Table of Contents

Tables

Figures

Appendices

J:\040190 Stanislaus & Tuolumne Rivers Gdwtr\GW Mgmt Plan\Public Draft 04-19-05\R-IRGMP Public Draft.doc

Abbreviations and Acronyms

AB 3030	Groundwater Management Act
Association	Stanislaus and Tuolumne Rivers Groundwater Basin Association
B-E/GEI	Bookman-Edmonston, a Division of GEI Consultants
bgs	below ground surface
BMOs	Basin Management Objectives
CVRWQCB	Central Valley Regional Water Quality Control Board
DBCP	dibromochloropropane
DEH	San Joaquin County Department of Environmental Health
DER	Stanislaus County Department of Environmental Resources
DWR	Department of Water Resources
DWSAP Program	Drinking Water Source Assessment and Protection Program
EC	electrical conductivity
EDP	ethylene dibromide
gpd/ft	gallons per day per foot
gpm	gallons per minute
IRGMP	Integrated Regional Groundwater Management Plan
MCL	maximum contaminant level
mg/l	milligrams per liter
mgd	million gallons per day
MID	Modesto Irrigation District
MRWTP	Modesto Regional Water Treatment Plant
OID	Oakdale Irrigation District
PBE	Physical Barrier Effectiveness
PCAs	Potential Contaminating Activities
PCE	perchloroethylene
SB 1938	Groundwater Management Planning Act of 2002

SB 1672	Integrated Regional Water Management Planning Act of 2002
SSJID	South San Joaquin Irrigation District
TCE	trichloroethylene
TDS	total dissolved solids
TID	Turlock Irrigation District
USGS	U.S. Geological Survey
VOCs	volatile organic compounds
WHPA	Wellhead Protection Area
µg/L	micrograms per liter
µmhos/cm	micromhos per centimeter

1 Introduction

1.1 Introduction

In April 1994, six agencies covering the Modesto Groundwater Subbasin formed the Stanislaus and Tuolumne Rivers Groundwater Basin Association (Association) to provide a forum for coordinated planning and management of the subbasin. These six agencies are:

- The City of Modesto
- The Modesto Irrigation District (MID)
- The City of Oakdale
- The Oakdale Irrigation District (OID)
- The City of Riverbank
- Stanislaus County

Since 1994, the Association has been actively engaged in management of the subbasin. In late 2003, the Association began developing an integrated regional groundwater management plan in compliance with the Groundwater Management Planning Act of 2002 (SB 1938) and the Integrated Regional Water Management Planning Act of 2002 (SB 1672). The Association selected Bookman-Edmonston, a Division of GEI Consultants (B-E/GEI), to assist in the preparation of this plan.

The six agencies rely on groundwater for some or all of their service area water needs. These agencies share the groundwater resource and, through the Association, provide coordinated planning to make the best use of groundwater to the mutual interests of the inhabitants. Throughout the planning process, other interested parties within the subbasin were encouraged to participate in the development of the plan. The Association coordinates its planning process with other neighboring water agencies as well as state agencies.

1.2 Integrated Regional Water Management Plan Subareas

The planning area includes the entire Modesto Groundwater Subbasin and part of the Eastern San Joaquin Groundwater Subbasin and includes all or most of the service areas of the six agencies constituting the Association.

The Modesto Groundwater Subbasin underlies all of MID, the City of Oakdale, and the City of Riverbank. However, a portion of OID overlies the Eastern San Joaquin Groundwater

Subbasin, and a portion of the City of Modesto service area overlies the Turlock Groundwater Subbasin. The entire subbasin and planning area is within Stanislaus County.

OID's jurisdictional boundaries reach beyond the boundaries of the Modesto Groundwater Subbasin, and the study area has been extended to include OID's complete jurisdiction. However, this management plan is simply called the Integrated Resources Groundwater Management Plan (IRGMP) for the Modesto Subbasin. A similar water planning effort is under way in the Turlock Groundwater Subbasin. The portion of the City of Modesto service area within the Turlock Subbasin is covered in the Turlock groundwater planning process. A map of the study area and agencies involved are shown in Figure 1-1.

1.3 Stanislaus and Tuolumne Rivers Groundwater Basin Association

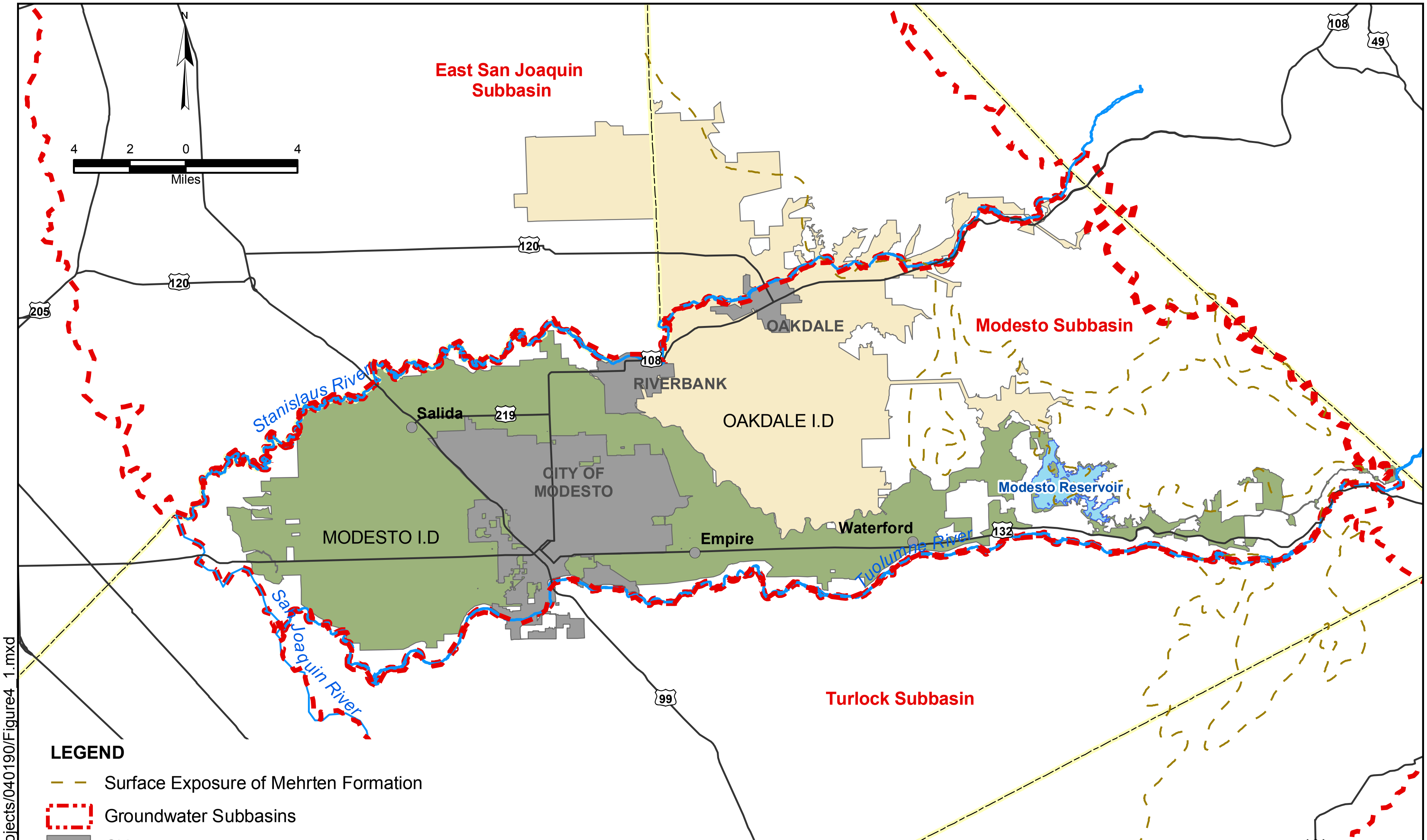
This IRGMP is a product of the efforts of the six cooperating agencies noted above that formed the Association through a memorandum of understanding signed in April 1994. The Association was created to provide a forum in which the parties could work cooperatively to combine the available talent and resources of the parties' respective organizations, to provide coordinated planning to make the best use of available water resources of the subbasin to meet the needs of the parties, and to accomplish the Association's stated purposes. A copy of the memorandum of understanding is presented in Appendix A. The purposes of the Association are:

- To determine and evaluate the subbasin's groundwater supply
- To promote coordination of groundwater management planning activities, including the preparation of the groundwater management plan
- To develop a hydrologic groundwater model of the groundwater basin
- To determine the subbasin's need for additional or improved water extraction, storage, delivery, conservation, and recharge facilities
- To provide information and guidance for the management, preservation, protection, and enhancement of groundwater quality and quantity in the subbasin

1.4 Accomplishments of the Stanislaus and Tuolumne Rivers Groundwater Basin Association

Since its inception, the Association has successfully provided for:

- Better understanding of the groundwater basin, its aquifers, geology, water quality, water level fluctuations, and potential sources and mitigation of contaminants.



SOURCES: City of Modesto, Modesto Irrigation District, City of Oakdale, Oakdale Irrigation District, City of Riverbank, CA Dept of Water Resources Groundwater Basins, 2002, California Spatial Library.

Bookman-Edmonston
A Division of GEI Consultants

INTEGRATED REGIONAL GROUNDWATER MANAGEMENT PLAN FOR THE MODESTO BASIN

Management Areas and Agencies

JUNE 2005

FIGURE 1-1

05-10-04 S:/GIS/Projects/040190/Figure4_1.mxd

- Cooperative working relationship among all agencies, combining their financial strength, and sharing of resources to better managing their groundwater.

- A forum for coordinated and uniform data collection, and water management activities.

- Regular meeting of the member agencies to share and learn from each other's experiences to discuss water management issues, and to assist one another to resolve those issues.

Some of the Association's specific accomplishments include:

- Six public agencies voluntarily working together under the umbrella of a locally controlled and managed groundwater association. The working relationship is defined by the Memorandum of Understanding Relating to the Formation and Operation of the Stanislaus and Tuolumne Rivers Groundwater Basin Association. Meetings of the Association are held at 2 p.m. on the first Thursday of every month in the MID offices, located at 1231 11th Street, Modesto, California. These meetings are open to the public.

- Development of a coordinated groundwater data collection and monitoring program, the extension of groundwater monitoring to selected privately owned wells to provide a more comprehensive view of groundwater elevations throughout the subbasin, and collecting spring and fall water levels throughout the Modesto Subbasin from all participating agencies' groundwater well networks.

- Developing a basin-wide integrated regional groundwater management plan consistent with SB 1938. The updated plan is scheduled for individual public agency adoption in early 2005.

- Formation of the Regional Water Management Planning Group consistent with SB 1672 (Costa).

- Entered into an agreement with the California Department of Water Resources through a Memorandum of Understanding to Work Cooperatively Together to Improve Surface Water and Groundwater Management and to Promote Conjunctive Use Projects and Programs in the Modesto Groundwater Subbasin (Appendix B).

- The Association provides local share funding for the multi-year, multi-phased study sponsored by the U.S. Geological Survey (USGS) (*Modesto Groundwater Basin Characterization,* November 2004). The study is entering its third phase. *Scientific Investigations Report 2004-5232,* published by the USGS in November 2004, summarizes the findings and recommendations from Phase One.

- The Association provided information and other input into the triennial report, *Recommendations for Improving Groundwater in Stanislaus County*.
- Implementation of an agreement between two members of the Association, MID and the City of Modesto, for the delivery of surface water to the City to reduce groundwater pumping, hence reducing localized overdraft and contaminant migration in the subbasin.
- Development of a wellfield optimization project.

1.5 Groundwater Management Subareas

For the purpose of developing this groundwater management plan, the study area has been divided into six management subareas representing the jurisdictional boundaries of the Association's member agencies. The groundwater management subareas are:

- The City of Modesto management subarea. This area includes the communities of Empire, Del Rio, and Salida and the service area of the City of Modesto that is north of the Tuolumne River. However, the City's service area south of the Tuolumne River in the Turlock Groundwater Subbasin is covered under a separate groundwater management plan being developed for the Turlock Subbasin.
- The Modesto Irrigation District management subarea. This area includes MID's service area and is entirely located within the Modesto Groundwater Subbasin.
- The City of Oakdale management subarea. This area includes the service area of the City of Oakdale and is located entirely within the Modesto Groundwater Subbasin.
- The Oakdale Irrigation District management subarea. This area covers OID's entire service area. About 60 percent of the OID service area is located within the Modesto Groundwater Subbasin and 40 percent is in the Eastern San Joaquin Groundwater Subbasin.
- The City of Riverbank management subarea. This area covers the service area of the City of Riverbank and is entirely within the Modesto Groundwater Subbasin.
- The Stanislaus County management subarea. This area includes the entire study area within the Modesto Groundwater Subbasin and that part of Stanislaus County in the Eastern San Joaquin Groundwater Subbasin that is not covered by the five management subareas listed above.

Figure 1-1 shows the six management subareas as described above.

1.6 Ongoing Groundwater Management-Related Activities

With the exception of some localized areas, groundwater levels are generally stable in the Modesto Groundwater Subbasin and OID service area in the Eastern San Joaquin Groundwater Subbasin. However, increased urban development and changes in irrigation management practices threaten the balance by increasing demand for groundwater and by reducing recharge. It is the objective of the participating agencies to ensure that overall groundwater levels are maintained to provide a reliable long-term source of water.

To manage the basin's groundwater resources, the Association member agencies regularly exchange information and arrange for uniform groundwater data collection and monitoring to better understand the groundwater basin. In 1998, the Association developed a data collection protocol to standardize the data collection procedures among the member agencies. Data is collected in a coordinated fashion biannually. A copy of the current data collection protocol is provided in Appendix C.

Conjunctive use management, in-lieu recharge through the local use of surface water for municipal and industrial purposes, and the protection of groundwater quality and water levels are actions that have been discussed for the long-term beneficial use of the basin. To that extent, MID and the City of Modesto developed and executed a treatment and delivery agreement under which MID supplies treated surface water to the City of Modesto, which uses it to augment is drinking water supply.

Another avenue for helping to maintain groundwater levels is urban water conservation and the installation of water meters. Implementation of the best management practices, including the installation of water meters, can reduce water consumption, improve the overall water supply reliability, and reduce stress on the groundwater system.

A detailed discussion of the water conservation is presented in the various agencies' urban water management plans.

In addition to maintaining groundwater levels, protecting groundwater quality is an important objective for the Association's member agencies. Actions that are being implemented or considered to achieve this objective include conducting a geological assessment to identify areas of poor water quality; controlling water table elevations to contain poor quality water; sealing and abandoning wells to eliminate pathways for contamination; and protecting natural recharge areas from exposure to pollutants.

Land surface subsidence in the basin is not significant. The potential for future land subsidence appears to be remote.

2 Need for Groundwater Management Planning

Groundwater is a precious resource. It is a reliable water source for the agricultural, urban, and industrial needs of the Modesto Subbasin. Increases in population and corresponding increases in groundwater use have resulted in a lower groundwater table in some areas of the Modesto Subbasin and may have contributed to groundwater degradation, especially within the boundaries of the City of Modesto. The water agencies in the subbasin agreed to reevaluate their groundwater management practices and examine opportunities for integration of their surface and groundwater resources. The agencies formed the Association and signed a memorandum of understanding to work cooperatively to resolve their water issues and manage the basin. The signatories also agreed to be involved and cooperate in the development of a groundwater management plan. They have agreed to build upon their recent achievements and prepare a regional and integrated water management plan. Therefore, this IRGMP is being developed as an integrated and regional plan in compliance with SB 1938 and SB 1672.

2.1 Legislative Requirements

SB 1938, as passed by California Legislature and signed into law by the Governor in 2002, amended the Water Code section 10750 *et seq.* to require that new groundwater management plans prepared under the Groundwater Management Act (AB 3030) include the components listed below:

- Documentation that a written statement was provided to the public describing the manner in which interested parties might participate in developing the groundwater management plan. This may include appointment of a technical advisory committee of the stakeholders in the basin.
- Development of Basin Management Objectives (BMOs).
- Adoption of monitoring protocols or a monitoring program capable of tracking changes in conditions for the purpose of meeting BMOs.
- Preparation of a map showing the area of the groundwater basin, as defined by the Department of Water Resources' (DWR) Bulletin 118, with the area of the local agencies subject to the plan as well as the boundaries of other agencies that overlie the basin in which the agency is developing a groundwater management plan.
- A description of the components relating to the monitoring and management of groundwater levels, groundwater quality, inelastic land surface subsidence, and

changes in surface flow and surface water quality that directly affect groundwater levels or groundwater quality.

- Preparation of a plan of actions by the managing entity to involve other agencies and that enables the local agencies to work cooperatively with other public entities whose area or boundaries overlie the groundwater basin.
- The Groundwater Management Plan must be adopted by the local managing agency.
- Provisions for periodic reporting of the groundwater management activities and groundwater basin conditions.

In 2002, SB 1672 was also passed by the legislature and signed into law. This law authorizes a regional water management group, as defined, to prepare and adopt a regional plan relating to water supply, water quality, flood protection, or related matters. This law defined procedures to form a regional water management group, to communicate to the public, and to prepare and adopt an integrated regional water management plan.

2.2 IRGMP Components

This plan has been prepared in accordance with requirements of SB 1672 and SB 1938. As such, the plan includes components of AB 3030 and SB 1938 (California Water Code Section 10750 *et seq.*) and SB 1672 (California Water Code Section 10540 *et seq.*). Table 2-1 lists the sections in which each component is addressed. Appendix D is the Groundwater Monitoring Plan (October 2004).

2.3 Purpose and Goals of the Groundwater Management Plan

The purpose of this IRGMP is to provide a framework for coordinating groundwater and surface water management activities into a cohesive set of management objectives and implementing the actions necessary to meet those objectives.

The goal of the IRGMP is to provide for the integrated use of groundwater and surface water within the basin to ensure the reliability of a long-term water supply to meet current and future beneficial uses including agricultural, industrial, and municipal water requirements while protecting the environment.

2.3.1 Water Management Strategies

The regional management actions, described later in this plan, reflect a comprehensive approach to managing water resources in the Modesto Groundwater Basin. In particular, these actions support the following water management strategies:

Table 2-1
Location of Association Groundwater Management Plan Components

A. CWC § 10750 *et seq*., Required Components (SB 1938)		
1.	Documentation of public involvement statement.	2.1, Section 7
2.	Basin Management Objectives (BMOs).	5.4
3.	Monitoring and management of groundwater elevations, groundwater quality, inelastic land surface subsidence, and changes in surface water flows and quality that directly affects groundwater levels or quality or are caused by pumping.	5.6, 5.7, 8.2, Appendix A
4.	Plan to involve other agencies located within groundwater basin.	1.2, 1.3, 2.3
5.	Adoption of monitoring protocols by basin stakeholders.	5.7, Appendix D
6.	Map of groundwater basin showing area of agency subject to GMP, other local agency boundaries, and groundwater basin boundary as defined in DWR Bulletin 118.	1.2, 5.3
7.	For agencies not overlying groundwater basins, preparation of GMP using appropriate geologic and hydrogeologic principles.	NA
B. DWR's Suggested Components		
1.	Management with guidance of advisory committee.	7.3
2.	Description of area to be managed under GMP.	1.2, 5.3
3.	Creation of link between BMOs and goals and actions of BMP.	Section 6, 8.2
4.	Description of GMP monitoring program.	5.7, Appendix D
5.	Description of integrated water management planning efforts.	2.3
6.	Report on implementation of GMP.	Section 8
7.	Periodical evaluations of GMP.	8.5
C. CWC § 10750 *et seq*., Voluntary Components (AB 3030)		
1.	Control of saline water intrusion.	2.5, 6.8
2.	Identification and management of wellhead protection areas and recharge areas.	2.5, 6.1
3.	Regulation of the migration of contaminated groundwater.	2.5, 6.2
4.	Administration of well abandonment and well destruction program.	2.5, 6.4
5.	Mitigation of conditions of overdraft.	2.5, 6.5
6.	Replenishment of groundwater extracted by water producers.	2.5, 6.6
7.	Monitoring of groundwater levels and storage.	2.5, 5.7, Appendix D
8.	Facilitating of conjunctive use operations.	2.5, 6.7
9.	Identification of well construction policies.	2.5, 6.3
10.	Construction and operation by local agency of groundwater contamination cleanup, recharge, storage, conservation, water recycling, and extraction projects.	2.5, 6.7
11.	Development of relationships with state and federal regulatory agencies.	2.5, 8.1
12.	Review of land use plans and coordination with land use planning agencies to assess activities that create reasonable risk of groundwater contamination.	2.5, 3.4
D. Integrated Regional Planning (SB 1672)		
1.	Integration of water resource managemen activities.	1.2, 5.2, 8.3, 8.6, 8.7
2.	Regional planning and management.	1.2, 5.2, 8.3, 8.6, 8.7,
3.	Formation of a regional management group	Section 7
4.	Public involvement.	2.1, Section 7
5.	Development of local, regional, and statewide priorities.	8.2, 8.7

- Increase local and regional water supply reliability and water use efficiency
- Promote groundwater recharge and management
- Support water conservation
- Implement watershed management programs
- Promote water recycling
- Foster conjunctive use
- Improve water quality
- Improve storm water capture and management

Other regional water management elements, such as providing for recreation and river restoration, are addressed in other planning documents prepared by the participating agencies.

2.4 Authority to Prepare Integrated Regional Groundwater Management Plan

The governing bodies of the Modesto and Oakdale Irrigation Districts and the Cities of Modesto, Oakdale, and Riverbank have elected, through the issuance of resolutions, to prepare this IRGMP to effectively manage the surface and groundwater resources of the basin. The specific authority of each agency is as follows:

- MID was formed on July 23, 1887, under the California Irrigation District Act (Wright Act) and is authorized to manage surface and groundwater resources for the benefits of the District landowners.
- OID was organized under the Wright Act on November 1, 1909, to manage its water resources, including surface water and groundwater supplies.
- The Cities of Modesto, Oakdale, and Riverbank are incorporated and authorized to provide for management and distribution of drinking water to their citizens.
- The County of Stanislaus is a water purveyor for a small public water system in the Modesto subbasin. It is a member of the Association and a member of the technical advisory committee to assist in and guide the preparation of the IRGMP. The County may choose, under SB 1672 and as a member of regional management group, to adopt the IRGMP after it is prepared.

3 Water Resources Setting

3.1 Land and Water Uses Within the Study Area

The Modesto Groundwater Subbasin lies between the Stanislaus River to the north and the Tuolumne River to the south and between the San Joaquin River on the west and crystalline basement rock of the Sierra Nevada foothills on the east. The surface area of the subbasin is 247,000 acres.

The northern, western, and southern boundaries are shared with the Eastern San Joaquin Groundwater, Delta-Mendota, and Turlock Groundwater Subbasins, respectively. The major water purveyors in the planning area include MID, OID, and the Cities of Modesto, Riverbank, and Oakdale. The southern 60 percent of OID is in the Modesto Groundwater Subbasin and 40 percent is in the Eastern San Joaquin Groundwater Subbasin. Modesto is in the southwestern portion of the subbasin, and a portion of the city is located south of the Tuolumne River in the Turlock Groundwater Subbasin. Oakdale and Riverbank lie in the north-central portion. Developed land uses within the Modesto Groundwater Subbasin are concentrated in two major categories, irrigated agricultural and urban land uses. The largest jurisdiction within the subbasin is MID, with a service area of 101,700 acres and an irrigated area of approximately 62,000 acres. Nested within MID is the city of Modesto and the communities of Waterford, Empire, Salida, and parts of Del Rio and Riverbank. Modesto alone occupies approximately 40 square miles or 25,600 acres.

OID has a total service area of approximately 72,000 acres, of which approximately 43,200 acres lie within the Modesto Groundwater Subbasin and the remaining 28,800 acres are within the Eastern San Joaquin Groundwater Subbasin. Nested within OID is the city of Oakdale, which covers approximately 2,000 acres and has not been detached from OID, and the city of Riverbank, which covers around 1,760 acres, much of which has been detached. The eastern portion of the subbasin is foothill lands that are primarily rangeland and undeveloped.

3.2 Major Water Purveyors in the Basin

3.2.1 City of Modesto

3.2.1.1 Background

The City of Modesto was first incorporated in 1877 and operates as a Charter City. It was originally to be named Ralston after the prominent San Francisco banker, William Ralston. However, when he declined the honor, the name of Modesto was selected. Since its founding, Modesto has grown to a city of over 200,000 people in 2004.

The City of Modesto has provided potable water service to its urban area since 1985 through the purchase and acquisition of several private water companies. The sole source of water supply until 1995 was groundwater from the Modesto and Turlock Groundwater Basins. Groundwater levels declined from 1924 through 1994 in the downtown area due to increasing urban uses.

In the early 1990s, the City, MID and the Del Este Water Company formed a partnership and signed a treatment and delivery agreement to utilize MID's surface water rights for municipal purposes. The Modesto Domestic Water Project and completion of the Modesto Regional Water Treatment Plant (MRWTP) were the result of this partnership. The project consists of a 30-million-gallon-per-day (mgd) surface water treatment plant and storage and delivery facilities, which were completed in January 1995. Its implementation has allowed the City of Modesto to reduce its groundwater pumping, which has led to a recovery in groundwater levels.

In the mid-1990s, the City of Modesto acquired the Del Este Water Company, which had previously served approximately 30 percent of the municipal customers in the Modesto area. As a result, the City became the retail water purveyor to the communities of Waterford, Hickman, Del Rio, Salida, Grayson, and parts of Ceres and Turlock, in addition to county islands within Modesto. The Modesto Domestic Water Project provides water to municipal customers served by the City of Modesto north of the Tuolumne River, which is the overlapping service area of both the City and MID.

3.2.1.2 Location

Modesto covers approximately 36 square miles in Stanislaus County (see Figure 1-1). The portion of the city north of the Tuolumne River encompasses 34 square miles (94 percent of the service area) and lies within the Modesto Groundwater Subbasin. The portion of the city south of the Tuolumne River encompasses 2 square miles (6 percent of the service area) and lies within the Turlock Groundwater Subbasin.

3.2.1.3 Water Supply

Sources of the City's water within the Modesto Groundwater Subbasin include groundwater from the Modesto Groundwater Subbasin and treated surface water from MID. The City of Modesto supplies approximately 60 percent of its water from City-owned and operated wells. Prior to the completion of the MRWTP, the City of Modesto and the surrounding communities relied solely on groundwater for their domestic supply. The MRWTP EIR noted that groundwater levels were declining, particularly near the center of Modesto, and that with declining water levels, water quality degradation had been observed.

3.2.1.4 Facilities

The City's water system includes over 70,000 water connections, 927 miles of water lines system, 118 water wells, and seven water tanks. Of these wells, 108 withdraw water from the Modesto Groundwater Subbasin. The City does not conduct land use planning in the areas it serves that were formerly within the Del Este system outside the City's Sphere of Influence.

Table 3-1 shows groundwater production by the City of Modesto from 1999 through 2003. Average groundwater use from the Modesto Groundwater management subarea during this period was 45,300 acre-feet per year, which, when combined with 33,600 acre-feet of surface water available from the MRWTP, results in a total supply to the joint MID-City of Modesto service area of 78,900 acre-feet. Assuming that the MRWTP's capacity is increased from 30 mgd to 60 mgd, the available normal year water supply for the joint service area would increase to about 112,000 acre-feet in 2008. During supply shortage years, the delivery of treated surface water by MID may be reduced in equal proportions with deliveries to its agricultural customers. The City, however, has the option of receiving its full contract surface water and making up these shortages by delivering groundwater for an amount equal to shortages to the irrigation canal system. The City presently operates 108 drinking water wells in the Modesto Groundwater Subbasin, including the former Del Este wells.

Table 3-1
Groundwater Production by the City of Modesto

Year	Acre-Feet
1999	45,140
2000	42,100
2001	44,900
2002	47,700
2003	46,780
Average	45,300

3.2.1.5 Ongoing Activities

The City of Modesto's partnership with MID to provide domestic water is an important conjunctive use effort. Other ongoing groundwater management activities by the City of Modesto include the following:

- Active participation in the Association to manage the basin's groundwater resources
- Conjunctive use of groundwater and surface water supplies
- Utilize a SCADA system for the remote operation and monitoring of wells
- Test water quality in accordance with Title 22
- Enacted a well ordinance adopting the California Wells Standards (Bulletin 74-81) and all supplements
- Implementing provisions of the certified Urban Water Management Plan

- Regulation of wastewater disposal

The City received a grant for a feasibility study for the Regional Water Recycling Project. This study investigated the feasibility of collecting the wastewater effluent from a number of cities, including Oakdale and Riverbank. The wastewater from the advanced wastewater treatment plant could be available to the City for non-potable reuse (i.e., crops and landscape irrigation) or water exchanges with other water agencies within the basin.

The City of Modesto Stormwater Program was established in 1993 to meet the objective of effectively eliminating illicit discharges to the storm drain system, reducing the discharge of pollutants from the system, and protecting the groundwater and surface water resources. To meet these objectives, the City prepared a Stormwater Management Plan that has served as the road map for the implementation of the City's storm water program. The plan consists of seven program elements to control the discharge of pollutants and a monitoring program to characterize storm water discharges and assess the health of the receiving waters.

The City currently irrigates approximately 3,000 acres of fodder and feed crops on City-owned land.

3.2.1.6 Issues of Concern

Declining water quality, combined with increasingly strict standards from state and federal regulatory agencies, have forced the City to take an average of 2.3 wells out of service each year (West Yost 2004). The City closely monitors groundwater quality and those wells showing high nitrates have remained out of service. The City employs some well-head treatment and uses granular activated carbon to remove organics and chlorination to disinfect the distribution system. The City has also identified four wells that will not currently meet the federal and state arsenic limits of 10 milligrams per liter without treatment (West Yost 2004). Ongoing USGS investigations have also identified uranium as a constituent of concern.

Future groundwater production may be limited by water quality issues and the cost and availability of well-head treatment technologies. In addition to arsenic, primary constituents of concern in groundwater are dissolved solids, hardness, major ions (probably iron and manganese), organics, radionuclides, and nitrates.

The City's general plan projects that its population will grow from a current population of approximately 206,200 to approximately 400,000 by build-out of the general plan area. With a limited groundwater supply and groundwater quality issues, meeting the City's future needs will be challenging and may require the identification of additional surface water supplies and the implementation of water management options, such as water conservation, recycling, and conjunctive use.

3.2.2 Modesto Irrigation District

3.2.2.1 Background

MID is a public utility that supplies surface water, groundwater, and electrical service to agricultural and municipal customers throughout its 101,700-acre service area. MID was formed on July 23, 1887, the second irrigation district to be established under the California Irrigation Districts Act (Wright Act). During its early years, MID developed numerous rights for Tuolumne River water and facilities to irrigate agricultural lands and to generate electricity using this water.

The primary economy within the district is agriculture or agriculture-related businesses. The primary crops grown within MID are trees (mostly almonds), vines, grain, row crops, and pasture. The average farm size is approximately 20 acres, and approximately 3,000 farms lie within the district. Currently, MID serves approximately 3,000 irrigation water customers and 62,000 irrigated acres.

3.2.2.2 Location

MID is located in eastern Stanislaus County and is bounded on the north by the Stanislaus River, on the south by the Tuolumne River, on the west by the San Joaquin River, and on the east by the Sierra Nevada Mountains (Figure 1-1). The district is located entirely within the Modesto Groundwater Subbasin.

3.2.2.3 Water Supply and Storage Facilities

MID obtains its surface irrigation water from the Tuolumne River. The river’s 1,880-square-mile watershed extends to the High Sierra and most of the river’s flow comes from snowmelt. Peak flows occur between April and July, when over 60 percent of the annual flow occurs. Annual Tuolumne River runoff average over 1,800,000 acre-feet, varying from a low of 383,000 acre-feet in 1977 to a high of 4,631,000 acre-feet in 1983.

MID’s first project as a public entity was the La Grange Dam, completed on December 13, 1893, in conjunction with Turlock Irrigation District (TID). Nearly ten years later, on June 27, 1903, the main canal was completed and farmers along this canal began receiving water. By September of that year, other fields were being served by lateral canals.

Storage and the regulation of main canal deliveries began in 1911 with the completion of the 28,000 acre-foot Dallas-Warner Reservoir (now known as Modesto Reservoir). Carryover storage to protect permanent crops from extended drought was unavailable until the completion of Don Pedro Reservoir in 1923. This reservoir allowed MID to store a maximum of 102,000 acre-feet each year and to begin generating electricity from a power plant developed to help defray the cost of irrigation facilities. In 1970, MID and TID enlarged their storage and power generation capacity with the completion of New Don Pedro

Dam and Reservoir, with a storage volume of 2,030,000 acre-feet. New Don Pedro Reservoir is owned, operated, and maintained jointly by MID and TID.

3.2.2.4 Water Distribution Facilities

MID distributes a combination of Tuolumne River water and groundwater via a network of storage facilities, canals, pipelines, pumps, water table control wells, and control structures. Table 3-2 provides a summary of these irrigation facilities.

Table 3-2
MID Irrigation Facilities

Facility Type	MID Facilities	Improvement District and Private Facilities
Canals (lined)	142.2 miles	9.8 miles
Canals (unlined)	23.7 miles	----
Pipelines	44.4 miles	152.8 miles
Wells/Deep Well Pumps	96	575*
Sidegates	1,317	----
Structures, SCADA-Monitored and/or –Controlled	13 headgates, 5 spills, and 4 flow measurements	0
Structures, Chart-Monitored, Manually Controlled	12 spills and 4 flow measurements	0

*Number of non-MID deep wells with MID represent staff's best estimate. This number was derived from MID's electric power records and may not reflect the actual number of private deep wells within the MID service area.

Source: MID Final Groundwater Management Plan, Table 2-1.

Groundwater management in MID has been influenced by Modesto's rapid growth. For much of its history, Modesto relied exclusively on groundwater, and thus, its population growth has been accompanied by declining groundwater levels. Between 1924 and 1994, groundwater levels under Modesto declined about 42 feet, with most of this decline occurring after World War II. In 1994, its sole reliance on groundwater ended when MID completed the MRWTP, a 30 mgd domestic water project that treats Tuolumne River water for delivery to the City. This municipal and industrial water treatment plant has helped offset declining groundwater levels in the Modesto area.

3.2.2.5 Groundwater Use

MID has both irrigation wells and drainage pumping wells. Prior to widespread urban development, the large influx of surface water for irrigation in MID led to the development of a shallow water table on the west side of the district. To protect crops from the rising water table, groundwater management through shallow groundwater pumping was initiated in 1918. MID now owns and operates 55 water table control wells that are used to maintain groundwater levels below crop root zones. These wells are shallow (usually less than 100 feet), are perforated throughout their depth, and are generally pumped during the irrigation season. Water table control pumping protects lands by promoting the aeration of the root zone and by allowing naturally occurring salts to leach from the root zone. To the extent feasible, water from the water table control wells is pumped into the irrigation system to supplement surface water.

In recent years, water table control pumping has become less important. The reasons for this change include increased groundwater pumping in the urban area, the use of irrigation conservation practices and new irrigation technologies, and increased groundwater pumping for agriculture. The combined effect has resulted in a lowering of groundwater levels, allowing some MID water table control wells to be converted to irrigation wells to augment the district's surface water supply.

Because of the availability of surface water, significant groundwater pumping for irrigated agriculture did not occur in MID until the late 1970s, during one of the most severe droughts on record. MID now owns and operates 44 wells developed for the specific purpose of water supply. These wells are often used to smooth canal flow fluctuations, to improve irrigation delivery service, and to reduce canal spills. Many landowners in MID also operate their own irrigation wells. MID irrigation and water table control wells are tallied in Table 3-3.

Table 3-3
Description of MID Irrigation and Drainage Wells

Irrigation Wells	44
Water Table Control Wells	55
Well Construction Summary	98 by cable tool 1 by gravel pack
Casing Depths	50 to 400 feet
Annular Seals?	Required after 1985
Typical Depth of Seal	50 to 100 feet

Source: MID Final Groundwater Management Plan, Table 3-2.

3.2.2.6 Ongoing Activities

The MID partnership with the City of Modesto to provide domestic water is an important conjunctive use effort. Other ongoing activities conducted by MID include:

- Active participation in the Association to manage the basin's groundwater resources
- Monthly monitoring of all groundwater wells
- Estimation of pumping from agricultural wells
- Periodic agricultural suitability testing on all irrigation and drainage wells
- Periodic mapping of groundwater elevations
- Implementation of water conservation projects
- Water table control through pumping of water table control wells

3.2.2.7 Issues of Concern

The fundamental issue of concern for MID is maintaining a sustainable balance between groundwater use and groundwater recharge. Municipal and industrial water demand is projected to grow in the basin in response to increasing population. Urban water conservation and reuse practices can help buffer growth in demand. At the same time that groundwater use is expected to grow, some important pathways for groundwater recharge are expected to decline because of the urbanization of farmland and conversion of fields now irrigated using surface irrigation techniques to more intensively managed techniques (such as drip irrigation) that reduce both water applications and deep percolation. Some agencies are concerned that changing irrigation methods (e.g., from flood irrigation to drip irrigation) will reduce groundwater recharge and contribute to future declines of groundwater levels.

Groundwater use in the MID management area varies from year to year and increases significantly during drought years, when groundwater is a more significant component of the water supply. Groundwater quality in some locations in MID has been degraded from urban, industrial, and agricultural operations, and as groundwater recharge is reduced by urban development, less blending of groundwater results. This leads to an increasing concentration of salts and other contaminants and the increased risk of degradation. Agricultural water use efficiency that reduces deep percolation could be detrimental to groundwater levels and groundwater quality in some areas.

MID has identified a need to coordinate the operation of its wells to better respond to water supply, water table control, water quality management, and energy use objectives. In addition, identifying and protecting areas that may serve as dedicated groundwater recharge zones are priorities.

3.2.3 City of Oakdale

3.2.3.1 Background

The City of Oakdale provided water to a population of approximately 15,800 persons in 2001. The water system also provides potable water to commercial, industrial, and public facilities throughout the city.

3.2.3.2 Location

Oakdale is located near the geographical center of OID (Figure 1-1) and lies entirely within the Modesto Groundwater Subbasin.

3.2.3.3 Water Supply

The City of Oakdale draws water from nine wells located in the Modesto Groundwater Subbasin. Water pumped from the aquifer meets the standards of Title 22 and is suitable for direct potable use without treatment. The City's water supply system is operated under a permit granted by the California Department of Health Services on August 20, 1964. The permit has been amended as needed to reflect changes in system facilities.

3.2.3.4 Facilities

The City's water system consists of nine deep wells that supply groundwater to a distribution pipe network; two of these wells are newly completed. Currently, there is one 500,000-gallon steel storage reservoir located in northeast Oakdale at the intersection of Valley View Drive and the Stanislaus River bluff. The majority of the water system is controlled and monitored by a remote telemetry system located at the Public Works Center at Fifth and I Streets in southeast Oakdale. Table 3-4 describes the service connections in the city. Table 3-5 describes the characteristics of wells owned and operated by the City.

Table 3-4
Service Connections in the City of Oakdale

Type	Metered	Flat Rate	Total
General and Residential	5,175	5	5,180
Commercial	81	13	94
Industrial	19	0	19
Agricultural (irrigated)	0	0	0
Other Water Systems	8	0	8
Total Active Connections	5,283	18	5,301
Inactive Connections			62
Fire Hydrants			±630
Backflow Prevention Devices			±167

Source: City of Oakdale, Water Master Plan, page 2-1.

There are two active booster pumps operating within the distribution system. The Burchell Hill booster station is located in northeast Oakdale and provides the pressure needed to supply the Burchell residential subdivision and an older residential area to the west. The booster station at the site of Well 5A serves a high-pressure zone in the southern part of the city.

Table 3-5
Description of City of Oakdale Wells

Public Water Supply Wells	9
Well Construction Summary	98 by cable tool 1 by gravel pack
Casing Depths	
Annular Seals?	Yes
Typical Depth of Seal	

The water distribution system contains approximately 392,500 feet of mains, ranging in diameter from 2 to 16 inches. The original distribution system was all steel pipe. Over the last 13 years, asbestos cement pipe has been introduced, and most recently, PVC pipe has been used for system extensions and upgrades.

3.2.3.5 Water Use

The demand for municipal water depends, generally, on climate, distribution of land use, cost of water, availability of private sources of supply, landscape demand, and cultural attitudes. In Oakdale, nearly all residential, commercial, and industrial users are metered and average daily per capita water use for 2000–2001 was estimated to be 248 gallons. This is a typical rate for small San Joaquin Valley cities with metered water supplies. Studies indicate that metering and associated pricing may result in an approximately 10 to 20 percent reduction in a community's water consumption, an estimate supported by the observation that the average daily per capita water consumption for some San Joaquin Valley communities without meters ranges from 300 to 350 gallons.

3.2.3.6 Influence of Land Use on Water Use

The mix of land uses within a city influences water use. Open spaces such as parks or schools also have a smaller water demand than most industrial areas. Table 3-6 presents the distribution of various land use categories in the City of Oakdale.

Table 3-6
Distribution of Land Uses in the City of Oakdale

Land Use per General Plan	Area (acres)	Percentage
Agricultural	4.39	0.1
Agricultural residential	29.92	1.5
Central business district	101.79	5.1
Estate	0.05	0
General commercial	186.88	9.3
High-density residential	6.58	0.3
Industrial	179.65	9.0
Low-density residential	1,109.31	55.0
Medium-density residential	209.56	10.5
Office	13.50	0.7
Open space	7.95	0.4
Park	46.20	2.3
Public/semi-public	75.37	3.8
School	15.99	0.8
Single/family light-density residential	17.17	0.9
Total	2,004.31	100.0

Source: City of Oakdale, Water Master Plan, page 3-5

Table 3-7 presents the estimated annual average and maximum per capita daily water demands for Oakdale, given a 3 percent rate of population growth and two scenarios for per capita water consumption.

Table 3-7
Water Demand Projections for the City of Oakdale

Year	Estimated Population	Average Day (gallons per minute)		Maximum Day (gallons per minute)	
		(1)	(2)	(1)	(2)
2005	17,773	3,086	3,679	5,863	6,990
2015	23,886	4,147	5,884	7,879	11,180
Build-Out per General Plan		----	7,569	----	14,381

Source: City of Oakdale, Water Master Plan, page 3-11.

(1) Based on population projections and an average water consumption of 250 gallons per capita per day.

(2) Based on land use development from the Oakdale Planning Department and corresponding demand coefficients for various land uses.

3.2.3.7 Ongoing Activities

Ongoing groundwater management activities by the City of Oakdale include the following:

- Active participation in the Association to manage the basin's groundwater resources
- Monitor water levels in all wells monthly
- Test water quality in accordance with Title 22
- Enacted a well ordinance adopting the California Wells Standards (Bulletin 74-81) and all supplements

3.2.3.8 Issues of Concern

Issues of concern for the City of Oakdale are primarily related to the potential future degradation of groundwater quality and development taking place over recharge areas. Water levels in some wells are impacted by production wells at adjacent industrial plants.

3.2.4 Oakdale Irrigation District

3.2.4.1 Background

OID was organized on November 1, 1909, under the Wright Act. In July 1910, the OID and its neighboring district, the South San Joaquin Irrigation District (SSJID), purchased an established ditch system, known as the Tulloch System. This system was developed in the 1880s by Charles H. Tulloch, who had purchased the water rights, a ditch, and a small diversion dam built for working placer gravel near Knights Ferry. Farmers later extended the ditch, known as the Old Tulloch Ditch, into the valley area to serve some 6,000 acres of farmland, including an area around Oakdale.

Currently, OID encompasses approximately 72,345 gross acres that support four major groups of crops—irrigated pasture, oats-corn (double crop), rice, fruits and nuts—and miscellaneous crops such as berries, melons, and onions.

3.2.4.2 Location

OID is located in Stanislaus and San Joaquin Counties on the eastern side of the San Joaquin Valley (Figure 1-1). Approximately three-fifths of its service area lies south of the Stanislaus River and is within the Modesto Groundwater Subbasin. The remaining two-fifths of the service area lie north of the Stanislaus River and are within the Eastern San Joaquin Groundwater Subbasin.

3.2.4.3 Water Supply and Storage Facilities

By 1912, OID and SSJID had abandoned the old miner's diversion dam and begun construction of the Goodwin Diversion Dam, an 80-foot-high, double concrete arch dam, which was completed in 1913. Between 1913 and 1925, the service area inflated to 20,000 acres, an increase of more than 300 percent over 12 years. Until 1925, irrigation was dependent upon the natural flow in the Stanislaus River, which was far from adequate to irrigate the 20,000-acre service area. In response to this, OID and SSJID voted $2,200,000 in bonds to finance construction of the 112,500 acre-foot Melones Reservoir, which was completed on December 15, 1926. The districts negotiated a contract with PG&E for the sale of the falling water benefits below the dam for hydropower generation. These payments completely amortized the bond issue without imposing a tax burden upon the landowners in the districts.

Between 1931 and 1938, OID constructed 25 deep wells to supplement its surface water supply and to meet the demand for water late in the irrigation season. Nevertheless, by 1938, both OID and SSJID found they were desperately short of irrigation water. To address this water supply problem, the Tri-Dam Project was developed, with power generation as a secondary purpose. In 1948, sites were approved at Donnells and Beardsley on the Middle Fork of the Stanislaus River and at Tulloch, above Goodwin Dam, and the project was completed in 1955. The combined storage capacity for the three reservoirs is 230,400 acre-feet, and the combined annual power generation is approximately 533,000 megawatt-hours. Additionally, in 1984, the Sand Bar Hydroelectric Powerhouse Project, which annually generates approximately 93,000 megawatt-hours, was completed.

In 1980, New Melones Dam was completed. With a reservoir capacity of 2.4 million acre-feet, New Melones Reservoir effectively submerges the original Melones project. New Melones Dam was constructed by the U.S. Army Corps of Engineers and transferred to the U.S. Bureau of Reclamation. The dam and the reservoir were then incorporated into the Central Valley Project. Releases from New Melones Dam are now the principal source of irrigation water for OID.

3.2.4.4 Water Distribution Facilities

OID's distribution facilities include two main canals, one on each side of the Stanislaus River. The North Main Canal extends approximately 15 miles down into the floor of the valley from the joint OID/SSJID diversion downstream of Goodwin Dam. The South Main Canal is approximately 22 miles in length. Approximately 250 miles of lateral and sublateral distribution networks are served from these two main canals. Table 3-8 describes OID's irrigation facilities.

3.2.4.5 Groundwater Use

OID operates 22 groundwater wells. These wells produce an average of about 6,300 acre-feet per year. The District also operates 43 drainage and several reclamation pumps. It is estimated that these facilities discharge around 13,000 acre-feet per year. Most of the private wells in the district are for small farm and domestic use. Table 3-9 summarizes the characteristics of OID wells.

Table 3-8
Oakdale Irrigation District Wells

Irrigation Wells	22
Drainage Wells	15
Reclamation Wells	28
Well Construction Summary	22 by cable tool
Casing Depths	40-250 feet
Annular Seals?	Required after 1985
Typical Depth of Seal	40-100 feet

Table 3-9
Oakdale Irrigation District Facilities

District Facilities	
Canals (lined)	105 miles
Canals (unlined)	125 miles
Pipelines	100 miles
Deep Wells	22
Reclamation/Drainage Pumps	43
Turnouts	3,500
SCADA	8 RTUs
Monitored	25
Improvement District Facilities	
Deep Wells, Domestic	18
Domestic Service Connections	650

3.2.4.6 Ongoing Activities

OID's ongoing groundwater management activities include:

- Active participation in the Association to manage the basin's groundwater resources
- Monthly water level monitoring of some wells
- Estimation of well discharge
- Water conservation programs

- Regulation of wastewater disposal

3.2.4.7 Issues of Concern

Issues of concern at OID include improving the coordination of groundwater pumping to reduce power consumption and to better manage groundwater levels and water quality.

3.2.5 City of Riverbank

3.2.5.1 Background

Located along the Stanislaus River and State Highway 108, Riverbank was incorporated in 1922 and had a population of 17,004 in 2002.

3.2.5.2 Location

Riverbank is located approximately five miles west of Oakdale and has, for the most part, been detached from OID (see Figure 1-1).

3.2.5.3 Water Supply

The City of Riverbank relies on the Modesto Groundwater Subbasin for its water supply. In 2002, it pumped 3,777 acre-feet of water from the subbasin, using six wells (see Table 3-10). Two additional wells have become operational since 2002. Groundwater from its wells conforms to the requirements of Title 22 and is used directly for domestic supply.

3.2.5.4 Facilities

Table 3-10 describes the City of Riverbank's wells. The City of Riverbank currently has 5,863 active connections, summarized in Table 3-11.

Table 3-10
Service Connections in the City of Riverbank

	Metered	Flat Rate	Total
General and Residential	5,658	7	5,665
Commercial	166	7	173
Industrial	5	2	7
Agricultural (Irrigated)	0	0	0
Other Water Systems	18	0	18
Total Active Connections	5,847	16	5,863
Inactive Connections			78

Table 3-11
City of Riverbank's Wells

Well	Year Con-structed	Annular Seals	Well Construction Method
#2 (8th Street)	1956	Yes	Cable tool
#3 (Jackson)	1965	Yes	Cable tool
#4 (Pioneer)	1972	Yes	Cable tool
#5 (River Heights)	1978	Yes	Cable tool
#6 (Whorten)	1981	Yes	Cable tool
#7 (Crossroads)	1990	Yes	Cable tool
#8 (Novi)	2001	Yes	Gravel pack
#9 (Prospector)	2004	Yes	Gravel pack

Groundwater quality is generally good. The City of Riverbank monitors groundwater quality to ensure the delivery of good quality water to its customers. The current level of groundwater monitoring by the City is as follows:

- General mineral and general physical — every 3 years
- Inorganic chemicals — every 3 years
- Nitrate — annually
- Regulated VOCs — every 3 years
- Regulated SOC (only DBCP, EDB, simazine, and atrazine) — every 3 years
- Gross alpha — 4 consecutive quarters every 4 years

3.2.5.5 Ongoing Activities

Ongoing groundwater management activities by the City of Riverbank include:

- Active participation in the Association to manage the basin's groundwater resources
- Utilize a SCADA system permitting remote operation and monitoring of the wells
- Test water quality in accordance with Title 22
- Enacted a well ordinance adopting the California Wells Standards (Bulletin 74-81) and all supplements.
- Regulation of wastewater disposal

3.2.5.6 Issues of Concern

Two concerns facing the City of Riverbank are (1) the preservation of groundwater quality and (2) the increasing demand for water fueled by its rapid population growth. This growth is illustrated by the increase in population from 1990 through 2002. During these 12 years, the population doubled from 8,547 to 17,004 inhabitants.

3.3 Stanislaus County

The participation of Stanislaus County in groundwater management planning is valuable because it encompasses the entire study area of the Modesto Groundwater Subbasin and OID service area within the Eastern San Joaquin Groundwater Subbasin and could represent areas outside the water purveyors' service areas where water requirements are met by private pumping. It also has oversight responsibility for land use planning activities, water well construction and destruction, groundwater contamination remediation, small public water systems, individual on-site sewage disposal systems, and hazardous materials within its jurisdiction. Therefore, the County's participation in development of this groundwater management plan serves the following functions:

- The County could represent water users not served by participating water purveyors.
- County participation enables the interaction between groundwater management activities and county land use planning.
- The County Department of Environmental Resources (DER) enforces the California Model Well Standards (Bulletin 74-81) and all supplements, as required by the California Water Code, in unincorporated areas.
- The DER issues permits for wells that supply small public water systems.
- The DER issues permits and inspects well construction and destruction in unincorporated areas and maintains a record of drilling logs of permitted wells.
- The DER issues permits to allow the use of hazardous materials.
- Groundwater elevations near approximately 150 contamination sites are reported to the DER.
- The DER has periodically mapped groundwater levels.
- The DER regulates, monitors, and inspects small public water systems for Title 22 compliance to ensure that safe, adequate, and dependable water supplies are available for domestic use. DER maintains a database and file records containing water quality monitoring records for approximately 200 small public water systems.
- The DER operates a pilot wellhead protection program.
- The DER identifies soil and groundwater contamination associated with leaking underground storage tanks and other point sources.
- The DER is responsible for regulating septic tanks and wastewater disposal in unincorporated areas.
- The Stanislaus County Public Works Department provides flood control in unincorporated areas.

Table 3-12 summarizes major programs that affect groundwater in the area of the Association.

Table 3-12
Major Programs Affecting Groundwater Within the Association's Boundaries

Facility or Operation	Involved Association Member(s)
Conjunctive use for irrigated agriculture	MID and OID
Domestic water supply	MID, Modesto, Riverbank, Oakdale, OID
Groundwater monitoring	All members
Storm water recharge basins	Modesto, Oakdale, County
Water conservation	All members
Drainage wells	MID and OID
Review and permitting of well construction	County, Modesto, Oakdale, Riverbank
Detection of soil and groundwater contamination	County
Pilot wellhead protection demonstration project	County
Regulation of small public water systems	County
Land use planning	County, Modesto, Oakdale, Riverbank
Wastewater management	County, Modesto, Oakdale, Riverbank
Flood control	County

Source: MID, Final Groundwater Management Plan, Table 3-1.

3.4 Land Use Planning Activities

Land use planning is a tool to manage the impacts of various land uses on the quantity and quality of the water supply, especially groundwater resources. The Association does not have any land use planning authority. Therefore, the Association's role is (1) to review current land use planning activities and guide the water planning efforts of the member agencies in regard to water management activities so that they consider future land development and (2) to encourage land use planning agencies to consider water management issues in their decision-making process. Some members of the Association (Stanislaus County and the three cities) have land use planning roles. In Stanislaus County, land use planning within the incorporated cities is carried out by the respective city. In most cases, Stanislaus County is not involved unless requested by the respective city. Both Stanislaus County and the irrigation districts are permitted to comment on city plans as part of the California Environmental Quality Act process. In unincorporated areas, land use planning is conducted by Stanislaus County's Planning Department and approved by the Board of Supervisors.

In land use planning, an important distinction needs to be made between *aquifer* (groundwater basin) and *groundwater management area*. Aquifer protection focuses on the entire groundwater basin. Groundwater management areas are subsets of the basin that can be delineated and prioritized for specific management purposes.

3.4.1 Agencies' Spheres of Influence

The sphere of influence is the potential area for annexation around an agency's service area and lands within the sphere of influence are subject to regulation by that agency. However, land within the sphere cannot be annexed until an environmental impact report has been completed and the appropriate Local Agency Formation Commission approves the annexation.

Annexation can be used as a tool in groundwater management. If an area currently served by groundwater is annexed by an irrigation district and is provided with surface water, this offers an opportunity for in-lieu recharge. This process can be used to balance the groundwater budget in a basin.

3.4.2 Planning for Growth

Stanislaus County is one of the fastest growing counties in California. Based on U.S. Census data, its population during the 1980s climbed from 265,000 to 370,000, for a total increase of 105,000 people (a 40 percent growth rate). This growth continued as the population grew to 454,600 in 2000, an increase of 84,600 (a 23 percent growth rate). Table 3-13 indicates that growth in Stanislaus County is projected to continue. Between 2000 and 2010, the County's population is expected to increase by 133,000 (29 percent) and between 2010 and 2020, by 124,500 (21 percent).

Since 1980, most of the population increase has occurred in the County's nine incorporated cities rather than the unincorporated area of the County. This concentration of growth in incorporated areas has increased the proportion of the County's population living in these areas and has fueled substantial increases in the spheres of influence of many incorporated areas. Planning for growth is being facilitated by the County and local agencies by their recognizing that increased cooperation is essential in addressing growth-induced issues.

Table 3-13
Projected Population Growth in Stanislaus County

Data Source	2000	2005	2010	2015	2020
DOF – 2000	454,600	522,700	587,600	646,800	712,100
DOF - 1998			585,519		708,950

Source: State of California Department of Finance 1998 and 2000.

3.4.3 Potential Future Annexations

Annexation by various entities within the Association is a tool for responding to population growth and for managing resources within their spheres of influence.

Annexation has the potential to improve water management by:

- Better linking the water service required by customers with the type of service available

- By providing service that meets broader water management objectives

For example, city annexation that provides city water services to small urban parcels now served by irrigation districts enables the customers to receive the flexible service they desire and enables the irrigation districts to focus their attention on lands best served by agricultural delivery schedules. This type of annexation provides water users with water service that is tailored to fit residential needs, while irrigation districts can focus on the basin's other water management issues. Irrigation district annexations of lands now being served by private wells allows surface water deliveries to replace groundwater pumping. This process, known as in-lieu recharge, supports aquifers by reducing the demand for groundwater pumping and increasing recharge from deep percolation of surface applied irrigation water. This process increases the overall water supply reliability of a region by enabling water agencies to conjunctively manage their surface and groundwater resources. In addition, water agencies can pump additional groundwater during drought periods without long-term groundwater overdraft in the basin. How annexation projects could impact or benefit a basin's groundwater levels and groundwater quality should be evaluated on a case-by-case basis.

Page intentionally left blank

4 Groundwater Resources in the Modesto Basin

4.1 Introduction

This chapter describes the geology, aquifers, groundwater quality, and water use in the Modesto Groundwater Subbasin and includes the southeastern portions of the adjacent San Joaquin Groundwater Subbasin. Both subbasins are part of the much larger San Joaquin Valley Groundwater Basin. The locations of the Modesto and East San Joaquin Groundwater Subbasins are shown in Figure 4-1. The Cities of Modesto, Oakdale, and Riverbank and the communities of Salida, Empire, and Waterford use groundwater to supply their residents. MID and OID provide both surface water and groundwater for agricultural use. There are several large industrial water users in the basin. Local residents also rely on groundwater for potable water through numerous small water supply wells. Figure 4-1 shows the service area locations of the cities and irrigation districts.

Residential and agricultural interests in the western portions of subbasins are impacted by the presence of shallow groundwater. Historic lowering of the groundwater levels within portions of the basin reversed the natural groundwater balance. Groundwater was depleted in areas near Modesto, which resulted in a cone of depression. Since 1994, when a surface water treatment plant was constructed, groundwater levels within the cone of depression have begun to recover. In addition, there is a potential for increases in the amount of outflow of groundwater from the subbasin, resulting from the anticipated increase in groundwater use outside the subbasin. Groundwater continues to be impacted locally by the increases in industrial and municipal needs. Water quality problems include the presence of salts, uranium, pesticides, and volatile organic chemicals (VOCs).

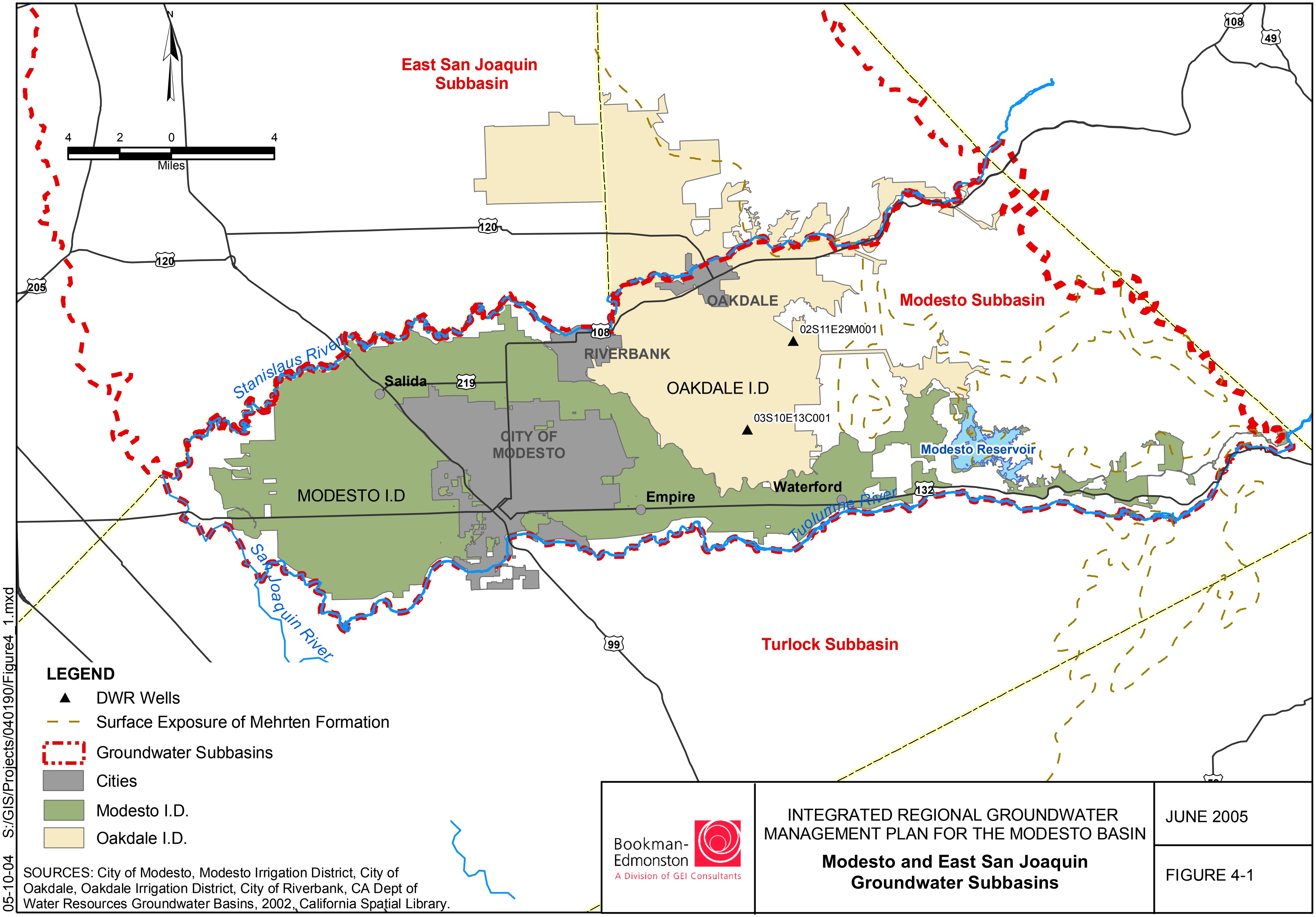
This chapter relates these occurrences and problems to geologic controlling features to allow conceptual planning of groundwater management options.

4.2 Hydrogeology

This section describes the geology, aquifers, hydraulic characteristics, groundwater levels, and the direction of groundwater flow.

4.2.1 Geology

The Modesto Groundwater Subbasin is located in the northern portion of the San Joaquin Valley, which is a structural trough about 200 miles long and 70 miles wide. The valley is filled with up to 32,000 feet of marine and continental sediments deposited during its periodic inundation by the Pacific Ocean and erosion of the surrounding mountains,



INTEGRATED REGIONAL GROUNDWATER MANAGEMENT PLAN FOR THE MODESTO BASIN

Modesto and East San Joaquin Groundwater Subbasins

JUNE 2005

FIGURE 4-1

respectively. Only the upper 800 feet of these sediments contain water that is considered potable or suitable for agricultural use. These sediments are generally categorized as consolidated and unconsolidated sediments. The sediments are generally coarser-grained in the eastern portion of the subbasin, having been deposited as coalescing alluvial fans and rivers near the Sierra Nevada Mountains, and fine-grained to the west. The sediment beds dip toward the west.

4.2.1.1 Consolidated Sediments

The consolidated sediment beds that form the fresh water aquifers consist of the Ione, Valley Springs, and Mehrten sediment formations (from oldest to youngest). These sediments are exposed at the ground surface in the eastern portion of the subbasin and dip gently under the basin to the west. Figure 4-2 shows the distribution of these sediments and the locations of ground surface exposure. Figure 4-3 correlates the historic and recent nomenclature and the approximate depths beneath the city of Modesto.

The Ione Formation can generally be thought of as continental, lagoons, and marshes with periodic invasions by the ocean (CDMG 1975). The sediments consist of white to red clays, sands, and rounded gravels with layers of black to brown coal. The sands and gravels are locally cemented or have a high clay content.

The Valley Spring Formation can generally be considered to be a non-marine sequence of light-colored sediments that were eroded from volcanic rock (rhyolite). Ash and tuff are also present. The sediments consist of sandstone, siltstone, claystone with sandy clay, and sand and gravel generally in a clay matrix.

The Mehrten Formation was also eroded from volcanic rocks, but instead of being light-colored, they are typically dark-colored (andesite). The formation is composed of up to 800 feet of sandstone, breccia, conglomerate, tuff, siltstone, and claystone (Page and Balding 1973). This formation is typically identified by well drillers as “black sands.” The sandstone and conglomerate are capable of transmitting large quantities of groundwater. The Mehrten Formation may lie as shallow as 400 feet beneath the city of Modesto (Burow et al. 2004). The top of the Mehrten Formation appears to be an irregular surface with valleys and hills. The reworking and redeposition of the formation sediments make distinguishing the boundary of this formation difficult.

4.2.1.2 Unconsolidated Sediments

Historically, the unconsolidated alluvium has been classified as continental deposits (deposited in a freshwater environment), lacustrine and marsh deposits (pertaining to lakes), and Older Alluvium, Younger Alluvium, and flood-basin deposits (Page and Balding 1973). Recent efforts have reclassified these sediments into formations and include, from oldest to youngest, the Laguna, Turlock Lake, Riverbank, and Modesto Formations, Holocene alluvium (associated with stream channel and flood basin deposits) (Burow et al. 2004).

Figure 4-2 shows the distribution of these sediments and where they are exposed on the ground surface. Figure 4-3 correlates the historic and recent nomenclature and their approximate depths beneath the City of Modesto.

The Laguna Formation is characterized by alluvial deposits of gravel, sand, and silt in at least two upward-coarsening units separated by a well-developed palesol, a buried soil layer (Marchand and Allwardt 1981). The formation is composed generally of dark-colored volcanic sediments eroded from the Mehrten Formation but also contains some light-colored sediments that are likely derived from the granites (specifically, the granodiotites) from the Sierra Nevada.

The Turlock Lake Formation is composed of sediments deposited by rivers from the Sierra Nevada. These sediments consist of two coarsening-upward sequences of silt, sand, and gravel that are likely the result of glacial outwash (Marchand and Allwardt 1981). The lower sequence of the formation contains dark volcanic sediments that were likely eroded from the Mehrten Formation and redeposited (Burow et al. 2004). Portions of the upper sequence are very coarse-grained sand and gravel incised valley fill and are potentially related to deposition from the Tuolumne River (Weissman et al. 2002).

The upper and lower sequences are separated in the western portion of the subbasin with a clay layer that formed in a large lake. An areally extensive diatomaceous lake clay occurs at the base of the upper unit of the Turlock Lake Formation and is referred to as the Corcoran clay (correlated to the occurrence of the E-clay in the southern portion of the San Joaquin Valley). This clay layer is regionally extensive with hydrologic significance. Although numerous silt and clay beds occur above and below the Corcoran clay, they cannot be correlated over large areas. Therefore, those beds are of only local importance to the confinement of groundwater (Page 1973).

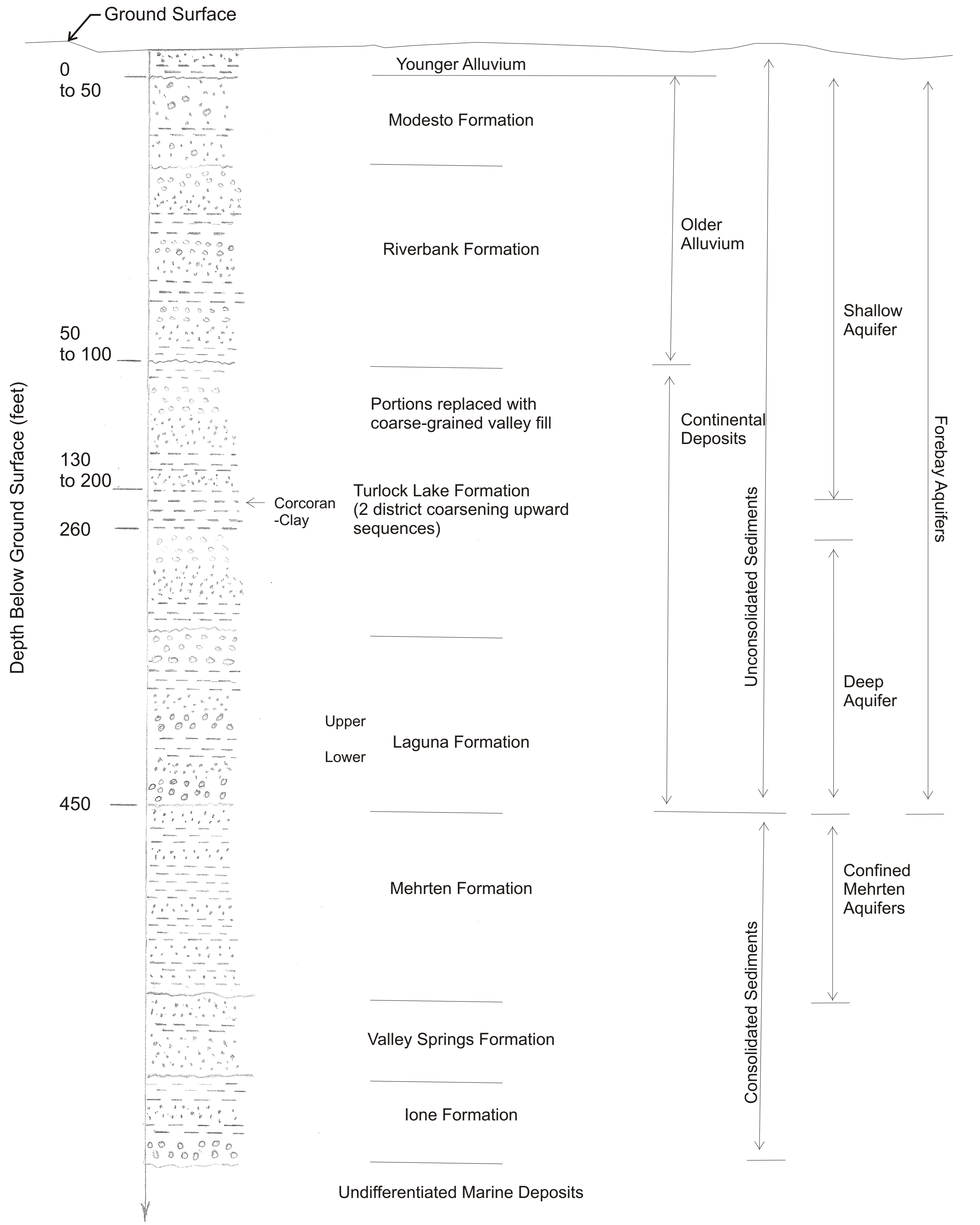
The Corcoran clay is present at a depth of about 200 feet below ground surface (bgs) in the western portion of the subbasin (Page and Balding 1973). The clay is about 20 to 60 feet thick and may be locally eroded. The approximate eastern extent of the Corcoran clay parallels Highway 99 and is shown on Figure 4-4 (Burow et al. 2004). To the east and north, the clay becomes more silty and difficult to recognize along the edges, where the unit either grades into coarser materials of the same age or wedges out (Davis et al. 1959). Near the confluence of the Stanislaus and San Joaquin Rivers, a small portion of the Corcoran clay may be thin or missing and replaced with coarse-grained sediments (Burow et al. 2004).

North of the Stanislaus River, the extent of the Corcoran clay aligns with Highway 99. The OID service area does not overlie any areas where the Corcoran clay is present.

Overlying the Turlock Lake Formation are the Riverbank and Modesto Formations. These formations consist of river-deposited, light-colored sand, gravel, and silt. These sediments are oxidized and are likely to be derived from granites in the Sierra Nevada. The Modesto

Figure 4-2 Geology Map

Back of 11 x 17



Bookman-Edmonston
A Division of GEI Consultants

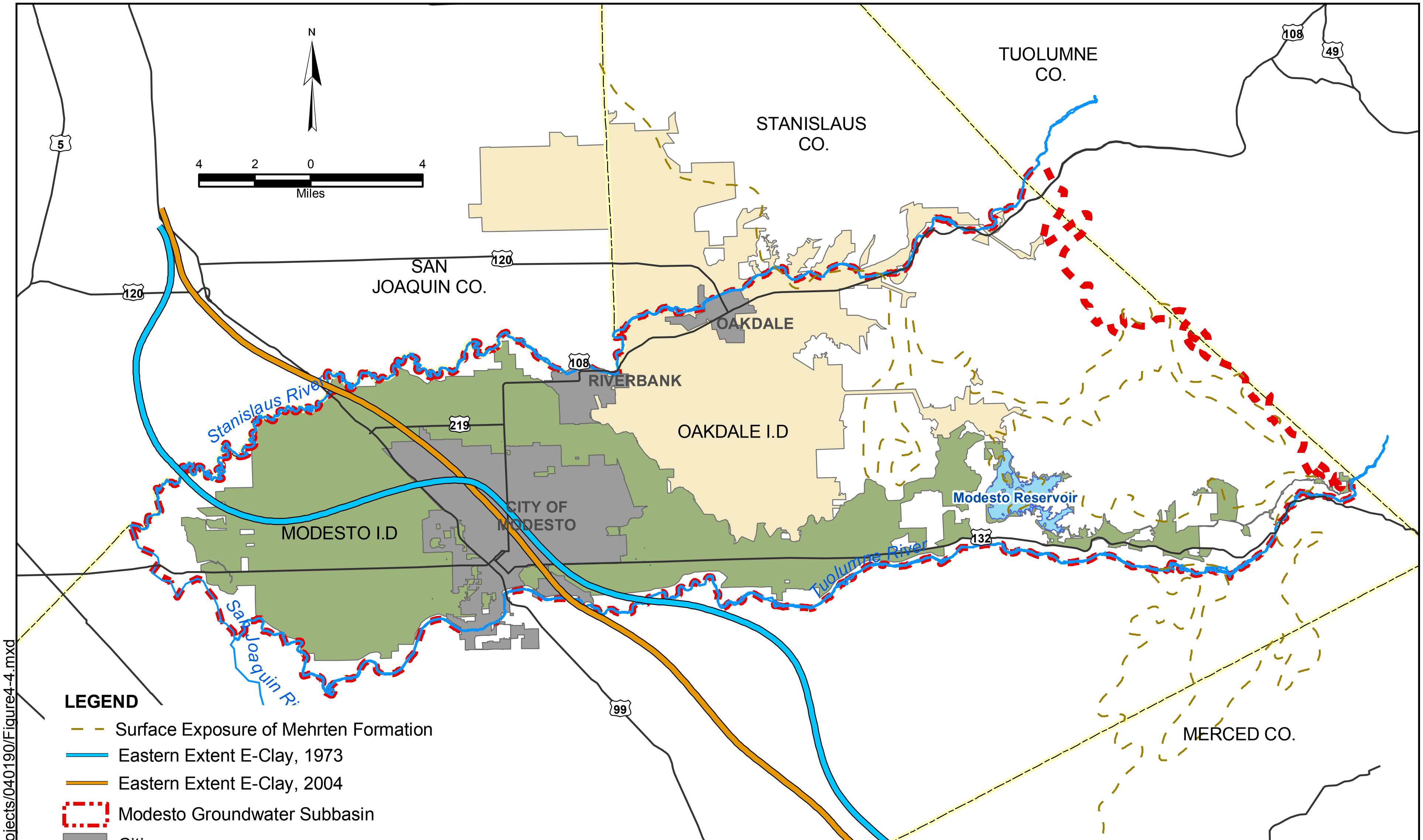
INTEGRATED REGIONAL GROUNDWATER
MANAGEMENT PLAN FOR THE MODESTO BASIN

Nomenclature and Their Depth Beneath
The City of Modesto

JUNE 2005

FIGURE 4-3

05-11-04 S:/GIS/Projects/040190/Corel/Figure 4-3.cdr



SOURCES: City of Modesto, Modesto Irrigation District, City of Oakdale, Oakdale Irrigation District, City of Riverbank, CA Dept of Water Resources Groundwater Basins, 2002, California Spatial Library.

Bookman-Edmonston
A Division of GEI Consultants

INTEGRATED REGIONAL GROUNDWATER MANAGEMENT PLAN FOR THE MODESTO BASIN

Cocoran Clay Extent

JUNE 2005

FIGURE 4-4

05-10-04 S:/GIS/Projects/040190/Figure4-4.mxd

Formation is exposed on the ground surface throughout most of the subbasin. Coarse-grained sediments typically occur in patterns parallel to the Stanislaus and Tuolumne Rivers with finer-grained sediments (clay, silt, and very fine-grained sand) present between the rivers.

Relatively discontinuous shallow clay layers may be present in the near-surface sediments. These clay layers may perch percolating water and cause some of the high groundwater conditions in the western part of the subbasin. The USGS has compiled a database with sediment types that could be queried to obtain the depth and extent of these clay layers, along with hardpan layers. A topographic map of the shallow clay and hardpan layers should be constructed for those clays within 20 feet of ground surface.

4.2.2 Aquifers

Groundwater is present in the consolidated and unconsolidated sediments. There are two principal aquifers in the western portions of the study area (separated by the Corcoran clay) and one aquifer east of the Corcoran clay. Underlying all of these aquifers is a fourth aquifer. The aquifers are:

- The shallow aquifer that is present generally west of Highway 99, above the Corcoran clay. High groundwater levels sometimes cause problems for certain agricultural crops.
- The deep aquifer that is also located west of Highway 99, but is below the Corcoran clay and the shallow aquifer.
- The forebay aquifers located east of the Corcoran clay and merge with the shallow and deep aquifers west of Highway 99. The eastern extent of the forebay aquifers is where the Mehrten Formation is exposed at the ground surface. Most of OID overlies the forebay aquifers.
- The confined aquifers within the Mehrten Formation that underlie all of these aquifers. These aquifers are separated from the overlying aquifers by 60 to 120 feet of clay.

Figures 4-5 and 4-6 show a generalized schematic profile of the aquifers. Figure 4-7 shows their locations regionally.

The aquifer above the Corcoran clay has been called the shallow aquifer system. This aquifer is about 130 to 220 feet thick (Page 1977). Groundwater in the shallow aquifer ranges from unconfined to semi-confined and is present both in the Modesto and Riverbank Formations and in the upper sequence of the Turlock Lake Formation.

The aquifer below the Corcoran clay has been designated as the deep aquifer system where groundwater occurs under confined conditions. It is present in the lower sequence of the Turlock Lake and upper Mehrten Formations and extends to the base of fresh water.

East of Highway 99, where the Corcoran clay is absent, groundwater occurs under unconfined to semi-confined conditions. This area supplies water to both the shallow and deep aquifers. These recharge areas are typically called forebays. The forebay area extends from the eastern extent of the Corcoran clay to the western limit of the exposed Mehrten Formation, as shown on Figure 4-7. The aquifer generally thickens to the west and thins to the east. Limited data show that the base of the forebay aquifer is a 20- to 40-foot-thick gravel (identified by the USGS as Laguna Formation) that daylights at the western exposure of the Mehrten Formation and dips at about 0.006 feet per foot. Figures 4-5 and 4-6 show the gravel layers in red and possible correlations. Because of the dip and the local occurrence of "lava" (breccia) overlying the gravel, this gravel may be within the Mehrten Formation. The gravel bed is pronounced south of the Stanislaus River, but its presence near the Toulumne River is uncertain. There are a few occurrences of gravel north of the Stanislaus River that could correlate with this marker bed. More data are needed to validate the extent and thickness of this gravel layer. Figures 4-5 and 4-6 show the location of the gravels.

The confined aquifer in the Mehrten Formation underlies all of the aquifers listed above. Limited data suggest that the aquifer is separated by a 60- to 120-foot clay layer beneath the area between the Stanislaus and Toulumne Rivers. Groundwater in the forebay and deep aquifers may be perched on top of this clay layer. Recharge to the Merthen Formation confined aquifers occurs in the individual sand beds that are exposed on ground surface or where sand beds intersect river alluvium in the eastern portion of the subbasin. Because of the clay, the aquifers probably receive little vertical recharge. North Stanislaus River clay is thinner and it appears to have been replaced with some sand beds. These beds may allow communication between the forebay and the confined Merthen Formation aquifers.

4.2.3 Groundwater Levels

Groundwater levels were sorted regionally, based on well screen depths and the three types of aquifers.

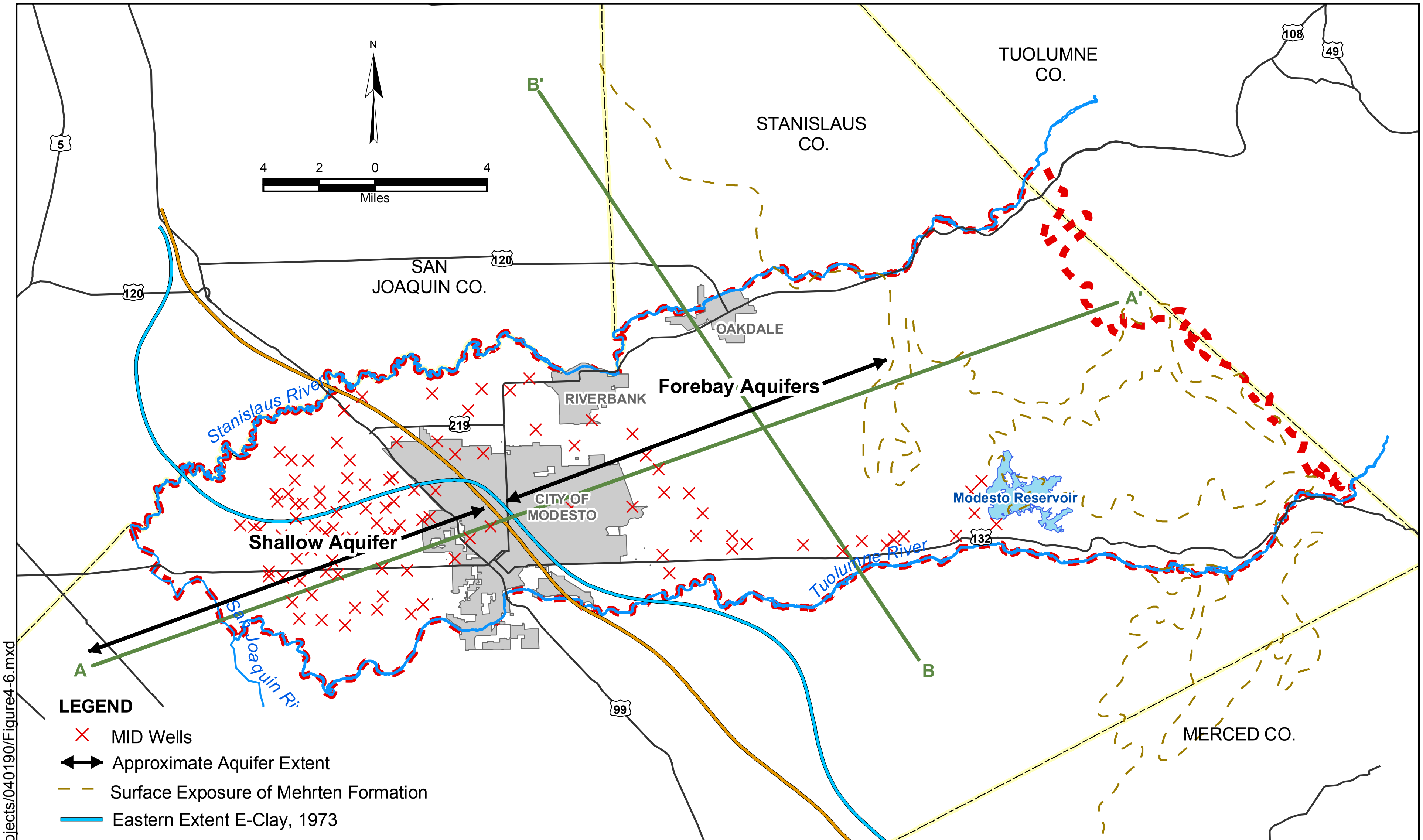
Groundwater levels in the shallow aquifer, above the Corcoran clay, typically range from about 10 to 30 feet bgs. Figure 4-8 shows the groundwater levels in the shallow aquifer. Figure 4-7 shows the well locations. Groundwater levels from 1969 though 1983 remained relatively stable. Between 1984 and 1994, groundwater levels declined in most wells (MID 39, 40, 61, 103, and 196), while other wells (MID 68 and 102) remained at levels similar to those from before 1983. It is likely that drainage pumping and pumping in the shallow aquifer to augment irrigation water and for the City of Modesto caused the decline in water levels. As shown on Figure 4-7, Well 30E (112 feet deep), is located in Modesto.

Figure 4-5 Schematic Profile of Aquifers—Geologic Section A-A'

Back of 11 x 17

Figure 4-6 Schematic Profile of Aquifers—Geologic Section B-B'

Back of 11 x 17



SOURCES: City of Modesto, City of Oakdale, City of Riverbank, CA Dept of Water Resources Groundwater Basins, 2002, California Spatial Library.

06-28-04 S:/GIS/Projects/040190/Figure4-6.mxd

Bookman-Edmonston
A Division of GEI Consultants

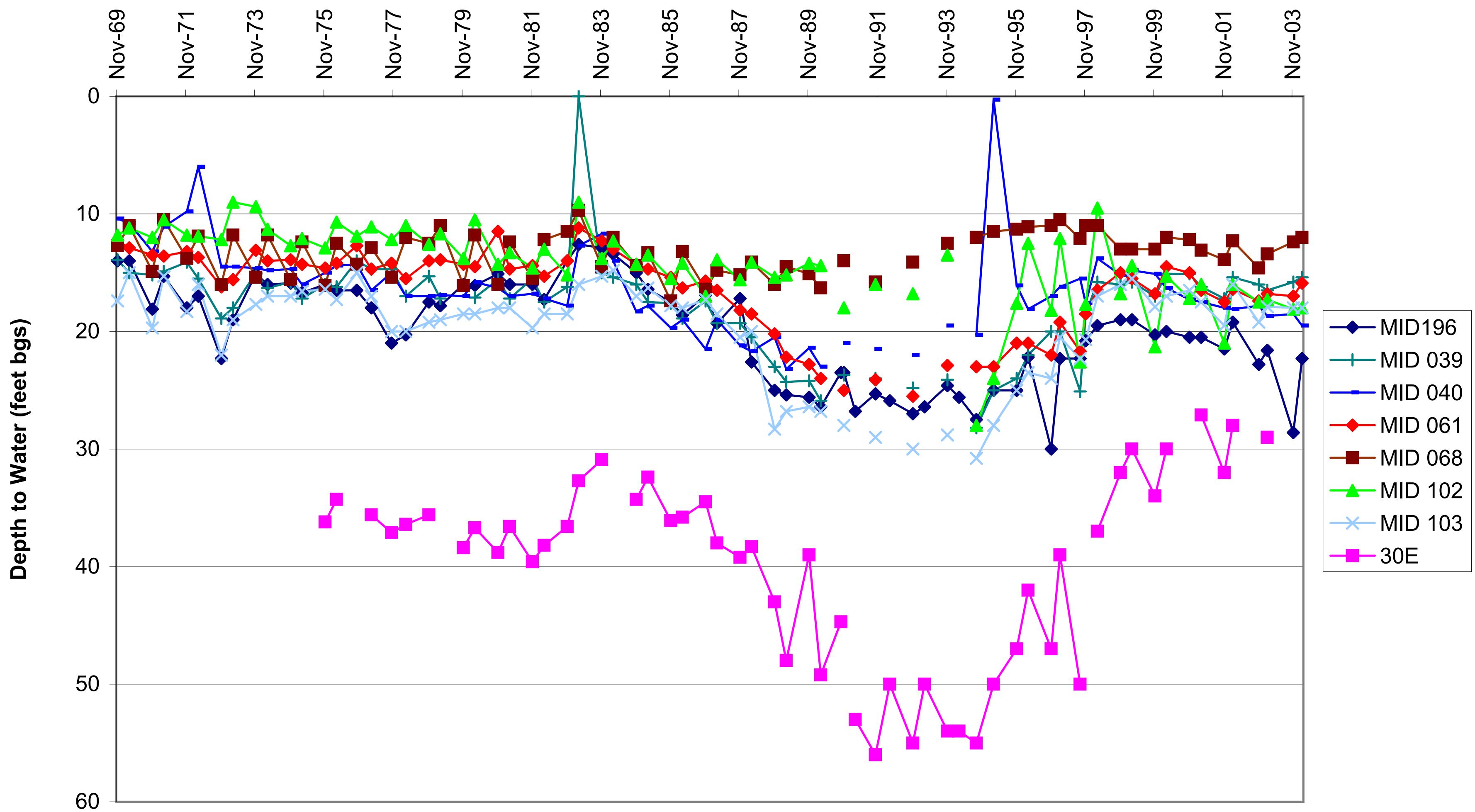
INTEGRATED REGIONAL GROUNDWATER MANAGEMENT PLAN FOR THE MODESTO BASIN

General Location of Aquifers

JUNE 2005

FIGURE 4-7

Figure 4-8
Integrated Regional Groundwater Management Plan for the Modesto Basin
SHALLOW AQUIFER GROUNDWATER LEVELS



The water levels in the deep aquifer, below the Corcoran clay, cannot be assessed at this time because wells reviewed by this plan appear to be constructed in both the shallow and deep aquifers, which would result in an aggregate water level. The USGS recently constructed one monitoring well cluster to assess the groundwater levels in the shallow and deep aquifers. Additional monitoring wells need to be constructed to assess the conditions in the deep aquifer. The water level in deep aquifer may be about 4 to 6 feet deeper than wells in the shallow aquifer (Burow et al. 2004).

Groundwater levels in the forebay area range from about 25 to 70 feet bgs. Figure 4-9 shows groundwater levels in wells in this area. The water levels have generally been declining since at least 1969. From late 1982 through 1983, water levels rose, but resumed their downward trend until 1995; between 1995 and 1999, water levels again rose. Since 1999, groundwater levels have resumed a gradual decline. Although there have been two periods of rising groundwater, both associated with wet years, water levels in this area have not returned to their pre-1969 levels.

Many of the irrigation wells used by OID and MID in the eastern portion of the subbasin are screened in both the forebay and confined aquifers of the Mehrten Formation. Figures 4-5 and 4-6 illustrate this point. Figure 4-10 shows that few groundwater levels were available from wells solely constructed in the Mehrten Formation confined aquifer. The water levels show trends similar to those of the forebay aquifers. Groundwater levels in the confined aquifer also declined about 20 feet between 1969 and 2004.

Groundwater levels were locally depressed (up to 1994) because of municipal pumping for the Modesto urban area and the Riverbank, Oakdale, and Salida areas (MID 1996). The pumping depression resulting from the Modesto urban area pumping extends beneath and south of the Tuolumne River. Since the completion of a surface water treatment plant in 1994, water levels have recovered and the pumping depression has been reduced (Burow et al. 2004). In Figure 4-8, well 30E shows the water level recovery in the shallow aquifer beneath Modesto since 1994. Groundwater levels measured in the City of Riverbank wells are about 60 feet bgs. The groundwater levels have remained relatively consistent over 40 years.

MID uses its wells to lower the water levels in the shallow aquifer area. However, from the records reviewed, groundwater levels appear to be 10 feet or more below the ground surface and would not affect crops. More likely, MID's pumping from the shallow aquifer has been successful at maintaining water levels below 10 feet.

4.2.4 Groundwater Flow Directions

Groundwater contour maps show the direction of groundwater flow, recharge areas, and areas of discharge. The groundwater flow direction is typically 90 degrees to the groundwater contour. Groundwater levels in the shallow and forebay aquifers are typically

Figure 4-9
Integrated Regional Groundwater Management Plan for the Modesto Basin
GROUNDWATER LEVELS IN THE FOREBAY AQUIFER

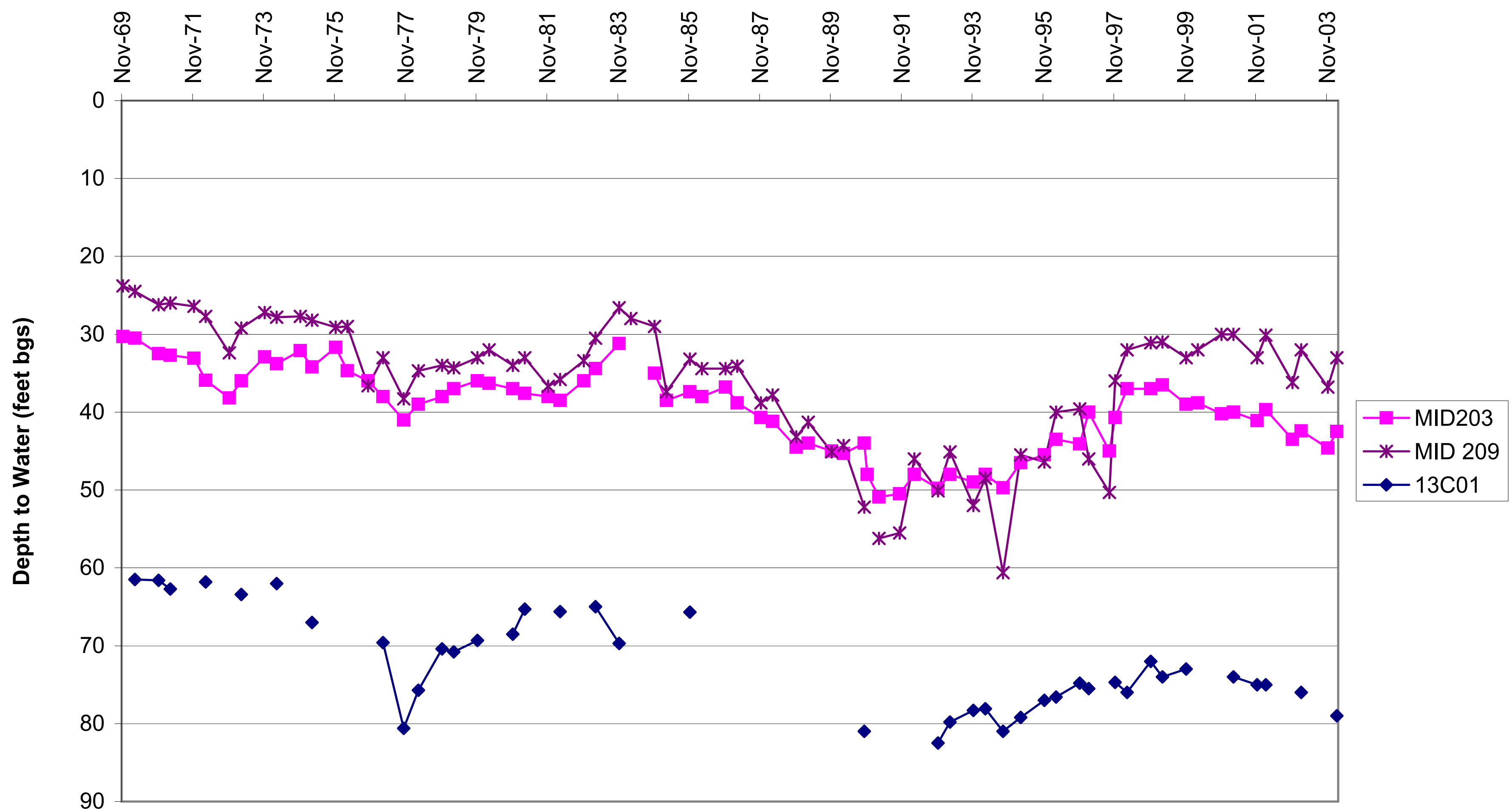
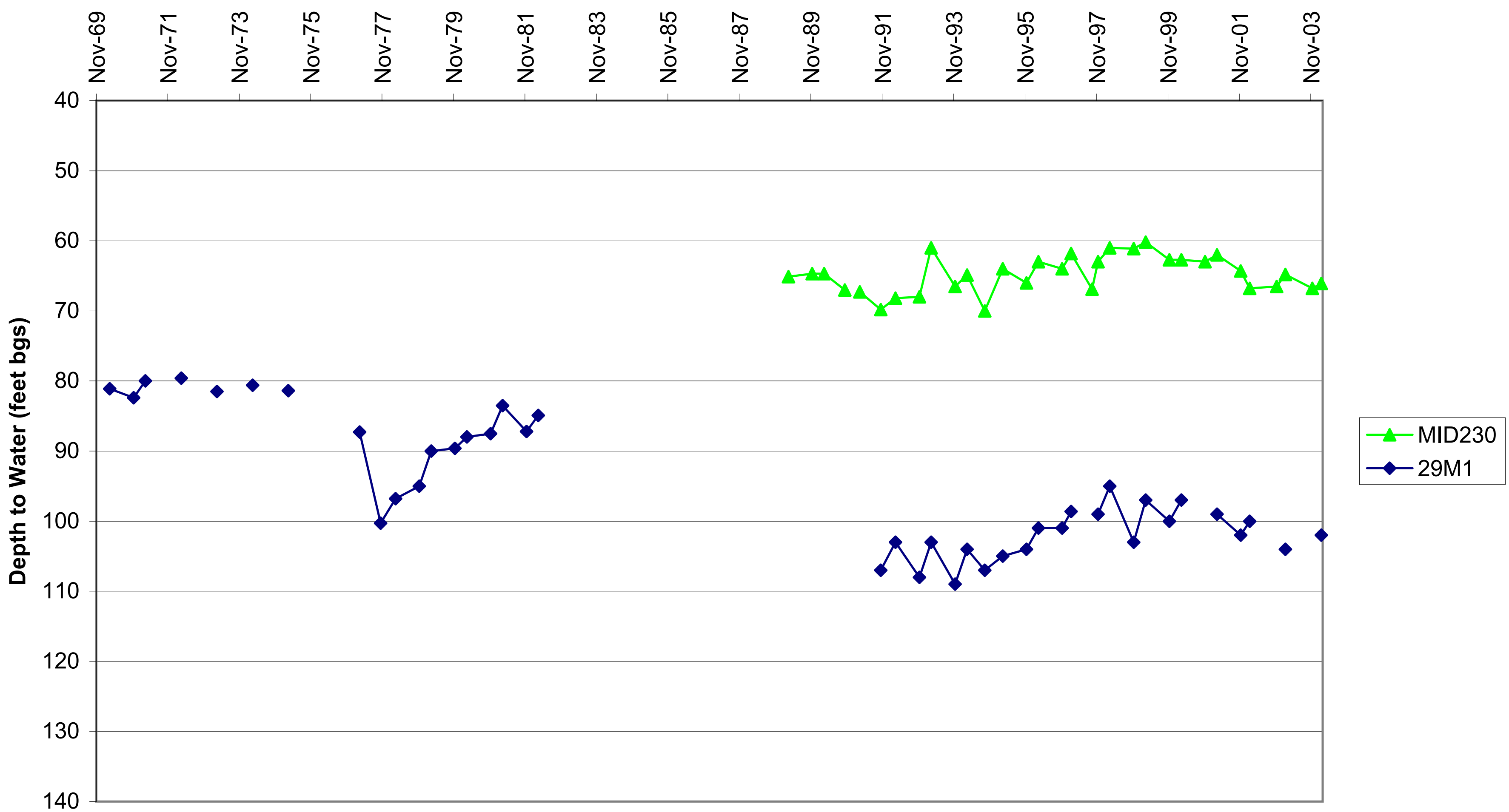


Figure 4-10
Integrated Regional Groundwater Management Plan for the Modesto Basin
GROUNDWATER LEVELS IN THE MEHRTEN CONFINED AQUIFERS



contoured together. In some instances, a few wells from the deep aquifers may also be contoured with these data, which may provide erroneous results. There are insufficient data at this time to develop a groundwater contour map for the deep aquifer (Burow et al. 2004). Figures 4-11 through 4-13 show groundwater contours in the shallow and forebay aquifers from 1971 through 2000. The maps show different flow directions, and therefore, the interpretation of the data varies considerably. There are also insufficient data near the rivers to determine true gaining and losing reaches and flow direction beneath the rivers. Conditions more likely change seasonally and by water year type. The discussion below is based on very limited available data.

In 1971, groundwater contours showed that groundwater generally flows from the east to west-southwest with recharge to the forebay aquifers occurring between the Stanislaus and Tuolumne Rivers (Page and Balding 1973). The contours suggest that groundwater is discharged to the San Joaquin and Tuolumne Rivers (gaining) along most of the reaches of the rivers. Because the contours generally cross the Stanislaus River at 90-degree angles, it suggests that the river is not a gaining stream nor does it recharge the groundwater. The map does not provide sufficient detail to assess whether groundwater is discharging to (gaining reaches) the Stanislaus and San Joaquin Rivers along the western edge of the subbasin.

Groundwater level contours were prepared for 1985, a period of relatively high rainfall (wet year), and for 1994, after a prolonged period of relatively low rainfall and runoff (dry year) (MID 1996). Both maps again show that groundwater flow is generally from east to west with recharge occurring between the Stanislaus and Tuolumne Rivers. Both maps show a pumping depression has formed beneath the city of Modesto.

The contours show that the rivers have both losing and gaining reaches. Figures 4-12 and 4-13 show these reaches.

In 1985, the only losing reach was an approximately five-mile-long reach of the Tuolumne River near central Modesto. By 1994, this reach had extended to the east by approximately five miles. All of the Stanislaus River east of Highway 99 was apparently a losing stream.

In 1985 and 1994, apparent gaining reaches include the San Joaquin River and approximately seven miles of the Stanislaus River upstream of the San Joaquin confluence. Changes in the gaining reaches are present from wet year to dry year. In 1985, the gaining portions of the rivers were the Stanislaus River east of Riverbank and the Tuolumne River upstream of Empire. In 1994, the gaining reaches were reduced to a nine-mile-long reach of the Tuolumne River near Waterford and approximately five miles of the Tuolumne River upstream of the confluence with the San Joaquin River.

Figure 4-11 Water Level Contours for the Unconfined Water Body, Spring 1971

Back of 11 x 17

Figure 4-12 Regional Water Level Elevation in Wells and Direction of Groundwater Flow, Spring 1985

Back of 11 x 17

Figure 4-13 Regional Water Level Elevation in Wells and Direction of Groundwater Flow, Spring 1994

Back of 11 x 17

Groundwater contours developed for the spring of 2000 continue to show a general east-west flow direction with recharge occurring between the Stanislaus and Tuolumne Rivers (Burow et al. 2004). The contours show that the Tuolumne River and portions of the Stanislaus River near Oakdale are gaining streams. However, the detail of the graphic does not allow conclusions to be drawn about the city of Modesto's effects on the river. South of Riverbank, the Stanislaus River does not appear to be affecting groundwater levels by either mounding groundwater, indicating recharge, or draining groundwater, indicating discharge to the river. The recharge and discharge areas may change seasonally.

4.2.5 Groundwater Recharge and Discharge Areas

Groundwater recharge to the shallow aquifer occurs from precipitation, applied water, and seasonally from infiltration from the rivers. The forebay also contributes water horizontally to the shallow aquifer. Subsurface recharge may also occur from adjacent subbasins if groundwater gradients are lower in the Modesto subbasin.

Groundwater recharge to the deep aquifer is from the shallow aquifer as a result of vertical seepage across the Corcoran clay and horizontally from the forebay aquifers. Groundwater can also exchange between the shallow and deep aquifers in wells with screens in both aquifers.

Groundwater recharges the forebay aquifers from precipitation, applied water, and infiltration from the rivers. Groundwater migrates both vertically and horizontally through the sediments. The coarse gravel at the base of the forebay aquifers is exposed at the ground surface, parallel to the western surface exposure of the Mehrten Formation sediments shown on Figure 4-5. The gravels are exposed along an approximately two-mile-wide area. The gravel bed appears to extend beneath and is probably connected to the sediments in the Stanislaus River. Unlined canals that cross this belt also likely provide additional recharge. North of the Stanislaus River and near the Tuolumne River, this gravel belt is poorly defined and needs further definition by a thorough review of well logs or through the USGS database.

Groundwater recharge to the Mehrten Formation confined aquifers is from areas between the eastern and western exposure of the Mehrten Formation, as shown on Figure 4-7. For the most part, the recharge is limited to seasonal precipitation that falls directly on the exposed aquifers. Some recharge is likely occurring where the Stanislaus and Tuolumne Rivers cross the aquifers. Recharge also probably occurs from the Modesto and the Woodward Reservoirs.

The groundwater contours show that groundwater recharge areas are in the eastern and central portions of the subbasin between the Stanislaus and Tuolumne Rivers. The Stanislaus River provides recharge to the forebay aquifers east of Salida. The Tuolumne River also provides recharge to the forebay aquifers near the cities of Modesto and Empire. For the most part, groundwater discharges to the Tuolumne River and locally controls groundwater levels. Portions of the upper reaches of the Stanislaus River may change from a recharge source to a discharge source during wet years. Increased groundwater pumping and the corresponding lowering groundwater levels may result in increased recharge of the basin by the rivers. This induced groundwater recharge may continue until an equilibrium condition has been established.

Groundwater recharge based on estimated land use and applied water indicates the highest recharge rates occur in the agricultural areas, which are in the central and western part of the basin (Burow et al. 2004). This water would recharge the shallow aquifers and portions of the forebay aquifers, which contribute water to both the shallow and deep aquifers. There is insufficient data to determine the relative amounts of discharge (outflow) from the subbasin. Outflow likely occurs along the San Joaquin River and lower portions of the Tuolumne and Stanislaus Rivers. The outflow would be from the shallow aquifers. Along these discharge areas, groundwater levels need to be maintained at levels that allow the discharge to the rivers to continue. This will prevent the accumulation of salts within the subbasin and prevent poor quality water from the San Joaquin River and water west of the river from intruding into the subbasin.

4.2.6 Hydraulic Characteristics

The hydraulic characteristics of sediments and aquifers are data that provide the foundation for predicting the effects of management options before their implementation. They are basic scientific parameters used to estimate and predict the speed and direction of groundwater movement, groundwater storage, and the potential effects of groundwater pumping on groundwater levels and other wells. These characteristics can be used to answer a number of questions: how should wells be spaced to avoid conflicts; how will the aquifers react to a reduction in recharge resulting from conservation measures; how much water should be removed (in areas with high groundwater table) to lower water levels to benefit agriculture; how much water will a well produce; and how will water quality be affected by the mixing of water from different sources.

The hydraulic characteristics of sediments and aquifers use several terms to quantify the ability to store and transmit water. The *hydraulic conductivity* is the ability of the sediments to transmit water in sediments. *Transmissivity*, a term applied to aquifers, is the hydraulic conductivity multiplied by the thickness of the sediments capable of conveying water. All sediments have some void space between the particles; this void space is reported as *porosity*. Water in the void spaces cannot be entirely removed. The *storage coefficient* is the percentage of water that can be removed from the pores by gravity drainage and is applied when describing unconfined aquifers. *Storativity* is similar to storage coefficient, but is the percentage of water that can be released from the pores by a decrease in pressure. Storativity is used when referring to semi-confined or confined aquifers.

In the eastern portion of the area, consolidated sediments (Ione, Valley Springs, and Mehrten Formations) are exposed on the ground surface. Because of the compact nature of their sandstone and conglomerate, an overall clay matrix, and fine ash, sediments of the Ione and Valley Springs Formations result in small-yielding aquifers. No large irrigation wells were found in the Ione Formation in the subbasin (Page and Balding 1973). It is likely the Mehrten Formation will also produce small-yielding wells in this area because the saturated thickness may be small because the formation laps up onto the Valley Springs Formation and the recharge to the area is from limited sources.

The Mehrten Formation underlies and is part of both the forebay and confined aquifer systems. Coarse-grained sediments are present in the upper portions of the formation. Wells drilled into the formation produce about 300 to 2,800 gallons per minute (gpm). The hydraulic conductivities ranged from 0.01 to about 67 feet per day (Page and Balding 1973). Transmissivities in the northeastern portion of the study area range from about 11,000 to 32,000 gallons per day per foot (gpd/ft).

The shallow and forebay aquifers (unconfined to semi-confined aquifer) yield large amounts of water to wells, with an average yield of 1,900 gpm reported for 96 large-capacity wells (Page and Balding 1973). Transmissivities above or east of the Corcoran clay range between 60,000 and 80,000 gpd/ft. The specific yield or storage coefficient for the shallow aquifer is estimated to be about 7 to 17 percent (Johnson 1967).

The deep aquifer has a transmissivity of about 28,000 to 35,000 gpd/ft (Page and Balding 1973). The storativity is estimated to be on the order of 0.0001 to 0.000001 (unitless).

The Corcoran clay is a regional layer that restricts movement between the shallow and intermediate aquifers and the underlying deep aquifer. Because the clay is permeable to some degree, water can migrate vertically through the layer but typically at very slow rates. Although this migration rate is very slow, the amount of water moving through the clay can be significant, given the large area covered by the clay and head differences across the clay. No test data are available for the Corcoran clay, but some groundwater models have “backed into” what appear to be reasonable permeability values. The vertical permeability estimated ranged from 0.01 to 0.007 feet per day (Burow et al. 2004). The Corcoran clay’s ability to act as a regional aquitard is uncertain because of the large number of wells. The gravel pack surrounding the wells and the wells themselves act to connect the shallow aquifer with the deep aquifer (Page and Balding 1973).

4.3 Groundwater Quality

Groundwater in the Modesto Subbasin is for the most part of good quality. Locally, some problem constituents include total dissolved solids (TDS), nitrates, radionuclides, dibromochloropropane (DBCP), and volatile organic compounds (VOCs). In addition to these constituents, localized areas of man-made contamination (gasoline, solvents, etc.) are present. The following sections discuss these problem constituents, contamination, and their relationship to the aquifers and sediments.

4.3.1 Total Dissolved Solids

TDS is a measure of the amount of salts in the water (typically obtained by evaporating the water and weighing the remaining salts). Electrical conductivity (EC) is also a measure of the salts in the water but uses the water's ability to pass an electric current. The TDS of water can be approximated by multiplying the EC by 0.55 to 0.70 (Hem 1989).

Salts are a concern for both potable and agricultural users. Salt-tolerance thresholds for permanent and vegetable crops may be as low as 600 milligrams per liter (mg/L). Drinking water standards provide recommended maximum contaminant levels (MCLs) of 500 mg/L. An upper limit of 1,000 mg/L is allowed if it is not reasonable or feasible to supply water with levels less than 500 mg/L. TDS concentrations in most wells in the subbasin are low and suitable for potable or agricultural use.

The entire Modesto Subbasin is underlain by saline water. The base of fresh water is the boundary between water of specific conductance greater than or less than 3,000 micromhos per centimeter (µmhos/cm) (a TDS of about 2,000 mg/L). In the Modesto Subbasin, the mapped base of fresh water ranges from about 200 feet bgs in the eastern part of the study area where the Mehrten Formation is shallow, to depths of 700 feet beneath the western part of the city of Modesto, and to depths of 400 feet bgs near the confluence of the Stanislaus and San Joaquin Rivers (Page 1973).

High salinity water may also be present in Ione Formation sediments exposed on the ground surface in the eastern portion of the subbasin. It appears saline waters may be present at relatively shallow depths beneath Waterford.

TDS concentrations in most wells in the forebay aquifers are low and the water is suitable for potable or agricultural use. Figure 4-14 shows the distribution of concentrations in the subbasin. However, two MID wells in the forebay area (wells 3S/10E-26 and 27) have TDS measurements of 1,300 to 1,700 mg/L. Several wells near the town of Empire also have TDS concentrations greater than 500 mg/L but less than 1,000 mg/L. Two wells near Waterford also have reported high TDS levels of about 1,700 mg/L and 8,300 mg/L. Well construction details were not available to assess the potential source of the poor quality water. It is possible that the wells penetrated the Ione or Valley Springs Formations or that the poor water quality is associated with wastewater disposal. Evaporation also may concentrate salts in discharge areas.

Water quality data indicate that near Modesto, water from the shallow aquifer (above the Corcoran clay) typically has TDS concentrations less than 500 mg/L (Page 1972).

Groundwater from the deep aquifer locally may contain TDS concentrations greater than 500 mg/L. Wells that are screened in both the shallow and deep aquifers typically have TDS concentrations greater than 500 mg/L, suggesting that the deep aquifer may be the source of

Figure 4-14 TDS Concentration in Water Wells

Back of 11 x 17

the higher salinity water. There also appears to be a geochemical signature that could be used to identify water from the deep aquifer, because chloride concentrations increase significantly in those wells that penetrate below the Corcoran clay. Although there appears to be a regionally downward gradient, it is possible that extended pumping within the deep aquifer could locally create an upward gradient that would allow saline water from below to upwell into the aquifer.

Increased groundwater pumping from the 1970s through 1990 has caused the net recharge of salt to be less than the net discharge (MID 1996). The response of the groundwater system to the increased pumping has been a decline in water levels and a slow decrease in salt discharge from the groundwater system to the rivers. Further work is needed to better understand and quantify the spatial and temporal variabilities in salinity and water quality in the Modesto Subbasin and the process affecting water quality. When it is calibrated, the USGS's groundwater flow model for the Modesto Subbasin could provide valuable salinity and water quality information.

4.3.2 Chloride

Chloride is a naturally occurring salt. Concentrations in excess of 100 mg/L can be harmful to plants. Drinking water standards have established a secondary MCL of 250 mg/L.

For the most part, chloride concentrations between 1959 and 1970 were below 100 mg/L in the shallow groundwater (Page and Balding 1973). Figure 4-15 shows the chloride concentrations in the area. One area west of Highway 99 and one area near Waterford had chloride concentrations that exceeded 100 mg/L. Only one well, located in the city of Modesto, exceeded the drinking water MCL. This well was screened both above and below the Corcoran clay. Two other wells in the city also had chloride concentrations that exceeded the MCL between 1970 and 1971 (Page 1972). One of these wells extends below the Corcoran clay. Test hole data from the City of Modesto show that chloride concentrations increase with depth, with concentrations exceeding the MCL at a depth of about 250 feet bgs.

Short-term, recent data from MID show chloride concentrations are variable and do not appear to be increasing in the area. Seasonal pumping may affect the concentrations produced. Figure 4-16 shows these seasonal variations. Figure 4-17 shows the well locations.

Sources of chloride may be from industrial wastewater, a shallow or intermediate source zone of sodium chloride water, the Tuolumne River, an upward flow from the underlying saline water body, or a buried flowing well tapping that body (Page 1972). Historically, improperly destroyed gas exploration wells with artesian conditions have discharged high TDS and chloride water to the Tuolumne River. Also, drill cuttings and mud from the drilling operations could be sources of chloride, sodium, and TDS. Figure 4-17 shows the locations of these wells (California Department of Conservation 2002).

Groundwater with elevated nitrate concentrations also tends to show an increase in chloride. Sulfate also increases, but to a lesser extent. Groundwater underlying agricultural areas may be expected to have higher salinity due to deep percolation of applied water and other agricultural activities. The affected water is characterized by increased concentrations of chloride and sulfate that result from the leaching of nitrogen and potash fertilizers and other agriculture-related compounds and from increased evaporation as groundwater is pumped and reapplied for irrigation.

4.3.3 Sodium

Sodium is a naturally occurring salt. Concentrations exceeding 69 mg/L can be harmful to plants. The secondary drinking water MCL for sodium is 250 mg/L.

Generally, most wells east of Highway 99 have concentrations below the MCL. Concentrations are typically higher in wells with high TDS concentrations. The sources of sodium are similar to those identified for chloride.

4.3.4 Nitrate

Nitrate is an essential element for plant growth. However, some permanent crops, including grapes, may be adversely affected by excess nitrate. High nitrate levels are also detrimental to human health. Drinking water standards establish 45 mg/L nitrate (as nitrate) or 10 mg/L when nitrate is reported as nitrogen as the MCL.

Nitrate concentrations in most wells in the subbasin are below the MCL for drinking water. Between 1959 and 1970, only one well in the area, located just south of the Tuolumne River, exceeded the MCL (Page and Balding 1973). Most of the shallow aquifer area contained water with concentrations between 10 to 20 mg/L. Concentrations in a few areas exceeded 20 mg/L. Most of the forebay area had concentrations less than 10 mg/L. Concentrations in the groundwater from the deep aquifer were less than 1 mg/L. Figure 4-18 shows the distribution of the nitrate concentrations. Figure 4-17 shows the location of these wells.

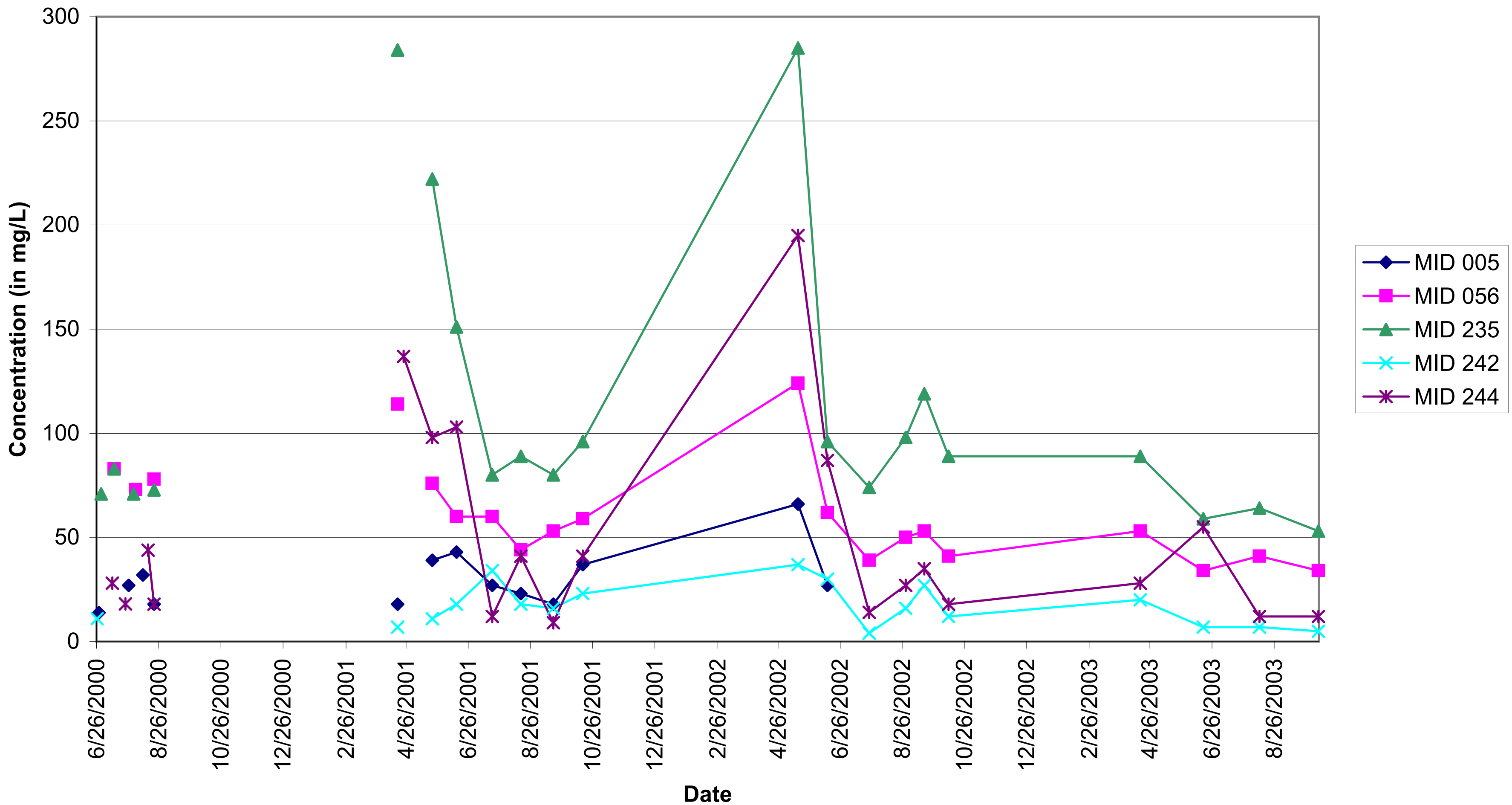
By 1990, nitrate concentrations in most of the shallow aquifer area west of Highway 99 had increased to more than 22 mg/L. Figure 4-19 shows the 1990 nitrate concentrations. A large zone of nitrate concentrations ranging from 64 to 96 mg/L was found in seven wells in this area. A second zone of nitrate concentrations exceeding the MCL was present beneath southwestern Modesto. Most of this high nitrate area coincides with Modesto’s former sewage effluent disposal area. Six other wells in north Modesto also had concentrations exceeding the MCL.

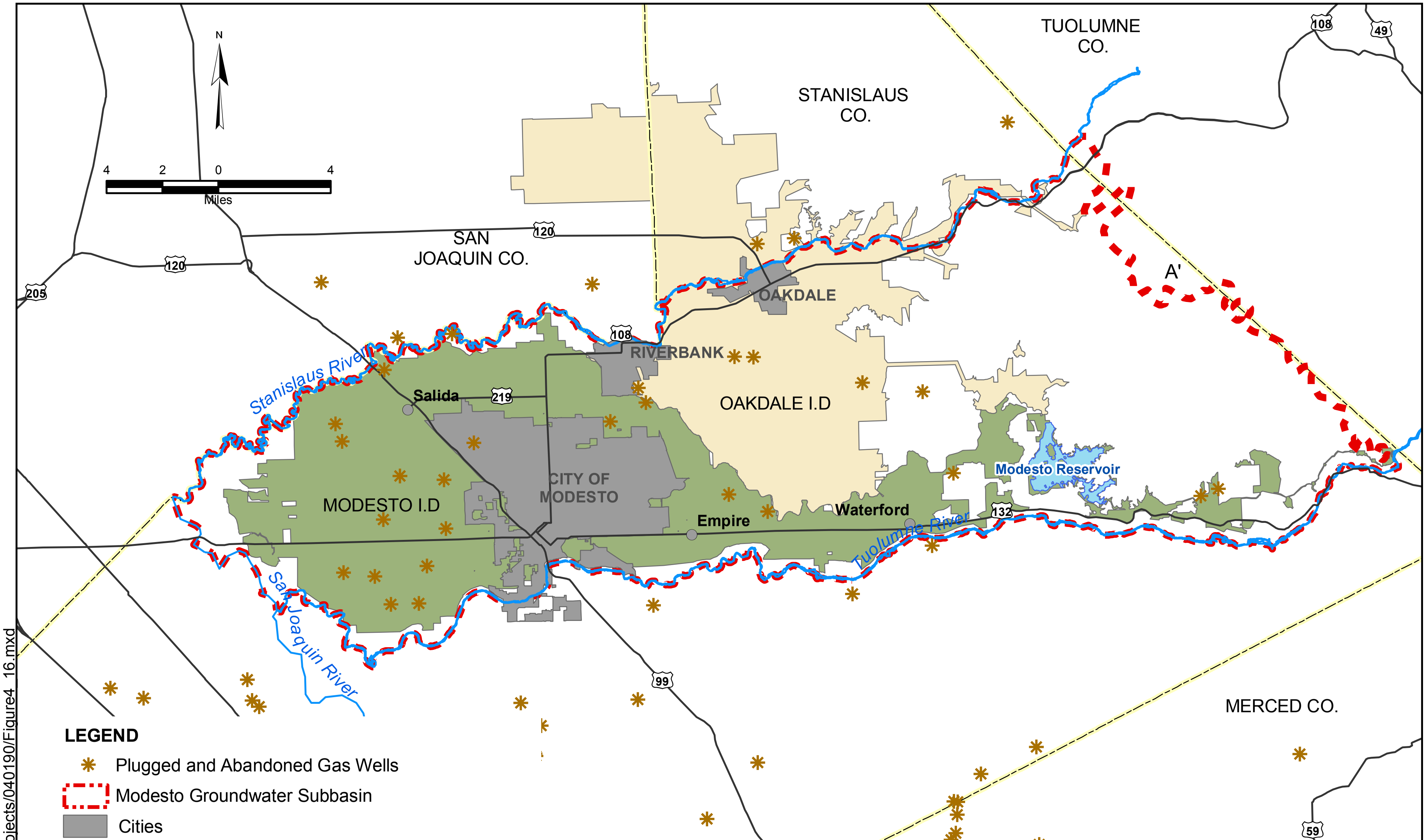
Nitrate in the forebay area was below the MCL in 1990, except for very high nitrate concentrations (243 to 275 mg/L) in water from wells 3S/10E-26 and 3S/10E-27. The TDS concentrations in these wells also exceeded 1,000 mg/L. Because nitrate is present with the high TDS, it is possible that the source may be related to wastewater disposal.

Figure 4-15 Chloride Concentrations in the Unconfined Water Body, with Selected Concentrations Shown in the Confined Water Body, 1959–70

Back of 11 x 17

Figure 4-16
Integrated Regional Groundwater Management Plan for the Modesto Basin
SEASONAL VARIATIONS IN CHLORIDE CONCENTRATIONS





SOURCES: City of Modesto, Modesto Irrigation District, City of Oakdale, Oakdale Irrigation District, City of Riverbank, CA Dept of Water Resources Groundwater Basins, 2002, Dept of Conservation, DOG, California Spatial Library.

05-10-04 S:/GIS/Projects/040190/Figure4_16.mxd

Bookman-Edmonston
A Division of GEI Consultants

INTEGRATED REGIONAL GROUNDWATER MANAGEMENT PLAN FOR THE MODESTO BASIN

Gas Wells

APRIL 2005

FIGURE 4-17

Figure 4-18 Distribution of Nitrate Concentrations in the Unconfined Water Body, with Selected Concentrations Shown in the Confined Water Body, 1959-1970

Back of 11 x 17

Figure 4-19 Nitrate (NO_3) Concentration in Water Wells in 1990

Back of 11 x 17

There is insufficient information to assess the nitrate concentrations in the deep aquifer at this time.

Future concentrations of nitrate in the area may potentially increase. Water quality samples collected from 2000 through 2003 show a slow increase in nitrate concentrations (MID 2004). Figure 4-20 shows results for several MID wells. The wells obtain water from multiple aquifers so the aquifer with the nitrate cannot be identified at this time. More data are needed to establish any definite trend in nitrate concentrations in the basin.

Nitrate concentrations generally decrease with depth because in the recharge areas, groundwater that is deeper in the flow system is generally older. There is a positive correlation between dissolved oxygen and nitrate concentration. Most of the water in the Modesto subbasin is oxic, containing oxygen. Well-oxygenated groundwater likely occurs in areas where the water rapidly infiltrates through coarse-grained sediments. Additional data are necessary to resolve which aquifers contain nitrate and the natural degradation processes that affect its concentrations.

4.3.5 Iron and Manganese

Iron and manganese are common elements in sediments and are essential nutrients for humans and plants. An upper limit has not been established for plants. A secondary MCL of 0.3 mg/L for iron and 0.05 mg/L for manganese has been established for drinking water.

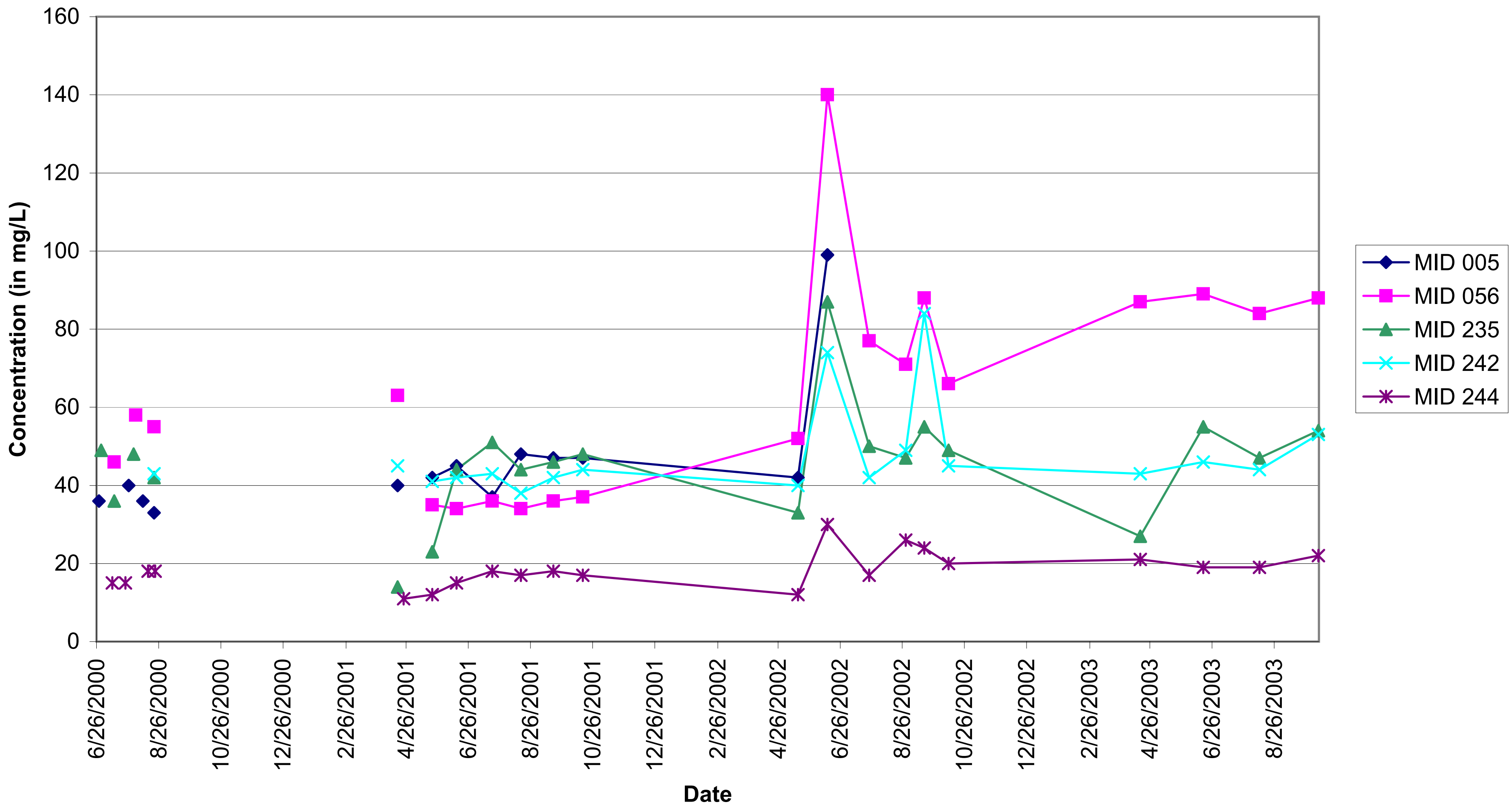
Groundwater in the western part of the subbasin near the San Joaquin River frequently has high concentrations of naturally occurring iron (MID 1996). Deeper groundwater is also found to have elevated levels of iron and manganese. Shallow groundwater near streams often shows high levels of manganese and occasionally high iron concentrations. The City of Modesto has encountered elevated iron and manganese levels in groundwater in a few test holes in eastern and southern Modesto. The Mehrten Formation typically produces water high in manganese.

4.3.6 Arsenic

Arsenic, a naturally occurring element, is used in pesticides and in poultry feed to combat disease. The current primary MCL for drinking water is 50 micrograms per liter (µg/L). The U.S. Environmental Protection Agency has mandated an MCL of 10 µg/L, and California has adopted the revised MCL.

Arsenic concentrations in the City of Riverbank wells, in the forebay aquifer, are typically less than 3 µg/L (City of Riverbank 2003). Similar concentrations are present beneath Oakdale, where the concentrations are less than 2 µg/L (City of Oakdale 2003) and at Waterford, where the concentrations range between 3 to 4 µg/L (City of Modesto 2003). The

Figure 4-20
Integrated Regional Groundwater Management Plan for the Modesto Basin
TRENDS IN NITRATE CONCENTRATIONS



lower concentrations may be the result of the recharge of river water into the aquifers. Arsenic concentrations near Salida are higher, ranging from 7 to 12 µg/L. Concentrations are more variable near Modesto, with levels ranging between non-detectable and 8 µg/L. The wide range may be the result of those wells taking water from two different aquifers, the shallow and deep aquifers. No data were available for the OID service area.

Arsenic is typically associated with elevated pH or some specific geochemical conditions. More data on the distribution of redox parameters and pH in the Modesto basin would help predict where elevated arsenic concentrations would be expected.

4.3.7 Radionuclides

Radioactive decay of certain elements produces radiation. The drinking water MCL for gross alpha, a general measure of the potential for radioactive substances to be in the water, is 15 picocuries per liter. The MCL for uranium is 20 picocuries per liter. If radiological constituents above the MCL are detected, additional testing is required for specific radioactive species. Sampling in the study area for radiological constituents has generally been limited to large public water system wells.

Groundwater with high uranium has been found in parts of Modesto and in Empire. Uranium activities in water from six wells ranged from 20 to 37 picocuries per liter in 1994 (MID 1996). Most of the area with high uranium concentrations is east of Highway 99 and northwest of Dry Creek. In 1994, two other wells in the southern part of this area produced water with alpha activities exceeding the MCL: a well in the Empire area had a uranium activity of 23 picocuries per liter and a small community public water system had uranium above the MCL. More recent data suggest concentrations may be as high as 28 µg/L (City of Modesto 2003).

In the northern portions of the forebay, the radiological concentrations are below the MCLs. The City of Oakdale reports a gross alpha between 0.53 and 1.02 picocuries per liter between 2000 and 2003. In Riverbank, the concentrations of gross alpha range from 0 to 7 picocuries per liter. These lower concentrations may be the result of recharge from the Stanislaus River.

4.3.8 Pesticides

DBCP, a pesticide usually associated with vineyards or orchards, was banned in 1977. The drinking water MCL is 0.2 µg/L.

Water samples collected in 1993 and 1994 detected low levels of DBCP in three localized areas within the subbasin that exceeded the MCL (MID 1996). Figure 4-21 shows sampling locations in the basin. The largest of these areas is between eastern Modesto and Empire and north of the Tuolumne River. The area extends about five to six miles from east to west and about two to three miles from north to south. The concentrations ranged from 0.21 to 0.57 µg/L. A second relatively large area of high DBCP levels is in central Modesto, primarily northeast of Highway 99. The third area is south of Del Rio, where the DBCP concentrations ranged from about 0.3 to 0.5 µg/L. The DBCP is in the shallow and forebay aquifers.

DBCP concentrations also exceeded the MCL at several scattered wells at different time periods. In the 1990s, DBCP was detected in one well at Salida, in another west of Modesto, and in another in north Modesto. DBCP has also been detected in wells in Waterford and in or near western Modesto but at concentrations below the MCL (MID 1996; City of Modesto 2003).

DBCP concentrations in most wells west of Highway 99 were below 0.01 µg/L. The Riverbank and Oakdale areas have not detected DBCP.

DBCP contamination is present primarily in the shallow groundwater (MID 1996). Positive correlations of nitrate to the occurrence of pesticides indicate that groundwater susceptible to nitrate contamination may also be susceptible to contamination from pesticides (Burow, Stork, and Dubrovsky 1998). Because DBCP is in the forebay and shallow aquifers and the groundwater flow direction is generally to the west, DBCP may migrate in the shallow aquifer west of Highway 99. It is possible that DBCP could enter the deep aquifer because of a downward flow path, pumping in the deep aquifer, and wells that are screened both in the shallow and deep aquifers.

Ethylene dibromide (EDB), another pesticide, has not been detected in groundwater in the area, other than for one unconfirmed incident (MID 1996).

4.3.9 Herbicides

Atrazine, cyanazine, deethylatrazine, diuron, ETPC, metolachloro, and simazine have been detected in domestic and monitoring wells located in almond orchards. Most of these herbicides do not have established drinking water MCLs. Those that do have MCLs are listed in Table 4-1.

Table 4-1
Concentrations of Herbicides in Area Wells

Herbicide	MCL (mg/L)	Concentration (µg/L)	Well Number	Land Use
Atrazine	0.003	0.008 to 0.059	3S/10E-35K1 3S/11E-30K1	Almond Orchard

Figure 4-21 DBCP Sampling Locations and Concentration in Water Wells

Back of 11 x 17

4.3.10 Volatile Organic Chemicals

VOCs are present in the groundwater near Modesto as the result of industrial activities. VOCs include trichlorofluormethane (freon 11), 1,1,2-trichloro-1,2,2-trifluroethane (freon 113), cis-1,2-dichloroethylene, perchloroethylene (PCE), trichloroethylene (TCE), carbon tetrachloride, disinfection by-products and petroleum fuel products (MID 1996; City of Modesto 2003). Along with these major chemicals are their daughter products, those that have decayed to other compounds. Several of these chemicals have been detected at concentrations above the MCLs, and some have resulted in the closure of municipal supply wells. Water from several wells is being treated.

Although most of the contamination is in the shallow aquifer, there is a potential that, with pumping below the Corcoran clay, contaminants could be pulled into the deep aquifer. There is insufficient information at this time to assess whether contaminants have migrated into the deep aquifer.

The City of Oakdale has not detected VOCs, except for PCE at 1.5 µg/L. No fuel hydrocarbons have been detected. VOCs have not been detected in the water supply wells at Riverbank.

4.3.11 Constituents of Concern

In summary, each of the aquifer systems has water quality problems, as listed below. For the most part, these problems affect only portions of the subbasin. In general, water quality north of the Modesto Subbasin, around the City of Oakdale and Riverbank, is of good quality. The City of Modesto has abandoned some of its wells because of water quality issues. High groundwater levels with high levels of TDS are present in the western portion of the subbasin.

- Shallow Aquifer – TDS, nitrate, DBCP, VOCs (localized to Modesto)
- Deep Aquifer – TDS, VOCs (localized to Modesto)
- Forebay Aquifers – TDS, DBCP, uranium (western part near Modesto and Empire)

Although iron and manganese are present, they can be easily removed by treating the water. Additional testing of the agricultural water supply wells and drainage wells should be performed to fully assess the distribution and concentrations in the area.

Both sodium and chloride are of local concern and are related to the occurrence of TDS. Nitrate and pesticides also have been correlated. Management actions to improve one of these problems will likely resolve multiple constituents.

4.3.12 Groundwater Quality Protection and Improvement

Groundwater quality problems can be managed through source control and managing the groundwater flow to contain the spread of contaminants in the basin. Improving groundwater quality requires long periods of time. Although active treatment systems can be effective in removing contaminants, they have not been discussed in this report.

Sources of TDS, sodium, and chloride include deep percolation from use of water for agriculture, wastewater disposal, naturally occurring water from the Mehrten Formation and below the Corcoran clay, and potentially improperly abandoned or residual wastes from gas wells. Source control can be accomplished by rehabilitating wells. For example, TDS concentrations can be reduced by 100 to 200 mg/L by plugging screen levels in the deep aquifer in wells that obtain water from both the shallow and deep aquifers. Source control may also include an evaluation of each of the gas well sites to assess whether there are artesian flowing conditions or residual wastes. Groundwater flow control can be accomplished by maintaining groundwater outflow to the San Joaquin, Stanislaus, and Tuolumne Rivers.

Nitrate sources may include wastewater from animal facilities, urban and agricultural wastewater disposal, and fertilizers. Wastewater control regulations should be supported, and where necessary, mitigating measures implemented by owners. Fertilizer application rates should be strictly followed. Modification of irrigation methods from flooding of fields to drip or spray irrigation may reduce the potential for nitrate to leach into the aquifers; however, this will reduce recharge. Pumping wells with high nitrate levels and reusing the water on vegetation can improve groundwater quality through groundwater flow control. Vegetation is probably the most effective way to remove nitrate from the water. Fertilizer applications may be reduced when using high nitrate waters. An agricultural laboratory should be consulted.

Source control of DBCP has already been implemented by banning its use. DBCP is moving through the deeper parts of the system and will degrade over time. DBCP may also be concentrated in the soils near product mixing areas, typically near a water source. Source control is to reduce the amount of leaching of the contaminant from the soils. Localized removal of soils with high concentrations may remove the potential source(s) and prevent further leaching into the groundwater. Groundwater control measures need to be implemented to prevent DBCP from spreading into adjacent portions of the aquifers. Reuse of water tainted with DBCP in the area where it is originally present can allow vegetation to remove the product without spreading the contaminants. However, before implementing this option, local regulatory agencies should be consulted to assess the regulatory and liability aspects of this approach.

Uranium is naturally occurring; therefore, source control is limited to identifying its horizontal and vertical extent and preventing its spread into adjacent areas. Anthropogenic activities may enhance its mobility, and therefore, mitigation of those activities may reduce the uranium. Passive treatment of the groundwater may be possible; installing filtration barriers may be possible, but would need a detailed assessment. Groundwater flow control may be possible and potable use of the water, likely by dilution with treated surface water, is considered a feasible and cost-effective solution.

4.4 Groundwater Use

The Modesto Groundwater Subbasin includes more than 247,000 acres, about 68 percent of which is irrigated agricultural land. Surface water supplies for MID are diverted from the Tuolumne River below La Grange Dam. Surface water supplies for OID are diverted from the Stanislaus River at Goodwin Dam. Both irrigation districts have a network of groundwater supply wells to augment their surface water supplies.

Since 1977, more than 5,000 wells have been completed in the area between the Stanislaus and Merced Rivers, east of the San Joaquin River. The number of domestic wells constructed during the 1970s through the 1990s increased. In contrast, fewer irrigation wells were constructed in the 1980s and 1990s than during the 1970s. These trends may reflect the increase in population and the decrease in irrigated farm acreage in the region (Burow et al. 2004).

The water demand for the Modesto Groundwater Subbasin was estimated at 590,000 acre-feet for water year 2000 (Burow et al. 2004). Surface water deliveries accounted for about 65 percent, or 382,500 acre-feet, of the total water supply. Groundwater accounted for about 35 percent, or about 206,500 acre-feet, of the total supply. Of the approximately 534,000 acre-feet used to meet irrigation demand, 68 percent was surface water and 32 percent was groundwater. Of the approximately 56,000 acre-feet used to meet urban demand, 42 percent was supplied by surface water and 58 percent was supplied by groundwater. Although two-thirds of the wells in the study area are domestic wells, the amount of water pumped has not been quantified.

The following quantities of groundwater are supplied to urban customers:

- City of Riverbank: 3,800 acre-feet during calendar year 2002
- City of Oakdale: 4,600 acre-feet during calendar year 2002
- City of Modesto: about 46,800 acre-feet during calendar year 2003

The total water recharge in the Modesto Groundwater Subbasin was about 310,000 acre-feet. The largest component of recharge is irrigation (57 percent), whereas precipitation in excess of crop requirements accounted for 41 percent of the recharge (Burow et al. 2004). Recharge in the Modesto urban area totaled 20,000 acre-feet, about 7 percent of the total recharge.

The highest recharge rates generally occur in the agricultural areas in the western part of the study area, along the canals north of the Tuolumne River and east of Modesto. The lowest recharge rates generally occur in the eastern part of the study area, in the foothills and adjacent uplands, and in the Modesto urban area. The highest pumpage rates generally occur in the agricultural areas in the western part of the study area (Burow et al. 2004).

The water supply and demand estimates do not estimate the amount of natural recharge along the Stanislaus or Tuolumne Rivers or the amount of discharge from the basin into the Stanislaus, Tuolumne, and San Joaquin Rivers.

Water demands are likely to increase as the area’s population increases. The California Department of Finance projected the population would reach 517,600 in 2000 and 670,000 in 2010 (Stanislaus County 1994). Census data for 2000 showed the population had only reached 245,000; therefore, growth is proceeding slower than anticipated (U.S. Census Bureau 2004). The conversion of agricultural lands to urban development may mitigate some of the water demand.

4.5 Summary

Significant basin-wide geologic and hydrogeologic studies have been completed. Information from historic and ongoing studies will be used to focus efforts on resolving uncertainties in the hydrogeologic conditions that govern groundwater movement in the subbasin. Focusing these efforts on limited portions of the subbasin will lead to sound groundwater management options and actions.

Based on only two geologic sections, which do not adequately define the three-dimensional nature of the aquifers, the subbasin contains four aquifers. Three are connected (shallow, deep, and forebay) and the fourth, which underlies all of the others, may be relatively isolated from the effects on the other aquifers. Because the three aquifers are interconnected, changes to water supply or demand in one aquifer will affect the other two aquifers. The vertical and horizontal extents of the shallow aquifer and the deep aquifers are relatively well defined. The bottom of the deep aquifer has been less precisely defined. The deep aquifer likely consists of several geologic formations (Turlock Lake, Laguna, and the upper portions of the Mehrten Formation). Although there may be different names for the geologic units, they likely are hydraulically connected.

Both the shallow and deep aquifers receive water from the forebay aquifers. In profile, the forebay aquifers represent a triangular wedge that thickens towards the west and thins towards the east. This conceptual picture is based on one geologic section drawn east-west about halfway between the Stanislaus and Tuolumne Rivers. The section showed a gravel bed that coincides with the Mehrten Formation’s western exposure at ground surface. Used by most wells, this gravel occurs to about the center of Modesto and could convey significant amounts of water into the central portion of the subbasin. Because it is exposed on the ground surface, it can be readily recharged. The gravel bed could be part of the Mehrten Formation because it has a dip of about 0.006 feet per foot and at one location the gravel is overlain by “lava” (“lava” or breccias are commonly associated with the Mehrten Formation). The gravel bed described above is not present in all wells. This is likely the result of historic topography in which the gravels were deposited in valleys but not on the low surrounding hills. The sediments in these hills are more of the typical claystone with thin-bedded sands. Overlying the Mehrten Formation sediments are younger sediments of the Turlock Lake, Riverbank, and Modesto Formations and Holocene alluvium. These sediments were laid down horizontally (or at a slight dip). The dipping sediments of the Mehrten Formation, therefore, will abut these younger sediments and allow water to be conveyed from the younger sediments into the upper Mehrten Formation sediments. The younger sediments act as a reservoir to feed the upper Mehrten Formation aquifers.

The horizontal extent of the gravel bed is poorly defined. It appears to extend from about the Stanislaus River to just north of the Tuolumne River. A few well logs from north of the Stanislaus River show gravel at about the right depth, suggesting this marker bed for the forebay aquifers may be present in this area but has not yet been fully defined. Further definition of the extent of this gravel bed is needed to identify potential recharge areas.

Underlying the three aquifers are the Mehrten Formation confined aquifers. These aquifers are locally separated from the overlying aquifers by a 60- to 120-foot clay layer. It is possible that the clay has been locally eroded and may allow some interconnectedness of the aquifers, but the current level of information is insufficient to identify those areas. There is currently insufficient information to confirm that the confined Mehrten Formation aquifers are indeed hydraulically separated from the overlying aquifers.

The Mehrten Formation confined aquifers conceptually differ greatly from the three other aquifers. Because the younger sediments are not resting over the aquifers and acting as a reservoir, these aquifers receive only local and seasonal recharge. Local recharge to the confined aquifers is likely derived from the Modesto and Woodward Reservoirs and from the area where the Stanislaus and Tuolumne Rivers cut across the surface exposure of the Mehrten Formation. Between these recharge sources, there will be limited seasonal recharge by rain. Groundwater levels between these sources will likely have the greatest changes. At some depth, the Mehrten Formation confined aquifers are likely to contain ancient water that has higher TDS concentrations.

All of the City of Oakdale wells, most of the OID wells, and some of the MID wells use these Mehrten Formation confined aquifers. Because recharge is limited, this aquifer needs careful monitoring. Groundwater levels are currently declining about one foot per year, according to the City of Oakdale and hydrographs from the DWR. Groundwater recharge efforts in the forebay aquifers will not have a significant benefit on the Mehrten Formation confined aquifers.

Many of the OID and MID wells are screened in both the forebay and Mehrten Formation confined aquifers. Because sediments in the forebay aquifers have a higher hydraulic conductivity, most of the water pumped from the wells will be derived from these aquifers. However, the forebay aquifers thin to the east and as such will experience the greatest changes in water levels. Increasing the groundwater gradient by pumping wells in the shallow and deep aquifers can easily increase the drawdown. The saturated thickness is directly related to the yield of the wells. When the yield from the forebay aquifers is diminished, greater amounts of water will be obtained from the Mehrten Formation confined aquifers. Most of the current groundwater level monitoring is done in production wells, and because most wells are screened in both aquifers, there is little definition of the groundwater levels and conditions in the forebay aquifers. Groundwater monitoring needs to be improved in the eastern extent of the forebay aquifers to assess the conditions and changes that may occur.

Based on the conceptual understanding of the geology and aquifers, we recommend that the following actions be undertaken to secure a more complete understanding of the hydrogeology.

Issue	Action
▪ Eastern extent of forebay aquifers poorly defined.	▪ Obtain well logs from DWR to prepare additional east-west geologic sections north of the Stanislaus River and near the Tuolumne River.
▪ Monitoring of the forebay aquifers is insufficient where they thin and the greatest changes in water levels may occur.	▪ Review well logs from DWR to identify wells with screens only in the forebay aquifers. Contact well owners to participate in groundwater level monitoring. Where necessary, construct additional monitoring wells.
▪ There is insufficient monitoring along the Stanislaus and Tuolumne Rivers to assess the surface water-to-aquifer interactions. Most wells being monitored are at depths well below the invert of the river.	▪ Review Regional Water Quality Control Board records to assess shallow wells that could provide groundwater gradients near the rivers.
▪ Insufficient monitoring in the Mehrten Formation confined aquifers as most OID wells are screened in both the Mehrten Formation and forebay aquifers.	▪ Review well logs from DWR to identify wells with screens only in the Mehrten Formation confined aquifers. Contact well owners to participate in groundwater level monitoring. Where necessary, construct additional

Issue	Action
	monitoring wells.
▪ Mehrten Formation confined aquifer recharge areas are poorly defined.	▪ Locate significant sand or gravel beds from well logs and project their occurrence to ground surface. Confirm the projections by drilling test holes for sediment types.
▪ Groundwater flow directions are poorly defined, and therefore, interpretations of recharge and discharge areas and of the interactions between aquifers may change greatly.	▪ Implement the groundwater monitoring plan (see Appendix D). A hydrogeologist should interpret the data and prepare groundwater contour maps. Identify uncertainties, refine the monitoring network, and propose resolution to improve the interpretations.
▪ The recharge areas and the interaction between the forebay and Mehrten Formation confined aquifers are poorly defined.	▪ Conduct oxygen isotope analysis on selected wells in the forebay and Mehrten Formation wells. Supplement where needed with tritium analysis.
▪ The full extent of the 20- to 40-foot gravel layer needs to be explored for potential recharge possibilities and beneficiaries.	▪ Conduct a review of well logs in the area for gravel beds.
▪ Outflow from the basin is poorly understood and needs to be maintained to prevent salt buildup.	▪ Implement monitoring program. Use results to position new monitoring wells.
▪ Drilling of new City production wells within the study area has the potential to yield new and important data, but is not currently being coordinated.	▪ Review well drillings while they are being taken.

This page left intentionally blank.

5 Groundwater Management Plan

5.1 Definition of Groundwater Basin and Map of Groundwater Basin and Subareas

This regional management plan covers the entire Modesto Subbasin and part of the Eastern San Joaquin Subbasin. DWR Bulletin 118 defines these basins as follows:

- The Modesto Subbasin lies between the Stanislaus River to the north and Tuolumne River to the south and between the San Joaquin River on the west and crystalline basement rock of the Sierra Nevada foothills on the east. The northern, western, and southern boundaries are shared with the Eastern San Joaquin Valley, Delta-Mendota, and Turlock Groundwater Subbasins, respectively. The subbasin comprises land primarily in MID and the southern two-thirds of OID. The City of Modesto is in the southwestern portion of the subbasin. Average annual precipitation for this subbasin is 11 to 15 inches, increasing eastward.

- The Eastern San Joaquin Groundwater Subbasin is defined by the areal extent of unconsolidated to semiconsolidated sedimentary deposits that are bounded by the Mokelumne River on the north and northwest; San Joaquin River on the west; Stanislaus River on the south; and consolidated bedrock on the east.

- The Eastern San Joaquin Groundwater Subbasin is bounded on the south, southwest, and west by the Modesto, Delta-Mendota, and Tracy Subbasins, respectively and on the northwest and north by the Solano, South American, and Cosumnes Subbasins.

Figure 5-1 shows the Modesto and East San Joaquin Groundwater Subbasins.

5.2 Basin Management Objectives

To meet the purposes and goals of the groundwater management plan stated in Section 2.4, the agencies will adopt the following BMOs. Two sets of BMOs have been developed reflecting the integrated and regional nature of this groundwater management plan: (1) the broad BMOs are designed to have basin-wide and regional perspectives, and (2) more specific BMOs have been developed for each management area.

5.2.1 Maintain Groundwater Levels

Except for some localized areas, groundwater levels in the basin are generally stable. However, an increase in urban development and reliance of urban areas on groundwater may cause the groundwater table to lower. The Association’s objective is to ensure that the overall groundwater levels in the basin are maintained over time to provide long-term reliable sources of water for the economic well-being of the area. Specific actions to achieve this objective include:

- Identification and mapping of the basin's natural recharge areas.
- Protection of groundwater recharge areas. This may include communication, coordination, and cooperation with land use planning agencies to encourage them to take actions that would limit incompatible land use development practices in the recharge area.
- Development of a water budget to determine if the basin is in overdraft and, if so, to determine the amount of overdraft.
- Feasibility evaluation of artificial recharge projects.
- Identification and feasibility evaluation of conjunctive use projects.
- Support and encourage water conservation programs.
- In-lieu recharge through the importation of a surface water supply to areas currently relying on groundwater.

5.2.2 Control Degradation of Groundwater Quality

Water quality in the basin is adequate for agricultural use. North of the basin, the Cities of Oakdale and Riverbank enjoy excellent water quality. However, the City of Modesto has lost some of its production wells because of the migration of pollutants into its management area. Specific water quality actions for the basin include:

- Maintaining groundwater levels to control the movement of poor quality water into and within the basin. Groundwater pumping that results in the lowering of groundwater levels in part of the basin could alter the natural groundwater flow direction in the basin. In the area with groundwater contamination, this change could result in the movement of poor quality water in the basin. The City of Modesto has reduced groundwater pumping in some parts of the basin, augmenting its groundwater with surface water deliveries to its customers. Other actions may include implementing the actions summarized for the groundwater level BMOs listed above.
- Conducting a detailed geologic assessment of the basin, focusing on the areas with poor water quality, to identify the sources of contaminants and poor quality water. Developing actions and projects to mitigate the migration of poor quality water into the basin where practical.

Figure 5-1 Modesto and East San Joaquin Groundwater Subbasins

Back of 11 x 17

- Continuing to support the development of in-lieu recharge projects in urban areas with poor quality water (i.e., continuing the delivery of additional surface water to the City of Modesto to reduce its reliance on groundwater).

- The Association will coordinate and communicate with land use planning. The agencies will work together to discourage land use practices within the recharge areas that may contribute to groundwater degradation. Agencies within the basin, particularly urban water agencies, are concerned about protecting natural recharge areas from pollutants and about the quality of water used for potential future groundwater recharge projects. Such projects within the basin will be developed in a coordinated fashion and through the Association to ensure that the groundwater quality concerns of all management areas are considered.

- Evaluating the impact of annexation practices on groundwater levels and groundwater quality.

- The Association will coordinate and facilitate implementation of groundwater protection measures. These measures are discussed in more detail in Section 6.

5.2.3 Protect Against Potential Inelastic Land Surface Subsidence

Historically land surface subsidence within the basin has not been significant. Given the balanced nature of groundwater storage in the basin, potential future land subsidence is remote. However, the agencies will document and investigate any changes in land surface elevations and take appropriate actions if inelastic subsidence is observed.

5.2.4 Groundwater Monitoring and Assessment

The agencies in the Modesto Groundwater Subbasin understand the value of groundwater monitoring and assessment in the management of the basin. Groundwater monitoring is needed to track and assess the potential effects from the water-related activities and the implementation of management objectives in order to protect the quality and quantity of the basin's groundwater. The Association, therefore, is evaluating its groundwater monitoring needs and has developed (and periodically updated) its groundwater monitoring plan (Appendix D). A database is being developed to facilitate the storage, retrieval, and archiving of the basin groundwater data. The Association will also develop a groundwater model for the basin that can be used to evaluate the effects of the various proposed projects and management actions on groundwater levels and quality in the basin.

5.2.5 Evaluate Feasible Water Conservation Measures

Certain water conservation practices may be evaluated to determine their ability to improve water levels and water quality in the basin. Typical water conservation practices may include:

- Blending: Currently, MID pumps water from the shallow aquifer and blends it with surface water before delivering it to its agricultural water users. The agencies within the basin could evaluate an expansion of the blending program in order to lower the high groundwater table and improve water quality.

- Reuse of poor quality water: Groundwater in areas with a high level of nitrates can be pumped for agricultural uses in order to improve water supply availability and groundwater quality.

- Water conservation: Water conservation in the form of incentive programs, water audits, water metering, sewage fees, and other measures can be a tool to reduce demand on the basin.

5.2.6 Coordination and Cooperation

- Provide and expand existing forum for coordination and cooperation between all water entities to manage the Modesto Subbasin. Assist in formulating regional projects and programs for protection and use of subbasin water resources.

- Provide a framework for coordination and cooperation with the state and federal agencies and neighboring water entities such as TID, Stockton East Water District, and SSJID.

- A number of industrial plants in the Modesto Subbasin use groundwater. Production wells in these plants frequently affect groundwater levels in neighboring municipal and industrial wells during peak demands in summers. The Association will provide for an education and outreach program to bring industrial water users to the table and to work with them to develop conjunctive use projects to reduce well interference.

5.3 Groundwater Management Areas Objectives

This section addresses the specific objectives for each management area. Although specific to each management area, these objectives may limit or constrain activities within other management areas. Therefore, the participation and cooperation of agencies within the basin will be needed for the successful implementation of these objectives.

5.3.1 City of Modesto Management Area

Until 1995, the City of Modesto relied solely on groundwater for its service area. Groundwater degradation and more stringent drinking water quality standards resulted in the abandonment of a number of wells within the City's service area. Currently, the City is augmenting its groundwater supplies in its contingency service area with surface water received from MID. Groundwater quality issues, including elevated levels of uranium and arsenic, are threatening the City's groundwater supply. To protect its groundwater and maintain groundwater as a viable drinking water source, the City of Modesto has formulated the following BMOs for its management area:

5.3.1.1 Groundwater Quality Protection

The City proposes to protect groundwater quality by developing and implementing specific actions to identify potential sources of contamination and to develop a management plan to control and curtail movement of contaminants into and within the basin. The specific actions may include the following:

- Develop a database and populate it with water quality data. Using the database information, develop tools to map contaminated areas as well as historic movement of the contaminants.

- Formulate and implement a geologic assessment to better understand the basin's aquifer characteristics and water movement and to evaluate and understand the sources of contaminants. Detect potential changes in water quality that could affect the long-term quality and quantity of the drinking water supply.

- Develop a well field management plan that will manage groundwater pumping to reduce or eliminate contaminant movement into and within the basin. Develop well design criteria, including proper spacing and screening of wells to manage groundwater pumping and the movement of contaminants.

5.3.1.2 Groundwater Levels

Groundwater levels, historically, were declining in this management area. Since 1995 and with the importation of surface water to augment the groundwater supply, groundwater levels have recovered. However, future population growth in and around the management area will increase groundwater use. To maintain groundwater levels in the management area, the City of Modesto formulated the following management objectives:

- Work with other entities in the subbasin to identify and protect the groundwater recharge area.

- Evaluate feasibility of groundwater recharge and conjunctive use projects including the development of artificial recharge areas, conjunctive use projects, and storage tanks with transmission mains for added reliability to the system.

- Work with MID to evaluate the feasibility of developing a cooperative in-lieu recharge and/or water exchange programs including the following:

    - Increase water treatment capacity and use of surface water to augment the groundwater supply.

- Develop an exchange program to mix the groundwater of marginal quality (for drinking water) with surface water and deliver it for agricultural use, golf courses, parks, and other open space areas in exchange for a surface water supply for the City of Modesto.

5.3.1.3 Water Conservation and System Improvement

The City of Modesto, under its Urban Water Management Planning function, will continue to evaluate water conservation and metering opportunities to reduce water demands in the service area. The City also plans to undertake a conveyance system interconnection improvement project to connect isolated delivery systems to its water delivery network. These actions will add flexibility to the system and enable the City to reduce pumping from the areas of poor water quality and reduce movement of contaminants in the basin.

5.3.2 Modesto Irrigation District Management Area

MID plays a major role in the groundwater management of the Modesto Groundwater Subbasin. MID and TID operate Don Pedro Reservoir and divert surface water for agricultural and urban uses to the basin. To manage groundwater levels and protect the basin groundwater quality, MID plans to implement the following BMOs:

- Develop a systemwide wellfield optimization program to actively manage MID's groundwater production and to manage its surface and groundwater resources conjunctively, in real time, to meet its water supply and energy management objectives.

- Manage MID's surface water and groundwater conjunctively in an integrated fashion. This would include importation and treatment of additional surface water supplies from MID to the City of Modesto to reduce pumping groundwater.

- Continue working with the City of Modesto to protect the management area from potential overdraft and movement of contaminants to the basin. In cooperation with the City of Modesto, develop a water exchange program to mix the groundwater of marginal quality (as potable water) pumped by the City with surface water and deliver it for agricultural use, golf courses, parks, cemeteries, and other open space areas in exchange for surface water delivery to the City of Modesto.

- Evaluate the feasibility of an expanded blending program and the use of shallow water acquired for delivery to agricultural water users.

5.3.3 City of Oakdale Management Area

The City of Oakdale relies solely on groundwater for its water supply. The City's goal is to protect its groundwater levels and quality for a sustainable water supply for its citizens.

5.3.3.1 Groundwater Levels

The City operates nine wells, two of which were recently constructed. Water levels in some wells are impacted by operations of production wells at the Hunts and Hershey industrial plants. To protect its groundwater levels, the City can:

- Conduct a systemwide optimization study to determine how its wells can be operated to maximize production while minimizing the impact from the other wells.
- Work with plant managers to minimize operation impacts during the City's peak water demand. Promote and encourage an industrial water conservation program.
- Work cooperatively with other water entities in the basin to promote and implement conjunctive management programs. Specifically, investigate the potential of treatment facilities for surface water that could be supplied by OID.
- Work cooperatively with other agencies to identify and develop groundwater recharge projects when possible.

5.3.3.2 Groundwater Quality Protection

- Construct a sanitary seal on all new wells and work with other groundwater users within the management area to ensure proper well construction methods are used for all new wells.
- Abandon wells within the management area in accordance with the Stanislaus County well abandonment ordinance.
- Regularly monitor wells adjacent to industrial areas to detect any potential water quality degradation. If degradation is detected, consult with the Regional Water Quality Control Board to encourage the implementation of necessary steps to control the migration of poor quality water.

5.3.4 City of Riverbank Management Area

Groundwater is the only source of water for the City of Riverbank. Currently, groundwater levels and water quality are stable within this management area. Groundwater quality protection is the only BMO designated for this management area. To protect the groundwater quality of the management area, the City can take the following actions:

- Monitor groundwater quality to ensure that it is not compromised by the operation of industrial facilities such as the wood treatment plant. If water quality degradation is detected, consult with the Regional Water Quality Control Board to encourage the implementation of actions to control the migration of poor quality water in the basin.

- The City is concerned about the operation of a future recharge project and the quality of water used for recharge. The City will work with other water agencies within the basin to ensure that the future recharge project operation will not compromise groundwater quality in the Riverbank management area.

5.3.5 Oakdale Irrigation District Management Area

The OID management area is divided between the Modesto Groundwater Subbasin and the East San Joaquin Groundwater Subbasin. About 60 percent of the OID management area is within the Modesto Subbasin. However, the issues of the management area north and south of the Stanislaus River are similar and the BMOs listed below will be applicable for the entire management area. Urbanization within and around the management area has increased groundwater production and the potential for future overdraft. OID plans to implement the following BMOs:

- Develop a systemwide well field optimization program to actively manage groundwater production and to manage surface and groundwater resources conjunctively, in real time, to meet OID's water supply and energy management objectives.

- Manage OID's surface water and groundwater resources conjunctively. This would include:

    - Investigating the feasibility of developing conjunctive use and groundwater recharge projects. Determine if groundwater recharge is a viable option to reduce the falling water table within the management area.

    - Promoting programs and actions that protect recharge areas within the management area.

    - Investigating the feasibility of annexing areas currently on groundwater in order to bring surface water to the area for in-lieu recharge programs. Evaluating the potential benefits of the annexation of adjacent farmland on falling groundwater table within the management area, which is reliant on groundwater, and converting it to surface water.

    - Investigate impacts of upstream development (urban or agriculture) on the water quality and groundwater level within the OID service area.

5.3.6 Stanislaus County Management Area

The County of Stanislaus is represented by the DER at Association meetings. Partnering with the Association in basin-wide groundwater management is consistent with the Board of Supervisors' priority of ensuring a safe and healthy community, facilitating economic development, and achieving multijurisdictional cooperation. To meet these priorities, the County promotes and participates in Association programs that:

- Preserve and protect the groundwater resource
- Enhance the understanding of groundwater resources through the gathering and sharing of information
- Provides factual information that may serve as a basis for land use decisions in the groundwater basin

5.4 Current Groundwater Monitoring Activities

Groundwater levels in the Modesto Subbasin have been measured in about 230 wells by the DWR and its cooperatives. The wells used for monitoring may be in different aquifers and at times have long screen intervals that make an interpretation of groundwater flow directions and water quality difficult. Some member agencies are reporting data to DWR and are included in this list.

The USGS, in partnership with member agencies of the Association, has monitored 17 wells in the area for the National Water Quality Assessment Program. It has also constructed or plans to construct additional monitoring wells in the City of Modesto to define hydraulic characteristics, water levels, and water quality in the shallow and confined aquifers. Appendix D contains a list of these wells.

The University of California-Davis with grant funding has constructed several monitoring wells to assess nitrates and nutrient management near dairies.

The Association's members, to varying extents, monitor groundwater production, levels, and quality. Table 5-1 summarizes the current level of monitoring through the member agencies.

Table 5-1
Current Level of Monitoring Efforts

Member Agency	Total Number of Wells	Pumping Totals Monthly	Number of Wells Where Groundwater Levels Are Measured			Number of Wells Where Groundwater Samples Are Analyzed for Water Quality			Water Quality Analyses Performed
			Monthly	Semiannual	Annual	Quarterly	Semiannual	Annual	
MID	104	104		96			15		General Mineral, Boron
								104	EC + pH
OID	17	17		17					
City of Modesto	62	86				14 (VOCs)			Per Title 22 and DHS
Ceres	4	4							Per Title 22 and DHS
Walnut Manor	1	1							Per Title 22 and DHS
Salida	7	7							Per Title 22 and DHS
Del Rio	3	3				1			Per Title 22 and DHS
Waterford	7	7							Per Title 22 and DHS
Hickerman	2	2				1			Per Title 22 and DHS
City of Oakdale	7	7							Per Title 22 and DHS
City of Riverbank	7	7							Per Title 22 and DHS
Total	**221**	**245**	**0**	**113**	**0**	**16**	**15**	**104**	

Source: CCR from City of Modesto; MID e-mail comunication, 2004; OID well location map; Oakdale Water Master Plan, Riverbank production totals

Member Agency	Total Number of Wells	Pumping Totals Monthly	Number of Wells Where Groundwater Levels Are Measured			Number of Wells Where Groundwater Samples Are Analyzed for Water Quality			Water Quality Analyses Performed
			Monthly	Semiannual	Annual	Monthly to Every Three Years			
DWR (including									
Cooperators)	230			230					
OID	15						15		Drinking Water Parameters
Department of Health							209		Per Title 22 and DHS
Services (Including									Per Title 22 and DHS
Cooperators)									Per Title 22 and DHS
Total	**245**			**230**			**224**		

Source: DWR, 2004, Bulletin 118

Other groundwater monitoring conducted in the basin assesses releases of hazardous materials to the environment. These wells are typically near metropolitan areas and the resulting data are provided to the Regional Water Quality Control Board. These wells are extremely useful because they typically monitor the first water encountered, which can be correlated with surface water gaging stations to evaluate the aquifer connectedness.

5.4.1 Subsidence Monitoring

Land subsidence in the Central Valley has occurred in three areas with an aggregate area of about 4,000 square miles. Subsidence has occurred in the area extending from Los Banos to Wasco, from Arvin to Maricopa, and in the Delta region east of Stockton. Subsidence has also occurred along the west side of the valley in Yolo, Solano, and Colusa Counties.

Subsidence can be elastic or inelastic. Elastic subsidence occurs when aquifers are pumped and the pore pressure is decreased. After recharge occurs and the heads increase, the land surface generally recovers. Elastic subsidence in the Sacramento Valley has been reported to be on the order of about 0.2 feet (Borchers et al. 1998). Inelastic subsidence results in permanent, irreversible declines in ground surface.

Inelastic subsidence is of three types in the Central Valley: oxidation of peat, lowering of the artesian head in confined aquifer systems, and near-surface compaction of moisture deficient alluvial fan deposits above the water table (Poland and Evenson 1966). Subsidence can also occur in areas where water-level declines in unconsolidated aquifers allow mineral grains to permanently adjust to a denser arrangement (Borchers et al. 1998). The mechanisms of subsidence in unconsolidated aquifers are governed by groundwater levels. If the water levels drop below their lowest historic level, inelastic subsidence may occur. In these cases, inelastic subsidence is generally due to compaction in thick clay beds.

The Association is in an area where subsidence has not been reported, although no specific studies have been conducted in the area. The potential for subsidence in the area is low because the sediments lack peat, the sediments were deposited with water, and the Corcoran clay is relatively thin and is not distributed throughout the area. Groundwater levels have declined in unconsolidated sediments through 1995 and may have resulted in some inelastic subsidence. It is not anticipated that groundwater levels will be lowered below these historic levels, and therefore the potential for subsidence in the area is low.

5.5 Facilitating Conjunctive Use Operations

The most significant conjunctive use operation in the Modesto basin is the construction of the Modesto Regional Water Treatment Plant and its associated storage and delivery systems, which treats surface water for delivery to areas that had previously relied solely on groundwater. This project has contributed to the recovery of groundwater levels in the Modesto area, improved the delivery system’s reliability, and has reduced pollutant movement in the basin. The program for expanding the treatment plant and its associated storage and delivery systems is under way. This conjunctive management of the basin's surface water and groundwater resources contributes to the protection of the basin, while providing a reliable water supply for the City of Modesto.

Other conjunctive use projects will be investigated. One key study to formulate conjunctive use projects will identify recharge areas in the basin.

6 Groundwater Protection Measures

A high priority of the IRGMP is protection of the groundwater resources. This will be accomplished through a series of actions, described below, that will be implemented by the Association members and facilitated by the Association.

6.1 Identification and Management of Wellhead Protection Area

The purpose of wellhead protection is to protect the groundwater used for public supply, thereby eliminating costly treatment to meet relevant drinking water quality standards. A Wellhead Protection Area (WHPA), as defined by the Federal Wellhead Protection Program established by Section 1428 of the Safe Drinking Water Act Amendment of 1986, is "the surface and subsurface area surrounding a water well or wellfield supplying a public water system, through which contaminants are reasonably likely to move toward and reach such water well or wellfield." The WHPA may also be the recharge area that provides the water to a well or wellfield. Unlike surface watersheds that can be easily determined from topography, WHPAs can vary in size and shape depending on subsurface geologic conditions, the direction of groundwater flow, pumping rates, and aquifer characteristics. WHPAs are not directly an agricultural issue. However, in the Modesto Basin, because of the relationship between agricultural and municipal water uses, some important considerations in delineating WHPAs are as follows:

- Location of existing public supply wells
- Identification of probable locations of future public supply wells
- Present direction of groundwater flow
- Probable direction of future groundwater flow
- Construction characteristics of public supply wells (i.e.; perforated intervals and annular seals)
- Subsurface geologic conditions (i.e., restricting layers, confining beds, and other features)
- Rate of current groundwater flow
- Pumping from upgradient areas
- Potential sources of contamination

- Forecasted future land use

Potential areas of water quality risk include:

- Areas without improved sewage collection systems
- Areas with leaky sewer pipes and septic systems
- Wells improperly abandoned
- Confined animal feedlots
- Agricultural practices where chemicals are used
- Areas with potential for spills of hazardous materials

Identification of wellhead protection areas is a component of the Drinking Water Source Assessment and Protection Program (DWSAP Program) administered by the Department of Health Services. It set a goal for all water systems statewide to complete Drinking Water Source Assessments by December 31, 2002. The Cities of Modesto, Riverbank, and Oakdale have completed their required assessments by performing the three major required components listed below:

- Delineation of capture zones around sources (wells)
- Inventory of Potential Contaminating Activities (PCAs) within protection areas
- Vulnerability analysis to identify the PCAs to which the source is most vulnerable

Delineation of capture zones includes using groundwater gradient and hydraulic conductivity data to calculate the surface area overlying the portion of the aquifer that contributes water to a well within specified time-of-travel periods. Typically, areas are delineated representing 2-, 5-, and 10-year time-of-travel periods. These protection areas need to be managed to protect the drinking water supply from viral, microbial, and direct chemical contamination.

Inventories of PCAs include identifying potential origins of contamination to the drinking water source and protection areas. PCAs may consist of commercial, industrial, agricultural, and residential sites, or infrastructure sources such as utilities and roads. Depending on the type of source, each PCA is assigned a risk ranking, ranging from *very high* for such sources as gas stations, dry cleaners, and landfills, to *low* for such sources as schools, lakes, and non-irrigated cropland.

Vulnerability analysis includes determining the most significant threats to the quality of the water supply by evaluating PCAs in terms of risk rankings, proximity to the well being surveyed, Physical Barrier Effectiveness (PBE), and whether contaminants have previously been detected. PBE takes into account factors that could limit infiltration of contaminants including type of aquifer, aquifer material (for unconfined aquifers), well operation, and well construction. The vulnerability analysis is based on a scoring system that assigns point values for PCA risk rankings, PCA locations within the wellhead protection area, and well area PBE. The PCAs to which drinking water wells are most vulnerable are apparent once vulnerability scoring is complete.

6.1.1 Actions

The Association will facilitate the following actions:

- A component of the DWSAP Program is an assessment of vulnerability of groundwater sources to quality degradation. The Association member agencies providing drinking water should obtain proper clearances for the release of information and prepare vulnerability summaries from the DWSAP Program to be used for guiding management decisions in the basin.

- Contact groundwater basin managers in other areas of the state for technical advice, effective management practices, and "lessons learned" regarding establishing wellhead protection areas.

- Attend groundwater conferences and technical workshops and meetings to learn more about groundwater management practices.

6.2 Regulation of the Migration of Contaminated Groundwater

The migration and remediation of contaminated groundwater is of primary concern to the Cities of Modesto, Riverbank and Oakdale. Also of concern is the localized contamination of groundwater by industrial point sources such as dry cleaning facilities, food processors and the numerous fuel stations throughout the Modesto Basin and OID service area north of the Stanislaus River.

While the Association does not have authority or responsibility for remediation of this contamination, it is committed to coordinating with responsible parties and regulatory agencies to keep Association members informed of the status of known groundwater contamination in the basin.

6.2.1 Actions

The Association will take the following actions:

- Coordinate with the USGS to expand the network of monitoring wells to provide for an early warning system for public supply wells.

- If detections occur in these monitoring wells, facilitate meetings between the responsible parties and potentially impacted member agency(ies) to develop strategies to minimize the further spread of contaminants. Specifically, the consideration of altering groundwater extraction patterns or altering production wells in the vicinity of a pollutant plume to change the groundwater gradient.

- Provide a forum to share all information on mapped contaminant plumes and Leaking Underground Storage Tank sites in order to develop groundwater extraction patterns and in site planning of future production or monitoring wells.

- Meet with representatives of the Central Valley Regional Water Quality Control Board (CVRWQCB) to establish a relationship and identify ways to have open and expedient communications with the CVRWQCB regarding any new occurrences of contamination, particularly when contamination is believed to have reached the water table.

- Track upcoming regulations on septic systems, agricultural discharges and other regulatory programs that pertain to water quality degradation.

6.3 Identification of Well Construction Policies

The Stanislaus County Department of Environmental Resources (DER) administers the well permitting program in the unincorporated areas of the Modesto Basin while the San Joaquin County Department of Environmental Health (DEH) administers well construction for the portion of OID lying within San Joaquin County. The standards in both counties for construction are consistent with those recommended in State Water Code Section 13801. This section requires counties, cities, and water agencies to adopt the State Model Well Ordinance as a minimum standard for well construction or a more rigorous standard if desired. Each city in the Association has enacted a well ordinance adopting the *California Well Standards, Bulletin 74-81*, and all supplements. This ordinance is utilized in wells constructed within the incorporated area of each city. Each city provides a review of well construction plans and specifications within the incorporated area. The Stanislaus County DER and the San Joaquin County DER have enacted well ordinances adopting the *California Well Standards, Bulletin 74-81* and all supplements for the unincorporated areas of these counties. The Stanislaus County DER and San Joaquin County DEH staffs also review applications and construction plans and specifications and issue permits for wells constructed or destroyed in unincorporated areas. Both counties require and maintain well logs and water well driller reports for constructed wells.

Standards also exist for contractors involved in well construction. Section 13750 of the California Water Code requires that well drillers possess a C-57 Water Well Contractors License, and Section 13751 requires well drillers to file a well completion log with DWR for every production or monitoring well constructed.

The number of service connections determines whether operating permits for wells used for public drinking water are provided through the Department of Health Services or either the Stanislaus County DER or the San Joaquin County DER. The Department of Health Services has jurisdiction over public water system wells with over 200 service connections. Wells that serve public water systems with fewer than 200 service connections fall under the jurisdiction of the county.

6.3.1 Actions

The Association will facilitate the following actions:

- Ensure that all member agencies are provided a copy of the applicable county well construction ordinance and understand the proper well construction procedures.
- Coordinate with member agencies to provide guidance, as appropriate, on well construction to prevent creating conduits through regionally confining beds. Where feasible and appropriate, this could include the use of USGS lithologic data prior to construction of the well to assist in well design.

6.4 Administration of Well Abandonment and Destruction Programs

There are many unknown, obsolete or abandoned water supply and natural gas wells within the Modesto Groundwater Basin. These wells provide potential locations for monitoring of groundwater levels, but more frequently serve as a source of contamination and should be abandoned.

One of the primary concerns of local agencies is the groundwater contamination risk posed by unused wells which have not been properly destroyed. Section 21 of DWR Bulletin 74-81 and revisions contained in Part II of Bulletin 74-90 allow classification of unused wells into two types, abandoned and inactive. An abandoned well is defined as one which has not been used for a period of one year, and whose owner has declared the well will not be used again. If the well has not been used during the past year, but the owner demonstrates his/her intention to use the well again for supplying water, the well is considered inactive. Four criteria must be met in order for a well to maintain the inactive, rather than abandoned, classification. These criteria are:

- The well has no defects
- The well is securely covered
- The well is clearly marked
- The surrounding area is kept clear of brush and debris

Failure to meet these criteria could result in the well being classified as abandoned under current regulations. All abandoned wells, exploration or test holes, and monitoring wells must be destroyed as stated in Section 22 of Bulletin 74-81 and revisions contained in Bulletin 74-90.

An abandonment program should focus on those wells which pose the greatest threat to groundwater; however, numerous factors make the abandonment and destruction of wells difficult. These factors include lack of consistency in records regarding well construction, location and use; cost of well destruction; and the defined classification for abandonment of wells. Well construction within the study area has taken place for nearly a century, with records and standards altered over time. Recent records pertinent to construction and location of new wells are more complete than earlier records which are often inconsistent. The lack of financial incentive for well owners to declare a well as abandoned also reduces the effectiveness of the well abandonment program.

Stanislaus County administers the well destruction program in most of the Modesto Basin while San Joaquin County administers the program in the portion of OID that lies within San Joaquin County. The standards for construction are identified in the county codes for these two counties and are based on State of California standards.

6.4.1 Actions

The Association members, including Stanislaus County and the cities, will take the following actions for lands within their jurisdictions:

- Ensure that all Association members are provided a copy of the code and understand the proper destruction procedures and support implementation of these procedures.
- Follow up with Association members on reported abandoned and destroyed wells to confirm information collected from DWR and receive information on abandoned and destroyed wells to fill gaps in county records.
- Obtain “wildcat” map from California Division of Oil and Gas to ascertain the extent of historic gas well drilling operations in the area as these wells could function as conduits of contamination if not properly destroyed.
- Seek funding to develop and implement a program to assist well owners in the proper destruction of abandoned wells.

OID will communicate with San Joaquin County staff to determine the status of abandoned and destroyed wells within the boundaries of OID and will coordinate with San Joaquin County on the procurement of “wildcat” maps from the California Division of Oil and Gas.

6.5 Mitigation of Overdraft Conditions

The Association supports activities such as those undertaken by the City of Modesto and MID providing surface water to areas once wholly dependent on groundwater and eliminating localized overdraft. The Association also supports actions by MID and OID to encourage customers to continue to receive surface water deliveries so that growers do not turn to groundwater as a more flexible source of irrigation supply during periods when surface water is abundant.

6.5.1 Actions

The Association will facilitate the following actions:

- Support programs that relieve aquifer overdraft through substitution of surface water for groundwater.
- Continue implementation of water conservation programs, including the water metering program, that will reduce reliance on groundwater pumping.
- Continue and enhance groundwater monitoring and groundwater use to ensure the balanced state of the groundwater basin
- Support programs by MID and OID to improve irrigation service to water users who may otherwise irrigate using groundwater because of the greater operational flexibility achievable through pumping.
- Seek funding for programs and projects that would identify and mitigate potential condition of overdraft in the basin.

6.6 Replenishment of Groundwater Extracted by Water Producers

A component of wellhead protection and an important groundwater management strategy is the protection of major recharge and withdrawal zones. This strategy has far-reaching effects in the Modesto and San Joaquin Basins because of the significant groundwater recharge occurring as a result of agricultural surface irrigation. Groundwater recharge must be adequate to replenish extracted groundwater, while withdrawal zones need protection from upgradient sources to ensure that the quality of extracted groundwater meets the standards established for the intended use.

A comprehensive approach to the protection and management of the major recharge and withdrawal zones is much more appropriate than the use of individual zoning techniques. Communities, in concert with neighboring towns and in coordination with the region, must develop comprehensive land and water resource management programs that go beyond simple zoning approaches for the protection of agricultural and urban areas.

The Association has evaluated surface geology within and directly adjacent to its boundary for the purpose of delineating areas having potentially high recharge rates. The basin contains numerous discontinuous recharge and withdrawal areas that do not allow for easily defined mapping of recharge zones. Nevertheless, a large portion of the study area has been determined to contribute to recharge. The Association supports land use measures that will preserve potential recharge areas from development that would reduce or eliminate their effectiveness as recharge sites.

6.6.1 Actions

The Association's member agencies will take the following actions:

- Identify areas having high potential for contributing to aquifer recharge and encourage agencies to communicate with land use planning entities to enact measures that will protect these lands from development that would reduce their value as recharge sites.

- Communicate with DWR and other governmental agencies studying groundwater and river interactions.

6.7 Construction and Operation of Recharge, Storage, Conservation, Water Recycling and Extraction Projects

Various Association members share responsibility for development and operation of recharge, storage, conservation, water recycling and extraction projects. The role of the Association is to promote cooperation and sharing of information between the agencies sponsoring water management projects and other member agencies. To the extent feasible, the Association will also support measures to coordinate development and optimize operation of facilities to improve the basin-wide effectiveness and efficiency of water management.

6.7.1 Actions

The Association will take the following actions:

- Encourage sharing of information on project planning, design and operation among member agencies.

- Promote a coordinated approach toward project development and operation to lower the costs and increase the benefits of water management efforts.

- Seek funding for projects and programs that will contribute to water conservation, recycling, and recharge of the groundwater basin.

6.8 Control of Saline Water Intrusion

Saline water intrusion from the San Joaquin River or from the west side of the San Joaquin Valley (including intrusion from the marine layers) is not well documented in the Modesto Groundwater Basin. Groundwater elevations prevalent in the basin have historically maintained a positive gradient preventing significant migration of saline water associated with groundwater from the western San Joaquin Valley. Maintaining the positive groundwater gradient will continue to prevent induced flow from the river or from groundwater west of the San Joaquin River.

6.8.1 Actions

The Association coordinates with member agencies and other local and state agencies to take the following actions:

- Continue collecting groundwater quality data along the San Joaquin River, and track the progression, if any, of saline water moving east from the San Joaquin River. This action will include communicating with DWR’s District Office on a biennial basis to check for significant changes to TDS concentrations in wells. DWR has a regular program of sampling water quality in selected domestic, agricultural and monitoring wells throughout the basin. These wells will be augmented by additional monitoring wells to develop an early warning system able to detect saline water intrusion from the river.

- The program of monitoring for intrusion of saline water will be supplemented by the Groundwater Monitoring Program described in this plan. The program includes provisions for monitoring groundwater levels and quality.

- Observe TDS concentrations in public supply wells that are routinely sampled under the DHS Title 22 Program.

Page left intentionally blank

7 Stakeholder Involvement

The Association's member agencies initiated a planning process to prepare an IRGMP. This plan is developed to comply with provisions of SB 1938 and SB 1672, including the provisions related to public involvement processes.

7.1 Involvement of Other Agencies and Entities

The six agencies forming the Association are the Cities of Modesto, Oakdale, and Riverbank, Stanislaus County, Oakdale Irrigation District, and Modesto Irrigation District. These agencies share the groundwater resources and worked together to formulate this management plan. The Association provides coordinated planning to make the best use of available resources to the mutual interests of the inhabitants and resources of the groundwater subbasin. Throughout this planning process, other interested agencies and entities within the subbasin were encouraged to participate in developing the plan. The Association will work with member agencies and other entities to implement the components of this plan. The County of Stanislaus, a member of the Association and the advisory committee to prepare this management plan, is representing other self-supplied groundwater producers. The Association should encourage a proactive outreach to these groups. One group of suppliers in particular is made up of the industrial groundwater users in the basin. The Association will develop an outreach process to meet with the group and work together for more effective management of the water resources of the basin.

7.2 Coordination with Other Agencies

The Association member agencies have also coordinated the planning process with other neighboring water agencies and subbasins. The City of Modesto is also participating in the development of a groundwater management plan for the Turlock Groundwater Subbasin and has been communicating the development of the management plan for the Modesto Subbasin to Turlock Subbasin stakeholders. Similarly, OID has been communicating the development of the management plan with the SSJID for the the Eastern San Joaquin Groundwater Subbasin. The Association plans to provide draft copies of this management plan to the neighboring subbasins.

7.3 Advisory Committee

The Association's member agencies formed an advisory committee to cooperate in the development of an integrated regional groundwater management plan. They met the first Thursday of each month to discuss the water management issues of the basin and guide the planning process to develop the plan. Through detailed discussion, the advisory committee has developed BMOs and a related implementation plan. This management plan is the result of the Advisory Committee's work over a 12-month period.

7.4 Public Involvement

An extensive public involvement process was planned for developing the IRGMP. The components of the public involvement process include the following:

- Each agency has published a notice informing the public of the intention of the agency to hold a public hearing to determine whether to adopt a resolution to prepare the agency's groundwater management plan. These notices are included in Appendix E. Stanislaus County, although actively participating in the preparation of the plan, has not published a notice informing the public of the intention of prepare such plan.

- The governing bodies of each agency, in their regularly scheduled meeting, held a hearing (after publication of notice) on whether to adopt a resolution of intent to prepare an IRGMP. At the conclusion of the hearing, each agency adopted a resolution to draft the plan and directed the staff to participate with other members of the Association to form a "Regional Water Management Group" to prepare an "Integrated Regional Groundwater Management Plan." In these hearings, the public was invited to comment on whether the agency should adopt the resolution and on the planning process. The public was informed on how to provide comments to the agency.

- At the conclusion of each agency hearing, the agency adopted a resolution of intent. The agency also provided "a written statement describing the manner in which interested parties may participate in developing the IRGMP."

- The Association also published a notice of intent, on behalf of its member agencies, to prepare an IRGMP. The notice included the schedule and location of a public hearing. The Association also acts as an advisory committee of the stakeholders in development of the management plan.

- After the publication of notice of intent, the Association held a public hearing to brief the public and interested parties about the planning process, schedule, content, and how the public can participate in the process and provide comments. Interested parties and the general public were invited and encouraged to attend the hearing and provide comments. After the hearing, a regional water management group was formed by the agencies who had decided to prepare an integrated regional groundwater management plan.

- When the public draft of the Integrated Regional Management Plan becamse available in April 2005, a notice was given (in the Modesto Bee and on the agency website) to notify the public about the availability of the draft plan. Copies of the draft plan were made available to the public upon request. A public meeting was also scheduled. The place, date, and the time of the meeting conducted by the Association was included in the notice.

- The governing bodies of the participating agencies will schedule, in their regular meeting, a discussion of the Draft Plan, provide information to the public as to the content of the Draft Plan, and receive comments. The contact person's name and address will be provided to the public for the submission of any written comments on the Draft Plan.

- The Regional Water Management Group will hold a public meeting to brief the public about the draft of the plan and will solicit public comment. It will decide whether to adopt the plan and submit it to the member agencies with a recommendation for its adoption. It will provide the name, phone number, and address of a contact person who will receive written comments from the public.

- Upon completion of the IRGMP, each agency will publish a notice of intent to hold a hearing as to whether the agency will adopt the plan. The notice will include a summary of the plan and will state the means of providing copies of the plan to interested parties.

- Each agency will hold a hearing to determine whether to adopt the plan. The agency shall consider protests to the adoption of the plan. If the agency determined that "a majority protest" has not been filed, the agency will adopt the IRGMP within 35 days after the conclusion of the hearing.

Detailed documentation of the public involvement processes is presented in Appendix E.

7.5 Developing Relationships with State and Federal Agencies

In mid-2004, the Association engaged in discussions with the DWR to initiate a cooperative relationship for the conjunctive management of the basin. As a result of these discussions, the Association and DWR signed a Memorandum of Understanding to work together to develop conjunctive use projects. A copy of that document is in Appendix B.

For the last several years, the Association has been working cooperatively with the USGS to study the geology and aquifers of the Modesto Subbasin. The Association and the USGS have entered into an agreement, under the National Water-Quality Assessment Program, to map the subsurface geology of the basin and to develop a data network and a three-dimensional model of the basin.

The Association member cities are also working with the Department of Health Services on issues related to compliance with Title 22, Drinking Water Quality Standards.

7.6 Dispute Resolution Process

The Association has been used effectively as a tool for the resolution of water management issues in the basin. Discussion of issues in Association meetings, in an open and transparent process, resulted in a cooperative relationship between water users of the basin. The Association will continue to provide a forum for discussion and early resolution of water issues in the basin.

8 Plan Implementation

This section includes a discussion of program integration and local, statewide, and regional water management priorities and illustrates how the structure of the IRGMP addresses these priorities. It then addresses the specifics of plan implementation.

Key features of the IRGMP are the linkages that have been established among program actions. These linkages transform a group of isolated measures into a coherent program where the whole is greater than the sum of the parts. Linkages have been established by emphasizing the objective of developing an integrated and regional approach. Specific instances where individual activities have been linked to generate broader, more complementary actions are discussed below.

8.1 Integration of Local, State and Federal Monitoring Activities

At present, a number of different agencies are responsible for different aspects of groundwater monitoring in the subbasins. One of the recommendations of the IRGMP is to continue the ongoing process of integrating local monitoring programs and improving access to and management of groundwater data. Local, state and federal entities expected to be involved in this process include DWR, USGS, Department of Health Services, and local water agencies. The objective of the recommendation is to have a groundwater monitoring and data management program that is comprehensive, efficient and provides data in a format that is easy to access to facilitate rapid recognition of problems and to support good management decisions. As a component of this management plan, a groundwater monitoring plan was also developed to ensure adequate data is collected to track the effect of implementation of BMOs.

8.1.1 Integration of Surface and Groundwater Operations

This linkage is at the heart of the IRGMP as it requires coordinated operation of surface and groundwater resources to attain the various BMOs. Specific opportunities for integrated surface and groundwater operations include development of recharge basins, increased use of groundwater to respond to fluctuations in irrigation demand, and increased use of surface water to meet growing municipal and industrial requirements, including the expansion of the Modesto Regional Water Treatment Plant and its associated storage and delivery systems.

8.1.2 Integration of Groundwater Use and Surface Water Delivery

One of the important recommendations of the IRGMP focuses on the potential to link optimization of groundwater use to surface water deliveries. This concept rests upon the idea that MID and OID could reduce system spillage by managing their use of groundwater to respond to fluctuations in demands by irrigators. Use of wells enables water to be introduced into the delivery systems close to the points of demand, thereby reducing the lag time between points of delivery and points where water is introduced into the system in response to changes in delivery orders. The benefits of using groundwater to fine tune surface water deliveries may be further enhanced by making priority use of wells in high water table areas to achieve flow augmentation. In this way, water supply and water table control benefits could be achieved through implementation of one program.

Optimization of well field operations and linkage with the surface water deliveries further integrates the districts' water conservation, energy conservation, and water quality objectives into the districts' daily operations by reducing operational spillage.

8.1.3 Integration of Water Management (MID and City of Modesto)

An example of collaboration between two local agencies has been the effort to supply surface water from MID to the MRWTP. This reallocation has enabled the City of Modesto to expand its capacity to supply treated water without requiring that the City expand pumping of groundwater. MID's ability to supply water to the City of Modesto has been supported by innovative water management practices within MID that have enabled this reallocation to take place without compromising service to other MID customers.

8.1.4 Integration of Water Quality Management for Both Surface Water and Groundwater

Association members have cited declining groundwater quality as one of their major concerns. Coordinated operation of pumps to contain groundwater contamination and recharge of high quality surface water are among the management options available.

8.2 Local, Statewide, and Regional Priorities

8.2.1 Local Priorities

The overriding local priority for implementation of the IRGMP is satisfying regional and local water management objectives as they are formulated through the development of BMOs. Local BMOs are specific approaches for achieving water management goals including groundwater supply, groundwater quality, and protecting against inelastic land surface subsidence. Because they are presented within the context of a basin-wide plan, the local BMOs illustrate the degree to which many of the local BMOs are common to more than one of the participating agencies and implementation of local BMOs is best achieved through cooperation among participating agencies.

Through their involvement in the development of the IRGMP, participating agencies have demonstrated their conviction that the most effective approach to local water management is through regional actions. Specific local BMOs are discussed later in this section.

8.2.2 Statewide Priorities

Implementation of the IRGMP will enable the Association and its member agencies to respond to a range of statewide water management initiatives. Key among these is the increasing emphasis placed on agencies to develop integrated regional solutions to water management problems and to coordinate the conjunctive management of surface water and groundwater for sustainable water supply reliability and water quality in California.

Completion and adoption of the IRGMP will allow participating agencies to satisfy one of the key prerequisites for grant funding through Chapter 8 of Proposition 50, the Integrated Regional Water Management Grant Program. The integrated plan also frames specific water management projects in the context of an integrated regional water management strategy. Although the plan emphasizes groundwater management, elements of the plan address the use of surface water supplies, water conservation, and water recycling and blending to meet demands that have previously been met with groundwater. This integration of surface and groundwater resources leads to a more comprehensive management of water supplies and provides a lucid framework for compliance with state and federal water quality standards.

In particular, by promoting effective water use in the Modesto Groundwater Subbasin, implementation of the IRGMP will:

- Increase California's water supply reliability
- Reduce conflicts among water users
- Contribute to meeting Delta water quality objectives
- Assist in the implementation of Regional Water Quality Control Board Watershed Management Initiatives Chapters, plans and policies

8.2.3 Regional Priorities

The IRGMP is an effort that recognizes that the most effective approach to managing a basin's water resources is an integrated plan that enlists the cooperation of the agencies whose political boundaries match the basin's physical boundaries. As noted above, the IRGMP includes a number of regional BMOs that have been agreed upon by all of the participating agencies. The overarching regional objective of the plan is to foster good stewardship of the resources and to promote wise management of regional resources that responds to regional and local BMOs. Providing reliable good quality water for the basin water users is essential for the economic wellbeing and welfare of the citizens of the region. Specific regional objectives include:

- Improve local water supply reliability
- Protect the region's groundwater resources

- Improve water quality
- Foster prudent stewardship of water resources
- Facilitate compliance with local, state, and federal water quality and public health regulations

8.2.4 Basin-Wide Water Management Strategies

The regional water management actions support a comprehensive approach to managing water resources in the Modesto groundwater basin. In particular, these actions provide a framework for developing projects that advance the following water management strategies:

- Increase local and regional water supply reliability and water use efficiency: Management actions supporting conjunctive management, policy assessment, and development of a basin-wide water budget will be key to the implementation of this strategy.
- Promote groundwater recharge and management: Actions encouraging the identification of natural recharge areas and the evaluation of artificial recharge areas will be used to implement this strategy.
- Support water conservation: Development of a basin-wide water budget will be used to identify water conservation opportunities. Management and optimization of well field operations will be used to reduce spillage from irrigation distribution systems. Support the urban water conservation programs and water metering programs.
- Implement watershed management programs: This strategy will be implemented through policy assessment, identification of natural recharge areas and evaluation of artificial recharge projects.
- Promote water recycling: Management and optimization of well field operations will provide the tools to recycle agricultural returns. Use of groundwater not meeting some of the drinking water standards for landscape irrigation and blending for agricultural use will further promote water recycling in the basin.
- Foster conjunctive use. Conjunctive use will be the central management action that serves as the cornerstone for most other activities. The most significant conjunctive use project in the basin is the expansion of the Modesto Regional Water Treatment Plant and its associated storage and delivery systems. This project will reduce pumping by the City of Modesto, improve reliability, and allow the groundwater level in the subarea to recover and reduce the movement of groundwater contaminants. Actions addressing natural and artificial recharge, groundwater

monitoring, well field optimization, and policy assessment will also contribute to the planning and implementation of groundwater conjunctive use.

- Improve water quality: The water quality management, groundwater monitoring and management, and conjunctive use projects (e.g., the expansion of the Modesto Regional Water Treatment Plant and its associated storage and delivery systems to increase surface water use) will improve groundwater basin water quality. Other projects such as the optimization of well field operations will contribute to improving water quality by reducing agricultural returns to the rivers and the Bay-Delta estuary.

- Improve storm water capture and management: Actions supporting public health programs and calling for capturing storm water in dry wells and in natural and artificial recharge facilities will reduce storm water discharges.

Other regional water management elements such as provisions for recreation and river restoration are addressed in planning documents prepared by the participating agencies. Water transfer strategies are considered as in-basin projects to help agencies within the Modesto subbasin meet their water needs. Other strategies such as desalting are not applicable to the region.

8.3 Implementation Plan

The Implementation Plan presents specific management actions that enable the Association to meet the BMOs. The overarching purpose of the BMOs and the associated management action is to encourage a balance of surface water and groundwater use that will protect the resources of the basin and maximize the reliable supply of high quality water to meet municipal, agricultural, and industrial demands now and in the future. The BMOs reflect issues that the participating agencies have recognized as jeopardizing the reliability or quality of local water supplies; the management actions are designed to resolve these issues.

8.3.1 Basin-Wide Recommendations

The following management actions are put forth as recommendations for the implementation of the BMOs:

- Protection of natural recharge areas

- Development of a calibrated, three-dimensional, basin-wide groundwater model

- Feasibility evaluation of artificial recharge projects

- Management and optimization of well field operations

- Identification and feasibility study of conjunctive use projects

- Support of public health programs
- Water quality management
- Groundwater monitoring and subsidence monitoring program
- Policy assessment
- Promoting coordination and cooperation between water entities

The first set of actions responds to basin-wide BMOs. These are followed by agency-specific recommendations intended to support the implementation of each agency's BMOs.

8.3.1.1 Identification of Natural Recharge Areas

Groundwater recharge has diminished because of the expansion of urban areas, and trends in agricultural irrigation practices have reduced deep percolation of applied water. These trends underscore the need to identify and map the remaining natural recharge areas and to use this mapping to protect important sources of recharge. The objective is to develop specific planning actions that offer varying degrees of protection, depending upon an area's significance as a source of recharge. Types of protection could include:

- Programs to educate public and planning entities about the importance of protecting recharge areas.
- Pricing and incentive programs to encourage the continued use of surface water for flood irrigation. Because irrigation of agricultural land is an important element of recharge in the basin, pricing and incentive programs should be promoted.

The first step in implementing this management action would be to identify recharge areas within the cities and the county, to develop a GIS-based map of natural recharge areas, to inform planning entities of the importance of these areas, and to make recommendations for the protection of these areas.

8.3.1.2 Development of a Basin-Wide Groundwater Model

To provide quantitative tools for water resource management in the Modesto groundwater basin, a transient optimization groundwater flow model is being developed. This model can be used to help identify the most effective ways to distribute groundwater pumpage, artificial recharge, and surface water deliveries to meet management objectives during normal and drought conditions. Further data collection and analysis are needed to complete the transient groundwater flow model and develop optimization parameters for the analysis of conjunctive use strategies.

During Phases I and II (Fiscal Years 2002 through 2005) of the Modesto groundwater basin investigations, a “geologic model” and a steady-state regional groundwater flow model were constructed. The geologic model currently consists of the conceptual understanding of the relationship between geologic units in the subsurface (such as the Corcoran clay, the Mehrten formation, and other marker beds), and a three-dimensional spatial interpolation model of “percentage of coarse-grained sediments” was completed, using data from the texture database.

Drilling and installation of multilevel monitoring wells at two sites, collection of continuous core and borehole geophysical logs, installation of continuous monitoring devices, collection of aquifer and slug test data to determine aquifer parameters, collection of borehole velocity logs, and stratigraphic analysis of the newly collected core and cuttings data were performed to address the primary data gaps identified in the interpretation of existing data. The regional groundwater flow model was then updated with the new geologic and hydraulic information obtained during Fiscal Year 2004. Currently, long-term data are being collected and formatted for easy import into the transient flow model in preparation for calibration.

The tasks required to complete this work include the following:

- **Quantify Groundwater-Surface Water Interaction:** Because the Modesto groundwater basin is surrounded on three sides by major streams, it is expected that changes in pumping stress will significantly affect stream flows. Quantitative data on the interaction between groundwater and surface water are needed to constrain the predictions from the groundwater flow model under scenario testing. Reconnaissance monitoring of temperature and salinity will help identify locations for more detailed data collection. Shallow monitoring wells and drive points will be installed at three to five sites and instrumented for water level and temperature monitoring. These data will be interpreted and used to develop parameters and input to the groundwater flow model, using the new MODFLOW stream flow routing package.

- **Investigate Incised Valley Fill Deposit:** An incised valley fill deposit identified beneath the Modesto urban area constitutes a major pathway for groundwater flow and contaminant transport and may enhance natural or artificial recharge in the basin. Reconnaissance mapping of the known extent of the incised valley fill will be followed by drilling, coring, well installation and monitoring, and characterization of hydraulic properties of the incised valley fill sediments. The more detailed data collected on the incised valley fill feature will be interpreted using stratigraphic modeling and incorporated directly into the groundwater flow model.

- **Extrapolation of Process-Level Water Quality Findings to Regional Scale:** Additional wellbore flow and depth-dependent sampling will be done at selected locations throughout the basin. Flow data will be used to improve the regional groundwater flow model. A suite of water quality samples will be collected to evaluate sources and movement of water in the subsurface, including major ions, nitrate, trace elements, and isotopes.

- **Groundwater Flow Model Transient Calibration:** The results of the groundwater-surface water interaction and incised valley-fill deposit aspects of the investigations will be incorporated into the transient model. The transient datasets collected and organized during the last phase of the investigation will be input to the groundwater flow model using the new "farm" package developed for MODFLOW. This package allows the enhanced use of variables in computing crop demands and allows both semi-routed and fully routed surface water diversions. The model will be "nested" within the recently updated USGS Central Valley model to provide a regional context for the local model. This will reduce the uncertainty along the boundaries and in parts of the model where transient data are unavailable (south of the Tuolumne River).

- **Development of Optimization Parameters and Scenario Testing:** Following calibration of the transient groundwater flow model, the USGS will work with the Association to develop the objectives and parameters for optimization. Depending on what optimization parameters are selected, this may require the collection of additional data to include these variables in the groundwater flow model. Following the development of the parameters, the model will be used to perform scenario testing in close communication with Association needs.

- **Continued Water Level Monitoring:** Continuous water level data will be collected in the newly drilled monitoring wells and the data will be input into the USGS's NWIS database.

The Association and the USGS staff will conduct quarterly reviews to discuss progress and results and to address any issues that have come up during that quarter.

Preliminary interpretations will be shared with the Association at quarterly meetings. A report documenting the transient groundwater flow model will be completed by the end of Fiscal Year 2008 and a final report on optimization and scenario testing will be completed by the end of Fiscal Year 2009.

8.3.1.3 Feasibility Evaluation of Artificial Recharge Projects

The basin-wide water balance, described above, will reveal whether the basin is in overdraft and will illustrate trends in the balance between groundwater recharge and groundwater use. If the water balance demonstrates either that the basin is in overdraft or is likely to fall into an overdraft condition in the near future, two broad options are available for sustaining and protecting basin recharge. The first option is a program to maintain natural recharge by protecting natural recharge areas; the second is the augmentation of natural recharge through an artificial recharge program.

The evaluation of artificial recharge projects will begin with the mapping of potential recharge sites, which will build on the mapping of natural recharge sites described previously.

The enhanced recharge management action will also develop in-lieu recharge projects. These projects would look at opportunities to reduce groundwater demand by supplying surface water to areas now served by groundwater. Such projects could include incentives for OID and MID irrigators to continue to receive surface water, investigations of annexation options to expand the MID and OID service areas, and water conservation programs or other approaches to ensure the districts' capacity to serve expanded areas. In addition, this management action would continue to support the development and expansion of conjunctive use projects in urban areas with poor groundwater quality (i.e., supplement the City of Modesto's water supply with additional surface water in order to reduce its reliance on groundwater, improve groundwater levels, and reduce the movement of contaminants in the basin) as well as program to evaluate the potential for storm water recharge.

8.3.1.4 Management and Optimization of Well Field Operation

A component of improved groundwater management is the optimization of well operations to accomplish specified management objectives. For example, each well in a well field can be instrumented and controlled so that the group of wells is operated to meet single or multiple objective functions. Examples of typical objective functions are:

- Minimizing the overall costs of pumping
- Maintaining groundwater levels within specified ranges
- Reducing or eliminating well interference where appropriate
- Avoiding the migration of contaminant plumes
- Controlling pumping into irrigation canals in response to delivery and cutoff orders, hence creating opportunities to conserve water by reducing spillage

In addition, well field optimization would support managing the quality of discharged water to be blended with surface deliveries. For example, MID pumps water from the shallow aquifer and blends it with surface water for delivery to agricultural water users. Similarly, urban wells can be used to deliver water to agricultural users when the urban wells fail drinking water standards. The agencies within the basin could evaluate an expansion of the blending program in order to lower the high groundwater table and improve downstream water quality.

Similarly, wells could be optimized and controlled to manage pumping of high nitrate groundwater as a source of irrigation supply.

8.3.1.5 Identification and Feasibility Study of Conjunctive Use Projects

Many of the management actions described above can be viewed as components of a broader conjunctive management program. The goal of this program would be the development of an integrated approach to balancing surface and groundwater use to support the BMOs. Implementation of a conjunctive management strategy may involve reduced groundwater pumping in some parts of the basin and broad controls on pumping to meet groundwater level BMOs.

8.3.1.6 Support of Public Health Programs

Well construction and demolition standards are designed specifically to protect groundwater quality. Management actions to assist local agencies in complying with public health standards include the following components:

- Installation of sanitary well seals on all new wells in accordance with the California Well Standards

- Abandonment of wells in accordance with the California Well Standards

This management action will be particularly valuable in unincorporated areas not served by a water purveyor.

8.3.1.7 Water Quality Management

The protection of groundwater quality is an increasing concern because the basin's population is growing. This management action would proceed by conducting a detailed geologic assessment of the basin that would focus on the areas with poor water quality and identify the sources of the contaminants. This assessment would result in coverage on a GIS system for mapping recharge areas and would be used to develop strategies to control the migration and movement of poor quality water into and throughout the basin.

8.3.1.8 Groundwater Monitoring and Subsidence Monitoring Program

Groundwater monitoring and analysis and the archiving of collected data are needed to implement several of the recommended management actions (e.g., conjunctive management and optimized operation of well fields). In addition, groundwater monitoring will be needed to meet the reporting requirements of the plan. The Association is developing a database to facilitate the storage, retrieval, and archiving of groundwater data. Monitoring data will be important in the development and calibration of the basin-wide groundwater model that will be used to evaluate the effects of proposed projects and management actions.

The Association plans to monitor and measure the rate of inelastic land surface subsidence within the basin. Given the ongoing efforts by Association members to prevent groundwater overdraft and conditions that might lead to subsidence, it appears unlikely that the insignificant subsidence that has occurred historically within the basin will be accelerated. However, the Association plans to monitor and document any future changes in land surface elevations and, if inelastic subsidence is observed, may recommend necessary actions to member agencies.

8.3.1.9 Policy Assessment

Several of the technical management actions introduced above have clear policy requirements and implications. For example, effective protection of natural recharge areas will require coordination and communication with entities responsible for land use policies. Similarly, annexations to expand agencies' service areas as part of an in-lieu recharge program presume clear policies regarding annexation and a process to evaluate the impacts of annexation on groundwater levels and groundwater quality.

The development of consistent policies would be assisted by a regional groundwater forum such as the Association. The purpose of this forum would be to foster coordination and cooperation among participating agencies to manage the Modesto Subbasin and to provide a framework for the formulation of regional projects and programs for the protection and use of subbasin water resources.

For example, given the mutual concern of agencies within the basin regarding the preservation of natural recharge areas and the protection of these areas from pollutants, local agencies could work through the forum to inform one another about land use practices that may contribute to groundwater degradation and the importance of reducing the occurrence of these land use practices.

Similarly, the forum could assist in the formulation of basin-wide water conservation measures including incentive programs, water audits, water metering programs and other measures to reduce demand on the basin.

8.3.1.10 Promoting Cooperation and Coordination Between Water Entities

The Association will continue to coordinate water management activities within the basin and to work cooperatively for implementation of agreed-upon BMOs. The Association will also develop an outreach and educational program to engage other water interests for management of the basin. One example of such outreach will be working cooperatively with industrial water users to improve water levels and water quality in the basin and to reduce localized well interference issues.

8.3.2 Area-Specific Recommendations

The following recommendations for management actions are intended to respond to the specific objectives of each of the management areas.

8.3.2.1 City of Modesto

Groundwater Quality Protection. The foundation of groundwater management is a good understanding of an area's hydrogeology. This project would analyze the transport of contaminants using wellbore velocity profiling and depth-dependent sampling in areas of known groundwater quality problems.

The well field management and optimization program described above would be valuable for managing pumping to reduce or eliminate contaminant movement into and within the basin. The well field management program would include well design criteria detailing the proper spacing and screening of wells to manage groundwater pumping and the movement of contaminants. It could also provide guidance and information needed to avoid siting new wells in areas of known poor water quality.

Groundwater Quality Treatment. The City of Modesto plans to study methods to improve the quality of water pumped from wells that currently experience groundwater quality issues. This investigation would determine, case-by-case, the most economical and effective treatment method for a domestic supply well, based on its location and the type of treatment, such as ion exchange or blending with treated surface water.

Groundwater Levels. To maintain groundwater levels, the City of Modesto plans to work with other planning entities to identify, encourage, and promote measures to protect groundwater recharge areas. The City and other members of the Association have agreed to evaluate the feasibility of groundwater recharge and conjunctive use projects, including the development of artificial recharge areas, in-lieu recharge projects, and surface water-groundwater exchange programs. Implementation of surface water-groundwater exchange programs will entail:

- Increased water treatment capacity and use of surface water to augment groundwater supplies
- Development of exchange programs to mix groundwater of marginal quality with surface water for delivery to agricultural users, golf courses, parks, and other open space areas in exchange for a surface water supply for the City of Modesto

Water Conservation and System Improvement. The City of Modesto, under its Urban Water Management Planning function, will implement water conservation and metering opportunities to increase water use efficiency in its service area.

8.3.2.2 Modesto Irrigation District Management Area

MID plays a major role in the groundwater and surface water management of the Modesto Groundwater Subbasin. MID and TID operate Don Pedro Reservoir and bring surface water for agricultural and urban uses to the basin.

Development of a system-wide well field optimization program would assist MID in managing groundwater levels, protecting groundwater quality, and managing its energy usage. Conjunctive management actions would enable better control of its surface water and groundwater resources, including the exportation and treatment of additional surface water supplies from MID to the City of Modesto to reduce groundwater pumping.

The City of Modesto and MID should work cooperatively to protect the City of Modesto's management area from potential overdraft and the movement of contaminants to the basin and to continue to develop a water exchange program that mixes City-pumped groundwater of marginal quality (as potable water) with surface water and delivers it for agricultural use and to golf courses, parks, cemeteries, and other open space areas in exchange for surface water delivery to the City of Modesto.

MID should also evaluate the feasibility of an expanded blending program and the use of shallow water acquired for delivery to agricultural water users.

8.3.2.3 City of Oakdale Management Area

The City of Oakdale relies solely on groundwater for its water supply. The City's goal is to protect its groundwater levels and quality for a sustainable water supply for its citizens.

Groundwater Levels. The City operates nine wells, two of which were recently constructed. Water levels in some wells are impacted by the production wells at the Hunts and Hershey industrial plants. To protect its groundwater levels, the City could pursue the following options:

- Participate in a well field management and optimization program to determine how its wells can be operated to maximize production, while minimizing the impact from the other wells
- Work with plant managers to minimize impacts during the City's peak water demand period and encourage industrial water conservation
- Work cooperatively with other water entities in the basin to promote and implement conjunctive management programs
- Work cooperatively with other agencies to identify and develop groundwater recharge projects

Groundwater Quality Protection. In the area of groundwater protection, the following actions are recommended for compliance with local objectives:

- Construct a sanitary seal on all new wells and work with other groundwater users within the management area to ensure proper well construction methods are used for all new wells
- Abandon wells within the management area in accordance with the Stanislaus County well abandonment ordinance
- Regularly monitor wells adjacent to industrial areas to detect any potential water quality degradation, and if degradation is detected, consult with the Regional Water Quality Control Board to encourage the implementation of necessary steps to control the migration of poor quality water

8.3.2.4 City of Riverbank Management Area

Groundwater is the only source of water for the City of Riverbank. Currently, groundwater levels and water quality are stable within this management area. To protect the groundwater quality of the management area, the City can take the following actions:

- Develop a monitoring program to ensure that there is no contamination from local industrial facilities. If water quality degradation is detected, consult with the CVRWQCB to encourage the implementation of actions to control the migration of poor quality water in the basin.
- To address its concerns about the operation of a future recharge project and the quality of water used for recharge, work with other water agencies within the basin to ensure that the future recharge project operation will not compromise groundwater quality in the Riverbank management area.

8.3.2.5 Oakdale Irrigation District Management Area

The OID management area is divided between the Modesto Groundwater Subbasin and the East San Joaquin Groundwater Subbasin. About 60 percent of the OID management area is within the Modesto Groundwater Subbasin. However, the issues of the management area north and south of the Stanislaus River are similar and recommended management actions apply to the entire management area. Urbanization within and around the management area has increased groundwater production and the potential for future overdraft. Recommended management actions for OID include:

- Participating in well field management and optimization program to actively manage groundwater production to meet OID's groundwater and energy management objectives.

- Investigating the feasibility of developing conjunctive use and groundwater recharge projects. Determining if groundwater recharge is a viable option to reduce the falling water table within the management area.

- Promoting programs and actions that protect recharge areas within the management area.

- Evaluating the potential benefits of the annexation of adjacent farmland, which relies on groundwater, and its conversion to surface water as part of an in-lieu recharge program. Assessing the effects of this program on aquifer levels and water quality.

- Investigating the impacts of upstream urban or agricultural development on water quality and groundwater levels within OID service area.

8.4 Data Management

To manage the basin's groundwater resources, the Association member agencies regularly exchange information and arrange for uniform groundwater data collection and monitoring to better understand the groundwater basin. In 1998, the Association developed a data collection protocol to standardize the data collection procedures among the member agencies. Data are collected in a coordinated fashion biannually. A copy of the current data collection protocol is provided in Appendix C.

Data management practices already initiated by the Association and its member agencies will be expanded and strengthened during implementation of the IRGMP.

8.5 Annual Implementation Report

Each year, the Association will prepare a report describing the progress made in implementing management activities and the effects of these activities on meeting basin-wide and local management area BMOs. The report will include maps of spring and fall groundwater elevations and tabular summaries of ongoing management actions. The report narrative will present details of implementation activities and describe developments in the basin that are not part of the groundwater management plan implementation but that impact groundwater conditions in the basin (e.g., hydrologic conditions, siting of new industrial facilities, newly identified contaminant plumes).

8.6 Financial Planning for Recommended Actions/Project Implementation

Progress toward the implementation of the IRGMP is contingent upon securing funding to complete the program. Two avenues that are available for funding are grant funding and funds generated internally by the Association members.

8.6.1 Grant Funding

Identified grant funding opportunities include the following:

- U.S. Bureau of Reclamation Challenge Grant Program – The FY 2005 Challenge Grant Program is expected to be better funded than was the FY 2004 program (the program's initial year) and the goals of the FY 2005 program are expected to encourage water conservation and judicious water management.

- CALFED/DWR Water Use Efficiency – This program provides grants for urban and agricultural water conservation projects.

- AB 303 Local Groundwater Assistance Program – This DWR-administered program funds groundwater data collection, modeling, monitoring and management studies, basin management and development of information systems. AB 303 is a potential source of funding for a range of management actions.

- Chapter 8 of Proposition 50, Integrated Regional Water Management Grant Program (administered jointly by the State Water Resources Control Board and DWR) – This chapter funds integrated water management projects that support water quality and water supply security objectives. Chapter 8 is well suited for funding conjunctive management actions.

- Agricultural Water Quality Grant Program – This program, administered by the State Water Resources Control Board, supports baseline monitoring, implementation of management measures, demonstration projects, and effectiveness monitoring. This program has been identified as a potential source of funding for actions that reduce the volume, improve the quality, or control the timing of surface water discharges (such as using groundwater to reduce lateral spillage).

8.6.2 Revenues Through Increased Water Rates

Revenue generated internally by local agencies from the sale of water and power is a second source of funding available for implementation of the plan. Internally generated revenues are important because they are controlled by the member entities and represent a local commitment to plan implementation and establishment of the BMOs. Local financial support is often required by grant programs and by other sources of outside financing. Therefore, while local support may be a factor agencies weigh in establishing budgets and reviewing rates, the willingness of local agencies to contribute to plan implementation is likely to aid agencies in their acquisition of outside funding. Successful pursuit of grant funding will, in turn, enable ratepayers to increase the benefits of their investment.

8.7 Periodic Review of the Integrated Regional Groundwater Management Plan

In addition to the annual reports of implementation progress, there is a need to periodically review and, if necessary, refine the IRGMP. These reviews would be scheduled at five-year intervals and would concentrate on analyzing information presented in the previous annual reports and consolidating the observations of local water managers. The reviews would identify areas where the plan has been successfully implemented as well as areas where deficiencies were apparent. In areas where implementation has proceeded satisfactorily, the plan revision might include increasingly detailed information regarding the specifics of implementation. In areas where progress was less than anticipated, approaches would be discussed to either bring implementation of specific actions back on track or to change course and focus efforts on other actions believed to have a higher likelihood of success.

8.8 Schedule and Implementation Sequence

The Regional Water Management Group discussed in detail the prioritization of project, programs, and strategies. The result of the discussions was the identification of phases instead of a specific priority list. Implementation of the actions recommended in the IRGMP is scheduled in three phases:

- **Phase I-Near Term Projects**: These projects are intended to be implemented within the next three years and include:

    - Management of the well fields: A decision support system to assist the districts to optimize groundwater production from their well fields, based on a set of established objectives.

    - Increase treatment, storage, and distribution capacities and improve system reliability for the City of Modesto.

    - Additional water blending projects: To help agencies meet their water quality objectives while increasing the beneficial use of groundwater.

    - Water conservation projects, including agricultural and urban water conservation projects, and residential water metering programs.

    - Identification of conjunctive use project concepts

    - Rockwell monitoring program

    - Wellhead treatment and remediation projects

    - Development of a calibrated, three-dimensional groundwater model of the basin

- **Phase II-Mid-Term Projects**: These projects are planned for implementation from four to seven years:
    - Identification of groundwater recharge areas.
    - Implementation of wastewater treatment and capacity enhancements.
    - Development of conjunctive use projects.
    - Development of the in-lieu recharge projects, including evaluation of annexation options to reduce groundwater pumping.
    - Ongoing development, enhancement, and optimization of the basin-wide groundwater model.
    - Development of a basin-wide database.
    - Continue water metering implementation and demand management programs.
- **Phase III-Long-Term Projects**: These projects are scheduled for implementation beyond seven years in the future and include:
    - Installation of subsidence monitoring station if needed.
    - Water exchange program.
    - Update water budget.
    - Feasibility evaluation of artificial recharge projects.

Other water management actions may continue throughout the planning horizon, including:

- Association monthly meetings
- Preparation of annual progress reports
- Groundwater monitoring and data sharing
- Coordination and cooperation with water entities, neighboring basins, and state and federal agencies
- Periodic review of groundwater monitoring and groundwater management

References

--------. 2000. California Safe Drinking Water Act and Related Laws. Seventh Edition. January 2000.

Balding, Gary O. and R. W. Page. 1971. Data for Wells in the Modesto-Merced Area, San Joaquin Valley, California. U.S. Department of the Interior, Geological Survey, Water Resources Division. Prepared in cooperation with the California Department of Water Resources. Open-File Report. Menlo Park, California.

Borchers, James W., M. Gerber, J. Wiley, and H.T. Mitten. 1998. "Using Down-Well Television Surveys to Evaluate Land Subsidence Damage to Water Wells in the Sacramento Valley, California." *In* Land Subsidence Case Studies and Current Research: Proceedings of the Dr. Joseph F. Poland Symposium. James W. Borchers, ed.

Boyle Engineering Corporation. 2003. Water Master Plan: City of Oakdale. November 2003.

Burow, Karen R., Jennifer L. Shelton, and Neil M. Dubrovsky. 1998. Occurrence of Nitrate and Pesticides in Ground Water Beneath Three Agricultural Land-Use Settings in the Eastern San Joaquin Valley, California, 1993–1995. U.S. Geological Survey. Water-Resources Investigation Report 97-4284. National Water-Quality Assessment Program. Sacramento, California.

Burow, Karen R., Jennifer L. Shelton, Joseph A. Hevesi, and Gary S. Weissmann. 2004. Hydrologic Characterization of the Modesto Area, San Joaquin Valley, California. Preliminary Draft. U.S. Geological Survey. Water-Resources Investigation Report. Prepared in cooperation with Modesto Irrigation District.

Burow, Karen R., Sylvia V. Stork, and Neil M. Dubrovsky. 1998. Nitrate and Pesticides in Ground Water in the Eastern San Joaquin Valley, California: Occurrence and Trends. U.S. Geological Survey. Water-Resources Investigation Report 98-4040a. Available at http://ca.water.usgs.gov/sanj/pub/usgs/wrir98-4040a/wrir98-4040a.html.

California Department of Conservation. 2002. California Spatial Library.

California Department of Water Resources. 2003. California's Groundwater: Bulletin 118—San Joaquin Valley Groundwater Basin, Modesto Subbasin. Update of October 1, 2003.

California Division of Mines and Geology. 1975. Geophysical Investigations in the Ione Area, Amador, Sacramento, and Calaveras Counties, California. Special Report 117. Sacramento, California. Prepared by Rodger H. Chapman and Charles C. Bishop.

Chapman, Rodger H., and Charles C. Bishop. 1975. Geophysical Investigations in the Ione Area, Amador, Sacramento, and Calaveras Counties, California. California Division of Mines and Geology. Special Report 117.

City of Modesto. 2003. 2003 Consumer Confidence Report.

City of Oakdale, California. 2003. Water Master Plan. Prepared by Boyle Engineering Corporation. November 2003.

City of Riverbank, California. 2003. 2002 Consumer Confidence Report and supporting data. April 15, 2003.

Davis, G.H., J.H. Green, F.H. Olmsted, and D.W. Brown. 1959. Ground-water conditions and storage capacity in the San Joaquin Valley, California. U.S. Geological Survey. Water-Supply Paper 1999-H.

Hem, John D. 1989. Study and Interpretation of the Chemical Characteristics of Natural Water. Third Edition. U.S. Geological Survey. Water-Supply Paper 2254.

Hotchkiss, W. R., and G.O. Balding. 1971. Geology, hydrology, and water quality of the Tracy-Dos Palos area, San Joaquin Valley, California. U.S. Geological Survey. Open-File Report.

Johnson, A. I. 1967. Specific Yield—Compilati8on of specific Yields for Various Materials. U.S. Geological Survey. Water-Supply Paper 1662-D. Prepared in Cooperation with the California Department of Water Resources.

Marchand, D. E., and A. Allwardt. 1981. Late Cenozoic stratigraphic units, northeastern San Joaquin Valley, California: U.S. Geological Survey Bulletin 1470.

MID, *see* Modesto Irrigation District.

Modesto Irrigation District. 1996. Final Groundwater Management Plan for the Modesto Irrigation District (Draft). March 1996.

Modesto Irrigation District. 2004. Water quality data spreadsheet.

Page, R. W. 1972. Preliminary Appraisal of Ground-Water Conditions in the Vicinity of Modesto, California. U.S. Department of the Interior, Geological Survey, Water Resources Division. Prepared in cooperation with the city of Modesto. Open-File Report. Menlo Park, California. October 2, 1972.

Page, R. W. 1973. Base of Fresh Ground Water (Approximately 3,000 Micromhos) in the San Joaquin Valley, California. U.S. Geological Survey. Prepared in cooperation with the California Department of Water Resources. Hydrologic Investigations Atlas HA-489.

Page, R. W. 1977. Appraisal of ground-water conditions in Merced, California, and vicinity. U.S. Geological Survey. Open-File Report.

Page, R. W. 1986. Geology of the Fresh Ground-Water Basin of the Central Valley, California, with Texture Maps and Sections: Regional Aquifer-System Analysis. U.S. Geological Survey. Professional Paper 1401-C.

Page, R. W. and Balding, G. O. 1973. Geology and Quality of Water in the Modesto-Merced Area, San Joaquin Valley, California, with a Brief Section on Hydrology. U.S. Geological Survey. Prepared in cooperation with the California Department of Water Resources. Water-Resources Investigation 6-73. September 1973.

Phillips, Steven P., Sherrill Beard, and R. J. Gilliom. 1991. Quantity and Quality of Ground-Water Inflow to the San Joaquin River, California. U.S. Geological Survey. Water-Resources Investigations Report 91-4109. Prepared in cooperation with the California Department of Water Resources and the California State Water Resources Control Board. Sacramento, California.

Poland, J.F. and R.E. Evenson. 1966. "Hydrogeology and Land Subsidence, Great Central Valley, California." *In* Geology of Northern California. Bulletin 190, California Division of Mines and Geology. Edgar H. Bailey, ed. San Francisco, California.

Stanislaus County. 1994. 1994 Stanislaus County General Plan.

U.S. Census Bureau. 2004. Population Statistics. Available at http://factfinder.census.gov. Accessed May 11, 2004.

U.S. Environmental Protection Agency. 2004. EPA Map of Radon Zones. Available at http://www.epa.gov/iaq/radon/zonemap/california.htm.

U.S. Geological Survey. 1999. Land Subsidence in the United States. Edited by Devin Galloway, David R. Jones, and S.E. Ignebritsen. Circular 1182. Reston, Virginia.

U.S. Geological Survey. 2004. San Joaquin-Tulare Basins NAWQA. Available at http://ca.water.usgs.gov/sanj/gw_cycle1.html. Accessed May 6, 2004.

Weissmann, G.S., J.F. Mount, and G.E. Fogg. 2002. Glacially driven cycles in accumulation space and sequence stratigraphy of a stream-dominated alluvial fan, San Joaquin Valley, California. Journal of Sedimentary Research, v. 72, no. 2, March 2002, pp. 240–251.

West-Yost. 2004. Engineer's Report: Justification and Cost Allocation for Proposed Water System Improvements. September 2, 2004.