California's Groundwater Update 2013

A Compilation of Enhanced Content for California Water Plan Update 2013

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State of California
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Department of Water Resources

SAN JOAQUIN RIVER HYDROLOGIC REGION

Tables

Figures

Acronyms and Abbreviations Used in This Chapter

AB	Assembly Bill
ACWA	Association of California Water Agencies
AWMP	agriculture water management plan
BMO	basin management objective
CASGEM	California Statewide Groundwater Elevation Monitoring
CDFA	California Department of Food and Agriculture
CDPH	California Department of Public Health
CVP	Central Valley Project
CV-SALTS	Central Valley Salinity Alternatives for Long-Term Sustainability
CWS	community water system
DAU	detailed analysis unit
DBCP	dibromochloropropane
DCE	dichloroethylene
Delta	Sacramento-San Joaquin River Delta
DPR	California Department of Pesticide Regulation
EPA	U.S. Environmental Protection Agency
GAMA	Groundwater Ambient Monitoring and Assessment
GIS	geographic information system
gpm	gallons per minute
gpm/ft	gallons per minute per foot
GPS	global positioning system
GWMP	groundwater management plan

HAL	health advisory levels
ILRP	Irrigated Lands Regulatory Program
InSAR	interferometric synthetic aperture radar
IRWM	integrated regional water management
ITRC	Irrigation Training and Research Center
LLNL	Lawrence Livermore National Laboratory
MCL	maximum contaminant level
NL	notification level
PA	Planning Area
PBO	Plate Boundary Observatory
RWMG	regional water management group
RWQCB	regional water quality control board
San Joaquin River region	San Joaquin River Hydrologic Region
SB	Senate Bill
SB X7-6	2009 Comprehensive Water Package legislation
SB X7-7	Water Conservation Bill of 2009
SMCL	secondary maximum contaminant level
SWN	state well number
SWP	State Water Project
SWRCB	State Water Resources Control Board
Sy	specific yield
taf	thousand acre-feet
TDS	total dissolved solids

UNAVCO	university-governed consortium for geosciences research using geodesy
USDA	U.S. Department of Agriculture
USGS	U.S. Geological Survey
UST	underground storage tank
UWMP	urban water management plan

Chapter 8. San Joaquin River Hydrologic Region Groundwater Update

Introduction

The primary goal of the San Joaquin River Hydrologic Region (San Joaquin River region) groundwater update is to expand information about region-specific groundwater conditions for *California Water Plan Update 2013*, and to guide more informed groundwater management actions and policies. A second goal is to steadily improve the quality of groundwater information in future California Water Plan updates to a level that will enable regional water management groups (RWMGs) to accurately evaluate their groundwater resources and implement management strategies that can meet local and regional water resource objectives within the context of broader statewide objectives. The final goal is to identify data gaps and groundwater management challenges meant to serve as a guidepost for prioritizing future data collection and funding opportunities relevant to the region.

This regional groundwater update is not intended to provide a comprehensive and detailed examination of local groundwater conditions, or be a substitute for local studies and analysis. However, where information is readily available, the update does report some aspects of the regional groundwater conditions in greater detail.

The San Joaquin River region, depicted in Figure 8-1, covers about 15,000 square miles and includes all of Calaveras, Tuolumne, Mariposa, Madera, San Joaquin, and Stanislaus counties; most of Merced and Amador counties; along with parts of Alpine, Fresno, Alameda, Contra Costa, Sacramento, El Dorado, and San Benito counties. The region includes all of the San Joaquin River drainage area, extending from the headwaters in the Sierra Nevada in eastern Madera and Fresno counties, through the north portion of the San Joaquin Valley, and to the southern boundaries of the Sacramento-San Joaquin River Delta (Delta). Major rivers draining the San Joaquin River region include the San Joaquin, Merced, Tuolumne, and Stanislaus.

The climate in the region is semi-arid to arid. The average annual precipitation along the valley floor averages approximately 26 inches and approximately 95 percent of the precipitation falls between October and April. The 2010 census information indicates an overall population of approximately 2,104,000 for the San Joaquin River region, with about 86 percent of the population living in the alluvial groundwater basin areas.

The groundwater update for the San Joaquin River region provides a regional overview of the groundwater supply and development, groundwater use, groundwater monitoring, aquifer conditions, groundwater management activities, and conjunctive water management practices. In addition, the regional update identifies groundwater data gaps, challenges and successes of sustainable groundwater management, and recommendations to further improve the overall sustainability of this valuable resource.

Figure 8-1 San Joaquin River Hydrologic Region

Findings, Data Gaps, and Recommendations

The following information is specific to the San Joaquin River region and summarizes the findings, data gaps, and recommendations.

Findings

The bulleted items in this section are adopted from more comprehensive information presented in this chapter, and generally reflect information that was readily available through August 2012. In some cases, the compiled information expands upon the data and recommendations included in *California Water Plan Update 2009*; however, much of the groundwater information, including well infrastructure discussions, water supply analysis, change in groundwater storage estimates, and groundwater management plan reviews, are new to *California Water Plan Update 2013*. The groundwater-specific data presented in this document will be used as the foundation for *California Water Plan Update 2018*, with the goal of generating information that can be used to make informed decisions related to sustainably managing California's groundwater resources. The following information highlights the groundwater findings for the San Joaquin River region.

Groundwater Supply and Development

- The San Joaquin River region contains 11 alluvial groundwater basins and subbasins recognized by California Department of Water Resources (DWR) Bulletin 118-2003, which underlie approximately 5,830 square miles, or 38 percent, of the hydrologic region (Figure 8-2 and Table 8-1).
- The total number of wells completed in the San Joaquin River region between 1977 and 2010 is approximately 73,447 and ranges from a high of 12,915 wells for Madera County to a low of 3,767 wells for Amador County (Figure 8-3 and Table 8-3).
- Based on the California Statewide Groundwater Elevation Monitoring (CASGEM) Basin Prioritization effort from December 2013, seven subbasins in the San Joaquin River region are identified as high priority, two subbasins are identified as medium priority, and two basins are listed as very low priority. The nine subbasins designated as high or medium priority include more than 99 percent of the annual groundwater use and more than 99 percent of the 2010 population living within the region's groundwater basin boundaries (Figure 8-6 and Table 8-4).

Groundwater Use and Aquifer Conditions

- The 2005-2010 average annual total water supply for the San Joaquin River region, based on planning area boundaries, is estimated at 8.4 million acre-feet (maf). Water demands in the region are met through a combination of local surface water supplies, State (State Water Project [SWP]) and federal (Central Valley Project [CVP]) surface water deliveries, groundwater, and reused/recycled water supplies (Figure 8-7).
- Groundwater contributes about 38 percent (3.2 maf) to the 2005-2010 average annual total water supply for the San Joaquin River region. Groundwater use in the region accounts for 19 percent of all groundwater pumping in California (Figure 8-7).
- Groundwater supplies, based on average annual estimates for 2005-2010, contribute 36 percent of the total agricultural water supply, 58 percent of the total urban water supply, and 38 percent of the total managed wetlands supply in the San Joaquin River region (Table 8-5).

- Between 2002 and 2010, annual groundwater use in the San Joaquin River region ranged between 2.4 maf (in 2005) and 3.7 maf taf (in 2008), and contributed between 31 percent and 43 percent toward the annual water supply (Figure 8-8).
- Of the groundwater pumped on an annual basis between 2002 and 2010, between 72 percent and 84 percent of the groundwater was used for agricultural purposes (Figure 8-9).
- Depth to groundwater and groundwater elevation contours using spring 2010 data were created for the San Joaquin Valley portion of the San Joaquin River region. While some areas of the northern San Joaquin Valley, primarily along the valley's eastern margin against the Sierra Nevada, showed groundwater levels at depths exceeding 200-250 feet below-ground-surface (bgs), most of the valley exhibited depth-to-groundwater levels of less than 150 feet (Figure 8-12).
- Groundwater elevations, according to available spring 2010 data, show cones of groundwater depression as much as 50 feet below mean sea level in the northern portion of the San Joaquin Valley, east of the cities of Galt and Stockton (Figure 8-13).
- Change in groundwater elevations between spring 2005 and spring 2010 show that most areas in the San Joaquin Valley have exhibited groundwater elevation declines; however, some areas in the southern part of the region have experienced groundwater-level declines in excess of 60 feet (Figure 8-15).
- A geographic information systems (GIS) tool developed by DWR was used to calculate change in groundwater-in-storage estimates using groundwater elevation data, where data were available, between spring 2005 and spring 2010 for the San Joaquin Valley portion of the San Joaquin River region. Using specific yield estimates ranging between 0.07 and 0.17, annual changes in groundwater elevation indicate a 2005 to 2010 reduction in groundwater in storage between 1,062 taf and 2,579 taf (Figure 8-16 and Table 8-12).

Groundwater Monitoring Efforts

- A total of 1,532 wells are actively monitored for groundwater-level information in the San Joaquin River region as of July 2012 (Figure 8-10 and Table 8-8).
- There are an estimated 433 community water systems (CWSs) in the San Joaquin River region with an estimated 1,046 active CWS wells; 288 of the CWS wells (24 percent) are identified as being affected by one or more chemical contaminants that exceed a maximum contaminant level (MCL). The affected wells are used by 104 CWSs in the region, with 80 of the 104 affected CWSs serving small communities.
- The most prevalent groundwater contaminants affecting community drinking water wells in the region include arsenic, nitrate, gross alpha particle activity, dibromochloropropane (DBCP), and uranium. In addition, 59 regional wells are affected by multiple contaminants (Tables 8-14, 8-15, and 8-16).
- Land subsidence investigations in the San Joaquin Valley include various monitoring efforts. Some of these monitoring efforts include elevation surveys along the California Aqueduct, borehole extensometer monitoring, satellite remote-sensing studies using interferometric synthetic aperture radar (InSAR), continuous and conventional global positioning system (GPS) measurements, and spirit-leveling surveying. The west side of the San Joaquin Valley has experienced dramatic land changes from subsidence, both in the amount of decline in the land surface elevation and in the geographic extent involved (see the "Groundwater Monitoring Efforts" and "Aquifer Conditions" sections of this chapter for more information and Appendix F).

Groundwater Management and Conjunctive Management

- There are 21 groundwater management plans (GWMP) within the San Joaquin River region that collectively cover about 79 percent of the Bulletin 118-2003 alluvial basin area in the region, and about 32 percent of the overall region (Figure 8-23 and Table 8-18).
- DWR's assessment of GWMPs in the San Joaquin River region determined that 13 of the 21 GWMPs have been developed or updated to include the legislative requirements of Senate Bill (SB) 1938 and are considered "active" for the purposes of the GWMP assessment.
- Three of the 21 GWMPs in the region address all of the required components identified in California Water Code Section 10753.7 (Table 8-19).
- Of the 89 agencies or programs identified as operating a conjunctive management or groundwater recharge program in California, five programs are located in the San Joaquin River region. The groundwater recharge methods employed include the use of surface-spreading basins and in-lieu recharge programs. The effort to fully characterize the 89 conjunctive management programs, as part of *California Water Plan Update 2013*, was largely unsuccessful because numerous agencies were reluctant to make details about their groundwater recharge operations publically available (see Appendix D).

Data Gaps

Gaps in groundwater information are separated into the following three categories: data collection and analysis, basin assessments, and sustainable management. Where possible, the discussion of gaps is specific to the San Joaquin River region; however, many of the identified gaps are applicable to several or all hydrologic regions in California. Addressing these data gaps at both the local level and State agency level will help ensure that groundwater resources throughout the state are better characterized and sustainably managed.

Data Collection and Analysis

The characterization of the alluvial aquifers in the San Joaquin River region is well-defined from a hydrogeological perspective in most areas, but more complete data are always necessary to better understand basin-wide and region-wide groundwater levels, groundwater quality, groundwater use, and the interaction between surface water and groundwater.

Information related to groundwater extraction, recharge, and groundwater basin budgets in the San Joaquin River region is extremely limited and has been estimated primarily through water supply balance and land use information derived from DWR's land use surveys. Very little information is known about the fractured-bedrock aquifers located outside the San Joaquin Valley and how they interact with the valley's groundwater system.

Many local water agencies in the San Joaquin River region are collecting groundwater data and are managing their basins by using the authorities they are given. However, locally collected and analyzed data, which could be used by regional water management groups and State agencies to better characterize the groundwater basins in the San Joaquin River region, are generally not readily available.

Basin Assessments

Region-wide depth-to-groundwater information and annual estimates of change in groundwater in storage are not well understood for many of the groundwater basins in the San Joaquin River region.

Further degradation of groundwater quality in the San Joaquin River region is unavoidable without a plan for removing salts from the basin. In addition to salts, high levels of nitrate concentrations have been reported throughout the San Joaquin River region, and studies have concluded that nitrate problems will likely worsen in the coming decades.

Land subsidence investigations in the San Joaquin River region include various monitoring efforts, but because of the documented increase in the depth to water and the reduction of groundwater supplies in storage throughout the San Joaquin Valley, land subsidence will continue to occur in areas that have already experienced subsidence and in those areas experiencing increased groundwater pumping.

Although five conjunctive management programs were identified in the San Joaquin River region, the survey conducted as part of *California Water Plan Update 2013* was unable to collect comprehensive information about those programs; as a result, a general understanding of the effectiveness of the region's groundwater recharge and conjunctive management programs could not be determined. In addition, it is unknown whether local agencies have complied with the groundwater recharge mapping requirements of Assembly Bill (AB) 359, which went into effect on January 1, 2013.

Sustainable Management

The 13 active GWMPs in the San Joaquin River region that meet some or all of the SB 1938 groundwater management requirements cover 67 percent of the alluvial groundwater basin area. Although over 80 percent of the region's GWMPs address groundwater overdraft policies in their plans, the San Joaquin River region, from 2005-2010, has depleted between 1,062 taf and 2,579 taf of its groundwater in storage from the portion of the region that reports groundwater elevation data from unconfined aquifers.

Implementing sustainable groundwater management practices at the local level is made more difficult by the limited authority of some agencies to assess management fees, restrict groundwater extraction, and regulate land use in groundwater-short areas.

Recommendations

While much information is known about some of the groundwater basins in the San Joaquin River region, comprehensive information that could provide a realistic water budget to determine groundwater sustainability in the region is largely unknown. To better characterize and sustainably manage the region's groundwater resources, the following recommendations are made for the San Joaquin River region.

- Increase collection and analysis of groundwater level, quality, use, and extraction data, as well as information regarding the surface-water-groundwater interaction in alluvial aquifers, to a level that allows for development of groundwater budgets, groundwater supply forecasting, and assessment of sustainable groundwater management practices.
- Increase data collection in fractured-bedrock aquifers to determine the degree of interaction that the foothill communities have with the San Joaquin Valley aquifers.
- Increase land subsidence monitoring to quantify the permanent loss of groundwater storage caused by excessive groundwater pumping.
- Continue to monitor groundwater quality throughout the region to better determine sources of natural and anthropogenic contamination and comply with all groundwater quality protection strategies recommended by the Central Valley Regional Water Quality Control Board.

- Update all existing GWMPs to meet the standards set forth in California Water Code and ensure that GWMPs are prepared for all high- and medium-priority groundwater basins as identified by CASGEM Basin Prioritization.
- DWR should determine the extent and effectiveness of the groundwater recharge and conjunctive management programs in the San Joaquin River region by working with local water managers to complete the conjunctive management survey information and ensure that the groundwater recharge mapping requirements of AB 359 are met.
- Ensure local agency goals, actions, and plans for sustainable groundwater management are compatible with, and roll-up to, a minimum set of goals and actions established by the overlying integrated regional water management (IRWM) plan.
- Provide local and regional agencies the authority to assess fees, limit groundwater extraction, and restrict land use in groundwater-short areas, as needed, to better establish a path toward sustainable groundwater management.
- Develop annual groundwater management reports that summarize groundwater management goals, objectives, and performance measures, along with the current and projected trends for groundwater use, groundwater levels, groundwater quality, land subsidence, and surface water-groundwater interaction. Annual reports should also evaluate how existing groundwater management practices contribute toward sustainable groundwater management and proposed actions for improvements.

Groundwater Supply and Development

This section provides an overview of the key aquifer systems that contribute groundwater to the regional supply, the well infrastructure used to develop these supplies, and an introduction to groundwater basin prioritization for the region.

Groundwater resources in the San Joaquin River region are supplied by alluvial aquifers and by fractured-rock aquifers. Alluvial aquifers are comprised of sand and gravel or finer-grained sediments, with groundwater stored within the voids, or pore space, among the alluvial sediments. Fractured-rock aquifers consist of impermeable granitic, metamorphic, volcanic, or hard sedimentary rocks, with groundwater being stored in fractures or other void spaces. The distribution and extent of alluvial and fractured-rock aquifers and water wells vary in the San Joaquin River region. A brief description of the alluvial aquifers for the region is provided in the following paragraphs. Additional information regarding alluvial and fractured-rock aquifers is available online from DWR Bulletin 118-2003 (http://www.water.ca.gov/groundwater/bulletin118/update_2003.cfm).

Alluvial Aquifers

DWR Bulletin 118-2003 identifies 11 alluvial groundwater basins and subbasins in the San Joaquin River region. The 11 basins and subbasins underlie approximately 5,830 square miles or 38 percent of the hydrologic region. Most of the groundwater in the San Joaquin River region is stored in alluvial aquifers. A detailed description of the aquifers in this hydrologic region is beyond the scope of this chapter. Additional information regarding groundwater basins in this hydrologic region may be obtained online from DWR Bulletin 118-2003 (http://www.water.ca.gov/groundwater/bulletin118/update_2003.cfm). Figure 8-2 shows the locations of the alluvial groundwater basins and subbasins, and Table 8-1 lists the names and numbers associated with the alluvial groundwater basins and subbasins.

Groundwater extracted by wells located outside the alluvial basins is supplied largely from fractured-rock aquifers. In some cases, groundwater stored in a thin overlying layer of alluvial deposits or a thick soil horizon may also contribute to a well's groundwater supply.

Groundwater extraction from the alluvial aquifer portion of the San Joaquin River region accounts for about 19 percent of California's total average annual groundwater extraction. The most heavily-used groundwater basins in the region include the eight subbasins within the northern San Joaquin Valley Groundwater Basin: Turlock, Merced, Madera, Delta-Mendota, Eastern San Joaquin, Modesto, and Chowchilla. Each of these subbasins is considered a high-priority basin under CASGEM Basin Prioritization and account for 92 percent of the groundwater used in the region. The addition of the Cosumnes and Tracy groundwater subbasins, both CASGEM medium-priority basins, bring the total groundwater used in the region to 99.9 percent. The two very-low-priority basins identified outside the San Joaquin Valley are the Los Banos Creek Valley and Yosemite Valley groundwater subbasins.

The descriptions of the alluvial aquifers in the San Joaquin River region are organized according to the major unconfined and confined aquifer systems, inside and outside the San Joaquin Valley Groundwater Basin, followed by a short overview of irrigation pump performance and aquifer susceptibility to land subsidence.

San Joaquin Valley Groundwater Basin

Aquifer systems in the San Joaquin River region consist mostly of continental sediments eroded from the nearby surrounding mountains and deposited in the valley. The alluvial aquifer system is a complex set of interbedded aquifers and aquitards that function regionally as a single water-yielding unit (Poland 1972, as quoted in Sneed 2001). The San Joaquin Valley aquifers are generally quite thick, with groundwater wells extending to depths of more than 1,000 feet (Page 1986). The aquifers consist of gravel, sand, silt, and clay lenses, which become increasingly interbedded with fine-grained lakebed deposits toward the center of the valley (U.S. Geological Survey 2011). The maximum thickness of freshwater deposits is about 4,400 feet and occurs at the south end of the valley.

Principal water-bearing formations that comprise the major aquifers on the east side of the San Joaquin River region include the Miocene-Pliocene Mehrten Formation and the Pliocene Laguna Formation. The sedimentary deposits increase in thickness from the base of the Sierra Nevada foothills and thicken from north to south along the valley axis. In the Madera and Chowchilla subbasin areas, the continental deposits bearing freshwater are as much as 3,000 feet thick (Shelton et al. 2009). The upper 800 feet of continental sediments are the primary source of groundwater in the Modesto Subbasin (Gunther and Schulmeister 2005). Shallow or deep zones in the primary water-bearing zones may differ from that of the primary aquifers; shallow aquifers may be thin and of poor quality, while deeper zones may contain saline remnant water from the deep marine formations.

Figure 8-2 Alluvial Groundwater Basins and Subbasins in the San Joaquin River Hydrologic Region

Table 8-1 Alluvial Groundwater Basins and Subbasins in the San Joaquin River Hydrologic Region

Basin/Subbasin		Basin Name
5-22		San Joaquin Valley
	5-22.01	Eastern San Joaquin
	5-22.02	Modesto
	5-22.03	Turlock
	5-22.04	Merced
	5-22.05	Chowchilla
	5-22.06	Madera
	5-22.07	Delta-Mendota
	5-22.15	Tracy
	5-22.16	Cosumnes
5-69		Yosemite Valley
5-70		Los Banos Creek Valley

On the west side of the San Joaquin Valley, the principal water-bearing formation is the Tulare Formation. Exposed at the land surface on the west side of the valley, the Tulare Formation deposits range from a thin edge at the base of the Diablo Range and increase in thickness to more than 4,000 feet toward the axis of the valley (Page 1983). The unit is divided into an upper unconfined to semi-confined aquifer and a lower confined zone separated by the confining Corcoran clay layer. The formation is a mixture of interbedded clay, silt, sand, and gravel of alluvial and deltaic origin, formed at the base of the Diablo Range. Floodplain, lake, and marsh deposits lie along the valley axis. The Tulare Formation is underlain by at least 10,000 feet of consolidated pre-Tertiary and Tertiary deposits and has little groundwater potential (Hotchkiss and Balding 1983).

Other water-bearing formations, important in the Kaweah, San Joaquin, Tule, and Kern County groundwater basins, include westward-dipping sediments that lie along the sloping face of the Sierran basement complex. These sediments included the Schenley sand member of the Kern River Formation, and the Olcese and Santa Margarita formations, which provide fresh water from very deep wells (Rodner 1950; Hilton et al. 1963).

Although several highly productive coarse-grained aquifers exist in the San Joaquin Valley portion of the San Joaquin River region, fine-grained sediments comprise more than 50 percent of the valley fill deposits (Faunt 2005). Abundant deposits of fine-grained material of varying thickness and distribution combine over the larger aquifer area to restrict the vertical flow of groundwater. The upper few hundred feet of alluvial aquifer tends to remain unconfined, grading to semi-confined and highly-confined conditions with increasing depth.

On a regional scale, the aquifer systems of the San Joaquin Valley Groundwater Basin can be divided into an upper unconfined to semi-confined aquifer, a series of geographically extensive confining clay layers, and a deep-confined aquifer.

Unconfined to Semi-Confined Aquifers

Alluvial deposits comprising the unconfined to semi-confined aquifers may be grouped into the Coast Ranges alluvium along the west side of the valley, Sierran alluvium on the east side of the valley, flood-basin deposits in the center of the valley, and buried river channel deposits in the alluvial fan and Pleistocene river courses (Faunt 2005).

Coast Ranges Alluvium

Coast Ranges alluvium varies considerably by size and location. Along stream channel reaches and upper alluvial fan areas, alluvial deposits are dominated by sand- and gravel-size sediments. Along the distal end of the alluvial fans, the grain size of the alluvial material grades to a finer mixture of silt and clay (Faunt 2005). Marine sediments, transported into San Joaquin Valley aquifers from eroding sands and shale of the Temblor Range, contain a high portion of silt and clay and a high salt content (Davis 1961). Dissolved salts from Coast Ranges runoff over the alluvial marine deposits are dominated by calcium, sodium, chloride, and sulfate ions.

Sierran Alluvium

Sierran alluvium consists generally of coarse-grained sand and gravel deposits that have been transported by Sierra Nevada runoff into the valley, as far as the axis of the valley trough. Runoff from Sierra Nevada streams and rivers have a much lower concentration of dissolved salts and consist primarily of calcium, magnesium, and bicarbonate ions. Alluvial material from the Coast Ranges and Sierra Nevada come together along the axis of the San Joaquin Valley, forming inter-fingered alluvial deposits from the two source areas.

Flood-Basin Deposits

Flood-basin deposits lie mostly along the trough axis of the San Joaquin Valley. Organic-rich deposits occur in the floodplain adjacent to the valley's river and stream channels, and can also be found in topographic lows associated with marshes, lakes, and ponds. Flood-basin deposits are predominantly silt and clay, with periodic lenses of sand that mark the former location of meandering stream beds.

Buried River Channel Deposits

The variable texture of the San Joaquin River region's alluvial aquifers is partly a function of the location and size of the transporting rivers and streams. The high-energy flows can produce coarse-grained channel deposits measuring more than 0.5 miles wide, as much as 90 feet deep, and extending the length of the fluvial fan (Weissmann 2004). Changes in river flows associated with the buried river channel deposits are related to the Pleistocene glacial outwash cycles in the Sierra Nevada (Weissmann 2004). In 2004, Weissmann characterized the buried channels as preferred pathways for groundwater movement between the shallow and deeper aquifer systems, causing increases in groundwater velocity along these pathways. In descending order of age are the high-energy glacial outwash Modesto Formation (Late Pleistocene) and the Riverbank Formation (Middle Pleistocene), Upper Turlock Lake and Lower Turlock Lake formations (Early Pleistocene), and a Pliocene basal unit representing the pre-glaciation period (Weissmann et al. 2002).

Principal Confining Unit — Corcoran Clay

Although a number of highly productive coarse-grained aquifers exist in the San Joaquin Valley portion of the San Joaquin River region, fine-grained sediments comprise more than 50 percent of valley fill deposits (Faunt 2005). Nearly continuous lake and/or marsh sediments have been present in the Tulare, Kern, and Buena Vista lakebeds since the Pliocene and Pleistocene epochs. These lake and marsh sediments formed thick clay plugs in the lakebed areas. The largest of these clay plugs is in the San Joaquin area. Now drained, the clay marks the presence of a succession of lakes that spread from the San Joaquin area, extending outward into larger- or smaller-size lakes. In the center of the spreading areas, the presence of thick (as much as 3,000 feet) and extensive clay layers limit the amount of available groundwater for water supply. Six distinct lake clay layers have been identified in the geologic record. The clay layers are named in alphabetical order, from A-clay (shallow and youngest) to F-clay (deepest and oldest).

The geographic extent and thickness of the clay layers provides a record of the interplay between the tectonic mountain building forces and climate variability. The Tulare Lake bed is near the center of an area of structural downwarping, with tectonic subsidence controlling the rate of sediment filling the basin (Burow et al. 2004). Page (1986) found the clay layers to be thinner in the northern San Joaquin Valley than in the southern portion of the valley because similar tectonic downwarping of the Sacramento Valley was not occurring (Burow 2004).

The largest of the ancestral lakes formed the “E-clay” or Corcoran clay. The lake was geographically extensive, covering the western half of the San Joaquin Valley from the Kern Lake bed to an area north of Modesto (Faunt 2009). The Corcoran clay is as much as 150 feet thick, occurs at a depth of about 250 feet below land surface along State Route 99 near Goshen and Pixley, and at a depth of 800 feet in the Tulare Lake bed area (Croft 1972). It is commonly described as “blue clay” on driller logs and is one of the identifiers for the clay.

The Corcoran clay has formed a nearly impermeable barrier, separating the unconfined to semi-confined groundwater above from the confined groundwater below. Confining conditions are apparent by the marked differences in water levels between wells penetrating above and below the Corcoran clay. The presence of the confined aquifer was noted during early groundwater studies in the valley when identifying areas of artesian wells (Mendenhall et al. 1916). The presence of confining layers is recognized by significant water quality conditions between the unconfined/semi-confined aquifer and the confined aquifer. Where Corcoran clay is present, groundwater salinity is generally lower below the clay layer relative to above the clay.

Alluvial Aquifers Outside the San Joaquin Valley

Two alluvial aquifers exist in groundwater basins outside the San Joaquin Valley, one each in the Yosemite Valley and Los Banos Creek Valley groundwater basins. Yosemite Valley groundwater management is under the purview of the National Park Service. For Los Banos Creek Valley, DWR was unable to locate any published literature describing the occurrence and quantity of groundwater in the basin.

Irrigation Pump Performance

Irrigation well performance varies according to a number of factors, including drilling methods, casing size, perforated casing area, pump horsepower and type, and the hydrogeologic properties of the aquifer. Irrigation wells are periodically tested to identify optimum well-production rates, pumping plant efficiency, and energy demands. Pump tests can also be used to help identify general aquifer characteristics and performance.

As part of the California Energy Commission Public Interest Energy Research program, the Irrigation Training and Research Center (ITRC) at California Polytechnic State University analyzed test data for the electric irrigation pumps used in the Sacramento Valley, Salinas Valley, and San Joaquin Valley groundwater basins (Burt 2011). In the San Joaquin Valley Groundwater Basin, about 9,000 irrigation pump test records were compiled and evaluated by the ITRC. In addition to evaluating the pump test data for well efficiency and energy requirements, the study also summarized, for each groundwater basin, the average flow rate, static groundwater level, and pumping drawdown. Using the compiled pump test results, the study also estimated the average specific capacity of wells in each groundwater basin. *Specific capacity* is the measure of the pumping rate divided by the drawdown. Although a portion of the pumping well drawdown is related to well performance and inefficiencies, much of the drawdown and related specific capacity can be correlated to the aquifer's ability to freely transmit water. Pump test information from the ITRC study is shown in Table 8-2. Average values shown in Table 8-2 are weighted by input horsepower of the pump motor and grouped according to a given range of values. Information in Table 8-2 is presented in order of increasing pumping rates.

Table 8-2 shows that the average groundwater pumping rates are lowest for the Tracy and Modesto groundwater subbasins and highest for the Delta-Mendota Groundwater Subbasin. Data from a combined 13 pump tests were used to determine the average pumping rates for the Tracy and Modesto groundwater subbasins; the average flow rate ranged between 677 gallons per minute (gpm) and 867 gpm. The average pumping rates for the Delta-Mendota Groundwater Subbasin range between 1,249 gpm and 1,438 gpm, based on data from 242 tests. The pumping rates for the other subbasins in the San Joaquin River region ranged between 868 gpm and 1,248 gpm.

Static groundwater levels, typically collected prior to the start of a pump test, are shallowest in the Tracy, Modesto, and Delta-Mendota groundwater subbasins (from 49 to 81 feet below ground surface). Groundwater levels are nearly triple in the Madera Groundwater Subbasin, ranging between 176 and 206 feet below ground surface. For the most part, pumping drawdowns ranged between 25 and 49 feet in the majority of the groundwater basins, but there were two outliers; drawdown in the Consumes Groundwater Subbasin showed a range between 8 and 24 feet, and the Tracy Groundwater Subbasin showed drawdown between 49 and 95 feet below ground surface.

Specific capacity values were estimated based on the average range of pumping rates and drawdown values reported in the ITRC study. Higher specific capacity values typically correlate to higher aquifer permeability, or increases in an aquifer's ability to transmit water. Table 8-2 shows that specific capacity estimates for the San Joaquin River region range from a low of 7 gallons per minute per foot (gpm/ft) of drawdown in the Tracy Groundwater Subbasin, to a high of 156 gpm/ft in the Consumes Groundwater Subbasin. Lower specific capacity values for the Tracy Groundwater Subbasin are probably the result of a combination of increases in fine-grained aquifer material and a decrease in the overall pumping-plant efficiency reported in the ITRC study.

Table 8-2 Irrigation Pump Test Data for the Northern San Joaquin Valley Basin Portion of the San Joaquin River Hydrologic Region

Groundwater Basins		Number of Tests	Average Flow Rate[a] (gpm)	Average Static Water Level[b] (ft)	Average Drawdown[c] (ft)	Specific Capacity[d,e,f] (gpm/ft)
Subbasin Name	Subbasin Number					
Eastern San Joaquin	5-22.01	75-237	868-1,057	82-112	25-29	30-42
Modesto	5-22.02	2-4	677-867	49-81	39-43	16-22
Turlock	5-22.03	22-45	1,058-1,248	82-112	35-38	28-36
Merced	5-22.04	181-606	1,058-1,248	113-143	39-43	25-32
Chowchilla	5-22.05	200-595	868-1,057	144-175	35-38	23-30
Madera	5-22.06	321-591	868-1,057	176-206	39-43	20-27
Delta-Mendota	5-22.07	55-242	1,249-1,438	49-81	44-48	26-33
Tracy	5-22.15	9	677-867	49-81	49-95	7-18
Cosumnes	5-22.16	3-10	1,058-1,248	113-143	8-24	44-156

Source: Irrigation Training and Research Center Report No. R11-004 (Burt 2011)

Notes:
ft = feet, gpm = gallons per minute
[a] Averages are weighted by input horsepower and grouped according to a given range of values.
[b] Static water level measured in feet below ground surface.
[c] Drawdown refers to groundwater pumping level drawdown measured in feet below static water level.
[d] Values are estimated from average data reported in Irrigation Training and Research Center study.
[e] *Lower range specific capacity* is the average minimum gpm/average maximum drawdown (ft).
[f] *Upper range specific capacity* is the average maximum gpm/average minimum drawdown (ft).

Land Subsidence and Aquifer Compaction

Land subsidence has serious effects on groundwater supply and development. Land subsidence resulting from aquifer compaction causes serious and costly damage to the gradient and flood capacity of conveyance channels, to water system infrastructure (including wells), and to farming operations. Declining aquifer pressure is thought to be the leading cause of aquifer compaction and land subsidence (Bull and Poland 1975). However, the overall magnitude and extent of land subsidence is typically the result of a combination of factors, such as the amount and rate of artesian head decline and the size and thickness of aquifer sediments (Bull and Poland 1975). As aquifer pressures within the alluvial fan decrease, interbedded layers of sand, silts, and clays become increasingly compressed until, in the case of inelastic subsidence, it results in irreversible compaction of the aquifer, permanent land surface subsidence, and permanent loss of aquifer storage capacity. Additional land subsidence information for the San Joaquin River region is provided in the "Land Subsidence Monitoring," "Aquifer Conditions," and "Land Subsidence" sections of this chapter. An overview of land subsidence is in Appendix F.

Fractured-Rock Aquifers

Fractured-rock aquifers are typically found in the mountain and foothill areas adjacent to the Consumes, Eastern San Joaquin, Modesto, Turlock, Merced, and Madera groundwater basins. With few exceptions, the consolidated sediments in the Coast Ranges are devoid of available groundwater. Fractured-rock aquifers in the hydrologic region are generally associated with igneous and metamorphic rocks in the Sierra Nevada. Groundwater from fractured-rock aquifers in the Sierra Nevada foothills and mountains tend to supply individual domestic and stock wells, or small CWSs. Fractured-rock aquifers tend to have less capacity and reliability than alluvial aquifers. In fractured rock, the ability to transmit and store water decreases rapidly with depth and is small compared with sand aquifers (Swanson 1972).

Crystalline bedrock generally has a porosity value of less than 1 percent, and in an unweathered and unfractured condition, it is considered non-water bearing. With the exception of isolated areas of limestone and marble, the Sierra Nevada aquifers consist of a thin zone of decomposed rock overlying interconnected rock fractures and faults. Rock fractures can be large at the surface, with planar openings of more than 1 or 2 inches. However, rock fracture openings generally diminish at depths ranging from 200 to 600 feet (Davis and Turk 1964). There are notable exceptions, with deep wells (900-1,000 feet) producing yields of more than 100 gpm from fractured rock. Hard-rock wells generally have low yields with a high degree of variability. Davis and Turk (1964) found that in unweathered rock, about 5 to 15 percent of the wells' median yields are less than 8 gpm, and 10 percent will have yields of 50 gpm or more. Crystalline rocks can be brittle to great depths, and open, water-bearing fractures may be present to depths of 1,000 feet or more (Shelton et al. 2010).

Water-bearing fractures are spaced from a few feet to several tens of feet apart. The presence of fractures does not necessarily indicate the potential for water production, as an isolated fracture will rapidly be pumped dry (Snow 1968). Water wells produce higher yields when they penetrate a network of interconnected fractures. Fractures provide limited storage, and recharge depends on proximity to thick decomposed rock zones, meadows, or lakes.

Fault zones in granitic rocks provide a higher degree of rock breakage and number of interconnected fractures. Fault zone fractures may provide better paths for groundwater flow and produce the opportunity for larger well yields (Turk 1963). Groundwater occurrence in faults has also been associated with saline and thermal water of ancient origin. Rock type plays a role in the number and size of the fractures. Granite and schist generally have the largest fractures and produce higher yields than wells in serpentine, phyllite, slate, and gabbro (Davis and Turk 1964).

Because of the highly variable nature of the void spaces within fractured-rock aquifers, wells drawing from fractured-rock aquifers tend to have less capacity and less reliability than wells drawing from alluvial aquifers. On average, wells drawing from fractured-rock aquifers yield less than 10 gpm. Although fractured-rock aquifers are less productive compared with the alluvial aquifers in the region, they are commonly the sole source of water and a critically important water supply for many communities.

Well Infrastructure

A key aspect to understanding the region's groundwater supply and development is identifying the age, distribution, and types of wells that have been completed in the region. A useful source of well information is the well completion reports, or well logs, submitted by licensed well drillers to DWR. Among other things, well logs identify well location, date of completion, and type of well use.

Well drillers have been required by law to submit well logs to the State since 1949. California Water Code Section 13751 requires drillers who construct, alter, abandon, or destroy a well to submit a well log to DWR within 60 days of the completed work. Confidentiality requirements (California Water Code

Section 13752) limit access to the well logs to governmental agencies making studies, to the owner of a well, and to persons performing environmental cleanup studies.

Well logs submitted to DWR for water supply wells completed during 1977 through 2010 were evaluated with respect to their distribution and the uses of groundwater wells in the region. DWR does not have well logs for all of the wells completed in the region, and for some well logs, information regarding well location or use is inaccurate, incomplete, ambiguous, or missing. As a result, some well logs could not be used in the evaluation. For a regional evaluation of well completion and distribution, the quality of the data is considered adequate and informative. Additional information regarding assumptions and methods of reporting well-log information is provided in Appendix A of this report.

The number and distribution of wells in the San Joaquin River region are grouped according to their location by county and according to six most common well-use types: domestic, irrigation, public supply, industrial, monitoring, and other. Wells identified as "other" include the less common types of wells, such as stock wells, test wells, or unidentified wells (meaning no information is listed on the well log).

The number and type of wells listed by county are not necessarily indicative of the number and type of wells within the entire hydrologic region. Well-log data for counties that fall in multiple hydrologic regions were assigned to the hydrologic region containing a majority of alluvial groundwater basins in the region. The well-log data for the San Joaquin River region includes wells from Amador, Calaveras, Contra Costa, San Joaquin, Stanislaus, Merced, Tuolumne, Mariposa, and Madera counties. Table 8-3 lists the number of well logs received by the DWR for wells completed in the San Joaquin River region from 1977 to 2010. Figures 8-3 and 8-4 illustrate the well data by use, for the individual counties in the region and the region as a whole.

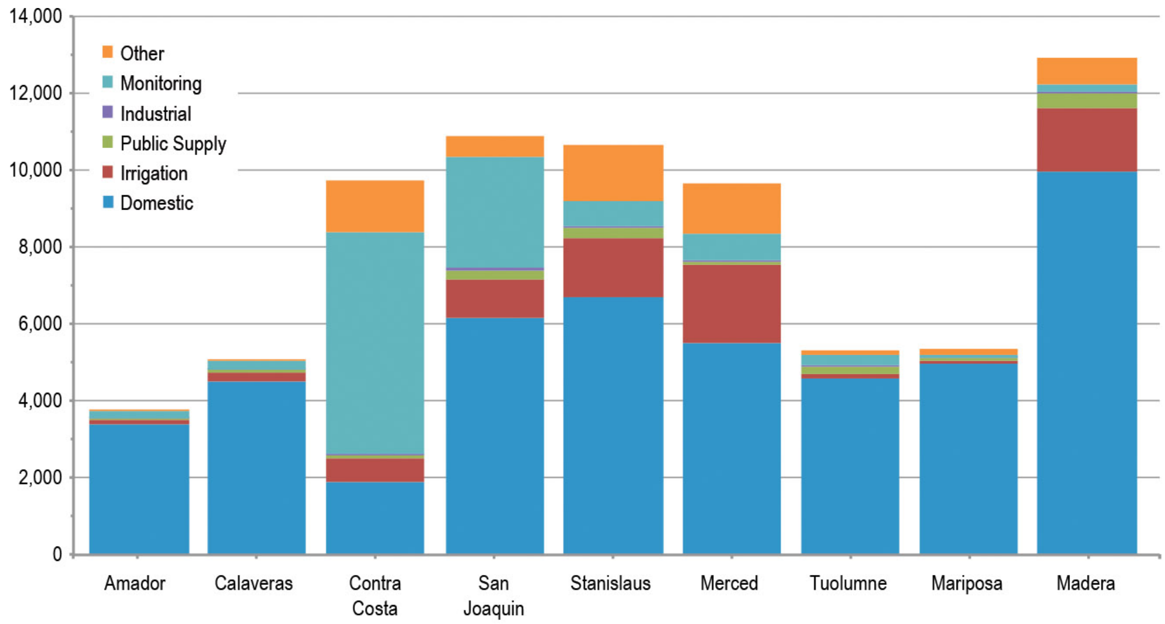
Table 8-3 and Figure 8-3 show that the distribution and number of wells vary widely by county and by use. The total number of wells completed in the San Joaquin River region between 1977 and 2010 is approximately 73,447, and ranges from a high of 12,915 wells for Madera County to a low of 3,767 wells for Amador County. San Joaquin County and Stanislaus County had the second and third highest number of well logs issued at 10,890 and 10,652, respectively. The high number of well logs for these three counties is related in part to the high proportion of the region's population living in the metropolitan areas within each of these counties.

For all but one county in the San Joaquin River region, domestic wells make up the majority of well logs on file at DWR. For Contra Costa County, the number of monitoring well logs (5,773 wells) greatly exceeds the number of domestic well logs (1,911 wells) for the 1977-2010 period. The lower number of domestic versus monitoring well logs in Contra Costa County is most likely the result of a more urban setting with residents mostly reliant on public water systems, coupled with groundwater contamination monitoring as a result of agriculture and industry. While the number of monitoring well logs in San Joaquin County did not outnumber domestic well logs, there were still 2,894 monitoring well logs generated for San Joaquin County during the period 1977-2010, which was the second highest total for the region. For the other counties in the region, the number of monitoring well logs ranged between a low of 76 for Mariposa County up to 718 for Merced County.

Table 8-3 Number of Well Logs, According to County and Type of Use, for the San Joaquin River Hydrologic Region (1977-2010)

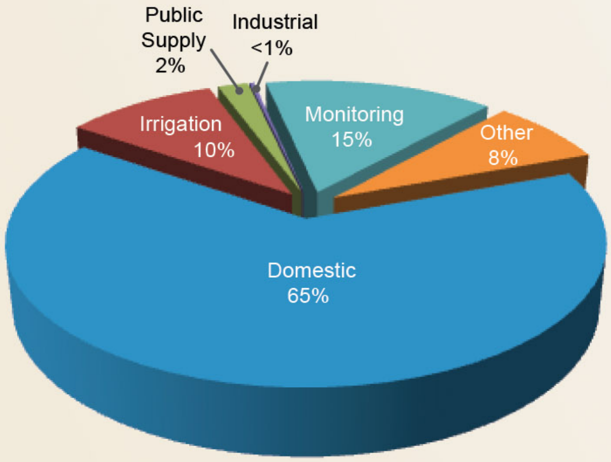
County	Total Number of Well Logs by Well Use						Total Well Records
	Domestic	Irrigation	Public Supply	Industrial	Monitoring	Other	
Amador	3,415	83	40	6	206	17	3,767
Calaveras	4,514	217	79	14	237	37	5,098
Contra Costa	1,911	620	72	22	5,773	1,355	9,753
Madera	9,986	1,630	396	31	210	662	12,915
Mariposa	4,977	74	74	1	76	164	5,366
Merced	5,513	2,032	87	22	718	1,301	9,673
San Joaquin	6,193	980	229	76	2,894	528	10,890
Stanislaus	6,715	1,520	269	39	657	1,452	10,652
Tuolumne	4,575	124	215	14	260	145	5,333
Total Well Records	**47,789**	**7,280**	**1,461**	**225**	**11,031**	**5,661**	**73,447**

Figure 8-3 Number of Well Logs, According to County and Type of Use, for the San Joaquin River Hydrologic Region (1977-2010)



Prepared by California Department of Water Resources for California's Groundwater Update 2013

Figure 8-4 Percentage of Well Logs, According to Type of Use, for the San Joaquin River Hydrologic Region (1977-2010)



San Joaquin River Well Logs Summary by Well Type

Well Type	Number of Well Logs
Domestic	47,789
Irrigation	7,280
Public Supply	1,461
Industrial	225
Monitoring	11,031
Other	5,661
Total	**73,447**

Prepared by California Department of Water Resources for California's Groundwater Update 2013

The three counties with the highest number of irrigation well logs are Merced (2,032 wells), Madera (1,630 wells), and Stanislaus (1,520 wells), which are located in the heart of the agricultural region of the northern San Joaquin Valley. The mountain counties of Amador and Mariposa reported the fewest number of irrigation wells with 83 and 74, respectively.

The pie diagram in Figure 8-4 shows the percentage breakdown of wells, by well use, for the San Joaquin River region between 1977 and 2010. Figure 8-4 shows that domestic, irrigation, and monitoring wells account for 90 percent of all wells installed in the region, with domestic wells comprising approximately 65 percent and irrigation wells accounting for approximately 10 percent of the total number of well logs for the region. Statewide, domestic and irrigation wells account for about 54 percent and 10 percent, respectively, of the total number of wells. The increase in domestic well logs is most likely the result of migration or urban expansion from the San Francisco Bay area into the San Joaquin Valley.

Monitoring wells account for about 15 percent of the total number of wells for the region, which is significantly lower than the statewide average of 24 percent per hydrologic region. About 8 percent of the wells in the region fall into the "other" category.

In addition to analyzing the number of wells by location and use, well logs were analyzed by well installation date (Figure 8-5). Evaluating the number and types of wells completed over time can help offer a perspective on the average age of the existing well infrastructure and the general pattern of wells installed during various hydrologic and economic cycles.

Figure 8-5 shows a cyclic pattern of well installation. Multiple factors are known to affect the annual number and type of wells drilled. Some of these factors include the annual variations in climate, economy, agricultural cropping trends, or alternative water supply availability. New well construction in the San Joaquin River region between 1977 and 2010 ranged from about 1,260 to 3,730 wells per year, with an average of about 2,160 wells per year.

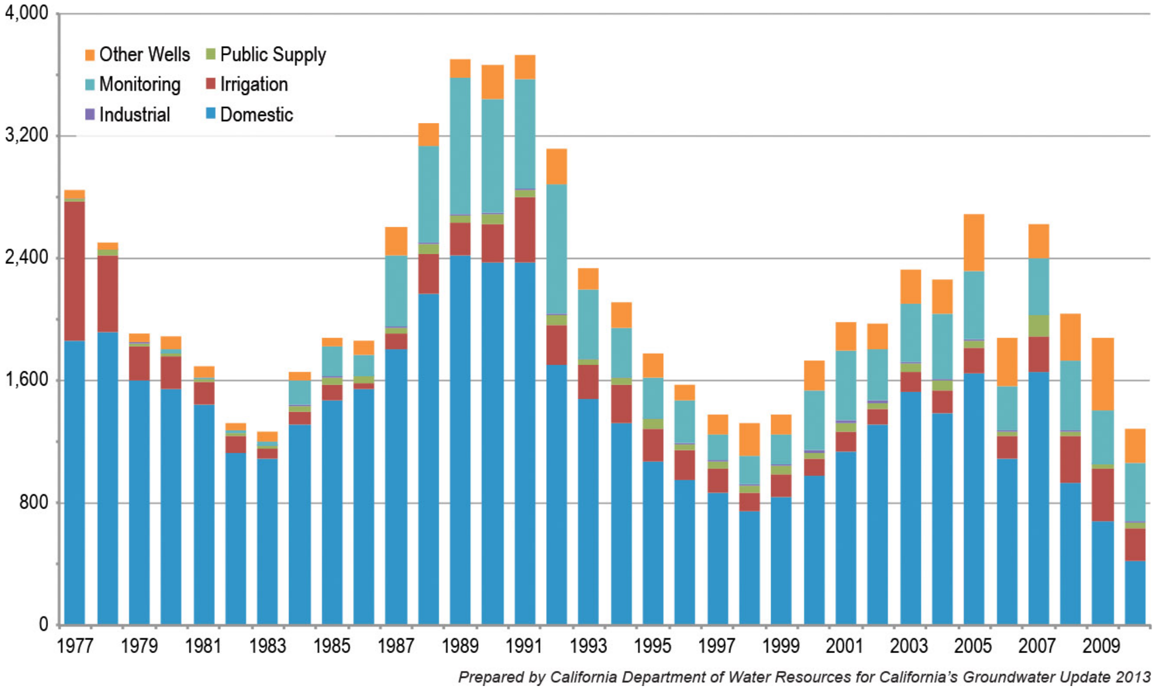
Installation trends for irrigation wells tend to more closely follow changes in annual weather conditions, cropping trends, and availability of alternate agricultural water supplies. Irrigation well installation in the San Joaquin River region peaked at around 900 wells per year following the 1976-1977 drought, and continued at an installation rate ranging between 115 to nearly 500 wells per year through 1982. Irrigation well installation dropped to approximately 44 wells in 1986, which corresponds with the wet years of the mid-1980s, before increasing to an average of 271 wells per year again during the 1989-1994 drought, and increasing further to an average of 330 wells per year during the 2008-2009 drought and related reduction in surface water deliveries. The DWR well-log database does not differentiate between new irrigation wells and the deepening of existing wells; as a result, a portion of irrigation well logs are likely attributed to the deepening of existing irrigation wells because of the increased depth to water in some areas of the San Joaquin River region's groundwater basins. Much of the irrigation well infrastructure installed during the late 1970s and early 1980s is still in use today.

Similar to irrigation well installation, domestic well construction also responds to changes in climatic conditions. Variations in domestic well-drilling activity can also be attributed to the economy and subsequent fluctuations in residential housing construction. The 2001 to 2007 increase in domestic well drilling in the San Joaquin River region is likely a reaction to noted increases in housing construction during this time. Similarly, the 2008 to 2010 decline in domestic well drilling is likely a reaction to the economic downturn and related drop in housing construction. A portion of the lower number of well logs recorded for 2010 could also be attributed to delays in receiving and processing well driller logs. As with irrigation wells, a portion of the new well logs submitted for domestic wells may involve the deepening of existing domestic wells because of declining groundwater levels in the hydrologic region.

Monitoring wells in the San Joaquin River region were first recorded in significant numbers in 1987, with approximately 466 wells installed; the number increased to a high of 887 in 1989. The onset of monitoring well installation in the late 1980s is likely associated with federal underground storage tank programs signed into law in during the 1980s. Starting in 1984, the State of California Underground Storage Tank (UST) program took effect. The program provided partial reimbursement of expenses associated with the cleanup of leaking underground storage tanks and quickly resulted in an increase in the installation of groundwater-quality monitoring wells. Beginning in 1987, changes in California Water Code Section 13751 required well drillers to begin submitting well logs for monitoring well completions. Well logs typically do not distinguish between monitoring wells installed as part of a groundwater cleanup project versus those installed primarily to collect changes in groundwater levels. Information on the well logs supports a conclusion that the majority of monitoring wells are completed for use in environmental assessments related to leaking USTs, waste disposal sites, and hazardous chemical spills.

Since 1984, monitoring well installation in the San Joaquin River region has averaged approximately 420 wells per year. The number of monitoring well records for the San Joaquin River region peaked in 1989 at 887 well logs submitted and then declined to a low of 170 records submitted for the year 1997. Since 1998, the number of monitoring well logs recorded for the hydrologic region has averaged approximately 360 per year. Overall, the total number and average number of monitoring well records for the San Joaquin River region appears to be low, considering the number of remedial action sites designated within the region by the California State Water Resources Control Board (SWRCB) (http://geotracker.waterboards.ca.gov/).

Figure 8-5 Number of Well Logs per Year, According to Use, for the San Joaquin River Hydrologic Region (1977-2010)



CASGEM Basin Prioritization

As part of the California 2009 Comprehensive Water Package legislation (SB X7-6), DWR implemented the CASGEM Program. The SB X7-6 Groundwater Monitoring legislation added Part 2.11 to Division 6 of the California Water Code Section 10920 et seq., which established provisions and requirements for local agencies to develop and conduct groundwater-level monitoring programs. The legislation requires DWR to identify the current extent of groundwater elevation monitoring in each of the alluvial groundwater basins defined under Bulletin 118-2003, and to prioritize those basins to help identify, evaluate, and determine the need for additional groundwater-level monitoring. The basin prioritization process directs DWR to consider, to the extent available, all of the following data components.

1. The population overlying the basin.
2. The rate of current and projected growth of the population overlying the basin.
3. The number of public supply wells that draw from the basin.
4. The total number of wells that draw from the basin.
5. The irrigated acreage overlying the basin.
6. The degree to which persons overlying the basin rely on groundwater as their primary source of water.
7. Any documented impacts on the groundwater within the basin, including overdraft, subsidence, saline intrusion, and other water quality degradation.
8. Any other information determined to be relevant by DWR.

Using groundwater reliance as the leading indicator of basin priority, DWR evaluated the 515 groundwater basins identified in Bulletin 118-2003 and categorized them into four prioritization groups: high, medium, low, and very low.

The CASGEM Basin Prioritization for the San Joaquin River region as of December 2013 is listed in Table 8-4 and shown in Figure 8-4. The final full listing of the CASGEM groundwater basin prioritization is provided in Appendix B. Groundwater extraction for the San Joaquin River region represents approximately 19 percent of the statewide average annual total groundwater usage. CASGEM Basin Prioritization results for the San Joaquin River region indicate that 7 of the 11 basins or subbasins are identified as high priority, with two subbasins identified as medium priority and the remaining two basins listed as very low priority. The nine subbasins designated as high or medium priority include more than 99 percent of the annual groundwater use and more than 99 percent of the 2010 population that overlies the alluvial basins in the region.

Although the primary intent of basin prioritization is to assist DWR in implementing the CASGEM Program, based on the comprehensive set of data included in the analysis, the basin prioritization effort is also a valuable statewide tool to help evaluate, focus, and align limited resources toward the implementation of effective groundwater management practices, as well as improving the statewide reliability and sustainability of groundwater resources. In the San Joaquin River region, implementation of sustainable groundwater resource management should initially be focused on the nine subbasins listed in Table 8-4 as having a medium or high priority.

Groundwater Use

The amount and timing of groundwater extraction, along with the location and type of groundwater use, are fundamental components for developing a groundwater basin budget and identifying effective options for groundwater management. While some types of groundwater uses are reported for some California basins, the majority of groundwater users are not required to monitor, meter, or record their annual groundwater extraction amount. Groundwater use estimates for this report are based on water supply and balance information derived from DWR land use surveys, and from groundwater use information voluntarily provided to DWR by water purveyors or other State agencies.

Groundwater extraction estimates derived from land and water use methods typically assume that local surface water supplies are first used to meet local water demands. Once surface water supplies have been fully allocated, if crop demand and water balance information indicates that additional water supplies are needed, groundwater supplies are then applied until the full water demand is met and the overall supply and demand for the area is balanced. For agricultural areas employing conjunctive management practices, which may involve frequent exchanges between surface water and groundwater supplies, making accurate estimates of annual groundwater extraction by using the land and water use method can be challenging.

Table 8-4 CASGEM Prioritization of Groundwater Basins in the San Joaquin River Hydrologic Region

Basin Priority	Count	Basin/Subbasin Number	Basin Name	Subbasin Name	2010 Census Population
High	1	5-22.05	San Joaquin Valley	Chowchilla	15,820
High	2	5-22.06	San Joaquin Valley	Madera	116,919
High	3	5-22.01	San Joaquin Valley	Eastern San Joaquin	582,662
High	4	5-22.02	San Joaquin Valley	Modesto	294,872
High	5	5-22.07	San Joaquin Valley	Delta-Mendota	107,879
High	6	5-22.04	San Joaquin Valley	Merced	173,731
High	7	5-22.03	San Joaquin Valley	Turlock	197,605
Medium	1	5-22.15	San Joaquin Valley	Tracy	268,175
Medium	2	5-22.16	San Joaquin Valley	Cosumnes	59,163
Low	0	None			
Very Low	1	5-69	Yosemite Valley		1,016
Very Low	2	5-70	Los Banos Creek Valley		0
Total	**11**	**Population of San Joaquin River Groundwater Basin Area:**			**1,817,842**[a]

Notes:

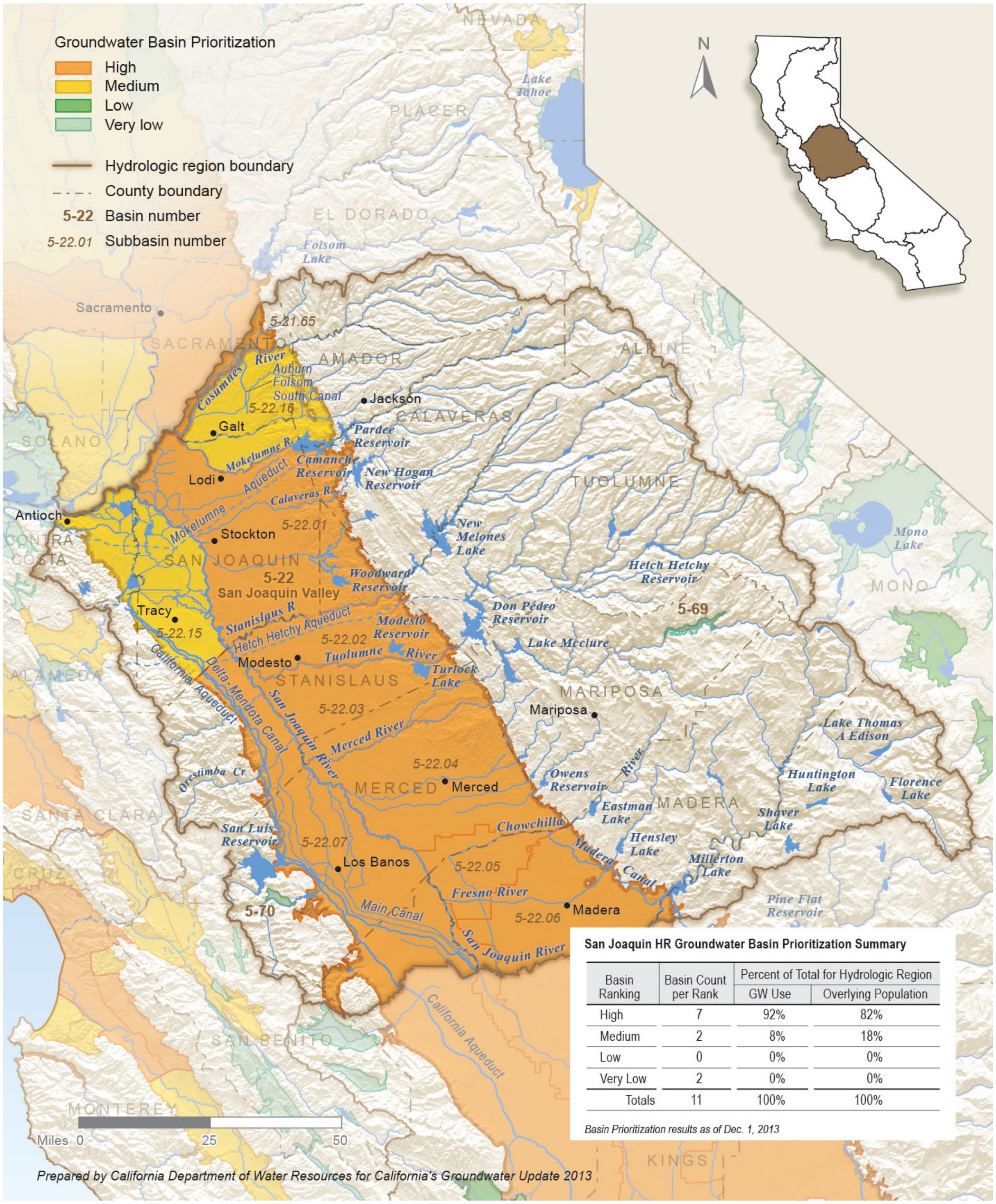
[a] Population of GW Basin Area includes the population of all basins in San Joaquin River Hydrologic Region

Ranking as of December 2013.

Senate Bill X7-6 (SB X7-6; Part 2.11 to Division 6 of the California Water Code Section 10920 et seq.) requires, as part of the California Statewide Groundwater Elevation Monitoring Program, DWR to prioritize groundwater basins to help identify, evaluate, and determine the need for additional groundwater-level monitoring by considering available data that include the population overlying the basin, the rate of current and projected growth of the population overlying the basin, the number of public supply wells that draw from the basin, the total number of wells that draw from the basin, the irrigated acreage overlying the basin, the degree to which persons overlying the basin rely on groundwater as their primary source of water, any documented impacts on the groundwater in the basin, including overdraft, subsidence, saline intrusion, and other water quality degradation, and any other information determined to be relevant by DWR.

Using groundwater reliance as the leading indicator of basin priority, DWR evaluated California's 515 alluvial groundwater basins and categorized them into four groups — high, medium, low, and very low.

Figure 8-6 CASGEM Groundwater Basin Prioritization for the San Joaquin River Hydrologic Region



San Joaquin HR Groundwater Basin Prioritization Summary

Basin Ranking	Basin Count per Rank	Percent of Total for Hydrologic Region: GW Use	Percent of Total for Hydrologic Region: Overlying Population
High	7	92%	82%
Medium	2	8%	18%
Low	0	0%	0%
Very Low	2	0%	0%
Totals	11	100%	100%

Basin Prioritization results as of Dec. 1, 2013

DWR water supply and balance data are collected and analyzed by hydrologic regions, which largely correspond to watershed boundaries. The land and water use data are first compiled and analyzed by detailed analysis units (DAUs). Water supply and balance data for DAUs are then compiled into larger planning areas and then into hydrologic regions, and finally into a statewide water supply and balance estimate. To assist local resource planning, DWR also generates water supply and balance information by county. Although some local groundwater management groups independently develop groundwater extraction estimates for their local groundwater basins, DWR does not currently generate groundwater use information by groundwater basin area.

Water use is reported by water year (October 1st through September 30th), and categorized according to urban, agriculture, and managed wetland uses. Reference to *total water supply* for a region represents the sum of surface water supplies, groundwater supplies, and reused/recycled water supplies. Reused/recycled water supplies also include desalinated water supplies. Groundwater use information is presented by planning area, county, and type of use. Additional information regarding water use analysis is provided in Appendix A, "Methods and Assumptions," and in Appendix C, "Groundwater Use Data."

2005-2010 Average Annual Groundwater Use

Water demands in the San Joaquin River region are met through a combination of local surface water supplies, federal (Central Valley Project [CVP]) and State (State Water Project [SWP]) surface water deliveries, groundwater, and reused/recycled water supplies. The 2005-2010 average annual total water supply for the region is estimated at 8,371 taf.

Local groundwater resources play a significant role in meeting annual water demands for the San Joaquin River region by contributing about 38 percent (3,198 taf) to the total overall supply, with the remaining portion of the water supply provided through the use of surface water, imported water, and recycled water. Groundwater use in the San Joaquin River region accounts for approximately 19 percent of all the groundwater pumping in California — the second highest amount of the hydrologic regions.

The San Joaquin River region includes ten planning areas. Table 8-5 lists the 2005-2010 average annual total water supply met by groundwater, sorted by planning area and type of use. The 2005-2010 precipitation for the region was about 97 percent of the 30-year average. Dry conditions and substantial regulatory cutback of imported surface water between 2007 and 2009 significantly increased the agricultural demand for groundwater during these years. Groundwater use in Table 8-5 is reported in units of taf and by the percentage that groundwater contributes to the total water supply for the region. Table 8-6 identifies the percentage of the San Joaquin River region's annual groundwater supply used in each planning area, and by type of use. Figure 8-7 shows the 2005-2010 average annual groundwater extraction, the average total supply, the distribution of groundwater use by planning area, and helps illustrate the information presented in Table 8-5 and Table 8-6.

Table 8-5 shows that, on average, from 2005-2010, groundwater contributed 38 percent of the total water supply in the San Joaquin River region. Evaluating groundwater supply by type of use indicates that groundwater contributes 36 percent (2,592 taf) toward the total annual agricultural water supply, 58 percent (415 taf) toward the total urban water supply, and 38 percent (191 taf) toward the total managed wetlands supply.

Agricultural groundwater use by planning area shows that the largest groundwater user in the region, Lower Valley East Side Planning Area (PA), relies on about 1,147 taf of groundwater pumping to meet 57 percent of their total agricultural water supply. The annual pumping volume is also high for the Valley West Side PA (555 taf), Eastern Valley Floor PA (427 taf), and Middle Valley East Side PA (330 taf). The annual reliance on groundwater for agricultural purposes was 100 percent for the East Side Uplands PA, and that area pumped approximately 3.1 taf of groundwater. Groundwater status reports from select groundwater management groups overlying some of these areas acknowledge that the average annual groundwater extraction commonly exceeds safe aquifer yield.

Six of the 10 planning areas in the San Joaquin River region rely on groundwater to meet between 69 and 100 percent of their total urban water supply needs, with the West Side Uplands PA, Middle Valley East Side PA, and Lower Valley East Side PA all relying upon groundwater for 100 percent of their urban water needs. The three largest groundwater users for urban purposes (Upper Valley East Side, Lower Valley East Side, and Middle Valley East Side PAs) comprise approximately 66 percent of all urban groundwater extraction in the region. The West Side Uplands PA uses the least amount of groundwater, but as noted above, is completely reliant on groundwater to meet its urban water needs.

Managed wetlands use approximately 6 percent of the region’s 2005-2010 average annual total groundwater supply, and groundwater sources supply about 38 percent of the total water used for managed wetlands (191 taf), with the rest coming from other sources, including surface water. The Valley West Side PA accounts for 93 percent (178 taf) of the managed wetlands groundwater use in the region, while six planning areas in the region do not use any groundwater for managed wetlands purposes.

A percentage breakdown of groundwater use by planning area and by type of use for the San Joaquin River region is shown in Table 8-6. Groundwater use information in Table 8-6 shows that approximately 81 percent of the groundwater extracted from the San Joaquin River region is for agricultural purposes. The two largest groundwater-using planning areas, Lower Valley East Side PA and Eastern Valley Floor PA, respectively, apply about 92 percent and 89 percent of their total groundwater extraction toward agricultural purposes. Groundwater for urban use accounts for approximately 13 percent of the region’s average annual groundwater extraction, with 5 of the 10 PAs (Upper West Side Uplands, San Joaquin Delta, West Side Uplands, Sierra Foothills, and East Side Uplands) in the San Joaquin River region relying more on groundwater for urban versus agricultural needs. Nine out of 10 of the PAs in the region apply 1 percent or less of the total groundwater extraction toward managed wetlands use.

Table 8-5 Average Annual Total Water Supply Met by Groundwater, According to Planning Area and Type of Use, for the San Joaquin River Hydrologic Region (2005-2010)

San Joaquin River Hydrologic Region		Agriculture Use Met by Groundwater		Urban Use Met by Groundwater		Managed Wetlands Use Met by Groundwater		Total Water Use[a] Met by Groundwater	
PA Number	PA Name	taf	%[b]	taf	%[b]	taf	%[b]	taf	%[b]
601	Upper West Side Uplands	5.4	17%	7.4	10%	0.0	0%	12.8	12%
602	San Joaquin Delta	0.8	0%	37.8	35%	0.0	0%	38.6	4%
603	Eastern Valley Floor	427.2	58%	51.7	44%	0.1	17%	479.1	56%
604	Sierra Foothills	1.7	8%	2.6	6%	0.0	0%	4.3	6%
605	West side Uplands	0.0	0%	0.2	100%	0.0	0%	0.2	100
606	Valley West Side	554.7	34%	27.8	88%	178.1	41%	760.6	36%
607	Upper Valley East Side	121.9	13%	102.9	69%	1.4	13%	226.3	21%
608	Middle Valley East Side	330.3	32%	74.9	100%	0.0	0%	405.2	37%
609	Lower Valley East Side	1,146.7	57%	95.4	100%	11.1	25%	1,253.1	58%
610	East Side Uplands	3.1	100%	15.3	97%	0.0	0%	18.4	98%
2005-2010 Annual Average HR Total		**2,591.8**	**36%**	**414.9**	**58%**	**190.7**	**38%**	**3,198.4**	**38%**

Notes:

HR = hydrologic region, PA = planning area, taf = thousand acre-feet

[a] Total water use = groundwater + surface water + reuse

[b] Percent use is the percent of the total water supply met by groundwater, by type of use.

2005-10 precipitation equals 97 percent of the 30-year average for the San Joaquin River Region.

Figure 8-7 Groundwater Use and Total Water Supply Met by Groundwater, According to Planning Area, for the San Joaquin River Hydrologic Region (2005-2010)

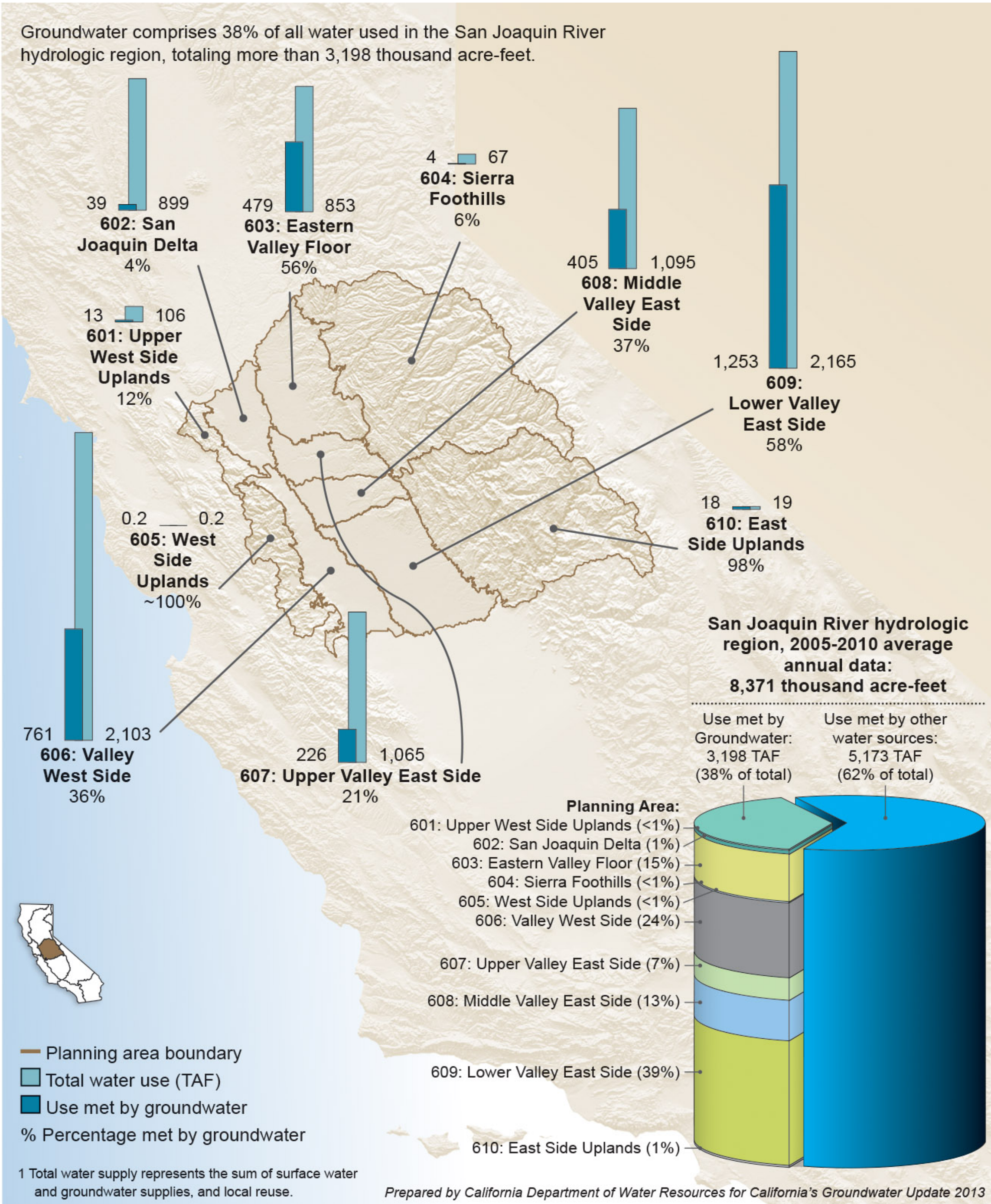


Table 8-6 Average Annual Total Water Supply Met by Groundwater, According to Planning Area and Type of Use, for the San Joaquin River Hydrologic Region (2005-2010)

San Joaquin River Hydrologic Region		Agriculture Use of Groundwater	Urban Use of Groundwater	Managed Wetlands Use of Groundwater	Groundwater Use by PA
PA Number	**PA Name**	**%[a]**	**%[a]**	**%[a]**	**%[b]**
601	Upper West Side Uplands	42%	58%	0%	<1%
602	San Joaquin Delta	2%	98%	0%	1%
603	Eastern Valley Floor	89%	11%	0%	15%
604	Sierra Foothills	39%	61%	0%	<1%
605	West Side Uplands	0%	100%	0%	0%
606	Valley West Side	73%	4%	23%	24%
607	Upper Valley East Side	54%	45%	1%	7%
608	Middle Valley East Side	82%	18%	0%	13%
609	Lower Valley East Side	92%	8%	1%	39%
610	East Side Uplands	17%	83%	0%	<1%
2005-2010 Annual Average HR Total		**81%**	**13%**	**6%**	**100%**

Notes:
HR = hydrologic region, PA = planning area
[a] Percent use is average annual groundwater use by planning area and type of use, compared to the total groundwater use for the hydrologic region.
[b] Percentage of hydrologic region total groundwater use.

Groundwater supply and use was also calculated by county. The counties included in the analysis for the San Joaquin River region are Amador, Calaveras, Contra Costa, Madera, Mariposa, Merced, San Joaquin, Stanislaus, and Tuolumne. There are other counties partially in the region; however, they are included in other regional groundwater reports. County boundaries do not align with planning area or hydrologic region boundaries, so groundwater use based on county areas will vary from estimates using planning area boundaries, as shown in Table 8-5. Tables showing groundwater use for all 58 California counties are provided in Appendix C.

Table 8-7 lists the 2005-2010 average annual total water supply met by groundwater, sorted by county and by type of use, for the nine counties included in the San Joaquin River region. The table shows that groundwater contributes less than 1 percent toward Mariposa County's total water needs and approximately 68 percent of Madera County's total water needs. Overall, the nine counties in the San Joaquin River region rely on groundwater to meet 37 percent of their total water supply. Based on county boundaries, groundwater contributes 35 percent (2,313 taf) toward the region's total agricultural water needs and 49 percent (404 taf) toward the region's total urban water needs. However, as noted on Table 8-7, of the 2,908 taf of total groundwater use by counties in the San Joaquin River region, 2,313 taf of groundwater (80 percent) are used for agricultural purposes.

Table 8-7 Average Annual Total Water Supply Met by Groundwater, According to County and Type of Use, for the San Joaquin River Hydrologic Region (2005-2010)

San Joaquin River Hydrologic Region	Agriculture Use Met by Groundwater		Urban Use Met by Groundwater		Managed Wetlands Use Met by Groundwater		Total Water Use Met by Groundwater	
County	**taf**	**%[a]**	**taf**	**%[a]**	**taf**	**%[a]**	**taf**	**%[a]**
Amador	3.5	23%	1.6	15%	0.0	0%	5.1	20%
Calaveras	1.3	16%	1.6	13%	0.0	0%	2.8	14%
Contra Costa	0.8	1%	24.9	9%	0.0	0%	25.7	6%
Madera	673.1	66%	40.7	100%	0.0	0%	713.7	68%
Mariposa	3.1	0%	4.6	1%	0.0	0%	7.7	0%
Merced	764.6	38%	84.6	97%	189.2	39%	1,038.3	40%
San Joaquin	354.1	22%	81.8	44%	0.0	0%	435.8	25%
Stanislaus	512.4	29%	162.8	85%	1.4	13%	676.6	35%
Tuolumne	0.4	7%	1.3	10%	0.0	0%	1.7	9%
2005-2010 Annual Average Total	**2,313.2**	**35%**	**403.7**	**49%**	**190.6**	**39%**	**2,907.5**	**37%**

Notes:
taf = thousand acre-feet
[a] Percent use is the percent of the total water supply met by groundwater, by type of use.
2005-2010 precipitation equals 97 percent of the 30-year average for the San Joaquin River Hydrologic Region.

Change in Annual Groundwater Use

Changes in annual amount and type of groundwater use may be related to a number of factors, such as changes in surface water availability, urban and agricultural growth, economic fluctuations, and water use efficiency practices. Recent agricultural cropping trends for the San Joaquin River region show a significant shift away from annual crops using surface water, toward high-value permanent crops reliant on groundwater. The trends toward increased permanent crop planting versus annual crop planting, leads to a hardening of the annual demand for groundwater, regardless of the water year type. Additional information regarding annual agricultural production trends by county may be found online at the United States Department of Agricultural (USDA), California agricultural statistics Web site (http://www.nass.usda.gov/Statistics_by_State/California/Publications/California_Ag_Statistics/Reports/index.asp).

Figure 8-8 illustrates the 2002 through 2010 total water supply trend for the San Joaquin River region. The right side of Figure 8-8 illustrates the total water supply volume by type (groundwater, surface water, and reused/recycled water), while the left side shows the percentage of the overall water supply met by those sources of water. The center column identifies the water year along with the corresponding amount of precipitation, shown as a percentage of the previous 30-year average for the hydrologic region.

Between 2002 and 2010, the total annual water supply for the San Joaquin River region fluctuated based on annual precipitation amounts (Figure 8-8). The total water supply during the 9-year period averages about 8,306 taf with a change of about 10 percent — between a low of 7,470 taf in 2005 to a high of 9,088 taf in 2008. For the years where rainfall exceeded 100 percent of the average (2005, 2006, and

2010), the total annual water supply was below 8,000 taf and was mostly met by a reduction in groundwater pumping, while the surface water supply in the same time frame remained relatively stable.

Groundwater extraction during the 2002-2010 period averaged about 3,100 taf. During the wet water years of 2005 and 2006, groundwater extraction was 2,351 taf and 2,815 taf, respectively. Conversely, during the dry years of 2008 and 2009, groundwater extraction in the San Joaquin River region increased to 3,864 taf and 3,848 taf, a nearly 20-percent increase over the average. Since groundwater contributes 36 percent toward the average annual total water supply for agriculture in the region, small reductions in precipitation from normal levels can result in large increases in groundwater pumping to offset the difference. The percentage of groundwater use change and its relationship to precipitation becomes more complex as a dry period extends to multiple years, compounded with land use changes that affect the amount of groundwater use during dry years.

The use of reuse or recycled water in the San Joaquin River region ranged from a low of 28 taf in 2002 to a high of 1,001 taf in 2004. Between 2002 and 2010, reuse water contributed as much as 12 percent of the San Joaquin River region's total water supply.

Figure 8-9 shows the 2002-2010 annual percentages and volumes of groundwater supply extracted to meet urban, agricultural, and managed wetland uses in the San Joaquin River region. The right side of Figure 8-9 illustrates the annual volume of groundwater extraction by type of use, while the left side shows the distribution percentage of San Joaquin groundwater extraction by type of use.

The percentage of groundwater extraction from the San Joaquin River region used to meet agricultural water needs ranged from a low of 72 percent in 2005 to a high of 84 percent in 2008 and 2009. Figure 8-9 also illustrates how, in areas of high water demand, small changes in the percentage of groundwater demand can result in large changes to the volume of groundwater extraction. For example, between 2005 and 2009, the contribution of groundwater toward the overall agricultural water supply increased from 72 to 84 percent. The 8 percentage point increase in groundwater used to meet the region's agricultural needs resulted in a nearly 95 percent increase of the amount of groundwater extraction; approximately 1,689 taf of groundwater was pumped for agricultural needs in 2005, while in 2009 an estimated 3,248 taf of groundwater was extracted for agricultural purposes. Groundwater extraction for agricultural purposes was estimated to have decreased to about 2,120 taf in 2010, as a result of higher precipitation in the region.

Groundwater pumping to meet urban water needs was generally stable during the nine-year period and ranged between 388 taf in 2010 and 475 taf in 2005, which met between 10 percent and 20 percent of the total urban water supply. Compared with agricultural needs, the application of groundwater supplies for managed wetland use is fairly minor. Use of groundwater for managed wetland purposes ranged from 136 taf in 2004 to 209 taf in 2002, which met between 4 and 8 percent of the total managed wetland water supply for the San Joaquin River region.

Figure 8-8 Annual Surface Water and Groundwater Supply Trend for the San Joaquin River Hydrologic Region (2002-2010)

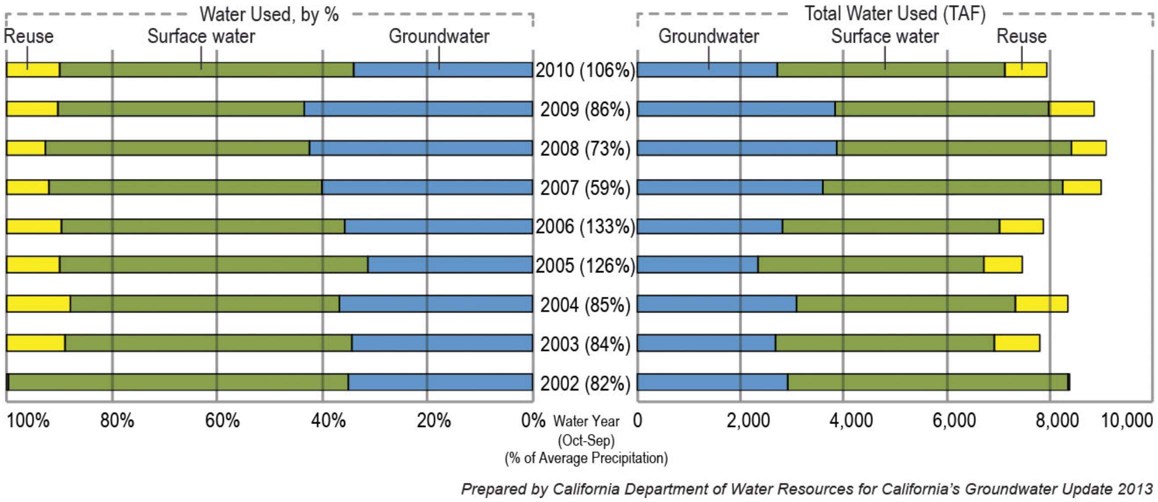
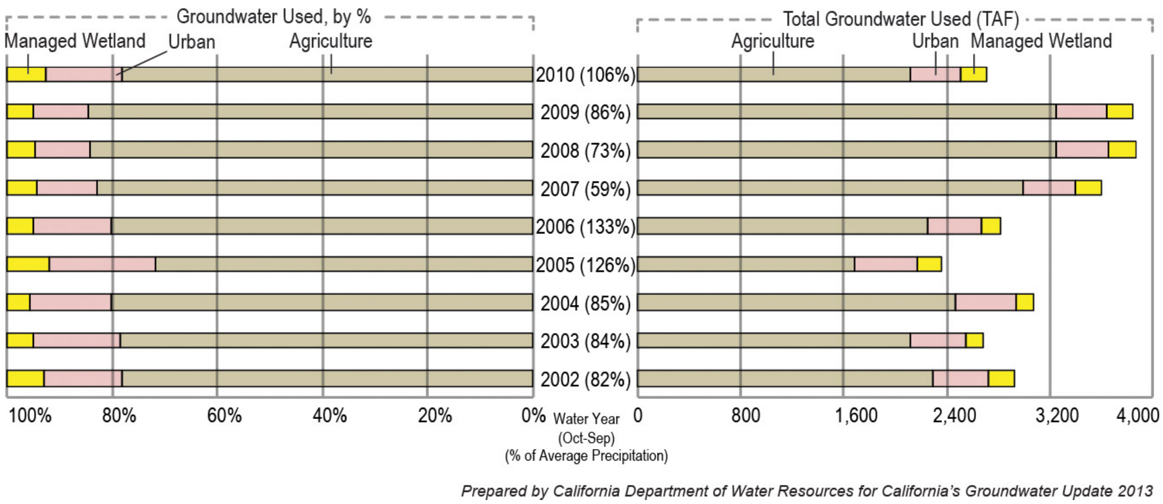


Figure 8-9 Annual Groundwater Supply Trend, According to Type of Use, for the San Joaquin River Hydrologic Region (2002-2010)



Groundwater Monitoring Efforts

Groundwater resource monitoring and evaluation is essential to understanding groundwater conditions, identifying effective resource management strategies, and implementing sustainable resource management practices. California Water Code Section10753.7 requires local agencies seeking state funds administered by DWR to prepare and implement GWMPs that include monitoring of groundwater levels, groundwater quality degradation, inelastic land subsidence, and changes in surface water flow and quality that directly affect groundwater levels or quality. The protocols associated with groundwater monitoring can vary greatly depending on the local conditions; but overall, monitoring protocols should be designed to generate information that promotes efficient and effective groundwater management.

This section summarizes some of the groundwater level, groundwater quality, and land subsidence monitoring activities in the San Joaquin River region. The summary includes publically available groundwater data compiled by DWR, SWRCB, California Department of Public Health (CDPH), and the U. S. Geological Survey (USGS). Information regarding the groundwater monitoring methods, assumptions, and data availability is provided in Appendix A.

Groundwater-Level Monitoring

State and federal agencies with groundwater-level monitoring programs in the region include DWR, U.S. Bureau of Reclamation (USBR), and the USGS. Groundwater-level monitoring is also performed by CASGEM-designated monitoring entities, as well as local cooperators that measure or contract others to measure groundwater levels. Groundwater-level information presented in this section is publically available through DWR or USGS online information systems. Privately collected and locally maintained groundwater-level information is not discussed in this section. Furthermore, the groundwater-level information in this section just includes active monitoring wells — those wells that have been measured since January 1, 2010, and monitoring groups that have entered data into the CASGEM or USGS online databases as of July 2012. Monitoring programs are frequently adjusted to meet changing demands and management actions. Consequently, groundwater-level information presented for the San Joaquin River region may not represent the most current information available. Updated groundwater-level information may be obtained online from the DWR CASGEM Program Web site (http://www.water.ca.gov/groundwater/casgem/), and through the USGS National Water Information System (http://waterdata.usgs.gov/nwis).

The San Joaquin River region has the third largest number of groundwater-level monitoring wells in all of the 10 hydrologic regions. A list of the number of monitoring wells by monitoring agencies, cooperators, and CASGEM-designated monitoring entities is provided in Table 8-8. The location of monitoring wells in the San Joaquin River region, sorted by monitoring entity and monitoring well type, is shown in Figure 8-10.

Table 8-8 shows that 1,532 wells in the San Joaquin River region have been actively monitored for groundwater levels. Federal and State agencies monitor 382 wells in eight subbasins and non-basin areas. Specifically, the USGS monitoring network consists of 38 wells in three subbasins, USBR monitors 227 wells in four subbasins and non-basin areas, and DWR monitors 117 wells in five subbasins and non-basin areas. The largest portion of the groundwater-level monitoring, consisting of 1,150 wells located throughout nine subbasins and non-basin areas, is performed by 11 cooperators and six CASGEM monitoring entities. The 428 groundwater-level monitoring wells measured by the CASGEM monitoring entities are located in seven of the nine subbasins identified as having a high to medium priority under the CASGEM basin prioritization. The two subbasins not monitored by a designated CASGEM monitoring entity are the Modesto and Turlock subbasins, both high-priority subbasins.

As part of the CASGEM basin-prioritization process, seven high-priority and two medium-priority subbasins were identified for the San Joaquin River region. A list of the high- and medium-priority basins for the San Joaquin River region, along with a breakdown of the number of groundwater-level monitoring wells, is provided in Table 8-9 and includes those wells that were entered into the CASGEM system as of July 2012. Table 8-9 shows that 1,518 wells are being monitored within the nine high- and medium-priority basins. The groundwater monitoring in these basins is being performed by federal and State agencies, cooperators, and designated CASGEM monitoring entities.

Table 8-8 Groundwater-Level Monitoring Wells, According to Monitoring Entity, for the San Joaquin River Hydrologic Region

State and Federal Agencies	Number of Wells
California Department of Water Resources	117
U.S. Geological Survey	38
U.S. Bureau of Reclamation	227
Total State and Federal Wells	**382**
Monitoring Cooperators	**Number of Wells**
Central California Irrigation District	41
Chowchilla Water District	147
Fresno Irrigation District	1
James Irrigation District	5
Madera Irrigation District	189
Merced Irrigation District	146
Modesto Irrigation District	87
City of Modesto	74
Sacramento County	3
San Joaquin County	8
San Luis Canal Company	21
Total Cooperator Wells	**722**
CASGEM Monitoring Entities	**Number of Wells**
Diablo Water District	20
Madera-Chowchilla Basin Regional Monitoring Group[a]	26
Merced Area Groundwater Pool Interests[a]	34
San Joaquin County Flood Control and Water Conservation District[a]	257
San Luis and Delta Mendota Water Authority[a]	85
Westlands Water District	6
Total CASGEM Entity Wells	**428**
Total Hydrologic Region Monitoring Wells	**1,532**

Notes:
CASGEM = California Statewide Groundwater Elevation Monitoring Program
[a] Designation as CASGEM monitoring entity pending.
Table represents monitoring information as of July 2012.
Table includes groundwater-level monitoring wells having publically available online data.

Table 8-9 Groundwater-Level Monitoring Wells within the CASGEM High- and Medium-Priority Basins for the San Joaquin River Hydrologic Region

Basin/Subbasin Number	Basin Name	Subbasin Name	Basin Priority	Number of Groundwater Level Monitoring Wells [a, b]
5-22.01	San Joaquin Valley	Eastern San Joaquin	High	293
5-22.02	San Joaquin Valley	Modesto	High	192
5-22.03	San Joaquin Valley	Turlock	High	11
5-22.04	San Joaquin Valley	Merced	High	208
5-22.05	San Joaquin Valley	Chowchilla	High	166
5-22.06	San Joaquin Valley	Madera	High	306
5-22.07	San Joaquin Valley	Delta-Mendota	High	269
5-22.15	San Joaquin Valley	Tracy	Medium	30
5-22.16	San Joaquin Valley	Cosumnes	Medium	43

Notes:

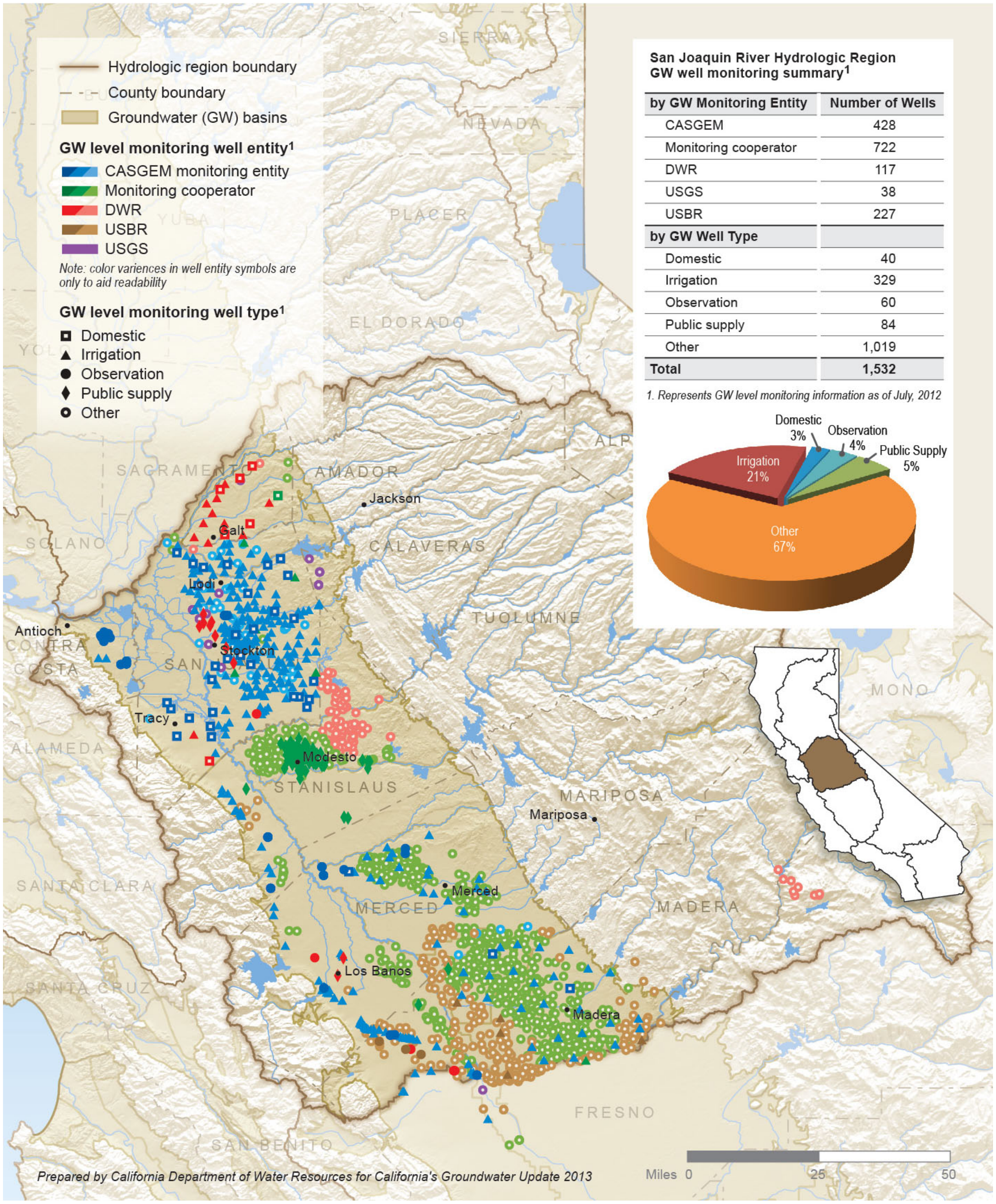
[a] Includes monitoring wells entered into the California Statewide Groundwater Elevation Monitoring Program or U.S. Geological Survey online databases as of July 2012.

[b] Total of 1,518 wells monitored as of July 2012.

Most of the groundwater-level monitoring networks include a variety of well-use types. The groundwater-level monitoring wells are categorized by the type of well, and these categories include irrigation, domestic, observation, public supply, and other. Groundwater-level monitoring wells identified as “other” include a combination of the less common well types, such as stock wells, test wells, industrial wells, or unidentified wells (no information listed on the well log). Wells listed as “observation” also include those wells described by drillers in the well logs as “monitoring” wells. Some of the domestic and irrigation wells used for groundwater-level monitoring include actively operating wells and some consist of older inactive or unused wells.

In the southern portion and along the eastern edge of the San Joaquin River region, well depths tend to be deeper than in other hydrologic regions. Declining groundwater levels, poor quality shallow aquifers, and highly productive, more deeply confined aquifer zones all contribute to the need for deeper well construction in the San Joaquin River region. However, in general, domestic wells tend to be relatively shallower and screened in the upper portion of the aquifer system, while irrigation wells tend to be constructed deeper in the aquifer system. Consequently, groundwater-level data collected from domestic wells typically represent shallow aquifer conditions, while groundwater-level data from irrigation wells represent middle-to-deep aquifer conditions. Some observation wells are constructed as a nested or clustered set of dedicated monitoring wells, designed to characterize groundwater conditions at specific and discrete intervals in the aquifer system.

Figure 8-10 Monitoring Well Location by Agency, Monitoring Cooperator, and CASGEM Monitoring Entity for the San Joaquin River Hydrologic Region



San Joaquin River Hydrologic Region
GW well monitoring summary[1]

by GW Monitoring Entity	Number of Wells
CASGEM	428
Monitoring cooperator	722
DWR	117
USGS	38
USBR	227
by GW Well Type	
Domestic	40
Irrigation	329
Observation	60
Public supply	84
Other	1,019
Total	**1,532**

1. Represents GW level monitoring information as of July, 2012

Figure 8-10 includes a table listing the number of San Joaquin River region groundwater-level monitoring wells by groundwater monitoring entity and well use. Groundwater-level monitoring information indicates that wells identified by use as "other" account for more than 67 percent of the groundwater-level monitoring wells in the region. Monitoring wells are distributed throughout the region with dense clusters in the Merced to Madera area and the Modesto to Lodi area. Irrigation and public supply wells comprise 21 percent and 5 percent, respectively, of the monitoring wells, while domestic wells account for 3 percent.

Groundwater Quality Monitoring

Groundwater quality monitoring is an important aspect of effective groundwater basin management and is one of the required groundwater management planning components enabling local agencies to be eligible for State funds administered by DWR. Numerous State, federal, and local agencies participate in groundwater-quality monitoring activities throughout California. A number of the existing groundwater quality-monitoring activities were initiated as part of the Groundwater Quality Monitoring Act of 2001, which implemented goals to improve and increase the statewide availability of groundwater quality data. A comprehensive presentation of the San Joaquin River region's groundwater-quality monitoring activities is beyond the scope of this chapter. A summary of the statewide and regional groundwater-quality monitoring activities and information is provided below.

Regional and statewide groundwater-quality monitoring information and data are available on the SWRCB Groundwater Ambient Monitoring and Assessment (GAMA) Web site (http://www.waterboards.ca.gov/gama/geotracker_gama.shtml), the GeoTracker GAMA groundwater information system developed as part of the Groundwater Quality Monitoring Act of 2001, and DWR's Water Data Library (http://www.water.ca.gov/waterdatalibrary/). The GAMA Web site describes the GAMA program and provides links to all published GAMA and related reports. The GeoTracker GAMA groundwater information system geographically displays information and includes analytical tools and reporting features to assess groundwater. This groundwater information system currently includes groundwater data from the SWRCB, regional water quality control boards (RWQCBs), CDPH, California Department of Pesticide Regulation (DPR), USGS, and Lawrence Livermore National Laboratory (LLNL). In addition to groundwater quality data, GeoTracker GAMA has oil and gas hydraulically fractured well information from the California Division of Oil, Gas, and Geothermal Resources. Groundwater quality data at DWR's Water Data Library includes primarily baseline minerals, metals, and nutrient data associated with regional monitoring.

Table 8-10 lists agency-specific groundwater quality information. Additional information regarding assessment and reporting of groundwater quality information is listed in the "Aquifer Conditions" section of this chapter.

Table 8-10 Sources of Groundwater Quality Information for the San Joaquin River Hydrologic Region

Agency	Links to Information
State Water Resources Control Board http://www.waterboards.ca.gov/	**Groundwater** http://www.waterboards.ca.gov/water_issues/programs/#groundwater) • Communities that Rely on a Contaminated Groundwater Source for Drinking Water http://www.waterboards.ca.gov/water_issues/programs/gama/ab2222/index.shtml • Hydrogeologically Vulnerable Areas http://www.waterboards.ca.gov/gama/docs/hva_map_table.pdf • Aquifer Storage and Recovery http://www.waterboards.ca.gov/water_issues/programs/asr/index.shtml • Central Valley Salinity Alternatives for Long-Term Sustainability (CV-Salts) http://www.waterboards.ca.gov/centralvalley/water_issues/salinity/ **Groundwater Ambient Monitoring and Assessment (GAMA) Program** http://www.waterboards.ca.gov/gama/index.shtml • GeoTracker GAMA (Monitoring Data) http://www.waterboards.ca.gov/gama/geotracker_gama.shtml • Domestic Well Project http://www.waterboards.ca.gov/gama/domestic_well.shtml • Priority Basin Project http://www.waterboards.ca.gov/water_issues/programs/gama/sw_basin_assesmt.shtml • Special Studies Project http://www.waterboards.ca.gov/water_issues/programs/gama/special_studies.shtml • California Aquifer Susceptibility Project http://www.waterboards.ca.gov/water_issues/programs/gama/cas.shtml **Contaminant Sites** • Land Disposal Program http://www.waterboards.ca.gov/water_issues/programs/land_disposal/ • Department of Defense Program http://www.waterboards.ca.gov/water_issues/programs/dept_of_defense/ • Underground Storage Tank Program http://www.waterboards.ca.gov/ust/index.shtml • Brownfields http://www.waterboards.ca.gov/water_issues/programs/brownfields/
California Department of Public Health http://www.cdph.ca.gov/Pages/DEFAULT.aspx	**Division of Drinking Water and Environmental Management** http://www.cdph.ca.gov/programs/Pages/DDWEM.aspx • Drinking Water Source Assessment and Protection (DWSAP) Program http://www.waterboards.ca.gov/drinking_water/certlic/drinkingwater/DWSAP.shtml • Chemicals and Contaminants in Drinking Water http://www.waterboards.ca.gov/drinking_water/certlic/drinkingwater/Chemicalcontaminants.shtml • Chromium-6 http://www.waterboards.ca.gov/drinking_water/certlic/drinkingwater/Chromium6.shtml • Groundwater Replenishment with Recycled Water http://www.waterboards.ca.gov/drinking_water/certlic/drinkingwater/RecycledWater.shtml

Agency	Links to Information
California Department of Water Resources http://www.water.ca.gov/	Groundwater Information Center http://www.water.ca.gov/groundwater/index.cfm • Bulletin 118-2003 Groundwater Basins http://www.water.ca.gov/groundwater/bulletin118/gwbasins.cfm • California Statewide Groundwater Elevation Monitoring (CASGEM) http://www.water.ca.gov/groundwater/casgem/ • Groundwater-Level-Monitoring http://www.water.ca.gov/groundwater/data_and_monitoring/gw_level_monitoring.cfm Groundwater Quality Monitoring http://www.water.ca.gov/groundwater/data_and_monitoring/gw_quality_monitoring.cfm • Well Construction Standards http://www.water.ca.gov/groundwater/wells/standards.cfm • Well Completion Reports http://www.water.ca.gov/groundwater/wells/well_completion_reports.cfm
California Department of Toxic Substance Control http://www.dtsc.ca.gov/	EnviroStor http://www.envirostor.dtsc.ca.gov/public/
California Department of Pesticide Regulation http://www.cdpr.ca.gov/	Groundwater Protection Program http://www.cdpr.ca.gov/docs/emon/grndwtr/index.htm • Well Sampling Database http://www.cdpr.ca.gov/docs/emon/grndwtr/gwp_sampling.htm • Groundwater Protection Area Maps http://www.cdpr.ca.gov/docs/emon/grndwtr/gwpa_maps.htm
U.S. Environmental Protection Agency http://www.epa.gov/safewater/	U.S. Environmental Protection Agency STORET Environmental Data System http://www.epa.gov/storet/
U.S. Geological Survey http://ca.water.usgs.gov/	U.S. Geological Survey Water Data for the Nation http://waterdata.usgs.gov/nwis

Land Subsidence Monitoring

Land subsidence has been shown to occur in areas experiencing a significant decline in groundwater levels. When groundwater is extracted from aquifers in sufficient quantity, the groundwater level is lowered and the water pressure, which supports the sediment grains structure, decreases. A decrease in water pressure causes more weight from the overlying sediments to be supported by the sediment grains in the aquifer. In unconsolidated deposits, the increased weight from overlying sediments may compact the fine-grained sediments and permanently decrease the porosity of the aquifer and the ability of the aquifer to store water. The partial collapse of the aquifer results in the subsidence of the land surface overlying the aquifer. *Elastic land subsidence* is the reversible and temporary fluctuation of Earth's surface in response to seasonal periods of groundwater extraction and recharge. *Inelastic land subsidence* is the irreversible and permanent decline in the earth's surface resulting from the collapse or compaction of the pore structure within the fine-grained portions of an aquifer system. (U.S. Geological Survey 1999) (http://pubs.usgs.gov/circ/circ1182/).

Land subsidence investigations in the southern San Joaquin Valley and San Joaquin River region consist of a variety of monitoring efforts. Some of these monitoring efforts include elevation surveys along the

California Aqueduct, borehole extensometer monitoring, satellite remote sensing studies using InSAR, continuous and conventional GPS measurements, and spirit-leveling surveying (USGS California Water Science Center, http://ca.water.usgs.gov/projects/central-valley/land-subsidence-monitoring-network.html). In addition, monitoring of ground surface elevation associated with non-land subsidence studies, such as periodic highway elevation surveys, can also result in data useful for monitoring land subsidence. A summary of these land subsidence monitoring activities is provided below. An overview of the results and findings associated with these land subsidence monitoring activities is provided under the "Aquifer Conditions" section of this chapter. Additional information regarding land subsidence in California is provided in Appendix F.

California Aqueduct Elevation Surveys

DWR performs periodic elevation surveys along the California Aqueduct to measure land subsidence effects along the canal and guide maintenance repairs as needed. Previous surveys were summarized by the USGS (Ireland 1986), including eight elevation profiles along the canal for 1966, 1968, 1971, 1972, 1975, 1977, 1978, and 1981. DWR surveys compare elevations along portions of the aqueduct in Fresno and Kings County for years 2000, 2006, and 2009. The results of the DWR aqueduct elevation monitoring are provided in the "Aquifer Conditions" section of this chapter.

Borehole Extensometer Monitoring

A borehole extensometer is designed to act as a benchmark anchored to a geologically stable portion of the lower aquifer. They are typically drilled and constructed using slip-joints to connect the borehole casing at periodic intervals. The slip-joints allow for vertical movement of the aquifer without collapse or damage to the extensometer casing. A concrete plug is placed in the bottom of the casing to serve as a stable benchmark. Steel pipe is then installed inside the extensometer casing and connected with a counterweight at the surface to limit compression of the pipe and allow it to carefully rest on the concrete plug, or benchmark. The steel pipe serves to transfer elevation readings from lower aquifer benchmark to the surface, where instrumentation is installed to continuously record very small movements in the aquifer. Extensometers are also commonly equipped to continuously monitor groundwater levels in one or more aquifer zones.

Most of the borehole extensometers in the San Joaquin Valley (Tulare Lake and San Joaquin hydrologic regions) were constructed in the 1950s and 1960s during the planning and construction of the State and federal water projects. After completion of the water projects and import of surface water, it was anticipated that the threat of land subsidence had largely been mitigated. As a result, land subsidence investigations became less of a priority and the borehole extensometer monitoring wells fell into disrepair. In 2009, the USGS evaluated 12 of the inactive borehole extensometers for potential repair and reuse (Sneed 2011). Four extensometers were selected to be rehabilitated. These extensometers include 12S/12E-16H2, 14S/13E-11D6, 18S/16E-33A1, and 20S/18E-6D1. Other active extensometers currently being monitored include 25S/22E-35B1 (Semitropic Water Storage District Extensometer) and 30S/25E-16L monitored by DWR.

Figure 8-11 shows the location of the seven active borehole extensometers and Table 8-12 provides information for both the active and inactive extensometers in the San Joaquin Valley.

Figure 8-11 Borehole Extensometer Locations for the San Joaquin Valley Portion of the San Joaquin River Hydrologic Region

Table 8-11 Borehole Extensometer Information for the San Joaquin Valley Portion of the San Joaquin River Hydrologic Region

State Well Number	HR	GW Basin	County	Latitude	Longitude	Well Depth	Initial Start of Data Record	Post-Rehab Start of Record
Active								
12S/12E-16H2	SJR	5.22-07	Merced	36.890	120.655	1,000	May 19, 1958	Feb. 27, 2012
13S/15E-35D5	TL	5.22-07	Fresno	36.760	-120.311	440	May 13, 1966	2002
14S/13E-11D6	TL	5-22.09	Fresno	36.733	-120.532	1358	Jan. 1, 1961 to 1974	Apr. 6, 2012
18S/16E-33A1	TL	5-22.09	Fresno	36.327	-120.230	1029	Mar. 10, 1965	Mar. 2, 2012
20S/18E-6D1	TL	5-22.09	Fresno	36.226	-120.065	1007	Jan. 1, 1965	Apr.5, 2012
25S/22E-35B1	TL	5-22.14	Kern	35.710	-119.535	880	2010	
30S/25E-16L5	TL	5-22.14	Kern	35.318	-119.297	780	June 1, 1994	
Inactive[a]								
13S/12E-20D1	SJR	5.22-07	Madera	36.790	-120.689	681	Abandoned 1974	
14S/12E-12H1	TL	5-22.09	Fresno	36.731	-120.605	913	Jan. 10, 1965[b]	
14S/13E-26N1	TL	5-22.09	Fresno	36.678	-120.529		1945[b]	
15S/13E-11D2	TL	5-22.09	Fresno	36.646	-120.529	958	Jan.1, 1965[b]	
15S/14E-14J1	TL	5-22.09	Fresno	36.622	-120.408	1010	Abandoned 1971	
15S/16E-31N3	TL	5-22.09	Fresno	36.575	-120.276	596	Mar. 23, 1967[b]	
16S/15E-34N1 to N4	TL	5-22.09	Fresno	36.495	-120.329	503, 703, 1096, 2000	Sept. 25, 1958[b]	
17S/15E-14Q1	TL	5-22.09	Fresno	36.445	-120.308	2315	Nov. 4, 1969[b]	
17S/15E-21N1	TL	5-22.09	Fresno	36.430	-120.354		1955[b]	
18S/19E-20P1	TL	5-22.09	Kings	36.345	-119.934	578	Mar. 24, 1967[b]	
19S/16E-23P2	TL	5-22.09	Fresno	36.256	-120.205	2200	Jan. 2, 1960 Abandoned 1974	
20S/18E-11Q1, Q2, Q3	TL	5-22.09	Fresno	36.198	-119.982	710, 845, 1930	July 24, 1964[b]	
22S/27E-30D2	TL	5-22.13	Tulare	35.992	-119.104	1246	Aug. 13, 1970[b]	
23S/25E-16N1, N3, N4	TL	5-22.13	Tulare	35.922	-119.284	250, 430, 760	June 24, 1959[b]	
24S/26E-34F1	TL	5-22.13	Tulare	35.800	-119.155	1510	Jan. 21, 1959[b]	

State Well Number	HR	GW Basin	County	Latitude	Longitude	Well Depth	Initial Start of Data Record	Post-Rehab Start of Record
24S/26E-36A2	TL	5-22.13	Tulare	35.804	-119.108	2200	May 12, 1959[b]	
25S/26E-1A2	TL	5-22.14	Kern	35.790	-119.117	875	Apr. 6, 1959 Abandoned 1978	
26S/23E-16H2, H3	TL	5-22.14	Kern	35.668	-119.492	355, 1002	Aug. 17, 1978[b]	
32S/28E-20Q1	TL	5-22.14	Kern	35.123	-118.992	970	Apr. 11, 1963 Abandoned 1975	
12N/21W-34Q1[c]	TL	5-22.14	Kern	35.078	-119.106	810	June 20, 1960 Abandoned 1974	
11N/21W-3B1 (SB BLM)	TL	5-22.14	Kern	35.076	-119.105	1480	Apr. 12, 1963[b]	

Notes:

GW = groundwater, HR = hydrologic region, SJR = San Joaquin River, TL = Tulare Lake

[a] Inactive Extensometers are not in use because of disrepair.

[b] Uncertain date when extensometer readings were terminated.

[c] San Bernardino Baseline and Meridian

Because of the small number of borehole extensometers in the San Joaquin River region (one active and one inactive), the extensometer information for the Tulare Lake and San Joaquin River regions have been combined in Figure 8-11 and Table 8-11. Results from the borehole extensometer monitoring are provided in the "Aquifer Conditions" section of this chapter.

USGS InSAR Monitoring

Interferometric Synthetic Aperture Radar (InSAR) is a remote sensing tool that uses satellite radar signals to measure deformation of the Earth's crust at a high degree of spatial detail and measurement resolution (U.S. Geological Survey 2000). By bouncing radar signals off the ground surface from the same point in space but at different times, the radar satellite can measure the change in distance between the satellite and ground as the land surface uplifts or subsides. Under optimum conditions, the measurement resolution of InSAR monitoring is estimated to be from 5 to 10 millimeters (U.S. Geological Survey 2003).

In cooperation with DWR and the U.S. Bureau of Reclamation, the USGS is currently evaluating the 2007-2011 InSAR survey data for evidence of subsidence in the San Joaquin and Tulare Lake regions. Results of the InSAR investigation is provided in the "Aquifer Conditions" section of this chapter.

Caltrans Highway Elevation Monitoring

Caltrans periodically resurveys their network of existing benchmarks along key sections of highway. In 1998 and again in 2004, Caltrans performed elevation surveys along State Route 152 across the San Joaquin Valley, from the San Luis Dam to State Route 99, with land elevations being compared to the 1972 survey results. Similar to the Caltrans surveys along State Route 198, a trough of subsidence was found with more than 5 feet of subsidence occurring from 1972 to 2004. The Caltrans surveys were performed at 16-year intervals and suggest that subsidence rates were more or less constant during the same 1972 to 2004 period. These linear surveys were performed along the right-of-way and did not extend out to surrounding areas. As a result, it is unlikely that the surveys were performed across areas of the valley with the greatest subsidence. Results from the Caltrans State Route 152 survey is provided in the "Aquifer Conditions" section of this chapter.

GPS Array Monitoring

A university-governed consortium for geoscience research, working with geodesy (UNAVCO), operates the Plate Boundary Observatory (PBO), employing precision GPS monitoring sites for western United States plate tectonics studies. The UNAVCO GPS stations enable continuous monitoring of the land surface elevation, providing a potential direct measurement of subsidence. There are 13 GPS stations in the San Joaquin Valley. Several of these are close to the edge of the valley and provide partial insight into the regional magnitude of subsidence, while others lie outside of areas susceptible to subsidence. However, a number of UNAVCO stations offer important information regarding changes in the land surface over time. Results from the UNAVCO GPS monitoring are provided in the "Aquifer Conditions" section of this chapter.

Aquifer Conditions

Aquifer conditions and groundwater levels change in response to varying supply, demand, and weather conditions. During years of normal or above-normal precipitation, or during periods of low groundwater use, aquifer systems tend to recharge and respond with rising groundwater levels. Direct and in-lieu recharge programs in the San Joaquin River region take advantage of increased runoff and surface water deliveries during years of normal and above-normal precipitation, which further contributes to raising groundwater levels. In some areas, if groundwater levels rise sufficiently, they reconnect to surface water systems, contributing to the overall base flow or directly discharging onto the ground surface via wetlands, seeps, and springs. However, for some of the San Joaquin River region, the groundwater table has been disconnected from surface water systems for decades and provides no contribution to base flow.

During dry years or periods of increased groundwater use, seasonal groundwater levels tend to fluctuate widely, and depending on the annual amount of natural and managed recharge, may respond with a long-term decline in groundwater levels, both locally and regionally. Excessive declines of groundwater levels require affected well owners to deepen wells or lower pumps to regain access to groundwater. Declining groundwater levels also affect the surface-water-groundwater interaction by increasing infiltration rates, capturing groundwater flow that would otherwise have contributed to the base flow of surface water systems, and by reducing groundwater discharge to surface-water systems. Extensive declines of groundwater levels can also result in land subsidence as a result of dewatering, compaction, and loss of storage within finer-grained aquifer systems.

In 1980, DWR Bulletin 118-80 identified 3 of the 11 San Joaquin River region groundwater basins and subbasins (Eastern San Joaquin [5-22.01], Chowchilla [5-22.05], and Madera [5-22.06]), as being subject to critical conditions of overdraft. Over 30 years later, San Joaquin River region groundwater supplies still account for about 19 percent of all groundwater extraction in California. In addition, reduced surface water supply reliability and recent agricultural shift toward more permanent crop planting serve to further harden the large demand for groundwater. Although significant efforts have been made by local groundwater management entities to reduce overdraft conditions in the region, a number of the GWMPs and more recent studies for these three key southern San Joaquin basins acknowledge that groundwater overdraft conditions continue today.

The following overview of aquifer conditions in the San Joaquin River region focuses on the highest groundwater use basins in the Central Valley portion of the region. The overview of aquifer conditions includes a regional description of groundwater occurrence and movement, estimates of spring 2005 to spring 2010 change in groundwater in storage, an overview of groundwater quality conditions, and a discussion of the effects of groundwater withdrawal on land subsidence. Additional information regarding the methods and assumptions associated with aquifer condition data is provided in Appendix A.

Groundwater Occurrence and Movement

In the simplest of terms, groundwater comes from infiltration of precipitation and from water in rivers, streams, canals, and other surface water systems, and moves from areas of higher to lower elevation. Under predevelopment conditions, the occurrence and movement of groundwater was largely controlled by the surface and the subsurface geology, the size and distribution of the natural surface-water systems, the average annual hydrology, and the regional topography. However, many decades of high-volume groundwater extraction to sustain the agricultural and urban land uses in the San Joaquin River region has considerably affected the natural occurrence and movement of groundwater. Areas of high groundwater extraction tend to redirect and capture groundwater underflow that may otherwise have contributed to nearby surface water systems. Thousands of high-capacity wells screened over multiple aquifer zones also lend themselves to vertical aquifer mixing, which can additionally alter natural groundwater flow conditions. In addition, infiltration along miles of unlined water conveyance canals, percolation of applied irrigation water, and direct recharge programs create significant groundwater recharge areas where none previously existed.

Groundwater occurrence and movement in the San Joaquin River region were evaluated using 2005-2010 spring groundwater-level data to develop contour maps. Springtime groundwater levels typically depict the highest groundwater levels of the year, as annual groundwater demands are at a minimum and aquifer recharge from winter rainfall runoff is at or near the annual maximum.

Groundwater contour maps provide a snapshot of groundwater conditions at a particular point in time, or between two particular time periods. As mentioned, groundwater levels are affected by a number of variables; as a result, the depth-to-water and groundwater elevation maps should be considered regional approximations — with potentially varying local conditions.

Groundwater contour maps were developed using groundwater-level data publically available online from DWR's CASGEM system (http://www.water.ca.gov/groundwater/casgem/) and DWR's Water Data Library (http://www.water.ca.gov/waterdatalibrary/). Additional groundwater-level information for the San Joaquin River region is publically available from the USGS National Water Information System (http://waterdata.usgs.gov/nwis/gw) and some groundwater management groups in the region. Groundwater contour maps for the San Joaquin River region are also generated by DWR's South Central Region Office (http://www.water.ca.gov/groundwater/index.cfm).

The following sections provide an overview of the San Joaquin River region depth to groundwater, groundwater elevations, and long-term groundwater-level trends associated with changing hydrologic conditions and local management actions. Additional information regarding the assumptions and methods associated with groundwater contours and change in storage estimates are provided in Appendix A.

Depth to Groundwater

Groundwater levels in the San Joaquin River region are declining in many areas, mostly in the southern portion and along the eastern edge of the San Joaquin Valley, because of a combination of drought conditions, diversion of surface water for environmental uses, an increasing population, and the trend toward more permanent crops. In 2008-2009, groundwater levels in many San Joaquin Valley groundwater basins again reached historic lows, providing concerns over renewed subsidence and declining groundwater ecosystem services. For smaller farming operations in the region, the lowering of groundwater levels are raising concerns that the cost of groundwater pumping for agricultural use may quickly become unaffordable.

Understanding local depth to groundwater provides a better awareness of the potential interaction between groundwater and surface water systems, the relationship between land use and groundwater levels, the potential for land subsidence, and the costs associated with well installation and groundwater extraction.

Under predevelopment aquifer conditions, changes in the depth to groundwater will generally correlate to changes in ground surface elevation. For example, with increasing ground surface elevation there is a corresponding increase in the depth to groundwater. In high-use basins or in basins where the groundwater storage area is conjunctively managed, the correlation between depth to water and ground surface elevation will eventually start to break down and show significant variability over areas having little change in ground surface elevation.

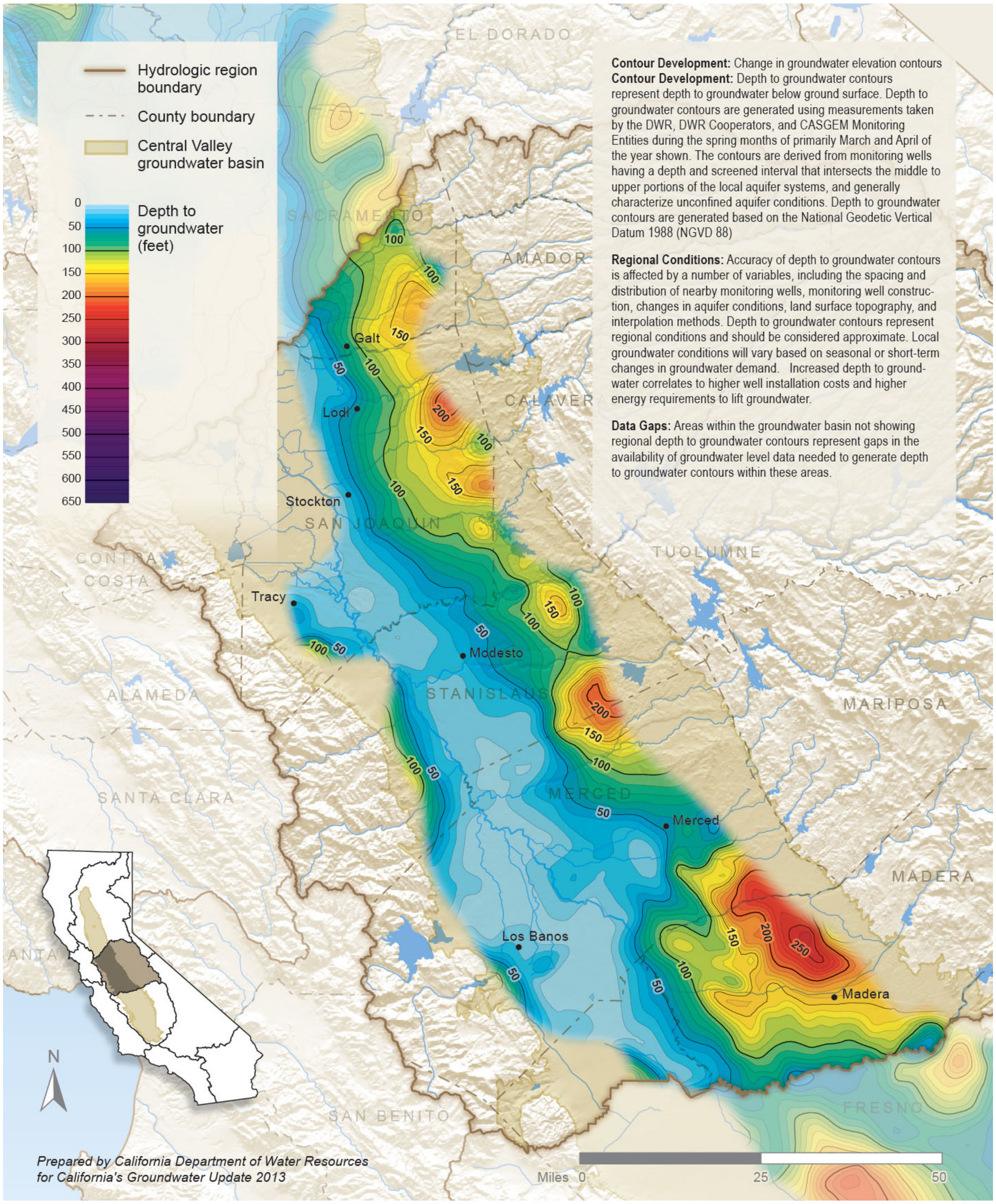
Figure 8-12 is a spring 2010 depth-to-groundwater contour map for the San Joaquin Valley portion of the San Joaquin River region. The contour lines represent areas having similar spring 2010 depth-to-groundwater measurements. Contour lines were developed for those areas having sufficient groundwater-level data and for those aquifers characterized by unconfined groundwater conditions. Because of the sparsely populated Los Banos Creek Valley Groundwater Basin (5-70), no contours were developed for this area. Depth-to-groundwater contours were also not developed for the Yosemite Valley area because of US National Park Service control over the basin. It should be noted that precipitation for water year 2010 was 106 percent of the previous 30-year average; however, precipitation for the preceding three years averaged just over 73 percent of normal.

Figure 8-12 shows that the depth to groundwater in the western portion of the San Joaquin Valley is shallowest along the valley floor adjacent to the San Joaquin River and its associated tributaries, and deepest along the eastern side of the valley where it abuts the lower foothills of the Sierra Nevada.

On the east side of the San Joaquin Valley, widespread agriculture development and a lack of surface water supplies have resulted in significant declines to the groundwater water table, and depth-to-groundwater levels exceeding 250 feet in the northeastern Madera Groundwater Subbasin, 200 feet in the eastern Turlock Groundwater Subbasin, and as much as 150 to 200 feet in the northeastern Cosumnes Groundwater Subbasin are common. The declines of groundwater elevation in the southern portion of the valley are more pronounced because of multiple factors, including higher annual temperatures and less annual precipitation, which results in more groundwater pumping for crop irrigation.

The depth to groundwater along the center of the valley ranges between 5 to 50 feet below ground surface, and is at its shallowest adjacent to the San Joaquin River. While intensive agricultural practices are predominant in this area, the volume of water transported by the tributaries of the San Joaquin River (Merced, Tuolumne, and Stanislaus rivers) has resulted in a high, near-surface water table as an outcome of recharging shallow aquifers. Because of limited groundwater data, there is limited depth-to-groundwater contouring along the west side of the San Joaquin Valley.

Figure 8-12 Spring 2010 Depth to Groundwater Contours for the San Joaquin Valley Portion of the San Joaquin River Hydrologic Region



Groundwater Elevations

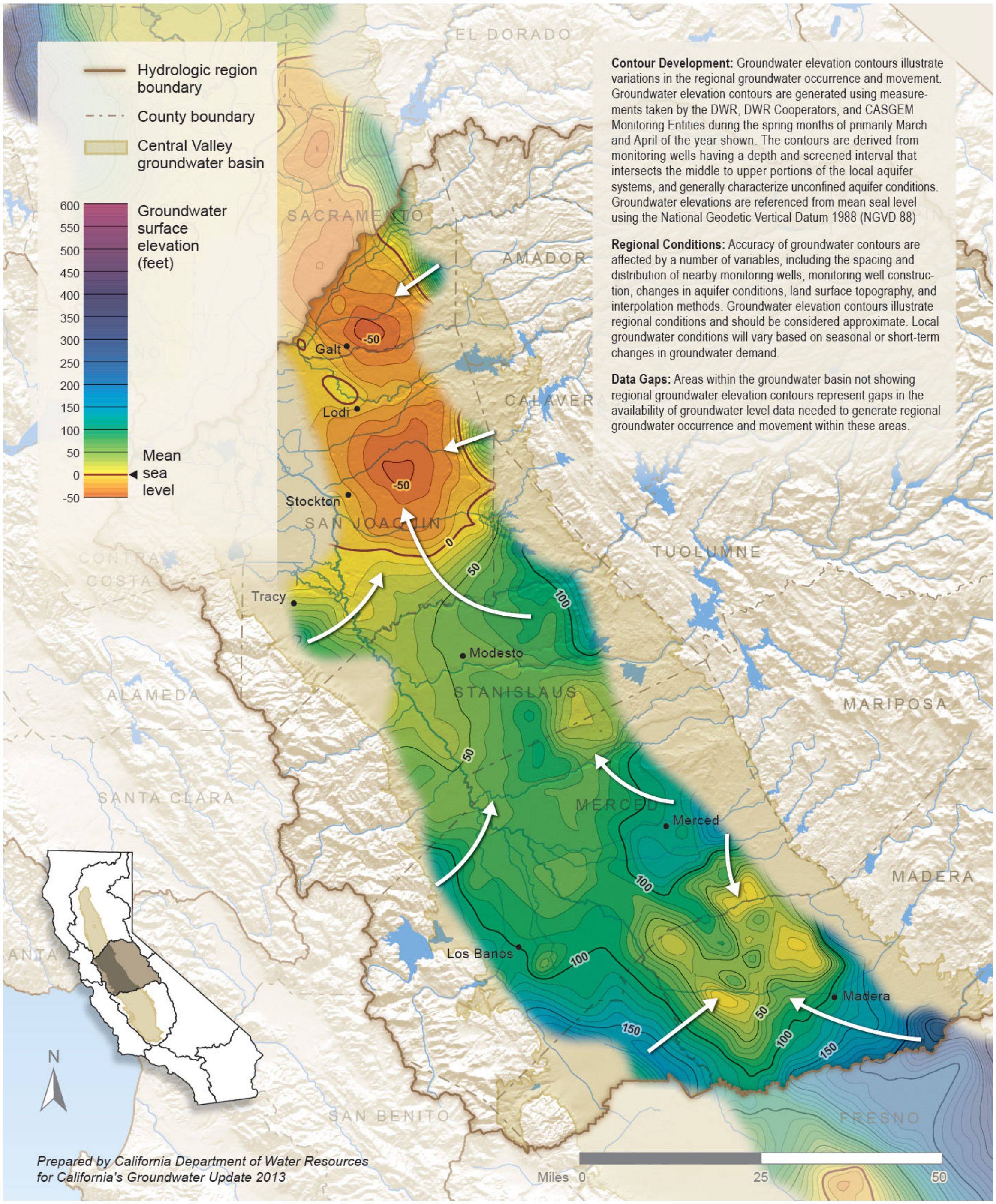
Groundwater elevation contours, which provide a good regional estimate of the occurrence and movement of groundwater in the San Joaquin River region, were developed using data publically available through DWR's Water Data Library database. The database contains data collected by DWR and other State, federal, and private cooperators. Under predevelopment conditions, the groundwater elevations typically follow a muted version of the overlying topography. The direction of groundwater flow follows a path perpendicular to the groundwater contours — moving from high elevation areas to lower elevation areas. In aquifer recharge areas, groundwater flow lines tend to diverge from the area in a radial flow pattern. In aquifer discharge areas, or in areas characterized by pumping depressions of the groundwater table, the groundwater flow lines will tend to converge toward the center of the discharge or pumping area.

Using similar principles, groundwater elevation contours along gaining stream reaches (streams where groundwater contributes to the base flow) will show a groundwater flow-line pattern that converges on the stream. Along losing stream reaches (streams that lose water to the aquifer), the groundwater contours will show a groundwater flow-line pattern that diverges from the stream.

Figure 8-13 is a spring 2010 groundwater elevation contour map for the San Joaquin River region. Groundwater movement direction is shown as a series of arrows along the groundwater flow path. Note that these flow direction arrows do not provide information regarding vertical flow within the local aquifer system. Similar to the spring 2010 depth-to-groundwater contours, groundwater elevation contours lines in Figure 8-13 were developed for those areas having sufficient groundwater-level data and for those aquifers characterized by unconfined groundwater conditions. Groundwater elevation contours were not developed for the Yosemite Valley Basin or Los Banos Creek Valley Basin because of a lack of groundwater-level data in those areas.

Figure 8-13 shows that the spring 2010 groundwater movement is generally from the eastern and western edges of the basin, moving toward the axis of the valley, and then flowing north following the San Joaquin River. Groundwater pumping and recharge activities tend to alter the spacing, pattern, and overall variability of groundwater elevation contours for some areas. In areas receiving little or no surface water, large pumping centers have developed cones of depression, drawing water levels to near sea level. A good example of a large pumping depression is the area that has formed in the eastern Madera and Chowchilla groundwater subbasins, where historic groundwater flows have been altered and now flow toward the cone formed around the area. Similar cones of depression have formed around the eastern Cosumnes and east portion of the Eastern San Joaquin groundwater subbasins; however, in these two areas, the groundwater elevations are approximately 50 feet below sea level.

Figure 8-13 Spring 2010 Groundwater Elevations Contours for the San Joaquin River Hydrologic Region



Groundwater-Level Trends

Depth-to-water measurements collected from a particular well, over time, can be plotted to create a hydrograph. Hydrographs assist in the presentation of data and the analysis of seasonal and long-term groundwater-level variability and trends over time. Because of the highly variable nature of the aquifer systems within each groundwater basin, and because of the variable nature of annual groundwater extraction, recharge, and surrounding land use practices, the hydrographs selected for discussion are not an attempt to represent average aquifer conditions over a broad region. Rather, the following hydrographs were selected to help tell a story of how the local aquifer systems respond to changing groundwater extractions and resource management practices. The hydrographs are identified according to the State Well Number (SWN) system. The SWN identifies a well by its location using the U.S. Public Land Survey System of township, range, and section. More information on the SWN system is provided in DWR's Water Fact No. 7 information brochure (http://www.water.ca.gov/pubs/conservation/waterfacts/numbering_water_wells_in_california_water_facts_7_/water_facts_7.pdf).

Figure 8-14 shows hydrograph examples for five selected groundwater elevation monitoring wells in the San Joaquin River region and provides a brief explanation of the hydrograph "story." More detailed information about the hydrograph, such as the location of the well, the well type, depth, well construction information, and surrounding land use information, as well as monitoring frequency and period of record, are provided in the following sections.

Hydrograph 05S09E07B001M

Figure 8-14a is a hydrograph for Well 05S09E07B001M, which is located on the west side of the Turlock Groundwater Subbasin (5-22.03), approximately 4 miles east of the San Joaquin River and within the boundaries of the Turlock Irrigation District. Similar to many wells in the San Joaquin Valley, water levels show a response to wet and dry years. In the instance of this well, the response is subdued. Based on the subsurface conditions, it is believed that the well is shallow and screened in an unconfined to semi-confined aquifer; however, the exact depth and construction details of the well are unknown. It is an unused well presently, but has been used for irrigation purposes in the past. The land use around the well is predominantly agriculture and is sparsely populated. Water level readings have been collected periodically since February 1965, but not on a standard rotating spring and/or fall schedule.

Groundwater at the well site is shallow, occurring at depths ranging from 5 to 10 feet below ground surface, which is typical for groundwater levels on the western portion of the groundwater basin. Groundwater levels have been relatively stable during the monitoring period, varying in depth by no more than about 10 feet. The drought years of 1987 to 1992 resulted in a 10-foot drop in water levels, but these levels returned to average conditions during subsequent wet years. During an exceptional wet year, such as 1983, water levels rose to near ground surface at a depth of 2.5 feet. As part of CASGEM Basin Prioritization, the Turlock Groundwater Subbasin has been designated as a high-priority basin.

Hydrograph 05S10E04D001M

Figure 8-14b is a hydrograph for Well 05S10E04D001M located within the Turlock Groundwater Subbasin (5-22.03). The well is located immediately northeast of Turlock in Stanislaus County, inside the boundaries of the Turlock Irrigation District. The hydrograph for this well highlights the successful role of an active in-lieu conjunctive management program in meeting increasing urban water demands while keeping long-term aquifer conditions stable. The well has been used in the past for irrigation, but the construction details and depth is unknown. Based on the subsurface conditions, it is believed that the well is screened in an unconfined to semi-confined aquifer. The land use surrounding this well is urban environment to the south and mixed agricultural row crops and orchards. Groundwater-level readings were first reported for the well in December 1960 and were collected periodically until approximately 1980. From 1980 to 1999, collection was changed to an annual spring and fall schedule. Since then, groundwater readings have returned to a periodic basis, usually every spring.

Groundwater at the well site has been in a gradual decline, likely associated with urban growth in Turlock. Turlock Irrigation District has an active conjunctive management program using surface water from the Tuolumne River during wet years and relying on groundwater pumping during dry years (Tulare Irrigation District per. comm. Q3 2011). Drought in 1987 to 1992 resulted in a 20-foot drop in water levels as a consequence of an increased reliance on pumping and a decreased availability of surface water supplies from the Tuolumne River. Water levels stabilized and underwent a multiyear rise between 1992 and 1998, a period of increased precipitation and resumption of surface water supplies. Declining water levels beginning in 1999 have been associated with an increase in urban land development, in addition to the influence of the previously referenced cone of depression in the Turlock Groundwater Subbasin. The cone of depression is created by groundwater pumping in areas east of the Turlock Irrigation District, where irrigated lands do not have access to surface water and solely rely on groundwater for their supply. A conservation effort combined with slowed economic growth stabilized water levels beginning in 2009. As part of CASGEM Basin Prioritization, the Turlock Groundwater Subbasin has been designated as a high-priority basin.

Hydrograph 05S12E11G001M

Figure 8-14c is a hydrograph for Well 05S12E11G001M, which is located in the Eastside Water District, approximately 10 miles east of Turlock in the Turlock Groundwater Subbasin (5-22.03). The hydrograph for this well highlights a successful stabilization of declining groundwater levels resulting from adopting drip and micro irrigation sprinkler systems beginning in 1990. The declining depth-to-groundwater trend resumed as a result of the expansion of agricultural lands into previously non-irrigated lands. The depth and construction details of the well are unknown; however, it is believed to be screened in an unconfined to semi-confined aquifer. The land use surrounding this well is established and newly planted orchards. Groundwater-level readings were first reported for the well in March 1971 and have been collected on a periodic but not routine basis, usually in the spring and/or fall.

Agricultural development in the water district intensified starting in the 1970s. Eastside Irrigation District has no surface water allocations, thus the increased agriculture development resulted in a reliance on groundwater for irrigation water, which caused a steady decline in groundwater water levels. A shift in irrigation practices from sprinkler use to drip irrigation and micro irrigation stabilized water levels from 1990 to 2002. The resumption in declining water levels in 2003 and 2004 is likely attributed to the increased agricultural development in areas that were previously non-irrigated rangeland. The 90-foot drop in water levels from 1970 to 2011 may require the deepening of existing wells and installation of new, deeper wells in the recently developed farmlands. As part of CASGEM Basin Prioritization, the Turlock Groundwater Subbasin has been designated as a high-priority basin.

Figure 8-14 Groundwater Hydrographs for the San Joaquin River Hydrologic Region, Page 1

Aquifer response to changing demand and management practices

Hydrographs were selected to help tell a story of how local aquifer systems respond to changing groundwater demand and resource management practices. Additional detail is provided within the main text of the report.

A Hydrograph 05S09E07B001M: illustrates an example of a typical well in the western portion of the Turlock Groundwater Basin. The wells extract water from the shallow unconfined to semi-confined aquifers which readily respond to the local hydrologic conditions.

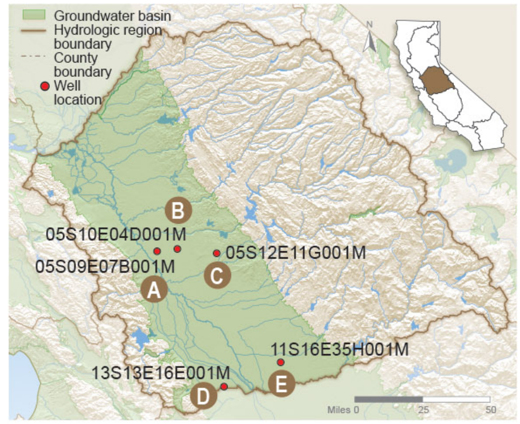
B Hydrograph 05S10E04D001M: highlights the successful role of conjunctive management of surface water and groundwater supplies in meeting the increasing urban water demands while keeping the long-term aquifer conditions stable.

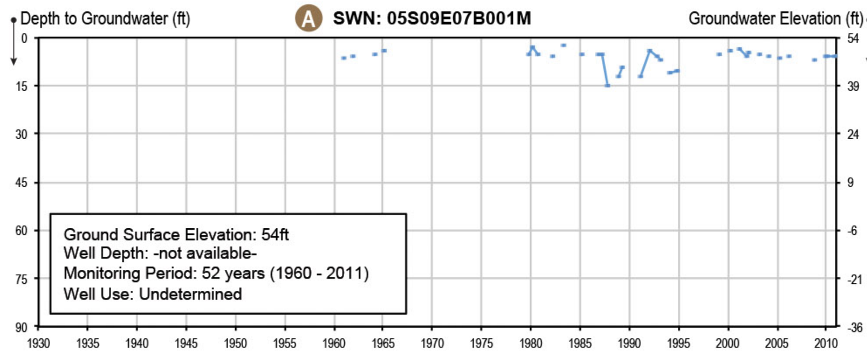
C Hydrograph 05S12E11G001M: shows the successful stabilization of declining groundwater levels associated with the technological advancement in the irrigation systems. The declining trend resumed, however, due to expansion of agricultural lands into previously non-irrigated lands.

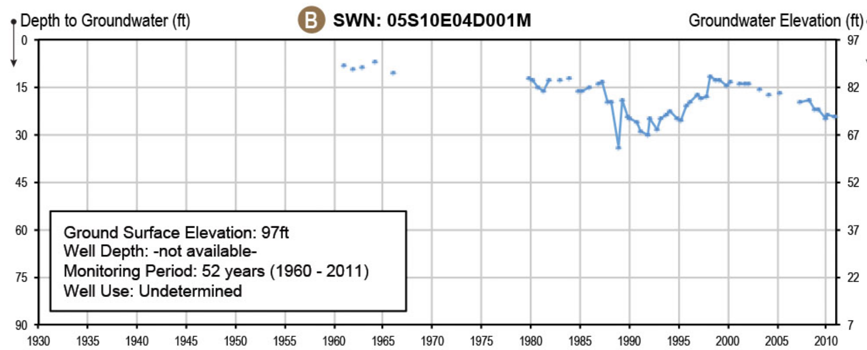
D Hydrographs 13S13E16E001M: highlights the successful recovery of declining groundwater conditions associated with the introduction of imported water.

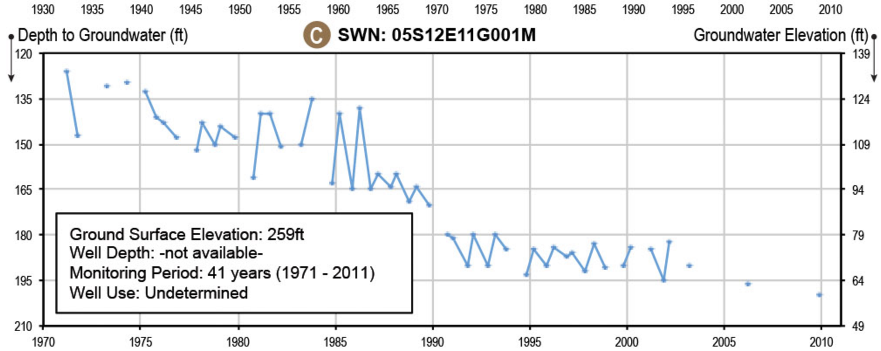
E Hydrographs 11S16E35H001M: shows an imbalance between aquifer recharge and groundwater extraction as a result of unsustainable reliance on the local groundwater resources in absence of surface water supplies.

Regional locator map



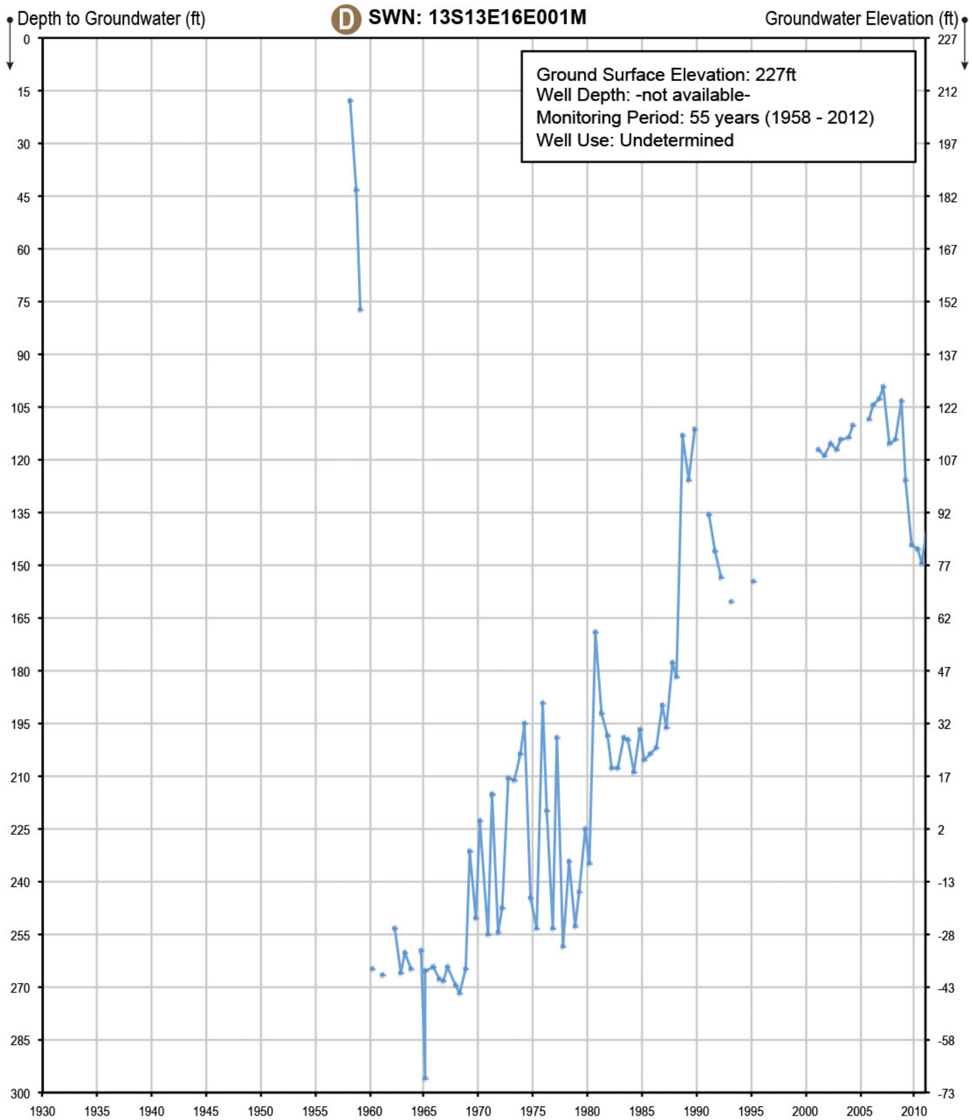


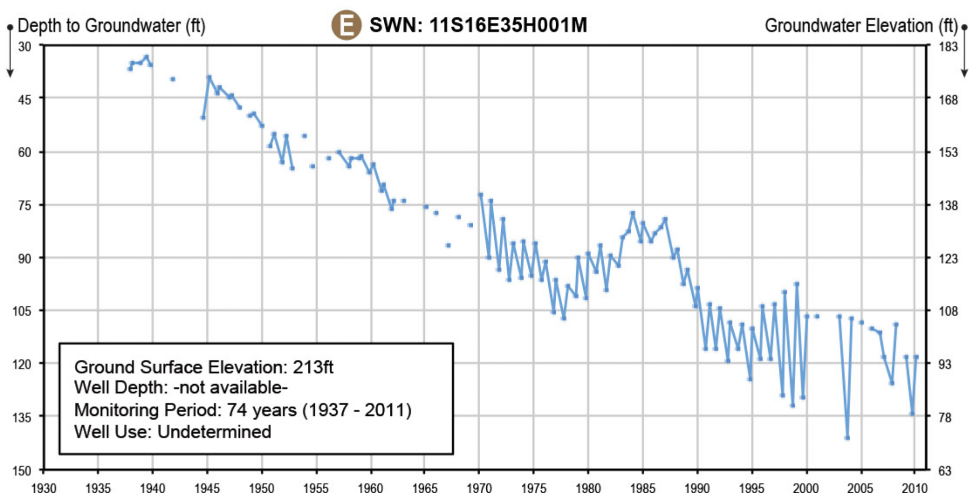




Prepared by California Department of Water Resources for California's Groundwater Update 2013

Figure 8-14 Groundwater Hydrographs for the San Joaquin River Hydrologic Region, Page 2





Hydrograph 13S13E16E001M

Figure 8-14d is a hydrograph for Well 13S13E16E001M located in Fresno County, approximately 10 miles west of the San Joaquin River in the Delta-Mendota Groundwater Subbasin (5-22.07). The hydrograph for this well highlights the successful recovery of declining groundwater conditions and stabilization of subsiding land through the introduction of water deliveries from the SWP. The well is located in an agricultural area of predominantly permanent crops. The depth and construction details for the well are unknown, but it is believed that the well is screened in an unconfined to semi-confined aquifer. The land use surrounding this well is established and newly planted orchards. Groundwater-level readings were first reported for the well in April 1958 and have been collected on a routine basis in the spring and fall.

Although the land in the area was for many decades considered too salty for crop production, decades of farming lower-value crops such as hay, cotton, and sugar beets developed the soil for permanent crops, such as grapes and almonds. Flushing of salt from the soil combined with recharge of fresh San Joaquin River water has produced a variable water quality, with the lowest salt content groundwater being generally located closer to the river. Wells for agricultural irrigation penetrated a confining layer of regional interest, the Corcoran clay. Rapidly falling water levels resulted in broad areas of land subsidence and Well 13S13E16E001M lies in an area that experienced 16 feet of subsidence from 1926 to 1970. The California Aqueduct was constructed in partial response to the land subsidence problem. Farms in the area were provided surface water from the canal and groundwater pumping was substantially reduced. The hydrograph shows groundwater-level recovery of more than 150 feet after completion of the SWP and beginning of water deliveries in the early 1960s. Dry years in 1992 and from 2007 to 2009 resulted in short-term falling water levels. Reduced water supplies have resulted in falling water levels and the renewed affects from subsidence have been observed in a number of areas. Investigation into these areas is ongoing. As part of CASGEM Basin Prioritization, the Delta-Mendota Groundwater Subbasin has been designated as a high-priority basin.

Hydrograph 11S16E35H001M

Figure 8-14e is a hydrograph for Well 11S16E35H001M located about 5 miles southwest of the city of Madera in Madera County within the Madera Groundwater Subbasin (5-22.06). The hydrograph for this well highlights an aquifer responsive to the type of water year, but still affected by a long-term imbalance between recharge and groundwater extraction, with water levels declining approximately 90 feet since 1940. The well is located in a predominantly agricultural area and the depth and the construction details are unknown. However, based on the subsurface conditions, it is believed that the well is screened in an unconfined to semi-confined aquifer. The land use surrounding this well is established and newly planted orchards. Groundwater-level readings for this well were first reported in November 1937, and subsequent readings have been routinely conducted in the spring and fall, with a few exceptions.

Groundwater conditions in the area around the well site are in a persistent and deepening decline because of agricultural extractions. This area has a mix of undeveloped range land, permanent crops (vines and tree fruit), and forage crops. There are no surface water supplies available and irrigation depends on groundwater to meet area needs. Water levels were more or less stable through the 1930s. After World War II, agricultural development intensified and water levels began a steady decline. Groundwater is replenished by subsurface inflow from surrounding areas, recharge from rainfall, and infiltration of applied irrigation water. The seasonal fluctuations have been increasing since the

1970s, with the greatest fluctuations occurring during the dryer years. As part of CASGEM Basin Prioritization, the Madera Groundwater Subbasin has been designated as a high-priority basin.

Change in Groundwater in Storage

Change in groundwater in storage is the difference in groundwater volume between two different time periods. Change in groundwater in storage is calculated by multiplying the difference in groundwater elevation between two time periods, by the overlying basin area, and by the average specific yield (or volume of pore space from which water may be extracted).

Evaluating the annual change in groundwater in storage over a series of years helps identify the aquifer response to changes in weather, land use, and groundwater management. If the change in groundwater in storage is negligible over a period represented by average hydrologic and land use conditions, the basin is considered to be in equilibrium. Declining groundwater levels and reduction of groundwater in storage during years of average hydrology and land use does not always indicate basin overdraft or unsustainable management — some additional investigation is typically required. Use of groundwater in storage during years of diminishing surface water supply, followed by active recharge of the aquifer when surface water or other alternative supplies become available, is a recognized and acceptable approach to conjunctively managing a groundwater basin. Additional information regarding risk and benefits of conjunctive management in California can be found in *California Water Plan Update 2013,* Volume 3, Chapter 9, “Conjunctive Management and Groundwater Storage.”

Annual and cumulative change of groundwater in storage for the San Joaquin Valley portion of the San Joaquin River region was calculated between 2005 and 2010 using spring groundwater elevation monitoring data, a range of specific yield values for the aquifer, and a standardized GIS data processing tool. Spring groundwater levels were used because of the tendency toward aquifer stability during the spring months. Beginning the change in storage calculation in 2005, a relatively average water year, allows for better comparison of the annual and cumulative change in storage values in subsequent years.

One key piece of data required to calculate the change in the amount of groundwater in storage is the aquifer’s specific yield information. Data from two vetted models were assessed for use in the change in groundwater-in-storage tool; the 2013 DWR California Central Valley Groundwater-Surface Water Simulation Model (C2VSim) and the 2009 USGS Central Valley Hydrologic Model (CVHM). These models have compiled and developed specific yield data for the Central Valley in a format readily useable in GIS. Based on data included in C2VSim and CVHM, minimum and maximum specific yield values of 0.07 and 0.17 were determined to be a good approximation of the range of aquifer storage parameters for the unconfined aquifers in the Central Valley. As with the groundwater elevation contour maps, groundwater basins having insufficient data to annually contour and compare the year-to-year changes in groundwater elevations were identified as “Non-Reporting” areas. Change in groundwater in storage was not estimated for these areas.

A standardized GIS tool was developed by DWR to generate annual groundwater elevation contours and subsequent change in storage estimates. The primary goal of using a standardized GIS approach was to implement a repeatable and transparent process for compiling groundwater elevation data and determining change in storage estimates. The GIS tool is intended to be for basin scale assessment of change in groundwater in storage and is not intended for local scale project analysis.

Change in groundwater in storage was calculated using groundwater-level data publically available online from DWR's Water Data Library (http://www.water.ca.gov/waterdatalibrary/) and DWR's CASGEM system (http://www.water.ca.gov/groundwater/casgem/). Additional groundwater-level information for the San Joaquin River region is publically available from the USGS National Water Information System (http://waterdata.usgs.gov/nwis/gw), and some groundwater management groups in the region.

Change in groundwater-in-storage estimates using groundwater-level data is also being developed by various groundwater management groups in the region. Change in groundwater-in-storage estimates have also been estimated for the San Joaquin River region using regional and local-scale groundwater modeling. A detailed comparison of the various methods and sources of change in storage data is beyond the scope of this report. Additional information regarding the methods and assumptions for calculating change in groundwater in storage is provided in Appendix E.

Spring 2005 to Spring 2010 Change in Groundwater in Storage

Figure 8-15 is a spring 2005 to spring 2010 change in groundwater elevation contour map for the San Joaquin Valley portion of the San Joaquin River region. The colored contours in Figure 8-15 represent lines of equal change in groundwater elevation between spring 2005 and spring 2010. Figure 8-15 shows a decline of as much as 60 feet or more in groundwater elevations in areas of Madera County and the southeast portion of Merced County. A decline in groundwater elevations ranging from 10 to 30 feet is also seen along the eastern edge of the region, which includes Merced, Stanislaus, and San Joaquin counties, where the alluvial basins abut the Sierra Nevada. Additionally, groundwater elevation declines as much as 30 to 40 feet or more were observed south of Los Banos in Merced County.

Increases in groundwater elevations are occurring in two places in the region, and both can be observed along the eastern margin of the valley in northern Fresno County and central Madera County. The largest increase, with more than 40 feet of positive change since 2005, is the area where the San Joaquin River exits the Sierra Nevada through Friant Dam and enters the Central Valley. Similar increases are also observed where the Fresno River, from Hidden Dam, enters the Central Valley. In both cases, surface water from reservoirs is recharging groundwater. A small area south of Tracy is also showing 30-foot increases in groundwater levels. The groundwater-level increases in this area could be attributed to flooded gravel pits acting as recharge ponds. Additional investigation is needed to understand the hydrology of the area.

Table 8-12 lists the average annual change in groundwater elevation and the estimated range of groundwater-in-storage change based on the minimum (0.07) and maximum (0.17) estimates of specific yield values. Table 8-12 also indicates the reporting and non-reporting areas used to calculate the change in groundwater in storage for the San Joaquin River region. Figure 8-16 is a bar chart depicting the San Joaquin River region annual and cumulative (2005-2010) change in groundwater in storage associated with the average change in groundwater levels shown in Table 8-12. Figure 8-16 also shows the generalized water year type (wet, above normal, below normal, dry, and critical) for the region, based on the average precipitation over the previous 30 years for the region. Additional tables and figures for individual basins and subbasins in the San Joaquin Valley portion of the San Joaquin River region are provided in Appendix E.

Table 8-12 and Figure 8-16 show that the average annual change in groundwater elevation and related change in groundwater in storage generally corresponds with the annual precipitation or water-year type. The 2005-2006 period is identified as a “wet” year, while the subsequent four years are characterized as critical, critical, below normal, and below normal. Table 8-12 shows a slight increase in average groundwater levels (1.1 feet) for the 2005-2006 period, followed by a decline of approximately 2.7 feet in groundwater levels for 2006-2007, a decline of 0.4 feet for 2007-2008, a sharp decline of 3.4 feet for 2008-2009, and a decline of 0.5 feet for the 2009-2010 period. The spring 2005-spring 2010 cumulative groundwater-level decline over the region is estimated at 6 feet.

Figure 8-16 shows the annual variability in groundwater in storage for the region is significant. The maximum single-year increase in groundwater in storage occurred during the 2005-2006 period, and ranged between approximately 189 taf and 458 taf. The maximum single-year decline in groundwater storage occurred during the 2008-2009 period, and ranged between 606 taf and 1,473 taf.

The 2008-2009 decline in groundwater in storage from the reporting area of the region is estimated to be 19 to 46 percent of the region’s 2005-2010 average annual groundwater use. The cumulative change in groundwater in storage loss over the 2005-2010 interval is estimated to be between 1,062 taf and 2,579 taf, which is between 33 percent and 81 percent of the San Joaquin River region’s 2005-2010 average annual groundwater extraction, and 6 percent to 16 percent of the average groundwater extraction for the entire state.

Groundwater Quality

In general, groundwater quality throughout the San Joaquin River region is suitable for most urban and agricultural uses. Groundwater in shallower aquifers generally contains higher concentrations of anthropogenic contaminants, such as nitrates and pesticides, than in deeper aquifers. The shallower part of the aquifer is generally younger water, indicating that it has been recently recharged. Shallower wells, such as private domestic supply wells, may provide better indication of pollutants from current land use activities. Pollutants from current land use activities may eventually affect deeper wells, such as public supply wells (Burow 2008). The following chemical contaminants affect groundwater use in the San Joaquin and at times require treatment:

- Total Dissolved Solids (TDS) or salinity.
- Gross Alpha and uranium.
- Arsenic.
- Boron.
- Chloride.
- Nitrate.
- (Volatile) Organic Compounds.

Figure 8-15 Change in Groundwater Elevation Contour Map for the San Joaquin Valley Portion of the San Joaquin Hydrologic Region (Spring 2005-Spring 2010)

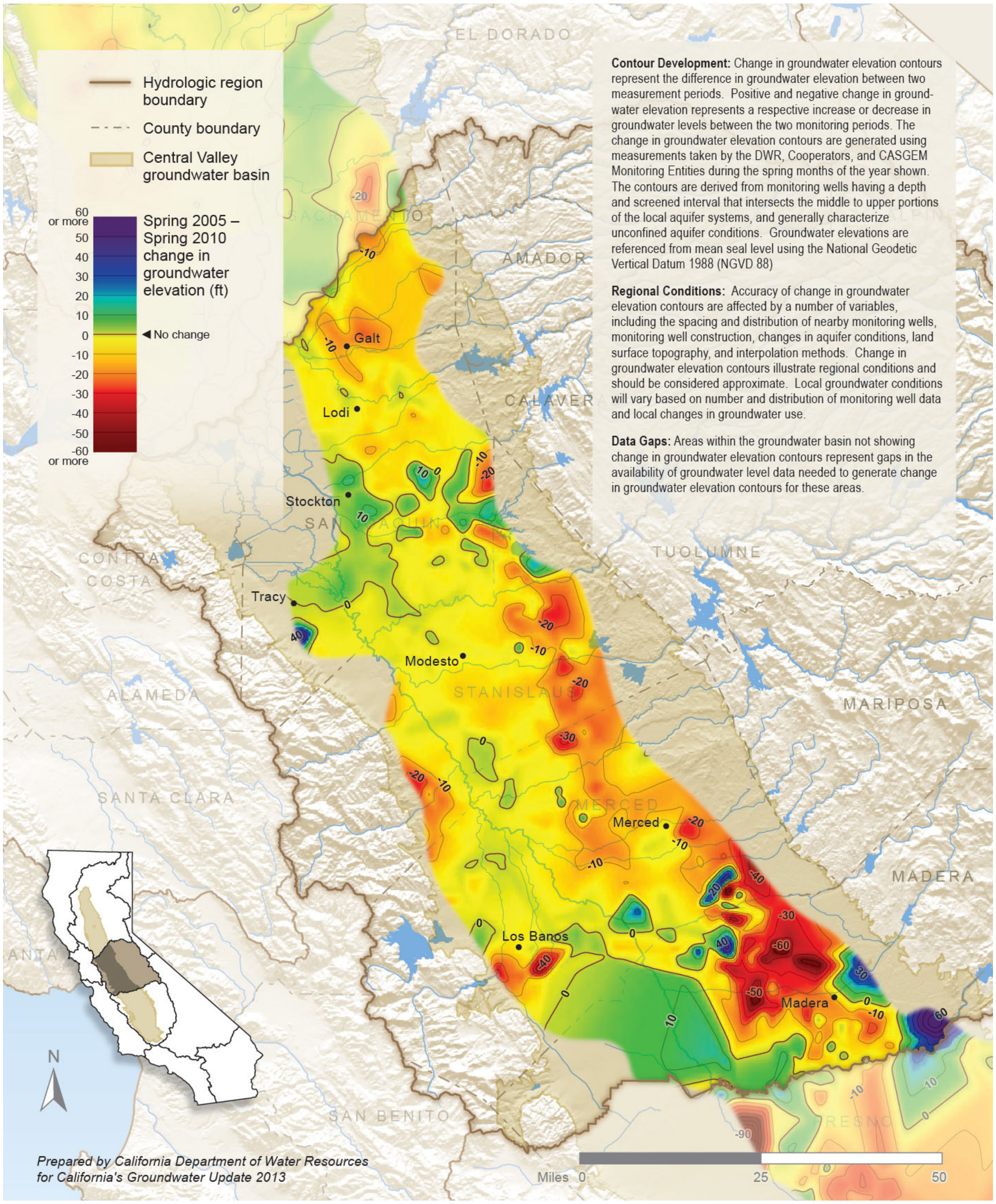
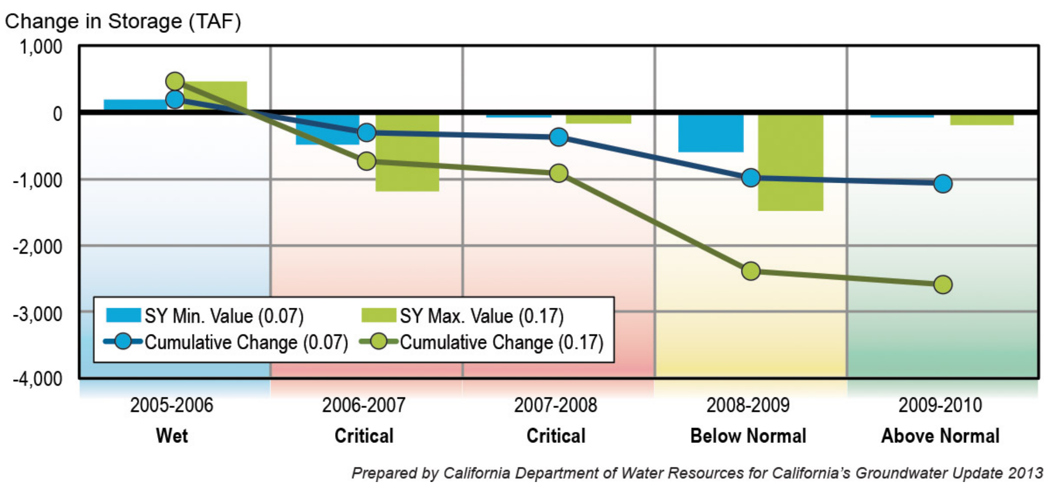


Table 8-12 Annual Change in Groundwater in Storage for the San Joaquin Valley Portion of the San Joaquin River Region (Spring 2005-Spring 2010)

Period Spring/Spring	Average Change in Groundwater Elevation (ft)	Estimated Change in Storage (taf)	
		Assuming Specific Yield = 0.07	Assuming Specific Yield = 0.17
2005-2006	1.1	189	458
2006-2007	-2.7	-487	-1,183
2007-2008	-0.4	-74	-179
2008-2009	-3.4	-606	-1,473
2009-2010	-0.5	-83	-203
Total (2005-2010)	**-6.0**	**-1,062**	**-2,579**

Notes:
ft = feet, taf = thousand acre feet
Groundwater elevation and change in storage is estimates are calculated within reporting area.
Reporting area: 2,535,865 acres.
Non-reporting area 1,180,392 acres.

Figure 8-16 Annual Change in Groundwater in Storage for the San Joaquin Valley Portion of the San Joaquin River Region (Spring 2005-Spring 2010)



The areas of high TDS content are primarily along the west side of the San Joaquin Valley and along the trough of the valley. High TDS content of west-side water is the result of stream flow recharge originating from marine sediments in the Coast Ranges. High TDS content along the valley axis is the result of evaporation and poor drainage. In the central and west-side portions of the valley, where the Corcoran clay confining layer exists, water quality is generally better beneath the clay than above it.

Boron and chloride are likely a result of concentration from evaporation near the valley trough. Organic contaminants can be broken into two categories, agricultural and industrial. Agricultural pesticides and herbicides have been detected in groundwater throughout the region, primarily along the east side of the San Joaquin Valley where soil permeability is higher and depth to groundwater is shallower. The most notable agricultural contaminant is dibromochloropropane (DBCP), a now-banned soil fumigant and known carcinogen once used extensively on grapes and cotton. Industrial organic contaminants include TCE, dichloroethylene (DCE), and other solvents, and are found in groundwater near industrial areas, landfills, and airports.

Salt management is the most serious long-term water quality issue in the San Joaquin Valley. The degradation of groundwater quality is unavoidable without a plan for removing salts from the region. Some of the salt load to the groundwater resource is primarily the result of natural processes in the region, but some also occurs because of water imported from other basins for the purpose of agricultural irrigation. Natural processes include salt loads leached from the soils by precipitation, valley floor runoff, and native surface waters. Approximately 600,000 tons of salt are imported annually into the western portion of the San Joaquin River region (west of the San Joaquin River) for crop irrigation and wetland management via State, federal, and local water projects. An additional 160,000 tons of salt are applied through irrigation from San Joaquin River diversions. Some of this salt is returned to the river through tailwater return flows and some is stored in the soil. Most, however, is purposefully leached below the root zone to maintain salt balance in the root zone. Much of this leached salt ends up in the groundwater. Other sources of salts includes imported water, soil leached by irrigation, animal and human waste, fertilizers and other soil amendments, municipal use, industrial wastewaters, and oil field wastewaters. These salt sources all contribute to increases in salinity and should be managed to the extent practicable to reduce the rate of groundwater quality degradation (Central Valley Regional Water Quality Control Board 2004).

The highest nitrate concentrations are in the alluvial fan areas of the eastern San Joaquin River region. On a regional scale, nitrate contamination is primarily a result of agricultural fertilizers and animal waste applied to cropland as reported in a 2012 UC Davis study (Harter et al. 2012). The UC Davis study also concluded that nitrate problems will likely worsen in the coming decades. Several State and federal GAMA-related groundwater quality reports that help assess and outline groundwater quality conditions for the San Joaquin River region are listed below in Table 8-13.

Groundwater Quality at Community Drinking Water Wells

The SWRCB recently completed a report to the legislature titled *Communities that Rely on a Contaminated Groundwater Source for Drinking Water*. The report focused on chemical contaminants found in active groundwater wells used by CWS. A *community water system* is defined under the California Health & Safety Code Section 116275 as “public water systems that serve at least 15 service connections used by yearlong residents or regularly serve at least 25 yearlong residents of the area served by the system.” Community water systems serve the same group of people, year round, from the same group of water sources. The findings of this report reflect the raw, untreated groundwater quality, and do not necessarily reflect the final quality of groundwater delivered to these communities.

Table 8-13 GAMA Groundwater Quality Reports for the San Joaquin River Hydrologic Region

Data Summary Reports

- Madera/Chowchilla
  http://www.waterboards.ca.gov/gama/docs/dsr_maderachowchilla.pdf
- Northern San Joaquin Valley
  http://www.waterboards.ca.gov/gama/docs/nsjv_dsr.pdf
- Central Eastside San Joaquin Valley
  http://www.waterboards.ca.gov/gama/docs/central_eastside_dsr.pdf
- Sierra Nevada
  http://www.waterboards.ca.gov/gama/docs/dsr_sierra_regional.pdf
- Central Sierra
  http://www.waterboards.ca.gov/gama/docs/central_sierra.pdf
- Western San Joaquin Valley
  http://pubs.usgs.gov/ds/706/

Assessment Reports

- Status and Understanding of Groundwater Quality in the Madera-Chowchilla Study Unit, 2008
  http://pubs.usgs.gov/sir/2012/5094/pdf/sir20125094.pdf
- Status and Understanding of Groundwater Quality in the two Southern San Joaquin Valley Study Units
  http://pubs.usgs.gov/sir/2011/5218/
- Status and Understanding of Groundwater Quality in the Tahoe-Martis, Central Sierra, and Southern Sierra Study Units 2006-2007
  http://pubs.usgs.gov/sir/2011/5216/
- Status and Understanding of Groundwater Quality in the Northern San Joaquin Basin, 2005
  http://www.waterboards.ca.gov/gama/docs/sir20105175.pdf
- Status and Understanding of Groundwater Quality in the Central-Eastside San Joaquin Basin
  http://www.waterboards.ca.gov/gama/docs/sir_sanjoaqinbasin.pdf

Fact Sheets

- Groundwater Quality in the Central Sierra Nevada
  http://pubs.usgs.gov/fs/2012/3010/
- Groundwater Quality in the Northern San Joaquin Valley
  http://www.waterboards.ca.gov/gama/docs/fs20103079.pdf
- Groundwater Quality in the Central Eastside San Joaquin Valley
  http://www.waterboards.ca.gov/gama/docs/gw_cesjv2010_factsheet.pdf

Domestic Well Project

- El Dorado County Focus Area
  http://www.waterboards.ca.gov/gama/docs/edc_draft120905version.pdf

Other Relevant Reports

- Communities that Rely on a Contaminated Groundwater Source for Drinking Water
  http://www.waterboards.ca.gov/water_issues/programs/gama/ab2222/index.shtml

In the San Joaquin River region there are an estimated 433 CWSs with an estimated 1,046 active CWS wells. Table 8-14 shows that 288 of the 1,046 CWS wells (22 percent) are identified as being affected by one or more chemical contaminants that exceed an MCL. The affected wells are used by 104 CWSs in the region, with 80 of the 104 affected CWSs serving small communities which commonly require financial assistance to construct water treatment facilities or alternative solutions to meet drinking water standards (Table 8-15). The most prevalent groundwater contaminants affecting community drinking water wells in the region include arsenic, nitrate, gross alpha particle activity, DBCP, and uranium (Table 8-16). In addition, 59 regional wells are affected by multiple contaminants.

Table 8-14 Summary of Community Drinking Water Wells that Exceed a Primary Maximum Contaminant Level Prior to Treatment in the San Joaquin River Hydrologic Region

Well Information	Community Water System[a] Wells
Number of Affected Wells[b]	228
Total Wells in the Region	1,046
Percentage of Affected Wells[b]	22%

Source: State Water Resources Control Board's report to the Legislature, *Communities that Rely on Contaminated Groundwater* (2013)
Notes:
[a] Community water system means a public water system that serves at least 15 service connections used by yearlong residents or regularly serves at least 25 yearlong residents of the areas served by the system (Health and Safety Code Section 116275).
[b] Affected wells exceeded a primary maximum contaminant level prior to treatment at least twice from 2002 to 2010. Gross alpha levels were used as a screening assessment and did not consider uranium correction.

Table 8-15 Community Drinking Water Systems that Rely on Groundwater Wells in the San Joaquin River Hydrologic Region

System Information	Community Water Systems[a]		
	Number of Affected Water Systems[b]	Total Water Systems in the Region	Percentage of Affected Water Systems[b]
Small Systems Population ≤ 3,300	80	369	22%
Medium Systems Population 3,301-10,000	8	35	23%
Large Systems Population > 10,000	16	29	55%
Total	**104**	**433**	**24%**

Source: State Water Resources Control Board's Report to the Legislature on Communities that Rely on Contaminated Groundwater (2013)
Notes:
[a] Community water system means a public water system that serves at least 15 service connections used by yearlong residents or regularly serves at least 25 yearlong residents of the areas served by the system (Health and Safety Code Section 116275).
[b] Affected water systems are those with one or more wells that exceed a primary maximum contaminant level prior to treatment at least twice from 2002 to 2010. Gross alpha particle levels were used as a screening assessment and did not consider uranium correction.
State small water systems are not included in the totals. These systems serve 5 to 14 service connections and do not regularly serve water to more than 25 people. In general, state small water systems are regulated by local county environmental health departments.

Table 8-16 Contaminants Affecting Drinking Water Systems in the San Joaquin River Hydrologic Region

Principal Contaminant (PC)	Number of Affected Water Systems[b] (PC exceeds the Primary MCL[d])	Number of Affected Wells[c.d.e.f] (PC exceeds the Primary MCL)
Arsenic	58	120
Gross alpha particle activity	38	76
Uranium	23	40
Nitrate	17	26
1,2-Dibromo-3-chloropropane (DBCP)	12	28
Tetrachloroethylene (PCE)	4	4
Ethylene dibromide (EDB)	2	2
Fluoride	2	2
Vinyl Chloride	2	2
Trichloroethylene (TCE)	1	2
Carbon tetrachloride	1	1
cis-1,2-Dichloroethylene	1	1

Source: State Water Resources Control Board's report to the Legislature, *Communities that Rely on Contaminated Groundwater* (2013)
Notes:
MCL = maximum contaminant level
[a] Community drinking water system means a public water system that serves at least 15 service connections used by yearlong residents or regularly serves at least 25 yearlong residents of the areas served by the system (Health and Safety Code Section 116275).
[b] Affected water systems are those with one or more wells that exceed a primary maximum contaminant level prior to treatment at least twice from 2002 to 2010. Gross alpha levels were used as a screening assessment and did not consider uranium correction.
[c] Affected wells exceeded a primary maximum contaminant level prior to treatment at least twice from 2002 to 2010. Gross alpha levels were used as a screening assessment and did not consider uranium correction.
[d] Forty-four wells are affected by two contaminants.
[e] Thirteen wells are affected by three contaminants.
[f] Two wells are affected by four contaminants.

While most large CWSs are able to construct, operate, and maintain a water treatment system to remove or reduce groundwater contaminants to below drinking water standards, small CWSs often cannot afford the high cost to operate and maintain a treatment system, and as a result, some are unable to provide drinking water that meets primary drinking water standards. As of February 2013, there were 25 small CWSs in the San Joaquin River region violating a principal drinking water standard primarily because of groundwater contaminants. Twenty of these small CWSs are affected by arsenic (California Department of Public Health 2013).

Chromium-VI is another groundwater contaminant expected to affect many community water systems when a state MCL is adopted by CDPH. In 2011, the State Office of Environmental Health Hazard Assessment set a public health goal for Chromium-VI at 0.02 ppb. Chromium-VI is found to naturally occur at low levels in the environment, and there are also areas of contamination as a result of historic industrial use, such as manufacturing of textile dyes, wood preservation, leather tanning, and anti-corrosion coatings (California Department of Public Health 2012). The SWRCB's *Communities that Rely on a Contaminated Groundwater Source for Drinking Water* report indicated that 1,378 of the 2,803 active community water system wells had two or more detections for Chromium-VI above 1 ppb. When the Chromium-VI MCL is implemented, it is expected to affect many California water systems. Additional information on Chromium-VI from the SWRCB and CDPH is available on Table 8-10.

Groundwater Quality — GAMA Priority Basin Project

The GAMA Priority Basin Project was initiated to provide a comprehensive baseline of groundwater quality in the state and to assess deeper groundwater basins that account for more than 95 percent of all groundwater used for public drinking water supply. The GAMA Priority Basin Project is grouped statewide into 35 groundwater basin groups called “study units,” and is being implemented by the SWRCB, the USGS, and the Lawrence Livermore National Laboratory.

The GAMA Priority Basin Project tests for constituents of concern in public supply wells. The list of constituents includes the following:

- Field Parameters.
- Organic Constituents.
- Pesticides.
- Constituents of Special Interest.
- Inorganic Constituents.
- Radioactive Constituents.
- Microbial Constituents.

For the San Joaquin River region, the USGS has completed data summary reports for the following study units.

- Madera/Chowchilla.
- Northern San Joaquin Valley.
- Central Eastside San Joaquin Valley.
- Sierra Nevada.
- Central Sierra.
- Western San Joaquin Valley.

These study units all reside in the San Joaquin River region with the exception of the Sierra Nevada and Western San Joaquin Valley Study Units. The Sierra Nevada Study Unit includes wells in the Sacramento River, San Joaquin River, Tulare Lake, and North Lahontan regions. The Western San Joaquin Valley Study Unit includes wells in the Tulare Lake and San Joaquin River regions.

For comparison purposes, groundwater quality results from these data summary reports were compared against public drinking water standards established by CDPH and/or the U.S. Environmental Protection Agency (EPA). These standards included primary MCLs, secondary maximum contaminant levels (SMCLs), notification levels (NLs), and lifetime health advisory levels (HALs). The summary of untreated groundwater quality results for these study units is shown on Table 8-17. In addition to these data summary reports, USGS has completed some Assessment Reports and Fact Sheets for the San Joaquin River region, listed in Table 8-13.

Table 8-17 Summary of Groundwater Quality Results from GAMA Data Summary Reports for the San Joaquin River Hydrologic Region

Constituent	Health-Based Threshold	Number of Detections Greater Than Health-Based Threshold						
		Northern SJV	Central Eastside SJV	Madera-Chowchilla	Western SJV[1] Delta-Mendota Subbasin	Sierra Nevada Study Unit[2]	Central Sierra	El Dorado County Domestic Wells[3]
Number of Wells		70	78	35	45	83	30	398
Microbial Contaminants								
Total Coliform	Presence							111
Fecal Coliform	Presence							14
Inorganic Constituents								
Aluminum	MCL							1
Antimony	MCL							2
Arsenic	MCL	3	4	4	5	5	6	15
Boron	NL	5			22	2		
Fluoride	MCL					1	2	
Molybdenum	HAL				3		3	
Nickel	MCL							1
Nitrate	MCL			2	9			7
Selenium	MCL				1	1		
Strontium	HAL		1	1	3			
Uranium	MCL		3	4	2	2	5	
Vanadium	NL		1	1				
Organic Constituents								
VOCs	MCL							1
Pesticides	MCL							
DBCP	MCL	2		3				
EDB	MCL	1		1				
Constituents of Special Interest								
Perchlorate	MCL							
NDMA	NL							
1,2,3 TCP	NL		3					

Constituent	Health-Based Threshold	Number of Detections Greater Than Health-Based Threshold						
		Northern SJV	Central Eastside SJV	Madera-Chowchilla	Western SJV[1] Delta-Mendota Subbasin	Sierra Nevada Study Unit[2]	Central Sierra	El Dorado County Domestic Wells[3]
Radioactive Constituents								
Gross Alpha	MCL			8		4	4	
Secondary Standards								
Aluminum	SMCL							26
Chloride[4]	SMCL	2	1	2	19			
Iron	SMCL	3	1		5	7	3	81
Manganese	SMCL	8	6	1	19	8	10	98
Sulfate[4]	SMCL	3			21			
Total Dissolved Solids[4]	SMCL	8	7	8	39	4		

Sources:
U.S. Geological Survey Report on Ground-Water Quality Data in the Northern San Joaquin Basin Study Unit, 2005; U.S. Geological Survey Report on Ground-Water Quality Data in the Central Eastside San Joaquin Basin 2006; U.S. Geological Survey Report on Ground-Water Quality Data in the Madera-Chowchilla Study Unit, 2008; U.S. Geological Survey Report on Ground-Water Quality Data in the Western San Joaquin Valley, 2010; U.S. Geological Survey Report on Ground-Water Quality Data for the Sierra Nevada Study Unit, 2008; U.S. Geological Survey Report on Ground-Water Quality Data in the Central Sierra Study Unit, 2006; State Water Resources Control Board Groundwater Ambient Monitoring and Assessment — Voluntary Domestic Well Assessment Project, El Dorado County Data Summary Report, 2005.

Notes:
HAL = lifetime health advisory level (U.S. Environmental Protection Agency), MCL = maximum contaminant level (State and/or federal), NL = notification level (State), SMCL = secondary maximum contaminant level (State), SJV = San Joaquin Valley, TDS = total dissolved solids, VOC = volatile organic compound

[a] The Western San Joaquin Valley Study Unit includes wells in the Tulare Lake and San Joaquin River hydrologic regions. Just those results from the Delta-Mendota subbasin in the San Joaquin River are shown.

[b] The Sierra Nevada Study Unit includes wells sampled in the Sacramento River, San Joaquin River, Tulare Lake, and North Lahontan hydrologic regions.

[c] The wells sampled in El Dorado County are located in the Sacramento River and San Joaquin River hydrologic regions.

[d] Wells that exceed secondary maximum contaminant levels for chloride, sulfate and total dissolved solids are greater than recommended levels.

Groundwater Quality at Domestic Wells

Private domestic wells are typically used by either single family homeowners or other groundwater-reliant systems not regulated by the State. Domestic wells generally tap shallower groundwater, making them more susceptible to contamination. Many domestic well owners are unaware of the quality of the well water because the State does not require well owners to test their water quality. Although private domestic well water quality is not regulated by the State, it is of concern to local health and planning agencies and to State agencies in charge of maintaining water quality.

In an effort to assess domestic well water quality, the SWRCB's GAMA Domestic Well Project samples domestic wells for commonly detected chemicals at no cost to well owners who voluntarily participate in the program. Results are shared with the well owners and used by the GAMA Program to evaluate the quality of groundwater used by private well owners. As of 2011, the GAMA Domestic Well Project had sampled 1,146 wells in six county Focus Areas (Monterey, San Diego, Tulare, Tehama, El Dorado, and Yuba counties).

The GAMA Domestic Well Project tests for chemicals most commonly a concern in domestic well water. These constituents include the following:

- Bacteria (total and fecal coliform).
- General minerals (sodium, bicarbonate, calcium, others).
- General chemistry parameters (pH, TDS, and others).
- Inorganics (lead, arsenic and other metals) and nutrients (nitrate, others).
- Organics (benzene, toluene, PCE, MTBE, and others).

In addition to the above constituents, the GAMA Domestic Well Project may analyze for locally known chemicals of concern. Some of these chemicals include radionuclides, perchlorate, pesticides, and chromium-VI.

In El Dorado County, the GAMA Domestic Well Project has sampled 398 private domestic wells located in the San Joaquin River and Sacramento River regions. For comparison purposes, groundwater quality results were contrasted with public drinking water standards established by CDPH. These standards included primary MCLs, SMCLs, and NLs. The untreated-groundwater-quality results include wells from both of the regions that make up El Dorado County and are summarized on Table 8-17.

Groundwater Quality Protection

In the Central Valley region a number of efforts are underway to protect groundwater quality. The Central Valley RWQCB has approved a Groundwater Quality Protection Strategy and is working on a comprehensive salt and nitrate management plan through Central Valley Salinity Alternatives for Long-Term Sustainability (CV-SALTS), which is a collaborative basin planning effort to address problems with salinity and nitrates in surface water and groundwater. These efforts are further discussed below.

Groundwater Quality Protection Strategy

In 2008, the Central Valley RWQCB started a public process to solicit information from stakeholders on groundwater quality protection concerns in the entire Central Valley Region, including the San Joaquin River region. In 2010, the Central Valley RWQCB approved the following recommended actions.

- Develop salt & nutrient management plan.

- Implement groundwater quality monitoring program.
- Implement groundwater protection programs through integrated regional water management (IRWM) plan groups.
- Broaden public participation in all programs.
- Coordinate with local agencies to implement well design & destruction program.
- Groundwater database.
- Alternative dairy waste disposal.
    - Develop individual and general orders for poultry, cattle feedlots, and other types of combined animal feeding operations.
- Implementation of long-term irrigated lands regulatory program (ILRP).
    - Coordinate with the California Department of Food and Agriculture (CDFA) to identify methods to enhance fertilizer program.
- Reduce site cleanup backlog.
- Draft waiver following recently adopted regulation based on AB 885.
    - Update guidelines for waste disposal for land developments.
- Develop methods to reduce backlog and increase facilities regulated.

Additional information on Central Valley RWQCB's groundwater quality protection strategy is available at http://www.waterboards.ca.gov/centralvalley/water_issues/groundwater_quality/index.shtml.

Salt and Nutrient Management Plans

The SWRCB's Recycled Water Policy was adopted in 2009 (Resolution No. 2009-0011) with a goal of managing salt and nutrients from all sources on a basin-wide or watershed-wide basis. This policy requires the development of regional or sub-regional salt and nutrient management plans for every groundwater basin/sub-basin in California, and each plan must include monitoring, source identification, and implementation measures.

Throughout the Central Valley, participating in the development of salt and nutrient management plans is of paramount importance to improve water quality in the region and provide for a sustainable economic and environmental future. The CV-SALTS is a strategic initiative to address problems with salinity and nitrates in surface water and groundwater in the Central Valley.

The long-term plan developed under CV-SALTS will require implementation of management measures aimed at the identification, reduction, and/or control of major sources of salt and nitrate. In addition, the plan will support those activities that alleviate known impairments to drinking water supplies. Since this issue affects all water users (stakeholders) in the Central Valley, it is important that all stakeholders participate in CV-SALTS to be part of developing the plan and having input regarding the implementation of salt and nitrate management in the Central Valley. Eventually, the salt and nitrate management plans will provide guidance for all of the Central Valley RWQCB's regulatory and non-regulatory programs on how to address salinity and nitrate concerns.

CV-SALTS will include basin plan amendments that establish regulatory structure, and policies to support basin-wide salt and nitrate management. The regulatory structure will have five key elements: (1) refinement of the agricultural supply, municipal and domestic supply, and groundwater recharge beneficial uses; (2) revision of water quality objectives for these uses; (3) establishment of policies for assessing compliance with the beneficial uses and water quality objectives; (4) establishment of management areas where there are large-scale differences in baseline water quality, land use, climate conditions, soil characteristics, and existing infrastructure, and where short- and long-term salt and/or nitrate management is needed; and (5) an overarching framework to provide consistency for the development of management plans in the management areas to facilitate implementation efforts and insure a sustainable future (CV-SALTS 2012a; CV-SALTS 2012b). Additional information on CV-SALTS is available at http://www.waterboards.ca.gov/centralvalley/water_issues/salinity/index.shtml and http://cvsalinity.org/.

Land Subsidence

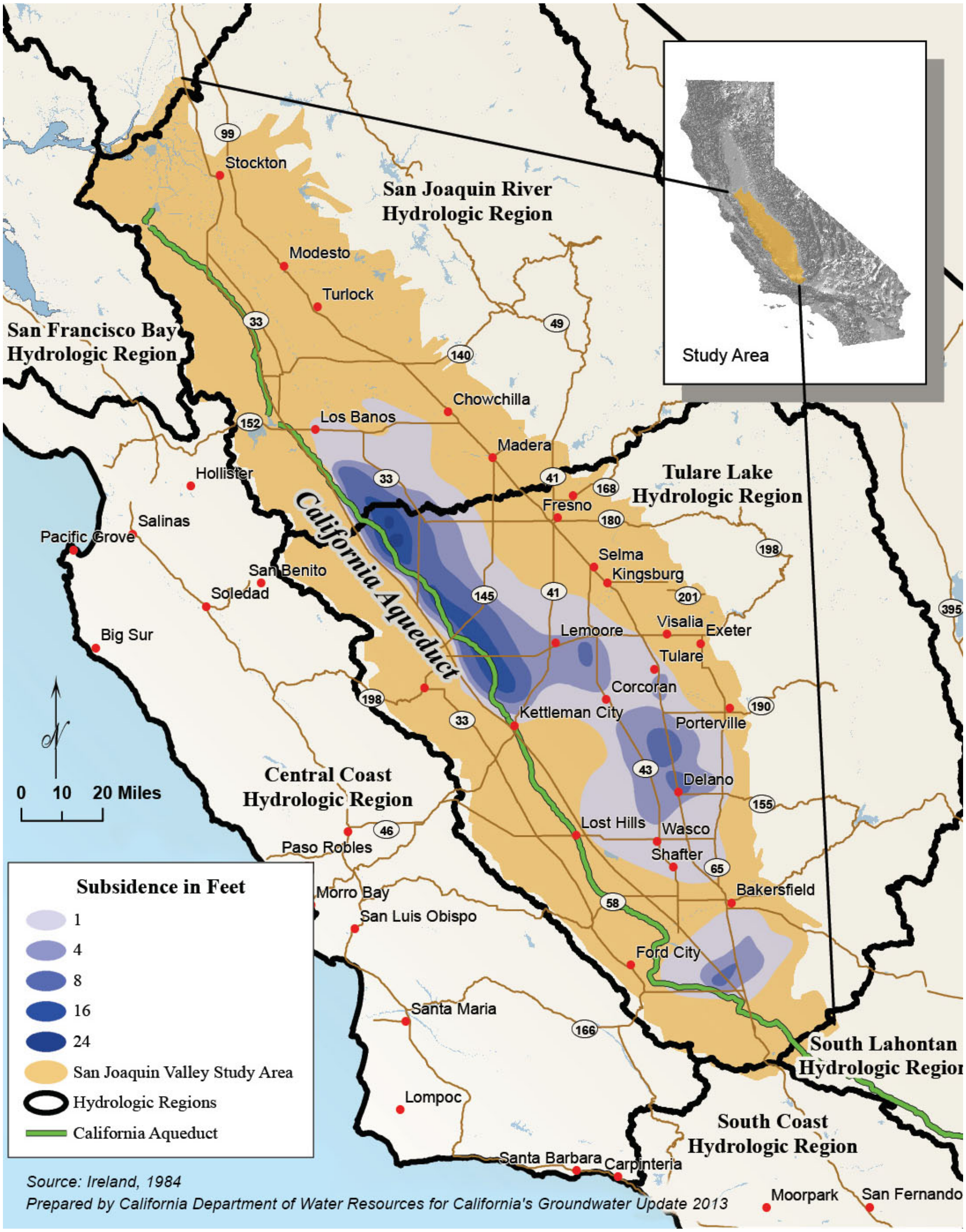
Although there are several kinds of land subsidence, the kind that has had the greatest economic affect in the San Joaquin River region is inelastic land subsidence caused by groundwater pumping from overdrafted aquifers. In a number of regions, available surface water supplies have failed to meet the water needs for farms and cities. The difference between water demand and water supply has generally been met by groundwater pumping.

Subsidence from groundwater pumping is not unique to the San Joaquin River region, and the effects extend broadly across much of the San Joaquin Valley into the adjoining Tulare Lake region. Additional discussion and region-specific information is contained in the “Tulare Lake Hydrologic Region” chapter of this report.

Land subsidence was first noted in the San Joaquin Valley in 1935 in the Delano area (Galloway et al. 1999). By the mid-1950s, land subsidence was a widely recognized problem, with the rapid subsidence on the west side of the valley being correlated with the rapid decline of confined aquifer pressure (Riley 1998). In 1955, about one-fourth of the total groundwater extracted for agricultural purposes in the United States was pumped from the San Joaquin Valley, and regional aquifer compaction was occurring at a rate of about 1-foot per year (Swanson 1995). As of 1960, water levels in the deep aquifer system were declining at a rate of about 10 feet per year (Galloway et.al. 1999).

In west Fresno County, during the highest pumping years of the 1960s, maximum subsidence exceeded 30 feet, and the regional ground surface was sinking at rates of 1.0 to 1.5 feet per year. By the late 1960s, more than 5,200 square miles of farmland, or one-half the entire San Joaquin Valley, had subsided by at least 1 foot (Ireland 1989). Figure 8-17 shows land subsidence within the San Joaquin Valley from 1926 to 1970, with the vast majority of subsidence occurring in the Tulare Lake region and in the southern central portion of the San Joaquin River region.

Figure 8-17 Land Subsidence in the San Joaquin Valley (1926 to 1970)



Surface water deliveries from the SWP and other regional conveyance facilities in the 1970s and 1980s significantly reduced the agricultural demand for groundwater. Between 1967 and 1974, groundwater levels in the deep aquifer recovered as much as 200 feet (Galloway et al. 1999). Although reduced groundwater pumping and imported surface water largely diminished the subsidence problem, subsidence still continued in some areas but at a slower rate, as a result of the time lag involved in the redistribution of pressures in the confined aquifers.

A combination of drought conditions, regulatory restrictions on imported surface water, increasing population, and an agricultural trend toward planting a greater number of permanent crops has incrementally led to a renewed reliance on groundwater pumping in the San Joaquin River region over the last few decades. In 1995, Swanson conducted a land subsidence update for the San Joaquin Valley and concluded that (1) subsidence is continuing in all subsidence areas but at lower rates than before the completion of the California Aqueduct, (2) subsidence centers have probably shifted to areas where groundwater pumping is concentrated, (3) subsidence rates are expected to increase in the near future because groundwater pumping replaces surface water diverted for environmental uses, and (4) subsidence may contribute to lost channel capacity and flooding in areas where these problems have been previously attributed entirely to other causes.

The west side of the San Joaquin Valley has experienced dramatic land changes from subsidence, both in the amount of decline in the land surface elevation and in the geographic extent involved. A surge in post-World War II farming activity resulted in a commensurate surge in deep well pumping from the confined aquifer, which exceeded the safe yield of the aquifer; as a result, groundwater levels declined.

Because of the higher amount of annual precipitation in 1983, groundwater levels across the valley rose, surface water supplies were abundant, and the need for groundwater pumping declined dramatically. As a result, fewer new wells were drilled. From 1987 through 1992, there was a surge in the number of new wells drilled; a reaction to the drought conditions. Wet years from 1995 to 1998 again provided sufficient surface water and fewer new wells were drilled. Beginning with the reduction in surface water supplies in 2007, farmers increased their use of groundwater to meet irrigation demand, which included increased pumping from existing deep wells and nearly tripling the number of new irrigation wells drilled. The consequences of additional groundwater pumping have been an intensification of declining water levels, a renewal of subsidence in areas where water levels declined below the historic low levels of 1967, and a spread of subsidence to areas formerly showing little or no subsidence.

Land subsidence investigations in the San Joaquin River region include various regional and local monitoring efforts (see the “Land Subsidence Monitoring” section). A discussion of the results from some of these land subsidence monitoring activities is provided below. Additional efforts to monitor, evaluate, and mitigate land subsidence are being conducted by some groundwater management groups in the region. Additional information regarding land subsidence in California is presented in Appendix F of this report.

California Aqueduct Subsidence

DWR performs periodic elevation surveys along the California Aqueduct to measure land subsidence effects along the canal and guide maintenance repairs as needed. DWR surveys compare elevations along portions of the aqueduct in Fresno and Kings County for years 2000, 2006, and 2009.

Figure 8-18 shows subsidence of as much as 0.8 feet from 2000 to 2009, with data showing an accelerated level of subsidence from 2006 to 2009.

Borehole Extensometer Data

There are seven active extensometers in the San Joaquin Valley being monitored for groundwater levels and land subsidence (Table 8-11). Extensometer 12S12E16H002M is the one extensometer in the San Joaquin River region being actively monitored by DWR. The extensometer site also includes groundwater-level monitoring wells constructed to monitor various depth intervals in the aquifer system.

USGS InSAR Monitoring

InSAR is a remote sensing tool that uses satellite radar signals to measure deformation of the Earth's crust at a high degree of spatial detail and measurement resolution (U.S. Geological Survey 2000). In cooperation with DWR and the U.S. Bureau of Reclamation, the USGS is currently evaluating 2007 to 2011 InSAR survey data for evidence of subsidence in the San Joaquin River region.

Preliminary InSAR survey results show two areas of subsidence within the greater San Joaquin Valley, one is in western Madera County and the second is a broad area in the central San Joaquin River region, located west of State Route 99 in Kings and Tulare counties. Data from the InSAR survey (January 2007 to March 2011) was in the process of being reviewed at the time of this report and the amount and rate of subsidence has not yet been determined.

Caltrans State Route 152 Elevation Monitoring

Caltrans periodically resurveys their network of existing benchmarks along key sections of highway. In 1972, 1988, and 2004, Caltrans surveyed a section of State Route 152 across the San Joaquin Valley from the San Luis Dam to State Route 99. The 2004 cross section shows the level of subsidence that has occurred in this area since the USGS subsidence studies in the 1960s. Figure 8-19 shows the location of the State Route 152 ground surface elevation survey and Figure 8-20 shows the cross section results of the survey.

Figure 8-20 shows that land subsidence at the western ends of the State Route 152 survey is negligible. However, moving toward the center of the valley near the San Joaquin River channel, a land subsidence trough of approximately 2.8 feet developed between 1972 and 1988. From 1988 to 2004, the rate of subsidence increased and the land subsided another 3.1 feet, approximately. The cumulative decline in land surface elevation between 1972 and 2004 was approximately 5.3 feet in this area. The extent and magnitude of land subsidence north and south of this cross section is unknown. Considering the 16 year cycle in between the three measurements, the next survey should be conducted by Caltrans in or about the year 2020.

Figure 8-18 Land Subsidence along the California Aqueduct in the San Joaquin River Hydrologic Region

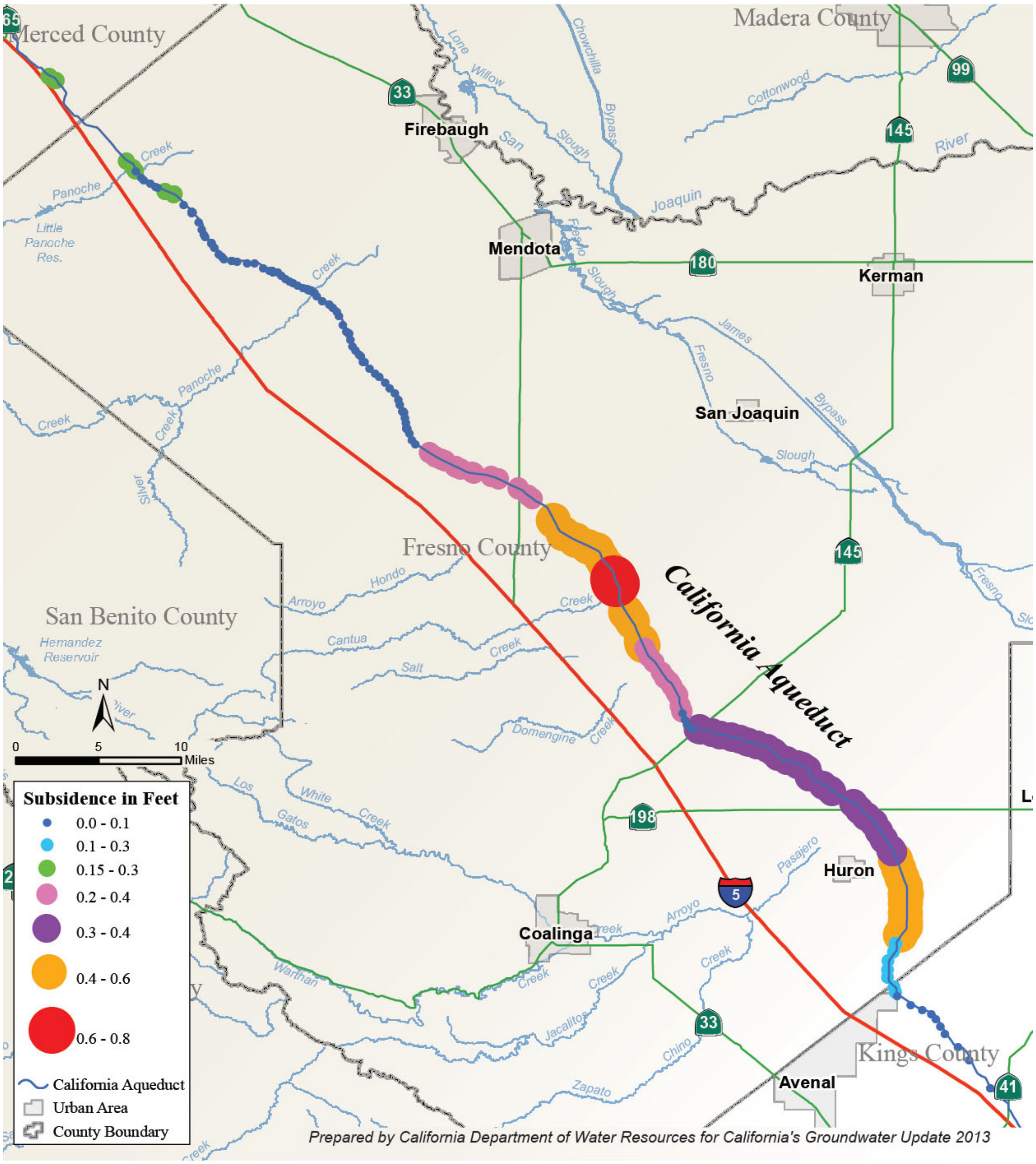


Figure 8-19 **Caltrans State Route 152 Ground Surface Elevation Survey**

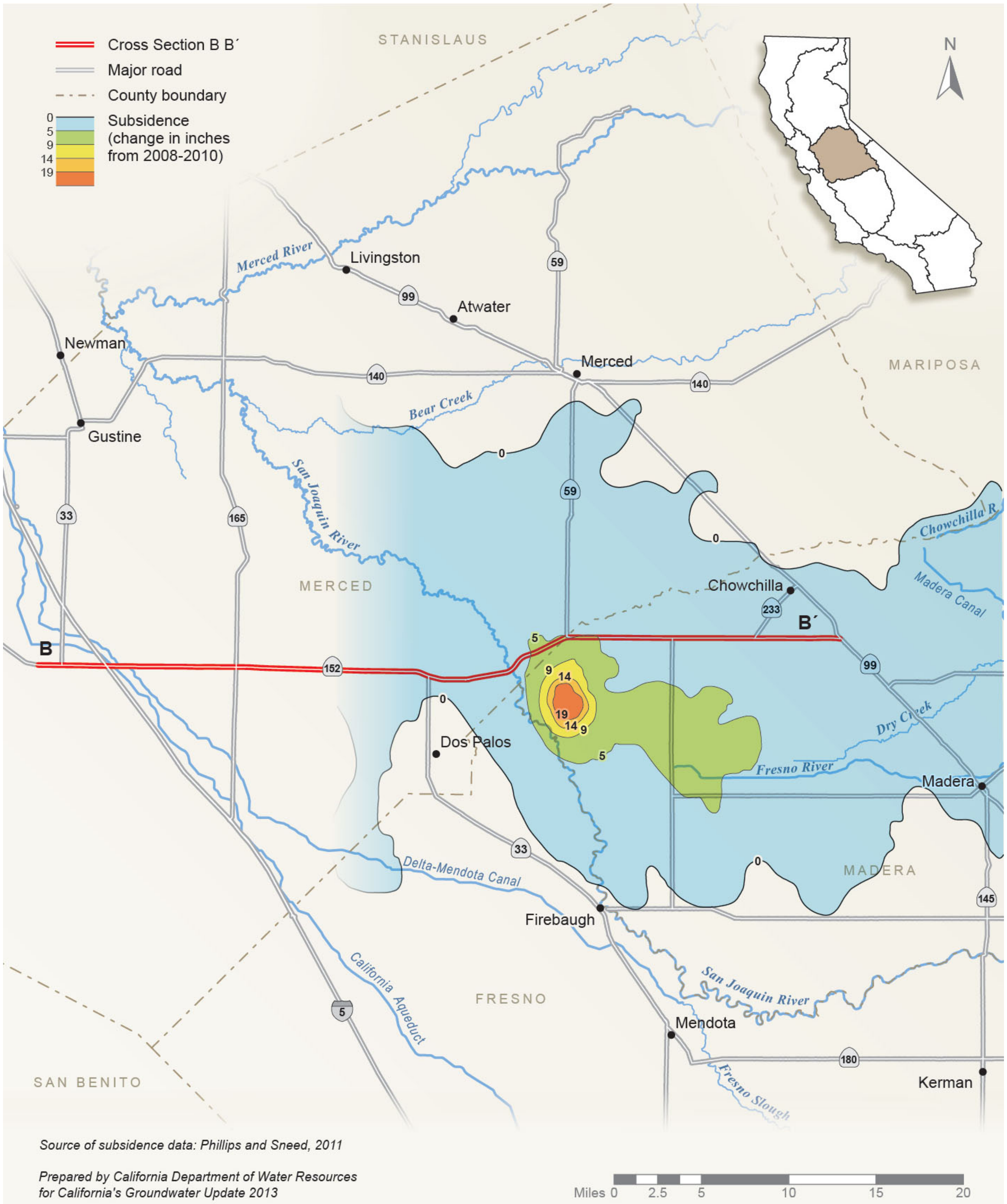
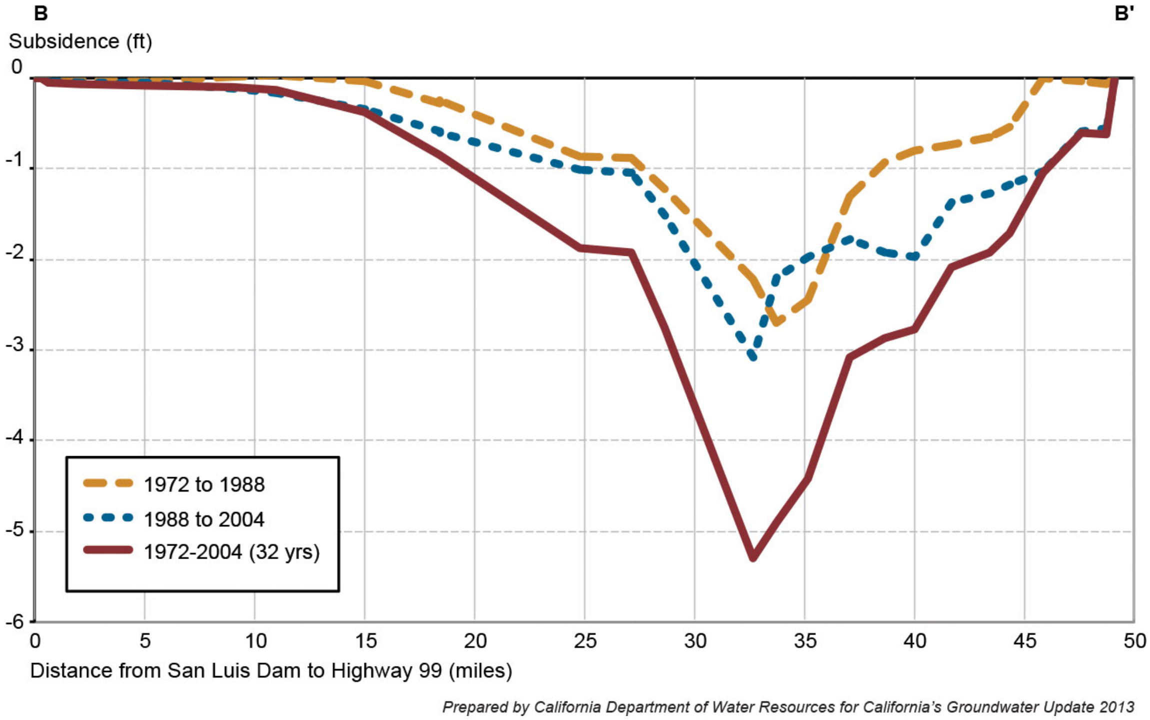


Figure 8-20 Land Subsidence Results from Caltrans State Route 152 Ground Surface Survey



GPS Array Monitoring

UNAVCO operates PBO and uses precision GPS monitoring sites for western United States plate tectonics studies. The UNAVCO GPS stations provide continuous monitoring of the land surface elevation, potentially providing a direct measurement of subsidence. Several of the stations are close to the edge of the valley and provide partial insight into the regional magnitude of subsidence, while others lie outside of areas susceptible to subsidence. However, a number of UNAVCO stations provide important information regarding changes in land surface for the San Joaquin Valley and the San Joaquin River region.

The locations of 13 UNAVCO San Joaquin Valley stations, along with graphical summaries of changes in ground surface elevation, are shown in Figure 8-21. A graph showing nearby depth to water beneath the Corcoran clay and the results from UNAVCO GPS Site P304 (near Mendota) is shown in Figure 8-22. Additional information regarding UNAVCO GPS monitoring results is available online at the UNAVCO Web site (http://pbo.unavco.org).

Many of the land surface displacement summary graphs in Figure 8-21 show a significant trend of declining land surface in the San Joaquin Valley. The graph in Figure 8-22 shows the correlation between the post-2007 decline in groundwater levels beneath the Corcoran clay and the decline in land surface elevations near Mendota. Between 2007 and 2010, groundwater levels in the Mendota area have declined by approximately 30 feet, while the vertical displacement in the land surface has followed with a decline of about 0.2 feet.

Figure 8-21 UNAVCO GPS Land Surface Displacement Monitoring Stations and Station Data Summary Graphs

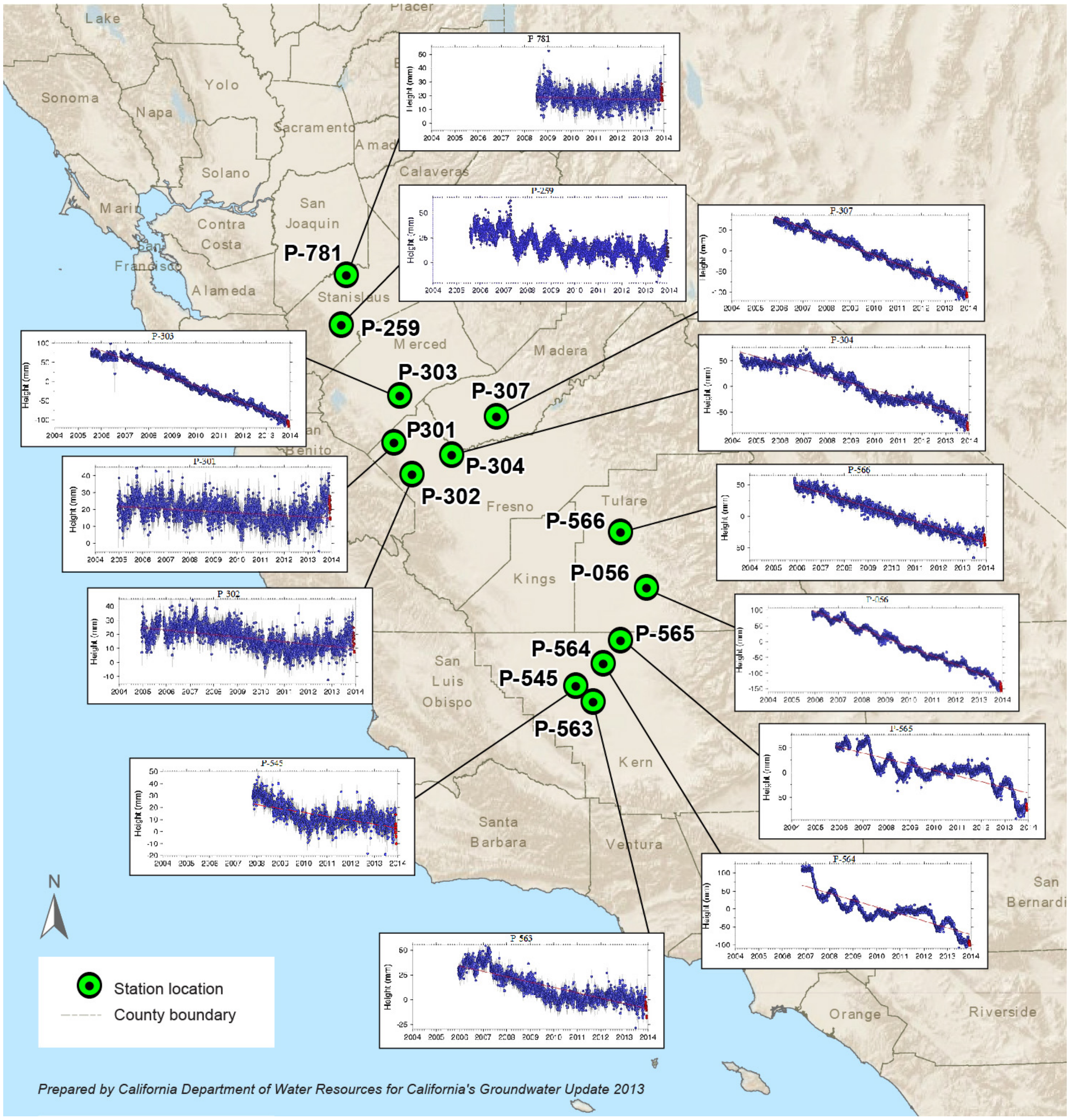


Figure 8-22 Depth to Water and Vertical Land Surface Displacement at UNAVCO GPS Site 304, near Mendota

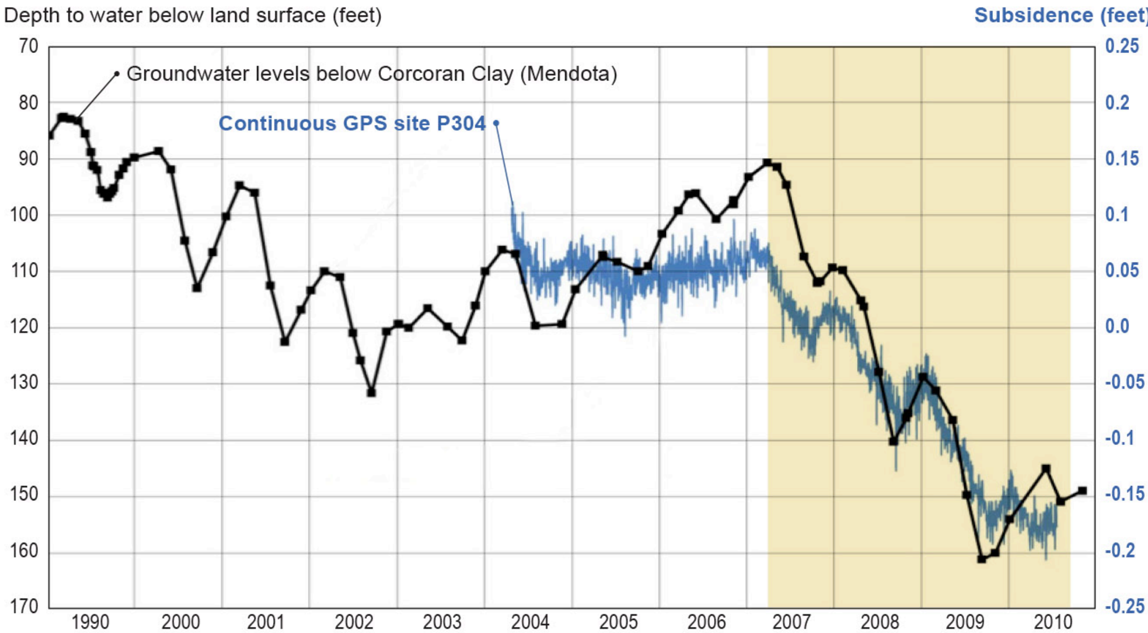


Figure Source: USGS 2011 presentation on Central Valley subsidence. Land surface elevation data from UNAVCO Station 304; depth to water data provided by Luhdorff and Scalmanini Consulting Engineers).

Groundwater-Level Monitoring and Subsidence

As shown in Figure 8-22, the rate, extent, and type (elastic versus inelastic) of land subsidence is directly related to the rate and extent of declining groundwater levels. In areas of that have undergone historic subsidence, the threat for renewed subsidence is commonly considered to be minimized if current groundwater levels can me maintained above historic lows.

Droughts in 2007 and 2008 and the court settlement of San Joaquin River water rights resulted in reduced surface water allocations for irrigation. The consequence was an increased reliance on groundwater to meet water needs, including the reactivation of old wells and an increase in the number of new wells drilled. It is anticipated that with the renewed increase in groundwater pumping, dropping water levels would cause a recurrence in land subsidence. Several elevation surveys by Caltrans have showed the effects of subsidence, not just from the recent period of renewed pumping and well drilling, but from typical (or normal) groundwater use. These surveys showed that subsidence has progressed into areas that had previously shown a more subdued response to pumping.

Groundwater pumping at rates and volumes that far exceed natural aquifer recharge, or the ability to actively recharge via conjunctive management practices, has resulted in a long-term economic boom for California's agriculture economy and allowed the San Joaquin Valley to become one of the world's most productive agricultural regions. These economic benefits have not gone without a broader cost to the infrastructure affected by land subsidence, to the quantity and quality of groundwater resources, to the increased energy required to pump groundwater, and to the decline in ecosystem services provided by the interaction of groundwater-surface water resources. In water-short regions, implementing effective groundwater management can be extremely challenging. Local water resource managers in the region currently utilize conjunctive management and water conservation measures to help reduce unsustainable demands on the aquifer systems; however, in many cases, groundwater levels continue to decline and evidence of renewed land subsidence remains. Existing agricultural and urban development should critically evaluate the broader and longer-term costs associated with unsustainable groundwater pumping, and take more aggressive actions to adjust water resource management and land use practices to help mitigate the escalation of future affects. Additional information regarding land subsidence in California is provided in Appendix F.

Groundwater Management

In 1992, the California Legislature provided an opportunity for formal groundwater management with the passage of AB 3030, the Groundwater Management Act (California Water Code Section 10750 et seq.). Groundwater management, as defined in DWR's Bulletin 118-2003, is "the planned and coordinated monitoring, operation, and administration of a groundwater basin, or portion of a basin, with the goal of long-term groundwater resource sustainability." Groundwater management needs are generally identified and addressed at the local level in the form of GWMPs. If disputes over how groundwater should be managed cannot be resolved at the local level, additional actions, such as enactment of ordinances by local entities with jurisdiction over groundwater, passage of laws by the Legislature, or decisions made by the courts (basin adjudications) may be necessary to resolve the conflict. Under current practice, DWR's role in groundwater management is to provide technical and financial assistance to support local agencies in their groundwater management efforts.

In addition to AB 3030, additional enacted legislation includes SB 1938, AB 359, and provisions of SB X7-6 and AB 1152. These significant pieces of legislation establish, among other things, specific procedures on how GWMPs are to be developed and adopted by local agencies. They define the required and voluntary technical components that must be part of a GWMP and CASGEM groundwater elevation monitoring plan. Assembly Bill 359, introduced in 2011, made changes to the California Water Code that, among other things, requires local agencies to provide a copy of their GWMP to DWR and requires DWR to provide public access to those plans. Prior to the passage of AB 359, which went into effect on January 1, 2013, local groundwater management planning agencies were not required to submit their GWMPs to DWR. As such, the groundwater management information included in this report is based on documents that were readily available or submitted to DWR as of August 2012 and may not be all-inclusive, especially for those plans that were in the process of being finalized and adopted in 2012.

Groundwater management in California also occurs through other resource planning efforts. Urban water management plans (UWMPs) incorporate long-term resource planning to meet existing and future water demands. Agriculture water management plans (AWMPs) advance irrigation efficiency that benefits both farms and the environment. IRWM planning is a collaborative effort to regionally identify and align all aspects of water resource management and planning. Given California's reliance on groundwater to meet municipal, agricultural, and environmental needs, developing a thorough understanding of the planning, implementation, and effectiveness of existing groundwater management in California is an important first step toward sustainable management of this valuable resource.

DWR's Groundwater Web site (http://water.ca.gov/groundwater/) has the most recent information on California's groundwater management planning efforts and includes a summary of the Sustainable Groundwater Management Act that was enacted in September 2014. The Sustainable Groundwater

Management Act, a three-bill legislative package, includes the provisions of SB 1168 (Pavley), AB 1739 (Dickinson), and SB 1319 (Pavley), which requires the formation of locally controlled groundwater sustainability agencies in high- and medium-priority groundwater basins with the goal of sustainably managing local groundwater resources. Many of the newly established components in the Sustainable Groundwater Management Act are based on the required, voluntary, and recommended groundwater management components assessed in the following sections.

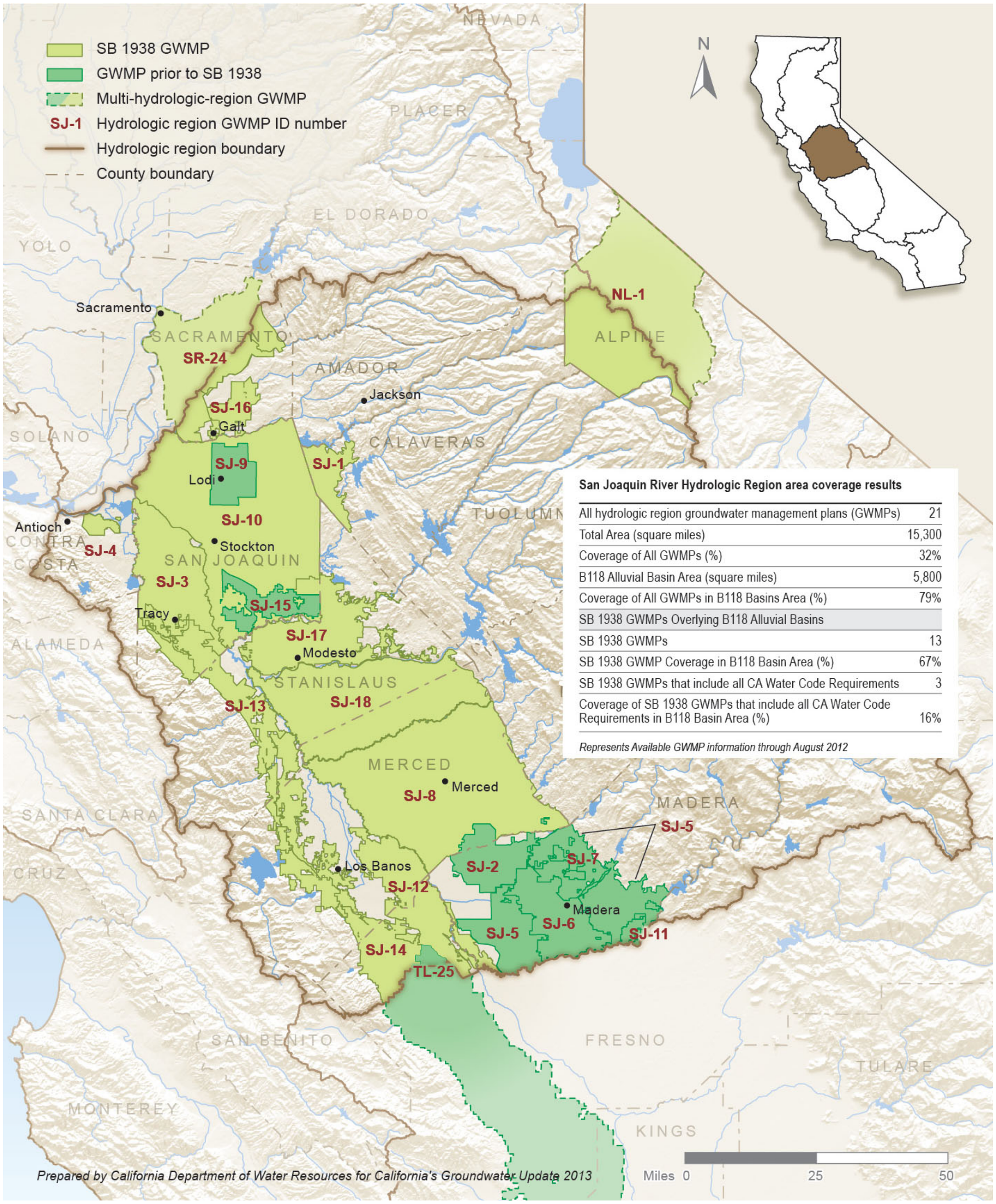
The following sections provide an inventory and assessment of GWMPs, groundwater basin adjudications, county ordinances, and other groundwater planning activities in the San Joaquin River region.

Groundwater Management Plan Inventory

Groundwater management information included in this study is based on GWMP documents that were readily available or submitted to DWR as of August 2012. The inventory of GWMPs identifies adopting and signatory agencies, the date of plan adoption, the location of plans by county, and the groundwater basins the plans cover. The inventory also identifies how many of the GWMPs were developed based on 1992 AB 3030 legislation and how many were developed or updated to meet the additional groundwater management requirements associated with the 2002 SB 1938 legislation.

The San Joaquin River region includes about 5,800 square miles of Bulletin 118-2003 alluvial groundwater basins. Figure 8-23 shows the location and distribution of the GWMPs within the San Joaquin River region and indicates pre- versus post-SB 1938 GWMPs. Table 8-18 lists the results of the GWMP inventory for the region by adopting agency, signatories, plan date, and groundwater basin. There are 21 submitted GWMPs within the San Joaquin River region. Collectively, the 21 GWMPs cover about 79 percent of the Bulletin 118-2003 alluvial basin area within the region, and about 32 percent of the overall regional area.

Figure 8-23 Groundwater Management Plans in the San Joaquin River Hydrologic Region



San Joaquin River Hydrologic Region area coverage results

All hydrologic region groundwater management plans (GWMPs)	21
Total Area (square miles)	15,300
Coverage of All GWMPs (%)	32%
B118 Alluvial Basin Area (square miles)	5,800
Coverage of All GWMPs in B118 Basins Area (%)	79%
SB 1938 GWMPs Overlying B118 Alluvial Basins	
SB 1938 GWMPs	13
SB 1938 GWMP Coverage in B118 Basin Area (%)	67%
SB 1938 GWMPs that include all CA Water Code Requirements	3
Coverage of SB 1938 GWMPs that include all CA Water Code Requirements in B118 Basin Area (%)	16%

Represents Available GWMP information through August 2012

Table 8-18 **Groundwater Management Plans in the San Joaquin River Hydrologic Region**

Map Label	Agency Name	Date	County	Basin Number	Basin Name
SJ-1	**Calaveras County Water District**	2007	Calaveras	5-22.01	Eastern San Joaquin Subbasin
	No signatories on file				
SJ-2	**Chowchilla Water District-Red Top Resource Conservation District Joint Powers Authority**	1997	Madera	5-22.05	Chowchilla Subbasin
	No signatories on file		Merced	5-22.04	Merced
SJ-3	**City of Tracy**	2007	San Joaquin	5-22.15	Tracy Subbasin
	Banta Carbona Irrigation District				
	Del Puerto Water District				
	Patterson Water District				
	Plain View Water District				
	West Stanislaus Irrigation District				
	Westside Irrigation District				
	San Joaquin County Flood Control & Water Conservation District				
SJ-4	**Diablo Water District**	2007	Contra Costa	5-22.15	Tracy Subbasin
	City of Brentwood				
	Town of Discovery Bay				
	East Contra Costa Irrigation District				
SJ-5	**Madera County**	1997	Madera	5-22.06	Madera Subbasin
	Chowchilla Water District-Red Top Resource Conservation District JPA				
	San Joaquin River Exchange Contractors Water Authority				
	Madera Irrigation District				
	Gravelly Ford Water District				
	Madera Water District				
	Aliso Water District				

Map Label	Agency Name	Date	County	Basin Number	Basin Name
	Root Creek Water District				
SJ-6	**Madera Irrigation District**	1999	Madera	5-22.06	Madera Subbasin
	No signatories on file				
SJ-7	**Madera Water District**		Madera	5-22.06	Madera Subbasin
	No signatories on file				
SJ-8	**Merced Area Groundwater Pool Interests (MAGPI)**	2008	Merced	5-22.04	Merced Subbasin
	Stevinson Water District			5-22.05	Chowchilla Subbasin
SJ-9	**North San Joaquin Water Conservation District**	1995	San Joaquin	5-22.01	Eastern San Joaquin Subbasin
	No signatories on file			5-22.16	Cosumnes Subbasin
SJ-10	**Northeastern San Joaquin County Groundwater Banking Authority**	2004	San Joaquin	5-22.01	East San Joaquin Subbasin
	City of Lodi			5-22.16	Cosumnes Subbasin
	Woodbridge Irrigation District				
	North San Joaquin Water Conservation District				
	Central San Joaquin Water Conservation District				
	Stockton East Water District				
	Central Delta Water Agency				
	South Delta Water Agency				
	San Joaquin County Flood Control and Water Conservation District				

	California Water Service Company				
	San Joaquin Farm Bureau Federation				
SJ-11	**Root Creek Water**	1997	Madera	5-22.06	Madera Subbasin
	No signatories on file				
SJ-12	**San Joaquin River Exchange Contractors Water Authority**	2008	Madera	5-22.07	Delta-Mendota Subbasin
	Central California Irrigation District		Stanislaus		
	Firebaugh Canal Water District		Merced		
	Columbia Canal Company		Madera		
	San Luis Canal Company				
SJ-13, 14	**San Luis and Delta Mendota Water Authority-North and South**	2007	Merced	5-22.15	Tracy Subbasin
	Banta Carbona Irrigation District		Stanislaus	5-22.07	Delta-Mendota Subbasin
	Del Puerto Water District		San Joaquin		Non-B118 Basin
	Patterson Irrigation District		Merced		
	Byron-Bethany Irrigation District (just the CVPSA)				
	West Stanislaus Irrigation District				
	Westside Irrigation District				
	City of Tracy				
	San Joaquin County Flood Control and Water Conservation District				
	Panoche Water District	2009			
	Eagle Field Water District				
	Oro Loma Water District				
	Widren Water District				
	Mercy Springs Water District				
	Broadview Water District				
	San Luis Water District				
SJ-15	**South San Joaquin Irrigation District**	1994	San Joaquin	5-22.01	Eastern San Joaquin Subbasin

	No signatories on file				
SJ-16	**Southeast Sacramento County Agricultural Water Authority**	2002	Sacramento		
	Clay Water District		San Joaquin	5-22.16	Cosumnes Subbasin
	Omochumne-Hartnell Water District			5-21.65	South American Subbasin
SJ-17	**Stanislaus and Tuolumne Rivers Groundwater Basin Association**	2005	Stanislaus	5-22.02	Modesto Subbasin
	Oakdale Irrigation District			5-22.01	East San Joaquin Subbasins
	Modesto Irrigation District				
	Stanislaus County				
	City of Riverbank				
	City of Modesto				
	City of Oakdale				
SJ-18	**Turlock Groundwater Basin Association**	2008	Stanislaus	5-22.03	Turlock Subbasin
	City of Turlock		Merced		
	City of Ceres				
	City of Modesto				
	Hilmar County Water District				
	Denair Community Services District				
	Eastside Water District				
	Ballico-Cortez Water District				
	Turlock Irrigation District				
	Keyes Community Services District				
	Delhi County Water District				
NL-1	**Alpine County**	2007	Alpine	6-6	Carson Valley Basin
	No signatories on file				Non-B118 Basin
TL-25	**Westlands Water District**	1996	Fresno	5-22.09	Westside Subbasin
	No signatories on file		Kings		
SR-24	**Sacramento Central County Water Agency**	2006	Sacramento	5-21.65	South American Subbasin

	City of Elk Grove			5-22.16	Cosumnes
	City of Folsom				
	City of Rancho Cordova				
	City of Sacramento				
	County of Sacramento				

Notes:
CVPSA = Central Valley Project Service Area
Table reflects the plans that were received by August 2012.

The inventory and assessment of GWMPs in the San Joaquin River region determined that 13 of the 21 GWMPs have been developed or updated to include the SB 1938 requirements and are considered "active" for the purposes of the GWMP assessment. The 13 active GWMPs cover about 67 percent of the Bulletin 118-2003 alluvial basin area. Detailed review of the GWMPs in the San Joaquin River region indicates that 3 of the 21 GWMPs cover all of the California Water Code requirements for groundwater management. These three GWMPs cover 16 percent of the alluvial basin area in the region.

As previously discussed in this chapter, approximately 19 percent of California's average annual groundwater extraction comes from the San Joaquin River region. Seven of the region's groundwater subbasins are identified as high-priority and two subbasins are considered medium-priority under CASGEM Basin Prioritization efforts. These high- and medium-priority basins account for more than 99 percent of the annual groundwater use within the region and about 99 percent of the 2010 population living within the groundwater basin boundaries.

Groundwater Management Plan Assessment

In 2011 and 2012, DWR partnered with the Association of California Water Agencies (ACWA) to survey local water agencies about their groundwater management, conjunctive management, and water banking practices to build a better understanding of existing groundwater management efforts in California. In addition to the information gleaned from the DWR/ACWA groundwater management survey, DWR independently reviewed the GWMPs to assess the following:

- How many of the post-SB 1938 GWMPs (2002) meet the six required components included in SB 1938 and incorporated into California Water Code Section 10753.7.
- How many of the post-SB 1938 GWMPs include the 12 voluntary components included in California Water Code Section 10753.8.
- How many of the implementing or signatory GWMP agencies are actively implementing the seven recommended components listed in DWR Bulletin 118-2003.

Groundwater management planning information collected through the DWR/ACWA survey and through DWR's assessment is not intended to be punitive in nature. It is widely understood that the application of effective groundwater management in California is ripe with jurisdictional, institutional, technological, and fiscal challenges. DWR is committed to assisting local agencies in developing and implementing effective, locally-planned, and locally-controlled groundwater management programs. DWR is also committed to helping promote State and federal partnerships, and coordinating with local agencies to expand groundwater data collection, management, and planning activities that promote sustainable local groundwater management. The overall intent of the GWMP assessment is to help identify groundwater management challenges and successes, and provide recommendations for local and statewide improvement.

As previously mentioned, information associated with the GWMP assessment is based on data that were readily available or received through August 2012. Requirements associated with the 2011 AB 359 (Huffman) legislation, related to groundwater recharge mapping and reporting, did not take effect until January 2013 and are not included in the GWMP assessment effort conducted as part of *California Water Plan Update 2013*. The following information will address the active plans determined by DWR to meet some or all of the SB 1938 requirements.

Required GWMP Components

California Water Code Section 10753.7 requires that six components be included in a GWMP for an agency to be eligible for state funding administered by DWR for groundwater projects, including projects part of an IRWM program or plan. The required components of a GWMP include the following:

1. **Basin Management Objectives (BMOs)**: BMOs include components relating to the monitoring and management of groundwater levels in the groundwater basin, groundwater quality degradation, inelastic land surface subsidence, changes in surface flow and surface water quality that directly affect groundwater levels or quality or are caused by groundwater pumping in the basin, and a description of how recharge areas identified in the plan substantially contribute to the replenishment of the groundwater basin.
2. **Agency Cooperation**: The plan will involve other agencies that enable the local agency to work cooperatively with other public entities whose service area or boundary overlies the groundwater basin.
3. **Mapping**: The plan will include a map that details the area of the groundwater basin, as defined in DWR's Bulletin 118-2003, and the area of the local agency subject to the plan, as well as the boundaries of other local agencies that overlie the basin in which the agency is developing a GWMP.
4. **Recharge Areas**: Commencing January 1, 2013, the GWMP shall include a map identifying the recharge areas for the groundwater basin, and provide the map to the appropriate local planning agencies and all interested persons, after adoption of the GWMP.
5. **Monitoring Protocols**: The local agency shall adopt monitoring protocols designed to detect changes in groundwater levels, groundwater quality, inelastic surface subsidence (in basins for which subsidence has been identified as a potential problem), and flow and quality of surface water that directly affect groundwater levels or quality or are caused by groundwater pumping in the basin.
6. **GWMPs Located Outside Bulletin 118 Groundwater Basins**: Plans located outside the DWR Bulletin 118-2003 alluvial groundwater basins will incorporate the above components and shall use geologic and hydrologic principles appropriate to those areas.

Three of the above components contain required subcomponents that were also evaluated. The requirement to develop a map of recharge areas was not required until January 1, 2013, and was consequently not evaluated. The requirement for local agencies located outside a Bulletin 118-2003 recognized groundwater basin was applicable for three of the GWMPs in the San Joaquin River region; all three of these plans have boundaries that extend into areas outside the groundwater basins, but the plans primarily focus on the alluvial areas.

Overall, DWR determined that 3 of the 13 active GWMPs incorporated all of the required components evaluated. Table 8-19 identifies the percentage of the 13 active plans meeting the required components and subcomponents listed in California Water Code Section 10753.7. A detailed description of the individual component assessment is provided below.

Basin Management Objectives

The basin management objectives (BMOs) assessment consists of four required subcomponents that were individually assessed. The subcomponents include the monitoring and management of (1) groundwater levels, (2) groundwater quality, (3) inelastic land subsidence, and (4) surface water and groundwater interaction. Seven of the 13 GWMPs met the overall BMO requirement by providing measurable objectives and actions that will occur when specific conditions are met for each of the BMO subcomponents. Four active GWMPs did not meet the overall BMO component, but did have the required information for one or more of the required BMO subcomponents. As a result, the GWMP was found to be in partial compliance. The remaining two active GWMPs did not meet any of the BMO subcomponents.

The most common BMO subcomponent missing or not adequately addressed in the 13 active GWMPs is the planning requirements for the monitoring and management of surface water and groundwater interaction. The majority of the assessed GWMPs in the San Joaquin River region mentioned this requirement, but did not describe how such a program would be initiated, measured, and managed.

Agency Cooperation

The GWMPs are required to provide details about how they intend to involve and work cooperatively with other public entities whose service area or boundary overlies the groundwater basin. The GWMP assessment revealed that 12 of 13 plans met the agency cooperation component. The remaining active GWMP did not provide sufficient details to meet this component.

Mapping

The mapping requirement of SB 1938 has three subcomponents. GWMPs are required to provide one or more maps which depict the GWMP area, the associated Bulletin 118-2003 groundwater basin(s), and all neighboring agencies located in the basin(s). The GWMP assessment determined that 9 of 13 plans met all three of the requirements for mapping, while two active GWMPs did not provide one or more of the required components. The remaining two active GWMPs did not meet any of the mapping subcomponents.

Table 8-19 Assessment of GWMP Required Components in the San Joaquin River Hydrologic Region

Senate Bill 1938 Required Components	Percentage of Plans that Meet Requirement
Basin Management Objectives	54%
BMO: Monitoring/Management Groundwater Levels	85%
BMO: Monitoring Groundwater Quality	85%
BMO: Inelastic Subsidence	77%
BMO: SW/GW Interaction and Affects to	62%

Senate Bill 1938 Required Components	Percentage of Plans that Meet Requirement
Groundwater Levels and Quality	
Agency Cooperation	92%
Map	69%
Map: Groundwater basin area	77%
Map: Area of local agency	77%
Map: Boundaries of other local agencies	77%
Recharge Areas (January 1, 2013)	Not Assessed
Monitoring Protocols	31%
MP: Changes in groundwater levels	100%
MP: Changes in groundwater quality	100%
MP: Subsidence	69%
MP: SW/GW Interaction and Affects to Groundwater Levels and Quality	38%
Met all required components, and subcomponents:	23%

Note:
GW = groundwater, GWMP = groundwater management plan, SW = surface water
Table reflects assessment results of Senate Bill 1938 plans that were received by August 2012.

Monitoring Protocols

The monitoring protocol component consists of four subcomponents. In accordance with the requirements of SB 1938, GWMPs are required to establish monitoring protocols for assessing groundwater levels, groundwater quality, inelastic land subsidence, and surface water and groundwater interaction.

The overall results of the assessment for the monitoring protocols component are similar to the BMO component. The monitoring protocols assessment determined that 4 of 13 active GWMPs met each of the required monitoring protocol subcomponents. The remaining nine active plans did not provide the details for one or more of the four subcomponents. Of the active plans, all 13 met the monitoring protocol requirements for measuring groundwater levels and groundwater quality, while nine active plans included monitoring protocols for inelastic subsidence.

The analysis of the GWMPs determined that eight plans did not identify activities to evaluate surface water and groundwater interaction. Specifically, these GWMPs did not develop sufficient monitoring protocols that would help ensure correctness and consistency when measuring, recording, and presenting field data. Four of the plans that failed to provided monitoring protocols for the surface and groundwater interaction also did not sufficiently establish BMOs or identify the necessary management actions that would be implemented in the event that BMOs were exceeded.

Voluntary GWMP Components

In addition to the six required components, Water Code Section 10753.8 provides a list of 12 components that may be included in a GWMP. The voluntary components include:

1. The control of saline water intrusion.
2. Identification and management of wellhead protection areas and recharge areas.
3. Regulation of the migration of contaminated groundwater.
4. The administration of a well abandonment and well destruction program.
5. Mitigation of conditions of overdraft.
6. Replenishment of groundwater extracted by water producers.
7. Monitoring of groundwater levels and storage.
8. Facilitating conjunctive use operations.
9. Identification of well construction policies.
10. The construction and operation by the local agency of groundwater contamination cleanup, recharge, storage, conservation, water recycling, and extraction projects.
11. The development of relationships with State and federal regulatory agencies.
12. The review of land use plans and coordination with land use planning agencies to assess activities which create a reasonable risk of groundwater contamination.

The percentage of GWMPs in the San Joaquin River region that included the voluntary components is shown on Table 8-20. The assessment of some voluntary components was expanded to include subcomponents, which aided in determining a level of inclusion; however, reporting was not done on a subcomponent level. In many cases, if the GWMP included one of more of the subcomponents, the plan was considered to fully meet the voluntary component.

Table 8-20 shows that wellhead protection and recharge and conjunctive topics use are represented in greater than 90 percent of the active GWMPs in the region. This is followed by information related to groundwater contamination, well abandonment and destruction, overdraft, groundwater monitoring, and regulatory agencies in over 80 percent of the plans.

Table 8-20 Assessment of GWMP Voluntary Components in the San Joaquin River Hydrologic Region

Voluntary Components	Percent of Plans that Include Component
Saline Intrusion	69%
Wellhead Protection and Recharge	92%
Groundwater Contamination	85%
Well Abandonment and Destruction	85%
Overdraft	85%
Groundwater Extraction and Replenishment	77%
Monitoring	85%
Conjunctive Use Operations	92%
Well Construction Policies	77%
Construction and Operation	54%
Regulatory Agencies	85%
Land Use	62%

Note:
Table reflects assessment results of Senate Bill 1938 plans that were received by August 2012.

The least-included of the voluntary components was consideration of construction and operation of groundwater contamination cleanup, recharge, storage, conservation, water recycling, and extraction projects. It is not clear from the plan reviews if the low percentage was attributed to timing of the GWMP development versus implementation, or if the agencies felt that documentation of this component was not pertinent or needed. Based on DWR's discussions with a few agencies around the state, it was apparent that agencies do not regularly update their GWMP as new projects are implemented. Thus, it is likely that the construction and operation of many existing projects have not been listed in the most recent GWMP document.

Groundwater extraction and replenishment, well construction policies, saline intrusion, and land use were not included in at least three and perhaps as many as five plans. In this case it appears the agencies did not consider the component a significant enough problem in their basin to warrant extensive planning activities or the issues were being managed externally to the GWMP.

Subsequent communications with agencies regarding omissions in GWMPs concerning the well abandonment and destruction component and the well construction component revealed that they were not discussed because the agency felt that existing county, State, and federal rules met the requirement. Unfortunately, GWMPs often do not mention reliance on external polices and ordinances to meet local groundwater management objectives. Effectively communicating how components of local groundwater management are being implemented was a challenge for many GWMPs throughout the state.

Bulletin 118-2003 Recommended GWMP Components

Bulletin 118-2003 contains suggestions on how GWMPs should be developed and provides details that should be included during development of a plan. Bulletin 118-2003, Appendix C provides a list of seven recommended components related to management, development, implementation, and evaluation of a GWMP that should be considered to help ensure effective and sustainable groundwater management. A summary of Bulletin 118-2003 recommended components include:

1. **Guidance:** Establish an advisory committee to assist in GWMP development and implementation.
2. **Management Area:** Describe the physical setting, aquifer characteristics, and background data.
3. **BMOs, Goals, and Actions:** Describe how the current or planned actions help to meet the overall management objectives and goals.
4. **Monitoring Plan Description:** Describe groundwater monitoring type, location, frequency, and aquifer interval.
5. **IRWM Planning:** Describe efforts to coordinate with other land use or water management planning.
6. **Implementation:** Develop status reports with management actions, monitoring activities, basin conditions, and achievements.
7. **Evaluation:** Periodic Assessment of conditions versus management objectives.

The percentage of GWMPs in the San Joaquin River region that included the recommended components is shown on Table 8-21. Six of the 13 active GWMPs in the San Joaquin River region included all seven of the Bulletin 118-2003 recommended components. Two additional plans partially met one or more of the recommended components while fully meeting the remaining components. Four GWMPs did not provide the necessary details for one or more of the components. The remaining GWMP did not provide any of the recommended components in the plan. However, many of the GWMPs did not sufficiently incorporate the Bulletin 118-2003 recommendation for a groundwater monitoring plan description. Eight of the 13 active GWMPs provided a description of their groundwater monitoring plan. Recommendations provided in Bulletin 118-2003 identify how monitoring plan descriptions should include maps showing sites used for monitoring and descriptions of the type of monitoring and measurements, along with the site-specific information. The GWMPs that did not provide an adequate groundwater monitoring plan description indicated that various aspects of monitoring are shared or provided by other organizations, or identified concerns about maintaining the privacy of participating landowners. Continued implementation of the CASGEM groundwater-level monitoring program may serve to resolve this common challenge. Establishing committees to assist in developing a GWMP was identified in 12 of the 13 plans. It is also the case for adequately defining the management area that the GWMP covers. It should be noted that 8 of the 13 GWMPs provide details on their involvement in IWRM planning. Because most plans are not updated unless required, events after plan adoption are not documented in the plans.

Table 8-21 Assessment of DWR Bulletin 118-2003 Recommended Components in the San Joaquin River Hydrologic Region

Recommended Components	Percentage of Plans that Include Component
GWMP Guidance	92%
Management Area	92%
BMOs, Goals, and Actions	85%
Monitoring Plan Description	62%
IRWM Planning	62%
GWMP Implementation	85%
GWMP Evaluation	85%

Notes:
BMO = basin management objective, IRWM = integrated regional water management,
GWMP = groundwater management plan
Table reflects assessment results of Senate Bill 1938 plans that were received by August 2012.

DWR/ACWA Survey — Key Factors for Successful GWMP Implementation

The DWR/ACWA survey asked respondents to identify key factors that contributed to the successful implementation of the agency's GWMP. Ten agencies from the San Joaquin River region participated in the survey. Of the participants, five provided feedback on what they thought were the key components that contributed to successful GWMP implementation. Table 8-22 summarizes the individual responses for these five responding agencies.

Data collection, sharing of ideas and information, developing an understanding of common interest, and having a water budget were selected by all five of the participating groundwater management entities as being important to their success. The remaining 6 key components were selected as key components by four of the five survey responders. One responding agency provided an additional component of collaboration that they considered important to their plan implementation success.

Table 8-22 Survey Results for Key Components Contributing to Successful GWMP Implementation in the San Joaquin River Hydrologic Region

Key Components that Contributed to Success	Respondents
Sharing of ideas and information with other water resource	5
Data collection and sharing	5
Adequate surface water supplies	4
Adequate regional and local surface storage and conveyance	4
Outreach and education	4
Developing an understanding of common interest	5
Broad stakeholder participation	4
Water budget	5
Funding	4
Time	4
Additional Components Supplied by Participating Agencies:	
Collaboration	1

Notes:
GWMP = groundwater management plan
Results from an online survey sponsored by DWR and conducted by the Association of California Water Agencies, 2011 and 2012.

DWR/ACWA Survey — Key Factors Impeding GWMP Success

The DWR/ACWA survey also asked survey participants to identify challenges that they felt impeded implementation of the GWMP. Five survey participants from the San Joaquin River region responded to the question. Table 8-23 includes the results of those five respondents. Overall, the shortage of funds for groundwater management projects was the biggest impediment to GWMP implementation, because many projects require significant amount of funds to implement and operate. The options to acquire money are limited to the agency funding the project themselves, or applying for grant funding from State and federal agencies. As a result, the lack of funding for groundwater management planning and projects was at the top of the list. Over half of the respondents reported that data collection and sharing, and limited surface storage and conveyance capacity, were difficult to overcome when implementing a GWMP. Each basin is different, but the degree of success is critically dependent on basin-wide data. Each agency in a basin will need access to all necessary data to review and use in developing GWMPs. More than 50 percent of the survey respondents indicated data collection and sharing limited their success.

Lastly, the survey asked if the respondents were confident in the long-term sustainability of their current groundwater supply. Four out of five respondents representing the central valley portion of the San Joaquin River region felt long-term sustainability of their groundwater supply was not possible.

Table 8-23 Survey Results for Factors that Limited the Successful GWMP Implementation in the San Joaquin River Hydrologic Region

Limiting Factors	Respondents
Participation across a broad distribution of	1
Data collection and sharing	3
Funding for groundwater management planning	4
Funding for groundwater management projects	5
Funding to assist in stakeholder participation	2
Understanding of the local issues	-
Outreach and education	-
Groundwater supply	1
Surface storage and conveyance capacity	3
Access to planning tools	-
Unregulated pumping	1
Lack of governance	1

Notes:
GWMP = groundwater management plan
Results from an online survey sponsored by DWR and conducted by the association of California Water Agencies, 2011 and 2012.

Groundwater Ordinances

Groundwater ordinances are laws adopted by local authorities, such as cities or counties, to manage groundwater. In 1995, the California Supreme Court declined to review a lower court decision (*Baldwin v. Tehama County*) that says that state law does not occupy the field of groundwater management and does not prevent cities and counties from adopting ordinances to manage groundwater under their police powers. Since 1995, the *Baldwin v. Tehama County* decision has remained untested; thus, the precise nature and extent of the police power of cities and counties to regulate groundwater is still uncertain.

As of August 2012, a number of groundwater-related ordinances have been adopted in the San Joaquin River region. The two most common ordinances are associated with groundwater wells. All 15 counties part of the hydrologic region have groundwater ordinances establishing well construction policies, ordinances that regulate the abandonment and destruction of groundwater wells, or both. Eight counties require permits to be submitted for water transfer projects, and one county has an ordinance pertaining to recharge projects or the creation of guidance committees. No counties used the county ordinance approach to establish basic groundwater management policies. Table 8-24 lists the ordinances being implemented by the counties in the San Joaquin River region as of August 2012.

Table 8-24 County Groundwater Ordinances for the San Joaquin River Hydrologic Region

County	Groundwater Management	Guidance Committees	Export Permits	Recharge	Well Abandonment and Destruction	Well Construction Policies
Alameda	-	-	-	-	Yes	Yes
Alpine	-	-	Yes	-	Yes	Yes
Amador	-	-	-	-	Yes	Yes
Calaveras	-	-	Yes	-	Yes	Yes
Contra Costa	-	-	-	-	Yes	-
El Dorado	-	-	-	-	Yes	Yes
Fresno	-	-	Yes	-	Yes	Yes
Madera	-	-	Yes	Yes	Yes	Yes
Mariposa	-	-	-	-	Yes	Yes
Merced	-	-	-	-	Yes	Yes
Sacramento	-	-	Yes	-	Yes	Yes
San Benito	-	-	Yes	Yes	Yes	Yes
San Joaquin	-	Yes	Yes	-	Yes	Yes
Stanislaus	-	-	-	-	Yes	Yes
Tuolumne	-	-	Yes	-	-	Yes

Notes:
GWMP = groundwater management plan
Table represents information as of August 2012.

Special Act Districts

Greater authority to manage groundwater has been granted to a few local agencies or districts created through a special act of the Legislature. The specific authority of each agency varies, but the agencies can be grouped into two general categories: (1) agencies having authority to limit export and extraction (upon evidence of overdraft or threat of overdraft), or (2) agencies lacking authority to limit extraction, but having authority to require reporting of extraction and to levy replenishment fees.

There are many special act districts established by the California State Legislature consisting of different authorities that may or may not have groundwater management authority. It is not part of the scope of *California Water Plan Update 2013* to identify individual types of special act districts or the established agencies. Included in this report are the GWMPs produced by these agencies and submitted to DWR, as discussed in the preceding section.

Court Adjudication of Groundwater Rights

Another form of groundwater management in California is through the courts. When the groundwater resources do not meet water demands in an area, landowners may turn to the courts to determine how much groundwater can be rightfully extracted by each overlying landowner or appropriator. The court typically appoints a watermaster to administer the judgment and to periodically report to the court. There are currently 24 groundwater adjudications in California, but there are no court-adjudicated groundwater basins in the San Joaquin River region.

Other Groundwater Management Planning Efforts

Groundwater management is also occurring through other avenues. IRWM incorporates the physical, environmental, societal, economic, legal, and jurisdictional aspects of water management into regional solutions through open and collaborative stakeholder processes to promote sustainable water use. UWMPs incorporate long-term resource planning to meet existing and future water demands. AWMPs advance irrigation efficiency that benefits both farms and the environment.

Integrated Regional Water Management Plans

IRWM improves water management and supports economic stability, environmental stewardship, and public safety. IRWM plans involve multiple agencies, stakeholders, individuals, and groups, and cross jurisdictional, watershed, and political boundaries. The methods used in IRWM planning include developing water management strategies that relate to water supply, water quality, water use efficiency, operational flexibility, as well as stewardship of land, natural resources, and groundwater resources. Statewide, the majority of IRWM plans address groundwater management in the form of goals, objectives, and strategies, and defer implementation of groundwater management and planning to local agencies through local GWMPs. Few IRWM plans actively manage groundwater. Efforts by IRWM RWMGs might include creating groundwater contour maps for basin operations criteria, monitoring groundwater elevations, and monitoring groundwater quality.

Statewide, there are 48 IRWM plans that have been accepted or conditionally accepted. The San Joaquin River region includes 12 of the 48 IRWM planning groups. Five of the 12 IRWM plans are actively implemented, while seven are in various stages of implementation. Two of the established IRWM plans extend northward into the Sacramento River Hydrologic Region. To the west, one plan in progress extends into the San Francisco Bay Hydrologic Region. To the south are two IRWM plans, one of which is active and extends into Tulare Lake Hydrologic Region. Table 8-25 lists the IRWM plans for the San Joaquin River region and Figure 8-24 shows the location and planning areas for the IRWM plans. Additional information regarding IRWM planning can be found on the DWR Web site (http://www.water.ca.gov/irwm/grants/index.cfm).

Two of the active IRWM planning areas rely on local entities that actively manage groundwater. These local entities are implementing groundwater-related projects that help improve groundwater management. Groundwater management is identified as one of the objectives in one planning area (Mokelumne/Amador/Calaveras), while the other area's main goal is to minimize regional conflict by addressing problems such as water supply reliability, overdraft, drainage, and water quality (Westside).

One of the IRWM plans was developed to define and integrate key water management strategies to establish the protocols and course of action for implementation of a conjunctive use program. This followed the previous establishment of a groundwater banking authority and GWMP for a nearby region. Individual agencies within this region manage groundwater, but found it difficult to exert the political and financial power necessary to mitigate the conditions of overdraft. They realized that a regional consensus-based approach to water resources planning and conjunctive water management would increase their chance for success. The IRWM group developed basin management objectives for groundwater levels, groundwater quality, and inelastic land subsidence; they further developed basin operations criteria which sets target groundwater levels and descriptive basin condition levels, consisting of a series of groundwater-level triggers that correspond to basin condition levels, to indicate the effectiveness or result of conjunctive use projects. The specific groundwater measurement criteria is based on historic groundwater levels shown on groundwater contour maps for the pre-1960 elevation, fall 1986 elevation, fall 1992 elevation, the basin reserve, and the basin terminal pool.

Another IRWM planning group says that groundwater in the region is poorly understood because of faulted and fractured geological conditions, and leaves groundwater management to city and county agencies and to irrigation districts. A few of the objectives of this group’s IRWM plan are to identify suitable groundwater management practices to prevent groundwater contamination, assure that groundwater recharge and extraction are balanced, and to support efforts to understand groundwater quantities and movement in the fractured-rock systems of the Sierra Nevada through more study and analysis.

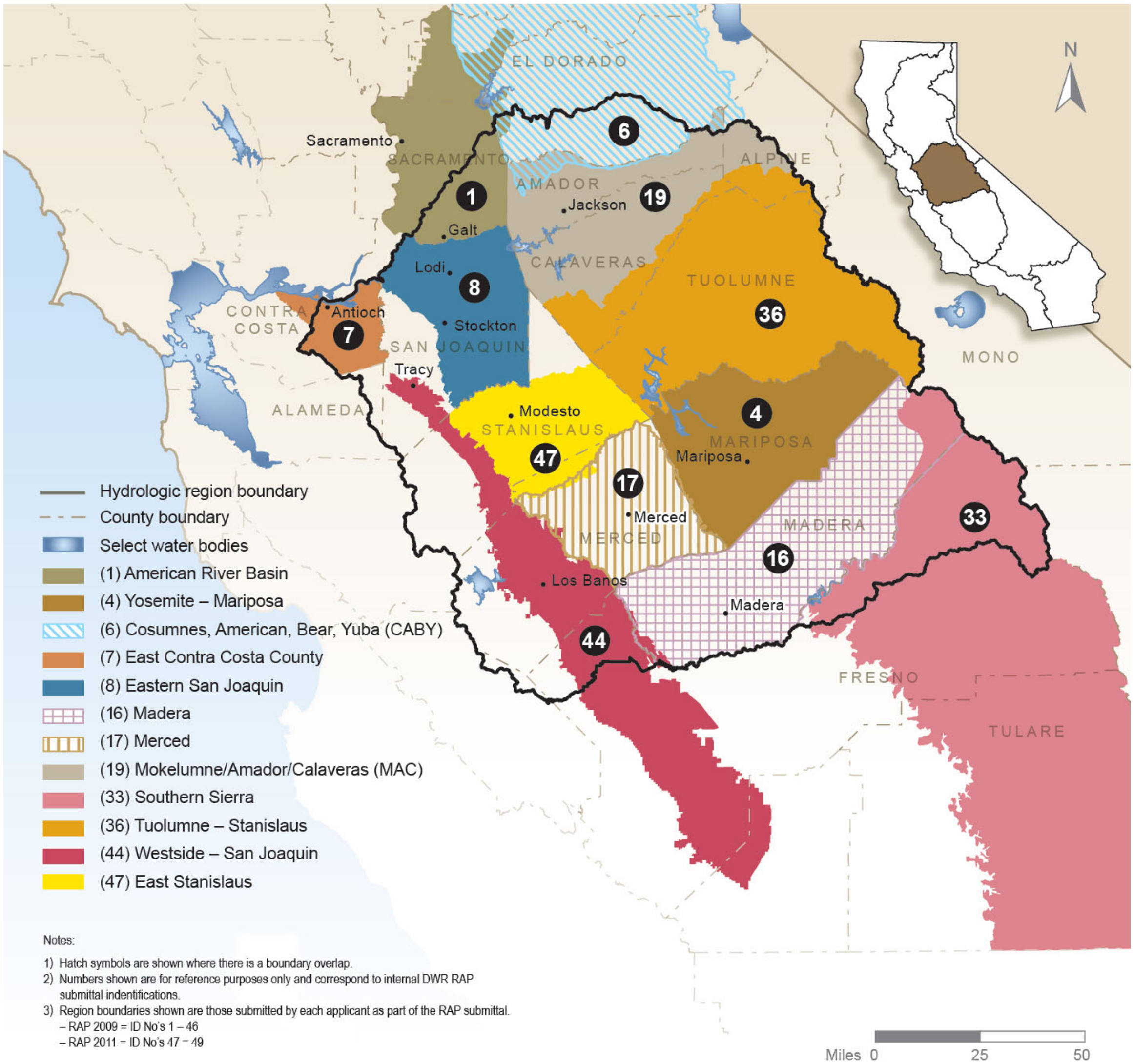
And lastly, a third IRWM planning group relies on four local agencies or authorities with active GWMPs. This IRWM planning area states that groundwater management is important to the IRWM region as a means of reducing water rights disputes and conflicts resulting from a heavy reliance on groundwater by agricultural and residential users for their water supply. A few of this IRWM region’s objectives are to identify and resolve issues connected with conjunctive use water management practices and groundwater contamination, and to evaluate the effectiveness of regional groundwater monitoring systems by identifying data gaps and making recommendations for improvements to the groundwater monitoring systems. However, as stated before, active groundwater management is left to local entities.

Table 8-25 Status of Integrated Regional Water Management Plans in the San Joaquin River Hydrologic Region

Hydrologic Region	IRWM Plan Name	Date	IRWM Plan Status	IRWM Map Number
San Joaquin River/ Sacramento River	American River Basin	2006	Active	1
San Joaquin River	Yosemite-Mariposa		In Progress	4
Sacramento River/ San Joaquin River	Cosumnes, American, Bear, and Yuba Watersheds	2007	Active	6
San Joaquin River/ San Francisco Bay	East Contra Costa County		In Progress	7
San Joaquin River	Eastern San Joaquin	2007	Active	8
San Joaquin River	Madera		In Progress	16
San Joaquin River	Merced		In Progress	17
San Joaquin River	Mokelumne/Amador/Calaveras	2006	Active	19
San Joaquin River	Tuolumne - Stanislaus		In Progress	36
San Joaquin River	East Stanislaus		In Progress	47
San Joaquin River/ Tulare Lake	Southern Sierra		In Progress	33
San Joaquin River/ Tulare Lake	Westside (San Luis Delta Mendota)	2006	Active	44
	IRWM Planning Regions		12	
	Active IRWM Plans		5	
	IRWM Plans In Development		7	
	IRWM Plans that Cross Hydrologic Boundaries		5	

Notes:
IRWM = integrated regional water management
Table represents information as of August 2012.

Figure 8-24 Integrated Regional Water Management Plans in the San Joaquin River Hydrologic Region



Prepared by California Department of Water Resources for California's Groundwater Update 2013

Urban Water Management Plans

UWMPs are prepared by California's urban water suppliers to support their long-term resource planning and to ensure adequate water supplies are available to meet existing and future water demands. UWMPs include system descriptions, demands, and supplies, as well as water shortage reliability and water shortage contingency planning. In addition, the Water Conservation Bill of 2009 (SB X7-7) requires that urban water suppliers:

- Develop a single standardized water use reporting form for urban water suppliers.
- Develop method(s) by July 1, 2011 to identify per capita targets, and update those methods in four years to meet the 20 percent reduction goal by 2020.
- Develop technical methodologies and criteria for calculating all urban water use.
- Convene a task force to develop alternative best management practices for commercial, industrial, and institutional water use.

Urban use of groundwater is one of the few uses that meter and report annual groundwater extraction volumes. The groundwater extraction data is currently submitted with the UWMP and then manually translated by DWR staff into a database. Online methods for urban water managers to directly enter their water use along with their UWMP updates are currently be evaluated. Additional information regarding urban water management and UWMPs can be found at http://www.water.ca.gov/urbanwatermanagement/.

Agricultural Water Management Plans

AWMPs are developed by water and irrigation districts to advance the efficiency of farm water management while benefitting the environment. The AWMPs provide another avenue for local groundwater management. Some of the efficient water management practices being implemented include controlling drainage problems through alternative use of lands, using recycled water that otherwise would not be used beneficially, improvement of on-farm irrigation systems, and lining or piping ditches and canals. In addition, SB X7-7 requires that agricultural water suppliers perform the following:

- Report the status of AWMPs and efficient water management practices and evaluate their effectiveness.
- Adopt regulations to measure the volume of water delivered and for adopting a pricing structure based on quantity delivered.
- Develop a method for quantifying efficiency of agricultural water use and a plan for implementation.
- Propose new statewide targets for regional water management practices for recycled water, brackish groundwater, and stormwater runoff.
- Promote implementation of regional water management practices through increased incentives and removal of barriers.

New and updated AWMPs addressing the SB X7-7 requirements were required to be submitted to DWR by December 31, 2012 for review and approval. More information about AWM planning can be found at http://www.water.ca.gov/wateruseefficiency/agricultural/agmgmt.cfm.

Conjunctive Management Inventory

Conjunctive management, or conjunctive use, refers to the coordinated and planned use and management of both surface water and groundwater resources to maximize the availability and reliability of water supplies to meet various management objectives in a region. Managing both resources together, rather than in isolation, allows water managers to use the advantages of both resources for maximum benefit.

Conjunctive management of surface water and groundwater has been utilized in the San Joaquin River region for decades to meet local water demands during surface water cutbacks, mitigate declining groundwater levels, and help limit land subsidence. To meet water demands throughout the region, groundwater use is supplemented by imported surface water from State, federal, and local water projects. Several agencies in the region have developed groundwater recharge facilities to capture peak runoff and to fully utilize imported surface water supplies.

As part of *California Water Plan Update 2013*, an inventory and assessment of conjunctive management programs in California was conducted. The overall intent of this effort was to (1) provide a statewide summary of conjunctive water management program locations, operational methods, and capacities, and (2) identify their challenges, successes, and opportunities for growth and then share the information with policymakers and other stakeholders to enable an informed decision-making process regarding groundwater and its management. Additional information regarding conjunctive management in California, as well as discussion on associated benefits, costs, and issues can be found online in *California Water Plan Update 2013*, Volume 3, Chapter 9, "Conjunctive Management and Groundwater Storage."

The statewide conjunctive management inventory and assessment consisted of a literature research, an online survey, personal communication with local agencies, and a documented summary of the conjunctive management programs in California. Information from these efforts was compiled into a comprehensive spreadsheet of projects and historic operational information, which was updated and enhanced through implementation of a DWR/ACWA-coordinated online survey. The online survey administered by ACWA requested the following conjunctive management program information from its member agencies:

- Location of conjunctive use project.
- Year project was developed.
- Capital cost to develop the project.
- Annual operating cost of the project.
- Administrator/operator of the project.
- Capacity of the project in units of acre-feet.

Although initial response to the survey was encouraging, the number of survey participants and the completeness of those responses were limited. In an attempt to build on the ACWA survey and develop a greater understanding of the size and diversity of conjunctive management projects in California, DWR's four regional offices contacted, either by telephone or through email, each of the entities identified as having a conjunctive water management program. DWR's follow-up information requested additional details regarding:

- Source of water received.
- Put and take capacity of the groundwater bank or conjunctive use project.
- Type of groundwater bank or conjunctive use project.
- Program goals and objectives.
- Constraints on development of conjunctive management or groundwater banking (recharge) program.

Statewide, 89 conjunctive management and groundwater recharge programs were identified. Because of confidentiality concerns expressed by some local agencies, information for some existing conjunctive management programs may not be reported. Conjunctive management and groundwater recharge programs that were in the planning and feasibility stage were not included in the inventory. A statewide map and series of tables listing the conjunctive management projects identified by DWR, grouped by hydrologic region and the questions noted in this section, is provided in Appendix D.

Conjunctive Management Inventory Results

Of the 89 agencies or programs identified as operating a conjunctive management or groundwater recharge program in California, five projects are located in the San Joaquin River region. The information in this section summarizes the details from the conjunctive management survey for the following agencies in the San Joaquin River region: Stockton East Water District, Northeastern San Joaquin County Groundwater Banking Authority, Madera Ranch Water Bank, Madera Irrigation District, and Root Creek Water District.

Stockton East Water District began the Farmington Groundwater Recharge Program in 2003 in the Eastern San Joaquin Groundwater Subbasin. The Farmington Program has a recharge capacity of approximately 35,000 acre-feet per year, using surface spreading basins for direct percolation, in addition to an in-lieu groundwater recharge program. According to the information provided to DWR during the conjunctive management survey, Stockton East Water District receives approximately 50,000 acre-feet of water from the CVP and approximately 31,500 acre-feet of water from local surface water sources. The recharge and extraction capacities of the program were reported by Stockton East Water District. On an annual basis, Stockton East Water District has been able to recharge 5,500 acre-feet of surface water for an approximate total of 50,000 acre-feet. Extraction volumes are estimated to be 300 acre-feet cumulatively, with an estimated dry-year take of as much as 3,500 acre-feet. In-lieu recharge estimates are 76,000 acre-feet annually and 630,000 acre-feet cumulatively, while cumulative extraction volumes from the in-lieu program are estimated at 1,260,000 acre-feet.

Stockton East Water District indicated that the goals and objectives of their recharge program include reversing groundwater overdraft and salinity intrusion, addressing water quality protection, meeting climate change challenges, and providing a sustainable water supply. The most significant constraints identified were regulatory and cost issues. Moderate constraints include political, legal, and institutional issues, while limited aquifer storage and water quality were identified as minimal issues. The Northeastern San Joaquin County Groundwater Banking Authority partners with Stockton East Water District on their groundwater recharge programs.

The Madera Ranch Water Bank, which is operated by Madera Irrigation District, indicated that its program goals and objectives are to integrate groundwater recharge with flood management. The estimated capacity of the program's direct percolation and in-lieu recharge efforts is 250,000 acre-feet.

Limited information was provided by Root Creek Irrigation District about their in-lieu groundwater recharge program, other than an annual recharge volume of 6,000 acre-feet.

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