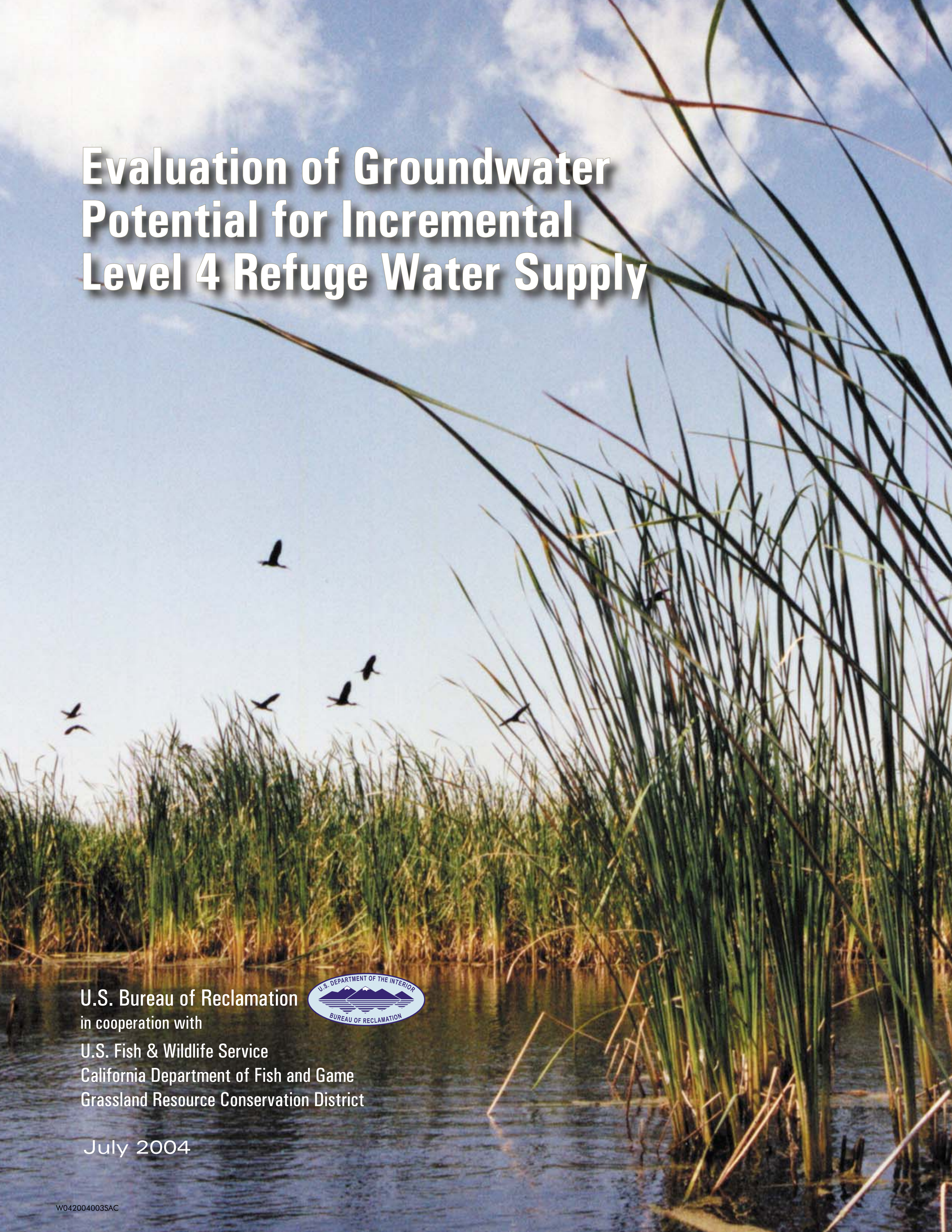

Evaluation of Groundwater Potential for Incremental Level 4 Refuge Water Supply

U.S. Bureau of Reclamation
in cooperation with
U.S. Fish & Wildlife Service
California Department of Fish and Game
Grassland Resource Conservation District

July 2004

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Cover photograph taken by Dale Garrison, USFWS

Acronyms and Abbreviations

µg/L	micrograms per liter
µmhos/cm	micro mhos per centimeter
ac-ft	acre-feet
AFB	Air Force Base
ASAR	adjusted sodium absorption ration
bgs	below ground surface
BMO	Basin Management Objectives
CALFED	California Bay-Delta Authority
CC	canal company
CCC	criterion continuous concentration
cfs	cubic feet per second
Cr(VI)	hexavalent chromium
CVGSM	Central Valley Ground-Surface Water Model
CVP	Central Valley Project
CVPIA	Central Valley Project Improvement Act
CVRWQCB	Central Valley Regional Water Quality Control Board
DBCP	dibromochloropropane
DFG	California Department of Fish and Game
DHS	California Department of Health Services
DOI	U.S. Department of the Interior
DW	domestic well
DWR	California Department of Water Resources
DWR DPLA	California Department of Water Resources, Division of Planning and Local Assistance
EC	electrical conductivity
EIS	environmental impact study
ESA	Endangered Species Act

Exchange Contractors	San Joaquin River Exchange Contractors Water Authority
FERC	Federal Energy Regulatory Commission
GIS	Geographic Information Systems
gpm	gallons per minute
GPS	global positioning system
hp	horsepower
ID	irrigation district
IDS	internal distribution system
IW	irrigation well
MAGPI	Merced Area Groundwater Pool Interests
MCL	maximum concentration limit
mg/kg	milligrams per kilogram
mg/L	milligrams per liter
MOU	memorandum of understanding
MW	monitoring well
NAWQA	National Water Quality Assessment Program
NEPA	National Environmental Policy Act
NHI	Natural Heritage Institute
NRCS	Natural Resources Conservation Service
NWR	National Wildlife Refuge
PG&E	Pacific Gas & Electric Company
PEIS	Programmatic Environmental Impact Statement
ppb	parts per billion
PVC	polyvinyl chloride
RCD	resource conservation district
RD	reclamation district
Reclamation	U.S. Bureau of Reclamation
Service	U.S. Fish and Wildlife Service
SJRGA	San Joaquin River Group Authority
SR	State Route

SWP	State Water Project
SWRCB	State Water Resources Control Board
TDS	total dissolved solids
TMDL	total maximum daily load
TW	test well
UC	University of California
USDA	U.S. Department of Agriculture
USEPA	U.S. Environmental Protection Agency
USGS	U.S. Geological Survey
VAMP	Vernalis Adaptive Management Plan
WA	State of California Wildlife Management Area
WAP	Water Acquisition Program
WC	water company
WSD	water storage district
WD	water district
WRIME	Water Resources and Information Management Engineering, Inc.

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Executive Summary

Nineteen wildlife refuges in the Sacramento and San Joaquin Valleys of California were evaluated for the potential to use groundwater to reduce the current dependence on annual (spot-market) acquisitions and meet a portion of Incremental Level 4 water supplies. Insufficient data were available at each refuge to recommend new or increased development of groundwater, but available data enabled refuges to be prioritized for further investigation. Six refuges were identified as having the highest potential for successful on-refuge direct use and/or conjunctive use of groundwater. It is recommended that current data be collected at these first-priority refuges to determine if conditions are favorable for groundwater development. If results are favorable, additional data may be acquired at other refuges, including four second-priority refuges to assess potential groundwater development. In addition to potential refuge development, four off-refuge conjunctive use projects were identified for potential partnership opportunities. Finally, to provide a regional groundwater benefit, two multiple-refuge projects were recommended for future consideration.

The refuges included in this evaluation are those identified specifically in the 1992 Central Valley Project Improvement Act (CVPIA) and include National Wildlife Refuges (NWR), State of California Wildlife Management Areas (WA), and the Grassland Resource Conservation District (Grassland RCD). The refuges are:

- Sacramento NWR
- Delevan NWR
- Colusa NWR
- Sutter NWR
- Gray Lodge WA
- San Luis NWR Complex (including the San Luis, West Bear Creek, East Bear Creek, Kesterson, and Freitas Units)
- Merced NWR
- Los Banos WA
- Volta WA
- North Grasslands WA (including the China Island and Salt Slough Units)
- Mendota WA
- Grassland RCD
- Pixley NWR
- Kern NWR

Approach

Using existing available information, conditions at each refuge were evaluated, resulting in recommendations for acquisition of critical additional data, opportunities for increased direct onsite groundwater use and onsite conjunctive use, and potential partnerships with offsite refuge conjunctive use projects. Specific physical criteria (such as aquifer characteristics, water quality conditions, and success of groundwater use at the refuge) and non-physical criteria (existing groundwater management, availability of spot-market water, and use of the Delta for refuge water conveyance) were used to assess which refuges had potential for developing implementable groundwater projects. Three overall types of groundwater projects were considered during this evaluation. These were:

- *Direct Use*—on-refuge use of new or existing wells to pump groundwater without intentional (or active) recharge
- *On-Refuge Conjunctive Use*—on-refuge use of new or existing wells to pump groundwater in addition to direct or in-lieu groundwater recharge
- *Off-Refuge Conjunctive Use*—regional groundwater banking projects where partnerships with organizations developing groundwater banking projects are created to support supply of reliable Level 4 refuge water

Preliminary analysis of these types of projects was conducted for the 19 refuges using the following approach:

- *Refuge Water Use and Local and Regional Groundwater Conditions Assessment*—summarized and assessed the historic and current water use, water quality data, and local and regional groundwater conditions for each groundwater basin, subbasin, and refuge
- *Initial Screening*—developed and applied evaluation criteria to the refuge assessment to develop a score, identified and evaluated potential direct use and on-refuge conjunctive use projects, and provided an overview of off-refuge regional conjunctive use groundwater projects for which partnerships could be established
- *Data Gaps Identification*—identified data gaps and additional work efforts needed in subsequent evaluation of potential direct use and on-refuge conjunctive use projects
- *Potential Projects Summary*—used the initial screening and data gaps identification to evaluate which refuges have a higher potential for development of direct use and/or on-refuge conjunctive use projects that could be implemented either in 1 to 5 years or in a longer-term time period of more than 5 years.

Findings

Available groundwater data from each refuge were insufficient or not recent enough to enable recommendations for implementation of groundwater development. Data were sufficient to prioritize additional data collection activities. Additionally, participation in off-refuge projects at Stony Creek Fan, Myers Farm, Semitropic WSD Water Bank, and other recharge projects in the Merced area were identified as potential partnerships to consider to supply Level 4 refuge water.

Specific recommended actions are:

- Conduct additional data acquisition tasks at the refuges identified as having the highest priority for both direct use and on-refuge conjunctive use opportunities with the focus on determining if conditions are favorable for groundwater development to provide Incremental Level 4 water supply. These refuges are: **Pixley NWR, West Bear Creek Unit of the San Luis Complex, Salt Slough Unit of the North Grasslands WA,** and **Grassland RCD.**
- Conduct additional data acquisition tasks at **Gray Lodge WA** and **Merced NWR** to support the use of groundwater to supply Incremental Level 4 water at these refuges using existing groundwater pumping capabilities.
- As resources become available, conduct additional data acquisition tasks at the other higher-ranked refuges (either direct use or on-refuge conjunctive use opportunities) to identify additional groundwater supply projects. These refuges are: **Sacramento NWR, Colusa NWR, China Island Unit,** and **Los Banos WA**.
- Commence discussions with sponsors of the high-potential off-refuge conjunctive use projects, including Stony Creek Fan, the proposed recharge project in the Merced area, the Meyers Farm project, and Semitropic WSD Water Bank, to determine if partnership opportunities exist.
- Install well meters at all unmetered refuge wells that are used or could be used to supply Incremental Level 4 refuge water, monitor water levels quarterly, and collect routine water quality samples from active and inactive wells to develop a database of groundwater use and conditions at refuges where groundwater is used. Maintain collected data in a format supportable and usable by the refuge and refuge managing agencies. This applies to **all refuges** except Colusa NWR and Volta WA.
- Consider two multiple-refuge projects—**Sacramento Complex** refuges, excluding Sutter NWR, and **Grassland RCD**. Refuges in both project areas were ranked lower individually than Pixley and West Bear Creek, but both areas showed strong potential for comprehensive project development and benefit. In the case of Grassland RCD, its close proximity to nine of the refuges, good interconnected conveyance systems, and local need support conducting a more focused feasibility study on regional groundwater or conjunctive use projects.

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SECTION 1

Introduction

1.1 Purpose of Report

This report summarizes initial evaluation of the potential for groundwater to meet a portion of the refuge Incremental Level 4 water contract quantities at National Wildlife Refuges (NWR), State of California Wildlife Management Areas (WA), and the Grassland Resource Conservation District (Grassland RCD), hereafter referred to as refuges.[1] The primary objective of this evaluation is to identify opportunities where groundwater can be used to reduce the current dependence on annual (spot-market) acquisitions of Incremental Level 4 water. Issues that prompted the U.S. Bureau of Reclamation (Reclamation) to evaluate in detail the potential for utilizing groundwater to assist in meeting refuge water supply needs include increasingly competitive demands for reliable water supplies and variable cost and availability of water acquired on the spot market. Development of groundwater may provide the refuges with Incremental Level 4 water supplies that are more reliable and that have costs that do not fluctuate based on market conditions.

The refuges included in this evaluation are located in the Sacramento and San Joaquin Valleys and are those identified specifically in the 1992 Central Valley Project Improvement Act (CVPIA) (Table 1-1, Figure 1-1). Although several refuges are managed as “complexes” (see Table 1-1), each refuge unit is discussed separately because of individual groundwater conditions and water supply issues. Using existing available information, an evaluation of each refuge was conducted, resulting in recommendations for acquisition of critical additional data, opportunities for increased direct onsite groundwater use and onsite conjunctive use, and potential partnerships with offsite refuge conjunctive use projects.

Reclamation and the U.S. Fish and Wildlife Service (Service) were the lead agencies conducting this effort. Other participating agencies and organizations that have provided information and resources include the California Department of Fish and Game (DFG) and Grassland RCD. Other agencies and organizations directly or indirectly involved in the project development provided feedback and input throughout the course of the project and are identified in Appendix A.

1.1.1 Background

Groundwater has been used historically at many of the refuges to supply all or part of their water needs. In most cases, groundwater was either the key or only source of water [2] to the land prior to its inclusion in the state or federal refuge system. When the lands were transferred to the refuge system, the wells were usually retained by the refuges and either used intermittently for refuge water supply or allowed to go inactive or abandoned if the refuge decided not to use groundwater.

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[1] Grassland RCD is not considered to be a refuge; it is a district. However, Grassland RCD is grouped into the “refuge” designation to distinguish it from other types of water districts referred to in this report.

[2] Agricultural return water was also available to many refuges, although records of quantities and accessibility were not maintained.

Evaluation of the groundwater resources at each refuge initially was conducted in the late 1980s. These findings are included in two documents—*Report on Refuge Water Supply Investigations* (Reclamation 1989) and the *San Joaquin Basin Action Plan/Kesterson Mitigation Plan* (Reclamation et al. 1989), which summarize known groundwater use at each of the refuges at the time of land transfer.

The passage of the CVPIA in 1992 modified the priorities for managing water resources of the California Central Valley Project (CVP), a major link in California's water supply network. CVPIA amended previous authorizations of the CVP to include fish and wildlife protection, restoration, and enhancement as project purposes having equal priority with agriculture, municipal and industrial, and power purposes. The CVPIA required the U.S. Department of the Interior (DOI), through Reclamation and the Service, to provide firm water supplies of suitable quality to maintain and improve wetland habitat areas on the Central Valley refuges covered in the two aforementioned 1989 reports. To meet water acquisition needs under CVPIA, DOI has developed a Water Acquisition Program (WAP), a joint effort by Reclamation and the Service.

Establishment of a reliable water supply is required for the refuges' long-term ability to achieve full habitat development. At the time of CVPIA passage, surface water was considered to be the optimal water supply for most of the refuges. However, many of the refuges were not connected at the time to the CVP or the State Water Project (SWP) via conveyance systems. Reclamation and the Service prepared the *Decision Document Report of Recommended Alternatives Refuge Water Supply and San Joaquin Basin Action Plan Lands* (Decision Document) in April 1995 to develop an approach to address the refuge conveyance constraints. The Decision Document described feasible conveyance system alternatives for each refuge to receive CVPIA water supplies by specifically addressing institutional and engineering requirements necessary to deliver peak flow water supplies. The use of existing and/or new on- and off-refuge groundwater extraction (and storage in some areas) facilities was considered during alternative formulation for each of the refuges. Because concerns related to water quality, local aquifer effects, reliability, and well operation and maintenance costs for many of the refuges were raised by refuge staff and adjacent water districts, groundwater as the sole supply source was not considered to be feasible for the refuges.

No additional comprehensive evaluation of groundwater data collected by agencies and refuges since completion of the 1989 reports had been conducted until the one presented in this report. Subsequent environmental documentation (Reclamation and DFG 1997a, 1997b, 1997c, Tetra Tech 2001, URS 2000) was prepared to implement construction of the surface water conveyance systems identified in the Decision Document.

1.1.2 Level 2 and Level 4 Water Supply Contract Quantities

Reclamation executed five service contracts in 2001 governing the provision of CVPIA refuge water based on the Level 2 and Level 4 water supply needs identified in the CVPIA. Two contracts were executed with DFG (one for Gray Lodge WA and one for state wildlife areas located south of the Delta), one with Grassland Water District (WD), and two with the Service (one for refuges located north of the Delta and one for those located south of the Delta). The contracts provide for supply of approximately 422,000 acre-feet of Level 2 water and approximately 133,000 acre-feet of Incremental Level 4 water, based on the refuge needs in accordance with CVPIA, as well as for the pooling, transfer, and exchange of that water among the refuges. Table 1-1 summarizes annual Level 2 and Level 4 water contract quantities for each refuge.

Because CVPIA specifies that Level 2 water cannot be reduced by more than 25 percent, it is considered a firm supply adequate for meeting "current" management needs, as identified in the 1989 reports. Generally, Level 2 water has been provided from the yield of the CVP with some exceptions[3].

Incremental Level 4 water is the additional water, above Level 2 water, needed for full habitat development and management of the refuges, as identified in the 1989 reports. Incremental Level 4 water is to be acquired from voluntary sellers within the CVP and outside of the CVP through measures including but are not limited to water conservation, conjunctive use, purchase, lease, or donation. CVPIA requires that 25 percent of the acquisition cost of Incremental Level 4 water be borne by the State of California.

Section 3406(d)(2) of the CVPIA requires that acquisition and delivery of Incremental Level 4 water be increased 10 percent per year beginning in 1993 with full Level 4 delivery in 2002. With the exception of one long-term water acquisition, the WAP has annually purchased Incremental Level 4 water supplies from willing sellers. The spot-market approach, which is subject to the variability inherent in water marketing, presents challenges for WAP to acquire the total 133,000 acre-feet of Incremental Level 4 water supplies needed to fulfill CVPIA obligations and meet refuge contract quantities.

1.2 Groundwater Use and Management

Groundwater currently is being used to meet a portion of demands at nine refuges. Four other refuges have operational wells but are not currently using groundwater. Two refuges (Delevan NWR and Volta WA) have no record of historic on-refuge groundwater use for irrigation. Table 1-2 summarizes the current status of groundwater use at the refuges. Concerns related to the adequacy and cost of operating wells, water quality, and the availability of surface supplies have previously limited the degree of groundwater use at many of the refuges.

Various water districts, counties, or other water supply entities throughout the Central Valley have prepared groundwater management plans or have enacted ordinances to control the transfer of groundwater within or out of their basins. Because these plans or ordinances may impact potential refuge groundwater projects, existing plans have been evaluated, where available, to assess whether local conditions may support or discourage proposed projects. Specific plans or ordinances are listed or described in the subbasin sections and in the individual refuge sections, as appropriate. Central Valley counties that have adopted groundwater management ordinances include Butte, Glenn, Kern, Sacramento, San Joaquin, Shasta, Tehama, and Yolo. A general discussion of groundwater management as it relates to refuge water supply is included in Appendix B.

3 Exceptions include refuges having their own water rights (Sacramento NWR and Gray Lodge WA), are receiving water from other sources (Merced NWR), or are wholly groundwater dependent (Pixley NWR).

1.3 Report Data, Approach, and Organization

1.3.1 Report Data

This report uses existing information and reports only. No new data were collected during this effort. Interviews with refuge staff, site visits, and reviews of existing files were completed to assimilate available information on present and past groundwater use and conditions. In most cases, numerous conversations and data exchanges occurred with refuge staff during October 2002 through January 2003. These communications are referred to as "communications with refuge staff." The support, cooperation, and dedication of these refuge staff members cannot be overstated.

In most cases, historic groundwater records were incomplete. Records from past groundwater activities may have been lost over time. Where possible, refuge staff provided direct knowledge or anecdotal information of past wells and related problems.

Information sources used to assess regional and local groundwater conditions include previously compiled summaries such the *CVPIA Programmatic Environmental Impact Statement* (PEIS) (Reclamation 1999) and the *Report on Refuge Water Supply Investigations* (Reclamation 1989), Department of Water Resources (DWR) Bulletin 118 (DWR 2003a), as well as United States Geological Survey (USGS) and other DWR reports and information. Relevant maps and other information obtained from these sources are provided in this report for background. Available data were compiled into electronic files and incorporated into a GIS-based system to provide a basis for maintaining any data or information collected in the future or for records of past activities that are found. These maps, electronic data, and direct information from the refuges were used to assess hydrogeologic conditions at the refuges and make recommendations for additional work.

1.3.2 Report Approach

The project data compilation and evaluation used the following approach:

- **Refuge Water Use and Local and Regional Groundwater Conditions Assessment**—summarized and assessed historic and current water use, water quality data, and local and regional groundwater conditions for each groundwater basin, subbasin, and refuge.
- **Initial Screening**—developed and applied evaluation criteria to the refuge assessment to identify and evaluate potential direct use and on-refuge conjunctive use projects and to provide an overview of off-refuge regional conjunctive use groundwater projects for which partnerships could be established.
- **Data Gaps Identification**—identified data gaps and additional work efforts that would be needed in subsequent evaluation to implement potential direct use and on-refuge conjunctive use projects.
- **Potential Projects Summary**—identified through the refuge evaluation which refuges have a higher potential for development of direct use and/or on-refuge conjunctive use projects able to be implemented in a shorter-term time period (1 to 5 years) and longer-term time period (longer than 5 years).

Each of these report approach components are discussed below.

1.3.2.1 Refuge Water Use and Local and Regional Groundwater Conditions

The 19 refuges discussed in this report overlie the Central Valley regional aquifer system, which generally coincides with the Central Valley itself. Groundwater within the Central Valley is divided into basins and subbasins depending on surface water hydrology, hydrogeology, and political boundaries. State basin and subbasin designations used in this report are consistent with those identified in the DWR Bulletin 118 (DWR 2003a).

The three groundwater basins within the Central Valley regional aquifer system are the Redding Area, Sacramento Valley, and San Joaquin Valley Basins. Each basin is divided into numerous subbasins. The San Joaquin Valley Basin includes two separate hydrologic regions (the state's major surface water drainage areas). For this reason, discussion of the San Joaquin Valley Basin is frequently divided into the San Joaquin River and Tulare Lake Regions, corresponding to the hydrologic regions (Figure 1-2).

This report discusses the project refuges based on the hydrologic region in which they occur: the Sacramento River (includes both the Redding and Sacramento Valley Basins), San Joaquin River, and Tulare Lake Regions. This is consistent with the approach previous Reclamation reports have used to group refuges and with that used by the CVPIA PEIS (Reclamation 1999), a major source for regional and water quality summaries in this report. The groundwater basins which these refuges overlie are included in Table 1-1 and shown on Figure 1-2.

Regional groundwater conditions vary between and within basins. Both high groundwater and overdraft conditions occur, as well as variable water quality conditions. The variability of these conditions is discussed on a regional basis, as well as by subbasin. For each refuge, available information for present and past groundwater use, as well as existing groundwater wells, was compiled and evaluated, as feasible.

1.3.2.2 Initial Screening

Groundwater could be used to supply Incremental Level 4 water through direct use of groundwater, development of on-refuge conjunctive use application, or participation in an off-refuge conjunctive use project, if local water quality, facilities, and aquifer characteristics support it. Each approach has been considered for the evaluated refuges.

Direct Use. Direct use of groundwater would entail pumping groundwater from either new or existing wells and using the water directly for wetland flooding. The ability of a refuge to pump groundwater directly would depend on the ability of the aquifer to sustain the installation of high-yield wells, the local aquifer safe yield, and groundwater quality that supports refuge habitat goals.

On-Refuge Conjunctive Use Opportunities. On-refuge conjunctive use approaches could be implemented in one of several ways, including:

- Recharge with groundwater basins
- Recharge by direct injection
- Groundwater substitution
- In lieu recharge

Local recharge could be increased by either developing recharge basins in more permeable areas of a refuge or by injecting treated surface water when the water is available.

Development of recharge basins could have the dual benefit of developing wetland habitat and augmenting local groundwater resources. Groundwater pumping could then be implemented or increased when surface water availability is lower. Evaluation of rates and periods of pumping versus recharge would have to be developed for individual refuges based on local hydrogeologic conditions. Groundwater substitution could be implemented, if local groundwater management allows, by pumping groundwater substituted for surface water that would normally have been delivered to the refuge. This surface water could be conveyed to another refuge lacking a reliable supply of Incremental Level 4 water. Finally, in lieu recharge could be implemented by providing available surface water to a local pumper in exchange for forgoing pumping.

Off-Refuge Conjunctive Use Opportunities. Numerous groundwater banking projects in each study region have been proposed and/or funded by state programs.[4] Although none of these projects directly includes any of the project refuges, Incremental Level 4 water contract quantities could be met in part or wholly through an agreement with the water project entity. Conveyance facilities would also be needed to move water from its banked location to the refuge.

Off-refuge conjunctive use projects were assessed based on the general information available regarding the scope and location of the project. Potential projects were considered and discussed for each refuge, but no additional screening of these projects was conducted at this time.

Refuge Summary and Scoring Matrix. Each refuge was screened for direct use and on-refuge conjunctive use opportunities using the following seven general categories:

- Surface Features
- Water Supplies and Infrastructure
- Local Water Use
- Soils and Hydrogeology
- Water Quality
- Operational Issues and Constraints
- Data Needs

For each of these categories, several criteria were established in a matrix format, and each criterion was rated according to a -1/0/+1 scale. This positive, neutral, or negative score is relative to the effect of the criterion on the refuge's potential for groundwater development. Categories with more criteria, such as Water Quality, are more heavily weighted than other categories with fewer criteria. Each refuge was evaluated using this approach, even if the refuge does not have identified Incremental Level 4 water needs because a potential project could be developed on a joint operational or multi-refuge basis.[5] A separate score for the potential direct use of groundwater or on-refuge conjunctive use opportunities for each refuge was developed by summing the results of the individual criteria applicable to each type of opportunity. These scores are referred to in this report as the Direct Use and On-Refuge Scores.

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4 Available funding sources for conjunctive use studies or projects include DWR Proposition 13 Groundwater Recharge Construction Loans (FY 2001-02, 2002-03), Proposition 13 Groundwater Storage and Construction Grants (FY 2001-02, 2002-03), and Proposition 50 (AB 303) Local Groundwater Assistance Fund Grants (FY 2001-02, 2002-03). Other projects or potential projects funded by other sources are also listed.

5 Refuges with no identified Incremental Level 4 water needs are Colusa NWR, Kesterson NWR, San Luis Unit, and Freitas Unit.

1.3.2.3 Data Gaps Identification

Insufficient data are available at each refuge to recommend implementation of specific groundwater projects. The data gaps range from lack of water quality data and aquifer parameter estimates (such as at Gray Lodge WA) to all types of hydrogeologic data because none is available (Volta WA). In many cases, available water quality data are at least 10 years old.

Data gaps and general approaches to recommended data collection are provided for some of the higher rated refuges. Detailed approaches and cost estimates are provided for two highly rated refuges (Gray Lodge WA and Pixley NWR). In general, both water quality and hydrogeologic data are recommended for collection at each refuge.

1.3.2.4 Potential Projects Summary

Based on the findings of the refuge assessments, potential refuge projects were then identified as either short term or long term. Short-term projects are those that should be able to be implemented within 1 to 5 years. Long-term would probably require more than 5 years to implement or would have among the largest amount of data to collect prior to implementation. The available groundwater data set was insufficient to rule out groundwater development at any refuge although relative assessment and prioritization was possible.

1.3.3 Report Organization

The report is organized into 6 sections and 5 appendices as follow:

- Section 1: Introduction
- Section 2: Sacramento River Region Refuges
- Section 3: San Joaquin River Region Refuges
- Section 4: Tulare Lake Region Refuges
- Section 5: Refuge Ranking and Proposed Projects
- Section 6: References
- Appendix A: Participating Agencies and Organizations
- Appendix B: Definitions and Explanations of Terms
- Appendix C: Possible Off-Refuge Conjunctive Use Projects
- Appendix D: Example Conceptual Project Approaches
- Appendix E: Refuge Groundwater Development Issues

Figures and tables are included at the end of each basin/subbasin summary and after each refuge assessment.

The refuge summaries are grouped in Sections 2 through 4 by study area (Sacramento River, San Joaquin River, and Tulare Lake Regions). Within each of the study areas, the refuges are grouped by subbasin based on common hydrogeologic conditions. The first three report approach components (Refuge Conditions, Initial Screening, and Data Gaps) are included in these sections. Potential on-refuge projects are screened for feasibility and known off-refuge conjunctive use projects are identified and qualitatively rated in the summary of each refuge. Section 5 summarizes the direct use and on-refuge project screening, discusses potential off-refuge conjunctive use projects, and presents recommended additional refuge data acquisition and next steps.

TABLE 1-1
Level 2 and Level 4 Water Contract Quantities by Refuge[a]
Evaluation of Groundwater Potential for Incremental Level 4 Refuge Water Supply

Region and Refuge			Level 2	100% Incremental Level 4[b]	Total Level 4
Sacramento River Region	Sacramento Complex[c]	Colusa NWR	25,000	0	25,000
		Delevan NWR	20,950	9,050	30,000
		Sacramento NWR	46,400	3,600	50,000
		Sutter NWR	23,500	6,500	30,000
	Gray Lodge Wildlife Area		35,400	8,600	44,000
		Subtotal	***151,250***	***27,750***	***179,000***
San Joaquin River Region	San Luis Complex[c]	East Bear Creek Unit	8,863	4,432	13,295
		Freitas Unit[d]	5,290[c]	0	5,290
		Kesterson Unit[d]	10,000[c]	0	10,000
		Merced NWR[e]	13,500	2,500	16,000
		San Luis Unit[d]	19,000[c]	0	19,000
		West Bear Creek Unit	7,207	3,603	10,810
	North Grasslands WA[f]	China Island Wildlife Area	6,967	3,483	10,450
		Salt Slough Wildlife Area	6,680	3,340	10,020
	Grassland Water District[g]		125,000	55,000	180,000
	Los Banos Wildlife Area		16,670	8,330	25,000
	Mendota Wildlife Area[d]		27,594[c]	2,056	29,650
	Volta Wildlife Area[d]		13,000[c]	3,000	16,000
		Subtotal	***259,771***	***85,744***	***345,515***
Tulare Lake Region	Kern NWR		9,950	15,050	25,000
	Pixley NWR		1,280	4,720	6,000
		Subtotal	***11,230***	***19,770***	***31,000***
		Total	**422,251**	**133,264**	**555,515**

Notes:

[a] As identified in Exhibit B of the Long Term Contracts.

[b] Without conveyance losses.

[c] Refuges are now referred to as a “complex” but will be referred to as separate refuges in this report for consistency with CVPIA designations.

[d] Includes Replacement water. Without replacement water: San Luis (13,350), Kesterson (3,500), Freitas (3,527), Mendota (18,500), Volta (10,000). Provided prior to CVPIA. To be replaced to the Project when available and acquired from willing sellers.

[e] Receives 15,000 ac-ft of mitigation water from Merced Irrigation District in accordance with Article 45 of their 1964 FERC license which expires Feb 28, 2014. The additional 1,000 ac-ft is met through groundwater pumping.

[f] China Island and Salt Slough are now referred to as “units” of North Grasslands WA.

[g] Water provided to Grassland WD for use by Grassland RCD.

TABLE 1-2
Summary of Refuge Groundwater Use
Evaluation of Groundwater Potential for Incremental Level 4 Refuge Water Supply

Refuge	Routine Use	Occasional Use	No Current Use[a]	Past Use	No Historic Use
China Island Unit		X			
Colusa NWR				X	
Delevan NWR					X
East Bear Creek Unit			X		
Freitas Unit			X		
Grassland RCD[b]		X			
Gray Lodge WA	X				
Kern NWR			X		
Kesterson Unit				X	
Los Banos WA		X			
Mendota WA				X	
Merced NWR	X				
Pixley NWR	X				
Sacramento NWR			X		
Salt Slough Unit		X			
San Luis Unit		X			
Sutter NWR				X	
Volta WA					X
West Bear Creek Unit		X			

Notes:
[a] These refuges have operational wells.
[b] Groundwater is used in the RCD by private owners but it is not routinely used for maintaining refuge wetland areas.

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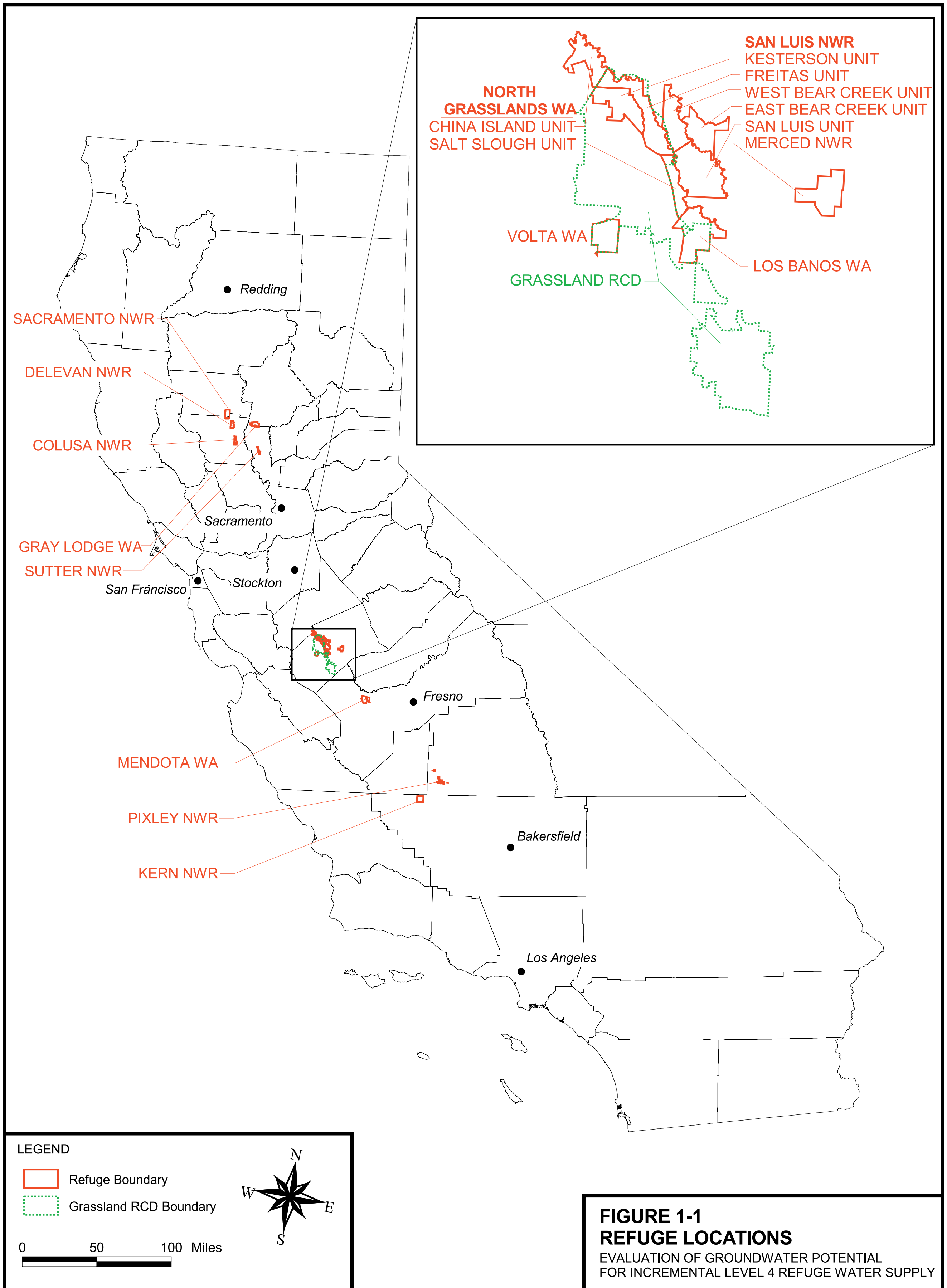

FIGURE 1-1
REFUGE LOCATIONS
EVALUATION OF GROUNDWATER POTENTIAL
FOR INCREMENTAL LEVEL 4 REFUGE WATER SUPPLY

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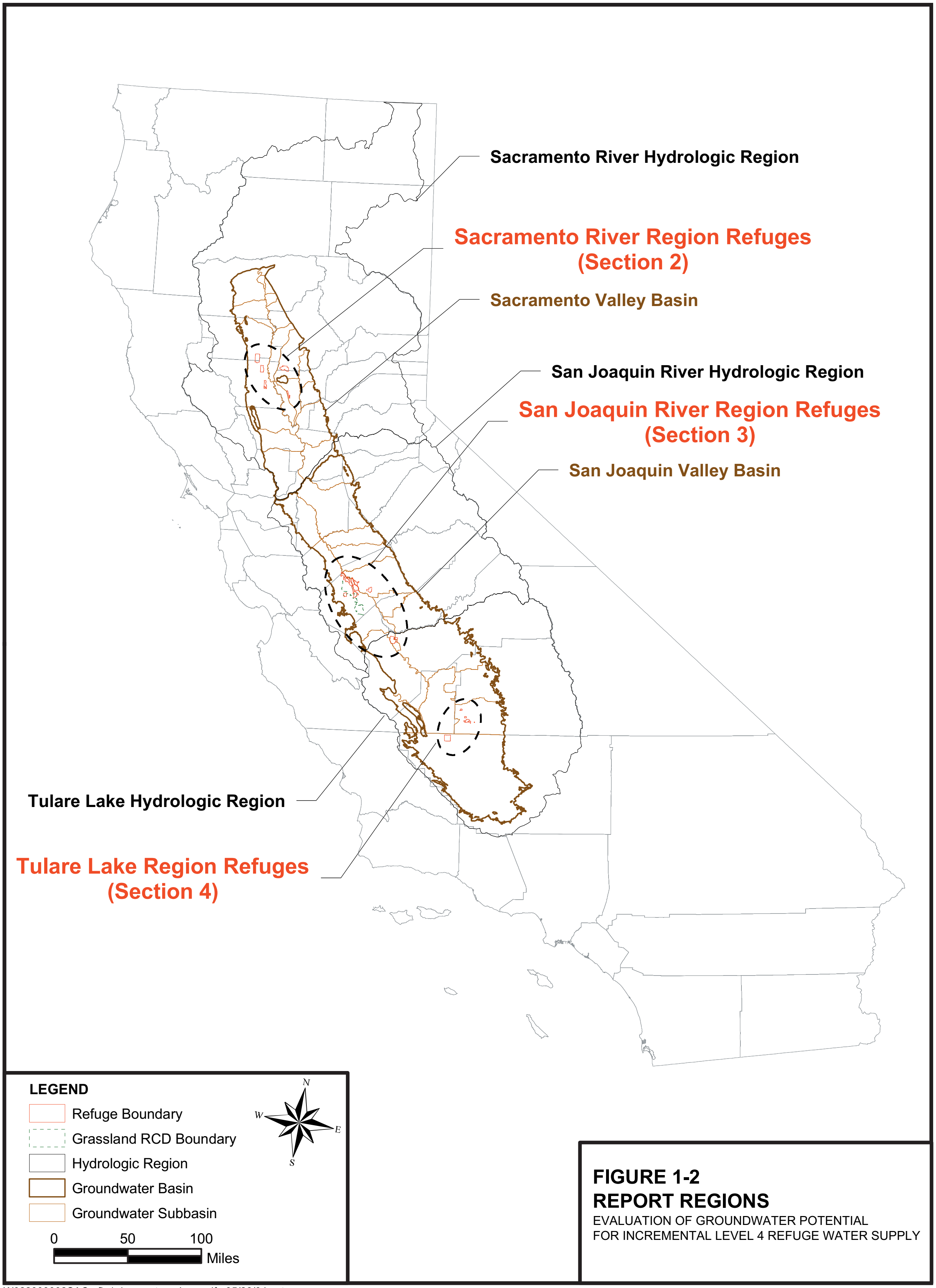

FIGURE 1-2
REPORT REGIONS
EVALUATION OF GROUNDWATER POTENTIAL
FOR INCREMENTAL LEVEL 4 REFUGE WATER SUPPLY

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SECTION 2

Sacramento River Region Refuges

2.1 Regional Characteristics

2.1.1 Physical Setting

The Sacramento River Region study area is bounded physically on the north by the Redding Area Basin, west by the Coast Range, south by the Delta and the American River Basin, and east by the Sierra Nevada. Five refuges are located within the Sacramento River Region study area (Figure 2-1) and are listed here in their geographic order from north to south:

- Sacramento NWR
- Delevan NWR
- Colusa NWR
- Gray Lodge WA
- Sutter NWR

The Sacramento River Region refuges are the northernmost of this study. Pursuant to the CVPIA, long-term refuge water supply agreements were executed for the Sacramento, Delevan, Colusa, and Sutter NWRs and the Gray Lodge WA in 2001. The Service collectively manages the Sacramento, Delevan, Colusa, and Sutter NWRs as the Sacramento NWR Complex. DFG manages Gray Lodge WA. These refuges were created to provide habitat for migratory waterfowl of the Pacific Flyway, and they now serve a variety of wildlife and conservation objectives. The Sacramento Valley supports approximately 44 percent of wintering waterfowl of the Pacific Flyway (Reclamation et al. 2001a).

The major physical features within the Sacramento River Region study area are the Sacramento River, which hydraulically divides the eastern and the western halves of the Sacramento Valley, and the Sutter Buttes, a remnant volcano that rises approximately 2,000 feet above the floor of the Central Valley. Geographically, the region is characterized by smaller, agriculturally based communities and numerous water districts.

2.1.2 Existing Water Supplies

Long-term Incremental Level 4 water acquisitions for the Sacramento Valley refuges total 6,300 ac-ft per year. In 1997, the Corning Canal water districts assigned back to Reclamation a portion of their CVP contract supply. Corning Canal WD released 2,300 ac-ft of surface water, the Proberta WD released 2,000 ac-ft, and the Thomes Creek WD released 2,000 ac-ft. The supporting environmental documentation limits the use of this water to Sacramento Valley refuges as Incremental Level 4 water supply. This water is referred to as the Corning Canal assignment water.

2.1.3 Groundwater Management

Several well-developed groundwater management programs have been created, primarily on a county basis, within the Sacramento Valley. Several of these programs could affect groundwater projects at the project refuges, and based on available information, are discussed here in detail. Groundwater management planning has the potential to impact how groundwater can be used and transferred both within a managed basin and to other basins. Groundwater management generally results in protection and awareness of local groundwater resources.

2.1.3.1 Butte County

Butte County has enacted several groundwater management tools. It has prepared an inventory of its groundwater resources (CDM 2001), developed and promulgated a county ordinance (discussed below), and cooperated with DWR to further understand the County's groundwater resources. The county ordinance (General Ordinance Chapter 33) addresses:

- **Transfers/substitutions**—groundwater transfers out of the county (section 5) or groundwater substitution (where groundwater is substituted for surface water and the surface water is used at another location outside the county) are allowed with a permit. The transferor is requested to provide supporting information that the request is consistent with historical practice.
- **Well spacing**—describes well requirements for spacing, construction methods, and destruction of abandoned wells.
- **Water level monitoring**—establishes water level monitoring network and reporting requirements.

The County is also in the process of amending Chapter 33 to establish Basin Management Objectives (BMO) for the groundwater-level, groundwater quality, and land-subsidence monitoring programs. This program is being modeled after the Glenn County program (discussed below).

Other surface and groundwater management activities in Butte County include:

- AB 3030 Groundwater Management Plans adopted by Biggs–West Gridley WD, Butte WD, Richvale ID, and Western Canal WD
- Urban Water Management Plans prepared by Chico, Oroville, Del Oro WC, Paradise ID, Thermalito ID, and Oroville-Wyandotte ID
- Agricultural Water Management Plan for the County

2.1.3.2 Glenn County

Glenn County's Water Technical Advisory Committee has developed BMOs for sub-areas within Glenn County as part of the implementation of its Groundwater Management Ordinance No. 1115 (Glenn County Water Advisory Committee 2001). These BMOs define "acceptable groundwater levels, groundwater quality, and land subsidence conditions required to meet management objectives." The ordinance establishes an acceptable range, as determined by the committee, for conditions specific to the sub-area of the County, within which groundwater levels are permitted to fluctuate. If groundwater levels fall outside this range, the sub-area will take enforcement actions it deems appropriate. These actions may include coordinating voluntary rescheduling or redistributing groundwater extractions, mandatory conservation measures, implementing active recharge programs, or prohibiting groundwater exports outside the basin. If the sub-area is unable to resolve the issue, recommendations will be made to the Board of Supervisors of the Water Advisory Committee (DWR Northern District 2000).

For example, the Glenn-Colusa Irrigation District (Glenn-Colusa ID) Sub-area (Sub-area 11), in which Sacramento NWR is physically located, determined three alert levels for groundwater declines. Known groundwater level monitoring wells within the area were identified, and groundwater levels were obtained at those wells using data maintained on the DWR Web site. The average and standard deviation were calculated for each well's entire life record using data from spring and autumn. The average of the data minus 1 standard deviation was determined to be Stage 1 alert for a particular well. A Stage 2 alert follows 1 year after a Stage 1 alert is issued if spring water levels have not recovered at the well. A Stage 3 alert occurs in any year when the groundwater levels fall below the lowest historical level since 1975 (Glenn Colusa Water Advisory Committee 2001; Glenn-Colusa ID 2001).

Glenn-Colusa ID adopted an AB 3030 Plan in May 1995, which applies to lands within the district. The district's primary groundwater management objectives are the protection of natural recharge and use of intentional recharge, the protection and planned maintenance of groundwater quality, the conjunctive use of groundwater storage with surface water from local and imported sources, and the monitoring of basin parameters for the primary purpose of preventing overdraft. The plan supports the investigation of natural recharge sites, spreading basins, and artificial recharge sites and facilitates conjunctive use operations when possible. The district therefore may support conjunctive use activities and/or construction of recharge basins at a refuge it serves, such as Sacramento NWR. The plan is silent regarding water transfers.

2.1.3.3 Sutter County

Sutter Extension WD adopted an AB 3030 Plan in November 1997. The district's AB 3030 Groundwater Management Plan states that in the event of water shortage, Sutter Extension WD may distribute available groundwater supplies to district landowners, although landowners are first encouraged to enter private agreements with other landowners for the use of well water. It also states that when the district has a surface water surplus and the state is experiencing water shortages, the groundwater storage capacity can be used conjunctively with surface water supplies to assist other areas outside the district's sphere of influence, as such programs do not (1) exceed the safe annual yield of the aquifer, (2) result in conditions of overdraft, and (3) result in uncompensated adverse impacts on neighboring landowners affected by the program (Sutter Extension WD 1995).

2.1.3.4 Potential Off-Refuge Conjunctive Use Projects

A number of groundwater management programs and projects for the Sacramento Region have been proposed and/or approved through state (DWR) grant and loan programs. Figure 2-2 presents the locations and status of these projects within the Sacramento Region. Details on these projects are provided in Appendix C, Table C-1. The information contained within Table C-1 is provided as guidance relative to projects that have been considered by water agencies, whether or not they have received funding or proceeded beyond the conceptual phase. Qualitative evaluation of these projects, conducted during the refuge summaries, indicates that some projects are more feasible than others for refuge involvement based on parameters such as proximity to refuge, type of project, conveyance opportunities, and project status. Projects range from well-developed conceptual plans, such as the Stony Creek Fan Project, to loosely defined "groundwater storage" projects. Refuge assessments identify which known projects may have application to that refuge. These include potential projects with Glenn-Colusa ID (Stony Creek Fan Project - #12 on Table C-1 and Figure 2-2), Maxwell ID (#7), Butte County (#3), and Sutter Extension WD (#19). See Table C-1 and the refuge assessments for additional discussion of these potential projects.

2.1.4 Regional Geology and Soils

Deposition of up to 10 vertical miles of unconsolidated continental and marine sediment has occurred over geologic time in the structural trough of the Sacramento Valley Basin. Alluvial deposits are found throughout the region and are the source of most groundwater pumped in the Sacramento Valley. The Sacramento Valley aquifer system is generally unconfined, although locally confined areas are found primarily in the older, deeper units (DWR 1978). Depth to the base of freshwater ranges from 1,000 feet in the Orland area to nearly 3,000 feet in the Sacramento area (Reclamation et al. 1999).

The predominant type of alluvial deposits include: alluvial fans originating from the Coast Range, Sierra Nevada, and Sutter Buttes; stream channel deposits found immediately adjacent to modern streams and along ancestral river channels; and floodplain deposits in the interior areas away from these other surficial processes. The alluvial fan and stream channel deposits are usually more permeable and the floodbasin deposits are generally finer and less permeable. Because of differences in source material and tectonics between the major upland areas bounding the Sacramento Valley, the sedimentary units on the east side and west side of the valley have significant differences. The Sacramento River generally defines the separation between the two regions (DWR 1978).

West of the Sacramento River, the Tehama Formation is the most extensive sedimentary unit in the fresh-water portion of the basin. The formation is generally fine-grained, but sufficient sand and gravel units occur to support the irrigation wells in the area. Some areas have a higher clay component, particularly between Willows and Williams (DWR 1978). East of the Sacramento River, the primary fresh-water units (DWR 1978), from oldest to youngest, are:

- **Tuscan Formation**—productive volcanic sands to low-permeability tuff breccia, found in the northeast part of the valley, about 900 feet deep
- **Mehrten Formation**—variable-permeability volcanic sand gravel with tuff breccia that is found south of Oroville
- **Laguna Formation**—fine-grained volcanic unit with some sands and gravels
- **Victor Formation (or Riverbank Formation)**—highly productive alluvial deposits that are found south of Gridley

- **Fanglomerate**—informally designated unit consisting of slightly cemented sand and gravel derived from the older Tuscan Formation, with intervals of clay and silt; productive north of Chico

Each of these units is an important aquifer in the Sacramento Valley. Use of any of these aquifers for groundwater banks would require geochemical evaluation of compatibility between the stored water and the receiving aquifer. Because these units are generally found at depth, evaluation would be required to determine whether recharge could occur to these aquifers from surficial recharge basins, or whether injection would be needed to store water. Treatment requirements for irrigation water would need to be evaluated to determine the feasibility of this approach.

Figure 2-3, a schematic representation of an unpublished draft cross section developed by DWR, provides a generalized representation of northern Sacramento Valley geology. The cross section runs east-west across the valley near the southern boundary of Sacramento NWR.

Saline and alkaline soils are found in the troughs of the Sacramento Valley, particularly near the Sacramento Valley refuges (Figure 2-4). These soils are characterized by excess salts (saline), excess sodium (sodic), or both (saline-sodic). In uncultivated areas, saline soils are used for saltgrass pasture and native range. Some of these soils support seasonal salt marshes. In areas of intermediate to low rainfall, the soils have excessive salts. In general, the refuges are located in areas of tight or clay-rich soils, which are conducive to development of surface ponds. The soils are rarely conducive to recharge, however, because they have low seepage rates.

2.1.5 Regional Hydrogeology

Aquifer recharge occurs from deep percolation of rainfall, the infiltration of river water through streambeds, and subsurface inflow along basin boundaries. Most of the recharge for the Sacramento Valley occurs along the north and east sides of the valley, where precipitation is highest. With introduction of agriculture to the region, aquifer recharge has been augmented by deep percolation of applied agricultural water and seepage from irrigation distribution and drainage canals (Reclamation et al. 1999).

Regionally, groundwater flows from the flanks to the valley axis, then south toward the Delta. However, development and the associated increased pumping locally have changed natural groundwater flow patterns. In areas of the region where groundwater pumping has increased more than other areas, such as areas within Sacramento, Yolo, and Solano Counties, groundwater movement is now toward areas of groundwater depression (Reclamation et al. 1999).

2.1.5.1 Groundwater Storage and Production

The DWR has estimated the usable Sacramento Valley groundwater storage capacity at 40 million ac-ft. “Usable storage capacity,” as defined by DWR, is based on aquifer properties (i.e., permeability), groundwater quality, and economic considerations such as well drilling and energy costs (DWR et al. 1994).

Safe yield is a concept commonly used in describing a groundwater basin. The definition of safe yield is “the amount of groundwater a basin can produce without causing sustained declines in regional groundwater levels." DWR also defines a related term, perennial yield, as "the amount of groundwater that can be extracted without lowering groundwater levels over the long term" (DWR 1994). Perennial yield is directly dependent upon the amount of recharge received by the groundwater basin, which may be different in the future than it has been in the past. The most recent estimate of perennial yield for the Sacramento Valley Basin, developed by DWR in the California Water Plan Update (Bulletin 160-93), is 2.4 million ac-ft per year. Definitions of these terms are also included in Appendix B.

Regional groundwater pumping estimates developed by DWR for 1990 conditions (normalized) indicate that 2.5 million ac-ft of groundwater pumping occurred in the Sacramento Valley Basin. This is higher than the estimated perennial yield by approximately 33,000 ac-ft, resulting in a regional overdraft for 1990 recharge conditions, which was during a 5-year drought (1988–1992). The slight overdraft condition is primarily associated with conditions in the southeastern portion of the region in the Sacramento County area (DWR 1994).

2.1.5.2 Groundwater Models

Many groundwater models have been developed for areas within the Sacramento Valley. These include:

- Central Valley Ground-Surface Water Model (CVGSM) (Reclamation et al. 1990).
- Central Valley Model, a regional model developed by the USGS (Williamson et al. 1989).
- Sacramento Valley Model, a regional model developed by DWR (DWR 1978).
- Sacramento County Groundwater System Model, developed by DWR (DWR 1974).
- American River Basin Models, including Sacramento and Sutter Counties, developed by Montgomery Watson Harza (MWH) (Integrated Groundwater-Surface Water Models [IGSM]).
- Beale Air Force Base (AFB) Model, developed by CH2M HILL to support groundwater investigations at the base.
- Stony Creek Fan Model, IGSM model developed by Water Resources and Information Management Engineering, Inc. (WRIME) for evaluation of the project potential.
- Butte Basin Area Groundwater Model, developed for the Butte Basin Water Users Association (HCI 1996).
- Yolo County Groundwater System Program Model, developed by University of California, Davis, 1980.
- Reconnaissance-level Groundwater Flow Model (MODFLOW) to simulate conjunctive use scenarios in Yolo, northern Solano, southeastern Sutter, and eastern Sacramento Counties (DWR et al. 1994).
- Sacramento Valley Superposition Model, being developed by CH2M HILL/MWH to evaluate the potential interaction between surface and groundwater systems during the implementation of conjunctive water management projects. The model will also be used

to estimate impacts to groundwater level changes associated with groundwater projects proposed as part of the Sacramento Valley Water Management Program.

This list is not comprehensive and represents only those models that are commonly discussed and referred to within the groundwater community. Some of these models may provide general information and summaries about assumed aquifer properties and groundwater conditions.

2.1.5.3 Groundwater Levels

Sacramento River Region groundwater levels have historically declined moderately during extended droughts, such as the 1988–1992 drought, with ensuing recovery to pre-drought levels during subsequent wetter periods. General evaluation of groundwater hydrographs of selected Sacramento Valley wells indicates that groundwater levels have recovered to pre-drought (prior to 1998–1992) conditions throughout most of the basin and are generally stable at this time (DWR 2003b). Periodic fluctuations of groundwater levels can occur, however, because of variable rainfall (and resulting groundwater recharge), aquifer conditions, local groundwater use, and other water budget components. Variability and uncertainty of local groundwater budget components are discussed in refuge summaries.

2.1.5.4 Groundwater Quality

Groundwater in the Sacramento River Region is considered to be of good quality; however, some localized areas have adverse groundwater quality conditions. The constituents listed in the following section have been identified in groundwater wells on and/or near the refuges and could adversely impact biological resources. Although there are no enforceable water quality standards for federal or California wildlife refuges, United States Environmental Protection Agency (USEPA) Freshwater Aquatic Life Protection Recommended Criteria (USEPA Office of Water 2002a), Agricultural Water Quality Goals (Ayers and Westcot 1985), and federal and state Maximum Contaminant Levels (MCLs) (USEPA Office of Water 2002a; CDHS 2003) may be used as reference points. These standards for selected constituents are provided in Table B-1 in Appendix B.

Arsenic. Arsenic, a naturally occurring trace element in the Central Valley, is regulated by the USEPA at a primary drinking water standard. The federal MCL of 10 micrograms per liter (µg/L) becomes effective in 2006. At high concentrations, arsenic can be toxic to both plants and animals. For irrigation use, the guidelines recommend that arsenic concentrations not exceed 100 µg/L (Ayers and Westcot 1985). The highest regional concentrations of arsenic identified in the Sacramento Valley north of the City of Sacramento are in the Yuba City/Sutter Buttes area, where concentrations are between 8 and 10 µg/L (NHI 2001), although arsenic at concentrations up to 90 µg/L has been observed in the domestic wells at the Gray Lodge WA.

Boron. Boron is a critical element in irrigation water. In small quantities, boron is essential for plant growth. However, concentrations of boron as low as 0.75 milligrams per liter (mg/L) may be toxic to boron-sensitive plants, and it is toxic to most crops at concentrations above 4 mg/L (California Regional Water Quality Control Board 2000; California Regional Water Quality Control Board 2002). Boron concentrations greater than 0.75 mg/L have been reported in an area east of Red Bluff and an area extending from Arbuckle to Davis (Figure 2-5) (Reclamation et al. 1999).

Chromium. Chromium has not been identified or extensively evaluated by previous investigators as a water quality parameter of concern. However, it has been identified at Sacramento NWR at concentrations above the criterion continuous concentration (CCC) of 11 μg/L as hexavalent chromium but below the MCL of 50 μg/L as total chromium (Hollinger 1991a). Neither the source nor extent of the elevated chromium has been determined.

Mercury. Mercury has been identified at the two existing wells at Sutter NWR, but at concentrations below the Freshwater Aquatic Life Criteria of 0.77 μg/L (Fields 1989; USEPA Office of Water 2002a). No regional summaries of mercury conditions in groundwater have been identified to indicate whether these conditions are anomalous or are indicative of regional conditions.

Nitrates. Nitrates (federal MCL of 10 mg/L as N and California MCL of 45 as NO_3) occur in the groundwater of many rural communities in California and have become increasingly widespread due to agricultural activities and sewage disposal on or below the land surface (USEPA Office of Water 2002b; CDHS 2003). Areas of potential nitrate problems in the northern Sacramento River Region include portions of Tehama, Glenn, and Butte Counties (Figure 2-5) (Reclamation et al. 1999).

Total Dissolved Solids. In the Sacramento Valley, total dissolved solids (TDS) concentrations generally do not exceed 500 mg/L. Two areas are found where TDS concentrations can range from 500 mg/L to 1,500 mg/L, although neither of these areas is near the Sacramento Valley refuges (Figure 2-6) (Reclamation et al. 1999). For reference, the federal and California secondary MCL for TDS is 500 mg/L (USEPA Office of Water 2002b; CDHS 2003).

2.1.5.5 Agricultural Subsurface Drainage

High water tables at or near the ground surface may contribute to subsurface drainage water problems that occur in several areas of the Sacramento River Region. The Colusa Basin Drain provides drainage and irrigation water for irrigated lands in the northwest part of the Sacramento River Region. High water tables in portions of Colusa County, particularly along the Sacramento River, periodically impair subsurface drainage functions of the Colusa Basin Drain and other local drainage facilities (Reclamation et al. 1999).

2.1.6 Subsidence

Land subsidence in the Sacramento Valley has been documented in the Davis-Zamora area (Figure 2-7). Up to 1973, subsidence of more than 2 feet has been documented east of Zamora and west of Arbuckle, and subsidence of more than 1 foot has been documented in the Davis area. Some additional subsidence occurred in this area during the 1987–1992 drought (Reclamation et al. 1999).

Sacramento Valley subsidence has been attributed to groundwater overdraft (Figure 2-8). Because of more readily available surface water and better groundwater recharge capabilities of the aquifer system, Sacramento Valley overdraft is not as extensive as in other parts of the state (Reclamation et al. 1999). Another probable contributing factor is that the Sacramento Valley does not have thick, continuous sequences of clay units that are more prevalent in the San Joaquin Valley (such as the Corcoran Clay) that are prone to collapse when dewatered.

2.1.7 Areas of Planned and Potential Groundwater Projects

Groundwater storage and use projects are being planned and evaluated throughout the Sacramento River Region. Known planned groundwater banking or direct groundwater use projects currently being considered include:

- Stony Creek Fan, a groundwater storage project currently undergoing pilot testing (see Appendix C)
- Maxwell ID, a proposed groundwater storage project (see Appendix C)
- Sacramento Valley Water Management Program, a program to meet Bay-Delta water quality requirements with the contribution of additional water from the Sacramento River
- Metropolitan WD one-year (2003) groundwater options with individual Glenn-Colusa ID landowners to meet anticipated short-falls because of the loss of Colorado River water deliveries

In 1992 and 1993, Butte County was the site of the State Drought Bank.[1] DWR implemented a groundwater banking project, which involved the purchase and transfer of water from willing sellers. Water was not added—or banked—prior to withdrawal. The final year of the project resulted in some local concern about declining water levels.

The California DWR completed a prefeasibility-level investigation of the potential for developing a conjunctive use project in eastern Yolo County. The report summarized the hydrogeology and water supply conditions of the area and presented a preliminary design of a conjunctive use project. Estimated costs and an economic and legal analysis were also conducted as part of this project (DWR et al. 1994).

The Natural Heritage Institute (NHI) developed an initial evaluation of the "hydrologic suitability index" of a series of potential groundwater storage sites (NHI 2001). The index was based on geology, water quality, and soil characteristics. Eight sites or areas were evaluated in the Sacramento Valley. The top three sites were considered to have very favorable conditions, based on the evaluated criteria. The sites were the Stony Creek Fan and Stone Valley in Glenn County and Clarks Ditch in Colusa County. The Stony Creek Fan site is the same site mentioned above that is currently being pilot tested.

2.2 Subbasin Characteristics

2.2.1 Colusa Subbasin

The Sacramento, Colusa, and Delevan NWRs are located in the Colusa Subbasin. The primary source of information used for the Colusa Subbasin summary is DWR's 2003

[1] The State Drought Bank wasn't a groundwater storage project, as presented in this report. That is, it didn't entail groundwater storage by either in-lieu or active recharge. It is, however, referred to as a "bank" and its potential impacts on proposed groundwater projects could be significant.

update of California's Groundwater, Bulletin 118 (DWR 2003a). Water districts within the Colusa Subbasin are shown in Figure 2-9.

2.2.1.1 Basin Boundaries and Hydrology

The Colusa Subbasin encompasses 1,434 square miles (918,380 acres). It is bounded on the east by the Sacramento River, on the west by the Coast Range and foothills, on the south by Cache Creek, and on the north by Stony Creek. Annual precipitation ranges from 17 to 27 inches, with the higher end of that range occurring in the western portion of the subbasin.

2.2.1.2 Hydrogeology

The Colusa Subbasin aquifer system is composed of continental deposits of late Tertiary to Quaternary age. Quaternary deposits include surficial Holocene stream channels, located adjacent to river channels, and basin deposits, located away from the stream, as well as Pleistocene Modesto and Riverbank Formations. The older Tertiary deposits consist of the Pliocene Tehama Formation and the Tuscan Formation.

Several sub-areas of the Colusa Subbasin are based on local variations in hydrogeologic conditions. The sub-areas include the Stony Creek Fan, located in the northern portion of the subbasin; the Willows to Williams Plain, which is located between Willows and Williams; the Arbuckle and Dunnigan Plains, which are found east of Hungry Hollow, at Dunnigan, and from Williams to Cache Creek; and the Cache Creek Floodplain, which is located north of the town of Yolo and extends to Knights Landing.

Groundwater Level Trends. Figure 2-10 shows groundwater level trends over time by means of hydrographs for selected DWR monitoring wells (DWR 2003b). Overall groundwater conditions (Figure 2-10) indicate that north of the Sutter Buttes, groundwater generally flows from north to south; south of the Buttes, it flows from west to east. Depth to groundwater ranges from near ground surface along the Sacramento River to more than 100 feet below ground surface (bgs) in the southern portion of the basin.

Long-term records in groundwater levels indicate a slight decline in groundwater levels associated with the 1976–77 and 1988–94 droughts, followed by recovery to pre-drought conditions of the early 1970s and 1980s. Groundwater data generally show an average seasonal fluctuation of approximately 5 feet for normal and dry years. Overall, increasing or decreasing trends in groundwater levels are not apparent.

Groundwater Yields. DWR estimated groundwater specific yield for the subbasin to be 7.1 percent, based on its 1997 estimate of Sacramento Valley specific yield. Specific yield is the amount of water that can be physically drained from a porous rock. It is a function of porosity and grain size. The estimated storage capacity to a depth of 200 feet is approximately 13 million ac-ft.

DWR's draft version of Bulletin 118 (DWR 2003a) indicates that irrigation well yields within the Colusa Subbasin range from 25 to 5,600 gallons per minute (gpm) and average 1,967 gpm. These rates are dependent on aquifer parameters and local pumping practices. The average production depth is 368 feet, and it ranges from 20 to 1,340 feet.

Groundwater Quality. Groundwater is generally of high quality within the subbasin. General chemistry parameters such as TDS values range from 120 to 1,220 mg/L and average 391 mg/L (DWR 2003a).

Local areas of groundwater impairment are found in some areas of the subbasin. High electrical conductivity (EC), TDS, adjusted sodium absorption ration (ASAR), nitrate, and manganese impairments have been identified near Colusa. High TDS and boron are found near Knights Landing. High nitrates occur in Arbuckle, Knights Landing, and Willows. Localized areas have high levels of manganese, fluoride, magnesium, sodium, iron, ASAR, chloride, TDS, ammonia, and phosphorus (Reclamation et al. 1999). Elevated chromium concentrations have also been identified at Sacramento NWR.

Groundwater Budget Components. Estimates of groundwater withdrawal for the Colusa Subbasin are based on surveys conducted by DWR in 1993, 1994, and 1999. Surveys included land use and sources of water. Estimates of groundwater extraction for agricultural, municipal and industrial, and environmental wetland uses are 310,000, 14,000, and 22,000 ac-ft, respectively. Deep percolation from applied water is estimated to be 64,000 ac-ft (DWR 2003a). Estimates of other groundwater budget components were not included in Bulletin 118 (DWR 2003a).

2.2.2 East Butte Subbasin

The Gray Lodge WA is located in the East Butte Subbasin and is shown in Figure 2-11. The primary source of information used for the East Butte Subbasin summary is Bulletin 118 (DWR 2003a), available on the DWR Web site. Water districts within the East Butte Subbasin also are shown in Figure 2-11.

2.2.2.1 Basin Boundaries and Hydrology

The East Butte Subbasin encompasses 415 square miles (253,390 acres) and is bounded on the west and northwest by Butte Creek, on the northeast by the Cascade Range, on the southeast by the Feather River, and on the south by the Sutter Buttes. The northeast boundary along the Cascade Range is primarily a geographic boundary with some groundwater recharge occurring beyond that boundary. The subbasin is contiguous with the West Butte Subbasin in the deeper portions of the aquifer. Annual precipitation is approximately 18 inches in the valley and increases to 27 inches toward the eastern foothills.

2.2.2.2 Hydrogeology

The aquifer system consists of deposits from the late Tertiary to Quaternary age. The Quaternary deposits include Holocene stream-channel deposits and basin deposits, Pleistocene deposits of the Modesto and Riverbank Formations, and Sutter Buttes alluvium. The Tertiary deposits include the Tuscan and Laguna Formations.

Groundwater Level Trends. Groundwater is used more heavily in the northern portion of the subbasin, resulting in seasonal water-level fluctuations averaging 15 feet during normal years and 30 to 40 feet during drought years. In the southern portion of the subbasin, seasonal fluctuations are about 4 feet in normal years and from 5 to 10 feet during drought years (Figure 2-12) (DWR 2003b).

Groundwater Yields. The estimated specific yield for the East Butte Subbasin is 5.9 percent. The estimated storage capacity to a depth of 200 feet is approximately 3.1 million ac-ft, based on Sacramento Valley specific yield estimates developed by DWR in 1978 (DWR 2003a).

DWR's draft version of Bulletin 118 (DWR 2003a) indicates that irrigation well yields within the East Butte Subbasin range from 0 to 4,500 gpm and average 1,839 gpm. The average production depth is 285 feet, with a range of 35 to 983 feet bgs.

The aquifer system is recharged by surface precipitation and at exposures of the aquifers along the foothills. Localized fluctuations in groundwater levels are observed just south of the Thermalito Afterbay as a result of variation in recharge from this surface water system.

Groundwater Quality. TDS ranges from 122 to 570 mg/L and averages 235 mg/L. Localized elevated levels of manganese, iron, magnesium, TDS, conductivity, ASAR, and calcium have been identified within the subbasin (DWR 2003a).

Groundwater Budget Components. Estimates of groundwater extraction are based on land-use and water-source surveys conducted by the DWR during 1993 and 1997. Estimates of groundwater extraction for agricultural, municipal and industrial, and environmental wetland uses are 104,000, 75,500, and 1,300 ac-ft annually, respectively. Deep percolation of applied water is estimated to be 126,000 ac-ft (DWR 2003a). Other groundwater budget components estimates were not included in Bulletin 118 (DWR 2003a).

2.2.3 Sutter Subbasin

Sutter NWR is located in the Sutter Subbasin and is shown in Figure 2-13. The primary source of information used for the Sutter Subbasin summary is Bulletin 118 (DWR 2003a). Water districts within the Sutter Subbasin also are shown in Figure 2-13.

2.2.3.1 Boundaries and Hydrology

The Sutter Subbasin encompasses 366 square miles (234,400 acres) in the central eastern portion of the Sacramento Valley Basin. It is bounded on the north by the Sutter Buttes, on the east by the Feather River, on the south by the confluence of the Feather River and the Sutter Bypass, and on the west by the Sacramento River. The subbasin lies entirely within the Sacramento River watershed, with the most notable hydrological features being the Sutter Bypass and the Feather and Bear Rivers.

Average precipitation ranges from 17 to 21 inches in the subbasin. Annual rainfall increases across the basin from the southwest to the northeast.

2.2.3.2 Hydrogeology

The subbasin is characterized by a thick sequence of generally flat-lying sedimentary units overlain by alluvium. The alluvium of the Central Valley ranges in thickness from a few inches near the foothills to more than 200 feet near the Sacramento River. The geologic formations of the Sutter Subbasin include pre-Cretaceous metamorphic and igneous rocks of the Sierra Nevada block that extend beneath the valley fill, which consists principally of Tertiary sedimentary units derived from these and other rocks exposed in the Sierra Nevada to the east. Volcanics are also found in and around the Sutter Buttes.

The sedimentary units are the primary aquifers in the subbasin, and are composed of continental sediments of Pleistocene and Recent age. The primary aquifers consist of up to 100 feet of Pleistocene sands and gravels overlain by up to 125 feet of recent alluvial fan, floodplain, and stream-channel deposits.

Groundwater Level Trends. Current DWR records indicated that groundwater levels have remained relatively constant since the 1950s. The water table is high and tends to be within about 10 feet of ground surface (Figure 2-14) (DWR 2003b).

Groundwater Quality. DWR maintains data for 11 water quality wells in the Sutter Subbasin. Data collected from these wells indicate a TDS range of 175 to 671 mg/L with a median of 347 mg/L. Some elements and compounds (not specified by DWR) occur in subbasin wells at levels above drinking water quality and aesthetic standards (DWR 2003a).

Groundwater Budget Components. DWR estimated the following components of the groundwater budget for the entire Sutter-Yuba Groundwater Basin, which includes both the East Butte and West Butte Subbasins. Estimated inflows include natural recharge at 40,000 ac-ft and applied water recharge at 22,100 ac-ft. Estimated outflows include urban extraction at 3,900 ac-ft and agricultural extraction at 171,400 ac-ft (DWR 2003a). Other groundwater budget component estimates were not included in Bulletin 118 (DWR 2003a).

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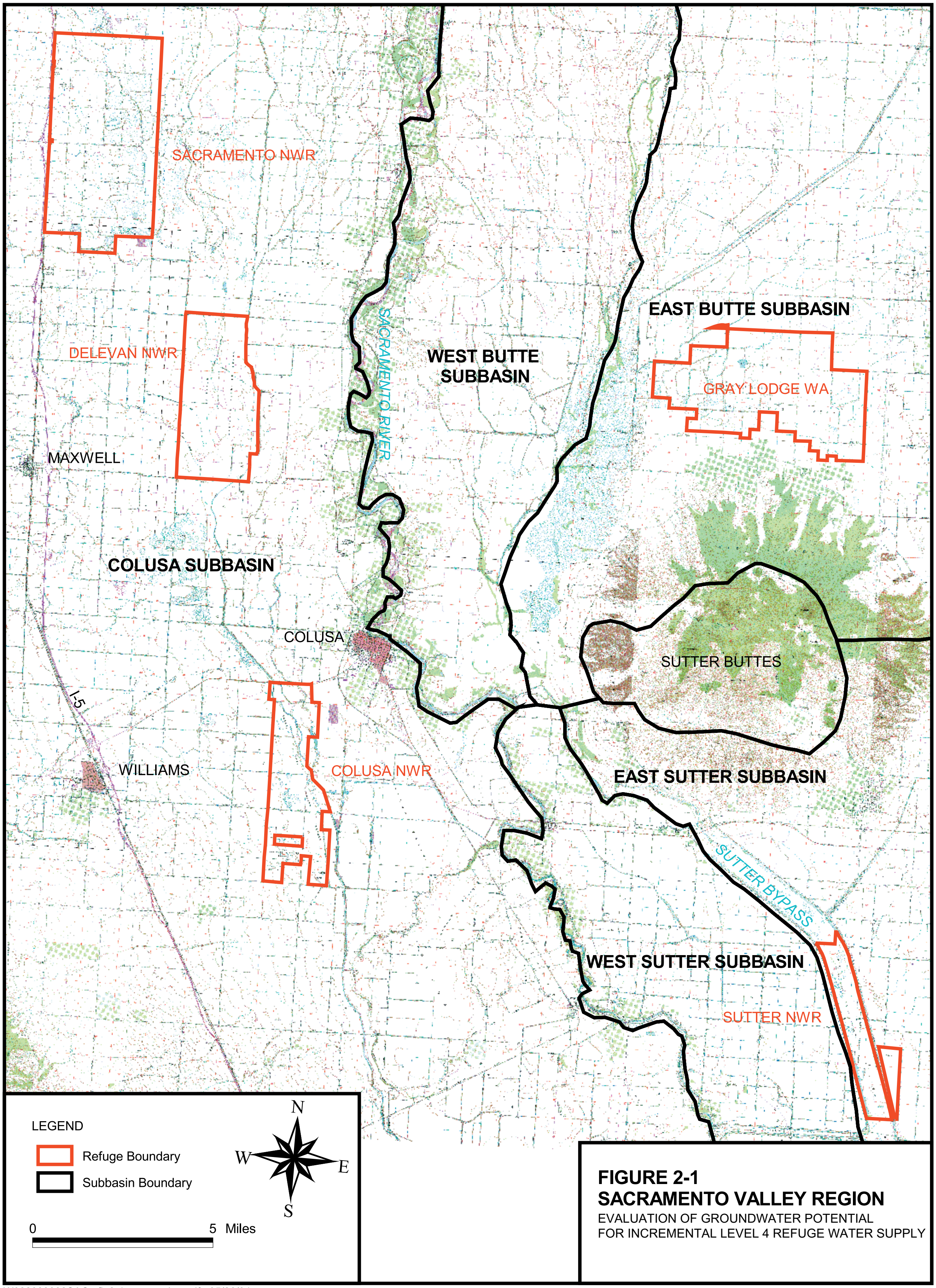

FIGURE 2-1
SACRAMENTO VALLEY REGION
EVALUATION OF GROUNDWATER POTENTIAL
FOR INCREMENTAL LEVEL 4 REFUGE WATER SUPPLY

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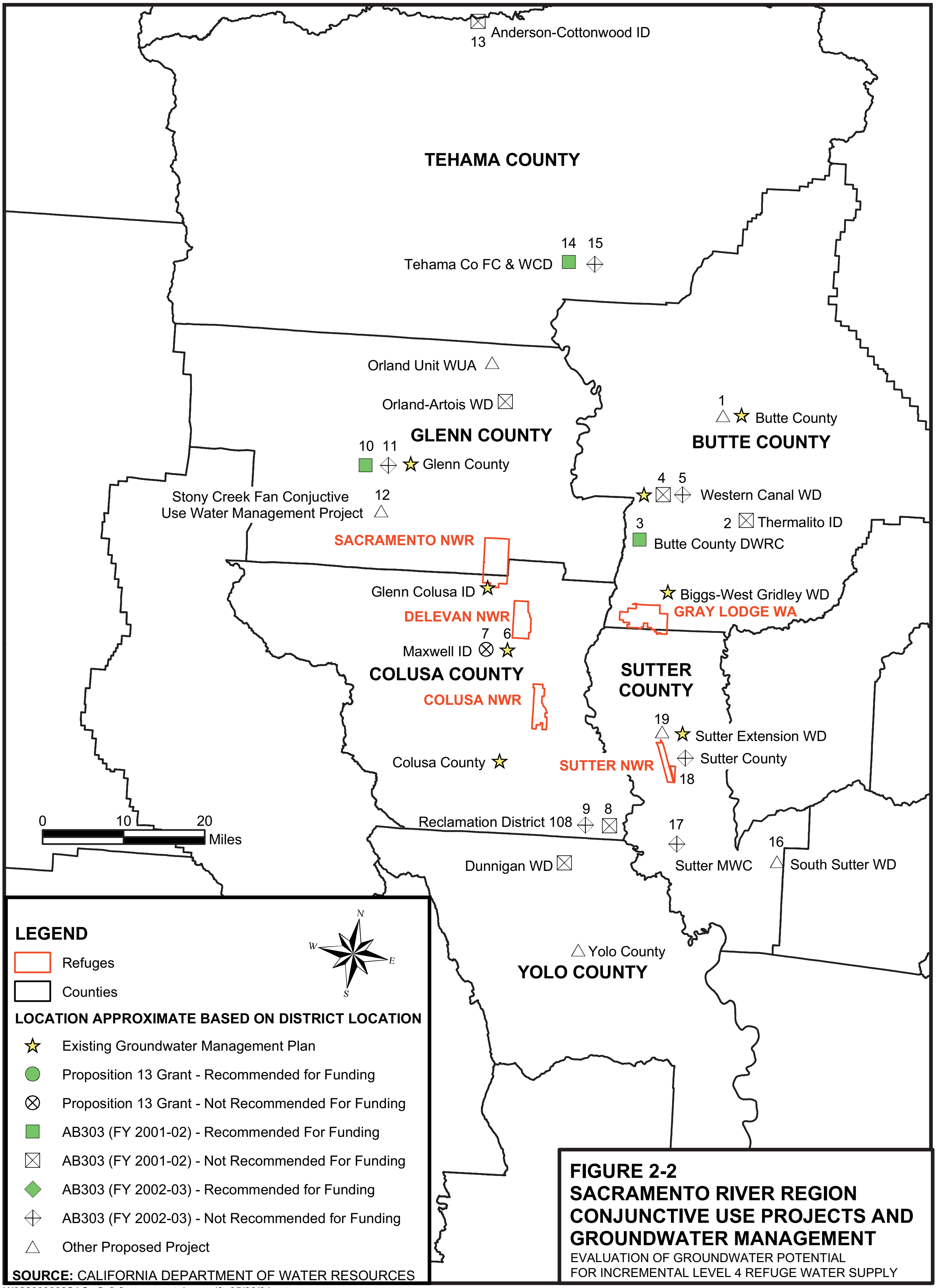

FIGURE 2-2
SACRAMENTO RIVER REGION CONJUNCTIVE USE PROJECTS AND GROUNDWATER MANAGEMENT
EVALUATION OF GROUNDWATER POTENTIAL FOR INCREMENTAL LEVEL 4 REFUGE WATER SUPPLY

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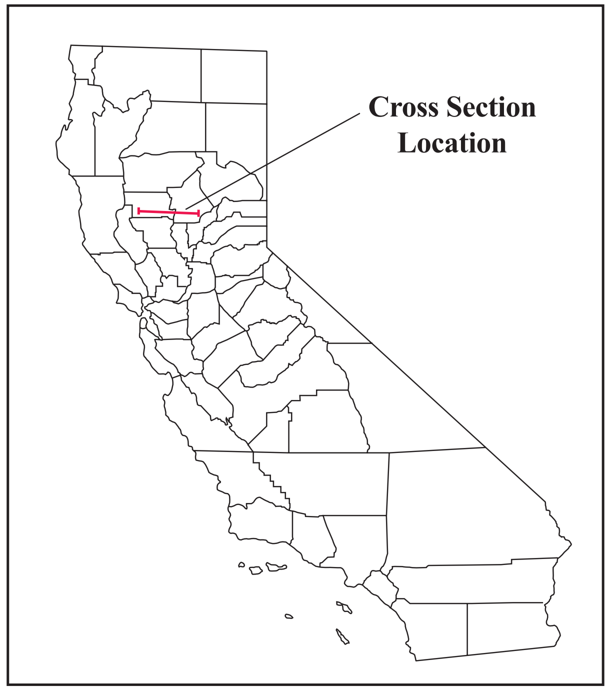
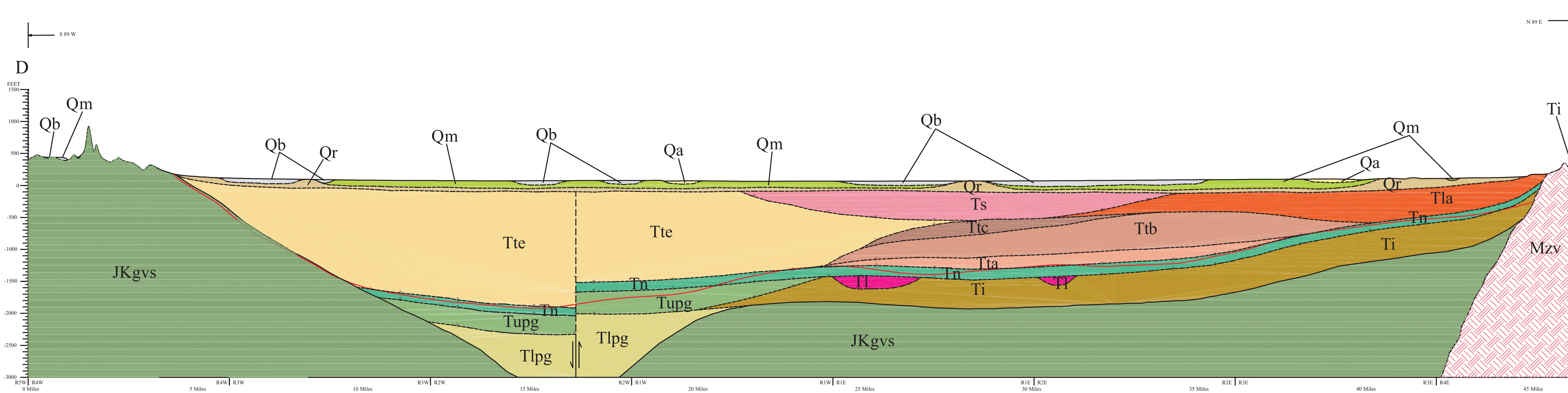


- **Qa** — **Alluvium** (Holocene)-Includes surficial alluvium and stream channel deposits of unweathered gravel, sand, and silt; maximum thickness 80 feet *(adapted from Helley & Harwood, 1985).*
- **Qb** — **Basin Deposits** (Holocene)-Fine-grained silt and clay derived from adjacent mountain ranges; maximum thickness up to 200 feet *(adapted from Helley & Harwood, 1985).*
- **Qm** — **Modesto Formation**, undifferentiated (Pleistocene)-Alluvial fan and terrace deposits consisting of unconsolidated weathered and unweathered gravel, sand, silt, and clay; maximum thickness approximately 200 feet *(adapted from Helley & Harwood, 1985).*
- **Qr** — **Riverbank Formation**, undifferentiated (Pleistocene)-Alluvial fan and terrace deposits consisting of unconsolidated to semi-consolidated gravel, sand, and silt; maximum thickness approximately 200 feet *(adapted from Helley & Harwood, 1985).*
- **Tte** — **Tehama Formation** (Plio Pleistocene)-Includes Red Bluff Formation on west side. Pale green, gray, and tan sandstone and siltstone with lenses of pebble and cobble conglomerate; maximum thickness 2,000 feet *(adapted from Helley & Harwood, 1985).*
- **Ttc** — **Tuscan Unit C** (Plio Pleistocene)-Includes Red Bluff Formation on east side. Volcanic lahars with some interbedded volcanic conglomerate and sandstone, and reworked sediments; maximum thickness 600 feet *(adapted from Helley & Harwood, 1985; DWR Bulletin 118-7, 2001, draft report).*
- **Ttb** — **Tuscan Unit B** (Pliocene)-Layered, interbedded lahars, volcanic conglomerate, volcanic sandstone, and siltstone; maximum thickness 600 feet *(adapted from Helley & Harwood, 1985; DWR Bulletin 118-7, 2001, draft report).*
- **Tta** — **Tuscan Unit A** (Pliocene)-Interbedded lahars, volcanic conglomerate, volcanic sandstone, and siltstone containing metamorphic rock fragments; maximum thickness 400 feet *(adapted from Helley & Harwood, 1985; DWR Bulletin 118-7 [in progress], 2001).*
- **Tla** — **Laguna Formation** (Pliocene)-Interbedded alluvial gravel, sand, and silt; maximum thickness 450 feet *(adapted from Helley & Harwood, 1985; Olmstead and Davis, 1961; DWR Bulletin 118-6, 1978).*
- **Ts** — **Sutter Formation** (Late Miocene to Early Pleistocene)-Volcanic fluvatile sediments with lacustrine deposits; maximum thickness approximately 1,800 feet *(adapted from Garrison, 1962).*
- **Tn** — **Neroly Formation** (Miocene)-Marine to non-marine sediments, tuffaceous andesitic sandstone with interbeds of tuff and tuffaceous shales, and occasional conglomerate lenses; maximum thickness 500 feet *(adapted from Redwine, 1972; Wagner and Saucedo, 1990).*
- **Tl** — **Lovejoy Basalt** (Miocene)-Black, dense, hard microcrystalline basalt; maximum thickness 65 feet *(adapted from Helley and Harwood, 1985).*
- **Tupg** — **Upper Princeton Gorge** (Late Oligocene to Early Miocene)-Non-marine sediments composed of sandstone with interbeds of mudstone and occasional conglomerate and conglomerate sandstone; maximum thickness 1,400 feet *(adapted from Redwine, 1972).*
- **Ti** — **Ione Formation** (Eocene)-Marine to non-marine deltaic sediments, light colored, commonly white congomerate, sandstone, and siltstone, which is soft and easily eroded; maximum thickness 650 feet *(adapted from DWR Bulletin 118-6, 1978; Creely, 1965).*
- **Tlpg** — **Lower Princeton Gorge** (Eocene)-Includes Capay Formation. Marine sandstone, congomerate, and interbedded silty shale, maximum thickness 2,400 feet *(adapted from Redwine, 1972).*
- **JKgvs** — **Great Valley Sequence** (Late Jurassic to Upper Cretaceous)-Marine clastic sedimentary rock consisting of siltstone, shale, sandstone, and conglomerate; maximum thickness 15,000 feet.
- **Mzv** — **Volcanic and Metavolcanic Rocks** (Mesozoic)-Undivided volcaninc and metavolcanic rocks, andesite rhyolite flow rocks, greenstone, and volcanic breccia *(adapted from Jennings, 1977).*



SOURCE: Used With Permission from DWR, 2002

FIGURE 2-3
NORTHERN SACRAMENTO VALLEY HYDROSTRATIGRAPHY

EVALUATION OF GROUNDWATER POTENTIAL FOR INCREMENTAL LEVEL 4 REFUGE WATER SUPPLY

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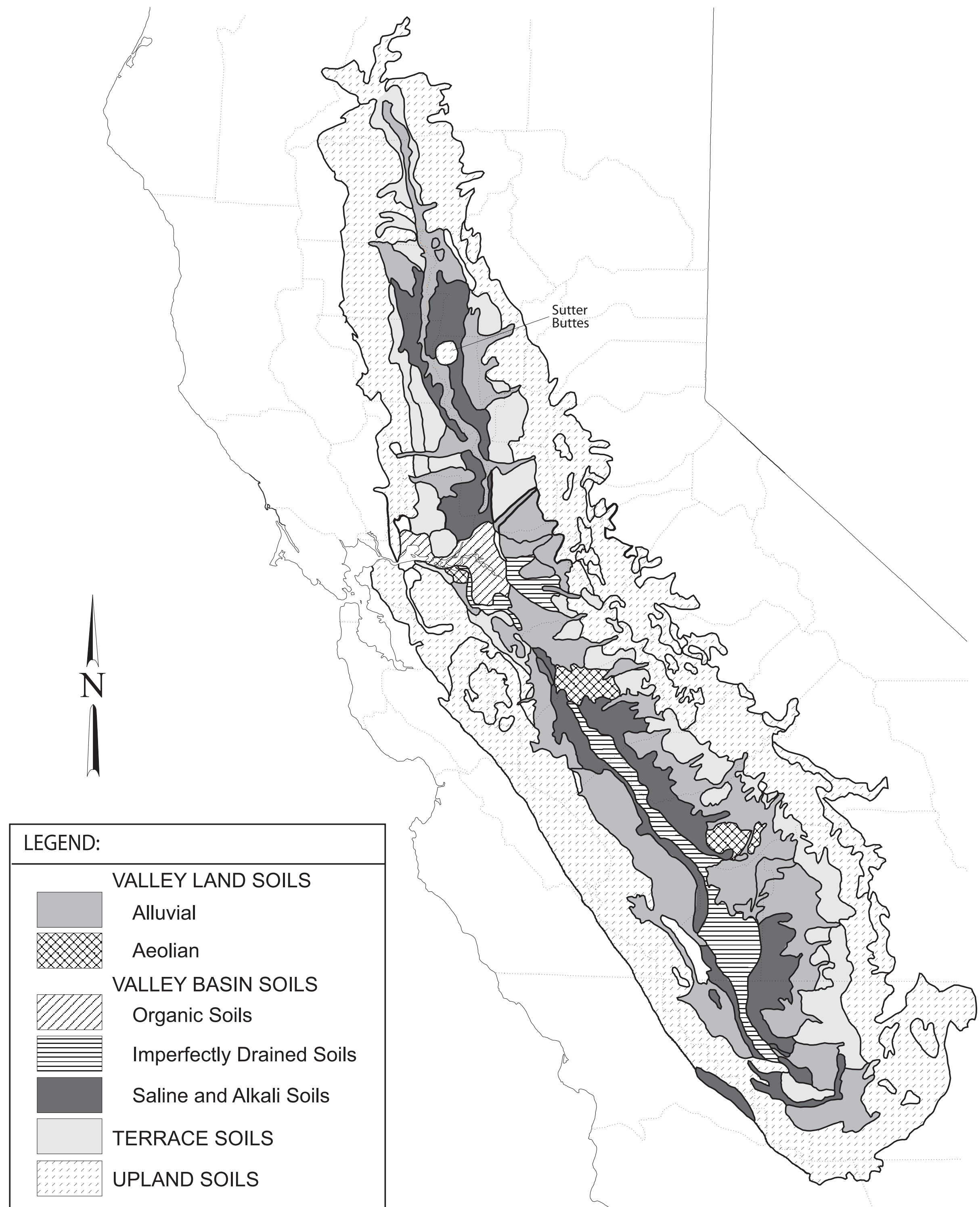

SOURCE: Reclamation 1999

FIGURE 2-4
SOIL TYPES IN THE CENTRAL VALLEY
EVALUATION OF GROUNDWATER POTENTIAL
FOR INCREMENTAL LEVEL 4 REFUGE WATER SUPPLY

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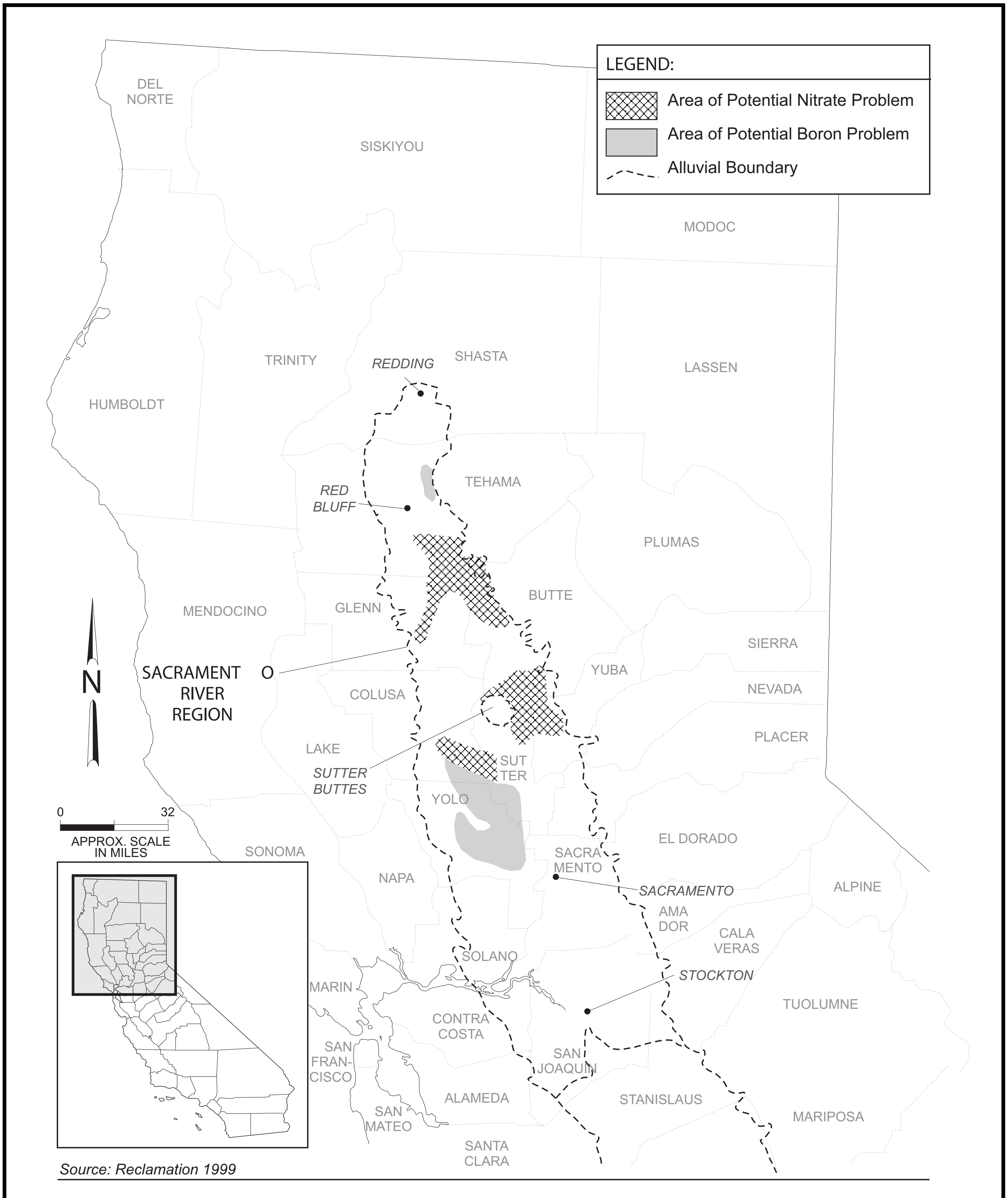

Source: Reclamation 1999

FIGURE 2-5
POTENTIAL NITRATE AND BORON PROBLEM AREAS IN THE SACRAMENTO VALLEY
EVALUATION OF GROUNDWATER POTENTIAL
FOR INCREMENTAL LEVEL 4 REFUGE WATER SUPPLY

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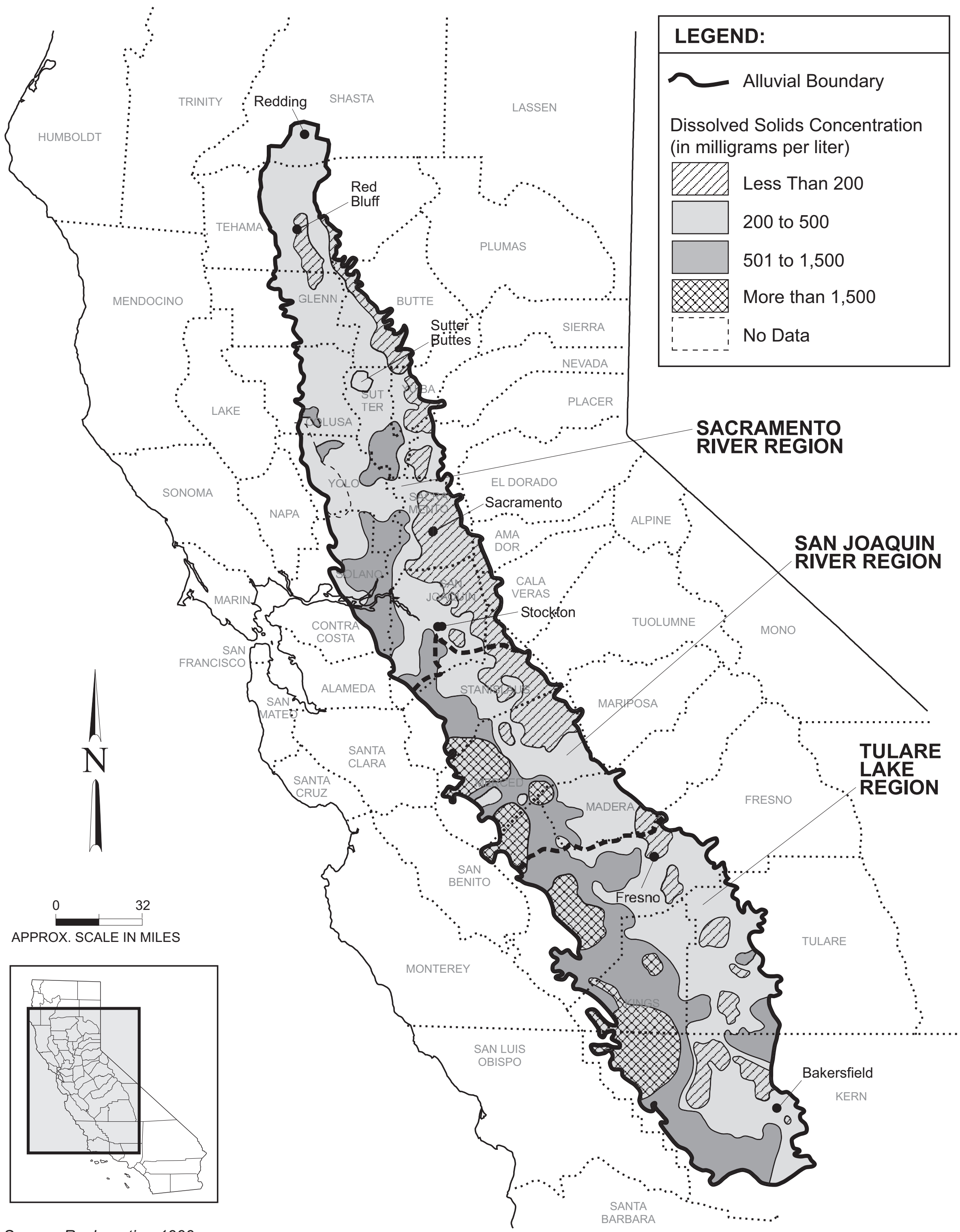

Source: Reclamation 1999

FIGURE 2-6
TDS CONCENTRATIONS IN THE GROUNDWATER AQUIFER OF THE CENTRAL VALLEY
EVALUATION OF GROUNDWATER POTENTIAL
FOR INCREMENTAL LEVEL 4 REFUGE WATER SUPPLY

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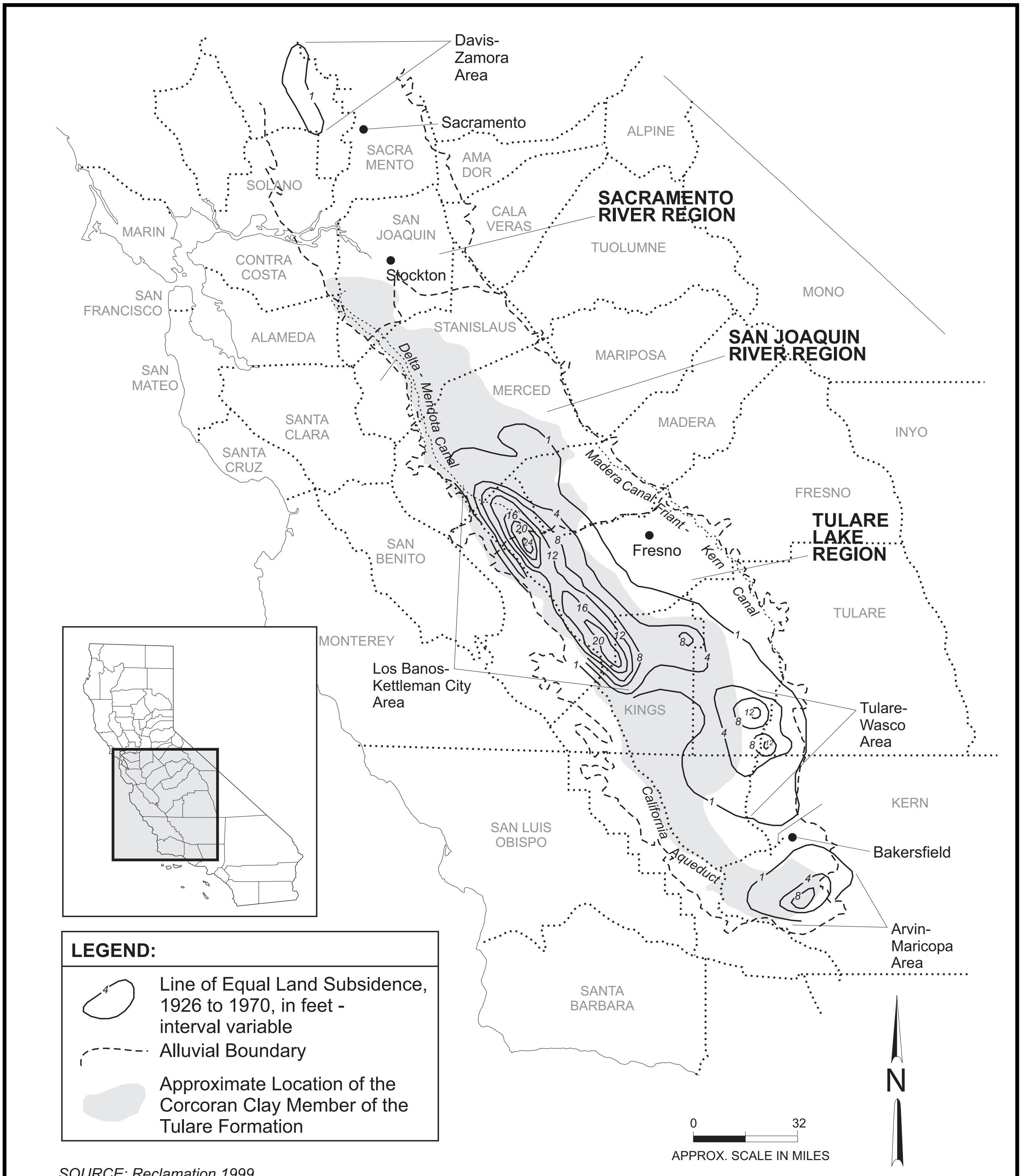

SOURCE: Reclamation 1999

FIGURE 2-7
AREAL EXTENT OF LAND SUBSIDENCE IN THE CENTRAL VALLEY DUE TO GROUNDWATER LEVEL DECLINE
EVALUATION OF GROUNDWATER POTENTIAL
FOR INCREMENTAL LEVEL 4 REFUGE WATER SUPPLY

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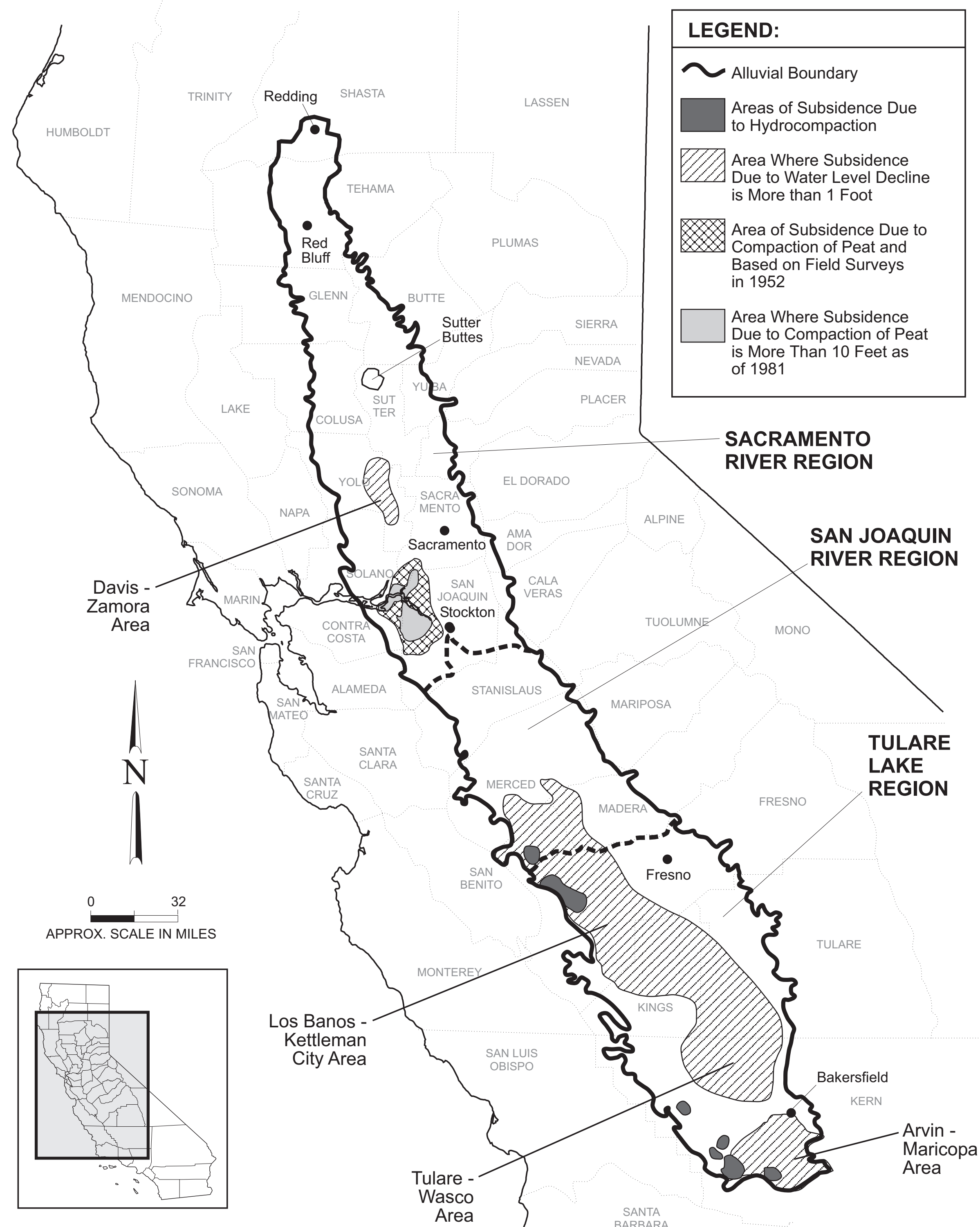

SOURCE: Reclamation 1999

FIGURE 2-8
AREAL EXTENT OF LAND SUBSIDENCE IN THE CENTRAL VALLEY
EVALUATION OF GROUNDWATER POTENTIAL
FOR INCREMENTAL LEVEL 4 REFUGE WATER SUPPLY

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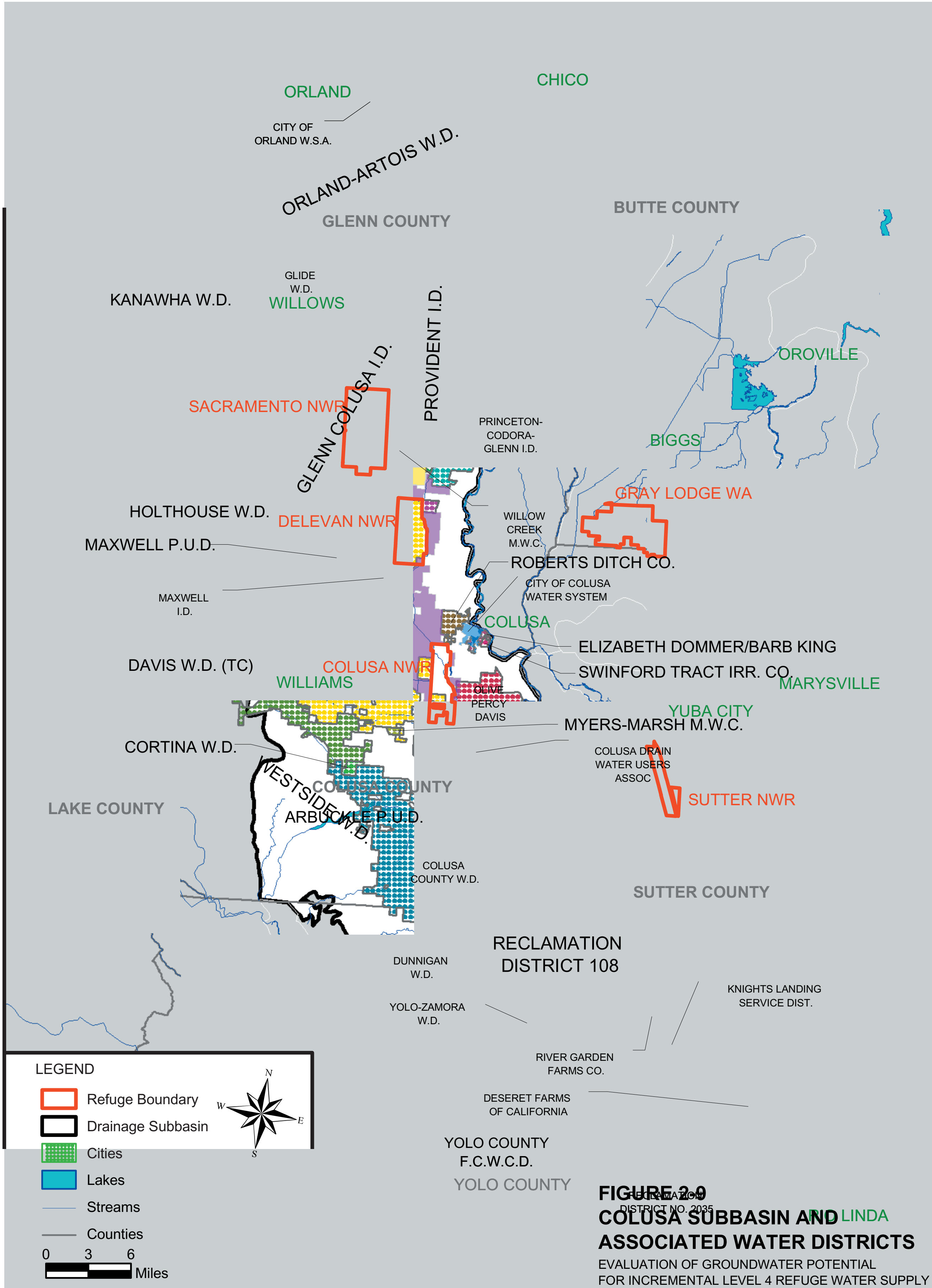

FIGURE 2-9
COLUSA SUBBASIN AND ASSOCIATED WATER DISTRICTS
EVALUATION OF GROUNDWATER POTENTIAL
FOR INCREMENTAL LEVEL 4 REFUGE WATER SUPPLY

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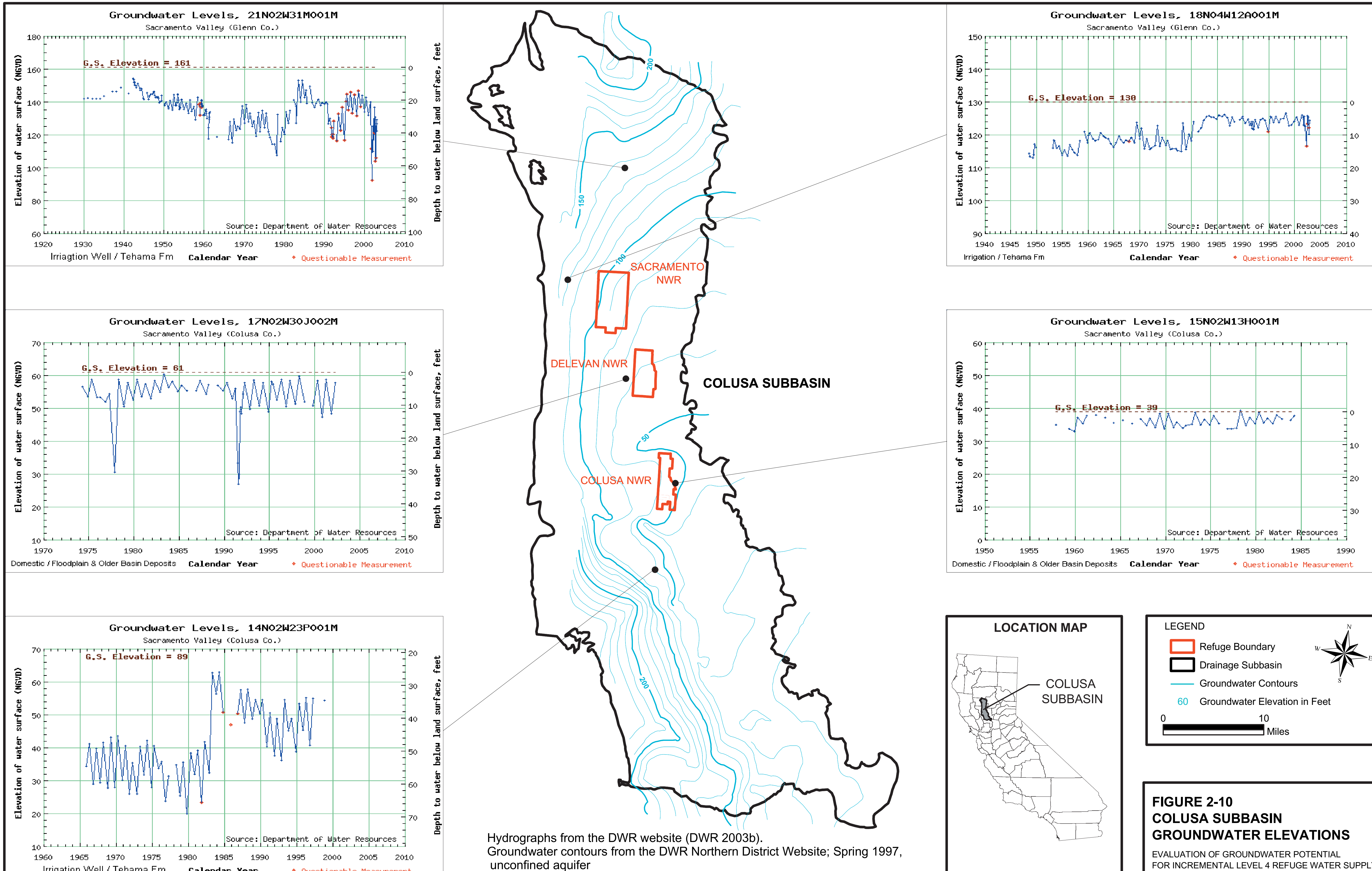

FIGURE 2-10
COLUSA SUBBASIN
GROUNDWATER ELEVATIONS

EVALUATION OF GROUNDWATER POTENTIAL
FOR INCREMENTAL LEVEL 4 REFUGE WATER SUPPLY

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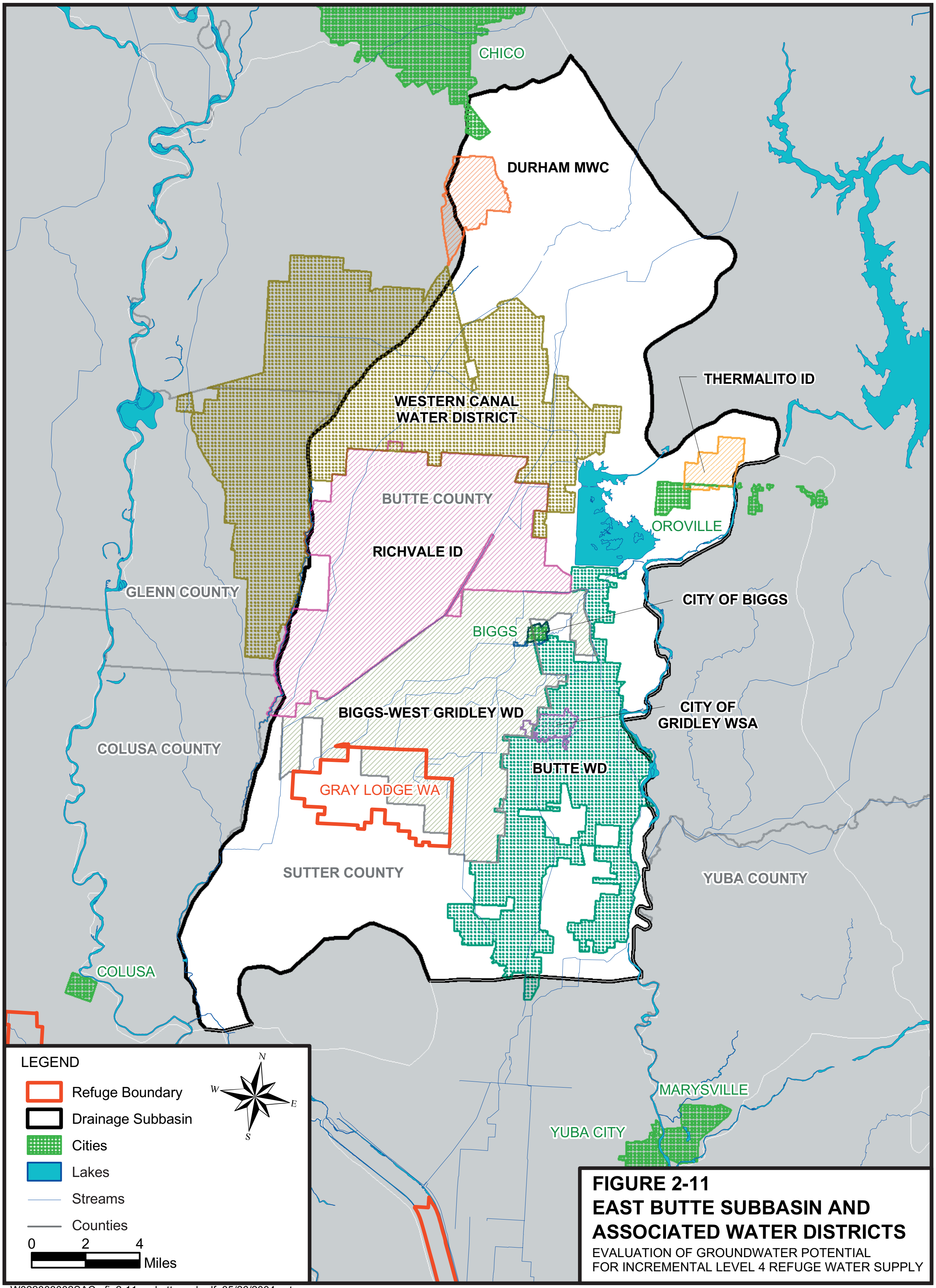

FIGURE 2-11
EAST BUTTE SUBBASIN AND ASSOCIATED WATER DISTRICTS
EVALUATION OF GROUNDWATER POTENTIAL
FOR INCREMENTAL LEVEL 4 REFUGE WATER SUPPLY

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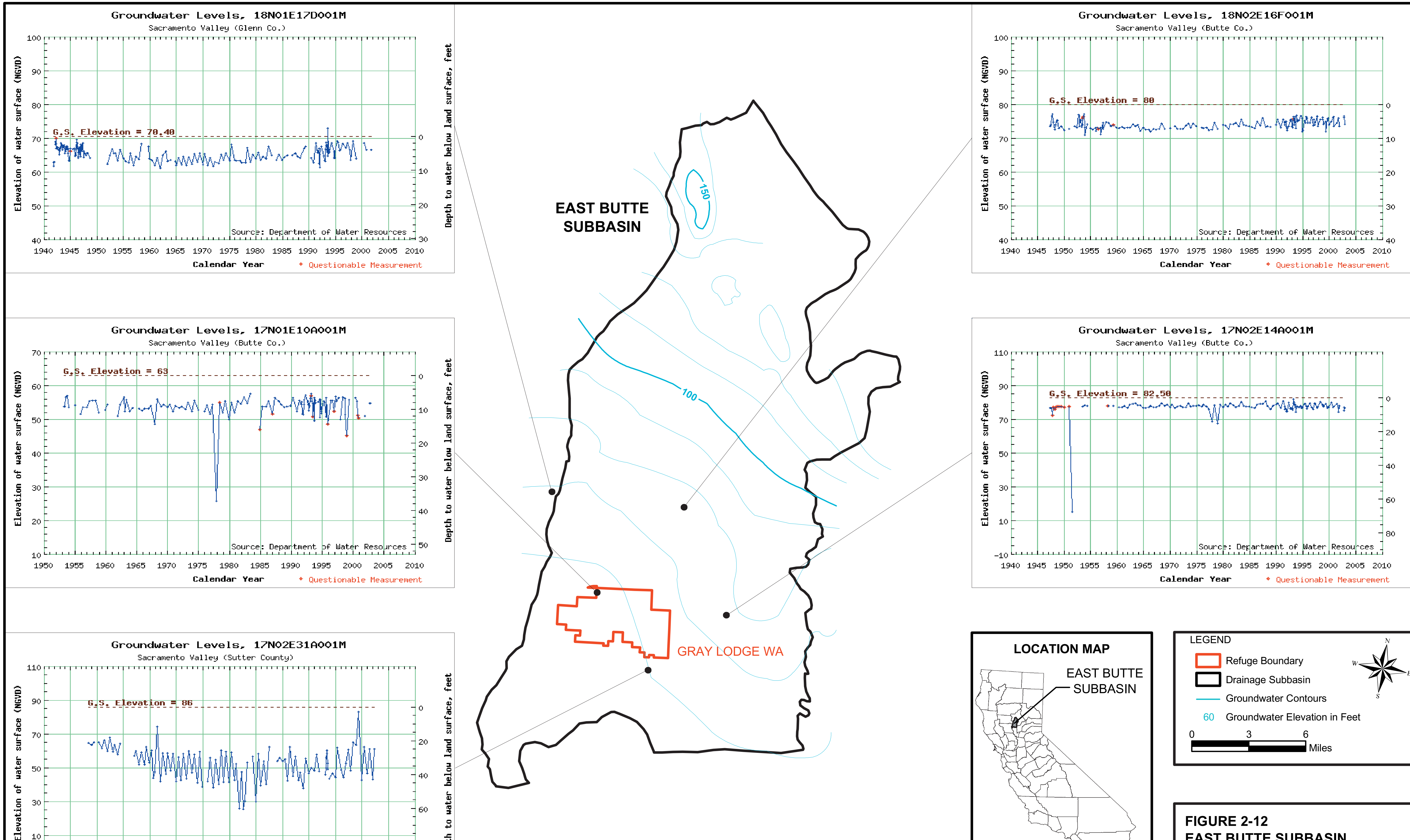

- Hydrographs from the DWR website (DWR 2003b).
- Groundwater contours from the DWR Northern District Website; Spring 1997, unconfined aquifer

FIGURE 2-12
EAST BUTTE SUBBASIN GROUNDWATER ELEVATIONS
EVALUATION OF GROUNDWATER POTENTIAL FOR INCREMENTAL LEVEL 4 REFUGE WATER SUPPLY

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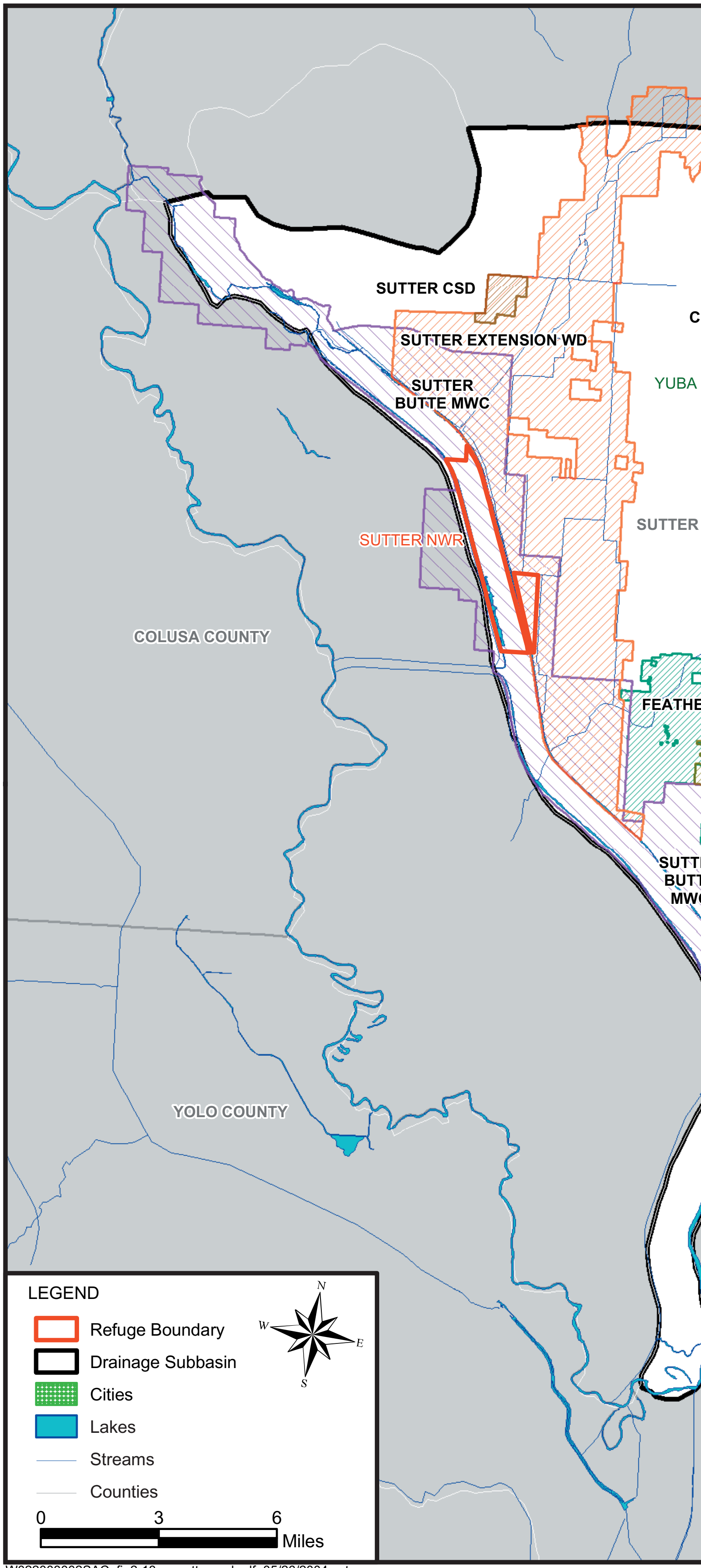

FIGURE 2-13
EAST SUTTER SUBBASIN AND ASSOCIATED WATER DISTRICTS
EVALUATION OF GROUNDWATER POTENTIAL FOR INCREMENTAL LEVEL 4 REFUGE WATER SUPPLY

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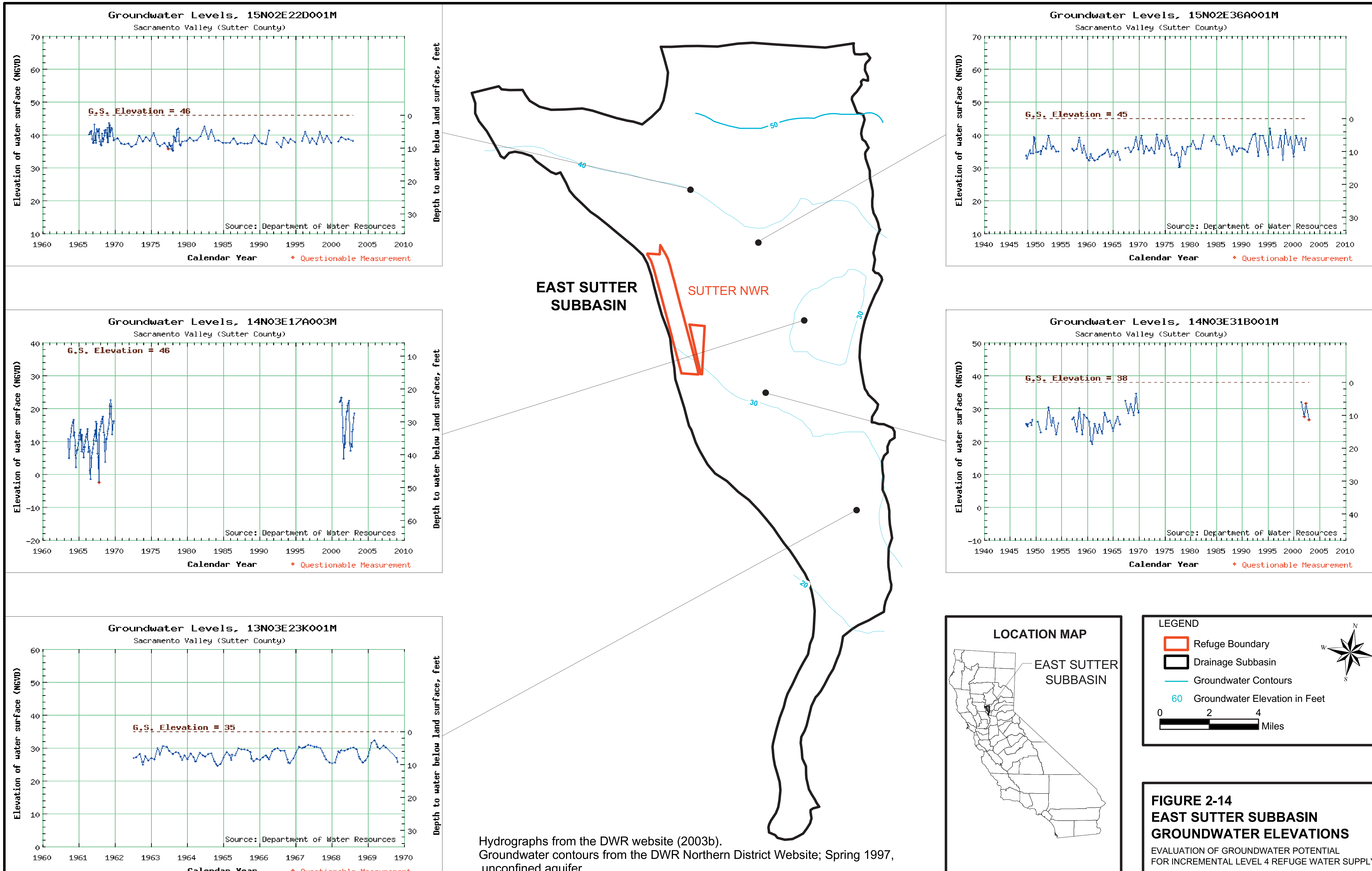

FIGURE 2-14
EAST SUTTER SUBBASIN GROUNDWATER ELEVATIONS
EVALUATION OF GROUNDWATER POTENTIAL FOR INCREMENTAL LEVEL 4 REFUGE WATER SUPPLY

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2.3 Sacramento NWR Assessment

County: Glenn and Colusa
Basin / Subbasin: Sacramento Valley Groundwater Basin / Colusa Subbasin
Level 2 / Incremental Level 4: 46,400 ac-ft / 3,600 ac-ft
2003 Acreage: 10,783
CVP Water Conveyor: Glenn-Colusa ID
Water District Service Area: Glenn-Colusa ID
Applicable Groundwater Management Regulations: Glenn-Colusa ID AB 3030

Sacramento NWR is located 5 miles south of the City of Willows and extends into both Glenn and Colusa Counties (Figure 2-15). Created in 1937, it currently encompasses 10,783 acres. Permanent ponds, seasonal wetlands, irrigated moist soil units, and uplands are located at the refuge. Refuge wetlands support wetland plant and invertebrate populations that serve as a food source for migratory waterfowl. Refuge upland areas support large concentrations of geese, upland birds, and other wildlife species (Reclamation et al. 2001a).

2.3.1 Hydrogeologic Assessment

2.3.1.1 Habitat Goals, Land Management, and Surface Features

As established by the 2002–2003 Habitat Management Plan for Sacramento NWR, the primary habitat type at the refuge is seasonal flooded marsh (approximately 80 percent of the wetland area). Eleven other habitat types are present at Sacramento NWR, including permanent ponds, summer water, unmanaged freshwater wetlands, watergrass production, annual grassland, perennial grassland, alkali meadows, vernal pools, vernal pool—alkali meadow complexes, riparian willow scrub, and cottonwood willow (Reclamation 2002).

Surface water features at the Sacramento NWR include North Fork Logan Creek and the 26-2 Lateral, owned by Glenn-Colusa ID. North Fork Logan Creek enters the refuge near the northwest corner, traverses the refuge from northwest to southeast, and leaves the refuge near the southeast corner. The 26-2 Lateral is located along the western boundary of the refuge. The closest water body east of the refuge is the 2047 Drain.

Other features at the refuge include an automobile tour route, with designated stopping points and a raised observation platform for wildlife viewing, in the central portion of the refuge. There are also two hiking trails and a visitor center at the refuge headquarters. A maintenance garage and facilities are located behind the refuge headquarters for storage of refuge equipment and supplies.

2.3.1.2 Identified Water Supply Contract Quantities

Figure 2-16 shows the Level 2 and Level 4 water supply contract quantities and the actual water deliveries to the refuge from 1999 through 2002. The annual Level 2 water supply to Sacramento NWR is 46,400 ac-ft. Based on the recent habitat water requirements, 35,000 to 38,000 ac-ft of water are being delivered and used at Sacramento NWR on an annual basis. In the past, Sacramento NWR has used between 35,000 and 40,000 ac-ft per year.

The full optimum habitat management water supply need (Total Level 4) for Sacramento NWR is 50,000 ac-ft per year. However, based on the current habitat water requirements, optimum management is being achieved with much less water than that identified as Total Level 4 water needs in 1989. Therefore, Sacramento NWR usually does not request Incremental Level 4 water at this time (Refuge staff 2002), although some Level 4 Corning Canal assessment water has been delivered to the refuge (see Figure 2-16).

Glenn-Colusa ID, with cost-sharing funding from Reclamation, has made improvements to its conveyance system to enable year-round water delivery to Sacramento NWR. Prior to these improvements, the Glenn-Colusa ID Main Canal was dewatered from late November to early April for maintenance, during which time Sacramento NWR could not receive water from Glenn-Colusa ID and so the refuge exercised its Logan Creek water rights (discussed below).

2.3.1.3 Surface Water Supplies and Infrastructure

Prior to the CVPIA, Sacramento NWR had a maximum annual water supply of 50,000 ac-ft, which was supplied by Glenn-Colusa ID. However, the contract that permitted the Sacramento NWR to obtain this water also allowed for up to a 25 percent reduction in delivery based on the water needs of higher priority uses (i.e., agriculture). Therefore, when CVPIA was passed, water delivered by GCID was not considered reliable enough for Level 2 designation.

The refuge also has four licenses that permit the diversion of up to 60 cubic feet per second (cfs) from Logan Creek. This water supplies about 3,000 acres of the refuge wetlands, mostly on the eastside of the refuge along Logan Creek (Refuge staff 2002). This water is not considered either Level 2 or Level 4 water.

The Glenn-Colusa ID Main Canal conveys CVP surface water to the refuge through the 26-2, 35-1C, and 25-1 Laterals. Water flow within the refuge generally is from north to south. Water is moved through the 26-2 Lateral by gravity flow to the northwest corner of the refuge, where it is distributed throughout the western and northern portions of the refuge. Water conveyed to the 35-1C Lateral is lifted into the west canal for distribution via gravity flow throughout the refuge. Excess surface water from the ponds and wetlands is directed to the outflow canals, which empty into Logan Creek. Surface water exits the refuge via Logan Creek near the southeast corner of the refuge (Reclamation et al. 2001a; Refuge staff 2002).

Quality of the delivered surface water is considered suitable by refuge staff for the wildlife habitat needs of the refuge.

2.3.1.4 Groundwater Supplies and Infrastructure

Currently, groundwater is being used at the refuge only for domestic purposes, although it has been used historically to meet a very small portion of refuge water demands (Refuge staff 2002). Inactive irrigation wells and test wells installed to evaluate groundwater conditions also occur at the refuge. Sacramento NWR well locations discussed in this subsection are shown on Figure 2-15. Table 2-1 summarizes available onsite refuge well information.

Irrigation and Production Wells. Reclamation drilled two irrigation wells on the refuge in 1977–78. Irrigation Well 1 (shown as SA-IW-01 in Figure 2-15) was 590 feet deep and had a reported water production of 500 gpm. Irrigation Well 2 (SA-IW-02, Figures 2-15 and 2-17) is 560 feet deep and produced 1,200 gpm when it was installed.[2] Well 1 (SA-IW-01) was not put into production because of low well yield, and it is reportedly capped (Hollinger 1991a). The well was sampled as recently as 1991 (test results described below). Well 2 (SA-IW-02) has been used periodically to supplement water to the permanent ponds immediately north of the refuge headquarters. The well has not been used for the past couple of years because operation cost was high and reliable surface water is now available year round (Refuge staff 2002).

Records indicate that three wells are located behind the refuge headquarters. According to available records (DHS 1995), the newest well (SA-DW-03), drilled in 1975, provides potable domestic water to the refuge. It may have been drilled to replace the other, older well at the refuge headquarters (SA-DW-02), which DHS's 1995 report indicates is used for irrigation. An older dug well (SA-DA-01) is also found behind the refuge headquarters, but it is reportedly not used and may have existed prior to when the refuge was established (Refuge staff 2002).

Test Wells. Three test wells (TW-1 through TW-3, or SA-TW-01 through SA-TW-03) were drilled on the refuge during the summer of 1991 to evaluate the potential for developing another irrigation well to support the refuge during the drought. Reclamation drilled the test wells to 600 feet and completed them with 4-inch polyvinyl chloride (PVC) casing with multiple perforations in permeable zones (Turner 1992b). TW-2 (SA-TW-02) flowed naturally at a rate of about 30 gpm. A 16-inch production well was installed in 1993 at location TW-3 (SA-TW-03) because it had the best water quality of the three sites (discussed later). Output from this well was about 629 to 675 gpm with measured drawdowns of 253 to 275 feet, which was determined to be insufficient for a useful irrigation well. Therefore, no further development of the well occurred, and the casing is assumed to be sealed (Kramer 1993).

Water Quality Data. Available groundwater quality data from onsite wells are shown in Table 2-2.

Water from the two irrigation wells located on the refuge have been considered unusable because of reported high levels of boron and arsenic (Reclamation et al. 2001a). However, the data from which these conclusions were made were not able to be located during the preparation of this report. Available refuge water quality data for boron and arsenic do not indicate water quality is unsuitable for use, based on the concentrations of these constituents.

Groundwater samples collected in 1989 from Irrigation Well 2 (SA-IW-02) contained elevated levels of total chromium (19 μg/L) and mercury (0.4 μg/L) relative to regional background levels. The well was resampled in 1990, which confirmed the previous chromium value (18 μg/L), but not mercury (<0.2 μg/L) (Hollinger 1991b).

[2] The depths of wells No. 1 and 2 are based on a Reclamation memorandum (1991). These depths conflict with the depths reported in the Refuge Water Supply Report, which indicated that the two refuge wells were 195 and 260 feet deep. The deeper well depths reported in the 1991 memorandum are more consistent with typical irrigation well depth and are also supported by a 207 feet drawdown reported during a 1982 pump test conducted by Pacific Gas & Electric (PG&E).

In 1991, Reclamation conducted a larger-scale sampling event at wells on and near the refuge. Water quality samples were collected from Irrigation Wells 1 (SA-IW-01) and 2 (SA-IW-02), 10 offsite production wells located within 1 mile of the eastern boundary of the refuge, and at discrete intervals from the test wells drilled at the refuge (Hollinger 1991a and 1991b). EC was measured, and samples were collected for hexavalent chromium (Cr(VI) analyses (Figure 2-18). Two of the offsite wells were also sampled for general metals. The results of this sampling indicated that Cr(VI) concentrations in six wells to the east of the refuge were at or below the detection level of 10 μg/L. The remaining four wells ranged from 12 to 14 μg/L. This indicates that CR(VI) concentrations to the east of the refuge are generally lower than those found at the northwest refuge wells (Hollinger 1991b), although concentrations may be above the federal Freshwater Aquatic Life Protection Recommended Criteria of 11 μg/L (continuous concentration) (USEPA Office of Water 2002a). Vertical variations in chromium concentrations are not evident based on available data, which are missing some well screen intervals (Figure 2-19). Additional investigation would be needed to determine if there are areas of Sacramento NWR where chromium concentrations are below the federal Freshwater Aquatic Life Protection Recommended Criteria of 11 μg/L.

2.3.1.5 Local Groundwater Use

Groundwater is used to meet both domestic and irrigation needs. Groundwater users in the local area consist of duck clubs, dairies, and the Willow Creek Mutual Water Company (MWC). Throughout Glenn-Colusa ID, there are more than 160 groundwater wells operated by Glenn-Colusa ID landowners (Glenn-Colusa ID 1995).

2.3.1.6 Refuge Soil and Aquifer Conditions

The surface soil characteristics for Sacramento NWR were evaluated using the May 1968 Soil Survey of Glenn County, California. Soils at the refuge generally have low permeability and are poorly drained. The majority of the surface soils are silty clay and clay. The average thickness of the soil profile at the refuge is about 60 inches.

The dominant surface soil types at Sacramento NWR are the Riz Series and the Willows Series, both of which are poorly drained, fine-grained alluvial soils ranging in thickness from 2 to 5 feet. In addition, the Arbuckle Series and Hillgate Series were identified at Sacramento NWR; however, their distribution is limited and sporadic.

The Arbuckle Series consists of gravelly loam or gravelly fine sand loam with moderate permeability, slow runoff, and slight erosion potential. It is located in only the extreme northeastern portion of the refuge. The Hillgate Series consists mainly of silt loam, silty clay loam, and clay loam with slow to very slow permeability, very slow runoff, and minimal erosion potential. It is located in the southwestern portion of the refuge.

Four tracts (Tracts 27, 28, 33, and 42), located in the southern half of the refuge, are considered by Refuge staff to be the “expensive” areas at Sacramento NWR because they require the most water to maintain their specific habitat requirements. During the last drought, refuge staff did not water these tracts because of reduced water supply to the refuge. When routine watering commenced after the end of the drought, staff reported that wetland habitat returned very quickly. Because of the natural high permeability of this area, it may be worthwhile to conduct further evaluations of leakage rates and the potential for surface recharge to be "stored." One of these tracts (Tract 33) is underlain by Hillgate Series soils. Otherwise, there is no distinct difference between the soils in these tracts and other soils on the refuge, based on available data.

Historically, subsidence has not been a significant issue in the northern Sacramento Valley, and it has not been documented in the vicinity of the refuge. Aquifer conditions consist mainly of unconfined alluvium. Expansive confining layers susceptible to compaction are not present.

Seasonal water level fluctuations occur in the subbasin. In the vicinity of the refuge, groundwater levels annually rebound to within 10 feet of the surface (DWR 2003b). Artesian conditions have also been reported at the refuge. The area around Irrigation Well 1 (SA-IW-01) was reported to be wet because water seeped out of the well (refuge staff 2002) and artesian conditions were also reported at test well 2 (SA-TW-02).

Reclamation estimated the annual safe yield of the aquifer beneath the refuge to be 12,900 ac-ft (Reclamation 1989).

2.3.1.7 Operational Issues and Data Needs

The refuge's dependence on Incremental Level 4 water is relatively minor compared to other refuges. Approximately seven percent of the water supply contract quantity for Sacramento NWR is Incremental Level 4 water. Incremental Level 4 water made available to Sacramento NWR is relatively stable in cost, and subjectivity to spot-market variability is low (Reclamation staff 2003). The refuge is located north of the Delta, and it is unnecessary to convey Level 4 water to the refuge through the Delta.

The following data gaps were identified during the completion of this study:

- Assessment of all identified wells on the refuge, including the old irrigation or domestic well behind the refuge headquarters.
- Confirmation of vertical and horizontal refuge groundwater quality conditions, particularly for chromium, throughout the refuge and at the refuge domestic well.
- Historical water-level data at refuge wells and those immediately adjacent to the refuge.
- Depth and permeability of soils in the northeast portion of the refuge, where the Arbuckle loam is located, and the southwest portion of the refuge, where the Hillgate silt loam is located.
- Aquifer parameters, such as hydraulic conductivity and thickness.
- Groundwater pumping records and schedules, both on and immediately surrounding the refuge.

Relative to the other refuges in this study, it was estimated that a "moderate" level of data collection is required at Sacramento NWR prior to recommending increased groundwater development.

2.3.2 Criteria Evaluation Summary

Sacramento NWR received total Hydrogeologic Scores of +2 for Direct Use of groundwater and -1 for On-Refuge Conjunctive Use, based on the criteria matrix evaluation. The criteria matrix specific to Sacramento NWR is shown as Table 2-3. The matrix includes a score for each criterion and a corresponding justification or reasoning for the score given.

Groundwater has not been used at the refuge for several years because existing surface water supplies were adequate for wetland management. Nevertheless, with the exception of some water quality concerns, the refuge is strong in several key areas supporting further direct use of groundwater. Support and limitations to further development of groundwater resources at Sacramento NWR are summarized below.

2.3.2.1 Support for Groundwater Development

- No surface water bodies in the refuge vicinity would be affected by increased groundwater use.
- A developed internal distribution system (IDS) allows water to move extensively throughout the refuge, supporting integration of groundwater infrastructure with current water management.
- No subsidence has occurred in the past in the refuge vicinity.
- Minimal potential exists for subsidence to occur with increased groundwater use.
- Surface water is delivered to the refuge and is therefore available for blending with groundwater.

2.3.2.2 Limitations to Groundwater Development

- At-surface soils primarily have low permeability and may not be conducive to groundwater recharge, with the exception of soils in Tracts 27, 28, 33, and 42.
- Aquifer storage is not available. Current and historical groundwater levels are approximately equivalent.
- Poor groundwater quality has limited groundwater use in the past. Parameters of concern have included boron, arsenic, mercury, and hexavalent chromium.
- Incremental Level 4 water made available to purchase Sacramento NWR is relatively stable in cost and availability.
- It is unnecessary to convey Incremental Level 4 water through the Delta. Higher priority for groundwater development may be considered for refuges which have the water conveyance constraint of moving this water through the Delta.
- Dependence on Incremental Level 4 water for refuge water supply is relatively minor compared to other refuges in the study.

2.3.3 Recommended Data Acquisition Activities

Collecting additional data is recommended at Sacramento NWR prior to further development of groundwater. Recommended data acquisition activities include:

- Investigate and assess all on-refuge wells. Video-log existing wells to determine condition and necessary repairs, and to diagnose failure, if appropriate. Assess the old irrigation or domestic well behind the refuge headquarters to determine if it is usable as a supply well.
- Conduct water quality testing at all wells capable of use for refuge water supply. Sample the existing irrigation well, domestic well, and test wells for general chemistry and metals, including arsenic, boron, chromium, mercury, and nitrates.
- Well-yield information from the state well logs for wells located just east of the refuge indicate production rates of 1,800 to 2,500 gpm. To determine whether these well yields are possible in other parts of the refuge, drill, sample, and test three boreholes on the northeast side of the refuge (Township 18 North, Range 3 West, Sections 12, 13, and 14) to establish aquifer properties and water quality conditions.
- Collect water-level data from available wells within and adjacent to the refuge. Monitor water levels quarterly, and collect routine water quality samples from active wells to develop a database of groundwater use and conditions. Maintain collected data in a format supportable and usable by the refuge.
- Evaluate existing groundwater pumping surrounding the refuge, particularly to the east. This may entail the installation of well meters and/or coordination with Glenn-Colusa ID and Willow Creek Mutual WC.
- Evaluate the recharge potential in the northeast portion of the refuge where the Arbuckle loam is located. Also, since refuge staff have reported that it is difficult to convey water to the southwest corner of the refuge, evaluate the recharge potential in the southwest corner where the Hillgate silt loam is located. Conduct shallow auguring to evaluate soil depth, permeability, and chromium concentration.
- Evaluate water chemistry compatibility and potential dilution resulting from mixing groundwater from Well No. 2 (SA-IW-02) and delivered water. Also identify potential impacts at the refuge resulting from using groundwater with Cr(VI) at concentrations identified in Well No. 2 (SA-IW-02).

2.3.4 Potential Projects

2.3.4.1 Direct Use

Incremental Level 4 supplies for Sacramento NWR are 3,600 ac-ft per year with a peak monthly incremental need in March. Assuming a well yield of 1,200 to 1,500 gpm (based on well production rates at and east of the refuge), five wells would be needed to meet this demand. The amount of 3,600 ac-ft represents approximately one-quarter of Reclamation's estimated safe yield of the aquifer beneath the refuge. If well locations with suitable aquifer properties and water quality can be identified at the refuge, it may be possible for direct use of groundwater to be considered to meet Incremental Level 4 contract quantities at Sacramento NWR. A proposed project is to install three production wells on the east side of the refuge to meet a portion of Incremental Level 4 contract quantities. This enables assessment of the groundwater refuge water supply prior to full-scale development. The east side of the refuge is considered to have higher potential for favorable aquifer conditions.

2.3.4.2 On-Refuge Conjunctive Use

Although most refuge soils would not support extensive onsite groundwater recharge, the four "expensive" tracts discussed earlier (Tracts 27, 28, 33, and 42) located in the southern half of the Sacramento NWR may be good candidates for groundwater recharge areas. Tracts 27, 33, and 42 currently are managed as seasonal flooded marsh, and Tract 28 is being managed as a watergrass production area.

Because well yields and water quality east of the refuge (as evidenced by the 1991 sampling) appear to be supportive of groundwater development, Sections 12, 13, or 14 warrant additional groundwater investigation. Wells in this area could be used to support wetlands in the eastern portion of the refuge, possibly using Logan Creek to convey the water. Water not used by Sacramento NWR could be conveyed south to Delevan NWR, possibly through Glenn-Colusa ID's canals.

2.3.4.3 Off-Refuge Conjunctive Use

Sacramento NWR is within the sphere of influence of the Glenn-Colusa ID Groundwater Management Plan (AB 3030). Groundwater is extracted in the district for individual residential use, agricultural use, and municipal and industrial use. The plan supports the investigation of natural recharge sites, spreading basins, and artificial recharge sites and facilitates conjunctive use operations when possible. The irrigation district, therefore, may support conjunctive use activities and/or construction of recharge basins at a refuge it serves, such as Sacramento NWR. The plan is silent regarding water transfers.

Two feasible groundwater projects are being considered by districts north of the refuge are the Stony Creek Fan and the Maxwell ID Conjunctive Use Project (see Table C-1 in Appendix C). Both of these projects are located hydraulically upstream of the refuge. The Glenn-Colusa ID, the refuge's surface water conveyor, is a participant in the Stony Creek Fan Project. The Stony Creek Fan is currently in the testing and development phase. Refuge participation in this project may be facilitated if water could be delivered to the refuge by its existing surface water conveyor, Glenn-Colusa ID. The Maxwell ID project includes proposed construction and operation of up to three new deep water wells adjacent to or near the district's existing conveyance canals. Conveyance of water to the refuge is uncertain at this time.

TABLE 2-1
Sacramento NWR Well Information[a]
Evaluation of Groundwater Potential for Incremental Level 4 Refuge Water Supply

GIS Well Number[b]	Common Well Name	Well Status[c]	2002 Yield (ac-ft)	Year Installed	Depth (ft)	Screen Interval (bgs)	Well Output (gpm)	Well Log?	Water Quality Data?	Comments
SA-TW-01	Test Well 1	Nonfunctional		1991	601	190–570	125	Y	Y	Specific screened intervals are: 190–210, 290–320, 360–430, 470–480, 510–570.
SA-TW-02	Test Well 2	Nonfunctional		1991	606	270–560	125	Y	Y	Specific screened intervals are: 270–310, 410–450, 490–500, 540–560.
SA-TW-03	Test Well 3	Nonfunctional		1991	606	115–435	100	Y	Y	Specific screened intervals are: 115–155, 185–225, 265–305, 375–405, 425–435.
SA-IW-03	Unknown	Nonfunctional		1993	550	290–550	629	Y	N	Well installed at TW-1 location. Testing indicated well operation was incompatible with irrigation needs, so it was capped (assumed).
SA-IW-01	Refuge Well 1	Destroyed		1978	670	?–590	500	N	Y	Refuge staff indicate that the well was drilled and capped in 1978 and that there was artesian flow at the well.
SA-IW-02	Refuge Well 2	Inactive		1978	560		1,372	N	Y	Well is inactive because it is not needed.
SA-DW-01	Dug Well	Unknown						N	N	
SA-DW-02	Old Domestic Well	Unknown						N	N	
SA-DW-03	Domestic Well	Active		1975	195	117–137	35	Y	N	

Notes:

[a] Based on data compiled from well logs, test records, communication with refuge staff (2002), and other previous documentation. Well locations are shown on Figure 2-15. On-refuge wells only are included in this table, although the GIS includes known wells within 1 mile of the refuge.

[b] Well type is indicated by the middle two letters of the GIS well number: IW = irrigation well, DW = domestic well, MW = monitoring well, TW = test well, and UN = unknown.

[c] Designation refers to the physical well only, not water quality issues. Designations are: *active* (currently operated), *inactive* (capable of operating, but currently is not), *nonfunctional* (cannot operate in current physical state), *destroyed* (well has been lost, abandoned, or filled), or *unknown* (no information regarding status is available).

Blank fields indicate that no information is available.

TABLE 2-2
Sacramento NWR Water Quality Data (1989–1992)
Evaluation of Groundwater Potential for Incremental Level 4 Refuge Water Supply

GIS Well Number	Sampled Interval (feet)*	Date	EC (μmhos/cm)	Arsenic (μg/L)	Boron (mg/L)	Cr(VI) (μg/L)	Chromium (μg/L)	Mercury (μg/L)
SA-TW-01	Well	06/19/1991				10		
	Well	11/08/1991	576			12		
	190–210	05/05/1992	652			6		
	290–320	05/05/1992	620			9		
	360–430	05/05/1992	700			<5		
	510–570	05/05/1992	682			<5		
SA-TW-02	Well	09/12/1991	561			37		
	Well	11/08/1991	546			26		
	270–310	05/05/1992	602			18		
	410–450	05/05/1992	579			19		
SA-TW-03	Well	11/08/1991	558			25		
	185–225	05/05/1992	603			18		
	265–305	05/05/1992	592			19		
	375–405	05/05/1992	581			18		
	425–435	05/05/1992	622			22		
	455–505	05/05/1992	630			18		
SA-IW-01	Well	06/19/1991	507			10		
SA-IW-02	Well	09/19/1989	512	1	0.2		19	0.4
	Well	07/19/1990	550	1		21	18	<0.2
	Well	08/16/1990	550			20		

Source: Fields 1989; Hollinger 1991a; Hollinger 1991b; Turner 1992b.

Notes:

* “Well” indicates that a nondiscrete sample was collected from the well as a whole.
Blank fields indicate that the constituent was not tested.
ND = not detected

TABLE 2-3
Sacramento NWR Evaluation
Evaluation of Groundwater Potential for Incremental Level 4 Refuge Water Supply

Criteria		Scoring Scale	Appl.[b]	Score	Refuge Score Justification
Surface[a]	Do surface water bodies exist that could be affected by increased groundwater use?	+1 = no 0 = to some degree –1 = yes, surface water bodies could be affected	D,N	+1	Off-refuge surface water bodies would not be impacted. The nearest water body is the 2047 Drain to the east of the refuge. The 2047 Drain is more likely to be impacted by off-refuge wells in its immediate vicinity than by additional refuge pumping.
Water Supplies and Infrastructure	Has groundwater been used previously at the refuge for ponds or irrigation?	+1 = yes, used successfully to meet at least 20 percent of annual refuge water demands 0 = yes, used to meet less than 20 percent (or unknown) of annual refuge water demands. –1 = no, has not been used	D,N	0	Groundwater has supplemented water supply in the past. Irrigation Well No.2 (SA-IW-02) has been used to flood adjacent ponds. However, the well has not been used in the past few years. The only well currently in operation at the refuge is the domestic well (SA-DW-03).
	Do wells exist on the refuge?	+1 = yes, active wells 0 = yes, inactive or nonfunctional wells –1 = yes, destroyed wells, or no wells exist on the refuge	D,N	0	Use of Refuge Well No. 1 (SA-IW-01) was discontinued in the early 1980s. Refuge Well No. 2 (SA-IW-02) is inactive because the refuge has a firm surface water supply.
	Does existing internal distribution system (IDS) support groundwater use?	+1 = water can move extensively around the refuge with existing IDS 0 = the IDS enables limited water movement within the refuge –1 = an IDS does not exist on the refuge or water flow relies exclusively on gravity	D,N	+1	Once the water is on the refuge, it moves throughout the refuge via several lateral ditches and canals.
Local Groundwater Use	Is groundwater used for agriculture or duck clubs in the immediate vicinity of the refuge?	+1 = groundwater is not used; or groundwater is minimally used, but use is not constrained 0 = groundwater is used in the area –1 = groundwater is not used due to physical or environmental constraints or is extensively used in the vicinity	D,N	0	Groundwater is used by duck clubs, dairies, and the Willows Creek Mutual WC. Throughout Glenn-Colusa ID, there are more than 160 groundwater wells operated by Glenn-Colusa ID landowners.
	Does municipal or domestic supply exist near the refuge?	+1 = no known domestic or municipal wells are located within 1 mile of the refuge 0 = municipal or domestic wells are likely located within 1 mile of the refuge –1 = municipal or domestic wells are located within 1 mile of the refuge	D,N	0	Many of the off-refuge wells are located within 1 mile of the eastern boundary of the refuge. Some of these may be domestic wells.
Soil and Hydrogeology	Are at-surface soils conducive to groundwater recharge?	+1 = soils are sandy or are reported to percolate well 0 = soils are silty or are reported to have some infiltration –1 = soils are clayey or are reported to hold water well	N	-1	The majority of the surface soils are mainly silty clay and clay. They are typically poorly drained and the permeability is slow.
	Could recharge basins be developed if surface soils were removed?	+1 = confining soil less than 2 feet thick 0 = confining soil 5 to 7 feet thick –1 = confining soil greater than 7 feet thick	N	0	The average thickness of the soil profile at the refuge is about 60 inches.
	Has subsidence occurred at or in the immediate vicinity of the refuge?	+1 = no 0 = yes, less than 2 feet –1 = yes, more than 2 feet	D,N	+1	Subsidence has not been documented in the vicinity of the refuge. It does not appear to be a major concern in northern parts of the Sacramento Valley.
	Does significant potential for subsidence exist if groundwater use is increased at the refuge?	+1 = minimal potential for subsidence 0 = some potential for subsidence –1 = significant potential for subsidence	D,N	+1	Historically, subsidence has not been an issue in the northern parts of the Sacramento Valley. Aquifer conditions consist mainly of unconfined alluvium. Expansive confining layers susceptible to compaction are not present.
	Is aquifer storage available in the subbasin?	+1 = yes, current water levels are greater than 30 feet lower than historical levels 0 = some, current water levels are between 10 and 30 feet lower than historical levels –1 = no	N	-1	Seasonal water level fluctuations do exist in the subbasin. However, in the vicinity of the refuge, groundwater levels rebound to within 10 feet of the surface.

Notes:

continued on next page

[a] Surface Features

[b] Application to Approach: D = Direct Use, N = On-Refuge Conjunctive Use

TABLE 2-3
Sacramento NWR Evaluation
Evaluation of Groundwater Potential for Incremental Level 4 Refuge Water Supply

Criteria		Scoring Scale	Appl.[b]	Score	Refuge Score Justification
Water Quality	Have groundwater quality conditions hindered groundwater use in the past?	+1 = no 0 = data are not available –1 = yes	D,N	-1	Boron, arsenic, and Cr(VI) have been detected at the refuge. Wells have not been used in-part because of groundwater quality concerns.
	Do adverse groundwater quality conditions exist in the subbasin?	+1 = no 0 = potential –1 = yes	D,N	0	There are localized areas of impaired groundwater. It is unknown if these impairments cover the entire subbasin.
	Is surface water available to enable blending of lower quality groundwater to meet proposed refuge standards?	+1 = yes 0 = during portions of the year –1 = no	D,N	+1	The refuge has a reliable year-round supply of surface water.
	Do groundwater conditions exceed USEPA Freshwater Aquatic Life Standards or Agricultural Water Quality Goals for multiple parameters?	+1 = no 0 = yes, two parameters, or no water quality testing has been conducted –1 = yes, three or more parameters	D,N	0	Chromium (VI) and arsenic are above standards. Boron and mercury have also been detected.
	Is refuge land use management compatible with seasonally or annually variable water quality from different sources?	+1 = yes 0 = some potential compatibility problems may exist –1 = no	D,N	0	The only water quality data available is from September to November. There is no data to determine if there are seasonal fluctuations.
	Does groundwater quality meet drinking-water standards (i.e., can it be used for refuge domestic supply)?	+1 = yes it is used, no treatment is necessary 0 = yes it is used, but some treatment is necessary for potable use; or it is not used for unknown reasons –1 = no, it is not used because of adverse water quality conditions	D	+1	The water is currently being used as a potable supply.
Operational Issues/Constraints	Does a significant percentage of total refuge water supply consist of "Incremental Level 4" water?	+1 = yes, 54% to 79% of total water supply is Incremental Level 4 0 = somewhat, 27% to 53% of total water supply is Incremental Level 4 –1 = minor, 0% to 26% of total water supply is Incremental Level 4	D,N	-1	Approximately seven percent of the water supply for Sacramento NWR consists of Incremental Level 4 water.
	Is the cost of local water high or low relative to the other refuges in this study?	+1 = costs may fluctuate highly or are subject to spot-market variability or price spikes –1 = costs are relatively stable and subjectivity to spot-market variability is low	D,N	-1	Incremental Level 4 water made available to Sacramento NWR is relatively stable in cost and subjectivity to spot-market variability is low.
	Is it necessary to convey Incremental Level 4 water through the Delta for refuge supply?	+1 = yes, Incremental Level 4 water must be conveyed through the Delta –1 = no, conveyance of Incremental Level 4 water through the Delta is not necessary	D,N	-1	No, conveyance of Incremental Level 4 through the Delta is unnecessary. The refuge is located north of the Delta.
Data Needs	Are there significant data needs to address prior to groundwater development?	+1 = no, data needs regarding refuge groundwater conditions are minor 0 = somewhat, some data are required prior to increasing groundwater development –1 = yes, significant data must be collected as there is little or no existing data	D,N	0	Some data are required prior to increasing groundwater development, including a thorough well assessment, confirmation of groundwater quality conditions, local aquifer conditions, and depth and permeability of soils in areas where recharge might be considered.
			Total Direct Use Score =	**+2**	
			Total On-Refuge Conjunctive Use Score =	**-1**	

Notes:
[a] Surface Features
[b] Application to Approach: D = Direct Use, N = On-Refuge Conjunctive Use

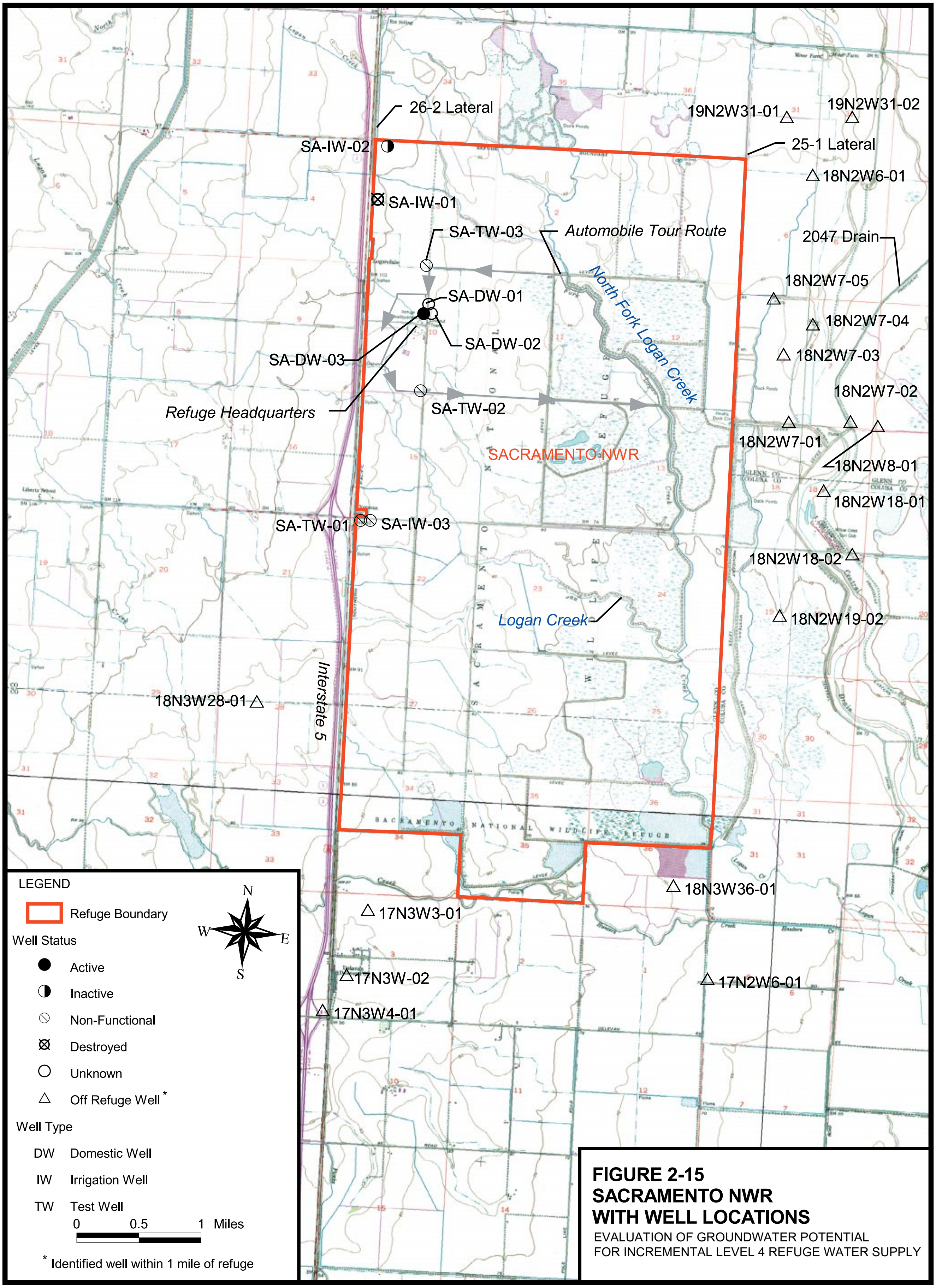

FIGURE 2-15
SACRAMENTO NWR
WITH WELL LOCATIONS
EVALUATION OF GROUNDWATER POTENTIAL
FOR INCREMENTAL LEVEL 4 REFUGE WATER SUPPLY

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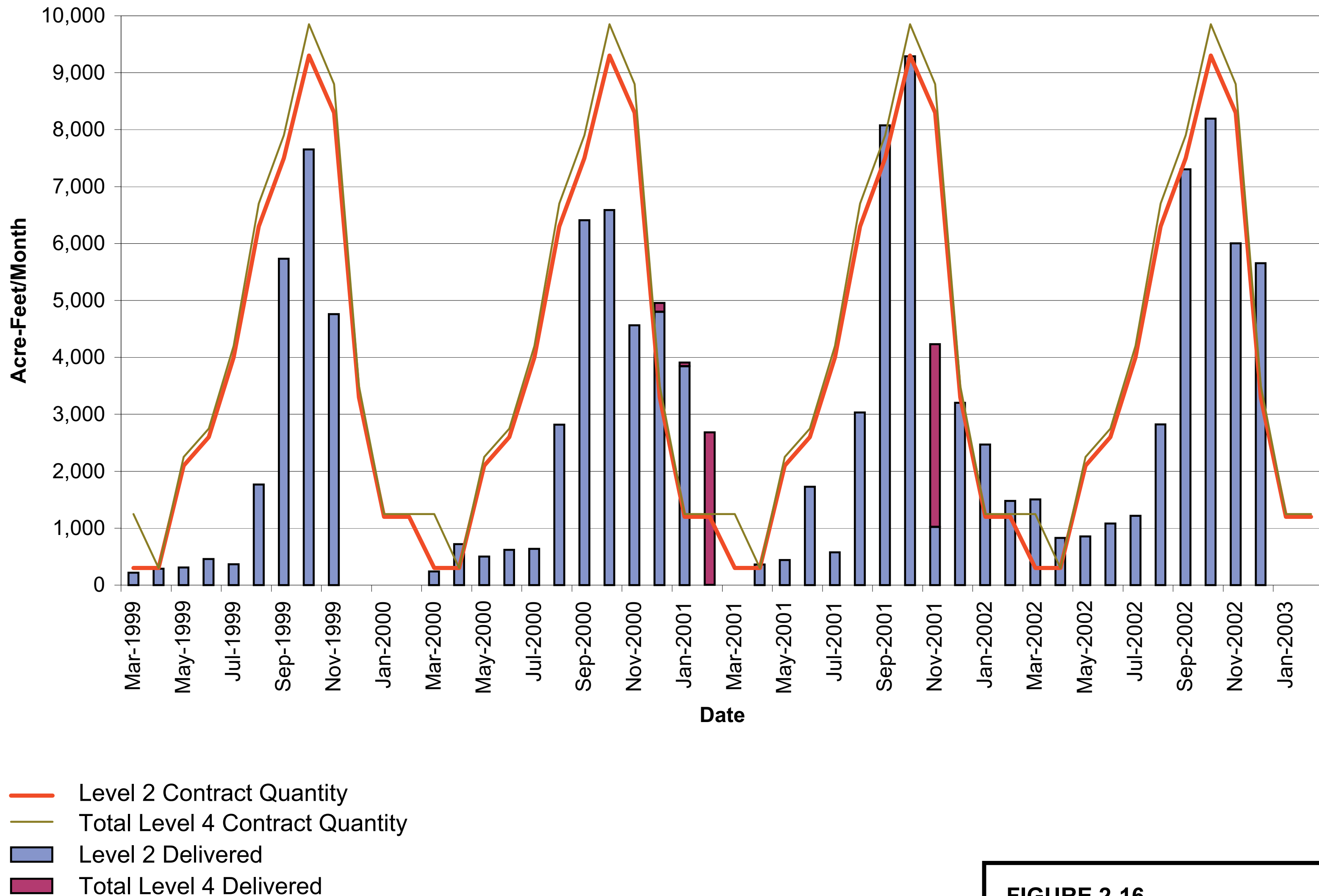

Note: Level 2 and Total Level 4 contract quantities are those indicated in Reclamation 1989 and Reclamation el al. 1989. Volumes indicated may not reflect current monthly management schedules and are shown to indicate an approximate monthly breakdown for management purposes. Total annual contract quantities may be scheduled based on availability, at the refuge manager's discretion.

FIGURE 2-16
1999-2002 SACRAMENTO NWR WATER DELIVERIES
EVALUATION OF GROUNDWATER POTENTIAL
FOR INCREMENTAL LEVEL 4 REFUGE WATER SUPPLY

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FIGURE 2-17
WELL NO. 2 (INACTIVE) AT SACRAMENTO NWR
EVALUATION OF GROUNDWATER POTENTIAL
FOR INCREMENTAL LEVEL 4 REFUGE WATER SUPPLY

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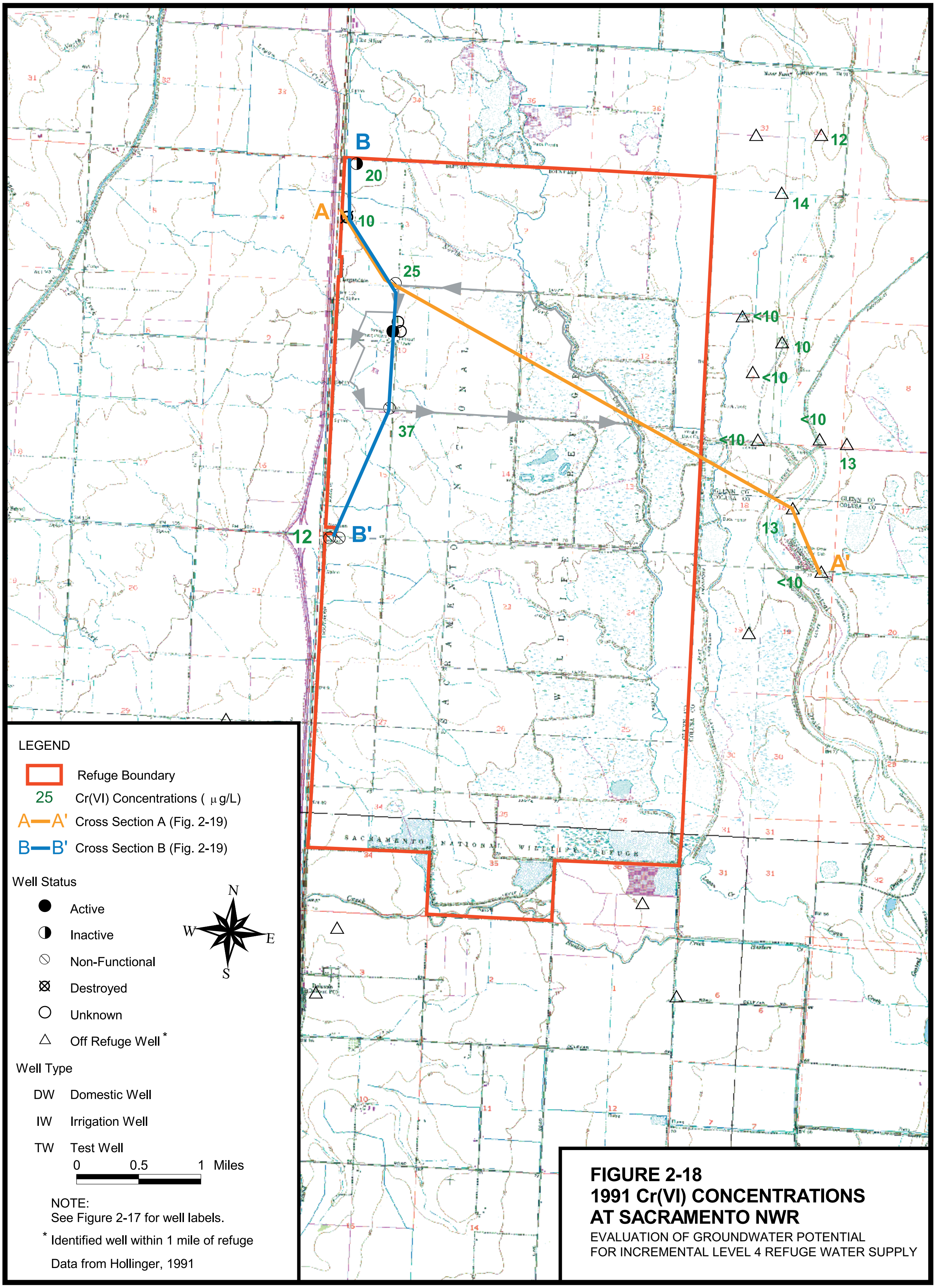

FIGURE 2-18
1991 Cr(VI) CONCENTRATIONS AT SACRAMENTO NWR
EVALUATION OF GROUNDWATER POTENTIAL FOR INCREMENTAL LEVEL 4 REFUGE WATER SUPPLY

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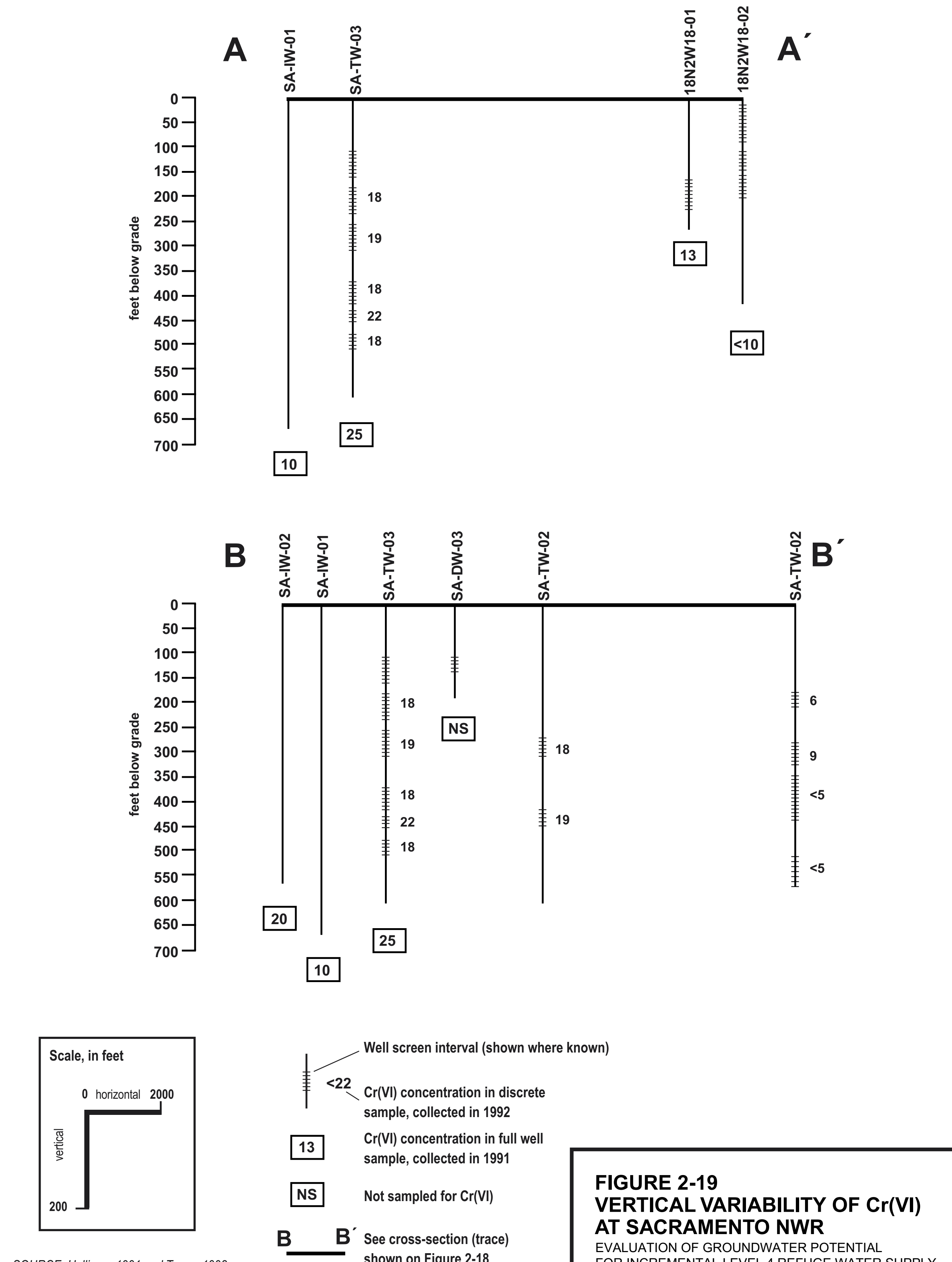

SOURCE: Hollinger 1991 and Turner 1992

FIGURE 2-19
VERTICAL VARIABILITY OF Cr(VI) AT SACRAMENTO NWR
EVALUATION OF GROUNDWATER POTENTIAL
FOR INCREMENTAL LEVEL 4 REFUGE WATER SUPPLY

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2.4 Delevan NWR Assessment

County: Colusa
Basin / Subbasin: Sacramento Valley Groundwater Basin / Colusa Subbasin
Level 2 / Incremental Level 4: 20,950 ac-ft / 9,050 ac-ft
2003 Acreage: 5,794
CVP Water Conveyor: Glenn-Colusa ID
Water District Service Area: Glenn-Colusa ID
Applicable Groundwater Management Regulations: Glenn-Colusa ID AB 3030 (adopted May 1995)

Delevan NWR was authorized in 1962 under the Migratory Bird Conservation Commission. Encompassing 5,794 acres, the refuge is located in Colusa County, midway between Sacramento NWR and Colusa NWR and approximately 4 miles east of the City of Maxwell (Figure 2-20). The Delevan NWR consists of permanent ponds, seasonal wetlands, watergrass fields, and uplands. The wetlands produce waterfowl food such as swamp timothy, watergrass, and invertebrate populations. The upland areas of the refuge provide habitat for geese, upland birds, and other wildlife (Reclamation et al. 2001a).

2.4.1 Hydrogeologic Assessment

2.4.1.1 Habitat Goals, Land Management, and Surface Features

The 2002–2003 Habitat Management Plan for Delevan NWR identifies seasonal flooded marsh as the primary habitat type at the refuge. Eleven other habitat types are present at Delevan NWR, including annual grassland, watergrass production, alkali meadows, perennial grassland, unmanaged freshwater wetlands, vernal pools, vernal pool-alkali meadow complexes, permanent ponds, summer water, riparian willow scrub, and cottonwood willows (Reclamation 2002).

Surface features at the refuge include the Northeast Drain, the Maxwell ID Main Canal, the East Drain, Stone Corral Creek, and the 2047 Drain. These features convey surface water to the refuge and support movement of water within the refuge. The refuge shop is located in the north-central portion of the refuge.

2.4.1.2 Identified Water Supply Contract Quantities

The Level 2 water allocation is 20,950 ac-ft per year. Generally, Delevan NWR fully uses its Level 2 allotment. Actual deliveries between 1999 and 2001 ranged from 15,537 to 19,005 ac-ft per year (Figure 2-21).

The Total Level 4 water supply contract quantity for Delevan NWR is 30,000 ac-ft per year. The refuge currently receives Incremental Level 4 water ranging from approximately 2,027 to 2,445 ac-ft per year of the Corning Canal assignment water. Delivery of full Level 4 water could be used to optimize current Delevan habitat (Refuge staff 2002).

2.4.1.3 Surface Water Supplies and Infrastructure

Delevan NWR receives CVP water conveyed by Glenn-Colusa ID (Reclamation et al. 2001a). Glenn-Colusa ID, with cost-share funding from Reclamation, has made improvements to its conveyance system to enable year-round water delivery to Delevan NWR. Prior to these improvements, the Glenn-Colusa ID Main Canal was dewatered from late November to early April for maintenance. During the annual shutdown of the Main Canal, Delevan NWR could receive water from other sources, such as Maxwell ID; however, according to refuge staff, these sources were never utilized. Prior to 1979, Maxwell ID was the primary water supplier for Delevan NWR. Glenn-Colusa ID became the primary supplier in 1979 because it could provide better quality water on a more reliable basis (Reclamation 1989).

Water for the refuge from the Glenn-Colusa ID Main Canal is transferred to Hunters Creek No. 2 Weir. The weir acts to back up water so it can be diverted to the refuge (Turner 1992b). The water provided by Glenn-Colusa ID via Hunters Creek only services the northern portions of the refuge. In the past, the Maxwell ID Main Canal hydraulically separated Tracts 25, 31, 35, and 41 from the rest of the refuge. These four areas are now connected to the rest of the refuge by siphons (Refuge staff 2002; Reclamation et al. 2001a).

Recent Incremental Level 4 water acquisitions from three Corning Canal water districts for the Sacramento Valley refuges total 6,300 ac-ft per year. Delevan NWR can receive partial Incremental Level 4 supplies through this contractual arrangement. The conveyance and internal distribution systems are capable of delivering the full Level 4 water supply.

The water provided to Delevan NWR is of suitable quality for use at the refuge (Turner 1992b).

2.4.1.4 Groundwater Supplies and Infrastructure

One domestic well (DE-DW-01) provides domestic water for the shop at the refuge. The well location is shown in Figure 2-20. Table 2-4 summarizes relevant refuge well information. No analytical results are currently available for the domestic well.

2.4.1.5 Local Groundwater Use

There are more than 160 groundwater wells in the area operated by Glenn-Colusa ID landowners in the district. Several groundwater users are in the immediate vicinity of Delevan NWR. These wells are used as private irrigation or domestic wells. Four known domestic wells are located within 1 mile of the refuge. An irrigation well near the southwest corner of the refuge has a reported initial production rate of approximately 1,875 gpm (DWR well logs on file).

2.4.1.6 Refuge Soil and Aquifer Conditions

The surface soil characteristics for Delevan NWR were determined by using the online Soil Survey of Colusa County, California (USDA 1996). The dominant surface soil type at Delevan NWR is the Willows silty clay, a poorly drained, fine-textured alluvial soil, characterized by very slow permeability. This silty clay soil profile may be up to 7 feet thick. This clay is saline within 40 inches of the surface.

The Willows silty clay is primarily a poorly drained, fine-textured alluvial soil. A typical soil profile will consist of up to 87 inches of silty clay with interbedded layers of clay between 72 and 87 inches below the surface. This clay is saline within 40 inches of the surface. The water table is typically very shallow or present at the surface. The permeability and runoff of this soil is very slow, and the water-holding capacity is high (approximately 8.9 inches).

Review of regional permeability maps indicate that southeast of the refuge, vertical resistance to flow may be lower (i.e., water may move more easily from near ground surface to deeper parts of the aquifer). It is possible that conditions in the southeast portion of the refuge (such as tract 44) could be favorable for recharge basins, which could also serve as refuge ponds.

Historically, subsidence has not been a significant issue in the northern Sacramento Valley. It has not been documented in the vicinity of the refuge. Aquifer conditions consist mainly of unconfined alluvium. Expansive confining layers susceptible to compaction are not present (Reclamation et al. 1999).

Seasonal water level fluctuations occur in the subbasin. In the vicinity of the refuge, groundwater levels rebound annually to within 10 feet of the surface (DWR 2003b).

2.4.1.7 Operational Issues and Data Needs

Approximately 30 percent of the refuge's water supply is Incremental Level 4. Incremental Level 4 water available to purchase for Delevan NWR is relatively stable in cost, and subjectivity to spot-market variability is low (Reclamation staff 2003). The refuge is located north of the Delta, so Incremental Level 4 water delivered to the refuge is not conveyed through the Delta.

The following data gaps were identified during the completion of this study:

- Thorough assessment of the refuge domestic well.
- Confirmation of refuge groundwater quality conditions at different locations and at several different depths below ground surface.
- Local aquifer conditions, including quarterly water-level data both on- and off-refuge, and a safe yield determination.
- Aquifer parameters, such as hydraulic conductivity and thickness.
- Groundwater pumping records and schedules, both at the refuge domestic well and in the area immediately surrounding the refuge.

Relative to the other refuges in this study, it was estimated that a "significant" level of data collection is required at Delevan NWR prior to recommending increased groundwater development because so little on-site data are available.

2.4.2 Criteria Evaluation Summary

Delevan NWR received total Hydrogeologic Scores of zero for Direct Use of groundwater and -3 for On-Refuge Conjunctive Use, based on evaluation with the criteria matrix. The criteria matrix specific to Delevan NWR is shown as Table 2-5. The matrix includes a score for each criterion and a corresponding justification or reasoning for the score given.

Although groundwater has not been used on the refuge in the past, available regional hydrogeologic data indicate that there is potential for successful development of direct use of groundwater on the refuge. Most limitations are related to insufficient existing data. Support and limitations to further development of groundwater resources at Delevan NWR are summarized below.

2.4.2.1 Support for Groundwater Development

- No surface water bodies in the refuge vicinity would be affected by increased groundwater use.
- No subsidence has occurred in the past in the refuge vicinity.
- Minimal potential exists for subsidence to occur with increased groundwater use.
- Surface water is delivered to the refuge throughout the year and is therefore available for blending with groundwater.
- Refuge land use management is compatible with seasonally or annually variable water quality from different sources.

2.4.2.2 Limitations to Groundwater Development

- Groundwater has not been used previously at the refuge.
- No irrigation wells exist on the refuge.
- Four known domestic wells are located within 1 mile of the refuge, which could be negatively impacted by increased local groundwater use.
- At-surface soils primarily have low permeability and are not conducive to recharge.
- Aquifer storage is not available. Current and historical groundwater levels are approximately equivalent and are within 10 feet of ground surface during the winter months.
- Incremental Level 4 water available to purchase for Delevan NWR is relatively stable in cost, and subjectivity to spot-market variability is low.
- It is unnecessary to convey Incremental Level 4 water through the Delta. Higher priority for groundwater development may be considered for refuges which have the water conveyance constraint of moving this water through the Delta.
- Data needs regarding refuge groundwater conditions are significant relative to other refuges in the study.

2.4.3 Recommended Data Acquisition Activities

Collecting additional data is recommended at Delevan NWR if groundwater is to be further developed. Recommended data acquisition activities to be conducted prior to implementing any potential project include:

- Based on the location of Delevan NWR and the interest in increasing the water supply for the refuge, install and test one or more on-refuge test wells. Drill, sample, and test two borings. Locations to consider are approximately 0.5 mile due south of the shop well, and in the southeast quarter of Section 28 (Township 17 North, Range 2 West) because of the potential for favorable surface recharge conditions. Estimate the potential groundwater extractions at the refuge under wet-, normal-, and dry-year conditions.

- Conduct water quality testing to confirm refuge groundwater quality conditions. Sample each test well and the domestic well for general chemistry and metals, including arsenic, boron, chromium, mercury, and nitrates.
- Evaluate the recharge potential near refuge Tract 44, which may have higher permeability than other parts of the refuge. Conduct shallow auguring to evaluate the depth and permeability of the soils.
- Collect water-level data from available wells within and adjacent to the refuge. Monitor water levels quarterly, and collect routine water quality samples from active wells to develop a database of groundwater use and conditions. Maintain collected data in a format supportable and usable by the refuge
- Evaluate existing groundwater pumping conditions. This may entail the installation of well meters or coordination with Glenn-Colusa ID landowners.

2.4.4 Potential Projects

2.4.4.1 Direct Use

Production wells could be installed to meet a portion of the Incremental Level 4 contract quantities at the refuge, particularly during times of peak water demand in autumn and early winter. The production rates of the additional wells could be estimated following further data acquisition and aquifer testing. One proposed project is to install two production wells at test well locations to meet a portion of Incremental Level 4 contract quantities at the refuge.

The refuge shop well, DE-DW-01, is a 6-inch well that had 1 to 2 feet of drawdown when tested at a rate of 60 gpm (DWR well log on file). This indicates that aquifer conditions favorable for direct use may be present at the refuge. Future testing to confirm conditions is warranted.

2.4.4.2 On-Refuge Conjunctive Use

Incremental Level 4 supplies are 9,050 ac-ft per year, with a monthly peak incremental demand of 1,325 ac-ft (November). Additional data acquisition (identified above) is necessary to estimate the number of wells needed to meet this demand and the estimated safe yield of the aquifer beneath the refuge.

DWR (1978) identified an area of “few barriers to the vertical flow of groundwater” within 1 mile of the southeast corner of the refuge. This refers to both surface soils and low-permeability intervals within the aquifer. It is possible that the southeastern portion of the refuge (such as Tract 44) could be an area to evaluate for groundwater recharge, although this area would not be hydraulically upgradient of any on-refuge groundwater development.

2.4.4.3 Off-Refuge Conjunctive Use

Like Sacramento NWR, Delevan NWR is within the sphere of influence of the Glenn-Colusa ID Groundwater Management Plan (AB 3030). Groundwater is extracted in the district for individual residential use, agricultural use, and municipal and industrial use. The plan is silent regarding water transfers.

As described for the Sacramento NWR, the possible groundwater banking projects for partnership within the Colusa Subbasin are the Maxwell ID Conjunctive Use Project and the Stony Creek Fan Project. The Maxwell ID borders Delevan NWR; the determining criteria for feasibility is the close proximity of Maxwell ID to the refuge. Delevan NWR is located within Glenn-Colusa ID's service area, which could reduce the potential of receiving water stored by Maxwell ID.

TABLE 2-4
Delevan NWR Well Information[a]
Evaluation of Groundwater Potential for Incremental Level 4 Refuge Water Supply

GIS Well Number[b]	Common Well Name	Well Status[c]	2002 Yield (ac-ft)	Year Installed	Depth (ft)	Screen Interval (bgs)	Well Output (gpm)	Well Log?	Water Quality Data?	Comments
DE-DW-01	Shop Well	Active		2000	261	240–260	60	Y	N	No water quality testing done. All faucets are posted as nonpotable.

Notes:

[a] Based on data compiled from well logs, test records, communication with refuge staff (2002), and other previous documentation. Well location is shown on Figure 2-20. On-refuge wells only are included in this table, although the GIS includes known wells within 1 mile of the refuge.

[b] Well type is indicated by the middle two letters of the GIS well number: IW = irrigation well, DW = domestic well, MW = monitoring well, TW = test well, and UN = unknown.

[c] Designation refers to the physical well only, not water quality issues. Designations are: *active* (currently operated), *inactive* (capable of operating, but currently is not), *nonfunctional* (cannot operate in current physical state), *destroyed* (well has been lost, abandoned, or filled), or *unknown* (no information regarding status is available).

Blank fields indicate that no information is available.

TABLE 2-5
Delevan NWR Evaluation
Evaluation of Groundwater Potential for Incremental Level 4 Refuge Water Supply

Criteria		Scoring Scale	Appl.[b]	Score	Refuge Score Justification
Surface[a]	Do surface water bodies exist that could be affected by increased groundwater use?	+1 = no 0 = to some degree –1 = yes, surface water bodies could be affected	D,N	+1	The Shop well is the only groundwater well at the refuge. If groundwater were to be used at the refuge it does not appear that there would be impacts to area surface water bodies.
Water Supplies and Infrastructure	Has groundwater been used previously at the refuge for ponds or irrigation?	+1 = yes, used successfully to meet at least 20 percent of annual refuge water demands 0 = yes, used to meet less than 20 percent (or unknown) of annual refuge water demands. –1 = no, has not been used	D,N	-1	Delevan relies 100 percent on surface water for wetland irrigation.
	Do wells exist on the refuge?	+1 = yes, active wells 0 = yes, inactive or nonfunctional wells –1 = yes, destroyed wells, or no wells exist on the refuge	D,N	-1	There are no irrigation wells located at the refuge. One domestic well provides potable water to the refuge headquarters.
	Does existing internal distribution system (IDS) support groundwater use?	+1 = water can move extensively around the refuge with existing IDS 0 = the IDS enables limited water movement within the refuge –1 = an IDS does not exist on the refuge or water flow relies exclusively on gravity	D,N	0	The IDS system relies on gravity flow and a series of siphons to distribute water.
Local Groundwater Use	Is groundwater used for agriculture or duck clubs in the immediate vicinity of the refuge?	+1 = groundwater is not used; or groundwater is minimally used, but use is not constrained 0 = groundwater is used in the area –1 = groundwater is not used due to physical or environmental constraints or is extensively used in the vicinity	D,N	0	Groundwater is used in the area. There are some irrigation wells within 1 mile of the refuge. There are more than 160 groundwater wells, which are operated by Glenn-Colusa ID landowners in the district.
	Does municipal or domestic supply exist near the refuge?	+1 = no known domestic or municipal wells are located within 1 mile of the refuge 0 = municipal or domestic wells are likely located within 1 mile of the refuge –1 = municipal or domestic wells are located within 1 mile of the refuge	D,N	-1	Four known domestic wells are located within 1 mile if the refuge. An irrigation well near the southwest corner of the refuge has a reported initial production rate of approximately 1,875 gpm.
Soil and Hydrogeology	Are at-surface soils conducive to groundwater recharge?	+1 = soils are sandy or are reported to percolate well 0 = soils are silty or are reported to have some infiltration –1 = soils are clayey or are reported to hold water well	N	-1	The majority of the surface soils consist of silty clay and clay. They are typically poorly drained and the permeability is slow.
	Could recharge basins be developed if surface soils were removed?	+1 = confining soil less than 2 feet thick 0 = confining soil 5 to 7 feet thick –1 = confining soil greater than 7 feet thick	N	0	The silty clay soil profile may be up to 7 feet thick.
	Has subsidence occurred at or in the immediate vicinity of the refuge?	+1 = no 0 = yes, less than 2 feet –1 = yes, more than 2 feet	D,N	+1	Subsidence has not been documented in the vicinity of the refuge. It does not appear to be a major concern in northern parts of the Sacramento Valley.
	Does significant potential for subsidence exist if groundwater use is increased at the refuge?	+1 = minimal potential for subsidence 0 = some potential for subsidence –1 = significant potential for subsidence	D,N	+1	Historically, subsidence has not been an issue in the northern parts of the Sacramento Valley. Aquifer conditions consist mainly of unconfined alluvium. Expansive confining layers susceptible to compaction are not present.
	Is aquifer storage available in the subbasin?	+1 = yes, current water levels are greater than 30 feet lower than historical levels 0 = some, current water levels are between 10 and 30 feet lower than historical levels –1 = no	N	-1	Seasonal water-level fluctuations do exist in the subbasin. However, in the vicinity of the refuge, groundwater levels rebound to within 10 feet of the surface.

continued on next page

Notes:

[a] Surface Features

[b] Application to Approach: D = Direct Use, N = On-Refuge Conjunctive Use

TABLE 2-5
Delevan NWR Evaluation
Evaluation of Groundwater Potential for Incremental Level 4 Refuge Water Supply

Criteria		Scoring Scale	Appl.[b]	Score	Refuge Score Justification
Water Quality	Have groundwater quality conditions hindered groundwater use in the past?	+1 = no 0 = data are not available –1 = yes	D,N	0	Groundwater has not been used in the past.
	Do adverse groundwater quality conditions exist in the subbasin?	+1 = no 0 = potential –1 = yes	D,N	0	EPA data from 1957–1967 for a well located 2,000 feet southeast of the refuge had boron concentrations between 100 and 200 µg/L.
	Is surface water available to enable blending of lower quality groundwater to meet proposed refuge standards?	+1 = yes 0 = during portions of the year –1 = no	D,N	+1	The refuge has a reliable year-round supply of surface water.
	Do groundwater conditions exceed USEPA Freshwater Aquatic Life Standards or Agricultural Water Quality Goals for multiple parameters?	+1 = no 0 = yes, two parameters, or no water quality testing has been conducted –1 = yes, three or more parameters	D,N	0	There is no on-refuge groundwater quality data available.
	Is refuge land use management compatible with seasonally or annually variable water quality from different sources?	+1 = yes 0 = some potential compatibility problems may exist –1 = no	D,N	+1	The refuge currently receives and uses water of variable quality. Some of the water that the refuge receives is agricultural return flow. This water is of poorer quality, but is considered adequate for refuge needs.
	Does groundwater quality meet drinking-water standards (i.e., can it be used for refuge domestic supply)?	+1 = yes it is used, no treatment is necessary 0 = yes it is used, but some treatment is necessary for potable use; or it is not used for unknown reasons –1 = no, it is not used because of adverse water quality conditions	D	+1	The water is not treated; however, there is no analytical data for the well.
Operational Issues/Constraints	Does a significant percentage of total refuge water supply consist of "Incremental Level 4" water?	+1 = yes, 54% to 79% of total water supply is Incremental Level 4 0 = somewhat, 27% to 53% of total water supply is Incremental Level 4 –1 = minor, 0% to 26% of total water supply is Incremental Level 4	D,N	0	Approximately thirty percent of the water supply for Delevan NWR consists of Incremental Level 4 water.
	Is the cost of local water high or low relative to the other refuges in this study?	+1 = costs may fluctuate highly or are subject to spot-market variability or price spikes –1 = costs are relatively stable and subjectivity to spot-market variability is low	D,N	-1	Incremental Level 4 water made available to Delevan NWR is relatively stable in cost and subjectivity to spot-market variability is low.
	Is it necessary to convey Incremental Level 4 water through the Delta for refuge supply?	+1 = yes, Incremental Level 4 water must be conveyed through the Delta –1 = no, conveyance of Incremental Level 4 water through the Delta is not necessary	D,N	-1	No, conveyance of Incremental Level 4 through the delta is unnecessary. The refuge is located north of the Delta.
Data Needs	Are there significant data needs to address prior to groundwater development?	+1 = no, data needs regarding refuge groundwater conditions are minor 0 = somewhat, some data are required prior to increasing groundwater development –1 = yes, significant data must be collected as there is little or no existing data	D,N	-1	A significant amount of data must be collected prior to recommending increased groundwater development. Needed data include a thorough well assessment, confirmation of groundwater quality conditions, local aquifer conditions including safe yield, and depth and permeability of soils in areas where recharge might be considered.
			Total Direct Use Score =	**0**	
			Total On-Refuge Conjunctive Use Score =	**-3**	

Notes:

[a] Surface Features

[b] Application to Approach: D = Direct Use, N = On-Refuge Conjunctive Use

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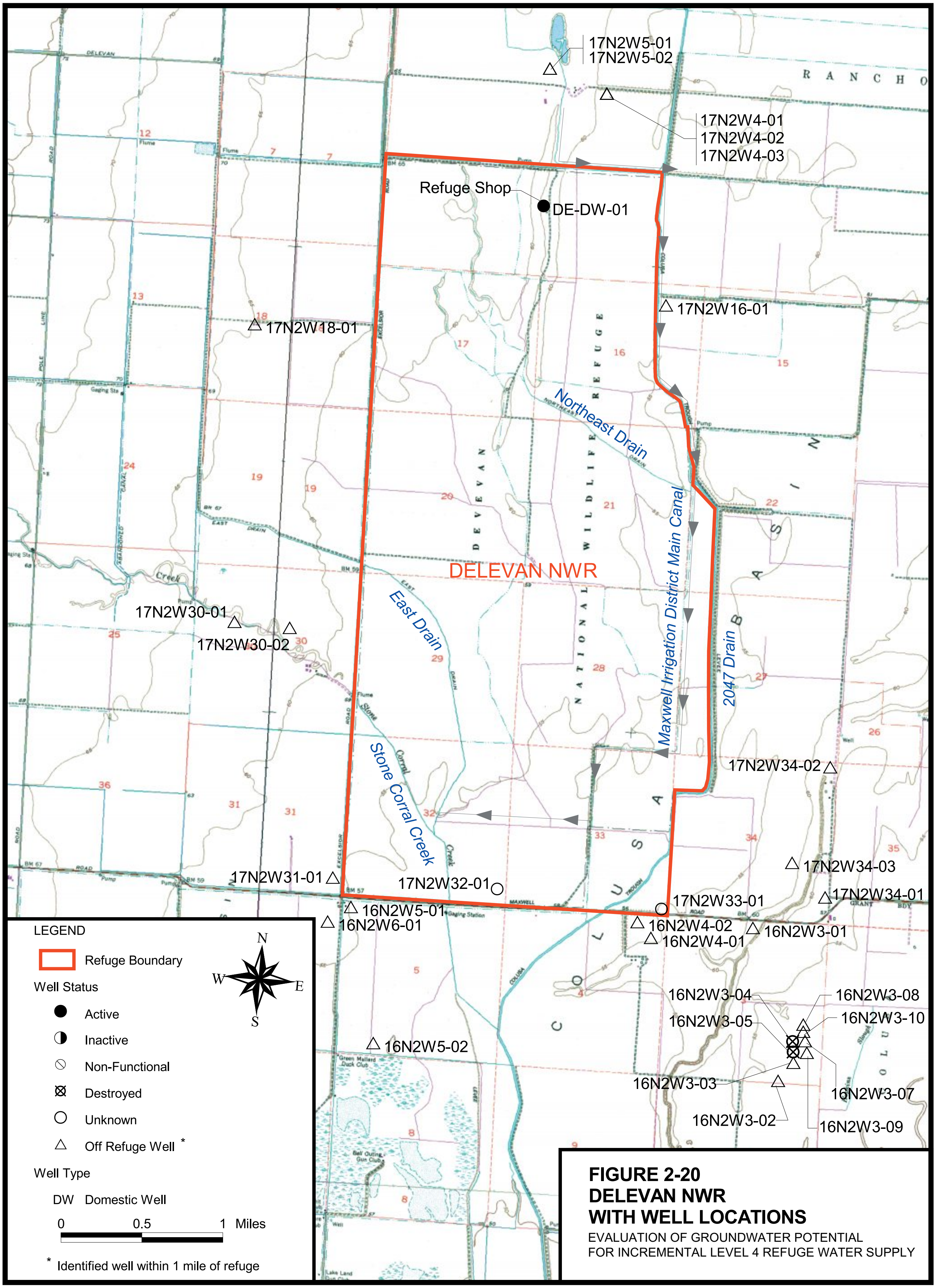

FIGURE 2-20
DELEVAN NWR
WITH WELL LOCATIONS
EVALUATION OF GROUNDWATER POTENTIAL
FOR INCREMENTAL LEVEL 4 REFUGE WATER SUPPLY

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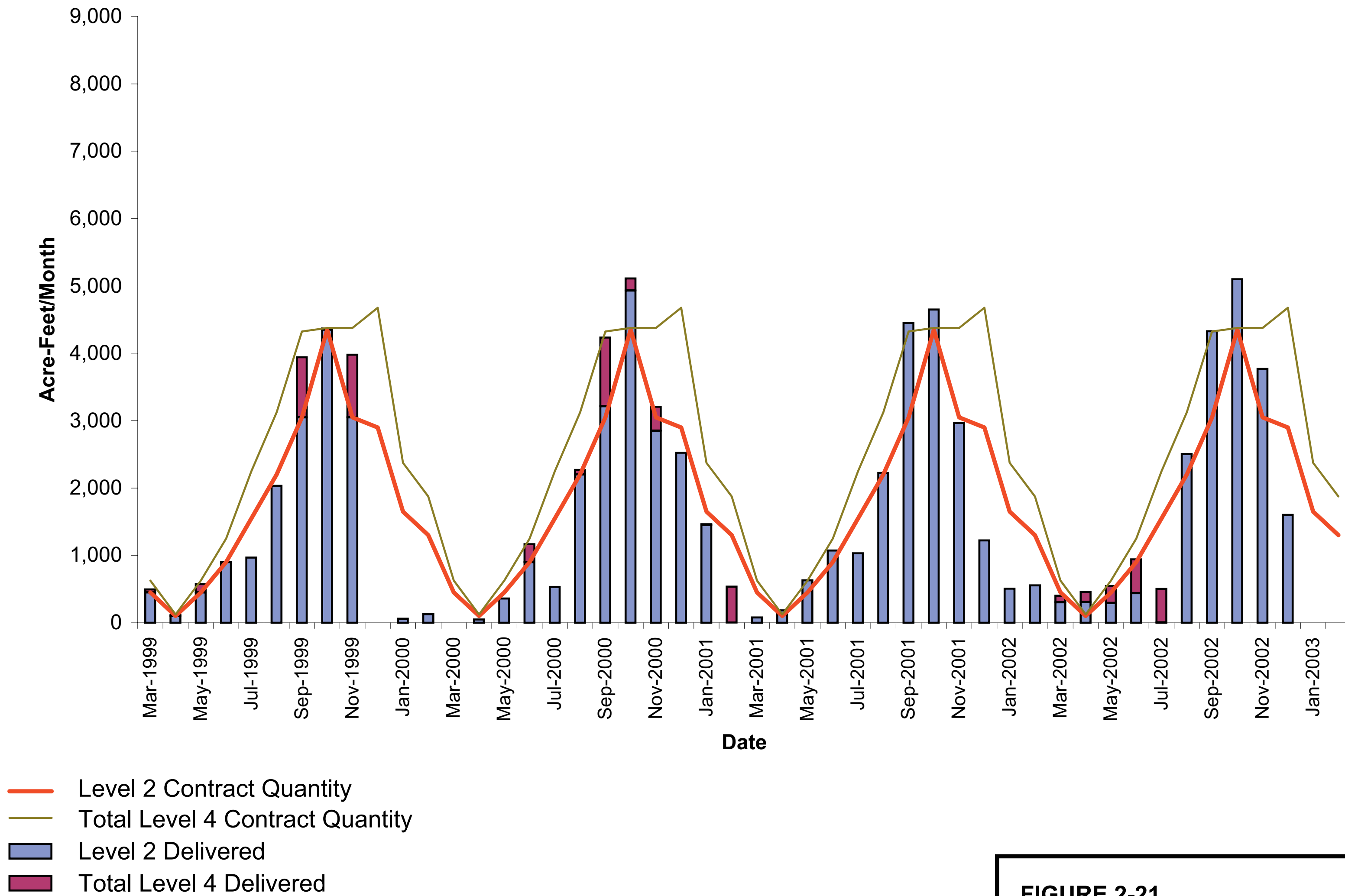

Note: Level 2 and Total Level 4 contract quantities are those indicated in Reclamation 1989 and Reclamation el al. 1989. Volumes indicated may not reflect current monthly management schedules and are shown to indicate an approximate monthly breakdown for management purposes. Total annual contract quantities may be scheduled based on availability, at the refuge manager's discretion.

FIGURE 2-21
1999-2002 DELEVAN WATER DELIVERIES
EVALUATION OF GROUNDWATER POTENTIAL
FOR INCREMENTAL LEVEL 4 REFUGE WATER SUPPLY

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2.5 Colusa NWR Assessment

County: Colusa
Basin / Subbasin: Sacramento Valley Groundwater Basin / Colusa Subbasin
Level 2 / Incremental Level 4: 25,000 ac-ft / 0 ac-ft
2003 Acreage: 4,626
CVP Water Conveyor: Glenn-Colusa ID
Water District Service Area: Glenn-Colusa ID
Applicable Groundwater Management Regulations: Glenn-Colusa ID AB 3030

Colusa NWR was established in 1944 and, according to refuge staff, currently occupies 4,626 acres approximately 2 miles southwest of the town of Colusa (Figure 2-22). The refuge provides wintering habitat and resting areas for ducks, geese, and shorebirds. The Colusa NWR consists of permanent ponds, seasonal wetlands, watergrass fields, and uplands. The wetlands produce waterfowl food such as swamp timothy, watergrass, and invertebrate populations. The upland areas of the refuge provide habitat for geese, upland birds, and other wildlife species (Reclamation et al. 2001a).

2.5.1 Hydrogeologic Assessment

2.5.1.1 Habitat Goals, Land Management, and Surface Features

The 2002–2003 Habitat Management Plan for Colusa NWR identifies the primary habitat type as seasonal flooded marsh (approximately 60 percent of the refuge). Nine other habitat types make up the remaining 40 percent; these include permanent ponds, summer water, watergrass production, annual grassland, perennial grassland, alkali meadows, vernal pools, vernal pool-alkali meadow complexes, and mixed riparian forest.

The refuge has several significant surface features. Among these are Powell Slough, the 2047 Drain, Abel Road, Ohm Road, the refuge shop, a refuge residence, and an automobile tour route. There are no large water bodies in the immediate vicinity of the refuge.

Powell Slough enters the refuge near its northeastern corner and exits the refuge at the southern border of Tract 9. The 2047 Drain enters near the northwest corner of the refuge, flows from northwest to southeast for approximately 2 miles, and eventually becomes the eastern boundary of Colusa NWR.

Two public roads cross the refuge. Abel Road is an east-west road that cuts through the refuge approximately 2 miles north of the refuge’s southernmost boundary. Ohm Road is a north-south road that cuts through approximately 2 miles of the southern portion of the refuge. The refuge shop and residence are located east of Powell Slough in Tract 9.

2.5.1.2 Identified Water Supply Contract Quantities

The Level 2 water allocation to Colusa NWR is 25,000 ac-ft per year (Figure 2-23). Actual deliveries to the refuge between 1999 and 2002 ranged from 10,281 to approximately 17,300 ac-ft per year. The optimum habitat management (Total Level 4) water need for Colusa NWR is 25,000 ac-ft per year, which is the same as the Level 2 water need.

2.5.1.3 Surface Water Supplies and Infrastructure

The conveyance system to Colusa NWR is well established. Colusa NWR receives CVP water from the 2047 Drain via the Highway Pump located near the northwest corner of the refuge and the Main Pump located approximately 0.5 mile south of the Highway Pump along the western boundary of the refuge. Furthermore, Colusa NWR receives water from 64-1 Lateral at the southwest corner of the refuge. Water delivered through the 2047 Drain and 64-1 Lateral is provided by Glenn-Colusa ID (Refuge staff 2002; Reclamation et al. 2001a).

Once the water reaches the refuge boundaries, it flows south from the 2047 Drain and north from 64-1 Lateral in the West Main Lateral that borders Colusa NWR on the west. Because topographic high points exist in the northern and southern portions of the refuge, gravity flow dominates the movement of water from these sources. The water is then distributed throughout the refuge from west to east by the IDS (Refuge staff 2002; Reclamation et al. 2001a). Glenn-Colusa ID, with cost-share funding from Reclamation, has improved its conveyance system to enable year-round water delivery to the refuge. Prior to these improvements, the Glenn-Colusa ID conveyance structures were dewatered from late November to early April for maintenance.

Recent improvements were made to the IDS as part of the Tract 24 wetland restoration. This includes siphons under both Abel Road and the J-Drain. These improvements enable the refuge to use water conveyed by Glenn-Colusa ID 64-1 Canal north to the main pump on the 2047 Drain. The 2047 Pump augments water deliveries and increases flow to the most northern refuge tracts. Refuge tracts east of the 2047 Drain receive water via the Highway pump and the 2047 Drain. The H-1 Canal is now rarely used because of the recent IDS improvements (Refuge staff 2003).

The portion of Colusa NWR south of Abel Road also receives water from Glenn-Colusa ID. Water is conveyed to the refuge by the 64-1, 64-C, and 64-2A Laterals. The quality of the delivered water is considered to be suitable for refuge use (Turner 1992b).

2.5.1.4 Groundwater Supplies and Infrastructure

There are three wells on Colusa NWR. One non-functional irrigation well, one non-functional or destroyed domestic well, and one active domestic well are at the refuge.

The refuge does not use groundwater for irrigation. The nonfunctional well (CO-IW-01) is located at the northwest corner of Tract 10 (Figure 2-24). The well was installed in the late 1970s, but the pump was removed from this well in the mid-to-late 1980s, according to refuge staff. When the well was active, it was used only a few times during the year to support available surface water supplies (Refuge staff 2002). A 1982 PG&E pump-test record of the well shows its production rate as approximately 2,600 gpm. Later well-test information from the irrigation well indicates that the production rate was 2,783 to 3,040 gpm based on well tests conducted in 1978 and 1989 (Hollinger 1989). Although this is a good well yield, refuge staff indicated that well operation was very expensive, and the single well was not capable of providing enough flow to fill the ponds adjacent to it. Refuge wells are shown on Figure 2-22. Table 2-6 summarizes relevant refuge well information.

The two domestic wells, one new (CO-DW-02) and one old (CO-DW-01), are located near the Colusa NWR shop and residence. The new well is at the north side of the shop parking area. Refuge staff have indicated that this well was installed between 2 and 4 years ago. This well services the shop and the adjacent residence. Refuge staff stated that the old well is still located at the refuge; however, surface evidence of the old well was not found.

The groundwater quality at Colusa NWR was tested in September 1989. Laboratory analysis identified mercury in groundwater at the refuge (Turner 1992b). However, the concentration of the detected mercury was not reported and is unknown at this time because the results were not able to be located. Refuge staff indicate that water from the new domestic well has an odor of sulfur (Refuge staff 2002).

2.5.1.5 Local Groundwater Use

Groundwater is used in the area primarily for agricultural purposes. One duck club is adjacent to the eastern boundary of the refuge. Several domestic wells are located in the immediate vicinity of the refuge.

2.5.1.6 Refuge Soil and Aquifer Conditions

The surface soil characteristics for Colusa NWR were determined using the Soil Survey of Colusa County, California (NRCS 2001). The soils are poorly-drained alluvial soils with slow to very slow permeability, except for Colusa loam, which is described as having moderate permeability. (Colusa loam is located in several parts of the refuge south of Abel Road.) The silty clay soil profile may be up to 7 feet thick.

The dominant surface soil type is Willows Series, particularly north of Abel Road. Scribners silty loam is also found at the northeastern edge of the refuge. South of Abel Road, Willows Series soils are less dominant, and Capay clay loam, Clear Lake clay, Alcapay clay, Mallard loam, and Colusa loam also occur.

Historically, subsidence has not been a problem in the northern Sacramento Valley. Subsidence has not been documented in the vicinity of the refuge. Aquifer conditions consist mainly of unconfined alluvium. Expansive confining layers susceptible to compaction are not present.

Seasonal water-level fluctuations occur in the subbasin based on DWR water level reports. These records indicate groundwater may be as shallow as 5 feet below grade in the vicinity of the refuge. Groundwater level measurements are not made at the refuge.

2.5.1.7 Operational Issues and Data Needs

The refuge does not have contracted quantities of Incremental Level 4 water. The refuge does not have an Incremental Level 4 requirement. Local water available for purchase on the spot market is relatively stable in cost (Reclamation staff 2003).

Some data gaps relative to refuge groundwater conditions were identified during the completion of this study.

- Thorough assessment of the new domestic well on the refuge and location and assessment of the old domestic well.
- Confirmation of horizontal and vertical refuge groundwater quality conditions, particularly for mercury.

- Local aquifer conditions, including quarterly water-level data both on- and off-refuge, and estimates of potential refuge groundwater extraction.
- Soil conditions south of Abel Road, where the Colusa Loam soils are located.
- Aquifer parameters, such as hydraulic conductivity and thickness.
- Groundwater pumping estimates and schedules, both at the domestic well and the area immediately surrounding the refuge.

Relative to the other refuges in this study, it was estimated that a "medium" level of data collection is required at Colusa NWR prior to recommending increased groundwater development.

2.5.2 Criteria Evaluation Summary

Colusa NWR received total Hydrogeologic Scores of +3 for Direct Use of groundwater and +2 for On-Refuge Conjunctive Use, based on evaluation with the criteria matrix (shown in Table 2-7). The matrix includes a score for each criterion and a corresponding justification or reasoning for the score given.

Groundwater has been used previously at Colusa NWR, and use has shown that sufficient permeable zones exist for well development. Available water quality also indicate that groundwater quality is adequate for direct use or on-refuge conjunctive use. Support and limitations to further development of groundwater resources at Colusa NWR are summarized below.

2.5.2.1 Support for Groundwater Development

- No surface water bodies in the refuge vicinity would be affected by increased groundwater use.
- No subsidence has occurred in the past in the refuge vicinity.
- Minimal potential exists for subsidence to occur with increased groundwater use.
- Limited groundwater has been used in the past.
- Surface water is delivered to the refuge throughout the year and is therefore available for blending with groundwater.
- Known groundwater conditions do not exceed Freshwater Aquatic Life Standards or Agricultural Water Quality Goals.
- Refuge land use management is compatible with seasonally or annually variable water quality from different sources.

2.5.2.2 Limitations to Groundwater Development

- Several domestic wells are located in the immediate vicinity of the refuge, which could be negatively impacted by local groundwater use.
- At-surface soils primarily have low permeability and are not conducive to recharge.

- Aquifer storage is not available. Current and historical groundwater levels are shallow and approximately equivalent.
- Colusa NWR does not have an Incremental Level 4 water need.

2.5.3 Recommended Data Acquisition Activities

Collection of additional data is recommended at Colusa NWR prior to further development of groundwater. Recommended data acquisition activities include:

- Investigate the physical status of the existing refuge irrigation well by lowering a video camera into the well to conduct a visual inspection of the well screen to determine its condition and interval and the condition of the well casing.
- Collect two groundwater samples during different seasons from the irrigation well and new domestic well. Confirm groundwater quality conditions.
- Determine the aquifer properties at the irrigation well by conducting a simple, low-cost aquifer test at the well. Install a transducer down the well to monitor changes in the water table in response to the operation of the irrigation well located on the western refuge boundary. Coordinate with the landowner to determine well pumping rate and well operation.
- Drill, sample, and test one test hole on the east side of the refuge, north of Abel Road.
- Investigate soil conditions south of Abel Road, where the Colusa Loam soils are located. Determine if conditions are adequate for recharge activities.

2.5.4 Potential Projects

2.5.4.1 Direct Use

No direct use projects to supplement Incremental Level 4 water supplies are recommended for Colusa NWR at this time, as the refuge has no Incremental Level 4 requirement.

2.5.4.2 On-Refuge Conjunctive Use

Total Level 4 water supplies are the same as Level 2 supplies for Colusa NWR, and the Level 2 supplies are reliable. Development of an onsite conjunctive use project to support other refuges with Incremental Level 4 needs would require assessment of whether water can be conveyed to other refuges. Alternatively, groundwater could be developed for use at Colusa by either installing new wells and/or rehabilitating the existing one, thereby freeing a portion of its Level 2 supply to be delivered to Sacramento and Delevan NWRs.

As with other Sacramento Valley refuges, depth to groundwater near the refuge is shallow. At Colusa NWR, it is less than 5 feet below grade (see Figure 2-10). Under current conditions, there is no available aquifer storage. To create opportunity for additional water storage, increased local groundwater use would need to occur. On-refuge recharge opportunities may be most feasible south of Abel Road, where the Colusa Loam soils are located.

2.5.4.3 Off-Refuge Conjunctive Use

Like Sacramento NWR and Delevan NWR, Colusa NWR is within the sphere of influence of the Glenn-Colusa ID Groundwater Management Plan (AB 3030). Groundwater is extracted in the district for individual residential use, agricultural use, and municipal and industrial use. The plan is silent regarding water transfers.

The Stony Creek Fan Project and Maxwell ID's proposed conjunctive use project, as described for the Sacramento NWR, could be potential options for storage of Colusa NWR water. Maxwell ID is adjacent to Delevan NWR. Water could be conveyed to Colusa NWR via the water conveyance system linking Delevan NWR and Colusa NWR.

TABLE 2-6
Colusa NWR Well Information[a]
Evaluation of Groundwater Potential for Incremental Level 4 Refuge Water Supply

GIS Well Number[b]	Common Well Name	Well Status[c]	2002 Yield (ac-ft)	Year Installed	Depth (ft)	Screen Interval (bgs)	Well Output (gpm)	Well Log?	Water Quality Data?	Comments
CO-IW-01	Refuge Well 1	Nonfunctional		Late 1970s			2,783	N	N	Time of installation provided by refuge staff.
CO-DW-01	Old Shop Well	Destroyed						N	N	Well is assumed to be destroyed because it could not be visually located within the well house.
CO-DW-02	Shop Well	Active		Late 1990s				N	N	Time of installation provided by refuge staff.

Notes:

[a] Based on data compiled from well logs, test records, communication with refuge staff (2002), and other previous documentation. Well locations are shown on Figure 2-22. On-refuge wells only are included in this table, although the GIS includes known wells within 1 mile of the refuge.

[b] Well type is indicated by the middle two letters of the GIS well number: IW = irrigation well, DW = domestic well, MW = monitoring well, TW = test well, and UN = unknown.

[c] Designation refers to the physical well only, not water quality issues. Designations are: *active* (currently operated), *inactive* (capable of operating, but currently is not), *nonfunctional* (cannot operate in current physical state), *destroyed* (well has been lost, abandoned, or filled), or *unknown* (no information regarding status is available).

Blank fields indicate that no information is available.

TABLE 2-7
Colusa NWR Evaluation
Evaluation of Groundwater Potential for Incremental Level 4 Refuge Water Supply

Criteria		Scoring Scale	Appl.[b]	Score	Refuge Score Justification
Surface[a]	Do surface water bodies exist that could be affected by increased groundwater use?	+1 = no 0 = to some degree –1 = yes, surface water bodies could be affected	D,N	+1	There are no large water bodies in the immediate vicinity of the refuge.
Water Supplies and Infrastructure	Has groundwater been used previously at the refuge for ponds or irrigation?	+1 = yes, used successfully to meet at least 20 percent of annual refuge water demands 0 = yes, used to meet less than 20 percent (or unknown) of annual refuge water demands. –1 = no, has not been used	D,N	0	One well was previously used at the refuge, but it is currently nonfunctional. The well apparently could not meet water demands at the refuge.
	Do wells exist on the refuge?	+1 = yes, active wells 0 = yes, inactive or nonfunctional wells –1 = yes, destroyed wells, or no wells exist on the refuge	D,N	0	There is one nonfunctional irrigation well.
	Does existing internal distribution system (IDS) support groundwater use?	+1 = water can move extensively around the refuge with existing IDS 0 = the IDS enables limited water movement within the refuge –1 = an IDS does not exist on the refuge or water flow relies exclusively on gravity	D,N	0	Recent improvements were made to the IDS as part of the Tract 24 wetland restoration. Water is moved around various fields of the refuge through a series of pumps and canals.
Local Groundwater Use	Is groundwater used for agriculture or duck clubs in the immediate vicinity of the refuge?	+1 = groundwater is not used; or groundwater is minimally used, but use is not constrained 0 = groundwater is used in the area –1 = groundwater is not used due to physical or environmental constraints or is extensively used in the vicinity	D,N	0	Groundwater is used in the area. Most of the water use in the area is for irrigation. One duck club is adjacent to the eastern boundary of the refuge.
	Does municipal or domestic supply exist near the refuge?	+1 = no known domestic or municipal wells are located within 1 mile of the refuge 0 = municipal or domestic wells are likely located within 1 mile of the refuge –1 = municipal or domestic wells are located within 1 mile of the refuge	D,N	-1	Several domestic wells are located within the immediate vicinity of the refuge.
Soil and Hydrogeology	Are at-surface soils conducive to groundwater recharge?	+1 = soils are sandy or are reported to percolate well 0 = soils are silty or are reported to have some infiltration –1 = soils are clayey or are reported to hold water well	N	-1	The majority of the surface soils are mainly silty clay and clay. They are typically poorly drained and the permeability is slow.
	Could recharge basins be developed if surface soils were removed?	+1 = confining soil less than 2 feet thick 0 = confining soil 5 to 7 feet thick –1 = confining soil greater than 7 feet thick	N	0	The silty clay soil profile may be up to 7 feet thick.
	Has subsidence occurred at or in the immediate vicinity of the refuge?	+1 = no 0 = yes, less than 2 feet –1 = yes, more than 2 feet	D,N	+1	Subsidence has not been documented in the vicinity of the refuge. It does not appear to be a major concern in northern parts of the Sacramento Valley.
	Does significant potential for subsidence exist if groundwater use is increased at the refuge?	+1 = minimal potential for subsidence 0 = some potential for subsidence –1 = significant potential for subsidence	D,N	+1	Historically, subsidence has not been an issue in the northern parts of the Sacramento Valley. Aquifer conditions consist mainly of unconfined alluvium. Expansive confining layers susceptible to compaction are not present.
	Is aquifer storage available in the subbasin?	+1 = yes, current water levels are greater than 30 feet lower than historical levels 0 = some, current water levels are between 10 and 30 feet lower than historical levels –1 = no	N	0	Seasonal water-level fluctuations do exist in the subbasin. However, on the refuge, groundwater levels are not well documented.

continued on next page

Notes:

[a] Surface Features

[b] Application to Approach: D = Direct Use, N = On-Refuge Conjunctive Use

TABLE 2-7
Colusa NWR Evaluation
Evaluation of Groundwater Potential for Incremental Level 4 Refuge Water Supply

Criteria		Scoring Scale	Appl.[b]	Score	Refuge Score Justification
Water Quality	Have groundwater quality conditions hindered groundwater use in the past?	+1 = no 0 = data are not available –1 = yes	D,N	+1	Poor groundwater quality has not hindered groundwater use in the past.
	Do adverse groundwater quality conditions exist in the subbasin?	+1 = no 0 = potential –1 = yes	D,N	0	High EC, TDS, and manganese have been found in the subbasin near Colusa.
	Is surface water available to enable blending of lower quality groundwater to meet proposed refuge standards?	+1 = yes 0 = during portions of the year –1 = no	D,N	+1	The refuge has a reliable year-round supply of surface water.
	Do groundwater conditions exceed USEPA Freshwater Aquatic Life Standards or Agricultural Water Quality Goals for multiple parameters?	+1 = no 0 = yes, two parameters, or no water quality testing has been conducted –1 = yes, three or more parameters	D,N	+1	Mercury was reportedly detected at the refuge in 1989, although the data have not been located. The current mercury concentrations are unknown. There is no other data to indicate that groundwater quality at the refuge is poor.
	Is refuge land use management compatible with seasonally or annually variable water quality from different sources?	+1 = yes 0 = some potential compatibility problems may exist –1 = no	D,N	+1	Some of the water that the refuge receives is agricultural return flow. This water is of poorer quality, but is considered adequate for refuge needs.
	Does groundwater quality meet drinking-water standards (i.e., can it be used for refuge domestic supply)?	+1 = yes it is used, no treatment is necessary 0 = yes it is used, but some treatment is necessary for potable use; or it is not used for unknown reasons –1 = no, it is not used because of adverse water quality conditions	D	0	Refuge staff indicated that the water has a sulfur odor. The water is being treated to remove the odor.
Operational Issues/Constraints	Does a significant percentage of total refuge water supply consist of "Incremental Level 4" water?	+1 = yes, 54% to 79% of total water supply is Incremental Level 4 0 = somewhat, 27% to 53% of total water supply is Incremental Level 4 –1 = minor, 0% to 26% of total water supply is Incremental Level 4	D,N	-1	Colusa NWR does not have an Incremental Level 4 water requirement.
	Is the cost of local water high or low relative to the other refuges in this study?	+1 = costs may fluctuate highly or are subject to spot-market variability or price spikes –1 = costs are relatively stable and subjectivity to spot-market variability is low	D,N	-1	Incremental Level 4 water made available to Colusa NWR is relatively stable in cost and subjectivity to spot-market variability is low.
	Is it necessary to convey Incremental Level 4 water through the Delta for refuge supply?	+1 = yes, Incremental Level 4 water must be conveyed through the Delta –1 = no, conveyance of Incremental Level 4 water through the Delta is not necessary	D,N	-1	No, conveyance of Incremental Level 4 through the Delta is unnecessary. The refuge is located north of the Delta.
Data Needs	Are there significant data needs to address prior to groundwater development?	+1 = no, data needs regarding refuge groundwater conditions are minor 0 = somewhat, some data are required prior to increasing groundwater development –1 = yes, significant data must be collected as there is little or no existing data	D,N	0	Some data are required prior to increasing groundwater development, including a thorough assessment and video log of the existing well, confirmation of groundwater quality conditions, aquifer parameters, and depth and permeability of soils in areas where recharge might be considered.
			Total Direct Use Score =	**+3**	
			Total On-Refuge Conjunctive Use Score =	**+2**	

Notes:

[a] Surface Features

[b] Application to Approach: D = Direct Use, N = On-Refuge Conjunctive Use

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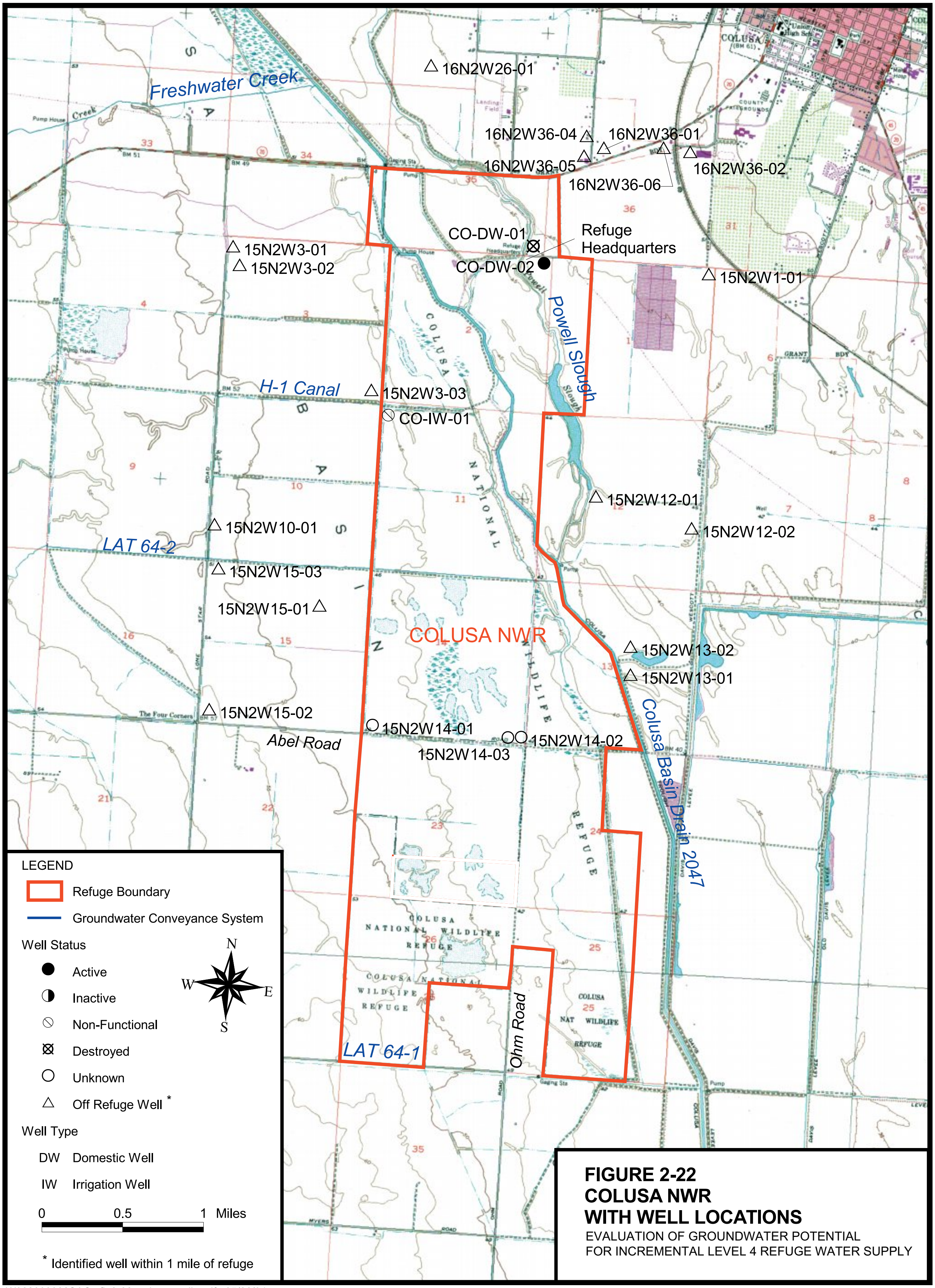

FIGURE 2-22
COLUSA NWR
WITH WELL LOCATIONS
EVALUATION OF GROUNDWATER POTENTIAL
FOR INCREMENTAL LEVEL 4 REFUGE WATER SUPPLY

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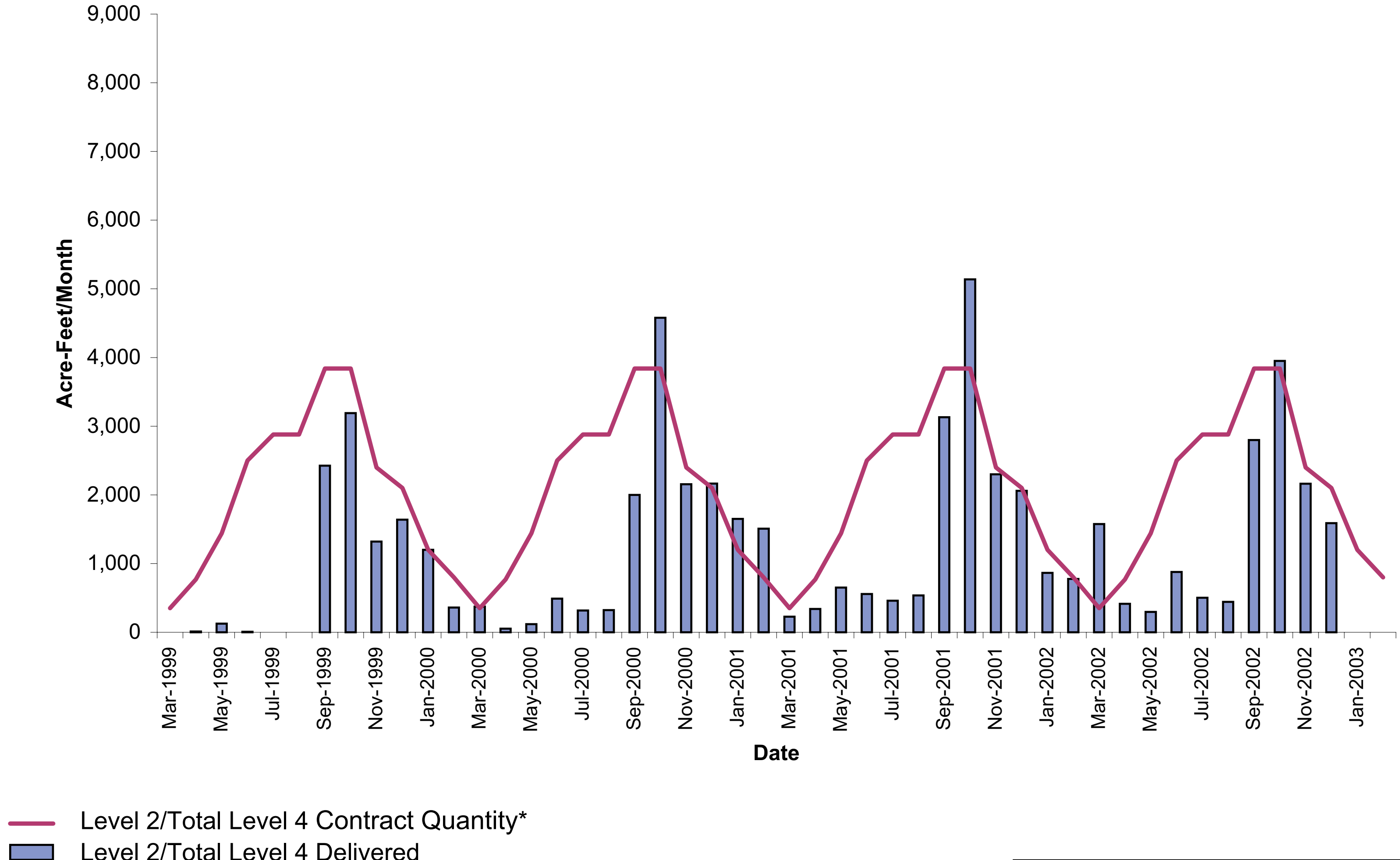

*Level 2 and Total Level 4 contract quantities are identical for Colusa NWR

Note: Level 2 and Total Level 4 contract quantities are those indicated in Reclamation 1989 and Reclamation el al. 1989. Volumes indicated may not reflect current monthly management schedules and are shown to indicate an approximate monthly breakdown for management purposes. Total annual contract quantities may be scheduled based on availability, at the refuge manager's discretion.

FIGURE 2-23
1999-2002 COLUSA NWR WATER DELIVERIES
EVALUATION OF GROUNDWATER POTENTIAL FOR INCREMENTAL LEVEL 4 REFUGE WATER SUPPLY

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FIGURE 2-24
EXISTING NONFUNCTIONAL WELL AT COLUSA NWR
EVALUATION OF GROUNDWATER POTENTIAL
FOR INCREMENTAL LEVEL 4 REFUGE WATER SUPPLY

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2.6 Gray Lodge WA Refuge Assessment

County: Butte and Sutter
Basin / Subbasin: Sacramento Valley Groundwater Basin / East Butte Subbasin
Level 2 / Incremental Level 4: 35,400 ac-ft / 8,600 ac-ft
2003 Acreage: 9,200
CVP Water Conveyor: Biggs–West Gridley WD
Water District Service Area: Biggs–West Gridley WD
Applicable Groundwater Management Regulations: Biggs–West Gridley WD AB 3030

Gray Lodge WA was established in 1931 and encompasses 9,200 acres in Sutter and Butte Counties near the City of Gridley (Figure 2-25). Approximately 2,600 acres of the refuge are within the Biggs–West Gridley WD service area. Gray Lodge WA is located adjacent to the Butte Sink, an overflow area of Butte Creek and the Sacramento River, and includes ponds, wetlands, crops, and pasture. Wetland areas support waterfowl food sources such as swamp timothy and invertebrate populations, and upland areas support habitat for geese, upland bird, and other species (Reclamation et al. 2001a).

2.6.1 Hydrogeologic Assessment

2.6.1.1 Habitat Goals, Land Management, and Surface Features

Gray Lodge WA is managed to achieve these three primary objectives:

1. Provide optimal habitat for wintering waterfowl.
2. Provide relief from agricultural crop depredation by waterfowl.
3. Provide recreational opportunity.

Habitats on Gray Lodge WA include permanent pond, seasonal wetlands, irrigated pastures and crops managed for cereal grains, and other upland habitat.

Seasonal wetlands are managed to provide food and cover for wintering waterfowl, shorebirds, and other wildlife. Management of seasonal wetlands and permanent ponds is similar to that described for the Sacramento NWR. However, if water is available, Gray Lodge WA irrigates moist soil impoundments several times during the summer.

Irrigated pasture and crop habitat consist of corn, vetch, milo, mixed grasses, and safflower grown to provide food and nesting cover for waterfowl. Irrigated crops include cereal grains and pasture; these require approximately 3.5 ac-ft per acre of irrigation water annually (USBR et al. 2001a).

Permanent water areas and irrigation ditches and canals provide aquatic habitat. Maintenance of permanent water in most of the ditches is complementary to the primary goal of maintaining habitat for wintering waterfowl. The popular warm-water fishery provides recreational opportunities for anglers.

Gray Lodge WA implements conservation and takes avoidance measures for several listed species: the giant garter snake, the valley elderberry longhorn beetle, Aleutian Canada geese, and bald eagle.

Pennington Road is a north-south road that separates the eastern one-third of the refuge from the western two-thirds. Many other roads throughout the refuge provide access for refuge residents, employees, and visitors.

Other surface features include a large parking lot near the Check Station and several smaller parking areas adjacent to the roads within the refuge. No large water bodies are located near the refuge.

2.6.1.2 Identified Water Supply Contract Quantities

On an annual basis, Gray Lodge has a Level 2 water need of 35,400 ac-ft and an Incremental Level 4 need of 8,600 ac-ft, totaling 44,000 ac-ft per year. Figure 2-26 shows Gray Lodge Level 2 and 4 water contract quantities, broken down by surface water deliveries and groundwater production, for water years 1999 through 2002. Other water sources (agricultural return flows, discussed later) are not included in these figures because the amount of these sources is not tracked.

Incremental Level 4 water has generally not been accessed because of a lack of a conveyance contract (discussed below). Corning Canal assignment water is available to Gray Lodge WA.

2.6.1.3 Surface Water Supplies and Infrastructure

As a landowner customer of the Biggs–West Gridley WD, Gray Lodge WA has both primary and secondary surface-water contractual supplies.[3] CVP surface water is supplied to the refuge by Biggs–West Gridley WD through the Schwind Lateral, Cassidy Lateral, and the Jakey Lateral. The CVP water supplied to Gray Lodge WA originates from Lake Shasta as CVP water and is exchanged with SWP water at Oroville. The water is conveyed to the refuge, and delivered by Biggs–West Gridley WD.

The refuge receives 8,000 ac-ft of dependable water from Biggs–West Gridley WD. The Biggs–West Gridley WD has allocated 12,000 ac-ft of water per year to the refuge, but only 8,000 ac-ft are available during the irrigation season from April to November. The refuge turnouts are located at the end of the Biggs–West Gridley WD system and cannot receive water when the Biggs–West Gridley WD canals are dewatered from January to April (Reclamation 1989). Gray Lodge WA is currently working with Reclamation to implement a multiyear, multimillion dollar upgrade of its IDS to improve system and delivery reliability.

A long-term conveyance contract with Reclamation was recently signed with Biggs–West Gridley WD. When it is implemented and constructed, a conveyance system will be able to deliver Incremental Level 4 water from the water district. Gray Lodge NWR will be able to receive partial Incremental Level 4 supplies through this contractual arrangement.

The refuge has several non-CVP water supplies. It may receive water from the RD 833 Drain and RD 2054 Drain when available and when water quality is acceptable. These canals convey agricultural return flow, which is available only during the summer and early fall when the rice fields are drained. The reclamation districts do not use or claim the agricultural return flows, which are at times diverted by the refuge under appropriative rights (Reclamation 1989). The amount of water available in these drains during the normal

[3] Primary supplies are those associated with refuge land when Biggs–West Gridley WD formed. Secondary supplies are related to lands that have been added to the refuge subsequent to the district's formation.

irrigation season has been decreasing as area farms improve irrigation efficiency and implement tailwater recycling programs. This is not considered a firm water supply for Gray Lodge WA (Refuge staff 2002).

CVP surface water delivered by Biggs–West Gridley WD is assumed by refuge staff to be of high quality (Refuge staff 2002). Agricultural return flows from non-CVP sources are of uncertain quality.

2.6.1.4 Groundwater Supplies and Infrastructure

The refuge maintains both irrigation wells and domestic supply wells. Twenty-one irrigation wells (19 are considered active) are used to supply a portion of refuge water, and three domestic wells provide water to the refuge headquarters, the check station, and residences. Groundwater has been used to supply up to 40 percent of the refuge's historical irrigation needs (USDOI et al. 1997). Limited pumping data (water years 1993, 1994, 1998-2001) indicate refuge pumping varies widely, from 2,605 ac-ft (May 1993 to April 1994) to 16,158 ac-ft (May to December 1994) (USDOI et al. 1997; refuge staff 2002). Specific available information about each refuge well is summarized in Table 2-8. Because many of the refuge wells (Figure 2-27) existed prior to the refuge formation, minimal information exists for some.

Most of the irrigation wells were acquired by Gray Lodge WA through land procurement. These irrigation wells are used to meet Level 2 water contract quantities from January to April each year, when surface water is not available, and to supplement surface water deliveries during the remainder of the year. Flow meters have been on the wells since August 1997 (Refuge staff 2002). Well use is monitored monthly and is summarized in Figure 2-28.

The three domestic wells are identified as the East Side Well (GL-DW-01), the Check Station Well (GL-DW-03), and the West Side Well (GL-DW-02). The East Side Well provides potable water to two residences, the Check Station Well provides a potable water source to the visitors to Gray Lodge WA, and the West Side Well provides potable water to four residences, the shop, the office, and public facilities (Refuge staff 2002).

In general, the groundwater at Gray Lodge WA is considered by refuge staff to be of good quality for refuge irrigation. The only sampling of the irrigation wells occurred in 1986, when nine wells were sampled for a limited number of constituents, including EC, selenium, and boron (DFG 1986). Additional water quality sampling has recently occurred, but the data are not yet available. Both parameters were below standards for Agricultural Water Quality Goals. Water quality data are shown in Table 2-9.

Each of the domestic water supply wells at Gray Lodge WA has been sampled for a suite of water quality parameters. Records for six samples each of the East Side (GL-DW-01) and West Side (GL-DW-02) domestic wells and seven samples from the Check Station (GL-DW-03) domestic well between 1993 and 2002 are available. Arsenic, detected above the USEPA-proposed MCL of 10 μg/L, is the only constituent identified at elevated concentrations. Historical arsenic concentrations in the East Side Well range from 7.4 to 90 μg/L. Arsenic has been detected in the Check Station Well at concentrations ranging from 4.9 to 20 μg/L. Arsenic concentrations in the West Side Well range from below detection levels to 32 μg/L (Monarch Laboratory, Inc. 1993). Wellhead treatment for the domestic wells is being implemented (Refuge staff 2002).

2.6.1.5 Local Groundwater Use

Numerous irrigation and domestic wells are located within 1 mile of the refuge boundaries. The irrigation wells are used for agricultural production and by local duck clubs to maintain waterfowl habitat. The domestic wells provide potable water for local land owners. One monitoring well was identified to the west of the refuge. The wells range in depth from 47 to 700 feet (DWR well logs on file).

2.6.1.6 Refuge Soil and Aquifer Conditions

The surface soil characteristics for Gray Lodge WA were summarized from the unpublished Soil Survey of Butte County, California (USDA 1995). A variety of soil types exist at the refuge, consisting primarily of low permeability silty clay and clay. Some areas of sandy loam may locally support groundwater recharge. Confining soils at the refuge are not known to be greater than 5 feet thick.

The dominant surface soil types at Gray Lodge WA are Neerdobe clay, Gridley-Haploxerolls complex, and the Subaco clay. Minor distributions of the Neerdobe clay loam, Gridley loam, Liveoak sandy clay loam, Gridley clay loam, and Esquon silty clay loam outwash were identified at the refuge.

The Neerdobe clay is a somewhat poorly drained, fine-textured alluvial soil. A typical soil profile will consist of up to 36 inches of gray to brown clay or clay loam underlain by hardpan. Salinity ranges from 0 to 2 micro mhos per centimeter (μmhos/cm). The Neerdobe clay soils located at Gray Lodge WA become flooded for brief periods of time from December to April. The water table is typically very shallow or present at the surface. The permeability of this soil is slow, and the water-holding capacity is high.

The Gridley-Haploxerolls complex is moderately well drained and consists of approximately 60 inches of brown and pale brown clay loam, and brown and pale brown sandy loam. Available data indicates that the salinity of the Gridley-Haploxerolls complex is between 4 and 8 μmhos/cm from 0 to 44 inches. The flooding potential of the Gridley-Haploxerolls complex is rare, with brief periods of potential occurring from December through March. The water table is very shallow, the permeability is slow to moderately rapid, and the water-holding capacity is low to moderate.

The Subaco clay is a somewhat poorly drained, fine-textured alluvial soil. A typical soil profile will consist of up to 29 inches of gray to brown clay or silty clay and is underlain by hardpan. Salinity ranges from 0 to 1 μmhos/cm. The water table is typically very shallow or present at the surface. The permeability of this soil is slow, and the water-holding capacity is low to moderate.

Historically, subsidence has not been a significant issue in the northern Sacramento Valley. Subsidence has not been documented in the vicinity of the refuge. Aquifer conditions consist mainly of unconfined alluvium. Expansive confining layers susceptible to compaction are not widespread.

Depth to water in the vicinity of the refuge is usually less than 10 feet with seasonal fluctuations of 5 feet or less. On the northern edge of the Sutter Buttes, depth to water is 2 to 40 feet below grade, with seasonal fluctuations of approximately 10 feet (DWR 2003b).

2.6.1.7 Operational Issues and Data Needs

Approximately 20 percent of the water supply contract quantity for Gray Lodge WA consists of Incremental Level 4 water. Incremental Level 4 water available to purchase for Gray Lodge WA is relatively stable in cost, and subjectivity to spot-market variability is low (Reclamation staff 2003). The refuge is located north of the Delta, and it is unnecessary to convey Incremental Level 4 water to the refuge through the Delta.

The following data gaps were identified during the completion of this study:

- Assessment of refuge wells, including the old irrigation or domestic well behind the refuge headquarters.
- Complete compilation of refuge groundwater data that is currently boxed and uncatalogued.
- Confirmation of refuge groundwater quality conditions.
- Aquifer parameters, such as hydraulic conductivity and thickness.

Relative to the other refuges in this study, it was estimated that a “low” or minor level of data collection is required at Gray Lodge WA prior to considering increased groundwater development.

2.6.2 Criteria Evaluation Summary

Gray Lodge WA received total Hydrogeologic Scores of +3 for Direct Use of groundwater and +3 for On-Refuge Conjunctive Use, based on the criteria matrix evaluation. The criteria matrix specific to Gray Lodge WA is shown as Table 2-10. The matrix includes a score for each criterion and a corresponding justification or reasoning for the score given.

Gray Lodge WA benefits by significant experience managing groundwater conjunctively with surface water supplies on the refuge. Several active wells are currently on the refuge, and increased direct use could be implemented and integrated with existing management to meet Incremental Level 4 contract quantities. Groundwater quality may be adequate, although collection of additional water quality could confirm perceptions of good water quality. Support and limitations to further development of groundwater resources at Gray Lodge WA are summarized below.

2.6.2.1 Support for Groundwater Development

- No surface water bodies in the refuge vicinity would be affected by increased groundwater use.
- Groundwater has been used historically to meet up to 40 percent of refuge water needs and has supplied 18 to 44 percent of refuge water between 1999 and 2002.
- Several irrigation wells are active on the refuge.

- No subsidence has occurred in the past in the refuge vicinity.
- Minimal potential exists for subsidence to occur with increased groundwater use.
- Known groundwater conditions do not exceed Freshwater Aquatic Life Standards or Agricultural Water Quality Goals.
- Refuge land use management for habitat support is compatible with some periodic water quality variability.
- Data needs identified for increasing groundwater development are minor relative to other refuges in the study.

2.6.2.2 Limitations to Groundwater Development

- Several domestic and irrigation wells are located in the immediate vicinity of the refuge, which could be negatively impacted by increased local groundwater use.
- At-surface soils primarily have low permeability and are not conducive to recharge.
- Dependence on Incremental Level 4 water for refuge water supply is relatively minor compared to other refuges in the study.
- Incremental Level 4 water available to purchase for Gray Lodge WA is relatively stable in cost, and subjectivity to spot-market variability is low.
- It is unnecessary to convey Incremental Level 4 water through the Delta.

2.6.3 Recommended Data Acquisition Activities

Several important pieces of information are necessary to assess the potential of additional and/or sustained groundwater use at the refuge. Recommended data acquisition activities include:

- Conduct an inventory of all refuge wells including date installed; physical well properties, including depth, operational status, operational deficiencies (i.e., broken or nonexistent pump, well collapse, etc.); and repair history. Photograph and collect global positioning system (GPS) coordinates for the wells. Survey the ground level elevation and the measuring point elevation of each well.
- Establish the water quality of the existing production wells by conducting at least two complete rounds of well sampling at the existing production wells located at the refuge. Collect these samples during two seasons, such as summer and winter, to assess potential seasonal variations. Measure, at a minimum, general chemistry parameters and metals, including arsenic, boron, chromium, mercury, and nitrates.
- Conduct two to three 72-hour aquifer tests at existing irrigation wells at Gray Lodge WA to determine an estimated refuge yield. Conduct these tests during a season in which the refuge is not irrigating. Use existing production wells where there are nearby inactive wells that can be monitored before and during the test. Collect pumping and recovery data. Such information would also enable evaluation of potential impacts to adjacent well users if Gray Lodge WA modifies existing groundwater use pattern.
- If previous data collection does not identify any inactive wells that could be used as monitoring wells, install three dedicated monitoring wells on the south, north, and east

sides of the refuge to record water level changes. This information would enable a better understanding of the aquifer response to seasonal conditions and changes in local water use.

- Install well meters on all unmetered wells that are used or may potentially be used for refuge water supply.
- Develop a groundwater budget for the refuge. Estimate potential refuge pumping under wet-, normal-, and dry-year conditions.

2.6.4 Potential Projects

2.6.4.1 Direct Use

Groundwater is currently used on the refuge as Level 2 water. Rehabilitation and replacement of existing wells could successfully provide increased quantities of water, including some Incremental Level 4. Replacing some of the oldest and/or open-hole (not having a screen or perforated casing) wells, rehabilitating wells, and replacing well pumps could improve well efficiency and support additional groundwater use at the refuge. Better recommendations as to the benefits of these actions could be made after the recommended well inventory is completed.

2.6.4.2 On-Refuge Conjunctive Use

Butte County completed an inventory of its water resources in 2001 (CDM 2001). This inventory indicates that the Biggs–West Gridley Sub-Unit extracts approximately 13,100 ac-ft per year and receives 34,900 ac-ft per year in deep percolation from surface water during a normal year. This includes current refuge groundwater use. Therefore, additional groundwater use appears to be feasible within the sub-unit in which the refuge occurs.

On-refuge groundwater storage potential may be limited because the aquifer is considered to be full. Other groundwater storage projects in the subbasin are being considered, as described under Areas of Planned Groundwater Projects in the East Butte Subbasin summary.

On-refuge recharge may be most feasible at the southern edge of the refuge. DWR (1978) indicates that the southeastern portion of the refuge has “few barriers to the vertical flow of groundwater,” similar to that indicated for southeast of Delevan NWR. Recharge in this portion of the refuge most likely flows off of the refuge, based on regional groundwater map information (see Figure 2-12).

2.6.4.3 Off-Refuge Conjunctive Use

The refuge is within the sphere of influence of the Biggs–West Gridley WD Groundwater Management Plan (AB 3030), but this document was not available for review. Butte County Ordinance Chapter 35-5 requires a permit for groundwater extraction for use outside the county, and Chapter 33-6 requires a permit for groundwater substitute pumping. In this county, a permit is required to substitute groundwater for surface water.

Butte County applied for and received an AB 303 grant in 2002. Potential for participation in this project with the applicant may exist.

TABLE 2-8
Gray Lodge WA Well Information[a]
Evaluation of Groundwater Potential for Incremental Level 4 Refuge Water Supply

GIS Well Number[b]	Common Well Name	Well Status[c]	2002 Yield (ac-ft)	Year Installed	Depth (ft)	Screen Interval (bgs)	Well Output (gpm)	Well Log?	Water Quality Data?	Comments
GL-IW-06	6	Active	223	1992	473	50–470	4,000	Y	N	
GL-IW-07	7	Active	109	1958	500	200–500	2,200	Y	Y	
GL-IW-09	9	Active	0	1958	500	173–500		Y	N	
GL-IW-10	10	Active	293	1992	540	220–510	3,500	Y	N	
GL-IW-12	12	Active	563					N	N	
GL-IW-14	14	Active	602		500		2,800–3,000	N	Y	
GL-IW-15	15	Active	0	1959	365	250–365	2,700	Y	Y	
GL-IW-17	17	Active	19	1958	500		1,800	Y	Y	
GL-IW-18	18	Active	0	1959	271	118–142	2,050	Y	Y	
GL-IW-19	19	Active	0		500	200–500	2,600	Y	N	
GL-IW-22	22	Inactive	0	1960	365	130–148		Y	Y	
GL-IW-24	24	Destroyed	0					N	N	
GL-IW-25	25	Inactive	0		224			Y	N	
GL-IW-26	26	Active	110	1948	237	Open Interval		Y	Y	
GL-IW-28	28	Active	647	1961	531		3,100	N	Y	
GL-IW-34	34	Active	0					N	N	
GL-IW-41	41	Active	20					N	N	
GL-IW-42	42	Active	6	1948	255	Open Interval		Y	N	
GL-IW-43	43	Active	10	1947	454	Open Interval	1,400	Y	N	
GL-IW-48	48	Active	114					N	N	

TABLE 2-8
Gray Lodge WA Well Information[a]
Evaluation of Groundwater Potential for Incremental Level 4 Refuge Water Supply

GIS Well Number[b]	Common Well Name	Well Status[c]	2002 Yield (ac-ft)	Year Installed	Depth (ft)	Screen Interval (bgs)	Well Output (gpm)	Well Log?	Water Quality Data?	Comments
GL-IW-49	49	Active	0		560			Y	N	
GL-IW-50	50	Active		1978	525	36–280 324–327		Y	N	
GL-DW-01	East Side Well	Inactive		2000	323	170–230		Y	Y	Well not in use because of high arsenic concentrations.
GL-DW-02	West Side Well	Active						N	Y	
GL-DW-03	Check Station Well	Active						N	Y	

Notes:

[a] Based on data compiled from well logs, test records, communication with refuge staff (2002), and other previous documentation. Well locations are shown on Figure 2-25. On-refuge wells only are included in this table, although the GIS includes known wells within 1 mile of the refuge.

[b] Well type is indicated by the middle two letters of the GIS well number: IW = irrigation well, DW = domestic well, MW = monitoring well, TW = test well, and UN = unknown.

[c] Designation refers to the physical well only, not water quality issues. Designations are: *active* (currently operated), *inactive* (capable of operating, but currently is not), *nonfunctional* (cannot operate in current physical state), *destroyed* (well has been lost, abandoned, or filled), or *unknown* (no information regarding status is available).

Blank fields indicate that no information is available.

TABLE 2-9
Gray Lodge WA Water Quality Data (1986–2001)
Evaluation of Groundwater Potential for Incremental Level 4 Refuge Water Supply

GIS Well Number	Sampled Interval (feet)*	Date	EC (μmhos/cm)	Arsenic (μg/L)	Boron (mg/L)	Mercury (μg/L)
GL-IW-07	200–500	10/22/1986	245		0.05	
GL-IW-14	?–500	10/22/1986	230		0.11	
GL-IW-15	250–365	10/22/1986	270		0.13	
GL-IW-17	?–500	10/22/1986	245		0.13	
GL-IW-18	118–142	10/22/1986	440		0.04	
GL-IW-22	130–148	10/22/1986	330		0.09	
GL-IW-26	Open Interval	10/22/1986	295		0.09	
GL-IW-28	?–531	10/22/1986	240		0.05	
GL-DW-01	170–230	04/06/1993		65		<0.2
		04/11/1994		65		
		07/11/1995	260	7.4		<1
		05/05/2000		90		
		02/06/2001		84		
		04/30/2002		71		
GL-DW-02		02/03/1993	400			
		04/06/1993		28		<0.2
		07/11/1995	340	32		<2
		05/03/1996		<2		
		06/09/1997	860	<2		<2
		02/06/2001		22		
GL-DW-03		02/03/1993	630			
		06/04/1993		20		
		02/17/2000		16		
		02/06/2001		18		
		06/12/2001		16		
		08/07/2001		20		
		11/09/2001		4.9		

Source: DFG 1986; Monarch Laboratory, Inc. 1993–2002.
Notes:
* Well depths shown as ?–500 do not have known screen intervals. Only the well depth (identified number) is known.
Blank fields indicate that the constituent was not tested.
ND = not detected

TABLE 2-10
Gray Lodge WA Evaluation
Evaluation of Groundwater Potential for Incremental Level 4 Refuge Water Supply

	Criteria	Scoring Scale	Appl.[b]	Score	Refuge Score Justification
Surface[a]	Do surface water bodies exist that could be affected by increased groundwater use?	+1 = no 0 = to some degree –1 = yes, surface water bodies could be affected	D,N	+1	Based on the current well locations, it does not appear that increased groundwater use would impact the surface water bodies. The surface water bodies are greater than 1 mile from any refuge wells.
Water Supplies and Infrastructure	Has groundwater been used previously at the refuge for ponds or irrigation?	+1 = yes, used successfully to meet at least 20 percent of annual refuge water demands 0 = yes, used to meet less than 20 percent (or unknown) of annual refuge water demands. –1 = no, has not been used	D,N	+1	Groundwater has been used to supply up to 40 percent of the refuge's water supply contract quantity.
	Do wells exist on the refuge?	+1 = yes, active wells 0 = yes, inactive or nonfunctional wells –1 = yes, destroyed wells, or no wells exist on the refuge	D,N	+1	There are 19 active irrigation wells at the refuge.
	Does existing internal distribution system (IDS) support groundwater use?	+1 = water can move extensively around the refuge with existing IDS 0 = the IDS enables limited water movement within the refuge –1 = an IDS does not exist on the refuge or water flow relies exclusively on gravity	D,N	0	IDS at the refuge is currently being improved. Lift pumps will be needed to get water to some areas of the refuge.
Local Groundwater Use	Is groundwater used for agriculture or duck clubs in the immediate vicinity of the refuge?	+1 = groundwater is not used; or groundwater is minimally used, but use is not constrained 0 = groundwater is used in the area –1 = groundwater is not used due to physical or environmental constraints or is extensively used in the vicinity	D,N	0	Groundwater is used mainly by duck clubs, farms, and for potable supply. The extent to which groundwater is used by these entities is unknown.
	Does municipal or domestic supply exist near the refuge?	+1 = no known domestic or municipal wells are located within 1 mile of the refuge 0 = municipal or domestic wells are likely located within 1 mile of the refuge –1 = municipal or domestic wells are located within 1 mile of the refuge	D,N	-1	Several domestic supply and irrigation wells are located within 1 mile of the refuge.
Soil and Hydrogeology	Are at-surface soils conducive to groundwater recharge?	+1 = soils are sandy or are reported to percolate well 0 = soils are silty or are reported to have some infiltration –1 = soils are clayey or are reported to hold water well	N	0	A variety of soil types exist at the refuge. For the most part, the soils consist of silty clay to clay; however, areas of sandy loam may make groundwater recharge possible.
	Could recharge basins be developed if surface soils were removed?	+1 = confining soil less than 2 feet thick 0 = confining soil 5 to 7 feet thick –1 = confining soil greater than 7 feet thick	N	0	The confining soils are no greater than 5 feet thick at the refuge according to the unpublished soil survey information.
	Has subsidence occurred at or in the immediate vicinity of the refuge?	+1 = no 0 = yes, less than 2 feet –1 = yes, more than 2 feet	D,N	+1	Subsidence has not been documented in the vicinity of the refuge. It does not appear to be a major concern in northern parts of the Sacramento Valley.
	Does significant potential for subsidence exist if groundwater use is increased at the refuge?	+1 = minimal potential for subsidence 0 = some potential for subsidence –1 = significant potential for subsidence	D,N	+1	Historically, subsidence has not been an issue in the northern parts of the Sacramento Valley. Aquifer conditions mainly consist of unconfined alluvium. Expansive confining layers susceptible to compaction are not widespread.
	Is aquifer storage available in the subbasin?	+1 = yes, current water levels are greater than 30 feet lower than historical levels 0 = some, current water levels are between 10 and 30 feet lower than historical levels –1 = no	N	0	Depth to water in the vicinity of the refuge is less than 10 feet, with seasonal fluctuations of 5 feet or less. On the northern edge of the Sutter Buttes (south of the refuge), depth to water is 2 to 40 feet below grade, with seasonal fluctuations of 10 feet.

Notes:
[a] Surface Features
[b] Application to Approach: D = Direct Use, N = On-Refuge Conjunctive Use

continued on next page

TABLE 2-10
Gray Lodge WA Evaluation
Evaluation of Groundwater Potential for Incremental Level 4 Refuge Water Supply

	Criteria	Scoring Scale	Appl.[b]	Score	Refuge Score Justification
Water Quality	Have groundwater quality conditions hindered groundwater use in the past?	+1 = no 0 = data are not available –1 = yes	D,N	+1	Arsenic above water quality standards has been detected in the East Side Domestic Well.
	Do adverse groundwater quality conditions exist in the subbasin?	+1 = no 0 = potential –1 = yes	D,N	0	Localized areas of impaired groundwater exist. It is unknown if these impairments cover the entire subbasin.
	Is surface water available to enable blending of lower quality groundwater to meet proposed refuge standards?	+1 = yes 0 = during portions of the year –1 = no	D,N	0	When Biggs–West Gridley WD does deliver water to the refuge in the future, it could be mixed with impaired groundwater.
	Do groundwater conditions exceed USEPA Freshwater Aquatic Life Standards or Agricultural Water Quality Goals for multiple parameters?	+1 = no 0 = yes, two parameters, or no water quality testing has been conducted –1 = yes, three or more parameters	D,N	+1	Arsenic has been detected at concentrations approaching the Aquatic Life Standard, but not exceeding standards. Other detected parameters are below standards.
	Is refuge land use management compatible with seasonally or annually variable water quality from different sources?	+1 = yes 0 = some potential compatibility problems may exist –1 = no	D,N	+1	Some of the water that the refuge receives is agricultural return flow. This water is considered to be of adequate quality for refuge needs.
	Does groundwater quality meet drinking-water standards (i.e., can it be used for refuge domestic supply)?	+1 = yes it is used, no treatment is necessary 0 = yes it is used, but some treatment is necessary for potable use; or it is not used for unknown reasons –1 = no, it is not used because of adverse water quality conditions	D	0	Water from the West Side and Check Station Wells is used. The East Side Well currently is not used. Two arsenic treatment plants are proposed for these irrigation wells.
Operational Issues/Constraints	Does a significant percentage of total refuge water supply consist of "Incremental Level 4" water?	+1 = yes, 54% to 79% of total water supply is Incremental Level 4 0 = somewhat, 27% to 53% of total water supply is Incremental Level 4 –1 = minor, 0% to 26% of total water supply is Incremental Level 4	D,N	-1	Approximately twenty percent of the water supply for Gray Lodge WA consists of Incremental Level 4 water.
	Is the cost of local water high or low relative to the other refuges in this study?	+1 = costs may fluctuate highly or are subject to spot-market variability or price spikes –1 = costs are relatively stable and subjectivity to spot-market variability is low	D,N	-1	Incremental Level 4 water made available to Sacramento NWR is relatively stable in cost and subjectivity to spot-market variability is low.
	Is it necessary to convey Incremental Level 4 water through the Delta for refuge supply?	+1 = yes, Incremental Level 4 water must be conveyed through the Delta –1 = no, conveyance of Incremental Level 4 water through the Delta is not necessary	D,N	-1	No, conveyance of Incremental Level 4 through the Delta is unnecessary. The refuge is located north of the Delta.
Data Needs	Are there significant data needs to address prior to groundwater development?	+1 = no, data needs regarding refuge groundwater conditions are minor 0 = somewhat, some data are required prior to increasing groundwater development –1 = yes, significant data must be collected as there is little or no existing data	D,N	+1	Data needs regarding refuge groundwater conditions are relatively minor. A thorough well assessment, confirmation of water quality, and a safe yield determination would be useful.
			Total Direct Use Score =	**+3**	
			Total On-Refuge Conjunctive Use Score =	**+3**	

Notes:
[a] Surface Features
[b] Application to Approach: D = Direct Use, N = On-Refuge Conjunctive Use

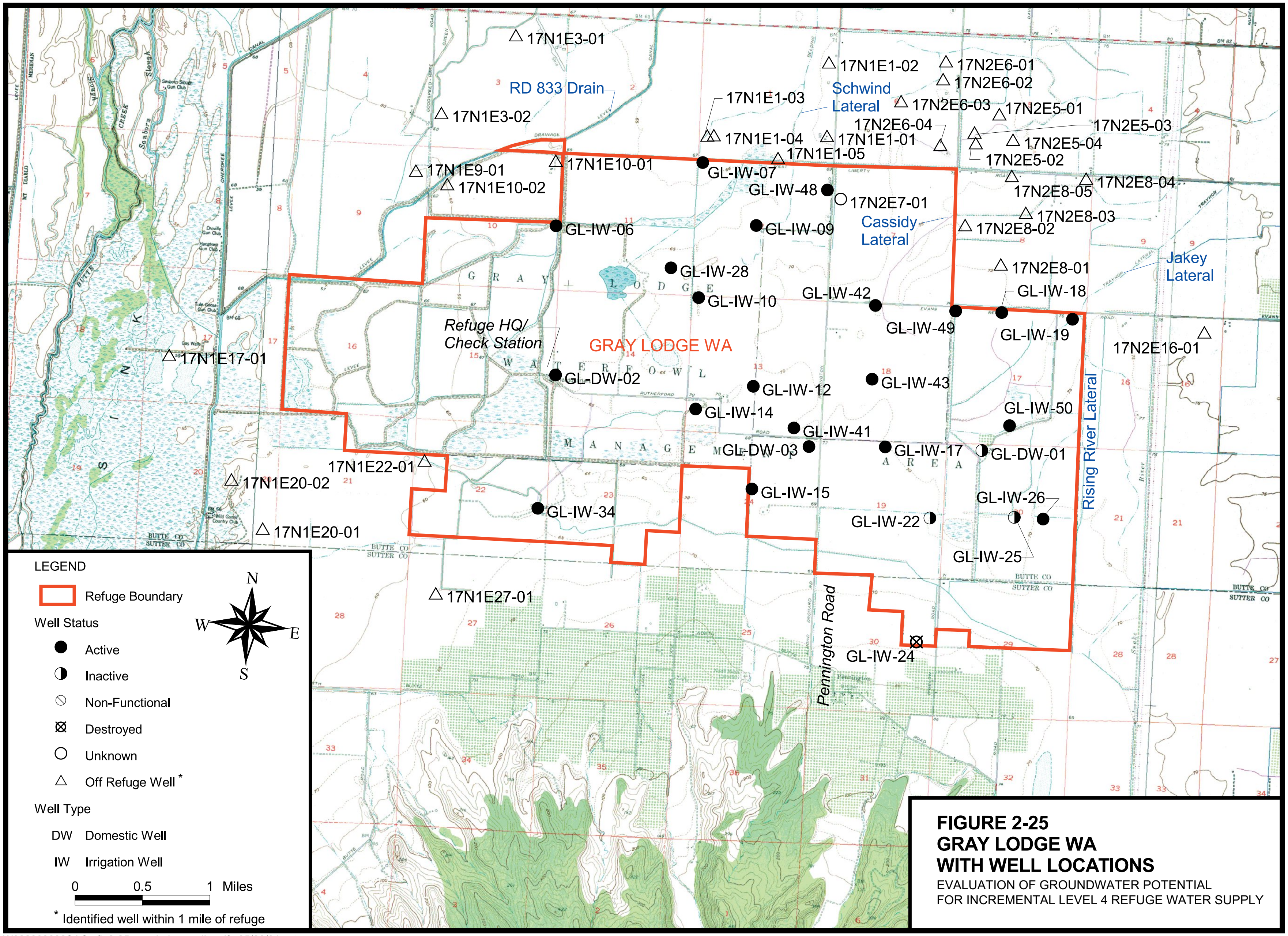

FIGURE 2-25
GRAY LODGE WA
WITH WELL LOCATIONS
EVALUATION OF GROUNDWATER POTENTIAL
FOR INCREMENTAL LEVEL 4 REFUGE WATER SUPPLY

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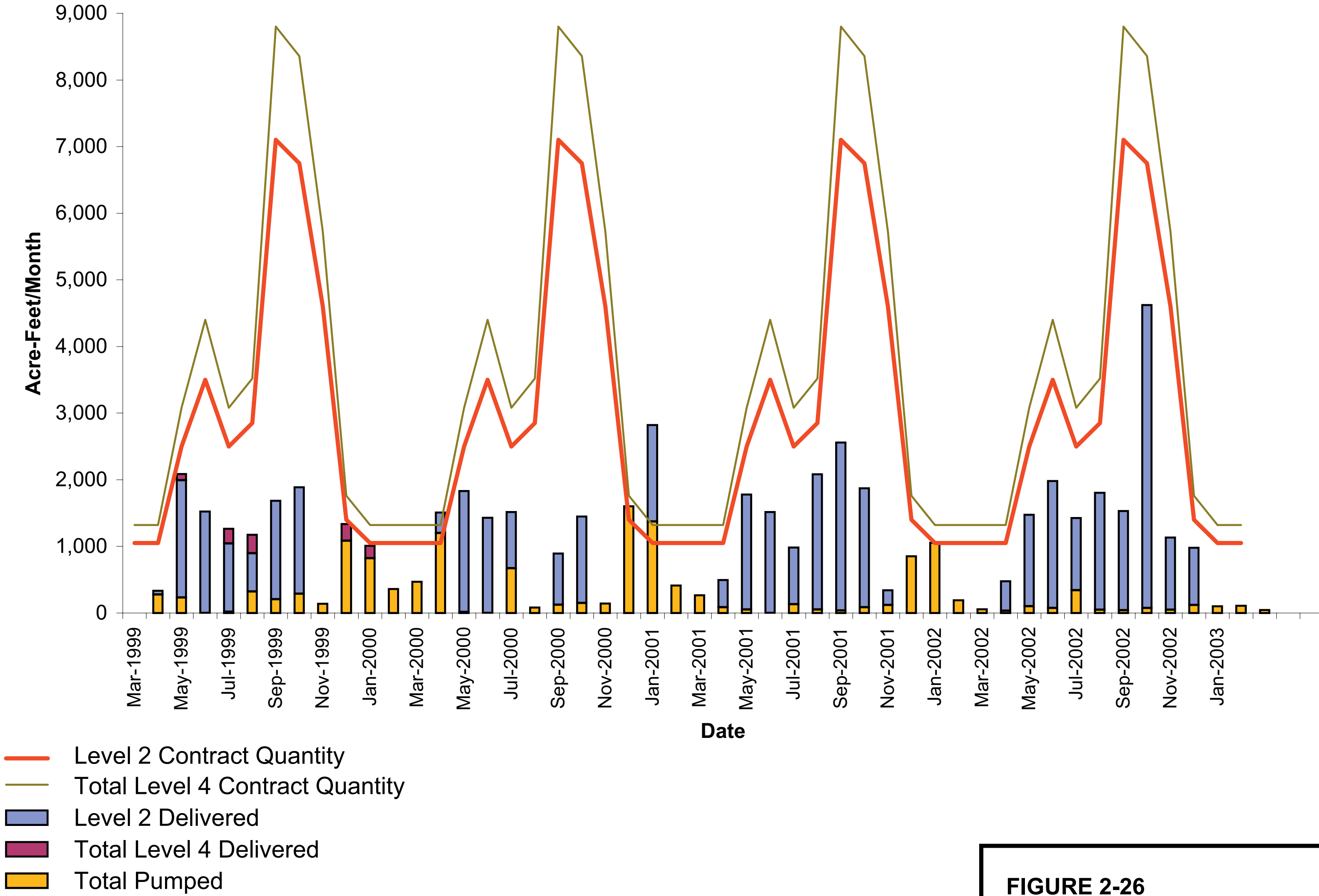

Note: Level 2 and Total Level 4 contract quantities are those indicated in Reclamation 1989 and Reclamation el al. 1989. Volumes indicated may not reflect current monthly management schedules and are shown to indicate an approximate monthly breakdown for management purposes. Total annual contract quantities may be scheduled based on availability, at the refuge manager's discretion.

FIGURE 2-26
1999-2002 GRAY LODGE WA WATER DELIVERIES
EVALUATION OF GROUNDWATER POTENTIAL FOR INCREMENTAL LEVEL 4 REFUGE WATER SUPPLY

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FIGURE 2-27
WELL 14 (ACTIVE) AT GRAY LODGE WA
EVALUATION OF GROUNDWATER POTENTIAL
FOR INCREMENTAL LEVEL 4 REFUGE WATER SUPPLY

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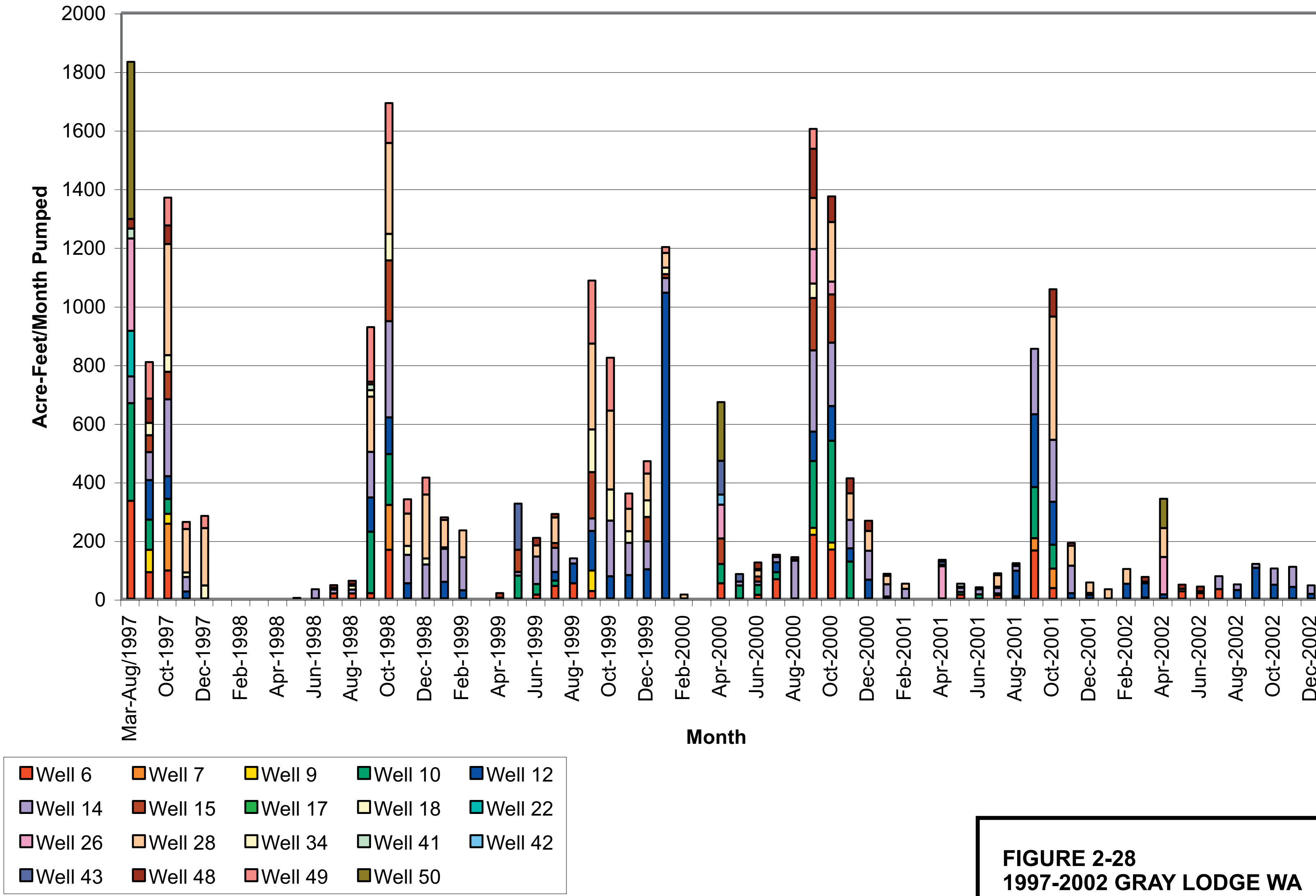

SOURCE: Refuge Staff 2002

FIGURE 2-28
1997-2002 GRAY LODGE WA
GROUNDWATER WELL USE
EVALUATION OF GROUNDWATER POTENTIAL
FOR INCREMENTAL LEVEL 4 REFUGE WATER SUPPLY

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2.7 Sutter NWR Assessment

County: Sutter
Basin / Subbasin: Sacramento Valley Groundwater Basin / Sutter Subbasin
Level 2 / Incremental Level 4: 23,500 ac-ft / 6,500 ac-ft
2003 Acreage: 2,591
CVP Water Conveyor: None (water is delivered from Sutter Bypass)
Water District Service Area: Sutter Extension WD, Sutter Butte Mutual WC
Applicable Groundwater Management Regulations: Sutter Extension WD AB 3030

Sutter NWR was established in 1944 and encompasses 2,591 acres in Sutter County, 8 miles southwest of Yuba City (Figure 2-29). Most of the refuge is located within the Sutter Bypass, north of its confluence with the Tisdale Weir. Historically, flood flows from the Sacramento River, Butte Sink, and Feather River inundated large portions of the Sutter Basin. However, most of this land has been protected from flooding by levees and has been developed for agricultural production. Water is used to maintain ponds and seasonal wetlands on the refuge. The wetlands support waterfowl food sources such as swamp timothy, watergrass, and invertebrate populations. Approximately 140 upland acres provide habitat for birds and other wildlife species (Reclamation et al. 2001a).

2.7.1 Hydrogeologic Assessment

2.7.1.1 Habitat Goals, Land Management, and Surface Features

The 2002–2003 Habitat Management Plan for Sutter NWR identifies the primary habitat type within the bypass as seasonal flooded marsh, which occupies approximately 1,645 acres. The seasonal flooded marsh within the bypass is bordered by a mixture of mixed riparian forest, unmanaged freshwater wetland, flooded willow, and valley oak riparian forest (Reclamation 2002).

The 2002–2003 Habitat Management Plan for the portion of Sutter NWR located outside the bypass, approximately 475 acres, is much different; approximately 248 acres is managed for watergrass production, approximately 85 acres will be occupied by summer water, and approximately 142 acres consist of perennial grassland.

Surface features near the refuge include the Sutter Bypass levees on the east and west sides of the refuge; Hughes Road, which crosses the refuge approximately 2 miles north of Tisdale Bypass; and East and West Borrow Ditches, which flow from north to south along the east and west sides of Sutter NWR.

2.7.1.2 Identified Water Supply Contract Quantities

The average annual Level 2 water need for Sutter NWR is 23,500 ac-ft (Figure 2-30). The optimum habitat management (Total Level 4) water need for Sutter NWR is 30,000 ac-ft per year. The only conveyance mechanism to deliver Incremental Level 4 to the refuge is the East Borrow Ditch of the Sutter Bypass. Corning Canal assignment water is available to Sutter NWR.

2.7.1.3 Surface Water Supplies and Infrastructure

Existing water supplies consist of the refuge's appropriative water rights, irrigation and return flows, flood flows, and water provided for in CVPIA. In recent years, Sutter NWR has received flood flows from the Sacramento River because of wet hydrologic conditions, so it has not accepted full water Level 2 deliveries (Reclamation et al. 2001a).

The refuge receives CVP water from East and West Borrow Ditches of Sutter Bypass and Sutter Extension WD. The surface water supplies originate at the Thermalito Afterbay and are conveyed to the East and West Borrow Ditches via the Sutter-Butte Canal. Most of the water supply to the refuge during the irrigation season is agricultural return flow. Flood flows are conveyed in the bypass during the winter (Turner 1992b).

Sutter NWR holds three appropriative water rights in Sutter Bypass. However, these contractual water rights do not have high priority; therefore, the refuge receives only surplus water. Because the water that Sutter NWR receives is not available during most of the year, these sources are not considered to be dependable (Turner 1992b). There is no conveyance capacity to receive Incremental 4 water at the refuge at this time.

The portion of Sutter NWR located outside the bypass receives water conveyed by Sutter Extension WD. The water is purchased from Sutter Extension WD by Reclamation and cooperative farmers. The water is conveyed to this portion of Sutter NWR through the Sutter-Butte Canal (Reclamation et al. 2001a).

Sutter NWR is improving the IDS at the refuge. The project began in the fall of 2002 and is scheduled for completion by August 2003. A CALFED grant was acquired by Ducks Unlimited, Inc. to fund the project. The project is managed by Ducks Unlimited, Inc. in conjunction with the Service. The main components of the project include deepening of the main north-south water delivery canal and raising the levees, installing new water control structures, and installing four new inline structures along the water delivery canal (Refuge staff 2003).

2.7.1.4 Groundwater Supplies and Infrastructure

Sutter NWR is not using groundwater. Four irrigation wells (1 through 4, or SU-IW-01 through SU-IW-04) once were located within the bypass; however, the wells were destroyed because of high pumping costs and poor water quality. Two operational wells (5 and 6, SU-IW-05 and SU-IW-06 respectively) exist on the portion of the refuge outside the bypass. Well production rates for these wells ranged from 1,800 to 3,000 gpm (Turner 1992b). Information for the existing and destroyed wells is shown in Table 2-11.

Water quality samples were obtained from refuge Wells 4 (SU-IW-04) and 6 (SU-IW-06) during September 1989. The resulting analysis identified arsenic concentrations of 300 μg/L and 280 μg/L in Wells 4 and 6, respectively, which are above the chronic Freshwater Aquatic Life Criterion (150 μg/L) and the Agricultural Water Quality Goal (100 μg/L). Mercury was identified at a concentration of 0.3 μg/L in both wells, which is below the Freshwater Aquatic Life standard of 0.77 μg/L. Cadmium and boron also have been detected in the groundwater at Sutter NWR (Fields 1989). Water quality data for Sutter NWR is provided in Table 2-12.

2.7.1.5 Local Groundwater Use

Many domestic and irrigation wells are located near Sutter NWR. Three domestic wells have been identified within 1 mile of the refuge. The wells range in depth from 80 feet to 775 feet. The production rates range from 1,300 gpm to 4,000 gpm (DWR well logs on file). Production rate is highly variable and depends on the depth at which the well was screened. In general, the deeper the screen depth, the higher the production rate.

2.7.1.6 Refuge Soil and Aquifer Conditions

The surface soil characteristics for Sutter NWR were determined by using the July 1988 Soil Survey of Sutter County, California, prepared by the United States Department of Agriculture (USDA) Soil Conservation Service. The primary soil type at the refuge is clay and silty clay with low permeability and holding capacity. The clay and silty clay profile can be up to 7 feet thick.

The dominant surface soil type is the Oswald clay, which is the only soil type present in the portion of the refuge within the bypass. The Oswald clay is a poorly drained, fine-textured alluvial soil with low permeability.

In addition to the Oswald clay, small distributions of the Gridley clay loam and Liveoak sandy clay loam are located at the portion of the refuge outside the bypass.

The Gridley clay loam is moderately well drained, permeability is slow, runoff is very slow, and erosion potential is slight. The Liveoak sandy clay loam is well drained, permeability is moderate, available water capacity is high, runoff is very slow, and erosion potential is slight.

Historically, subsidence has not been a significant issue in the northern Sacramento Valley. No subsidence has been documented near the refuge. Aquifer conditions consist mainly of unconfined alluvium and other sediments. Expansive confining layers susceptible to compaction are not present.

Historical groundwater levels are within 10 feet of the ground surface (DWR 2003b).

2.7.1.7 Operational Issues and Data Needs

Approximately 20 percent of the water supply contract quantity for Sutter NWR consists of Incremental Level 4. Incremental Level 4 water made available to Sutter NWR is relatively stable in cost, and subjectivity to spot-market variability is low (Reclamation staff 2003). The refuge is located north of the Delta, and it is unnecessary to convey Incremental Level 4 water to the refuge through the Delta.

Some data gaps were identified during the completion of this study:

- Assessment of all wells on the refuge, including the old irrigation or domestic well behind the refuge headquarters. Confirmation of refuge groundwater quality conditions for several different parameters of concern, particularly arsenic and mercury.
- Assessment of local aquifer conditions, including quarterly water-level data both on- and off-refuge, and a safe yield determination.
- Estimation of aquifer parameters, such as hydraulic conductivity and thickness.

- Record of groundwater pumping records and schedules, both on and immediately surrounding the refuge. This may entail the installation of well meters.

Relative to the other refuges in this study, it was estimated that a "medium" level of data collection is required at Sutter NWR prior to recommending increased groundwater development.

2.7.2 Criteria Evaluation Summary

Sutter NWR received total Hydrogeologic Scores of –4 for Direct Use of groundwater and -6 for On-Refuge Conjunctive Use, based on evaluation with the Hydrogeologic criteria matrix. The criteria matrix specific to Sutter NWR is shown as Table 2-13. The matrix includes a score for each criterion and a corresponding justification or reasoning for the score given.

Groundwater has been used historically at Sutter NWR, but water quality has significantly limited well use for wetland management. Groundwater quality would likely also limit on-refuge recharge efforts, and surface soils have slow permeability. Support and limitations to further development of groundwater resources at Sutter NWR are summarized below:

2.7.2.1 Support for Groundwater Development

- The existing IDS allows extensive water transport throughout the refuge. Integration would be possible with future groundwater infrastructure.
- No subsidence has occurred in the past in the refuge vicinity.
- Minimal potential exists for subsidence to occur with increased groundwater use.
- Refuge land use management is compatible with seasonally or annually variable water quality from different sources.

2.7.2.2 Limitations to Groundwater Development

- Nearby surface water bodies could be affected by increased groundwater use on the refuge, which could be negatively impacted by increased local groundwater use.
- Three domestic wells have been identified within 1 mile of the refuge.
- At-surface soils primarily have low permeability and are not conducive to recharge.
- Aquifer storage is not available. Current and historical groundwater levels are approximately equivalent.
- Regionally elevated concentrations of TDS have been detected in the subbasin.
- Poor groundwater quality has hindered groundwater use in the past. Cadmium, arsenic, mercury, and boron have been identified at elevated concentrations at the refuge. Some parameters have exceeded standards.
- Dependence on Incremental Level 4 water for refuge water supply is relatively minor compared to other refuges in the study.

- Incremental Level 4 water available to purchase for Sutter NWR is relatively stable in cost, and subjectivity to spot-market variability is low.
- It is unnecessary to convey Incremental Level 4 water through the Delta. Higher priority for groundwater development may be considered for refuges which have the water conveyance constraint of moving this water through the Delta.

2.7.3 Recommended Data Acquisition Activities

Although direct use of groundwater on this refuge is not recommended at this time, the following data should be collected prior to development of groundwater in the future:

- Conduct an inventory and assessment of refuge wells including date installed; physical well properties, including depth, operational status, operational deficiencies (i.e., broken or nonexistent pump, well collapse, etc.); and repair history. Photograph and collect GPS coordinates for the wells. Survey the ground level elevation and the measuring point elevation of each well. Conduct a video log of the existing wells.
- Conduct water quality testing to confirm refuge groundwater quality conditions. Sample each test well and the domestic well for general chemistry and metals, including arsenic, boron, chromium, mercury, and nitrates.
- Determine local aquifer conditions and parameters, such as hydraulic conductivity and thickness, and a safe yield for the refuge.
- Install well meters on all unmetered wells which may be used for refuge supply.
- Collect water-level data from available wells within and adjacent to the refuge. Monitor water levels quarterly, and collect routine water quality samples from active wells to develop a database of groundwater use and conditions. Maintain collected data in a format supportable and usable by the refuge.

2.7.4 Potential Projects

2.7.4.1 Direct Use

Installation of a production well within the Sutter Bypass is only recommended if installed above flood stage. Such a construction may not be compatible with the refuge objectives. Water quality concerns raised during previous groundwater sampling events within and outside the bypass have identified elevated concentrations of arsenic and mercury. Based on the identified concentrations, groundwater development at the refuge may not be feasible without treatment.

2.7.4.2 On-Refuge Conjunctive Use

Potential recharge opportunities could be considered at the portion of the refuge outside the bypass. If soil and aquifer conditions are favorable, floodwaters from the bypass could be diverted to the refuge for groundwater recharge. A test infiltration pond could be installed at the refuge to evaluate this potential scenario period, although groundwater quality conditions would most likely hinder groundwater use at the refuge.

2.7.4.3 Off-Refuge Conjunctive Use

Sutter Extension WD AB 3030 Groundwater Management Plan, adopted in November 1997, states that in circumstances where shortages of water in the state occur and Sutter Extension WD has a surplus, the groundwater storage capacity can be used conjunctively with surface water. Transfers are acceptable following evaluation of significant impacts to affected parties.

Several agencies in the Sutter Subbasin are considering groundwater banking projects that may provide a potential for refuge participation. Agencies actively considering projects are South Sutter WD, Sutter Mutual WC, Sutter County, and Sutter Extension WD.

TABLE 2-11
Sutter NWR Well Information[a]
Evaluation of Groundwater Potential for Incremental Level 4 Refuge Water Supply

GIS Well Number[b]	Common Well Name	Well Status[c]	2002 Yield (ac-ft)	Year Installed	Depth (ft)	Screen Interval (bgs)	Well Output (gpm)	Well Log?	Water Quality Data?	Comments
SU-IW-01	Well 1	Destroyed						N	N	Location unknown.
SU-IW-02	Well 2	Destroyed					2,254	N	N	Location unknown.
SU-IW-03	Well 3	Destroyed					3,245	N	N	Location unknown.
SU-IW-04	Well 4	Inactive					1,315	N	Y	Well #4 is located in the portion of the refuge located outside the bypass. Refuge staff believe the pump and motor are still present.
SU-IW-05	Well 5	Inactive					2,999	N	N	Well #5 is located in the portion of the refuge located outside the bypass. Refuge staff believe the pump and motor are still present.
SU-IW-06	Well 6	Destroyed					2,002	N	Y	Location unknown.
SU-TW-01	Test Hole 1	Unknown		1977	710			Y	N	

Notes:

[a] Based on data compiled from well logs, test records, communication with refuge staff (2002), and other previous documentation. Well locations are shown on Figure 2-29. On-refuge wells only are included in this table, although the GIS includes known wells within 1 mile of the refuge.

[b] Well type is indicated by the middle two letters of the GIS well number: IW = irrigation well, DW = domestic well, MW = monitoring well, TW = test well, and UN = unknown.

[c] Designation refers to the physical well only, not water quality issues. Designations are: *active* (currently operated), *inactive* (capable of operating, but currently is not), *nonfunctional* (cannot operate in current physical state), *destroyed* (well has been lost, abandoned, or filled), or *unknown* (no information regarding status is available).

Blank fields indicate that no information is available.

TABLE 2-12
Sutter NWR Water Quality Data (1989)
Evaluation of Groundwater Potential for Incremental Level 4 Refuge Water Supply

GIS Well Number	Sampled Interval (feet)	EC (µs/cm)	Arsenic (µg/L)	Boron (mg/L)	Cadmium (µg/L)	Mercury (µg/L)
SU-IW-04		1,372	300	0.6	10	0.3
SU-IW-06		1,850	280	0.7	<2	0.3

Source: Fields 1989.

Blank fields indicate that the constituent was not tested.
ND = not detected

TABLE 2-13
Sutter NWR Evaluation
Evaluation of Groundwater Potential for Incremental Level 4 Refuge Water Supply

	Criteria	Scoring Scale	Appl.[b]	Score	Refuge Score Justification
Surface[a]	Do surface water bodies exist that could be affected by increased groundwater use?	+1 = no 0 = to some degree –1 = yes, surface water bodies could be affected	D,N	-1	The East and West Borrow Ditches of the Sutter Bypass border the refuge.
Water Supplies and Infrastructure	Has groundwater been used previously at the refuge for ponds or irrigation?	+1 = yes, used successfully to meet at least 20 percent of annual refuge water demands 0 = yes, used to meet less than 20 percent (or unknown) of annual refuge water demands. –1 = no, has not been used	D,N	0	Groundwater was previously used at the refuge; however, the degree to which the wells met the water demand at the refuge is unknown. Wells used in the past have been able to provide significant quantities of water.
	Do wells exist on the refuge?	+1 = yes, active wells 0 = yes, inactive or nonfunctional wells –1 = yes, destroyed wells, or no wells exist on the refuge	D,N	0	Four wells are located on the portion of the refuge inside the bypass, and two wells are located outside of the bypass. Refuge staff indicate that these wells are not used, but the pumps and motors are present.
	Does existing internal distribution system (IDS) support groundwater use?	+1 = water can move extensively around the refuge with existing IDS 0 = the IDS enables limited water movement within the refuge –1 = an IDS does not exist on the refuge or water flow relies exclusively on gravity	D,N	+1	Gravity flow currently dominates most of the water movement throughout the refuge, but improvements are being made to the IDS. The canal is being deepened, the levees are being raised, and control structures and inline structures are being installed.
Local Groundwater Use	Is groundwater used for agriculture or duck clubs in the immediate vicinity of the refuge?	+1 = groundwater is not used; or groundwater is minimally used, but use is not constrained 0 = groundwater is used in the area –1 = groundwater is not used due to physical or environmental constraints or is extensively used in the vicinity	D,N	0	Groundwater is used in the area. Most of the water use in the area is for irrigation. One duck club is located within 1 mile of the refuge. All but one of the wells are located outside the bypass.
	Does municipal or domestic supply exist near the refuge?	+1 = no known domestic or municipal wells are located within 1 mile of the refuge 0 = municipal or domestic wells are likely located within 1 mile of the refuge –1 = municipal or domestic wells are located within 1 mile of the refuge	D,N	-1	Three domestic wells have been identified within 1 mile of the refuge.
Soil and Hydrogeology	Are at-surface soils conducive to groundwater recharge?	+1 = soils are sandy or are reported to percolate well 0 = soils are silty or are reported to have some infiltration –1 = soils are clayey or are reported to hold water well	N	-1	The primary soil type at the refuge is clay and silty clay with low permeability and holding capacity.
	Could recharge basins be developed if surface soils were removed?	+1 = confining soil less than 2 feet thick 0 = confining soil 5 to 7 feet thick –1 = confining soil greater than 7 feet thick	N	0	The clay and silty clay soil profile can be up to 7 feet thick.
	Has subsidence occurred at or in the immediate vicinity of the refuge?	+1 = no 0 = yes, less than 2 feet –1 = yes, more than 2 feet	D,N	+1	Subsidence has not been documented near the refuge. It does not appear to be a major concern in northern parts of the Sacramento Valley.
	Does significant potential for subsidence exist if groundwater use is increased at the refuge?	+1 = minimal potential for subsidence 0 = some potential for subsidence –1 = significant potential for subsidence	D,N	+1	Historically, subsidence has not been an issue in the northern parts of the Sacramento Valley. Aquifer conditions consist mainly of unconfined alluvium and other sediments. Expansive confining layers susceptible to compaction are not present.
	Is aquifer storage available in the subbasin?	+1 = yes, current water levels are greater than 30 feet lower than historical levels 0 = some, current water levels are between 10 and 30 feet lower than historical levels –1 = no	N	-1	Historical groundwater levels are within 10 feet of the ground surface.

continued on next page

Notes:

[a] Surface Features

[b] Application to Approach: D = Direct Use, N = On-Refuge Conjunctive Use

TABLE 2-13
Sutter NWR Evaluation
Evaluation of Groundwater Potential for Incremental Level 4 Refuge Water Supply

	Criteria	Scoring Scale	Appl.[b]	Score	Refuge Score Justification
Water Quality	Have groundwater quality conditions hindered groundwater use in the past?	+1 = no 0 = data are not available –1 = yes	D,N	-1	Cadmium, arsenic, mercury, and boron have been identified at elevated concentrations at the refuge.
	Do adverse groundwater quality conditions exist in the subbasin?	+1 = no 0 = potential –1 = yes	D,N	-1	Regionally elevated concentrations of TDS have been detected.
	Is surface water available to enable blending of lower quality groundwater to meet proposed refuge standards?	+1 = yes 0 = during portions of the year –1 = no	D,N	0	Although the refuge does not have a reliable water supply, surface water supplies have been adequate for blending with lower quality groundwater in recent years.
	Do groundwater conditions exceed USEPA Freshwater Aquatic Life Standards or Agricultural Water Quality Goals for multiple parameters?	+1 = no 0 = yes, two parameters, or no water quality testing has been conducted –1 = yes, three or more parameters	D,N	-1	Boron and arsenic exceed Aquatic Life Standards and Agricultural Water Quality Goals. EC exceeds Agricultural Water Quality Goals. Mercury and cadmium have also been detected.
	Is refuge land use management compatible with seasonally or annually variable water quality from different sources?	+1 = yes 0 = some potential compatibility problems may exist –1 = no	D,N	+1	Some of the water that the refuge receives is agricultural return flow. This water is of poorer quality, but is considered to be adequate for refuge needs.
	Does groundwater quality meet drinking-water standards (i.e., can it be used for refuge domestic supply)?	+1 = yes it is used, no treatment is necessary 0 = yes it is used, but some treatment is necessary for potable use; or it is not used for unknown reasons –1 = no, it is not used because of adverse water quality conditions	D	0	There is no domestic supply well at the refuge.
Operational Issues/Constraints	Does a significant percentage of total refuge water supply consist of "Incremental Level 4" water?	+1 = yes, 54% to 79% of total water supply is Incremental Level 4 0 = somewhat, 27% to 53% of total water supply is Incremental Level 4 –1 = minor, 0% to 26% of total water supply is Incremental Level 4	D,N	-1	Approximately twenty-two percent of the water supply for Sutter NWR consists of Incremental Level 4 water.
	Is the cost of local water high or low relative to the other refuges in this study?	+1 = costs may fluctuate highly or are subject to spot-market variability or price spikes –1 = costs are relatively stable and subjectivity to spot-market variability is low	D,N	-1	Incremental Level 4 water made available to Sutter NWR is relatively stable in cost and subjectivity to spot-market variability is low.
	Is it necessary to convey Incremental Level 4 water through the Delta for refuge supply?	+1 = yes, Incremental Level 4 water must be conveyed through the Delta –1 = no, conveyance of Incremental Level 4 water through the Delta is not necessary	D,N	-1	No, conveyance of Incremental Level 4 through the Delta is unnecessary. The refuge is located north of the Delta.
Data Needs	Are there significant data needs to address prior to groundwater development?	+1 = no, data needs regarding refuge groundwater conditions are minor 0 = somewhat, some data are required prior to increasing groundwater development –1 = yes, significant data must be collected as there is little or no existing data	D,N	0	Some data are required prior to increasing groundwater development, including a thorough well assessment, confirmation of groundwater quality conditions, local aquifer conditions, and water levels.
		Total Direct Use Score =		**-4**	
		Total On-Refuge Conjunctive Use Score =		**-6**	

Notes:

[a] Surface Features

[b] Application to Approach: D = Direct Use, N = On-Refuge Conjunctive Use

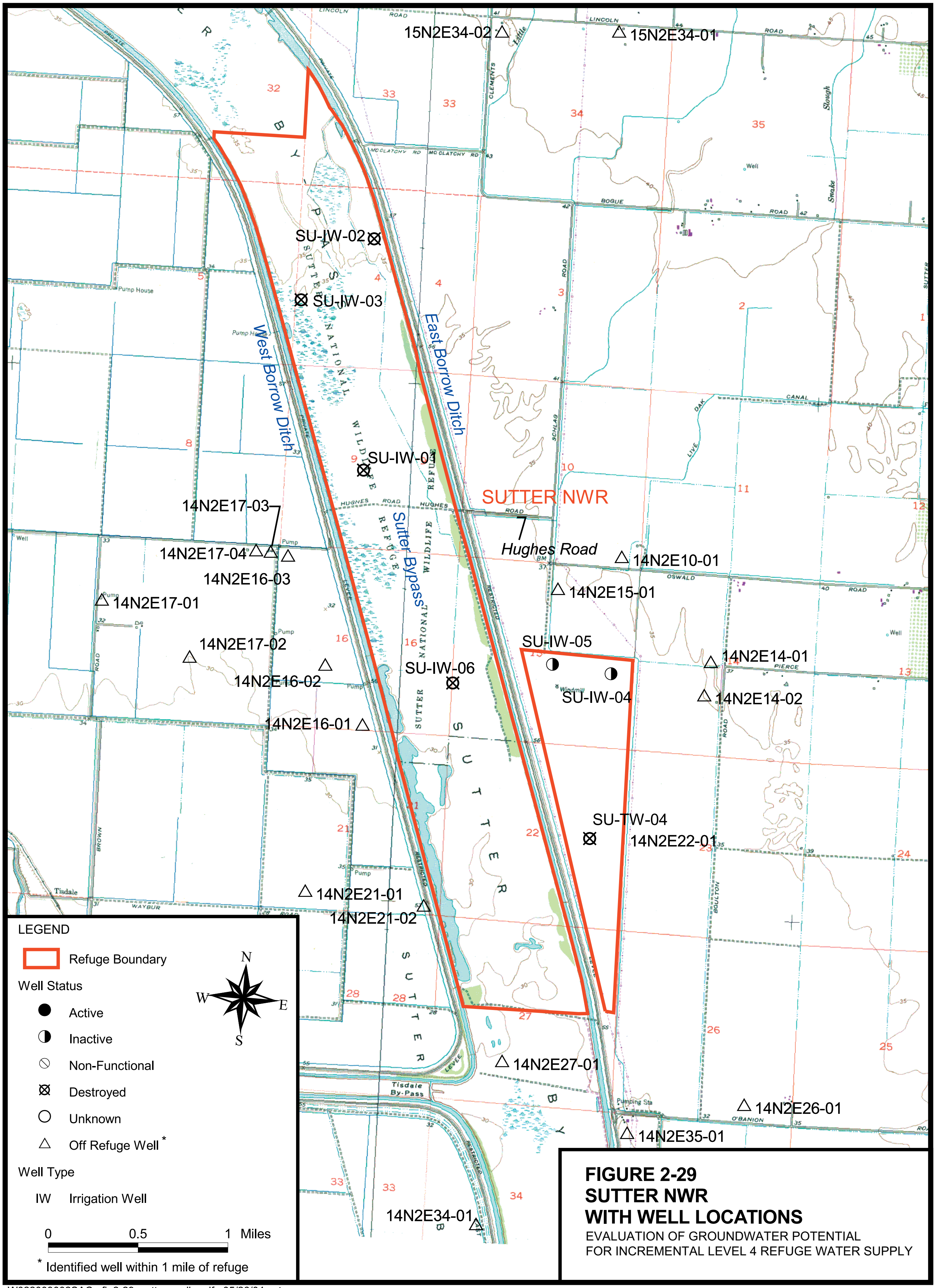

FIGURE 2-29
SUTTER NWR
WITH WELL LOCATIONS
EVALUATION OF GROUNDWATER POTENTIAL
FOR INCREMENTAL LEVEL 4 REFUGE WATER SUPPLY

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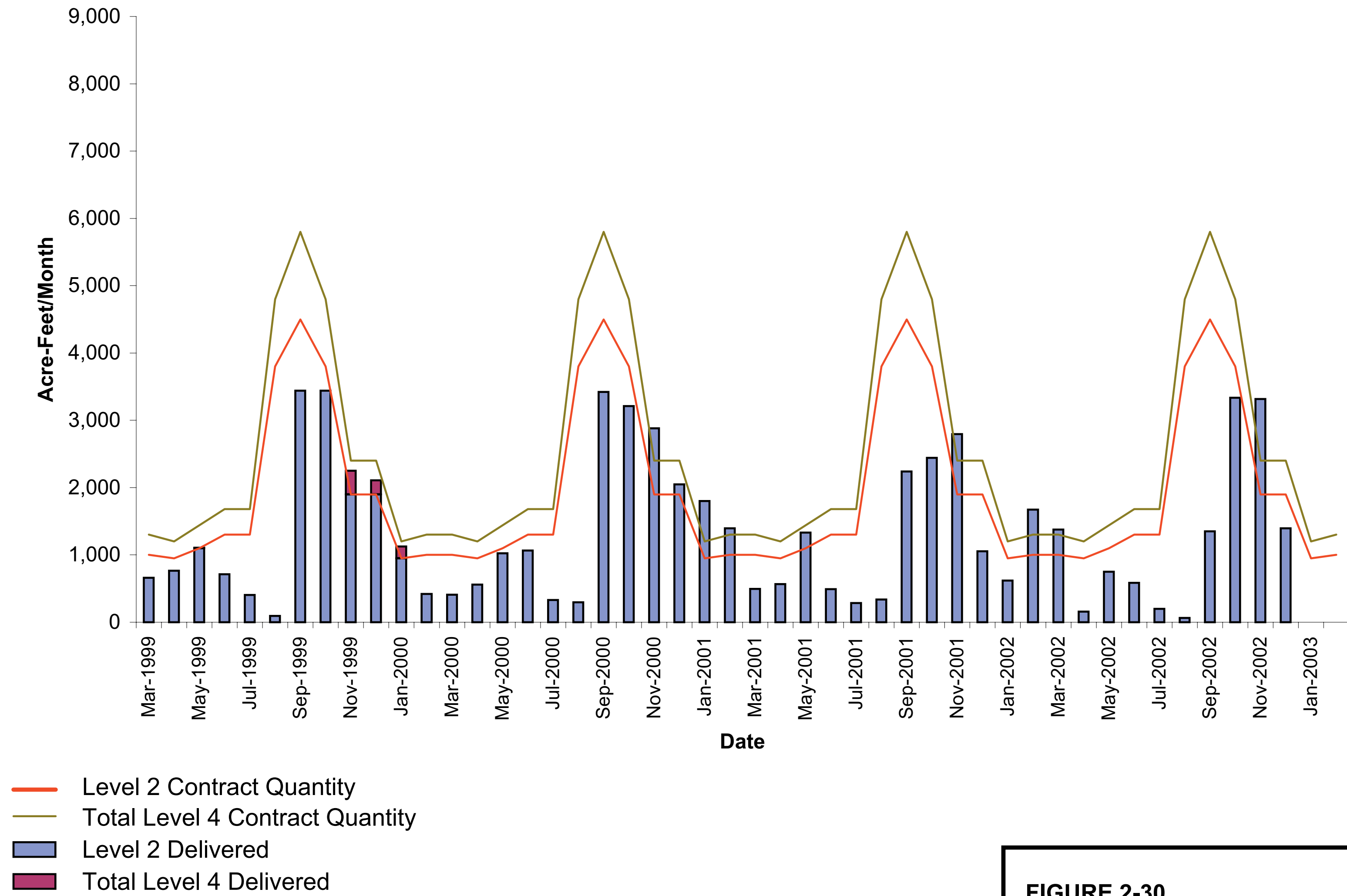

Note: Level 2 and Total Level 4 contract quantities are those indicated in Reclamation 1989 and Reclamation el al. 1989. Volumes indicated may not reflect current monthly management schedules and are shown to indicate an approximate monthly breakdown for management purposes. Total annual contract quantities may be scheduled based on availability, at the refuge manager's discretion.

FIGURE 2-30
1999-2002 SUTTER NWR WATER DELIVERIES
EVALUATION OF GROUNDWATER POTENTIAL
FOR INCREMENTAL LEVEL 4 REFUGE WATER SUPPLY

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SECTION 3

San Joaquin River Region Refuges

3.1 Regional Characteristics

3.1.1 Physical Setting

The San Joaquin River Region encompasses the northern half of the San Joaquin Valley and the San Joaquin Valley Basin. The 13,500 square miles of the region extend from just south of the Delta to just north of Fresno, where it is adjacent to the Tulare Lake Region (see Section 4). The following refuges are located in the San Joaquin River Region (Figure 3-1):

- North Grasslands WA
  - China Island Unit
  - Salt Slough Unit

- San Luis NWR Complex
  - Freitas Unit
  - Kesterson Unit
  - West Bear Creek Unit
  - East Bear Creek Unit
  - San Luis Unit
  - Merced NWR

- Los Banos WA
- Grassland RCD
- Volta WA
- Mendota WA

These refuges are located within three groundwater subbasins, as defined by the DWR Bulletin 118 – 2003 Update (DWR 2003a). The Delta-Mendota and Merced Subbasins are located within the San Joaquin River Hydrologic Region. Although Mendota WA (Kings Subbasin) is physically located within the Tulare Lake Region, its water supply originates from hydrologic basins to the north. The refuge is therefore included in this section (San Joaquin River Region).

The San Joaquin River Region is bounded by the Coast Range to the west, the Sierra Nevada to the east, the Delta and the Sacramento Valley Basin to the north, and the San Joaquin River to the south. The two major aqueducts, the Delta-Mendota Canal and the California Aqueduct, are near the western edge of the region. Geographically, the larger communities of Merced and Los Banos occur within the region, as well as numerous smaller ones. The area is agriculturally strong, and numerous major water districts, irrigation districts, and canal companies (CCs) operate in the region. The refuges themselves are a significant presence around Los Banos because they encompass such a large portion of the surrounding area. Urbanization in the Los Banos region is placing pressure on rural land-use practices.

Several of the San Joaquin River Region refuges have additional units not considered within the scope of this project. Generally, these additional units are newer acquisitions and are not included under CVPIA. Where groundwater data or issues for these units are relevant, the information is discussed with the applicable refuge. These additional units include:

- Arena Plains Unit (Merced NWR)
- Blue Goose Unit (San Luis NWR Complex)
- Gadwall Unit (Grasslands WA)
- Mud Slough Unit (Los Banos WA)

3.1.2 Existing Water Supplies

Pursuant to the CVPIA, long-term refuge water supply agreements were executed for each of the San Joaquin River Region refuges in 2001. The federal refuges are managed collectively by the Service as the San Luis NWR Complex, but are discussed individually by unit in this section. The four state WAs are each managed by DFG, and Grassland RCD is managed by Grassland WD.

3.1.3 Groundwater Management

Groundwater management within the San Joaquin River Region occurs under existing California code, through development of local ordinances, and by the development and implementation of specific groundwater management plans, as discussed in Section 1 and Appendix B. Where available, groundwater management plans or ordinances with direct or indirect bearing on the refuges described in this section were reviewed for this report. The following entities have adopted groundwater management plans or groundwater ordinances.

3.1.3.1 Merced Groundwater Basin

The Merced Groundwater Basin AB 3030 Groundwater Management Plan was adopted in December 1997. The Merced Area Groundwater Pool Interests (MAGPI) guide the management of the GMP. Several agencies within the basin have developed regional groundwater management plans to locally manage groundwater resources. The Merced Groundwater Basin AB 3030 GMP applies to those areas outside of the boundaries of other agencies that have adopted groundwater management plans (MAGPI 1997). Merced NWR and the East Bear Creek Unit fall under the jurisdiction of this plan.

The State Water Resources Control Board (SWRCB) stated in the revised Water Right Decision 1641 (D-1641) that groundwater substitution in the Merced Groundwater Basin would be appropriate only if conducted with either an in-lieu recharge (conjunctive use) or an actual recharge program (direct recharge using surface water) to balance additional groundwater pumping. The decision also required that such a recharge program be implemented if groundwater substitution was undertaken to prevent exacerbation of overdraft conditions (SWRCB 2000).

The Water Acquisition Program has acquired water from the San Joaquin River Group Authority (SJRGA) and its member agencies to provide additional spring and fall fishery flows on the Stanislaus, Tuolumne, Merced, and lower San Joaquin rivers. Until 1999 these flows were negotiated on an annual basis. In 1999 a long-term agreement known as the

San Joaquin River Agreement (SJRA) was signed establishing water acquisitions for the next 11 years from SJRGA. These water acquisitions support the Vernalis Adaptive Management Plan (VAMP), a scientifically based fishery management plan to determine the relationships between flows, exports, and other factors on fish survival in the Delta. Under this agreement the amount of flows to be purchased to meet VAMP requirements are determined for each year using established hydrologic criteria.

The SJRA allows for other arrangements between the members to provide water as long as the VAMP pulse flow is met (CH2M HILL 2001). Through agreements made in conjunction with members of the SJRGA, it may be possible to supply water to refuges through the VAMP program. Water that a member district has allocated to VAMP may, in theory, be able to supply a refuge as long as another entity supplies that volume of water to VAMP.

3.1.3.2 Merced Irrigation District

The Merced ID adopted its own AB 3030 Groundwater Management Plan prior to the adoption of the Merced Groundwater Basin Plan. The Merced ID AB 3030 plan contains provisions for coordination with the MAGPI regional groundwater management plan (Merced ID 1997). Although NWRs are outside the Merced ID service area, Merced ID is responsible for supplying Merced NWR with surface water through a Federal Energy Regulatory Commission (FERC) agreement.

The Merced Water Supply Plan (Phase I, 1993, and Phase III, 1995) is a long-range water supply study jointly commissioned by Merced ID and the City of Merced to address increasing urban water demand and use of groundwater in the agricultural sector and to determine new water supplies from both surface and groundwater sources. The report identifies existing water entitlements, evaluates available water supplies, identifies present and future water demands, presents a preferred alternative plan to utilize surface water for urban demands, and develops financing and institutional arrangements. Planning strategies and policies were developed to address these water-supply issues (CH2M HILL 1993). This report was updated in 2001 (CH2M HILL 2001).

Transfers of surface water or groundwater outside the Merced ID service area are not supported by Merced ID or the Merced Water Supply Plan because groundwater cones of depression have been identified in the Merced area. During severe drought Merced ID permits the discharge of groundwater from privately owned wells into Merced ID’s water conveyance system (Merced ID 1997).

3.1.3.3 Exchange Contractors

The Exchange Contractors adopted an AB 3030 groundwater management plan in 1997. Participating agencies include the Central California ID, Firebaugh Canal WD, San Luis CC, and Columbia CC, which are located in the Delta-Mendota Subbasin. Several of these districts, including Central California ID and San Luis CC, are involved in conveying water to refuges included in this study. Central California ID, Firebaugh Canal ID, and San Luis CC allow groundwater substitution transfers outside their sphere of influence, and Columbia CC does not (Exchange Contractors 1997).

3.1.3.4 Mendota Pool Group

The Mendota Pool Group ("pool pumpers"), an unincorporated association comprising agricultural contractors within Westlands WD, was created to provide supplemental water on several properties within Westlands WD and San Luis WD to offset reductions in contract water supplies attributable to the CVPIA, the Endangered Species Act (ESA), and new Delta water quality rules. Local well owners and members of the Mendota Pool Group pump groundwater on demand into Mendota Pool during the nonirrigation season to provide water for the irrigation season. Agricultural contractors receive credit for the groundwater pumped into Mendota Pool and, in exchange, Reclamation provides deliveries to Westlands WD. Water may be pumped directly from Mendota Pool to adjacent CVP agricultural contractors (DOI 2001). Some Exchange Contractors also receive substitute water from Mendota Pool as part of their Exchange Contract with Reclamation (Exchange Contractors 1997).

3.1.3.5 Potential Off-Refuge Conjunctive Use Projects

A number of groundwater management programs and projects for the San Joaquin River Region have been proposed and/or approved through state (DWR) grant and loan programs. Figure 3-2 presents the locations and status of these projects within the San Joaquin River Region. Details on these projects are provided in Conjunctive Use—San Joaquin River Region in Appendix C, Table C-2. The information contained within Table C-2 is provided as guidance relative to projects that have been proposed by water agencies, whether or not they have received funding or proceeded beyond the conceptual phase. Projects range from well-developed conceptual plans, such as the Stony Creek Fan Project, to loosely defined "groundwater storage" projects. Refuge assessments identify which known projects may have application to that refuge. These include potential projects with Eastside ID (Conjunctive Use Study - #31 on Table C-2 and Figure 3-2), Merced ID (#29 and #30) and Marvin Meyers (#22). Qualitative evaluation of these projects, conducted during the refuge summaries, indicates that some projects are more feasible than others for refuge involvement based on parameters such as proximity to refuge, project type, conveyance opportunities, and project status. See Table C-2 and the refuge assessments for additional discussion of these potential projects.

3.1.4 Regional Geology and Soils

The San Joaquin Valley Basin accumulated up to 6 vertical miles of unconsolidated continental land and marine sediment in the structural trough, with continental sequences dominating as the sequence becomes younger. The terrace, alluvial, and flood-basin deposits of the Tulare Formation are the predominant geologic unit in the uppermost portion of the subsurface (Figure 3-3). As these sediments accumulated over the last 24 million years, large lakes periodically filled and drained, resulting in deposition of laterally extensive clay layers with variable thickness of sands and silts. The most extensive of these is the Corcoran Clay Member of the Tulare Formation (Figure 3-4), which ranges in thickness from zero to 160 feet thick. In the San Joaquin River Region, the Corcoran Clay occurs at depths of 100 to 400 feet bgs. The Corcoran Clay shallows and thins in the northern portion of the basin and is absent in the extreme northern and eastern parts of the region.

3.1.5 Regional Hydrogeology

The extensive clay layers in the San Joaquin Valley form significant barriers to the vertical movement of groundwater in the basin. The Corcoran Clay, also referred to as the E-clay, plays the most dominant role in the regional hydrogeology and divides the groundwater system into two major aquifers: a confined aquifer below the clay layer and a semi-confined aquifer above the layer. Other clay layers are present above and below the Corcoran Clay, and these may affect local groundwater conditions (Reclamation et al. 1999). The more laterally extensive of these clays are often given alphabetic designations, such as A-clay and C-clay.

Natural recharge to the semi-confined upper aquifer generally occurs from stream seepage, deep percolation of rainfall, and subsurface inflow along basin boundaries. Recharge is augmented with deep percolation of applied agricultural irrigation water and seepage from the distribution systems used to convey this water. Recharge of the lower, confined aquifer consists of subsurface inflow from the valley floor and foothill areas east of the Corcoran Clay's eastern boundary. Clay layers, including the Corcoran Clay, are not continuous in some areas and are also penetrated by wells screened above and below the clay. These conditions result in some seepage through the confining layer from the semi-confined aquifer above (Reclamation et al. 1999).

Historically, groundwater recharged streams in most of the San Joaquin River Region. After the 1950s, increased groundwater pumping in the region lowered groundwater levels, which resulted in surface water recharging the underlying aquifer through streambed seepage. Areas where this has occurred include the eastern San Joaquin and Merced Counties and western Madera County. Similar to the Sacramento River Region, the largest stream losses have occurred during the drought periods of 1976–77 and 1987–92 (Reclamation et al. 1999).

Prior to the development of the Central Valley, groundwater in the San Joaquin River Region flowed from the valley flanks to the axis, then north toward the Delta. Large-scale groundwater development during the 1960s and 1970s, combined with the introduction of imported surface water supplies, have modified the natural groundwater flow pattern. Because of groundwater pumping, groundwater flow largely occurs from areas of recharge toward areas of lower groundwater levels (Bertoldi et al. 1991). Numerous cones of depression occur throughout the region and are discussed more thoroughly in the subbasin discussions.

3.1.5.1 Groundwater Storage and Production

DWR's 1994 estimate of the usable storage capacity for the San Joaquin River Region was approximately 24 million ac-ft, with an estimated perennial yield of approximately 3.3 million ac-ft (DWR 2003a). This perennial yield is directly dependent upon the amount of recharge received by the groundwater basin, which may vary in the future as a result of drought conditions or changing agricultural practices.

As in the Sacramento River Region, urban growth during the 1980s and 1990s has contributed to an increase in groundwater pumping in the San Joaquin River Region. DWR estimated groundwater pumping for 1990 conditions (normalized) to be 3.5 million ac-ft.

This exceeds the estimated perennial yield by approximately 200,000 ac-ft. All subbasins within the San Joaquin River Region experienced some overdraft (DWR 1994).

3.1.5.2 Groundwater Models

Several groundwater models have been developed within the San Joaquin River Region. These include:

- Central Valley Ground-Surface Water Model (CVGSM) (Reclamation et. al. 1990)
- San Joaquin County (Integrated Groundwater-Surface Water Model, IGSM)
- Madera Ranch (NHI 2001)
- Hydrologic-Economic Model of the San Joaquin Valley, DWR Bulletin 214, 1982 (USGS 1989)
- Groundwater flow models cited in the USGS report (1989) prepared in 1983 by Mitten and Londquist to study the aquifer system of the Fresno-Madera area
- Land subsidence model developed by Corapcioglu and Brutsaert in 1977 cited in the USGS report (1989) to simulate land subsidence caused by pumping at sites in the San Joaquin Valley

This list is not comprehensive and represents only those models which are commonly discussed and referred to in the groundwater community. These models may not include wetlands hydrology or specific refuge details. Some of these models may provide general information and summaries about assumed aquifer properties and groundwater conditions.

3.1.5.3 Groundwater Levels

Expansion of agricultural practices between 1920 and 1950 caused declines in groundwater levels in many areas of the region. These declines continued with the increase in groundwater use after the 1950s and as a result of urban growth in the 1980s and 1990s. Along the east side, declines have ranged between 40 and 80 feet since conditions which existed prior to human settlement (1860) (Williamson et al. 1989). Groundwater levels declined more than 80 feet in Madera County, which depends heavily on groundwater for irrigation (Williamson et al. 1989).

Substantial deficiencies in surface water deliveries and corresponding increases in groundwater pumping. Water levels declined by 20 to 30 feet throughout most of the central and eastern parts of the San Joaquin Valley during the 1987-1992 drought (Westlands WD 1995). Cones of depression, resulting from groundwater withdrawals, occur along the east side of the San Joaquin River Region in Merced and Madera Counties.

Refer to subbasin sections for more specific information on changes in local groundwater levels.

3.1.5.4 Groundwater Quality

Groundwater quality conditions in the region vary throughout the area. Parameters associated with regional problems are discussed in specific subbasins. In general, groundwater is of lower quality in the San Joaquin Valley as compared to the Sacramento

Valley. Adverse water quality conditions frequently correlate with the occurrence of the Corcoran Clay, possibly because the clay restricts vertical flow. Although there are no enforceable water quality standards for federal or California refuges, USEPA Freshwater Aquatic Life Protection Recommended Criteria (USEPA Office of Water 2002a), Agricultural Water Quality Goals (Ayers and Westcot 1985), and federal and state MCLs (USEPA Office of Water 2002a; CDHS 2003) may be used as reference points. These standards for selected constituents are provided in Table B-1 of Appendix B.

Arsenic, Boron, and Molybdenum. Molybdenum, boron, and arsenic are commonly detected at elevated concentrations in groundwater above the Corcoran Clay (Figure 3-5). Agricultural use of groundwater is impaired because of elevated boron concentrations (greater than 0.75 mg/L) in eastern Stanislaus and Merced Counties. Municipal use of groundwater as a drinking water supply is impaired because of elevated arsenic concentrations (greater than the primary MCL of 50 μg/L) in Stanislaus and Merced Counties and in western San Joaquin County (Reclamation et al. 1999; USEPA Office of Water 2002b). Elevated levels of molybdenum may be present at toxic and potentially toxic concentrations in some soils and in shallow groundwater on the western side of the San Joaquin River and Tulare Lake Regions.[1] The Agricultural Water Quality Goal for molybdenum is 10 μg/L (Ayers and Westcot 1985).

Dibromochloropropane. Dibromochloropropane (DBCP), a soil fumigant nematicide, has been detected in many groundwater wells in the eastern portions of the San Joaquin River Region and in north-central Merced County. Municipal use of groundwater as drinking-water supply is impaired because of elevated DBCP concentrations (greater than the MCL of 0.2 μg/L) in groundwater near several cities in the region, including Chowchilla, Madera, Merced, and the Modesto-Turlock area (Reclamation et al. 1999; USEPA Office of Water 2002b; CDHS 2003).

Nitrates. Municipal use of groundwater as a drinking water supply is impaired because of elevated nitrate concentrations (greater than the MCL of 45 mg/L as NO_3) in the Tracy, Modesto-Turlock, Merced, and Madera areas (Reclamation et al. 1999; CDHS 2003).

Selenium. Selenium in groundwater has been detected at elevated concentrations above the Corcoran Clay. Selenium is found naturally in soils and groundwater on the west side of the region, where concentrations in shallow groundwater have been highest south of Los Banos and Mendota (greater than 200 μg/L) (Figure 3-6). Use of groundwater to support aquatic species may be impaired because of elevated concentrations (chronically above 5 μg/L, the USEPA Freshwater Aquatic Life Criteria) (USEPA Office of Water 2002a).

TDS and Salinity. TDS concentrations vary considerably in the San Joaquin River Region, depending upon the vertical or horizontal groundwater zone (Figure 3-7). TDS concentrations in groundwater along the east side of the San Joaquin Valley are lower in comparison to concentrations in the west side of the San Joaquin River Region. This distribution reflects the low concentrations of dissolved solids in recharge water that originates from the snowmelt in the Sierra Nevada. In the central and east side of the valley, TDS concentrations generally do not exceed 500 mg/L. On the west side, TDS

[1] Although the CVPIA Programmatic EIS was not specific for molybdenum regarding the definition of “elevated,” the Agricultural Water Quality Goal for this constituent is 10 μg/L.

concentrations are generally greater than 500 mg/L, and in excess of 2,000 mg/L along the western boundary of the valley (Reclamation et al. 1999). Concentrations may exceed 2,000 mg/L in the shallow aquifer above the Corcoran Clay throughout the region.

Municipal use of groundwater as drinking-water supply is impaired because of elevated TDS concentrations (above the secondary MCL of 500 mg/L) at several locations throughout the San Joaquin River Region (Reclamation et al. 1999; USEPA Office of Water 2002b; CDHS 2003).

Salinity, as measured by EC, also provides an indication of dissolved salts in groundwater. Figure 3-7 shows the ranges of EC in the groundwater above the Corcoran Clay. In the San Joaquin River Region, EC can be greater than 10,000 µmhos/cm. The Agricultural Water Quality Goal for EC is 700 µmhos/cm (Ayers and Westcot 1985).

3.1.5.5 Agricultural Subsurface Drainage

Inadequate drainage and accumulating salts have been persistent problems for more than 100 years for irrigated agriculture along the west side and in parts of the east side of the San Joaquin River Region. The most extensive drainage problems exist on the west side of the San Joaquin River Region, where depth to groundwater is commonly less than 20 feet (Figure 3-8).

The soils on the west side of the region are derived from marine sediments and are high in salts and trace elements. Irrigation of these soils has mobilized these compounds and facilitated their movement into shallow groundwater. Much of this irrigation has been with imported water, resulting in rising groundwater and increasing soil salinity. Where agricultural drains have been installed to control rising water tables, drainage water frequently contains high concentrations of salts and trace elements (SJVDP 1990).

The area of subsurface drainage problems extends along the western side of the San Joaquin River and Tulare Lake Regions from the Delta on the north to the Tehachapi Mountains south of Bakersfield. In some portions of the San Joaquin River Region, natural drainage conditions are inadequate to allow deep percolation of rainfall and applied water. Therefore, groundwater levels often rise into the root zone of agricultural crops, and subsurface drainage must be facilitated (such as by tiling) for irrigation to be sustained.

3.1.6 Subsidence

Land subsidence in the San Joaquin Valley has occurred in areas confined by the Corcoran Clay, where pressure changes caused by groundwater pumping promote greater compressive stress than in the unconfined zone (DWR 1977). Land subsidence of up to 30 feet (for the period 1926–70) in the San Joaquin Valley has occurred in the Los Banos-Kettleman City area (see Section 2, Figure 2-7) (Reclamation et al. 1999). A 5,200 square-mile area with at least 1 foot of subsidence extends from Merced County to Kings County. This is the largest of the three land subsidence areas in the San Joaquin River and Tulare Lake Regions.

3.1.7 Areas of Planned Groundwater Projects

Merced ID is planning a large groundwater recharge project in the central part of the Merced Subbasin. Recharge basins will be the primary method of groundwater recharge. See the Merced NWR refuge assessment for more information.

A cooperative effort is underway by the Cities of Fresno and Clovis, Fresno ID, and Fresno Metropolitan Flood Control District to use individually owned facilities to recharge water in greater urban areas. The Fresno-Clovis metropolitan area uses water from a regional wastewater treatment facility to supply percolation ponds for groundwater recharge southwest of Fresno (DWR 2003a). There are plans to develop a 40-acre groundwater recharge facility near the future water treatment plant located near International and Maple in northeast Fresno.

The City of Fresno Department of Public Utilities uses surface water to artificially recharge groundwater by the use of spreading basins at the City-owned Leaky Acres site, located near the Fresno Yosemite International Airport. Built in 1970, the project currently consists of 26 ponds covering over 200 acres. An average of 55 ac-ft per day of surface water is applied to the site nearly year-round (City of Fresno 2003).

The Fresno Metropolitan Flood Control District also partners with the City of Fresno to recharge groundwater. The City's surface water is delivered to the Flood Control District's recharge basins located throughout the urban area during summer and fall. The City is developing new recharge sites in southeast Fresno.

MAGPI recently completed a Conjunctive Use Site Assessment at various areas surrounding the City of Merced (MAGPI 2003) to identify suitable groundwater recharge locations within the Basin. Sites were considered near Livingston-Atwater, the planned University of California (UC) at Merced, and El Nido. Based on depth to water, hydraulic conductivity, and specific yield on the analysis, the Livingston-Atwater site is considered to be best suited for recharge, followed by UC Merced and El Nido. Livingston-Atwater and UC Merced both have relatively high hydraulic conductivity; however, the Livingston-Atwater site has a thicker unsaturated zone and higher specific yield. El Nido has relatively low hydraulic conductivity, specific yield, and depth to water (MAGPI 2003). No known further action has been taken on developing the recommended sites.

The Meyers Farm is a privately funded groundwater bank currently being planned for the Mendota area. Some investigation of groundwater conditions has occurred, but details are not publicly available. The site is located northwest of the Mendota WA.

3.2 Subbasin Characteristics

3.2.1 Delta-Mendota Subbasin

Eight refuges are located within the Delta-Mendota Subbasin. The primary source of information used for the Delta-Mendota Subbasin summary in this report is the summary prepared for the Bulletin 118 – 2003 Update (DWR 2003a). Water districts within the Delta-Mendota Subbasin are shown on Figure 3-9. This subbasin contains the highest concentration of refuges in this study, and includes:

- North Grasslands WA—China Island and Salt Slough Units
- San Luis NWR—Kesterson, West Bear Creek, and San Luis Units
- Volta WA
- Los Banos WA
- Grassland RCD

3.2.1.1 Basin Boundaries and Hydrology

The Delta-Mendota Subbasin encompasses 1,170 square miles (747,000 acres). It is bordered by the Stanislaus/San Joaquin County line on the north, the Coast Range on the west, and Tranquility ID to the south. The San Joaquin River, the eastern boundary of the Columbia CC, the Chowchilla Bypass, and the eastern border of the Farmers WD form the eastern border of the subbasin. Annual precipitation ranges from 9 to 11 inches, with the higher amounts occurring in the northern portion of the subbasin.

The San Joaquin River, the California Aqueduct, and the Delta-Mendota Canal are major conveyances in the subbasin. Several smaller tributary streams—such as Salt Slough, Mud Slough, and Los Banos Creek—locally influence surface water and groundwater conditions.

3.2.1.2 Hydrogeology

The Tulare Formation is the primary subsurface geologic unit in the Delta-Mendota Subbasin. It consists of laterally variable to discontinuous interbedded intervals of clay, sand, and gravel. Younger terrace, alluvial, and flood-basin deposits are found above the Tulare Formation. The Corcoran Clay Member of the Tulare Formation occurs at depths between 100 and 500 feet in the basin. Pleistocene terrace deposits are coarser-grained than the Tulare Formation and frequently are found above the present streambeds. The water table is often located near the base of these deposits.

In general, the subbasin has three distinct groundwater intervals. The lower zone is the confined lower interval of the Tulare Formation. The upper zone is a confined, semi-confined, and unconfined interval within the upper portion of the Tulare Formation. The shallow zone is an unconfined interval located within 25 feet of ground surface (DWR 2003a).

Groundwater Level Trends. Overall groundwater conditions indicate that groundwater flows in a northeasterly direction toward the San Joaquin River (Figure 3-10). Depth to groundwater ranges from near surface to 60 feet bgs, although shallower groundwater conditions exist in certain areas.

Between 1970 and 2000, the subbasin water level increased 2.2 feet, but with intervals of declines because of drought periods. Water levels peaked in 1985 at 7.5 feet above 1970s levels. Subsidence was significant in the area prior to 1970 (DWR 2003a).

Groundwater Yields. The specific yield of the subbasin is estimated at 11.8 percent, based on DWR's San Joaquin District estimate. The subbasin's estimated storage capacity is 30.4 million ac-ft to a depth of 300 feet and 81.8 million ac-ft to the groundwater base. Bulletin 118 – 2003 Update (DWR 2003a) indicates that irrigation wells in the subbasin yield between 20 and 5,000 gpm, and average between 800 and 2,000 gpm. Production depth for municipal and irrigation wells ranges from 50 to 800 feet, and averages between 400 to 600 feet.

Groundwater Quality. TDS ranges from 200 to 1,750 mg/L, with average readings from 44 public wells between 700 and 1,000 mg/L. Shallow and saline groundwater is widely present within 10 feet of the surface, and localized areas of high iron, fluoride, nitrate, and boron also occur.

Groundwater Budget Components. DWR estimated groundwater demand based on land and water use data from the 1990 normalized year. The data were later incorporated into a water budget spreadsheet to estimate applied water demands, agricultural groundwater pumping, urban pumping demand, and other water use data. Natural recharge was estimated to be 8,000 ac-ft. Artificial recharge was not determined, but applied water recharge is approximately 74,000 ac-ft. Annual urban and agricultural groundwater extractions were estimated at 17,000 ac-ft and 491,000 ac-ft, respectively. Subsurface outflow was not determined (DWR 2003a). Other groundwater budget components estimates were not included in Bulletin 118 (DWR 2003a). A general, regional groundwater budget analysis was also estimated by Reclamation in 1999 (Reclamation et al. 1999).

3.2.2 Merced Subbasin

The East Bear Creek and Merced Units of the San Luis NWR Complex are within the Merced Subbasin. The primary sources of information used for the Merced Subbasin summary are subbasin descriptions prepared for the Bulletin 118 – 2003 Update (DWR 2003a).

3.2.2.1 Basin Boundaries and Hydrology

The Merced Subbasin consists of approximately 750 square miles located south of the Merced River between the San Joaquin River and the Sierra Nevada foothills (Figure 3-11). The southern boundary extends along the Madera-Merced County line and the southern edge of the Le Grand–Athlone WD, and the northern edge of the Chowchilla WD and El Nido ID.

3.2.2.2 Hydrogeology

Aquifers within the Merced Subbasin include the Ione, the Valley Springs, and the Mehrten Formations. The Mehrten Formation is a significant aquifer in the subbasin. The Corcoran Clay is located in the western half of the basin at a depth between 50 to 200 feet bgs. Unconsolidated deposits consist of continental, lacustrine and marsh (including the Corcoran Clay), alluvium, and flood-basin deposits. The consolidated deposits and older alluvium yield the largest volume of water. The marsh deposits and flood-basin deposits, including the Corcoran Clay, yield little water to wells (DWR 2003a).

Groundwater occurs under confined, semi-confined, and unconfined conditions in the subbasin. An unconfined zone occurs in unconsolidated deposits above and to the east of the Corcoran Clay. In the western part of the subbasin, clay lenses result in semi-confined conditions. Below the Corcoran Clay, groundwater conditions are confined.

Groundwater Level Trends. Within the subbasin, the directional groundwater flow is mainly to the west-southwest. Two cones of depression are located south of the City of Merced (Figure 3-12). Groundwater levels have declined in some areas because of increased local pumping. The 2001 Merced Water Supply Plan Update identified several local aquifer depressions resulting from increased groundwater pumping (CH2M HILL 2001). Water-level changes were also monitored by DWR. Subbasin water levels have declined approximately 30 feet between 1970 and 2000, 15 feet of which occurred between 1970 and 1978. Sharp declines also occurred in the early 1990s, but water levels rebounded slightly (5 to 10 feet) between 1996 and 2000. Declines are more significant in the eastern area of the subbasin (DWR 2003a). DWR is not specific regarding the magnitude of these declines.

The SWRCB received contradictory evidence regarding the existence of overdraft conditions in the Merced Subbasin. Although some testimony by the SJRGA indicates that the groundwater subbasin is in relative balance, DWR Bulletin 160-93 and the Merced Groundwater Basin Groundwater Management Plan indicate that a condition of local groundwater overdraft exists and is worsening (SWRCB 2000).

Groundwater Yields. The estimated specific yield of the subbasin is about 9 percent, based on an estimate from DWR and cooperators. Based on this figure, the subbasin's total storage capacity was estimated to be 21.1 million ac-ft to a depth of 300 feet and 47.6 million ac-ft to the base of the freshwater aquifer (DWR 2003a).

Bulletin 118 – 2003 Update (DWR 2003a) estimates irrigation and municipal well yields to range from 100 to 4,500 gpm, with an average between 1,500 and 1,900 gpm. Well depths range from 100 to 800 feet bgs for irrigation and municipal wells.

Groundwater Quality. TDS values in the subbasin typically range from 200 to 400 mg/L. DHS reports TDS values between 150 to 424 mg/L and averaging 231 mg/L (DWR 2003a). EC values, measured in ten subbasin wells, range from 260 to 410 μmhos/cm. Localized areas of high iron, nitrate, and chloride are also found in this subbasin (DWR 2003a).

Groundwater Budget Components. Groundwater demand was estimated by DWR based on the 1990 normalized year and on data from land and water use. Subsequent analysis by DWR yielded estimates for agricultural groundwater pumping, urban pumping demand, and other extraction data. Natural recharge was estimated at 47,000 ac-ft, but values for artificial recharge and subsurface inflow were not determined. Applied water recharge is approximately 243,000 ac-ft. Urban and agricultural extractions are 54,000 ac-ft and 492,000 ac-ft per year, respectively (DWR 2003a). Other groundwater budget components estimates were not included in Bulletin 118 (DWR 2003a). A general, regional groundwater budget analysis was also conducted by Reclamation in 1999 (Reclamation et al. 1999).

3.2.3 Kings Subbasin

The Kings Subbasin includes the Mendota WA. The primary source of information used for the Kings Subbasin summary is the summary prepared for Bulletin 118 – 2003 Update (DWR 2003a).

3.2.3.1 Basin Boundaries and Hydrology

The Kings Subbasin is bounded by the San Joaquin River to the north; the Delta-Mendota Subbasin and the Westlands WD to the east; and the Empire–West Side ID, Laguna ID, Kings County WD, and the southern fork of the Kings River to the south (Figure 3-13). The eastern boundary is formed by the Sierra Nevada foothills.

3.2.3.2 Hydrogeology

The aquifer in the basin consists of unconsolidated continental Tertiary and Quaternary deposits. These deposits yield a small amount of water to wells in the southeastern part of the subbasin. The Quaternary deposits in particular, subdivided into alluvium, lacustrine, marsh and floodplain, crop out over most of the basin and yield more than 90 percent of well water. The older alluvium consists of mixed clay, silt, sand, and gravel, and yields a significant amount of water. The lacustrine and marsh deposits in the subsurface are virtually impermeable and in some cases restrict the vertical movement of water. The Corcoran Clay (also known as E-clay) underlies the western third of the subbasin and divides the groundwater into unconfined and confined systems. The Corcoran Clay is located at depths ranging from 250 to 550 feet. The A-clay and C-clay lie above the Corcoran Clay but are less extensive. Younger alluvium ranges in permeability from highly permeable beneath river channels to poorly permeable beneath floodplains. Few wells derive water from flood basin deposits, which are exposed along the Fresno Slough (DWR 2003a).

Groundwater Level Trends. Groundwater flows generally to the southwest. Cones of depression are centered in the Fresno urban area and in the Raisin City WD. Groundwater recharge typically occurs from river and stream seepage, and irrigation percolation.

During the 1987–92 drought, water levels declined 10 to 40 feet below those recorded in the late 1970s. In the western subbasin, water levels fell between 10 and 50 feet during the early 1990s (DWR 2003a). Groundwater levels in the west and southeast areas are recovering to 1980s levels (Figure 3-14).

Groundwater Yields. The specific yield of the subbasin is estimated by DWR to be 11.3 percent. Well yields range from 20 to 3,000 gpm and average between 500 and 1,500 gpm. Production depths of completed irrigation and municipal wells range from 100 to 500 feet bgs and average 210 feet (DWR 2003a).

Groundwater Quality. Bicarbonate water is the primary groundwater characterization in the subbasin. Calcium, magnesium, and sodium are present. Sodium concentration is highest in the western part of the subbasin. TDS levels in the region are typically between 40 and 570 mg/L, averaging 240 mg/L in 414 samples from water supply wells. DBCP and nitrates have been found in groundwater along the eastern side of the subbasin. High fluoride, boron, and sodium levels have also been found in localized areas (DWR 2003a).

Groundwater Budget Components. A detailed groundwater budget was not available for this subbasin from DWR's Bulletin 118. A general, regional groundwater budget analysis was performed by Reclamation in 1999 (Reclamation et al. 1999).

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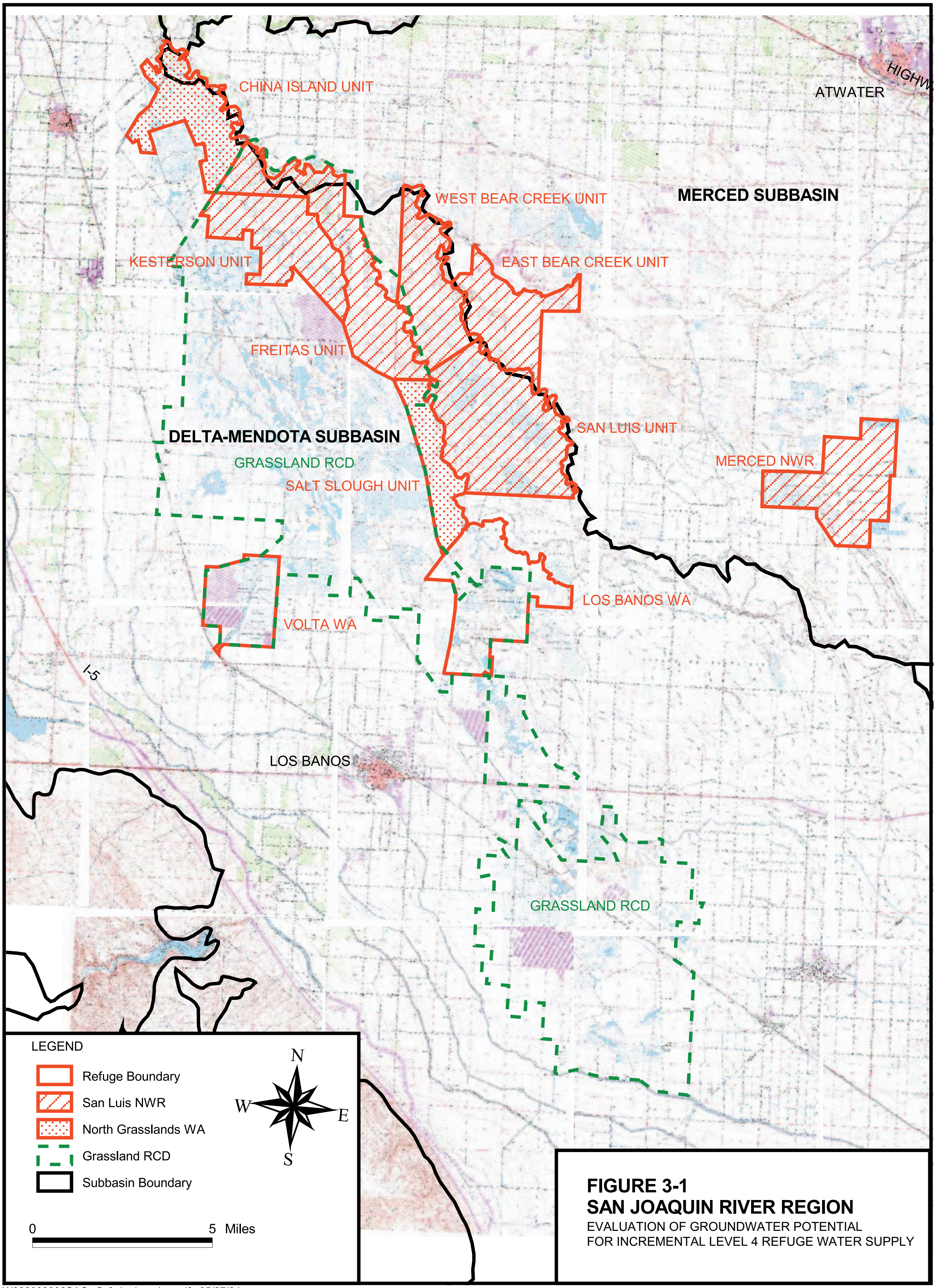

FIGURE 3-1
SAN JOAQUIN RIVER REGION
EVALUATION OF GROUNDWATER POTENTIAL
FOR INCREMENTAL LEVEL 4 REFUGE WATER SUPPLY

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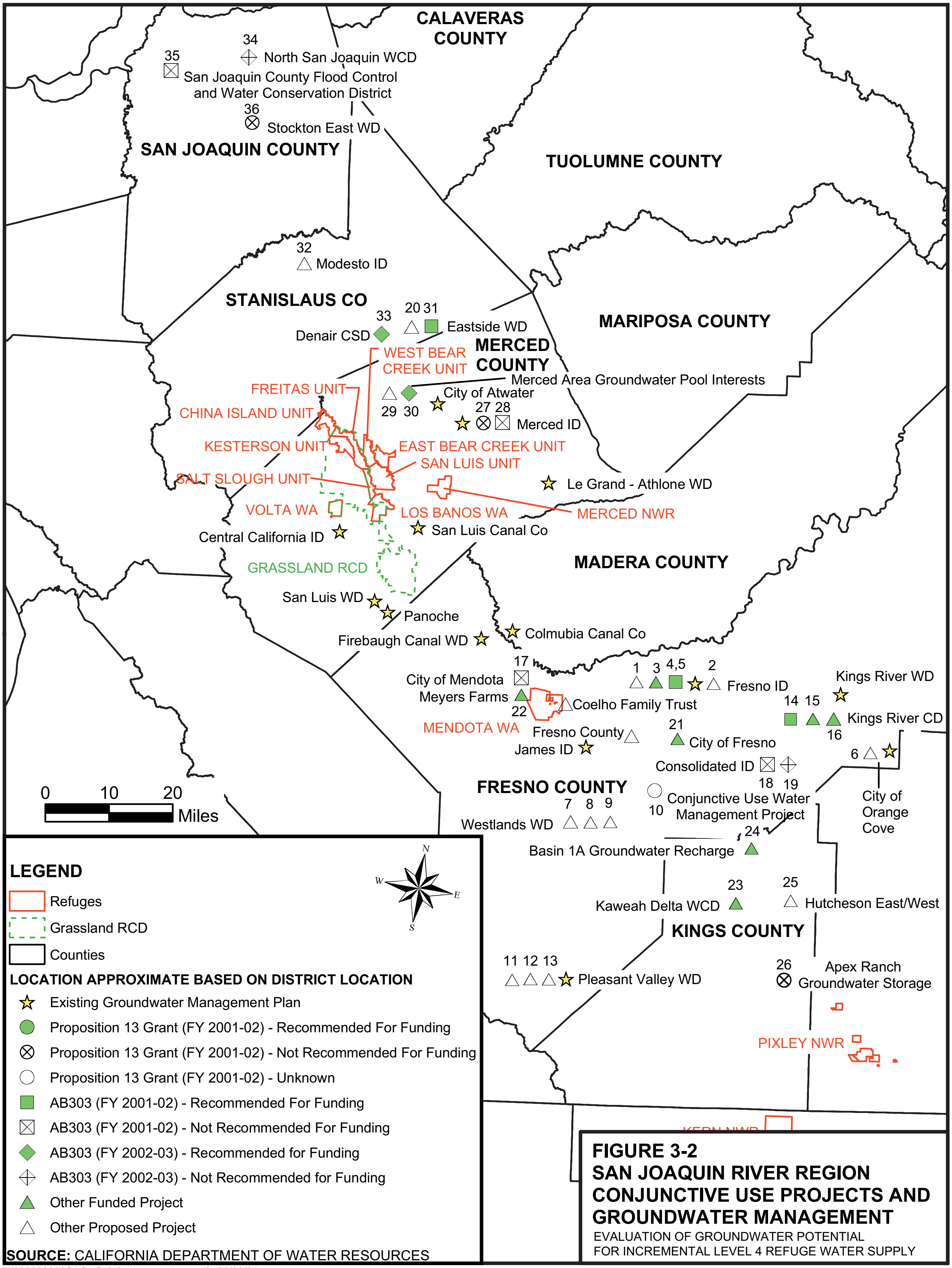

SOURCE: CALIFORNIA DEPARTMENT OF WATER RESOURCES

FIGURE 3-2
SAN JOAQUIN RIVER REGION CONJUNCTIVE USE PROJECTS AND GROUNDWATER MANAGEMENT
EVALUATION OF GROUNDWATER POTENTIAL FOR INCREMENTAL LEVEL 4 REFUGE WATER SUPPLY

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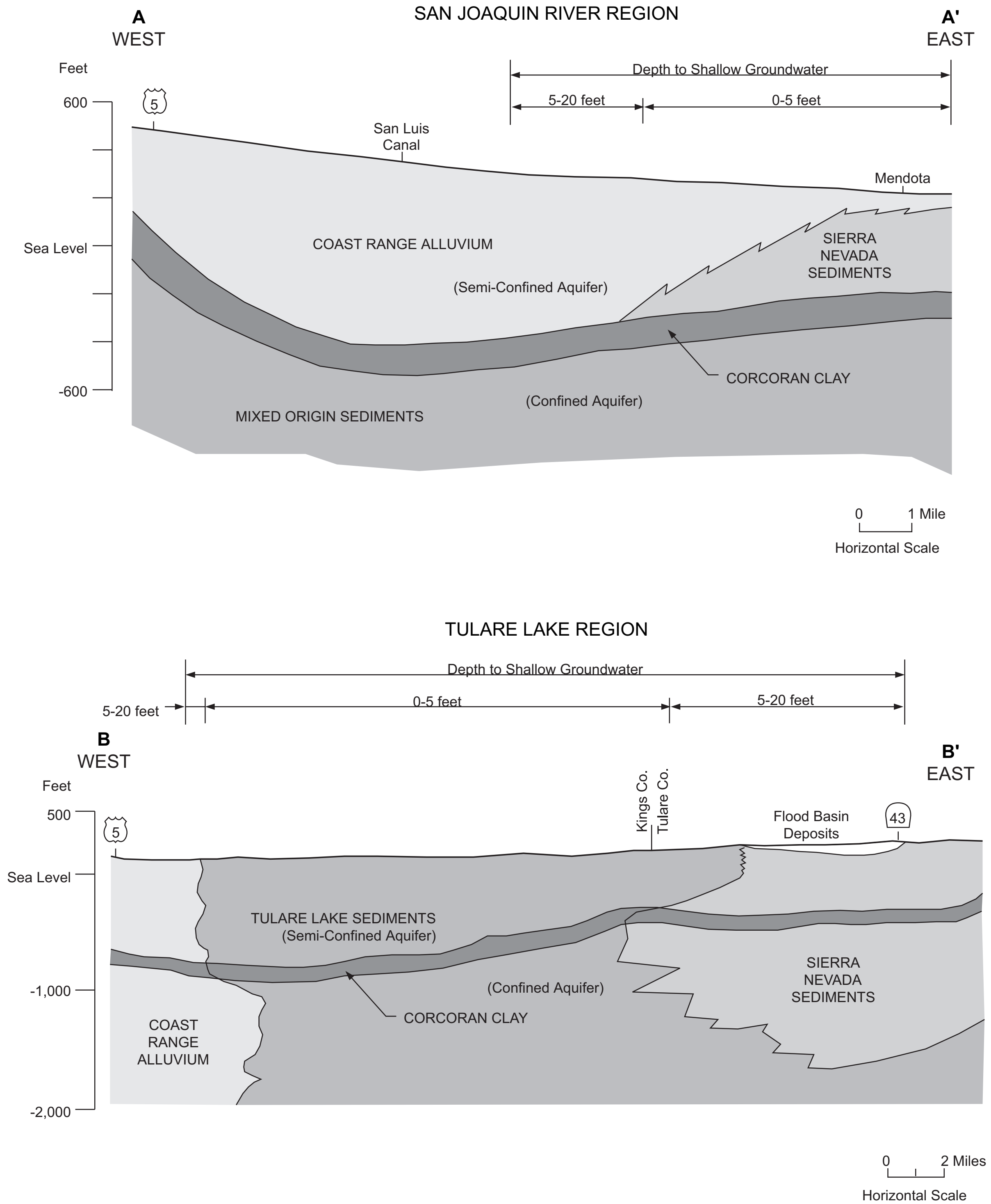
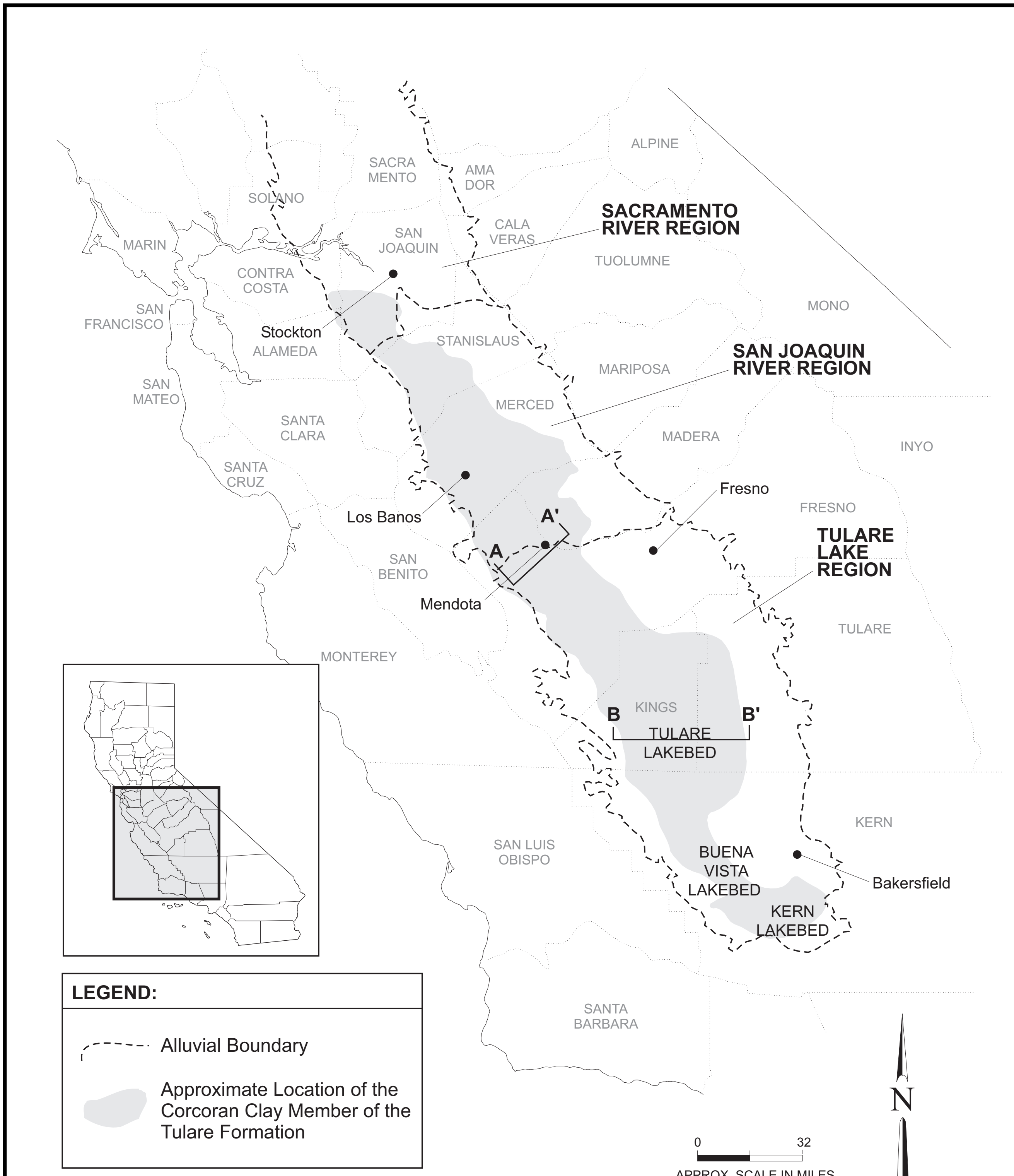


SOURCE: Reclamation 1999

FIGURE 3-3
GENERALIZED HYDROGEOLOGICAL CROSS-SECTIONS IN THE SAN JOAQUIN RIVER AND TULARE LAKE REGIONS (LOCATIONS SHOWN IN FIGURE 3-4)

EVALUATION OF GROUNDWATER POTENTIAL
FOR INCREMENTAL LEVEL 4 REFUGE WATER SUPPLY



SOURCE: Reclamation 1999

FIGURE 3-4
APPROXIMATE BOUNDARY OF THE CORCORAN CLAY MEMBER
EVALUATION OF GROUNDWATER POTENTIAL
FOR INCREMENTAL LEVEL 4 REFUGE WATER SUPPLY

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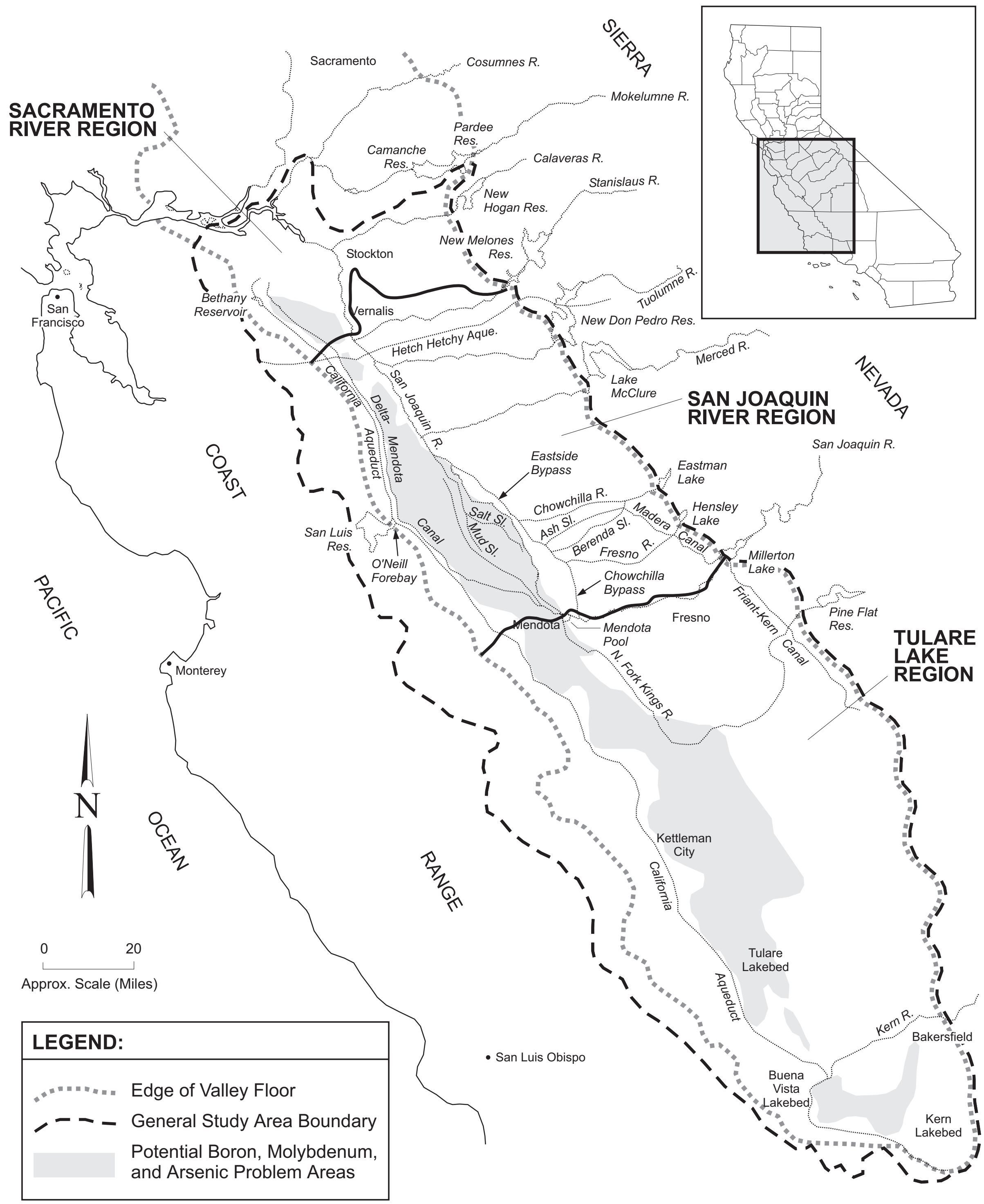

SOURCE: Reclamation 1999

FIGURE 3-5
POTENTIAL BORON, MOLYBDENUM, AND ARSENIC PROBLEM AREAS IN SHALLOW GROUNDWATER OF THE SAN JOAQUIN VALLEY
EVALUATION OF GROUNDWATER POTENTIAL
FOR INCREMENTAL LEVEL 4 REFUGE WATER SUPPLY

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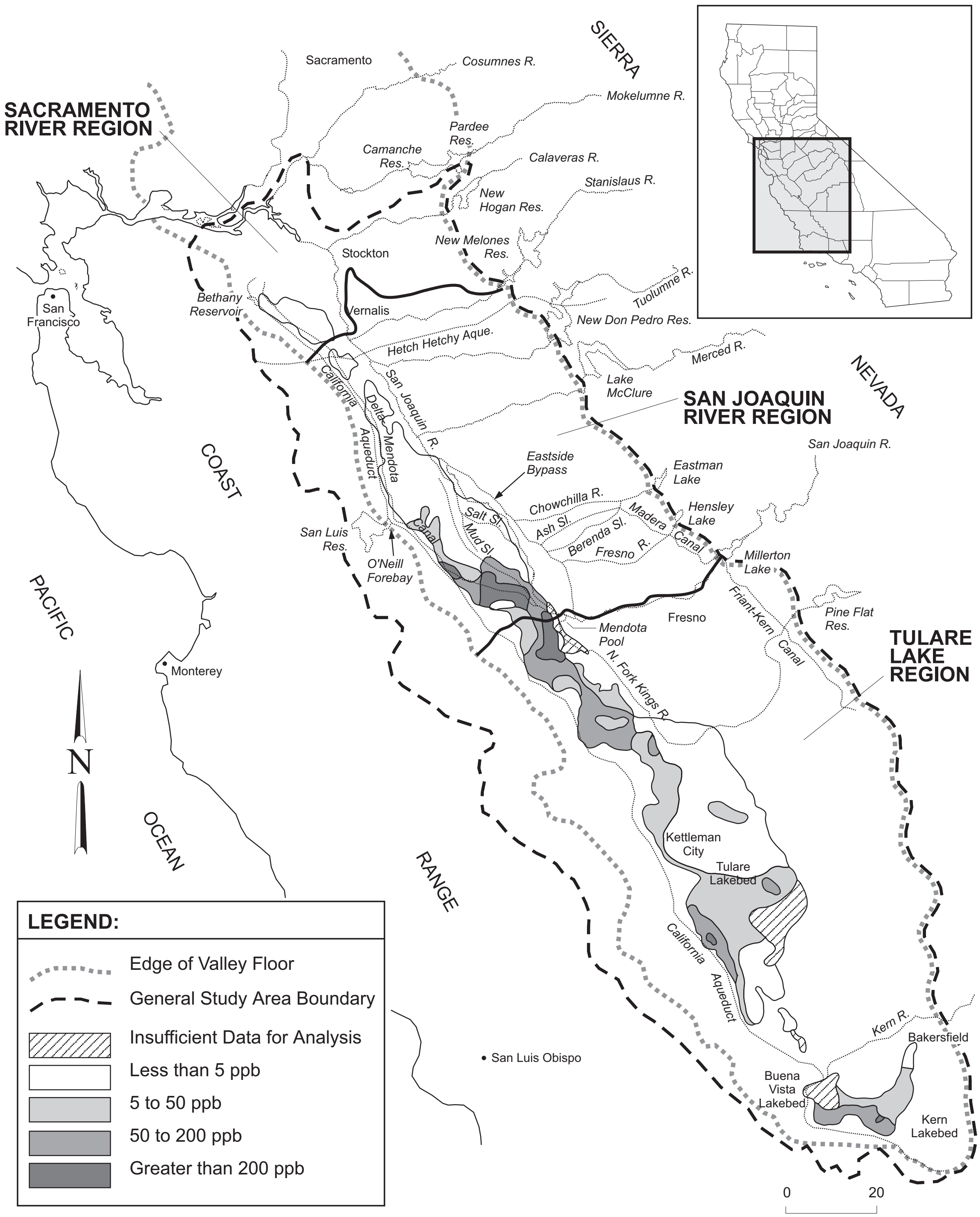

SOURCE: Reclamation 1999

FIGURE 3-6
SELENIUM CONCENTRATIONS IN SHALLOW GROUNDWATER, SAMPLED BETWEEN 1984 AND 1989
EVALUATION OF GROUNDWATER POTENTIAL
FOR INCREMENTAL LEVEL 4 REFUGE WATER SUPPLY

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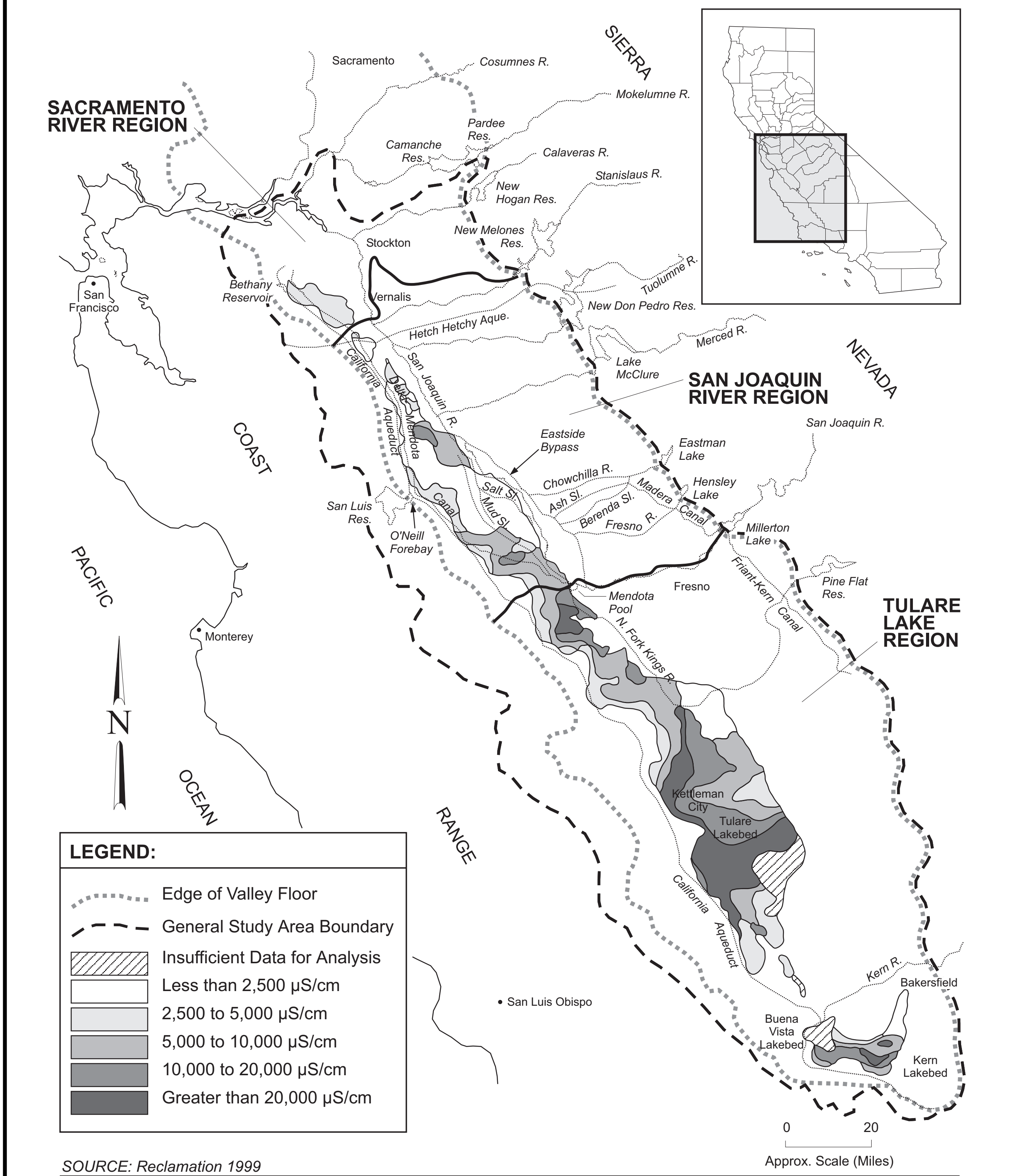

FIGURE 3-7
SALINITY IN SHALLOW GROUNDWATER, SAMPLED BETWEEN 1984 AND 1989
EVALUATION OF GROUNDWATER POTENTIAL
FOR INCREMENTAL LEVEL 4 REFUGE WATER SUPPLY

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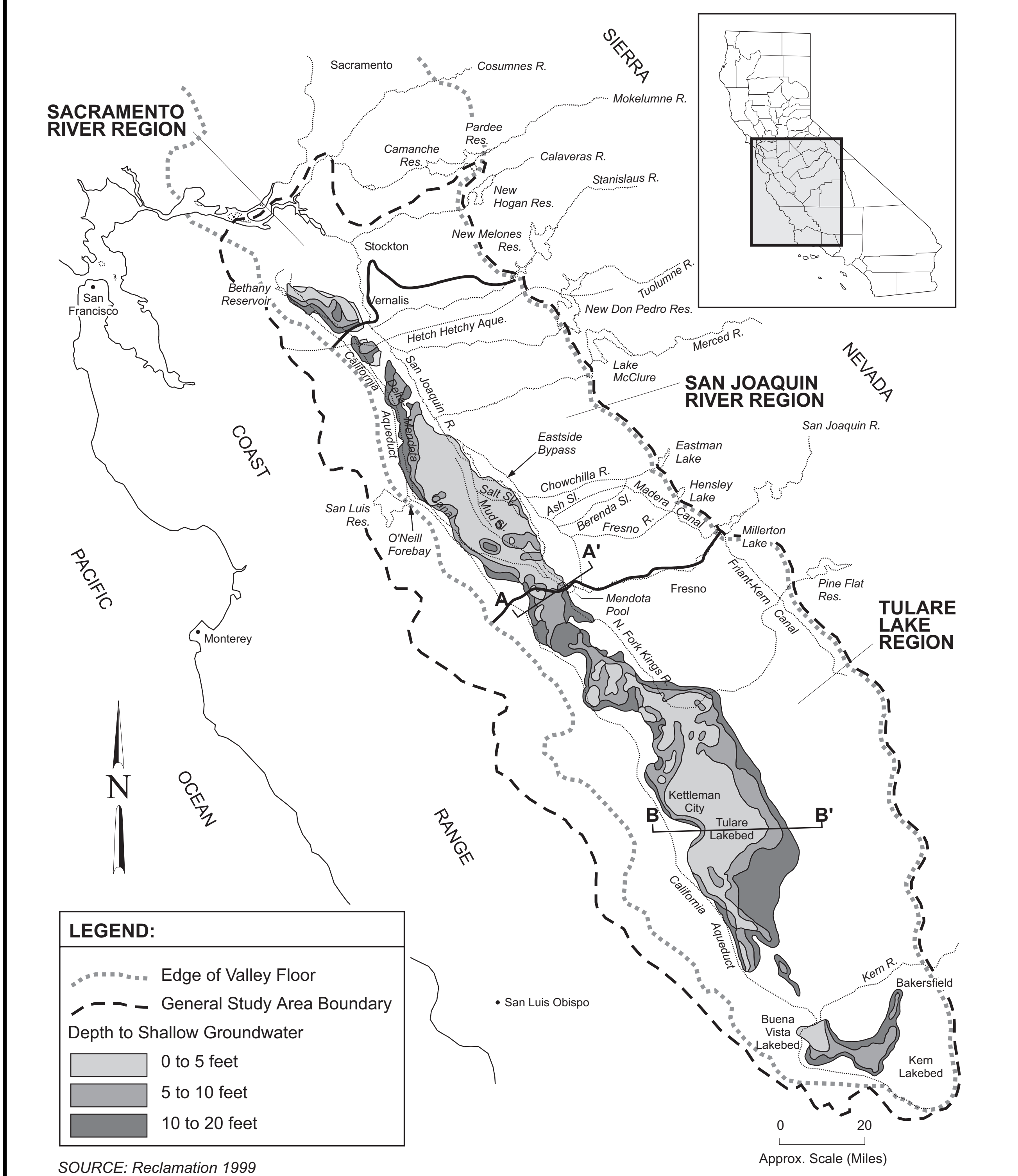

SOURCE: Reclamation 1999

FIGURE 3-8
AREAS OF SHALLOW GROUNDWATER, 1987
EVALUATION OF GROUNDWATER POTENTIAL
FOR INCREMENTAL LEVEL 4 REFUGE WATER SUPPLY

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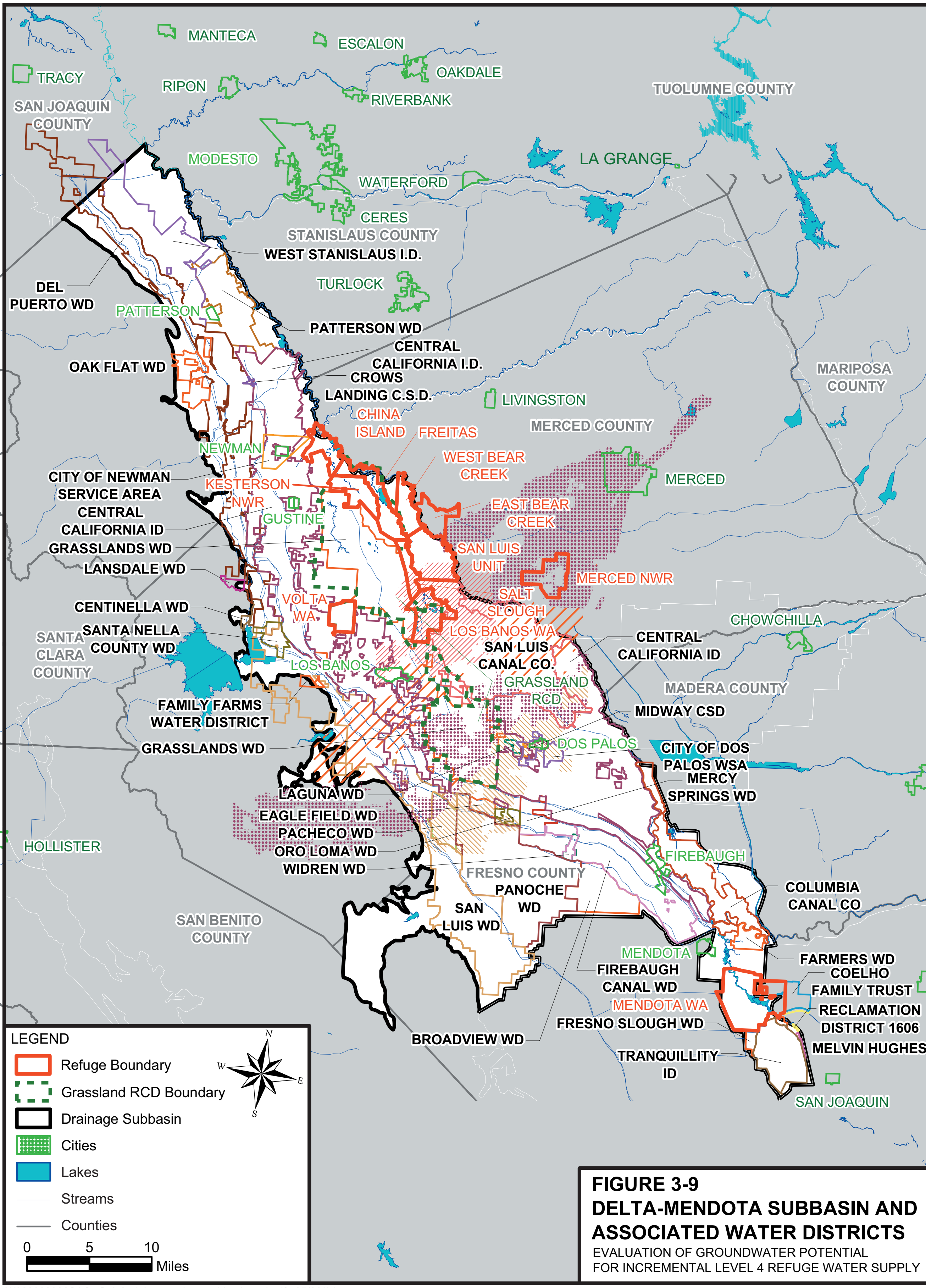

FIGURE 3-9
DELTA-MENDOTA SUBBASIN AND ASSOCIATED WATER DISTRICTS
EVALUATION OF GROUNDWATER POTENTIAL FOR INCREMENTAL LEVEL 4 REFUGE WATER SUPPLY

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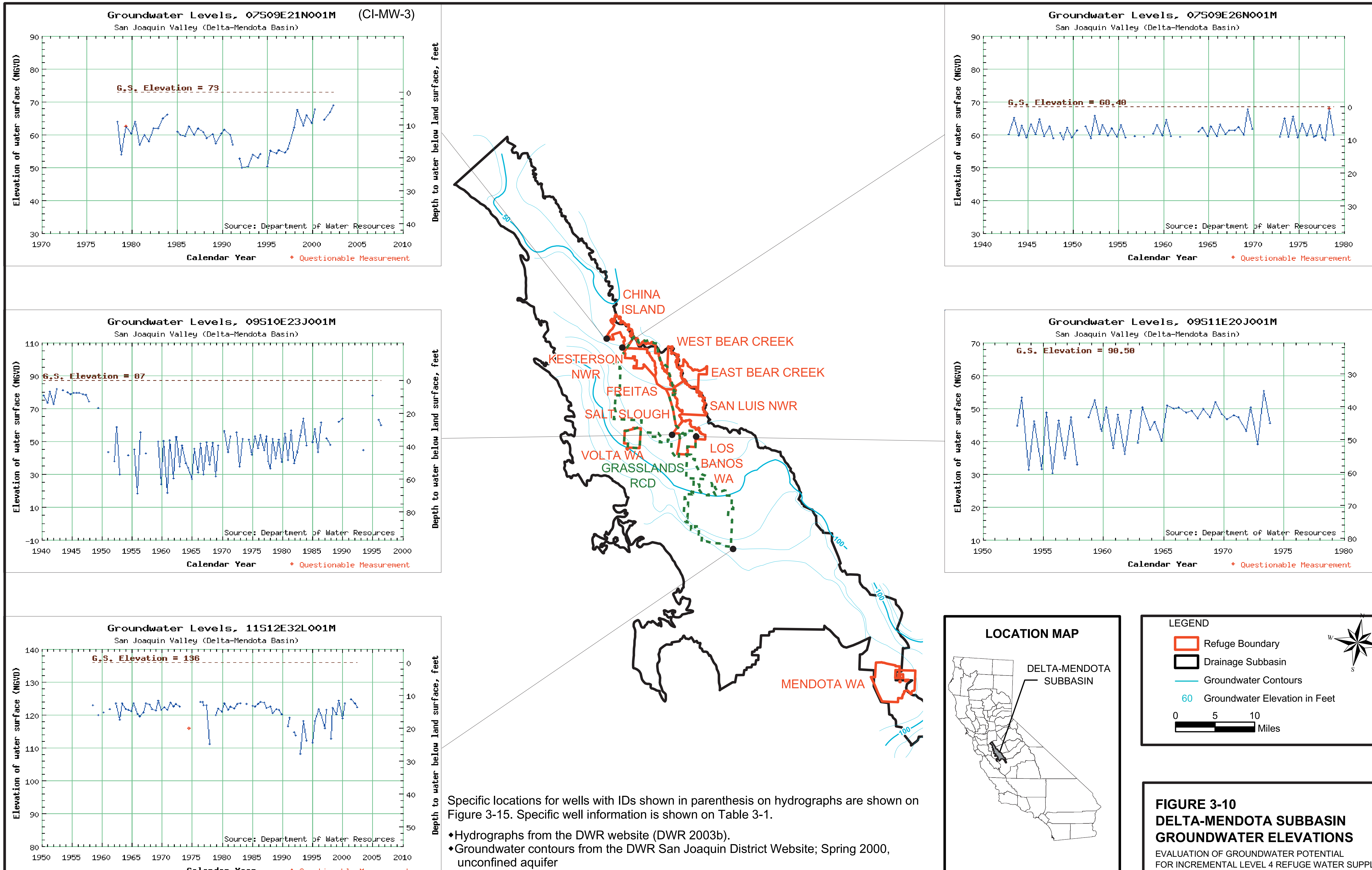

Specific locations for wells with IDs shown in parenthesis on hydrographs are shown on Figure 3-15. Specific well information is shown on Table 3-1.

- Hydrographs from the DWR website (DWR 2003b).
- Groundwater contours from the DWR San Joaquin District Website; Spring 2000, unconfined aquifer

FIGURE 3-10
DELTA-MENDOTA SUBBASIN GROUNDWATER ELEVATIONS
EVALUATION OF GROUNDWATER POTENTIAL FOR INCREMENTAL LEVEL 4 REFUGE WATER SUPPLY

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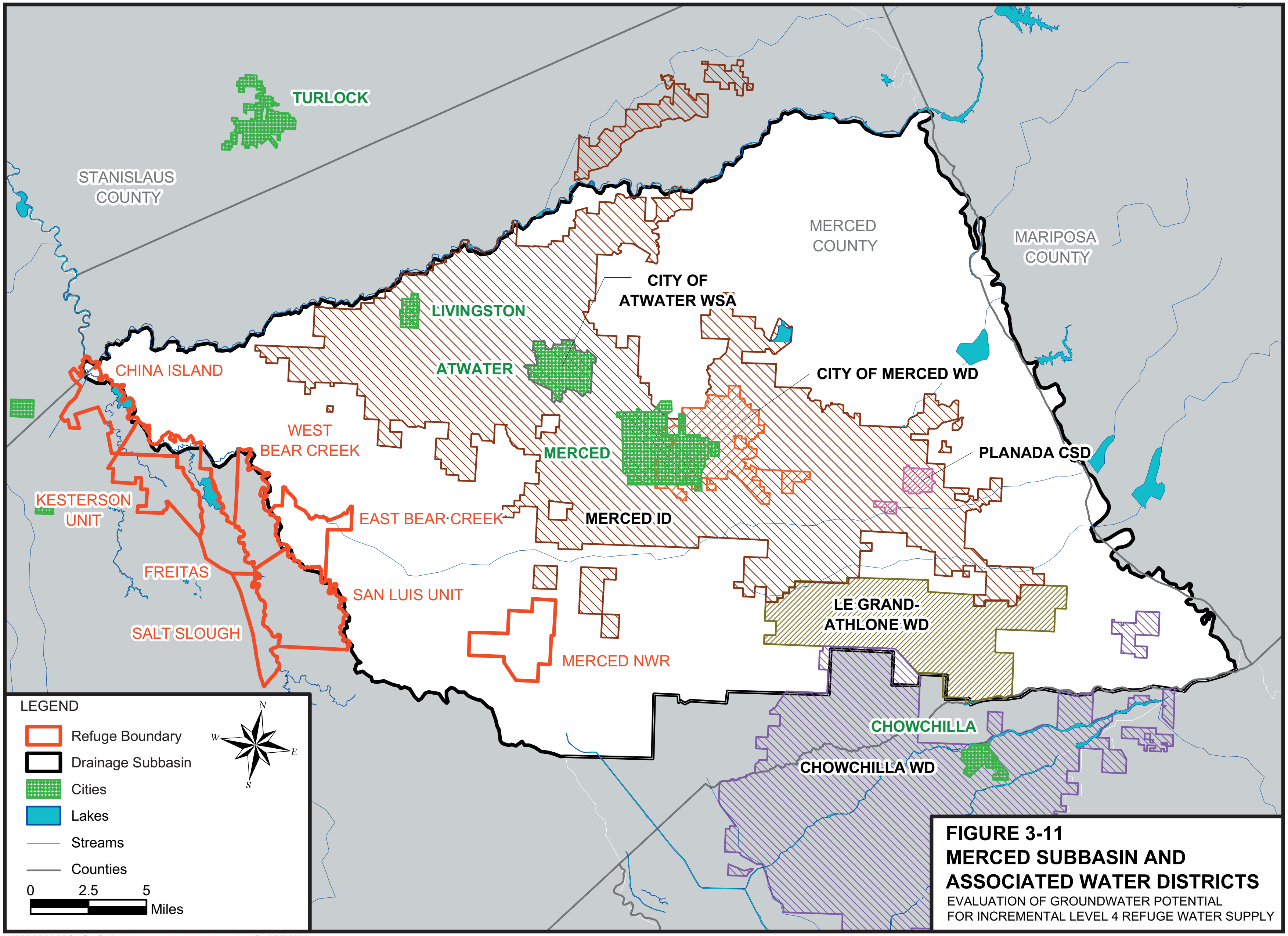

FIGURE 3-11
MERCED SUBBASIN AND ASSOCIATED WATER DISTRICTS
EVALUATION OF GROUNDWATER POTENTIAL
FOR INCREMENTAL LEVEL 4 REFUGE WATER SUPPLY

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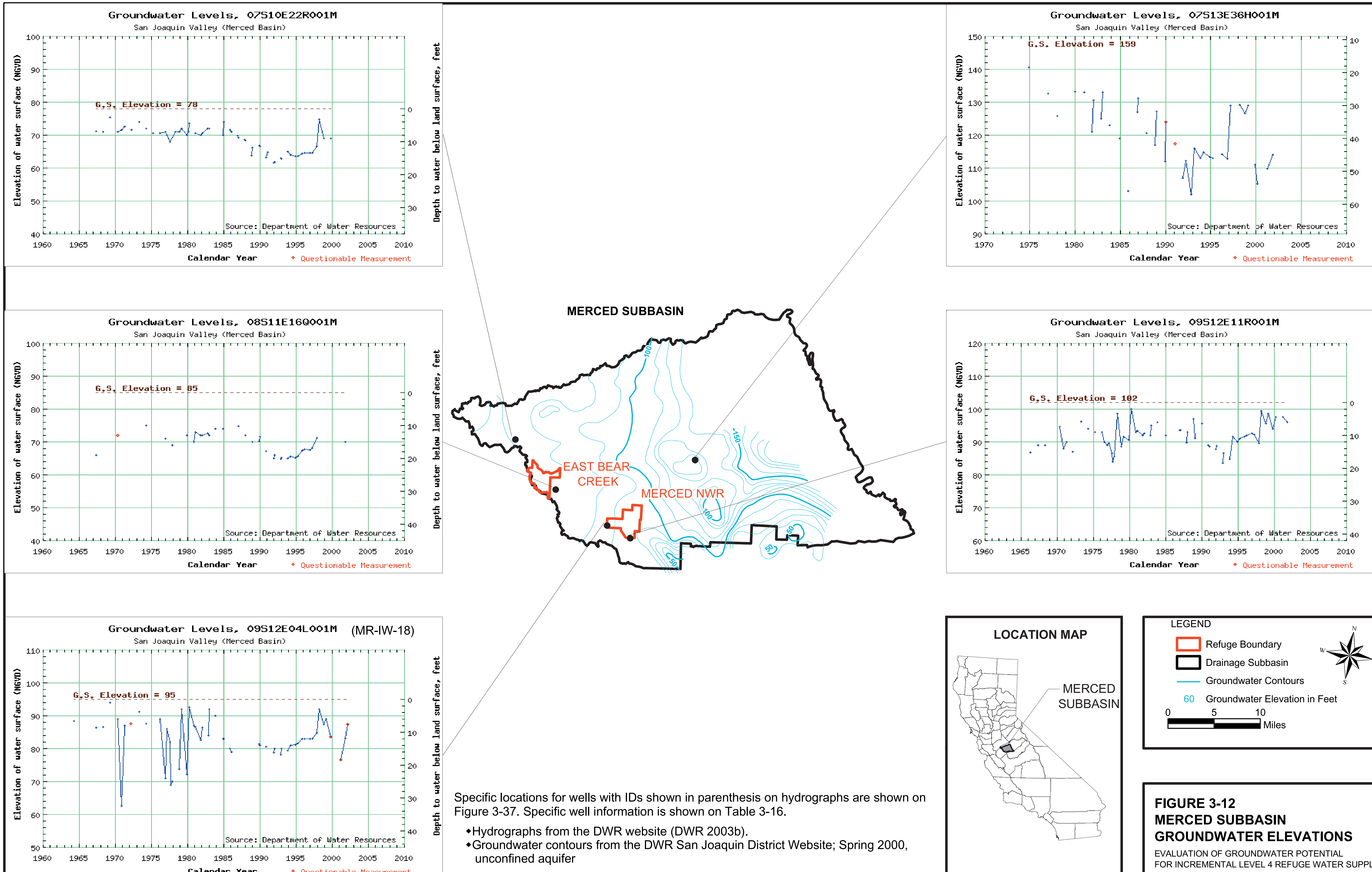

Specific locations for wells with IDs shown in parenthesis on hydrographs are shown on Figure 3-37. Specific well information is shown on Table 3-16.

- Hydrographs from the DWR website (DWR 2003b).
- Groundwater contours from the DWR San Joaquin District Website; Spring 2000, unconfined aquifer

FIGURE 3-12
MERCED SUBBASIN
GROUNDWATER ELEVATIONS
EVALUATION OF GROUNDWATER POTENTIAL
FOR INCREMENTAL LEVEL 4 REFUGE WATER SUPPLY

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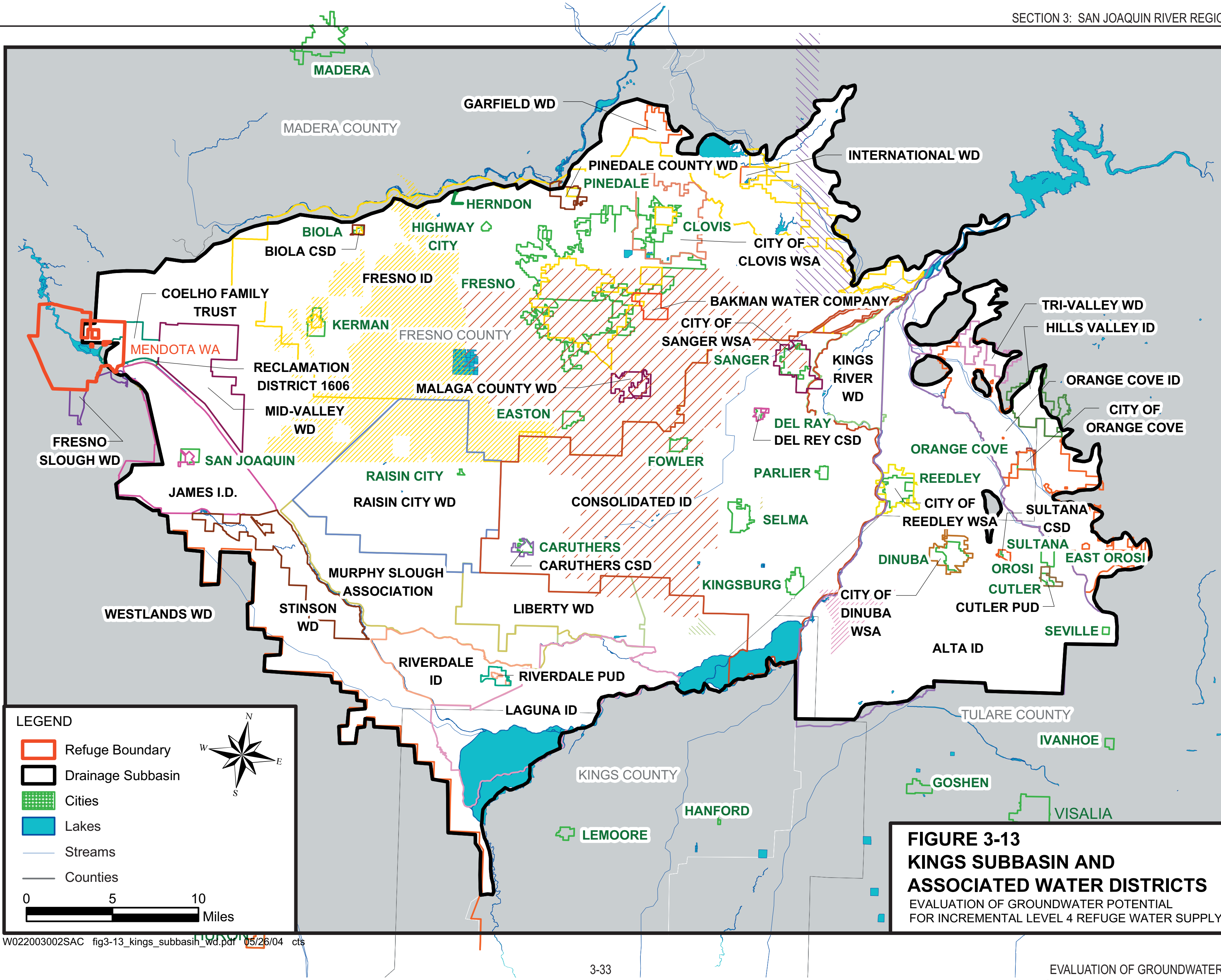

FIGURE 3-13
KINGS SUBBASIN AND ASSOCIATED WATER DISTRICTS
EVALUATION OF GROUNDWATER POTENTIAL
FOR INCREMENTAL LEVEL 4 REFUGE WATER SUPPLY

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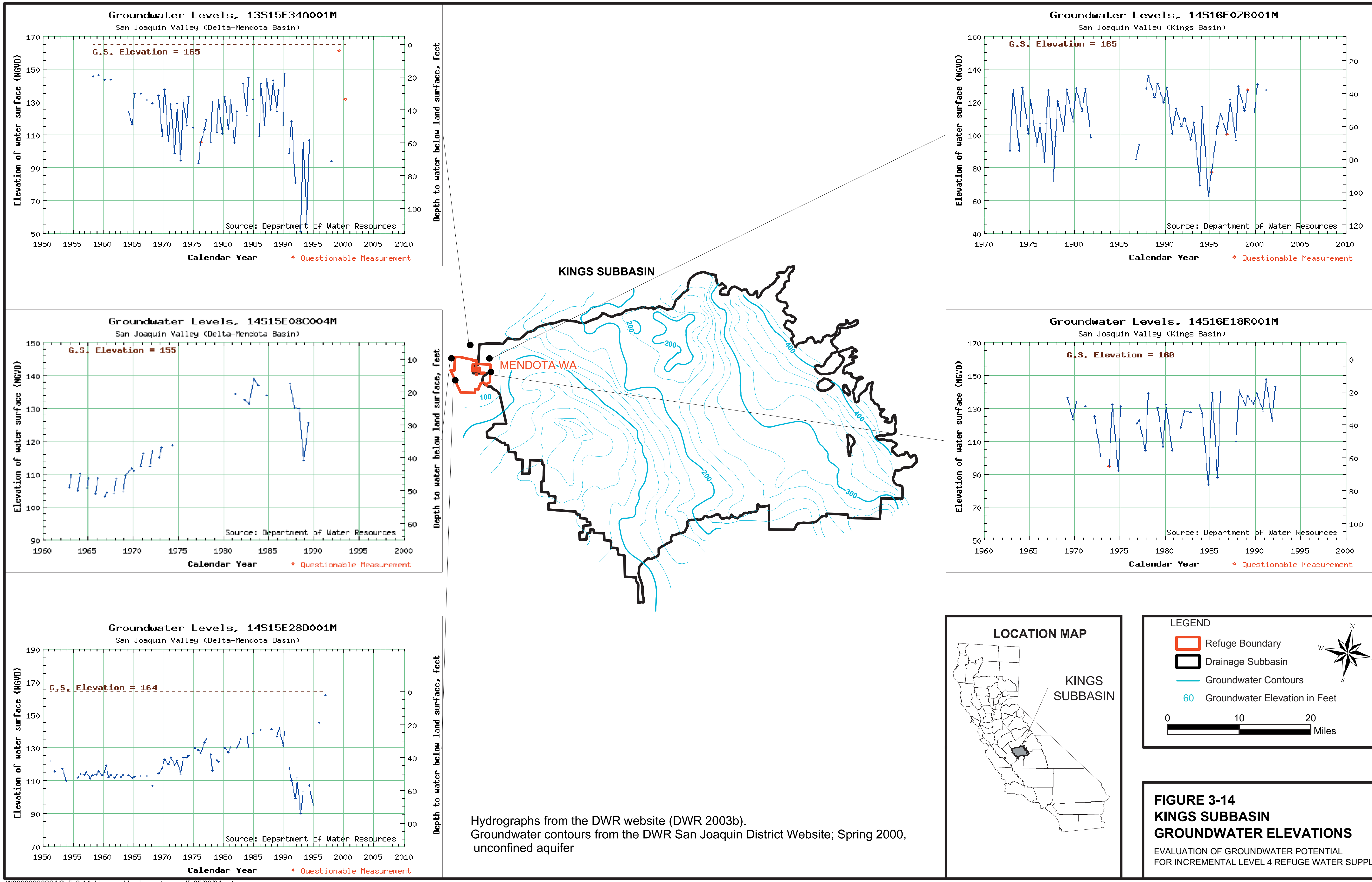

FIGURE 3-14
KINGS SUBBASIN GROUNDWATER ELEVATIONS
EVALUATION OF GROUNDWATER POTENTIAL FOR INCREMENTAL LEVEL 4 REFUGE WATER SUPPLY

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3.3 China Island Unit Refuge Assessment (North Grasslands Wildlife Area)

County: Merced
Basin / Subbasin: San Joaquin Valley Groundwater Basin / Delta-Mendota Subbasin
Level 2 / Incremental Level 4: 6,967ac-ft / 3,483 ac-ft
2003 Acreage: 3,315
CVP Water Conveyor: Central California ID
Water District Service Area: None
Applicable Groundwater Management Regulations: None

The China Island Unit consists of 3,315 acres located in Merced County (Figure 3-15). The unit borders the San Joaquin River and is located southwest of the confluence with the Merced River. Part of the western border of the refuge follows the Newman Wasteway and Hills Ferry Road.

3.3.1 Hydrogeologic Assessment

3.3.1.1 Habitat Goals, Land Management, and Surface Features

The primary goals of this refuge include endangered and threatened species conservation, migratory bird refuge and breeding, natural resource protection, recreation, wildlife management, and wetlands conservation (Reclamation 2002).

The China Island Unit is managed within the North Grasslands WA. It was acquired by the state of California in 1990. The majority of the area is maintained as irrigated pasture and natural grasslands, and smaller areas are maintained as woodland/riparian habitat. The unit was used as a cattle ranch before being acquired by the state, and restoration has focused on increasing wetland and riparian habitat ideal for many forms of wildlife such as wetland-dependent wildlife species (Reclamation et al. 2001b).

Mud Slough flows through the refuge, and the San Joaquin River forms the eastern boundary of the unit. Few roads are within the refuge boundaries. Several large, private duck clubs are located just south of the refuge's southern boundary.

3.3.1.2 Identified Water Supply Contract Quantities

Figure 3-16 shows the Level 2 and Level 4 water contract quantities and the actual water deliveries to the refuge from 1999 through 2001. Total annual Level 2 water demand is approximately 6,967 ac-ft, and the Level 4 increment is approximately 3,483 ac-ft, totaling 10,450 ac-ft (Reclamation et al. 2001b). Groundwater use is not shown because quantities and period of use are not known.

3.3.1.3 Surface Water Supplies and Infrastructure

CVP water is generally supplied to the refuge from the Delta-Mendota Canal via the Central California ID Community Ditch to the J-Lateral. The J-Lateral consists of an open canal from the Wasteway until just past the "Deep Well" (CI-IW-5). Downstream of the Deep Well, the J-Lateral is constructed of pressurized PVC piping. The J-Lateral can service most of the refuge area and terminates into a 5-acre refuge pond. Two recirculation pumps also service the area. One is adjacent to Well No. 1 (CI-IW-1) near the Newman Wasteway. The other is located at the parking lot near the center of the refuge, south of Well No. 3 (CI-IW-3). This recirculation pump picks up water near the slough channel, into which the wetlands drain. Three PVC pipelines distribute water throughout the refuge. An additional fourth pipeline is planned (Refuge staff 2002).

Well No. 1 and the 75-hp Deep Well (CI-IW-5) deliver groundwater into the J-Lateral. Water from Wells No. 2 and 4 is distributed within the refuge via the in-ground PVC piping. No domestic supply is drawn from these wells.

Conveyance facilities are available to deliver full Level 4 water to the refuge.

The quality of the delivered water is considered to be adequate for refuge irrigation, according to refuge staff. The water used has caused no perceptible ill effects on plants or wildlife.

3.3.1.4 Groundwater Supplies and Infrastructure

Historically, groundwater has been important in providing water to the refuge, particularly during droughts. Wells were used exclusively for refuge water supply until the J-Lateral was completed, which gave the refuge the capacity to fully use CVPIA supplies. Well failure, water quality, and budget constraints have led to greater reliance on surface water supplies, according to refuge staff. Groundwater is not used for domestic supply on the refuge. Well and test well locations are shown on Figure 3-15. Table 3-1 summarizes on-refuge well information.

Test Wells. In 1992, DFG drilled five test wells to evaluate water quality and potential irrigation well sites. Irrigation wells were installed at three of these locations: one near the center of the refuge and two near State Route (SR) 140.

Irrigation and Production Wells. Five groundwater wells located along the northwestern side of the refuge were present when the state obtained the refuge land. [2] Prior to the land transfer, the wells provided the land's only water supply (Reclamation et al. 1989). Four of six irrigation wells now present at China Island are considered active. The four active wells are three of the original refuge wells (Wells No. 1, 2, and 4, referred to as CI-IW-01, CI-IW-02, and CI-IW-04 on Figure 3-15) and the "75-hp Deep Well" (shown as CI-IW-05 on Figure 3-15). Well No. 3 (CI-IW-03), one of the original refuge wells, produced water with high EC (up to 6,000 μmhos/cm) and has been abandoned per county code because of poor water quality. One of the wells installed by DFG in 1992, the Highway 140 Well, is nonfunctional because the casing has failed (Refuge staff 2002). Reasons for well failure have not been established, but one possibility is that corrosive soil conditions or extremely poor-quality shallow groundwater (as indicated by high salinity measured in wells up to 20 feet deep) degraded the well casing.

The China Island wells are not metered. The only record of well operations are PG&E invoices, which record electrical meter use. Refuge staff indicate that Well No. 1 (CI-IW-01, Figure 3-17) is used most often, and Wells No. 2 (CI-IW-02) and 4 (CI-IW-03) are used less

[2] The San Joaquin Basin Action Plan/Kesterson Mitigation Plan indicates that there were five wells on the Freitas-McPike (Wolfen) property, as the China Island Unit was previously known. However, only four wells from prior to the transfer are currently on the property. No records or information are available for the fifth well.

often. Well No. 1 (CI-IW-01) has the best water quality (EC approximately 1,000 µmhos/cm) and the highest output. The operation frequency of the 75-hp Deep Well (CI-IW-05) is unknown. No pumped groundwater is considered part of the refuge's CVPIA contractual quantity.

Groundwater Quality Data. Groundwater quality tests have identified elevated concentrations of boron above and below the Corcoran Clay and selenium above the Corcoran Clay. Both of these constituents exceeded Freshwater Aquatic Life Standards and/or Agricultural Water Quality Goals. The 1992 Reclamation test wells were sampled at discrete intervals above and below the Corcoran Clay. Boron concentrations in samples collected from the test wells ranged from 0.3 to 8.2 mg/L. The only samples where boron was below 1 mg/L were collected from TW-1 (CI-TW-01), located at the west side of the refuge. Selenium concentrations above the Corcoran Clay ranges between 5 and 26 µg/L, as observed at TW-2 (CI-TW-02) and TW-3 (CI-TW-03). Table 3-2 summarizes the water quality data collected by Reclamation from the test wells (Zaffran 1994).

Significant variation in EC readings were observed at the refuge. Above the Corcoran Clay, EC values range from 700 to 17,200 µmhos/cm, with the higher values detected in the eastern portion of the refuge. The two groundwater samples collected from the westernmost test well, TW-1 (CI-TW-01), had EC values of 700 and 1,400 µmhos/cm. Below the clay, EC values ranged from 1,500 to 2,700 µmhos/cm. No samples were collected from TW-1 below the clay (Zaffran 1994). Most EC measurements exceeded the Freshwater Aquatic Life Standards for salinity.

3.3.1.5 Local Groundwater Use

Groundwater is used throughout the region to supply agricultural irrigation, private duck clubs, and domestic use. The community of Gustine uses groundwater for municipal supply (USEPA 2003). Domestic wells are located within 1 mile east of the refuge (DWR well logs on file).

3.3.1.6 Refuge Soil and Aquifer Conditions

The China Island Unit consists mainly of four soil types: Dospalos clay loam (partially drained) in the northern quarter of the refuge, Dospalos-Bolfar complex in the eastern quarter, Britto clay loam (leveled) in the west, and Agnal clay loam mainly in the southern quarter. The permeability of these soils is slow because the clay content is high. Available water capacity varies, but is typically high. A seasonally high water table rises within 1 foot of the surface from October through March, and the land is subject to periods of ponding between December and March. Confining surface soil is several inches thick (USDA 1990).

Between 1 and 2 feet of subsidence has occurred near the China Island Unit (USDA 1990). Future subsidence may be possible if groundwater use substantially increases.

Groundwater levels in and around the refuge range from near ground surface to 20 feet bgs. Based on DWR water-level data, seasonal variation appears to result in a slight groundwater level fluctuation between 2 and 5 feet (DWR 2003b). Water levels in the subbasin have increased approximately 2.2 feet since 1970 (DWR 2003a).

3.3.1.7 Operational Issues and Data Needs

Incremental Level 4 water is subject to wide fluctuations in cost and variable spot-market availability. If water is available, it would be necessary to convey Incremental Level 4 water through the Delta. A more stable source of Incremental Level 4 water both in terms of cost and reliability would be beneficial to refuge water supply management. Approximately 33 percent of the refuge's water supply is Incremental Level 4 water.

The following data gaps were identified during the completion of this study:

- Thorough assessment of all refuge wells to determine well conditions.
- Confirmation of refuge groundwater quality conditions at different locations and at several different depths below ground surface, both above and below the Corcoran Clay. In particular, verify EC, boron, selenium, and molybdenum concentrations in groundwater to determine potential for deleterious effects on wildlife.
- Local aquifer conditions, including quarterly water-level data both on- and off-refuge, and data to estimate local aquifer properties.
- Aquifer parameters, such as hydraulic conductivity and thickness.
- Groundwater pumping records and schedules, both on and immediately surrounding the refuge.

Relative to the other refuges in this study, it was estimated that a "medium" level of data collection is required at the China Island Unit prior to recommending specific groundwater development projects.

3.3.1.8 Other Studies

Refuge staff indicated that an investigation of water conditions had been conducted as part of a study to determine if solar energy could be used to power water infrastructure at the refuge. Test Well #1 (CI-TW-01) was explored by Reclamation as part of the San Joaquin Basin Action Plan for installation of a proposed solar-powered well field. No other information is available for this investigation, but refuge staff had been told anecdotally that the water was good in the area and wells installed there could easily be linked to the J-Lateral. The area was generally identified as the southwestern-most portion of the refuge, near the Newman Wasteway.

Central California ID has conducted extensive summaries and investigations for groundwater use and quality within its boundaries (San Joaquin River Exchange Contractors 1997; Central California ID 1997). The northern area of the study included areas near the Cities of Gustine and Newman, which both use groundwater for potable supply. High salinity groundwater is present northeast of Gustine, likely due to historic evaporation of shallow groundwater. Sampling of the upper aquifer near Gustine has indicated high nitrate, boron, chloride, and TDS concentrations (Central California ID 1997). Northeast of the City of Newman, groundwater has been highly saline, and iron and nitrate have also been of concern (Central California ID 1997). Specific concentrations were not provided in the report.

3.3.2 Criteria Evaluation Summary

The China Island Unit received total Hydrogeologic Scores of +2 for Direct Use of groundwater and zero for On-Refuge Conjunctive Use, based on criteria matrix evaluation. Table 3-3 shows the criteria matrix specific to this refuge. The matrix includes a score for each criterion and a corresponding reasoning for the score given.

This refuge may be suited to increased groundwater use because of its past successful use of groundwater to contribute to refuge water needs. Water quality has not been fully evaluated; however, previous testing has shown that high levels of salinity, boron, and selenium may exist at sampling levels above the Corcoran Clay, particularly in the north and east of the refuge. On-refuge conjunctive use projects have limited potential. Although the hydraulic conductivity of the subsurface aquifer is supportive of groundwater storage, subbasin water levels have increased, and little groundwater storage capacity is available. Soil conditions at this location are also not conducive to recharge basins.

Support and limitations to increased groundwater development are summarized below.

3.3.2.1 Support for Groundwater Development

- Groundwater has been used in the past to meet a significant percentage of water demand.
- There are six total wells on the refuge property. Four irrigation wells are currently active.
- The refuge IDS includes the J-Lateral and other PVC pipelines, which allow surface water and groundwater to be distributed throughout the refuge. The refuge also borders the Newman Wasteway, which could enable transport of water to and from the refuge land if capacity is available in the canal.
- Surface water is delivered reliably to the refuge and is therefore available for blending with groundwater.
- It is necessary to convey Incremental Level 4 water through the Delta to serve the refuge.
- The cost of local water is high relative to the other refuges in the study. Cost and reliability is subject to spot-market variability.

3.3.2.2 Limitations to Groundwater Development

- Domestic wells are located within 1 mile of the refuge property. The nearby town of Gustine is also using groundwater for municipal supplies.
- Clay surface soils primarily have low permeability and are probably not conducive to construction of recharge basins.
- Aquifer storage is not available. Current and historic groundwater levels are approximately equivalent.
- Poor groundwater quality has hindered groundwater use. It is probable that corrosive soil conditions or extremely poor quality shallow groundwater degraded the well

casing, causing well failure. Alternative well construction and/or materials could be considered.

- Freshwater Aquatic Life Standards and/or Agricultural Water Quality Goals have been exceeded for boron, EC, and selenium in some areas of the refuge

3.3.3 Recommended Data Acquisition Activities

The following activities are recommended for further evaluation of the potential for additional groundwater use and/or groundwater storage at China Island:

- Install well meters at all active, unmetered refuge wells; monitor water levels quarterly; and collect routine water quality samples from active wells to develop a database of groundwater use and conditions at refuges where groundwater is used. Maintain collected data in a format supportable and usable by the refuge and refuge managing agencies.
- Video-log each well that existed when the refuge lands were obtained. This will provide information on well screen intervals, condition of well screens and casings, and well depths. It may also provide information regarding why Well No. 3 (CI-IW-03) has such poor water quality. For example, the well casing could have a hole in the area with poor water quality, or the well-screen interval could be significantly different from the other wells.
- Install and test one or two test holes to below the Corcoran Clay in the southwestern portion of the refuge to investigate water quality and aquifer conditions.
- If initial test well indications are favorable, install at least one monitoring well nest (two to three monitoring wells installed at the same location but screened in different intervals) to assess groundwater quality variability among the different aquifers. Consider teaming with the USGS National Water Quality Assessment Program (NAWQA), which may install monitoring wells as part of its program in areas where current water data are limited.
- Evaluate existing groundwater pumping conditions.

3.3.4 Potential Projects

3.3.4.1 Direct Use

This refuge may be suited to increased groundwater use. Although groundwater has been used at China Island, the wells deteriorated, most likely a result of well casing corrosion caused by adverse shallow groundwater conditions. Therefore, replacement of existing nonfunctional wells with double-cased wells constructed with corrosion-resistant casing could be an option.

The southern area of the refuge could also be investigated for future groundwater development by verifying water quality, aquifer conditions, and groundwater yields in the area by drilling one or two test holes. If test results are positive, existing wells could be rehabilitated or replaced to supplement Incremental Level 4 water supplies on the refuge.

3.3.4.2 On-Refuge Conjunctive Use

The subbasin summary for the Bulletin 118 – 2003 Update (DWR 2003) indicates that terrace deposits in the Delta-Mendota Subbasin have potential as groundwater recharge sites. It has not been determined that terrace deposits exist at the China Island Unit. Existing water quality data from the refuge indicates that shallow groundwater is of very low quality and local and regional groundwater levels are shallow. Therefore, groundwater recharge with recharge basins would probably be of low benefit.

Water quality and water-level data specific to the deeper aquifer units at the refuge is insufficient to determine whether there is potential for groundwater storage within them. If both water quality and aquifer conditions are conducive to development of a groundwater banking project, water could be diverted from the Newman Wasteway—possibly during the winter when water demands are low—and banked. That water could then be conveyed to other refuges when needed.

3.3.4.3 Off-Refuge Conjunctive Use

China Island is not in the sphere of influence of any groundwater management plan or ordinance.

At this time, no off-refuge conjunctive use projects have been identified for potential partnership.

TABLE 3-1
China Island Unit Well Information[a]
Evaluation of Groundwater Potential for Incremenal Level 4 Refuge Water Supply

GIS Well Number[b]	Common Well Name	Well Status[c]	2002 Yield (ac-ft)	Year Installed	Depth (ft)	Screen Interval (bgs)	Well Output (gpm)	Well Log?	Water Quality Data?	Comments
CI-TW-01	TH 1	Nonfunctional		1992	255	80–185[d]		Y	Y	Tested intervals: 80–100 and 165–185
CI-TW-02	TH 2	Unknown		1992	570	60–550[d]	3,007	Y	Y	Tested intervals: 60–84, 126–147, 336–357, 525–550
CI-TW-03	TH 3	Unknown		1992	560	80–437[d]	2,244	Y	Y	Tested intervals: 80–100, 207–227, 312–332, 417–437
CI-TW-04	TH 4	Unknown		1992	535	40–521[d]	2,244	Y	Y	Tested intervals: 40–60, 164–184, 312–332, 501–521
CI-TW-05	TH 5	Destroyed		1992	530	84–440[d]	763–1,077	Y	Y	Tested intervals: 84–105, 189–210, 294–315, 421–440
CI-IW-01	China Island Well 1	Active		Prior to 1990	350		2,244–2,693	N	N	Used most often. Best water quality, lowest EC, highest output; hooked into J-Lateral.
CI-IW-02	China Island Well 2	Active		Prior to 1990	350		1,346	N	N	Used second most. Not hooked into J-Lateral.
CI-IW-03	China Island Well 3	Destroyed		Prior to 1990	350			N	N	Not used because of poor water quality (high EC). Destroyed in 1997.
CI-IW-04	China Island Well 4	Active		Prior to 1990	355		898–1,346	N	N	Used least of wells 1, 2, and 4. Not hooked into J-Lateral.
CI-IW-05	75-hp deep well	Active		1992	565		1,346–1,795	Y	N	Contribution to water supply is unknown. Directly hooked into J-Lateral.
CI-IW-06		Nonfunctional						N	N	
CI-MW-01	21DCBD	Unknown						N	N	
CI-MW-02	21DBCB	Unknown						N	N	
CI-MW-03	21CACB	Unknown						N	N	
CI-MW-04	21ABBD	Unknown			23.8	7.5–23.8		N	Y	
CI-MW-05	22BAAD	Unknown			24.8	5.6–24.9		N	Y	
CI-MW-06	10CACB	Unknown			24.7	12.7–23.7		N	Y	
CI-MW-07	10DDCD	Unknown			22.9	11.1–22.9		N	Y	

TABLE 3-1
China Island Unit Well Information[a]
Evaluation of Groundwater Potential for Incremenal Level 4 Refuge Water Supply

GIS Well Number[b]	Common Well Name	Well Status[c]	2002 Yield (ac-ft)	Year Installed	Depth (ft)	Screen Interval (bgs)	Well Output (gpm)	Well Log?	Water Quality Data?	Comments
CI-MW-08	15ADBC	Unknown			24.0	8.2–24.0		N	Y	
CI-MW-09	15CABD	Unknown			23.0	10.9–23.0		N	Y	
CI-MW-10	14CCAA	Unknown			24.6	13.7–24.6		N	Y	
CI-MW-11	14BBDA	Unknown			24.4	13.9–24.4		N	Y	
CI-MW-12	22AADD	Unknown			24.9	14.2–24.9		N	Y	
CI-MW-13	23AAAB	Unknown			21.8	10.6–21.8		N	Y	
CI-MW-14	23DAAD	Unknown			24.8	8.8–24.8		N	Y	
CI-MW-15	24CAAC	Unknown			24.6	10.8–24.6		N	Y	
CI-MW-16	25BCBB	Unknown			24.3	7.8–24.3		N	Y	
CI-MW-17	26DCDA	Unknown			24.7	12.6–24.7		N	Y	
CI-MW-18	OW-02-01	Active		2002	39.0	14.0–39.0		Y	N	Reclamation observation well
CI-MW-19	OW-02-02	Active		2002	38.7	16.0–36.0		Y	N	Reclamation observation well
CI-MW-20	OW-02-03	Active		2002	34.0	13.5–33.5		Y	N	Reclamation observation well
CI-MW-21	OW-02-04	Active		2002	33.0	12.0–32.0		Y	N	Reclamation observation well

Notes:

[a] Based on data compiled from well logs, test records, communication with refuge staff (2002), and other previous documentation. Well locations are shown on Figure 3-15. On-refuge wells only are included in this table, although the GIS includes known wells within 1 mile of the refuge.

[b] Well type is indicated by the middle two letters of the GIS well number: IW = irrigation well, DW = domestic well, MW = monitoring well, TW = test well, and UN = unknown.

[c] Designation refers to the physical well only, not water quality issues. Designations are: *active* (currently operated), *inactive* (capable of operating, but currently is not), *nonfunctional* (cannot operate in current physical state), *destroyed* (well has been lost, abandoned, or filled), or *unknown* (no information regarding status is available).

[d] See Comments for specific screened intervals within the range shown.

Blank fields indicate that no information is available.

TABLE 3-2
China Island Unit Water Quality Data (1992)[a]
Evaluation of Groundwater Potential for Incremental Level 4 Refuge Water Supply

GIS Well Number	Sampled Interval (feet)	EC (µmhos/cm)	Boron (mg/L)	Selenium (µg/L)	Molybdenum (mg/L)
CI-TW-01	80–100	1,400	0.5		
	165–185	700	0.3		
CI-TW-02	60–84	2,600	1.7	5	ND
	126–147	5,150	1.9	5	ND
	336–357	2,300	2	ND	ND
	525–550	2,700	2.6	ND	ND
CI-TW-03	80–100	10,700	4.2	26	ND
	207–227	14,000	6.8	12	ND
	312–332	2,060	2.6	ND	ND
	417–437	1,710	2.4	ND	ND
CI-TW-04	40–60	10,800	5.7	ND	
	164–184	16,800	8.2	ND	
	312–332	1,500	2.7	ND	
	501–521	1,900	3	ND	
CI-TW-05	84–105	16,300	7.6	ND	
	189–210	17,200	7.8	ND	
	294–315	1,700	2.5	ND	
	421–440	1,900	2.7	ND	
CI-MW-01					
CI-MW-02					
CI-MW-03					
CI-MW-04	7.5–23.8	16,000			
CI-MW-05	5.6–24.9	5,850			
CI-MW-06	12.7–23.7	5,690			
CI-MW-07	11.1–22.9	4,250			
CI-MW-08	8.2–24.0	8,240			
CI-MW-09	10.9–23.0	6,480			

TABLE 3-2
China Island Unit Water Quality Data (1992)[a]
Evaluation of Groundwater Potential for Incremental Level 4 Refuge Water Supply

GIS Well Number	Sampled Interval (feet)	EC (µmhos/cm)	Boron (mg/L)	Selenium (µg/L)	Molybdenum (mg/L)
CI-MW-10	13.7–24.6	2,570			
CI-MW-11	13.9–24.4	7,110			
CI-MW-12	14.2–24.9	8,090			
CI-MW-13	10.6–21.8	16,900			
CI-MW-14	8.8–24.8	3,310			
CI-MW-15	10.8–24.6	17,130			
CI-MW-16	7.8–24.3	13,270			
CI-MW-17	12.6–24.7	9,830			
CI-MW-18	14.0–39.0				
CI-MW-19	16.0–36.0				
CI-MW-20	13.5–33.5				
CI-MW-21	12.0–32.0				

Source: Test well and irrigation well data from Zaffran 1994; Monitoring well information from field notebook data (Oct 1992 test results) on file at refuge headquarters.

Notes:

a Test well data are based upon Reclamation test well sampling results.

Well locations are shown on Figure 3-15.
ND = not detected

TABLE 3-3
China Island Unit Evaluation
Evaluation of Groundwater Potential for Incremental Level 4 Refuge Water Supply

	Criteria	Scoring Scale	Appl.[b]	Score	Refuge Score Justification
Surface[a]	Do surface water bodies exist that could be affected by increased groundwater use?	+1 = no 0 = to some degree –1 = yes, surface water bodies could be affected	D,N	-1	The San Joaquin River, Mud Slough, and Newman Wasteway are near major wells. High pumping rates from shallow aquifers could affect these water bodies.
Water Supplies and Infrastructure	Has groundwater been used previously at the refuge for ponds or irrigation?	+1 = yes, used successfully to meet at least 20 percent of annual refuge water demands 0 = yes, used to meet less than 20 percent (or unknown) of annual refuge water demands. –1 = no, has not been used	D,N	+1	Groundwater has been used in the past to meet a significant percentage of water demand. However, well failure and water quality concerns have lead to decreased use of groundwater.
	Do wells exist on the refuge?	+1 = yes, active wells 0 = yes, inactive or nonfunctional wells –1 = yes, destroyed wells, or no wells exist on the refuge	D,N	+1	Four of six total irrigation wells are active on the refuge property.
	Does existing internal distribution system (IDS) support groundwater use?	+1 = water can move extensively around the refuge with existing IDS 0 = the IDS enables limited water movement within the refuge –1 = an IDS does not exist on the refuge or water flow relies exclusively on gravity	D,N	+1	The J-Lateral and other PVC pipelines service the area. Several existing wells are connected to these pipelines.
Local Groundwater Use	Is groundwater used for agriculture or duck clubs in the immediate vicinity of the refuge?	+1 = groundwater is not used; or groundwater is minimally used, but use is not constrained 0 = groundwater is used in the area –1 = groundwater is not used due to physical or environmental constraints or is extensively used in the vicinity	D,N	0	Groundwater is used in the area for agricultural irrigation and local duck clubs. Several large duck ponds are located immediately south of the refuge land.
	Does municipal or domestic supply exist near the refuge?	+1 = no known domestic or municipal wells are located within 1 mile of the refuge 0 = municipal or domestic wells are likely located within 1 mile of the refuge –1 = municipal or domestic wells are located within 1 mile of the refuge	D,N	-1	Domestic wells are located within 1 mile of the eastern refuge boundary. The community of Gustine is also using groundwater for municipal supplies.
Soil and Hydrogeology	Are at-surface soils conducive to groundwater recharge?	+1 = soils are sandy or are reported to percolate well 0 = soils are silty or are reported to have some infiltration –1 = soils are clayey or are reported to hold water well	N	-1	Soils are typically clay or clay loam, with slow permeability and high water capacity.
	Could recharge basins be developed if surface soils were removed?	+1 = confining soil less than 2 feet thick 0 = confining soil 5 to 7 feet thick –1 = confining soil greater than 7 feet thick	N	0	Confining surface soil is several inches thick.
	Has subsidence occurred at or in the immediate vicinity of the refuge?	+1 = no 0 = yes, less than 2 feet –1 = yes, more than 2 feet	D,N	0	Between 1 and 2 feet of subsidence has occurred near the China Island Unit.
	Does significant potential for subsidence exist if groundwater use is increased at the refuge?	+1 = minimal potential for subsidence 0 = some potential for subsidence –1 = significant potential for subsidence	D,N	0	Future subsidence is possible if groundwater use substantially increases.
	Is aquifer storage available in the subbasin?	+1 = yes, current water levels are greater than 30 feet lower than historic levels 0 = some, current water levels are between 10 and 30 feet lower than historic levels –1 = no	N	-1	Subbasin water levels have increased approximately 2.2 feet since 1970.

Notes:
a Surface Features
b Application to Approach: D = Direct Use, N = On-Refuge Conjunctive Use

continued on next page

TABLE 3-3
China Island Unit Evaluation
Evaluation of Groundwater Potential for Incremental Level 4 Refuge Water Supply

	Criteria	Scoring Scale	Appl.[b]	Score	Refuge Score Justification
Water Quality	Have groundwater quality conditions hindered groundwater use in the past?	+1 = no 0 = data are not available –1 = yes	D,N	-1	It is probable that corrosive soil conditions or extremely poor quality shallow groundwater degraded well casing, causing well failure. Refuge managers are also reluctant to use poor quality groundwater.
	Do adverse groundwater quality conditions exist in the subbasin?	+1 = no 0 = potential –1 = yes	D,N	-1	High levels of EC (>17,000 µmhos/cm), boron (>7.0 mg/L), and selenium (>0.02 mg/L) have been gauged at sampling levels above the Corcoran Clay, particularly in the north and east areas of the refuge.
	Is surface water available to enable blending of lower quality groundwater to meet proposed refuge standards?	+1 = yes 0 = during portions of the year –1 = no	D,N	+1	China Island had a reliable supply of surface water delivered in 2002 via the Delta Mendota Canal and Newman Wasteway.
	Do groundwater conditions exceed USEPA Freshwater Aquatic Life Standards or Agricultural Water Quality Goals for multiple parameters?	+1 = no 0 = yes, two parameters, or no water quality testing has been conducted –1 = yes, three or more parameters	D,N	-1	Aquatic Life Standards and Agricultural Water Quality Goals have been exceeded for boron, EC, and selenium.
	Is refuge land use management compatible with seasonally or annually variable water quality from different sources?	+1 = yes 0 = some potential compatibility problems may exist –1 = no	D,N	+1	Both groundwater and delivered water are currently used for wetland management.
	Does groundwater quality meet drinking-water standards (i.e., can it be used for refuge domestic supply)?	+1 = yes it is used, no treatment is necessary 0 = yes it is used, but some treatment is necessary for potable use; or it is not used for unknown reasons –1 = no, it is not used because of adverse water quality conditions	D	0	Groundwater is not used for domestic supply on the refuge.
Operational Issues/Constraints	Does a significant percentage of total refuge water supply consist of "Incremental Level 4" water?	+1 = yes, 54% to 79% of total water supply is Incremental Level 4 0 = somewhat, 27% to 53% of total water supply is Incremental Level 4 –1 = minor, 0% to 26% of total water supply is Incremental Level 4	D,N	0	Approximately 33 percent of the water supply for the China Island Unit consists of Incremental Level 4 water.
	Is the cost of local water high or low relative to the other refuges in this study?	+1 = costs may fluctuate highly or are subject to spot-market variability or price spikes –1 = costs are relatively stable and subjectivity to spot-market variability is low	D,N	+1	Incremental Level 4 water made available to the China Island Unit is subject to wide fluctuations in cost and variable spot-market availability.
	Is it necessary to convey Incremental Level 4 water through the Delta for refuge supply?	+1 = yes, Incremental Level 4 water must be conveyed through the Delta –1 = no, conveyance of Incremental Level 4 water through the Delta is not necessary	D,N	+1	Incremental Level 4 water must be conveyed through the Delta given current water supply sources.
Data Needs	Are there significant data needs to address prior to groundwater development?	+1 = no, data needs regarding refuge groundwater conditions are minor 0 = somewhat, some data are required prior to increasing groundwater development –1 = yes, significant data must be collected as there is little or no existing data	D,N	0	Some data are required prior to increasing groundwater development.
			Total Direct Use Score =	**+2**	
			Total On-Refuge Conjunctive Use Score =	**0**	

Notes:
a Surface Features

b Application to Approach: D = Direct Use, N = On-Refuge Conjunctive Use

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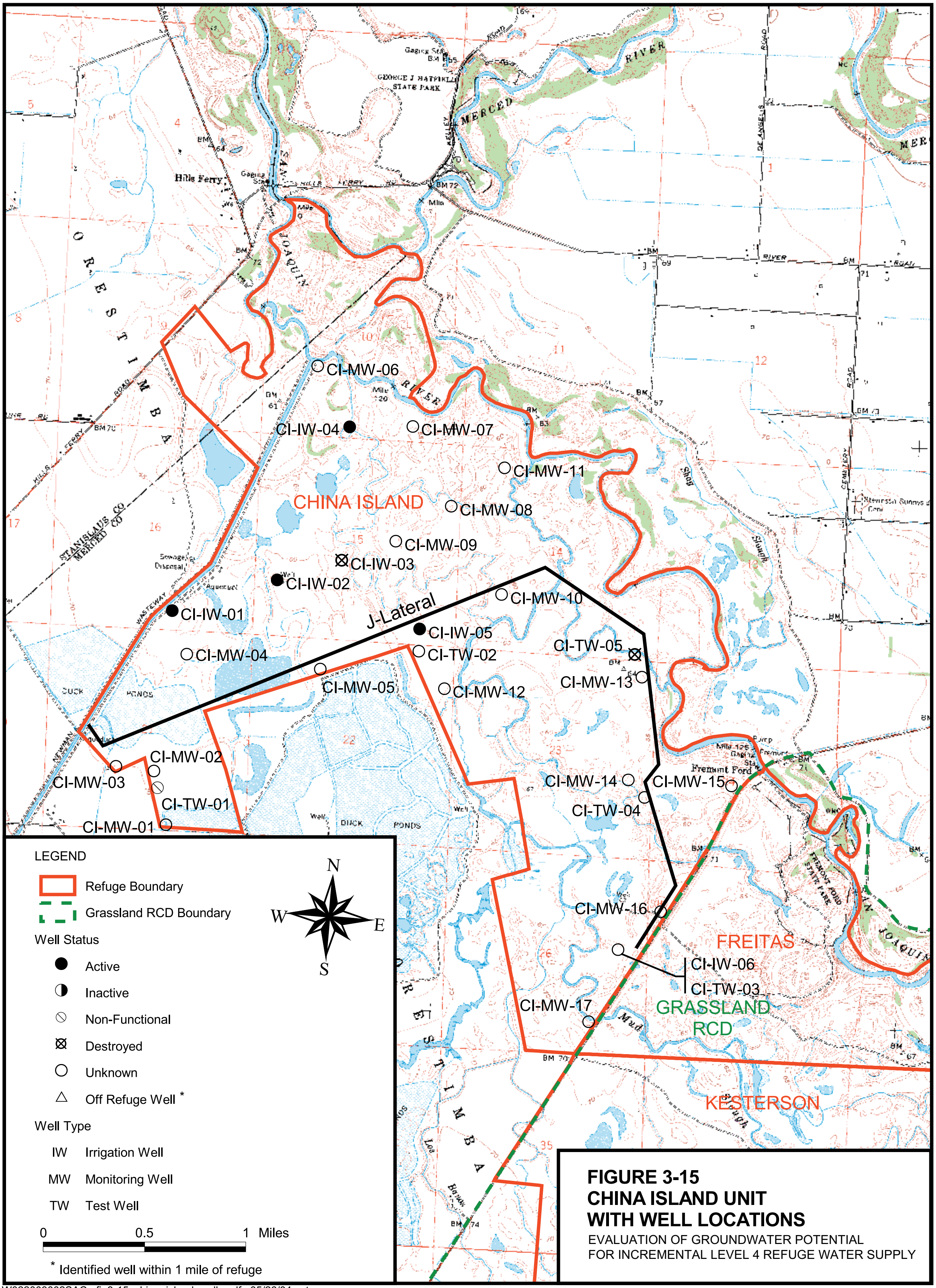

FIGURE 3-15
CHINA ISLAND UNIT
WITH WELL LOCATIONS
EVALUATION OF GROUNDWATER POTENTIAL
FOR INCREMENTAL LEVEL 4 REFUGE WATER SUPPLY

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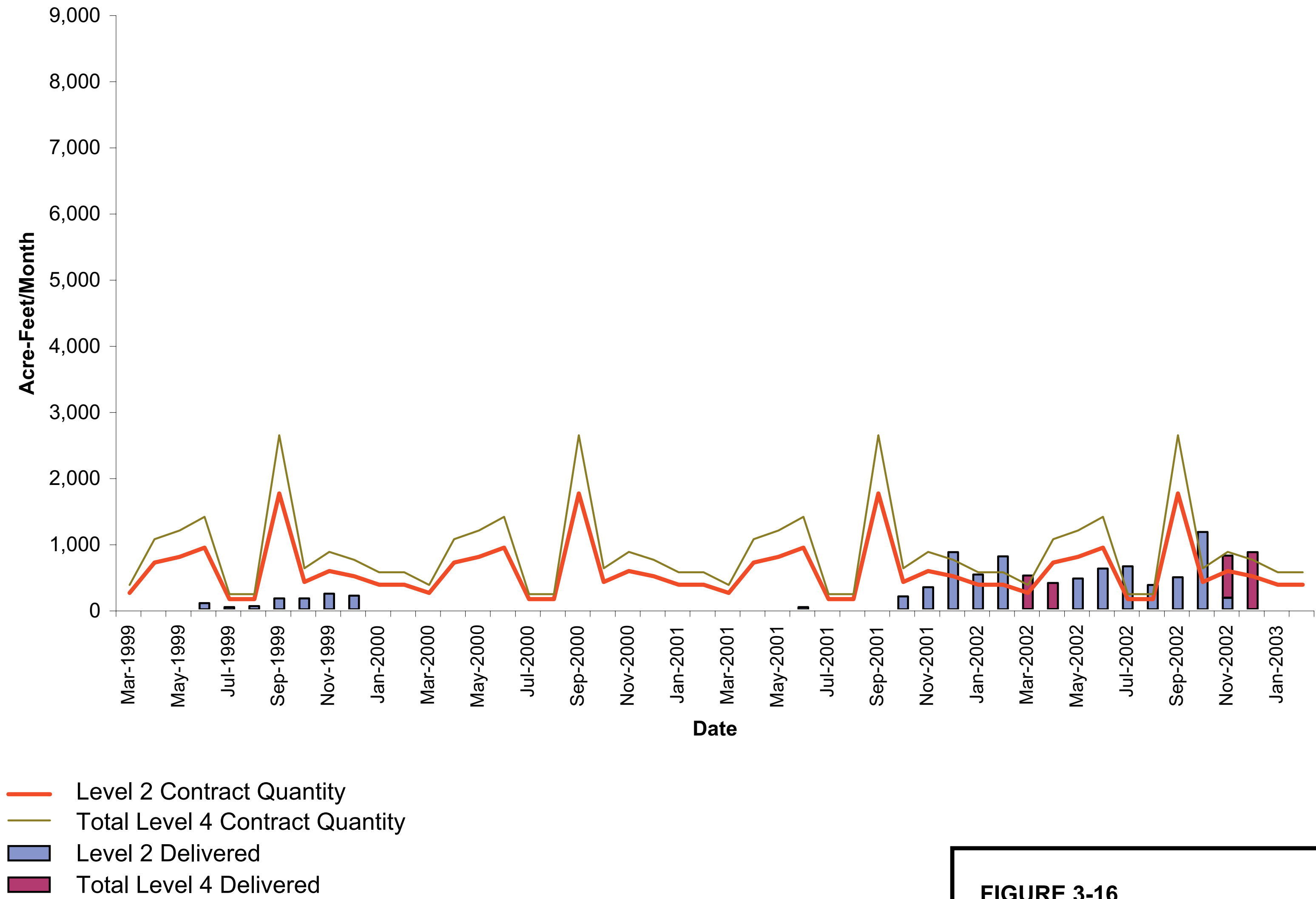

Note: Level 2 and Total Level 4 contract quantities are those indicated in Reclamation 1989 and Reclamation el al. 1989. Volumes indicated may not reflect current monthly management schedules and are shown to indicate an approximate monthly breakdown for management purposes. Total annual contract quantities may be scheduled based on availability, at the refuge manager's discretion.

FIGURE 3-16
1999-2002 CHINA ISLAND WILDLIFE AREA WATER DELIVERIES
EVALUATION OF GROUNDWATER POTENTIAL
FOR INCREMENTAL LEVEL 4 REFUGE WATER SUPPLY

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FIGURE 3-17
CHINA ISLAND UNIT
WELL CI-IW-01
EVALUATION OF GROUNDWATER POTENTIAL
FOR INCREMENTAL LEVEL 4 REFUGE WATER SUPPLY

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3.4 Freitas Unit Refuge Assessment (San Luis NWR Complex)

County: Merced
Basin / Subbasin: San Joaquin Valley Groundwater Basin / Delta-Mendota Subbasin
Level 2 / Incremental Level 4: 5,290 ac-ft / 0 ac-ft
2003 Acreage: 5,600
CVP Water Conveyor: Grassland WD
Water District Service Area: None
Applicable Groundwater Management Regulations: None

The Freitas Unit of the San Luis NWR Complex, located in Merced County, extends south of the San Joaquin River and along the west side of the Salt Slough to the northern border of the Salt Slough Unit (Figure 3-18). The western boundary is formed in part by the San Luis Canal. The unit also shares borders with the China Island Unit, Kesterson Unit, and West Bear Creek Unit.

3.4.1 Hydrogeologic Assessment

3.4.1.1 Habitat Goals, Land Management, and Surface Features

The 5,600-acre Freitas Unit is managed as part of the larger San Luis NWR Complex. Formerly managed as a cattle ranch, habitat now managed in the unit includes native grassland, seasonal wetlands, slough, and oxbows (Reclamation et al. 2001b).

Several branches of Salt Slough flow along and throughout the refuge unit. SR 165 runs north-south through the center of the refuge.

3.4.1.2 Identified Water Supply Contract Quantities

Figure 3-19 shows the Level 2 and Level 4 water contract quantities and the actual water deliveries to the refuge from 1999 through 2001. The contract quantity for Level 2 and Level 4 is 5,290 ac-ft per year since there is no Incremental Level 4 contract quantity at the Freitas Unit (Reclamation et al. 2001b).

3.4.1.3 Surface Water Supplies and Infrastructure

Most water is provided through CVP contracts. Reclamation has provided the full 5,290 ac-ft supply, as available, since 1990. CVP water is also wheeled through Grassland WD canals (Reclamation et al. 2001b). Water moves from southeast to north via gravity flow at this refuge.

The refuge managers consider the quality of the delivered water to be adequate for refuge irrigation needs.

3.4.1.4 Groundwater Supplies and Infrastructure

Two wells present on the Freitas property prior to acquisition by the federal government were destroyed, although no records were identified regarding the location of the wells or the method of destruction (Refuge staff 2002). Available information for these wells is summarized in Table 3-4. Groundwater is not used for domestic supply on the refuge.

Test Wells. A test well was drilled by Reclamation in 1992 prior to installation of the irrigation well. This test well was referred to as KRT-1 or KST-1 (FR-TW-01).

Irrigation and Production Wells. One irrigation well exists on the Freitas Unit; it is operated only during periods of drought. This irrigation well was formerly located within the boundaries of the Kesterson Unit and was referred to as Kesterson No. 1 (shown as FR-IW-01 in Figure 3-18).

Groundwater Quality Data. Water quality data for the Freitas Unit consists of one sample collected from the irrigation well (screened at 250 to 460 bgs) in 1995 and the samples from discrete intervals (below 300 feet) collected from the test well in 1992. EC from the irrigation well was 3,980 µmhos/cm, TDS was 2,440 mg/L, boron was 2.4 mg/L, and molybdenum was 20 µg/L (Turner 1992a). Freshwater Aquatic Life Standards and/or Agricultural Water Quality Goals were exceeded for these parameters. These values are consistent with those observed during the test well sampling. Available water quality data from Freitas Unit wells are summarized on Table 3-5. It is unknown if poor groundwater quality has hindered groundwater use in the past.

3.4.1.5 Local Groundwater Use

Groundwater is used in the vicinity to supply agricultural irrigation, private duck clubs, and occasionally domestic use. No known municipal or domestic wells have been located within 1 mile of the refuge (DWR well logs on file).

3.4.1.6 Refuge Soil and Aquifer Conditions

Several types of deep and poorly drained clay and loam surface soils dominate the refuge area. In the south-central and western refuge areas, Edminster loam is fairly extensive. Clay loam extends several feet. Dospalos clay is widely spread in the southern tip and central region of the refuge. A band of Dospalos clay and Bolfar clay loam stretches from the western to eastern refuge boundaries in the north. Finally, a small area in the east-central part of the refuge consists of Edminster Variant sand (USDA 1990).

The permeability of most soils in this area is very slow, and water capacity is moderate. Confining soils are several feet thick. Runoff is typically slow, and brief ponding is possible from December through March. The soil is also limited by a high salt concentration and poor drainage. The exception is the area consisting of Edminster Variant sand, which has rapid permeability to a depth of 25 inches and moderately slow permeability below this depth. Brief ponding may occur on this soil only after extended storms during December through February (USDA 1990).

DWR water-level data indicate that depth to groundwater at Freitas Unit ranges between 5 and 20 feet bgs, with the shallow groundwater more common in the western portion of the refuge. Water levels are several feet higher than those recorded in the 1960s and 1970s (DWR 2003b).

Between 1 and 2 feet of subsidence has occurred in the vicinity of the refuge (DWR 2003a). Future subsidence may occur if groundwater use substantially increases.

3.4.1.7 Operational Issues and Data Needs

The refuge does not depend on Incremental Level 4 water supplies for wetland management since it does not have an Incremental Level 4 contract agreement with Reclamation.

Local water in the region is subject to wide fluctuations in cost and variable spot-market availability. Developing groundwater at the refuge may be beneficial if it could allow other refuges to have a local source of cost-effective and reliable Incremental Level 4 water.

The following data gaps were identified during the completion of this study:

- Thorough assessment of the refuge irrigation well to determine well conditions.
- Confirmation of refuge groundwater quality conditions at several different locations and at depths both above and below the Corcoran Clay. In particular, verify TDS, EC, boron, and molybdenum concentrations in groundwater to determine potential for deleterious effects on wildlife.
- Local aquifer conditions, including quarterly water-level data both on- and off-refuge, and data to estimate aquifer properties at the refuge.
- Aquifer parameters, such as hydraulic conductivity and thickness.
- Groundwater pumping records and schedules, both on and immediately surrounding the refuge.

Relative to the other refuges in this study, it was estimated that a "significant" level of data collection is required at the Freitas Unit prior to recommending specific groundwater development projects.

3.4.2 Criteria Evaluation Summary

The Freitas Unit received total Hydrogeologic Scores of –1 for Direct Use of groundwater and –3 for On-Refuge Conjunctive Use based on criteria matrix evaluation. Table 3-6 shows the criteria matrix specific to this refuge. The matrix includes a score for each criterion and a corresponding justification or reasoning for the score given.

Increased groundwater use at Freitas would require extensive groundwater quality testing and improved infrastructure. Soil conditions limit development of recharge basins. Support and limitations to groundwater development at this refuge are summarized below.

3.4.2.1 Support for Groundwater Development

- One irrigation well is active on refuge property. This well is used during periods of drought.
- No known domestic or municipal wells have been located within 1 mile of the refuge.
- Surface water is delivered reliably to the refuge and is therefore available for blending with groundwater, if necessary.
- The cost of local water is high relative to the other refuges in the Sacramento Valley. Cost and reliability is subject to spot-market variability.

3.4.2.2 Limitations to Groundwater Development

- Water distribution on the refuge relies on gravity flow.
- The majority of surface soils consist of clay and clay loam, characterized by slow percolation. The soils are not conducive to construction of recharge basins.
- Aquifer storage is not available. Current and historic groundwater levels are approximately equivalent.
- Freshwater Aquatic Life Standards and/or Agricultural Water Quality Goals have been exceeded in groundwater at the refuge for boron, EC, molybdenum, and TDS based on limited testing.
- The Freitas Unit does not have an Incremental Level 4 water need.
- Significant data collection is necessary prior to recommending groundwater development.

3.4.3 Recommended Data Acquisition Activities

Substantial additional data acquisition would be needed to support groundwater development. Because this refuge has a low priority to develop groundwater relative to the other refuges in this study, no data acquisition relative to specific groundwater development projects is recommended at this time. However, since the refuge has an active well, data relative to that well should be collected and maintained to support potential future groundwater investigations. These actions include measuring water levels quarterly from accessible nearby wells and collecting water quality samples from active wells to develop a database of groundwater use and conditions at refuges where groundwater is used. Collected data should be maintained in a format supportable and usable by the refuge and refuge managing agencies.

3.4.4 Potential Projects

3.4.4.1 Direct Use

Based on limited existing data, the shallow groundwater beneath the refuge has marginal water quality. Further investigation is needed to determine whether there are laterally continuous intervals of better water quality (that is, low EC and boron, etc). No direct use projects to supplement Level 4 water supplies are recommended for the Freitas Unit at this time, since the refuge has no Incremental Level 4 need.

3.4.4.2 On-Refuge Conjunctive Use

Freitas is not within the sphere of influence of any groundwater management plan or ordinance. With the exception of the small area of permeable Edminster Variant sand, existing groundwater quality and soil information does not indicate favorable conditions for groundwater storage at this refuge. The limited surface area of that site may not justify establishing recharge basins in this area. Depth to groundwater is shallow, so aquifer space for storage may be limited.

3.4.4.3 Off-Refuge Conjunctive Use

At this time, no off-refuge conjunctive use projects have been identified for potential partnership.

TABLE 3-4
Freitas Unit Well Information[a]
Evaluation of Groundwater Potential for Incremental Level 4 Refuge Water Supply

GIS Well Number[b]	Common Well Name	Well Status[c]	2002 Yield (ac-ft)	Year Installed	Depth (ft)	Screen Interval (bgs)	Well Output (gpm)	Well Log?	Water Quality Data?	Comments
FR-IW-01	Kesterson 1	Inactive		1992	715	250–460	1,800	Y	Y	Drilled after successful test well FR-TW-01 drilled at this site.
FR-TW-01	KST-1 or KRT-1	Inactive		1992	701	310–660[d]		Y	Y	Test well leading to the development of a deep well at this location. Specific screened intervals are: 310–330, 355–375, 440–460, 530–550, 640–660.

Notes:

[a] Based on data compiled from well logs, test records, communication with refuge staff (2002), and other previous documentation. Well locations are shown on Figure 3-18. On-refuge wells only are included in this table, although the GIS includes known wells within 1 mile of the refuge.

[b] Well type is indicated by the middle two letters of the GIS well number: IW = irrigation well, DW = domestic well, MW = monitoring well, TW = test well, and UN = unknown.

[c] Designation refers to the physical well only, not water quality issues. Designations are: *active* (currently operated), *inactive* (capable of operating, but currently is not), *nonfunctional* (cannot operate in current physical state), *destroyed* (well has been lost, abandoned, or filled), or *unknown* (no information regarding status is available).

[d] See Comments for specific screened intervals within the range shown.

Blank fields indicate that no information is available.

TABLE 3-5
Freitas Unit Water Quality Data (1992)
Evaluation of Groundwater Potential for Incremental Level 4 Refuge Water Supply

GIS Well Number	Sampled Interval (feet)	EC (µmhos/cm)	Boron (mg/L)	Selenium (µg/L)	Molybdenum (mg/L)	TDS (mg/L)
FR-IW-01	250–460	3,980	2.4	ND	0.02	2,440
FR-TW-01	310–330	2,390	2.4	ND	0.021	1,400
	355–375	2,150	2.4	ND	0.014	1,300
	440–460	1,970	2.6	ND	0.023	1,200
	530–550	2,700	2.3	ND	0.023	1,600
	640–660	3,930	2.1	ND	0.03	2,200

Source: Turner 1992a.

Notes:

Well locations are shown on Figure 3-18.
ND = not detected

TABLE 3-6
Freitas Unit Evaluation
Evaluation of Groundwater Potential for Incremental Level 4 Refuge Water Supply

	Criteria	Scoring Scale	Appl.[b]	Score	Refuge Score Justification
Surface[a]	Do surface water bodies exist that could be affected by increased groundwater use?	+1 = no 0 = to some degree –1 = yes, surface water bodies could be affected	D,N	-1	Several branches of Salt Slough run throughout the refuge. Several private duck clubs are located southwest of the refuge boundary, near the existing wells.
Water Supplies and Infrastructure	Has groundwater been used previously at the refuge for ponds or irrigation?	+1 = yes, used successfully to meet at least 20 percent of annual refuge water demands 0 = yes, used to meet less than 20 percent (or unknown) of annual refuge water demands. –1 = no, has not been used	D,N	0	One irrigation well is used only during periods of drought. This well is not regularly used to meet refuge water demand.
	Do wells exist on the refuge?	+1 = yes, active wells 0 = yes, inactive or nonfunctional wells –1 = yes, destroyed wells, or no wells exist on the refuge	D,N	+1	There is one active irrigation well on the property, and one corresponding test well. Two other wells have been destroyed, but there is no record as to their location or method of destruction.
	Does existing internal distribution system (IDS) support groundwater use?	+1 = water can move extensively around the refuge with existing IDS 0 = the IDS enables limited water movement within the refuge –1 = an IDS does not exist on the refuge or water flow relies exclusively on gravity	D,N	-1	Water naturally flows from southeast to north to distribute water through the refuge.
Local Groundwater Use	Is groundwater used for agriculture or duck clubs in the immediate vicinity of the refuge?	+1 = groundwater is not used; or groundwater is minimally used, but use is not constrained 0 = groundwater is used in the area –1 = groundwater is not used due to physical or environmental constraints or is extensively used in the vicinity	D,N	0	Groundwater is occasionally used in the area for irrigation and to supply private duck clubs. The extent of groundwater use in the immediate vicinity of the refuge is not clearly known.
	Does municipal or domestic supply exist near the refuge?	+1 = no known domestic or municipal wells are located within 1 mile of the refuge 0 = municipal or domestic wells are likely located within 1 mile of the refuge –1 = municipal or domestic wells are located within 1 mile of the refuge	D,N	+1	No known municipal or domestic wells have been located within 1 mile of the refuge.
Soil and Hydrogeology	Are at-surface soils conducive to groundwater recharge?	+1 = soils are sandy or are reported to percolate well 0 = soils are silty or are reported to have some infiltration –1 = soils are clayey or are reported to hold water well	N	-1	The refuge area is dominated by clay and loam soils, except for a small area in the central east which consists of Edminster Variant sand, which has rapid permeability.
	Could recharge basins be developed if surface soils were removed?	+1 = confining soil less than 2 feet thick 0 = confining soil 5 to 7 feet thick –1 = confining soil greater than 7 feet thick	N	0	Confining surface soils are several feet thick.
	Has subsidence occurred at or in the immediate vicinity of the refuge?	+1 = no 0 = yes, less than 2 feet –1 = yes, more than 2 feet	D,N	0	Between 1 and 2 feet of subsidence has occurred in the refuge vicinity.
	Does significant potential for subsidence exist if groundwater use is increased at the refuge?	+1 = minimal potential for subsidence 0 = some potential for subsidence –1 = significant potential for subsidence	D,N	0	Future subsidence is possible if groundwater use substantially increases.
	Is aquifer storage available in the subbasin?	+1 = yes, current water levels are greater than 30 feet lower than historic levels 0 = some, current water levels are between 10 and 30 feet lower than historic levels –1 = no	N	-1	Water levels in the refuge vicinity seem to have recovered to pre-1970s levels.

Notes:
a Surface Features
b Application to Approach: D = Direct Use, N = On-Refuge Conjunctive Use

continued on next page

TABLE 3-6
Freitas Unit Evaluation
Evaluation of Groundwater Potential for Incremental Level 4 Refuge Water Supply

	Criteria	Scoring Scale	Appl.[b]	Score	Refuge Score Justification
Water Quality	Have groundwater quality conditions hindered groundwater use in the past?	+1 = no 0 = data are not available –1 = yes	D,N	0	It is unknown if groundwater quality has hindered groundwater use in the past.
	Do adverse groundwater quality conditions exist in the subbasin?	+1 = no 0 = potential –1 = yes	D,N	-1	Test wells showed high EC (>3,900 µmhos/cm), boron (>2.1 mg/L), and molybdenum (>0.03 mg/L) at depths above and below the Corcoran Clay. Water quality tests at the irrigation well showed high EC (>3,980 µmhos/cm), boron (2.4 mg/L), and molybdenum (0.02 mg).
	Is surface water available to enable blending of lower quality groundwater to meet proposed refuge standards?	+1 = yes 0 = during portions of the year –1 = no	D,N	+1	Water is delivered reliably as requested most of the year.
	Do groundwater conditions exceed USEPA Freshwater Aquatic Life Standards or Agricultural Water Quality Goals for multiple parameters?	+1 = no 0 = yes, two parameters, or no water quality testing has been conducted –1 = yes, three or more parameters	D,N	-1	Aquatic life standards and agricultural water quality goals have been exceeded in groundwater for boron, EC, molybdenum, and TDS.
	Is refuge land use management compatible with seasonally or annually variable water quality from different sources?	+1 = yes 0 = some potential compatibility problems may exist –1 = no	D,N	0	Only delivered water is primarily used to meet refuge water demands. Water from other sources is used only during times of drought.
	Does groundwater quality meet drinking-water standards (i.e., can it be used for refuge domestic supply)?	+1 = yes it is used, no treatment is necessary 0 = yes it is used, but some treatment is necessary for potable use; or it is not used for unknown reasons –1 = no, it is not used because of adverse water quality conditions	D	0	Groundwater is not used for domestic supply on the refuge.
Operational Issues/Constraints	Does a significant percentage of total refuge water supply consist of "Incremental Level 4" water?	+1 = yes, 54% to 79% of total water supply is Incremental Level 4 0 = somewhat, 27% to 53% of total water supply is Incremental Level 4 –1 = minor, 0% to 26% of total water supply is Incremental Level 4	D,N	-1	The Freitas Unit does not have an Incremental Level 4 need.
	Is the cost of local water high or low relative to the other refuges in this study?	+1 = costs may fluctuate highly or are subject to spot-market variability or price spikes –1 = costs are relatively stable and subjectivity to spot-market variability is low	D,N	+1	Local water in this region is subject to wide fluctuations in cost and variable spot-market availability.
	Is it necessary to convey Incremental Level 4 water through the Delta for refuge supply?	+1 = yes, Incremental Level 4 water must be conveyed through the Delta –1 = no, conveyance of Incremental Level 4 water through the Delta is not necessary	D,N	+1	Incremental Level 4 water must be conveyed through the Delta given current water supply sources.
Data Needs	Are there significant data needs to address prior to groundwater development?	+1 = no, data needs regarding refuge groundwater conditions are minor 0 = somewhat, some data are required prior to increasing groundwater development –1 = yes, significant data must be collected as there is little or no existing data	D,N	-1	Significant data are required prior to recommending increased groundwater development.
			Total Direct Use Score =	**-1**	
			Total On-Refuge Conjunctive Use Score =	**-3**	

Notes:
a Surface Features

b Application to Approach: D = Direct Use, N = On-Refuge Conjunctive Use

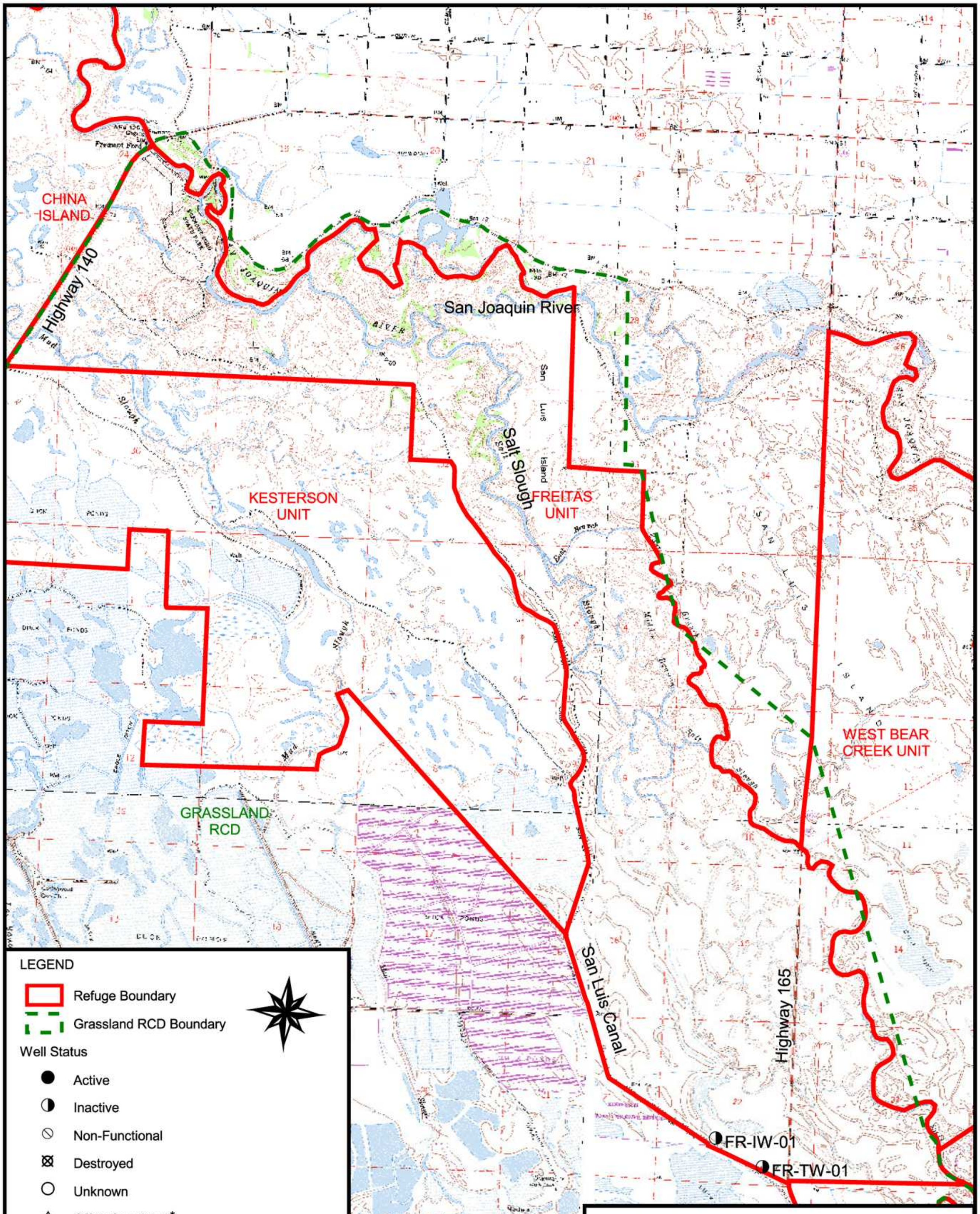

FIGURE 3-18
FREITAS UNIT
WITH WELL LOCATIONS
EVALUATION OF GROUNDWATER POTENTIAL
FOR INCREMENTAL LEVEL 4 REFUGE WATER SUPPLY

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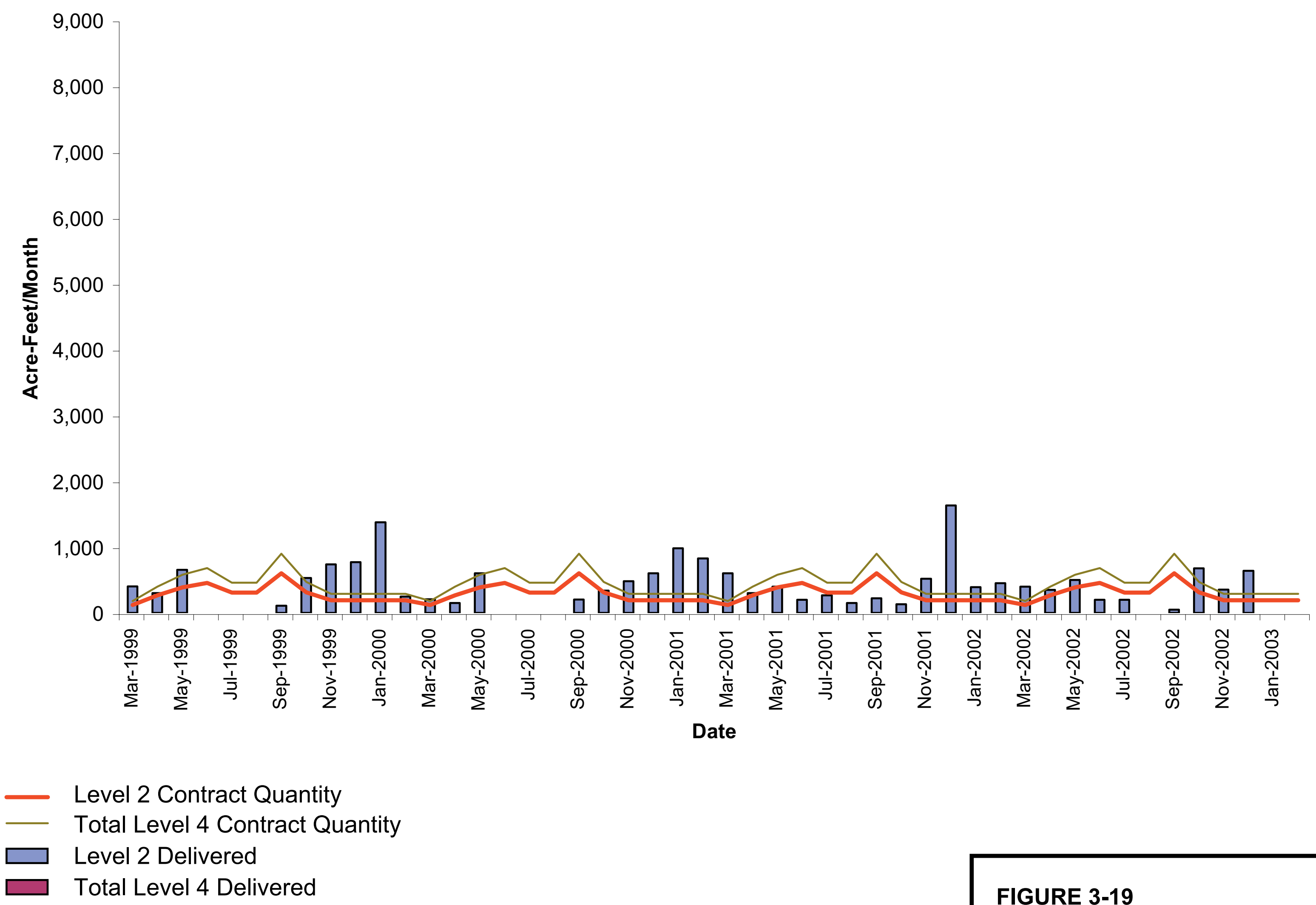

Note: Level 2 and Total Level 4 contract quantities are those indicated in Reclamation 1989 and Reclamation el al. 1989. Volumes indicated may not reflect current monthly management schedules and are shown to indicate an approximate monthly breakdown for management purposes. Total annual contract quantities may be scheduled based on availability, at the refuge manager's discretion.

FIGURE 3-19
1999-2002 FREITAS NWR WATER DELIVERIES
EVALUATION OF GROUNDWATER POTENTIAL
FOR INCREMENTAL LEVEL 4 REFUGE WATER SUPPLY

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3.5 Kesterson Unit Refuge Assessment (San Luis NWR Complex)

County: Merced
Basin / Subbasin: San Joaquin Valley Groundwater Basin / Delta-Mendota Subbasin
Level 2 / Incremental Level 4: 10,000 ac-ft / 0 ac-ft
2003 Acreage: 5,600
CVP Water Conveyor: Grassland WD
Water District Service Area: None
Applicable Groundwater Management Regulations: None

The Kesterson Unit is located in Merced County, 4 miles east of Gustine, and southeast of the China Island Unit (Figure 3-20). The northern and eastern borders of the refuge coincide with the western border of the Freitas Unit. The eastern border follows the San Luis Canal. Part of the refuge's western border follows the Newman Wasteway.

3.5.1 Hydrogeologic Assessment

3.5.1.1 Habitat Goals, Land Management, and Surface Features

The purpose of the refuge is to provide habitat for migratory waterfowl, endangered species, and other wildlife. Wetlands and grassland/vernal pool habitats are maintained to achieve this purpose. Water is used to irrigate soil, maintain seasonal wetlands, and produce food sources for wildlife (Reclamation et al. 2001b).

Mud Slough flows through the central part of the refuge. Salt Slough flows just to the east of the eastern border of the refuge. Several duck ponds are found throughout the area, including two major tracts in the western and southeastern corners.

3.5.1.2 Identified Water Supply Contract Quantities

Figure 3-21 shows the Level 2 and Level 4 water contract quantities and the actual water deliveries to the refuge from 1999 through 2001. The Level 2 water supply contract quantity for the refuge is met contractually with 10,000 ac-ft per year. There are no identified Incremental Level 4 water contract quantities at this refuge (Reclamation et al. 2001b).

3.5.1.3 Surface Water Supplies and Infrastructure

Surface water supplies are received from CVP through Reclamation and Grassland WD, as available. The Santa Fe and San Luis Canals deliver CVP water to the Kesterson Unit (Reclamation et al. 2001b).

Water generally flows from south to north via gravity flow. Fields are flooded or irrigated depending on the habitat of a specific area. A small ditch running southeast to northwest transports CVP water delivered from the San Luis Canal (Refuge staff 2002).

The refuge managers consider the quality of the delivered water to be adequate for refuge irrigation needs.

3.5.1.4 Groundwater Supplies and Infrastructure

Known well locations at the Kesterson Unit are shown in Figure 3-20. Well information is summarized in Table 3-7. No wells are used for domestic supply on the refuge.

Test Wells. A test well, KST-2 (KS-TW-01), located along the southern boundary near Mud Slough, was drilled by Reclamation during the same investigation as the test well KST-1 (FR-TW-01), now located on the Freitas Unit.

Irrigation and Production Wells. One irrigation well, 9F1 (shown as KS-IW-01 in Figure 3-20), is located on the Kesterson Unit near the southeastern refuge boundary. The well is inactive because of water quality concerns. According to refuge staff, this well may have been filled (destroyed). Two other irrigation wells have been destroyed. No records are available regarding the location or the destruction of these wells. An irrigation well was not installed at KST-2 (KS-TW-01) because of insufficient permeable zones (Refuge staff 2002).

Well 9F1 (KS-IW-01) produced between 480 and 1,980 ac-ft per year between 1987 and 1991 (Turner 1992b). The well is screened below the Corcoran Clay and has a depth of 630 feet (DWR well logs on file).

Groundwater Quality Data. Field EC measurements at the irrigation well when it operated ranged between 1,700 and 4,040 µmhos/cm, exceeding Agricultural Water Quality Goals. No water quality data were collected during drilling of the KST-2 test well (KS-TW-01) because the aquifer characteristics did not support production well installation (Refuge staff 2002).

3.5.1.5 Local Groundwater Use

Groundwater is occasionally used in the area for agricultural irrigation and to supply private duck clubs. No known domestic or municipal wells have been identified within 1 mile of the refuge (DWR well logs on file).

3.5.1.6 Refuge Soil and Aquifer Conditions

Three soil types make up the majority of the refuge area: Turlock sandy loam, Edminster loam, and Agnal clay loam. Agnal clay loam extends several feet in depth. Permeability of these soils is slow to very slow, and runoff typically ponds. The soils are limited by a high concentration of salts and poor drainage (USDA 1990).

Soils are characterized by Turlock sandy loam in the western side of the refuge, extending to the southeastern area along the San Luis Drain. Edminster loam is found near and along SR 140, stretching in a band from the northwest to the southeast through the central part of the refuge near Mud Slough. A mix of clay loams extends several feet below ground surface, and soil is highly saline. Agnal clay loam is found in the northwest and stretches to the central part of the refuge. The substrata consist of dark, saline-sodic clay (USDA 1990).

Groundwater levels are mostly shallow on the refuge. Depth to groundwater is consistently between 10 and 20 feet bgs according to DWR data. Water levels in the refuge vicinity have recovered to conditions prior to the drought in the 1970s (DWR 2003b).

Between 1 and 2 feet of subsidence has occurred in the vicinity of the refuge (DWR 2003a). Future subsidence may be possible if groundwater use substantially increases.

3.5.1.7 Operational Issues and Data Needs

The refuge does not depend on Level 4 water supplies for wetland management. The Kesterson Unit does not have an Incremental Level 4 need.

Local water in the region is subject to wide fluctuations in cost and variable spot-market availability. It is also necessary to convey Level 4 water through the Delta to deliver water to nearby refuges. Developing groundwater at the refuge could be beneficial if it could support the water needs of other refuges and a local, reliable, and cost-effective source of Incremental Level 4 water.

The following data gaps were identified during the completion of this study:

- Thorough assessment of the refuge irrigation well (KS-IW-01) if it still exists.
- Confirmation of refuge groundwater quality conditions at several different locations and at depths both above and below the Corcoran Clay. In particular, verify salinity and determine TDS, boron, and molybdenum concentrations in groundwater.
- Local aquifer conditions, including quarterly water-level data both on- and off-refuge, and data to estimate aquifer properties at the refuge.
- Aquifer parameters, such as hydraulic conductivity and thickness.
- Groundwater pumping records and schedules, both on and immediately surrounding the refuge.

Relative to the other refuges in this study, it was estimated that a “high” level of data collection is required at the Kesterson Unit prior to recommending specific groundwater development projects.

3.5.2 Criteria Evaluation Summary

The Kesterson refuge received total Hydrogeologic Scores of zero for Direct Use of groundwater and –2 for On-Refuge Conjunctive Use based on criteria matrix evaluation. Table 3-8 shows the specific criteria matrix and scores for this refuge.

Further development of groundwater for direct use would require extensive groundwater quality data collection and well infrastructure improvement. Although external conveyance facilities are conveniently available to transport water to and from the refuge, inadequate soil conditions preclude this site from groundwater banking via recharge basins. Support and limitations of increased groundwater development are summarized below.

3.5.2.1 Support for Groundwater Development

- No known municipal or domestic wells have been identified within 1 mile of the refuge.
- Surface water is delivered reliably to the refuge and is therefore available for blending with groundwater, if necessary.
- The San Luis Canal, Santa Fe Canal, and Newman Wasteway are near the refuge. The San Luis and Santa Fe Canals are used by the refuge to convey delivered water.

- The cost of local water is high relative to the other refuges in the study. Cost and reliability is subject to spot-market variability.

3.5.2.2 Limitations to Groundwater Development

- The IDS allows only limited water movement through the refuge, relying on gravity flow.
- Clay surface soils primarily have low permeability and high salt content and are not conducive to construction of recharge basins.
- Aquifer storage is not available. Current and historic groundwater levels are approximately equivalent. Overdraft conditions do not exist in the subbasin.
- Poor groundwater quality has hindered groundwater use in the past. Well 9F1 (KS-IW-01) remains inactive because of water quality concerns, particularly high salinity.
- Sufficient permeable zones were not found at test well KST-2 (KS-TW-01) to warrant installation of an irrigation well.
- The Kesterson Unit does not have an Incremental Level 4 water contract quantity.
- A high level of data collection is necessary prior to recommending groundwater development.

3.5.3 Recommended Data Acquisition Activities

Substantial additional data acquisition would be needed to support groundwater development. Because this refuge has a low priority to develop groundwater relative to the other refuges in this study, no data acquisition is recommended at this time. If well 9F1 (KW-IW-01) still exists, however, and if it is used to supply refuge water, then it is recommended that data be collected from that well to support any future groundwater investigations. These data includes measuring water levels quarterly from accessible nearby wells and collecting water quality samples from active wells to develop a database of groundwater use and conditions at refuges where groundwater is used. Collected data should be maintained in a format supportable and usable by the refuge and refuge managing agencies.

3.5.4 Potential Projects

3.5.4.1 Direct Use

No direct use projects to supplement Level 4 water supplies are recommended for the Kesterson Unit at this time, since the refuge has no Incremental Level 4 contract quantity.

3.5.4.2 On-Refuge Conjunctive Use

Existing groundwater quality and soil information does not indicate favorable conditions for groundwater storage at this refuge. No on-refuge conjunctive use project is recommended at this time. If additional data acquisition indicates groundwater conditions differ from the current understanding, then this recommendation could be reconsidered.

3.5.4.3 Off-Refuge Conjunctive Use

Kesterson is not within the sphere of influence of any groundwater management plan or ordinance. At this time, no off-refuge conjunctive use projects have been identified for potential partnership.

TABLE 3-7
Kesterson Unit Well Information[a]
Evaluation of Groundwater Potential for Incremental Level 4 Refuge Water Supply

GIS Well Number[b]	Common Well Name	Well Status[c]	2002 Yield (ac-ft)	Year Installed	Depth (ft)	Screen Interval (bgs)	Well Output (gpm)	Well Log?	Water Quality Data?	Comments
KS-IW-01	9F1	Inactive		Prior to 1987	633	380–633	2,132	N	Y	Below Corcoran Clay. Peerless Turbine GE electric motor.
KS-TW-01	KST-2 or KRT-2	Destroyed		1992	701			Y	N	Deep well never drilled at this location because of “insufficient permeable zones.”

Notes:

[a] Based on data compiled from well logs, test records, communication with refuge staff (2002), and other previous documentation. Well locations are shown on Figure 3-20. On-refuge wells only are included in this table, although the GIS includes known wells within 1 mile of the refuge.

[b] Well type is indicated by the middle two letters of the GIS well number: IW = irrigation well, DW = domestic well, MW = monitoring well, TW = test well, and UN = unknown.

[c] Designation refers to the physical well only, not water quality issues. Designations are: *active* (currently operated), *inactive* (capable of operating, but currently is not), *nonfunctional* (cannot operate in current physical state), *destroyed* (well has been lost, abandoned, or filled), or *unknown* (no information regarding status is available).

Blank fields indicate that no information is available.

TABLE 3-8
Kesterson Unit Evaluation
Evaluation of Groundwater Potential for Incremental Level 4 Refuge Water Supply

	Criteria	Scoring Scale	Appl.[b]	Score	Refuge Score Justification
Surface[a]	Do surface water bodies exist that could be affected by increased groundwater use?	+1 = no 0 = to some degree –1 = yes, surface water bodies could be affected	D,N	0	Mud Slough flows through the central part of the refuge, and Salt Slough flows just to the east of the refuge. Several duck ponds are found throughout the area, particularly on the west side. No irrigation wells are located near these ponds, however.
Water Supplies and Infrastructure	Has groundwater been used previously at the refuge for ponds or irrigation?	+1 = yes, used successfully to meet at least 20 percent of annual refuge water demands 0 = yes, used to meet less than 20 percent (or unknown) of annual refuge water demands. –1 = no, has not been used	D,N	0	Well 9F1 (KS-IW-01) has been used to meet a fraction of water demand; however, the well is currently inactive. One test well (KST-2, KS-TW-01) did not find sufficient permeable zones to warrant an irrigation well.
	Do wells exist on the refuge?	+1 = yes, active wells 0 = yes, inactive or nonfunctional wells –1 = yes, destroyed wells, or no wells exist on the refuge	D,N	0	Well 9F1 (KS-IW-01) is inactive, and KST-2 (KS-TW-01) is nonfunctional.
	Does existing internal distribution system (IDS) support groundwater use?	+1 = water can move extensively around the refuge with existing IDS 0 = the IDS enables limited water movement within the refuge –1 = an IDS does not exist on the refuge or water flow relies exclusively on gravity	D,N	-1	Water flows from south to north via gravity flow. A small ditch running southeast to northwest transports delivered water from the San Luis Canal.
Local Groundwater Use	Is groundwater used for agriculture or duck clubs in the immediate vicinity of the refuge?	+1 = groundwater is not used; or groundwater is minimally used, but use is not constrained 0 = groundwater is used in the area –1 = groundwater is not used due to physical or environmental constraints or is extensively used in the vicinity	D,N	0	Groundwater is occasionally used in the area for irrigation and to supply duck clubs. The extent of groundwater use in the immediate vicinity of the refuge is not clearly known.
	Does municipal or domestic supply exist near the refuge?	+1 = no known domestic or municipal wells are located within 1 mile of the refuge 0 = municipal or domestic wells are likely located within 1 mile of the refuge –1 = municipal or domestic wells are located within 1 mile of the refuge	D,N	+1	No known domestic or municipal wells have been identified within 1 mile of the refuge.
Soil and Hydrogeology	Are at-surface soils conducive to groundwater recharge?	+1 = soils are sandy or are reported to percolate well 0 = soils are silty or are reported to have some infiltration –1 = soils are clayey or are reported to hold water well	N	-1	Surface soils consist of Turlock sandy loam, Edminster loam, or Agnal clay loam, all of which have slow or very slow permeability and high salt content.
	Could recharge basins be developed if surface soils were removed?	+1 = confining soil less than 2 feet thick 0 = confining soil 5 to 7 feet thick –1 = confining soil greater than 7 feet thick	N	0	Olive gray clay loam extends several feet in depth.
	Has subsidence occurred at or in the immediate vicinity of the refuge?	+1 = no 0 = yes, less than 2 feet –1 = yes, more than 2 feet	D,N	0	Between 1 and 2 feet of subsidence has occurred in the refuge vicinity.
	Does significant potential for subsidence exist if groundwater use is increased at the refuge?	+1 = minimal potential for subsidence 0 = some potential for subsidence –1 = significant potential for subsidence	D,N	0	Future subsidence is possible if groundwater use substantially increases.
	Is aquifer storage available in the subbasin?	+1 = yes, current water levels are greater than 30 feet lower than historic levels 0 = some, current water levels are between 10 and 30 feet lower than historic levels –1 = no	N	-1	Water levels in the refuge vicinity seem to have recovered to pre-1970s levels.

Notes:
a Surface Features
b Application to Approach: D = Direct Use, N = On-Refuge Conjunctive Use

continued on next page

TABLE 3-8
Kesterson Unit Evaluation
Evaluation of Groundwater Potential for Incremental Level 4 Refuge Water Supply

	Criteria	Scoring Scale	Appl.[b]	Score	Refuge Score Justification
Water Quality	Have groundwater quality conditions hindered groundwater use in the past?	+1 = no 0 = data are not available –1 = yes	D,N	-1	Well 9F1 remains inactive because of water quality concerns, particularly high EC, which ranged between 1,700 and 4,040 µmhos/cm.
	Do adverse groundwater quality conditions exist in the subbasin?	+1 = no 0 = potential –1 = yes	D,N	0	Regionally, EC, boron, and molybdenum have been high; however, no tests were performed for boron or molybdenum within the Kesterson boundaries.
	Is surface water available to enable blending of lower quality groundwater to meet proposed refuge standards?	+1 = yes 0 = during portions of the year –1 = no	D,N	+1	Water is delivered reliably during the year, but may decrease in summer months during dry years.
	Do groundwater conditions exceed USEPA Freshwater Aquatic Life Standards or Agricultural Water Quality Goals for multiple parameters?	+1 = no 0 = yes, two parameters, or no water quality testing has been conducted –1 = yes, three or more parameters	D,N	0	Agricultural water quality goals have been exceeded for EC, but test results for other constituents are not available.
	Is refuge land use management compatible with seasonally or annually variable water quality from different sources?	+1 = yes 0 = some potential compatibility problems may exist –1 = no	D,N	0	Only delivered water is used for wetland management; groundwater is not used because of quality concerns.
	Does groundwater quality meet drinking-water standards (i.e., can it be used for refuge domestic supply)?	+1 = yes it is used, no treatment is necessary 0 = yes it is used, but some treatment is necessary for potable use; or it is not used for unknown reasons –1 = no, it is not used because of adverse water quality conditions	D	0	Groundwater is not used for domestic supply on the refuge.
Operational Issues/Constraints	Does a significant percentage of total refuge water supply consist of "Incremental Level 4" water?	+1 = yes, 54% to 79% of total water supply is Incremental Level 4 0 = somewhat, 27% to 53% of total water supply is Incremental Level 4 –1 = minor, 0% to 26% of total water supply is Incremental Level 4	D,N	-1	The Kesterson Unit does not have an Incremental Level 4 contract quantity.
	Is the cost of local water high or low relative to the other refuges in this study?	+1 = costs may fluctuate highly or are subject to spot-market variability or price spikes –1 = costs are relatively stable and subjectivity to spot-market variability is low	D,N	+1	Local water in this region is subject to wide fluctuations in cost and variable spot-market availability.
	Is it necessary to convey Incremental Level 4 water through the Delta for refuge supply?	+1 = yes, Incremental Level 4 water must be conveyed through the Delta –1 = no, conveyance of Incremental Level 4 water through the Delta is not necessary	D,N	+1	Incremental Level 4 water must be conveyed through the Delta given current water supply sources.
Data Needs	Are there significant data needs to address prior to groundwater development?	+1 = no, data needs regarding refuge groundwater conditions are minor 0 = somewhat, some data are required prior to increasing groundwater development –1 = yes, significant data must be collected as there is little or no existing data	D,N	-1	Significant data are required prior to recommending increased groundwater development.
			Total Direct Use Score =	**0**	
			Total On-Refuge Conjunctive Use Score =	**-2**	

Notes:
a Surface Features

b Application to Approach: D = Direct Use, N = On-Refuge Conjunctive Use

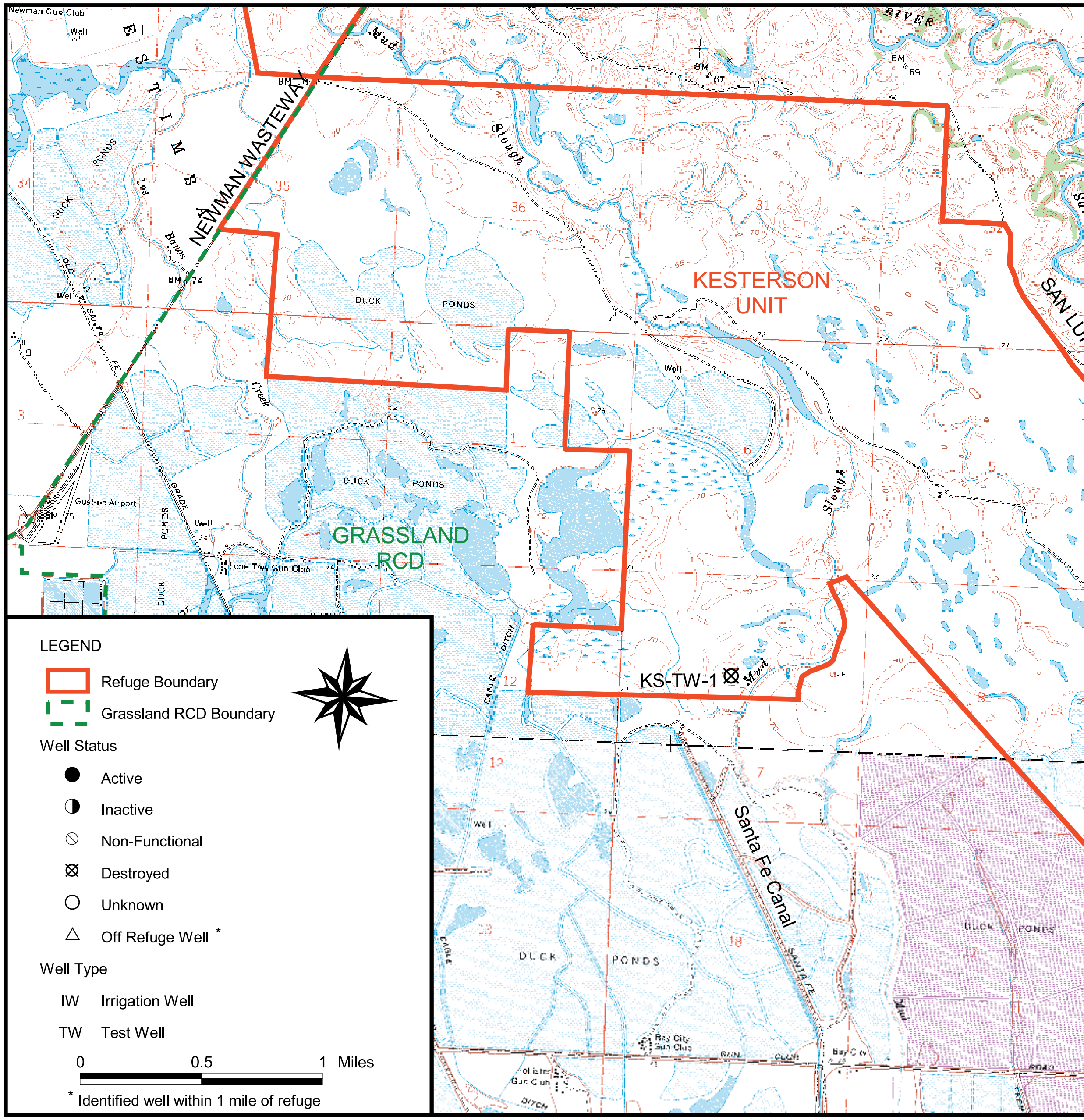

FIGURE 3-20
KESTERSON UNIT
WITH WELL LOCATIONS
EVALUATION OF GROUNDWATER POTENTIAL
FOR INCREMENTAL LEVEL 4 REFUGE WATER SUPPLY

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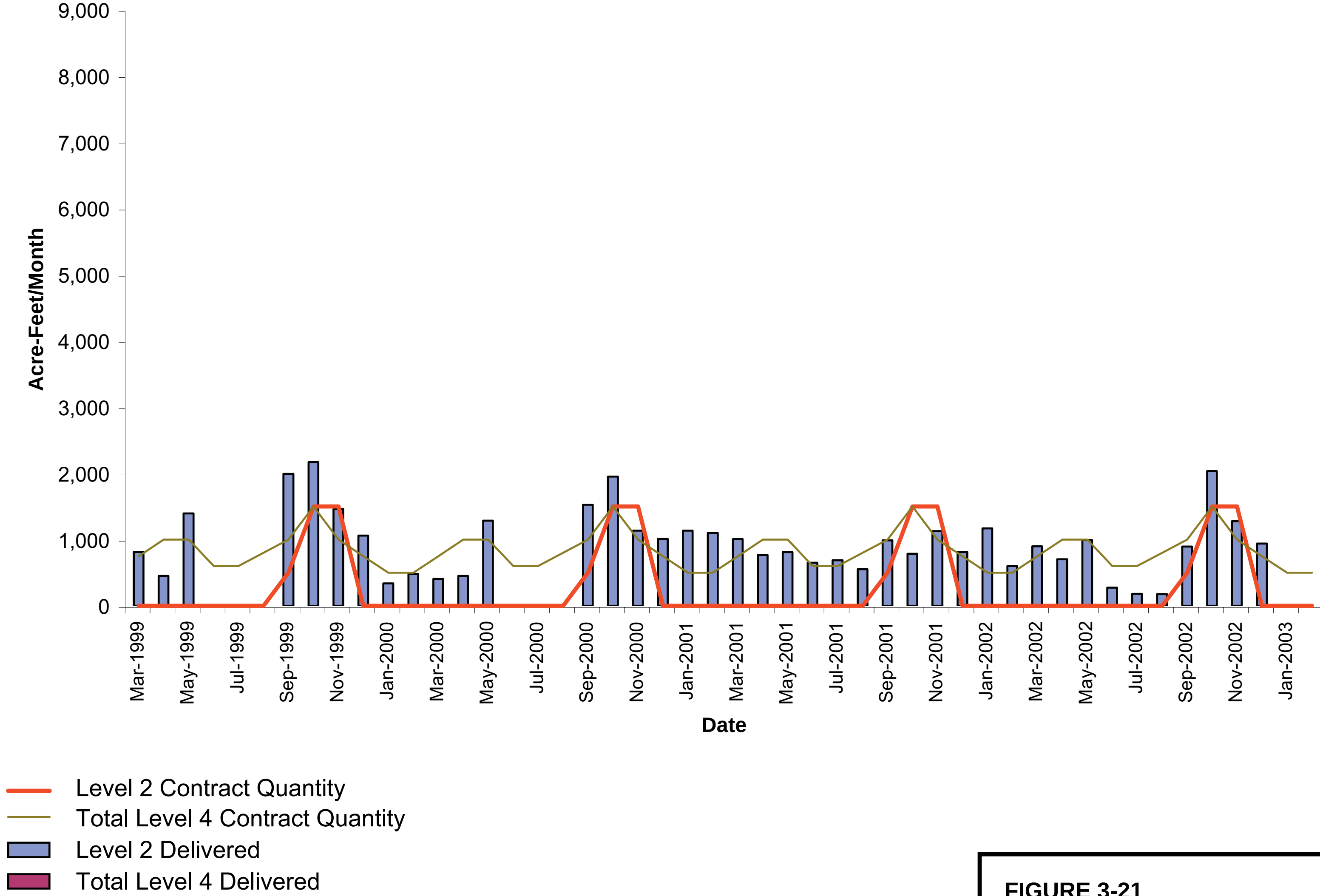

Note: Level 2 and Total Level 4 contract quantities are those indicated in Reclamation 1989 and Reclamation el al. 1989. Volumes indicated may not reflect current monthly management schedules and are shown to indicate an approximate monthly breakdown for management purposes. Total annual contract quantities may be scheduled based on availability, at the refuge manager's discretion.

FIGURE 3-21
1999-2002 KESTERSON NWR WATER DELIVERIES
EVALUATION OF GROUNDWATER POTENTIAL FOR INCREMENTAL LEVEL 4 REFUGE WATER SUPPLY

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3.6 West Bear Creek Unit Refuge Assessment (San Luis NWR Complex)

County: Merced
Basin / Subbasin: San Joaquin Valley Groundwater Basin / Delta-Mendota Subbasin
Level 2 / Incremental Level 4: 7,207 ac-ft / 3,603 ac-ft
2003 Acreage: 3,892
CVP Water Conveyor: San Luis CC
Water District Service Area: None
Applicable Groundwater Management Regulations: None

The West Bear Creek Unit (Figure 3-22) is located adjacent to and north of the San Luis Unit, west of the East Bear Creek Unit, and east of the Freitas Unit. The extreme western portion of the West Bear Creek Unit is within the Grassland RCD. The San Joaquin River forms the eastern border of the unit. SR 165 and Salt Slough form the western refuge border.

3.6.1 Hydrogeologic Assessment

3.6.1.1 Habitat Goals, Land Management, and Surface Features

This refuge, formerly known as West Gallo, is managed as part of the San Luis NWR Complex. The primary purposes of this refuge are: endangered and threatened species conservation; migratory bird refuge, breeding, and sanctuary; natural resource protection; recreation; wildlife management and control; and wetlands conservation. Prior to acquisition by the federal government in 1990, it was managed as a cattle ranch as part of the Gallo Farms property. Key special status species include the Aleutian Canada goose, bald eagle, giant garter snake, and the San Joaquin kit fox (Reclamation 2002).

3.6.1.2 Identified Water Supply Contract Quantities

Figure 3-23 shows the Level 2 and Level 4 water contract quantities and the actual water deliveries to the refuge from 1999 through 2001. The Level 2 water supply contract quantity is 7,207 ac-ft per year. The Level 4 increment is 3,603 ac-ft per year, totaling 10,810 ac-ft per year for the West Bear Creek Unit (Reclamation et al. 2001b). Groundwater use at the refuge is not shown on Figure 3-23 because quantity and timing of use for the time period shown in the figure is unknown.

3.6.1.3 Surface Water Supplies and Infrastructure

Approximately 6,225 ac-ft of CVP water is conveyed by the San Luis CC, if available. The Exchange Contractors provided 20,000 ac-ft between April 1999 to February 2000 to meet Level 4 contract quantities (Reclamation et al. 2001b). An IDS system provides limited water movement around the refuge (Refuge staff 2002). Refuge managers consider the quality of delivered water adequate for refuge irrigation.

3.6.1.4 Groundwater Supplies and Infrastructure

Ten groundwater wells formerly were used as the property water supply when the area was managed as ranchland. When the land was transferred to the federal government, three of the ten wells were nonfunctional. At least two wells are capped with steel plates but not destroyed. Little information on these ten wells is available, according to refuge staff and records. Known well locations are shown on Figure 3-22, and well information is summarized in Table 3-9.

Irrigation and Production Wells. Only two West Bear Creek Unit wells, Well No. 3 (shown as WB-IW-01 on Figure 3-22) and Well No. 8 (WB-IW-02), are still active. They are used periodically throughout the year. The pumps run on diesel engines. No water meters are attached to existing wells. The refuge managers estimate that the wells are used 2 to 3 weeks per year for fall flooding. Each well produces 4 to 5 cfs (Refuge staff 2002). Several other nonfunctional wells may be located throughout the property, but have not been located. Groundwater is not used for domestic supply on the refuge.

Water Quality Data. The only available water quality data for West Bear Creek Unit wells are periodic, nonrecorded checks on the EC of the extracted water from the two active wells. Refuge staff indicate that EC is approximately 1,000 to 1,500 µmhos/cm. Water quality tests in 1992 yielded EC results between 2,000 and 2,500 µmhos/cm from these wells (Turner 1992a), which exceed Agricultural Water Quality Goals for salinity. No known analytical tests have been performed for boron or molybdenum within the boundaries of the refuge. Groundwater quality has not hindered groundwater use at the refuge in the past.

3.6.1.5 Local Groundwater Use

Groundwater is used occasionally in the area to supply agricultural irrigation and private duck clubs. No known domestic or municipal wells have been located within 1 mile of the refuge (DWR well logs on file).

3.6.1.6 Refuge Soil and Aquifer Conditions

The majority of the northern half of the refuge area is characterized by Alros clay loam. The southern half is dominated by either Kesterson-Edminster complex or Edminster-Kesterson complex. The soil is primarily mixed clay loam, which is saline-sodic in the subsoil and saline in the substratum. Confining clay is found in various areas of the refuge below the at-surface soils. The clay may be up to several feet deep (USDA 1990).

The permeability of Alros clay loam is low, in part because of sodium in the subsoil. Other areas have excess lime in the substratum. Available water capacity is moderate to high. This land is subject to ponding from December through March. The soils in the south have very slow permeability, and available water capacities are low to moderate (USDA 1990).

Groundwater levels near the West Bear Creek Unit are mostly shallow, deepening slightly east of the refuge unit. According to DWR monitoring data, water levels average between 2 and 10 feet bgs, with occasional declines during dry years. East of the refuge, groundwater levels average between 10 and 20 feet bgs according to DWR data. Groundwater levels in the area appear to have recovered to conditions prior to the drought in the 1970s (DWR 2003b).

Between 1 and 2 feet of subsidence has occurred in the vicinity of the refuge (DWR 2003a). Future subsidence may be possible if groundwater use substantially increases.

3.6.1.7 Operational Issues and Data Needs

Incremental Level 4 water made available to the West Bear Creek Unit is subject to wide fluctuations in cost and variable spot-market availability. It is also necessary to convey Level 4 water through the Delta. A more stable source of Incremental Level 4 water, both in terms of cost and reliability, would be beneficial to refuge water supply management. Approximately 33 percent of the refuge's water supply is Incremental Level 4.

The following data gaps were identified during the completion of this study:

- Thorough assessment of all refuge wells recommended.
- Confirmation of refuge groundwater quality conditions at different locations and at several different depths below ground surface, both above and below the Corcoran Clay. At a minimum, verify EC, TDS, boron, and molybdenum concentrations in groundwater to determine potential for deleterious effects on wildlife.
- Local aquifer conditions, including quarterly water-level data both on- and off-refuge, and data to estimate aquifer properties at the refuge.
- Aquifer parameters, such as hydraulic conductivity and thickness.
- Groundwater pumping records and schedules, both on and immediately surrounding the refuge.

Relative to the other refuges in this study, it was estimated that a "medium" level of data collection is required at the West Bear Creek Unit prior to recommending specific groundwater development projects.

3.6.2 Criteria Evaluation Summary

The West Bear Creek Unit received total Hydrologic Scores of +6 for Direct Use of groundwater and +4 for On-Refuge Conjunctive Use based on criteria matrix evaluation. Table 3-10 gives the specific criteria matrix and scores for this refuge.

Increased groundwater use may be feasible at this refuge. The refuge had positive infrastructure and groundwater quality scores. Two active wells are present on the refuge. As poor groundwater quality has been an issue regionally - specifically for EC, boron, and molybdenum - further water quality testing on the refuge would be recommended prior to groundwater development. Support and limitations to increased groundwater development are summarized below.

3.6.2.1 Support for Groundwater Development

- Two active wells are present on the refuge and used periodically. Several wells were used previously to meet a percentage of water demand.
- No known municipal or domestic wells have been identified within 1 mile of the refuge.
- Although little groundwater quality data are available, groundwater quality has not limited groundwater use in the past.
- Surface water is delivered reliably to the refuge and is therefore available for blending with groundwater, if necessary.

- It is necessary to convey Incremental Level 4 water through the Delta to serve the refuge.
- The cost of local water is high relative to the other refuges in the study. Cost and reliability is subject to spot-market variability.

3.6.2.2 Limitations to Groundwater Development

- Clay and clay loam surface soils primarily have low permeability and high water capacity and are not conducive to construction of recharge basins.
- Aquifer storage is not available. Current and historic groundwater levels are approximately equivalent.

3.6.3 Recommended Data Acquisition Activities

Prior to deciding if groundwater should be further developed on the refuge, the following data acquisition tasks are recommended:

- Conduct an inventory of all refuge wells, including date installed; physical well properties, including depth, operational status, operational deficiencies (i.e., broken or nonexistent pump, well collapse, etc.); and repair history. Photograph and collect GPS coordinates for the wells. Video-log wells which are active or may have benefit for sampling or rehabilitation. Survey the ground level elevation and the measuring point elevation of each well.
- Assess all ten refuge wells for potential testing. It is unlikely, given the age and probable lack of maintenance, that any but the two active wells will provide much usable information.
- Collect and analyze groundwater samples from the two active wells to confirm the previous indication of high water quality. Determine well depth, if possible, so that an estimation can be made whether the wells are producing from above or below the Corcoran Clay. Collect these samples during two seasons, such as summer and winter, to assess potential seasonal variations. Measure, at a minimum, general chemistry parameters and metals, including arsenic, boron, chromium, mercury, and nitrates.
- Conduct test hole drilling and sampling. Drill one or two test holes at locations to be determined after completion of the well inventory.
- Conduct one or two 72-hour aquifer tests at the existing irrigation wells to estimate groundwater potential at the refuge. Conduct these tests during a season in which the refuge is not irrigating. Use existing production wells where there are nearby inactive wells that can be monitored before and during the test, or install three dedicated monitoring wells near the tested wells to record water-level changes.
- Develop a groundwater budget for the refuge. Estimate groundwater level changes when pumping under wet-, normal-, and dry-year conditions.
- Install well meters at all active, unmetered refuge wells; monitor water levels quarterly; and collect routine water quality samples from active wells to develop a database of groundwater use and conditions at refuges where groundwater is used. Maintain

collected data in a format supportable and usable by the refuge and refuge managing agencies.

3.6.4 Potential Projects

3.6.4.1 Direct Use

Increased groundwater use may be considered at this refuge. Two active wells are present, although little information is known about the wells. Testing is required to verify aquifer, water quality, and existing well conditions prior to groundwater development to supplement Level 4 water supplies. If testing indicates positive conditions, increased use of the active wells or rehabilitation of inactive wells is possible.

It is recommended that existing inactive or non-functional wells without potential for rehabilitation or use as a monitoring well be destroyed according to state requirements to prevent potential cross-communication between groundwater located above and below the Corcoran Clay.

3.6.4.2 On-Refuge Conjunctive Use

On-refuge conjunctive use may be feasible at this refuge if further evaluation of soil and aquifer conditions allow.

3.6.4.3 Off-Refuge Conjunctive Use

West Bear Creek is not within the sphere of influence of a groundwater management plan or ordinance. At this time, no off-refuge conjunctive use projects have been identified for potential partnership.

TABLE 3-9
West Bear Creek Unit Well Information[a]
Evaluation of Groundwater Potential for Incremental Level 4 Refuge Water Supply

GIS Well Number[b]	Common Well Name	Well Status[c]	2002 Yield (ac-ft)	Year Installed	Depth (ft)	Screen Interval (bgs)	Well Output (gpm)	Well Log?	Water Quality Data?	Comments
WB-IW-01	WBC 3	Active					1,346–1,795	N	Y	Used 2–3 weeks per year for fall flooding. No meter. Pumps on diesel generator.
WB-IW-02	WBC 6	Active					1,795–2,244	N	Y	Used 2–3 weeks per year for fall flooding. No meter. Pumps on diesel generator.
WB-UN-01	North Well	Destroyed			180			N	N	Destroyed in September 1997.
WB-UN-02	Well 1	Destroyed			178			N	N	Destroyed in September 1997.
WB-UN-03	Well 2	Destroyed			210			N	N	Destroyed in September 1997.
WB-UN-04	South Well	Destroyed			260			N	N	Destroyed in August 1997.
7S10E35-1		Unknown		1991	141	95–141		Y	N	Domestic well drilled for private owner.
7S10E35-2		Unknown		1980	184	89–174[d]		Y	N	Irrigation well drilled by former property owner. Specific screened intervals: 89–96, 108–126, 151–174.
		Unknown		1980	188	95–172[d]	2,264	Y	N	Irrigation well drilled within current refuge boundary by former property owner. Exact location unknown. Specific screened intervals: 95–133, 155–172.
		Unknown		1980	196	120–174	1,880	Y	N	Irrigation well drilled within current refuge boundary by former property owner. Exact location unknown.
		Unknown		1980	184	89–175[d]	2,268	Y	N	Irrigation well drilled within current refuge boundary by former property owner. Exact location unknown. Specific screened intervals: 89–99, 111–128, 140–175.
		Unknown		1981	156	68–144	2,520	Y	N	Irrigation well drilled within current refuge boundary by former property owner. Exact location unknown.
		Unknown		1981	176	95–172[d]		Y	N	Irrigation well drilled within current refuge boundary by former property owner. Exact location unknown. Specific screened intervals: 95–133, 155–172.

Notes:
[a] Based on data compiled from well logs, test records, communication with refuge staff (2002), and other previous documentation. Well locations are shown on Figure 3-22. On-refuge wells only are included in this table, although the GIS includes known wells within 1 mile of the refuge.
[b] Well type is indicated by the middle two letters of the GIS well number: IW = irrigation well, DW = domestic well, MW = monitoring well, TW = test well, and UN = unknown.
[c] Designation refers to the physical well only, not water quality issues. Designations are: *active* (currently operated), *inactive* (capable of operating, but currently is not), *nonfunctional* (cannot operate in current physical state), *destroyed* (well has been lost, abandoned, or filled), or *unknown* (no information regarding status is available).
[d] See Comments for specific screened intervals within the range shown.
Blank fields indicate that no information is available.

TABLE 3-10
West Bear Creek Unit Evaluation
Evaluation of Groundwater Potential for Incremental Level 4 Refuge Water Supply

	Criteria	Scoring Scale	Appl.[b]	Score	Refuge Score Justification
Surface[a]	Do surface water bodies exist that could be affected by increased groundwater use?	+1 = no 0 = to some degree –1 = yes, surface water bodies could be affected	D,N	-1	There are several duck ponds located in the southern part of the refuge. The San Joaquin River and Salt Slough form refuge boundaries.
Water Supplies and Infrastructure	Has groundwater been used previously at the refuge for ponds or irrigation?	+1 = yes, used successfully to meet at least 20 percent of annual refuge water demands 0 = yes, used to meet less than 20 percent (or unknown) of annual refuge water demands. –1 = no, has not been used	D,N	0	Several wells were previously used to meet a portion of water demand. Two wells are still active and used periodically, particularly during fall flood-up. Estimated contribution to total supply is unknown at this time.
	Do wells exist on the refuge?	+1 = yes, active wells 0 = yes, inactive or nonfunctional wells –1 = yes, destroyed wells, or no wells exist on the refuge	D,N	+1	Two active wells are present on the refuge. At least two other wells have been destroyed. Ten wells were formerly used prior to refuge acquisition, but little information is known regarding the fate of these wells.
	Does existing internal distribution system (IDS) support groundwater use?	+1 = water can move extensively around the refuge with existing IDS 0 = the IDS enables limited water movement within the refuge –1 = an IDS does not exist on the refuge or water flow relies exclusively on gravity	D,N	0	IDS allows limited water movement within the refuge.
Local Groundwater Use	Is groundwater used for agriculture or duck clubs in the immediate vicinity of the refuge?	+1 = groundwater is not used; or groundwater is minimally used, but use is not constrained 0 = groundwater is used in the area –1 = groundwater is not used due to physical or environmental constraints or is extensively used in the vicinity	D,N	0	Groundwater is occasionally used in the area for irrigation and to supply private duck clubs.
	Does municipal or domestic supply exist near the refuge?	+1 = no known domestic or municipal wells are located within 1 mile of the refuge 0 = municipal or domestic wells are likely located within 1 mile of the refuge –1 = municipal or domestic wells are located within 1 mile of the refuge	D,N	+1	No known domestic or municipal wells have been located within 1 mile of the refuge.
Soil and Hydrogeology	Are at-surface soils conducive to groundwater recharge?	+1 = soils are sandy or are reported to percolate well 0 = soils are silty or are reported to have some infiltration –1 = soils are clayey or are reported to hold water well	N	-1	The northern half of the refuge is dominated by Alros clay loam and gray clay. Permeability is slow and water capacity is high. In the south, Kesterson sandy loam and Edminster loam are common. These soils have slow permeability and low-to-moderate water conductivity.
	Could recharge basins be developed if surface soils were removed?	+1 = confining soil less than 2 feet thick 0 = confining soil 5 to 7 feet thick –1 = confining soil greater than 7 feet thick	N	0	Confining clay is found in various areas of the refuge below the at-surface soils, up to several feet deep.
	Has subsidence occurred at or in the immediate vicinity of the refuge?	+1 = no 0 = yes, less than 2 feet –1 = yes, more than 2 feet	D,N	0	Between 1 and 2 feet of subsidence has occurred in the refuge vicinity.
	Does significant potential for subsidence exist if groundwater use is increased at the refuge?	+1 = minimal potential for subsidence 0 = some potential for subsidence –1 = significant potential for subsidence	D,N	0	Future subsidence is possible if groundwater use substantially increases.
	Is aquifer storage available in the subbasin?	+1 = yes, current water levels are greater than 30 feet lower than historic levels 0 = some, current water levels are between 10 and 30 feet lower than historic levels –1 = no	N	-1	Water levels in the refuge vicinity seem to have recovered to pre-1970s levels.

Notes:
a Surface Features
b Application to Approach: D = Direct Use, N = On-Refuge Conjunctive Use

continued on next page

TABLE 3-10
West Bear Creek Unit Evaluation
Evaluation of Groundwater Potential for Incremental Level 4 Refuge Water Supply

	Criteria	Scoring Scale	Appl.[b]	Score	Refuge Score Justification
Water Quality	Have groundwater quality conditions hindered groundwater use in the past?	+1 = no 0 = data are not available –1 = yes	D,N	+1	Water quality data are not extensively available; however, poor groundwater quality has not hindered groundwater use in the past.
	Do adverse groundwater quality conditions exist in the subbasin?	+1 = no 0 = potential –1 = yes	D,N	0	Regionally, EC, boron, and molybdenum have been high, but no tests were performed for boron or molybdenum within the boundaries of West Bear Creek. Periodic, nonrecorded checks on the EC of extracted water have allowed refuge staff to estimate EC at 1500 µmhos/cm.
	Is surface water available to enable blending of lower quality groundwater to meet proposed refuge standards?	+1 = yes 0 = during portions of the year –1 = no	D,N	+1	Delivery is available year-round from the San Luis CC. Other Exchange Contractors have also provided water.
	Do groundwater conditions exceed USEPA Freshwater Aquatic Life Standards or Agricultural Water Quality Goals for multiple parameters?	+1 = no 0 = yes, two parameters, or no water quality testing has been conducted –1 = yes, three or more parameters	D,N	0	Water quality standards have not been exceeded for EC at the domestic well; however, no other constituent test results were available.
	Is refuge land use management compatible with seasonally or annually variable water quality from different sources?	+1 = yes 0 = some potential compatibility problems may exist –1 = no	D,N	+1	Both groundwater and delivered water (higher quality) are currently used for wetland management. Groundwater is only used to a limited extent.
	Does groundwater quality meet drinking-water standards (i.e., can it be used for refuge domestic supply)?	+1 = yes it is used, no treatment is necessary 0 = yes it is used, but some treatment is necessary for potable use; or it is not used for unknown reasons –1 = no, it is not used because of adverse water quality conditions	D	0	Groundwater is not used for domestic supply on the refuge; however, there is no evidence to show that it could not be used.
Operational Issues/Constraints	Does a significant percentage of total refuge water supply consist of "Incremental Level 4" water?	+1 = yes, 54% to 79% of total water supply is Incremental Level 4 0 = somewhat, 27% to 53% of total water supply is Incremental Level 4 –1 = minor, 0% to 26% of total water supply is Incremental Level 4	D,N	0	Approximately 33 percent of the water supply for the West Bear Creek Unit consists of Incremental Level 4 water.
	Is the cost of local water high or low relative to the other refuges in this study?	+1 = costs may fluctuate highly or are subject to spot-market variability or price spikes –1 = costs are relatively stable and subjectivity to spot-market variability is low	D,N	+1	Incremental Level 4 water made available to West Bear Creek is subject to wide fluctuations in cost and variable spot-market availability.
	Is it necessary to convey Incremental Level 4 water through the Delta for refuge supply?	+1 = yes, Incremental Level 4 water must be conveyed through the Delta –1 = no, conveyance of Incremental Level 4 water through the Delta is not necessary	D,N	+1	Incremental Level 4 water must be conveyed through the Delta given current water supply sources.
Data Needs	Are there significant data needs to address prior to groundwater development?	+1 = no, data needs regarding refuge groundwater conditions are minor 0 = somewhat, some data are required prior to increasing groundwater development –1 = yes, significant data must be collected as there is little or no existing data	D,N	0	Some data are required prior to recommending increased groundwater development.
			Total Direct Use Score =	**+6**	
			Total On-Refuge Conjunctive Use Score =	**+4**	

Notes:
a Surface Features

b Application to Approach: D = Direct Use, N = On-Refuge Conjunctive Use

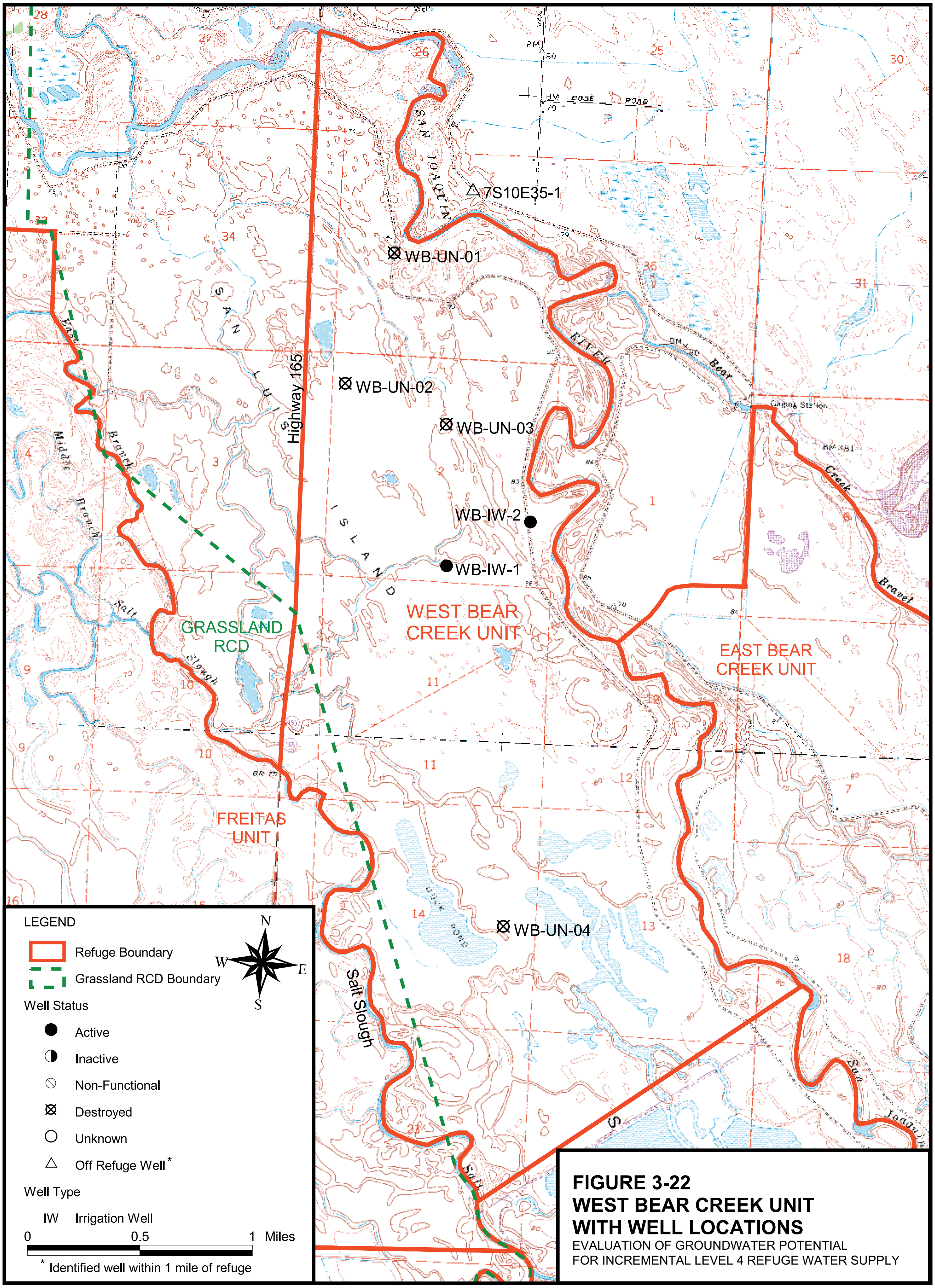

FIGURE 3-22
WEST BEAR CREEK UNIT
WITH WELL LOCATIONS
EVALUATION OF GROUNDWATER POTENTIAL
FOR INCREMENTAL LEVEL 4 REFUGE WATER SUPPLY

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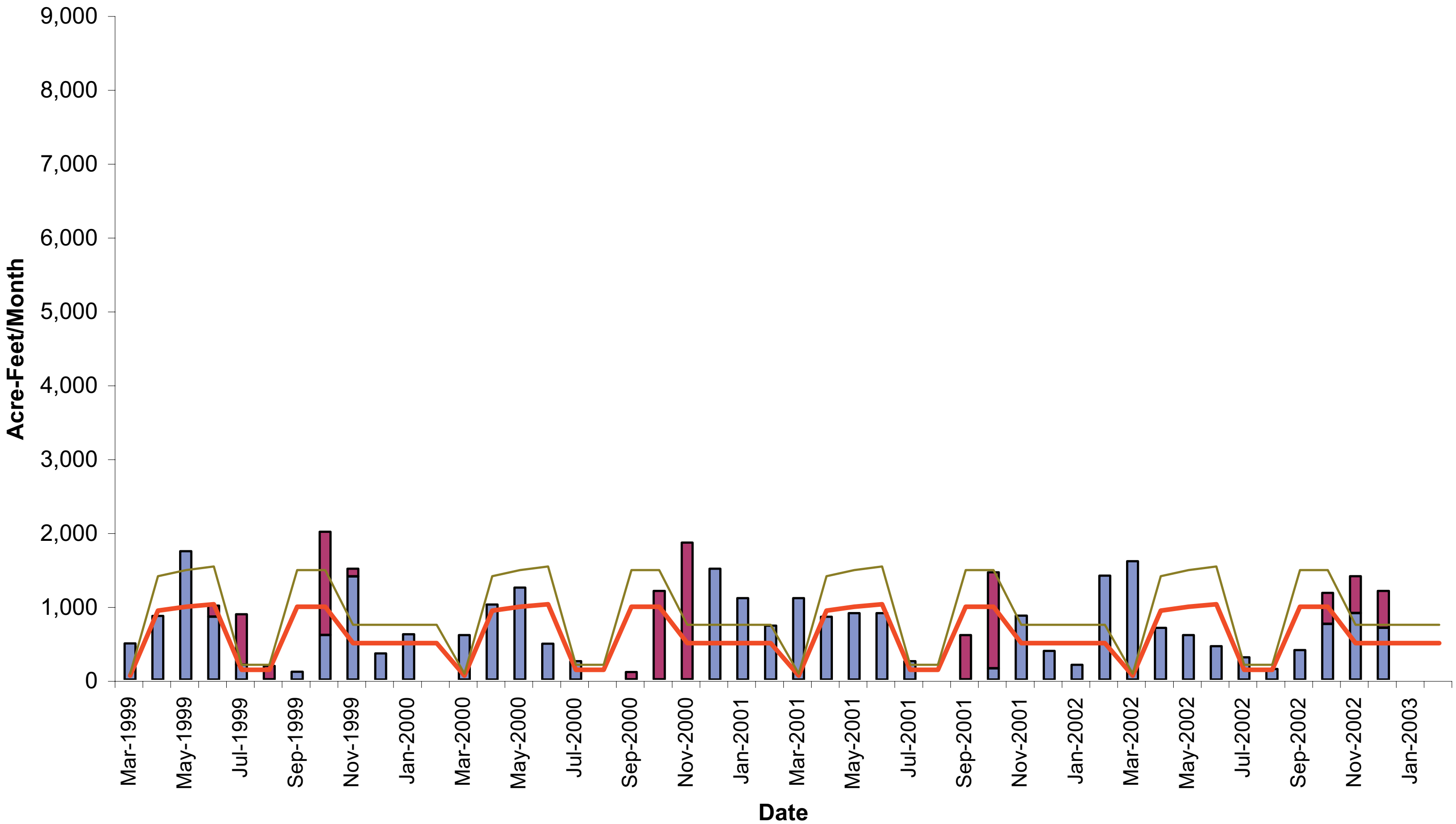

Note: Level 2 and Total Level 4 contract quantities are those indicated in Reclamation 1989 and Reclamation el al. 1989. Volumes indicated may not reflect current monthly management schedules and are shown to indicate an approximate monthly breakdown for management purposes. Total annual contract quantities may be scheduled based on availability, at the refuge manager’s discretion.

FIGURE 3-23
1999-2002 WEST BEAR CREEK NWR WATER DELIVERIES
EVALUATION OF GROUNDWATER POTENTIAL
FOR INCREMENTAL LEVEL 4 REFUGE WATER SUPPLY

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3.7 San Luis Unit Refuge Assessment (San Luis NWR Complex)

County: Merced
Basin / Subbasin: San Joaquin Valley Groundwater Basin / Delta-Mendota Subbasin
Level 2 / Incremental Level 4: 19,000 ac-ft / 0 ac-ft
2003 Acreage: 7,430
CVP Water Conveyors: Central California ID, Grassland WD, San Luis CC
Water District Service Area: None
Applicable Groundwater Management Regulations: None

The San Luis Unit is located 12 miles northwest of the City of Los Banos, just east of SR 165 and south of SR 140 (Figure 3-24). The refuge area borders Salt Slough and the Salt Slough Unit on the west. The San Joaquin River forms the eastern border. The refuge also borders the West Bear Creek Unit to the north, the East Bear Creek Unit to the northeast, and a portion of Grassland State Park in the northwest corner.

3.7.1 Hydrogeologic Assessment

3.7.1.1 Habitat Goals, Land Management, and Surface Features

The San Luis Unit is managed as part of the San Luis NWR Complex. This 7,430-acre refuge unit was established under the Migratory Bird Conservation Act in 1966. The purpose of the refuge is to provide nesting and wintering habitat for waterfowl and other migratory birds and endangered species, and other wildlife. The primary habitats are wetland and native grassland (Reclamation et al. 2001b).

Wolfsen Road crosses the southern refuge boundary on the westside and continues as an unpaved road through the refuge. Several unpaved roads cross the refuge, as well as canals with names such as "Island Canal A," "Island Canal D," and so on. Deadmans Slough runs northwest-southeast, for the several large duck ponds covering a large percentage of the northern half of the refuge unit. San Luis Drain No. 1 also runs northwest-southeast, but is not used for any refuge water conveyance; currently, it conveys agricultural drain water to a grower south of the refuge.

3.7.1.2 Identified Water Supply Contract Quantities

Figure 3-25 shows the Level 2 water contract quantities and the actual water deliveries to the refuge from 1999 through 2001. The Level 2 water supply contract quantity is 19,000 ac-ft per year. There is no Incremental Level 4 water contract quantity. Groundwater use is not included in this figure because no information is available for operational timing and quantity of water produced.

3.7.1.3 Surface Water Supplies and Infrastructure

CVP surface water is conveyed to the refuge by diversions from the Delta-Mendota Canal. Riparian rights also allow water to be directly diverted from Salt Slough. The slough is a permanent stream that flows along the western boundary of the refuge and eventually into the San Joaquin River. Most of this water originates from operational spills or agricultural return flows from Grassland WD, San Luis CC, and Central California ID (Reclamation et al. 2001b).

A significant part of refuge water drains into Deadmans Slough. Two lift pumps are used to recirculate water from the slough and back throughout the refuge. Water is also lift-pumped from the San Luis Unit to the West Bear Creek Unit. Water in the refuge flows in a northwesterly direction and is conveyed either by gravity flow through canals or by lift-pumps, according to refuge staff.

3.7.1.4 Groundwater Supplies and Infrastructure

Four active irrigation wells are present on the refuge. These wells are used periodically to supplement delivered water supply. Their locations are shown on Figure 3-24, and well information is summarized in Table 3-11.

Test Wells. Reclamation drilled two test wells, SLT-1 (SL-TW-01) and SLT-2 (SL-TW-02), near two of the Service test wells to collect discrete water quality samples. SLT-1 (SL-TW-01) was drilled adjacent to Service Test Well 3, and SLT-2 (SL-TW-02) was drilled adjacent to Service Test Well 1.

Irrigation and Production Wells. Irrigation Wells No. 1 (SL-IW-01), 2 (SL-IW-02), 3 (SL-IW-03), and 4 (SL-IW-04) are located at or near the sites of four Service test wells. No wells are used for domestic supply on the refuge.

Irrigation Well No. 1 (SL-IW-01), located in the southeast corner of the refuge, discharges to the wetland or adjacent canal. Well No. 2 (SL-IW-02), located in the northeastern portion of the refuge, produces water with a high EC (4,000 to 7,400 µmhos/cm) and is used only if necessary (Turner 1992a). Well No. 3 (SL-IW-03), located at the southern border of the refuge is active and discharges into the adjacent wetland. The groundwater from Well No. 4 (SL-IW-04), located in the northeast corner of the refuge (but which may have been destroyed), produces low-quality water according to refuge managers and is also used only if necessary. The wells are not metered.

Groundwater has not been used extensively for refuge water supply because its cost is higher than delivered surface water and because of concern about salt buildup. If groundwater use is required, on- and off-refuge canals are used to distribute the water. Off-refuge canals used for distributing pumped groundwater occasionally go offline for maintenance in the fall and winter months, making some groundwater unavailable when water is needed most for refuge flooding (Refuge staff 2002).

Water Quality Data. Water quality data from two of the test wells drilled prior to irrigation well installation are summarized in Table 3-12. These data show significant variability in water quality and indicate that several clay intervals locally affect water quality conditions. At test well SLT-1 (SL-TW-01), groundwater encountered above the Corcoran Clay, at about 165 feet bgs, is of significantly higher quality than groundwater below the clay. Water samples from above the Corcoran Clay had EC values of 849 and 335 µmhos/cm, but below the clay had an EC of 6,180 µmhos/cm (Turner 1992a), exceeding Agricultural Water Quality Goals.

Water quality data from SLT-2 (SL-TW-02) also indicated vertical variability in EC and TDS. Data from this well indicate that an interval of low-quality water (EC ranging from 6,000 to

7,000 µmhos/cm) between 120 to 200 feet bgs is present below the higher-quality, shallowest groundwater near the ground surface (50 to 70 feet bgs). This higher quality water ranges between 1,000 to 3,000 µmhos/cm. Below the Corcoran Clay (about 300 feet bgs), EC ranges from 1,700 to 4,700 µmhos/cm and increases with depth (Turner 1992a). This is contrary to the usual vertical water quality variations above and below the Corcoran Clay. These variations may indicate local clay intervals may be acting as barriers to vertical groundwater flow.

Boron and molybdenum have been detected at both test wells (1992 testing). Boron ranges from less than 1.0 mg/L in the shallow aquifer (above 150 feet bgs) to over 2.0 mg/L below the Corcoran Clay (300 feet bgs). Molybdenum levels are highly variable, ranging from 0.006 to 0.05 mg/L (Turner 1992a). These levels exceed Freshwater Aquatic Life Standards and/or Agricultural Water Quality Goals.

3.7.1.5 Local Groundwater Use

Groundwater is used for agricultural purposes in some areas near the refuge. The San Luis CC has several deep wells within their district near the San Luis Unit southern boundary (Zahm 1992). Groundwater is used occasionally to supply private duck clubs.

3.7.1.6 Refuge Soil and Aquifer Conditions

The San Luis Unit consists mainly of Turlock sandy loam, Kesterson sandy loam, Edminster loam, and Elnido sandy loam. Soils are characterized by Turlock sandy loam throughout significant stretches of habitat, primarily in the northern half of the refuge area. Kesterson sandy loam is located in the northeast, south-central, and southeast portions of the refuge area. A central stretch of refuge area is characterized by poorly drained Edminster loam. Wet Elnido sandy loam is found along the western and southwestern areas (USDA 1990).

The soil is greater than 8 feet deep and poorly drained. Permeability is generally slow to very slow. Water capacity is low, and runoff typically ponds. Most soil types in this area have a seasonally high water table.

Small areas along Salt Slough are moderately permeable. Elnido sandy loam has moderately rapid permeability and moderate available water capacity. The soil is subject to brief ponding after storms, but does not typically support standing water (USDA 1990).

DWR groundwater data indicate shallow water levels throughout the refuge and in the area surrounding it. Depth to water ranges from 5 to 15 feet bgs, with little seasonal variation. Water levels in the vicinity appear to have recovered to conditions prior to the drought in the 1970s (DWR 2003b).

Between 1 and 2 feet of subsidence has occurred in the vicinity of the refuge (DWR 2003a). Future subsidence may be possible if groundwater use substantially increases.

3.7.1.7 Operational Issues and Data Needs

The refuge does not depend on Level 4 water supplies for wetland management. The San Luis Unit does not have an Incremental Level 4 contract quantity.

Local water in the region is subject to wide fluctuations in cost and variable spot-market availability. Developing groundwater at the refuge could be beneficial if it provides a reliable source of local and cost-effective Incremental Level 4 water.

The following data gaps were identified during the completion of this study:

- Thorough assessment of the refuge irrigation wells to assess well conditions.
- Confirmation of refuge groundwater quality conditions at irrigation and test wells at depths both above and below the Corcoran Clay. In particular, verify salinity, TDS, boron, and molybdenum concentrations in groundwater.
- Local aquifer conditions, including quarterly water-level data both on- and off-refuge, and a safe yield determination.
- Aquifer parameters, such as hydraulic conductivity and thickness.
- Groundwater pumping records and schedules, both within (if applicable) and immediately surrounding the refuge.

Relative to the other refuges in this study, it was estimated that a “moderate” level of data collection is required at the San Luis Unit prior to recommending specific groundwater development projects.

3.7.2 Criteria Evaluation Summary

The San Luis Unit received total Hydrogeologic Scores of zero for Direct Use of groundwater and –1 for On-Refuge Conjunctive Use based on criteria matrix evaluation. Table 3-13 shows the criteria matrix and scores specific to this refuge.

Existing groundwater and conveyance infrastructure could be used to further develop or increase groundwater use at this site if groundwater quality testing supports the action. The land within the refuge boundaries likely is not conducive to groundwater banking by means of recharge basins, however. Support and limitations to increased groundwater development are summarized below.

3.7.2.1 Support for Groundwater Development

- Four active irrigation wells and several test wells are present on the refuge.
- A developed IDS allows water to move extensively throughout the refuge, supporting integration of groundwater infrastructure with current water management. Water is distributed through canals or pumps.
- Surface water is delivered reliably to the refuge and is therefore available for blending with groundwater, if necessary. The San Luis Canal is accessible to the refuge.
- The cost of local water is high relative to the other refuges in the study. Cost and reliability is subject to spot-market variability.

3.7.2.2 Limitations to Groundwater Development

- The San Luis CC has several deep wells within their district which are close to the southern portion of the refuge.

- Although water quality has not been fully evaluated, Freshwater Aquatic Life Standards and/or Agricultural Water Quality Goals have been exceeded at various locations on the refuge for boron, EC, molybdenum, selenium, and TDS.
- Aquifer storage is not available. Current and historic groundwater levels are approximately equivalent and groundwater occurs at relatively shallow depths, ranging from 5 to 15 feet bgs.
- The San Luis Unit does not have an Incremental Level 4 water contract quantity.
- Significant data collection is necessary prior to recommending groundwater development.

3.7.3 Recommended Data Acquisition Activities

Although the San Luis Unit does not have identified Incremental Level 4 contract quantity, collection of routine groundwater data could facilitate understanding of groundwater conditions in the area and support future groundwater investigation conducted at the refuge. Recommended data acquisition activities include:

- Install well meters at all active, unmetered refuge wells; monitor water levels quarterly; and collect routine water quality samples from active wells to develop a database of groundwater use and conditions at refuges where groundwater is used. Maintain collected data in a format supportable and usable by the refuge and refuge managing agencies.
- Reclamation test well water quality data indicate that there may be a lens or interval of water with EC values of less than 2,000 μmhos/cm. Establish the water quality of the existing irrigation wells, particularly the well screened above the Corcoran Clay, by conducting at least two complete rounds of well sampling at the existing production wells located at the refuge. Collect these samples during two seasons, such as summer and winter, to assess potential seasonal variations. Measure, at a minimum, general chemistry parameters and metals, including arsenic, boron, molybdenum, selenium, and nitrates.
- Coordinate with San Luis CC regarding local groundwater conditions and data available from their wells

3.7.4 Potential Projects

3.7.4.1 Direct Use

Although active existing wells are present on the refuge, no increased groundwater development to supplement Level 4 water supplies is recommended for the San Luis Unit at this time, as the refuge has no Incremental Level 4 contract quantity.

3.7.4.2 On-Refuge Conjunctive Use

Groundwater recharge using surface ponds could be considered further at this refuge if data indicate that groundwater above the Corcoran Clay is of higher quality over a wide enough area, and that soil conditions would enable surface recharge to reach this interval.

3.7.4.3 Off-Refuge Conjunctive Use

Eastside WD, located to the northeast of the San Luis Unit, has recently received funding for a conjunctive use study project. The project consists of developing preliminary plans for several conjunctive water management alternatives that have the potential of improving water supply reliability, protecting water quality, and providing environmental benefits. Locations and facilities necessary to reduce overdraft will be identified. The project potentially could provide a groundwater partnership opportunity based on its location to the San Luis NWR Complex. Further analysis is required for information on existing off-refuge conveyance facilities that could provide outside water to the refuge units within the San Luis NWR Complex.

TABLE 3-11
San Luis Unit Well Information[a]
Evaluation of Groundwater Potential for Incremental Level 4 Refuge Water Supply

GIS Well Number[b]	Common Well Name	Well Status[c]	2002 Yield (ac-ft)	Year Installed	Depth (ft)	Screen Interval (bgs)	Well Output (gpm)	Well Log?	Water Quality Data?	Comments
SL-TW-01	SLR-1 or Test Well 3 or SLT-1	Destroyed		1991	220	85–200[d]	35	Y	Y	Specific screened intervals: 85–105, 130–150, 180–200.
SL-TW-02	SLR-2 or SLT-2 (or Test Well 2)	Unknown		1991	704	50–555[d]	35	Y	Y	Deepened in 1992 from 220 to 705 feet. Specific screened intervals: 50–70, 118–138, 170–190, 390–410, 300–320, 435–510, 535–555.
SL-TW-03	SL-3 or Test Well 4	Unknown		1991	220			Y	N	
SL-TW-04	SL-4 (or Test Well 1)	Unknown		1991	220			Y	N	
SL-IW-01	Deep Well 1	Active						N	N	Drilled at SL-TW-01 location. Discharges to the wetland or adjacent canal.
SL-IW-02	Deep Well 2	Active						N	N	Drilled at SL-TW-02 location. Used only if necessary.
SL-IW-03	Deep Well 3	Active						N	N	Drilled at SL-TW-03 location. Discharges into the adjacent wetland.
SL-IW-04	Deep Well 4	Active?						N	N	Drilled at SL-TW-04 location. Used only if necessary.

Notes:

[a] Based on data compiled from well logs, test records, communication with refuge staff (2002), and other previous documentation. Well locations are shown on Figure 3-24. On-refuge wells only are included in this table, although the GIS includes known wells within 1 mile of the refuge.

[b] Well type is indicated by the middle two letters of the GIS well number: IW = irrigation well, DW = domestic well, MW = monitoring well, TW = test well, and UN = unknown.

[c] Designation refers to the physical well only, not water quality issues. Designations are: *active* (currently operated), *inactive* (capable of operating, but currently is not), *nonfunctional* (cannot operate in current physical state), *destroyed* (well has been lost, abandoned, or filled), or *unknown* (no information regarding status is available).

[d] See Comments for specific screened intervals within the range shown.

Blank fields indicate that no information is available.

TABLE 3-12
San Luis Unit Water Quality Data (1992)
Evaluation of Groundwater Potential for Incremental Level 4 Refuge Water Supply

GIS Well Number	Sampled Interval (feet)	EC (µmhos/cm)	Boron (mg/L)	Selenium (µg/L)	Molybdenum (mg/L)	TDS (mg/L)
SL-TW-01	85–105	849	0.11	ND	ND	470
	130–150	335	0.099	ND	0.0059	210
	180–200	6,180	1.1	ND	0.03	3,600
SL-TW-02	50–70	4,390	0.85	ND	0.036	2,400
	118–138	7,370	0.65	ND	0.017	4,100
	170–190	7,750	1.0	2.6	0.022	4,400
	300–320	1,720	2.3	ND	0.049	1,000
	390–410	2,490	2.1	ND	0.039	1,500
	435–455	2,940	2.1	ND	0.022	1,600
	490–510	3,800	2.2	ND	0.019	2,200
	535–555	4,740	2.1	ND	0.021	2,600

Source: Turner 1992a.

Notes:

Well locations are shown on Figure 3-24.
ND = not detected

TABLE 3-13
San Luis Unit Evaluation
Evaluation of Groundwater Potential for Incremental Level 4 Refuge Water Supply

	Criteria	Scoring Scale	Appl.[b]	Score	Refuge Score Justification
Surface[a]	Do surface water bodies exist that could be affected by increased groundwater use?	+1 = no 0 = to some degree –1 = yes, surface water bodies could be affected	D,N	-1	Several large duck ponds cover a significant percentage of the northern half of the refuge unit. Salt Slough borders the refuge on the west.
Water Supplies and Infrastructure	Has groundwater been used previously at the refuge for ponds or irrigation?	+1 = yes, used successfully to meet at least 20 percent of annual refuge water demands 0 = yes, used to meet less than 20 percent (or unknown) of annual refuge water demands. –1 = no, has not been used	D,N	0	Groundwater has been used at the refuge, but the exact contribution to total supply is unknown.
	Do wells exist on the refuge?	+1 = yes, active wells 0 = yes, inactive or nonfunctional wells –1 = yes, destroyed wells, or no wells exist on the refuge	D,N	+1	Four active irrigation wells are present on the refuge. Test wells are also present.
	Does existing internal distribution system (IDS) support groundwater use?	+1 = water can move extensively around the refuge with existing IDS 0 = the IDS enables limited water movement within the refuge –1 = an IDS does not exist on the refuge or water flow relies exclusively on gravity	D,N	+1	Several canals cross the refuge, including Deadmans Slough and San Luis Drain No. 1. Water is distributed through the refuge via canals or pumps. Existing wells typically discharge to an adjacent field or canal.
Local Groundwater Use	Is groundwater used for agriculture or duck clubs in the immediate vicinity of the refuge?	+1 = groundwater is not used; or groundwater is minimally used, but use is not constrained 0 = groundwater is used in the area –1 = groundwater is not used due to physical or environmental constraints or is extensively used in the vicinity	D,N	0	Groundwater is occasionally used in the area for agricultural irrigation and to supply private duck clubs.
	Does municipal or domestic supply exist near the refuge?	+1 = no known domestic or municipal wells are located within 1 mile of the refuge 0 = municipal or domestic wells are likely located within 1 mile of the refuge –1 = municipal or domestic wells are located within 1 mile of the refuge	D,N	-1	The San Luis CC has several deep wells within their district which are close to the southern portion of the refuge.
Soil and Hydrogeology	Are at-surface soils conducive to groundwater recharge?	+1 = soils are sandy or are reported to percolate well 0 = soils are silty or are reported to have some infiltration –1 = soils are clayey or are reported to hold water well	N	0	Surface soils are typically sandy loam, followed by clay loam at greater depths in some areas. The permeability is low. In some areas in the western side of the refuge, wet Elnido sandy loam has moderately rapid permeability and moderate water capacity.
	Could recharge basins be developed if surface soils were removed?	+1 = confining soil less than 2 feet thick 0 = confining soil 5 to 7 feet thick –1 = confining soil greater than 7 feet thick	N	0	In most areas, with the exception of the areas dominated by Elnido sandy loam, confining soil of clay loam extends several feet in depth.
	Has subsidence occurred at or in the immediate vicinity of the refuge?	+1 = no 0 = yes, less than 2 feet –1 = yes, more than 2 feet	D,N	0	Between 1 and 2 feet of subsidence has occurred in the refuge vicinity.
	Does significant potential for subsidence exist if groundwater use is increased at the refuge?	+1 = minimal potential for subsidence 0 = some potential for subsidence –1 = significant potential for subsidence	D,N	0	Future subsidence is possible if groundwater use substantially increases.
	Is aquifer storage available in the subbasin?	+1 = yes, current water levels are greater than 30 feet lower than historic levels 0 = some, current water levels are between 10 and 30 feet lower than historic levels –1 = no	N	-1	Water levels in the refuge vicinity seem to have recovered to pre-1970s levels.

Notes:

continued on next page

a Surface Features

b Application to Approach: D = Direct Use, N = On-Refuge Conjunctive Use

TABLE 3-13
San Luis Unit Evaluation
Evaluation of Groundwater Potential for Incremental Level 4 Refuge Water Supply

	Criteria	Scoring Scale	Appl.[b]	Score	Refuge Score Justification
Water Quality	Have groundwater quality conditions hindered groundwater use in the past?	+1 = no 0 = data are not available –1 = yes	D,N	0	Concern about salt buildup is one reason groundwater has not been used extensively on the refuge.
	Do adverse groundwater quality conditions exist in the subbasin?	+1 = no 0 = potential –1 = yes	D,N	-1	Water quality tests performed in the 1990s showed EC varying between 335 and 7,750 µmhos/cm. Boron tests showed levels up to 2.3 mg/L. Molybdenum was also detected up to 0.05 mg/L. Lenses of good water quality can be seen but the location of these has not been verified.
	Is surface water available to enable blending of lower quality groundwater to meet proposed refuge standards?	+1 = yes 0 = during portions of the year –1 = no	D,N	+1	The DMC is available to convey water to the refuge year-round. According to refuge staff, this water is not always of high quality and may have elevated EC.
	Do groundwater conditions exceed USEPA Freshwater Aquatic Life Standards or Agricultural Water Quality Goals for multiple parameters?	+1 = no 0 = yes, two parameters, or no water quality testing has been conducted –1 = yes, three or more parameters	D,N	-1	Aquatic Life Standards and/or Agricultural Water Quality Goals have been exceeded at various locations for all constituents tested, including boron, EC, molybdenum, selenium, and TDS.
	Is refuge land use management compatible with seasonally or annually variable water quality from different sources?	+1 = yes 0 = some potential compatibility problems may exist –1 = no	D,N	+1	Both groundwater and delivered water are currently used for wetland management. Groundwater is only used to a limited extent.
	Does groundwater quality meet drinking-water standards (i.e., can it be used for refuge domestic supply)?	+1 = yes it is used, no treatment is necessary 0 = yes it is used, but some treatment is necessary for potable use; or it is not used for unknown reasons –1 = no, it is not used because of adverse water quality conditions	D	0	Groundwater is not used for domestic supply on the refuge; however, there is no evidence to show that it could not be used.
Operational Issues/Constraints	Does a significant percentage of total refuge water supply consist of "Incremental Level 4" water?	+1 = yes, 54% to 79% of total water supply is Incremental Level 4 0 = somewhat, 27% to 53% of total water supply is Incremental Level 4 –1 = minor, 0% to 26% of total water supply is Incremental Level 4	D,N	-1	The San Luis Unit does not have an Incremental Level 4 contract quantity.
	Is the cost of local water high or low relative to the other refuges in this study?	+1 = costs may fluctuate highly or are subject to spot-market variability or price spikes –1 = costs are relatively stable and subjectivity to spot-market variability is low	D,N	+1	Local water in this region is subject to wide fluctuations in cost and variable spot-market availability.
	Is it necessary to convey Incremental Level 4 water through the Delta for refuge supply?	+1 = yes, Incremental Level 4 water must be conveyed through the Delta –1 = no, conveyance of Incremental Level 4 water through the Delta is not necessary	D,N	+1	Incremental Level 4 water must be conveyed through the Delta given current water supply sources.
Data Needs	Are there significant data needs to address prior to groundwater development?	+1 = no, data needs regarding refuge groundwater conditions are minor 0 = somewhat, some data are required prior to increasing groundwater development –1 = yes, significant data must be collected as there is little or no existing data	D,N	-1	Significant data are required prior to recommending increased groundwater development.
			Total Direct Use Score =	**0**	
			Total On-Refuge Conjunctive Use Score =	**-1**	

Notes:
a Surface Features

b Application to Approach: D = Direct Use, N = On-Refuge Conjunctive Use

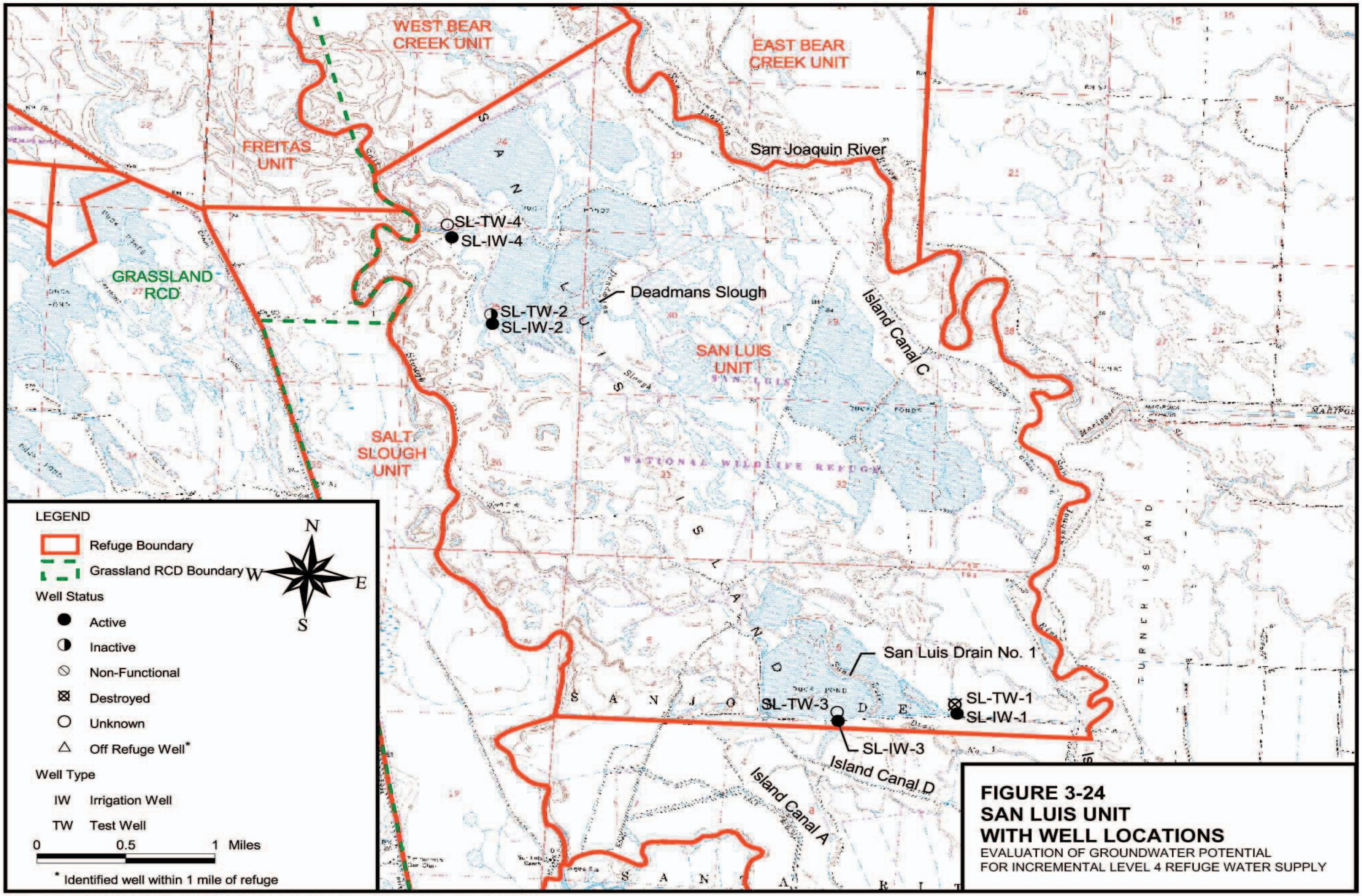

FIGURE 3-24
SAN LUIS UNIT WITH WELL LOCATIONS
EVALUATION OF GROUNDWATER POTENTIAL FOR INCREMENTAL LEVEL 4 REFUGE WATER SUPPLY

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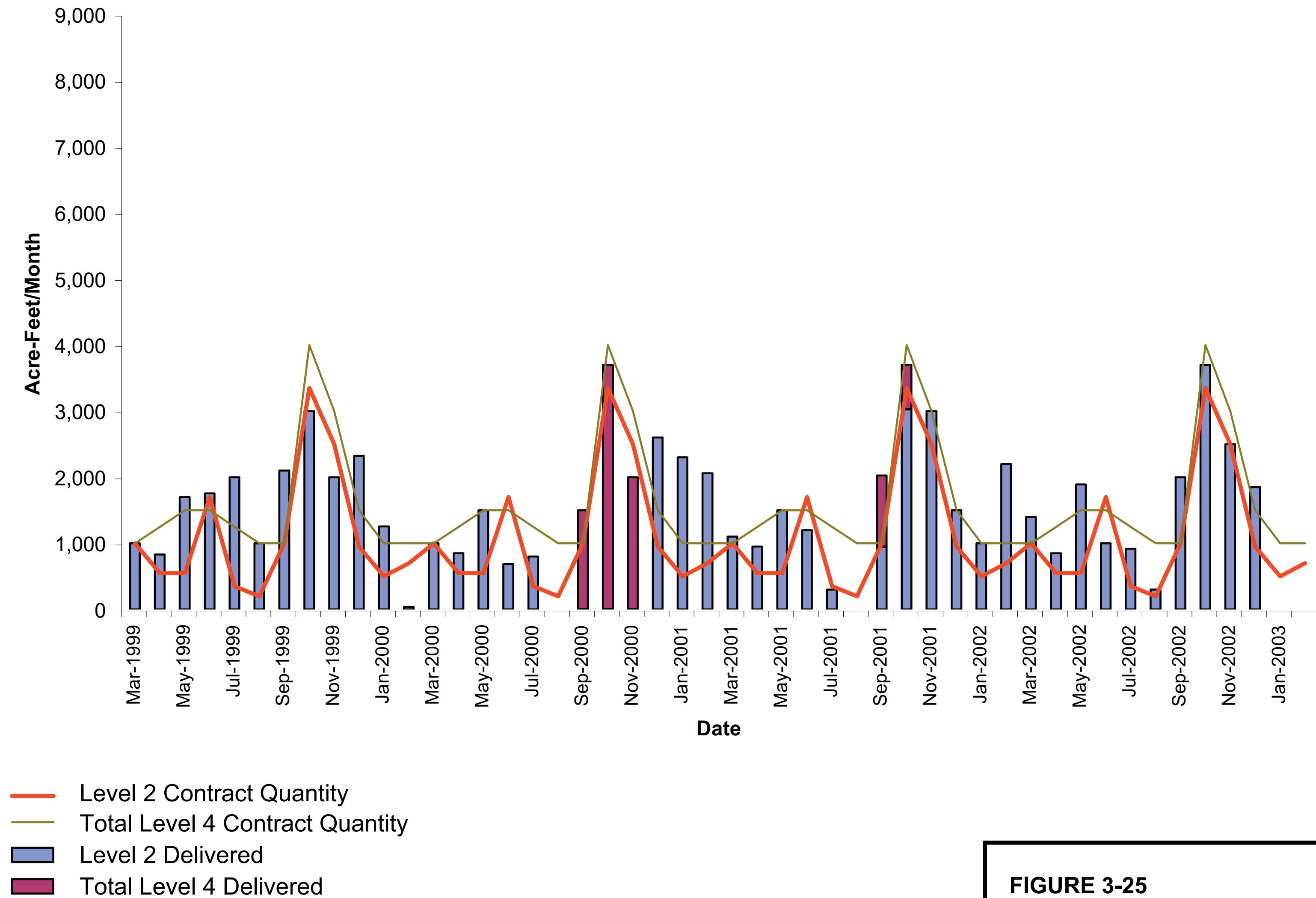

Note: Level 2 and Total Level 4 contract quantities are those indicated in Reclamation 1989 and Reclamation el al. 1989. Volumes indicated may not reflect current monthly management schedules and are shown to indicate an approximate monthly breakdown for management purposes. Total annual contract quantities may be scheduled based on availability, at the refuge manager's discretion.

FIGURE 3-25
1999-2002 SAN LOUIS NWR WATER DELIVERIES
EVALUATION OF GROUNDWATER POTENTIAL
FOR INCREMENTAL LEVEL 4 REFUGE WATER SUPPLY

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3.8 Salt Slough Unit Refuge Assessment (North Grasslands WA)

County: Merced
Basin / Subbasin: San Joaquin Valley Groundwater Basin / Delta-Mendota Subbasin
Level 2 / Incremental Level 4: 6,680 ac-ft / 3,340 ac-ft
2003 Acreage: 2,214
CVP Water Conveyors: Grassland WD, Central California ID
Water District Service Area: None
Applicable Groundwater Management Regulations: None

The Salt Slough Unit is adjacent to the San Luis Unit on the east, the Freitas Unit to the north, Grassland RCD to the west, and Los Banos WA to the south (Figure 3-26). SR 165 forms the western border of the refuge. The southern refuge border is formed by Wolfsen Road, which leads to the former San Luis Ranch at the southeast corner of the refuge.

3.8.1 Hydrogeologic Assessment

3.8.1.1 Habitat Goals, Land Management, and Surface Features

The Salt Slough Unit consists of 2,214 acres managed with the China Island Unit as part of the North Grasslands WA. Prior to acquisition, the land was managed as a cattle ranch (Reclamation et al. 2001b). Currently, the refuge includes seasonal wetland, watergrass, marshland, upland, and pond habitat. The refuge provides irrigated lands for food, wintering, and nesting habitat for waterfowl and other wildlife. Purposes of this refuge are: endangered and threatened species conservation, migratory bird refuge and breeding ground, natural resource protection, recreation, wildlife management and control, and wetlands conservation (Reclamation 2002).

3.8.1.2 Identified Water Supply Contract Quantities

Figure 3-27 shows the Level 2 and Level 4 water contract quantities and the actual water deliveries to the refuge from 1999 through 2001. The Level 2 contract quantity is 6,680 ac-ft per year. The Incremental Level 4 contract quantity is 3,340 ac-ft, totaling 10,020 ac-ft per year (Reclamation et al. 2001b). This figure does not include groundwater use. Groundwater from one well is blended with CVP supplies on a limited basis, but the timing and quantity of groundwater use are not recorded.

3.8.1.3 Surface Water Supplies and Infrastructure

The main source of water for the Salt Slough Unit is from CVP water delivered by Grassland WD to the Wolfsen Ditch at the south end of the unit. Through an appropriative right of diversion, water is directly diverted from Salt Slough, but impaired water quality (salts and trace elements) limits the use of this surface water source. Approximately 2,335 ac-ft of Level 4 was is provided by a variety of willing sellers (Reclamation et al. 2001b). CVP water is conveyed by Grassland WD and transferred from the Delta-Mendota Canal (Reclamation et al. 2001b). Water is delivered from the San Luis Canal to the head of Wolfsen Ditch. Wolfsen Ditch becomes an 18-inch PVC pipeline on the north side of the refuge. A lift pump recirculates water out of the West Drain Ditch and onto the wetlands and uplands. Salt

Slough receives water leaving the refuge at numerous sites along the slough (Refuge staff 2002).

3.8.1.4 Groundwater Supplies and Infrastructure

Existing refuge well information is summarized in Table 3-14. A well located on the Blue Goose Unit of the San Luis NWR Complex, located just west of the western boundary of the Salt Slough Unit, is discussed here to provide additional information to characterize water quality conditions at the Salt Slough Unit. Groundwater is not used for domestic supply on the refuge (Refuge staff 2002).

Test Wells. Three test wells were drilled in the southern half of the Salt Slough Unit in 1992. The wells were sampled at discrete intervals to evaluate vertical changes in water quality conditions.

Irrigation and Production Wells. One operational deep well is on the refuge. The Salt Slough Deep Well (shown as SS-IW-01 on Figure 3-26) is 560 feet deep and is located near the southeastern end of the unit. The well is used only occasionally, when electricity costs are low. The well pumps water into the IDS (Refuge staff 2002).

The Blue Goose Well produces about 2,000 gpm from a depth of 300 to 480 feet bgs. This well is used about 10 days per year during fall flood-up. TDS at this well has been measured at 1,090 mg/L. Refuge staff indicate that no other water quality information is available from this well.

Water Quality Data. Water quality data collected at Salt Slough Unit are summarized in Table 3-15. These data indicate that water conditions differ above and below the Corcoran Clay. Above the clay (about 230 to 325 feet bgs), EC ranges from 4,070 to 4,440 µmhos/cm. Below the clay EC ranges from 1,610 to 2,540 µmhos/cm. Boron values at Salt Slough show the opposite distribution above and below the Corcoran Clay, with the higher values (2.2 to 4.6 mg/L) occurring below the clay and the lower values (1.3 to 1.4 mg/L) occurring above the clay. (Fields 1995). Agricultural Water Quality Goals have been exceeded for boron and salinity. Neither selenium nor molybdenum occurred above method detection levels in the Salt Slough test wells.

3.8.1.5 Local Groundwater Use

Groundwater is used intermittently in the region to supply private duck clubs, although water quality impairments such as high selenium have restricted this use in the past. A domestic well is located near the southern end of the refuge. The San Luis CC has several deep wells in their district located near the refuge (Zahm 1992).

3.8.1.6 Refuge Soil and Aquifer Conditions

The most extensive soil in the central and northern portion of Salt Slough is partially drained Elnido sandy loam. Permeability of this soil is moderately rapid, and runoff is slow. The Alros clay loam, a deep and poorly drained soil with slow permeability, occurs in the southern-central area of the refuge. Partially drained Palazzo sandy loam has limited occurrence in the northwest portion of the refuge. The Palazzo sandy loam has moderately rapid permeability to a depth of 22 inches and moderately slow permeability at greater depths. In a small area at the southern part of the refuge, near the Wolfsen Drain and along

Highway 165, surface soil is primarily Marcuse clay. This soil is saline-sodic throughout and permeability is slow. Most soils in this area are also characterized by slow runoff and moderate to high water capacity. Confining surface soils extend to depths greater than 2 feet (USDA 1990).

DWR data indicate that groundwater levels are shallow; they range between 5 and 10 feet bgs along the west side of the refuge on SR 165.Water levels have recovered to conditions prior to the drought in the 1970s (DWR 2003b).

Between 1 and 2 feet of subsidence has occurred in the vicinity of the refuge (DWR 2003a). Future subsidence may be possible if groundwater use is substantially increased.

3.8.1.7 Operational Issues and Data Contract Quantities

Incremental Level 4 water made available to the Salt Slough Unit is subject to wide fluctuations in cost and variable spot-market availability. It is also necessary to convey Level 4 water through the Delta. A more stable source of Incremental Level 4 water both in terms of cost and reliability would be beneficial to refuge water supply management. One third of the refuge's water supply is identified as Incremental Level 4 water.

The following data gaps were identified during the completion of this study:

- Thorough assessment of all refuge wells, including the refuge deep well and the Blue Goose well.
- Confirmation of refuge groundwater quality conditions at different locations and at several different depths below ground surface, both above and below the Corcoran Clay. At a minimum, verify EC, TDS, and boron concentrations in groundwater to determine potential for deleterious effects on wildlife.
- Local aquifer conditions, including quarterly water-level data both on- and off-refuge, and data to estimate aquifer properties.
- Aquifer parameters, such as hydraulic conductivity and thickness.
- Groundwater pumping records and schedules, both on and immediately surrounding the refuge.

Relative to the other refuges in this study, it was estimated that a "medium" level of data collection is required at the Salt Slough Unit prior to recommending specific groundwater development projects.

3.8.2 Criteria Evaluation Summary

The Salt Slough Unit received total Hydrogeologic Scores of +4 for Direct Use of groundwater and +3 for On-Refuge Conjunctive Use based on criteria matrix evaluation. Table 3-16 gives the criteria matrix and scores specific to this refuge.

Groundwater use is primarily limited by uncertainty about water quality conditions. Further groundwater testing would be recommended if groundwater use was further developed. Site soil conditions vary. A significant area in the central and northern parts of the refuge consists of moderately permeable sandy loam, potentially conducive to the development of recharge basins in a limited area. Local groundwater elevations are high, however, limiting potential for aquifer storage. Support and limitations to increased groundwater development are summarized below.

3.8.2.1 Support for Groundwater Development

- Two active deep wells are present on the refuge. Groundwater has been used within the refuge boundaries since before refuge land was acquired.
- A developed IDS allows water to move throughout the refuge, supporting integration of groundwater infrastructure with current water management. Water is distributed through the refuge by a PVC pipeline.
- Although limited groundwater quality data are available, groundwater quality has not limited groundwater use at the refuge in the past (although it has at the Blue Goose well, located immediately west of the Salt Slough Unit).
- Surface water is delivered reliably year round by Grassland WD through the San Luis Canal and is therefore available for blending with groundwater, if necessary.
- It is necessary to convey Incremental Level 4 water through the Delta to serve the refuge.
- The cost of local water is high relative to the other refuges in the study. Cost and reliability is subject to spot-market variability.

3.8.2.2 Limitations to Groundwater Development

- A domestic well is located near the southern end of the refuge. The San Luis CC has several deep wells in their district located near the refuge.
- Boron has been detected above and below the Corcoran Clay. Agricultural Water Quality Goals have been exceeded for boron and EC.
- Aquifer storage is not available. Current and historic groundwater levels are approximately equivalent; depth to groundwater is approximately 5 to 10 feet bgs.

3.8.3 Recommended Data Acquisition Activities

Recommended data acquisition activities include:

- Collect two rounds of water quality samples from the Blue Goose Unit, the deep well, and the test wells (if accessible) to confirm or refute anecdotal water quality conditions. Consider coordinating sampling with San Luis CC. Collect these samples during two seasons, such as summer and winter, to assess potential seasonal variations. Measure, at a minimum, general chemistry parameters and metals, including arsenic, boron, chromium, mercury, selenium, and nitrates.
- Conduct one to two 72-hour aquifer tests at existing irrigation wells to estimate aquifer properties. Conduct these tests during a season in which the refuge is not irrigating. Install two or three dedicated monitoring wells at three locations on the refuge to record water-level changes.
- Develop a groundwater budget for the refuge. Estimate groundwater changes when pumping under wet-, normal-, and dry-year conditions.

- Install a well meter at the active, unmetered refuge well; monitor water levels quarterly; and collect routine water quality samples to develop a database of groundwater use and conditions at refuges where groundwater is used. Maintain collected data in a format supportable and usable by the refuge and refuge managing agencies.

3.8.4 Potential Projects

3.8.4.1 Direct Use

Increased groundwater use may be considered at this refuge. Testing is required to verify aquifer, water quality, and existing well conditions prior to groundwater development to supplement Level 4 water supplies. If testing indicates positive conditions, increased use of the active wells and installation of new production wells is possible.

3.8.4.2 On-Refuge Conjunctive Use

A significant area in the central and northern parts of the refuge consists of moderately permeable sandy loam, potentially conducive to the development of recharge basins in a limited area. Groundwater levels in the area are relatively high, however, which may limit potential for aquifer storage. Water quality and aquifer conditions should be thoroughly assessed before a potential on-refuge conjunctive use project is proposed.

3.8.4.3 Off-Refuge Conjunctive Use

The Salt Slough Unit is not located within the sphere of influence of any groundwater management plan or ordinance. The Exchange Contractor's groundwater management plan does not influence groundwater on the Salt Slough Unit (San Joaquin River Exchange Contractors Water Authority 1997).

At this time, no off-refuge conjunctive use projects have been identified for potential partnership.

TABLE 3-14
Salt Slough Unit Well Information[a]
Evaluation of Groundwater Potential for Incremental Level 4 Refuge Water Supply

GIS Well Number[b]	Common Well Name	Well Status[c]	2002 Yield (ac-ft)	Year Installed	Depth (ft)	Screen Interval (bgs)	Well Output (gpm)	Well Log?	Water Quality Data?	Comments
SS-TW-01	TH 12	Inactive		1992	560	160–440[d]		Y	Y	Specific screened intervals: 160–180, 340–360, 420–440.
SS-TW-02	TH 2	Inactive		1992	565			Y	N	
SS-TW-03	TH 11	Inactive		1992	560	80–394[d]		Y	Y	Specific screened intervals: 80–100, 374–394.
SS-TW-04	TH 10	Inactive		1992	560	144–417[d]		Y	Y	Specific screened intervals: 144–164, 397–417.
SS-IW-01	Salt Slough Deep Well	Active		1991	570		1,346–1,571	N	Y	Not metered. Used occasionally. High EC has been problematic.
SS-DW-01	Domestic well	Active						N	N	

Notes:

[a] Based on data compiled from well logs, test records, communication with refuge staff (2002), and other previous documentation. Well locations are shown on Figure 3-26. On-refuge wells only are included in this table, although the GIS includes known wells within 1 mile of the refuge.

[b] Well type is indicated by the middle two letters of the GIS well number: IW = irrigation well, DW = domestic well, MW = monitoring well, TW = test well, and UN = unknown.

[c] Designation refers to the physical well only, not water quality issues. Designations are: *active* (currently operated), *inactive* (capable of operating, but currently is not), *nonfunctional* (cannot operate in current physical state), *destroyed* (well has been lost, abandoned, or filled), or *unknown* (no information regarding status is available).

[d] See Comments for specific screened intervals within the range shown.

Blank fields indicate that no information is available.

TABLE 3-15
Salt Slough Unit Water Quality Data (1992)
Evaluation of Groundwater Potential for Incremental Level 4 Refuge Water Supply

GIS Well Number	Sampled Interval (feet)	EC (µmhos/cm)	Boron (mg/L)	Molybdenum (µg/L)	Selenium (µg/L)
SS-TW-01	160–180	4,420	1.3	ND	ND
	340–360	1,610	4.6	ND	ND
	420–440	1,790	2.4	ND	ND
SS-TW-03	80–100	4,440	1.3	ND	ND
	374–394	1,903	2.5	ND	ND
SS-TW-04	144–164	4,070	1.4	ND	ND
	397–417	2,500	3.1	ND	ND

Source: DFG files (1992 data).

Notes:

Well locations are shown on Figure 3-26.
ND = not detected

TABLE 3-16
Salt Slough Unit Evaluation
Evaluation of Groundwater Potential for Incremental Level 4 Refuge Water Supply

	Criteria	Scoring Scale	Appl.[b]	Score	Refuge Score Justification
Surface[a]	Do surface water bodies exist that could be affected by increased groundwater use?	+1 = no 0 = to some degree –1 = yes, surface water bodies could be affected	D,N	-1	Wetlands are maintained near the refuge property, and Salt Slough forms the eastern boundary of the refuge.
Water Supplies and Infrastructure	Has groundwater been used previously at the refuge for ponds or irrigation?	+1 = yes, used successfully to meet at least 20 percent of annual refuge water demands 0 = yes, used to meet less than 20 percent (or unknown) of annual refuge water demands. –1 = no, has not been used	D,N	0	Groundwater has been used within the refuge boundaries since before the refuge land was acquired, but use was not extensive.
	Do wells exist on the refuge?	+1 = yes, active wells 0 = yes, inactive or nonfunctional wells –1 = yes, destroyed wells, or no wells exist on the refuge	D,N	+1	There is one active deep well on the refuge. Another deep well, located on the Blue Goose Unit, is just outside the refuge boundary.
	Does existing internal distribution system (IDS) support groundwater use?	+1 = water can move extensively around the refuge with existing IDS 0 = the IDS enables limited water movement within the refuge –1 = an IDS does not exist on the refuge or water flow relies exclusively on gravity	D,N	+1	Wolfsen Ditch becomes an 18-inch PVC pipeline on the north side of the refuge, where it moves water from the Wolfsen Drain up to the lift pump. A lift pump recirculates water out of the West Drain Ditch and onto the wetlands and uplands.
Local Groundwater Use	Is groundwater used for agriculture or duck clubs in the immediate vicinity of the refuge?	+1 = groundwater is not used; or groundwater is minimally used, but use is not constrained 0 = groundwater is used in the area –1 = groundwater is not used due to physical or environmental constraints or is extensively used in the vicinity	D,N	0	Groundwater is used intermittently to supply private duck clubs, but use has occasionally been restricted because of water quality impairments.
	Does municipal or domestic supply exist near the refuge?	+1 = no known domestic or municipal wells are located within 1 mile of the refuge 0 = municipal or domestic wells are likely located within 1 mile of the refuge –1 = municipal or domestic wells are located within 1 mile of the refuge	D,N	-1	A domestic well is located on the southern end of Salt Slough Refuge in Section 12. The San Luis CC has several deep wells in their district located near the refuge.
Soil and Hydrogeology	Are at-surface soils conducive to groundwater recharge?	+1 = soils are sandy or are reported to percolate well 0 = soils are silty or are reported to have some infiltration –1 = soils are clayey or are reported to hold water well	N	0	A significant area in the central and northern parts of the refuge consists of Elnido sandy loam, with moderately rapid permeability. Over much of the rest of the refuge, clay loams are common and permeability is slow.
	Could recharge basins be developed if surface soils were removed?	+1 = confining soil less than 2 feet thick 0 = confining soil 5 to 7 feet thick –1 = confining soil greater than 7 feet thick	N	0	Confining surface soils extend to depths greater than 2 feet.
	Has subsidence occurred at or in the immediate vicinity of the refuge?	+1 = no 0 = yes, less than 2 feet –1 = yes, more than 2 feet	D,N	0	Between 1 and 2 feet of subsidence has occurred in the refuge vicinity.
	Does significant potential for subsidence exist if groundwater use is increased at the refuge?	+1 = minimal potential for subsidence 0 = some potential for subsidence –1 = significant potential for subsidence	D,N	0	Future subsidence is possible if groundwater use substantially increases.
	Is aquifer storage available in the subbasin?	+1 = yes, current water levels are greater than 30 feet lower than historic levels 0 = some, current water levels are between 10 and 30 feet lower than historic levels –1 = no	N	-1	Water levels in the refuge vicinity seem to have recovered to pre-1970s levels.

Notes:
a Surface Features
b Application to Approach: D = Direct Use, N = On-Refuge Conjunctive Use

continued on next page

TABLE 3-16
Salt Slough Unit Evaluation
Evaluation of Groundwater Potential for Incremental Level 4 Refuge Water Supply

	Criteria	Scoring Scale	Appl.[b]	Score	Refuge Score Justification
Water Quality	Have groundwater quality conditions hindered groundwater use in the past?	+1 = no 0 = data are not available –1 = yes	D,N	+1	Groundwater quality concerns have not limited groundwater use in the past.
	Do adverse groundwater quality conditions exist in the subbasin?	+1 = no 0 = potential –1 = yes	D,N	-1	Boron has been detected above and below the Corcoran Clay. Boron has been detected at higher levels, ranging from 2.2 to 4.6 mg/L, below the clay. EC below the Corcoran Clay ranges from 1,610 to 2,540 µmhos/cm.
	Is surface water available to enable blending of lower quality groundwater to meet proposed refuge standards?	+1 = yes 0 = during portions of the year –1 = no	D,N	+1	Delivered water is reliable throughout the year.
	Do groundwater conditions exceed USEPA Freshwater Aquatic Life Standards or Agricultural Water Quality Goals for multiple parameters?	+1 = no 0 = yes, two parameters, or no water quality testing has been conducted –1 = yes, three or more parameters	D,N	0	Agricultural water quality goals have been exceeded in groundwater tests for boron and EC.
	Is refuge land use management compatible with seasonally or annually variable water quality from different sources?	+1 = yes 0 = some potential compatibility problems may exist –1 = no	D,N	+1	Both groundwater and delivered water (higher quality) are currently used for wetland management, although contribution of groundwater to total supply is unknown.
	Does groundwater quality meet drinking-water standards (i.e., can it be used for refuge domestic supply)?	+1 = yes it is used, no treatment is necessary 0 = yes it is used, but some treatment is necessary for potable use; or it is not used for unknown reasons –1 = no, it is not used because of adverse water quality conditions	D	0	Groundwater is not used for domestic supply on the refuge; however, there is no evidence to show that it could not be used.
Operational Issues/Constraints	Does a significant percentage of total refuge water supply consist of "Incremental Level 4" water?	+1 = yes, 54% to 79% of total water supply is Incremental Level 4 0 = somewhat, 27% to 53% of total water supply is Incremental Level 4 –1 = minor, 0% to 26% of total water supply is Incremental Level 4	D,N	0	Approximately 33 percent of the water supply for the Salt Slough Unit consists of Incremental Level 4 water.
	Is the cost of local water high or low relative to the other refuges in this study?	+1 = costs may fluctuate highly or are subject to spot-market variability or price spikes –1 = costs are relatively stable and subjectivity to spot-market variability is low	D,N	+1	Incremental Level 4 water made available to the Salt Slough Unit is subject to wide fluctuations in cost and variable spot-market availability.
	Is it necessary to convey Incremental Level 4 water through the Delta for refuge supply?	+1 = yes, Incremental Level 4 water must be conveyed through the Delta –1 = no, conveyance of Incremental Level 4 water through the Delta is not necessary	D,N	+1	Incremental Level 4 water must be conveyed through the Delta given current water supply sources.
Data Needs	Are there significant data needs to address prior to groundwater development?	+1 = no, data needs regarding refuge groundwater conditions are minor 0 = somewhat, some data are required prior to increasing groundwater development –1 = yes, significant data must be collected as there is little or no existing data	D,N	0	Some data are required prior to recommending increased groundwater development.
			Total Direct Use Score =	**+4**	
			Total On-Refuge Conjunctive Use Score =	**+3**	

Notes:
a Surface Features

b Application to Approach: D = Direct Use, N = On-Refuge Conjunctive Use

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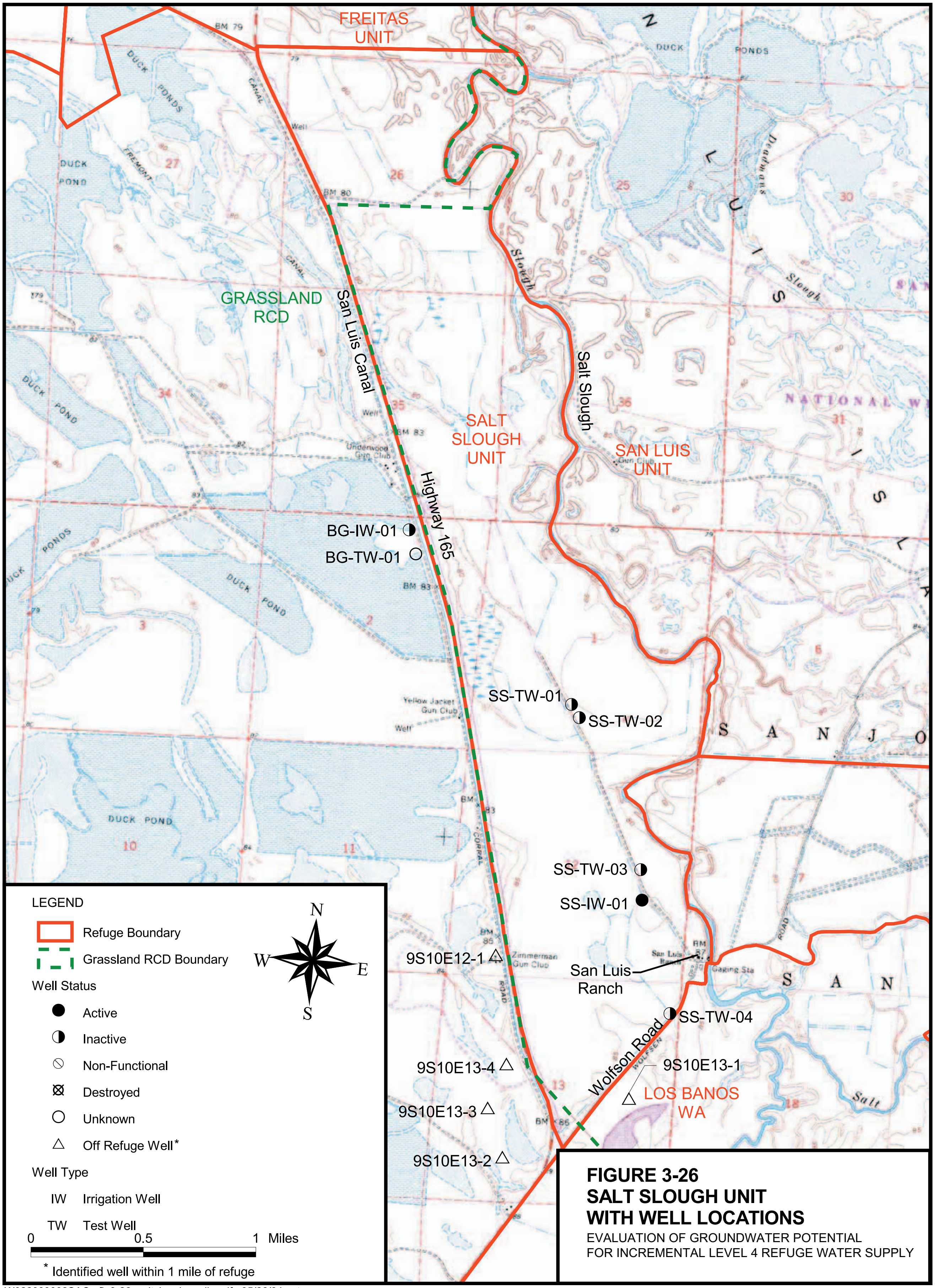

FIGURE 3-26
SALT SLOUGH UNIT
WITH WELL LOCATIONS
EVALUATION OF GROUNDWATER POTENTIAL
FOR INCREMENTAL LEVEL 4 REFUGE WATER SUPPLY

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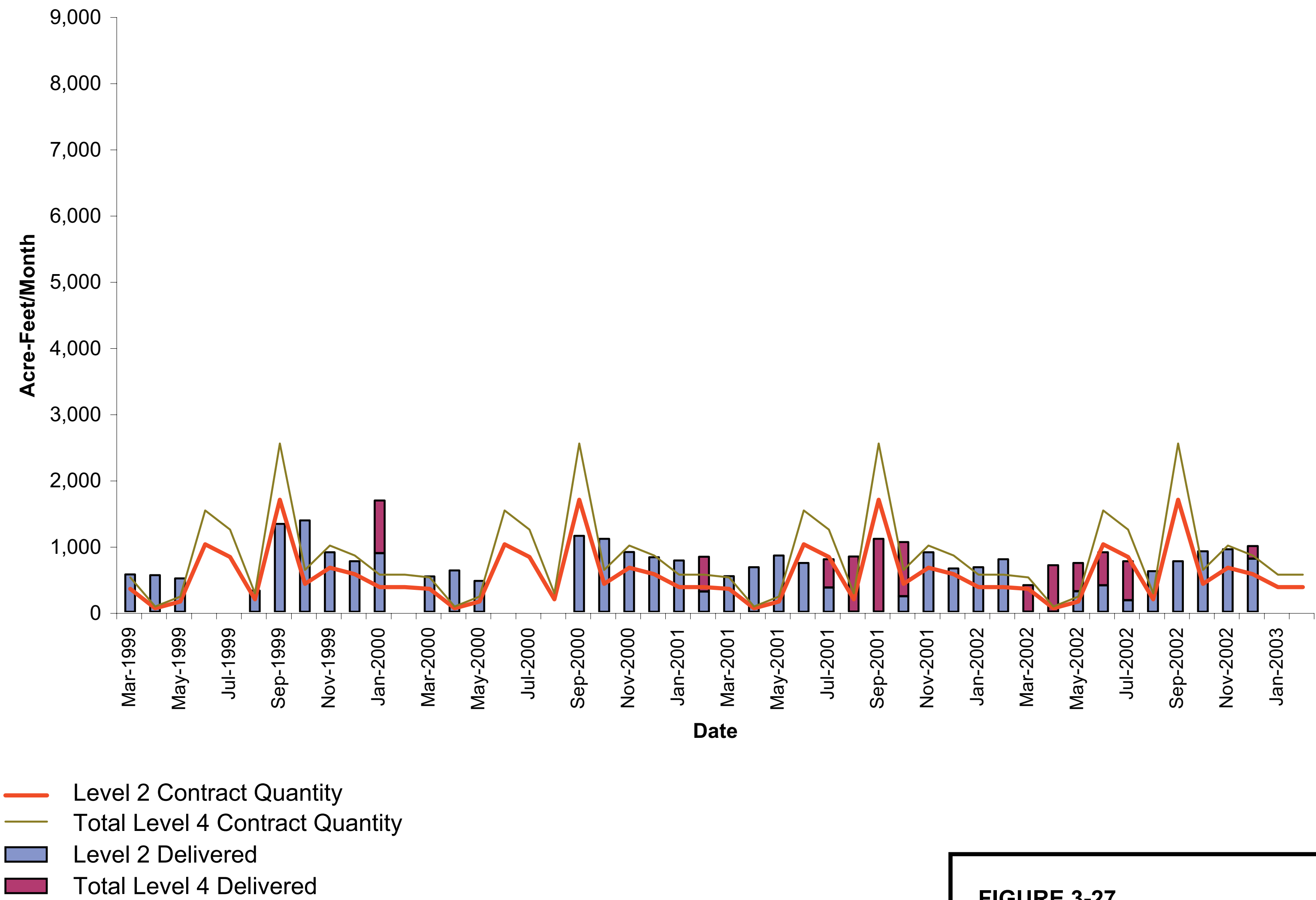

Note: Level 2 and Total Level 4 contract quantities are those indicated in Reclamation 1989 and Reclamation el al. 1989. Volumes indicated may not reflect current monthly management schedules and are shown to indicate an approximate monthly breakdown for management purposes. Total annual contract quantities may be scheduled based on availability, at the refuge manager's discretion.

FIGURE 3-27
1999-2002 SALT SLOUGH WILDLIFE AREA WATER DELIVERIES
EVALUATION OF GROUNDWATER POTENTIAL FOR INCREMENTAL LEVEL 4 REFUGE WATER SUPPLY

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3.9 Los Banos WA Refuge Assessment

County: Merced
Basin / Subbasin: San Joaquin Valley Groundwater Basin / Delta-Mendota Subbasin
Level 2 / Incremental Level 4: 16,670 ac-ft / 8,330 ac-ft
2003 Acreage: 5,586
CVP Water Conveyors: San Luis CC, Grassland WD
Water District Service Area: Grassland WD
Applicable Groundwater Management Regulations: None

Los Banos WA is located in Merced County, just northeast of the town of Los Banos (Figure 3-28). The refuge boundaries are formed by Salt Slough on the north, the San Luis Drain and the Wolfsen Canal on the west, and the Porter-Blake Bypass on the south. Section boundaries and former property boundaries form the eastern and southeastern refuge boundaries. The northwestern border is also shared with the southern Salt Slough Unit border. Approximately the southern two-thirds of the refuge also falls within the Grassland RCD. Los Banos WA also includes the Mud Slough Unit, located south of the main portion of the refuge, which is not included in the CVPIA and is not discussed separately in this report.

3.9.1 Hydrogeologic Assessment

3.9.1.1 Habitat Goals, Land Management, and Surface Features

Los Banos includes 5,586 acres of seasonal wetland, watergrass, marshland, upland, and pond habitat. The refuge provides irrigated lands for food, wintering, and nesting habitat for waterfowl and other wildlife. The primary purposes of this refuge are: endangered and threatened species conservation, migratory bird refuge and breeding ground, natural resource protection, recreation, wildlife management and control, and wetlands conservation (Reclamation 2002).

Features within the refuge include the Devon Drain (Boundary Drain), which flows through the refuge's center, entering the refuge in the southeast and converging with Mud Slough. Mud Slough flows north to converge with Salt Slough, which forms the northeastern boundary of the refuge. Little Buttonwillow Lake and Big Buttonwillow Lake are large water bodies in the northern half of the refuge. Olson Pond is found in the east-central area. Lower Ruth Lake and Upper Ruth Lake play a significant role in the water flow through the western half of the refuge.

3.9.1.2 Identified Water Supply Contract Quantities

Figure 3-29 shows the Level 2 and Level 4 water contract quantities and the actual water deliveries to the refuge from 1999 through 2001. The Level 2 water supply level is 16,670 ac-ft per year. The Level 4 increment is 8,330 ac-ft per year, totaling 25,000 ac-ft per year to meet refuge water demands (Reclamation et al. 2001b).

3.9.1.3 Surface Water Supplies and Infrastructure

CVP provides Level 2 supplies through two contracts. Approximately half of the Level 2 water supply is delivered from CVP via the San Luis Canal by Grassland WD. Three in-canal weirs provide sufficient head for 11 turnouts along the refuge boundary. The refuge relies on gravity flow to receive water from the San Luis CC via the San Luis Canal, the San Pedro Canal, Devon Drain, West Delta Canal, and Salt Slough. Delivered water is typically high in TDS (Reclamation et al. 2001b). The refuge has available water supplies of 10,000 to 15,000 ac-ft per year through a contract with the San Luis CC. Periodically, the San Luis CC cannot provide water during maintenance events (Refuge Staff 2003).

In addition, the San Luis CC and the Grassland WD convey 50 percent of the Level 4 water to Los Banos WA (Refuge staff 2002). Conveyance facilities are available to deliver full Incremental Level 4 water, if requested (Reclamation staff 2003).

3.9.1.4 Groundwater Supplies and Infrastructure

Groundwater wells have been used historically and are used currently at Los Banos (Reclamation et al. 2001b) to supply a portion of the refuge's water contract quantities. Most wells at Los Banos were abandoned in the 1970s for several reasons, including elevated levels of boron and well collapse (possibly from casing corrosion). Also, high energy costs made surface water deliveries considerably cheaper than pumping (Refuge staff 2002). Three new wells were installed in 1992 to support refuge contract quantities during the drought. Known well and test well locations are shown on Figure 3-28. Well information is summarized in Table 3-17.

Irrigation and Production Wells. Two wells installed in 1992 still function. Each provides water to the ponds near it. One well, PR Deep Well (shown as LB-IW-02 on Figure 3-28), is at the southeast corner of the refuge, near the Boundary Drain. The second active well, Sand Dam (LB-IW-01), is located at the eastern tip of the refuge and has recently been rehabilitated. A third well, the HQ Well (LB-IW-03), shown in Figure 3-30, is located next to the refuge headquarters parking lot and is nonfunctional, according to refuge staff. If operational, the well would discharge to the adjacent internal delivery ditch. Pumping rates for the three wells is reported by refuge staff to be between 1,350 and 2,250 gpm (3 and 5 cfs). Refuge staff indicates that well output is limited by the pumps, the aquifer, and operational costs. Refuge managers also report that shallow groundwater use affects neighboring property owners by limiting their ability to pump groundwater. Two other test wells were drilled in 1992 to investigate refuge groundwater conditions, but production wells were not installed at those locations. Groundwater is not being used for refuge domestic water supply (Refuge staff 2002).

The wells do not have flow meters. Flow is gauged by electricity use, which is recorded by PG&E. Output from the existing wells is not high enough to maintain the refuge's water requirements, so the refuge staff use wells only occasionally to augment available surface water supply (Refuge staff 2002). The historic production rates are unknown.

Water Quality Data. Water quality varies throughout the refuge, but both EC and boron have been reported at elevated levels. Water quality results from of the 1992 test wells (Table 3-18) indicate significant variation in both lateral and vertical water quality conditions. Similar to what was observed at San Luis Unit, directly north of Los Banos, an interval of lower quality water (EC ranging from 3,000 to 7,000 μmhos/cm) is present at an intermediate interval of about 150 to 300 bgs at Los Banos WA. EC above and below this interval generally ranges from 1,350 to 3,500 μmhos/cm, but was also observed at 4,600 μmhos/cm in the test well at the Sand Dam Well at a depth of 479 to 500 feet bgs. Boron levels ranged from 0.27 to

7.5 mg/L, with the highest levels observed at the HQ Well test well location. (Twining Laboratories, Inc. 1992a). EC tests from the PR Deep Well are reported by refuge staff to average between 1,500 to 2,100 µmhos/cm. These test results indicate that Agricultural Water Quality Goals have been exceeded at Los Banos WA for boron and salinity.

Numerous shallow piezometers and monitoring wells are also located throughout the refuge. Water-level and EC measurements have been collected from them in the past, but these are no longer monitored and previous records are not available. Most reach to only 20 feet in depth, therefore, results would represent water quality readings from the shallowest portion of the aquifer.

3.9.1.5 Local Groundwater Use

Groundwater is used throughout the area to supply agricultural irrigation, private duck clubs, and occasionally for domestic supply. Domestic wells are used in the Mud Slough Unit of the Los Banos WA. The San Luis CC has several deep wells in their district which are located near the refuge (Zahm 1992). The city of Los Banos also uses groundwater for municipal supplies (USEPA 2003).

Based on a regional study, EC values greater than 1,800 µmhos/cm occur in shallow groundwater in areas recharged by creeks south of Los Banos Creek and northeast of the City of Los Banos. Higher salinity groundwater (between 1,800 and 2,400 µmhos/cm or greater) is locally present below the Corcoran Clay in the Los Banos area. Also in this area, high selenium concentrations have been found in groundwater in a zone aligned with Ortipalita Creek and in another area northeast of Los Banos. In Los Banos municipal wells, however, concentrations of inorganic constituents were below MCLs (Central California ID 1997).

3.9.1.6 Refuge Soil and Aquifer Conditions

Significant areas of the refuge are characterized by Kesterson loam (ponded), fluvaquents (channeled), Elnido clay loam, and Dospalos clay and clay loam (partially drained). Surface soils in the northern part of the refuge are dominated by Kesterson loam and fluvaquents. These soils are loamy, with areas of clay overlying several feet of loamy sand and loamy coarse sand. Throughout the refuge, particularly in the southern end, partially drained Dospalos clay loam and Dospalos clay are significant. Dospalos is deep and poorly drained, with a surface layer of 2 feet of very dark gray clay, followed by several feet of sandy clay loam (USDA 1990).

Surface soils throughout the Los Banos refuge typically have slow to moderate permeability and moderate to high water capacity. Sandy clay loam extends several feet in depth, particularly in the southern end of the refuge. The seasonal water table is high. Kesterson loam in the northeastern part of the refuge has slow to very slow permeability and low water capacity. Permeability of fluvaquents, located in the north-central area of the refuge along rivers and in areas of the south, varies from slow to rapid. Water capacity also varies to a high degree. Elnido clay loam in the northwest and Dospalos clay scattered throughout the refuge are characterized by low permeability clays overlying moderately high permeable sands. These soils are subject to ponding and runoff is slow (USDA 1990).

Depth to groundwater in the far north and south ends of the refuge are typically less than 10 feet. At the far west and the east sides of the refuge area, groundwater is slightly deeper, between 35 and 40 feet bgs. Current groundwater levels have recovered to early-1970s levels (DWR 2003b).

Between 1 and 2 feet of subsidence has occurred in the vicinity of the refuge (DWR 2003a). Future subsidence may be possible if groundwater use substantially increases.

3.9.1.7 Operational Issues and Data Contract Quantities

Incremental Level 4 water made available to Los Banos WA is subject to wide fluctuations in cost and variable spot-market supply. It is also necessary to convey Level 4 water through the Delta. A more stable source of Incremental Level 4 water both in terms of cost and reliability would be beneficial to refuge water supply management. Approximately 33 percent of the refuge's water supply is Incremental Level 4. The following data gaps were identified during the completion of this study:

- Thorough assessment of all refuge wells, including identification of test well locations and current status. Further searching for records and locations of the older refuge wells. Identification of location and well screen intervals for the Los Banos municipal wells.
- Confirmation of refuge groundwater quality conditions at different locations and at several different depths below ground surface, both above and below the Corcoran Clay. At a minimum, verify EC, TDS, and boron concentrations in groundwater to determine potential for deleterious effects on wildlife.
- Local aquifer conditions, including quarterly water-level data both on- and off-refuge, and collection of data to estimate groundwater conditions under wet, average, and dry conditions.
- Aquifer parameters, such as hydraulic conductivity and thickness.
- Groundwater pumping records and schedules, both on and immediately surrounding the refuge.

Relative to the other refuges in this study, it was estimated that a "medium" level of data collection is required at Los Banos WA prior to recommending specific groundwater development projects.

3.9.2 Criteria Evaluation Summary

The Los Banos WA received total Hydrogeologic Scores of +2 for Direct Use of groundwater and zero for On-Refuge Conjunctive Use based on criteria matrix evaluation. Table 3-19 gives the specific criteria matrix and scores for this refuge.

Although infrastructure is in place for groundwater use, poor groundwater quality could limit further groundwater development. Soil conditions are not conducive to recharge basins, and aquifer conditions do not support storage via injection.

Support and limitations to further groundwater development are summarized below.

3.9.2.1 Support for Groundwater Development

- Three wells are currently active on the refuge. Groundwater is used occasionally for refuge water supply.
- A developed IDS allows water to move throughout the refuge, supporting integration of groundwater infrastructure with current water management. Wells discharge to adjacent canals and sloughs to distribute water to refuge ponds.
- Surface water is delivered reliably year-round by Grassland WD and the San Luis Canal and is therefore available for blending with groundwater, if necessary.
- It is necessary to convey Incremental Level 4 water through the Delta to serve the refuge.
- The cost of local water is high relative to the other refuges in the study. Cost and reliability is subject to spot-market variability.

3.9.2.2 Limitations to Groundwater Development

- Several lakes are located within and near the refuge boundaries which may be affected by increased groundwater use. Refuge managers also report that shallow groundwater use affects neighboring property owners.
- Domestic wells are used in the Mud Slough Unit of the Los Banos WA. The San Luis CC has several deep wells located near the refuge. The City of Los Banos uses groundwater for municipal supplies.
- Groundwater is typically high in salinity and boron. Agricultural Water Quality Goals have been exceeded for boron and EC. It has been speculated that well collapse may have occurred because casing corrosion resulting from saline conditions.
- At-surface soils primarily have low permeability and are not conducive to groundwater recharge.
- Aquifer storage is not available. Current and historic groundwater levels are approximately equivalent and depth to groundwater.

3.9.3 Recommended Data Acquisition Activities

Additional data collection is recommended prior to increased groundwater development:

- Conduct an inventory of all past and present refuge wells and test wells, including date installed; physical well properties, including depth, operational status, operational deficiencies (i.e., broken or nonexistent pump, well collapse, etc.); and repair history. Photograph and collect GPS coordinates for the wells. Survey the ground level elevation and the measuring point elevation of each well.
- Collect and analyze groundwater samples from the three active and non-functional wells to confirm the previous indication of high water quality. Determine well depth where unknown, if possible, so that an estimation can be made whether the wells are producing from above or below the Corcoran Clay. Collect these samples during two seasons, such as summer and winter, to assess potential seasonal variations. Measure, at

a minimum, general chemistry parameters and metals, including arsenic, boron, chromium, mercury, and nitrates.

- Conduct one or two 72-hour aquifer tests at existing active irrigation wells to determine an estimated refuge yield. Conduct these tests during a season in which the refuge is not irrigating. Use existing production wells near inactive wells or install three dedicated monitoring wells at three locations on the refuge to record water-level changes.
- Develop a groundwater budget for the refuge. Estimate the groundwater conditions at the refuge under wet-, normal-, and dry-year conditions.
- Install well meters at all active, unmetered refuge wells; monitor water levels quarterly; and collect routine water quality samples from active wells to develop a database of groundwater use and conditions at refuges where groundwater is used. Maintain collected data in a format supportable and usable by the refuge and refuge managing agencies.

3.9.4 Potential Projects

3.9.4.1 Direct Use

Increased groundwater use may be considered at this refuge. Several wells are present, although little information is known about the wells. Testing is required to verify aquifer, water quality, and existing well conditions prior to increased groundwater development to supplement Level 4 water supplies. If testing indicates positive conditions, increased use of the active wells or rehabilitation of inactive wells is possible.

3.9.4.2 On-Refuge Conjunctive Use

Existing groundwater quality and soil information does not indicate favorable conditions for groundwater banking at this refuge. Also, water levels indicate that minimal aquifer space is available for groundwater storage.

3.9.4.3 Off-Refuge Conjunctive Use

A portion of the refuge is within the Grasslands WD, but the district has not implemented a groundwater management plan. At this time, no off-refuge conjunctive use projects have been identified for potential partnership.

TABLE 3-17
Los Banos WA Well Information[a]
Evaluation of Groundwater Potential for Incremental Level 4 Refuge Water Supply

GIS Well Number[b]	Common Well Name	Well Status[c]	2002 Yield (ac-ft)	Year Installed	Depth (ft)	Screen Interval (bgs)	Well Output (gpm)	Well Log?	Water Quality Data?	Comments
LB-IW-01	Sand Dam Well	Active		1992	560		1,350–2,250	Y	Y	Recently rehabilitated. Drilled at TW-9 location.
LB-TW-01	TW-9	Unknown		1992	560			Y	N	Tested intervals: 42–63, 160–140, 479–500.
LB-IW-02	PR Deep Well	Active		1992	560	310-480	1,350–2,250	Y	N	Drilled at TW-7 location. Screen interval shown is based on handwritten notes on drillers' log.
LB-TW-02	TW-7	Unknown		1992	560			Y	Y	Tested intervals: 122–143, 207–227, 360–380, 440-475.
LB-IW-03	HQ Well	Nonfunctional		1992	571	350-385	1,350–2,250	Y	N	Produces best quality groundwater. No water meter. Screen interval shown is based on handwritten notes on drillers' log. Other intervals may also have been perforated. Drilled at TW-6 location.
LB-TW-03	TW-6	Unknown		1992	248			Y	Y	Tested intervals: 80–100, 207–227, 418–438, 522–542
LB-TW-04	TW-15	Unknown		1992	550			Y	N	Tested intervals: 160–180, 410–430.
LB-TW-05	TW-8	Unknown		1992	500			Y	Y	Tested interval: 400–420

Notes:

[a] Based on data compiled from well logs, test records, communication with refuge staff (2002), and other previous documentation. Well locations are shown on Figure 3-28. On-refuge wells only are included in this table, although the GIS includes known wells within 1 mile of the refuge.

[b] Well type is indicated by the middle two letters of the GIS well number: IW = irrigation well, DW = domestic well, MW = monitoring well, TW = test well, and UN = unknown.

[c] Designation refers to the physical well only, not water quality issues. Designations are: *active* (currently operated), *inactive* (capable of operating, but currently is not), *nonfunctional* (cannot operate in current physical state), *destroyed* (well has been lost, abandoned, or filled), or *unknown* (no information regarding status is available).

Blank fields indicate that no information is available.

TABLE 3-18
Los Banos WA Water Quality Data (1992)[a]
Evaluation of Groundwater Potential for Incremental Level 4 Refuge Water Supply

GIS Well Number	Sampled Interval (feet)	EC (µmhos/cm)	Boron (mg/L)	Selenium (µg/L)
LB-TW-01	42–63	1,350	0.27	ND
	140–160	3,200	0.53	ND
	479–500	4,600	1.9	ND
LB-TW-02	122–143	2,600	1	ND
	207–227	6,500	2.9	ND
	360–380	1,900	2.4	ND
	440–475	2,200	2.2	ND
LB-TW-03	80–100	3,500	5.4	ND
	207–227	6,300	7.5	ND
	418–438	1,500		
	522–542	1,600		
LB-TW-04	160–180	3,105	0.67	ND
	410–430	2,170	2.2	ND
LB-TW-05	400–420	2,390	2.8	ND

Source: Twining Laboratories, Inc. 1992a.

Notes:

[a] Testing was completed on March 10 and 17.

Well locations are shown on Figure 3-28.
ND = not detected

TABLE 3-19
Los Banos WA Evaluation
Evaluation of Groundwater Potential for Incremental Level 4 Refuge Water Supply

	Criteria	Scoring Scale	Appl.[b]	Score	Refuge Score Justification
Surface[a]	Do surface water bodies exist that could be affected by increased groundwater use?	+1 = no 0 = to some degree –1 = yes, surface water bodies could be affected	D,N	-1	Big and Little Buttonwillow Lakes, Olson Pond, Upper and Lower Ruth Lakes, and Mud Slough are located within the refuge boundaries. Refuge managers report that shallow groundwater use affects neighbors.
Water Supplies and Infrastructure	Has groundwater been used previously at the refuge for ponds or irrigation?	+1 = yes, used successfully to meet at least 20 percent of annual refuge water demands 0 = yes, used to meet less than 20 percent (or unknown) of annual refuge water demands. –1 = no, has not been used	D,N	0	Five groundwater wells have been used on the refuge. The exact contribution is unknown. Flow is gauged by electricity use.
	Do wells exist on the refuge?	+1 = yes, active wells 0 = yes, inactive or nonfunctional wells –1 = yes, destroyed wells, or no wells exist on the refuge	D,N	+1	Three wells are currently active on the refuge.
	Does existing internal distribution system (IDS) support groundwater use?	+1 = water can move extensively around the refuge with existing IDS 0 = the IDS enables limited water movement within the refuge –1 = an IDS does not exist on the refuge or water flow relies exclusively on gravity	D,N	+1	There are 11 turnouts along the San Luis Canal to receive water and distribute it throughout the refuge. Wells (when functional) typically discharge to adjacent canals and sloughs that cross the center of the refuge.
Local Groundwater Use	Is groundwater used for agriculture or duck clubs in the immediate vicinity of the refuge?	+1 = groundwater is not used; or groundwater is minimally used, but use is not constrained 0 = groundwater is used in the area –1 = groundwater is not used due to physical or environmental constraints or is extensively used in the vicinity	D,N	0	Groundwater is used in the area for irrigation and to supply private duck clubs. The extent of groundwater use in the immediate vicinity of the refuge is not clearly known.
	Does municipal or domestic supply exist near the refuge?	+1 = no known domestic or municipal wells are located within 1 mile of the refuge 0 = municipal or domestic wells are likely located within 1 mile of the refuge –1 = municipal or domestic wells are located within 1 mile of the refuge	D,N	-1	Domestic wells are used in the Mud Slough Unit of the Los Banos WA. The San Luis CC has several deep wells in their district located near the refuge. The City of Los Banos uses groundwater for municipal supplies.
Soil and Hydrogeology	Are at-surface soils conducive to groundwater recharge?	+1 = soils are sandy or are reported to percolate well 0 = soils are silty or are reported to have some infiltration –1 = soils are clayey or are reported to hold water well	N	-1	Clay and clay loam in soils throughout the refuge typically have slow-to-moderate permeability and moderate-to-high water capacity.
	Could recharge basins be developed if surface soils were removed?	+1 = confining soil less than 2 feet thick 0 = confining soil 5 to 7 feet thick –1 = confining soil greater than 7 feet thick	N	0	Sandy clay loam extends several feet bgs, particularly in the southern end of the refuge. Surface soils in the northern part consist of clay loam and sandy loam extending approximately 2 feet bgs, followed by several feet of gray sand.
	Has subsidence occurred at or in the immediate vicinity of the refuge?	+1 = no 0 = yes, less than 2 feet –1 = yes, more than 2 feet	D,N	0	Between 1 and 2 feet of subsidence has occurred in the refuge vicinity.
	Does significant potential for subsidence exist if groundwater use is increased at the refuge?	+1 = minimal potential for subsidence 0 = some potential for subsidence –1 = significant potential for subsidence	D,N	0	Future subsidence is possible if groundwater use substantially increases.
	Is aquifer storage available in the subbasin?	+1 = yes, current water levels are greater than 30 feet lower than historic levels 0 = some, current water levels are between 10 and 30 feet lower than historic levels –1 = no	N	-1	Water levels in the refuge vicinity seem to have recovered to pre-1970s levels.

Notes:
a Surface Features
b Application to Approach: D = Direct Use, N = On-Refuge Conjunctive Use

continued on next page

TABLE 3-19
Los Banos WA Evaluation
Evaluation of Groundwater Potential for Incremental Level 4 Refuge Water Supply

	Criteria	Scoring Scale	Appl.[b]	Score	Refuge Score Justification
Water Quality	Have groundwater quality conditions hindered groundwater use in the past?	+1 = no 0 = data are not available –1 = yes	D,N	0	High boron was one reason wells were abandoned in the 1970s. Well collapse may have occurred, in part, from casing corrosion.
	Do adverse groundwater quality conditions exist in the subbasin?	+1 = no 0 = potential –1 = yes	D,N	-1	Groundwater is typically high in EC and boron. Test results (1992) show an interval (150 to 300 ft bgs) of lower quality water (EC ranging 4,000 to 7,000 µmhos/cm) within better water quality (1,350 to 3,500 µmhos/cm). Boron was detected above standards.
	Is surface water available to enable blending of lower quality groundwater to meet proposed refuge standards?	+1 = yes 0 = during portions of the year –1 = no	D,N	0	Surface water is delivered reliably most months of the year.
	Do groundwater conditions exceed USEPA Freshwater Aquatic Life Standards or Agricultural Water Quality Goals for multiple parameters?	+1 = no 0 = yes, two parameters, or no water quality testing has been conducted –1 = yes, three or more parameters	D,N	0	Agricultural water quality goals have been exceeded in groundwater tests for boron and EC.
	Is refuge land use management compatible with seasonally or annually variable water quality from different sources?	+1 = yes 0 = some potential compatibility problems may exist –1 = no	D,N	+1	Groundwater and delivered water (higher quality) are currently used for wetland management, although contribution of groundwater to total supply is unknown.
	Does groundwater quality meet drinking-water standards (i.e., can it be used for refuge domestic supply)?	+1 = yes it is used, no treatment is necessary 0 = yes it is used, but some treatment is necessary for potable use; or it is not used for unknown reasons –1 = no, it is not used because of adverse water quality conditions	D	0	Groundwater is not used for domestic supply on the refuge; however, there is no evidence to show that it could not be used.
Operational Issues/Constraints	Does a significant percentage of total refuge water supply consist of "Incremental Level 4" water?	+1 = yes, 54% to 79% of total water supply is Incremental Level 4 0 = somewhat, 27% to 53% of total water supply is Incremental Level 4 –1 = minor, 0% to 26% of total water supply is Incremental Level 4	D,N	0	Approximately 33 percent of the water supply for Los Banos WA consists of Incremental Level 4 water.
	Is the cost of local water high or low relative to the other refuges in this study?	+1 = costs may fluctuate highly or are subject to spot-market variability or price spikes –1 = costs are relatively stable and subjectivity to spot-market variability is low	D,N	+1	Incremental Level 4 water made available to Los Banos WA is subject to wide fluctuations in cost and variable spot-market availability.
	Is it necessary to convey Incremental Level 4 water through the Delta for refuge supply?	+1 = yes, Incremental Level 4 water must be conveyed through the Delta –1 = no, conveyance of Incremental Level 4 water through the Delta is not necessary	D,N	+1	Incremental Level 4 water must be conveyed through the Delta given current groundwater supply sources.
Data Needs	Are there significant data needs to address prior to groundwater development?	+1 = no, data needs regarding refuge groundwater conditions are minor 0 = somewhat, some data are required prior to increasing groundwater development –1 = yes, significant data must be collected as there is little or no existing data	D,N	0	Some data are required prior to recommending increased groundwater development.
			Total Direct Use Score =	**+2**	
			Total On-Refuge Conjunctive Use Score =	**0**	

Notes:
a Surface Features

b Application to Approach: D = Direct Use, N = On-Refuge Conjunctive Use

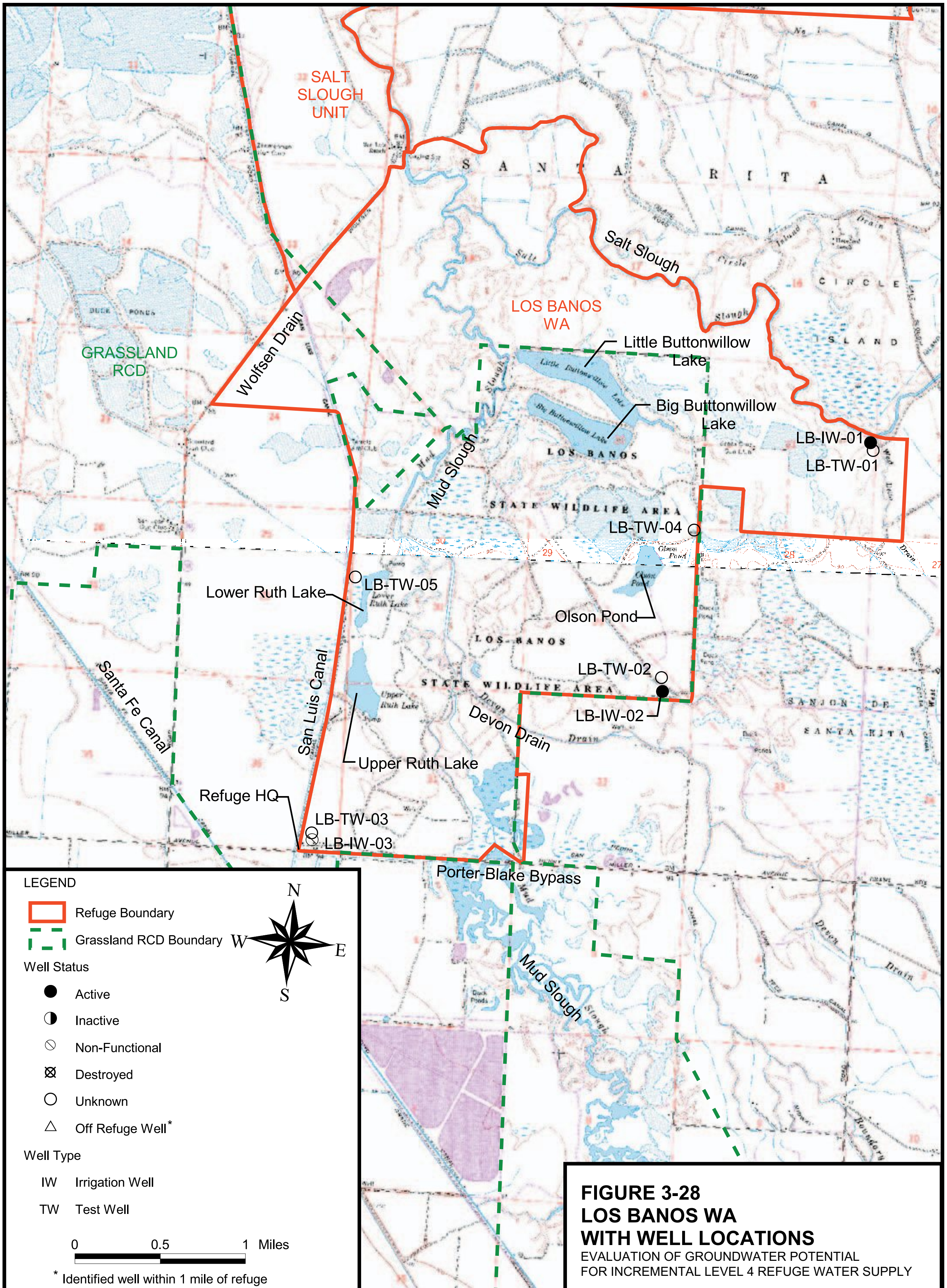

FIGURE 3-28
LOS BANOS WA
WITH WELL LOCATIONS
EVALUATION OF GROUNDWATER POTENTIAL
FOR INCREMENTAL LEVEL 4 REFUGE WATER SUPPLY

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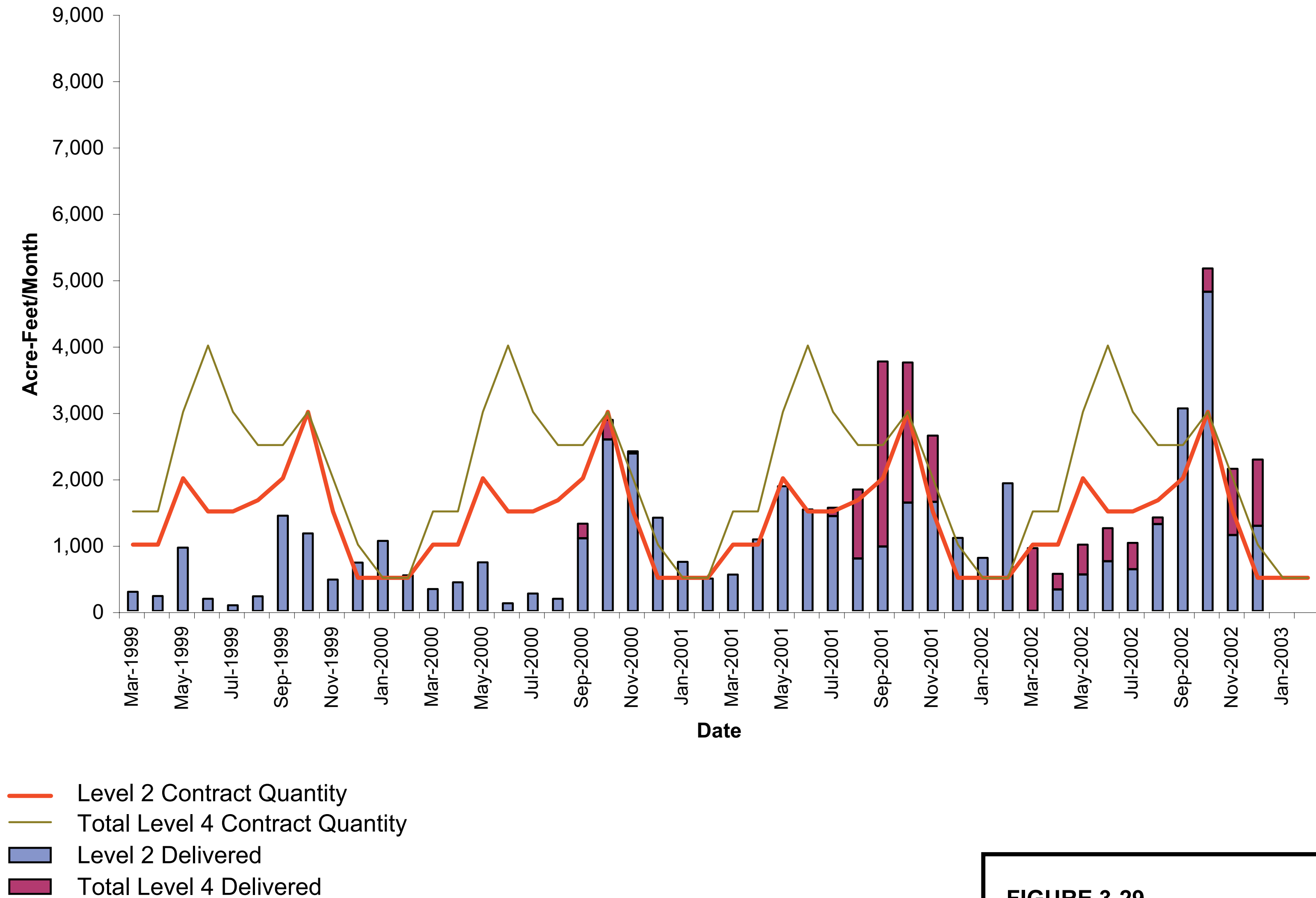

Note: Level 2 and Total Level 4 contract quantities are those indicated in Reclamation 1989 and Reclamation el al. 1989. Volumes indicated may not reflect current monthly management schedules and are shown to indicate an approximate monthly breakdown for management purposes. Total annual contract quantities may be scheduled based on availability, at the refuge manager's discretion.

FIGURE 3-29
1999-2002 LOS BANOS WILDLIFE AREA WATER DELIVERIES
EVALUATION OF GROUNDWATER POTENTIAL FOR INCREMENTAL LEVEL 4 REFUGE WATER SUPPLY

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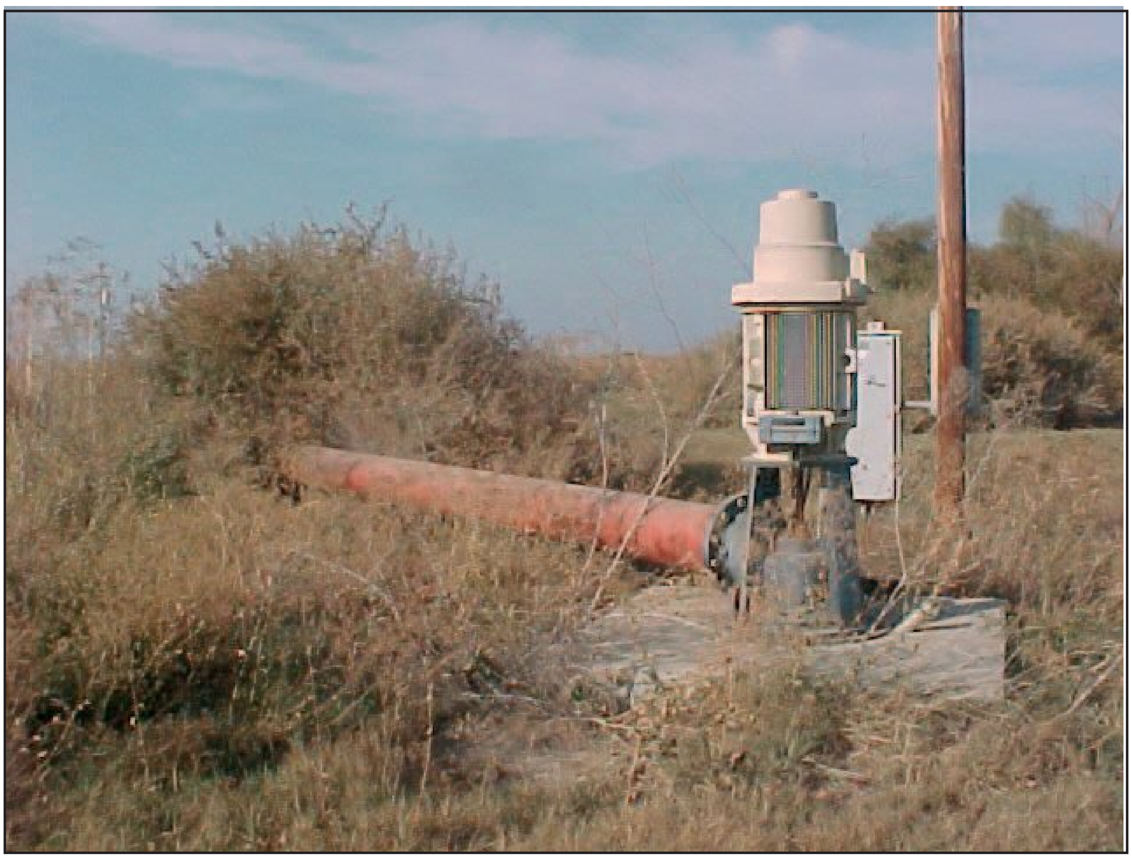

FIGURE 3-30
LOS BANOS WILDLIFE AREA
WELL LB-IW-03
EVALUATION OF GROUNDWATER POTENTIAL
FOR INCREMENTAL LEVEL 4 REFUGE WATER SUPPLY

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3.10 Grassland RCD Assessment

County: Merced
Basin / Subbasin: San Joaquin Valley Groundwater Basin / Delta-Mendota Subbasin
Level 2 / Incremental Level 4: 125,000 ac-ft / 55,000 ac-ft
2003 Acreage: 50,000+
CVP Water Conveyors: Grassland WD, Central California ID, Semitropic Water Storage District (WSD)
Water District Service Area: Grassland WD
Applicable Groundwater Management Regulations: None

Grassland RCD consists of two major areas; the larger area is north of the City of Los Banos, and the smaller is south of Los Banos and Highway 33, just north of the Merced-Fresno County line. The northern area contains portions of several state and national refuges, including the Volta WA, Kesterson Unit, Freitas Unit, and portions of the West Bear Creek Unit, Salt Slough Unit, and Los Banos WA (Figure 3-31).

3.10.1 Hydrogeologic Assessment

3.10.1.1 Habitat Goals, Land Management, and Surface Features

Grassland RCD includes more than 50,000 acres of hunting clubs, privately owned wetland areas, and portions of state and federal refuges. Grassland RCD is the largest area of contiguous wetlands remaining in the Central Valley along the Pacific Flyway (Reclamation et al. 2001b). The primary purposes of the RCD are: endangered and threatened species conservation, migratory bird refuge and breeding ground, natural resource protection, recreation, wildlife management and control, and wetlands conservation. Up to 30 percent of the Central Valley wintering population of waterfowl use this area for wintering and feeding. Grassland WD delivers water to wetlands and wildlife areas within the RCD, which is primarily CVP water. Grassland WD includes about 165 separate ownerships, most privately owned wetlands (Reclamation et al. 2001b). Grassland RCD administers conservation programs and manages wetlands based on guidelines set up by the California Public Resources code. Grassland RCD may request assistance for habitat improvements through several USDA programs, including the Conservation Reserve Program, the Wetland Reserve Program, and the Wildlife Habitat Incentive Program, all administered by the Natural Resources Conservation Service. Grassland WD is responsible for CVP water conveyance and distribution within its boundaries, including the Grassland RCD. Separate boards govern the two districts (Reclamation et al. 1995).

Several roads cross the northern and southern portions of the RCD because Grassland RCD contains private and public lands requiring regular access. The Southern Pacific Railroad once crossed the southern area of the RCD, but the tracks have been removed.

3.10.1.2 Identified Water Supply Contract Quantities

Figure 3-32 shows the Level 2 and Level 4 water contract quantities and the actual water deliveries to the RCD from 1999 through 2001. The Level 2 water supply contract quantity is 125,000 ac-ft per year. Additional water required to meet Level 4 demands is 55,000 ac-ft, totaling 180,000 ac-ft per year (Reclamation et al. 2001b).

3.10.1.3 Surface Water Supplies and Infrastructure

The Grassland WD was established to receive and distribute CVP water to wetland areas and other entities within its boundaries, and to maintain the distribution systems. CVP water is transported to the RCD by the Grassland WD from the Delta-Mendota Canal through Central California ID or the San Luis Wasteway. Water quality decreases as EC increases in the water running through the Volta area, however (District staff 2002).

Grassland WD has an extensive canal system that runs between the northern and southern areas of the RCD. In addition to the RCD, Grassland WD currently delivers water to other refuges via its canal system. The main arteries of the canal system usually transport water year-round. Some smaller canals may be taken down seasonally for maintenance (District staff 2002). Conveyance is available for delivery of full Incremental Level 4 water.

Garzas and Los Banos Creeks may also provide surface water supplies. However, because natural flows on the creeks occur mainly in winter during flood events, the water is rarely diverted for use on the wetlands (Reclamation et al. 2001b).

The quality of the delivered water is governed by the Grassland RCD water supply contract, which states in part that "The (delivered) water... shall be of suitable quality to maintain and improve wetland habitat areas..." (Reclamation 2001).

3.10.1.4 Groundwater Supplies and Infrastructure

Irrigation and Production Wells. High costs and poor water quality of shallow groundwater allow wells to be used only to provide a supplemental source of supply for the RCD (Reclamation et al. 2001b). Periodically, private irrigation wells throughout the northern and southern areas of the RCD are used for primarily agricultural purposes. Grassland WD staff maintain good information on the location, status, and ownership of these wells, but information about extracted volumes, rates, and water quality are not maintained. Information on RCD wells is not included in this report because they are privately owned wells. Information on public wells located on refuge lands that fall within the RCD is included in tables specific to that refuge. Groundwater is used for nonpotable domestic supply within the RCD.

Water Quality Data. Periodic measurements indicate that EC values range between 2,200 and 2,600 μmhos/cm. These levels exceed Agricultural Water Quality Goals. Higher EC and boron values are found in shallower groundwater and in the southern region of the RCD, according to district staff, although no specific test results are available.

Water quality is the primary constraint relative to the use of groundwater within the RCD. Grassland WD may have to meet total maximum daily load (TMDL) standards being discussed for the San Joaquin River, to which tailwater from the RCD is discharged. Grassland WD is currently monitoring tailwater discharge, but results were unavailable.

3.10.1.5 Local Groundwater Use

Private land owners within Grassland RCD operate approximately 25 irrigation wells, although several are inactive or have been capped. Groundwater pumping facilities exist on at least 15 of 165 hunting clubs in the area. Some domestic wells exist within the RCD, but the water is high in EC and considered nonpotable. Where wells are in use, groundwater is typically used for wildlife, cattle, or other agricultural purposes. RCD staff indicate that wells may be operated directly for the owner, or the water may be pumped into the Santa Fe Canal, San Luis Canal or San Luis Spillway Ditch, or into Los Banos Creek.

3.10.1.6 Refuge Soil and Aquifer Conditions

Because the RCD incorporates extensive acreage, site-specific soil conditions within the RCD have not been assessed in detail. However, soil conditions are generally alkaline layers of clay and clay loam, characterized by low permeability (USDA 1990).

Groundwater levels vary throughout the RCD between ground surface and approximately 70 feet bgs. Wells monitored by DWR along SR 165 show water levels increasing in depth from north to south, subject to seasonal variation. At the far north, groundwater levels are between 5 and 10 feet bgs, and at the southern end, between 20 and 30 feet. Groundwater levels have rebounded from levels in the 1960s and 1970s, when depth to groundwater dipped to as much as 60 feet bgs. In the southern portion of the RCD, south of SR 152, groundwater levels are shallow, generally between 2 and 5 feet bgs but as much as 10 and 15 feet bgs in the southern end of the RCD (DWR 2003b).

Hydrologic conditions discussed in a report produced by the Central California ID indicate that the regional direction of groundwater flow in the upper aquifer is to the northeast throughout much of the Central California ID, which is adjacent to the RCD. In the lower aquifer below the Corcoran Clay, sub-regional directions of groundwater flow are evident. Groundwater northeast of a divide from Mendota to north of Highway 152 and the San Joaquin River flows toward the Madera area. Southwest of this divide and south of Los Banos, groundwater flows to the south. North of Highway 152, groundwater flows toward a depression in the northern area of Grassland WD (Central California ID 1997).

Subsidence in the vicinity of the RCD varies between 1 and 4 feet (USDA 1990). Future subsidence may be possible if groundwater use substantially increases.

3.10.1.7 Operational Issues and Data Needs

Incremental Level 4 water made available to Grassland RCD is subject to wide fluctuations in cost and variable spot-market availability. It is also necessary to convey Level 4 water through the Delta. A more stable source of Incremental Level 4 water both in terms of cost and reliability would be beneficial to water supply management at the RCD. Approximately 31 percent of the RCD's water supply is Incremental Level 4 water.

The following data gaps were identified during the completion of this study:

- Thorough evaluation and testing of existing agricultural and irrigation wells within the RCD to determine condition and retrofit possibilities.
- Assessment of local hydrostratigraphy and groundwater quality of accessible wells within the RCD.
- Local aquifer conditions, including quarterly water-level data both on- and off the RCD and collect data to estimate groundwater conditions under wet, average, and dry years.
- Aquifer parameters, such as hydraulic conductivity and thickness.

- Groundwater pumping records and schedules, both on and immediately surrounding the RCD.

Relative to the other refuges in this study, it was estimated that a "medium" level of data collection is required at the RCD prior to recommending specific groundwater development projects.

3.10.1.8 Other Studies

Central California ID has conducted extensive summaries and investigation for groundwater use and quality within its boundaries (San Joaquin River Exchange Contractors 1997; Central California ID 1997). Although these summary reports do not include Grassland RCD, they are immediately adjacent to it and provide good supporting information for assessment of groundwater conditions within Grassland RCD. The reports summarize water-level elevations and lateral and vertical directions of groundwater flows during both normal and drought conditions. Water quality conditions are also discussed.

Data presented in the report indicate that relatively low EC values occur in the upper aquifer and along the east side of the district between Highway 152 to the Mendota area, corresponding roughly to the southeastern portion of Grassland RCD. This likely coincides with stream recharge near the San Joaquin River. Upper aquifer EC values typically range between 1,200 to 2,400 µmhos/cm. Boron values in the upper aquifer range between 0.5 and 2.5 mg/L and follow similar quality trends as EC. Higher concentrations of boron are likely due to historic evaporation of shallow groundwater at the downslope ends of the Coast Range alluvial fans (Central California ID 1997).

Water quality in the lower aquifer is less well understood. In general, in the northern and western part of the district, TDS concentrations in groundwater are lower below the Corcoran Clay. Higher salinity groundwater is locally present below the Corcoran Clay in the areas of Los Banos, Dos Palos, the San Luis CC service area, Firebaugh, and Mendota. High concentrations of hydrogen sulfide, iron, and manganese are present in the lower aquifer in some areas (Central California ID 1997). Although specific concentrations are not listed, the report may be used as a guide for choosing constituents to test in groundwater in these areas.

Other constituents which have been of concern in the study area are selenium, boron, nitrate, molybdenum, and several other trace metals. Little data was available for these constituents, since they were not the focus of the report (Central California ID 1997).

The report notes that Grassland WD is an area in which data gaps exist for water levels and water quality, particularly in the lower aquifer.

3.10.2 Criteria Evaluation Summary

Grassland RCD received total Hydrogeologic Scores of +5 for Direct Use of groundwater and +4 for On-Refuge Conjunctive Use based on criteria matrix evaluation. Table 3-20 gives the specific criteria matrix and scores for the RCD.

Several active wells (most maintained by private land owners) are present on the RCD. An extensive canal system allows water conveyance and distribution between the northern and southern portions of the RCD and to other refuges to the north. The San Luis Wasteway is also accessible. Minimal groundwater quality data are available. Increased groundwater development for wetland use should be preceded by substantial groundwater quality testing. According to DWR monitoring data, overdraft conditions do not exist in the area, limiting potential aquifer storage capacity (DWR 2003b).

Support and limitations to increased groundwater development are summarized below.

3.10.2.1 Support for Groundwater Development

- There are several active wells in the RCD. Groundwater has been used to meet some water demands of private irrigators within the bounds of the RCD.
- A developed IDS allows water to move extensively throughout the RCD, supporting integration of groundwater infrastructure with current water management. The Volta Wasteway is also used by the RCD.
- Surface water is delivered reliably year-round by Grassland WD and the San Luis Canal and is therefore available for blending with groundwater, if necessary.
- It is necessary to convey Incremental Level 4 water through the Delta to serve the RCD.
- The cost of local water is high relative to the other refuges in the study. Cost and reliability is subject to spot-market variability.
- The location of the RCD is ideal for development of a groundwater project to support the refuges.

3.10.2.2 Limitations to Groundwater Development

- Water quality may be impaired in some areas. Potential boron, molybdenum, arsenic, and selenium may be found regionally, particularly in shallow groundwater.
- Aquifer storage is not available. Current and historic groundwater levels are approximately equivalent.

3.10.3 Recommended Data Acquisition Activities

Recommended data acquisition activities include:

- Collect water quality samples at wells for which discrete well screens can be determined in order to provide information to augment and expand previous work by Central California ID. At least 8 to 10 samples distributed throughout the RCD are recommended. Collect samples from domestic and irrigation wells if possible. These sample results would provide the basis for determining whether additional investigation, such as borehole drilling, should be conducted in order to delineate aquifer conditions and water quality.
- Evaluate existing well locations and conditions to determine if well retrofit is feasible. Conduct a visual assessment of the well, obtain past well use and output information and determine well location using a GPS.
- To determine the groundwater banking potential of water at the RCD, conduct a detailed feasibility study. Evaluate existing groundwater wells to assess the

hydrostratigraphy of the RCD and compare to water quality conditions relative to potential banking opportunities. Conduct a water chemistry analysis of the water received by the RCD to determine potential geochemical compatibility issues. Investigate potential treatment requirements. Complete a cost and need assessment of a banking program.

- Install well meters at all active, unmetered wells at the RCD (if possible); monitor water levels quarterly; and collect routine water quality samples from active wells to develop a database of groundwater use and conditions at refuges where groundwater is used. Maintain collected data in a format supportable and usable by the RCD and its managing agency.

3.10.4 Potential Projects

3.10.4.1 Direct Use

Increased groundwater use may be considered at the RCD. Several active wells, maintained by private landowners, are present at the RCD. Testing is required to verify aquifer, water quality, and existing well conditions prior to groundwater development to supplement Level 4 water supplies, as discussed above.

3.10.4.2 On-Refuge Conjunctive Use

There are significant benefits to developing groundwater banking at the RCD. Groundwater storage by injection could be achieved by retrofitting existing private inactive wells to receive surface water. Grassland RCD is in an excellent geographical location relative to the national and state refuges, and it has the conveyance facilities to support groundwater storage. Banked water could easily be transferred to refuges that border Grassland RCD. If the findings of the recommended data acquisition efforts are favorable, because of its optimal location and conveyance infrastructure, one storage project would have the ability to supply and benefit many refuges according to need.

3.10.4.3 Off-Refuge Conjunctive Use

A portion of the RCD is within Grasslands WD, but Grasslands WD does not have a groundwater management plan. Central California ID and Semitropic WSD convey water to Grassland RCD, but the RCD is not within either water entity's sphere of influence, so it is not affected by the groundwater management plans of either entity.

At this time, no off-refuge conjunctive use projects have been identified for potential partnership.

TABLE 3-20
Grassland RCD Evaluation
Evaluation of Groundwater Potential for Incremental Level 4 Refuge Water Supply

	Criteria	Scoring Scale	Appl.[b]	Score	Refuge Score Justification
Surface[a]	Do surface water bodies exist that could be affected by increased groundwater use?	+1 = no 0 = to some degree –1 = yes, surface water bodies could be affected	D,N	0	Several privately owned wetlands are within the bounds of the RCD.
Water Supplies and Infrastructure	Has groundwater been used previously at the refuge for ponds or irrigation?	+1 = yes, used successfully to meet at least 20 percent of annual refuge water demands 0 = yes, used to meet less than 20 percent (or unknown) of annual refuge water demands. –1 = no, has not been used	D,N	0	Groundwater has been used to meet some water demands of private irrigators within the bounds of the RCD. Groundwater has not been heavily used, however.
	Do wells exist on the refuge?	+1 = yes, active wells 0 = yes, inactive or nonfunctional wells –1 = yes, destroyed wells, or no wells exist on the refuge	D,N	+1	There are active wells in the district, but most are maintained by private land owners. Refuge managers do not operate these wells.
	Does existing internal distribution system (IDS) support groundwater use?	+1 = water can move extensively around the refuge with existing IDS 0 = the IDS enables limited water movement within the refuge –1 = an IDS does not exist on the refuge or water flow relies exclusively on gravity	D,N	+1	Conveyance exists across Grassland WD, and simple IDS systems move water from wetland to wetland.
Local Groundwater Use	Is groundwater used for agriculture or duck clubs in the immediate vicinity of the refuge?	+1 = groundwater is not used; or groundwater is minimally used, but use is not constrained 0 = groundwater is used in the area –1 = groundwater is not used due to physical or environmental constraints or is extensively used in the vicinity	D,N	0	Private irrigation wells throughout the northern and southern areas of the district are used periodically for both wildlife and agricultural use. Groundwater pumping facilities exist on at least 15 of 165 hunting clubs in the area.
	Does municipal or domestic supply exist near the refuge?	+1 = no known domestic or municipal wells are located within 1 mile of the refuge 0 = municipal or domestic wells are likely located within 1 mile of the refuge –1 = municipal or domestic wells are located within 1 mile of the refuge	D,N	-1	There are some private domestic wells in the immediate vicinity. Water is considered nonpotable, however.
Soil and Hydrogeology	Are at-surface soils conducive to groundwater recharge?	+1 = soils are sandy or are reported to percolate well 0 = soils are silty or are reported to have some infiltration –1 = soils are clayey or are reported to hold water well	N	-1	Although geologic conditions were not assessed in detail, soil conditions are generally alkaline layers of clay and clay loam, characterized by low permeability.
	Could recharge basins be developed if surface soils were removed?	+1 = confining soil less than 2 feet thick 0 = confining soil 5 to 7 feet thick –1 = confining soil greater than 7 feet thick	N	0	Soil depth varies significantly. Generally, confining soils extend greater than 2 feet deep.
	Has subsidence occurred at or in the immediate vicinity of the refuge?	+1 = no 0 = yes, less than 2 feet –1 = yes, more than 2 feet	D,N	0	Subsidence in the vicinity of the refuge varies between 1 and 4 feet only in the southern part of the RCD.
	Does significant potential for subsidence exist if groundwater use is increased at the refuge?	+1 = minimal potential for subsidence 0 = some potential for subsidence –1 = significant potential for subsidence	D,N	0	Future subsidence is possible if groundwater use substantially increases.
	Is aquifer storage available in the subbasin?	+1 = yes, current water levels are greater than 30 feet lower than historic levels 0 = some, current water levels are between 10 and 30 feet lower than historic levels –1 = no	N	-1	According to DWR monitoring data, most groundwater levels in the vicinity of the refuge are steady and have recovered to pre-drought conditions.

Notes:
a Surface Features
b Application to Approach: D = Direct Use, N = On-Refuge Conjunctive Use

continued on next page

TABLE 3-20
Grassland RCD Evaluation
Evaluation of Groundwater Potential for Incremental Level 4 Refuge Water Supply

	Criteria	Scoring Scale	Appl.[b]	Score	Refuge Score Justification
Water Quality	Have groundwater quality conditions hindered groundwater use in the past?	+1 = no 0 = data are not available –1 = yes	D,N	0	EC is high and water is considered nonpotable, but data were not available to support this conclusion.
	Do adverse groundwater quality conditions exist in the subbasin?	+1 = no 0 = potential –1 = yes	D,N	-1	Potential boron, molybdenum, arsenic, and selenium may be found in various areas of the RCD, particularly in shallow groundwater. EC is also high in some areas. Spot checks by refuge staff yielded EC between 2,200 and 2,600 µmhos/cm.
	Is surface water available to enable blending of lower quality groundwater to meet proposed refuge standards?	+1 = yes 0 = during portions of the year –1 = no	D,N	0	Surface water from a variety of sources may be available for blending on the RCD.
	Do groundwater conditions exceed USEPA Freshwater Aquatic Life Standards or Agricultural Water Quality Goals for multiple parameters?	+1 = no 0 = yes, two parameters, or no water quality testing has been conducted –1 = yes, three or more parameters	D,N	0	Agricultural Water Quality Goals have been exceeded in groundwater for EC, based on estimations by refuge managers. No other constituents have been tested, however.
	Is refuge land use management compatible with seasonally or annually variable water quality from different sources?	+1 = yes 0 = some potential compatibility problems may exist –1 = no	D,N	+1	Groundwater and delivered water (higher quality) are currently used for wetland management, although contribution of groundwater to total supply is unknown.
	Does groundwater quality meet drinking-water standards (i.e., can it be used for refuge domestic supply)?	+1 = yes it is used, no treatment is necessary 0 = yes it is used, but some treatment is necessary for potable use; or it is not used for unknown reasons –1 = no, it is not used because of adverse water quality conditions	D	0	Groundwater is used for nonpotable domestic supply.
Operational Issues/Constraints	Does a significant percentage of total refuge water supply consist of "Incremental Level 4" water?	+1 = yes, 54% to 79% of total water supply is Incremental Level 4 0 = somewhat, 27% to 53% of total water supply is Incremental Level 4 –1 = minor, 0% to 26% of total water supply is Incremental Level 4	D,N	0	Approximately 31 percent of the water supply for Grassland RCD consists of Incremental Level 4 water.
	Is the cost of local water high or low relative to the other refuges in this study?	+1 = costs may fluctuate highly or are subject to spot-market variability or price spikes –1 = costs are relatively stable and subjectivity to spot-market variability is low	D,N	+1	Incremental Level 4 water made available to Grassland RCD is subject to wide fluctuations in cost and variable spot-market availability.
	Is it necessary to convey Incremental Level 4 water through the Delta for refuge supply?	+1 = yes, Incremental Level 4 water must be conveyed through the Delta –1 = no, conveyance of Incremental Level 4 water through the Delta is not necessary	D,N	+1	Incremental Level 4 water must be conveyed through the Delta given current water supply sources.
Data Needs	Are there significant data needs to address prior to groundwater development?	+1 = no, data needs regarding refuge groundwater conditions are minor 0 = somewhat, some data are required prior to increasing groundwater development –1 = yes, significant data must be collected as there is little or no existing data	D,N	0	Some data are required prior to recommending increased groundwater development.
			Total Direct Use Score =	**+5**	
			Total On-Refuge Conjunctive Use Score =	**+4**	

Notes:
a Surface Features

b Application to Approach: D = Direct Use, N = On-Refuge Conjunctive Use

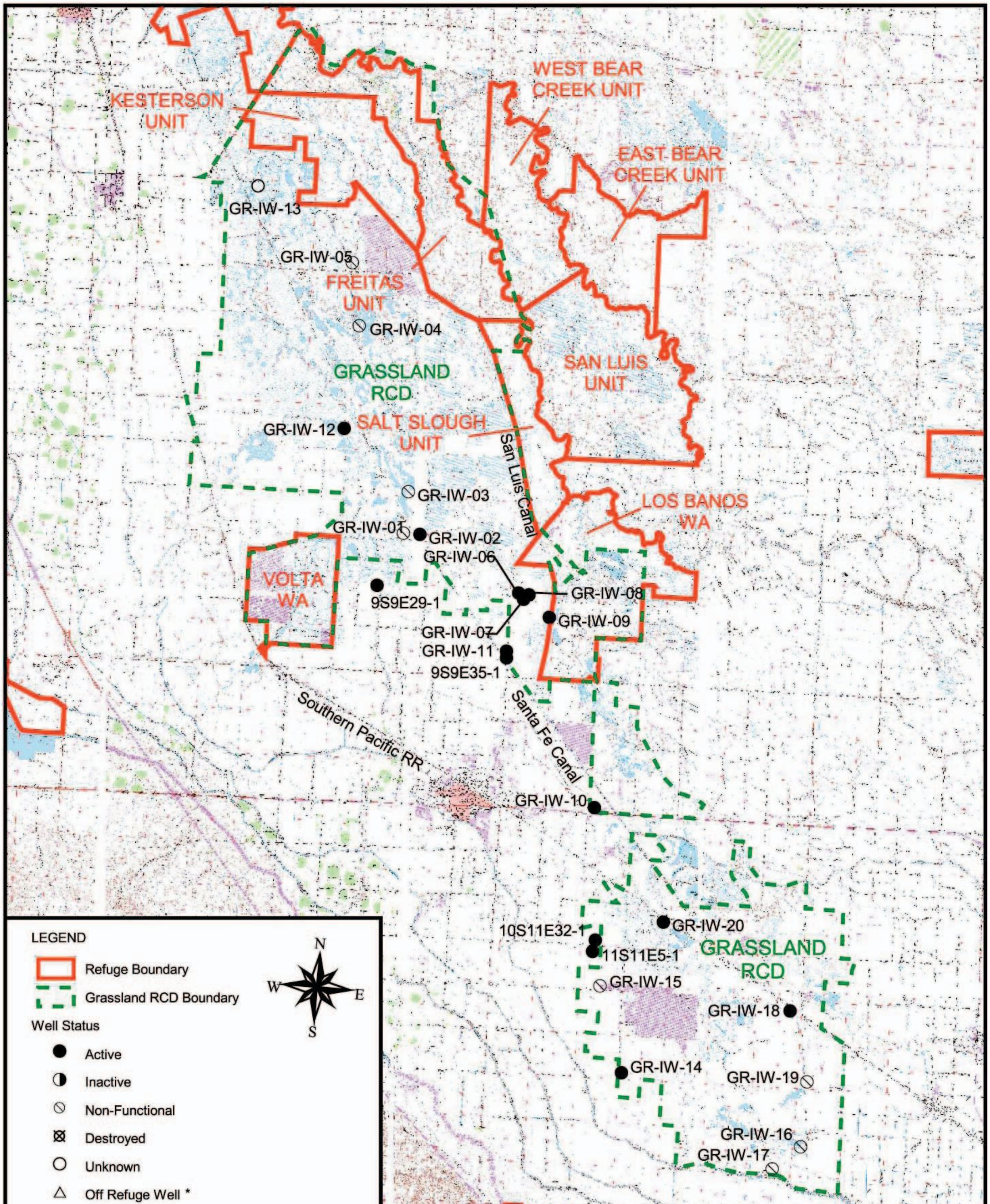

FIGURE 3-31
GRASSLAND RCD
WITH WELL LOCATIONS
EVALUATION OF GROUNDWATER POTENTIAL
FOR INCREMENTAL LEVEL 4 REFUGE WATER SUPPLY

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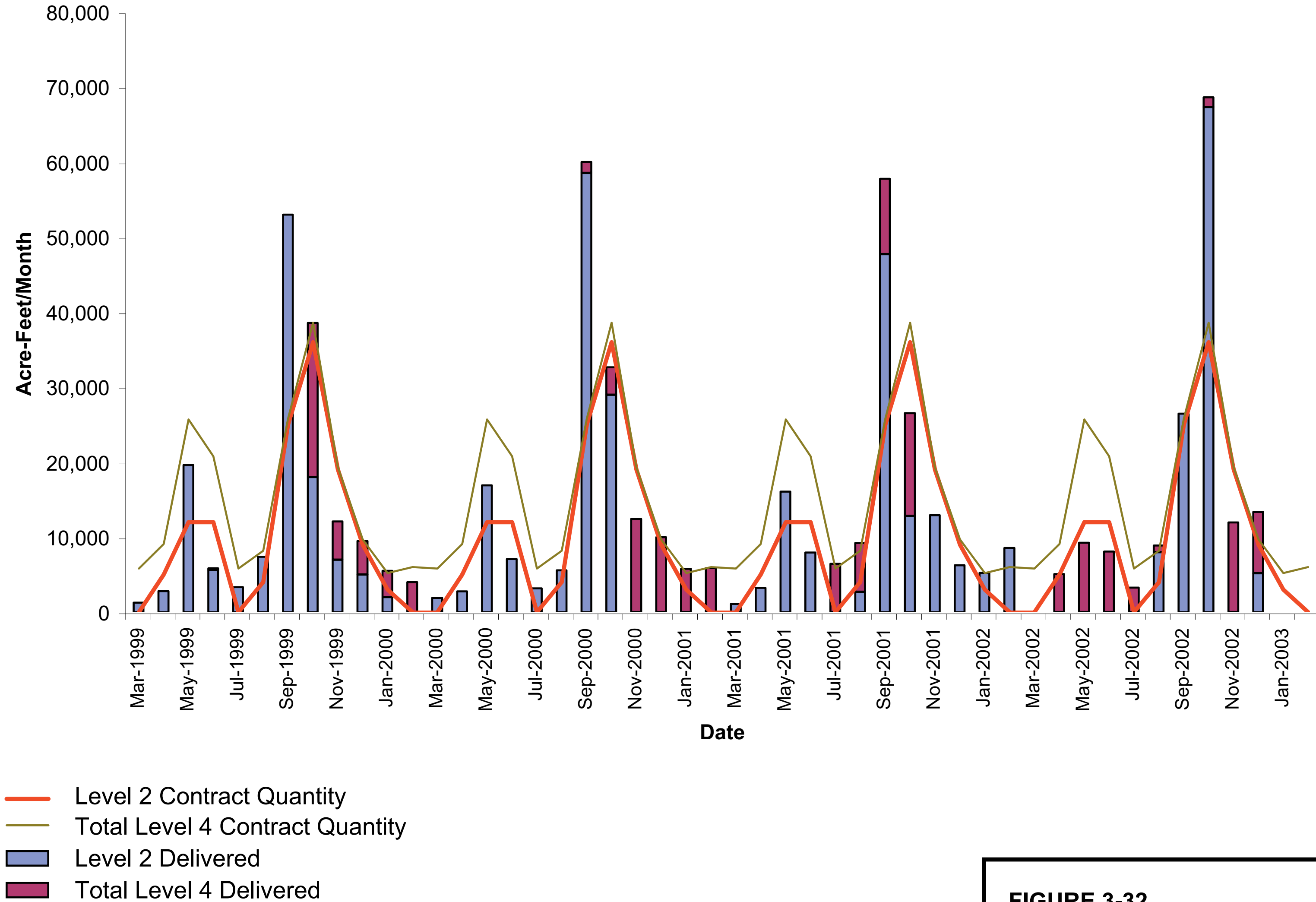

Note: Level 2 and Total Level 4 contract quantities are those indicated in Reclamation 1989 and Reclamation el al. 1989. Volumes indicated may not reflect current monthly management schedules and are shown to indicate an approximate monthly breakdown for management purposes. Total annual contract quantities may be scheduled based on availability, at the refuge manager's discretion.

FIGURE 3-32
1999-2002 GRASSLAND RCD WATER DELIVERIES
EVALUATION OF GROUNDWATER POTENTIAL
FOR INCREMENTAL LEVEL 4 REFUGE WATER SUPPLY

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3.11 Volta WA Refuge Assessment

County: Merced
Basin / Subbasin: San Joaquin Valley Groundwater Basin / Delta-Mendota Subbasin
Level 2 / Incremental Level 4: 10,000 ac-ft / 6,000 ac-ft
2003 Acreage: 3,000
CVP Water Conveyor: San Luis Delta-Mendota Water Authority
Water District Service Area: None
Applicable Groundwater Management Regulations: None

Volta WA is 6 miles northwest of the City of Los Banos, southwest of the San Luis NWR Complex, in the southwest corner of the northern area of Grassland RCD (Figure 3-33). The area is positioned between SR 33 on both the west and south, west of SR 165, and north of Henry Miller Avenue. Ingomar Road and the Southern Pacific Railroad curve along and meet the southwest corner of the refuge. Volta WA is contained entirely within the Grassland RCD.

3.11.1 Hydrogeologic Assessment

3.11.1.1 Habitat Goals, Land Management, and Surface Features

Volta WA provides approximately 3,000 acres of alkali scrub and marshland habitat. The area has been managed by DFG since 1952. The purposes of this refuge are endangered and threatened species conservation, migratory bird refuge and breeding, recreation, wildlife management and control, and wetlands conservation. Key special status species include the Aleutian Canada goose, bald eagle, and giant garter snake (Reclamation 2002).

The San Luis Wasteway flows through the refuge from the southwest to the northeast corner. Much of the refuge land is flooded. No roads cross the refuge.

3.11.1.2 Identified Water Supply Contract Quantities

Figure 3-34 shows the Level 2 and Level 4 water contract quantities and the actual water deliveries to the refuge from 1999 through 2001. The Level 2 water supply contract quantity for Volta WA is 10,000 ac-ft per year. The Level 4 increment is 6,000 ac-ft, totaling 16,000 ac-ft per year for the refuge. Groundwater has not been used on the refuge (Reclamation et al. 2001b).

3.11.1.3 Surface Water Supplies and Infrastructure

The refuge has a Level 2 contractual supply of 13,000 ac-ft of CVP water, which is diverted directly from the San Luis Wasteway, as per contract No. 8-07-20-L6866 between Reclamation and DFG (Reclamation et al. 2001b; Refuge staff 2002). Water flows naturally from the San Luis Wasteway and moves through a network of ponds by gravity flow (DFG staff 2003). Water flows out of the refuge through the Mosquito Ditch and Grassland Cross Canal to Grassland WD. Conveyance facilities are available for delivery of full Incremental Level 4 water.

3.11.1.4 Groundwater Supplies and Infrastructure

Groundwater has not been used on the refuge (Reclamation et al. 2001b; Refuge staff 2002). No wells are used for refuge domestic supply.

Salt accumulation and inadequate drainage have reportedly resulted in highly saline shallow groundwater throughout much of the area. Boron, molybdenum, and arsenic are potential constituents of concern in the region; however, no known water quality testing has been conducted on the refuge (Refuge staff 2002).

3.11.1.5 Local Groundwater Use

The Exchange Contractors have developed wells in areas around the refuge. South of the refuge, domestic and agricultural wells have been developed. Agricultural wells have also been developed to the east (Refuge staff 2002). The Volta urban community is using groundwater for municipal supplies (USEPA 2003).

3.11.1.6 Refuge Soil and Aquifer Conditions

Triangle clay is found in the northeastern quarter and stretches to the far southeast along the eastern border. Large cracks form to several feet in depth when dry. This soil is saline-sodic. The western half of the refuge is covered by Santanela loam, which stretches from the west to the south-central areas of the refuge. The clay and loam soils are deep and very poorly drained (USDA 1990).

Permeability of both soils is very slow, and water capacity varies from low to high. Runoff over both soil types is ponded (USDA 1990).

Data from wells monitored by DWR show shallow groundwater conditions in the area. Along the west and southwest refuge boundaries, depth to groundwater ranges 5 to 10 feet bgs. Directly east of the refuge at SR 165, groundwater depths average between 30 and 40 feet. Shallow groundwater elevations appear to have recovered to conditions prior to the drought in the 1970s (DWR 2003b).

Little to no subsidence has occurred in the immediate vicinity of the refuge (DWR 2003b). Given the soil conditions and that the deep aquifer is confined in the Volta area, subsidence may be possible with a substantial increase in groundwater use.

3.11.1.7 Operational Issues and Data Needs

Incremental Level 4 water made available to Volta WA is subject to wide fluctuations in cost and variable spot-market availability. It is also necessary to convey Level 4 water through the Delta. A more stable source of Incremental Level 4 water both in terms of cost and reliability would be beneficial to refuge water supply management. Approximately 19 percent of the refuge’s water supply is Incremental Level 4 water.

The following data gaps were identified during the completion of this study:

- On-refuge water quality conditions both above and below the Corcoran Clay.
- Quarterly water-level data both on- and off-refuge and collection of data to estimate groundwater conditions under wet, average, and dry years.

- Detailed evaluation of refuge soil characteristics to determine permeability and recharge potential.
- Evaluation of local groundwater use, particularly in the Volta community.
- Aquifer parameters, such as hydraulic conductivity and thickness.
- Groundwater pumping records and schedules immediately surrounding the refuge.

Minimal information is available regarding the groundwater and aquifer conditions on the Volta refuge. Relative to the other refuges in this study, it was estimated that a "high" level of data collection is required at Volta WA prior to recommending specific groundwater development projects.

3.11.2 Criteria Evaluation Summary

Volta WA received total Hydrogeologic Scores of –1 for Direct Use of groundwater and -4 for On-Refuge Conjunctive Use based on criteria matrix evaluation. Table 3-21 shows the specific criteria matrix and scores for this refuge.

Although the refuge has external conveyance potential, groundwater has not been used at this refuge, and managers are reliant on natural land contours for water distribution. Given the questionable groundwater quality in the region, potentially costly on-refuge groundwater quality testing would be necessary before development of groundwater infrastructure at the refuge. Soil conditions are characterized by low-permeability clays, limiting potential for recharge basins. Little aquifer storage capacity is available in the shallow aquifer.

3.11.2.1 Support for Groundwater Development

- There are no significant water bodies on the refuge that could be affected by increased groundwater use.
- Surface water is delivered reliably to the refuge and is therefore available for blending with groundwater, if necessary.
- Little to no subsidence has occurred in the vicinity of the refuge.
- It is necessary to convey Incremental Level 4 water through the Delta to serve the refuge.
- The cost of local water is high relative to the other refuges in the study. Cost and reliability is subject to spot-market variability.
- The community of Volta is using groundwater for municipal supplies, suggesting groundwater quality in the area may be suitable for use by the refuge.

3.11.2.2 Limitations to Groundwater Development

- Groundwater has not been used on the refuge. No well infrastructure currently exists.
- Municipal wells are located near the refuge. The community of Volta is using groundwater for municipal supplies.

- Water quality may be impaired in some areas. Inadequate drainage and accumulating salts have resulted in high salinity in the basin, according to refuge staff. Potential boron, molybdenum, and selenium may be found regionally, particularly in shallow groundwater.
- At-surface soils primarily have low permeability and are not conducive to groundwater recharge. Clay soils extend to several feet in depth.
- Aquifer storage is not available. Current and historic groundwater levels are approximately equivalent.
- Dependence on Incremental Level 4 water for refuge water supply is relatively minor compared to other refuges in the study.
- Significant data collection is necessary prior to recommending groundwater development.

3.11.3 Recommended Data Acquisition Activities

Significant data collection would be required prior to recommending specific groundwater development projects. Installation and testing of one or two test wells on the refuge would provide information on the aquifer characteristics and groundwater quality data. Because this refuge has a low priority to develop groundwater relative to the other refuges in this study, no data acquisition is recommended at this time.

3.11.4 Potential Projects

3.11.4.1 Direct Use

No wells exist on the refuge. Boron, molybdenum, and arsenic are potential constituents of concern in the region, but no refuge water quality information is available. Substantial aquifer and water quality information would have to be assessed to determine if groundwater development is feasible. Additionally, direct use of groundwater may require the construction of an IDS. This potentially high-cost undertaking is only recommended after groundwater is developed successfully at other refuges in this study.

3.11.4.2 On-Refuge Conjunctive Use

Water is delivered to Volta WA directly from the San Luis Wasteway, which is diverted directly from the Delta Mendota Canal. This water, therefore, is probably of the highest quality available for storage in the Los Banos-area refuges. However, groundwater levels measured in the wells around the Volta WA indicate that depth-to-water is generally less than 10 feet. Data from recommended test wells could be used as the foundation for an assessment of storage options at Volta. Ideally, such a study would be conducted as part of an overall conjunctive use assessment at Grassland RCD.

3.11.4.3 Off-Refuge Conjunctive Use

Volta WA is not located within the sphere of influence of any groundwater management plan or ordinance. At this time, no off-refuge conjunctive use projects have been identified for potential partnership.

TABLE 3-21
Volta WA Evaluation
Evaluation of Groundwater Potential for Incremental Level 4 Refuge Water Supply

	Criteria	Scoring Scale	Appl.[b]	Score	Refuge Score Justification
Surface[a]	Do surface water bodies exist that could be affected by increased groundwater use?	+1 = no 0 = to some degree –1 = yes, surface water bodies could be affected	D,N	+1	There are no significant water bodies on the refuge that could be affected by increased groundwater use.
Water Supplies and Infrastructure	Has groundwater been used previously at the refuge for ponds or irrigation?	+1 = yes, used successfully to meet at least 20 percent of annual refuge water demands 0 = yes, used to meet less than 20 percent (or unknown) of annual refuge water demands. –1 = no, has not been used	D,N	-1	Groundwater has not been used on the refuge.
	Do wells exist on the refuge?	+1 = yes, active wells 0 = yes, inactive or nonfunctional wells –1 = yes, destroyed wells, or no wells exist on the refuge	D,N	-1	Groundwater has not been used on the refuge.
	Does existing internal distribution system (IDS) support groundwater use?	+1 = water can move extensively around the refuge with existing IDS 0 = the IDS enables limited water movement within the refuge –1 = an IDS does not exist on the refuge or water flow relies exclusively on gravity	D,N	-1	The refuge relies on gravity to flood the wetland areas.
Local Groundwater Use	Is groundwater used for agriculture or duck clubs in the immediate vicinity of the refuge?	+1 = groundwater is not used; or groundwater is minimally used, but use is not constrained 0 = groundwater is used in the area –1 = groundwater is not used due to physical or environmental constraints or is extensively used in the vicinity	D,N	0	Exchange contractors have developed agricultural wells to the east. South of the refuge, domestic and agricultural wells have also been developed.
	Does municipal or domestic supply exist near the refuge?	+1 = no known domestic or municipal wells are located within 1 mile of the refuge 0 = municipal or domestic wells are likely located within 1 mile of the refuge –1 = municipal or domestic wells are located within 1 mile of the refuge	D,N	-1	The community of Volta is using groundwater for municipal supplies.
Soil and Hydrogeology	Are at-surface soils conducive to groundwater recharge?	+1 = soils are sandy or are reported to percolate well 0 = soils are silty or are reported to have some infiltration –1 = soils are clayey or are reported to hold water well	N	-1	Permeability of clay and loam soils is very slow, and water capacity varies from low to high. Runoff over both soil types is ponded.
	Could recharge basins be developed if surface soils were removed?	+1 = confining soil less than 2 feet thick 0 = confining soil 5 to 7 feet thick –1 = confining soil greater than 7 feet thick	N	-1	Clay soils are reported to extend very deep.
	Has subsidence occurred at or in the immediate vicinity of the refuge?	+1 = no 0 = yes, less than 2 feet –1 = yes, more than 2 feet	D,N	+1	Little to no subsidence has occurred in the immediate vicinity of the refuge.
	Does significant potential for subsidence exist if groundwater use is increased at the refuge?	+1 = minimal potential for subsidence 0 = some potential for subsidence –1 = significant potential for subsidence	D,N	0	Subsidence is possible with a substantial increase in groundwater use.
	Is aquifer storage available in the subbasin?	+1 = yes, current water levels are greater than 30 feet lower than historic levels 0 = some, current water levels are between 10 and 30 feet lower than historic levels –1 = no	N	-1	Shallow groundwater elevations appear to have recovered to pre-1970s levels.

Notes:
a Surface Features
b Application to Approach: D = Direct Use, N = On-Refuge Conjunctive Use

continued on next page

TABLE 3-21
Volta WA Evaluation
Evaluation of Groundwater Potential for Incremental Level 4 Refuge Water Supply

	Criteria	Scoring Scale	Appl.[b]	Score	Refuge Score Justification
Water Quality	Have groundwater quality conditions hindered groundwater use in the past?	+1 = no 0 = data are not available –1 = yes	D,N	0	Groundwater has not been used on the refuge.
	Do adverse groundwater quality conditions exist in the subbasin?	+1 = no 0 = potential –1 = yes	D,N	-1	Inadequate drainage and accumulating salts have resulted in high EC in shallow groundwater in much of the basin. Boron, molybdenum, and arsenic are potential problems in some areas regionally.
	Is surface water available to enable blending of lower quality groundwater to meet proposed refuge standards?	+1 = yes 0 = during portions of the year –1 = no	D,N	+1	Water deliveries are reliable most of the year but may decrease during the spring.
	Do groundwater conditions exceed USEPA Freshwater Aquatic Life Standards or Agricultural Water Quality Goals for multiple parameters?	+1 = no 0 = yes, two parameters, or no water quality testing has been conducted –1 = yes, three or more parameters	D,N	0	No water quality tests have been performed on refuge groundwater.
	Is refuge land use management compatible with seasonally or annually variable water quality from different sources?	+1 = yes 0 = some potential compatibility problems may exist –1 = no	D,N	0	Delivered water is the only source of water used for wetland management, so compatibility with other sources is unknown.
	Does groundwater quality meet drinking-water standards (i.e., can it be used for refuge domestic supply)?	+1 = yes it is used, no treatment is necessary 0 = yes it is used, but some treatment is necessary for potable use; or it is not used for unknown reasons –1 = no, it is not used because of adverse water quality conditions	D	0	Groundwater is not used for refuge domestic supply for unknown reasons.
Operational Issues/Constraints	Does a significant percentage of total refuge water supply consist of "Incremental Level 4" water?	+1 = yes, 54% to 79% of total water supply is Incremental Level 4 0 = somewhat, 27% to 53% of total water supply is Incremental Level 4 –1 = minor, 0% to 26% of total water supply is Incremental Level 4	D,N	0	Approximately nineteen percent of the water supply for Volta WA consists of Incremental Level 4 water.
	Is the cost of local water high or low relative to the other refuges in this study?	+1 = costs may fluctuate highly or are subject to spot-market variability or price spikes –1 = costs are relatively stable and subjectivity to spot-market variability is low	D,N	+1	Incremental Level 4 water made available to Volta WA is subject to wide fluctuations in cost and variable spot-market availability.
	Is it necessary to convey Incremental Level 4 water through the Delta for refuge supply?	+1 = yes, Incremental Level 4 water must be conveyed through the Delta –1 = no, conveyance of Incremental Level 4 water through the Delta is not necessary	D,N	+1	Incremental Level 4 water must be conveyed through the Delta given current water supply sources.
Data Needs	Are there significant data needs to address prior to groundwater development?	+1 = no, data needs regarding refuge groundwater conditions are minor 0 = somewhat, some data are required prior to increasing groundwater development –1 = yes, significant data must be collected as there is little or no existing data	D,N	-1	Significant data are required prior to recommending increased groundwater development.
			Total Direct Use Score =	**-1**	
			Total On-Refuge Conjunctive Use Score =	**-4**	

Notes:
a Surface Features

b Application to Approach: D = Direct Use, N = On-Refuge Conjunctive Use

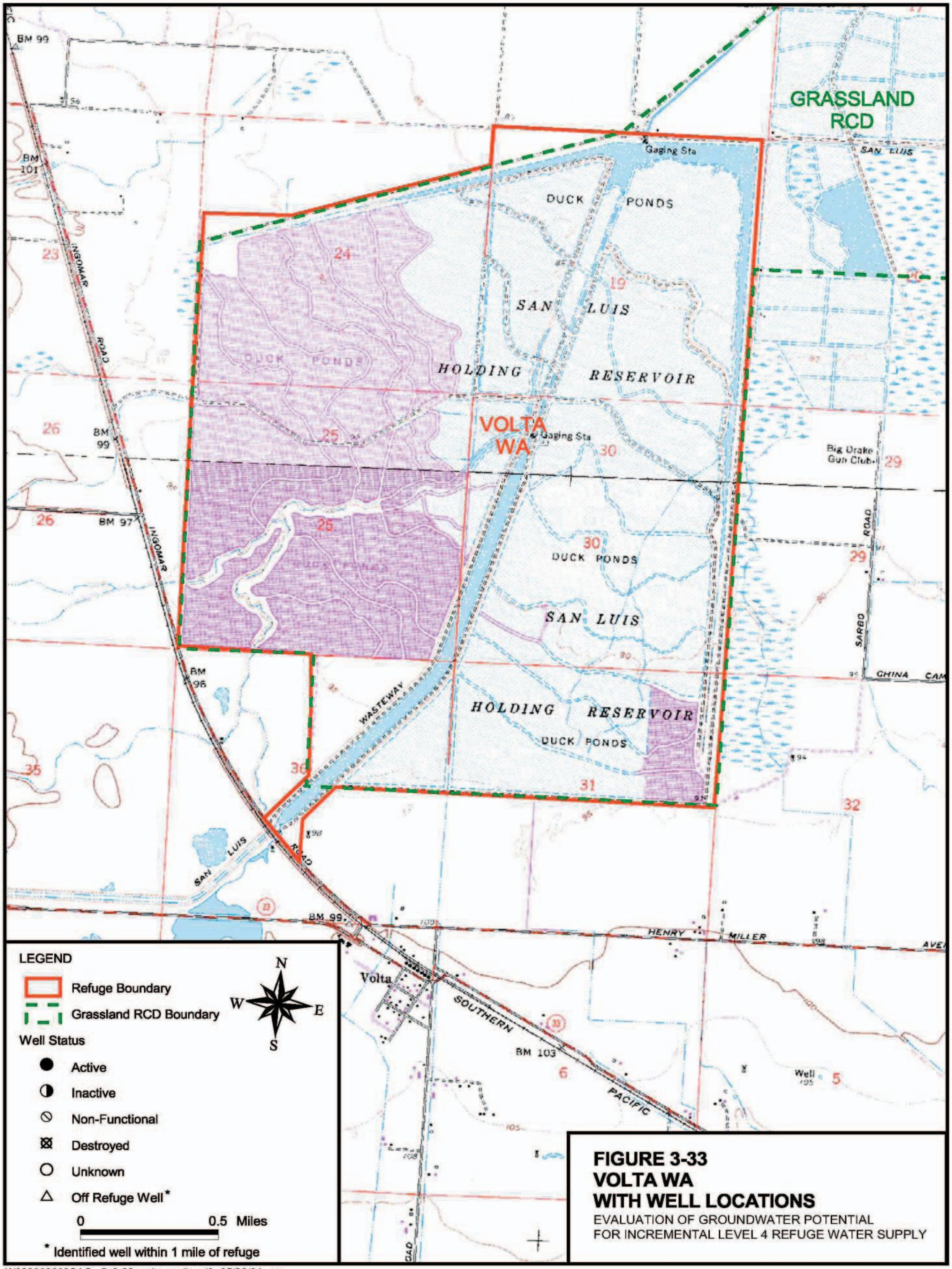

FIGURE 3-33
VOLTA WA
WITH WELL LOCATIONS
EVALUATION OF GROUNDWATER POTENTIAL
FOR INCREMENTAL LEVEL 4 REFUGE WATER SUPPLY

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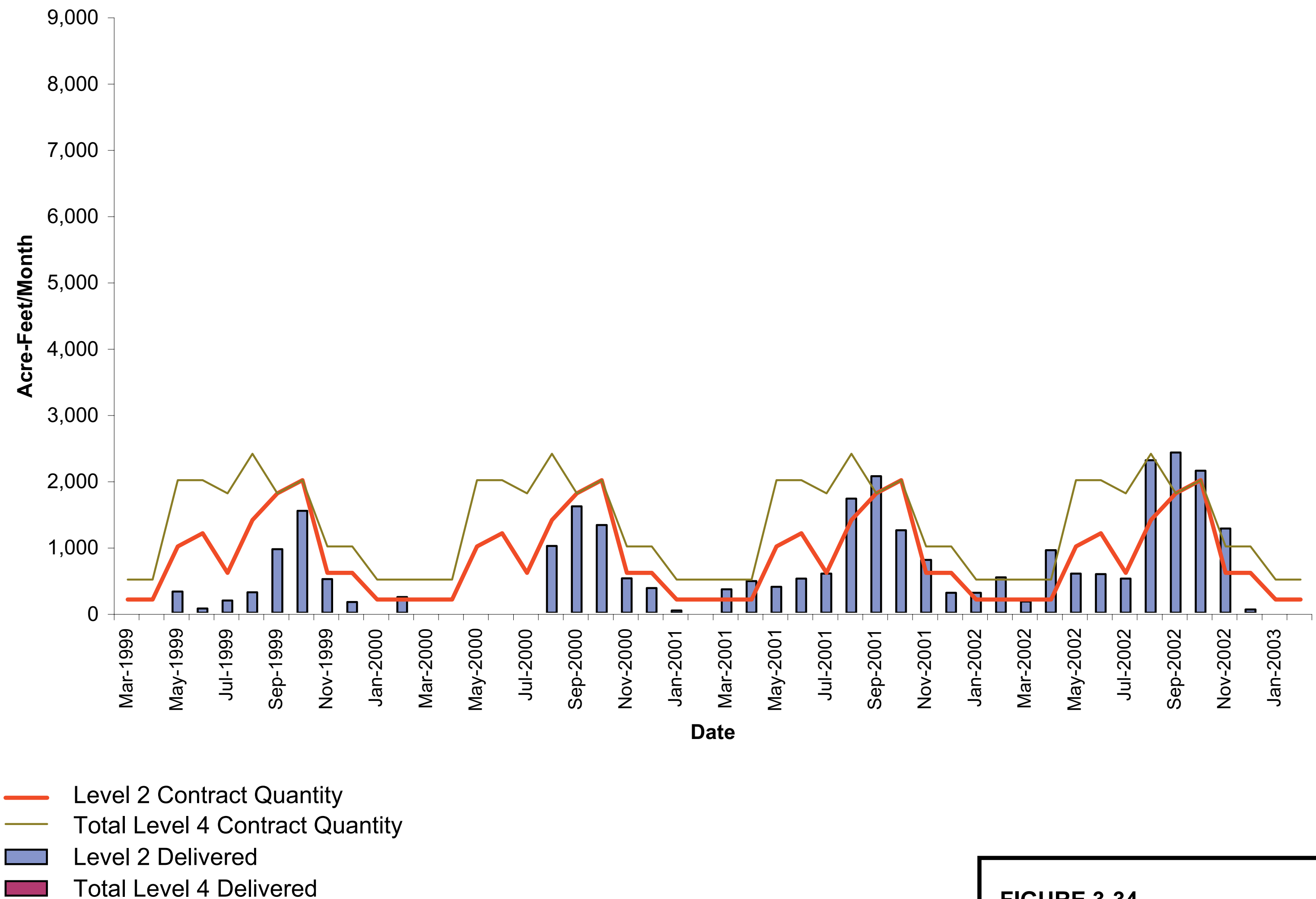

Note: Level 2 and Total Level 4 contract quantities are those indicated in Reclamation 1989 and Reclamation el al. 1989. Volumes indicated may not reflect current monthly management schedules and are shown to indicate an approximate monthly breakdown for management purposes. Total annual contract quantities may be scheduled based on availability, at the refuge manager's discretion.

FIGURE 3-34
1999-2002 VOLTA WILDLIFE AREA WATER DELIVERIES
EVALUATION OF GROUNDWATER POTENTIAL
FOR INCREMENTAL LEVEL 4 REFUGE WATER SUPPLY

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3.12 East Bear Creek Unit Refuge Assessment (San Luis NWR Complex)

County: Merced
Basin / Subbasin: San Joaquin Valley Groundwater Basin / Merced Subbasin
Level 2 / Incremental Level 4: 8,863 ac-ft / 4,432 ac-ft
2003 Acreage: 4,000
CVP Water Conveyor: San Luis CC
Water District Service Area: None
Applicable Groundwater Management Regulations: None

The East Bear Creek Unit is located in Merced County. The San Joaquin River forms the western and southern borders of the refuge and separates the East Bear Creek Unit from the West Bear Creek Unit. Bear Creek and Bravel Slough form the northern boundary of the refuge. The eastern refuge border follows section lines (Figure 3-35).

3.12.1 Hydrogeologic Assessment

3.12.1.1 Habitat Goals, Land Management, and Surface Features

The primary purposes of this refuge are endangered and threatened species conservation; migratory bird refuge, breeding, and sanctuary; natural resource protection; recreation; wildlife management and control; and wetlands conservation (Reclamation 2002).

The 4,000 acres of East Bear Creek Unit were purchased from the Gallo family in 1993. The area consists of wetland and grassland habitat, vernal pools, and riparian floodplain. Prior to acquisition, the land was managed as irrigated pasture (Reclamation et al. 2001b). East Bear Creek Unit is managed within the San Luis NWR Complex.

The San Joaquin River, Bear Creek, and Bravel Slough border the refuge. Two small roads traverse the west side of the unit.

3.12.1.2 Identified Water Supply Contract Quantities

Figure 3-36 shows the Level 2 and Level 4 water contract quantities and the actual water deliveries to the refuge from 1999 through 2001. Level 2 water supply for the East Bear Creek Unit is 8,863 ac-ft. The Level 4 increment is 4,432 ac-ft, totaling 13,295 ac-ft per year (Reclamation et al. 2001b).

3.12.1.3 Surface Water Supplies and Infrastructure

The primary refuge water supply is obtained from the Merced ID via Bear Creek. When available, up to 38 cfs can be diverted, but only from March 1 through October 31 (Reclamation et al. 2001b). The C-Canal can also provide water to the unit's riparian habitat. The full Level 4 amount has not been received because the refuge has not been fully developed. Also, there is no conveyance available to deliver Level 4 water. Improvements to the conveyance system are being designed. One option being considered is the construction of a 36-inch-diameter pipeline on the east side of the refuge. Internal levees provide water conveyance throughout the refuge (Refuge staff 2002).

Refuge staff consider the quality of the delivered water to be adequate for refuge irrigation needs.

3.12.1.4 Groundwater Supplies and Infrastructure

Irrigation and Production Wells. This refuge unit has three wells—Wells 11 (EB-IW-01), 12 (EB-IW-02), and 13 (EB-IW-03)—screened above the Corcoran Clay, which is at depths varying between 150 and 300 feet. A fourth well (well 10, EB-IW-04) has been destroyed. No wells are used for refuge domestic supply. Refuge irrigation well locations are shown on Figure 3-35, and well information is summarized on Table 3-22.

Well 11 (EB-IW-01) is located in the southern tip of the refuge, near the San Joaquin River Pump Station. Former Well 10 (EB-IW-04) and Well 12 (EB-IW-02) are also located in the southern part of the refuge. Well 13 (EB-IW-03) is located on the northeast side of the refuge, along the planned pipeline route. Well tests in 1998 determined refuge well production to be between 838 gpm (Well 12) and 1,700 gpm (Well 13). These irrigation wells are no longer used, however, because of poor water quality (Refuge staff 2002; Turner 2001). Although the wells are along the proposed pipeline, it is not planned to use them in conjunction with the pipeline.

Water Quality Data. Agricultural Water Quality Goals have been exceeded for salinity, molybdenum, and TDS in samples collected from the existing refuge wells. Water quality tests in 2001 (Table 3-23) from these wells indicated EC ranged from 1,800 to 3,200 µmhos/cm, molybdenum from 0.02 to 0.03 mg/L, and TDS from 980 to 1,650 mg/L (Turner 2001). Boron and selenium were not detected. Overall, Well No. 12 (EB-IW-02) has slightly better groundwater quality than Well 11 (EB-IW-01) to the south or Well 13 (EB-IW-03) to the north. It has been previously recommended that the western area of the refuge should be further investigated for adequate groundwater quality if conjunctive use is considered to be an option and that sub-Corcoran Clay aquifer conditions be evaluated (Turner 2001).

3.12.1.5 Local Groundwater Use

Groundwater is used throughout the region to supply agricultural irrigation, private duck clubs, and occasionally for domestic purposes (Refuge staff 2002). No known domestic wells are located within 1 mile of the refuge, however (DWR well logs on file).

3.12.1.6 Refuge Soil and Aquifer Conditions

The East Bear Creek Unit is characterized by several major soil types, including Merced, Rossi, Fresno, Waukena, and Temple soils (USDA 1991).

The northwest quarter of the refuge consists mainly of Merced clay loam, Rossi clay loam, Fresno loam, and Waukena, all moderately to strongly saline-alkali. The northeast and west consist mainly of Rossi clay loam, and the south is dominated by Temple clay loam with small areas of Columbia soils (channeled). Most soils are fine grained. Small areas of Merced clay loam soils in the northwest part of the refuge have 5 to 12 inches of moderately permeable surface soil. In general, confining soils extend several feet in depth (USDA 1991).

In general, permeability is slow to very slow through the surface and subsoil, and the water-holding capacity varies from low to high. Temple soils have moderate permeability. Surface and internal drainage are very slow, and salt content is high (USDA 1991).

Less than 1 foot of subsidence has occurred in the vicinity of the refuge (USDA 1991). There is some potential for subsidence to occur in the region if groundwater use is substantially increased.

Groundwater depth at the refuge is shallow, varying between 2 and 20 feet bgs according to DWR test well results (DWR 2003b). Subbasin-wide, DWR shows that the subbasin water level has declined 30 feet between 1970 and 2000 (DWR 2003a).

3.12.1.7 Operational Issues and Data Needs

The refuge depends somewhat on Level 4 water supplies. Approximately 33 percent of the refuge's water supply is Incremental Level 4. Incremental Level 4 water made available to the East Bear Creek Unit is subject to wide fluctuations in cost and variable spot-market availability. It is also necessary to convey Level 4 water through the Delta. A more stable source of Incremental Level 4 water both in terms of cost and reliability would be beneficial to refuge water supply management.

The following data gaps were identified during the completion of this study:

- Thorough assessment of all refuge wells to determine well conditions.
- Confirm refuge groundwater quality conditions at different locations and at several different depths below ground surface, both above and below the Corcoran Clay. At a minimum, EC, TDS, and boron concentrations in groundwater should be verified to determine potential for deleterious effects on wildlife.
- Local aquifer conditions, including quarterly water-level data both on- and off-refuge, and collection of data to estimate groundwater conditions under wet, average, and dry conditions.
- Aquifer parameters, such as hydraulic conductivity and thickness.
- Groundwater pumping records and schedules, both on and immediately surrounding the refuge.

Relative to the other refuges in this study, it was estimated that a "medium" level of data collection is required at the East Bear Creek Unit prior to recommending specific groundwater development projects.

3.12.2 Criteria Evaluation Summary

East Bear Creek Unit received total Hydrogeologic Scores of zero for Direct Use of groundwater and zero for On-Refuge Conjunctive Use based on criteria matrix evaluation. Table 3-24 gives the specific criteria matrix and scores for this refuge.

Although three wells are present on the refuge, they are no longer used because of water quality concerns. Further evaluation of groundwater quality below the Corcoran Clay would be necessary prior to increased groundwater use. Surface soils consist mainly of clays, but there are small areas in which Merced clay loam soils have a more moderately permeable surface layer (USDA 1991). According to DWR monitoring data, the subbasin water levels have declined 30 feet in the last 30 years, so aquifer storage capacity may be available (DWR 2003b).

Support and limitations of increased groundwater development at East Bear Creek are summarized below.

3.12.2.1 Support for Groundwater Development

- There are few significant water bodies on the refuge that could be affected by increased groundwater use.
- Two inactive wells and one non-functional well are present on the refuge.
- No known domestic wells are located within 1 mile of the refuge.
- According to DWR data, the subbasin water level has declined 30 feet between 1970 and 2000. Aquifer storage may be available.
- It is necessary to convey Incremental Level 4 water through the Delta to serve the refuge.
- The cost of local water is high relative to the other refuges in the study. Cost and reliability is subject to spot-market variability.

3.12.2.2 Limitations to Groundwater Development

- Poor water quality has limited groundwater use. Wells are no longer used because of high pumping cost and water quality concerns.
- Elevated levels of EC and molybdenum have been detected at irrigation wells. Agricultural Water Quality Goals have been exceeded for EC, molybdenum, and TDS.
- At-surface soils primarily have low permeability and are not conducive to groundwater recharge. Some small areas of Merced clay loam may be more permeable.

3.12.3 Recommended Data Acquisition Activities

Prior to deciding if groundwater should be further developed on the refuge, the following data acquisition tasks are recommended:

- Install and test one or two test wells below the Corcoran Clay on the refuge, as previously recommended by Reclamation, to provide information on the aquifer characteristics and groundwater quality data.
- Conduct one or two 72-hour aquifer tests at existing irrigation wells to determine an estimated refuge yield. Conduct these tests during a season in which the refuge is not irrigating. Use existing production wells where there are nearby inactive wells that can be monitored before and during the test.
- Develop a groundwater budget for the refuge. Estimate groundwater conditions at the refuge under wet-, normal-, and dry-year conditions.
- If any of the existing inactive wells are to be used for refuge water supply, install well meters at all irrigation wells at the refuge and record monthly water use at each well.
- Investigate areas of Merced clay loam to determine permeability and sub-surface aquifer conditions for potential recharge sites.

3.12.4 Potential Projects

3.12.4.1 Direct Use

Existing water supply and infrastructure do not strongly support increased use of groundwater. Although three wells are present on the refuge, they are no longer used because of water quality concerns. Refuge water quality above and below the Corcoran Clay should be verified to determine the feasibility of further groundwater development.

3.12.4.2 On-Refuge Conjunctive Use

Aquifer storage space may be available in the subbasin. While existing groundwater quality information does not indicate favorable conditions for groundwater banking, more data are needed to make this determination. Some small areas of Merced clay loam may provide permeable areas for on-site recharge. These areas should also be investigated before a recommendation is made.

3.12.4.3 Off-Refuge Conjunctive Use

Although the Exchange Contractors, of which the San Luis CC is a member, has adopted an AB 3030 Groundwater Management Plan, the refuge itself is not in the Exchange Contractors' jurisdiction, so the refuge is not affected by the groundwater management plan (San Joaquin River Exchange Contractors Water Authority 1997).

The Merced Water Supply Plan recommends that groundwater recharge be implemented to address regional groundwater conditions. Partnership with this program could potentially be used to support the East Bear Creek Unit and Merced NWR. No other off-refuge conjunctive use projects have been identified for potential partnership at this time.

TABLE 3-22
East Bear Creek Unit Well Information[a]
Evaluation of Groundwater Potential for Incremental Level 4 Refuge Water Supply

GIS Well Number[b]	Common Well Name	Well Status[c]	2002 Yield (ac-ft)	Year Installed	Depth (ft)	Screen Interval (bgs)	Well Output (gpm)	Well Log?	Water Quality Data?	Comments
EB-IW-01	11	Inactive			287	60–287	1,716	N	Y	Well potential deemed "good." Encrusted perforations 60 to 118 ft, open and in good condition 120 to 220 ft, possible break in casing at 178 to 180 ft (2001).
EB-IW-02	12	Inactive			185	78–185	838	N	Y	Well potential deemed "poor." Heavy scale 34 to 79 ft, very encrusted perforations from 79 feet to bottom (2001).
EB-IW-03	13	Nonfunctional			149	86–149	1,218	N	Y	Well capacity deemed "fair." Possible breaks at 37 and 72 ft, hole in casing at 90 ft, break or very corroded joint at 97 ft, rough joint at 121 ft, very encrusted perforations at 86 to 100 ft, moderate encrustation 100 ft to bottom (2001).
EB-IW-04	10	Destroyed						N	N	

Notes:

[a] Based on data compiled from well logs, test records, communication with refuge staff (2002), and other previous documentation. Well locations are shown on Figure 3-35. On-refuge wells only are included in this table, although the GIS includes known wells within 1 mile of the refuge.

[b] Well type is indicated by the middle two letters of the GIS well number: IW = irrigation well, DW = domestic well, MW = monitoring well, TW = test well, and UN = unknown.

[c] Designation refers to the physical well only, not water quality issues. Designations are: *active* (currently operated), *inactive* (capable of operating, but currently is not), *nonfunctional* (cannot operate in current physical state), *destroyed* (well has been lost, abandoned, or filled), or *unknown* (no information regarding status is available).

[d] Deep wells 1 through 4 were present on the refuge land prior to DFG acquisition.

Blank fields indicate that no information is available.

TABLE 3-23
East Bear Creek Unit Water Quality Data (2001)
Evaluation of Groundwater Potential for Incremental Level 4 Refuge Water Supply

GIS Well Number	Sampled Interval (feet)	EC (µmhos/cm)	Boron (mg/L)	Selenium (µg/L)	Molybdenum (mg/L)	TDS (mg/L)	Manganese (mg/L)
EB-IW-01	60–287	2,953	ND	ND	0.03	1,640	0.71
EB-IW-02	78–185	1,871	ND	ND	0.024	982	0.64
EB-IW-03	86–149	3,214	ND	ND	0.021	1,650	0.63

Source: Turner 2001.

Notes:

Well locations are shown on Figure 3-35.
ND = not detected

TABLE 3-24
East Bear Creek Unit Evaluation
Evaluation of Groundwater Potential for Incremental Level 4 Refuge Water Supply

	Criteria	Scoring Scale	Appl.[b]	Score	Refuge Score Justification
Surface[a]	Do surface water bodies exist that could be affected by increased groundwater use?	+1 = no 0 = to some degree –1 = yes, surface water bodies could be affected	D,N	-1	The San Joaquin River, Bear Creek, and Bravel Slough border the refuge, but few water bodies would be impacted by increased groundwater use.
Water Supplies and Infrastructure	Has groundwater been used previously at the refuge for ponds or irrigation?	+1 = yes, used successfully to meet at least 20 percent of annual refuge water demands 0 = yes, used to meet less than 20 percent (or unknown) of annual refuge water demands. –1 = no, has not been used	D,N	0	Four shallow wells have been used to contribute to refuge water supply.
	Do wells exist on the refuge?	+1 = yes, active wells 0 = yes, inactive or nonfunctional wells –1 = yes, destroyed wells, or no wells exist on the refuge	D,N	0	Three wells between 150 and 300 feet deep are present on the refuge, but are no longer used because of water quality concerns. One well has been destroyed.
	Does existing internal distribution system (IDS) support groundwater use?	+1 = water can move extensively around the refuge with existing IDS 0 = the IDS enables limited water movement within the refuge –1 = an IDS does not exist on the refuge or water flow relies exclusively on gravity	D,N	0	Internal levees currently provide water distribution throughout the refuge. Improvements are being evaluated, including a 36-inch pipeline on the east side of the refuge.
Local Groundwater Use	Is groundwater used for agriculture or duck clubs in the immediate vicinity of the refuge?	+1 = groundwater is not used; or groundwater is minimally used, but use is not constrained 0 = groundwater is used in the area –1 = groundwater is not used due to physical or environmental constraints or is extensively used in the vicinity	D,N	0	Groundwater is typically used in the area for agricultural irrigation and duck clubs.
	Does municipal or domestic supply exist near the refuge?	+1 = no known domestic or municipal wells are located within 1 mile of the refuge 0 = municipal or domestic wells are likely located within 1 mile of the refuge –1 = municipal or domestic wells are located within 1 mile of the refuge	D,N	+1	No known domestic wells are located within 1 mile of the refuge.
Soil and Hydrogeology	Are at-surface soils conducive to groundwater recharge?	+1 = soils are sandy or are reported to percolate well 0 = soils are silty or are reported to have some infiltration –1 = soils are clayey or are reported to hold water well	N	-1	Surface soils consist mainly of slowly permeable clays and clay loams. Exceptions are small areas of Merced clay loam soils that have 5 to 12 inches of moderately permeable surface soil, found in the northwest part of the refuge.
	Could recharge basins be developed if surface soils were removed?	+1 = confining soil less than 2 feet thick 0 = confining soil 5 to 7 feet thick –1 = confining soil greater than 7 feet thick	N	0	Confining soil typically extends several feet in depth.
	Has subsidence occurred at or in the immediate vicinity of the refuge?	+1 = no 0 = yes, less than 2 feet –1 = yes, more than 2 feet	D,N	0	Less than 1 foot of subsidence has occurred in the vicinity of the refuge.
	Does significant potential for subsidence exist if groundwater use is increased at the refuge?	+1 = minimal potential for subsidence 0 = some potential for subsidence –1 = significant potential for subsidence	D,N	0	There is potential for subsidence to occur in the region if groundwater use is substantially increased.
	Is aquifer storage available in the subbasin?	+1 = yes, current water levels are greater than 30 feet lower than historic levels 0 = some, current water levels are between 10 and 30 feet lower than historic levels –1 = no	N	+1	According to DWR data, the subbasin water level has declined 30 feet between 1970 and 2000.

Notes:
a Surface Features
b Application to Approach: D = Direct Use, N = On-Refuge Conjunctive Use

continued on next page

TABLE 3-24
East Bear Creek Unit Evaluation
Evaluation of Groundwater Potential for Incremental Level 4 Refuge Water Supply

	Criteria	Scoring Scale	Appl.[b]	Score	Refuge Score Justification
Water Quality	Have groundwater quality conditions hindered groundwater use in the past?	+1 = no 0 = data are not available –1 = yes	D,N	-1	Wells are not currently used because of water quality concerns. Elevated levels of EC (>3,000 µmhos) and molybdenum (>0.03 mg/L) have been detected at irrigation wells.
	Do adverse groundwater quality conditions exist in the subbasin?	+1 = no 0 = potential –1 = yes	D,N	0	The western side of the refuge has not been evaluated for water quality conditions.
	Is surface water available to enable blending of lower quality groundwater to meet proposed refuge standards?	+1 = yes 0 = during portions of the year –1 = no	D,N	0	Water is delivered to the refuge during some months of the year.
	Do groundwater conditions exceed USEPA Freshwater Aquatic Life Standards or Agricultural Water Quality Goals for multiple parameters?	+1 = no 0 = yes, two parameters, or no water quality testing has been conducted –1 = yes, three or more parameters	D,N	-1	Agricultural water quality goals have been exceeded for EC, molybdenum, and TDS. Selenium and boron were not detected.
	Is refuge land use management compatible with seasonally or annually variable water quality from different sources?	+1 = yes 0 = some potential compatibility problems may exist –1 = no	D,N	0	Delivered water is the only source of water used for wetland management, so compatibility with other sources is unknown.
	Does groundwater quality meet drinking-water standards (i.e., can it be used for refuge domestic supply)?	+1 = yes it is used, no treatment is necessary 0 = yes it is used, but some treatment is necessary for potable use; or it is not used for unknown reasons –1 = no, it is not used because of adverse water quality conditions	D	0	Groundwater is not used for domestic supply for unknown reasons.
Operational Issues/Constraints	Does a significant percentage of total refuge water supply consist of "Incremental Level 4" water?	+1 = yes, 54% to 79% of total water supply is Incremental Level 4 0 = somewhat, 27% to 53% of total water supply is Incremental Level 4 –1 = minor, 0% to 26% of total water supply is Incremental Level 4	D,N	0	Approximately 33 percent of the water supply for the East Bear Creek Unit consists of Incremental Level 4 water.
	Is the cost of local water high or low relative to the other refuges in this study?	+1 = costs may fluctuate highly or are subject to spot-market variability or price spikes –1 = costs are relatively stable and subjectivity to spot-market variability is low	D,N	+1	Incremental Level 4 water made available to the East Bear Creek Unit is subject to wide fluctuations in cost and variable spot-market availability.
	Is it necessary to convey Incremental Level 4 water through the Delta for refuge supply?	+1 = yes, Incremental Level 4 water must be conveyed through the Delta –1 = no, conveyance of Incremental Level 4 water through the Delta is not necessary	D,N	+1	Incremental Level 4 water must be conveyed through the Delta given current water supply sources.
Data Needs	Are there significant data needs to address prior to groundwater development?	+1 = no, data needs regarding refuge groundwater conditions are minor 0 = somewhat, some data are required prior to increasing groundwater development –1 = yes, significant data must be collected as there is little or no existing data	D,N	0	Some data are required prior to recommending increased groundwater development.
			Total Direct Use Score =	**0**	
			Total On-Refuge Conjunctive Use Score =	**0**	

Notes:
a Surface Features

b Application to Approach: D = Direct Use, N = On-Refuge Conjunctive Use

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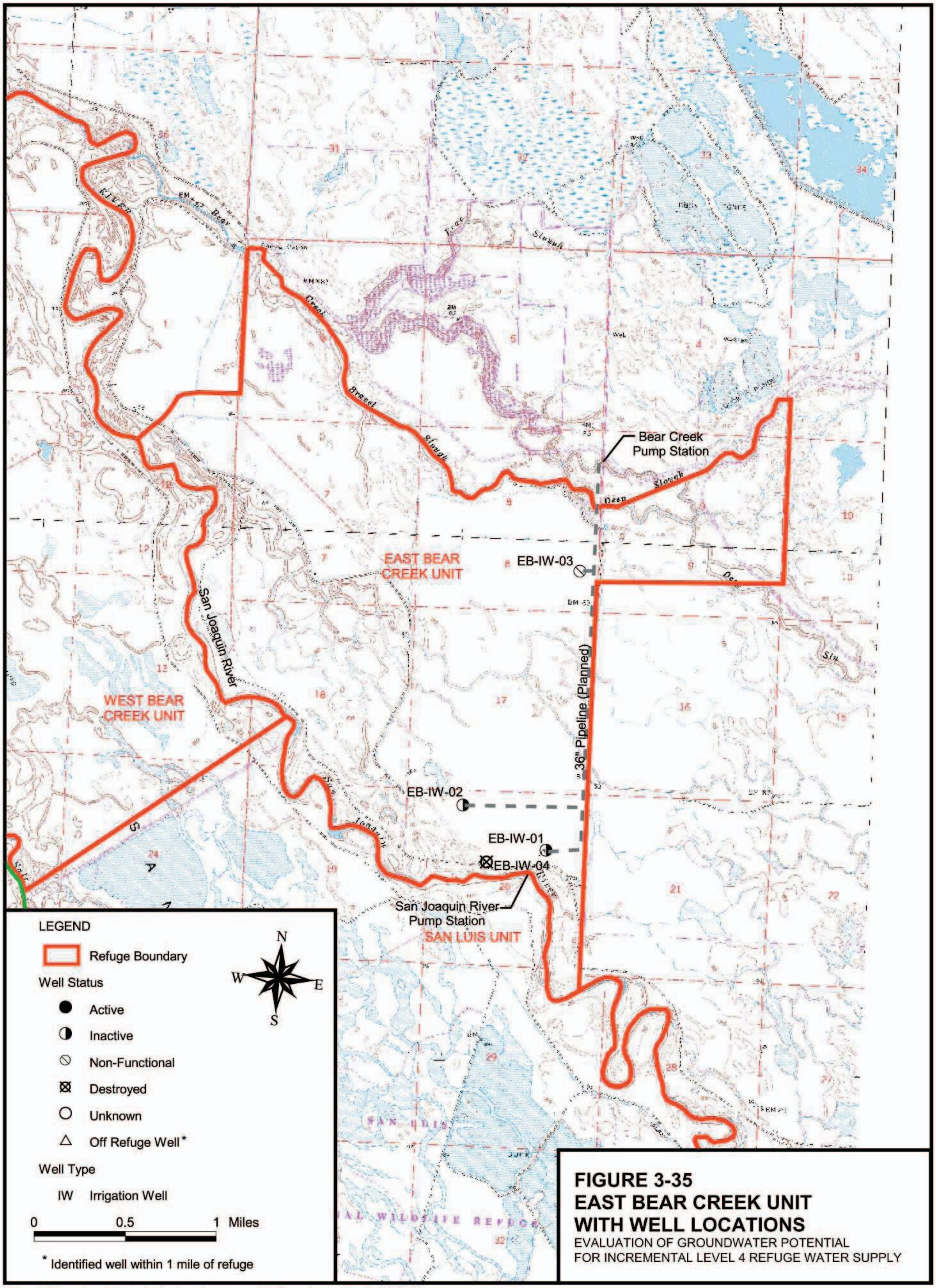

FIGURE 3-35
EAST BEAR CREEK UNIT WITH WELL LOCATIONS
EVALUATION OF GROUNDWATER POTENTIAL
FOR INCREMENTAL LEVEL 4 REFUGE WATER SUPPLY

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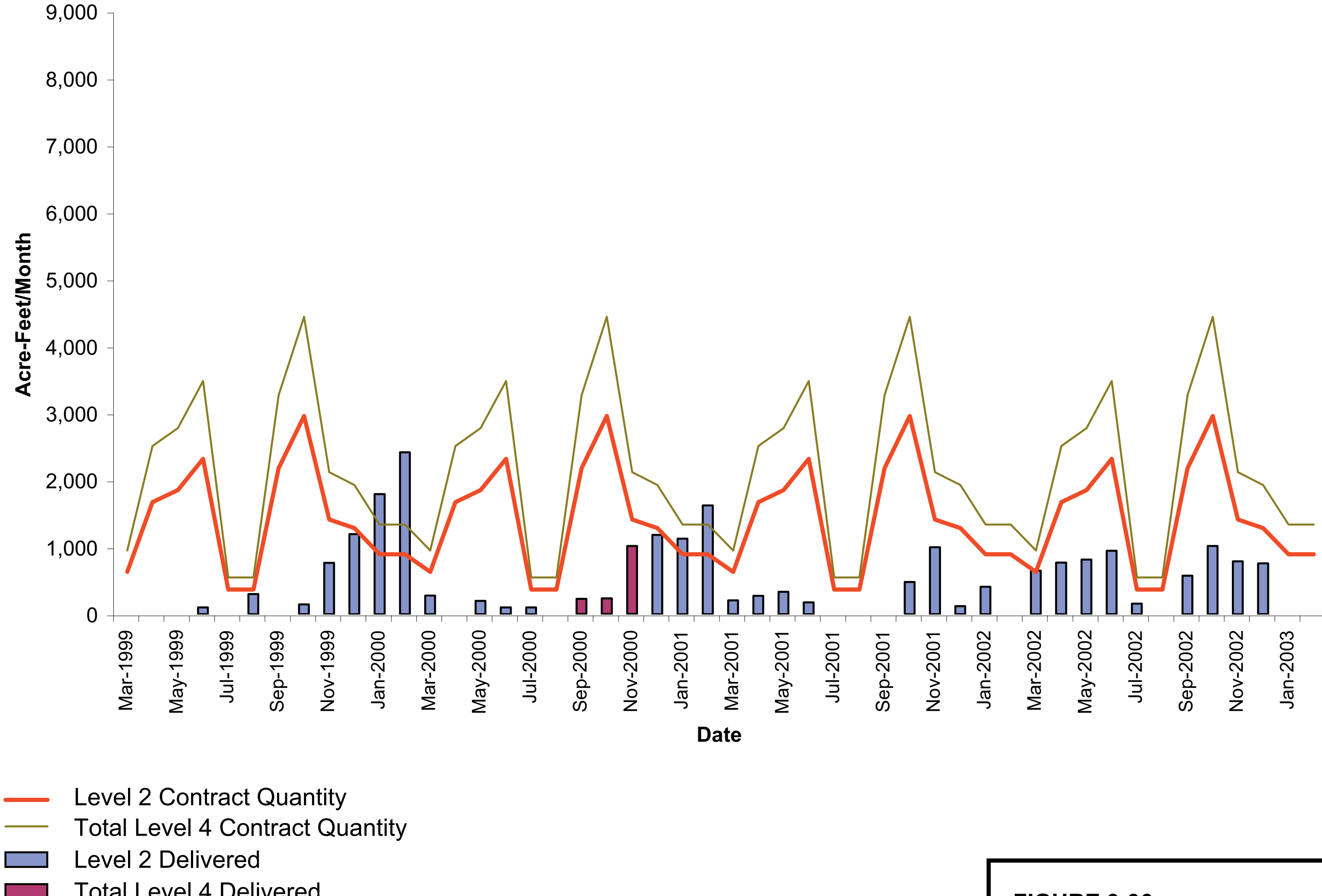

Note: Level 2 and Total Level 4 contract quantities are those indicated in Reclamation 1989 and Reclamation el al. 1989. Volumes indicated may not reflect current monthly management schedules and are shown to indicate an approximate monthly breakdown for management purposes. Total annual contract quantities may be scheduled based on availability, at the refuge manager's discretion.

FIGURE 3-36
1999-2002 EAST BEAR CREEK UNIT WATER DELIVERIES
EVALUATION OF GROUNDWATER POTENTIAL FOR INCREMENTAL LEVEL 4 REFUGE WATER SUPPLY

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3.13 Merced NWR Refuge Assessment

County: Merced
Basin / Subbasin: San Joaquin Valley Groundwater Basin / Merced Subbasin
Level 2 / Incremental Level 4: 13,500 ac-ft / 2,500 ac-ft
2003 Acreage: 4,400
CVP Water Conveyor: Merced ID
Water District Service Area: None
Applicable Groundwater Management Regulations: None

The Merced NWR is located in Merced County, east of the San Luis NWR Complex, southwest of the city of Merced, and centered between SRs 165, 140, 59, and 33. Sandy Mush Road divides the northern and southern portions of the refuge (Figure 3-37).

3.13.1 Hydrogeologic Assessment

3.13.1.1 Habitat Goals, Land Management, and Surface Features

The refuge provides approximately 4,400 acres of grasslands, fields, and permanent wetlands. The primary purposes of this refuge are endangered and threatened species conservation; migratory bird refuge, breeding, and sanctuary; natural resource protection; recreation; wildlife management and control; and wetlands conservation (Reclamation 2002).

Merced NWR provides one of the most important wintering areas in California for snow goose, Ross's goose, and sandhill crane (Reclamation et al. 2001b). Grain and forage crops are grown on the refuge as food sources for wildlife.

Deadman Creek flows west through the center of the refuge, Mariposa Slough flows across the north boundary of the refuge, and the East Side Bypass crosses through the southwest to the northwest. Cinnamon Slough curves through the southernmost part of the refuge. Several duck ponds are located throughout the area, especially in the southwest and northeast. The Merced NWR headquarters building is located in the center of the refuge at the southernmost point of Deadman Creek.

3.13.1.2 Identified Water Supply Contract Quantities

Level 2 water supplies for the refuge are 13,500 ac-ft. The Level 4 increment is 2,500 ac-ft, totaling 16,000 ac-ft (Reclamation et al. 2001b).

3.13.1.3 Surface Water Supplies and Infrastructure

Surface water supplies, totaling approximately 3,000 ac-ft of federal water as available, enters the refuge via the East Side Bypass from Deadman Creek. CVP water is available only during the irrigation season between April and October (Reclamation et al. 2001b; Refuge staff 2002). The primary water supplier is Merced ID. In accordance with Article 45 of the 1964 Merced ID FERC license, Merced ID agreed to provide up to 15,000 ac-ft of return flows to the Merced Unit (Merced ID 1997). Recent records indicate that during the 2001 water year, Merced ID delivered approximately 11,560 ac-ft. Between November 2001 and July 2002, approximately 6,343 ac-ft was delivered, comparable to the similar time span during the previous year (Refuge staff 2002). Level 4 conveyance facilities are available to the refuge.

Eastern farm fields and grasslands are maintained with surface water pumped from Deadman Creek at the Main Pump Station near Well R4 (MR-IW-27). The Main Pump Station can also provide water to north ponds and fields, including Duck Slough, other nearby farm fields, and tree areas along Deadman Creek (Refuge staff 2002).

Refuge staff indicate that surface water sources are considered to be of adequate quality for refuge irrigation needs.

3.13.1.4 Groundwater Supplies and Infrastructure

Groundwater is used extensively at this refuge. Before surface water became available from Merced ID, groundwater was the primary water supply. Currently, groundwater is used to supplement surface water supplies or when surface water is not available during winter canal dewatering. After November 1, refuge water is supplied by groundwater. From March through November, well water is blended with Merced ID water, which is lifted into the pipe distribution system. Groundwater is used only as a supplemental or emergency source during that time (Refuge staff 2003).

Irrigation and Production Wells. Merced NWR has 21 irrigation wells. A domestic well behind the refuge headquarters (“Merced Shop Well” [MR-DW-01]) serves both the shop and the residence there. Well and pump locations are shown on Figure 3-37. Table 3-25 summarizes available well information. Wells located on the north of Sandy Mush Road have an informal well designation with an “R.”

Merced wells have been metered since 2001 and are monitored monthly. Figure 3-38 shows monthly well use since these records were initiated. A total of 2,048 ac-ft was pumped during the 2001 water year. Pumping occurred between November and March, when Merced ID deliveries were lowest. A total of 3,113 ac-ft was pumped between November and March of the 2002 water year (Refuge staff 2003).

Most functioning wells on the site are being used. During winter, 21 operational wells are typically used throughout the refuge. One of the newer production wells, P-17 (MR-IW-17), is shown in Figure 3-39.

Operating status of the wells varies. The pump motor for Well R3 (MR-IW-26) has been rebuilt and replaced. Wells 11 (MR-IW-11) and 16 (MR-IW-16) have been destroyed, and Well 23 (MR-IW-23) has been disconnected. The pump and meter for Well 23 are still onsite, however. Well 8 (MR-IW-08) has been converted to supply water for cattle that graze on parts of the refuge. Well R1 (MR-IW-24), located near the creek, is less efficient and pumps air. This well is not often used. Well water may be pumped into the canal, but most is pumped directly into fields. (Refuge staff 2002).

Northern wells are used for flooding northern ponds when water from Merced ID is not available. Three wells and pumps, R1 (MR-IW-24), R2 (MR-IW-25), and R3 (MR-IW-26), are connected to the main pipeline system. A gate valve at the north end of the pipeline can be opened to allow water into the Duck Slough channel. R6 (MR-IW-29) pumps water directly into the Duck Slough channel. Pump R7 services only the area immediately surrounding it. Wells R7 (MR-IW-30), P17 (MR-IW-17), and P18 (MR-IW-18) also supply their adjacent marshes. Other wells discharge into the canals that service other areas of the refuge (Refuge staff 2002).

Groundwater Quality Data. The only available groundwater analyses are from the domestic well. Results indicated EC at 1,300 μmhos/cm and TDS at 700 mg/L (Twining Laboratories, Inc. 1998). These readings exceed Agricultural Water Quality Goals. No known water quality testing has been recorded for the irrigation wells. Refuge staff indicated that groundwater sources are considered to be adequate for refuge irrigation needs. There have been no perceptible ill effects on wildlife (Refuge staff 2002).

3.13.1.5 Local Groundwater Use

Groundwater is used throughout the region to supply agricultural irrigation, private duck clubs, and occasionally for domestic purposes. Private agricultural wells are located near the refuge boundaries (Refuge staff 2002). The refuge headquarters and residence are served by a domestic well. Additionally, the City of Merced, located approximately 11 miles northeast of the refuge, uses some groundwater for municipal supplies (USEPA 2003).

3.13.1.6 Refuge Soil and Aquifer Conditions

The Merced refuge land consists mainly of Rossi, Traver, Landlow, and Merced soil types. The west side of the refuge is characterized by Rossi clay loam and Rossi clay. The north side of the refuge has areas of Traver fine sandy loam and Landlow clay. The east-central part of the refuge consists of Traver fine sandy loam, and the southern portion of the refuge has areas of Rossi clay and Merced clay. All are moderately to strongly saline-alkali. Some areas of the refuge have moderately permeable soils, but much of the refuge is underlain by impermeable hardpan. Surface runoff is ponded, and salts are likely to accumulate (USDA 1991).

Less than 1 foot of subsidence has occurred in the vicinity of the refuge (USDA 1991). Given the geology of the area, there is some potential for subsidence to occur in the region if groundwater use is substantially increased.

Groundwater levels near the refuge's southern boundary are shallow according to DWR monitoring records. These monitoring wells indicate water levels between 2 and 10 feet bgs. Groundwater levels have shown significant annual variation in the north half of the refuge, particularly during the drought years of the 1970s. In the north, groundwater levels average between 10 and 30 feet bgs. Since the mid-1990s, however, groundwater levels in the vicinity of the refuge have shown less seasonal variation, and in some locations, data has indicated a rise of several feet in average groundwater levels (DWR 2003b).

3.13.1.7 Operational Issues and Data Needs

The dependence of the refuge on Level 4 water supplies is relatively minor. Approximately 19 percent of the refuge's water contract quantity is Incremental Level 4. Incremental Level 4 water has not been supplied to Merced NWR.

Potential Incremental Level 4 water supplies available to Merced NWR are subject to wide fluctuations in cost and variable spot-market availability. It is also necessary to convey Level 4 water through the Delta. A more stable source of Incremental Level 4 water both in terms of cost and reliability would be beneficial to refuge water supply management.

The following data gaps were identified during the completion of this study:

- Thorough assessment of all on-refuge wells to determine mechanisms, if appropriate. Installation of well meters on all wells used for refuge water supply is recommended.
- Confirmation of refuge groundwater quality conditions at wells used for refuge water supply, both above and below the Corcoran Clay. At a minimum, verify EC, TDS, and boron concentrations in groundwater to determine potential for deleterious effects on wildlife.
- Local aquifer conditions, including quarterly water-level data both on- and off-refuge, and an estimate of local groundwater use.
- Aquifer parameters, such as hydraulic conductivity and thickness.
- Groundwater pumping records and schedules, both on and immediately surrounding the refuge.

Relative to the other refuges in this study, it was estimated that a "low" or minimal level of data collection is required at Merced NWR prior to recommending specific groundwater development projects.

3.13.1.8 Other Studies

Findings from the 1995 Merced Water Supply Plan and the 2001 Merced Water Supply Plan Update show that the current trend toward increasing use of groundwater for irrigation coupled with less reliable surface water supplies may result in a significant future groundwater overdraft in the basin. In response, the 2001 Merced Water Supply Plan Update recommended stabilizing groundwater at 1999 levels (CH2M HILL 2001). The 1995 Merced Water Supply Plan and the 2001 Merced Water Supply Plan Update both recommended the implementation of an intentional recharge program that would augment existing groundwater recharge with additional water diverted from the Merced River (when surface water is available) to shallow basins constructed in the area (CH2M HILL 2001). Constructed recharge facilities recommended by the plans are expected to recharge approximately 87,000 ac-ft per year. A potential area to be considered for recharge sites is a band of land between 2 and 6 miles wide located east of U.S. 99, extending from Atwater to Planada. This area is to the east of the Corcoran Clay and is characterized by more permeable soils than in other areas of the county (URS 2002). Although the plan has been accepted by Merced ID, recharge basins have not yet been developed.

3.13.2 Criteria Evaluation Summary

Merced NWR received total Hydrogeologic Scores of +6 for Direct Use of groundwater and +5 for On-Refuge Conjunctive Use based on criteria matrix evaluation. Table 3-26 shows the specific criteria matrix and scores for this refuge.

This refuge may be a candidate for increased groundwater use. The refuge has several active wells within the boundaries that are used regularly to meet refuge water needs. This water is distributed by an extensive IDS, including piping and canals. There are no known adverse groundwater quality conditions in the immediate surrounding area, although water quality from the domestic well is questionable. Also, although soils on the refuge are dominated by silty clays with fairly slow permeability, recharge basins may be feasible only in the north and east-central parts of the refuge, where areas of Traver fine sandy loam have moderately permeable surface soils. Hardpans found at depths of 5 feet over much of the refuge may require removal, however, if recharge was to be investigated at this site. Support and limitations of increased groundwater development are summarized below:

3.13.2.1 Support for Groundwater Development

- Groundwater is currently used to meet a significant percentage of refuge water demand. Several wells are active on the property.
- A developed IDS allows water to move extensively throughout the refuge, supporting integration of groundwater infrastructure with current water management. Water is distributed by a piping and canal system, along with Duck Slough.
- Groundwater quality is considered adequate by refuge staff, although water quality testing has not been conducted at the irrigation wells. There are no known adverse groundwater quality conditions in the immediate vicinity of the refuge.
- A domestic well serves the Merced headquarters and residence. Treatment of the water is not necessary.
- Surface water is delivered to the refuge and is therefore available for blending with groundwater.
- Water levels at the refuge are currently at or slightly below historic levels. The Merced Water Supply Plan has forecasted groundwater overdraft if current use trends continue. Aquifer storage may be available.
- It is necessary to convey Incremental Level 4 water through the Delta to serve the refuge.
- The cost of local water is high relative to the other refuges in the study. Cost and reliability is subject to spot-market variability.
- Data needs regarding refuge groundwater and aquifer conditions are relatively minor compared with other refuges in this study.

3.13.2.2 Limitations to Groundwater Development

- The refuge headquarters and residence are served by a domestic well, which may be impacted by increased groundwater use. The City of Merced uses some groundwater for municipal supplies.
- Poor water quality has limited groundwater use. Wells are no longer used because of cost and water quality concerns.
- Dependence on Incremental Level 4 water for refuge water supply is relatively minor compared to other refuges in the study.

3.13.3 Recommended Data Acquisition Activities

Several important tasks are recommended to assess the potential of additional and/or sustained groundwater use at the refuge. These are similar to those suggested for Gray Lodge WA in Section 2. Recommended data acquisition activities include:

- Conduct an inventory of all refuge wells, including date installed; physical well properties, including depth, operational status, operational deficiencies (i.e., broken or nonexistent pump, well collapse, etc.); and repair history. Photograph, video-log, and collect GPS coordinates for the wells. Survey the ground level elevation and the measuring point elevation of each well.
- Establish the water quality of the existing production wells by conducting at least two complete rounds of well sampling at the existing production wells located at the refuge. Collect these samples during two seasons, such as summer and winter, to assess potential seasonal variations. Measure, at a minimum, general chemistry parameters and metals, including arsenic, boron, chromium, mercury, and nitrates.
- Conduct two to three 72-hour aquifer tests at existing irrigation wells at Merced NWR to determine an estimated refuge yield. Conduct these tests during a season in which the refuge is not irrigating. Use existing production wells where there are nearby inactive wells that can be monitored before and during the test. Collect pumping and recovery data. Such information would also enable evaluation of potential impacts to adjacent well users if Merced NWR modifies use of its existing or expanded groundwater potential.
- If previous data collection does not identify any inactive wells that could be used as monitoring wells, install three dedicated monitoring wells on the south, north, and east sides of the refuge to record water-level changes. This information would enable a better understanding of the aquifer response to seasonal conditions and changes in local water use.
- Develop a groundwater budget for the refuge. Estimate groundwater conditions under wet-, normal-, and dry-year conditions.
- Collect water-level data from available wells within and adjacent to the refuge. Monitor water levels quarterly and collect routine water quality samples from active wells to develop a database of groundwater use and conditions. Maintain collected data in a format supportable and usable by the refuge.

3.13.4 Potential Projects

3.13.4.1 Direct Use

The refuge may be a candidate for increased groundwater development. The refuge has several active wells that are used regularly and distributed by an extensive IDS. Following data acquisition, it is recommended to replace two existing wells, rehabilitate two wells, and replace two well pumps, for a total of up to six replaced or rehabilitated wells.[3] Production

[3] Which wells to be replaced or rehabilitated would be determined after an evaluation of refuge wells. The number of wells to be replaced or rehabilitated is provided for budgeting purposes only.

rates of each replaced or rehabilitated well is estimated to be 1,500 gpm. At this production rate, two wells can meet Incremental Level 4 contract quantities.

3.13.4.2 On-Refuge Conjunctive Use

One possibility for development on an on-refuge conjunctive use project is development of an in-lieu arrangement with Merced ID to have the refuge use groundwater in exchange for VAMP water. Although significant potential for future groundwater storage in the vicinity of the refuge may exist, current decisions indicate that banking at Merced NWR likely would not be beneficial to refuge water management. Because of recent studies identifying aquifer depressions in the subbasin, the transfer of groundwater or banked water outside of the subbasin is not supported by local groundwater management policies. Therefore, groundwater "banked" by Merced NWR, either on- or off-refuge, could only be transferred to East Bear Creek, which is the only other refuge within the Merced Subbasin. Additional discussions with Merced area water purveyors would need to occur prior to implementation of this potential project.

3.13.4.3 Off-Refuge Conjunctive Use

One option for off-refuge conjunctive use involves Merced ID, which supplies surface water to the refuge. The Merced Water Supply Plan recommends that groundwater recharge be implemented to address regional groundwater conditions. Partnership with this program could be used to support Merced NWR and potentially East Bear Creek Unit, which is also within the Merced Subbasin.

The refuge is not located within the sphere of influence of any water entity and is not under the direct jurisdiction of a groundwater management plan. However, as a result of cones of depression and increasing urban water demands in other parts of the subbasin, regional plans such as the Merced Water Supply Plan describe policies that discourage increased groundwater use and transfer of groundwater or banked water outside the Merced Subbasin (CH2M HILL 2001). Decision 1641 adopted by the SWRCB also states that groundwater substitution in the basin should be allowed only if performed in conjunction with an in-lieu or direct recharge program (SWRCB 2000). Banked water would not be transferred out of the basin, however, because of basin-wide water policies to protect against groundwater overdraft. This limits the ability of the Merced NWR to indirectly supply water to other refuges outside the Merced subbasin.

TABLE 3-25
Merced NWR Well Information[a]
Evaluation of Groundwater Potential for Incremental Level 4 Refuge Water Supply

GIS Well Number[b]	Common Well Name	Well Status[c]	2002 Yield (ac-ft)	Year Installed	Depth (ft)	Screen Interval (bgs)	Well Output (gpm)	Well Log?	Water Quality Data?	Comments
MR-IW-01	P 1	Active		1997	652	274–620	1,300	Y	N	Specific screened intervals: 274–280, 292–294, 360–364, 371–376, 492–496, 547–556, 564–620.
MR-IW-02	P 2	Active		1979	640	245–605	1,218	Y	N	Specific screened intervals: 245–270, 285–295, 435–460, 525–535, 595–605.
MR-IW-04	P 4	Active					1,413	N	N	
MR-IW-05	P 5	Active					1,351	N	N	
MR-IW-06	P 6	Active			300		1,437	N	N	Deepened from 200 to 300 ft in 1964.
MR-IW-08	8	Active					821	N	N	Rehabilitated (new pump) in 1992. Used for watering cattle, not for other wildlife use.
MR-IW-09	P 9	Active					1,146	N	N	
MR-IW-10	P 10	Active					1,520	N	N	
MR-IW-11	P 11	Destroyed					1,536	N	N	Oil on surface of water recorded in 1994.
MR-IW-12	P 12	Active					1,285	N	N	
MR-IW-13	P 13	Active					1,149	N	N	Poor hydraulic suction recorded in 1994.
MR-IW-14	14	Unknown		1956	141		1,032	Y	N	
MR-IW-15	P 15	Active		1956	197	100–184	1,099	Y	N	
MR-IW-16	16	Destroyed		1956	181		1,297	Y	N	Destroyed 8/26/1999.
MR-IW-17	P 17	Active		1997	408	200–404	1,741	Y	N	Replaced recently.
MR-IW-18	P 18	Active		1998	452	120–272	2,866	Y	N	Replaced recently. Specific screened intervals are: 120–190, 230–272.
MR-IW-19	P 19	Active					1,101	N	N	New pump in 1999.
MR-IW-20	P 20	Active		1964	190	108–189	1,300	N	N	Repaired and received new pump in 1999.
MR-IW-21	P 21	Active		1993	410	242–410	987	Y	N	Specific screened intervals: 242–308, 370–392, 400–410.
MR-IW-23	P 23	Nonfunctional					1,136	N	N	Pump and meter present onsite.

TABLE 3-25
Merced NWR Well Information[a]
Evaluation of Groundwater Potential for Incremental Level 4 Refuge Water Supply

GIS Well Number[b]	Common Well Name	Well Status[c]	2002 Yield (ac-ft)	Year Installed	Depth (ft)	Screen Interval (bgs)	Well Output (gpm)	Well Log?	Water Quality Data?	Comments
MR-IW-24	R 1	Active					1,182	N	N	Obstruction at 60 ft recorded in 1993. Pump sucks air.
MR-IW-25	R 2	Active		1979	640		1,206	N	N	Oil on surface of water in well recorded in 1993.
MR-IW-26	R 3 or Deep Well 3	Active		1979	660	245–625	1,293	N	N	Oil on surface of water in well recorded in 1993. Recently rehabilitated. Specific screened intervals: 245–275, 315–325, 400–410, 435–445, 495–525, 595–625.
MR-IW-27	R 4	Destroyed		1979	580	250–550	1,850	N	N	1.8 ac-ft used in 1995. Pumped for one day only. Specific screened intervals were: 250–280, 295–305, 325–340, 385–405, 450–475, 535–550.
MR-IW-28	R 5	Unknown						N	N	
MR-IW-29	R 6 or Deep Well 6	Active					1,412	N	N	Pumps directly into Duck Slough Canal.
MR-IW-30	R 7	Active					1,403	N	N	
MR-DW-01	Merced Shop Well	Active		1998	330	138–330		Y	Y	
9S12E04-1	Test Well	Unknown		1991	820			Y	N	Owned by Turner Island Water District.
9S12E04-2	Irrigation Well	Unknown		1992	400	200–400		Y	N	Owned by Turner Island Water District.

Notes:

[a] Based on data compiled from well logs, test records, communication with refuge staff (2002), and other previous documentation. Well locations are shown on Figure 3-37. On-refuge wells only are included in this table, although the GIS includes known wells within 1 mile of the refuge.

[b] Well type is indicated by the middle two letters of the GIS well number: IW = irrigation well, DW = domestic well, MW = monitoring well, TW = test well, and UN = unknown.

[c] Designation refers to the physical well only, not water quality issues. Designations are: *active* (currently operated), *inactive* (capable of operating, but currently is not), *nonfunctional* (cannot operate in current physical state), *destroyed* (well has been lost, abandoned, or filled), or *unknown* (no information regarding status is available).

Blank fields indicate that no information is available.

TABLE 3-26
Merced NWR Evaluation
Evaluation of Groundwater Potential for Incremental Level 4 Refuge Water Supply

	Criteria	Scoring Scale	Appl.[b]	Score	Refuge Score Justification
Surface[a]	Do surface water bodies exist that could be affected by increased groundwater use?	+1 = no 0 = to some degree –1 = yes, surface water bodies could be affected	D,N	0	Several canals and sloughs flow through the refuge, including Deadman Creek, Mariposa Slough, East Side Bypass, and Cinnamon Slough.
Water Supplies and Infrastructure	Has groundwater been used previously at the refuge for ponds or irrigation?	+1 = yes, used successfully to meet at least 20 percent of annual refuge water demands 0 = yes, used to meet less than 20 percent (or unknown) of annual refuge water demands. –1 = no, has not been used	D,N	+1	Groundwater is used to meet a significant percentage of water demand.
	Do wells exist on the refuge?	+1 = yes, active wells 0 = yes, inactive or nonfunctional wells –1 = yes, destroyed wells, or no wells exist on the refuge	D,N	+1	Several active wells exist on the refuge property.
	Does existing internal distribution system (IDS) support groundwater use?	+1 = water can move extensively around the refuge with existing IDS 0 = the IDS enables limited water movement within the refuge –1 = an IDS does not exist on the refuge or water flow relies exclusively on gravity	D,N	+1	Water is distributed by an extensive piping and canal system. Duck Slough also plays a major role in the refuge IDS. Not all wells are hooked to this system, however. Some pumps service only the fields in their immediate area.
Local Groundwater Use	Is groundwater used for agriculture or duck clubs in the immediate vicinity of the refuge?	+1 = groundwater is not used; or groundwater is minimally used, but use is not constrained 0 = groundwater is used in the area –1 = groundwater is not used due to physical or environmental constraints or is extensively used in the vicinity	D,N	0	Agricultural wells are located near the refuge boundaries.
	Does municipal or domestic supply exist near the refuge?	+1 = no known domestic or municipal wells are located within 1 mile of the refuge 0 = municipal or domestic wells are likely located within 1 mile of the refuge –1 = municipal or domestic wells are located within 1 mile of the refuge	D,N	-1	The refuge headquarters and residence are served by a domestic well. The City of Merced uses some groundwater for municipal supplies.
Soil and Hydrogeology	Are at-surface soils conducive to groundwater recharge?	+1 = soils are sandy or are reported to percolate well 0 = soils are silty or are reported to have some infiltration –1 = soils are clayey or are reported to hold water well	N	0	Surface soils are dominated by fine sandy loam or silty clay. Areas of Traver fine sandy loam located in the north and central-east parts of the refuge have moderately permeable surface soils.
	Could recharge basins be developed if surface soils were removed?	+1 = confining soil less than 2 feet thick 0 = confining soil 5 to 7 feet thick –1 = confining soil greater than 7 feet thick	N	0	Confining soils and hardpans are found to depths of 5 feet.
	Has subsidence occurred at or in the immediate vicinity of the refuge?	+1 = no 0 = yes, less than 2 feet –1 = yes, more than 2 feet	D,N	0	Less than 1 foot of subsidence has occurred in the vicinity of the refuge.
	Does significant potential for subsidence exist if groundwater use is increased at the refuge?	+1 = minimal potential for subsidence 0 = some potential for subsidence –1 = significant potential for subsidence	D,N	0	There is potential for subsidence to occur in the region if groundwater use is substantially increased.
	Is aquifer storage available in the subbasin?	+1 = yes, current water levels are greater than 30 feet lower than historic levels 0 = some, current water levels are between 10 and 30 feet lower than historic levels –1 = no	N	0	Water levels at or near the refuge have been subject to significant variation according to DWR records; however, water levels at the refuge are currently at or slightly below historic levels. The Merced Water Supply Plan has forecasted groundwater overdraft if current use trends continue.

continued on next page

Notes:
a Surface Features
b Application to Approach: D = Direct Use, N = On-Refuge Conjunctive Use

TABLE 3-26
Merced NWR Evaluation
Evaluation of Groundwater Potential for Incremental Level 4 Refuge Water Supply

	Criteria	Scoring Scale	Appl.[b]	Score	Refuge Score Justification
Water Quality	Have groundwater quality conditions hindered groundwater use in the past?	+1 = no 0 = data are not available –1 = yes	D,N	+1	Groundwater quality is considered adequate by refuge staff for wildlife contract quantities, however, no water quality testing has been performed at irrigation wells. Domestic well tests show good quality water.
	Do adverse groundwater quality conditions exist in the subbasin?	+1 = no 0 = potential –1 = yes	D,N	+1	There are no known adverse groundwater quality conditions in the immediate vicinity of the refuge.
	Is surface water available to enable blending of lower quality groundwater to meet proposed refuge standards?	+1 = yes 0 = during portions of the year –1 = no	D,N	0	Surface water is delivered from Merced ID from March to November. The canal is dewatered during the winter.
	Do groundwater conditions exceed USEPA Freshwater Aquatic Life Standards or Agricultural Water Quality Goals for multiple parameters?	+1 = no 0 = yes, two parameters, or no water quality testing has been conducted –1 = yes, three or more parameters	D,N	0	Agricultural water quality goals have been exceeded in groundwater for EC and TDS.
	Is refuge land use management compatible with seasonally or annually variable water quality from different sources?	+1 = yes 0 = some potential compatibility problems may exist –1 = no	D,N	+1	Groundwater and delivered water are currently used for wetland management.
	Does groundwater quality meet drinking-water standards (i.e., can it be used for refuge domestic supply)?	+1 = yes it is used, no treatment is necessary 0 = yes it is used, but some treatment is necessary for potable use; or it is not used for unknown reasons –1 = no, it is not used because of adverse water quality conditions	D	+1	A domestic well serves the Merced headquarters and residence. Treatment is not necessary.
Operational Issues/Constraints	Does a significant percentage of total refuge water supply consist of "Incremental Level 4" water?	+1 = yes, 54% to 79% of total water supply is Incremental Level 4 0 = somewhat, 27% to 53% of total water supply is Incremental Level 4 –1 = minor, 0% to 26% of total water supply is Incremental Level 4	D,N	-1	Approximately 16 percent of the water supply for Merced NWR consists of Incremental Level 4 water.
	Is the cost of local water high or low relative to the other refuges in this study?	+1 = costs may fluctuate highly or are subject to spot-market variability or price spikes –1 = costs are relatively stable and subjectivity to spot-market variability is low	D,N	+1	Incremental Level 4 water made available to Merced NWR is subject to wide fluctuations in cost and variable spot-market availability.
	Is it necessary to convey Incremental Level 4 water through the Delta for refuge supply?	+1 = yes, Incremental Level 4 water must be conveyed through the Delta –1 = no, conveyance of Incremental Level 4 water through the Delta is not necessary	D,N	-1	Incremental Level 4 water must be conveyed through the Delta given current water supply sources.
Data Needs	Are there significant data needs to address prior to groundwater development?	+1 = no, data needs regarding refuge groundwater conditions are minor 0 = somewhat, some data are required prior to increasing groundwater development –1 = yes, significant data must be collected as there is little or no existing data	D,N	+1	Data needs regarding refuge groundwater conditions are relatively minor.
			Total Direct Use Score =	**+6**	
			Total On-Refuge Conjunctive Use Score =	**+5**	

Notes:
a Surface Features

b Application to Approach: D = Direct Use, N = On-Refuge Conjunctive Use

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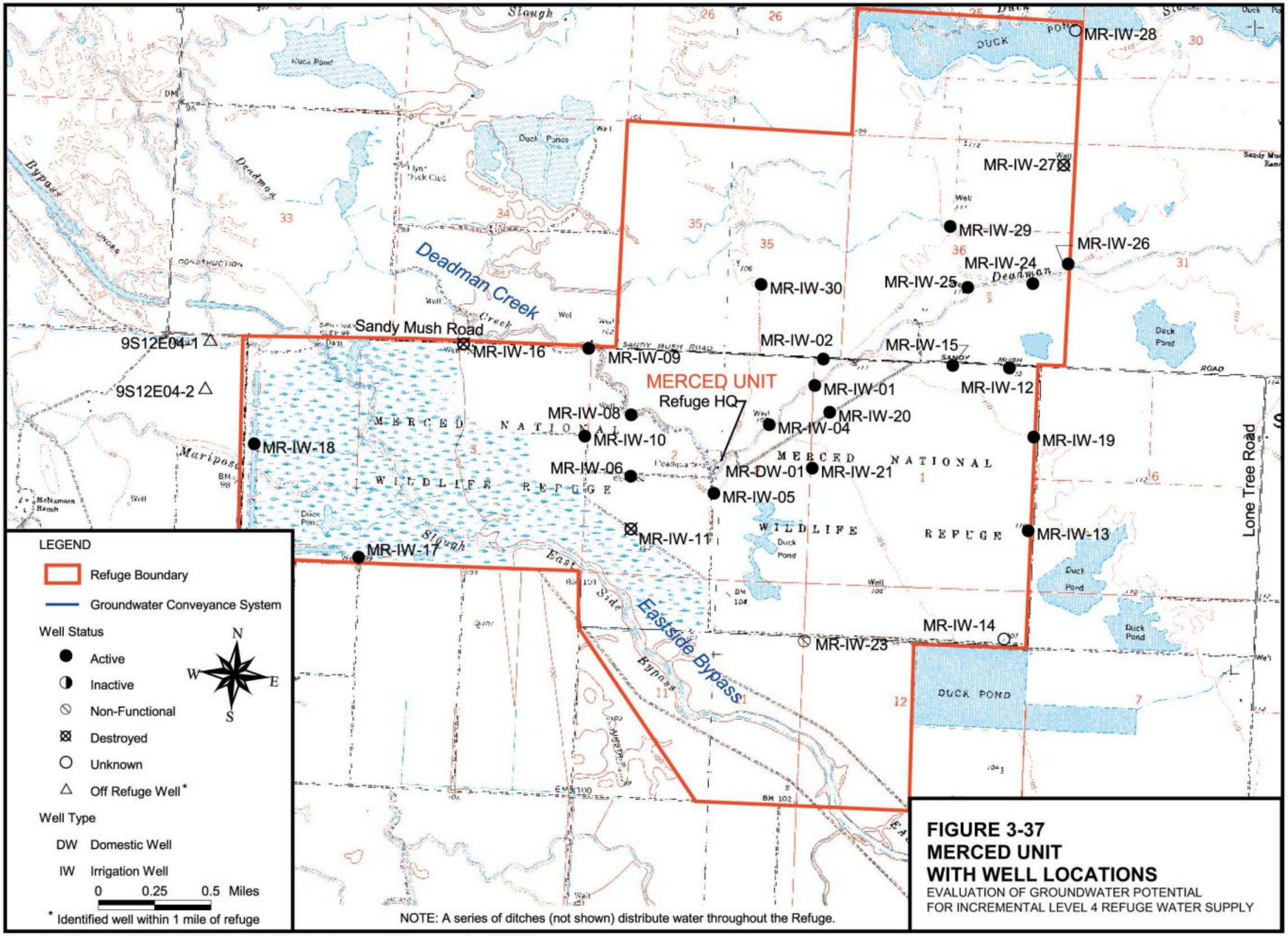

FIGURE 3-37
MERCED UNIT
WITH WELL LOCATIONS
EVALUATION OF GROUNDWATER POTENTIAL
FOR INCREMENTAL LEVEL 4 REFUGE WATER SUPPLY

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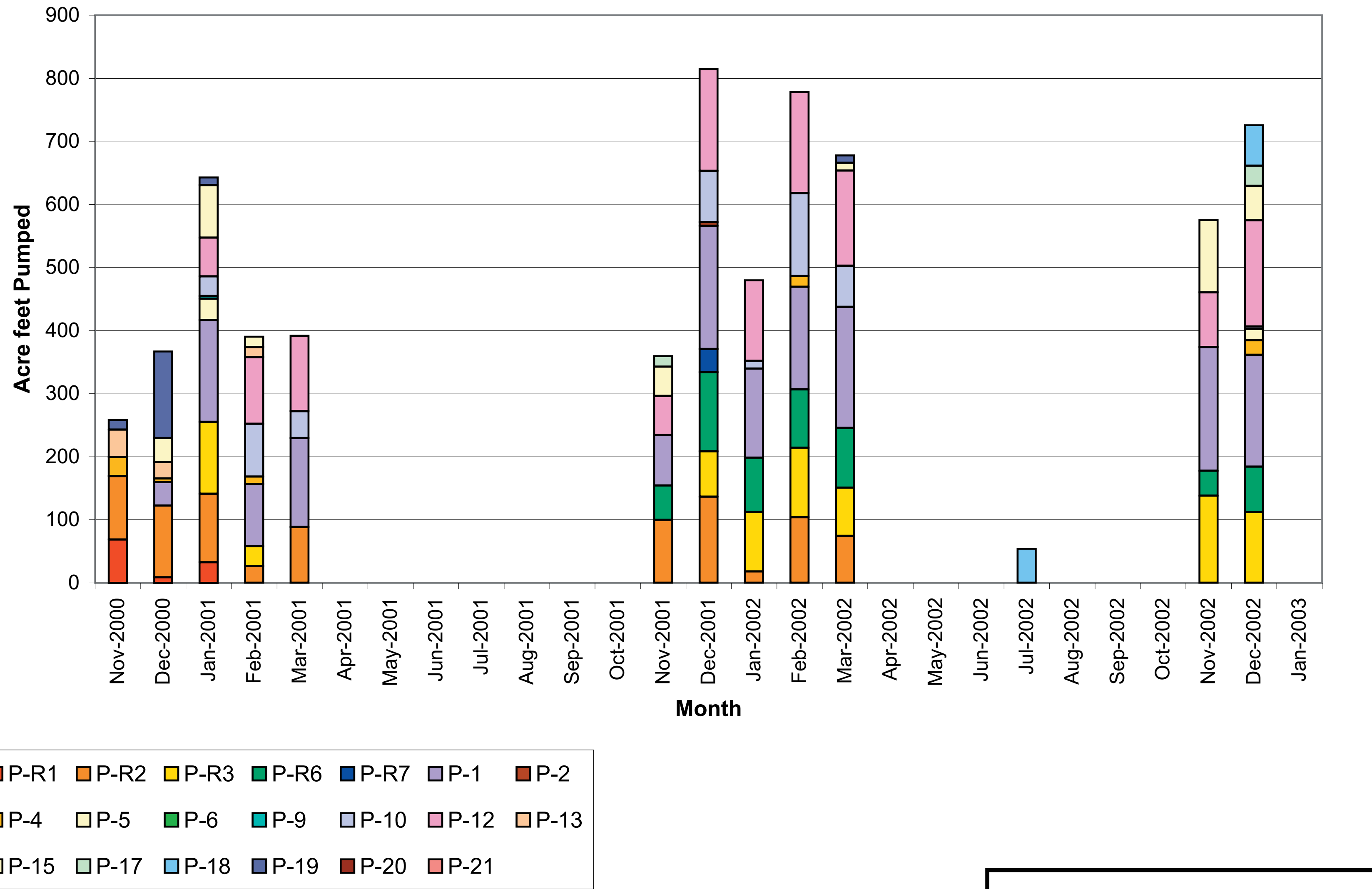

SOURCE: Refuge Staff, 2002

FIGURE 3-38
2000-2002 MERCED WELL USE
EVALUATION OF GROUNDWATER POTENTIAL
FOR INCREMENTAL LEVEL 4 REFUGE WATER SUPPLY

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FIGURE 3-39
MERCED NWR
WELL MR-IW-17
EVALUATION OF GROUNDWATER POTENTIAL
FOR INCREMENTAL LEVEL 4 REFUGE WATER SUPPLY

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3.14 Mendota WA Refuge Assessment

County: Fresno
Basin / Subbasin: San Joaquin Valley Groundwater Basin / Kings Subbasin
Level 2 / Incremental Level 4: 27,594 ac-ft / 2,056 ac-ft
2003 Acreage: 12,425
CVP Water Conveyors: Tracy Pumping Plant Authority and San Luis / Delta-Mendota Water Authority
Water District Service Area: Coelho Family Trust
Applicable Groundwater Management Regulations: None

Mendota WA consists of 12,425 acres located 4 miles southeast of Mendota (Figure 3-40). Washington Avenue forms the southern boundary of the refuge. The Santa Fe Grade forms the diagonal western border. SR 180 touches the northwestern border, and the Southern Pacific Railroad forms most of the northern border running east-southeast.

3.14.1 Hydrogeologic Assessment

3.14.1.1 Habitat Goals, Land Management, and Surface Features

The land has been managed by DFG since it was purchased by the California State Wildlife Conservation Board between 1954 and 1966. The refuge is used to provide seasonal wetland habitat and natural food crops for wildlife. Other primary purposes of this refuge are endangered and threatened species conservation, land conservation, migratory bird refuge and breeding ground, recreation, wildlife management and control, and wetlands conservation. Key special status species found in the area include the Palmate-bracted bird's beak and the San Joaquin kit fox (Reclamation 2002).

Fresno Slough flows through the refuge from northwest to southeast.[4] The slough surrounds Tule Island in the center of the refuge, located just east of a large area with closed access. Four private hunting club inholdings are located on the east side of Fresno Slough. The refuge headquarters building is located along the Santa Fe Grade on the west side of the refuge (Refuge staff 2002).

3.14.1.2 Identified Water Supply Contract Quantities

A time record of surface water supplies and deliveries is shown in Figure 3-41. Level 2 water supplies are nearly 27,594 ac-ft per year. Level 4 adds only 2,000 ac-ft per year to that amount, bringing the total to 29,650 ac-ft per year. Some Level 4 water was available and utilized in 2002, but full Level 4 conveyance is not available (Refuge and Reclamation staff 2002).

3.14.1.3 Surface Water Supplies and Infrastructure

The refuge has contracts with Reclamation for 29,650 ac-ft per year of water. Surface water is provided from the Mendota Pool via the Fresno Slough, but water is currently unavailable during late November through January when the pool is dewatered for dam safety inspections (Reclamation et al. 2001b; Refuge staff 2002).

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[4] If the Kings River is flowing under flood conditions, the Fresno Slough may flow in the reverse direction through the refuge.

The agricultural contractors who pump into the Mendota Pool, also known informally as "pool pumpers," pump groundwater into Mendota Pool during winter in exchange for credits that allow them to use higher quality surface water for summer irrigation. The pool is dewatered every other year from late November through mid-February for dam inspection, as required by DWR Division of Safety and Dams. During October through December, however, Mendota WA has significant water requirements (Refuge staff 2002).

Currently, all water supplying the refuge is conveyed from the pool through a series of gates, ditches, and pumps. Several lift pumps are on the refuge. Lands immediately east of the Mendota Pool rely on gravity flow, which is not charged against the refuge water allocation. Depending on the Mendota Pool's water level, parts of the refuge served by gravity flow essentially become part of the Mendota Pool during winter (Refuge staff 2002).

Mendota WA collects surface water quality samples twice per month. One of these monthly samples is sent for lab analysis. Samples are taken at the SR 180 bridge and at Pump 3 at the back part of the Fresno Slough. The Delta-Mendota Canal is also sampled where it flows into the Mendota Pool. The Exchange Contractors have installed a meter and a data logger on the SR 180 bridge to record flow (Refuge staff 2002).

Peaks in selenium have been observed and have been generally correlated by refuge staff to selenium peaks in water received from the Delta-Mendota Canal. Arsenic has been detected and may also be accumulating. In March 2002, a sample collected at Pump 6 indicated a value of 6 μg/L arsenic. In 2002, Pump 5 recorded arsenic at 4 μg/L in the Delta-Mendota Canal (Mendota WA 2002). EC has been acceptable from intakes, however, at approximately 900 μmhos/cm in the Mendota Pool, and 300 μmhos/cm in the Delta-Mendota Canal. EC consistently tests below 1,000 μmhos/cm from delivered water (Refuge staff 2002).

3.14.1.4 Groundwater Supplies and Infrastructure

Irrigation and Production Wells. Seven wells have been drilled in the area, and all but one have been capped because of water quality problems (particularly boron) or because of well collapse (Refuge staff 2002). No existing wells are used for groundwater supply at Mendota WA. Wells are not used for domestic supply on the refuge. Available refuge well information is summarized in Table 3-27.

Water Quality Data. Water quality has been of concern throughout the Mendota region. EC values of up to 9,600 μmhos/cm have been observed in groundwater at depths ranging from 120 to 130 feet bgs. Boron and selenium were also detected at these depths, with boron ranging from 2.1 to 5.0 mg/L, and selenium detected at 0.007 μg/L. Below 460 feet bgs, selenium was not detected and boron tested at lower concentrations (approximately 1.4 mg/L). EC measurements, however, remained greater than 2,000 μmhos/cm (Twining Laboratories 1992b). Agricultural Water Quality Goals were exceeded in groundwater for boron, EC, and selenium. Available refuge water quality information is summarized in Table 3-28.

3.14.1.5 Local Groundwater Use

Agricultural contractors have developed wells near the refuge. Groundwater is pumped extensively in the area by the Exchange Contractors of the Mendota Pool Group. No domestic or municipal wells have been identified within 1 mile of the refuge; however, the nearby cities of Mendota and Firebaugh use groundwater for municipal supplies (USEPA 2003).

High manganese concentrations have been a problem in City of Firebaugh wells. High manganese and hydrogen sulfide odor have been a problem in water from the City of Mendota wells. In recent years, groundwater salinity in the area has markedly increased (Central California ID 1997).

3.14.1.6 Refuge Soil and Aquifer Conditions

Soil in the northeastern part of the refuge can be classified into three associations: Traver-Calhi in the far north, followed by Rossi-Waukena, progressing to the Merced-Temple association near Fresno Slough. Waukena Loam is found on the northern side of the refuge and Merced Clay is found in a large area between Fresno Slough and the eastern refuge boundary. Both Merced Clay and Waukena Loam have high surface and subsoil permeability. The available water-holding capacity is high. Soils on the northern side of the refuge consist of sandy loam or loamy coarse sand at depths of 2 feet. Clay subsoil has been found in some areas, however (USDA 1956).The Corcoran Clay lies beneath this refuge at approximately 600 feet bgs (DWR 1981).

Severe subsidence has occurred in areas southwest of Mendota. Future subsidence is possible in the upper aquifer where it is confined (Central California ID 1997).

Water levels vary widely immediately surrounding the refuge according to DWR test well data (DWR 2003b). Test data show seasonal variations between 20 and 100 feet bgs at some locations. The average of this variation is between 20 and 40 feet bgs. In some areas in the immediate vicinity of the refuge, groundwater levels are significantly below historic levels, according to DWR data.

3.14.1.7 Operational Issues and Data Needs

Incremental Level 4 water made available to Mendota WA is subject to wide fluctuations in cost and variable spot-market availability. It is also necessary to convey Level 4 water through the Delta. A more stable source of Incremental Level 4 water both in terms of cost and reliability would be beneficial to refuge water supply management. Approximately seven percent of the refuge’s water supply is Incremental Level 4 water.

The following data gaps were identified during the completion of this study:

- Thorough assessment of all existing refuge wells to determine well conditions.
- Confirmation of refuge groundwater quality conditions at different locations and at several different depths below ground surface, both above and below the Corcoran Clay.
- At a minimum, verify EC, TDS, boron, and selenium concentrations in groundwater to determine potential for deleterious effects on wildlife.
- Local aquifer conditions, including quarterly water-level data both on- and off-refuge, and a safe yield determination.
- Verification of soil conditions, particularly on the northern and eastern sides of the refuge, for recharge compatibility.

- Aquifer parameters, such as hydraulic conductivity and thickness.
- Groundwater pumping records and schedules, on and immediately surrounding the refuge.

Relative to the other refuges in this study, it was estimated that a “significant” level of data collection is required at Mendota WA prior to recommending specific groundwater development projects.

3.14.1.8 Other Studies

Central California ID has conducted extensive summaries and investigations for groundwater use and quality within its boundaries (San Joaquin River Exchange Contractors 1997; Central California ID 1997). These reports provide good supporting information on groundwater flow, water quality, and aquifer conditions near the Mendota Pool area.

According to Central California ID studies, the direction of groundwater flow is generally to the northeast in the Mendota area. Electrical conductivities greater than 1,800 μmhos/cm are found in an area southwest of the City of Mendota, corresponding to the Mendota Pool area. Higher salinity groundwater may be locally present below the Corcoran Clay in the Firebaugh and Mendota areas. Shallow groundwater in this area also contains high boron concentrations greater than 2.5 mg/L (Central California ID 1997).

Evaluation of groundwater conditions is also known to have occurred northeast of the refuge, at the Meyers Farm site. The landowner is considering development of a groundwater bank.

3.14.2 Criteria Evaluation Summary

Mendota WA received total Hydrogeologic Scores of –3 for Direct Use of groundwater and -3 for On-Refuge Conjunctive Use based on criteria matrix evaluation. Table 3-29 summarizes specific criteria ratings for this refuge.

Although groundwater has been used previously, use was unsuccessful at the refuge because of water quality problems or well collapse, according to refuge staff. Developing groundwater systems further would only be recommended if the refuge was to contribute to the Mendota Pool supplies. The refuge is located in an area of groundwater overdraft, and subsurface conditions are marginally supportive of groundwater banking. Areas of surface soil consisting of Waukena loam and Merced clay, found on the northern and eastern sides of the refuge, have high surface and subsoil permeability and high water holding capacity (USDA 1956). These areas may be suitable for development of recharge basins if groundwater quality conditions showed improvement.

Support and limitations of increased groundwater development are summarized below.

3.14.2.1 Support for Groundwater Development

- A developed IDS allows water to move throughout the refuge, supporting integration of groundwater infrastructure with current water management. Several low-lift and two return pumps service the refuge area.

- According to DWR data, groundwater levels are significantly below historic levels in some areas in the immediate vicinity of the refuge.
- Surface water is delivered to the refuge and is therefore available for blending with groundwater.
- It is necessary to convey Incremental Level 4 water through the Delta to serve the refuge.
- The cost of local water is high relative to the other refuges in the study. Cost and reliability is subject to spot-market variability.

3.14.2.2 Limitations to Groundwater Development

- All but one of seven former wells have been capped because of poor groundwater quality or well collapse.
- Water quality tests have shown elevated levels of boron and salinity, particularly in shallow groundwater. Agricultural Water Quality Goals have been exceeded in groundwater for boron, EC, and selenium in one water quality test.
- Poor water quality has limited groundwater use. Wells are no longer used because of cost and water quality concerns.
- Dependence on Incremental Level 4 water for refuge water supply is relatively minor compared to other refuges in the study.
- Significant data collection is necessary prior to recommending groundwater development.

3.14.3 Recommended Data Acquisition Activities

Substantial additional data acquisition would be needed to support groundwater development. Because this refuge has a low priority to develop groundwater relative to the other refuges in this study, no onsite data acquisition is recommended at this time.

3.14.4 Potential Projects

3.14.4.1 Direct Use

Although inactive wells are present on the refuge, direct groundwater use has been unsuccessful due to poor water quality or well collapse. Water quality conditions would require verification prior to consideration of groundwater development. Because this refuge has a low priority to develop groundwater relative to the other refuges in the study, no further groundwater development for direct refuge use is recommended.

3.14.4.2 On-Refuge Conjunctive Use

No on-refuge conjunctive use projects are recommended at this time.

3.14.4.3 Off-Refuge Conjunctive Use

Water conveyors to the refuge are the Tracy Pumping Plant Water Authority (for which no groundwater management plan information was available) and the San Luis/Delta-Mendota Water Authority (which has adopted an AB 3030 Groundwater Management Plan). Mendota

WA is not within the sphere of influence of either water entity, and is therefore not affected by a groundwater management plan.

A cooperative effort by the Cities of Fresno and Clovis, Fresno ID, and Fresno Metropolitan Flood Control District is underway to use individually owned facilities to recharge water in greater urban areas. The Fresno-Clovis metropolitan area uses water from a regional sewage treatment facility to supply percolation ponds for groundwater recharge southwest of Fresno. No future plans or studies are known at this time.

A potential local groundwater bank is being considered to the northeast of the Mendota WA. The Meyers Farm project is being investigated, funded, and developed privately. Additional evaluation is needed to evaluate whether this project could be used to support the refuge.

TABLE 3-27
Mendota WA Well Information[a]
Evaluation of Groundwater Potential for Incremental Level 4 Refuge Water Supply

GIS Well Number[b]	Common Well Name	Well Status[c]	2002 Yield (ac-ft)	Year Installed	Depth (ft)	Screen Interval (bgs)	Well Output (gpm)	Well Log?	Water Quality Data?	Comments
MN-TW-01	Test Well 13	Destroyed		1992	530	120–485		Y	Y	Near parking lot #16. Specific screened intervals are: 120–135, 300–340, 460–485.
MN-TW-02	Test Well 14	Nonfunctional		1992	565	340–550		Y	Y	Near parking lot #22. Collapsed. Specific screened intervals are: 340–360, 530–550.
MN-IW-01		Destroyed			675			Y	N	Destroyed in 1992.
MN-IW-02		Destroyed			105			Y	N	Destroyed in 1992.
MN-IW-03		Destroyed			550			Y	N	Destroyed in 1992.
MN-IW-04		Destroyed			100			Y	N	Destroyed in 1992.
MN-IW-05		Destroyed			424			Y	N	Destroyed in 1992.
MN-IW-06		Destroyed			498			Y	N	Destroyed in 1992.

Notes:

[a] Based on data compiled from well logs, test records, communication with refuge staff (2002), and other previous documentation. Well locations are shown on Figure 3-40. On-refuge wells only are included in this table, although the GIS includes known wells within 1 mile of the refuge.

[b] Well type is indicated by the middle two letters of the GIS well number: IW = irrigation well, DW = domestic well, MW = monitoring well, TW = test well, and UN = unknown.

[c] Designation refers to the physical well only, not water quality issues. Designations are: *active* (currently operated), *inactive* (capable of operating, but currently is not), *nonfunctional* (cannot operate in current physical state), *destroyed* (well has been lost, abandoned, or filled), or *unknown* (no information regarding status is available).

Blank fields indicate that no information is available.

TABLE 3-28
Mendota WA Water Quality Data (1992)[a]
Evaluation of Groundwater Potential for Incremental Level 4 Refuge Water Supply

GIS Well Number	Sampled Interval (feet)	EC (µmhos/cm)	Boron (mg/L)	Selenium (µg/L)
MN-TW-01	120–135	9,640	5.0	ND
	300–340	7,760	2.1	7
	460–485	2,340	1.4	ND
MN-TW-02	340–360	5,601	2.2	ND
	530–550	2,640	1.3	ND

Source: Twining Laboratories 1992b.

Notes:

[a] Testing was completed on April 13 and 14.

Well locations are shown on Figure 3-40.
ND = not detected

TABLE 3-29
Mendota WA Evaluation
Evaluation of Groundwater Potential for Incremental Level 4 Refuge Water Supply

	Criteria	Scoring Scale	Appl.[b]	Score	Refuge Score Justification
Surface[a]	Do surface water bodies exist that could be affected by increased groundwater use?	+1 = no 0 = to some degree –1 = yes, surface water bodies could be affected	D,N	-1	Several duck ponds are found on the refuge. Fresno Slough flows through the refuge from northwest to southeast.
Water Supplies and Infrastructure	Has groundwater been used previously at the refuge for ponds or irrigation?	+1 = yes, used successfully to meet at least 20 percent of annual refuge water demands 0 = yes, used to meet less than 20 percent (or unknown) of annual refuge water demands. –1 = no, has not been used	D,N	0	Groundwater has been used previously, but use was unsuccessful because of water quality problems or well collapse.
	Do wells exist on the refuge?	+1 = yes, active wells 0 = yes, inactive or nonfunctional wells –1 = yes, destroyed wells, or no wells exist on the refuge	D,N	-1	All but one of seven former wells have been capped because of water quality problems or well collapse. The status of the existing well is unknown.
	Does existing internal distribution system (IDS) support groundwater use?	+1 = water can move extensively around the refuge with existing IDS 0 = the IDS enables limited water movement within the refuge –1 = an IDS does not exist on the refuge or water flow relies exclusively on gravity	D,N	+1	Several low lift and two return pumps service the refuge area. Part of the west-central area of the refuge is dependent on gravity flow.
Local Groundwater Use	Is groundwater used for agriculture or duck clubs in the immediate vicinity of the refuge?	+1 = groundwater is not used; or groundwater is minimally used, but use is not constrained 0 = groundwater is used in the area –1 = groundwater is not used due to physical or environmental constraints or is extensively used in the vicinity	D,N	0	Groundwater is pumped extensively in the area by the Mendota Pool Group.
	Does municipal or domestic supply exist near the refuge?	+1 = no known domestic or municipal wells are located within 1 mile of the refuge 0 = municipal or domestic wells are likely located within 1 mile of the refuge –1 = municipal or domestic wells are located within 1 mile of the refuge	D,N	-1	No wells have been identified within 1 mile of the refuge; however, the Cities of Mendota and Firebaugh use groundwater for municipal supply.
Soil and Hydrogeology	Are at-surface soils conducive to groundwater recharge?	+1 = soils are sandy or are reported to percolate well 0 = soils are silty or are reported to have some infiltration –1 = soils are clayey or are reported to hold water well	N	0	Waukena loam is found on the northern side of the refuge and Merced clay is found in a large area between Fresno Slough and the eastern boundary. Both soils have high surface and subsoil permeability, with high water holding capacity.
	Could recharge basins be developed if surface soils were removed?	+1 = confining soil less than 2 feet thick 0 = confining soil 5 to 7 feet thick –1 = confining soil greater than 7 feet thick	N	0	The soils on the northern side of the refuge consist of sandy loam or loamy coarse sand at depths of 2 feet. Clay subsoil has been found in some areas, however.
	Has subsidence occurred at or in the immediate vicinity of the refuge?	+1 = no 0 = yes, less than 2 feet –1 = yes, more than 2 feet	D,N	0	Severe subsidence has occurred in areas southwest of Mendota.
	Does significant potential for subsidence exist if groundwater use is increased at the refuge?	+1 = minimal potential for subsidence 0 = some potential for subsidence –1 = significant potential for subsidence	D,N	0	Future subsidence is possible in the upper aquifer where it is confined.
	Is aquifer storage available in the subbasin?	+1 = yes, current water levels are greater than 30 feet lower than historic levels 0 = some, current water levels are between 10 and 30 feet lower than historic levels –1 = no	N	0	In some areas in the immediate vicinity of the refuge, groundwater levels are significantly below historic levels, according to DWR data.

Notes
a Surface Features

b Application to Approach: D = Direct Use, N = On-Refuge Conjunctive Use

continued on next page

TABLE 3-29
Mendota WA Evaluation
Evaluation of Groundwater Potential for Incremental Level 4 Refuge Water Supply

	Criteria	Scoring Scale	Appl.[b]	Score	Refuge Score Justification
Water Quality	Have groundwater quality conditions hindered groundwater use in the past?	+1 = no 0 = data are not available –1 = yes	D,N	-1	All but one of seven former wells have been capped because of water quality problems or well collapse. Boron has been recorded as high as at 5.0 mg/L in shallow groundwater. EC at the same depth was greater than 9,000 µmhos/cm.
	Do adverse groundwater quality conditions exist in the subbasin?	+1 = no 0 = potential –1 = yes	D,N	-1	Peaks in selenium and arsenic have been observed in delivered water. Boron, selenium, and EC tested high in groundwater throughout the region. These parameters are higher in shallow groundwater and lower below the Corcoran Clay.
	Is surface water available to enable blending of lower quality groundwater to meet proposed refuge standards?	+1 = yes 0 = during portions of the year –1 = no	D,N	+1	Water is delivered monthly. Delivery has been reliable during the last three years.
	Do groundwater conditions exceed USEPA Freshwater Aquatic Life Standards or Agricultural Water Quality Goals for multiple parameters?	+1 = no 0 = yes, two parameters, or no water quality testing has been conducted –1 = yes, three or more parameters	D,N	-1	Agricultural water quality goals were exceeded in groundwater for boron, EC, and selenium for one water quality test.
	Is refuge land use management compatible with seasonally or annually variable water quality from different sources?	+1 = yes 0 = some potential compatibility problems may exist –1 = no	D,N	0	Only delivered water is currently used for wetland management; however, the source of delivered water is both surface water and groundwater from the Mendota Pool Group.
	Does groundwater quality meet drinking-water standards (i.e., can it be used for refuge domestic supply)?	+1 = yes it is used, no treatment is necessary 0 = yes it is used, but some treatment is necessary for potable use; or it is not used for unknown reasons –1 = no, it is not used because of adverse water quality conditions	D	0	Wells are not used for domestic supply on the refuge. (Domestic water supply comes from Westlands WD.)
Operational Issues/Constraints	Does a significant percentage of total refuge water supply consist of "Incremental Level 4" water?	+1 = yes, 54% to 79% of total water supply is Incremental Level 4 0 = somewhat, 27% to 53% of total water supply is Incremental Level 4 –1 = minor, 0% to 26% of total water supply is Incremental Level 4	D,N	0	Approximately seven percent of the water supply for Mendota WA consists of Incremental Level 4 water.
	Is the cost of local water high or low relative to the other refuges in this study?	+1 = costs may fluctuate highly or are subject to spot-market variability or price spikes –1 = costs are relatively stable and subjectivity to spot-market variability is low	D,N	+1	Incremental Level 4 water made available to Mendota WA is subject to wide fluctuations in cost and variable spot-market availability.
	Is it necessary to convey Incremental Level 4 water through the Delta for refuge supply?	+1 = yes, Incremental Level 4 water must be conveyed through the Delta –1 = no, conveyance of Incremental Level 4 water through the Delta is not necessary	D,N	+1	Incremental Level 4 water must be conveyed through the Delta given current water supply sources.
Data Needs	Are there significant data needs to address prior to groundwater development?	+1 = no, data needs regarding refuge groundwater conditions are minor 0 = somewhat, some data are required prior to increasing groundwater development –1 = yes, significant data must be collected as there is little or no existing data	D,N	-1	Significant data are required prior to recommending increased groundwater development.
			Total Direct Use Score =	**-3**	
			Total On-Refuge Conjunctive Use Score =	**-3**	

Notes
a Surface Features

b Application to Approach: D = Direct Use, N = On-Refuge Conjunctive Use

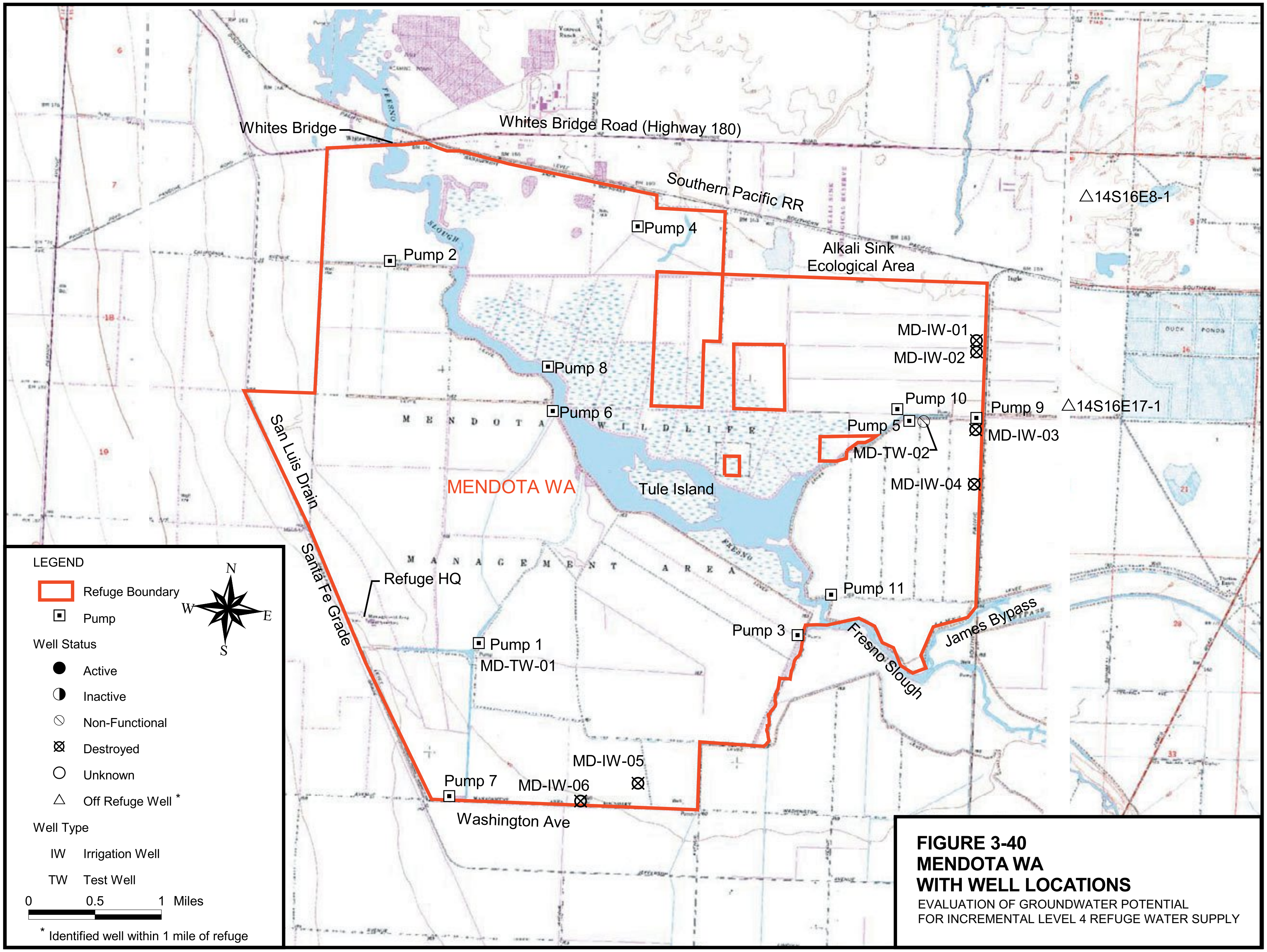

FIGURE 3-40
MENDOTA WA
WITH WELL LOCATIONS
EVALUATION OF GROUNDWATER POTENTIAL
FOR INCREMENTAL LEVEL 4 REFUGE WATER SUPPLY

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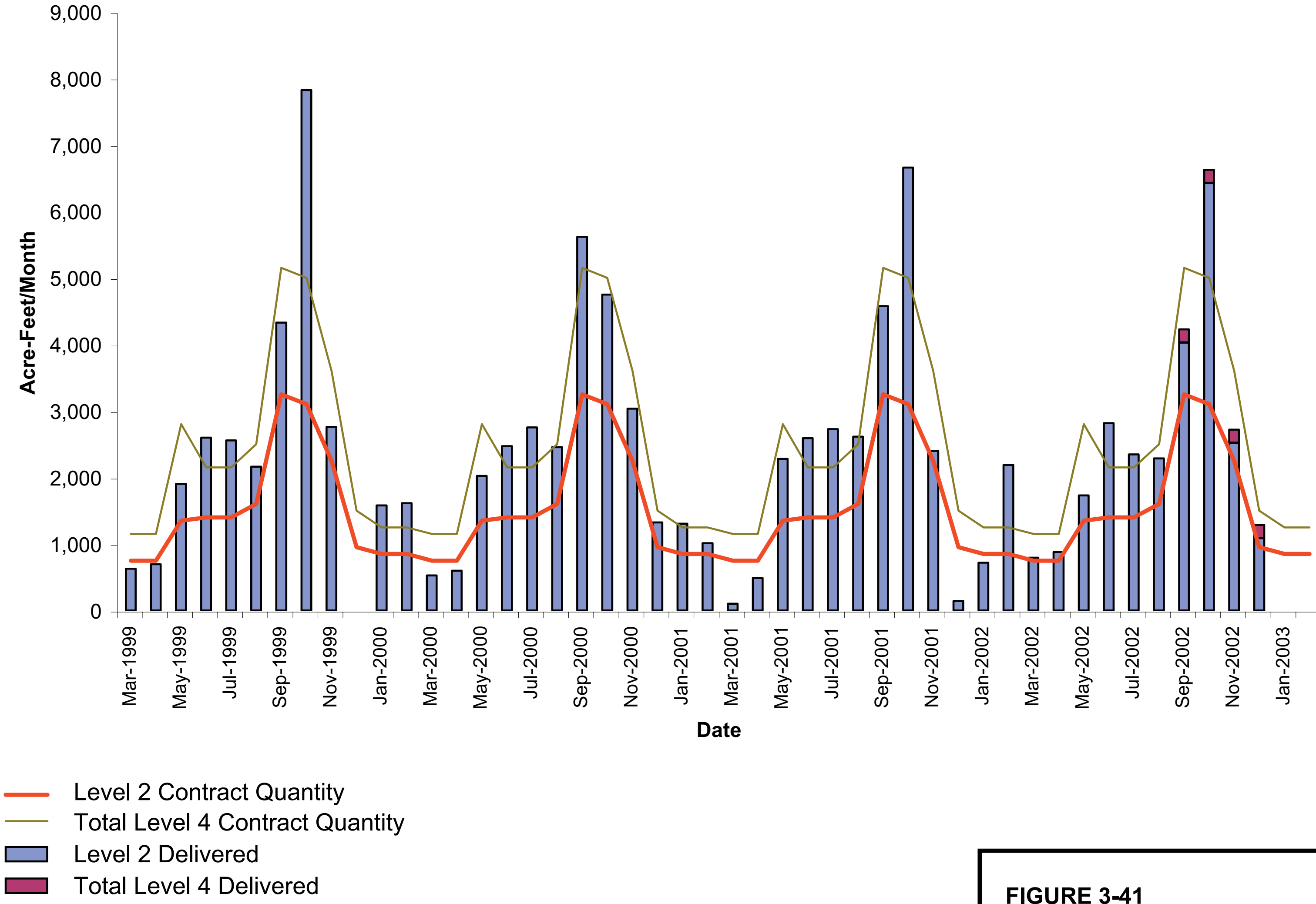

Note: Level 2 and Total Level 4 contract quantities are those indicated in Reclamation 1989 and Reclamation el al. 1989. Volumes indicated may not reflect current monthly management schedules and are shown to indicate an approximate monthly breakdown for management purposes. Total annual contract quantities may be scheduled based on availability, at the refuge manager's discretion.

FIGURE 3-41
1999-2002 MENDOTA WILDLIFE AREA WATER DELIVERIES
EVALUATION OF GROUNDWATER POTENTIAL
FOR INCREMENTAL LEVEL 4 REFUGE WATER SUPPLY

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SECTION 4

Tulare Lake Region Refuges

4.1 Regional Characteristics

4.1.1 Physical Setting

The San Joaquin Valley Basin south of the San Joaquin River is referred to as the Tulare Lake Region. The Tulare Lake Region consists primarily of agricultural land. Prior to European settlement, the study area supported vast wetland habitats for migrating waterfowl. Although much of the land has been converted to agricultural use, small areas of wetland habitat remain (Reclamation and Service 2001).

Two project refuges are located in the Tule and Kern Subbasins, two of the seven Tulare Lake Region groundwater subbasins defined by DWR Bulletin 118 (Figure 4-1). These refuges are:

- Pixley NWR
- Kern NWR

These are the two southernmost refuges of this study. They are managed independently but are operated from a common headquarters located at Kern NWR.

The Mendota WA is also physically located within the Tulare Lake Region, but because its water supply originates from hydrologic basins to the north, it is discussed in the San Joaquin Region refuge sections.

The Tulare Lake Region comprises the southern half of the San Joaquin Valley. It is surrounded on three sides by mountains: the Sierra Nevada to the east, the Tehachapi Mountains to the south, and the Coast Range to the west. The region is bounded to the north by the San Joaquin River.

The main urban areas within the region are Fresno and Bakersfield. Smaller regional urban centers are the towns of Corcoran in Kings County, Pixley in Tulare County, and Delano and Wasco in Kern County. The region includes southeast Kings, southwest Tulare, and north-central Kern counties. Several major irrigation districts are within the region. The water districts play a significant role in guiding regional water issues.

4.1.2 Existing Water Supplies

Pursuant to the CVPIA, long-term refuge water supply agreements were executed for each of the Tulare Lake Region refuges in 2001. The federal refuges, Pixley NWR and Kern NWR, are each managed by the Service. CVP water is conveyed to Kern NWR by Buena Vista WSD. The refuge occasionally accepts flood flows from Poso Creek. Pixley NWR currently relies solely on groundwater from an on-refuge irrigation well for its water supply. In the past, excess water from Pixley ID was provided to the refuge, but this supply source was unreliable.

4.1.3 Groundwater Management

Groundwater management within the Tulare Lake Basin occurs under existing California code, through development of local ordinances, and by the development and implementation of specific groundwater management plans, as described in Section 1. Some districts in the Tulare Lake Region have not formally adopted a groundwater management plan but have entered into a memorandum of understanding (MOU) with joint power authority or a cooperative agreement with other agencies to manage groundwater. Where readily available, groundwater management plans or ordinances with direct or indirect bearing on either Kern or Pixley NWR were reviewed. Groundwater management activities that apply directly to Pixley and Kern NWR include:

- **Kern NWR**—Semitropic WSD manages groundwater under the authority of California Water Code Division 14, "California Water Storage District Law." The majority of eastern Kern NWR is located within Semitropic WSD. Kern NWR is not a partner in the planned Semitropic Water Bank, which is discussed below. The western portion of Kern NWR is located within the Lost Hills WD, which does not have a groundwater management plan.
- **Pixley NWR**—Pixley ID and Lower Tule ID entered into an MOU in March of 1995 to undertake groundwater management. Most of central Pixley NWR is located within Pixley ID, and another smaller portion is located within the Lower Tule ID.

Recharge and in-lieu programs within the Tulare Lake Basin are operated by various water districts, the City of Bakersfield, and the Kern County Water Agency. A number of districts have drafted or are in the process of drafting AB 3030 water management plans, including West Kern WD, Kern Delta WD, Rosedale–Rio Bravo Water Service District (completed in 1996), and Cawelo WD (completed in 1994). Other entities have adopted AB 255 plans. None of these districts would directly influence the water management of either Kern or Pixley NWR.

4.1.4 Regional Geology and Soils

Similar to the formation of the San Joaquin River Region, the 6 to 8 miles of sediments that fill the San Joaquin Valley consist of older marine sediments that grade upward into non-marine and continental deposits. The Tulare Formation is the most prevalent shallow sedimentary unit (Figure 3-3) and consists of terrace, alluvium, and flood-basin deposits.

There has been no external outlet for local precipitation runoff and drainage from the surrounding uplands for the past 5 million years (Norris and Webb 1990). All drainage emptied into large lakes such as the historic Lake Corcoran and the modern Tulare, Buena Vista, and Kern Lakes, which once covered the majority of the regional surface area during spring runoff. As these lakes repeatedly filled and drained, laterally-extensive clay layers with variable layers of sands and silts were deposited, the most extensive of which is the Corcoran Clay Member of the Tulare Formation (Figure 3-4). With the increased management of water resources in the state, including the damming of many of the rivers that once provided water to them, these extensive lakes rarely occur.

The western half of the Tulare Lake Region, generally west of the Arvin-Maricopa area, is underlain by the Corcoran Clay. The Corcoran Clay is found at depths between 300 and 900 feet bgs, which is slightly deeper than in the San Joaquin River Region.

Several prominent folds and faults are located in the Tulare Lake Region. These include the subsurface Bakersfield Arch, which is bounded by the White Wolf fault at the southern end of the region and the Kettleman Hills, an anticlinal fold near Avenal. Other faults include the Kern Front fault and the Buena Vista fault, both of which are considered to be active (Norris and Webb 1990). Extensive oil and gas fields have been developed through the region, particularly within the folded area parallel to the Coast Ranges.

Soils in the Tulare Lake Region consist primarily of imperfectly drained soils and saline/alkaline soils (Reclamation et al. 1999), which are characterized as clay to clay loam. The imperfectly drained soils tend to be dark clay and have a high water capacity. These soils also may be alkaline. Saline-alkali soils may contain excess salt or sodium. When irrigated, salts may be leached from the soil into the shallow aquifer, which exacerbates adverse groundwater conditions. Soil salinity is more common in the western and southern portion of the San Joaquin Valley, where soils are derived from the marine sediments of the Coast Ranges (Reclamation et al. 1999).

4.1.5 Regional Hydrogeology

Like the San Joaquin River Region, the Corcoran Clay plays the most dominant role in regional hydrogeology and divides the groundwater system into two major aquifers—a confined aquifer below the clay layer and a semi-confined aquifer above the layer. Other clay layers are present above and below the Corcoran Clay, impacting local groundwater conditions (Reclamation et al. 1999). Semi-confined aquifer conditions exist on the west side of the Tulare Lake Region above the Corcoran Clay layer, as well as to the east, where the clay is not present. Locally, faults may affect groundwater movement.

Recharge of the semi-confined aquifer in the Tulare Lake Region is primarily derived from seepage from streams and canals, infiltration of applied water, and subsurface inflow. Precipitation on the valley floor provides some recharge, but only in abnormally wet years. Seepage from streams and canals is highly variable depending on annual hydrologic conditions. Recharge to the lower confined aquifer takes place largely through lateral inflow from the semi-confined aquifer. Present information indicates that the clay layers, including the Corcoran Clay, are not continuous in some areas, and some seepage from the semi-confined aquifer above does occur through the confining layer.

Early agricultural development (pre-1900s) in this region, together with more arid conditions than in the northern two-thirds of the Central Valley, has resulted in areas with significant groundwater level declines. This has caused a change in stream-aquifer dynamics. In the period of predevelopment, the interaction was very dynamic; water was exchanged in both directions depending upon variations in hydrologic conditions. With the onset and rapid growth of the agricultural sector in the region, groundwater was heavily developed, resulting in regional groundwater level declines. Subsequently, the infiltration of surface water flows to underlying aquifers became the prevailing condition. In some areas of severe overdraft, such as some areas in the counties of Kings and Kern, complete disconnection between groundwater and overlying surface water systems has occurred (Reclamation et al. 1999).

4.1.5.1 Groundwater Storage and Production

DWR estimated usable storage capacity for the Tulare Lake Region to be approximately 28 million ac-ft and the perennial yield to be approximately 4.6 million ac-ft (DWR 1994).

This perennial yield is directly dependent on the amount of recharge received by the groundwater basin.

Groundwater was the primary regional water supply from the 1920s to the 1960s. Pumping increased steadily as more land came into agricultural production. Both overdraft conditions and subsidence were recognized as significant problems in the 1960s. Introduction of local surface water facilities and imports of CVP water from the San Luis Division and SWP water from the California Aqueduct greatly reduced regional groundwater pumping. Additional CVP supplies were imported into the southern half of the region with the introduction of the Cross Valley Canal in the mid-1970s. This continued to reduce the demands on regional groundwater pumping and improve overdraft conditions. Groundwater pumping increased in the region in the late 1980s and early 1990s for several reasons, similar to those in the San Joaquin River Region. First, surface water deliveries to Central Valley water users were reduced as a result of the imposition of environmental requirements on the operation of surface water facilities. Also, surface water supplies were less reliable as a result of critically dry hydrologic conditions during the 1987-1992 drought period (DWR 1994).

The DWR estimated groundwater pumping for 1990 conditions (normalized) in the Tulare Lake Region to be 5.2 million ac-ft. This is higher than the estimated perennial yield by approximately 630,000 ac-ft (DWR 1994).

4.1.5.2 Groundwater Models

Several groundwater models have been developed within the Tulare Lake Region. These include:

- Central Valley Ground-Surface Water Model (CVGSM) (Reclamation et. al. 1990)
- West San Joaquin Valley (IGSM)
- Friant Service Area (IGSM)
- Semitropic WSD (FEMFLOW)
- Kern County area in Tulare Basin model, developed in 1977 by DWR in cooperation with Kern County Water Agency (USGS 1989)

This list is not comprehensive and represents only those models which are commonly discussed and referred to within the groundwater community. Some of these models may provide general information and summaries about assumed aquifer properties and groundwater conditions.

4.1.5.3 Groundwater Levels

The 1987–1992 drought resulted in substantial deficiencies in surface water deliveries and corresponding increases in groundwater pumping. Water levels declined by 20 to 30 feet throughout most of the central and eastern parts of the San Joaquin Valley (Westlands WD 1995). Cones of depression resulting from groundwater withdrawals are indicated in the midvalley area near the center of Fresno County, near the City of Fresno, and in parts of Kern County (see Figure 3-8). In the Tulare Lake Region, groundwater levels are most shallow in northern Kings County.

4.1.5.4 Groundwater Quality

Regional groundwater quality conditions in the Tulare Lake Region are similar to those in the San Joaquin River Region. Constituents commonly found in groundwater in this region include arsenic, boron, selenium, nitrates, and salts. Although there are no enforceable water quality standards for federal or California wildlife refuges, USEPA Freshwater Aquatic Life Protection Recommended Criteria (USEPA Office of Water 2002a), Agricultural Water Quality Goals (Ayers and Westcot 1985), and federal and state MCLs (USEPA Office of Water 2002a; CDHS 2003) may be used as reference points. These standards for selected constituents are provided in Table B-1 in Appendix B.

Arsenic, Boron, and Molybdenum. Arsenic, boron, and molybdenum are commonly elevated in groundwater in the Tulare Lake Region above the Corcoran Clay (Figure 3-5). Municipal use of groundwater as a drinking supply is impaired because of elevated arsenic concentrations (greater than the primary MCL of 50 μg/L) in the southwest corner of the Tulare Lake Region (Reclamation et al. 1999; USEPA Office of Water 2002b). Agricultural use of groundwater is impaired because of elevated boron concentrations (greater than the Agricultural Water Quality Goal of 100 μg/L) in western Fresno and Kings Counties (Ayers and Westcot 1985). In the southern portion of the Tulare Lake Region, high concentrations of boron are generally found in areas southwest to Bakersfield (greater than 3 mg/L) and southeast of Bakersfield (1 to 4 mg/L) (Bertoldi et al. 1991). Concentrations as high as 4.2 mg/L have been measured near Buttonwillow Ridge and Buena Vista Slough (Reclamation et al. 1999). It is unknown if these constituents were measured above or below the Corcoran Clay.

Molybdenum may also be present at potentially toxic concentrations in soil and shallow (less than 20 feet bgs) groundwater in the central Tulare Lake Region (Reclamation et al. 1999). The Agricultural Water Quality Goal for Molybdenum is 10 μg/L (Ayers and Westcot 1985).

Selenium. Use of groundwater to support aquatic species is impaired because of elevated selenium concentrations (chronically greater than 5 μg/L) in the Tulare Lake Region near Kettleman City, and in western portions of Fresno and Kings Counties (Figure 3-6) (Reclamation et al. 1999). Selenium measurements are highest in the northern part of the Tulare Lake Region, and decrease to the south. Generally, selenium concentrations are less than 5 μg/L in much of the basin.

Nitrates. Nitrate (NO_3-N) concentrations greater than 10 mg/L are found in several localized areas of the Tulare Lake Region. These include areas south and north of Bakersfield, around the Fresno metropolitan area, and scattered areas of the Sierra Nevada foothills in the Hanford-Visalia area. Municipal use of groundwater as drinking water supply is impaired because of elevated nitrate concentrations (greater than the MCL of 45 mg/L as NO_3) in numerous areas throughout the Tulare Lake Region (Reclamation et al. 1999).

Dibromochloropropane. DBCP has been detected in many groundwater wells in the Tulare Lake Region. Municipal use of groundwater as drinking water supply is impaired due to elevated DBCP concentrations (greater than the MCL of 0.2 μg/L) near several cities within the Tulare Lake Region, including Visalia, Bakersfield, the Fresno area, and scattered locations in southwest Tulare County (Reclamation et al. 1999; USEPA Office of Water 2002b; CDHS 2003).

TDS and Salinity. TDS characteristics of the Tulare Lake Region are similar to those found in the San Joaquin River Region, and vary considerably depending on the groundwater zone (see Figure 2-6). TDS ranges from 500 mg/L below the Corcoran Clay to over 2,000 mg/L above it. Agricultural groundwater use is impaired because of high TDS concentrations (greater than the Agricultural Water Quality Goal of 450 mg/L) above the Corcoran Clay in the western portion of Fresno and Kings Counties (Reclamation et al. 1999; Ayers and Westcot 1985).

EC provides a measure of salinity in groundwater while also indicating the presence of other dissolved constituents. Figure 3-7 shows the ranges of EC in the groundwater above the Corcoran Clay. EC may be over 20,000 µmhos/cm in some areas of the Tulare Lake Region. The Agricultural Water Quality Goal for EC is 700 µmohs/cm (Ayers and Westcot 1985).

4.1.5.5 Agricultural Subsurface Drainage

The subsurface drainage problems associated with the west side of the San Joaquin Valley extend from north to south in the Tulare Lake Region (Figure 3-8). Recent reports indicate that long-term groundwater storage in these regions is increasing, further aggravating the problem (DWR 1994). As in the San Joaquin River Region, salinity and trace elements in some soils and shallow groundwater on the western side of the Tulare Lake Region are also of concern.

4.1.6 Subsidence

Groundwater level declines in the San Joaquin Valley have resulted in subsidence over large areas of the Tulare Lake Region. Significant historic land subsidence caused by excessive groundwater pumping has been observed in the Kettleman City area, the Tulare-Wasco area, and the Arvin-Maricopa area (see Figure 2-8). In the Tulare-Wasco area, subsidence exceeded 12 feet in local areas (Ireland et al. 1982).

Subsidence has continued to occur in some areas of the Tulare Lake Region. Subsidence of up to 1.3 feet was measured near the Mendota Pool and about 2 feet approximately 25 miles northeast of Mendota Pool (Central California ID 1996).

4.1.7 Areas of Planned Groundwater Projects

A number of groundwater management programs and projects for the Tulare Lake Region have been proposed and/or approved for funding through grant and loan opportunities. Figure 4-2 presents the locations and status of these projects within the Tulare Lake Region. Details on these projects are located in Appendix A, Table A-3. Analysis indicates that some projects are more feasible than others for refuge involvement based on parameters such as proximity to refuge, type of project, conveyance opportunities, and project status. Refer to specific refuge assessments for recommended projects.

4.2 Subbasin Characteristics

4.2.1 Tule Subbasin

Pixley NWR is located within the Tule Subbasin. Water districts within the Tule Subbasin are shown in Figure 4-3.

4.2.1.1 Basin Boundaries and Hydrology

The Tule Subbasin includes 733 square miles (467,000 acres) and is bounded primarily by the Tulare County line on the west, the Lower Tule ID and Porterville ID to the north, the alluvium of the Sierra Nevada foothills to the east, and the Tulare-Kern County line to the south. Annual precipitation ranges from 7 to 11 inches, with more rain falling to the east. The Tule River, Deer Creek, and White River are the major drainages of the subbasin, which empty into the Tule lakebed area. The Tule and White Rivers are losing streams throughout most of the basin. Horizontal groundwater barriers do not appear to exist in the subbasin, according to historical groundwater elevation maps.

4.2.1.2 Hydrogeology

Groundwater Level Trends. Groundwater level trends within the subbasin (Figure 4-4) show that overall, groundwater levels are comparable to levels in the 1970s. General declines in water levels were observed during the droughts of the late 1970s and from 1988 to 1994. A sharp decrease in water levels of up to approximately 30 feet occurred from 1988 to 1995, reaching several feet below 1970 water levels. Since the drought of the 1970s, groundwater levels have recovered to predrought conditions (DWR 2003b).

Groundwater Yields. DWR estimated that the average specific yield for this subbasin is 9.5 percent. The total storage capacity of the subbasin is estimated to be 14.6 million ac-ft to a depth of 300 feet and 94.1 million ac-ft to the base of fresh groundwater as of 1995 (DWR 2003a).

Irrigation well yields vary widely within the Tule Subbasin and range from 50 to 3,000 gpm. Groundwater is obtained from both above and below the Corcoran Clay with average well production depth ranging from 200 to 1,400 ft (DWR 2003a).

Groundwater Quality. TDS values typically range from 200 to 600 mg/L within the subbasin. Some areas with shallow, saline water and drainage water problems occur in the western portion of the subbasin, where TDS values can be as high as 30,000 mg/L. Localized areas of high arsenic concentrations are also found within the subbasin. The City of Hanford has reported odors caused by elevated levels of hydrogen sulfide (DWR 2003a).

Groundwater Budget Components. DWR has not completed a detailed water budget for the subbasin. However, an estimate of groundwater demand was calculated based on the 1990 normalized year and on data from land and water use. A subsequent analysis was done by DWR to estimate overall applied water demands, agricultural groundwater pumpage, urban pumping demand, and other extraction data. The natural recharge into the subbasin is estimated at 34,400 ac-ft, primarily from stream recharge and irrigation percolation. Annual urban and agricultural extraction are estimated to be 19,300 ac-ft and 641,000 ac-ft, respectively (DWR 2003a). Other groundwater budget components estimates were not included in Bulletin 118 (DWR 2003a).

4.2.2 Kern County Subbasin

Kern NWR is located within the Kern County Subbasin. Water districts within the Kern County Subbasin are shown in Figure 4-5.

4.2.2.1 Basin Boundaries and Hydrology

The Kern County Subbasin is bounded by the Kern County line on the north and surrounded by mountains on all other sides: the Sierra Nevada foothills on the east, the Tehachapi Mountains on the south, the San Emigdio Mountains on the southwest, and the Coast Range on the west. Average precipitation ranges from 5 inches in the subbasin interior to 13 inches at the southern, eastern, and western borders (DWR 2003a). Major rivers in the subbasin include the Kern River and Poso Creek.

4.2.2.2 Hydrogeology

Groundwater Level Trends. Overall, the average subbasin groundwater level was essentially unchanged from 1970 to 2000. During the drought periods, however, groundwater levels declined by up to 15 feet (Figure 4-6). However, in general, net water level changes in different portions of the subbasin were variable through the 1970–2000 period. Groundwater levels have increased by more than 30 feet at the southeast valley margin and in the Lost Hills-Buttonwillow areas and have decreased 25 and 50 feet in the Bakersfield area and McFarland-Shafter areas, respectively (DWR 2003b).

Groundwater Yields. Unconfined and semi-confined groundwater exists in most areas of the basin. In the western portion of the subbasin where the Corcoran Clay is present, confined groundwater exists beneath the Corcoran Clay. Specific yields for the Tulare and Kern River Formations and overlying alluvium range from 5.3 to 19.6 percent and average 11.8 percent from the surface to 300 feet below grade, according to the DWR's San Joaquin District office. DWR's Bulletin 118 indicates that the highest specific-yield values are found in the Kern River Fan sediments, west of Bakersfield (DWR 2003a). Typical irrigation well yields range from 1,200 to 1,500 gpm. Average production depths range from 200 to 250 feet.

Groundwater Quality. TDS values range from 150 to 5,000 mg/L in the subbasin, with average values between 400 and 450 mg/L. High concentrations of TDS, sodium chloride, and sulfates coincide with the axial trough of the basin. In various areas of the basin, nitrates and DBCP are found in concentrations that exceed MCLs. Elevated concentrations of arsenic are also associated with dry lakebeds (DWR 2003a).

Groundwater Budget Components. Estimates of groundwater withdrawal are based on a 1997 DWR and Kern County Water Agency groundwater model. Subbasin outflows comprise urban extraction of 154,000 ac-ft per year, agricultural extraction of 1.16 million ac-ft per year, and other oil-industry related extractions of 86,333 ac-ft, for a total subbasin outflow of 1.4 million ac-ft per year. Kern County Water Agency has estimated the total stored (banked) water at the subbasin to be 50,000,000 ac-ft and dewatered aquifer storage to be 19,000,000 ac-ft. Natural recharge is from the Kern River and applied irrigation water (DWR 2003a). Other groundwater budget components estimates were not included in Bulletin 118 (DWR 2003a).

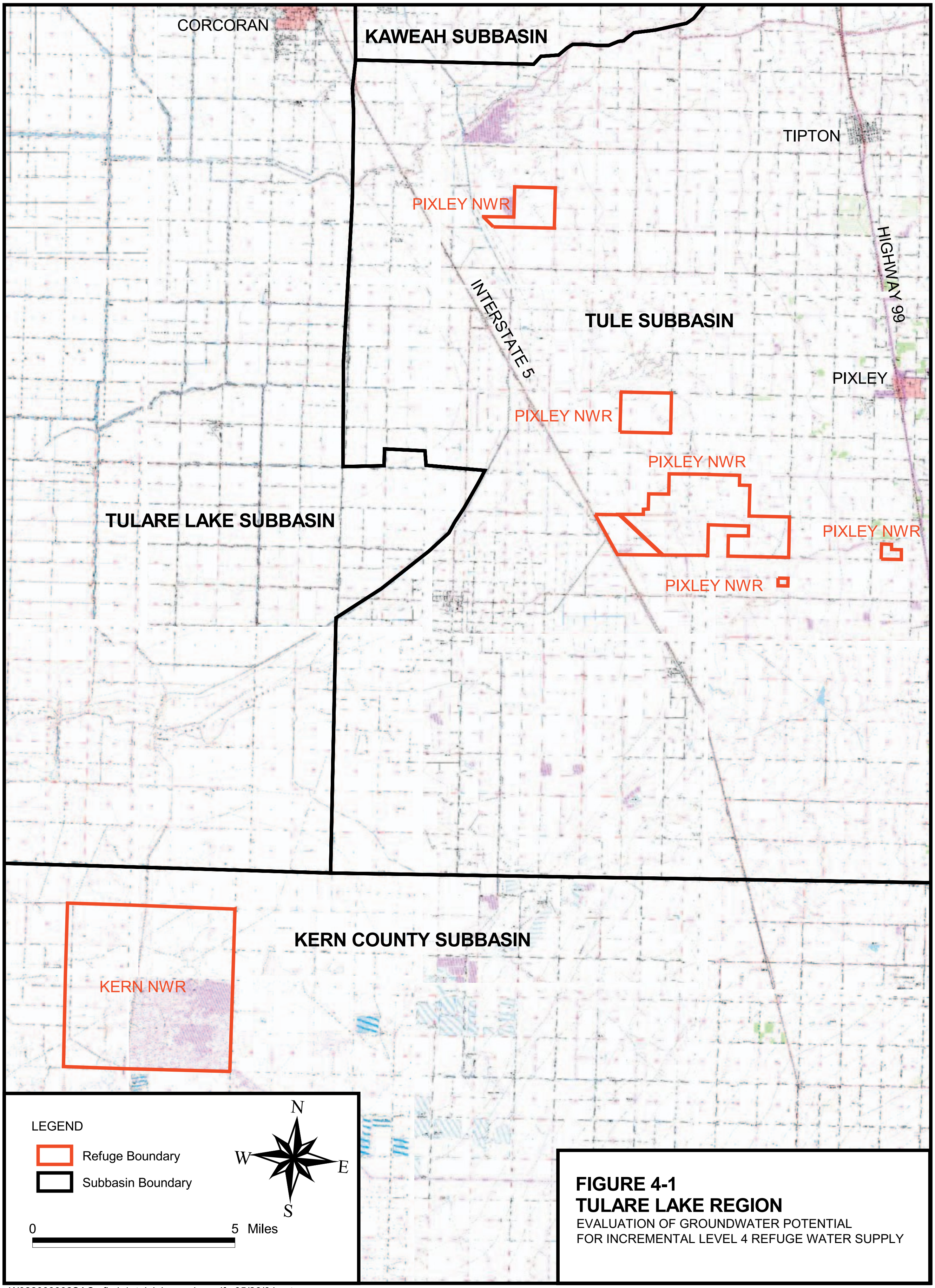

FIGURE 4-1
TULARE LAKE REGION
EVALUATION OF GROUNDWATER POTENTIAL
FOR INCREMENTAL LEVEL 4 REFUGE WATER SUPPLY

W022003002SAC fig4-1_tulelake_region.pdf 05/26/04 cts

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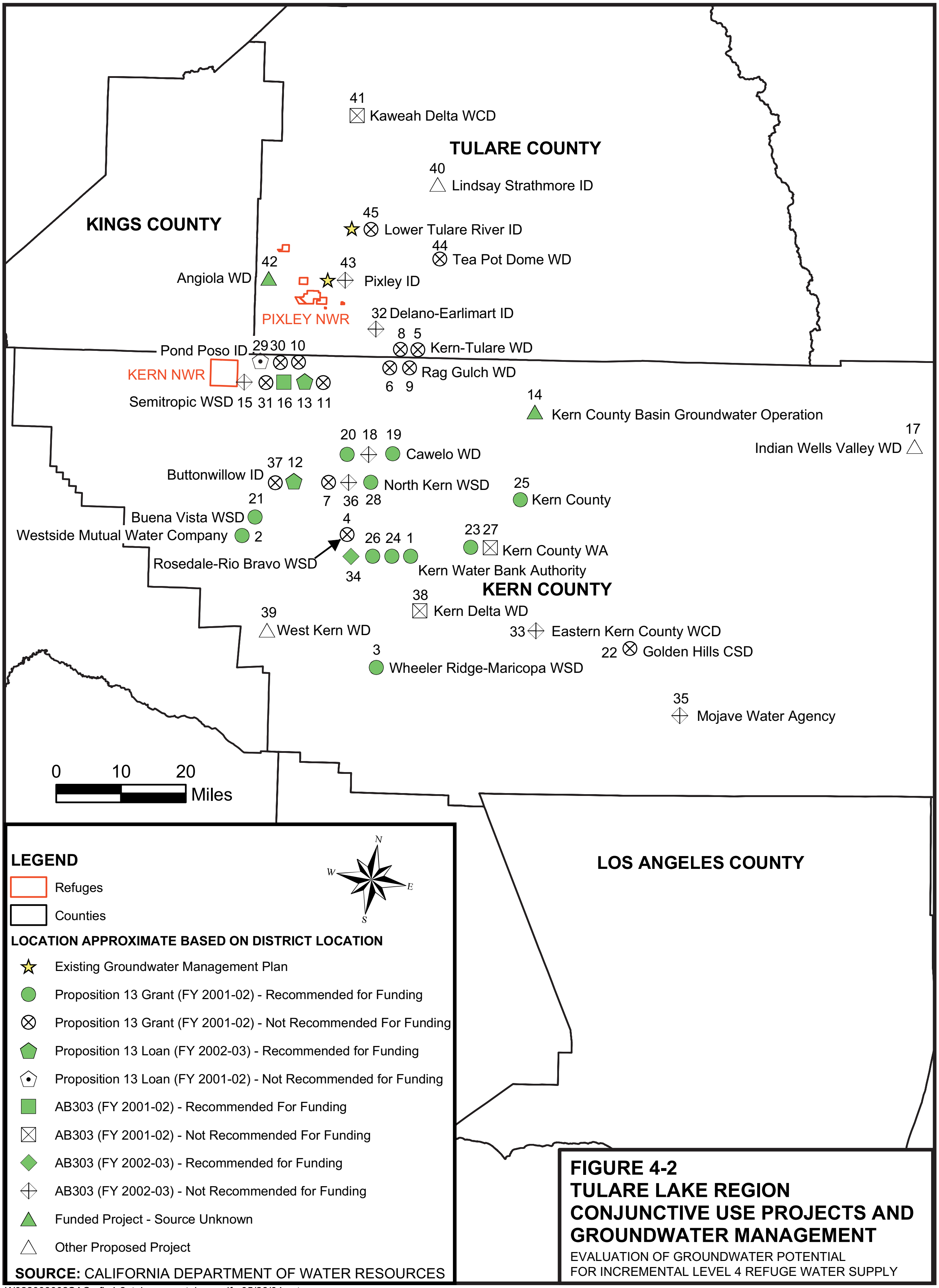

FIGURE 4-2
TULARE LAKE REGION CONJUNCTIVE USE PROJECTS AND GROUNDWATER MANAGEMENT
EVALUATION OF GROUNDWATER POTENTIAL
FOR INCREMENTAL LEVEL 4 REFUGE WATER SUPPLY

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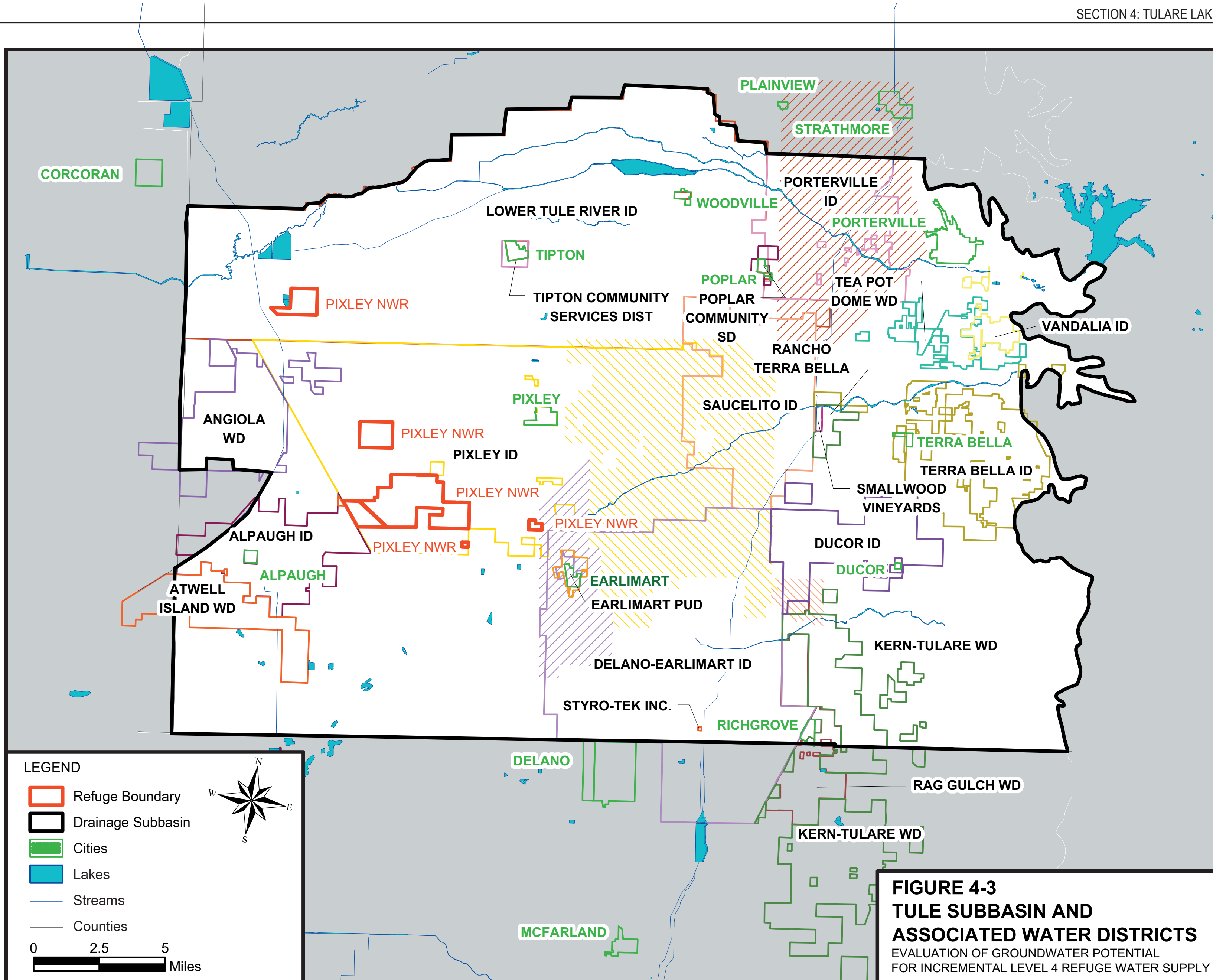

FIGURE 4-3
TULE SUBBASIN AND ASSOCIATED WATER DISTRICTS
EVALUATION OF GROUNDWATER POTENTIAL
FOR INCREMENTAL LEVEL 4 REFUGE WATER SUPPLY

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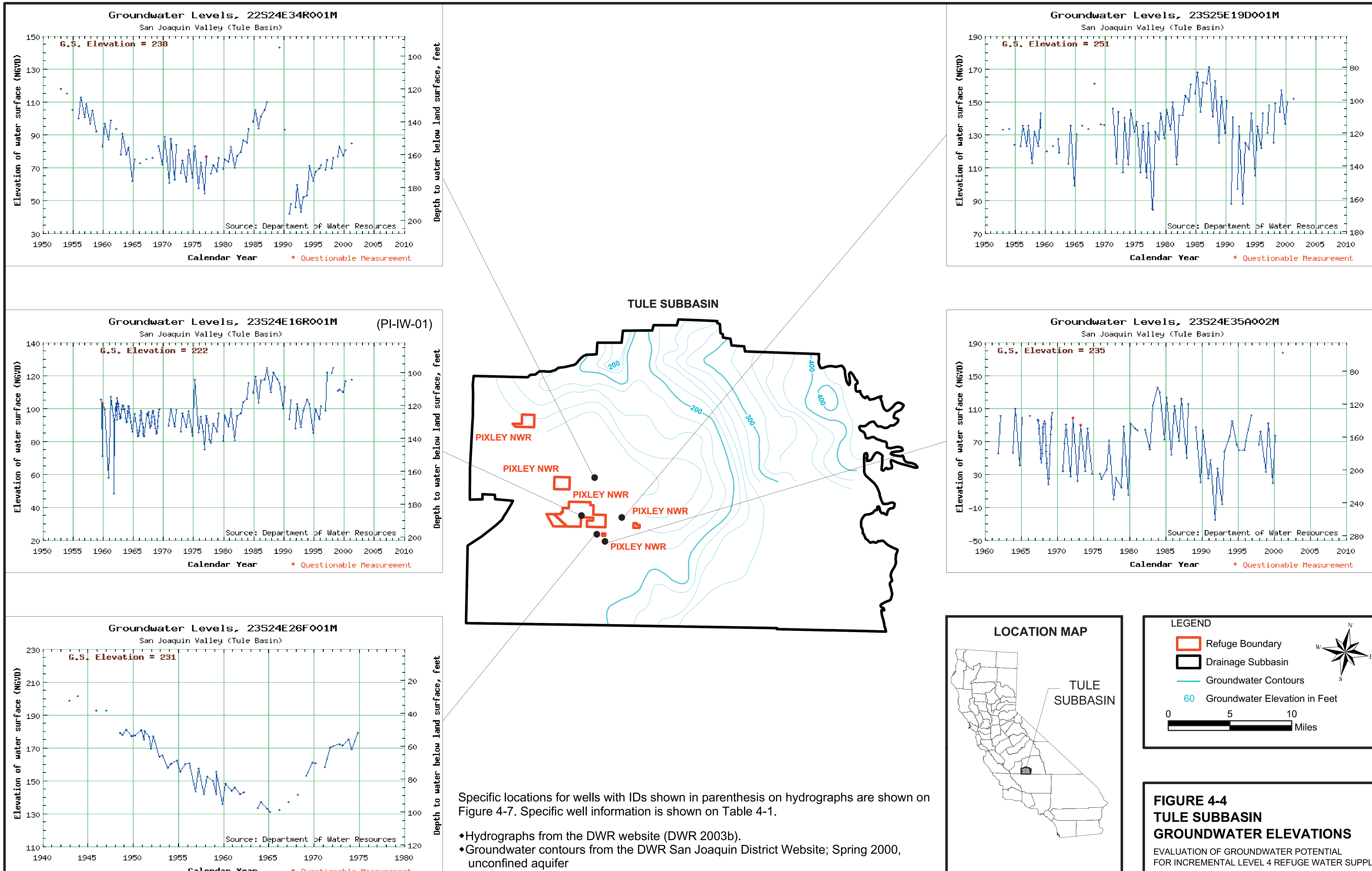

Specific locations for wells with IDs shown in parenthesis on hydrographs are shown on Figure 4-7. Specific well information is shown on Table 4-1.

- Hydrographs from the DWR website (DWR 2003b).
- Groundwater contours from the DWR San Joaquin District Website; Spring 2000, unconfined aquifer

FIGURE 4-4
TULE SUBBASIN
GROUNDWATER ELEVATIONS
EVALUATION OF GROUNDWATER POTENTIAL
FOR INCREMENTAL LEVEL 4 REFUGE WATER SUPPLY

W022003002SAC fig4-4_tule_subbasin_contours.pdf 05/26/04 cts

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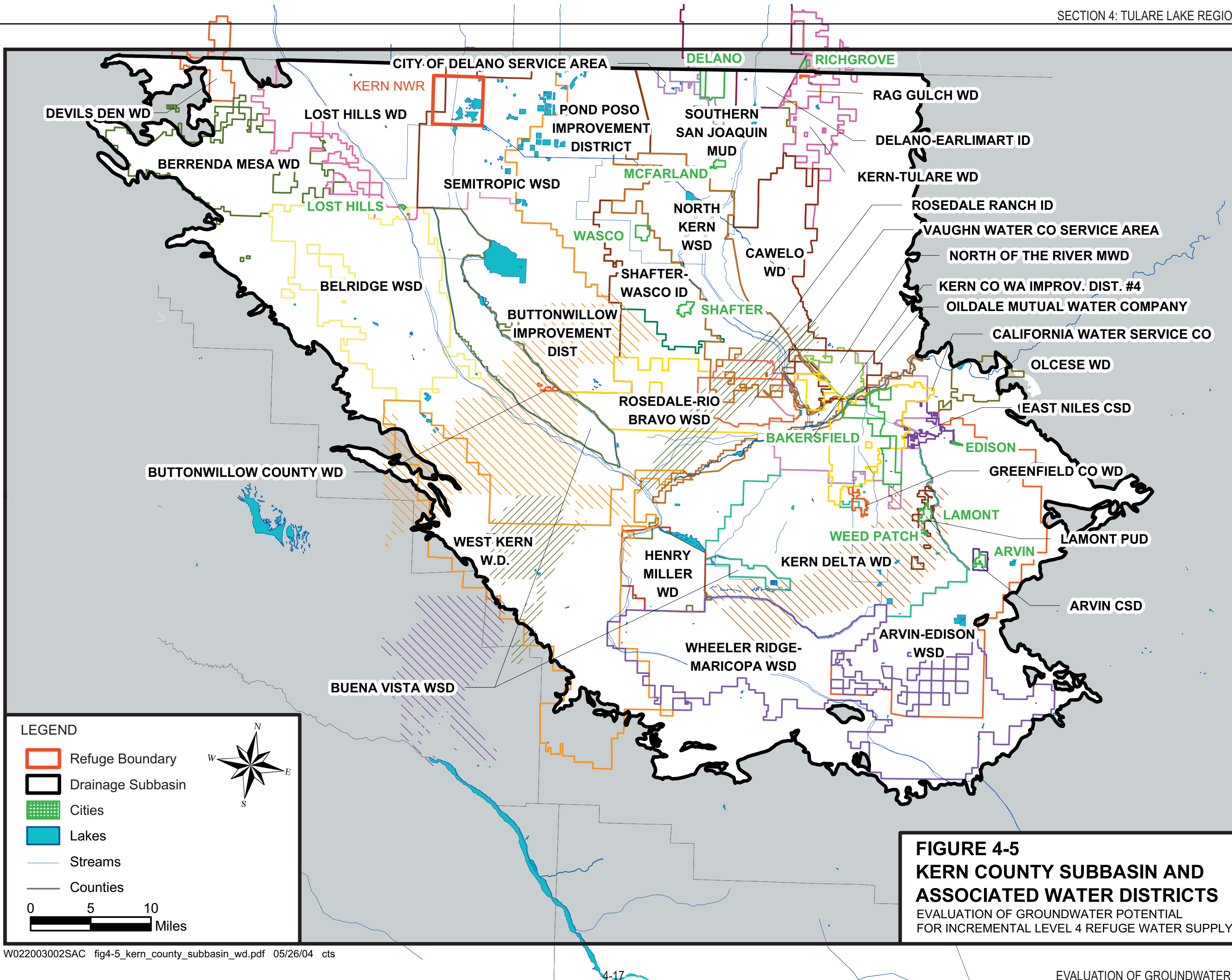

FIGURE 4-5
KERN COUNTY SUBBASIN AND ASSOCIATED WATER DISTRICTS
EVALUATION OF GROUNDWATER POTENTIAL FOR INCREMENTAL LEVEL 4 REFUGE WATER SUPPLY

W022003002SAC fig4-5_kern_county_subbasin_wd.pdf 05/26/04 cts

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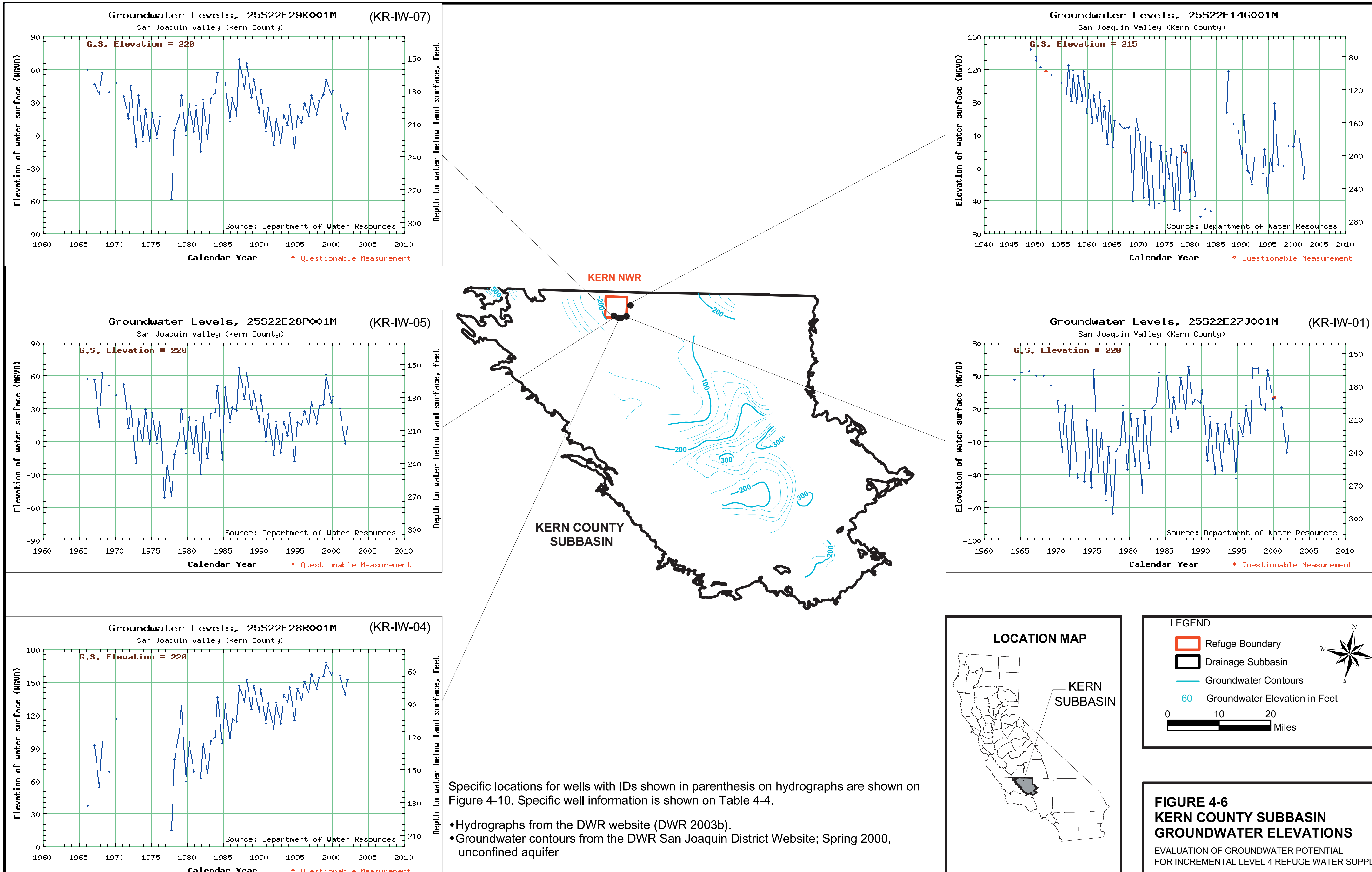

Specific locations for wells with IDs shown in parenthesis on hydrographs are shown on Figure 4-10. Specific well information is shown on Table 4-4.

◆Hydrographs from the DWR website (DWR 2003b).
◆Groundwater contours from the DWR San Joaquin District Website; Spring 2000, unconfined aquifer

FIGURE 4-6
KERN COUNTY SUBBASIN GROUNDWATER ELEVATIONS
EVALUATION OF GROUNDWATER POTENTIAL FOR INCREMENTAL LEVEL 4 REFUGE WATER SUPPLY

W022003002SAC fig4-6_kern_county_subbasin_contours.pdf 05/26/04 cts

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4.3 Pixley NWR Assessment

County: Tulare
Basin/Subbasin: San Joaquin Valley Groundwater Basin/Tule Subbasin (see page 4-7)
Level 2 / Incremental Level 4: 1,280 ac-ft / 4,720 ac-ft
2003 Acreage: 6,385
CVP Water Conveyor: None (groundwater is currently the only source)
Water District Service Area: Pixley ID and Lower Tule ID
Applicable Groundwater Management Regulations: None

Pixley NWR consists of one main area and four smaller discontinuous tracts of land located in Tulare County west of SR 99, east of SR 43, and south of SR 190 between the towns of Pixley and Earlimart. Figure 4-7 shows Pixley NWR and the locations of its wells. Onsite well information is summarized in Table 4-1.

4.3.1 Hydrogeologic Assessment

4.3.1.1 Habitat Goals, Land Management, and Surface Features

Pixley NWR includes native valley grasslands, vernal pools, and marshland. The refuge is primarily an endangered-species habitat for the blunt-nose leopard lizard and other endangered species and is a seasonal resting spot for up to 5,000 sandhill cranes. The primary purposes of this refuge are endangered and threatened species conservation, land conservation, bird migration sanctuary, natural resource protection, wildlife management, and wetlands conservation (Reclamation 2002).

A small area of land in the southwest part of the main area of the refuge has been developed as wetland habitat. This area is the only part of the refuge that is supplied with water.

4.3.1.2 Identified Water Supply Contract Quantities

Figure 4-8 shows the Level 2 and Level 4 water needs for the refuge. Water supply on the refuge is currently derived from a single, on-site irrigation well. A well meter is installed on the irrigation well. Pixley ID also supplies some water for groundwater recharge purposes on the refuge. Total annual Level 2 water need is approximately 1,280 ac-ft and the Level 4 increment is 4,720 ac-ft, totaling 6,000 ac-ft per year (Reclamation and Service 2001).

4.3.1.3 Surface Water Supplies and Infrastructure

Pixley NWR did not have an identified surface water supply when the refuge was established. Groundwater has provided 100 percent of its water supply since the refuge's inception. Passage of the CVPIA defined Level 2 and Level 4 surface water supplies, but adequate conveyance facilities do not exist to deliver surface water to the refuge. Therefore, the refuge depends entirely on groundwater for its water supply (Refuge staff 2002).

Currently, surface water is not being delivered to the refuge, although Pixley ID is providing water for groundwater recharge (see below). A reliable surface conveyance system between Pixley NWR and Delano-Earlimart ID is planned for construction sometime between 2005 and 2008, as required under the mandates of CVPIA. The project involves the installation of several miles of pipeline to transport water to the refuge from east of SR 99.

Following completion, groundwater will be used in conjunction with delivered water to fully meet Level 4 needs (DFG staff 2003).

Pixley ID is delivering surface water to Pixley NWR for groundwater recharge. This has been ongoing since 1981. Annual amounts of water delivered to the refuge range from 0 acre-feet (during the 1987 to 1994 drought) to 3,330 acre-feet[1], but usually is less than 1,000 acre-feet. Water is delivered to the refuge via Deer Creek. Additional information is recommended to be collected on this ongoing recharge to evaluate the groundwater benefits this effort is providing, Deer Creek leakage, and how the refuge integrates this recharge into its overall management of refuge water resources.

4.3.1.4 Groundwater Supplies and Infrastructure

Irrigation and Production Wells. A new refuge well was installed in 1993 near the south-central boundary of the refuge to support refuge water supply reliability. This well (shown as PI-IW-01 on Figure 4-9 and commonly referred to as Pixley Well 3) currently supplies 100 percent of the refuge water used for management (Refuge staff 2002). The 150-hp pump motor draws from an aquifer beneath the Corcoran Clay at approximately 1,200 feet bgs (well logs on file at Kern NWR Headquarters). Well production ranges from 1,700 to 1,800 gpm in the spring, then drops to 1,500 gpm later in the season (Refuge staff 2002). A well meter is installed and monitored daily. While other wells are present on the refuge, the condition of those wells is not known. PI-IW-01 is currently the only well used to supply groundwater to the refuge. Water for domestic supply is not available at the refuge.

Capacity of the existing well is minimally sufficient to meet Level 2 needs. However, the refuge managers are hesitant to rely on well water because of local growers' concerns about local overdraft conditions (Refuge staff 2002). The refuge is also located in an area of groundwater overdraft (Reclamation and Service 2001).

Local water levels recorded by DWR indicate seasonal variation of up to 40 feet as a result of local groundwater use during the irrigation season (DWR 2003b).

Water Quality Data. Available water quality data from the operating refuge irrigation well indicate that the water is generally of good quality except for arsenic (Table 4-2). Data are available from sampling conducted in 1998 and 2003. Data indicate that EC is 190 to 200 μmhos/cm and TDS is 150 to 180 mg/L. The arsenic concentration was 48 μg/L (in 2003) and 110 μg/L (in 1998). Agricultural Water Quality Goals and Freshwater Aquatic Life Standards have been exceeded for arsenic (>100 μg/L) in the 1998 sample, but met standards for five other constituents and in the 2003 arsenic analysis (BSK Analytical Laboratories 1998; Zalco Laboratories 2003).

4.3.1.5 Local Groundwater Use

Groundwater is used throughout the region to supply agricultural irrigation, food processing facilities, private duck clubs, and occasionally for domestic supply. West of Pixley NWR, Alpaugh ID operates several wells, each between 1,500 and 1,600 feet deep. One of these wells, located just west of SR 43, is an excellent producer, operating at

[1] The volume of water actually reaching the refuge is unknown. Measurements are taken by Pixley ID where the water is released to Deer Creek. The release point is several miles upstream of the refuge, and Deer Creek is known to have a very high, although undetermined, leakance rate.

1,800 gpm with 32 feet of drawdown (well logs on file at Kern NWR Headquarters). Pixley ID also operates wells north and east of the refuge. Although no municipal or domestic wells have been located within 1 mile of the refuge, Pixley and Earlimart Public Utility Districts use groundwater for municipal supplies (USEPA 2003).

4.3.1.6 Refuge Soil and Aquifer Conditions

Soil conditions throughout the majority of Pixley NWR are characterized by slow permeability, high corrosivity, and varying water capacity. The area is dominated by Gareck, Garces, Lethent, and Gambogy-Biggriz soils (USDA 1993).

The western and eastern quarters of the main refuge area consist mainly of Gareck and Garces soils. The central half of the main refuge area consists of Lethent silt loam. Portions of the two northern sections of the refuge are characterized by the Gambogy-Biggriz (saline-sodic) soil type. The soils are saline, and corrosivity is high on steel and concrete. Permeability is slow to moderately slow. Confining soils are at least 5 to 6 feet deep. Although the soils are not ideal for the establishment of recharge basins, recharge projects are currently underway in the vicinity of the refuge (USDA 1993).

Between 4 and 8 feet of subsidence has occurred in the Pixley region. Additional subsidence is possible in the region (USDA 1993).

Near the center of Pixley NWR, water levels average between 120 and 130 feet bgs. On the central-east side of the refuge, water levels have rebounded since the drought of the 1970s and currently vary between 70 and 80 feet bgs. Near a small refuge area south of the main area, water levels have fluctuated between 125 to 250 feet bgs over the past 10 years (DWR 2003b).

4.3.1.7 Operational Issues and Data Needs

Approximately 79 percent of the water supply for Pixley NWR consists of Incremental Level 4 water. The refuge therefore depends significantly on Incremental Level 4 water to meet habitat goals.

Incremental Level 4 water which would be made available to Pixley NWR is subject to wide fluctuations in cost and variable spot-market availability, although it is unnecessary to convey Incremental Level 4 water through the Delta. A more stable source of Incremental Level 4 water both in terms of cost and reliability would be beneficial to refuge water supply management.

Several data gaps were identified during the completion of this study. Prior to recommending increased groundwater development, the following data should be collected:

- Confirmation of refuge groundwater quality conditions, particularly arsenic concentrations.
- Local aquifer conditions, including water-level data and safe yield.
- Location and thorough assessment of all wells on the refuge, including the existing production well, the on-refuge “stock water” well, the Service well, and the possible piezometer north of the stock well.

- Effects of groundwater recharge conducted by Pixley ID.
- Aquifer parameters, such as hydraulic conductivity and thickness.
- Groundwater pumping records and schedules, both on and immediately surrounding refuge.

Relative to the other refuges in this study, it was estimated that a "medium" level of data collection is required at Pixley NWR prior to recommending increased groundwater development.

4.3.2 Criteria Evaluation Summary

Pixley NWR received total Hydrogeologic Scores of +5 for Direct Use of groundwater and +4 for On-Refuge Conjunctive Use based on criteria matrix evaluation. The criteria matrix specific to Pixley NWR is shown in Table 4-3. The matrix includes a score for each criterion and a corresponding justification or reasoning for the score given.

Pixley NWR has strong potential for further groundwater development. Groundwater from a single high-quality well currently provides 100 percent of refuge water supply. The well pumps from beneath the Corcoran Clay. A pipeline is used to transport water pumped by the Pixley irrigation well to the managed wetland area. An existing 16-inch "stock water" well, screened in the shallow aquifer, could be evaluated and considered to supplement the existing groundwater supply. Although groundwater is of comparably good quality, additional groundwater testing for arsenic should be conducted prior to further development of resources. Support and limitations to further development of groundwater resources at Pixley NWR may be summarized below.

4.3.2.1 Support for Groundwater Development

- No surface water bodies in the refuge vicinity would be affected by increased groundwater use.
- One active irrigation well is used successfully to meet refuge water demands and currently provides 100 percent of refuge water supply.
- Groundwater quality has not hindered groundwater use in the past. Low-salinity water is currently pumped from beneath the Corcoran Clay. Subbasin groundwater quality conditions are generally good.
- Seventy-nine percent of the refuge's total water supply is Incremental Level 4 water. The refuge is dependent on this water for wetland management.
- The cost of local water is high relative to the other refuges in the study. Cost and reliability is subject to spot-market variability.

4.3.2.2 Limitations to Groundwater Development

- It is unnecessary to convey Incremental Level 4 water through the Delta to serve the refuge. Unlike other refuges in this study, Pixley NWR is not subject to this surface water conveyance complexity.

- Development of recharge basins would not be desirable because at-surface soils consist primarily of clays and have low permeability, and the refuge habitat management focuses in part on providing habitat to several dry-land species.
- Arsenic at concentrations exceeding Freshwater Aquatic Life Standards and Agricultural Water Quality Goals has been detected in two groundwater quality tests from the refuge irrigation well.
- There is strong concern from nearby landowners that the subbasin is in overdraft conditions; additional groundwater development may not be locally supported.
- Between 4 and 8 feet of subsidence has occurred within the subbasin.

4.3.3 Recommended Data Acquisition Activities

The following specific activities are recommended for additional data acquisition prior to implementation of any potential project. Activities focus on verifying on-refuge groundwater conditions and evaluating near-refuge groundwater conditions to address concerns that groundwater is locally overdeveloped. Recommended data acquisition activities include:

- Locate and assess the existing production well, the on-refuge "stock water" well, the Service well, the possible piezometer north of the stock well, and any other wells that may be located at the refuge. Coordinate with DWR regarding their groundwater level monitoring of the wells on and near the refuge. Consider video-logging wells that do not have well logs or that have potential to be modified for use as irrigation wells.
- Sample the existing production well, the on-refuge "stock water" well, the Service well, any other wells identified at the refuge, and the Alpaugh ID well located just west of the refuge to confirm refuge groundwater quality conditions. The collected samples should be analyzed for general chemistry and metals including arsenic, boron, mercury, and selenium.
- Evaluate the ongoing groundwater recharge being conducted by Pixley ID. Include evaluation of the amount of water that is conveyed and then actually delivered to the refuge (because of potential losses through the permeable bottom of Deer Creek), recharge rates observed in the field, observed changes in groundwater levels, and integration of this water resource into the refuge's water supply operations. If measurable amounts of water are reaching the refuge, consider installing one to three monitoring wells to measure the effects of the recharge.
- Collect water-level data from available wells within and adjacent to the refuge. Ideally, water-level data would be collected from the inactive well located north of the existing production well during the startup of the existing production well. This would enable a general evaluation and estimate of aquifer characteristics to support siting of a second production well.
- Conduct an aquifer test using the existing irrigation well and up to three wells nearby that are estimated to be affected by the pumping. Include monitoring at the stock well to confirm the hydraulic separation between the shallow and deep aquifers.

- Based on the results of the previous task, estimate the safe yield of the refuge under wet-, normal-, and dry-year conditions.

Relative to the other refuges in this study, it was estimated that a “medium” level of data collection is required at Pixley NWR prior to recommending increased groundwater development.

4.3.4 Potential Projects

4.3.4.1 Direct Use

If data acquisition yields favorable aquifer and water quality results, increased groundwater use at Pixley NWR is feasible. Two projects are recommended. First, rehabilitate the existing stock well, if appropriate, and install a new higher-capacity pump. Existing records indicate that the well casing is 16 inches in diameter. If a higher-capacity pump is installed, that well should be capable of producing an estimated 750 gpm. Second, install two 1,200-foot production wells[2]. The estimated production rates of each new irrigation well is 1,500 gpm.

Completion of these two projects should contribute a total additional 450 to 550 ac-ft per month to refuge water supply. This approach would meet 100 percent of Level 2 and Level 4 needs at the refuge for five months of the year and 40 to 80 percent of Level 4 needs for the remaining seven months (Appendix D, Figure D-3). These estimates do not assume any additional surface water deliveries from Pixley ID.

4.3.4.2 On-Refuge Conjunctive Use

Groundwater recharge at this location using spreading basins or permeable river beds may have limited potential. The Corcoran Clay effectively separates the shallow and deep aquifers; therefore, surface recharge would have limited beneficial effect on the aquifer from which the existing production wells produce. An additional limitation to extensive spreading/recharge basins is that the refuge provides habitat for the blunt-nosed leopard lizard, San Joaquin kit fix, and Tipton Kangaroo rats, endangered species that do not tolerate flooding.

Groundwater storage by injection, although possible because of the favorable aquifer conditions, would entail identifying or constructing a reliable surface water conveyance system and possibly pre-treating delivered water prior to injection, depending on available water quality. Based on previous experience by CH2M HILL, the cumulative costs for construction and pre-treatment for groundwater injection may be higher relative to more cost-effective approaches to the use of groundwater at the refuge.

4.3.4.3 Off-Refuge Conjunctive Use

Pixley ID and Lower Tule ID entered into an MOU for groundwater management in March of 1995. A groundwater management plan has not been identified, so it is uncertain if groundwater management has been implemented in the area. Bulletin 118 indicates that there is no groundwater management in the subbasin (DWR 2003a).

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[2] The location and number of new irrigation wells would be based on locational need, proximity to off-site wells (to minimize well interference), and existing infrastructure requirements.

Funded and proposed groundwater banking or development projects that are currently being evaluated for the Tule Subbasin include the Angiola WD in-lieu groundwater recharge project and the Pixley ID feasibility study. These projects are recommended potential conjunctive use projects applicable to Pixley NWR. The determining criteria is based on their proximity to the refuge and the type of project.

Two potential projects which may be feasible for Pixley NWR include:

- Angiola WD has been funded to perform a feasibility study to construct an in-lieu groundwater storage project within the district. The project, if feasible, would involve the construction and operation of a surface water storage reservoir within the district.
- Pixley ID has applied for funding to identify and evaluate alternatives for improving the availability and distribution of water resources within its district.

TABLE 4-1
Pixley NWR Well Information[a]
Evaluation of Groundwater Potential for Incremental Level 4 Refuge Water Supply

GIS Well Number[b]	Common Well Name	Well Status[c]	Year Installed	Depth (ft)	Screen Interval (bgs)	Well Output (gpm)	Well Log?	Water Quality Data?	Comments
PI-IW-03	Pixley NWR Well 3	Active	1993	1,256	603–1,253	1,500	Y	Y	Well output varies from 1,300 to 1,800 gpm depending on season and other pumping in region.
PI-IW-01	Pixley NWR Well 1	Unknown	1963	808	508–808		Y	N	Location unknown.
PI-IW-02	Pixley NWR Well	Unknown	1972	250	130–250		Y	N	Possibly “Well 2” (referred to as the “stock well”).
23S24E16-2	USBR	Unknown	1951/53?	1,400			Y	N	DWR water levels (DWR 2003b). Test hole drilled and e-logged in 1951.

Notes:

[a] Based on data compiled from well logs, test records, communication with refuge staff (2002), and other previous documentation. Well locations are shown on Figure 4-7. On-refuge wells only are included in this table, although the GIS includes known wells within 1 mile of the refuge.

[b] Well type is indicated by the middle two letters of the GIS well number: IW = irrigation well, DW = domestic well, MW = monitoring well, TW = test well, and UN = unknown.

[c] Designation refers to the physical well only, not water quality issues. Designations are: *active* (currently operated), *inactive* (capable of operating, but currently is not), *nonfunctional* (cannot operate in current physical state), *destroyed* (well has been lost, abandoned, or filled), or *unknown* (no information regarding status is available).

Blank fields indicate that no information is available.

TABLE 4-2
Pixley NWR Water Quality Data (1998 – 2003)
Evaluation of Groundwater Potential for Incremental Level 4 Refuge Water Supply

GIS Well Number	Test Year	Sampled Interval (feet)	EC (μmhos/cm)	Boron (μg/L)	Selenium (μg/L)	Molybdenum (mg/L)	TDS (mg/L)	Arsenic (μg/L)
PI-IW-01	1998	603–1,253	200	ND	ND	ND	150	110
PI-IW-01	2003	603–1,253	190	<100	<5.0	<100	180	48

Source: Analysis by: BSK Analytical Laboratories 1998; Zalco Laboratories 2003.

Notes:
Well locations are shown on Figure 4-7.
ND = not detected

TABLE 4-3
Pixley NWR Evaluation
Evaluation of Groundwater Potential for Incremental Level 4 Refuge Water Supply

	Criteria	Scoring Scale	Appl.[b]	Score	Refuge Score Justification
Surface[a]	Do surface water bodies exist that could be affected by increased groundwater use?	+1 = no 0 = to some degree –1 = yes, surface water bodies could be affected	D,N	+1	Few surface water bodies on the refuge could be impacted by increased groundwater use. Only a small area of land in the main area of the refuge has been developed as wetland habitat.
Water Supplies and Infrastructure	Has groundwater been used previously at the refuge for ponds or irrigation?	+1 = yes, used successfully to meet at least 20 percent of annual refuge water demands 0 = yes, used to meet less than 20 percent (or unknown) of annual refuge water demands. –1 = no, has not been used	D,N	+1	Groundwater is currently used for 100 percent of annual refuge water demands.
	Do wells exist on the refuge?	+1 = yes, active wells 0 = yes, inactive or nonfunctional wells –1 = yes, destroyed wells, or no wells exist on the refuge	D,N	+1	There is one active irrigation well on the refuge which supplies 100 percent of the refuge's water supply.
	Does existing internal distribution system (IDS) support groundwater use?	+1 = water can move extensively around the refuge with existing IDS 0 = the IDS enables limited water movement within the refuge –1 = an IDS does not exist on the refuge or water flow relies exclusively on gravity	D,N	0	A pipeline transports water pumped by the Pixley NWR irrigation well.
Local Groundwater Use	Is groundwater used for agriculture or duck clubs in the immediate vicinity of the refuge?	+1 = groundwater is not used; or groundwater is minimally used, but use is not constrained 0 = groundwater is used in the area –1 = groundwater is not used due to physical or environmental constraints or is extensively used in the vicinity	D,N	0	Groundwater is used in the area for agricultural use and on private duck clubs. Alpaugh ID owns wells near the western refuge boundary.
	Does municipal or domestic supply exist near the refuge?	+1 = no known domestic or municipal wells are located within 1 mile of the refuge 0 = municipal or domestic wells are likely located within 1 mile of the refuge –1 = municipal or domestic wells are located within 1 mile of the refuge	D,N	0	Although no municipal or domestic wells have been located within 1 mile of the refuge, Pixley Public Utility District and the Earlimart Public Utility District use groundwater for municipal supply.
Soil and Hydrogeology	Are at-surface soils conducive to groundwater recharge?	+1 = soils are sandy or are reported to percolate well 0 = soils are silty or are reported to have some infiltration –1 = soils are clayey or are reported to hold water well	N	-1	Soil consists mainly of Gareck, Garces, Lethent, and Gambogy-Biggriz. This soil is typically grayish brown clay and clay loam, as well as sandy loam and clay. All have slow to very slow permeability and low-to-high water capacity.
	Could recharge basins be developed if surface soils were removed?	+1 = confining soil less than 2 feet thick 0 = confining soil 5 to 7 feet thick –1 = confining soil greater than 7 feet thick	N	0	Confining soil is at least 5 to 6 feet deep.
	Has subsidence occurred at or in the immediate vicinity of the refuge?	+1 = no 0 = yes, less than 2 feet –1 = yes, more than 2 feet	D,N	-1	Between 4 and 8 feet of subsidence has occurred in the Pixley region.
	Does significant potential for subsidence exist if groundwater use is increased at the refuge?	+1 = minimal potential for subsidence 0 = some potential for subsidence –1 = significant potential for subsidence	D,N	0	Additional subsidence is possible in the region.
	Is aquifer storage available in the subbasin?	+1 = yes, current water levels are greater than 30 feet lower than historic levels 0 = some, current water levels are between 10 and 30 feet lower than historic levels –1 = no	N	0	While groundwater levels on a subbasin level average 4 feet above 1970s levels, DWR groundwater data show that water levels are more than 10 feet below historic levels in most areas surrounding the refuge.

Note:
a Surface Features
b Application to Approach: D = Direct Use, N = On-Refuge Conjunctive Use

continued on next page

TABLE 4-3
Pixley NWR Evaluation
Evaluation of Groundwater Potential for Incremental Level 4 Refuge Water Supply

	Criteria	Scoring Scale	Appl.[b]	Score	Refuge Score Justification
Water Quality	Have groundwater quality conditions hindered groundwater use in the past?	+1 = no 0 = data are not available –1 = yes	D,N	+1	Groundwater quality has not been a problem at the refuge.
	Do adverse groundwater quality conditions exist in the subbasin?	+1 = no 0 = potential –1 = yes	D,N	+1	Deep groundwater at the refuge is of very good quality. Occasionally high levels of TDS, boron, and arsenic have been found in shallow groundwater, however.
	Is surface water available to enable blending of lower quality groundwater to meet proposed refuge standards?	+1 = yes 0 = during portions of the year –1 = no	D,N	-1	Surface water is not currently delivered to the refuge.
	Do groundwater conditions exceed USEPA Freshwater Aquatic Life standards or Agricultural Water Quality Goals for multiple parameters?	+1 = no 0 = yes, two parameters, or no water quality testing has been conducted –1 = yes, three or more parameters	D,N	+1	Agricultural Water Quality Goals and Aquatic Life Standards have been exceeded for arsenic in one groundwater test, but met standards for five other constituents.
	Is refuge land use management compatible with seasonally or annually variable water quality from different sources?	+1 = yes 0 = some potential compatibility problems may exist –1 = no	D,N	0	Only good-quality groundwater is currently used for wetland management on the refuge. Compatibility with other sources is unknown.
	Does groundwater quality meet drinking-water standards (i.e., can it be used for refuge domestic supply)?	+1 = yes it is used, no treatment is necessary 0 = yes it is used, but some treatment is necessary for potable use; or it is not used for unknown reasons –1 = no, it is not used because of adverse water quality conditions	D	0	For unknown reasons, there are no domestic wells on the refuge.
Operational Issues/Constraints	Does a significant percentage of total refuge water supply consist of "Incremental Level 4" water?	+1 = yes, 54% to 79% of total water supply is Incremental Level 4 0 = somewhat, 27% to 53% of total water supply is Incremental Level 4 –1 = minor, 0% to 26% of total water supply is Incremental Level 4	D,N	+1	Approximately 79 percent of the water supply for Pixley NWR consists of Incremental Level 4 water.
	Is the cost of local water high or low relative to the other refuges in this study?	+1 = costs may fluctuate highly or are subject to spot-market variability or price spikes –1 = costs are relatively stable and subjectivity to spot-market variability is low	D,N	+1	Incremental Level 4 water made available to Pixley NWR is subject to wide fluctuations in cost and variable spot-market availability.
	Is it necessary to convey Incremental Level 4 water through the Delta for refuge supply?	+1 = yes, Incremental Level 4 water must be conveyed through the Delta –1 = no, conveyance of Incremental Level 4 water through the Delta is not necessary	D,N	-1	It is unnecessary to convey Incremental Level 4 water through the Delta.
Data Needs	Are there significant data needs to address prior to groundwater development?	+1 = no, data needs regarding refuge groundwater conditions are minor 0 = somewhat, some data are required prior to increasing groundwater development –1 = yes, significant data must be collected as there is little or no existing data	D,N	0	Some data are required. Activities focus on evaluating on-refuge and near-refuge groundwater conditions and addressing concerns that groundwater is locally overdeveloped.
		Total Direct Use Score =		**+5**	
		Total On-Refuge Conjunctive Use Score =		**+4**	

Note:
a Surface Features

b Application to Approach: D = Direct Use, N = On-Refuge Conjunctive Use

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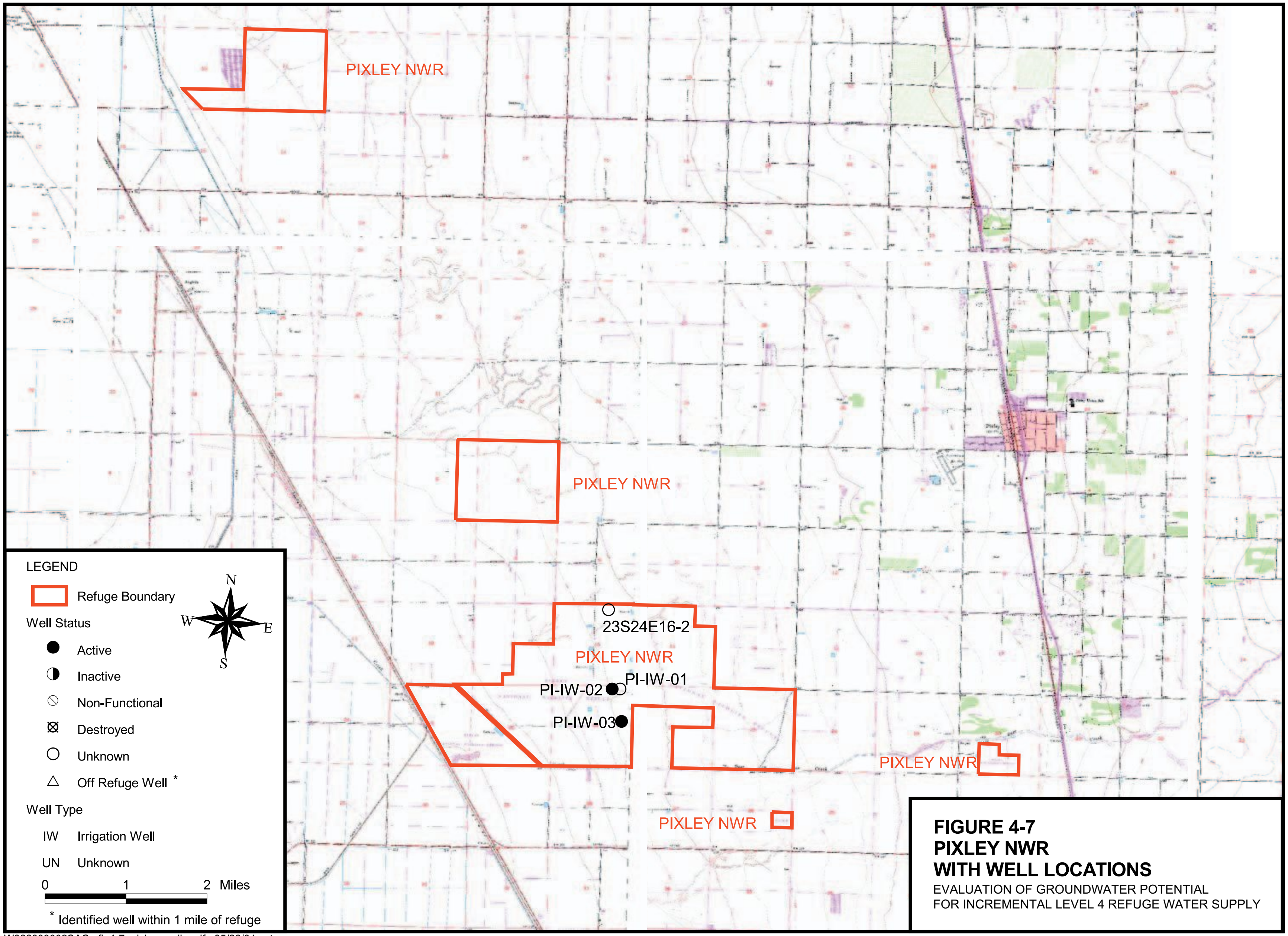

FIGURE 4-7
PIXLEY NWR
WITH WELL LOCATIONS
EVALUATION OF GROUNDWATER POTENTIAL
FOR INCREMENTAL LEVEL 4 REFUGE WATER SUPPLY

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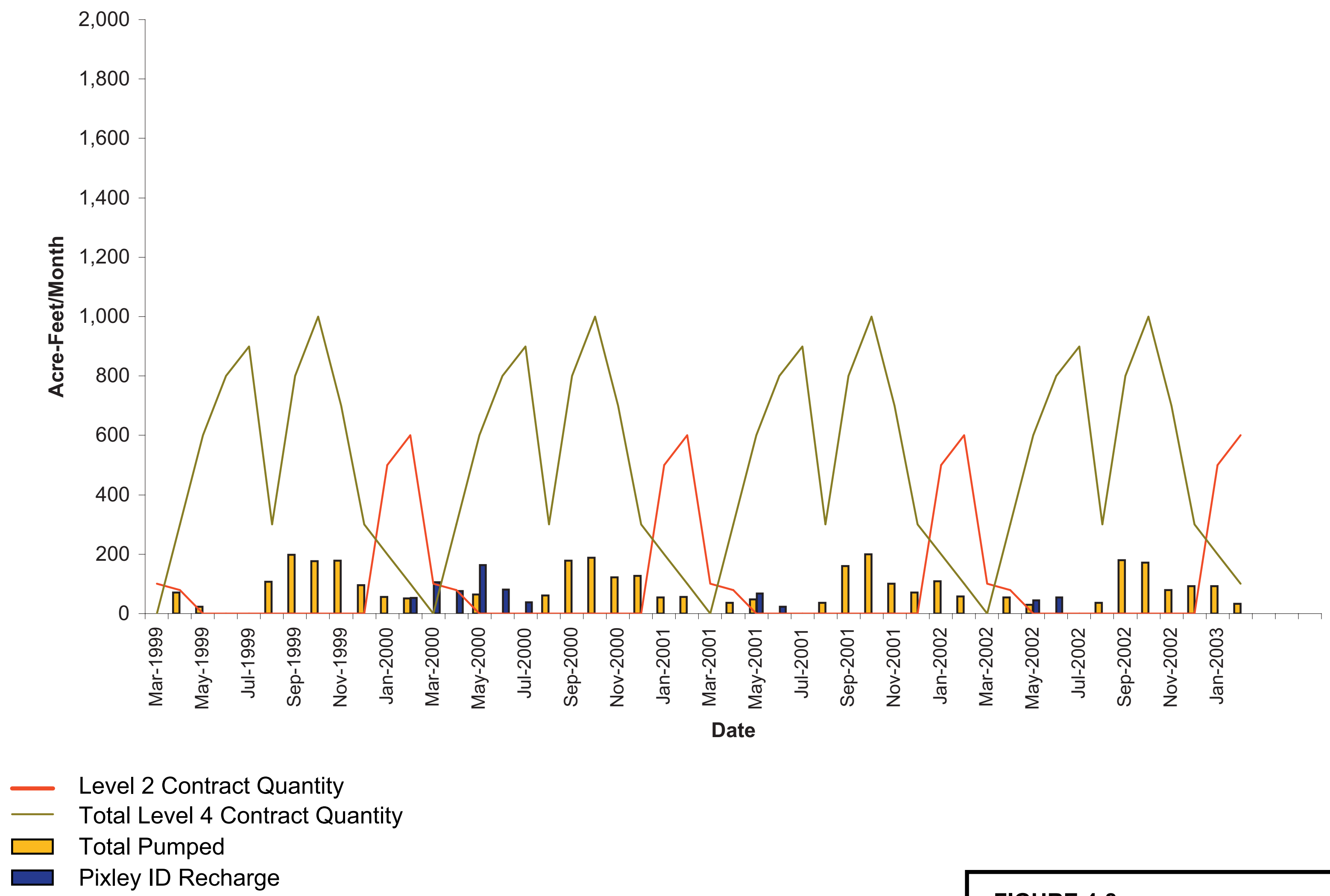

Note: Level 2 and Total Level 4 contract quantities are those indicated in Reclamation 1989 and Reclamation el al. 1989. Volumes indicated may not reflect current monthly management schedules and are shown to indicate an approximate monthly breakdown for management purposes. Total annual contract quantities may be scheduled based on availability, at the refuge manager's discretion.

FIGURE 4-8
1999-2003 PIXLEY NWR WATER SUPPLIES
EVALUATION OF GROUNDWATER POTENTIAL FOR INCREMENTAL LEVEL 4 REFUGE WATER SUPPLY

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FIGURE 4-9
ACTIVE DEEP WELL (PI-IW-01)
AT PIXLEY NWR
EVALUATION OF GROUNDWATER POTENTIAL
FOR INCREMENTAL LEVEL 4 REFUGE WATER SUPPLY

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4.4 Kern NWR Assessment

County: Kern
Basin / Subbasin: San Joaquin Valley Groundwater Basin / Kern Subbasin (see page 4-8)
Level 2 / Incremental Level 4: 9,950 ac-ft / 15,050 ac-ft
2003 Acreage: 10,618
CVP Water Conveyors: Semitropic WSD (spot supply only), Buena Vista WSD (water conveyance only)
Water District Service Area: Semitropic WSD and Lost Hills WD
Applicable Groundwater Management Regulations: Semitropic WSD (Water Code Division 14)

Kern NWR is located in northern Kern County, northeast of Lost Hills, and just northeast of the intersection of Interstate 5 and SR 46. The refuge is bordered by Dairy Avenue on the east. A map of Kern NWR and the locations of its wells is shown on Figure 4-10.

4.4.1 Hydrogeologic Assessment

4.4.1.1 Habitat Goals, Land Management, and Surface Features

Kern NWR habitats include grassland and developed marshland, providing habitat for special-status species. The primary purposes of this refuge are: endangered and threatened species conservation, land conservation and utilization, migratory bird sanctuary, natural resource protection, recreation, wildlife management and control, and wetlands conservation (Reclamation 2002).

Goose Lake Canal runs north-south through the center of the refuge. A few unpaved roads cross the center of the refuge between ponds and encircle the refuge area. The refuge headquarters building is located just inside the eastern border of the refuge, along with a few other maintenance facilities and residences.

Approximately 95 percent of the refuge area east of the Goose Lake Canal is currently flooded and managed as waterfowl habitat and about 1,130 acres west of Goose Lake Canal was developed in 2002. This newly restored wetland area will be suitable for flooding in 2003, depending on water availability. No other new wetland habitat development is planned on Kern NWR at this time (Refuge staff 2003).

4.4.1.2 Identified Water Supply Contract Quantities

Figure 4-11 shows the Level 2 and Level 4 water needs and the actual water deliveries from 1999 through 2001. Total annual Level 2 water need at Kern NWR is approximately 9,950 ac-ft. The Level 4 increment brings this total to 25,000 ac-ft per year (Reclamation and Service 2001).

4.4.1.3 Surface Water Supplies and Infrastructure

Groundwater was the sole source of water at the refuge from its creation in 1961 until the late 1960s, when it was determined that pumping was expensive because of declining water levels. The refuge then purchased surface water, obtained flood water from Poso Creek, and used supplemental groundwater until the passage of CVPIA.

Level 2 water is primarily supplied through CVP contracts. The Semitropic WSD has also contributed to Incremental Level 4 demands at Kern through spot supply (Reclamation and

Service 2001). SWP contractors have been used to supply a portion of the Level 4 requirement, but the entire Level 4 increment has never been requested by the refuge (Refuge staff 2002). Conveyance infrastructure of full Level 4 water is currently in design and construction, and should be completed in FY 2004 (Reclamation staff 2003). Buena Vista WSD is responsible for delivery of 95 percent of all water to Kern NWR (Refuge staff 2003).

Surface water supplies are currently reliable. Historically, Kern NWR received, at best, 6,000 ac-ft per year. The refuge is currently guaranteed 9,950 ac-ft per year. The refuge has never received the full Level 4 increment because the entire property has not yet been developed. An additional 1,100 acres is currently being developed in the western portion of the refuge, and the full Level 4 water will be requested once development is completed. With this increment, total water supply will reach 25,000 ac-ft per year (Refuge staff 2002). The quality of the delivered water is considered by the refuge managers to be adequate for waterfowl.

Delivered water enters the refuge via Goose Lake Canal. Once in the main distribution sump at the junction of Poso Creek and Goose Lake Canal, water can be sent to the fill the west side of the refuge, or it can be sent east down Poso Creek to serve the eastern half of the refuge. After water flows into the refuge from Poso Creek at the southeast corner of the refuge, fields are filled in a northerly direction by gravity flooding.

Currently, the refuge has no legal contract to discharge water or dispose of flood flows the refuge periodically receives from Poso Creek. The refuge managers usually find a grower to take the water (free of charge) from the canal on the north side of the refuge (Refuge staff 2002).

4.4.1.4 Groundwater Supplies and Infrastructure

Irrigation and Production Wells. Water supply for the refuge was a series of ten wells drilled around the perimeter of the southern edge of the refuge in the early 1960s. These wells were drilled to depths of 800 to 1,500 feet (DWR well logs on file).

Wells have not been used since the passage of CVPIA because of electricity costs, variable production, and operational issues such as pumping sand. Several have had the pumps removed, or were abandoned and destroyed. Inactive Wells No. 7 (KR-IW-05), 8 (KR-IW-06), 9 (KR-IW-07), and 11 (KR-IW-09) were tested in September 2000. Well No. 9 (KR-IW-07) operated adequately, and the others pumped sand. Well No. 11 (KR-IW-09) pumped so much sand that the pump meter could not be turned on nor the water tested (Refuge staff 2002). These refuge well locations are shown in Figure 4-10, and well information is summarized in Table 4-4.A small domestic well (KR-DW-01) supplies the office and residences at the refuge with nonpotable water. Filters were recently installed to remove odor and color from the groundwater. The water has been clear for a short period of time, but odor problems are persistent in the well water. Arsenic has been detected in wells in the area, and refuge staff have no intention of developing a potable groundwater supply (Refuge staff 2002).

Test Wells. A research well (KR-TW-01) located in the northeast corner of the refuge is not currently operational; the pump is in place, but the 200-hp motor has been removed. The well was used for experimental marsh work for a research project in the 1960s (Refuge staff 2002).

Water Quality Data. Water quality of refuge wells is generally poor. Although Well No. 4A (KR-IW-02), shown in Figure 4-12, has not been used in over two decades, the high salt content of shallow groundwater is evident in the well's basin by the extensive salt crust, caused by groundwater intrusion (Refuge staff 2002) (Figure 4-13). Boron and arsenic were detected at elevated concentrations in the 2002 water samples from Wells No. 7 (KR-IW-05), 8 (KR-IW-06), and 9 (KR-IW-07) (BSK Analytical Laboratories 2000; Zalco Laboratories, Inc. 2002). Results are listed in Table 4-5. These constituents exceeded Agricultural Water Quality Goals and/or Freshwater Aquatic Life Standards. According to available data, the best water quality at the refuge is at the domestic well (KR-DW-01), which is shallower (300 feet) than the refuge irrigation wells (800 to 1,500 feet) (well logs on file at Kern NWR).

4.4.1.5 Local Groundwater Use

There is some agricultural groundwater use in the region. Tranquility ID relies on some groundwater supplies (USEPA 2003). Municipal groundwater use in the area includes the Lost Hills Utility District and the City of San Joaquin (USEPA 2003).

Local groundwater withdrawals may be increasing in the future with the development of the Semitropic Water Bank. This project is discussed in this section under Other Studies.

4.4.1.6 Refuge Soil and Aquifer Conditions

Soils throughout the Kern refuge consist mainly of Nahrub or Lethent soils. Nahrub clay is found in the drained condition across the northern half of the refuge and in the partially drained condition in the southwest quarter. The Nahrub-Lethent complex is found in the drained condition in the northern half of the refuge, and in the partially drained condition in the southern half. The soils are strongly saline-alkali, and levels of boron potentially toxic to plants and wildlife are present in some areas. Areas of Twisselman clay are found along the northern border of the refuge. The clay is moderately to strongly saline-alkali. In general, clay extends to at least 5 feet in depth (USDA 1988a).

Soil conditions on this refuge are not ideal for the establishment of groundwater recharge basins. The permeability of Nahrub clay is very slow, and available water capacity is moderate or high. Runoff is slow or ponded. The permeability of Lethent silt loam and Twisselman clay is also very slow, and available water capacity is low or moderate. Runoff is also slow (USDA 1988a).

According to DWR monitoring data, groundwater levels in the immediate area of Kern NWR vary seasonally by as much as 80 feet. Groundwater is deep, averaging more than 200 feet bgs throughout much of the refuge. In many areas, water levels have rebounded somewhat since the late 1970s, but groundwater levels in the vicinity of the refuge are up to 100 feet lower than historic levels (DWR 2003b). Figure 4-6 shows these water level conditions for four refuge wells.

Between 1 and 4 feet of subsidence has occurred in the Kern refuge area (USDA 1988a). Further subsidence is possible if groundwater use significantly increases. Up to 3 feet of subsidence is modeled to occur under full development withdrawals at the Semitropic Water Bank (Semitropic WSD 1999).

4.4.1.7 Operational Issues and Data Needs

Approximately 60 percent of the water supply for Kern NWR consists of Incremental Level 4 water. The refuge therefore depends significantly on Incremental Level 4 water to meet habitat goals.

Incremental Level 4 water made available to Kern NWR is subject to wide fluctuations in cost and variable spot-market availability. It is also necessary to convey Level 4 water through the Delta. A more stable source of Incremental Level 4 water both in terms of cost and reliability would be beneficial to refuge water supply management.

Several data gaps were identified during the completion of this study. Prior to recommending increased groundwater development, the following data should be collected:

- Location and thorough assessment of all wells on the refuge.
- Confirmation of refuge groundwater quality conditions, particularly arsenic and boron concentrations, both above and below the Corcoran Clay.
- Local aquifer conditions, including quarterly water-level data both on- and off-refuge, and a safe yield determination.
- Subsidence monitoring data.
- Aquifer parameters, such as hydraulic conductivity and thickness.
- Groundwater pumping records and schedules, both on and immediately surrounding the refuge. This may entail the installation of well meters.

Relative to the other refuges in this study, it was estimated that a "medium" level of data collection is required at Kern NWR prior to recommending increased groundwater development.

4.4.1.8 Other Studies

NHI completed an initial evaluation of a series of potential groundwater storage sites, assessing the Kern Water Bank and Semitropic Ridge sites within the Kern County Subbasin. Kern Water Bank was rated highly for soil Hydraulic Connectivity and Semitropic Ridge was rated highly for Geology. Both sites were given lower-than-average ratings for Water Quality. These sites were given average total index ratings for groundwater banking via recharge basins (NHI 2001).

A final environmental impact study (EIS) has been submitted for a Stored Water Recovery Project involving in-lieu recharge for the Semitropic WSD in association with several other water districts in California (Metropolitan WD, Santa Clara Valley WD, Alameda County WD, Zone 7 WD, and Vidler WD). Water is considered by these districts to be "in storage" because over the past few years these districts have been providing surface water "in lieu" to existing groundwater users in exchange for not pumping and "storing" the groundwater that would have been used. A 50-well well field has been proposed in a 3-square-mile area adjacent to the southeast corner of the refuge. This area was chosen because it is located at the deepest part of the aquifer, which can maximize groundwater storage. An 8-foot pipeline will connect the well field to the aqueduct. Production is expected to be between 250,000 and 500,000 ac-ft per year. Subsidence of up to 3 feet has been modeled under proposed operational conditions (Semitropic WSD 1999). This could impact Kern NWR because its water conveyance system relies on flow by gravity.

This project may provide a legal way for the refuge to dispose of flood water. It may also provide the means for the refuge to be a secondary banking partner with the other water districts. This would allow the refuge to bank water and extract it when needed at relatively low cost. If the proposal is successful, the water districts would also deliver surface water from the pipeline, which may be of higher quality than current supplies. Currently, a 17-mile open channel conveys water north from the canal. Agricultural return flows mix with the water as it is conveyed to the refuge (Refuge staff 2002).

There are also several disadvantages to the proposed water bank from the refuge's perspective. Increased local pumping could impact local groundwater levels. Subsidence may also negatively impact the conveyance system at the refuge (Refuge staff 2002).

4.4.2 Criteria Evaluation Summary

Kern NWR received total Hydrogeologic Scores of +2 for Direct Use of groundwater and +2 for On-Refuge Conjunctive Use based on criteria matrix evaluation. The criteria matrix specific for Kern NWR is shown in Table 4-6. The matrix includes a score for each criterion and a corresponding justification or reasoning for the score given.

Kern NWR has some limited potential for further groundwater development. Although there is significant well infrastructure currently on the refuge and groundwater has been used in the past, poor groundwater quality and significant potential for future subsidence could limit an increase in groundwater use. A water banking project adjacent to the refuge property may limit the construction of significant groundwater banking or recharge basins on the refuge property.

Ssupport and limitations to further groundwater development at Kern NWR are summarized below.

4.4.2.1 Support for Groundwater Development

- No local surface water bodies would be impacted by increased groundwater use.
- Groundwater has historically been used at the refuge to meet at least 20 percent of annual refuge water demands. Wells have been used to varying degrees since the 1960s.
- There is significant existing well infrastructure on the refuge. Currently, ten wells on the refuge are either inactive, nonfunctional, or destroyed.
- According to DWR data, groundwater levels in the refuge vicinity are up to 100 feet lower than historic levels and subject to seasonal variation. Aquifer storage is therefore available in the local region.
- Sixty percent of the refuge's total water supply is Incremental Level 4 water. The refuge is dependent on this water for wetland management.
- It is necessary to convey Incremental Level 4 water through the Delta to serve the refuge.

- The cost of local water is high relative to the other refuges in the study. Cost and reliability is subject to spot-market variability.

4.4.2.1 Limitations to Groundwater Development

- At-surface soils primarily have low permeability and are not conducive to development of recharge basins.
- There is significant potential for subsidence in the subbasin with increased on-site groundwater use.
- Potentially, subsidence and locally decreased groundwater levels resulting from the adjacent water bank could restrict groundwater use.
- Municipal and domestic wells have been identified within 1 mile of the refuge.
- Poor groundwater quality has hindered groundwater use in the past. Refuge managers speculate that soils are highly saline, leading to corrosion of well casing. Boron and arsenic have also been detected in water quality tests from some on-refuge wells. Regionally, high levels of salts, boron, and selenium are found in groundwater.

4.4.3 Recommended Data Acquisition Activities

Additional data are required at Kern NWR prior to recommending increased groundwater development:

- Investigate and assess all on-refuge wells. Video-log existing wells to determine condition and necessary repairs, and to diagnose failure, if appropriate.
- Conduct water quality testing at all wells capable of use for refuge water supply. Confirm water quality above and below the Corcoran Clay.
- Install well meters at all unmetered refuge wells if used for refuge water supply.
- Collect water-level data from available wells within and adjacent to the refuge. Monitor water levels quarterly, and collect routine water quality samples from active wells to develop a database of groundwater use and conditions. Maintain collected data in a format supportable and usable by the refuge.

Two recommendations are made relative to subsidence monitoring by Semitropic Water Bank and maintenance of the existing refuge wells:

- Subsidence monitoring should be implemented by the Semitropic Water Bank prior to withdrawal of any water from the water bank. It is recommended that this monitoring occur at the extreme northwest corner of the Semitropic Water Bank, which is in close proximity to the refuge. This monitoring should be funded by and conducted by Semitropic WSD.
- Two to three of the refuge’s existing operational irrigation wells should be regularly maintained and operated periodically to retain the groundwater capability of the refuge. Wells KR-IW-02 (refuge well 4A), KR-IW-06, and KR-IW-07 are three such wells. Although existing data indicate that water quality is poor in these wells, some

groundwater capability may be advantageous and could be blended with delivered surface water.

4.4.4 Potential Projects

4.4.4.1 Direct Use

Although several on-refuge wells are present and groundwater has been used in the past for refuge water supply, the presence of low-quality groundwater, including high salinity and potentially high boron and arsenic, could restrict future refuge groundwater use. Additionally, locally decreased water levels from the adjacent water bank could potentially limit future groundwater use. Therefore, no direct use project at Kern NWR is recommended at this time.

4.4.4.2 On-Refuge Conjunctive Use

On-refuge surface soil permeability is slow, and clays are found at depths of about 5 feet, limiting the practicality of recharge basins. The Tulare and Kern Formations, which underlie the Kern refuge and form the main aquifer of the subbasin, are moderately to highly permeable. Recharge by injection could be investigated further. However, because of the proximity of the refuge to the Semitropic Water Bank, on-refuge banking opportunities are not recommended at this time.

4.4.4.3 Off-Refuge Conjunctive Use

Kern County Water Agency has estimated the total stored (banked) water at the subbasin to be 50,000,000 ac-ft and dewatered aquifer storage to be 19,000,000 ac-ft. Numerous groundwater projects are being planned and developed in the Kern County area to take advantage of this potential storage. Planned groundwater banking or development projects that are recommended for partnership within the Kern County Subbasin include the Semitropic WSD Conjunctive Use Programs. These programs include existing, funded, and conceptual projects such as groundwater banking, installation of monitoring wells, and infrastructure construction. The determining criteria is the proximity of Semitropic WSD to Kern NWR, the number and type of projects currently in progress or in the planning stages, and the size of the projects.

Two projects which may be feasible for partnership include:

- Kern County Basin Groundwater Banking Operation: A large groundwater banking operation currently underway where SWP water is imported and banked to meet local annual water demands and maintain groundwater quality. Participants include the Kern Water Bank Authority, Kern County Water Agency, Semitropic WSD, Didley Ridge WD, and Tejon Castac WD.

- Semitropic WSD In-lieu Water Bank: Located near Kern NWR. Various grant and loan applications have been submitted for monitoring and test well installation, as well as construction of surface water delivery systems. Partnerships include various water districts such as Pond-Poso Improvement District and Buttonwillow Improvement District. See Appendix A, Table A-3 for a full project list.

TABLE 4-4
Kern NWR Well Information[a]
Evaluation of Groundwater Potential for Incremental Level 4 Refuge Water Supply

GIS Well Number[b]	Common Well Name	Well Status[c]	Year Installed	Depth (ft)	Screen Interval (bgs)	Well Output (gpm)	Well Log?	Water Quality Data?	Comments
KR-IW-01	4	Nonfunctional	1963	800		1,159	Y	N	Pump test in 1964. Water-level data 1972–1991. No motor or power. DWR water levels (DWR 2003b).
KR-IW-02	4A	Nonfunctional	1963	1,200	220–1,200	1,700	Y	N	No power supply. Specific screened intervals are 220–600, 600-1200.
KR-IW-03	5	Nonfunctional	1963	800		462	Y	N	Water-level data 1981–1991. No motor or pump.
KR-IW-04	6	Nonfunctional	1962	801	500–820	925	Y	N	Pump test in 1964. Water-level data 1976–1991. No motor, power, or pump. DWR water levels (DWR 2003b).
KR-IW-05	7	Inactive	1962	1,007	450–850	786	Y	Y	Pump test in 1964. Water-level data 1972–1991. Can function, but no power supply. Pumps sand and motor needs bearings. DWR water levels (DWR 2003b).
KR-IW-06	8	Inactive	1962	901		1,210	Y	Y	Pump test in 2000. Water-level data 1972–1991. Pumps sand.
KR-IW-07	9	Inactive	1962	1,000	500–900	1,469	Y	Y	Pump test in 2000. Water-level data 1972–1991. DWR water levels (DWR 2003b).
KR-IW-08	10	Destroyed	1962	1,000	700–1,000	1,124	Y	Y	Pump test in 1964. Water-level data 1972–1991.
KR-IW-09	11	Inactive	1965	1,513		1,338	Y	N	Unable to measure flow during pump test; water-level data 1972-1991. Pumps sand.
KR-TW-01	Research Well	Inactive	1967	1,200		1,657	Y	N	Water-level data 1972–1976.
KR-DW-01	Domestic Well (at HQ)	Active	1961	300			N	Y	Water-level data 1972–1991.

Notes:
[a] Based on data compiled from well logs, test records, communication with refuge staff (2002), and other previous documentation. Well locations are shown on Figure 4-10. On-refuge wells only are included in this table, although the GIS includes known wells within 1 mile of the refuge.
[b] Well type is indicated by the middle two letters of the GIS well number: IW = irrigation well, DW = domestic well, MW = monitoring well, TW = test well, and UN = unknown.
[c] Designation refers to the physical well only, not water quality issues. Designations are: *active* (currently operated), *inactive* (capable of operating, but currently is not), *nonfunctional* (cannot operate in current physical state), *destroyed* (well has been lost, abandoned, or filled), or *unknown* (no information regarding status is available).
Blank fields indicate that no information is available.

TABLE 4-5
Kern NWR Water Quality Data (2000–2002)
Evaluation of Groundwater Potential for Incremental Level 4 Refuge Water Supply

GIS Well Number	Sampled Interval (feet)	EC (μmhos/cm)	Boron (mg/L)	Selenium (μg/L)	Arsenic (μg/L)
KR-IW-05	450–850		0.2	ND	150
KR-IW-06			0.3	ND	86
KR-IW-07	500–900		0.2	3	140
KR-DW-01		170	0.11	ND	30

Source: BSK Analytical Laboratories 2000 (KR-IW-05, KR-IW-06, KR-IW-07); Zalco Laboratories 2002 (KR-DW-01).

Notes:
Well locations are shown on Figure 4-10.
ND = not detected
Blank fields indicate that the constituent was not tested.

TABLE 4-6
Kern NWR Evaluation
Evaluation of Groundwater Potential for Incremental Level 4 Refuge Water Supply

	Criteria	Scoring Scale	Appl.[b]	Score	Refuge Score Justification
Surface[a]	Do surface water bodies exist that could be affected by increased groundwater use?	+1 = no 0 = to some degree –1 = yes, surface water bodies could be affected	D,N	+1	Few surface water bodies near the refuge could be impacted by increased groundwater use.
Water Supplies and Infrastructure	Has groundwater been used previously at the refuge for ponds or irrigation?	+1 = yes, used successfully to meet at least 20 percent of annual refuge water demands 0 = yes, used to meet less than 20 percent (or unknown) of annual refuge water demands. –1 = no, has not been used	D,N	+1	Wells have been used to varying degrees since the 1960s. In the early 1960s, groundwater was the sole source of water supply until surface water was deemed cheaper than pumping costs, and CVPIA was passed. It has been ten years since wells were used.
	Do wells exist on the refuge?	+1 = yes, active wells 0 = yes, inactive or nonfunctional wells –1 = yes, destroyed wells, or no wells exist on the refuge	D,N	0	Ten wells between 800 and 1,200 feet in depth are inactive, nonfunctional, or destroyed.
	Does existing internal distribution system (IDS) support groundwater use?	+1 = water can move extensively around the refuge with existing IDS 0 = the IDS enables limited water movement within the refuge –1 = an IDS does not exist on the refuge or water flow relies exclusively on gravity	D,N	0	After water flows into the refuge from Poso Creek at the southeast corner of the refuge, fields are filled in a northerly direction by gravity flooding. Lift pumps also operate from the southeast corner, and the service ditch carries the water to the west and north. Once the area west of the Goose Lake Canal is developed, these units on the west side of the refuge will be supplied by a gravity system from the Goose Lake Canal.
Local Groundwater Use	Is groundwater used for agriculture or duck clubs in the immediate vicinity of the refuge?	+1 = groundwater is not used; or groundwater is minimally used, but use is not constrained 0 = groundwater is used in the area –1 = groundwater is not used due to physical or environmental constraints or is extensively used in the vicinity	D,N	0	Groundwater is used in the area for private duck clubs as well as for agricultural irrigation. The Tranquility ID uses groundwater supplies.
	Does municipal or domestic supply exist near the refuge?	+1 = no known domestic or municipal wells are located within 1 mile of the refuge 0 = municipal or domestic wells are likely located within 1 mile of the refuge –1 = municipal or domestic wells are located within 1 mile of the refuge	D,N	-1	A small domestic well is used to supply the Kern refuge headquarters and residences with nonpotable water. The Lost Hills Utility District and City of San Joaquin use groundwater for municipal supply.
Soil and Hydrogeology	Are at-surface soils conducive to groundwater recharge?	+1 = soils are sandy or are reported to percolate well 0 = soils are silty or are reported to have some infiltration –1 = soils are clayey or are reported to hold water well	N	-1	Permeability of most soils including Twisselman clay, Nahrub clay, and Lethent silt loam is very slow, and water capacity is low to moderate.
	Could recharge basins be developed if surface soils were removed?	+1 = confining soil less than 2 feet thick 0 = confining soil 5 to 7 feet thick –1 = confining soil greater than 7 feet thick	N	0	Clay or clay loam is found at depths to 5 feet.
	Has subsidence occurred at or in the immediate vicinity of the refuge?	+1 = no 0 = yes, less than 2 feet –1 = yes, more than 2 feet	D,N	0	Between 1 and 2 feet of subsidence has occurred in the Kern refuge area.
	Does significant potential for subsidence exist if groundwater use is increased at the refuge?	+1 = minimal potential for subsidence 0 = some potential for subsidence –1 = significant potential for subsidence	D,N	-1	Further subsidence is possible if groundwater use significantly increases. Up to 3 feet of subsidence is modeled to occur under full development withdrawals at the Semitropic Water Bank.
	Is aquifer storage available in the subbasin?	+1 = yes, current water levels are greater than 30 feet lower than historic levels 0 = some, current water levels are between 10 and 30 feet lower than historic levels –1 = no	N	+1	According to DWR data, groundwater levels in the refuge vicinity are up to 100 feet lower than historic levels and subject to seasonal variation.

Note:
continued on next page

a Surface Features

b Application to Approach: D = Direct Use, N = On-Refuge Conjunctive Use

TABLE 4-6
Kern NWR Evaluation
Evaluation of Groundwater Potential for Incremental Level 4 Refuge Water Supply

	Criteria	Scoring Scale	Appl.[b]	Score	Refuge Score Justification
Water Quality	Have groundwater quality conditions hindered groundwater use in the past?	+1 = no 0 = data are not available –1 = yes	D,N	-1	Refuge managers speculate that water reuse has concentrated salts in soils, leading to corrosion of well casing. Boron and arsenic have also been detected in water quality tests from Wells 7, 8, and 9.
	Do adverse groundwater quality conditions exist in the subbasin?	+1 = no 0 = potential –1 = yes	D,N	0	Elevated levels of salinity (EC), boron, and selenium have been detected in the region.
	Is surface water available to enable blending of lower quality groundwater to meet proposed refuge standards?	+1 = yes 0 = during portions of the year –1 = no	D,N	0	Water is generally not delivered during spring months, particularly in March and April. Delivery is reliable when water is ordered.
	Do groundwater conditions exceed USEPA Freshwater Aquatic Life standards or Agricultural Water Quality Goals for multiple parameters?	+1 = no 0 = yes, two parameters, or no water quality testing has been conducted –1 = yes, three or more parameters	D,N	0	Groundwater quality standards have been exceeded in groundwater for two constituents, arsenic and selenium. Boron was also detected. EC has not been tested from the irrigation wells.
	Is refuge land use management compatible with seasonally or annually variable water quality from different sources?	+1 = yes 0 = some potential compatibility problems may exist –1 = no	D,N	0	Only delivered surface water is currently used for wetland management at the refuge.
	Does groundwater quality meet drinking-water standards (i.e., can it be used for refuge domestic supply)?	+1 = yes it is used, no treatment is necessary 0 = yes it is used, but some treatment is necessary for potable use; or it is not used for unknown reasons –1 = no, it is not used because of adverse water quality conditions	D	0	The Kern refuge domestic well is used for nonpotable supply; treatment would be necessary for potable use, particularly for arsenic removal, as well as for odor control.
Operational Issues/Constraints	Does a significant percentage of total refuge water supply consist of "Incremental Level 4" water?	+1 = yes, 54% to 79% of total water supply is Incremental Level 4 0 = somewhat, 27% to 53% of total water supply is Incremental Level 4 –1 = minor, 0% to 26% of total water supply is Incremental Level 4	D,N	+1	Approximately 60 percent of the water supply for Kern NWR consists of Incremental Level 4 water.
	Is the cost of local water high or low relative to the other refuges in this study?	+1 = costs may fluctuate highly or are subject to spot-market variability or price spikes –1 = costs are relatively stable and subjectivity to spot-market variability is low	D,N	+1	Incremental Level 4 water made available to Kern NWR is subject to wide fluctuations in cost and variable spot-market availability.
	Is it necessary to convey Incremental Level 4 water through the Delta for refuge supply?	+1 = yes, Incremental Level 4 water must be conveyed through the Delta –1 = no, conveyance of Incremental Level 4 water through the Delta is not necessary	D,N	+1	Yes, Incremental Level 4 must be conveyed through the Delta, given current supply sources.
Data Needs	Are there significant data needs to address prior to groundwater development?	+1 = no, data needs regarding refuge groundwater conditions are minor 0 = somewhat, some data are required prior to increasing groundwater development –1 = yes, significant data must be collected as there is little or no existing data	D,N	0	Some data are required prior to increasing groundwater development.
			Total Direct Use Score =	**+2**	
			Total On-Refuge Conjunctive Use Score =	**+2**	

Note:

a Surface Features

b Application to Approach: D = Direct Use, N = On-Refuge Conjunctive Use

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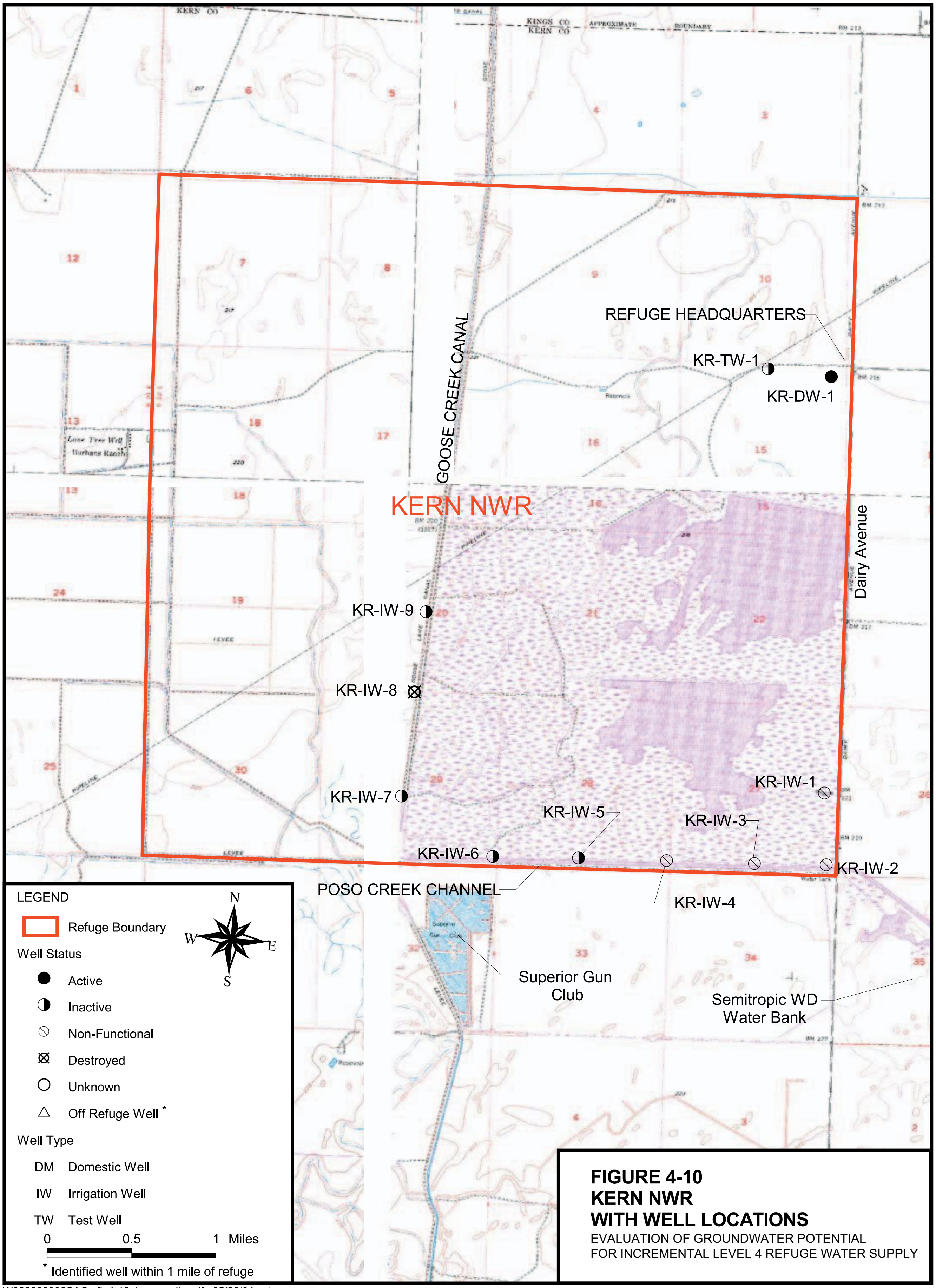

FIGURE 4-10
KERN NWR
WITH WELL LOCATIONS
EVALUATION OF GROUNDWATER POTENTIAL
FOR INCREMENTAL LEVEL 4 REFUGE WATER SUPPLY

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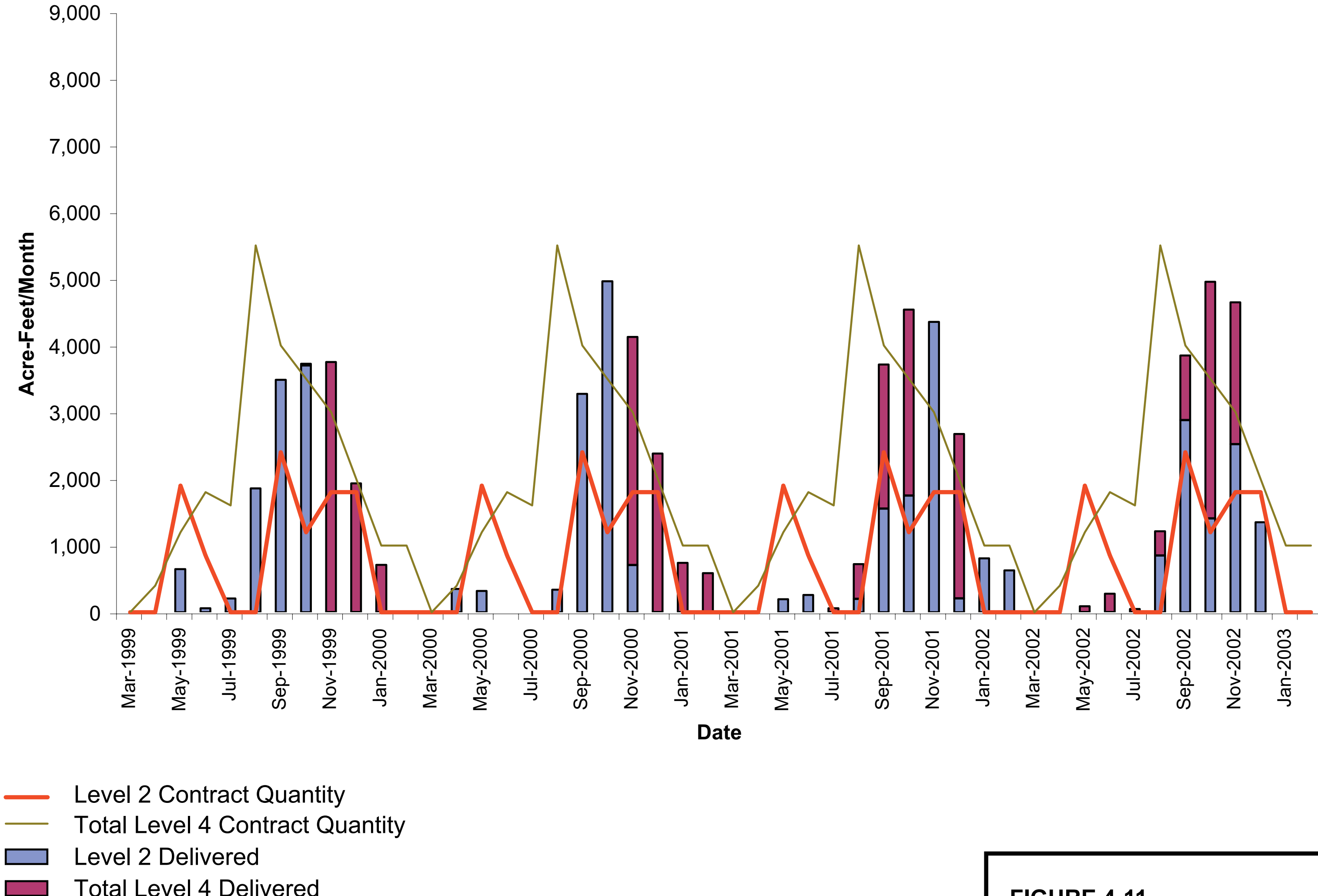

Note: Level 2 and Total Level 4 contract quantities are those indicated in Reclamation 1989 and Reclamation el al. 1989. Volumes indicated may not reflect current monthly management schedules and are shown to indicate an approximate monthly breakdown for management purposes. Total annual contract quantities may be scheduled based on availability, at the refuge manager's discretion.

FIGURE 4-11
1999-2002 KERN NWR WATER DELIVERIES
EVALUATION OF GROUNDWATER POTENTIAL
FOR INCREMENTAL LEVEL 4 REFUGE WATER SUPPLY

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FIGURE 4-12
WELL 4A (KR-IW-02) AT KERN NWR
EVALUATION OF GROUNDWATER POTENTIAL
FOR INCREMENTAL LEVEL 4 REFUGE WATER SUPPLY

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FIGURE 4-13
WELL 4A (KR-IW-02) BASIN WITH SALT CRYSTALS AT KERN NWR
EVALUATION OF GROUNDWATER POTENTIAL
FOR INCREMENTAL LEVEL 4 REFUGE WATER SUPPLY

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SECTION 5

Refuge Ranking and Proposed Projects

5.1 Review of Project Approach

As described in Section 1 and discussed in Sections 2 through 4, there are three overall types of groundwater projects considered during this evaluation. These are:

- *Direct Use*—on-refuge use of new or existing wells to pump groundwater without intentional (or active) recharge
- *On-Refuge Conjunctive Use*—on-refuge use of new or existing wells to pump groundwater in addition to direct or in-lieu groundwater recharge
- *Off-Refuge Conjunctive Use*—regional groundwater banking projects where partnerships with organizations developing groundwater banking projects are created to support supply of reliable Level 4 refuge water

Preliminary analysis of these types of projects was conducted for the 19 refuges (grouped into three study areas) using the approach presented in Section 1 and repeated below. The first three project approach bullets were addressed specifically in Sections 2 though 4. The fourth bullet is addressed in this section (Section 5).

- *Refuge Water Use and Local and Regional Groundwater Conditions Assessment*—summarized and assessed the historic and current water use, water quality data, and local and regional groundwater conditions for each groundwater basin, subbasin, and refuge
- *Initial Screening*—developed and applied evaluation criteria to the refuge assessment to develop a score, identified and evaluated potential direct use and on-refuge conjunctive use projects, and provided an overview of off-refuge regional conjunctive use groundwater projects for which partnerships could be established
- *Data Gaps Identification*—identified data gaps and additional work efforts needed in subsequent evaluation of potential direct use and on-refuge conjunctive use projects
- *Potential Projects Summary*—used the initial screening and data gaps identification to evaluate which refuges have a higher potential for development of direct use and/or on-refuge conjunctive use projects that could be implemented in 1 to 5 years (referred to as first priority projects) and in a longer-term time period of more than 5 years (referred to as second priority projects).

5.2 Additional Data Needs

Available groundwater data from each refuge are insufficient or not recent enough to enable recommendations for implementation of groundwater development. Therefore, additional data acquisition is necessary prior to development of specific recommendations for development of groundwater projects to meet Incremental Level 4 contract quantities.

Additional data acquisition tasks were identified for each refuge to fill the identified data gaps. In general, collection of groundwater quality data from existing wells, measurement of water levels (recommended timing would be, at a minimum, just before the beginning of the irrigation season, at maximum refuge pumping, and at the end of the irrigation season), and installation of well meters at wells not currently metered is recommended at all refuges where groundwater is used to meet any component of the refuge's water supply. This will provide guidance to further evaluation of groundwater use at that refuge and will support subsequent groundwater development, if it is feasible.

Examples of approaches to collecting identified additional data are found in Appendix D. Data acquisition tasks are specified for both Pixley NWR and Gray Lodge WA.

5.3 Direct Use and On-Refuge Conjunctive Use Opportunities

Table 5-1 compiles the individual screenings conducted for each refuge in Sections 2 through 4 and uses the applied criteria to evaluate the hydrogeologic suitability, water quality, operational constraints, and data needs for each refuge. Scores for direct use and on-refuge conjunctive use opportunities were developed based on assessments of the individual criteria as they pertain to each refuge. Off-refuge conjunctive use opportunities were evaluated separately (see below). The criteria scores for each refuge were summed to determine the refuges' total score for both direct use and on-refuge conjunctive use opportunities. The total refuge scores ranged from –6 to 6. The higher or more positive score indicates a greater potential for additional groundwater development to meet Incremental Level 4 contract quantities. Both direct use and on-refuge conjunctive use scores are shown in the bottom two rows of Table 5-1.

Table 5-2 summarizes the total scores presented in Table 5-1, grouping potential Direct Use and On-Refuge Conjunctive Use opportunities by region in descending order of score. Because the scores are based on criteria subject to interpretation, the scores are most appropriately considered for relative ranking and should be considered as a guide, not an absolute value.

Scoring and potential project recommendations were approached by region to support focus on locally available water. This approach will support improving Incremental Level 4 availability and reliability by reducing losses, cross-Delta conveyance constraints, and transfer issues. Refuges with identical scores are grouped together.

In general, the refuges located in the Sacramento River Region had higher scores in the Hydrogeology and Water Quality criteria than those refuges located to the south. Overall water quality is better in the Sacramento Valley than in many parts of the San Joaquin Valley. In addition, because subsidence and overdraft are not as common and water is often of higher quality, hydrogeologic conditions are often more favorable in the Sacramento Valley for direct and on-refuge conjunctive use projects. The San Joaquin River and Tulare Lake Region refuges generally had higher scores for Operational Issues and Constraints because the water supply for many of the refuges is conveyed through the Delta and a high percentage of the refuges' water supply is designated as Incremental Level 4.

5.3.1 Refuges Removed from Evaluation

Several refuges were removed from further evaluation because of water supply issues. These include refuges for which there is no identified Incremental Level 4 contract quantity and refuges with surplus groundwater capacity.

5.3.1.1 No Incremental Level 4 Contract Quantity

Four refuges do not have an identified Incremental Level 4 contract quantity. These are Colusa NWR and Freitas Unit, Kesterson Unit, and San Luis Unit of the San Luis Complex. A Direct Use score was not assigned to these refuges because there are no Incremental Level 4 contract quantities for which to develop an on-refuge groundwater supply. However, these refuges were given an On-Refuge Conjunctive Use score because the refuges could be considered for inclusion in a future multi-refuge or regional project.

5.3.1.2 Surplus Groundwater Supply

Merced NWR and Gray Lodge WA currently and historically obtain a portion of their water supply from groundwater pumped at the refuge. For Merced NWR, 6 to 15 percent of the refuge water supply is groundwater (based on 2000 to 2002 data). Gray Lodge WA pumps between 14 to 31 percent of its water supply (based on 1999 to 2002 data). Each of these refuges has a reliable supply of surface water to meet Level 2 needs, which enables each refuge to use existing surplus well capacity to meet Incremental Level 4 contract quantities.

It is recommended that the well capacity at these refuges be maintained by performing routine well and pump maintenance and water quality monitoring. In addition, the data acquisition tasks identified in each refuge summary, should be conducted to support both refuges' continued use and support of groundwater, as well as provide information relative to potential future uses.

5.3.1.3 Adjacent Water Bank

Kern NWR was not considered for additional direct use or on-refuge conjunctive use opportunities at this time for two reasons. First, Semitropic Water Storage District (WSD) is developing a groundwater storage bank immediately adjacent to the refuge. Because full-scale development of this bank will impact local groundwater conditions, it is recommended that additional groundwater development beyond the refuge's existing wells not be considered to reduce the potential for competing local groundwater use. Second, surface water delivery contracts have been signed to supply the refuge with reliable water.

5.3.2 Direct Use Opportunities

The highest ranked refuges for potential direct use opportunities within each region (Table 5-2), excluding the refuges without Incremental Level 4 contract quantities and refuges with surplus groundwater capacity, are:

- Sacramento River Region
  - Sacramento NWR
- San Joaquin River Region
  - West Bear Creek Unit
  - Grassland RCD

  - Salt Slough Unit
  - China Island Unit
  - Los Banos WA
- Tulare Lake Region
  - Pixley NWR

Each of these refuges has a Direct Use ranking score of 2 or greater, based on an observed break in scores and has potential identified projects that could be developed if the results of the recommended additional data acquisition indicate favorable groundwater conditions. Existing data indicates installation of production wells at each of these facilities is feasible.

Based on currently available information, each of these 8 refuges has potential for development of direct use projects within a "short-term" implementation time frame of 1 to 5 years. Depending on project needs and water supply issues, agency prioritization could consider collecting the additional data identified at one or more of these refuges.

Projects at the remaining refuges may also be viable on a longer-term basis of greater than 5 years, but currently available data indicate that either groundwater conditions do not appear to be as favorable or data gaps are greater than the other refuges and would probably take longer to collect and thoroughly evaluate.

5.3.3 On-Refuge Conjunctive Use Opportunities

The following refuges are identified as having potential for development of on-refuge conjunctive use opportunities, based on the ranking shown in Table 5-2. Again, those refuges with a score of greater than 2 are viewed as having the best potential based on a natural break in the scores. These refuges are:

- Sacramento River Region
  - Colusa NWR
- San Joaquin River Region
  - West Bear Creek Unit
  - Grassland RCD
  - Salt Slough Unit
- Tulare Lake Region
  - Pixley NWR

With the exception of Colusa NWR, which doesn't have an Incremental Level 4 water contract quantities, each of these refuges also were identified as having strong potential for short-term direct use opportunities. Collecting the data to address identified gaps could be conducted at any of these refuges, based on agency prioritization.

As with the direct use projects, the remaining refuges each have potential to have projects that could be developed. However, either because data acquisition needs are greater or initial data are not as favorable, projects at the other refuges should be considered to be "long-term," that is, they could require more than 5 years to implement.

5.4 Off-Refuge Conjunctive Use Opportunities

Numerous potential partnerships for groundwater storage projects have been identified. These projects, presented on a regional basis and discussed in each applicable refuge summary could provide numerous benefits relative to increasing Level 4 supply reliability. These benefits include:

- *Support of local groundwater conditions*—groundwater banking projects will store water either by active or in-lieu recharge.
- *Facilitation of local project development*—in partnership with water districts, Reclamation's financial and logistical assistance could facilitate implementation of proposed projects.
- *Supply of local source of water*—stored water would be available either in the basin or subbasin within which the refuge occurs and so could be more readily available to the refuge than other water that would have to be conveyed over longer distances or through the Delta.
- *Improved reliability of water supply*—because water would be locally stored and available, there would be less reliance on the spot market for Incremental Level 4 water.

Strong relationships with the agencies or water districts developing the projects will be key to creation of successful partnerships. There are also potential constraints associated with these projects, which should be considered prior to finalizing partnerships. These include:

- *Conveyance*—conveyance limitations may exist and/or separate wheeling agreements needed to convey stored water to the refuge.
- *Funding*—projects may be seeking additional funding, which could fall on Reclamation, if state groundwater funding mechanisms disappear.
- *Development time*—these projects generally take several years to develop because of the extensive planning, testing, environmental documentation, and local coordination required.
- *Inter-basin transfer*—transfer of water outside the groundwater subbasin may require special permitting or negotiation.
- *Probable higher cost of water*—groundwater storage projects require development capital and then ongoing monitoring and maintenance.

Although there are numerous potential constraints, the identified off-refuge conjunctive use projects have strong potential to play a role in future Incremental Level 4 water supply for the refuges. Table 5-3 summarizes the off-refuge conjunctive use projects, identified from the list included in Appendix A, as warranting further evaluation for specific refuges.

5.5 Summary

Evaluation of regional, local, and refuge groundwater conditions; operational issues relative to obtaining Incremental Level 4 water at each refuge; and the additional data needs indicated that insufficient data were available at any refuge to recommend development of groundwater to meet Level 4 contract quantities. Similarly, available data were also insufficient to completely rule out groundwater development at any of the refuges. However, data were sufficient to prioritize future efforts and to recommend specific actions.

The evaluation also focused on maintaining a geographic balance by grouping refuges by region. This approach was used because of constraints and uncertainties in moving water across the Delta and policies of groundwater management plans, which focus on maintaining groundwater resources locally. It also supports the goal of identifying projects that have the highest potential to be implemented and succeed in subsequent phases of this project. Evaluating the refuges on a geographic basis also allowed identification of potential multi-refuge projects that could be considered in future work efforts. These projects would need additional effort in evaluating conveyance and coordination issues.

Recommended actions are:

- Conduct additional data acquisition tasks (listed in the refuge assessment) at the refuges identified as having the highest priority for both direct use and on-refuge conjunctive use opportunities with the focus on determining if conditions are favorable for groundwater development to provide Incremental Level 4 water supply. These refuges are: **Pixley NWR**, **West Bear Creek Unit of the San Luis Complex**, **Salt Slough Unit of the North Grasslands WA**, and **Grassland RCD**.
- Conduct additional data acquisition tasks at **Gray Lodge WA** and **Merced NWR** to support the use of groundwater to supply Incremental Level 4 water at these refuges using existing groundwater pumping capabilities.
- As resources become available, conduct additional data acquisition tasks at the other higher-ranked refuges (either direct use or on-refuge conjunctive use opportunities) to identify additional groundwater supply projects. These refuges are: **Sacramento NWR**, **Colusa NWR**, **China Island Unit**, and **Los Banos WA**.
- Commence discussions with sponsors of the high-potential off-refuge conjunctive use projects, including Stony Creek Fan, the proposed recharge project in the Merced area, the Meyers Farm project, and Semitropic WSD Water Bank, to determine if partnership opportunities exist.
- Install well meters at all unmetered refuge wells that are used or could be used to supply Incremental Level 4 refuge water, monitor water levels quarterly, and collect routine water quality samples from active and inactive wells to develop a database of groundwater use and conditions at refuges where groundwater is used. Maintain collected data in a format supportable and usable by the refuge and refuge managing agencies. This applies to **all refuges** except Colusa NWR and Volta WA.
- Consider two multiple-refuge projects—**Sacramento Complex** refuges, excluding Sutter NWR, and **Grassland RCD**. Refuges in both project areas were ranked lower individually than Pixley and West Bear Creek, but both areas showed strong potential for comprehensive project development and benefit. In the case of Grassland RCD, its close proximity to nine of the refuges, good interconnected conveyance systems, and local need support conducting a more focused feasibility study on regional groundwater or conjunctive use projects.

TABLE 5-1
Selection Matrix for Refuge Groundwater Development
Evaluation of Groundwater Potential for Incremental Level 4 Refuge Water Supply

	CRITERIA	Application to Approach[b]	Sacramento Region					San Joaquin River Region												Tulare Lake Region		CRITERIA RATING SCALE
			Sutter NWR	Colusa NWR	Sacramento NWR	Delevan NWR	Gray Lodge WA	East Bear Creek Unit	Freitas Unit	Kesterson Unit	Merced NWR	San Luis Unit	West Bear Creek Unit	Grassland RCD	Los Banos WA	Mendota WA	Volta WA	China Island Unit	Salt Slough Unit	Kern NWR	Pixley NWR	
Surface Features	Do surface water bodies exist that could be affected by increased groundwater use?	D,N	-1	+1	+1	+1	+1	-1	-1	0	0	-1	-1	0	-1	-1	+1	-1	-1	+1	+1	+1 = no 0 = to some degree –1 = yes, surface water bodies could be affected
Water Supplies and Infrastructure	Has groundwater been used previously at the refuge?	D,N	0	0	0	-1	+1	0	0	0	+1	0	0	0	0	0	-1	+1	0	+1	+1	+1 = yes, used successfully to meet at least 20 percent of annual refuge water demands 0 = yes, used to meet less than 20 percent (or unknown) of annual refuge water demands. –1 = no, has not been used
	Do wells exist on the refuge?	D,N	0	0	0	-1	+1	0	+1	0	+1	+1	+1	+1	+1	-1	-1	+1	+1	0	+1	+1 = yes, active wells 0 = yes, inactive or nonfunctional wells –1 = yes, destroyed wells, or no wells exist on the refuge
	Does existing IDS support groundwater use?	D,N	+1	0	+1	0	0	0	-1	-1	+1	+1	0	0	+1	+1	-1	+1	+1	0	0	+1 = water can move extensively around the refuge with existing IDS 0 = the IDS enables limited water movement within the refuge –1 = an IDS does not exist on the refuge or water flow relies exclusively on gravity
Local Ground-water Use	Is groundwater used for agriculture or duck clubs in the immediate vicinity of the refuge?	D,N	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	+1 = groundwater is not used; or groundwater is minimally used, but use is not constrained 0 = groundwater is used in the area –1 = groundwater is not used due to physical or environmental constraints or is extensively used in the vicinity
	Does municipal or domestic supply exist near the refuge?	D,N	-1	-1	0	-1	-1	+1	+1	+1	-1	-1	+1	0	-1	-1	-1	-1	-1	-1	0	+1 = no known domestic or municipal wells are located within 1 mile of the refuge 0 = municipal or domestic wells are likely located within 1 mile of the refuge –1 = municipal or domestic wells are located within 1 mile of the refuge
Soil and Hydrogeology	Are at-surface soils conducive to groundwater recharge?	N	-1	-1	-1	-1	0	-1	-1	-1	0	0	-1	0	-1	0	-1	-1	0	-1	-1	+1 = soils are sandy or are reported to percolate well 0 = soils are silty or are reported to have some infiltration –1 = soils are clayey or are reported to hold water well
	Could recharge basins be developed if surface soils were removed?	N	0	0	0	0	0	0	0	0	0	0	0	0	0	0	-1	0	0	0	0	+1 = confining soil less than 2 feet thick 0 = confining soil 5 to 7 feet thick –1 = confining soil greater than 7 feet thick
	Has subsidence occurred at or in the immediate vicinity of the refuge?	D,N	+1	+1	+1	+1	+1	0	0	0	0	0	0	0	0	0	+1	0	0	0	-1	+1 = no 0 = yes, less than 2 feet –1 = yes, more than 2 feet
	Does significant potential for subsidence exist if groundwater use is increased at the refuge?	D,N	+1	+1	+1	+1	+1	0	0	0	0	0	0	0	0	0	0	0	0	-1	0	+1 = minimal potential for subsidence 0 = some potential for subsidence –1 = significant potential for subsidence
	Is aquifer storage available?	N	-1	0	-1	-1	0	+1	-1	-1	0	-1	-1	-1	-1	0	-1	-1	-1	+1	0	+1 = yes, current water levels are greater than 30 feet lower than historic levels 0 = some, current water levels are between 10 and 30 feet lower than historic levels –1 = no
Water Quality	Have groundwater quality conditions hindered groundwater use in the past?	D,N	-1	+1	-1	0	-1	-1	0	-1	+1	0	+1	0	0	-1	0	-1	+1	-1	+1	+1 = no 0 = data are not available –1 = yes
	Do adverse groundwater quality conditions exist in the subbasin?	D,N	-1	0	0	0	0	0	-1	0	+1	-1	0	0	-1	-1	-1	-1	-1	0	+1	+1 = no 0 = potential –1 = yes
	Is surface water available to enable blending of lower quality groundwater to meet proposed refuge standards? [a]	D,N	0	+1	+1	+1	0	0	+1	+1	0	+1	+1	+1	0	+1	+1	+1	+1	0	-1	+1 = yes 0 = during portions of the year –1 = no
	Do multiple constituents exceed USEPA Freshwater Aquatic Life standards or Agricultural Water Quality Goals?	D,N	-1	+1	0	0	+1	-1	-1	0	0	-1	0	0	0	-1	0	-1	0	0	+1	+1 = no 0 = yes, two parameters, or no water quality testing has been conducted –1 = yes, three or more parameters
	Is refuge land use management compatible with seasonally or annually variable water quality from different sources? [a]	D,N	+1	+1	0	+1	+1	0	0	0	+1	+1	+1	+1	+1	0	0	+1	+1	0	0	+1 = yes 0 = some potential compatibility problems may exist –1 = no
	Does groundwater quality meet drinking-water standards (i.e., can it be used for refuge domestic supply)?	N	0	0	+1	+1	0	0	0	0	+1	0	0	0	0	0	0	0	0	0	0	+1 = yes it is used, no treatment is necessary 0 = yes it is used with treatment for potable use; or it is not used for unknown reasons –1 = no, it is not used because of adverse water quality conditions

TABLE 5-1
Selection Matrix for Refuge Groundwater Development
Evaluation of Groundwater Potential for Incremental Level 4 Refuge Water Supply

			Sacramento Region					San Joaquin River Region												Tulare Lake Region		
	CRITERIA	Application to Approach[b]	Sutter NWR	Colusa NWR	Sacramento NWR	Delevan NWR	Gray Lodge WA	East Bear Creek Unit	Freitas Unit	Kesterson Unit	Merced NWR	San Luis Unit	West Bear Creek Unit	Grassland RCD	Los Banos WA	Mendota WA	Volta WA	China Island Unit	Salt Slough Unit	Kern NWR	Pixley NWR	CRITERIA RATING SCALE
Operational Issues and Constraints	Does a significant percentage of total refuge water supply consist of "Incremental Level 4" water?	D,N	-1	-1	-1	0	-1	0	-1	-1	-1	-1	0	0	0	0	0	0	0	+1	+1	+1 = yes, 54% to 79% of total water supply is Incremental Level 4 0 = somewhat, 27% to 53% of total water supply is Incremental Level 4 –1 = minor, 0% to 26% of total water supply is Incremental Level 4
	Is the cost of local water high or low relative to the other refuges in this study?	D,N	-1	-1	-1	-1	-1	+1	+1	+1	+1	+1	+1	+1	+1	+1	+1	+1	+1	+1	+1	+1 = costs may fluctuate highly or are subject to spot-market variability or price spikes –1 = costs are relatively stable and subjectivity to spot-market variability is low
	Is it necessary to convey Incremental Level 4 water through the Delta for refuge supply?	D,N	-1	-1	-1	-1	-1	+1	+1	+1	-1	+1	+1	+1	+1	+1	+1	+1	+1	+1	-1	+1 = yes, Incremental Level 4 water must be conveyed through the Delta –1 = no, conveyance of Incremental Level 4 water through the Delta is not necessary
Data Needs	Are there significant data needs to address prior to groundwater development?	D,N	0	0	0	-1	+1	0	-1	-1	+1	-1	0	0	0	-1	-1	0	0	0	0	+1 = no, data needs regarding refuge groundwater conditions are minor 0 = somewhat, some data is required prior to increasing groundwater development –1 = yes, significant data must be collected as there is little or no existing data
	TOTAL DIRECT USE SCORE =		-4	c	2	0	3	0	c	c	6	c	6	5	2	-3	-1	2	4	2	5	
	TOTAL ON-REFUGE SCORE =		-6	2	-1	-3	3	0	-3	-2	5	-1	4	4	0	-3	-4	0	3	2	4	

Notes:
[a] Definitive recommendations for this criterion cannot be made without detailed evaluations of water chemistry compatibility and site-specific conditions.
[b] D=direct, N=on-refuge projects
[c] Direct Use score was not identified because the refuge does not have an identified Incremental Level 4 water need.

TABLE 5-2
Comparison of Direct Use and On-Site Conjunctive Use Rankings[a]
Evaluation of Groundwater Potential for Incremental Level 4 Refuge Water Supply

Study Region	Direct Use: Refuge	Direct Use: Score	On-Site Project: Refuge	On-Site Project: Score
Sacramento River	Gray Lodge WA	3	Gray Lodge WA	3
	Sacramento NWR	2	Colusa NWR	2
	Delevan NWR	0	Sacramento NWR	-1
	Sutter NWR	-4	Delevan NWR	-3
	Colusa NWR	*b*	Sutter NWR	-6
San Joaquin River	Merced NWR	6	Merced NWR	5
	West Bear Creek Unit	6	West Bear Creek Unit Grassland RCD	4
	Grassland RCD	5		
	Salt Slough Unit	4	Salt Slough Unit	3
	China Island Unit Los Banos WA	2	China Island Unit East Bear Creek Unit Los Banos WA	0
	East Bear Creek Unit	0	San Luis Unit	-1
	Volta WA	-1	Kesterson Unit	-2
	Mendota WA	-3	Frietas Unit Mendota WA	-3
	Frietas Unit *Kesterson Unit* *San Luis Unit*	*b*	Volta WA	-4
Tulare Lake	Pixley NWR	5	Pixley NWR	4
	Kern NWR	2	Kern NWR	2

Notes:

[a] Based on the matrix summarized in Table 5-1.

[b] Direct Use score was not assigned because the refuge does not have an identified Incremental Level 4 water need.

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SECTION 6

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APPENDIX A

Participating Agencies and Organizations

The U.S. Bureau of Reclamation (Reclamation) and the U.S. Fish and Wildlife Service (Service) were the lead agencies conducting this effort and were direct participants in the development of the report.

This report uses existing information and reports only. No additional data were collected during this effort. Interviews with refuge staff, site visits, and review of existing files were completed to assimilate available information on present and past groundwater use and conditions. In most cases, numerous conversations and data exchanges occurred with refuge staff during October 2002 through January 2003. These communications are not cited individually as "personal communications," but are generally referred to as "communications with refuge staff." The support, cooperation, and dedication of these refuge staff members cannot be overstated. These people include:

- Mike Womack/California Department of Fish and Game (DFG), Gray Lodge Wildlife Area (WA)
- Greg Mensik/Service, Sacramento Complex
- Bill Cook and John Beam/DFG, Los Banos WA
- Steve Brueggemann and Bill Huddleston/DFG, Mendota WA
- Chris Shoemann and Rich Albers/Service, San Luis Complex
- Dave Hardt/Service, Kern and Pixley National Wildlife Refuge (NWR)

Other participating agencies and organizations that have provided information and resources include the DFG, Grassland Resource Conservation District (RCD), and Nigel Quinn of the Berkeley National Laboratory (through a contract with Reclamation).

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APPENDIX B

Definitions and Explanations of Terms

This appendix provides additional explanation of some terms and concepts discussed in the report. It is not intended to be inclusive of all concepts, just those for which additional explanation as to their application to this report is necessary.

Safe Yield, Perennial Yield, and Recharge Terms

The following yield terms are defined in California Department of Water Resources (DWR) Bulletin 118 – Update 2003 (DWR 2003):

- **Perennial Yield** – The maximum quantity of water that can be annually withdrawn from a groundwater basin over a long period of time (during which water supply conditions approximate average conditions) without developing an overdraft condition
- **Safe Yield** – The maximum quantity of water that can be continuously withdrawn from a groundwater basin without adverse effect

Development of the numbers associated with these terms can be problematic since the definition of "adverse effect," "overdraft," and "average conditions" can be subject to interpretation. Additionally, the delineation of the basins, subbasins, or areas to which these terms apply can also be open to discussion and influenced by several factors, including political boundaries.

Several groundwater water recharge terms are also defined in Bulletin 119 – Update 2003 (DWR 2003) and are provided here for clarification:

- **Recharge** – Water added to an aquifer or the process of adding water to an aquifer. Groundwater recharge occurs either naturally as the net gain from precipitation, or artificially as the result of human influence.
- **Natural Recharge** – Natural replenishment of an aquifer, generally from snowmelt and runoff, through seepage from the surface.
- **Artificial Recharge** – The addition of water to a groundwater reservoir by human activity, such as putting surface water into dug or constructed spreading basins or injecting water through wells.

Groundwater Management

Groundwater management can be enacted in California through a variety of methods, including local water agencies, local groundwater management ordinances, or court adjudication. California Department of Water Resources (DWR) Bulletin 118 (public review draft, April 2003) summarizes the different mechanisms available to and used by agencies and organizations to develop and implement groundwater management plans and practices.

California Water Code (CWC) Sections 10750 *et seq*. specifically address groundwater management. CWC 10753.7 identifies the specific components of a groundwater management plan. Commonly used groundwater management tools in California include:

- **AB 3030**—Allows assessment of fees to carry out the groundwater management plan for groundwater basins defined in DWR Bulletin 118, if authorized by election of the regulated community. Twelve specific components (CWC 10753.8) can be included in the AB 3030 groundwater management plan of an individual or group of water agencies/districts.
- **AB 255**—1991 amendment to the CWC allows local agencies overlying critically overdrafted groundwater basins to develop groundwater management plans. This portion of the CWC was replaced by AB 3030.
- **Coordinated Plan** – A plan developed by agencies that have entered into a joint powers authority, joint powers agreement, memorandum of understanding, cooperative agreement, or some type of less formal agreement to develop a coordinated groundwater management plan with other agencies in the groundwater basin (CWC 10755.2).
- **Other Statutory Authority**—Some agencies may have the ability to manage groundwater under their enabling legislation or other provisions of the CWC (CWC 60220 to 60232, 60300 to 60352, and 60245 to 60257). Prior to the enactment of AB 3030, other legislation enacted statutes establishing separate groundwater management districts or agencies.

Well Identifiers

Key issues discussed and observed during the refuge site visits were related to the use and status of the wells. Several approaches were developed to standardize this information. Because most refuges had a common (local) refuge designation such as “Well 1,” unique well identifiers were assigned to each well to accommodate data maintenance in a Geographic Information Systems (GIS) database. Wells were also assigned a status type and well-use type. This resulted in a six-character well identifier with the following format:

KR-IW-01

The three pairs of characters describe well characteristics as follows:

- The first two letters refer to the first and second letters of the refuge name. In the case of two refuges having the same first two letters, the first and third letters are used, e.g., Kern (KR) and Kesterson (KS).
- The second two letters refer to the well type: IW = irrigation well, DW = domestic well, MW = monitoring well, TW = test well, and UN = unknown.
- The third two numbers are the sequential well number, which usually corresponds to a refuge’s original local well number.

Unique identifiers for non-refuge wells are based on township, range, and section followed by a dash and a two-digit sequential number. Non-refuge wells are either outside refuge boundaries or are wells for which a state log was identified yet are not known or used by the refuge. The "official" state well numbers could not be used because, for most wells, the numbers were not provided with the well logs or were not otherwise available.

Five well status types were developed. The well status refers only to the well's ability to operate. In all cases, offsite wells identified in this report were designated as "unknown" because no information on their current operational status was obtained. The well status types are:

- **Active**—The well is currently operating.
- **Inactive**—The well is physically capable of operating, but for some reason is not. Reasons for inactive status generally have to do with adverse water quality, expense, or lack of need.
- **Nonfunctional**—The well is physically incapable of operating because either some or all of the well infrastructure (such as the pump or motor) is missing or electrical service has been disconnected.
- **Destroyed or Historic**—The well has been physically filled in or someone knew that a well had "once been there." Generally, no physical features at the ground surface indicate the presence of a well.
- **Unknown**—The well is known to exist, but insufficient information is available to accurately designate its status.

Each refuge summary in this report retains the use of that refuge's local well names (for example, Well 4) because that is how most parties identify the wells. Each refuge's well table, provided at the end of each section in this report, cross references these local well names with the newly created GIS database well identifier, which is used on the refuge-specific figures.

Water Quality

A table of selected water quality standards is included below. These standards are listed to provide a reference point by which to compare the water quality data given for each refuge and are not meant to indicate enforceable refuge water quality standards.

TABLE B-1
Water Quality Standards, Criteria, and Goals
Evaluation of Groundwater Potential for Incremental Level 4 Refuge Water Supply

Water Quality Standard, Criteria, or Goal		EC (µS/cm)[a]	TDS (mg/L)	Arsenic (µg/L)	Boron (mg/L)	Chromium *Hexavalent* (µg/L)	Chromium *Total* (µg/L)	DBCP (µg/L)	Mercury (µg/L)	Molybdenum (µg/L)	Nitrate (mg/L)	Selenium (mg/L)
USEPA Primary MCL		–	500[d]	50	–	–	100	0.2	2	–	10 [b]	0.05
CDHS Primary MCL		–	500[d]	50	–	–	50	0.2	2	–	45 [c]	0.05
USEPA Freshwater Aquatic Life Protection	Continuous Concentration (4-day Avg)	–	–	150	–	11	–	–	0.77	–	–	0.005[e]
	Maximum Concentration (1-hr Avg)	–	–	340	–	16	–	–	1.4	–	–	– [f]
Agricultural Water Quality Goals		700	450	100	0.7 – 0.75	100	–	–	–	10	–	0.02

Sources: Ayers and Westcot 1985; CDHS 2003; Marshack 2003; USEPA Office of Water 2002a; USEPA Office of Water 2002b.

Notes:

[a] µS is equivalent to µmhos/cm
[b] as N
[c] as NO_3
[d] Only Secondary MCLs defined for this constituent
[e] Total recoverable
[f] USEPA is currently undertaking a reassessment of selenium, and expects the 304(a) criteria will be revised based on the final assessment. Until such criteria for selenium are published, the recommended water quality criteria listed here are USEPA's current 304(a) criteria.

APPENDIX C

Possible Off-Refuge Conjunctive Use Projects

Numerous groundwater banking projects in each study region have been proposed or are now underway. These projects are listed by study region and county in tables C-1, C-2, and C-3 based on the general information available regarding the scope and location of the project. Although none of these projects directly includes any of the refuges in this study, Incremental Level 4 water needs could be met in part or wholly through an agreement with the water project entity. Refer to the individual refuge sections for a discussion of selected projects relative to refuge partnership potential.

Funding sources for the listed projects vary and may consist of state or federal grants and loans, water district partnerships, or private investments. Available funding sources for conjunctive use studies or projects include:

- California Department of Water Resources (DWR) Proposition 13 Groundwater Recharge Construction Loans (FY 2001–02, 2002–03)
- Proposition 13 Groundwater Storage and Construction Grants (FY 2001–02, 2002–03)
- Proposition 50 (AB 303) Local Groundwater Assistance Fund Grants (FY 2001–02, 2002-03)
- Other public or private sources, as indicated

Original source files for these tables were produced by Saracino-Kirby-Snow, which was preparing them for the Bulletin 118 update. The tables have been updated and revised based on the DWR Web site and available information from individual projects.

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TABLE C-1
Sacramento Region Off-Refuge Conjunctive Use Projects[1]
Evaluation of Groundwater Potential for Incremental Level 4 Refuge Water Supply

Mapped Number	Project Name/Participant(s)	Project Description	Funding Source/ Project Status	Operable Storage (ac-ft)	Annual Yield (ac-ft)	Recharge Type	Source of Water (if applicable)	Withdrawal Purpose	Grant Request/ Award/ Total Project Cost
	Butte County								
1	Butte County Conjunctive Use (local coordination effort between adjoining counties, water districts, and the state)	Objective is to protect water table elevations and coordinate surface water operations such as flood control with in-stream and groundwater resources. Stakeholder assessment, existing simulation model evaluation, and monitoring well installation have been completed. Currently completing documentation of an Integrated Water Management Plan.	No funding information available. Conceptual plan.						
2	Thermalito Irrigation District	No description available.	Applied for AB 303 Grant in FY 2001–02. Project not funded.						
3	Butte County Department of Water Resource Conservation	Install two multi-completion monitoring wells (total depth of approximately 1,000 ft) equipped with extensometers in Butte Basin. The wells will be located in areas where water level and subsidence information is needed.	Applied for AB 303 Grant in FY 2001–02. Project funded.						Grant Award $249,000. Total Cost $249,968.
4	Western Canal Water District	No description available.	Applied for AB 303 Grant in FY 2001–02. Project not funded.						
5	Western Canal Water District	The proposal consists of installing three monitoring wells to provide information to develop a conjunctive use program.	Applied for AB 303 Grant in FY 2002–03. Project not funded.						Requested $250,000
	Colusa County								
6	Maxwell Irrigation District Conjunctive Use Project	Development of up to three deep wells located near the District's existing conveyance canals to supplement the District's existing surface water supplies from the Sacramento River. The project will assure the availability and reliability of good quality water for the District's permanent and agriculturally induced wetlands. Project will provide the opportunity to supply water to additional lands within the Colusa sub-basin, such as the **Delevan NWR,** during times of critical need.	Applied for CALFED Water Use Efficiency Grant in 2001. Project not funded. Rationale specified that project would be more appropriately funded by the CALFED Conjunctive Program.		10,500		Groundwater substitution for Sacramento River CVP contracts.	Water supply for permanent and agriculturally induced wetlands.	Requested $545,000. Total Cost $640,000.
7	Maxwell Irrigation District Conjunctive Use Project	See Project #6 above.	Applied for Prop 13 Groundwater Storage Program Construction Grant in FY 2001–02. Project not funded.		5,460			local use only	
	Colusa County and Yolo County								
8	Reclamation District No. 108	No description available.	Applied for AB 303 Grant in FY 2001–02. Project not funded.						
9	Reclamation District No. 108	Installation of a pilot well within an area of the District currently under study by DWR where little information about groundwater exists.	Applied for AB 303 Grant in FY 2002–03. Project not funded.						Requested $250,000.
	Glenn County								
10	Glenn County	Installation of one multi-completion well and two dual completion wells, which are expected to complement those wells to be installed using 2000/2001 AB 303 funds.	Applied for AB 303 Grant in FY 2001–02. Project funded.						Grant Award $250,000. Total Cost $250,000.
11	Glenn County	Glenn County proposes to install two monitoring wells, convert unused agricultural wells into monitoring wells, install a subsidence monitoring system, and perform aquifer tests.	Applied for AB 303 Grant in FY 2002–03. Project funded.						Grant Award $250,000. Total Cost $250,000.

TABLE C-1
Sacramento Region Off-Refuge Conjunctive Use Projects[1]
Evaluation of Groundwater Potential for Incremental Level 4 Refuge Water Supply

Mapped Number	Project Name/Participant(s)	Project Description	Funding Source/ Project Status	Operable Storage (ac-ft)	Annual Yield (ac-ft)	Recharge Type	Source of Water (if applicable)	Withdrawal Purpose	Grant Request/ Award/ Total Project Cost
12	Stony Creek Fan CU Water Management/Orland-Artios Water District, Orland Unit Water User's Association, Glenn-Colusa Irrigation District	Ongoing pilot project to test in-lieu and direct recharge using existing facilities and privately-owned wells. Five components include: (1) Feasibility Study; (2) Groundwater Production Investigation; (3) Groundwater Monitoring program; (4) Groundwater-Surface water model; (5) Outreach plan.	Applied for Prop 13 Groundwater Storage Program Construction Grant in FY 2001–02. Project not funded.		5,000		Stony Creek or Sacramento River		
	Tehama County								
13	Anderson-Cottonwood Irrigation District	Currently funded by CALFED to drill 6 groundwater extraction wells. Total project envisions 12 wells.	Applied for Prop 13 Groundwater Storage Program Construction Grant in FY 2001–02. Project not funded.		5,000				
14	Tehama County Flood Control and Water Conservation District	Conduct an in-depth, detailed inventory and analysis of the groundwater in Tehama County, including the documentation and analysis of surface/subsurface geology, fresh groundwater bearing units and movement of groundwater.	Applied for AB 303 Grant in FY 2001–02. Project funded.						Grant Award $200,000. Total Cost $217,000.
15	Tehama County Flood Control and Water Conservation District	Installation of 1 triple-completion and 2 single-completion dedicated monitoring wells and at least 20 data logging stations in 10 groundwater subbasins.	Applied for AB 303 Grant in FY 2002–03. Project not funded.						Requested $249,867
-	Stony Creek Fan CU Water Management/Orland-Artios Water District, Orland Unit Water User's Association, Glenn-Colusa Irrigation District (refer to Glenn County Projects)	See Project #12 above.	Applied for Prop 13 Groundwater Storage Program Construction Grant in FY 2001–02. Project not funded.		5,000		Stony Creek or Sacramento River		
	Sutter County								
16	South Sutter Water District	South Sutter Water District proposes to install up to four monitoring wells in the southern part of the District to better understand the falling water levels in this area (includes Placer County).[2]	Identified conceptual project. Funding status unknown.						Requested $247,505.
17	Sutter Mutual Water Company (Reclamation District No. 1500)	The project seeks funds to install two new monitoring wells as part of the Phase 8 short-term agreement.	Applied for AB 303 Grant in FY 2002–03. Not funded.						Requested $249,999.
18	Sutter County	The proposal is to develop county-wide groundwater management plan to facilitate coordinated management of the basin resource.	Applied for AB 303 Grant in FY 2002–03. Not funded.						Requested $250,000.
19	Sutter Extension Water District	Two groundwater production wells, a recharge program, monitoring program, and a conjunctive use education program.	Identified conceptual project. Funding status unknown.						Total cost $1,534,104.

Notes:
[1] Based on state grant and loan applications (CALFED 2001; DWR 2003c; DWR 2002; DWR 2002b; DWR 2002c; Maxwell ID 2001)
[2] Also refer to Proposition 13 Groundwater Storage Construction Grants, 2003.

TABLE C-2
San Joaquin River Region Off-Refuge Conjunctive Use Projects[1]
Evaluation of Groundwater Potential for Incremental Level 4 Refuge Water Supply

Mapped Number	Project Name/Participant(s)	Project Description	Funding Source/ Project Status	Operable Storage (ac-ft)	Annual Yield (ac-ft)	Recharge Type	Source of Water (if applicable)	Withdrawal Purpose	Grant Request/ Award/ Total Project Cost
	Fresno County								
1	Fresno Irrigation District	Examine the potential for groundwater recharge and storage by enlarging the existing Waldron pond site or identifying an alternative site.	Identified conceptual project. Funding status is unknown.						
2	Upper Kings River Conjunctive Use/facilities in Consolidated ID and Fresno ID	Four water districts have signed a MOU with DWR to pursue activity to reduce groundwater overdraft and develop recharge opportunities and facilities in Consolidated ID and Fresno ID.	Identified conceptual project. Funding status is unknown.						
3	Fresno Irrigation District Waldron Pond Groundwater Recharge (in partnership with the City of Clovis)	Feasibility study to identify and locate a site for a groundwater recharge basin within the Fresno ID. (Feasibility study completed, January 2004. Proceeding with construction.) Involves the expansion and operation of Fresno ID's existing Waldron Pond Recharge/Regulation Pilot Project Basin. Waldron Pond is located near Belmont and Bishop Avenues, west of the City of Fresno.	Hydrogeologic Evaluation of Potential for Recharge and Water Banking in the Pleasant Valley Water District. Project funded. To be completed in 2006.		9,000	spreading basins over 220 acres	Water Banking Partners		Total Cost $4.65 million.
4, 5	Expansion of the Artificial Recharge Basin at the Marion and Alluvial Avenue Project/City of Clovis, City of Fresno, Fresno Irrigation District, Fresno Metropolitan Flood Control District	Storage project consisting of the expansion of the artificial recharge basin in the northern portion of the City of Clovis along Big Dry Creek. Facilities include the construction of 8 basins covering about 40 acres, turnout structures, and pipeline facilities needed to deliver water to the basins. Project will recharge approximately 3,000 ac-ft annually.	Applied for Prop 13 Groundwater Storage Program Construction Grants in FY 2001–02. Project funded.	13,500	2,850	active, spreading basins on 8 parcels of land (40 acres)	Kings river, flood flows from Kern River and local stream group (Dry Creek, Dog Creek, Pup Creek, Redbank Slough, Fancher Creek, Mud Creek).		Grant Award $2,031,245. Total Cost $4,273,745.
6	Orange Cove Groundwater Recharge Feasibility Study/City of Orange Cove	Feasibility study to evaluate the alternatives for recharging and storage of groundwater. Establish strategic locations for soil borings at several alternative recharge sites in order to ascertain aquifer characteristics and the optimal recharge and storage potential.	Identified conceptual project. Funding status is unknown.						
7, 8	Cantua Creek and Panoche Creek/Westlands Water District	Direct (long-term) recharge/recovery. Project will perform exploratory drilling to evaluate recharge potential along two creeks to increase the District's knowledge of the water bearing properties at the two sites. The plan is to drill, log and construct monitoring wells at 45 locations.	Applied for AB 303 Grant in FY 2000-2001. Project funded.					Local use only.	Grant Award $72,900. Total Cost $72,900.
9	Arroyo Pasajero Fan Recharge Feasibility/Westlands Water District	Land purchases and infrastructure improvements capable of recharging up to 50,000 ac-ft for a 6-month period (approximately 8,400 ac-ft per month) and withdrawing up to 8,000 ac-ft per month through groundwater pumping. Additional pipeline facilities are included in the project to connect the Coalinga Canal to the project site.	Identified conceptual project. Funding status is unknown.		28,500		CVP rescheduled water, Kings Flood Water.	Local use only.	
10	Conjunctive Use Water Management Project/Westlands Water District	Land purchases and infrastructure improvements capable of recharging up to 50,000 ac-ft for a 6-month period (approximately 8,400 ac-ft per month) and withdrawing up to 8,000 ac-ft per month through groundwater pumping.	Applied for Prop 13 Groundwater Storage Program Construction Grant in FY 2001–02. Project not funded.		41,400	active (spreading basins)		Local use only.	
11	Zapato Chino Creek/Pleasant Valley Water District	Groundwater banking project.	Identified conceptual project. Funding status is unknown.				Possible banking partnerships with MWD, SCWA.	Export from basin only.	

TABLE C-2
San Joaquin River Region Off-Refuge Conjunctive Use Projects[1]
Evaluation of Groundwater Potential for Incremental Level 4 Refuge Water Supply

Mapped Number	Project Name/Participant(s)	Project Description	Funding Source/ Project Status	Operable Storage (ac-ft)	Annual Yield (ac-ft)	Recharge Type	Source of Water (if applicable)	Withdrawal Purpose	Grant Request/ Award/ Total Project Cost
12	Pleasant Valley Water District	Feasibility study to analyze water availability, site selection, and storage volumes; and to determine long-term percolation rates, conceptual design, water quality and environmental impacts, construction schedule, cost estimates, resultant groundwater levels, and pumping impacts to neighboring wells.	Identified conceptual project. Funding status is unknown.						
13	Los Gatos Creek/Pleasant Valley Water District	Groundwater banking project.	Identified conceptual project. Funding status is unknown.						
14	Kings River Conservation District	Installation of four or five well clusters (three wells per cluster) near production wells so that water level and water quality data for each water-bearing zone can be collected. Data will be used in groundwater monitoring program in Management Area C.	Applied for AB 303 Grant in FY 2001–02. Project funded.						$250,000/ $250,000/ $299,046
15	Kings River Conservation District	Feasibility study to evaluate the potential of a recharge program to alleviate groundwater overdraft in a portion of the Kings River Conservation District (KRCD). Includes studying three recharge basins at site number 1, and a channel which will terminate in a regulating basin at site number 2.	Project funded, but funding source is unknown.						
16	Kings River Conservation District	Evaluate the development of a recharge program to alleviate groundwater overdraft in a portion of the Kings River Conservation District (KRCD). Includes the study of three recharge basins at site number 1, and a channel which will terminate in a regulating basin at site number 2.	Project funded, but funding source is unknown.						
17	City of Mendota	No description available.	Applied for AB 303 Grant in FY 2001–02. Project not funded.						
18	Consolidated Irrigation District	No description available.	Applied for AB 303 Grant in FY 2001–02. Project not funded.						
19	Consolidated Irrigation District (also includes Kings County)	Replace approximately 25 of 46 monitoring wells in the Consolidated Irrigation District's 82 well monitoring grid.	Applied for AB 303 Grant in FY 2002–03. Project not funded.						Requested $250,000.
20	Groundwater Recharge Master Plan and Feasibility Study/Eastside Water District	Feasibility study of various groundwater recharge projects in the District.	Identified conceptual project. Funding status is unknown.						
21	Leaky Acres Groundwater Recharge/City of Fresno	Leaky Acres Groundwater Recharge: Surface water is used to recharge groundwater at the Leaky Acres site, located near the Fresno Yosemite International Airport. Built in 1970, the site currently consists of 26 ponds covering over 200 acres. An average of 55 ac-ft per day is applied year-round.	Project ongoing. Funding source is the City of Fresno Department of Public Utilities Water Division and other urban district partners.			active spreading basins over 200 acres	Bureau contract for San Joaquin River, Fresno ID contract for Kings river		$1.3 million approximate annual cost (FY 2000)
22	Meyers Farms Groundwater Bank Investigation	Privately funded groundwater bank currently being planned for the Mendota area. Some investigation of groundwater conditions has occurred, but details are not publicly available.	Privately funded. Pilot study commenced in 1998. Status not publicly available.						
-	Upper Kings Basin Integrated Storage Implementation Phase 1	Expand two existing recharge basins, construct two new basins, and increase the capacity of an existing basin. In two project sites, retrofit canal structures with automatic water level control to allow in-lieu surface water deliveries to the neighboring parcels.	Applied for Prop 13 Groundwater Storage Program Construction Grant in FY 2001–02. Conceptual only; not funded.		7,806	active (spreading basins, new and existing basins)	Groundwater substitution for Sacramento River CVP contracts.		

TABLE C-2
San Joaquin River Region Off-Refuge Conjunctive Use Projects[1]
Evaluation of Groundwater Potential for Incremental Level 4 Refuge Water Supply

Mapped Number	Project Name/Participant(s)	Project Description	Funding Source/ Project Status	Operable Storage (ac-ft)	Annual Yield (ac-ft)	Recharge Type	Source of Water (if applicable)	Withdrawal Purpose	Grant Request/ Award/ Total Project Cost
-	Turlock Airport Pilot Groundwater Recharge Project/Eastside Water District	Pilot groundwater recharge project, consisting of construction of a 0.25-acre basin and some exploratory borings.	Identified conceptual project. Funding status is unknown.						
	Kings County								
23	Kaweah Delta Water Conservation (also includes Tulare County)	Evaluate the feasibility of the Hannah Ranch site, which lies directly adjacent to the Kaweah River, for groundwater recharge, primarily using excess stream flows from the Kaweah River. Assess the optimum recharge design configuration and operational characteristics of the Hannah Ranch site.	Project funded, but funding source is unknown.						
24	Basin 1a Groundwater Recharge (also includes Tulare County)	Construction of a diversion structure, feed pipeline, and a regulating recharge basin with spillovers into an existing adjacent deep basin.	Conceptual project identified in DWR database. Project is funded, but funding source is unknown.						
25	Hutcheson East/West (also includes Tulare County)	Project complements an existing recharge basin within the District through excavation of ponds and construction of check structures, an inlet headwall, and pipeline.	Conceptual project identified in DWR database. Funding status unknown.						
26	Apex Ranch Groundwater Storage	Develop additional local water supplies for the District by capturing and storing surface water that would otherwise be lost from the District. Includes modification of a ditch diversion, a pipeline, and eight new wells.	Applied for Prop 13 Groundwater Storage Program Construction Grant in FY 2001–02. Project not funded.		8,612	combination	Capture and store surface water.	Local use only.	
-	CPCDo Basin Site	Construction of recharge basins to complement existing basins. Consists of excavation work as well as "replacing existing pipeline and intake facilities to accommodate a higher flow rate than currently exists."	Identified conceptual project. Funding status is unknown.						
	Merced County								
27	Merced Irrigation District	No project description, not recommended for funding.	Applied for Prop 13 Grant 2001–02. Project not funded.						
28	Merced Irrigation District	No project description, not recommended for funding.	Applied for Prop 13 Grant 2001–02. Project not funded.						
29	Merced Area Groundwater Pool Interests Conjunctive Use	Conjunctive use study and planning activity pursuant to the Cressey Recharge Basin Assessment Project has included a basin assessment report; the drilling of eight monitoring wells; and management, planning, and stakeholder assessment assistance.	Identified conceptual project. Funding status is unknown.						
30	Merced Area Groundwater Pool Interests Survey	Merced ID will conduct a survey of all public supply wells within the Merced Groundwater Basin and install 22 monitoring wells to evaluate the influence of eastern Bear Creek on the basin.	Applied for AB 303 Grant in FY 2002–03. Project funded.						Grant Award $250,000. Total Cost $250,000.
	Stanislaus County								
31	Eastside Water District	Develop preliminary plans for several conjunctive water management alternatives that have the potential of improving water supply reliability, protecting water quality, and providing environmental benefits. This study project will identify locations and facilities needed to reduce overdraft.	Applied for AB 303 Grant in FY 2001–2002. Project funded.						Grant Award $200,000. Total Cost $294,453.

TABLE C-2
San Joaquin River Region Off-Refuge Conjunctive Use Projects[1]
Evaluation of Groundwater Potential for Incremental Level 4 Refuge Water Supply

Mapped Number	Project Name/Participant(s)	Project Description	Funding Source/ Project Status	Operable Storage (ac-ft)	Annual Yield (ac-ft)	Recharge Type	Source of Water (if applicable)	Withdrawal Purpose	Grant Request/ Award/ Total Project Cost
32	Modesto Irrigation District	"Define" the hydrogeologic framework of the basin using existing data and information, collect and analyze new hydrogeologic data to refine the conceptual model of the system, collect and analyze data to quantify fluxes at stream boundaries, and develop a preliminary groundwater flow model.	Identified conceptual project. Funding status is unknown.						
33	Denair Community Services District	DCSD proposed to construct two multi-completion monitoring wells. Information from these wells, along with other wells, will be used to support advancement of an existing hydrogeologic model.	Applied for AB 303 Grant in FY 2002–03. Project funded.						Requested $200,000
	San Joaquin County								
34	North San Joaquin Flood Control and Water Conservation District	The project consists of a hydrogeologic investigation of the aquifer underlying NSJWCD using two new agricultural wells and an aquifer pump test. Two monitoring wells will also be drilled.	Applied for AB 303 Grant in FY 2002–03. Project not funded.						Requested $250,000.
35	San Joaquin County Flood Control and Water Conservation District	No description available.	Applied for AB 303 Grant in FY 2001–02. Project not funded.						
36	Stockton East Water District	No description available.[2]	Applied for Prop 13 Grant in FY 2001–02. Project not funded.						
-	Prop 50 Loans and Grants	$923,527 has been appropriated for Groundwater Management	Prop 50 Loans and Grants						

Notes:

[1] Based on state grant and loan applications (CALFED 2001; DWR 2003c; DWR 2002; DWR 2002b; DWR 2002c; City of Clovis 2002).
[2] Also refer to Proposition 13 Groundwater Storage Construction Grants, 2003.

TABLE C-3
Tulare Lake Region Off-Refuge Conjunctive Use Projects[1]
Evaluation of Groundwater Potential for Incremental Level 4 Refuge Water Supply

Mapped Number	Project Name/Participant(s)	Project Description	Funding Source/ Project Status	Operable Storage (ac-ft)	Annual Yield (ac-ft)	Recharge Type	Source of Water (if applicable)	Withdrawal Purpose	Grant Request/ Award/ Total Project Cost
	Kern County								
1, 2, 3	Completion of the Kern Water Bank River Area Recharge and Recovery Project/Kern Water Bank Authority, Westside Mutual Water Company, Wheeler Ridge-Maricopa Water District	The purpose of the project is to increase project yield and help sustain project recovery capabilities as recovery conditions become more adverse, such as in the event of an extended drought. Consists of construction of 9 additional wells, installation of pumps into 16 recovery wells, and construction of conveyance piping for all 16 wells. One end of the conveyance piping will be connected to the Kern Water Bank Canal and the other to the Cross Valley Canal. Also includes the construction of a life station (11 cfs capacity) to convey water for recharge purposes. KWB has a well-established management plan, has sold water in the past to EWA, and intends to sell water to various entities in the future. Also see project #26.	Applied for Prop 13 Groundwater Storage Program Construction Grant. Project funded. Also see project #26.	104,000	9,023	active (spreading basins); project involved creating the conveyance to enable delivery to the Kern Fan.	Surface water, active recharge. Source of water is excess high flow water from the SWP, Kern River and possibly CVP.	Local use with some available for export (transfer).	Requested $3,375,000. Grant Award $3,375,000. Total Cost $6,750,000.
4	Rosedale/Kern River Diversion Facility & Superior Road Recharge/Roadside-Rio Bravo Water Storage District	Project entails the construction of an additional 20 acres of recharge basins. The District will also replace the existing Kern River headworks structure with a new structure able to accommodate flows up to 600 cfs. This will allow the capture of more Kern River flood water when it is available.	Applied for Prop 13 Groundwater Storage Program Construction Grant in FY 2001-02. Project not funded.			Construction of additional 20 acres of recharge basins.	Surface storage for recharge. SWP, Friant-Kern Canal, and Kern River (wetter years).	local use with some available for export (transfer)	
5, 6	Expansion of Conjunctive Use Program/Kern-Tulare and Rag Gulch Water Districts	Program would increase the water distribution system capability in the Kern-Tulare and Rag Gulch Water Districts to reduce groundwater pumping and improve groundwater conditions.	Applied for Prop 13 Groundwater Storage Program Construction Grant in FY 2001-02. Project not funded.			active (spreading basins)	surface water in lieu of private wells		
7, 8, 9	Northern Kern Banking P13/North Kern Water Storage District, Kern-Tulare Water District, Rag Gulch Water District	Construction of conveyance facilities that would be used to import wet year flows for banking purposes. The new facilities would be used to bank flows for others or for the district.	Applied for Prop 13 Groundwater Storage Program Construction Grant in FY 2001-02. Project not funded.		1,600	active (spreading basins)	Section 215 water (purchased by Kern-Tulare and Rag Gulch WDs), Flood Waters (King, Kaweah and Tule Rivers), and Purchased CVP (Friant Class 2 water and Kern River water, by exchange).	Banked water used for export and local purposes.	
10, 11	P667 System Completion and P-1030 System/Pond-Poso Improvement District, Semitropic Water Storage District	In-lieu groundwater recharge project. Includes construction of additional facilities necessary to deliver surface water to 3,040 acres of land, in lieu of pumping groundwater to meet water demand.	Applied for Prop 13 Groundwater Storage Program Construction Grant in FY 2001-02. Project not funded.		>3,219	active (spreading basins)	surface water in lieu of groundwater pumping	local use only	
12, 13	The B-369 Distribution System/Buttonwillow Improvement District, Semitropic Water Storage District	Construction of an additional 2,560 acres of surface water delivery service area for use in place of pumping groundwater. Up to 8,960 ac-ft of water may be recharged/banked annually in this manner.	Applied for Prop 13 Groundwater Storage Program Construction Loan in FY 2001-02. Project funded.	8,960			surface water delivery in place of pumping	local use only	Loan Award $5,000,000. Total Cost $5,400,417.
14	Kern County Basin Groundwater Banking Operation/Kern Water Bank Authority, including the Kern Water Agency, Semitropic Water Storage District, Dudley Ridge Water District, Tejon Castac Water District	A large groundwater banking operation where SWP water is imported and stored to meet local annual water demands and maintain groundwater quality.	Existing project (AGWA 2000).	4,000,000	785,000	combination	Native groundwater and imported water. SWP is the largest source of imported water.	local use with some available for export (transfer)	

TABLE C-3
Tulare Lake Region Off-Refuge Conjunctive Use Projects[1]
Evaluation of Groundwater Potential for Incremental Level 4 Refuge Water Supply

Mapped Number	Project Name/Participant(s)	Project Description	Funding Source/ Project Status	Operable Storage (ac-ft)	Annual Yield (ac-ft)	Recharge Type	Source of Water (if applicable)	Withdrawal Purpose	Grant Request/ Award/ Total Project Cost
15	Semitropic Water Storage District	This project will install two monitoring wells and one extensometer to aid the water banking operations currently performed by the SWSD.	Applied for AB 303 Grant in FY 2002–03. Project not funded.						Requested $250,000.
16	Semitropic Water Storage District	Develop four monitoring wells. Complete water-quality management operations study. Develop GIS groundwater database. Study the potential of increasing aqueduct return when pumping.	Applied for AB 303 Grant in FY 2001–02. Project funded.						Grant Award $250,000. Total Cost $627,938.
17	Indian Wells Valley Water District	On District-owned property, construction of two 1-acre test infiltration basins equipped with sensors to monitor discharge, depth, and evaporation rates; and two test borings including borehole geophysics and piezometer installation.	Active project. Funded, but funding source unknown.						
18	Cawelo Water District	The project proposes installing nine monitoring wells onsite at the Poso Creek and Famoso groundwater recharge project sites to detail subsurface geology and monitor groundwater recharge operations.	Applied for AB 303 Grant in FY 2002–03. Project not funded.						Requested $190,455
19	Poso Creek/Cawelo Water District	Provide facilities for groundwater storage for high flow periods and recovery during dry periods. Involves construction of 100 acres of spreading fields for storing high flow period water. Diversion construction needed to exercise appropriate right to Poso Creek. Reservoir constructed to provide additional capacity for the District's distribution system north of Poso Creek.[3]	Applied for Prop 13 Groundwater Storage Program Construction Grant. FY unknown. Project funded.		9,700	Active recharge and in-lieu.	Poso Creek, oilfield produced water, Kern River, surplus SWP, CVP, and others. In-lieu recharge will occur in the winter using the reservoir facility.	Local use only	
20	Groundwater Storage and Conjunctive Management of Surface Water and Groundwater Project/Cawelo Water District	Provide facilities for conjunctive use of available surface water and groundwater. Water would be diverted or imported through the District's existing distribution system for delivery to the proposed reservoir and basins.[3]	Applied for Prop 13 Groundwater Storage Program Construction Grant in FY 2001–02. Project funded.					local use with some available for export (transfer)	Requested $6,430,000. Grant Award $1,430,000. Total Cost $13,856,470.
21	Buena Vista Groundwater Supply Program/Buena Vista Water District	Construction of three new extraction wells and associated conveyance pipelines to deliver up to 5,000 ac-ft of additional banked groundwater per year.	Applied for Prop 13 Groundwater Storage Program Construction Grant in FY 2001–02. Project funded.		5,000				Grant Award $500,000 Total Cost $1,000,000.
22	Antelope Dam Conjunctive use Project/Golden Hills Community Services District (conveyance facilities operated by Tehachapi-Cummings County Water District)	Uses existing conveyance and recharge facilities owned and operated by the Tehachapi-Cummings County Water District to convey and recharge SWP water supply into groundwater storage.	Applied for Prop 13 Groundwater Storage Program Construction Grant in FY 2001–02. Project not funded.		402		SWP		

TABLE C-3
Tulare Lake Region Off-Refuge Conjunctive Use Projects[1]
Evaluation of Groundwater Potential for Incremental Level 4 Refuge Water Supply

Mapped Number	Project Name/Participant(s)	Project Description	Funding Source/ Project Status	Operable Storage (ac-ft)	Annual Yield (ac-ft)	Recharge Type	Source of Water (if applicable)	Withdrawal Purpose	Grant Request/ Award/ Total Project Cost
23, 24, 25	Kern County Groundwater Storage and Water Conveyance Infrastructure Improvement Program/Kern County Water Agency, Kern Water Bank Authority, Kern County	DWR database description: Through several water conveyance capacity improvements, the proposed project will improve water supply reliability for water districts in Kern and Tulare counties by developing 25.7 thousand ac-ft of dry year yield. In wet years, it will increase the ability to store highly variable water supplies from multiple sources and convey those supplies to key storage facilities on the Kern Fan.[2] The project creates greater import conveyance capability for banking water. Prop 13 description: This project includes several improvements that will increase the ability to store highly variable water supplies and convey them to key groundwater storage facilities. Includes construction an 800 cfs tie between the Cross Valley Canal (CVC) and the Friant-Kern Canal, installation of pump stations on the Friant-Kern Canal to convey from the CVC to northern Kern County, and raising of the lining of the CVC to reliably convey 500 cfs of water.	Applied for Prop 13 Groundwater Storage Program Construction Grant in FY 2001–02. Project funded.		25,700	active (spreading basins)	SWP entitlements, high flow years. Kern River, Friant-Kern Canal, SWP. Bank SWP water in high flow years.	Local use only. Program recovery yields are assumed to supplement shortages in SWP entitlement deliveries in a dry year.	
26	Kern Water Bank River Area Recharge and Recovery Project/Kern Water Bank Authority	Construction of 16 additional recovery wells and a conveyance pipeline to route water to the California Aqueduct. Also includes the construction of a lift station to convey water for recharge purposes. The purpose of the project is to increase project yield and help sustain project recovery capabilities as recovery conditions become more adverse, such as in the event of an extended drought.	Applied for Prop 13 Groundwater Storage Program Construction Grant in FY 2001–02. Project funded.						Requested $3,375,000. Grant Award $3,375,000. Total Cost $6,750,000.
27	Kern County Water Agency	No description available.	Applied for AB 303 Grant in FY 2001–02. Project not funded.						
28	North Kern Groundwater Storage Project/North Kern Water Storage District	This project will provide water banking services to neighboring water agencies and maintenance of the groundwater resource underlying North Kern. New facilities would include a turnout from the Friant-Kern Canal and four 1,000-ft deep wells with the capability of discharging into the Friant-Kern Canal. All other facilities, including conveyance and spreading facilities, are existing.	Applied for Prop 13 Groundwater Storage Program Construction Grant in FY 2001–02. Project funded.			spreading basins			Requested $1,912,487. Grant Award $1,131,000. Total Cost $2,262,487.
29	Pond-Poso Improvement District	No description available.	Applied for Prop 13 Loan in FY 2001–02. Project not funded.						
30	Pond-Poso Improvement District	No description available.	Applied for Prop 13 Grant in FY 2001–02. Project not funded.						
31	Semitropic Water Storage District	No description available.[3]	Applied for Prop 13 Grant in FY 2001–02. Project not funded.						
32	Delano-Earlimart Irrigation District	The project is to investigate and determine if the District can become the sole provider of irrigation water through control of groundwater and surface water supplies.	Applied for AB 303 Grant in FY 2002–03. Project not funded.						Requested $200,300.
33	Eastern Kern County Water Conservation District	The proposed project consists of filing data gaps identified in the development of the conceptual hydrogeologic model with existing data sources, updating the hydrologic budget, and developing an outreach program for small systems.	Applied for AB 303 Grant in FY 2002–03. Project not funded.						Requested $249,960

TABLE C-3
Tulare Lake Region Off-Refuge Conjunctive Use Projects[1]
Evaluation of Groundwater Potential for Incremental Level 4 Refuge Water Supply

Mapped Number	Project Name/Participant(s)	Project Description	Funding Source/ Project Status	Operable Storage (ac-ft)	Annual Yield (ac-ft)	Recharge Type	Source of Water (if applicable)	Withdrawal Purpose	Grant Request/ Award/ Total Project Cost
34	Kern Water Bank Authority	The Kern Water Bank Authority will install one within completion monitoring well, 17 data loggers, and continue database development to map the stratigraphy of the Kern Fan.	Applied for AB 303 Grant in FY 2002–03. Project funded.						Requested $250,000.
35	Mojave Water Agency, Kern/L.A./San Bernardino Counties	This proposal is to integrate 10,000 existing bore logs into the Agency's GIS database as well as perform high resolution aerial photography of the entire management area.	Applied for AB 303 Grant in FY 2002–03. Project not funded.						Requested $2,250,000
36	North Kern Water Storage District	This proposal consists of aquifer tests, groundwater model development activities, and enhancement of the groundwater monitoring plan.	Applied for AB 303 Grant in FY 2002–03. Project not funded.						Requested $198,353
37	Buttonwillow Improvement District	No description available.	Applied for Prop 13 Grant in FY 2001–02. Project not funded.						
38	Kern Delta Water District	No description available.	Applied for AB 303 Grant in FY 2001–02. Project not funded.						
39	Groundwater Extraction Wells/ West Kern Water District	Drilling of 5 new extraction wells and associated conveyance pipelines that could deliver up to 10,500 ac-ft of additional banked groundwater per year.	Identified conceptual project. Funding status unknown.					Local use only	
-	Auxiliary Reservoir C" Dam Construction/Cawelo Water District	Construction of Auxiliary C" Dam, spillway, outlet works, inlet and pump-back facilities, and wells for the surface storage, groundwater storage, in-lieu groundwater storage, and extraction of banked groundwater for irrigation within the CWD.	Identified conceptual project. Funding status is unknown.						
-	Stored Water Recovery Unit Project/Semitropic Water Storage District	Well field is in an undeveloped area that is underlain by a deep aquifer. Water will be stored in wet and surplus years by in-lieu recharge.	Identified conceptual project. Funding status unknown.		56,400		native groundwater (deep aquifer)	export from basin only (transfer)	
-	Kern County	Groundwater programs, $2,070,094.	Prop 50 Loans and Grants						
	Tulare County								
40	Lindsay Strathmore Irrigation District	Feasibility study of the construction of multiple cell groundwater recharge basins with all associated conveyance structures, potentially leading to the incorporation of extraction wells for banking.	Identified conceptual project. Funding status unknown.						
41	CPCDo Basin Site/Kaweah Delta Water Conservation District (refer to Kings County)		Applied for AB 303 Grant in FY 2001-02. Project not funded.						
42	Angiola Water District	Feasibility study for constructing an in-lieu groundwater recharge project within the Angiola Water District. The in-lieu groundwater recharge project, if determined to be feasible, would involve the construction and operation of a surface water storage reservoir within the District.	Identified active project. Funded, but source is unknown.						
43	Pixley Irrigation District	The project will identify and evaluate alternatives for improving the availability and distribution of water resources in Pixley ID.	Applied for AB 303 Grant in FY 2002–03. Project not funded.						Requested $175,000.

TABLE C-3
Tulare Lake Region Off-Refuge Conjunctive Use Projects[1]
Evaluation of Groundwater Potential for Incremental Level 4 Refuge Water Supply

Mapped Number	Project Name/Participant(s)	Project Description	Funding Source/ Project Status	Operable Storage (ac-ft)	Annual Yield (ac-ft)	Recharge Type	Source of Water (if applicable)	Withdrawal Purpose	Grant Request/ Award/ Total Project Cost
44	Groundwater Storage and Conjunctive Management Project/Tea Pot Dome Water District	Construction of a turnout from the Friant-Kern Canal, construction of a 10-acre recharge basin, installation of an extraction well, and construction of a pipeline for the delivery of the extracted water.	Applied for Prop 13 Groundwater Storage Program Construction Grant in FY 2001–02. Project not funded.		359				
45	Water Supply Enhancement Project/Lower Tule River Irrigation District	Construction of two miles of new canal and the deepening and widening of four miles of existing canals. The conveyed water will be used for both direct recharge and in-lieu recharge. Involves expansion of irrigation canals.	Applied for Prop 13 Groundwater Storage Program Construction Grant in FY 2001–02. Project not funded.			active (spreading basins)		local use only	
-	Hutcheson East/West (refer to Kings County)								
-	Basin 1a Groundwater Recharge (refer to Kings County)								
-	Kings River Conservation District (refer to Fresno County)								
-	Tulare County	Groundwater recharge, $382,000.							

Notes:
[1] Based on state grant and loan applications (CALFED 2001; DWR 2003c; DWR 2002; DWR 2002b; DWR 2002c; AGWA 2000).
[2] Components of the proposed project are: A) raising the Cross Valley Canal liner so that it matches the elevation of a SWP aqueduct pool, allowing gravity back flow from the Cross Valley Canal to the aqueduct; B) improvements to the Pioneer recharge facility consisting of levee improvements, new levees, and conduits between recharge cells; C) improvements on the Kern Bank Canal to increase capacity and delivery capabilities; D) extension of the Kern Bank Canal so that additional deliveries can be made to the Pioneer recharge facility; E) a bi-directional inter-tie between the Cross Valley Canal and the Friant-Kern Canal to increase delivery flexibility of the system; and F) installation of back pump stations around three check points on the Friant-Kern Canal to aid back flow deliveries in the canal.
[3] Also refer to Proposition 13 Groundwater Storage Construction Grants, 2003.

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APPENDIX D

Example Conceptual Project Approaches

Example Conceptual Project Approaches

CH2M HILL Two highly scored refuges, Pixley National Wildlife Refuge (NWR) and Gray Lodge Wildlife Area (WA), were selected to develop a more involved approach to collecting the data acquisition tasks identified above. These two conceptual designs are provided as examples and guidance to data acquisitions tasks recommended to be conducted to fully assess and recommend potential for groundwater to supply Incremental Level 4 at the identified refuges.

Pixley NWR

Data acquisition tasks for Pixley NWR focus on collecting data to verify water quality conditions (the only existing sample from the production well indicates elevated arsenic levels) and evaluating near-refuge groundwater conditions to address concerns that groundwater is locally overdeveloped. The proposed project includes installation of an additional refuge production well and installation of a supply-level pump in the existing stock well or the U.S. Fish and Wildlife Service (FWS) well, if locatable and useable.

Data Acquisition Tasks

Six data acquisition tasks are proposed. Task PI.01 is a new task, which renumbered the subsequent tasks. Tasks PI.04 and PI.06 were also added to complement data collection efforts. The data acquisition tasks are:

- Task PI.01—Existing Well Evaluation
- Task PI.02 – Water Quality Data Collection
- Task PI.03 – Existing Recharge Evaluation
- Task PI.04 – Aquifer Test*
- Task PI.05 – Safe Yield Estimate
- Task PI.06 – Identification of Well Locations*

Figure D-1 shows the internal distribution system (IDS) at the refuge and components of the water conveyance system incorporated into the Geographic Information Systems (GIS). Figure D-2 shows specific areas mentioned in the data acquisition tasks, including potential areas for recharge.

Task PI.01—Existing Well Evaluation*

There are four on-refuge wells/features to be assessed during this task:

- Visually evaluate and operationally test and assess the condition of the two known existing refuge wells (the irrigation well and the stock well) for potential repair, rehabilitation, or replacement, leading to potential well contribution to refuge water supply.

- Locate the FWS well, drilled between 1951 and 1953, if possible. California Department of Water Resources (DWR) measures water levels at a location similar to that described on the existing electronic log for the FWS well. Coordinate with DWR staff regarding their measuring activities at that well to determine if the two wells are the same. Also determine if there are water quality samples collected by DWR or if there are any other nearby wells the agency monitors. If so, visually assess the condition of the well and collect information DWR may have on the well.
- There is a feature located north of the stock well that may be a piezometer. Determine if this is a shallow monitoring point and if it is related to the U.S. Bureau of Reclamation (Reclamation) monitoring that occurred at the San Joaquin refuges.
- Identify the well screen intervals and frequency of operation of the well located immediately west of the refuge by communicating with Alpaugh Irrigation District (ID). Determine if there are other wells in the vicinity of the refuge operated by Alpaugh ID or Pixley ID.

Task PI.02—Water Quality Data Collection (TM1 Task PI.01)

Sample four existing wells on and adjacent to the refuge. These wells are:

- Existing production well (PI-IW-03), screened in the deep aquifer
- On-refuge stock well (PI-IW-02), screened in the shallow aquifer
- FWS (Well 23S24E16-2 on Figure D-1) well (which will be conclusively located), screened in the deep aquifer
- Alpaugh ID well, located just west of the refuge, assumed to be screened in the deep aquifer

This will provide local water quality data for three wells in the deep aquifer, the primary producing zone for any new irrigation wells, as well as the shallow aquifer, which is being locally recharged at the refuge with water supplied by Pixley ID.

Collected samples would be analyzed for general chemistry constituents and metals, including arsenic, boron, mercury, and selenium. Based on a single sample previously analyzed, the concentration of arsenic is elevated and is the primary water quality parameter of concern. Analysis of additional constituents in the four proposed samples will provide supplemental water quality information and support the implementation of ongoing water quality monitoring at the refuge.

It is assumed that it is possible to sample the identified wells and that the FWS well, drilled in 1951 or 1953, can be located during task PI.01. Coordinate with DWR staff regarding their local water quality monitoring activities at other nearby wells (if any).

Task PI.03—Existing Recharge Evaluation (TM1 Task PI.02)

Assess the operation of the Pixley ID recharge by reviewing available records, visiting the site, and meeting with Pixley ID staff. Currently, Pixley ID measures the amount of water released for recharge at the diversion point to Deer Creek, which is then used to convey the water to the delivery point at the refuge. The anticipated substantial conveyance losses along Deer Creek have been a primary reason the use of the creek to convey refuge water supplies has been eliminated from further consideration. Evaluation of the leakage rate along Deer Creek would support understanding of local groundwater recharge, as well as optimization of shallow aquifer recharge and refuge water deliveries.

Specific actions to be conducted during this task include:

- Identify opportunities for installing a weir at the point where the water is delivered to the refuge
- Estimate evapotranspiration losses and water losses along Deer Creek
- Estimate probable groundwater recharge from these activities
- Assess how the water deliveries benefit the refuge's current water supply

It is assumed for completion of this task that Pixley ID is willing and able to meet with staff and provide needed information and data regarding their recharge project.

Installation of three monitoring wells to the water table (approximately 160 feet below ground surface [bgs]) to monitor changes in groundwater elevation and impacts by groundwater recharge is also planned.

Task PI.04—Aquifer Test*

Conduct an aquifer test to determine aquifer parameters. A brief 24-hour aquifer test using Well PI-IW-03 and available existing wells (determined to be influenced by PI-IW-03) may allow aquifer conditions to be inexpensively estimated.

Task PI.05—Safe Yield Estimate (TM1 Task PI.04)

Estimate the safe yield of the refuge under wet-, normal-, and dry-year conditions, based on available information. It is assumed that the results of the previous tasks will be used to determine this estimate, that readily-available water budget information will be sufficient to estimate safe yield, and that groundwater modeling will not be conducted.

Task PI.06—Well Location Identification*

It is estimated that refuge Level 2 and Level 4 water needs could be met for 11 months of the year with 3 new wells (Figure D-3) if:

- The existing refuge irrigation well is dedicated to meeting Level 2 supply from January through March and is available to meet Level 4 needs during the remainder of the year
- A larger-capacity pump is installed in the stock well
- The estimated safe yield indicates that groundwater can support refuge needs
- Newly installed well(s) produce 1,500 gallons per minute (gpm)

This does not account for any recharge water that may be delivered to the refuge by Pixley ID. Before installation of the proposed project production well, locations for these three wells should be identified and recommended. The choice of well locations should account for existing off-refuge irrigation wells, minimize well interference, and be located in the vicinity of the existing "wet" portions of the refuge to minimize conveyance needs. The proposed project well would be installed at one of these locations.

Proposed Project

The proposed project consists of two activities. First, rehabilitate the existing stock well, if appropriate, and install a new higher-capacity pump. Existing records indicate that the well casing is 16 inches in diameter. If a higher-capacity pump is installed, that well should be capable of producing several hundred gpm. Second, install one production well, approximately 1,200 feet deep, at one of the proposed well locations identified in Task PI.06.

The estimated production rate of the new irrigation well is 1,500 gpm and the rehabilitated stock well is 750 gpm.

Production of the existing irrigation well is estimated between 1,500 and 1,800 gpm. At this production rate, the new and existing (irrigation and stock) wells should contribute 450 to 550 acre feet (ac-ft) per month. This would meet 100 percent of Level 2 and Level 4 needs at the refuge for five months of the year and 40 to 80 percent of Level 4 needs for the remaining seven months. These estimates do not assume any additional surface water deliveries from Pixley ID.

Financial Resources

Data Acquisition

Estimated costs associated with the above data acquisition tasks for Pixley NWR are shown in Table D-1.

Proposed Project

Estimated costs associated with the proposed groundwater project for Pixley NWR are shown in Table D-2. Capital costs for the project, future investment, and operation and maintenance (O&M) are reflected in the first year total, while annual costs (following the first year) include future investment and O&M.

Gray Lodge WA

Groundwater has been a significant component of water supply at Gray Lodge WA since its inception. Like Merced NWR, however, key hydrogeologic information has not been collected. The data acquisition tasks focus on obtaining this information.

Many refuge wells existed and were transferred to the refuge when it was formed. These wells are now 70 to 80 years old and are near the end of their expected longevity. Also, many of them are “open hole” completion; that is, they do not have a well screen or sand pack, and are prone to well collapse or sand production. Therefore, it is anticipated that modification or replacement of some of these wells will support the refuge in its continued use of groundwater. The proposed project entails rehabilitating or replacing up to three wells at the refuge.

Data Acquisition Tasks

Several onsite wells supplement existing primary and secondary water rights. Ten wells are of unknown age or were installed before 1950. Providing that adequate water quality and aquifer conditions may be confirmed, rehabilitating several of these wells may allow groundwater to be further developed at this refuge. The refuge is in a portion of the East Butte Subbasin where groundwater use is low relative to the groundwater component of the local groundwater budget, based on Butte County documents. Five data acquisition tasks are recommended:

- Task GL.01—Existing Well Inventory
- Task GL.02 – Water Quality Data Collection
- Task GL.03 – Aquifer Test
- Task GL.04 – Monitoring Well Installation
- Task GL.05 – Safe Yield Estimate

Figure D-4 shows the water conveyance and internal distribution system at the refuge.

Task GL.01—Existing Well Inventory

Conduct an inventory of all known wells located on the refuge, including irrigation wells and other wells that have been found at the refuge. Data to be compiled include the date installed; physical well properties, including depth, operational status, operational deficiencies (i.e., broken or nonexistent pump, well collapse, etc.); and repair history. Photograph and GPS coordinates for the wells. Survey the ground level elevation and the measuring point elevation of each well.

Task GL.02—Water Quality Data Collection

Collect two complete rounds of water quality samples analyzing, at a minimum, general chemistry parameters and metals – including arsenic, boron, chromium (total and hexavalent), mercury, and nitrates – at the existing production wells located at the refuge. The water samples will be obtained at the well's discharge point before entering the internal distribution system. Collect these samples during two seasons, such as summer and winter. Coordinate this sampling with the sampling of the domestic wells.

Task GL.03—Aquifer Test

Conduct two 72-hour aquifer tests at existing irrigation wells at the refuge to determine an estimated refuge yield. Conduct these tests during the nonirrigation season. Use existing production wells where there are nearby inactive wells that can be monitored before and during the test. Collect pumping and recovery data.

These actions assume that inactive wells may be used as monitoring wells during the aquifer tests, and that it is possible to access the existing wells.

Task GL.04—Monitoring Well Installation

If Task GL.01 has not identified any inactive wells that could be used as monitoring wells, install three dedicated monitoring wells on the south, north, and east sides of the refuge to record water level changes in response to seasonal conditions and changes in local water use. However, if inactive wells are identified, a sampling port may be attached to the existing well casing to allow for future sampling and groundwater level monitoring.

Task GL.05—Safe Yield Estimate

Based on the aquifer properties determined during Task GL.03 and water level records available for the refuge and the vicinity, develop a groundwater budget for the refuge. Estimate the safe yield of the refuge under wet-, normal-, and dry-year conditions.

Proposed Project

Replace 3 existing wells, rehabilitate 3 wells, and replace 3 well pumps, for a total of up to 9 replaced or rehabilitated wells. Applicable wells will be determined based on the results of Task GL.01. Production rates for each of the replaced or rehabilitated wells is conservatively estimated to be 2,000 gpm. At this production rate, 8 wells currently not operating can meet incremental Level 4 needs (Figure D-5).

Financial Resources

Data Acquisition

Estimated costs associated with the data acquisition tasks for Gray Lodge WA are shown in Table D-3.

Proposed Project

Estimated costs associated with the proposed groundwater project for Gray Lodge WA are shown in Table D-4. Capital costs for the project, future investment, and O&M are reflected in the first year total, while annual costs (following the first year) include future investment and O&M.

TABLE D-1
Estimated Costs for Data Acquisition at Pixley NWR
Conceptual Design of Tier 1: Additional Data Activities and Proposed Projects

Task	Description	Estimated Cost
PI.01	Existing Well Evaluation	$7,000 – $9,000
PI.02	Water Quality Data Collection	$12,000 – $15,000
PI.03	Existing Recharge Evaluation	$39,000 – $44,000
PI.04	Aquifer Test	$11,000 – $13,000
PI.05	Safe Yield Estimate	$18,000 – $25,000
PI.06	Identification of Well Locations	$6,000 – $8,000
Total Cost Range of Data Acquisition		***$93,000 – $114,000***

TABLE D-2
Estimated Annualized Costs for Proposed Project at Pixley NWR
Conceptual Design of Tier 1: Additional Data Activities and Proposed Projects

Description	Estimated Cost
Proposed Project	
New Well Installation and Conveyance	$460,000 – $490,000
Well Rehabilitation (Stock Well)	$90,000 – $100,000
Total Capital Costs	*$550,000 – $590,000*
Investment for Future Capital	
Total Annual Capital Investment Costs	*$39,000 – $45,000*
O&M	
Total Annual O&M Costs	*$58,000 – $60,000*

TABLE D-3
Estimated Costs for Data Acquisition at Gray Lodge WA
Conceptual Design of Tier 1: Additional Data Activities and Proposed Projects

Task	Description	Estimated Cost
GL.01	Existing Well Inventory	$16,000 – $19,000
GL.02	Water Quality Data Collection	$13,000 – $15,000
GL.03	Aquifer Test	$20,000 – $23,000
GL.04	Monitoring Well Installation	$170,000 – $200,000
GL.05	Safe Yield Estimate	$20,000 – $25,000
Total Cost Range of Data Acquisition		***$239,000 – $282,000***

TABLE D-4
Estimated Annualized Costs for Proposed Project at Gray Lodge WA
Conceptual Design of Tier 1: Additional Data Activities and Proposed Projects

Description	Estimated Cost
Proposed Project	
Well Installation (Three Wells)	$730,000 – $780,000
Well Rehabilitation (Three Wells)	$40,000 – $45,000
Pump Replacement (Three Pumps)	$190,000 – $210,000
Total Capital Costs of Proposed Project	*$960,000 – $1,035,000*
Investment for Future Capital	
Total Annual Capital Investment Costs	*$66,000 – $70,000*
O&M	
Total O&M Costs	*$157,000 – $165,000*

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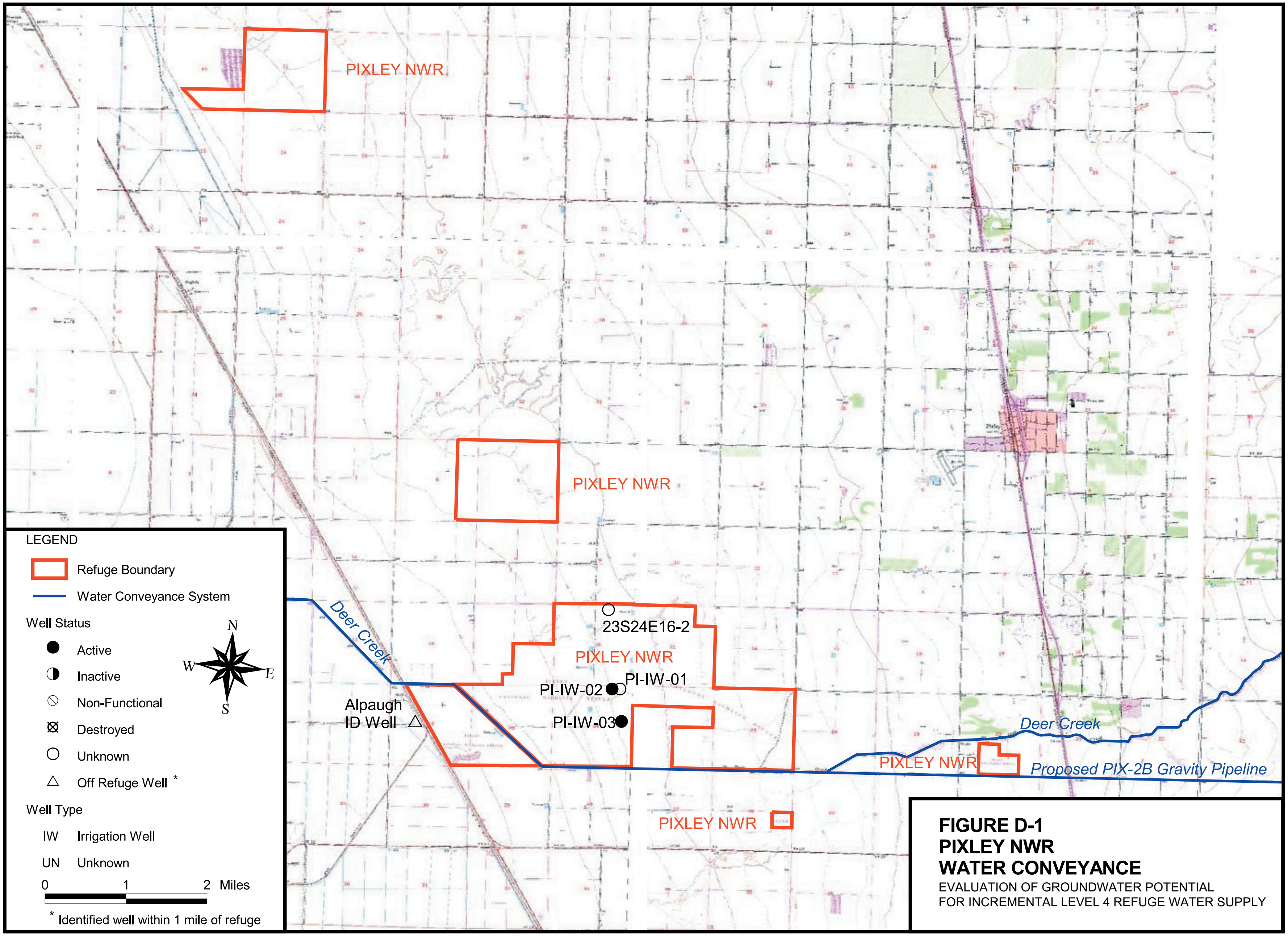

FIGURE D-1
PIXLEY NWR
WATER CONVEYANCE
EVALUATION OF GROUNDWATER POTENTIAL
FOR INCREMENTAL LEVEL 4 REFUGE WATER SUPPLY

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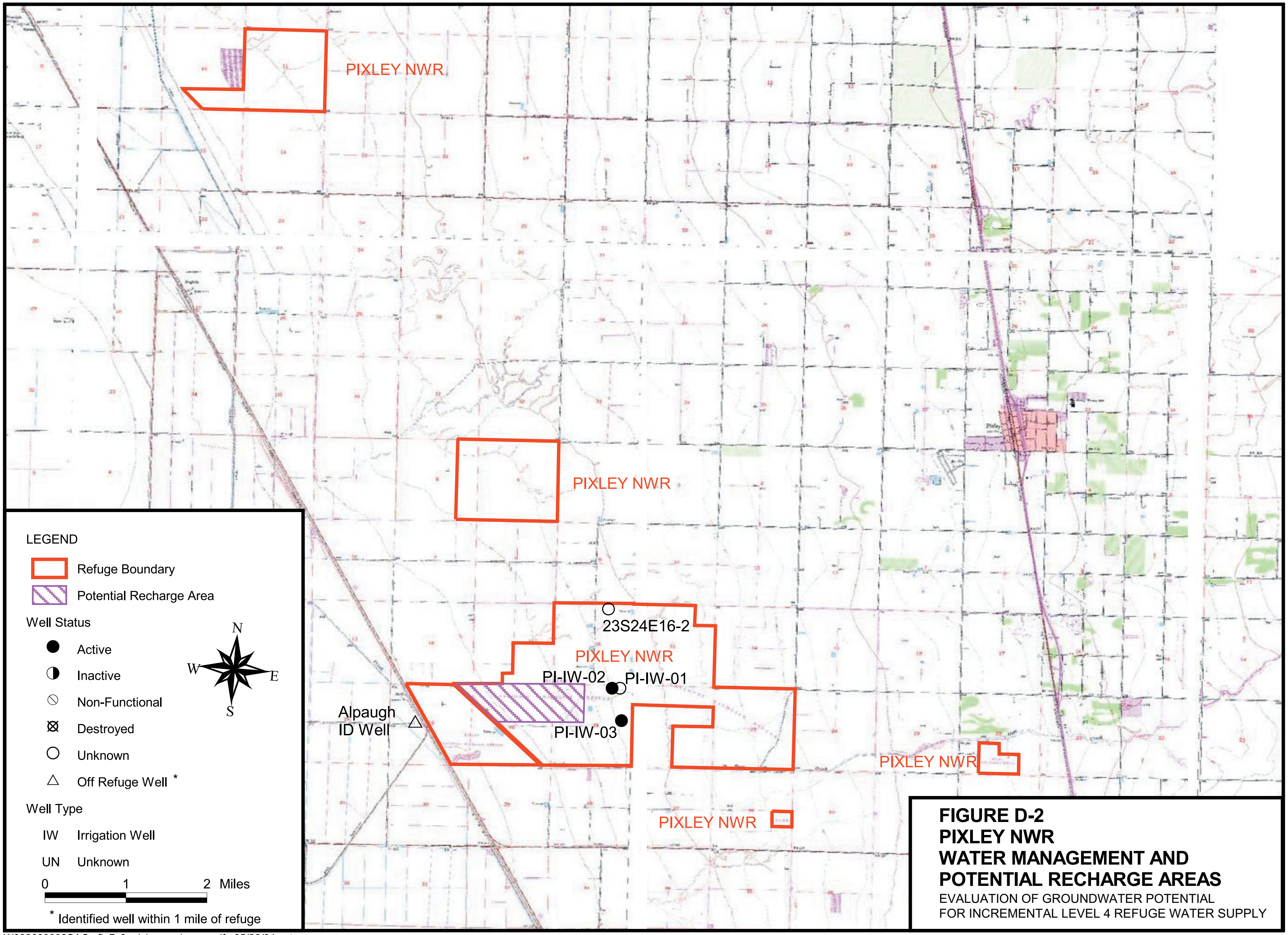

FIGURE D-2
PIXLEY NWR
WATER MANAGEMENT AND POTENTIAL RECHARGE AREAS
EVALUATION OF GROUNDWATER POTENTIAL
FOR INCREMENTAL LEVEL 4 REFUGE WATER SUPPLY

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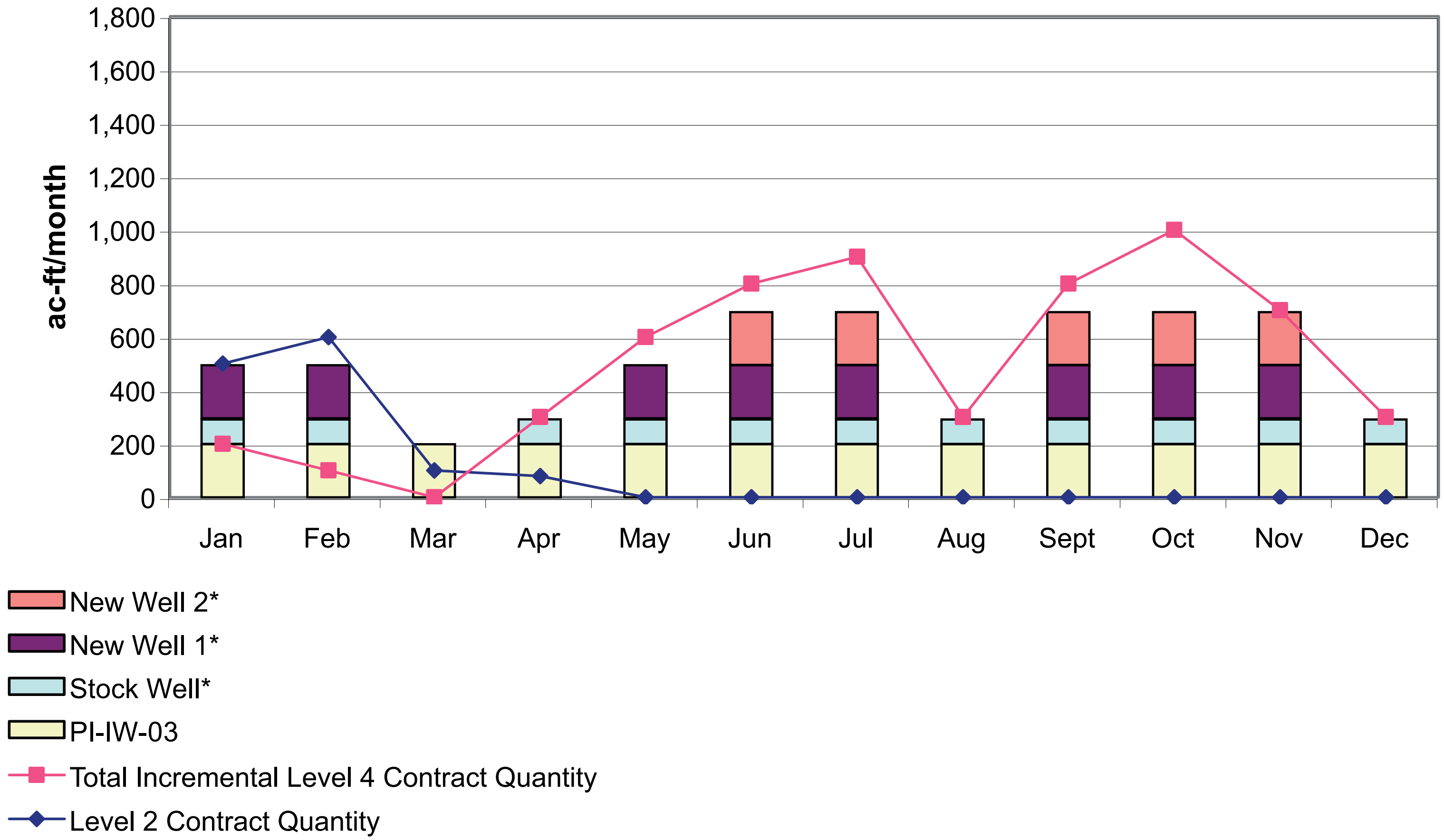

* Assumed production rates of 750 gpm (stock well) and 1,500 gpm (all others).

FIGURE D-3
INCREMENTAL LEVEL 4 WATER SUPPLY AT PIXLEY NWR WITH THREE ADDITIONAL WELLS
EVALUATION OF GROUNDWATER POTENTIAL
FOR INCREMENTAL LEVEL 4 REFUGE WATER SUPPLY

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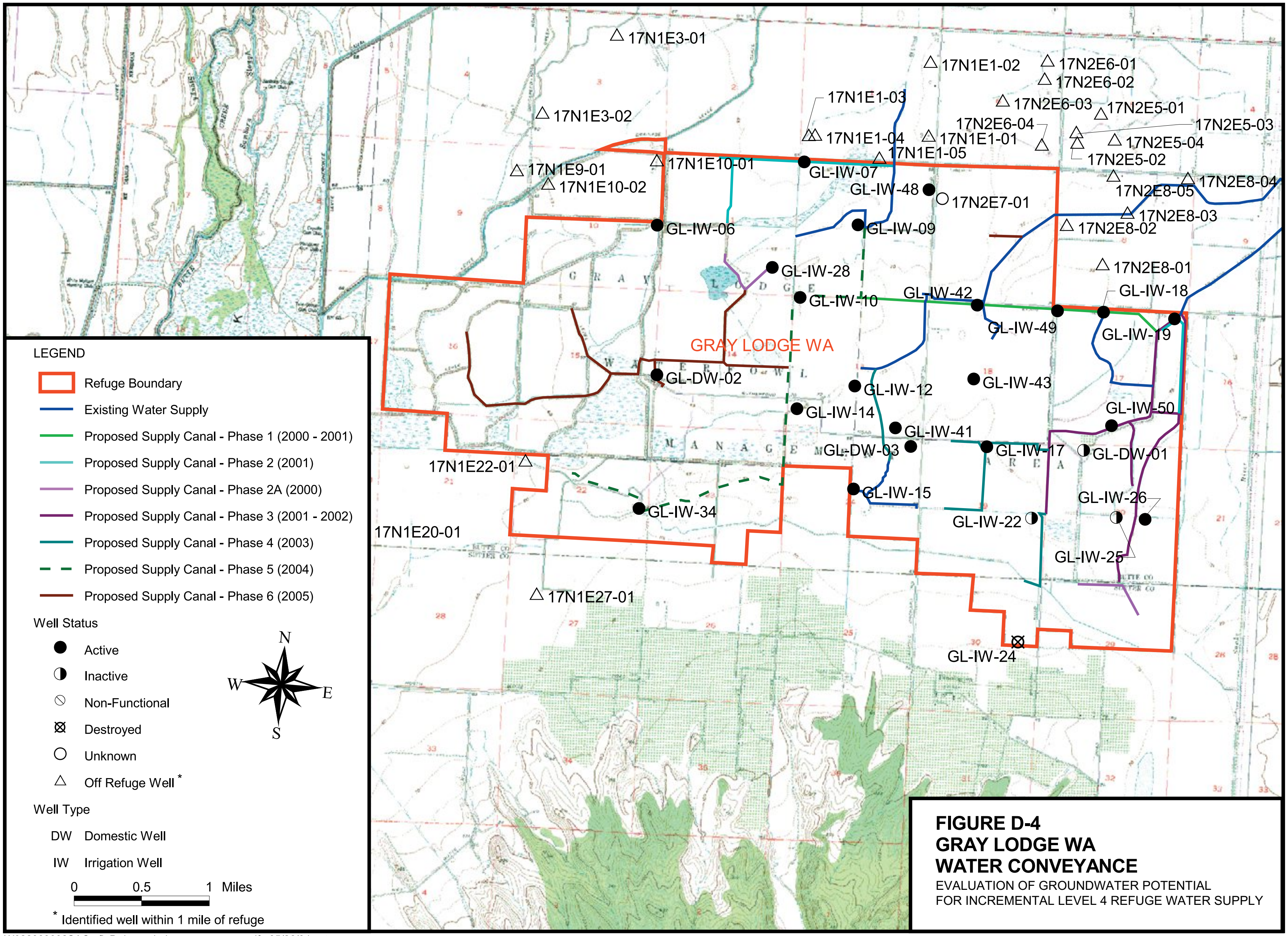

FIGURE D-4
GRAY LODGE WA
WATER CONVEYANCE
EVALUATION OF GROUNDWATER POTENTIAL
FOR INCREMENTAL LEVEL 4 REFUGE WATER SUPPLY

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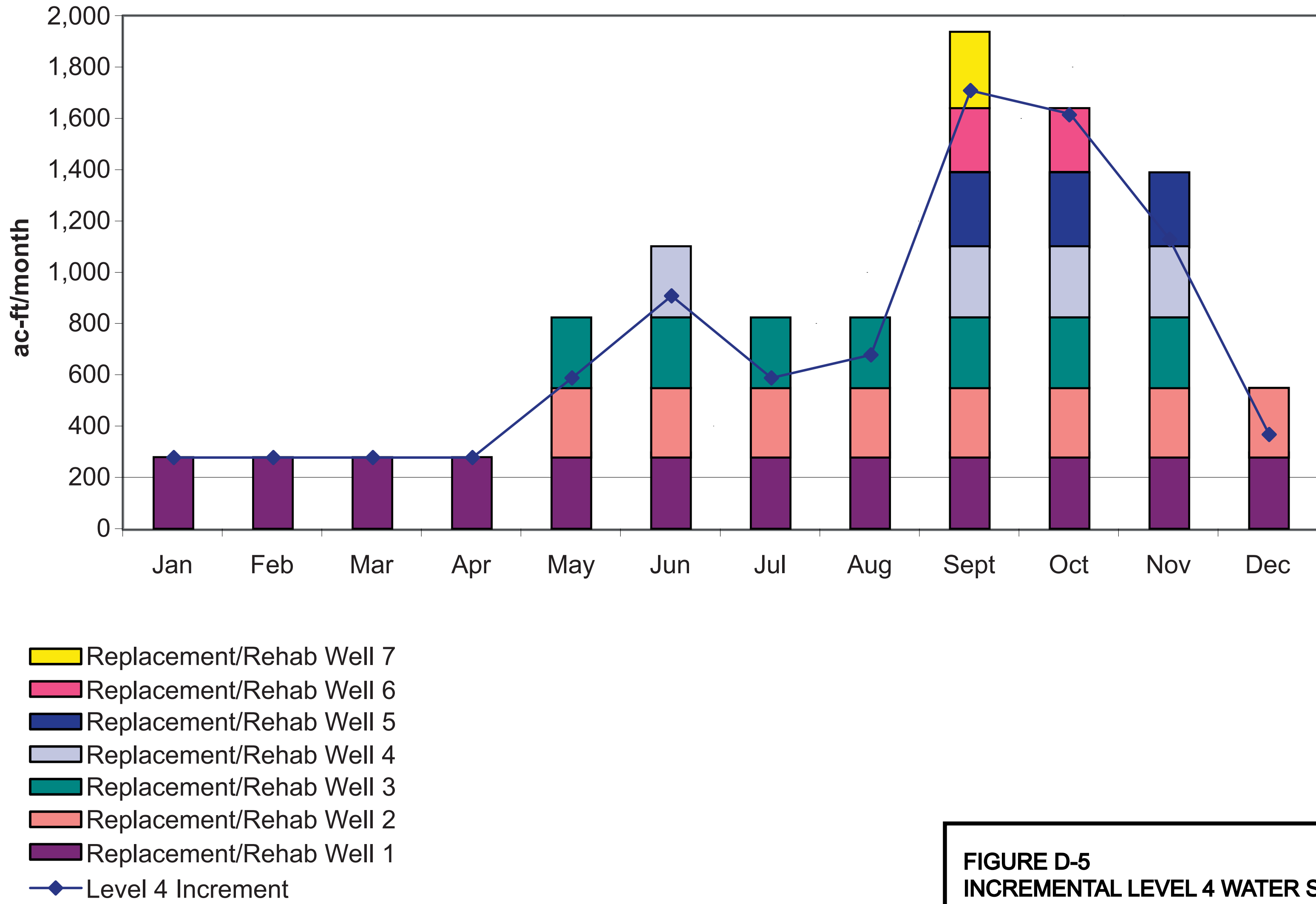

Note: Assumed production rate of 2,000 gpm per well.

FIGURE D-5
INCREMENTAL LEVEL 4 WATER SUPPLY AT GRAY LODGE WILDLIFE AREA WITH DEDICATED USE OF NINE WELLS
EVALUATION OF GROUNDWATER POTENTIAL
FOR INCREMENTAL LEVEL 4 REFUGE WATER SUPPLY

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APPENDIX E

Refuge Groundwater Development Issues

Several issues arose during refuge meetings, evaluation of data, and consideration of potential projects. Some of these issues could not be addressed directly during the completion of this report, but may affect subsequent consideration or implementation of future groundwater projects. They are presented and discussed here briefly to indicate their potential importance to implementing use of groundwater to supply Level 4 water to any of the refuges.

- **Water Quality Goals**—The quality of water the refuges use for irrigation and habitat management varies according to region, available water supply, and habitat management. An interagency group is establishing a series of consistent goals. Protection of water quality and habitat is one of the highest priorities for refuge staff.
- **Facility Condition/Energy Costs—** As shown on Table 1-2, the majority of the refuges use groundwater as a source of supply only occasionally (generally in drier year type conditions) or not at all. Few of the existing on-refuge wells are routinely maintained. Reasons wells have not been used recently include concern about water quality, availability of surface supplies, and relatively high pumping costs. Escalating energy costs (associated with pumping) continue to be a concern statewide; on-refuge pumping operational costs may also be limited by federal funding availability.
- **Aquifer Impacts—**Limited detailed information is available in many areas (particularly the Sacramento Valley) with respect to groundwater pumping and potential impacts to groundwater levels. Pumping in some areas has been discouraged due to concerns over possible local aquifer impacts and would need to be further investigated depending on the degree of pumping proposed for some refuges.
- **San Joaquin River Water Quality and Total Maximum Daily Loads (TMDL)**—Watershed managers are increasingly considering TMDLs and impacts to local surface water bodies. If water discharged from a refuge is of a significantly different water quality because a refuge is using groundwater, then those impacts will need to be considered as part of a subsequent feasibility evaluation. This could not be determined at this phase of the investigation, because specific water quality data for wells to be considered for use were not available.
- **CVRWQCB (Central Valley Regional Water Quality Control Board) Conditional Waiver of Waste Discharge Requirements for Discharges from Irrigated Lands**—This recent decision by the CVRWQCB may apply to refuges. Implications will be evaluated further as the Board clarifies its position.
- **Level 4, 25 Percent Cost**—CVPIA requires that 25 percent of the cost to supply Level 4 water be borne by the managing agency. For the state refuges, this is a significant issue and cost factor. With ongoing state budget issues, this may be an unsupportable financial component. The questions of which agencies will pay and how they will pay for the increased costs associated with using groundwater will be an issue addressed outside the scope of this report.

- **Long-Term Loss of Surface Water**—Most refuge operations rely wholly or primarily on the availability of high-quality surface water. This water is considered to be optimal for refuge management because it is easily accessible and of high quality. It is important for the managers to have the ability to maintain "flow-through" of their ponds to minimize disease and periodically "flush" their systems. There is a concern that if refuges use more groundwater, thereby freeing up the surface water they currently use, their ability to access the surface water in the future will be diminished.

- **Environmental Protection**—Refuges would like to support each other; if they free up surface water, they would support the use of that water for improvements to or expansion of the refuge system.