5. Groundwater Conditions

This section provides a description of historical and current groundwater conditions in the Subbasin. The North American Subbasin (NASb or Subbasin) can be divided into three areas (Eastern, Central, and Western) from a water resources standpoint based on the differences in groundwater conditions. Groundwater conditions between areas vary for several reasons, the primary reason being the extent to which surface water is accessible as a source in a given area. In order to understand how and why conditions vary, it is helpful to consider the historical development of water resources in the basin.

5.1 General

Current groundwater conditions are the result of both historical and current availability of surface water. Historically, where surface water was not available groundwater was used for agricultural, industrial, and urban growth.

In the Eastern and Western areas of the Subbasin, surface water has been available and delivered for agricultural and urban development. Today, both the Eastern and Western areas of the Subbasin continue to be served primarily with surface water, with some urban areas (city of Sacramento) in the Western area being served both groundwater and surface water. As a result of surface water availability, groundwater levels in the Eastern and Western areas of the Subbasin have remained relatively stable.

In the Central area of the Subbasin, a groundwater pumping depression (a lowering of groundwater levels as a result of pumping) developed by the mid-1960s. This was largely due to widespread agricultural and urban development and the lack of available surface water to this part of the basin. The pumping depression started in Sutter County, moving to the east and south.

Agricultural development in the 1950s relied exclusively on groundwater to meet crop demands and resulted in groundwater level declines through 1960. As a result of these declining water levels SSWD constructed Camp Far West Reservoir in 1964 and began supplying a portion of the crop demands with surface water. This action reversed the overall decline in water levels.

Demand on groundwater in the Central area also increased markedly around the 1950s as military and industrial facilities, such as McClellan AFB, were established accompanied by rapid suburban development. Groundwater wells provided water for the industrial and urban development. Falling groundwater levels moved the Sacramento County Board of Supervisors to take management actions and initiated the Water Forum Agreement and Sacramento Groundwater Authority (SGA).

Since the mid-1990s, water suppliers in the northern Sacramento County portion of the Central area implemented conjunctive use projects, thereby reversing the decline of groundwater levels, but the pumping depression still remains in the Central area of the Subbasin and extends into Placer and Sutter counties.

5.2 Groundwater Levels

Groundwater levels are used to track the use and recharge of groundwater in the Subbasin to avoid long-term lowering of groundwater levels. Historically, when downward trending groundwater levels have been observed in the Subbasin, management actions have been taken.

Groundwater levels are recorded at more than 160 wells in the Subbasin and reported to the CASGEM system. Groundwater levels were historically measured twice per year (Spring and Fall), but the frequency of the measurement in some wells has been increased to monthly or more frequently where wells have been instrumented with continuous recorders (transducers). Wells that were only measured a few times or where measurements were discontinued many years ago were not evaluated to establish groundwater conditions.

Figure 5-1 shows the location of 91 wells in the Subbasin evaluated to illustrate the groundwater conditions for this GSP. All of these wells have long-term records or are dedicated monitoring wells with shorter-term records. The dedicated monitoring wells with shorter-term records are used in place of CASGEM "voluntary wells" (privately owned domestic or agricultural wells) where groundwater levels may be affected by pumping at the well or construction details are not available. Due to the number of wells and the long CASGEM identification numbers, each well was provided with a unique number (**Figure 5-1**). A table correlating the unique numbers to CASGEM identification numbers is provided in **Appendix G** with well construction details and the DWR-defined aquifer being monitored. For those wells with known construction details there is a high degree of certainty that the groundwater levels are representative of the principal aquifer, other than for two wells that monitored perched water levels (water that has percolated from ground surface, but has yet to reach the principal aquifer). Where the well construction details (mostly voluntary wells) are unknown there is less certainty, but the hydrographs are provided to provide a long-term condition of the groundwater levels. **Appendices G through I** contain time-series groundwater level measurements (hydrographs) for wells in the Western, Central, and Eastern areas. All of the hydrographs, have consistent date ranges (1950 to present or 2004 to present) and vertical scales were attempted to be maintained at a consistent range unless otherwise noted.

All sediments, to some extent, contain groundwater in the pores between particles. Near ground surface sediment pores are filled with mostly air but have some moisture. This moisture will gradually migrate down to the groundwater surface where the sediment pores will be entirely filled with water. At times there are low permeability sediment layers with a limited horizontal extent, where the moisture accumulates and fully fills the sediment pores, but the underlying sediments and pores are not filled with water. These occurrences are called perched water and do not constitute a principal aquifer. Evidence to support that the groundwater levels in these areas is perched are that the groundwater levels are higher than in underlying aquifers (principal aquifers) and that the groundwater levels in the principal aquifers never rise to the levels of the perched water, showing they are disconnected.

The following sections include a description of the depth to groundwater and trends by area. **Figure 5-2** shows the depth to groundwater in the Subbasin. **Figure 5-3** shows representative time series graphs of groundwater levels (hydrographs) to show general trends in groundwater levels for each of the areas. **Appendices G through I** contain time-series groundwater level measurements (hydrographs) for wells by the Western, Central, and Eastern areas.

5.2.1 Western Area

The Western area of the Subbasin is bounded by the Feather and Sacramento rivers on the west and approximately by the Sutter/Placer County Line and Natomas East Main Drainage Canal on the east (**Figure 5-1)**. The Western area has surface water deliveries, but groundwater is used to supplement the surface water supplies. In general, groundwater levels in this area are stable and have historically been near the surface.

Groundwater levels in the Western area in shallow wells typically range from near ground surface to 20 feet below ground surface (bgs) (**Figure 5-2**). The shallow groundwater levels are due to the area being at the topographic bottom of the Subbasin and potentially from the adjacent rivers. Groundwater levels in deep wells in this area have slightly deeper groundwater levels, ranging from about 15 to 40 feet bgs.

Figure 5-3 shows the trends in groundwater levels in some wells in the Subbasin to illustrate the differences in groundwater levels and general trends in different portions of the Subbasin. The wells typically experience seasonal fluctuations. During the most recent drought, 2012 through 2016, groundwater was relied upon more heavily and the groundwater levels declined in response to increased pumping, but then recovered to pre-drought levels as of 2019, although a few wells have not fully recovered. **Appendix G** provides hydrographs for wells in this area.

Perched groundwater has not been documented in this area.

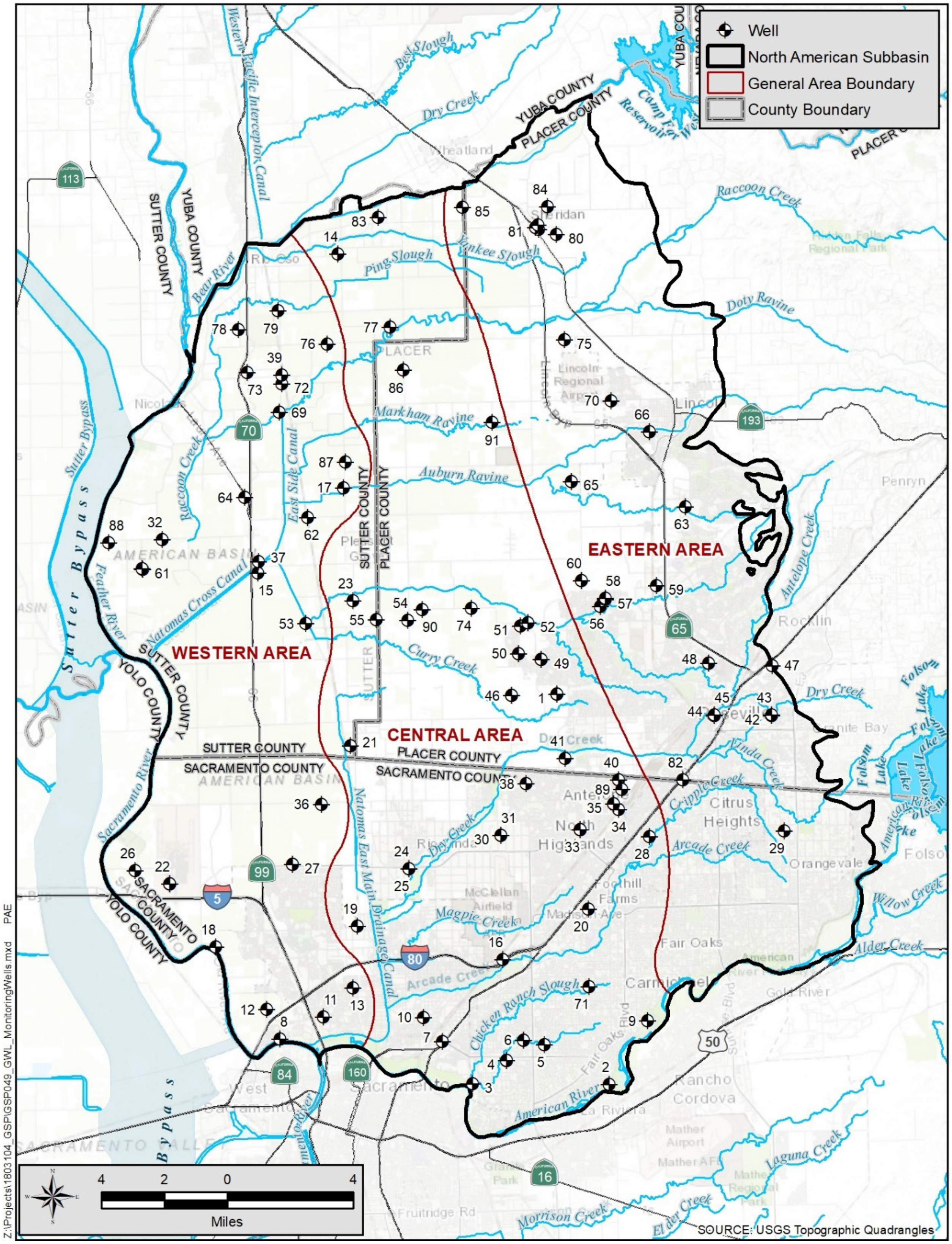

Figure 5-1. Groundwater Level Monitoring Wells

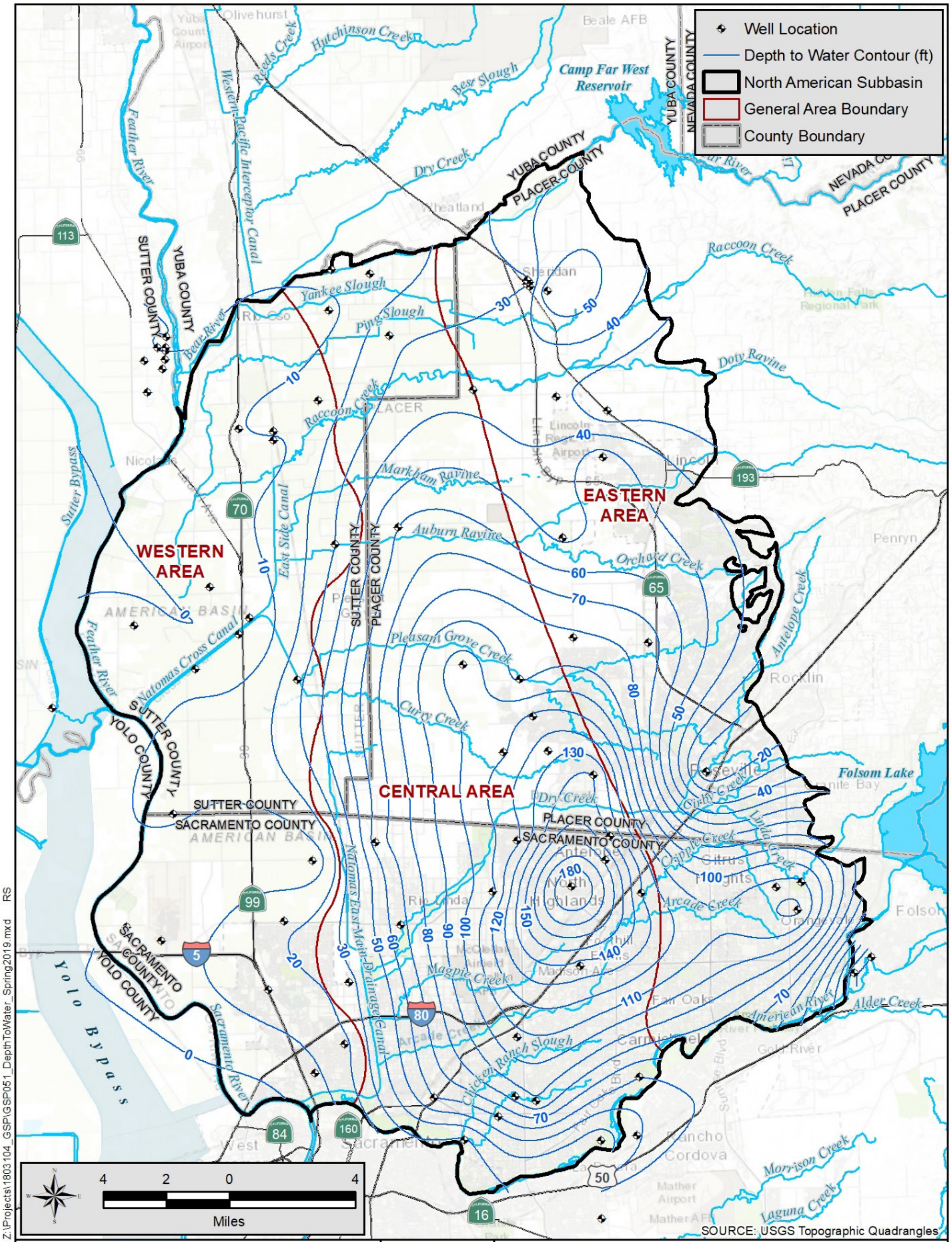

Figure 5-2. Depth to Groundwater – Spring 2019

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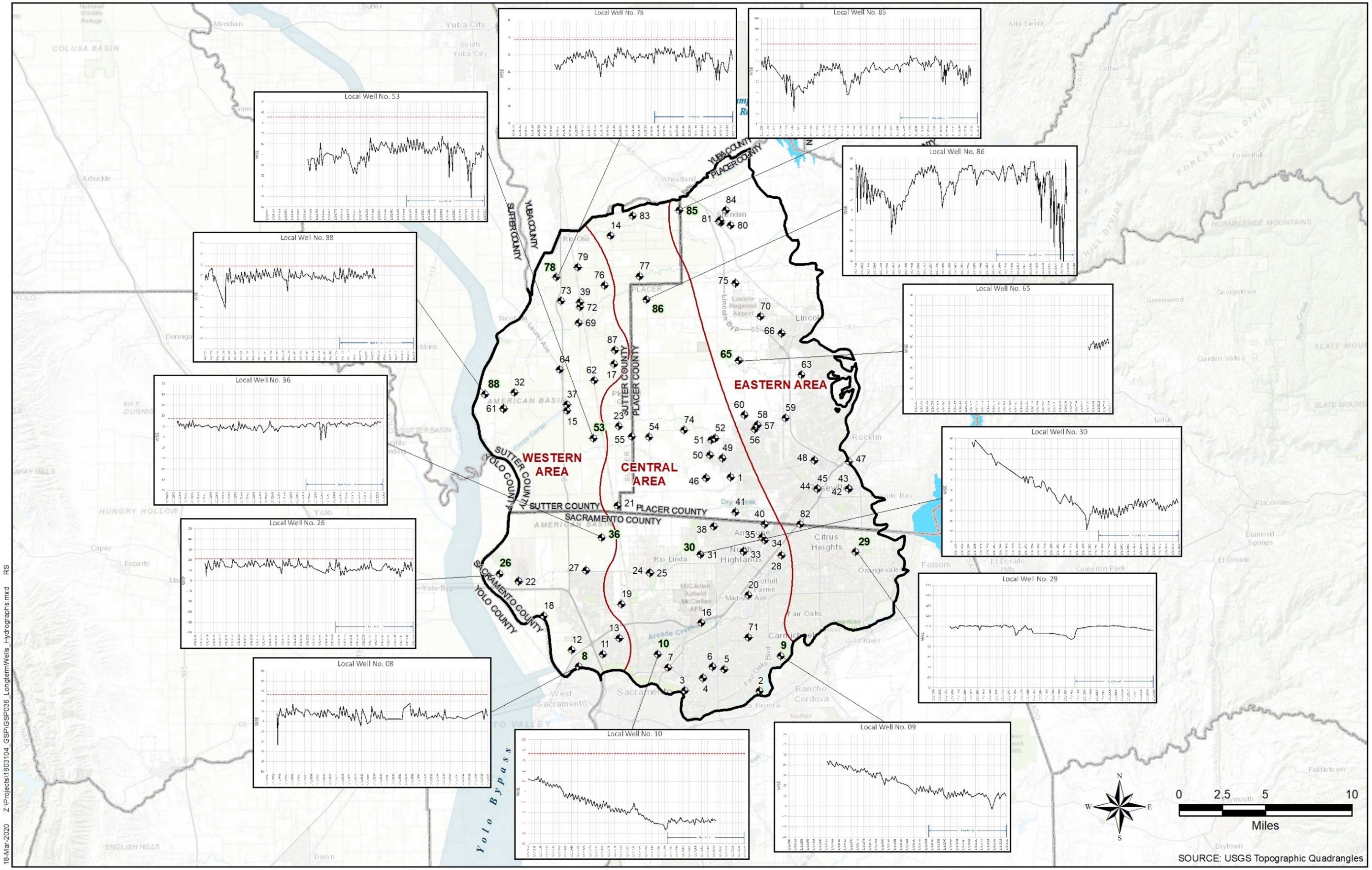

Figure 5-3. Representative Groundwater Level Hydrographs

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5.2.2 Central Area

The Central area of the Subbasin is bounded generally on the west by the Sutter/Placer County Line and the Natomas East Main Drainage Canal and extends east to about Citrus Heights and the city of Lincoln (*refer to* **Figure 5-1**). **Appendix H** provides hydrographs for the Central area. This area historically relied predominantly on groundwater. Groundwater levels in this area have shown a wide range of fluctuations but since the mid-1990s are relatively stable and sometimes rising. Currently the groundwater levels are between 0 and 15 feet bgs near the American and Bear rivers with as much as 150 feet bgs within the Sacramento County portion of the area (*refer to* **Figure 5-2**).

Two groundwater level trend patterns are present in the northern (Placer and Sutter counties) and southern (Sacramento County) portions of the Central area (*refer to* **Figure 5-3**).

In the Placer and Sutter counties portion of the Central area, groundwater levels declined by about 30 to 40 feet between the early 1950s and 1960s, until Camp Far West Reservoir was completed in 1964 (MBK, 2016). Groundwater levels rose in response to decreased groundwater use but still vary in response to climatic conditions when surface water availability decreases and groundwater pumping increases. Seasonal fluctuations in this portion of the Central area are greater than those seen in Sacramento County. Groundwater levels declined noticeably during the 2012 to 2016 drought, but began to recover following the end of that drought. However, they have not generally fully recovered to pre-drought levels.

In the Sacramento County portion of the Central area, groundwater levels declined at a rate of nearly 1.5 feet per year from around the 1950s through the mid-1990s, with groundwater levels being lowered by up to 60 feet. Groundwater levels stabilized in the mid-1990s due, in substantial part, to expanded conjunctive-use operations, making surface water available to this area. Groundwater levels have continued to rise overall since that time, with slight declines from 2007 through 2009 when dry conditions were experienced throughout California. During the most recent drought conditions of 2012 to 2016 groundwater levels declined slightly, but recovered following the end of that drought as of 2019, except for a few wells.

Perched water can be present in the Central area. Perched water was observed during the construction of a nested monitoring well (*refer to* **Figure 5-**1, monitoring well number 91) at a depth of 4 feet bgs, while the depth-to-water in monitoring well 91 was 70 feet bgs. Several contamination site investigations within the Roseville area also show perched groundwater levels.

5.2.3 Eastern Area

The Eastern area extends roughly from Citrus Heights and the City of Lincoln east to the edge of the Subbasin. There are only a few wells in the Eastern area with long-term historic measurements because this area primarily utilizes surface water. **Appendix I** provides hydrographs for the Eastern area. With urbanization of the area and development of groundwater management organizations, over 40 monitoring wells have been constructed since 2003.

The depth to groundwater in the Eastern area ranges from about 5 to 70 feet bgs and groundwater levels are generally stable (*refer to* **Figures 5-2 and 5-3**). Shallower groundwater levels are typically seen in monitoring wells near the foothills and near streams or where perched water is present. Long-term groundwater level trends are limited in this area, with most monitoring wells in this area being constructed in about 2003. **Appendix I** provides hydrographs for these shorter-term groundwater levels and show that for the most part groundwater levels are rising in this area, but a few did not recover completely since the 2012 to 2016 drought as of 2019.

A small pumping depression is present near the City of Lincoln and varies in depth seasonally by about 5- to 10-feet and based on the water year type. The depression was first identified in 2012, but may have been present in earlier years. Monitoring wells 65, 66, 70 and 75 provide the hydrographs for this area. Groundwater levels in these wells rose between 2003 and 2011. At well 65, groundwater levels recovered and are currently at or about 2 feet higher than in 2011. Groundwater levels in wells 66, 70 and 75 are still about 3 feet lower than pre-drought conditions as of 2019.

Perched groundwater is present locally in the Eastern area. Perched water has been found in MW 1-4 (monitoring well number 65) located near Auburn Ravine and at multiple locations within the city of Roseville, generally in the area north and south of Dry Creek (GEI, 2018). Perched water may also be present in the area north of Lincoln and east of old Highway 65 on top of the Ione Formation (GEI, 2019).

5.3 Historic Groundwater Contours

Groundwater contours reflect the historical groundwater use in the Subbasin. In general, groundwater conditions from the early 1900s through the 1950s essentially remained unchanged because there was little groundwater use. From the 1950s through the 1990s, pumping created a depression. After 1990 the groundwater levels stabilized or rebounded. Snapshots of the changes in groundwater contours during these periods are provided in **Figures 5-4 and 5-5**.

Contours representing little to no use of groundwater in the Subbasin were developed for the early 1900s (Bryan, 1923), as shown on **Figure 5-4**. The contours show groundwater entering the Subbasin from the east moving toward the west. The Eastern area of the Subbasin has depths to groundwater greater than 50 feet bgs, while the Western area has groundwater levels of about 15 feet bgs, similar to current conditions.

Groundwater contours did not change until about 1960 when a small depression, due to pumping, began to form near the junction of the Sutter/Placer/Sacramento County lines and extended up to Pleasant Grove (DWR, 1997). By 1970, the pumping depression was established as shown on **Figure 5-5** (MWH, 2005). Gradually over the years the depth of the central pumping depression became deeper and shifted to the east and south, extending from Placer County to almost the American River. By 1995, the pumping depression reached its maximum depth, to more than 40 feet below mean sea level, as shown on **Figure 5-5**. Between 1995 and 2004, groundwater elevations stabilized, as shown on **Figure 5-5**. From 2004 to 2019, significant recoveries of groundwater elevations have been observed within the main pumping depression in Sacramento County. As shown on **Figure 5-**6, groundwater elevations in the main depression have recovered from 10 to 20 feet. This stabilization and subsequent improvement is primarily due to groundwater management activities stemming from the Sacramento Suburban Water District's in-lieu groundwater recharge program in combination with regional water efficiency measures decreasing overall public water supply demand.

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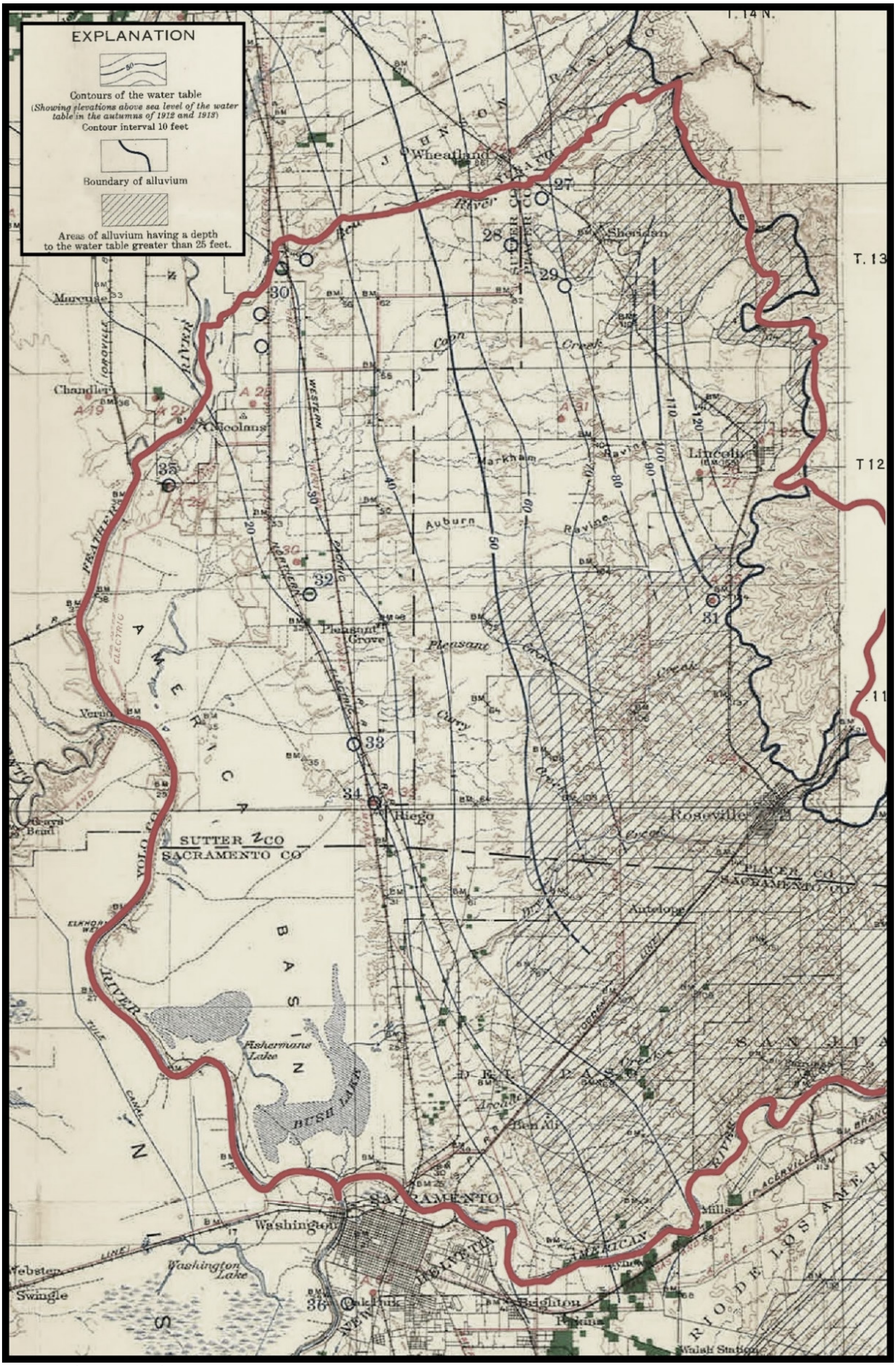

Figure 5-4. Groundwater Contours – Early 1900s

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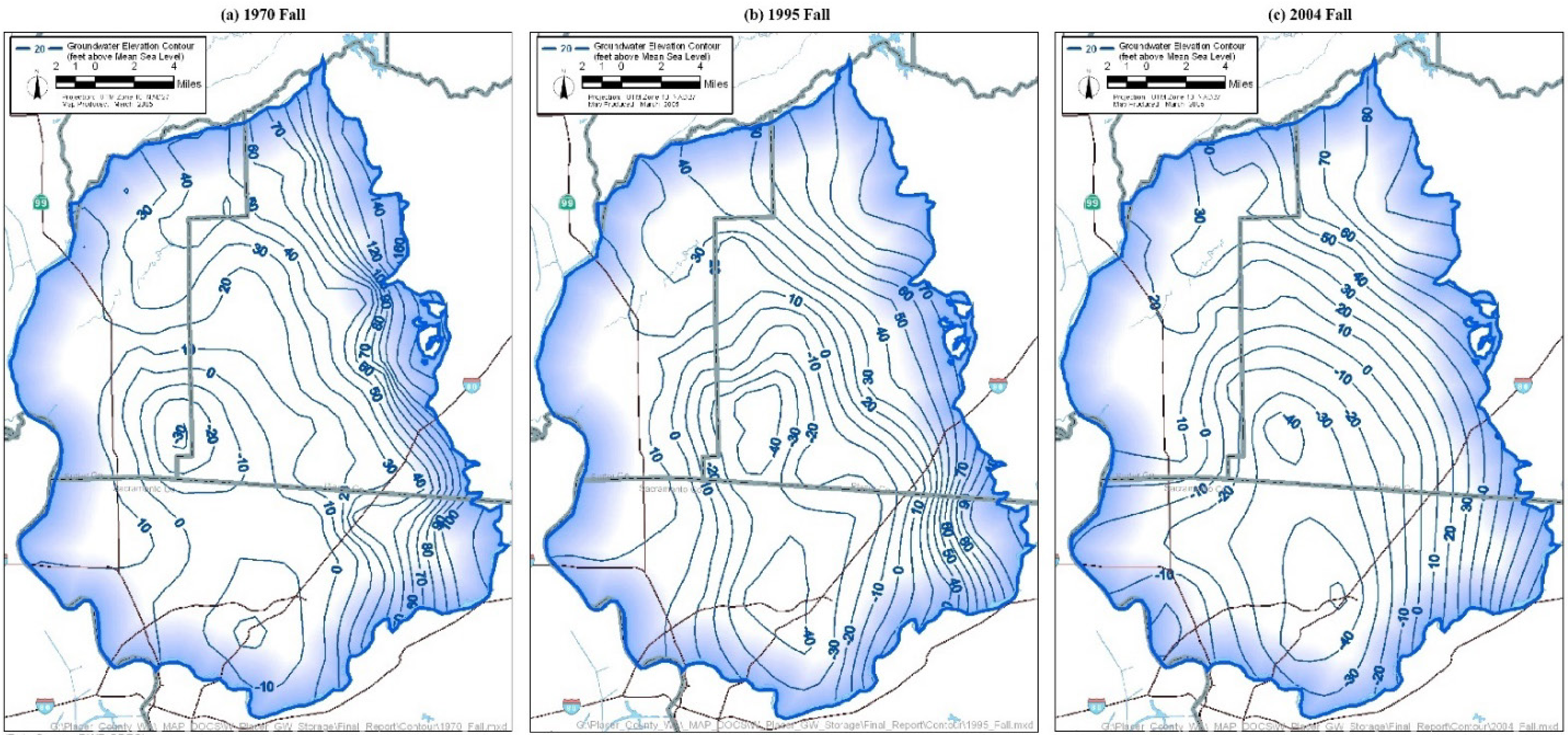

(Data Source: DWR CDEC)

Figure 5-5. Groundwater Contours – 1970 through 2004

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5.4 Current Groundwater Contours

Current groundwater surface elevation contours were developed to show the seasonal high and low water levels, groundwater flow directions, and regional pumping effects. These contours were based on Spring and Fall of 2019 groundwater levels using shallow wells (less than 300 feet total depth) as shown on **Figures 5-6 and 5-7,** respectively**.**

The current groundwater contours show a pumping depression in the center of the Subbasin that is about 20 feet below mean sea level. Groundwater flows radially toward this depression, from the fringes of the Subbasin toward the center. The depression extends from the American River but stops before reaching the Bear and Feather rivers. The depression extends westward toward the Sacramento River. This depression was created when groundwater pumping exceeded the natural recharge. The depression has been stabilized, with groundwater levels remaining similar or rising, by reducing pumping so that it is equal to or less than recharge. When a long-term pumping depression such as this one is created, sediments that previously contained groundwater are dewatered and there is groundwater-in-storage depletion. This condition is beneficial for management of the Subbasin by allowing for conjunctive use.

In the northern portions of the NASb, near the Bear River, the groundwater flow direction is perpendicular to the river, the contours do not show that the aquifer is receiving significant recharge from the river, and there is little inflow from the South Yuba Subbasin. Near the Feather and Sacramento rivers, the groundwater flow direction is parallel to the rivers, suggesting there is recharge from the rivers and potentially subsurface inflow from adjacent subbasins (Yolo and Sutter). Slight changes in the contours along the eastern side of the basin suggest recharge is occurring along the upper reaches of Dry Creek, Auburn Ravine, and Racoon Creek. The groundwater contours concur with the assessment of groundwater recharge and discharge areas discussed presented in **Section 4.12 – Groundwater Recharge and Discharge Areas**. The contours, along with the depths-to-water, provide an indication of areas where groundwater and surface water may be interconnected.

The groundwater gradients near the pumping depression are similar except from the east where they are steeper, potentially due to groundwater recharge effects. **Table 5-1** provides the gradients for Fall 2019.

Table 5-1. Groundwater Gradients Toward the Central Area

Groundwater Gradients (ft/ft)			
West	East	North	South
0.001	0.06	0.001	0.002

The current seasonal changes in groundwater levels were assessed for Spring and Fall of 2019, a wet water year. Changes in groundwater levels in the upper aquifer vary across the Subbasin. In the upper aquifer the seasonal changes from Spring to Fall range from about +2 to -14 feet.

These seasonal changes do not account for pumping levels at individual wells and may be greater in exceptionally dry years when reliance on groundwater is greater due to the reduction of surface water supplies.

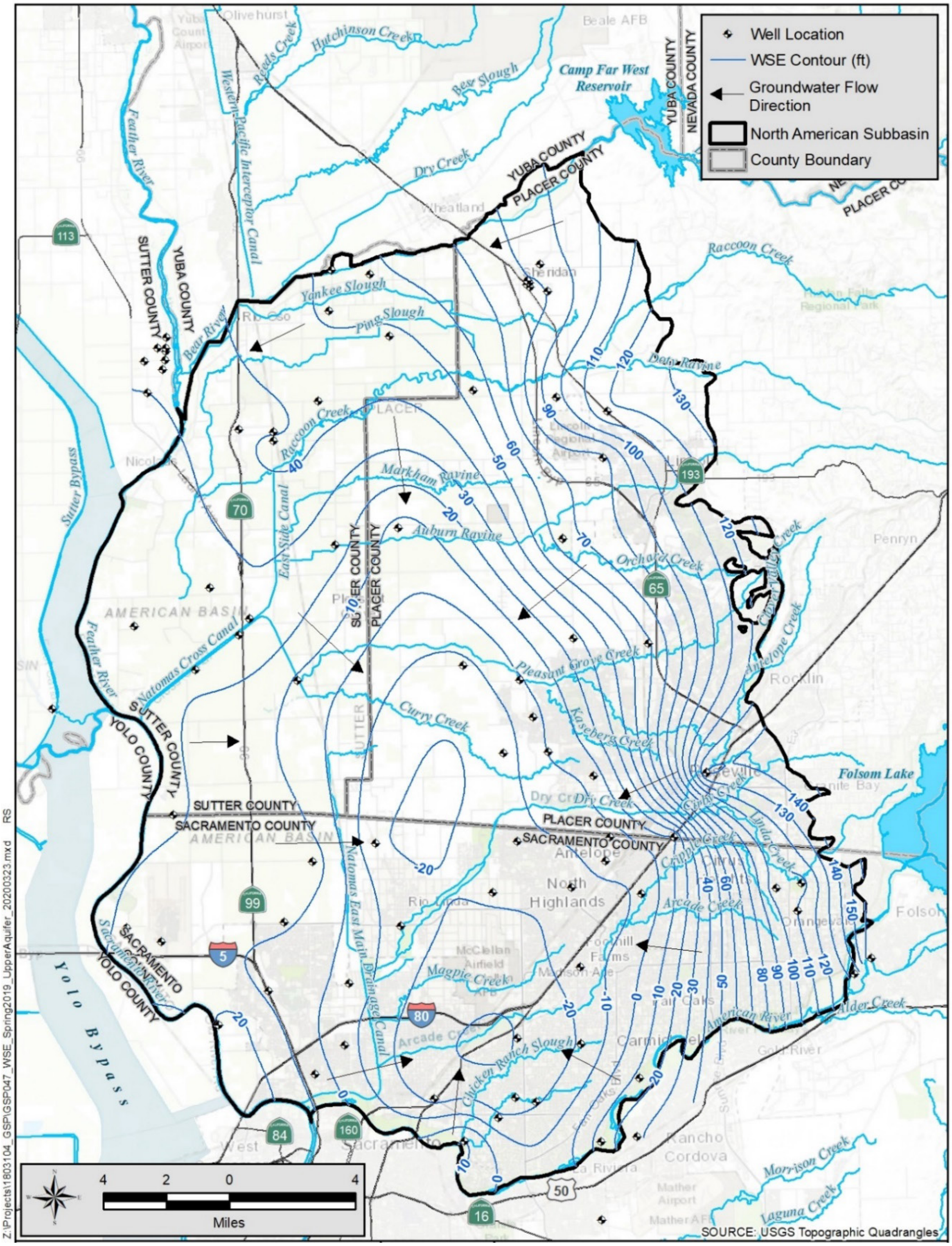


Figure 5-6. Groundwater Contours – Spring 2019

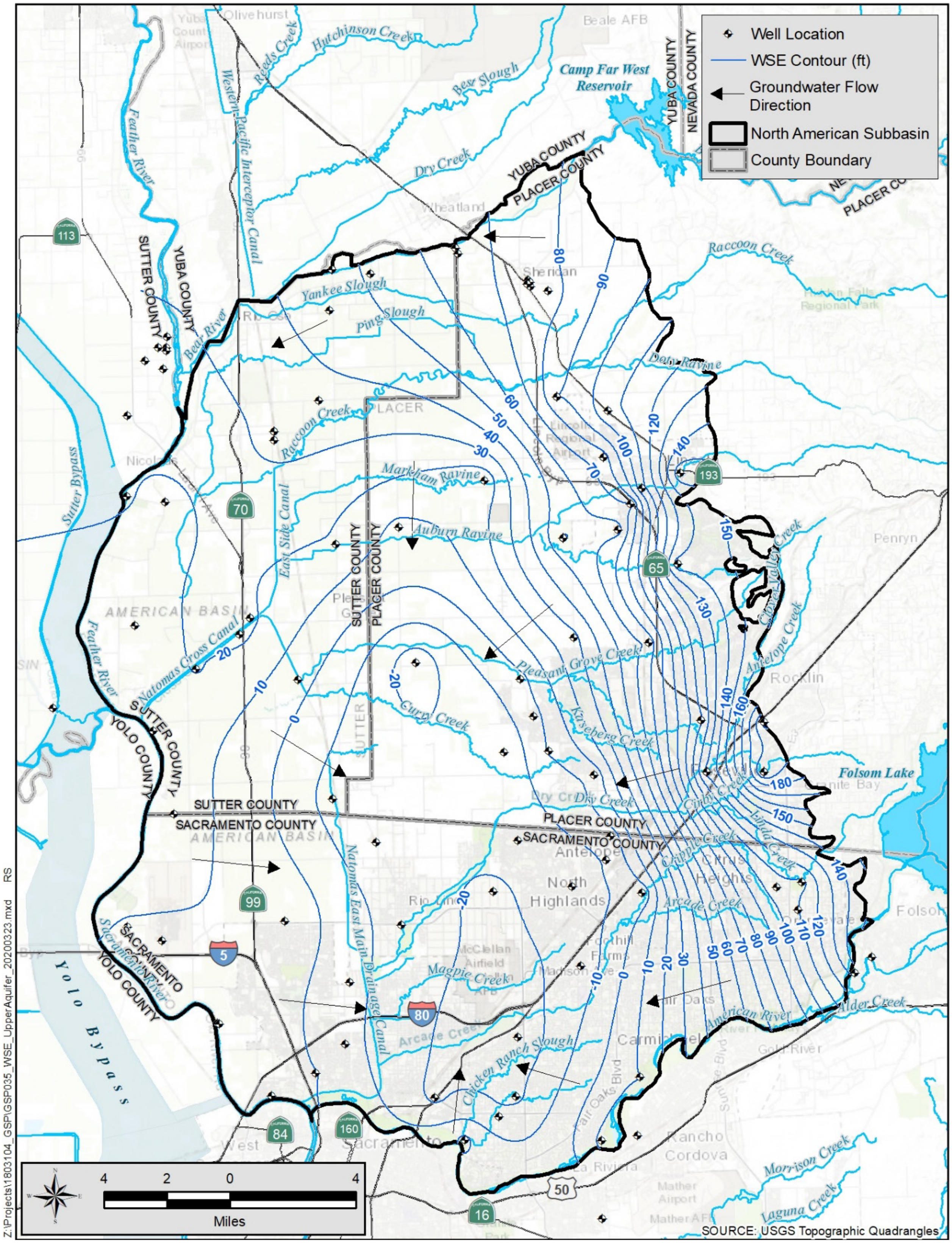


Figure 5-7. Groundwater Contours – Fall 2019

5.5 Hydraulic Gradients Between Aquifers

Since the mid-1970s dedicated monitoring wells have been constructed to monitor discrete intervals within the aquifer. When multiple monitoring wells are constructed in the same hole they are referred to as nested wells. Monitoring wells that are closely located but monitor different discrete intervals are called clustered wells. Nested and clustered monitoring wells were used to evaluate vertical groundwater gradients at varying depths of the aquifers, as sorted by the formation in which the aquifer occurs. There are 31 nested and clustered monitoring well locations in the Subbasin with up to five multiple-completion monitoring wells at each location (**Figure 5-8**). **Appendix J** contains the hydrographs for each set of nested or clustered wells. In some cases, the nested or clustered wells are all in the same aquifer or a monitoring well has been constructed below the base of fresh water into the marine formations (monitoring well number 39), potentially the Central Valley Formation.

Generally, the aquifer in the Tulare Lake and Laguna formations has been found to exhibit unconfined aquifer characteristics. Confinement has been found to increase with depth and to the west in the deeper portions of the aquifer (DWR, 1997). The deeper portions of the aquifer (Mehrten Formation) typically exhibit delayed responses to pumping and recharge effects imposed in the shallower portions of the aquifer, confirming hydraulic interconnection.

Figure 5-8 provides a graphic representation of vertical groundwater gradients (heads) between the shallower and deeper portions of the aquifer (in Fall 2019), just after high groundwater use in the summer months, when the difference in groundwater levels should be the greatest:

- In the Western area, the vertical gradients are all downward and the greatest groundwater level differences in the Subbasin, downward by 23 feet, occurs at AB-4. The head differences are less near the rivers and greater toward the east. The head differences in this area are likely due to the deeper portion of the aquifer being more confined allowing for greater differences in groundwater levels.
- In the Central area, the vertical gradients are not consistent and have both upward and downward heads, ranging from about +7 to -7 feet. This suggests unconfined to semi-confined conditions with increasing depth in the aquifer may be present.
- In the Eastern area, the groundwater head differences are small suggesting unconfined conditions.

Although there are head differences, hydrographs show that groundwater levels in the different depths of the aquifer have similar trends, indicating the interconnectedness and a similar recharge area.

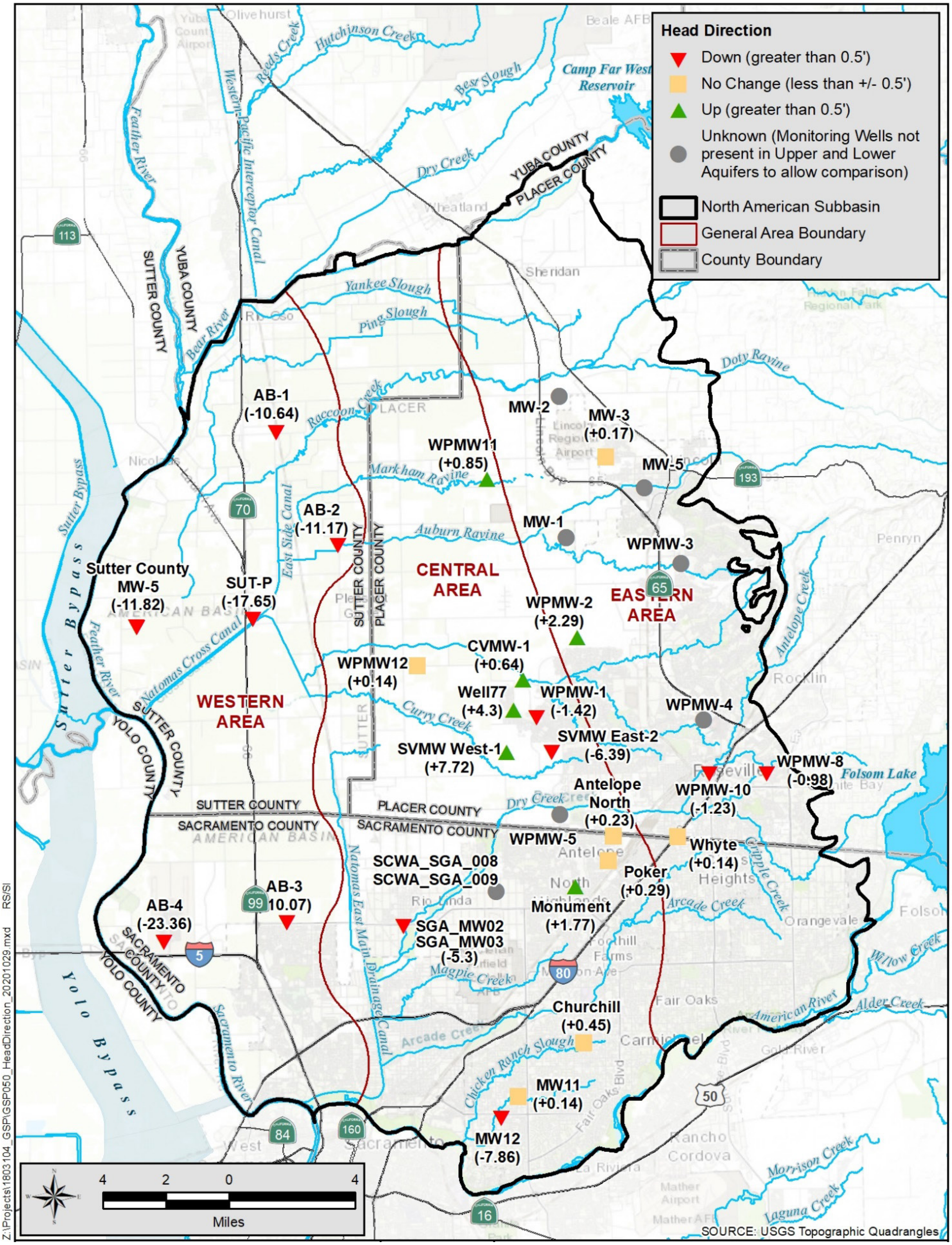


Figure 5-8. Vertical Gradients Upper to Lower Portions of the Aquifer – Fall 2019

5.6 Hydraulic Gradients Between Fresh and Non-Fresh Water Formations

Three of the deeper nested monitoring wells (monitoring wells 48, 63, 66, or wells MW5-2, WPMW-3B, and WPMW-4B) were constructed into the Ione Formation in the Eastern area of the Subbasin. These wells consistently have higher heads in the marine Ione Formation than in the other aquifers, indicating an upward head and suggesting the groundwater in the Ione Formation could discharge to the fresh-water aquifers. **Appendix K** provides these hydrographs which show the head differences are up to 50 feet upward at monitoring well 48.

One monitoring well (monitoring well 39 or AB-1 deep) was constructed below the base of fresh water, potentially into the Valley Springs or Central Valley Formation, in the Western area of the Subbasin. Groundwater levels (piezometric) in the formation in comparison to the fresh-water aquifers change seasonally, apparently due to pumping influences. During the winter months groundwater levels in the fresh water-bearing aquifers are higher than in the formation. During the summer months the groundwater levels are higher in the formation than in the fresh water. During the summer months the water in the formation could up-well into the fresh water-bearing formations. Historically, prior to 2006, the head differences during the summer months were only a few feet, but since then up to 15 feet of head differences have occurred. The greater head differences suggest an increase in groundwater pumping occurred locally in this area.

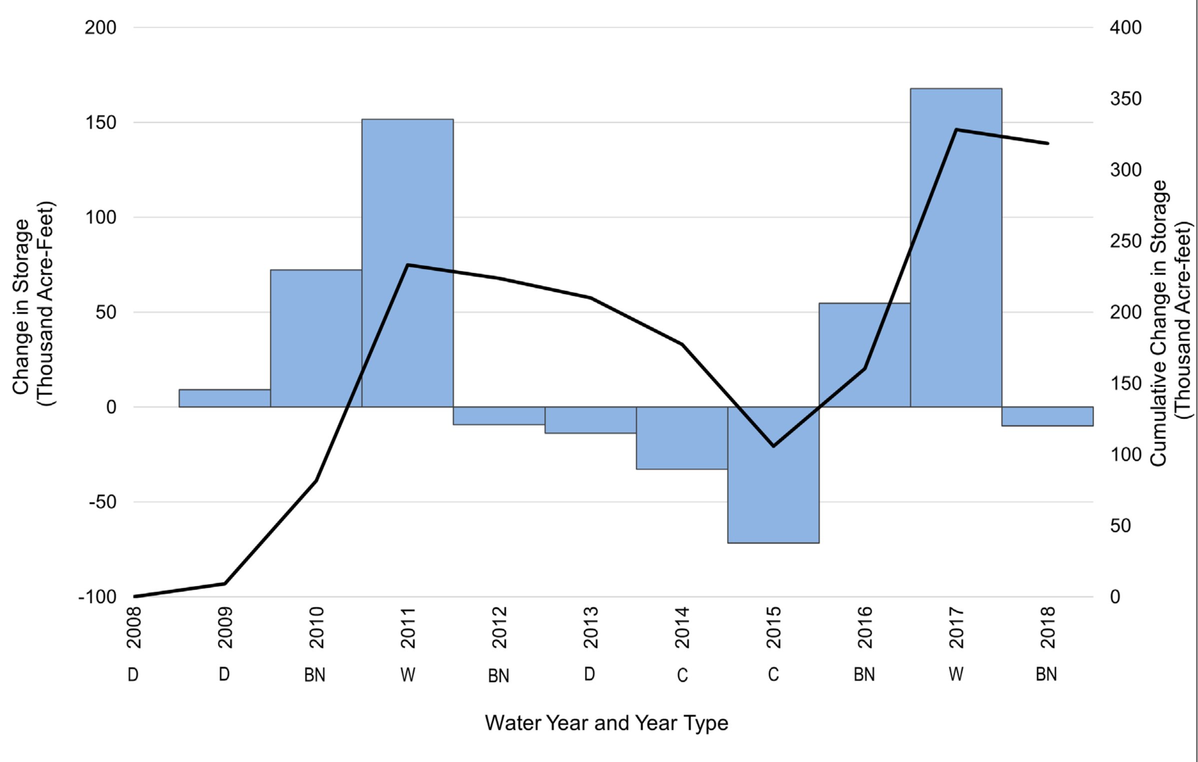
5.7 Change in Groundwater Storage

The amount of groundwater in storage changes annually and seasonally depending on the amount of groundwater use and recharge. The change in storage provides an indication of how much groundwater is in storage for dry years when there is more reliance on groundwater. The change in groundwater storage was estimated for the entire NASb using the calibrated groundwater model. The model includes actual groundwater pumping from municipal water purveyors and estimated groundwater pumping for agricultural areas from the NASb.

Table 5-2 shows the NASb-wide groundwater pumping for water years 2009 through 2018. **Figure 5-9** shows both the annual and cumulative changes in groundwater in storage in the Subbasin. The cumulative change in storage during this period, increased by about 300,000 acre-feet (AFY) which included the recent drought, or on average by about 30,000 AFY.

Table 5-2. Summary of Annual Extraction and Change in Storage

Water Year	Groundwater Extraction (acre-feet)	Change in Storage (acre-feet)	Water Year Classification
2009	313,120	9,395	Dry
2010	273,566	72,314	Below Normal
2011	252,800	152,057	Wet
2012	293,862	-9,524	Below Normal
2013	298,785	-13,615	Dry
2014	301,847	-32,603	Critical
2015	357,224	-71,725	Critical
2016	279,422	54,642	Below Normal
2017	279,942	168,082	Wet
2018	306,763	-10,024	Below Normal



Note: Water year type is based on the Sacramento Valley Water Year Hydrologic Classification Index.
2008 is included to highlight the starting point (zero) for the cumulative change in storage value. Annual storage change values are not shown for 2008
W=wet, AN=above normal, BN=below normal, D=dry, and C=critical

Figure 5-9. Annual and Cumulative Change in Storage

5.8 Groundwater Quality

Generally, the quality of groundwater in the Subbasin is suitable for nearly all uses, with the exception of contamination plumes and localized, naturally-occurring and human-caused quality issues, which may affect the supply, beneficial uses, and potential management of groundwater in the Subbasin. This section describes the distribution, concentration and trends of the more commonly encountered and primarily naturally-occurring dissolved constituents in groundwater, along with human-caused water quality contamination issues.

5.8.1 Occurrence of Commonly Evaluated Constituents in Groundwater

While there are over 50 elements (general minerals and metals) with established drinking water and agricultural standards, only a few elements typically occur in the Sacramento Valley at levels that warrant evaluation and tracking to assess their occurrence and distribution. The concentration and depth of the elements varies widely over the NASb and at any given location. Various studies have been performed and each has evaluated similar elements, and a few have evaluated additional elements. A Groundwater Quality Vulnerability Assessment of the SGA portion of the Subbasin identified seven elements (arsenic, chromium (total and hexavalent), iron, manganese, nitrate, total dissolved solids, and radon) that provide a general condition of the groundwater quality (SGA, 2011). It should be noted that some of these naturally-occurring elements may be either sourced from, or increased by, human activities. This GSP evaluates six of these seven elements (not radon), which were also identified and analyzed in other studies, plus boron because its presence can affect agriculture.

The groundwater quality presented in this GSP was developed using information from the California State Water Resources Control Board (SWRCB) Division of Drinking Water (DDW), which maintains a database of public water systems' water quality analyses. DDW requires each public water system to analyze water quality for over 300 elements at intervals ranging from weekly to every 3 years. Because large portions of Placer and Sutter counties are agricultural, public water systems are scarce within those areas. Therefore, data from the DDW was supplemented with data from one well (monitoring well 61, *refer to* **Figure 3-15**) monitored for the Irrigated Lands Regulatory Program Sacramento Valley Water Quality Coalition Groundwater Quality Trend Monitoring program and data from domestic wells used by the USGS for their *Groundwater Quality Data in the Southern Sacramento Valley, California, 2005 – Results from the California Groundwater Ambient Monitoring and Assessment (GAMA) Program* (Milby, et. al. 2005 and 2018) and water quality from local programs.

Water quality samples were collected from 24 domestic wells, between 2013 and 2017, with an average screen interval 129 to 178 feet bgs. The results showed TDS ranged between 70 and 459 mg/L. Nitrate (as nitrogen) ranged between 0.1 and 1.4 mg/L (Bennett, 2019). The concentrations indicate the water is suitable for drinking water with all concentrations below the secondary and primary drinking water standards (California Code of Regulations (CCR)-Title

22, 2021). However, about 15 percent of the wells had arsenic and manganese above their respective MCLs (Bennett, 2019).

Figures 5-10 through 5-16 show the most recent analyses and distribution of the selected elements in the Subbasin. The analyses dates range from 1967 to 2019. These figures also show where monitoring wells are located that could be used to supplement the data set. **Appendix L** provides a detailed list of the water quality analysis and wells used to create the figures. **Table 5-3** provides a list of the constituents, the number of samples analyzed, their minimum and maximum concentrations, and the average and percent of samples exceeding the MCL or Notification Level.

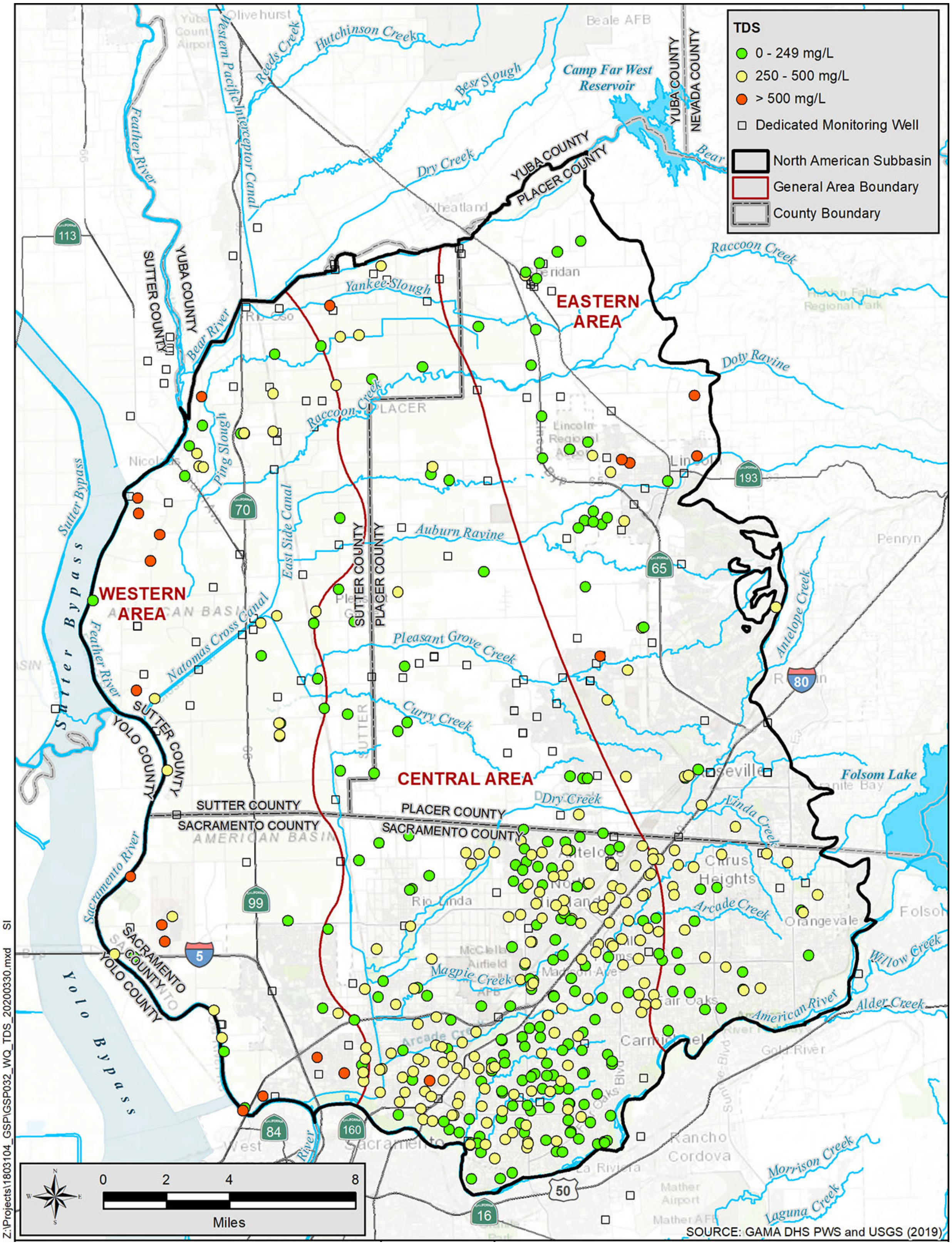


Figure 5-10. Distribution of TDS Concentrations

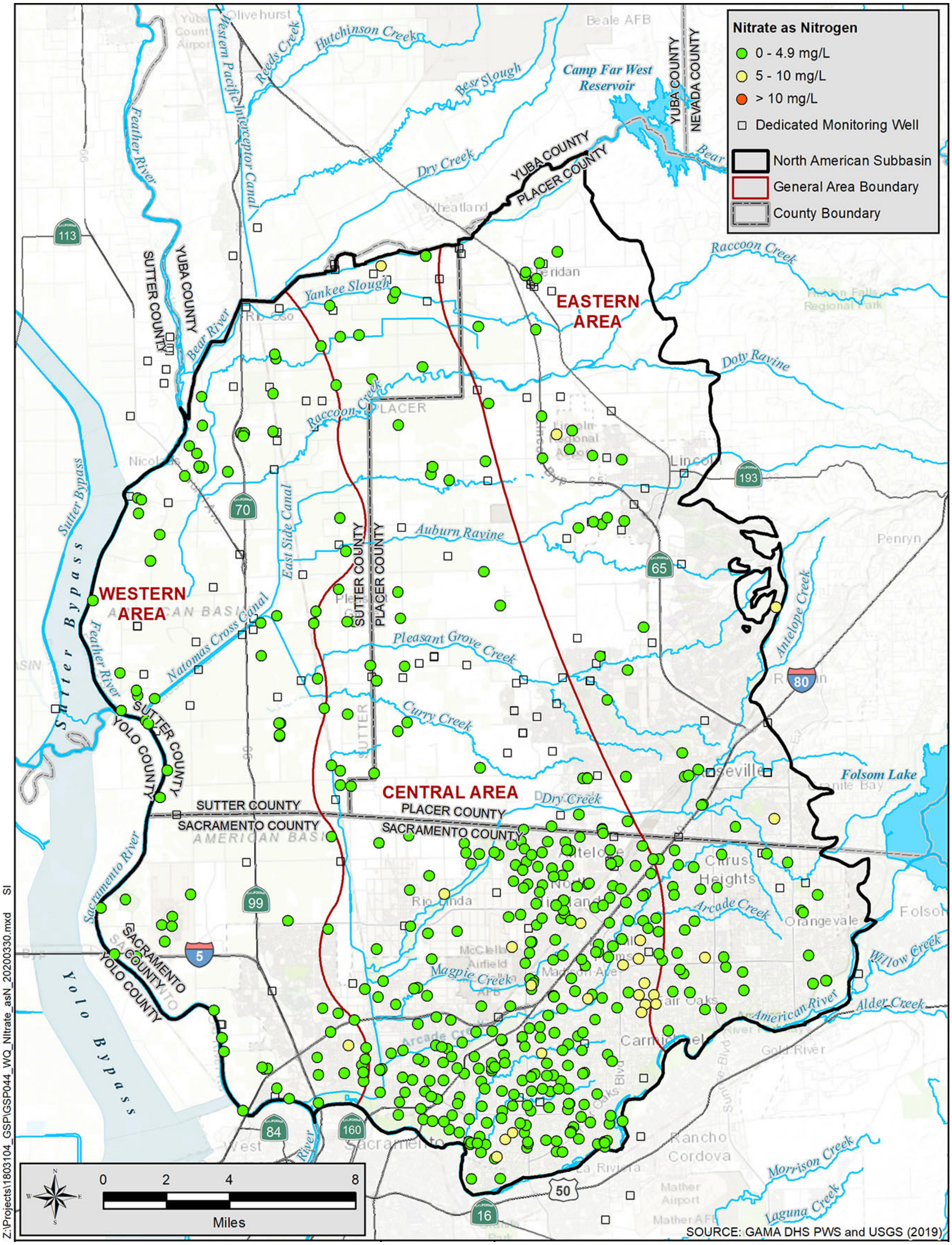


Figure 5-11. Distribution of Nitrate as Nitrogen Concentrations

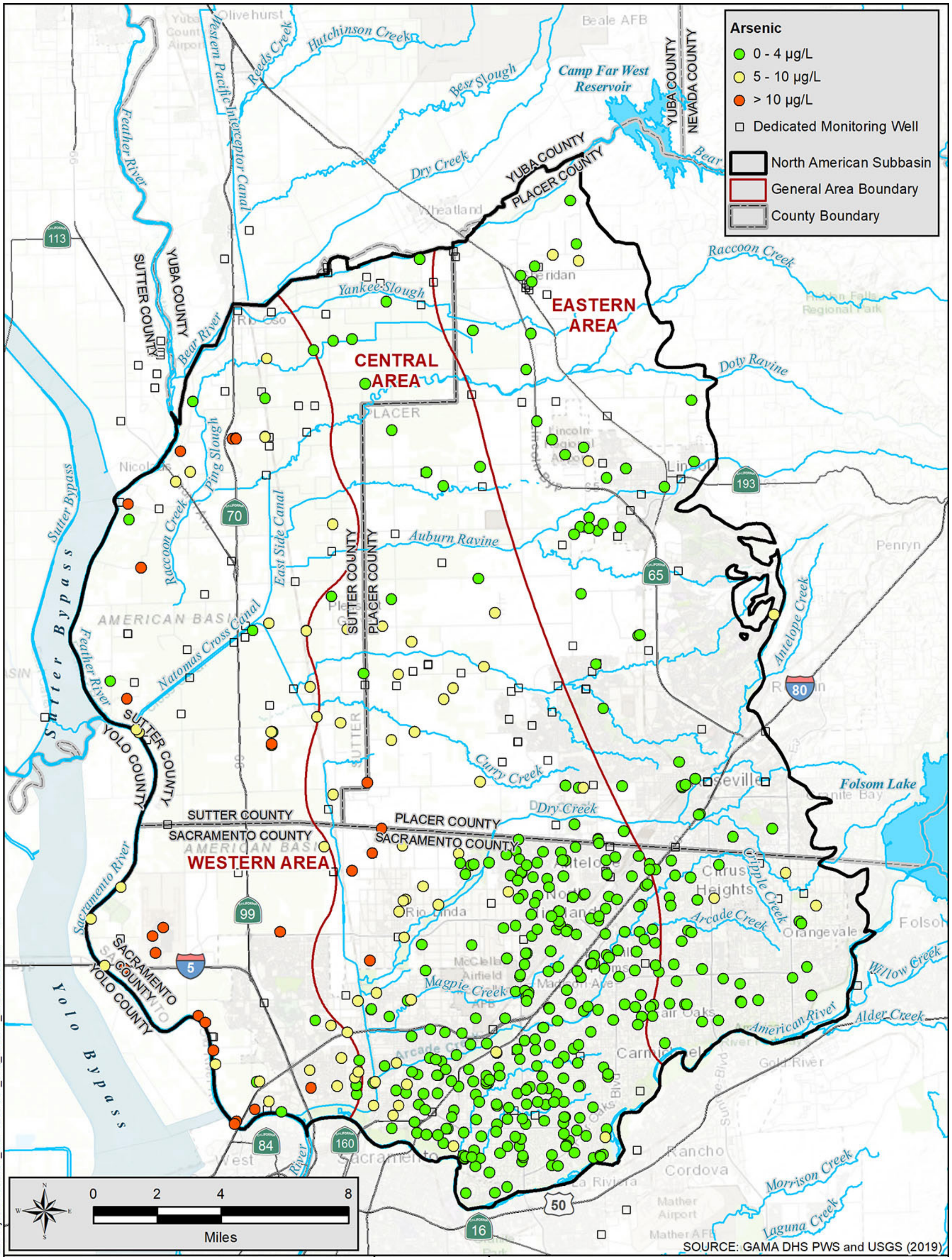


Figure 5-12. Distribution of Arsenic Concentrations

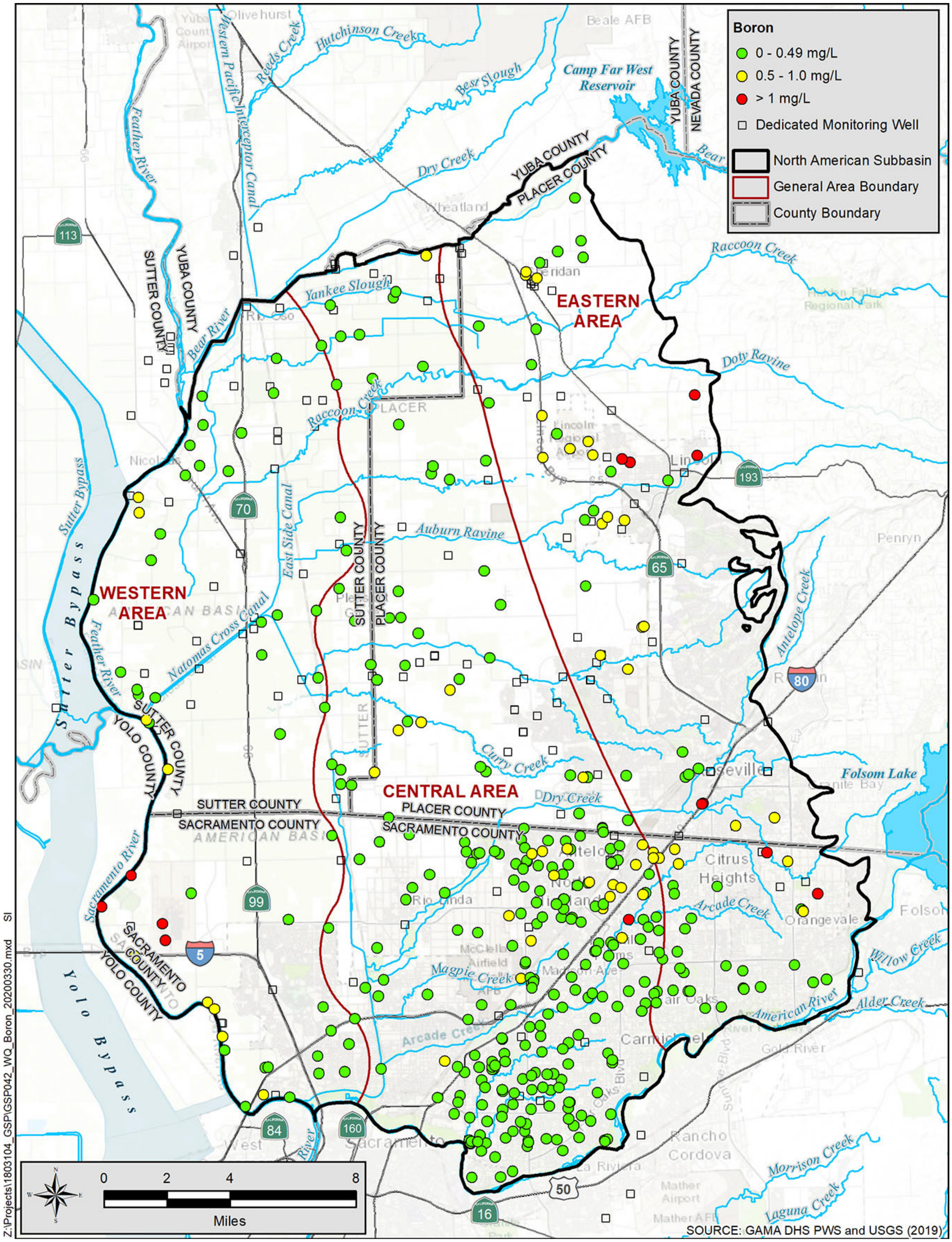


Figure 5-13. Distribution of Boron Concentrations

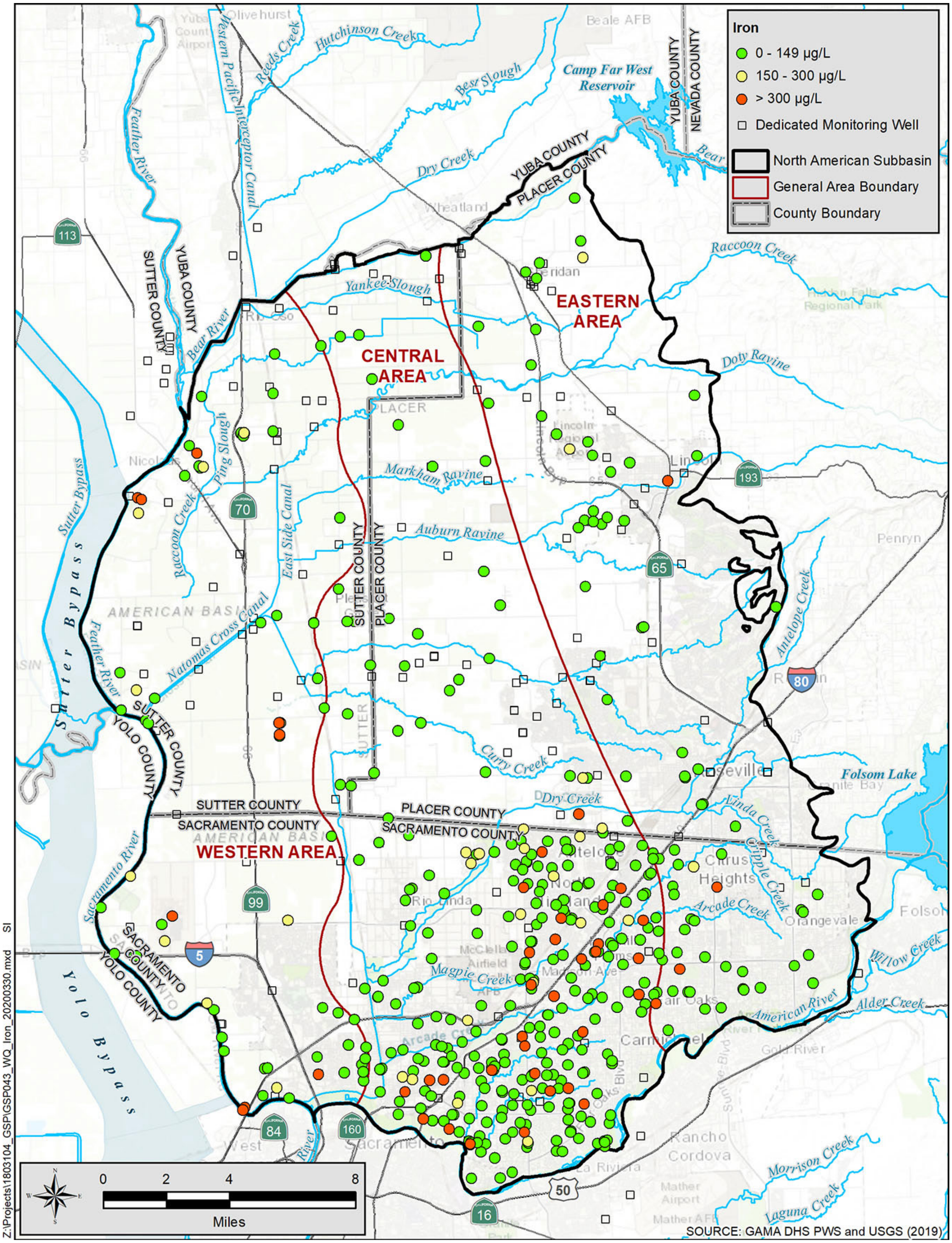


Figure 5-14. Distribution of Iron Concentrations

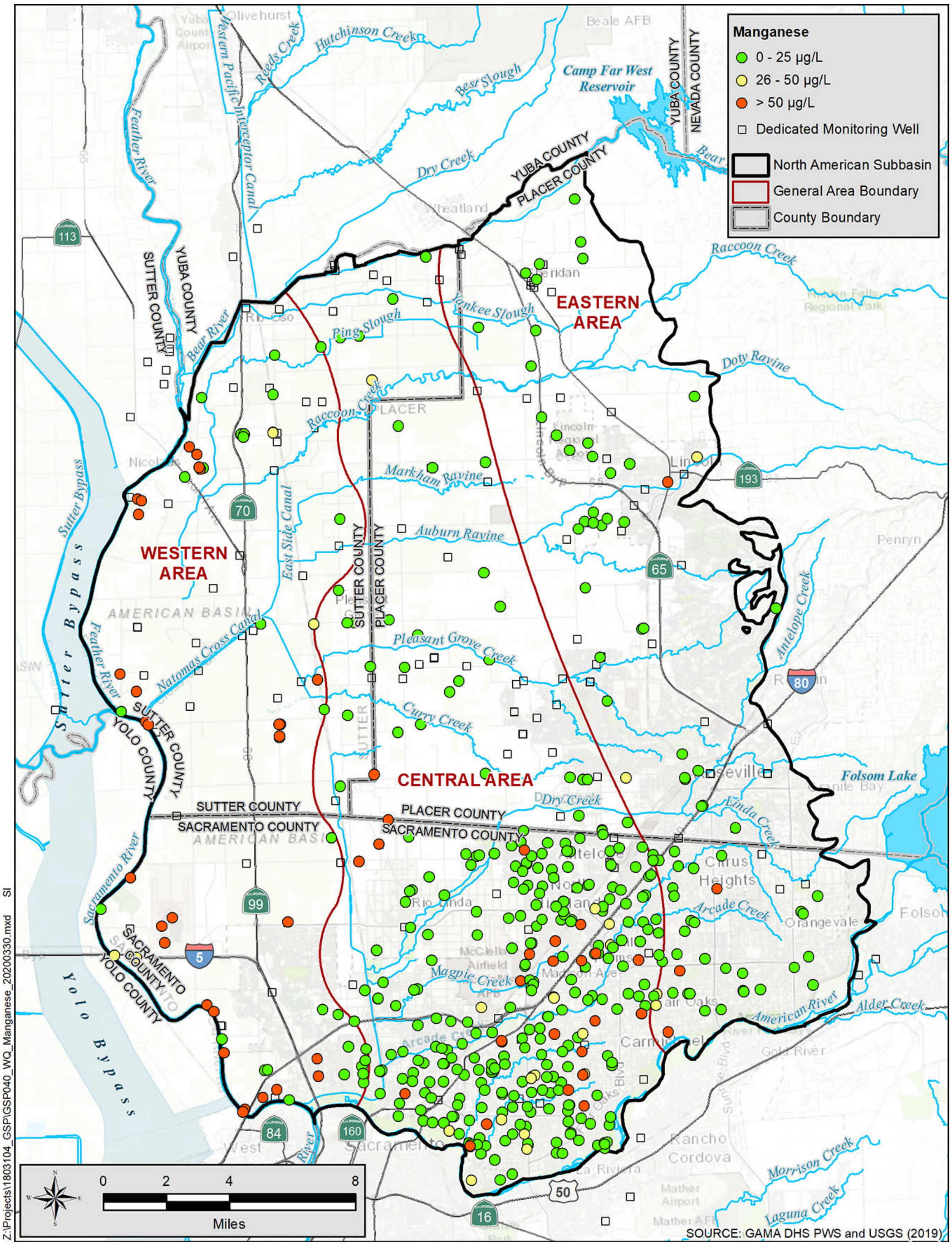


Figure 5-15. Distribution of Manganese Concentrations

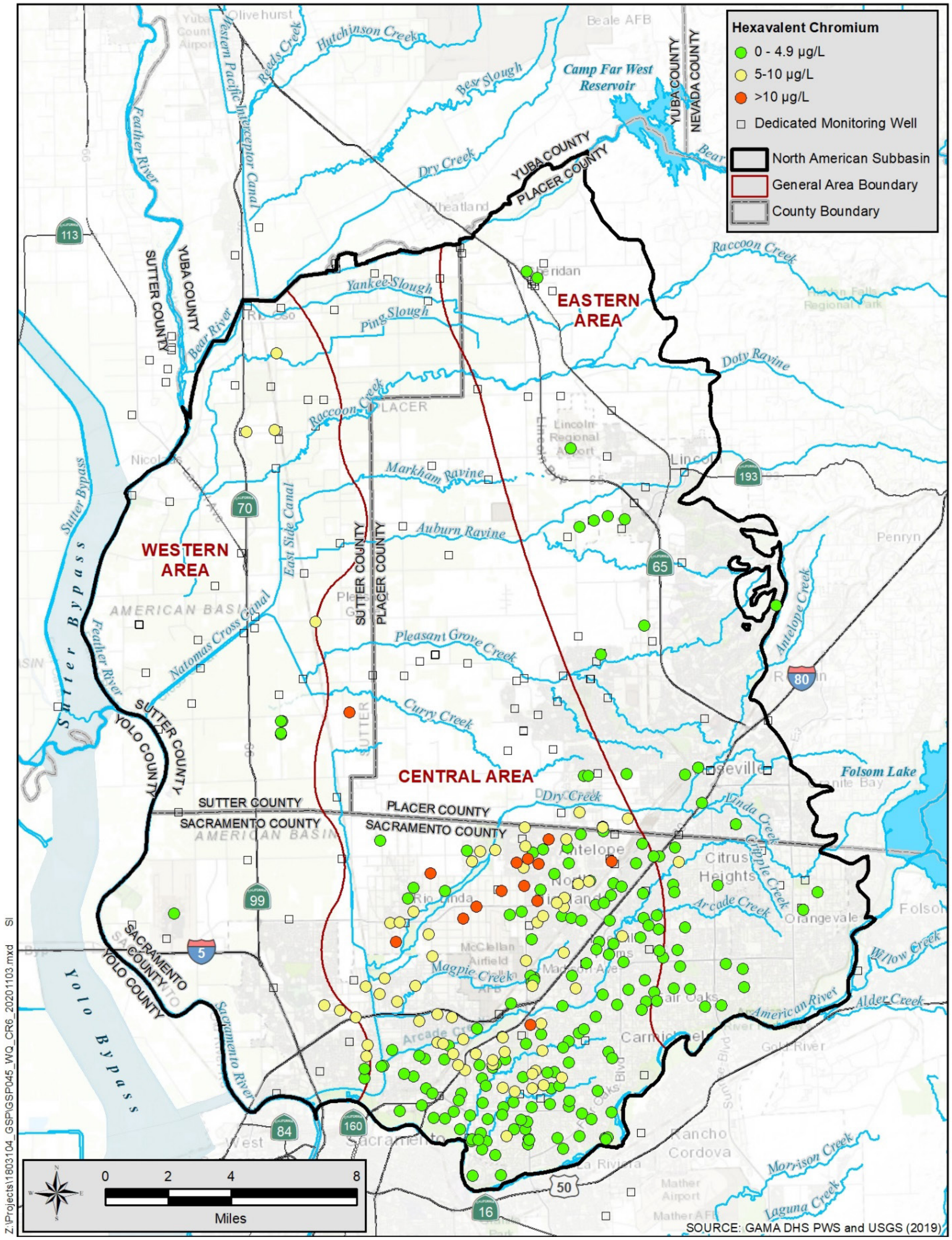


Figure 5-16. Distribution of Hexavalent Chromium Concentrations

Table 5-3. General Water Quality Summary

Constituents	Units	MCL or Notification Level	Number of wells with analytical results	Minimum Concentration[4]	Maximum Concentration	Average	Number of wells with most recent analysis exceeding MCL	Range of analysis (years)
Arsenic	ug/L	10	482	<2.0	78.1	4.09	29	1967-2019
Boron	mg/L	1[1]	410	<0.1	6.8	0.2	14	1969-2018
Hexavalent Chromium	ug/L	10[2]	252	<0.05	14	4.17	-	2001-2019
Iron	mg/L	0.3	488	<0.03	5.5	0.16	44	1957-2019
Manganese	mg/L	0.05	488	<0.01	3.6	0.05	62	1970-2019
Nitrate as Nitrogen	mg/L	10	494	<0.023	10	1.7	0	1964-2019
TDS	mg/L	500[3]	451	97	1,360	268.7	22	1969-2019

Notes: 1 = Notification level, no MCL
2 = No MCL, previous MCL shown
3 = Secondary standard, recommended level shown
4 = Reporting limit, may vary with historic analysis

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Water quality in each of the areas varies and some elements with elevated levels are only present in a one or more areas while not in others. These findings align with previous studies in the Subbasin. Where concentrations are elevated, wells are often constructed into different aquifers where the water quality is better. In summary:

- In the Western area, elevated concentrations of arsenic, boron, and TDS are present near the Feather and Sacramento rivers. Studies in the area show variable water quality in the aquifers. Poor-quality water is present in the adjacent Sutter Subbasin. It is unknown if the poor-quality water is present in the Yolo Subbasin.
- In the Central area, elevated levels of arsenic and hexavalent chromium are generally found in the western portion of this area, in the vicinity of Rio Linda (SGA, 2011) with scattered occurrences elsewhere in the Subbasin. The areas of biggest concern for hexavalent chromium appear to be north of Interstate 80 near the communities of Rio Linda, Antelope, and North Highlands.
- In the Eastern area, scattered locations near Sheridan, Lincoln, and Roseville have elevated boron and TDS levels. High TDS concentrations are commonly associated with sodium chloride types of water and may be related to connate water from the marine Ione Formation. The effects of the Ione Formation water in this area appear to be of limited extent. Sodium chloride types of water are also present in deeper wells in the Subbasin near or below the base of fresh water.

Nitrate concentrations are typically below the MCL for drinking water in all three areas; however, nitrate concentrations are trending upward in many parts of the Subbasin. Elevated levels of boron appear to be present in most areas with some concentrated areas in the Western area south of Highway 5 and in the SGA area. Elevated iron and manganese levels (**Figures 5-15 and 5-16**) could be encountered in any of the three areas. Elevated levels of hexavalent chromium appear to be more concentrated in the SGA area, but this could in part be due to SGA having a greater number of wells with analyses.

5.8.2 Groundwater Quality Trends

Groundwater quality trends are evaluated to assess trends and where management actions may be required to reduce future degradation and keep the water potable. Water quality sampling in the Subbasin has been conducted for over 40 years as part of state and federal efforts to evaluate water quality throughout the state and nation and where future studies may be needed to maintain potable water supplies. Although many of the elements are naturally occurring, human activities may result in increased concentrations of elements and produce upward trends. In general, water quality trends in the NASb are not showing rising concentrations and are remaining in a consistent range with a few exceptions.

5.8.2.1 Previous Analyses

Water quality trends for TDS (a primary indicator of naturally occurring water quality) and nitrates (a primary indicator of human activities) were analyzed in historical reports and concluded the following trends.

In the SGA area, a Water Quality Vulnerability Assessment in 2011 using just public water supply wells found:

- TDS trends are, for the most part, stable and not increasing (SGA, 2014).
- In 19 wells, nitrate concentrations were rising somewhat over the period of record (earliest records in the database are generally from the mid-1980s or later) (SGA, 2014). In 10 wells, nitrate concentrations were trending downward. SGA concluded that there was no discernible overall trend in the data at that time. Regardless, SGA concluded there were no trends that would constitute a health concern with respect to nitrates in the SGA area.

In the West Placer GSA area:

- TDS levels are generally stable or decreasing but are increasing at one water supply well (GEI, 2020).
- Nitrate trends were not evaluated.

A Groundwater Assessment Report for most of the Sacramento Valley was performed as part of the Irrigated Lands Regulatory Program, which used all wells in the GAMA data files (CH2MHill, 2014). This report provides water quality covering the SGA, West Placer, SSWD, RD 1001 and Sutter GSA areas. It used a modified Mann-Kendall statistical approach. In the NASb:

- TDS levels trends were consistent.
- Nitrate concentrations are increasing at seven out of 20 wells, in the agricultural areas of west Placer County and Sutter County.

A Groundwater Assessment Report for rice areas in the Sacramento Valley, including in part some portion of all of the GSAs, was also performed as part of the Irrigated Lands Regulatory Program. No rigorous trend analysis was performed but graphs were provided for some wells. This analysis only used 12 wells in the NASb (CH2MHill, 2013). In the NASb:

- TDS concentrations were very consistent.
- Data was only sufficient at one well to evaluate nitrate trends (decreasing).

5.8.2.2 Current Analyses

Groundwater quality trends for this GSP were developed using data from public water supply wells, and USGS and DWR wells were used to develop the water quality distribution (*refer to* **Figures 5-10 through 5-16**). A statistical trend analysis of the data was performed using the Mann-Kendall method when a well had more than five samples for a given element. This method is a non-parametric (for example, does not assume a distribution in the data) test for identifying trends in time-series data. **Appendix M** provides the analysis and trend graphs for each constituent**. Figures 5-17 through 5-23** show the trends for each element. **Table 5-4** provides a summary of the analysis.

Table 5-4. Water Quality Trend Summary

Element	Units	Number of Wells with Greater Than Five Samples	Increasing Trends	Decreasing or Flat Trends
Arsenic	ug/L	245	7	238
Boron	mg/L	71	3	68
Hexavalent Chromium	ug/L	115	1	114
Iron	mg/L	241	9	232
Manganese	mg/L	241	2	239
Nitrate as Nitrogen	mg/L	316	69	247
TDS	mg/L	267	8	259

Similar to historical assessments, this GSP finds that groundwater quality is stable with the exception of nitrate. Although nitrate has the greatest number of wells with upward trends, and these upward trends are present in all areas, nitrate concentrations are well below the safe drinking water standard throughout the Subbasin. The nitrate is likely present due to historical agricultural fertilization practices, septic systems, and leaky sewers.

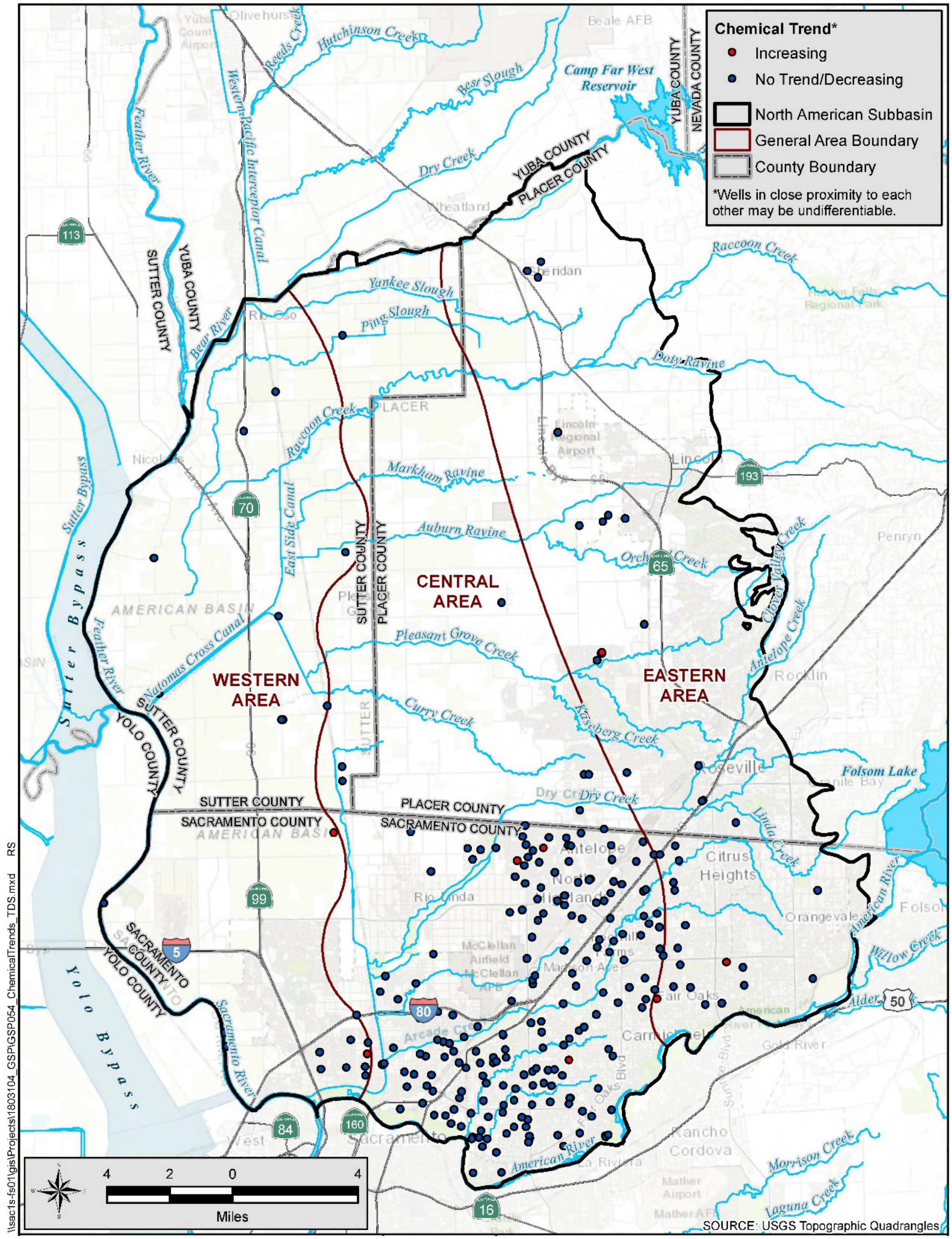

Figure 5-17. TDS Trends

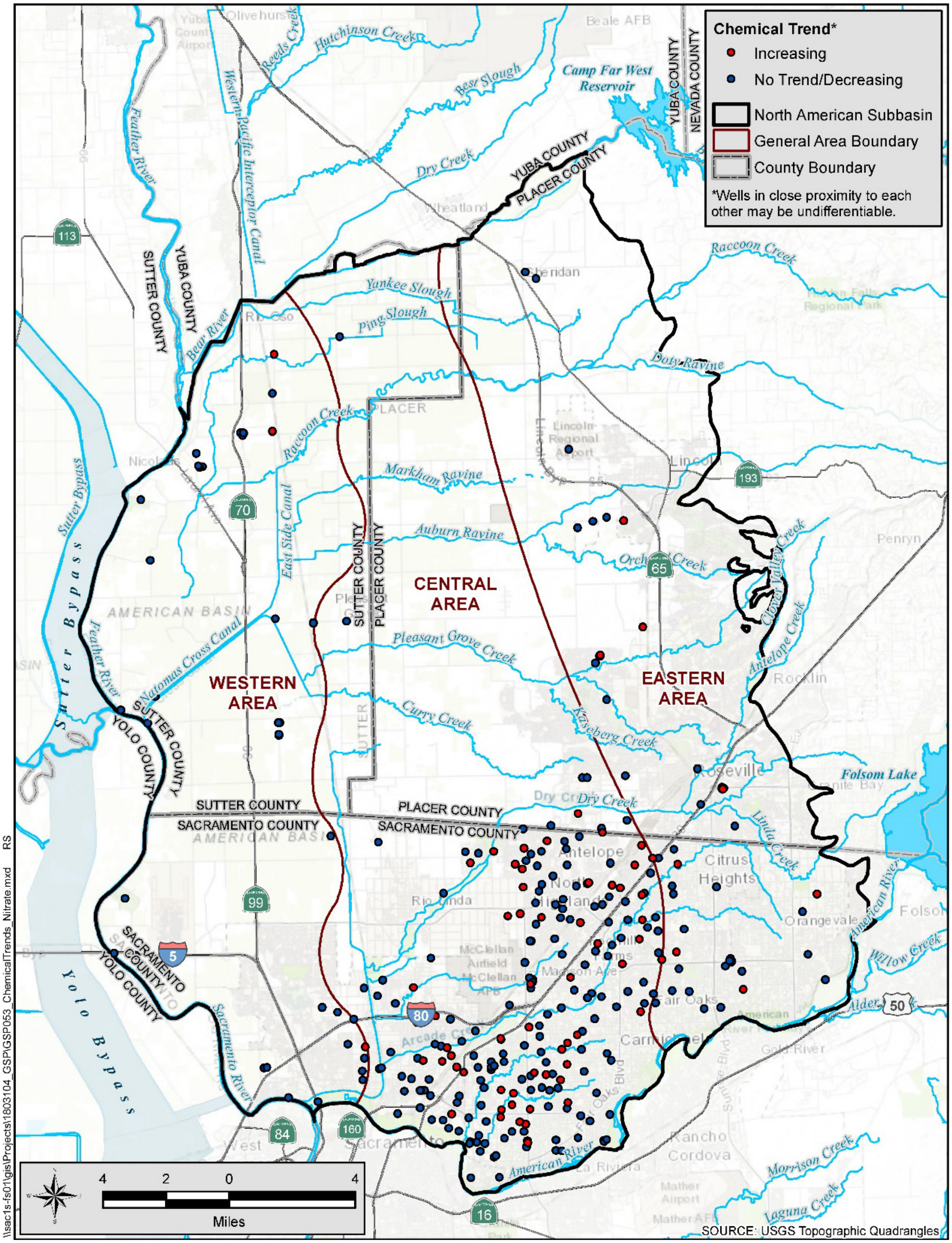

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Figure 5-18. Nitrate as Nitrogen Trends

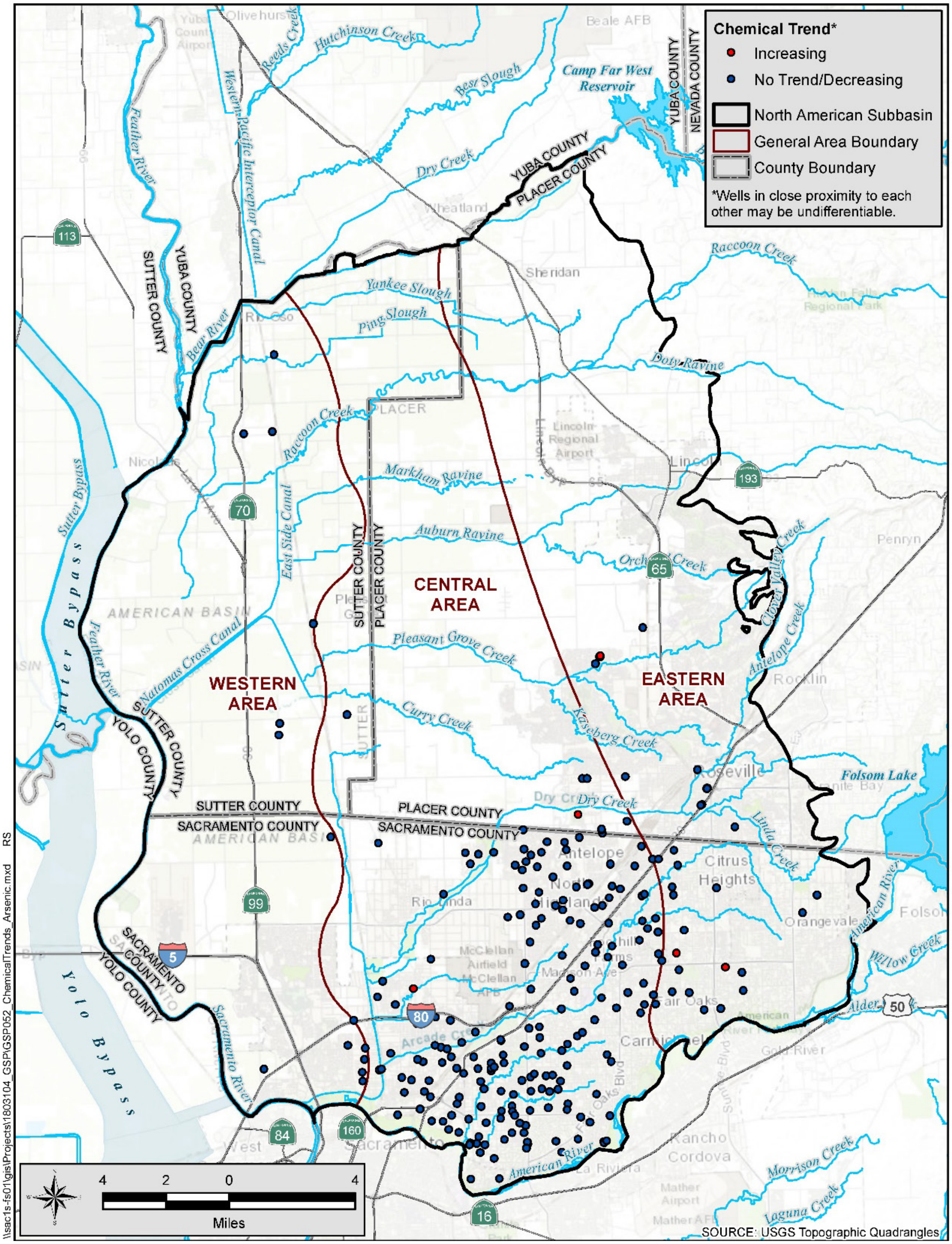

Figure 5-19. Arsenic Trends

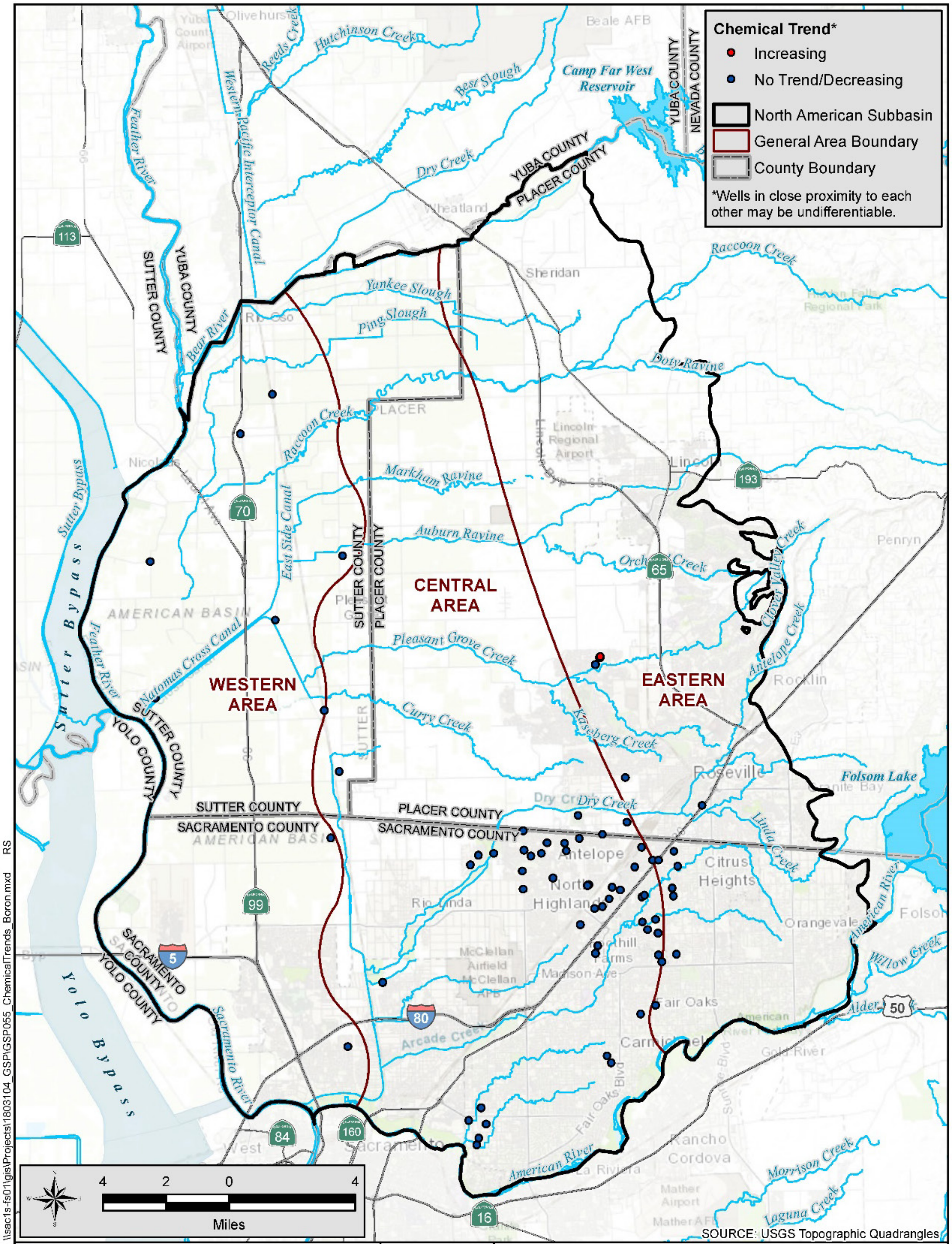

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Figure 5-20. Boron Trends

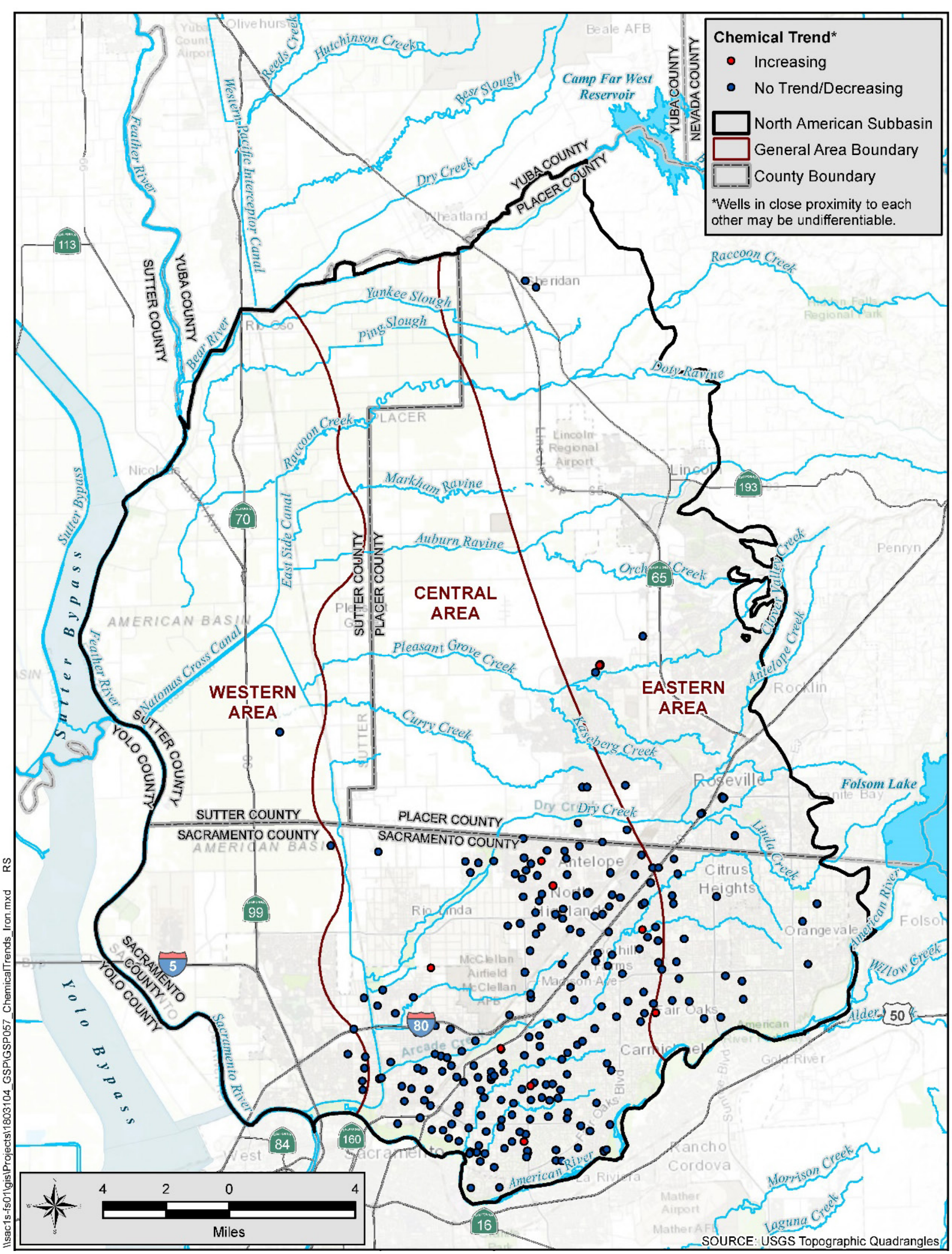

Figure 5-21. Iron Trends

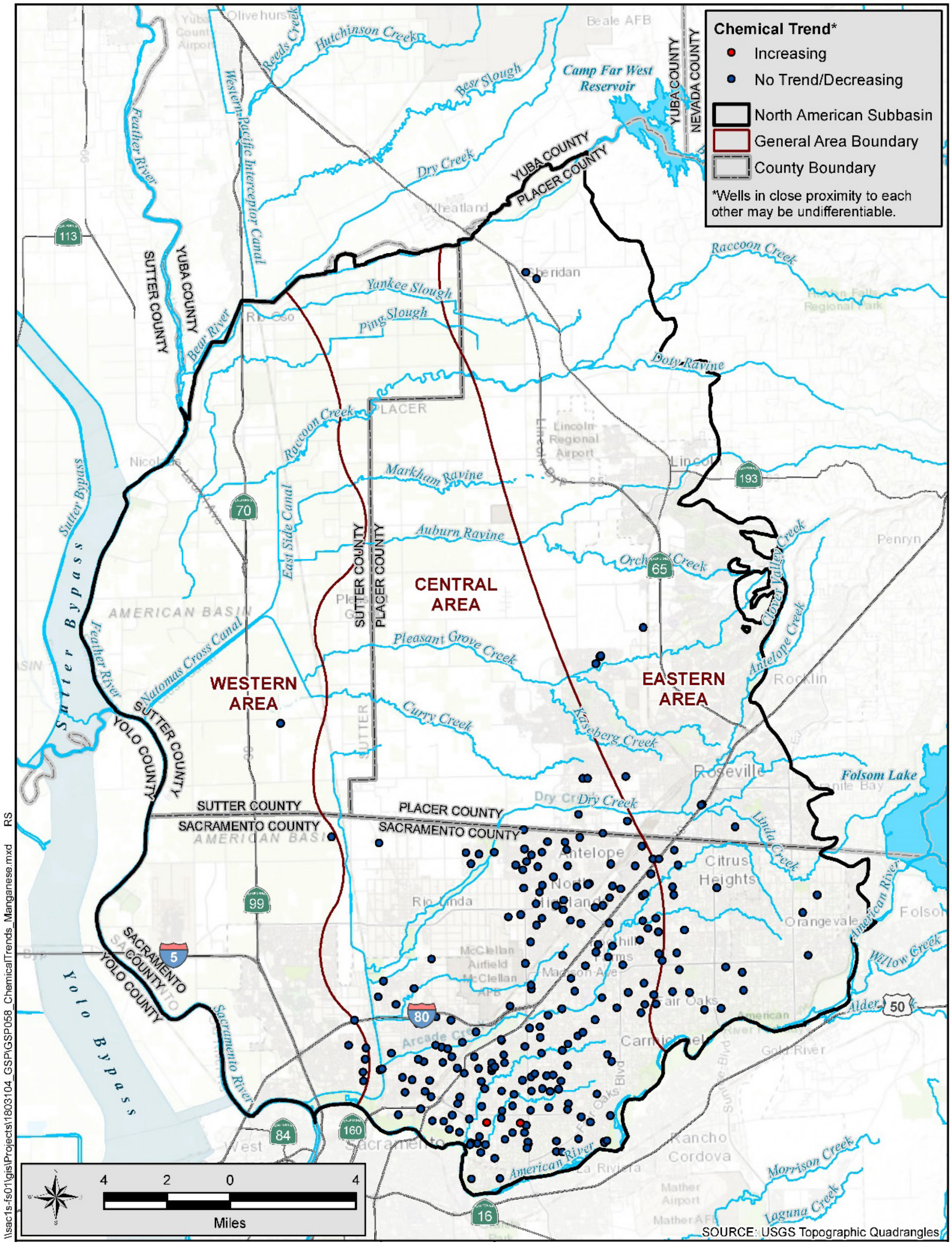

Figure 5-22. Manganese Trend

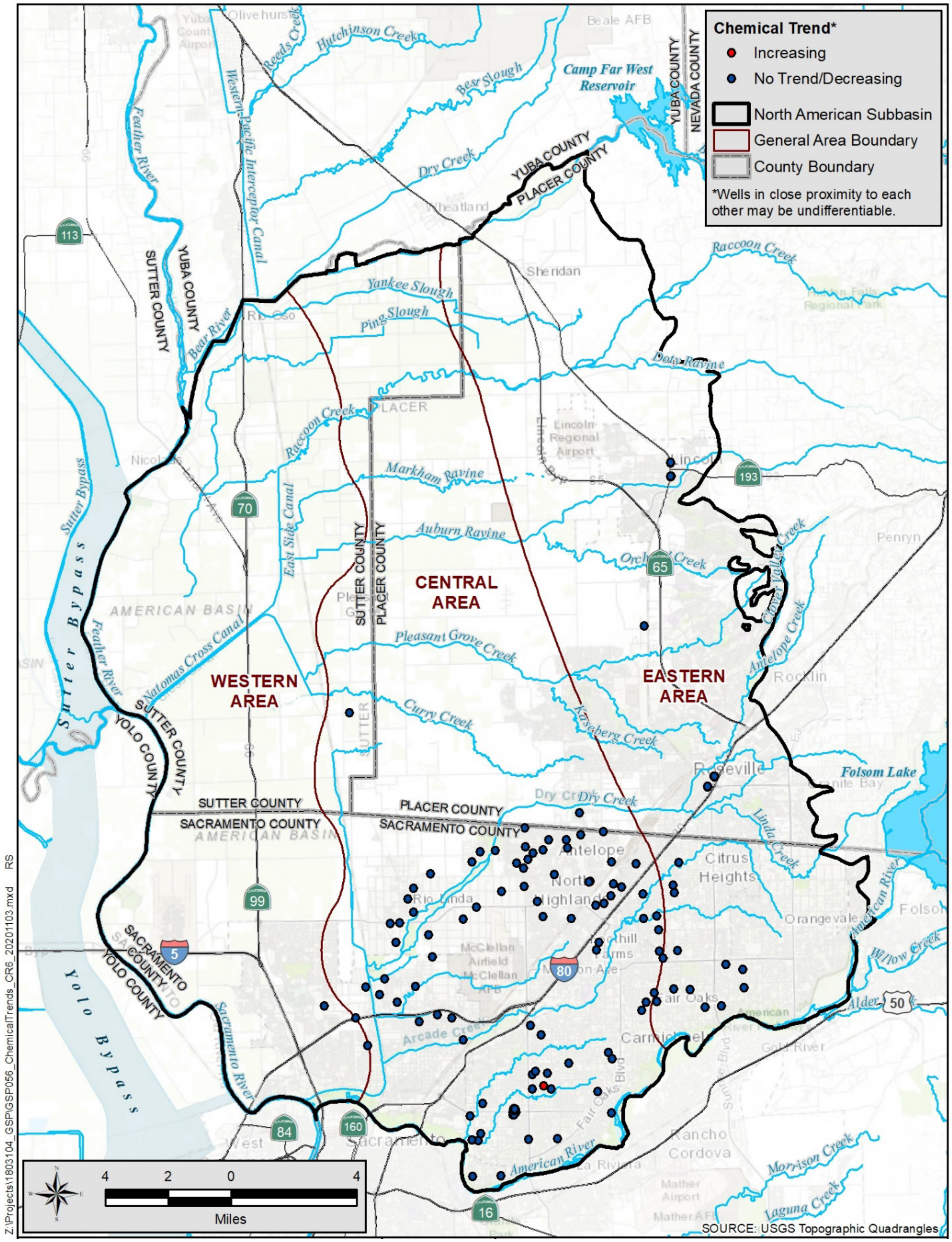

Figure 5-23. Hexavalent Chromium Trend

5.8.3 Groundwater Contamination Sites and Plumes

In the NASb, there are a few large and known groundwater contamination sites that could affect supply and beneficial uses of groundwater in the Subbasin. The most significant of these sites are the former McClellan AFB and the Aerojet Superfund Site (adjacent to the NASb to the south). **Figure 5-24** shows the extent of the plumes at these sites. Cleanup activities, as overseen by the U.S. Environmental Protection Agency, SWRCB, and the California Department of Toxic Substances Control, have been in progress for multiple years and contaminants appear to be contained. As described in the SGMA, the GSAs are required to manage the groundwater basin to avoid significant and unreasonable degradation of water quality. However, GSA's authorities under SGMA do not limit or supersede the authorities of the State Water Resources Control Board (SWRCB), the Regional Water Quality Control Boards to order investigations or remediation activities.

At the former McClellan AFB, one of the cleanup methods in use is air-sparging, which injects air up to depths of 106 feet bgs and requires groundwater levels to remain below this depth for the clean-up to be effective. The former McClellan AFB is within the Central area of the NASb and is part of the reason the pumping depression remains in this area. Their groundwater cleanup program is well established; mandated by Comprehensive Environmental Response, Compensation, and Liability Act and is not discretionary; and their pumping is relatively small, on the order of 2,000 acre-feet per year and will likely remain the same for years if not decades.

Although the Aerojet site is in the South American Subbasin, a contaminant plume (including perchlorate, trichloroethene or TCE, tetrachloroethene or PCE, and N-Nitrosodimethylamine or NDMA) extends north from Aerojet, under the American River, and into the NASb into the communities of Carmichael and Fair Oaks. The plumes are being remediated by Aerojet by pumping and treating the water to remove the contaminants.

There are other localized areas of groundwater contamination in the Subbasin that are generally smaller in size and the extent of contamination is typically localized near the properties and is being remediated (*refer to* **Figure 5-24)**.

PCE contamination is present near Interstate 80 and the Sacramento and Placer counties boundaries (Roseville, Citrus Heights, and Lincoln Oaks areas), but the source(s) has not been defined. A study by the SGA defined the extent of the plume. Currently, there are no active cleanup activities.

The Union Pacific Railroad site is located near Roseville Road and Vernon Street in Roseville. The primary constituents of concern are total petroleum hydrocarbons (including diesel, oil, and gasoline), volatile organic compounds (TCE, PCE, and others), semi-volatile organic compounds, dissolved arsenic, nickel and lead. Groundwater contamination assessment and remediation is in progress.

Remedial activities are occurring at two landfills in West Placer County along with cleanup activities of nitrate and perchlorate at the Alpha Explosives facility.

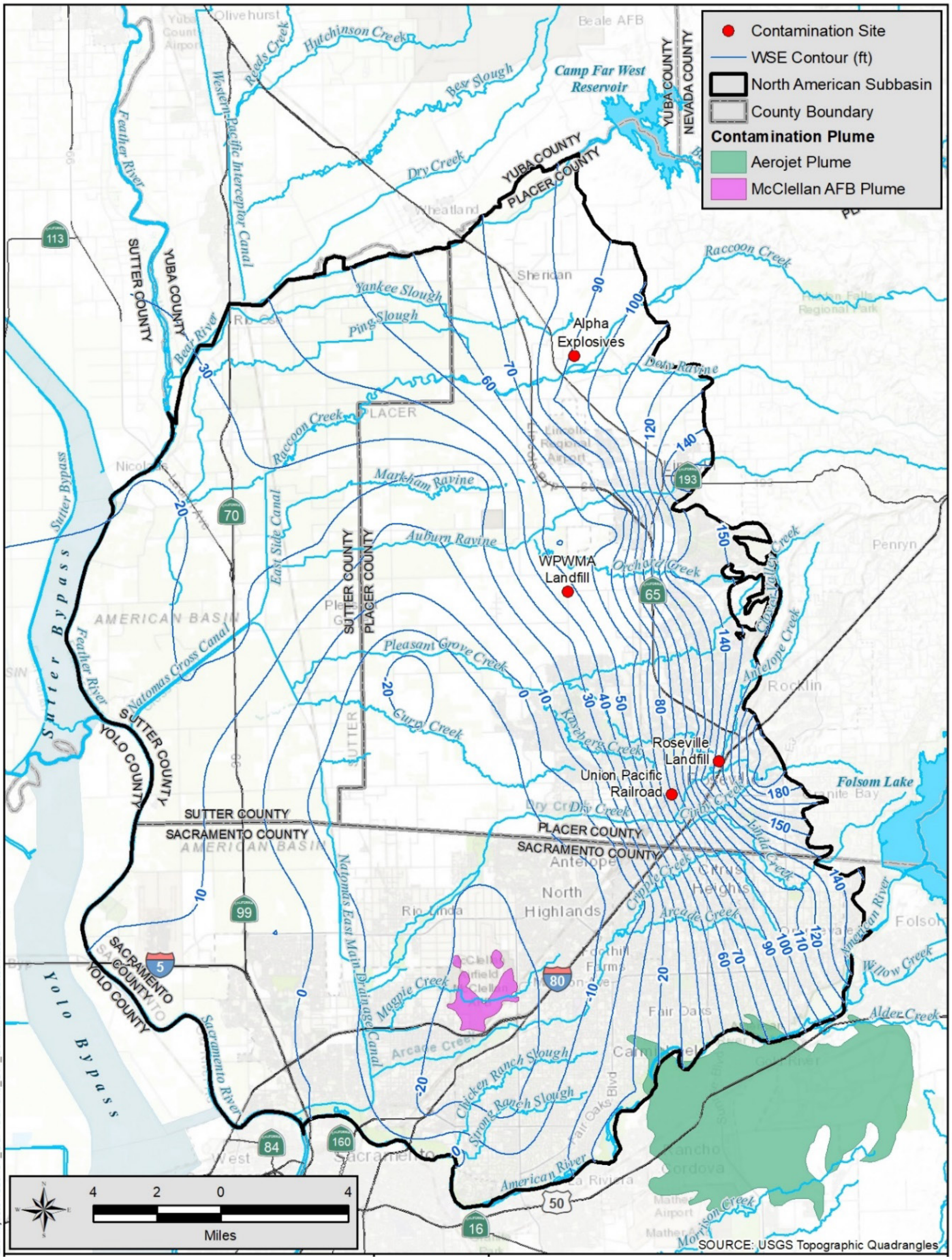

Figure 5-24. Groundwater Contamination Sites and Plumes

The presence of groundwater contamination plumes associated with defense-related and other industrial activities has been an issue of particular interest to the SGA. This contamination is known to limit local water purveyors' access to groundwater in a significant portion of the basin due to an exclusion zone for wells enforced by Sacramento County around the former McClellan Air Force Base. The SGA concern has been that if groundwater contamination is not managed properly, the region could potentially increase its reliance on surface water. This could in turn threaten the region's ability to implement the Water Forum Agreement.

In February 2004, SGA learned that NDMA associated with a contaminant plume from the Aerojet facility near Rancho Cordova had been detected in a monitoring well within Carmichael Water District north of the American River within the SGA area (see **Figure 5-24**). In response, SGA joined forces with the Sacramento Water Forum to establish what is now known as the Regional Contamination Issues Committee (RCIC) in June 2004. The RCIC is a forum for water purveyors, regulators and responsible parties to raise issues and discuss solutions for dealing with groundwater contamination issues that impact the region. The group has met continually since that time. Standing meetings are scheduled on a quarterly basis. State agencies represented include the Central Valley Regional Water Quality Control Board, the Department of Toxic Substances Control, and the SWRCB Division of Drinking Water. The federal government has been represented by the United States Environmental Protection Agency. The group has been very successful at collaborating on solutions that have kept these plumes from mobilizing, while progress on remediation has been made. There is active consultation and evaluation process established to understand the potential effects of new proposed municipal production as it relates to wells to ensure prevention of plume mobilization. Continued monitoring around the perimeter of the plumes shows that concentrations of contaminants are not increasing.

In 2011, an analysis of the capture effectiveness of the McClellan and Aerojet contamination was completed for the SGA (RMC, 2011). The study evaluated expanded conjunctive use operations by municipal water suppliers in the SGA area. Based on the analysis results, SGA concluded that the facilities each had effective capture of contaminants within the SGA area.

Finally, it is worth noting that Per- and poly-fluoroalkyl substances (PFAS) are a groundwater contaminant of emerging concern nationwide. Preliminary testing is being conducted under order of the State Water Resources Control Board to assess the extent of PFAS in groundwater. The NASb GSAs will closely monitor as results become available and consider appropriate actions to the extent that contamination could cause water quality concerns related to future use or management actions resulting from this GSP.

5.9 Seawater Intrusion

The NASb is more than 80 miles inland from the Pacific Ocean. However, tidal action and Delta outflow work to create a long and gradual salinity gradient from the ocean up the Sacramento River. Before Shasta Dam was constructed in 1943, seawater (defined as chloride concentration greater than 1,000 mg/L or about 5% seawater) had intruded up-river beyond Courtland (DWR, 1995), about 20 miles from the NASb. Since 1943, seawater intrusion into the river has remained below Isleton, about 40 miles from the NASb. Therefore, seawater intrusion is unlikely to occur in the vicinity of or in the Subbasin.

5.10 Land Subsidence

Substantial land subsidence could interfere with storm water drainage, canal delivery systems and transportation infrastructure. Subsidence monitoring in the NASb consists of one extensometer, two continuous positioning ground stations (CGPS) stations and benchmark surveys. The amount of subsidence is small with the maximum displacement, in a very small portion of the Subbasin, within the last 20 years being -0.25 foot or an average of -0.05 feet per year. **Figures 5-25 through 5-29** present the different surveys and stations results.

Historically, benchmark surveys showed about 0.3 feet of subsidence most likely due to groundwater levels declining by about 30 feet from the 1950s through 1970s or about 0.01 foot of land subsidence per foot of groundwater level decline (MWH, 2002); **Figure 5-25** shows this correlation. The location of the well that was used for this correlation is shown on **Figure 5-29**.

In 1994, DWR constructed the Sutter extensometer (SUT-Ext) and a nested monitoring well (SUT-P) in the Western area of the Subbasin, their locations are shown on **Figure 5-29**. **Figure 5-27** shows the changes in ground surface as they relate to the maximum change in groundwater levels at this location. Since 1994, the groundwater levels have remained stable, with Fall lows only changing by about 20 feet between 1994 and 2019, a 26-year period. The ground surface shows elastic response and potentially some inelastic subsidence of up to 0.04 foot (about one-half inch) or an average rate of -0.002 feet per year. The inelastic response during this time period is less than that predicted from earlier benchmark survey data.

The Subbasin also has two CGPS stations (LCN1 and LCN2) but both stations appear to be at the same location. They are located about the center of the Subbasin in Placer County. **Figure 5-29** show their locations as a single point. **Figures 5-27 and 5-28** show the changes in ground surface as they relate to the maximum change in groundwater levels at this location. Vertical displacements range from -0.01 to -0.025 feet depending upon the evaluation period, from the last 1 to 10 years. The total displacement for the period of record (Oct 2004 through September 2019) was -0.026 feet or an average of -0.002 feet per year. The rate of vertical displacement ranges from -0.001 to -0.005 feet per year depending upon the evaluation period, from the last 1 to 10 years.

DWR performed a regional subsidence assessment by surveying benchmarks in the Sacramento Valley in 2008 and then again in 2017. **Figure 5-29** shows subsidence throughout the Subbasin over this 10-year period (DWR, 2018). The least amount of change has occurred in the Eastern area of the Subbasin with the greatest changes, -0.177 foot or 2 inches, in the south-Central and Western areas of the Subbasin. With any type of survey, there is some amount of error and uncertainty, which for this survey was approximately 0.17 foot. Therefore, any change less than

0.17 foot is not considered statistically significant (DWR, 2018). This uncertainty helps explain an inconsistency between the data from the DWR benchmark survey data report and the extensometer data, the report indicating 0.134 foot of subsidence whereas the more accurate extensometer only shows about -0.04 foot, so the subsidence in the Western portion may be less.

DWR's SGMA Data Viewer (DWR 2021) provides land subsidence based on satellite-based imagery (InSAR). The estimated error in the InSAR data is 0.1 foot. The interpretation of the results do not indicate whether the subsidence is elastic or inelastic subsidence. The InSAR data (**Figure 5-30**) from January 2015 through October 2020, shows land subsidence ranged from 0 to -0.25 feet with most of the area with less than -0.05 foot and just a small area in the western portion of the Subbasin where the subsidence is greater than -0.15 foot. In the northern portion of the Subbasin there are areas with subsidence up to -0.1 foot. The maximum average rate of displacement would be -0.05 feet per year.

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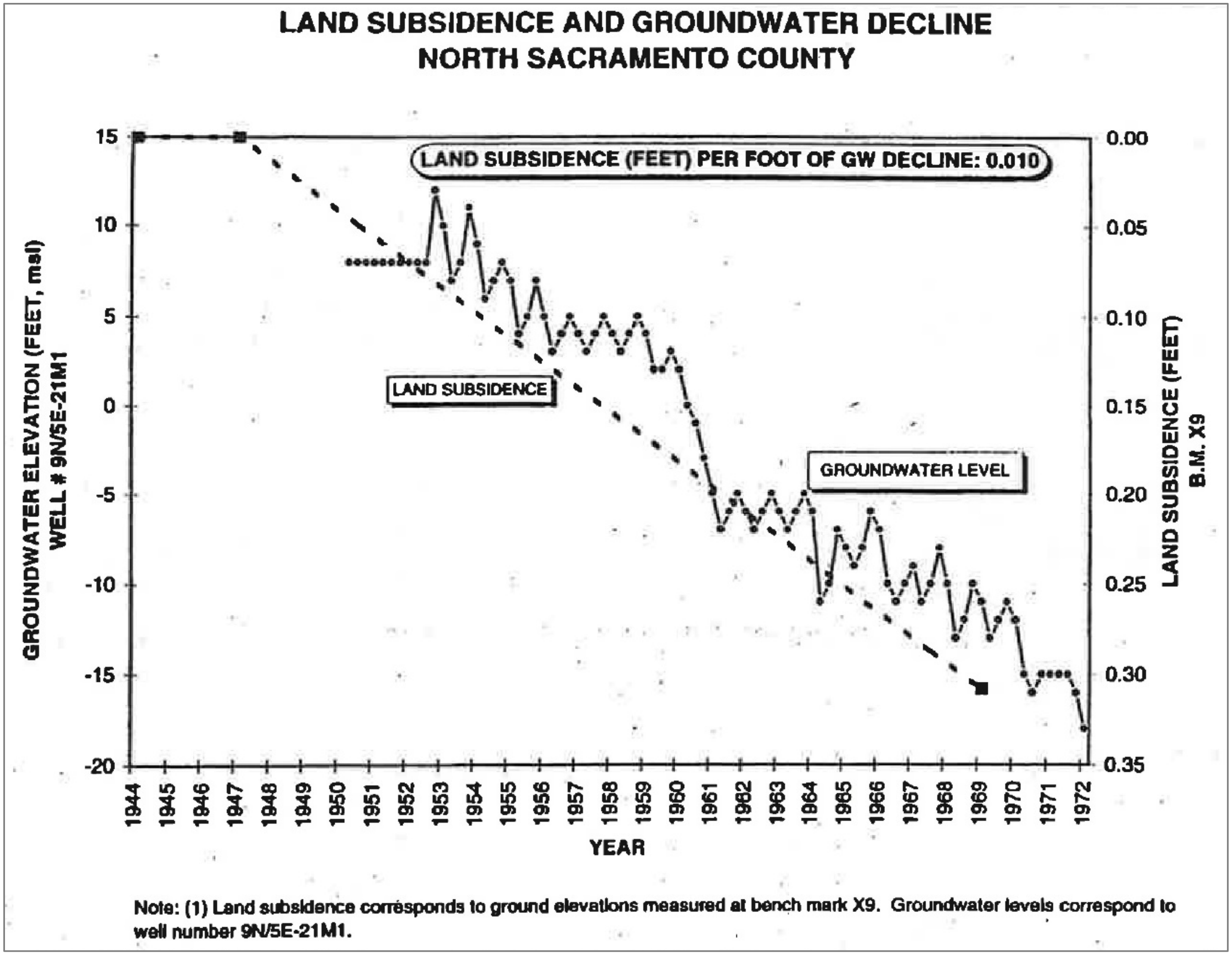

Figure 5-25. Land Subsidence and Groundwater Level Decline Correlation

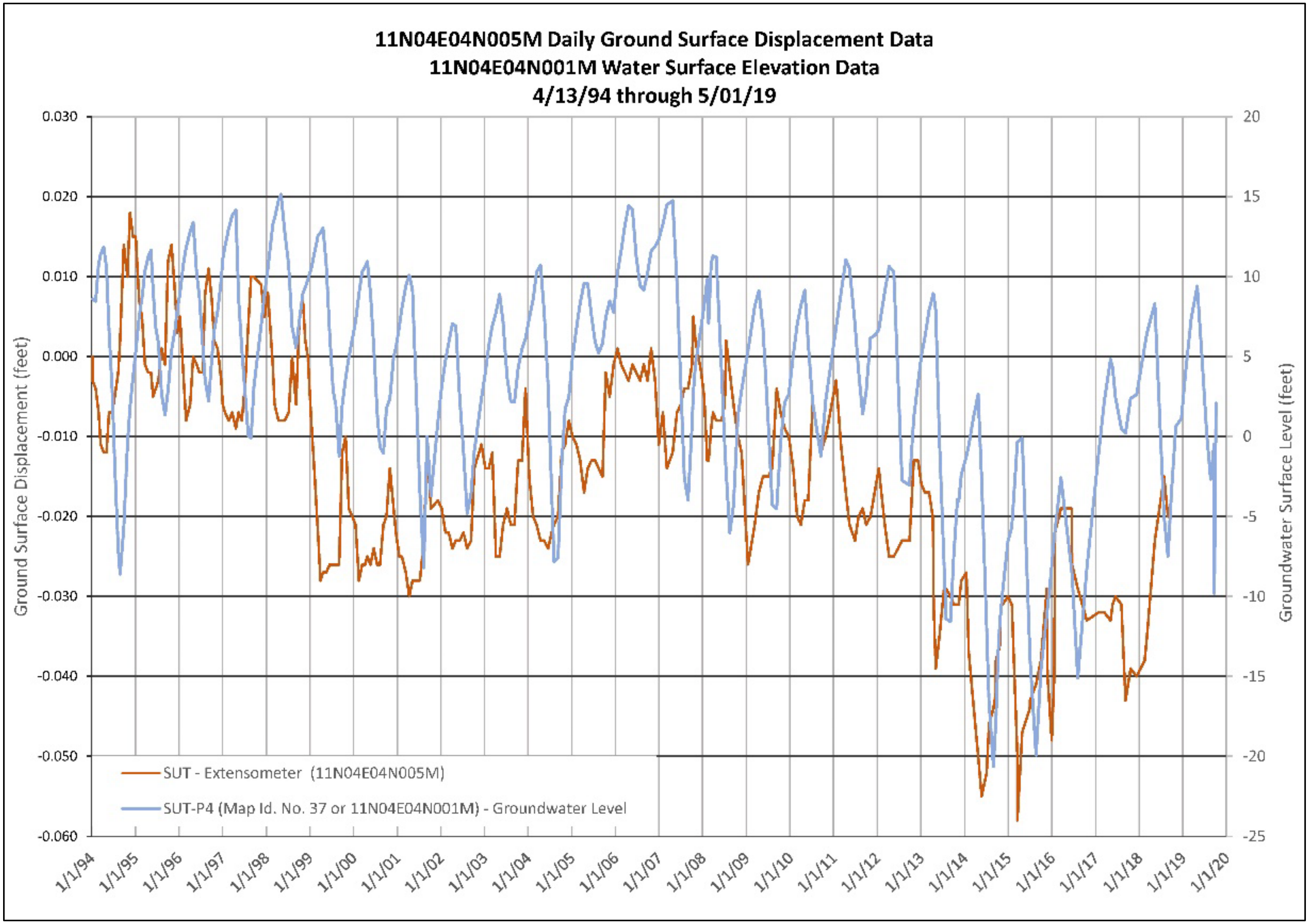

Figure 5-26. Extensometer versus Groundwater Levels

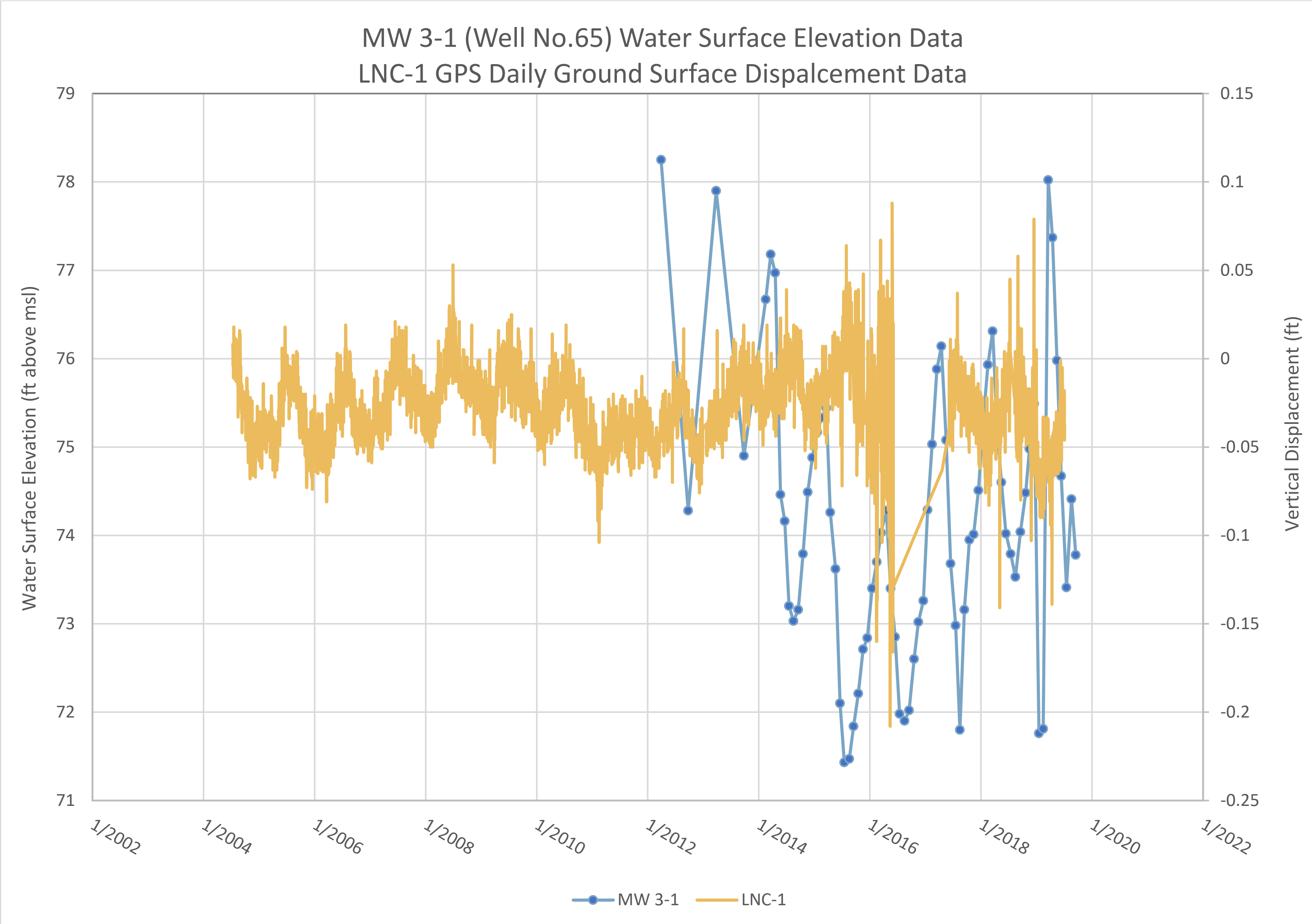

Figure 5-27. CGPS Station LCN1 versus Groundwater Levels

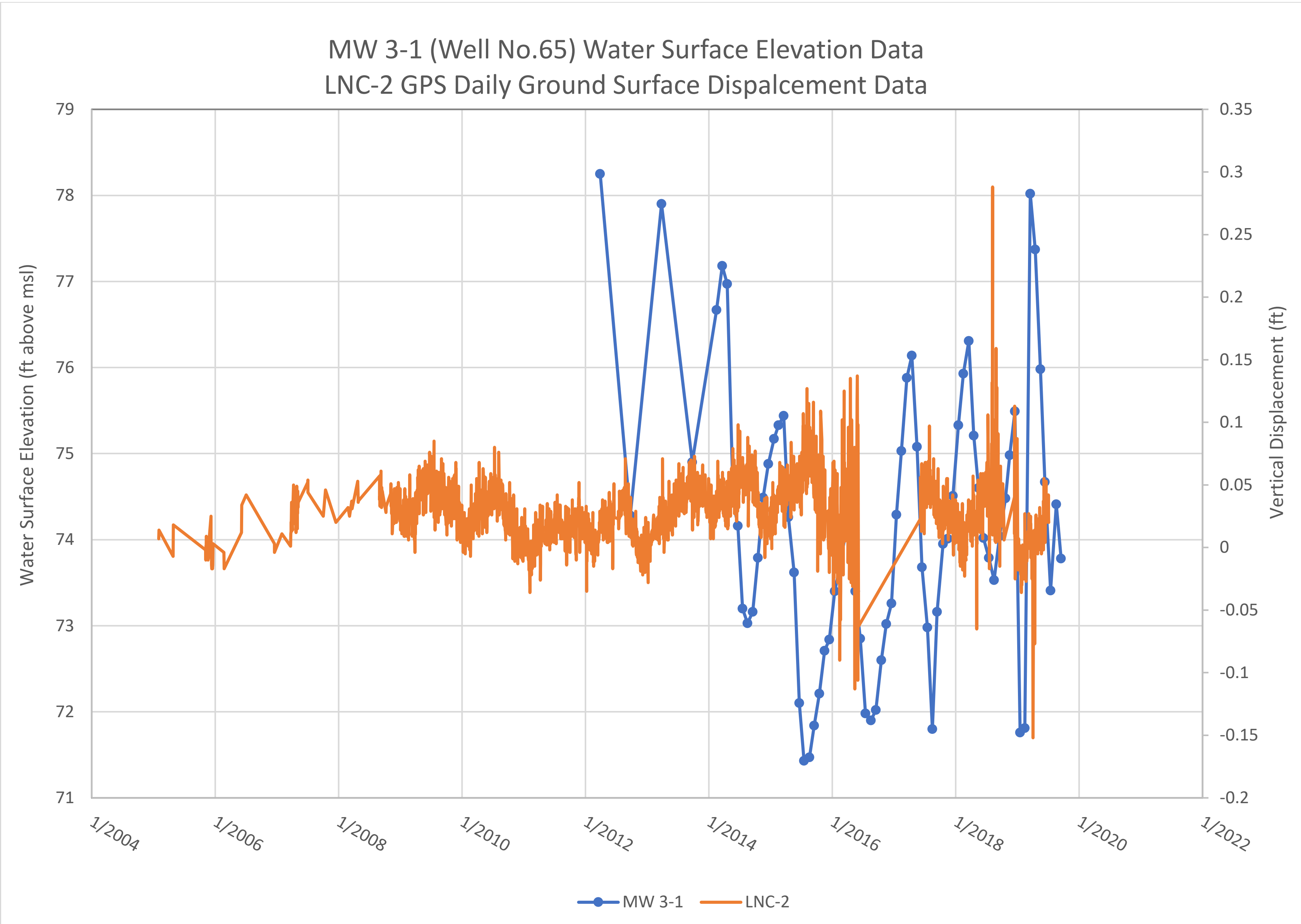

Figure 5-28. CGPS Station LCN2 versus Groundwater Levels

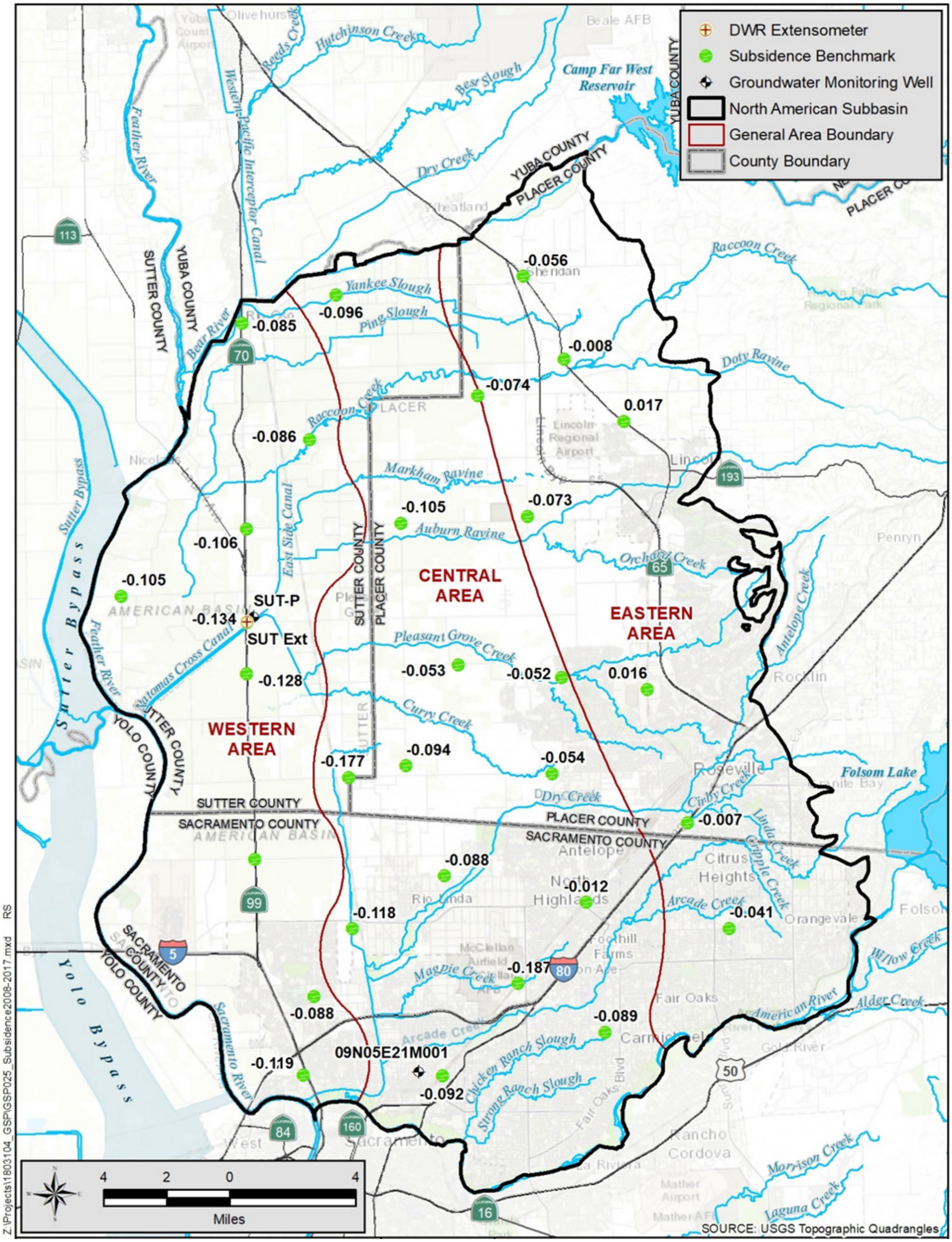

Figure 5-29. Benchmark Differences 2008-2017 (in Feet)

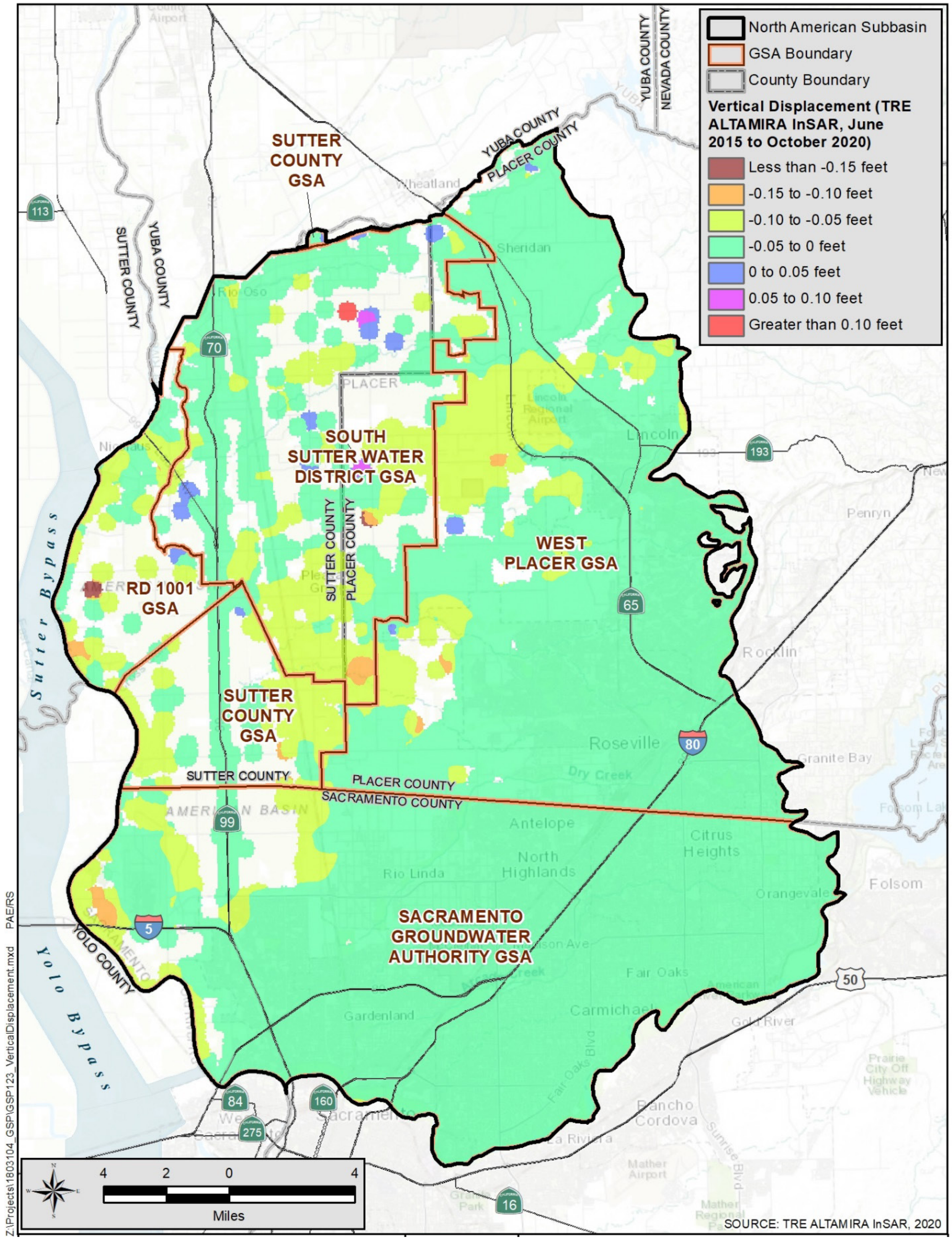

Figure 5-30. InSAR Subsidence 2015-2020 (in Feet)

5.11 Interconnected Surface Water

Interconnected surface water refers to surface water that is hydraulically connected at any point by a continuous saturated zone to the underlying aquifer and the overlying surface water is not completely depleted (DWR, 2016). In other words, all of the sediment pores in the area are filled with water, from ground surface to the groundwater table. The depth-to-water map provides an initial indication of whether the rivers and creeks are interconnected or disconnected. For purposes of this GSP, the rivers and creeks were assumed to be interconnected when the depth to water is less than 30 feet bgs (*see* **Appendix O** for description of methods used to determine depth to groundwater). In general, surface water and groundwater are considered interconnected along portions of the American, Bear, Feather, and Sacramento rivers.

Understanding interconnected surface water is important, because where this occurs lowering of groundwater levels regionally or by local pumping of groundwater has the potential to deplete surface water (to an extreme case of rivers or creeks going dry) and affect habitat and species dependent on surface water. In the NASb, California Department of Fish and Wildlife RareFind5 database, Central Valley Steelhead and Chinook Salmon are important aquatic species known to use the American, Sacramento, and Feather rivers for either spawning or migration. The species are not noted in the Bear River. Interior to the NASb, Central Valley Steelhead are noted in the Dry Creek system in western Placer County, and in Auburn Ravine in western Placer County. To get into these systems, fish migrate through Steelhead Creek and the Natomas Cross Canal, respectively, from the Sacramento River.

Monitoring wells have been constructed in the Subbasin at various locations along the rivers and creeks to evaluate the interconnectedness of surface water and groundwater based on groundwater levels and in some cases supported by water quality (stable isotopes; *refer to* **Figure 5-1** for monitoring well locations). Monitoring wells were also constructed along the Sacramento River to evaluate the levees and the effects of installation of man-made slurry walls. **Appendix N** contains the hydrographs from the wells along with surface water elevations and additional hydrographs from the levee studies.

Two patterns emerge from evaluating the groundwater level hydrographs and water quality parameters – groundwater levels that respond to changes in surface water (interconnected) and those that do not (disconnected). For example, at monitoring wells 94 and 95 (RDMW-103 and -104), groundwater levels do not respond to changes in water levels in the Bear River, and stable isotopes indicate the groundwater is from local origin and not from higher elevations in the watershed that flow through the river. The conclusion is that the river is not interconnected with groundwater at this location. Conversely, along the Feather River, at RDMW-101, the groundwater levels track similarly to water levels in the river and the stable isotopes show the influence of surface water in the groundwater (GEI, 2020).

With this documented relationship, groundwater levels in the monitoring wells adjacent to the rivers and creeks were evaluated for interconnectedness. **Figure 5-31** shows the locations where the hydrographs show the rivers and creeks are interconnected.

- In the Western area, groundwater is connected with the Sacramento and Feather rivers. Even within short distances this condition may change, as shown along the Sacramento River in studies performed for SAFCA (*see* Kleinfelder report in **Appendix N**).
- In the Central area, as described in **Section 5.2.2**, most groundwater levels are over 100 feet bgs and there is no continuous saturated zone as proven along lower Dry Creek at WPMW-5A (monitoring well number 41) where the shallow monitoring well constructed into the first sand and gravel layer is dry (the well has a screen interval from 80 to 100 feet bgs). The newly constructed WMPW-11A (monitoring well number 91), which is adjacent to Markham Ravine, also encountered groundwater during hand-auguring at about 4 feet bgs while the depth to groundwater at this location is over 70 feet bgs indicating a continuous saturated interval is not present (disconnected from the underlying aquifer). Along portions of the American and Bear rivers, the groundwater is interconnected with the rivers.
- In the Eastern area, there is interconnection along upper portions of Dry Creek and its tributaries, potentially along Auburn Ravine as it enters the Subbasin and Raccoon Creek west of Highway 65 as indicated by shallow depths to water. Studies along the upper reaches of Raccoon Creek, generally east of Highway 65, show the area is underlain by the Ione Formation and, due to its low permeability, would tend to perch water. Therefore, the surface water is not connected to the principal aquifer. East of Highway 65, near Raccoon Creek, groundwater levels decrease rapidly so the creek is not interconnected with groundwater. Groundwater levels are generally interconnected along the American River, with the exception of a segment that is disconnected near Rancho Cordova. Groundwater levels are generally interconnected along the Bear River, with the exception of a segment near well RDMW-103.

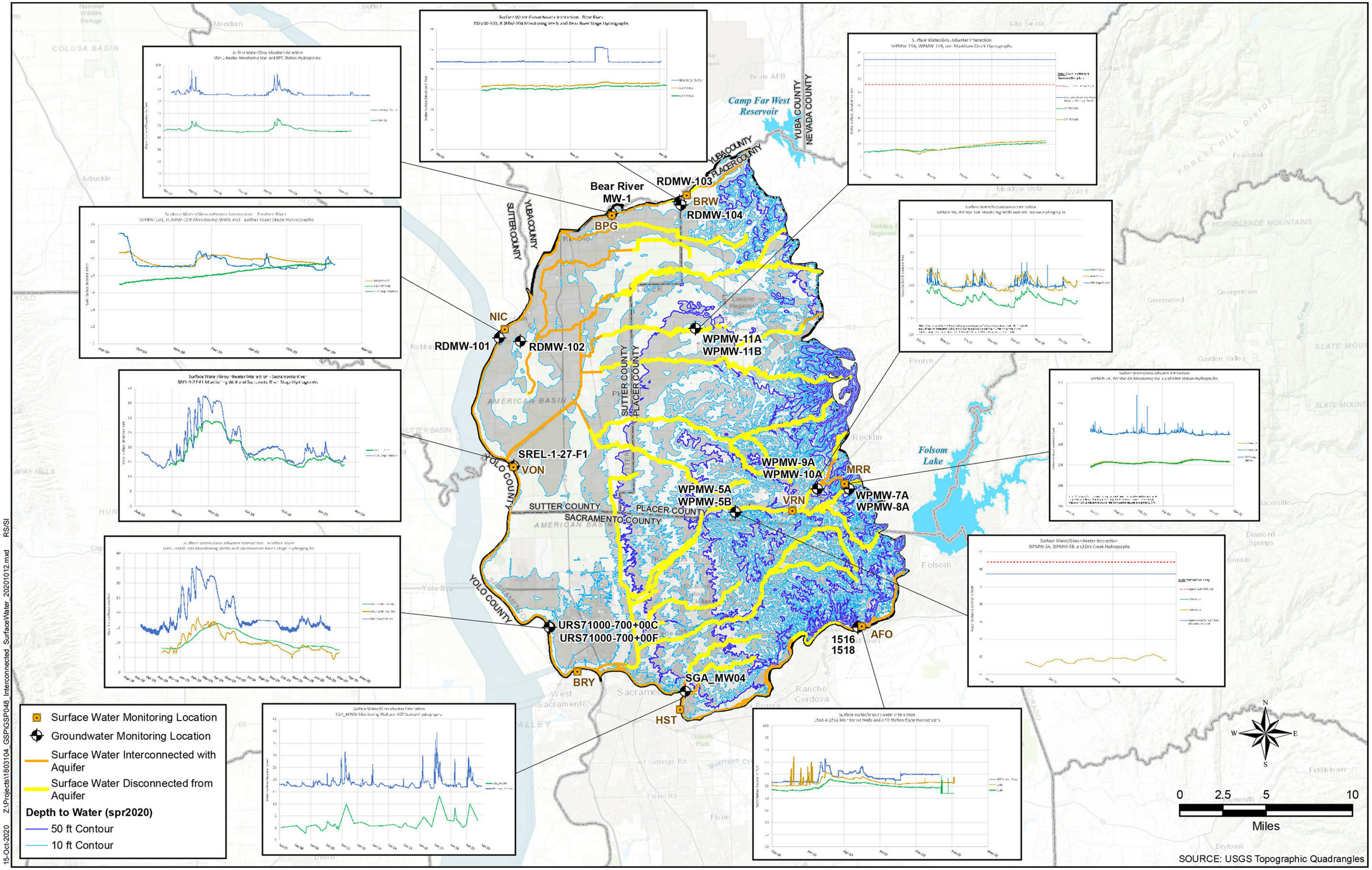

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Figure 5-31. Interconnected Surface Water

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5.12 Groundwater-Dependent Ecosystems

The Natural Communities Commonly Associated with Groundwater dataset (NCCAG, 2018) was used to provide the locations of potential GDEs. Likely GDEs were developed by plotting the depth to groundwater developed from shallow monitoring wells, those with screen intervals between 20 and 300 feet bgs along with ground surface elevations from the National Elevation Dataset and elevations of the bottom of the rivers and slough channels. Water surface elevations were then subtracted from ground surface elevations to obtain the depth to water throughout the Subbasin. Areas where groundwater levels are less than 30 feet bgs are areas where likely GDEs are present. All of the potential GDEs were then evaluated for the types of vegetation or species present to further refine whether the potential GDEs are likely, less likely or not likely to be present. **Figure 5-32** shows the results of this classification efforts. The likely and less likely GDE areas were then evaluated further based on whether critical species, diverse vegetation or a combination of both were present to prioritize those areas. **Figure 5-33** shows the results of this ranking. **Appendix O** contains a detailed description of the approach used.

The 30-foot bgs interval was used to identify GDEs, because it is associated with the overwhelming majority of GDE plant species' maximum rooting depths, and thus would most likely contain groundwater-supported priority habitat. While some Valley Oak (Quercus lobata) has been noted at rooting depths of up to 80 feet, the optimal depth is more in the vicinity of 33 feet (Howard, 1992). To better assess whether using 30 feet bgs would represent a meaningful difference in terms of identifying or protecting GDEs, a map of the occurrence of Valley Oak from the NCCAG dataset was prepared using depth intervals of less than 30 feet bgs, from 30 to 80 feet bgs, and greater than 80 feet bgs. The resulting map is shown on **Figure 5-34**. In the NASb, there are 4,335 acres identified as having Valley Oak. Of those, about 37 percent (1,618 acres) are at depths of less than 30 feet and about 44 percent (1,925 acres) are at depths between 30 and 80 feet bgs. Additionally, 18 percent (792) of Valley Oak are noted in the same channels where depth to groundwater is greater than 80 feet bgs, which would not be supported by groundwater.

For the areas that are between 30 and 80 feet bgs (shown in orange on **Figure 5-34),** note that almost all Valley Oak is located along creeks, ravines, and rivers. Auburn Ravine, Pleasant Grove Creek, and Dry Creek all receive year-round flows from wastewater treatment plants (see **Figure 3-12**) and other urban runoff, Arcade Creek has year-round flow associated with urban runoff based on records from the Sacramento County stormwater monitoring program, and the American River has year-round flow as managed by the Bureau of Reclamation. Based on this occurrence data, the NASb GSAs believe that the Valley Oak occurring at greater than 30 feet bgs is maintained by surface water flow and is not groundwater supported.

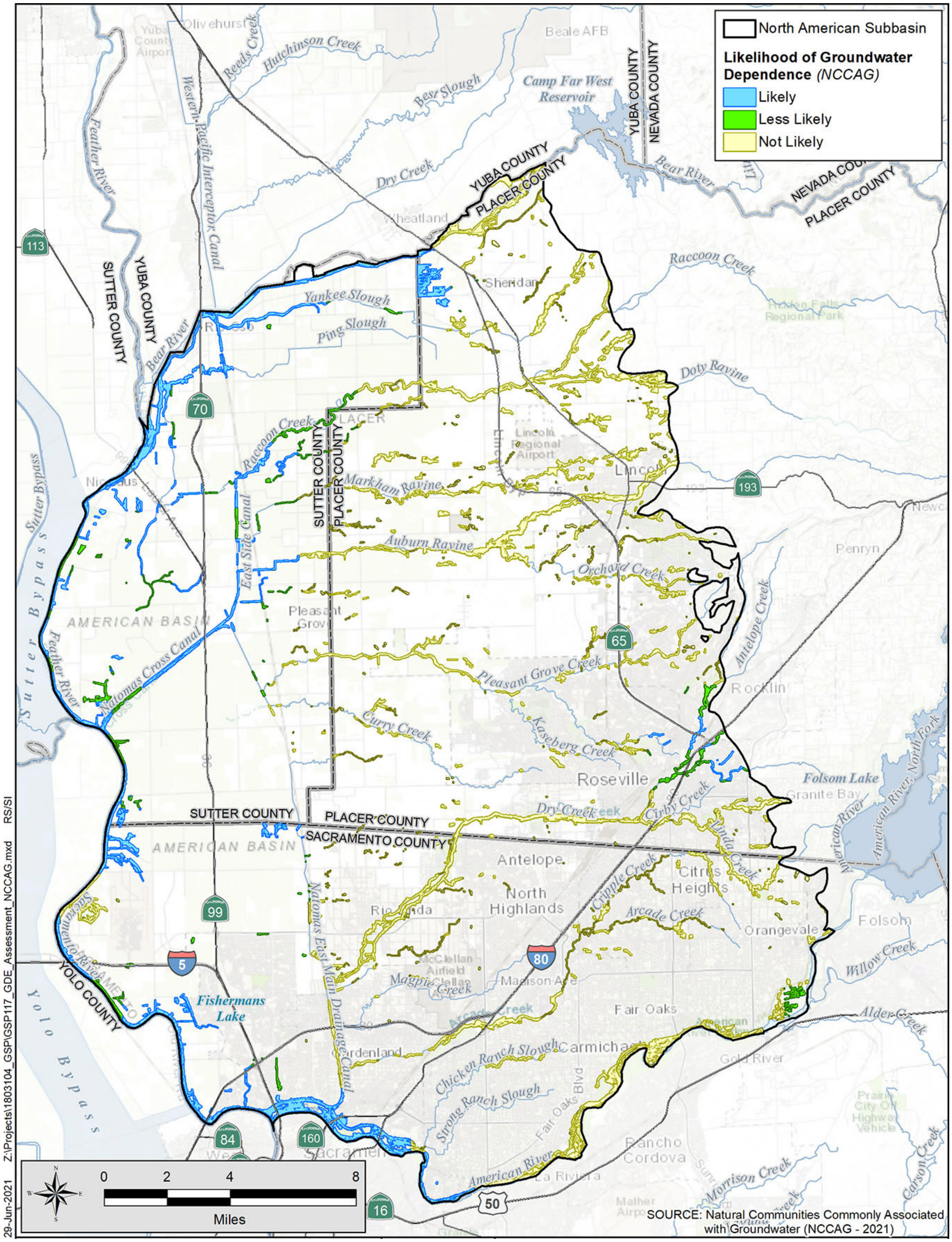

Figure 5-32. Likely Groundwater Dependent Ecosystems

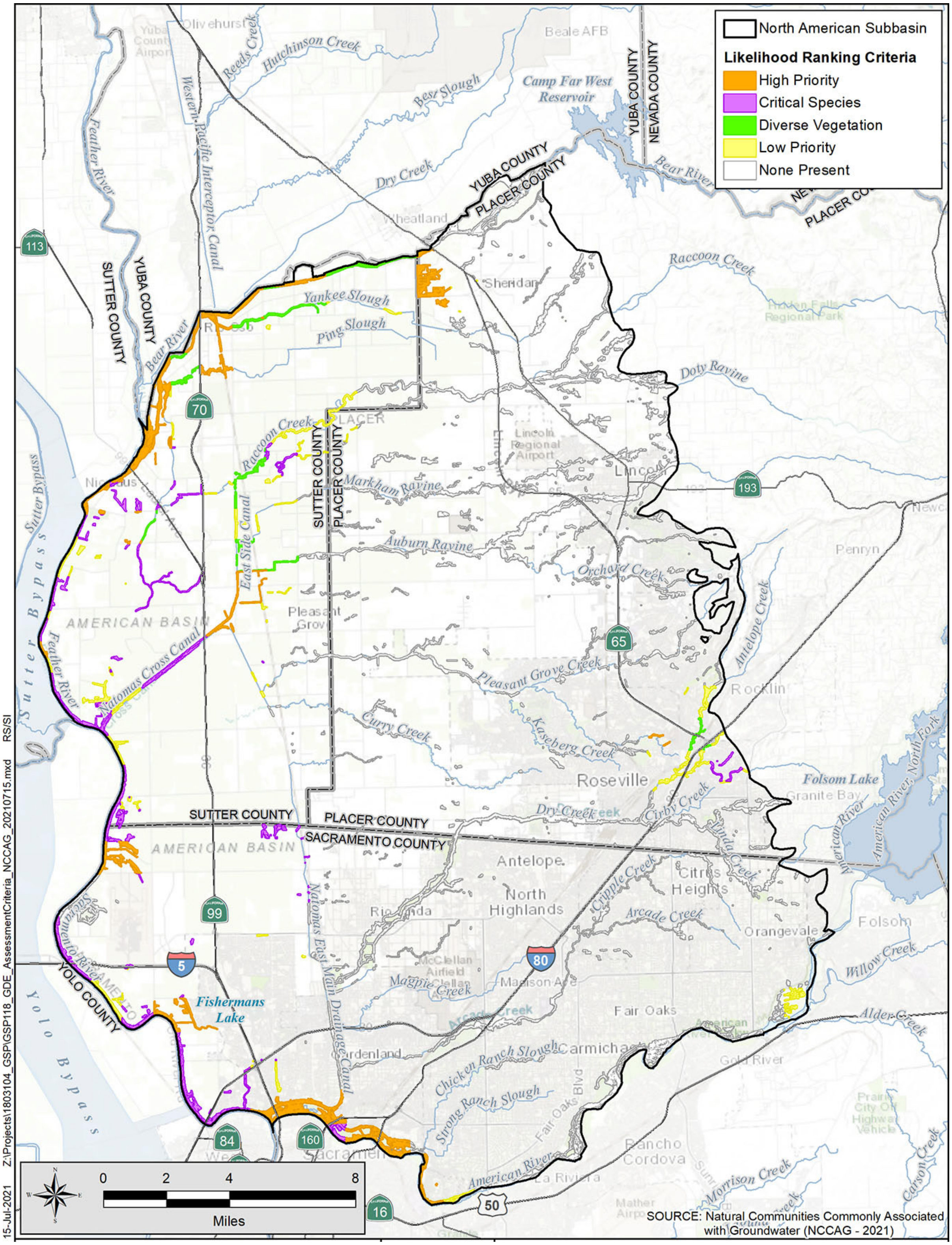

Figure 5-33. Rankings of Likely and Less Likely GDE Areas

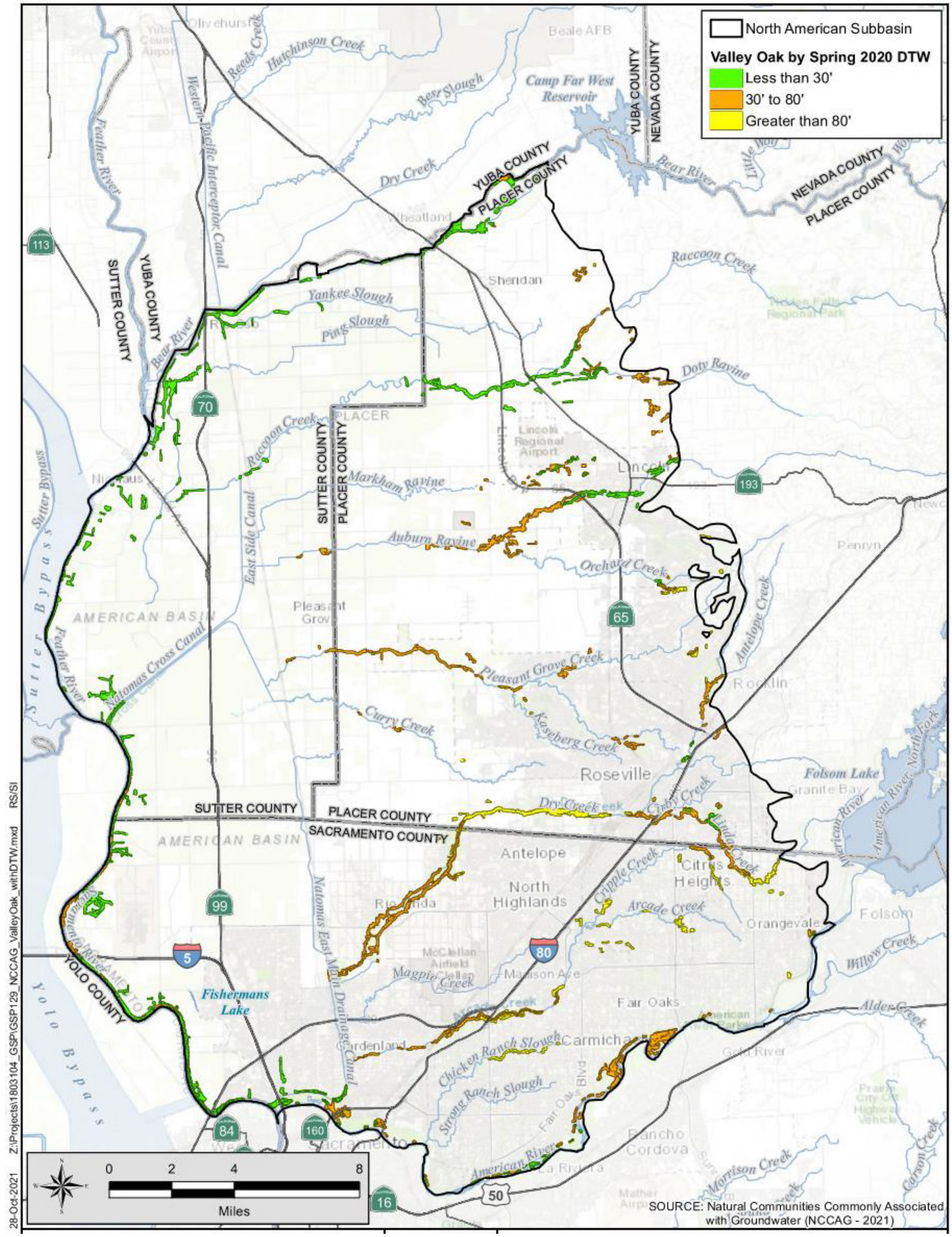

Figure 5-34. Occurrence of Quercus Lobata (Valley Oak)

5.13 Data Gaps

The groundwater conditions in the NASb have been investigated and documented since at least 1912 through present. Most of the recent improvements to data gathering were the construction of new monitoring wells to replace voluntary wells to improve the quality of groundwater level data. At this time, there are no data gaps in the understanding of groundwater conditions that would affect the ability to sustainably manage the Subbasin.

Information that would improve the overall knowledge of groundwater conditions in the Subbasin are:

- **Water Quality** – continued water quality sampling should provide enough water quality data to further assess water quality trends in the northern portions of the Subbasin.
- **Aquifers Assessment** – groundwater levels in the aquifers are stable as shown by the hydrographs but warrant further assessment in the Western area because groundwater levels in deeper nested monitoring wells in the Mehrten Formation are up to 23 feet deeper than groundwater levels in the Laguna Formation as seen in most monitoring wells in the Central and Eastern areas. Further evaluation could include the following:
    - groundwater pumping in adjacent Subbasins in the deeper aquifers
    - relation of the Willows Fault to the affected aquifers
    - use of new geophysical tools to map the extent of aquifers (statewide program proposed by DWR)
- **Interconnected Surface Water –** confirmation of areas likely to be interconnected.

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