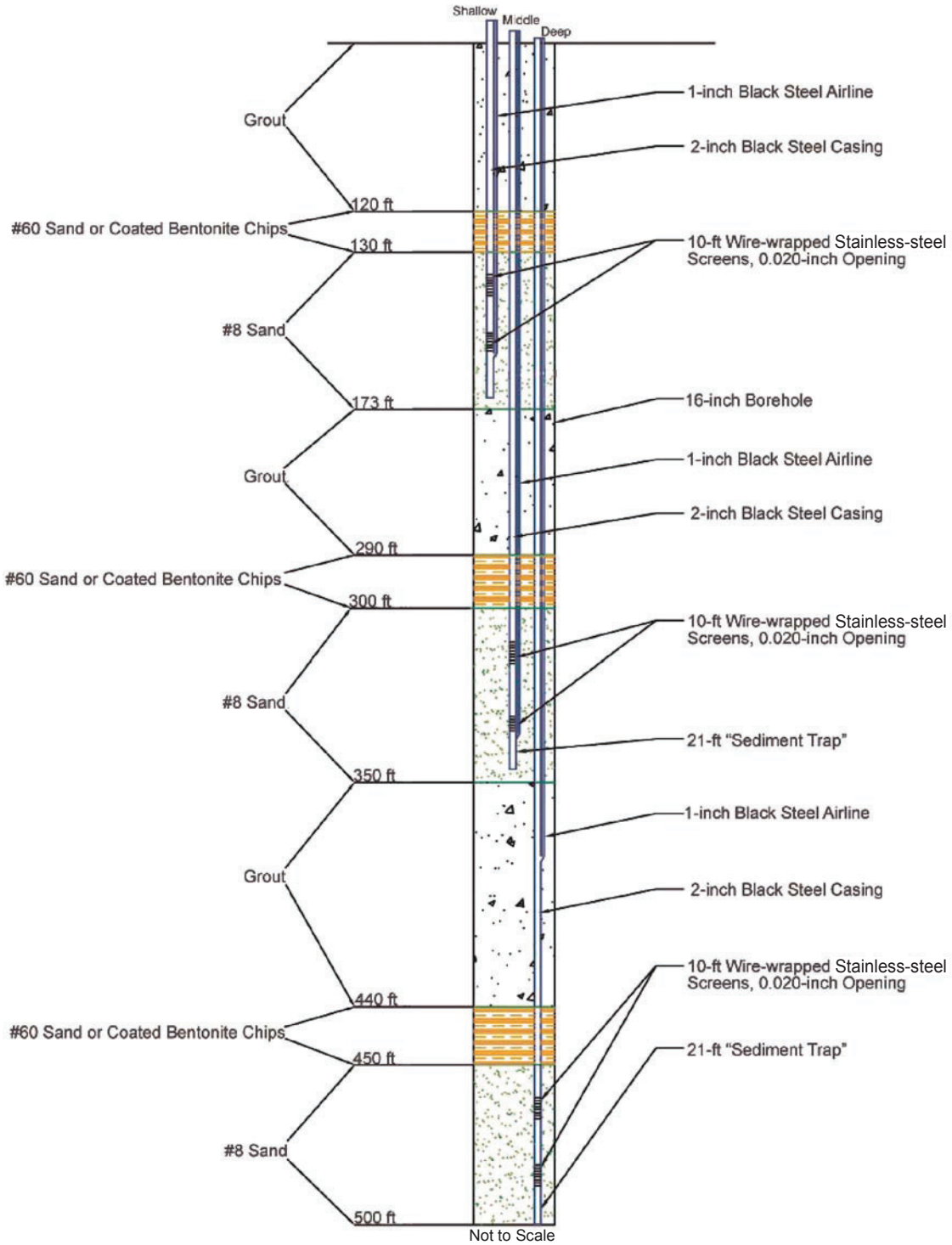


FIGURE 3-4
RD 1500 California Statewide Groundwater Elevation Monitoring (CASGEM) Map
RD 1500 and Sutter Basin Partners
Groundwater Management Plan
Sutter County, California

CH2MHILL®



NOTES:

1. Information shown on this drawing should be considered general design guidelines and does not reflect a final well design. Each well is designed based on actual local conditions found at the time of construction.

2. Design drawing provided by DWR, Division of Local Assistance (Northern District). Dated 01/15/2002.

Not for Construction

FIGURE 3-5
Multi-completion Groundwater Monitoring Well Design, Typical
RD 1500 and Sutter Basin Partners Groundwater Management Plan
Sutter County, California

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SECTION 4

Groundwater Management Plan Implementation

This section identifies the Sutter Basin Partners' proposed approach to implementing the GMP and associated key planning efforts. Implementation of the GMP will continue to be refined over time as information is needed and obtained. The Sutter Basin Partners will continue their groundwater management planning efforts as needs evolve. This section addresses principles of GMP implementation to help achieve the following: (1) meet the minimum requirements of SB 1938 compliance, (2) create a foundation on which the Sutter Basin Partners' groundwater management activities can be based, and (3) promote and implement an adaptive management approach consistent with the Sutter Basin Partners' mission.

4.1 Objectives

The overall GMP goal set the framework for the following objectives; Section 4.2 presents strategies stemming from these objectives:

- **Maintain Sutter Basin long-term agricultural viability** – The viability of Sutter Basin is directly tied to consistent, long-term, and reliable water supply for the Sutter Basin Partners, as well as other Sutter Basin water users.
- **Promote resource sustainability –** Expand knowledge of the Sutter Basin groundwater, and determine feasibility of developing groundwater supplies to add flexibility in water management decisions, improve the timing of flow and availability of water supplies, and support sustainable agriculture and environmental benefit through delivery of high quality irrigation water. This objective directly relates to groundwater management, as defined in DWR Bulletin 118 – Update 2003, *California's Groundwater*: "planned and coordinated monitoring, operation, and administration of a groundwater basin or portion of a groundwater basin with the goal of long-term sustainability of the resource" (DWR, 2003a).
- **Increase long-term water supply reliability –** In 2005, SMWC was one of only two large Sacramento River Settlement Contractors that received a reduction in its surface water contract supply during the settlement negotiations with Reclamation. As a result, Sutter Basin has a reduced reliability of water supply. Because the SMWC, PMWC, and RD 1500 water systems are inter-tied, water use efficiency is one component of meeting the local needs of Sutter Basin during critically dry years. Inherent in this objective is the need to improve critical-period water supply reliability, alleviate localized water shortages, and control the cost of water supply for its users. Even with maximum surface water reuse in dry years, water shortages could occur, especially during critical years. Sutter Basin Partners must confirm that an adequate water supply is available to meet future water needs.

- **Promote cooperative regional outreach and regulatory compatibility –** Endorse and participate in external activities (such as regulatory programs, public outreach and regional groundwater planning) that support these GMP objectives.

These GMP objectives are expected to evolve but will remain consistent with Sutter Basin history, projected use, available information, and the Sutter Basin Partners mission.

4.2 Strategies

The Sutter Basin Partners plan to achieve the previously outlined objectives through implementation of the following GMP strategies:

- Continue and improve groundwater information management through groundwater monitoring, data collection, and evaluation of aquifer properties and subsurface flow; better understand Sutter Basin groundwater quality; study recharge; and support similar analyses and additional groundwater studies.
- Maximize sustainable agricultural production without causing a long-term decline in groundwater quality, and minimize long-term groundwater level drawdown.
- Continue to integrate Sutter Basin's groundwater resource as a supplemental supply through conjunctive use and make water available for in-basin and out-of-basin transfers to improve statewide water supply reliability, while sustaining Sutter Basin water supply and agricultural production.
- Expand knowledge of local aquifer characteristics through continued groundwater monitoring, evaluation of aquifer properties and water flow, and groundwater flow modeling analyses checked against measured hydrologic data.
- Compile additional qualitative information over time to allow for the most efficient use of this resource. Although groundwater in the Sutter Basin has been studied for decades, it is recognized the system is complex, and knowledge of the groundwater quality and quantity, and aquifer properties remains limited.
- Coordinate with other regulatory plans and programs.
  - Participate in the CASGEM program (DWR, 2011b). RD 1500 is coordinating local groundwater monitoring with DWR and local partners as appropriate and as funding allows.
  - Cooperate, where appropriate and applicable, with the groundwater management objectives developed through the ongoing Sutter County GMP process.
  - Comply with SB 1938 and Assembly Bill 3030. The Sutter Basin Partners recognize the importance of being eligible for the funding necessary to develop and monitor the local groundwater resource.
- Update and revise management objectives and strategies as needed, and as groundwater management activities progress. This may include collaborating with local partners to develop additional qualitative and quantitative objectives appropriate to the local groundwater basin's geology and hydrogeology.

District staff will provide an annual report on implementation of the GMP to the RD 1500 Board of Trustees. Updates and modifications will be made, as appropriate, as the groundwater program develops; as funding is obtained for increased monitoring; and as partnerships continue to evolve.

SECTION 5

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Appendix A
1997 Groundwater Management Plan

RECLAMATION DISTRICT NO. 1500

GROUNDWATER MANAGEMENT REPORT

May 1997

Prepared by:

Laugenour and Meikle
608 Court Street
Woodland, CA 95695
(916)662-1755

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PLAN IMPLEMENTATION ..... Page 8

COORDINATION WITH OTHER AGENCIES ..... Page 8

May 22, 1997

RECLAMATION DISTRICT NO. 1500
GROUNDWATER MANAGEMENT PLAN

INTRODUCTION:

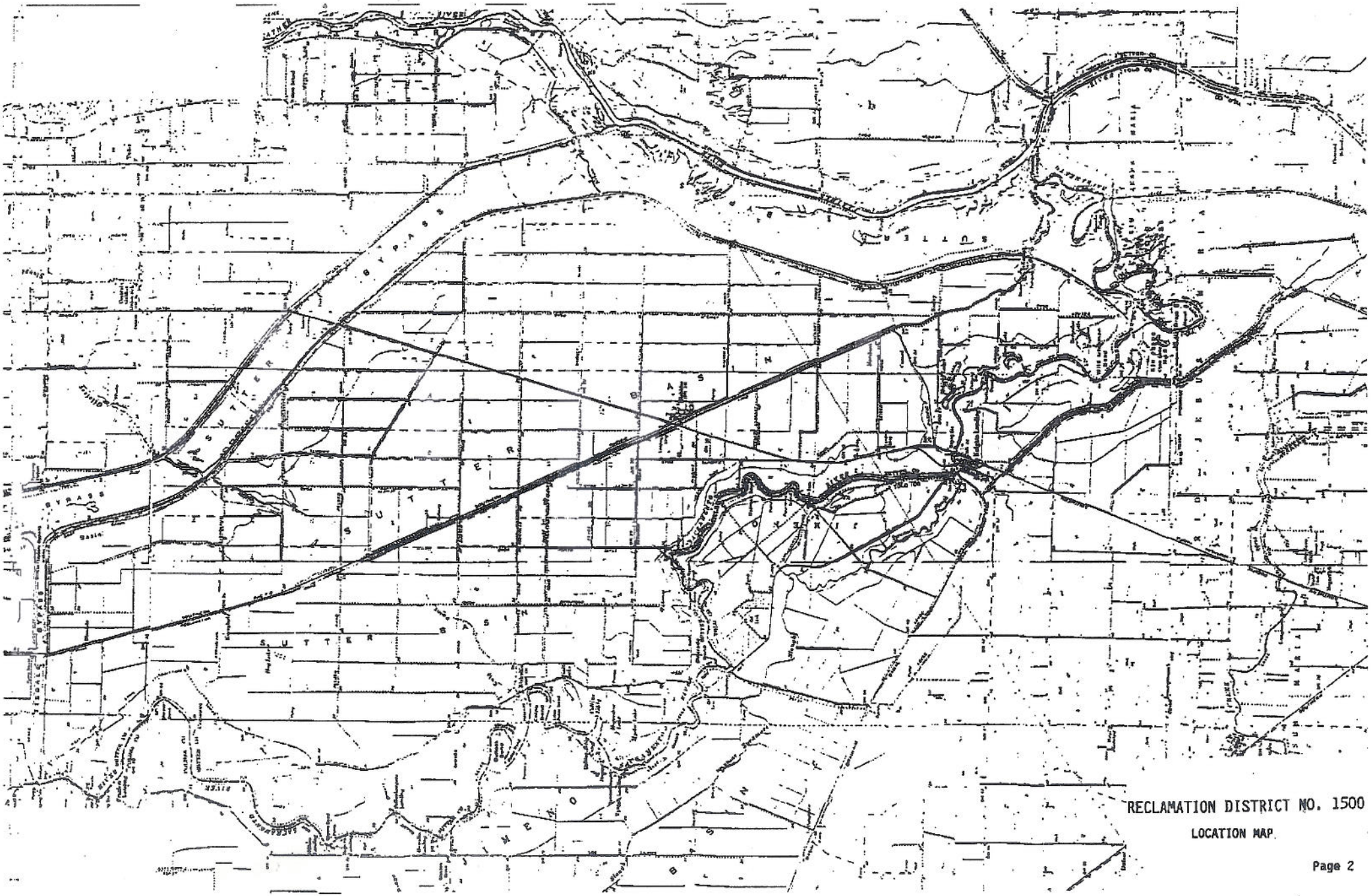
Reclamation District No. 1500 (District) was formed by special act of the State Legislature in 1913 for the purposes of providing drainage and reclamation of the lands within its boundary. The District includes that part of Sutter County lying south of the Tisdale Bypass between the Sacramento River and Sutter Bypass. The gross land area within the District is approximately 67,850 acres.

Within the District, Sutter Mutual Water Company, Pelger Mutual Water Company and landowners supply irrigation water to most of the lands within the service area. The majority of the irrigation water in the study area is surface water diverted from the Sacramento River with a small number of wells scattered along the westerly portion of the District along the Sacramento River.

The service area for this study occupies the Sutter Basin. This nearly level trough is bounded on the south and west by the slightly elevated, recent alluvial deposits of the Sacramento River; and on the north and east by the engineered floodways of the Tisdale Bypass and Sutter Bypass, respectively.

The District is relatively flat, sloping generally in a southeasterly direction, the lowest elevation being near the southeasterly boundary. Slopes vary from 0.05% in the easterly portion of the District to 0.50% in places along the Sacramento River.

The District adopted a Resolution of Intention to draft a Groundwater Management Plan pursuant to Water Code Section 10753 for the purpose of conducting a program for coordinating the collection of data necessary to develop and implement a plan to efficiently manage and monitor the groundwater resources within the District.



RECLAMATION DISTRICT NO. 1500

LOCATION MAP

BASIN RESOURCES:

The irrigation service area enjoys an adequate supply of surface water from the Sacramento River available through riparian and appropriative water rights as well as secured water under contracts with the U. S. Bureau of Reclamation.

- **GROUNDWATER RESOURCES:**

  Approximately 24 irrigation wells exist in the project area ranging in depth from 72 feet to 1,500 feet and with measured total dissolved solids (TDS) concentrations from 248 to 5,970 mg/l. A mound of artesian connate water has been identified in the project area, as shown in the ASAE Soil and Water Division, Paper No. 74-2029, January 1975, by K. K. Tanji, Etal, although insufficient data exists to delineate boundaries between the freshwater and saltwater underlying the area. Figure 1 is a cross-section across the basin depicting the known and conjectured relationships of river, connate and groundwater.

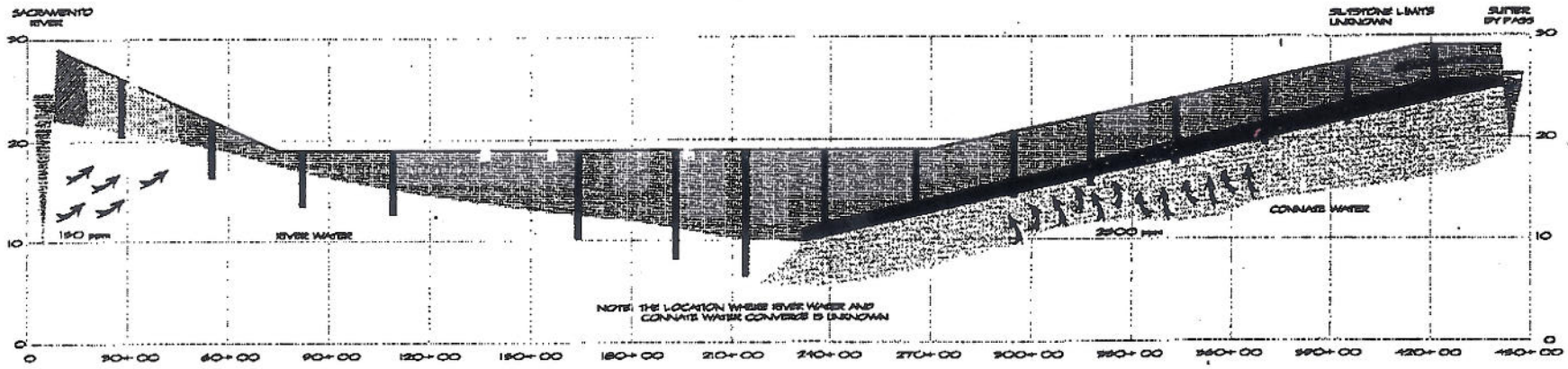
  The high water table in the study area consists of seepage from the river, subsurface interbasin inflow from the surrounding area, and rising connate water under artesian pressure. Due to its high salt content, the groundwater is not used for irrigation except in limited areas along the Sacramento River, where the salt content can be much lower.

  One potential source for salt buildup in the groundwater is the upward movement of deep lying connate water driven by freshwater under an artesian head.

  The concentration of salts increases with depth below ground. Ten to 20 feet below the surface the electrical conductivity (EC) ranges from 1,000 to 4,000 micromhos/cm while 100 to 300 feet below surface the EC range increases from 8,000 to 13,000 micromhos/cm (Tanji, 1975).

  The salt-laden groundwater seeps into the drain ditches and causes an increase in EC in the drains. The salt concentration in the main drain is typically much higher during the winter than during the irrigation season. The good quality irrigation water dilutes the salty ground and drain waters. The irrigation season runs from April through October. During this season from 1987 to 1992 the EC of the main drain at Karnak varied from 380 to 780 micromhos/cm. In the winter the EC ranged from 420 to 1,500 micromhos/cm (USDA Natural Resources Conservation Service, February 1996).

FIGURE 1



SECTION A - A

For the location of SECTION A-A see the DRAINAGE MAP

LEGENDS

SOILS		SUB-STRATUM	
SILTY CLAY LOAM		SILTSTONE	
SILT LOAM		SANDSTONE	
CLAY			
IRRIGATION DITCH		DRAINAGE DITCH	

U.S. DEPARTMENT OF AGRICULTURE
NATURAL RESOURCES CONSERVATION SERVICE

TITLE: TYPICAL VALLEY X-SECTION

DRAWING NO.

DESIGNED BY | CHECKED BY | APPROVED BY

SCALE: As Shown | DRAWN BY: G. M. Shown | DATE | SHEET OF

A report of Supplemental Water Supplies for Sutter Mutual Water Company, prepared by William R. Gianelli, September 1962, investigated groundwater alternatives other than Central Valley Project Water. However, the nature of the quality of the groundwater was not well understood at that time, and implementation of the alternatives may exacerbate the high salt concentrations already found in some areas.

- **CONNATE WATER:**

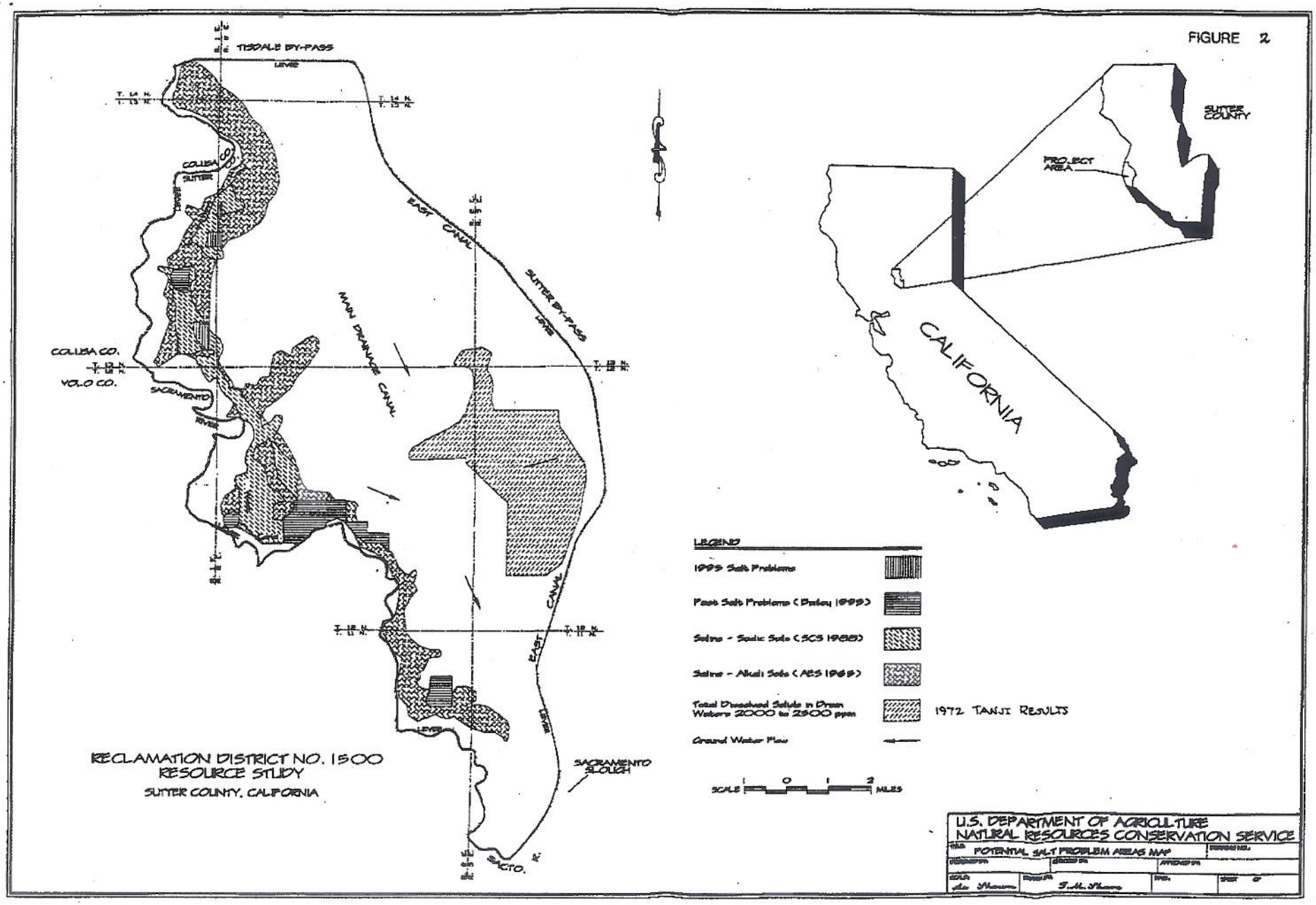
  In 1972, based on the EC of drain waters, Ken Tanji delineated the area shown on Figure 2 having TDS ranging from 2,000 to 2,500 parts per million (ppm) (Tanji, 1972).

  This area coincides with a saline groundwater mound referred to as connate water lying at a depth of approximately 1,968 feet in alluvial and non-marine sediments as shown in "a three-dimensional finite element groundwater mode", Contrib. 152, 119 pp., Water Resource Center, University of California, Davis, 1975, by S. K. Gupta, Etal. An inland sea is believed to have been trapped during the Late Paleocene Period leaving a mound of connate water in the Kione Formation, Upper Cretaceous. This connate water, containing principally sodium and chloride, is thought to rise upwards along the Sutter Basin Fault under artesian pressure. The pressure is created by inflows of fresh water into the Kione sand formation at Sutter Buttes. The hydraulic head is estimated to be 262 to 426 feet (Tanji, 1975). The 1971 Hydrogeology of the Sutter Basin, Sacramento Valley, California M.S. Thesis, University of Arizona, 83 pp., by G. Curtin and Tanji's (1975) findings pointed to the major salt load in discharges at Karnak as being rising connate water, altered somewhat in cationic composition due to ion exchange.

Since inception of the Groundwater Management Plan the District has initiated a groundwater monitoring program collecting well level data and water quality information relating to surface water quality within the service area.

The District has worked closely with State and Federal agencies to evaluate the potential groundwater resource. Additionally, coordination of these activities will be pursued with adjoining districts to evaluate variations of groundwater levels over time and to quantify safe yield to protect the groundwater basin and to promote development of guidelines to preserve the resource.

FIGURE 2


TISDALE BY-PASS
LEVEE
COLUSA
SUTTER
COLUSA CO.
YOLO CO.
SACRAMENTO
RIVER
MAIN DRAINAGE CANAL
EAST CANAL
SUTTER BY-PASS
LEVEE
SACRAMENTO SLOUGH
SACTO. R.
SUTTER COUNTY
PROJECT AREA
CALIFORNIA
LEGEND
1995 Salt Problems
Past Salt Problems (Bailey 1999)
Saline - Sodic Soils (SCS 1988)
Saline - Alkali Soils (ABS 1969)
Total Dissolved Solids in Drain Waters 2000 to 2500 ppm
Ground Water Flow
1972 TANJI RESULTS
SCALE 1 0 1 2 MILES
RECLAMATION DISTRICT NO. 1500
RESOURCE STUDY
SUTTER COUNTY, CALIFORNIA
U.S. DEPARTMENT OF AGRICULTURE
NATURAL RESOURCES CONSERVATION SERVICE
POTENTIAL SALT PROBLEM AREAS MAP

PLAN COMPONENTS:

The objective of the District is to monitor and analyze the groundwater resource and develop a complete inventory of known and potential sources and areas of groundwater. Primary components of the District's Plan include the following:

1. Compile water level measurements within the groundwater basin and evaluate the data to determine variations of groundwater levels over time:

   The District began monitoring of wells in 1983 with the goal of developing information on the groundwater basin to provide a reliable basis for water resource management in the area. This activity included gathering information on irrigation wells within the District, monitoring static and pumping levels during the irrigation season. Additionally EC sampling was undertaken to supplement ongoing water quality testing.

2. Sample and test groundwater for chemical constituents to determine background data on water quality:

   The District since the early 1970's has worked with the University of California, Davis in investigating the historic groundwater movement and quality within the study area. The U.S. Geological Survey (USGS) in 1997 will be conducting a study of shallow groundwater quality in the Sacramento Valley to also obtain information on the water chemistry and the effects certain crops have on water quality.

3. Provide recommendations on conjunctive use of groundwater and limitations, if any, on commingling with surface water supplies:

   The water purveyors within the study area currently utilize conjunctive use concepts through use of drain water recycling, thereby, reusing groundwater and surface water supplies, where feasible for augmenting the irrigation water resource. The existence of saline groundwater in the District has diminished the desire to use groundwater to a greater extent and until the results of the monitoring program are known, there will be no immediate plans to enhance a conjunctive use project utilizing the groundwater supply.

PLAN IMPLEMENTATION:

The District will continue to study the groundwater quality in the area and in conjunction with USGS and water quality and quantity monitoring being conducted by the DWR in Yolo and Colusa County adjacent to the District will compile information on the groundwater basin. The District will then evaluate the data and consider such further action as may be deemed appropriate, following the analysis, to implement the plan.

COORDINATION WITH OTHER AGENCIES:

The District will meet, at least annually, with other local agencies within the same groundwater basin conducting groundwater management programs to coordinate the respective programs pursuant to Water Code Section 10755.3.

Appendix B
Resolutions

RESOULTION 2012 - 1

**RESOULTION OF THE BOARD OF TRUSTEES
OF RECLAMATION DISTRICT 1500
TO ADOPT THE RECLAMATION DISTRICT 1500/SUTTER BASIN PARTNERS'
GROUNDWATER MANAGEMENT PLAN**

WHEREAS, on March 29, 2011, Reclamation District 1500 provided notice of their intent to prepare a Groundwater Management Plan pursuant to California Water Code §10750 *et seq*, AB 3030, and SB 1938; and

WHEREAS, any local agency, whose service area includes a groundwater basin, or a portion of a groundwater basin, that is not subject to groundwater management pursuant to other provisions of law or a court order, judgment, or decree, may by ordinance, or by resolution if the local agency is not authorized to act by or ordinance, adopt and implement a Groundwater Management Plan; and

WHEREAS, Reclamation District 1500 has prepared a Groundwater Management Plan pursuant to California Water Code §10750 *et seq*, AB 3030, and SB 1938; and

WHEREAS, prior to resolving to adopt a Groundwater Management Plan the local agency must hold a public hearing pursuant to Water Code §10753.5(a), and said meeting must be noticed pursuant to Water Code §10753.2(a); and

WHEREAS, such a hearing was so noticed and held on February 28, 2012, at 9:00 a.m. in the District Office at 15094 Cranmore Road, Robbins, California.

NOW, THEREFORE, BE IT RESOLVED that Reclamation District 1500 does hereby adopt, and direct the implementation of, the Reclamation District 1500/Sutter Basin Partners' Groundwater Management Plan pursuant to Water Code §10753.6(c)(3).

PASSED AND ADOPTED this **28th day of February 2012**, the following Trustees voting thereon:

Aye:	6
No:	0
Abstain:	0
Absent:	1

Vice President, Board of Trustees

Attest:

Secretary, Board of Trustees

Reclamation District No. 1500

RESOLUTION NO. 2011-2

RESOLUTION OF THE BOARD OF TRUSTEES OF RECLAMATION DISTRICT NO. 1500 TO APPROVE THE FINAL ENVIRONMENTAL ASSESSMENT/INITIAL STUDY AND AUTHORIZE FILING OF THE NOTICE OF DETERMINATION FOR THE PELGER MUTUAL WATER COMPANY GROUNDWATER PRODUCTION ELEMENT PROJECT AND SUTTER MUTUAL WATER COMPANY GROUNDWATER MONITORING PROJECT – INTEGRATED REGIONAL WATER MANAGEMENT PROGRAM

WHEREAS, Reclamation District No. 1500 is the lead agency for a project known as the Pelger Mutual Water Company Groundwater Production Element Project and Sutter Mutual Water Company Groundwater Monitoring Project - Integrated Regional Water Management Program; and

WHEREAS, the Board of Trustees has caused the preparation of documentation under the California Environmental Quality Act (CEQA) to evaluate the environmental impacts of the proposed projects; and

WHEREAS, a Mitigation Monitoring and Reporting Program has been prepared for the projects; and

WHEREAS, the EA/IS have been prepared for Reclamation District No. 1500 in accordance with CEQA and have been circulated for public review and comment in accordance with the Guidelines under CEQA; and

WHEREAS, the Board, based on: the Draft EA/IS; changes to the Draft EA/is; and consideration of the comments and responses to the draft documents, has determined there is no substantial evidence that the projects, as mitigated, will have a significant effect on the environment; and

WHEREAS, the Final EA/IS and Mitigated Negative Declaration reflects the independent judgment of the Board of Trustees for Reclamation District No. 1500.

NOW THEREFORE BE IT RESOLVED by the Board of Trustees of Reclamation District No. 1500 that the Final Environmental Assessment/Initial Study and Mitigated Negative Declaration, and the Mitigation Monitoring and Reporting Program for the Pelger Mutual Water Company Groundwater Production Element Project and Sutter Mutual Water Company Groundwater Monitoring Project - Integrated Regional Water Management Program are hereby approved; and

BE IT FURTHER RESOLVED that the General Manager of Reclamation District No. 1500 is directed to file a Notice of Determination with the State Clearinghouse and with the Clerk of Sutter County within five days of the date of this resolution.

PASSED AND ADOPTED this **sixth** day **of December, 2011** at **Kirkville, CA**, the following Trustees voting thereon:

Aye:	7
No:	0
Abstain:	0
Absent:	0

Scott C Tucker

President of the Board of Trustees

Attest:

Assistant Secretary to the Board of Trustees

No. 2011-2
Resolution of the Board of Trustees
Of the Reclamation District No. 1500
Notice of Intent
to
Prepare a Groundwater Management Plan Update

WHEREAS, the Legislature finds and declares that groundwater is a valuable natural resource in California and should be managed to ensure both its safe production and its quality; and

WHEREAS, it is the intent of the Legislature through the passage of AB 3030 (Stats 1992) and SB 1938 (Stats 2000) codified as the Water Code 10750 *et seq.* to encourage local agencies to work cooperatively to manage groundwater resources within their jurisdictions; and

WHEREAS, the Legislature also finds and declares that the additional study of groundwater resources is necessary to better understand how to manage groundwater effectively to ensure the safe production, quality, and proper storage on groundwater in this state; and

WHERAS, the adoption of a Groundwater Management Plan and periodic update are encouraged, but not required by law; and

WHEREAS, Reclamation District No. 1500 has committed to responsible water resource management within the Basin and is interested in working through regional partnerships to update the Groundwater Management Plan drafted in 1997; and

WHEREAS, prior to adopting a resolution of intent to draft an update to the groundwater management plan, Reclamation District No. 1500 is committed to holding a public meeting as to whether to adopt a resolution of intention to update the Groundwater Management Plan; and

WHEREAS, such a public meeting was noticed pursuant to Government Code 6066 and held on March 29, 2011, at 11:00 am at the Reclamation District No. 1500 office at 15094 Cranmore Rd, Robbins, CA 95676; and

WHEREAS, at the conclusion of the hearing, the local agency may draft a resolution of intention to adopt a groundwater management plan update for the purposes of implementing the plan and continuing to investigate and potentially establish a groundwater management program.

NOW, THEREFORE, BE IT RESOLVED, that the Board of Trustees of the Reclamation District No. 1500 hereby agree to:

1. Adopt a Resolution of Intent to Update the District's Groundwater Management Plan
2. Direct the Secretary of the Board to publish the Resolution of Intent under Government Code 6066 pursuant to Water Code 10753.3 (a)
3. Direct the management to have the groundwater management plan update prepared.
4. Direct the management to have the groundwater management plan update prepared within one year of the date of the Resolution of Intent

PASSED and ADOPTED by the Board of Trustees of the Reclamation District No. 1500 on this the 29th day of March, 2011 by the following vote:

AYES:	7
NOES:	0
ABSENT:	0
NOT VOTING:	0

George Van Ruiten
President of the Board

ATTEST:
Max Sakato
General Manager and Secretary of the Board

BY _____

No. 2011-1
Resolution of the Board of Trustees of Reclamation District No. 1500 (RD 1500)

Participation and Registration in the DWR-CASGEM Program

Whereas, on November 4, 2009 the State Legislature amended the California Water Code with SBx7-6, which mandates a statewide groundwater elevation monitoring program to track seasonal and long-term trends in groundwater elevations in California's groundwater basins, and

Whereas, to achieve that goal, the amendment requires collaboration between local monitoring entities and California Department of Water Resources (DWR) to collect groundwater elevation data, and

Whereas, collection and evaluation of such data on a statewide scale is an important fundamental step toward improving management of California's groundwater resources, and

Whereas, in accordance with this amendment to the California Water Code, DWR developed the California Statewide Groundwater Elevation Monitoring (CASGEM) program with the intent to establish a permanent, locally managed program of regular and systematic monitoring in all of California's alluvial groundwater basins, and

Whereas, the CASGEM program will rely and build on the many, established, local long-term groundwater monitoring and management programs; and DWR's role is to coordinate the CASGEM program, work cooperatively with local entities, and maintain the collected elevation data in a readily and widely available public database, and

Whereas, the law anticipates that the monitoring of groundwater elevations required by the enacted legislation will be performed by local entities, and

Whereas, the law requires local entities to notify DWR in writing, preferably by January 1, 2011, if the local agency or party seeks to assume groundwater monitoring functions in accordance with the law, and

Whereas, local parties may assume responsibility for monitoring and reporting groundwater elevations, and

Whereas, if local parties (for example, counties) do not volunteer to perform the groundwater monitoring functions, and DWR assumes those functions, then those parties become ineligible for water grants or loans from the state, and

Whereas, legal counsel has confirmed that RD 1500 has legal basis for participation in the program,

NOW THEREFORE BE IT RESOLVED, that the RD 1500 Board of Trustees has authorized RD 1500 to participate and act as the lead agency for fulfilling the monitoring and reporting

requirements under the CASGEM program, while including Sutter Mutual Water Company and Pelger Mutual Water Company as cooperative joint partners; and authorizes the RD 1500 General Manager to act in all and any manners to comply with the California Water Code and SBx7-6 law requirements and CASGEM criteria.

PASSED and ADOPTED by the RD 1500 Board of Trustees on this the 22th day of February 2011, by the following vote:

AYES:	4
NOES:	0
ABSENT:	3
NOT VOTING:	0

George Van Ruiten
President

ATTEST:
Max Sakato
General Manager and Secretary

BY _____

RATIFICATION OF RESOLUTION NO. 2010-1

A RESOLUTION OF THE BOARD OF DIRECTORS OF SUTTER MUTUAL WATER COMPANY AUTHORIZING ITS GENERAL MANAGER TO REPRESENT THE COMPANY IN PLANNING A PROPOSITION 50 GROUNDWATER PROJECT

WHEREAS, Sutter Mutual Water Company ("Sutter Mutual") is planning a groundwater enhancement project ("Project") under the Sacramento Valley Integrated Regional Water Management Plan, to be funded through the Water Security, Clean Drinking Water, Coastal and Beach Protection Act of 2002, Water Code Section 79500 *et seq.* ("Proposition 50");

WHEREAS, in connection with this Project Sutter Mutual must complete preliminary planning, conduct environmental review and prepare environmental documentation, and secure state grant funding under Proposition 50 as well as possible federal funding;

WHEREAS, in order to undertake this planning process in an expeditious manner, Sutter Mutual must participate in negotiations with other entities, attend meetings, enter into agreements, and prepare documents; and

WHEREAS, the Board of Directors of Sutter Mutual has determined that it is in Sutter Mutual's best interest to participate in such negotiations and meetings, execute such agreements and documents, and undertake all other work necessary to allow for expeditious planning and environmental review of the Project, and to secure state and/or federal funding for the Project.

NOW, THEREFORE, BE IT RESOLVED:

1. The General Manager of Sutter Mutual is hereby authorized to represent Sutter Mutual in all negotiations and meetings concerning the Project, and to execute all necessary agreements and documents on behalf of Sutter Mutual regarding the Project, including state or federal environmental review and funding.

2. The General Manager of Sutter Mutual may take action to bind Sutter Mutual to financial obligations relating to the Project.

3. This Resolution is effective as of January 13, 2010.

RATIFIED by vote of the Board of Directors on June 9, 2010.

By: _____

Title: President BOD.

CERTIFICATION

I, MAX SAKATO, certify that I am, and at all times mentioned herein was, the duly appointed, qualified and acting Secretary of the Board of Directors of Sutter Mutual Water Company; that the foregoing is a full, true and correct copy of a Resolution duly and regularly ratified at a meeting of the Board of Directors of said Company duly and regularly held the 9th day of June 2010, a majority and quorum of the members of said Board being present and voting in favor of said Resolution; and that said Resolution has not been modified, rescinded, altered or amended and is now in full force and effect.

WITNESS my hand this 9th day of June, 2010.

Max Sakato

Secretary, Board of Directors

Appendix C
California Statewide Groundwater Elevation Monitoring Plan

APPENDIX C

Reclamation District No. 1500 CASGEM Groundwater Elevation Monitoring Plan

This document outlines the groundwater monitoring plan for Reclamation District No. 1500 (RD 1500) in cooperation with local water purveyors Sutter Mutual Water Company (SMWC) and Pelger Mutual Water Company (PMWC). This monitoring plan is compliant with the California Statewide Groundwater Elevation Monitoring (CASGEM) program administered by the California Department of Water Resources (DWR). This plan outlines RD 1500's groundwater elevation monitoring program in conjunction with DWR's ongoing groundwater elevation monitoring program, including well network, monitoring schedule, field methods, and monitoring rational.

DWR currently conducts biannual groundwater elevation monitoring in the Sutter Subbasin. In the future, DWR may not have the ability to conduct this regular sampling. RD 1500, in cooperation with SMWC and PMWC (Sutter Basin Partners), will coordinate with DWR to administer biannual groundwater elevation monitoring now and in the future.

Monitoring Well Network

The Sutter Subbasin monitoring well network consists of twelve wells (including three well clusters) in the Sutter Subbasin. Figure 1 presents a map showing the existing monitoring well network. Table 1 provides a summary of the CASGEM network. The proposed monitoring well (MW) location, RD 1500 MW-1, will be constructed as a multi-completion monitoring well. CASGEM wells were selected jointly by Sutter Basin Partners and DWR to monitor groundwater levels (and corresponding elevations) in the Sutter Subbasin.

TABLE 1
RD 1500 CASGEM Network Summary
Reclamation District No. 1500 CASGEM Groundwater Elevation Monitoring Plan

General Location Within RD 1500	State Well Number
North Central	RD 1500 MW-1a
	RD 1500 MW-1b (potential middle completion)
	RD 1500 MW-1c (potential deep completion)
Northwest	13N01E24G002M
	13N01E24G003M
	13N01E24G004M
Southeast	12N02E23H001M
	12N02E23H002M
	12N02E23H003M
	12N02E23H004M

TABLE 1
RD 1500 CASGEM Network Summary
Reclamation District No. 1500 CASGEM Groundwater Elevation Monitoring Plan

Southwest	12N02E21Q001M
	12N02E21Q002M
	12N02E21Q003M
South	11N03E20H003M

Monitoring Schedule

Groundwater elevation monitoring is conducted biannually (once in the spring and again in the fall), at a minimum, at each of the active monitoring wells in RD 1500's network that are accessible for monitoring. Consistent with minimum CASGEM requirements, this monitoring is conducted to measure seasonal high and low groundwater elevations for the Sutter Subbasin. Several of the well clusters are instrumented with data-logging pressure transducers, which provide a continuous record of groundwater levels.

Field Methods

To collect quality, consistent, and reliable monitoring data, RD 1500 will conduct monitoring in conjunction with the following established field methods, which are consistent with the DWR Groundwater Elevation Monitoring Guidelines (see Attachment 1):

1. Steps for establishing reference point
    - Determine monitoring location measurement reference point.
    - Refer to specific reference point elevation.
    - Record reference point elevation for monitoring site on the Groundwater Elevation Monitoring Form.
2. Ensure that static (non-pumping) condition exists at monitoring location
    - Record any known current pumping occurring in the vicinity of the current monitoring location.
3. Steps to measure depth to water
    - Lower electronic wire water level indicator down existing well casing.
    - Continue to lower water level indicator into the well until contact buzzer sounds.
    - Raise and lower water level indicator to accurately establish water level.
    - Read level measurement from the reference point.
4. Record measurement
    - Record depth to water level on Groundwater Elevation Monitoring Form.

- Calculate well elevation by subtracting water level measurement from reference point elevation.
- Record water elevation on Groundwater Elevation Monitoring Form.
- An example of the Groundwater Elevation Monitoring Form is attached.

Monitoring Plan Rationale

Specifics about Sutter Subbasin groundwater, including a history of groundwater monitoring in Sutter Subbasin, aquifer features, and groundwater conditions, can be found in the *Reclamation District No. 1500 and Sutter Basin Water Management Partners Groundwater Management Plan* (GMP) (CH2M HILL, 2011). The GMP also defines the conjunctive use of the Sutter Basin Partners to efficiently manage sustainable groundwater recourses in the Sutter Subbasin.

DWR has historically monitored groundwater elevations through biannual water level surveys in the Sutter Subbasin. In the future, the administration of this monitoring program may be transferred from DWR to the Sutter Basin Partners.

Works Cited

CH2M HILL. 2011. *Reclamation District No. 1500 and Sutter Basin Water Management Partners Groundwater Management Plan*. December.

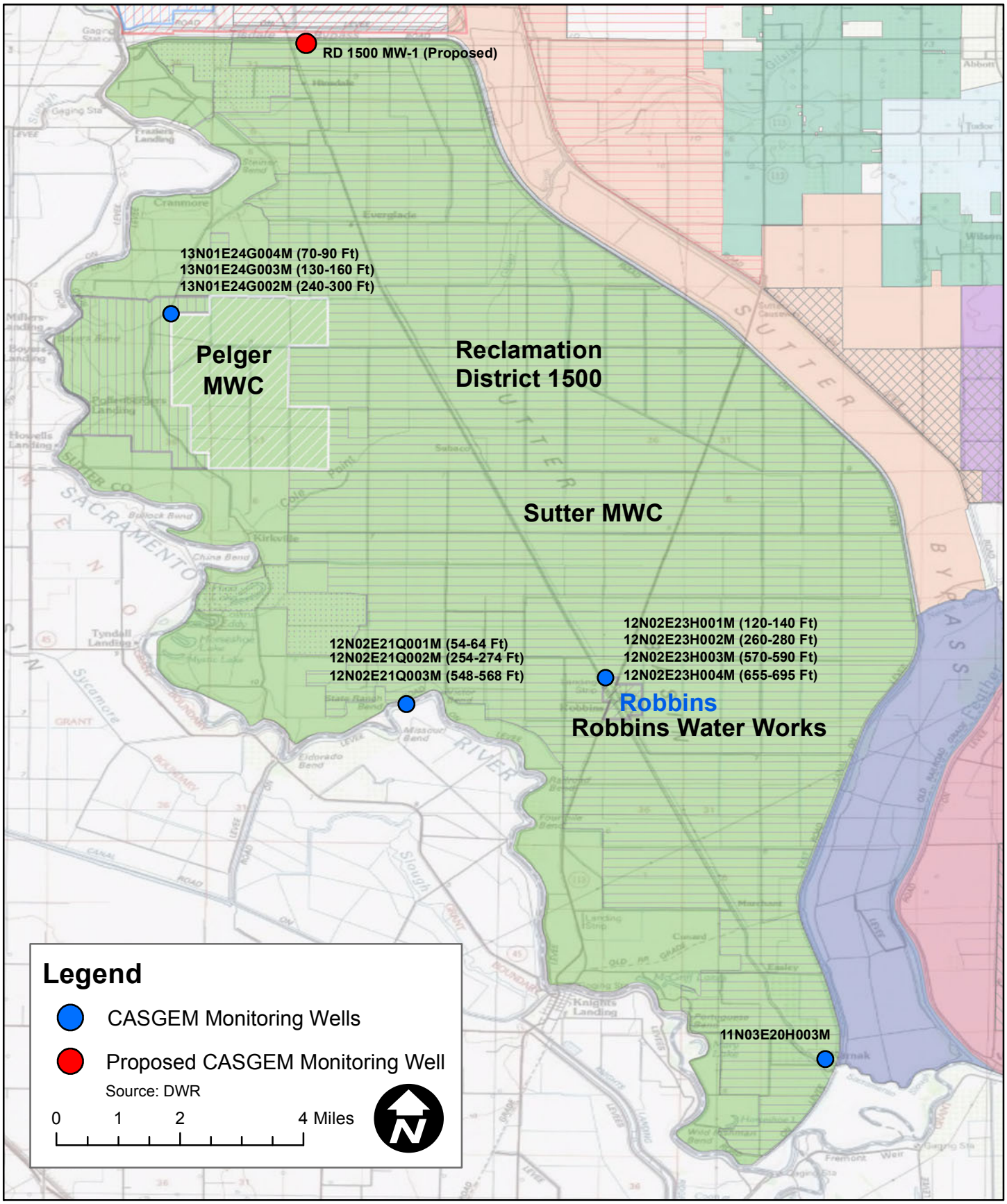


FIGURE 1
RD 1500 California Statewide Groundwater Elevation Monitoring (CASGEM) Map
Reclamation District No. 1500
CASGEM Elevation Monitoring Plan

CH2MHILL®

WBG072511212716RDD_E-01

Attachment 1
California Department of Water Resources
Groundwater Elevation Monitoring Guidelines

Department of Water Resources

Groundwater Elevation Monitoring

Guidelines

December 2010

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INTRODUCTION TO THE CASGEM PROGRAM

On November 4, 2009 the state legislature amended the Water Code with SB 6, which mandates a statewide, locally-managed groundwater elevation monitoring program to track seasonal and long-term trends in groundwater elevations in California's groundwater basins. To achieve that goal the amendment requires collaboration between local Monitoring Entities and the Department of Water Resources (DWR) to collect groundwater elevation data. In accordance with the amendment, DWR developed the California Statewide Groundwater Elevation Monitoring (CASGEM) program.

If no local entities volunteer to monitor groundwater elevations in a basin or part of a basin, DWR may be required to develop a monitoring program for that part. If DWR takes over monitoring of a basin, certain entities in the basin may not be eligible for water grants or loans administered by the state.

DWR will report findings of the CASGEM program to the Governor and the Legislature by January 1, 2012 and thereafter in years ending in 5 or 0.

PURPOSE OF GUIDELINES FOR DWR MONITORING

The following Guidelines were developed to assist DWR by establishing criteria for the selection and measurement of monitoring wells in the event that DWR is required to perform the groundwater monitoring functions in lieu of a local monitoring agency pursuant to Water Code Section 10933.5(a).

The primary objective of the CASGEM monitoring program is to define the seasonal and long-term trends in groundwater elevations in California's groundwater basins. The scale for this evaluation should be the static, regional groundwater table or potentiometric surface. A secondary objective is to provide sufficient data to draw representative contour maps of the elevations. These maps could be used to estimate changes in groundwater storage and to evaluate potential areas of overdraft and subsidence.

Although it is not an objective of the CASGEM program, it would be valuable to include monitoring wells near localized features that impact more dynamic groundwater elevations. These features would include wells near aquifer storage and recovery projects, near high volume pumping wells, and near rivers.

NETWORK DESIGN CONCEPTS

SELECTION OF MONITORING WELLS FOR MONITORING PLANS

The number of groundwater wells that need to be monitored in a basin to adequately represent static water levels (and corresponding elevations) depends on several factors, some of which include: the known hydrogeology of the basin, the slope of the groundwater table or potentiometric surface, the existence of high volume production wells and the frequency of their use, and the availability of easily-accessible monitoring wells. Dedicated groundwater monitoring wells with known construction information are preferred over production wells to determine static water levels, and monitoring wells near rivers or aquifer storage and recovery projects should be avoided due to the potential for rapidly fluctuating water levels and engineered groundwater systems. The selection of wells should be aquifer-specific and wells which are screened across more than one aquifer should not be candidates for selection.

Heath (1976) suggested a density of groundwater monitoring wells ranging from 2 wells per 1,000 square miles (mi^2) for a large area in which only major features are to be mapped, to 100 wells per 1,000 mi^2 for a complex area to be mapped in considerable detail. The objective of the Heath (1976) design was to evaluate the status of groundwater storage and the areal extent of aquifers.

Sophocleous (1983) proposed a redesign of a water-level monitoring program for the state of Kansas based on efficiency, economics, statistical analysis, comparison of water-level hydrographs, and consistency across the state. The Sophocleous study recommended a “square well network” with a density of 1 observation well per 16 mi^2.

The Texas Water Development Board proposed varying well network densities for counties according to the amount of groundwater pumpage. These densities range from 0.7 wells per 100 mi^2 for counties with 1,000-2,500 acre-feet per year (AF/yr) of pumpage to 4 wells per 100 mi^2 for counties with over 100,000 AF/yr of pumpage (Hopkins, 1994). These densities were converted to pumpage per 100 mi^2 area by dividing by the size of an average county in Texas of about 1,000 mi^2 (Table 2)

Most designs of water-level monitoring programs rely on a probabilistic approach. Alley (1993) discussed four probabilistic designs: (1) simple random sampling throughout an aquifer; (2) stratified random sampling within different strata of an aquifer; (3) systematic grid sampling (e.g., at the midpoint of each section within an aquifer); and (4) random sampling within blocks (e.g., randomly selected wells within each section of an aquifer). The Sophocleous (1983) program used the third approach, systematic grid sampling. The guidelines on well density from the programs mentioned above are summarized in Table 2.

Based on the few referenced studies with specific recommendations, the consensus appears to fall between 2 and 10 groundwater monitoring wells per 100 mi^2. The

exceptions to this density range include the lower end of the Heath (1976) range and the low-use counties in Texas.

There will always be a tradeoff between the improved spatial (and temporal) representation of water levels in an aquifer and the expense of monitoring. A higher-resolution contour map would be warranted in an area with a greater reliance upon groundwater in order to anticipate potential problems, such as supply and groundwater contamination concerns, while a lower-resolution contour map might be sufficient in an area with few people or a low reliance upon groundwater. Ideally, areas with relatively steep groundwater gradients or areas of high recharge or discharge would have a greater density of monitoring wells.

The illustrations in Figure 1 show a local groundwater elevation contour map developed with different numbers of wells. The examples cover the same area and use the same dataset, with wells randomly deleted by grid area from the full dataset to create a less dense network of wells. The resulting range of plotting density is 2 to 20 groundwater monitoring wells per 100 mi^2. The contours in Figure 1 show how the accuracy and resolution of the contour map increases with the density of wells used for plotting. To avoid presenting misleading contour maps, only wells with the best possible elevation accuracies should be used. These accuracies are a combination of the accuracies in the water-level measurement and the reference point (RP) measurement. Unless the RP elevation has been surveyed, it will be the limiting factor on elevation accuracy.

Program and(or) Reference	**Density of monitoring wells (wells per 100 mi^2)**
Heath (1976)	0.2 – 10
Sophocleous (1983)	6.3
Hopkins (1994) (a) Basins with >10,000 AF/yr groundwater pumping per 100 mi^2 area	4.0
(b) Basins with 1,000-10,000 AF/yr groundwater pumping per 100 mi^2 area	2.0
(c) Basins with 250-1,000 AF/yr groundwater pumping per 100 mi^2 area	1.0
(d) Basins with 100--250 AF/yr groundwater pumping per 100 mi^2 area	0.7

Table 1. Recommended density of monitoring wells for groundwater-level monitoring programs.

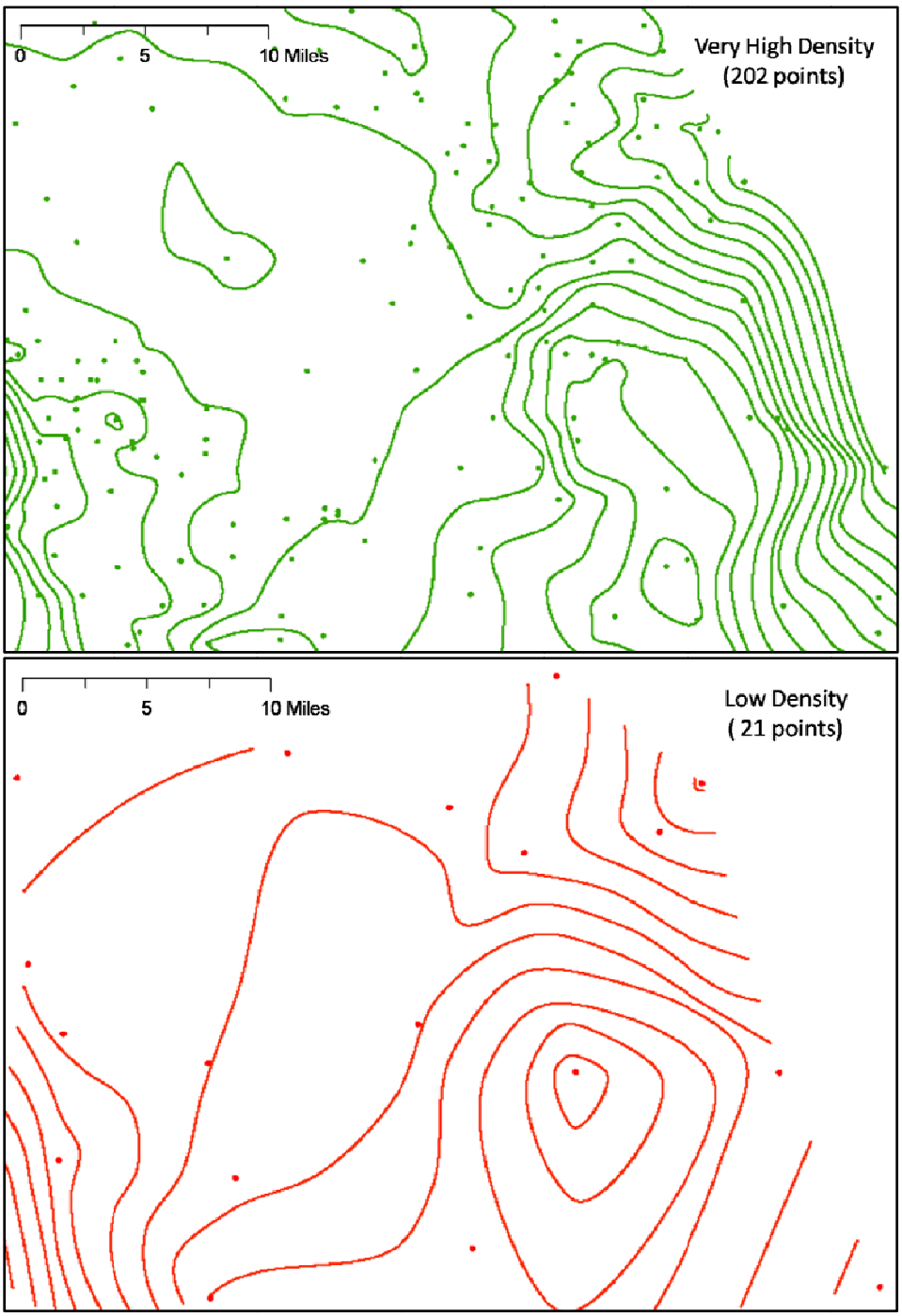

Figure 1. Contour maps – Contours of a very high-density well network (about 20 wells per 100 mi^2) compared to a low-density well network (about 2 wells per 100 mi^2).

FREQUENCY OF WATER-LEVEL MEASUREMENTS

To determine and define seasonal and long-term trends in groundwater levels a consistent measurement frequency must be established. At minimum, semi-annual monitoring of the designated wells in each basin or subbasin should be conducted to coincide with the high and low water-level times of year for each basin. However, quarterly- or monthly-monitoring of wells provides a better understanding of groundwater fluctuations. The DWR office responsible for monitoring a particular basin should use independent judgment to determine when the high and low water-level times occur in a groundwater basin, and to provide a justification for measurement rationale. The semi-annual frequency is a compromise between more frequent measurements (continuous, daily, monthly, or quarterly) and less frequent measurements (annual). A good discussion of water level measurement frequency and other issues related to the design of water-level monitoring programs can be found in the USGS Circular 1217 (Taylor and Alley, 2001).

An example of the effect of different measurement frequencies on the water-level hydrographs in a Northern California well is shown in Figure 2. The data shows that higher-frequency monitoring (e.g., daily or monthly) best captures the seasonal fluctuations in the groundwater levels, quarterly monitoring identifies some of the elevation change, but semi-annual measurements often miss the true seasonal highs and lows.

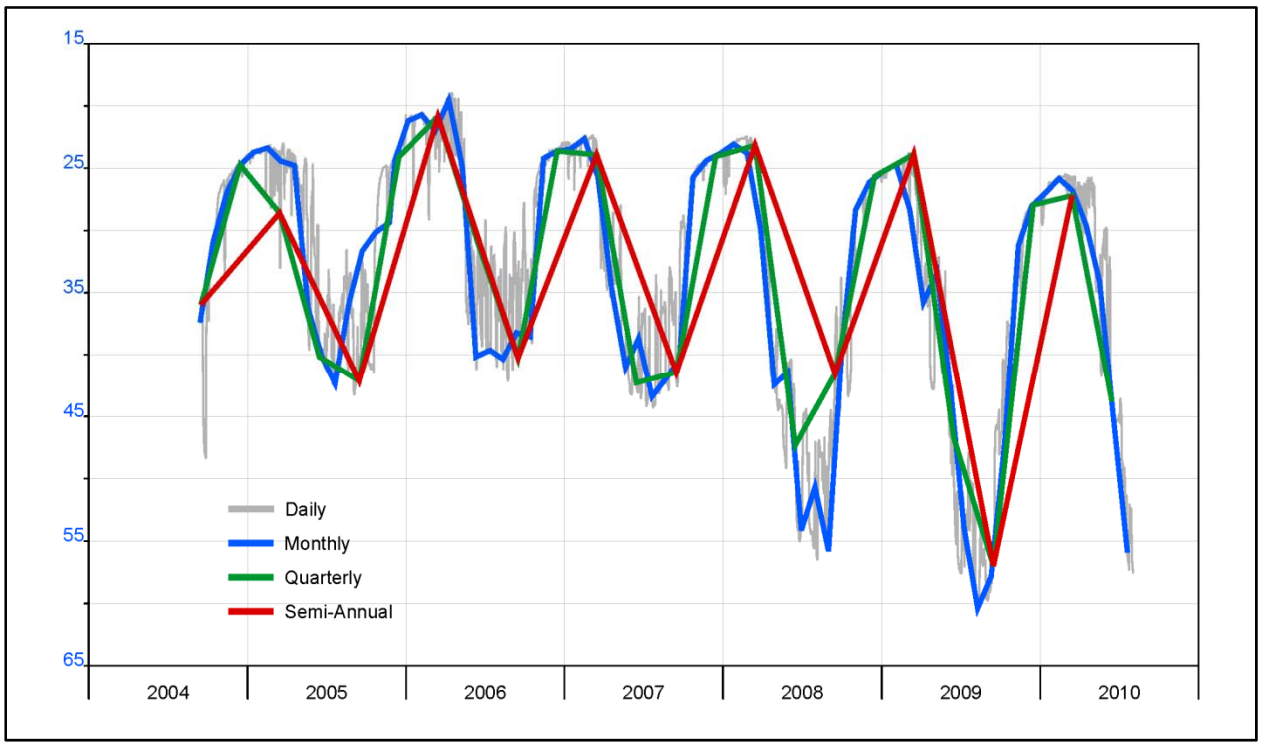

Figure 2. Groundwater Hydrographs – Groundwater elevation changes in a monitoring well over time comparing various measurement frequencies.

The Subcommittee on Ground Water of the Advisory Committee on Water Information generally recommends more frequent measurements than are being required by the CASGEM program; quarterly to annually for aquifers with very few groundwater withdrawals, monthly to quarterly for aquifers with moderate groundwater withdrawals, and daily to monthly for aquifers with many groundwater withdrawals (Table 2). The general effect of environmental factors on the recommended measurement frequency is illustrated in Figure 3.

Measurement Type	**Aquifer Type**	**Nearby Long-Term Aquifer Withdrawals**		
		Very Few Withdrawals	***Moderate Withdrawals***	***Many Withdrawals***
Baseline Measurements	**All aquifer types**	Once per month	Once per day	Once per hour
Surveillance Measurements	**All aquifer types:** "low" hydraulic conductivity (<200 ft/d), "low" recharge (<5 in/yr)	Once per year	Once per quarter	Once per month
	All aquifer types: "high" hydraulic conductivity (>200 ft/d), "high" recharge (>5 in/yr)	Once per quarter	Once per month	Once per day
Data made available to NGWMN	All aquifer types, throughout range of hydraulic conductivity	As stored in local database, but at least annually	As stored in local database, but at least annually	As stored in local database, but at least annually

Table 2. Information on recommended minimum water-level measurement frequency from the Subcommittee on Ground Water of the Advisory Committee on Water Information (2009) (abbreviations: ft/d, feet per day; in/yr, inches per year; NGWMN, National Ground Water Monitoring Network). NOTE: These are not recommendations of the CASGEM program.

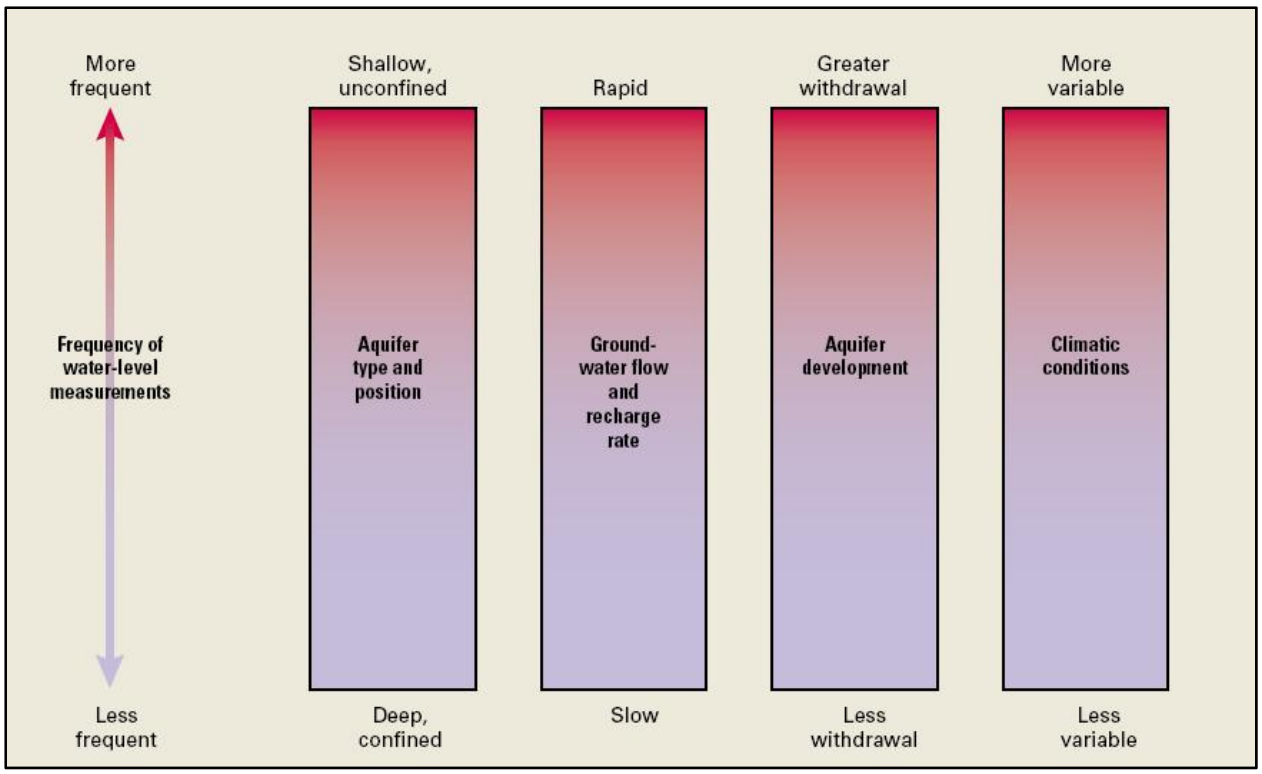

Figure 3. Common environmental factors that influence the choice of frequency of water-level measurements (from Taylor and Alley, 2001).

FIELD GUIDELINES FOR CASGEM WATER-LEVEL MEASUREMENTS

INTRODUCTION

This document presents guidelines for measuring groundwater levels in wells for the CASGEM program to ensure consistency between DWR offices. Following these guidelines will help ensure that groundwater level measurements are accurate and consistent in both unconfined and confined aquifers. Although a well network comprised entirely of dedicated monitoring wells (hereafter referred to as monitoring wells) is preferred, by necessity active production wells used for irrigation or domestic purposes and abandoned production wells that were used for domestic, irrigation, and public supply purposes will also need to be included. **The portions of these guidelines that apply to only production wells will be shown in bold throughout.** DWR does not currently plan to include public supply wells in the CASGEM well networks due to security concerns of the California Department of Public Health.

The main reference used for these guidelines is the United States Geological Survey (USGS) National Field Manual (NFM) (U.S. Geological Survey, 2006). The final report of the Subcommittee on Groundwater (SOGW) of the Advisory Committee on Water Information was also used as a main reference, although in general it relied on the USGS guidelines (Subcommittee on Ground Water of the Advisory Committee on Water Information, 2009). The water-level measurement portion of the USGS guidelines were written for monitoring wells and not for production wells (Taylor and Alley, 2001; U.S. Geological Survey, 2006). Thus, although the USGS guidelines have been adopted with only minor modifications for the monitoring well guidelines of the CASGEM program, additional modifications have been incorporated in the guidelines for production wells. **The most significant changes made to the USGS guidelines for production wells are: (1) reducing the required precision for consecutive depth to water measurements, (2) checking for obstructions in the well, and (3) not attaching weights to the steel tape so as not to hang up on obstructions.**

The guidelines presented in this document are for the use of steel tape, electric sounding tape, sonic water-level meters, or pressure transducers. Although the semi-annual measurements required by the CASGEM program can be satisfied with the use of a steel or electric sounding tape or sonic meter, a pressure transducer with a data logger provides a much better picture of what is happening with water levels over time. The use of the air-line or flowing-well methods should not be needed in most basins. However, if they are, guidelines for these methods are available in sections A4-B-4 (pages B17-B20) and A4-B-5 (pages B21-B24), respectively of the NFM (U.S. Geological Survey, 2006).

Establishing the Reference Point

Water-level measurements from a given well must be referenced to the same datum (the reference point, or RP) to ensure data comparability (see Figure 4). For monitoring wells, the RP should be marked on the top of the well casing. For production wells, the RP will most likely be the top of the access tube or hole to the well casing. The RP must be as permanent as possible and be clearly visible and easily located. It can be marked with a permanent marker, paint, imprinting a mark with a chisel or punch, or by cutting a slot in the top of the casing. In any case, the location of the RP should be clearly described on DWR Form 429 (see Table 3). A photograph of the RP, with clear labeling, should be included in the well folder. In some cases, it may be valuable to establish multiple RPs for a well, depending on the consistent accessibility of the primary RP. In this case, each RP should be clearly described on DWR Form 429 and labeled in the field. The RP should be established with the following coordinate system: horizontal location (decimal latitude and longitude referenced to the North American Datum of 1983; NAD83) and vertical elevation (referenced to the North American Vertical Datum of 1988; NAVD88, in feet).

The land-surface datum (LSD) is established by the person making the initial water-level measurement at the well. The LSD is chosen to represent the average elevation of the ground around the well. Because LSD around a well may change over time, the distance between the RP and LSD should be checked every 3 to 5 years. If appropriate, a concrete well pad or well vault may be chosen as the LSD, since they will be more permanent than the surrounding ground surface.

The elevation of the RP can be determined in several ways: (1) surveying to a benchmark, (2) using a USGS 7.5’ quadrangle map, (3) using a digital elevation model (DEM), or (4) using a global positioning system (GPS). While surveying is the most accurate (± 0.1 ft), it is also the most expensive. Depending on the distance to the nearest benchmark, the cost can be prohibitive. The latitude and longitude of the well can be established accurately using a handheld GPS. From this information, the LSD can be located on a USGS quadrangle and the elevation estimated. However, the accuracy is only about ± one half of the contour interval. Thus, for a contour interval of 5 feet, the accuracy of the elevation estimate would be about ± 2.5 feet. The contour interval of high quality DEMs is currently about 30 feet. Therefore, the accuracy of using

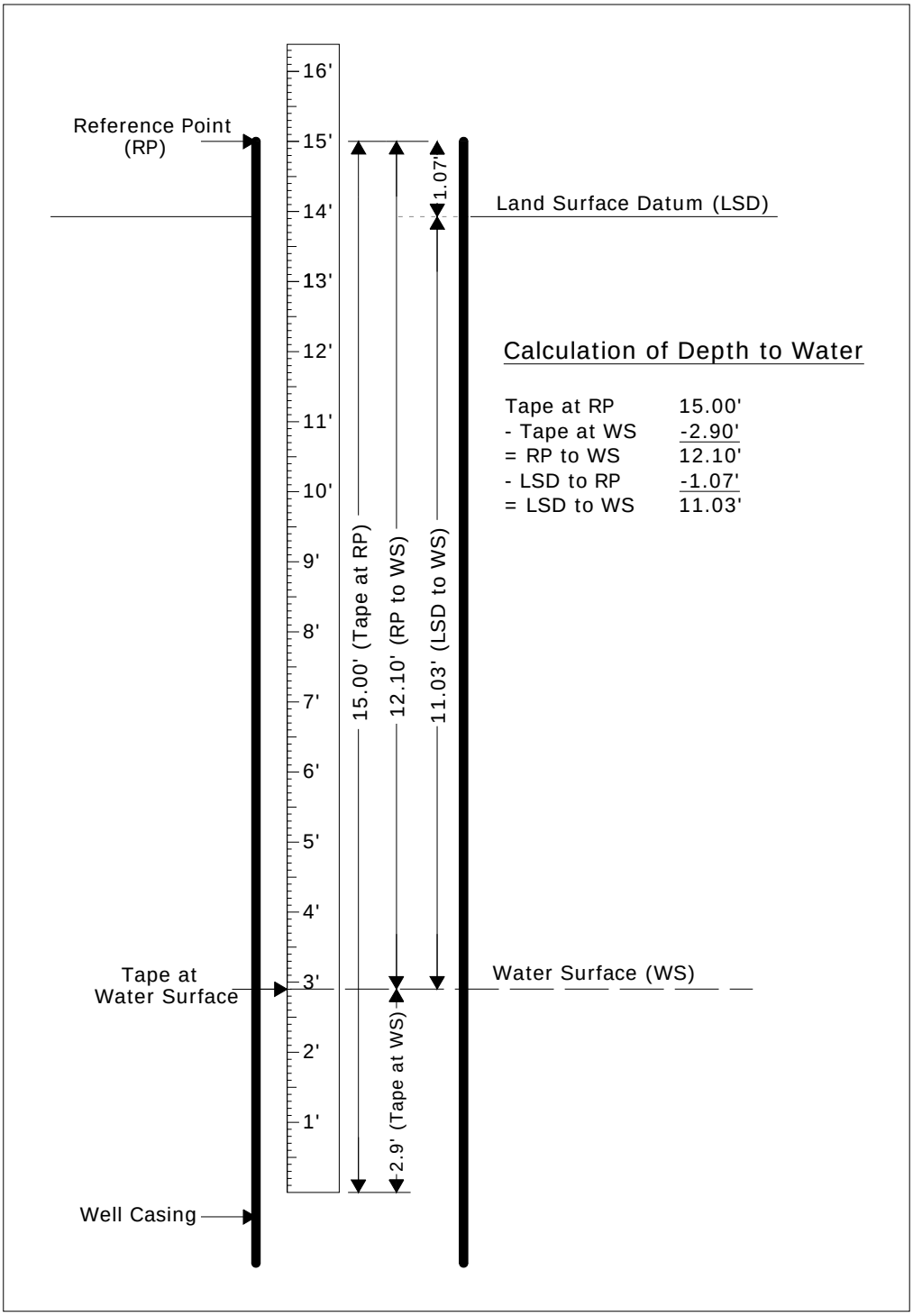

Figure 4. Groundwater-level measurements using a graduated steel tape (modified from U.S. Geological Survey, 2006).

State of California | DEPARTMENT OF WATER RESOURCES | California Natural Resources Agency

WELL DATA

State No. _____

District _____

OWNER			STATE NO.	
ADDRESS			OTHER NO.	
TENANT				
ADDRESS				
TYPE OF WELL	☐ SPECIAL STUDIES	☐ MONTHLY	☐ SEMI ANNUAL	☐ WATER QUALITY
LOCATION: COUNTY		BASIN		NO.
U.S.G.S. QUAD.			QUAD NO.	
1/4	1/4 SECTION	TWP.	RGE.	MD ☐ SB BASE & MERIDIAN H ☐
COORDINATES X:	Y:		SOURCE:	
DESCRIPTION				
REFERENCE POINT DESCRIPTION				
WHICH IS FT.	ABOVE ☐ BELOW ☐	LAND SURFACE.	GROUND ELEVATION	FT.
REFERENCE POINT ELEVATION	FT.	DETERMINED FROM		
WELL: USE	CONDITION		DEPTH	FT.
CASING, SIZE	IN.,	PERFORATIONS		
MEASUREMENTS BY:	☐ DWR	☐ USGS	☐ USBR	☐ COUNTY ☐ IRR. DIST. ☐ WATER DIST. ☐ CONS. DIST.
CHIEF AQUIFER: NAME		DEPTH TO TOP AQ.	DEPTH TO BOT. AQ.	
TYPE OF MATERIAL		PERM. RATING	THICKNESS	
GRAVEL PACKED?	☐ YES	☐ NO	DEPTH TO TOP GR.	DEPTH TO BOT GR.
SUPP. AQUIFER		DEPTH TO TOP AQ.	DEPTH TO BOT. AQ.	
DRILLER		DATE DRILLED:	LOG NUMBER:	
EQUIPMENT: PUMP, TYPE			MAKE	
SERIAL NO.	SIZE OF DISCHARGE PIPE	IN.	WATER ANALYSIS: MIN. (1)	SAN. (2) H.M. (3)
POWER, KIND	MAKE		WATER LEVELS AVAILABLE: YES (1)	NO
H.P.	MOTOR SERIAL NO		PERIOD OF RECORD: BEGIN	END
ELEC. METER NO.	TRANSFORMER NO.		COLLECTING AGENCY:	
YIELD	G.P.M. PUMPING LEVEL	FT.	PROD. REC. (1)	PUMP TEST (2) YIELD (3)
SKETCH			REMARKS	
N			RECORDED BY:	
			DATE:	

DWR 429 (Rev. 1/09)

Table 3. General well data form (DWR Form 429).

DEMs to determine the elevation of the LSD is about ± 15 feet. While a handheld GPS unit is not very accurate for determining elevation, more expensive units with the Wide Area Augmentation System can be more accurate. However, GPS readings are subject to environmental conditions, such as weather conditions, overhead vegetative cover, topography, interfering structures, and location. Thus, the most common method of determining the elevation will probably be the use of USGS quadrangles. The method used needs to be identified on DWR Form 429 (Table 3). The important matter is that all measurements at a well use the same RP, as the elevation of that point can be more accurately established at a later date. The equipment and supplies needed for establishing the RP are shown in Table 4.

If possible, establish a clearly displayed reference mark (RM) in a location near the well; for example, a lag bolt set into a nearby telephone pole or set in concrete in the ground. The RM is an arbitrary datum established by permanent marks and is used to check the RP or to re-establish an RP should the original RP be destroyed or need to be changed. Clearly locate the RP and RM on a site sketch that goes into the well folder (see Table 3). Include the distance and bearing between the RP and the RM and the height of the lag bolt above the ground surface. Photograph the site, including the RP and RM locations; draw an arrow to the RP and RM on the photograph(s) using an indelible marker, and place the photos in the well file.

Table 4. Equipment and Supply List

Equipment and supplies needed for (a) all measurements, (b) establishing permanent RP, (c) steel tape method, (d) electric sounding tape method, (e) sonic water-level meter, and (f) automated measurements with pressure transducer.
(a) All measurements
GPS instrument, digital camera, watch, calculator, and maps
General well data form (DWR Form 429; see Table 3)
Pens, ballpoint with non-erasable blue or black ink, for writing on field forms and equipment log books
Well file with previous measurements
Measuring tape, graduated in feet, tenths, and hundredths of feet
Two wrenches with adjustable jaws and other tools for removing well cap
Key(s) for opening locks and clean rags
(b) Establishing a permanent reference point
Steel tape, graduated in feet, tenths, and hundredths of feet
Calibration and maintenance log book for steel tape
Paint (bright color), permanent marker, chisel, punch, and(or) casing-notching tool

Table 4. Equipment and Supply List (continued)

(c) Steel tape method
DWR field form 1213 (see Table 5)
Steel tape, graduated in feet, tenths, and hundredths of feet
Calibration and maintenance log book for steel tape
Weight (stainless steel, iron, or other noncontaminating material – do not use lead)
Strong ring and wire, for attaching weight to end of tape. Wire should be strong enough to hold weight securely, but not as strong as the tape, so that if the weight becomes lodged in the well the tape can still be pulled free.
Carpenters' chalk (blue) or sidewalk chalk
Disinfectant wipes, and deionized or tap water for cleaning tape.
(d) Electric sounding tape method
DWR field form 1213 (see Table 5)
Steel tape, graduated in feet, tenths, and hundredths of feet
An electric tape, double-wired and graduated in feet, tenths, and hundredths of feet, accurate to 0.01 ft. Electric sounding tapes commonly are mounted on a hand-cranked and powered supply reel that contains space for the batteries and some device ("indicator") for signaling when the circuit is closed.
Electric-tape calibration and maintenance log book; manufacturer's instructions.
Disinfectant wipes, and deionized or tap water for cleaning tape.
Replacement batteries, charged.
(e) Sonic water-level meter method
DWR field form 1213 (see Table 5)
Temperature probe with readout and cable
Sonic water-level meter with factory cover plate
Custom sized cover plates for larger well diameters
Replacement batteries
(f) Automated measurements with pressure transducer
Transducer field form (see Figures 1 and 2 in Drost, 2005: http://pubs.usgs.gov/of/2005/1126/pdf/ofr20051126.pdf)
Transducer, data logger, cables, suspension system, and power supply.
Data readout device (i.e., laptop computer loaded with correct software) and data storage modules.
Spare desiccant, and replacement batteries.
Well cover or recorder shelter with key.
Steel tape (with blue carpenters' chalk or sidewalk chalk) or electric sounding tape, both graduated in hundredths of feet.
Tools, including high-impedance (digital) multimeter, connectors, crimping tool, and contact-burnishing tool or artist's eraser.

GUIDELINES FOR MEASURING WATER LEVELS

Monitoring wells typically have a cap on the wellhead. After the cap is removed, the open top of the well is easily accessible for sampling water levels and water quality. If the well is to be sampled for water quality in addition to water level, the water-level measurement should be made before the well is purged. Before discussing the detailed measurement steps for different methods, some guidance is provided on the common issues of well caps, recovery time after pumping, and cascading water in a well.

Well caps are commonly used in monitoring wells to prevent the introduction of foreign materials to the well casing. There are two general types of well caps, vented and unvented. Vented well caps allow air movement between the atmosphere and the well casing. Unvented well caps provide an airtight seal between the atmosphere and the well casing.

In most cases it is preferred to use vented well caps because the movement of air between the atmosphere and the well casing is necessary for normal water level fluctuation in the well. If the cap is not vented the fluctuation of groundwater levels in the well will cause increased or decreased air pressure in the column of air trapped above the water in the casing. The trapped air can prevent free movement of the water in the casing and potentially impact the water level that is measured. Vented caps will allow both air and liquids into the casing so they should not be used for wells where flooding with surface water is anticipated or contamination is likely from surface sources near the well.

Unvented well caps seal the top of the well casing and prevent both air and liquid from getting into the well. They are necessary in areas where it is anticipated that the well will be flooded from surface water sources or where contamination is likely if the casing is not sealed. Because the air above the water in the casing is trapped in the casing and cannot equalize with the atmospheric pressure, normal water level fluctuation may be impeded. When measuring a well with an unvented cap it is necessary to remove the cap and wait for the water level to stabilize. The wait time will vary with many different factors, but if several sequential water-level measurements yield the same value it can be assumed the water level has stabilized.

Unlike monitoring wells, production wells have obstructions in the well unless it is an abandoned production well and the pump has been removed. In addition, the wellhead is not always easily accessible for monitoring water levels. Since pumping from the production wells will create a non-static water level, the water-level measurement should ideally not be made until the water level has returned to static level. However, this recovery time will vary from site to site. Some wells will recover from pumping level to static level within a few hours, while many wells will take much longer to recover. Some wells will recover from pumping level to static level within a few hours, while many wells will take much longer to recover. Thus, as a general recommendation, measurements should not be collected until 24 hours after pumping has ceased, however, site specific

conditions may require deviating from this. The time since pumping should be noted on the field form.

Water may enter a well above the water level, drip or cascade down the inside of the well, and lead to false water level measurements. Sometimes cascading water can be heard dripping or flowing down the well and other times it is discovered when water levels are abnormally shallow and/or difficult to determine. Both steel tapes and electric sounding tapes can give false readings. A steel tape may be wet from the point where water is entering the well making it hard to see the water mark where the tape intersects the water level in the well. An electric sounding tape signal may start and then stop as it is lowered down the well. If this happens, you can lightly shake the tape. The signal often becomes intermittent when water is running down the tape, but remains constant in standing water. On most electric sounding tapes, the sensitivity can be turned down to minimize false readings. It should be noted when a water level measurement is taken from a well with cascading water.

(1) Steel Tape Method

The graduated steel-tape (wetted-tape) procedure is considered to be the most accurate method for measuring water levels in nonflowing wells. A graduated steel tape is commonly marked to 0.01 foot. When measuring deep water levels (>500 ft), thermal expansion and stretch of the steel tape starts to become significant (Garber and Koopman, 1968). The method is most accurate for water levels less than 200 feet below land surface. The equipment and supplies needed for this method are shown in Table 4.

The following issues should be considered with this method:

- It may be difficult or impossible to get reliable results if water is dripping into the well or condensing on the well casing.
- If the well casing is angled, instead of vertical, the depth to water should be corrected, if possible. This correction should be recorded in the field folder.
- **Check that the tape is not hung up on obstructions.**

Before making a measurement:

1. Maintain the tape in good working condition by periodically checking the tape for rust, breaks, kinks, and possible stretch. Record all calibration and maintenance data associated with the steel tape in a calibration and maintenance log book.

2. If the steel tape is new, be sure that the black sheen on the tape has been dulled so that the tape will retain the chalk.

3. Prepare the field forms (DWR Form 1213; see Table 5). Place any previous measured water-level data for the well into the field folder.

4. Check that the RP is clearly marked on the well and accurately described in the well file or field folder. If a new RP needs to be established, follow the procedures above.

5. In the field, wipe off the lower 5 to 10 feet of the tape with a disinfectant wipe, rinse with de-ionized or tap water, and dry the tape.

6. If possible, attach a weight to the tape that is constructed of stainless steel or other noncontaminating material to protect groundwater quality in the event that the weight is lost in the well. **Do not attach a weight for production wells.**

Making a measurement:

1. If the water level was measured previously at the well, use the previous measurement(s) to estimate the length of tape that should be lowered into the well. Preferably, use measurements that were obtained during the same season of the year.

2. Chalk the lower few feet of the tape by pulling the tape across a piece of blue carpenter's chalk or sidewalk chalk (the wetted chalk mark identifies that part of the tape that was submerged).

3. Slowly lower the weight (for monitoring wells only) and tape into the well to avoid splashing when the bottom end of the tape reaches the water. Develop a feel for the weight of the tape as it is being lowered into the well. A change in this weight will indicate that either the tape is sticking to the side of the casing or has reached the water surface. Continue to lower the end of the tape into the well until the next graduation (a whole foot mark) is at the RP and record this number on DWR Form 1213 (Table 5) next to "Tape at RP" as illustrated on Figure 4.

4. Rapidly bring the tape to the surface before the wetted chalk mark dries and becomes difficult to read. Record the number to the nearest 0.01 foot in the column labeled as "Tape at WS."

5. If an oil layer is present, read the tape at the top of the oil mark to the nearest 0.01 foot and use this value for the "Tape at WS" instead of the wetted chalk mark. Mark an "8" in the QM column of DWR Form 1213 (see Table 5) to indicate a questionable measurement due to oil in the well casing. There are methods to correct for oil, such as the use of a relatively inexpensive water-finding paste. The paste is applied to the lower end of the steel tape and the top of the oil shows as a wet line and the top of the water shows as a distinct color change. Since oil density is about three-quarters that of water, the water level can be estimated by adding three-quarters of the thickness of the oil layer to the oil-water interface elevation (U.S. Geological Survey, 2006).

6. Subtract the “Tape at WS” number from the “Tape at RP” number and record the difference (to the nearest 0.01 ft) as “RP to WS”. This reading is the depth to water below the RP.

7. Wipe and dry off the tape and re-chalk based on the first measurement.

8. Make a second measurement by repeating steps 3 through 5, recording the time of the second measurement on the line below the first measurement (Table 5). The second measurement should be made using a different “Tape at RP” than that used for the first measurement. If the second measurement does not agree with the original within 0.02 of a foot **(0.2 of a foot for production wells)**, make a third measurement, recording this measurement and time on the row below the second measurement with a new time. If more than two readings are taken, record the average of all reasonable readings.

After making a measurement:

1. Clean the exposed portion of the tape using a disinfectant wipe, rinse with de-ionized or tap water, and dry the tape. Do not store a steel tape while dirty or wet.

Table 5. Groundwater level data form for manual measurements (DWR Form 1213).

GROUNDWATER LEVEL DATA FORM
MANUAL MEASUREMENTS

WELL ID NUMBER	WELL NAME	STATE WELL NUMBER	COUNTY	B-118 BASIN OR SUBBASIN	MEASURING AGENCY	LAND SURFACE DATUM (LSD) ELEV.	RP TO LAND SURFACE DATUM (LSD), IN FT	REFERENCE POINT (RP) ELEV.

NO MEASUREMENT (NM)
0. Measurement discontinued
1. Pumping
2. Pump house locked
3. Tape hung up
4. Can't get tape in casing
5. Unable to locate well
6. Well has been destroyed
7. Special
8. Casing leaky or wet
9. Temporarily inaccessible

QUESTIONABLE MEASUREMENT (QM)
0. Caved or deepened
1. Pumping
2. Nearby pump operating
3. Casing leaky or wet
4. Pumped recently
5. Air or pressure gauge measurement
6. Other
7. Recharge operation at or nearby well
8. Oil in casing

MEASUREMENT METHOD (MM)
0. Steel tape
1. Electric sounding tape
2. Other

DATE	TIME	N M	Q M	MM	TAPE at RP	TAPE at WS	RP to WS	LSD to WS	OBS	COMMENTS

[For explanation of terms, see figure 1.]

DWR Form 1213 (modified 6/28/2010) (data for Water Data Library)

(2) Electric Sounding Tape Method

The electric sounding tape procedure for measuring depth to the water surface is especially useful in wells with dripping water or condensation, although there are still precautions needed as noted in the beginning of this section. Other benefits of this method include:

- Easier and quicker than steel tapes, especially with consecutive measurements in deeper wells.
- Better than steel tapes for making measurements in the rain.
- Less chance for cross-contamination of well water than with steel tapes, as there is less tape submerged.

The accuracy of electric sounding tape measurements depends on the type of tape used and whether or not the tape has been stretched out of calibration after use. Tapes that are marked the entire length with feet, tenths, and hundredths of a foot should be read to 0.01 ft. Electric sounding tapes are harder to keep calibrated than are steel tapes. As with steel tapes, electric sounding tapes are most accurate for water levels less than 200 ft below land surface, and thermal expansion and stretch start to become significant factors when measuring deep water levels (>500 ft) (see Garber and Koopman, 1968). Equipment and supplies needed for this method are shown in Table 4.

The following issues should be considered with this method:

- If the well casing is angled, instead of vertical, the depth to water will have to be corrected, if possible. This correction should be recorded in the field folder.
- **Check that the electric sounding tape is not hung up on an obstruction in the well.**
- The electric sounding tape should be calibrated annually against a steel tape in the field (using monitoring wells only) as follows: Compare water-level measurements made with the electric sounding tape to those made with a steel tape in several wells that span the range of depths to water encountered in the field. The measurements should agree to within ± 0.02 ft. If this accuracy is not met, a correction factor should be applied. All calibration and maintenance data should be recorded in a calibration and maintenance log book for the electric sounding tape.
- **Oil on the surface of the water may interfere with obtaining consistent readings and could damage the electrode probe. If oil is present, switch to a steel tape for the water-level measurement.**
- If using a repaired/spliced tape: see section A4-B-3(b) (page B16) of the NFM (U.S. Geological Survey, 2006).

Before making a measurement:

1. Inspect the electric sounding tape and electrode probe before using it in the field. Check the tape for wear, kinks, frayed electrical connections and possible stretch; the

cable jacket tends to be subject to wear and tear. Test that the battery and replacement batteries are fully charged.

2. Check the distance from the electrode probe's sensor to the nearest foot marker on the tape, to ensure that this distance puts the sensor at the zero foot point for the tape. If it does not, a correction must be applied to all depth-to-water measurements. Record this in an equipment log book and on the field form.

3. Prepare the field forms (DWR Form 1213; see Table 5) and place any previous measured water-level data for the well into the field folder.

4. After reaching the field site, check that the RP is clearly marked on the well and is accurately described in the well file or field folder. If a new RP needs to be established, follow the procedures above.

5. Check the circuitry of the electric sounding tape before lowering the electrode probe into the well. To determine proper functioning of the tape mechanism, dip the electrode probe into tap water and observe whether the indicator needle, light, and/or beeper (collectively termed the "indicator" in this document) indicate a closed circuit. For an electric sounding tape with multiple indicators (sound and light, for instance), confirm that the indicators operate simultaneously. If they do not operate simultaneously, determine which is the most accurate and use that one.

6. Wipe off the electrode probe and the lower 5 to 10 feet of the tape with a disinfectant wipe, rinse with de-ionized or tap water, and dry.

Making a measurement:

1. If the water level was measured previously at the well, use the previous measurement(s) to estimate the length of tape that should be lowered into the well. Preferably, use measurements that were obtained during the same season of the year.

2. Lower the electrode probe slowly into the well until the indicator shows that the circuit is closed and contact with the water surface is made. Avoid letting the tape rub across the top of the well casing. Place the tip or nail of the index finger on the insulated wire at the RP and read the depth to water to the nearest 0.01 foot. Record this value in the column labeled "Tape at RP", with the appropriate measurement method code and the date and time of the measurement (see Table 5).

3. Lift the electrode probe slowly up a few feet and make a second measurement by repeating step 2 and record the second measurement with the time in the row below the first measurement in Table 5. Make all readings using the same deflection point on the indicator scale, light intensity, or sound so that water levels will be consistent between measurements. If the second measurement does not agree with the first measurement within 0.02 of a foot **(0.2 of a foot for production wells)**, make a third measurement,

recording this measurement with the time in the row below the second measurement. If more than two readings are taken, record the average of all reasonable readings.

After making a measurement:

1. Wipe down the electrode probe and the section of the tape that was submerged in the well water, using a disinfectant wipe and rinse thoroughly with de-ionized or tap water. Dry the tape and probe and rewind the tape onto the tape reel. Do not rewind or otherwise store a dirty or wet tape.

(3) Sonic Water-Level Meter Method

This meter uses sound waves to measure water levels. It requires an access port that is 5/8 – inch or greater in diameter and measurement of the average air temperature in the well casing. The meter can be used to quickly measure water levels in both monitoring wells and production wells. Also, since this method does not involve contact of a probe with the water, there is no concern over cross contamination between wells. However, the method is not as accurate as the other methods, with a typical accuracy of 0.2 ft for water levels less than 100 ft or 0.2% for water levels greater than 100 ft. Equipment and supplies needed for this method are shown in Table 4.

The following issues should be considered with this method:

- The accuracy of the meter decreases with well diameter and should not be used with well diameters greater than 10 inches.
- An accurate air temperature inside the well casing is necessary so that the variation of sound velocity with air temperature can be accounted for.
- **Obstructions in the well casing can cause erroneous readings, especially if the obstruction is close to half the well diameter or more.**

Before making a measurement:

1. Check the condition of the meter, especially the batteries. Take extra batteries to the field.

2. Take a temperature probe with a readout and 50-ft cable.

3. If open wellheads with diameter greater than the factory cover plate and less than 10 inches will be monitored, fabricate appropriately-sized cover plates using plastic or sheet metal.

4. Prepare the field forms (DWR Form 1213; see Table 5). Place any previous measured water-level data for the well into the field folder.

5. Check that the RP is clearly marked on the well and accurately described in the well file or field folder. If a new RP needs to be established, follow the procedures above.

Making a measurement:

1. If the water level was measured previously at the well, lower the temperature probe to about half that distance in the well casing. Preferably, use measurements that were obtained during the same season of the year.

2. Record this temperature in the comments column of DWR form 1213 (see Table 5). Use this temperature reading to adjust the temperature toggle switch on the sonic meter.

3. Select the appropriate depth range on the sonic meter.

4. For a covered wellhead, insert the meter duct into the access port and push the power-on switch. Record the depth from the readout.

5. For an open wellhead, slip the provided cover plate onto the wellhead to provide a seal. If the cover plate is not large enough, use a fabricated cover plate for diameters up to 10 inches. Record the depth from the readout.

After making a measurement:

1. Make sure the temperature probe and the sonic meter are turned off and put away in their cases.

(4) Pressure Transducer Method

Automated water-level measurements can be made with a pressure transducer attached to a data logger. Care should be taken to choose a pressure transducer that accurately measures the expected range of groundwater levels in a well. Pressure-transducer accuracy decreases linearly with increases in the depth range (also known as pressure rating). A pressure transducer with a depth range of 0 to 10 ft (0 to 4.3 psi) has an accuracy of 0.01 ft while a pressure transducer with a depth range of 0 to 100 ft (0 to 43 psi) has an accuracy of 0.1 ft. But if the measurement range exceeds the depth range of a pressure transducer, it can be damaged. So it is important to have a good

idea of the expected range of groundwater levels in a well, and then refer to the manufacturer's specification when selecting a pressure transducer for that well.

Some of the advantages of automated monitoring include:

- No correction is required for angled wells, as pressure transducers only measure vertical water levels.
- A data logger can be left unattended for prolonged periods until data can be downloaded in the field.
- Downloaded data can be imported directly into a spreadsheet or database.

Some of the disadvantages of automated monitoring include:

- It may be necessary to correct the data for instrument drift, hysteresis, temperature effects, and offsets. Most pressure transducers have temperature compensation built-in.
- Pressure transducers operate only in a limited depth range. The unit must be installed in a well in which the water level will not fluctuate outside the operable depth range for the specific pressure transducer selected. Wells with widely fluctuating water levels may be monitored with reduced resolution or may require frequent resetting of the depth of the pressure transducer.
- With some data loggers, previous water-level measurements may be lost if the power fails.

There are two types of pressure transducers available for measuring groundwater levels; non-vented (absolute) and vented (gauged). A non-vented pressure transducer measures absolute pressure, is relative to zero pressure, and responds to atmospheric pressure plus pressure head in a well (see Figure 5). A vented pressure transducer measures gauge pressure, is relative to atmospheric pressure, and only responds to pressure head in a well.

Non-vented pressure transducer data require post processing. Barometric pressure data must be collected at the same time as the absolute pressure data at the well, and subtracted from each absolute pressure data record before the data can be used to calculate groundwater levels. Thus, if a non-vented pressure transducer is used, a barometric pressure transducer will also be needed near the well. This subject is usually covered in more detail by the manufacturer of the pressure transducer. In an area with little topographic relief, a barometer at one site should be sufficient for use by other sites within a certain radius (9 miles reported by Schlumberger http://www.swstechnology.com/ groundwater-monitoring/groundwater-dataloggers/baro-diver and 100 miles reported by Global Water http://www.globalw.com/support/barocomp.html). In an area of significant topographic relief, it would be advisable to have a barometer at each site.

Vented pressure transducers can be programmed so no post processing of the data is necessary. The vent is usually a small tube in the communication cable that runs from the back of the pressure transducer to the top of the well. This vent enables the pressure transducer to cancel the effect of atmospheric pressure and record groundwater level as the distance from the RP to the WS (see Figure 5). However, if the vent is exposed to excessive moisture or submerged in water it can cause failure and damage to the pressure transducer.

The existing well conditions should be considered when deciding which type of pressure transducer to use. Non-vented pressure transducers should be used when the top of a well or its enclosure may at any time be submerged in water. This can happen when artesian conditions have been observed or are likely, the well is completed at or below the LSD, or the well or its enclosure are susceptible to periods of high water. Otherwise, it is advisable to use a vented pressure transducer.

The following guidelines are USGS guidelines from Drost (2005) and Freeman and others (2004) for the use of pressure transducers. These USGS guidelines have not been incorporated as yet in the NFM. The equipment and supplies needed for automated measurements of water level using a pressure transducer are shown in Table 4.

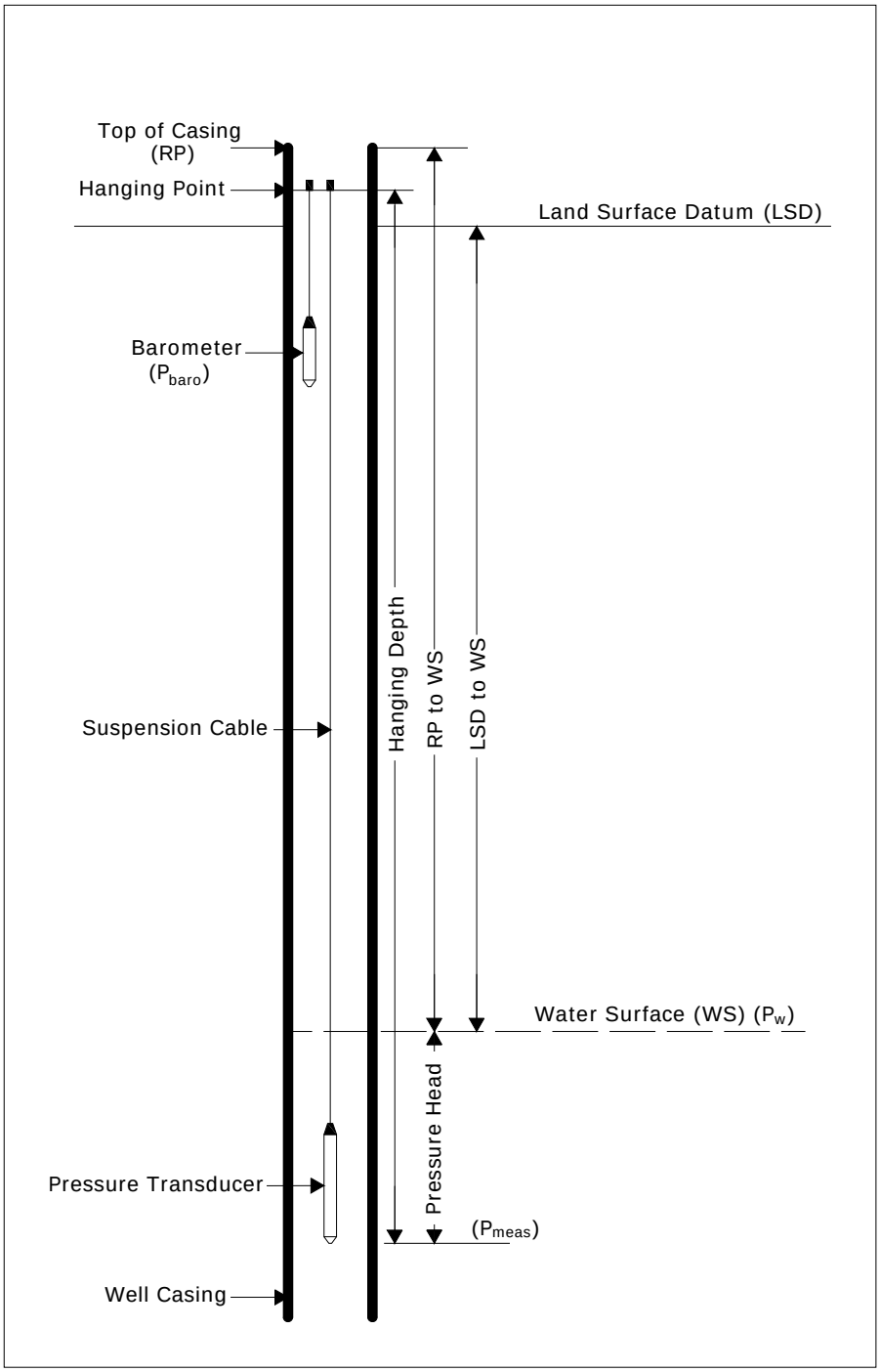

Figure 5. Groundwater-level measurements using a pressure transducer (vented or non-vented) (modified from Drost, 2005).

Before making a measurement:

1. Keep the pressure transducer packaged in its original shipping container until it is installed.

2. Fill out the DWR field form (Table 6), including the type, serial number, and range of measurement device; and what units are being measured (ft, psi).

3. Take a reading from the pressure transducer before placing into the well. For a vented pressure transducer the reading should be zero. For a non-vented pressure transducer the reading should be a positive number equivalent to atmospheric pressure. Configure the units (ft, psi) on a barometric pressure transducer the same as the non-vented pressure transducer. A reading from the barometric pressure transducer should be the same as the non-vented pressure transducer reading.

4. Lower the pressure transducer into the well slowly. Conduct a field calibration of the pressure transducer by raising and lowering it over the anticipated range of water-level fluctuations. Take two readings at each of five intervals, once during the raising and once during the lowering of the pressure transducer. Record the data on the DWR field form (see Table 6). If using a non-vented pressure transducer, take a reading from the barometric pressure transducer at the same time as the other readings.

5. Lower the pressure transducer to the desired depth below the water level (caution: do not exceed the depth range of the pressure transducer).

6. Fasten the cable or suspension system to the well head using tie wraps or a weatherproof strain-relief system. If the vent tube is incorporated in the cable, make sure not to pinch the cable too tightly or the vent tube may be obstructed.

7. Make a permanent mark on the cable at the hanging point, so future slippage, if any, can be determined.

8. Measure the static water level in the well with a steel tape or electric sounding tape. Repeat if measurements are not consistent within 0.02 ft **(0.2 ft for production wells)**.

9. Record the well and RP configuration, with a sketch. Include the RP height above the LSD, the hanging point, and the hanging depth (see Figure 5).

Table 6. Groundwater level data form for vented or non-vented pressure transducer with data logger.

GROUNDWATER LEVEL DATA FORM
VENTED OR NON-VENTED PRESSURE TRANSDUCER WITH DATALOGGER

Station Information						Transducer Information						
Well ID Number	Well Name	State Well Number	County	Bulletin 118 GW Basin or Subbasin	Measuring Agency	Type of Pressure Transducer -- (A) Gauged (vented) or (B) Absolute (non-vented)?	Manufac-turer	Model	Serial Number	PSI Rating	Cable Length	Barometer Serial Number

Datum Measurements (in feet) [Date of Measurements:]

Reference Point (RP) Elevation (MSL) [from DWR Form 429]	RP to Land Surface Datum (LSD)	(1) RP to Hanging Point	(2) Hanging Depth	(3) RP to Pressure Transducer

Manual Readings									Datalogger Readings					Datalogger Servicing			
Date	Time	Obser-ver	NM	QM	MM	(4) Tape at RP	(5) Tape at WS	(6) RP to WS	(7) Transducer pressure (psi)	(8) Barometric pressure (psi)	(9) WS pressure (psi)	(10) WS above transducer (ft)	(11) RP to WS (ft)	Test Name	Download-ed data? (Y/N)	Batt. life left / new batteries? (%; Y/N)	Comments

These cells only need to be filled out for non-vented transducers (which will have a barometer at the well in addition to the transducer)

Notes about calculated entries in form (referenced by number in cell): (3) = (1) + (2); (6) = (4) - (5) for steel tape; (6) = (4) for electric sounding tape; (9) = (7) - (8) for non-vented transducer; (9) = (7) for vented transducer; (10) = 2.3067 * (9); (11) = (3) - (10) [for explanation of terms, see figure 2]

NM (No Measurement) Codes: 0--Measurement discontinued 1--Pumping 2--Pump house locked 3--Tape hung up 4--Can't get tape in casing 5--Unable to locate well 6--Well has been destroyed 7--Special 8--Casing leaky or wet 9--Temporarily inaccessible	QM (Questionable Measurement) Codes: 0--Caved or deepened 1--Pumping 2--Nearby pump operating 3--Casing leaky or wet 4--Pumped recently 5--Air or pressure gauge measurement 6- -Other 7--Recharge operation at or nearby well 8--Oil in casing	MM (Measurement Method) Codes: 0--Steel tape 1--Electric sounding tape 2--Other

DWR Form xxxx (data for Hydstra)

10. Connect the data logger, power supply, and ancillary equipment. Configure the data logger to ensure the channel, scan intervals, units, etc., selected are correct. Activate the data logger. Most data loggers will require a negative slope in order to invert water levels for ground-water applications (i.e., distance from the RP to the WS). If using a non-vented pressure transducer the data logger will not require a negative slope, but atmospheric pressure data will need to be collected by a barometric pressure transducer.

Making a measurement:

1. Retrieve water-level data (to 0.01 ft) using instrument or data logger software. If using a non-vented pressure transducer, retrieve barometric pressure data.

2. Measure the water level with a steel tape or electric sounding tape (to 0.01 ft) and compare the reading with the value recorded by the pressure transducer and data logger. Record the reading and time in the file folder. If using a non-vented pressure transducer, subtract the barometric pressure value from the transducer pressure value to obtain the water level pressure value. The water level pressure can then be multiplied by 2.3067 to convert from psi of pressure to feet of water (Freeman and others, 2004). Report the calculated water level to the nearest 0.01 ft.

3. If the tape and pressure transducer readings differ by more than **(the greater of 0.2 ft or)** two times the accuracy of the specific pressure transducer, raise the pressure transducer out of the water and take a reading to determine if the cable has slipped, or whether the difference is due to drift. The accuracy of a pressure transducer is typically defined as 0.001 times the full scale of the pressure transducer (e.g., a 0 to 100 ft pressure transducer has a full scale of 100 ft). The accuracy of a specific pressure transducer should be specified by the manufacturer's specifications.

4. If drift is significant, recalibrate the pressure transducer as described using a steel tape. If using a non-vented pressure transducer, keep the pressure transducer out of the water and calibrate to the barometric pressure transducer value. If field calibration is not successful, retrieve the transducer and send back to the manufacturer for re-calibration.

5. Use the multimeter (see Table 4) to check the charge on the battery, and the charging current supply to the battery. Check connections to the data logger, and tighten as necessary. Burnish contacts if corrosion is occurring.

6. Replace the desiccant, battery (if necessary), and data module. Verify the data logger channel and scan intervals, document any changes to the data logger program and activate the data logger.

7. If possible, wait until data logger has logged a value, and then check for reasonableness of data.

Glossary of Terms

The following terms are used in this document. Although many are commonly used in the groundwater- and data-management fields, they are defined here to avoid confusion.

Aquifer – A geologic formation from which useable quantities of groundwater can be extracted. A confined aquifer is bounded above and below by a confining bed of distinctly less permeable material. The water level in a well installed in a confined aquifer stands above the top of the confined aquifer and can be higher or lower than the water table that may be present in the material above it. In some cases, the water level can rise above the ground surface, yielding a flowing well. An unconfined aquifer is one with no confining beds between the saturated zone and the ground surface. The water level in a well installed in an unconfined aquifer stands at the same level as the groundwater outside of the well and represents the water table. An alternative and equivalent definition for an unconfined aquifer is an aquifer in which the groundwater surface is at atmospheric pressure.

Atmospheric or barometric pressure – The force per unit area exerted against a surface by the weight of the air above that surface at any given point in the Earth's atmosphere. At sea level, the atmospheric pressure is 14.7 psi. As elevation increases, atmospheric pressure decreases as there are fewer air molecules above the ground surface. The atmospheric pressure is measured by a barometer. This pressure reading is called the barometric pressure. Weather conditions can increase or decrease barometric pressure.

Blue carpenter's chalk – A primarily calcium carbonate chalk with some silica. It is primarily used to make chalk-lines for long lasting bright marks. Some other formulations of chalk (e.g., sidewalk chalk) substitute different ingredients such as rice starch for silica.

Data logger – A microprocessor-based data acquisition system designed specifically to acquire, process, and store data. Data usually are downloaded from onsite data loggers for entry into office data systems. The storage device within a data logger is called the data module. A desiccant, such as, silica gel, calcium sulfate, or calcium chloride, is used to absorb and keep moisture away from the data module.

Dedicated monitoring well – A well designed for the sole purpose of long-term monitoring.

Domestic well – A water well used to supply water for the domestic needs of an individual residence or systems of four or fewer service connections.

DWR Bulletin 118 – DWR publication on the status of California's groundwater. Prior to this 2003 update, the latest Bulletin 118 was published in 1980. This publication defines the 515 basins to be monitored in the SB 6 monitoring program. The report reference is: California Department of Water Resources, 2003, California's groundwater: Bulletin 118, 246 p., available online at: http://www.water.ca.gov/pubs/groundwater/bulletin_118/california's_groundwater__bulletin_118_-_update_2003_/bulletin118_entire.pdf

Electric sounding tape – This term is used in this document to mean both the electric tape and the electrode probe attached to the end of the tape. This water-level measuring device is also known by many other names, including a sounder, an electric tape, an E tape, an electric sounder, an electric well sounder, a depth sounder, etc.

Electrode probe – This is the electronic sensor in the electronic sounder attached to the end of the electric tape. It senses water based on the electrical conductivity and triggers an alert.

GPS – This stands for global positioning system. These devices come in many sizes and costs. The handheld devices are capable of very accurate locations in the xy plane (latitude longitude). However, only very expensive and large GPS units are currently capable of accurate readings for the altitude (z direction).

Groundwater – Water occurring beneath the ground surface in the zone of saturation.

Groundwater basin – An alluvial aquifer or a stacked series of alluvial aquifers with reasonably well-defined boundaries in a lateral direction and having a definable bottom.

Groundwater elevation – The elevation (generally referenced to mean sea level as the datum) to which water in a tightly cased well screened at a given location will rise. Other terms that may be used include groundwater level, hydraulic head, piezometric head, and potentiometric head.

Groundwater surface – The highest elevation at which groundwater physically occurs in a given location in an aquifer (i.e., top of aquifer formation in a confined aquifer and the groundwater level or water table in an unconfined aquifer). Also referred to as a water surface in this document.

Groundwater subbasin – A subdivision of a groundwater basin created by dividing the basin using geologic and hydrologic conditions or institutional boundaries.

Hysteresis – The maximum difference in output, at any measured value within the specified range, when the value is approached first with an increasing and then a decreasing measured property. Hysteresis is expressed in percent of the full-scale output.

Instrument Drift – A change in instrument output over a period of time that is not a function of the measured property. Drift is normally specified as a change in zero (zero drift) over time and a change in sensitivity (sensitivity drift) over time.

Irrigation well – A well used to irrigate farmland. The water from the well is not intended for domestic purposes.

Metadata – "data about data"; it is the data describing context, content and structure of records and their management through time.

NFM – This stands for National Field Manual. This is a living, online, document of the USGS. It is the protocol document for USGS methods of surface water, groundwater, and water quality field activities. The portion of the NFM that related to the field methods of collecting groundwater levels is in the following reference: U.S. Geological Survey, 2006, Collection of water samples (ver. 2.0): U.S. Geological Survey Techniques of Water-Resources Investigations, book 9, chap. A4, September, accessed 12/30/09 at: http://pubs.water.usgs.gov/twri9A4/

Nonflowing well – A well in which the water level is below the land surface.

Pressure head – The height of a column of groundwater above a point that is supported by pressure at that point.

Pressure transducer – A type of measurement device that converts pressure-induced mechanical changes into an electrical signal.

Production well – A well with a pump installed that is used to bring groundwater to the land surface. This is a general term that can be applied to a domestic well, irrigation well, or public-supply well.

Public-supply well – A well that pumps groundwater from a relatively extensive saturated area and is used as part of a public water system, supplying water for human consumption to at least 3,300 people.

SOGW – This stands for Subcommittee on Groundwater. This is a subcommittee of the Advisory Committee on Water Information, which is developing a national framework for groundwater in the United States. The reference for the SOGW work is: Subcommittee on Ground Water of the Advisory Committee on Water Information, 2009, A national framework for ground-water monitoring in the United States: final version approved by the Advisory Committee on Water Information, June 2009, 78 p., accessed 1/11/10 at: http://acwi.gov/sogw/pubs/tr/index.html

Static water level – Groundwater level in a well during non-pumping conditions.

Vent tube – A tube in the cable which connects to the pressure transducer, allowing atmospheric pressure to be in contact with one side of the strain gauge in the pressure sensor. It cancels out the barometric effects in the readings.

Well casing – The metal or plastic pipe separating the well from the surrounding geologic material.

Wellhead – The top of the well containing the casing hanger and the point at which the motor is attached for a vertical line shaft turbine pump or where the seal is secured for a submersible pump.

Well purging – Pumping out standing groundwater from a monitoring well. This is done prior to water quality sampling of wells, but **not** before taking a water-level measurement.

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Appendix D
Landowner Outreach Program

APPENDIX D

Landowner Outreach Program Survey Summary

As part of a groundwater public outreach program, a survey was sent to landowners in the Reclamation District No. 1500 (RD 1500 or District) service area. The anonymous survey requested information related to groundwater use and management (see Attachment 1). Results from the survey helped the Sutter Basin Partners expand their understanding of existing well, monitoring infrastructure, and groundwater use.

The following is a brief summary of survey results:

- Forty-nine landowners responded to the survey. Figure 1 shows the distribution of respondents; figures are located at the end of this summary.
- As shown on Figure 2, the majority of landowners use only surface water for irrigation and do not use groundwater.
- Respondents using groundwater included those who use groundwater for domestic use only, as their primary irrigation source, or as supplemental irrigation supply. One respondent has only a groundwater monitoring well.
- Figure 3 presents the distribution of groundwater use.
- Of the survey respondents who currently use groundwater for agricultural irrigation, groundwater well depths are typically between 150 and 200 feet deep.
- Domestic wells vary between 100 and 220 feet deep.
- Agricultural irrigation well production rates range from 800 to 4,200 gallons per minute, and domestic well production rates are typically 10 to 20 gallons per minute.
- Water from the irrigation and domestic wells varies in quality, depending on well location, depth, and frequency of use.
- Seven production wells are powered by electric motors, and one is powered by a 50- to 75-horsepower diesel motor.
- Agricultural irrigation wells that are used as a supplemental source for conjunctive water management typically run continuously for 4 to 8 weeks during July and August during dry years only.

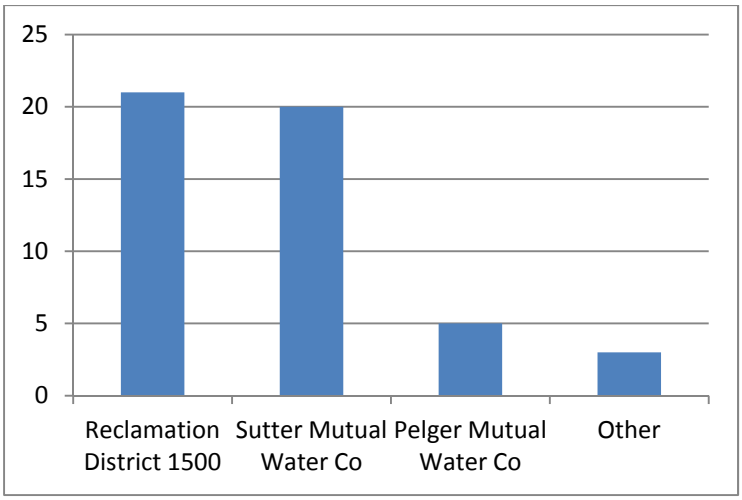

FIGURE 1
RD 1500 Service Area Distribution of Survey Respondents

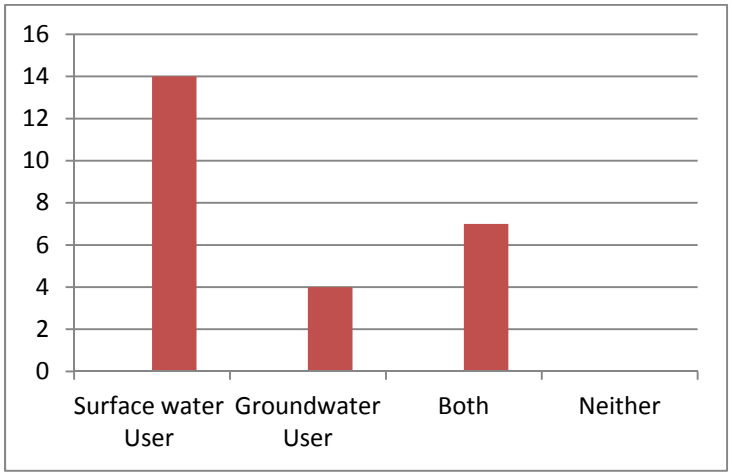

FIGURE 2
RD 1500 Service Area Water Usage Summary

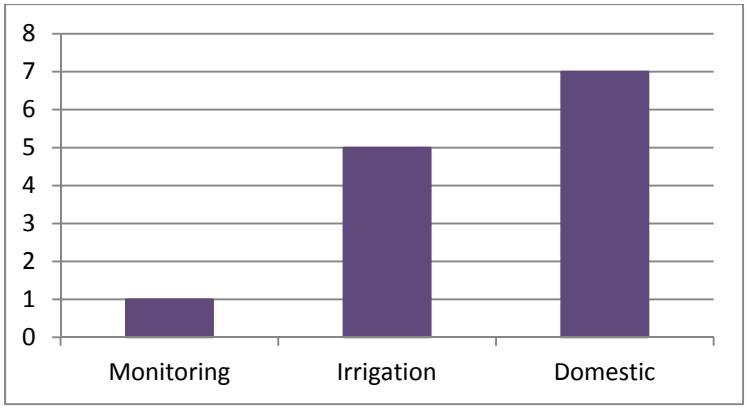

FIGURE 3
RD 1500 Service Area Groundwater Well Summary

Attachment 1
Landowner Outreach Program Survey

Please fill out and return to the Reclamation District No. 1500 office no later than January 10, 2011.

Dear Water User:

Thank you for taking the time to read and fill out this survey. If you would prefer to not provide certain information, please leave that portion of the survey blank and continue to the next portion. We would appreciate any information that you are willing to share with us.

Sincerely,
The Sutter Basin Water Partners (RD 1500, SMWC, and PMWC)

Water User Information*. Feel free to leave blank if you want to remain anonymous.*			
Name			
Address		**Phone No.**	
City		**Email**	

Question		***Yes or No***	***Any Comments?***
Water District or Company Member?	Reclamation District 1500		
	Sutter Mutual Water Co.		
	Pelger Mutual Water Co.		
	Other? (If yes, what?)		
	Not Applicable		

Contact the following with any questions:
RD 1500/SMWC: Max Sakato at (916) 765-0187 or Dennis Peterson at (530) 738-4423
PMWC: Scott Tucker at ((530) 908-8421

Question		*Yes or No*	*Any Comments?*
Surface Water User or Groundwater User?			
	Surface Water User		
	Groundwater User		
	Both		
	Neither		
If you are a groundwater user, what type of groundwater well do you have?			
	Monitoring		
	Irrigation		
	Domestic		
	Other? (If other, please describe)		

Question	*Description*
Describe your groundwater well location. If you are willing to give an exact location, please do that. If you would like to be more general, please indicate which area (A, B, C, D, or E) your well is located on the attached map.	
How deep is your well?	

Question	*Description*
What can you tell us about the construction of your well? For example, casing materials, casing size, pump size, screening intervals, etc..	
What can you tell us about the quality of the water from your well? For example, do you see seasonal changes in the quality of your water? Do you need to blend your groundwater with surface water for acceptable water quality? What constituents do you see in your well (e.g. TDS, arsenic, etc.).	
What is the output of your well in gallons per minute?	
How is your well powered? Electric or Diesel or Other?	
How often do you use your well? (Every year, every day, etc.?)	
How do you run your well? (For example, 24 hrs a day, 7 days a week during irrigation season? Only on off-peak times? 2-3 times a week?)	
Would you be willing to provide us with your well logs? If so, please provide your contact information (e.g. phone number or email address).	

Please return your surveys by hand or by mail to the Reclamation District No. 1500's office at

15094 Cranmore Rd.
PO Box 128
Robbins, CA 95676

Appendix E
California Department of Water Resources Groundwater Basins

Sacramento Valley Groundwater Basin, Sutter Subbasin

- Groundwater Basin Number: 5-21.62
- County: Sutter
- Surface Area: 234,400 acres (366 square miles)

Boundaries and Hydrology

The Sutter Subbasin lies in the eastern central portion of the Sacramento Valley Groundwater Basin. It is bounded on the north by the confluence of Butte Creek and the Sacramento River and Sutter Buttes, on the west by the Sacramento River, on the south by the confluence of the Sacramento River and the Sutter Bypass, and on the east by the Feather River. The subbasin lies entirely within the Sacramento River watershed with the most notable hydrological features being the Sacramento and Feather Rivers. Other notable features are Tisdale Bypass and Sutter Bypass. The manmade Sutter Bypass acts as a flood control overflow for the Sacramento River.

The topography of the subbasin is comprised primarily of the gentle flatlands of the Sacramento River Valley. The only prominent topographic feature near the subbasin is the Sutter Buttes at its northern boundary, a Pliocene volcanic plug which rises abruptly 2,000 feet above the surrounding valley floor.

Average precipitation ranges from 17 to 21 inches in the subbasin. Annual rainfall increases across the basin from the southwest to the northeast. (PMC, 1996).

Hydrogeologic Information

Water Bearing Formations

The geologic formations of the Sutter Subbasin include pre-Cretaceous metamorphic and igneous rocks of the Sierra Nevada block, which extends beneath the valley fill overlain principally by Tertiary sedimentary formations derived from these and other rocks which are exposed in the Sierra Nevada to the east. The sedimentary rocks are of both marine and continental origin and are frequently interbedded with tuff-breccias. Volcanic rocks are also represented in the area in and around Sutter Buttes, which are erosional remnants of an extinct Pliocene volcano. Only the sedimentary rocks can be considered as being water bearing to any appreciable degree.

The Sutter Subbasin aquifer system is comprised of continental deposits of Quaternary (Recent) to Late Tertiary (Miocene) age. The cumulative thickness of these deposits increases from a few hundred feet near the Sierra Nevada foothills on the east to over 2,000 feet along the western margin of the basin (DWR 1978). Groundwater and geology information for this aquifer system was referenced from Olmsted and Davis 1961, DWR 1978, Page 1986, and B-E 1992.

Holocene Stream Channel and Floodplain Deposits. These alluvial materials occur as coarse sand and gravel along present stream channels of

the Yuba, Feather, and Sacramento Rivers. Coarser grained materials occur near streams with thicknesses up to about 100 feet. Both grain size and thickness decrease with increased distance from streams. These deposits are highly permeable and provide for large amounts of groundwater recharge within the subbasin. Well yields are reported in the range of 2,000 to 4,000 gpm.

Pleistocene Floodplain Deposits. These deposits occur as gravelly sand, silt, and clay from flood events along the Feather River and its tributaries. This unit overlies the Older Alluvium, underlies Quaternary Deposits, and ranges in thickness up to about 100 feet. These deposits provide a good medium for groundwater recharge, provided the groundwater can pass the lower contact with the Older Alluvium.

Pleistocene Victor Formation (Old Alluvium). Victor Formation ranges in thickness up to about 100 feet. This formation is comprised of Sierran alluvial fan deposits of loosely compacted silt, sand, and gravel with lesser amounts of clay deposits. The deposits occur as lenticular beds with decreasing thickness and grain size with increasing distance from the Yuba River and the foothills. Hardpan and claypan soils have developed to form an impermeable surface, but below this the Older Alluvium is moderately permeable and provides for most of the groundwater from domestic and shallow irrigation wells. Wells in the older alluvium have yields up to 1,000 gpm.

Pliocene Laguna Formation. This formation consists of compacted layers of sand, silt, and clay with hardpan in surface soils. In the subsurface, this formation has a thickness of about 300 feet but is estimated to be up to 1,000 feet along the valley axis. Although the occurrence of thin sand and gravel zones is common, many of them have reduced permeability due to cementation. This coupled with its fine-grained character, leads to an overall low permeability for the Laguna Formation. This formation is an important source of water for southeastern Sacramento Valley.

Miocene - Pliocene Mehrten Formation. The Mehrten Formation is a sequence of volcanic and volcaniclastic rocks of late Miocene through middle Pliocene age. The formation ranges in thickness from about 200 feet to over 1,000 feet along the axis of the valley. The Mehrten Formation is composed of two distinct units: One unit occurs as intervals of gray to black, well-sorted fluvial andesitic sand (up to 20 feet thick), with andesitic stream gravel lenses and brown to blue clay and silt beds. These sand intervals are highly permeable and wells completed in them can produce high yields; The second unit is an andesitic tuff-breccia that acts as a confining layer between sand intervals. This formation is also an important source of water for southeastern Sacramento Valley.

Oligocene - Miocene Valley Springs Formation. The Valley Springs Formation consists of gravel, sand, silt, and clay, siltstone, and tuffaceous beds which all contain rhyolitic material. This unit is reported to have a maximum thickness of about 200 feet. The Valley Springs Formation deposits typically have low permeabilities and therefore, yield only small quantities of water to wells.

Recharge Areas

DWR, Bulletin 118-6, indicates stream percolation, deep percolation of rainwater, and percolation of irrigation water are the principal sources of groundwater recharge in the Sacramento Valley.

Groundwater Level Trends

Current DWR records indicates groundwater levels have remained relatively constant. DWR hydrographs indicate a shallow-depth water table. Most groundwater levels in Sutter Subbasin tend to be within about 10 feet of ground surface. (DWR, 1992)

Groundwater Storage

Groundwater Storage Capacity. DWR's 1992 California Water Plan estimated a useable storage potential of five million-acre feet for Sutter County. There are no published reports, which specifically discuss the amount of groundwater in storage for the Sutter Subbasin.

Groundwater in Storage. There are no published reports, which specifically discuss the amount of groundwater in storage. A change in storage is discussed in DWR, Bulletin 6, 1952 and Bulletin 118-6, 1978.

Groundwater Quality

Characterization. DWR maintains data for 38 water quality wells in the Sutter Subbasin. Data collected from these wells indicate a TDS range of 133 to 1,660 mg/l. The primary groundwater chemistry in the subbasin is calcium, magnesium, sodium, chloride, sulfate and bicarbonate, which may occur in any combination. Groundwater containing calcium magnesium bicarbonate or magnesium calcium bicarbonate can be found in the northwest portion of the subbasin (Bertoldi, 1991). Recent groundwater quality data collected indicates some wells drilled to various depths contain chemical elements and compounds in amounts that exceed drinking water quality safety and aesthetic standards. (PMC, 1996).

Impairments. Groundwater resources in some portions of the County have naturally occurring levels of minerals, which present some concerns. Groundwater quality is expected to deteriorate unless additional steps are taken to decrease the amounts of contaminants that exist in the ground and are applied to the ground. Steps also must be taken to decrease the ability of wells and other excavations to transmit contaminants from upper regions of the ground to lower regions that provide well water. (PMC, 1996).

Groundwater Budget (Type B)

As part of its water planning process, DWR estimated the following components of the ground water budget for the entire Sutter Subbasin. The calculations are for a 1990 level of development. Estimated inflows include natural recharge at 40,000 acre-feet and applied water recharge at 22,100 acre-feet. There was no artificial recharge. Estimated outflows include urban extraction at 3,900 acre-feet and agricultural extraction at 171,400 acre-feet.

Well Characteristics

	Well yields (gal/min)	
Municipal/Irrigation	Range: 500-2000	Average: 728 (DWR, Bulletin 118-6, 1978)
	Total depths (ft)	
Domestic	Range: 35-320	Average: 121 (496 Well Completion Reports)
Municipal/Irrigation	Range: 60-672	Average: 205 (131 Well Completion Reports)

Active Monitoring Data

Agency	Parameter	Number of wells /measurement frequency
DWR	Groundwater levels	2 wells semi-annually, 1 well monthly
Yuba County		21 wells semi-annually
Sutter County		10 wells semi-annually
DWR	Mineral, nutrient, & minor element.	13 wells semi-annually
Department of Health Services (including co-operators)	Title 22	115 wells annually

Basin Management

Groundwater management:	Reclamation District 1500, Draft AB3030 7/97. Feather WD adopted a groundwater management plan on November 8, 2005.
Water agencies	
Public	Sutter Mutual Water Company, Meridian Farms Water Company, Butte Slough Irrigation Company, Tisdale Irrigation District, Pelger Mutual Water Company, Sutter Extension Water District, Feather Water District, Oswald Water District, Tudor Mutual Water Company, Garden Highway Municipal Water Company
Private	Garden Highway Municipal Water Company, Reclamation District 70, Reclamation District 1660, Reclamation District 1500

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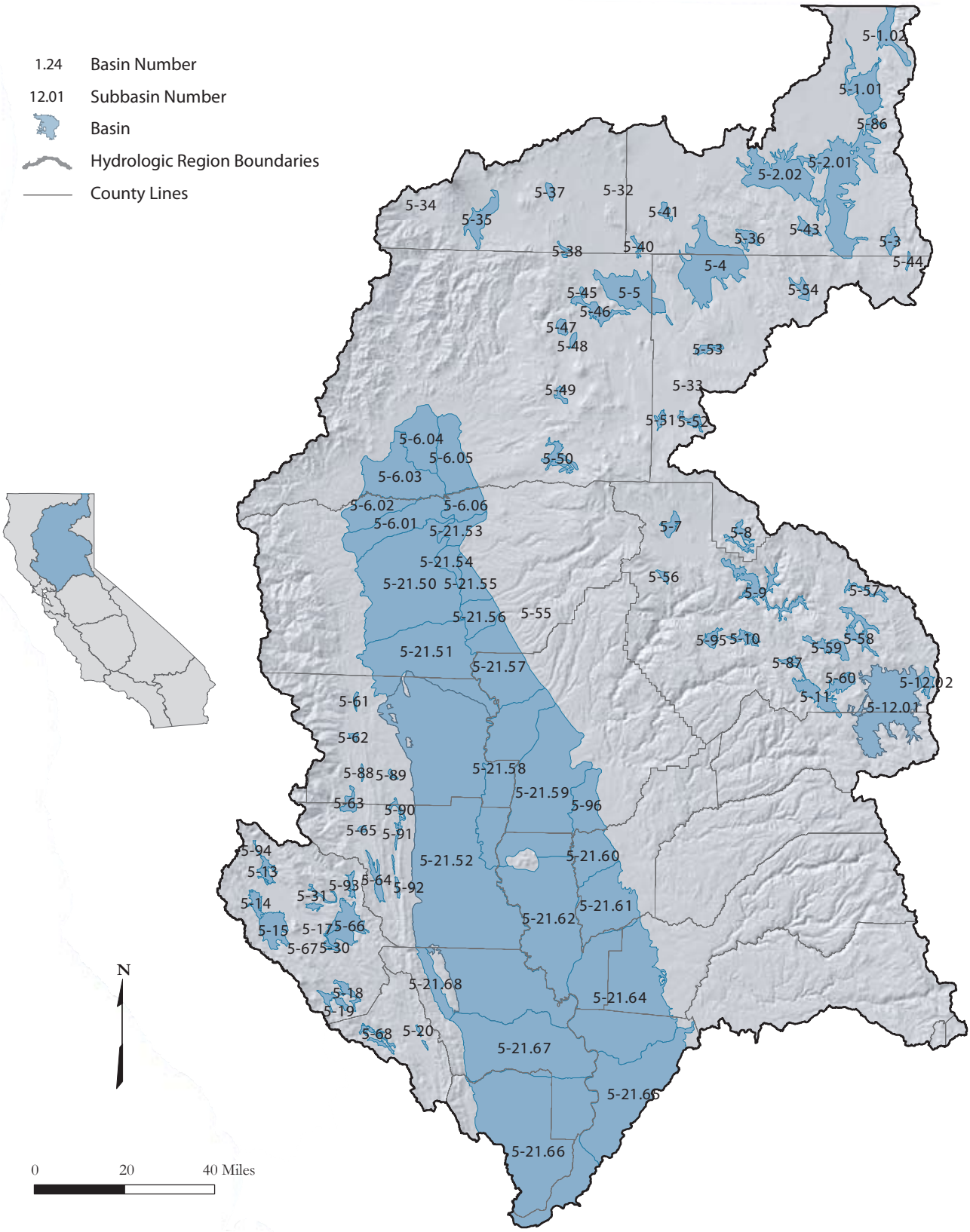
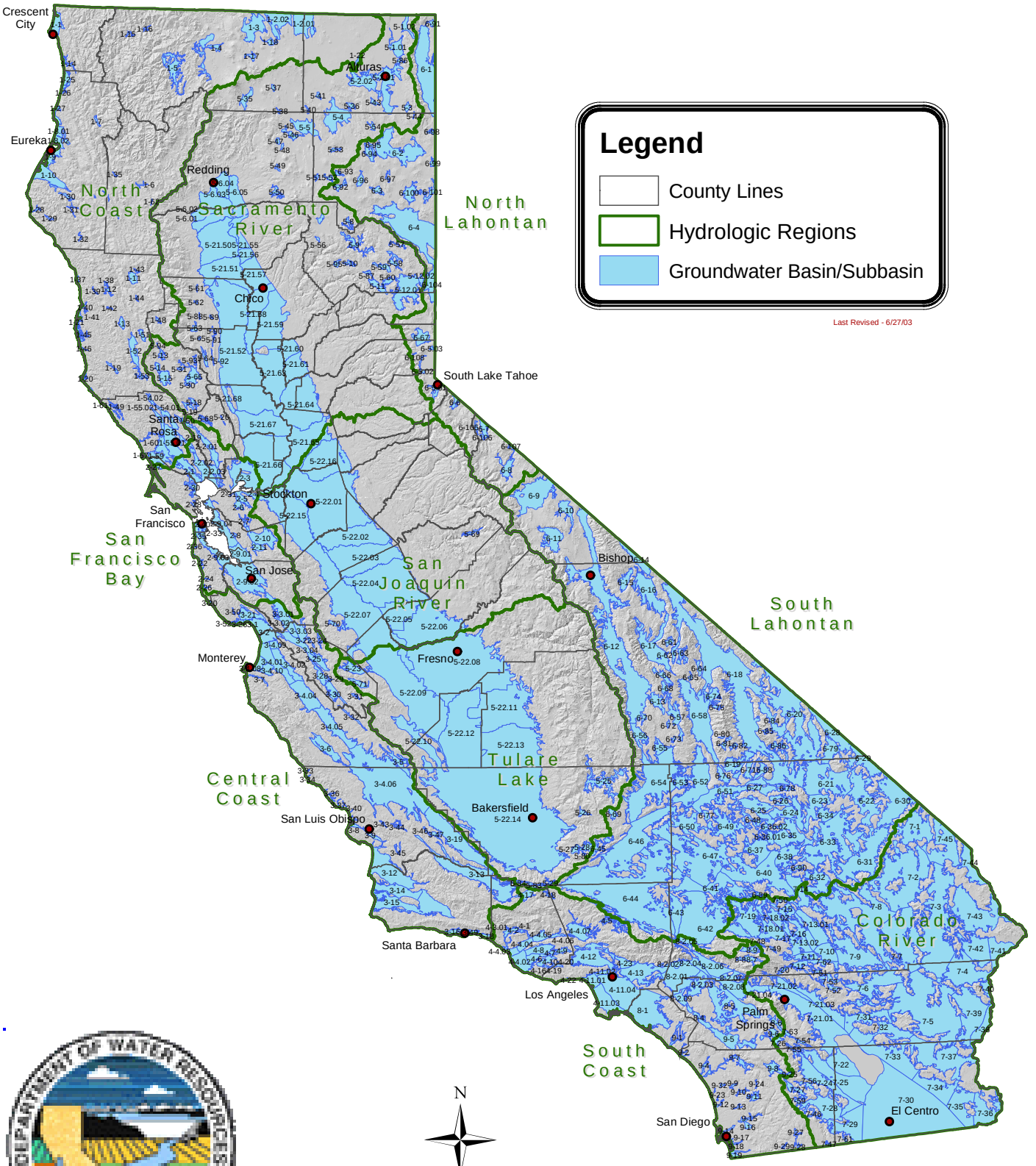
Errata

Updated groundwater management plan information. (1/20/06)



Sacramento River Hydrologic Region

Groundwater Basins in California



Appendix F
Natural Resources Study for Reclamation District No. 1500 and Sutter Mutual Water Company and Supporting References

United States
Department of
Agriculture

Natural
Resources
Conservation
Service

February 1996

RECLAMATION DISTRICT NO. 1500

RESOURCE STUDY

SUTTER COUNTY, CALIFORNIA

NATURAL RESOURCES STUDY

FOR

RECLAMATION DISTRICT 1500

AND

SUTTER MUTUAL WATER COMPANY

FEBRUARY 1996

Prepared by

USDA Natural Resources Conservation Service

USDA Forest Service

in cooperation with

Sutter County Resource Conservation District

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EXECUTIVE SUMMARY

Purpose and Objectives of Study

The Natural Resources Conservation Service (NRCS), formerly the Soil Conservation Service, was requested by the Sutter County Resource Conservation District, Sutter Mutual Water Company (Company), and Reclamation District 1500 (District) to study the resource issues and opportunities for resource enhancement within the District's boundaries in the Sutter Basin.

The District and Company are interested in and concerned with water conditions in their service area. While they are mandated to update their water management plan, they are also interested in the potential effects reduced water use may have on the environment and farmland. One example is that the drainage water from this area is currently discharged into the Sacramento River from the Karnak pumping plant and changes in water use or management made in the study area would impact the river. Currently, the irrigation water used in the summer helps dilute the saline drain water in the area. Improvements in water conservation may increase the salinity of the return discharges to the Sacramento River.

The Reclamation Reform Act and the Central Valley Project Improvement Act require that entities contracting for Federal water project supplies develop water conservation plans. These plans must examine existing water management practices, evaluate other water management strategies, and determine how to implement appropriate water conservation measures. The Bureau of Reclamation has identified 14 potential additional measures that should be evaluated for suitability in reaching water conservation goals. This report evaluates these measures with respect to conditions in the study area and summarizes the results for applicability and feasibility to the Sutter Basin.

Resource Features of Study Area

The study area is approximately 68,000 acres and is completely enclosed by three levee systems. The town of Robbins, 22 miles northwest of Sacramento, is the central business and residential center of the area.

The climate of the area is typical of a Mediterranean climate with hot, dry summers and cool, moist winters.

It has been suggested that during the Late Paleocene Period, an inland sea was trapped in the Sacramento Valley, leaving a mound of saline connate water underground. It is believed that this connate water, containing principally sodium and chloride, rises upwards through the Sutter Basin Fault under artesian pressure. Before the construction of the levees, the Sutter Basin was covered with water during most of the spring months, and in summer the land was swampy in places and covered with tules. Natural precipitation and flooding kept the salts in the soil leached. After levee construction proper irrigation and drainage have kept the salts under control.

The two major crops grown in the study area are rice and tomatoes, the latter in rotation with wheat, corn, safflower, and beans. Rice may be grown in rotation with crops such as wheat, safflower, beans, and melons though some growers grow rice seven to eight years in a row.

Water quality concerns in the area center on salinity. The water supply from the river is of excellent quality and averages 130 micromhos/cm electrical conductivity (EC). Water running off of fields flows into the drains where it picks up volume and salinity from the subsurface water seeping into the drains. The EC of the water at the main drain is typically ten-fold greater than that of the supply water before and after the irrigation season and five-fold greater during the irrigation season. The water used for crop irrigation apparently dilutes the salt concentration in the drain water. From 1987 to 1992 the EC of the

main drain at Karnak varied from 380 to 780 micromhos/cm during the irrigation season. In the winter the EC ranged from 420 to 1,500 micromhos/cm.

While the conversion to agriculture has reduced riparian, prairie, and marsh habitat and the species associated with these habitats, other wildlife species have been favored by agricultural development. Species such as the western yellow-billed cuckoo, Swainson's hawk, bank swallow, wood duck, bald eagle, giant garter snake, western pond turtle, California tiger salamander, California red-legged frog, Chinook salmon, valley elderberry longhorn beetle, and the California hibiscus are only found at low levels and some are even listed as State or Federal threatened or endangered species. On the other hand, migratory waterfowl are doing very well in those areas where rice, wheat, barley, milo, corn, and beans are being grown. Grain provides good nesting habitat and the rice fields also provide good habitat throughout the summer and into the fall and, in some cases, through the winter. The ditches are good habitat for blue and channel catfish, carp, crayfish, and bullfrogs while the banks and levees are used by pheasants for nesting.

Water Resources Inventory

In the early 1900s levees were constructed as protection against overflow from flood waters and for navigation. Shortly after the levees were built, the irrigation and drainage systems for the basin were constructed.

Most of the irrigation water in the study area is pumped from the Sacramento River. A small number of wells are used and some drainwater reuse exists within the service area.

In 1990, 197,200 acre-feet of water were diverted from the river by the Company. The Company maintains and operates four pumping plants. In addition, the Company operates 8 booster pumps and one internal recirculation system with a total combined capacity of 290 cubic feet per second (cfs) per day.

The manner in which rice is irrigated is unique among all the crops in the basin. Rice has a higher evapotranspiration rate than other crops and needs to be in a fully saturated field. The rice fields raise the water table in the surrounding fields because the water table becomes the water surface of the rice field. If the water table approaches the root zone of the crop, the crop can obtain water without irrigation. Less water is applied to melons than the crop needs because the crop meets its water needs from the water table. An estimated seventy-one of the 136 growers of tomatoes, beans, and melons are able to apply less than the crop actually needs.

The average crop irrigation requirement for the period 1981 through 1990 was approximately 85,800 acre-feet per year. Dividing the average crop irrigation requirement for the period by the average irrigation delivery of 172,800 acre-feet yields a service area-wide average on-farm efficiency of approximately 50 percent. Up to 1991 average efficiencies ranged from 45 to 55 percent with open ditch systems having lower efficiencies than piped systems. Since then efficiencies have increased to 60 percent due to water reuse and other practices. An arbitrary target efficiency of 80 percent was set in this study for the evaluation of the proposed changes in water management discussed in this report. The high water table in the area consists of seepage from the river, subsurface interbasin inflow from the surrounding area, and rising connate water under artesian pressure. Due to its high salt content, the ground water is not used for irrigation except along the Sacramento River, where the salt content is much lower. One potential source for salt buildup in the ground water is the upward movement of deep lying connate water driven by freshwater under an artesian head.

The concentration of salts increases with depth below ground. Studies performed on the saline connate water in the area indicate total dissolved solids concentrations in the ground water ranging from 248 to 5,970 mg/l in wells drilled from 72 to 1,500 feet deep. Ten to 20 feet below the surface the EC ranges

from 1,000 to 4,000 micromhos/cm while 100 to 300 feet below the surface the EC range increases from 8,000 to 13,000 micromhos/cm.

The salt-laden ground water seeps into the drain ditches and causes an increase in EC in the drains. The salt concentration in the main drain is typically much higher during the winter than during the irrigation season. The good quality irrigation water dilutes the salty ground and drain waters.

Water and Salt Budgets

To establish a water budget, the year 1993 was used. The rainfall record from the Tisdale pumping plant produced a precipitation estimate of 22.14 inches. Records indicate that 184,532 acre-feet of water were diverted from the Sacramento River by the Company. Other Bureau of Reclamation contractors diverted an additional 26,034 acre-feet. It was assumed that water to the area was used for evapotranspiration (Et), lost to deep percolation, or drained into the drainage network. The estimated Et for the basin in 1993 was 224,537 acre-feet. The discharge at the Karnak plant was 201,275 acre-feet. The amount of water pumped from the river and wells by rimland farmers was estimated by Et. Rimlands and rim water are the local terminology for non-Company areas.

There are more salts leaving the basin than entering the basin. One theory is that previously accumulated salts are coming out of the soil profile. The average estimated salt load in surface water inputs was 0.14 tons per acre-foot, and the estimated drain outflow was 1.07 tons per acre-foot, an 8.5-fold increase.

Connate and rim waters were estimated to contribute about 40 percent of drain water outflow and roughly 20 percent of the salt outflow. The salt budget implies that 58 percent of the salt load from this area to the Sacramento River is leached from the basin's soils.

Description and Analysis of Water Conservation Measures

The Reclamation Reform Act and the Central Valley Project Improvement Act require that entities contracting for Federal water project water supplies develop water conservation plans. These plans need to examine existing water management practices, evaluate other water management strategies, and determine how to implement appropriate water conservation measures. The 14 measures recommended by the Bureau of Reclamation should be evaluated based on applicability to the district, technical feasibility, financial feasibility, improved efficiency of water delivery and use, quantity of water to be saved, and environmental impacts. These suggested measures have a demonstrated record of effectiveness in reducing losses of, making more efficient use of, or otherwise conserving water. Due to its lack of legal expertise, NRCS did not evaluate the measures for their legality under state and federal law. The 14 measures are as follows:

1. Incentive Pricing: Implement an increasing tiered block water pricing structure, or other water pricing structure, that promotes the efficiency of water use.

In 1993 the Company separated charges into a flat maintenance charge of $13 per acre per year plus a charge of $8 per acre-foot for water purchased. This charge applies to 50,083 acres in the study area.

Generally, this measure is applicable to the District both technically and financially. While it was not possible to determine the actual impacts of tiered pricing in the Sutter Basin, an attempt was made to estimate the potential water savings. The present overall on-farm irrigation efficiency for the major row crops of tomatoes, melons, and beans exceeds 100 percent because part of the water requirement is met by the shallow water table. However, water use data indicates some water savings is possible on a portion of these croplands. With data available from 75 percent of the total growers in the area and a target efficiency of 80 percent, it was estimated that the potential amount of water saved is 2,700 acre-

feet. Expanding this to the other 25 percent growers would produce a potential water savings of 3,600 acre-feet. This is less than two percent of the total water diverted in 1993. This irrigation efficiency increase is only possible on cropland. Rice acreage irrigation water use is a function of crop water use which is fixed and soil seepage which varies by soil type.

Negative impacts include the reduction of water available for reuse, the reduction of water discharged at Karnak and available downstream, and the potential increase in salinity in the drains as a result of less dilution effect.

2. On-Farm Program Incentives: Facilitate and/or provide financial incentives and assistance for on-farm water use efficiency improvements.

As estimated under the discussion on tiered water pricing, only 3,600 acre-feet would potentially be saved with this type of incentive measure. While this measure is applicable to the District and technically feasible, it applies mostly to the row crops. Rice is generally grown in closed systems or with tailwater return systems so only minimal improvements to irrigation efficiency could be made. Only 12,000 of the remaining row crop acres would need to be improved to reach the target efficiency of 80 percent. On-farm educational and technical assistance to achieve this goal would cost $12 per acre-foot while system improvements could cost in excess of $50 per acre. Potential negative impacts are the same as those listed for the incentive pricing measure.

3. Drought/Water Shortage Contingency Plan: Develop a drought/water shortage contingency plan for the district that outlines the policies and procedures for operation and allocation during water supply shortages.

The Company has a mechanism in place to deal with drought/water shortage situations. This measure is applicable to the area and technically and economically feasible. The quantity of water saved and any environmental impacts from this measure are unknown.

4. Water Transfers: Facilitate voluntary transfers that do not unreasonably affect the district, the environment, or third parties.

The Company is currently exploring water transfer opportunities and needs to further examine the potential impacts on the Company, the environment, and third parties. This measure is applicable to the District and is technically feasible. While there is the potential for landowners or the Company to receive supplemental income, the local economy may be negatively impacted by the resulting reduction in agricultural input needs and crop processing services. The environment may also be impacted from additional salt buildup due to reduced irrigation applications.

5. Conjunctive Use: Increase conjunctive use of surface and ground water within the district, begin working with appropriate entities to develop a ground water management plan.

The District currently performs a form of conjunctive use by manipulating the water level in the drainage ditches. Any further form of conjunctive use is not applicable in this area due to the high water table and saline conditions of the ground water. This measure is not technically feasible to the area for this reason because another area would need to be found in which to store water underground. It would be costly to build a system to transport the water to another district, pump the water from the ground, and then transport it to another area as needed.

6. Land Management: Facilitate alternative uses for lands with exceptionally high water duties, or whose irrigation contributes to significant problems (e.g. drainage that does not meet discharge standards).

Present land management practices, cultivation, and irrigation water management are done in a manner that minimizes problems that relate to water discharges which exceed standards. In the high salinity areas irrigation has actually helped to make the land more viable for agriculture.

This measure is applicable to the District and technically feasible. Financial feasibility is limited due to the lack of other income-producing uses for the land. Some water would be saved if land was taken out of production but there may be a corresponding salt buildup in the soils, leading to an overall decrease in suitable habitat for the current species found in the area.

7. Operational Practices and Procedures: Evaluate potential district operational policy and institutional changes that could allow more flexibility in water delivery and carryover storage.

The existing system is fairly flexible. Current Company policy states that irrigation water delivery to growers requires a 48-hour advance notice and a 12-hour advance notice for shut off. The current system is effectively an on-demand schedule. Present policy allows ditch tenders to shut gates where water is obviously being wasted.

While this measure is applicable to the District, it may not be technically feasible due to the time required to allow water from Shasta Dam to reach the area. There would be costs associated with hiring more personnel to be available for water delivery and shut-off. There would also be costs associated with the installation of additional water management equipment. This measure would create more flexibility in water delivery, though not necessarily an increase in water use efficiency. Landowners might be able to save additional water if they had more flexibility in water delivery and shut-off, but there would also be less water in the ditches and canals which would reduce water edge habitat.

8. Irrigation System Scheduling: Implement a program of distribution system scheduling based on area-wide crop demand modeling or advanced demand requirements.

The responsibility of ordering water belongs to the grower.

This measure is applicable to the District and is technically feasible. As mentioned previously, 3,600 acre-feet could be saved by increasing the least efficient growers' efficiency to 80 percent. The assumption is made that, if growers are informed how much water they are using in comparison to other growers, they may see how they can also reduce their own water use. Care must be taken not to reduce irrigation levels below the amount needed to manage the connate water and continue leaching the salts from the soil. Saline soil would affect existing habitats and land uses.

9. On-Farm Scheduling: Facilitate the delivery of crop water use and on-farm delivery information to district customers for on-farm irrigation scheduling.

The Company is already distributing information in the growers' bills. Typical water use for each crop and the distribution of water orders in the area so growers can compare their use to that of other growers are examples of the type of information being made available. The maximum amount of potential water savings is the same 3,600 acre-feet discussed previously. There would be some cost associated with hiring personnel to provide landowners with education, information, and technical assistance.

10. Pump Efficiency Evaluations: Coordinate the evaluation of district and private pumps with local utilities, evaluating both energy and water efficiency.

The Company currently supports PG&E's pump testing program. This measure is applicable to the District and technically feasible. Energy and water cost savings could be increased, but there would be some expense associated with equipment and personnel costs for monitoring. There would probably be a negligible effect on the environment and no actual water savings.

11. Distribution Control: Modify distribution facilities and controls to increase the flexibility of water deliveries.

Ditch riders are currently allowed to close or reduce delivery to customers who are spilling water from their fields. This measure may be applicable to the District but is not technically feasible. The need to order water two days in advance from Shasta Dam limits flexibility of delivery. There would be many costs involved with automating equipment and hiring additional personnel. With the two-day advance notice limitation, there would be no significant increase in water delivery efficiency. There would be no significant environmental changes with this measure.

12. Reuse Systems: Construct district operational spill reuse system.

The Company presently reuses up to 15,000 to 16,000 acre-feet per year with an additional 15,000 to 16,000 acre-feet used by growers who pump from the drainage system. These figures will vary each year. Some growers also operate individual on-farm reuse systems.

A basin-wide recirculation system would lift water from Bohannon Dam upstream to the main canal. The estimate for 1994 of water which could have been available for reuse is 24,655 acre-feet. The discharge to the Sacramento River at Karnak would have an average EC of 2,263 micromhos/cm for July and 2,215 micromhos/cm for August and would have been reduced in volume. Salt would be stored in the soil profile during the irrigation season. If this water were recirculated in the basin, a much higher winter EC would become typical.

If the installation and maintenance costs of a reuse system are distributed over the Company's service area of 50,083 acres and amortized for 25 years at eight percent interest, the annual per acre cost of installation and maintenance is $5.50. The power cost for lifting the water back to the main canal is about four times the cost for lifting the water from the Sacramento River.

This measure is applicable to the District and is technically feasible. The efficiency of water use or delivery would not significantly change. For evaluation purposes, assuming that 50 percent of water discharged into the Sacramento River is available for reuse, an additional 52,500 acre-feet could be incorporated into a reuse program during the irrigation season. These figures are based on a water year similar to the year 1993.

There is a strong potential for increasing the concentration of natural salts in the basin due to the connate ground water source and less fresh water for leaching. The reduced amount of drain water that continues to be returned to the Sacramento River may involve higher concentrations of salts. There will be a need to mix fresh water with the reuse water to maintain the District's recommended EC level of 750 micromhos/cm. Growers would need to closely monitor the quality of the water they are applying.

13. Distribution System Lining: Line distribution ditches or canals or convert to pipe.

Conversion to Lined Ditch

Two ditch lining options were considered: lining approximately 34.4 miles of the 167 miles of ditch and lining 5.0 miles of ditch. The ditch segments recommended for lining are those in which the soils allow excessive amounts of irrigation water to seep into the ground water. The amount of water lost to seepage would be reduced by 37,100 acre-feet per year for 34.4 miles of lining and 19,700 acre-feet per year for 5.0 miles of lining. The analysis shows that 97 percent of the seepage losses from the canal system is lost from 34.4 miles, or 21 percent, of the ditch system. Fifty-two percent of the water is lost from three percent, or 5.0 miles, of the system.

This measure is applicable to the area and is technically feasible for those segments with excessive seepage. Lining 34.4 miles of ditch would cost $12.8 million, while lining 5.0 miles would cost $2.3

million. The average annual costs, based on 10 years, would be $1,852,000, or $50 per acre-foot of water, for 34.4 miles of lining and $337,000, or $17 per acre-foot, for 5.0 miles of lining. This is about twice the current per acre-foot cost that the water user pays the Company.

There would be no significant improved efficiency of on-farm water use or delivery. The Company would have increased efficiency of water delivery. Lining would eliminate the same number of miles of water edge and open water habitat.

Conversion to Pipeline

Maintenance of a piped system would require replacement every 25 years. Estimated pipe maintenance costs are $1,500 per pipe mile. The estimated cost of 34.4 miles of a pipeline system is $75 million. The minimum average annual cost would be $9.5 million. The estimated cost per acre-foot would be $225 and could be much higher. The added cost would raise the annual fee for the assessed gross acres of 50,083 by about $190 per acre.

The Company could manage water delivery more easily and efficiently; however, there would still be a need to order water from Shasta Dam in advance. Drain water reuse in the basin would no longer be able to take place. Approximately 42,000 acre-feet of water would be saved with this measure.

Piping the ditches would eliminate 613 acres of open water habitat and 840 acres of water edge habitat. There is a strong potential of increasing the salt concentration in the basin with the decrease in the dilution effect of the seeped water into the connate water. The drain water returned to the Sacramento River may involve higher concentrations of salts.

14. Construction or Lining of Regulatory Reservoirs: Construct or line regulating reservoirs.

Currently, the Company's control of water delivery is limited. There is no Company regulating reservoir; however, the main canals have significant storage capacity and function as regulating reservoirs. Between 3,600 and 76,000 acre-feet of water could be stored to be used at a later time depending on the types of improvements made.

This measure is applicable to the area and is technically feasible. The Company would need to gain support of the growers and provide appropriate incentives to implement a significant modification to the way growers manage their farming operations. Growers would need to pay for the infrastructure and operation costs in terms of higher assessments. The Company would be faced with the purchase cost of land, cost associated with construction of the water-holding basin and associated infrastructure, and annual operation and maintenance expense.

Some agricultural land would need to be taken out of production for the construction of a basin. Some additional wetland habitat could be created with the development of a basin.

Table 7 summarizes these measures.

Opportunities and Considerations

For this study a resource inventory was performed and the information developed was used to assess the recommended Bureau of Reclamation water conservation measures. Bureau contractors such as Sutter Mutual Water Company are required to prepare a water conservation plan evaluating these measures.

The result of this assessment indicates that, while there is room for slight improvements, local growers, Sutter Mutual Water Company, and Reclamation District 1500 are efficiently utilizing the water resources available to them. Any dramatic modifications to the way water is managed in this basin

requires further research and understanding of ground water fluctuations and the movement of the connate water.

A relatively small amount of water, 3,600 acre-feet or two percent of the District's total water diverted in 1993, could be saved with the implementation of suggested measures such as tiered pricing, on-farm incentives, or changes in irrigation or delivery scheduling. More water, up to 84,500 acre-feet, could be saved with measures such as reuse and lining or piping of ditches. These measures, however, may severely impact irrigation water quality and the ability to produce crops, may have negative environmental impacts, or may not actually save water. Water reuse to its highest level will potentially increase salinity in the soil and water to unmanageable levels. Water seeping from the ditches is not actually "lost"; rather, due to the high water table, most of the ground water seeps into the drain ditches and is discharged at Karnak. In fact, this water actually helps dilute the saline ground water, producing a higher quality water for discharge into the Sacramento River. The elimination of wildlife habitat would also be significant.

There are some opportunities for environmental enhancement. While present agricultural practices and the water distribution system are beneficial to many fish and wildlife species, there are practices which could offer further enhancement. The Company has become well informed about the installation of fish screens on pipes removing water from the Sacramento River and is ascertaining the best design and related costs of controlling fish at the pump inlet. Establishing nesting boxes or windbreaks near rice fields will help attract and maintain wood ducks. Planting fence rows, ditch banks, and row or field edges to native grasses with clovers provides cover for wildlife and can eventually out compete weeds, reducing the need to burn or spray.

It is recommended that the U.S. Geological Survey be consulted to formulate a plan to study the ground water and develop a three-dimensional isoconcentration map. A well management plan and a ground water model could be the product of this plan.

There are some limited opportunities for water conservation on 12,000 acres of row crops, excluding rice, in the study area. The amount of water saved would not exceed 3,600 acre-feet. Switching to sprinklers for early irrigations, eliminating one or two unnecessary irrigations, and shortening sets were preliminary suggestions developed from the use of the AGWATER computer model.

It was determined in this study that growers are not planning any significant changes in land or resource use in the foreseeable future. There is a stable and healthy farming economy with a stable crop pattern. Drastic cutbacks in water availability would most likely lead to an increase in soil salinity and impact crop productivity and have an adverse impact on wildlife habitats and populations.

SECTION I

INTRODUCTION

Background

The Natural Resources Conservation Service (NRCS), formerly the Soil Conservation Service, was requested by the Sutter County Resource Conservation District, Sutter Mutual Water Company (Company), and Reclamation District 1500 (District) to study the resource issues and opportunities for resource enhancement within the District's boundaries in the Sutter Basin.

Reclamation District 1500 is a Special District formed by a special act of the legislature in 1913, with a primary purpose of agricultural drainage, flood control, and levee maintenance.

The Sutter Mutual Water Company was incorporated in 1919 and has been continuously delivering irrigation water to lands for over 72 years.

Major Concerns and Opportunities

The District and Company are interested in and concerned with water conditions in their service area. They requested a study addressing water quality, water management and conservation, and excess drainage.

The District and Company wanted to evaluate their historic use of water and land use. While they are mandated to update their water management plan, they are also interested in the potential effects reduced water use may have on the environment and farmland. One example is that the drainage water from this area is currently discharged into the Sacramento River and changes in water use or management made in the study area would impact the Sacramento River. Currently, the irrigation water used in the summer helps dilute the saline drain water in the area. Improvements in water management may increase the salinity of the return discharges to the Sacramento River. The District also wanted to investigate resource enhancement opportunities for water and soil use and wildlife habitat.

Objectives

There are three identified objectives for this document:

1. Present an inventory and assessment of the present use of the area's water, soil, and environmental resources.

2. Discuss the enhancement opportunities for these resources.

3. Predict the potential impacts of significant changes in resource uses or allocations.

Ecosystem-Based Concepts

An ecosystem is a community of living things and their chemical and physical environment. A field can be considered an ecosystem, as can an entire farm or watershed. Changes in a small ecosystem may have impacts on a larger ecosystem. Ecosystem management considers the interaction of human and natural resources to reach a desired condition. Decisions are based on sustaining ecosystem health while providing social and economic benefits.

In an ecosystem such as the study area, knowledge of the interaction and characteristics of both the surface and ground waters are essential to the understanding of the dynamics of the area and for opportunities to be recognized. This is also true of the biological habitat found in the area. The rotation of crops creates a fluid, ever-changing ecosystem. Evaluating strictly on a field by field basis would not present the whole picture of the habitat values in the area.

Ecosystem-based resource planning fosters development of plans on a watershed basis and forms a complementary mechanism to apply management and conservation practices on the individual land units. In this document all of the measures and opportunities considered will be viewed using the ecosystem concept. It is recommended that this approach be used in the future as well.

Use of This Product

This final document will be used by the District and Company to develop a total water, land use, and wildlife management plan which addresses the efficient and beneficial uses of the existing and potentially available water, soil, and other natural resources in the area. This report will assist the District in making sound business and resource management decisions and in being proactive to identified problem areas instead of reactive.

SECTION II
STUDY AREA RESOURCES

Location and Size

The study area lies in the Sutter Basin, approximately 22 miles northwest of Sacramento and 100 miles northeast of San Francisco (see Location Map, Figure 1). The area encompasses approximately 68,000 acres and is completely enclosed by three levee systems totaling 55 miles. The town of Robbins is the central business and residential center of the area.

Generalizations can be made within the study area but three areas appear to have distinct characteristics (Figure 2). These areas are: (1) the silt loams paralleling the Sacramento River (rim area), (2) the area above the mounded connate ground water (connate area), and (3) the remainder of the study area. When needed, options will be considered separately for these distinct areas.

The rim area is the only portion of the study area that historically has incurred salt buildup in the A horizon of the mapped soils. Any water conservation or management practice must determine the extent of leaching required to prevent recurrence of salt build up. The effects of selected practices must be analyzed on a worst case scenario or by continuous simulation since climatic fluctuation effects are apt to be lost in an analysis of averages.

Drainage ditches intercept subsurface connate water in the connate area, causing drain water to test high in salts. Both the rim and connate areas are atypical of irrigation management in that they are adversely affected by salts in the rising ground water.

The remaining area is more typical of irrigation management and can be looked at in the conventional manner of best practices for applied irrigation water and drainage.

Agricultural History of Area

All swamp and overflow lands were given over by the United States to the State of California on the condition that they be reclaimed. These lands were then conveyed to private owners on the condition that the owners reclaim the lands. In 1913, Reclamation District 1500 was created under California law for the purpose of reclaiming lands within the Sutter Basin.

By 1919, levees and ample irrigation and drainage facilities were in place in the Sutter Basin. Before that time the Sutter Basin was covered with water during most of the spring months, and in summer the land was swampy in places and covered with tules. Natural precipitation and flooding kept the salts in the soil leached before this time. The only land cultivated was that in private ownership bordering the river.

The main crops grown in the 1920s were alfalfa, asparagus, barley, oats, wheat, rice, beans, sugar beets, grapes for juice, orchards, and garden/truck crops such as melons, potatoes, onions, cucumbers, and pumpkins. The orchards were mainly peaches, pears, prunes, and plums. Other miscellaneous crops included seed peas, corn, Sudan grass seed, and peppermint. There were also several dairies in the basin during this time. Most of the land was summer fallowed as part of rotational cropping sequences. Salt levels in the soil probably increased during this time. Other areas that were not farmed were used for grazing, primarily by sheep. Most crops harvested during the 1920s and 1930s were trucked, shipped by rail, or barged down the Sacramento River to markets. These cropping patterns stayed essentially the same until the early 1940s, which was the beginning of the U. S. involvement in World War II.

During and after World War II the cropping patterns started to change. Many vegetable crops produced reasonable yields, but the area proved to be too far from the market place and only honeydew melons remain of these early crops (Sutter Mutual Water Company [SMWC], 1992). Rice acreage started to increase so that by 1968 in excess of 26,000 acres were in rice production. Since that time, rice production has declined to between 15,000 acres and 19,000 acres for the last ten years. Processing tomatoes are also one of the major crops grown with more than 15,000 acres in production in 1993. Other crops have changed and many of the orchard crops that were productive in the early years are no longer grown. Today only small acreages of walnuts and apples are grown (SMWC, 1992).

Today, most of the agricultural land has been leveled to facilitate better water management and sustain crop productivity.

Climate

The climate of the study area is typical of a Mediterranean climate with hot, dry summers and cool, moist winters. The average monthly temperature ranges from 45 degrees Fahrenheit in January to 77 degrees Fahrenheit in August. There are wide ranges in the annual temperatures with recorded lows around 20 degrees and highs exceeding 110 degrees. Daily maximum temperatures in July and August normally range between 90 and 100 degrees Fahrenheit (SMWC, 1992).

Between 1963 and 1993 the precipitation ranged between 10 and 25 inches per year with the average over this 30 year period being 19 inches. The average low for this time frame was 9.72 inches, while the average high was 24.75 inches. Ninety percent of the rainfall, or about 13.5 inches, falls from November through April. The amount and distribution of rainfall in the study area creates a situation where the summer crops are irrigated (SMWC, 1992).

Although the growing season is long, during most years the area is subject to killing frosts. The frost-free growing season is about 220 days (SMWC, 1992).

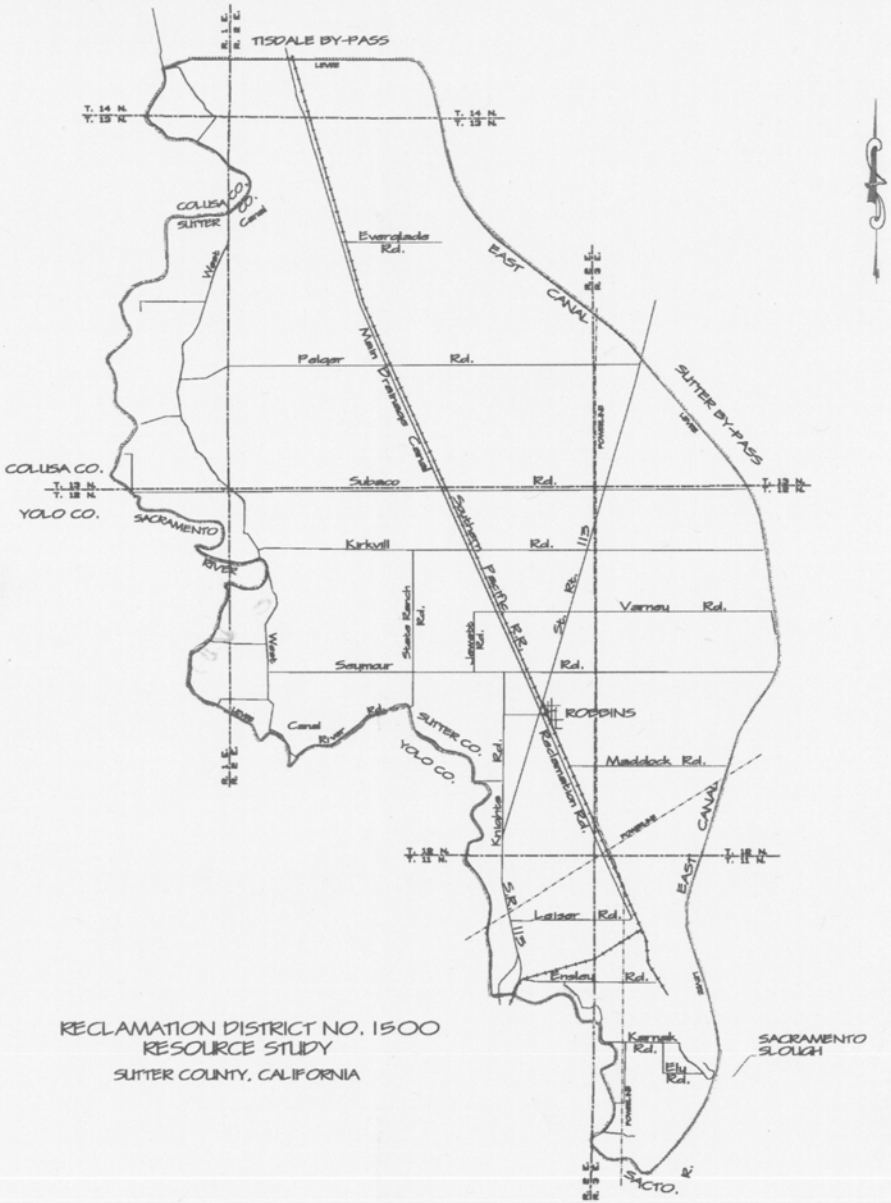
Soils

Prior to the construction of the levee system, floodwaters containing fine-grained sediments frequently spilled over into the lower-lying land adjacent to the Sacramento and Feather Rivers. Because of this, soil parent materials in the area are predominantly unconsolidated clay and silt. Coarser-grained parent materials occur along the periphery of the study area (SMWC, 1992).

The most commonly occurring soils in the study area are the Clear Lake, Sacramento, and Capay soils. These are deep, fine to very fine textured, somewhat poorly drained soils with restricted permeabilities. These soils must be carefully managed to minimize problems associated with slow intake rates, slow permeability, and soil tilth (SMWC, 1992).

Less commonly occurring soils are the Byington soil, which is formed from coarser-grained material and occupies stream channels and natural levees, and the Subaco and Marcum soils, which are formed from layers of coarse and fine-grained material and which occupy the outer edge or rim of the basin. Byington soils are medium-textured and often have a fluctuating water table within 60 inches of the soil surface. Subaco and Marcum soils are moderately to poorly drained and moderately deep to deep over a dense, massive, very slowly permeable subsoil (SMWC, 1992).

FIGURE 1



LEGEND

- Watershed Boundary
- Drainage \ Waterway
- Range \ Township Line
- Road
- Railroad
- Powerline

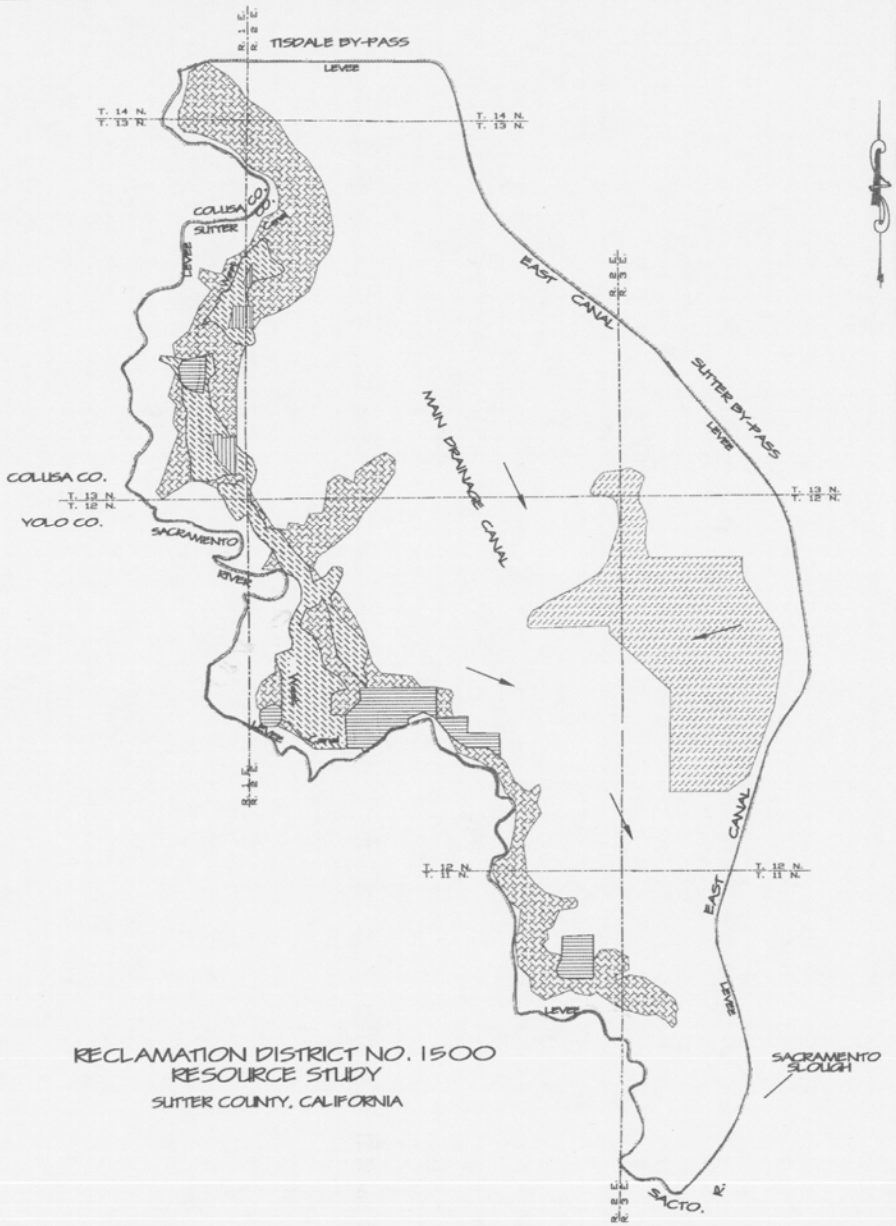
SCALE 1 0 1 2 MILES

RECLAMATION DISTRICT NO. 1500
RESOURCE STUDY
SUTTER COUNTY, CALIFORNIA

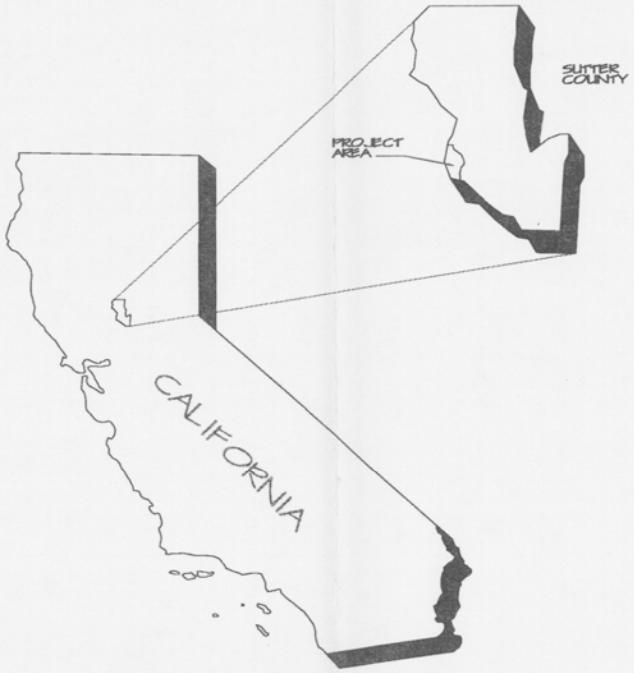
U.S. DEPARTMENT OF AGRICULTURE
NATURAL RESOURCES CONSERVATION SERVICE

TITLE: LOCATION MAP			DRAWING NO.:
DESIGNED BY:	CHECKED BY:	APPROVED BY:	
SCALE: As Shown	DRAWN BY: J.M. Shara	DATE:	SHEET OF

FIGURE 2



RECLAMATION DISTRICT NO. 1500
RESOURCE STUDY
SUTTER COUNTY, CALIFORNIA



LEGEND

- 1995 Salt Problems
- Past Salt Problems (Bailey 1995)
- Saline - Sodic Soils (SCS 1988)
- Saline - Alkali Soils (AES 1965)
- Total Dissolved Solids in Drain Waters 2000 to 2500 ppm
- Ground Water Flow

SCALE 1 0 1 2 MILES

U.S. DEPARTMENT OF AGRICULTURE
NATURAL RESOURCES CONSERVATION SERVICE

TITLE: POTENTIAL SALT PROBLEM AREAS MAP			DRAWING NO.:
DESIGNED BY:	CHECKED BY:	APPROVED BY:	
SCALE: As Shown	DRAWN BY: J.M. Shore	DATE:	SHEET OF

Depths from the soil surface to the shallow ground water table, measured during the winter of 1986-87, range from two to ten feet but may be as little as eighteen inches in recent alluvial soils. The basin and basin rim soils are not well suited to deep rooted crops (SMWC, 1992).

A pattern of past and present saline/sodic soils is seen in this area. The previously mentioned Byington silt loam is a saline/sodic soil.

The features shown on Figure 2 suggest a hydraulic connection between the Sacramento River and a band of silt loam soil paralleling the levee system along the river. This area had past salt problems but is now successfully cropped, the salinity problems apparently being overcome through proper irrigation and drainage.

Table 1 lists the soils occurring in the study area and describes some of the soil features related to water.

Geology

The study area is in the central portion of the Sacramento Valley. The major topographic feature is the Sutter Buttes. This feature is the erosional remnant of a laccolith and volcano formed during the late Pliocene time.

The other topographic features in the area are of low relief and are related to the fluvial deposition of the Sacramento River and its tributaries. Bryan (1923) estimated that before any reclamation had been accomplished, 60 percent of the Valley was subject to overflow including the river rim lands and a considerable portion of the low plains.

The trough underlying the Sacramento Valley consists of the thickest sediments and the most nearly complete late Mesozoic sections in North America (Olmstead and Davis, 1961). The Upper Jurassic, Lower Cretaceous, and Upper Cretaceous sequences have a thickness in excess of 10.6 miles. The Upper Cretaceous and pre-Pliocene sediments are tilted upwards at Sutter Buttes. Approximately 20 miles down, these sediments are vertically offset 500 feet by the N 70 degrees W striking, vertical Sutter Basin Fault.

It has been suggested that during the Late Paleocene Period, an inland sea was trapped in the Sacramento Valley, leaving a mound of connate water in the Kione Formation, Upper Cretaceous.

It is believed that this connate water, containing principally sodium and chloride, rises upwards through the Sutter Basin Fault under artesian pressure. The pressure is created by inflows of fresh water into the Kione sand formation at Sutter Buttes. The hydraulic head is estimated to be 262 to 426 feet (Tanji et al, 1975).

Socioeconomics

Sutter County encompasses an area of 385,720 acres. According to the 1990 Census of Agriculture (U.S. Department of Commerce, 1992), there are 318,000 acres of land in farms in Sutter County. The gross valuation of all agricultural products in Sutter County in 1993 totaled $292 million. Compared to all counties in California, Sutter ranks 18th in terms of the valuation of agricultural production. Fruit and nut crops continue to lead all commodity categories with a production value totaling $120 million. Rice is the leading field crop both in acreage and valuation.

TABLE 1 - SOILS FEATURES RELATED TO WATER

Soil Name and Map Symbol	Profile Depths (Inches)	Effective Rooting Depth (Inches)	Permeability (In/hr)	Available Water Capacity (In/In)	Runoff	Water Erosion Hazard	Shrink Swell Potential	Water Management Features Affecting Irrigation	Soil And Water Features Of Concern: Flooding Frequenc	Flooding Duration	Flooding Months	High Water Table Depth Range Ft.	High Water Table Kind	High Water Table Months Highest	How Soils Drain	Bedrock Depth In	Bedrock Hardnes	Cemented P Depth In	Cemented P Hardnes
103 Byington silt loam	0-13 13-60	60+	0.6-2.0 0.6-2.0	0.16-0.18 0.15-0.19	very slow	slight	----	Wetness, erodes easily	Rare	----	----	2 to 3	Apparent	Dec-Apr		>60	----	----	----
104 Capay silty clay	0-36 36-60	60+	0.06-0.2 0.06-0.2	0.14-0.16 0.17-0.19	very slow	slight	high	Slow intake, percs slowly	Rare	----	----	6 to 6	----	----	mod. well	>60	----	----	----
107 Capay Silty Clay	0-32 32-50	40-60	0.06-0.2 0.06-0.2	0.14-0.16 0.17-0.19	very slow	slight	high	Slow intake, percs slowly	Rare	----	----	3 to 5	Perched	Dec-Apr	mod. well	40 - 60	Soft	----	----
108 Capay silty clay, wet	0-16 16-60	60+	0.06-0.2 0.06-0.2	0.13-0.16 0.16-0.19	very slow	slight	high	Slow intake, percs slowly	Rare	----	----	4 to 6	Apparent	Jan-Dec	---	>60	----	----	----
110 Clear Lake silt loam	0-15 15-60	60+	0.6-2.0 0.06-0.2	0.17-0.19 0.12-0.16	very slow	slight	----	Percs slowly, erodes easily	Rare	----	----	3 to 6	Apparent	Dec-Apr	---	>60	----	----	----
111 Clear Lake silt loam, frequently flooded	0-15 15-60	60+	0.6-2.0 0.06-0.2	0.17-0.19 0.12-0.16	very slow	slight	----	Percs slowly, erodes easily, flooding	Frequent	Long	Dec-Apr	3 to 6	Apparent	Dec-Apr	---	>60	----	----	----
112 Clear Lake clay	0-42 42-60	60+	0.06-0.2 0.06-0.2	0.12-0.16 0.12-0.16	very slow	slight	high	Slow intake, percs slowly	Rare	----	----	3 to 6	Apparent	Dec-Apr	poorly	>60	----	----	----
113 Clear Lake clay, frequently flooded	0-42 42-60	60+	0.06-0.2 0.06-0.2	0.12-0.16 0.12-0.16	very slow	slight	high	Slow intake, percs slowly, flooding	Frequent	Long	Dec-Apr	3 to 6	Apparent	Dec-Apr	poorly	>60	----	----	----
115 Clear Lake clay, siltstone substratum	0-42 42-48 48	36 - 60	0.06-0.2 0.06-0.2 -----	0.14-0.16 0.14-0.16 ----	very slow	slight	high	Slow intake, percs slowly	Rare	----	----	3 to 5	Perched	Jan-Dec	poorly	40-60	Soft	----	----
117 Columbia fine sandy loam	0-14 14-60	60+	2.0-6.0 2.0-6.0	0.1-0.12 0.1-0.12	very slow	slight	----	Droughty	Rare	----	----	3 to 5	Apparent	Dec-Apr	---	>60	----	----	----
118 Columbia fine sandy loam, channeled	0-14 14-60	60+	2.0-6.0 2.0-6.0	0.1-0.12 0.1-0.12	very slow	severe	----	Droughty, Flooding	Frequent	Long	Dec-Apr	3 to 5	Apparent	Dec-Apr	---	>60	----	----	----
119 Columbia fine sandy loam, clay substratum	0-15 15-52 52-60	40 - 60	2.0-6.0 2.0-6.0 0.06-0.2	0.1-0.12 0.8-0.11 0.14-0.16	very slow	slight	----	Droughty, percs slowly	Rare	----	----	3 to 5	Apparent	Dec-Apr	---	>60	----	----	----
121 Columbia fine sandy loam, frequently floods	0-14 14-60	60+	2.0-6.0 2.0-6.0	0.1-0.12 0.1-0.12	very slow	severe	----	Droughty, flooding	Frequent	Long	Dec-Apr	3 to 5	Apparent	Dec-Apr	---	>60	----	----	----
122 Columbia loam	0-25 25-60	60+	0.6-2.0 2.0-6.0	0.14-0.16 0.08-0.11	very slow	slight	----	Favorable	Rare	----	----	3 to 5	Apparent	Dec-Mar	---	>60	----	----	----
133 Holillipah loamy sand	0- 8 8-60	60+	6.0-20.0 6.0-20.0	0.06-0.08 0.06-0.09	very slow	slight	----	Droughty, slow intake, soil blowing	Rare	----	----	6 to 6	----	----	Somewhat excessive	>60	----	----	----
138 Liveoak sandy clay loam	0-13 13-53 53-60	60+	0.6-2.0 0.6-2.0 2.0-6.0	0.14-0.16 0.14-0.16 0.08-0.11	very slow	slight	----	Favorable	None	----	----	6 to 6	----	----	Well	>60	----	----	----
141 Marcum clay loam	0-16 16-28 28-40 40-43 43	40 - 60	0.2-0.6 0.2-0.6 0.06-0.2 0.2-0.6 ----	0.17-0.19 0.17-0.19 0.14-0.16 0.17-0.19 ----	very slow	slight	high	Percs slowly	None	----	----	6 to 6	----	----	Moderately Well	40-60	Soft	----	----
143 Marcum-Gridley clay loams	0-16 16-28 28-40 40-43 43	40 - 60	0.2-0.6 0.2-0.6 0.06-0.2 0.2-0.6 ----	0.17-0.19 0.17-0.19 0.14-0.16 0.17-0.19 ----	very slow	slight	high	Percs slowly	Rare	----	----	6 to 6	----	----	Moderately Well	40-60 (Marcum) 20-40 Gridley)	Soft Soft	----	----
144 Nueva loam	0-17 17-42 42-60	60+	0.6-2.0 0.6-2.0 0.2-0.6	0.15-0.17 0.14-0.16 0.17-0.20	very slow	slight	----	Erodes easily	Rare	----	----	4 to 6	Apparent	Dec-Apr	---	>60	----	----	----
153 Oswald clay	0-15 15-33 33	20 - 40	0.06-0.2 0.06-0.2 ----	0.14-0.17 0.14-0.17 ----	very slow	slight	high	Wetness, slow intake, percs slowly	Rare	----	----	1.5 to 3.5	Perched	Dec-Apr	Moderately Well	20-40	Soft	----	----
161 Shanghai fine sandy loam	0-15 15-60	60+	0.6 - 2.0 0.6 - 2.0	0.12-o.14 0.15-0.19	very slow	moderate	low moderate	Erodes easily, flooding	Frequent	Long	Dec-Apr	3 to 5	Apparent	Dec.-Apr.	Somewhat poorly	>60	---	---	---
162 Shanghai silt loam	0- 9 9-60	60+	0.6-2.0 0.6-2.0	0.15-0.19 0.15-0.19	slow	moderate	----	Erodes easily	Rare	----	----	3 to 5	Apparent	Dec-Apr	Somewhat poorly	>60	----	----	----
163 Shanghai silt loam	0-12 12-41 41-60	40 - 60	0.6-2.0 0.6-2.0 0.06-0.2	0.15-0.19 0.15-0.19 0.14-0.16	very slow	slight	----	Percs slowly, erodes eaasily	Rare	----	----	4 to 6	Apparent	Dec-Apr	Somewhat poorly	>60	----	----	----
164 Shanghai silt loam	0-12 12-41 41-60	40 - 60	0.6-2.0 0.6-2.0 0.06-0.2	0.15-0.19 0.15-0.19 0.14-0.16	very slow	moderate	----	Percs slowly, erodes eaasily	Frequent	Long	Dec-Apr	4 to 6	Apparent	Dec-Apr	Somewhat poorly	>60	----	----	----
165 Shanghai silt loam	0-11 11-60	60+	0.6-2.0 0.6-2.0	0.15-0.19 0.15-0.19	very slow	moderate	----	Erodes easily, flooding	Frequent	Long	Dec-Apr	3 to 5	Apparent	Dec-Apr	---	>60	----	----	----
166 Shangai silt loam wet	0- 8 8-60	60+	0.6-2.0 0.6-2.0	0.15-0.19 0.15-0.19	very slow	moderate	----	Wetness, erodes easily, flooding	Frequent	Long	Dec-Apr	2.5 to 5	Apparent	Jan-Dec	Somewhat poorly	>60	----	----	----
167 Shanghai silty clay loam	0-38 38-60	60+	0.2-0.6 0.6-2.0	0.17-0.20 0.15-0.19	very slow	slight	----	Erodes easily	Rare	----	----	3 to 5	Apparent	Dec-Apr	Somewhat poorly	>60	----	----	----
173 Subaco clay	o-13 13-26 26	20 - 40	0.06-0.2 0.06-0.2 ----	0.14-0.16 0.14-0.16 ----	very slow	slight	high	Wetness, slow intake, percs slowly	Rare	----	----	1.5 to 3.5	Perched	Dec-Apr	Somewhat poorly	20-40	Soft	----	----
174 Tisdale clay loam	0-11 11-31 31	20 - 40	0.2-0.6 0.2-0.6 ----	0.17-0.19 0.14-0.19 ----	very slow	slight	----	Depth to rock	None	----	----	6 to 6	----	----	Well	20-40	Soft	----	----
175 Yuvas loam	0-16 16-24 24-38 38	20 - 40	0.6-2.0 < 0.06 ---- ----	0.14-0.16 0.06-0.08 ---- ----	very slow	slight	----	Percs slowly, depth to rock, cemented pan	None	----	----	6 to 6	----	----	Well	20-40	Soft	20-38	Thick

The population of Sutter County in 1994 was 73,100 with about half of the people living in unincorporated regions of the county. The per capita income in 1992 was $18,100 which is 85 percent of the California average.

According to the 1990 census, using the corresponding tract which is larger but includes the study area, about 78 percent of the population is white, 2 percent is Native American and 20 percent of the citizens are listed as other. Of this population, 27 percent identified themselves as being of Hispanic origin.

The study area is a highly productive rural area consisting of approximately 155 farm landowners and 145 residential landowners. Many of the farm operator families have been farming in the area since the 1930s. A typical farming operation includes 1,500 to 3,000 acres with a significant portion of the land leased. The gross crop value generated from this area is approximately $60 to $72 million (SMWC, 1992).

Land Use and Crops

Table 2 provides a breakdown of the acreages of the various crops grown in the study area in 1993. Although cropping patterns have changed to some extent over the years, the types of crops and acreages grown have basically stayed the same. Yearly acreage changes are due to rotations by the individual ownerships. Local landowners feel that in the coming years the acreages and types of crops grown in the basin will remain the same unless water availability and costs change dramatically.

Most tillage operations for all crops in the basin are conventional. Much of the sediment from cultivation and irrigation practices is kept from reaching drainage ways and sumps by erosion control drop structures at the ends of fields. Sediment reaching the drains and sumps is removed periodically and spread on the fields. To most landowners and managers erosion is not perceived as a problem. Removal and spreading is thought of as part of the normal operation and cost of doing business.

The two major crops are processing tomatoes grown in rotation with wheat, corn, safflower, and beans and rice. Rice may be grown in rotation with crops such as wheat, safflower, beans, and melons though some growers grow rice seven to eight years in a row.

Rice stubble decomposition is being practiced throughout the basin because stubble burning is being phased out by the State of California. Rice stubble needs to decompose before the next year's crop is grown. In the past burning was an easy, fairly inexpensive method of removing stubble but its effects on air quality have proved intolerable. New technology is being tried to find better methods of decomposition. Many landowners chop and incorporate the stubble to a depth of 10 to 20 inches and leave the field dry except for winter precipitation or submerge the field under water throughout the winter. Currently one- to two-acre feet of irrigation water is being used to flood rice fields for decomposition. Some landowners feel that flooding is the best way to decompose rice stubble and provides other side benefits such as additional habitat for waterfowl. Rice decomposition costs $25 per acre for flooding and $50 per acre to incorporate stubble into the soil. If both methods are used, costs can average $75 per acre.

Orchards in the basin are mostly walnuts grown on the higher ground along the Sacramento River. Soil along the river is deeper and has better drainage than the majority of the soils in the area. Some orchards have tile drains six to eight feet below the surface because the water table is high and affects root growth. The average life of a walnut orchard is 30 years. Trees are either replaced in large blocks or the whole orchard is replaced. The average yield for walnuts is two to three tons per acre. The orchard floor is mowed and noncultivated with the tree rows strip sprayed.

TABLE 2: Landuse Categories and Acreages for Sutter County in 1993

RECLAMATION 1500 LANDUSE CATEGORY	ACRES
RICE	19,322
TOMATO	15,035
SAFFLOWER	8,262
WHEAT	4,625
MELON	4,526
WHEAT BEANS	3,682
RICE DECMP	3,101
BEANS	2,893
SET ASIDE (Idle)	1,735
WALNUT	922
CORN	836
WHEAT MILO	508
SEED	433
WHEAT MELON	261
SUNFLOWER	249
BEETS	243
WHEAT SAFFLOWER	217
ALFALFA HAY	203
SAFF PREIR	155
WHEAT PREIR	153
SORGHUM	85
PASTURE	76
URBAN	33
APPLES	31
NATURAL AREA	26
SURFACE WATER	15
FARMSTEAD	9
TOTAL	**67,636**

Water Quality

Water quality concerns in the area center on salinity. Arsenic has been a problem in the ground water under the town of Robbins, but ground water is not generally used for agriculture and arsenic has not been detected in the drains. The District monitors its drains for herbicides to insure that herbicide concentrations meet current standards.

The water supply from the river is of excellent quality and averages 130 micromhos/cm electrical conductivity (EC). The water finds its way into the drains and picks up volume and salinity from subsurface water. The EC of the water at the main drain before and after the irrigation season is typically ten times greater than that of the supply water and about five times greater during the irrigation season. The water used for crop irrigation apparently dilutes the salt concentration in the drain water. The irrigation season runs from April through October. During the irrigation season from 1987 to 1992 the EC of the main drain at Karnak varied from 380 to 780 micromhos/cm. In the winter the EC ranged from 420 to 1500 micromhos/cm.

Biology

The pre-agricultural vegetation of southern Sutter County was a patchwork of California prairie, tule marsh, and riparian forest (Kuchler, 1964). The California prairie was probably the most common of the three types, and consisted of a perennial bunch grass prairie with annual grasses and herbs interspersed. Purple needlegrass dominated the valley grassland along with creeping wild rye, blue wild rye, Idaho fescue, California oniongrass, California bluegrass, and others (Barbour and Major, 1977). This grassland supported tule elk, pronghorn antelope, and California grizzly bear, and provided nesting habitat or forage areas for waterfowl like mallards and Canada geese.

The low-lying ground within the grassland was probably covered by tule marsh. This freshwater emergent wetland was dominated by common tule and cattail with **Carex** and **Juncus** species as lesser components. These marsh areas were extensively used by tule elk and migratory birds, especially waterfowl.

The natural banks along the Sacramento and Feather Rivers supported extensive areas of riparian forest. The mixed riparian forest was dominated by Fremont cottonwood with an understory of Gooding's black willow near the river with increasing amounts of valley oak, California sycamore, California black walnut, box elder, red willow, and yellow willow along the top and outside of the natural levees. Vertical structure was added by shade-tolerant shrub species like Oregon ash, buttonwillow, blue elderberry, and poison oak. Areas with woody vines like wild grape and virgin's bower had a distinct jungle character. Field examinations of existing vegetation indicate the upland areas along the natural banks supported large valley oak stands which was probably graded into a savanna at the interface with the prairie.

This mosaic of native vegetation has been changed as the study area was converted to its present agricultural character. The California prairie and its associated large mammals has been reduced, and only small remnants of tule marsh, riparian forest, or valley oak woodland remain. This change is not unique to the study area, but is typical of the widespread change in the Sacramento Valley. The loss of riparian habitat and its ability to support diverse insect and vertebrate populations has had a severe impact on some species. In addition to the species already gone from the area, several are at very low levels and many are presently quite rare and even listed as State or Federal threatened or endangered species. Those species within or near the study area include the western yellow-billed cuckoo, Swainson's hawk, bank swallow, wood duck, bald eagle, giant garter snake, western pond turtle, California tiger salamander, California red-legged frog, Chinook salmon, valley elderberry, longhorn beetle, and the California hibiscus.

The agricultural development of the area has favored other wildlife species. Migratory waterfowl are doing very well in those areas where rice, wheat, barley, milo, corn, and beans are being grown. Grain plants which are planted in the fall and not harvested until May or June provide good nesting habitat for waterfowl, especially if they are near rice fields. The rice fields provide very good habitat throughout the summer and into the fall and, in some cases, through the winter. This habitat mix attracts and supports some of the highest waterfowl densities in the state. Ring-necked pheasants, an introduced species, also do well in the drier parts of this habitat mix and make good use of ditch banks and irrigation levees for nesting. The ditches themselves provide good habitat for blue and channel catfish, carp, crayfish, and bullfrogs. These aquatic species support a local sport fishery which is accessible to the public.

Using "A Guide to Wildlife Habitats of California" (Mayer and Laudenslayer, 1988), today's major habitat types are cropland, orchard, and pasture. The tule marsh remnant is present as fresh emergent wetland, and the riparian forest is present as patches of valley foothill riparian or small areas of valley oak woodland. The wildlife habitat relationships (WHR) database provides a listing of animal species commonly associated with these habitat types in Sutter County, and a copy of the listing is included in Appendix A.

The "California Natural Diversity Database Rare Find Report" noted the occurrence of the Swainson's hawk, western yellow billed cuckoo, willow flycatcher, bank swallow, tricolored blackbird, giant garter snake, great valley mixed riparian forest, and California hibiscus in or near the study area. The only listings actually found in the study area are the Swainson's hawk and the bank swallow. Field checks verified the Swainson's hawk to be in the study area along the Sacramento River between the Yolo Bypass and the Tisdale Bypass. There are several bank swallow colonies along the Sacramento River with at least one on the Sutter County side. This nesting site is located on a wide meander just upstream from the pumping plant at State Ranch Bend, near one of few remnant riparian vegetation sites on the Sutter County side of the Sacramento River. No bank swallows were observed as the site was checked after the active nesting season. The report's comments noted that the tricolored blackbird colonies had disappeared due to habitat loss, and no tricolored blackbirds were observed during field inventories. Table 3 lists the threatened and endangered species cataloged in the study area.

TABLE 3 - Federal and State listed threatened, endangered, and candidate species that are known to occur in the Reclamation District 1500 Project Area.
December 1994

NAME Scientific	Common	FEDERAL STATUS	STATE STATUS
INVERTEBRATES			
Desmocerus californicus dimorphus	Valley elderberry longhorn beetle	T	
FISHES			
Onchrhynchus tsawytscha	Winter-run chinook	T	E
AMPHIBIANS			
Ambystoma californiense	California tiger salamander	C1	
REPTILES			
Thamnophis gigas	Giant garter snake	Proposed T	T
Clemmys marmorata marmorata	Northwestern pond turtle	C2	P
BIRDS			
Buteo swainsoni	Swainson's hawk	P	T
Coccyzus americanus occidentalis	Western yellow-billed cuckoo	P	E
Empidonax trailii	Willow flycather	E	E
Riparia riparia	Bank swallow	P	T
Agelaius tricolor	Tricolored blackbird	C2	SC
MAMMALS			
PLANTS			
Hibiscus lasiocarpus	California hibiscus	C2	

STATUS:
E Endangered : Listed as Endangered
T Threatened : Listed as Threatened
C1 Candidate 1 : Sufficient biological data to support a proposal to list as threatened or endangered
C2 Candidate 2 : Existing information may warrant listing, but substantial biological support for listing is lacking.
SC Special concern : California species that has either declined in numbers or its range reduced, population is monitored to see if more study is warranted.
P Protected either by Federal or State Laws/Regulations

See the Wildlife Habitat Relationships printout for a complete listing of all potential species that could possibly occur in the area.

SECTION III

WATER RESOURCES INVENTORY

History of Irrigation and Drainage Systems in the Basin

In the early 1900s, the plan of reclamation consisted of the construction of levees as protection against overflow from flood waters; the construction of levee and bank protection work to prevent erosion of the banks and levees; the construction and operation of a pumping plant for the disposal of seepage water and rain, and later irrigation runoff; and the construction of a drainage system to conduct the seepage and rain waters to the pumping plant at the lower end of the basin.

The original levees that were constructed had a height of 20 to 25 feet above ground elevation for the bypass levees and 12 feet for the river levees. In the late 1930s, the bypass levees were weakened but were later rebuilt and raised eight feet in the early 1940s. The Sacramento River levees were also reconstructed and brought up to federal standards in the 1940s and 1950s. Of the 34 miles of river levees only four and one-half miles have not been reconstructed to date.

After the levees were built, the drainage system for the basin was constructed. This system consisted of a pumping plant, the main drainage canal, and laterals and sublaterals located to drain every one-quarter section of land conveying water to the main drain and the pumping plant. These drains were designed and built to keep the water table, in all cases, five feet below the ground surface. In 1922, a gravity outlet was constructed at the lower end of the drainage canal to automatically drain irrigation waters from the basin during low summer flows of the Sacramento River. This allowed the pumping plant to be shut down in summer months and saved operating costs during that time. The drainage system was designed to work with an irrigation system which was considered a necessity from the inception of the reclamation work.

Shortly after the levees and drainage systems were built, the irrigation system, including pumping plants, was completed by the Sutter Basin Corporation, a private corporation. The main irrigation system was laid out using a plane table survey with six-inch contour intervals. The system consisted of main canals, lateral canals, and sublaterals designed to deliver water to each individual farm. Delivery was designed to provide irrigation to each 40-acre tract at an elevation at least one foot higher than the highest land in the tract. The highlands along the Sacramento River in private ownership, with a few exceptions, were not covered by the system. Nearly all of the main structures, such as headgates, checks, drops, turnouts, or delivery structures, were built of reinforced concrete. The larger structures were equipped with screw stem gates while the other structures had redwood flashboards.

By 1926, the basin also had 180 miles of graded roads, 136 miles of graveled roads, and four miles of concrete paved roads.

Surface Water Resources

Sources

Most of the irrigation water is diverted from the Sacramento River under appropriative rights that date back to 1917 (SMWC, 1992). Later, in 1964, the Company and several individual landowners secured water under a contract with the U.S. Bureau of Reclamation (BOR). A smaller amount of water is provided by drainwater reuse within the service area. There are also some individuals pumping directly out of the river and a small number of wells.

Irrigation Delivery Network

In 1990, 197,200 acre-feet of water were diverted through canals from the Sacramento River by the Company. Figure 3 is a map of this network of canals. The Company maintains and operates three pumping plants: Tisdale Pumping Plant (906 cfs total capacity), State Ranch Bend Pumping Plant (125 cfs), and Portugese Bend Pumping Plant (100 cfs). In addition, the Company operates eight booster pumps and one internal recirculation system with a total combined capacity of 290 cfs per day. These pumps are located in the central and northeast portion of the area for the purpose of drainwater reuse.

There is a total of 56 miles of irrigation water delivery canals and 144 miles of laterals in the study area. Water is distributed through this system of unlined canals by gravity. Due to topography, the canals have an average slope of three inches per mile and a velocity of 1.0 foot per second or less (SMWC, 1992). Portions of the main channels are chained during the irrigation season to control weeds.

Company policy states that irrigation water delivery to growers requires a 48-hour advance notice and a 12-hour advance notice for shut off. The Company estimates a water order from the BOR on Monday of each week during the irrigation season. The area is divided into six service areas with six ditch riders working together to achieve flexibility in delivery and service so the resulting system is much more flexible than the existing policy.

Water Measurement

Water pumped from the river is measured at the pumping plants. Meters are installed, maintained, and monitored by the BOR at these locations with the exception of the Tisdale plant, which is measured with a series of rating tables. All field deliveries are measured using Armco Gate Opening Rating Tables. The daily deliveries are recorded by the ditch rider and tabulated for billing.

Irrigation Efficiencies

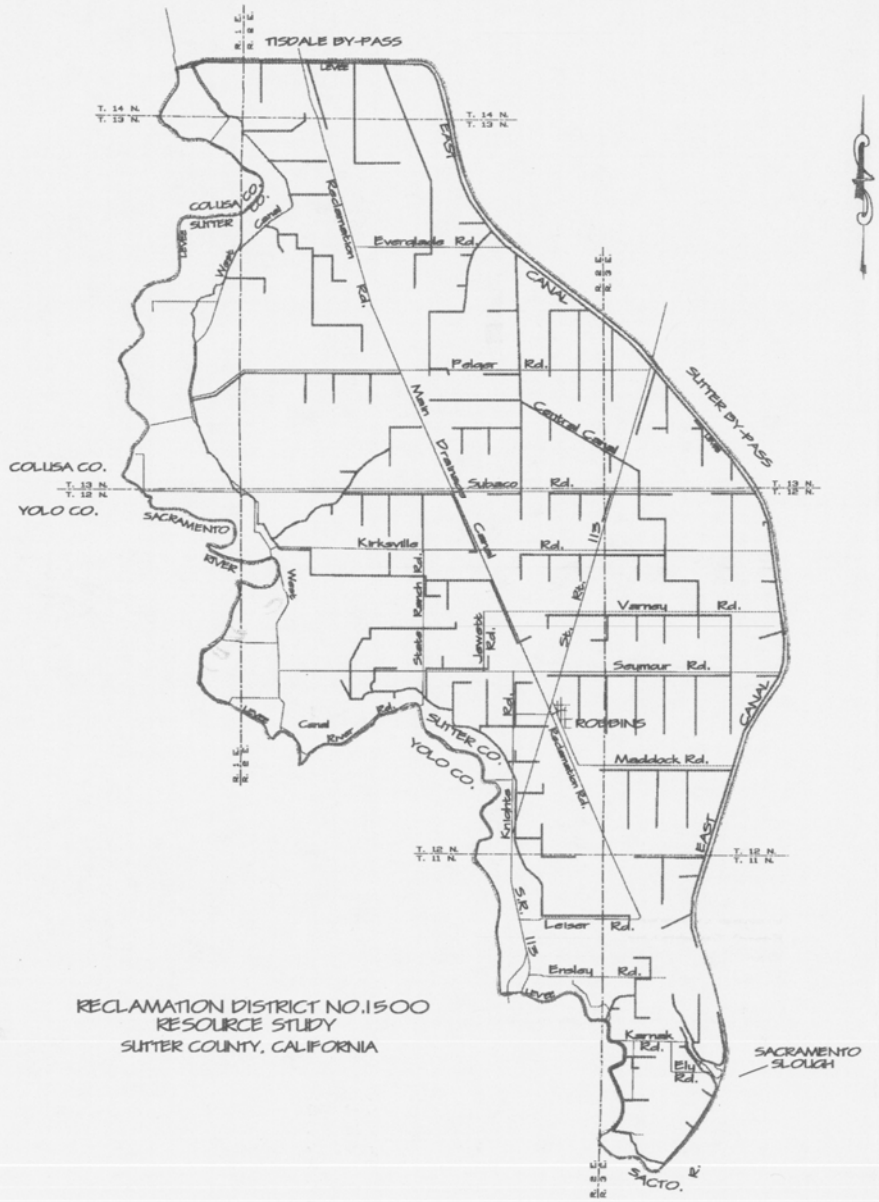
Efficient on-farm irrigation water use is concerned with four things:

1. how well the irrigation system distributes the water over the field into the soil, also called distribution uniformity;
2. how much water leaves the end of the field (surface loss);
3. how much of the applied water goes below the root zone (deep percolation); and
4. how often the field is irrigated.

The distribution uniformity is influenced by the irrigation system design and operation. Surface irrigation methods have distribution uniformities which can be quite high on medium and fine textured soils if stream sizes are large enough. Furrow systems trade off surface losses and deep percolation losses. Surface systems can have distribution uniformities in excess of 95 percent. Sprinkler irrigation systems have distribution uniformities between 70 and 80 percent. Surface systems usually need a minimum application to function well. The frequency of irrigation is the single most important factor in maximizing irrigation efficiency. If a manager irrigates too frequently and too much water is applied, the irrigation efficiencies will be low. An irrigation efficiency of 80 percent is considered quite good.

There are two mechanisms for irrigation water loss - deep percolation and tailwater. Tailwater loss is easy to see; it is the water leaving the field on the surface during and after the irrigation set. Tailwater reuse systems and properly designed sprinkler systems eliminate this loss. Tailwater volume is minimal at the start of an irrigation and is at a maximum at the end of the irrigation. Deep percolation loss is the water which goes past the root zone of the crop. Early in the irrigation season, water may go past the immature crop's root zone but still be used as the root zone goes deeper. Deep percolation losses are stored in the soil profile and delivered to the drainage system over a period of time. Losses are reduced by minimizing these losses through system improvements and management.

FIGURE 3



RECLAMATION DISTRICT NO.1500
RESOURCE STUDY
SUTTER COUNTY, CALIFORNIA

LEGEND

- Watershed Boundary
- Drainage\Waterway
- Range\Township Line
- Road
- Irrigation Canal

SCALE 1 0 1 2 MILES

U.S. DEPARTMENT OF AGRICULTURE
NATURAL RESOURCES CONSERVATION SERVICE

TITLE: IRRIGATION SYSTEM MAP			DRAWING NO.:
DESIGNED BY:	CHECKED BY:	APPROVED BY:	
SCALE: As Shown	DRAWN BY: J.M. Shara	DATE:	SHEET OF

Rice culture is unique among all the crops in the basin. Rice has a high evapotranspiration rate, greater than some other crops. However, the need of the crop to be in a fully saturated field also affects how much water is applied to the crop. The continual flow of water on the field is governed by two factors, the crop evapotranspiration and water percolation. Water loss goes from the field down gradient to the drainage system; in some cases there are other crops between the rice field and the drainage net. The rice fields raise the water table in the surrounding fields because the water table becomes the water surface of the rice field. The water table is also manipulated by raising the water surface in the drainage ditches using water control structures.

Field characteristics vary throughout the basin. Soils, crop selection, depth to water table variability through the irrigation season, field slope or lack of it, and surrounding crops, all influence irrigation operations throughout the season. If the water table approaches the root zone of the crop, the crop can obtain water without irrigation. For example, less water is applied to all the melons than the crop needs. While melons are all under irrigated in the basin, it is a successful crop because it meets its water needs from the water table. Seventy-one of the 136 growers of tomatoes, melons, and beans are able to apply less than the estimated crop needs. While underapplication of water is usually a poor technique with implications of increasing soil salinization and future declining yields, this has not been the case in this area due to the amount of rainfall the area receives and the presence of the drainage system. Winter rainfall and the lowering of the water table helps to remove salts from the fields. Problems might occur in double cropped fields and in drought years when these salts concentrate and are not leached from the soil.

The average crop irrigation requirement for the period 1981 through 1990 was approximately 85,800 acre-feet per year. Dividing the average crop irrigation requirement for the period by the average irrigation delivery of 172,800 acre-feet yields a service area-wide average on-farm efficiency of approximately 50 percent. Average efficiencies from 1991 to 1994 were up to 60 percent. On-farm efficiencies ranged from 45 to 55 percent with open ditch systems having lower efficiencies than piped systems (SMWC, 1992). This is not necessarily undesirable due to the fact that drainage is returned to the river for use by downstream users or instream flows.

On-Farm Irrigation Practices

Basin flood, furrow, and sprinkler irrigation are the most common methods of irrigation. In some parts of the study area the water table is only a few feet from the surface and many of the crops utilize this water by subsurface irrigation and require less surface irrigation water.

Processing tomatoes are grown on five-foot beds with one or two rows of vines per bed, depending on the variety of the tomato grown. Irrigation is mostly by sprinkler throughout the growing season although some acres are sprinkled the first two irrigations and then furrow irrigated the remainder of the growing season. All other crops are surface irrigated. Safflower and wheat are usually dry cropped with one pre-irrigation, if needed.

Rice is basin irrigated with berms generally following the contour of the field. Water management has been improved since water cannot be released from the field into drainage ditches until it is held in the field for a minimum of 30 days after pesticide applications. This is done to reduce the pesticides used in rice culture from reaching the Sacramento River in the runoff from the rice fields.

Irrigation of orchards is mostly done by solid set impact sprinklers, hand moved impact sprinklers, or micro-sprinklers. A few of the orchards are border irrigated.

Present irrigation and drainage practices have kept salt levels in the soil down to a manageable level.

Due to the low EC of the irrigation supply water, it was estimated that less than one percent of the applied irrigation water is needed for leaching purposes, even for the more sensitive crops. The leaching requirement is based on soil salinity equilibrium conditions throughout the irrigated area. The leaching requirement for connate water suppression has not been estimated. Continual productivity indicates the leaching requirement is being maintained. Actual soil leaching requirements vary throughout the area (SMWC, 1992).

Drainage Network

The drainage network of unlined ditches outletting at the Karnak pumping plant has a capacity of 3,800 acre-feet per day with some possible additional gravity discharge. There are 18 miles of unlined main drainage canals and 425 miles of unlined laterals. Figure 4 is a map of the drainage network.

The drainage system consists mostly of open ditches carrying irrigation runoff, seepage from the river, connate water, and winter rainfall runoff. The system has collector and sub-collector drains varying in depth from six to ten feet with bottom widths from three to ten feet. There are also a few subsurface tile drains installed near the river where orchards are planted.

Ground Water Resources

Approximately 38 wells have been drilled in the project area. The depth of drilled wells ranges from 72 feet to 1,500 feet and measured total dissolved solids (TDS) concentrations range from 248 to 5,970 mg/l. Many of these wells have been abandoned. A mound of artesian connate water has been identified in the project area (Tanji, 1975). Insufficient data exists to delineate boundaries between the freshwater and saltwater underlying the study area. Figure 5 is a cross-section across the basin depicting the known and conjectured relationships of river, connate, and ground waters.

The high water table in the study area consists of seepage from the river, subsurface interbasin inflow from the surrounding area, and rising connate water under artesian pressure. Due to its high salt content, the ground water is not used for irrigation except in limited areas along the Sacramento River, where the salt content can be much lower.

One potential source for salt buildup in the ground water is the upward movement of deep lying connate water driven by freshwater under an artesian head.

The concentration of salts increases with depth below ground. Ten to 20 feet below the surface the EC ranges from 1,000 to 4,000 micromhos/cm while 100 to 300 feet below surface the EC range increases from 8,000 to 13,000 micromhos/cm (Tanji, 1975).

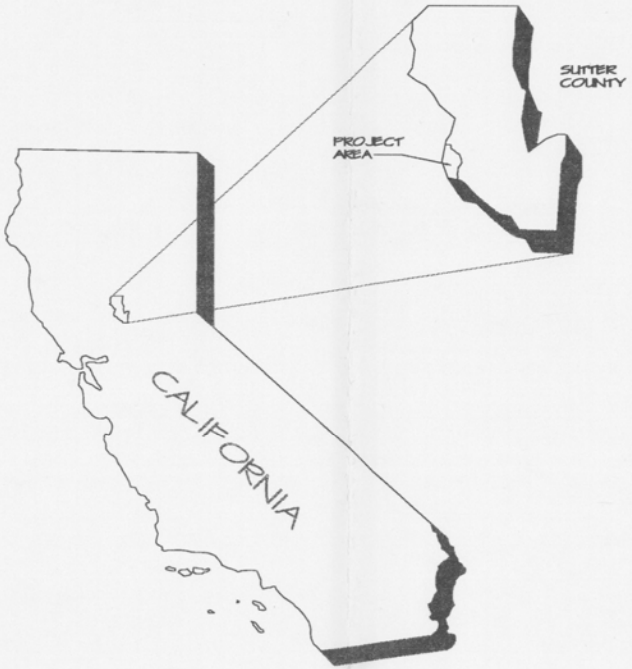
The salt-laden ground water seeps into the drain ditches and causes an increase in EC in the drains. The salt concentration in the main drain is typically much higher during the winter than during the irrigation season. The good quality irrigation water dilutes the salty ground and drain waters. The irrigation season runs from April through October. During this season from 1987 to 1992 the EC of the main drain at Karnak varied from 380 to 780 micromhos/cm. In the winter the EC ranged from 420 to 1500 micromhos/cm. Figure 6 shows the measured EC of drain ditches in the area in January and February of 1972 (Tanji, 1975).

Connate Water

In 1972, based on the EC of drain waters, Ken Tanji delineated the area shown on Figure 2 having total dissolved solids (TDS) ranging from 2,000 to 2,500 parts per million (ppm) (Tanji, 1972).

FIGURE 4

RECLAMATION DISTRICT 1500
RESOURCE STUDY
SUTTER COUNTY, CALIFORNIA



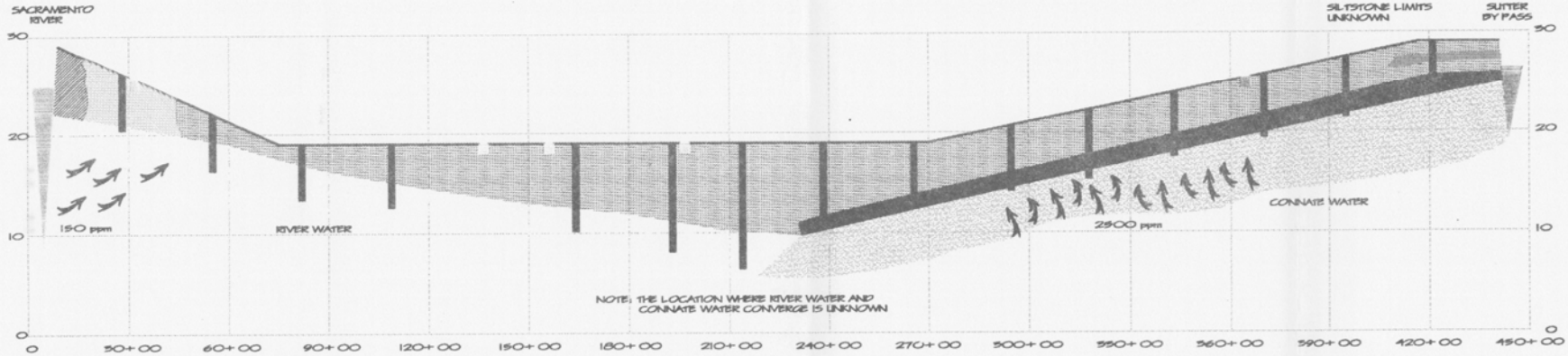
LEGEND
- Watershed Boundary
- Drainage \ Waterway
- Range \ Township Line
- Road
- Drainage Ditch

SCALE 1 0 1 2 MILES

U.S. DEPARTMENT OF AGRICULTURE
NATURAL RESOURCES CONSERVATION SERVICE

TITLE: DRAINAGE SYSTEM MAP			DRAWING NO.:
DESIGNED BY:	CHECKED BY:	APPROVED BY:	
SCALE: As Shown	DRAWN BY: T.M. Share	DATE:	SHEET OF

FIGURE 5



SECTION A - A

For the location of SECTION A-A see the DRAINAGE MAP

LEGENDS

SOILS		SUB-STRATUM	
SILTY CLAY LOAM		SILTSTONE	
SILT LOAM		SANDSTONE	
CLAY			
IRRIGATION DITCH		DRAINAGE DITCH	

U.S. DEPARTMENT OF AGRICULTURE
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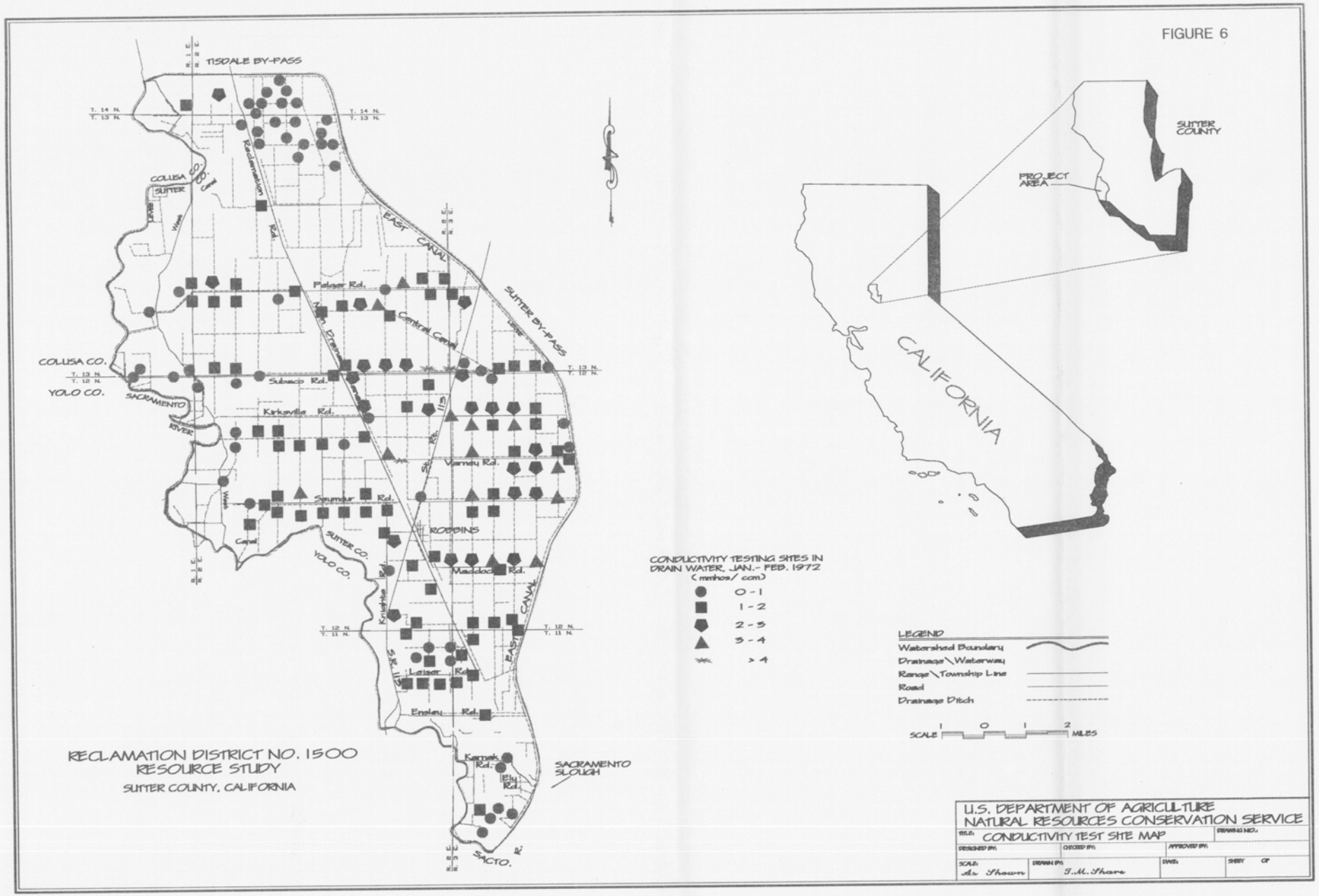
FIGURE 6


TISDALE BY-PASS
T. 14 N.
T. 13 N.
COLUSA
SUTTER
Drain
Weir
Reclamation Rd.
EAST CANAL
SUTTER BY-PASS
Pelger Rd.
Main Drainage Canal
Central Canal
COLUSA CO.
T. 13 N.
T. 12 N.
YOLO CO.
SACRAMENTO
RIVER
Sibato Rd.
Kirkville Rd.
S.R. 113
Varney Rd.
Sumer Rd.
Weir
Canal
ROBBINS
SUTTER CO.
YOLO CO.
Kristine Rd.
Waddoc Rd.
EAST CANAL
T. 12 N.
T. 11 N.
S.R. 113
Leiser Rd.
Engley Rd.
Kennek Rd.
Ely Rd.
SACRAMENTO SLOUGH
SACTO.
R. 1 E.
R. 2 E.
R. 3 E.
CONDUCTIVITY TESTING SITES IN DRAIN WATER, JAN.- FEB. 1972 (mmhos/ cm)
0 - 1
1 - 2
2 - 3
3 - 4
> 4
LEGEND
Watershed Boundary
Drainage \ Waterway
Range \ Township Line
Road
Drainage Ditch
SCALE 1 0 1 2 MILES
SUTTER COUNTY
PROJECT AREA
CALIFORNIA
RECLAMATION DISTRICT NO. 1500
RESOURCE STUDY
SUTTER COUNTY, CALIFORNIA
U.S. DEPARTMENT OF AGRICULTURE
NATURAL RESOURCES CONSERVATION SERVICE
TITLE: CONDUCTIVITY TEST SITE MAP
DRAWING NO.:
DESIGNED BY:
CHECKED BY:
APPROVED BY:
SCALE: As Shown
DRAWN BY: J.M. Shore
DATE:
SHEET OF

This area coincides with a saline ground water mound lying at a depth of approximately 1,968 feet in alluvial and non-marine sediments (Gupta, 1975).

The saline ground water mound is called connate water. An inland sea is believed to have been trapped during the Late Paleocene Period leaving a mound of connate water in the Kione Formation, Upper Cretaceous. This connate water, containing principally sodium and chloride, is thought to rise upwards along the Sutter Basin Fault under artesian pressure. The pressure is created by inflows of fresh water into the Kione sand formation at Sutter Buttes. The hydraulic head is estimated to be 262 to 426 feet (Tanji, 1975). Curtin's (1971) and Tanji's (1975) findings pointed to the major salt load in discharges at Karnak as being rising connate water, altered somewhat in cationic composition due to ion exchange.

To date, there has been no substantiated account of salt buildup in soils in this area of high TDS. To address the concern of salt buildup in soils, the University of California, Davis tested for saturation extract conductivities and chloride concentration at representative sites from 1971 to 1978. Eleven of the 32 regular sample sites were located in the delineated areas of high TDS in drain waters. Based on these analyses Henderson (1978) recommended discontinuance of sampling. Henderson stated that there was no trend in the salinity or chloride of sampled soils over the period 1971 to 1978.

A number of factors contribute to the lack of buildup of salts in the soils overlying the connate water. These factors include but are not necessarily limited to: 1) a siltstone at a depth of approximately 40 inches occurring in patches over the area, 2) leaching and drainage, and 3) clay soils overlying a sandstone.

The sandstone appears to be the most important of the preceding factors. The top of the sandstone has been encountered at depths of three to five feet in the east central portion of Sutter Basin and appears to be dipping southwest, being encountered at depths up to 10 feet in the southwest areas of Sutter Basin (Henderson, 1972). Tanji (Tanji, 1975) stated that this sandstone-like material readily conducts water and appears to act as a built-in underdrain. Henderson (Henderson, 1972) noted:

> "Typically, when a test hole is drilled, no water or obviously saturated soil is encountered until the "sandstone" is penetrated. Then the hole fills quickly and the water level rises well above the layer. A 2 1/2 inch diameter hole can be pumped with a small hand pump at a rate of 1 to 2 gpm but the water level drops only a short distance and recovers quickly when pumping stops. The flow is thus quite rapid."

Excavation of drainage ditches through this sandstone is the apparent cause of the high TDS area shown on Figure 2. This sandstone layer is probably truncated on the western edge of Sutter Basin. The cause of this truncation is past migration of the Sacramento River across ancient flood plains. Containment of the upward driven connate water by the sandstone would cause it to be found deeper in the western and southern portions of Sutter Basin.

Potential Salt Buildup

Inspection of soil maps and interviews with local experts revealed a potential for salt buildup in silt loam soils paralleling the Sacramento River levee. The pattern of the silt loam soils, mapped as saline-alkali soils in 1965 and/or saline sodic soils in 1988, suggest an old river channel under the present Sacramento River levee.

The 1915 Reconnaissance Soil Survey of the Sacramento Valley (Holmes, 1915) classified the preceding silt loams as excellent. This suggests that prior to the construction of a contiguous levee in the 1920s, salt buildup in these soils was practically non-existent. Frequent river overflows would have promoted the flushing of any salts that might have accumulated.

A 1965 Reconnaissance Soil Survey (Gowans, 1965) mapped an extensive band of saline-alkali soils. A 1988 Soil Survey of Sutter County (Lytle, 1988) mapped a smaller area of saline/sodic soils. Areas with past salt problems identified by Gordon Bailey (1995) are also shown on Figure 2.

The historical sequence suggests a hydraulic connection between the Sacramento River and the silt loam band inside the levee. The gradient between high river levels and the silt loam soils, established by construction of a contiguous levee in the 1920s, promotes upwelling of waters in the silt loam soils.

The implied reduction of saline soils from 1965 to 1988 suggests that a salt buildup can be managed by leaching and drainage. Evapotranspiration over time, without downward leaching, causes salts to build up. The amount of irrigation required to provide the desired leaching can be established. Land owners and operators appear to be applying ample irrigation at present to prevent salt buildup in the soils and apparently have leached formerly saline soils.

Rice as a crop insures prevention of salt buildup. In 1972 Henderson conducted a study of 20 rice fields to determine downward percolation of water. Seepage rates ranged from 0.1 to over 0.5 inches per day. Henderson stated: "Even the lowest rates would be more than adequate to wash out any previous accumulation of salts in the upper soil. There is little doubt that rice culture contributes to the control of salt accumulation in Sutter Basin soils" (Henderson, 1972).

Water Budget

To establish a water budget, the year 1993 was selected (see Table 4). The Company has records on the amount of water sold to each grower and the amount of acreage planted for the 1993 crop year. The acreage outside the Company service area was assumed to be the same crop pattern as the 1990 Department of Water Resources (DWR) land use maps. The rainfall record from the Tisdale pumping plant was used for the precipitation estimate of 22.14 inches. BOR water diversion records at the three Company pumping plants were used for pumped water from the Sacramento River of 184,532 acre-feet. Other BOR records, where they existed, were also used. BOR records show that the volume of water diverted from the Sacramento River by other BOR contractors is 26,034 acre-feet. There were areas where no records existed for actual water pumped from the river or wells. It was assumed that water from the entire area was either used for evapotranspiration (Et) or was lost to deep percolation or direct run off into the drainage net. The records show that the discharge at the Karnak pumping plant was 201,275 acre-feet for 1993.

Crop Et was estimated using CIMIS reference crop Et data from the Nichols station and appropriate crop coefficients. The cropland acreage, other land use data, and the Et estimates were combined to estimate the basin Et use of 224,537 acre-feet for 1993.

The greatest uncertainty exists in estimating the division of water from the ground water table into connate water discharged under artesian pressure and ground water discharged under the pressure associated with water surface elevations in the Sacramento River, Sutter Bypass, and the Feather River. The identified connate water area is drained by nine percent of the drainage system in the basin. If connate water discharge is related to this percentage of drainage system, then 7,300 acre-feet of ground water discharged at Karnak came from the connate ground water body (equivalent area influence). The remaining 73,000 acre-feet of ground water came from the area influenced by the river and bypass system. This estimate is the minimum reasonable amount of connate water possible. If the connate area is under greater hydraulic pressure in the basin, then the volume of connate water would be 29,200 acre-feet and the river and bypass system ground water volume would be 51,100 acre-feet (connate head four times larger). These two values represent a range of possible values for partitioning the ground water entering the basin from these sources. These values are shown in Table 4 and Figure 7.

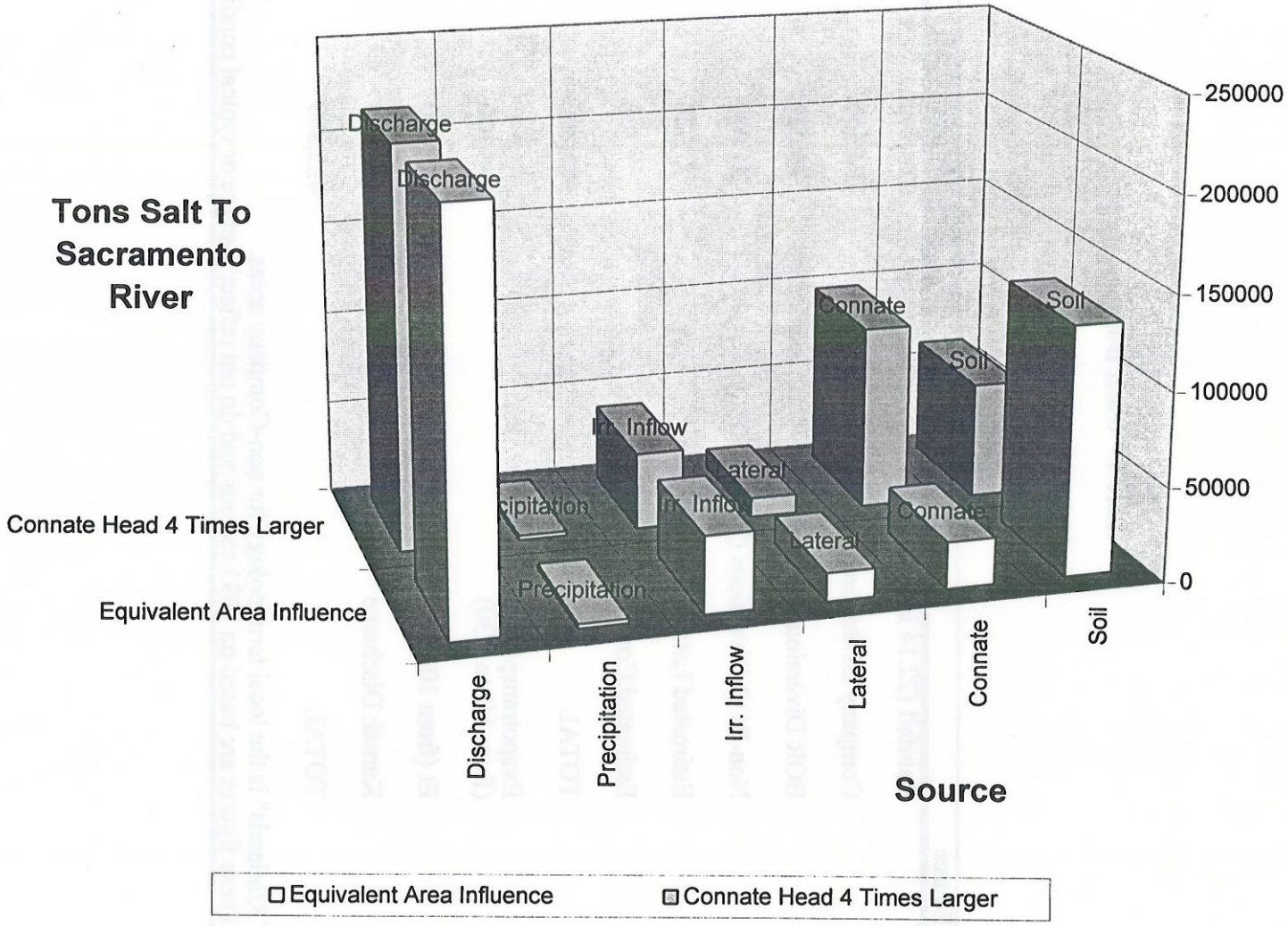
Table 4 - Water Budget

Based on 1993 Records

Water Source	Volume (acre-feet)
Rainfall (22.14 inches)	113,700
Company Diversions	184,500
BOR Diversions (Rimlands)*	26,000
Non-BOR Diversions (Rimlands)*	21,000
Estimated Lateral River Seepage	73,300
Estimated Connate Portion	7,300
TOTAL	425,800
Evapotranspiration (from 1/1 to 9/30)	176,100
Et (from 10/1 to 12/31)	48,400
Karnak Discharge	201,300
TOTAL	425,800

Note: "Rimlands" is the local terminology for non-Company areas.
These figures are based on 1993 records and do not reflect average or typical conditions.

Figure 7. Range of Salt Sources In Drainage District



There is no area in the basin which is not within 10 feet of the water table. Most areas are within five feet and some areas are within 18 inches. The water table is controlled by the drainage ditch system, Sacramento River elevations, elevation of water in the Sutter Bypass, the elevation of the Feather River, and artesian pressure in the "connate" water area. The entire basin is essentially a depression where the combination of river and irrigation ditch hydraulic head, drainage ditch water surface manipulation, precipitation, and irrigation water surface and deep losses control the Karnak outflow.

Salt Budget

Salt enters the basin by precipitation, ground water, soils, and river diversions. The river and bypass system ground water quality is quite good with an estimated 0.20 tons of salt per acre-foot. The connate water quality is distinctly different with an estimated 3.38 tons of salt per acre-foot.

The estimated salt discharge at Karnak in 1993 was 214,700 tons of salt. The salt brought into the basin from precipitation and irrigation diversions was 50,000 tons. Using the partitioning of ground water sources in Table 4, the connate salt was between 24,700 tons and 98,700 tons. Total salts from the ground water system were between 10,200 tons and 15,000 tons. The remaining salt must have come from soil sources and ranged between 55,800 and 125,000 tons. These ranges are shown in Figure 7.

Connate and rim waters were estimated to contribute about 40 percent of drain water outflow and roughly 20 percent of the salt outflow. This estimate of salt contribution from connate and rim waters is much smaller than the 70 percent estimated by Tanji (Tanji, 1975). The salt budget presented here implies that 58 percent of the salt load from this area to the Sacramento River is leached from the basin's soils. There is a lot of uncertainty in these estimates and more work should be done to characterize the area before significant modifications to the system are made.

SECTION IV
DESCRIPTION AND ANALYSIS OF WATER CONSERVATION MEASURES

As the January 10, 1995, "Draft Guidelines and Criteria for Water Conservation Plans" (Western states) by the BOR states: "Water conservation is not an end in itself. It is a means of achieving specific goals such as: saving money, higher crop yields, reduced soil erosion, reduced drainage problems, improved water supply and delivery reliability, or water supplies for additional use."

The Reclamation Reform Act and the Central Valley Project Improvement Act require that entities contracting for Federal water project water supplies develop water conservation plans. These plans need to examine existing water management practices, evaluate other water management strategies, and determine how to implement appropriate water conservation measures.

One of the most important components of the plan is to identify and evaluate water conservation measures. The BOR has identified 14 potential measures that should be evaluated for suitability in reaching the water conservation goals.

The measures should be evaluated based upon (A) applicability to the district, (B) technical feasibility, (C) the evaluation of legality under state/federal law, (D) financial feasibility for the district, (E) improved efficiency of water delivery and use, (F) quantity of water to be saved, and (G) environmental impacts. The 14 measures identified by the BOR have a demonstrated record of effectiveness in reducing losses of, making more efficient use of, or otherwise conserving, water. Due to the lack of legal expertise in NRCS, item (C) will not be analyzed.

1. Incentive Pricing: Implement an increasing tiered block water pricing structure, or other water pricing structure, that promotes the efficiency of water use.

Block rate pricing could be used to motivate growers through price incentives to reduce the amount of irrigation water that is applied to the fields. A higher price for water applied in excess of what the crop requires could motivate growers to modify their operation to reduce water use. The concept is to encourage the irrigator to develop the best possible irrigation system and management practices in order to minimize the need to purchase the more expensive, or tiered, irrigation water. This price incentive mechanism can have a significant positive impact on irrigation water use while having minimal impact on the total farm-level expenditure on water.

Although growers are motivated by many factors such as risk, irrigation management, requirements for proper crop rotation, employee skills, and other factors, the economic principle of profit maximization plays a key part in explaining the effect that tiered water pricing could have on water conservation. Profit maximization is based on the belief that businesses respond to input and output prices. Raise the price of a key input used in a business and the owner either cuts back production, switches to a substitute input, or changes the goods produced.

In the case of a farm operation the full response depends on feasible crop rotations, land quality, grower's responsiveness to irrigation water prices such as do they cut back a little or a lot, the substitutability of fertilizer or other inputs for irrigation water, the magnitude of water price increase, irrigation water expense as a share of total crop budget, and other factors. A full study of these factors, such as one carried out with economic models, would give a better understanding of how tiered pricing would affect this irrigation district and its growers.

(A) applicability to the district, (B) technical feasibility, (D) financial feasibility for the district, (E) improved efficiency of water delivery and use, (F) quantity of water to be saved, and (G) environmental impacts.

Calculation of the water conservation savings that could be anticipated by the District from raising irrigation water prices is difficult. As mentioned in the previous paragraphs, a wide number of factors influence how growers will respond to price increases.

The actual setting of prices needed to carry this out can be done in a number of ways. Perhaps the most practical is to talk to irrigation district managers that have used tiered pricing and draw from their experiences. Trial and error may be needed to find the rates that meet the objectives of the District and its customers. Any approach to establish tiered pricing must include technological standards such as what is the minimum amount of water required to produce a particular crop.

In this region, another factor that must be seriously considered is how water price changes might limit the growers to rotate crops. For example, in some locations in the Sutter Basin growers will use rice in their crop rotation specifically to manage the salts in the soil. To successfully manage the salts a significant amount of water may need to be applied. An outside viewer of this may mistakenly presume that excess water is being applied.

Tiered pricing has been used by other purveyors. The Broadview Water District implemented a program to encourage a reduction in drain water. It should be noted that the Broadview Water District, in the San Joaquin Valley, is located in a different area than Reclamation District 1500 and the main concern was to minimize drainage from agriculture rather than to achieve a salt balance in the area. It is referenced in this document to show the types of effects that tiered pricing has had in a real world, though different, situation.

Present Conditions:

In 1993 the Company separated charges between a flat maintenance charge of $13 per acre per year plus a charge of $8 per acre-foot for water purchased. The annual maintenance charge is received from 50,083 acres, whereas the water cost is based on the actual amount of water purchased for the different crops.

Factors Considered:

A. This measure is applicable to the area.

B. The Company would need to determine the appropriate tiered price and gain the support of the landowners. To set the tier for which irrigation water would be priced higher, an analysis of the characteristics of the basin would be necessary. Typically, this would require a determination of the water needs of each crop for the various soils on which they are grown and adding some flexibility to account for other variations. An inherent requirement for incentive pricing to be effective is that growers have technically viable actions to take, such as a change in equipment or management practices, that will allow them to reduce the amount of irrigation water used for that particular crop.

For instance, tomatoes grown in this area generally require 2.38 acre-feet of water. A tiered price for water for this crop could logically be set slightly above this required level of water. The same logic could be used to establish the point at which the additional water purchases would be more expensive.

Currently, crops in the basin require consumptive use water in the range of 0.66 to 3.33 acre-feet/acre. In fact, in 1993 only 26 percent of growers were applying significant amounts of water above the crop needs. Therefore, only a small proportion of the growers might be responsive to tiered water costs and a higher water cost might elicit a relatively minor reduction in applied water.

D. Presently a specific price incentive program in the Sutter Basin to encourage greater water conservation is not in place. It should be pointed out that the current water pricing schedule does not encourage excessive water usage either.

(A) applicability to the district, (B) technical feasibility, (D) financial feasibility for the district, (E) improved efficiency of water delivery and use, (F) quantity of water to be saved, and (G) environmental impacts.

A complete analysis of the financial consequences of implementing tiered pricing was not possible in this study. However, an example of potential economic impacts is presented. Two scenarios are given in Tables 5 and 6; 1) growers do not adjust water applications with increased water cost, and 2) growers completely adjust water application with the increase in water cost. In this example it is assumed that irrigation water purchases above the requirements of each crop will be priced at $30 per acre foot. This price per acre-foot was selected to demonstrate the economic change depending on how growers respond to the increase in water cost.

For this example the current price of $9 per acre-foot of water is used and therefore the typical irrigation water purchase cost for each crop is: tomatoes, at 2.38 acre-feet, averages $21.42; rice, at 6.33 acre-feet, averages $56.97; melons, at 0.66 acre-feet, averages $5.94; and beans, at 2.43 acre-feet, averages $21.87. Only a few of the major crops were included in this analysis.

Table 5 (Scenario 1) shows the economic impacts when all growers who are over applying do not reduce irrigation water application to a level at or below when the $30 tiered price kicks in (inelastic response).

Table 6 (Scenario 2) shows the economic impacts when all growers who are currently over applying reduce irrigation water application enough to avoid increased water costs (tiered price $30).

The actual impacts of tiered water pricing in Sutter Basin would fall somewhere between these two scenarios. Clearly, some growers would accept some additional water costs and continue to apply water above the tiered level based on their specific conditions such as the need to manage the salts in the soil; others would adjust their water purchases downward. They would be more likely to reduce water application if the conservation practices and/or management changes are perceived to be less expensive than the added water cost. The Company would also face some revenue impacts depending on the growers' response to tiered pricing. Administrative expenses associated with implementing the tiered price program would also be incurred; however, this might be offset by the reduced purchase of river water and pumping costs.

This limited analysis shows the total quantity of water that could be conserved by price incentives is relatively small, though it appears to be an economically viable option to be considered.

The Broadview Water District, in the San Joaquin Valley, found some significant reduction in drain water using incentive pricing. Their use of incentive pricing was for drainage control, as opposed to water conservation. The goal set was to reduce the average amount of water applied by the growers by 10 percent. The existing base price of water was $16 per acre foot. Average water application rates were determined for each crop. Water application levels of 10 percent less were identified and the amount of water used above this level was priced at $40 per acre foot. This pricing program in 1989 resulted in the application of water on melons to drop an average eight percent.

E. & F. The present on-farm overall irrigation efficiency for the major row crops of tomatoes, melons, and beans exceeds 100 percent because part of the water requirement is met by the shallow water table. Beans are the lowest with 69 percent and melons are the highest. Data is available for 136 non-rice growers farming a total of 42,000 acres of cropland. These growers represent 75 percent of the total growers in the area. Assuming a target efficiency of 80 percent, 33 growers have irrigation efficiencies less than this. The amount of irrigation water reduction required for these growers to achieve the target irrigation efficiency is 2,700 acre-feet. Assuming these numbers are representative of the entire area, the total area-wide irrigation water reduction would be 3,600 acre-feet. This is less than two percent of the total water use. Some water savings , approximately 7,800 acre-feet, associated with rice production may also be possible. However, given the irrigation method currently employed the feasibility to reduce water usage further without significant crop impacts is much less likely.

Table 5: Impacts If Growers Continue To Apply Excess Water After Tiered Pricing Is Implemented.

CROP	ESTIMATED NUMBER OF FIELDS RECEIVING EXCESS IRRIGATION WATER	ESTIMATED NUMBER OF ACRES RECEIVING EXCESS IRRIGATION WATER (acres)	ESTIMATED AMOUNT OF EXCESS IRRIGATION WATER APPLIED **** Total (acre-feet)	Avg. per Acre (acre-feet/acre)	EXAMPLE TIER PRICE FOR EXCESS WATER APPLIED ($/acre-feet)	ADDITIONAL WATER COST TO GROWER WITH TIERED PRICE ($/acre)	TOTAL ADDITIONAL WATER COST FOR ALL ACRES WITH EXCESS IRRIGATION WATER APPLIED ($/crop)
Tomatoes	22	1,566	1,340	0.86	$30	$18	$28,190
Rice *	33	3,000	7,800	2.60	$30	$54.60	$163,800
Beans	11	1,135	1,080	0.95	$30	$19.88	$22,680
Melons **	-	-	-	-	-	-	-
TOTAL	66	5,701	10,220				$214,670 ***

* A significant proportion of these rice growers may not be using more water than required for their particular soil on which the rice is grown.

** Melon growers have generally been successful at utilizing the water table to supplement their irrigations, therefore there is no excess irrigation water applied.

*** This is also an estimate of additional revenue that the Irrigation Company would receive if growers continued to apply the same amount of water with tiered pricing implemented.

**** Only the major water using crops grown in the basin were included in this estimate.

Table 6: Impacts If Growers Respond To Tiered Pricing By Reducing Irrigation Water Application To Just Below Level Where Increased Water Cost Would Start to Be Incurred.

CROP	ESTIMATED NUMBER OF FIELDS RECEIVING EXCESS IRRIGATION WATER	ESTIMATED NUMBER OF ACRES RECEIVING EXCESS IRRIGATION WATER (acres)	ESTIMATED AMOUNT OF EXCESS IRRIGATION WATER APPLIED ***** Total (acre-feet)	Avg. per Acre (acre-feet/acre)	EXAMPLE TIER PRICE FOR EXCESS WATER APPLIED	REDUCED WATER COST TO GROWER WITH TIERED PRICE ($/acre)	TOTAL REDUCED WATER COST FOR ALL ACRES WITH EXCESS IRRIGATION WATER APPLIED *** ($/crop)
Tomatoes	22	1,566	1,340	0.86	$30	$7.75	$12,136
Rice *	33	3,000	7,800	2.60	$30	$23.4	$70,200
Beans	11	1,135	1,080	0.95	$30	$8.55	$9,704
Melons **	-	-	-	-	-	-	-
TOTAL	66	5,701	10,220				$92,040 ****

* A significant proportion of these rice growers may not be using more water than required, for their particular soil on which the rice is grown.

** Melon growers have generally been successful at utilizing the water table to supplement their irrigations, therefore there is no excess irrigation water applied.

*** This estimate does not include possible added grower costs such as equipment and/or management in order to reduce water application.

**** This is also an estimate of the loss in revenue to the irrigation company if growers eliminated over-application of irrigation water.

***** Only the major water using crops grown in the basin were included in the estimate.

The amount of drain water reuse that currently takes place in the basin would no longer be possible. The volume of water discharged at Karnak and/or the volume available for reuse would be reduced by 3,600 acre-feet. This would result in a corresponding but unknown change in water quality in the area and the discharge to the river.

G. There may be several potential environmental effects. If the Company could reduce the amount of water diverted from the Sacramento River, they could avoid any thermal impacts that may be associated with routing the water through the area before it is returned to the River. Some riparian habitat may be lost. There is some potential of increasing the concentration of natural salts in the basin due to the combination of reduced irrigation and the connate ground water source. The drainwater that continues to be returned to the Sacramento River may involve higher concentrations of salts for this reason. A loss of water bird habitat is also expected if the rice acreage is reduced.

Analysis of This Measure:

Rice agriculture in the study area is basically the maintenance of a surface water table in the rice check. If the system has a tailwater return system or is a closed system, then the amount of water use is dependent on the Et of the crop and the permeability of the soil. Neither of these two factors is changeable by management or system design. While water use could be reduced by changing crops, this is not the intent of the measure. The deep percolation losses from rice in the basin can be considered constant for the irrigation season once equilibrium conditions exist.

If implemented, this measure would demand of growers very detailed and extremely accurate record keeping and water measurement.

2. <u>On-Farm Program Incentives</u>: Facilitate and/or provide financial incentives and assistance for on-farm water use efficiency improvements (e.g. lease, low interest loans, or water charge rebates for on-farm conservation measures).

Present Conditions:

The District currently has no programs in place to do this.

Description of Action:

Any incentive program will require some funding mechanism. These funds could come from a flat price increase in water costs, block pricing funds, or other funding sources. The funding sources could be used to fund on-farm efficiency improvements.

Factors Considered:

A. This measure is applicable to the area.

B. This measure is technically feasible. On-farm improvements may include structural and management measures. Irrigation water management, sprinkler systems, and tailwater return systems are examples of potential on-farm improvements.

D. The District would be required to determine and then manage a source of financial funds for such programs. This would result in some added expense that would need to be passed on to the growers through water costs. While management measures on some farms could be inexpensive, system improvements could be in excess of $50 per acre.

(A) applicability to the district, (B) technical feasibility, (D) financial feasibility for the district, (E) improved efficiency of water delivery and use, (F) quantity of water to be saved, and (G) environmental impacts.

When considering educational and technical assistance for water conservation, the typical costs for on-farm water management for irrigation consultants is about $5 per irrigated-acre. Using this cost, targeting 2,700 acres per year, and a farm visit every five years, the cost for assistance would be $2,700 per year. The targeted areas would be bean and cropland where excess water is applied. The typical success rate would be a water use reduction of about 10 percent of the excess water. With 2,400 acre-feet of excess water applied, this would be a reduction of 240 acre-feet per year, at a cost of $12 per acre-foot.

E. Presently, the rice lands have tailwater return or closed systems so irrigation efficiency improvements would be minimal. The remaining 47,000 acres could be eligible for this type of assistance. There would only be 12,000 acres which could be improved to 80 percent. The remainder of the area is above 80 percent. Systems operate efficiently only when the proper management is present.

F. Approximately 3,600 acre-feet of water would not be ordered from Shasta in this situation as discussed in the Incentive Pricing section previously. This is less than three percent of the total water use in the District. The estimate for water savings for rice is unquantified and it is assumed the rice growers are currently fairly efficient.

Depending on the effectiveness of the on-farm water conservation incentives, available drain water for reuse may be limited, requiring some growers to purchase additional District water.

G. The environmental effects of reduced irrigation water used would be the same as discussed in the Incentive Pricing section.

3. Drought/Water Shortage Contingency Plan: Develop a drought/water shortage contingency plan for the district that outlines the policies and procedures for operation and allocation during water supply shortages.

Present Conditions:

At the beginning of the irrigation season the BOR tells its contractors how much water is available for that year. In short water years the Company may allocate this water to its customers by crop in accordance with the Reclamation Reform Act of 1986. In 1992, the contracted amount was reduced by 25 percent. The Company does have a mechanism in place to deal with drought/water shortage situations.

A. This measure is applicable to the area.

B. This measure is technically feasible.

D. This measure is economically feasible.

E. Unknown.

F. Unknown.

G. Unknown.

4. Water Transfers: Facilitate voluntary transfers that do not unreasonably affect the district, the environment, or third parties.

(A) applicability to the district, (B) technical feasibility, (D) financial feasibility for the district, (E) improved efficiency of water delivery and use, (F) quantity of water to be saved, and (G) environmental impacts.

Present conditions:

The Company is currently exploring water transfer opportunities. The Company owns the water rights to the water and is the contractor with the BOR. The water rights are enjoyed mutually by landowners and not as individuals. The impacts of transfers on the Company, the environment, or third parties need to be examined.

Factors Considered:

A. This measure is applicable to the area.

B. This measure is technically feasible.

D. There is the potential for individual landowners and/or the Company to receive additional financial resources that could supplement income as well as reduce per acre irrigation water cost. However, the local economy may be negatively impacted. Fewer agricultural inputs and crop processing services may impact the business community.

E. Probably none.

F. Probably none.

G. There may be problems due to additional salt buildup in the soil due to reduced irrigation applications.

5. Conjunctive Use: Increase conjunctive use of surface and ground water within the district, begin working with appropriate entities to develop a ground water management plan.

Present Conditions:

In 1993, 201,300 acre-feet of water was returned to the Sacramento River. However, 95,400 acre-feet of this water is rainfall in the winter or lateral flows to the drainage net and cannot be captured for uses during the irrigation season.

Of the 105,000 acre-feet of water which leaves the area during the irrigation season, several questions need to be answered before a commitment to full or partial use is made. The questions are: what is the distribution of salinity in the basin and how much water is available in those areas which have suitable water quality?

For the purposes of this report, it was assumed that approximately 50 percent of the 105,000 acre-feet, or a total of 52,500 acre-feet, of this water could be recirculated based on available 1993 data.

An unknown volume of freshwater underlies the basin. Although the sources of recharge have not been quantified, the Sacramento River is thought to be a major source and is, therefore, not a legitimate source of new water. The ground water in the lower section of the basin is generally not suitable for irrigation use due to the effects of the connate water. Tapping of ground water should be discouraged until sufficient data exists to allocate withdrawals that will not create adverse impacts.

The ground water table in the area is generally five feet under the surface. During the irrigation season it can be brought to less than 18 inches below the surface by manipulating the water level in the drainage ditches. This can be considered a form of conjunctive use.

(A) applicability to the district, (B) technical feasibility, (D) financial feasibility for the district, (E) improved efficiency of water delivery and use, (F) quantity of water to be saved, and (G) environmental impacts.

Factors Considered:

A. This measure is not applicable to the area due to the high water table and saline conditions of the ground water.

B. This measure is not technically feasible in the service area. Another area would need to be found in which to store water underground.

D. Because storing ground water in the basin is not an option, the Company would need to cover the cost of the infrastructure required to transport the water to another district, pump the water from the ground, and transport the water back to the area when it is needed. Some administrative expense would also be incurred to monitor the quality of the increased amount of reused water. While the Company would reduce pumping costs for water pumped from the Sacramento River, the cost of pumping water from the ground with a lift of 50 feet and transporting the water to and from another area would surpass this cost and costs would actually increase.

E. Not applicable to this area due to the lack of technical feasibility.

F. Not applicable to this area due to the lack of technical feasibility.

G. The Company could possibly reduce the amount of water diverted from the Sacramento River but this is offset by the reduction of water discharged back into the River. It is unlikely that water could be stored in the service area's ground water basin due to the detrimental crop and wildlife effects the increase in salinity would create.

Analysis of This Measure:

The basin is underlain by water that is too saline for agricultural use. It is likely that all of the area is underlain by saline water at some depth. The largest quantity of shallow saline water is associated with the underground connate water. An unknown volume of usable water is also present. Most of the usable water has been found along the western half of the basin and very likely has a direct hydraulic link to the river system. The District presently manipulates the ground water table by adjusting the water level in the drain ditches which does increase conjunctive use by crops, particularly those adjacent to the rice fields.

Conjunctive use usually implies the storage of water in the ground water basin during years of excess supply and use of the stored water during drought years. This only works when there is no direct link between the ground water and surface water sources. The Company would need to identify an area outside the district with suitable hydrogeologic characteristics, contract for storage, and then find a method for delivery to and from this area.

6. Land Management: Facilitate alternative uses for lands with exceptionally high water duties, or whose irrigation contributes to significant problems (e.g. drainage that does not meet discharge standards).

Present Conditions:

There are no lands which have high water duties or problems. The connate water salinity is a function of geology, not irrigation. Present land management practices, cultivation, and irrigation water management are done in a manner that minimizes problems that relate to water discharges which exceed standards. Rice, which has the potential to contribute to degradation of water quality and exceed water quality standards, is being grown and managed in closed systems. Rotations in which rice, tomatoes, melons, grain, and safflower are being grown are managed efficiently. Problems associated with

irrigated crops are seepage from fields into drains and the timing of drainage amongst neighboring growers. In most all cases, drainage discharge standards are not being exceeded.

In the high salinity areas irrigation has actually helped to make the land more viable for agriculture.

Factors Considered:

A. This measure is applicable to the area.

B. This measure is technically feasible.

D. Financially, feasibility is limited due to the lack of other income-producing uses for the land. Financial compensation would need to be found for landowners putting land out in retirement.

E. This measure would not change water use efficiency in this area.

F. If land was taken out of production, some water would be saved since it would no longer be needed for irrigation.

G. There would be salt buildup in the soils of the area, leading to an overall decrease in suitable habitat for the current species found in the area.

7. Operational Practices and Procedures: Evaluate potential district operational policy and institutional changes that could allow more flexibility in water delivery and carry over storage.

Present Conditions:

Company policy states that irrigation water delivery to growers requires a 48 hour advance notice and a 12 hour advance notice for shut off. The current system is effectively an on-demand schedule. The Company advises the BOR of estimated water needs on Monday for one week. The area is divided into six service areas with six ditch riders working together to achieve flexibility in delivery and service. Present policy allows ditch tenders to shut gates where water is obviously being wasted.

Factors Considered:

A. This measure is applicable to the area.

B. This measure may not be technically feasible without a regulating reservoir due to the time required to allow water from Shasta Dam to reach the area.

D. There would be cost associated with hiring more District personnel to be available for water delivery and shut-off. There would also be additional cost associated with the installation of additional water management equipment.

E. There would be more flexibility in water delivery, though not necessarily an increase in water use efficiency.

F. There would be a certain amount of water saved if landowners had more flexible delivery and shut-off.

G. There would be less water in the ditches and canals, reducing water edge habitat.

Analysis of This Measure:

(A) applicability to the district, (B) technical feasibility, (D) financial feasibility for the district, (E) improved efficiency of water delivery and use, (F) quantity of water to be saved, and (G) environmental impacts.

The existing delivery system is fairly flexible. If the District increases the use of drainage water, it could order less and/or assign this water to carry-over storage. This assignment to carry over storage is especially desirable due to BOR costs assigned to full delivery of contract water. This carry over water would have to be stored in other ground water basins and "traded" or sold during drought years. If there is a lack of capacity for flood storage, this carry-over water would be released and lost downstream.

8. Irrigation System Scheduling: Implement a program of distribution system scheduling based on area wide crop demand modeling or advanced demand requirements.

Present Conditions:

The responsibility of ordering water belongs to the grower.

Factors Considered:

A. This measure is applicable to the area.

B. This measure is technically feasible.

D. There would be additional costs associated with hiring more District personnel to implement the program and the installation of water management equipment.

E. There would be some improved efficiency of water use on the least efficient acres irrigated as mentioned previously in the Incentive Pricing section. However, this is only three percent of the total water use in the District.

F. As mentioned previously, 3,600 acre-feet could be saved by increasing the least efficient growers' efficiency to 80 percent. The assumption is made that, if growers are informed how much water they are using in comparison to other growers, they may see how they can also reduce their own water use.

G. Care must be taken not to reduce irrigation levels below the amount needed to continue leaching the salts from the soil. Saline soil would affect existing habitats and land uses.

Analysis of This Measure:

Computer models could be used with the crop acreage figures, planting dates, and other information to check or anticipate water orders. The Company would assume considerable risk if it took over water ordering responsibility from the growers. The information could be used to identify growers who could use assistance in increasing water use efficiency. Flexibility could also be increased by better drainage water quality assessments and storage/yield estimation. If the Company knew the "typical" flows and quality from the drainage laterals, it could adjust its orders to use this water.

9. On-Farm Scheduling: Facilitate the delivery of crop water use and on-farm delivery information to district customers for on-farm irrigation scheduling.

(A) applicability to the district, (B) technical feasibility, (D) financial feasibility for the district, (E) improved efficiency of water delivery and use, (F) quantity of water to be saved, and (G) environmental impacts.

Present Conditions:

Presently, growers in the area have access to CIMIS data and the AGWATER programs. These programs need to be used with caution in high water table areas such as the Sutter Basin.

Factors Considered:

A. This measure is applicable to the area.

B. This measure is technically feasible.

D. There would be cost associated with hiring personnel to provide landowners with education, information, and technical opportunities.

E. There would be some improved efficiency of water use on the least efficient acres irrigated as mentioned previously in the Incentive Pricing section. However, this is only three percent of the total water use in the District.

F. As mentioned previously, 3,600 acre-feet could be saved by increasing these growers to an efficiency of 80 percent.

G. Care must be taken to irrigate often enough and with enough water to continue the leaching of the salts through the soil. Saline soil would affect the existing habitats and land uses.

Analysis of Measure:

The Company could become more involved with training and information transfer of irrigation information and technology. For instance, the Company has available the typical water use for each crop and distribution of water orders in the area, so growers could compare their use to that of other growers. This information is already being distributed in bills.

10. Pump Efficiency Evaluations: Coordinate the evaluation of district and private pumps with local utilities, evaluating both energy and water efficiency.

Present Conditions:

Currently the Company supports PG&E's pump testing program.

Factors Considered:

A. This measure is applicable to the area.

B. This measure is technically feasible.

D. This measure could increase energy and water cost savings, but there would be some expense associated with equipment and personnel costs for monitoring.

E. Water efficiency would increase with properly functioning pumps.

F. Some water would be saved if efficiencies increased.

G. There would probably be negligible effect on the environment.

(A) applicability to the district, (B) technical feasibility, (D) financial feasibility for the district, (E) improved efficiency of water delivery and use, (F) quantity of water to be saved, and (G) environmental impacts.

11. Distribution Control: Modify distribution facilities and controls to increase the flexibility of water deliveries (e.g. automate canal structures, institute variable turn off times, etc.).

Present Conditions:

The ditch riders are presently allowed to close or reduce delivery to customers who are spilling water from their fields. Growers are charged for what is ordered, whether it is used or spilled.

Factors Considered:

A. This measure is applicable to the area.

B. This measure is not technically feasible without a regulating reservoir for storage. If the District adheres strictly to policy to order water two days in advance, this limits the opportunities to increase flexibility of distribution. If such an option was feasible, however, there would be more delivery and use flexibility for the individual grower.

D. There would be almost $5.7 million in costs involved with automating equipment and hiring additional personnel.

E. If the two-day advance limitation is adhered to, there would be no significant increase in water delivery efficiency without a regulating reservoir.

F. For the same reason, no significant water would be saved.

G. There would be no significant environmental changes with this measure.

Analysis of This Measure:

In 1993, the Company charged its customers for 143,000 acre-feet of water. Rice used 107,000 acre-feet of water, generally with closed or tailwater return systems. The assumption that 30 percent of the remaining 36,000 acre-feet could be spilled leaves 10,800 acre-feet. Control gates to spill this water into the Sacramento River or a regulating reservoir would cost $4,700,000 while the reservoir would add an additional $1 million in costs. The annual cost for these gates at eight percent interest with a 50-year life would be $384,000. If the "saved" water was spilled back into the Sacramento River, the difference in water use would be dependent on where the water returns to the River. There may be some thermal changes in the returned water.

12. Reuse Systems: Construct district operational spill reuse systems.

Present Conditions:

Currently, rice growers operate closed basin or tailwater return irrigation systems rather than flow through systems, so there is no opportunity to improve irrigation water use on these lands. The remaining crop land could incorporate a tailwater return system that could improve the on-farm irrigation water use efficiencies.

The Company presently reuses up to 15,000 to 16,000 acre-feet per year using its facilities. There is also an estimated 15,000 to 16,000 acre-feet used by growers who pump from the drainage system. These figures total 30,000 to 32,000 acre-feet and are based on 1994 records. Some growers operate on-farm reuse systems.

(A) applicability to the district, (B) technical feasibility, (D) financial feasibility for the district, (E) improved efficiency of water delivery and use, (F) quantity of water to be saved, and (G) environmental impacts.

Potential Basin-Wide Recirculation System

A recirculation system to move drainage and tail water upslope to the main canal would lift additional water from Bohannon Dam (mile 8.2) at mile 7.5 to the canal at mile 19.5. There are several design constraints for this system: (1) recirculation at this scale may not be possible given the salinity of the system; (2) the present invert of the ditch should remain the same; (3) the maximum water surface should be four feet below the ground surface; (4) the water surface should never be higher than elevation 14 at Karnak; (5) velocities in the ditch system should be nonerosive.

The volume discharged from Karnak during the 1994 irrigation season was 71,000 acre-feet. The District estimates that 80 percent of the drainage water in the service area is generated upstream of Bohannon Dam. If the system is designed to recirculate this water back to the main canal, this would contribute an additional 320 cfs that would be available for recirculation.

If the discharge record for 1993 is used to estimate the amount of water which could have been recirculated in the system, the total volume recirculated would be 24,655 acre-feet for July and August of 1993. The average discharge from Karnak would have been 50 cfs or 6,149 acre-feet. The drainage discharge to the Sacramento River during July and August would have averaged an EC of 2,263 micromhos/cm for July and 2,215 micromhos/cm for August if the salt content remained constant. It is more likely, however, that salt would be stored in the soil profile during the irrigation season. Downstream water users would have had to find another source of water to replace the water the District was no longer discharging.

Currently, the EC of the drainage water at Karnak during the initial portion of the irrigation season is less than the EC during the winter due to the dilution effect of the additional irrigation water. The EC eventually stabilizes between 400 and 750 micromhos/cm. If more water were recirculated in the basin, this would change dramatically and an even higher winter EC would become more typical. Instead of the dilution of the salts occurring in summer, the salts would build up and not be flushed out until winter, creating a higher winter EC than usual. In order to maintain productivity, the salts accumulating in the soil need to be removed by leaching. It does not matter what the source of these salts is: agricultural productivity is damaged if the salts are not properly managed.

An analysis of the impacts from recirculating water in the basin was done using EC data from July and August 1990 to 1993 and Karnak discharge data to develop a regression equation for discharge at Karnak versus EC of the drainage water. The R-squared value was 47 percent for the unculled data set and 66 percent for the data set with four points removed. It also appears that if more water is recirculated the intercept changes. The intercept for the four points which were dropped was 810 with a nearly identical slope.

The results of this study show that in 1994, a low water year, the soils of the total basin stored an additional 1,100 tons of salt during the irrigation season. Recirculation efforts were maximized due to the low water supply.

If a recirculation system was built to bring eighty percent of the remaining 1994 drainage water back to the company supply system, the increase in soil salinity would be 48,000 tons of salt. The estimated mean discharge EC at Karnak would increase to between 790 and 810 micromhos/cm for the months of April through September.

The additional salt would need to be leached from the system by precipitation or additional water at some future date to maintain long term productivity. A more detailed analysis of the relationships between Karnak discharge, amount diverted, Et, EC, recirculation, and precipitation needs to be developed in order to reduce risk and uncertainty which would be associated with the installation of a basin-wide recalculation system.

(A) applicability to the district, (B) technical feasibility, (D) financial feasibility for the district, (E) improved efficiency of water delivery and use, (F) quantity of water to be saved, and (G) environmental impacts.

Factors Considered:

A. This measure is applicable to the area.

B. This measure is technically feasible to the area.

D. The Company would need to gain the support of the landowners and provide appropriate incentives to implement a significant modification to the way growers manage their farming operation. Growers would be faced with some additional costs. The typical installation cost of a tailwater return system is $200 per acre and the operation and maintenance (O&M) cost is $10 per acre. The average annual cost is estimated to be $30 per acre for an on-farm system.

For a basin-wide system, the canal upstream of station 540+00 (mile 10.2 or 2 miles north of the dam) would need to be widened to 46 feet to the main canal. This would require the excavation of 459,500 cubic yards of material. The pumping plant would consist of four groups of three 100 cfs propeller or axial flow 300 horsepower pumps (Model 52 pmr 505 RPM @ $90,000 for the pump and $39,000 for each motor). The cost of the three pumphouses was estimated at $50,000 each. The Bohannon Dam plant would be optional and was not used for the cost estimate. There would be no requirement for storage reservoirs because the ditch could store 431 acre-feet of water. An additional 510 acre-feet would be stored below elevation 14 from Bohannon Dam to the Karnak pumping plant. The cost of the pumps was obtained from Byron Jacobs Company in Chico (916-342-3551). The estimated excavation and disposal cost of the material is $2 per cubic yard. The design life of the system is 25 years. Maintenance of the plant is restricted to embankments and pumps because the drainage system costs are presently taken care of by Reclamation District 1500. Installation costs would be approximately $2,500,000. The estimated maintenance cost is estimated to be five percent of installation costs. Power costs would be approximately $7 per acre-foot.

If the installation and maintenance costs are distributed over the service area of 62,500 acres and amortized for 25 years at eight percent interest, the annual per acre cost of installation and maintenance is $5.50 per acre. The power cost for lifting the water back to the main canal is about four times the cost for lifting the water from the Sacramento River.

E. The efficiency of water use or delivery would not significantly change.

F. There were 105,000 acre-feet discharged to the Sacramento River during the 1993 irrigation season. The year 1993 was a high water year for the river and contractors received 100 percent of their allocations. The Company did not have a recapture program in 1993 though some of the landowners recaptured water on their own. For evaluation purposes, assuming that 50 percent of this water could be available for reuse, 52,500 acre-feet could be incorporated into the reuse program during the irrigation season only. This assumption is based on the amount of water lost in the irrigation ditches, the volume of deep percolation losses from rice fields, and the estimate of lateral-flow water from the river during the irrigation season. These three sources of water are known to be of good quality. The quality is degraded by salt concentration from evaporation, remnant salts in the soil profile, and connate water.

In a short water year, such as 1994, where allocations are cut by 25 percent, the District would tend to reuse the same amount of water available as in 1994, or 15,000 to 16,000 acre-feet per year, with an additional 15,000 to 16,000 acre-feet being reused by individual growers. The amount available for reuse will vary widely from year to year and will depend on the quality and quantity of the drain water.

This system would decrease flows in the Sacramento River below Karnak by 270 cfs for a water year similar to 1993. This would mean less water available for recapture and reuse. The Company could also have reduced the diversions from the Sacramento River to 108,000 acre-feet if all possible reuse had taken place.

G. There is some potential of increasing the concentration of natural salts in the basin due to the connate ground water source and less freshwater for leaching. The reduced amount of drain water that would continue to be returned to the Sacramento River may involve higher concentrations of salts. Less water would be ordered and/or discharged to the river, reducing the amount of water in the river downstream.

Growers would need to closely monitor the quality of the water they are applying. This may result in a level of uneasiness in the growers until this higher level of water reuse is proven in the field to not significantly reduce crop productivity.

To maintain high water quality all reused water should follow the standard of a maximum EC of 750 micromhos/cm.

Analysis of This Measure:

Between the Company's reuse system and private individuals reusing water, an estimated total of 30,000 to 32,000 acre-feet was reused in 1994. There is the potential for more water to be reused but currently as much water as the system allows is being used. To increase the amount of reused water would require costs for the installation of an upgraded system. It is also only an assumption that the water will be of high enough quality to be reused. Sometimes there is the need to mix fresh water with the water available for reuse to maintain an EC of 750 micromhos/cm.

13. Distribution System Lining: Line distribution ditches and canals or convert to pipe.

Conversion to Lined Ditch

Present Conditions:

Two ditch lining options were identified and evaluated (see Figure 8). One option considers lining approximately 34.4 miles of the 167 miles of the unlined irrigation water distribution ditches in the service area while the second option considers the lining of 5.0 miles of ditch. The ditches that were evaluated to be lined with concrete are the segments for which the soils allow excessive amounts of irrigation water to seep into the ground water. In 1993, the Company diverted approximately 185,000 acre-feet of water from the Sacramento River using three pumping plants. Approximately 42,000 acre-feet per year of this water was not used for irrigation due to evaporation, seepage in the drainage system, and return flows to the Sacramento River. The lining of the ditches would prevent some of this water seepage.

There are 167 miles of distribution ditches in the service area. These ditches vary in depth and cross section. The loss associated with an irrigation ditch is a function of the soil, the wetted perimeter, and the height of the water surface over the mean ground water table. The Soil Survey was used to obtain the unified classification for the soil; the Civil Engineer's Standard Desk Reference was used to estimate the k factor, or coefficient of permeability, associated with the soil classification; and the Company's ditch map and soils maps were overlaid to obtain reach lengths of each soil type. Typical ditch dimensions were obtained from an interview with the Company Field Manager. The average head was obtained by matching the estimated ditch loss for the study area during the 1993 irrigation season to the obtained ditch characteristics.

Concrete lining was assumed at a cost of $150 per cubic yard. The k factor for concrete is about twice the k for a CH soil (0.0000001 versus 0.00000005). This means that some soils would not benefit from the installation of a lining material. These soils were not considered for lining.

Factors Considered:

(A) applicability to the district, (B) technical feasibility, (D) financial feasibility for the district, (E) improved efficiency of water delivery and use, (F) quantity of water to be saved, and (G) environmental impacts.

A. This measure is applicable to the area.

B. This measure is technically feasible for only some of the ditches in the service area. Only the ditch segments where the soil allows for large amounts of water seepage were considered for lining.

Maintenance of the lined segments would require replacement every 10 years.

D. Lining 34.4 miles would cost $12.8 million, while lining 5.0 miles would cost $2.3 million. The average annual costs, based on 10 years, would be $1,852,000 for 34.4 miles of lining and $337,000 for 5.0 miles of lining. The average annual cost per acre-foot of water prevented from seeping is $50 for 34.4 miles of lining. This is over five times the current per acre-foot cost that the water user pays the Company. For 5.0 miles of lining, the average annual cost per acre-foot of water prevented from seeping is $17. This is about twice the current per acre-foot cost that the water user pays the Company.

The Company would need to cover the costs of installation and maintenance through landowner fees. Currently the cost to the landowner is $14.50 per acre per year. For 34.4 miles of lining, the added cost would raise the annual fee for the assessed gross acres of 50,083 by $37 per acre per year. For 5.0 miles of lining the added cost would be about $7 per acre per year.

The Company could reduce some pumping costs because less water would need to be diverted from the Sacramento River. This could amount to $65,000, or $1.30 per gross acre, saved for 34.3 miles of lining and $21,200, or $0.42 per gross acre, for 5.0 miles of lining with an assumed pumping cost of $1.75 per acre-foot.

Landowners would not be required to modify their current farming operation.

E. There would be no significant improved efficiency of on-farm water use or delivery. The Company would have increased efficiency of water delivery.

F. The amount of water lost to seepage would be reduced by 37,100 acre-feet per year for 34.4 miles of lining and 19,700 acre-feet per year for 5.0 miles of lining.

G. Lining would eliminate the same number of miles of water edge and open water habitat. There is some potential of increasing the concentration of natural salts in the remaining drainage water returned to the Sacramento River due to the connate ground water source.

Analysis of This Measure:

The results of the analysis shows that 37,100 acre-feet, or 97 percent of the estimated seepage losses from the canal system is lost to the drainage system and Sacramento River from 34.4 miles, or 21 percent, of the ditch system. Also, 19,700 acre-feet, or 52 percent, of the water is lost from 3 percent of the ditch system. If a project was selected to line the latter areas, or approximately 5.0 miles, the cost of installation would be $2,283,000 and the cost of the saved water would be slightly more than $17 per acre-foot. The cost of lining the 34.4 miles would be $12,800,000 for a cost of about $51 per acre-foot.

(A) applicability to the district, (B) technical feasibility, (D) financial feasibility for the district, (E) improved efficiency of water delivery and use, (F) quantity of water to be saved, and (G) environmental impacts.

Conversion to Pipeline

The Present Conditions are the same as the conversion to lined ditch option.

Factors Considered:

A. This measure is applicable to the area.

B. This measure is technically feasible for only some of the ditches in the service area. Only the ditch segments where the soil allows for large amounts of water seepage were considered for piping.

Maintenance of the piped system would require replacement every 25 years.

D. Estimated pipeline maintenance costs are $1,500 per pipe mile. The estimated cost of 34 miles of a pipeline system is $75 million. The minimum average annual cost would be $9.5 million. The estimated cost per acre-foot would be $225 and could be much higher.

The Company would need to cover the installation and maintenance costs of the pipe work through landowner fees. Currently the annual per acre fee is $14.50. This added cost would raise the annual fee for the assessed gross acres of 50,083 by about $190 per acre.

The Company could reduce pumping costs because less water would need to be diverted from the Sacramento River. If you assume a pumping cost of $1.75 per acre foot, the savings is $73,500 or $1.47 per gross acre in the area (50,083 acres).

E. The Company may be able to manage the water delivery more easily and more efficiently. The landowners would most likely be able to order more precisely the amount of water needed and not be required to modify their current farming operations.

F. The drain water reuse that currently takes place in the basin may no longer be possible. The drain water reuse would need to be replaced by additional water purchases by the growers. Approximately 42,000 acre-feet of water would be saved with this measure.

G. Piping the ditches would eliminate 613 acres of open water habitat and 840 acres of water edge habitat.

There is the potential of increasing the concentration of natural salts in the basin due to the connate ground water source. The drain water that remains to be returned to the Sacramento River may involve higher concentrations of salts.

Analysis of This Measure:

Converting from ditch systems to pipeline systems has been offered as an economical water conservation option offering advantages for on-demand water delivery and reduced seepage and evaporation losses. Pipeline installation would not be less expensive than channel lining but the assumption is made that it could be done for 1.5 times the cost.

One advantage of a pipeline system is the on-demand feature it could provide. However, the Company would still need to order water three days in advance for expected customer needs. The customer could then "turn off" the water at the turnout. This would result in spillage back to the river at the pumping plant and no net savings. If spillage at the river is desired, the canal system could be modified by the addition of automatic gates which could respond to changes in downstream demand. Presently the potential amount of spillage remains unquantified.

Water seeping from the ditches in this area is not actually "lost". The ground water is so shallow that this water generally seeps into the drain ditches and is discharged into the Sacramento River.

It should be pointed out that the water lost to the drainage ditch system and Sacramento River would need to be replaced for the downstream users. If the Company reduced its order from Shasta Dam because it became more internally efficient, the downstream water users would not have the "excess" water the district had been releasing to the system. The portion of the Company water users which supplement their water purchases by pumping from the drainage system would also need to purchase water to make up for the reduced water in the drainage system.

14. Construction or Lining of Regulatory Reservoirs Construct or line regulating reservoirs.

Present Conditions:

Currently, the Company's control of water delivery is limited. With the installation of an in-basin water storage facility, deliveries could be more efficiently provided. Additional channel controls would also help in the regulation of water deliveries.

There is no Company regulating reservoir; however, the main canals have significant storage capacity and function as regulating reservoirs.

Factors Considered:

A. This measure is applicable to the area.

B. This measure is technically feasible. The Company would need to gain the support of the landowners and provide appropriate incentives to implement a significant modification to the way growers manage their farming operations.

D. Growers would be required to pay for the infrastructure and operation costs in terms of higher assessments. With an estimated 50,083 acres in the area, the per acre cost would go up from the current $14.50 per acre. The Company could reduce pumping costs because less water would need to be diverted from the Sacramento River. If you assume a pumping cost of $1.75 per acre foot, the savings is $2.62 per gross acre.

The Company would be faced with the purchase cost of land, cost associated with construction of the water-holding basin and associated infrastructure, and annual operation and maintenance expense.

Some agricultural land would need to be taken out of production for the water holding basin.

E. This measure would increase the flexibility of water delivery.

F. Between 3,600 to 76,000 acre-feet of water could be saved based on the types of improvements made. This range is dependent on the BOR allotment received, the salinity of the stored water, and the ability of the District to find the facilities to build a reservoir.

G. Some additional wetland habitat could be created with the development of a water-holding basin.

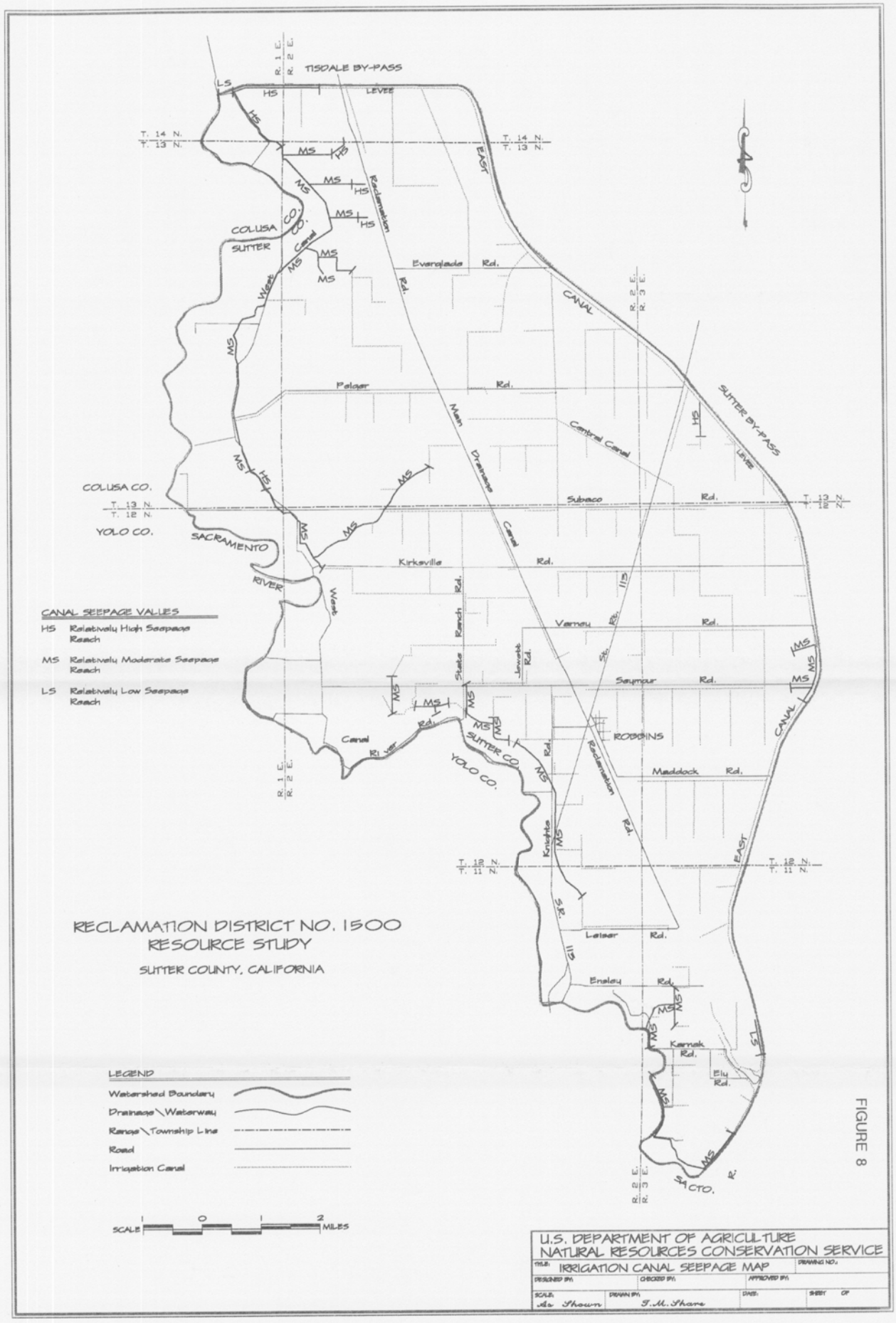

RECLAMATION DISTRICT NO. 1500
RESOURCE STUDY
SUTTER COUNTY, CALIFORNIA
CANAL SEEPAGE VALUES
HS Relatively High Seepage Reach
MS Relatively Moderate Seepage Reach
LS Relatively Low Seepage Reach
LEGEND
Watershed Boundary
Drainage \ Waterway
Range \ Township Line
Road
Irrigation Canal
SCALE 1 0 1 2 MILES
TISDALE BY-PASS
LEVEE
SUTTER BY-PASS
EAST CANAL
West Canal
Main Drainage Canal
Reclamation Rd.
Central Canal
COLUSA CO.
SUTTER CO.
YOLO CO.
SACRAMENTO RIVER
SACTO. R.
ROBBINS
T. 14 N.
T. 13 N.
T. 12 N.
T. 11 N.
R. 1 E.
R. 2 E.
R. 3 E.
Everglade Rd.
Pelger Rd.
Subaco Rd.
Kirksville Rd.
Verney Rd.
Seymour Rd.
Maddock Rd.
Leiser Rd.
Ensley Rd.
Karnak Rd.
Ely Rd.
Stake Ranch Rd.
Jewett Rd.
Knights Rd.
S.R. 113
U.S. DEPARTMENT OF AGRICULTURE
NATURAL RESOURCES CONSERVATION SERVICE
TITLE: IRRIGATION CANAL SEEPAGE MAP
DRAWING NO.:
DESIGNED BY:
CHECKED BY:
APPROVED BY:
SCALE: As Shown
DRAWN BY: J. M. Share
DATE:
SHEET OF

FIGURE 8

(A) applicability to the district, (B) technical feasibility, (D) financial feasibility for the district, (E) improved efficiency of water delivery and use, (F) quantity of water to be saved, and (G) environmental impacts.

Analysis of This Measure:

Installation of a regulating reservoir without changing the canal control systems and installation of a water return system would not serve any function without the implementation of a combination of measures. The main canals currently serve as storage.

Section Summary

Table 7 summarizes the issues addressed in this section.

TABLE 7: SUMMARY OF ISSUES

Potential Water Conservation Treatments	Factors Considered When Additional Water Conservation Measures Were Analyzed							
	(a) Applicable to District?	(b) Technically Feasible	(c) Legal Under State/Fed. Law	(d) Cost Considerations		(e) Improved Efficiency Water Use/ Delivery	(f) Amount of Water Saved (acre feet) [2]	(g) Environmental Impacts (+,-)
				Company	Land Owner			
1. Incentive Pricing	Yes	Yes	[1]	Example Range: Increased Cost = $90,000/yr to Reduced Cost = $210,000/yr. (Depends on program management costs and water use in response to pricing change.) [3]	Example Range: Reduced Cost = $90,000/yr to Increased Cost = $210,000/yr. (Depends on program management costs and water use in response to pricing change.) [3]	Yes	3,600 - 10,200	Wetland loss.
2. On-farm Program	Yes	Yes	[1]	Unknown	$5 to $61 acre/yr.	Yes	240 - 3,600	Wetland loss. Salt Build-up.
3. Drought Plan (Already Implemented)	Yes	Yes	[1]	Unknown	Unknown	Yes	Currently achieving under present management.	Salt Build-up Less Volume in River.
4. Water Transfers	Yes	Yes	[1]	Unknown	Unknown	No	- 0 -	Wetland increase.
5. Conjunctive Use	No	No	[1]	N/A	N/A	N/A	N/A	N/A
6. Land Management	Yes	Yes	[1]	Limited	Some landowners may lose some income associated with farm land that is no longer irrigated.	No	Yes	Habitat loss. Salt Build-up.
7. District Operational Practice Changes	Yes	Uncertain	[1]	Management and equipment costs.	N/A	Yes	- 0 - Unless combined with regulating reservoir.	Habitat loss. Salt Build-up.
8. Irrigation System Scheduling	Yes	Yes	[1]	+	N/A	Yes	3,600	Habitat loss. Salt Build-up.
9. On-farm Irrigation Scheduling	Yes	Yes	[1]	+/-	Additional Management Costs	Yes	3,600	Habitat loss. Salt Build-up.
10. Pump Efficiency Evaluations	Yes	Yes	[1]	Some energy cost savings.	N/A	Yes	- 0 -	Negligible.
11. Distribution Control	Yes	No	[1]	+ Equipment and personnel cost.	N/A	Yes	10,200 When combined with regulating reservoir.	Negligible.
12. Reuse Systems	Yes	Yes	[1]	$360,000 +/yr and pumping costs	$30/ acre/yr	Yes	Up to 52,000 (Currently up to 32,000 ac-ft are being reused.)	Significant salt build-up. Reduced volume to Sacramento River. Habitat Loss
13. System Lining	Yes	Yes	[1]	A: 34 miles - $1.8 million/yr B: 5 miles - $337,000/yr C: 162 miles of pipeline - $9.5 million/yr	A: $37 /acre/yr B: $7 /acre/yr C: $190 /acre/yr (Cost passed on from company.)	Yes	20,000 to 40,000	Habitat loss. Increase salinity.
14. Regulatory Reservoir	Yes	Yes	[1]	+ $250,000 to $1 million	Company costs would be passed on to landowner.	Yes	3,600 to 52,000 (0 unless included with other systems modifications.)	Increased habitat. Salt Build-up

1 - Legal issues were not explored in this study.

2 - "Saved" water values indicate the net change in the amount of Sacramento River water circulated through the Reclamation District Irrigation System.

3 - Example water cost range assuming a tier price of $30/acre-ft. for excess irrigation water application.

SECTION V

OPPORTUNITIES AND CONSIDERATIONS

The three objectives for this study identified at the beginning of this document were:

1. Present a resource inventory and assessment of the present use of all the area's water, soil, and environmental resources.

2. Discuss the enhancement opportunities of these resources.

3. Predict the potential impacts of significant changes in resource uses or allocations.

Addressing these objectives in the same order:

1. Present a resource inventory and assessment of the present use of all the area's water, soil, and environmental resources.

A resource inventory is presented in Sections II and III. Instead of presenting a separate assessment of these resources, the information developed in the inventory was used to assess the Bureau of Reclamation water conservation measures recommended for consideration in the publication "Draft Guidelines and Criteria for Water Conservation Plans". The results of these assessments demonstrate that, while there is some room for slight improvements, the local growers, Sutter Mutual Water Company, and Reclamation District 1500 are efficiently utilizing the water resources available to them.

One example of this is the relatively small amount of water that could be saved by the implementation of the suggested water conservation measures. Up to 3,600 acre-feet, or two percent of the District's total water diverted in 1993, could be saved with the implementation of tiered pricing, on-farm program incentives, or changes in irrigation or delivery scheduling. Many of the measures, in assuming the acre-feet of water that can be saved, are very dependent on the BOR allotment received and the quality of the water found in the drains. It is impossible to predict if these water amounts can be relied on under actual circumstances.

It is also a fact that due to the high concentrations of salts in the subsurface water in this area, salinity levels in both the surface water and soil may increase to very high levels. The fact that many crops are grown productively implies that the growers are handling their irrigation and drainage well and salinity levels are being kept within the limits needed for agricultural uses. The high salinity of the connate water affects the drain water, leaching requirement, and habitat values, making for very restrictive solutions.

2. Discuss the enhancement opportunities of these resources.

As mentioned before, while the local growers are doing a good job of managing their resources, there are some opportunities for enhancement.

<u>Fish and Wildlife Enhancement Opportunities</u>

Wildlife, in general, needs four essential things to be a part of any environment. Two of these are obvious: food and water. The other two things are less obvious and more difficult to assess: suitable

Wildlife, in general, needs four essential things to be a part of any environment. Two of these are obvious: food and water. The other two things are less obvious and more difficult to assess: suitable cover and successful reproduction needs. Together these four elements will determine the suitability of a particular habitat to attract and maintain a particular animal and the quality of these elements will determine the number of individuals that a habitat will support, or the carrying capacity. While this is not the complete picture, it is useful to keep these four elements in mind because, if one of them is limited or missing, the wildlife populations will definitely be affected. Migratory animals, for example, may not need each element to be in a specific habitat all the time, but animals that spend their lives in one area will need each element sometime during their life cycle.

Present agricultural practices and the water distribution system in the study area are beneficial to many fish and wildlife species. Cropping patterns, ditch maintenance, and water management provide abundant food and water for wildlife. Less frequent clearing of ditches, increasing use of no-till agriculture, and tree plantings are improving the amount of permanent cover available for wildlife. Opportunities to improve overall habitat diversity and wildlife population levels still exist.

Some general opportunities exist to enhance present management to favor improved fish and wildlife populations. Both the availability of waterfowl feeding areas and reproduction success can be enhanced by continuing the present trend towards early flooding of rice fields and harvesting grains after waterfowl nesting is completed, usually in June. Combining this with more permanent tailwater holding ponds where young ducks can escape predation and grain harvest activities will improve their survival after they leave the nest.

The SMWC's Water Management Plan identifies the possible installation of fish screens on pipes which remove water from the Sacramento River as an opportunity. It is predicted that future pumping from the river will be controlled at certain times of the year and/or fish exclusion devices at the pump inlet will be required. The Company has become well informed on this issue and is ascertaining the best design and related costs of controlling fish at the pump inlet (SMWC, 1992).

The following are specific recommendations for wildlife management in southern Sutter County.

Waterfowl

One of the best ways to attract migratory waterfowl is to provide food and water. This means the landowners should not drain ponds and marshes or let them dry out during the season they want to attract waterfowl. Food can be provided by flooding harvested crops such as rice, corn, millet, wheat, and barley in the fall just prior to the arrival of the first flights. This practice may be limited by flood control and drainage requirements and responsibilities during the winter. Low-lying areas can be planted and allowed to flood naturally when it rains, or some extra rows can be planted near wetlands and left for wildlife use.

Ducks, like mallards and wood ducks, do stay in the area year round because cover is provided and they can reproduce. Mallards nest in dry areas covered with grasses about 18 inches high that are relatively free from disturbance by equipment or predators. Wheat fields planted in the fall benefit mallards. The harvest of grain in June allows the broods to move out of the fields. The mallards move their broods to ponds, ditches, and streams to feed on water plants, insects, and other invertebrates, so these brooding areas should be nearby for optimum success.

Wood ducks nest in tree cavities. Establishing nesting boxes near rice fields or wet areas will favor them, especially if nesting boxes are provided on young trees until natural cavities form. Similar to mallards, nearby brooding water is important. Establishing windbreaks or shelterbelts anywhere near the rice fields or bypass areas will attract and maintain wood ducks in addition to the general environmental benefits.

Upland Game

The term upland game includes wildlife like quail, pheasants, and cottontail rabbits. They are present year round so food and cover are especially important. Water would only rarely be a limiting factor in this area. Cover is probably the most limiting factor at present. Cover provides protection from extremes of heat and cold, allows successful reproduction, and provides protection from predators. Fence rows, ditch banks, equipment storage areas, power line or other rights-of-way, odd corners, or wet spots can be developed or maintained to provide good cover. Windbreaks and shelterbelts can be designed to provide both food and cover. The elimination of burning or mowing, or the delay until after nesting is complete, will improve habitat for upland game. Leaving patchy crop areas unharvested will provide both food and cover. So will planting fence rows, ditch banks, and row or field edges to native grasses with clovers. When properly done, this kind of planting will usually out-compete weeds and reduce the need to burn or spray. Orchard prunings can be piled and left to provide cover. Marginal lands can often be managed for wildlife, and the hunting rights sold for more than the crops would be worth.

Regional Levee and Berm Management

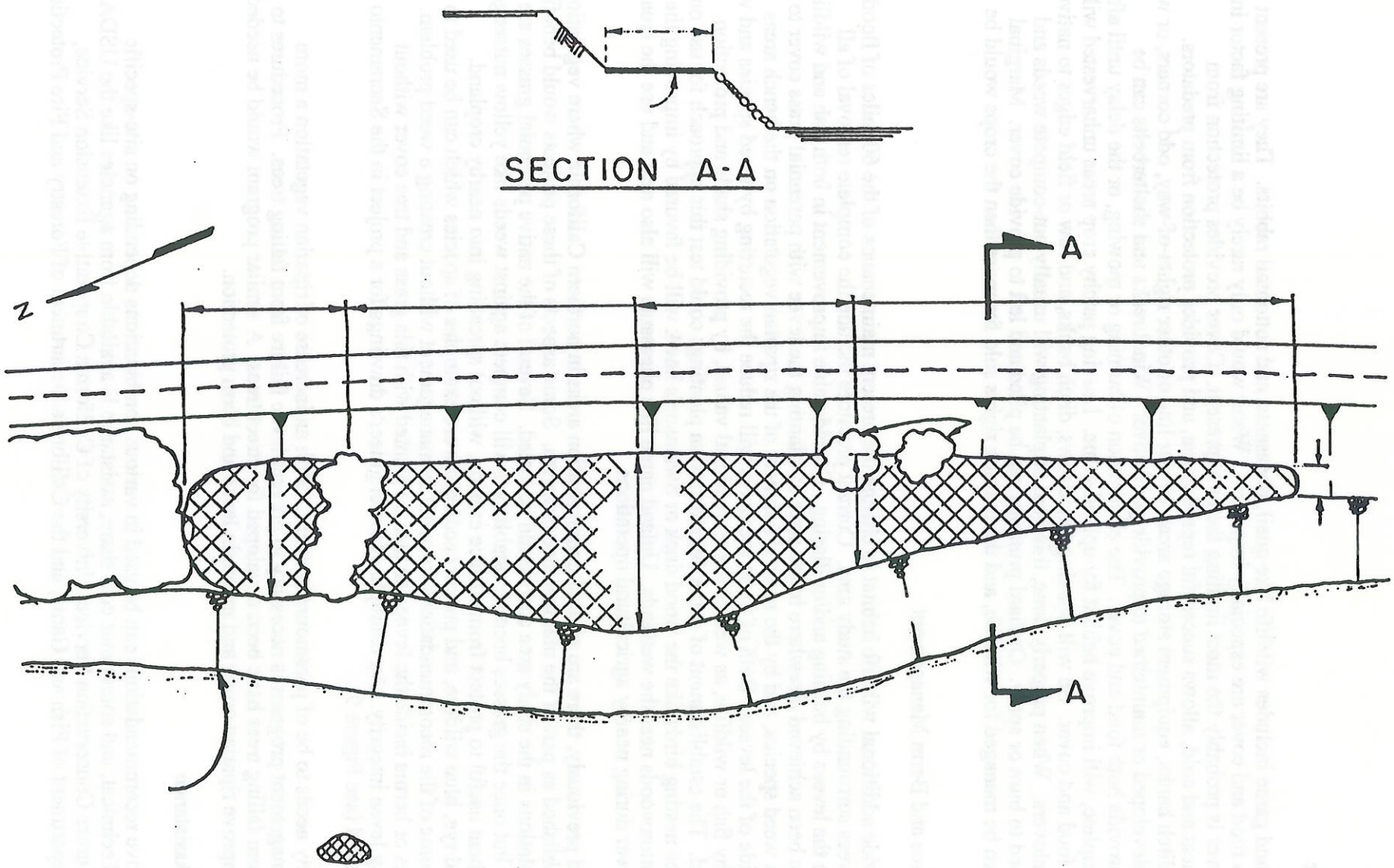
It would provide additional wildlife habitat to change the present maintenance of the 60 miles of flood protection levees surrounding the study area. Current practices include the complete removal of all vegetation on the levees by burning and/or discing. Considerable improvement in both fish and wildlife numbers have been achieved elsewhere in the state by planting the levee with perennial grass cover to compete with weed species, and by the re-establishment of the riparian vegetation on the bench areas along the inside of the levees. Both of these measures will reduce the recurring by weed species and will enhance use by fish or wildlife, as well as the recreational values, by providing shade and protection from the wind. The establishment of some demonstration plantings could test this approach for use on this area. Tree nesting birds like the wood duck or Swainson's hawk will be favored by improving the number of cottonwoods near the wetlands. Upland game like pheasants will also nest and use the areas for escape cover during nearby agricultural operations.

As mentioned previously, there are several demonstration areas in northern California where vegetation has been established as part of the maintenance program. Some aspects of these projects would benefit wildlife populations in the study area and should be tested. Several of the native perennial grasses are non-invasive but once the grasses become established will compete against weeds like yellow nutsedge. This makes them useful to protect from surface erosion, without spreading into nearby cropland. Creeping wild rye, blue wildrye, and purple needlegrass are examples of species which can be used to accomplish some of the recommendations for wildlife management without creating a weed problem. Some benches or berms inside the levee can also be planted with this grass and tree cover without compromising levee integrity. An example of the engineer's drawings for a project in the Sacramento River is enclosed (see Figure 9).

Levee integrity needs to be of paramount concern. With an increase of riparian vegetation a more proactive management program is necessary to prevent levee failure from falling trees. Procedures to assess risk from falling trees have been developed for street trees. A similar program would be needed in order to improve riparian cover and maintain levee and berm protection.

Landowner Assistance

All of the above recommendations can be used in various combinations depending on site-specific conditions. Technical, and sometimes cost share, assistance is available from agencies like the USDA Natural Resources Conservation Service, University of California Cooperative Extension Service, California Department of Fish and Game, and the California Department of Forestry and Fire Protection.



SACRAMENTO RIVER RM 19.2 LEFT

NOT TO SCALE

FIGURE 9

Opportunities For Water Conservation

There are some limited opportunities for water conservation on 12,000 acres in the study area to be improved. The amount of total water saved would not exceed 3,600 acre-feet for these acres. Some preliminary suggestions coming from AGWATER runs include eliminating one or two unnecessary early irrigations, switching to sprinklers for early irrigations, and shortening sets. Some of the BOR measures which would accomplish this include on-farm incentive programs, incentive pricing, and on-farm irrigation scheduling.

Lining or piping the distribution ditches could save from 19,700 to 42,000 acre-feet of water per year. This measure would prevent the seepage from these ditches along the segments where the soil type allows excessive amounts of seepage. The cost of these options is significant, however. Additionally, the cost to wildlife habitat is significant.

It appears that the most cost effective water conservation method for Reclamation District 1500 to implement is grower and community education for on-farm water management.

Opportunities For Education/Information Programs

A public education and information campaign needs to be a part of any area-based program. There are many ways to educate and inform the public.

Information on water conservation can be handed out or mailed along with local water bills. Goal-oriented information should be provided so everyone knows what the needs are for a successful program.

Since landowners most often seek information and advice from neighboring landowners, recruiting growers who have implemented conservation practices or have effectively conserved water to assist in tours and field demonstrations could help provide landowners with good information.

3. Predict the potential impacts of significant changes in resource uses or allocations.

The third objective was to predict the potential impacts of significant changes in resource uses or allocations. It was determined through interviews that growers are not planning any significant changes in resources uses or allocations in the foreseeable future unless irrigation water costs change significantly. The growers were able to cope during the recent water cutbacks and had no need to change cropping patterns. There are no plans to dramatically change land use in the study area. There is a stable and healthy farming economy with a stable crop pattern. Processing tomatoes and rice will most likely continue to be the crop mainstays in the area.

If water prices ever increased to make the cost of growing rice prohibitive, a 50 percent reduction in rice acreage might result and would possibly create an overall reduction in water orders. Assume that the rice acreage is converted to a similar crop mix of locally grown crops with a similar water use pattern. Cropland may increase by 9,000 acres to a total of 51,000 acres. The water diverted for rice would decrease from 107,250 acre-feet to 53,625 acre-feet. If the 9,000 acres were irrigated at an 80 percent efficiency, the irrigation water order for these crops would be 20,625 acre-feet. This is a net reduction in ordered water of 33,000 acre-feet. The water which would reach Karnak from the 9,000 acres of cropland would be 4,125 acre-feet.

The bean, melon, and tomato crops use an estimated 10,300 acre-feet of water from the ground water table. If it is assumed that the ground water table would remain the same, the net effect would be a decrease in the discharge at Karnak or an increase in connate and lateral flow. There would also be an

unquantified decrease in the better quality subsurface water available to the surrounding cropland. This would either require an unknown increase in irrigation water for leaching salts or a potential increase in the risk of soil salinization. The impacted landowners include all of the melon growers, and a significant number of bean and tomato growers.

If the water needs of the crops can be met from the ground water table and there is no salt increase in connate and lateral flows, then the net effect would be an increase in the salt concentration of the discharge water of Karnak. If the rim flows increase, there would be no net increase because the lateral flows come from the river system. However, if connate flows increase, then the salt concentration could increase significantly.

Recommendation For Future Study

Before considering ground water as a water supply in the study area, three-dimensional isoconcentration maps need to be developed for the underlying ground water and transmissivities within the ground water body, with all connecting water bodies determined. The U.S. Geological Survey (USGS) should be consulted to develop an investigation plan.

Once this basic data set is available, a well management plan and accompanying model can be developed to prevent contamination of the existing freshwater mass, and well interference and mining of the Sacramento River. The USGS should be consulted to develop a well management plan and develop a ground water model for the project area.

An attempt was made in this report to account for salt transfers in the basin. This attempt failed to give an accounting of inflows versus outflows because it was only possible to deal with one point in time as opposed to a dynamic state. A previous attempt by Tanji (Tanji, 1975) was also inadequate. In addition to the preceding recommendations to enhance the understanding of water transfers, salt fluxes across water boundaries need to be quantified. These studies need to encompass the spatial and temporal variances peculiar to this basin.

An increase in salinity would impact the habitat system in the area and a reduction of rice acreage would reduce the open water areas for ducks.

Drastic cutbacks in water availability would most likely lead to an increase in soil salinity and have an adverse impact on wildlife habitats and populations. Water allocations below the current levels would change cropping patterns and create a loss of economic stability in the region.

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With special thanks to the assistance provided by the board members and employees of the Sutter Mutual Water Company and Reclamation District 1500 and Max Sakato, General Manager.

APPENDIX A

WILDLIFE HABITAT RELATIONSHIP DATABASE PRINTOUT

CALIFORNIA WILDLIFE HABITAT RELATIONSHIPS SYSTEM
Supported by the
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SPECIES SUMMARY LIST

SELECTION CRITERIA:

Locations:
SUTTER COUNTY

Habitats:

1 VALLEY OAK WOODLAND	SEEDLING TREE			(1)
2 VALLEY OAK WOODLAND	SAPLING TREE	SPARSE	10-24%	(2S)
3 VALLEY OAK WOODLAND	SAPLING TREE	OPEN	25-39%	(2P)
4 VALLEY OAK WOODLAND	SAPLING TREE	MODRTE	40-59%	(2M)
5 VALLEY OAK WOODLAND	SAPLING TREE	DENSE	60-100%	(2D)
6 VALLEY OAK WOODLAND	POLE TREE	SPARSE	10-24%	(3S)
7 VALLEY OAK WOODLAND	POLE TREE	OPEN	25-39%	(3P)
8 VALLEY OAK WOODLAND	POLE TREE	MODRTE	40-59%	(3M)
9 VALLEY OAK WOODLAND	POLE TREE	DENSE	60-100%	(3D)
10 VALLEY OAK WOODLAND	SMALL TREE	SPARSE	10-24%	(4S)
11 VALLEY OAK WOODLAND	SMALL TREE	OPEN	25-39%	(4P)
12 VALLEY OAK WOODLAND	SMALL TREE	MODRTE	40-59%	(4M)
13 VALLEY OAK WOODLAND	SMALL TREE	DENSE	60-100%	(4D)
14 VALLEY OAK WOODLAND	MED/LARGE TREE	SPARSE	10-24%	(5S)
15 VALLEY OAK WOODLAND	MED/LARGE TREE	OPEN	25-39%	(5P)
16 VALLEY OAK WOODLAND	MED/LARGE TREE	MODRTE	40-59%	(5M)
17 VALLEY OAK WOODLAND	MED/LARGE TREE	DENSE	60-100%	(5D)
18 VALLEY-FOOTHILL RIPARIAN	SEEDLING TREE			(1)
19 VALLEY-FOOTHILL RIPARIAN	SAPLING TREE	SPARSE	10-24%	(2S)
20 VALLEY-FOOTHILL RIPARIAN	SAPLING TREE	OPEN	25-39%	(2P)
21 VALLEY-FOOTHILL RIPARIAN	SAPLING TREE	MODRTE	40-59%	(2M)
22 VALLEY-FOOTHILL RIPARIAN	SAPLING TREE	DENSE	60-100%	(2D)
23 VALLEY-FOOTHILL RIPARIAN	POLE TREE	SPARSE	10-24%	(3S)
24 VALLEY-FOOTHILL RIPARIAN	POLE TREE	OPEN	25-39%	(3P)
25 VALLEY-FOOTHILL RIPARIAN	POLE TREE	MODRTE	40-59%	(3M)
26 VALLEY-FOOTHILL RIPARIAN	POLE TREE	DENSE	60-100%	(3D)
27 VALLEY-FOOTHILL RIPARIAN	SMALL TREE	SPARSE	10-24%	(4S)
28 VALLEY-FOOTHILL RIPARIAN	SMALL TREE	OPEN	25-39%	(4P)
29 VALLEY-FOOTHILL RIPARIAN	SMALL TREE	MODRTE	40-59%	(4M)
30 VALLEY-FOOTHILL RIPARIAN	SMALL TREE	DENSE	60-100%	(4D)
31 VALLEY-FOOTHILL RIPARIAN	MED/LARGE TREE	SPARSE	10-24%	(5S)
32 VALLEY-FOOTHILL RIPARIAN	MED/LARGE TREE	OPEN	25-39%	(5P)
33 VALLEY-FOOTHILL RIPARIAN	MED/LARGE TREE	MODRTE	40-59%	(5M)
34 VALLEY-FOOTHILL RIPARIAN	MED/LARGE TREE	DENSE	60-100%	(5D)
35 ANNUAL GRASS	SHORT HERB	SPARSE	2-09%	(1S)
36 ANNUAL GRASS	SHORT HERB	OPEN	10-39%	(1P)

SPECIES SUMMARY LIST

Habitats: (Cont)

37 ANNUAL GRASS	SHORT HERB	MODRTE	40-59%	(1M)
38 ANNUAL GRASS	SHORT HERB	DENSE	60-100%	(1D)
39 ANNUAL GRASS	TALL HERB	SPARSE	2-09%	(2S)
40 ANNUAL GRASS	TALL HERB	OPEN	10-39%	(2P)
41 ANNUAL GRASS	TALL HERB	MODRTE	40-59%	(2M)
42 ANNUAL GRASS	TALL HERB	DENSE	60-100%	(2D)
43 PERENNIAL GRASS	SHORT HERB	SPARSE	2-09%	(1S)
44 PERENNIAL GRASS	SHORT HERB	OPEN	10-39%	(1P)
45 PERENNIAL GRASS	SHORT HERB	MODRTE	40-59%	(1M)
46 PERENNIAL GRASS	SHORT HERB	DENSE	60-100%	(1D)
47 PERENNIAL GRASS	TALL HERB	SPARSE	2-09%	(2S)
48 PERENNIAL GRASS	TALL HERB	OPEN	10-39%	(2P)
49 PERENNIAL GRASS	TALL HERB	MODRTE	40-59%	(2M)
50 PERENNIAL GRASS	TALL HERB	DENSE	60-100%	(2D)
51 FRESH EMERGENT WETLAND	SHORT HERB	SPARSE	2-09%	(1S)
52 FRESH EMERGENT WETLAND	SHORT HERB	OPEN	10-39%	(1P)
53 FRESH EMERGENT WETLAND	SHORT HERB	MODRTE	40-59%	(1M)
54 FRESH EMERGENT WETLAND	SHORT HERB	DENSE	60-100%	(1D)
55 FRESH EMERGENT WETLAND	TALL HERB	SPARSE	2-09%	(2S)
56 FRESH EMERGENT WETLAND	TALL HERB	OPEN	10-39%	(2P)
57 FRESH EMERGENT WETLAND	TALL HERB	MODRTE	40-59%	(2M)
58 FRESH EMERGENT WETLAND	TALL HERB	DENSE	60-100%	(2D)
59 PASTURE				(1)
60 BARREN				(1)
61 DECIDUOUS ORCHARD	SEED/SAPLING TREE			(1)
62 DECIDUOUS ORCHARD	YOUNG TREE			(2)
63 DECIDUOUS ORCHARD	MATURE TREE			(3)
64 IRRIGATED GRAIN CROPS	SEEDLING TREE			(1)
65 DRYLAND GRAIN CROPS	SEEDLING TREE			(1)
66 IRRIGATED ROW AND FIELD CROPS	SEEDLING TREE			(1)
67 RIVERINE	OPEN WATER			(1)
68 RIVERINE	SUBMERGED	ORGANIC		(2O)
69 RIVERINE	SUBMERGED	MUD		(2M)
70 RIVERINE	SUBMERGED	SAND		(2S)
71 RIVERINE	SUBMERGED	GRAVEL/COBBLE		(2G)
72 RIVERINE	SUBMERGED	RUBBLE/BOULDERS		(2R)
73 RIVERINE	SUBMERGED	BEDROCK		(2B)
74 RIVERINE	PERIODIC FLOODING	ORGANIC		(3O)
75 RIVERINE	PERIODIC FLOODING	MUD		(3M)
76 RIVERINE	PERIODIC FLOODING	SAND		(3S)
77 RIVERINE	PERIODIC FLOODING	GRAVEL/COBBLE		(3G)

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SPECIES SUMMARY LIST

Habitats: (Cont)

78 RIVERINE	PERIODIC FLOODING	RUBBLE/BOULDERS	(3R)
79 RIVERINE	PERIODIC FLOODING	BEDROCK	(3B)
80 RIVERINE	SHORE	ORGANIC	(4O)
81 RIVERINE	SHORE	MUD	(4M)
82 RIVERINE	SHORE	SAND	(4S)
83 RIVERINE	SHORE	GRAVEL/COBBLE	(4G)
84 RIVERINE	SHORE	RUBBLE/BOULDERS	(4R)

Elements Excluded:
JETTY
KELP
PACK STATIONS
SALT PONDS
SPRINGS, HOT
SPRINGS, MINERAL
STEEP SLOPE
TIDEPOOLS
WHARF

ID	SPECIES NAME	SCIENTIFIC NAME	FAMILY	STATUS 123456789 FFCCCCFBH ETETPSSS	C P S
A014	CALIFORNIA SLENDER SALAMANDER	Batrachoseps attenuatus	PLETHODONTIDAE		
A028	WESTERN SPADEFOOT	Scaphiopus hammondi	PELOBATIDAE		
A032	WESTERN TOAD	Bufo boreas	BUFONIDAE		
A039	PACIFIC TREEFROG	Hlya regilla	HYLIDAE		
A040	RED-LEGGED FROG	Rana aurora	RANIDAE		
A043	FOOTHILL YELLOW-LEGGED FROG	Rana boylei	RANIDAE		
A046	BULLFROG	Rana catesbeiana	RANIDAE		9
B006	PIED-BILLED GREBE	Podilymbus podiceps	PODICIPEDIDAE		
B010	WESTERN GREBE / CLARK'S GREBE	Aechmophorus occidentalis / Clarkii	PODICIPEDIDAE		
B049	AMERICAN BITTERN	Botaurus lentiginosus	ARDEIDAE		
B050	LEAST BITTERN	Ixobrychus exilis	ARDEIDAE		6
B053	SNOWY EGRET	Egretta thula	ARDEIDAE		
B057	CATTLE EGRET	Bubulcus ibis	ARDEIDAE		
B058	GREEN-BACKED HERON	Butorides striatus	ARDEIDAE		
B062	WHITE-FACED IBIS	Plegadis chihi	THRESKIORNITHIDAE		6
B067	TUNDRA SWAN	Cygnus columbianus	ANATIDAE		
B070	GREATER WHITE-FRONTED GOOSE	Anser albifrons	ANATIDAE		9
B071	SNOW GOOSE	Chen caerulescens	ANATIDAE		9
B072	ROSS' GOOSE	Chen rossii	ANATIDAE		9
B075	CANADA GOOSE	Branta canadensis	ANATIDAE		9

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ID	SPECIES NAME	SCIENTIFIC NAME	FAMILY	STATUS 123456789 FFCCCCFBH ETETPSSS	C P S
B076	WOOD DUCK	Aix sponsa	ANATIDAE		9
B077	GREEN-WINGED TEAL	Anas crecca	ANATIDAE		9
B079	MALLARD	Anas platyrhynchos	ANATIDAE		9
B080	NORTHERN PINTAIL	Anas acuta	ANATIDAE		9
B082	BLUE-WINGED TEAL	Anas discors	ANATIDAE		9
B083	CINNAMON TEAL	Anas cyanoptera	ANATIDAE		9
B085	GADWALL	Anas strepera	ANATIDAE		9
B086	EURASIAN WIGEON	Anas penelope	ANATIDAE		9
B089	CANVASBACK	Aythya valisineria	ANATIDAE		
B090	REDHEAD	Aythya americana	ANATIDAE		9
B091	RING-NECKED DUCK	Aythya collaris	ANATIDAE		9
B094	LESSER SCAUP	Aythya affinis	ANATIDAE		9
B105	COMMON MERGANSER	Mergus merganser	ANATIDAE		9
B108	TURKEY VULTURE	Cathartes aura	CATHARTIDAE		
B111	BLACK-SHOULDERED KITE	Elanus caeruleus	ACCIPITRIDAE	5	
B113	BALD EAGLE	Haliaeetus leucocephalus	ACCIPITRIDAE	1 3 5	
B114	NORTHERN HARRIER	Circus cyaneus	ACCIPITRIDAE	6	
B115	SHARP-SHINNED HAWK	Accipiter striatus	ACCIPITRIDAE	6	
B116	COOPER'S HAWK	Accipiter cooperii	ACCIPITRIDAE	6	
B119	RED-SHOULDERED HAWK	Buteo lineatus	ACCIPITRIDAE		
B121	SWAINSON'S HAWK	Buteo swainsoni	ACCIPITRIDAE	4	
B123	RED-TAILED HAWK	Buteo jamaicensis	ACCIPITRIDAE		
B127	AMERICAN KESTREL	Falco sparverius	FALCONIDAE		
B131	PRAIRIE FALCON	Falco mexicanus	FALCONIDAE	7	
B133	RING-NECKED PHEASANT	Phasianus colchicus	PHASIANIDAE		9
B140	CALIFORNIA QUAIL	Callipepla californica	PHASIANIDAE		9
B145	VIRGINIA RAIL	Rallus limicola	RALLIDAE		
B146	SORA	Porzana carolina	RALLIDAE		
B148	COMMON MOORHEN	Gallinula chloropus	RALLIDAE		9
B150	SANDHILL CRANE	Grus canadensis	GRUIDAE	5	
B159	MOUNTAIN PLOVER	Charadrius montanus	CHARADRIIDAE		
B199	COMMON SNIPE	Gallinago gallinago	SCOLOPACIDAE		
B250	ROCK DOVE	Columba livia	COLUMBIDAE		9
B259	YELLOW-BILLED CUCKOO	Coccyzus americanus	CUCULIDAE	3	
B260	GREATER ROADRUNNER	Geococcyx californianus	CUCULIDAE		
B262	COMMON BARN OWL	Tyto alba	TYTONIDAE		
B264	WESTERN SCREECH OWL	Otus kennicottii	STRIGIDAE		
B265	GREAT HORNED OWL	Bubo virginianus	STRIGIDAE		
B267	NORTHERN PYGMY OWL	Glaucidium gnoma	STRIGIDAE		
B269	BURROWING OWL	Athene cunicularia	STRIGIDAE	6	
B272	LONG-EARED OWL	Asio otus	STRIGIDAE	6	
B273	SHORT-EARED OWL	Asio flammeus	STRIGIDAE	6	

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ID	SPECIES NAME	SCIENTIFIC NAME	FAMILY	STATUS 123456789 FFCCCCFBH ETETPSSS	C P S
B275	LESSER NIGHTHAWK	Chordeiles acutipennis	CAPRIMULGIDAE		
B277	COMMON POORWILL	Phalaenoptilus nuttallii	CAPRIMULGIDAE		
B282	WHITE-THROATED SWIFT	Aeronautes saxatalis	APODIDAE		
B286	BLACK-CHINNED HUMMINGBIRD	Archilochus alexandri	TROCHILIDAE		
B287	ANNA'S HUMMINGBIRD	Calypte anna	TROCHILIDAE		
B294	LEWIS' WOODPECKER	Melanerpes lewis	PICIDAE		
B296	ACORN WOODPECKER	Melanerpes formicivorus	PICIDAE		
B299	RED-BREASTED SAPSUCKER	Sphyrapicus ruber	PICIDAE		
B302	NUTTALL'S WOODPECKER	Picoides nuttallii	PICIDAE		
B303	DOWNY WOODPECKER	Picoides pubescens	PICIDAE		
B307	NORTHERN FLICKER	Colaptes auratus	PICIDAE		
B323	SAY'S PHOEBE	Sayornis saya	TYRANNIDAE		
B326	ASH-THROATED FLYCATCHER	Myiarchus cinerascens	TYRANNIDAE		
B333	WESTERN KINGBIRD	Tyrannus verticalis	TYRANNIDAE		
B337	HORNED LARK	Eremophila alpestris	ALAUDIDAE		
B339	TREE SWALLOW	Tachycineta bicolor	HIRUNDINIDAE		
B340	VIOLET-GREEN SWALLOW	Tachycineta thalassina	HIRUNDINIDAE		
B341	NORTHERN ROUGH-WINGED SWALLOW	Stelgidopteryx serripennis	HIRUNDINIDAE		
B342	BANK SWALLOW	Riparia riparia	HIRUNDINIDAE	4	
B344	BARN SWALLOW	Hirundo rustica	HIRUNDINIDAE		
B348	SCRUB JAY	Aphelocoma coerulescens	CORVIDAE		
B353	AMERICAN CROW	Corvus brachyrhvnchos	CORVIDAE	9	
B358	PLAIN TITMOUSE	Parus inornatus	PARIDAE		
B360	BUSHTIT	Psaltriparus minimus	AEGITHALIDAE		
B361	RED-BREASTED NUTHATCH	Sitta canadensis	SITTIDAE		
B362	WHITE-BREASTED NUTHATCH	Sitta carolinensis	SITTIDAE		
B364	BROWN CREEPER	Certhia americana	CERTHIIDAE		
B367	CANYON WREN	Catherpes mexicanus	TROGLODYTIDAE		
B368	BEWICK'S WREN	Thryomanes bewickii	TROGLODYTIDAE		
B369	HOUSE WREN	Troglodytes aedon	TROGLODYTIDAE		
B370	WINTER WREN	Troglodytes troglodytes	TROGLODYTIDAE		
B372	MARSH WREN	Cistothorus palustris	TROGLODYTIDAE		
B375	GOLDEN-CROWNED KINGLET	Regulus satrapa	MUSCICAPIDAE		
B376	RUBY-CROWNED KINGLET	Regulus calendula	MUSCICAPIDAE		
B377	BLUE-GRAY GNATCATCHER	Polioptila caerulea	MUSCICAPIDAE		
B380	WESTERN BLUEBIRD	Sialia mexicana	MUSCICAPIDAE		
B381	MOUNTAIN BLUEBIRD	Sialia currucoides	MUSCICAPIDAE		
B386	HERMIT THRUSH	Catharus guttatus	MUSCICAPIDAE		
B389	AMERICAN ROBIN	Turdus migratorius	MUSCICAPIDAE		
B390	VARIED THRUSH	Ixoreus naevius	MUSCICAPIDAE		
B391	WRENTIT	Chamaea fasciata	MUSCICAPIDAE		
B393	NORTHERN MOCKINGBIRD	Mimus polyglottos	MIMIDAE		

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ID	SPECIES NAME	SCIENTIFIC NAME	FAMILY	STATUS 123456789 FFCCCCFBH ETETPSSS	C	P	S
B398	CALIFORNIA THRASHER	Toxostoma redivivum	MIMIDAE				
B404	WATER PIPIT	Anthus spinoletta	MOTACILLIDAE				
B407	CEDAR WAXWING	Bombycilla cedrorum	BOMBYCILLIDAE				
B408	PHAINOPEPLA	Phainopepla nitens	PTILOGONATIDAE				
B409	NORTHERN SHRIKE	Lanius excubitor	LANIIDAE				
B410	LOGGERHEAD SHRIKE	Lanius ludovicianus	LANIIDAE				
B417	HUTTON'S VIREO	Vireo huttoni	VIREONIDAE				
B425	ORANGE-CROWNED WARBLER	Vermivora celata	EMBERIZIDAE				
B435	YELLOW-RUMPED WARBLER	Dendroica coronata	EMBERIZIDAE				
B436	BLACK-THROATED GRAY WARBLER	Dendroica nigrescens	EMBERIZIDAE				
B461	COMMON YELLOWTHROAT	Geothlypis trichas	EMBERIZIDAE			6	
B467	YELLOW-BREASTED CHAT	Icteria virens	EMBERIZIDAE			6	
B475	BLACK-HEADED GROSBEAK	Pheucticus melanocephalus	EMBERIZIDAE				
B476	BLUE GROSBEAK	Guiraca caerulea	EMBERIZIDAE				
B477	LAZULI BUNTING	Passerina amoena	EMBERIZIDAE				
B483	RUFOUS-SIDED TOWHEE	Pipilo erythrophthalmus	EMBERIZIDAE				
B484	BROWN TOWHEE	Pipilo fuscus	EMBERIZIDAE				
B494	VESPER SPARROW	Pooecetes gramineus	EMBERIZIDAE				
B495	LARK SPARROW	Chondestes grammacus	EMBERIZIDAE				
B499	SAVANNAH SPARROW	Passerculus sandwichensis	EMBERIZIDAE		3	6	
B504	FOX SPARROW	Passerella iliaca	EMBERIZIDAE				
B505	SONG SPARROW	Melospiza melodia	EMBERIZIDAE			6	
B506	LINCOLN'S SPARROW	Melospiza lincolnii	EMBERIZIDAE				
B509	GOLDEN-CROWNED SPARROW	Zonotrichia atricapilla	EMBERIZIDAE				
B510	WHITE-CROWNED SPARROW	Zonotrichia leucophrys	EMBERIZIDAE				
B519	RED-WINGED BLACKBIRD	Agelaius phoeniceus	EMBERIZIDAE				
B520	TRICOLORED BLACKBIRD	Agelaius tricolor	EMBERIZIDAE			6	
B521	WESTERN MEADOWLARK	Sturnella neglecta	EMBERIZIDAE				
B522	YELLOW-HEADED BLACKBIRD	Xanthocephalus xanthocephalus	EMBERIZIDAE				
B530	HOODED ORIOLE	Icterus cucullatus	EMBERIZIDAE				
B532	NORTHERN ORIOLE	Icterus galbula	EMBERIZIDAE				
B543	LESSER GOLDFINCH	Carduelis psaltria	FRINGILLIDAE				
B545	AMERICAN GOLDFINCH	Carduelis tristis	FRINGILLIDAE				
B546	EVENING GROSBEAK	Coccothraustes vespertinus	FRINGILLIDAE				
M001	VIRGINIA OPOSSUM	Didelphis virginiana	DIDELPHIDAE				
M018	BROAD-FOOTED MOLE	Scapanus latimanus	TALPIDAE				
M023	YUMA MYOTIS	Myotis yumanensis	VESPERTILIONIDAE				
M028	CALIFORNIA MYOTIS	Myotis californicus	VESPERTILIONIDAE				
M032	BIG BROWN BAT	Eptesicus fuscus	VESPERTILIONIDAE				
M033	RED BAT	Lasiurus borealis	VESPERTILIONIDAE				
M034	HOARY BAT	Lasiurus cinereus	VESPERTILIONIDAE				
M037	TOWNSEND'S BIG-EARED BAT	Plecotus townsendii	VESPERTILIONIDAE			6	

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and maintained by the
CALIFORNIA DEPARMENT OF FISH AND GAME
Database Version: 5.0

SPECIES SUMMARY LIST

ID	SPECIES NAME	SCIENTIFIC NAME	FAMILY	STATUS 123456789 FFCCCCFBH ETETPSSS	C P S
M038	PALLID BAT	Antrozous pallidus	VESPERTILIONIDAE	6	
M039	BRAZILIAN FREE-TAILED BAT	Tadarida brasiliensis	MOLOSSIDAE		
M045	BRUSH RABBIT	Sylvilagus bachmani	LEPORIDAE	6	9
M047	DESERT COTTONTAIL	Sylvilagus audubonii	LEPORIDAE		9
M051	BLACK-TAILED HARE	Lepus californicus	LEPORIDAE		9
M072	CALIFORNIA GROUND SQUIRREL	Spermophilus beecheyi	SCIURIDAE		
M081	BOTTA'S POCKET GOPHER	Thomomys bottae	GEOMYIDAE		
M087	SAN JOAQUIN POCKET MOUSE	Perognathus inornatus	HETEROMYIDAE	6	
M105	CALIFORNIA KANGAROO RAT	Dipodomys californicus	HETEROMYIDAE	6	
M112	BEAVER	Castor canadensis	CASTORIDAE		
M117	DEER MOUSE	Peromyscus maniculatus	CRICETIDAE	6	
M134	CALIFORNIA VOLE	Microtus californicus	CRICETIDAE	1 3 6	
M139	MUSKRAT	Ondatra zibethicus	CRICETIDAE		9
M140	BLACK RAT	Rattus rattus	MURIDAE		
M141	NORWAY RAT	Rattus norvegicus	MURIDAE		
M145	PORCUPINE	Erethizon dorsatum	ERETHIZONTIDAE		
M147	RED FOX	Vulpes vulpes	CANIDAE	4 78	
M158	MINK	Mustela vison	MUSTELIDAE		9
M160	BADGER	Taxidea taxus	MUSTELIDAE	6	9
M163	RIVER OTTER	Lutra canadensis	MUSTELIDAE	6	
R022	WESTERN FENCE LIZARD	Sceloporus occidentalis	IGUANIDAE		
R029	COAST HORNED LIZARD	Phrynosoma coronatum	IGUANIDAE		
R036	WESTERN SKINK	Eumeces skiltonianus	SCINCIDAE		
R037	GILBERT'S SKINK	Eumeces gilberti	SCINCIDAE		
R039	WESTERN WHIPTAIL	Cnemidophorus tigris	TEIIDAE		
R040	SOUTHERN ALLIGATOR LIZARD	Gerrhonotus multicarinatus	ANGUIDAE		
R048	RINGNECK SNAKE	Diadophis punctatus	COLUBRIDAE		
R051	RACER	Coluber constrictor	COLUBRIDAE		
R052	COACHWHIP	Masticophis flagellum	COLUBRIDAE		
R053	CALIFORNIA WHIPSNAKE	Masticophis lateralis	COLUBRIDAE		
R057	GOPHER SNAKE	Pituophis melanoleucus	COLUBRIDAE		
R058	COMMON KINGSNAKE	Lampropeltis getulus	COLUBRIDAE		
R060	LONG-NOSED SNAKE	Rhinocheilus lecontei	COLUBRIDAE		
R061	COMMON GARTER SNAKE	Thamnophis sirtalis	COLUBRIDAE		
R062	WESTERN TERRESTRIAL GARTER SNAKE	Thamnophis elegans	COLUBRIDAE		
R063	WESTERN AQUATIC GARTER SNAKE	Thamnophis couchi	COLUBRIDAE		
R071	NIGHT SNAKE	Hypsiglena torquata	COLUBRIDAE		
R076	WESTERN RATTLESNAKE	Crotalus viridis	VIPERIDAE		

TOTAL SPECIES: 184

Status Definitions:

1. FE: Federally Endangered
2. FT: Federally Threatened
3. CE: California Endangered
4. CT: California Threatened
5. CP: California Protected
6. CS: California Special Concern
7. FS: Forest Service Sensitive
8. BS: BLM Sensitive
9. H : Harvest

CPS: Candidate or Proposed Candidate Species

APPENDIX B

AGWATER SUMMARY

APPENDIX B

ON-FARM WATER MANAGEMENT

AGWATER RESULTS AND NARRATIVE SUMMARY

The AGWATER irrigation computer program was used to provide a "snapshot" of current on-farm water management practices and performances within the boundaries of the study area. AGWATER is a diagnostic tool, not a predictive tool. Information used in the program was provided by the growers. These results should not be used to statistically represent conditions in the district as only ten growers were interviewed.

The following were the primary objectives:

1. Get an idea of the magnitude of runoff and deep percolation.

2. Achieve an understanding of typical practices such as irrigation scheduling and systems operations.

3. Get an idea of the magnitude of shallow ground water uptake by crops.

4. Identify typical opportunities for improvement if reducing runoff and deep percolation and improving the root zone moisture environment are needed.

Sprinkler Irrigated Tomatoes

All four sprinkler evaluations were in areas of very shallow water tables. Shallow water table refers to water levels at one to four feet below the ground surface. Growers indicated that the higher level of control provided by sprinklers over furrow irrigation is necessary to prevent water logging when working with a high water table.

Although the evapotranspiration (Et) rate for tomatoes is 23 inches, the growers applied only 13 to 17 inches. Growers indicated that yields are comparable to other non-water table areas. This suggests that six to 10 inches of crop Et is met through uptake from the water table.

Growers indicated there is little or no runoff from sprinkler irrigated fields. The grower's irrigation scheduling decisions, such as when to irrigate and how much to apply, were about as good as could be expected for the first two or three irrigations. Scheduling decisions could not be evaluated for later irrigations because AGWATER is not capable of tracking uptake from shallow water tables.

Opportunities exist to reduce deep percolation by improving system distribution uniformities (DU). DU's ranged from 58 to 69 percent. Uniformities could be increased to about 75 percent if alternate sets are used and pressure losses along the wheel lines are reduced. Switching to lower flow nozzles should be considered to reduce pressure losses.

Furrow Irrigated Tomatoes

All four furrow evaluations were in areas with no water tables within the root zone. The growers evaluated were infiltrating about five inches of water with each irrigation. During the first two or three irrigations the soil could only hold one to two inches. It is typical of surface irrigation systems that amounts of water under three inches are difficult to apply uniformly. Additionally, it appears that some of the irrigations could have been delayed several days, which would have provided for more water

storage when irrigations are applied. This resulted in significant deep percolation of 12 to 21 inches for the season.

Season-long runoff ranged from zero inches, when on a tailwater recovery system was used, to six to 12 inches from the other fields. One grower described the necessity to "runby" or not apply up to 25 percent of the water delivered to him during certain periods. Another grower indicated his desire to be able to cutback furrow flow rates after the water advances to the end of the field to reduce runoff.

With the exception of one field, DU's were fair to good, averaging 75 percent. There is not much room for improving uniformities on the evaluated furrow systems.

Excessive deep percolation can be reduced significantly by using sprinklers to apply smaller amounts of water during the early developing root zone period and switching to furrow irrigation later when adequate soil water storage is available. Soil moisture monitoring or climate based crop water use irrigation scheduling methods can improve irrigation timing decisions. It's likely that one early season irrigation could have been eliminated on two of the fields evaluated.

Beans

Only two bean fields were evaluated. One was furrow irrigated, the other furrow irrigated followed by sprinkler irrigation. On the furrow only field the average seasonal deep percolation was seven inches, runoff was 14 inches, and DU was 90 percent. Deep percolation and runoff could be reduced significantly if sets are shortened. Lower flow rates, allowing for a small reduction in DU, would reduce the volume of runoff.

Case Studies

Two case studies of tomato crops, one furrow irrigated, the other sprinkler irrigated, are presented to represent the "typical" practices used to grow this crop.

'Table : Tabular Summary of Agwater Evaluations and Grower Interviews.

Tomatoes

Irrigation Method	ET Inches	Applied Inches	Runoff Inches	Deep Perc. Inches	DU percent	Irr. Eff. percent	Comments
Sprinkler	23	13	0	1.5	61	1/	First irr. too soon, others scheduled well, high table apparently supplying significant water to meet
Sprinkler	NA	17	0	2.3	67	1/	First 2 irr. run about twice as long as needed, timing good, high water table apparently suppling 5" to ET.
Sprinkler	23	13	0	1	69	1/	Scheduling very good, 10"+/– water from w.t. or sig. yield loss,
Sprinkler	24	13	0	1	69	1/	W.T. at 1–3', apparently sig. w.t. uptake, good scheduling.
Furrow	23	41	6	17	75	40	Too much water 1st 2 irr., could have waited longer before 2nd and 3rd irr., runby (25% of last irr. deliver) indicated as a problem by grower
Furrow	22	43	12	12	77	31	Could have waited longer before 2nd irr., amounts high but timing good on 3 and 4 irr. a little late on 5 and 6. He would like to be able to use cutbacks to reduce runoff.
Furrow	22	51	12	21	75	30	First 3 irr. too early, furrow irr. can't efficiently apply small amounts (<3 inches).
Furrow	22	22	0	12	65	40	First irr. too early, applied 5 – needed 1, difficult to apply less than 3" efficiently significant apparent crop stress (under irr.), end of season, no w.t.

Beans

Irrigation Method	ET Inches	Applied Inches	Runoff Inches	Deep Perc. Inches	DU percent	Irr. Eff. percent	Comments
Furrow	22	30	14	7	90	NA	Sets were too long. They can be reduced. Apparent crop stress.

Melons

Typically preirrigated only. About 9–12 " applied with 25 to 50 percent or more drained from the surface (runoff) to prepare seedbeds. Crop survives off of stored soil water only

95 percent of all melons in the area grown this way.

Rice (Grower Comments)

Some "heavy" soils deep perc. a lot of water. The use of small "light" dikes encourages more requests for emergency water releases.

Some rice fields with clay (112) soil will take 11 ac–ft/ac water to grow a crop.

He runs a "little" over the last weir. "Nothing like they used to." He applies an average of 8 feet of water. Seepage does occur!

1/ Irrigation Efficiencies could not be calculated due to water table contributions to ET.

NA Not Available
ET Evapotranspiration

RD 1500 Case Study: Tomatoes, Furrow Irrigated

Setting: Water Table deeper than 6ft. throughout the season
Soils – silt loam
40 acre field

Crop: Plant emergence – April 1st
Harvest – Aug. 10

Irrigation Practices: Every furrow irrigated during each set
Flow rate delivered to field – 3 cfs (1346 gpm)
Flow to each furrow cutback (reduced) after water reaches end of field

Irrigation Date	Set time (hours)	Applied (inches)	Runoff (inches)	Soaked in (inches)	Used by Crop (inches)	*Deep perc. (inches)
4/17	24	6.2	0.9	5.1	0.7	4.9
5/17	48	8.9	1.2	7.3	1.7	6
5/30	24	5.4	0.7	4.4	1.8	2.6
6/13	24	5.4	0.7	4.4	2.9	1.5
6/27	24	5.4	0.7	4.4	4	0.3
7/11	12	5.4	1.5	3.6	4.3	0
7/18	6	4.5	0	4.2	2.1	1.4
Harvest					4.9	
Totals		41.2	5.7		22.4	16.7

* Irrigation water which moves below the rootzone and is not available for crop use.

RD 1500 Case Study: Tomatoes, Sprinkler Irrigated

Setting: Water Table at 2 to 3 ft. throughout the season
Soils – clay
80 acre field

Crop: Plant emergence – May 8th
Harvest – Sept. 7

Irrigation Practices: Alternate sets are NOT used
Nozzle size – 3/32
Difference in sprinkler pressure down the wheel line – 17 psi

Irrigation Date	Set time (hours)	Applied (inches)	Used by Crop (inches)	2/ Deep perc. (inches)	3/ Distribution Uniformity %
5/1	9	1.3	0.2	1.2	58
5/4	7	1	0.5	0.4	58
5/7	6	0.9	0.6	0.3	58
5/30	9	1.3	1.9	0	58
6/15	14	2.1	1.8	0	56
6/26	14	2.1	1.6	0	56
7/7	15	2.2	2.2	0	58
7/18	13	1.9	1/ 2.8	0	58
Harvest			1/ 12.3		
Totals		12.8	23.8	1.9	

1/ Assume difference between irrigation applied and water needed by crop is made up from the water table.
2/ Irrigation water which moves below the rootzone and is not available for crop use
3/ Relatively poor distribution uniformity caused by not useing alternate sprinkler sets and a relatively large pressure difference along the wheel line.

APPENDIX C

CALCULATIONS APPENDIX

SAMPLE CALCULATIONS FOR WATER CONSERVATION MEASURES

Distribution Control Systems

There are many options for modification of the existing irrigation ditch system. These include pipelines, canal level control structures, regulating reservoirs, lining for canals and reservoirs, modification of the drainage system to increase recirculation or a combination of these options. The ideal combination would either provide water to the system at a lower cost than present or provide water when deliveries are reduced. This solution would not negatively impact fish and wildlife resources, and would maintain the salt balance in the district. Unfortunately, none of the options examined would provide water at a cheaper cost than the present system. They all increase net operating costs for the water users. These systems will make more water available in the service area during short water years.

Calculations were based on data obtained from District and Company records and the Soil Survey; permeability was estimated using the Unified Soil Classification system and the Civil Engineering Standard Desk Reference by McGraw Hill; typical costs for equipment were obtained from distributors; channel dimensions were obtained from Company employees; and costs for concrete, excavation, and other work was estimated using contract costs from other projects.

Ditch Lining Option

The Company billed its customers for approximately 144,000 acre-feet of water in 1993. BOR and Company records show that about 184,000 acre-feet were diverted from the Sacramento River in 1993. This difference was assumed to be lost to seepage in the ditch system. Leakage is a function of wetted surface area, soil permeability, and water depth. Concrete is not an impermeable membrane and a CH or CL soil material has about one-half the permeability as a concrete lining. The Unified Soil type of the irrigation ditch system (Figure 3) was overlaid on the Soil Survey maps. The length of each soil type was measured, the channel dimensions and depths for that reach were used to calculate mean depth and wetted areas. It was assumed that the ditch system was full for the entire irrigation season. The calculation for water loss is:

$$Q = k A h t$$

In this equation "k" is the permeability factor in feet per second per foot of head, "A" is the wetted area in square feet, "h" is the mean distance between the ditch centroid and the water table, and "t" is time in seconds. This equation calculates a flow in cubic feet per second for the ditch section. This calculation was done for the Company ditch system. The results gave an estimate for leakage potential for the entire system in acre-feet after dividing the total 43,560 cubic feet per acre-foot. The results of this calculation was an estimated leakage for the irrigation season of approximately 41,600 acre-feet. This was in good agreement with the estimated loss from the system for 1993 after factoring in an average daily evaporation loss from the ditch surface of 0.25 inches per day.

All soils other than the CH and CL soils were expected to be lined and the k factor of 0.0000001 feet per second was used. The leakage was recalculated and compared with the initial leakage estimate for each section. The difference was the estimated water savings for each lined reach. A four-inch layer of concrete was assumed for each treated section covering the wetted perimeter. It is possible to reduce the cross section with concrete but the earthfill and compaction would have increased the cost beyond the

estimated lining of the entire section. The cost of lining was estimated to be $150 per cubic yard of concrete assuming a neat line section.

Volume of Concrete = A * 4 inches/ 12 inches * 1 cubic yard/ 9 cubic feet

"A" is the wetted perimeter of the channel multiplied by the section length and is in square feet.

The volume of water saved was divided by the cost of the concrete lining to estimate the installation cost per acre-foot of leakage reduced. The length of the three groups were 4.5 miles, 29.8 miles, and 0.75 miles, respectively. Approximately 125 miles would not need to be lined. If the first group lining was installed it would reduce seepage loss by about 19,000 acre-feet. If the entire 34.4 miles were lined the ditch seepage would be reduced approximately 37,000 acre-feet. The expected 10-year life of the lining was used for development of the operation and maintenance costs. It was expected that the system would be fully replaced in its design life. An interest rate of eight percent was used for amortization. The amortization factor for a ten-year life at an eight percent interest rate is 0.14903. This results in a $17, $88, and $117 per acre-foot cost for each acre-foot of seepage reduced for each class of ditch.

The estimated project installation cost for the 4.5 mile option, and 34.4 mile option are $2.3 million and $12.8 million respectively.

The calculation for pipeline replacement was assumed to be an equivalent concrete lined section for the entire ditch system and multiplied by 1.5 for other costs. The design life for the pipeline system was estimated to be 25 years and the maintenance cost was estimated to be $1,500 per mile. The project installation cost was estimated to be $75 million dollars.

Modification of the canal system to spill water back into the Sacramento River or into a regulating reservoir. The canal gates would need to be placed into concrete sections which the manufacturer (Waterman AVIS gates) estimates would cost the same as the gate. The estimated cost for the canal modification would be $4.7 million dollars for the 82 gates. Without the installation of a regulating reservoir there would be no net water savings. The regulating reservoir(s) would cost about $1 million dollars. The combined project would cost $5.7 million dollars. There is no estimate available for uncontrolled spills, which makes it impossible to estimate a price for each acre-foot of water saved.

Basin Wide Recirculation System

The preliminary design of a recirculation system which would move drainage and tail water upslope into the main canal would need to lift approximately 50 cfs from the Bohanan Dam at mile 7.5 to the canal at mile 19.5.

Presently the District and farmers recirculates a total of 30,000 to 32,000 re-feet of drainage water in short years. The volume discharged at Karnak during the 1994 irrigation season was 71,000 acre-feet. The District estimates that 80 percent of this drainage water is generated upstream of Bohanon Dam. If the system is designed to recirculate this back to the main canal this would be a maximum volume of 320 cfs as a design discharge in addition to the present recirculation capacity of the system.

If the discharge record for 1993 is used to estimate the amount of water which could have been recirculated in the system the total volume for July and August of 1994 is 24,655 acre-feet. The average discharge from Karnak would have been 50 cfs or 6,149 acre-feet. The drainage discharge to the Sacramento River during July and August would have an average EC of 2,263 and 2,215 micromhos/cm, respectively, if the salt discharge was held constant.

Appendix G
Sacramento Valley Water Management Agreement

The Sacramento Valley

Water Management Agreement

September 2001

The Sacramento Valley Water Management Agreement is a grassroots, collaborative effort to increase water supplies for farms, cities, and the environment

Sacramento Valley Water Resources

Sacramento Valley at a Glance

- The Sacramento River supplies 80 percent of the water flowing into the Delta.
- The Sacramento River and its tributaries are major habitat and spawning grounds for threatened and endangered fish species.
- The Sacramento Valley has more than 20 percent of California's total irrigated acreage.
- Sacramento Valley water shortages are predicted to continue for both average and drought years.
- The Sacramento Valley is a major resting point for millions of migratory waterfowl on the Pacific Coast Flyway.
- The Sacramento Valley is home to 2 million people.

The Sacramento Valley Water Management Agreement

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Pg. 8 Workplans for Implementation

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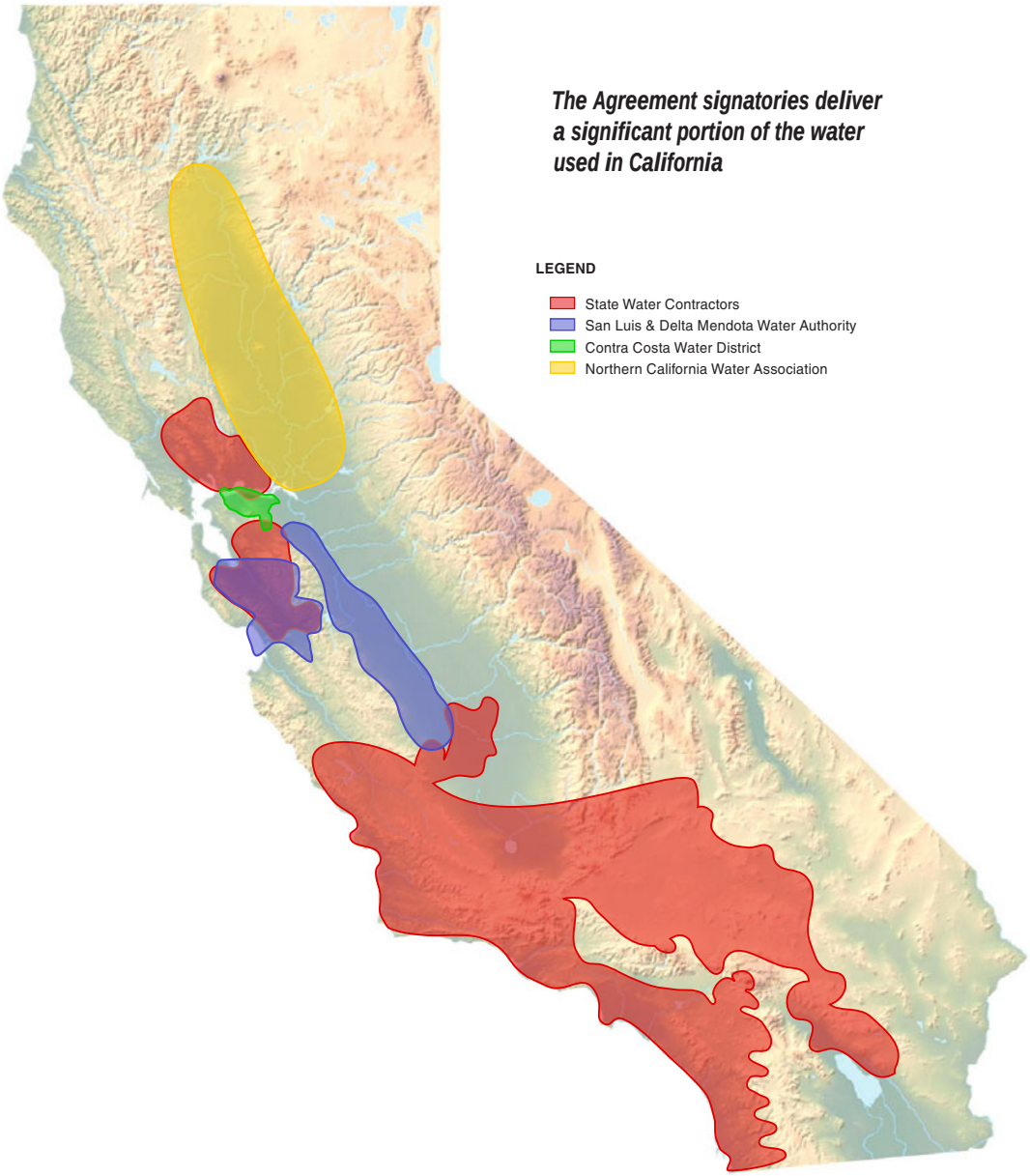
Pg.17 Appendix B - U.S. Bureau of Reclamation and California Department of Water Resources Letter

Pg.19 Appendix C - State Water Resources Control Board Decision

The Sacramento Valley Water Management Agreement

In April 2001, more than 100 organizations reached an unprecedented agreement to manage water in a way that meets water supply, water quality, and environmental needs in the Sacramento Valley and throughout California.



Agreement Benefits

Increased supplies for all uses

Through integrated water management strategies, upstream and export water users will be able to optimize existing water supplies, enhance water quality, and develop additional supplies. This will enable them to meet existing and future water needs and enhance their water management flexibility.

Sustainable solution

The Sacramento Valley Water Management Agreement (Agreement) calls for solutions to complex problems, rather than stopgap measures. Solutions will be implemented in two tiers, based on how quickly the project can be implemented and begin providing benefits.

Timely resolution

The Agreement provides firm milestones to complete a joint workplan for short-term projects within the first 180 days. These projects will provide benefits for the 2002 and 2003 water years; a long-term workplan will be completed within 1 year.

Environmental restoration

The programs and projects provided for in the Agreement will avoid unmitigated impacts to Delta water quality and the environment and will be developed and implemented to provide environmental benefits, including benefits to fish and wildlife, in the Sacramento River watershed.

Water quality standards will be met

The California Department of Water Resources and the U.S. Bureau of Reclamation will continue to voluntarily meet the requirements in the State Water Resources Control Board 1995 Water Quality Control Plan to protect the Bay-Delta until a long-term solution is negotiated as a part of the Agreement.

Consistent with other water management activities

The projects implemented under this Agreement are consistent with the August 2000 CALFED Bay-Delta Program Record of Decision and with the CALFED Integrated Storage Investigation.

A 40-Year Struggle for

Bay-Delta Water Quality

1959
Delta Protection Act passed.

1971
State Water Resources Control Board (SWRCB) issues Delta Water Right Decision 1379.

1973
California Department of Fish and Game (DFG) conclude Peripheral Canal best Delta water facility.

1974
Department of Water Resources (DWR), DFG, U.S. Bureau of Reclamation (USBR) and U.S. Fish and Wildlife Service (USFWS) sign statement of intent that agencies will provide protection of Delta fish and

1977
California experiences driest year on record.

1978
SWRCB issues Water Right Decision 1485 (D-1485) requiring Central Valley Project (CVP) and State Water Project (SWP) operations to meet Delta water quality standards.

1979
USBR announces CVP will voluntarily comply with D-1485 until mandatory compliance is resolved.

1982
Voters defeat Proposition 9 – the Peripheral Canal Measure.

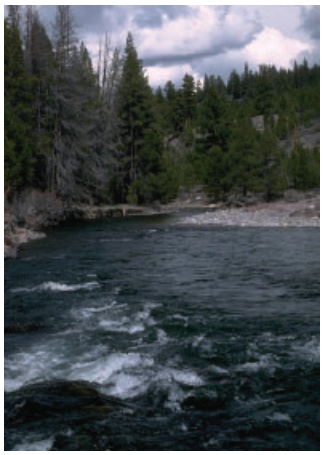
1986
Racanelli Appellate Court Decision requires SWRCB to revise water rights and water quality process.

Historic USBR-DWR Coordinated Operation Agreement authorized by Congress.

California's Sacramento Valley is rich in agricultural and environmental resources and serves as a major resting point for millions of migratory waterfowl on the Pacific Coast Flyway. The Sacramento River is the lifeblood of this Valley. The Sacramento River and its tributaries are major habitat and spawning grounds for threatened and endangered fish species and supply more than 80 percent of the inflows to the Sacramento-San Joaquin Delta. The Delta is the largest estuary on the west coast and serves as the hub for California's water system.

Competing agricultural, environmental, and urban uses create serious water management challenges within the Sacramento Valley. Current forecasts predict continuing statewide water shortages in both average and drought years. Water managers are striving to ensure that the water supply is of both adequate quantity and quality for the many uses.

For nearly 40 years, the State of California has struggled to develop the appropriate water quality standards for the Bay-Delta and to determine which water sources are required to meet those standards. This struggle has involved years of contention and litigation and has been elevated to the United States Supreme Court.



A major breakthrough occurred in late 1994 with the so-called Bay-Delta Accord (Accord). The Accord set water quality standards and required the State Water Resources Control Board (Board) to determine which water users would be responsible to meet these standards. In 1995 the Board adopted the Water Quality Control Plan (Plan) as a tool to implement the Accord. The California Department of Water Resources (Department) and the U.S. Bureau of Reclamation (Bureau) have been voluntarily meeting the Plan's water quality standards on an interim basis. Meanwhile, the Board held water rights proceedings to determine final responsibility for meeting the standards.

1987
SWRCB begins proceedings to revise D-1485 upon U.S. Environmental Protection Agency (USEPA) declaration that it is inadequate to protect Bay-Delta water quality.

1988
Senate Bill 34 passes, providing $120 million over 10 years for Delta levee maintenance.

1991
SWRCB releases new salinity control plan for Bay-Delta.

USEPA calls for more stringent standards.

1992
President George Bush signs CVP Improvement Act, requiring among other things, 800,000 a.f. of water annually for the environment.

1993
Delta smelt declared federal threatened species. SWRCB resumes work on permanent Delta Water Quality Standards.

USEPA proceeds with setting federal Bay-Delta standards.

1994
Bay-Delta Accord signed. CALFED formed.

Sacramento River winter-run chinook salmon listed as federal endangered species.

1995
SWRCB adopts new water quality standards and begins water rights proceedings.

1997
Steelhead listed as federal threatened species.

1998
CALFED released programmatic draft EIS/EIR offering three alternatives for Delta restoration.

1999
Splittail minnow and spring-run chinook salmon listed as federal threatened species.

2000
CALFED Record of Decision.

San Joaquin River Agreement.

2001
Sacramento Valley Water Managment Agreement.

Bay-Delta Water at a Glance

- More than 22 million people depend on the Delta for drinking water.
- More than 750 species of plants and animals call the Bay-Delta home, making it the richest ecosystem on the west coast.
- Seven million acres of the nation's most productive agricultural lands depend on Bay-Delta water to irrigate crops and water livestock.
- The Delta is a critical source of freshwater to blend with high salinity waters in other areas of the state to provide safe water for agricultural, environmental, and urban uses.

Phases 1 through 7 of the water rights proceedings involved the San Joaquin Valley and other Delta issues. After completion of these phases, the contentious Sacramento Valley issues (Phase 8) loomed over the State's water users.

In Phase 8, the Department and the Bureau claim that certain water rights holders in the Valley must cease diversions or release water from storage to help meet Delta water quality standards. Sacramento Valley water users believe their use has not contributed to water quality problems in the Delta; and as senior water right holders and water users within the watershed and counties of origin, they contend they are not responsible for meeting these standards. The Phase 8 process would ultimately determine which entities and individuals (if any) would be responsible for meeting water quality standards.

Agreement Partners

California Department of Water Resources
U.S. Bureau of Reclamation
State Water Contractors

San Luis & Delta-Mendota Water Authority
Contra Costa Water District
Northern California Water Association

San Luis & Delta-Mendota Water Authority includes the following:

Banta-Carbona Irrigation District
Broadview Water District
Central California Irrigation District
Centinella Water District
City of Tracy
Columbia Canal Company
Del Puerto Water District
Eagle Field Water District
Firebaugh Canal Water District
Fresno Slough Water District
Grassland Water District
James Irrigation District
Laguna Water District
Mercey Springs Water District
Oro Loma Water District
Pacheco Water District
Pajaro Valley Water Management Agency
Panoche Water District
Patterson Irrigation District
Plain View Water District
Pleasant Valley Water District
Reclamation District 1606
San Benito County Water District
San Luis Canal Company
San Luis Water District
Santa Clara Valley Water District
Tranquility Irrigation District
Tummer Island Water District
West Side Irrigation District
West Stanislas Irrigation District
Westlands Water District
Widren Water District

Northern California Water Association includes the following:

Brophy Water District
Browns Valley Irrigation District
Cordua Irrigation District
Feather Water District
Garden Highway Mutual Water Company
Glenn-Colusa Irrigation District
Joint Water Districts Board
- Biggs-West Gridley Water District
- Butte Water District
- Richvale Irrigation District
- Sutter Extension Water District

Maxwell Irrigation District
Natomas Mutual Water Company
Pelger Mutual Water Company
Plumas Mutual Water Company
Princeton-Codora-Glenn Irrigation District
Provident Irrigation District
Ramirez Water District
Reclamation District 108
Reclamation District 1004
South Sutter Water District
South Yuba Water District
Sutter Bypass-Butte Slough Water UA
Sutter Mutual Water Company
Tehama-Colusa Canal Authority
- Colusa County Water District
- Corning Water District
- Cortina Water District
- Davis Water District
- Dunnigan Water District
- 4-M Water District
- Glenn Valley Water District
- Glide Water District
- Holthouse Water District
- Kanawha Water District
- Kirkwood Water District
- LaGrande Water District
- Myers-Marsh Mutual Water Co.
- Orland-Artois Water District
- Proberta Water District
- Thomes Creek Water District
- Westside Water District

Thermalito Irrigation District
Tudor Mutual Water Company
Western Canal Water District
Yuba County Water Agency

State Water Contractors includes the following:

Alameda County Flood Control and Water Conservation District Zone 7
Alameda County Water District
Antelope Valley-East Kern Water Agency
Casitas Municipal Water District
Castaic Lake Water Agency
Central Coast Water Authority
City of Yuba City
Coachella Valley Water District
County of Kings
Crestline-Lake Arrowhead Water Agency
Desert Water Agency
Dudley Ridge Water District
Empire-West Side Irrigation District
Kern County Water Agency
Littlerock Creek Irrigation District
Metropolitan Water District of Southern California
Mojave Water Agency
Napa County Flood Control and Water Conservation District
Oak Flat Water District
Palmdale Water District
San Bernardino Valley Municipal Water District
San Gabriel Valley Municipal Water District
San Gorgonio Pass Water Agency
San Luis Obispo County Flood Control and Water Conservation District
Santa Clara Valley Water District
Solano County Water Agency
Tulare Lake Basin Water Storage District

DEPARTMENT OF WATER RESOURCES
DATED: 3/23/01
By Thomas M. Hannigan, Director

Approved as to legal form and sufficiency
Asst. Chief Counsel, DWR
APPROVED AS TO LEGAL FORM AND SUFFICIENCY
Office of Regional Solicitor
Department of the Interior
DATED: 3/16/01

UNITED STATES BUREAU OF RECLAMATION
MID-PACIFIC REGION
By Lester A. Snow, Regional Director

STATE WATER CONTRACTORS
DATED: 4/3/01
By John C. Coburn, General Manager

SAN LUIS & DELTA-MENDOTA WATER AUTHORITY
DATED: 3/30/01
By David G. Nelson, Executive Director

CONTRA COSTA WATER DISTRICT
DATED: 4/3/01
By Walter J. Bishop, General Manager

NORTHERN CALIFORNIA WATER ASSOCIATION
DATED: 4/4/01
By David J. Guy, Executive Director

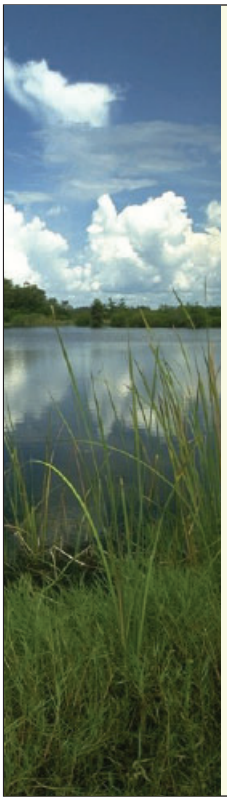
Unprecedented Cooperation

The Sacramento Valley Water Management Agreement is a grassroots, collaborative effort to increase water supplies to farms, cities, and the environment.

Proceeding with Phase 8 could involve litigation and judicial review for nearly 10 years. This extended process could result in adverse impacts to the environment and undermine progress on other statewide water management initiatives. To avoid the consequences of delay, the Sacramento Valley water users, the Department, the Bureau, and export water users developed the Sacramento Valley Water Management Agreement (Agreement). This Agreement establishes a framework to meet water supply, water quality, and environmental needs in the areas of origin and throughout California in an unprecedented cooperative spirit. The Board on April 26, 2001, issued an order to postpone and possibly dismiss Phase 8 of its Bay-Delta water rights proceedings and allow implementation of the Agreement, thus providing an amicable way to resolve these contentious issues.

Regional Strategy Based on Collaboration

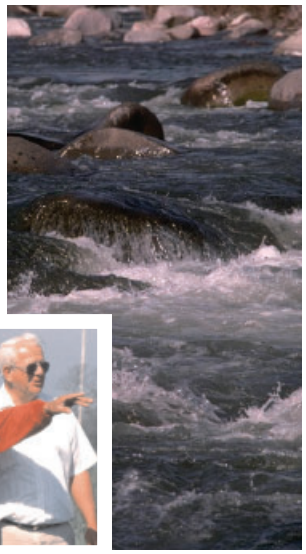
The cornerstone of the Agreement is that it was achieved and will be implemented through a collaborative process including Sacramento Valley water users, the Department, the Bureau, and export water users. This will include active participation by water district managers, technical consultants, and local political leaders. The Agreement provides the foundation for a regional strategy to ensure that local water needs are fully met while helping improve water supplies throughout the state.



Agreement Principles

- The state and federal export projects will continue to meet water quality standards in the Delta until a long-term solution is negotiated as a part of the Agreement.
- The parties fully commit to an integrated water management and water supply development program for the Sacramento Valley that will meet 100% of the water needs in the Sacramento Valley, improve the water supplies and quality for other areas of the state, and provide water for environmental purposes.
- The parties will work together to secure public funding for water management and supply projects in the Sacramento Valley that will help assure environmental restoration, optimize the use of existing water supplies and enable local interests to develop additional water supplies in areas of origin.
- By the end of 2001, the parties will prepare a joint workplan for short-term Sacramento Valley water management projects to implement the Agreement. Workplans on longer-term projects will follow in 2002.
- The parties will evaluate the projects and workplans against the Agreement's goals and principles on an ongoing basis to ensure that water needs are being met.

Next Steps: Workplans for Implementation

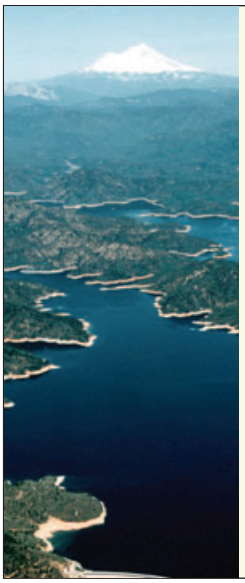


To implement the Agreement, the parties are preparing joint workplans. The workplans will describe certain Sacramento Valley projects and provide an estimate of the quantity of water or other water management benefits that can be realized by implementing these projects. The short-term workplan will provide benefits for 2002 and 2003 and will be completed by the end of 2001. The long-term workplan will be completed by May 2002.

The workplans will identify a palette of voluntary water management measures that will lead to an integrated water management program. The program will include the coordinated use of storage facilities, management and recovery of tailwater through major drains, water conservation, conjunctive management of surface water and groundwater, and transfers and exchanges among Sacramento Valley water users and other water users in the state. Furthermore, the Agreement contains a commitment to implement Sites Reservoir as an integral component of the water management and water supply development program for the Sacramento Valley.

The workplans are being developed through the process illustrated in Figure 1. It is a locally driven process, with

Figure 1 **Project Development Process**



Management Tools

Implementation of voluntary water management measures are key to accomplishing the goals of this Agreement. These include:

- Coordinated use of storage facilities
- Conjunctive management of surface water and groundwater
- Management and recovery of tailwater through major drains
- Water conservation
- Transfers and exchanges among Sacramento Valley water users and other water users in the state
- Increased surface storage

extensive involvement by all stakeholders. More than 50 stakeholders completed detailed questionnaires to propose projects for the short-term workplan. The proposed projects will be screened on the basis of a broad range of potential benefits and broad geographic coverage in the Valley.

Those projects will then be reviewed and evaluated on the basis of more detailed project summaries. From that review, projects will be selected for inclusion in the short-term workplan and implementation plans will be developed.

The next steps will be:

- Conduct environmental review and obtain necessary permits
- Secure appropriate funding
- Provide for public participation

Environmental review is a part of all projects, even those that will generate positive net effects on the environment. Environmental documentation will be prepared for all projects, and cumulative impacts will be addressed.

Funding will be pursued from a number of sources. As most of the projects will provide multiple benefits to various participants, cost-sharing arrangements will be negotiated to reflect those benefits. Many of the projects will also provide public benefits, primarily environmental, and efforts will be made to obtain state and federal funds to support those benefits. Potential funding sources include Proposition 13, Proposition 204, and state and federal funding through the CALFED program.

Public support will be crucial to successful development of the projects. Public meetings will be held to provide opportunities for full input into the planning process.

Appendix A

AGREEMENT REGARDING RESOLUTION OF PHASE 8 ISSUES, DEVELOPMENT AND MANAGEMENT OF WATER SUPPLIES, AND A BINDING COMMITMENT TO PROCEED PURSUANT TO SPECIFIED TERMS

This Agreement is in furtherance of a resolution of Phase 8 of the State Water Resources Control Board's (hereinafter "SWRCB") current Bay-Delta Water Rights Hearings. The Parties will work together to settle issues related to obligations or potential obligations to meet existing Bay-Delta water quality and flow objectives by developing a cooperative water management partnership among (a) those south of the Sacramento-San Joaquin Delta who possess water rights or are State Water Project ("SWP") or Central Valley Project ("CVP") water users; (b) the Contra Costa Water District and those who derive SWP water from the North Bay Aqueduct (hereinafter (a) and (b) for the purposes of this Agreement referred to collectively as "Export Water Users"); (c) those who possess water rights or are water users within the watershed of the Sacramento River and its tributaries (hereinafter "Upstream Water Users"); (d) the California Department of Water Resources (hereinafter "DWR"); and (e) the United States Bureau of Reclamation on behalf of the CVP (hereinafter "Reclamation"), all of which are hereafter referred to as the Parties.

Now therefore, it is mutually agreed as follows:

1. Goals and Principles

The Parties hereto agree to the following statement of goals and principles that shall guide the implementation of all aspects of this Agreement, including development of a cooperative water management partnership. This Agreement, during its term, is intended to:

(a) Provide the mechanism for satisfying the flow-related objectives of the SWRCB's 1995 Bay-Delta Water Quality Control Plan (hereinafter the "1995 WQCP");
(b) Be implemented in lieu of proceeding with Phase 8 of the SWRCB's Bay-Delta process;
(c) Facilitate the development of integrated water management strategies that will enhance the Upstream and Export Water Users' abilities to optimize use of their existing supplies, enable them to develop additional supplies to meet their existing and future water needs, and enhance their water management flexibility;
(d) Facilitate the development of protections to ensure that water stored and released by the SWP and the CVP is available for meeting downstream flow-related objectives and for SWP and CVP purposes, including exports from the Delta;
(e) Be implemented in a manner compatible with CALFED's goals;
(f) Facilitate the development of new near- and long-term water supplies through agreements among the Parties, and through the Governor's drought contingency plan, in ways that do not detract from the ability to meet the existing and future needs of Upstream Water Users;
(g) Avoid unmitigated impacts to Delta water quality or the environment;
(h) Provide net water quality benefits for Upstream Water Users, Export Water Users, and the Delta;
(i) Be implemented in a manner that provides that the comprehensive program will, among other factors, be cost effective, financially feasible, and affordable; and
(j) Result in state-wide water resource and environmental benefits and, therefore, receive funding from state and federal sources where appropriate.

2. Initial Elements of the Cooperative Management Partnership.

It is intended that the Goals and Principles adopted with this Agreement be implemented through the development of specific programs and projects. The development of these programs and projects will be an ongoing process and may, over time, involve numerous entities not signatories to this Agreement. These may include agencies of the state or federal government including, but not limited to, the United States Fish & Wildlife Service ("USFWS"), the National Marine Fisheries Service ("NMFS"), and the California Department of Fish and Game ("CDFG"), and may also include in-Delta water users. Moreover, over time, the Parties may decide to employ a facilitator or mediator to assist them in moving forward with project development and implementation. In this light, the following specific matters are intended only as the initial scope of work under this Agreement, with future work to be developed and implemented as appropriate. Future work plans, if appropriate, can become amendments to this Agreement or can be the subject of subsequent related agreements.

(a) *Quantifying Water Demands and Supplies*. The Parties recognize a need to develop reliable estimates of the quantities of water that are currently being used, present unmet demands and projected future demands within the watershed of the Sacramento River and its tributaries. The Parties also need to develop estimates of the quantities of new water supplies that could be made available to Upstream areas, Export areas, and to meet the 1995 WQCP standards based on the measures included in the programs and projects described below. The Parties agree to establish a technical committee to begin immediately to develop, collect and analyze this information.
(b) *Unmet and Future Demands in the Upstream Areas.* The Parties recognize that Upstream Water User demands may vary and that the following approximates the categories of upstream demands that will be provided for:

(i) Urban needs and uses within the watershed of the Sacramento River and its tributaries.

(ii) Needs and uses within the Tehama-Colusa and Corning Canal service areas.

(iii) Needs and uses within the Sacramento River Water Rights Settlement Contractors' collective service area.

(iv) Needs and uses within areas that obtain supply from the drains and bypasses within the Sacramento Valley.

(v) Needs and uses within the areas tributary to the Sacramento, American, and Feather Rivers.

(c) *Export Water Supplies.* The Parties recognize that Export Water Users have experienced water supply reductions as a result of regulatory and other actions. The programs and projects provided for in this Agreement will improve the water supplies on both a short- and long-term basis, and improve the water quality.

(d) *Environmental Benefits.* The Parties recognize that programs and projects provided for in this Agreement will be developed and implemented not only to meet the needs of Upstream and Export Water Users and the flow-related objectives of the 1995 WQCP, but also to provide environmental benefits, including benefits to fish and wildlife, in the watershed of the Sacramento River.

(e) *Role of Sites Reservoir.* The Parties recognize that new off-stream surface storage is an essential part of the long-term water management program, and agree that Sites Reservoir is a potentially significant off-stream surface-water storage project that could help meet the goals and objectives of this Agreement, including providing capacity to increase the reliability of water supplies for Upstream and Export Water Users, flexibility during critical fish migration periods on the Sacramento River, and storage benefits for other CALFED programs. Work being undertaken pursuant to CALFED's Sites MOU will be integrated into this Agreement and the Parties will work with CALFED to accelerate feasibility studies and completion of appropriate environmental and permitting processes for the reservoir.

(f) *Enlarged Shasta*. The Parties agree that other significant surface water storage opportunities may exist, including the enlargement of Shasta Reservoir. The Parties shall take all appropriate efforts to advance these other opportunities and shall integrate the benefits associated with these projects into the programs provided for in this Agreement.

(g) *Role of the Basin-Wide Management Plan.* Reclamation and certain Upstream Water Users are currently developing a Basin-Wide Management Plan for the purpose of improving water management within portions of the Sacramento Valley. The Basin-Wide Management Plan that Reclamation and certain Upstream Water Users are developing shall serve as a model for implementation of this Agreement and could be expanded to incorporate other areas of the watershed of the Sacramento River and its tributaries, as appropriate.

(h) *Management Tools for this Agreement.* A key to accomplishing the goals of this Agreement will be the identification and implementation of a "palette" of voluntary water management measures (including cost and yield data) that could be implemented to develop increased water supply, reliability, and operational flexibility. Some of the measures that may be included in the palette are:

(i) Basin-Wide Water Management Plan identified above;

(ii) Conjunctive uses of surface water and groundwater;

(iii) Coordinated use of storage facilities;

(iv) Management and recovery of tailwater through major drains;

(v) Transfers and exchanges among Upstream Water Users and with the CVP and SWP water contractors, either for water from specific reservoirs, or by substituting groundwater for surface water;

(vi) Substitution of water from potential north of Delta reservoirs, such as Sites Reservoir, for groundwater, or river diversions, or maintaining water quality in the Delta; and

(vii) Water conservation.

3. Resolution of Phase 8 Issues

(a) The Parties agree that while this Agreement remains in effect, DWR and Reclamation shall assume responsibility for meeting the Sacramento River and its tributaries' portions of flow-related objectives established in the 1995 WQCP. Upstream Water Users shall have no obligation to release stored water, extract groundwater or forego diversions in order to help implement the flow-related objectives included in the 1995 WQCP.

(b) In conjunction with the SWRCB, the Parties shall jointly develop a program to prevent unauthorized diversions, provided that the program is consistent with this Agreement.

(c) The Export Water Users, DWR, and Reclamation agree that while this Agreement is in effect they shall take no action before the SWRCB or elsewhere, nor shall they support any such action to insert Term 91, or its regulatory equivalent, into existing water rights permits or licenses, or modify riparian or pre-1914 water rights through the application of the regulatory equivalent of Term 91. The Parties recognize that the SWRCB will continue to implement Term 91 according to its existing terms.

(d) Notwithstanding the foregoing, nothing herein shall be interpreted as waiving the Parties' legal positions or rights in the event that the SWRCB proceeds with the Phase 8 hearings or otherwise attempts to determine the legal obligations of water users to meet adopted water quality or flow standards in the Bay-Delta or in streams tributary to the Bay-Delta. In addition, the Parties acknowledge and agree that nothing herein shall limit their ability to initiate a new or additional water right or water supply, transfer an existing water right, or change or modify an existing water right or a contract relating to a water supply; nor shall a Party be precluded from arguing that Term 91 should be applied or not applied by the SWRCB in any of these proceedings or that a new water right, transfer, or change or modification of an existing water right will or will not cause injury to a lawful water user.

(e) This Agreement shall become effective on the day the SWRCB enters an order that:

(i) Provides for a Stay of Phase 8 of the current Bay-Delta water rights proceeding pending development and approval of the Workplans described in Paragraphs 5(a) and 5(b) of this agreement;

(ii) Provides that, should either of the Workplans not be completed or approved, and this Agreement is therefore terminated, the Parties shall immediately notify the SWRCB and the SWRCB will lift the stay and proceed with Phase 8;

(iii) Under the circumstances provided for in sub-paragraph 3(e)(ii), extends the expiration of the SWP's and CVP's obligations under Conditions 1 and 2 of the Order in Revised Decision 1641 to the earlier of the completion of a resumed Phase 8 or one year from the date of a notice to the SWRCB of termination of this Agreement; and

(iv) Provides that, should the Workplans described in Paragraphs 5(a) and (b) both be completed and approved, Notice of the approval provided to the SWRCB (a) automatically dismisses the Phase 8 proceedings and (b) further extends the expiration of the SWP's and CVP's obligations under Conditions 1 and 2 of the Order in Revised Decision 1641 to one year after the Notice of the termination of this Agreement to the SWRCB or such sooner time as a water rights proceeding allocating the responsibilities to meet Bay-Delta standards is completed; and

(v) Provides that the dates set forth in sub-paragraphs 3(e)(iii) and (iv) above may be extended for up to one year if after notice and hearing the SWRCB determines that the additional time is necessary for it to fully consider and decide the matter.

4. Resolution of Related Issues

The Parties acknowledge that there are a number of administrative, regulatory, legislative and judicial actions currently ongoing or reasonably to be anticipated that could have major effects on the Parties' ability to implement the terms of this Agreement.

In this regard, the Parties acknowledge and agree that developments in any of these or other matters may have a material effect on any Party's ability to implement this Agreement and meet the Milestones set forth in Paragraph 5 below. The Parties agree that they will work together to attempt to deal with the factual/legal situation that then exists in order to allow the Parties to proceed with the programs identified in this Agreement. Nonetheless, failure to meet Milestones, for whatever reason, shall remain a cause for the termination of this Agreement.

5. Milestones

(a) *Short-Term Projects.* Within one hundred eighty days of the Effective Date of this Agreement, the Parties shall, working together, prepare a joint work plan listing short-term projects that can be used to implement this Agreement. Such projects are defined as those which can provide benefits for the 2002 and 2003 water years.

(b) *Medium and Long-Term Projects.* Within one year of the Effective Date of this Agreement, the Parties shall, working together, prepare a joint work plan listing medium- and long-term projects that can be used to implement this Agreement. Medium-term projects are defined as those which will be operational by December 31, 2005. Long-term projects are defined as those which are operational by December 31, 2010.

(c) *Workplan Standards.* For each project identified in the respective Workplan, the appropriate Workplan shall:

(i) Briefly describe the project, including expected 10 net benefits and their proposed allocations;

(ii) Provide a preliminary estimate of the quantity of water or the nature of other water management benefits that can be realized by implementing the project;

(iii) Provide a preliminary estimate of the cost of the project;

(iv) Identify any major environmental issues associated with the project; and

(v) Describe how the project could best be implemented (including a plan for financing for the project).

Each Workplan shall also provide a timetable for implementation of identified projects, which shall then constitute additional Milestones for this Agreement.

(d) *Funding.* The Parties shall immediately jointly seek funding for the development of the two Workplans identified above from general state and/or federal sources. In addition, the Parties shall also seek funding, pursuant to Proposition 204 and other possible funding sources, to cover the cost of implementing programs identified within the respective Workplans. Milestones identified within this Agreement may need to be adjusted in order to provide ample time for the Parties to secure adequate state and federal funding to allow work to proceed. Such adjustments must be accomplished pursuant to mutual agreement of all Parties. The Parties shall not seek to acquire funds that are obligated to other programs within CALFED, and shall not seek funding that may otherwise conflict with funding commitments under the Central Valley Project Improvement Act Restoration Fund.

(e) *Workplan Updates.* The Parties shall review and update the medium/long-term Workplan annually to incorporate information learned as a result of the cooperative process contemplated by this Agreement or as a result of other efforts.The Parties may also revise the list of projects contained in the medium/long-term Workplan, the estimates of the water supply or other benefits associated with such projects, the cost estimates for such projects, the environmental issues associated with such projects, and the implementation plan for each project. The Parties may review and update the medium/long-term Workplan as necessary in the event that circumstances identified in Paragraph 4 above occur.

(f) *Sites Reservoir Milestones.* Because of the potential significance of Sites Reservoir or other north of Delta offstream storage to achieving the

goals of this Agreement, the following additional specific Milestones shall be adhered to:

(i) finalize a Purpose and Needs Statement for the project satisfactory to the Parties no later than March 9, 2001;
(ii) initiate initial scoping sessions associated with appropriate environmental review by April 9, 2001;
(iii) initiate negotiations on all relevant Planning Agreements called for within the Sites MOU, including addressing issues dealt with in Paragraphs 7.4, 7.5 and 7.6 of the Sites MOU, by January 31, 2001;
(iv) complete all environmental and planning documentation for the project not later than August 2004;
(v) make a final decision with respect to the implementation and construction of the project, including obtaining all relevant permits/biological opinions, including compliance with Clean Water Act section 404(b)(1) or 404(r) by August 2005; and
(vi) assuming a decision to proceed, initiate project construction not later than August 2006.

6. Term and Termination

(a) *Term.* Except as may be otherwise expressly provided, the term of this Agreement shall be until December 31, 2010.

(b) *Annual Reviews.* The Parties shall agree upon the Workplan identified in Paragraph 5(a) of this Agreement within 60 days of its completion. A failure to do so shall cause the immediate termination of this Agreement. The Parties shall agree upon the Workplans identified in Paragraph 5(b) of this Agreement within 60 days of their completion. A failure to do so shall cause the immediate termination of this Agreement. Assuming approvals of the Workplans identified in Paragraphs 5(a) and 5(b), the Parties shall thereafter, on an annual basis as scheduled by the Parties, jointly review the status of development and implementation of all Workplans, as well as the meeting of Milestones provided for herein and in the Workplans. Each annual review shall include a detailed examination of the status of Workplan and Milestone implementation including, without limitation, project feasibility and design, environmental review, permitting and funding. Except as provided for above, this Agreement may only be terminated following an annual review performed in accordance with this Paragraph 6.

(c) *Termination for Failure to Meet Milestones.* Any Party may terminate this Agreement if, following an annual review and after the mediation provided for in Paragraph 7 of this Agreement, it determines:

(i) that either reasonable progress in achieving the Milestones established under this Agreement or in the Workplans cannot be made through the exercise of reasonable diligence by the Parties; or the Milestones established under this Agreement or in the Workplans have not been substantially achieved; and
(ii) that the Milestones established under this Agreement or in the Workplans cannot be revised to result in the reasonable achievement of the Milestones of this Agreement.

(d) *Termination on Modification in 1995 WQCP.* In the event the flow-related objectives contained in the 1995 WQCP are increased or decreased, the Parties shall meet and, if necessary, employ the process outlined in Paragraph 7 of this Agreement, in an attempt to address the changed circumstances associated with modified flow-related objectives. A failure to reach agreement shall cause the termination of this Agreement.

(e) *Petition on Termination.* In the event the Workplans are not completed or approved or this Agreement is terminated, the Parties shall immediately petition the SWRCB to conduct a water rights hearing to consider the issues described in the SWRCB's Revised Notice of Phase 8 Hearing dated May 6, 1998.

7. Resolution of Disputes

Resolution of disputes, and issues which a Party believes may subject this Agreement to termination shall first be submitted to a mediator, mutually selected by the Parties, with experience in water-related disputes. The Parties will use their best efforts to resolve the issues within 30 days. The costs of any such mediation will be borne equally among the Parties.

8. Effect of this Agreement on Other Matters

Nothing in this Agreement, and nothing incorporated by reference into the terms of this Agreement, is intended or shall be construed as a precedent or other basis for any argument that the Parties to this Agreement have waived or compromised their rights which may be available under State or Federal law except as to the matters addressed in this Agreement, nor shall it be construed as an admission or determination of any Party's responsibility for meeting the requirements of the 1995 WQCP.

9. Contingent Upon Appropriations

The expenditure or advance of any money or the performance of any obligation of the United States under this Agreement shall be contingent upon appropriation or allotment of funds. No liability shall accrue to the United States in case funds are not appropriated or allotted.

10. Technical and Management Committees

The Parties shall form two committees. The first shall be a technical committee which shall have the initial responsibility to develop the Workplans and related Milestones. The second shall be a management committee which shall provide policy direction to the technical committee and review and approve Workplans and Milestones. The committees shall together, in a manner that they determine, be responsible for the implementation of the Workplans. Each Party to this Agreement shall appoint one or more representatives to each of these committees.

11. Public Participation

The Parties shall hold periodic public meetings to provide an opportunity for nonparticipating individuals and entities to have input into the planning process.

12. Other Agreements

The Parties recognize that as program development progresses there will be a need to either amend this Agreement or to enter into additional agreements. In this regard, the Parties acknowledge that this Agreement will complement other relevant local partnerships and/or CALFED agreements and shall, as a consequence, be flexible enough to accommodate those other partnerships and agreements.

13. Environmental Compliance

In carrying out actions which may ultimately result from this Agreement, its amendments or subsequent agreements, the Parties hereto are committed to completing all required environmental review including all procedures and documents required by the National Environmental Policy Act and the California Environmental Quality Act, and to complying with all applicable statutes, including the federal and state Endangered Species Act. The costs of funding this environmental work and compliance shall be among the funding issues dealt with herein. Nothing contained herein is intended to affect DWR's and USBR's compliance with regulatory constraints that are imposed under the Federal Endangered Species Act, the Central Valley Project Improvement Act, the Federal Clean Water Act, or any other applicable state or federal law or regulation, including those incorporated into Tier 1 in the CALFED Record of Decision dated August 28, 2000.

14. Counterparts

This Agreement may be executed simultaneously or in one or more counterparts, each of which shall be an original but all of which together shall constitute one and the same document.

15. Notices

All notices shall be sent to the following: DWR: Thomas R. Hannigan Director Department of Water Resources P.O. Box 942836 Sacramento, CA 94236-0001 Reclamation; Lester Snow Regional Director United States Department of the Interior Bureau of Reclamation, MP-100 2800 Cottage Way Sacramento, CA 95825; Export Water Users: John Coburn, General Manager, State Water Contractors, 455 Capitol Mall, Sacramento, CA 95814; Daniel Nelson, General Manager, San Luis & Delta-Mendota Water Authority, 842 – 6th Street, Suite 7, P.O. Box 2135, Los Banos, CA 93635, Walter J. Bishop, General Manager, Contra Costa Water District, 1331 Concord Avenue, P.O. Box H2O, Concord, CA 94524; Upstream Water Users: David J. Guy Executive Director Northern California Water Association, 455 Capitol Mall, Suite 335, Sacramento, CA 95814.

16. Cooperation

The Parties shall cooperate in carrying out the Mutual Goals and Principles contained herein and the provisions and intent of this Agreement.

17. Effective Date

This Agreement shall become effective upon its full execution by all of the Parties hereto and the satisfaction of the conditions set forth in Paragraph 3(e) of this Agreement.

DATED: 3/23/01

Approved as to legal form and sufficiency:

Asst. Chief Counsel, DWR
APPROVED AS TO LEGAL FORM AND SUFFICIENCY

Office of Regional Solicitor
Department of the Interior

DATED: 3/16/01

DEPARTMENT OF WATER RESOURCES

By _____
Thomas M. Hannigan
Director

UNITED STATES BUREAU OF RECLAMATION
MID-PACIFIC REGION

By _____
Lester A. Snow
Regional Director

DATED: 4/3/01

STATE WATER CONTRACTORS

By _____
John C. Coburn
General Manager

DATED: 3/30/01

SAN LUIS & DELTA-MENDOTA
WATER AUTHORITY

By _____
Daniel G. Nelson
Executive Director

DATED: 4/3/01

CONTRA COSTA WATER DISTRICT

By _____
Walter J. Bishop
General Manager

DATED: 4/2/01

NORTHERN CALIFORNIA WATER
ASSOCIATION

By _____
David J. Guy
Executive Director

Appendix B

United States Department of the Interior

BUREAU OF RECLAMATION
Mid-Pacific Regional Office
2800 Cottage Way
Sacramento, California 95825-1898

IN REPLY REFER TO:
MP-[illegible]
WTR-4.00

APR [illegible] 2001

Mr. Harry M. Schueller
Chief, Division of Water Rights
State Water Resources Control Board
PO Box 2000
Sacramento CA 95812-2000

Dear Mr. Schueller:

In a separate letter dated April 2[illegible], 2001, the United States Bureau of Reclamation (USBR) and the California Department of Water Resources (DWR) submitted comments to the Draft Order for the San Francisco Bay/Sacramento-San Joaquin Estuary, dated April 11, 2001, by the State Water Resources Control Board (SWRCB). On March 16, 2001, and March 29, 2001, respectively, the USBR and the DWR executed the "Agreement Regarding [illegible] Losses, Development and Management of Water Supplies, and a Binding Commitment to Proceed Pursuant to Specified Terms." The Agreement was later executed by the remaining settlement parties.

The USBR and DWR hereby agree to an extension of Conditions 1 and 2 of the Water Right Decision 1641, provided that the SWRCB adopts a final order in accordance with the Draft Order of April 11, 2001, including the proposed modifications to the Draft Order contained in the April 20, 2001 comments of USBR and DWR. A copy of the April 20, 2001, comments is attached hereto and incorporated herein by reference.

Concur:

for Kirk C. Rodgers
Acting Regional Director
Mid-Pacific Region
U.S. Bureau of Reclamation

Thomas M. Hannigan
Director
California Department of Water Resources

Attachment

Appendix C

STATE OF CALIFORNIA
STATE WATER RESOURCES CONTROL BOARD

ORDER WR 2001 - 05

In the Matter of
Implementation of Water Quality Objectives
for the San Francisco Bay/Sacramento-San Joaquin Delta Estuary,
Amending License 1986 (Application 23) and Permits 11315, 11316, 11885, 11886, 11887, 11967, 11968, 11969, 11970, 11971, 11972, 11973, 12364, 12721, 12722, 12723, 12725, 12726, 12727, 12860, 15735, 16597, 16600, and 20245 (Applications 13370, 13371, 234, 1465, 5638, 5628, 15374, 15375, 15376, 16767, 16768, 17374, 17376, 5626, 9363, 9364, 9366, 9367, 9368, 15764, 22316, 14858A, 19304, and 14858B, respectively) of the United States Bureau of Reclamation and Permits 16478, 16479, 16481, 16482, and 16483 (Applications 5630, 14443, 14445A, 17512, and 17514A, respectively) of the Department of Water Resources.

Sources: Sacramento and San Joaquin Rivers and their tributaries, and the Sacramento-San Joaquin Delta Estuary

ORDER STAYING AND DISMISSING PHASE 8 OF THE BAY-DELTA WATER RIGHTS HEARING AND AMENDING REVISED DECISION 1641

By The Board:

1.0 Introduction

By this order, the State Water Resources Control Board (SWRCB) takes actions to facilitate negotiations that may lead to a settlement of the potential responsibilities of numerous water users to implement the objectives in the *Water Quality Control Plan for the San Francisco Bay/Sacramento-San Joaquin Delta Estuary*, adopted May 22, 1995 (1995 BayDelta Plan).[1]

In the absence of this order, the SWRCB would promptly convene the remainder of Phase 8 of the Bay-Delta Water Rights Hearing to consider the water users' potential responsibilities that have not yet been determined.

This order stays the resumption of Phase 8 for eighteen months from the date of this order. This order automatically dismisses Phase 8 at the end of eighteen months, unless the SWRCB receives notice from the Department of Water Resources (DWR) or the United States Bureau of Reclamation (USBR), within eighteen months, requesting resumption of Phase 8. This order extends the responsibilities of the DWR and the USBR under Conditions 1 and 2 to meet the water quality objectives in the 1995 Bay-Delta Plan. Unless the SWRCB issues a further order after notice and an opportunity for a hearing, the extension of their responsibilities will expire no later than one year after the DWR or the USBR requests a hearing. Upon request of the DWR or USBR, the SWRCB will resume Phase 8, or, after dismissal, will commence a new hearing. The SWRCB will expedite any hearing conducted pursuant to this order, to issue a decision within two years after receiving a request from the DWR or the USBR.

The SWRCB will, at least every six months, commencing not later than October 1, 2001, conduct a public informational workshop. The purpose of these workshops will be to provide the public and the SWRCB with information regarding the then-current status of negotiations and plans to implement the flow-dependent objectives, including information about the opportunities for non-parties to the negotiations to provide input.

2.0 Background

2.1 Procedural History

This order is part of a series of actions by the SWRCB to protect the beneficial uses of water in the Bay-Delta Estuary against the adverse effects of water diversions. In the BayDelta proceedings, the SWRCB adopts water quality objectives that, when implemented, will protect the beneficial uses. The SWRCB implements the objectives through water right orders and by requesting or directing that other agencies take appropriate actions including water quality control measures to be implemented by the Regional Water Quality Control Boards.

The 1995 Bay-Delta Plan contains the current water quality objectives. D-1641 and Order WR 2000-10 contain the current water right requirements to implement the BayDelta flowdependent objectives. D-1641 includes both long-term and temporary implementation requirements. Order WR 2000-10 requires partial implementation that will remain in effect up to thirtyfive years. In D-1641 and in Order WR 2000-10, the SWRCB assigned responsibilities, for specified periods, to water users (including the USBR and the DWR in D-1641, and the DWR in Order

WR 2000-10) in the watersheds of the San Joaquin River upstream of Vernalis, the Mokelumne River, Putah Creek, Cache Creek, within the boundaries of the North Delta Water Agency, and within the Bear River watershed. These responsibilities need not be revisited in the near future. These responsibilities require that the water users in these watersheds will contribute specified amounts of water, and that the DWR and/or the USBR will ensure that the objectives are met in the Delta.

To meet the potential responsibilities that are not yet assigned, but may be assigned to water users in areas not yet addressed, D-1641, in Conditions 1 and 2 on page 146 thereof, requires that the DWR and the USBR temporarily implement the objectives. Conditions 1 and 2 also require that the DWR and USBR meet certain objectives that the SWRCB does not contemplate assigning to other parties, such as export limits and gate closure requirements. D1641 provides that Conditions 1 and 2 will remain in effect only until the SWRCB makes further decisions establishing the responsibilities of water right holders in the areas where the potential responsibilities have not yet been determined. D-1641 sets these conditions to expire no later than November 30, 2001.

The SWRCB considered and heard comments on earlier drafts of this order at a Board meeting on March 7, 2001 and at a Board meeting on April 4, 2001.

2.2 Physical Setting

The Bay-Delta Estuary includes the Sacramento-San Joaquin Delta, Suisun Marsh, and the embayments upstream of the Golden Gate. The Delta and Suisun Marsh are located at the confluence of the Sacramento and San Joaquin rivers, which converge to flow westward through San Francisco Bay. The watershed of the Bay-Delta Estuary produces water that is used in much of the state for municipal, industrial, agricultural, and environmental purposes. The watershed is a source of drinking water for two-thirds of the state's population. The State Water Project, operated by the DWR, and the Central Valley Project, operated by the USBR, store water upstream of the Delta, release the stored water into the Delta, and export both the stored water and uncontrolled flows[2] from the Delta. The two projects export water from the Delta to areas south and west of the Delta through a system of water conveyance facilities.

Fish, wildlife, and other public trust resources also use the waterways of the Bay-Delta Estuary and its tributaries. Some of the fish that reside in the estuary or migrate through it are protected under the state or federal Endangered Species Act. Additionally, migratory birds and other animals use the marshlands of the estuary for food and habitat.

3.0 Discussion

It is the policy of the SWRCB in the Bay-Delta proceedings to encourage the parties to resolve among themselves the responsibilities for meeting the objectives in the 1995 Bay-Delta Plan, and to bring their joint proposals for establishing responsibilities to the SWRCB for approval.

The DWR, the USBR, some of their water supply contractors, and the members of the Northern California Water Association approached the SWRCB at a workshop on January 11, 2001, with a draft of an agreement among these parties. The parties proposed that the SWRCB adopt an order staying Phase 8 of the Bay-Delta Water Rights Hearing and automatically dismissing Phase 8 after the parties to the agreement complete and approve work plans for developing water supply projects. The parties presented an executed agreement to the SWRCB on April 4, 2001. The agreement includes a commitment by the DWR and the USBR to meet the objectives implemented under Conditions 1 and 2 in D-1641 so long as the agreement remains in effect, and for a period thereafter. This order is not based on the commitment in the agreement.

At the April 4, 2001, meeting, the SWRCB informed the parties to the agreement that, to be able to dismiss Phase 8 as requested, the SWRCB would need an independent commitment from the DWR and the USBR to meet the flow-dependent objectives for an interim period, and that the commitment could not be dependent on the agreement or on progress in implementing water supply projects pursuant to the agreement. The SWRCB further informed the parties that if it received the two projects' independent commitment to meet the objectives for an indefinite interim period and accept an indefinite extension of Conditions 1 and 2, it would (1) stay Phase 8 of the Bay-Delta Water Rights Hearing for up to eighteen months, (2) automatically dismiss Phase 8 after eighteen months had passed, (3) upon request of the DWR or the USBR at any time during the stay or after dismissal of Phase 8, convene a hearing to consider allocating responsibilities to meet the flow-dependent objectives to other parties, (4) set Conditions 1 and 2 to expire no later than two years after the request for hearing unless the SWRCB issues a further order after notice and opportunity for hearing, and (5) expedite the hearing to issue a decision within two years after the request for hearing.

The SWRCB has received the necessary commitment from the DWR and the USBR, by letter dated April 25, 2001. This order is based on that commitment. During the interim period, the SWRCB assumes that the DWR, the USBR, and other parties will conduct further negotiations. The SWRCB will take no part in the negotiations, and takes no position with respect to the direction of such negotiations.

After the DWR or the USBR requests a hearing to determine the responsibilities of the parties to meet the flow-dependent objectives, a hearing is likely to require two years or more. Therefore, an extension of Conditions 1 and 2 after the request for a hearing will help ensure that any necessary additional environmental documentation can be prepared and will ensure that the implementation of the objectives does not lapse. During any further hearing, the objectives in the 1995 Bay-Delta Plan must be met. A lapse in implementation could have serious consequences for the beneficial uses the objectives are intended to protect.[3] In the absence of a hearing, the SWRCB could not place responsibility for meeting

the objectives on a party or parties other than the DWR and the USBR.[4] Accordingly, the most reasonable approach is to retain the existing responsibilities to meet the objectives until the SWRCB is able to complete a hearing and make a decision after the hearing.[5]

A stay is appropriate for eighteen months, with the DWR and the USBR meeting the objectives. A dismissal after the stay is appropriate only if the objectives will be met for a reasonable, albeit interim, period. The DWR and the USBR will meet the objectives for an adequate period. Therefore, this order stays and dismisses Phase 8, effective eighteen months after the date of this order, unless either the DWR or the USBR requests, within eighteen months, that the SWRCB resume Phase 8. The stay and subsequent dismissal apply to proceedings to determine the responsibilities of the water right holders and water users within the watersheds of the Sacramento, Calaveras and Cosumnes Rivers to meet the flow-dependent objectives in the 1995 Bay-Delta Plan.

The administrative record of this order includes the entire evidentiary hearing record of the BayDelta Water Rights Hearing, from July 1, 1998, through April 12, 2000, and the notices and correspondence sent or received by the SWRCB regarding Phase 8 through the date of this order.

4.0 Environmental Considerations

Under the California Environmental Quality Act (CEQA) (Pub. Resources Code §§ 21000, et seq.), the SWRCB is the lead agency for preparation of environmental documentation for this order. The SWRCB has prepared and certified a final *Environmental Impact Report for the Implementation of the 1995 Bay-Delta Water Quality Control Plan* (BayDelta EIR). The BayDelta EIR fully analyzes the effects of several alternatives for assigning responsibility to water right holders in the watershed of the Bay-Delta Estuary, including Flow Alternative 2, under which the DWR and the USBR are jointly responsible for meeting all of the flowdependent objectives in the 1995 Bay-Delta Plan. D-1641 adopts Flow Alternative 2 as an interim measure, by including Conditions 1 and 2 in the water rights of the DWR and the USBR. This order amends Conditions 1 and 2 of D-1641 by extending the periods for which the requirements set forth in those conditions are effective.

CEQA contemplates that agencies may make serial decisions relying on a single EIR. (Cal. Code Regs., tit. 14, §§ 15165, 15168.) This order is one in a series of orders relying on the Bay-Delta EIR.

Except as applied to the Joint Point of Diversion and the San Joaquin River Agreement, the findings set forth in D-1641 in sections 14.3.1, 14.3.4, 14.3.5, 14.3.6, 14.3.7, 14.3.8, and 14.4 are applicable to the inclusion of Conditions 1 and 2 in the permits of the DWR and the USBR for an extended period. Those findings are incorporated herein by reference to the extent that they are applicable to this order. The SWRCB will file a Notice of Determination under CEQA after it adopts this order, and the Notice of Determination will state that this order relies on the BayDelta EIR.

ORDER

A. IT IS HEREBY ORDERED that Phase 8 of the Bay-Delta Water Rights Hearing is stayed for a period of eighteen months from the date of this order. Phase 8 will be automatically dismissed at the end of eighteen months from the date of this order unless the DWR or the USBR notifies the SWRCB in writing, before the end of the eighteen month period, that it is requesting the SWRCB to resume Phase 8.[6] The purpose of the stay and dismissal is to allow water right holders whose rights might be amended after Phase 8 to negotiate toward a mutual settlement of their responsibilities to meet the flow-dependent objectives in the 1995 Bay-Delta Plan. If the DWR or the USBR requests in writing a hearing to allocate responsibilities to meet the flow-dependent objectives to other parties, the SWRCB expeditiously will convene a water right hearing, will determine whether the water right holders in the watersheds of the Sacramento, Cosumnes, and Calaveras Rivers have responsibility to meet the flow-dependent objectives in the 1995 Bay-Delta Plan, and will determine the amount of such responsibility in a decision or order.

B. IT IS HEREBY ORDERED that License 1986 (Application 23) and Permits 11315, 11316, 11885, 11886, 11887, 11967, 11968, 11969, 11970, 11971, 11972, 11973, 12364, 12721, 12722, 12723, 12725, 12726, 12727, 12860, 15735, 16597, 16600, and 20245 (Applications 13370, 13371, 234, 1465, 5638, 5628, 15374, 15375, 15376, 16767, 16768, 17374, 17376, 5626, 9363, 9364, 9366, 9367, 9368, 15764, 22316, 14858A, 19304, and 14858B, respectively) of the United States Bureau of Reclamation and Permits 16478, 16479, 16481, 16482, and 16483 (Applications 5630, 14443, 14445A, 17512, and 17514A, respectively) of the Department of Water Resources shall be amended by revising Conditions 1 and 2 in SWRCB Decision 1641 as follows.

1. Licensee/Permittee shall ensure that the water quality objectives for municipal and industrial beneficial uses and agricultural beneficial uses for the western Delta, interior Delta, and export area as set forth in Tables 1 and 2, attached, are met on an interim basis until the Board adopts a further decision assigning responsibility for meeting these objectives. Unless it is renewed pursuant to a further order after notice and an opportunity for hearing, this condition shall expire no later than one year after the DWR or the USBR requests in writing that the SWRCB convene a water right proceeding to determine whether to replace this condition with another condition that meets the objectives in Tables 1 and 2. Any extension hearing shall be for the limited purpose of determining whether additional time is necessary, and shall not include consideration of changes in allocation of responsibility. The SWRCB shall expedite any proceeding it conducts to assign long term responsibility to meet the objectives in Tables 1 and 2, in an effort to keep the proceeding under two years. This condition does not mandate that the Licensee/Permittee use water under this license/permit if it uses other sources of water or other means to meet this condition.

2. Licensee/Permittee shall ensure that the water quality objectives for Delta outflow and for Sacramento River flow at Rio Vista for fish and wildlife beneficial uses as set forth in Table 3, attached, are met on an interim basis until the Board adopts a further decision in the BayDelta Water Rights Hearing assigning responsibility for meeting these objectives. Any extension hearing shall be for the limited purpose of determining whether additional time is necessary, and shall not include consideration of changes in allocation of responsibility. Unless it is renewed pursuant to a further order after notice and an opportunity for hearing, this condition shall expire no later than one year after the DWR or the USBR requests in writing that the SWRCB convene a water right proceeding to determine whether to replace this condition with another condition that meets the objectives in Table 3. The SWRCB shall expedite any proceeding it conducts to assign long term responsibility to meet the objectives in Table 3, in an effort to keep the proceeding under two years. This condition does not mandate that the Licensee/Permittee use water under this license/permit if it uses other sources of water or other means to meet this condition.

CERTIFICATION

The undersigned, Clerk to the Board, does hereby certify that the foregoing is a full, true, and correct copy of an order duly and regularly adopted at a meeting of the State Water Resources Control Board held on April 26, 2001.

AYES: Art G. Baggett
Pete S. Silva
Richard Katz

NOS: None

ABSTAIN: None

ORIGINAL SIGNED BY Maureen Marché
Clerk to the Board

Footnotes:

[1] From July 1, 1998 through December 21, 1999, the SWRCB conducted Phases 1 through 7 of the BayDelta Water Rights Hearing. On December 29, 1999, the SWRCB adopted Decision 1641, determining some of the responsibilities for meeting the objectives in the 1995 Bay-Delta Plan and resolving other related issues. On April 11 and 12, 2000, the SWRCB conducted a session of Phase 8 of the Bay-Delta Water Rights Hearing to consider a petition for change filed by South Sutter Water District in connection with a settlement agreement to resolve the responsibilities of water right holders on the Bear River. The SWRCB approved the petition on July 20, 2000, in Order WR 2000-10.

[2] Uncontrolled flows include both natural flow and abandoned flow.

[3] Conditions 1 and 2 require full implementation of the objectives for municipal, industrial, and agricultural beneficial uses, and require full implementation of the flow-dependent objectives for fish and wildlife beneficial uses for an interim period. The objectives protect the public interest.

[4] The hearing record for D-1641 supports continuing the implementation by the DWR and the USBR of the objectives in the 1995 BayDelta Plan as provided by this order. See, for example, the Bay-Delta EIR, which analyzes the effects of imposing Conditions 1 and 2 on the DWR and the USBR.

[5] This conclusion addresses the need to extend the responsibilities of the DWR and the USBR for an adequate interim period. This conclusion does not predetermine the allocation of responsibility after completion of any further proceedings before the SWRCB, should further proceedings become necessary. The DWR and the USBR historically have been responsible for meeting Bay-Delta objectives. SWRCB Decision 1641 continues the responsibility of the DWR and the USBR to meet the municipal, industrial, and agricultural objectives, and the flowdependent fish and wildlife objectives on an interim basis. To stay or dismiss of Phase 8, it is necessary to continue the interim requirements imposed on the DWR and the USBR. If it did not extend the responsibility of the DWR and the USBR for at least two years beyond the date when the DWR or the USBR requests resumption or initiation of a hearing, the SWRCB would have to conduct a hearing to determine whether to require a party or parties to meet the objectives pending completion of the hearing. Considering their historical involvement, the public interest in continuously implementing the objectives, their role as public entities managing vast quantities of the state's water supply, and the lack of any other means for setting interim requirements, it is reasonable to continue the responsibility of the DWR and the USBR until the SWRCB establishes other responsibilities to meet the objectives.

[6] The stay and dismissal do not apply to the following proceedings related to the Bay-Delta Proceedings:

(a) Any proceedings necessary to respond to a writ of mandate or other court order, decision or opinion issued in connection with litigation to which the SWRCB is a party.

(b) An order necessary to implement new water quality objectives or amendments to the 1995 Bay-Delta Plan.

(c) A proceeding on an issue that is sufficiently unrelated [e.g. carriage water] to the subject of long term responsibility to meet the

flow-dependent objectives in the 1995 Bay-Delta Plan that the proceeding will not adversely affect any negotiations among the parties seeking to settle their responsibilities to meet the BayDelta objectives. The SWRCB shall hold a workshop to obtain input from the parties before initiating any such proceedings.

(d) A proceeding relating to the implementation of the narrative salmon doubling objective set forth in Table 3 of the objectives in the 1995 Bay-Delta Plan. The existing D-1641 terms and conditions for fish and wildlife protection provide reasonable protection for a range of aquatic species in the Bay-Delta Estuary and help implement all of the objectives, including the narrative salmon doubling objective. Compliance with the existing flow objectives and other objectives in the 1995 Bay-Delta Plan may be sufficient to implement the salmon objective. Moreover, statutorily mandated non-flow fish restoration programs currently being implemented in other forums (e.g., CVPIA implementation and CALFED) will help implement the salmon objective. As other programs are implemented and monitored, the SWRCB will review the progress toward meeting the objective and may take additional action if needed.

Maureen Marché
Administrative Assistant to the Board.

Sacramento Valley Water Management Agreement Signatories

California Department of Water Resources

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Sacramento, CA 94236-0001

U.S. Bureau of Reclamation Mid-Pacific Region

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Contra Costa Water District

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Appendix H
Technical Memorandum #2, 2003 Technical Measurement and Monitoring Committee Summary Report

Sacramento Valley Water Management Agreement Technical Measurement and Monitoring Committee

Technical Memorandum #2 2003 Technical Measurement and Monitoring Committee Summary Report

Introduction

This report summarizes the activities of the Technical Measurement and Monitoring Committee (TMMC), as specified in Task 7 of Exhibit A, Attachment 3 to the Sacramento Valley Water Management Agreement (SVWMA) Program Scope of Work. As specified in Task 7, the TMMC Annual report will:

- Evaluate the performance of any short-term projects undertaken in 2003
- Summarize the results of initial measurement and monitoring activities during 2003
- Document the measurement and monitoring activities undertaken by short-term projects in 2003

As described in the body of this report, due to hydrological and operational circumstances occurring in 2003, no short-term projects proceeded in 2003 (although water supply commitments were proposed by Upstream Users as part of a draft Annual Operating Plan). Consequently, most of the specific deliverables identified in the SVWMA Scope of Work are not applicable. The remainder of this report describes the events that occurred during 2003, the issues considered by the TMMC, and the results of TMMC efforts.

SVWMA Background

Based on discussions in 2002, the SVWMA was expected to be in operation by the beginning of 2003, if not earlier. However, actual execution of the SVWMA did not occur until early 2003, which did not provide sufficient time to complete the necessary environmental documentation prior to project implementation. This resulted in a change in focus for the first year activities of the TMMC from that in the scope of work under the Northern California Water Agency contract with DWR.

Early in 2003, water supply conditions were dry and reservoir storage levels were low, creating interest among water users in implementing short-term projects that could supply 50,000 acre-feet of water. Sacramento Valley participants to the SVWMA began efforts to identify potential short-term programs through the

development of a draft Annual Operating Plan. At the same time, potential California Environmental Quality Act (CEQA) compliance approaches were identified. Due to the compressed time frame for implementation in 2003, development of the Short-Term Projects and completion of environmental documentation were determined to be challenging. Consequently, the Management Team determined that the program should not be implemented in 2003, but rather the initiation date be moved out two years to allow for adequate environmental review.

TMMC Activities during 2003

The initial meeting of the TMMC on March 7 included a review of its responsibilities under the SVWMA along with discussions of the required 2003 Annual Operations Plan, definition of the operational baseline, and identification of the short-term projects. The TMMC was aware that there was some question at that time about whether the short-term projects would proceed, but needed to be ready to support their implementation. A Groundwater Subcommittee was thus identified by the TMMC to take the lead with respect to development of a groundwater monitoring plan, prediction of project impacts and support for environmental documentation efforts. Members of the TMMC and the Groundwater Subcommittee are reported in Attachment 1.

At their March 31 meeting, the TMMC reviewed additional detail on potential short-term projects for Glenn-Colusa Irrigation District, Maxwell Irrigation District and Yuba County Water Agency. Operational issues and potential monitoring requirements were discussed for each possible project, along with a review of the likely permitting approach.

The initial Groundwater Subcommittee meeting was held on April 1. At this meeting, the responsibilities of the Subcommittee were reviewed and the detailed monitoring needs for the identified Short-Term Projects were discussed.

During April, water supply conditions improved dramatically and export water users indicated that they would not request the water potentially available through the Short-Term Water Supply Projects. Without an imminent need for evaluation of 2003 projects, the TMMC did not have any more meetings during 2003.

Groundwater Subcommittee Activities

The Groundwater Subcommittee of the TMMC did continue to have meetings; however, its activities shifted from monitoring program development to providing an evaluation of potential water level and related impacts for the SVWMA Short-Term Programmatic Environmental Impact Study/Report (EIS/EIR).

The focus of the Subcommittee's activity was developing an evaluation approach that could be used to evaluate stream and acquifer interaction, to assist in

quantifying available water and predict water level impacts for the purposes of subsequently developing a monitoring plan.

Superposition modeling was selected as the analytical methodology, with supplemental use of existing calibrated groundwater models where available and as applicable (as in the Stony Creek Fan and Yuba County). Superposition modeling allows detailed specification of program geometry and stratigraphy, without requiring identification of all background groundwater pumping, recharge and discharge. An advantage of the superposition modeling is that its output can be interpreted to identify potential impacts which, in turn, can serve as a basis for developing a monitoring program for ultimate measurement of actual impacts (and comparison to predicted impacts as appropriate). Superposition modeling provides information on potential groundwater level and direct stream-aquifer impacts that will be utilized in the environmental documentation. A description of the Superposition Modeling approach used by the Groundwater Subcommittee in contained in Attachment 2. This quantitative approach was not originally envisioned as part of the assessment process, but was selected by the Subcommittee to be a necessary and useful step to assessing stream/aquifer interaction and potential local and regional impacts, and to provide a basis for the development of a monitoring approach and plan. A presentation summarizing the overall proposed evaluation (including modeling) approach was made to the Management Team on September 15, 2003 (Attachment 3).

In addition to development of the Superposition Modeling analysis, the Groundwater Subcommittee also began development of a quasi-quantitative analysis of aquifer recharge, after pumping cycles, based on historical groundwater basin conditions following selected short-term localized pumping activities. The Subcommittee also reviewed prior monitoring programs in the Sacramento Valley, discussed potential monitoring needs and reviewed other available groundwater modeling activities in the Sacramento Valley. Updated descriptions of likely Short-Term Water Projects were reviewed in detail.

Next Steps

As described above, the TMMC's activities were considerably different than anticipated, primarily due to the deferral of Short-Term Water Supply Projects. A proposed revised scope of work for the TMMC is being prepared to reflect the change in project implementation schedule and the increased emphasis on support of the ongoing environmental analyses. The revised scope of work will be submitted to the Management Committee for consideration in 2004. In addition, during 2004, the TMMC activities will include the following:

- In cooperation with DWR and USBR design and, to the extent practicable, implement a monitoring program to provide information on pre-project conditions.

- Propose monitoring well specifications and measurement and monitoring protocols for groundwater levels and other selected parameters, e.g. groundwater quality, stream stage and/or flow, surface water quality, land subsidence, etc.
- Summarize the results of initial measurement and monitoring activities during 2004.
- Coordinate with local project sponsors to design and, to the extent practicable, implement project-specific monitoring programs for projects expected to be implemented in 2005.
- Complete input to the development of the EIS/EIR.

ATTACHMENT 1

Technical Measurement/Monitoring and Groundwater Subcommittee List of Members

Technical Measurement/Monitoring Committee Members

Marc Van Camp/MBK Engineers
Terry Erlewine/State Water Contractors
Laura King Moon/State Water Contractors
Jim Snow/WWD
Tom Bettner/WWD
Tom Boardman/MWD
Mary Wells/TCCA
Tom Barandes/NCMWC
Tracy Slavin/USBR
Jerry Johns/DWR
John Fielden/DWR
C. Creel/DWR
J. Leahigh/DWR
Dave Schuster/SWRI
Steve Grinnell/MWH
Roger Putty/MWH
Gary Nuss/CH2M HILL
Mark Oliver/CH2M HILL

Groundwater Subcommittee Members

Joe Scalmanini/Luhdorff & Scalmanini
Terry Erlewine/State Water Contractors
John Fielden/DWR
Toccoy Dudley/DWR
George Matanga/USBR
Bob Niblack/DWR
William Shipp/USBR
Steve Grinnell/MWH
Roger Putty/MWH
Fritz Carlson/CH2M HILL
Peter Lawson/CH2M HILL

ATTACHMENT 2

Groundwater Model Documentation

1.0 Model Objectives

The Sacramento Valley Water Management Program (SVWMP) is a collaborative program involving numerous State and Federal Agencies and water districts. The SVWMP is seeking to improve the reliability of water supply throughout the Sacramento Valley by implementing conjunctive water management (CWM) projects. Two oversight committees were developed to provide guidance in evaluating the potential benefits and impacts of implementing such projects: the Technical Measurement and Monitoring Committee, and the Groundwater Subcommittee. These two committees include agency, water district, and consultant experts (see Attachment 1 for a list of members).

The two most critical potential impacts from additional groundwater pumping are depression of local groundwater levels and changing the hydraulic relationship between the surface water and groundwater systems in the area. Two primary impacts can potentially occur to surface streams. The first is interception and resultant reduction of groundwater discharge to surface streams. The second is reversing the direction of the hydraulic gradient between the aquifer and the surface stream, resulting in direct leakage from the stream to the underlying aquifer. The timing of these impacts is critical, especially in the case of potential surface water impacts, because acceptable impacts to surface water flows at one time of year may be unacceptable during others. Given the absence of an accepted holistic analytical approach, a numerical groundwater modeling tool was developed to evaluate the impacts of CWM projects proposed in the SVWMP on groundwater levels and stream flows near the proposed project sites. Specific objectives of the modeling effort include:

- Development of a regional-scale superposition model covering the Sacramento Valley groundwater basin
- Quantification of both cumulative and project-specific impacts to streams resulting from the implementation of actions proposed in the SVWMP
- Calculation of program-wide and project-specific drawdown in groundwater levels resulting from the implementation of CWM projects

The final component of the groundwater system that will be analyzed is the recharge characteristics of the groundwater basin over the winter months. Historical data suggest that during past groundwater substitution projects, water levels that were depressed due to project pumping fully recovered by the start of the following irrigation season. A combination of historical water level data and model simulations will be used to estimate the basin response to pumping from year to year.

2.0 Geologic Setting

The Sacramento Groundwater Basin is a north-northwestern trending asymmetrical trough filled with as much as 10 miles of both marine and continental rocks and sediment (Page, 1986). On the eastern side, the basin overlies basement bedrock that rises relatively gently to form the Sierra Nevada; on the western side, the underlying basement bedrock rises more steeply to form the Coast Ranges. Overlying the basement bedrock are marine sandstone, shale, and conglomerate rocks, which generally contain brackish or saline water. The more recent continental deposits overlying the marine sediments contain fresh water. These continental deposits are generally 2,000 to 3,000 feet (ft) thick (Page, 1986). The depth to the base of fresh water typically ranges from 1,000 to 3,000 ft below ground surface (bgs) (Bertoldi et al., 1991).

In the Sacramento Valley Groundwater Basin, groundwater users pump primarily from deeper continental deposits. Groundwater is recharged by deep percolation of applied water, rainfall infiltration from streambeds, and lateral inflow along the basin boundaries. The quantity and timing of snowpack melt are the predominant factors affecting the surface water and groundwater hydrology, and peak runoff in the basin typically lags peak precipitation by 1 to 2 months (Bertoldi et al., 1991). The main surface-water feature in the Sacramento Groundwater Basin is the Sacramento River, which has several major tributaries draining the Sierra Nevada, including the Feather River, Yuba River, and American River. Stony Creek, Cache Creek, and Putah Creek, draining the Coast Range, are the main west-side tributaries of the Sacramento River.

3.0 Model Design

3.1 Model Code Description

MicroFEM (Hemker, 1997), an integrated groundwater modeling package developed in the Netherlands, was chosen by the Groundwater Subcommittee to simulate the groundwater flow system in the Sacramento Valley. The current version of the program (3.60.15) has the ability to simulate up to 25 layers and 250,000 surface nodes. MicroFEM is capable of modeling saturated, single-density groundwater flow in layered systems. Horizontal flow is assumed in each layer, as is vertical flow between adjacent layers. A layered aquifer system or different aquifers within a multiple-aquifer system can be modeled in this manner.

In addition to there currently being no universally accepted tool or approach to evaluating benefits and impacts, the MicroFEM model was selected for the following reasons:

- The finite-element scheme allowed the construction of a model grid covering over 5,955 square miles (9,589 square kilometers [km^2]) with a coarse node spacing outside of the simulated project areas and a finer node spacing within areas of high project density. The finer node spacing near simulated extraction wells provides greater resolution of simulated groundwater levels and stream impacts.

- The graphical interface allows rapid assignment of aquifer parameters and allows proofing of these values by graphical means.

3.2 Model Construction

3.2.1 Model Grid

The Sacramento Valley CWM projects were evaluated using a six-layer, transient superposition model. The premise of this type of model is that all existing groundwater sources and sinks represent baseline conditions and are not explicitly simulated in the model. The impacts identified by this modeling effort will be only those created by project operations and will not reflect forecasts of the total groundwater or stream impacts that will be experienced in the Sacramento Valley.

The Sacramento Valley model grid consists of 152,261 nodes and 304,011 elements. Nodal spacing varies from 6,562 ft (2,000 meters [m]) near the model boundary and in areas with no or few CWM projects to 410 ft (125 m) in areas with a high density of projects (Figure 1). Thirteen zones of refined nodal spacing are located throughout the model domain, where projects or groups of projects in close proximity are located. The finer spacing in the area of interest allows for a more refined estimate of the groundwater levels and groundwater/surface water interaction in the project areas. The model boundary represents the extent of the fresh water aquifer in the Sacramento Valley.

The total model thickness represents the thickness of the fresh water aquifer (approximately 3,000 micromhos/cm) as defined by Berkstresser (1973). Contour lines of the base of fresh water, along with measurements from borings were digitized and used to generate an x,y,z file containing the elevation of the base of fresh groundwater at regularly spaced intervals. The elevation (z) of the base of fresh groundwater was then subtracted from the land surface elevation at all x,y locations to produce a total aquifer thickness distribution. This total thickness was assigned to every node in the model and subsequently divided into six layers. The default layering system was designed such that the first five layers have a total thickness of 750 ft (Layer 1 = 0 to 50 ft bgs, Layer 2 = 50 to 150 ft bgs, Layer 3 = 150 to 250 ft bgs, Layer 4 = 250 to 350 ft bgs, Layer 5 = 350 to 750 ft bgs). Any thickness in excess of 750 ft was apportioned to Layer 6 (750 ft bgs to the base of fresh groundwater). The assumed thicknesses for Layers 1 through 5 are based on typical screened intervals of wells in the Sacramento Valley. In areas where the total aquifer thickness was less than 750 ft, Layer 6 was assigned a thickness of 3.281 ft (1 m) and Layers 1 through 5 were assigned a value based on the ratio of layer thickness to a total thickness of 750 ft in the default layering scenario (Layer 1 = 50 ft/750 ft or 6.67 percent; Layers 2, 3, and 4 = 100 ft/750 ft or 13.3 percent; and Layer 5 = 400 ft/750 ft or 53.3 percent). For example, if the total thickness at a model node were 400 ft, individual layer thickness would be approximately 27 ft (Layer 1), 53 ft (Layers 2, 3, and 4), 211 ft (Layer 5), and 3 ft (Layer 6). This approach enabled relative ratio of layer thickness to be maintained as the total thickness decreased toward the model boundary.

3.2.2 Boundary Conditions

Boundary conditions are mathematical statements describing either the head or the flux at specific locations within the model domain (Anderson & Woessner, 1992). Boundary conditions can represent either physical boundaries, such as impermeable rock, or hydraulic

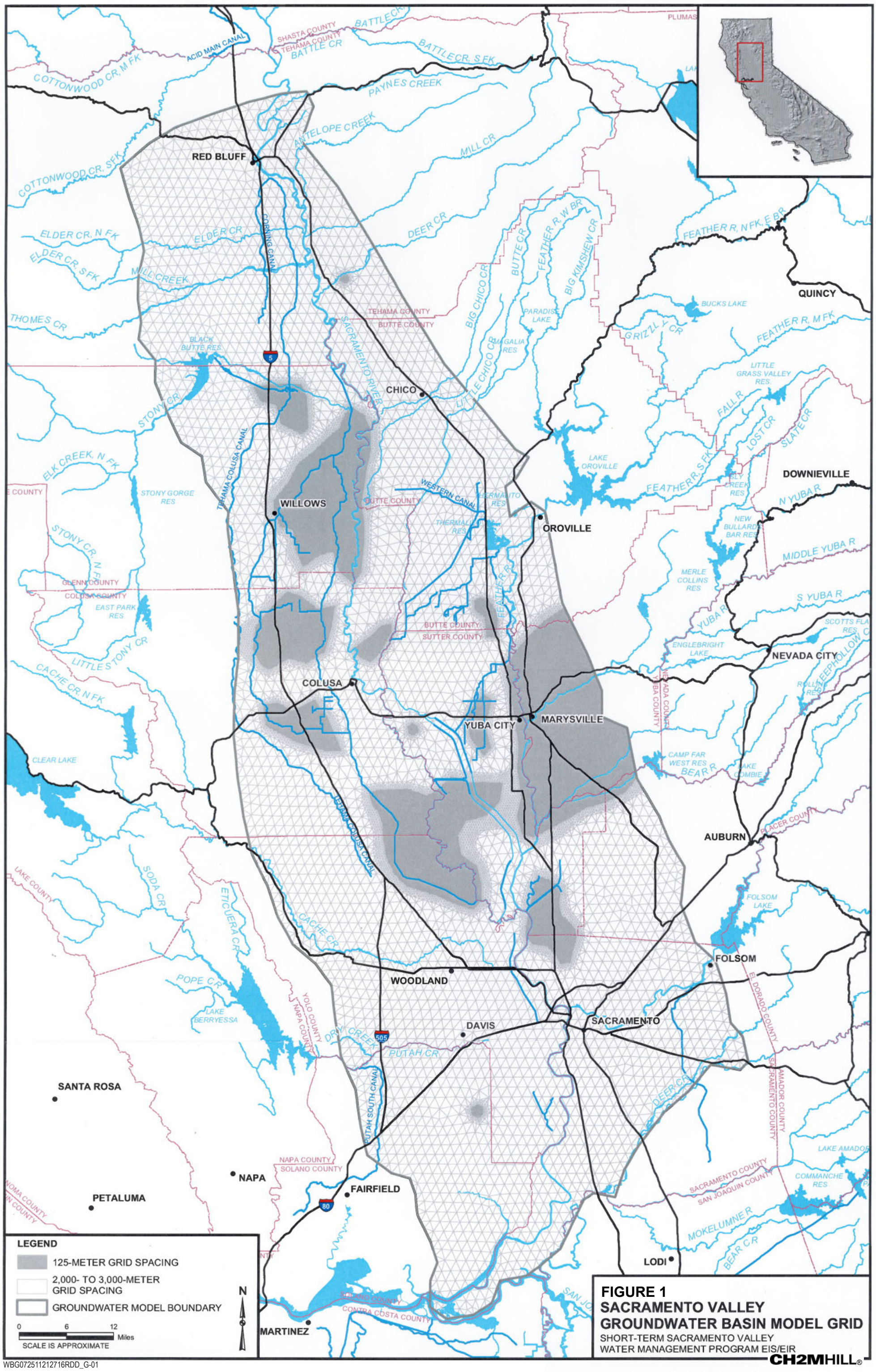

FIGURE 1
SACRAMENTO VALLEY GROUNDWATER BASIN MODEL GRID
SHORT-TERM SACRAMENTO VALLEY WATER MANAGEMENT PROGRAM EIS/EIR

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boundaries, such as groundwater divides or streamlines. The three types of boundary conditions include: specified head boundaries, where a constant head is defined along the boundary; specified flow boundaries, where a constant flux is defined along the boundary; and head-dependent flow boundaries, where the flux across the boundary is calculated as a function of a calculated head gradient and a conductance term, which regulates seepage.

A head-dependent boundary condition was chosen to simulate streams within the Sacramento Valley. The MicroFEM river system was used to implement streams within the model domain. MicroFEM's river package calculates the magnitude and direction of nodal fluxes based on the relative values of stream stage (rh1) and the head in the aquifer (h1) as follows:

Stream discharge to the aquifer will occur if h1<rh1:

$$Q_{inflow} = a * (rh1-h1)/ \left| ri1 \right|, \text{ where a = nodal area} \quad (1)$$

Stream recharge will occur if h1 > rh1:

$$Q_{outflow} = a * (h1-rh1)/ \left| rc1 \right| \quad (2)$$

Nodal area is a grid-dependent parameter that can be automatically calculated within MicroFEM. In general, the nodal area is greater than the river surface area. The effective resistance terms (rc1 and ri1) incorporate an areal correction to account for this discrepancy. Additionally, river resistance terms account for the relationship between the streambed sediments and aquifer properties in the upper half of Layer 1 when calculating stream seepage. River resistances are calculated, using the following equation:

$$rc1 \text{ or } ri1 = ((Dr/Kr) +((0.5 * mt1)/Kv1))* (a/LW) \quad (3)$$

where:

Dr = thickness of streambed sediments

Kr = vertical hydraulic conductivity of streambed sediments

mt1 = thickness of Layer 1

Kv1 = vertical hydraulic conductivity of Layer 1

A = nodal area

L = stream length within the model node

W = width of the wetted river channel in nodal area

Streams included in the model were selected according to size and location with respect to Phase 8 CWM projects (Figure 2). Table 1 contains a list of streams simulated in the model. Stream locations were digitized from existing basemaps and imported into the model grid. Stream length within a given node is a grid-dependent variable calculated by MicroFEM at each river node. The stream length term is generally overestimated by MicroFEM at stream confluences. Manual corrections of this term were made where necessary. Streambed thickness was assumed to be 3.281 ft (1 m) for all river nodes. The remaining components of the effective resistance parameter vary by stream; values for each are listed in Table 1.

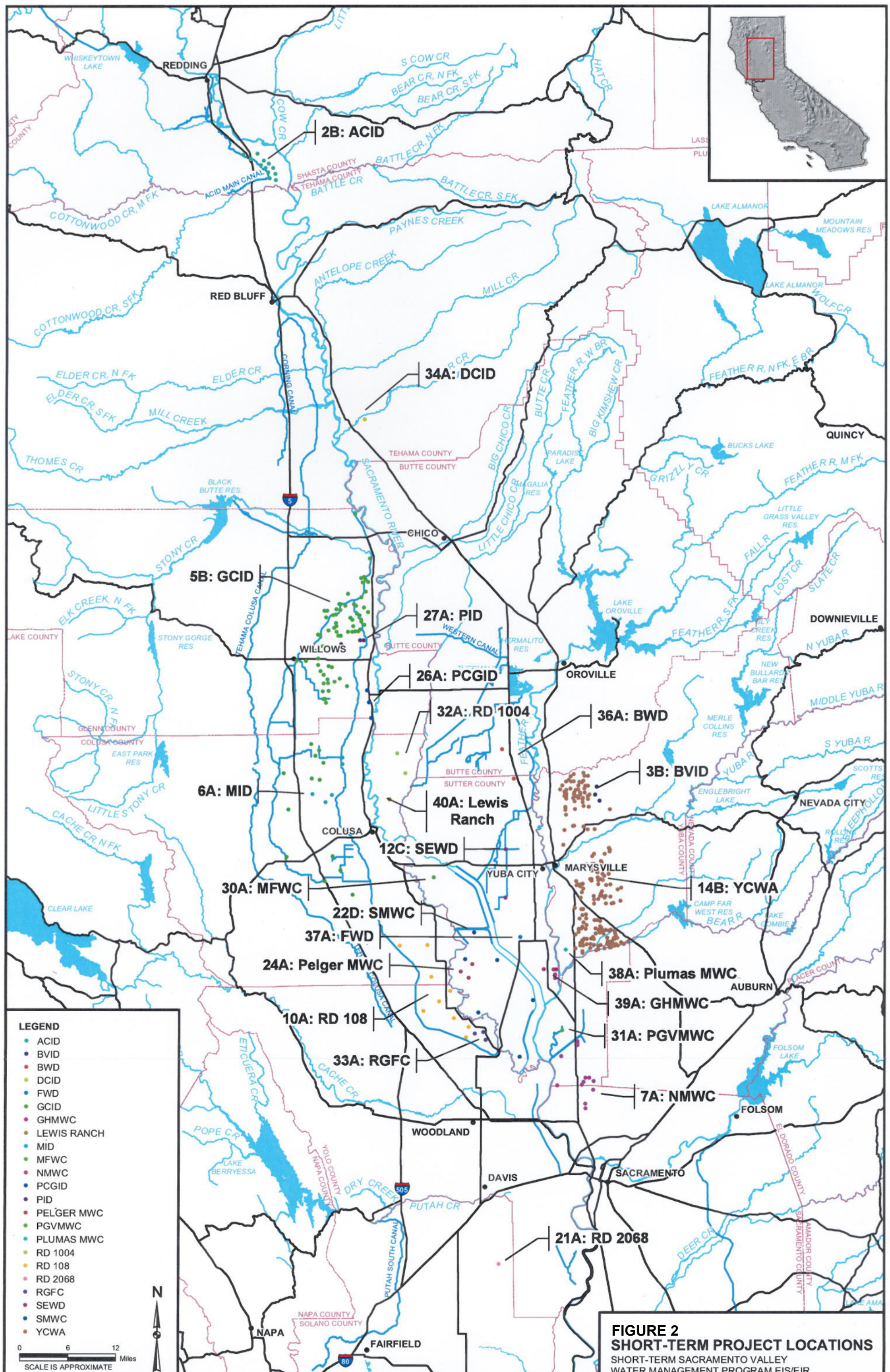

FIGURE 2
SHORT-TERM PROJECT LOCATIONS
SHORT-TERM SACRAMENTO VALLEY
WATER MANAGEMENT PROGRAM EIS/EIR

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Assumptions of vertical hydraulic conductivity (Kv) of streambed sediments were based on the type of streambed deposits expected for a given stream size. Wetted stream width was calculated from aerial photographs along each stream.

A no-flow boundary was used along the margins of the model domain to simulate the lateral extent of sediments in fresh water in the Sacramento Valley.

TABLE 1
Components of River Resistance Term
Groundwater Model Documentation

Stream Name	Streambed Kv (ft/day)	Minimum Wetted Stream Width (ft)	Maximum Wetted Stream Width (ft)
American River	1.00	181.39	461.60
Angel Slough	0.10	20.67	20.67
Antelope Creek	0.10	21.96	21.96
Bear River	0.10	80.41	100.76
Big Chico Creek	0.10	46.29	74.49
Butte Creek	0.10	63.94	98.07
Cache Creek	0.10	31.22	120.78
Colusa Basin Drain	0.03	32.83	124.98
Consumnes River	0.10	42.31	42.31
Deer Creek - Sac. Co.	0.10	39.72	39.72
Deer Creek - Tehama Co.	0.10	39.72	43.60
Dry Creek - Yolo Co.	0.10	29.82	29.82
Dry Creek - Yuba Co.	0.10	14.75	38.11
Elder Creek	0.10	40.05	83.32
Feather River	1.00	115.83	670.98
French Creek	0.10	19.38	21.96
Funks Creek	0.10	26.59	51.13
GCID Canal	0.03	46.29	100.44
Little Chico Creek	0.10	20.67	20.67
Mill Creek - Tehama Co.	0.10	30.14	56.73
Mill Creek - Thomes Branch	0.10	26.58	26.58
Mokelumne River	1.00	71.48	685.62
North Fork Walker Creek	0.10	19.38	19.38
North Mokelumne River	1.00	126.60	467.20
Paynes Creek	0.10	11.52	31.22
Putah Creek	0.10	24.33	73.52
Sacramento River	1.00	283.44	2684.78
Salt Creek	0.10	10.55	67.28
San Joaquin River	1.00	2689.09	2689.09
Sand Creek	0.10	8.50	21.64
Sevenmile Creek	0.10	25.30	25.30
South Fork Walker Creek	0.10	26.59	35.42
South Fork Willow Creek	0.10	11.52	29.17
Stone Corral Creek	0.10	38.11	51.13
Stony Creek	1.00	86.33	207.66

TABLE 1
Components of River Resistance Term
Groundwater Model Documentation

Stream Name	Streambed Kv (ft/day)	Minimum Wetted Stream Width (ft)	Maximum Wetted Stream Width (ft)
Thomes Creek	1.00	26.59	228.32
Walker Creek	0.10	17.44	46.94
Willow Creek	0.10	20.67	30.46
Wilson Creek	0.10	18.41	35.42
Yuba River	1.00	144.04	148.66

3.2.3 Aquifer Properties

A limited amount of quantitative information is available regarding aquifer properties in the Sacramento Valley. The sources of information used to develop the initial groundwater flow model are reports prepared by the California Department of Water Resources (the Department) and the U.S. Geological Survey. The distribution of aquifer transmissivity used in the Sacramento Valley model was derived from that reported by Bloyd (1978). Polygons, representing the reported transmissivity distribution, were first digitized into an electronic format, then sampled at 164 ft (50 m) centers to produce an x,y,z file containing aquifer transmissivity at 50-m intervals. It was assumed that the published transmissivity reflects the upper 750 ft of saturated sediments; therefore, the reported transmissivity was divided by 750 ft to obtain the horizontal hydraulic conductivity at every model node. The hydraulic conductivity was then multiplied by the thickness of each layer, resulting in a corrected transmissivity value at each model node. In areas with less than 750 ft of fresh water thickness, the reported transmissivity value was assumed to represent the total transmissivity for the available thickness of the fresh water aquifer at that location. The transmissivity for each layer was then assigned based on the percentage of total aquifer thickness represented by that layer.

There were regions where the study area of Bloyd (1978) did not cover an area equal to or greater than the Sacramento Valley model; therefore, no published transmissivity data was available at these locations. In these instances, transmissivity was calculated and assigned by using the hydraulic conductivity value of the nearest model node for which there was data available. A map of the total transmissivity for all model layers can be found in Figure 3.

The method for assigning transmissivity values described above was also used to assign specific yield values to Layer 1, using specific yield values reported by Bloyd (1978). A uniform specific storage of $2x10^{-6}$ per foot of aquifer thickness was assumed for Layers 2 through 6. An initial ratio of 100:1 between horizontal and vertical hydraulic conductivity was assumed throughout the model domain.

3.2.4 Distribution of Groundwater Pumping

Twenty-one proposed CWM projects were simulated with the Sacramento Valley model (Figure 2). Prior to and during model construction, information was gathered regarding the groundwater component of each project (number, location, target pumping rates, and construction details of existing and proposed extraction wells), the maximum annual project

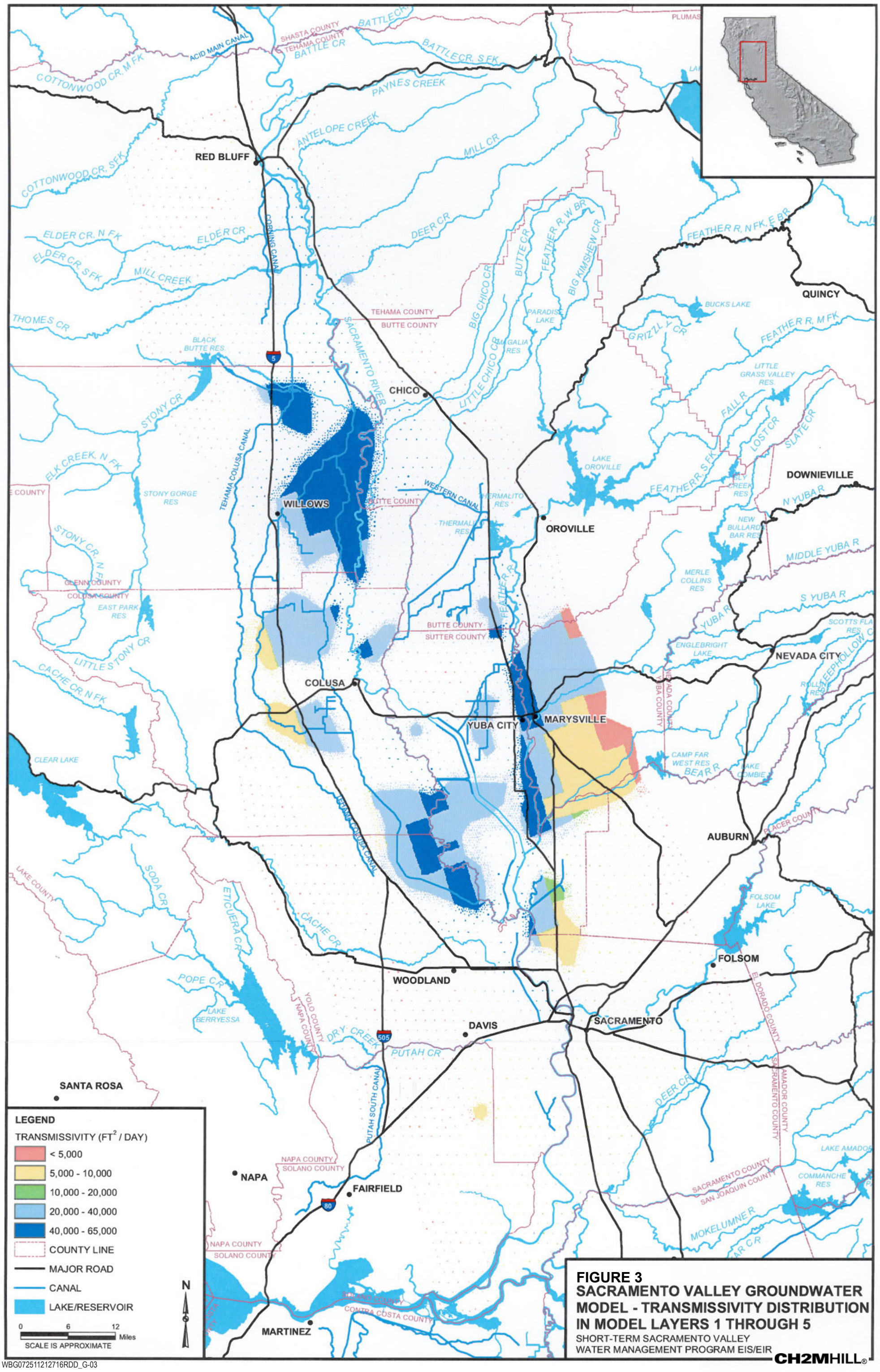

FIGURE 3
SACRAMENTO VALLEY GROUNDWATER MODEL - TRANSMISSIVITY DISTRIBUTION IN MODEL LAYERS 1 THROUGH 5
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supply, and the operation schedule for all projects. Data sources included the Department, individual water districts and their consultants, grant proposals, and the SVWMA Short-Term Workplan. Despite efforts to obtain the most current and accurate information, extensive data was not available for all projects. In such cases, baseline assumptions regarding the project were prepared. A summary of each project is located in Table 2.

Reported operation schedules ranged from two to six months in length, spanning a variety of schedules between April and October. In order to incorporate all 21 CWM projects into the model, it was assumed that all projects would operate 24 hours per day for a 153 day period (June – October). Other simplifying assumptions regarding the distribution of groundwater pumping include:

- Where screen interval information was available, pumping was proportioned vertically to match the relative screen length in each model layer.
- Where screen interval information was not available, pumping was assigned to the model layers representing depths from which typical agricultural wells in the project area produce.
- If target pumping rates were specified by the water districts or other sources, those rates were used in the model. In some cases, it was necessary to modify the reported pumping rate due to differences between the supplied operation schedule and the model's assumed operation period of 153 days.
- If target pumping rates were not available, the rate necessary to achieve the annual project supply was assigned equally to all extraction wells.
- In some instances, the reported pumping rates were either not sufficient to meet the annual project supply or the estimated pumping rates would be unrealistically high given the reported number of extraction wells. In these cases, additional well locations were incorporated into the model such that realistic pumping rates were assumed for the 153 day operation period.

Table 2 outlines the differences between reported project design and how each project was simulated in the model. Figure 2 shows the locations of extraction wells incorporated in the model.

4.0 Model Simulations

The model calculation consists of three stress periods. The first represents the 153 day period from June through October. During this period, all CWM projects are actively extracting groundwater. The model next simulates a post-pumping recovery period of approximately 61 days. This period represents the time in November and December when agricultural pumping has stopped and substantial groundwater recharge resulting from the rainy season has not yet begun. The final period represents the remainder of the year from January through the end of May. During this period there is continued recovery of ground-water levels and recharge from precipitation. Drawdown and stream leakage rates are calculated at the end of each stress period. Multiple model simulations were run in this

TABLE 2
Summary of Supplied Project Information vs. Model Implementation
Groundwater Model Documentation

Project Index	Proponent	Groundwater Component Description	Maximum Project Supply (ac-ft)	Target Pumping Rate (gpm)	Screened Interval (ft bgs)	Number of Wells Simulated	Simulated Pumping Rate (gpm)
Redding Sub-basin							
2B	ACID	Installation of 12 production wells	20,000	2,000 to 3,500	200 to 500	12	2,450
Feather/Butte Sub-basin							
32A	RD 1004	Install one well	1,000	4,000	350-450[a]	1	1,500
36A	Butte Water District	Installation of two groundwater extraction wells.	7,400	4,000	150 to 660 (two screen intervals per well)	3	3,650
37A	Feather Water District	Installation of one extraction well[a]	1,000[a]	1,500[a]	350-450[a]	1	1,500
39A	Garden Highway Mutual Water Company	Installation of one extraction well[a]	1,000[a]	1,500[a]	350-450[a]	1	1,500
12C	Sutter Extension Water District	Installation of two groundwater extraction wells. Nine MWs, three sites nested	7,400	4,000	150-390 and 520-680 (two screen intervals per well)	3	3,650
40A	Lewis Ranch	Installation of up to four groundwater extraction wells.	2,000	1,000 to 2,000	350 to 450	4	750
Colusa Sub-basin							
5B	Glen Colusa Irrigation District	Full utilization of private landowner wells used in the 2001 Forbearance Agreement (up to 71 wells). 20 MWs.	30,000	1,000 to 5,000	20 to 685	71	31 to 1,488
6A	Maxwell Irrigation District	Installation of up to three production wells	13,000	5,000 to 5,600	600 to 800	5	3,600-5,000
10A	RD 108	Development of five production wells and analysis of basin response	20,000	2,000 to 3,500	600 to 700	9	3,300

TABLE 2
Summary of Supplied Project Information vs. Model Implementation
Groundwater Model Documentation

Project Index	Proponent	Groundwater Component Description	Maximum Project Supply (ac-ft)	Target Pumping Rate (gpm)	Screened Interval (ft bgs)	Number of Wells Simulated	Simulated Pumping Rate (gpm)
26A	Princeton-Codora-Glenn Irrigation District (PCGID)	Construct three groundwater extraction wells	5,000	2,500	150-250[a]	3	2,500
27A	Provident Irrigation District (PID)	Construct three groundwater extraction wells	5,000	2,500	150-250[a]	3	2,500
33A	River Garden Farms	Construct three groundwater extraction wells (one already installed, other two awaiting funding)	5,000	1,500 (existing well); 2,500 to 3,000 (2 additional wells)	365 to 570	3	1,500-3,000
34A	Deer Creek ID	Installation of one extraction well[a]	1,000[a]	1,500[a]	150-250[a]	1	1,500
Yuba Sub-basin							
14AB	Yuba County Water Agency (YCWA)	Use of 189 existing wells.	15,000	1,000 to 4,000	119.25[a]	189	119.25
38A	Plumas Mutual Water Company	Installation of one extraction well[a]	1,000[a]	1,500[a]	150-250[a]	1	1,500
Sutter Sub-basin							
22D	Sutter Mutual Water Company	Installation of five additional monitoring wells, monitoring and data collection (feasibility study). One well in corner of district.	5,000	1,500 to 1,800	800-850	5	1,500
24A	Pelger Mutual Water Company	Installation of three extraction wells	1,000	500	127-250[a]	3	500
30A	Meridian Farms	Installation of one extraction well	1,500	3,000	150-250[a]	1	2,225
American Sub-basin							

TABLE 2
Summary of Supplied Project Information vs. Model Implementation
Groundwater Model Documentation

Project Index	Proponent	Groundwater Component Description	Maximum Project Supply (ac-ft)	Target Pumping Rate (gpm)	Screened Interval (ft bgs)	Number of Wells Simulated	Simulated Pumping Rate (gpm)
7A	Natomas Central Mutual Water Company	Pump 13 existing wells, monitoring and analyzing results after one season	15,000	800 to 3,500	150-300 (11 wells) 400-500 (2 wells) based on well logs in the area	13	680-2,975
31A	Pleasant-Grove-Verona Water	Installation of one extraction well[a]	1,000[a]	1,500[a]	150-250[a]	1	1,500
Delta Sub-basin							
21A	RD 2068	Develop a single production well to determine conjunctive use potential	2,000	1,000 to 2,000	300 to 500	1	3,000

Notes:

[a] Denotes an Assumed Project Component

manner to evaluate the effects of varying streambed and aquifer properties on drawdown and stream leakage.

Typical model output that can be used to support decision making for the overall program include:

- Groundwater contour maps at various times and at different depths in the aquifer
- Groundwater hydrographs that show the variation in groundwater levels over time at a particular location and depth in the aquifer
- The magnitude of the hydraulic gradient between the surface water and groundwater systems at various location across the model due to project pumping
- The spatial variability of stream impacts – i.e., the combined quantity of groundwater flow that would have discharge to a surface stream that was intercepted by project pumping along with any direct leakage from the river induced by the project (with the modeling techniques used here, these two components can not be individually estimated)

The results of the groundwater modeling analysis are in progress and will be presented under separate cover during the first quarter of 2004.

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