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Chapter 5

180/400-Foot Aquifer Subbasin Groundwater Sustainability Plan

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SECTION 5 GROUNDWATER CONDITIONS

This chapter describes the current and historical groundwater conditions in the 180/400-Foot Aquifer Subbasin. In accordance with the SGMA emergency regulations §354.16, current conditions are any conditions occurring after January 1, 2015. By implication, historical conditions are any conditions occurring prior to January 1, 2015. The chapter focuses on information required by the GSP regulations and information that is important for developing an effective plan to achieve sustainability.

This chapter provides a description of current and historical groundwater conditions at a scale and level of detail appropriate for meeting the GSP sustainability requirements under SGMA.

The organization of Chapter 5 aligns with the six sustainability indicators, including:

1. Chronic lowering of groundwater elevations
2. Changes in groundwater storage
3. Seawater intrusion
4. Subsidence
5. Depletion of interconnected surface waters and
6. Groundwater quality

5.1 GROUNDWATER ELEVATIONS

5.1.1 DATA SOURCES

The following assessment of groundwater elevation conditions is largely based on data collected by MCWRA from 1944 through the present. At the time of this report, MCWRA regularly collects groundwater level measurements from 166 locations in the 180/400-Foot Aquifer Subbasin for various monitoring programs.

The water level data are primarily obtained from private well owners that have provided data on a confidential basis. Therefore, the contoured water levels are available for public release, but the underlying data and well locations are not publicly available and are not used as a basis for the GSP.

MCWRA collects groundwater elevation data at specific times of the year to understand seasonal changes and monitor longer term trends. Some of the wells actively monitored for water levels are equipped with pressure transducers that take automated measurements hourly. Other wells are measured monthly, annually for the Fall measurement program, and/or annually for the August trough measurement program (MCWRA, 2018a).

From mid-November to mid-December, MCWRA conducts their Fall measurement program to observe groundwater levels after the irrigation season ends but before the rainy season begins (Brown and Caldwell, 2015). The Fall measurements are intended to provide the most representative year-to-year comparison because the water levels are not greatly influenced by either the cones of depression due to irrigation or the rise in water levels associated with each variable wet season. The Fall measurements provide insight into long-term storage trends in the aquifers (Brown and Caldwell, 2015).

During August, MCWRA conducts a localized August Trough measurement program in the 180/400-Foot Aquifer Subbasin and the East Side Subbasin to observe groundwater levels at the peak of the irrigation pumping season. Groundwater levels in August are assumed to represent the lowest groundwater elevations of the year. The August Trough measurements provide insight into how groundwater pumping affects groundwater head gradients.

In addition to the Fall and August Trough groundwater level measurement programs, MCWRA recently became the primary local Monitoring Entity for the Salinas Valley Basin under the California Statewide Groundwater Elevation Monitoring Program (CASGEM). Created by the State in 2009, CASGEM is a statewide program to collect groundwater elevations and make the data accessible to the public.

In the 180-400 Foot Aquifer Subbasin, 23 wells are monitored through the CASGEM program. The locations of these wells are shown on Figure 5-1. Wells were selected for the CASGEM program based on their distribution throughout Monterey County, the availability of detailed and reliable well construction data, and relative ease of data collection (MCWRA, 2015). Fifteen wells are equipped with transducers that record groundwater levels hourly; 8 others are monitored manually on a monthly basis (MCWRA, 2015). The average period of record for these wells is 10 years. The earliest groundwater elevations were recorded in 2003.

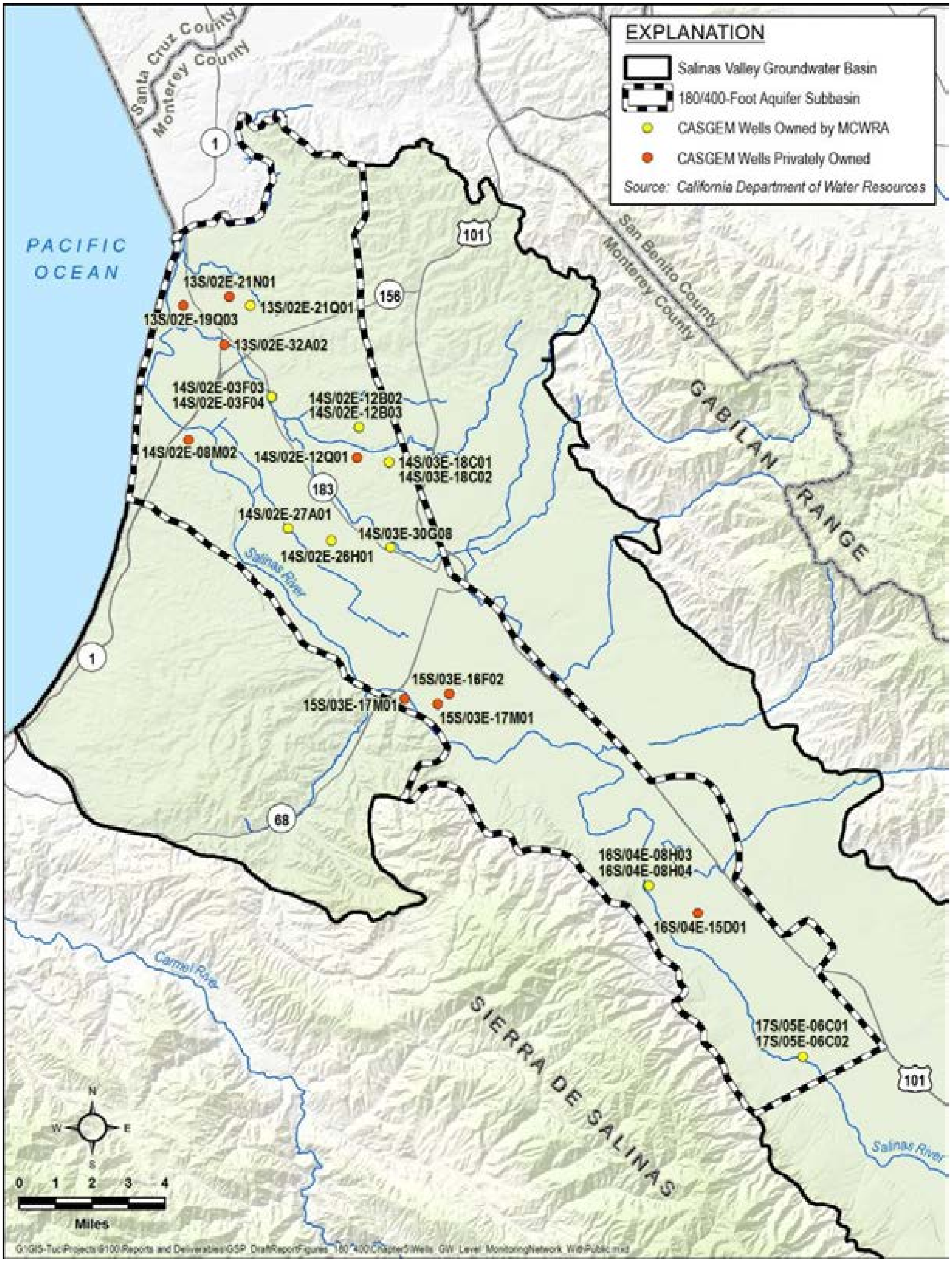


Figure 5-1: CASGEM Well Locations

As described in Chapter 4, groundwater levels in the Salinas Valley are highly dependent on two sources of climatic variability.

- Annual variation between wet season and dry season that is reinforced and amplified by agricultural irrigation.
- Wet and dry climatic cycles, characterized by multi-year drought and wet cycles, with a complete cycle often lasting a decade or more.

The groundwater level at any well can also be strongly influenced by local processes such as pumping from nearby wells which lower groundwater levels. Given the various regional and local influences on groundwater levels, it is illustrative to characterize the Basin groundwater elevation conditions through at least three distinct methodologies:

- Maps of groundwater level contours that show the lateral distribution of groundwater levels at a specific time. These contours represent the elevation above sea level of the groundwater levels in the Subbasin. The contour interval is 10 feet, meaning each blue line represents an area where groundwater levels are either 10 feet higher or 10 feet lower than the nearby blue line.
- Hydrographs in individual wells that plot the variation in groundwater level at that well over an extended period.
- Vertical hydraulic gradients in a single location to assess vertical groundwater flow direction and magnitude.

For this GSP, all three approaches are used to develop the following descriptions of current and historical water level conditions in terms of maps, temporal trends, and vertical gradients. Sections 5.1.1, 5.1.2, and 5.1.3 provide the background information that are used to develop the Sustainable Management Criteria (SMC) for water levels in Section 7.

5.1.2 Groundwater Elevation Contours and Horizontal Groundwater Gradients

MCWRA produces groundwater elevation contour maps for the Salinas Valley Groundwater Basin in odd-numbered years using data from the Fall measurement programs (MCWRA, n.d. website). In the 180/400-Foot Aquifer Subbasin, MCWRA also produces separate contour maps for each of the 180-Foot and 400-Foot Aquifers.

The following eight maps present the Current (2017) and Historical (1995) groundwater elevation contours developed by MCWRA.

Figure #	Year	Season	Aquifer
Figure 5-2	Current (2017)	Fall	180-Foot
Figure 5-3	Current (2017)	August Trough	180-Foot
Figure 5-4	Current (2017)	Fall	400-Foot
Figure 5-5	Current (2017)	August Trough	400-Foot
Figure 5-6	Historical (1995)	Fall	180-Foot
Figure 5-7	Historical (1995)	August Trough	180-Foot
Figure 5-8	Historical (1995)	Fall	400-Foot
Figure 5-9	Historical (1995)	August Trough	400-Foot

The contours on each of these eight maps originated from contours developed by MCWRA. Therefore, the contours only cover the portions of the basin monitored by MCWRA. Contours do not always extend to the basin margins; nor do they cover the entire 180/400-Foot Aquifer Subbasin. This is a data gap that will be addressed during GSP implementation.

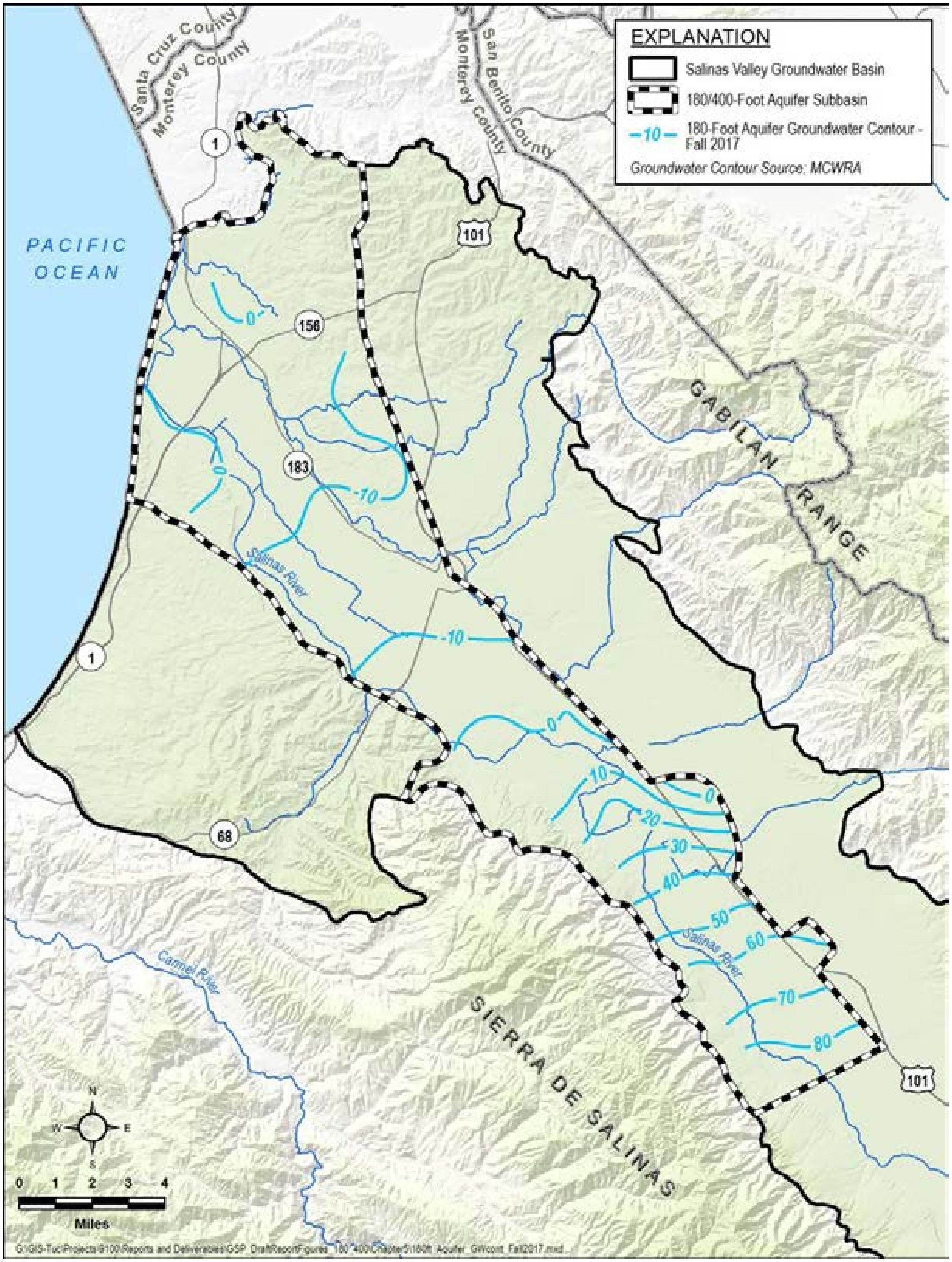


Figure 5-2: Fall 2017 180-Foot Aquifer Groundwater Level Contours

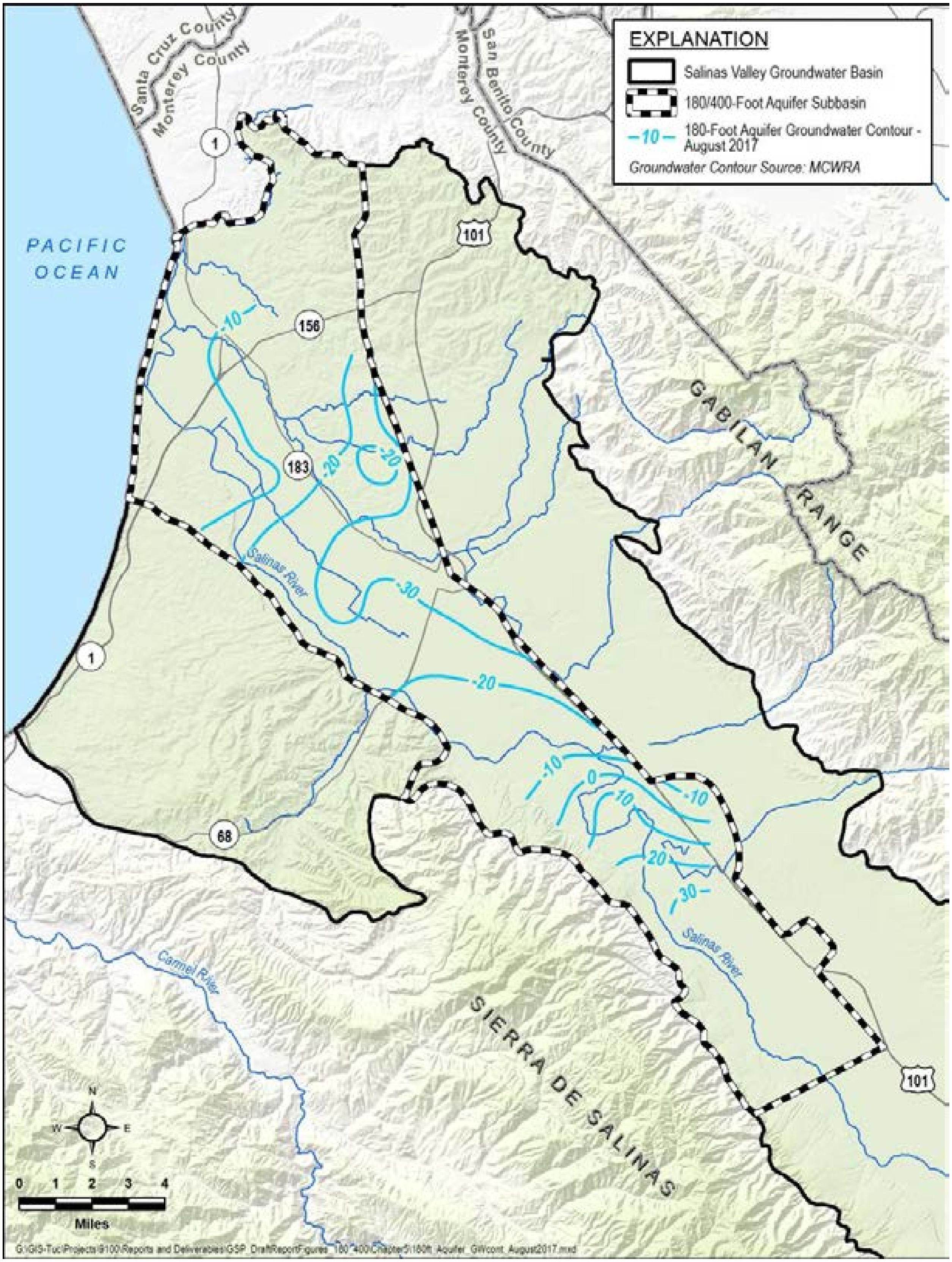


Figure 5-3: August 2017 180-Foot Groundwater Level Contours

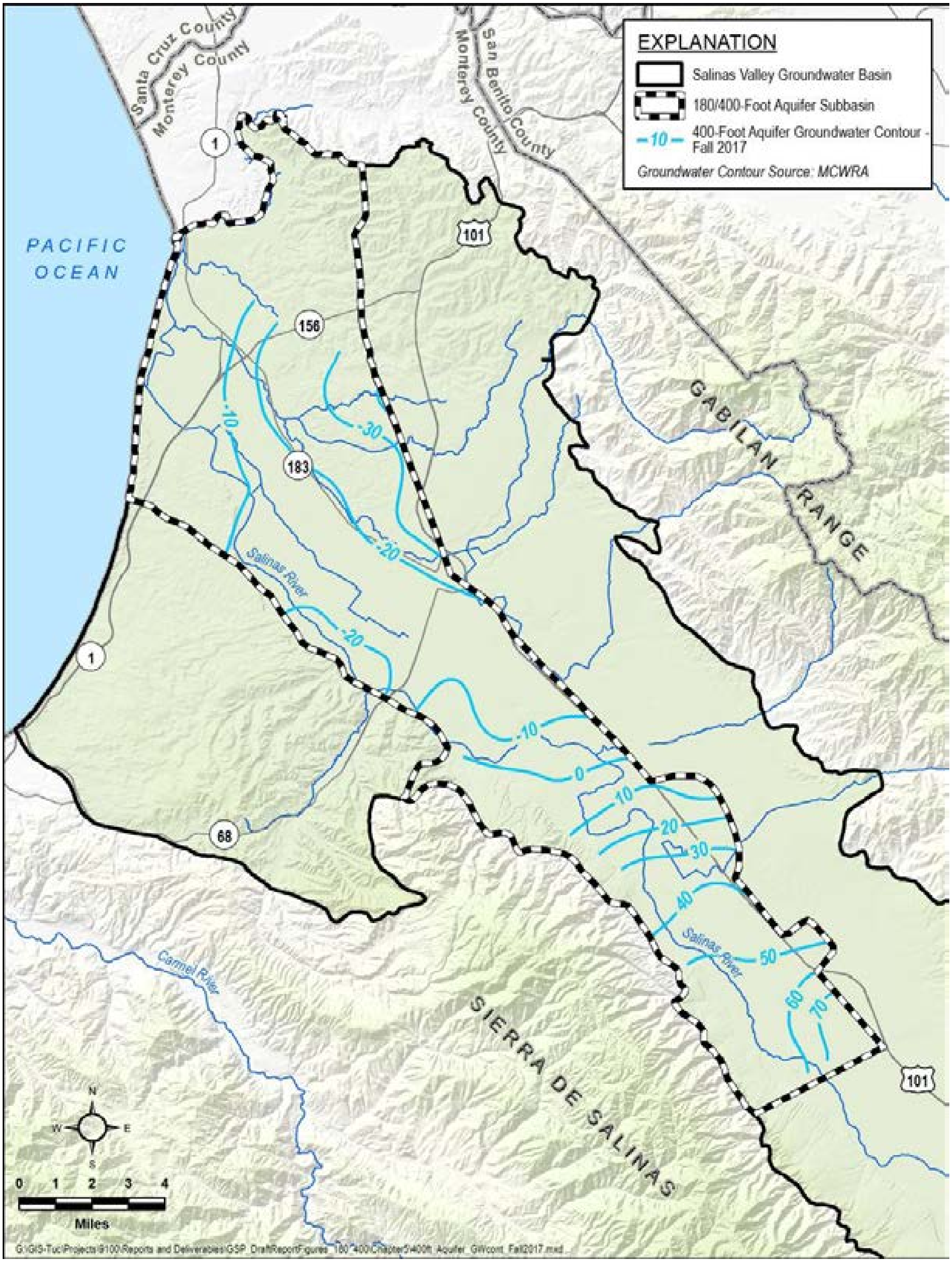


Figure 5-4: Fall 2017 400-Foot Aquifer Groundwater Level Contours

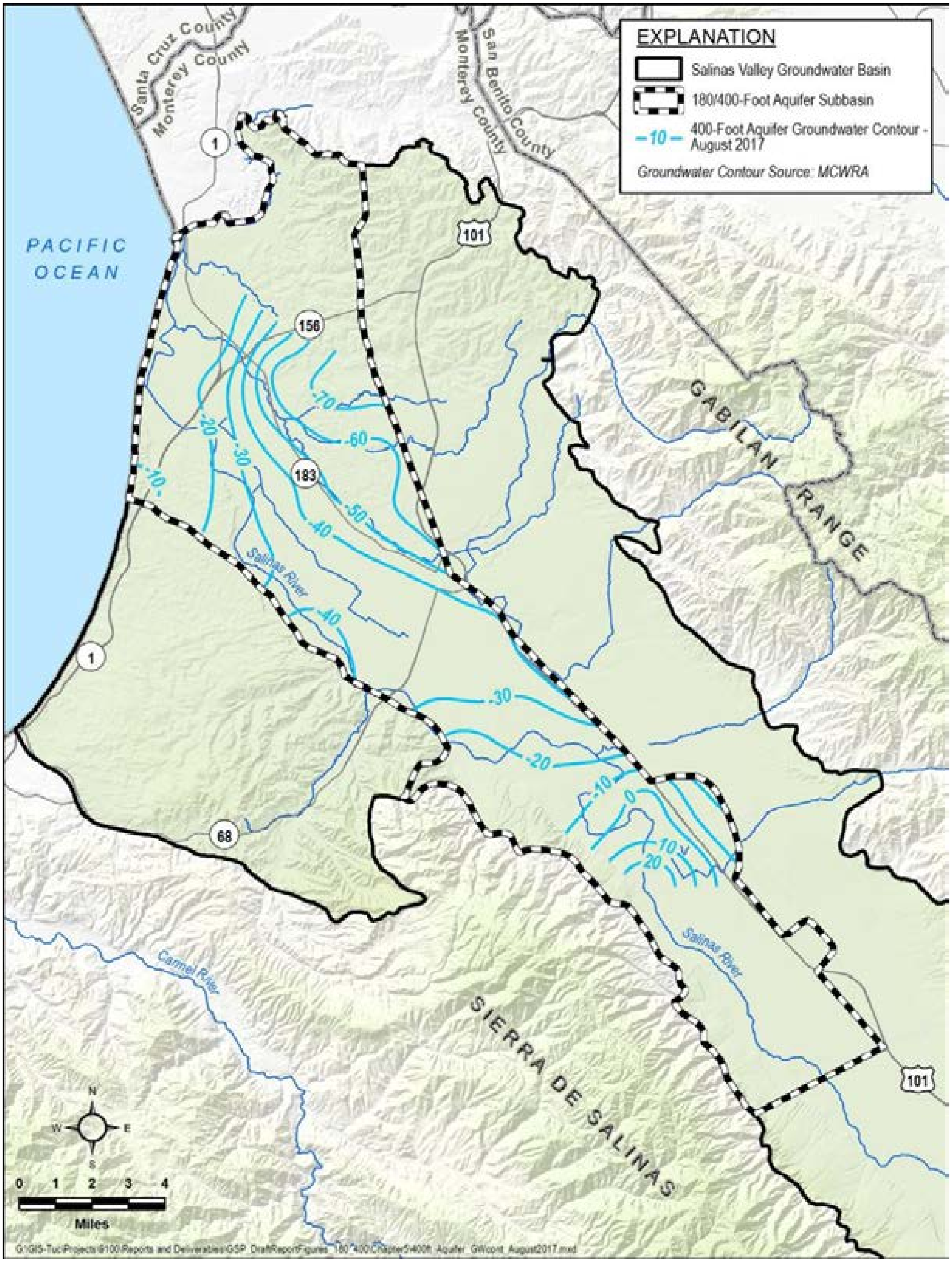


Figure 5-5: August 2017 400-Foot Aquifer Groundwater Level Contours

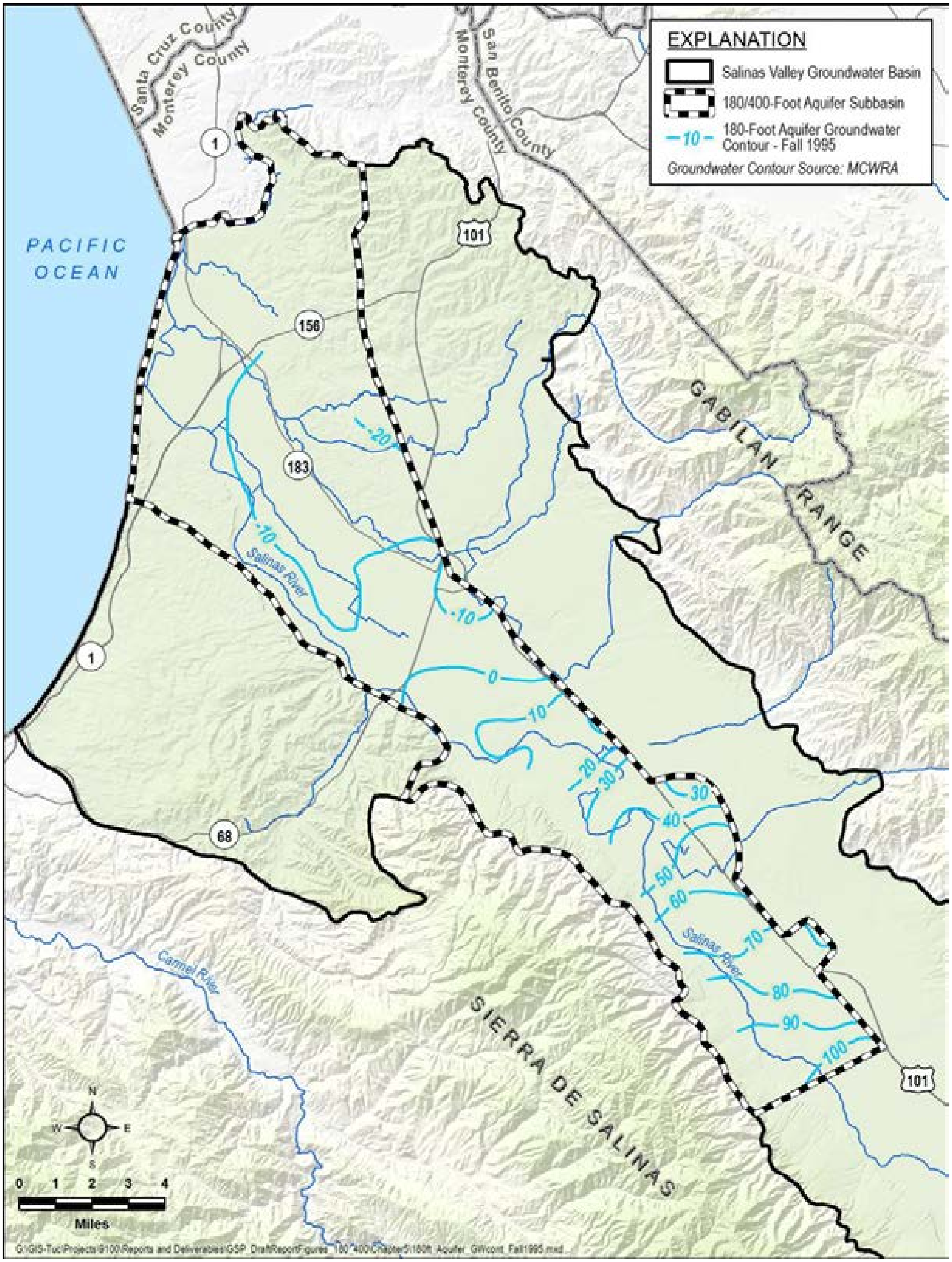


Figure 5-6: Fall 1995 180-Foot Aquifer Contour

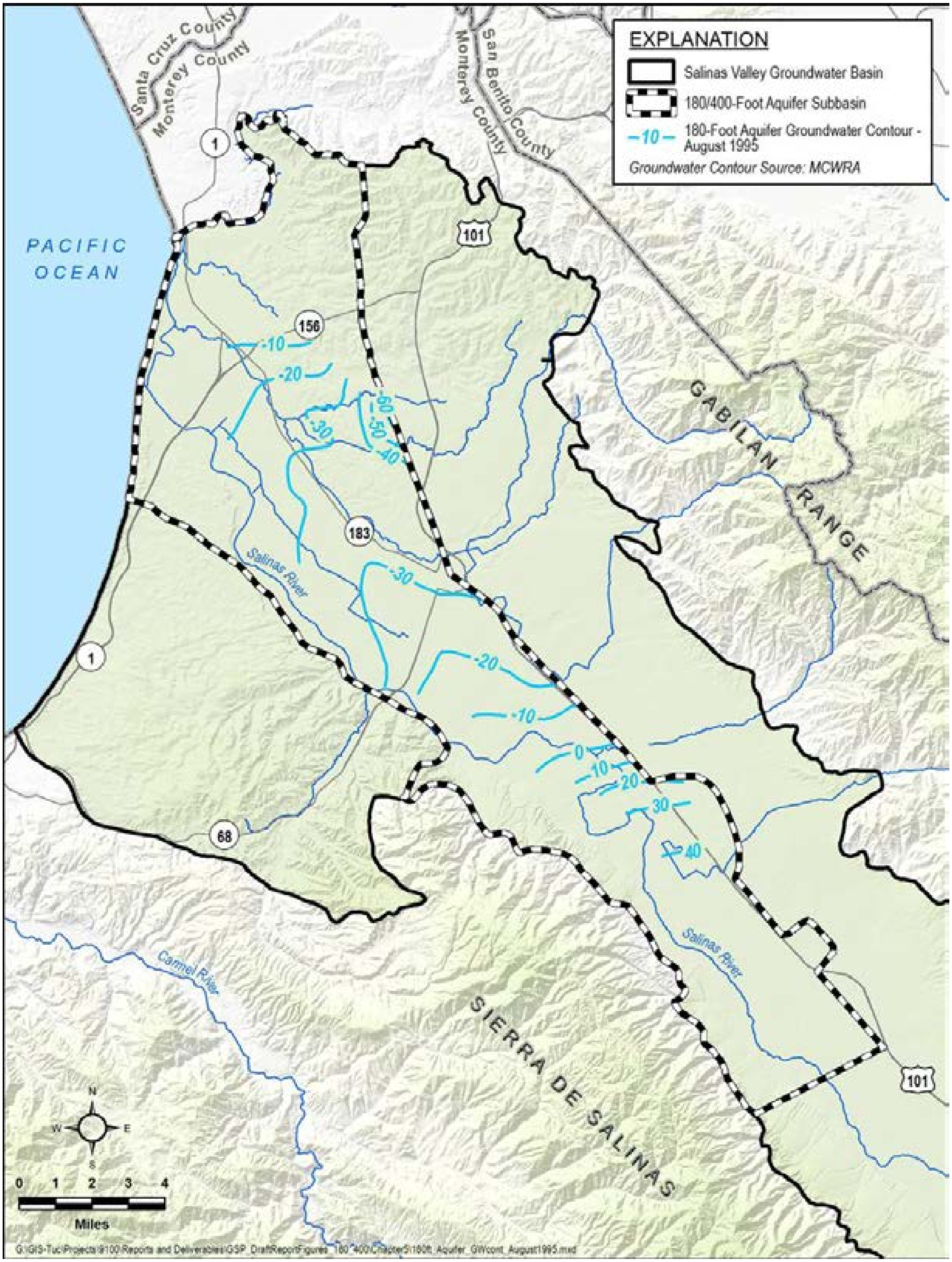


Figure 5-7August 1995 180-Foot Aquifer Groundwater Levels

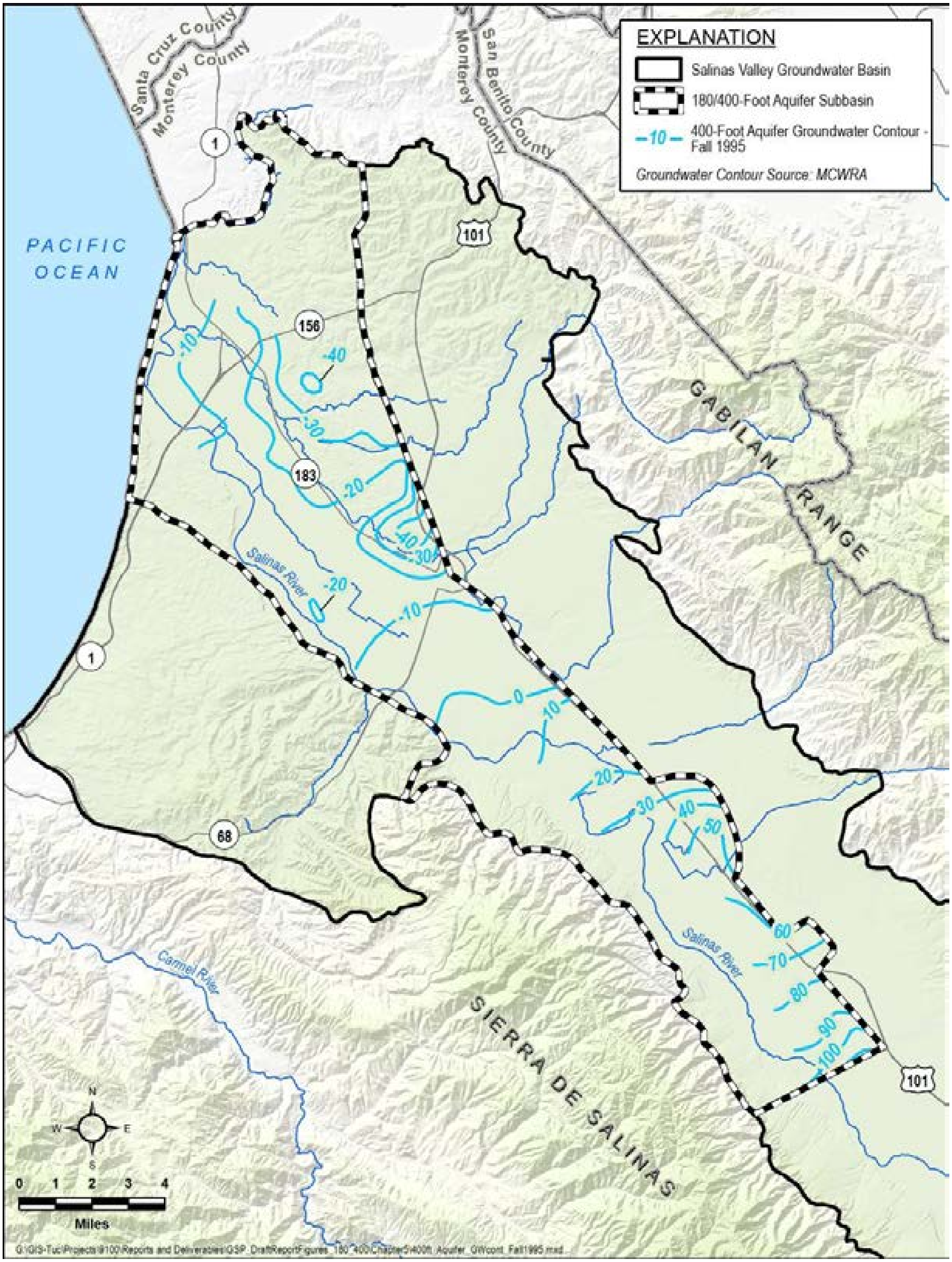


Figure 5-8: Fall 1995 400-Foot Aquifer Groundwater Levels

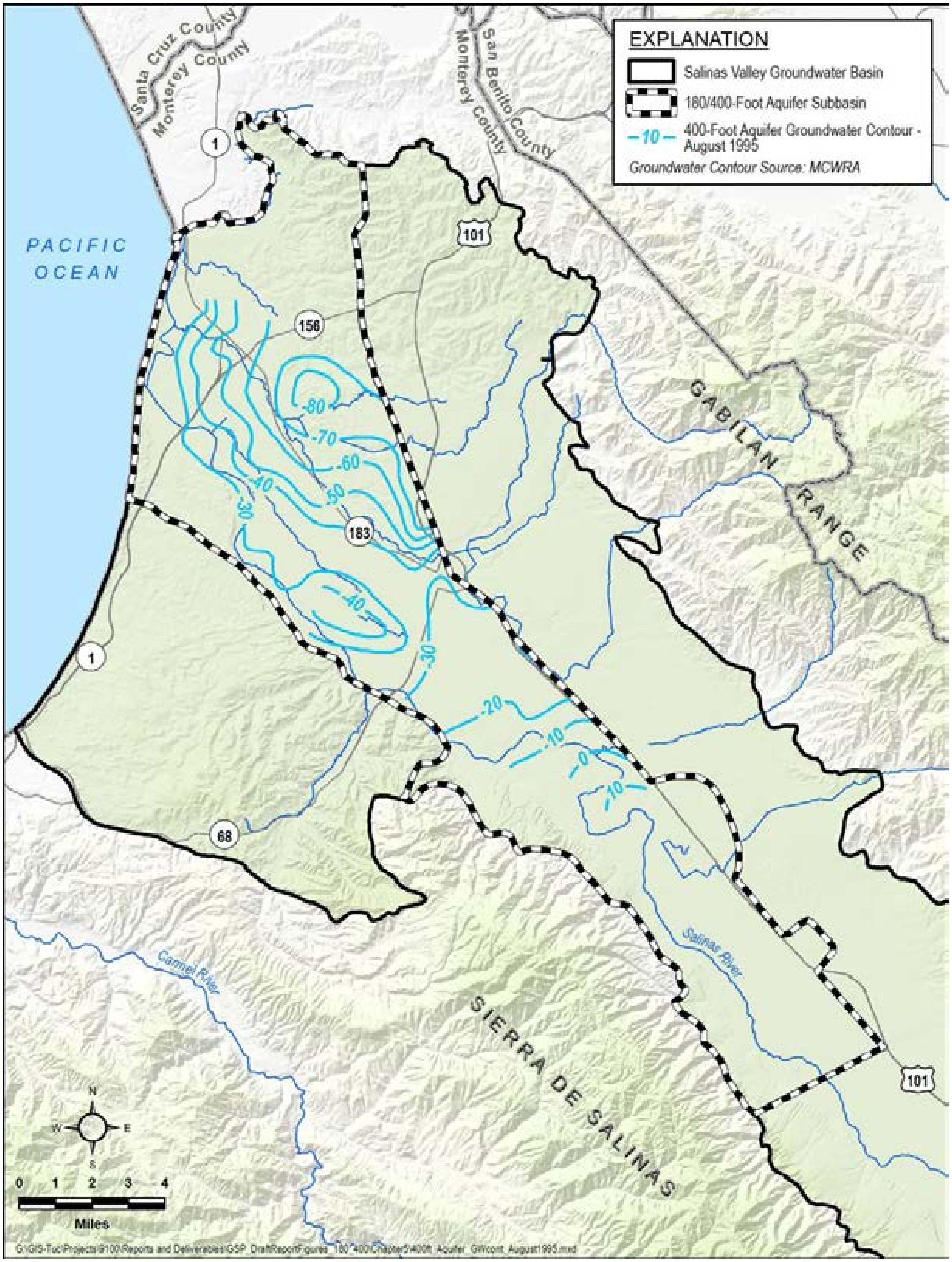


Figure 5-9: August 1995 400-Foot Aquifer Groundwater Levels

The contours indicate that groundwater flow directions are similar in the 180- and 400-Foot Aquifers. However, groundwater levels in the 400-Foot Aquifer are lower than groundwater levels in the 180-Foot Aquifer during both 1995 and 2017.

Under current conditions (Figure 5-2 through Figure 5-4), groundwater levels in the 180/400-Foot Aquifer Subbasin are below sea level as indicated by the negative values on the contour lines in the northern two-thirds of the Subbasin. The lowest water levels in the Subbasin are along the boundary with the Eastside Subbasin near the City of Salinas. In the 180-Foot Aquifer, with minimum water levels are approximately -20 ft MSL during the Fall measurements and -40 ft MSL during the August measurements. In the 400-Foot Aquifer, minimum groundwater levels are approximately -30 ft MSL during the Fall measurements and -70 ft MSL during the August measurements. These low water levels are related to a pumping trough centered north of Salinas in the Eastside Subbasin. In this area, groundwater flow gradients are not parallel to the Valley's long axis, but rather are cross-valley towards the pumping trough. The hydraulic gradient steepens in the vicinity of the pumping trough, with observed gradients of approximately 0.003 ft/ft, or 16 ft/mile.

Groundwater levels increase toward the northwestern boundary of the Subbasin until they are near sea level near the Monterey Bay coastline. As described below in Section 5. 2 and 5.3.2, the groundwater levels near the coast are maintained near sea level through the hydraulic connection to the ocean. The process of seawater intrusion counteracts the lowering groundwater levels in both the 180-Foot and the 400-Foot Aquifers and creates an influx of high salinity water into the subbasin.

Groundwater levels also increase toward the southern boundary, with groundwater level elevations of approximately 90 ft MSL and 75 ft MSL in the 180-Foot and 400-Foot Aquifers at the boundary with the Forebay Subbasin.

Under the historical conditions of 1995, the same flow pattern was present in both aquifers; however, the magnitude of the pumping trough has varied over time. A discussion of historical groundwater level changes is presented in Section 5.1.3.

The MCWRA does not produce groundwater level maps of the deep aquifer. Insufficient data currently exist to map flow directions and groundwater elevations in the deep aquifer.

5.1.3 180/400-Foot Aquifer Subbasin Hydrographs

Representative temporal trends in groundwater levels can be assessed with hydrographs – graphs that plot changes in groundwater levels over time. Groundwater level data from wells within the Subbasin are available from monitoring conducted and reported by MCWRA.

Figure 5-10 depicts the locations and hydrographs of representative wells monitored by MCWRA within the 180-Foot Aquifer Subbasin and their hydrographs. Larger versions of the hydrographs shown on Figure 5-10 are included in Figure 5-11 through Figure 5-14. Figure 5-15 depicts the locations and hydrographs of representative wells monitored by MCWRA within the 400-Foot Aquifer. Larger versions of the hydrographs shown on Figure 5-15 are included in Figure 5-16 through Figure 5-19.

Representative wells were chosen based on their distribution across Subbasin, and the length and continuity of their monitoring record. Hydrographs for all wells in the 180/400-Foot Aquifer Subbasin monitored by MCWRA that are not limited by confidentiality agreements are included in Appendix 5A. The locations of all of these wells are shown on Figure 5-20. Hydrographs are not available for wells completed in the Deep Aquifer. This is a data gap that will be filled during the GSP implementation.

In addition to the hydrographs of the representative wells, there is value in looking at representative average water level at a subbasin scale. Figure 5-21 presents the graph of cumulative groundwater level change for the MCWRA-designated Pressure subarea. The Pressure subarea overlaps the 180/400-Foot Aquifer Subbasin and most of the Monterey Subbasin and includes part of the adjudicated Seaside Subbasin (Figure 5-22).

The plot in Figure 5-21 is based on calculations performed by MCWRA where the annual change in water level is averaged for all wells in the subarea each year, beginning in 1945. The cumulative groundwater level change plot is therefore an estimation of the average hydrograph for the subarea. Although this plot does not reflect the water level change at any specific location, it provides a clear illustration of the average water level impact within the subarea in response to the historical changes in climatic cycles, cycles, groundwater extraction, and water-resources management at the Subbasin scale.

Based on the cumulative data presented in Figure 5-21, and the specific hydrographs presented in Figure 5-10 the following general observations can be made.

- Groundwater levels in the 180/400-Aquifer Subbasin show a general decline over time.
- The high groundwater levels observed in 1983 suggest that groundwater levels previously had the capacity to recover to earlier levels in response to significant recharge events.
- Groundwater levels have declined since 1983 with no indication that they will recover to pre-1983 levels.

MCWRA's subarea cumulative groundwater level change calculations include groundwater levels measured in privately-owned wells. As these data are considered confidential, they are not presented in this document.

The cumulative groundwater level change graph shown on Figure 5-21 shows an apparent drop in average groundwater elevations following activation of the CSIP system in 1998; and another apparent drop in average groundwater elevations following activation of the SVWP in 2010. These apparent drops in average groundwater elevations are not the result of either of these projects, but are rather the result of natural climatic variation. The water year type information shown behind the hydrographs on Figure 5-11 through Figure 5-14 indicate that there was a dry period between 2000 and 2005, soon after the CSIP project was initiated. Similarly, the SVWP project came online during an alternating climatic period, and just before an extended dry period. These climatic variations influenced groundwater elevations much more than the benefits realized from the projects.

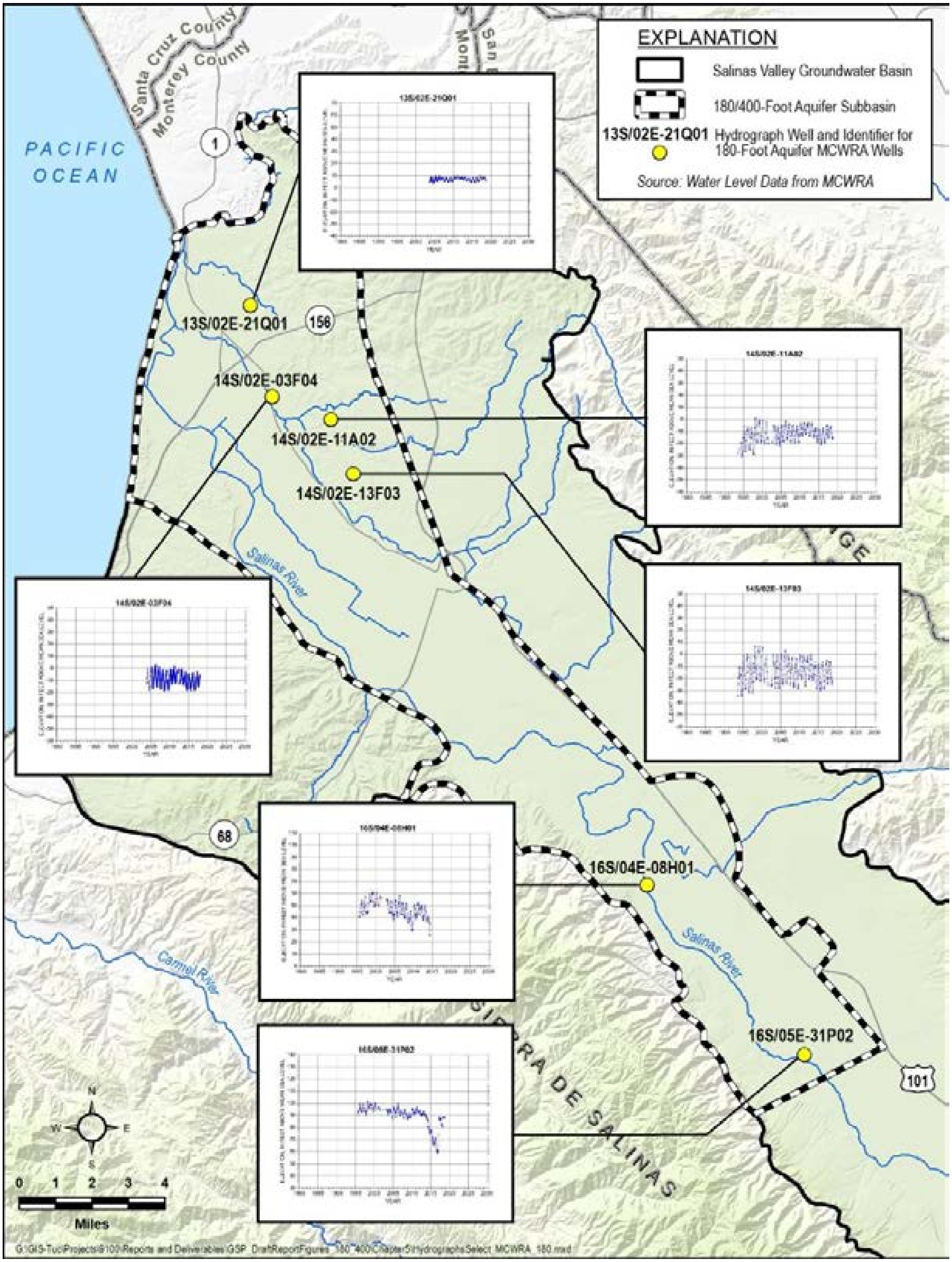
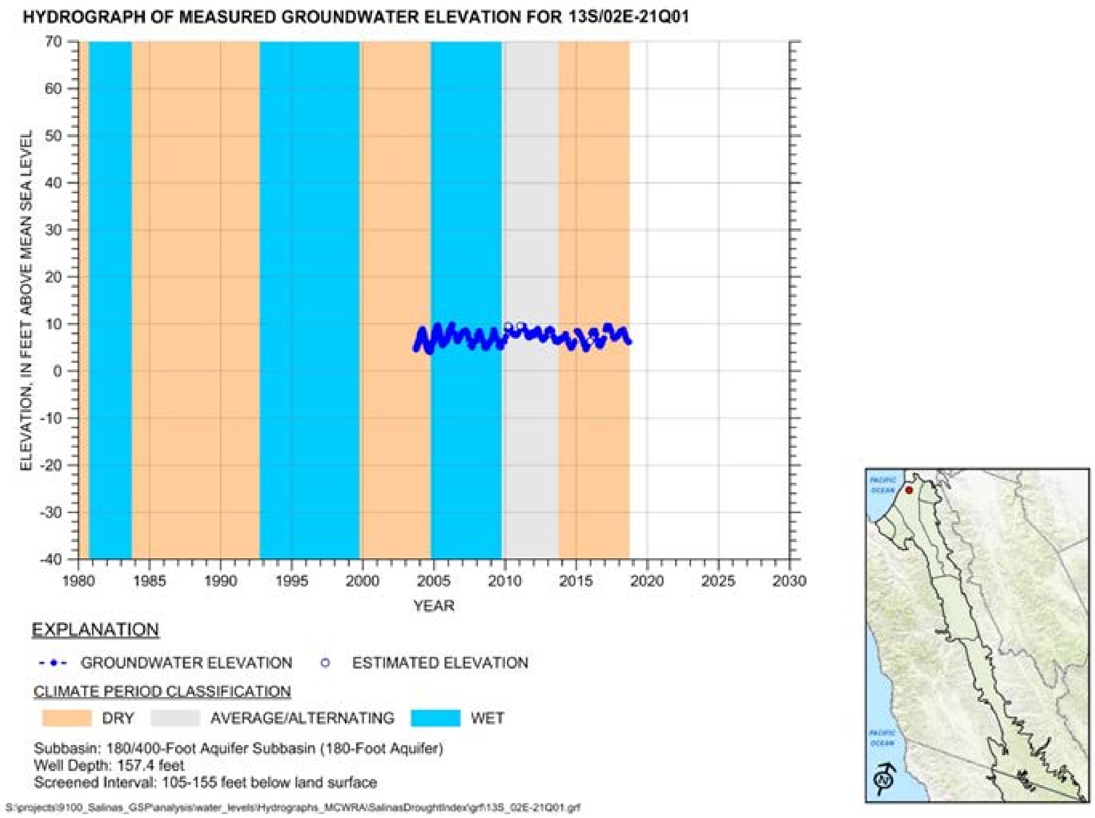


Figure 5-10: Representative Hydrographs in the 180-Foot Aquifer Subbasin



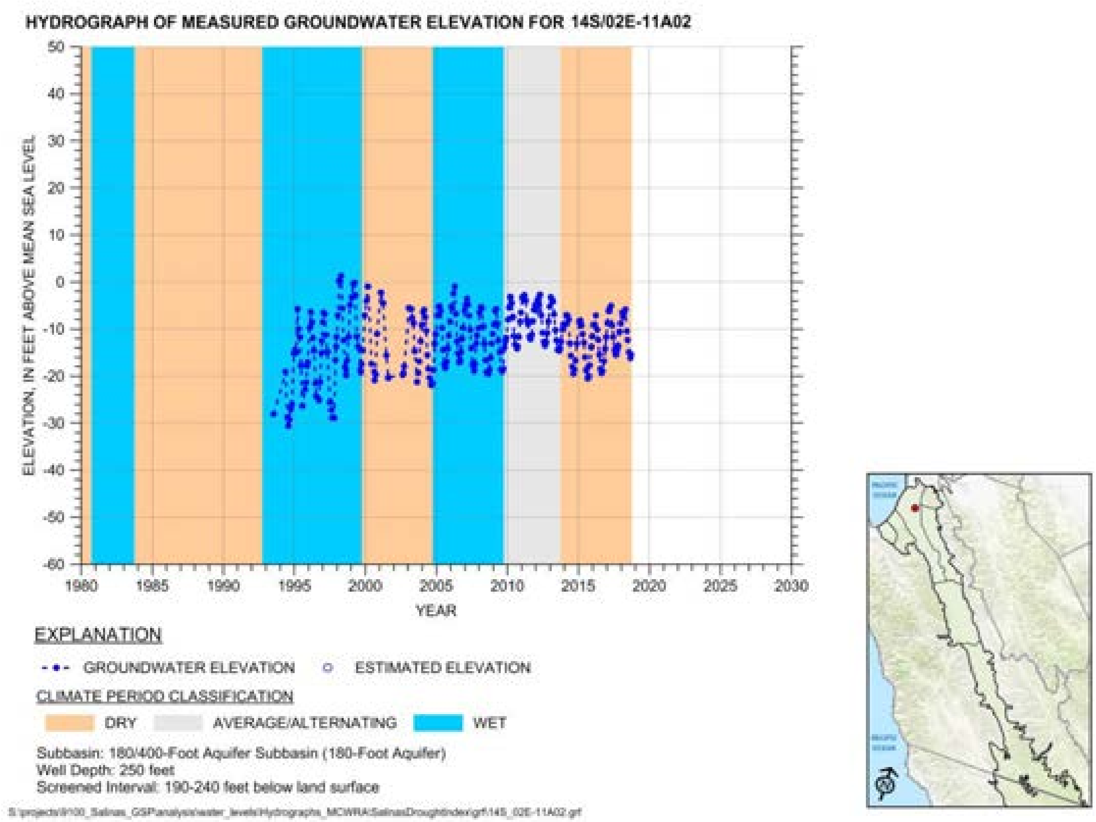


Figure 5-11: Representative Hydrographs Shown on the 180-Foot Aquifer Map (1)

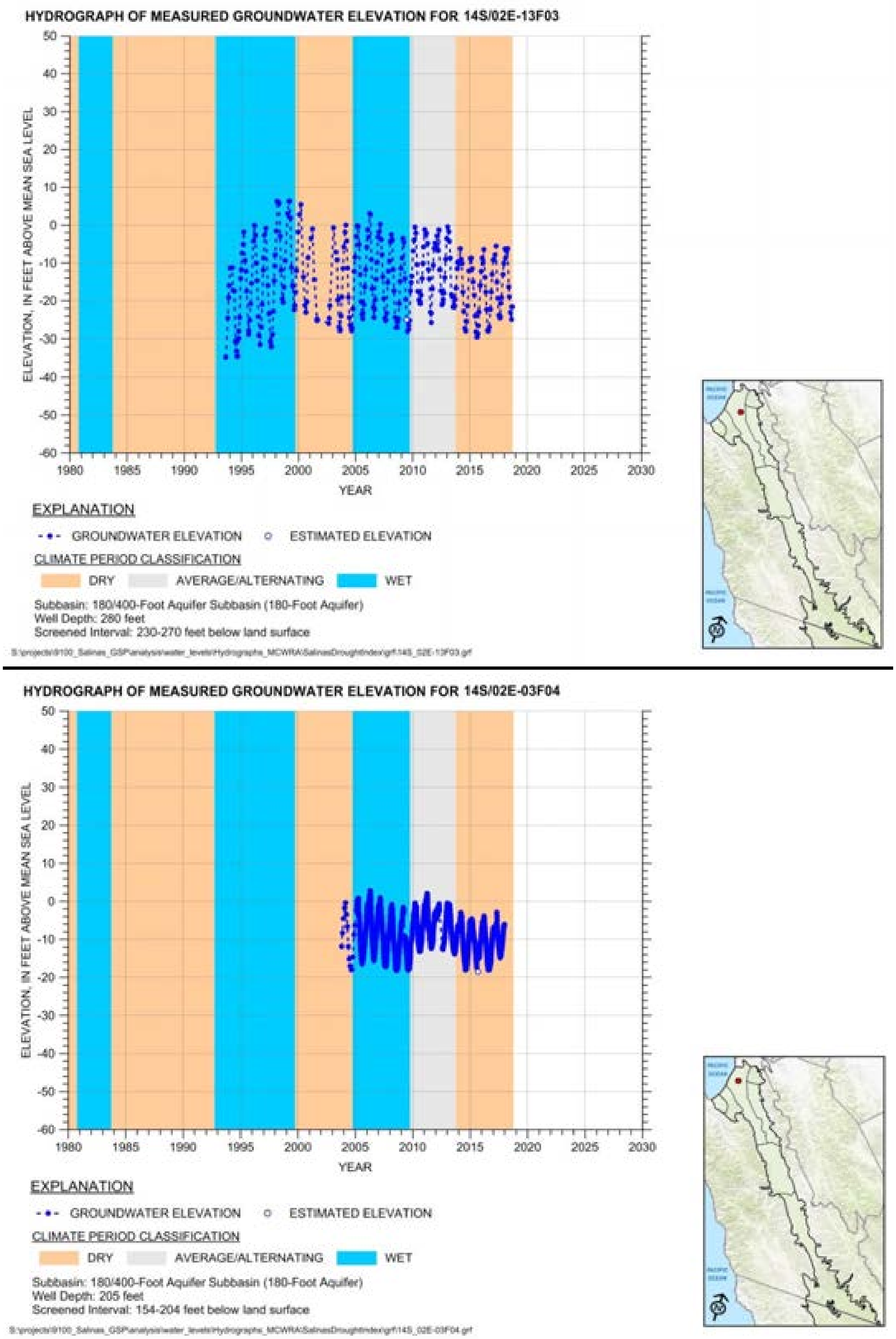
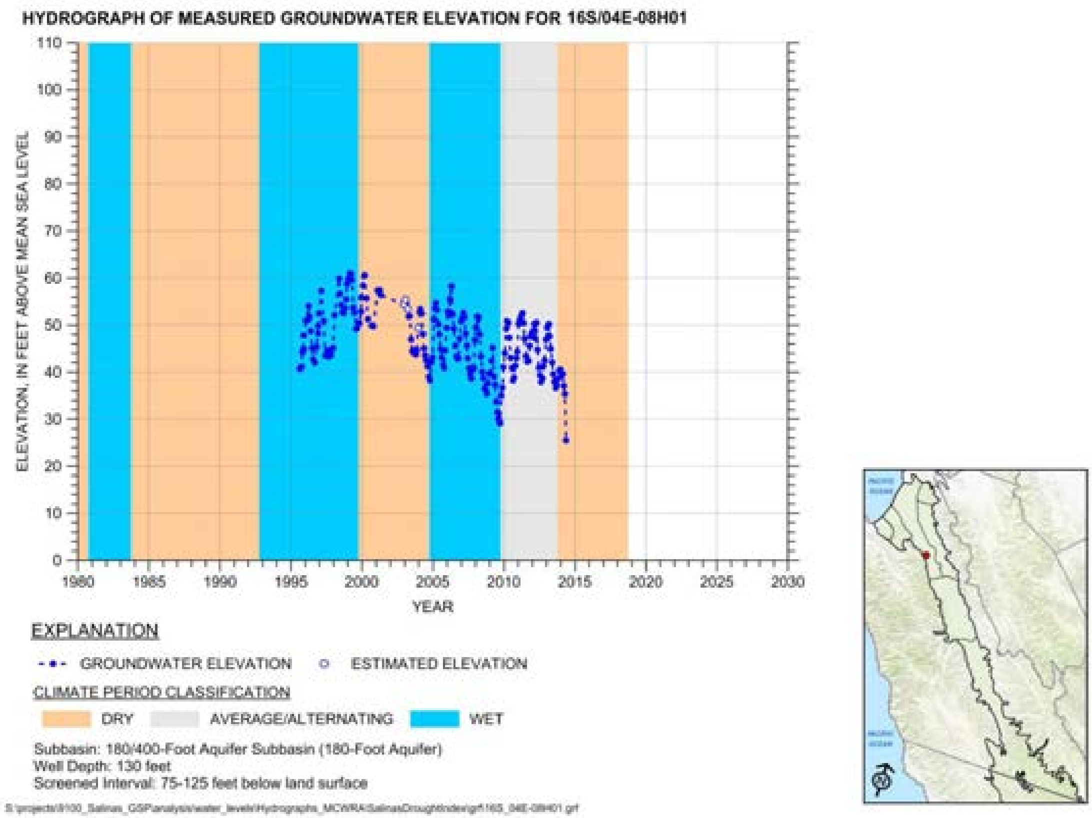


Figure 5-12: Representative Hydrographs Shown on the 180-Foot Aquifer Map (2)



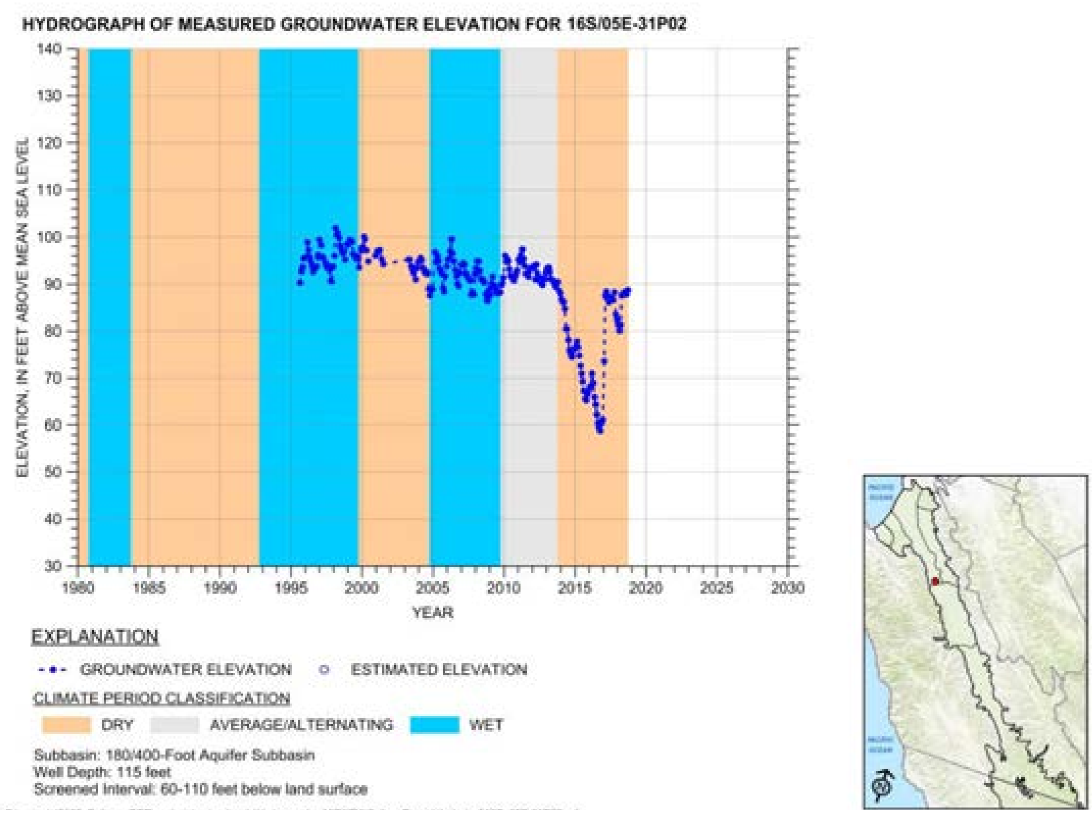
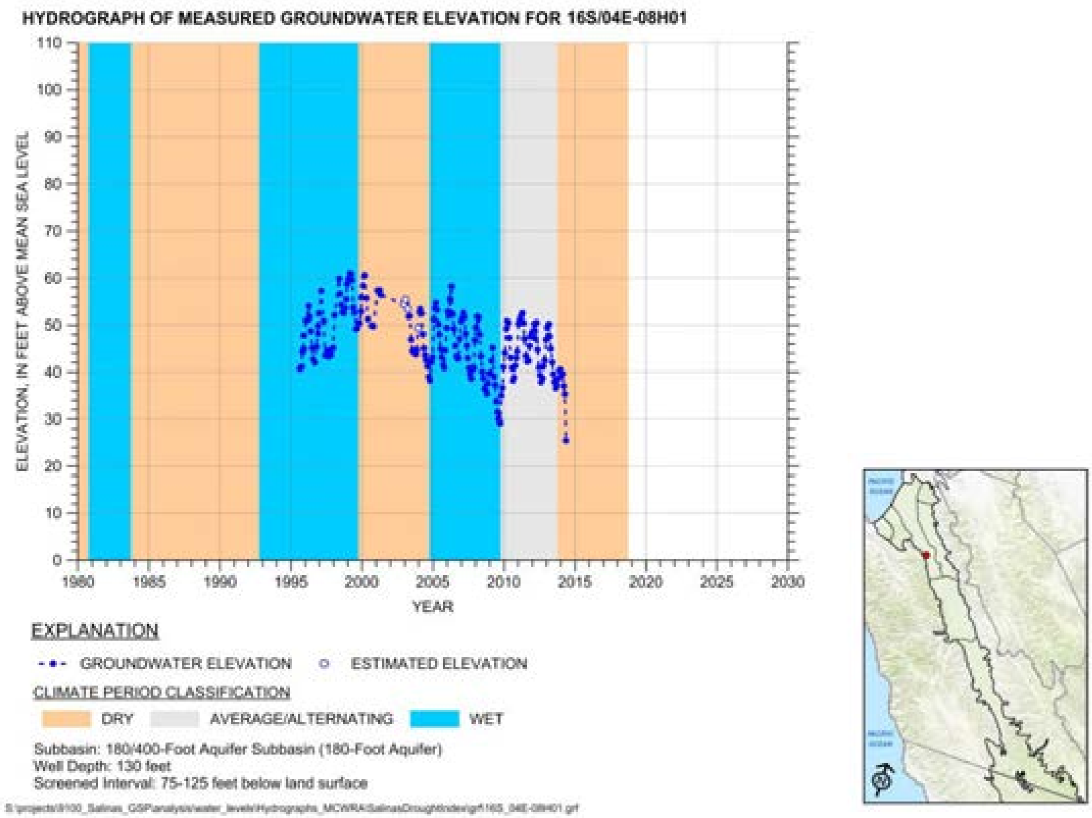


Figure 5-13: Representative Hydrographs Shown on the 180-Foot Aquifer Map (3)



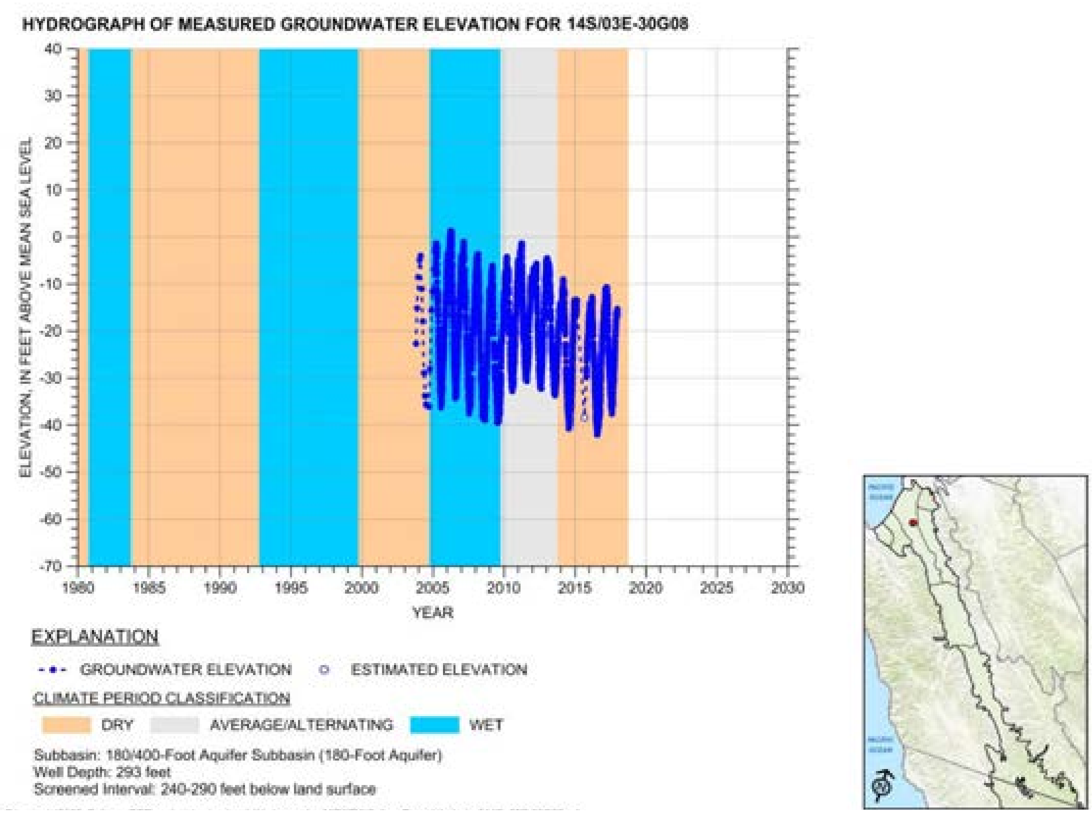


Figure 5-14: Representative Hydrographs Shown on the 180-Foot Aquifer Map (4)

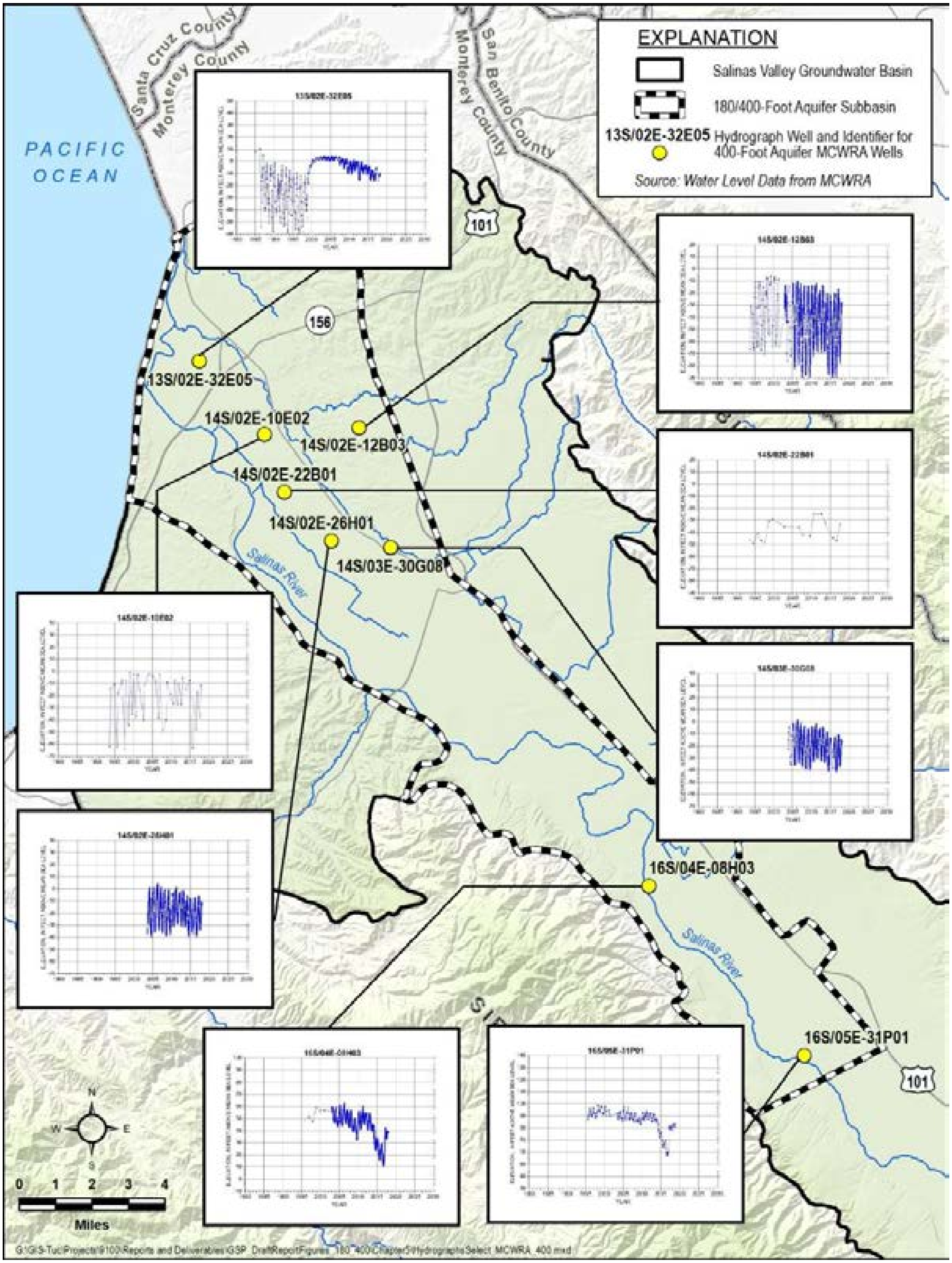
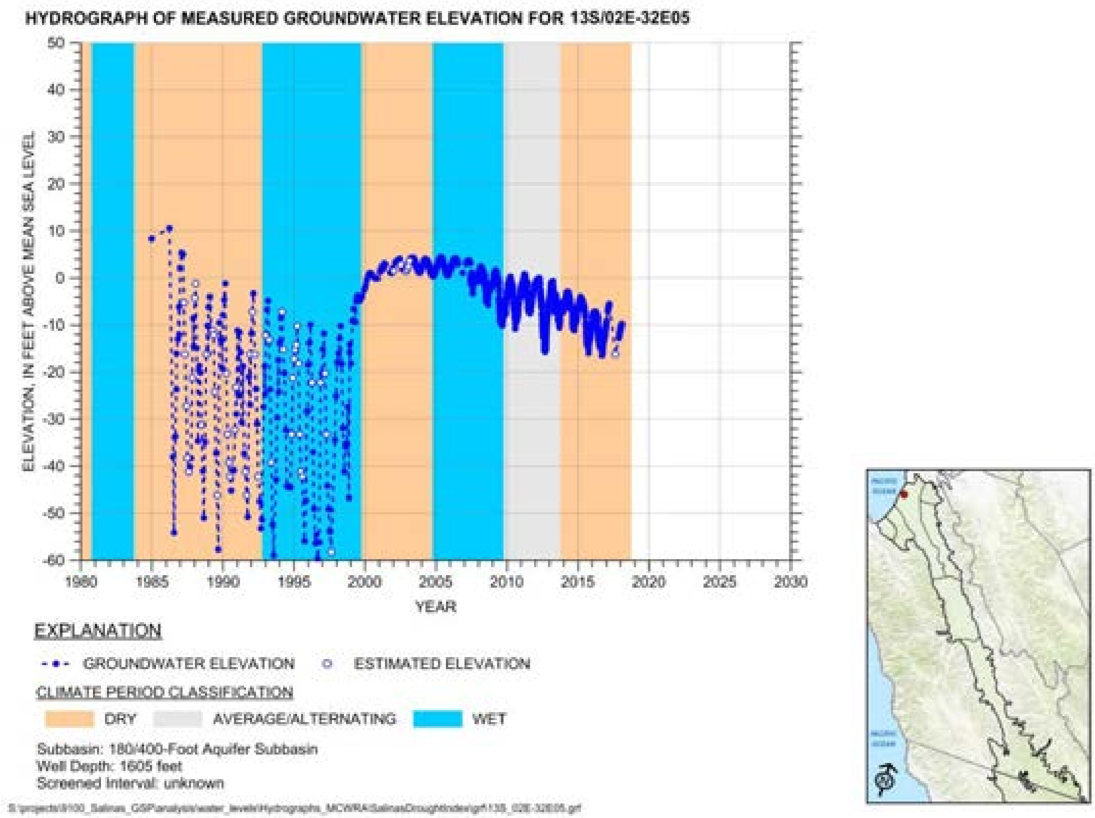


Figure 5-15: Representative Hydrographs in the 400-Foot Aquifer



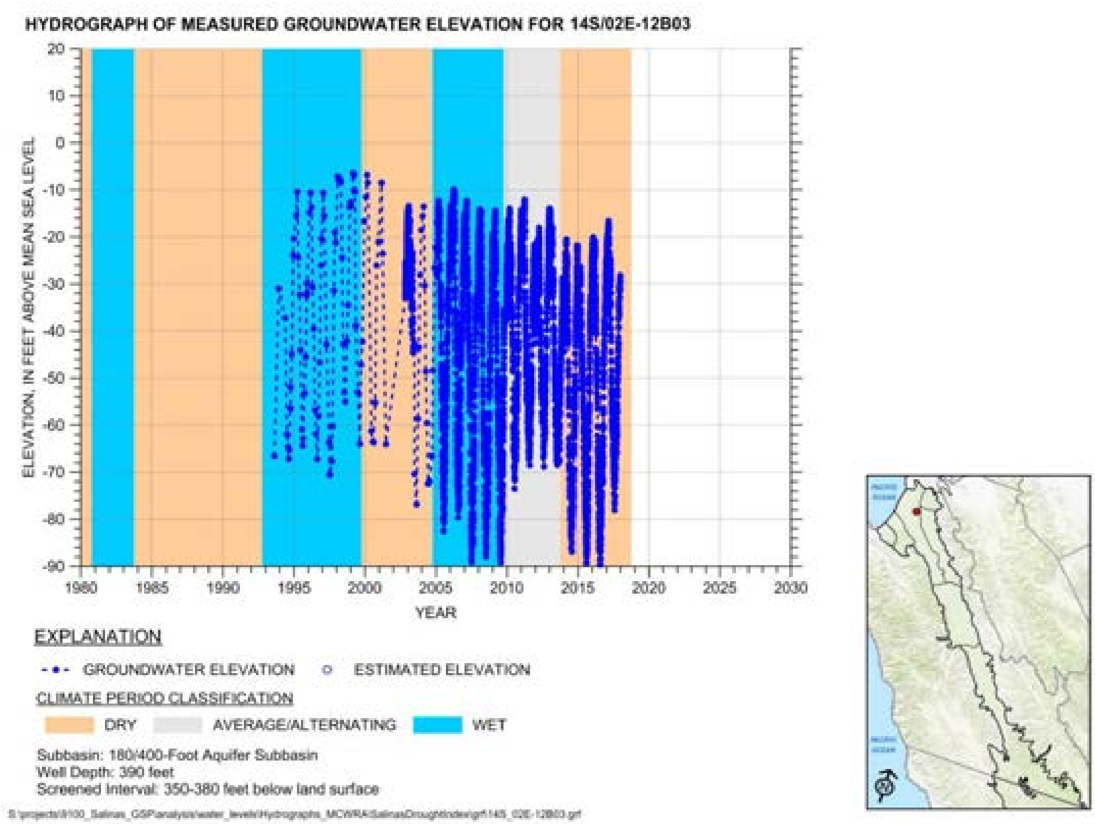


Figure 5-16: Representative Hydrographs Shown on the 400-Foot Aquifer Map (1)

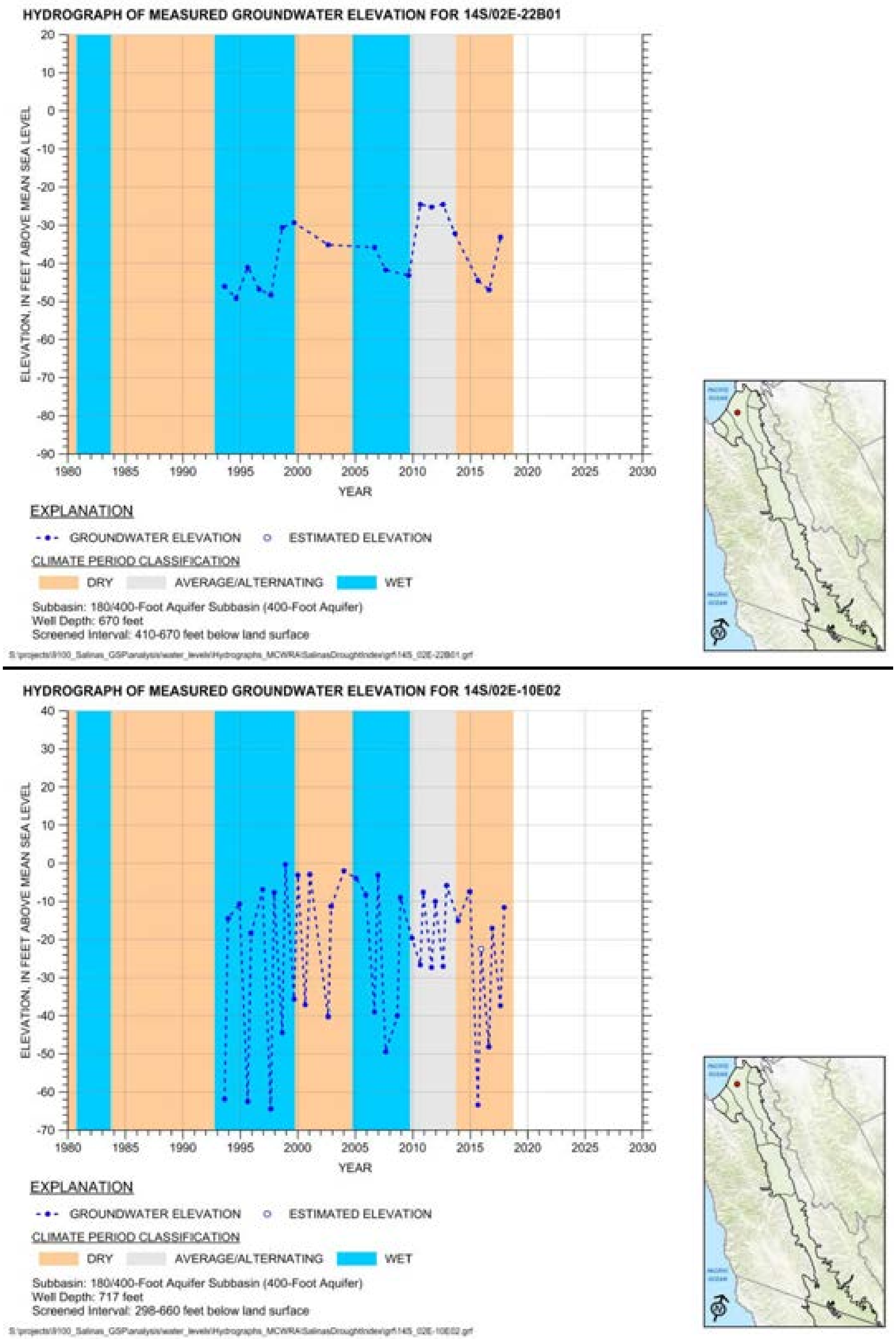
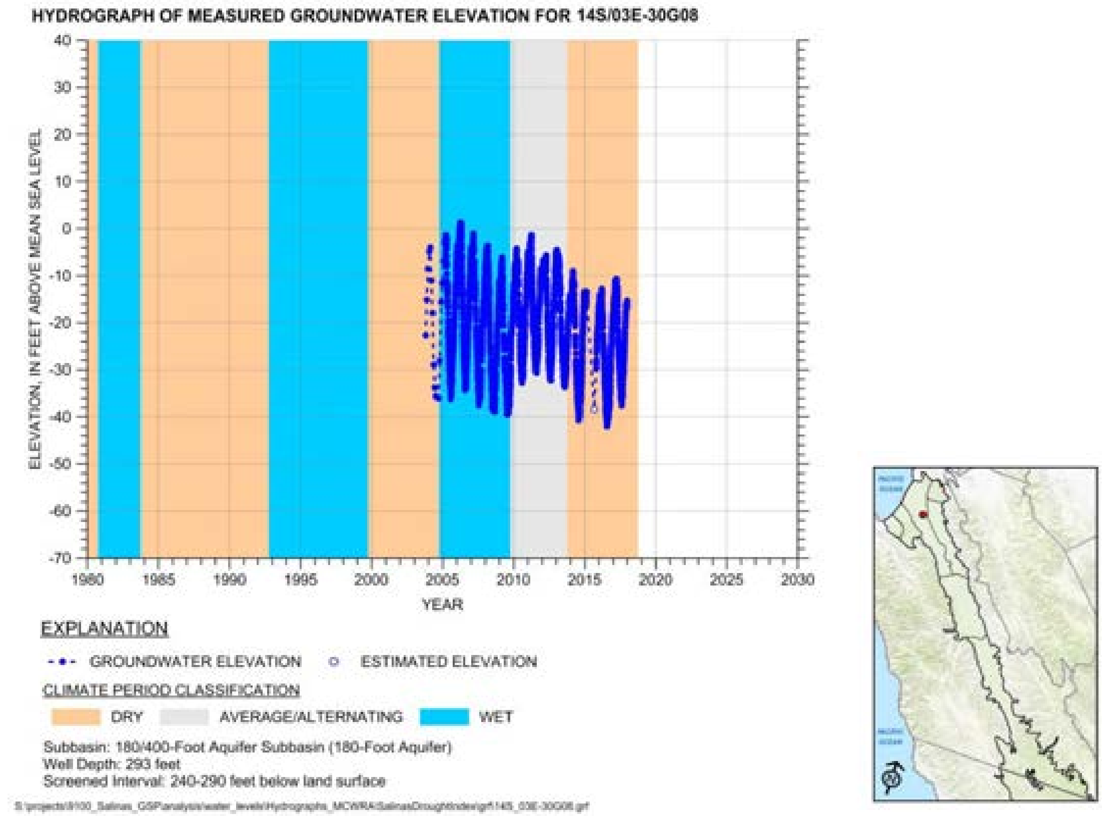


Figure 5-17: Representative Hydrographs Shown on the 400-Foot Aquifer Map (2)



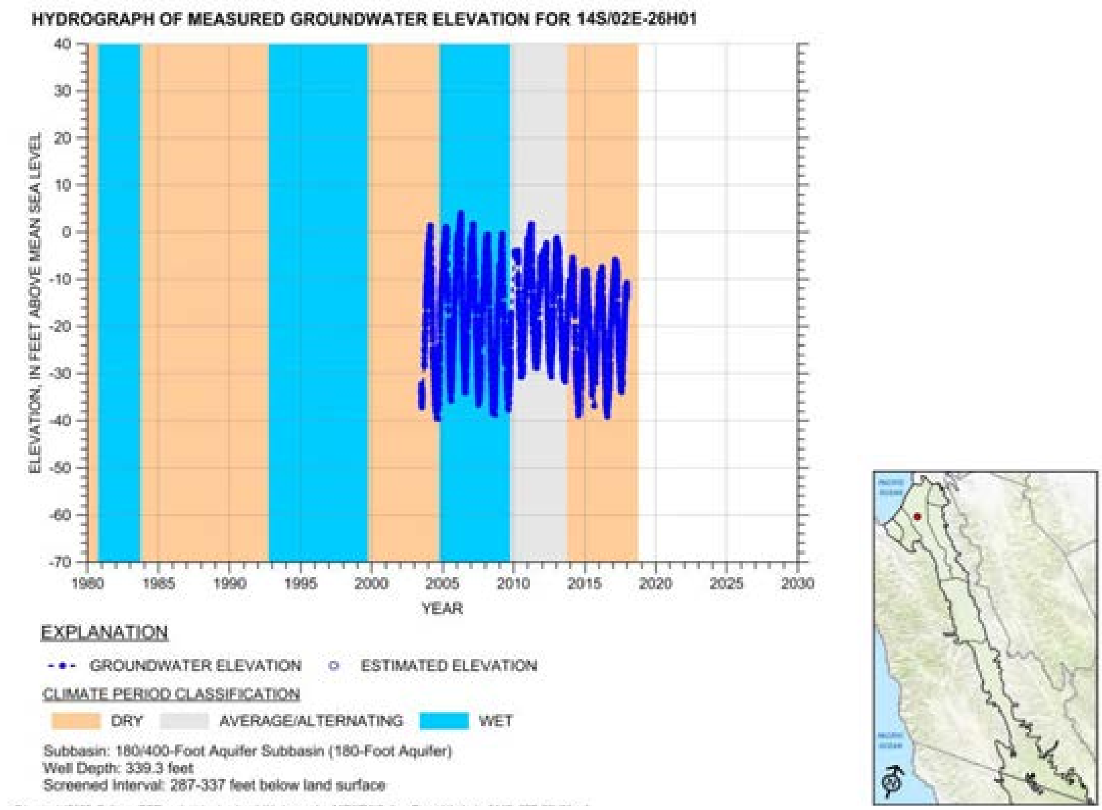
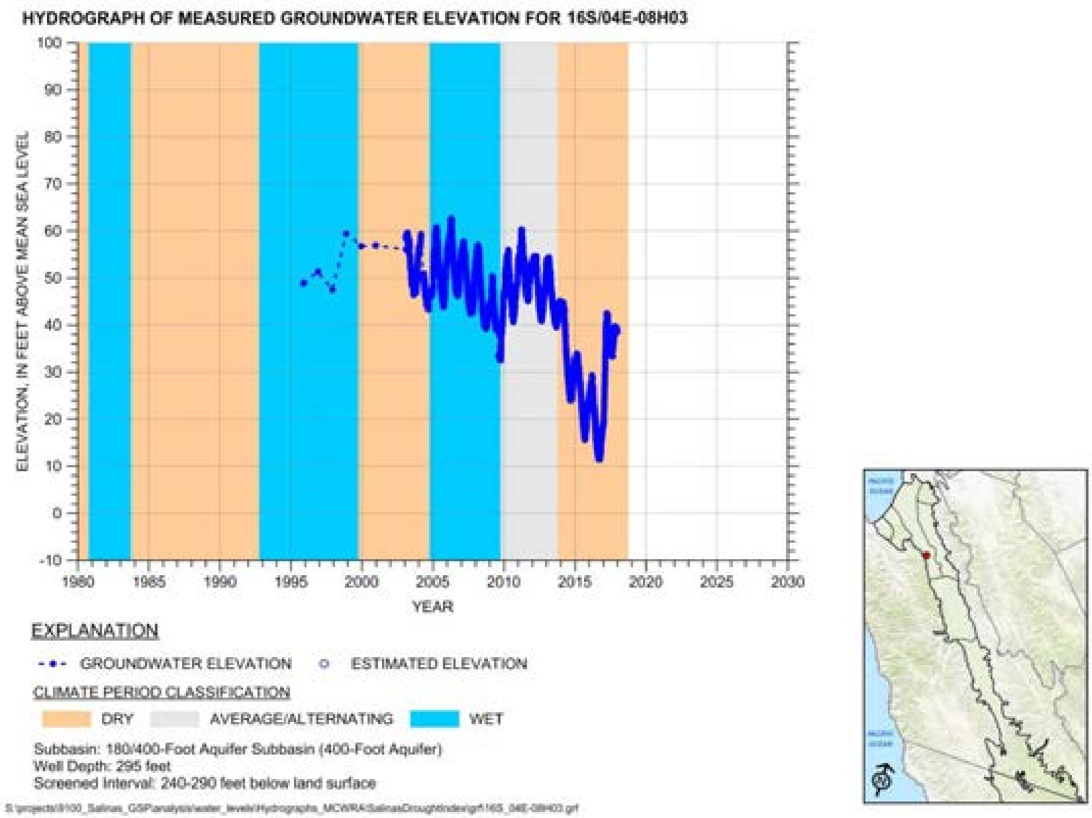


Figure 5-18: Representative Hydrographs Shown on the 400-Foot Aquifer Map (3)



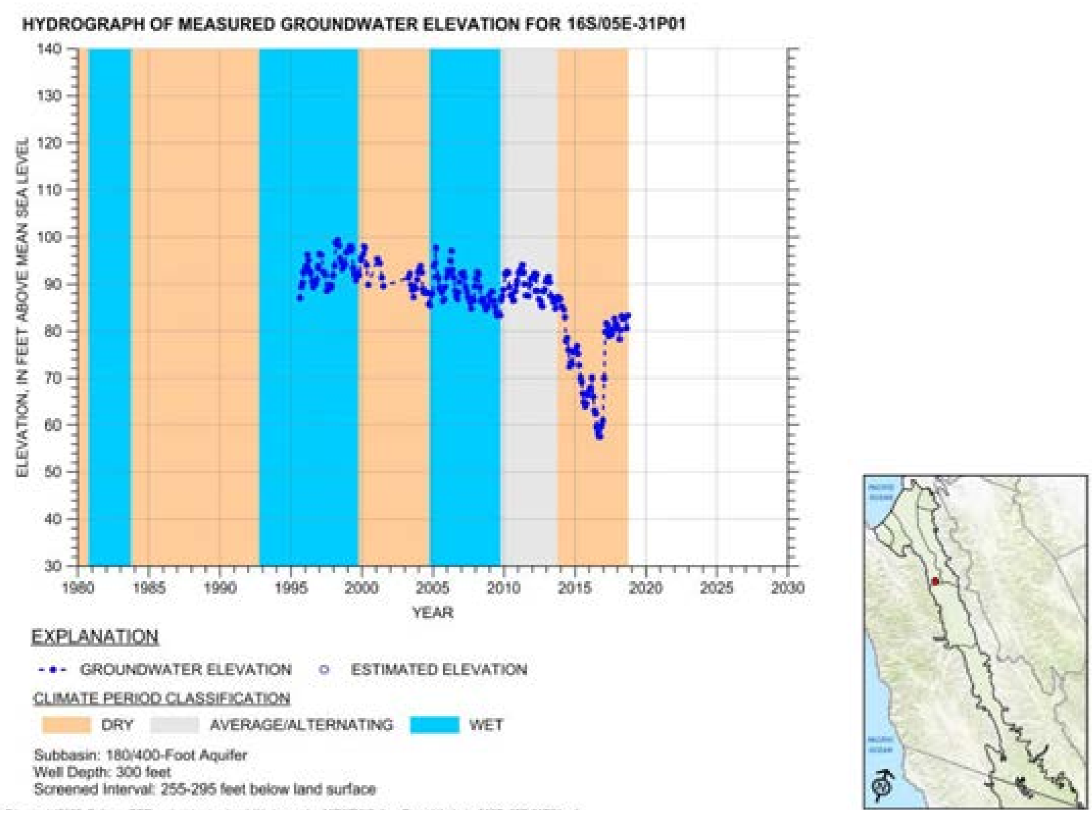


Figure 5-19: Representative Hydrographs Shown on the 400-Foot Aquifer Map (4)

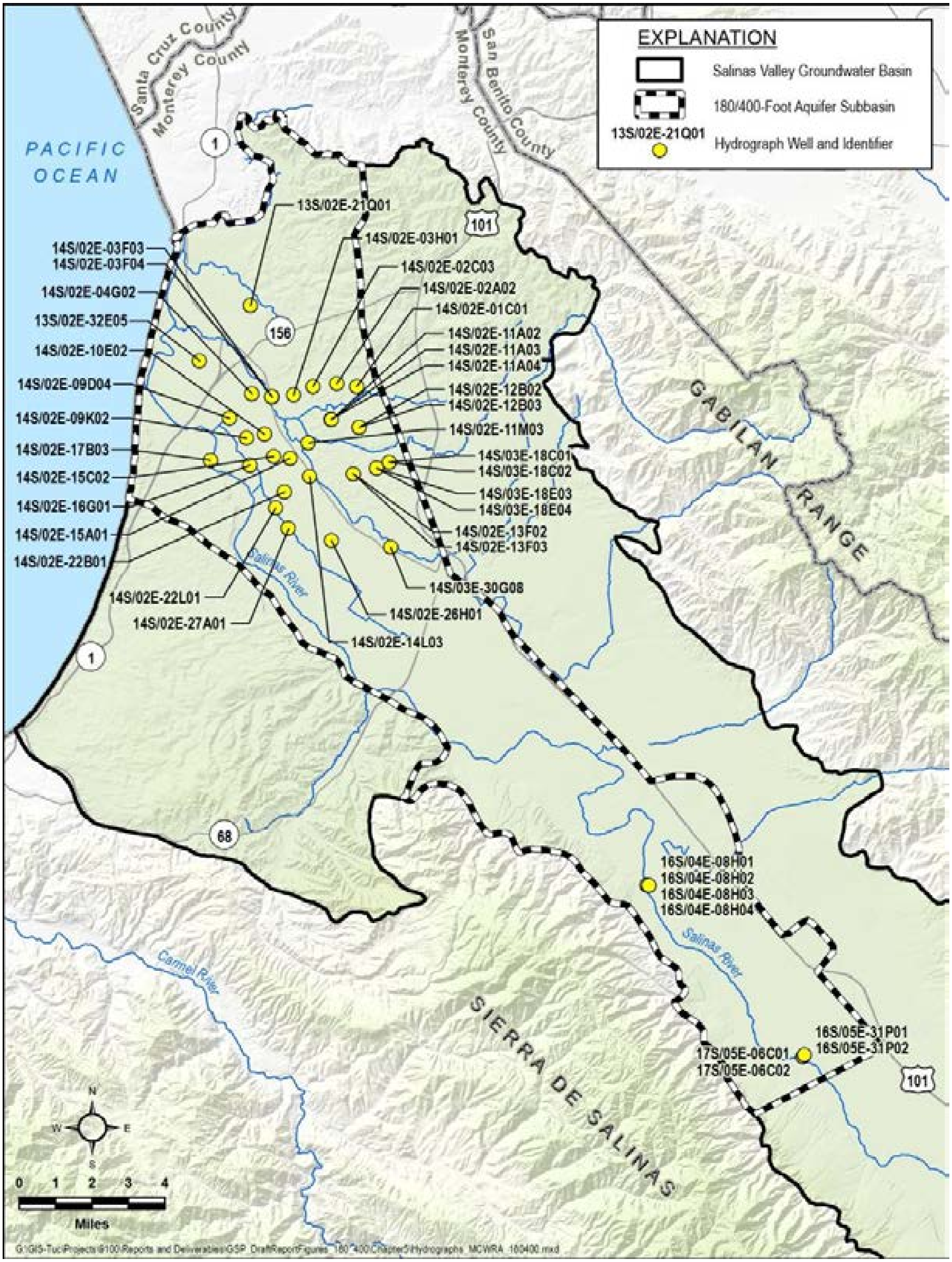


Figure 5-20: Locations of Wells with Hydrographs Included in Appendix 5A

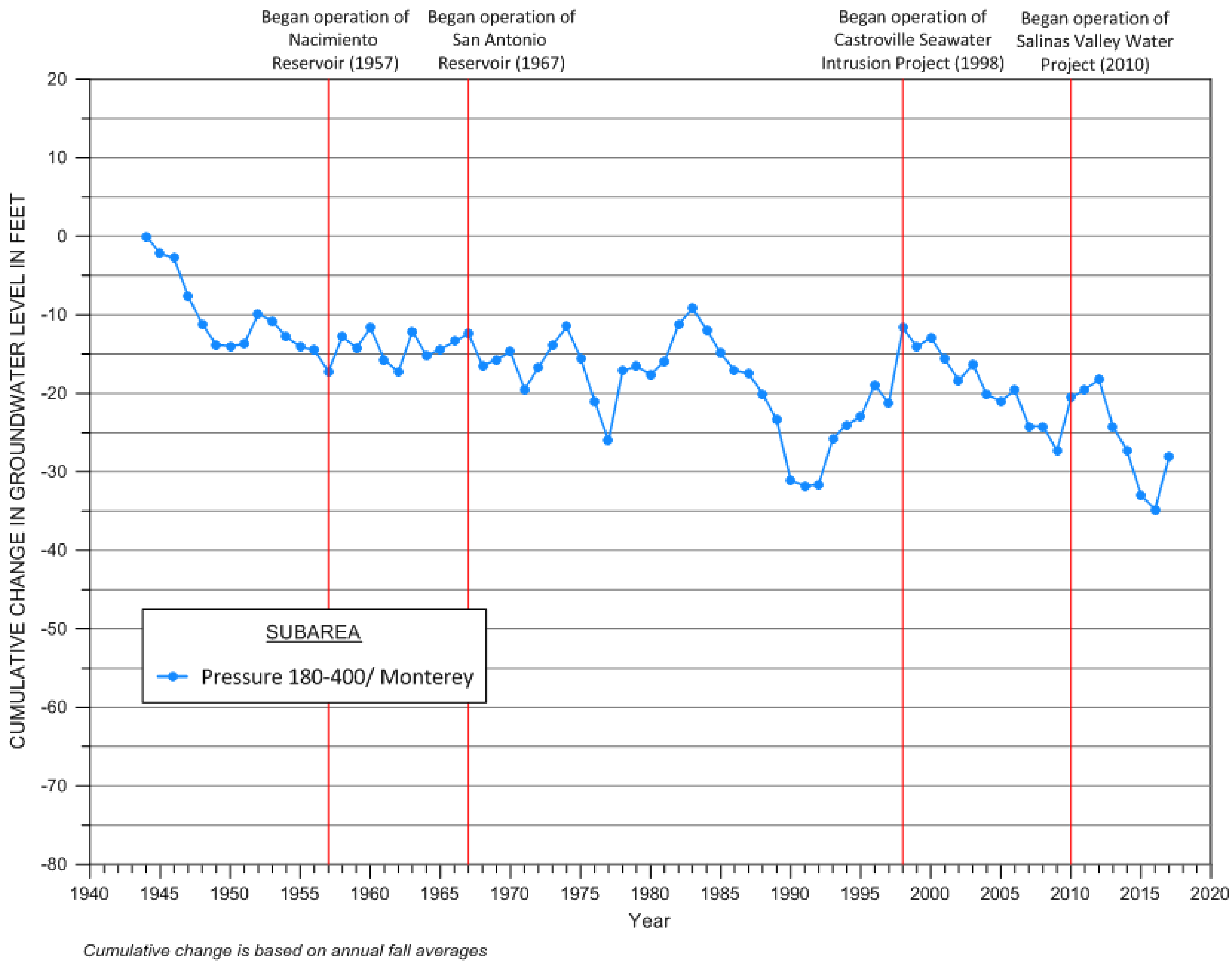


Figure 5-21: Cumulative Groundwater Change Graph for the MCWRA Pressure Subarea (from MCWRA, 2018b)

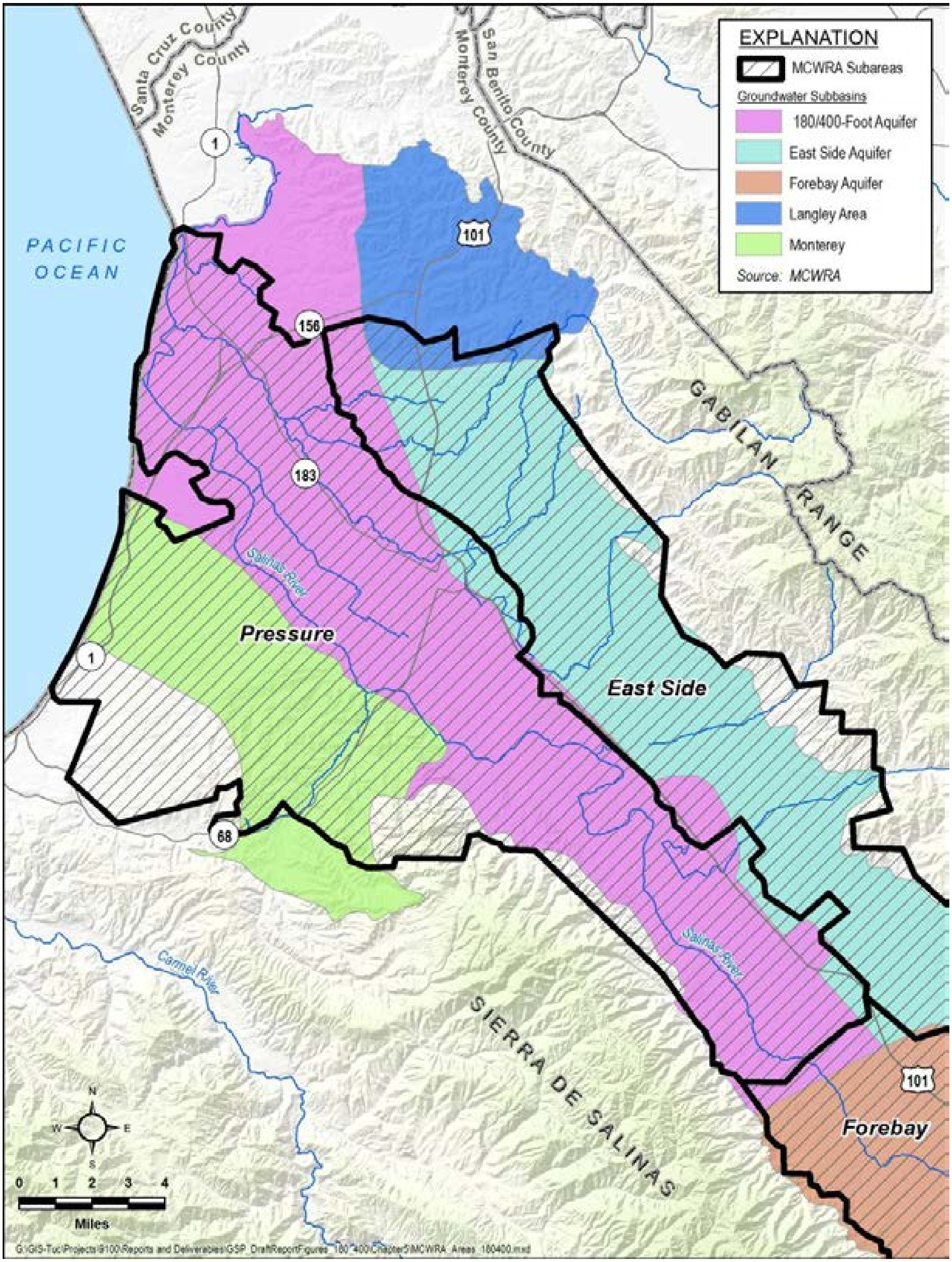


Figure 5-22: MCWRA Management Areas

5.1.4 Vertical Groundwater Gradients

In addition to the horizontal hydraulic gradients discussed above, there are vertical hydraulic gradients associated with vertical groundwater flow in the Subbasin. With groundwater recharge occurring at the ground surface and groundwater withdrawal from wells at depth, there is a basin-wide vertical downward flow that results in observed downward hydraulic gradients. The practical impact of the vertical gradients is that wells completed at deeper depths may have lower water levels than shallow wells. These vertical groundwater gradients can impact the location and amount of natural groundwater discharge to groundwater dependent ecosystems.

In the 180/400-Foot Aquifer Subbasin, the laterally extensive aquitards result in notable vertical hydraulic gradients, with water levels approximately 20 to 50 feet lower in deeper wells than in shallower wells. Because the downward vertical gradients are caused by pumping, the magnitudes of the vertical gradients in many areas are greater during the irrigation season.

Figure 5-23 illustrates the vertical gradients at representative well pairs vary throughout the subbasin. Each representative well pair consists of two adjacent wells with different well depths. The hydrographs for each well pair illustrate the difference in water level between wells of different depths at the same location. Well pair 1, in the northern portion of the subbasin, has noticeably different groundwater levels at the two depths, while well pair 3, in the southern portion of the subbasin shows no appreciable water level difference between wells.

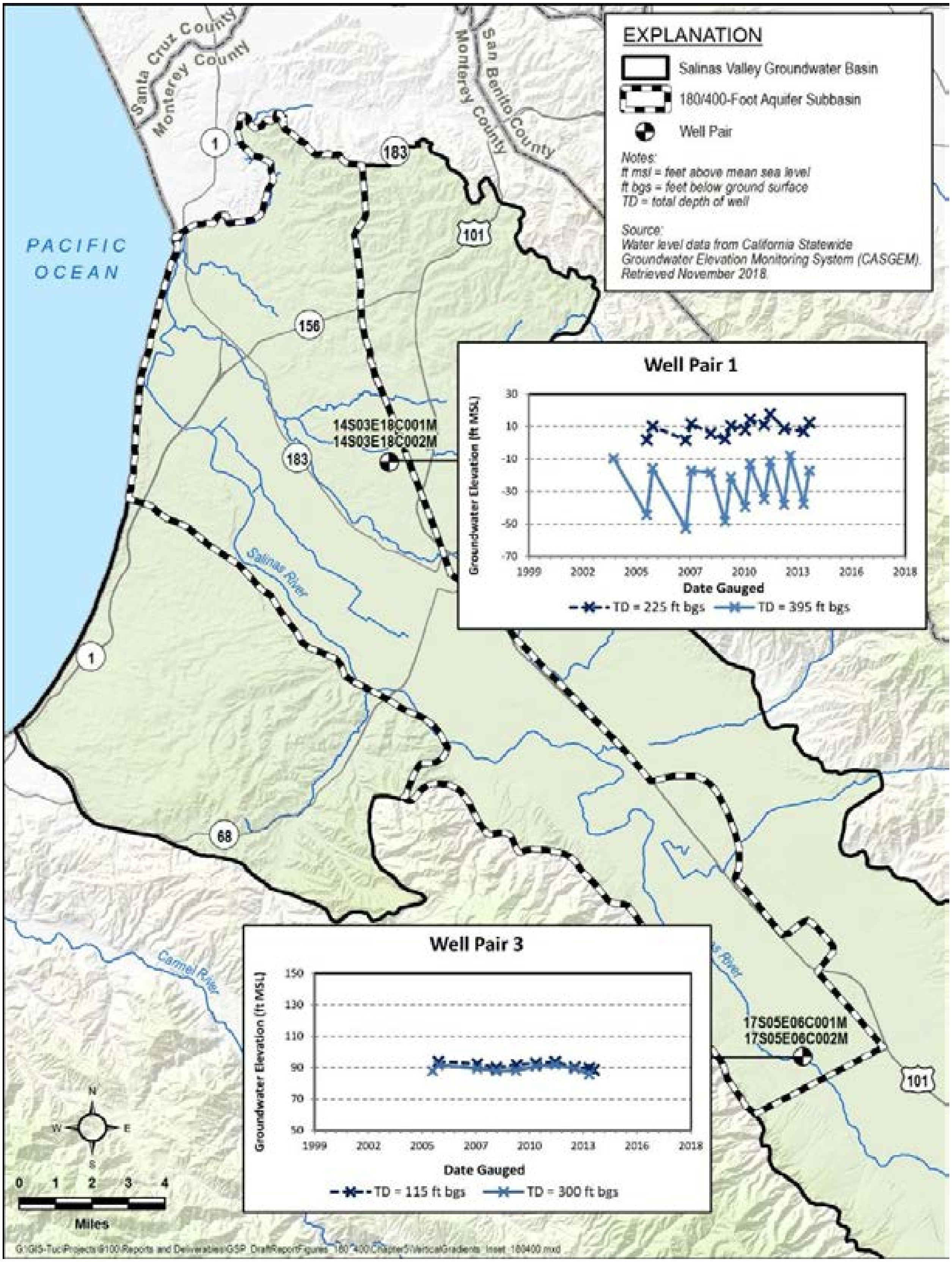


Figure 5-23: Vertical Gradients

5.2 SEAWATER INTRUSION

The 180-Foot and 400-Foot Aquifers have been subject to seawater intrusion for more than 70 years, as demonstrated by increased salt content in wells near the Monterey Bay coastline. The negative impact of seawater intrusion on local water resources and the agricultural economy has been the primary motivation for many studies dating back to 1946 (DWR, 1946). MCWRA and others have implemented a series of engineering and management projects including well construction moratoriums, developing the Castroville Seawater Intrusion Project (CSIP) system, and implementing the Salinas Valley Water Project (SVWP), among other actions to halt seawater intrusion. Although those actions have managed to slow the advance of intrusion and reduce its impacts, seawater intrusion remains an ongoing threat.

The extent and advance of seawater intrusion over time has been well-monitored and reported by MCWRA. Monitoring seawater intrusion has been on-going since the Agency formed in 1947 and currently includes a network of 96 agricultural wells and 25 dedicated monitoring wells that are sampled twice annually: in June and August. The water samples are analyzed for general minerals; and the analytical results are used by MCWRA to analyze and report the following:

- Maps and graphs of historical chloride and specific conductivity trends
- Stiff diagrams and Piper diagrams
- Plots of chloride concentration vs. Na/Cl molar ratio trends

MCWRA publishes estimates of the extent of seawater intrusion every two years. The MCWRA maps define the extent of seawater intrusion as the inferred location of the 500 mg/L chloride concentration. This chloride concentration is significantly lower than the 19,000 mg/L chloride concentration typical of seawater, but it represents a concentration that may begin to impact use of the water.

Figure 5-24 and Figure 5-25 present the most recent MCWRA maps of the current and historical extent of seawater intrusion for the 180-Foot Aquifer and the 400-Foot Aquifer, respectively. In each of the two figures, the extent of the shaded contours represents the extent of groundwater with chloride exceeding 500 mg/L during the 2017 monitoring period. The historical progression of the 500 mg/L extent is also illustrated on these figures through the colored overlays that represent the extent observed during selected years.

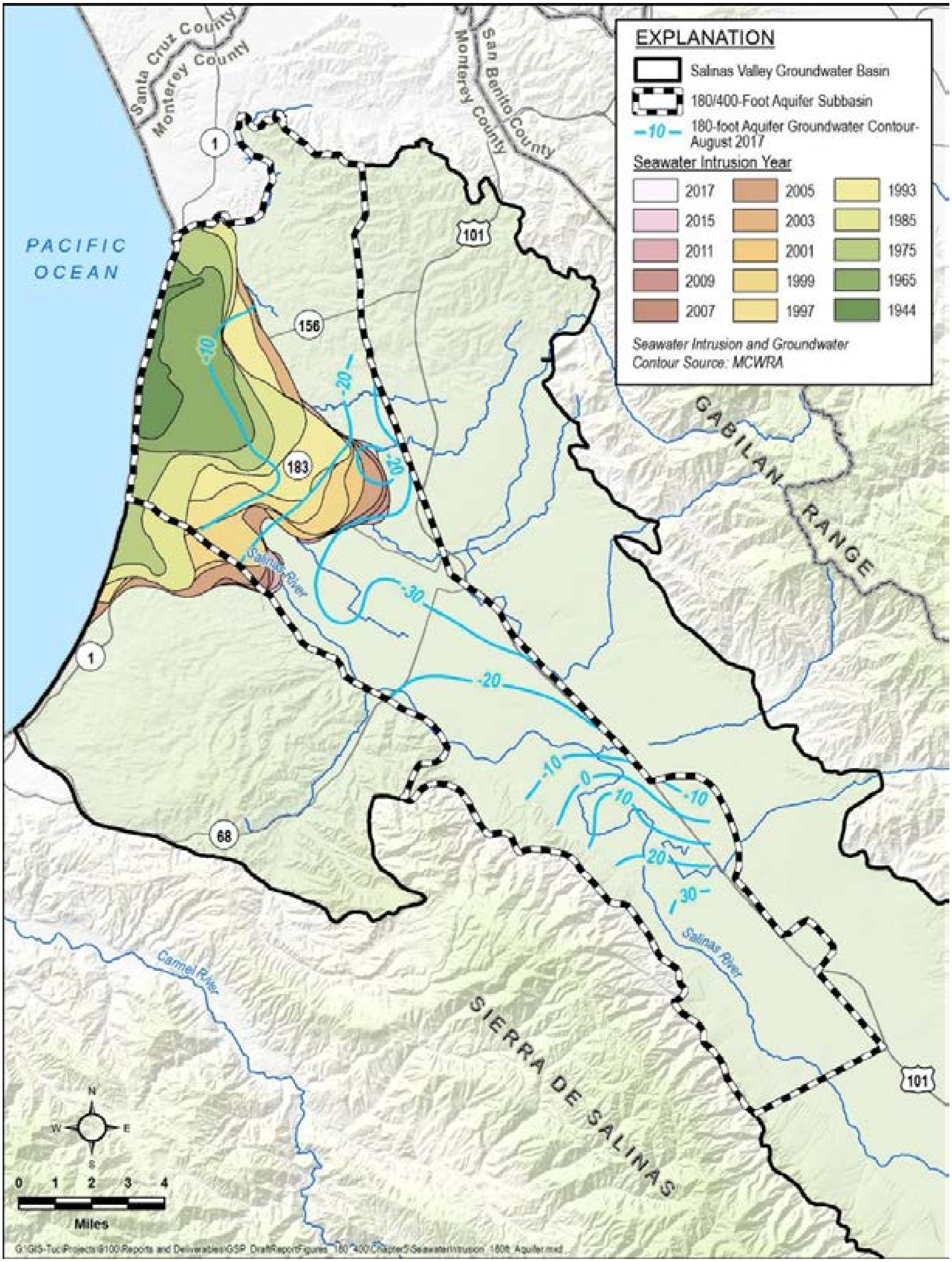


Figure 5-24: Seawater Intrusion in the 180-Foot Aquifer (from MCWRA)

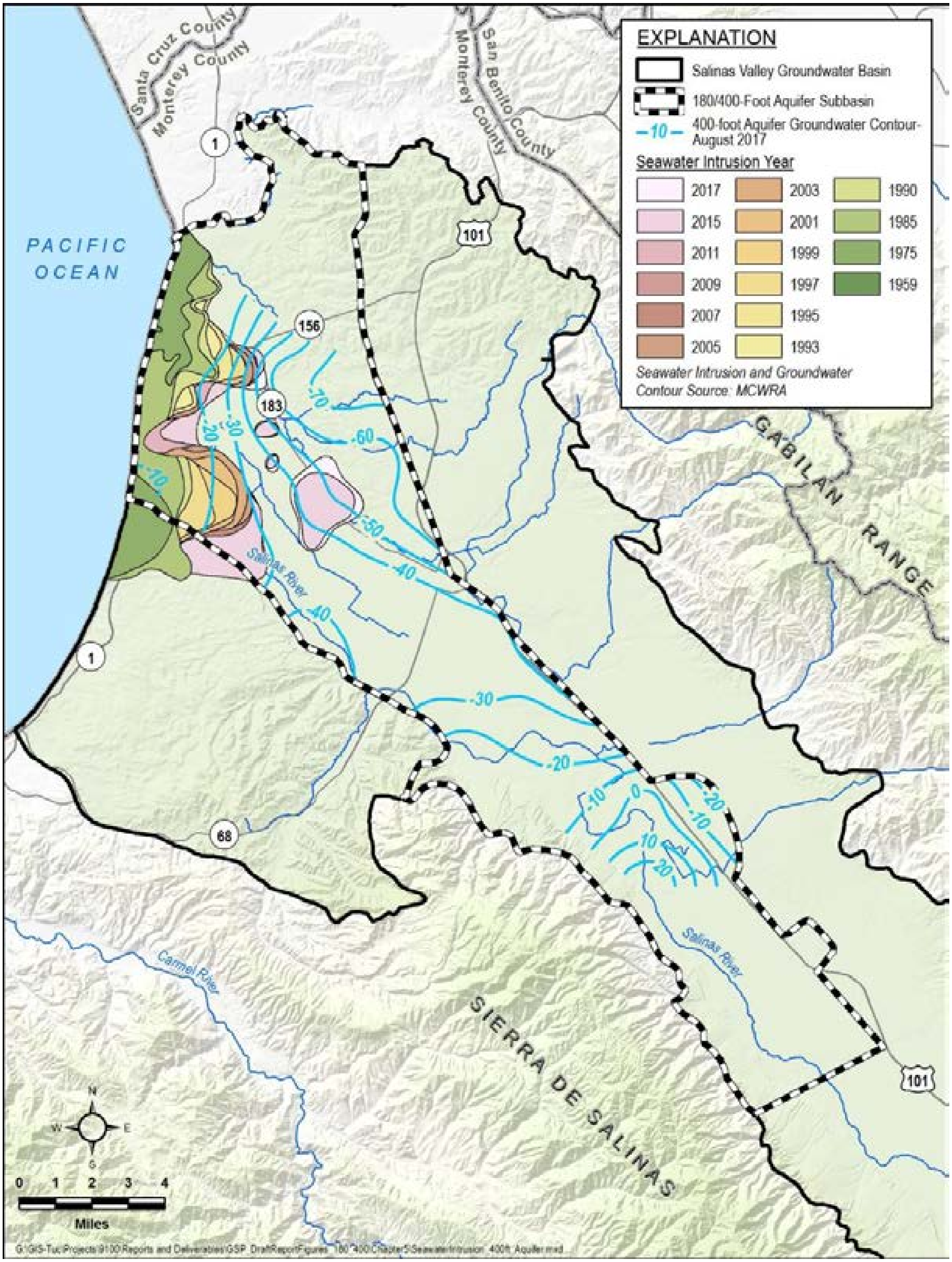


Figure 5-25: Seawater Intrusion in the 400-Foot Aquifer (from MCWRA)

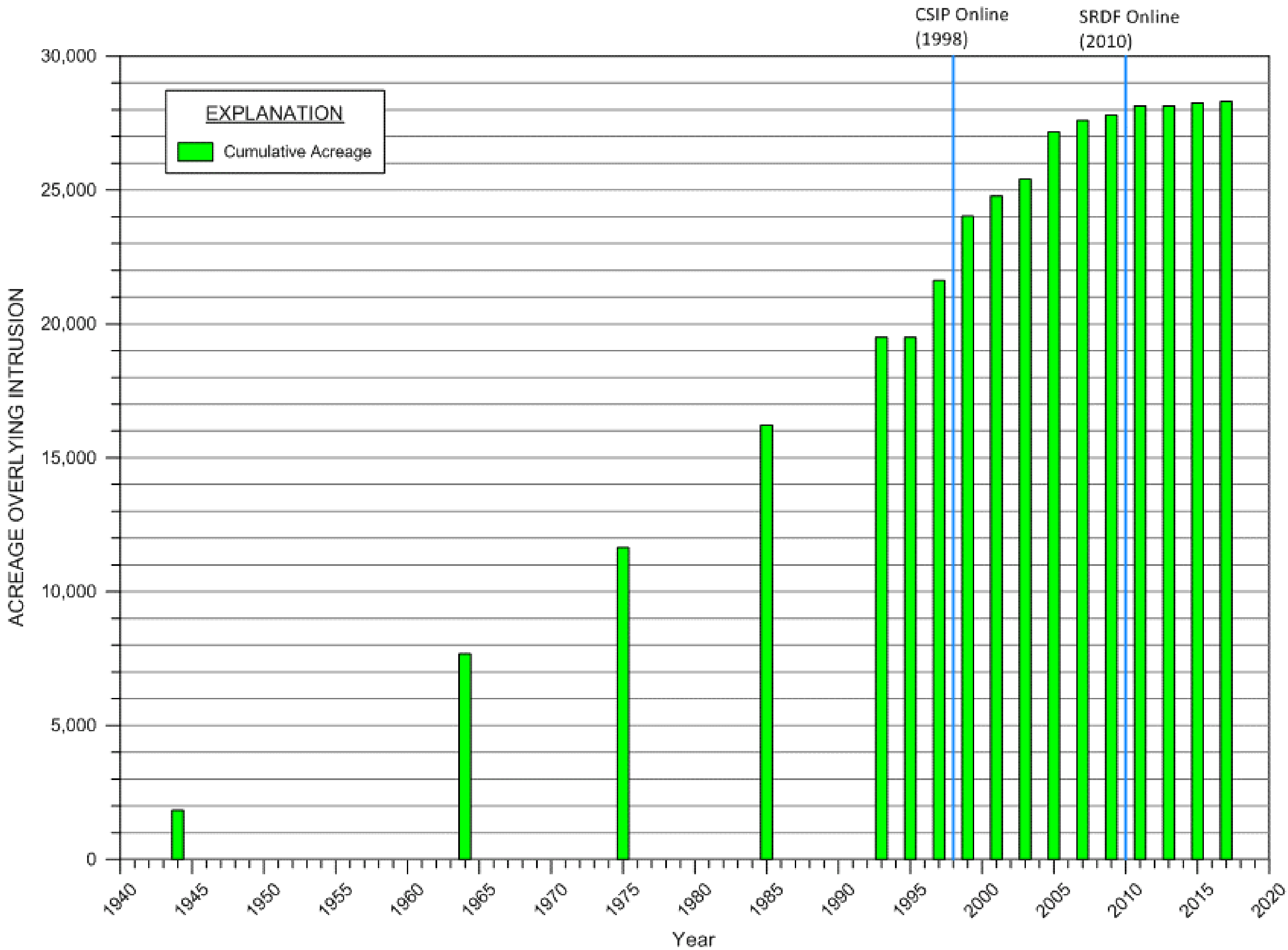
Figure 5-24 and Figure 5-25 also present the mapped August 2017 groundwater elevations for the 180-Foot Aquifer and the 400-Foot Aquifer. These maps show the seasonally low groundwater elevations that drive seawater intrusion. Figure 5-24 shows that the extent of seawater intrusion in the 180-Foot Aquifer has approximately reached a local cone of depression; represented by the small circular water level contour with a -20 foot msl label. This partially explains why the rate of seawater intrusion has slowed in recent years: the seawater intrusion is reaching a local low point and is not being drawn further inland.

Figure 5-26 and Figure 5-27 present the time series graphs of the total acreage that overlies groundwater with chloride concentration greater than 500 mg/L. Figure 5-26 shows the time series of acreage overlying seawater intrusion in the 180-Foot Aquifer. Figure 5-27 shows the time series of acreage overlying seawater intrusion in the 400-Foot Aquifer.

Seawater intrusion is observed in both the 180/400-Foot Aquifer Subbasin and the adjacent Monterey Subbasin. The characterization of the intrusion extent in Figure 5-26 and Figure 5-27 is not subdivided by subbasin, but in 2017 the total acreage overlying the 500 mg/L chloride concentration was 89% in the 180/400-Foot Aquifer Subbasin for the 180-Foot aquifer and 78% in the 180/400-Foot Aquifer Subbasin for the 400-Foot aquifer.

As shown in Figure 5-26, seawater intrusion into the 180-Foot Aquifer covered approximately 20,000 acres in 1995 and had expanded to approximately 28,000 acres by 2010. Since then, the rate of expansion has decreased, with an overlying area of 28,300 acres in 2017.

The area overlying intrusion into the 400-Foot Aquifer is not as extensive, with an overlying area of approximately 12,000 acres in 2010. However, between 2013 and 2015, the 400-Foot Aquifer experienced a significant increase in the area of seawater intrusion, from approximately 12,500 acres to approximately 18,000 acres. This apparent rapid increase in area is likely the result of localized downward migration of high chloride groundwater from the 180-Foot Aquifer to the 400-Foot Aquifer. The process of downward migration between aquifers may be in part attributed to wells that are screened across both aquifers. Regardless of the specific pathways, the presence of vertical downward hydraulic gradients from the 180-Foot Aquifer to the 400-Foot Aquifer presents a risk that eventually the intruded area of the 400-Foot Aquifer will be as large as that of the 180-Foot Aquifer.



Source: Special Joint Meeting of MCWRA BOD and Monterey County BOS

Figure 5-26: Acreage Overlying Seawater Intrusion in the 180-Foot Aquifer (from MCWRA)

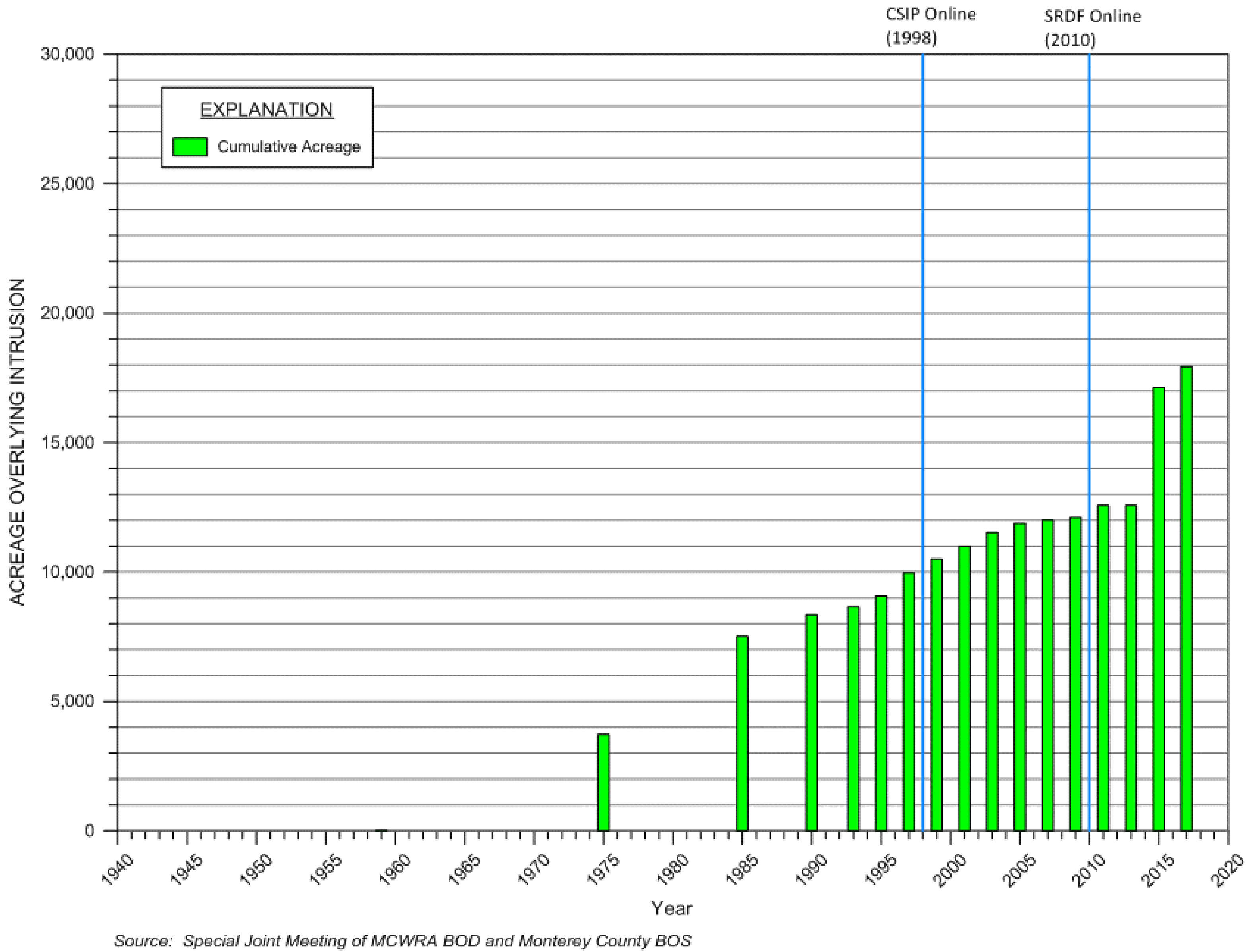


Figure 5-27: Acreage Overlying Seawater Intrusion in the 400-Foot Aquifer (from MCWRA)

To date, seawater intrusion has not been reported in the Deeper Aquifers. However, due to concern over this risk, the County has a current moratorium under its Ordinance 5302 on the construction of new wells in the Deeper Aquifers beneath the areas impacted by seawater intrusion.

The volume of seawater flowing into the subbasin every year does not strictly correspond to the acreages overlying the seawater-intruded area that is shown in Figure 5-26 and Figure 5-27. As the seawater intrusion front approaches pumping depressions, the front will slow down and stop at the lowest point in the pumping depression. The seawater intrusion front will then appear to stop; and no more acreage will be added every year. However, seawater will continue to flow in from the ocean towards the pumping depression.

The *State of the Salinas River Groundwater Basin* report estimated that approximately 11,000 acre-feet of seawater flows into the Pressure subarea every year. Previous estimates have ranged between 14,000 and 18,000 acre-feet per year (AFY) of seawater intrusion (Brown and Caldwell, 2016). These seawater inflow estimates include portions of the Monterey Subbasin. The length of coastline subject to seawater intrusion is approximately 75% in the 180/400-Foot Aquifer Subbasin and therefore we estimate the flow into the 180/400-Foot Aquifer Subbasin is approximately 8,250 to 13,500 AFY. For this analysis, we have adopted a middle value of 10,500 acre-feet per year.

5.3 CHANGE IN GROUNDWATER STORAGE

This GSP adopts the concept of change in usable groundwater storage; defined as the annual average increase or decrease in groundwater that can be safely used for municipal, industrial, or agricultural purposes. Change in usable groundwater storage is the sum of change in storage due to groundwater level changes and the change in storage due to seawater intrusion.

5.3.1 CHANGE IN GROUNDWATER STORAGE DUE TO GROUNDWATER LEVEL CHANGES

One component of the change in groundwater storage is calculated from groundwater levels in the Subbasin. The amount of groundwater stored in the Subbasin depends on variations in both seasonal and multi-year climatic cycles. The observed groundwater level changes provide a measure of the amount of groundwater that has moved into and out of storage during each year, not accounting for seawater intrusion. The change in storage can be calculated by multiplying a change in groundwater elevation by a storage coefficient. Storage coefficients depend on the hydraulic properties of the aquifer materials and are commonly measured through long-term pumping tests or laboratory tests.

The average groundwater level change that is shown on Figure 5-21 is used to estimate annual changes in water storage through the following relationship:

$$\Delta S = \Delta WL \times A \times SC$$

Where: ΔS = Annual change in storage volume in the Subbasin (ac-ft/yr.)
ΔWL= Annual change in average water level in the Subbasin (ft/yr.)
A = Land area of Subbasin (acres)
SC = Storage coefficient (ft^3/ft^3)

The estimated storage coefficient for the 180-400 Foot Aquifer Subbasin was estimated at 0.04 based on MCWRA's *State of the Basin Report* using (Brown and Caldwell, 2015). The area of the 180/400-Foot Aquifer Subbasin is approximately 90,000 acres.

Figure 5-28 presents a time series graph from 1944 through 2017 showing the estimated cumulative change in groundwater storage in the 180/400-Foot Aquifer Subbasin.

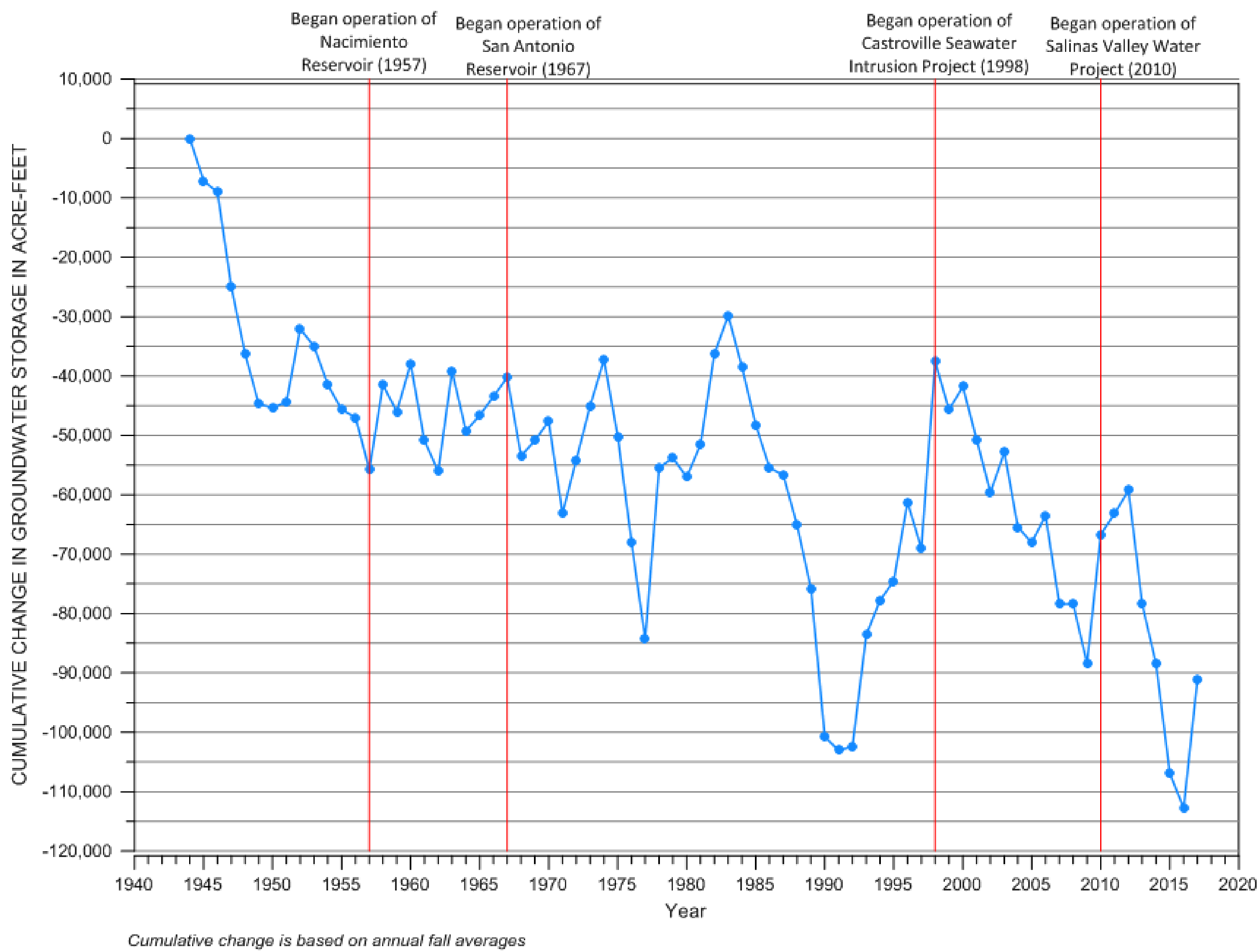


Figure 5-28: Cumulative Change in Groundwater Storage Based on Groundwater Elevations (From MCWRA, 2018b)

The timing of groundwater storage declines and recovery match the groundwater level patterns described in Section 5.1.3. However, the magnitudes of the groundwater storage changes are scaled by the storage coefficient and size of the Subbasin.

The following observations are evident from Figure 5-28.

- The 180/400-Foot Aquifer Subbasin shows a steady decline in groundwater storage due to lowering groundwater elevations. The average annual storage loss due to lowering groundwater levels in the 180/400-Foot Aquifer Subbasin between 1944 and 2017 is approximately 1,200 AFY. However, this measure of storage loss does not include the amount of storage that has been lost to seawater intrusion, as described below. Changes in the total basin groundwater storage can be divided into the following three periods:
  - 1944 to 1948: decrease of 40,000 ac-ft in groundwater storage
  - 1947 to 1998: trend of steadily-decreasing groundwater storage in most years with marked increases in 1974, 1983, and 1997
  - 1998 to 2017: decrease of approximately 50,000 ac-ft in groundwater storage.

5.3.2 CHANGE IN GROUNDWATER STORAGE DUE TO SEAWATER INTRUSION

As noted in Section 5.2, estimates of groundwater storage losses due to seawater intrusion have ranged from 8,000 to 14,000 AFY. For this GSP, we have adopted a mid-range estimate of 10,500 AFY of storage loss due to seawater intrusion in the 180/400-Foot Aquifer Subbasin. This storage loss is in addition to the change in groundwater storage due to changes in groundwater levels.

5.3.3 TOTAL CHANGE IN GROUNDWATER STORAGE

The total change in groundwater storage is the sum of the changes in groundwater storage due to groundwater level changes and seawater intrusion. Seawater intrusion adds 11,000 acre-feet of lost groundwater storage to the 180/400-Foot Aquifer Subbasin calculations. The total annual loss in groundwater storage due to the additive effects of groundwater level changes and seawater intrusion is therefore:

- Annual storage loss due to groundwater level decrease 1,200 AFY
- Annual loss due to seawater intrusion 10,500 AFY
- Total annual loss of storage 11,700 AFY

5.4 SUBSIDENCE

Land subsidence has not been reported in Salinas Valley and is not closely monitored. There are only limited data available to monitor subsidence. The National Aeronautics and Space Administration (NASA) Jet Propulsion Laboratory (JPL) processes Interferometric Synthetic Aperture Radar (InSAR) satellite data to estimate subsidence. Figure 5-29 presents a map of interpreted subsidence for the Subbasin area for the period April 2016 to April 2017. InSAR data are available for only the edges of the Subbasin. While the limited data indicate little to no land subsidence is indicated in the 180/400-Foot Aquifer Subbasin, there is clearly a lack of data necessary for establishing subsidence rates with any certainty. This is a data gap that will be addressed during GSP implementation.

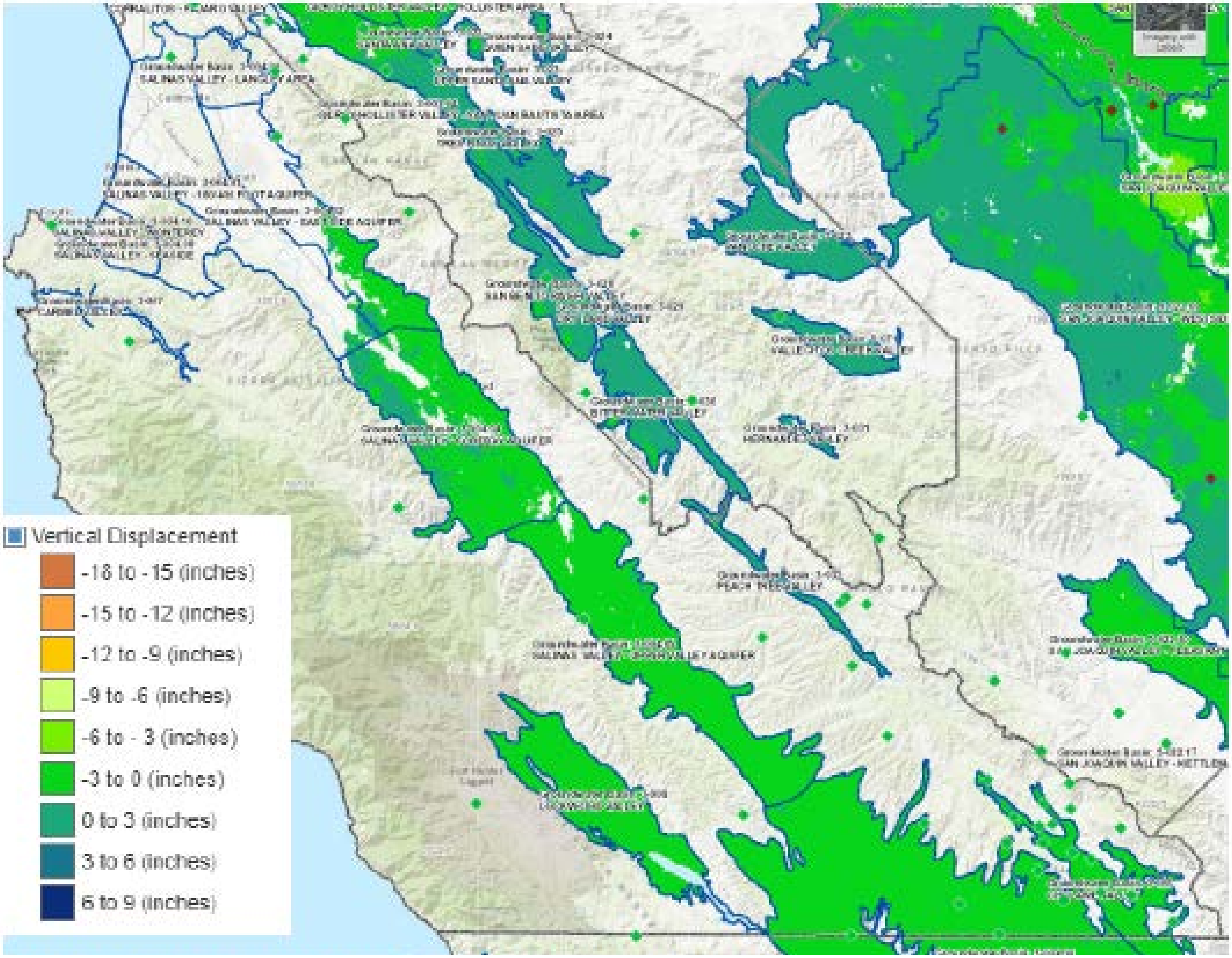


Figure 5-29: Estimated InSAR Subsidence in Salinas Valley

source: https://sgma.water.ca.gov/webgis/?appid=SGMADataViewer

5.5 INTERCONNECTED SURFACE WATER

Surface water that is connected to the groundwater flow system is referred to as interconnected surface water. If the groundwater elevation is higher that the water level in the stream, the stream is said to be a gaining stream, because it gains water from the surrounding groundwater. If the groundwater elevation is lower than the water level in the stream, it is termed a losing stream, because it loses water to the surrounding groundwater flow system. If the groundwater level is below the stream bottom, the stream and groundwater are disconnected. SGMA does not require that disconnected stream reaches be analyzed or managed. These concepts are illustrated in Figure 5-30, below.

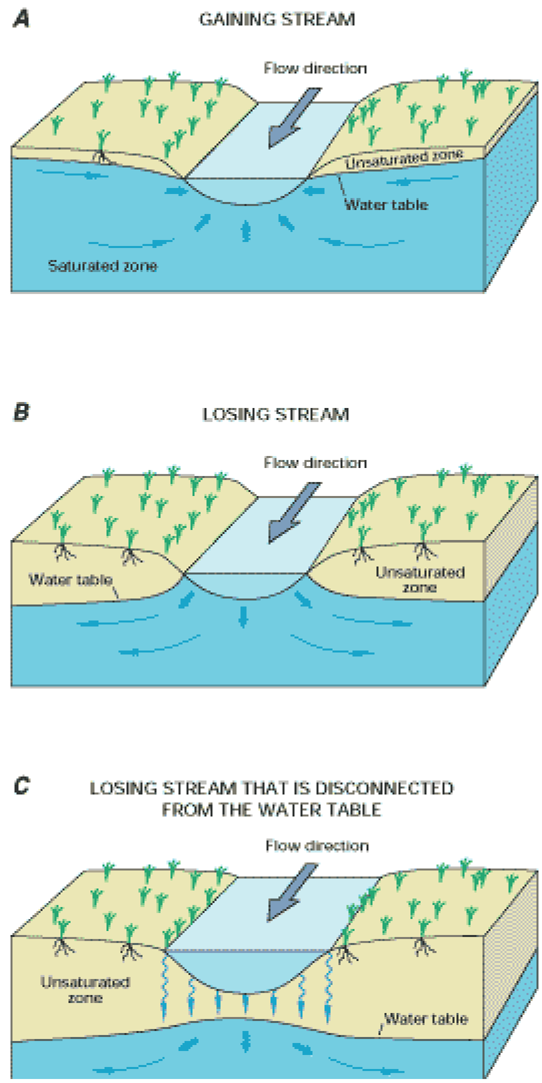


Figure 5-30: Conceptual Representation of Interconnected Surface water (Source: USGS)

The primary characteristic of the 180/400-Foot Aquifer Subbasin is the presence of the Salinas Valley Aquitard – a shallow laterally extensive clay layer that effectively separates the Salinas River from the underlying aquifers. As mentioned in Chapter 4, this aquitard is not completely continuous, and there are locations where the 180-Foot Aquifer may be in hydraulic communication with overlying sediments. However, groundwater in the 180- and 400-Foot Aquifers is generally not considered to be hydraulically connected to the Salinas River or its tributaries. This aspect of the 180/400-Foot Aquifer Subbasin has been well documented in multiple independent studies (DWR, 1946; DWR, 2018; Durbin, *et al.*, 1978; Kennedy-Jenks, 2004).

Even with the physical clay barrier between surface water and the 180-Foot Aquifer; an additional evaluation of the connection between surface water and the 180-Foot Aquifer is warranted. An additional check on the potential locations of interconnected surface waters was conducted by comparing the depth to groundwater below ground surface. If the depth to groundwater is less than 20 feet from ground surface, it is possible that groundwater and the surface water are interconnected.

To document this relationship, the water levels measured in the Fall of 2013 in the 180-Foot Aquifer were compared to ground surface elevation to estimate the depth to groundwater. Fall 2013 was selected because it is a recent year with groundwater levels mapped by MCWRA that does not represent the end of a drought period. For this analysis, any area with a depth to groundwater of less than 20 feet is assumed to be an area of potentially interconnected surface water. Figure 5-31 presents the results of that analysis and shows that groundwater in the 180-Foot Aquifer is greater than 20 feet below ground surface in most of the 180/400-Foot Subbasin. These areas of the Subbasin are not connected to surface water.

For areas of the Subbasin that are connected to surface water, a detailed analysis of hydraulic connection is required. There are two limited areas where the depth to groundwater in 2013 was less than 20 feet below ground surface: the northern end of the Subbasin where the Salinas River discharges into the Monterey Bay and near the southern boundary of the Subbasin adjacent to the Salinas River. These areas may require additional evaluation of hydraulic interaction.

This identification of interconnected surface water is supported by numerical groundwater modeling conducted by Durbin *et. al* (1978). Figure 5-32 Figure 5-32 is a profile of the Salinas Valley Basin showing simulated groundwater elevations in May 1971 and September 1970 relative to the thalweg, or lowest point, of the Salinas River. Although this profile is developed for the entire Valley, the left side of the profile is relevant to the 180/400-Foot Aquifer Subbasin. This profile shows that between the Arroyo Seco Confluence and

Spreckels; groundwater levels have historically been much deeper than Salinas River, indicating that the surface water is disconnected from groundwater.

This analysis of locations of interconnected surface water is based on best available data, but contains significant uncertainty. Additional data are needed to reduce uncertainty and refine the map of interconnected surface waters. The main source of these data will be the Valley-wide model when it becomes available. Additional shallow groundwater monitoring wells may be necessary to verify groundwater levels adjacent to surface water bodies. This is a data gap that will be addressed during GSP implementation.

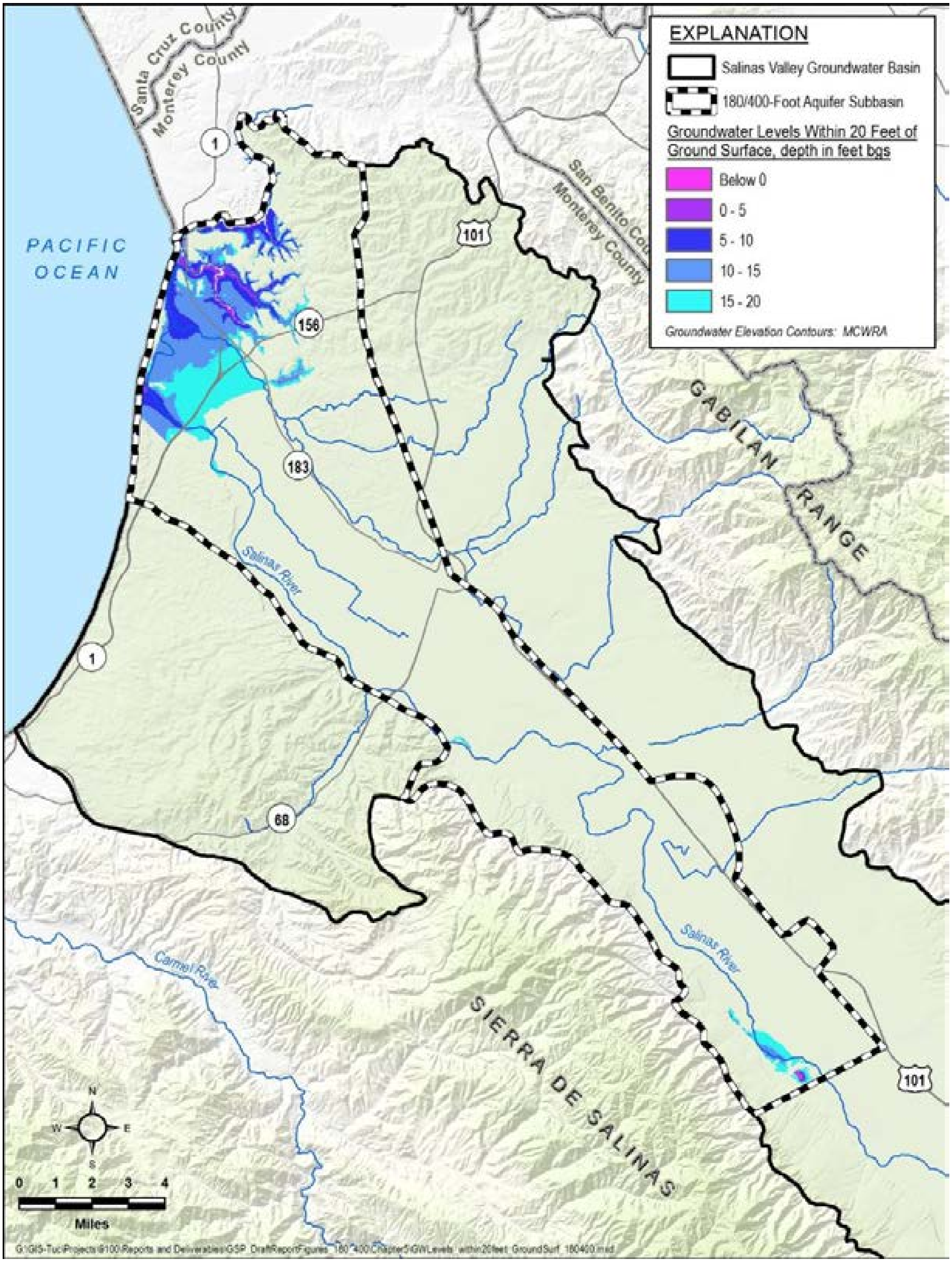


Figure 5-31: Groundwater Within 20 Feet of Land Surface

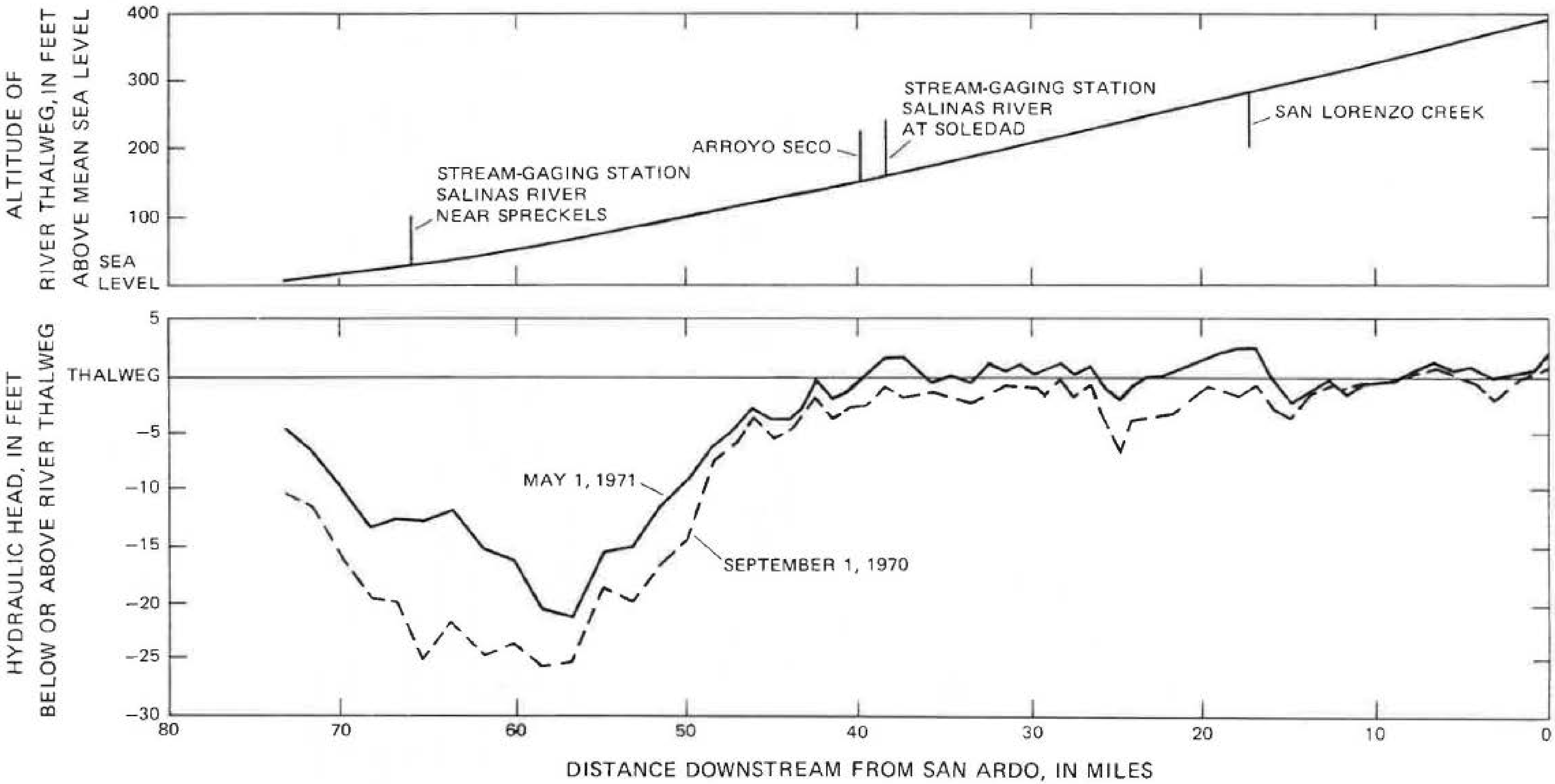


Figure 5-32: Groundwater Profiles Computed by Two-Dimensional Groundwater Model and Thalweg Profile Along the Salinas River (Durbin et al., 1978)

5.6 GROUNDWATER QUALITY DISTRIBUTION AND TRENDS

This section presents a summary of current groundwater quality conditions. The SVBGSA does not have regulatory authority over groundwater quality and is not charged with improving groundwater quality in the Salinas Basin. Projects and actions implemented by the SVBGSA are not required to improve groundwater quality; however, they must not further degrade groundwater quality.

Groundwater quality samples have been collected and analyzed in the Subbasin for various studies and programs. Groundwater quality samples have also been collected on a regular basis for compliance with regulatory programs. In particular, a broad survey of groundwater quality was conducted in 2015 by the Central Coast Groundwater Coalition (LSCE, 2015).

Groundwater quality in the Salinas Valley Basin and adjacent areas was evaluated by the USGS in two studies under the Groundwater Ambient Monitoring and Assessment Program (GAMA) - a statewide groundwater quality monitoring program established in 2000 by the California State Water Resources Control Board (SWRCB). The USGS investigated water quality in groundwater resources used for public supply and in the shallow aquifer used for domestic wells (USGS, 2005; USGS 2018). These GAMA projects sampled 22 wells in the 180/400-Foot Aquifer Subbasin; and the samples were analyzed for up to 270 constituents and water-quality indicators including volatile organic compounds (VOCs), pesticides, pesticide degradates, nutrients, major and minor ions, trace elements, radioactivity, microbial indicators, dissolved noble gases, and naturally occurring isotopes (USGS, 2005). In addition, through the voluntary GAMA Domestic Well Project, 10 domestic wells in the 180/400-Foot Aquifer Subbasin were sampled for 208 constituents, including volatile organic compounds, pesticides, trace elements, isotopic tracers, and radioactivity. All quality-assured data collected for the GAMA Program are publicly available through the USGS National Water Information System (NWIS) web interface (http://waterdata.usgs.gov/ca/nwis/) and the SWRCB GeoTracker groundwater information system (https://geotracker.waterboards.ca.gov/gama/) (USGS, 2018).

5.6.1 POINT SOURCES OF GROUNDWATER POLLUTANTS

Because of overlapping agency responsibilities, clean-up and monitoring of point source pollutants may be under the responsibility of either the Regional Board or the California State Department of Toxic Substances Control (DTSC). The Regional Board and DTSC make all related materials available to the public through two public portals: GeoTracker (https://geotracker.waterboards.ca.gov/) managed by the Regional Board and Envirostor (https://www.envirostor.dtsc.ca.gov/public/) managed by DTSC.

Figure 5-33 presents a map with the location of active clean-up sites within the subbasin and Table 5-1 provides a summary of the active clean-up sites. Table 5-1 does not include sites that have leaking underground storage tanks, which are not overseen by DTSC or the Regional Board.

Table 5-1: Active Cleanup Sites

Label	Site Name	Site Type	Status	Constituents of Concern (COCs)	Address	City
1	Dynegy Moss Landing	Corrective Action	Active	metals, petroleum, polychlorinated biphenyls (PCBs), volatile organic compounds (VOCs)	Highway 1 & Dolan Road	Moss Landing
2	Moss Landing Power Plant	Cleanup Program Site	Open - Verification Monitoring	metals/heavy metals, petroleum/fuels/oils, polynuclear aromatic hydrocarbons, volatile organic compounds (VOCs)	Highway 1 & Dolan Road	Moss Landing
3	National Refractories (Former)	Cleanup Program Site	Open - Remediation	chromium, trichloroethylene (TCE)	7697 California Highway 1	Moss Landing
4	Union Pacific Railroad - Salinas Yard	Cleanup Program Site	Open - Verification Monitoring	petroleum hydrocarbons, polycyclic aromatic hydrocarbons (PAHs), naphthalene, VOCs, metals	Rico and West Lakes Streets	Salinas
5	Toro Petroleum-Agt	Cleanup Program Site	Open - Verification Monitoring	benzene, petroleum hydrocarbons	308 West Market Street	Salinas
6	Pacific Gas & Electric (PG&E), Salinas Manufactured Gas Plant (MPG)	Voluntary Cleanup	Active	cyanide, metals, contaminated soil, hydrocarbon mixtures	2 Bridge Street	Salinas
7	Borina Foundation	Cleanup Program Site	Open - Remediation contaminated soil was excavated in 2013. Soil vapor extraction remedy is operating to treat soil gas	halogenated volatile organic compounds (VOCs) in soil and soil gas	110-124 Abbott Street	Salinas
8	Crop Production Services, Inc. - Salinas	Cleanup Program Site	Open - Remediation Pump and treat system in place	nitrate, pesticides in shallow aquifer	1143 Terven Avenue	Salinas
9	Pure-Etch Co	Corrective Action	Active - dual phase extraction remedy implemented	benzene, ethylbenzene, petroleum hydrocarbon-gas, toluene, xylenes	1031 Industrial Street	Salinas
10	NH3 Service Company	Cleanup Program Site	Open - Verification Monitoring Pump and treat system in place	nitrate	945 Johnson Avenue	Salinas
11	Firestone Tire (Salinas Plant)	National Priorities List	Delisted	1,2-dichloroethylene (DCE), tetrachloroethylene (PCE)	340 El Camino Real South	Salinas

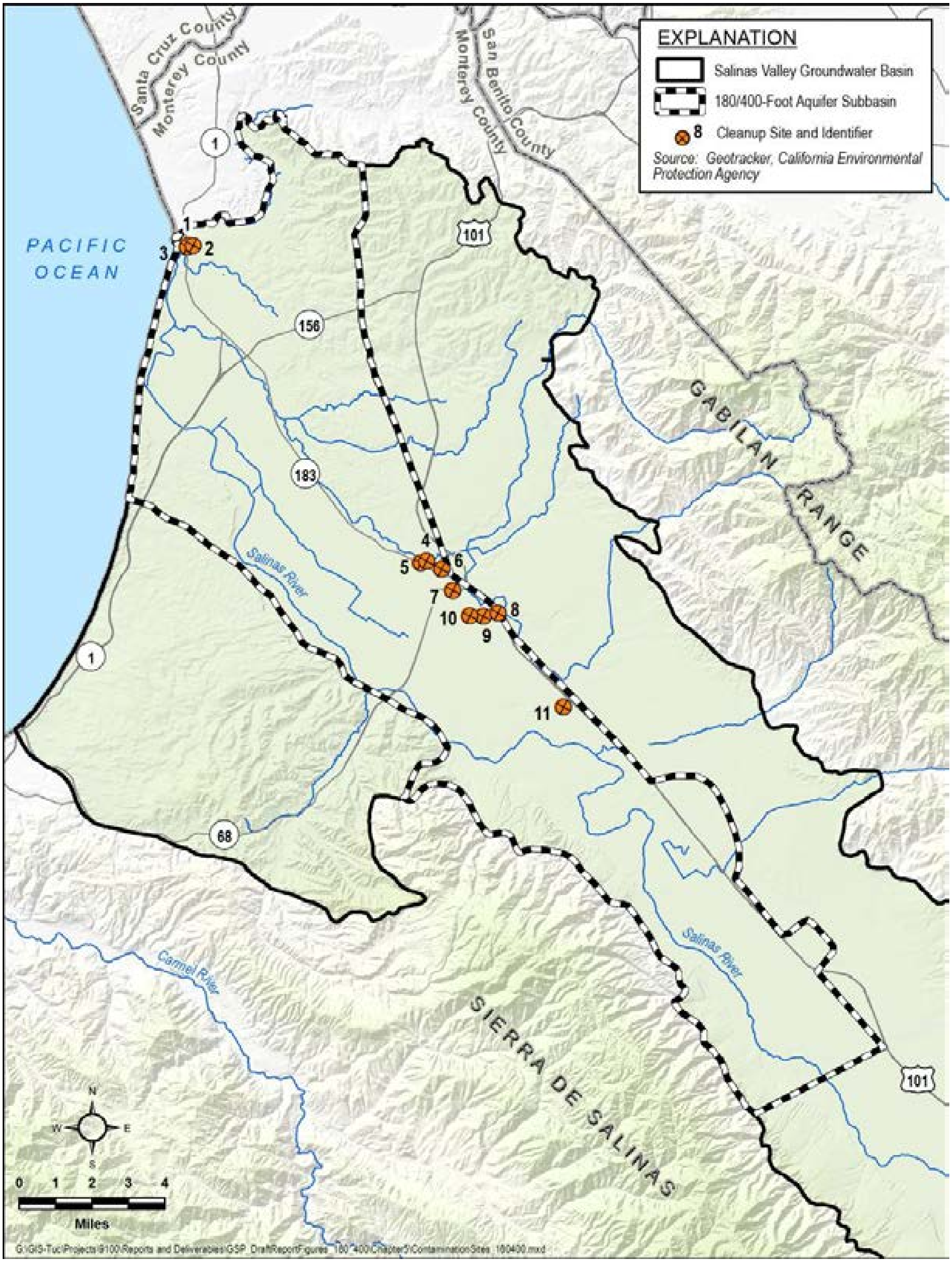


Figure 5-33: Active Cleanup Sites

5.6.2 Distribution and Concentrations of Diffuse or Natural Groundwater Constituents

In addition to the point sources described above, the Regional Board monitors and regulates activities and discharges that can contribute to non-point pollutants, which are constituents that are released to groundwater over large areas. In the Subbasin, the most prevalent non-point source water quality concern is nitrate. The current distribution of nitrate was extensively monitored and evaluated by the CCGC and documented in a report submitted to the Regional Board (LSCE, 2015).

Figure 5-34 presents a map of nitrate distribution in the Subbasin prepared by LSCE (2015) and included in the report prepared for CCGC. This map is a focused portion of a larger map that covers the entire Salinas Valley. The blurry quality of this map results from zooming in on a small portion of the original map. The orange and red areas illustrate the portions of the Subbasin where groundwater has nitrate concentrations above 45 mg/L as NO_3 – the maximum contaminant level (MCL) for drinking water and the Basin Plan Water Quality Objective set by the Regional Board.

Figure 5-35 presents maps of measured nitrate concentration from six decades of monitoring for the entire Salinas Valley. These maps, prepared by MCWRA, indicate that elevated nitrate concentrations in groundwater were locally present through the 1960s, but significantly increased in 1970s and 1980s. It appears that the extensive distribution of nitrate concentrations above the MCL as shown in Figure 5-34 has been present for 20 to 30 years.

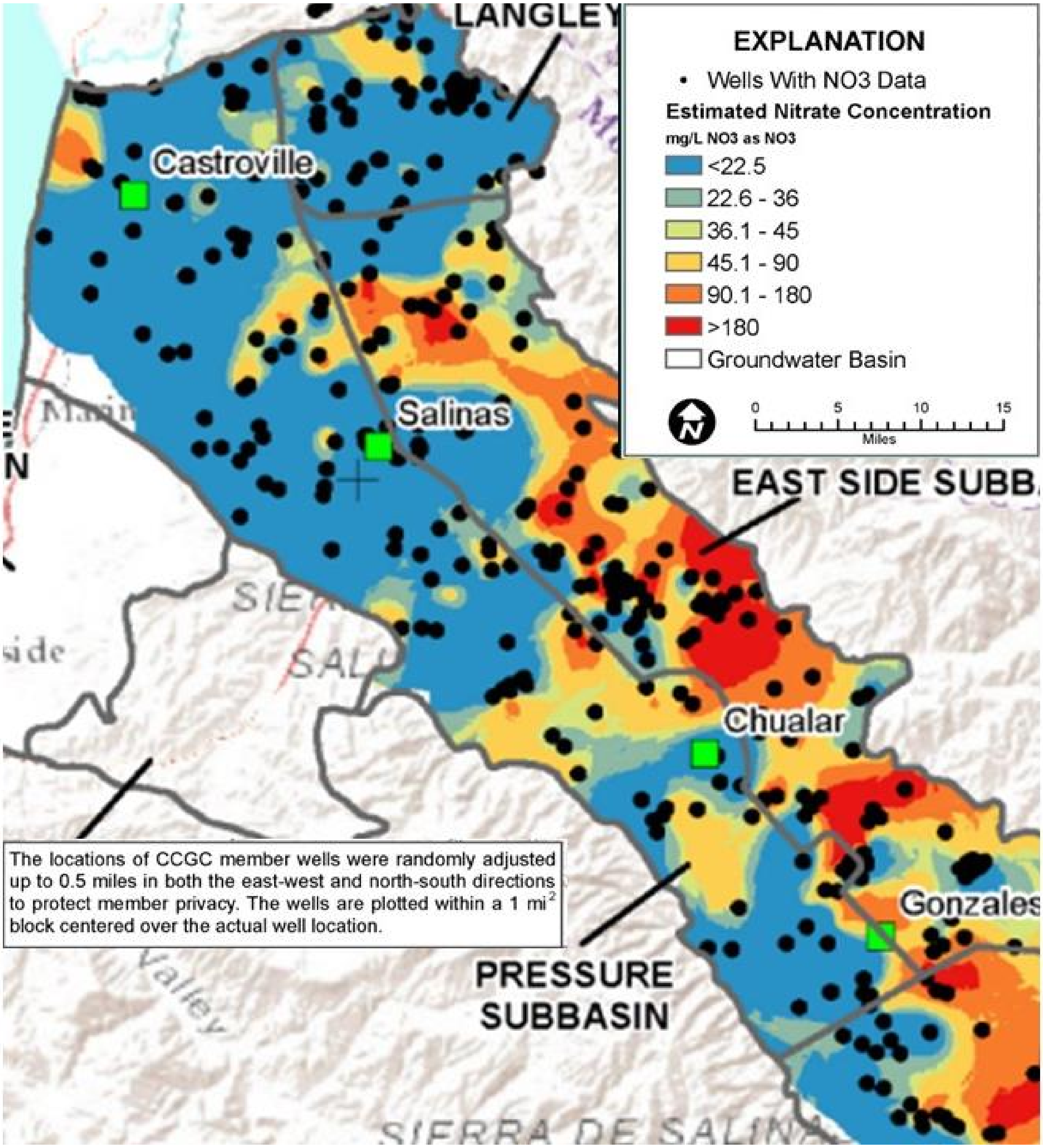


Figure 5-34: Estimated Nitrate Concentrations (from LSCE, 2015)

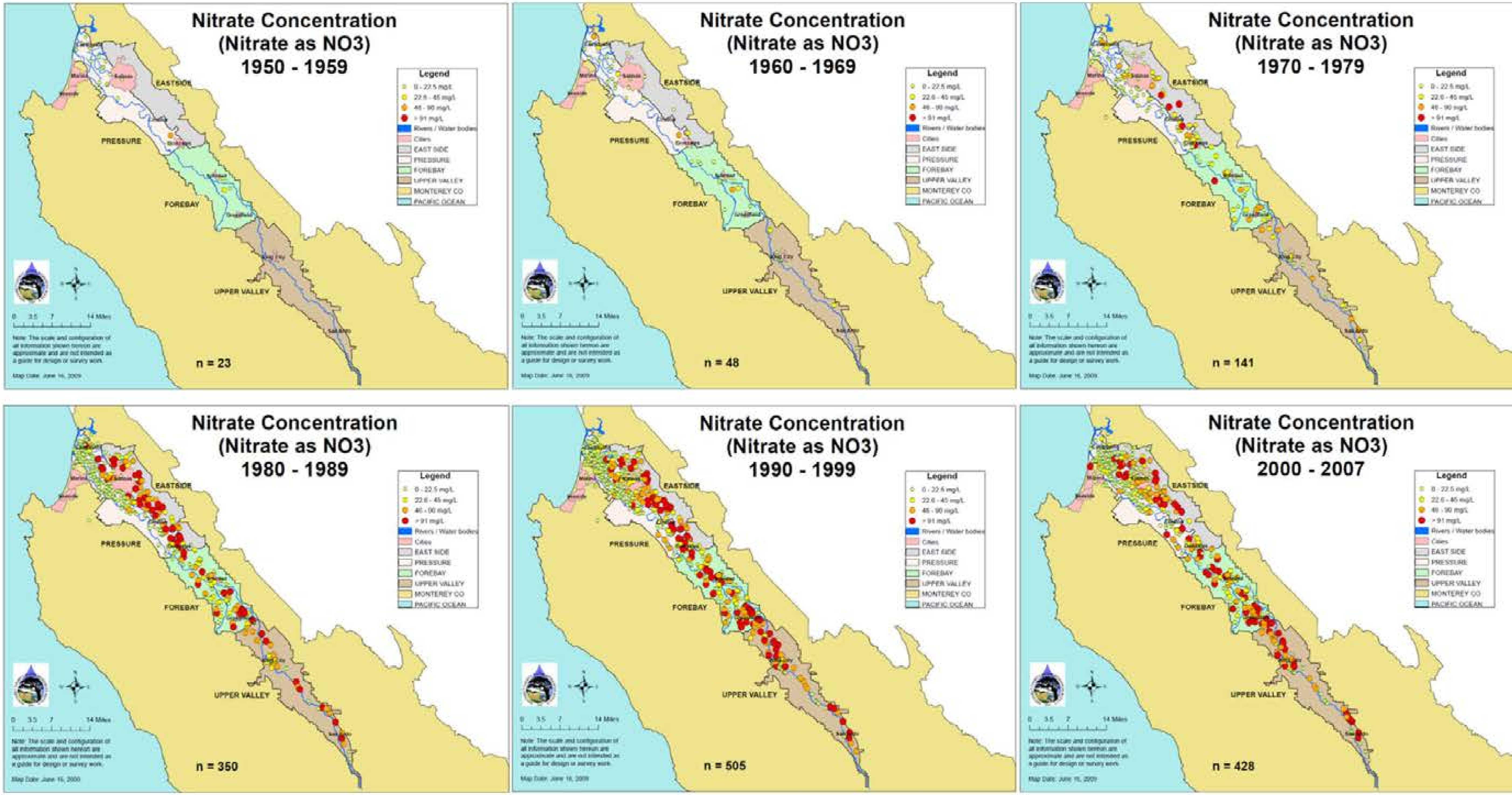


Figure 5-35: Nitrate Concentrations, 1950 to 2007 (from MCWRA)

Additional water quality conditions in the basin are summarized below based on the two USGS water quality studies for the GAMA Priority Basin Project in the Salinas Valley Basin (USGS, 2005; USGS, 2018) as well as data from the GAMA Domestic Well Project.

The 2005 GAMA study in Salinas Valley characterized deeper groundwater resources used for public water supply (USGS, 2005). The 2018 GAMA study characterized shallower groundwater resources used primarily as a water supply for domestic wells (USGS, 2018). For these two studies, a total of 22 wells were sampled in the 180/400-Foot Aquifer Subbasin. Out of the 270 constituents analyzed, one constituent was detected at concentrations above the maximum contaminant level (MCL) and two constituents were detected at concentrations above the secondary maximum contaminant level (SMCL), which are levels set for aesthetic rather than health-based reasons.

- Nitrate was detected in 100% of the 19 samples analyzed for nitrate. Nitrate concentrations above the MCL of 10 mg/L as N occurred in 32% of these samples
- Total dissolved solids were detected at concentrations above the SMCL of 1,000 mg/L in 26% of 19 samples
- Chloride was detected at concentrations above the SMCL of 500 mg/L in 11% of 19 samples

Groundwater samples for the GAMA Domestic Well Project were collected from 10 wells in the 180/400-Foot Aquifer Subbasin on a voluntary basis in 2011. Samples were analyzed for 208 constituents, including volatile organic compounds, pesticides, trace elements, isotopic tracers, and radioactivity. Five constituents were detected at concentrations above the MCL: cadmium, thallium, fluoride, perchlorate, and nitrate. Iron and manganese were detected at concentrations above the SMCL.

- Cadmium was detected in 2 of 10 wells. One sample had concentrations above the MCL of 5 micrograms per liter (μg/L)
- Thallium was detected in 5 of 10 wells. One sample had concentrations above the MCL of 2 μg/L
- Fluoride was detected in 5 of 10 wells. One sample had concentrations above the MCL of 2 mg/L
- Perchlorate was detected in 8 of 10 wells. One sample had concentrations above the MCL of 6 μg/L
- Nitrate was detected in 9 of 10 wells. One sample had concentrations above the MCL of 10 mg/L
- Iron was detected in 7 of the 10 wells. One sample had concentrations above the SMCL of 300 μg/L

- Manganese was detected in 5 out of 10 wells. Two samples had concentrations above the SMCL of 50 (µg/L)

Of these constituents, most were detected at concentrations above regulatory limits in a small percentage of the sampled wells (<10%). Since constituents with low detection frequency do not represent groundwater quality issues throughout the entire Subbasin, these constituents will not be considered further in this report. More information can be found in the original reports (USGS, 2005; USGS, 2018) and at the GeoTracker GAMA online database (http://geotracker.waterboards.ca.gov/gama/gamamap/public/#).

The following constituents have been identified in the California Water Service Company's Salinas District wellfields: nitrate, Methyl tert-butyl ether (MTBE), and hexavalent chromium (Cr(VI)). Six of Cal Water's wells have been placed on inactive status due to water quality issues (Cal Water UWMP, 2016). Wellhead treatment is used to reduce nitrate and Cr(VI) concentrations to levels that meet applicable standards. Cal Water is currently in compliance with the USEPA standard for arsenic (10 ppb) but may be impacted if the standard is lowered to 5 ppb (Cal Water UWMP, 2016).

5.6.3 Groundwater Quality Summary

Based on the water quality information presented in the previous sections, the following constituents will be considered for inclusion in the GSP monitoring program:

- 1,2,3-trichloropropane,
- arsenic,
- cadmium
- chloride
- fluoride
- hexavalent chromium,
- iron
- manganese
- methyl tert-butyl ether
- nitrate
- perchlorate
- TDS
- thallium

The monitoring system is further defined in Chapter 7. The constituents listed above are the constituents of concern for all aquifers in the 180/400-Foot Aquifer Subbasin.

5.7 References

Brown and Caldwell, 2015. State of the Salinas River Groundwater Basin. Prepared for the Monterey County Water Resource Management Agency.

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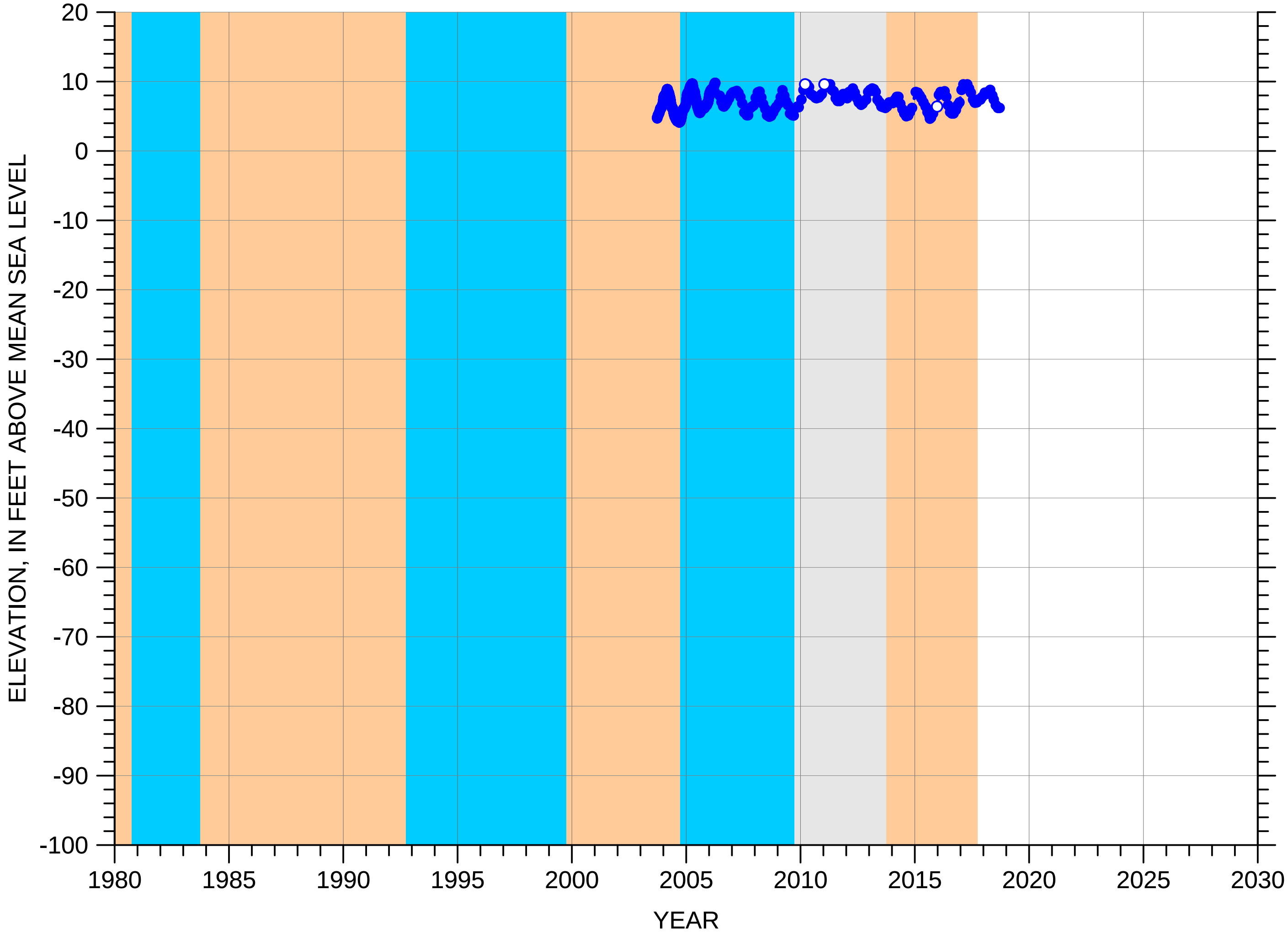
APPENDIX 5A
HYDROGRAPHS

HYDROGRAPH OF MEASURED GROUNDWATER ELEVATION FOR 13S/02E-21Q01



EXPLANATION

GROUNDWATER ELEVATION   ESTIMATED ELEVATION

CLIMATE PERIOD CLASSIFICATION

DRY   AVERAGE/ALTERNATING   WET

Subbasin: 180/400-Foot Aquifer Subbasin (180-Foot Aquifer)
Well Depth: 157.4 feet
Screened Interval: 105-155 feet below land surface

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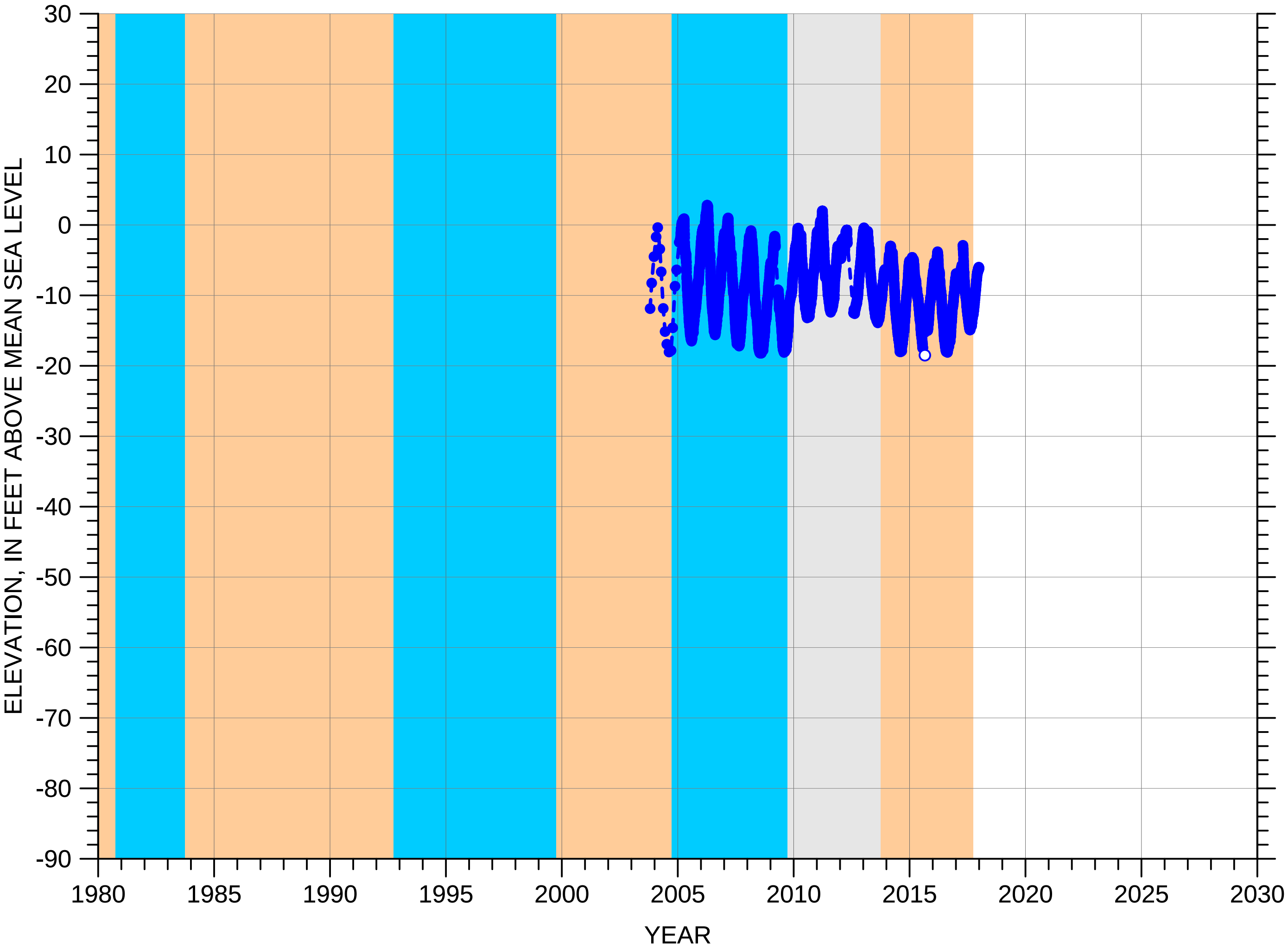
HYDROGRAPH OF MEASURED GROUNDWATER ELEVATION FOR 14S/02E-03F04



EXPLANATION

GROUNDWATER ELEVATION   ESTIMATED ELEVATION

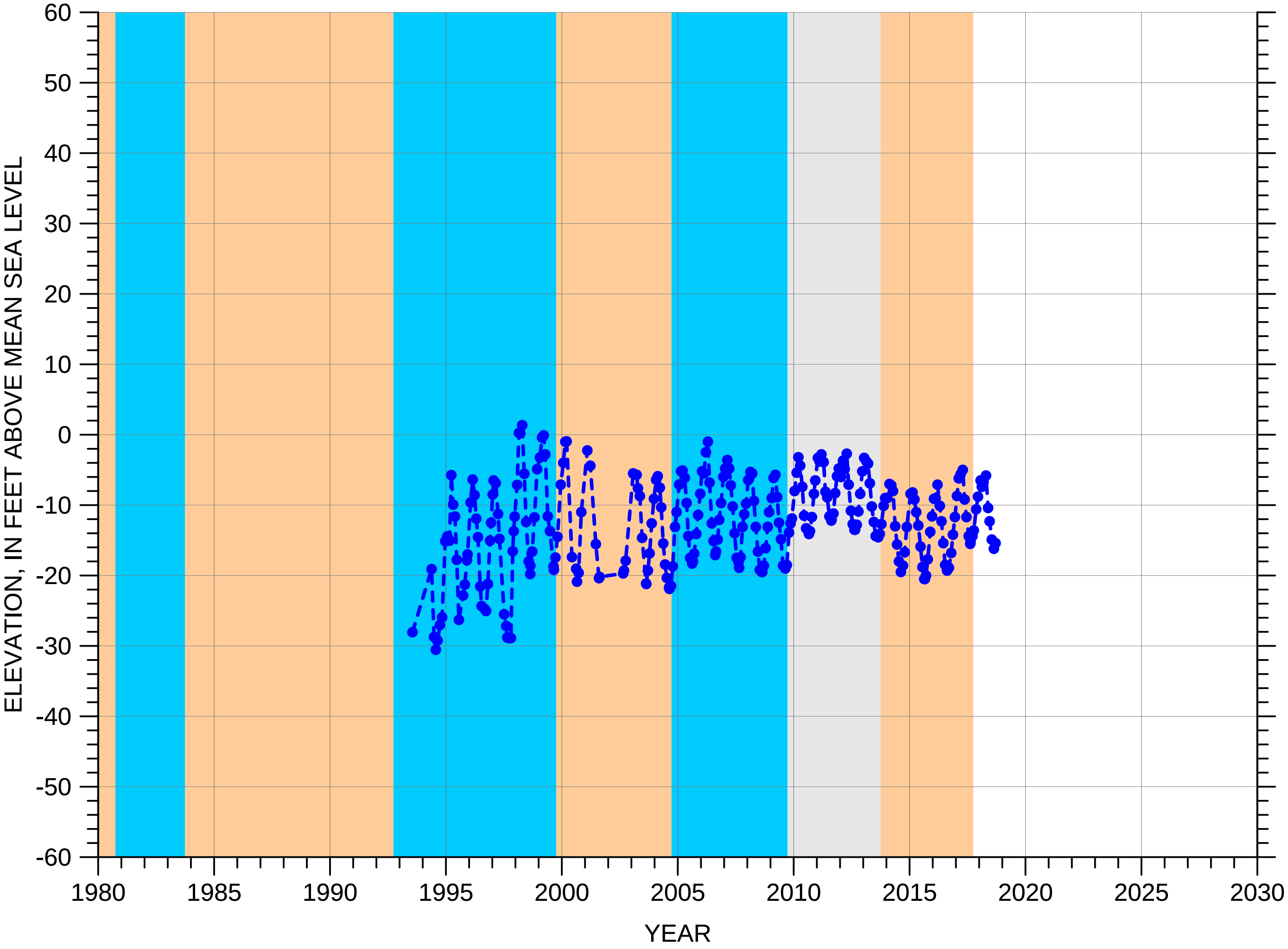
CLIMATE PERIOD CLASSIFICATION

DRY   AVERAGE/ALTERNATING   WET

Subbasin: 180/400-Foot Aquifer Subbasin (180-Foot Aquifer)
Well Depth: 205 feet
Screened Interval: 154-204 feet below land surface

S:\projects\9100_Salinas_GSP\analysis\water_levels\Hydrographs_MCWRA\SalinasDroughtIndex\grf_noConstruction\14S_02E-03F04.grf

HYDROGRAPH OF MEASURED GROUNDWATER ELEVATION FOR 14S/02E-11A02



EXPLANATION

GROUNDWATER ELEVATION ESTIMATED ELEVATION

CLIMATE PERIOD CLASSIFICATION

DRY AVERAGE/ALTERNATING WET

Subbasin: 180/400-Foot Aquifer Subbasin (180-Foot Aquifer)
Well Depth: 250 feet
Screened Interval: 190-240 feet below land surface

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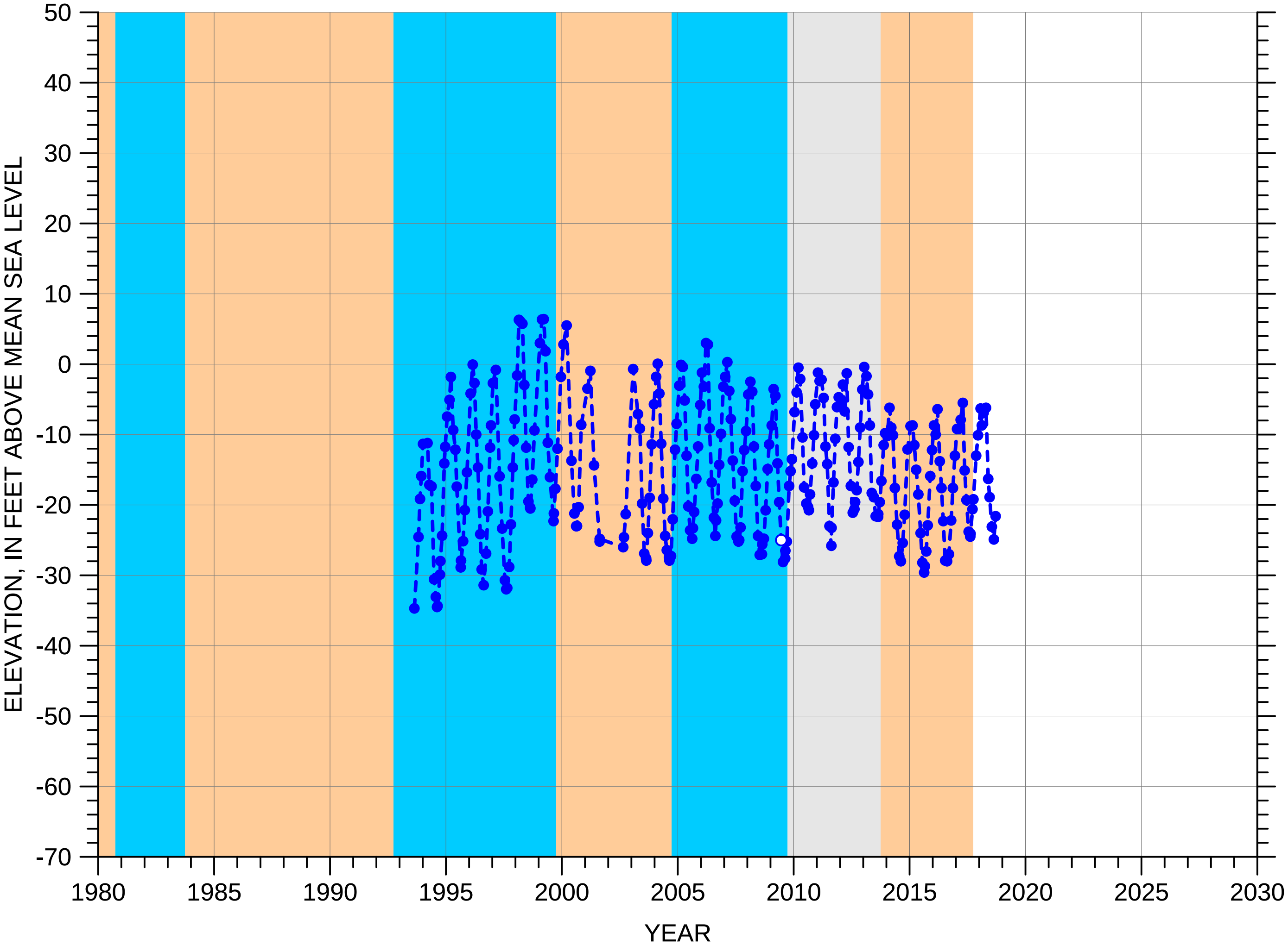
HYDROGRAPH OF MEASURED GROUNDWATER ELEVATION FOR 14S/02E-13F03



EXPLANATION

GROUNDWATER ELEVATION   ESTIMATED ELEVATION

CLIMATE PERIOD CLASSIFICATION

DRY   AVERAGE/ALTERNATING   WET

Subbasin: 180/400-Foot Aquifer Subbasin (180-Foot Aquifer)
Well Depth: 280 feet
Screened Interval: 230-270 feet below land surface

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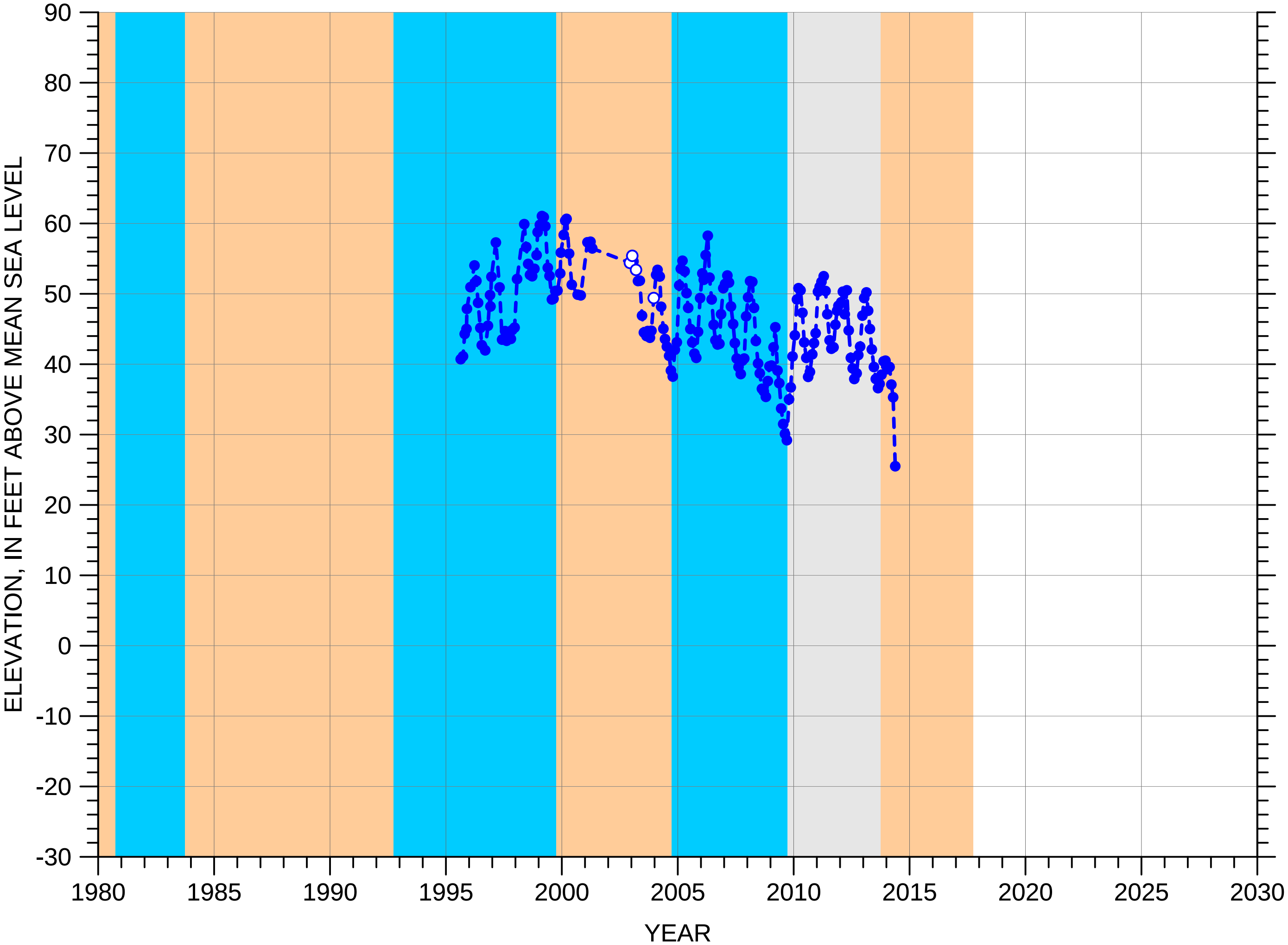
HYDROGRAPH OF MEASURED GROUNDWATER ELEVATION FOR 16S/04E-08H01



EXPLANATION

GROUNDWATER ELEVATION   ESTIMATED ELEVATION

CLIMATE PERIOD CLASSIFICATION

DRY   AVERAGE/ALTERNATING   WET

Subbasin: 180/400-Foot Aquifer Subbasin (180-Foot Aquifer)
Well Depth: 130 feet
Screened Interval: 75-125 feet below land surface

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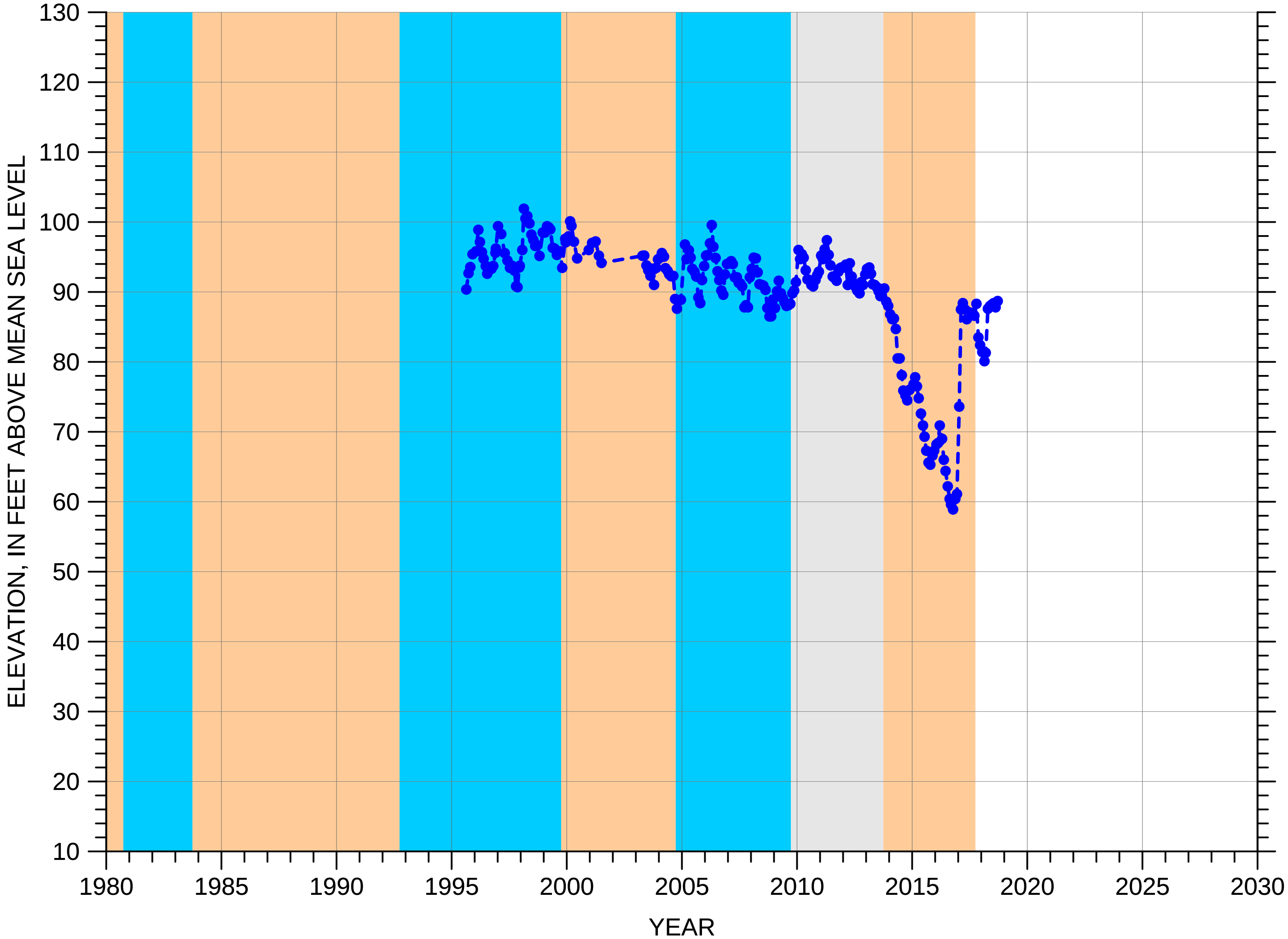
HYDROGRAPH OF MEASURED GROUNDWATER ELEVATION FOR 16S/05E-31P02



EXPLANATION

GROUNDWATER ELEVATION   ESTIMATED ELEVATION

CLIMATE PERIOD CLASSIFICATION

DRY   AVERAGE/ALTERNATING   WET

Subbasin: 180/400-Foot Aquifer Subbasin
Well Depth: 115 feet
Screened Interval: 60-110 feet below land surface

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