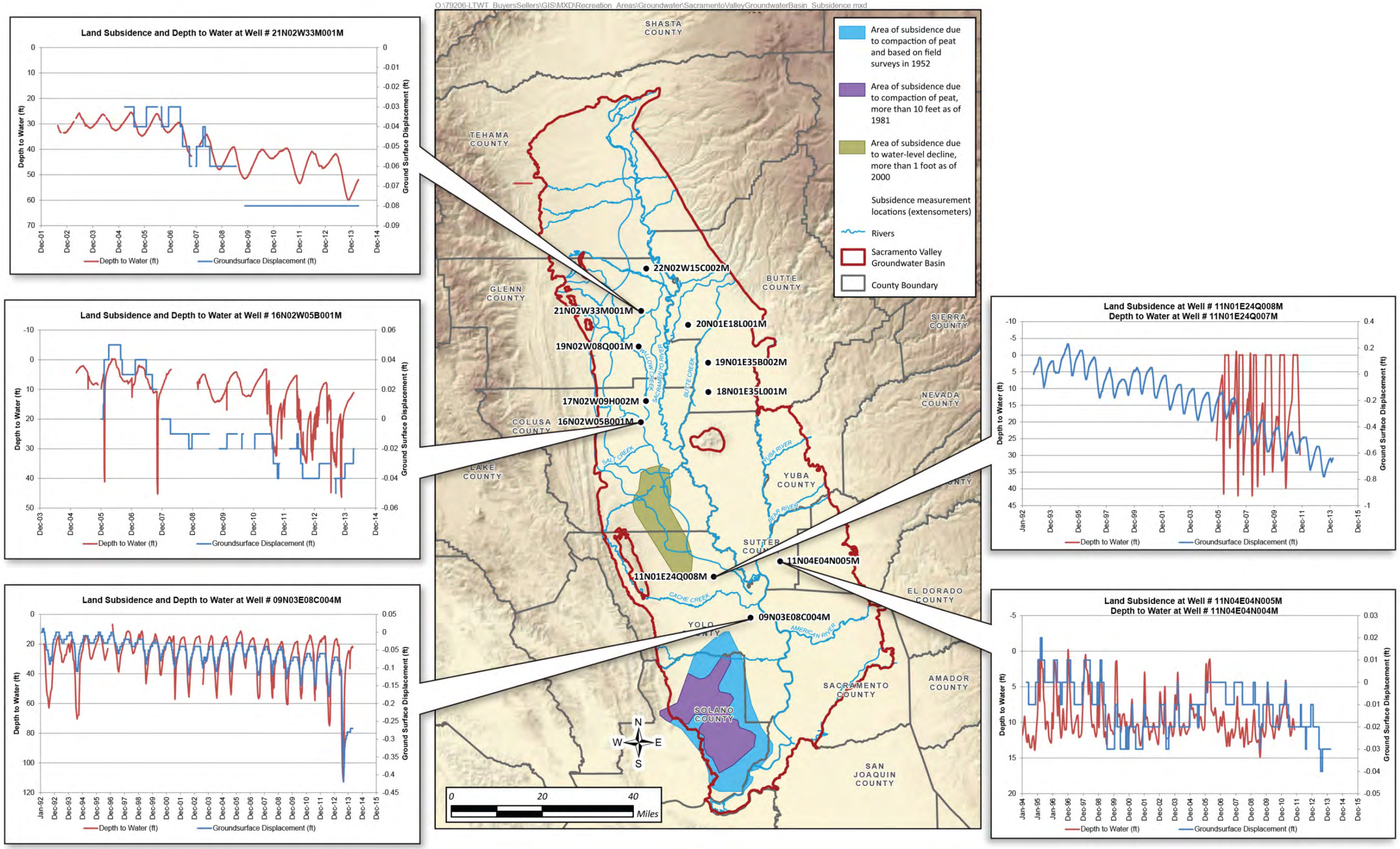

Source: DWR 2010b

Figure 3.3-~~11.~~-15. Sacramento Valley Groundwater Basin Land Subsidence

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Groundwater Quality

Groundwater quality in the Sacramento Valley Groundwater Basin is generally good and sufficient for municipal, agricultural, domestic, and industrial uses. However, there are some localized groundwater quality issues in the basin. In general, groundwater quality is influenced by stream flow and recharge from the surrounding Coast Range and Sierra Nevada. Runoff from the Sierra Nevada is generally of higher quality than runoff from the Coast Range because of the presence of marine sediments in the Coast Range. Specific groundwater quality issues are discussed below.

Within the Sacramento Valley, water quality issues may include occurrences of high TDS or elevated levels of nitrates, naturally occurring boron, and other introduced chemicals. The SWRCB's Groundwater Ambient Monitoring and Assessment (GAMA) Program's Priority Basin Project evaluated statewide groundwater quality and sampled 108 wells within the Central Sacramento Valley region and 96 wells in the Southern Sacramento Valley region in 2005 and 2006. Water quality data was analyzed for inorganic constituents (e.g., nutrients, radioactive constituents, TDS and iron/manganese); special interest constituents (e.g., perchlorate); and organic constituents (e.g., solvents, gasoline additives, and pesticides).

Inorganic Constituents

Arsenic and boron were the two trace elements that were most frequently detected at concentrations greater than the maximum contaminant level (MCL) within the basin. Arsenic was detected above the MCL in 22 percent of the primary aquifers. Boron was detected in seven percent of the primary aquifers. Aluminum, chromium, lead, and fluoride were also detected in concentrations above the MCLs, but in less than one percent of the primary aquifers. Concentrations of radioactive constituents were above the MCLs in less than one percent of the primary aquifers within the Central Sacramento Valley region. Most of the radioactivity in groundwater comes from decay of naturally occurring isotopes of uranium and thorium in minerals in the sediments of the aquifer (Bennett 2011a, 2011b).

Nutrient concentrations within the Central Sacramento Valley region were above the MCLs in about three percent of the primary aquifers. In the southern portion of the basin, nutrients were detected above the MCLs in about one percent of the primary aquifers (Bennett 2011a, 2011b).

CDPH and U.S. Environmental Protection Agency's (USEPA's) secondary drinking water standard for TDS is 500 mg/L, and the agricultural water quality goal for TDS is 450 mg/L. TDS concentrations were above these standards in about four percent of the primary aquifers in the central portion of the valley. TDS levels in the Sacramento Valley Groundwater Basin are generally between 200 and 500 mg/L. TDS levels in the southern part of the basin are higher because of the local geology (DWR 2003). Along the eastern boundary of the basin, TDS concentrations tend to be less than 200 mg/L, indicative of the low concentrations of TDS in Sierra Nevada runoff. Several areas in the basin have naturally occurring high TDS, with concentrations that exceed 500 mg/L. TDS concentrations as high as 1,500 mg/L have been recorded (Bertoldi 1991). One of these high TDS areas is west of the Sacramento River, between Putah Creek and the confluence of the Sacramento and San Joaquin Rivers; another is in the south-central part of the Sacramento Basin, south of Sutter Buttes, in the area between the confluence of the Sacramento and Feather Rivers.

Chloride concentrations, a component of TDS, were observed to be above the MCL in two percent of the primary aquifers. TDS concentrations between the recommended and upper limit[4] were detected in about 11 percent of the primary aquifers in the central portion of the valley. In the southern portion of the valley, TDS concentrations were greater than the upper limit (1,000 mg/L) in only about one percent of the primary aquifers and were between the recommended (500 mg/L) and upper limits (1,000 mg/L) in about 22 percent of the primary aquifers (Bennett 2011a, 2011b).

Organic Constituents

Volatile organic compounds (VOCs) are present in many household, commercial, industrial, and agricultural products used as solvents, and are characterized by their tendency to volatilize into the air. Solvents have been used for a number of purposes, including manufacturing and cleaning. Solvents were detected at concentrations greater than the MCLs in less than one percent of the primary aquifers throughout the basin. The solvent present at higher concentrations than the MCL was perchloroethylene. Gasoline additives were detected at higher concentrations in less than one percent of the primary aquifers throughout the basin. The gasoline additives detected at higher concentrations were benzene and tert-butyl alcohol (Bennett 2011a, 2011b). Additionally, groundwater wells around Chico have exceeded standards for VOCs (trichloroethylene and perchloroethylene) (City of Chico 2006).

Other VOCs (trihalomethanes and organic synthesis reagents) were not detected at concentrations above the MCLs in the primary aquifers (Bennett 2011a, 2011b).

Special Interest Constituents

Perchlorate is an inorganic constituent that has been regulated in California drinking water since 2007. Perchlorate was not detected at concentrations above the MCLs in the primary aquifers (Bennett 2011a, 2011b).

[4] The State of California has a recommended and an upper limit for TDS in drinking water. The recommended limit in 500 mg/L and the upper limit is 1,000 mg/L.

DWR Monitoring

From 1994 to 2000, water quality data from 1,356 public supply water wells indicated that 1,282 wells, or 95 percent, met the primary MCLs for drinking water. In the remaining five percent, analysis detected at least one constituent above a primary MCL. Out of the five percent of samples that had a constituent over the MCL, the ~~exceedences~~exceedances included 33 percent for nitrates, 32 percent for VOCs and semi-VOCs (mostly tetrachloroethylene, trichloroethylene, and benzene), 26 percent for inorganic compounds (mostly manganese and iron), five percent for radiological compounds (gross alpha 4), and four percent for pesticides (di(2-ethylhexyl)phthalate) (DWR 2003).

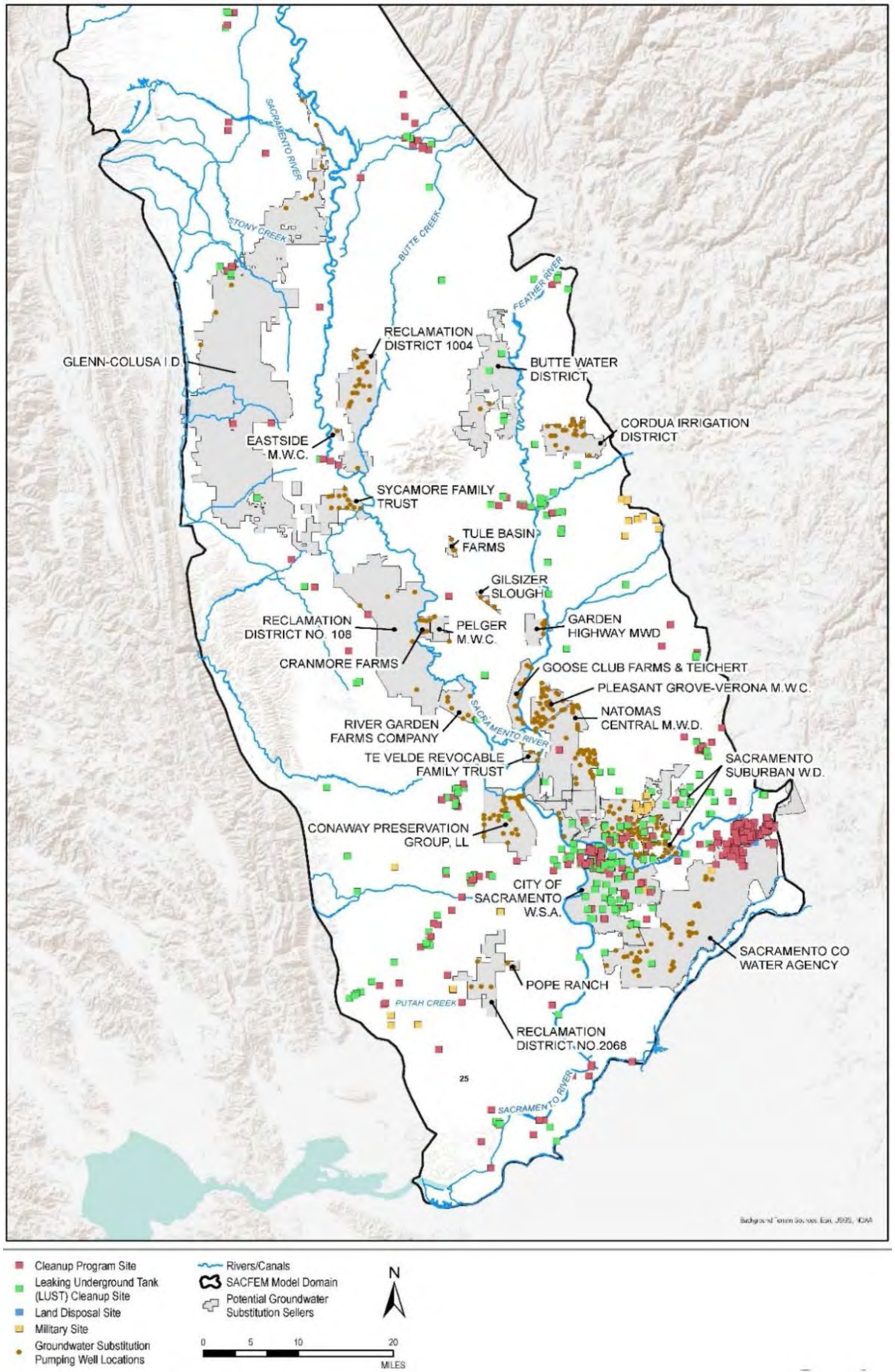
GeoTracker Clean-Up Sites

Figure 3.3.-16 below shows the active and open “clean-up” sites from SWRCB’s GeoTracker database. The Sacramento Valley has 481 active clean-up program sites, 234 leaking underground tank (UST) sites, 54 Military sites (includes military privatized UST sites), and one land disposal site as of December 29, 2014 (SWRCB 2014). These sites are in various stages of open investigation which includes site assessment, remediation, and/or monitoring. Most of the clean-up sites shown in Figure 3.3-16 are clustered around urban areas.

3.3.1.3.3 San Joaquin Valley Groundwater Basin

The San Joaquin Valley Groundwater Basin extends over the southern two-thirds of the Central Valley regional aquifer system and has an area of approximately 13,500 square miles. ~~The northern portion of the~~The San Joaquin Valley Groundwater Basin, shown on Figure 3.3-~~12~~17, extends from just north of Stockton in San Joaquin County to ~~north of Fresno in Fresno~~Kern County~~, covering approximately 5,800 square miles~~.

The southern portion of the San Joaquin Valley Groundwater Basin extends from the Fresno-Madera County line through Kings and Tulare counties into Kern County. The South San Joaquin Groundwater Basin covers approximately 8,000 square miles.



Source: SWRCB 2014

Figure 3.3-16. Active Geotracker Clean-Up Sites as of December 29, 2014

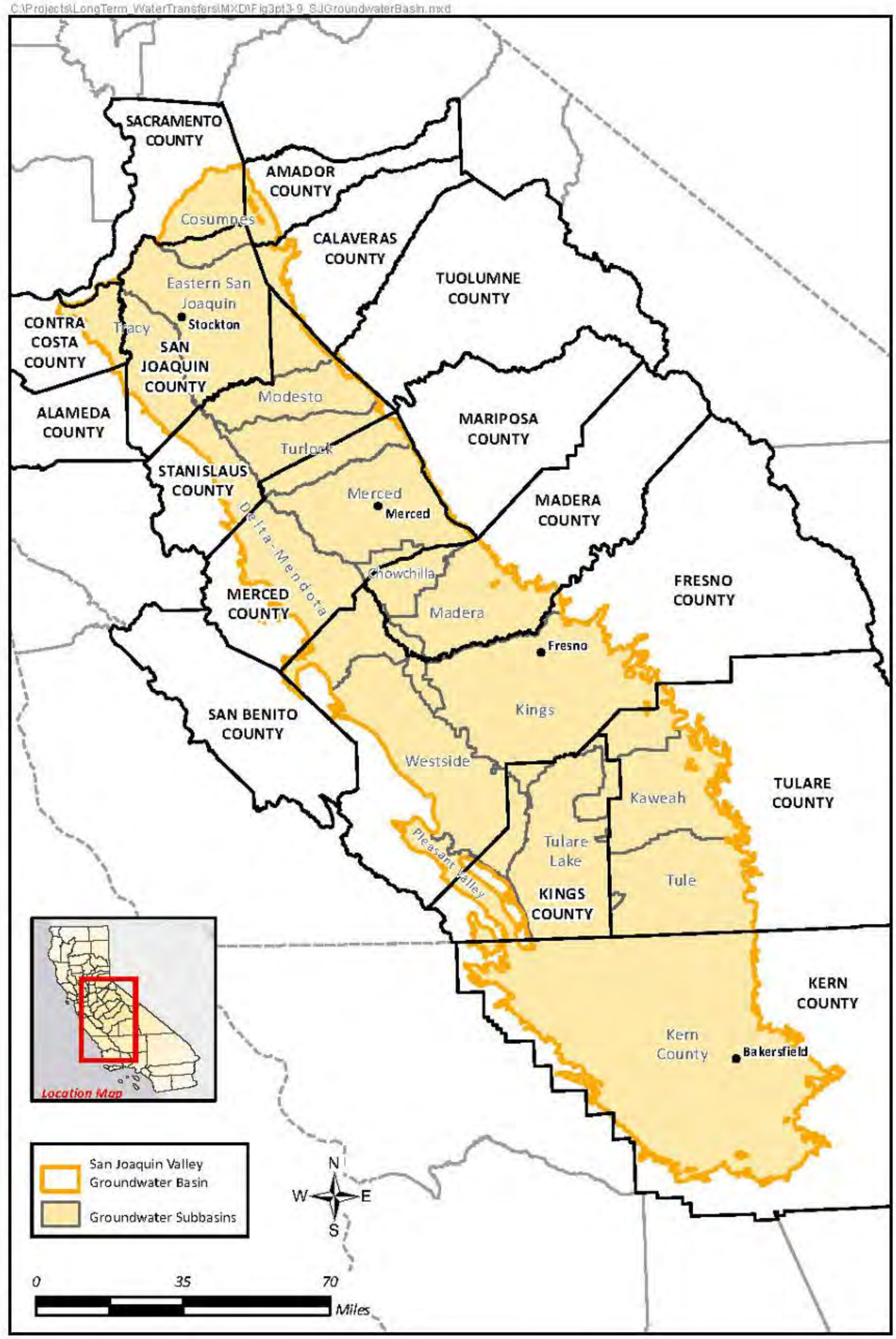


Figure 3.3-17. San Joaquin Valley Groundwater Basin

Geology, Hydrogeology, and Hydrology

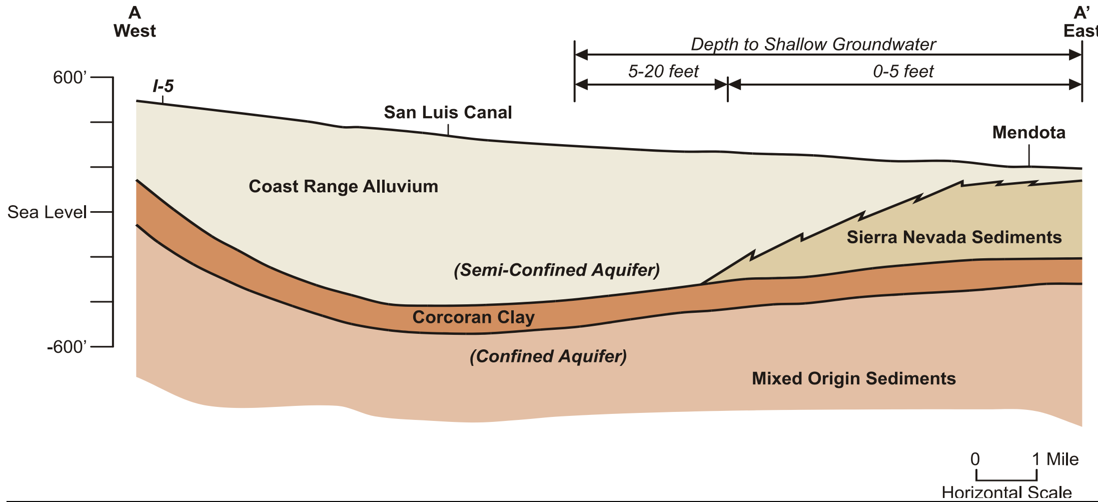
The northern portion of the San Joaquin Valley Groundwater Basin is similar in shape to the Sacramento Valley Groundwater Basin and was formed by the deposition of several miles of sediment in a north-northwestern trending trough. The Sierra Nevada lies on the eastern side of the basin, and the Coast Range is to the west.

The aquifer system in the northern portion of the San Joaquin Valley Groundwater Basin is comprised of continental and marine deposits up to six miles thick, of which the upper 2,000 feet generally contain freshwater (Page 1986). A significant hydrogeologic feature in the basin is the Corcoran Clay. This clay layer divides the aquifer system into two distinct zones, an upper unconfined to semi-confined aquifer and a lower confined aquifer. Both aquifers are composed of formations derived from the deposition of Sierra Nevada sediment in the eastern portions of the basin, and from deposition of Coast Range sediments in the western portions of the basin. Overlying these formations are flood-plain deposits. The formations in the eastern portions of the basin are derived from the granitic Sierra Nevada and are generally more permeable than the sediments derived from the western marine formations. Sediments derived from marine rocks generally contain more silt and clay and also contain higher concentrations of salts. The lower confined aquifer system contains sediments of mixed origin.

Historically, these aquifers were two separate systems; however, wells in the western side of the basin have penetrated both aquifers and are commonly perforated directly above and below the Corcoran Clay. This has allowed "almost free flow [of groundwater] through the well casings and gravel packs" (Williamson 1989) and has resulted in groundwater interaction between the upper and lower aquifer in some localized areas (Reclamation 1990).

In the southern portion of the basin, the central axis of the basin contains Tulare Lake sediments. These Tulare Lake sediments are estimated to be more than 3,600 feet thick, with a lateral extent of more than 1,000 square miles (Page 1986).

Figure 3.3-~~13~~18a shows a generalized geologic cross section of the northern portion of the San Joaquin Valley Groundwater Basin and Figure 3.3-~~14~~18b shows a generalized geologic cross section for the southern portion of the basin. Figure 3.3-~~15~~18c shows the location of these cross sections.



Source: Reclamation 1997

Figure 3-3.18a. Geologic Cross Section of the Northern Portion of the San Joaquin Valley Groundwater Basin

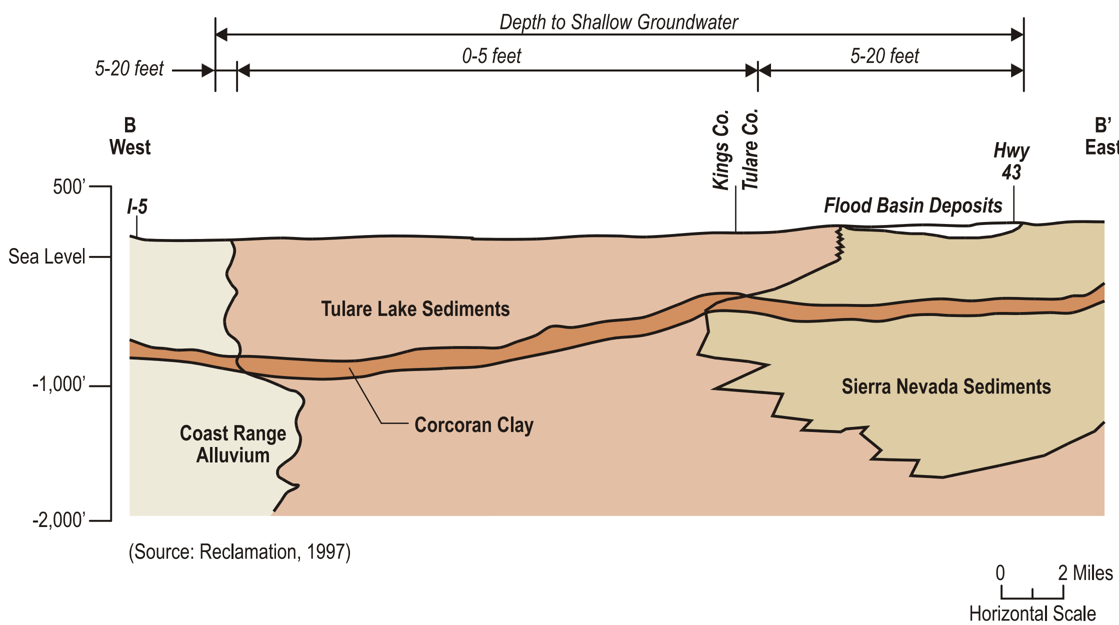


Figure 3.3-18b. Geologic Cross Section of the Southern Portion of the San Joaquin Valley Groundwater Basin

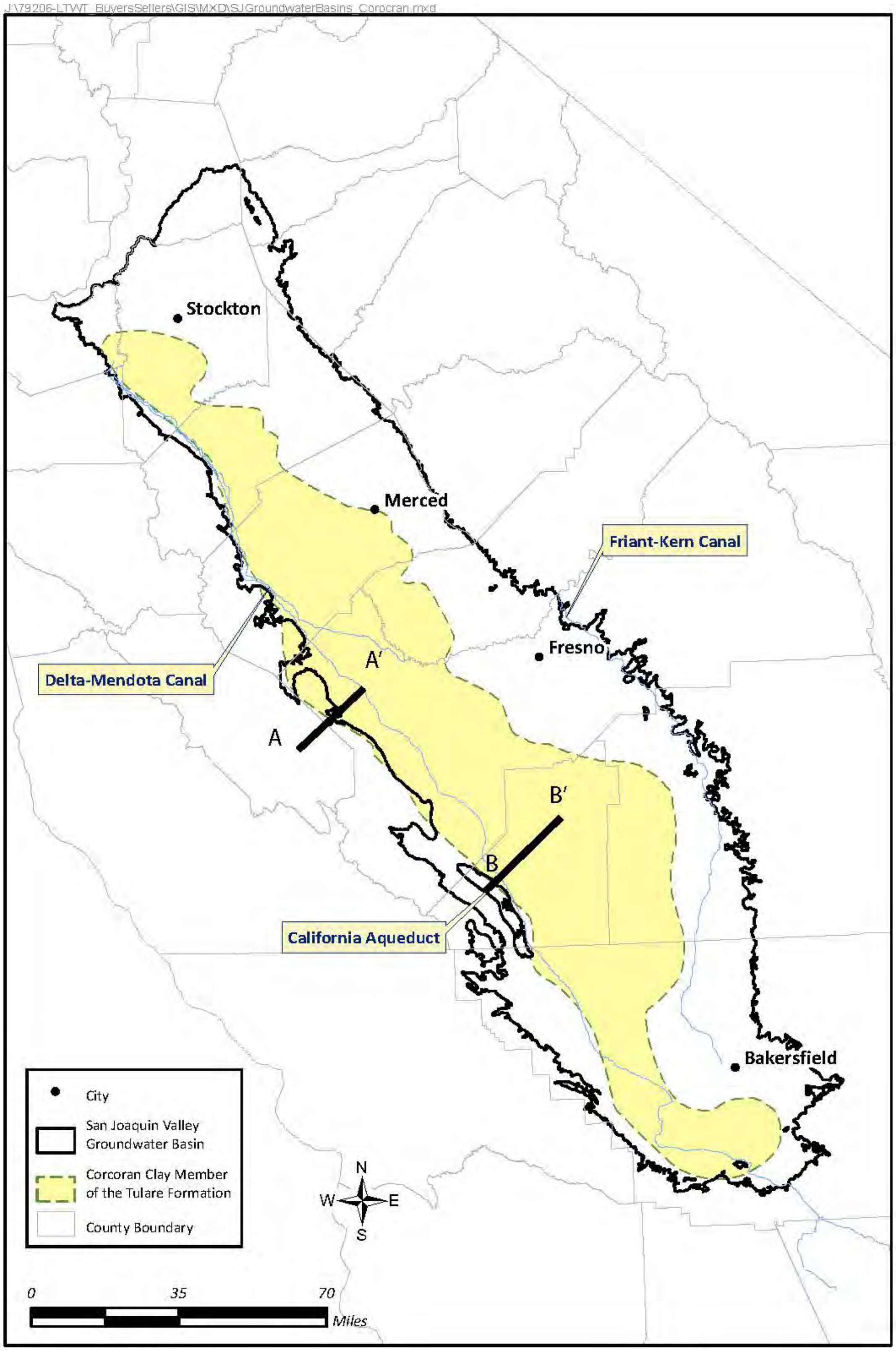


Figure 3.3-18c. Location of Geologic Cross-Sections and Lateral Extent of the Corcoran Clay in the San Joaquin Valley Groundwater Basin

The Corcoran Clay, the most extensive of several clay layers, was formed by the periodic filling and draining of ancient lakes in the San Joaquin Valley. Six laterally extensive clays, designated Clays A through F, have been mapped (Page 1986). The Modified E-Clay includes the Corcoran Clay, which is between 0 and 160 feet thick at depths between 100 and 400 feet bgs.

Historically, groundwater in the unconfined to semi-confined upper aquifer system was recharged by streambed infiltration, rainfall infiltration, and lateral inflow along the basin boundaries. Average annual precipitation in the area is significantly less than in the Sacramento Valley Groundwater Basin and ranges from five to 18 inches (Faunt 2009). The percolation of applied agricultural surface water supplements natural groundwater replenishment. The lower confined aquifer is recharged primarily from lateral inflow from the eastern portions of the basin, beyond the eastern extent of the Corcoran Clay. Precipitation in the Sierra Nevada to the east of the basin can be as high as 65 to 75 inches, although much of it is in the form of snow. Peak runoff in the basin generally lags precipitation by five to six months (Bertoldi 1991).

The main surface water feature in the northern portion of the San Joaquin Valley Groundwater Basin is the San Joaquin River, which has several major tributaries draining the Sierra Nevada, including the Fresno, Chowchilla, Merced, Tuolumne, and Stanislaus rivers. Historically, these streams were "gaining" streams (i.e., they had a net gain of water from groundwater discharge into the river). With the decline of groundwater levels in the basin, areas of substantial pumping have reversed the local groundwater flow, and reaches of streams now lose water to the aquifer system (losing streams). The main surface water features in the southern portion of the San Joaquin Valley Groundwater Basin (Tulare Lake Hydrologic Region) are the Kern, Kaweah, and Kings Rivers. Agricultural development and groundwater pumping in the area, with the resultant decline in groundwater levels, has caused the majority of the rivers and streams to lose water to the aquifer system (losing streams).

Groundwater Production, Levels, and Storage

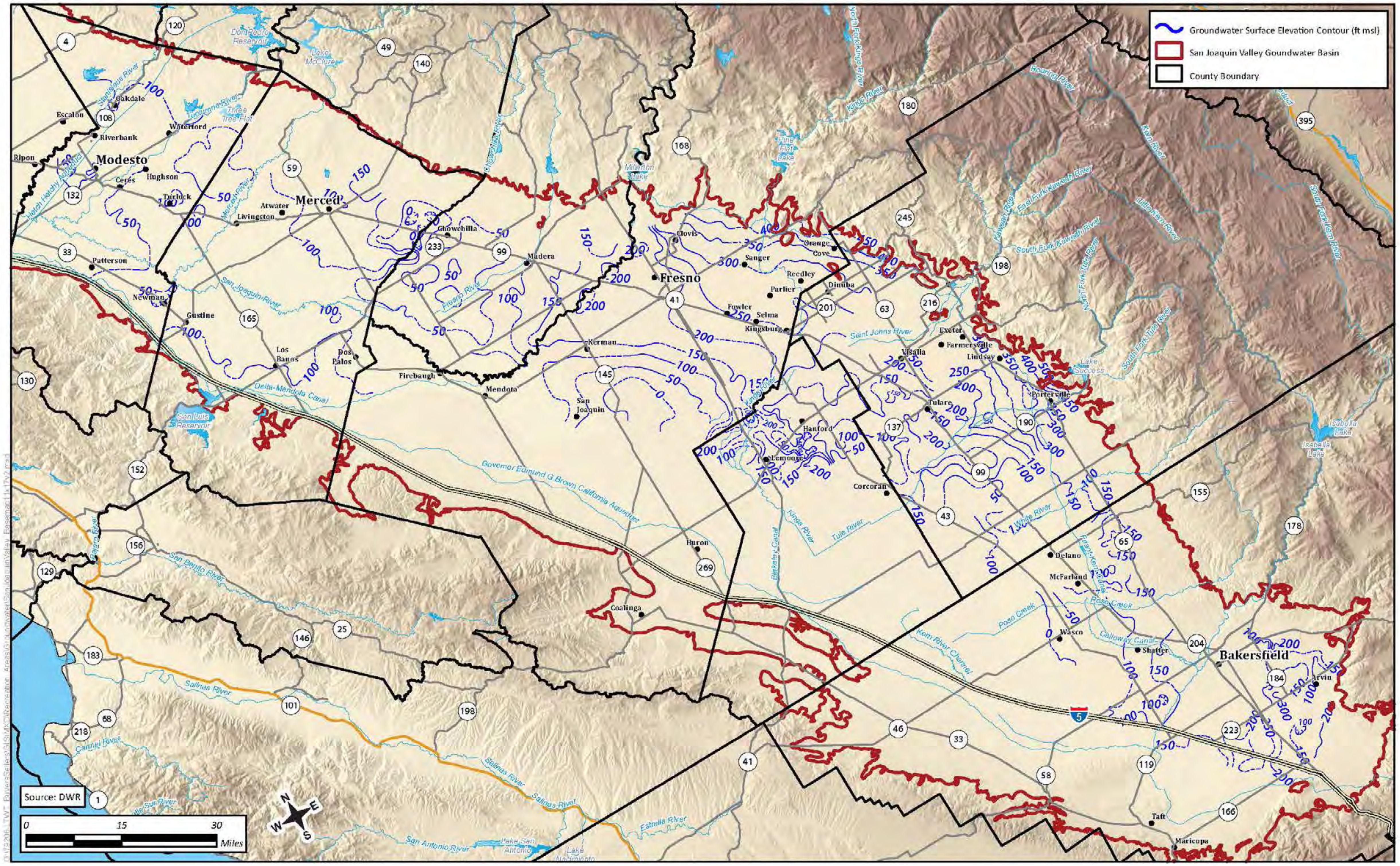
Prior to the large-scale development of irrigated agriculture, groundwater in the basin generally flowed from areas of higher elevation (i.e., the edges of the basin) toward the San Joaquin River and ultimately to the Delta. Most of the water in the San Joaquin Valley moved laterally, but a small amount leaked upward through the intervening confining unit (Planert and Williams 1995). Upward vertical flow to discharge areas from the deep confined part of the aquifer system was impeded partially by the confining clay beds, particularly the Corcoran Clay. Extensive groundwater pumping and irrigation (with imported surface water) have modified local groundwater flow patterns and in some areas, groundwater depressions are evident. Groundwater flow has become more rapid and complex. Groundwater pumping and percolation of excess irrigation water has resulted in steeper hydraulic gradients as well as shortened flow paths between sources and sinks (Faunt 2009).

Irrigated agriculture in the northern portion of the San Joaquin Valley Groundwater Basin increased from about one million acres in the 1920s to more than 2.2 million acres by the early 1980s (Reclamation 1997). Two water balance subregions (12 and 13) in the USGS's ~~Central Valley Hydrologic Model (CVHM),~~CVHM, show average groundwater pumping to be 799,000 AF per year from 1962 through 2003 (Faunt 2009).

Figure 3.3-~~16~~19 shows Spring 2010 groundwater elevation contours for the San Joaquin Valley Groundwater Basin. ~~The~~According to CVHM, the cumulative change in groundwater storage for the entire San Joaquin Valley Groundwater Basin was relatively constant from 1962 through 2003 ~~according to the CVHM~~ (Figure 3.3-~~10). Similar to the Sacramento Valley Groundwater Basin,~~14a), storage ~~tends to drop~~dropped during dry periods and ~~increase~~increased during wetter years. However according to C2VSim (Figure 3.3-14b), storage within the San Joaquin Valley has been showing a steady decline since the 1940s. Annual average groundwater production in the basin was estimated to be 0.9 million AF in the CVHM model (Faunt 2009).

Groundwater-Related Land Subsidence

From the 1920s until the mid-1960s, the use of groundwater for irrigation of crops in the San Joaquin Valley increased rapidly, causing land subsidence throughout the west and southern portions of the valley. From 1920 to 1970, almost 5,200 square miles of irrigated land in the San Joaquin River Watershed showed at least one foot and as much as 28 feet of land subsidence in northwest Fresno County (CALFED 2000). Land subsidence is concentrated in areas underlain by the Corcoran Clay. Figure 3.3-~~17~~20a shows areas of subsidence in the San Joaquin Valley as of 2000.



Source: DWR 2011

Figure 3.3-~~16.~~-19. San Joaquin Valley Spring 2010 Groundwater Elevation Contours

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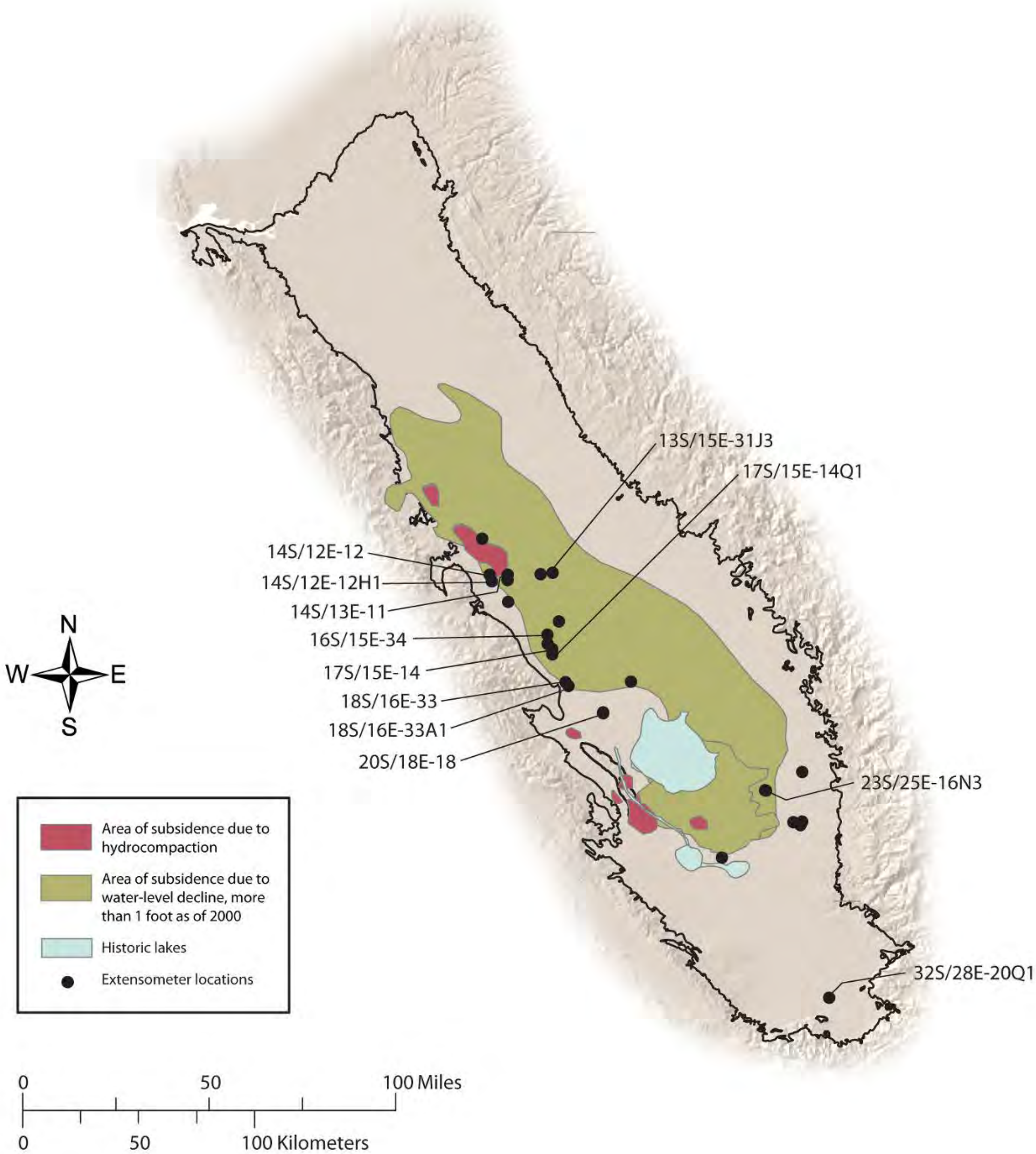

Source: Faunt 2009

Figure 3.3-~~17.~~-20a. Areas of Subsidence in the San Joaquin Valley, as of 2000

Land subsidence studies conducted during the 1950s and 1970s focused on the vicinity of the California Aqueduct. During this period, the ~~State~~California was considering construction of the California Aqueduct, and subsidence due to the large amount of groundwater extraction in the area was a major concern. Following construction, delivery of surface water conveyed by the aqueduct reduced the irrigators' need to extract groundwater, thus reducing the rate of subsidence. Interferometric Synthetic Aperture Radar (InSAR) analyses conducted over the San Joaquin Valley in 2013 indicates substantial subsidence at (1) approximately 7,000 square kilometers of area west of Tulare and east of Kettleman City; and (2) 3,100 square kilometers of area near El Nido (South of Merced and west of Madera). Land elevation benchmark surveys conducted by Caltrans along Highway 198 corroborate the InSAR analyses and indicate 9.37 feet of subsidence occurring in this area between 1960 and 2004.

Land subsidence measurements have shown that an increase in groundwater pumping ~~during 1984-1996~~from1984 to1996 resulted in land subsidence of up to two feet along the Delta-Mendota Canal (CALFED 2000). Similarly, increased pumping caused Westlands WD to experience up to two feet of subsidence between 1983 and 2001, with most of the subsidence occurring after 1989 (Westlands WD 2000). Six extensometers near the California Aqueduct measure subsidence, as shown in Figure 3.3-~~17~~20a. Figure 3.3-~~18~~20b shows the extent of subsidence from 1983 to 1998. Data beyond 1998 was not available from DWR for these locations.

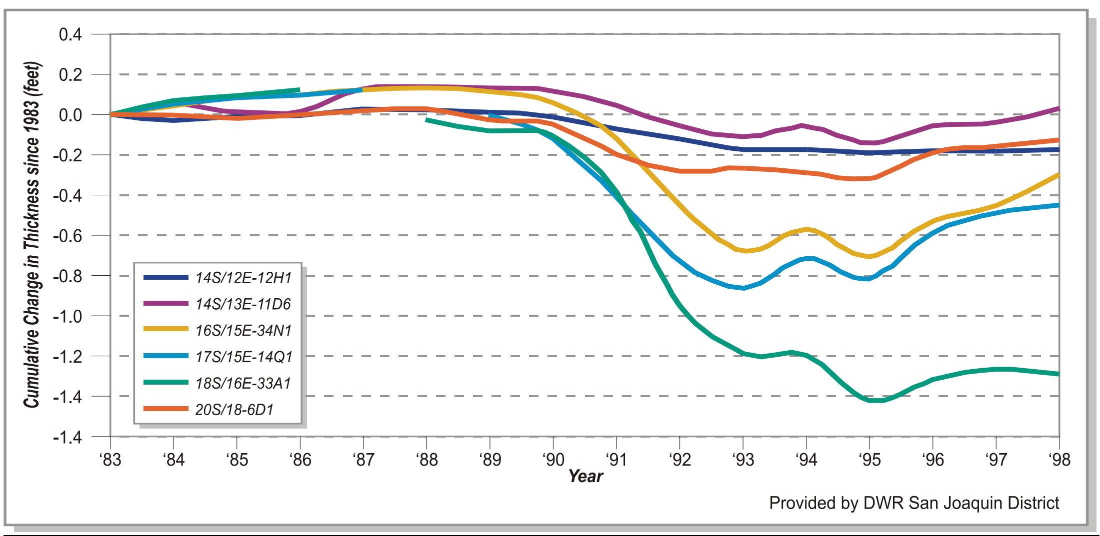

Figure 3.3-20b. Measured Land Subsidence in the San Joaquin Valley, 1983 through 1998

A 2013 USGS study found that the northern portion of the Delta-Mendota Canal was stable or experienced little subsidence from 2003-2010. The southern portion of the Delta-Mendota Canal subsided as part of a large area of subsidence centered near the town of El Nido. Subsidence measurements indicated more than 20 millimeters of subsidence from 2008 to 2010 (Sneed et al 2013). Land subsidence will continue if overdraft of the underlying aquifers continues.

Groundwater Quality

Groundwater quality varies throughout the San Joaquin Valley Groundwater Basin. The GAMA Program's Priority Basin Project evaluates statewide groundwater quality and sampled 67 wells in the northern San Joaquin Valley region; 79 wells in the central region (includes Modesto, Turlock, Merced, and Uplands subbasins) and 126 wells in the southern region (Kings, Kaweah, Tule, and Tulare basins) between 2004 and 2006. Water quality data was analyzed for inorganic constituents (e.g., nutrients, radioactive constituents, TDS, and iron/manganese); special interest constituents (e.g., perchlorate) and organic constituents (e.g., solvents, gasoline additives, and pesticides).

Inorganic Constituents:

Arsenic, vanadium and boron were the trace elements that were most frequently detected at concentrations greater than the MCL within the basin. Aluminum, barium, lead, antimony, mercury, valadium, and fluoride were also detected at concentrations above the MCL in less than two percent of the primary aquifers (Belitz 2010, Bennett 2010, Burton 2012).

Nutrients such as nitrate and nitrite are naturally present at low concentrations in groundwater. High and moderate concentrations generally occur as a result of human activities, such as applying fertilizer to crops. Livestock, when in concentrated numbers, and septic systems also produce nitrogenous waste that can leach into groundwater. Nitrate was present at concentrations greater than the MCL in two percent of the primary aquifers in the northern and central portion of the basin and six percent of the primary aquifers in the southern region of the basin (Belitz 2010, Bennett 2010, Burton 2012).

CDPH and USEPA's secondary drinking water standard for TDS is 500 mg/L, and the agricultural water quality goal for TDS is 450 mg/L. TDS concentrations were greater than the upper limit in about two percent of the primary aquifers in the central portion of the valley and in about six percent of the primary aquifers in the northern portions of the basin (Belitz 2010, Bennett 2010, Burton 2012). TDS concentrations in the northern portion of the San Joaquin Valley Groundwater Basin are generally higher than in the Sacramento Valley Groundwater Basin. Concentrations of TDS along the east side of the Basin are generally lower than along the west side, as a result of higher quality water recharging the aquifer and soil types.

Organic Constituents:

Solvents were detected at concentrations greater than the MCL in less than one percent of the primary aquifers within the basin. Other VOCs (e.g., trihalomethanes and organic synthesis reagents) were not detected at concentrations above MCLs in the primary aquifers (Belitz 2010, Bennett 2010, Burton 2012).

3.3.1.3.4 Santa Clara Valley Groundwater Basin (Santa Clara Valley Subbasin)

Buyers in the San Francisco Bay area include Santa Clara WD, Contra Costa WD, and East Bay MUD.

Santa Clara WD is the only buyer within the San Francisco Bay area that relies on groundwater resources to meet their existing water supply demands. Santa Clara WD underlies the Santa Clara Valley Groundwater Basin and the Gilroy-Hollister Valley Groundwater Basin. The Santa Clara Valley Groundwater Basin contains the Santa Clara Valley, San Mateo Plain and East Plain subbasins. The Santa Clara subbasin occupies a structural trough parallel to the northwest trending Coast Range. The Diablo Range bounds it on the west and the Santa Cruz Mountains form the basin boundary on the east. It extends from the northern border of Santa Clara County to the groundwater divide near the town of Morgan Hill. Figure 3.3-~~19~~21 shows the Santa Clara Valley Groundwater Basin and subbasins within the area of analysis.

Contra Costa WD does not rely on groundwater resources as a significant part of its water supply (Contra Costa WD 2011). The water transfers alternatives discussed in this document are not anticipated to change the use of groundwater resources within the Contra Costa WD area; therefore, details of groundwater conditions in this area are not discussed here.

East Bay MUD also does not rely on groundwater resources but provides surface water supplies from the Mokelumne River and local runoff (East Bay MUD 2012). Thus, similar to the Contra Costa WD, the alternatives discussed in this document are not anticipated to change the use of groundwater resources within the East Bay MUD service area.

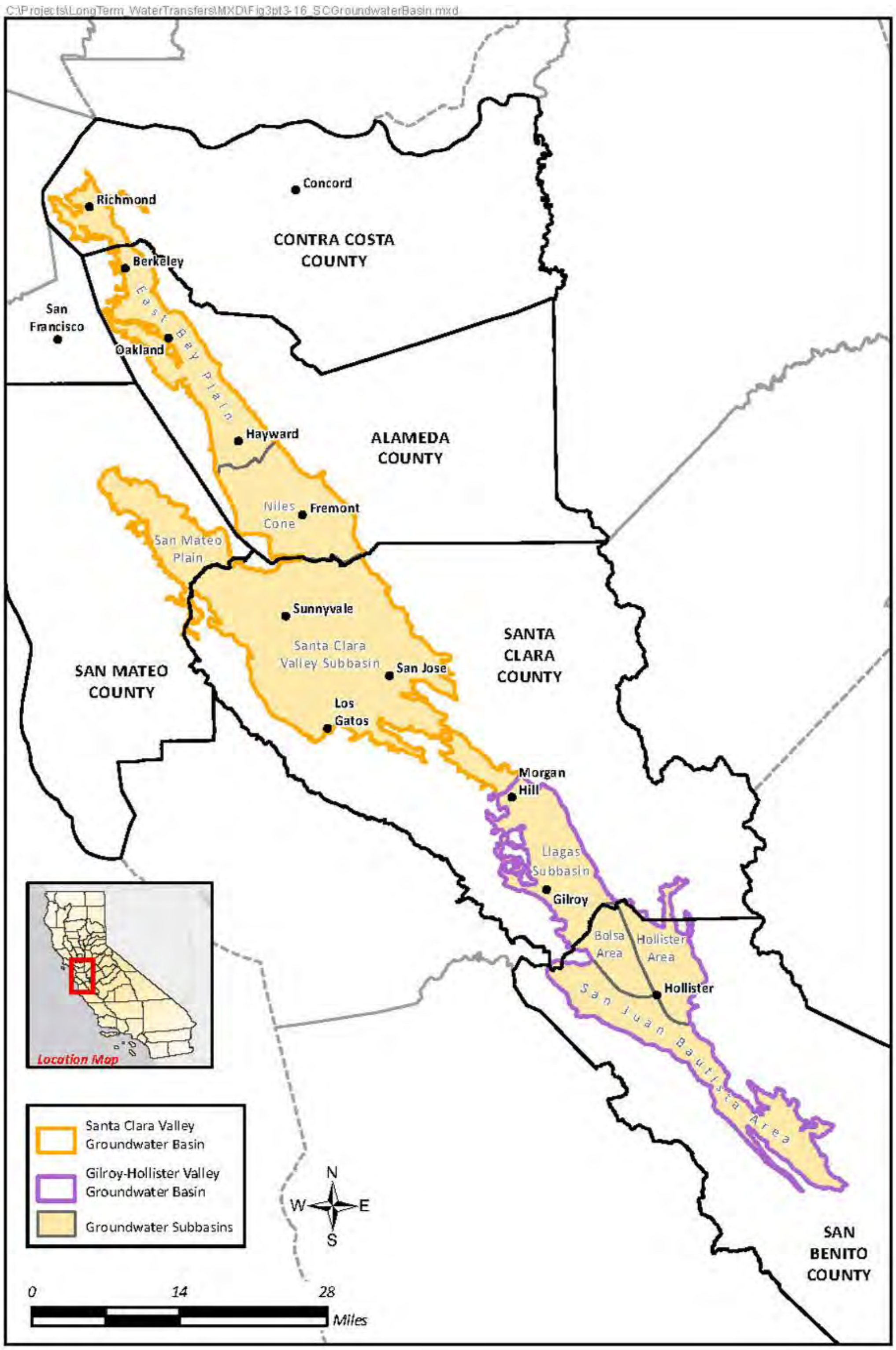

Figure 3.3-~~19.~~-21. Santa Clara Valley and Gilroy-Hollister Valley Groundwater Basins

Geology, Hydrogeology, and Hydrology

The Santa Clara Valley Subbasin includes continental deposits of unconsolidated to semi-consolidated gravel, sand, silt, and clay. Two members form this group, the Santa Clara Formation of Plio-Pleistocene age and the younger alluvium of Pleistocene to Holocene age (DWR 1975). The combined thickness of these two units likely exceeds 1,500 feet (DWR 1967).

The Santa Clara Formation rests unconformably on impermeable rocks that mark the bottom of the groundwater subbasin (DWR 1975). The Santa Clara Formation is exposed only on the west and east sides of the Santa Clara Valley. The exposed portions are composed of poorly sorted deposits ranging in grain size from boulders to silt (DWR 1975). Well logs indicate that permeability increases from west to east and that in the central part of the valley permeability and grain size decrease with depth (DWR 1975).

In the Santa Clara Valley, groundwater occurs in Pleistocene to Holocene alluvium deposits. The permeability of the valley alluvium is generally high and all large production wells derive their water from it (DWR 1975). Valley alluvium is deposited as a series of convergent alluvial fans generally comprised of unconsolidated gravel, sand, silt, and clay. It becomes progressively finer grained in the central portion of the valley. A confined aquifer zone is present in the northern portion of the subbasin where it is overlain by a low-permeability clay layer (Santa Clara Valley WD 2001). The southern portion of the subbasin is generally unconfined and contains no thick clay layers (Santa Clara Valley WD 2001).

Natural recharge occurs principally as infiltration from streambeds that exit the upland areas within the drainage basin and from direct percolation of precipitation that falls on the basin floor. Annual precipitation for the Santa Clara Valley Groundwater basin ranges from less than 16 inches in the valley to more than 28 inches in the upland areas (DWR 2003).

The main surface water features in the Santa Clara Valley Groundwater Basin are the tributaries to San Francisco Bay including Coyote Creek, Guadalupe River, and Los Gatos Creek. The Santa Clara Valley WD conducts an artificial recharge program by releasing locally conserved or imported water to in-stream and off-stream facilities (Santa Clara Valley WD 2001). District-wide controlled in-stream recharge accounts for about 45 percent of groundwater recharge in district facilities (Santa Clara Valley WD 2001). In-stream recharge occurs along stream channels in the alluvial apron upstream from the confined zone. Spreader dams (creating temporary or permanent impoundments in the stream channel) are a key component of the in-stream recharge program, increasing recharge capacity by approximately ten percent (Santa Clara Valley WD 2001).

Groundwater Production, Levels and Storage

Santa Clara Valley WD manages the Santa Clara Valley Subbasin. Groundwater is pumped within the district by major water retailers, well owners, and agricultural users. Annual average groundwater pumping within the Santa Clara Valley Subbasin has remained relatively constant over time. Figure 3.3-~~20~~22 shows historic groundwater pumping from 2000 to 2009 within the subbasin.

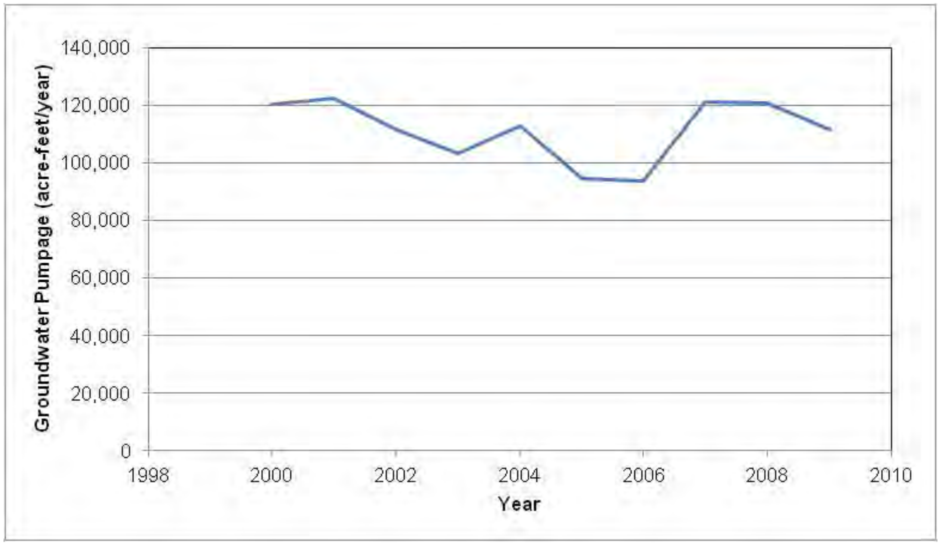

Figure 3.3-~~20.~~-22. Historic Groundwater Pumping in the Santa Clara Valley Subbasin

Historically, since the early 1900s through the mid-1960s groundwater level declines from groundwater pumping have induced subsidence in the Santa Clara Valley Subbasin and caused degradation of the aquifer adjacent to the bay from saltwater intrusion. Prior to surface water import via the Hetch Hetchy and South Bay Aqueducts and the introduction of an artificial recharge program, water levels declined more than 200 feet in the Santa Clara Valley (Santa Clara Valley WD 2000). Santa Clara Valley WD has also implemented various recharge programs that use local runoff and imported water deliveries to recharge groundwater through approximately 390 acres of recharge ponds and 90 miles of local creeks to stop groundwater overdraft and land subsidence (Santa Clara Valley WD 2001). Groundwater levels have generally increased since 1965 as a result of increased in-stream and off-stream recharge programs and decreased pumping due to increase in availability of imported surface water (Santa Clara Valley WD 2001). Figure 3.3-~~21~~23 shows the location of selected monitoring wells within the Santa Clara Valley Subbasin and the groundwater elevation at the wells.

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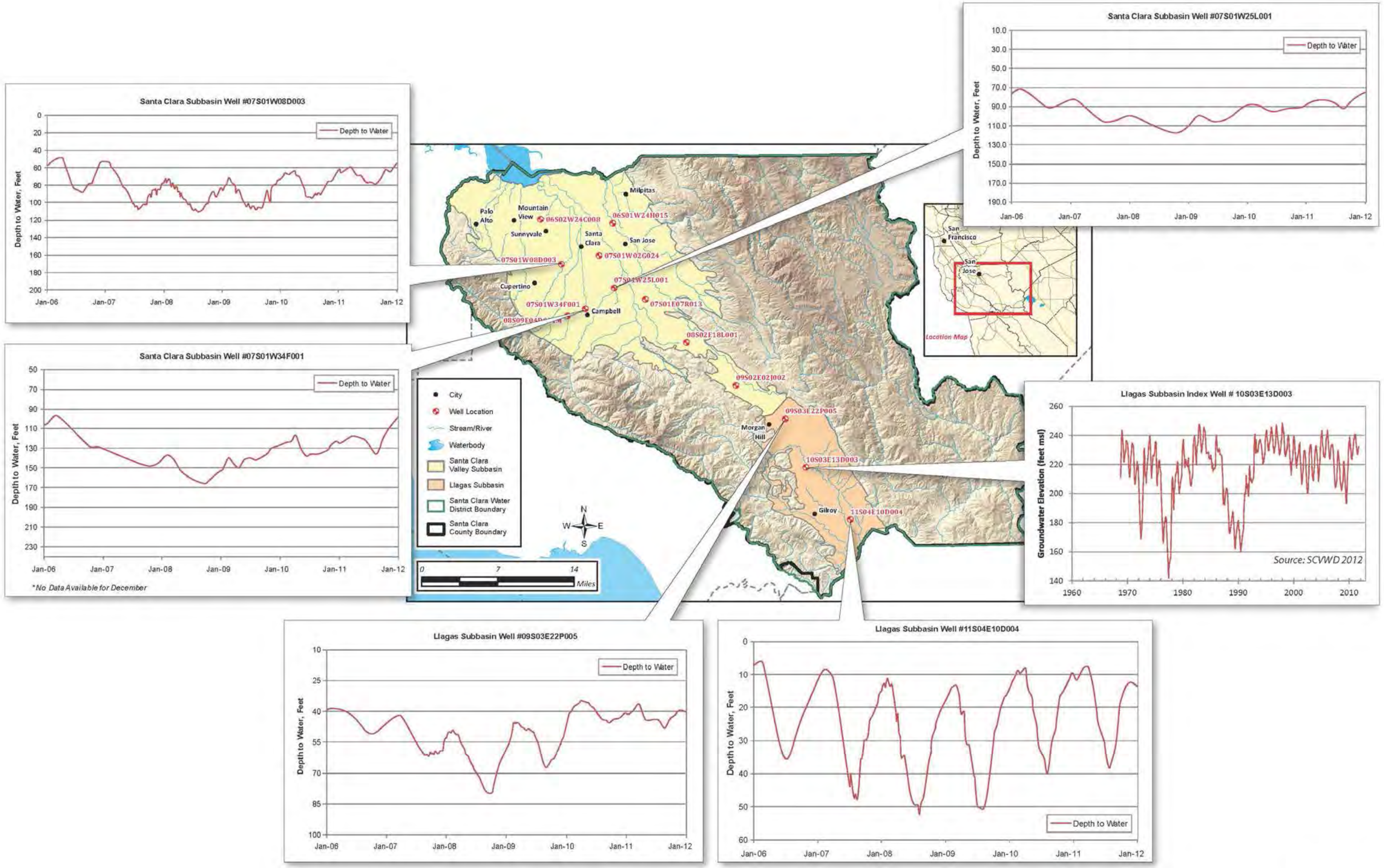

Figure 3.3-~~21.~~-23. Historic Groundwater Elevations at Selected Wells in the Santa Clara Valley Subbasin

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The operational storage capacity of the Santa Clara Valley Subbasin is estimated to be 350,000 AF (Santa Clara Valley WD 2001). The operation storage capacity is less than the total storage capacity of the basin and accounts for available pumping capacity, avoidance of land subsidence, and problems associated with high groundwater levels. This estimate of operation storage capacity is based on an area defined by Santa Clara Valley WD that is approximately 15 square miles smaller than the Santa Clara Valley Subbasin boundaries as defined in DWR's Bulletin 118 (DWR 2003).

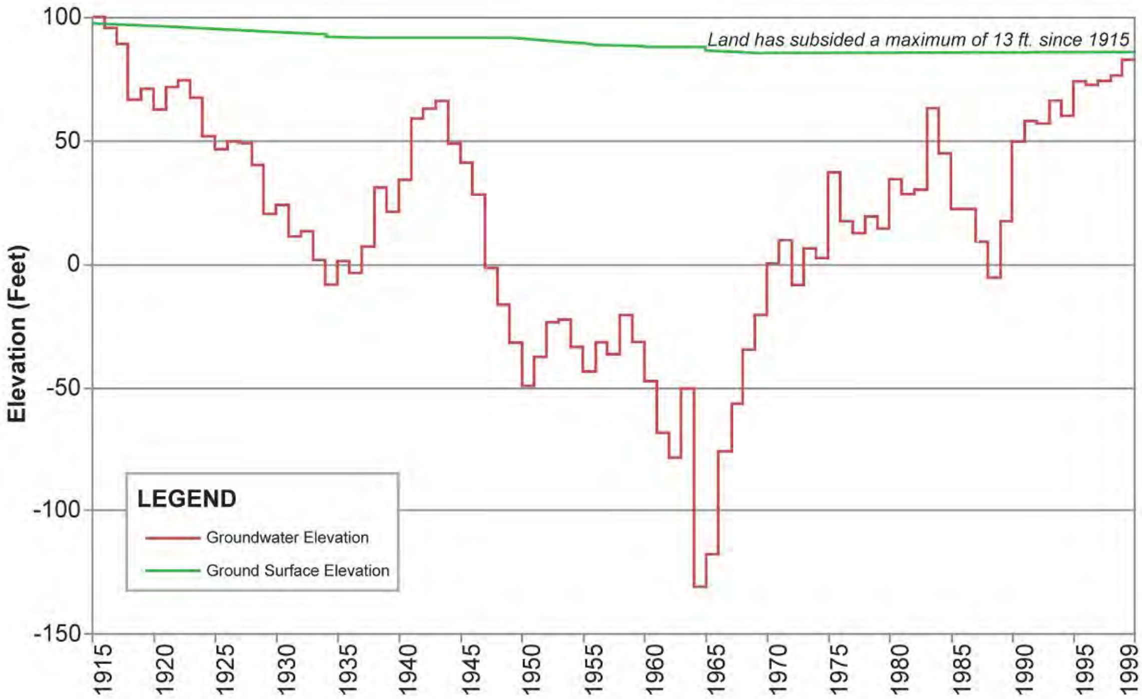
Groundwater-Related Land Subsidence

Historically, Santa Clara County has experienced as much as 13 feet of subsidence caused by excessive pumping of groundwater. One serious consequence of subsidence in Santa Clara County was that lands near the San Francisco Bay sank below sea level between 1940 and 1970, enabling salt water to intrude upstream through the mouths of rivers dramatically affecting the riparian habitat of the rivers. Figure 3.3-~~22~~24 reflects the elevation of groundwater at the downtown San Jose index well (7S01E07R013) and the land surface elevation measured at First and St. James Streets in San Jose. The figure illustrates the increase in groundwater levels since 1965 through the implementation of Santa Clara Valley WD's groundwater recharge, treated water ground reinjection and water use efficiency programs. The figure also illustrated the substantial reduction in land subsidence due to groundwater level recovery. Santa Clara Valley WD conducts routine groundwater elevation, quality and land subsidence monitoring within the valley. Land Subsidence monitoring in the valley show the reduction in subsidence to an average of 0.01 feet per (Santa Clara Valley WD 2001).

Groundwater Quality

Though groundwater in the Santa Clara Valley Groundwater Basin is hard, it is suitable for most uses and drinking water standards are met at public supply wells without the use of treatment methods (Santa Clara Valley WD 2001). Groundwater alkalinity in the Santa Clara Valley Groundwater Basin is generally a bicarbonate type with sodium and calcium being the principal cations (DWR 1975).

Groundwater in the region has elevated mineral levels which could be associated with historical saltwater intrusion observed in the northern basin due to land subsidence (Santa Clara Valley WD 2001). Some wells with elevated nitrate concentration have been identified in the southern portion of the basin (Santa Clara Valley WD 2001).



Source: Santa Clara Valley WD 2000

Figure 3.3-~~22.~~-24. Land Subsidence at the San Jose Index Well

3.3.1.3.5 Gilroy-Hollister Valley Groundwater Basin (Llagas Subbasin)

The Llagas subbasin is part of the Gilroy-Hollister Valley Groundwater Basin. The Llagas subbasin occupies a northwest trending structural depression. The Diablo Range bounds it on the east and the Santa Cruz Mountains form the subbasin boundary on the west. The subbasin extends from the groundwater divide at Cochran Road near the town of Morgan Hill in the north to the Pájaro River in the south (Santa Clara Valley WD 2001).

Geology, Hydrogeology, and Hydrology

The Llagas subbasin is similar to the Santa Clara Valley subbasin and was formed by continental deposits of unconsolidated to semi-consolidated gravel, sand, silt and clay (DWR 1981). The water bearing formation of the subbasin includes the Santa Clara Formation and the valley fill material (alluvial and alluvial fan deposits) (DWR 1981).

The Santa Clara Formation is of Plio-Pleistocene age. This formation underlies much of the valley and unconformably overlies older non-water bearing sediments (DWR 1981). It consists of fairly well consolidated clay, silt, and sand with lenses of gravel. These sediments are generally of fluvial origin with an estimated maximum thickness of 1,800 feet (DWR 1981). The lower portions of deeper wells within the subbasin likely intersect the Santa Clara Formation. Alluvial fan deposits of Holocene age occur at the margin of the valley basin. They are composed of a heterogeneous mixture of unconsolidated to semi-consolidated clay, silt, sand, and gravel that are partially confined locally (DWR 1981). The alluvial fan deposits range in thickness from three to 125 feet and overlie the Santa Clara Formation and other older non-water-bearing deposits (DWR 1981). A number of wells supply groundwater of excellent quality for irrigation and municipal purposes (DWR 1981).

Older Alluvium of Plio-Pleistocene age is distributed in the central portion of the valley from the northern boundary of the subbasin to Gilroy. Older Alluvium consists of unconsolidated clay, silt, and sand formed by floodplain processes. It characteristically is identified by a dense clayey subsoil that acts as an aquitard to vertical movement of water and limits recharge potential (DWR 1981). It provides adequate yields to wells up to 100 feet in depth and water obtained from this formation is generally suitable for most uses (DWR 1981). Younger alluvium of Holocene age occurs in the flat lying areas from Gilroy south to the subbasin's southern boundary. Similar to the Older Alluvium, the Younger Alluvium has been formed principally as a floodplain deposit but it does not have a well-defined clay subsoil. The Younger Alluvium has a maximum thickness of about 100 feet and generally overlies the Older Alluvium and alluvial fan deposits (DWR 1981). Groundwater in the Younger Alluvium is generally unconfined and the quality of water is acceptable for domestic purposes (DWR 1981).

The dominant geohydrologic feature in the subbasin is an inland valley that is drained to the south by tributaries of the Pájaro River, including Uvas and Llagas creeks. Annual precipitation for the Llagas subbasin ranges from less than 16 inches in the south to more than 24 inches in the north (DWR 2003).

Groundwater Production, Levels and Storage

Santa Clara Valley WD manages the Llagas subbasin and groundwater is pumped within the district by major water retailers, well owners and agricultural users. Figure 3.3-~~23~~25 shows historic groundwater pumping from 2000 to 2009 within the basin.

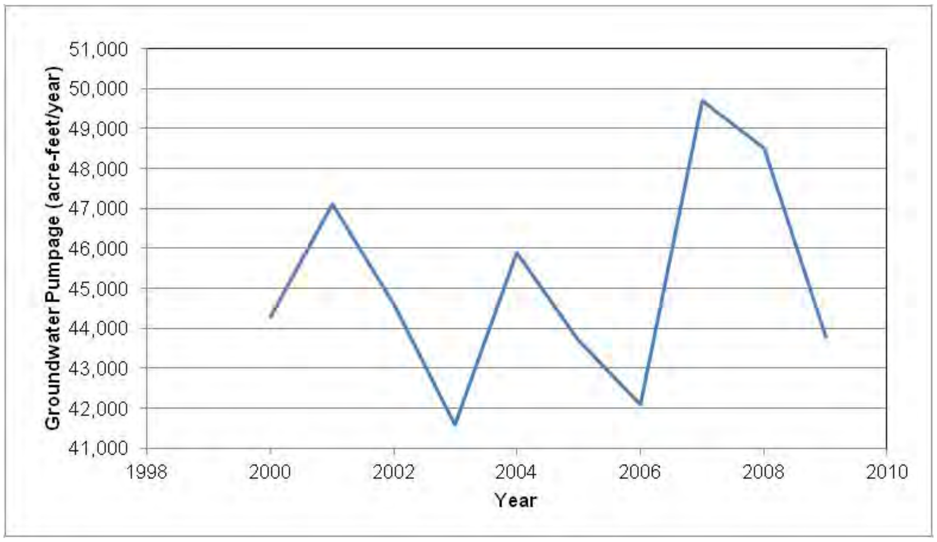


Figure 3.3-25. Historic Groundwater Pumping Within the Llagas Subbasin

~~21~~Figure 3.3-23 shows the groundwater elevation in the Llagas subbasin index well (10S03E13D003). Groundwater levels remained relatively stable over the period of record with the exception of water level declines and subsequent recovery associated with the 1976-1977 and 1987-1992 drought periods. While groundwater elevations in the index well are not indicative of elevations in all wells within the subbasin, it is representative of relative changes in groundwater levels within the subbasin (Santa Clara Valley WD 2001).

Natural groundwater recharge based on the long-term average for the Llagas subbasin is estimated to be 44,300 AF per year (Santa Clara Valley WD 2001). Total facility recharge (Artificial Recharge) countywide is estimated to be 157,200 AF (Santa Clara Valley WD 2001). The operational storage capacity of the Llagas subbasin is estimated to be between 150,000 and 165,000 AF (Santa Clara Valley WD 2010). The operation storage capacity is less than the total storage capacity of the subbasin and accounts for available pumping capacity, avoidance of land subsidence, and problems associated with high groundwater levels.

Groundwater-Related Land Subsidence

Historically, Santa Clara County has experienced as much as 13 feet of subsidence caused by excessive pumping of groundwater. Most of the subsidence occurred in the Santa Clara Valley subbasin (Santa Clara Valley WD 2000).

Groundwater Quality

Groundwater alkalinity in the Llagas subbasin is generally high, similar to the Santa Clara Valley subbasin. Though the water is hard, it is suitable for most uses and drinking water standards are met at public supply wells without the use of treatment methods (Santa Clara Valley WD 2001).

The Santa Clara Valley WD created a Nitrate Management Program in October 1991 to investigate and remediate increasing nitrate concentrations in the Llagas subbasin (Santa Clara Valley WD 2001). Nitrate concentrations appear to be increasing over time and elevated concentrations of nitrate still exist in the Llagas subbasin (Santa Clara Valley WD 2001). Since 1997, more than 600 wells in south Santa Clara County including the Llagas and Coyote subbasins have been tested for nitrate. The 2009 median nitrate concentration for the principal aquifer zone of the Llagas Subbasin was 30 mg/L, with a maximum value of 155 mg/L (Santa Clara Valley WD 2010).

3.3.2 Environmental Consequences/Environmental Impacts

This section describes assessment methods and presents effects of the proposed alternatives on groundwater resources in the area of analysis. Groundwater substitution and cropland idling transfers could alter the existing subsurface hydrology and thus result in a variety of effects to groundwater levels, land subsidence, or groundwater quality, which are further described below.

Groundwater Levels: Changes in groundwater levels could cause multiple secondary effects. Declining groundwater levels could result in: (1) increased groundwater pumping costs due to increased pumping depth; (2) decreased yield from groundwater wells due to reduction in the saturated thickness of the aquifer; or (3) lowered groundwater table elevation to a level below the vegetative root zone, which could result in environmental effects. This groundwater analysis examines effects associated with item (2~~); pumping~~). Pumping costs are considered in Section 3.10, Regional Economics~~,~~; impacts to fisheries are included in Section 3.7, Fisheries; and effects to vegetation are considered in Section 3.8, Vegetation and Wildlife.

Land Subsidence: Excessive groundwater extraction from confined and unconfined aquifers could lower groundwater levels and decrease pore-water pressure. The reduction in pore-water pressure could result in a loss of structural support for clay and silt beds, which could lower the ground surface elevation (land subsidence). The compression of fine-grained deposits, such as clay and silt, is largely permanent. Infrastructure damage to buildings, conveyance and drainage facilities, and wells and alteration of drainage patterns are possible consequences of land subsidence.

Groundwater Quality: Changes in groundwater levels and the potential change in groundwater flow directions could cause a change in groundwater quality through a number of mechanisms. One mechanism is the potential mobilization of areas of poorer quality water, drawn down from shallow zones, or drawn up into previously unaffected areas. Changes in groundwater gradients and flow directions could also cause (and speed) the lateral migration of poorer quality water.

3.3.2.1 Assessment Methods

3.3.2.1.1 Numerical Modeling of Regional Groundwater Level Declines

Numerical groundwater modeling analysis was performed using the Sacramento Valley Finite Element Groundwater Model (SACFEM2013) developed to simulate groundwater conditions in the Sacramento Valley. SACFEM2013 was selected as the numerical modeling tool for this analysis based on the state of the model and its capabilities to simulate groundwater conditions at a greater level of detail than other potential modeling tools within the Seller Service Area. Reclamation commissioned a peer review of the SACFEM2013 model in 2010 (WRIME 2011). Revisions were made to the model and the revised model was used for the impacts analysis described here.

SACFEM2013 uses the MicroFEM finite-element numerical modeling code. MicroFEM is capable of simulating multiple aquifer systems in both steady state and transient conditions. The model is capable of simulating groundwater conditions and groundwater/surface water interactions in the valley. SACFEM2013 was also used to estimate how groundwater pumping and recharge affects surface water; these impacts are assessed in Section 3.1, Water Supply.

SACFEM2013 covers the entire Sacramento Valley Groundwater Basin from just north of Red Bluff to the Cosumnes River in the south (see Figure 3.3-~~24~~26). The model was calibrated to historic conditions from Water Years (WY) 1970 through WY 2009. This SACFEM2013 model simulation, which includes highly variable hydrology (from very wet periods to very dry periods), was used as a basis for simulating groundwater substitution pumping.

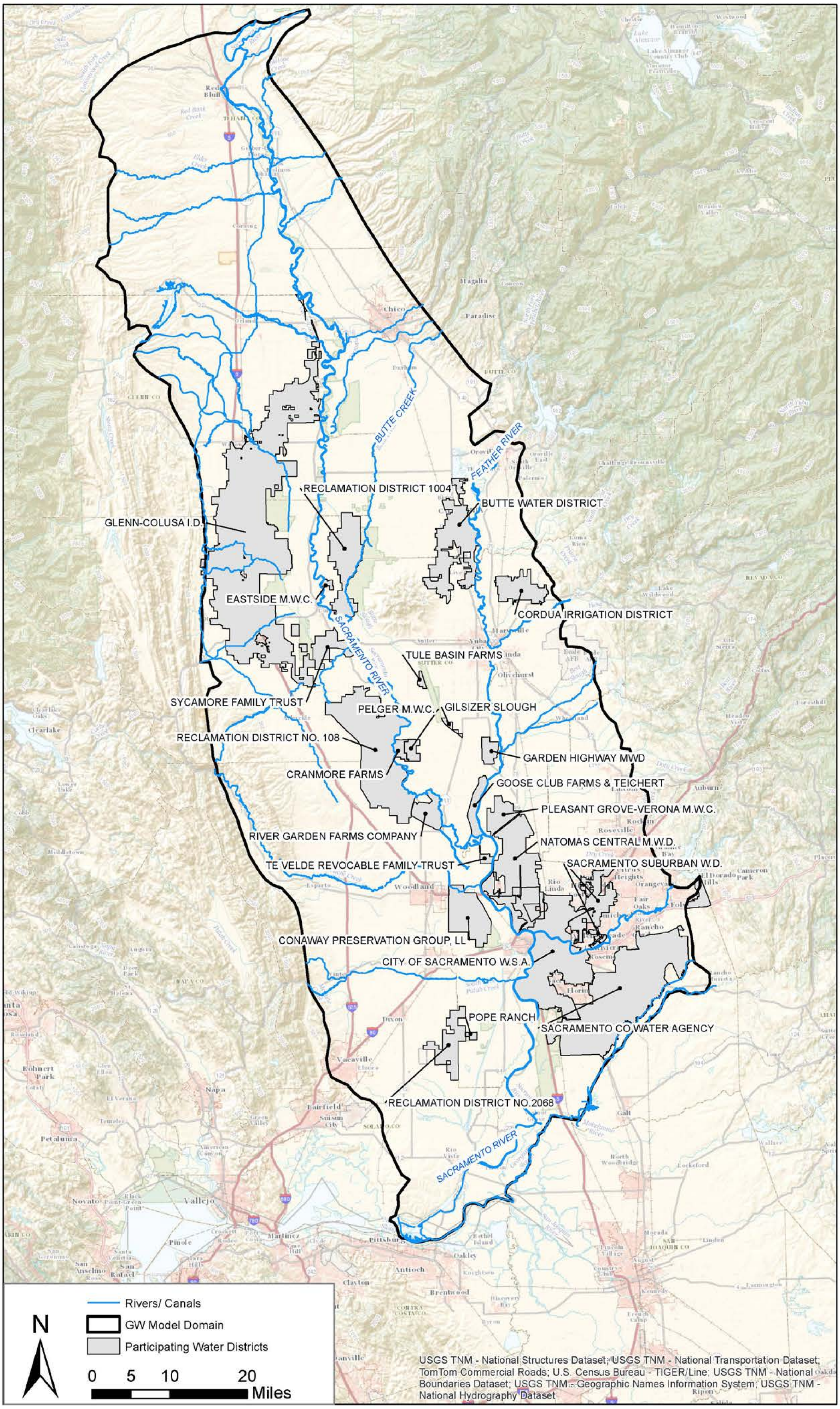


Figure 3.3-26. The SACFEM2013 Groundwater Model Domain

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Groundwater substitution pumping was simulated as an additional pumping stress on the system, above the baseline pumping volume. The annual volume of transfers was determined by comparing the supply in the seller service area to the demand in the buyer service area. The availability of supplies in the seller service area was determined based on data provided by the potential sellers. The demand was estimated using demand data provided by East Bay MUD and Contra Costa WD as well as the available capacity at the Delta export pumps to convey transfers. The available export capacity was determined from CalSim II model results. The CalSim II model currently only simulates conditions through WY 2003. The available capacity for south of delta exports was typically more limiting than the south of delta water supply demand. Because CalSim II results are only available through 2003, the SACFEM2013 model simulation was truncated at the end of WY 2003.

The analysis of supply and demand resulted in the potential to export groundwater substitution pumping transfers through the Delta during 12 of the years from WY 1970 through WY 2003 (33 years, SACFEM2013 simulation period). Each of the 12 annual transfer volumes was included in a single model simulation. Including each of the 12 years of transfer pumping in one simulation rather than 12 individual simulations allows for the potential compounding effects from pumping from prior years. Appendix D, Groundwater Model Documentation; and Appendix M, SACFEM User's Manual, includes more information about the use of SACFEM2013 in this analysis.

3.3.2.1.2 Qualitative Assessments

The groundwater model area includes most, but not all, of the potential sellers. Anderson-Cottonwood ID is not in the Sacramento Valley and is located outside of the area that is covered by the groundwater model. Therefore, changes to groundwater conditions in the Anderson-Cottonwood ID were assessed qualitatively. The buyers are also not included in the groundwater model, so the potential effects are analyzed qualitatively.

Potential land subsidence and changes in groundwater quality were also assessed qualitatively because these processes are not part of the numerical groundwater model. For land subsidence, the modeled groundwater drawdown was compared to areas with existing subsidence to identify areas that may be susceptible to impacts. Additionally simulated groundwater drawdown was compared to estimates of preconsolidated heads/historic low heads. Groundwater quality impacts were assessed by considering areas of known water quality concerns and determining whether modeled groundwater drawdown could cause those areas to migrate.

3.3.2.2 Significance Criteria

An impact would be potentially significant if implementation of groundwater substitution transfers or cropland idling would result in:

- A net reduction in groundwater levels that would result in substantial adverse environmental effects or effects to non-transferring parties;
- Permanent land subsidence caused by significant groundwater level declines; or~~.~~
- Degradation in groundwater quality such that it would exceed regulatory standards or would substantially impair reasonably anticipated beneficial uses of groundwater~~; or~~.

3.3.2.3 Alternative 1: No Action/No Project

3.3.2.3.1 Seller Service Area

Groundwater pumping would not affect groundwater levels, land subsidence, or groundwater quality. There would be no groundwater substitution pumping transfers in the Seller Service Area under the No Action/No Project Alternative. Groundwater pumping would be expected to continue on the same pattern as currently observed. Therefore, the potential for groundwater level declines, increased land subsidence, or groundwater quality degradation in the Seller Service Area would be the same as existing conditions.

3.3.2.3.2 Buyer Service Area

Increased groundwater pumping would not result in temporary groundwater level declines. Under the No Action/No Project Alternative, water users in the Buyer Service Area may use groundwater pumping to meet shortages, which could result in temporary groundwater level declines. Potential buyers have already taken steps to address shortages that have occurred in recent years, and several potential buyers rely heavily on groundwater to meet their water supply demands (see Table 3.3-~~2~~4 for details). Groundwater pumping in these areas has the potential to lower groundwater levels and affect the performance of wells nearby the pumping wells. However, existing pumping activities in the Buyer Service Area already include groundwater pumping to cover existing shortages, and future shortages are anticipated to follow current annual/seasonal and long-term trends. Therefore, the potential for groundwater level declines in the Buyer Service Area would be the same as existing conditions.

Table 3.3-4. Historic Groundwater Pumping and Groundwater Basin Safe Yields for Potential Buyers

Potential Buyer Agency	Underlying Groundwater Basin	Safe Yield of Groundwater Basin (AF)	Groundwater Pumping (AF/year)
Westlands WD[1]	Westside Subbasin	200,000	15,000 – 600,000[2]
Santa Clara Valley WD[3]	Santa Clara Plain Subbasin	373,000 – 383,000	93,500 - 122,300[4]
	Llagas Subbasin	150,000 – 165,000	41,600 - 49,700[4]
Contra Costa WD[5]	-	-	3,000

[1] Source: Westlands WD 1996 1 Based on data from 1988 to 2011.
[2] Average pumping is approximately 218,600 AF/yr
[3] Source: Santa Clara Valley WD 2012
[4] Based on data from 2000 to 2009.Average pumping is approximately 156,330 AF/yr
[5] Source: Contra Costa WD 2011

Groundwater pumping would not cause groundwater level declines that would lead to permanent land subsidence or migration of poor quality groundwater. In the Buyer Service Area, additional groundwater pumping may be expected during shortage periods. However, pumping activities in the Buyer Service Area already include groundwater pumping to cover shortages. Therefore, the potential for groundwater level declines that would cause permanent land subsidence or migration of poor quality groundwater in the Buyer Service Area would be the same as existing conditions.

Idling cropland would not decrease applied water recharge to the local groundwater system underlying the barren (idled) fields that would result in a decline in groundwater levels. Under the No Action/No Project Alternative, agricultural water users in the Buyer Service Area may increase the amount of cropland idling to meet shortages and reduce the amount of groundwater recharge. However, cropland idling activities in the Buyer Service Area already include actions to cover shortages. Therefore, the potential for changes in groundwater levels due to cropland idling in the Buyer Service Area would be the same as existing conditions.

3.3.2.4 Alternative 2: Full Range of Transfers (Proposed Action)

3.3.2.4.1 Seller Service Area: Redding Area Groundwater Basin

Increased groundwater substitution pumping could affect groundwater levels and may result in temporary declines of groundwater levels. The proposed Anderson-Cottonwood ID transfer would extract up to 5,130 AF/year of groundwater from production wells (see Table 3.3-~~3~~5 for details on number of wells and pumping capacity).

Unlike other groundwater substitution transfers, Anderson-Cottonwood ID's proposed transfer was not simulated in the SACFEM2013 because the model area does not include the Redding Area Basin. However, Anderson-Cottonwood ID has tested operation of these wells in the past at similar production rates and has observed no substantial impacts on groundwater levels or groundwater supplies (Anderson-Cottonwood ID 2013). Based on the results of the aquifer tests, effects from groundwater substitution transfers are likely to be less than significant. However, because of the uncertainty surrounding groundwater levels changes, especially during a very dry year, Anderson-Cottonwood ID would implement the Monitoring and Mitigation Plans described in GW-1 (see Section 3.3.4.1 for details).

Increased groundwater pumping may lead to permanent land subsidence caused by water level declines. Land subsidence has not been monitored in the Redding Area Groundwater Basin. However, there would be potential for subsidence in some areas of the basin if groundwater levels were substantially lowered. The groundwater basin west of the Sacramento River is composed of the Tehama Formation; this formation has exhibited subsidence in Yolo County and the similar hydrogeologic characteristics in the Redding Area Groundwater Basin could allow subsidence. Therefore, the effect of potential land subsidence in the Redding Area Groundwater Basin could be significant. To reduce these effects, the Mitigation Measure GW-1 (Section 3.3.4.1) specifies that transferring agencies establish monitoring and mitigation programs for groundwater substitution transfers. These programs will include periodic determination of land surface elevation in strategic locations throughout the transfer area. Mitigation Measure GW-1 would reduce the impacts to less than significant.

Changes in groundwater levels, or in the prevailing groundwater flow regime, could cause a change in groundwater quality. Additional pumping is not expected to be in locations or at rates that would cause substantial long-term changes in groundwater levels that would cause changes to groundwater quality. Consequently, changes to groundwater quality due to increased pumping would be less than significant in the Redding Area Groundwater Basin.

3.3.2.4.2 Seller Service Area: Sacramento Valley Groundwater Basin

Water Transfers via groundwater substitution could affect groundwater levels, land subsidence, and groundwater quality. Figure 3.3-~~25~~27 shows the potential water transferred through groundwater substitution through the period of analysis under the Proposed Action in the SACFEM2013 Model.

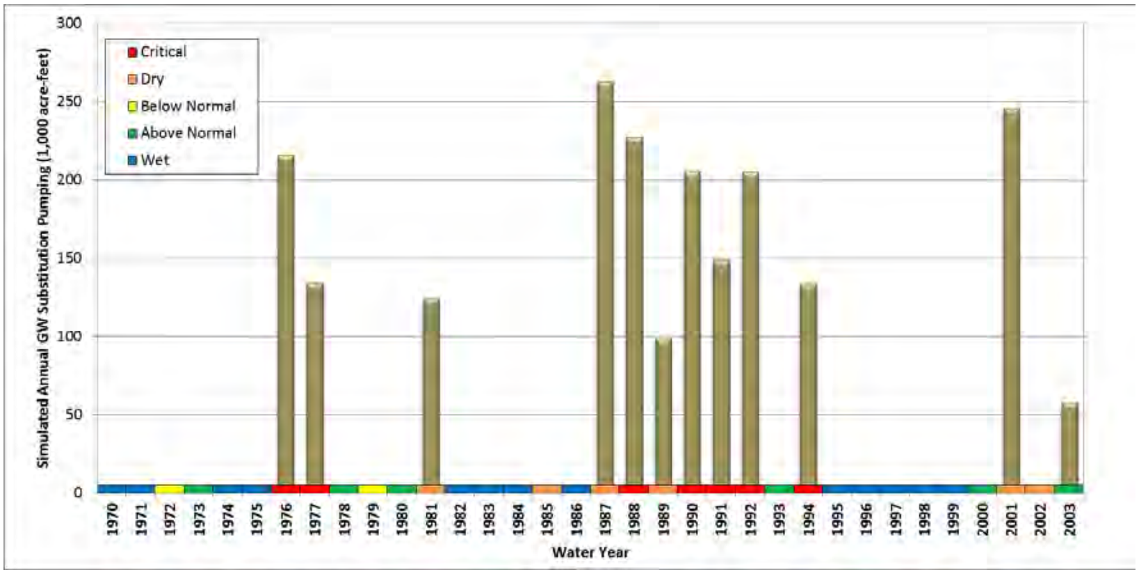

Figure 3.3-~~25.~~-27. Simulated Groundwater Substitution Transfers under the Proposed Action in the SACFEM2013 Model

Increased groundwater substitution pumping may result in temporary declines of groundwater levels. Groundwater substitution pumping would occur when the buyers have capacity to divert the water from the Sacramento River or the Delta.

The effects of the potential groundwater substitution shown in Figure 3.3-~~25~~27 from pumping 327 wells simultaneously based on data collected from potential sellers (listed in Table 3.3-~~3~~5) within the Sacramento Valley have been modeled in SACFEM2013 to estimate effects to groundwater resources. Additional information about the assignment of groundwater pumping in SACFEM2013 can be found in Appendix D, Groundwater Model Documentation. Figures 3.3-~~26~~28 through 3.3-~~28~~30 show the simulated drawdown of groundwater elevations under September 1976 hydrologic conditions (WY 1976 was historically a critical dry year). This time period represents the peak drawdown resulting from the first year of transfers in the groundwater model simulation period (WY 1970 through WY 2003). These figures show simulated drawdown at the water table (Figure 3.3-~~26~~28); at approximately 200-300 feet bgs (Figure 3.3-~~27~~29) and at approximately 700-900 feet bgs (Figure 3.3-~~28~~30). Drawdown at the water table (Figure 3.3-~~26~~28) represents the estimated decline in the water surface within the shallow, unconfined portion of the aquifer (i.e., the height of water within a shallow groundwater well). The changes in the deeper portion of the aquifer (Figure 3.3-~~27~~29 and Figure 3.3-~~28~~30) represent a change in piezometric head in a well that is screened in this lower portion of the aquifer.

A decrease in the head in the deeper aquifer would increase the work (and energy) required to withdraw the same amount of water from the deeper aquifer. The amount of drawdown in a deep well would vary depending on the aquifer characteristics, depth and screened interval of the well.

Similarly, Figures 3.3-~~29~~31 through 3.3-~~31~~33 show the simulated drawdown of groundwater elevations under September 1990 hydrologic conditions. This period represents the fourth year of a multi-year drought with transfers occurring in each year of the drought. Similar to the September 1976 figures, drawdown in 1990 is shown for the water table (Figure 3.3-~~29~~31); at approximately 200-300 feet bgs (Figure 3.3-~~30~~32) and at approximately 700-900 feet bgs (Figure 3.3-~~31~~33). Each of these figures show the cumulative effects of multi-year transfers as groundwater substitution pumping was simulated in 1987, 1988, 1989, and 1990. Because groundwater substitution transfers were simulated during each year of this drought period, the groundwater table does not completely recover to pre-substitution conditions during this period. Groundwater level drawdown and subsequent recovery ~~are~~ can also be viewed at a specific location through the entire 33 year simulation period. Representative hydrographs were extracted from the model results at the 42 locations shown with pink triangles in Figures 3.3-~~26~~28 through 3.3-~~31~~33. Appendix E, Groundwater Modeling Results, includes hydrographs for all 42 locations and seven simulated model layers (varying depths throughout the model).

~~Three~~ Five of the 42 locations are presented here to illustrate the simulated groundwater drawdown and recovery process within the Sacramento Valley. These ~~three~~ five locations were selected as they are spread out over the Sacramento Valley and ~~are~~ show~~s~~ the largest drawdowns within the 42 representative hydrograph locations.

Table 3.3-5. Water Transfer through Groundwater Substitution under the Proposed Action

Groundwater Basin	Potential Seller	Number of Wells	Pumping Rate per well (gpm)	Well Depth (ft)
Redding Area Valley	Anderson-Cottonwood ID	2	1,000-5,500	150-455
Sacramento Valley	Butte WD	2	4,000-4,200	263-580
	City of Sacramento	32	373-1,400	80-578
	Conaway Preservation Group	37	1,400-3,500	70-580
	Cordua ID	23	900-2,400	200-400
	Cranmore Farms	6	3,000-3,000	150-275
	Eastside MWC	1	3,800-3,800	150-240
	Garden Highway MWC	7	2,200-3,200	90-235
	Glenn-Colusa ID	11	2,389-3,305	500-1200
	Gilsizer Slough Ranch	3	2,016-2,016	150-275
	Goose Club Farms and Teichert Aggregates	13	3,000-3,000	150-275
	Natomas Central MWC	13	5,500-5,500	150-350
	Pelger MWC	3	4,700-4,700	101-485
	Pleasant Grove-Verona MWC	32	1,500-5,000	99-300
	Pope Ranch	2	2,117-2,117	150-275
	RD 1004	20	1,000-5,800	56-430
	RD 108	5	1,700-5,900	250-680
	RD 2068	4	1,500-1,500	209-438
	River Garden Farms	7	1,700-2,990	170-686
	Sacramento County Water Agency	39	455-3,000	170-1368
	Sacramento Suburban WD	47	180-3,500	131-750
	Sycamore MWC	12	2,500-3,500	256-900
	Te Velde	5	2,200-4,656	115-300
	Tule Basin Farms	3	3,050-4,850	150-275

Key:
ft = feet
gpm = gallons per minute
ID = Irrigation District
MWC = Mutual Water Company
RD = Reclamation District
WD = Water District

Location 21 is near Sycamore Mutual Water Company and is in the northwestern portion of the Sacramento Valley approximately four miles from the Sacramento River and Butte Creek intersection and two miles from the Sacramento River and Sycamore Creek intersection. Figures 3.3-~~32~~34a and 3.3-~~33~~34b show the simulated groundwater ~~level~~elevation over time ~~(i.e., hydrographs)~~ at Location 21. Groundwater levels at this location return to near-baseline conditions approximately three to four years after the single year ~~groundwater~~groundwater substitution transfer event in WY 1981. Recovery occurs after approximately six years following the multi-year transfer event from WY 1986 to WY 1994. ~~These drawdown and recovery periods are shown in Figure 3.3-34.~~Figure 3.3-34c shows the change in groundwater level between the baseline and the proposed action. Most of the recovery near the pumping zone occurs in the year following the transfer event. Recovery at the water table was more gradual. Groundwater level recovery is highly dependent on (1) hydrology ~~of~~ in the ~~following~~ year following the groundwater substitution tranfer~~,~~; (2) proximity of the pumping well to surface water ~~and~~; (3) pumping in the following year (i.e., if the subsequent year also includes groundwater substitution transfer pumping); and (4) aquifer properties.

Location 14 is near Cordua ID in the northeastern portion of the valley and approximately three miles from the Yuba River. Figures 3.3-~~35~~35a and 3.3-~~36~~35b show the simulated groundwater ~~level~~ head over time at Location 14. Groundwater recovery at this location takes longer than at Location 21 (see Figure 3.3-~~37).~~35c which plots simulated changes in groundwater ~~level~~head). It should be noted that Location 14 is located near the boundary of the model where the aquifer is thinner.

Location 31 is near the Sacramento County Water Agency in the southeastern portion of the Valley and approximately six miles from the American River. Figures 3.3-~~38~~36a and 3.3-~~39~~36b show the simulated groundwater ~~level~~ head over time at Location 31. Figure 3.3-~~40~~36c shows the change in groundwater heads at Location 31. Groundwater recovery at Location 31 is slower than at Location 21. Similar to Location 21 most of the recovery near the pumping zone occurs in the year after the transfer event. Groundwater levels return to approximately 75 percent of the baseline level five years after the single year transfer event in WY 1981 and between 50-75 percent six years after the multi-year transfer event from WY 1986 to WY1994 (see Figure 3.3-~~40~~36c).

Location 4 is near Butte Water District in the northwestern portion of the valley and approximately four miles from the Feather River and twelve miles from the Butte River. Figures 3.3-37a and 3.3-37b show the simulated groundwater ~~level~~ head over time at Location 4. Though the magnitude of drawdown at Location 4 is lesse~~r~~ than Location 31, the recovery period is nearly identical (see Figure 3.3.37c).

Location 6 is near Glenn-Colusa ID in the northern portion of the valley and approximately a mile and half from the confluence of the Sacramento River and Stony Creek. Figures 3.3-38a and 3.3-38b show the simulated groundwater level over time at Location 6. Groundwater ~~levels~~head at this location almost completely recover four years after a single year transfer event and six years after a multi-year transfer event from WY-1988 to WY 1991.

Most areas in the model exhibit smaller drawdown changes than those shown in Figure 3.3-~~32~~34 through ~~Figure~~ 3.3-~~40~~38. Appendix E, Groundwater Modeling Results, includes hydrographs for all 42 representative hydrograph locations.

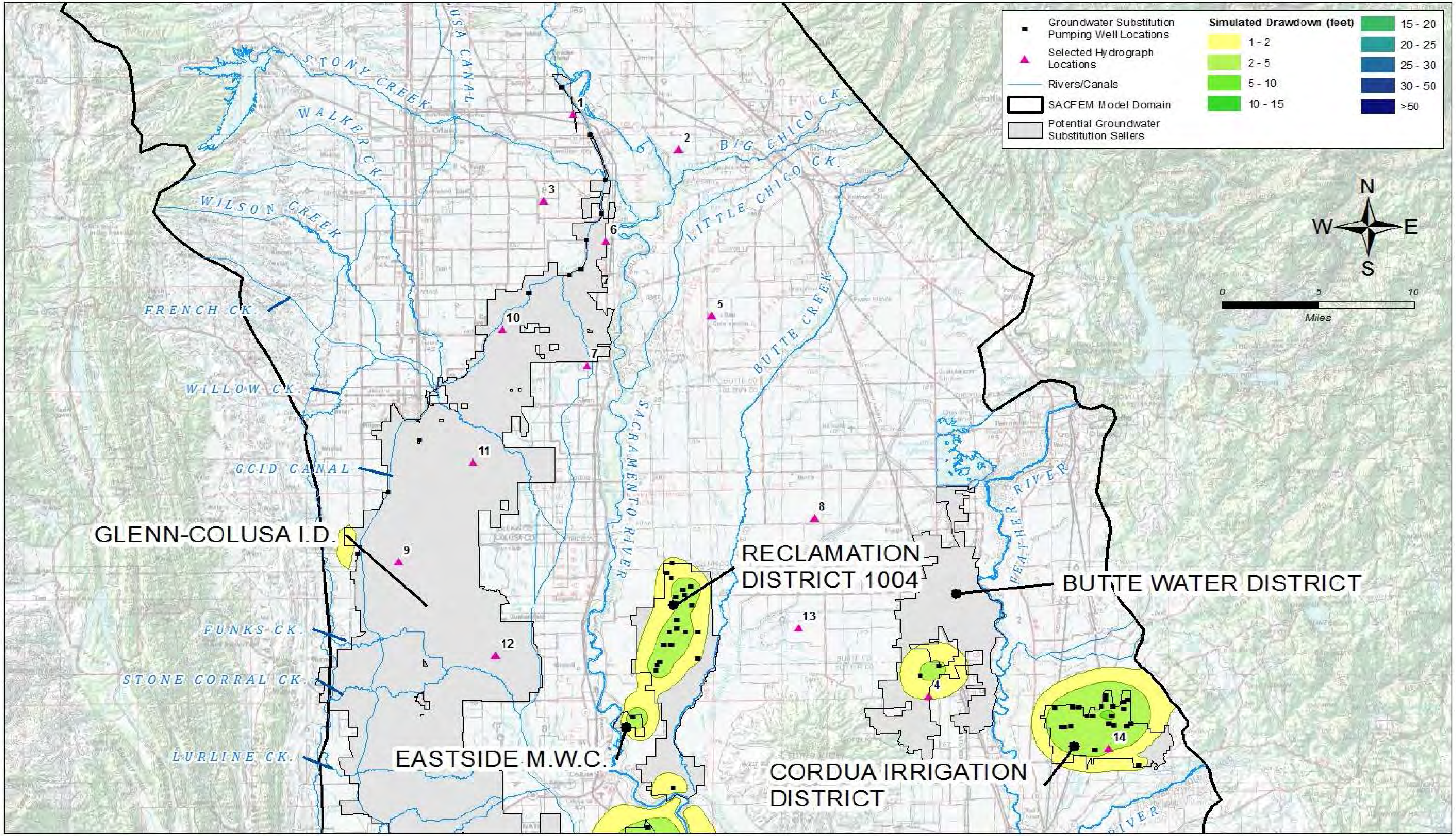

Figure 3.3-~~26.~~-28a. Simulated Change in Water Table Elevation (Aquifer Depth up to Approximately 35 feet), Based on September 1976 Hydrologic Conditions

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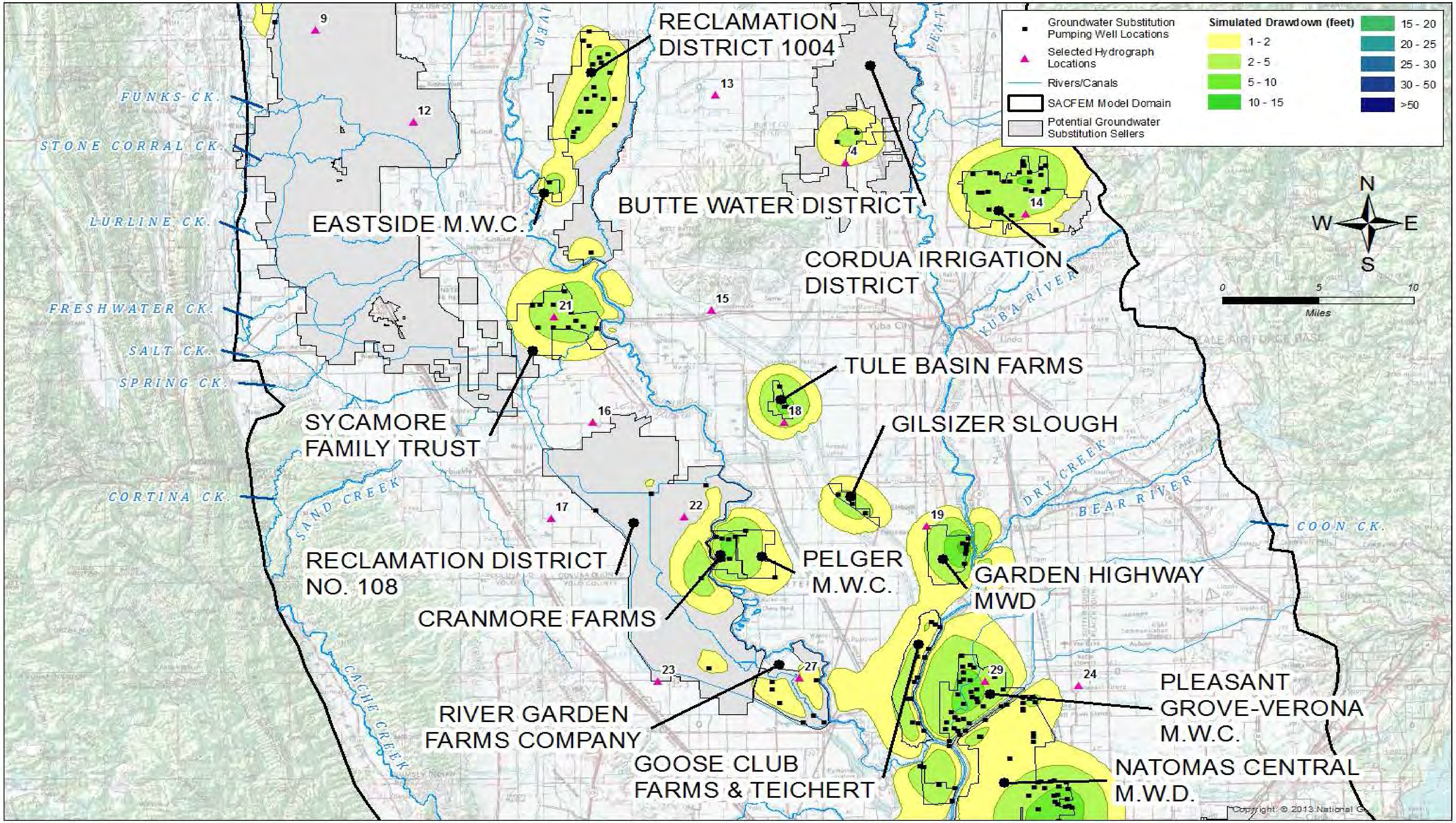

Figure 3.3-28b. Simulated Change in Water Table Elevation (Aquifer Depth up to Approximately 35 feet), Based on September 1976 Hydrologic Conditions

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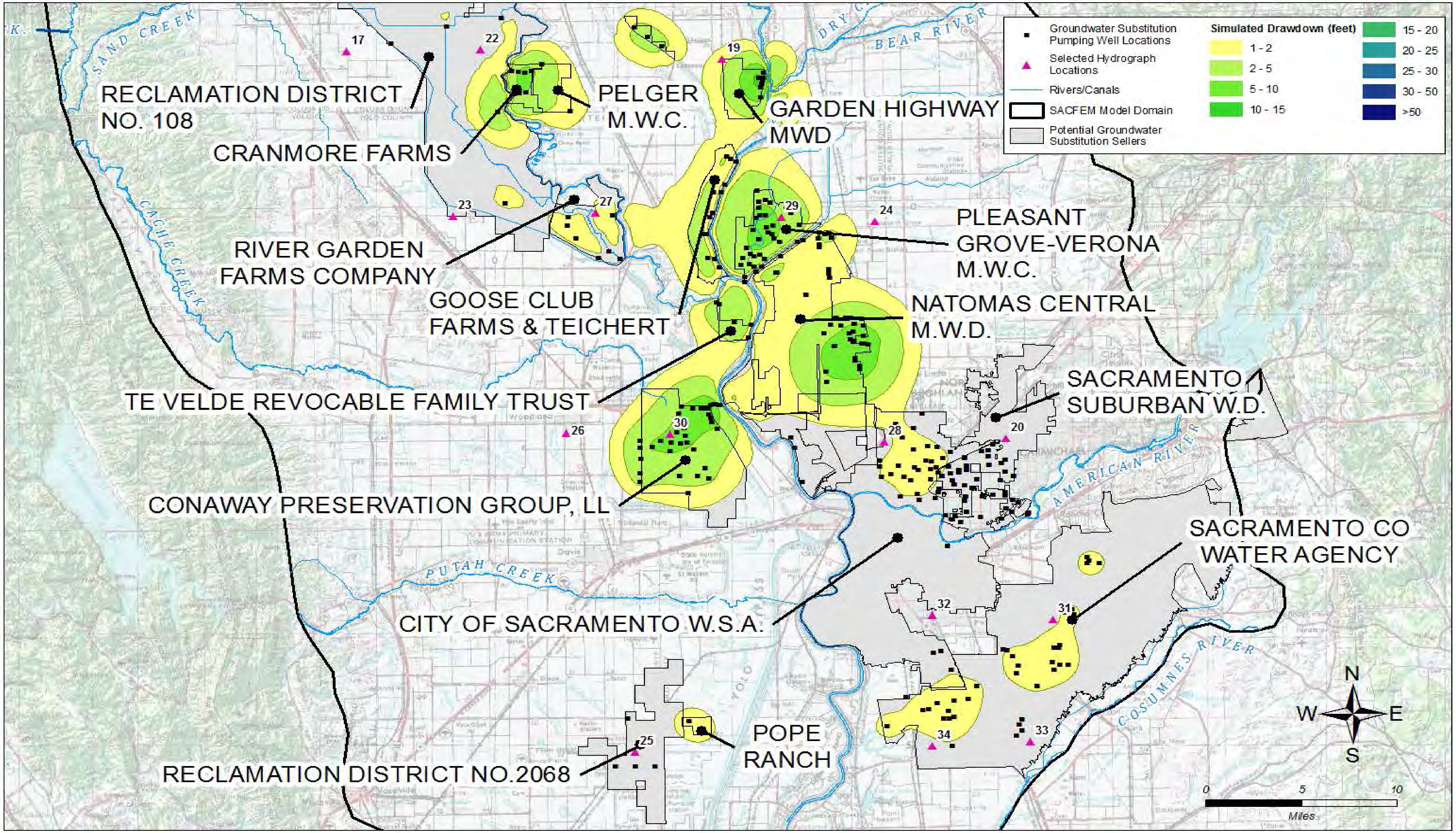

Figure 3.3-28c. Simulated Change in Water Table Elevation (Aquifer Depth up to Approximately 35 feet), Based on September 1976 Hydrologic Conditions

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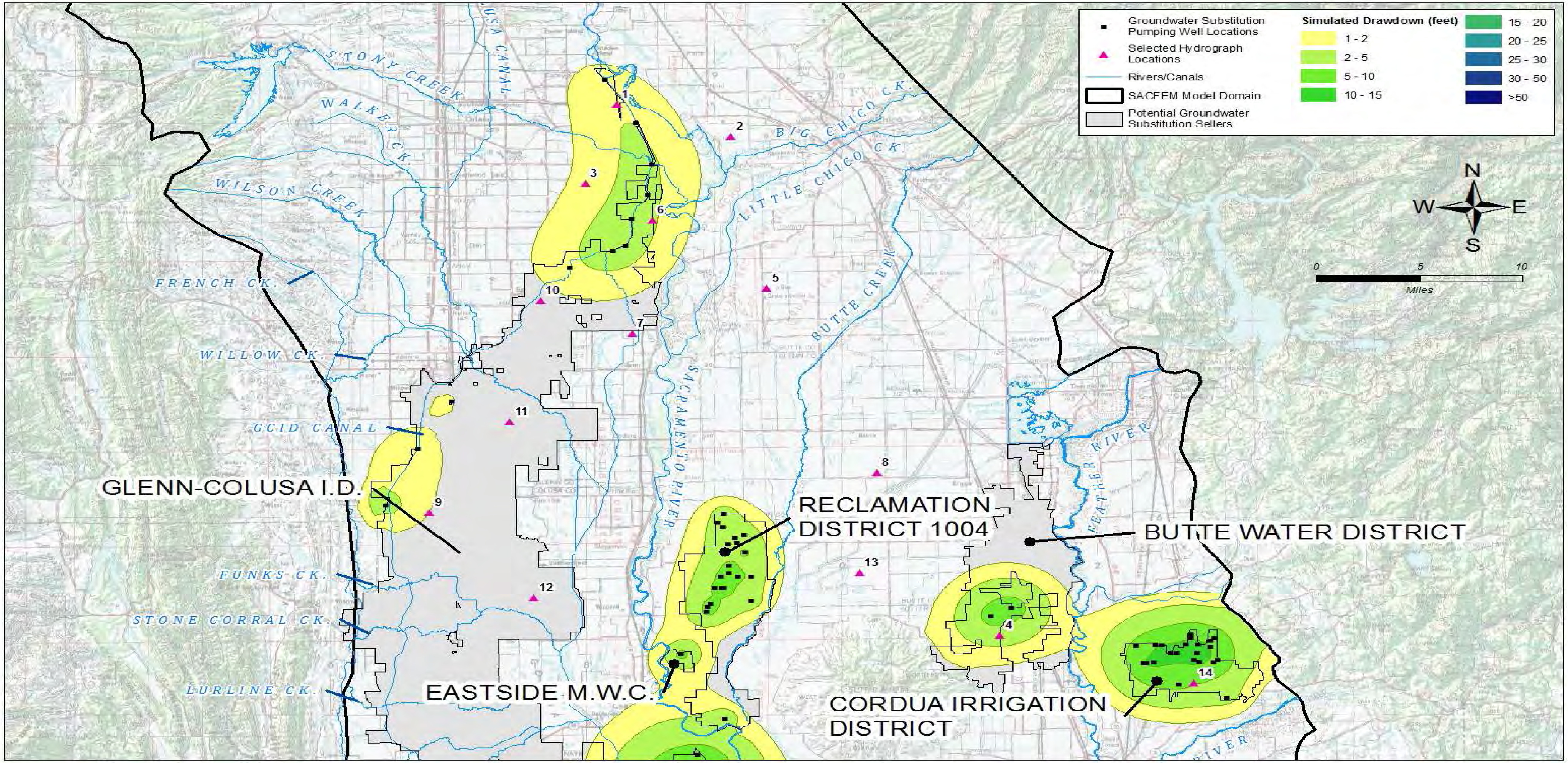

Figure 3.3-29a. Simulated Change in Groundwater Head (Aquifer Depth of Approximately 200 to 300 feet), Based on September 1976 Hydrologic Conditions

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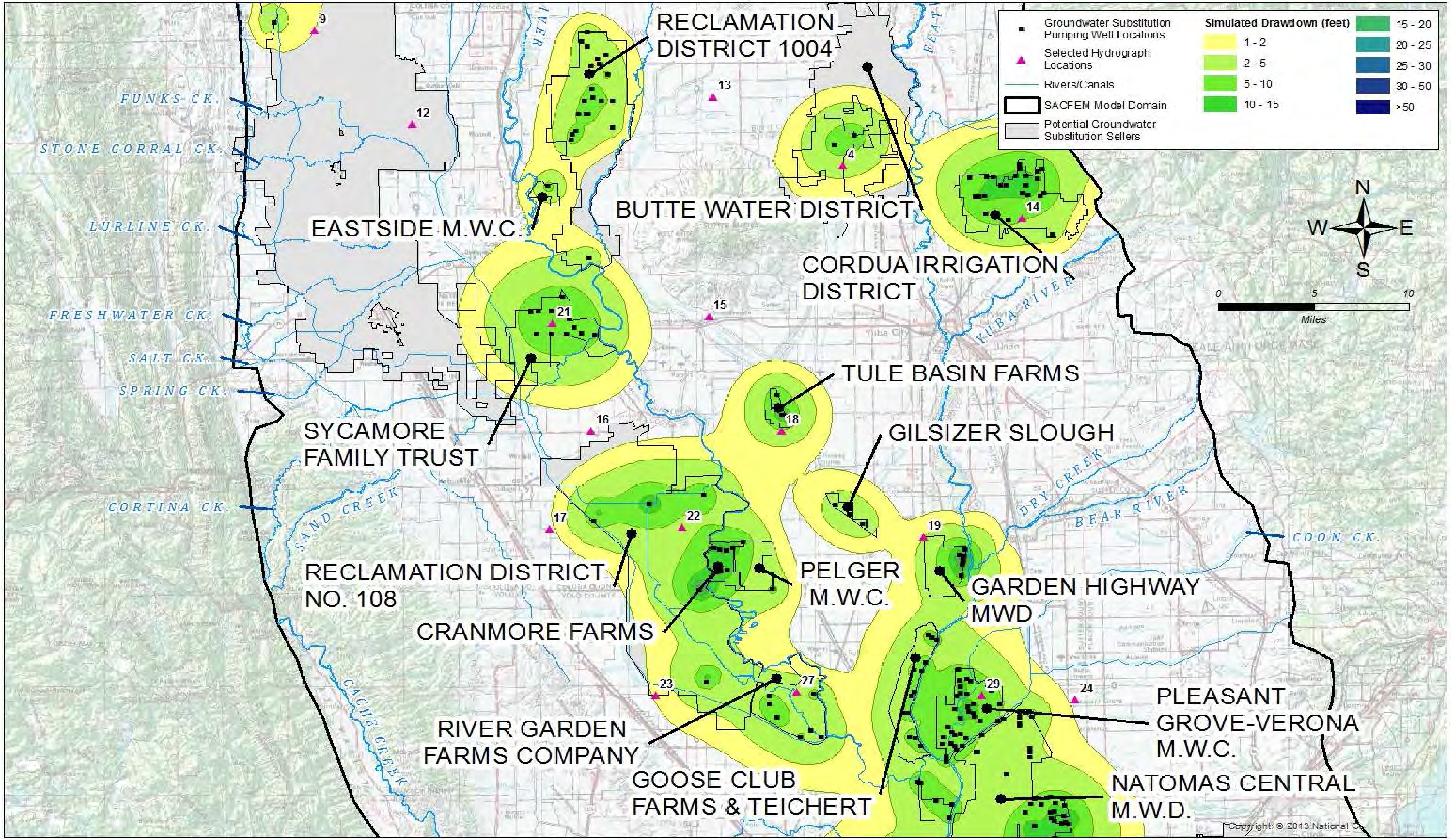

Figure 3.3-29b. Simulated Change in Groundwater Head (Aquifer Depth of Approximately 200 to 300 feet), Based on September 1976 Hydrologic Conditions

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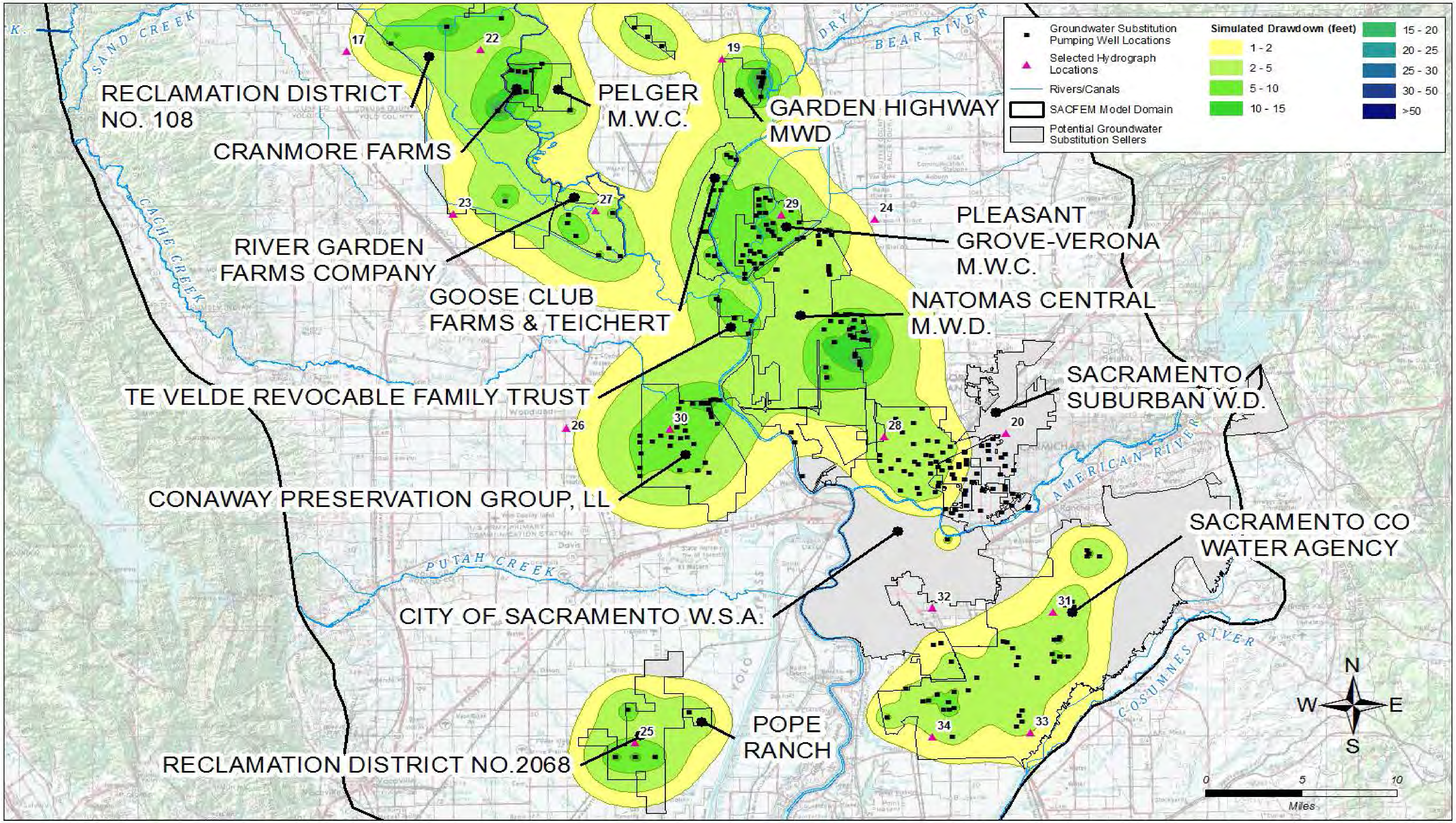

Figure 3.3-29c. Simulated Change in Groundwater Head (Aquifer Depth of Approximately 200 to 300 feet), Based on September 1976 Hydrologic Conditions

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