Section 5

Basin Setting

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5. BASIN SETTING

5.1 OVERVIEW

The Basin Setting chapter to the Northern & Central Delta-Mendota Region Groundwater Sustainability Plan (GSP) contains information about the physical setting and hydrogeologic characteristics of the Northern and Central Delta-Mendota Regions, as well as current condition of the basin and anticipated future conditions. The basin setting serves as a basis for defining and assessing reasonable sustainable management criteria and projects and management actions. This chapter includes four main sections that are pursuant to the GSP Emergency Regulations Article 5. Plan Contents, Subarticle 2. Basin Setting (§ 354.12 – 354.20):

- **Hydrogeologic Conceptual Model (HCM) –** The HCM section (**Section 5.2**) provides the geologic and hydrogeologic information needed to understand how water moves throughout the Plan area and the Delta-Mendota Subbasin. This section includes information about geological formations, aquifers, structural features, and topography.
- **Groundwater Conditions –** The Groundwater Conditions section (**Section 5.3**) describes historical groundwater conditions in the Plan area, including data from January 1, 2015 to recent conditions. Groundwater trends, groundwater levels, hydrographs, contour maps, estimated change in groundwater storage, groundwater quality issues, land subsidence, and interconnected surface water systems over historical conditions through present day are presented in this section.
- **Water Budget –** The Water Budget section (**Section 5.4**) describes the data used to develop the required historic water budget, current water budget, and projected water budgets. This section also discusses the methods used in developing estimates for each water budget scenario. Sustainable yield is also described in this section.
- **Management Areas –** The Management Area section (**Section 5.5**) describes the management areas established to facilitate implementation of the GSP and how setting different sustainable management criteria than the Plan area avoids undesirable results and aids in achieving sustainability in the Subbasin by 2040.

5.2 HYDROGEOLOGIC CONCEPTUAL MODEL

This section describes the hydrogeologic conceptual model (HCM) for the Delta-Mendota Subbasin primarily as a whole based on technical studies and qualified maps that characterize the physical components and interaction of the surface water and groundwater systems, pursuant to Article 5 Plan Contents, Subarticle 2 Basin Setting, § 354.14 Hydrogeologic Conceptual Model of the Groundwater Sustainability Plan (GSP) Emergency Regulations. The physical description of the Delta-Mendota Subbasin included in this section is based on information originally published in the *Western San Joaquin River Watershed Groundwater Quality Assessment Report* (GAR) (Luhdorff & Scalmanini, 2015), *Grassland Drainage Area Groundwater Quality Assessment Report* (Luhdorff & Scalmanini, 2016), and *Groundwater Overdraft in the Delta-Mendota Subbasin* (Schmidt, 2015).

The Northern and Central Delta-Mendota Regions generally include the northern quarter of the Subbasin, the western margin of the central portion of the Subbasin (including the larger portion of the Subbasin near the southwestern boundary and within San Benito County), and the southern tip of the Subbasin (in the Tranquillity area). Due to the disperse nature of the areas covered by this GSP, the HCM presented below has been prepared predominantly on a Subbasin level.

5.2.1 Regional Geologic and Structural Setting

The Delta-Mendota Subbasin is located in the northwestern portion of the San Joaquin Valley Groundwater Basin within the southern portion of the Central Valley (**Figure 5-1**). The San Joaquin Valley is a structural trough up to 200 miles long and 70 miles wide filled with up to 32,000 feet of marine and continental sediments deposited during periodic inundation by the Pacific Ocean and by erosion of the surrounding Sierra Nevada and Coast Range mountains, respectively (DWR, 2006). Continental deposits shed from the surrounding mountains form an alluvial wedge that thickens from the valley margins toward the axis of the structural trough. This depositional axis is slightly west of the series of rivers, lakes, sloughs, and marshes which mark the current and historic axis of surface drainage in the San Joaquin Valley.

The Delta-Mendota Subbasin (California Department of Water Resources [DWR] Basin No. 5-22.07) is bounded on the west by the tertiary and older marine sediments of the Coast Ranges, on the north generally by the San Joaquin-Stanislaus County line, on the east generally by the San Joaquin River and Fresno Slough, and on the south by the Tranquillity Irrigation District boundary near the community of San Joaquin. Surface waters culminate from the Fresno, Merced, Tuolumne, and Stanislaus Rivers into the San Joaquin River, which drains toward the Sacramento-San Joaquin Delta.

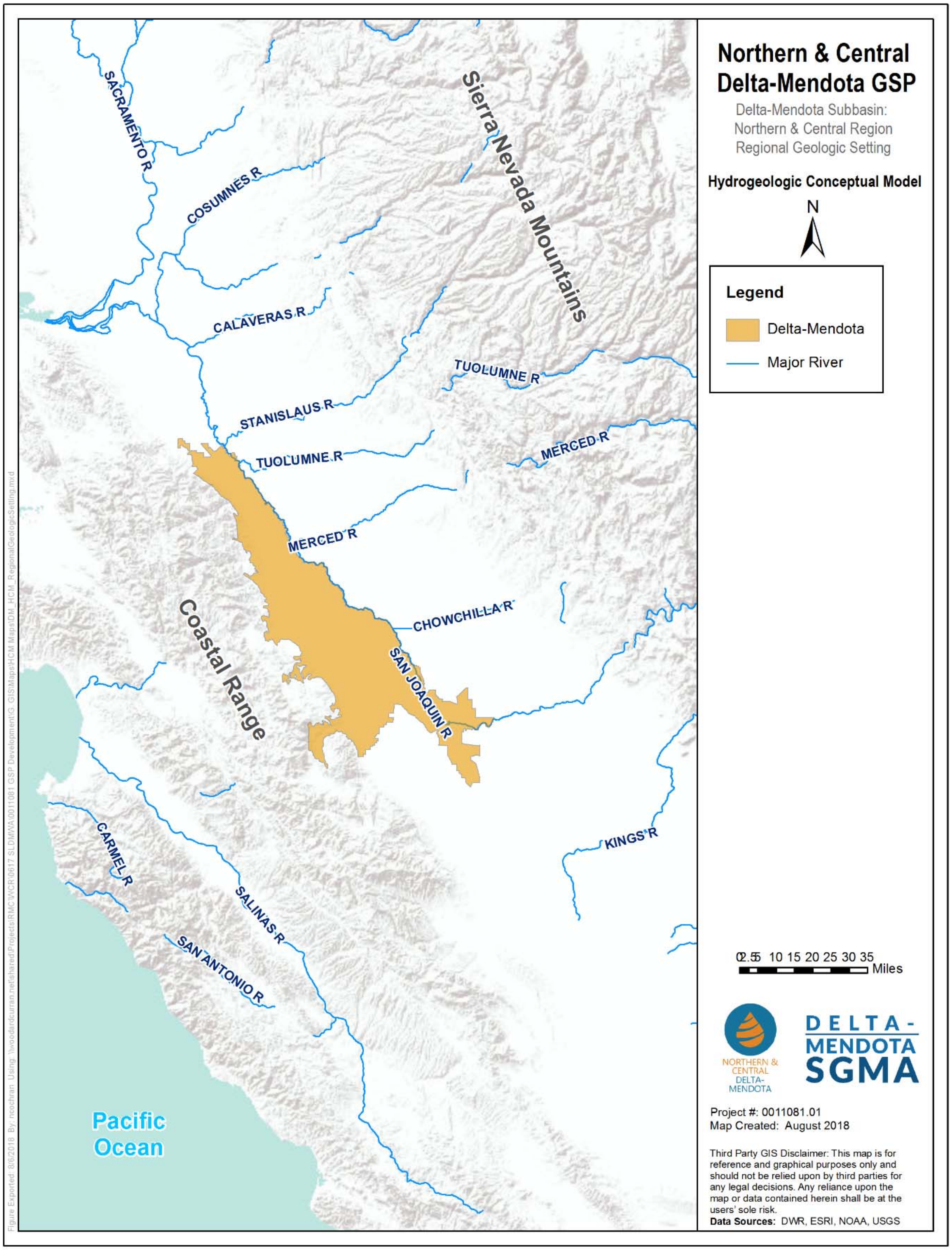

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Figure 5-1. Regional Geologic Setting, Delta-Mendota Subbasin

5.2.2 Geologic History

Approximately three million years ago, tectonic movement of the Oceanic and Continental plates associated with the San Andreas Fault system gave rise to the Coast Range which sealed off the Central Valley from the Pacific Ocean (LSCE, 2015). As this occurred, the floor of the San Joaquin Valley began to transition from a marine depositional environment to a freshwater system with ancestral rivers bringing alluvium to saltwater bodies (Mendenhall et al., 1916). The Coast Ranges on the western side of the San Joaquin Valley consist mostly of complexly folded and faulted consolidated marine and non-marine sedimentary and crystalline rocks ranging from Jurassic to Tertiary age (**Figure 5-2**), dipping eastward and overlying the basement complex in the region (Croft, 1972; Hotchkiss and Balding, 1971). The Central Valley Floor within the Delta-Mendota Subbasin consists of Tertiary and Quaternary-aged alluvial and basin fill deposits (**Figure 5-2** and **Figure 5-3**). The fill deposits mapped throughout much of the valley extend vertically for thousands of feet, and the texture of sediments varies in the east-west direction across the valley. Coalescing alluvial fans have formed along the sides of the valley created by the continuous shifting of distributary stream channels over time. This process has led to the development of thick fans of generally coarse texture along the margins of the valley and a generally fining texture towards the axis of the valley (Faunt et al., 2009 and 2010).

Deposits of Coast Range and Sierra Nevada sources interfinger within the Delta-Mendota Subbasin. Steeper fan surfaces, with slopes as high as 80 feet per mile, exist proximal to the Coast Range, whereas more distal fan surfaces consist of more gentle slopes of 20 feet per mile (Hotchkiss and Balding, 1971). In contrast to the east side of the valley, the more irregular and ephemeral streams on the western side of the valley floor have less energy and transport smaller volumes of sediment resulting in less developed alluvial features, including alluvial fans, which are less extensive, although steeper, than alluvial fan features on the east side of the valley (Bertoldi et al., 1991). Lacustrine and floodplain deposits also exist closer to the valley axis as thick silt and clay layers. Lakes present during the Pleistocene epoch in parts of the San Joaquin Valley deposited great thicknesses of clay sediments.

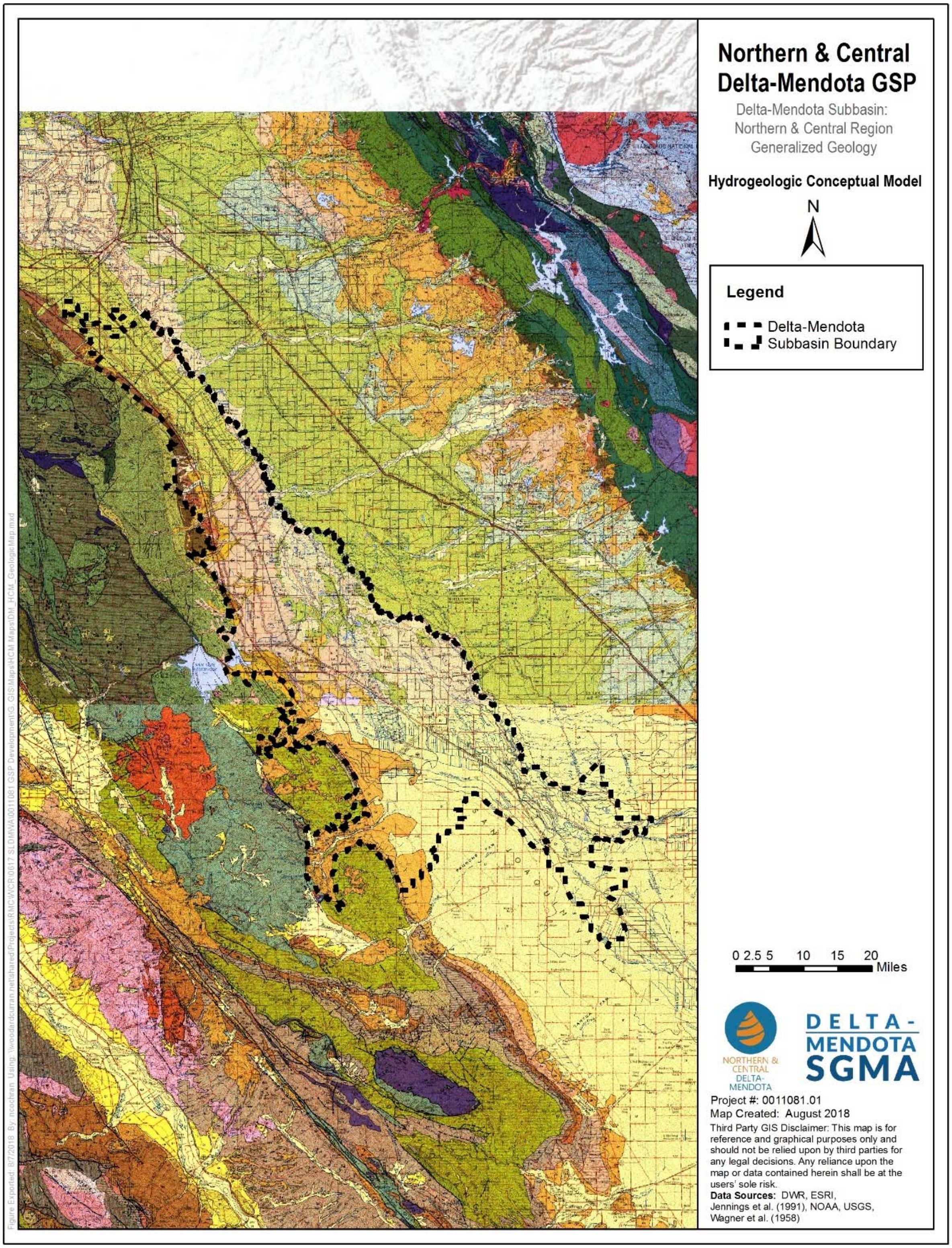
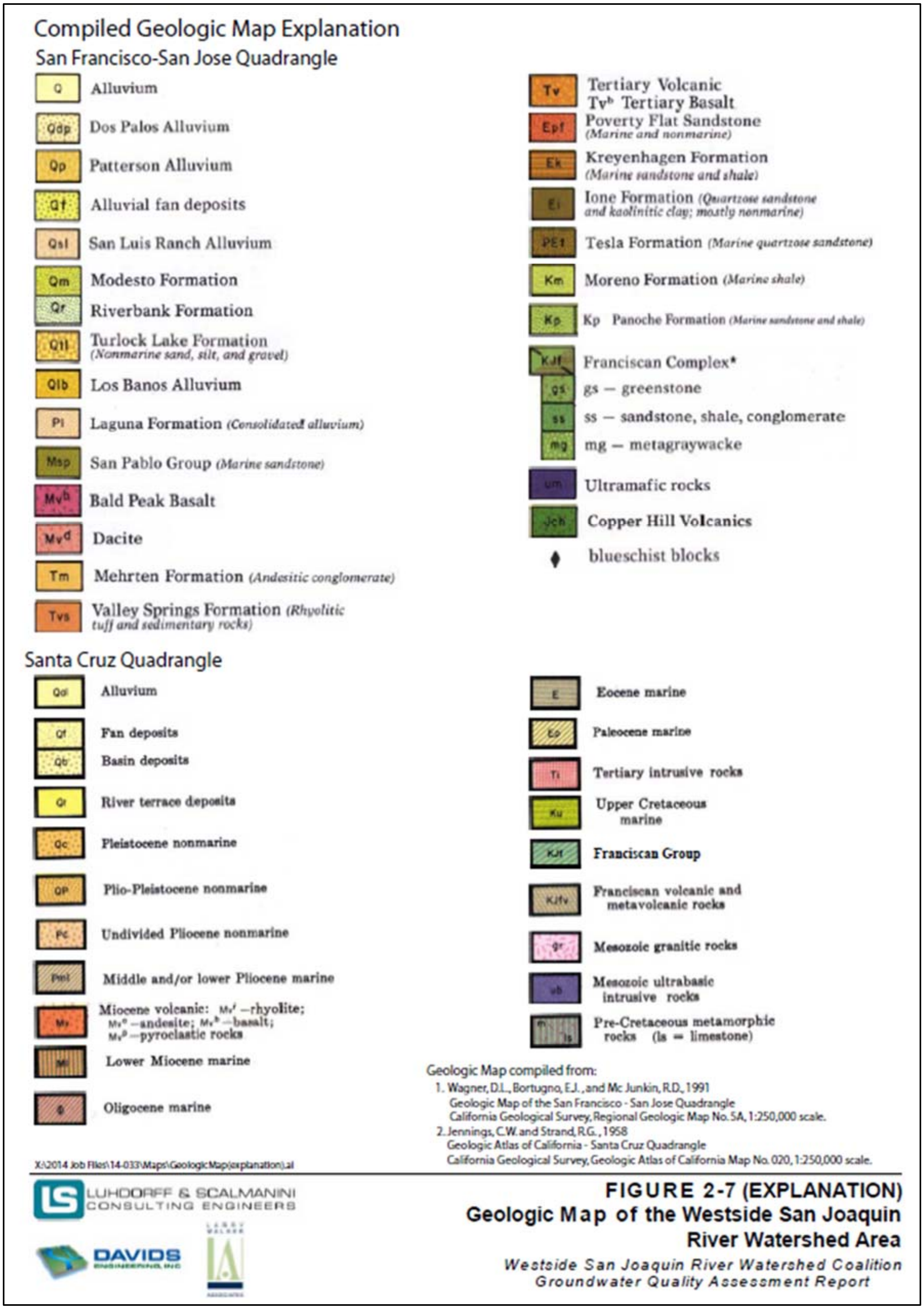


Figure 5-2. Geologic Map, Delta-Mendota Subbasin



Compiled Geologic Map Explanation

San Francisco-San Jose Quadrangle

Q	Alluvium
Qdp	Dos Palos Alluvium
Qp	Patterson Alluvium
Qf	Alluvial fan deposits
Qsl	San Luis Ranch Alluvium
Qm	Modesto Formation
Qr	Riverbank Formation
Qtl	Turlock Lake Formation *(Nonmarine sand, silt, and gravel)*
Qlb	Los Banos Alluvium
Pl	Laguna Formation *(Consolidated alluvium)*
Msp	San Pablo Group *(Marine sandstone)*
Mv^b	Bald Peak Basalt
Mv^d	Dacite
Tm	Mehrten Formation *(Andesitic conglomerate)*
Tvs	Valley Springs Formation *(Rhyolitic tuff and sedimentary rocks)*
Tv	Tertiary Volcanic Tv^b Tertiary Basalt
Epf	Poverty Flat Sandstone *(Marine and nonmarine)*
Ek	Kreyenhagen Formation *(Marine sandstone and shale)*
Ei	Ione Formation *(Quartzose sandstone and kaolinitic clay; mostly nonmarine)*
PEt	Tesla Formation *(Marine quartzose sandstone)*
Km	Moreno Formation *(Marine shale)*
Kp	Kp Panoche Formation *(Marine sandstone and shale)*
KJf	Franciscan Complex*
gs	gs — greenstone
ss	ss — sandstone, shale, conglomerate
mg	mg — metagraywacke
um	Ultramafic rocks
Jch	Copper Hill Volcanics
♦	blueschist blocks

Santa Cruz Quadrangle

Qal	Alluvium
Qf	Fan deposits
Qb	Basin deposits
Qt	River terrace deposits
Qc	Pleistocene nonmarine
QP	Plio-Pleistocene nonmarine
Pc	Undivided Pliocene nonmarine
Pml	Middle and/or lower Pliocene marine
Mv	Miocene volcanic: Mv^r —rhyolite; Mv^a —andesite; Mv^b —basalt; Mv^p —pyroclastic rocks
Ml	Lower Miocene marine
Φ	Oligocene marine
E	Eocene marine
Ep	Paleocene marine
Ti	Tertiary intrusive rocks
Ku	Upper Cretaceous marine
KJf	Franciscan Group
KJfv	Franciscan volcanic and metavolcanic rocks
gr	Mesozoic granitic rocks
ub	Mesozoic ultrabasic intrusive rocks
m ls	Pre-Cretaceous metamorphic rocks (ls = limestone)

Geologic Map compiled from:

1. Wagner, D.L., Bortugno, E.J., and Mc Junkin, R.D., 1991
   Geologic Map of the San Francisco - San Jose Quadrangle
   California Geological Survey, Regional Geologic Map No. 5A, 1:250,000 scale.
2. Jennings, C.W. and Strand, R.G., 1958
   Geologic Atlas of California - Santa Cruz Quadrangle
   California Geological Survey, Geologic Atlas of California Map No. 020, 1:250,000 scale.

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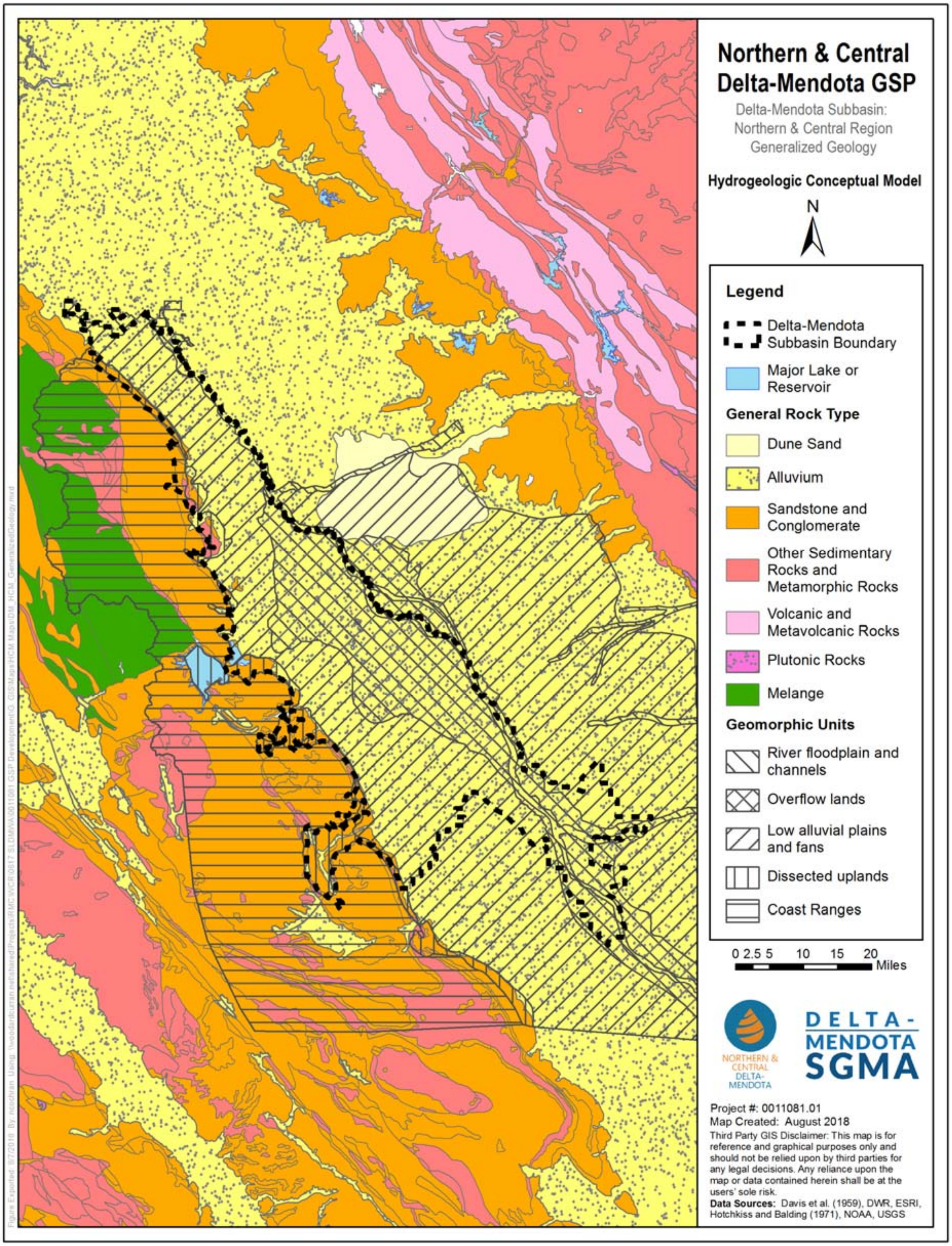
LUHDORFF & SCALMANINI CONSULTING ENGINEERS

DAVIDS ENGINEERING, INC

LARRY WALKER ASSOCIATES

FIGURE 2-7 (EXPLANATION)
Geologic Map of the Westside San Joaquin River Watershed Area
Westside San Joaquin River Watershed Coalition
Groundwater Quality Assessment Report

Figure 5-2. Geologic Map, Delta-Mendota Subbasin (continued)



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Data Sources: Davis et al. (1959), DWR, ESRI, Hotchkiss and Balding (1971), NOAA, USGS

Figure 5-3. Generalized Geology, Delta-Mendota Subbasin

5.2.3 Geologic Formations and Stratigraphy

Distinct geomorphic units exist within the Delta-Mendota Subbasin, defining areas of unique hydrogeologic environments. The geomorphic units are mapped and described by Hotchkiss and Balding (1971) and Davis et al. (1959) and are shown in Figure 5-3. The two primary geomorphic units within the Central Valley Floor area of the Delta-Mendota Subbasin include the overflow lands geomorphic unit and the alluvial fans and plains geomorphic unit. Overflow lands are defined as areas of relatively poorly draining soils with a shallow water table. The overflow lands geomorphic unit is located in the southeastern portion of the Subbasin and is dominated by finer-grained floodplain deposits that are the result of historical episodic flooding of this low-land area. This has formed poorly draining soils with generally low hydraulic conductivity characteristics. In contrast, the alluvial fans and plains geomorphic unit is characterized by relatively better drainage conditions, with sediments comprised of coalescing and somewhat coarser-grained alluvial fan materials deposited by higher-energy streams flowing out of the Coast Range (Hotchkiss and Balding, 1971). The alluvial fans and plains geomorphic unit covers much of the Delta-Mendota Subbasin along the western margins of the Central Valley Floor at the base of the Coast Range.

The primary groundwater bearing units within the Delta-Mendota Subbasin consist of Tertiary and Quaternary-aged unconsolidated continental deposits and older alluvium of the Tulare Formation. Subsurface hydrogeologic materials covering the Central Valley Floor consist of lenticular and generally poorly sorted clay, silt, sand, and gravel that make up the alluvium and Tulare Formation. These deposits are thickest along the axis of the valley with thinning along the margins towards the Coast Range mountains (DWR, 2003; Hotchkiss and Balding, 1971). A zone of very shallow groundwater, generally within 25 feet of the ground surface, exists throughout large areas of the Subbasin, with considerable amounts (greater than 50 percent) of farmland in the area estimated to have very shallow depths to groundwater of less than 10 feet (Hotchkiss and Balding, 1971). Many of these areas are naturally swampy lands adjacent to the San Joaquin River.

The Tulare Formation extends to several thousand feet deep and to the base of freshwater throughout most of the area and consists of interfingered sediments ranging in texture from clay to gravel of both Sierra Nevadan and Coast Range origin. The formation is composed of beds, lenses, and tongues of clay, sand, and gravel that have been alternatively deposited in oxidizing and reducing environments (Hotchkiss and Balding, 1971). Terrace deposits of Pleistocene age lie up to several feet higher than present streambeds and are comprised of yellow, tan, and light-to-dark brown silt, sand, and gravel with a matrix that varies from sand to clay (Hotchkiss and Balding, 1971). The water table generally lies below the bottom of the terrace deposits; however, the relatively large grain size of the terrace deposits suggests their value as possible recharge sites. Alluvium is composed of interbedded, poorly to well-sorted clay, silt, sand, and gravel and is divided based on its degree of dissection and soil formation. The flood-basin deposits are generally composed of light-to-dark brown and gray clay, silt, sand, and organic material with locally high concentrations of salt and alkali. Stream channel deposits of coarse sand and gravel are also included.

The Tulare Formation also includes the Corcoran Clay (E-Clay) member, a diatomaceous clay or silty clay of lake bed origin which is a prominent aquitard in the San Joaquin Valley, separating the upper zone from the lower zone and distinguishing the semi-confined Upper Aquifer from the confined Lower Aquifer (Hotchkiss and Balding, 1971). However, the depth and thickness of the Corcoran Clay are variable within the Central Valley Floor, and it is not present in peripheral areas (outside the Central Valley Floor) of the Subbasin. Within the Upper Aquifer, additional clay layers exist within the upper zone and also provide varying degrees of confinement, including other clay members of the Tulare Formation and layers of white clay identified by Hotchkiss and Balding (1971). These clays are variable in extent and thickness, but the white clay is noted to be as much as 100 feet thick in areas providing very effective confinement of underlying zones (Croft, 1972; Hotchkiss and Balding, 1971). The Tulare Formation is hydrologically the most important geologic formation in the Delta-Mendota Subbasin because it contains most of the fresh water-bearing deposits. Most of the natural recharge that occurs in the Subbasin is in the alluvial fan apex areas along Coast Range stream channels (Hotchkiss and Balding, 1971).

5.2.4 Faults and Structural Features

The valley floor portion of the Delta-Mendota Subbasin contains no major faults and is fairly geologically inactive. There are few faults along the western boundary of the Subbasin within the Coast Range mountains, but they are not known to inhibit groundwater flow or impact water conveyance infrastructure (Figure 5-4).

5.2.5 Basin Boundaries

The Delta-Mendota Subbasin is defined by both geological and jurisdictional boundaries. The Delta-Mendota Subbasin borders all subbasins within the San Joaquin Valley Groundwater Basin with the exception of the Cosumnes Subbasin (Figure 5-5). The following subsections describe the lateral boundaries of the Subbasin, boundaries with neighboring subbasins, and the definable bottom of the Delta-Mendota Subbasin.

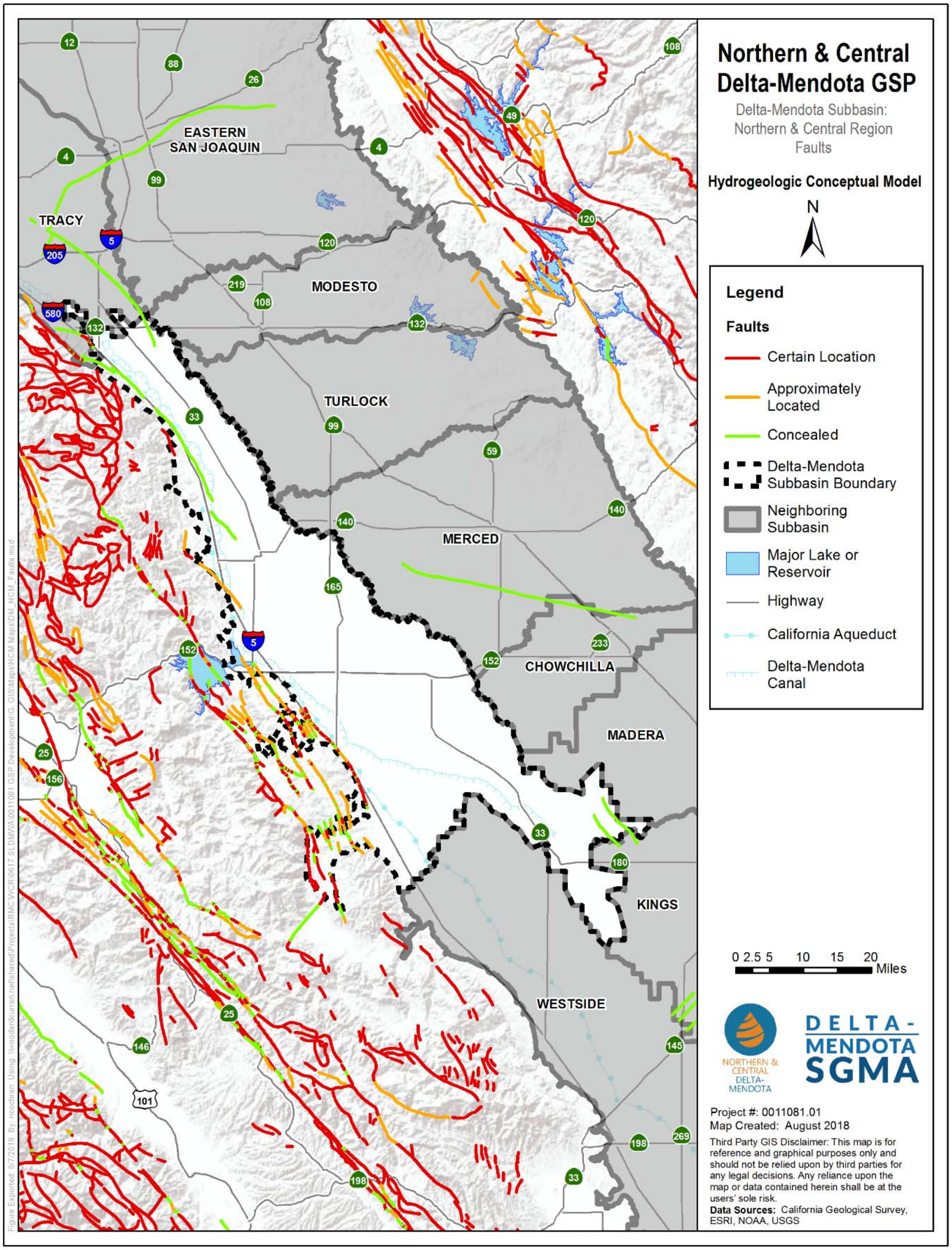
5.2.5.1 Lateral Boundaries

The Delta-Mendota Subbasin is geologically and topographically bounded to the west by the Tertiary and older marine sediments of the Coast Ranges, and to the east generally by the San Joaquin River. The northern, central, and southern portion of the eastern boundary are dictated by jurisdictional boundaries of water purveyors within the Delta-Mendota Subbasin.

The northern boundary (from west to east) of the Delta-Mendota Subbasin begins on the west by following the Stanislaus County/San Joaquin County line, then deviates to the north to encapsulate all of the Del Puerto Water District before returning back to the Stanislaus County/San Joaquin County line. The boundary continues east, and then deviates north again to encapsulate all of the West Stanislaus Irrigation District before returning back to the Stanislaus County/San Joaquin County line. The boundary continues to follow the Stanislaus County/San Joaquin County line east until it intersects with the San Joaquin River.

The southern boundary of the Subbasin (from east to west) matches the northerly boundaries of the Westlands Water District legal jurisdictional boundary as last revised in 2006. The boundary then proceeds west along the southernmost boundary of San Luis Water District. The boundary projects westward from this alignment until intersecting the Delta-Mendota Subbasin western boundary delineated by the extent of the Tertiary and older marine sediments.

The eastern boundary (from north to south) follows the San Joaquin River to within Township 11S, where it jogs eastward along the northern boundary of Columbia Canal Company. From there, the boundary continues along the eastern boundary of Columbia Canal Company until intersecting the northern boundary of the Aliso Water District. The boundary then heads east following the northern and then eastern boundary of the Aliso Water District until intersecting the Madera County/Fresno County line. The boundary then heads westerly following the Madera County/Fresno County line to the eastern boundary of the Farmers Water District. The boundary then continues southerly along the eastern boundary of the Farmers Water District and then southerly along the section line to the intersection with the railway lines. The boundary then heads east along the railway line until intersecting with the western boundary of the Mid-Valley Water District. The boundary then heads south along the western boundary of the Mid-Valley Water District to the intersection with the northern boundary of Reclamation District 1606. From there, the boundary heads west and then south following the boundary of Reclamation District 1606 and James Irrigation District until its intersection with the Westlands Water District boundary.



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Data Sources: California Geological Survey, ESRI, NOAA, USGS

Figure 5-4. Faults, Delta-Mendota Subbasin

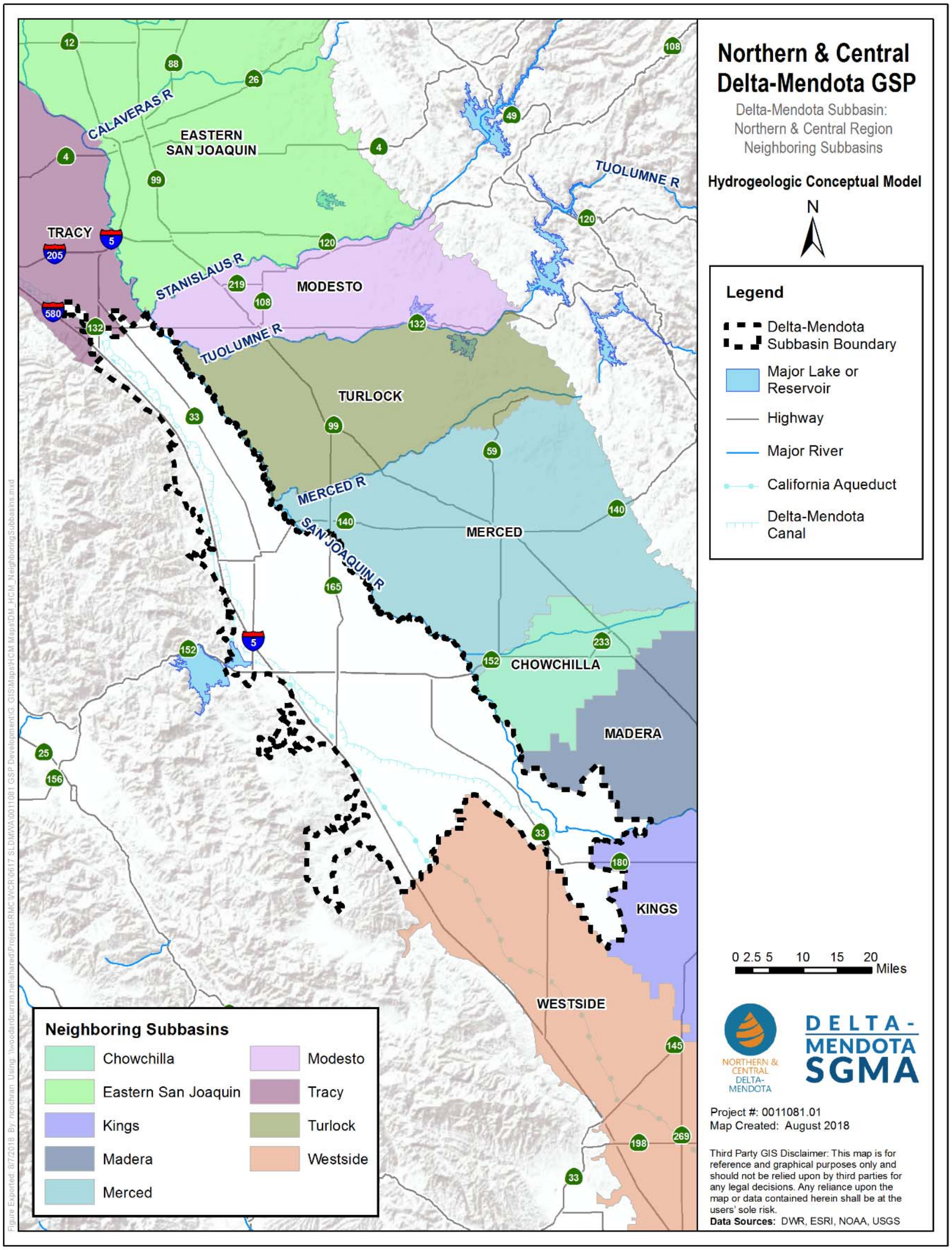

Figure 5-5. Neighboring Subbasins, San Joaquin Valley Groundwater Basin

5.2.5.2 Definable Bottom of Basin

In the San Joaquin Valley, the bottom of the Delta-Mendota Subbasin is typically defined as the interface of saline water of marine origin within the uppermost beds of the San Joaquin Formation. The San Joaquin Formation is characterized by blue and green fine-grained rocks and principally composed of fine-grained silty sands, silt, and clay (Foss and Blaisdell 1968). The San Joaquin Formation is predominantly marine in origin and is considered late Pliocene and possibly early Pleistocene in age. This formation is the upper shaley part of the Pliocene sequence. The top of the San Joaquin Formation is generally encountered around -2,000 feet above mean sea level throughout the Delta-Mendota Subbasin. For the purposes of this GSP, the base of freshwater is defined by a total dissolved solids (TDS) concentration of 3,000 micromhos per centimeter at 25 °C (or about 2,000 mg/L), as presented by Page (1973).

5.2.6 Principal Aquifers and Aquitards

DWR's Groundwater Glossary defines an aquifer as "a body of rock or sediment that is sufficiently porous and permeable to store, transmit, and yield significant or economic quantities of groundwater to wells, and springs". There are two primary aquifers within the Delta-Mendota Subbasin: a semi-confined aquifer above the Corcoran Clay and a confined aquifer below the Corcoran Clay, with the Corcoran Clay acting as the principal aquitard within the Delta-Mendota Subbasin. Figure 5-6 shows the locations of the representative cross-sections for the Northern & Central Delta-Mendota Region GSP Plan area, where Figure 5-7 through Figure 5-16 show the hydrostratigraphy of the representative cross-sections.

While the two-aquifer system described above is generally true across the Delta-Mendota Subbasin, there are portions of the basin where the Corcoran Clay does not exist (predominantly along the western margin of the Subbasin) and hydrogeology is generally controlled by localized interfingering clays, and/or where local hydrostratigraphy results in shallow groundwater conditions that differ, to some extent, from that seen in the Subbasin as a whole. Additionally, in the southern portion of the Subbasin in the Mendota and Tranquillity areas, there are A and C Clay layers in addition to the Corcoran Clay that inhibit groundwater flow. However, while there are localized complexities throughout the Subbasin, the Corcoran Clay (or E Clay) extends through much of the Delta-Mendota Subbasin generally creating a two-aquifer system.

5.2.6.1 Principal Aquifers

In the Delta-Mendota Subbasin, there are two primary aquifers composed of alluvial deposits separated by the Corcoran Clay (Schmidt, 2015): a semi-confined Upper Aquifer zone (generally the ground surface to the top of the Corcoran Clay), and a confined Lower Aquifer zone starting at the bottom of the Corcoran Clay to the base of fresh water. However, as previously described, the localized presence of the A and C Clay layers in the southern portion of the Subbasin, the absence of the Corcoran Clay at the western margin of the Subbasin and/or local hydrostratigraphy result in differing shallow groundwater conditions and/or perched groundwater conditions in some portions of the Subbasin. To this end, in addition the descriptions of the two principal aquifers in the Delta-Mendota Subbasin, a description of 'Very Shallow Unconfined Groundwater' is also provided for those portions of the basin where such conditions are present.

Upper Aquifer

The Upper Aquifer is represented by materials extending from the upper groundwater table to the top of the Corcoran Clay. The Upper Aquifer includes shallow geologic units of younger and older alluvium and upper parts of the Tulare Formation. Sediments within the upper Tulare Formation have variable sources and subdivision of units can be distinguished between eastern and western sourced materials. Alluvial fan materials above the Corcoran Clay in the Delta-Mendota Subbasin are generally more extensive than older alluvial fan deposits within the Tulare Formation below the Corcoran Clay. As shown in Figure 5-17 by the depth to the top of the Corcoran Clay, the Upper Aquifer extends to depths ranging between approximately 150 feet and greater than 350 feet. Other notable mapped clay units also exist within the upper part of the Tulare Formation in the Delta-Mendota Subbasin, including the A and C Clay members of the Tulare Formation and a white clay mapped by Hotchkiss and Balding (1971).

The A and C Clay occur near the Mendota and Tranquillity areas in the southeastern portion of the Delta-Mendota Subbasin. The mapped extent and elevation of the A and C Clay layers, as presented by Croft (1972) and Hotchkiss and Balding (1971), are shown in Figure 5-19 indicating areas where considerable barriers to vertical groundwater movement within the Upper Aquifer are known to exist. As shown in Figure 5-19, the extent and thickness of both the A and C Clays are somewhat uncertain, although they have been mapped to exist in the general area of Mendota. The A Clay occurs at elevations ranging from about 100 to 160 feet above mean sea level, corresponding to depths of generally between 100 and 200 feet below the ground surface. The deeper C Clay exists at correspondingly lower elevations from between 20 to 100 feet above mean sea level (Figure 5-19).

A traceable continuous white clay layer, mapped by Hotchkiss and Balding (1971), exists within the northern part of the Delta-Mendota Subbasin in the vicinity and north of Patterson. This layer ranges in thickness from 30 to 60 feet at depths between 100 and 200 feet below grade and is an effective confining layer in many areas. Although not explicitly mapped, less extensive and unmapped clay units within the Upper Aquifer also exist in other parts of the Subbasin.

Lower Aquifer

The Lower Aquifer is the portion of the Tulare Formation that is confined beneath the Corcoran Clay, extending downward to the underlying San Joaquin Formation and the interface of saline water of marine origin within its uppermost beds. The Lower Aquifer is generally characterized by groundwater that tends to be dominantly sodium-sulfate type, which is often of better quality than the Upper Aquifer (Davis et al., 1957; Hotchkiss and Balding, 1971). Exceptions to this quality do exist in the Subbasin, particularly in the southwestern portion of the Subbasin. Because of its relatively shallow depth within the Delta-Mendota Subbasin and lower salinity in areas when compared to other groundwater resources, the Lower Aquifer is heavily utilized as a source of groundwater for agricultural and drinking water uses within the Subbasin, where groundwater is beyond suitable for these uses in some areas.

The base of the Lower Aquifer generally decreases from south to north, changing in depth from about 1,100 to 1,200 feet deep in the south to about 600 feet to the north. Depth to the top of the Corcoran Clay ranges from less than 100 feet on the west near Interstate 5 (I-5) to more than 500 feet in the area near Tranquillity. The Corcoran Clay pinches out or is above the water level near the California Aqueduct in the western part of the Subbasin, where the Upper and Lower Aquifers merge into interfingered layers of sand, gravel, and clay.

Corcoran Clay

The Corcoran Clay, as a regional aquitard, is a notable hydrogeologic feature throughout most of the Delta-Mendota Subbasin, impeding vertical flow between the Upper and Lower Aquifers. The Corcoran Clay is present at varying depths across most of the Central Valley floor (Figure 5-17 and Figure 5-18). The depths to the top of the Corcoran Clay ranges between approximately 150 and 500 feet below the ground surface throughout most of the Subbasin, with a general spatial pattern of deepening to the south and east. In the far southeastern area of the Subbasin, in the vicinity of Mendota and Tranquillity, the top of the Corcoran Clay is at depths of greater than 350 feet (Figure 5-17). The thickness of the Corcoran Clay, which likely influences the degree of hydraulic separation between the Upper and Lower Aquifers, is greater than 50 feet across most of the Delta-Mendota Subbasin with thicknesses of more than 75 feet in central Subbasin areas in the vicinity of Los Banos and Dos Palos, and 140 feet in the eastern portions of the Subbasin. The Corcoran Clay appears thinner in areas north of Patterson, between Patterson and Gustine, and also in the vicinity of Tranquillity to the south (Figure 5-18). Along the westernmost portions of the Delta-Mendota Subbasin, the Corcoran Clay layer is generally non-existent or is exists as Corcoran-equivalent clays (clays existing at the same approximate depth but not part of the mapped aquitard) (Figure 5-17 and Figure 5-18).

Very Shallow Unconfined Groundwater

Floodplain deposits along the eastern side of the Subbasin, and the associated poorly-drained soils, cause naturally percolating water and applied irrigation water to build up in the very shallow zone. Shallow groundwater stagnation (where soils remain saturated within about 5 feet of the land surface) can increase salt accumulation in shallow soils and groundwater resulting from evaporation occurring directly from the water table (Corwin, 2012). The increased presence of the fine-grained floodplain deposits towards the Central Valley axis on the eastern side of the Delta-Mendota Subbasin results in low-permeability shallow soils that restrict the percolation of water, creating very shallow groundwater commonly within 25 feet of the ground surface. The combined effect of the many very shallow fine-grained lenses impeding vertical flow, especially in the distal fan and floodplain areas closer to the valley axis, can be great and represent a more substantial barrier to vertical movement of water (Bertoldi et al., 1991).

Tile drains are typically used in the eastern and southern portions of the Delta-Mendota Subbasin within the zone of Very Shallow Water (0 to 15 feet below ground surface) to manage impacts of shallow groundwater on the root zone. If groundwater within the semi-confined Upper Aquifer rises into the Very Shallow Water zone, tile drains can intercept and route such groundwater to sump pumps for removal via surface drainage networks. Further, it should be noted that some tile drains are likely within perched water zones that are not connected to the principal aquifers. Because of the generally shallow nature and high salinity, very shallow groundwater is not used to provide a major supply of water for agricultural or drinking uses within the Subbasin, although some projects are being developed to reuse this water on more salt-tolerant crops.

5.2.6.2 Aquifer Properties

The following subsections include discussion of generalized aquifer properties within the Delta-Mendota Subbasin. These include hydraulic conductivity, transmissivity, specific yield and specific storage.

DWR defines hydraulic conductivity as the “measure of a rock or sediment’s ability to transmit water” and transmissivity as the “aquifer’s ability to transmit groundwater through its entire saturated thickness” (DWR, 2003). High hydraulic conductivity values correlate with areas of transmissive groundwater conditions with transmissivity generally equaling hydraulic conductivity times the saturated thickness of the formation. Storage of water within the aquifer system can be quantified in terms of the specific yield for unconfined groundwater flow and the storage coefficient for confined flow, respectively (Faunt et al., 2009). Specific yield represents gravity-driven dewatering of shallow, unconfined sediments at a declining water table, but also accommodates a rising water table. The specific yield is dimensionless and represents the volume of water released from or taken into storage per unit head change per unit area of the water table. Specific yield is a function of porosity and specific retention of the sediments in the zone of water-table fluctuation.

Where the aquifer system is confined, storage change is governed by the storage coefficient, which is the product of the thickness of the confined-flow system and its specific storage. The specific storage is the sum of two component specific storages – the fluid (water) specific storage and the matrix (skeletal) specific storage, which are governed by the compressibilities of the water and skeleton, respectively (Jacob, 1940). Specific storage has units of 1 over length and represents the volume of water released from or taken into storage in a confined flow system per unit change in head per unit volume of the confined flow system (Faunt et al., 2009). Therefore, the storage coefficient of a confined flow system is dimensionless and, similar to specific yield, represents the volume of water released from or taken into storage per unit head change.

5.2.6.2.1 Hydraulic Conductivity

Figure 5-20 shows the saturated C-horizon vertical hydraulic conductivity of surficial soils within the Delta-Mendota Subbasin based on the National Resource Conservation Service (NRCS) Soil Survey Geographic Database (SSURGO). Soil survey data for counties within the Subbasin were combined using the weighted harmonic mean of these representative layers to depict the saturated hydraulic conductivity of the C-horizon for each soil map unit. The soil profile represented by these data is variable but commonly extends to a depth of 6 or more feet.

Floodplain deposits are evident as soils with relatively low hydraulic conductivity (less than 0.5 feet per day [ft/day]) blanketing much of the Central Valley Floor, although localized areas of soils with higher hydraulic conductivity are present in association with modern and ancient surface waterways and alluvial fan features (**Figure 5-20**). Coarse soils of distributary alluvial fan sediments deposited by Del Puerto Creek, Orestimba Creek, and Little Panoche Creek, in addition to other ephemeral northeasterly creek flows off the Coast Ranges, are notably apparent as areas of soils of high hydraulic conductivity located along active and inactive stream channels extending eastward from the fan apex areas along the Valley Floor margins to the current alignment of the San Joaquin River in the valley axis. Additionally, soils in areas adjacent to the active channel of the San Joaquin River also exhibit high hydraulic conductivities, including values of greater than 4 ft/day which are particularly apparent in an area north of Mendota. Soils of similarly high hydraulic conductivity trending as linear features in a general northwest-southeast alignment to the north of Dos Palos and Los Banos are likely the result of historical depositional processes and paleochannels associated with the San Joaquin River (**Figure 5-20**). In areas peripheral to the Central Valley floor, soils tend to be characterized by relatively low hydraulic conductivity, although soils of somewhat higher hydraulic conductivity associated with distinct geologic units are mapped across much of the peripheral area to the west of Patterson and Gustine and also in localized bands associated with surface water courses.

5.2.6.2.2 Transmissivity

Transmissivity varies greatly above the Corcoran Clay, within the Corcoran Clay, and below the Corcoran Clay within the Delta-Mendota Subbasin, with transmissivities in the confined Lower Aquifer generally being larger than those in the semi-confined Upper Aquifer. Based on testing conducted at multiple locations within both the Upper and Lower Aquifers of the Delta-Mendota Subbasin, average transmissivities in the Subbasin are approximately 109,000 gallons per day per square foot (gpd/ft^2) (SJRECWA, 2018).

5.2.6.2.3 Specific Yield

DWR defines specific yield as the “amount of water that would drain freely from rocks or sediments due to gravity and describes the proportion of groundwater that could actually be available for extraction” (DWR, 2003). Specific yield is a measurement specific to unconfined aquifers.

The estimated specific yield of the Delta-Mendota Subbasin is 0.118 (DWR, 2006). Within the southern portion of the Delta-Mendota Subbasin, specific yield ranges from 0.2 to 0.3 (Beltiz et al., 1993). Specific yield estimates for the Delta-Mendota Subbasin are fairly limited in literature since the Upper Aquifer above the Corcoran Clay is semi-confined and the Lower Aquifer below the Corcoran Clay is confined. Therefore, specific yield values only characterize the shallow, unconfined groundwater within the Subbasin.

5.2.6.2.4 Specific Storage

Values for specific storage were extracted from the Central Valley Hydrologic Model 2 (CVHM2), which is currently under development by the United States Geological Survey (USGS) and includes refinements for the Delta-Mendota Subbasin. Specific storage varies above, within, and below the Corcoran Clay with CVMH2. Above the Corcoran Clay, specific storage ranges from 1.34 x 10^{-6} to 6.46 x 10^{-2} meters^{-1} (m^{-1}) with average values ranging from 6.16 x 10^{-3} to 1.97 x 10^{-2} m^{-1}. Specific storage within the Corcoran Clay is considerably smaller than above the Corcoran Clay, ranging between 1.41 x 10^{-6} and 2.35 x 10^{-6} m^{-1} and average values between 1.96 x 10^{-6} and 2.02 x 10^{-6} m^{-1}. Below the Corcoran Clay, specific storage is comparable to within the Corcoran Clay with overall ranges the same as within the Corcoran Clay and average values ranging from 1.86 x 10^{-6} to 2.01 x 10^{-6} m^{-1}. Therefore, specific storage is greatest within the semi-confined aquifer overlying the Corcoran Clay layer, with considerably smaller specific storage values with the low permeability Corcoran Clay and confined aquifer underlying the Corcoran Clay layer.

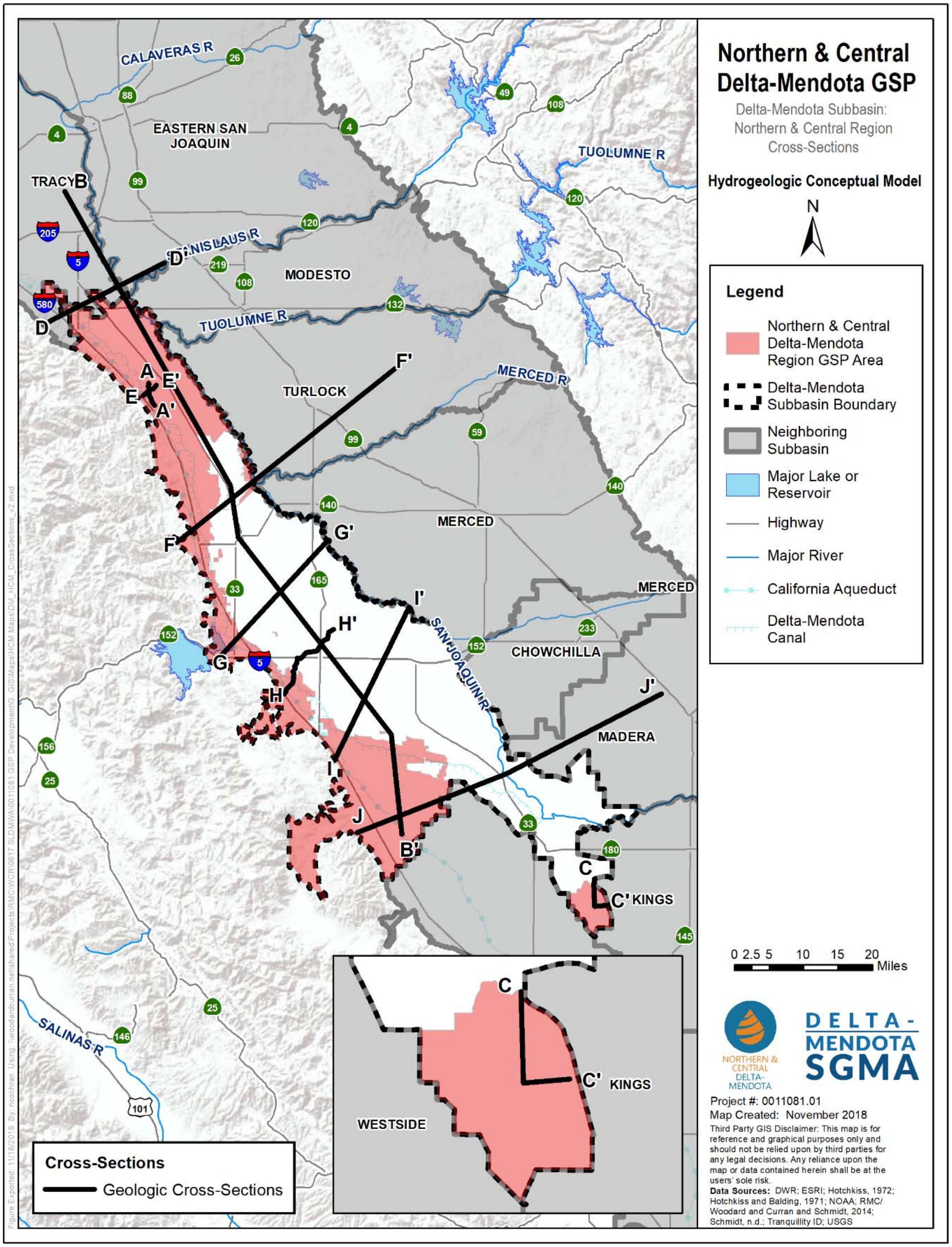

Figure 5-6. Representative Cross-Sections, Northern & Central Delta-Mendota Region GSP

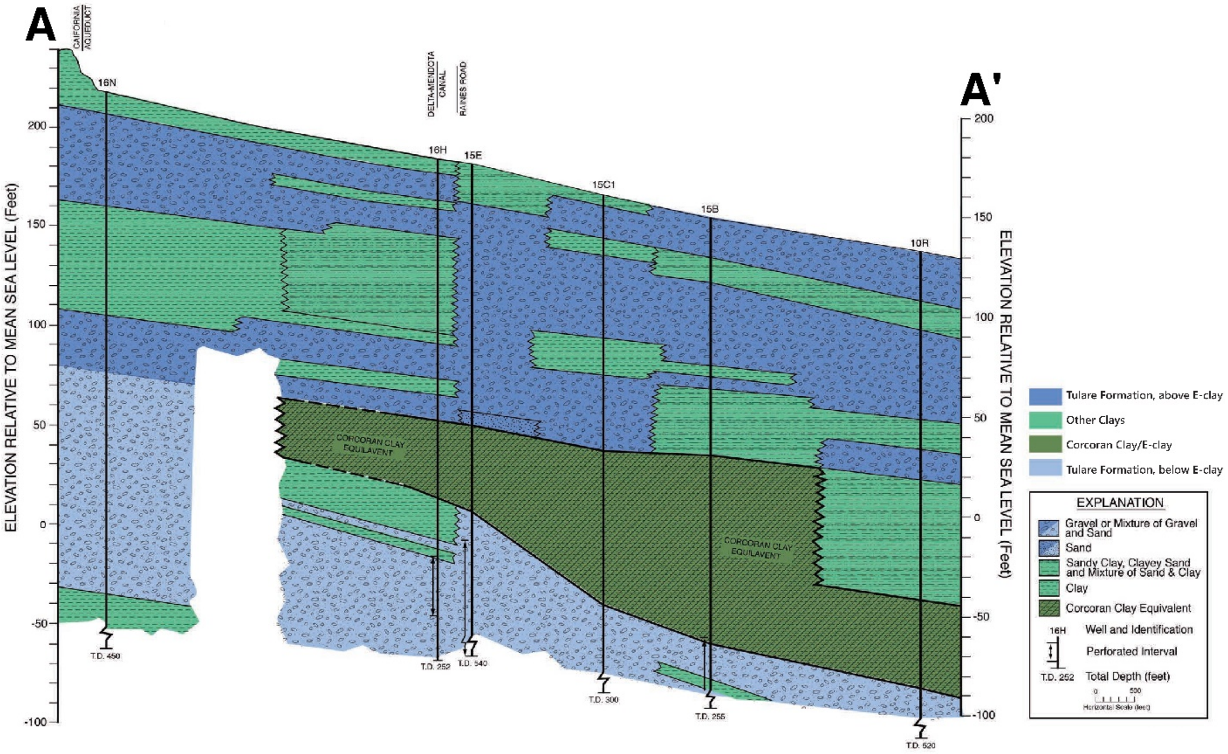

Figure 5-7. Cross-Section A-A’ (RMC/W&C and Schmidt, 2014)

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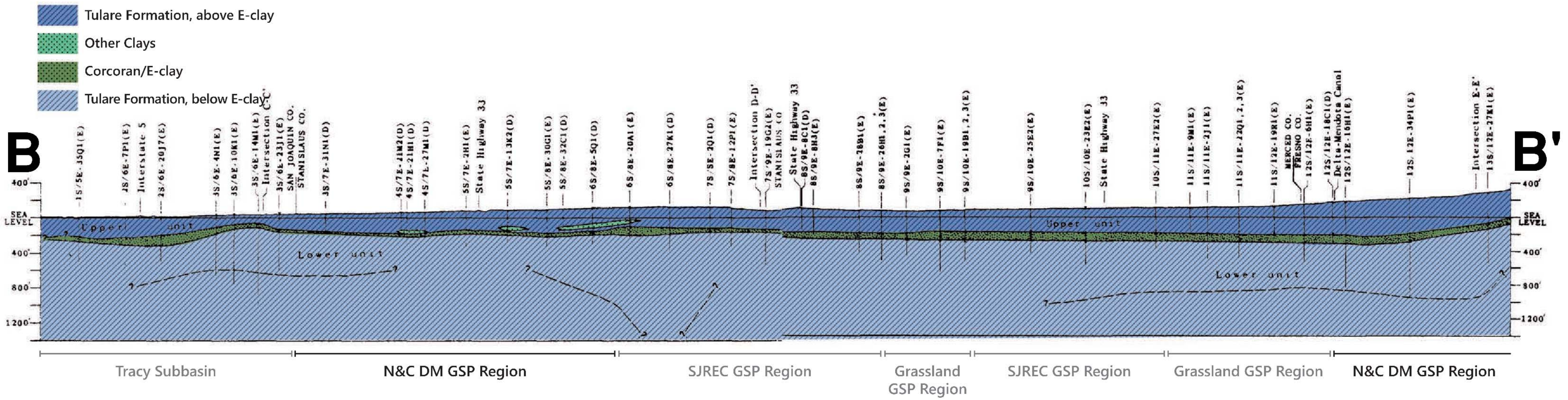

Figure 5-8. Cross-Section B-B' (Hotchkiss, 1972)

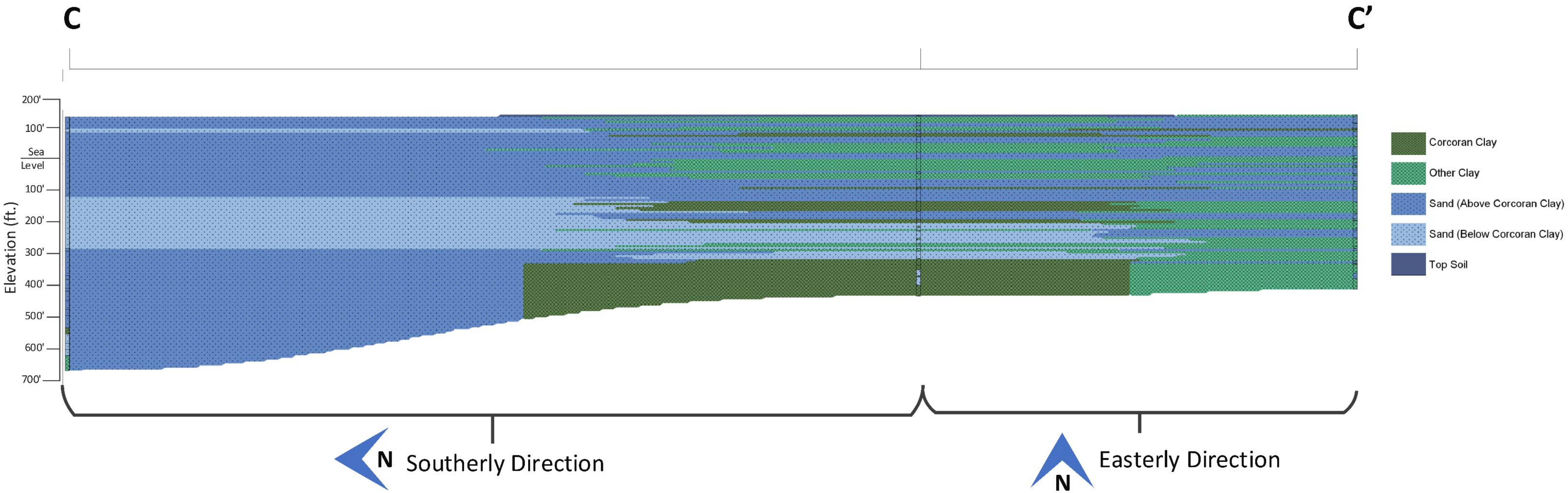

Figure 5-9. Cross-Section C-C’ (Tranquillity ID, 1994 and 2000 and LSCE, 2011)

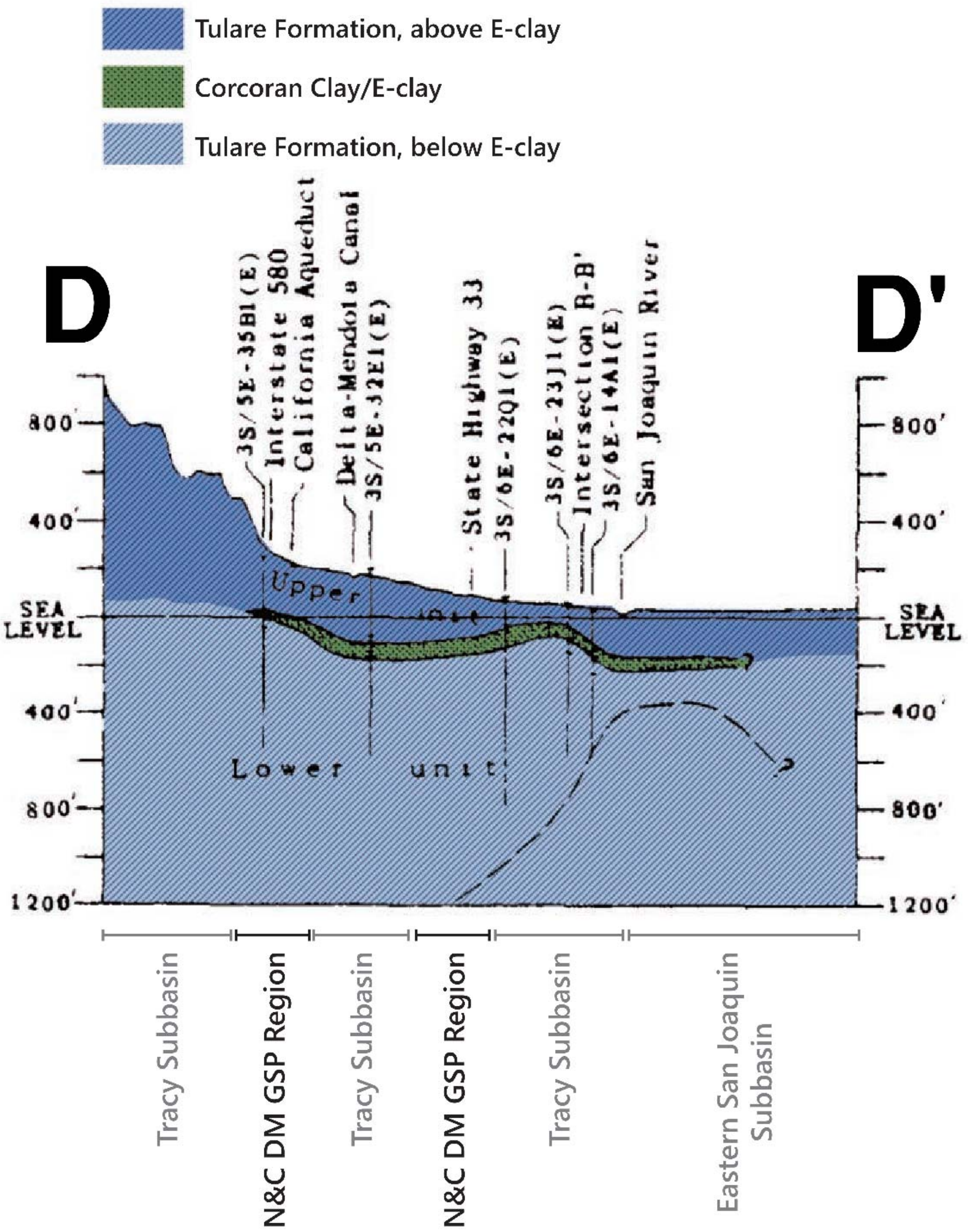

Figure 5-10. Cross-Section D-D' (Hotchkiss, 1972)

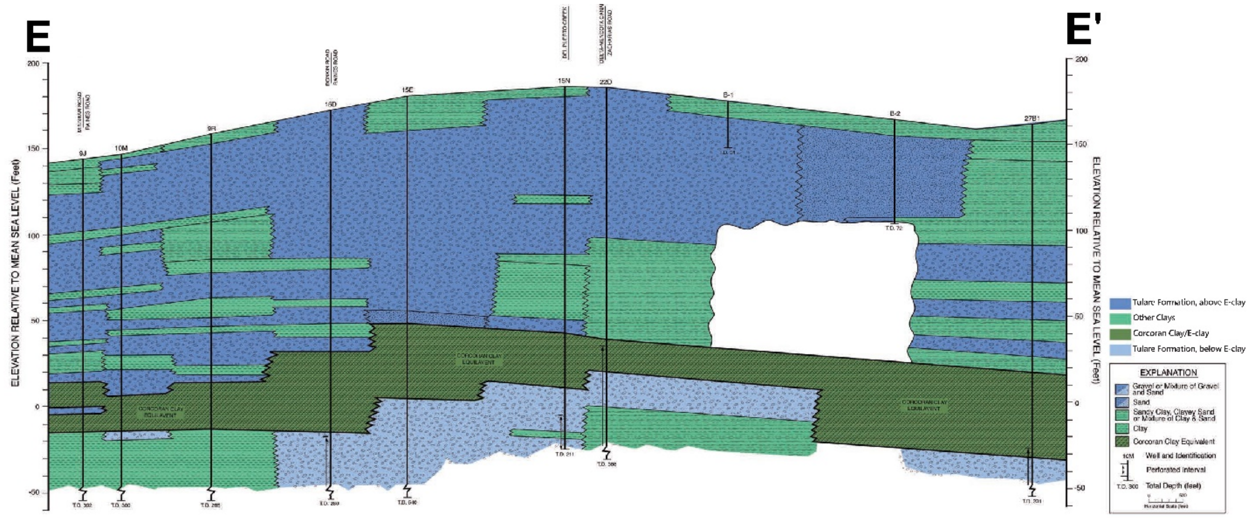

Figure 5-11. Cross-Section E-E’ (RMC/W&C and Schmidt, 2014)

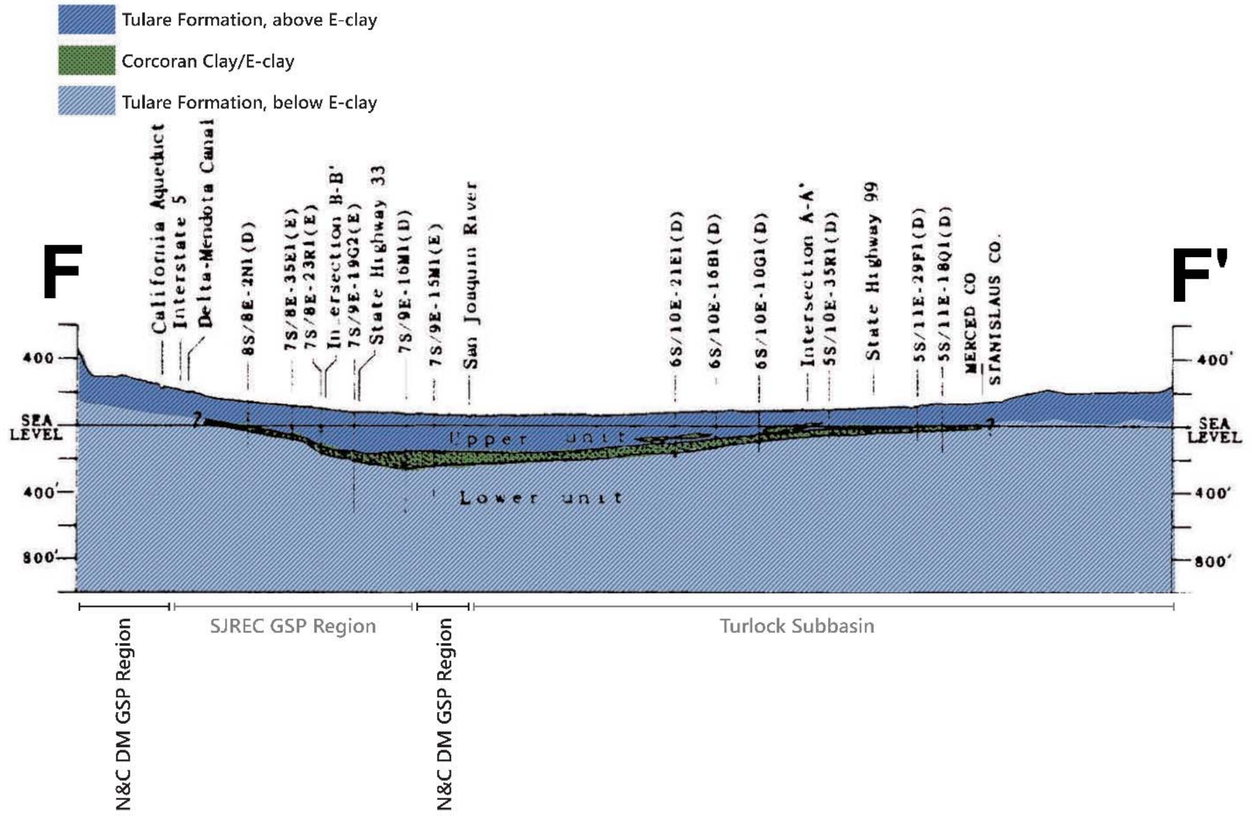

Figure 5-12. Cross-Section F-F’ (Hotchkiss, 1972)

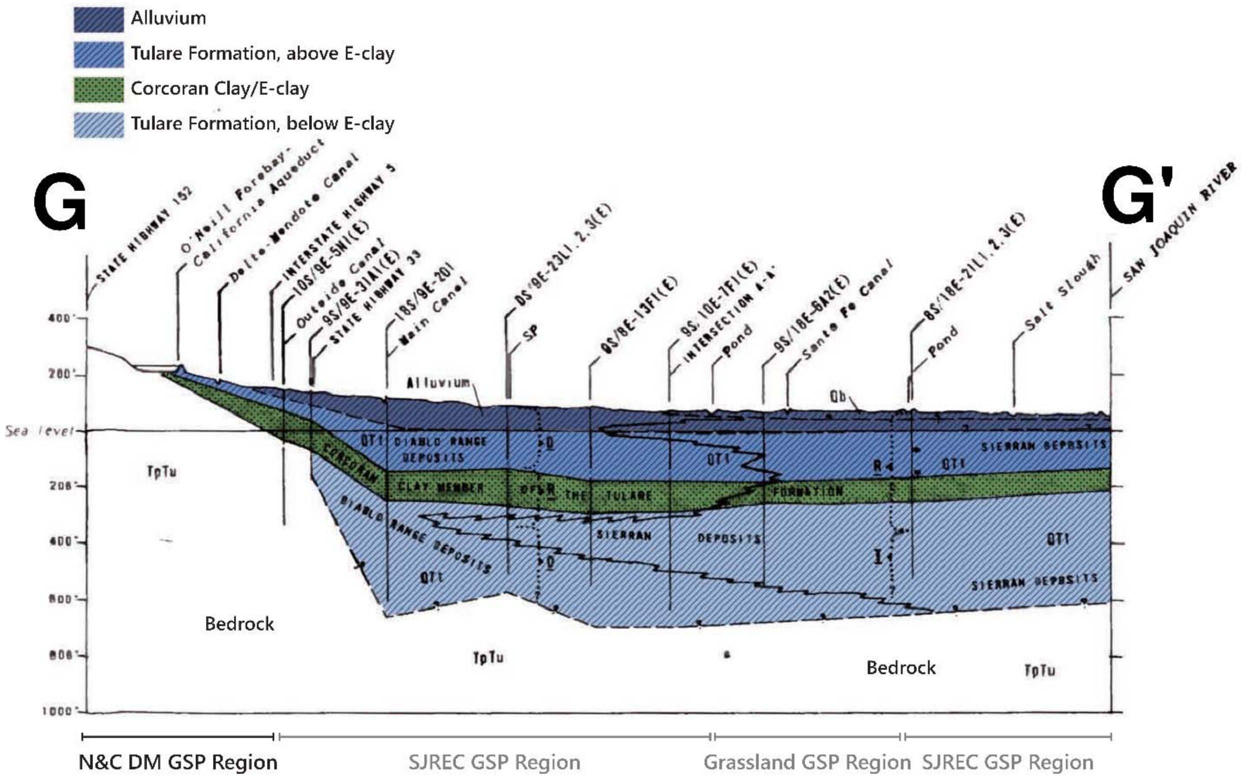

Figure 5-13. Cross-Section G-G' (Hotchkiss & Balding, 1971)

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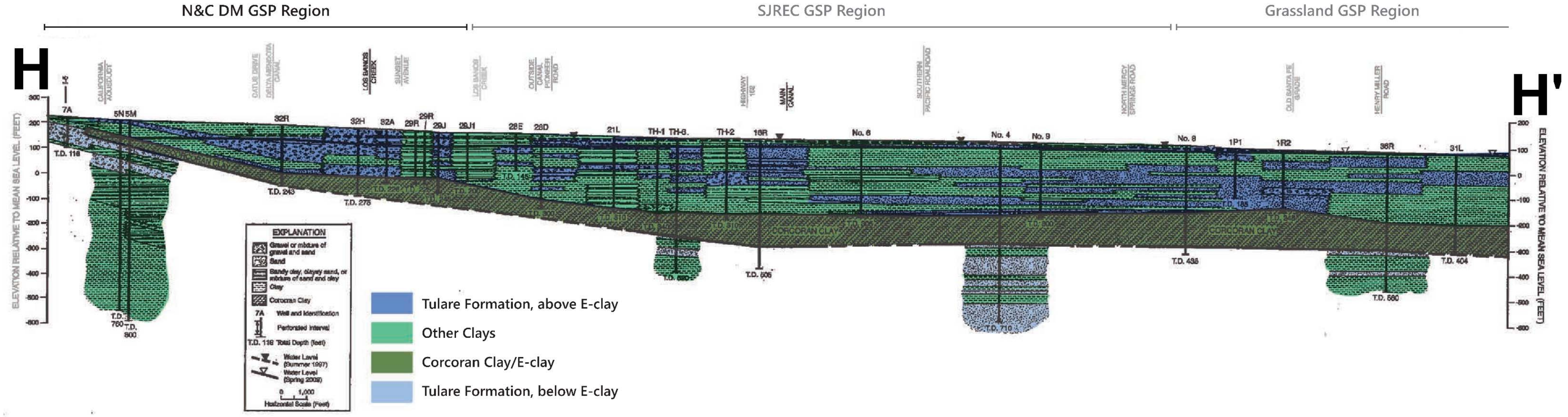

Figure 5-14. Cross-Section H-H' (Schmidt, 2018)

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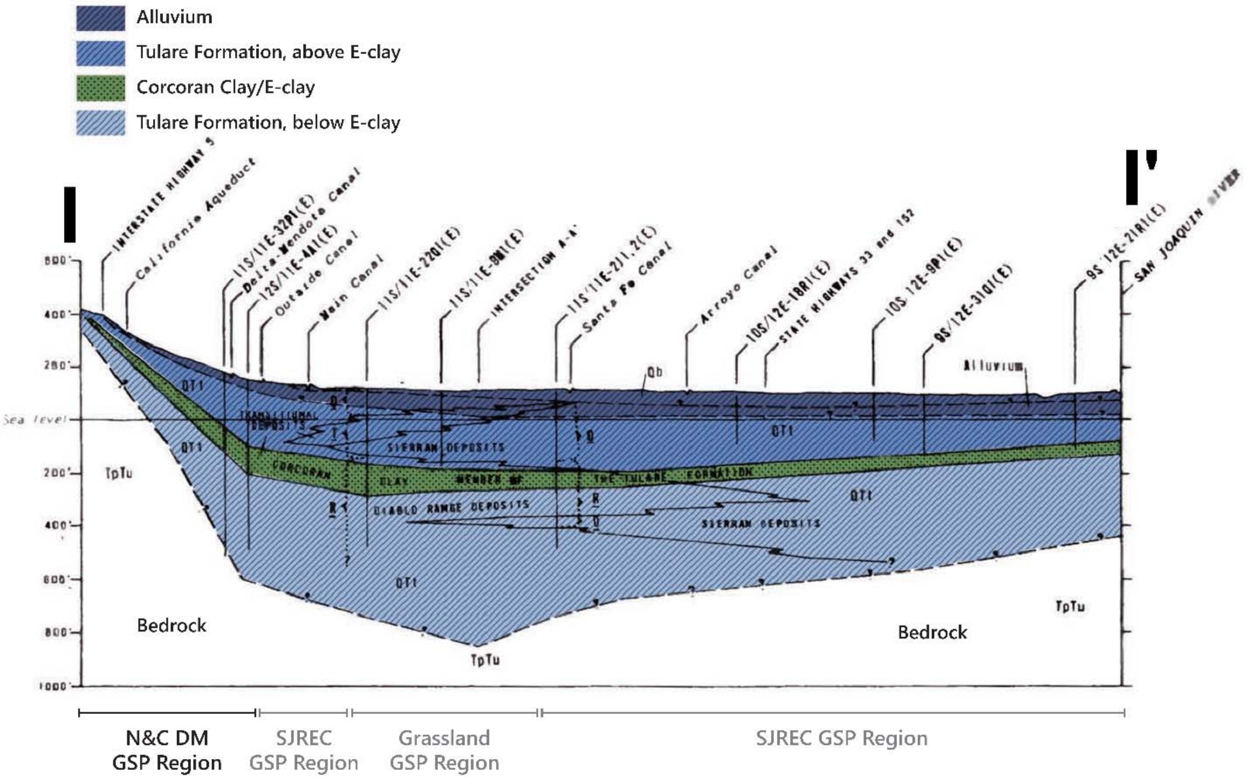


Figure 5-15. Cross-Section I-I’ (Hotchkiss & Balding, 1971)

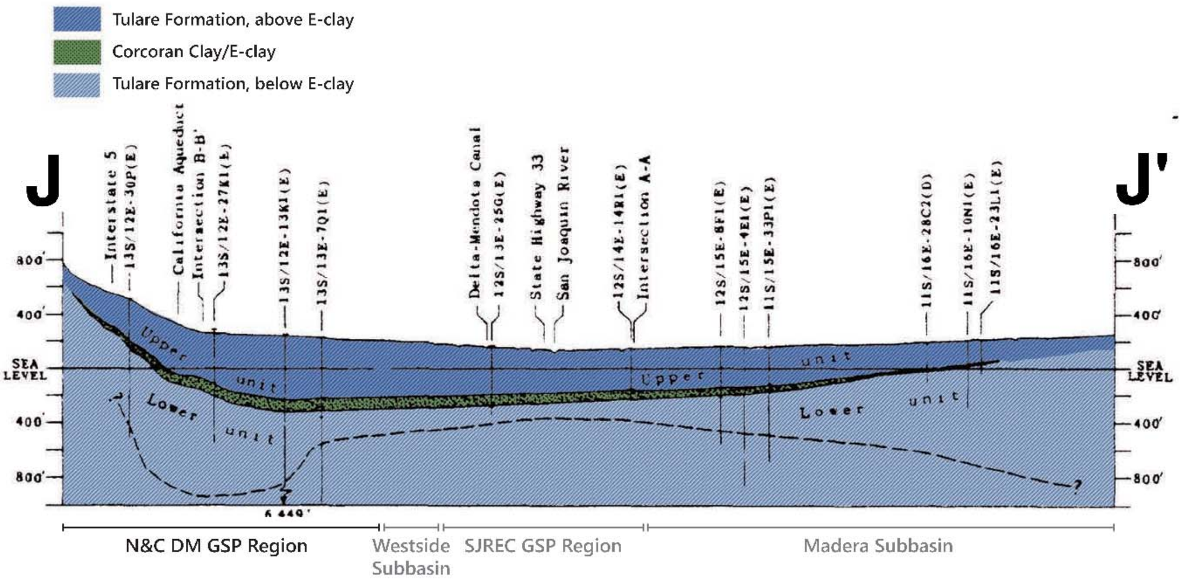


Figure 5-16. Cross-Section J-J’ (Hotchkiss, 1972)

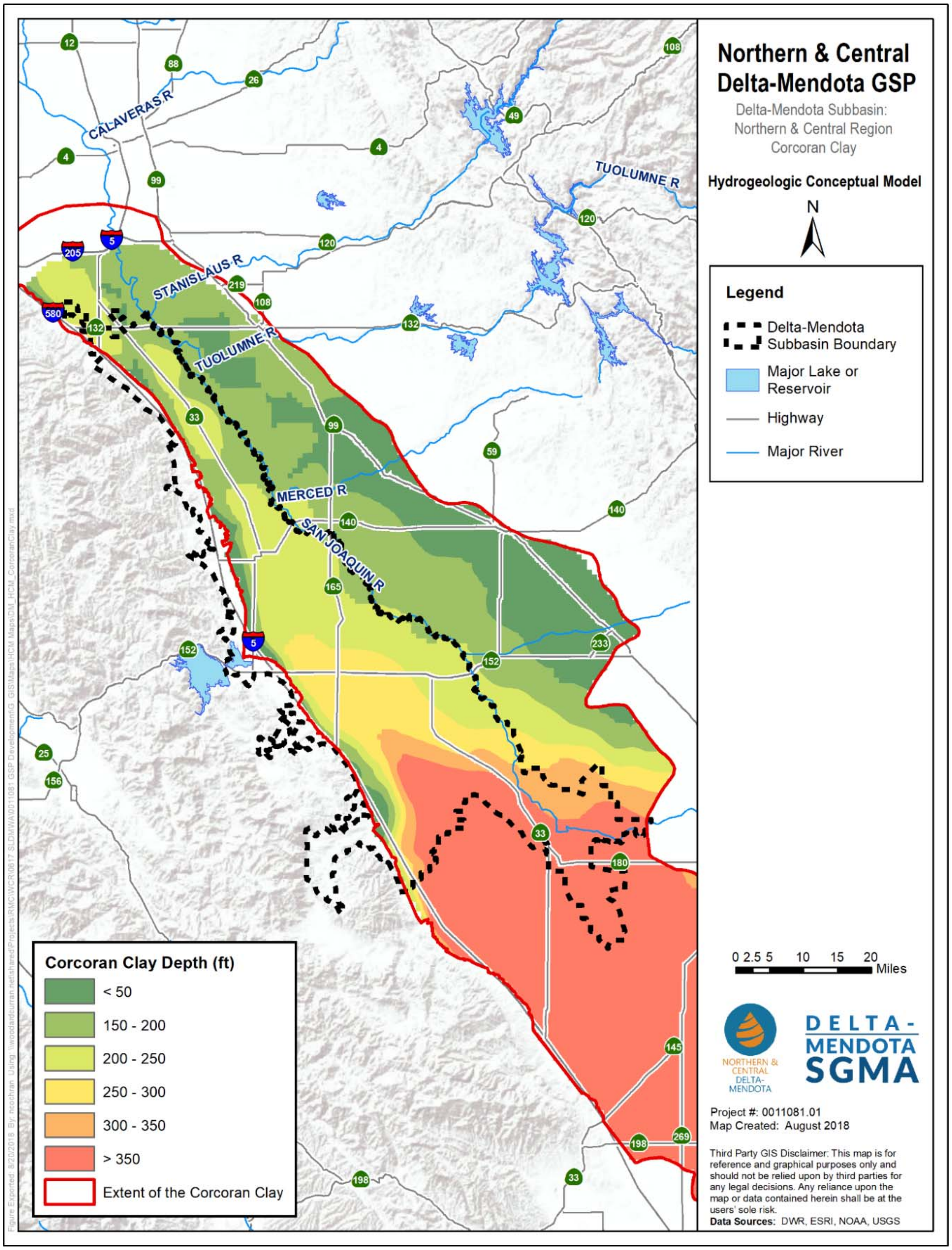
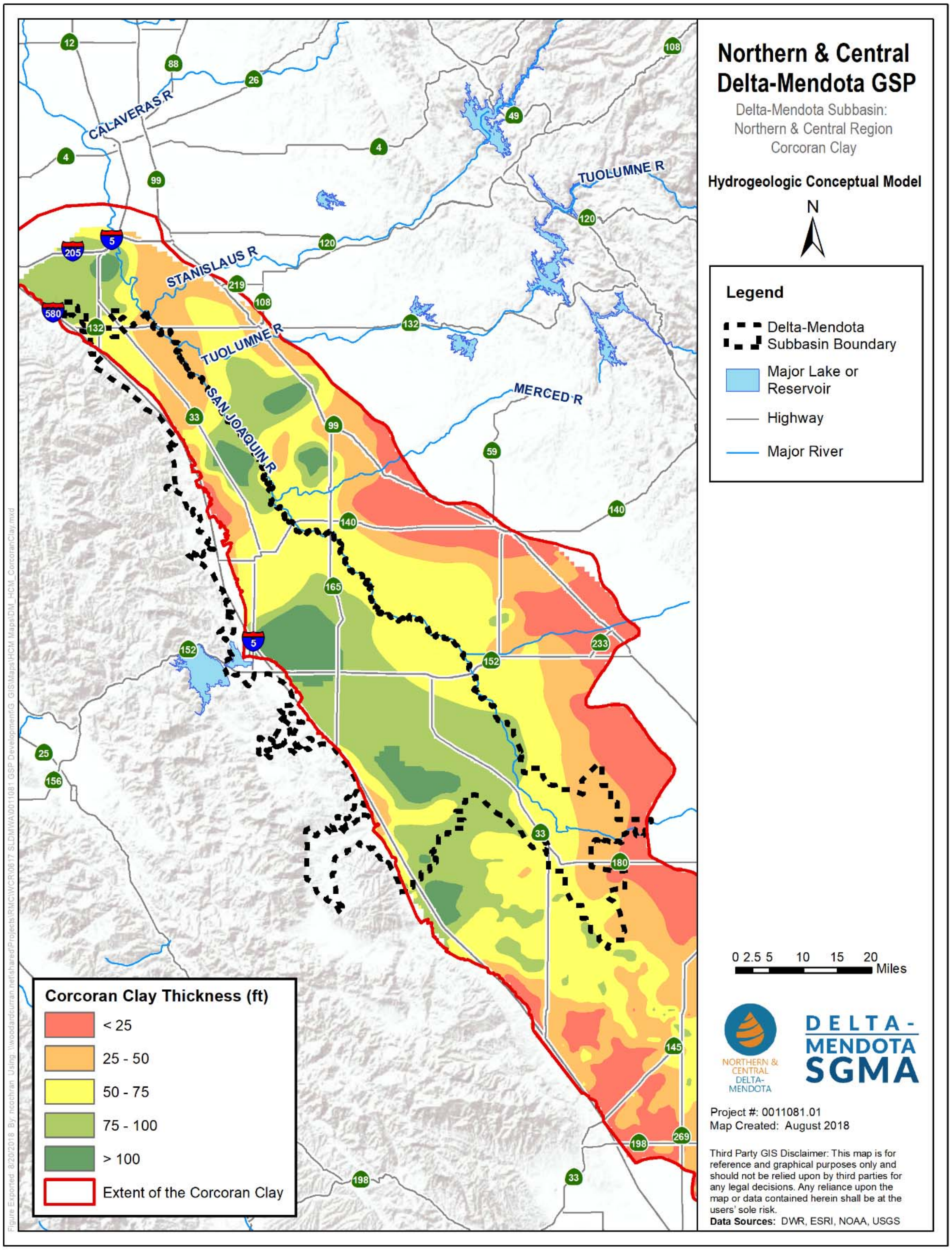


Figure 5-17. Depth to Corcoran Clay, Delta-Mendota Subbasin



Project #: 0011081.01
Map Created: August 2018

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Data Sources: DWR, ESRI, NOAA, USGS

Figure 5-18. Thickness of Corcoran Clay, Delta-Mendota Subbasin

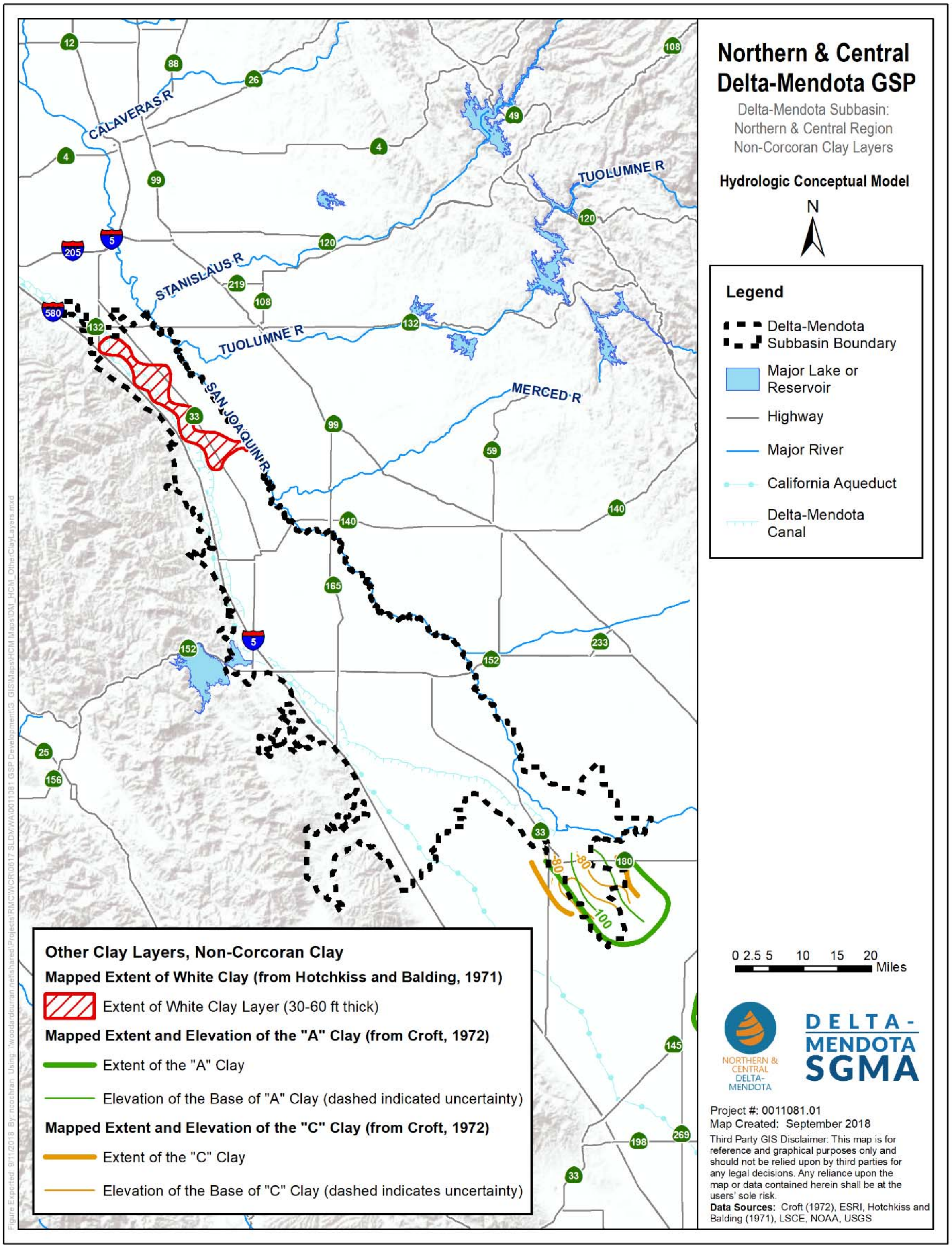


Figure 5-19. Non-Corcoran Clay Layers, Delta-Mendota Subbasin

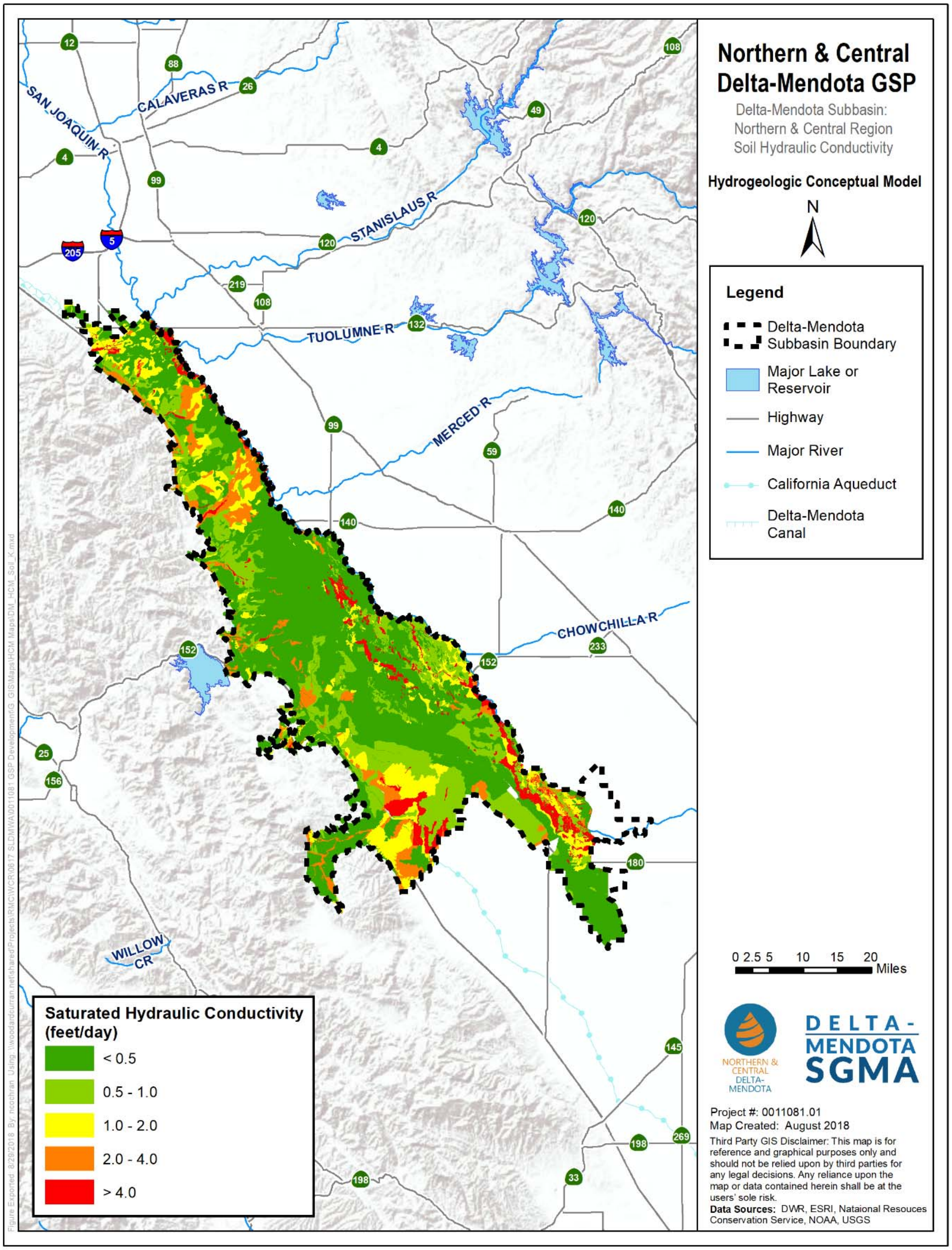


Figure 5-20. Soil Hydraulic Conductivity, Delta-Mendota Subbasin

5.2.7 Structural Properties and Restricted Groundwater Flow

Under natural (pre-development) conditions, the prevailing groundwater flow within the Upper and Lower Aquifer systems of the western San Joaquin Valley was predominantly in a generally northeasterly direction from the Coast Range towards and parallel to the San Joaquin River and the Sacramento-San Joaquin Delta (LSCE, 2015; Hotchkiss and Balding, 1971; Schmidt, 2015). Historically, numerous flowing artesian wells within the Lower Aquifer existed throughout the Delta-Mendota Subbasin (Mendenhall et al., 1916) and the pressure gradient for groundwater flow was upward from the Lower Aquifer to the Upper Aquifer. These flowing artesian conditions have disappeared in many areas as a result of increased development of groundwater resources within the Tulare Formation, changing the vertical flow gradient between groundwater zones (Hotchkiss and Balding, 1971). Additionally, the Delta-Mendota Subbasin has experienced periods of considerable decline in groundwater levels during which hydraulic heads decreased considerably in some areas due to heavy pumping (Bertoldi et al., 1991).

Despite the presence of local pumping depressions within parts of the Subbasin, the prevailing northeastward flow direction for groundwater within the region has remained (AECOM, 2011; DWR, 2010; Hotchkiss and Balding, 1971). Groundwater flows outward from the Delta-Mendota Subbasin, except along the western margin where there is some recharge from local streams and canal seepage (Schmidt, 2015). Within the Upper Aquifer, there are similar groundwater flow directions in most of the Subbasin with groundwater outflow to the northeast or towards the San Joaquin River in much of the Subbasin during wet and dry periods. One exception is in the Orestimba Creek area west of Newman where groundwater flows to the west during drought conditions and east during wet periods. Calculations based on aquifer transmissivity indicate the net groundwater outflow in the Upper Aquifer has been about three times greater during drought periods than during normal periods (Schmidt, 1997a and 1997b).

Within the Lower Aquifer, there is a groundwater divide in the area between Mendota and the point near the San Joaquin River in the Turner Island area, northeast of Los Banos. Groundwater southwest of this divide generally flows southwest toward Panoche Water District. Groundwater northeast of this divide flows to the northeast into Madera and Merced Counties. Net groundwater outflow in the Lower Aquifer under drought conditions has been about two and a half times greater than for normal conditions (Schmidt, 1997a and 1997b). Based on current and historical groundwater elevation maps, groundwater barriers do not appear to exist in the Delta-Mendota Subbasin (DWR, 2006).

The combined effect of pumping below the Corcoran Clay and increased leakage from the Very Shallow zone to the Upper Aquifer has developed a generally downward flow gradient in the Tulare Formation which changes with variable pumping and irrigation over time (Bertoldi et al., 1991). Periods of great groundwater level declines have also resulted in inelastic compaction of fine-grained materials in some locations, particularly between Los Banos and Mendota, potentially resulting in considerable decreases (between 1.5 and 6 times) in permeability of clay members within the Tulare Formation, including the Corcoran Clay (Bertoldi et al., 1991). However, the number of wells penetrating the Corcoran Clay may be enabling vertical hydraulic communication across the Corcoran Clay aquitard and other clay layers (Davis et al., 1959; Davis et al., 1964).

5.2.8 Water Quality

Groundwater in the Delta-Mendota Subbasin is characterized by mixed sulfate to bicarbonate water types in the northern and central portion of the Subbasin, with areas of sodium chloride and sodium sulfate waters in the central and southern portions (DWR, 2003). TDS values range from 400 to 1,600 mg/L in the northern portion, and 730 to 6,000 mg/L in the southern portion of the Delta-Mendota Subbasin (Hotchkiss and Balding, 1971). The Department of Health Services (DHS), which monitors Title 22 water quality standards, reports TDS values in 44 public supply wells in the Subbasin ranging in value from 210 to 1,750 mg/L, with an average value of 770 mg/L. Shallow, saline groundwater also occurs within about 10 feet of the ground surface over a large portion of the Delta-Mendota Subbasin. There are also localized areas of high iron, fluoride, nitrate, selenium, and boron in the Delta-Mendota Subbasin (Hotchkiss and Balding, 1971).

5.2.8.1 Historic Water Quality

Alluvial sediments derived from west-side streams are composed of material derived from serpentine, shale, and sandstone parent rock, which results in soil and groundwater types entirely different from those on the east side of the San Joaquin Valley (LSCE, 2015). In contrast with the siliceous mineralogy of the alluvial sands and gravels on the eastern side of the Central Valley that are derived from the Sierra granitic rocks (which are coarser and more resistant to chemical dissolution), the sulfate and carbonate shales and sandstones of Coast Range sediments on the western side are more susceptible to dissolution processes. Some soils and sediments within the western San Joaquin Valley that are derived from marine rocks of the Coast Range have notably high concentrations of naturally-occurring nitrogen, with particularly higher nitrate concentrations in younger alluvial sediments (Strathouse and Sposito, 1980; Sullivan et al., 1979). These naturally-occurring nitrogen sources may contribute to nitrate concentrations in groundwater within the Delta-Mendota Subbasin, although it is not well known where this may occur and to what degree. Naturally-high concentrations of TDS in groundwater are known to have existed historically within parts of the Subbasin due to the geochemistry of the Coast Range rocks, the resulting naturally-high TDS of recharge derived from Coast Range streams, the dissolvable materials within the alluvial fan complexes, and the naturally-poor draining conditions which tend to concentrate salts in the system. The chemical quality of waters in the Coast Range streams can be closely correlated with the geologic units within their respective catchments. Groundwater flows discharging from these marine and non-marine rocks into streams introduce a variety of dissolved constituents, resulting in variable groundwater types. The water quality and chemical makeup in westside streams can be highly saline, especially in more northern streams, including Corral Hollow and Del Puerto Creeks, where historical baseflow TDS concentrations have typically exceeded 1,000 milligrams per liter (mg/L) with measured concentrations as high as 1,790 mg/L (Hotchkiss and Balding, 1971). This is in contrast with TDS concentrations typically below 175 mg/L in streams draining from the Sierras. The contribution of water associated with these Coast Range sediments has resulted in naturally high salinity in groundwater within and around the Delta-Mendota Subbasin, which has been recognized as early as the 1900s (Mendenhall et al., 1916). Groundwater in some areas within the immediate vicinity of the San Joaquin River is influenced by lower-salinity surface water discharging from the east side of the San Joaquin Valley Groundwater Basin (Davis et al., 1957).

Areas of historical high saline groundwater documented by Mendenhall *et al*. (1916) indicate somewhat high TDS concentrations approaching or greater than 1,000 mg/L in wells sampled throughout many parts of the Delta-Mendota Subbasin. Areas of locally higher TDS concentrations (1,500-2,400 mg/L) have existed between Mendota and Los Banos; whereas the trend in deeper groundwater (average well depth of 450 feet) south of Mendota indicates slightly lower historical salinity conditions, but still somewhat high with an average TDS concentration of greater than 1,000 mg/L. In the northern part of the Subbasin, north of Gustine, the average historical TDS concentration of wells was also relatively high (930 mg/L). Historically low TDS concentrations (<500 mg/L) existed in groundwater from wells with an average depth of 209 feet in the central Subbasin area between Los Banos and Gustine.

The general chemical composition of groundwater in the Subbasin is variable based on location and depth. Groundwater within the Upper Aquifer is largely characterized as transitional type with less area characterized as predominantly of chloride, bicarbonate, and sulfate water types. Transitional water types, in which no single anion represents more than 50 percent of the reactive anions, occurs in many different combinations with greatly ranging TDS concentrations. Chloride type waters occur generally in grasslands areas east of Gustine and around Dos Palos, with sodium chloride water present in northern areas near Tracy and also extending south from Dos Palos. These waters also exhibit greatly varying salinity with typical TDS concentrations, ranging from less than 500 mg/L to greater than 10,000 mg/L and of high sodium makeup (50-75 percent of cations present) (Hotchkiss and Balding, 1971). Areas of bicarbonate groundwater within the Upper Aquifer of relatively lower TDS concentrations are directly associated with intermittent streams of the Coast Range near Del Puerto, Orestimba, San Luis, and Los Banos Creeks. Sulfate water in the central and southern Subbasin areas has TDS concentrations decreasing from west (1,200 mg/L) to east (700 mg/L) towards the San Joaquin River, similar to the bicarbonate water areas, although areas of sulfate water south of Dos Palos have much higher TDS concentrations (1,900 to 86,500 mg/L) (Hotchkiss and Balding, 1971).

Groundwater in the Lower Aquifer below the Corcoran Clay is also spatially variable, consisting of mostly transitional sulfate waters in the northern part of the Delta-Mendota Subbasin to more sodium-rich water further south in the grasslands areas. In the northern part of the Delta-Mendota Subbasin, the Lower Aquifer exhibits relatively lower TDS concentrations, ranging from 400 to 1,600 mg/L, with a sulfate-chloride type makeup near the valley margin trending to sulfate-bicarbonate type near the valley axis. Farther south, TDS concentrations in the Lower Aquifer increase with values ranging as high as 6,000 mg/L of high sodium content (Hotchkiss and Balding, 1971).

Natural conditions of groundwater salinity exist throughout the Upper and Lower Aquifers as a result of the contribution of salts from recharge off the Coast Range mountains. Surface water and groundwater flowing over and through Coast Range sediments of marine origin have dissolved naturally-occurring salts, contributing to the historical and current presence of salinity in groundwater within the Delta-Mendota Subbasin. In addition to natural salinity contributed from the Coast Range sediments, a number of other mechanisms are believed to further contribute to increased salinity in the groundwater in the region. Poorly draining soil conditions are extensive within the southern and eastern areas of the Subbasin, extending from the vicinity of Tranquillity to near Gustine, and these types of soil, combined with a shallow water table, contribute to a build-up of soil salinity.

5.2.8.2 Recent Groundwater Quality

Primary constituents of concern within the Delta-Mendota Subbasin are nitrates, TDS, and pesticides. In the Grassland Drainage Area and southern portions of the Subbasin, both selenium and boron are naturally occurring and are managed to mitigate impacts to irrigated agriculture. The maximum detected concentrations, as well as recent (about 2000 to 2014) concentrations, of these constituents are discussed in the following subsections (LSCE, 2015 and LSCE, 2016).

5.2.8.2.1 Nitrate Concentrations

The maximum nitrate (as N) concentrations observed in all wells throughout the Delta-Mendota Subbasin are depicted in Figure 5-21. The majority of wells have maximum concentrations below 5 mg/L; however, several areas exist with a greater density of wells with maximum concentrations exceeding the primary maximum contaminant level (MCL) of 10 mg/L (as N), especially in the area immediately south of Los Banos and trending northwest along Highway 33 to north of Patterson. Historical and current land use in this area consists mainly of alfalfa, almonds, cotton, corn, and tomatoes. There are a few wells around Dos Palos and southward toward Tranquillity with maximum nitrate concentrations exceeding the MCL, but most concentrations are non-detect. Figure 5-22 shows the most recent nitrate concentrations (for a period of around 2000 to 2014) in all the wells in the Subbasin. The overall picture illustrated by the nitrate data in Figure 5-22 is very similar, though slightly improving, to that seen in Figure 5-21 for maximum nitrate concentrations.

Above Corcoran Clay

Figure 5-23 depicts maximum nitrate concentrations above the Corcoran Clay. Available data are limited for shallow wells above the Corcoran Clay, though the majority of the nitrate concentrations are below the nitrate (as N) MCL of 10 mg/L. The few wells that do exceed the MCL do not have a consistent spatial pattern, except in the southern central portion of the Subbasin where the majority of the drainage water in very shallow wells has maximum concentrations exceeding the MCL of 10 mg/L. Compared to shallow wells (typically less than 50 feet deep), deeper wells in the Upper Aquifer (ranging in depth from 50 feet to the top of the Corcoran Clay) have more wells with maximum nitrate concentrations exceeding the MCL. The majority of these exceedances extend from south of Los Banos northwestward to north of Patterson. Wells around Dos Palos and southeast of Tranquillity tend to have lower concentrations of nitrate, typically less than 2.5 mg/L. Similar spatial patterns are evident in shallow wells presenting the most recent nitrate concentrations, although several wells near Los Banos and Patterson indicate recently improved nitrate concentrations (Figure 5-24). The most recent nitrate concentrations in shallow Upper Aquifer wells are lower at many sample locations in the area northeast and east of Los Banos. The most recent nitrate concentrations in deeper wells throughout the Upper Aquifer show the same pattern as the maximum concentrations; however, a fewer number of these wells have concentrations exceeding 10 mg/L.

Tile drains located predominantly in the southern portion of the Subbasin are designed to capture applied water that percolates below the root zone and to drain the water table in areas where it is perched or very shallow. Consequently, it is expected that water sampled from tile drains and from very shallow wells (less than 15 feet) would exhibit higher concentrations of nitrate resulting from land use practices. The most recent nitrate concentrations in deeper wells appear to be slightly improved relative to the maximum concentrations as fewer wells show most recent values above 10 mg/L compared to the maximum nitrate concentrations. Nevertheless, the spatial patterns in the most recent nitrate concentrations shown in Figure 5-24 are similar to the maximum concentrations evident in Figure 5-23.

Below Corcoran Clay

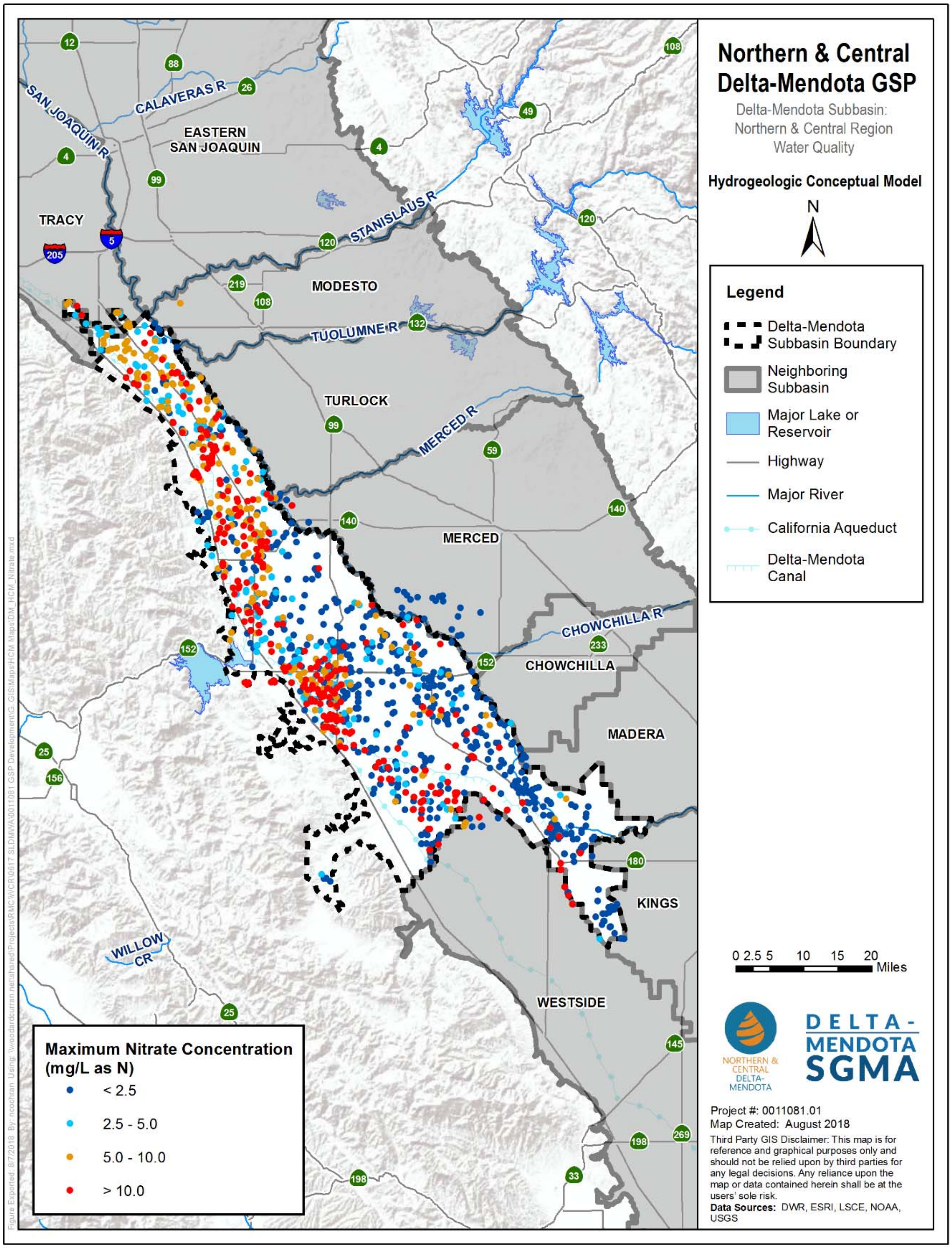
Fewer data are available relating to nitrate concentrations below the Corcoran Clay as compared to above the Corcoran Clay, primarily because most irrigation wells in the Subbasin (from which the predominance of data are available) are completed in the Upper Aquifer. Figure 5-25 displays the maximum nitrate concentrations in wells interpreted to be in the Lower Aquifer and shows the lack of data southwest of Los Banos. As is evident in Figure 5-25, most wells in the Lower Aquifer, from Gustine to north of Patterson and west of Highway 33, have a maximum nitrate (as N) concentration above 5 mg/L. However, in the most recent nitrate data, a fewer number of the Lower Aquifer wells have concentrations exceeding 10 mg/L (Figure 5-26). Limited and scattered wells south of Gustine show a maximum nitrate concentration of less than 5 mg/L. Clusters of higher nitrate concentrations in the Lower Aquifer are generally concentrated in areas where the Corcoran Clay is either thin or non-existent as seen in Figure 5-25, most notably to the west and northwest of Gustine.

Composite Wells

As seen in Figure 5-27, the maximum nitrate concentrations in the composite wells (wells screened both above and below the Corcoran Clay) are mostly above 5 mg/L nitrate as N. The maximum nitrate concentration data in composite wells are similar to the most recent data (Figure 5-28), with a few wells with recent results showing improved nitrate concentrations.

Wells of Unknown Depth

Many of the wells for which nitrate data are available could not be classified into a depth category (above or below the Corcoran Clay) because of the lack of information relating to well construction and type. The spatial distribution of nitrate concentrations in these wells of unknown depth is shown in Figure 5-29 and Figure 5-30. The majority of these wells have maximum nitrate as N concentrations below 5 mg/L, although a greater density of wells with maximum nitrate concentrations exceeding 10 mg/L can be seen in the area south of Los Banos (Figure 5-29) and extending northwest along Highway 33 to north of Patterson. This area also exhibits elevated nitrate concentrations in both the Upper and Lower Aquifers (Figure 5-23 through Figure 5-26). Other wells exceeding 10 mg/L are more sparsely distributed in the area between Dos Palos and Tranquillity.



Note: Maximum concentrations are based on all data collected to date for the identified wells.

Figure 5-21. Maximum Nitrate Concentrations, All Wells

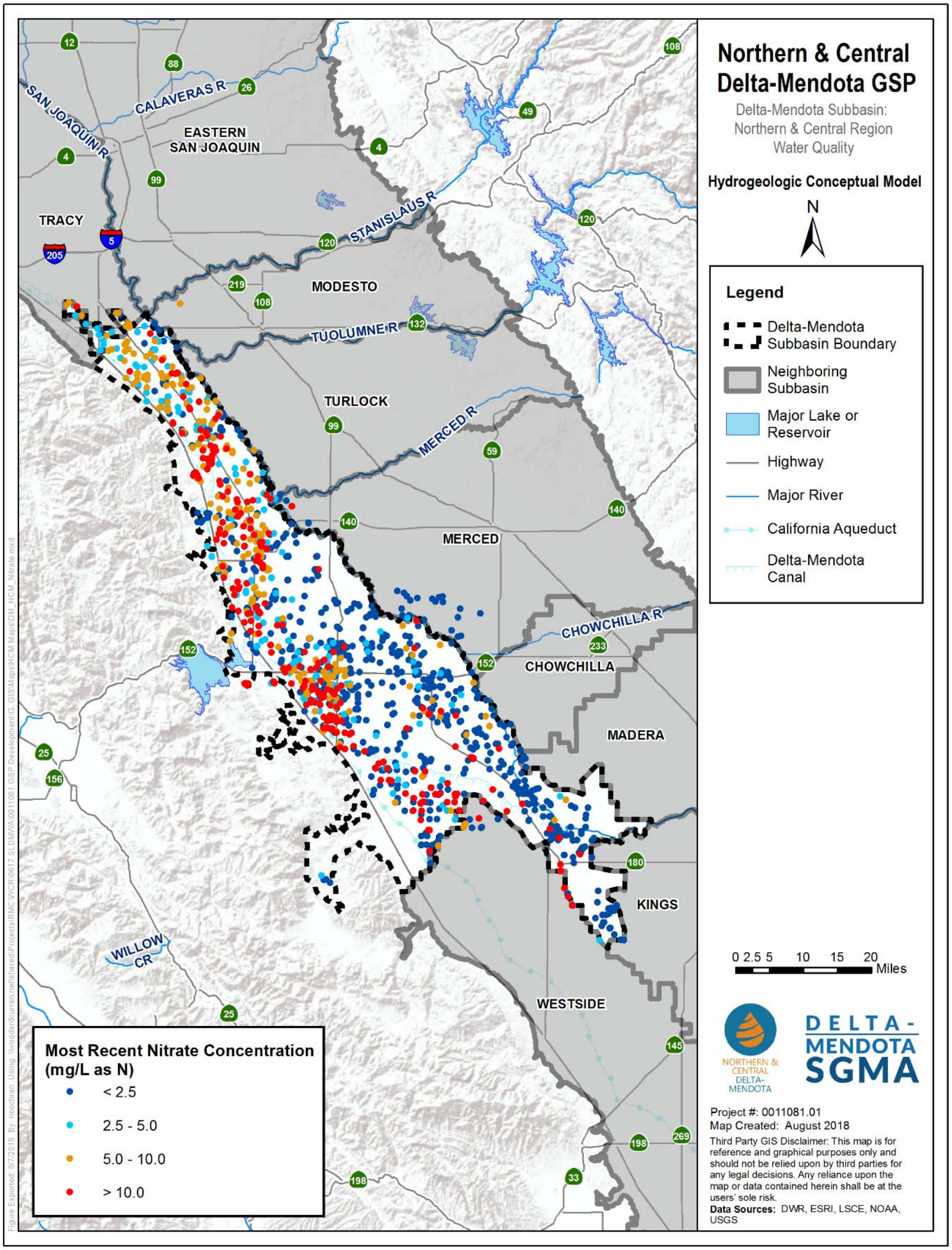
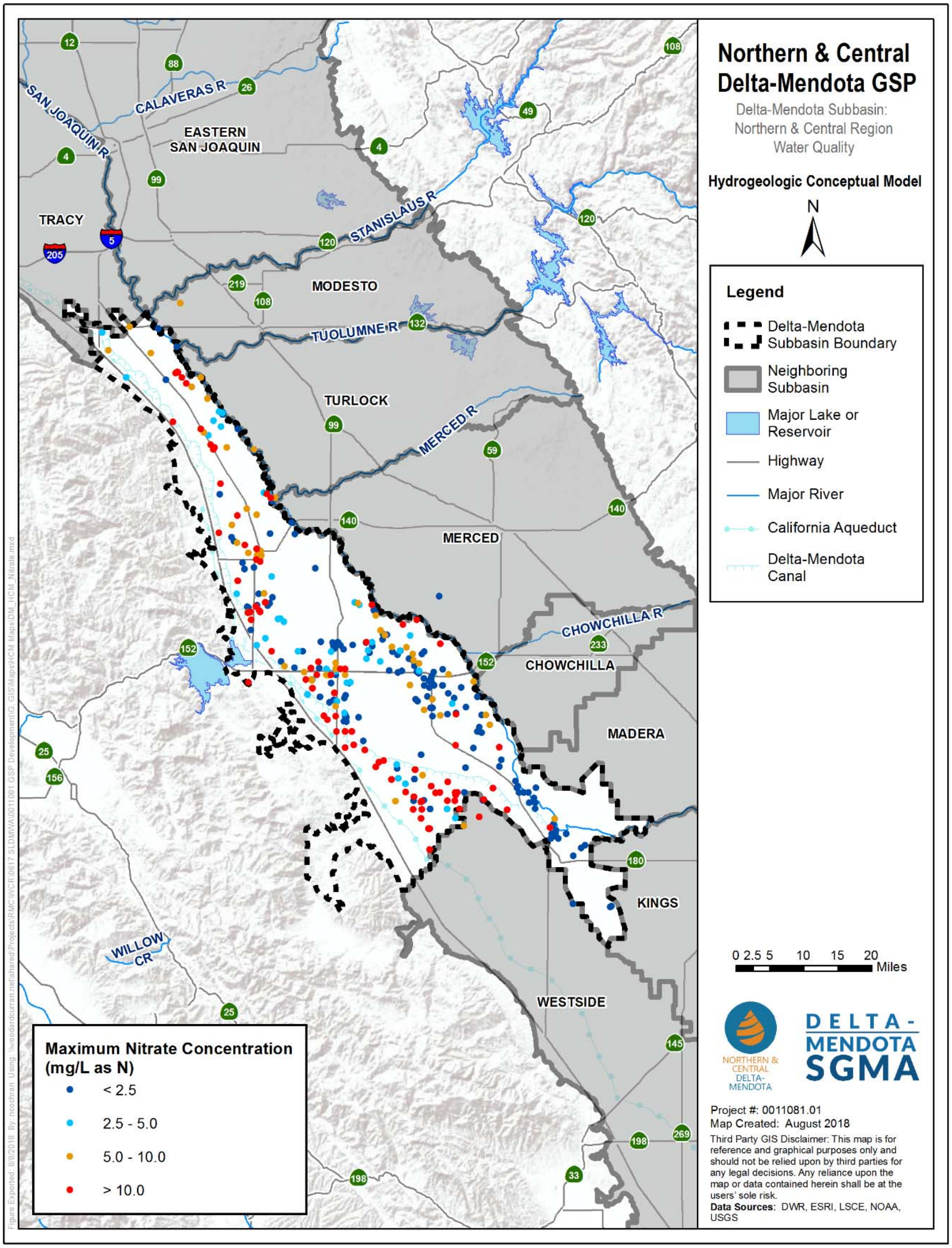


Figure 5-22. Most Recent (2000-2014) Nitrate Concentrations, All Wells



Note: Maximum concentrations are based on all data collected to date for the identified wells.

Figure 5-23. Maximum Nitrate Concentrations, Above Corcoran Clay

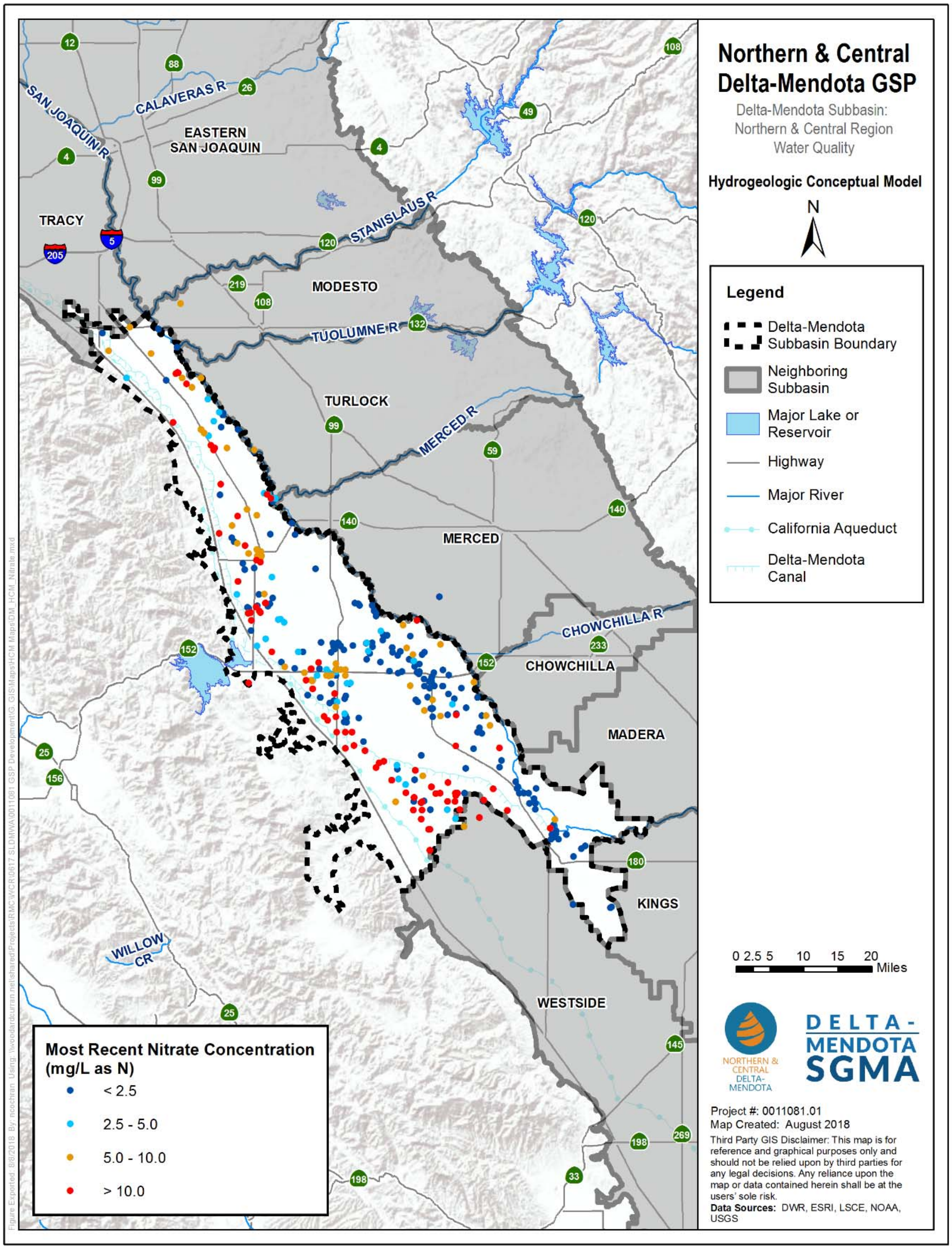
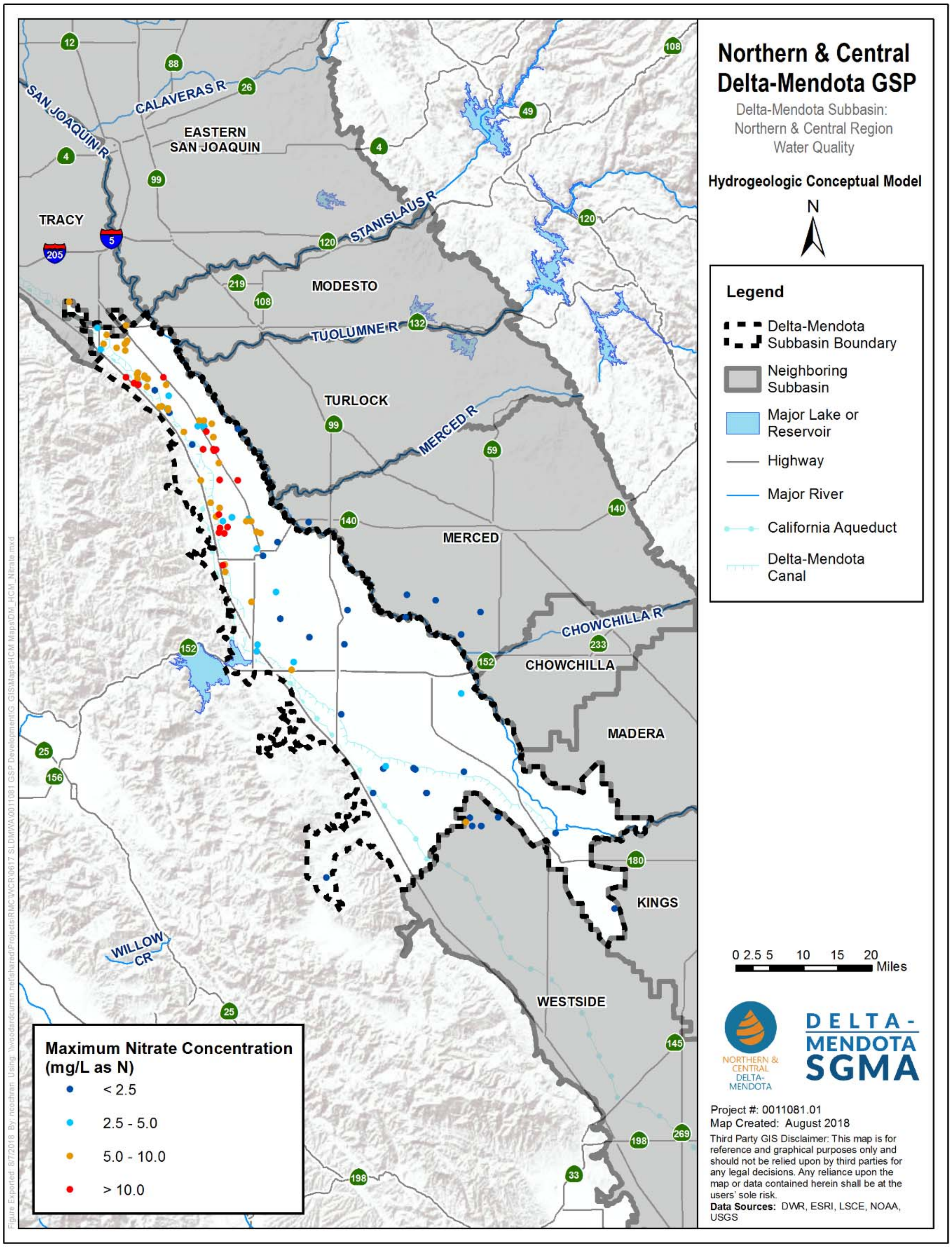


Figure 5-24. Most Recent (2000-2014) Nitrate Concentrations, Above Corcoran Clay



Note: Maximum concentrations are based on all data collected to date for the identified wells.

Figure 5-25. Maximum Nitrate Concentrations, Below Corcoran Clay

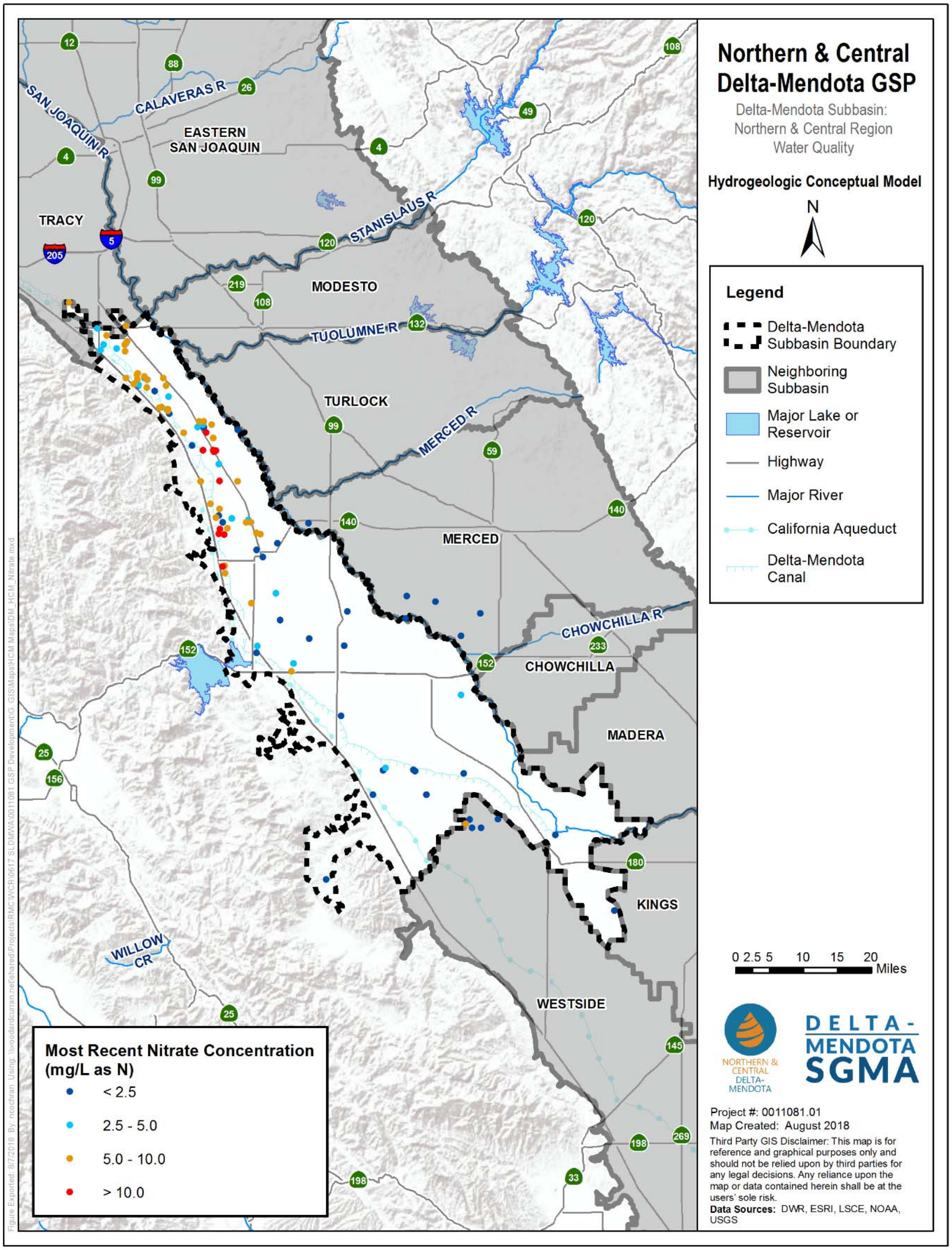
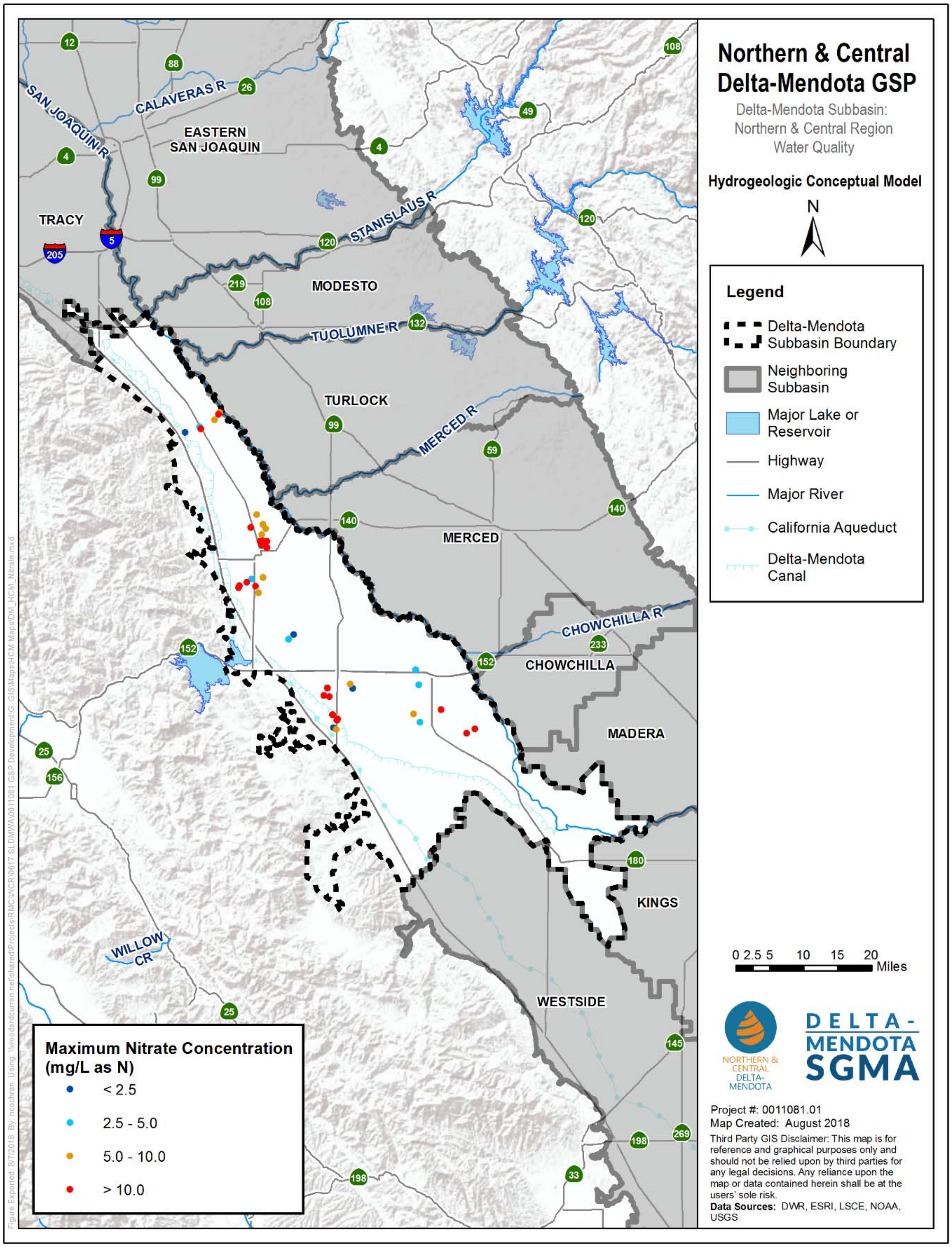


Figure 5-26. Most Recent (2000-2014) Nitrate Concentrations, Below Corcoran Clay



Note: Maximum concentrations are based on all data collected to date for the identified wells.

Figure 5-27. Maximum Nitrate Concentrations, Composite Wells

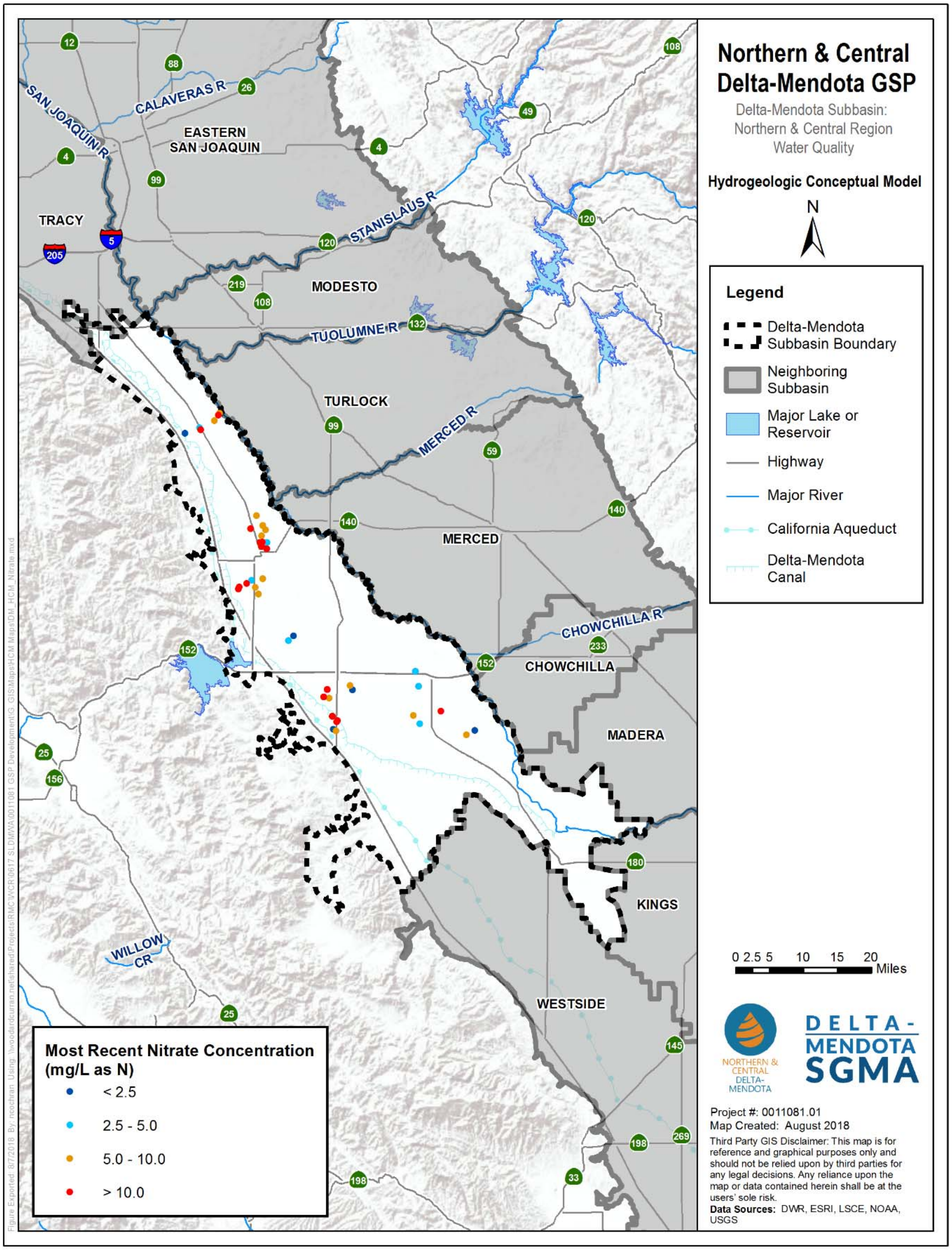
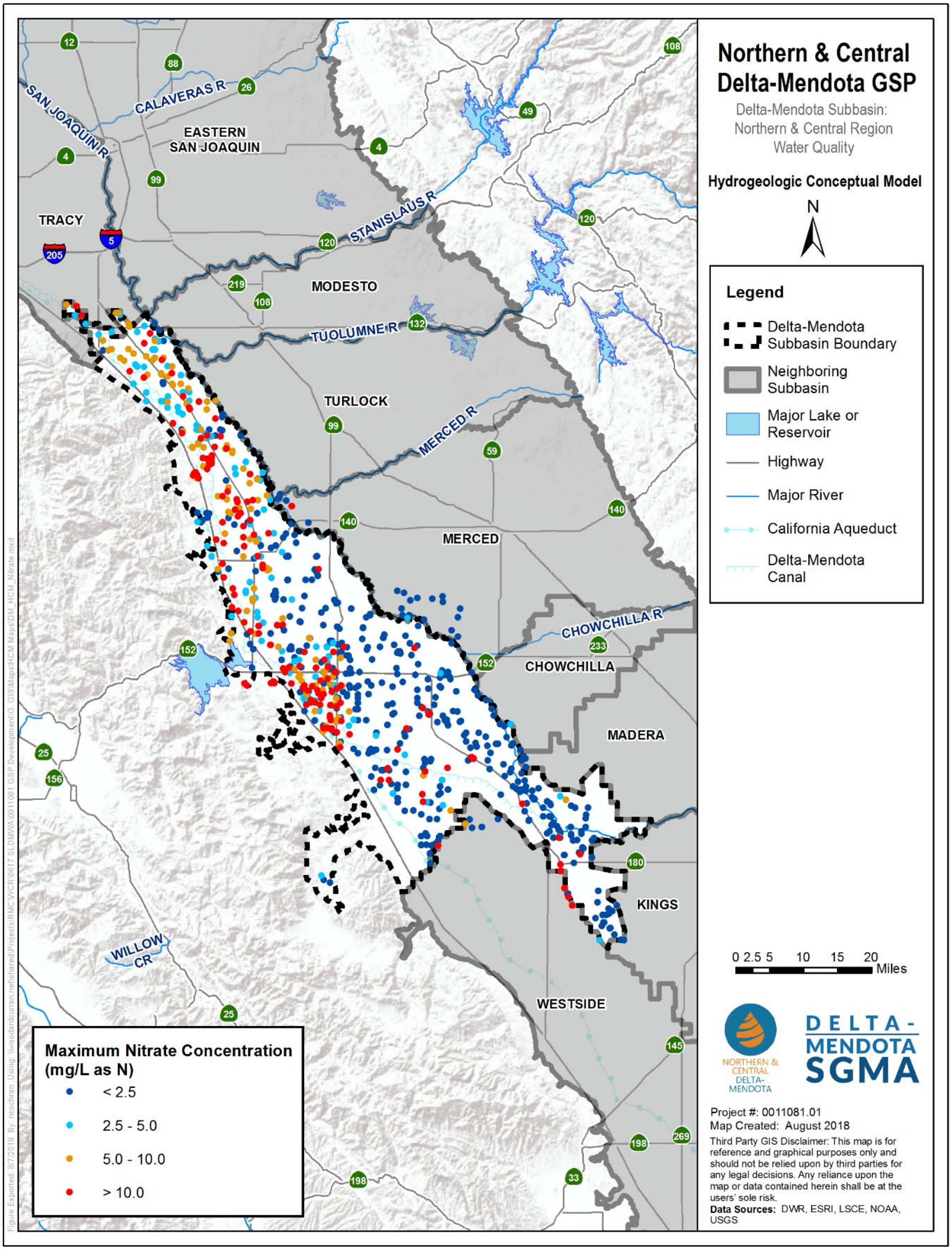


Figure 5-28. Most Recent (2000-2014) Nitrate Concentrations, Composite Wells



Note: Maximum concentrations are based on all data collected to date for the identified wells.

Figure 5-29. Maximum Nitrate Concentrations, Wells of Unknown Depth

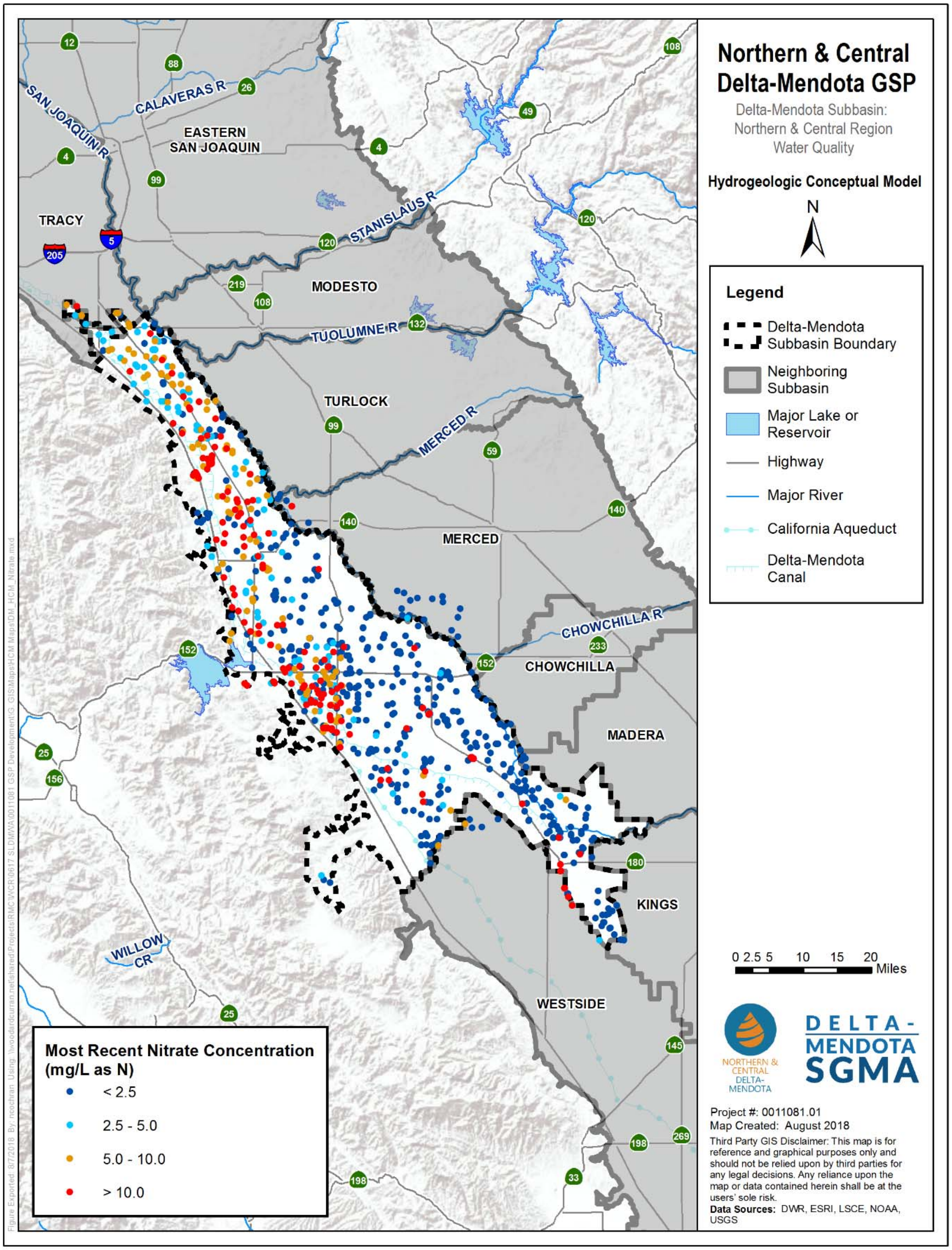


Figure 5-30. Most Recent (2000-2014) Nitrate Concentrations, Wells of Unknown Depth

5.2.8.2.2 TDS Concentrations

Figure 5-31 through Figure 5-40 present the maximum and most recent (for the period around 2000-2014) TDS concentrations in wells within the Delta-Mendota Subbasin and indicate the general salinity of groundwater. The concentration of TDS in drinking water is regulated as a Secondary Drinking Water Standard and the standards are established for aesthetic reasons such as taste, odor, and color and not based on public health concerns. TDS concentrations in groundwater, as shown in Figure 5-31 through Figure 5-40, are symbolized by five classes related to the Secondary MCL (SMCL): less than 500 mg/L, a concentration which is equivalent to the recommended SMCL; 500 to 1,000 mg/L (1,000 mg/L is equivalent to the upper level of the SMCL); 1,000 to 1,500 mg/L; 1,500 to 3,000 mg/L, equivalent and greater than the short-term level of the SMCL; and greater than 3,000 mg/L. The spatial distribution of available TDS data is similar in density to the nitrate data.

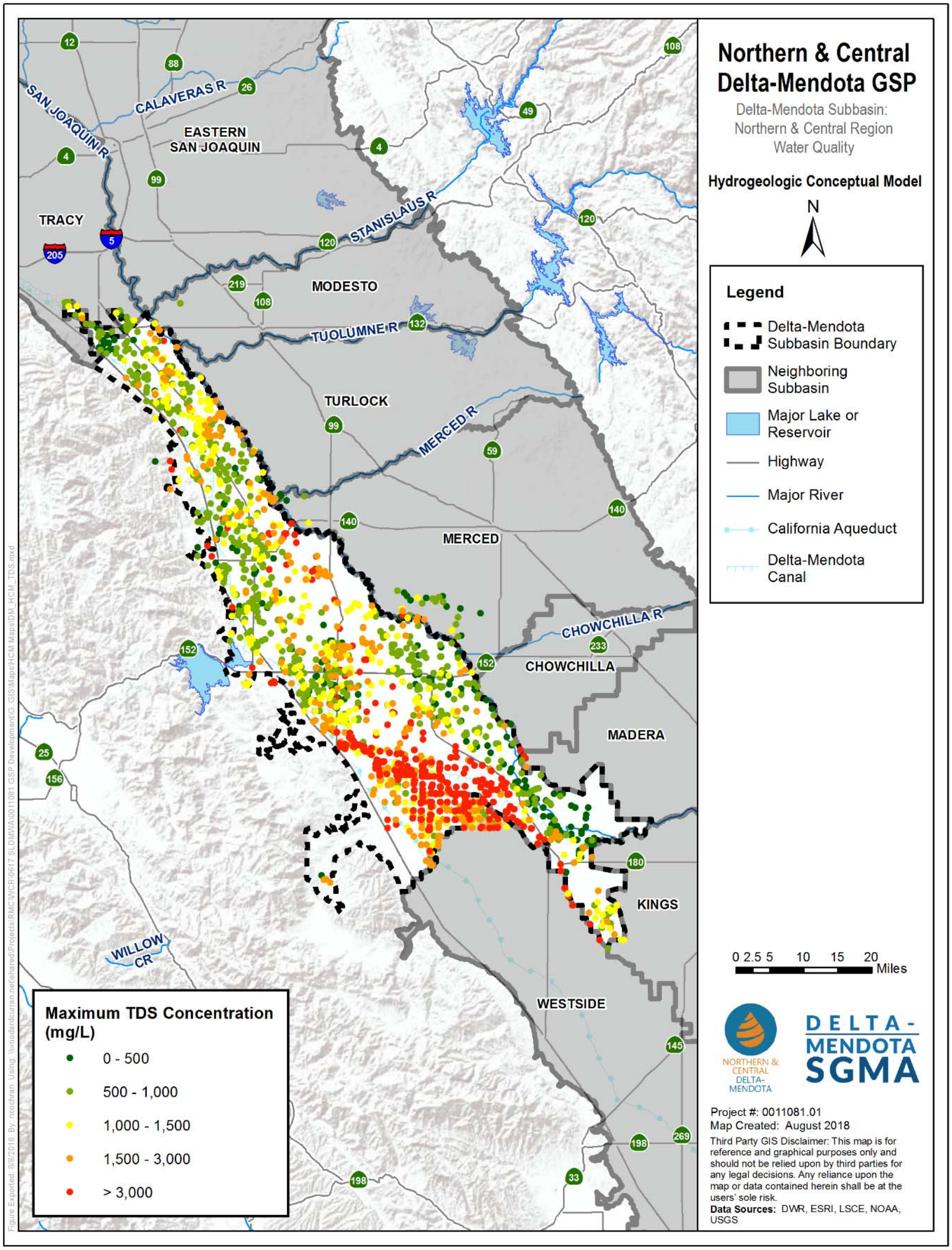
The majority of wells within Delta-Mendota Subbasin have maximum TDS concentrations below 1,000 mg/L, and a general spatial pattern of lower TDS from north of Dos Palos to Mendota is evident in Figure 5-31 and Figure 5-32. An apparent higher density of wells with TDS concentrations greater than 1,500 mg/L is evident in wells from south and southwest of Dos Palos, northwestward to north of Patterson (Figure 5-31). The most recent TDS concentrations (Figure 5-32) are generally below 1,500 mg/L indicating a slight improvement in some wells since the maximum TDS sample was taken.

<u>Above Corcoran Clay</u>

The majority of shallow wells in the Delta-Mendota Subbasin have TDS concentrations that are below 1,500 mg/L and are located near Los Banos and east of Dos Palos (Figure 5-33). Shallow wells with TDS concentrations above 1,500 mg/L are scattered between the area south of Dos Palos to north of Patterson. The most recent TDS concentration data show a similar pattern (Figure 5-34) with a few shallow wells near Los Banos with improving TDS concentrations. No TDS data for shallow wells are available for the Mendota and Tranquillity area. Higher TDS concentrations (greater than 1,500 mg/L) in deeper wells above the Corcoran Clay are observed in the area south of Los Banos and to the north and along the San Joaquin River where poor drainage conditions may exist. TDS concentrations in the remaining Subbasin are largely below 1,500 mg/L (Figure 5-33). The most recent data (Figure 5-34) show very similar patterns as the maximum concentration data with some wells showing improved TDS concentrations.

The majority of very shallow wells (<50 feet in depth) in the southern-central portion of the Subbasin have concentrations exceeding 3,000 mg/L (Figure 5-33). Wells to the south of W. Nees Avenue and east of N. Fairfax Avenue have relatively lower TDS values concentrated. There is a lack of data for very shallow wells in the proximity of the California Aqueduct. A clear trend of decreased TDS values can be seen when comparing the most recent TDS concentrations with the historical maximum values for very shallow wells (Figure 5-34). The area with the greatest number of wells with decreased TDS values is the area bounded by the Delta-Mendota Canal, Merced-Fresno County line, and W. Nees Avenue. For shallow wells, there is a gap in data to the north of the Delta-Mendota Canal (Figure 5-33). A clear trend of increasing TDS values to the east is evident in Figure 5-33 with a majority of the wells located to the east of N. Russell Avenue exceeding 3,000 mg/L. This is in contrast with a considerably high number of wells to the west of N. Russell Avenue having concentrations below 1,000 mg/L.

TDS concentrations seem to be improving in shallow wells (Figure 5-33 and Figure 5-34). Specifically, the most prevalent reductions in TDS concentrations can be observed in the area enclosed by the Delta-Mendota Canal, Merced-Fresno County line, W. Nees Avenue and N. Russell Avenue. TDS data for wells deeper in the Upper Aquifer are sparse (Figure 5-33 and Figure 5-34); all available data points exceed 1,000 mg/L.



Note: Maximum concentrations are based on all data collected to date for the identified wells.

Figure 5-31. Maximum TDS Concentrations, All Wells

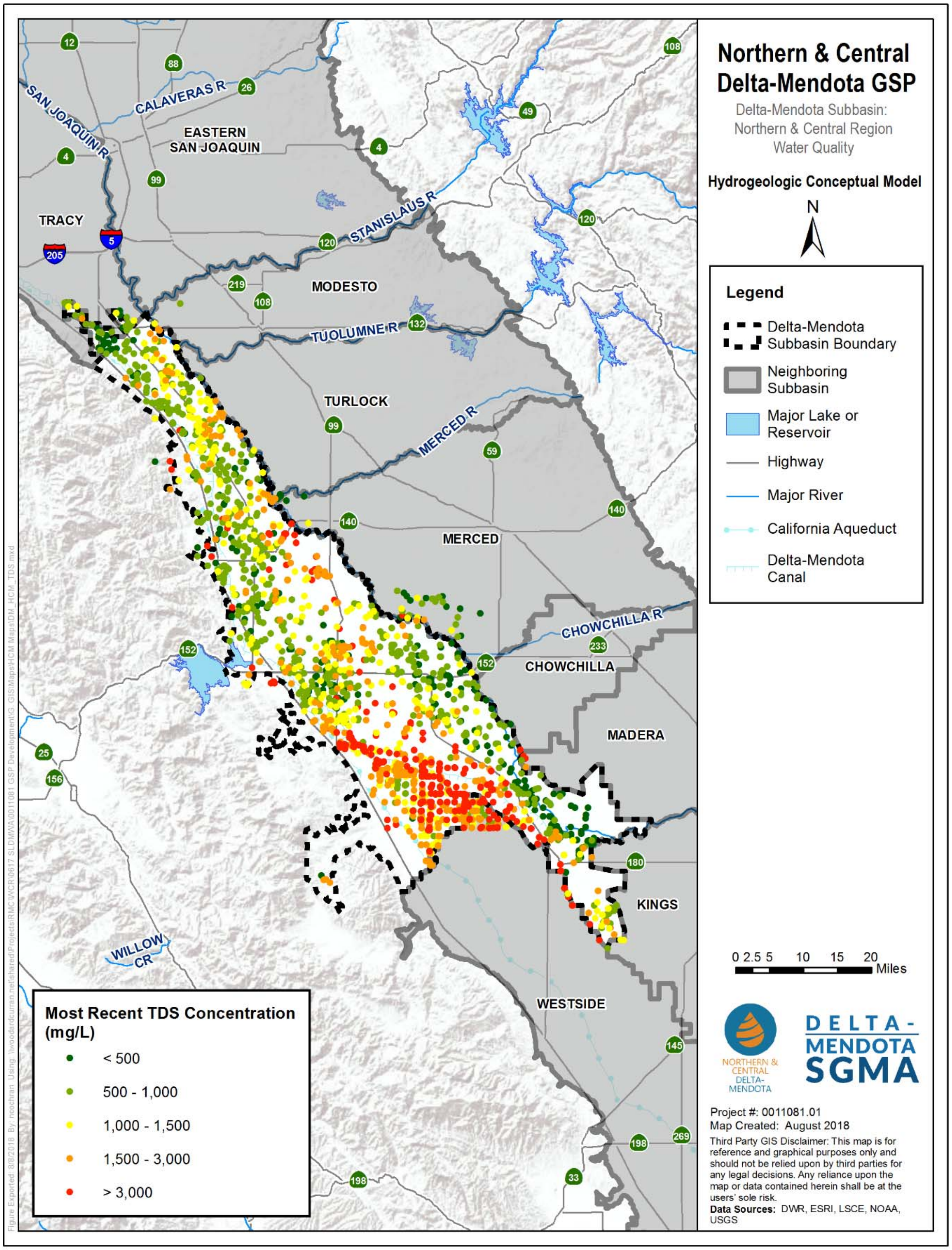
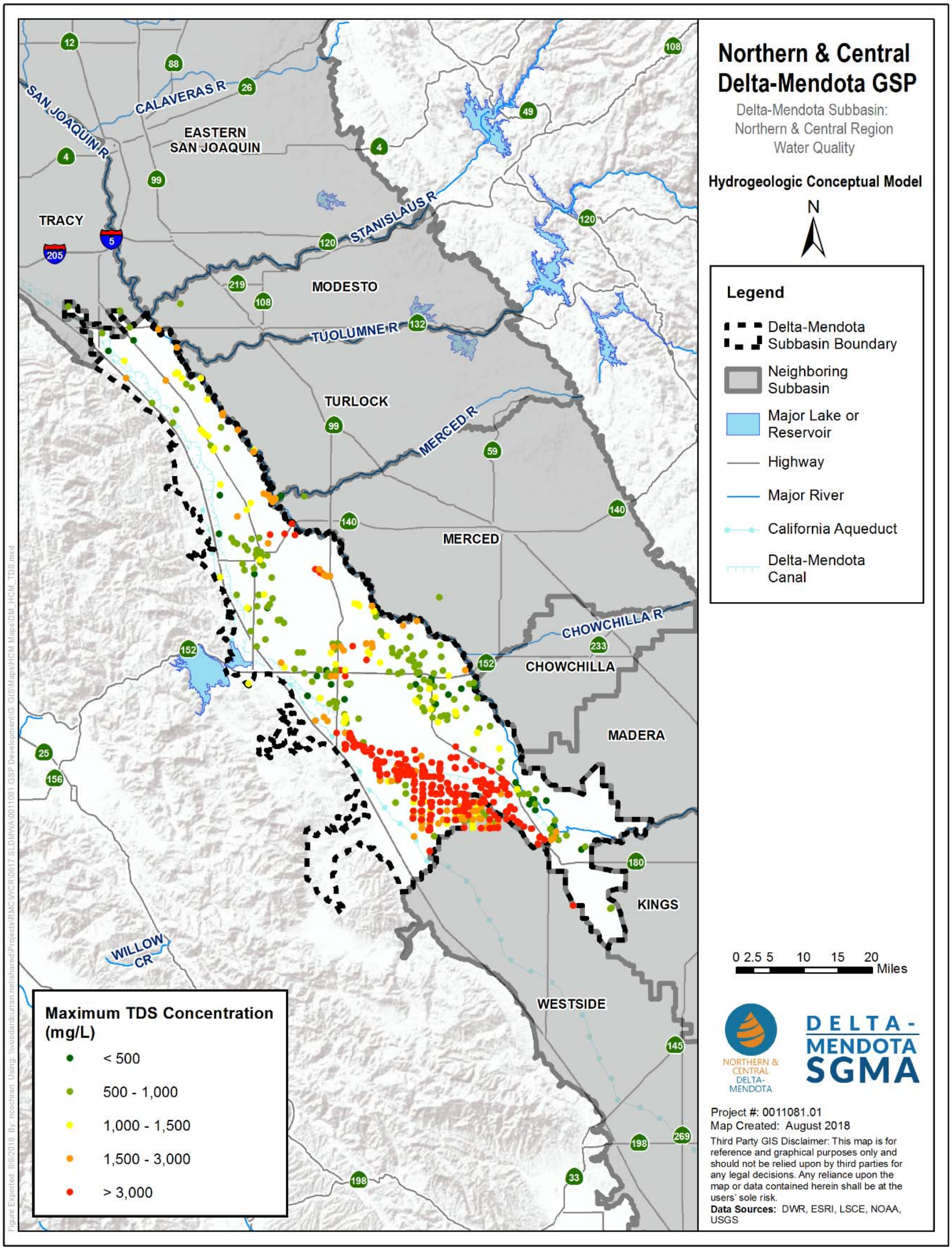


Figure 5-32. Most Recent (2000-2014) TDS Concentrations, All Wells



Note: Maximum concentrations are based on all data collected to date for the identified wells.

Figure 5-33. Maximum TDS Concentrations, Above Corcoran Clay

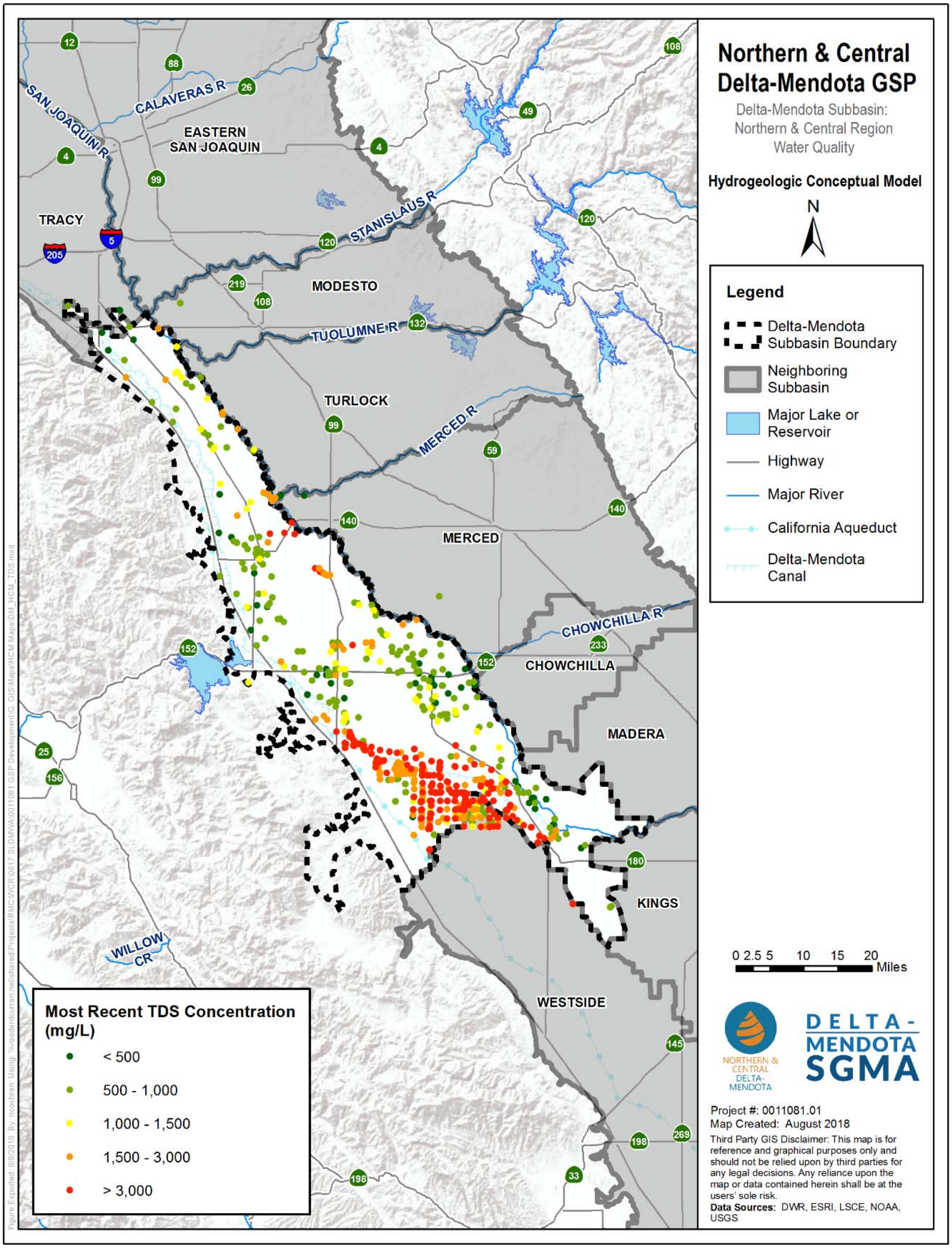


Figure 5-34. Most Recent (2000-2014) TDS Concentrations, Above Corcoran Clay

Below Corcoran Clay

As seen in Figure 5-35 and Figure 5-36, TDS concentration data for wells below the Corcoran Clay are limited compared to above the Corcoran Clay well data and are notably scarce between Los Banos and Tranquillity. However, TDS concentrations north of Los Banos indicate overall lower salinity in the Lower Aquifer than is evident in the Upper Aquifer. A majority of the wells in the Lower Aquifer show maximum TDS concentrations below 1,500 mg/L with maximum TDS concentrations below 1,000 mg/L in most wells along the northwestern edge of the Delta-Mendota Subbasin (Figure 5-35). A few wells with TDS concentrations above 1,500 mg/L are scattered between Los Banos and north of Patterson. The most recent data (Figure 5-36) highlight the same patterns evident in the maximum concentration data. Few TDS concentration data exist southeast of Los Banos for the Lower Aquifer, although the minimally available data suggest deeper TDS concentrations in these areas are mostly less than 1,500 mg/L.

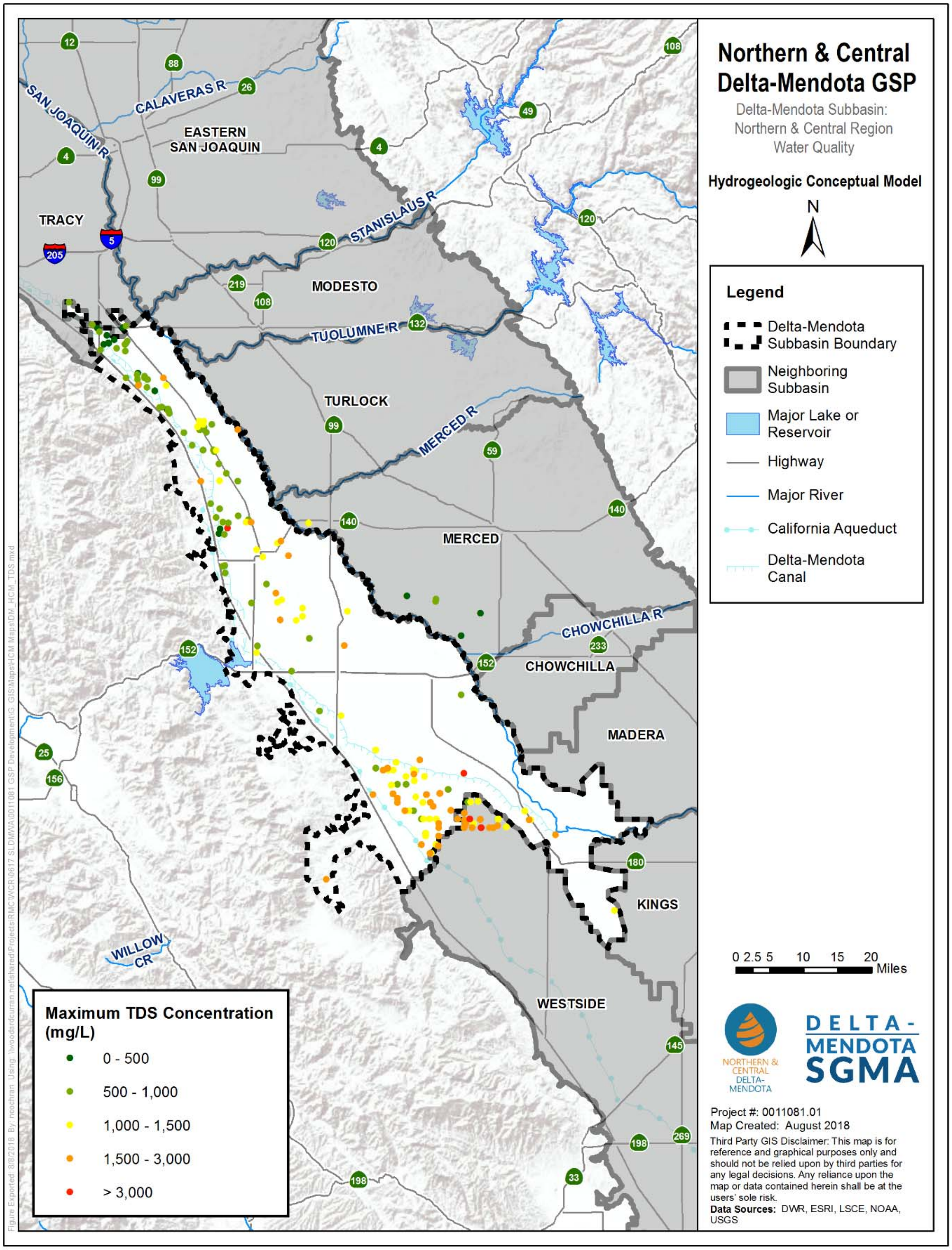
In the south-central portion of the Subbasin, the majority of data points from the Lower Aquifer exceed 1,000 mg/L (Figure 5-35). Wells with data are dispersed throughout this portion of the Subbasin with very little data available north of the Delta-Mendota Canal. A similar data distribution is seen in Figure 5-36 with very little data available north of the Delta-Mendota Canal. Most recent TDS concentrations also reflect historic maximums with most samples exceeding 1,000 mg/L.

Composite Wells

Figure 5-37 depicts maximum TDS concentration data for composite wells screened both above and below the Corcoran Clay, whereas Figure 5-38 presents the most recent concentration data for composite wells. Very few TDS concentrations are available for the composite well category, but most results are below 1,500 mg/L.

Wells of Unknown Depth

As shown in Figure 5-39 and Figure 5-40, much TDS concentration data exist for wells of unknown depth. These figures show a similar pattern to the Upper Aquifer TDS Concentration maps (Figure 5-33 and Figure 5-34) with the exception of a band of wells that exceed 1,500 mg/L south of Dos Palos and also south of Mendota that may be related to the saline front originating in the Coast Range. Several areas with higher densities of wells with lower TDS concentrations can be seen in Figure 5-39 and Figure 5-40. The area north of Dos Palos, and also the area between Dos Palos and Mendota, have a particularly high density of wells of unknown depth with lower TDS concentrations that are mostly less than 1,000 mg/L.



Note: Maximum concentrations are based on all data collected to date for the identified wells.

Figure 5-35. Maximum TDS Concentrations, Below Corcoran Clay

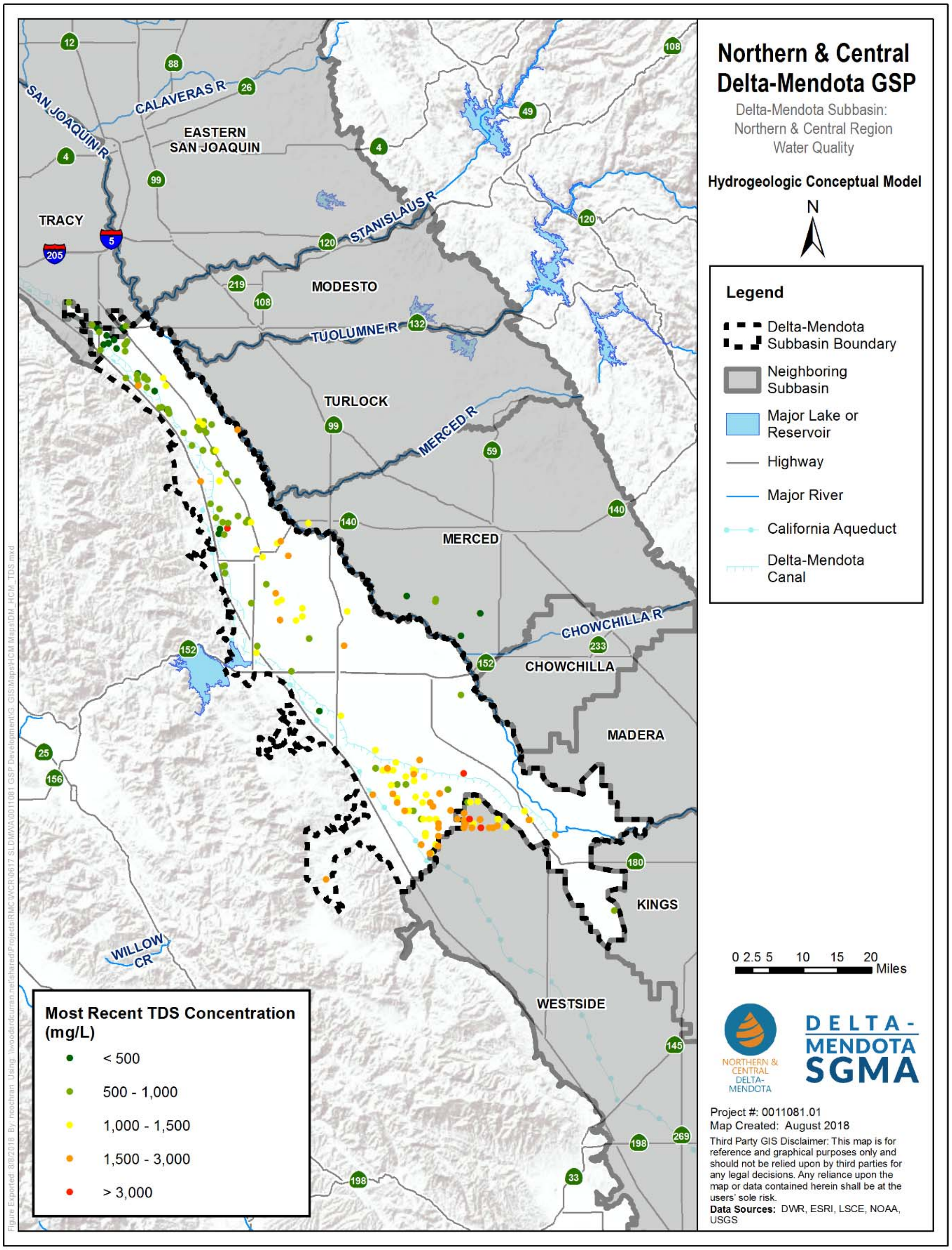
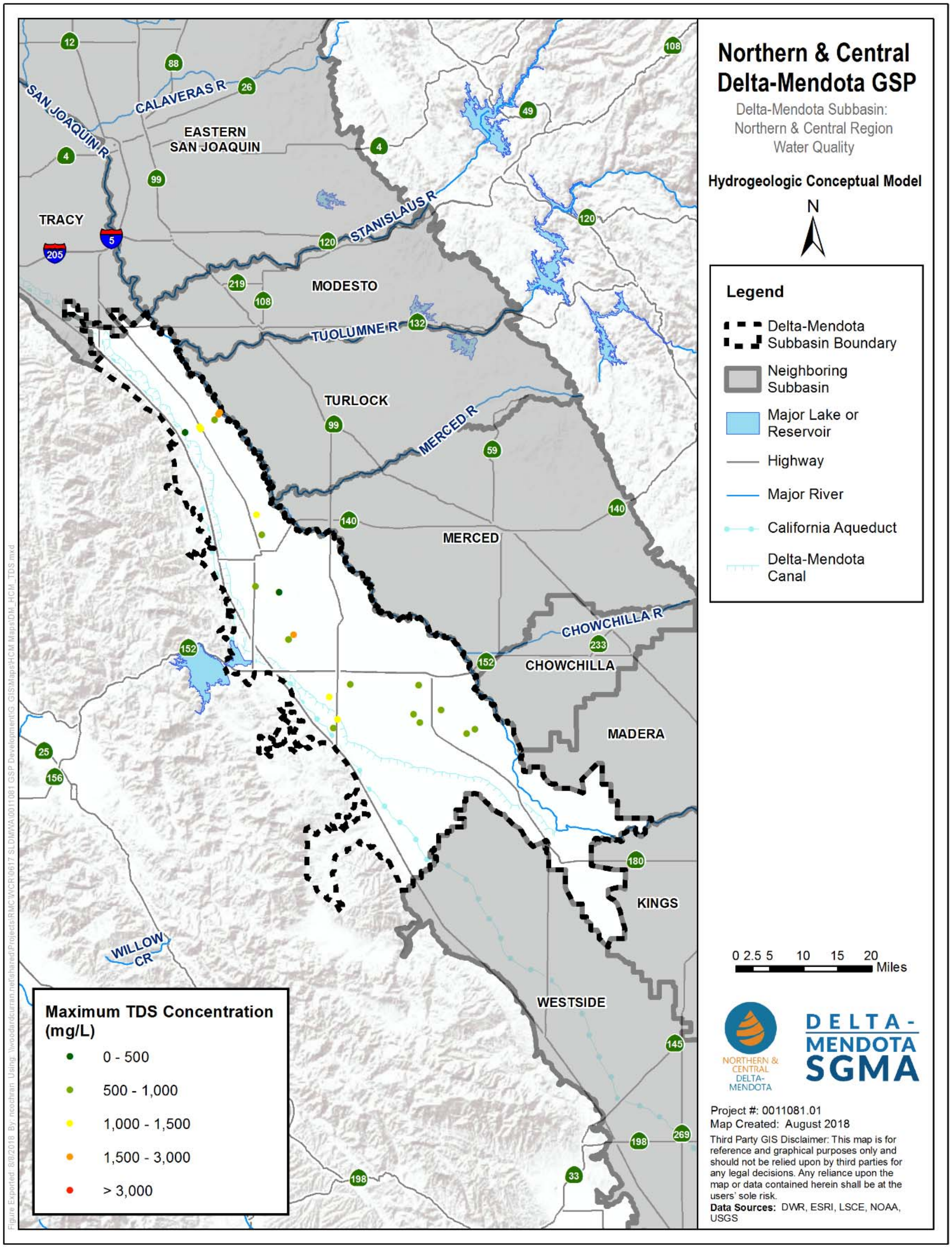


Figure 5-36. Most Recent (2000-2014) TDS Concentrations, Below Corcoran Clay



Note: Maximum concentrations are based on all data collected to date for the identified wells.

Figure 5-37. Maximum TDS Concentrations, Composite Wells

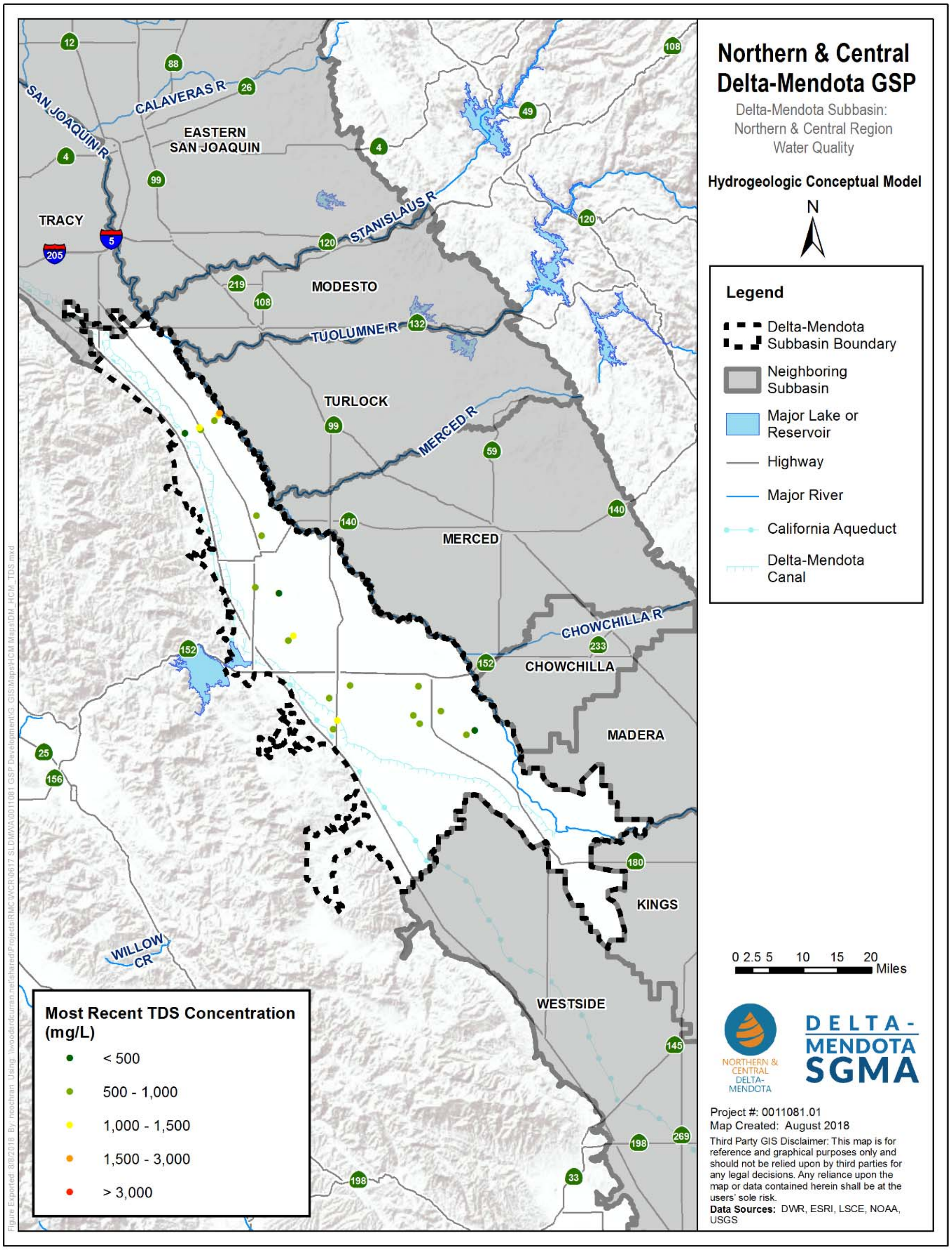
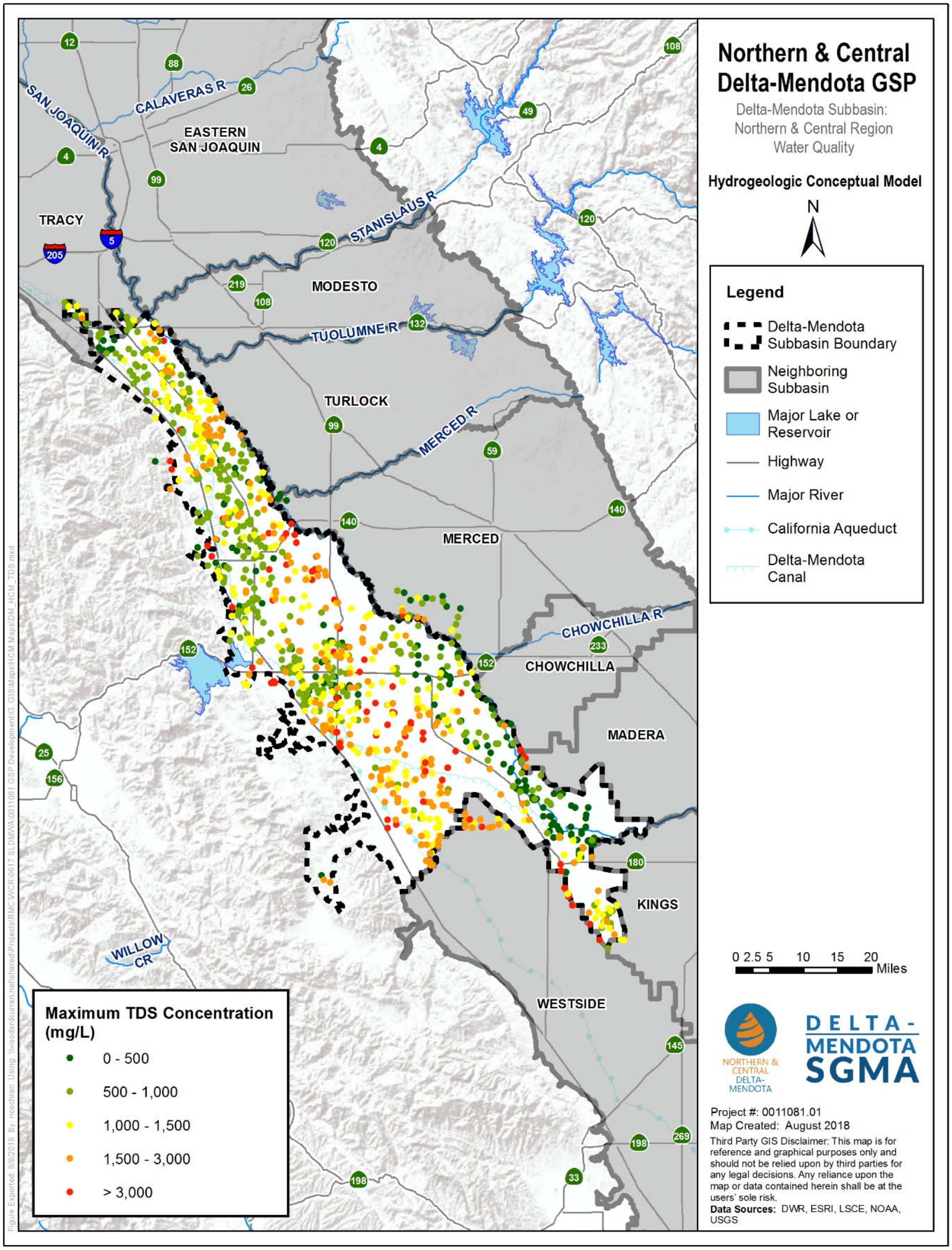


Figure 5-38. Most Recent (2000-2014) TDS Concentrations, Composite Wells



Note: Maximum concentrations are based on all data collected to date for the identified wells.

Figure 5-39. Maximum TDS Concentrations, Wells of Unknown Depth

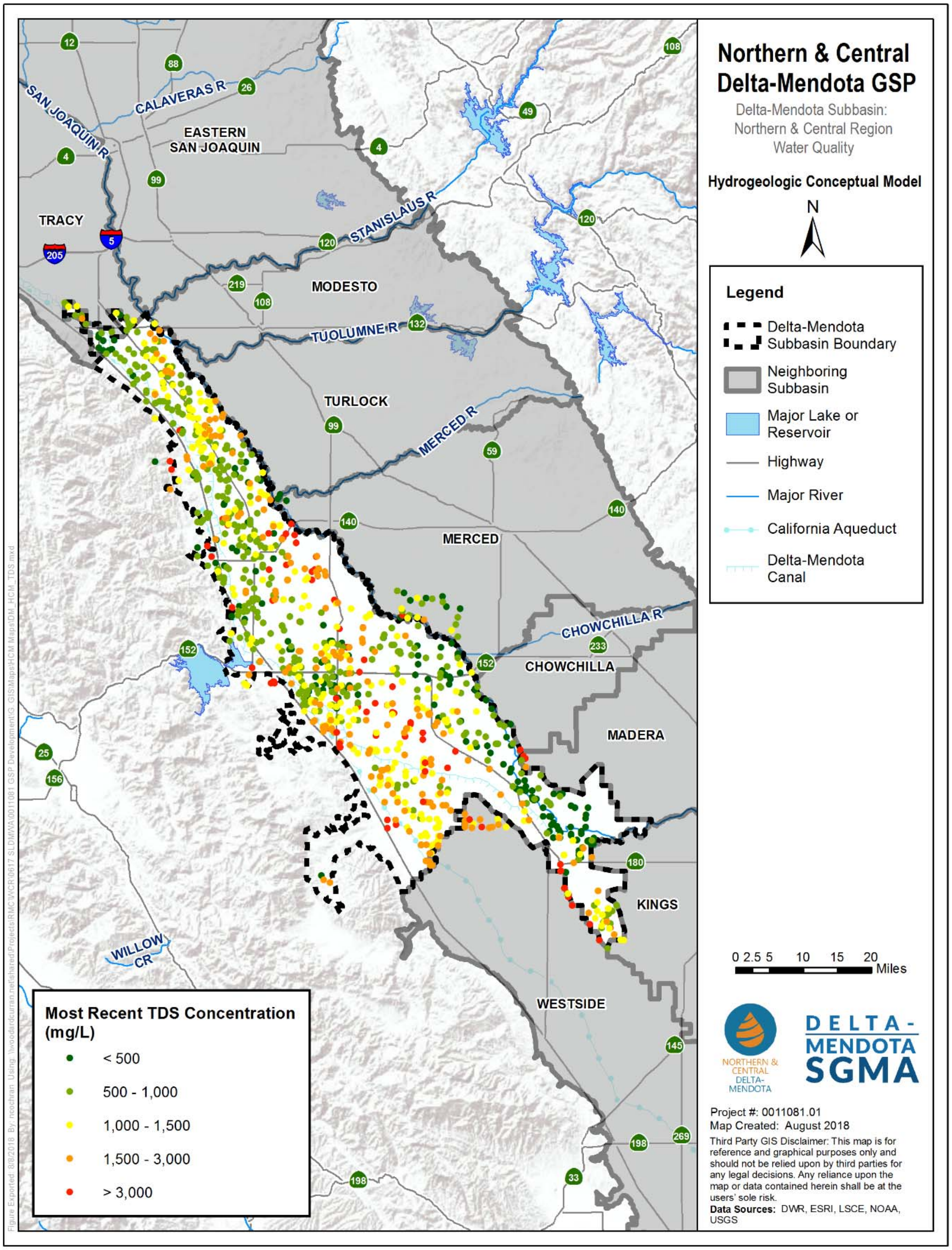


Figure 5-40. Most Recent (2000-2014) TDS Concentrations, Wells of Unknown Depth

5.2.8.2.3 Pesticides

Pesticide concentration data for the Delta-Mendota Subbasin are limited to data obtained from the California Department of Pesticide Regulation (DPR), as originally presented in Luhdorff & Scalmanini Consulting Engineers (LSCE) (2015) and LSCE (2016). Pesticide data available from DPR are for wells, but locations are only provided at the spatial resolution of the Public Land Survey System (PLSS) section in which the well is located and well depths are not reported or available for most wells. Figure 5-41 shows the locations of sections where wells have been sampled for pesticides and where pesticide test results are reported by DPR and include sections that may only be partially within the Subbasin. Because well locations are not provided with these pesticide data, it is possible that wells in sections that are only partly within the subbasin actually fall outside of the Subbasin.

Sections with detected concentrations of pesticides exceeding levels provided in the State Water Resources Control Board (SWRCB) Water Quality Goals Online Database are symbolized red in Figure 5-41; sections where pesticide detections have occurred at concentrations below the identified exceedance threshold are symbolized as orange, and green sections signify areas where pesticides were not detected. Figure 5-41 shows all available pesticide sample data from DPR within the Delta-Mendota Subbasin. Table 5-1 summarizes pesticides that have been detected in wells that are in sections that overlap with the Subbasin completely or partially, as reported in the DPR database. The threshold values used as a basis for identifying pesticide exceedances are also included in Table 5-1. The thresholds used to define pesticide exceedances were based first on a California Primary MCL; otherwise, the California Notification (action) Level and U.S. Environmental Protection Agency (EPA) Health and Water Quality advisory concentrations were used for comparison, as available.

Data for a total of 475 wells (in 258 PLSS sections) tested for pesticides in the study area were available from DPR. Of the 475 wells tested, eight unique wells had detectable concentrations of a pesticide (Table 5-1). As shown in Table 5-1, 486 instances of pesticide detections were recorded within the Delta-Mendota Subbasin; however, some wells had detectable concentrations of multiple pesticides. Of the 258 sections that had wells tested, 62 sections had wells with detectable concentrations of a pesticide and 6 sections had wells with exceedances. As shown in Figure 5-41, a higher density of pesticide detections and exceedances has occurred in the northern part of the Delta-Mendota Subbasin, from south of Gustine to north of Patterson.

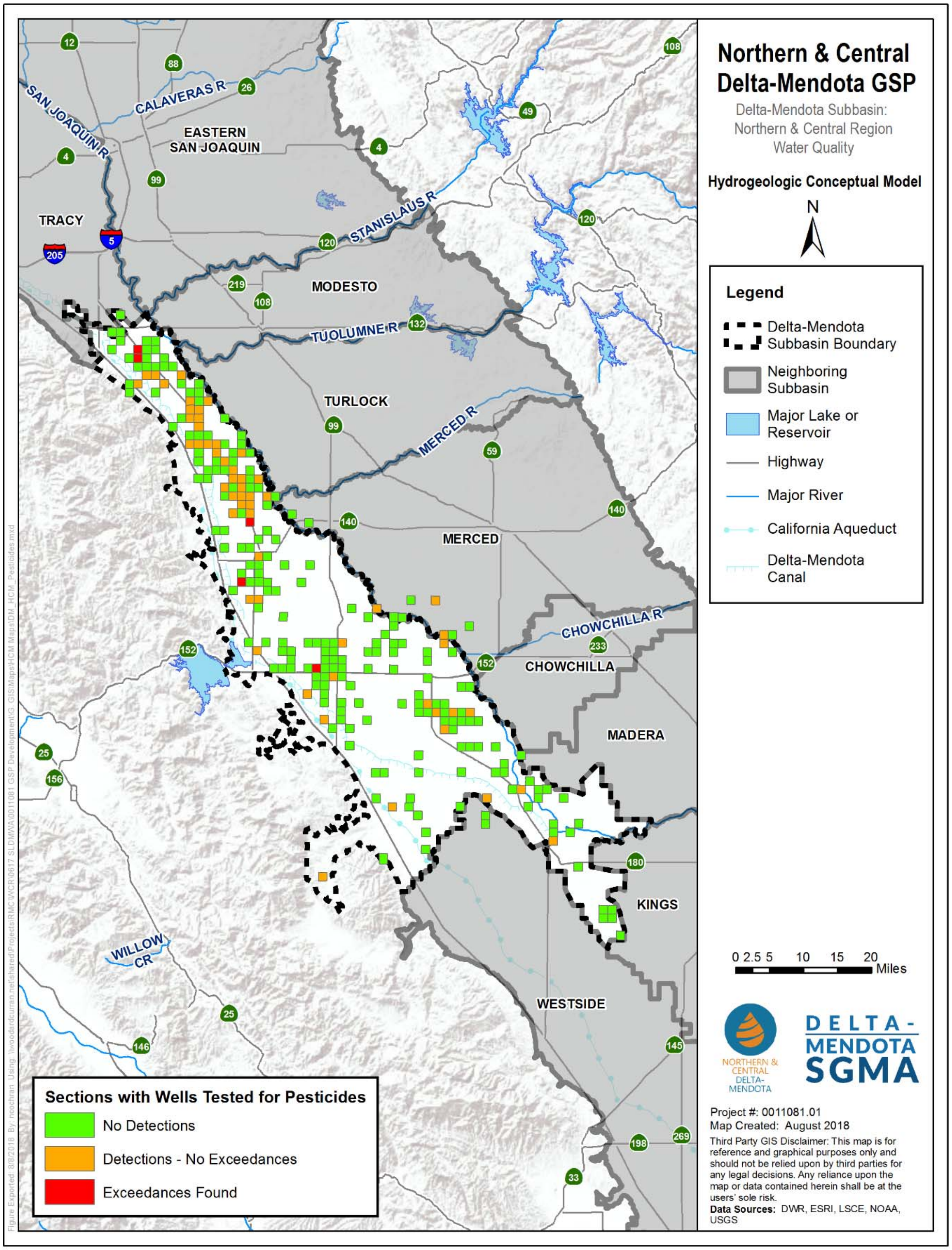


Figure 5-41. Pesticide Detections and Exceedances by Section

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Table 5-1. Summary of Pesticide Detections and Exceedances

Pesticide	Wells Sampled	Wells with Detection	Number of Sample Detections	Wells with Exceedance	Sections Sampled	Sections with Detection	Sections with Exceedance	Concentration in Samples with Detections (µg/L)			Exceedance Threshold[1] (µg/L)	Basis for Exceedance Threshold[1]
								Average	Minimum	Maximum		
1,2-Dichloropropane (Propylene Dichloride)	204	1	1	0	129	1	0	0.039	0.039	0.039	5	
2,6-Diethylaniline	45	1	1	0	34	1	0	0.005	0.005	0.005	-	-
2-Hydroxycyclohexyl Hexazinone	8	1	1	0	6	1	0	0.126	0.126	0.126	-	-
3,4-Dichloro Aniline	45	5	5	0	34	4	0	0.048	0.004	0.215	-	-
3,5-Dichloro Aniline	40	1	1	0	30	1	0	0.004	0.004	0.004	-	-
ACET (Deisopropylatrazine)	68	1	1	0	46	1	0	0.052	0.052	0.052	-	-
Alachlor ESA	40	18	23	0	28	11	0	0.53	0.05	1.38	4	WI DNR PAL
Alachlor OXA	36	1	2	0	24	1	0	0.051	0.05	0.051	-	-
Atrazine	314	10	14	0	189	8	0	0.063	0.006	0.2	1	CA Primary MCL
Carbon Disulfide	64	3	3	0	43	3	0	0.373	0.03	1.06	160	California State Notification (Action) Level
Chlorthal-Dimethyl	52	1	1	0	40	1	0	0.004	0.004	0.004	-	-
DBCP (Dibromochloropropane)	214	15	292	2	123	10	2	0.234	0.005	10.1	0.2	CA Primary MCL
Deethyl-Atrazine (DEA)	113	11	11	0	80	9	0	0.012	0.005	0.028	-	-
Diaminochlorotriazine (DACT)	60	1	1	0	38	1	0	0.091	0.091	0.091	-	-
Diuron	165	7	17	0	104	7	0	0.204	0.07	0.73	2	U.S. EPA Health Advisory Cancer[2]
EPTC	57	5	5	0	43	5	0	0.03	0.008	0.074	40	MN HBV (Chronic)
Ethylene Dibromide	158	3	6	3	98	3	3	0.266	0.08	0.48	0.05	CA Primary MCL
Hexazinone	148	10	11	0	94	9	0	0.047	0.009	0.094	-	-

Pesticide	Wells Sampled	Wells with Detection	Number of Sample Detections	Wells with Exceedance	Sections Sampled	Sections with Detection	Sections with Exceedance	Concentration in Samples with Detections (µg/L) Average	Minimum	Maximum	Exceedance Threshold[1] (µg/L)	Basis for Exceedance Threshold[1]
Metalaxyl	47	2	2	0	36	1	0	0.035	0.015	0.054	-	-
Metolachlor	133	4	4	0	73	2	0	0.024	0.013	0.045	44	U.S. EPA Water Quality Advisory Concentration[3]
Metolachlor ESA	36	25	31	0	24	17	0	2.928	0.05	24	-	-
Metolachlor OXA	36	11	15	0	24	8	0	0.473	0.05	2.65	-	-
Molinate	114	3	3	0	59	3	0	0.01	0.007	0.01	20	CA Primary MCL
Prometon	236	8	8	0	157	8	0	4.413	0.021	13.4	-	-
Prometryn	217	2	2	0	136	2	0	0.004	0.001	0.006	-	-
Simazine	309	22	24	1	183	19	1	0.59	0.004	6.8	4	CA Primary MCL
Tebuthiuron	60	1	1	0	48	1	0	0.011	0.011	0.011	-	-

"-" No threshold established or identified

1. Source of threshold: California Environmental Protection Agency, State Water Resources Control Board, Compilation of Water Quality Goals (https://www.waterboards.ca.gov/water_issues/programs/water_quality_goals/)
2. U.S. EPA Health Advisory, Cancer Risk Level. Likely to be carcinogenic to humans.
3. National Recommended Ambient Water Quality Criteria to protect human health from consumption of water and aquatic organisms, cancer risk level

Reference: *Western San Joaquin River Watershed Groundwater Quality Assessment Report* (LSCE, 2015).and *Grassland Drainage Area Groundwater Quality Assessment Report* (LSCE, 2016)

5.2.8.2.4 Selenium and Boron

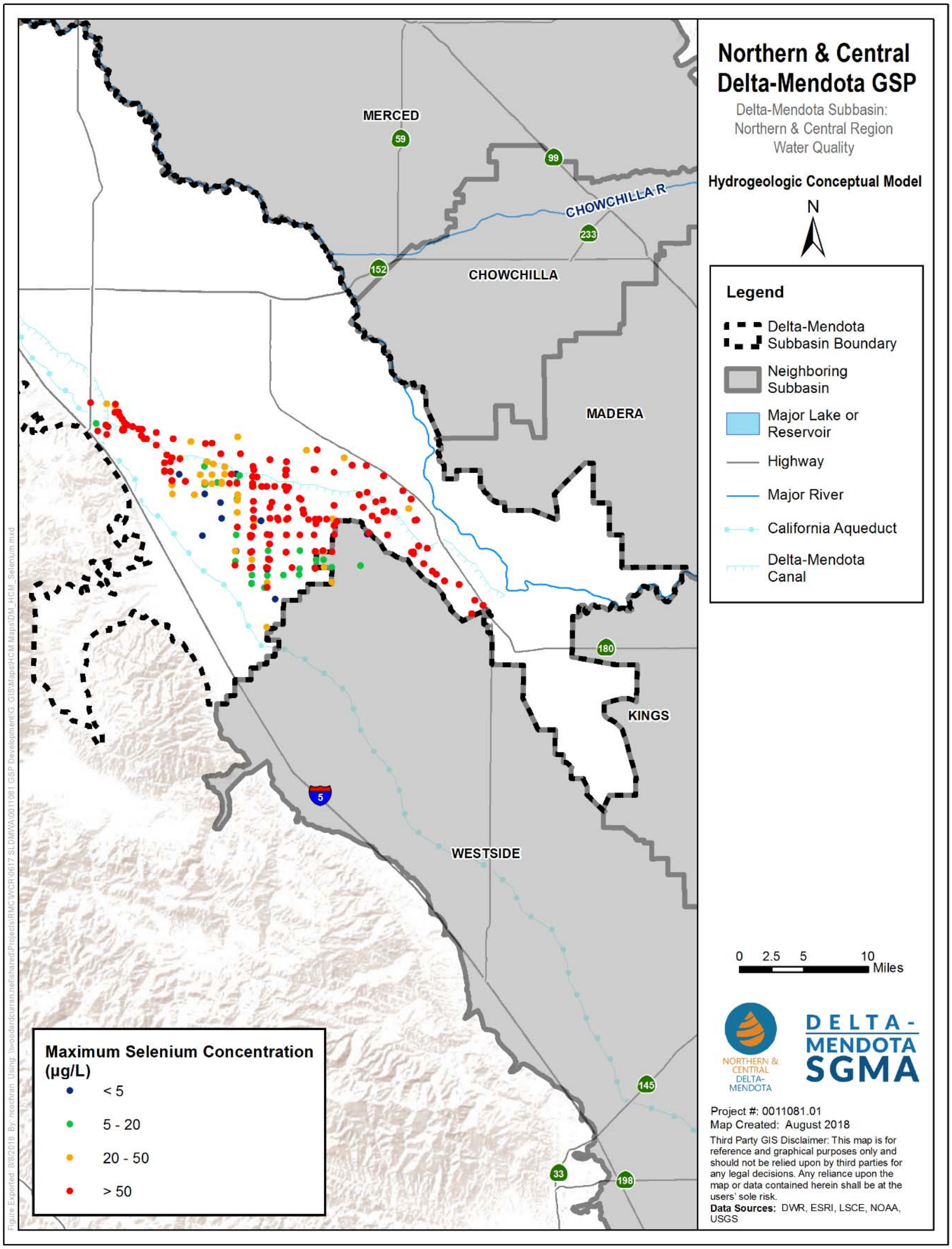
Although both selenium and boron are naturally occurring in the Delta-Mendota Subbasin and are not necessarily a product of impacts from irrigated agriculture, understanding the patterns and trends of their concentrations in groundwater within the Subbasin is helpful for the management of irrigated agriculture, particularly as it relates to sources of selenium in drainage water and boron concentrations in groundwater used for irrigation. Selenium is a natural element commonly found in soils and also occurring in groundwater. High selenium concentrations in groundwater and drainage water, especially in the southern portion of the Subbasin, have been a persistent issue. Selenium is an essential nutrient for humans; however, high concentrations can present health concerns. Selenium has a Primary MCL for drinking water of 50 micrograms per liter (µg/L) and a California Public Health Goal of 30 µg/L. Selenium can be toxic for aquatic wildlife at considerably lower levels and selenium concentrations in discharges of drainage water to surface waterways regulated under the Grassland Bypass Project Water Discharge Requirements (WDRs) have thresholds below the MCL and Public Health Goal.

Boron has no drinking water MCL, although it has a California Action Level of 1.0 mg/L and an agricultural goal of 0.7 mg/L. Many agricultural crops are sensitive to high boron concentrations and its presence in groundwater is a consideration for use of groundwater for irrigation purposes.

Figure 5-42 through Figure 5-57 depict the historical maximum and most recent concentrations (about 2000 to 2014) for selenium and boron in the southern portion of the Delta-Mendota Subbasin, the portion of the subbasin where these constituents are of key concern. These figures are also divided by primary aquifer for each of the constituents. The units for selenium concentrations displayed on the figures are in micrograms per liter (µg/L) whereas boron concentrations are presented in milligrams per liter (mg/L).

Figure 5-42 highlights the maximum concentrations of selenium observed historically within the southern portion of the Subbasin. The majority of the datapoints show maximum historical concentrations exceeding the MCL of 50 µg/L, but an improvement is evident in the most recent concentrations of selenium in Figure 5-43. Although most locations exhibit concentrations above 50 µg/L, some pockets of lower selenium concentrations exist, most notably in the area to the northwest of the W. Nees Avenue and N. Russell Avenue intersection where concentrations are below 20 µg/L.

Historical maximum concentration data for boron above and below the Corcoran Clay is shown in Figure 5-50, and the most recent data are presented in Figure 5-51. Most of these data show historical boron concentrations above 2 mg/L, a level which is considerably above the agricultural goal of 0.7 mg/L.



Note: Maximum concentrations are based on all data collected to date for the identified wells.

Figure 5-42. Maximum Selenium Concentrations, All Wells

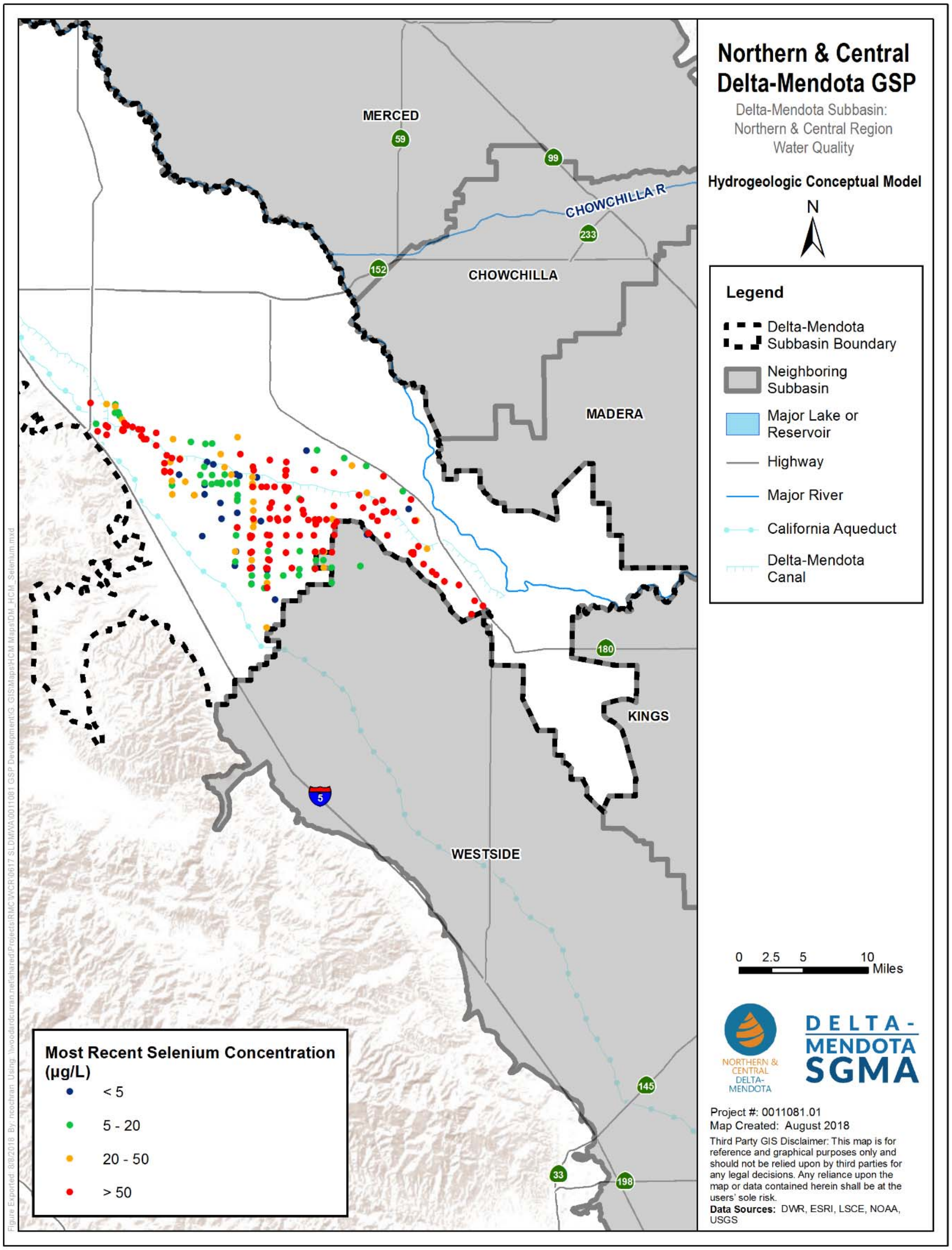
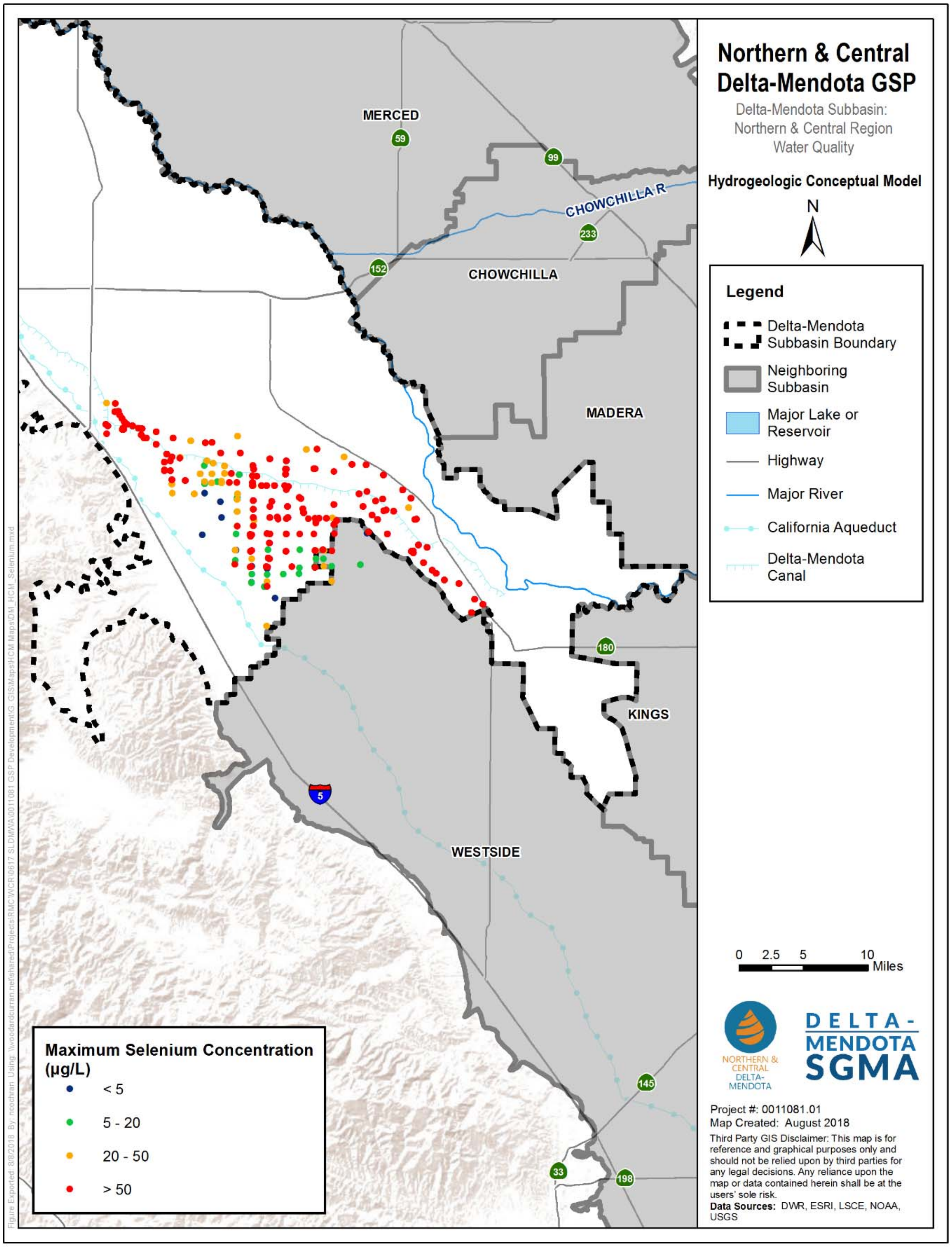


Figure 5-43. Most Recent (2000-2014) Selenium Concentrations, All Wells



Note: Maximum concentrations are based on all data collected to date for the identified wells.

Figure 5-44. Maximum Selenium Concentrations, Above Corcoran Clay

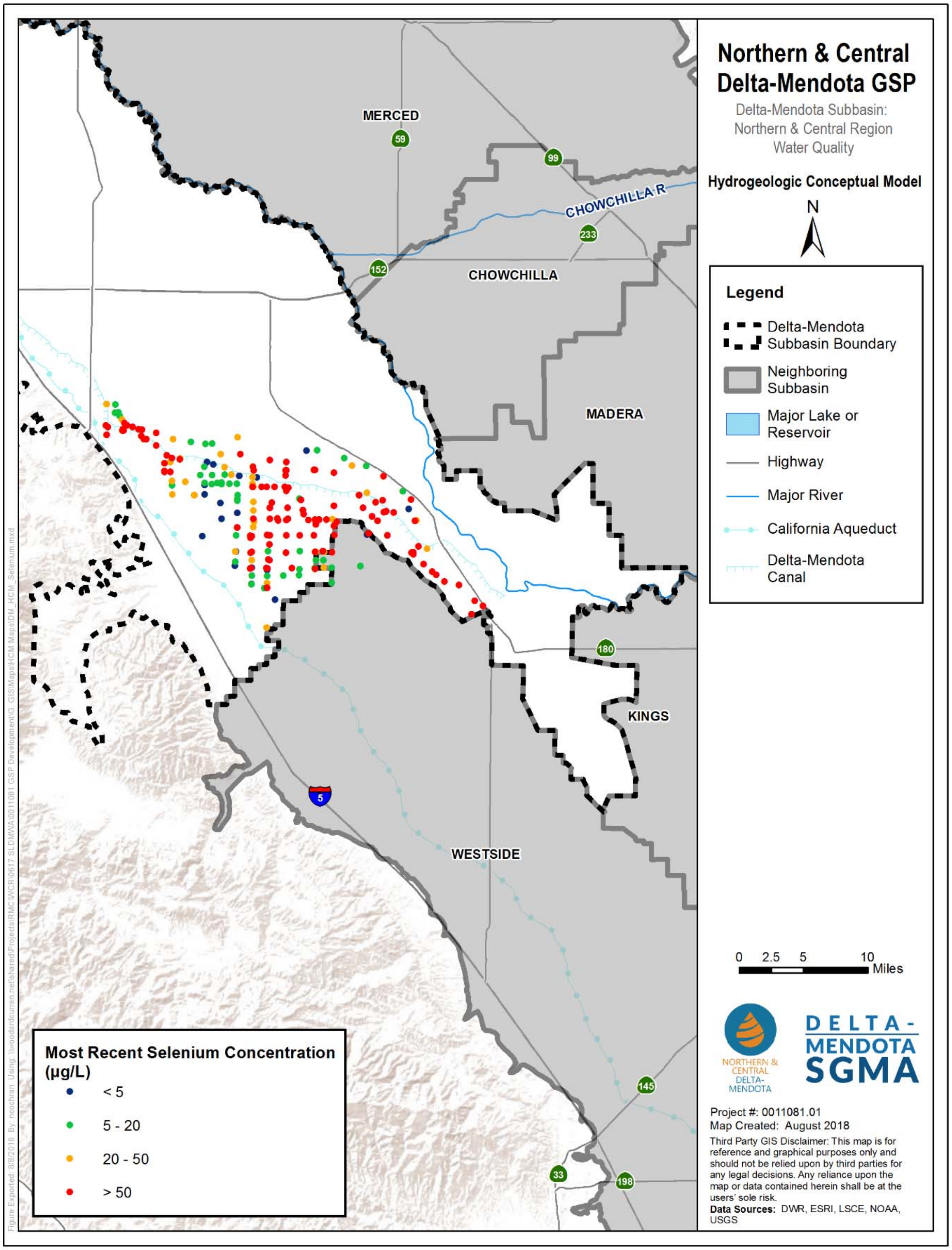
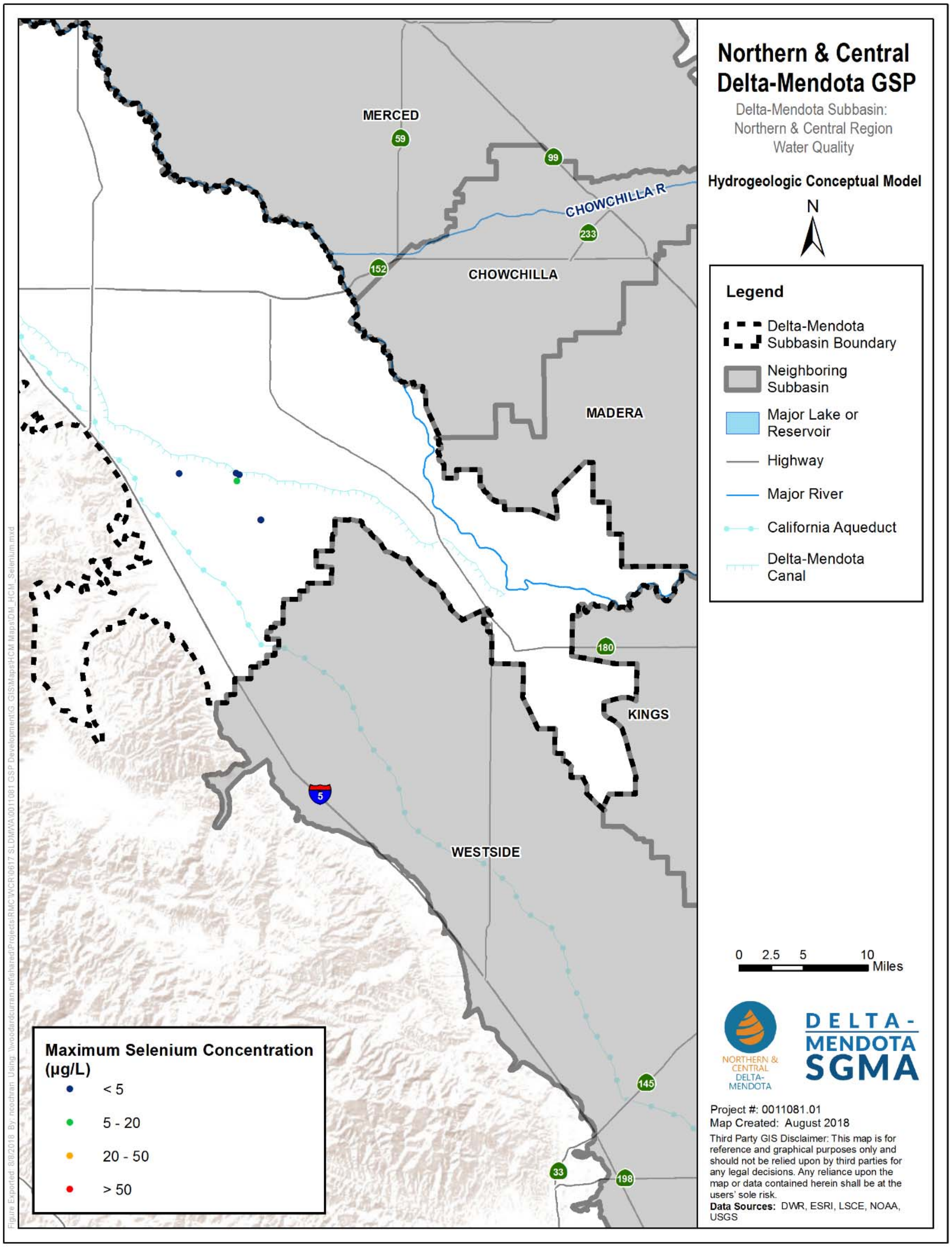


Figure 5-45. Most Recent (2000-2014) Selenium Concentrations, Above Corcoran Clay



Note: Maximum concentrations are based on all data collected to date for the identified wells.

Figure 5-46. Maximum Selenium Concentrations, Below Corcoran Clay

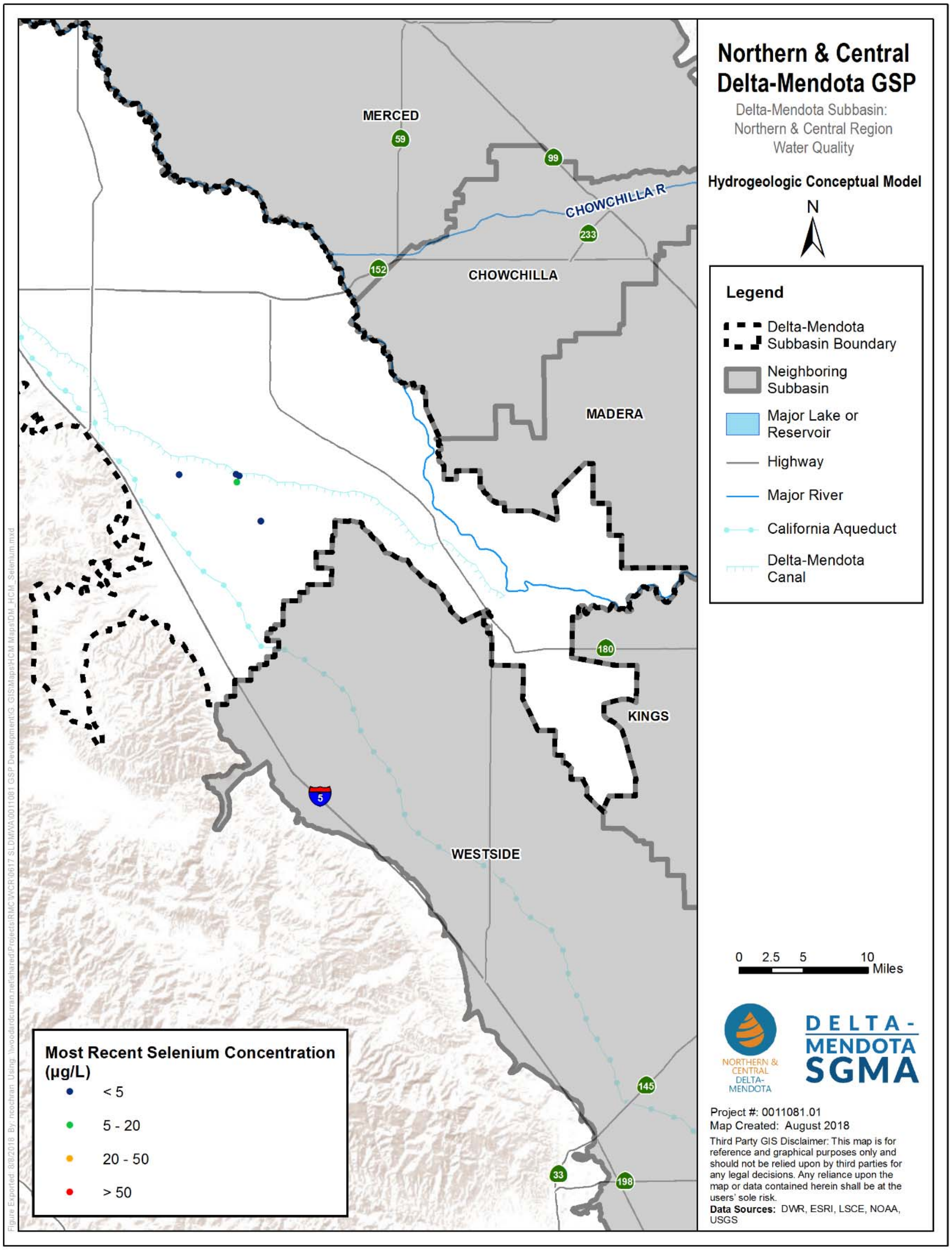
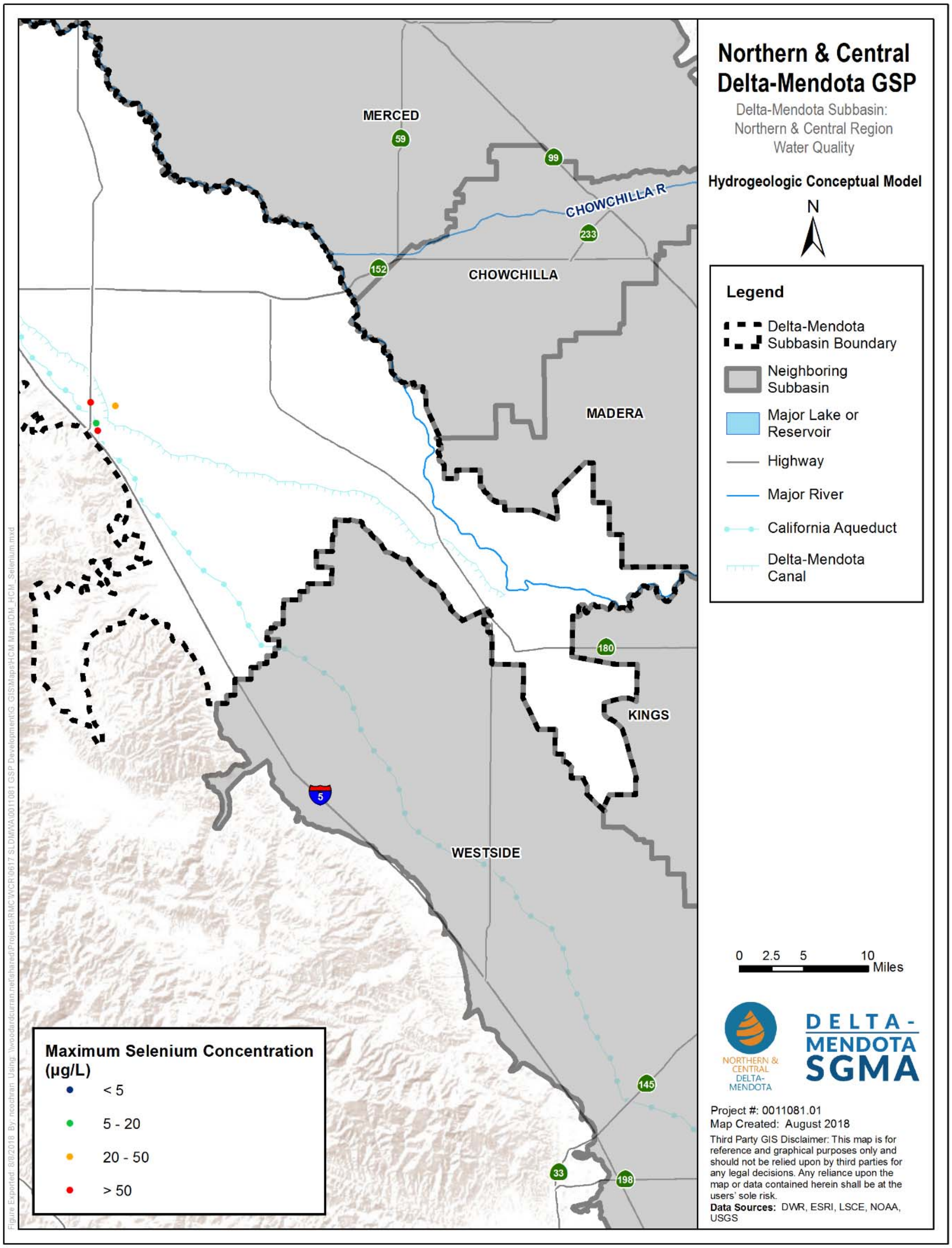


Figure 5-47. Most Recent (2000-2014) Selenium Concentrations, Below Corcoran Clay



Note: Maximum concentrations are based on all data collected to date for the identified wells.

Figure 5-48. Maximum Selenium Concentrations, Wells of Unknown Depth

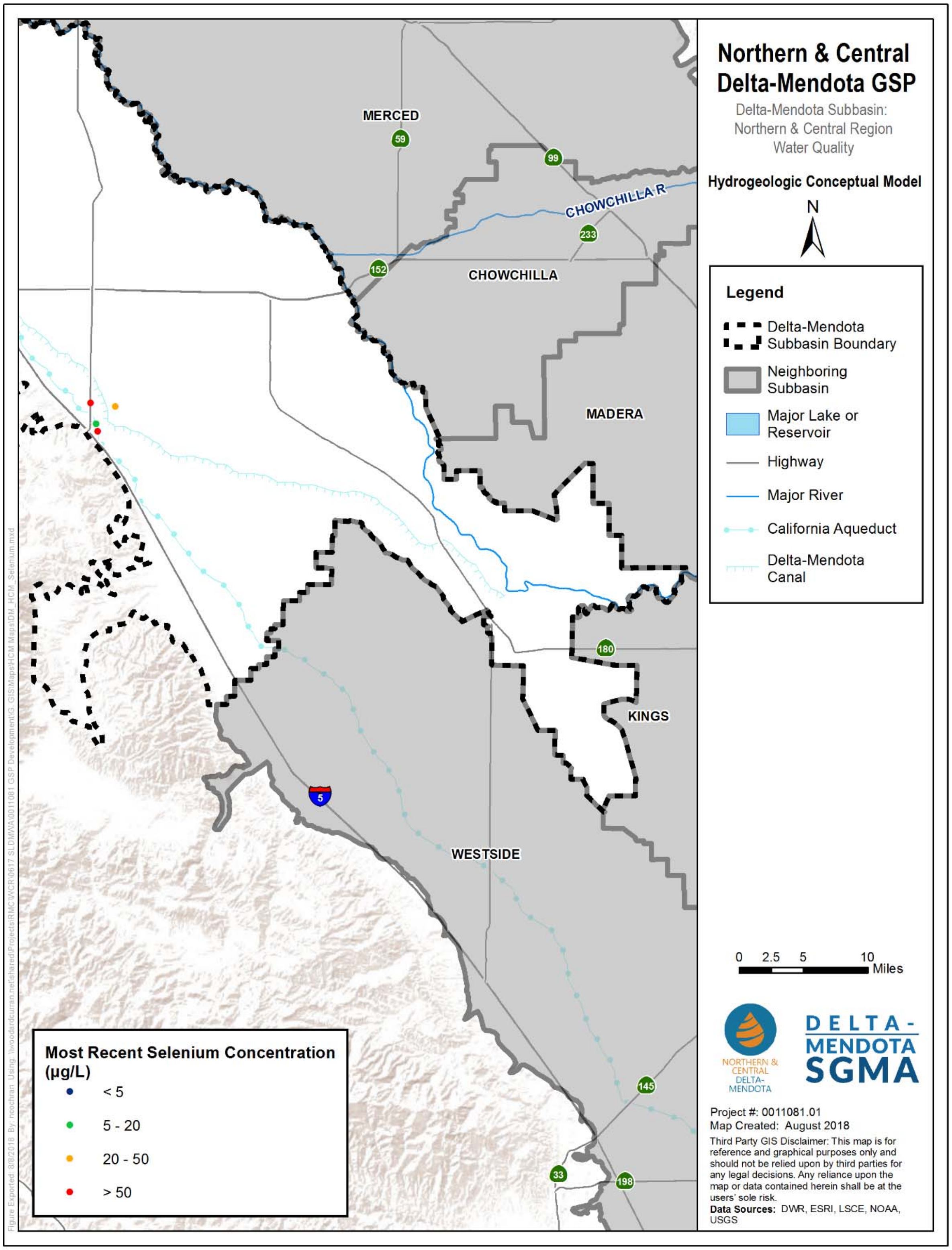
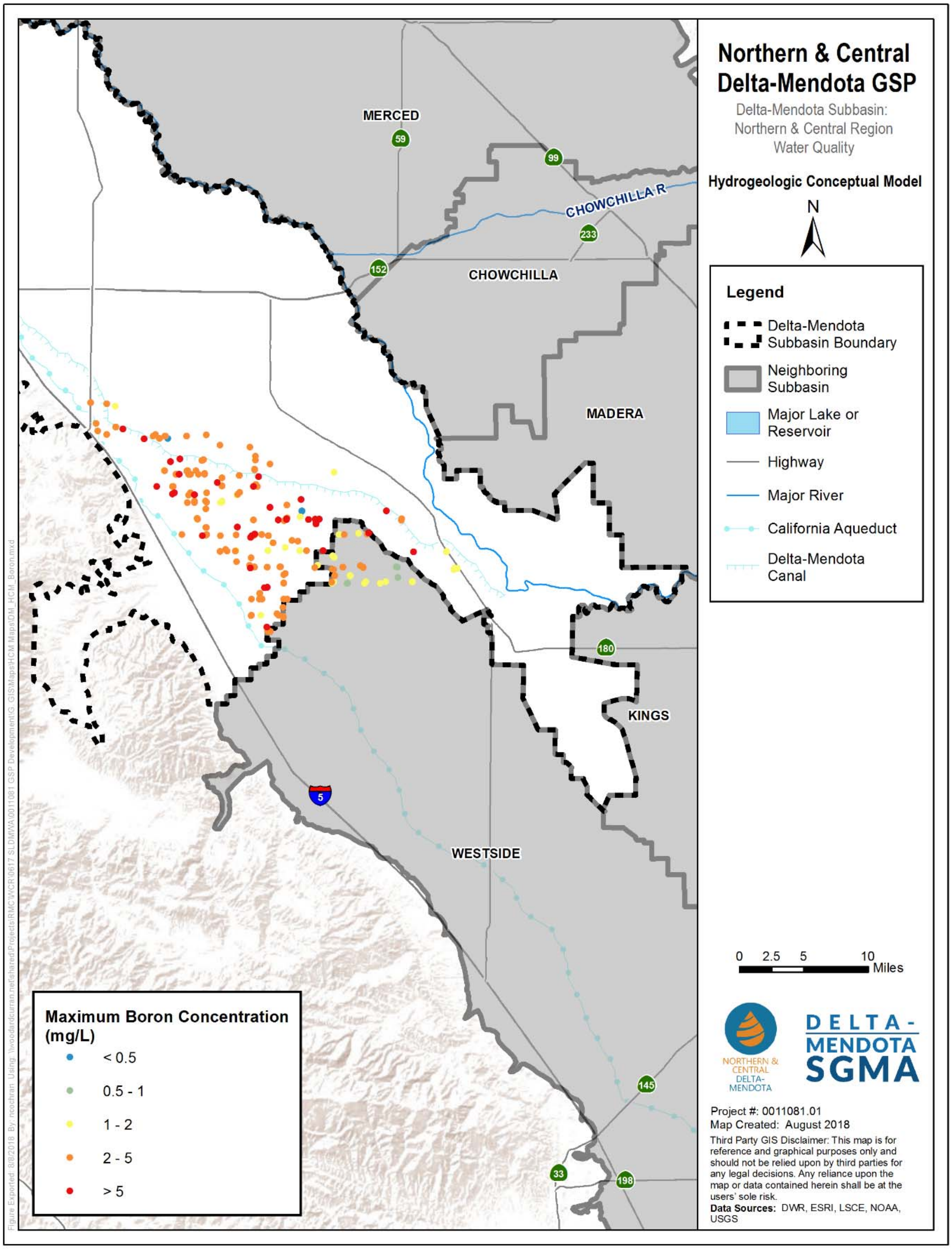


Figure 5-49. Most Recent (2000-2014) Selenium Concentrations, Wells of Unknown Depth



Note: Maximum concentrations are based on all data collected to date for the identified wells.

Figure 5-50. Maximum Boron Concentrations, All Wells

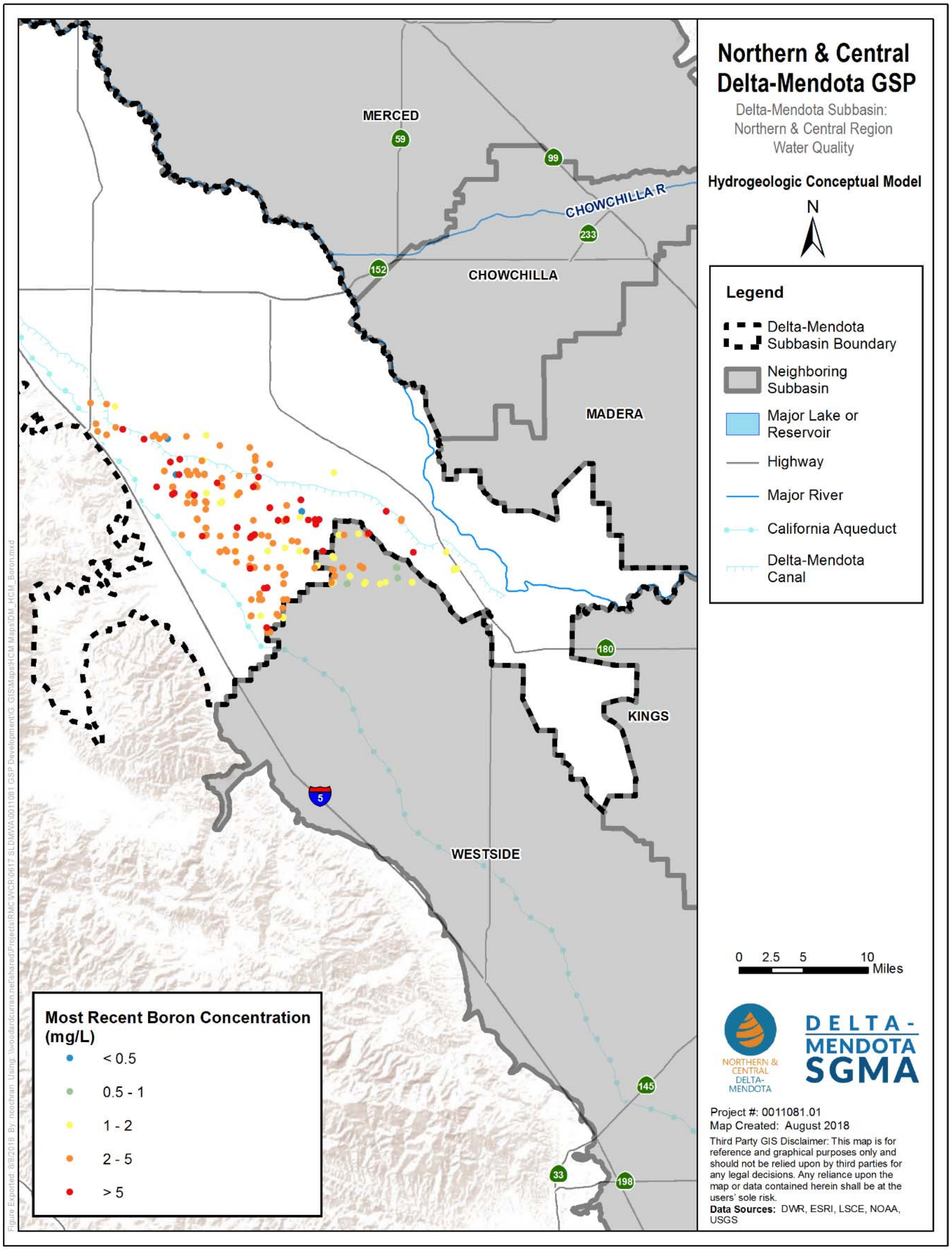
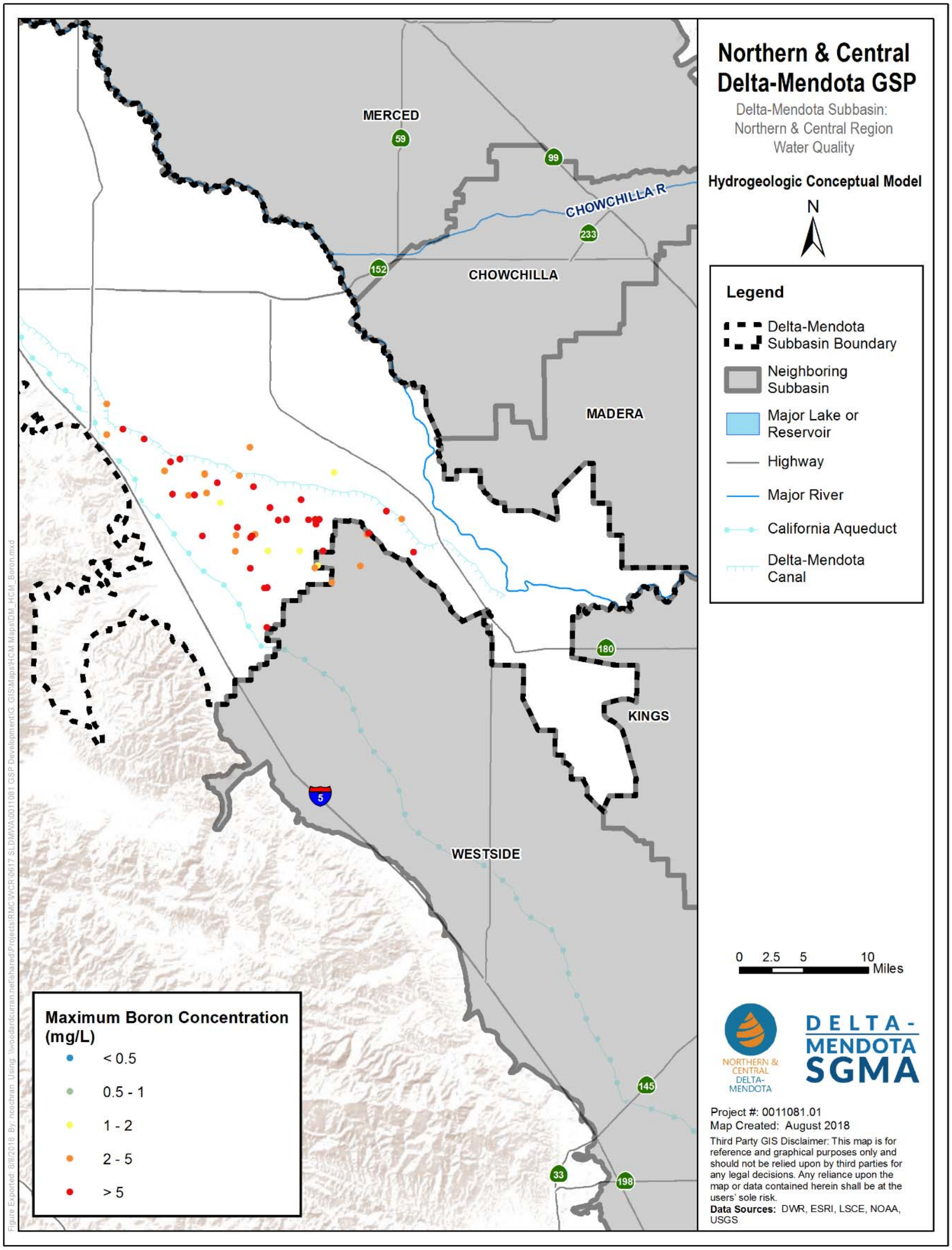


Figure 5-51. Most Recent (2000-2014) Boron Concentrations, All Wells



Note: Maximum concentrations are based on all data collected to date for the identified wells.

Figure 5-52. Maximum Boron Concentrations, Above Corcoran Clay

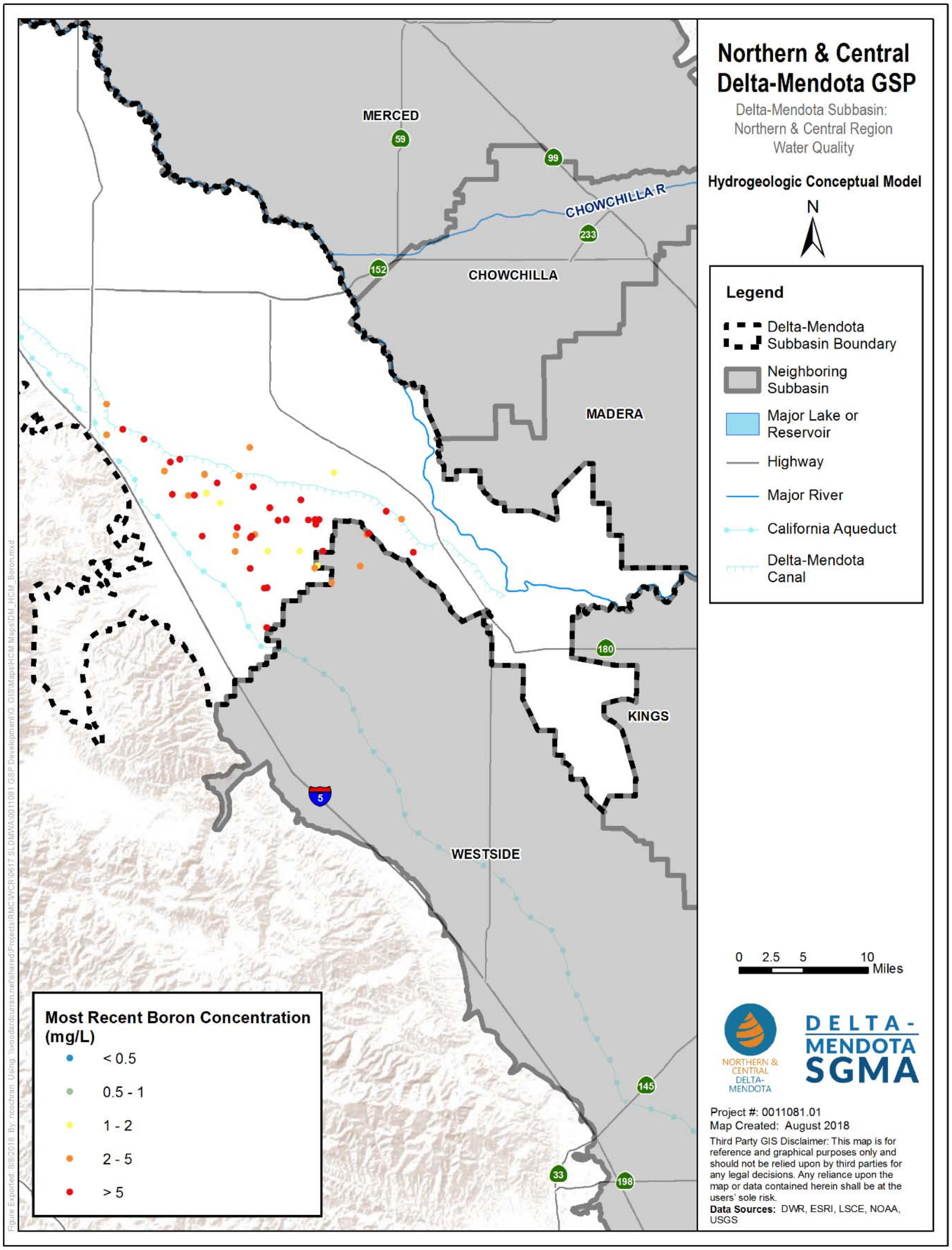
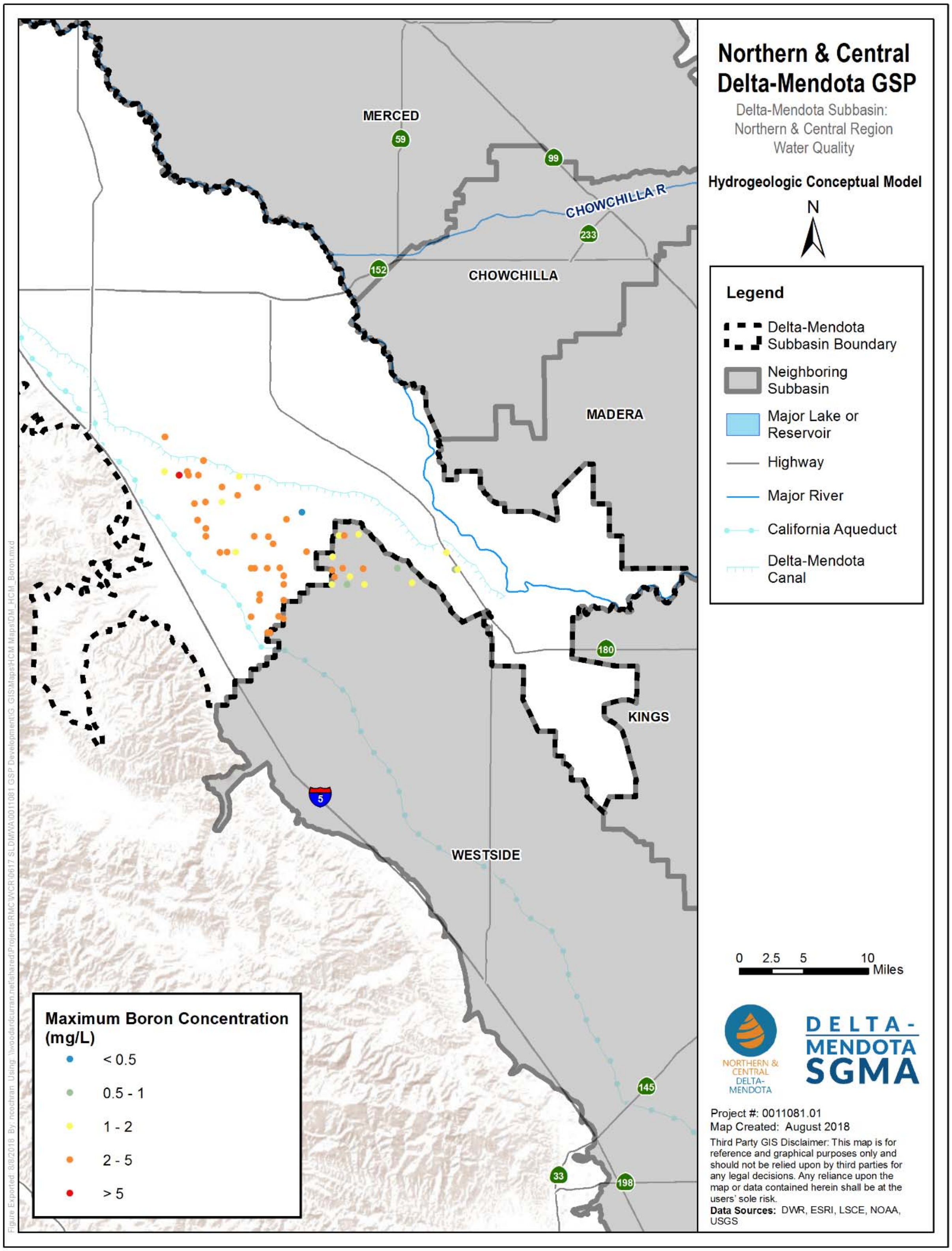


Figure 5-53. Most Recent (2000-2014) Boron Concentrations, Above Corcoran Clay



Northern & Central Delta-Mendota GSP

Delta-Mendota Subbasin: Northern & Central Region Water Quality

Hydrogeologic Conceptual Model

Project #: 0011081.01
Map Created: August 2018

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Data Sources: DWR, ESRI, LSCE, NOAA, USGS

Note: Maximum concentrations are based on all data collected to date for the identified wells.

Figure 5-54. Maximum Boron Concentrations, Below Corcoran Clay

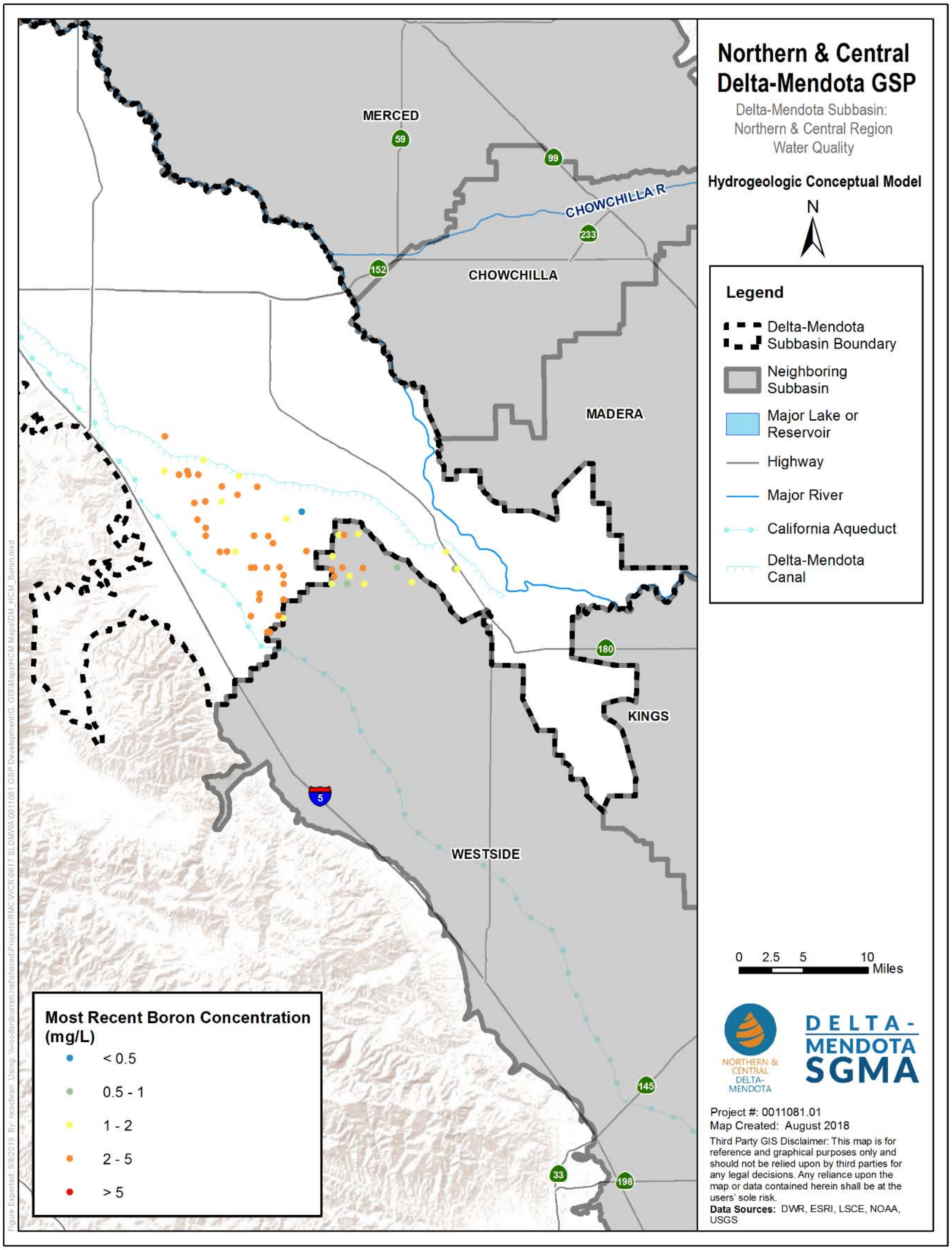
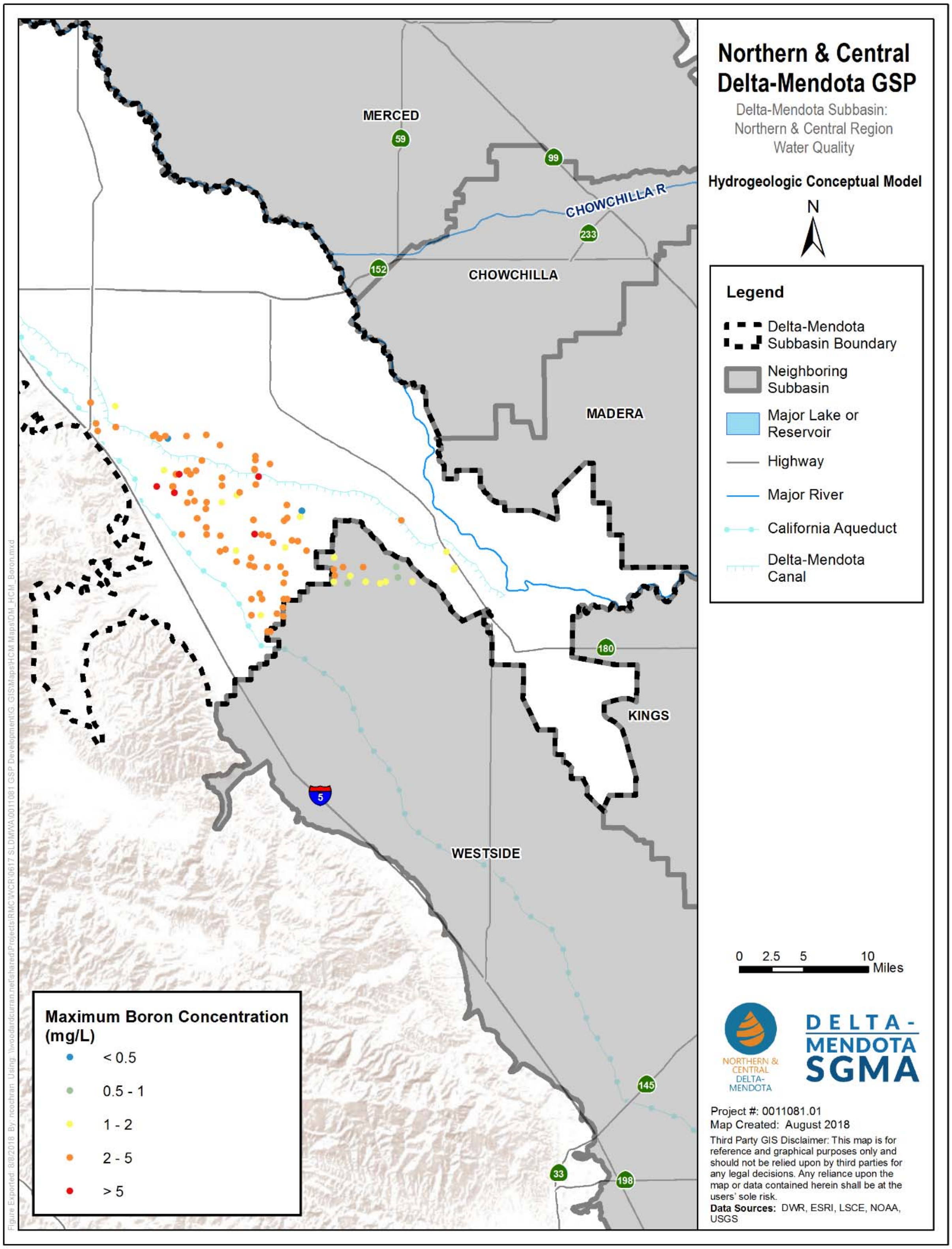


Figure 5-55. Most Recent (2000-2014) Boron Concentrations, Below Corcoran Clay



Note: Maximum concentrations are based on all data collected to date for the identified wells.

Figure 5-56. Maximum Boron Concentrations, Wells of Unknown Depth

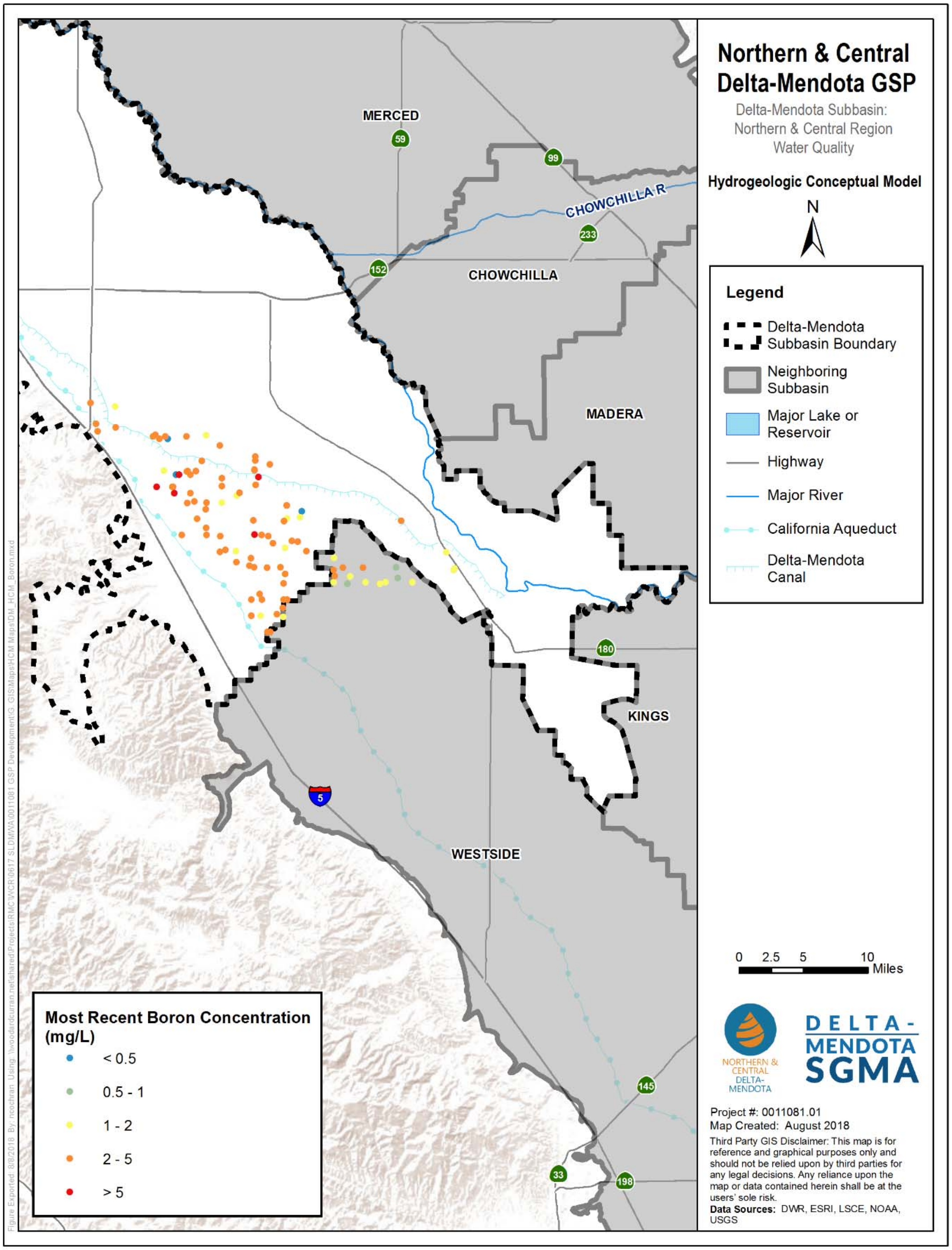


Figure 5-57. Most Recent (2000-2014) Boron Concentrations, Wells of Unknown Depth

5.2.8.3 Aquifer Use

The Delta-Mendota Subbasin is located in the San Joaquin Valley, one of the most agriculturally productive regions in California and the United States. Groundwater is one of the primary sources of water supply for agricultural uses within the Subbasin and is typically used to offset demands not met by surface water from the San Joaquin River, Central Valley Project and State Water Project. Groundwater is also the sole source of supply for many communities and cities throughout the Delta-Mendota Subbasin.

In general, most irrigation wells and many private domestic supply wells are screened in the Upper Aquifer of the Subbasin. Most municipal production wells and many larger irrigation production wells in the Northern and Central Delta-Mendota Regions are screened in the Lower Aquifer, below the Corcoran Clay.

5.2.9 Topography, Surface Water, Recharge, and Imported Supplies

This section describes the topography, surface water, soils, and groundwater recharge potential in the Delta-Mendota Subbasin.

5.2.9.1 Topography

As previously described, the Delta-Mendota Subbasin lies on the western side of the Central Valley and extends from the San Joaquin River on the east, along the axis of the Valley, to the Coast Range divide on the west side (LSCE, 2015). The Subbasin has ground surface elevations ranging from less than 100 feet above mean sea level (msl) along parts of the eastern edge to greater than 1,600 feet msl in the Coast Range mountains (Figure 5-58). Most of the lower elevation areas occur east of Interstate 5, in the eastern parts of the Delta-Mendota Subbasin; although some lower elevation areas also extend westward into the Coast Range, such as in Los Banos Creek Valley. Low elevation areas generally coincide with the extent of the Central Valley floor. Topography within the Delta-Mendota Subbasin consists largely of flat areas across the Central Valley floor, where slopes are generally less than 2 percent, with steepening slopes to the west. The topography outside of the Central Valley floor in the Coast Range mountains is characterized by steeper slopes, generally greater than 6 percent.

5.2.9.2 Surface Water Bodies

The San Joaquin River is the primary natural surface water feature within the Delta-Mendota Subbasin, flowing from south to north along the eastern edge of the Subbasin (LSCE, 2015). The Stanislaus, Tuolumne, Merced, and Chowchilla Rivers are tributaries to the San Joaquin River along the Subbasin boundary and generally flow east to west from the Sierra Nevada. During the 1960s, the San Joaquin River exhibited gaining flow conditions through much of the Subbasin (Hotchkiss and Balding, 1971). Numerous intermittent streams from the Coast Range enter the Delta-Mendota Subbasin from the west; however, none of these maintain perennial flow and only Orestimba Creek and Del Puerto Creek have channels that extend eastward to a junction with the San Joaquin River. Most of the flow in other notable west-side creeks, including Quinto Creek, San Luis Creek, Little Panoche Creek, and Los Banos Creek, is lost to infiltration (Hotchkiss and Balding, 1971). Flow from Los Banos and San Luis Creeks are impounded by dams on their respective systems. When flood releases are made from Los Banks Creek Reservoir, the vast majority of flows tend to be evacuated to the San Joaquin River as they tend to occur during times when demand isn’t for beneficial use. The San Luis Reservoir on San Luis Creek, which is located along the western boundary of the Delta-Mendota Subbasin, is an artificial water storage facility for the Central Valley Project and California State Water Project and has no notable natural surface water inflows. Outflows from the reservoir go into the system of federal and state operated canals and aqueducts comprising the Central Valley and California State Water Projects. Surface water use within the Delta-Mendota Subbasin is derived largely from water deliveries provided by these projects, including from the California Aqueduct (sometimes referred to as San Luis Canal) and Delta-Mendota Canal, and also from the San Joaquin River (Figure 5-59).

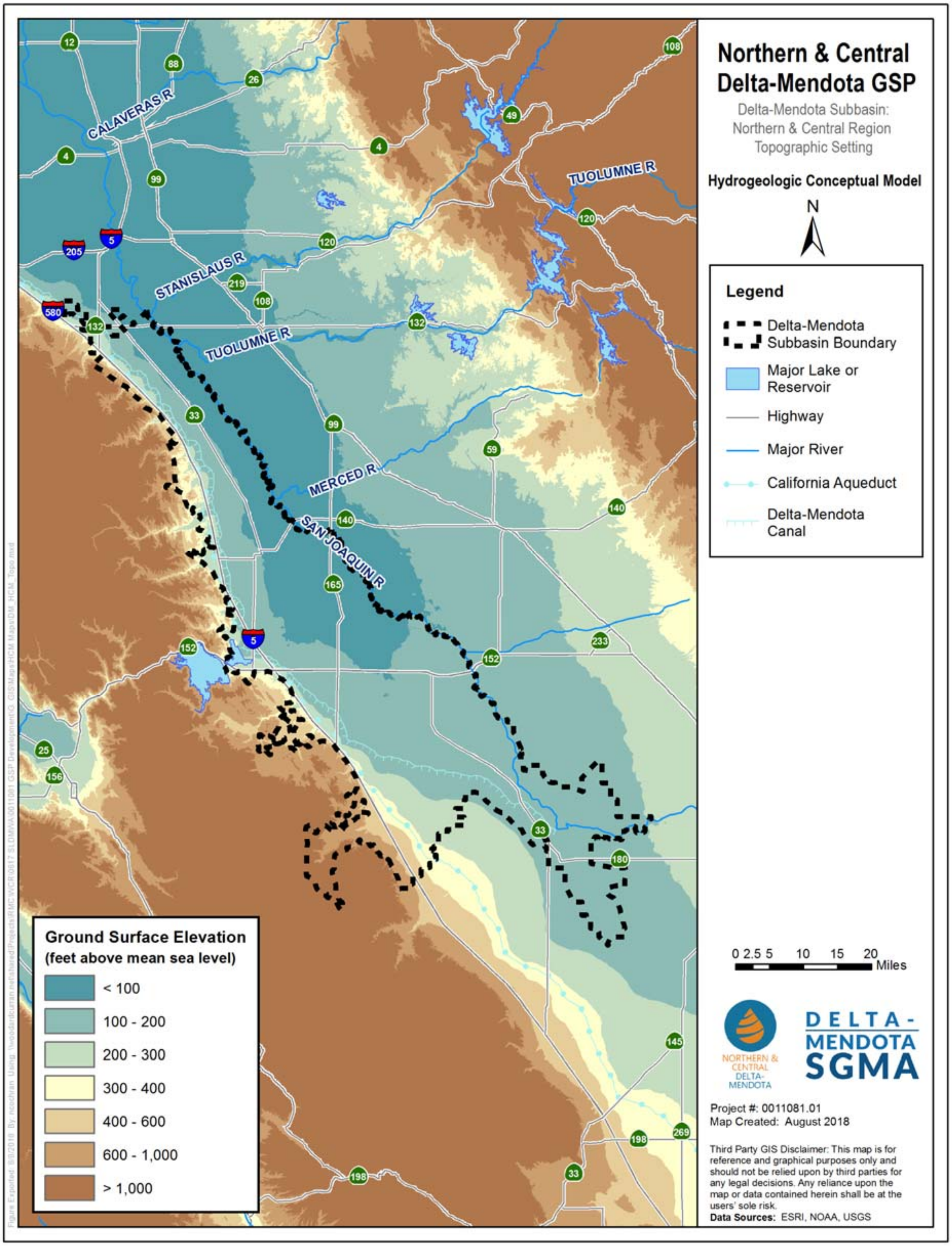


Figure 5-58. Ground Surface Elevation, Delta-Mendota Subbasin

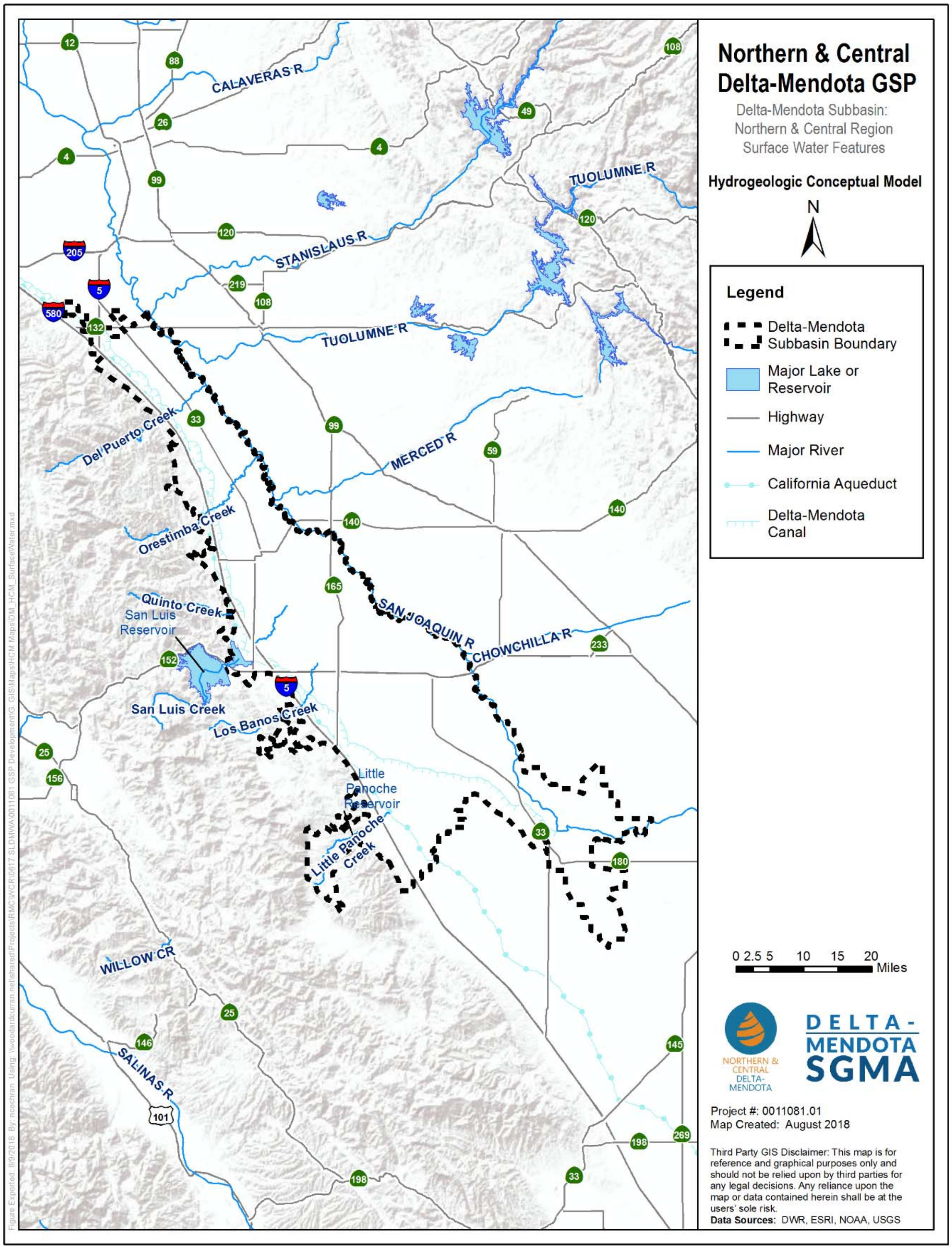


Figure 5-59. Surface Water Features, Delta-Mendota Subbasin

5.2.9.3 Soils

The predominant soil hydrologic groups within the Delta-Mendota Subbasin are soil types C and D (**Figure 5-60**). Group C soils have moderately high runoff potential when thoroughly wet (NRCS, 2009) with water transmission through the soil somewhat restricted. Group C soils typically have between 20 percent and 40 percent clay and less than 50 percent sand and have loam, silt loam, sandy clay loam, clay loam, and silty clay loam textures. Group D soils have a high runoff potential when thoroughly wet and water movement through the soil is restricted or very restricted. Group D soils typically have greater than 40 percent clay, less than 50 percent sand, and have clayey textures. In some areas, they also have high shrink-swell potential.

Soil hydraulic conductivity groups are closely related to soil drainage characteristics and hydraulic conductivity. The fine-grained floodplain deposits present across much of the southeastern area of the Subbasin are evidenced as soils with lower hydraulic conductivity in **Figure 5-20** and accordingly, these characteristics also make these areas poorly drained. Poorly draining soil conditions are extensive within the southern and eastern areas of the Subbasin extending from the vicinity of Tranquillity to near Gustine. As early as the 1950s, farmers in parts of the western San Joaquin Valley began implementing structural and land treatment approaches to manage areas with poorly drained soils and the associated shallow water table and build-up of soil salinity (Fio, 1994; Hotchkiss and Balding, 1971). Soils in the northern and western parts of the Delta-Mendota Subbasin exhibit better drainage characteristics, although areas of poorly drained soils are also present in the north and west in proximity to surface water courses, including most notably directly adjacent to the San Joaquin River and Los Banos Creek channels. Many of the upland soils, which are of generally coarser texture and located proximal to sediment sources derived from the Coast Range hill slopes, are characterized as moderately well drained.

Groundwater recharge potential on agricultural land based on the Soil Agricultural Groundwater Banking Index (SAGBI) is shown in **Figure 5-62**. The SAGBI is based on five major factors: deep percolation, root zone residence time, topography, chemical limitations, and soil surface conditions. The predominant recharge potential classification throughout the Delta-Mendota Subbasin ranges from Moderately Poor to Very Poor (571,572 acres out of 731,820 acres of agricultural and grazing land, or about 78%). Along the eastern portion of the Subbasin, the recharge potential is generally poorer than the western portion of the Subbasin, which contains soils with higher recharge potential (Excellent, Good, and Moderately Good).

In areas with low hydraulic conductivity, corresponding to areas without adequate natural drainage, tile drains are present to remove shallow groundwater from the rooting zone. Known tile drain locations are shown in **Figure 5-61**, which are primarily located along the eastern boundary of the Delta-Mendota Subbasin as well as the southern portion of the Subbasin in the Grassland Drainage Area. The Grassland Drainage Area contains a tile drainage system as part of the Grassland Bypass Project (also known as the San Joaquin River Improvement Project) to route drainage water through the Grassland Bypass Channel, which is then used for irrigated agriculture with a high salinity tolerance.

5.2.9.4 Areas of Recharge, Potential Recharge, and Groundwater Discharge Areas

The primary process for groundwater recharge within the Central Valley floor area is from percolation of applied irrigation water, although some groundwater subbasin recharge does occur in the Delta-Mendota Subbasin along the western boundary due to mountain front recharge. Within the Northern and Central Delta-Mendota Regions, SAGBI data categorizes 103,524 acres out of 288,785 acres (36%) of agricultural and grazing land within the regions as having Excellent, Good, or Moderately Good (**Figure 5-62**) recharge properties, and 185,261 acres out of 288,785 acres (or 64%) of agricultural and grazing land as having Moderately Poor, Poor, or Very Poor recharge properties. Of the 36% of land categorized as either having Excellent, Good, or Moderately Good recharge properties, the Northern and Central Delta-Mendota Regions contain the majority of the land in the Subbasin with the highest recharge potential, with 5,106 acres out of 7,916 total acres (64%) of land classified as having Excellent recharge properties. “Modified” SAGBI data shows higher potential for recharge than unmodified SAGBI data because the modified data assumes that soils have been or will be ripped to a depth of six feet, which can break up fine grained materials at the surface to improve percolation. The modified data set was determined to more accurately represent the Delta-Mendota Subbasin due to the heavy presence of agriculture. In almost all cases, recharge from applied water on irrigated lands recharges the Upper Aquifer of the Subbasin.

The Corcoran Clay is a known barrier restricting vertical flow between the Upper and Lower Aquifers (Figure 5-17 and Figure 5-18). Therefore, recharge of the Lower Aquifer is most likely restricted where the Corcoran Clay is present, including across most of the Central Valley floor. Primary recharge areas to the Lower Aquifer are most likely in western parts of the Central Valley floor, particularly in the vicinity and west of Los Banos, Orestimba, and Del Puerto Creeks, along the western margin of the Subbasin.

Groundwater discharge areas are identified as springs located within the Delta-Mendota Subbasin and the San Joaquin River. Figure 5-62 shows the location of historic springs identified by USGS. There are only six springs/seeps identified by USGS, which are located in the southwestern corner of the Subbasin. The springs shown represent a dataset collected by USGS and are not a comprehensive map of springs in the Subbasin.

5.2.9.5 Imported Supplies

Both the California Aqueduct and Delta-Mendota Canal run the length of the Delta-Mendota Subbasin, primarily following the Interstate 5 corridor (Figure 5-63). The following water purveyors in the Delta-Mendota Subbasin receive water from the Central Valley Project via the Delta-Mendota Canal: Central California Irrigation District, Columbia Canal Company, Del Puerto Water District, Eagle Field Water District, Firebaugh Canal Water District, Fresno Slough Water District, Grassland Water District, Laguna Water District, Mercy Springs Water District, Oro Loma Water District, Pacheco Water District, Panoche Water District, Patterson Irrigation District, San Luis Canal Company, San Luis Water District, Tranquillity Irrigation District, Turner Island Water District, West Stanislaus Irrigation District. Oak Flat Water District is the only recipient of State Water Project (SWP) water in the Delta-Mendota Subbasin. Oak Flat Water District initially bought into the SWP in 1968 and has a contracted Table A annual volume of 5,700 acre-feet (AF).

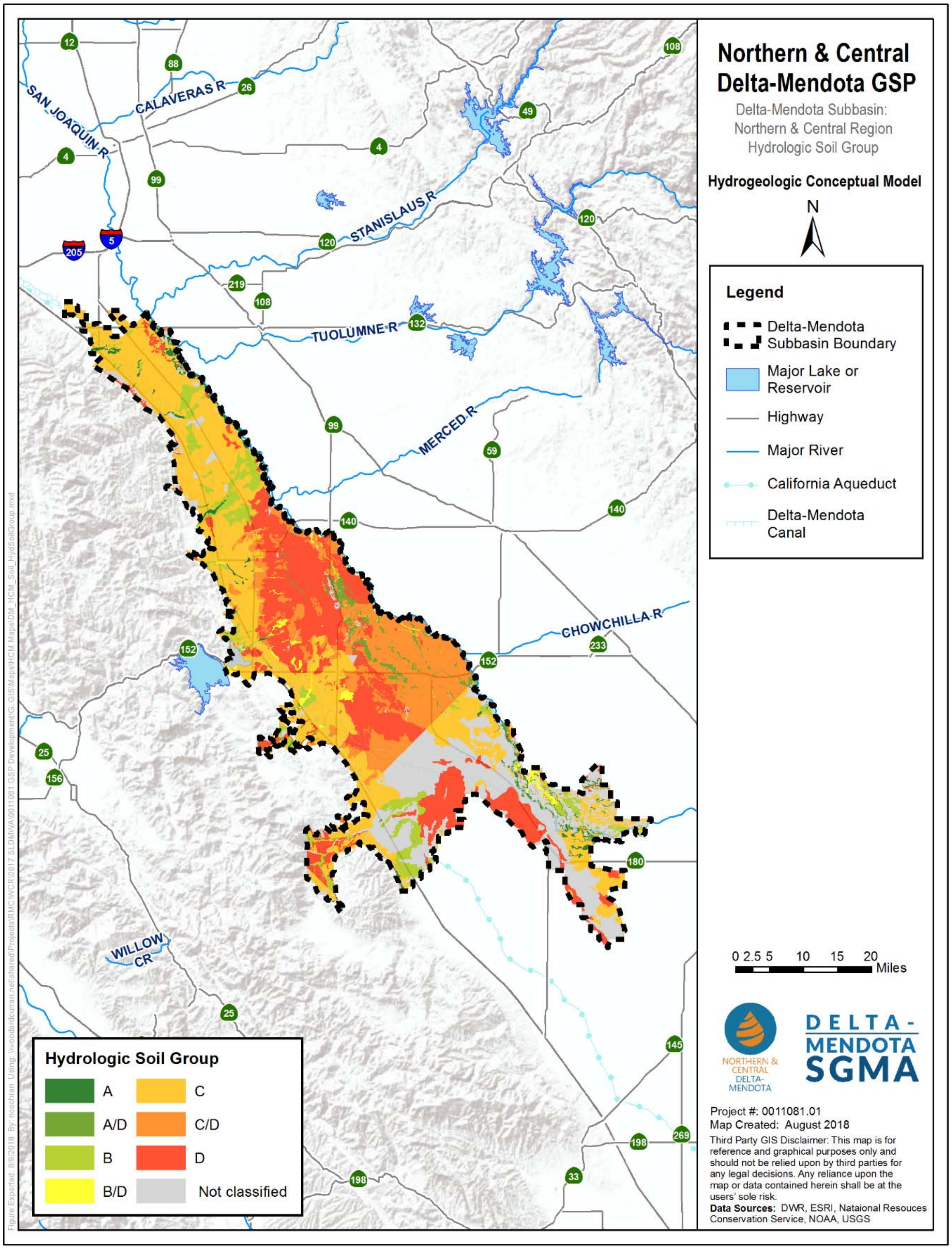


Figure 5-60. Hydrologic Soil Groups, Delta-Mendota Subbasin

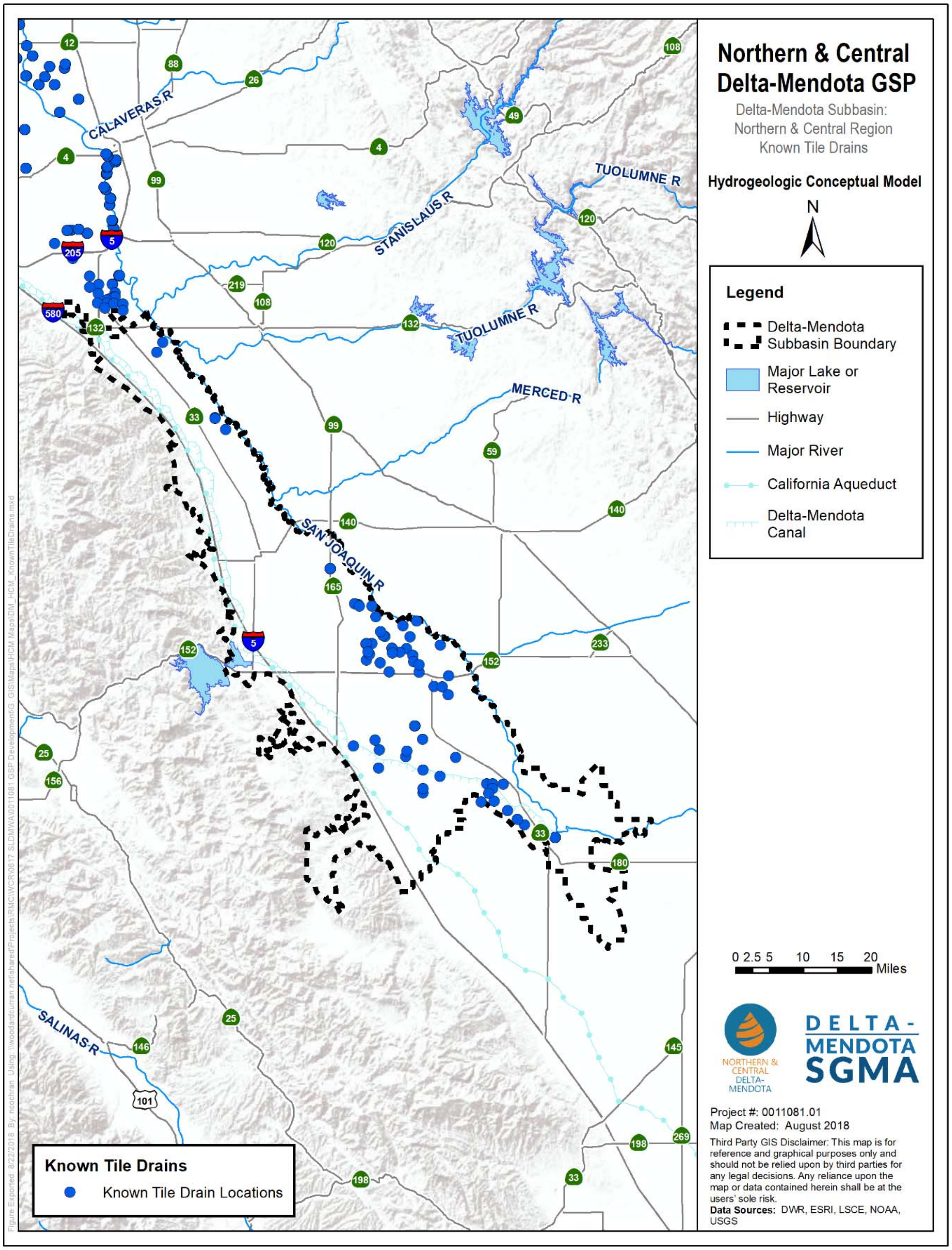


Figure 5-61. Tile Drains, Delta-Mendota Subbasin

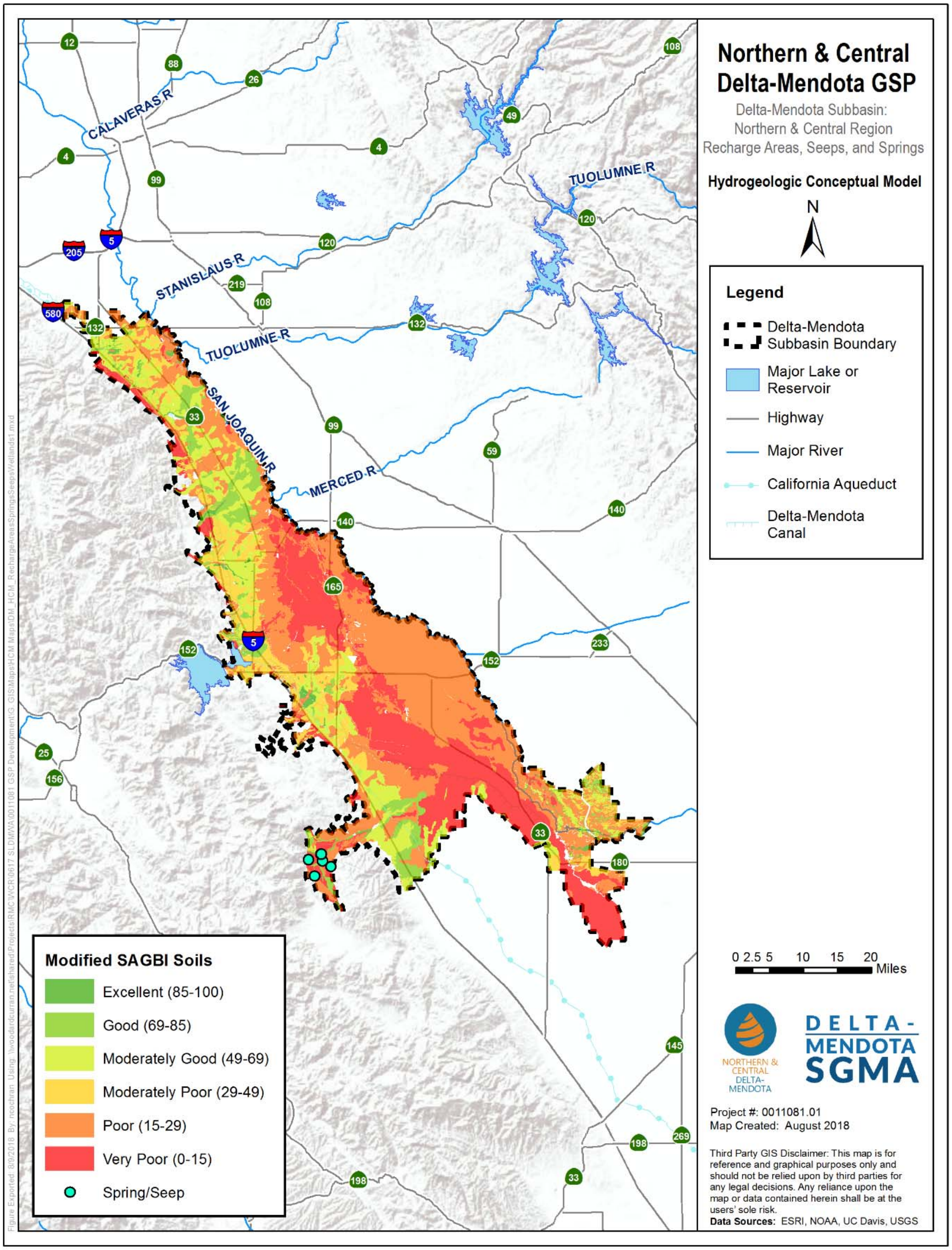


Figure 5-62. Recharge Areas, Seeps and Springs, Delta-Mendota Subbasin

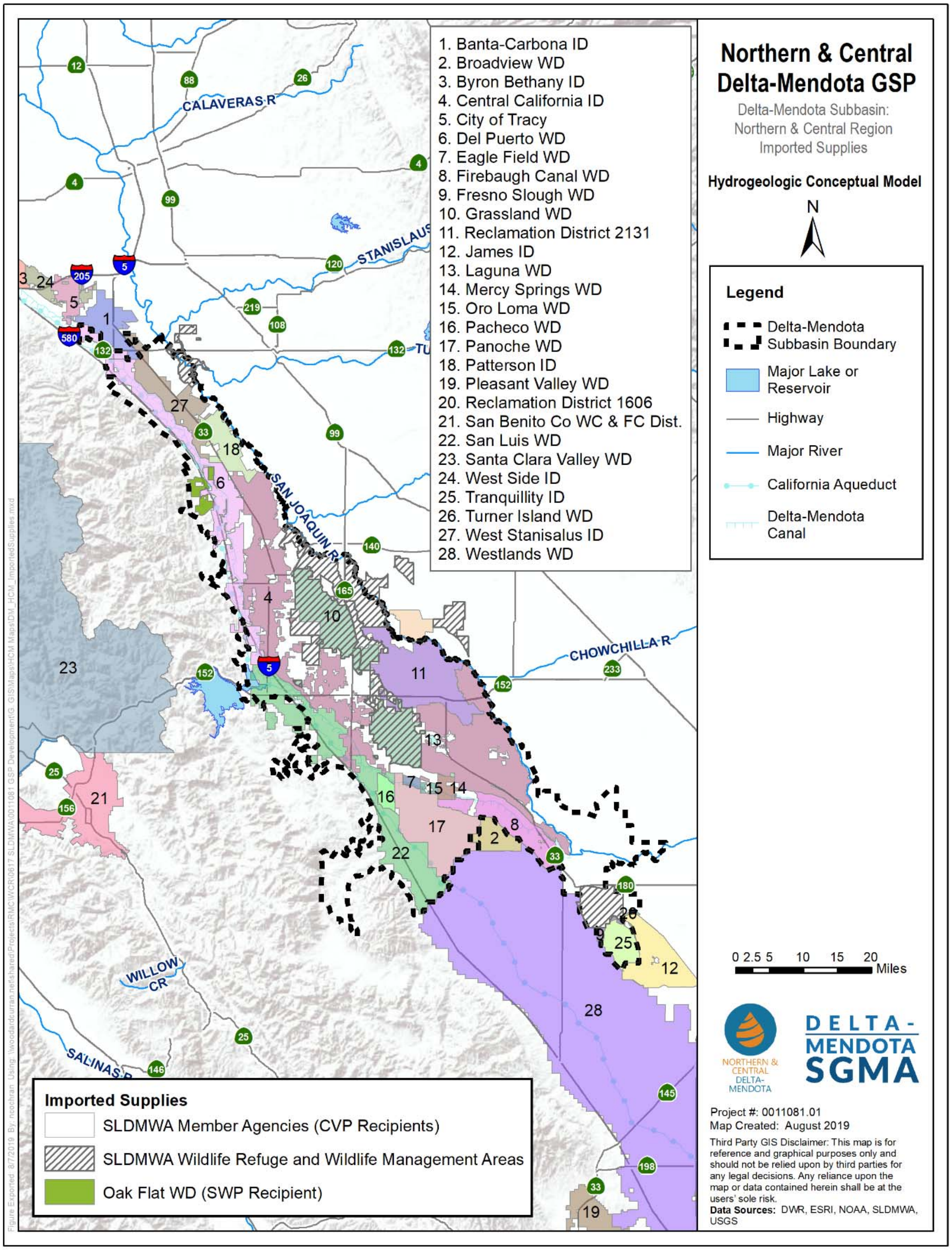


Figure 5-63. Imported Supplies, Delta-Mendota Subbasin

5.3 GROUNDWATER CONDITIONS

This section describes the current and historic groundwater conditions in the Northern and Central Regions of the Delta-Mendota Subbasin (Plan area of this Groundwater Sustainability Plan [GSP]), including data from January 1, 2015 to current conditions, for the following parameters: groundwater elevations, groundwater storage, groundwater quality, land subsidence, interconnected surface water systems, and groundwater dependent ecosystems (GDEs) (pursuant to Article 5 Plan Contents, Subarticle 2 Basin Setting, § 354.16 Groundwater Conditions of the GSP Emergency Regulations). Seawater intrusion is not discussed herein as the Delta-Mendota Subbasin is inland and is not impacted by seawater intrusion. For the purposes of this GSP, “current conditions” is represented by Water Year (WY) 2013 conditions, which is consistent with the year representing the Current Conditions Water Budget (see Section 5.4 for more information about Water Budgets). Data post-WY 2013 through present day are presented when available.

The purpose of describing groundwater conditions, as contained in this section, is to establish baseline conditions that will be used to monitor changes relative to measurable objectives and minimum thresholds. Therefore, these established baseline conditions will help support monitoring to demonstrate measurable efforts in achieving sustainability goals for the Northern and Central Regions as well as the whole Delta-Mendota Subbasin.

5.3.1 Useful Terminology

This groundwater conditions section includes descriptions of the amounts, quality, and movement of groundwater, among other related components. A list of technical terms and a description of the terms are listed below. The terms and their descriptions are identified here to guide readers through the section and are not a definitive definition of each term:

- **Depth to Groundwater** – The distance from the ground surface to first-detected non-perched groundwater, typically reported at a well.
- **Upper Aquifer** – The alluvial aquifer above the Corcoran Clay (or E-clay) layer.
- **Lower Aquifer** – The alluvial aquifer below the Corcoran Clay (or E-clay) layer.
- **Horizontal gradient** – The slope of the groundwater surface from one location to another when one location is higher or lower than the other. The gradient is shown on maps with an arrow showing the direction of groundwater flow in a horizontal direction.
- **Vertical gradient** – Describes the movement of groundwater perpendicular to the ground surface. Vertical gradient is measured by comparing the elevations of groundwater in wells that are of different depths. A downward gradient is one where groundwater is moving down into the ground towards deeper aquifers and an upward gradient is one where groundwater is upwelling towards the ground surface.
- **Contour Map** – A contour map shows changes in groundwater elevations by interpolating groundwater elevations between monitoring sites. The elevations are shown on the map with the use of a contour line, which represents groundwater being at the indicated elevation along the contour line. Contour maps can be presented in two ways:
  - Elevation of groundwater above mean sea level (msl), which can be used to identify the horizontal gradients of groundwater, and
  - Depth to water (i.e. the distance from the ground surface to groundwater), which can be used to identify areas of shallow or deep groundwater.
- **Hydrograph** – A graph that shows the changes in groundwater elevation or depth to groundwater over time at a specific location. Hydrographs show how groundwater elevations change over the years and indicate whether groundwater is rising or descending over time.
- **Maximum Contaminant Level (MCL)** – MCLs are standards that are set by the State of California and the U.S. Environmental Protection Agency for drinking water quality. MCLs are legal threshold limits on the amount of an identified constituent that is allowed in public drinking water systems. At both the State and

Federal levels, there are Primary MCLs, set to be protective of human health, and Secondary MCLs for constituents that do not pose a human health hazard but do pose a nuisance through either smell, odor, taste, and/or color. The MCL is different for different constituents and have not been established for all constituents potentially found in groundwater.

- Assimilative Capacity – The difference between the ambient concentration of a water quality constituent of concern and the regulatory threshold.
- Elastic Land Subsidence – Reversible and temporary fluctuations in the elevation of the earth's surface in response to seasonal periods of groundwater extraction and recharge.
- Inelastic Land Subsidence – Irreversible and permanent decline in the elevation of the earth's surface resulting from the collapse or compaction of the pore structure within the fine-grained portions of an aquifer system.
- Gaining Stream – A stream in which groundwater flows into a streambed and contributes to a net increase in surface water flows across an identified reach.
- Losing Stream – A stream in which surface water is lost through the streambed to the groundwater, resulting in a net decrease in surface water flows across an identified reach.
- Conjunctive Use – The combined use of surface water and groundwater supplies, typically with more surface water use in wet years and more groundwater use in dry years.

5.3.2 Groundwater Elevations

This section describes groundwater elevation data utilized and trends. Groundwater conditions vary widely across the Delta-Mendota Subbasin. Historic groundwater conditions through present day conditions, the role of imported surface water in the Subbasin, and how conjunctive use has impacted groundwater trends temporally and spatially are discussed. Groundwater elevation contour maps associated with current seasonal high and seasonal low for each principal aquifer, as well as hydrographs depicting long-term groundwater elevations, historical highs and lows, and hydraulic gradients (both horizontal and vertical), are also described.

5.3.2.1 Available Data

Groundwater elevation data, and accompanying well construction information, within the Delta-Mendota Subbasin from the following sources and associated programs were utilized in this GSP:

- California Department of Water Resources (DWR)
    - California Statewide Groundwater Elevation Monitoring Program (CASGEM)
    - Water Data Library (WDL)
- Central Valley Regional Water Quality Control Board
    - Irrigated Lands Regulatory Program (ILRP)
        - Western San Joaquin Groundwater Quality Assessment Report (GAR)
        - Grassland Drainage Area GAR
- Local Agency Data

Data provided by these sources included well information such as location, well construction, owner, ground surface elevation and other related components, as well as groundwater elevation data (including information such as date measured, depth to water, groundwater surface elevation, questionable measurement code, and comments). At the time that this analysis was performed, groundwater elevation data were available for the time period from 1930 through 2018. There are many wells with monitoring data from some time in the past, but no recent data, while a small number of wells have monitoring data recorded for periods of greater than 50 years.

Not all groundwater elevation data received were used in preparing the groundwater elevation contour maps for both principal aquifers (defined in this GSP as the Upper and Lower Aquifers which are divided by the Corcoran Clay [E-clay] layer). Some groundwater elevation data were associated with wells with unknown screened depths and/or composite well screens constructed across the Corcoran Clay. Groundwater elevation data associated with wells with composite screens and/or unknown screened depths were removed from the data set, along with any data point that appears to be an outlier when compared with surrounding data from the same period. Duplicate well measurements were also removed prior to contouring and only one observation for a given well was used for the identified season, rather than averaging all measurements at a given well during the same season.

Figure 5-64 shows the locations of wells with known screened depths within the Delta-Mendota Subbasin as well as known spatial gaps where no well information is currently available. These wells include those monitored under CASGEM, the Delta-Mendota Canal Well Pump-in Program, and local owners or agencies. Monitoring data available for these wells varies by local owner and agency. Well locations were provided by local agencies to the best of their knowledge at the time of writing and may include wells that have been destroyed or are no longer in service.

5.3.2.2 Historic Conditions

Historic groundwater trends can generally be divided by the first deliveries of imported water deliveries to the Delta-Mendota Subbasin. Construction of the Delta-Mendota Canal (DMC) and the California Aqueduct herald the introduction of significant surface water supplies into the Subbasin and reduced dependence on groundwater as the primary water supply. These conveyance systems have resulted in significant increases in the conjunctive use of surface water and groundwater throughout the Subbasin. Various drought periods also punctuate critical understandings of groundwater use patterns throughout the Subbasin, as well as what is known regarding response and recovery of groundwater levels following notable droughts.

Prior to Imported Water Deliveries (1850-1950s)

Prior to 1850, the majority of agriculture and development in the San Joaquin Valley consisted of rain-fed grain and cattle production, with irrigated development beginning sporadically during this time via river and perennial stream diversions (SWRCB, 2011). Construction of the railroad through the San Joaquin Valley from 1869 through 1875 increased demand for more extensive agriculture, making markets in larger coastal cities more accessible to valley farmers. Significant irrigation sourced from surface water and resulting production began in the western side of the San Joaquin Valley in 1872 when the San Joaquin River was diverted through the Miller and Lux canal system west of Fresno (DWR, 1965). Within the Northern Delta-Mendota Region, diversions from the San Joaquin River by West Stanislaus Irrigation District, Patterson Irrigation District, El Solyo Water District, White Lake Mutual Water Company, and other private diverters began in the early 1900s and were the primary water supply for irrigation in this Region. By the 1890s and early 1900s, sizable areas of the San Joaquin Valley were being forced out of production by salt accumulation and shallow water tables. Much of this land lay idle until the 1920s when development of reliable electric pumps and the energy to power them accelerated the expansion of irrigated agriculture with the availability of vast groundwater resources. The resultant groundwater pumping lowered the water table in many areas (SWRCB, 1977 and Ogden, 1988) and allowed the leaching of salts, particularly near the valley trough and western side of the valley. Groundwater pumping for irrigation from around 1920 to 1950 drew the water table down as much as 200 feet in areas along the westside of the San Joaquin River (Belitz and Heimes, 1990). Declining water tables were causing higher pumping costs and land subsidence, and farmers were finding poorer quality water as water tables continued to decline. These issues created a desire for new surface water supplies, which would be fulfilled by the Central Valley Project.

Post-Imported Water Deliveries (1950s-2012)

Surface water deliveries from the Central Valley Project (CVP) via the Delta-Mendota Canal began in the early 1950s, and from the State Water Project (SWP) via the California Aqueduct in the early 1970s (Sneed et al., 2013). The CVP is the primary source of imported surface water in the Northern and Central Delta-Mendota Regions, where only Oak Flat Water District receives deliveries from the SWP. Introduction of imported water supplies to the Delta-Mendota Subbasin resulted in a decrease in groundwater pumping from some parts of the Subbasin and the greater Central Valley, which was accompanied by a steady recovery of water levels. During the droughts of 1976-1977 and 1987-1992, diminished deliveries of imported surface water prompted increased pumping of groundwater to meet irrigation demands, bringing water levels to near-historic lows. Following periods of drought, recovery of pre-drought water levels has been rapid, especially in the Upper Aquifer. This trend has been observed in historic hydrographs for wells across the Northern and Central Delta-Mendota Regions.

5.3.2.3 Current Conditions

Recent Drought (2012-2016)

During the most recent drought, from 2012 through 2016, similar groundwater trends were observed as during the 1976-1977 and 1987-1992 droughts. With diminished imported surface water deliveries, groundwater pumping increased throughout the Subbasin to meet irrigation needs. This resulted in historic or near-historic low groundwater levels during the height of the drought in 2014 and 2015, when CVP and SWP allocations were 0% and post-1914 surface water rights in the San Joaquin River watershed were curtailed. In June 2015, senior water rights holders with a priority date of 1903 or later in the San Joaquin and Sacramento watersheds and the Delta were ordered by the State Water Resources Control Board to curtail diversions (State of California, 2015). This marked the first time in recent history that pre-1914 water rights holders were curtailed.

Post-Drought (2016-present)

With wetter conditions following the 2012-2016 drought, groundwater levels began to recover and reach near historic highs by 2017, comparable to 2012 pre-drought levels (Figure 5-65 and Figure 5-66). This was largely a result of CVP allocations reaching 100% and full water rights supplies available from the San Joaquin River in 2017. Additionally, inelastic subsidence also drastically decreased in 2017 as imported water supplies were once again available, resulting in decreased groundwater pumping particularly from the Lower Aquifer. This pattern of increased drought-driven groundwater pumping, accompanied by declining groundwater elevations, followed by recovery is a predominant factor to be considered in the sustainable management of the Delta-Mendota Subbasin.

5.3.2.4 Groundwater Trends

Groundwater levels can fluctuate greatly throughout time due to various natural and anthropogenic factors, including long-term climatic conditions, adjacent well pumping, nearby surface water flows, and seasonal groundwater recharge or depletion (LSCE, 2015). As discussed in the Hydrogeologic Conceptual Model section of this GSP, the Delta-Mendota Subbasin is generally a two-aquifer system consisting of an Upper and Lower Aquifer that are subdivided by the Corcoran Clay layer, a regional aquitard. The Corcoran Clay layer, or E-Clay equivalent, restricts flow between the upper semi-confined aquifer and lower confined aquifer. The presence of a tile drain network along the Subbasin's eastern boundary, as well as the Grassland Drainage Area on the southern end of the Northern and Central Delta-Mendota Regions, affect the lateral and vertical water movement in the shallow groundwater zone (LSCE, 2016). The majority of production wells are perforated above the Corcoran Clay layer.

The Delta-Mendota Subbasin has a general flow direction to the east, where it loses groundwater to the adjoining San Joaquin River and its neighboring subbasins. Most recharge throughout the Subbasin is attributed to applied irrigation water, with other sources of recharge including local streams, canal seepage, and infiltration along the western margin of the Subbasin from the Coast Range.

Upper Aquifer

For very shallow groundwater (less than 50 feet depth to water), select hydrographs illustrating temporal groundwater level trends in very shallow wells across the Central Valley Floor area of the Subbasin are shown in Figure 5-67. Note, the hydrographs shown display different ranges of elevations on the vertical axes and all groundwater elevations are in relation to the North American Vertical Datum of 1988 (NAVD88). During the period from the 1970s through the early 2000s, wells in the western part of the Valley Floor tended to see an overall increase of around five feet in groundwater elevation during this time period, whereas in the eastern portion of the Subbasin, particularly nearer the San Joaquin River, hydrographs from very shallow wells indicate a decreased water table elevation over that same period of time.

For the Upper Aquifer, Figure 5-68 presents select hydrographs illustrating temporal groundwater level trends in the Upper Aquifer wells within the Subbasin. Hydrographs shown on Figure 5-68 are displayed with different ranges of elevation values on the vertical axes and all groundwater elevations are in relation to NAVD88. Wells in the Upper Aquifer exhibit decreasing trends to somewhat stable water levels until the mid-1980s, and increasing or stable water levels thereafter.

Figure 5-69 presents select hydrographs illustrating temporal groundwater level trends in the Grassland Drainage Area (including areas covered by the Central Delta-Mendota, Oro Loma Water District, and Widren Water District Groundwater Sustainability Agencies [GSAs]) at various depths. The three select hydrographs representing wells each show less than 10 years of available data, where all groundwater elevations are in relation to NAVD88. The two wells in the shallower portion of the Upper Aquifer show slight declines of about 10 feet or less from about 2003 through 2013. The one well in the deeper portion of the Upper Aquifer shows more drastic elevation changes, ranging from 100 ft msl to -20 ft msl over a 5-year period from 2010 to 2016.

Figure 5-70 through Figure 5-75 show contours of groundwater elevations (relative to NAVD88) in the shallower (upper 50 feet) portion of the Upper Aquifer and for wells screened in the deeper portions of the Upper Aquifer for recent spring and fall time periods in the Delta-Mendota Subbasin. Recent groundwater elevations include all available data from 2000 through 2016. Spring is defined as the months of January through April, and fall is defined as September through November. All available data for each season for each well were averaged to produce a single value of groundwater elevations for each season for that well in order to develop contour maps.

Both spring and fall maps indicate a prevailing southwest to northeast flow gradient above the Corcoran Clay (or E-Clay) layer. In general, little variation is apparent in groundwater elevations in spring (Figure 5-70, Figure 5-72, Figure 5-74, and Figure 5-75) relative to fall (Figure 5-71 and Figure 5-73). Spring piezometric heads were generally higher than those in the fall throughout most of the Subbasin. An area of lower groundwater elevation is observed in the vicinity of the San Joaquin River Improvement Project (SJRIP), potentially corresponding to areas of groundwater pumping (Figure 5-75). The effects of pumping and the resulting depression in groundwater elevations within the Upper Aquifer in the SJRIP vicinity may result in a more northernly gradient, instead of the natural northeastern flow direction (Figure 5-75).

Lower Aquifer

Figure 5-76 presents select hydrographs illustrating temporal groundwater level trends in Lower Aquifer wells, which are perforated below the Corcoran Clay layer within the Subbasin. Note, hydrographs shown on Figure 5-76 displayed different ranges of elevation on the vertical axes and all groundwater elevations are in relation to NAVD88. In the Lower Aquifer, piezometric head typically increased or remained relatively stable during the period from the 1980s through the early 2000s.

Figure 5-69 presents select hydrographs illustrating temporal groundwater level trends in the Grassland Drainage Area (including the Central Delta-Mendota, Oro Loma Water District, and Widren Water District GSAs) at various depths. The two select hydrographs representing wells in the Lower Aquifer each show similar elevation patterns post-2010 with a total elevation change of 50 ft msl or more (relative to NAVD88). USGS1000489 shows fairly stable and increasing groundwater elevation trends from the late 1950s through the mid-1980s with a data gap from the mid-1980s through 2010, where after 2010 groundwater levels have a steep decline through 2016.

Patterns in recent spring and fall groundwater elevations (relative to NAVD88) within the Lower Aquifer are illustrated in Figure 5-77 through Figure 5-79. Recent groundwater elevations include all available data from 2000 through

2016. Spring is defined as the months of January through April, and fall is defined as September through November. All available data for each season for each well were averaged to produce a single value of water level for each season for that well in order to develop contour maps.

The Lower Aquifer exhibits less seasonal difference in groundwater elevations than the Upper Aquifer. Throughout most of the Subbasin, the Lower Aquifer shows lower piezometric heads than the Upper Aquifer suggesting a downward vertical gradient where subsurface geologic conditions provide lesser hydraulic separation between these zones. Figure 5-79 shows a distinct trough-like depression in the Lower Aquifer's groundwater elevation indicative of groundwater pumping/depletion within the Central Delta-Mendota, Oro Loma Water District, and Widren Water District GSAs, which could induce deep southwestern direction groundwater flows from the valley axis toward these GSAs as indicated by the flow direction vectors. There are also deep northeast groundwater flows within the Lower Aquifer from the Coast Ranges toward the Central Delta-Mendota, Oro Loma Water District, and Widren Water District GSAs, which could result in deep, pumping-enhanced mixing of different quality groundwater within the Lower Aquifer groundwater trough.

Vertical Gradients

Throughout most of the Delta-Mendota Subbasin, the Corcoran Clay layer acts as a regional aquitard, limiting the vertical migration of groundwater. In areas outside the Corcoran Clay layer (along the western margin of the Subbasin), localized interfingered clays minimize the downward migration of groundwater; although in areas where the clay layers are not competent or non-existent, groundwater migrates from shallower to deeper groundwater zones. Similarly, in areas where the Corcoran Clay has been compromised by the construction of composite wells, groundwater generally flows from the Upper Aquifer to the Lower Aquifer, especially in areas where the Lower Aquifer is actively used as a water supply (lowering the potentiometric head in that zone).

Groundwater Contours

Figure 5-80 and Figure 5-81 depict groundwater surface elevation for the seasonal high (Spring 2013) and seasonal low (Fall 2013) for the Upper Aquifer relative to NAVD88. Spring is defined as groundwater surface elevation measurements from January 1 through April 8; where Fall is defined as groundwater surface elevation measurements from August 1 through October 31. For wells where multiple Spring 2013 or Fall 2013 measurements were available, the highest elevation for each season was used for contouring. In the Upper Aquifer, during Spring 2013, the general flow of groundwater in the Delta-Mendota Subbasin was from the Coastal Range along the western boundary of the Subbasin toward the San Joaquin River along the eastern boundary. In the southern-central portion of the Subbasin, groundwater flow was to the southwest toward Los Banos; while in the southern portion of the Subbasin, groundwater flow is to the southeast toward Aliso Water District and the Tranquillity area. Groundwater elevations tend to increase moving south throughout the Subbasin.

Spring groundwater elevations are the lowest within Stanislaus County, ranging between 40 and 80 feet above msl, and become increasingly higher in Merced and Fresno Counties, ranging between 80 and 140 feet above msl (Figure 5-80) with general Upper Aquifer groundwater flow directions to the east and north east. For Fall 2013, groundwater flows in a similar direction (west to east and northeast) with groundwater elevations in Stanislaus County still the lowest (ranging between 40 and 80 feet above msl). As with Spring 2013, groundwater elevations in Fall of 2013 (Figure 5-81) become increasingly higher in Merced County (ranging between 60 and 140 feet above msl) and Fresno County (ranging from 60 and 120 feet above msl).

Due to insufficient data, groundwater elevation contour maps for the Lower Aquifer for the seasonal high and low (Spring 2013 and Fall 2013, respectively) could not be accurately prepared. Figure 5-82 and Figure 5-83 show available groundwater elevation measurements for Spring 2013 and Fall 2013. Available Spring 2013 measurements range from -127 to 12 feet above msl in Stanislaus County, from -65 to 124 feet above msl in Merced County, and from -5 to 88 feet above msl in Fresno County (Figure 5-82). Available Fall 2013 measurements range from -138 to

156 feet above msl in Stanislaus County, from -94 to 19 feet above msl in Merced County, and from -72 to -4 feet above msl in Fresno County (Figure 5-83).

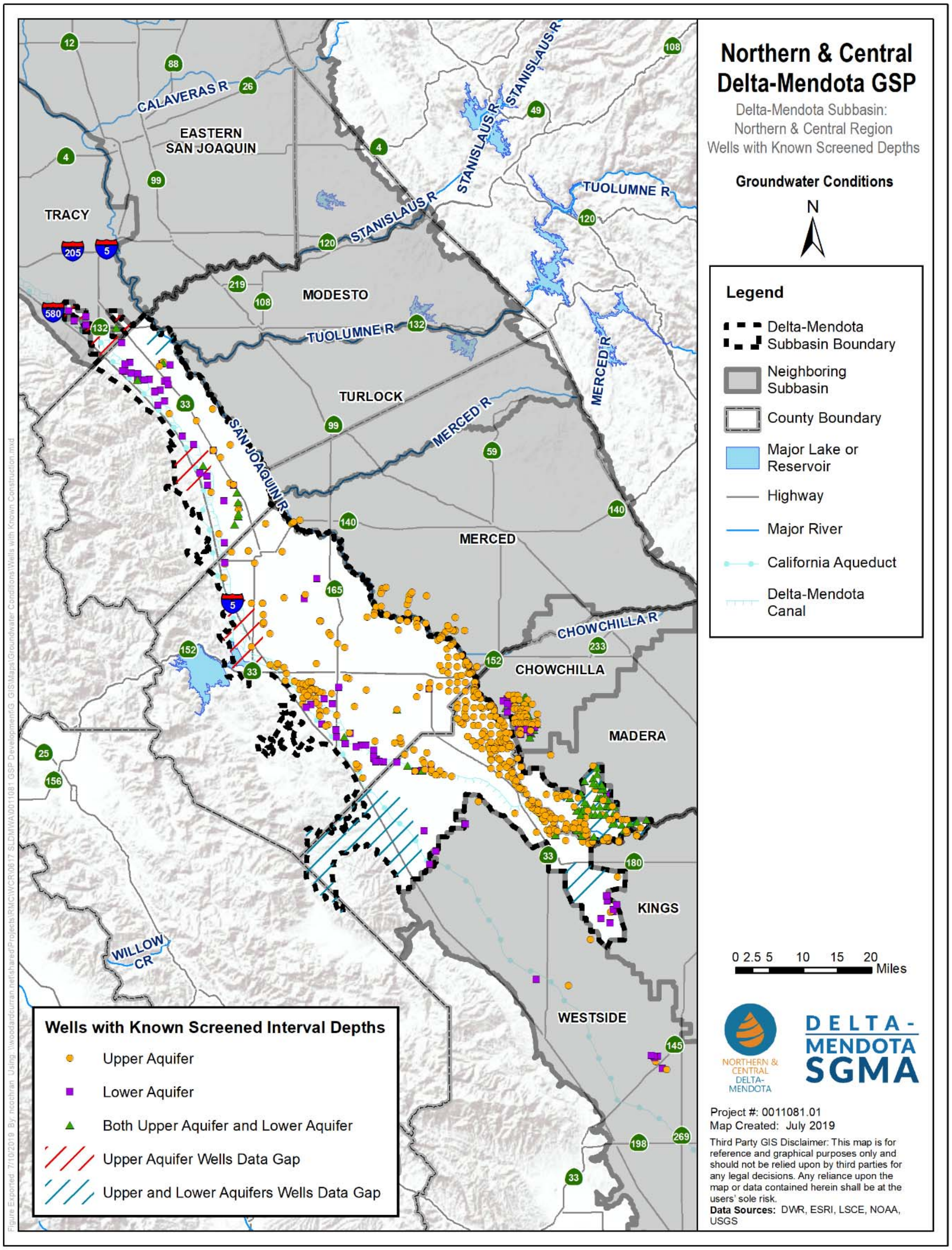


Figure 5-64. Wells with Known Screened Interval Depths, Delta-Mendota Subbasin

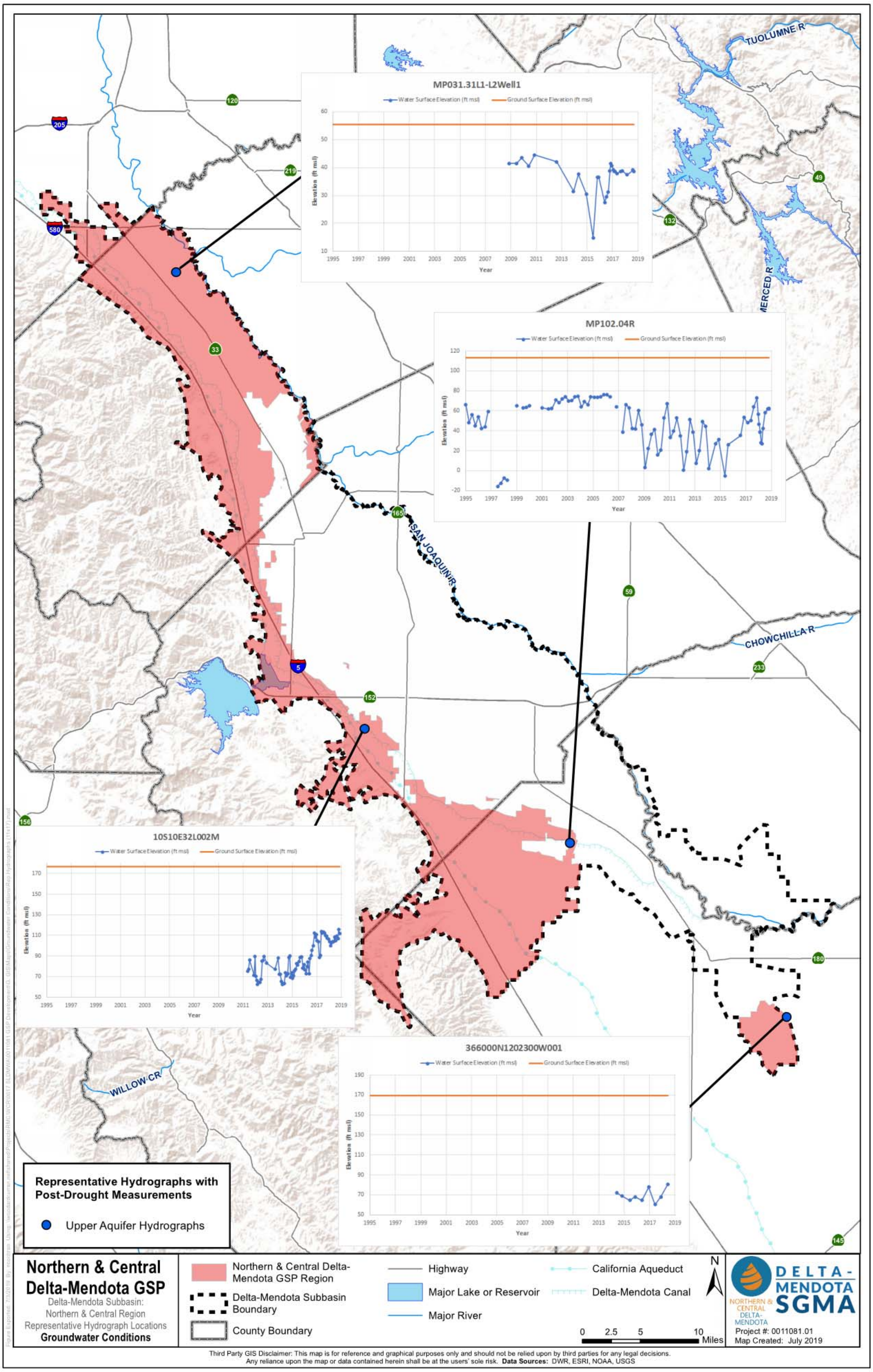


Figure 5-65. Representative Hydrographs with Post-Drought Measurements, Upper Aquifer

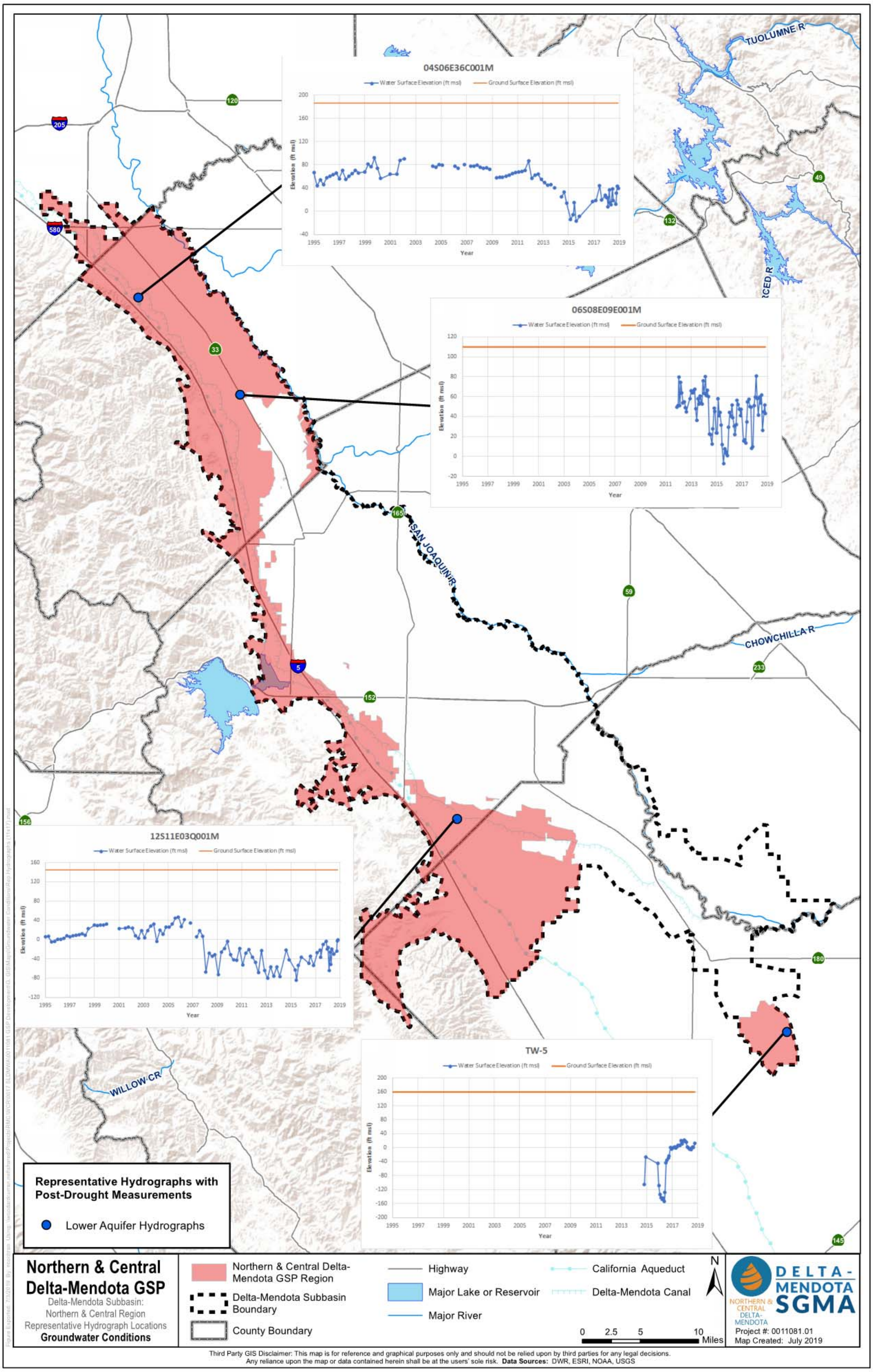


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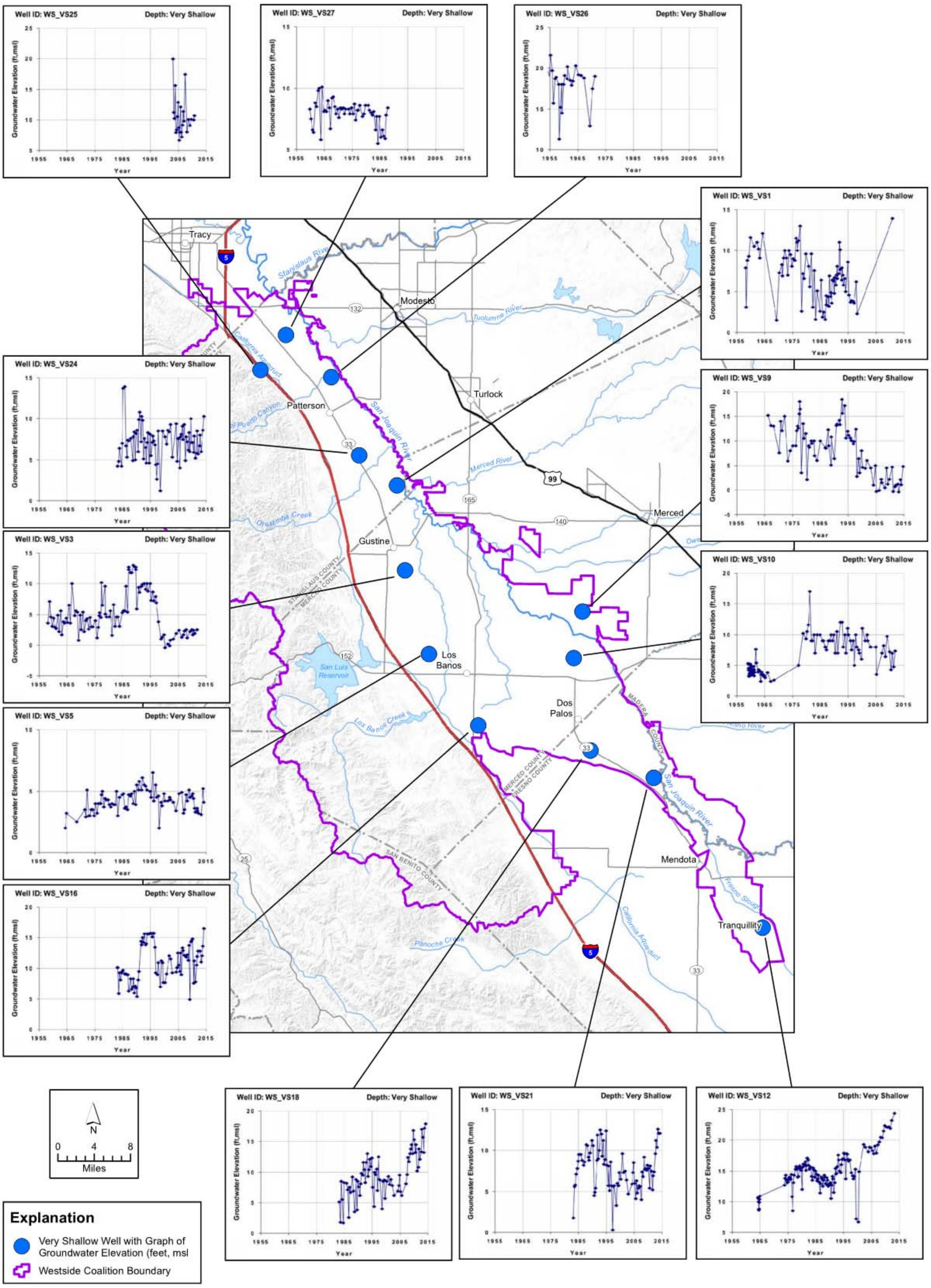
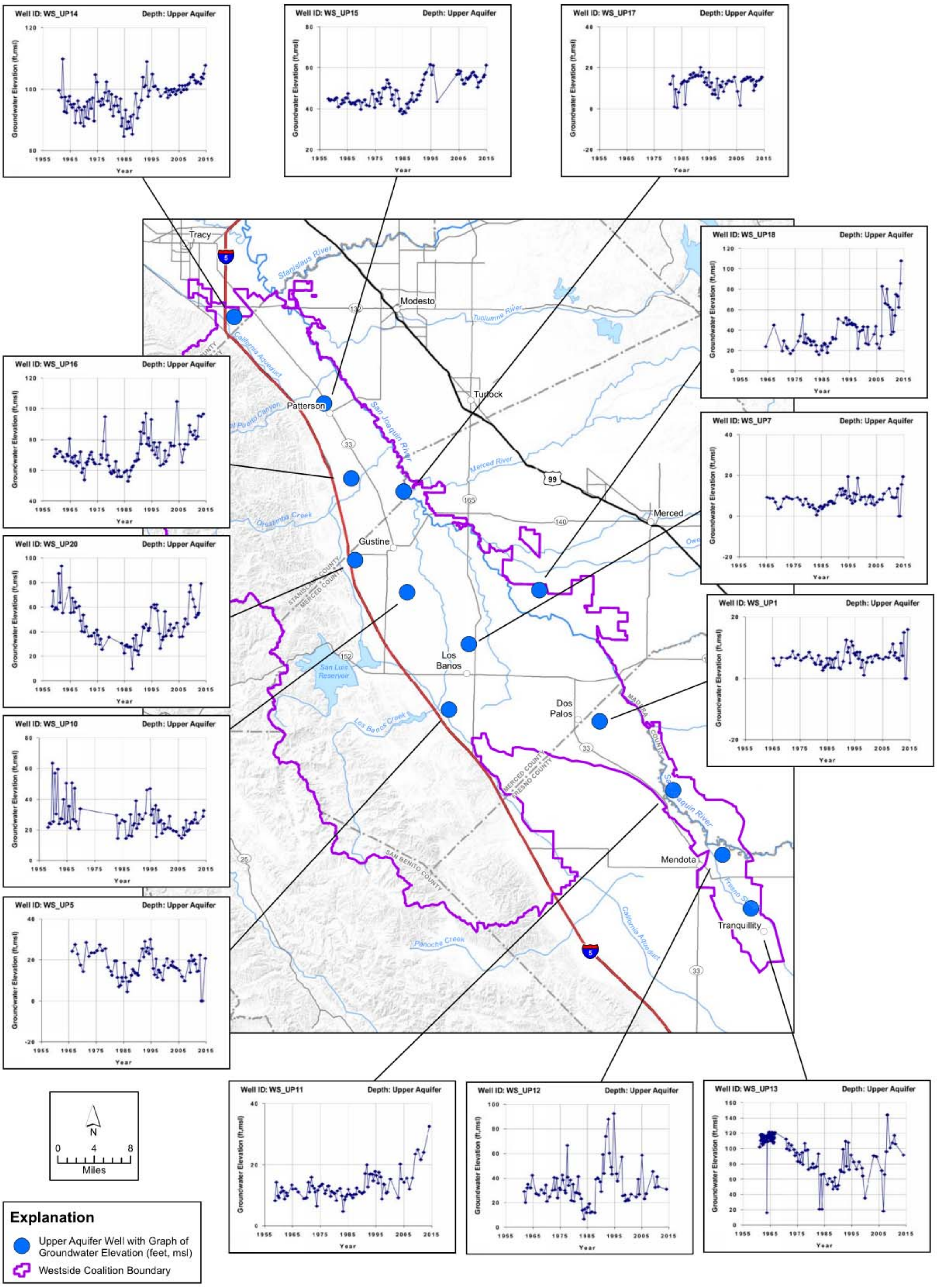
Figure 5-66. Representative Hydrographs with Post-Drought Measurements, Lower Aquifer



Source: *Western San Joaquin River Watershed Groundwater Quality Assessment Report*, 2015
Notes:

1. Figure not to scale.
2. The intent of these hydrographs is to generally demonstrate groundwater trends across the Delta-Mendota Subbasin.

Figure 5-67. Select Graphs of Groundwater Elevations, Very Shallow Groundwater

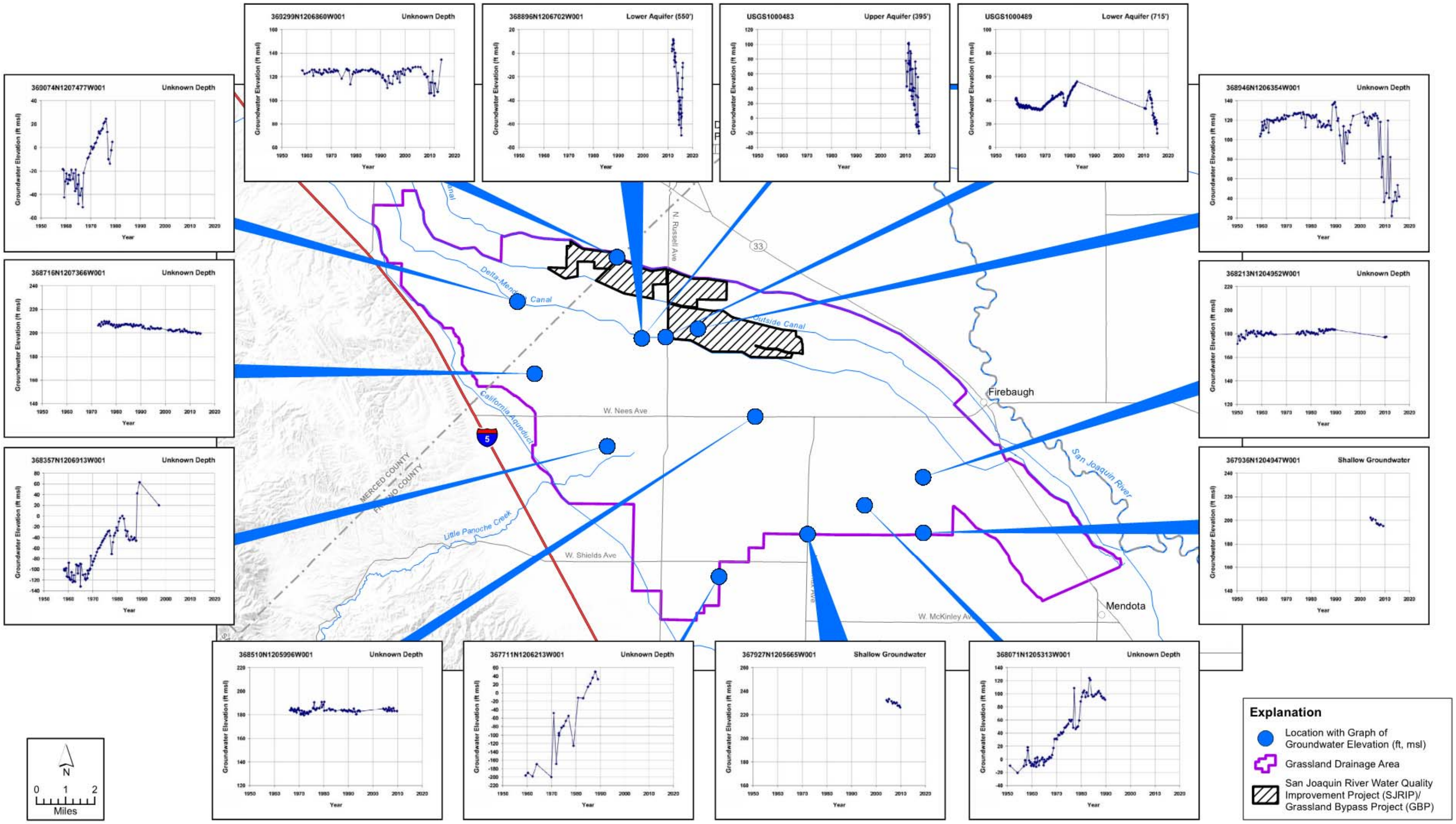


Source: *Western San Joaquin River Watershed Groundwater Quality Assessment Report*, 2015

Notes:

1. Figure not to scale.
2. The intent of these hydrographs is to generally demonstrate groundwater trends across the Delta-Mendota Subbasin.

Figure 5-68. Select Graphs of Groundwater Elevations, Upper Aquifer



Source: *Grassland Drainage Area Groundwater Quality Assessment Report*, 2016

Notes:

1. Figure not to scale.
2. The intent of these hydrographs is to generally demonstrate groundwater trends across the Delta-Mendota Subbasin.

Figure 5-69. Select Graphs of Groundwater Elevations, Various Depths

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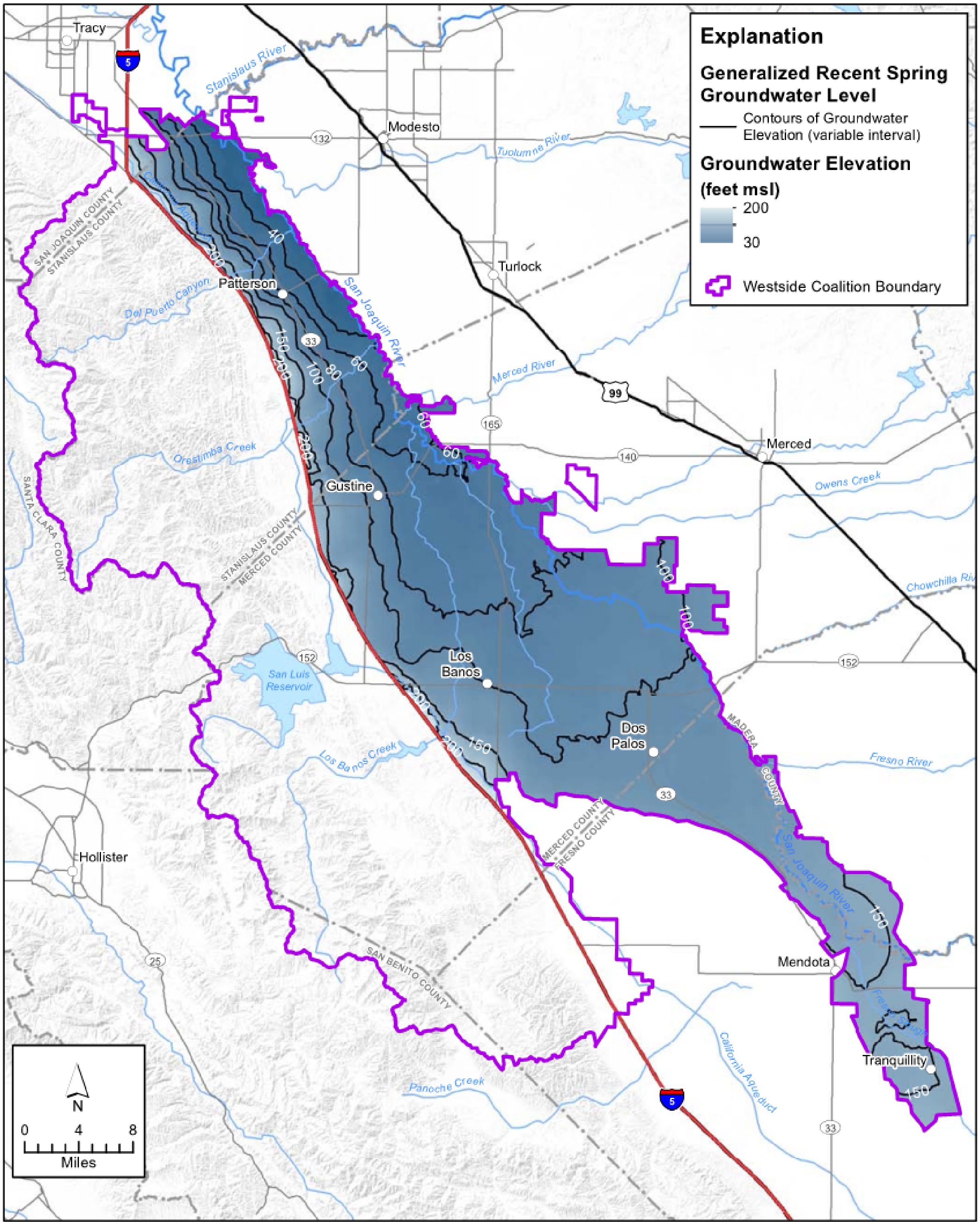
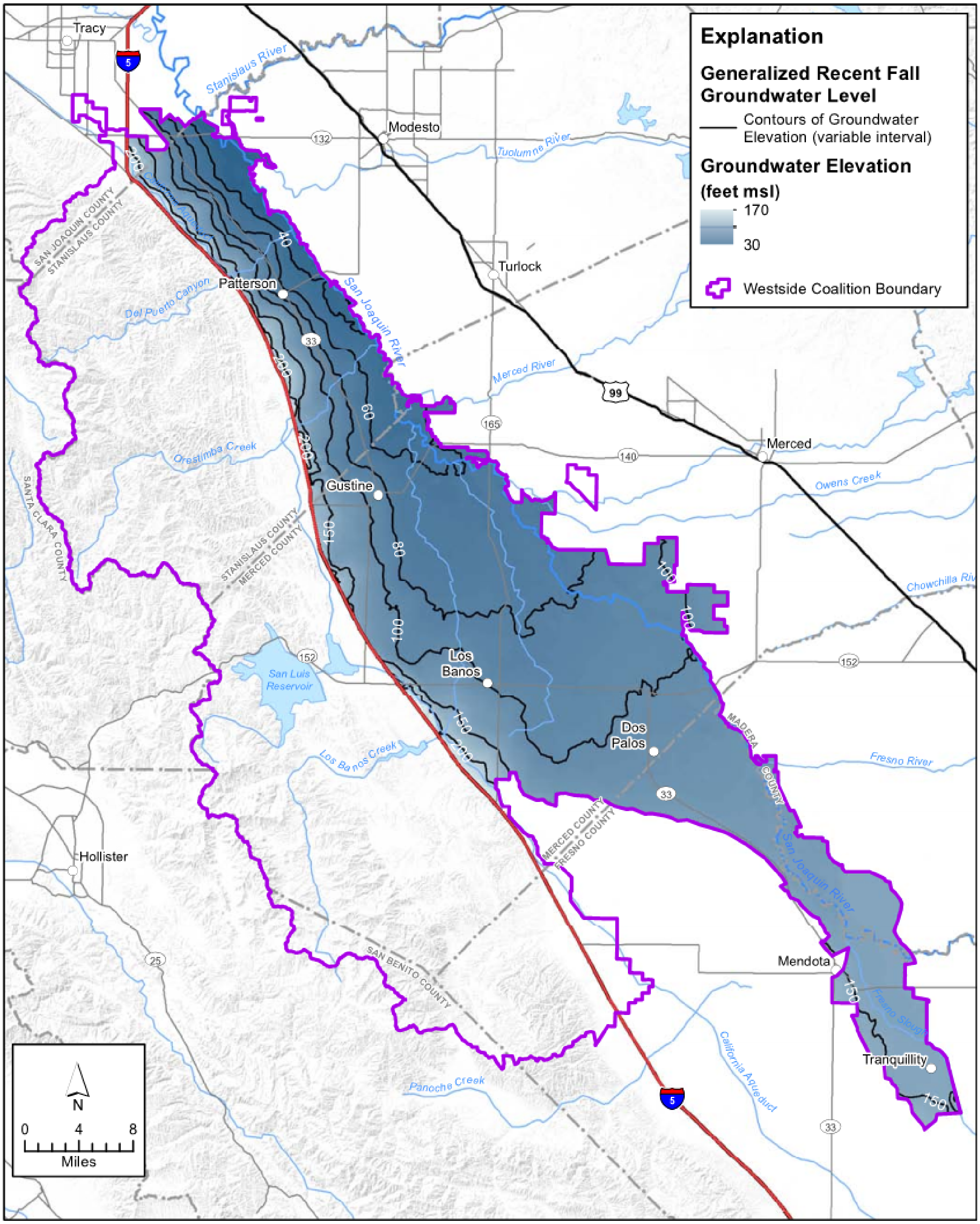


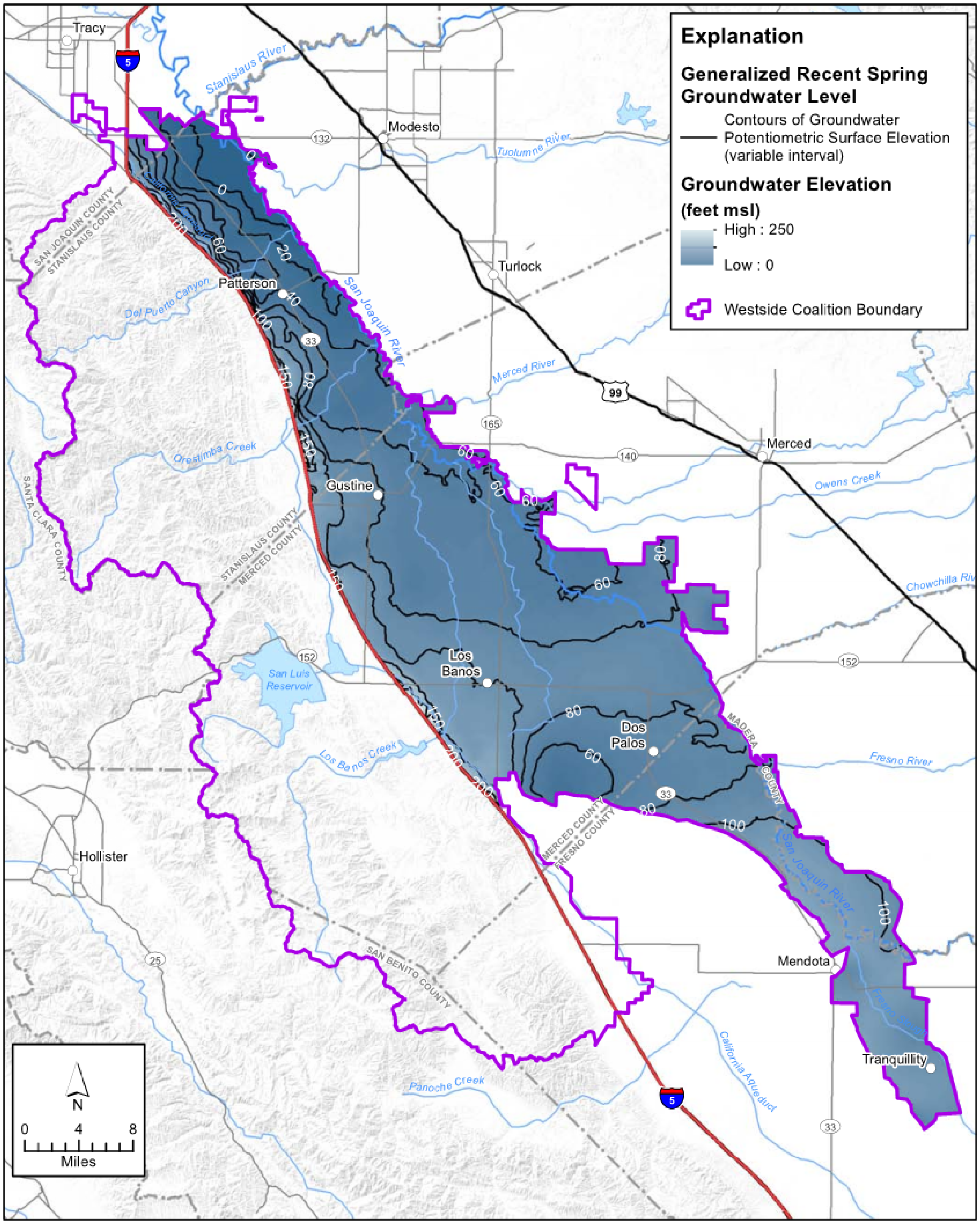
Source: *Western San Joaquin River Watershed Groundwater Quality Assessment Report*, 2015

Figure 5-70. Map of Spring Groundwater Elevation (2000-2016 Average), Very Shallow Groundwater



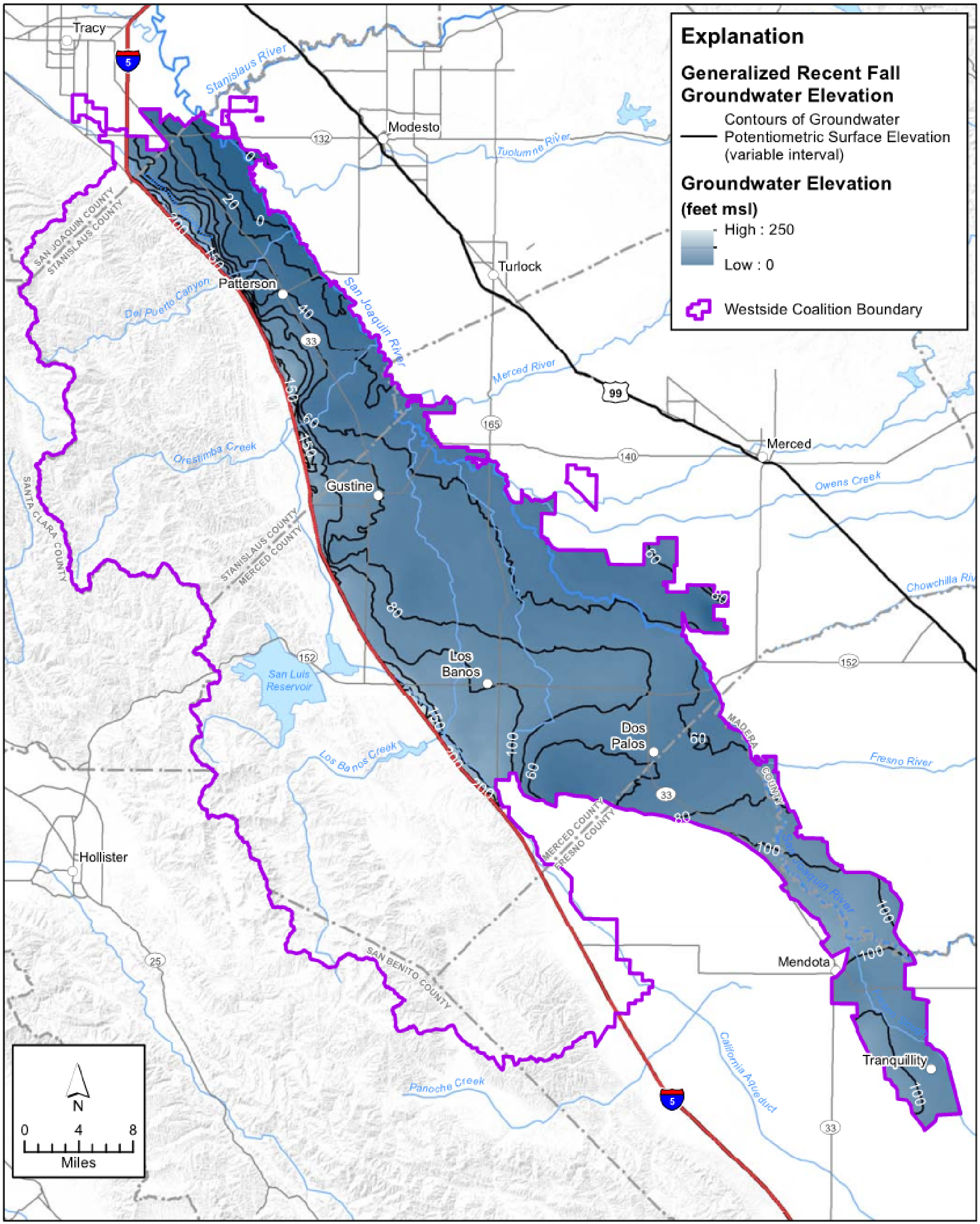
Source: *Western San Joaquin River Watershed Groundwater Quality Assessment Report*, 2015

Figure 5-71. Map of Fall Groundwater Elevation (2000-2016 Average), Very Shallow Groundwater



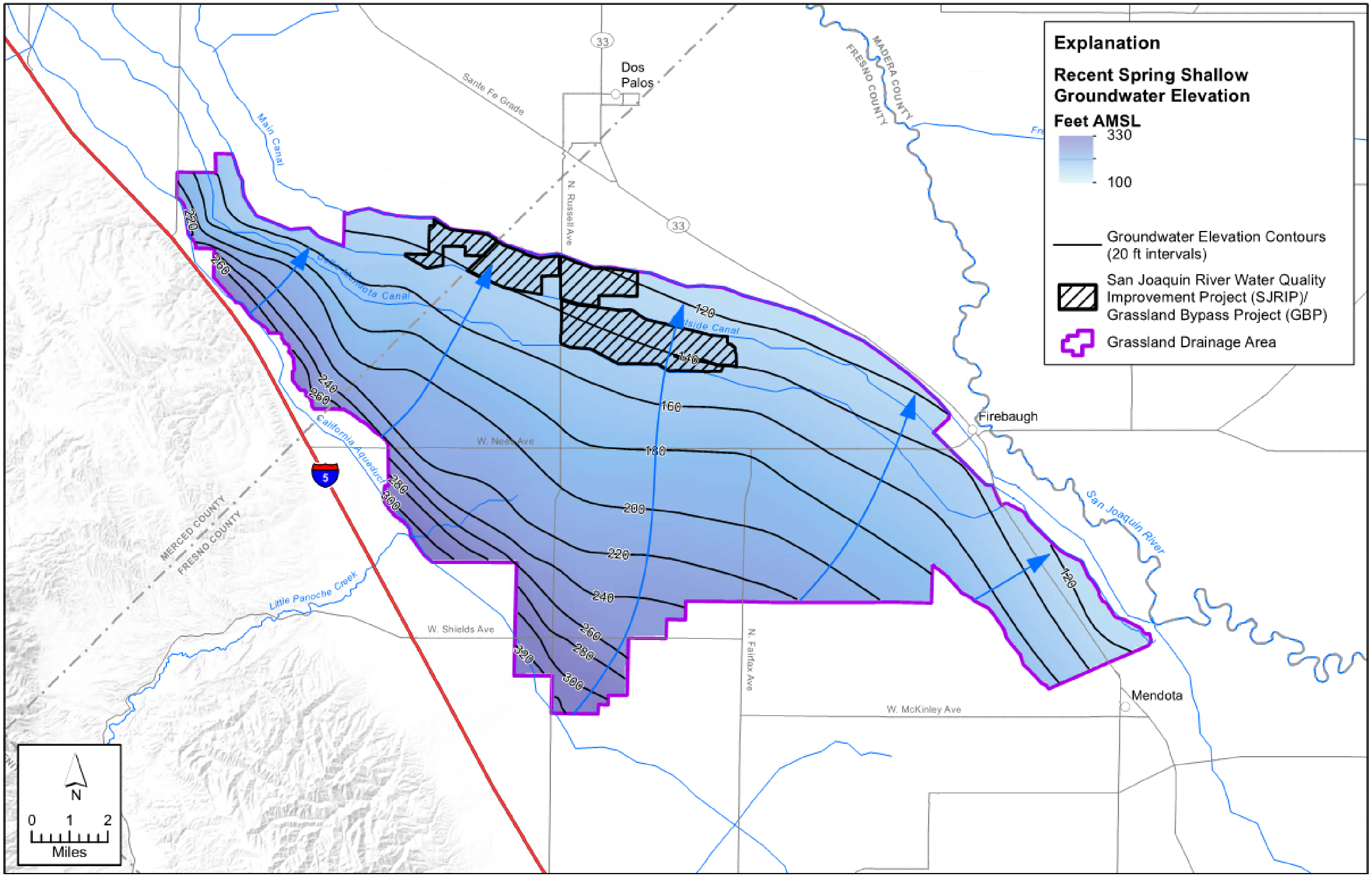
Source: *Western San Joaquin River Watershed Groundwater Quality Assessment Report*, 2015

Figure 5-72. Map of Spring Groundwater Elevation (2000-2016 Average), Upper Aquifer



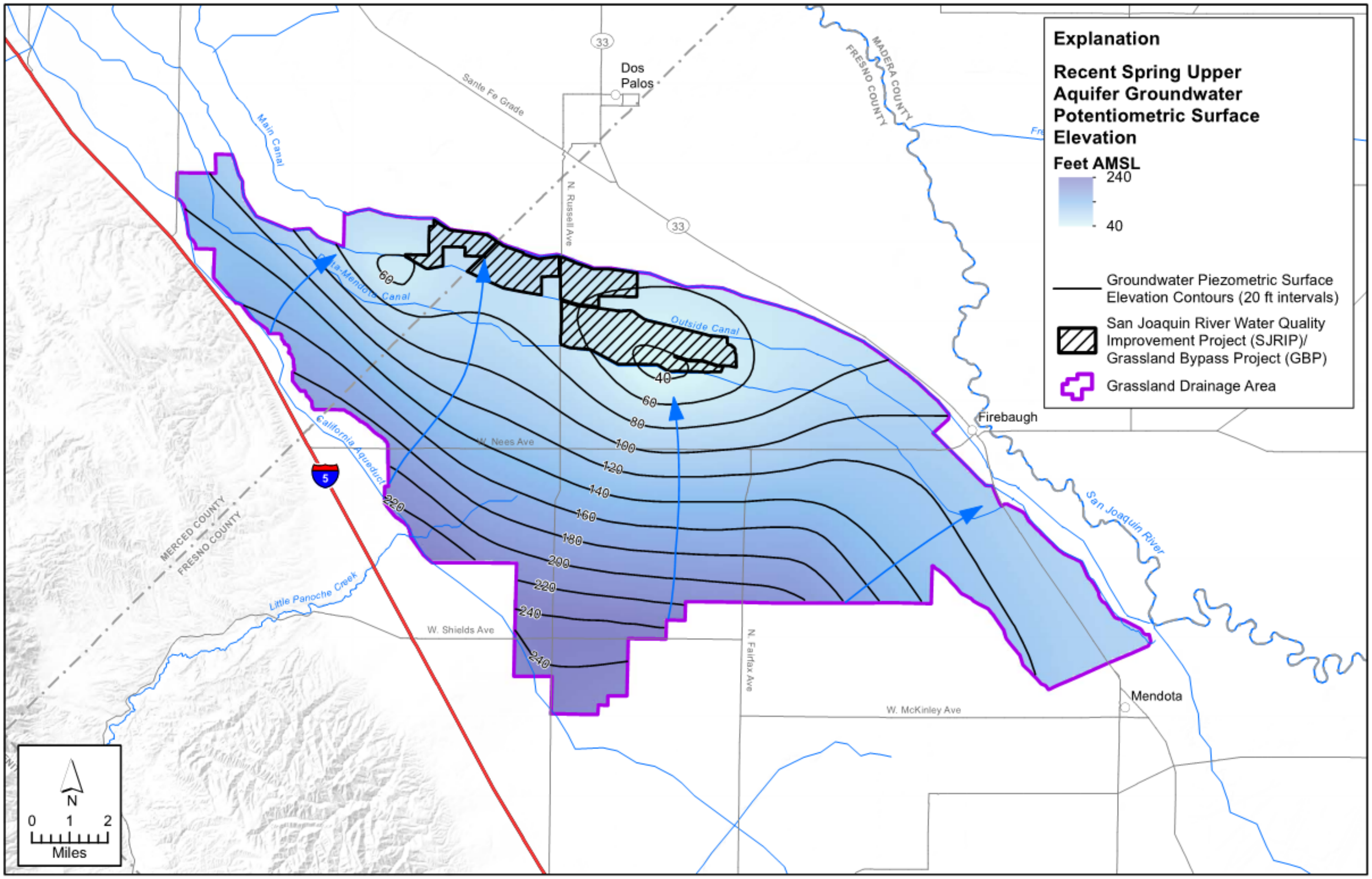
Source: *Western San Joaquin River Watershed Groundwater Quality Assessment Report*, 2015

Figure 5-73. Map of Fall Groundwater Elevation (2000-2016 Average), Upper Aquifer



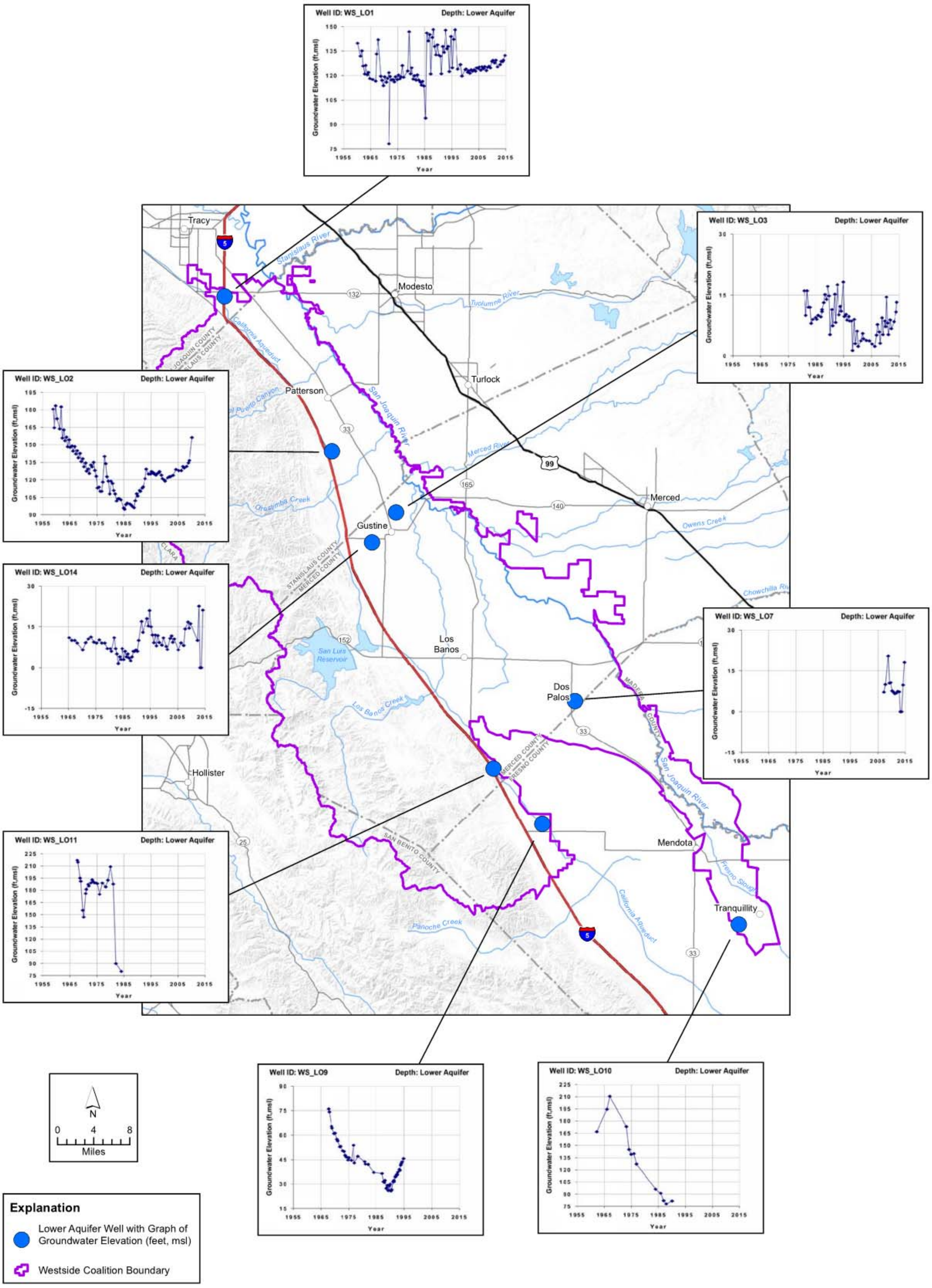
Source: *Grassland Drainage Area Groundwater Quality Assessment Report*, 2016

Figure 5-74. Map of Spring Groundwater Elevation (2000-2016 Average), Shallow Groundwater



Source: *Grassland Drainage Area Groundwater Quality Assessment Report*, 2016

Figure 5-75. Map of Spring Groundwater Elevation (2000-2016 Average), Upper Aquifer



Source: *Western San Joaquin River Watershed Groundwater Quality Assessment Report*, 2015

Note: The intent of these hydrographs is to generally demonstrate groundwater trends across the Delta-Mendota Subbasin.

Figure 5-76. Select Graphs of Groundwater Elevations, Lower Aquifer

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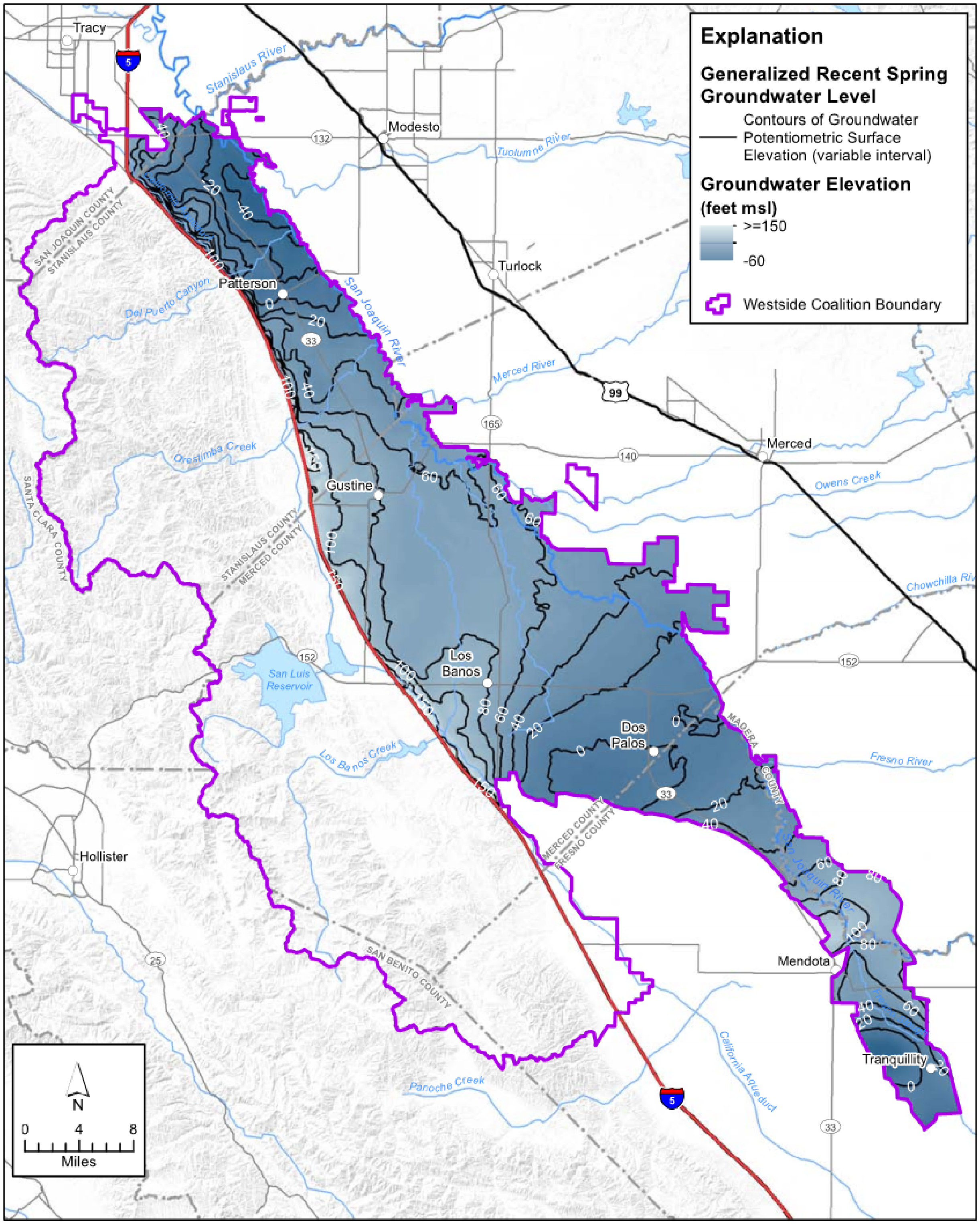
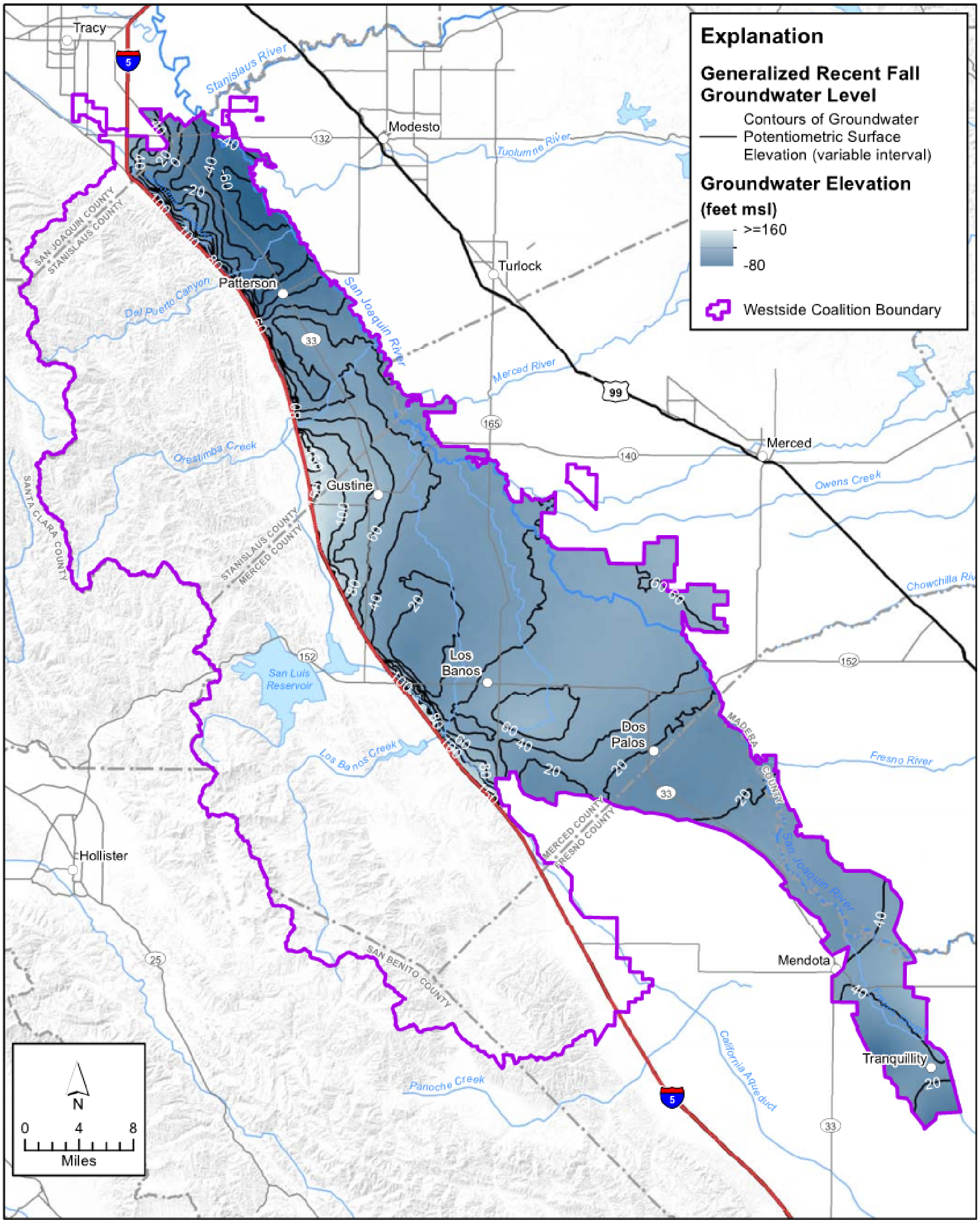


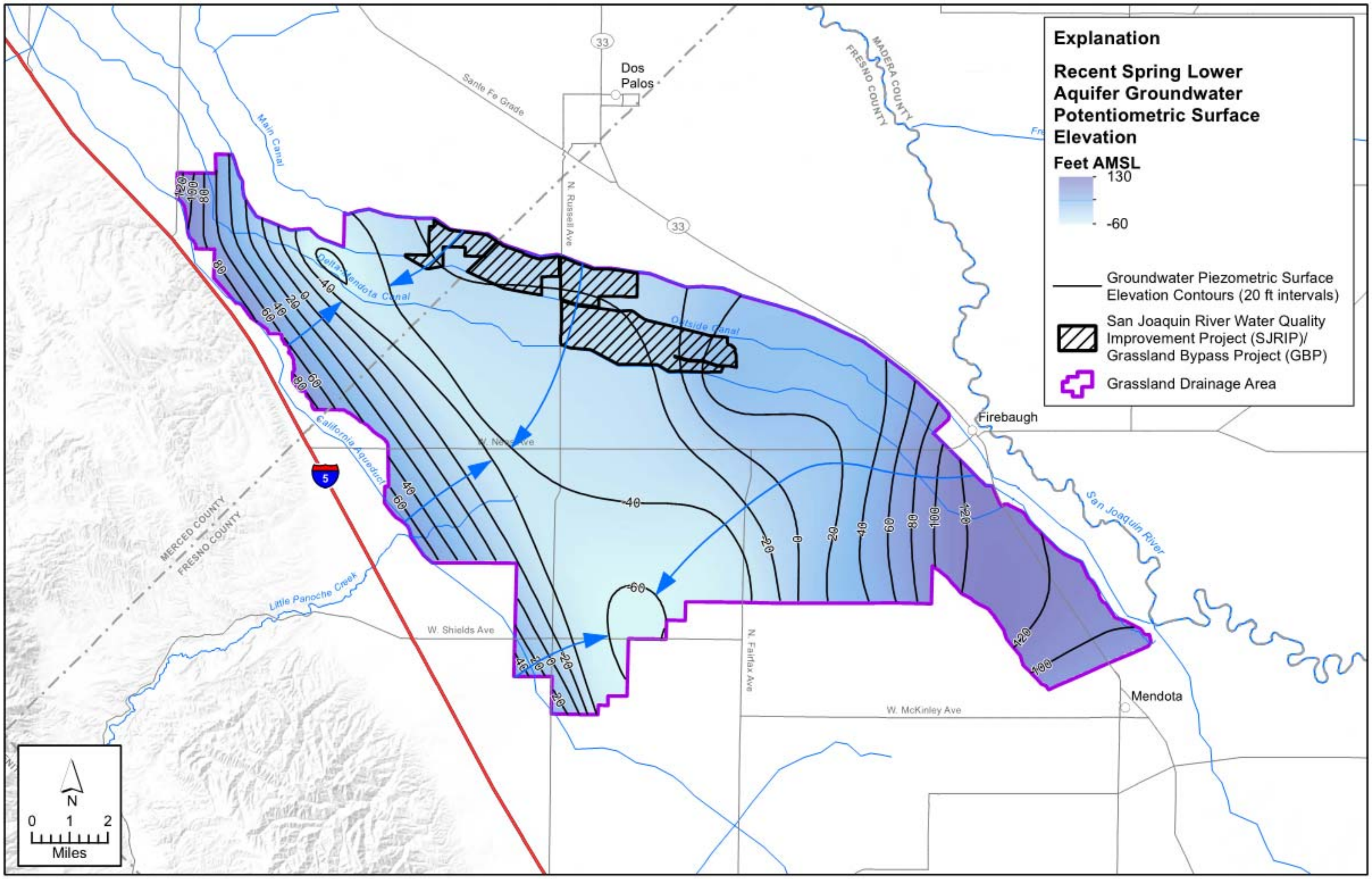
Source: *Western San Joaquin River Watershed Groundwater Quality Assessment Report*, 2015

Figure 5-77. Map of Spring Groundwater Elevation (2000-2016 Average), Lower Aquifer



Source: *Western San Joaquin River Watershed Groundwater Quality Assessment Report*, 2015

Figure 5-78. Map of Fall Groundwater Elevation (2000-2016 Average), Lower Aquifer



Source: *Grassland Drainage Area Groundwater Quality Assessment Report*, 2016

Figure 5-79. Map of Spring Groundwater Elevation (2000-2016 Average), Lower Aquifer

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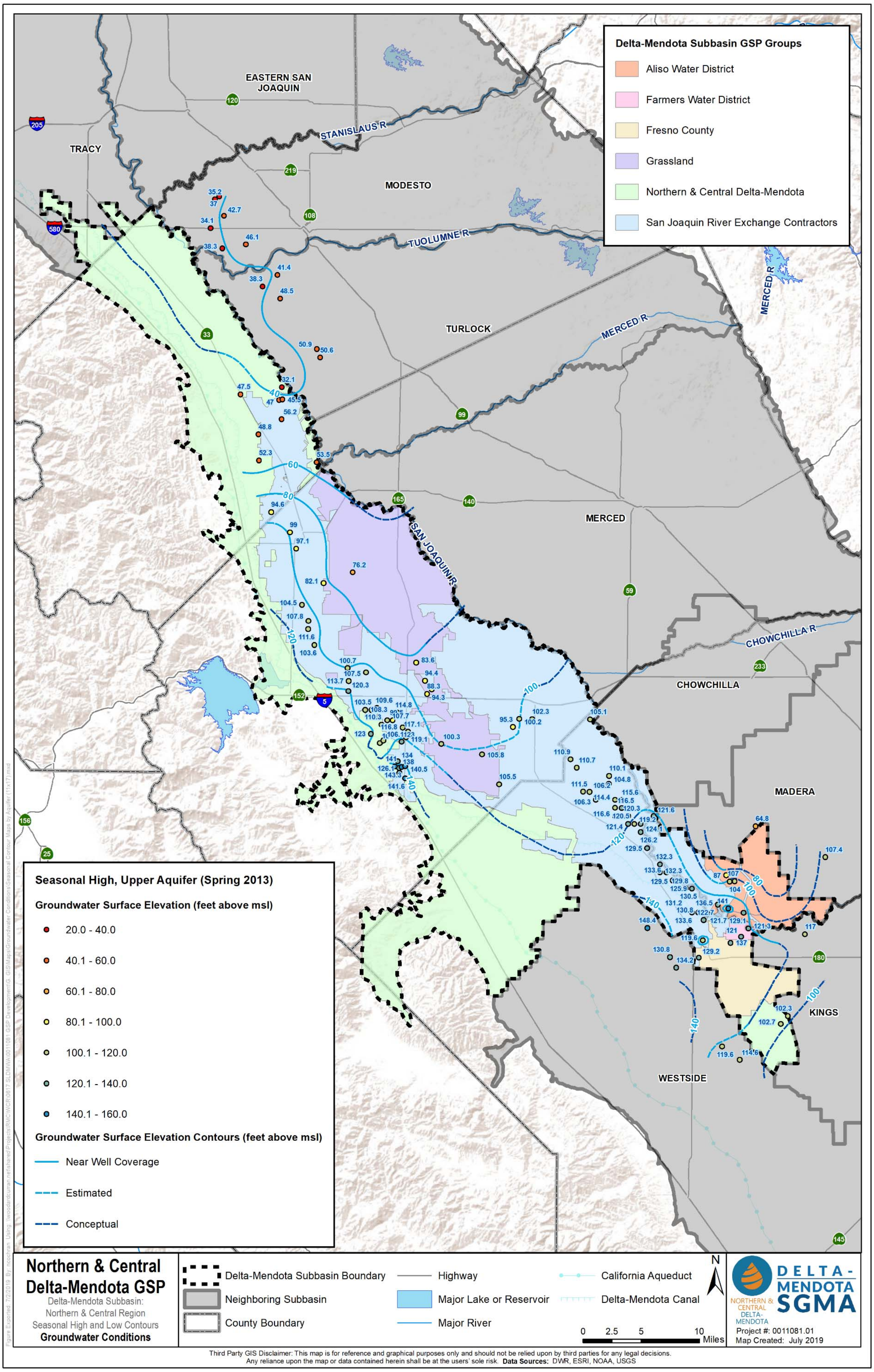


Figure 5-80. Spring 2013 Upper Aquifer Groundwater Contour Map, Delta-Mendota Subbasin

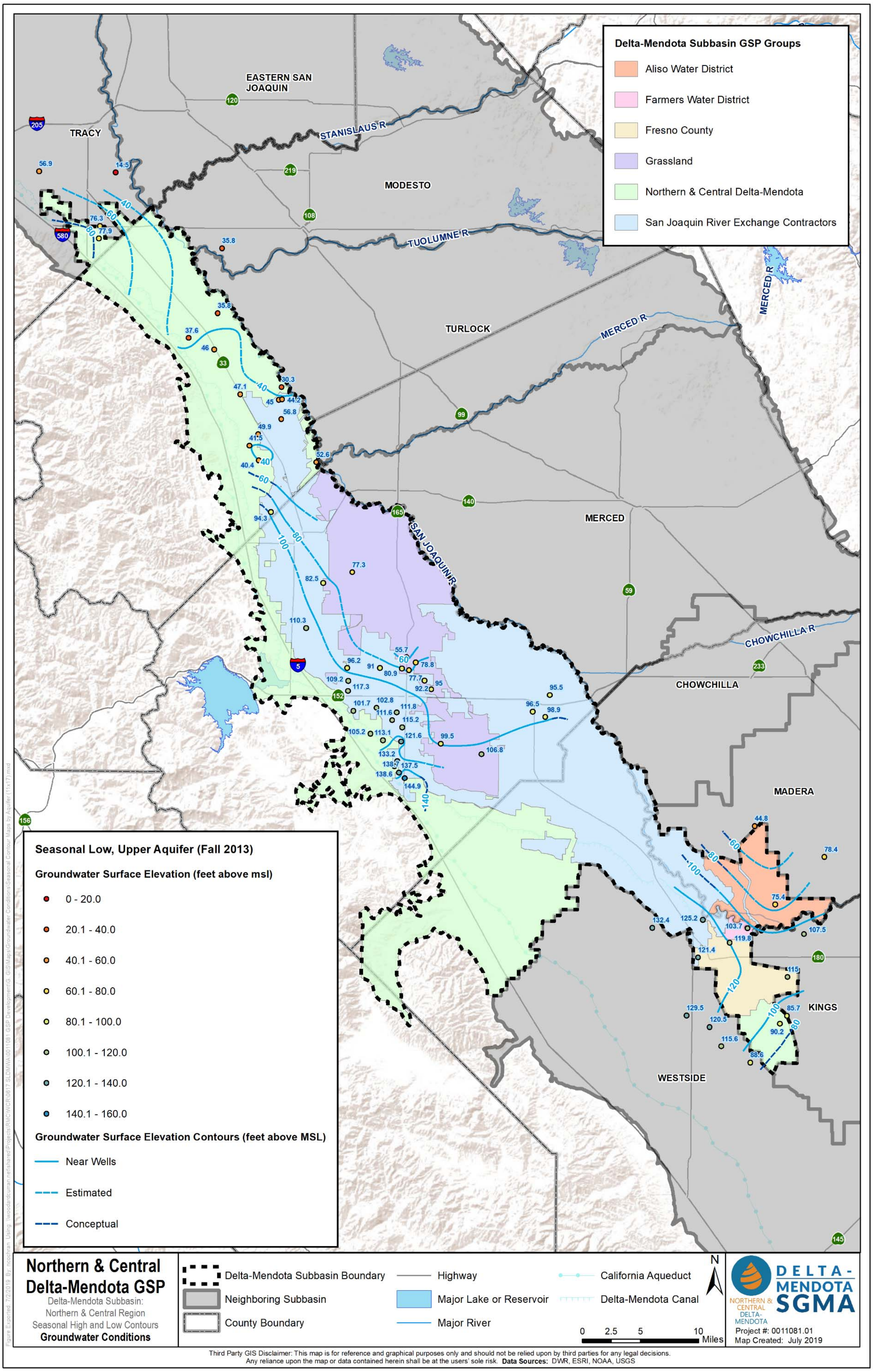


Figure 5-81. Fall 2013 Upper Aquifer Groundwater Contour Map, Delta-Mendota Subbasin

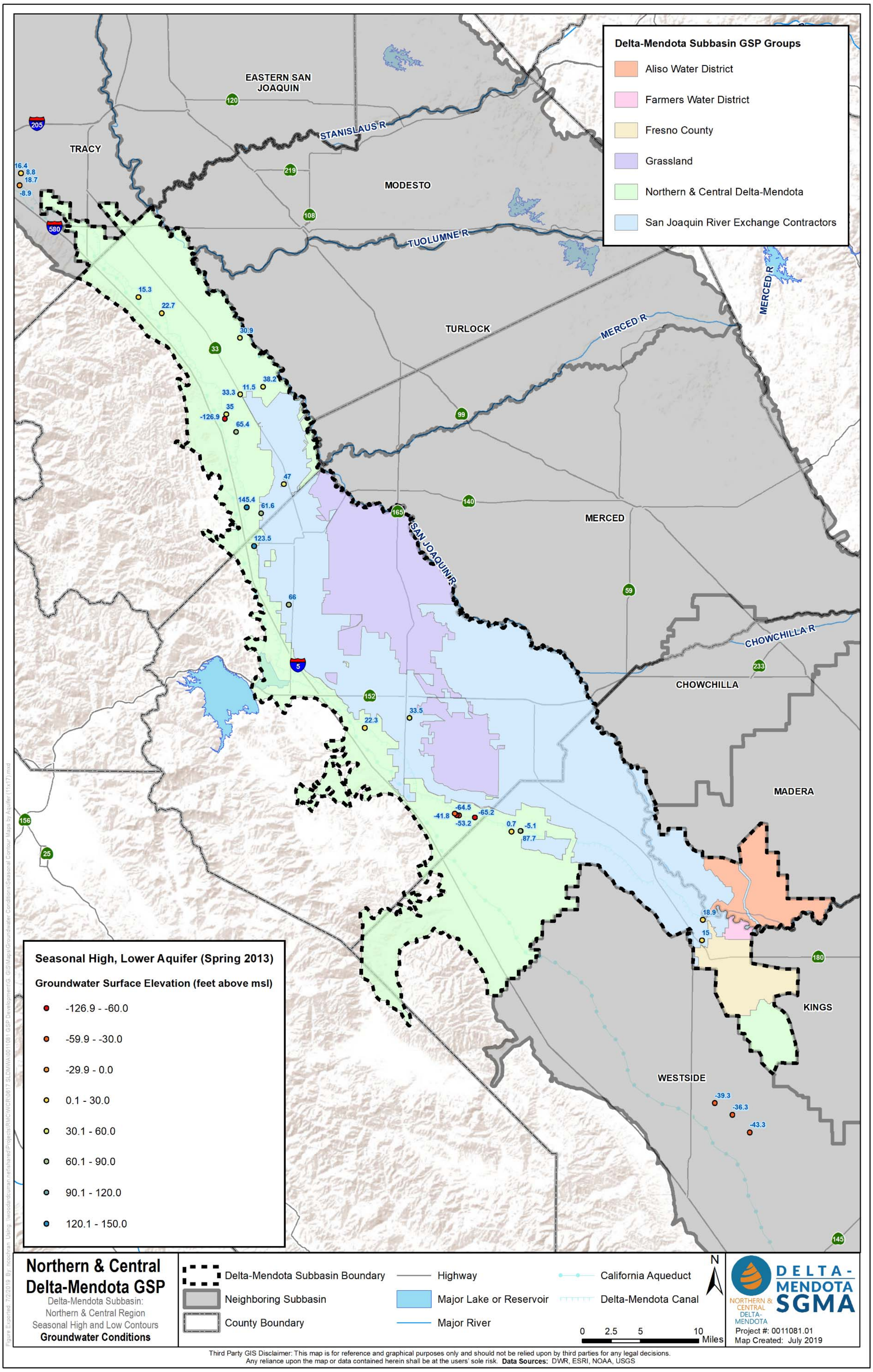
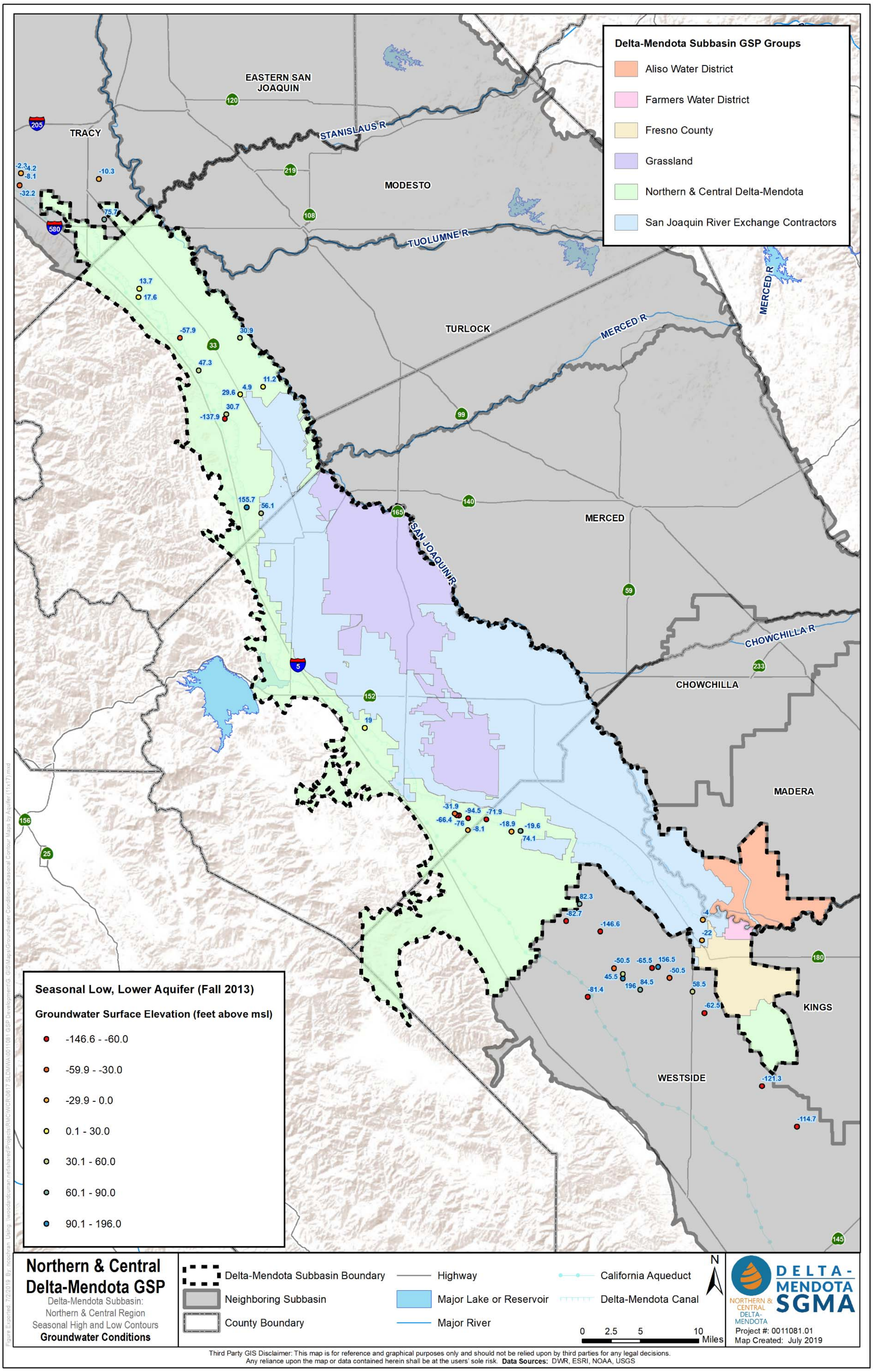


Figure 5-82. Spring 2013 Lower Aquifer Groundwater Elevation Measurements, Delta-Mendota Subbasin



Third Party GIS Disclaimer: This map is for reference and graphical purposes only and should not be relied upon by third parties for any legal decisions. Any reliance upon the map or data contained herein shall be at the users' sole risk. **Data Sources:** DWR, ESRI, NOAA, USGS

Figure 5-83. Fall 2013 Lower Aquifer Groundwater Elevation Measurements, Delta-Mendota Subbasin

5.3.3 Groundwater Storage

Annual change in groundwater storage for both the Upper and Lower Aquifers in the Northern and Central Delta-Mendota Regions was generated through the development of the historic and current water budgets (WY2003-2013). Aquifer-specific hydrographs available within the Northern and Central Delta-Mendota Regions were used to estimate annual and cumulative change in storage relative to the start of the historic water budget period in WY2003. Please refer to the Water Budget section (Section 5.4) and Water Budgets Model Development Technical Memorandum (Appendix D) for more detail regarding how change in storage was calculated.

Figure 5-84 and Figure 5-85 show annual change in storage, cumulative change in storage, and water year type for the Upper Aquifer and Lower Aquifer, respectively, from WY2003 through WY2018 for the Northern and Central Delta-Mendota Regions. Cumulative change in storage from WY2003 through WY2013 was derived from annual change in storage based on available hydrograph data (represented as a solid line in Figure 5-84 and Figure 5-85). Cumulative change in storage from WY2014 through WY2018 was estimated from annual change in storage based on the average change in storage by water year type from WY2003 to WY2013 (represented as a dashed line in Figure 5-84 and Figure 5-85). For the purposes of the water budget four water year types were utilized: wet, average (corresponding to above and below normal water years from the San Joaquin River Index), dry (corresponding to dry and critical water years from the San Joaquin River Index) and Shasta critical.

Change in storage is negative for 12 out of the 16 years and negative for 4 out of the 8 Wet and Average water year types in both the Upper Aquifer and Lower Aquifer. Despite periods of wet conditions with recharge outpacing extractions, an overall declining trend in groundwater storage can be observed in both the Upper and Lower Aquifers. Cumulative change in storage declined more rapidly in the Upper Aquifer compared to the Lower Aquifer, declining by about 830,000 acre-feet (AF) in the Upper Aquifer and 160,000 AF in the Lower Aquifer between WY2003 and WY2018.

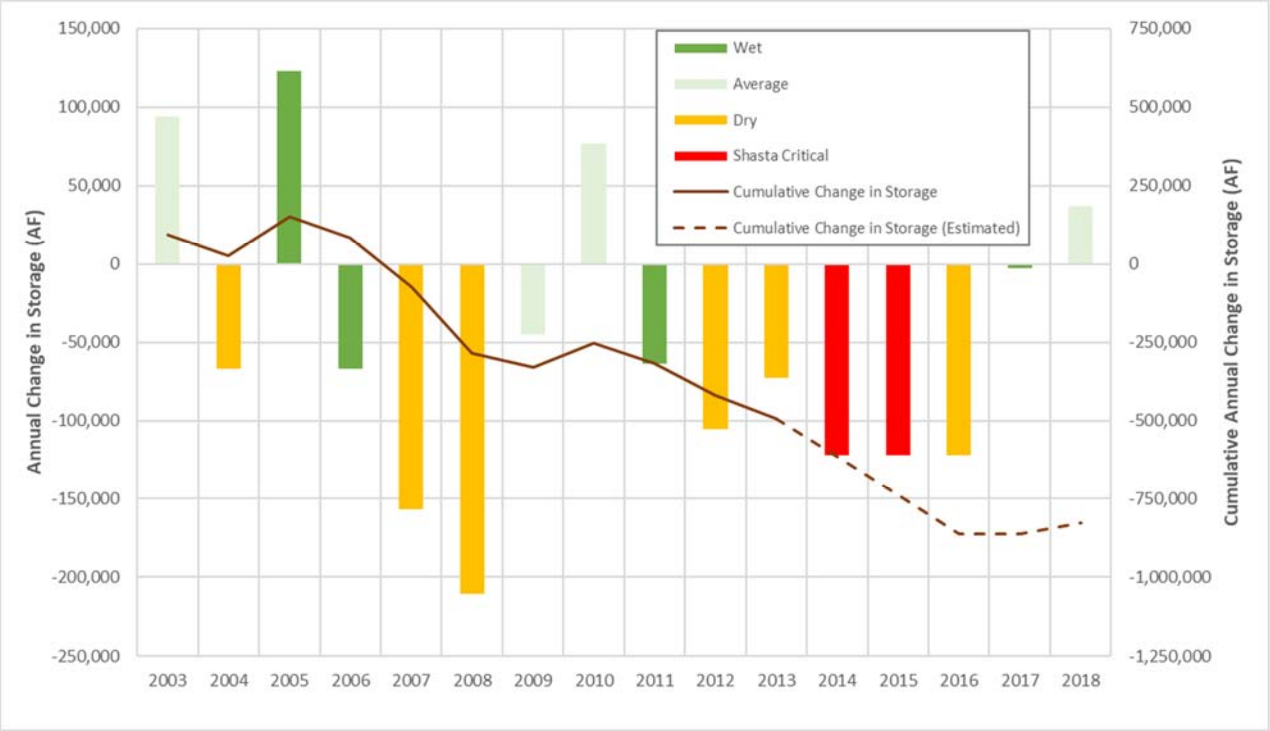


Figure 5-84. Calculated Upper Aquifer Change in Storage, Annual and Cumulative

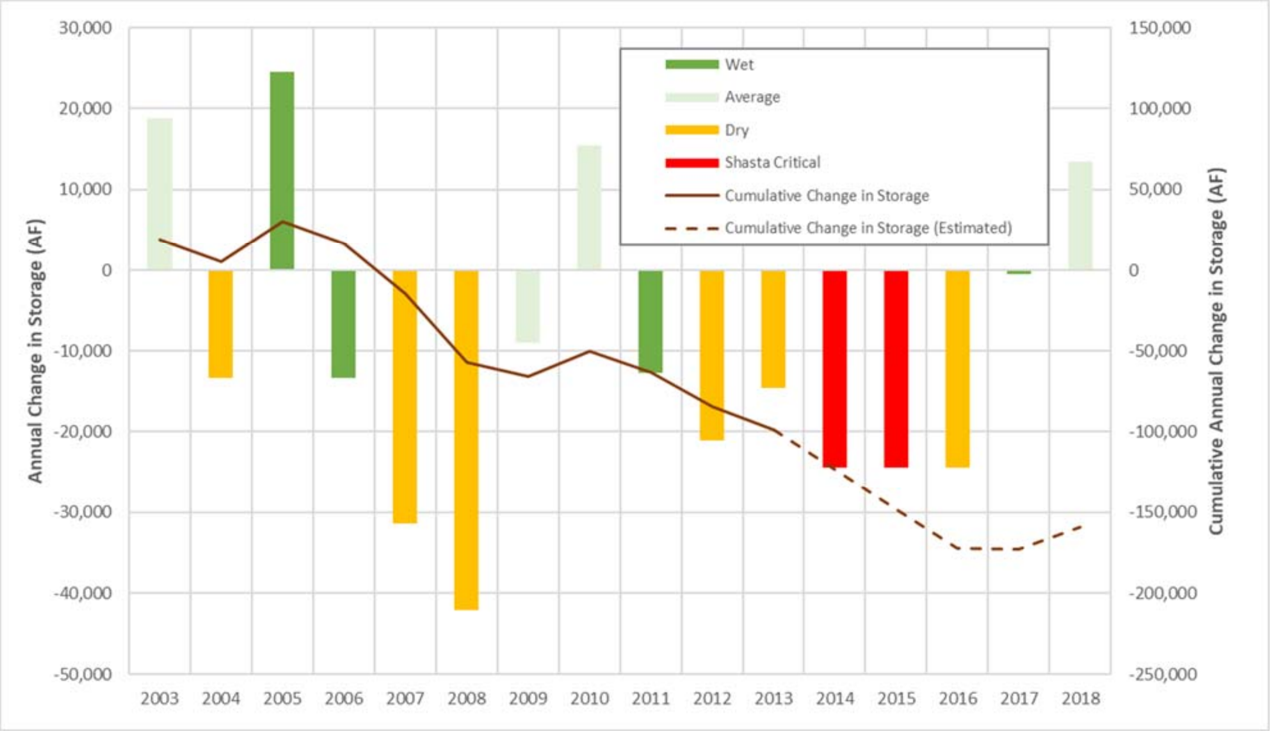


Figure 5-85. Calculated Lower Aquifer Change in Storage, Annual and Cumulative

5.3.4 Seawater Intrusion

Seawater intrusion is not an applicable sustainability indicator for the Delta-Mendota Subbasin as a whole. The Subbasin is located inland from the Pacific Ocean; thus, groundwater conditions related to seawater intrusion are not applicable to the Delta-Mendota Subbasin.

5.3.5 Groundwater Quality

Groundwater quality is a primary factor in groundwater supply reliability. There are no known groundwater contamination sites or plumes within the Northern and Central Delta-Mendota Regions. Groundwater quality concerns within the Northern and Central Delta-Mendota Regions are largely related to non-point sources and/or naturally-occurring constituents. Constituents of concern, both natural and anthropogenic, can impact human health and agricultural production. The following subsections attempt to identify and analyze available groundwater quality data and summarize groundwater quality conditions through a literature review and evaluation of existing publicly available data sets. It should be noted that constituents of concern discussed in this GSP are not exhaustive of all constituents of concern present in groundwater in the Delta-Mendota Subbasin. The presented constituents of concern were selected based on available data, the potential to impact existing or future groundwater use, the ability to address groundwater quality impacts through projects and/or management actions, and the source of the constituent.

Primary constituents of concern within the Northern and Central Delta-Mendota Regions are nitrate, total dissolved solids (TDS), and boron, which all have anthropogenic as well as natural sources. Table 5-2 includes the State and federal primary and secondary MCLs for drinking water in milligrams per liter (mg/L). These are also the Water Quality Objectives (WQOs) in the Central Valley Regional Water Quality Control Board's (CV-RWQCB) *Water Quality Control Plan for the Sacramento and San Joaquin River Basins* (or Basin Plan) (2009) for waters designated as having municipal (MUN) beneficial use. Table 5-3 includes WQOs for irrigated agriculture. Agricultural WQOs identified in Table 5-3 are derived from the *Delta-Mendota Canal Non-Project Water Pump-in Program Monitoring Plan* (2018).

While there are other constituents known to be found in localized areas throughout the Northern and Central Delta-Mendota Regions, these constituents generally characterize groundwater quality in the region of interest. It is important to note that the following discussion and analysis of ambient groundwater quality is not reflective of drinking water quality where treatment is applied to remove such constituents before public consumption.

Other known constituents of concern within the Delta-Mendota Subbasin include arsenic, selenium, and hexavalent chromium. These constituents are naturally occurring in the Delta-Mendota Subbasin and have been detected at concentrations above the WQOs at various locations throughout the Delta-Mendota Subbasin. Concentrations of these constituents do not appear to be linked to groundwater elevations, and as such, these constituents (and their associated concentrations) are considered to be existing conditions. There are no specific projects and/or management practices that can be implemented to mitigate for these constituents (other than groundwater treatment) that are not currently being implemented through other regulatory programs (such as the Irrigated Lands Regulatory Program). Therefore, these constituents are not considered manageable as part of this GSP other than through the coordination of GSP implementation with existing and anticipated future regulatory programs. Sustainability goals and indicators will therefore not be developed for these constituents. The water quality monitoring program will, however, continue to collect data relative to ongoing groundwater concentrations for these constituents for future assessment in coordination with other existing and anticipated future regulatory programs.

Table 5-2. State and Federal Primary and Secondary MCLs for Drinking Water, Constituents of Concern

Constituent	U.S. Environmental Protection Agency		State of California	
	Primary MCL (mg/L)	Secondary MCL (mg/L)	Primary MCL (mg/L)	Secondary MCL (mg/L)
Nitrate [1]	10 (as N)	-	45 (as NO_3)	-
TDS [2]	-	-	-	500 (Recommended) 1,000 (Upper) 1,500 (Short-term)
Boron [1]	N/A	N/A	N/A	N/A

[1] SWRCB, March 2018.
[2] State of California, 2006.

Table 5-3. Water Quality Objectives for Irrigation

Constituent	Water Quality Objective	Units
Nitrate (as Nitrogen) [1]	10	mg/L
TDS [2]	1,000	mg/L
Boron [3]	0.7	mg/L

[1] State of California (December 2017); Title 22. Table 64431-A Maximum Contaminant Levels, Inorganic Chemicals
[2] State of California (December 2017); Title 22. Table 64449-B Secondary Maximum Contaminant Levels "Consumer Acceptance Contaminant Level Ranges"
[3] Ayers and Westcot (1985), Table 21

5.3.5.1 Available Data

Groundwater quality data within the Delta-Mendota Subbasin are available from the following sources and associated programs:

- Central Valley Regional Water Quality Control Board
    - ILRP
        - Western San Joaquin GAR
        - Grassland Drainage Area GAR
- State Water Resources Control Board (SWRCB)
    - Central Valley Salinity Alternatives for Long-term Sustainability (CV-SALTS)
    - Geotracker Groundwater Ambient Monitoring and Assessment Program (GAMA)
- United States Bureau of Reclamation
    - Delta-Mendota Canal Warren Act Pump-in Program
- Local Agency Data

Data provided by these sources include information such as parameter sampled, sample location, sample date, sampling method, concentration, and other related information, such as questionable measurement code, well construction information, and well type. These data were synthesized to support the following discussions of constituents of concern. Data were obtained predominantly from the data sets identified above to characterize groundwater quality from 2000 to 2018. Figure 5-86 through Figure 5-87 show the locations of wells with available water quality monitoring data and known aquifer designation. Groundwater quality varies based on location and depth by constituent. The following discusses the primary water quality data and analyses recently completed for the Delta-Mendota Subbasin and utilized herein.

Central Valley Salt and Nutrient Management Plan (SNMP). The Central Valley SNMP, prepared under the CV-SALTs program administered under the CV-RWQCB, contains an analysis of nitrate and TDS concentrations for the entire Central Valley. For the purposes of this GSP, data from the SNMP are summarized for the Delta-Mendota Subbasin.

The SNMP examined ambient conditions and Assimilative Capacity for both TDS and nitrate using data ranging from pre-1960 through 2012. Assimilative Capacity was computed by taking the difference between the ambient concentration and the regulatory threshold (or WQO). For the purposes of this GSP, discussion focuses on data analyzed for the Upper Zone (defined generally in the SNMP as the vadose zone generally where domestic wells are perforated) and the production zone (defined generally in the SNMP as a combination of the Upper Zone and Lower Zone, which extends to the top of the Corcoran Clay where present, correlating to the Upper Aquifer defined in this GSP, as discussed in the Hydrogeologic Conceptual Model [HCM] [see Section 5.2]).

Western San Joaquin River Watershed Groundwater Quality Assessment Report. The Western San Joaquin River Watershed Coalition ("Coalition") published a GAR in March 2015 (LSCE, 2015). The GAR covers the Coalition region, which encompasses the Delta-Mendota and Merced Subbasins, as well as the Los Banos Creek Valley Groundwater Basin located in the Coast Range mountains. The intent of the GAR is to characterize groundwater quality conditions within the area. Data on nitrate, salinity (TDS and specific conductance or electrical conductivity [EC]), and pesticides were gathered from Coalition members, as well as from the California Department of Public Health's (CDPH's) Water Quality Analysis Data Files, DWR's Water Data Library, United States Geological Survey's (USGS) National Water Information System, SWRCB Geotracker GAMA, and the California Department of Pesticide Regulation (DPR) pesticide sampling database. Sampling dates for nitrate range from 1944 to 2014, while sampling dates for TDS range from 1930 to 2014. Although some data extends past 2012 (the end of the "historic" period for GSP purposes), information from the GAR is still considered to fall under historic conditions given the overall data range. Pesticide data for the GAR were limited to data obtained from the DPR. DPR well locations were not provided with pesticide data; they were associated with a Public Land Survey System (PLSS) section (one square mile) for analysis.

Grasslands Drainage Area Groundwater Quality Assessment Report. The Grassland Drainage Area published a GAR in July 2016 (LSCE, 2016). The Grassland Drainage Area GAR covers a portion of the Delta-Mendota Subbasin generally south of Dos Palos, east of Firebaugh, and north of the boundary with the Westside Subbasin (which encompasses portions of the Central Delta-Mendota, Oro Loma Water District, and Widren Water District GSAs). The GAR contains information on nitrate, salinity (TDS and EC), selenium, boron, and pesticides. Data was gathered from Coalition members, as well as CDPH's Water Quality Analysis Data Files, DWR's Water Data Library, USGS's National Water Information System, SWRCB Geotracker GAMA, and the DPR pesticide sampling database. Sampling dates for nitrate, TDS, and boron range from the 1940s through 2010s. Sampling dates for selenium range from the 1980s through 2010s. Pesticide data for the GAR were limited to data obtained from the DPR. DPR well locations were not provided with pesticide data; they were associated with a PLSS section (one square mile) for analysis.

Groundwater Quality in the Western San Joaquin Valley Study Unit, 2010: California GAMA Priority Basin Project. Water quality in groundwater resources used for public drinking-water supply in the Western San Joaquin Valley (WSJV) was investigated by the USGS in cooperation with the California SWRCB as part of its GAMA

Program Priority Basin Project (SWRCB, July 2018). The WSJV includes two study areas: the Delta–Mendota and Westside Subbasins of the San Joaquin Valley Groundwater Basin. As documented in the published study entitled *Groundwater Quality in the Western San Joaquin Valley Study Unit, 2010: California GAMA Priority Basin Project* (Scientific Investigations Report 2017-5032 by Miranda Fram), the study objectives included two assessment types: (1) a status assessment yielding quantitative estimates of the current (2010) status of groundwater quality in the groundwater resources used for public drinking water, and (2) an evaluation of natural and anthropogenic factors that could be affecting the groundwater quality. The assessments characterized the quality of untreated groundwater based on data collected from 43 wells sampled by the USGS for the GAMA Priority Basin Project (USGS-GAMA) in 2010 and data compiled in the SWRCB Division of Drinking Water (DDW) database for 74 additional public-supply wells sampled for regulatory compliance purposes between 2007 and 2010. To provide context, concentrations of constituents measured in groundwater were compared to U.S. Environmental Protection Agency (EPA) and DDW regulatory and non-regulatory benchmarks for drinking-water quality.

In general, the study found that groundwater resources used for public drinking water in the WSJV study unit are among the most saline and most affected by high concentrations of inorganic constituents of all groundwater resources used for public drinking water that have been assessed by the GAMA Priority Basin Project statewide. Among the 82 GAMA Priority Basin Project study areas statewide, the Delta–Mendota Subbasin ranked above the 90th percentile for aquifer-scale proportions of groundwater resources having concentrations of TDS, sulfate, chloride, manganese, boron, hexavalent chromium, selenium, and strontium above benchmarks. The study also found that recharge of water used for irrigation has direct and indirect effects on groundwater quality. Elevated nitrate concentrations and detections of herbicides and fumigants in the Delta-Mendota Subbasin generally were associated with greater agricultural land use near wells and with water recharged during the last 60 years.

5.3.5.2 Historic and Current Conditions and Trends

As previously noted, arsenic, hexavalent chromium, and selenium are naturally-occurring constituents in the Delta-Mendota Subbasin whose ambient concentrations sometimes exceed the WQO from the Basin Plan. However, these constituents are ubiquitous, and concentrations cannot be directly correlated to groundwater elevations or other groundwater management practices. As such, these constituents are considered to be ‘unmanageable’ by the GSAs and therefore sustainability indicators have not been developed. Constituents for which sustainability indicators have been developed include nitrate, TDS, and boron.

Nitrate

Using data from the Central Valley SNMP for the period ranging from 2000 through 2016, concentrations of nitrate (as N) in excess of 10 mg/L were found to exist north of Patterson, south of Dos Palos, and southwest of Patterson extending southwest past Los Banos. The ambient concentrations of nitrate in the upper zone are elevated north of Patterson, on the western side of the Subbasin (roughly from Patterson to Los Banos), and south of Dos Palos, with similar patterns seen in the production zone (Figure 5-88). Figure 5-89 displays nitrate (as N) concentration in the production zone for the entire Delta-Mendota Subbasin. Lower nitrate (as N) concentrations (<2.5 mg/L) were found to exist in the areas east of Los Banos and south of Firebaugh.

Throughout the Delta-Mendota Subbasin, nitrate concentrations were below 5 mg/L (nitrate as N) in the majority of wells, as described in the Western San Joaquin GAR (LSCE, 2015). However, there are several areas where higher concentrations occur, including locations where the MCL of 10 mg/L is exceeded. In the Upper Aquifer, notable areas of elevated nitrate concentrations occur immediately south of Los Banos and northwest, along Highway 33, toward Patterson. Geologic formations with naturally-occurring elevated levels of nitrate have been identified in Origalita Creek alluvium in the southern portion of the Subbasin. In the Lower Aquifer, fewer data are available, but most wells have a maximum nitrate concentration above 5 mg/L. In the most recent available data, some Lower Aquifer wells have concentrations greater than 10 mg/L. In general, higher nitrate concentrations in the Lower Aquifer occur in areas where the Corcoran Clay is thin or non-existent (particularly to the west and northwest of Gustine) (LSCE, 2015). In the Grassland Drainage Area, only six wells in the Upper Aquifer had nitrate data available. Of these, only one had a nitrate concentration above 10 mg/L; other wells were below 2.5 mg/L. Data for the Lower Aquifer were also limited, including only 14 wells. The majority of observed nitrate concentrations were below 2.5 mg/L, with none exceeding 10 mg/L (LSCE, 2016).

Nitrate (as N) concentrations in the Upper Aquifer (above the Corcoran Clay) have been mostly low and stable over time since 1985 (Figure 5-90 and Figure 5-91). Overall, in the northern portion of the Subbasin, nitrate (as N) concentrations in the Upper Aquifer were generally below the MCL of 10 mg/L, with concentrations generally increasing further south in the Subbasin and reaching and stabilizing at a maximum of 15 mg/L south of Dos Palos since 2007. Similar to the Upper Aquifer, nitrate concentrations in the Lower Aquifer (below the Corcoran Clay) have been low and stable since 1985 with no recorded exceedances above the MCL (Figure 5-92). Generally, timeseries data for nitrate concentrations south of Dos Palos within Fresno County was largely unavailable with sufficient temporal range to warrant evaluation and presentation through timeseries graphs, with most data only available for a short timeframe from the late 1980s to the early 1990s.

The Western San Joaquin and Grassland Drainage Area GARs also assessed the present temporal trends in nitrate for all available historical data through 2016 (wells with a minimum of three sampling events) using a linear regression trend analysis with a p-value of 0.05 and 0.1 indicating significance, respectively from each GAR. Table 5-4 indicates the degree of trends for nitrate as presented in the GARs. Figure 5-93 illustrates statistically-significant temporal trends in nitrate concentration in the Upper Aquifer. Significant trends in the increasing and decreasing directions are observed in the Upper Aquifer. Wells near Patterson, Gustine, and Los Banos largely show Mildly Increasing trends with a cluster of wells near the San Joaquin River in central Merced County, and two wells south of Dos Palos showing Mildly Decreasing and Decreasing trends. Wells with very small changes in nitrate concentration are scattered throughout the Subbasin.

Figure 5-94 illustrates statistically significant temporal trends in nitrate concentration in the Lower Aquifer. Wells with sufficient data to demonstrate a statistically significant trend are limited to the Stanislaus County portion of the Delta-Mendota Subbasin and south of Dos Palos. Trends show largely Mildly Increasing and Increasing nitrate concentrations with a few wells showing Mildly Decreasing and Decreasing trends northwest of Gustine. South of Dos Palos, one well shows a very small change in nitrate concentration and another shows a Mildly Increasing trend. Figure 5-95 illustrates statistically significant temporal trends in nitrate concentration in composite wells screened in both the Upper Aquifer and Lower Aquifer. Only two composite wells with statistically significant trends in nitrate concentration are present in the Delta-Mendota Subbasin. One well located near Dos Palos has a Mildly Increasing trend, with the other well located south of Gustine has a Mildly Decreasing trend.

Table 5-4. Nitrate (as N) Trend Significance

from Western San Joaquin and Grassland GARs

Trend	Nitrate (mg/L/year)
Increasing	> 1.0
Mildly Increasing	0.1 - 1.0
Very Small Change	-0.1 - 0.1
Mildly Decreasing	-1.0 - -0.1
Decreasing	< -1.0

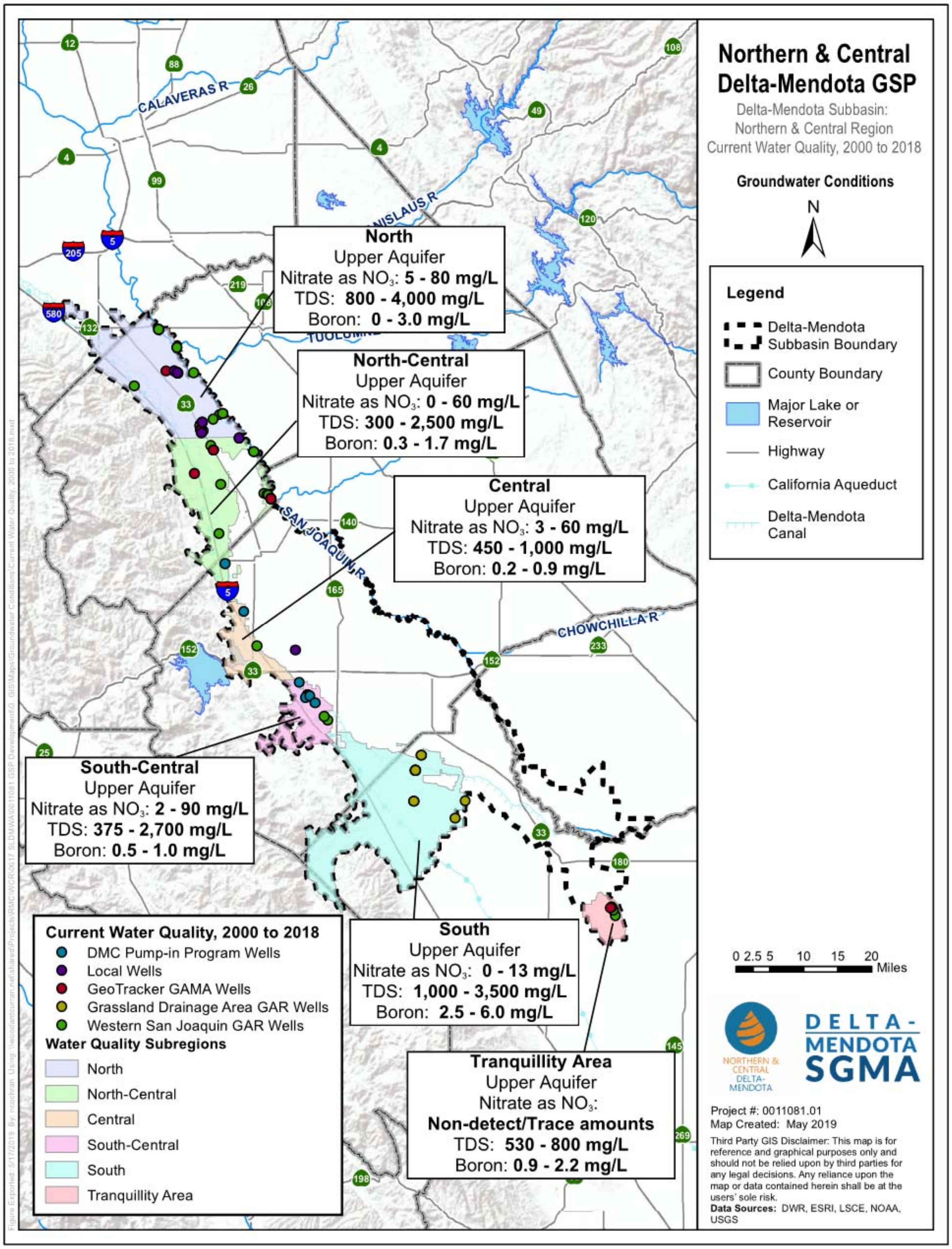


Figure 5-86. Upper Aquifer, Current Groundwater Quality (2000-2018)

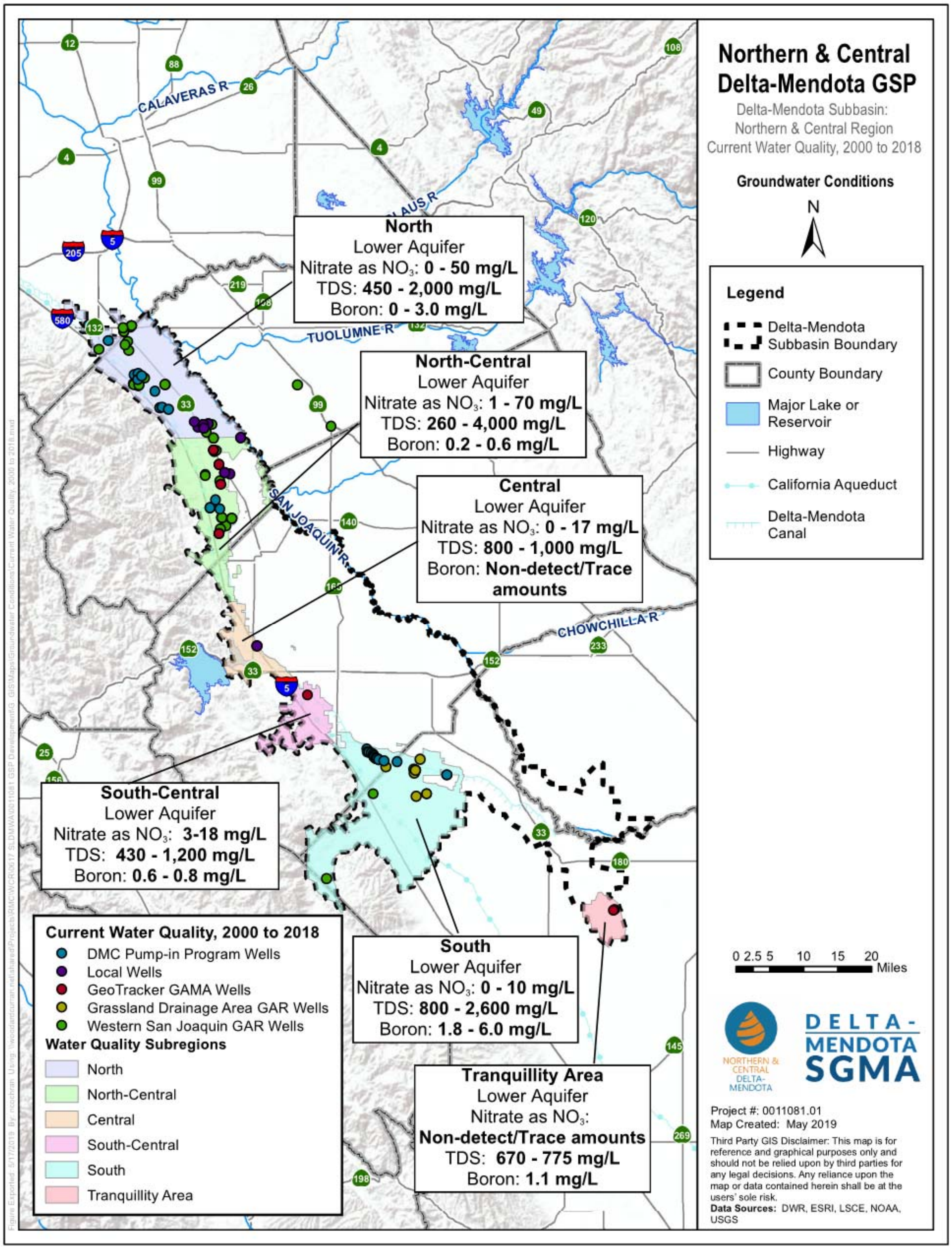
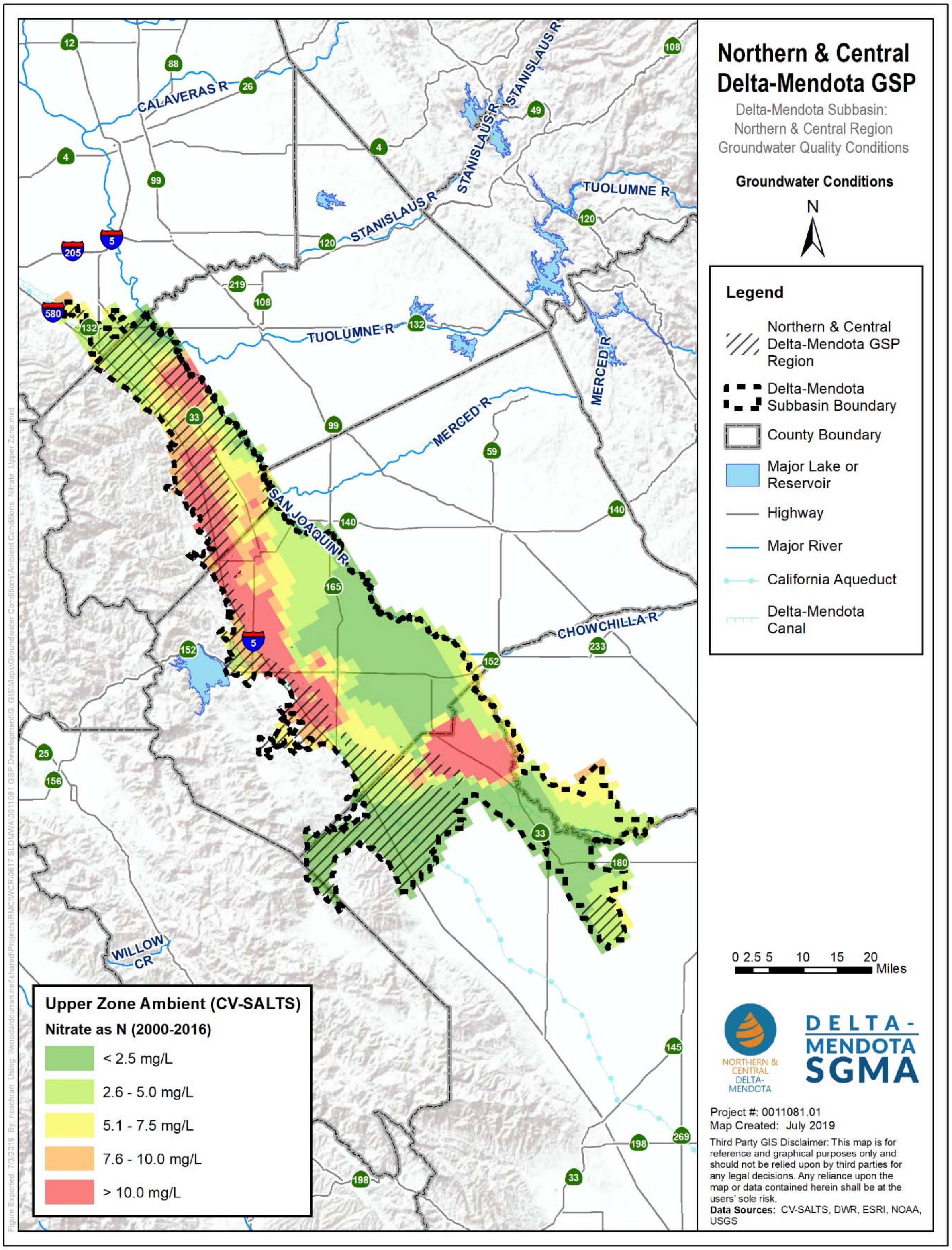


Figure 5-87. Lower Aquifer, Current Groundwater Quality (2000-2018)



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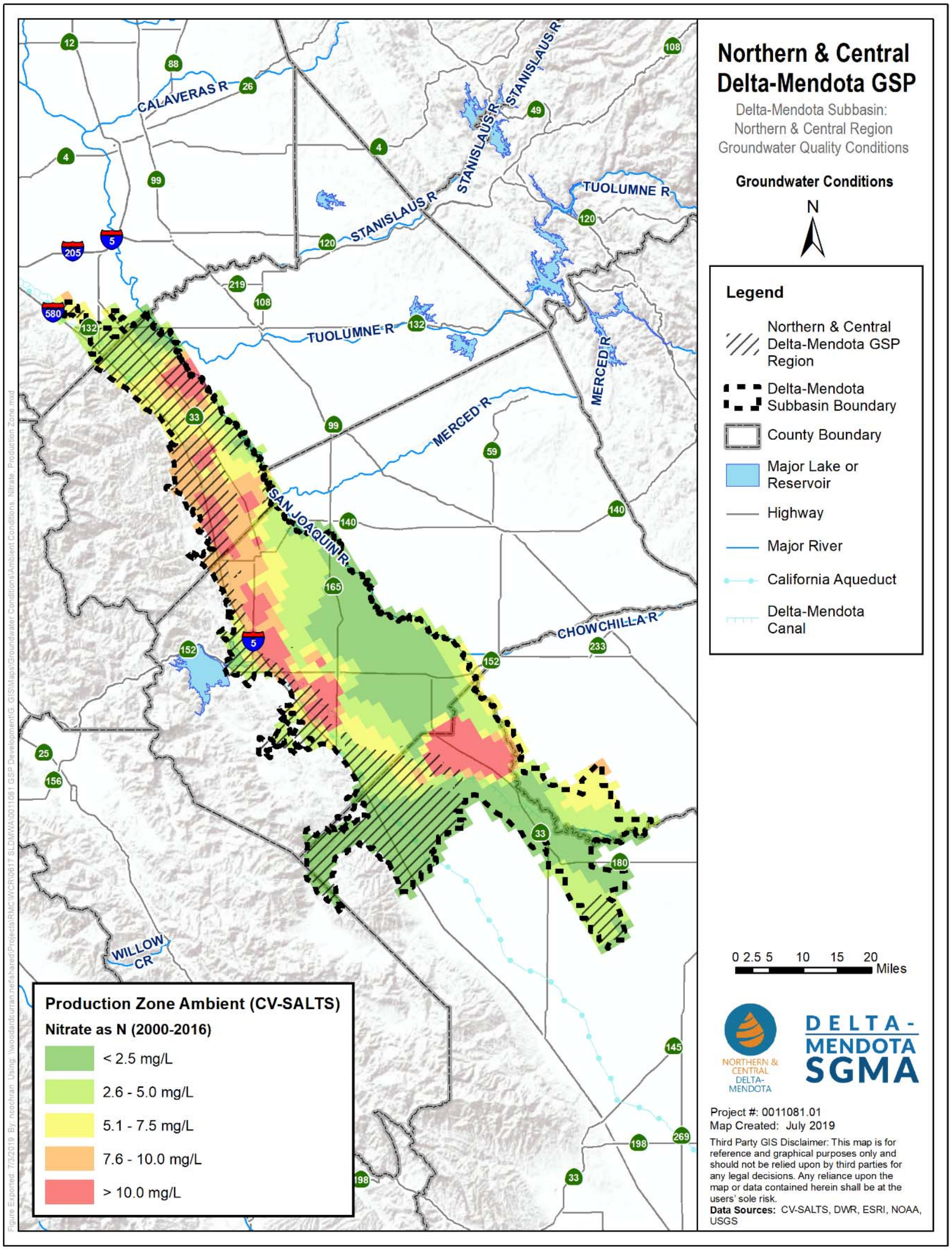
Data Sources: CV-SALTS, DWR, ESRI, NOAA, USGS

Figure 5-88. Upper Zone Ambient Nitrate as N, Delta-Mendota Subbasin



Project #: 0011081.01
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Data Sources: CV-SALTS, DWR, ESRI, NOAA, USGS

Figure 5-89. Production Zone Ambient Nitrate as N, Delta-Mendota Subbasin

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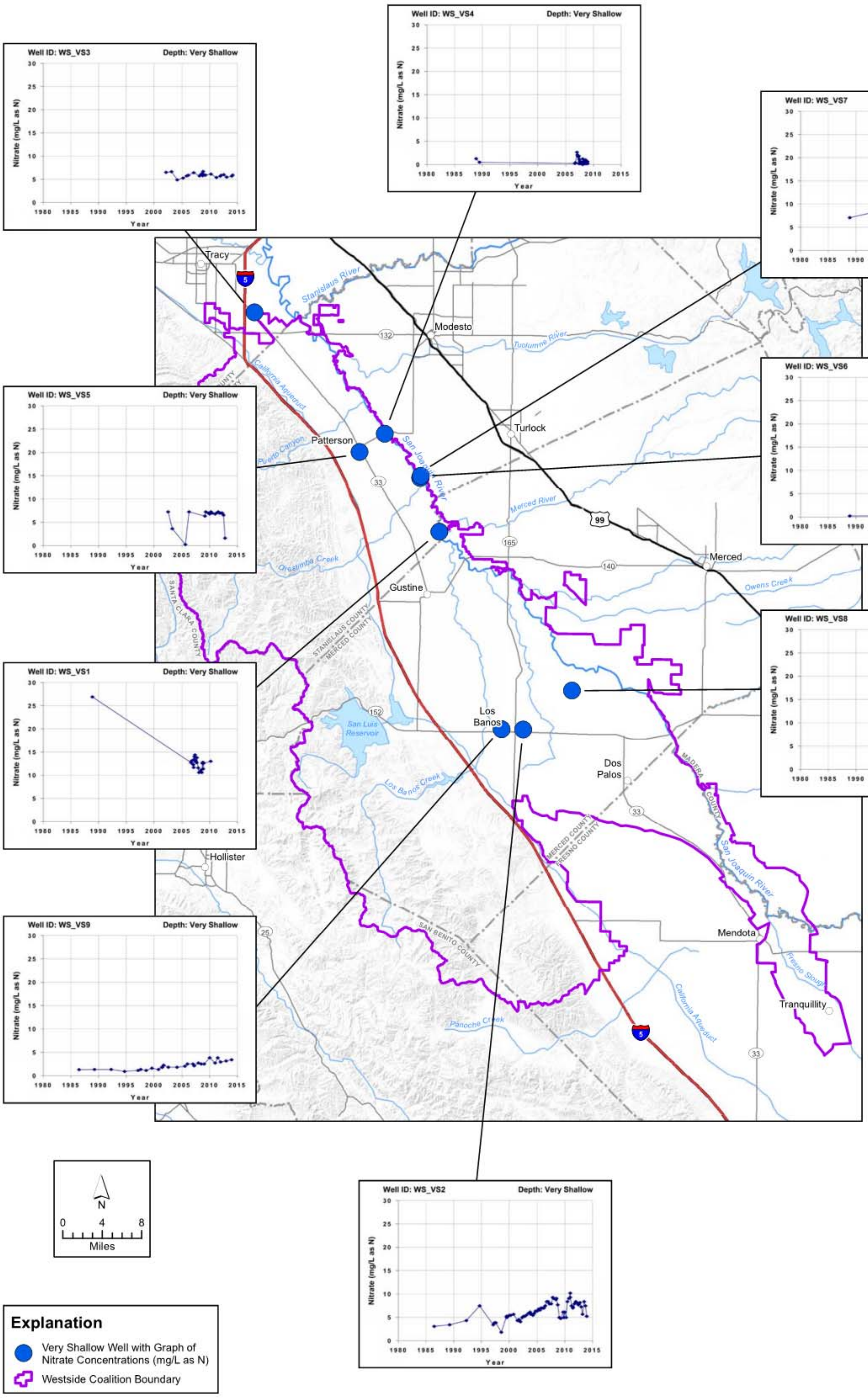
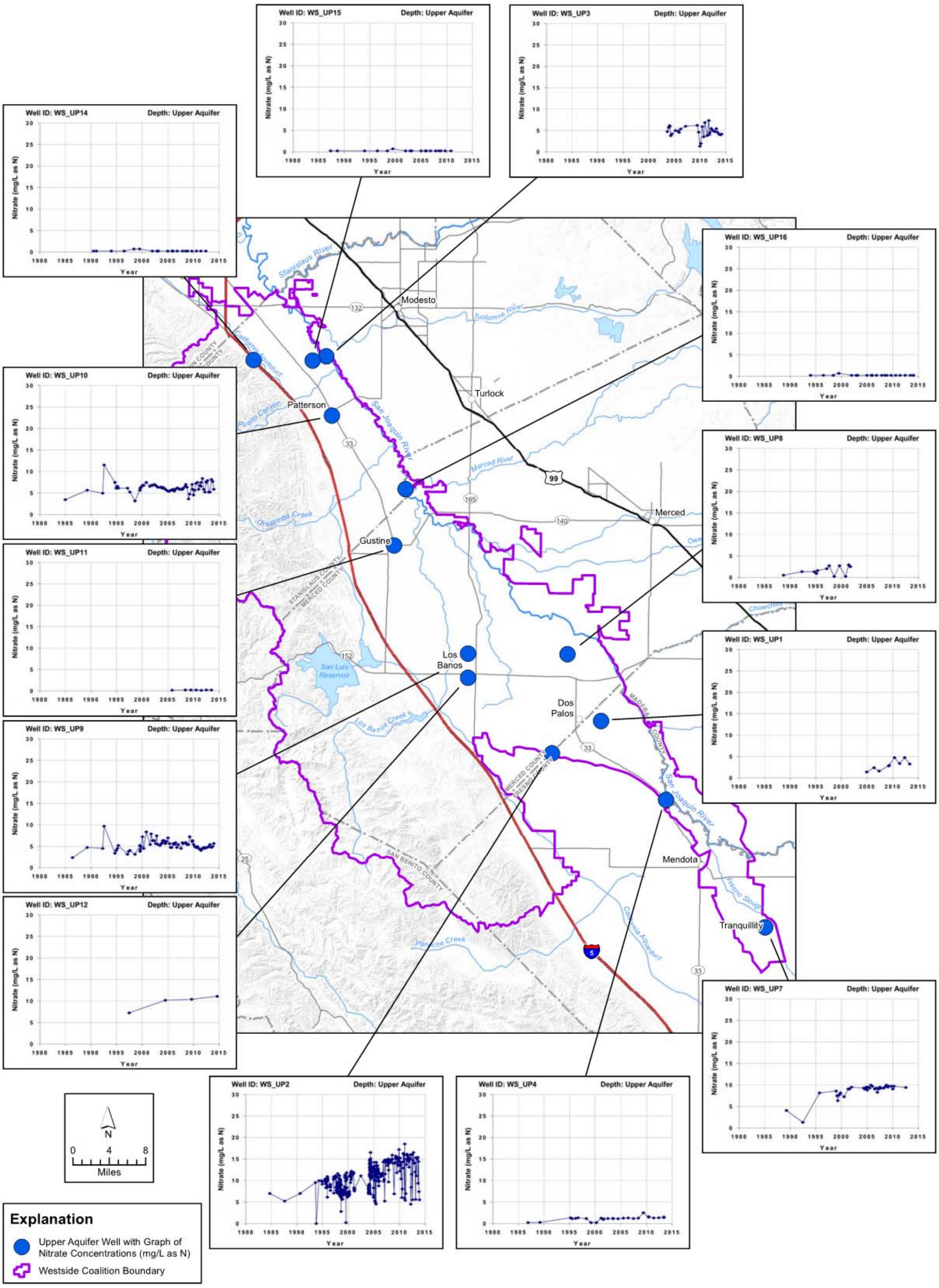


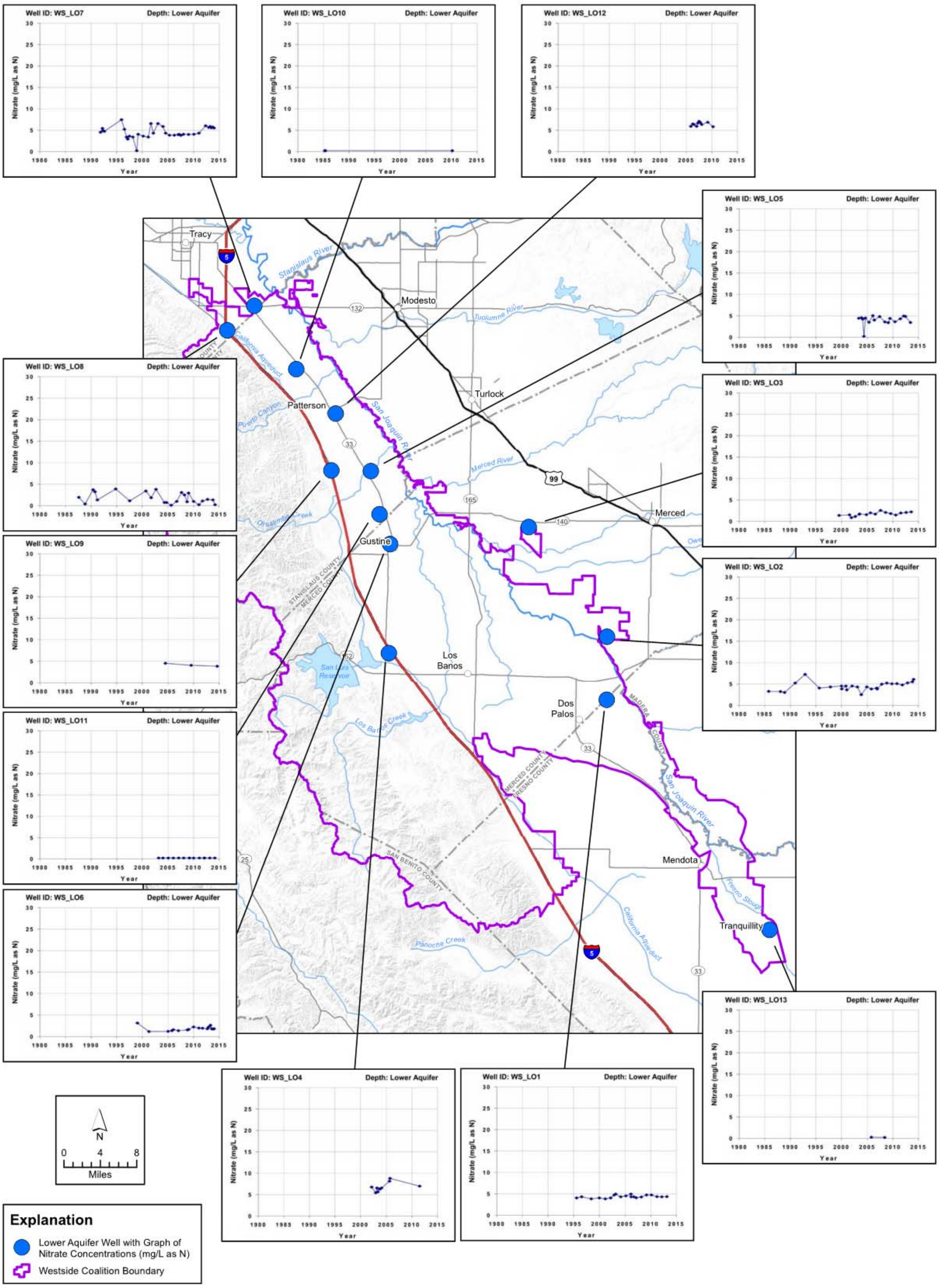
Source: *Western San Joaquin River Watershed Groundwater Quality Assessment Report*, 2015

Figure 5-90. Select Graphs of Nitrate Concentrations, Shallow Groundwater



Source: *Western San Joaquin River Watershed Groundwater Quality Assessment Report*, 2015

Figure 5-91. Select Graphs of Nitrate Concentrations, Upper Aquifer



Source: *Western San Joaquin River Watershed Groundwater Quality Assessment Report*, 2015

Figure 5-92. Select Graphs of Nitrate Concentrations, Lower Aquifer

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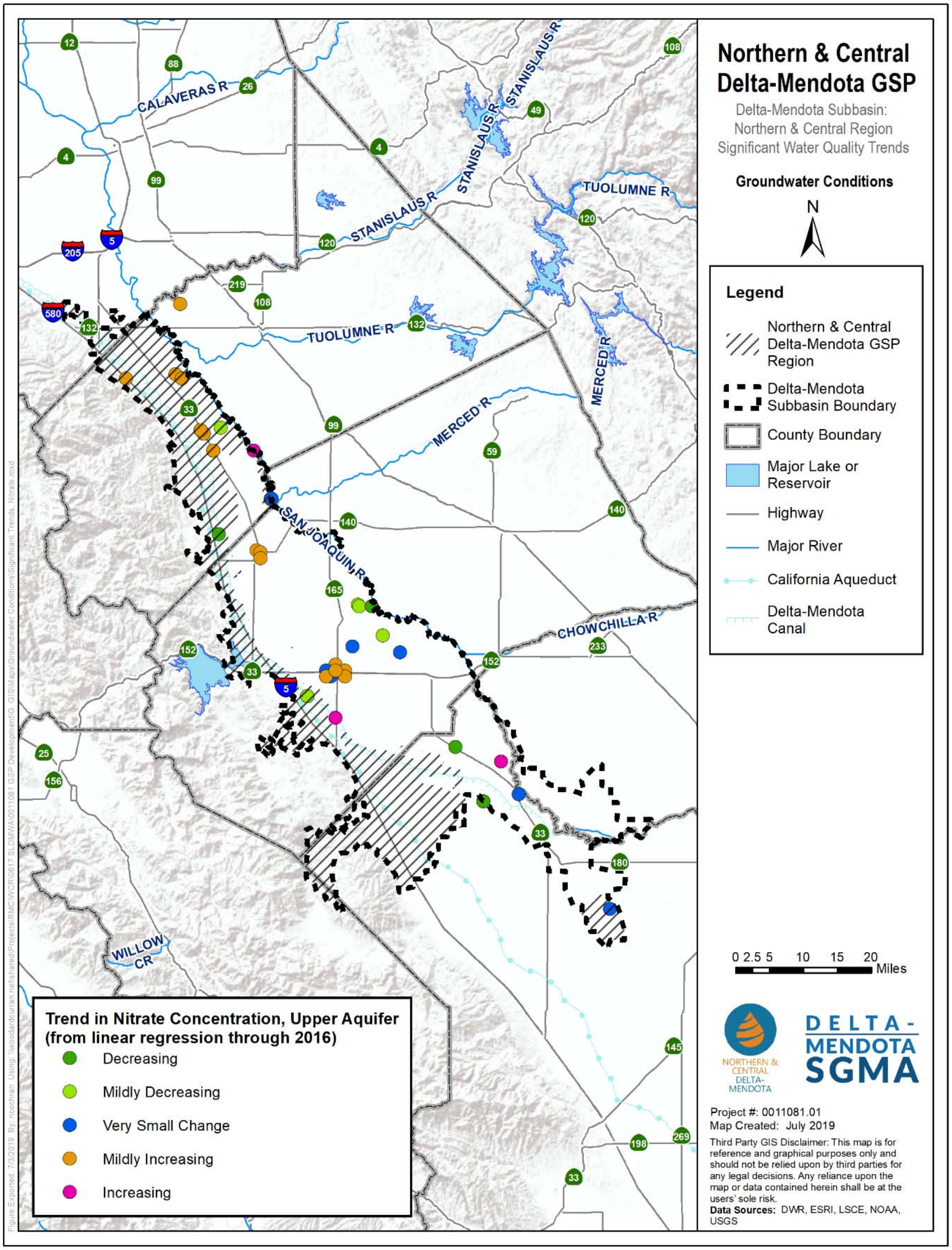

Figure 5-93. Significant Temporal Trends in Nitrate Concentrations, Upper Aquifer

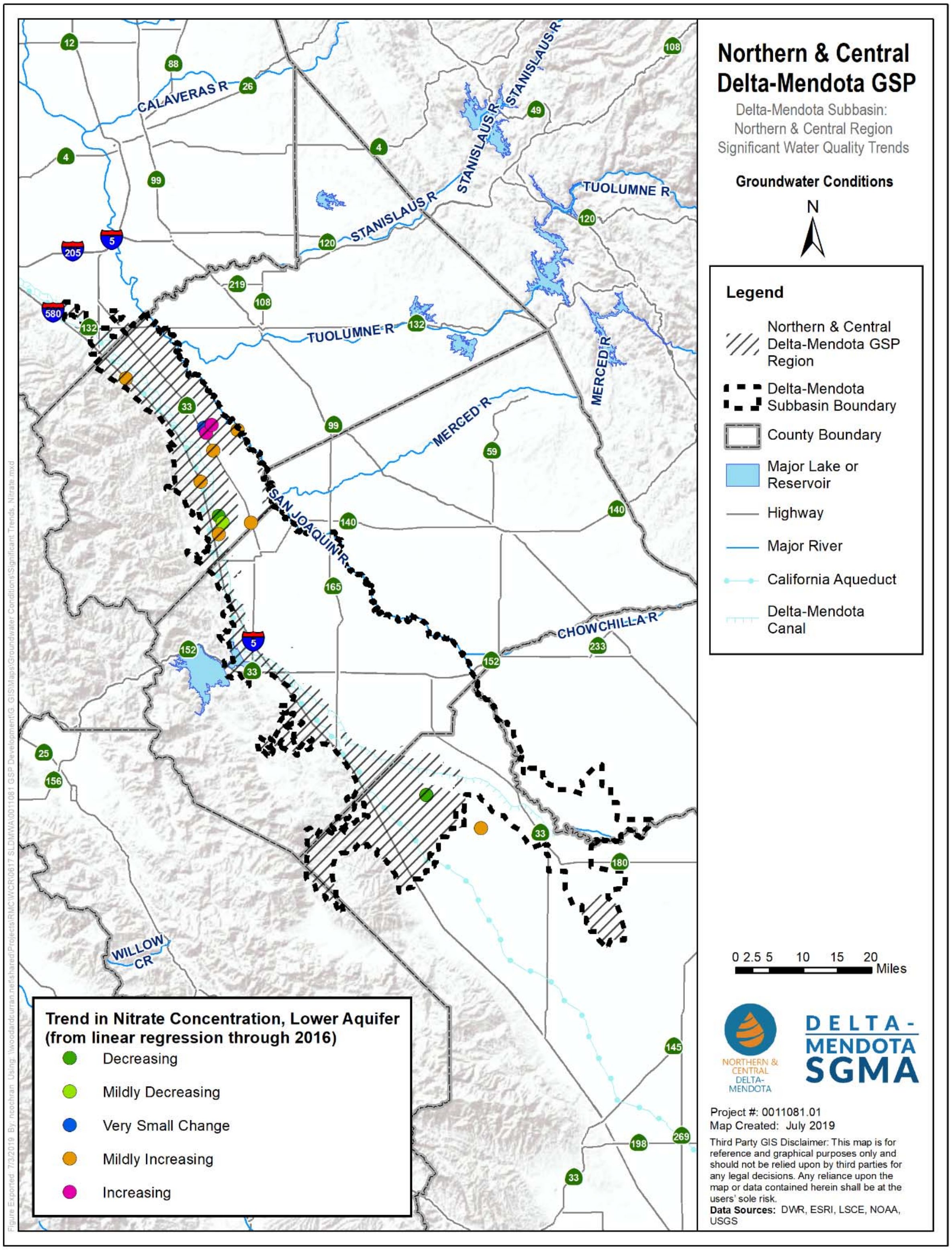

Figure 5-94. Significant Temporal Trends in Nitrate Concentrations, Lower Aquifer

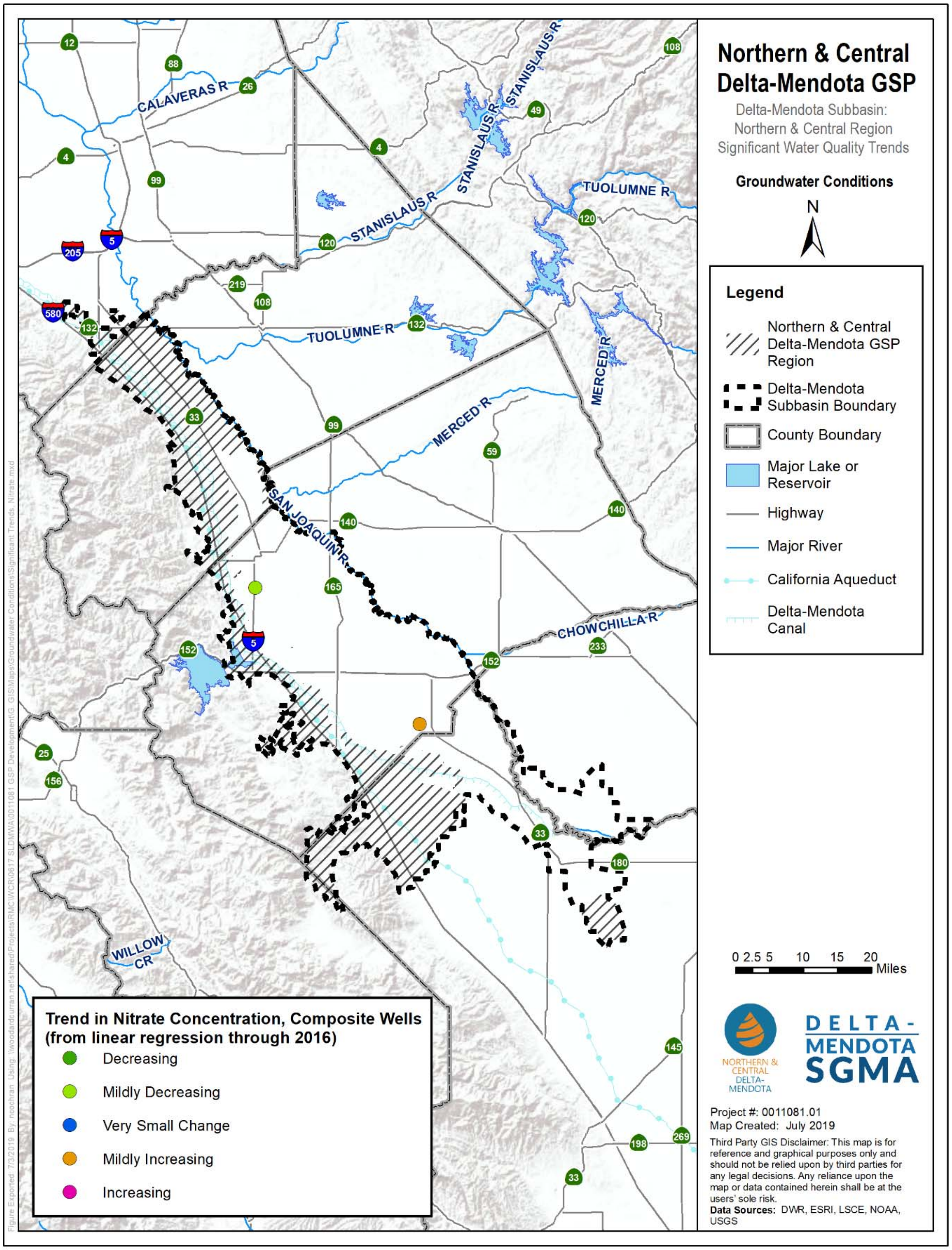

Figure 5-95. Significant Temporal Trends in Nitrate Concentrations, Composite Wells

Total Dissolved Solids

The Central Valley SNMP's analysis of TDS showed elevated concentrations throughout much of the Delta-Mendota Subbasin. Ambient TDS conditions follow similar patterns in the upper zone as in the production zone (Figure 5-96 and Figure 5-97). Ambient TDS concentrations exceed 1,000 mg/L in areas to the south and west of Dos Palos, extending to the western and southern borders of the Subbasin, and to the north and southeast of Patterson. The areas of lowest TDS concentration (<250 mg/L) exist on the western border of the Subbasin, west of Newman and Gustine, and just west of Los Banos.

The Western San Joaquin GAR's analysis of TDS data found similar spatial patterns as with nitrate. The majority of wells in the Coalition region have maximum TDS concentrations below 1,000 mg/L. In the Upper Aquifer, higher TDS concentrations (>1,500 mg/L) exist south of Los Banos and to the north along the San Joaquin River (an area with poor drainage). In the Lower Aquifer, data were limited, but most wells had maximum TDS concentrations below 1,500 mg/L. Along the northwestern edge of the Coalition region, TDS concentrations were mostly below 1,000 mg/L (LSCE, 2015). The Grassland GAR's analysis of TDS showed that most TDS concentrations in both the Upper and Lower Aquifers exceeded 1,000 mg/L, although as with nitrate, data were limited (LSCE, 2016).

TDS concentrations in the Upper Aquifer show a combination of stable trends near or below the TDS Secondary MCL of 1,000 mg/L and increasing TDS concentrations exceeding 1,500 mg/L, with data available back to the 1980s (Figure 5-98 and Figure 5-99). In the portion of the Subbasin south of Dos Palos, TDS concentrations are generally higher than the rest of the Subbasin with concentrations considerably higher than 1,500 mg/L; though, noticeable decreases are observed from the 1990s through the early 2000s and since 2010. In the Lower Aquifer, TDS concentrations since the 1990s appear to be largely stable, with exceedances above 1,000 mg/L observed (Figure 5-100). Wells south of Dos Palos in the Lower Aquifer have limited data available, but generally concentrations range from 1,000 to 2,000 mg/L. In general, increasing TDS trends in the Upper Aquifer stem from a myriad of causes, including increased salinity concentrations from the leaching of salts from naturally-occurring high salinity formations and land-applied soil amendments, an increasing salinity front from the San Joaquin River and adjacent tile drains, and localized causes such as seepages on Little Panoche Creek, downstream of Little Panoche Creek Reservoir, potentially the result of the concentration of salts in the impoundment through evaporation.

Both the Western San Joaquin (LSCE, 2015) and Grassland Drainage Area (LSCE, 2016) GARs assessed temporal trends of TDS concentrations for all available historical data through 2016 (wells with a minimum of three sampling events) using linear regression trend analysis, with a p-value of 0.05 and 0.1 indicating significance, respectively from each GAR.

Table 5-5 indicates the degree of trends TDS as presented in the GARs. Figure 5-101 illustrates statistically significant temporal trends in TDS concentration in the Upper Aquifer. There is no discernable spatial pattern in trend direction throughout much of the northern portion of the Delta-Mendota Subbasin except near Los Banos where TDS is Mildly Increasing and Increasing. Southwest of Dos Palos along the Delta-Mendota Canal, there is a cluster of wells with an Increasing trend in TDS concentration, whereas moving downstream along the canal, there are more wells with a Decreasing trend in TDS concentration. Figure 5-102 illustrates statistically significant temporal trends in TDS concentration in the Lower Aquifer. While sufficient data available for trend analysis are unavailable for the Lower Aquifer, there are several wells near and north of Gustine and near the San Luis Reservoir showing Mildly Increasing trends in TDS concentration. South of Dos Palos, there are two wells showing Decreasing trends and one well showing an Increasing trend in TDS concentration. Figure 5-103 illustrates statistically significant temporal trends in TDS concentration in composite wells. Only one composite well exhibited statistically significant TDS trends and is located near Patterson showing a very small change.

Table 5-5. TDS Trend Significance

from Western San Joaquin and Grassland GARs

Trend	TDS (mg/L/year)
Increasing	> 50
Mildly Increasing	10 - 50
Very Small Change	-10 - 10
Mildly Decreasing	-50 - -10
Decreasing	< -50

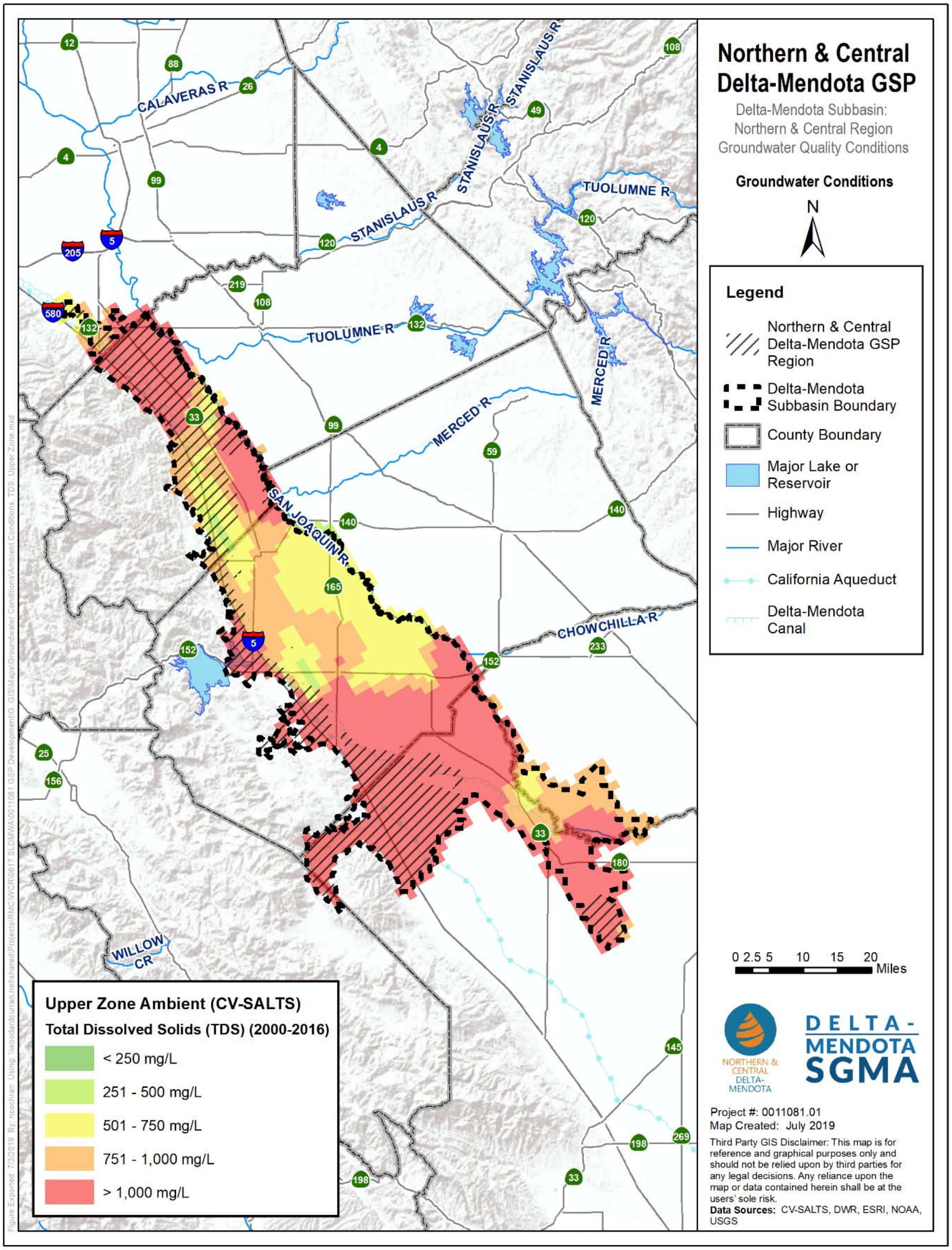

Figure 5-96. Upper Zone Ambient TDS, Delta-Mendota Subbasin

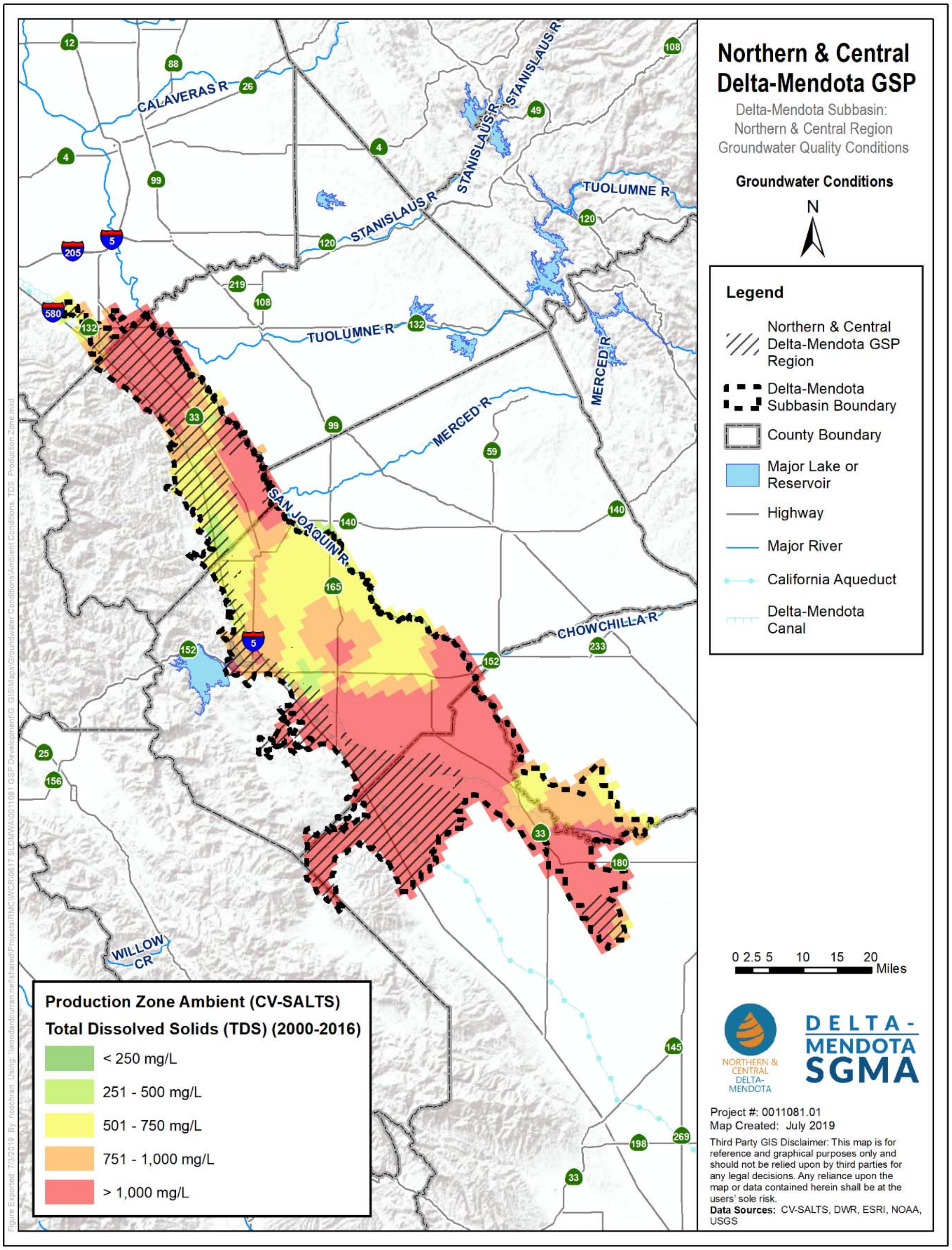

Figure 5-97. Production Zone Ambient TDS, Delta-Mendota Subbasin

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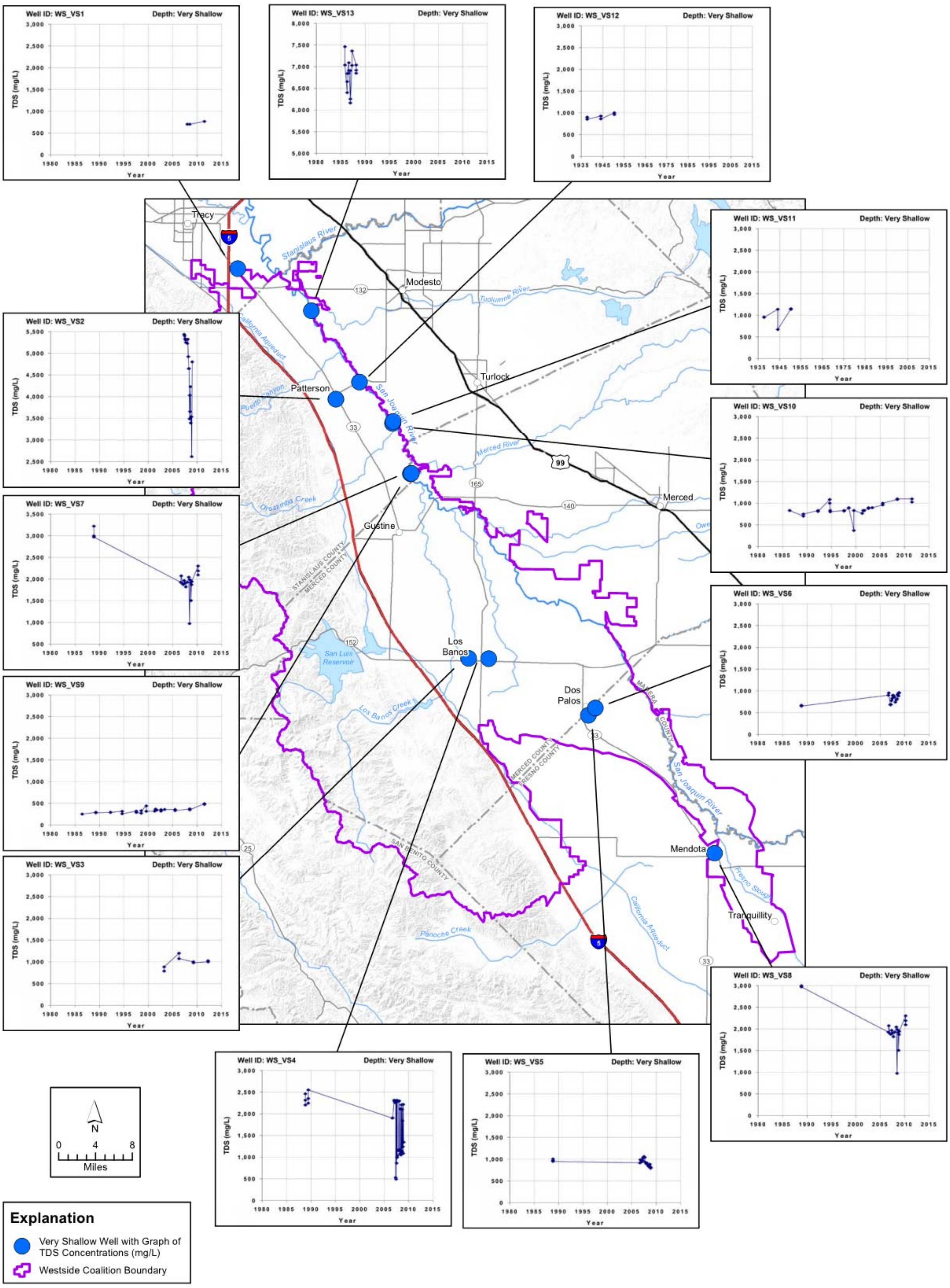
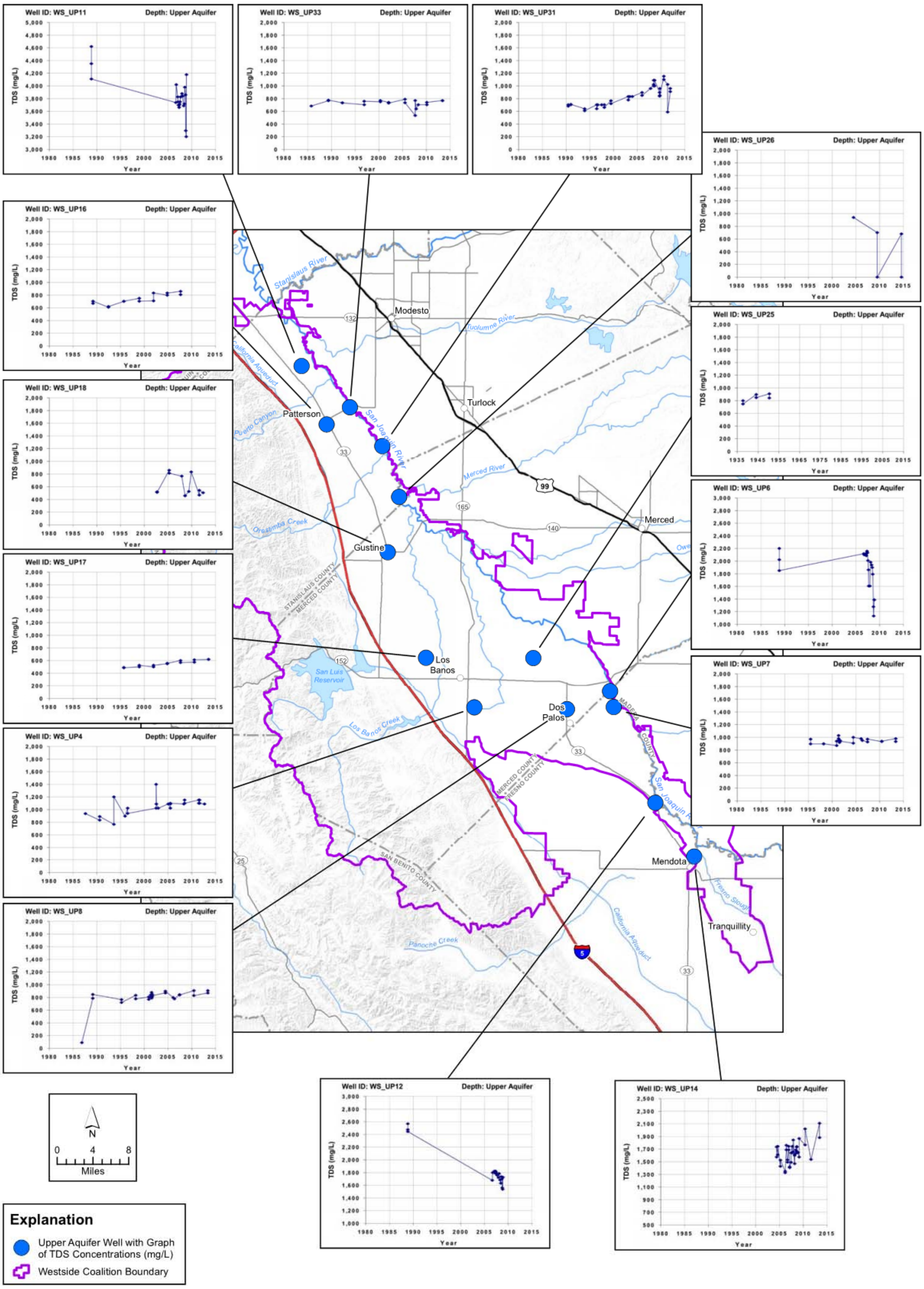


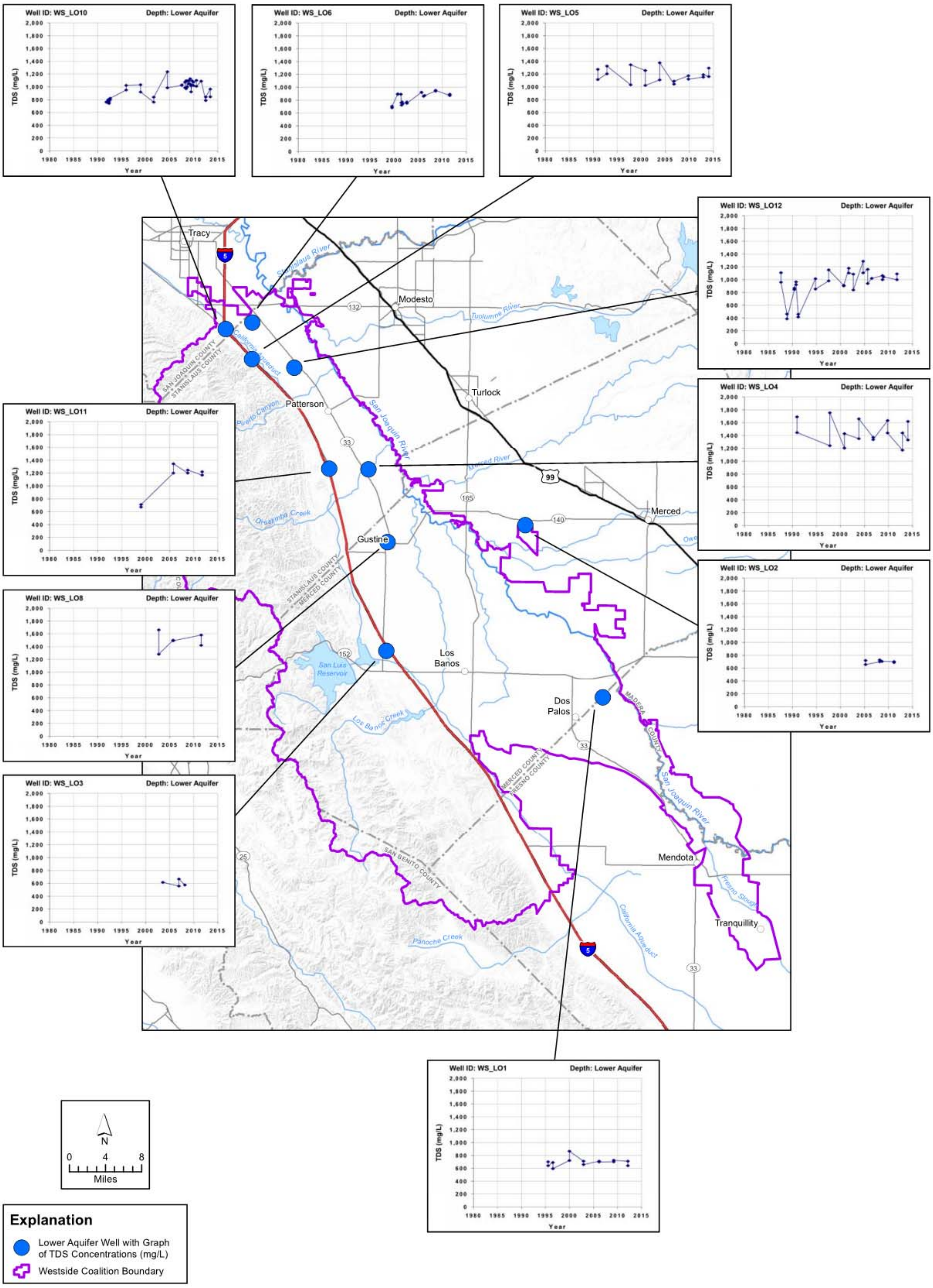
Source: *Western San Joaquin River Watershed Groundwater Quality Assessment Report*, 2015

Figure 5-98. Select Graphs of TDS Concentrations, Shallow Groundwater



Source: *Western San Joaquin River Watershed Groundwater Quality Assessment Report*, 2015

Figure 5-99. Select Graphs of TDS Concentrations, Upper Aquifer



Source: *Western San Joaquin River Watershed Groundwater Quality Assessment Report*, 2015

Figure 5-100. Select Graphs of TDS Concentrations, Lower Aquifer

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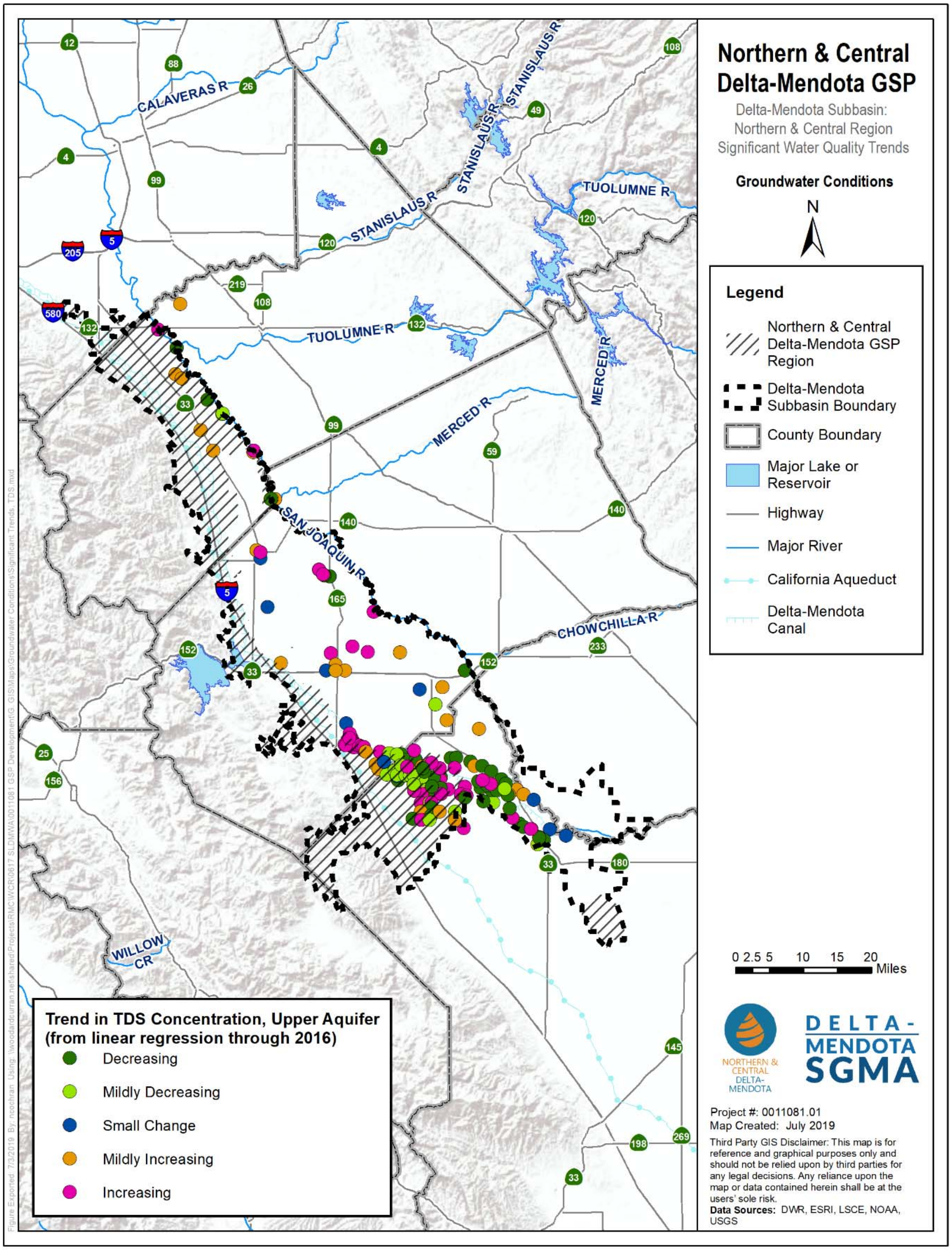


Figure 5-101. Significant Temporal Trends in TDS Concentrations, Upper Aquifer

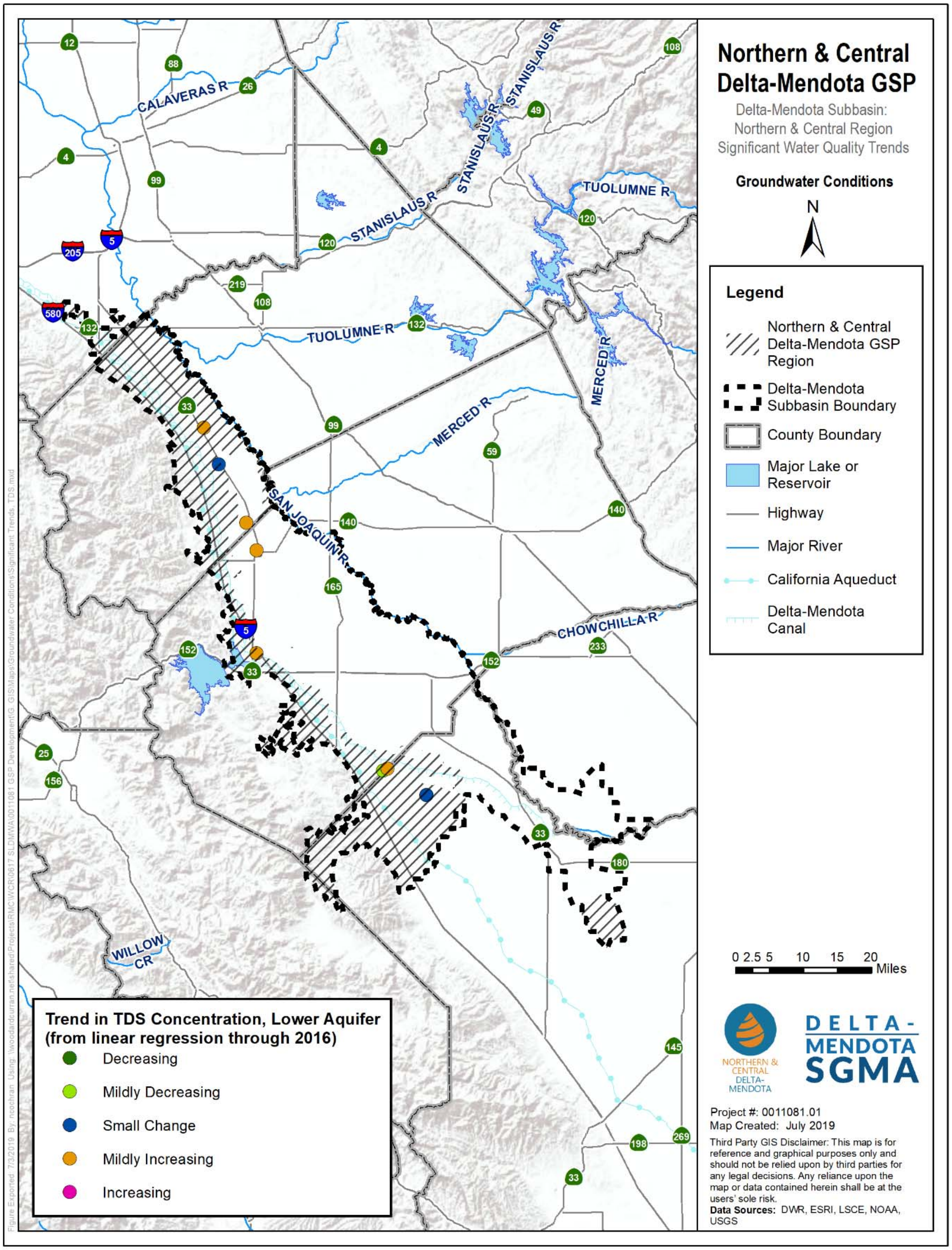
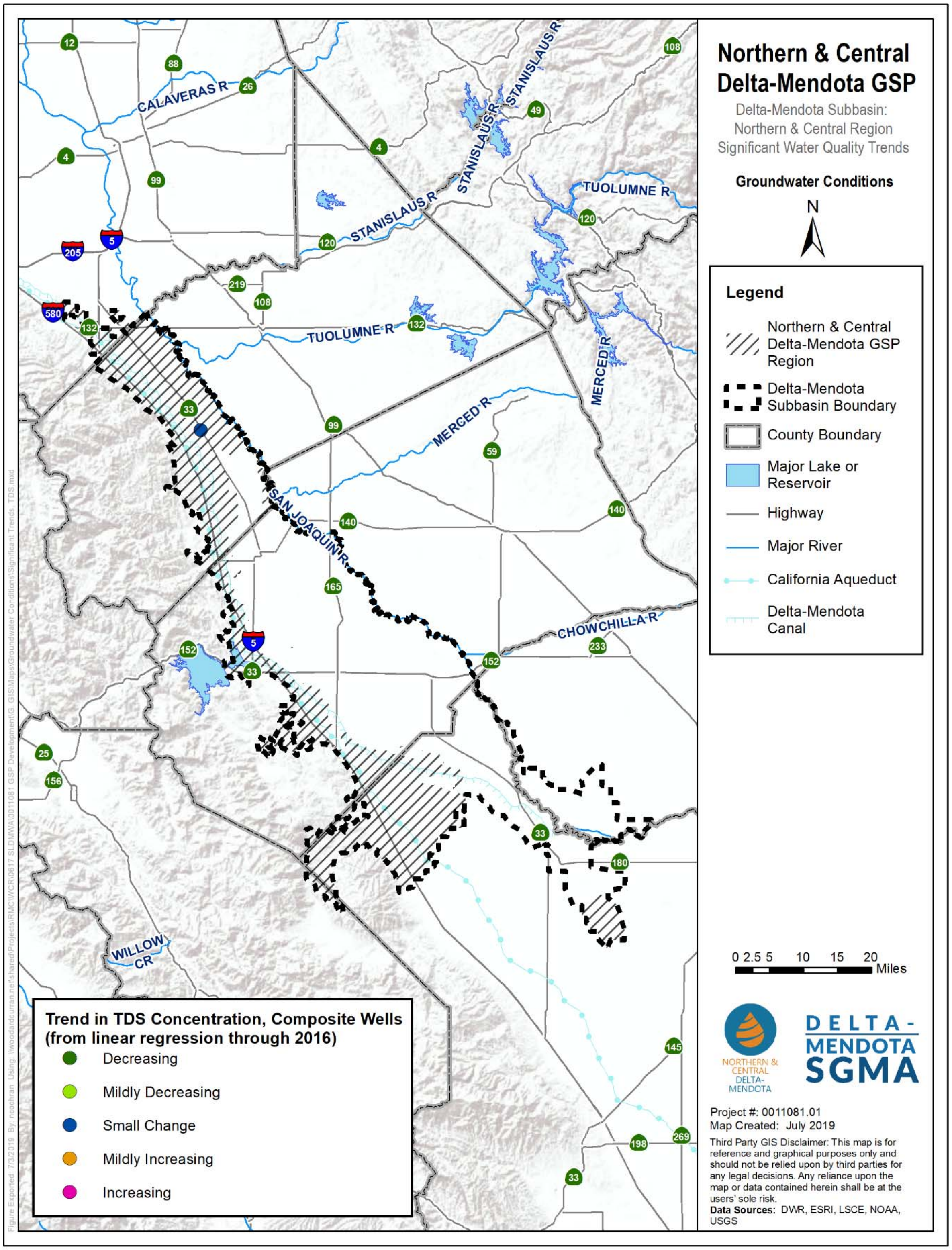


Figure 5-102. Significant Temporal Trends in TDS Concentrations, Lower Aquifer



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Data Sources: DWR, ESRI, LSCE, NOAA, USGS

Figure 5-103. Significant Temporal Trends in TDS Concentrations, Composite Wells

Boron

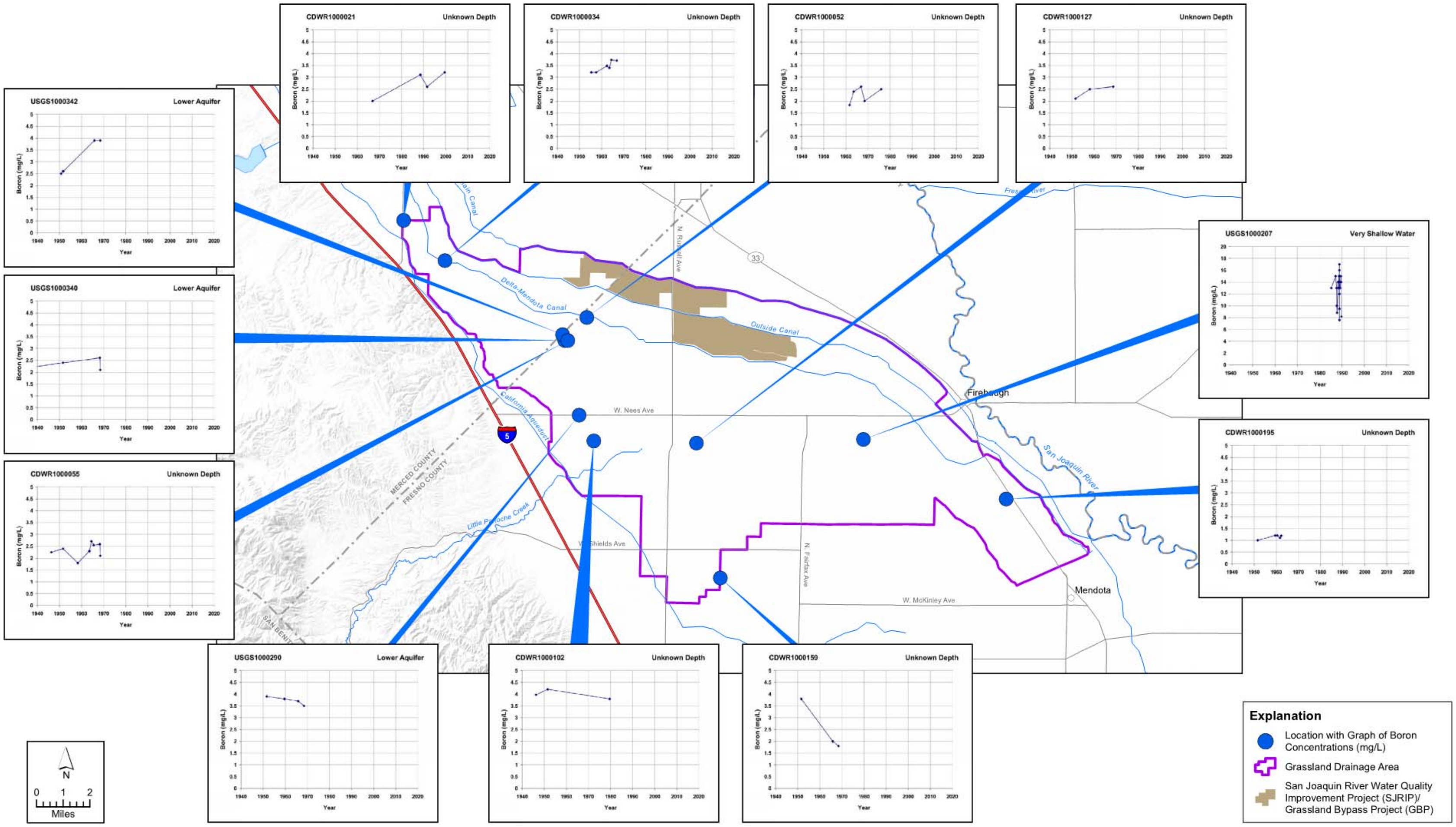
Although boron has no MCL, it has an agricultural goal of 0.7 mg/L as many crops are sensitive to high boron concentrations. Historical data from within the Grassland Drainage Area shows boron concentrations of greater than 2 mg/L, well above the agricultural goal (LSCE, 2016). The City of Patterson Consumer Confidence Reports from 2011 to 2013 show boron levels consistently near 0.4 mg/L. Boron trends were also analyzed within the Grassland Drainage Area (which encompasses portions of the Central Delta-Mendota, Oro Loma Water District, and Widren Water District GSAs). Time series charts of boron concentrations in the Upper Aquifer and Lower Aquifer are presented together in **Figure 5-104** due to a limited number of sites with sufficient data to warrant graphing. Boron trends are generally stable but relatively high, with some seasonal fluctuations likely resulting from irrigation influences.

Table 5-6 indicates the degree of trends for boron as presented in the GAR for all available historical data through 2016 (wells with a minimum of three sampling events). No statistically-significant temporal trends in boron concentrations were observed in the Upper Aquifer for boron. Two wells in the Lower Aquifer have significant trends in boron concentration, one with an Increasing trend and the other with a Mildly Decreasing trend (**Figure 5-105**).

Table 5-6. Boron Trend Significance

from Grassland GAR

Trend	Boron (mg/L/year)
Increasing	> 0.05
Mildly Increasing	0.01 - 0.05
Very Small Change	-0.01 - 0.01
Mildly Decreasing	-0.05 - -0.01
Decreasing	< -0.05



Source: *Grassland Drainage Area Groundwater Quality Assessment Report*, 2016

Figure 5-104. Select Graphs of Boron Concentrations, Various Depths

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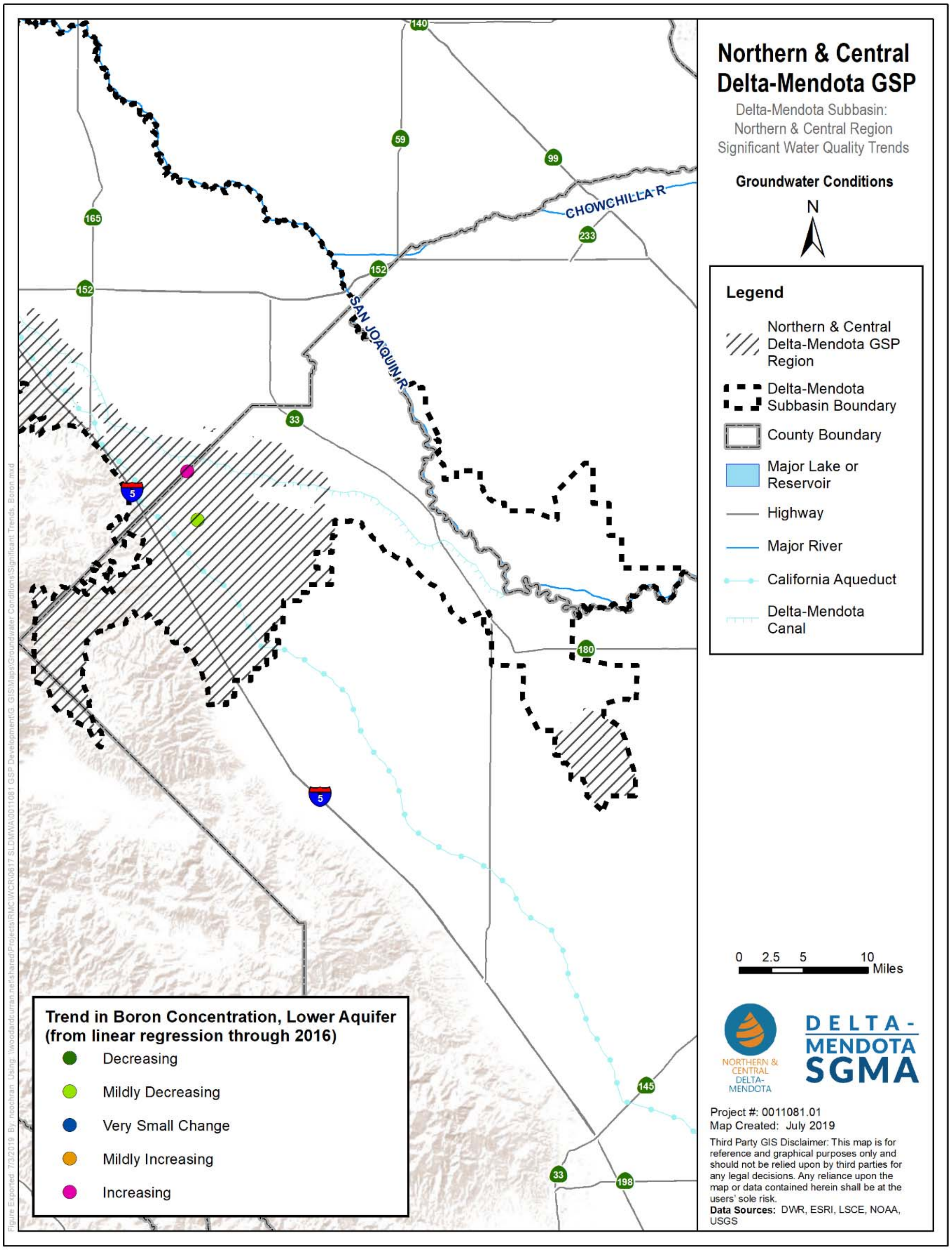

Figure 5-105. Significant Temporal Trends in Boron Concentrations, Lower Aquifer

5.3.6 Land Subsidence

Long-term groundwater level declines can result in a one-time release of "water of compaction" from compacting silt and clay layers (aquitards) resulting in inelastic land subsidence (Galloway et al., 1999). There are several other types of subsidence in the San Joaquin Valley, including subsidence related to hydrocompaction of moisture-deficient deposits above the water table, subsidence related to fluid withdrawal from oil and gas fields, subsidence caused by deep-seated tectonic movements, and subsidence caused by oxidation of peat soils that is a major factor in the Sacramento-San Joaquin Delta (Sneed et al., 2013). However, aquifer-system compaction caused by groundwater pumping causes the largest magnitude and areal extent of land subsidence in the San Joaquin Valley (Poland et al., 1975; Ireland et al., 1984; Farrar and Bertoldi, 1988; Bertoldi et al., 1991; Galloway and Riley, 1999).

Land subsidence is a prevalent issue in the Delta-Mendota Subbasin as it has impacted prominent infrastructure of statewide importance, namely the DMC and the California Aqueduct, as well as local canals, causing serious operational, maintenance, and construction-design issues (Sneed et al., 2013). Reduced freeboard and flow capacity for the DMC and California Aqueduct have rippling effects on imported water availability throughout the State. Even small amounts of subsidence in critical locations, especially where canal gradients are small, can impact canal operations (Sneed and Brandt, 2015). Differential land subsidence can also result in piping ruptures, resulting in the loss of water or other substances. While some subsidence is reversable (referred to as elastic subsidence), inelastic or irreversible subsidence is caused mainly by pumping groundwater from below the Corcoran Clay, thus causing compaction and reducing storage in the lower confined aquifer as well as damaging well infrastructure. As a result, important and extensive damages and repairs have resulted in the loss of conveyance capacity in canals that deliver water or remove floodwaters, the realignment of canals as their constant gradient becomes variable, the raising of infrastructure such as canal check stations, and the releveling of furrowed fields.

5.3.6.1 Available Data

There are six University NAVSTAR Consortium (UNAVCO) Continuous Global Positioning System (CGPS) locations that monitor subsidence within the Delta-Mendota Subbasin, five of which are within the Northern and Central Delta-Mendota Regions (Figure 5-106). Changes in land surface elevation have also been measured at DMC Check Structures (Figure 5-106). Figure 5-107 through Figure 5-112 show the vertical change in land surface elevation from a given time point (specified on charts) for the UNAVCO CGPS stations within the Delta-Mendota Subbasin, along with annual CVP allocations. Table 5-7 summarizes the greatest land subsidence rate and corresponding year(s) of that change at each UNAVCO CGPS station. Overall, the greatest monthly subsidence rates occurring after January 1, 2015 occurred during the Spring of 2016 to the Spring of 2017.

Land subsidence was measured by United States Bureau of Reclamation (USBR) showing annual subsidence rates from December 2011 to December 2014 (Figure 5-113). Based on these data, within the majority of the Northern and Central Delta-Mendota Regions, annual subsidence rates were between -0.15 and 0 feet/year during this period (or between -0.45 and 0 feet of total subsidence over this 3-year period). A small portion within the southwestern horn of the Delta-Mendota Subbasin saw an uplifting of land surface between 0.15 and 0.3 feet/year during this period (0.45 and 0.9 feet total subsidence during this period). From July 2012 to December 2016, during the most recent drought period, subsidence rates increased (Figure 5-114). Throughout the majority of the Northern and Central Delta-Mendota Region, subsidence was less than 0.5 feet/year (or less than 2.25 feet total over this 4.5-year period). In the Tranquillity Irrigation District (TRID) area, subsidence rates were higher, around 1 to 1.5 foot/year or more, during the drought years.

Table 5-7. Subsidence Monitoring Trends,
UNAVCO CGPS Stations

Station ID	Greatest Monthly Land Subsidence Rate as of January 1, 2015 (feet)	Year(s) of Greatest Monthly Land Subsidence Rate
P255	-0.0292	Spring 2016 to 2017
P259	-0.0183	Spring 2016 to 2017
P252	-0.033	Spring 2016 to 2017
P303	-0.2190	Spring 2016 to 2017
P301	-0.0029	Spring 2016 to 2017
P304	-0.0003	Spring 2013 to 2017

5.3.6.2 Historic Conditions

Along the DMC in the northern portion of the San Joaquin Valley, extensive withdrawal of groundwater from unconsolidated deposits caused subsidence exceeding 8.5 meters (or about 28 feet) between 1926 and 1970 (Poland et al., 1975), reaching 9 meters (or about 30 feet) in 1980 (Ireland, 1986). Land subsidence from groundwater pumping began in the San Joaquin Valley in the mid-1920s (Poland et al., 1975; Bertoldi et al., 1991; Galloway and Riley, 1999) and by 1970, about half of the San Joaquin Valley had land subsidence of more than 0.3 meters (or about 1 foot) (Poland et al., 1975). While groundwater pumping decreased in the Delta-Mendota Subbasin following imported water deliveries from the CVP via the DMC in the early 1950s, compaction rates were reduced in certain areas and water levels recovered. Notable droughts of 1976-1977 and 1987-1992 saw renewed compaction during these periods, with increased groundwater pumping as imported supplies were reduced or unavailable. However, following these droughts, compaction virtually ceased, and groundwater levels rose to near pre-drought levels quite rapidly (Swanson, 1998; Galloway et al., 1999). Similarly, during the 2007-2009 and 2012-2015 droughts, groundwater levels declined during these periods in response to increased pumping, approaching or surpassing historical low levels, which reinstated compaction (Sneed and Brandt, 2015).

Subsidence contours for 1926-1970 (Poland et al., 1975) show the area of maximum active subsidence was southwest of the community of Mendota. Historical subsidence rates in the Mendota area exceeded 500 millimeters/year (or about 20 inches/year) during the mid-1950s and early 1960s (Ireland et al., 1984). The area southwest of Mendota has experienced some of the highest levels of subsidence in California, where from 1925 to 1977, this area sustained over 29 feet of subsidence (USGS, 2017). Historical subsidence rates along Highway 152 calculated from leveling-survey data from 1972, 1988, and 2004 show that for the two 16-year periods (1972-1988 and 1988-2004), maximum subsidence rates of about 50 millimeters/year (or about 2 inches/year) were found just south of El Nido (Sneed et al., 2013). Geodetic surveys completed along the DMC in 1935, 1953, 1957, 1984, and annually from 1996-2001 indicated that subsidence rates were greatest between 1953 and 1957 surveys, and that the maximum subsidence along the DMC (about 3 meters, or about 10 feet) was just east of DMC Check Structure Number 18.

Subsidence related to the California Aqueduct, which runs parallel and in close proximity to the Delta-Mendota Canal across the Subbasin, is of statewide importance. During the construction of the California Aqueduct, it was thought that subsidence within the San Joaquin Valley would cease with the delivery of water from the State Water Project, though additional freeboard to attempt to mitigate future subsidence was incorporated into the design and construction of the Aqueduct (DWR, June 2017). After water deliveries from the Aqueduct began, subsidence rates decreased to an average of less than 0.1 inches/year during normal to wet hydrologic years. During dry to critical hydrologic years, subsidence increased to an average of 1.1 inches per year. The 2012-2015 drought produced subsidence similar to those seen before the Aqueduct began delivering water, with some areas experiencing nearly 1.25 inches of sinking per month (based on NASA Uninhabited Aerial Vehicle Synthetic Aperture Radar [UAVSAR] flight measurements). Dry and critically dry water years since Aqueduct deliveries began have resulted in extensive groundwater withdrawals, causing some areas near the Aqueduct to subside nearly 6 feet.

After 1974, land subsidence was demonstrated to have slowed or largely stopped (DWR, June 2017); however, land subsidence remained poised to resume under certain conditions. Such an example includes the severe droughts that occurred between 1976 and 1977 and between 1987 and 1991. Those droughts lead to diminished deliveries of imported water, which prompted some water agencies and farmers (especially in the western Valley) to refurbish old pumps, drill new water wells, and begin pumping groundwater to make up for cutbacks in the imported water supply. The decisions to renew groundwater pumping were encouraged by the fact that groundwater levels had recovered to near-predevelopment levels. During the most recent drought of 2012-2015, subsidence rates were greatest between March 2015 and August 2015 with as much as nearly 9 inches of subsidence in 6 months along the Aqueduct. With water levels near or below historical lows were observed during the most recent drought, it indicates that preconsolidation stress was likely exceeded, meaning the resulting subsidence is likely mostly permanent (Sneed and Brandt, 2015).

5.3.6.3 Current Conditions

Based on subsidence rates observed over the last decade, it is anticipated that subsidence will continue to impact operations of the DMC and California Aqueduct without mitigation. For example, recently, Reach 4A of the San Joaquin River near Dos Palos (at the lower end of the Northern and Central Delta-Mendota Regions, where most land subsidence has historically occurred) experienced between 0.38 and 0.42 feet/year in subsidence between 2008 and 2016. As a result of subsidence, freeboard in Reach 4A is projected to be reduced by 0.5 foot by 2026 as compared to 2016, resulting in a 50 percent reduction in designed flow capacity (DWR, May 2018). Reduced flow capacities in the California Aqueduct will impact deliveries and transfers throughout the State and result in the need to pump more groundwater, thus contributing to further subsidence.

More recent subsidence measurements indicate subsidence hot spots within and adjacent to the Subbasin, including the area east of Los Banos and the TRID area. The USGS began periodic measurements of the land surface in parts of the San Joaquin Valley over the last decade. Between December 2011 and December 2014, total subsidence in the area east of Los Banos, within the Merced Subbasin (also referred to as the El Nido-Red Top area, ranged from 0.15 to 0.75 feet, or 1.8 to 9 inches respectively (Schmidt, 2015). The National Aeronautics and Space Administration Jet Propulsion Laboratory (NASA JPL) at the California Institute of Technology has also been monitoring subsidence in California using interferometric synthetic aperture radar (or InSAR), and a recent progress report documenting data for the period from May of 2015 to September of 2016 indicates that the two previously-identified primary subsidence areas near the community of Corcoran (and centered on El Nido) was joined by a third area of significant subsidence near TRID. For the study period (as shown in Figure 5-115), maximum total subsidence of 22 inches was measured near Corcoran, while the El Nido area subsided 16 inches and the TRID area subsided around 20 inches. Analyses at two particular stations near El Nido show interesting trends. At Station P303, between 2007 and 2014, 50 mm of subsidence occurred at this location (or nearly 2 inches). Vertical displacement at P303 showed subsidence at fairly consistent rates during and between drought periods (Figure 5-116), indicating that these areas continued to pump groundwater despite climatic variations (possibly due to a lack of surface water availability). Residual compaction may also be a factor. Vertical displacement at Station P304 indicated that most subsidence occurred during drought periods and very little subsidence occurring between drought periods (Figure 5-116). This suggests that this area received other sources of water, most likely surface water, between drought periods, and also that residual compaction did not significantly occur in this area. These two areas demonstrate a close link between the availability of surface water, groundwater pumping, and inelastic land subsidence. Total land subsidence in the San Joaquin Valley from May 7, 2015 to September 10, 2016 is shown in Figure 5-116.

As managers of the DMC, the San Luis & Delta-Mendota Water Authority (SLDMWA) has been making periodic subsidence surveys along the DMC to identify key areas of active land subsidence and to estimate subsidence rates. Table 5-8 summarizes the average yearly elevation change along the DMC between 2014, 2016 and 2018. Figure 5-117 shows the change in land surface elevation between the 2014 and 2016 and the 2014 and 2018 subsidence surveys performed by SLDMWA at each milepost along the DMC.

Lower Aquifer groundwater extractions has been identified as one of the key causes of inelastic land subsidence in the Delta-Mendota Subbasin. The City of Patterson, which is the only major municipality within the Plan area, relies solely on groundwater from the Lower Aquifer for potable supply. The City of Patterson is located directly east of the DMC within Pool 7, where subsidence occurred at a rate of 0.22 feet/year during the most recent drought (2014-2016) and decreased to 0.06 feet/year immediately following the drought (2016-2018) (Table 5-8); thus reinforcing the connection between Lower Aquifer groundwater pumping and inelastic subsidence.

Table 5-8. Subsidence Rates Along the Delta-Mendota Canal
in the Northern and Central Delta-Mendota Regions
Elevation Differences between 2014, 2016, and 2018 Subsidence Surveys

Pool	Milepost Range	Checkpoints	Average Yearly Elevation Change (ft/yr)		
			2014-2016	2016-2018	2014-2018
3	16.20-20.63	2 – 3	-0.08	-0.12	-0.1
4	20.64 - 24.43	3 – 4	-0.11	-0.14	-0.13
5	24.44 - 29.82	4 – 5	-0.15	-0.11	-0.13
6	29.83 - 34.42	5 – 6	-0.19	-0.11	-0.15
7	34.43 - 38.68	6 – 7	-0.22	-0.06	-0.14
8	38.69 - 44.26	7 – 8	-0.27	-0.01	-0.14
9	44.27 - 48.62	8 – 9	-0.26	0.02	-0.12
10	48.63 - 54.41	9 – 10	-0.26	0.02	-0.12
11	54.42 - 58.28	10 – 11	-0.24	0.01	-0.12
12	58.29 - 63.98	11 – 12	-0.21	-0.03	-0.12
13	63.99 - 70.01	12 – 13	-0.17	-0.04	-0.1
14	70.02 - 74.40	13 – 14	-0.14	-0.01	-0.07
15	74.41 - 79.64	14 – 15	-0.14	0.02	-0.07
16	79.65 - 85.09	15 – 16	-0.15	0.01	-0.08
17	85.10 - 90.54	16 – 17	-0.17	-0.05	-0.11
18	90.55 - 96.81	17 – 18	-0.23	-0.09	-0.16

For the TRID area at the southern end of the Northern & Central Delta-Mendota Region GSP Plan area, regular surveys of wellhead elevations between 2014 and 2018 have provided insight into subsidence rates in this area. Per these data, TRID has experienced over two feet of subsidence between 2014 and 2018, with an average subsidence rate of 0.53 feet/year for that period.

5.3.6.4 Groundwater Trends

The rapid decline of groundwater levels in the San Joaquin Valley during post-1975 droughts in response to relatively small volumes of pumping (compared to those of the 1960s) results from a loss of storage space in the aquifer system — mostly from inelastic compaction of aquitards during the 1950s and 1960s — and from reduced hydraulic conductivity (permeability) of those compacted aquitards that restrict drainage of water to permeable parts of the aquifer system (Borchers and Carpenter, 2014). Observations showed that Lower Aquifer water levels were considerably higher than during the 1960s, yet there was renewed land subsidence during droughts. Since 1962, groundwater storage in the Central Valley aquifer system has been depleted at an average rate of 1.85 km^3/year (or about 1.5 million AF/year) and at more than twice this rate during the most recent drought of 2012-2015 (Faunt et al., 2015). This illustrates the complex effects of unequal distribution of preconsolidation stress within the aquitards and between the aquitards and more permeable units of the aquifer system.

Subsidence monitoring in the Delta-Mendota Subbasin, and in the San Joaquin Valley as a whole, demonstrated significant inelastic land subsidence as a result of the last drought, with effects continuing to the present time (as evidenced by continued subsidence between 2016 and 2018 through the SLDMWA surveys). While the impacts appeared to have slowed, the temporal and spatial impacts of continued subsidence have not yet been evaluated.

Land use changes in some parts of the San Joaquin Valley are likely to impact future subsidence. Trends toward the planting of permanent crops since 2000, such as vineyards and orchards, and away from non-permanent land uses like rangeland and row crops can result in “demand hardening,” which requires stable water supplies to irrigate crops that cannot be fallowed (Sneed et al., 2013 and Faunt et al., 2015). As land use and surface water availability continue to vary in the San Joaquin Valley, additional water level declines and associated subsidence are likely to occur. Increased monitoring of groundwater levels and land subsidence will be essential to better understand the connection between land use, groundwater levels, and subsidence and enable management strategies to mitigate subsidence hazards and impacts while optimizing water supplies.

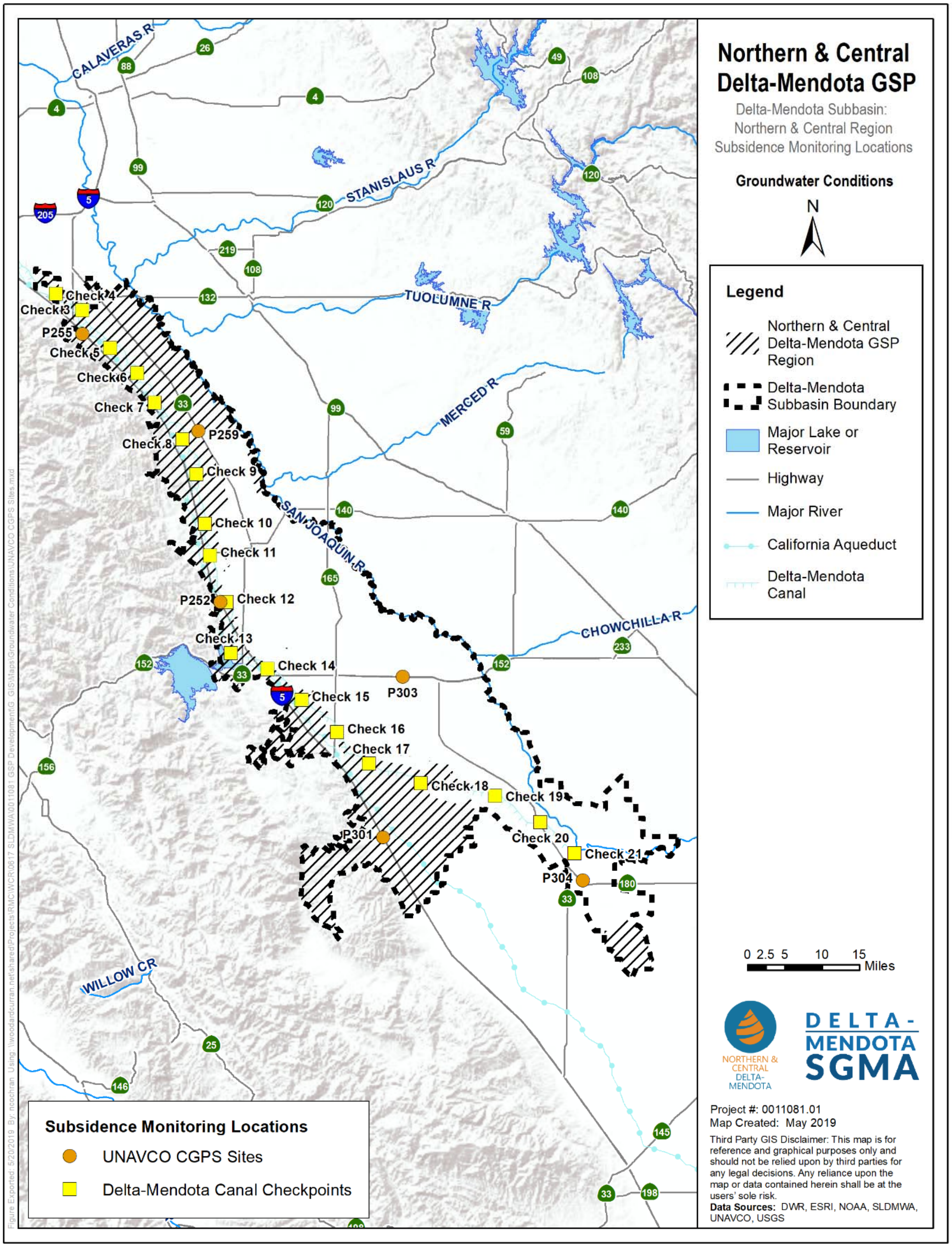

Figure 5-106. Subsidence Monitoring Locations, Delta-Mendota Subbasin

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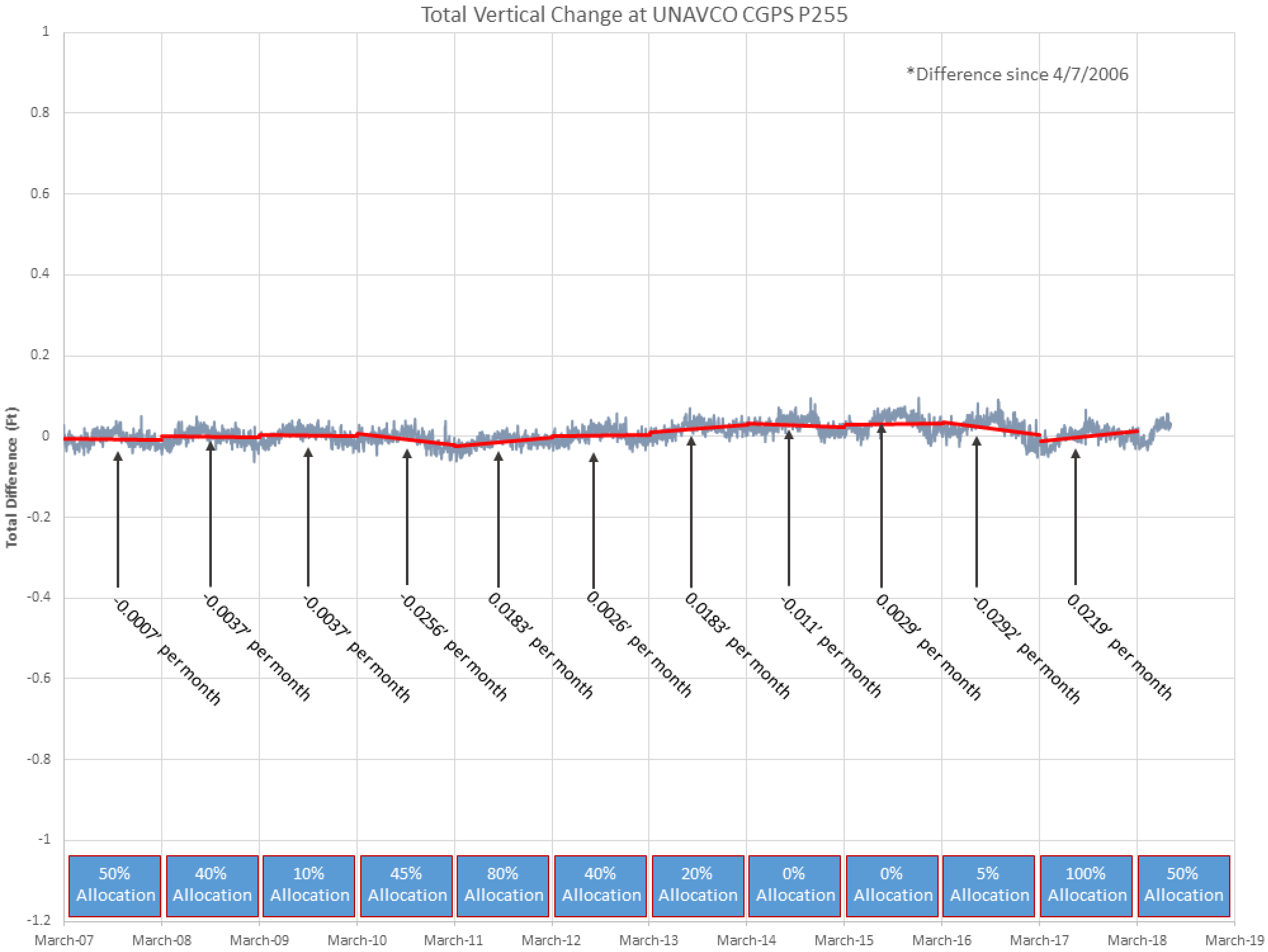

Figure 5-107. Vertical Elevation Change at UNAVCO CGPS P255, Spring 2007 to 2018

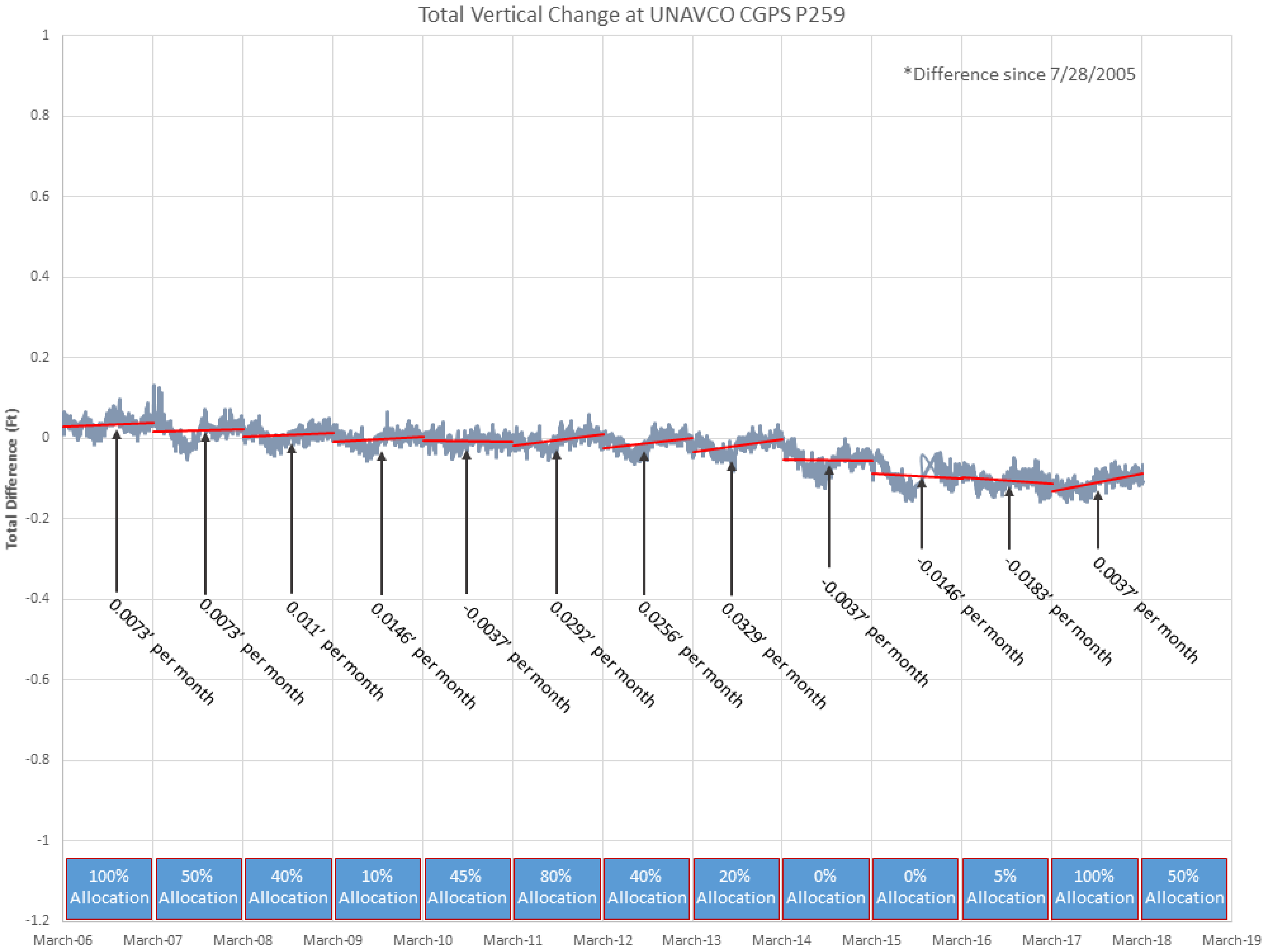

Figure 5-108. Vertical Elevation Change at UNAVCO CGPS P259, Spring 2006 to 2018

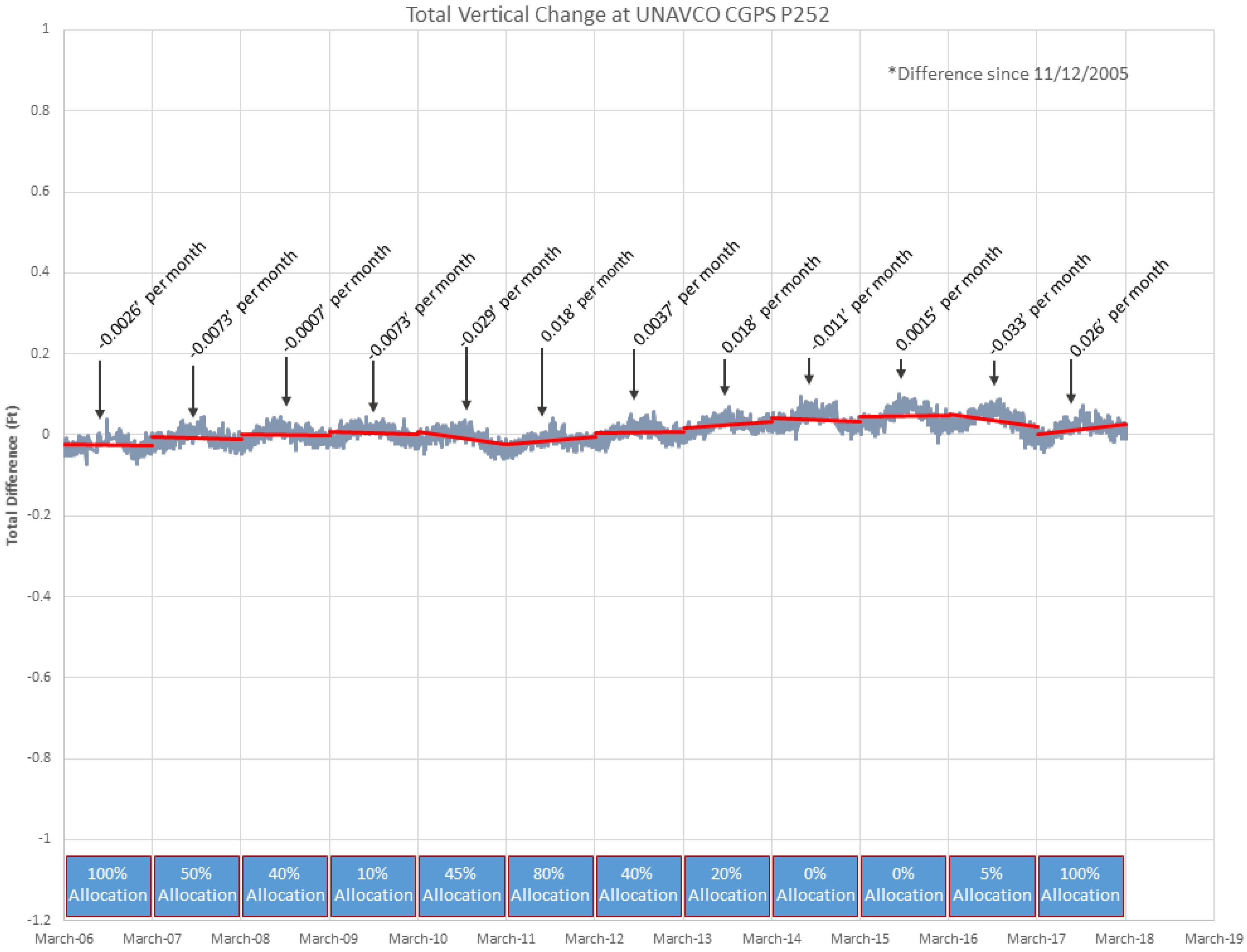

Figure 5-109. Vertical Elevation Change at UNAVCO CGPS P252, Spring 2006 to 2018

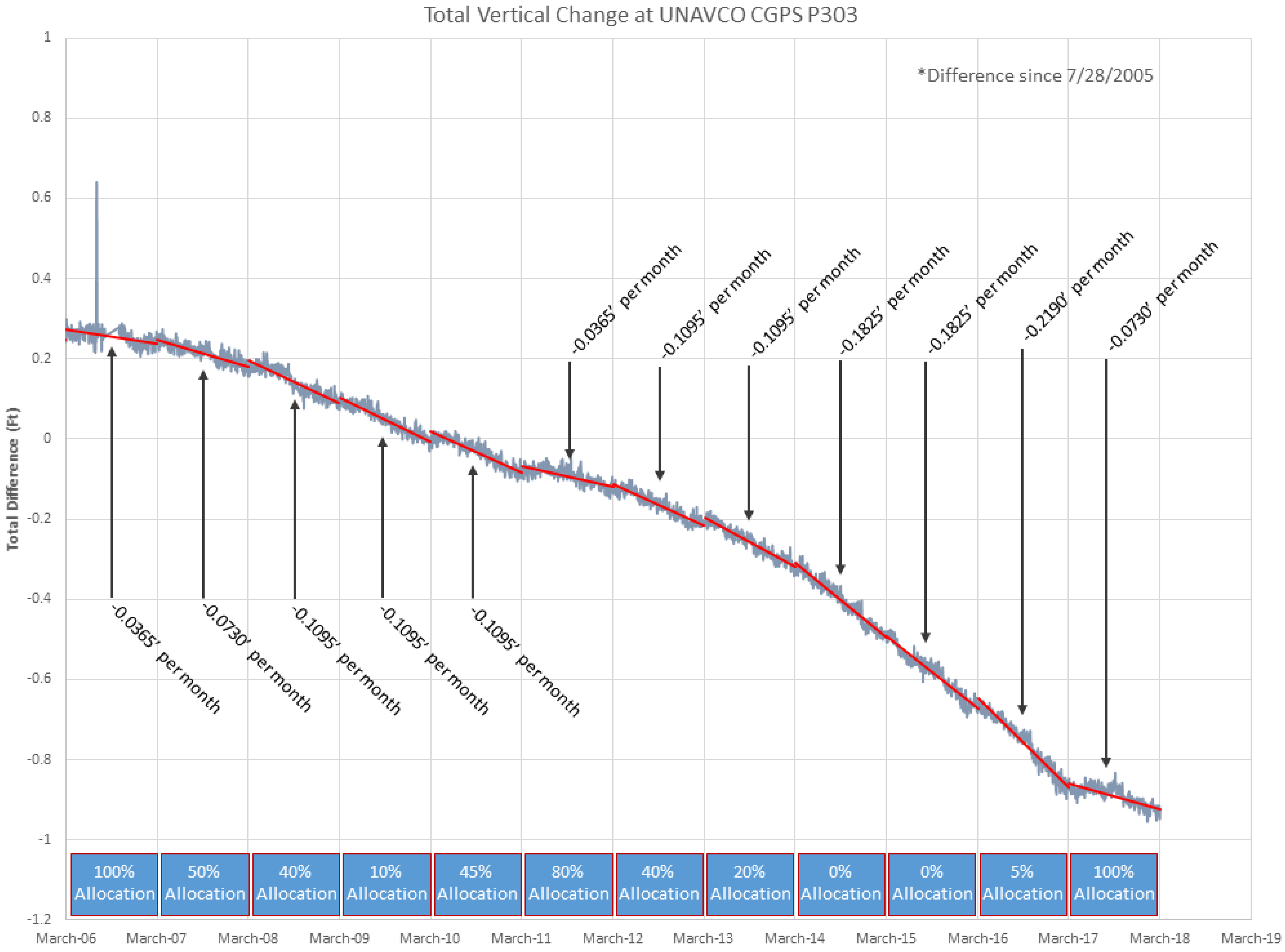

Figure 5-110. Vertical Elevation Change at UNAVCO CGPS P303, Spring 2006 to 2018

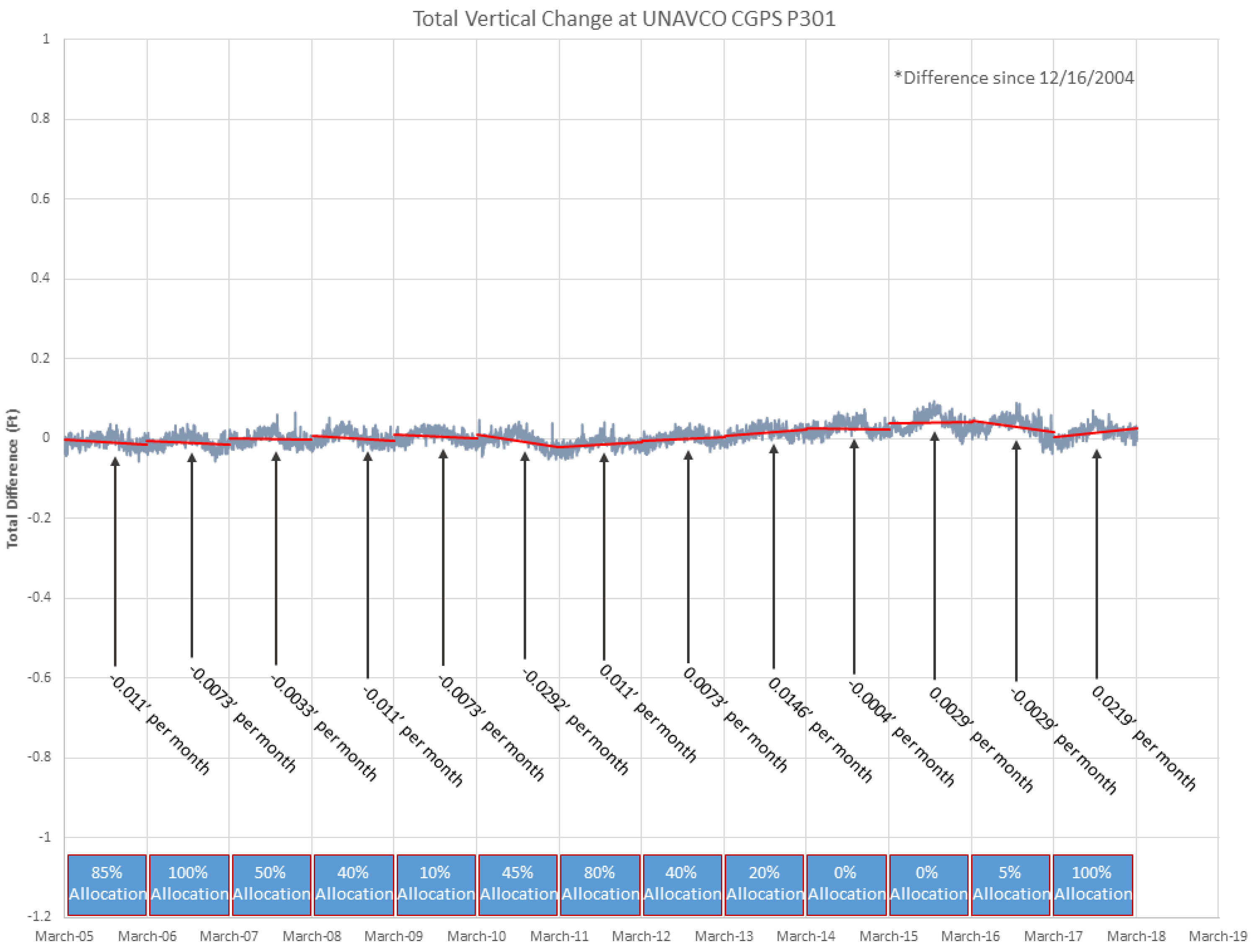

Figure 5-111. Vertical Elevation Change at UNAVCO CGPS P301, Spring 2005 to 2018

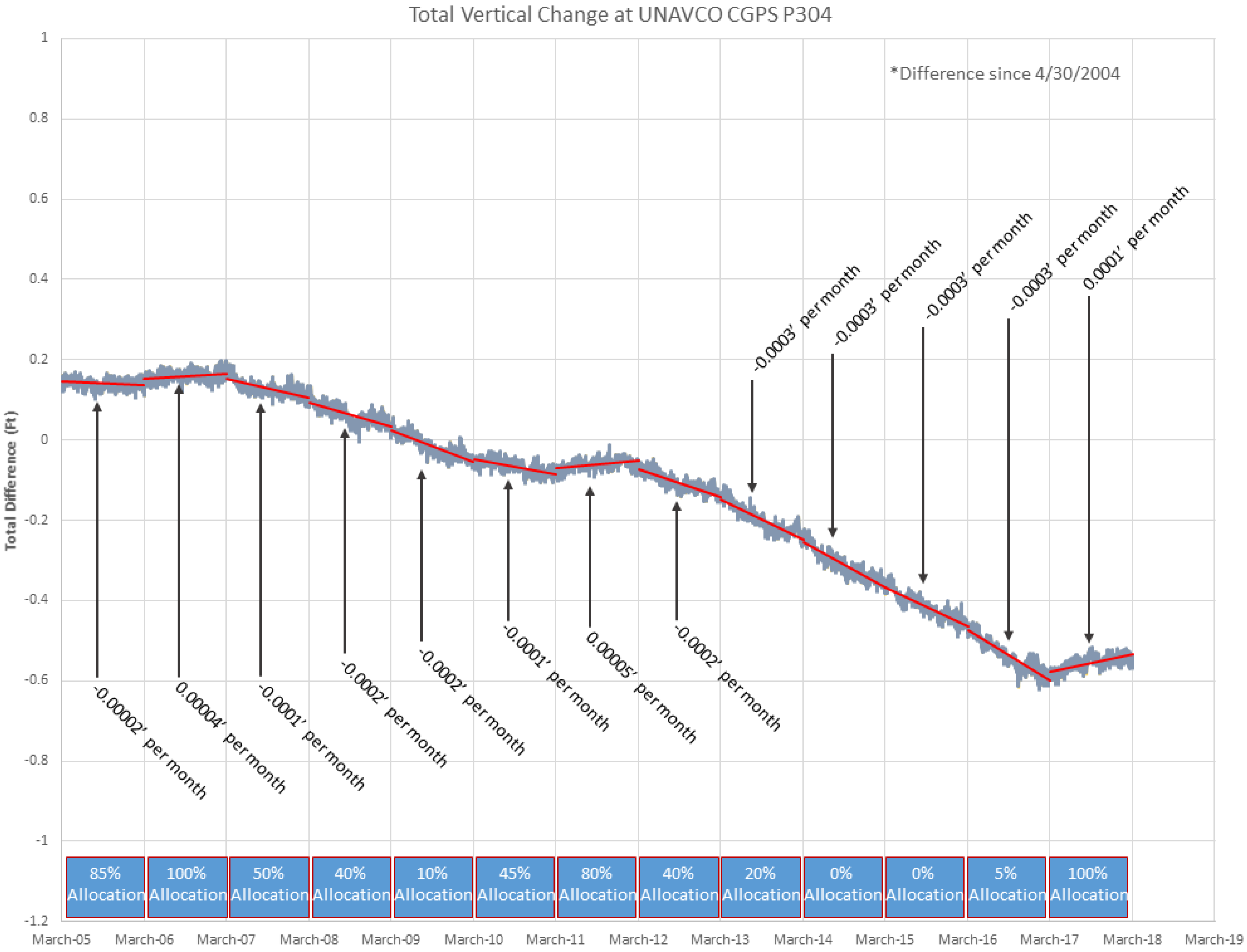

Figure 5-112. Vertical Elevation Change at UNAVCO CGPS P304, Spring 2005 to 2018

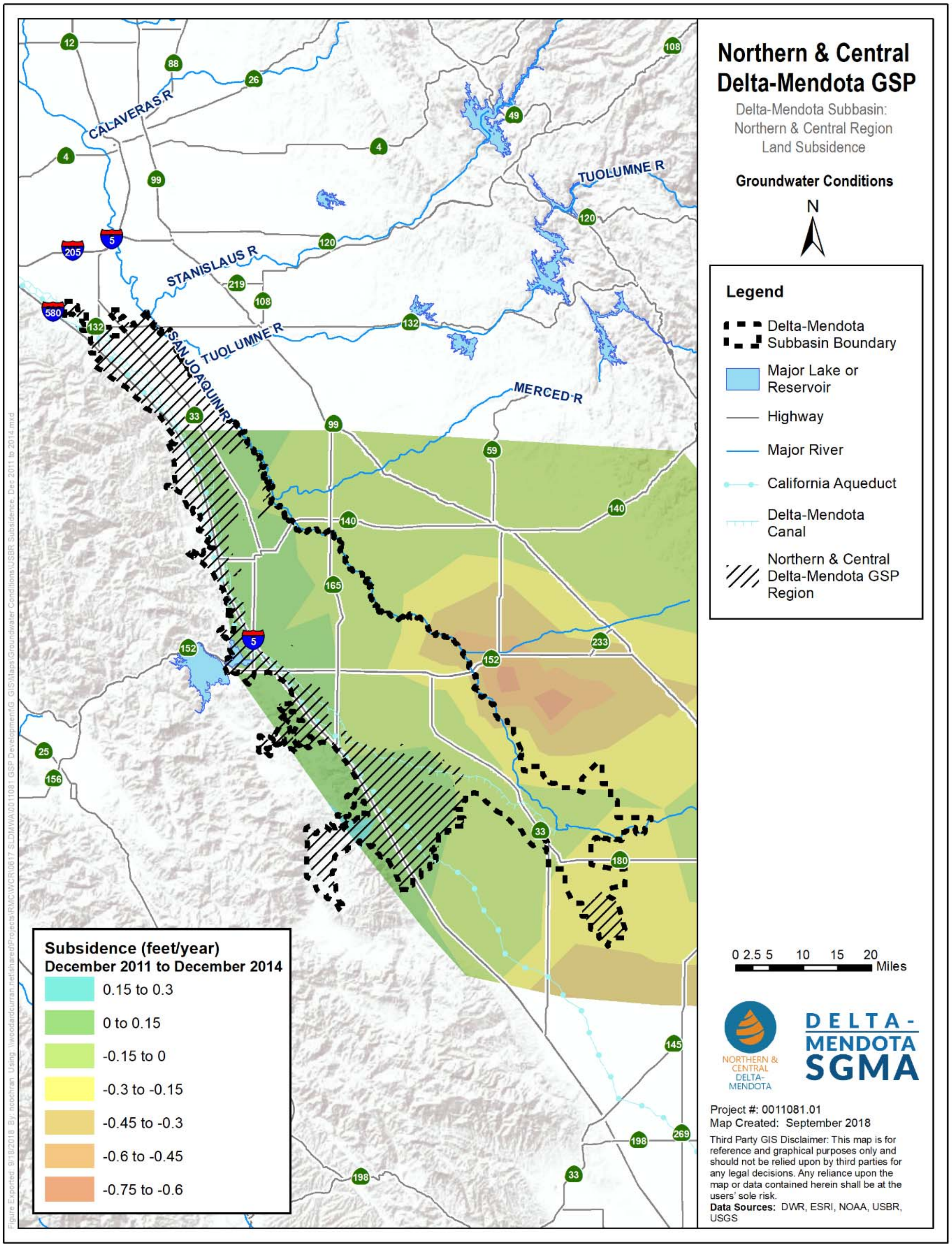

Figure 5-113. Land Subsidence, December 2011 to December 2014

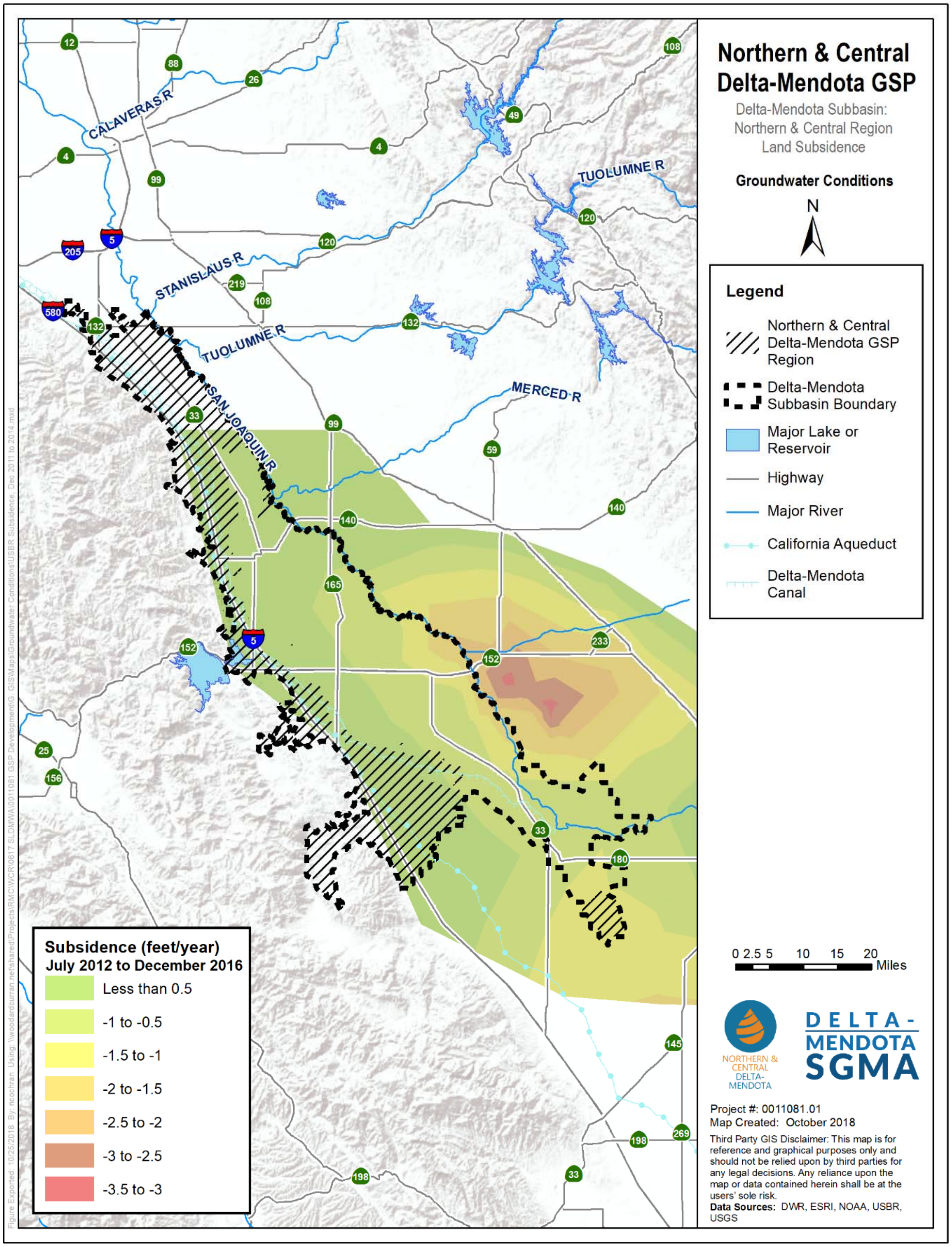

Figure 5-114. Land Subsidence, July 2012 to December 2016

Figure 5-115. Recent Land Subsidence at Key San Joaquin Valley Locations (Source: *Progress Report: Subsidence in California, March 2015 – September 2016*, Farr et. al. JPL, 2017)

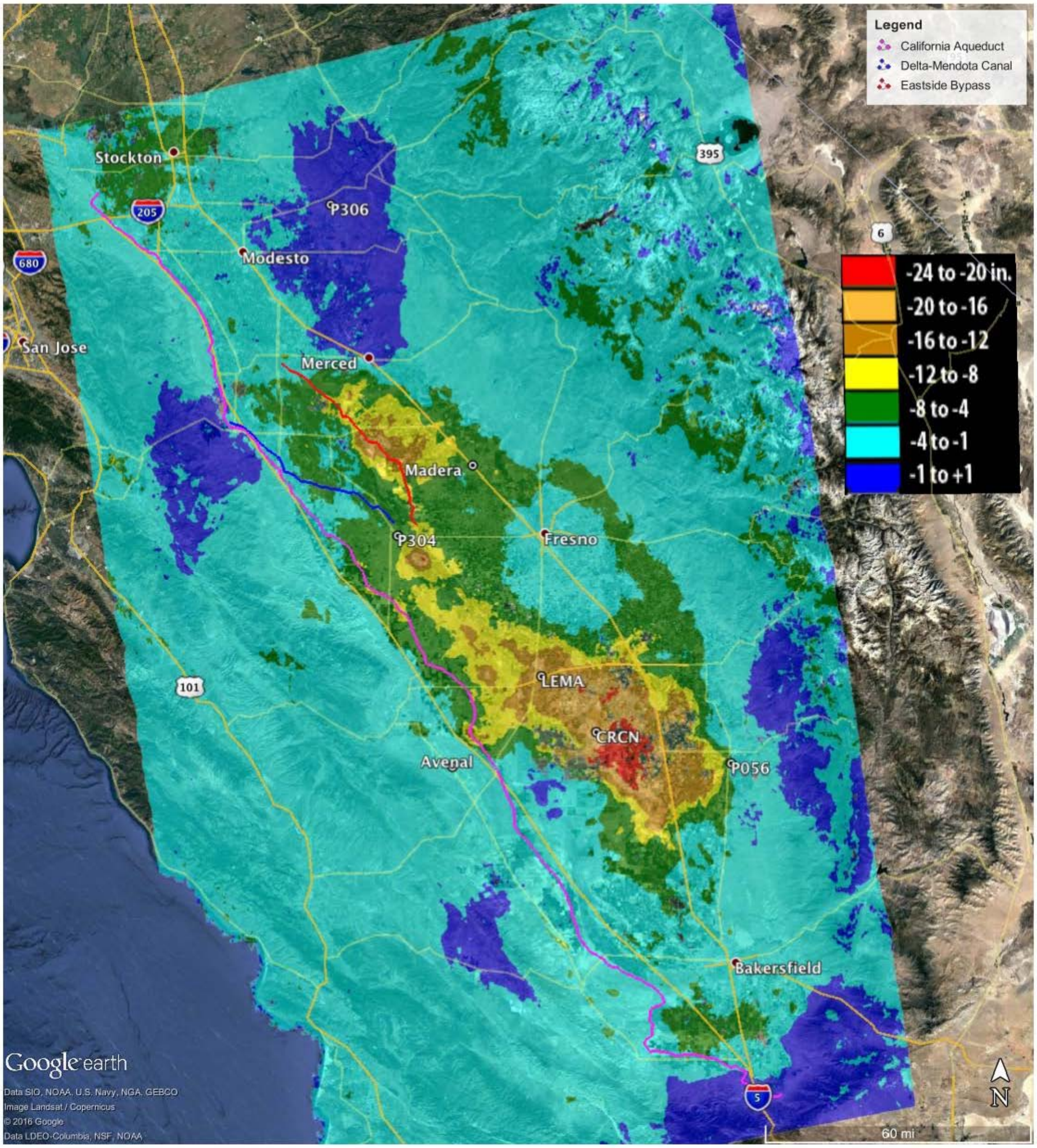

Figure 5-116. Total Land Subsidence in San Joaquin Valley from May 7, 2015 – September 10, 2016 as measured by ESA's Sentinel-1A and processed by JPL (Source: *Progress Report: Subsidence in California, March 2015 – September 2016*, Farr et. al. JPL, 2017

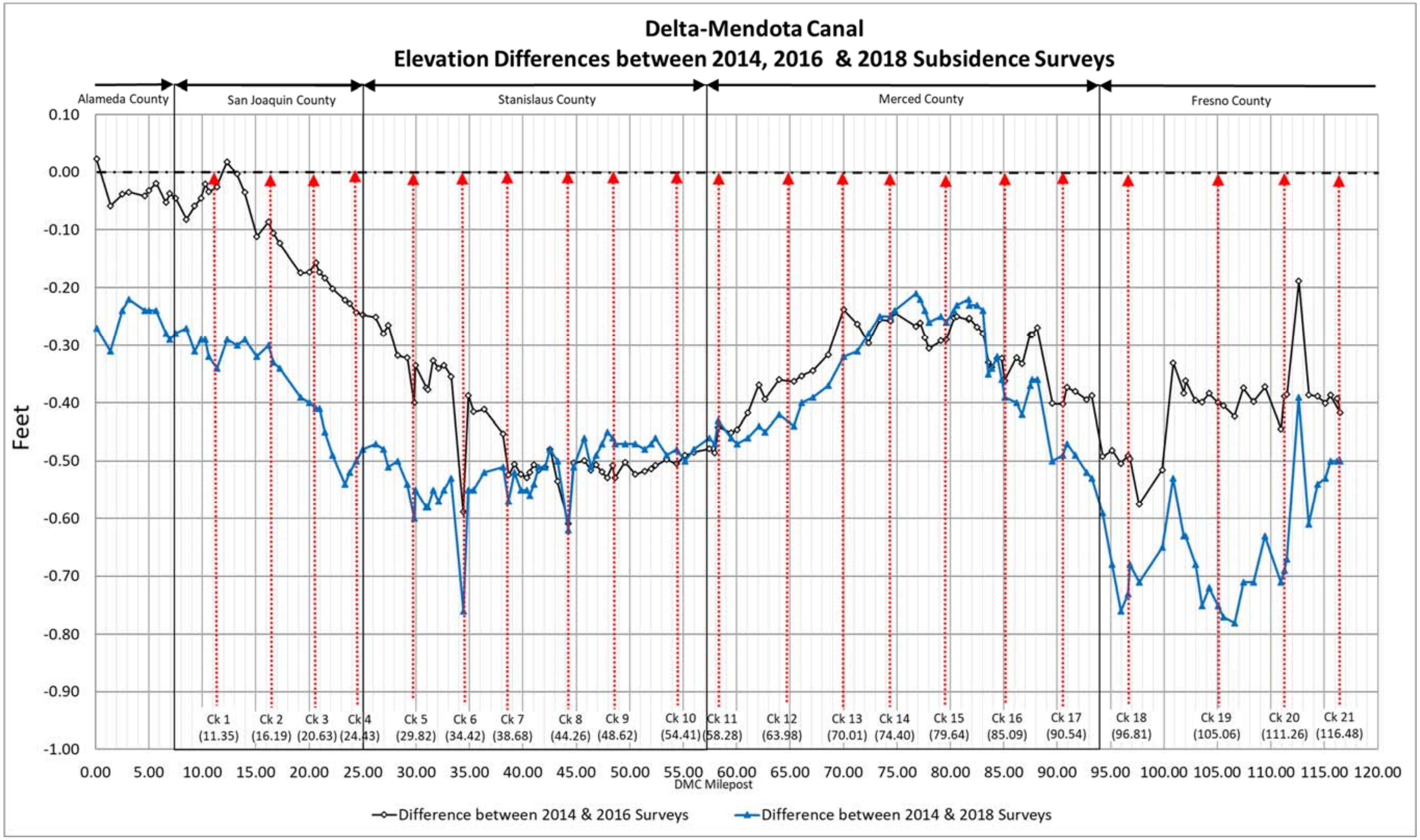

Figure 5-117. Elevation Change along the Delta-Mendota Canal, 2014 through 2018

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5.3.7 Interconnected Surface Water Systems

Understanding the location, timing and magnitude of groundwater pumping impacts on interconnected surface water systems is important for the proper management of groundwater resources in order to minimize impacts on interconnected surface waters and the biological communities and permitted surface water diverters that rely on those resources. Historically, throughout the San Joaquin Valley, many interconnected stream reaches have transitioned from net-gaining to net-losing streams (TNC, 2014). Gaining streams occur when streamflows increase as a result of groundwater contribution, and losing streams occur when streamflows decrease due to infiltration into the surrounding groundwater basin through the bed of the stream (McBain & Trush, Inc., 2002). Lowered groundwater levels have the ability to result in stream depletion similar in amount to the consumptive use of applied water, with the nature, rate, and location of increased pumping being a function of distance to the river, as well as depth, timing, and rate of groundwater pumping; however, it is important to recognize that groundwater pumping adjacent to an interconnected surface water body may be one of many causes of loss of surface water flows.

5.3.7.1 Available Data

Two communities in the Northern and Central Delta-Mendota Regions are most vulnerable to impacts from the loss of interconnected surface water as a result of the lowering of groundwater elevations: San Joaquin River surface water diverters and GDEs. These communities represent the primary users of interconnected surface water and groundwater. Permitted San Joaquin River diverters at the northern end of the Delta-Mendota Subbasin include West Stanislaus Irrigation District (post-1914 appropriative rights holder) and Patterson Irrigation District (which holds a pre-1914 water right), in addition to smaller agencies and private diverters. Similarly, GDEs in the Northern and Central Delta-Mendota Regions are found adjacent to the San Joaquin River, predominantly at the San Joaquin National Wildlife Refuge, which provides important habitat to birds and wildlife. Streams stemming from the west side of the Delta-Mendota Subbasin are ephemeral in nature, and only two of these creeks reach the San Joaquin River (Del Puerto Creek and Orestimba Creek). These creeks lose their flows to the underlying vadose zone (net-losing streams) and therefore do not represent areas of potential GDEs.

Groundwater dependent ecosystems are defined under Article 2 Definitions, § 351 Definitions of the GSP Emergency Regulations as “ecological communities or species that depend on groundwater emerging from aquifers or on groundwater occurring near the ground surface.” The Natural Communities Commonly Associated with Groundwater (NCCAG) dataset (2018a) provided by DWR in conjunction with The Nature Conservancy (TNC) was initially used to identify GDEs within the Delta-Mendota Subbasin, following the associated guidance document provided by TNC (Rohde et al., 2018). Local verification efforts were conducted in the Delta-Mendota Subbasin by different GSA representatives to ground-truth GDEs based on local knowledge. Specifically, areas where natural communities have been urbanized or otherwise modified were eliminated from the data set use to identify GDEs.

5.3.7.2 Identification of Interconnected Surface Water Systems

The San Joaquin River is the primary surface water body interconnected with Delta-Mendota Subbasin groundwater. Within the Northern and Central Delta-Mendota Regions, four reaches of the San Joaquin River have been identified as gaining streams with their associated California Data Exchange Center (CDEC) stream gauges: Newman (NEW) to Crows Landing (SCL), Crows Landing to Patterson (SJP), Patterson to Maze Road Bridge (MRB), and Maze Road Bridge to Vernalis (VNS). These reaches of the San Joaquin River were identified as gaining from a compendium of sources including a 2014 analysis of diversion water demand for diverters of the San Joaquin River between Hills Ferry Bridge and Mossdale Bridge (Provost & Pritchard, June 2014) as well as the following:

- Babbit, C., D.M. Dooley, M. Hall, R.M. Moss, D.L. Orth, and G.W. Sawyers. July 2018. *Groundwater Pumping Allocations under California’s Sustainable Groundwater Management Act: Considerations for Groundwater Sustainability Agencies*.

https://www.edf.org/sites/default/files/documents/edf_california_sgma_allocations.pdf. Accessed on November 13, 2018.

- Cantor, A., D. Owen, T. Harter, N.G. Nylen, and M. Kiparsky. March 2018. *Navigating Groundwater-Surface Water Interactions under the Sustainable Groundwater Management Act*. Center for Law, Energy & the Environment, UC Berkeley School of Law, Berkeley, CA. 50 pp. https://doi.org/10.15779/J23P87. Accessed on August 7, 2018.
- Hall, M., C. Babbitt, A.M. Saracino, and S.A. Leake. 2018. *Addressing Regional Surface Water Depletions in California: A Proposed Approach for Compliance with the Sustainable Groundwater Management Act*. https://www.edf.org/sites/default/files/documents/edf_california_sgma_surface_water.pdf. Accessed on November 13, 2018.
- McBain & Trush, Inc. 2002. *San Joaquin River Restoration Study Background Report*, prepared for Friant Water Users Authority, Lindsay, CA, and Natural Resources Defense Council. https://www.waterboards.ca.gov/waterrights/water_issues/programs/bay_delta/bay_delta_plan/water_quality_control_planning/docs/sjrf_spprtinfo/mcbainandtrush_2002.pdf. Accessed on October 1, 2018.
- San Joaquin River Restoration Program. April 2011. *DRAFT Program Environmental Impact Statement/Report, Chapter 12.0 Hydrology – Groundwater*. https://www.usbr.gov/mp/nepa/includes/documentShow.php?Doc_ID=7557. Accessed on August 29, 2018.
- San Joaquin River Restoration Program. August 2013. *Flow Loss Analysis (DRAFT)*. http://www.restoresjr.net/?wpfb_dl=686. Accessed on August 28, 2018.
- San Luis & Delta-Mendota Water Authority. March 22, 2011. *Guidelines for Use of the San Luis Drain during Flood Conditions*. Received via personal communication via Andrew Garcia on October 2, 2018.
- The Nature Conservancy. 2014. Groundwater and Stream Interaction in California's Central Valley: Insights for Sustainable Groundwater Management. https://www.scienceforconservation.org/assets/downloads/GroundwaterStreamInteraction_2016.pdf. Accessed on August 29, 2018.
- The Nature Conservancy. January 2018. *Groundwater Dependent Ecosystems under the Sustainable Groundwater Management Act: Guidance for Preparing Groundwater Sustainability Plans*. https://www.scienceforconservation.org/assets/downloads/GDEsUnderSGMA.pdf. Accessed on February 1, 2018.
- United States Bureau of Reclamation. April 2005. *CALSIM II San Joaquin River Model (DRAFT)*. http://www.calwater.ca.gov/science/pdf/calsim/CALSIMSJR_DRAFT_072205_1-50.pdf and http://www.calwater.ca.gov/science/pdf/calsim/CALSIMSJR_DRAFT_072205_51-100.pdf. Accessed on December 28, 2018.

5.3.7.3 Historic Conditions

The San Joaquin River and its tributaries drain approximately 13,500 mi^2 (measured at the USGS gaging station at Vernalis) along the western flank of the Sierra Nevada and eastern flank of the Coast Range, and flows northward into the Sacramento-San Joaquin Delta where it is joined by the Calaveras and Mokelumne Rivers before combining with the Sacramento River. Typical of Mediterranean climate catchments, river flows vary widely seasonally and from year to year. Three major tributaries join the San Joaquin from the east: the Merced, Tuolumne, and Stanislaus Rivers. Smaller tributaries include the Fresno River, Chowchilla River, Bear Creek, and Fresno Slough (from the Kings River). Precipitation is predominantly snow above about 5,500 to 6,000 feet in the Sierra Nevada, with rain in the middle and lower elevations of the Sierra foothills and in the Coast Range. As a result, the natural hydrology historically reflected a mixed runoff regime dominated by winter-spring rainfall runoff and spring-summer snowmelt runoff. Most flow is derived from snowmelt from the Sierra Nevada, with relatively little runoff contributed from the western side of the drainage basin in the rain shadow of the Coast Range. The unimpaired average annual water yield (WY 1906-2002) of the San Joaquin River, as measured immediately above Millerton Reservoir, is 1,801,000 AF (USBR, 2002); the post-Friant Dam average annual water yield (WY 1950-2000) to the lower San Joaquin River is 695,500 AF (USGS, 2000). As average precipitation decreases from north to south, the San Joaquin River basin (including the Stanislaus, Tuolumne, and Merced Rivers) contributes about 22% of the total runoff to the Delta (DWR, 1998).

5.3.7.4 Current Conditions

Historically, most of the San Joaquin River, which forms the great majority of the Delta-Mendota Subbasin's eastern border, was a gaining reach. Snowmelt runoff during the spring and early summer resulted in these conditions through a good portion of the year. However, significant decreases in groundwater elevations due to pumping, storage, and upstream diversions on the river have reversed this condition so most reaches are now losing reaches. Some localized gaining reaches still remain on the lower river, such as between the Stanislaus and Merced Rivers, corresponding to the reaches of the San Joaquin River boarding the Northern and Central Delta-Mendota Regions.

5.3.7.5 Estimates of Timing and Quantity of Gains/Depletions

Using available data, the quantity of gains and/or depletions from the groundwater at each reach of the San Joaquin River identified along the Northern and Central Delta-Mendota Regions was estimated. Table 5-9 summarizes these estimates. Estimates of the timing of gains and/or depletions were unavailable in related literature, and insufficient data were available to estimate the timing of losses and gains in the Northern and Central Delta-Mendota Regions. Such information will be gathered through future monitoring efforts related to this GSP.

Table 5-9. Estimated Quantity of Gains/Depletions for Interconnected Stream Reaches, Northern and Central Delta-Mendota Regions

Reach	Quantified Gain (cubic feet per second [cfs])	Reach Length (mile [mi])
Newman to Crows Landing [1]	50	11
Crows Landing to Patterson [1]	-50 to 200	10
Patterson to Maze Road Bridge [2]	190	30.8
Maze Road Bridge to Vernalis [2]		

[1] Provost & Pritchard, 2014

[2] Cooley, 2001

5.3.7.6 Groundwater Dependent Ecosystems

A GDE is defined under the GSP Emergency Regulations as referring "to ecological communities or species that depend on groundwater emerging from aquifers or on groundwater occurring near the ground surface" (§351(m)). Under §354.16(g) of the GSP Emergency Regulations, each Plan is required to identify GDEs within the subbasin utilizing data provided by the Department of Water Resources, or the best available information. The following section describes the process for verifying GDEs within the Delta-Mendota Subbasin and the location of verified and potential GDEs.

The NCCAG dataset (2018a) provided by DWR was used in conjunction with information provided by TNC to identify GDEs within the Delta-Mendota Subbasin. To further screen available information regarding GDEs, the following standards were set for identifying GDEs in the Northern and Central Delta-Mendota Regions: (1) areas with depths to groundwater levels greater than 30 feet were eliminated unless the vegetation identified in those areas were consistent with species with deep root systems (e.g. live oaks); (2) seasonally-managed areas and wetlands were eliminated due to their dependence on applied surface water; and (3) a 100-foot buffer was applied around the San Joaquin River within the Northern Delta-Mendota Region to include all communities in the NCCAG dataset as potential GDEs, except where professional judgement and local knowledge determined GDEs were not present. The selected 100-foot buffer corresponds with Caltrans standards under the Coastal Act that requires a 100-foot setback around wetland resources for their protection during project construction. To determine where groundwater is typically deeper than 30 feet below the ground surface, Spring 2015 depth to water contour mapping was used as a basis for establishing a connection between shallow groundwater and potential GDEs. The ESRI World Imagery layer (2017) was also used by local GSA representatives for ground-truthing and identifying potential mapping errors.

Based on the screening process described above, GDE polygons determined not to be GDEs were removed from the mapping. There were no GDE communities added to the mapping for the Northern and Central Delta-Mendota Regions. Figure 5-118 and Figure 5-119 summarize the results of the GDE analysis for the Subbasin, where red polygon indicates the Northern and Central Delta-Mendota Regions. Results are compiled into two habitat classes: wetlands (Figure 5-118) and vegetation (Figure 5-119). Wetland features are commonly associated with surface expression of groundwater under natural, unmodified conditions. Vegetation feature types are commonly associated with the sub-surface presence of groundwater (phreatophytes – deep rooted plants). Out of a total of 13,253 acres identified in the NCCAG dataset within the Northern and Central Delta-Mendota Regions, 11,711 acres were retained as Possible GDEs. Confirmed GDEs have been grouped into larger polygons based on proximity and aquifer connection.

In general, identified Possible GDEs are located along the San Joaquin River corridor. Possible GDEs in the Northern and Central Delta-Mendota Regions are located primarily in the northern portion of the Plan area, within about two miles from the San Joaquin River. Possible GDEs have also been identified along streams originating from the Coast Range; however, these areas are topographically disconnected from the Subbasin's principal aquifers and are located in areas of *de minimus* or zero groundwater use and are therefore are unmanageable through the Sustainable Groundwater Management Act (SGMA). Table 5-10 includes all freshwater species within the Northern and Central Delta-Mendota Regions, as identified by TNC (2018). These species (listed in Table 5-10) have either been observed or have the potential to exist within the Northern and Central Delta-Mendota Regions. Future efforts in GDE mapping prior to the 2025 5-Year GSP Update will further refine GDE locations within the Plan area.

As a result of the identification of Possible GDEs for the purpose of this GSP under SGMA, no land use protections for GDEs are conveyed unless the law otherwise requires. Management and protection of GDEs may require more focus on land use or irrigation activities more so than groundwater management. This rigorous analysis to identify potential GDEs was developed to focus groundwater management activities on the most appropriate areas.

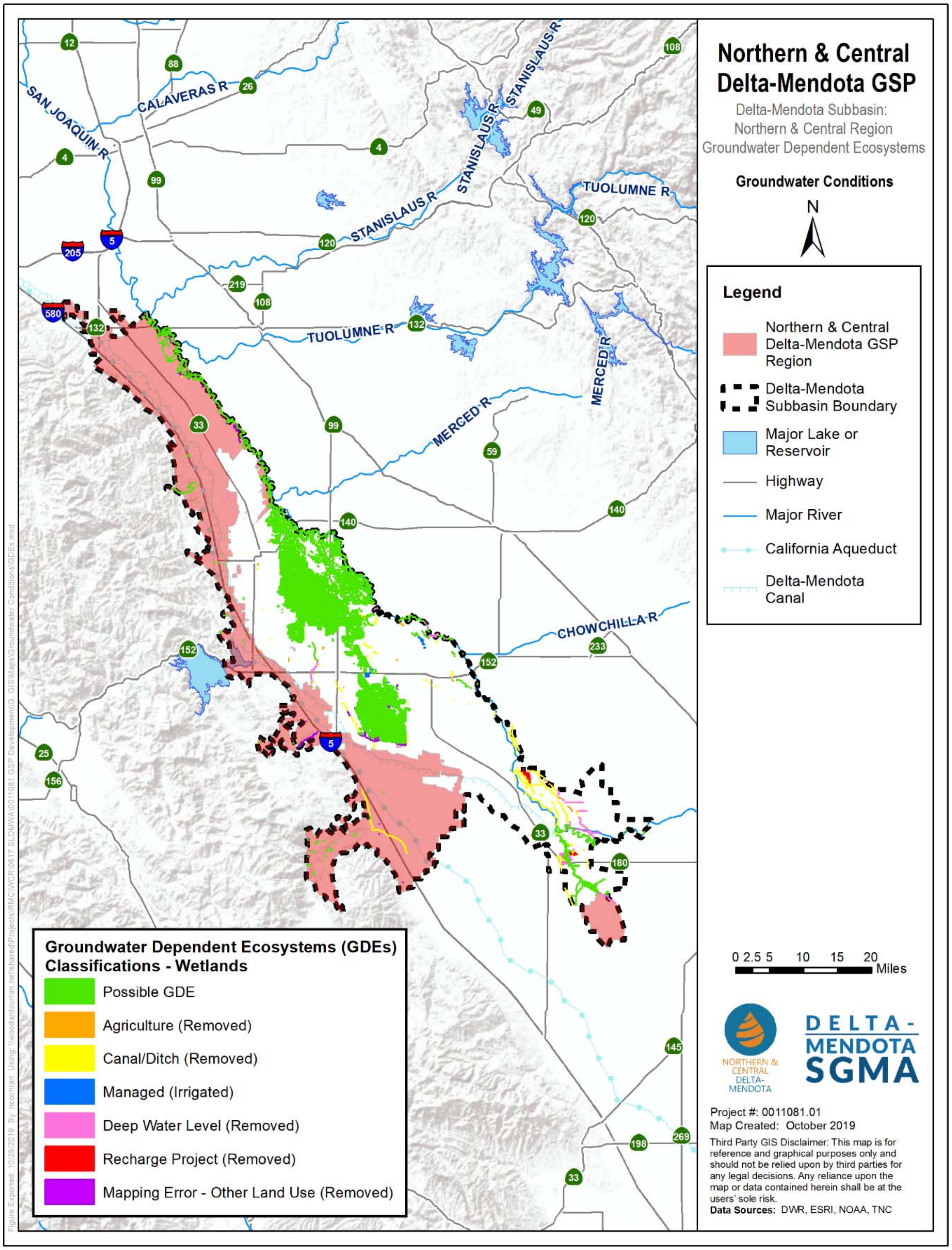

Figure 5-118. Groundwater Dependent Ecosystems in the Delta-Mendota Subbasin, Wetlands

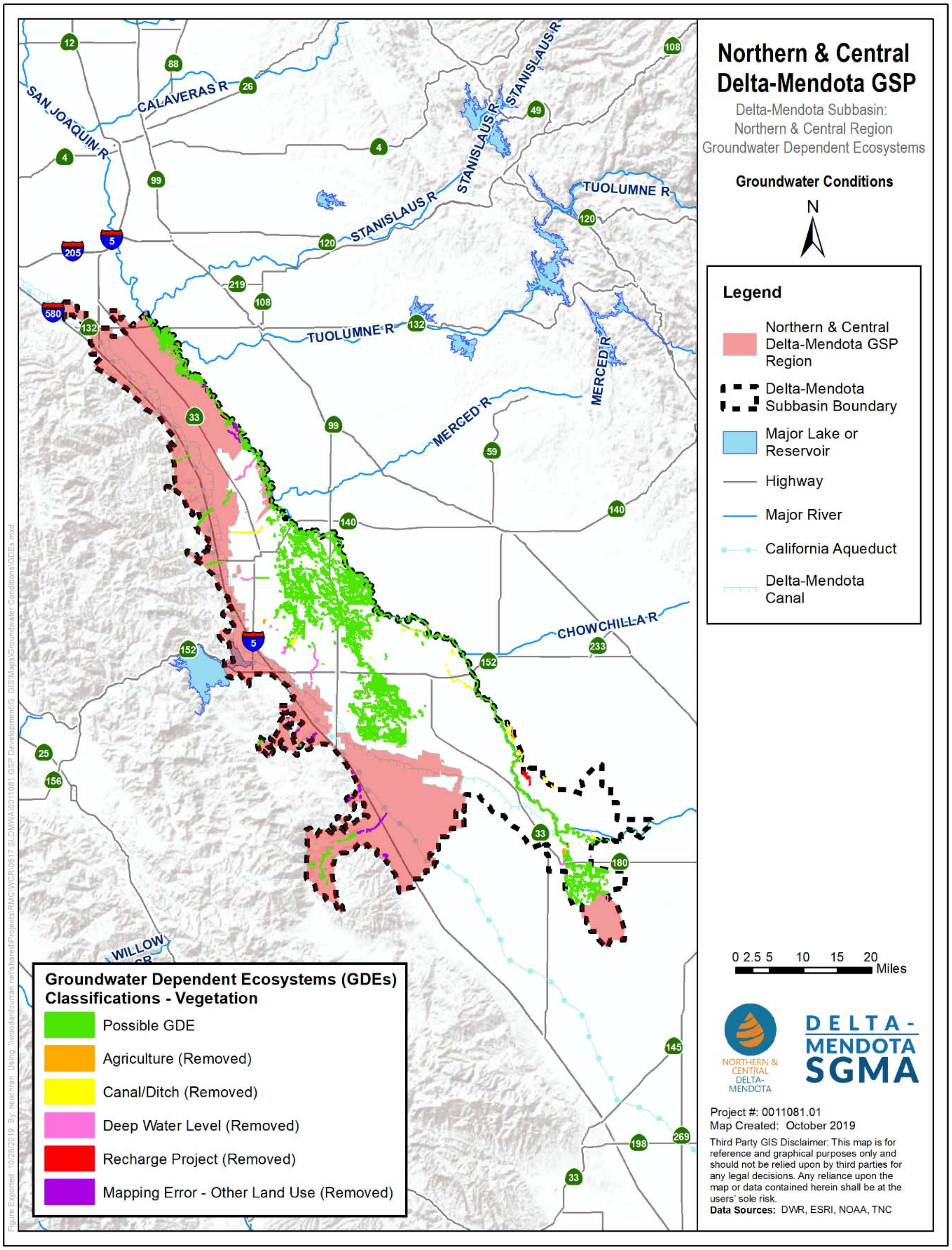

Figure 5-119. Groundwater Dependent Ecosystems in the Delta-Mendota Subbasin, Vegetation

Table 5-10. List of Potential Freshwater Species, Northern and Central Delta-Mendota Regions

Scientific Name	Common Name	Group	Federal Protection Status	State Protection Status
Actitis macularius	Spotted Sandpiper	Birds		
Aechmophorus clarkii	Clark's Grebe	Birds		
Aechmophorus occidentalis	Western Grebe	Birds		
Agelaius tricolor	Tricolored Blackbird	Birds	Bird of Conservation Concern	Special Concern
Aix sponsa	Wood Duck	Birds		
Anas acuta	Northern Pintail	Birds		
Anas americana	American Wigeon	Birds		
Anas clypeata	Northern Shoveler	Birds		
Anas crecca	Green-winged Teal	Birds		
Anas cyanoptera	Cinnamon Teal	Birds		
Anas discors	Blue-winged Teal	Birds		
Anas platyrhynchos	Mallard	Birds		
Anas strepera	Gadwall	Birds		
Anser albifrons	Greater White-fronted Goose	Birds		
Ardea alba	Great Egret	Birds		
Ardea herodias	Great Blue Heron	Birds		
Aythya affinis	Lesser Scaup	Birds		
Aythya americana	Redhead	Birds		Special Concern
Aythya collaris	Ring-necked Duck	Birds		
Aythya marila	Greater Scaup	Birds		
Aythya valisineria	Canvasback	Birds		Special
Botaurus lentiginosus	American Bittern	Birds		
Bucephala albeola	Bufflehead	Birds		
Bucephala clangula	Common Goldeneye	Birds		
Butorides virescens	Green Heron	Birds		
Calidris alpina	Dunlin	Birds		
Calidris mauri		Birds		
Calidris minutilla	Least Sandpiper	Birds		
Chen caerulescens	Snow Goose	Birds		
Chen rossii	Ross's Goose	Birds		
Chlidonias niger	Black Tern	Birds		Special Concern
Chroicocephalus philadelphia	Bonaparte's Gull	Birds		

Scientific Name	Common Name	Group	Federal Protection Status	State Protection Status
Cistothorus palustris	Marsh Wren	Birds		
Cygnus columbianus	Tundra Swan	Birds		
Cypseloides niger	Black Swift	Birds	Bird of Conservation Concern	Special Concern
Egretta thula	Snowy Egret	Birds		
Empidonax traillii	Willow Flycatcher	Birds	Bird of Conservation Concern	Endangered
Fulica americana	American Coot	Birds		
Gallinago delicata	Wilson's Snipe	Birds		
Gallinula chloropus		Birds		
Geothlypis trichas		Birds		
Grus canadensis	Sandhill Crane	Birds		
Haliaeetus leucocephalus	Bald Eagle	Birds	Bird of Conservation Concern	Endangered
Himantopus mexicanus	Black-necked Stilt	Birds		
Icteria virens	Yellow-breasted Chat	Birds		Special Concern
Limnodromus scolopaceus	Long-billed Dowitcher	Birds		
Lophodytes cucullatus	Hooded Merganser	Birds		
Megaceryle alcyon	Belted Kingfisher	Birds		
Mergus merganser	Common Merganser	Birds		
Mergus serrator	Red-breasted Merganser	Birds		
Numenius americanus	Long-billed Curlew	Birds		
Numenius phaeopus	Whimbrel	Birds		
Nycticorax	Black-crowned Night-Heron	Birds		
Oxyura jamaicensis	Ruddy Duck	Birds		
Pandion haliaetus		Birds		Watch list
Pelecanus erythrorhynchos	American White Pelican	Birds		Special Concern
Phalacrocorax auritus	Double-crested Cormorant	Birds		
Phalaropus tricolor	Wilson's Phalarope	Birds		
Plegadis chihi	White-faced Ibis	Birds		Watch list
Pluvialis squatarola	Black-bellied Plover	Birds		
Podiceps nigricollis	Eared Grebe	Birds		
Podilymbus podiceps	Pied-billed Grebe	Birds		
Porzana carolina	Sora	Birds		
Rallus limicola	Virginia Rail	Birds		
Recurvirostra americana	American Avocet	Birds		
Riparia	Bank Swallow	Birds		Threatened

Scientific Name	Common Name	Group	Federal Protection Status	State Protection Status
Setophaga petechia	Yellow Warbler	Birds		
Tachycineta bicolor	Tree Swallow	Birds		
Tringa melanoleuca	Greater Yellowlegs	Birds		
Tringa semipalmata	Willet	Birds		
Vireo bellii		Birds		
Vireo bellii pusillus		Birds	Endangered	Endangered
Xanthocephalus		Birds		Special Concern
Branchinecta lynchi	Vernal Pool Fairy Shrimp	Crustaceans	Threatened	Special
Lepidurus packardi	Vernal Pool Tadpole Shrimp	Crustaceans	Endangered	Special
Oncorhynchus mykiss - CV		Fishes	Threatened	Special
Oncorhynchus mykiss irideus		Fishes		
Pogonichthys macrolepidotus		Fishes		Special Concern
Actinemys marmorata	Western Pond Turtle	Herps		Special Concern
Ambystoma californiense	California Tiger Salamander	Herps	Threatened	Threatened
Anaxyrus boreas	Boreal Toad	Herps		
Pseudacris regilla	Northern Pacific Chorus Frog	Herps		
Rana boylii	Foothill Yellow-legged Frog	Herps	Under Review in the Candidate or Petition Process	Special Concern
Rana draytonii	California Red-legged Frog	Herps	Threatened	Special Concern
Spea hammondii	Western Spadefoot	Herps	Under Review in the Candidate or Petition Process	Special Concern
Thamnophis atratus		Herps		
Thamnophis elegans		Herps		
Thamnophis gigas	Giant Gartersnake	Herps	Threatened	Threatened
Thamnophis sirtalis	Common Gartersnake	Herps		
Capnia hitchcocki		Insects & other inverts		
Mesocapnia bulbosa		Insects & other inverts		
Paraleptophlebia associata		Insects & other inverts		
Castor canadensis	American Beaver	Mammals		
Lontra canadensis		Mammals		
Neovison vison	American Mink	Mammals		
Ondatra zibethicus	Common Muskrat	Mammals		
Anodonta californiensis	California Floater	Mollusks		Special
Margaritifera falcata	Western Pearlshell	Mollusks		Special
Pyrgulopsis diablensis		Mollusks		Special
Arundo donax		Plants		

Scientific Name	Common Name	Group	Federal Protection Status	State Protection Status
Baccharis salicina		Plants		
Cotula coronopifolia		Plants		
Eryngium castrense		Plants		
Eryngium spinosepalum		Plants		Special
Eryngium vaseyi vallicola		Plants		
Eryngium vaseyi		Plants		
Hydrocotyle verticillata		Plants		
Juncus xiphioides		Plants		
Ludwigia peploides		Plants		
Persicaria lapathifolia		Plants		
Persicaria maculosa		Plants		
Phacelia distans		Plants		
Pilularia americana		Plants		
Plantago elongata		Plants		
Potamogeton foliosus		Plants		
Puccinellia simplex	Little Alkali Grass	Plants		
Salix gooddingii		Plants		
Schoenoplectus acutus occidentalis		Plants		
Schoenoplectus americanus		Plants		
Typha domingensis		Plants		

5.3.8 Data Gaps

The Delta-Mendota Subbasin is an extensive subbasin covering a large area extending along the northwestern end of the San Joaquin Valley. While there is a significant amount of data available regarding various groundwater-related aspects of the Subbasin, much is still not known in multiple locations around the Northern and Central Delta-Mendota Regions. To this end, the following data gaps have been identified and will be addressed as part of the interim period between adoption of this GSP and its first 5-year update.

- Information regarding subsidence varies in extent around the region. While there is a large amount of land elevation survey data available in association with the DMC and other regional infrastructure, other areas in the Northern and Central Delta-Mendota Regions require additional data collection to both further establish and monitor future land subsidence rates.
- Only three shallow groundwater wells exist proximate to the San Joaquin River within the Northern and Central Delta-Mendota Regions, the primary interconnected surface water body in the Delta-Mendota Subbasin. Additional nested or clustered monitoring wells are required adjacent to the river to evaluate horizontal and vertical groundwater gradients, and in connection with river stage monitoring, an assessment of the interconnection between the San Joaquin River and the Delta-Mendota Subbasin.
- There are a large number of wells in the Northern and Central Delta-Mendota Regions where no construction information available. Video surveys and other surveys should be conducted to (1) identify where the wells are screened, and (2) determine if the well(s) are appropriate as additions to the Regions' groundwater monitoring programs.
- Mapping of GDEs in the Northern and Central Delta-Mendota Regions, as contained in this GSP, is an initial assessment of their location. This mapping needs to be refined using most recent groundwater elevation/depth to water contour mapping.
- Monitoring networks contained in this GSP are preliminary and were formulated based on existing well information. As additional wells are installed in the Subbasin and additional well construction information is obtained for existing wells, these networks will need to be refined to improve on the spatial (areal and vertical) distribution of monitoring points and the data collected for evaluation of conditions of the groundwater basin.
- In developing the water budgets contained herein, it was discovered that several of the California Irrigation Management Information System (CIMIS) stations available for use have questionable data. Additional CIMIS and/or other weather stations need to be established around the Subbasin, both to provide good quality data and to further refine the spatial variability of precipitation and evapotranspiration (ET) around the Subbasin.
- The sustainable yield estimates contained in this GSP for both the Upper and Lower Aquifers were developed using limited data. As additional data are collected over the first five years, improved sustainable yield estimates and estimates of water in storage in both principle aquifers should be prepared utilizing the new data.
- An updated DMC Conveyance Capacity Analysis should be conducted to provide data for refining the sustainability indicators for subsidence in the Northern and Central Delta-Mendota Regions.

5.4 WATER BUDGETS

This section describes the historic, current, and projected water budgets developed for the Northern and Central Delta-Mendota Regions as required by §354.18 of the Groundwater Sustainability Plan (GSP) Emergency Regulations. These water budgets provide an accounting and assessment of the total annual volume of groundwater and surface water entering and leaving the Northern and Central Regions of the Delta-Mendota Subbasin under the respective conditions, and the change in volume of water stored. Specifically, the water budgets quantify the following:

- Total surface water entering and leaving the Plan area by water source type
- Inflow to the groundwater system by water source type
- Outflows from the groundwater system by water use sector
- The change in the annual volume of groundwater in storage between seasonal high conditions
- If overdraft conditions occur, a quantification of overdraft over a period of years during which water year and water supply conditions approximate average conditions
- The water year type associated with the annual supply, demand, and change in groundwater stored
- An estimate of sustainable yield for the Delta-Mendota Subbasin

5.4.1 Useful Terms

A list and description of technical terms used throughout this section to discuss water budgets are included below. The terms and their descriptions are identified here to guide readers through this section and are not a definitive definition of each term.

- **Land Surface System** - The collective term for the land surface area above an aquifer and the interacting flows and into and out of that control volume.
- **Groundwater System** - The collective term for the groundwater aquifer and the interacting flows into and out of the groundwater aquifer(s).
- **Water Budget** - An accounting of water flows into and out of a defined area, which are tabulated as total volumes transmitted over a given time period.
- **Land Surface Budget** - An accounting of water flows into and out of the land surface above an aquifer within a defined area. Inflows and outflows include flow between adjacent land surface areas, the atmosphere, and the groundwater aquifer below.
- **Groundwater Budget** - An accounting of water flows into and out of the groundwater aquifer(s) within a defined area. Inflows and outflows include flow between adjacent aquifer areas and the above land surface.
- **Balance Error** - The difference between actual inflow and outflow equals actual change in storage (Inflow – Outflow – Change in Storage = 0). The difference between estimated inflow and estimated outflow does not equal estimated change in storage, where this difference is the balance error (Estimated Inflow – Estimated Outflow – Estimated Change in Storage = Balance Error).
- **Applied Water** - The collective name for water applied to the land surface, excluding precipitation.

- **ET_0 -** Crop Evapotranspiration (Crop-ET_0) is a value used for calculating reference and crop evapotranspiration from meteorological data and crop coefficients.

- **Water Losses -** The collective name for water leaving the land surface.

- **Water Year -** The annual period beginning October 1st of a specific year and ending September 30th of the subsequent year.

- **Historic Water Budget -** Water budget tabulating the flows into and out of the Northern & Central Delta-Mendota Region GSP Plan area during Water Years (WYs) 2003 through 2012, which is an accounting of annual observed flows and calculated flows.

- **Current Water Budget -** Water budget tabulating the flows into and out of the Northern & Central Delta-Mendota Region GSP Plan area during WY2013. This is an accounting of observed flows and calculated flows for the 'current year.'

- **Baseline Projected Water Budget -** Water budget tabulating predicted flows into and out of the Northern & Central Delta-Mendota Region GSP Plan area during WYs 2014 through 2070. This is an accounting of annual predicted flows based on the existing climate scenario, without the influence of additional projects or management actions for the purposes of the Sustainable Groundwater Management Act (SGMA) and for establishing changes in the system as a result of projected future land use and water use patterns.

- **Projected Water Budget with Climate Change (CC) -** Water budget tabulating predicted flows into and out of the Northern & Central Delta-Mendota Region GSP Plan area during the WYs 2014 through 2070 with the California Department of Water Resources' (DWR's) climate change factors (CCFs) applied to Subbasin hydrology. This is an accounting of annual predicted flows based on the climate change scenario, without the influence of additional projects or management actions for the purposes of SGMA and evaluating the impacts of CCF application to the water budget.

- **Projected Water Budget with Climate Change and Projects & Management Actions -** Water budget tabulating predicted flows into and out of the Northern & Central Delta-Mendota Region GSP Plan area during WYs 2014 through 2070. This is an accounting of annual predicted flows based on the climate change scenario with the additional influence of additional projects and management actions for the purposes of SGMA and evaluating the impacts of future projected conditions on the GSP region.

5.4.2 Water Budget Purpose and Information

Historic, current and projected water budgets were developed to provide a quantitative accounting of water entering and leaving the Northern and Central Delta-Mendota Regions over a specified period of time. Water entering the Plan area includes water entering at the surface and through the subsurface. Similarly, water leaving the Plan area leaves at the surface and through the subsurface. Water enters and leaves naturally, such as through precipitation and streamflow, and through human activities, such as pumping and recharge from irrigation. Figure 5-120 presents a simplified vertical slice through the land surface and underlying aquifers of the Delta-Mendota Subbasin to summarize the water balance components used in the following analysis.

The values presented in the water budgets provide information about historic, current, and projected conditions as they relate to hydrology, water demand, water supply, land use, population, climate change, groundwater and surface water interaction, and subsurface groundwater flow. This information can assist in managing groundwater in the Plan area by identifying the scale of different uses, highlighting potential risks, and identifying potential opportunities to improve water supply conditions.

Water budgets can be developed on different spatial scales. For agricultural purposes, water budgets may be limited to the root zone in soil, improving irrigation techniques by estimating the inflows and outflows of water from the upper portion of the soil accessible to plants through their roots. In a strictly groundwater study, water budgets may be limited to water flow in the subsurface, helping analysts understand how water flows beneath the surface. In this section, consistent with the SGMA regulations, water budgets investigate the combined land surface and groundwater system in the Northern and Central Delta-Mendota Regions. The combined water budgets for the entire Delta-Mendota Subbasin are presented in the Delta-Mendota Subbasin Common Chapter.

Water budgets can be developed at various temporal scales. Daily water budgets may be used to demonstrate how evaporation and transpiration increase during the day and decrease at night. Monthly water budgets may be used to demonstrate how groundwater pumping increases in the dry, hot summer months and decreases in the cool, wet winter months. In this section, and consistent with SGMA regulations, the water budgets contained herein are annual, representing a full water year (i.e., the 12 months spanning from October of the previous year to September of the current year).

The SGMA regulations require that annual water budgets are based on three different periods: a ten-year historic period, the ‘current’ year, and a 50-year (minimum) projected period. The historic water budget is intended to evaluate availability and reliability of past surface water supply deliveries, aquifer response to water supply, and demand trends relative to water year type. The current water budget is intended to evaluate the effects of current land and water use on groundwater conditions, and to accurately estimate current inflows and outflows. The projected water budgets are used to estimate future conditions of supply, demand, and aquifer response to Plan implementation, and to identify the uncertainties of these projected water budget components.

Water budgets are developed to capture typical conditions during an identified time period. Typical conditions are developed by averaging over hydrologic conditions that incorporate droughts, wet periods, and normal periods. By incorporating these varied conditions in the water budgets, an analysis of the water system under certain hydrologic conditions, such as drought, can be performed along with and compared to an analysis of long-term average conditions.

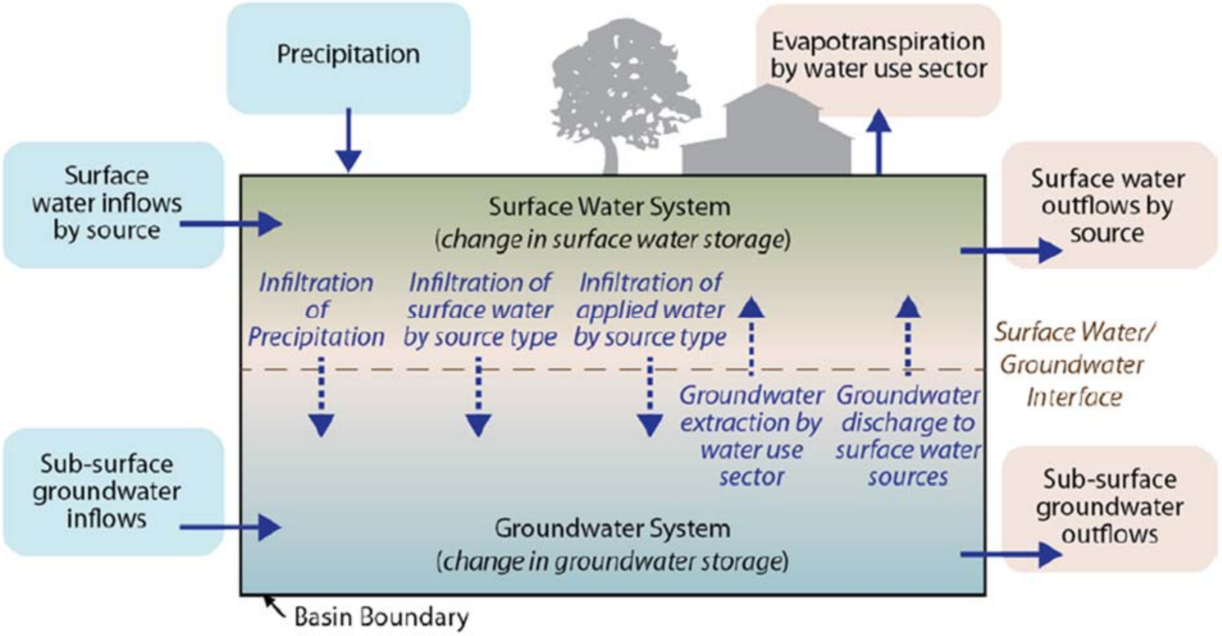

Figure 5-120. Generalized Water Budget Diagram

5.4.3 Key Coordinated Water Budget Decisions

The hydrologic time periods for the historic, current, and projected water budgets of the Delta-Mendota Subbasin were the recommendation of the Delta-Mendota Subbasin Technical Working Group (Technical Working Group), approved by the Delta-Mendota Subbasin Coordination Committee (Coordination Committee), and implemented by the Northern and Central Delta-Mendota Regions in their GSP-specific water budgets. This section documents those decisions, along with other key coordinated decisions agreed upon by all GSPs developed within the Delta-Mendota Subbasin, such as hydrologic period selection and application of climate change factors. A list of all common assumptions and decisions reached by the Delta-Mendota Subbasin GSP Groups may be found as an attachment to the Subbasin Coordination Agreement (Appendix A).

Historic Water Budget

The historic water budget period is defined as WY2003 through WY2012. The Coordination Committee determined that the WY2003-2012 timeframe captured a balance of wet and dry conditions largely prior to the most recent drought (Figure 5-121). The selected time period is also consistent with GSP Emergency Regulations §354.18(c)(2)(C), which requires "a quantitative assessment of the historic water budget, starting with the most recently available information and extending back a minimum of 10 years…," where WY2013 is defined as the year with the most recently available information.

Current Water Budget

The current water budget year is defined as WY2013. While "current water budget conditions" are defined in the GSP Emergency Regulations §354.18(c)(1) as the year with "the most recent population, land use, and hydrologic conditions," WY2015, WY2016 and WY2017 were not thought to be representative of the Delta-Mendota Subbasin under "normal" or "average" conditions. Response to the most recent drought began in WY2014 with some initial fallowing of lands. By WY2015 and WY2016, which are both classified as dry years, more lands were fallowed throughout the Subbasin in response to multiple dry year conditions. Agricultural production was higher in WY2017, compared to WY2015 and WY2016, but the delivery allocations from the Central Valley Project (CVP) came late in the season, so a considerable amount of land was still fallowed. By WY2018, agricultural land production increased and was similar to conditions in WY2013, however complete datasets were not yet available for use in the water budgets. Therefore, the Coordination Committee agreed that WY2013 represents the most recent water year with a complete data set representing typical demands and supplies.

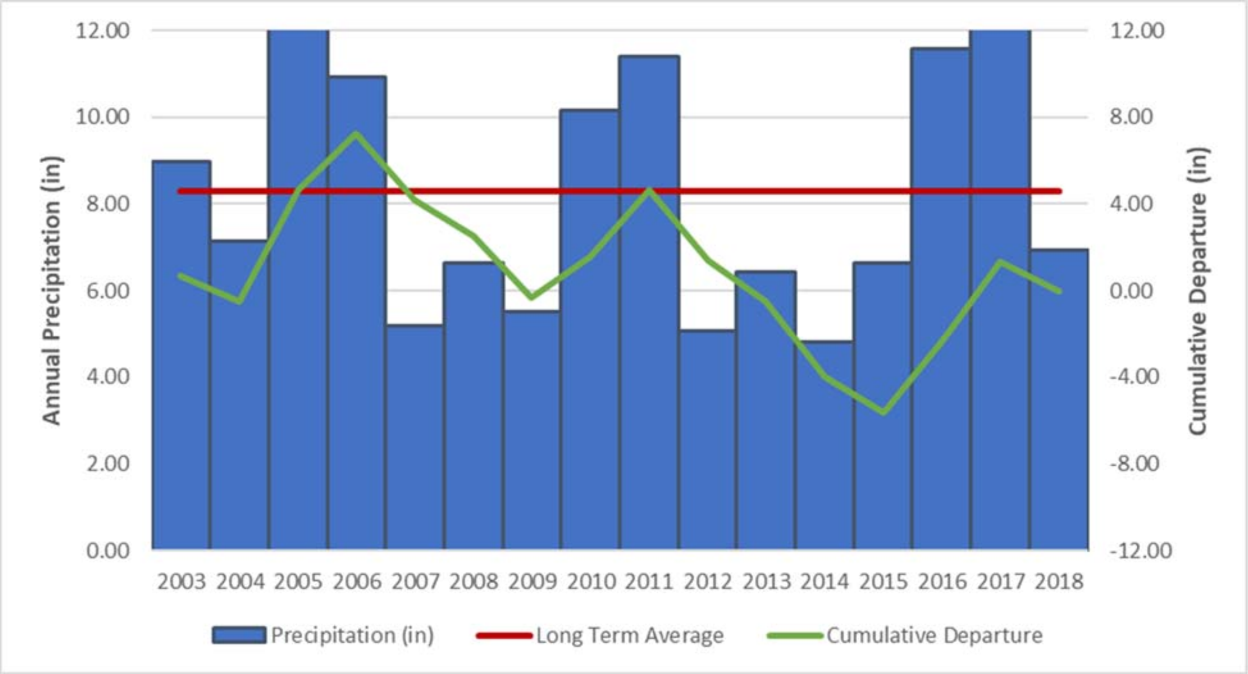

Figure 5-121. Precipitation and Cumulative Departure from Mean, WY2003-2018

Projected Water Budgets

The projected water budget period is defined as WY2014 through WY2070. According to the GSP Emergency Regulations §354.18(c)(3)(A), "projected hydrology shall utilize 50 years of historical precipitation, evapotranspiration, and streamflow information as the baseline condition for estimating future hydrology." The selected period for the projected water budgets meets this requirement by establishing a 50-year period, where the timeframe is continuous between the historic, current, and projected water budgets. Where available, actual data was incorporated for WY2014 through WY2018.

Based on discussion among the Technical Working Group members, the hydrologic period for simulating the projected water budget hydrologic schema was chosen as WY1979-2017, then wrapping around to include WY1965-1978 hydrology to fill the projected water budget period. Actual data and hydrology were used for WY2014 through WY2017, with the representative water years simulating WY2018 and beyond (e.g. WY2018 is represented by the hydrology from WY1979; WY2019 is represented by the hydrology from WY1980; and so forth).

Climate change data under 2030 and 2070 conditions was provided by DWR for use in development of the projected water budgets with climate change conditions (DWR, 2018b). These data, however, did not span the full projection period, with a gap in CCFs provided for WY2051 through WY2056. Per communications with DWR and in coordination with the Technical Working Group and Coordination Committee, hydrologic water years from the DWR dataset were selected for these years in order to identify the appropriate CCF. The methodology for applying DWR-provided climate change factors was agreed upon by the Technical Working Group. Climate change factors under 2030 conditions were applied to WY2018 through WY2045 and climate change factors under 2070 conditions were applied to WY2046 through WY2070. The precipitation and evapotranspiration datasets provided by DWR include monthly climate change factors from Calendar Year 1915 through 2011. The hydrologic years chosen to fill gaps in the CCF dataset for the precipitation and evapotranspiration climate change factors for representative WY2012 through WY2017 are shown in Table 5-11. These hydrologic years were selected to best approximate the water conditions of the representative water year.

Streamflow climate change factors from DWR were not applied within the Northern and Central Delta-Mendota Regions' projected water budgets as they were based on out-of-date modeling and, when applied, resulted in skewed results for future surface water deliveries that were not deemed to be reasonable. Agencies within the Northern and Central Delta-Mendota Regions instead provided projections by water year type for future surface water deliveries.

Table 5-11. Representative Water Years for Climate Change Factors, Precipitation, and Evapotranspiration

Simulated Projected Water Budget Year	Hydrologic Year	Proxy Water Year for Climate Change Factors
2051	2012	2001
2052	2013	1992
2053	2014	1976
2054	2015	1977
2055	2016	2002
2056	2017	2011

Other Common Decisions

The following water year type designations were agreed upon by all GSP Groups: Wet, Average, Dry, and Shasta Critical (Table 5-12). Wet and Dry water year designations are consistent with the San Joaquin River Index and "Average" combines the Above Normal and Below Normal designations from the San Joaquin River Index. Shasta Critical years are also designated upon the request of the San Joaquin River Exchange Contractors (SJREC), as it impacts surface water deliveries to exchange contracts through the CVP. Shasta Critical designations are dependent on the volume of storage in Shasta Reservoir and U.S. Bureau of Reclamation's operating rules for CVP deliveries.

Since there are no known barriers restricting horizontal gradients between GSP Groups, boundary flows to and from portions of the Delta-Mendota Subbasin adjacent to the Northern and Central Delta-Mendota Regions were coordinated with the GSP Groups preparing those water budgets and compared for consistency prior to the adoption of the historic and current water budgets. Representatives from the Northern and Central Delta-Mendota Regions met with the SJREC and Fresno County GSP Groups to compare boundary flow conditions.

Table 5-12. Modeled Water Year by Water Year Type

Modeled Year	Hydrologic Year	San Joaquin River Index Water Year Type	Delta-Mendota Subbasin Water Year Type	Modeled Year	Hydrologic Year	San Joaquin River Index Water Year Type	Delta-Mendota Subbasin Water Year Type
2003	2003	Below Normal	Average	2037	1998	Wet	Wet
2004	2004	Dry	Dry	2038	1999	Above Normal	Average
2005	2005	Wet	Wet	2039	2000	Above Normal	Average
2006	2006	Wet	Wet	2040	2001	Dry	Dry
2007	2007	Critical	Dry	2041	2002	Dry	Dry
2008	2008	Critical	Dry	2042	2003	Below Normal	Average
2009	2009	Below Normal	Average	2043	2004	Dry	Dry
2010	2010	Above Normal	Average	2044	2005	Wet	Wet
2011	2011	Wet	Wet	2045	2006	Wet	Wet
2012	2012	Dry	Dry	2046	2007	Critical	Dry
2013	2013	Critical	Dry	2047	2008	Critical	Dry
2014	2014	Critical	Shasta Critical	2048	2009	Below Normal	Average
2015	2015	Critical	Shasta Critical	2049	2010	Above Normal	Average
2016	2016	Dry	Dry	2050	2011	Wet	Wet
2017	2017	Wet	Wet	2051	2012	Dry	Dry
2018	1979	Above Normal	Average	2052	2013	Critical	Dry
2019	1980	Wet	Wet	2053	2014	Critical	Shasta Critical
2020	1981	Dry	Dry	2054	2015	Critical	Shasta Critical
2021	1982	Wet	Wet	2055	2016	Dry	Dry
2022	1983	Wet	Wet	2056	2017	Wet	Wet
2023	1984	Above Normal	Average	2057	1965	Wet	Wet
2024	1985	Dry	Dry	2058	1966	Below Normal	Average
2025	1986	Wet	Wet	2059	1967	Wet	Wet
2026	1987	Critical	Dry	2060	1968	Dry	Dry
2027	1988	Critical	Dry	2061	1969	Wet	Wet
2028	1989	Critical	Dry	2062	1970	Above Normal	Average
2029	1990	Critical	Dry	2063	1971	Below Normal	Average
2030	1991	Critical	Shasta Critical	2064	1972	Dry	Dry
2031	1992	Critical	Shasta Critical	2065	1973	Above Normal	Average
2032	1993	Wet	Wet	2066	1974	Wet	Wet
2033	1994	Critical	Dry	2067	1975	Wet	Wet
2034	1995	Wet	Wet	2068	1976	Critical	Dry
2035	1996	Wet	Wet	2069	1977	Critical	Dry
2036	1997	Wet	Wet	2070	1978	Wet	Wet

5.4.4 Methodology Selected and Spreadsheet Model Development

Groundwater Sustainability Agencies (GSAs) in the Northern and Central Delta-Mendota Regions initially planned to use the Central Valley Hydrologic Model 2 (CVHM2) to develop water budgets for their GSP regions. In recent years, local agencies within the Delta-Mendota Subbasin invested in a cooperative agreement with the U.S. Geological Survey (USGS) to refine CVHM2 and increase the amount of local data from the Subbasin incorporated in the model update. Funding and data were provided to USGS from local agencies for this effort. As of July 2019, CVHM2 remains under development by the USGS and therefore not available for use in developing the required water budgets.

A beta version of CVHM2 was released in April 2018 for use by the Northern and Central Delta-Mendota Regions, with a subsequent updated version provided in July 2018. An evaluation of the calibration status of the July 2018 version determined that this version of CVHM2 was not adequately calibrated to the Plan area and therefore would not produce reasonable and usable water budgets. Additional groundwater pumping, surface water delivery, and canal seepage data from local entities were provided to the USGS for further local calibration in July and August 2018. However, as previously noted, as of July 2019, USGS is still in the process of further calibrating CVHM2 within the Plan area. Due to differences in USGS's timeline for the release of CVHM2 and the timeline for this GSP, an alternative approach was selected for developing the required water budgets.

The selected alternative approach for water budget development for the Northern and Central Delta-Mendota Regions is a hybrid approach that combines the use of local data and CVHM2 parameters with standard numerical calculations derived from peer-reviewed literature or professional judgment. All water budgets presented herein are based primarily on local land use, water supply, and groundwater elevation data received from agencies as well as data from publicly available sources. Where local data are unavailable, data from CVHM2 is used. Groundwater gradient, underflow, and change in storage calculations are derived from available hydrograph data for the historic and current water budget time periods. Inputs related to approved projects and management actions were derived from other planning documents, such as Integrated Regional Water Management Plans, or from local agencies. For more detail regarding the spreadsheet model developed for the Northern and Central Delta-Mendota Regions, refer to Appendix D *Water Budgets Model Development Technical Memorandum*.

The spreadsheet model for the Northern and Central Delta-Mendota Regions was used to develop five water budget scenarios:

- Historic water budget represents land surface system and groundwater system conditions from WY2003 through WY2012.
- Current water budget represents land surface system and groundwater system conditions during WY2013.
- Projected Baseline water budget represents the simulated future condition of the land surface system and groundwater system from WY2014 through WY2070 under historic hydrologic conditions and water use patterns within the Plan area.
- Projected water budget with Climate Change (CC) represents the simulated future condition of the land surface system and groundwater system from WY2014 through WY2070 relative to the projected baseline water budget with the addition of the application of DWR's climate change factors.
- Projected water budget with Climate Change (CC) and Projects & Management Actions (P&MAs) represents simulated future condition of the land surface system and groundwater system from WY2014 through WY2070 relative to the projected baseline water budget with the addition of DWR's climate change factors as well as projects and management actions to achieve groundwater sustainability within the Plan area by 2040, as required by SGMA.

5.4.5 Water Budget Definitions and Assumptions

The spreadsheet model simulates the major hydrologic processes that affect the flow of surface water and groundwater within the Northern and Central Delta-Mendota Regions. The primary components of the land surface budget and groundwater budget are presented in Table 5-13 and Table 5-14, respectively.

Table 5-13. Land Surface Budget Category Definitions

Water Budget Flow Category	Definition
Inflow	*Includes volumes that are applied to the land surface within the defined budget area.*
Precipitation	Total atmospheric precipitation that occurs onto the defined budget area.
Pumping	Total volume of water applied to the defined budget area from production wells within the defined budget area.
Tile Drainage	Total volume of water applied to the defined budget area from tile drains within the defined budget area.
Surface Water Deliveries	Total volume of water delivered to the defined budget area from diversions off the San Joaquin River, Delta-Mendota Canal, California Aqueduct, and other local surface water sources.
Outflow	*Includes volumes that flow out of the land surface within the defined budget area. This includes flows to the aquifer and to other land surface budget areas.*
Deep Percolation	Total volume of water that seeps past the root zone and into the groundwater aquifer. This includes applied water seepage, as well as stream seepage (from the San Joaquin River, Delta-Mendota Canal, and California Aqueduct) and delivery losses.
Runoff	Total volume of water that leaves the defined budget area through surface runoff. This does not include river flows but is a portion of applied water and precipitation.
Evapotranspiration	Total volume of water that returns to the atmosphere through either evaporation or through transpiration.

Note: Surface water flows are not directly tabulated in the water budgets, but river seepage is accounted for in the Deep Percolation category. This limitation is discussed in Appendix D *Water Budgets Model Development Technical Memorandum*.

Table 5-14. Groundwater Budget Category Definitions

Water Budget Flow Category	Definition
Inflow	*Includes volumes that flow into the groundwater aquifer within the defined budget area. This includes volumes coming from the surface water budget and from adjacent budget areas.*
Deep Percolation	Total volume of water that seeps past the root zone and into the groundwater aquifer. This includes applied water seepage, as well as stream seepage (from the San Joaquin River, Delta-Mendota Canal, and California Aqueduct) and delivery losses.
Upper Aquifer Underflows	Groundwater inflows into the defined budget area in the Upper Aquifer from adjacent water budgets.
Lower Aquifer Underflows	Groundwater inflows into the defined budget area in the Lower Aquifer from adjacent water budgets.
Outflow	*Includes volumes that flow out of the groundwater aquifer within the defined budget area. This includes volumes pumped to the surface and flows to adjacent budget areas.*
Pumping	Total volume of water extracted from the defined budget area from production wells within the defined budget area.
Tile Drainage	Total volume of water removed from the defined budget area from tile drains within the defined budget area.
Upper Aquifer Underflows	Groundwater flows out of the defined budget area in the Upper Aquifer into adjacent water budgets.
Lower Aquifer Underflows	Groundwater flows out of the defined budget area in the Lower Aquifer into adjacent water budgets.
Change in Storage	*Includes volumetric differences of storage in the aquifer as compared to the previous water year. In an ideal case, volumes should sum to be equal to inflows minus outflows.*
Upper Aquifer Change in Storage	Change in storage in the Upper Aquifer compared to prior the water year. This is not a total storage amount.
Lower Aquifer Change in Storage	Change in storage in the Lower Aquifer compared to prior the water year. This is not a total storage amount.

Note: Surface water flows are not directly tabulated in the budgets, but river seepage is accounted for in the Deep Percolation category. This limitation is discussed in Appendix D *Water Budgets Model Development Technical Memorandum*.

Historic and Current Water Budget Assumptions

The historic and current water budgets are presented side-by-side and operate under the same assumptions and with the same data sources. Assumptions and sources for each of the budget flow categories are listed in Table 5-15 and Table 5-16.

Table 5-15. Historic and Current Land Surface Budget Assumptions

Water Budget Flow Category	Data Source	Data Assumptions
Precipitation	Various CIMIS stations	CIMIS data was applied across the Plan area so that the nearest or most representative station's data were applied to each GSA member agency. The monthly precipitation data were then used to calculate yearly precipitation volumes.
Pumping	GSA member agencies historic agricultural pumping, and urban pumping historic data	Agricultural pumping was combined with urban pumping volumes.
Tile Drainage	GSA member agencies tile drainage historic data	All reported tile drainage was reapplied and treated as another applied water source.
Surface Water Deliveries	GSA member agencies surface water delivery and diversion historic data	All reported surface water delivery data counted as a source for applied water. The differences between diversions and deliveries (where available) were used to quality check calculated Deep Percolation rates.
Deep Percolation	Calculated from other applied water volumes	CVHM2 trends were aggregated and trends in applied water and precipitation proportions becoming deep percolation were used for the Historic & Current Period. Since Deep Percolation in CVHM2 accounts for Delta-Mendota Canal, California Aqueduct, and San Joaquin River seepage, these rates implicitly account for stream seepage volumes.
Runoff	Calculated from other applied water volumes	CVHM2 trends were aggregated based on Water Year Types during the Historic & Current period. Trends in applied water and precipitation proportions becoming runoff were used.
Evapotranspiration	Various CIMIS Stations ET_0 data, Cal Poly ITRC Crop Coefficient data, GSA member agencies historic land use data	CIMIS data was applied across the Plan area so that the nearest or most representative station's data were applied to each GSA member agency. The monthly ET_0 data were then used with observed seasonal land use trends, and crop coefficients (for each crop type from the Cal Poly Crop Coefficients) to calculate evapotranspiration volumes.

Table 5-16. Historic and Current Groundwater Budget Assumptions

Water Budget Flow Category	Data Source	Data Assumptions
Deep Percolation	See Table 5-15	See Table 5-15
Upper Aquifer Underflows	GSA member agencies observation well data, CASGEM observation well data, Westside Subbasin's Groundwater Model results, SJREC transmissivity data	Hydrographs were created and considered with transmissivity data to calculate intra-subbasin underflows. The Westside Subbasin's Groundwater Model results were used on the southern Subbasin boundary with the Westside Subbasin to determine underflows. Hydrographs were also developed to evaluate underflows to Tracy, Modesto, Turlock, and Kings Subbasins.
Lower Aquifer Underflows	Calculated from Upper Aquifer Underflows	Lower Aquifer Underflows were assumed to be a portion of Upper Aquifer Underflows. The proportion utilized was the same as the proportion of pumping volumes from the Upper Aquifer versus the Lower Aquifer.
Pumping	See Table 5-15	See Table 5-15
Upper Aquifer Change in Storage	GSA member agencies observation well data, CASGEM observation well data, CVHM2 storativity data	Hydrographs were grouped spatially into designated zones in the Plan area for the calculation of change in storage on a sub-regional basis. Change in water surface elevations between water years were determined for each sub-regional zone. These data and local storativity values were combined to determine the change in storage for each sub-regional zone for each water year.
Lower Aquifer Change in Storage	Calculated from Upper Aquifer Change in Storage	Lower Aquifer Change in Storage was assumed to be a portion of Upper Aquifer Change in Storage. The proportion was based on professional judgment and local knowledge.

Projected Water Budget Data Sources

The results of the three projected water budgets are presented separately, but they operate under the same assumptions and with the same data sources. Assumptions and sources for the flow categories in the baseline projected water budget are listed in Table 5-17 and Table 5-18. Differences in assumptions and sources between the three projected budgets are described in Table 5-19. To estimate future flows, historic data were applied according to the representative years selected for the projected budget timeline. Those years are specified in Table 5-11, and the assignment of the representative water years is discussed in Section 5.4.3.

Table 5-17. Projected Land Surface Budget Assumptions

Water Budget Flow Category	Data Source	Data Assumptions
Precipitation	Various CIMIS stations	CIMIS data were applied across the Plan area so that the nearest or most representative station's data were applied to each GSA area. The monthly precipitation data were then used to calculate yearly precipitation volumes.
Pumping	Calculated	For irrigated lands, precipitation and surface water (where available) were assumed to be used to meet crop demands with groundwater used to meet any remaining crop demand. Pumping was therefore calculated to meet the remaining agricultural demand after applied water, precipitation, and water losses were accounted for. Additional runoff and deep percolation were then accounted for after groundwater was 'applied'. Agricultural demands were calculated seasonally, by crop type, and by GSA member agencies operational patterns.
Tile Drainage	GSA member agencies tile drainage historic data	All reported tile drainage was assumed to be reapplied as irrigation and therefore was treated as another applied water source.
Surface Water Deliveries	GSA member agencies surface water delivery and diversion historic data	All reported surface water delivery data counted as a source for applied water. The differences between diversions and deliveries (where available) were used to quality check calculated deep percolation rates.
Deep Percolation	Calculated from other applied water volumes	CVHM2 trends were aggregated and trends in applied water and precipitation proportions becoming deep percolation were used for the Historic & Current Period and aggregated into trends by Water Year Type. Since Deep Percolation in CVHM2 accounts for Delta-Mendota Canal, California Aqueduct, and San Joaquin River seepage, these rates implicitly account for stream seepage volumes.
Runoff	Calculated from other applied water volumes	CVHM2 trends were aggregated and trends in applied water and precipitation proportions becoming runoff were used for the Historic & Current Period and aggregated by Water Year Type.
Evapotranspiration	Various CIMIS Stations ET_0 data, Cal Poly Crop Coefficient data, GSA member agencies historic land use data	CIMIS data were applied across the Plan area so that the nearest or most representative station's data were applied to each GSA area. The monthly ET_0 data were then used with observed seasonal land use trends and crop coefficients (for each crop type from the Cal Poly Crop Coefficients[1]) to calculate Evapotranspiration volumes.

[1] Cal Poly ITRC Crop Coefficient data for Zone 14, aggregated by irrigation type, water year type, and crop type.

Table 5-18. Projected Groundwater Budget Assumptions

Water Budget Flow Category	Data Sources	Data Assumptions
Deep Percolation	See Table 5-17	See Table 5-17
Upper Aquifer Underflows	See Table 5-16	Underflows were averaged from the historic period according to water year type and by principal aquifer. Underflows were adjusted in the two projected water budgets with CCF and P&MAs budgets to reflect changes in interactions with the land surface.
Lower Aquifer Underflows	See Table 5-16	
Pumping	See Table 5-17	See Table 5-17
Upper Aquifer Change in Storage	GSA member agencies observation well data, CASGEM observation well data, CVHM2 storativity data	Hydrographs were grouped spatially into sub-regional zones in the Plan area. Change in water surface elevations between water years were determined for each sub-regional zone. These data and local storativity data were combined to determine the change in storage for each sub-regional zone for each water year in the projected period. These changes were averaged by water year type and used for each projected year.
Lower Aquifer Change in Storage	Calculated from Upper Aquifer Change in Storage	Lower Aquifer Change in Storage was assumed to be a portion of Upper Aquifer Change in Storage. The proportion was based on professional judgment and local knowledge.

Table 5-19. Differences in Sources and Assumptions Between Projected Water Budgets

Water Budget Flow Category	Changes Made between the Baseline Projected Budget and Budget with CC	Changes Made between Budget with CC and the P&MAs Budget
Precipitation	Precipitation rates were adjusted according to multipliers from the VIC hydrological gridded data set.[1] Precipitation was scaled according to the spatial overlap of the gridded data set and the Plan area.	No additional changes were made.
Pumping	Additional estimated pumping volume is due to the changes in Precipitation and Evapotranspiration.	The decreased estimated pumping volume in the P&MAs budget is due to the effects of Projects & Management Actions on increased Surface Water Deliveries.
Tile Drainage	No changes were made.	No changes were made.
Surface Water Deliveries	No changes were made.[2]	Additional volume of surface water deliveries in the P&MAs budget is due to the effects of Projects & Management Actions. (which are anticipated to increase surface water deliveries to the GSP area)
Deep Percolation	Additional volume of deep percolation estimated is due to the changes in Precipitation and Evapotranspiration.	Additional volume of deep percolation in the P&MAs budget is due to the effects of anticipated increases in applied surface water resulting from the Projects & Management Actions
Runoff	Additional volume of runoff is due to the changes in Precipitation and Evapotranspiration.	Additional volume of percolation in the P&MAs budget is due to the effects of anticipated increases in applied surface water resulting from the Projects & Management Actions.
Evapotranspiration	ET_0 rates were adjusted according to multipliers from the VIC hydrological gridded data set.[1] ET_0 was scaled according to the spatial overlap of the VIC hydrological gridded data set* and the GSP Area.	No additional changes were made.
Upper Aquifer Underflows	No changes were made.[2]	No changes were made.
Lower Aquifer Underflows	No changes were made. [2]	No changes were made.
Upper Aquifer Change in Storage	Additional Pumping volumes were split between the Upper and Lower Aquifer Change in Storage volumes. Additional Deep Percolation volumes were applied to the Upper Aquifer Change in Storage volume.	Reduced Pumping volumes were split between the Upper and Lower Aquifer Change in Storage volumes. Additional Deep Percolation volumes were applied to the Upper Aquifer Change in Storage volume.
Lower Aquifer Change in Storage	Additional Pumping volumes were split between the Upper and Lower Aquifer Change in Storage volumes.	Reduced pumping volumes were split between the Upper and Lower Aquifer Change in Storage volumes. Reductions that were due to projects and management actions specifically targeted at Lower Aquifer Pumping rates were not split between the Aquifers but were attributed entirely to the Lower Aquifer Change in Storage volume.

[1] Gridded Statewide Precipitation and Evapotranspiration (ET) Change Factors were developed for the Water Storage Investment Program (WSIP), using the Variable Infiltration Capacity (VIC) Macroscale Hydrology Model. (CA DWR 2018).

[2] Projected surface water deliveries were based on volumes provided by the GSAs Member Agencies. These volumes represent their anticipated future supplies. Climate change factors provided by DWR were not applied to Historic and Current surface water deliveries as they are based on an outdated model. These climate change factors, when applied, result in projected future surface water deliveries that do not represent anticipated future conditions.

5.4.6 Water Budget Estimates

Flow category definitions, data sources, and their assumptions are described in Section 5.4.5. The annual estimates for the historic, current, and projected water budgets are detailed in the following tables in acre-feet per year (AFY):

- Historic Water Budget
    - Land Surface Budget (Table 5-20)
    - Groundwater Budget (Table 5-21)
    - Change in Storage (Table 5-22)
- Current Water Budget
    - Land Surface Budget (Table 5-23)
    - Groundwater Budget (Table 5-24)
    - Change in Storage (Table 5-25)
- Baseline Projected Water Budget
    - Land Surface Budget (Table 5-26)
    - Groundwater Budget (Table 5-27)
    - Change in Storage (Table 5-28)
- Projected Water Budget with Climate Change
    - Land Surface Budget (Table 5-29)
    - Groundwater Budget (Table 5-30)
    - Change in Storage (Table 5-31)
- Projected Water Budget with Climate Change and Projects & Management Actions
    - Land Surface Budget (Table 5-32)
    - Groundwater Budget (Table 5-33)
    - Change in Storage (Table 5-34)

Table 5-20. Land Surface Budget, Historic Water Budget (AFY)

Land Surface Budget														
Simulated Water Year	Delta-Mendota Subbasin Water Year Type	Inflows									Outflows			
		Surface Water Deliveries				Groundwater Pumping		Tile Drainage	Precipitation	Total Inflows	Runoff [1]	Deep Percolation	Evapotranspiration	Total Outflows
		San Joaquin River	Central Valley Project	State Water Project	Local Supplies	Municipal & Industrial	Agricultural							
2003	Average	78,000	365,000	4,000	0	3,000	92,000	30	200,000	742,000	63,000	66,000	606,000	736,000
2004	Dry	85,000	359,000	5,000	0	3,000	86,000	30	174,000	711,000	52,000	57,000	580,000	688,000
2005	Wet	79,000	347,000	4,000	0	4,000	102,000	30	312,000	848,000	62,000	75,000	662,000	799,000
2006	Wet	66,000	353,000	4,000	0	4,000	99,000	30	248,000	774,000	60,000	65,000	663,000	788,000
2007	Dry	93,000	344,000	4,000	0	4,000	97,000	30	114,000	656,000	33,000	47,000	560,000	639,000
2008	Dry	97,000	269,000	2,000	0	4,000	140,000	30	142,000	654,000	56,000	47,000	598,000	700,000
2009	Average	109,000	234,000	2,000	0	4,000	128,000	30	125,000	602,000	28,000	42,000	647,000	717,000
2010	Average	105,000	271,000	3,000	0	4,000	112,000	30	227,000	721,000	49,000	60,000	590,000	699,000
2011	Wet	104,000	356,000	3,000	0	4,000	76,000	30	258,000	802,000	60,000	68,000	682,000	811,000
2012	Dry	124,000	316,000	3,000	0	4,000	106,000	30	112,000	665,000	28,000	47,000	559,000	634,000
Historic Average		94,000	322,000	3,000	0	4,000	104,000	30	191,000	718,000	49,000	58,000	615,000	722,000

[1] Runoff includes return flows to all surface water sources leaving the Plan area. Return flows were not separated due to model limitations.

Table 5-21. Groundwater Budget, Historic Water Budget (AFY)

Groundwater Budget										
Simulated Water Year	Delta-Mendota Subbasin Water Year Type	Inflows				Outflows				
		Deep Percolation	Upper Aquifer Underflows	Lower Aquifer Underflows	Total Inflows	Groundwater Pumping	Tile Drainage	Upper Aquifer Underflows	Lower Aquifer Underflows	Total Outflows
2003	Average	66,000	50,000	27,000	143,000	95,000	30	60,000	32,000	186,000
2004	Dry	57,000	56,000	29,000	142,000	89,000	30	65,000	34,000	188,000
2005	Wet	75,000	73,000	39,000	187,000	105,000	30	54,000	29,000	188,000
2006	Wet	65,000	61,000	32,000	158,000	103,000	30	54,000	29,000	186,000
2007	Dry	47,000	35,000	18,000	100,000	101,000	30	67,000	36,000	204,000
2008	Dry	47,000	40,000	21,000	108,000	144,000	30	76,000	40,000	259,000
2009	Average	42,000	36,000	19,000	98,000	132,000	30	67,000	35,000	234,000
2010	Average	60,000	56,000	30,000	146,000	115,000	30	60,000	32,000	207,000
2011	Wet	68,000	63,000	33,000	164,000	80,000	30	61,000	32,000	173,000
2012	Dry	47,000	38,000	20,000	105,000	110,000	30	66,000	35,000	212,000
Historic Average		58,000	51,000	27,000	136,000	108,000	30	63,000	33,000	204,000

Table 5-22. Change in Storage, Historic Water Budget (AFY)

Change in Storage				
Simulated Water Year	Delta-Mendota Subbasin Water Year Type	Change in Storage		
		Upper Aquifer	Lower Aquifer	Total Change in Storage
2003	Average	94,000	19,000	113,000
2004	Dry	(67,000)	(13,000)	(80,000)
2005	Wet	123,000	25,000	147,000
2006	Wet	(67,000)	(13,000)	(80,000)
2007	Dry	(157,000)	(31,000)	(188,000)
2008	Dry	(211,000)	(42,000)	(253,000)
2009	Average	(45,000)	(9,000)	(54,000)
2010	Average	77,000	15,000	92,000
2011	Wet	(64,000)	(13,000)	(76,000)
2012	Dry	(105,000)	(21,000)	(126,000)
Historic Average		(42,000)	(8,000)	(50,000)

Table 5-23. Land Surface Budget, Current Water Budget (AFY)

Land Surface Budget														
Simulated Water Year	Delta-Mendota Subbasin Water Year Type	Inflows									Outflows			
		Surface Water Deliveries				Groundwater Pumping		Tile Drainage	Precipitation	Total Inflows	Runoff [1]	Deep Percolation	Evapotranspiration	Total Outflows
		San Joaquin River	Central Valley Project	State Water Project	Local Supplies	Municipal & Industrial	Agricultural							
2013	Dry	127,000	283,000	3,000	0	4,000	119,000	30	149,000	685,000	51,000	50,000	568,000	669,000

[1] Runoff includes return flows to all surface water sources leaving the Plan area. Return flows were not separated due to model limitations.

Table 5-24. Groundwater Budget, Current Water Budget (AFY)

Groundwater Budget										
Simulated Water Year	Delta-Mendota Subbasin Water Year Type	Inflows				Outflows				
		Deep Percolation	Upper Aquifer Underflows	Lower Aquifer Underflows	Total Inflows	Groundwater Pumping	Tile Drainage	Upper Aquifer Underflows	Lower Aquifer Underflows	Total Outflows
2013	Dry	50,000	42,000	22,000	114,000	124,000	0	52,000	27,000	203,000

Table 5-25. Change in Storage, Current Water Budget (AFY)

Groundwater Budget				
Simulated Water Year	Delta-Mendota Subbasin Water Year Type	Change in Storage		
		Upper Aquifer	Lower Aquifer	Total Change in Storage
2013	Dry	(73,000)	(15,000)	(88,000)

Table 5-26. Land Surface Budget, Baseline Projected Water Budget (AFY)

Land Surface Budget														
Simulated Water Year	Delta-Mendota Subbasin Water Year Type	Inflows									Outflows			
		Surface Water Deliveries				Groundwater Pumping		Tile Drainage	Precipitation	Total Inflows	Runoff [1]	Deep Percolation	Evapotranspiration	Total Outflows
		San Joaquin River	Central Valley Project	State Water Project	Local Supplies	Municipal & Industrial	Agricultural							
2014	Shasta Critical	105,000	229,000	2,000	0	4,000	197,000	8,000	127,000	671,000	47,000	61,000	578,000	686,000
2015	Shasta Critical	60,000	210,000	1,000	0	4,000	198,000	8,000	134,000	615,000	38,000	48,000	542,000	628,000
2016	Dry	80,000	231,000	3,000	0	4,000	136,000	11,000	260,000	724,000	55,000	87,000	572,000	714,000
2017	Wet	74,000	303,000	3,000	0	4,000	123,000	12,000	264,000	784,000	65,000	90,000	648,000	803,000
2018	Average	60,000	320,000	2,000	0	4,000	121,000	10,000	196,000	713,000	51,000	74,000	585,000	710,000
2019	Wet	118,000	332,000	4,000	0	4,000	85,000	12,000	342,000	897,000	76,000	107,000	683,000	867,000
2020	Dry	141,000	272,000	3,000	0	5,000	115,000	11,000	211,000	757,000	50,000	67,000	584,000	700,000
2021	Wet	118,000	332,000	4,000	0	4,000	86,000	12,000	342,000	898,000	76,000	107,000	683,000	867,000
2022	Wet	118,000	332,000	4,000	0	5,000	79,000	12,000	410,000	960,000	81,000	114,000	697,000	893,000
2023	Average	126,000	310,000	3,000	0	5,000	109,000	10,000	327,000	891,000	66,000	93,000	617,000	776,000
2024	Dry	141,000	272,000	3,000	0	5,000	110,000	11,000	320,000	863,000	65,000	89,000	594,000	748,000
2025	Wet	118,000	332,000	4,000	0	5,000	80,000	12,000	461,000	1,012,000	87,000	120,000	695,000	902,000
2026	Dry	141,000	272,000	3,000	0	6,000	111,000	11,000	304,000	848,000	62,000	86,000	593,000	741,000
2027	Dry	141,000	272,000	3,000	0	6,000	110,000	11,000	336,000	879,000	67,000	92,000	585,000	744,000
2028	Dry	141,000	272,000	3,000	0	6,000	112,000	11,000	277,000	823,000	58,000	77,000	601,000	735,000
2029	Dry	141,000	272,000	3,000	0	6,000	115,000	11,000	217,000	764,000	49,000	64,000	575,000	689,000
2030	Shasta Critical	122,000	244,000	2,000	0	6,000	186,000	8,000	155,000	722,000	47,000	59,000	585,000	691,000
2031	Shasta Critical	122,000	244,000	2,000	0	6,000	186,000	8,000	165,000	732,000	48,000	63,000	582,000	694,000
2032	Wet	118,000	332,000	4,000	0	6,000	97,000	12,000	334,000	903,000	76,000	106,000	699,000	881,000
2033	Dry	141,000	272,000	3,000	0	6,000	116,000	11,000	189,000	739,000	48,000	63,000	564,000	676,000
2034	Wet	118,000	332,000	4,000	0	6,000	80,000	12,000	341,000	893,000	76,000	107,000	659,000	842,000
2035	Wet	118,000	332,000	4,000	0	6,000	91,000	12,000	332,000	894,000	74,000	101,000	695,000	870,000
2036	Wet	118,000	332,000	4,000	0	6,000	140,000	12,000	289,000	900,000	72,000	98,000	719,000	889,000
2037	Wet	118,000	332,000	4,000	0	6,000	83,000	12,000	393,000	948,000	85,000	127,000	653,000	866,000
2038	Average	126,000	310,000	3,000	0	6,000	152,000	10,000	196,000	805,000	59,000	84,000	593,000	735,000
2039	Average	126,000	310,000	3,000	0	6,000	167,000	10,000	177,000	800,000	55,000	72,000	615,000	742,000
2040	Dry	141,000	272,000	3,000	0	6,000	141,000	11,000	199,000	773,000	54,000	77,000	573,000	704,000
2041	Dry	141,000	272,000	3,000	0	7,000	153,000	11,000	152,000	739,000	48,000	62,000	571,000	682,000
2042	Average	126,000	310,000	3,000	0	6,000	153,000	10,000	200,000	809,000	58,000	81,000	606,000	746,000
2043	Dry	141,000	272,000	3,000	0	7,000	151,000	11,000	174,000	759,000	53,000	73,000	580,000	706,000
2044	Wet	118,000	332,000	4,000	0	6,000	110,000	12,000	312,000	894,000	75,000	105,000	662,000	842,000
2045	Wet	118,000	332,000	4,000	0	7,000	121,000	12,000	248,000	841,000	68,000	89,000	663,000	820,000

Land Surface Budget														
Simulated Water Year	Delta-Mendota Subbasin Water Year Type	Inflows									Outflows			
		Surface Water Deliveries				Groundwater Pumping		Tile Drainage	Precipitation	Total Inflows	Runoff [1]	Deep Percolation	Evapotranspiration	Total Outflows
		San Joaquin River	Central Valley Project	State Water Project	Local Supplies	Municipal & Industrial	Agricultural							
2046	Dry	141,000	272,000	3,000	0	7,000	156,000	11,000	114,000	704,000	44,000	52,000	560,000	656,000
2047	Dry	141,000	272,000	3,000	0	7,000	170,000	11,000	142,000	746,000	47,000	57,000	598,000	702,000
2048	Average	126,000	310,000	3,000	0	6,000	209,000	10,000	125,000	790,000	53,000	63,000	647,000	762,000
2049	Average	126,000	310,000	3,000	0	6,000	130,000	10,000	227,000	814,000	60,000	90,000	590,000	740,000
2050	Wet	118,000	332,000	4,000	0	7,000	124,000	12,000	258,000	854,000	66,000	84,000	682,000	832,000
2051	Dry	141,000	272,000	3,000	0	7,000	153,000	11,000	112,000	699,000	44,000	52,000	559,000	654,000
2052	Dry	141,000	272,000	3,000	0	7,000	143,000	11,000	149,000	726,000	47,000	57,000	568,000	672,000
2053	Shasta Critical	122,000	244,000	2,000	0	7,000	220,000	8,000	128,000	729,000	49,000	62,000	601,000	711,000
2054	Shasta Critical	122,000	244,000	2,000	0	7,000	216,000	8,000	138,000	735,000	40,000	48,000	562,000	650,000
2055	Dry	141,000	272,000	3,000	0	7,000	152,000	11,000	262,000	848,000	56,000	87,000	587,000	730,000
2056	Wet	118,000	332,000	4,000	0	7,000	156,000	12,000	275,000	903,000	68,000	91,000	696,000	855,000
2057	Wet	118,000	332,000	4,000	0	7,000	96,000	12,000	342,000	911,000	77,000	107,000	683,000	868,000
2058	Average	126,000	310,000	3,000	0	6,000	147,000	10,000	199,000	803,000	57,000	78,000	607,000	741,000
2059	Wet	118,000	332,000	4,000	0	7,000	96,000	12,000	342,000	911,000	77,000	107,000	683,000	868,000
2060	Dry	141,000	272,000	3,000	0	7,000	126,000	11,000	211,000	770,000	50,000	67,000	584,000	701,000
2061	Wet	118,000	332,000	4,000	0	7,000	96,000	12,000	342,000	911,000	77,000	107,000	683,000	868,000
2062	Average	126,000	310,000	3,000	0	6,000	147,000	10,000	199,000	803,000	57,000	78,000	607,000	741,000
2063	Average	126,000	310,000	3,000	0	6,000	147,000	10,000	199,000	803,000	57,000	78,000	607,000	741,000
2064	Dry	141,000	272,000	3,000	0	7,000	126,000	11,000	211,000	770,000	50,000	67,000	584,000	701,000
2065	Average	126,000	310,000	3,000	0	6,000	147,000	10,000	199,000	803,000	57,000	78,000	607,000	741,000
2066	Wet	118,000	332,000	4,000	0	7,000	96,000	12,000	342,000	911,000	77,000	107,000	683,000	868,000
2067	Wet	118,000	332,000	4,000	0	7,000	96,000	12,000	342,000	911,000	77,000	107,000	683,000	868,000
2068	Dry	141,000	272,000	3,000	0	7,000	126,000	11,000	211,000	770,000	50,000	67,000	584,000	701,000
2069	Dry	141,000	272,000	3,000	0	7,000	126,000	11,000	211,000	770,000	50,000	67,000	584,000	701,000
2070	Wet	118,000	332,000	4,000	0	7,000	96,000	12,000	342,000	911,000	77,000	107,000	683,000	868,000
Projected Average		124,000	295,000	3,000	0	6,000	132,000	11,000	246,000	817,000	61,000	83,000	620,000	764,000

[1] Runoff includes return flows to all surface water sources leaving the Plan area. Return flows were not separated due to model limitations.

Table 5-27. Groundwater Budget, Baseline Projected Water Budget (AFY)

Groundwater Budget										
Simulated Water Year	Delta-Mendota Subbasin Water Year Type	Inflows				Outflows				
		Deep Percolation	Upper Aquifer Underflows	Lower Aquifer Underflows	Total Inflows	Groundwater Pumping	Tile Drainage	Upper Aquifer Underflows	Lower Aquifer Underflows	Total Outflows
2014	Shasta Critical	61,000	45,000	24,000	*131,000*	201,000	8,000	65,000	34,000	*308,000*
2015	Shasta Critical	48,000	45,000	24,000	*117,000*	203,000	8,000	65,000	34,000	*310,000*
2016	Dry	87,000	45,000	24,000	*157,000*	140,000	11,000	65,000	34,000	*251,000*
2017	Wet	90,000	73,000	38,000	*201,000*	127,000	12,000	56,000	30,000	*226,000*
2018	Average	74,000	51,000	27,000	*153,000*	125,000	10,000	62,000	33,000	*230,000*
2019	Wet	107,000	73,000	38,000	*219,000*	89,000	12,000	56,000	30,000	*188,000*
2020	Dry	67,000	45,000	24,000	*136,000*	119,000	11,000	65,000	34,000	*230,000*
2021	Wet	107,000	73,000	38,000	*219,000*	90,000	12,000	56,000	30,000	*189,000*
2022	Wet	114,000	73,000	38,000	*226,000*	84,000	12,000	56,000	30,000	*182,000*
2023	Average	93,000	51,000	27,000	*172,000*	114,000	10,000	62,000	33,000	*219,000*
2024	Dry	89,000	45,000	24,000	*158,000*	115,000	11,000	65,000	34,000	*226,000*
2025	Wet	120,000	73,000	38,000	*232,000*	85,000	12,000	56,000	30,000	*184,000*
2026	Dry	86,000	45,000	24,000	*155,000*	116,000	11,000	65,000	34,000	*227,000*
2027	Dry	92,000	45,000	24,000	*161,000*	116,000	11,000	65,000	34,000	*227,000*
2028	Dry	77,000	45,000	24,000	*146,000*	118,000	11,000	65,000	34,000	*229,000*
2029	Dry	64,000	45,000	24,000	*134,000*	121,000	11,000	65,000	34,000	*231,000*
2030	Shasta Critical	59,000	45,000	24,000	*128,000*	192,000	8,000	65,000	34,000	*299,000*
2031	Shasta Critical	63,000	45,000	24,000	*133,000*	192,000	8,000	65,000	34,000	*299,000*
2032	Wet	106,000	73,000	38,000	*218,000*	103,000	12,000	56,000	30,000	*202,000*
2033	Dry	63,000	45,000	24,000	*133,000*	122,000	11,000	65,000	34,000	*233,000*
2034	Wet	107,000	73,000	38,000	*219,000*	86,000	12,000	56,000	30,000	*185,000*
2035	Wet	101,000	73,000	38,000	*213,000*	97,000	12,000	56,000	30,000	*196,000*
2036	Wet	98,000	73,000	38,000	*209,000*	146,000	12,000	56,000	30,000	*244,000*
2037	Wet	127,000	73,000	38,000	*239,000*	89,000	12,000	56,000	30,000	*188,000*
2038	Average	84,000	51,000	27,000	*162,000*	158,000	10,000	62,000	33,000	*263,000*
2039	Average	72,000	51,000	27,000	*151,000*	173,000	10,000	62,000	33,000	*279,000*
2040	Dry	77,000	45,000	24,000	*146,000*	147,000	11,000	65,000	34,000	*258,000*
2041	Dry	62,000	45,000	24,000	*132,000*	159,000	11,000	65,000	34,000	*270,000*
2042	Average	81,000	51,000	27,000	*160,000*	159,000	10,000	62,000	33,000	*264,000*
2043	Dry	73,000	45,000	24,000	*143,000*	158,000	11,000	65,000	34,000	*269,000*
2044	Wet	105,000	73,000	38,000	*217,000*	116,000	12,000	56,000	30,000	*215,000*
2045	Wet	89,000	73,000	38,000	*201,000*	127,000	12,000	56,000	30,000	*226,000*
2046	Dry	52,000	45,000	24,000	*122,000*	163,000	11,000	65,000	34,000	*274,000*

Groundwater Budget										
Simulated Water Year	Delta-Mendota Subbasin Water Year Type	Inflows				Outflows				
		Deep Percolation	Upper Aquifer Underflows	Lower Aquifer Underflows	Total Inflows	Groundwater Pumping	Tile Drainage	Upper Aquifer Underflows	Lower Aquifer Underflows	Total Outflows
2047	Dry	57,000	45,000	24,000	*127,000*	177,000	11,000	65,000	34,000	*288,000*
2048	Average	63,000	51,000	27,000	*142,000*	215,000	10,000	62,000	33,000	*321,000*
2049	Average	90,000	51,000	27,000	*169,000*	137,000	10,000	62,000	33,000	*242,000*
2050	Wet	84,000	73,000	38,000	*195,000*	130,000	12,000	56,000	30,000	*229,000*
2051	Dry	52,000	45,000	24,000	*121,000*	160,000	11,000	65,000	34,000	*271,000*
2052	Dry	57,000	45,000	24,000	*127,000*	150,000	11,000	65,000	34,000	*260,000*
2053	Shasta Critical	62,000	45,000	24,000	*131,000*	227,000	8,000	65,000	34,000	*334,000*
2054	Shasta Critical	48,000	45,000	24,000	*117,000*	223,000	8,000	65,000	34,000	*330,000*
2055	Dry	87,000	45,000	24,000	*156,000*	159,000	11,000	65,000	34,000	*270,000*
2056	Wet	91,000	73,000	38,000	*203,000*	162,000	12,000	56,000	30,000	*261,000*
2057	Wet	107,000	73,000	38,000	*219,000*	103,000	12,000	56,000	30,000	*202,000*
2058	Average	78,000	51,000	27,000	*156,000*	154,000	10,000	62,000	33,000	*259,000*
2059	Wet	107,000	73,000	38,000	*219,000*	103,000	12,000	56,000	30,000	*202,000*
2060	Dry	67,000	45,000	24,000	*136,000*	132,000	11,000	65,000	34,000	*243,000*
2061	Wet	107,000	73,000	38,000	*219,000*	103,000	12,000	56,000	30,000	*202,000*
2062	Average	78,000	51,000	27,000	*156,000*	154,000	10,000	62,000	33,000	*259,000*
2063	Average	78,000	51,000	27,000	*156,000*	154,000	10,000	62,000	33,000	*259,000*
2064	Dry	67,000	45,000	24,000	*136,000*	132,000	11,000	65,000	34,000	*243,000*
2065	Average	78,000	51,000	27,000	*156,000*	154,000	10,000	62,000	33,000	*259,000*
2066	Wet	107,000	73,000	38,000	*219,000*	103,000	12,000	56,000	30,000	*202,000*
2067	Wet	107,000	73,000	38,000	*219,000*	103,000	12,000	56,000	30,000	*202,000*
2068	Dry	67,000	45,000	24,000	*136,000*	132,000	11,000	65,000	34,000	*243,000*
2069	Dry	67,000	45,000	24,000	*136,000*	132,000	11,000	65,000	34,000	*243,000*
2070	Wet	107,000	73,000	38,000	*219,000*	103,000	12,000	56,000	30,000	*202,000*
Projected Average		83,000	56,000	30,000	169,000	138,000	11,000	62,000	32,000	243,000

Table 5-28. Change in Storage, Baseline Projected Water Budget (AFY)

Groundwater Budget				
Simulated Water Year	Delta-Mendota Subbasin Water Year Type	Change in Storage		
		Upper Aquifer	Lower Aquifer	Total Change in Storage
2014	Shasta Critical	(128,000)	(28,000)	(156,000)
2015	Shasta Critical	(127,000)	(27,000)	(154,000)
2016	Dry	(102,000)	(14,000)	(115,000)
2017	Wet	(12,000)	(5,000)	(17,000)
2018	Average	41,000	8,000	48,000
2019	Wet	4,000	3,000	7,000
2020	Dry	(111,000)	(19,000)	(130,000)
2021	Wet	4,000	3,000	7,000
2022	Wet	18,000	10,000	28,000
2023	Average	67,000	22,000	88,000
2024	Dry	(89,000)	(7,000)	(97,000)
2025	Wet	28,000	15,000	43,000
2026	Dry	(93,000)	(9,000)	(102,000)
2027	Dry	(86,000)	(6,000)	(92,000)
2028	Dry	(98,000)	(12,000)	(110,000)
2029	Dry	(110,000)	(18,000)	(128,000)
2030	Shasta Critical	(123,000)	(25,000)	(147,000)
2031	Shasta Critical	(121,000)	(24,000)	(144,000)
2032	Wet	2,000	2,000	4,000
2033	Dry	(116,000)	(21,000)	(137,000)
2034	Wet	4,000	3,000	6,000
2035	Wet	2,000	2,000	4,000
2036	Wet	(7,000)	(3,000)	(9,000)
2037	Wet	14,000	8,000	22,000
2038	Average	41,000	8,000	48,000
2039	Average	37,000	6,000	43,000
2040	Dry	(114,000)	(20,000)	(134,000)
2041	Dry	(123,000)	(25,000)	(148,000)
2042	Average	41,000	8,000	50,000
2043	Dry	(119,000)	(23,000)	(141,000)
2044	Wet	(2,000)	0	(2,000)
2045	Wet	(15,000)	(7,000)	(22,000)
2046	Dry	(131,000)	(29,000)	(160,000)

Groundwater Budget				
Simulated Water Year	Delta-Mendota Subbasin Water Year Type	Change in Storage		
		Upper Aquifer	Lower Aquifer	Total Change in Storage
2047	Dry	(125,000)	(26,000)	(151,000)
2048	Average	26,000	0	27,000
2049	Average	47,000	11,000	58,000
2050	Wet	(13,000)	(6,000)	(19,000)
2051	Dry	(131,000)	(29,000)	(160,000)
2052	Dry	(124,000)	(25,000)	(149,000)
2053	Shasta Critical	(128,000)	(27,000)	(155,000)
2054	Shasta Critical	(126,000)	(26,000)	(152,000)
2055	Dry	(101,000)	(13,000)	(114,000)
2056	Wet	(9,000)	(4,000)	(14,000)
2057	Wet	4,000	3,000	7,000
2058	Average	41,000	8,000	49,000
2059	Wet	4,000	3,000	7,000
2060	Dry	(111,000)	(19,000)	(130,000)
2061	Wet	4,000	3,000	7,000
2062	Average	41,000	8,000	49,000
2063	Average	41,000	8,000	49,000
2064	Dry	(111,000)	(19,000)	(130,000)
2065	Average	41,000	8,000	49,000
2066	Wet	4,000	3,000	7,000
2067	Wet	4,000	3,000	7,000
2068	Dry	(111,000)	(19,000)	(130,000)
2069	Dry	(111,000)	(19,000)	(130,000)
2070	Wet	4,000	3,000	7,000
Projected Average		(43,000)	(7,000)	(50,000)

Table 5-29. Land Surface Budget, Projected Water Budget with Climate Change (AFY)

Land Surface Budget														
Simulated Water Year	Delta-Mendota Subbasin Water Year Type	Inflows									Outflows			
		Surface Water Deliveries				Groundwater Pumping		Tile Drainage	Precipitation	Total Inflows	Runoff [1]	Deep Percolation	Evapotranspiration	Total Outflows
		San Joaquin River	Central Valley Project	State Water Project	Local Supplies	Municipal & Industrial	Agricultural							
2014	Shasta Critical	105,000	229,000	2,000	0	4,000	208,000	8,000	131,000	686,000	48,000	63,000	598,000	709,000
2015	Shasta Critical	60,000	210,000	1,000	0	4,000	196,000	8,000	141,000	620,000	39,000	49,000	543,000	631,000
2016	Dry	80,000	231,000	3,000	0	4,000	130,000	11,000	280,000	738,000	57,000	93,000	574,000	724,000
2017	Wet	74,000	303,000	3,000	0	4,000	125,000	12,000	259,000	781,000	64,000	88,000	649,000	801,000
2018	Average	60,000	320,000	2,000	0	4,000	120,000	10,000	200,000	717,000	52,000	75,000	586,000	712,000
2019	Wet	118,000	332,000	4,000	0	4,000	84,000	12,000	347,000	900,000	76,000	109,000	684,000	869,000
2020	Dry	141,000	272,000	3,000	0	5,000	117,000	11,000	200,000	749,000	48,000	64,000	583,000	695,000
2021	Wet	118,000	332,000	4,000	0	4,000	83,000	12,000	351,000	904,000	76,000	109,000	685,000	870,000
2022	Wet	118,000	332,000	4,000	0	5,000	77,000	12,000	437,000	984,000	84,000	118,000	701,000	902,000
2023	Average	126,000	310,000	3,000	0	5,000	106,000	10,000	342,000	903,000	67,000	97,000	618,000	783,000
2024	Dry	141,000	272,000	3,000	0	5,000	109,000	11,000	325,000	866,000	65,000	89,000	596,000	750,000
2025	Wet	118,000	332,000	4,000	0	5,000	79,000	12,000	460,000	1,010,000	86,000	119,000	696,000	901,000
2026	Dry	141,000	272,000	3,000	0	6,000	108,000	11,000	315,000	856,000	63,000	88,000	595,000	746,000
2027	Dry	141,000	272,000	3,000	0	6,000	108,000	11,000	343,000	884,000	68,000	94,000	587,000	748,000
2028	Dry	141,000	272,000	3,000	0	6,000	110,000	11,000	296,000	839,000	60,000	80,000	604,000	744,000
2029	Dry	141,000	272,000	3,000	0	6,000	113,000	11,000	223,000	768,000	49,000	65,000	577,000	691,000
2030	Shasta Critical	122,000	244,000	2,000	0	6,000	185,000	8,000	156,000	722,000	46,000	59,000	586,000	691,000
2031	Shasta Critical	122,000	244,000	2,000	0	6,000	184,000	8,000	173,000	738,000	49,000	65,000	584,000	697,000
2032	Wet	118,000	332,000	4,000	0	6,000	93,000	12,000	347,000	911,000	77,000	109,000	699,000	885,000
2033	Dry	141,000	272,000	3,000	0	6,000	115,000	11,000	196,000	743,000	49,000	64,000	565,000	679,000
2034	Wet	118,000	332,000	4,000	0	6,000	79,000	12,000	345,000	895,000	76,000	108,000	660,000	843,000
2035	Wet	118,000	332,000	4,000	0	6,000	88,000	12,000	342,000	901,000	75,000	104,000	695,000	874,000
2036	Wet	118,000	332,000	4,000	0	6,000	128,000	12,000	337,000	936,000	78,000	110,000	719,000	908,000
2037	Wet	118,000	332,000	4,000	0	6,000	87,000	12,000	382,000	940,000	83,000	124,000	654,000	861,000
2038	Average	126,000	310,000	3,000	0	6,000	152,000	10,000	199,000	806,000	59,000	84,000	593,000	736,000
2039	Average	126,000	310,000	3,000	0	6,000	169,000	10,000	171,000	796,000	54,000	71,000	615,000	740,000
2040	Dry	141,000	272,000	3,000	0	6,000	139,000	11,000	204,000	777,000	54,000	77,000	574,000	706,000
2041	Dry	141,000	272,000	3,000	0	7,000	151,000	11,000	158,000	743,000	49,000	63,000	573,000	685,000
2042	Average	126,000	310,000	3,000	0	6,000	150,000	10,000	207,000	813,000	58,000	82,000	608,000	748,000
2043	Dry	141,000	272,000	3,000	0	7,000	146,000	11,000	197,000	777,000	55,000	80,000	582,000	717,000
2044	Wet	118,000	332,000	4,000	0	6,000	107,000	12,000	320,000	900,000	76,000	106,000	663,000	846,000
2045	Wet	118,000	332,000	4,000	0	7,000	123,000	12,000	241,000	836,000	67,000	86,000	665,000	817,000

Land Surface Budget														
Simulated Water Year	Delta-Mendota Subbasin Water Year Type	Inflows									Outflows			
		Surface Water Deliveries				Groundwater Pumping		Tile Drainage	Precipitation	Total Inflows	Runoff [1]	Deep Percolation	Evapotranspiration	Total Outflows
		San Joaquin River	Central Valley Project	State Water Project	Local Supplies	Municipal & Industrial	Agricultural							
2046	Dry	141,000	272,000	3,000	0	7,000	157,000	11,000	112,000	703,000	44,000	51,000	560,000	655,000
2047	Dry	141,000	272,000	3,000	0	7,000	167,000	11,000	158,000	759,000	48,000	60,000	601,000	709,000
2048	Average	126,000	310,000	3,000	0	6,000	210,000	10,000	119,000	786,000	52,000	61,000	648,000	760,000
2049	Average	126,000	310,000	3,000	0	6,000	127,000	10,000	238,000	821,000	61,000	92,000	591,000	744,000
2050	Wet	118,000	332,000	4,000	0	7,000	123,000	12,000	259,000	854,000	65,000	82,000	685,000	832,000
2051	Dry	141,000	272,000	3,000	0	7,000	153,000	11,000	112,000	699,000	44,000	51,000	560,000	655,000
2052	Dry	141,000	272,000	3,000	0	7,000	142,000	11,000	149,000	726,000	45,000	55,000	570,000	671,000
2053	Shasta Critical	122,000	244,000	2,000	0	7,000	222,000	8,000	121,000	725,000	48,000	59,000	600,000	707,000
2054	Shasta Critical	122,000	244,000	2,000	0	7,000	216,000	8,000	138,000	735,000	40,000	47,000	563,000	650,000
2055	Dry	141,000	272,000	3,000	0	7,000	155,000	11,000	252,000	841,000	54,000	82,000	590,000	725,000
2056	Wet	118,000	332,000	4,000	0	7,000	154,000	12,000	279,000	905,000	67,000	90,000	699,000	856,000
2057	Wet	118,000	332,000	4,000	0	7,000	97,000	12,000	339,000	909,000	75,000	104,000	687,000	866,000
2058	Average	126,000	310,000	3,000	0	6,000	149,000	10,000	193,000	798,000	55,000	74,000	609,000	738,000
2059	Wet	118,000	332,000	4,000	0	7,000	96,000	12,000	345,000	913,000	77,000	107,000	685,000	869,000
2060	Dry	141,000	272,000	3,000	0	7,000	130,000	11,000	198,000	762,000	49,000	63,000	584,000	695,000
2061	Wet	118,000	332,000	4,000	0	7,000	95,000	12,000	347,000	913,000	76,000	106,000	688,000	869,000
2062	Average	126,000	310,000	3,000	0	6,000	150,000	10,000	192,000	798,000	55,000	75,000	609,000	739,000
2063	Average	126,000	310,000	3,000	0	6,000	148,000	10,000	197,000	801,000	56,000	76,000	609,000	740,000
2064	Dry	141,000	272,000	3,000	0	7,000	127,000	11,000	211,000	772,000	50,000	65,000	585,000	700,000
2065	Average	126,000	310,000	3,000	0	6,000	145,000	10,000	206,000	808,000	57,000	78,000	609,000	744,000
2066	Wet	118,000	332,000	4,000	0	7,000	97,000	12,000	340,000	909,000	75,000	105,000	687,000	867,000
2067	Wet	118,000	332,000	4,000	0	7,000	94,000	12,000	349,000	915,000	76,000	107,000	687,000	871,000
2068	Dry	141,000	272,000	3,000	0	7,000	126,000	11,000	205,000	765,000	49,000	63,000	586,000	698,000
2069	Dry	141,000	272,000	3,000	0	7,000	125,000	11,000	210,000	770,000	50,000	65,000	586,000	700,000
2070	Wet	118,000	332,000	4,000	0	7,000	95,000	12,000	344,000	911,000	76,000	106,000	687,000	868,000
Projected Average		124,000	295,000	3,000	0	6,000	131,000	11,000	250,000	820,000	60,000	83,000	622,000	765,000

[1] Runoff includes return flows to all surface water sources leaving the Plan area. Return flows were not separated due to model limitations.

Table 5-30. Groundwater Surface Budget, Projected Water Budget with Climate Change (AFY)

Groundwater Budget										
Simulated Water Year	Delta-Mendota Subbasin Water Year Type	Inflows				Outflows				
		Deep Percolation	Upper Aquifer Underflows	Lower Aquifer Underflows	Total Inflows	Groundwater Pumping	Tile Drainage	Upper Aquifer Underflows	Lower Aquifer Underflows	Total Outflows
2014	Shasta Critical	63,000	45,000	24,000	132,000	*212,000*	*8,000*	*65,000*	*34,000*	319,000
2015	Shasta Critical	49,000	45,000	24,000	118,000	*200,000*	*8,000*	*65,000*	*34,000*	308,000
2016	Dry	93,000	45,000	24,000	162,000	*134,000*	*11,000*	*65,000*	*34,000*	244,000
2017	Wet	88,000	73,000	38,000	199,000	*129,000*	*12,000*	*56,000*	*30,000*	228,000
2018	Average	75,000	51,000	27,000	154,000	*124,000*	*10,000*	*62,000*	*33,000*	229,000
2019	Wet	109,000	73,000	38,000	220,000	*88,000*	*12,000*	*56,000*	*30,000*	186,000
2020	Dry	64,000	45,000	24,000	133,000	*122,000*	*11,000*	*65,000*	*34,000*	232,000
2021	Wet	109,000	73,000	38,000	221,000	*87,000*	*12,000*	*56,000*	*30,000*	186,000
2022	Wet	118,000	73,000	38,000	229,000	*82,000*	*12,000*	*56,000*	*30,000*	180,000
2023	Average	97,000	51,000	27,000	176,000	*111,000*	*10,000*	*62,000*	*33,000*	216,000
2024	Dry	89,000	45,000	24,000	159,000	*115,000*	*11,000*	*65,000*	*34,000*	225,000
2025	Wet	119,000	73,000	38,000	231,000	*84,000*	*12,000*	*56,000*	*30,000*	183,000
2026	Dry	88,000	45,000	24,000	157,000	*113,000*	*11,000*	*65,000*	*34,000*	224,000
2027	Dry	94,000	45,000	24,000	163,000	*114,000*	*11,000*	*65,000*	*34,000*	225,000
2028	Dry	80,000	45,000	24,000	149,000	*116,000*	*11,000*	*65,000*	*34,000*	227,000
2029	Dry	65,000	45,000	24,000	135,000	*118,000*	*11,000*	*65,000*	*34,000*	229,000
2030	Shasta Critical	59,000	45,000	24,000	128,000	*191,000*	*8,000*	*65,000*	*34,000*	298,000
2031	Shasta Critical	65,000	45,000	24,000	134,000	*190,000*	*8,000*	*65,000*	*34,000*	297,000
2032	Wet	109,000	73,000	38,000	221,000	*98,000*	*12,000*	*56,000*	*30,000*	197,000
2033	Dry	64,000	45,000	24,000	134,000	*121,000*	*11,000*	*65,000*	*34,000*	231,000
2034	Wet	108,000	73,000	38,000	219,000	*84,000*	*12,000*	*56,000*	*30,000*	183,000
2035	Wet	104,000	73,000	38,000	216,000	*93,000*	*12,000*	*56,000*	*30,000*	192,000
2036	Wet	110,000	73,000	38,000	222,000	*134,000*	*12,000*	*56,000*	*30,000*	232,000
2037	Wet	124,000	73,000	38,000	235,000	*92,000*	*12,000*	*56,000*	*30,000*	191,000
2038	Average	84,000	51,000	27,000	163,000	*158,000*	*10,000*	*62,000*	*33,000*	263,000
2039	Average	71,000	51,000	27,000	149,000	*175,000*	*10,000*	*62,000*	*33,000*	281,000
2040	Dry	77,000	45,000	24,000	147,000	*146,000*	*11,000*	*65,000*	*34,000*	256,000
2041	Dry	63,000	45,000	24,000	133,000	*158,000*	*11,000*	*65,000*	*34,000*	269,000
2042	Average	82,000	51,000	27,000	161,000	*156,000*	*10,000*	*62,000*	*33,000*	262,000
2043	Dry	80,000	45,000	24,000	149,000	*153,000*	*11,000*	*65,000*	*34,000*	263,000
2044	Wet	106,000	73,000	38,000	218,000	*114,000*	*12,000*	*56,000*	*30,000*	213,000
2045	Wet	86,000	73,000	38,000	197,000	*129,000*	*12,000*	*56,000*	*30,000*	228,000
2046	Dry	51,000	45,000	24,000	120,000	*164,000*	*11,000*	*65,000*	*34,000*	274,000

Groundwater Budget										
Simulated Water Year	Delta-Mendota Subbasin Water Year Type	Inflows				Outflows				
		Deep Percolation	Upper Aquifer Underflows	Lower Aquifer Underflows	Total Inflows	Groundwater Pumping	Tile Drainage	Upper Aquifer Underflows	Lower Aquifer Underflows	Total Outflows
2047	Dry	60,000	45,000	24,000	129,000	*174,000*	*11,000*	*65,000*	*34,000*	284,000
2048	Average	61,000	51,000	27,000	140,000	*217,000*	*10,000*	*62,000*	*33,000*	322,000
2049	Average	92,000	51,000	27,000	171,000	*133,000*	*10,000*	*62,000*	*33,000*	238,000
2050	Wet	82,000	73,000	38,000	194,000	*129,000*	*12,000*	*56,000*	*30,000*	228,000
2051	Dry	51,000	45,000	24,000	120,000	*160,000*	*11,000*	*65,000*	*34,000*	270,000
2052	Dry	55,000	45,000	24,000	125,000	*149,000*	*11,000*	*65,000*	*34,000*	260,000
2053	Shasta Critical	59,000	45,000	24,000	129,000	*229,000*	*8,000*	*65,000*	*34,000*	336,000
2054	Shasta Critical	47,000	45,000	24,000	117,000	*223,000*	*8,000*	*65,000*	*34,000*	330,000
2055	Dry	82,000	45,000	24,000	151,000	*161,000*	*11,000*	*65,000*	*34,000*	272,000
2056	Wet	90,000	73,000	38,000	201,000	*160,000*	*12,000*	*56,000*	*30,000*	259,000
2057	Wet	104,000	73,000	38,000	216,000	*104,000*	*12,000*	*56,000*	*30,000*	202,000
2058	Average	74,000	51,000	27,000	153,000	*156,000*	*10,000*	*62,000*	*33,000*	261,000
2059	Wet	107,000	73,000	38,000	219,000	*102,000*	*12,000*	*56,000*	*30,000*	201,000
2060	Dry	63,000	45,000	24,000	132,000	*137,000*	*11,000*	*65,000*	*34,000*	247,000
2061	Wet	106,000	73,000	38,000	217,000	*101,000*	*12,000*	*56,000*	*30,000*	200,000
2062	Average	75,000	51,000	27,000	153,000	*156,000*	*10,000*	*62,000*	*33,000*	261,000
2063	Average	76,000	51,000	27,000	154,000	*154,000*	*10,000*	*62,000*	*33,000*	260,000
2064	Dry	65,000	45,000	24,000	135,000	*134,000*	*11,000*	*65,000*	*34,000*	244,000
2065	Average	78,000	51,000	27,000	157,000	*152,000*	*10,000*	*62,000*	*33,000*	257,000
2066	Wet	105,000	73,000	38,000	216,000	*104,000*	*12,000*	*56,000*	*30,000*	202,000
2067	Wet	107,000	73,000	38,000	218,000	*101,000*	*12,000*	*56,000*	*30,000*	199,000
2068	Dry	63,000	45,000	24,000	132,000	*133,000*	*11,000*	*65,000*	*34,000*	244,000
2069	Dry	65,000	45,000	24,000	135,000	*132,000*	*11,000*	*65,000*	*34,000*	243,000
2070	Wet	106,000	73,000	38,000	217,000	*102,000*	*12,000*	*56,000*	*30,000*	201,000
Projected Average		83,000	56,000	30,000	169,000	137,000	11,000	62,000	32,000	242,000

Table 5-31. Change in Storage, Projected Water Budget with Climate Change (AFY)

Groundwater Budget				
Simulated Water Year	Delta-Mendota Subbasin Water Year Type	Change in Storage		
		Upper Aquifer	Lower Aquifer	Total Change in Storage
2014	Shasta Critical	(135,000)	(29,000)	(164,000)
2015	Shasta Critical	(123,000)	(26,000)	(148,000)
2016	Dry	(87,000)	(10,000)	(97,000)
2017	Wet	(17,000)	(6,000)	(23,000)
2018	Average	43,000	8,000	52,000
2019	Wet	7,000	4,000	11,000
2020	Dry	(119,000)	(20,000)	(139,000)
2021	Wet	10,000	4,000	14,000
2022	Wet	28,000	13,000	41,000
2023	Average	76,000	24,000	100,000
2024	Dry	(88,000)	(7,000)	(94,000)
2025	Wet	28,000	15,000	43,000
2026	Dry	(86,000)	(7,000)	(93,000)
2027	Dry	(81,000)	(4,000)	(85,000)
2028	Dry	(90,000)	(9,000)	(99,000)
2029	Dry	(106,000)	(17,000)	(123,000)
2030	Shasta Critical	(121,000)	(24,000)	(146,000)
2031	Shasta Critical	(115,000)	(22,000)	(138,000)
2032	Wet	12,000	4,000	16,000
2033	Dry	(112,000)	(20,000)	(132,000)
2034	Wet	6,000	3,000	10,000
2035	Wet	10,000	4,000	13,000
2036	Wet	26,000	4,000	30,000
2037	Wet	5,000	7,000	12,000
2038	Average	42,000	8,000	50,000
2039	Average	33,000	5,000	37,000
2040	Dry	(111,000)	(19,000)	(130,000)
2041	Dry	(120,000)	(24,000)	(144,000)
2042	Average	46,000	9,000	55,000
2043	Dry	(103,000)	(19,000)	(122,000)
2044	Wet	3,000	1,000	4,000
2045	Wet	(22,000)	(8,000)	(30,000)
2046	Dry	(133,000)	(29,000)	(162,000)

Groundwater Budget				
Simulated Water Year	Delta-Mendota Subbasin Water Year Type	Change in Storage		
		Upper Aquifer	Lower Aquifer	Total Change in Storage
2047	Dry	(116,000)	(24,000)	(140,000)
2048	Average	22,000	(1,000)	21,000
2049	Average	54,000	13,000	67,000
2050	Wet	(13,000)	(6,000)	(19,000)
2051	Dry	(132,000)	(29,000)	(161,000)
2052	Dry	(125,000)	(25,000)	(150,000)
2053	Shasta Critical	(133,000)	(28,000)	(162,000)
2054	Shasta Critical	(126,000)	(26,000)	(153,000)
2055	Dry	(110,000)	(15,000)	(125,000)
2056	Wet	(8,000)	(3,000)	(12,000)
2057	Wet	0	2,000	2,000
2058	Average	35,000	7,000	42,000
2059	Wet	5,000	3,000	9,000
2060	Dry	(122,000)	(21,000)	(142,000)
2061	Wet	5,000	4,000	8,000
2062	Average	35,000	7,000	42,000
2063	Average	38,000	8,000	46,000
2064	Dry	(114,000)	(19,000)	(133,000)
2065	Average	45,000	9,000	54,000
2066	Wet	0	3,000	3,000
2067	Wet	7,000	4,000	11,000
2068	Dry	(117,000)	(19,000)	(137,000)
2069	Dry	(113,000)	(19,000)	(132,000)
2070	Wet	3,000	3,000	7,000
Projected Average		(42,000)	(6,000)	(48,000)

Table 5-32. Land Surface Budget, Projected Water Budget with Climate Change and Projects & Management Actions (AFY)

Land Surface Budget														
Simulated Water Year	Delta-Mendota Subbasin Water Year Type	Inflows									Outflows			
		Surface Water Deliveries [1]				Groundwater Pumping		Tile Drainage	Precipitation	Total Inflows	Runoff [2]	Deep Percolation	Evapotranspiration	Total Outflows
		San Joaquin River	Central Valley Project	State Water Project	Local Supplies	Municipal & Industrial	Agricultural							
2014	Shasta Critical	105,000	229,000	2,000	0	4,000	208,000	8,000	131,000	686,000	48,000	63,000	598,000	709,000
2015	Shasta Critical	60,000	210,000	1,000	0	4,000	196,000	8,000	141,000	620,000	39,000	49,000	543,000	631,000
2016	Dry	80,000	231,000	3,000	0	4,000	130,000	11,000	280,000	738,000	57,000	93,000	574,000	724,000
2017	Wet	74,000	303,000	3,000	0	4,000	125,000	12,000	259,000	781,000	64,000	88,000	649,000	801,000
2018	Average	60,000	320,000	2,000	0	4,000	114,000	10,000	200,000	710,000	51,000	75,000	586,000	712,000
2019	Wet	118,000	332,000	4,000	2,000	4,000	76,000	12,000	347,000	895,000	76,000	108,000	684,000	868,000
2020	Dry	141,000	272,000	3,000	9,000	5,000	111,000	11,000	200,000	752,000	48,000	67,000	583,000	698,000
2021	Wet	118,000	332,000	4,000	7,000	4,000	76,000	12,000	351,000	904,000	76,000	119,000	685,000	881,000
2022	Wet	118,000	332,000	4,000	7,000	5,000	70,000	12,000	437,000	984,000	83,000	128,000	701,000	912,000
2023	Average	126,000	310,000	3,000	6,000	5,000	98,000	10,000	342,000	901,000	67,000	100,000	618,000	785,000
2024	Dry	141,000	272,000	3,000	6,000	5,000	106,000	11,000	325,000	869,000	65,000	92,000	596,000	753,000
2025	Wet	118,000	332,000	4,000	7,000	5,000	72,000	12,000	460,000	1,010,000	86,000	130,000	696,000	912,000
2026	Dry	141,000	272,000	3,000	52,000	6,000	64,000	11,000	315,000	864,000	63,000	94,000	595,000	753,000
2027	Dry	141,000	272,000	3,000	49,000	6,000	67,000	11,000	343,000	893,000	68,000	103,000	587,000	758,000
2028	Dry	141,000	272,000	3,000	50,000	6,000	69,000	11,000	296,000	847,000	60,000	89,000	604,000	753,000
2029	Dry	141,000	272,000	3,000	55,000	6,000	66,000	11,000	223,000	778,000	50,000	75,000	577,000	701,000
2030	Shasta Critical	122,000	244,000	2,000	49,000	6,000	138,000	8,000	156,000	725,000	46,000	68,000	586,000	700,000
2031	Shasta Critical	122,000	244,000	2,000	51,000	6,000	136,000	8,000	173,000	741,000	49,000	74,000	584,000	706,000
2032	Wet	118,000	332,000	4,000	46,000	6,000	62,000	12,000	347,000	925,000	78,000	131,000	699,000	909,000
2033	Dry	141,000	272,000	3,000	60,000	6,000	68,000	11,000	196,000	757,000	50,000	75,000	565,000	690,000
2034	Wet	118,000	332,000	4,000	47,000	6,000	49,000	12,000	345,000	913,000	77,000	130,000	660,000	867,000
2035	Wet	118,000	332,000	4,000	48,000	6,000	55,000	12,000	342,000	917,000	76,000	126,000	695,000	898,000
2036	Wet	118,000	332,000	4,000	50,000	6,000	97,000	12,000	337,000	955,000	79,000	133,000	719,000	931,000
2037	Wet	118,000	332,000	4,000	49,000	6,000	58,000	12,000	382,000	961,000	85,000	146,000	654,000	885,000
2038	Average	126,000	310,000	3,000	53,000	6,000	105,000	10,000	199,000	812,000	59,000	99,000	593,000	751,000
2039	Average	126,000	310,000	3,000	52,000	6,000	123,000	10,000	171,000	801,000	54,000	86,000	615,000	756,000
2040	Dry	141,000	272,000	3,000	66,000	6,000	94,000	11,000	204,000	797,000	55,000	88,000	574,000	717,000
2041	Dry	141,000	272,000	3,000	62,000	7,000	99,000	11,000	158,000	753,000	49,000	73,000	573,000	695,000
2042	Average	126,000	310,000	3,000	51,000	6,000	104,000	10,000	207,000	819,000	59,000	97,000	608,000	763,000
2043	Dry	141,000	272,000	3,000	68,000	7,000	98,000	11,000	197,000	797,000	57,000	90,000	582,000	729,000
2044	Wet	118,000	332,000	4,000	53,000	6,000	70,000	12,000	320,000	916,000	77,000	129,000	663,000	870,000
2045	Wet	118,000	332,000	4,000	53,000	7,000	78,000	12,000	241,000	844,000	67,000	108,000	665,000	840,000

Land Surface Budget														
Simulated Water Year	Delta-Mendota Subbasin Water Year Type	Inflows									Outflows			
		Surface Water Deliveries [1]				Groundwater Pumping		Tile Drainage	Precipitation	Total Inflows	Runoff [2]	Deep Percolation	Evapotranspiration	Total Outflows
		San Joaquin River	Central Valley Project	State Water Project	Local Supplies	Municipal & Industrial	Agricultural							
2046	Dry	141,000	272,000	3,000	68,000	7,000	100,000	11,000	112,000	714,000	44,000	61,000	560,000	666,000
2047	Dry	141,000	272,000	3,000	64,000	7,000	111,000	11,000	158,000	768,000	48,000	70,000	601,000	719,000
2048	Average	126,000	310,000	3,000	49,000	6,000	161,000	10,000	119,000	786,000	52,000	75,000	648,000	775,000
2049	Average	126,000	310,000	3,000	62,000	6,000	98,000	10,000	238,000	854,000	63,000	108,000	591,000	762,000
2050	Wet	118,000	332,000	4,000	54,000	7,000	83,000	12,000	259,000	869,000	66,000	105,000	685,000	856,000
2051	Dry	141,000	272,000	3,000	69,000	7,000	102,000	11,000	112,000	718,000	45,000	61,000	560,000	666,000
2052	Dry	141,000	272,000	3,000	67,000	7,000	97,000	11,000	149,000	747,000	47,000	66,000	570,000	682,000
2053	Shasta Critical	122,000	244,000	2,000	47,000	7,000	178,000	8,000	121,000	728,000	48,000	68,000	600,000	716,000
2054	Shasta Critical	122,000	244,000	2,000	34,000	7,000	187,000	8,000	138,000	740,000	40,000	55,000	563,000	658,000
2055	Dry	141,000	272,000	3,000	49,000	7,000	115,000	11,000	252,000	851,000	54,000	91,000	590,000	735,000
2056	Wet	118,000	332,000	4,000	46,000	7,000	109,000	12,000	279,000	906,000	67,000	112,000	699,000	878,000
2057	Wet	118,000	332,000	4,000	55,000	7,000	63,000	12,000	339,000	930,000	77,000	127,000	687,000	891,000
2058	Average	126,000	310,000	3,000	54,000	6,000	100,000	10,000	193,000	803,000	55,000	90,000	609,000	754,000
2059	Wet	118,000	332,000	4,000	55,000	7,000	62,000	12,000	345,000	935,000	78,000	130,000	685,000	893,000
2060	Dry	141,000	272,000	3,000	69,000	7,000	78,000	11,000	198,000	779,000	50,000	73,000	584,000	706,000
2061	Wet	118,000	332,000	4,000	55,000	7,000	61,000	12,000	347,000	936,000	77,000	128,000	688,000	894,000
2062	Average	126,000	310,000	3,000	58,000	6,000	100,000	10,000	192,000	806,000	56,000	90,000	609,000	755,000
2063	Average	126,000	310,000	3,000	54,000	6,000	99,000	10,000	197,000	806,000	56,000	91,000	609,000	756,000
2064	Dry	141,000	272,000	3,000	70,000	7,000	77,000	11,000	211,000	792,000	51,000	76,000	585,000	712,000
2065	Average	126,000	310,000	3,000	58,000	6,000	98,000	10,000	206,000	818,000	57,000	94,000	609,000	760,000
2066	Wet	118,000	332,000	4,000	55,000	7,000	63,000	12,000	340,000	931,000	77,000	127,000	687,000	891,000
2067	Wet	118,000	332,000	4,000	55,000	7,000	61,000	12,000	349,000	938,000	78,000	130,000	687,000	895,000
2068	Dry	141,000	272,000	3,000	69,000	7,000	75,000	11,000	205,000	782,000	50,000	73,000	586,000	709,000
2069	Dry	141,000	272,000	3,000	66,000	7,000	75,000	11,000	210,000	785,000	50,000	75,000	586,000	712,000
2070	Wet	118,000	332,000	4,000	55,000	7,000	62,000	12,000	344,000	933,000	77,000	128,000	687,000	892,000
Projected Average		124,000	295,000	3,000	45,000	6,000	96,000	11,000	250,000	830,000	61,000	95,000	622,000	778,000

[1] Projects & Management Actions aim to increase the amount of Surface Water transfers between GSA Member Agencies by approximately 45,000 AFY. The source of these Surface Water volumes is yet to be determined. The total volume of these transfers will not exceed the cumulative volumes remaining after demands are met within each GSA Member Agency. For a more detailed explanation of these Projects & Management Actions, see Section 7.1 of the *Sustainability Implementation* chapter.

[2] Runoff includes return flows to all surface water sources leaving the Plan area. Return flows were not separated due to model limitations.

Table 5-33. Groundwater Budget, Projected Water Budget with Climate Change and Projects & Management Actions (AFY)

Groundwater Budget										
Simulated Water Year	Delta-Mendota Subbasin Water Year Type	Inflows				Outflows				
		Deep Percolation	Upper Aquifer Underflows	Lower Aquifer Underflows	Total Inflows	Groundwater Pumping	Tile Drainage	Upper Aquifer Underflows	Lower Aquifer Underflows	Total Outflows
2014	Shasta Critical	63,000	45,000	24,000	132,000	212,000	8,000	65,000	34,000	319,000
2015	Shasta Critical	49,000	45,000	24,000	118,000	200,000	8,000	65,000	34,000	308,000
2016	Dry	93,000	45,000	24,000	162,000	134,000	11,000	65,000	34,000	244,000
2017	Wet	88,000	73,000	38,000	199,000	129,000	12,000	56,000	30,000	228,000
2018	Average	75,000	51,000	27,000	153,000	118,000	10,000	62,000	33,000	223,000
2019	Wet	108,000	73,000	38,000	220,000	81,000	12,000	56,000	30,000	179,000
2020	Dry	67,000	45,000	24,000	136,000	115,000	11,000	65,000	34,000	226,000
2021	Wet	119,000	73,000	38,000	231,000	80,000	12,000	56,000	30,000	179,000
2022	Wet	128,000	73,000	38,000	239,000	75,000	12,000	56,000	30,000	173,000
2023	Average	100,000	51,000	27,000	179,000	103,000	10,000	62,000	33,000	208,000
2024	Dry	92,000	45,000	24,000	161,000	111,000	11,000	65,000	34,000	222,000
2025	Wet	130,000	73,000	38,000	241,000	78,000	12,000	56,000	30,000	176,000
2026	Dry	94,000	45,000	24,000	164,000	70,000	11,000	65,000	34,000	180,000
2027	Dry	103,000	45,000	24,000	172,000	73,000	11,000	65,000	34,000	183,000
2028	Dry	89,000	45,000	24,000	158,000	74,000	11,000	65,000	34,000	185,000
2029	Dry	75,000	45,000	24,000	144,000	72,000	11,000	65,000	34,000	183,000
2030	Shasta Critical	68,000	45,000	24,000	137,000	144,000	8,000	65,000	34,000	251,000
2031	Shasta Critical	74,000	45,000	24,000	143,000	142,000	8,000	65,000	34,000	249,000
2032	Wet	131,000	73,000	38,000	243,000	67,000	12,000	56,000	30,000	166,000
2033	Dry	75,000	45,000	24,000	144,000	74,000	11,000	65,000	34,000	185,000
2034	Wet	130,000	73,000	38,000	242,000	55,000	12,000	56,000	30,000	153,000
2035	Wet	126,000	73,000	38,000	238,000	61,000	12,000	56,000	30,000	160,000
2036	Wet	133,000	73,000	38,000	244,000	102,000	12,000	56,000	30,000	201,000
2037	Wet	146,000	73,000	38,000	258,000	64,000	12,000	56,000	30,000	163,000
2038	Average	99,000	51,000	27,000	178,000	111,000	10,000	62,000	33,000	216,000
2039	Average	86,000	51,000	27,000	164,000	129,000	10,000	62,000	33,000	234,000
2040	Dry	88,000	45,000	24,000	157,000	100,000	11,000	65,000	34,000	211,000
2041	Dry	73,000	45,000	24,000	143,000	106,000	11,000	65,000	34,000	216,000
2042	Average	97,000	51,000	27,000	176,000	110,000	10,000	62,000	33,000	216,000
2043	Dry	90,000	45,000	24,000	160,000	104,000	11,000	65,000	34,000	215,000
2044	Wet	129,000	73,000	38,000	241,000	77,000	12,000	56,000	30,000	176,000
2045	Wet	108,000	73,000	38,000	220,000	84,000	12,000	56,000	30,000	183,000
2046	Dry	61,000	45,000	24,000	131,000	107,000	11,000	65,000	34,000	218,000

Groundwater Budget										
Simulated Water Year	Delta-Mendota Subbasin Water Year Type	Inflows				Outflows				
		Deep Percolation	Upper Aquifer Underflows	Lower Aquifer Underflows	Total Inflows	Groundwater Pumping	Tile Drainage	Upper Aquifer Underflows	Lower Aquifer Underflows	Total Outflows
2047	Dry	70,000	*45,000*	*24,000*	139,000	*118,000*	*11,000*	*65,000*	*34,000*	229,000
2048	Average	75,000	*51,000*	*27,000*	154,000	*168,000*	*10,000*	*62,000*	*33,000*	273,000
2049	Average	108,000	*51,000*	*27,000*	187,000	*104,000*	*10,000*	*62,000*	*33,000*	209,000
2050	Wet	105,000	*73,000*	*38,000*	216,000	*90,000*	*12,000*	*56,000*	*30,000*	189,000
2051	Dry	61,000	*45,000*	*24,000*	131,000	*109,000*	*11,000*	*65,000*	*34,000*	220,000
2052	Dry	66,000	*45,000*	*24,000*	135,000	*104,000*	*11,000*	*65,000*	*34,000*	214,000
2053	Shasta Critical	68,000	*45,000*	*24,000*	138,000	*185,000*	*8,000*	*65,000*	*34,000*	292,000
2054	Shasta Critical	55,000	*45,000*	*24,000*	125,000	*194,000*	*8,000*	*65,000*	*34,000*	301,000
2055	Dry	91,000	*45,000*	*24,000*	161,000	*122,000*	*11,000*	*65,000*	*34,000*	233,000
2056	Wet	112,000	*73,000*	*38,000*	223,000	*116,000*	*12,000*	*56,000*	*30,000*	215,000
2057	Wet	127,000	*73,000*	*38,000*	239,000	*70,000*	*12,000*	*56,000*	*30,000*	169,000
2058	Average	90,000	*51,000*	*27,000*	168,000	*106,000*	*10,000*	*62,000*	*33,000*	212,000
2059	Wet	130,000	*73,000*	*38,000*	242,000	*69,000*	*12,000*	*56,000*	*30,000*	167,000
2060	Dry	73,000	*45,000*	*24,000*	143,000	*85,000*	*11,000*	*65,000*	*34,000*	196,000
2061	Wet	128,000	*73,000*	*38,000*	240,000	*68,000*	*12,000*	*56,000*	*30,000*	167,000
2062	Average	90,000	*51,000*	*27,000*	169,000	*106,000*	*10,000*	*62,000*	*33,000*	212,000
2063	Average	91,000	*51,000*	*27,000*	169,000	*105,000*	*10,000*	*62,000*	*33,000*	210,000
2064	Dry	76,000	*45,000*	*24,000*	145,000	*84,000*	*11,000*	*65,000*	*34,000*	195,000
2065	Average	94,000	*51,000*	*27,000*	172,000	*104,000*	*10,000*	*62,000*	*33,000*	210,000
2066	Wet	127,000	*73,000*	*38,000*	239,000	*70,000*	*12,000*	*56,000*	*30,000*	169,000
2067	Wet	130,000	*73,000*	*38,000*	241,000	*68,000*	*12,000*	*56,000*	*30,000*	166,000
2068	Dry	73,000	*45,000*	*24,000*	143,000	*82,000*	*11,000*	*65,000*	*34,000*	192,000
2069	Dry	75,000	*45,000*	*24,000*	145,000	*82,000*	*11,000*	*65,000*	*34,000*	193,000
2070	Wet	128,000	*73,000*	*38,000*	240,000	*68,000*	*12,000*	*56,000*	*30,000*	167,000
Projected Average		95,000	56,000	30,000	181,000	102,000	11,000	62,000	32,000	207,000

Table 5-34. Change in Storage, Projected Water Budget with Climate Change and Projects & Management Actions (AFY)

Groundwater Budget				
Simulated Water Year	Delta-Mendota Subbasin Water Year Type	Change in Storage		
		Upper Aquifer	Lower Aquifer	Total Change in Storage
2014	Shasta Critical	(135,000)	(29,000)	(164,000)
2015	Shasta Critical	(123,000)	(26,000)	(148,000)
2016	Dry	(87,000)	(10,000)	(97,000)
2017	Wet	(17,000)	(6,000)	(23,000)
2018	Average	43,000	14,000	57,000
2019	Wet	9,000	9,000	18,000
2020	Dry	(112,000)	(17,000)	(129,000)
2021	Wet	22,000	10,000	31,000
2022	Wet	40,000	19,000	58,000
2023	Average	80,000	31,000	110,000
2024	Dry	(84,000)	(4,000)	(88,000)
2025	Wet	39,000	21,000	60,000
2026	Dry	(45,000)	2,000	(43,000)
2027	Dry	(39,000)	5,000	(35,000)
2028	Dry	(48,000)	0	(48,000)
2029	Dry	(60,000)	(7,000)	(67,000)
2030	Shasta Critical	(80,000)	(10,000)	(90,000)
2031	Shasta Critical	(73,000)	(8,000)	(81,000)
2032	Wet	57,000	12,000	69,000
2033	Dry	(63,000)	(13,000)	(75,000)
2034	Wet	52,000	10,000	62,000
2035	Wet	55,000	13,000	68,000
2036	Wet	65,000	18,000	83,000
2037	Wet	52,000	10,000	63,000
2038	Average	92,000	20,000	112,000
2039	Average	81,000	17,000	99,000
2040	Dry	(63,000)	(11,000)	(74,000)
2041	Dry	(68,000)	(13,000)	(81,000)
2042	Average	95,000	21,000	116,000
2043	Dry	(55,000)	(9,000)	(63,000)
2044	Wet	53,000	10,000	64,000
2045	Wet	31,000	6,000	37,000
2046	Dry	(79,000)	(16,000)	(96,000)

Groundwater Budget				
Simulated Water Year	Delta-Mendota Subbasin Water Year Type	Change in Storage		
		Upper Aquifer	Lower Aquifer	Total Change in Storage
2047	Dry	(63,000)	(11,000)	(75,000)
2048	Average	68,000	17,000	85,000
2049	Average	90,000	22,000	112,000
2050	Wet	37,000	6,000	43,000
2051	Dry	(82,000)	(17,000)	(100,000)
2052	Dry	(80,000)	(14,000)	(94,000)
2053	Shasta Critical	(94,000)	(15,000)	(109,000)
2054	Shasta Critical	(97,000)	(19,000)	(116,000)
2055	Dry	(69,000)	(7,000)	(76,000)
2056	Wet	43,000	11,000	55,000
2057	Wet	46,000	13,000	59,000
2058	Average	86,000	21,000	107,000
2059	Wet	51,000	13,000	65,000
2060	Dry	(71,000)	(10,000)	(80,000)
2061	Wet	51,000	14,000	64,000
2062	Average	86,000	21,000	108,000
2063	Average	89,000	22,000	110,000
2064	Dry	(64,000)	(8,000)	(73,000)
2065	Average	94,000	23,000	117,000
2066	Wet	46,000	13,000	59,000
2067	Wet	53,000	14,000	67,000
2068	Dry	(66,000)	(9,000)	(75,000)
2069	Dry	(63,000)	(8,000)	(71,000)
2070	Wet	50,000	13,000	63,000
Projected Average		(4,000)	3,000	(1,000)

5.4.7 Historic and Current Water Budgets

The historic water budget is a quantitative evaluation of historic hydrology, water supply, water demand, and land use information covering the 10-year period from WY2003 to WY2012. The current water budget (WY2013) quantifies the same information for current inflows and outflows for the Plan area using the most recent hydrology, water supply, water demand, and land use information. The goal of the water budget analysis is to characterize water supply and demand while summarizing hydrologic conditions and flows within the Plan area, including the movement of all primary sources of water such as rainfall, irrigation, streamflow, and subsurface flow.

Figure 5-122 and Figure 5-123, respectively, summarize the average annual historic and current land surface inflows and outflows in the Northern and Central Delta-Mendota Regions. Figure 5-124 shows the annual time series of historic and current land surface inflows and outflows.

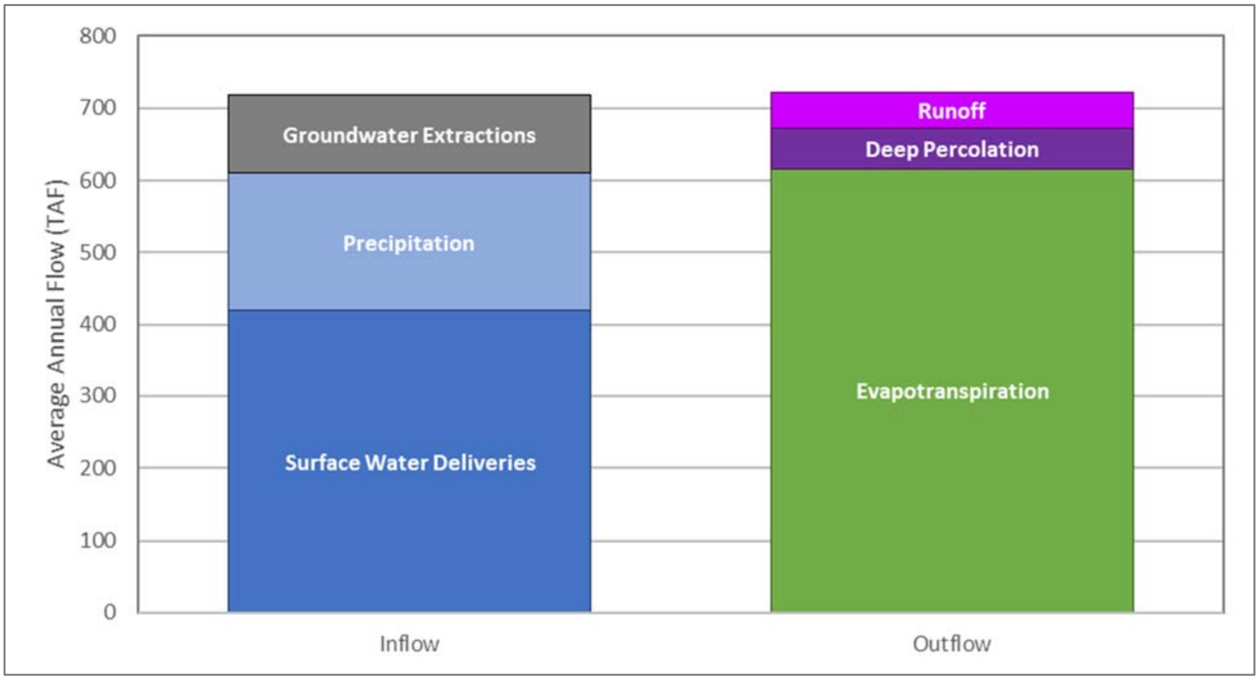

Figure 5-122. Average Historic Land Surface Budget (WY2003-2012)

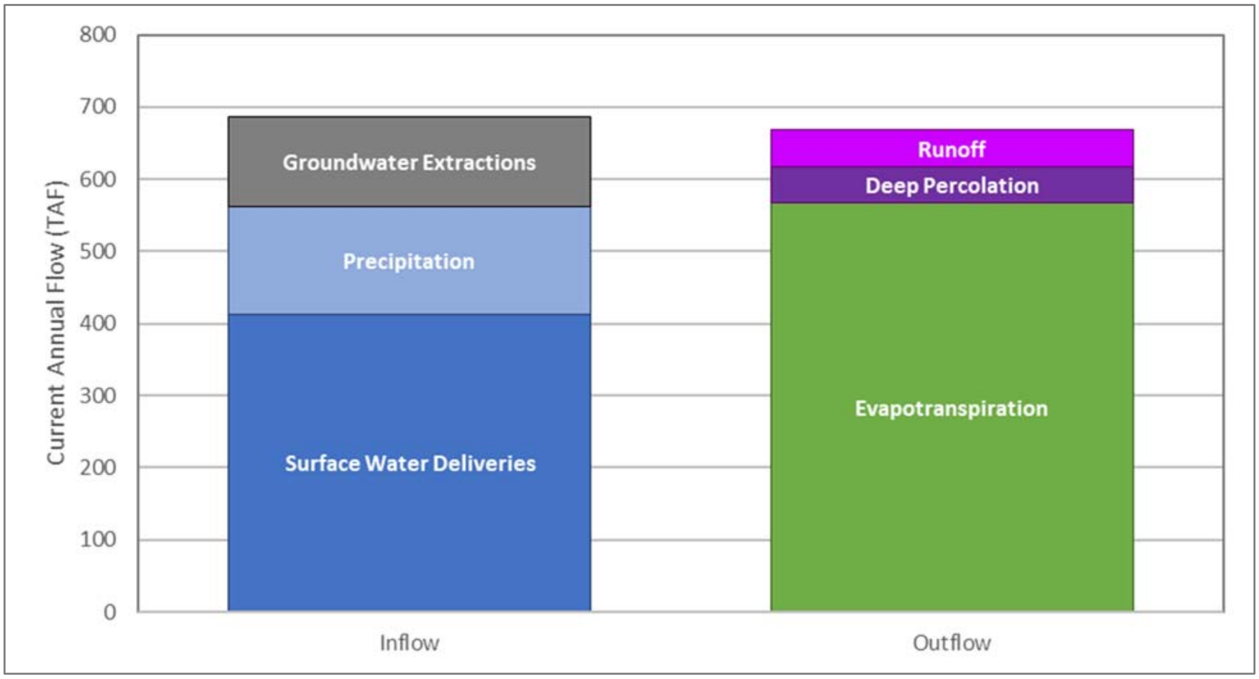

Figure 5-123. Current Land Surface Budget (WY2013)

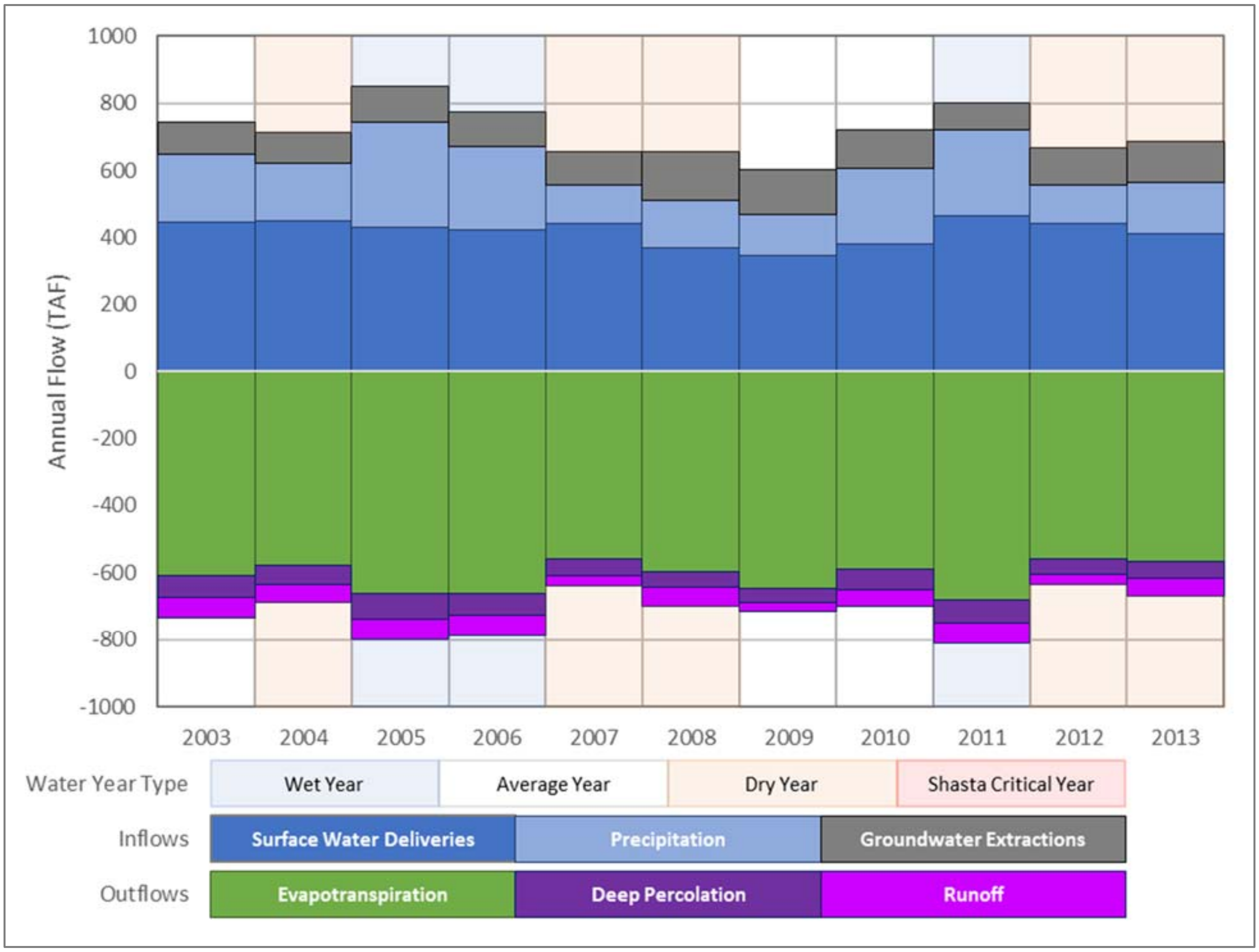

Figure 5-124. Annual Land Surface Budget Over Historic and Current Periods

The land surface budget estimated that the Northern and Central Delta-Mendota Regions experienced about 718,000 AFY of inflows on average between WY2003 and WY2012, including a combination of surface water deliveries (419,000 AFY), applied groundwater (pumped) (108,000 AFY), and precipitation (191,000 AFY) (Figure 5-122). Outflows from the land surface system were estimated to be similar in magnitude to inflows (722,000 AFY total) and are comprised of runoff (49,000 AFY), deep percolation (58,000 AFY), and evapotranspiration (615,000 AFY). Under current water year conditions (WY2013), total inflow to the land surface system was estimated to exceed outflows by approximately 16,000 acre-feet (AF) (685,000 AF and 669,000 AF, respectively) (Figure 5-123). During WY2013, inflows consisted of surface water deliveries (413,000 AF), applied groundwater (123,000 AF), and precipitation (149,000 AF), while outflows consisted of runoff (51,000 AF), deep percolation (50,000 AF) and evapotranspiration (568,000 AF).

Annual inflows and outflows in the land surface budget during the historic and current water budget period ranged from 602,000 AF (WY2009) to 848,000 AF (WY2005) and 634,000 AF (WY2012) to 811,000 AF (WY2011), respectively (Figure 5-124). The highest annual inflow and outflow were experienced during wet water years (WY2005, 2006, and 2011) when precipitation and surface water deliveries are highest. The least inflow and outflow from the land surface system was estimated to occur during dry years and years immediately following consecutive dry years as groundwater pumping increased but did not meet the entire surface water delivery deficit. Overall, inflows and outflows in the land surface budget were mostly balanced on an annual basis from WY2003 through WY2013.

Figure 5-125 and Figure 5-126, respectively, summarize the average annual historic and current groundwater inflows and outflows in the Northern and Central Delta-Mendota Regions. Figure 5-127 shows the annual time series of historic and current groundwater inflows and outflows.

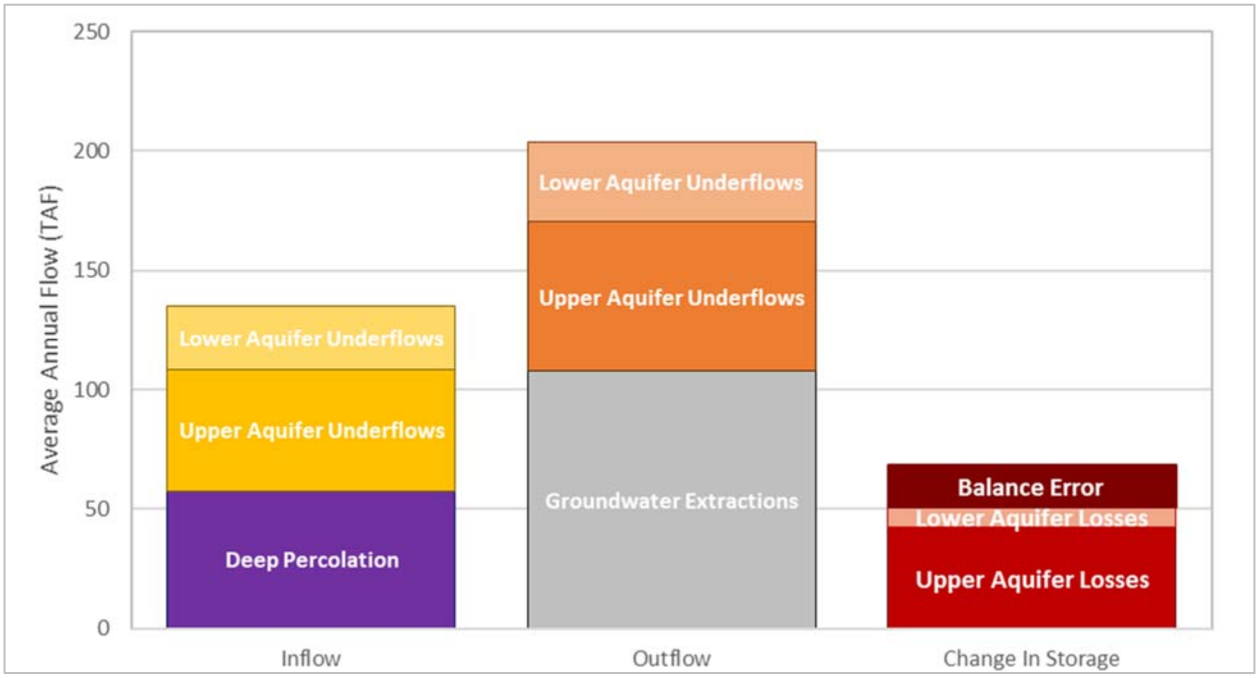

Figure 5-125. Average Historic Groundwater Budget (WY2003-2012)

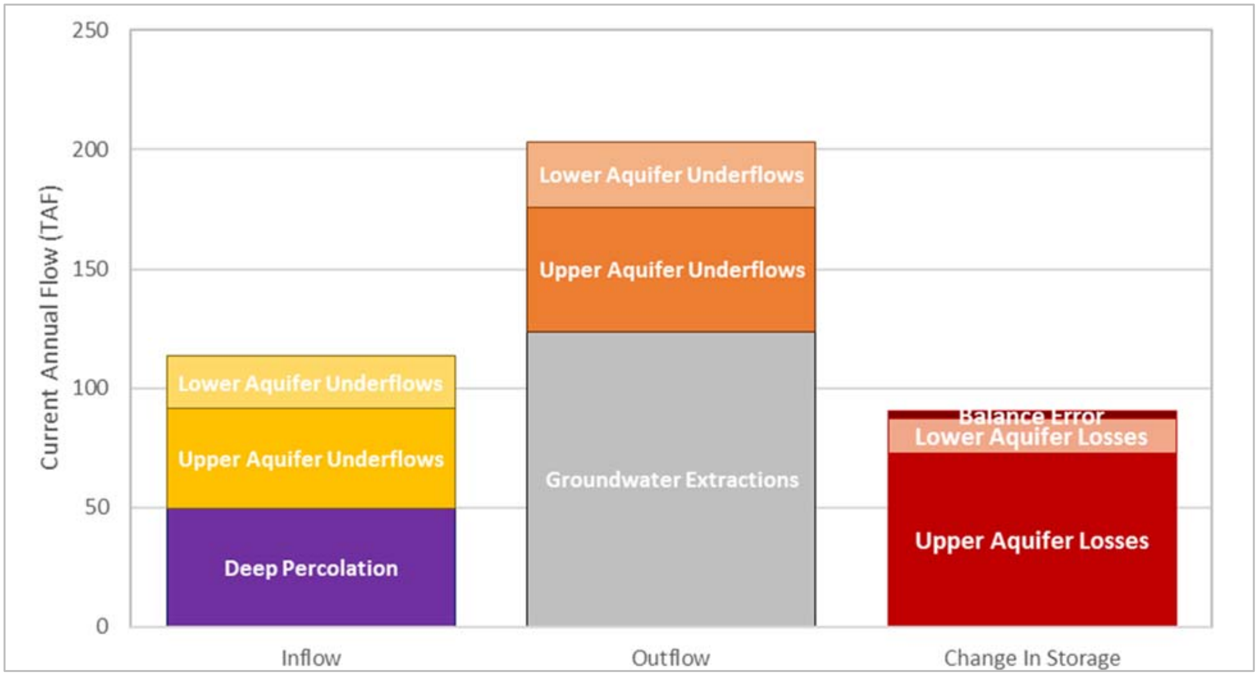

Figure 5-126. Current Groundwater Budget (WY2013)

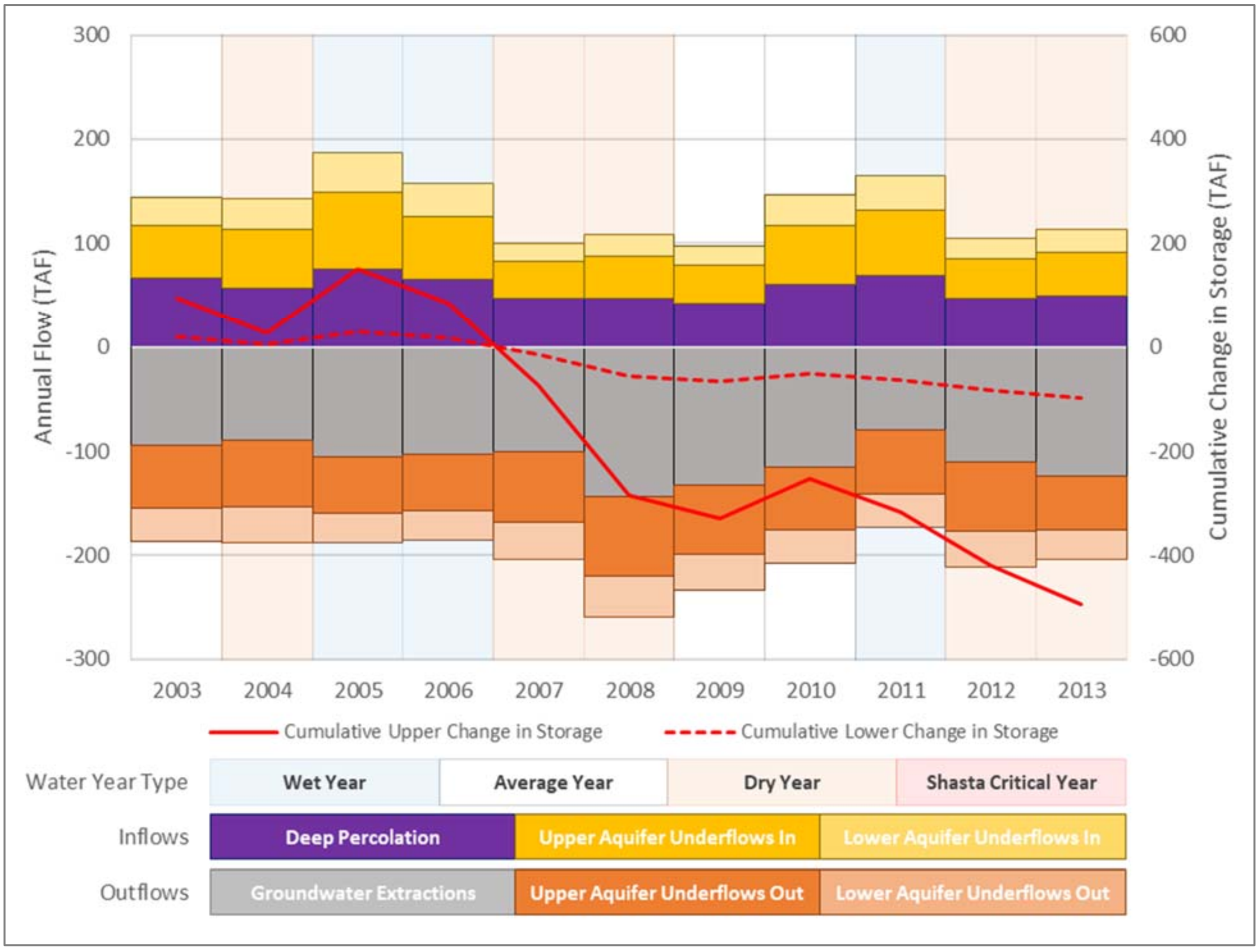

Figure 5-127. Historic and Current Annual Groundwater Budget

The groundwater budget estimated that the Northern and Central Delta-Mendota Regions experienced 136,000 AFY of total inflow on average during the historic water budget period, which includes 58,000 AFY of deep percolation, 51,000 AFY of Upper Aquifer underflows, and 27,000 AFY of Lower Aquifer underflows (Figure 5-125). Outflows from the groundwater system were estimated to be 204,000 AFY on average, which includes 108,000 AFY of groundwater pumping, 30 AFY of tile drainage, 63,000 AFY of Upper Aquifer underflows, and 33,000 AFY of Lower Aquifer underflow. In WY2013 (current condition), a total of 114,000 AF of inflow to the Northern and Central Delta-Mendota Regions was estimated to be comprised of 50,000 AF of deep percolation, 42,000 AF of Upper Aquifer underflows, and 22,000 AF of Lower Aquifer underflows (Figure 5-126). Estimated outflows from the groundwater system in WY2013 totaled 203,000 AF and was comprised of 124,000 AF of groundwater pumping, 30 AFY of tile drainage, 52,000 AF of Upper Aquifer underflows, and 27,000 AF of Lower Aquifer underflows. Overall, there is estimated to be 68,000 AFY and 89,000 AFY greater outflow than inflow under historic and current conditions, respectively. This includes balance error, Upper Aquifer losses, and Lower Aquifer losses.

On average, outflows were estimated to be greater than inflows throughout the historic and current water budget periods, meaning inflows did not meet the entire groundwater demand and resulted in decreased groundwater storage. This pattern is observed annually regardless of water year type, but the negative balance between inflows and outflows is less during wet years as compared to dry and normal years (Figure 5-127). Within the Northern and Central Delta-Mendota Regions, estimated average annual change in storage (i.e. overdraft) was -42,000 AFY in the Upper Aquifer and -8,000 AFY in the Lower Aquifer over the historic water budget period (50,000 AFY of total overdraft). During the current budget period, estimated Upper Aquifer storage decreased by 73,000 AF and Lower Aquifer storage decreased by 15,000 AF. Cumulative change in storage over the historic and current water budget periods in the Upper Aquifer and Lower Aquifer show overall downward trends (Figure 5-127). Between the beginning of WY2003 and WY2012, the estimated cumulative change in storage within the Upper Aquifer was -1.33 AF/acre, and -0.27 AF/acre in the Lower Aquifer (over the 316,000-acre Plan area). In WY2013, the estimated change in storage within the Upper Aquifer was -0.23 AF/acre and -0.05 AF/acre in the Lower Aquifer. Therefore, overdraft within the Northern and Central Delta-Mendota Regions is largely driven by conditions in the Upper Aquifer.

5.4.8 Projected Baseline Water Budget

The projected baseline water budget is used to estimate future (WY2014-2070) baseline conditions of supply, demand, and aquifer response to Plan implementation. More specifically, the baseline projected water budget was prepared to evaluate potential impacts from future changes in land use, cropping patterns, surface water supplies and groundwater demands, independent of climate change and mitigation measures (e.g. projects and management actions). Average annual historic hydrologic conditions were applied by water year type to each projected water year in correlation with the assigned representative water year.

Figure 5-128 summarizes the average annual projected baseline land surface inflows and outflows in the Northern and Central Delta-Mendota Regions. Figure 5-129 shows the annual time series of projected baseline land surface inflows and outflows.

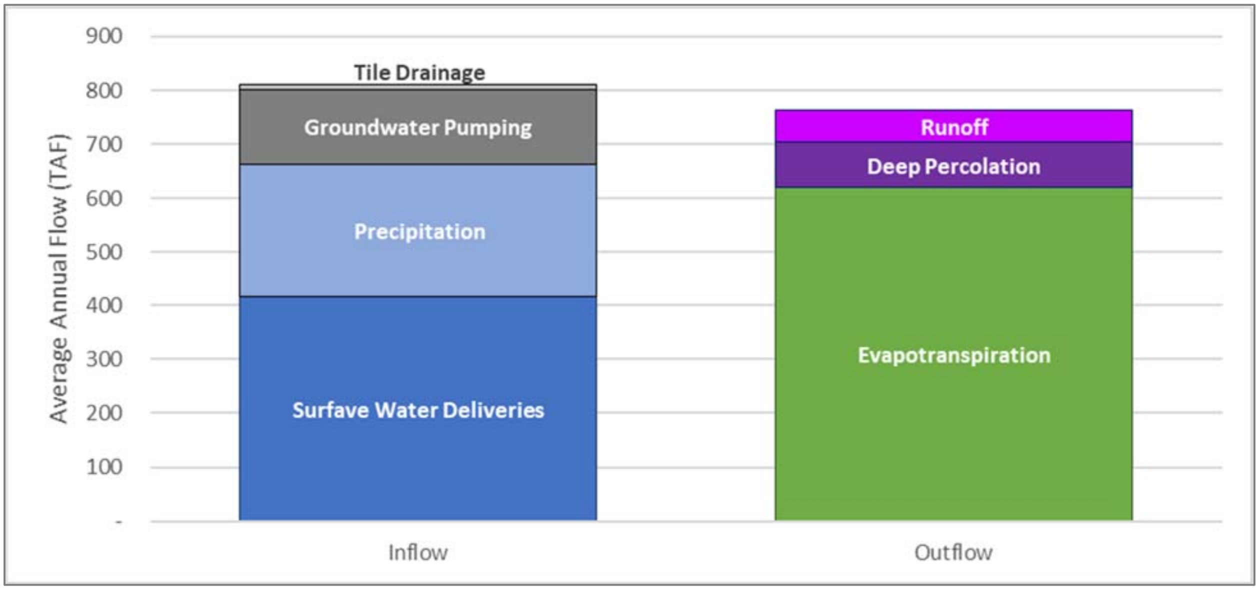

Figure 5-128. Projected Baseline Average Annual Land Surface Budget (WY2014-2070)

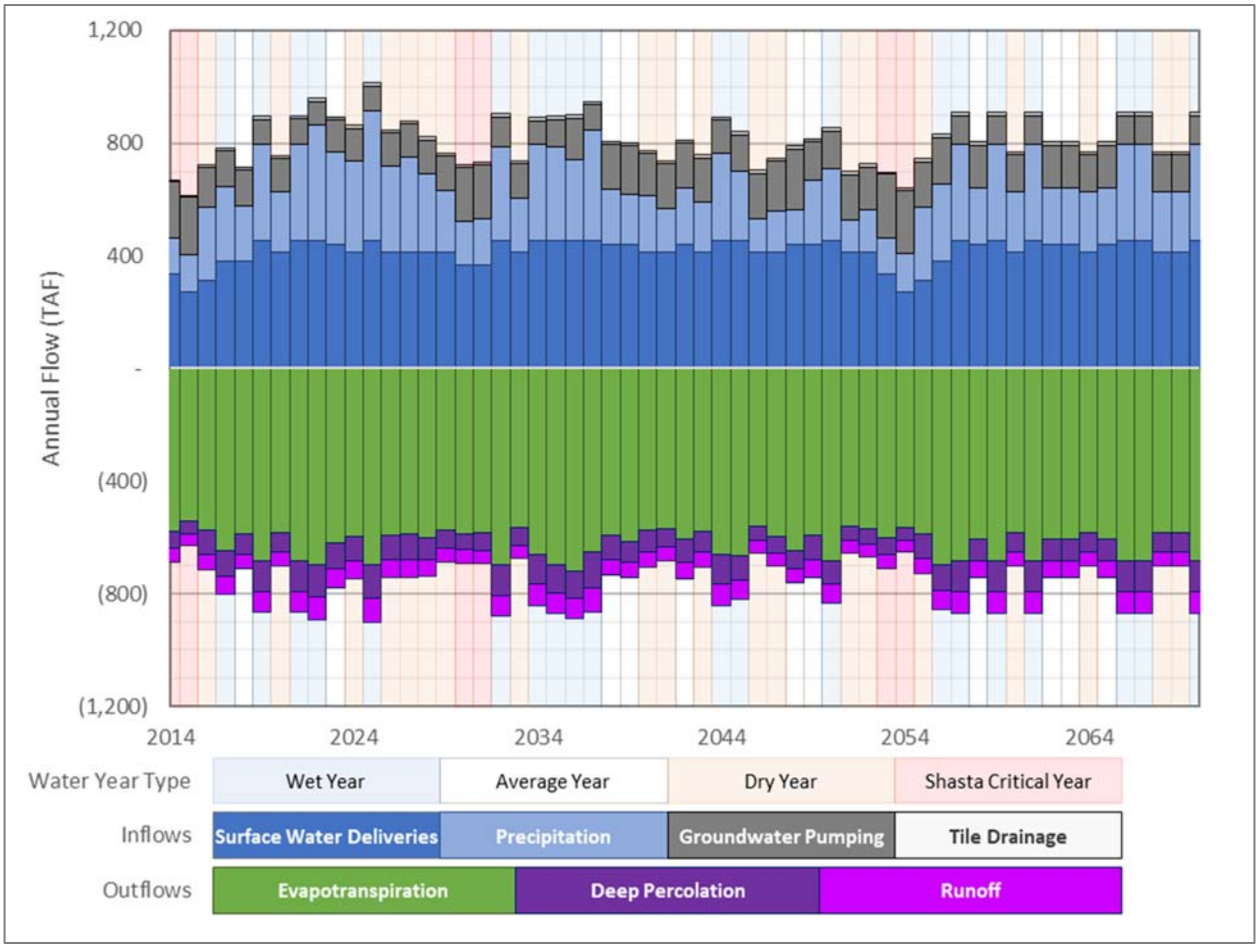

Figure 5-129. Projected Baseline Annual Land Surface Budget (WY2014-2070)

The land surface budget under projected baseline conditions shows inflows exceeding outflows on average by 53,000 AFY, where total average inflows and outflows are 817,000 AFY and 764,000 AFY, respectively (Figure 5-128). Inflows are comprised of surface water deliveries (422,000 AFY), applied groundwater (pumped) (138,000 AFY), tile drainage (11,000 AFY), and precipitation (246,000 AFY). Outflows are comprised of runoff (61,000 AFY), deep percolation (83,000 AFY), and evapotranspiration (620,000 AFY).

Annual inflows and outflows in the land surface budget during the projected baseline water budget period range from 615,000 AF (WY2015) to 1,012,000 AF (WY2025) and 628,000 AF (WY2015) to 902,000 AF (WY2025), respectively (Figure 5-129). Inflows and outflows from the land surface system are estimated to be largely balanced over the projected baseline water budget time period. Shasta Critical water years and dry water years preceding Shasta Critical water years show the least amount of inflow and outflow from the land surface system due to reduced surface water availability and precipitation. Figure 5-130 summarizes the average annual projected baseline groundwater inflows and outflows in the Northern and Central Delta-Mendota Regions. Figure 5-131 shows the annual time series of projected baseline inflows and outflows.

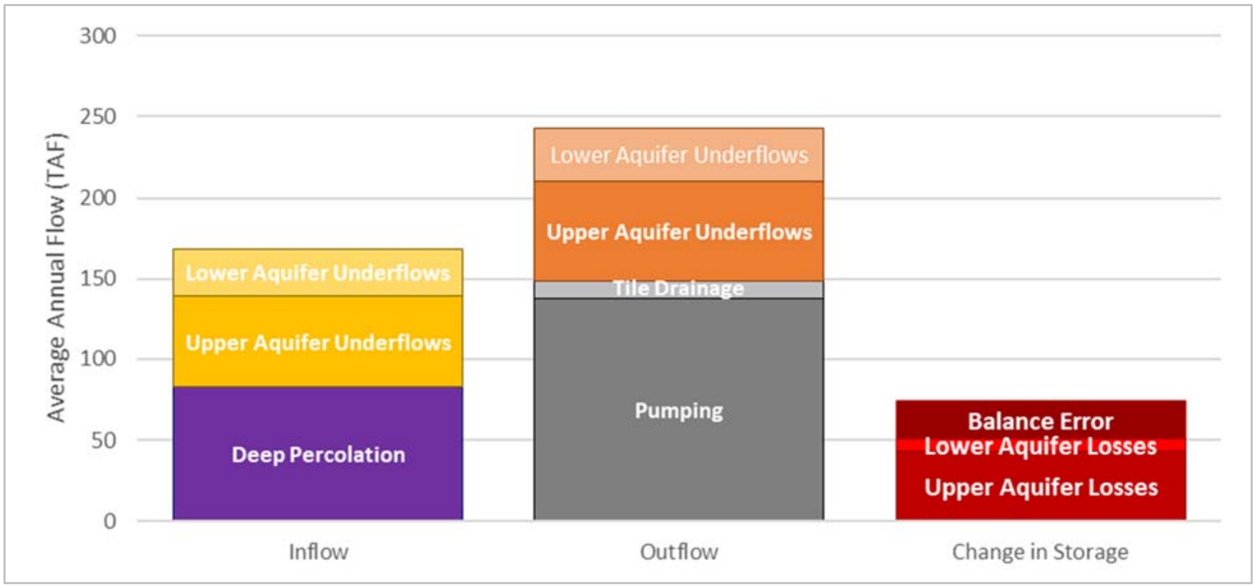

Figure 5-130. Projected Baseline Average Annual Groundwater Budget (WY2014-2070)

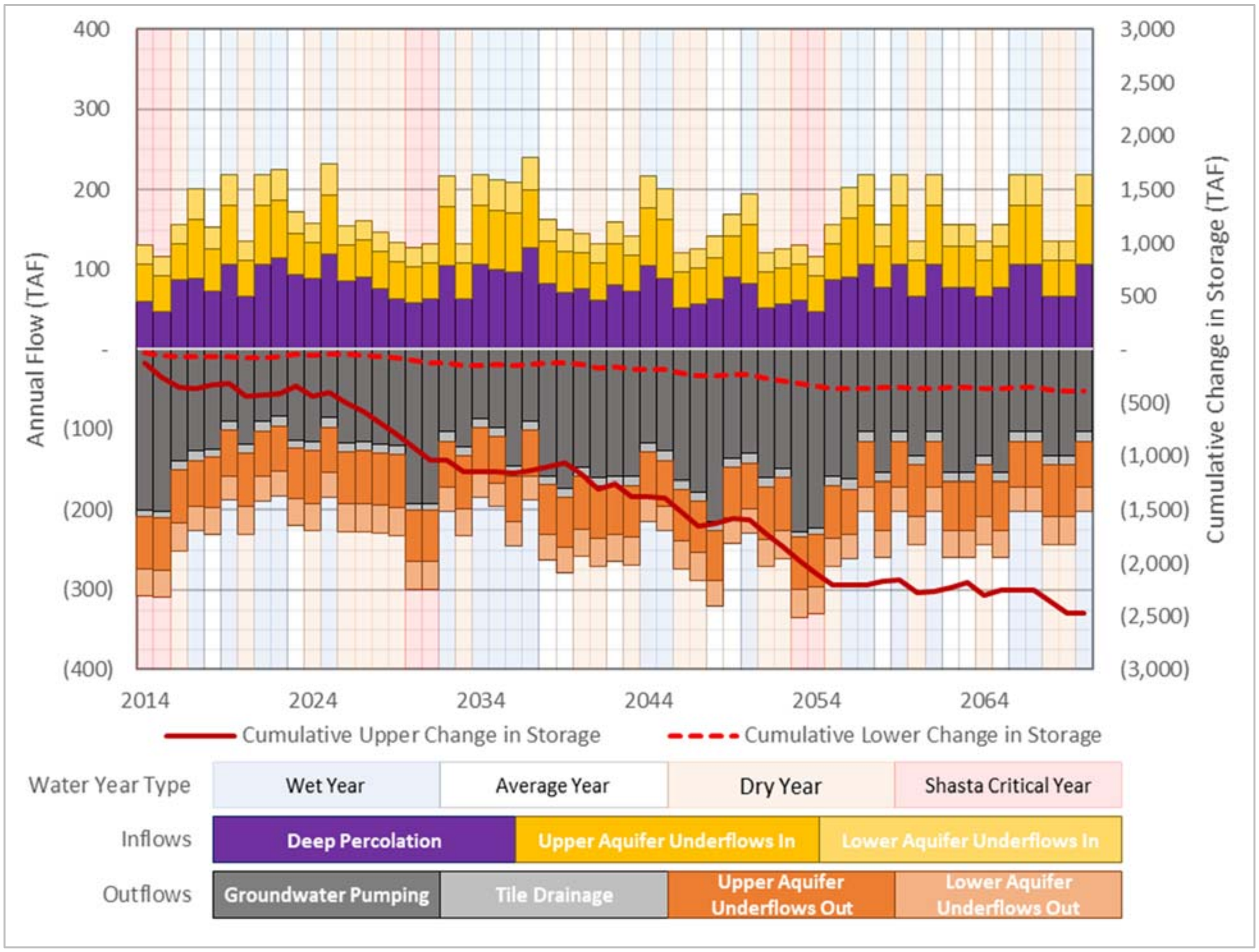

Figure 5-131. Projected Baseline Annual Groundwater Budget (WY2014-2070)

Under projected baseline conditions, the Northern and Central Delta-Mendota Regions are estimated to experience, on average, 169,000 AFY of inflow, of which 83,000 AFY is from deep percolation, 56,000 AFY is from Upper Aquifer underflows, and 30,000 AFY is from Lower Aquifer underflows (Figure 5-130). A total average annual outflow under the same conditions of 243,000 AFY consists of 138,000 AFY from groundwater pumping, 11,000 AFY from tile drainage, 62,000 AFY of Upper Aquifer underflows, and 32,000 AFY of Lower Aquifer underflows. Overall, there is 74,000 AFY greater outflow than inflow under projected baseline conditions that includes balance error, Upper Aquifer losses, and Lower Aquifer losses.

On average, outflows are estimated to be greater than inflows under projected baseline conditions, meaning continual declines in groundwater storage persist in the Northern and Central Delta-Mendota Regions. From WY2014 to WY2070, average annual change in storage is -43,000 AFY in the Upper Aquifer and -7,000 AFY in the Lower Aquifer (-50,000 AFY total). Cumulative change in storage in both the Upper and Lower Aquifer show overall declining trends over the baseline projected water budget period (Figure 5-131). By WY2070, cumulative change in storage in the Upper Aquifer and Lower Aquifer are -7.80 AF/acre and -1.24 AF/acre, respectively. Declines in groundwater storage in the Upper Aquifer continues to be dominant within the Northern and Central Delta-Mendota Regions over the projected baseline water budget period.

5.4.9 Projected Water Budget with Climate Change

The projected water budget with climate change is used to estimate future conditions of supply, demand, and aquifer response to Plan implementation without projects and management actions as precipitation, evapotranspiration, and streamflow patterns change. The projected water budget with CCF applied is used to evaluate projected baseline conditions with where applied climate change factors for precipitation and evapotranspiration provided by the California Department of Water Resources (DWR) (2018) and surface water delivery projections from local water purveyors were utilized from WY2014 through WY2070.

Figure 5-132 summarizes the average annual projected land surface inflows and outflows with CCF applied in the Northern and Central Delta-Mendota Regions. Figure 5-133 shows the annual time series of projected land surface inflows and outflows with climate change.

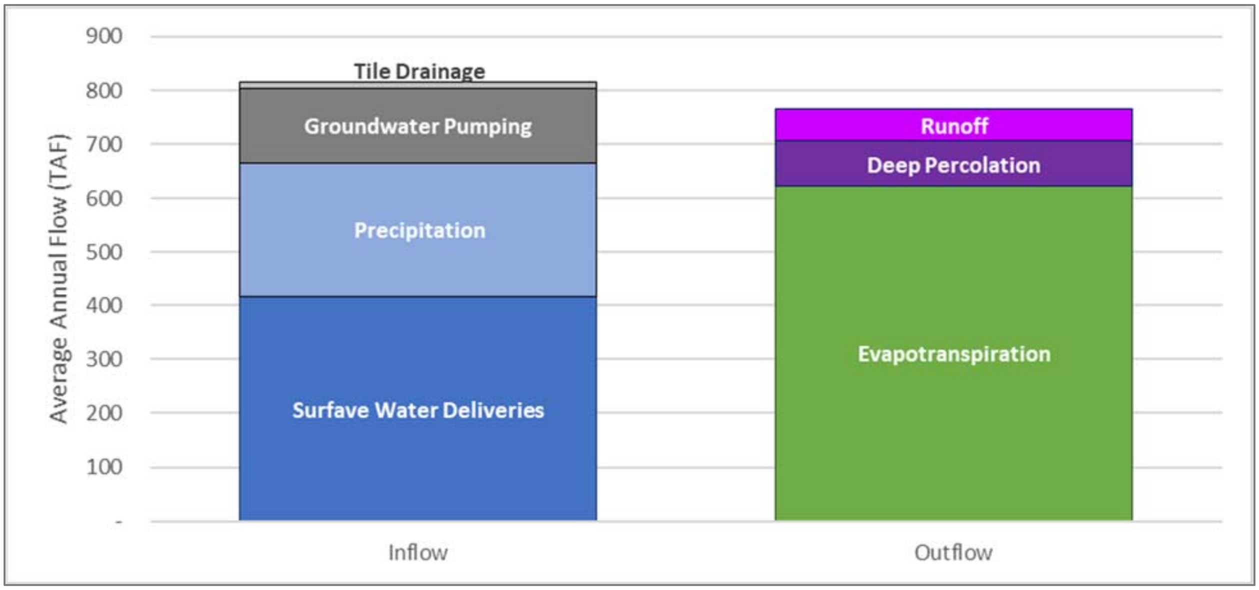

Figure 5-132. Projected Average Annual Land Surface Budget with Climate Change (WY2014-2070)

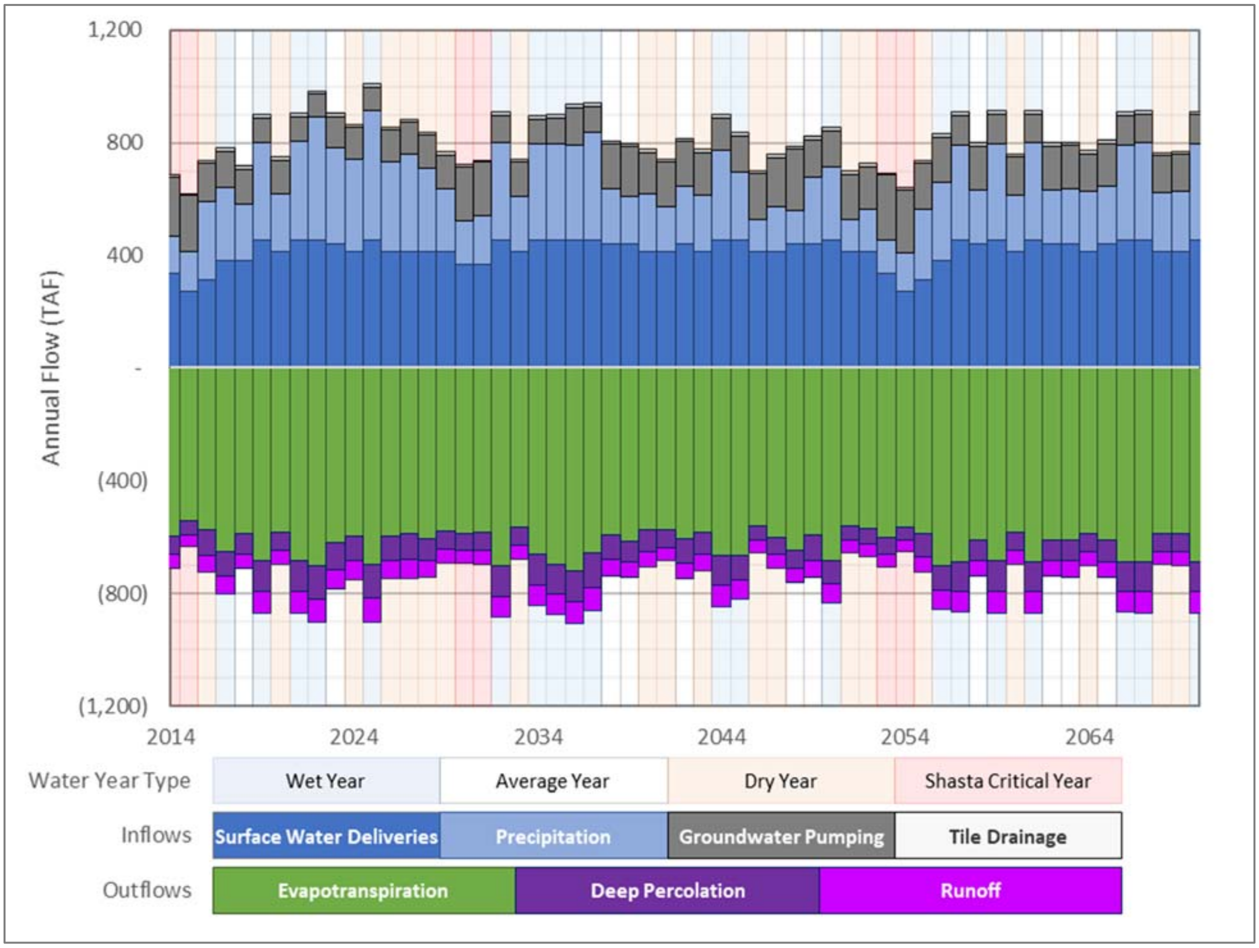

Figure 5-133. Projected Annual Land Surface Budget with Climate Change (WY2014-2070)

The land surface budget under projected conditions with climate change shows inflows exceeding outflows on average by 55,000 AFY, where total average inflows and outflows are 820,000 AFY and 765,000 AFY, respectively (Figure 5-132). Inflows are comprised of surface water deliveries (422,000 AFY), applied groundwater (pumped) (137,000 AFY), tile drainage (11,000 AFY), and precipitation (250,000 AFY). Outflows are comprised of runoff (60,000 AFY), deep percolation (83,000 AFY), and evapotranspiration (622,000 AFY).

Annual inflows and outflows in the land surface budget during the projected conditions with climate change water budget period range from 620,000 AF (WY2015) to 1,010,000 AF (WY2025) and 631,000 AF (WY 2015) to 908,000 AF (WY2036), respectively (Figure 5-133). Inflows and outflows from the land surface system are estimated to be largely balanced over the projected water budget time period under climate change. Shasta Critical water years and dry water years preceding Shasta Critical water years show the least amount of inflow and outflow from the land surface system due to reduced surface water availability.

Figure 5-134 summarizes the average annual projected conditions groundwater inflows and outflows with CCF applied in the Northern and Central Delta-Mendota Regions. Figure 5-135 shows the annual time series of projected conditions inflows and outflows with climate change.

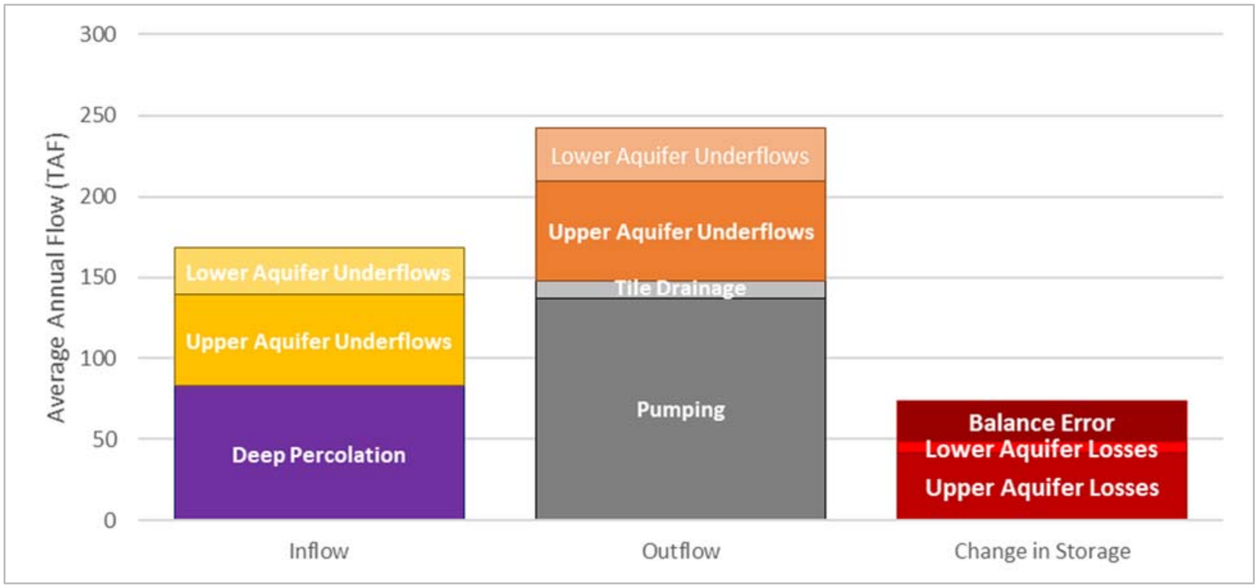

Figure 5-134. Projected Average Annual Groundwater Budget with Climate Change (WY2014-2070)

Figure 5-135. Projected Annual Groundwater Budget with Climate Change (WY2014-2070)

Under projected conditions with climate change, the Northern and Central Delta-Mendota Regions experiences, on average, 169,000 AFY of inflow of which 83,000 AFY is from deep percolation, 56,000 AFY is from Upper Aquifer underflows, and 30,000 AFY is from Lower Aquifer underflows (Figure 5-134). A total average annual outflow under the same conditions of 242,000 AFY consists of 137,000 AFY from groundwater pumping, 11,000 AFY from tile drainage, 62,000 AFY of Upper Aquifer underflows, and 32,000 AFY of Lower Aquifer underflows. Overall, there is 73,000 AFY greater outflow than inflow under projected conditions with climate change that includes balance error, Upper Aquifer losses, and Lower Aquifer losses.

On average, outflows are greater than inflows under projected conditions with climate change, meaning overdraft conditions persist in the Northern and Central Delta-Mendota Regions. From WY2014 to WY2070, average annual change in storage is -42,000 AFY in the Upper Aquifer and -6,000 AFY in the Lower Aquifer (-48,000 AFY total). Cumulative change in storage in both the Upper and Lower Aquifer show overall declining trends over the time period for the projected water budget with CCF applied (Figure 5-135). By WY2070, cumulative change in storage in the Upper Aquifer and Lower Aquifer are -7.51 AF/acre and -1.14 AF/acre, respectively. Compared to projected baseline conditions, cumulative change in storage under climate change conditions is 93,000 AF less in the Upper Aquifer and 33,000 AF less in the Lower Aquifer by WY2070. Overdraft in the Upper Aquifer continues to be the primary driver of overall overdraft within the Northern and Central Delta-Mendota Regions under projected conditions with climate change.

5.4.10 Projected Water Budget with Climate Change and Projects & Management Actions

The projected water budget with climate change is used to estimate future conditions of supply, demand, and aquifer response to Plan implementation as precipitation, evapotranspiration, and streamflow patterns change. The projected water budget with CCF applied and P&MAs is used to evaluate the projected baseline conditions with applied climate change factors provided by DWR from WY2014 through WY2070 as well as projects and management actions that will be implemented within the Plan area to help achieve sustainability by 2040. For more information regarding projects and management actions incorporated into this water budget, refer to Chapter 7 *Sustainability Implementation*, Section 7.1 *Projects & Management Actions*.

Figure 5-136 summarizes the average annual projected land surface inflows and outflows with CCF applied and P&MAs in the Northern and Central Delta-Mendota Regions. Figure 5-137 shows the annual time series of projected land surface inflows and outflows with CCF applied and P&MAs.

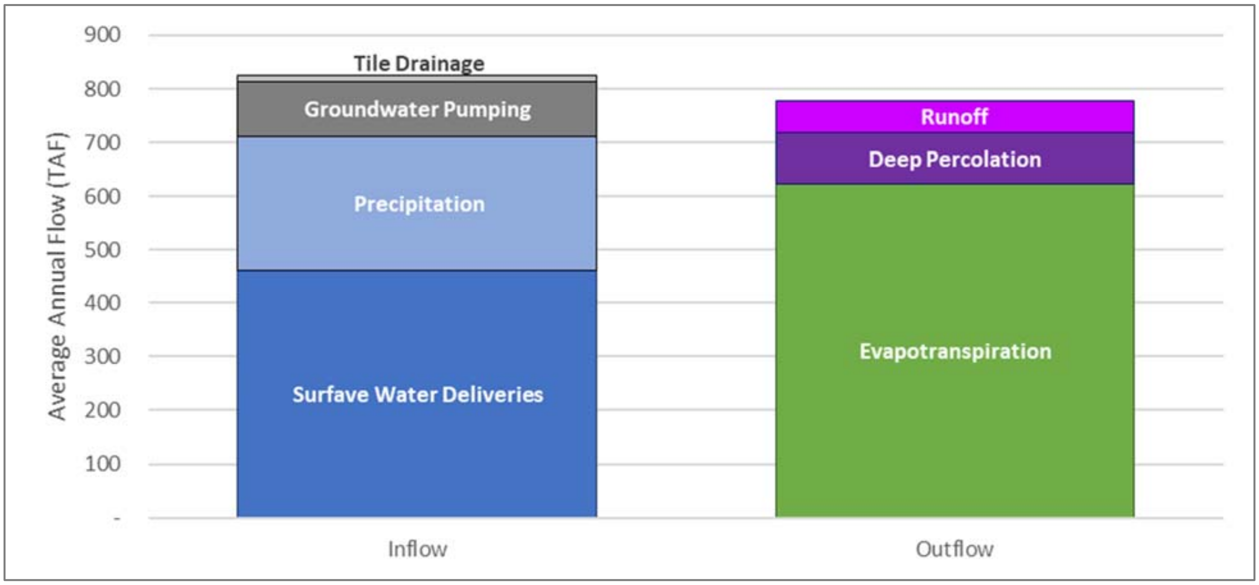

Figure 5-136. Projected Average Annual Land Surface Budget with Climate Change and Projects & Management Actions (WY2014-2070)

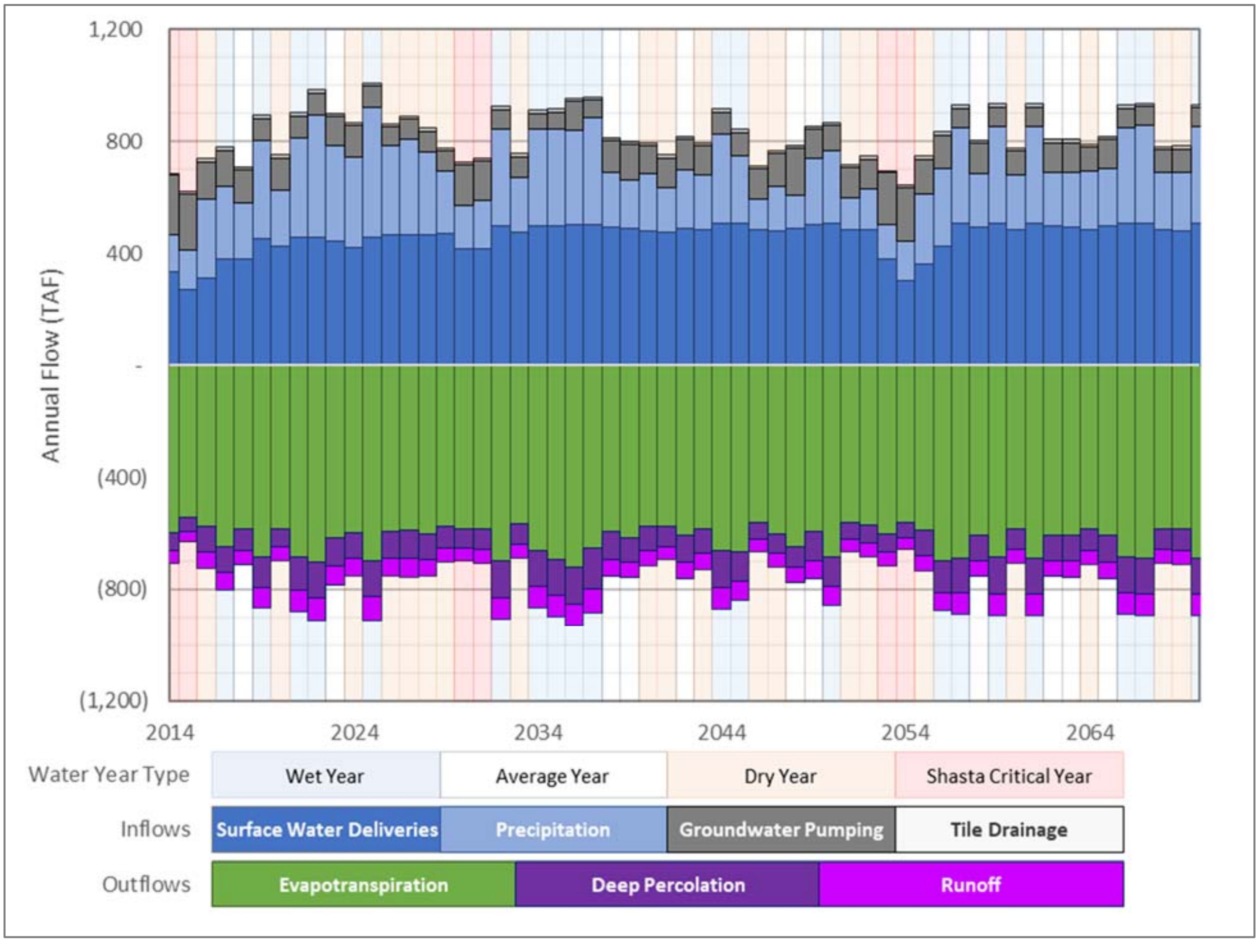

Figure 5-137. Projected Annual Land Surface Budget with Climate Change and Projects & Management Actions (WY2014-2070)

The land surface budget under projected conditions with CCF and P&MAs shows inflows exceeding outflows on average by 52,000 AFY, where total average inflows and outflows are 830,000 AFY and 778,000 AFY, respectively (Figure 5-136). Inflows are comprised of surface water deliveries (467,000 AFY), applied groundwater (pumped) (102,000 AFY), tile drainage (11,000 AFY), and precipitation (250,000 AFY). Outflows are comprised of runoff (61,000 AFY), deep percolation (95,000 AFY), and evapotranspiration (622,000 AFY).

Annual inflows and outflows in the land surface budget under projected conditions with CCF applied and P&MAs range from 620,000 AF (WY2015) to 1,010,000 AF (WY2025) and 631,000 AF (WY2015) to 931,000 AF (WY2036), respectively (Figure 5-137). Inflows and outflows from the land surface system are estimated to be largely balanced over the projected water budget with CCF applied and P&MAs time period. Shasta Critical water years and dry water years preceding Shasta Critical water years show the least amount of inflow and outflow from the land surface system due to reduced surface water availability and precipitation. Figure 5-138 summarizes the average annual projected conditions groundwater inflows and outflows with CCF applied and P&MAs in the Northern and Central Delta-Mendota Regions. Figure 5-139 shows the annual time series of projected conditions inflows and outflows with CCF applied and P&MAs.

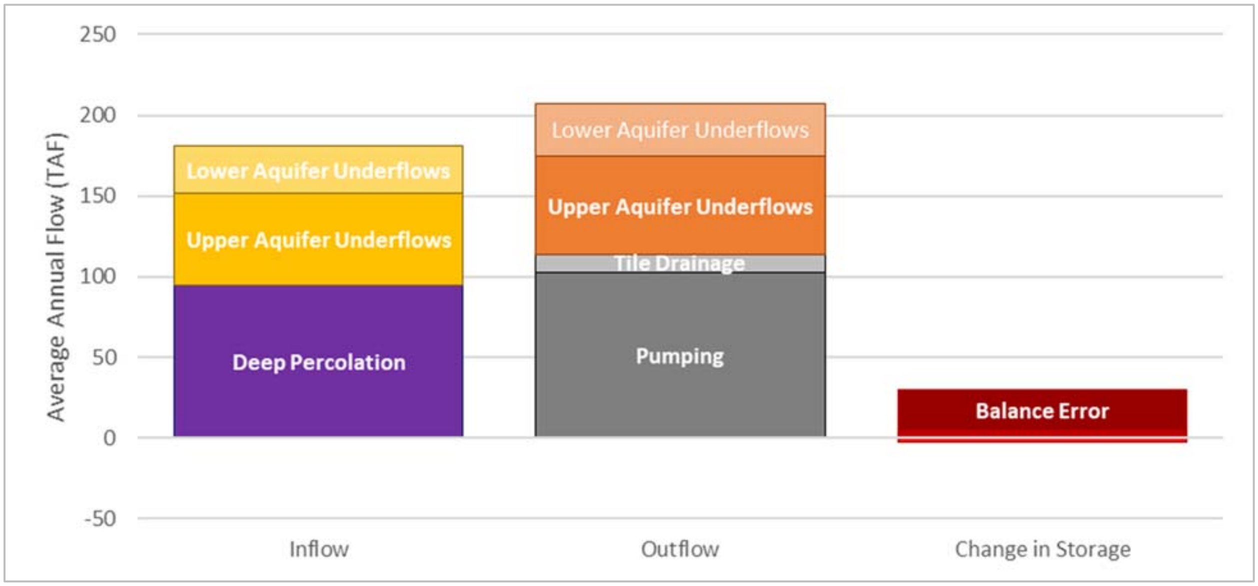

Figure 5-138. Projected Average Annual Groundwater Budget with Climate Change and Projects & Management Actions (WY2014-2070)

** Upper Aquifer Losses and Lower Aquifer Gains too small to label.*

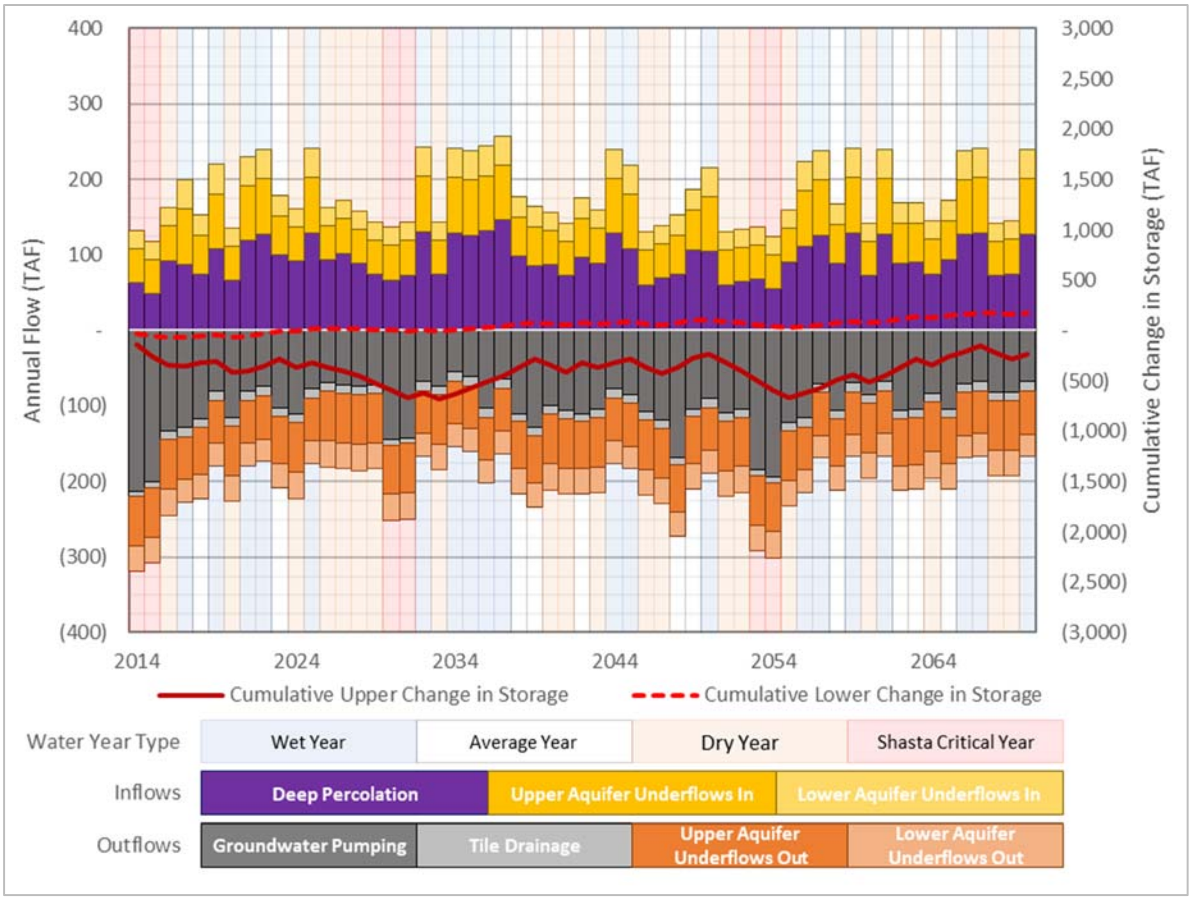

Figure 5-139. Projected Annual Groundwater Budget with Climate Change and Projects & Management Actions (WY2014-2070)

Under projected conditions with CCF and P&MAs, the Northern and Central Delta-Mendota Regions experience, on average, 181,000 AFY of inflow of which 95,000 AFY is from deep percolation, 56,000 AFY is from Upper Aquifer underflows, and 30,000 AFY is from Lower Aquifer underflows (Figure 5-138). A total average annual outflow under the same conditions of 207,000 AFY consists of 102,000 AFY from groundwater pumping, 11,000 AFY from tile drainage, 62,000 AFY of Upper Aquifer underflows, and 32,000 AFY of Lower Aquifer underflows. Overall, there is 26,000 AFY greater outflow than inflow under projected conditions with climate change factors applied and projects & management actions, including balance error, Upper Aquifer losses, and Lower Aquifer losses.

With the addition of CCF and P&MAs, projected long-term declines in groundwater storage are nearly reversed in both principal aquifers on an average annual basis in the Northern and Central Delta-Mendota Regions. From WY2014 to WY2070, average annual change in storage is -4,000 AFY in the Upper Aquifer and +3,000 AFY in the Lower Aquifer (-1,000 AFY total over the 316,000 acres comprising the Northern and Central Delta-Mendota Regions). From WY2034 onward, the Lower Aquifer no longer experiences overdraft conditions. Cumulative change in storage in both the Upper and Lower Aquifer show overall increasing trends over the projected water budget period with the addition of climate change and projects & management actions (Figure 5-139). By WY2070, cumulative change in storage in the Upper Aquifer and Lower Aquifer are -0.75 AF/acre and +0.55 AF/acre, respectively.

By WY2040, cumulative change in storage is -1.09 AF/acre in the Upper Aquifer and +0.22 AF/acre in the Lower Aquifer, for a total GSP-regional change in storage of approximately -0.87 AF/acre. By WY2040, the downward trend of cumulative change in storage has been corrected as compared to projected baseline conditions. However, these water budgets have been developed using approximate methodologies with a projected hydrology and land and water use patterns that are subject to change over the 20-year implementation period. It is anticipated that, as more data are collected and water budgets are refined, that projects and management actions will also be modified as needed to ensure that the sustainability goals for groundwater elevations and storage are achieved.

5.4.11 Sustainable Yield Estimates

Under SGMA, sustainable yield is defined as “the maximum quantity of water, calculated over a base period representative of long-term conditions in the basin and including any temporary surplus, that can be withdrawn annually from a groundwater supply without causing an undesirable result.” (California Water Code [CWC] 10721(w)). Sustainable yield estimates for the Upper Aquifer and Lower Aquifer have been developed in a coordinated fashion for the entire Delta-Mendota Subbasin by Delta-Mendota Technical Working Group and approved by the Delta-Mendota Coordination Committee.

Upper Aquifer Sustainable Yield Estimate

Methodologies for calculating Upper Aquifer sustainable yield were discussed by both the Delta-Mendota Coordination Committee and an ad-hoc Technical Working Group of the Coordination Committee. During a workshop dedicated to this effort, several basic concepts and principles were discussed to calculate the Upper Aquifer sustainable yield estimate. Consideration was given to several potential options with increasing detail, including some combination of the following: total Subbasin Upper Aquifer pumping volumes, total Subbasin Upper Aquifer change in storage, and Subbasin Upper Aquifer subsurface inflows and outflows. Inflow from certain neighboring subbasins, based on groundwater flow direction, as well as subsurface inflow from the Coast Range at existing gradients (as part of the inflow to the Northern & Central Delta-Mendota Region GSP area) was considered. Outflow to neighboring subbasins at existing gradients was also considered in certain applicable areas along the Delta-Mendota Subbasin boundary based on groundwater flow characteristics.

Based on these considerations, the following formula was selected for estimating Upper Aquifer sustainable yield:

$$Upper\ Aquifer\ Sustainable\ Yield\ =\ (Pumping + Change\ in\ Storage)\ +\ (Outflow - Inflow)$$

Given existing Subbasin data gaps and uncertainties associated with the data used to develop the water budgets and this estimate, it was also decided that a +/- 10% factor should be applied to determine a range for the Upper Aquifer sustainable yield value. The +/- 10% factor is applied based on the percentage difference between the values from change in storage Subbasin contour mapping for the historic water budget period and reported changes in storage from the Subbasin consolidated historic water budgets (WY2003-2012) for the Upper Aquifer.

The formula for determining Upper Aquifer sustainable yield was applied to the following compiled Delta-Mendota Subbasin projected water budgets (WY2014-2070):

- *Projected Baseline values with Climate Change Factors*
- *Projected Baseline values with Climate Change Factors and Projects and Management Actions*

This analysis resulted in an Upper Aquifer Sustainable Yield estimate ranging from 325,000 AF to 480,000 AF, demonstrating the Subbasin’s Upper Aquifer sustainable yield estimated without implementing any projects and management actions (low end of range) and how the Subbasin’s Upper Aquifer sustainable yield will be impacted by implementing projects and management actions (high end of range).

The Upper Aquifer sustainable yield values, derived from calculations using the best available, but limited data, are considered to be preliminary estimations only and will be updated to an anticipated higher level of accuracy in future GSP updates. The intention of the Delta-Mendota Subbasin GSAs, following GSP submission in 2020, is to increase Subbasin-wide data collection efforts. Improved data, modeling results, and understanding of subsurface flows will allow the GSAs and each GSP Group to improve estimated sustainable yield values for future GSP updates.

The Upper Aquifer sustainable yield calculated range reflects the principle that the GSAs within the Delta-Mendota Subbasin reserve the right to claim or retain some portion of subbasin outflow generated by the lowering of groundwater levels from neighboring subbasins and the equitable portion of sources of recharge shared between two subbasins, by physical or non-physical means, in the future if the Delta-Mendota Subbasin GSAs determine that doing so will improve Subbasin sustainability or will prevent undesirable results due to chronic lowering of groundwater. Furthermore, intrabasin coordination during GSP development, followed by continuing interbasin coordination discussions and data collection after GSP adoption, will allow the GSAs to further refine these determinations.

Lower Aquifer Sustainable Yield Estimate

Currently, within the Delta-Mendota Subbasin, the distribution of known Lower Aquifer water level data and extraction volume data are not sufficient to allow for an accurate calculation of Lower Aquifer sustainable yield. Following discussions by both the Coordination Committee and the ad-hoc Technical Working Group of the Coordination Committee, a consensus was reached to establish a Lower Aquifer sustainable yield estimate for the Subbasin by evaluating other regional studies previously conducted in the San Joaquin Valley.

The Westlands Water District (WWD) GSA has completed a recent study using groundwater modeling, in conjunction with the Westside GSP development, to estimate sustainable yield for that subbasin. Based on an analysis of available data and an initial assumption of lower aquifer sustainable yield equivalent to approximately 0.35 acre-feet per acre within the Westside Subbasin (Westlands Water District GSA, Groundwater Management Strategy Concepts presentation to the WWD Board on October 16, 2018) the GSA estimates a sustainable yield of 230,000 to 250,000 AF, with historic conditions suggesting a range from 250,000 to 300,000 AF (Westlands Water District GSA, Westside Subbasin's Groundwater Model Forecast and Augmentation Strategies presentation to the WWD Board on April 3, 2019). Using Westlands Water District GSA's analysis, the Coordination Committee recommended a slightly more conservative sustainable yield value of one-third (0.33) an acre-foot per acre for the Delta-Mendota Subbasin. Using this more conservative value, the estimated sustainable yield is approximately 250,000 acre-feet per year over the approximately 750,000-acre subbasin. It should be noted that sustainable management of the Lower Aquifer is governed by significant and unreasonable subsidence rather than sustainable yield. Sustainable yield is not uniform throughout the Subbasin, and it will be the responsibility of each GSA in the Subbasin to manage Lower Aquifer pumping to prevent significant and unreasonable subsidence.

Because DWR classified the Delta-Mendota Subbasin as critically-overdraft due to subsidence issues, the more conservative acre-foot per acre value for a Lower Aquifer sustainable yield estimation is considered valid as a starting point for the Subbasin. Lower Aquifer groundwater extractions may be managed to a stricter criterion in some areas in order to reduce or eliminate the potential for future inelastic land subsidence.

The Lower Aquifer sustainable yield estimate will be refined in the future based on data collected and compiled for the Subbasin. This current sustainable yield approximation highlights the importance of an accepted Subbasin-level subsidence monitoring program concurrent with improved estimates of sub-Corcoran Clay groundwater extractions.

5.5 MANAGEMENT AREAS

This section describes the management areas established for the Northern and Central Regions of the Delta-Mendota Subbasin. The Groundwater Sustainability Plan (GSP) Emergency Regulations § 351(r) states that a "'management area' refers to an area within a basin for which the Plan [GSP] may identify different minimum thresholds, measurable objectives, monitoring, or projects and management actions based on differences in water use sector, water source type, geology, aquifer characteristics, and other factors." Management areas were identified and established pursuant to the requirements under Article 5: Plan Contents, Subarticle 2: Basin Setting, § 354.20 Management Areas of the GSP Emergency Regulations. When a management area is identified, the area must be evaluated based on the sustainability indicators for the Subbasin as a whole. Management area descriptions must include (1) the reason for the creation of each management area; (2) minimum thresholds and measurable objectives established for each management area and an explanation of the rationale for selecting those values, if different from the basin at large; (3) the level of monitoring analysis appropriate for each management area; and (4) an explanation of how the management area can operate under different minimum thresholds and measurable objectives without causing undesirable results outside the management area for each sustainability indicators applicable to the Plan Area as a whole. Maps of established management areas for each sustainability indicator are also included within each description, where applicable.

5.5.1 Chronic Lowering of Groundwater Levels

No management areas are delineated for the purposes of managing the chronic lowering of groundwater levels sustainability indicator.

5.5.2 Reduction of Groundwater Storage

No management areas are delineated for the purposes of managing the long-term reduction of groundwater storage sustainability indicator.

5.5.3 Seawater Intrusion

Seawater intrusion is not applicable to the Delta-Mendota Subbasin as a whole, since the Subbasin is located inland from the Pacific Ocean and no known sources of seawater water are present within or surrounding the Subbasin. Therefore, this undesirable result is not applicable to the Delta-Mendota Subbasin and no management areas are delineated.

5.5.4 Degraded Water Quality

No management areas are delineated for the purposes of managing the degraded water quality sustainability indicator.

5.5.5 Land Subsidence

There are two management areas (MAs) established for land subsidence within the Plan Area: the West Stanislaus Irrigation District and Patterson Irrigation District (WSID-PID) MA and the Tranquillity Irrigation District (TRID) MA (Figure 5-140). The WSID-PID MA includes the entirety of the WSID and PID Groundwater Sustainability Agencies (GSAs), located primarily within Stanislaus County and extending into San Joaquin County. The TRID MA is located at the southeastern tip of the Delta-Mendota Subbasin and encompasses both the TRID and Fresno Slough Water District service areas. The following subsections describe the reason for these MAs, an explanation and rationale for selecting minimum thresholds and measurable objectives established for each MA, the level of monitoring and analysis appropriate for each MA, and an explanation of how the established MAs can operate under different minimum thresholds and measurable objectives without causing undesirable results outside the MAs.

5.5.5.1 Reason for Management Areas

The WSID-PID and TRID MAs have been established to better manage progress toward sustainability through sustainable management criteria for the land subsidence sustainability indicator, as detailed in Chapter 6 *Sustainable Management Criteria*. Subsidence in the remaining Northern and Central Delta-Mendota Regions outside of the established MAs has the potential to impact water conveyance infrastructure of statewide importance, which includes the California Aqueduct and Delta-Mendota Canal (DMC) that run nearly the entire length of the remaining Plan Area. The WSID-PID and TRID MAs have been delineated to account for their respective unique, localized circumstances and conditions and to help facilitate implementation of the Plan to aid in achieving the sustainability goal for the Delta-Mendota Subbasin by 2040.

WSID and PID both hold appropriative water rights to divert from the San Joaquin River and contract with the U.S. Bureau of Reclamation for surface water deliveries from the Central Valley Project through diversions off the DMC. With adequate surface water supplies to meet demand within these districts, minimal groundwater pumping occurs from the Lower Aquifer (the primary cause of inelastic land subsidence in the Delta-Mendota Subbasin) within these district's boundaries. As a result, subsidence occurring within this MA is expected to be minimal and is not anticipated to have significant potential to impact water conveyance infrastructure of statewide importance. Impacts to the capacity of WSID's and PID's respective distribution systems as a result of potential increased groundwater pumping-related subsidence and the associated reduced ability to deliver surface water supplies diverted from the San Joaquin River (in addition to the DMC) would trigger an undesirable result or be considered "significant and unreasonable," and necessitates the establishment of this MA.

The TRID MA is established because it is geographically separated from the remainder of the Plan Area and distant from the DMC (Figure 5-140). Impacts from subsidence within the TRID MA are largely related to levees for flood protection and local water conveyance infrastructure, as the California Aqueduct and DMC do not run through the TRID MA. In 2017, the freeboard on the TRID levee system was raised approximately two (2) feet above the maximum flow condition as an emergency effort to counter inelastic land subsidence resulting from the prior drought period. This was done to both protect the local community and farmed lands from inundation and to ensure adequate channel capacity during subsequent wet years. As a result, sustainable management criteria have been established to manage this sustainability indicator according to the unique subsidence-related concerns within the TRID MA (see Chapter 6 *Sustainable Management Criteria* for more detail).

5.5.5.2 Minimum Thresholds and Measurable Objectives

Minimum thresholds and measurable objectives specific to each representative monitoring location within the WSID-PID and TRID MAs, as well as those for the remaining Plan Area, and the rationale for selecting values can be found in Chapter 6 *Sustainable Management Criteria*.

The minimum thresholds and measurable objectives specific to each representative monitoring site within the WSID-PID and TRID MAs are identified in Table 5-35. For monitoring sites within the WSID-PID MA, numeric values for minimum thresholds and measurable objectives will be developed following data collection efforts occurring between 2020 and 2025 and will be included in the first 5-Year Update to this GSP. Subsidence monitoring benchmarks were constructed within the WSID-PID MA due to subsidence impacts observed along the DMC in Stanislaus County. However, land surface elevation measurements at these benchmarks has not formally commenced and therefore data are limited in the respective MAs. Without available historical data to establish numeric minimum thresholds and measurable objectives, benchmark surveys will be performed within the first five (5) years of GSP implementation to develop numeric criteria to evaluate progress toward sustainability within the WSID-PID MA. As such, the minimum thresholds and measurable objectives for each representative monitoring site have been set as "to be determined" (TBD) until sufficient data are collected to establish these numeric values.

For the TRID MA, minimum thresholds and measurable objectives in ground surface elevation (in feet relative to the North American Vertical Datum of 1988 [NAVD88] or [ft ground surface elevation (GSE)]) at each representative monitoring site are identified in Table 5-35. These values have been established relative to the identified level of tolerance for additional subsidence relative to 2019 levee elevations. An additional two (2) feet of subsidence and an additional four (4) feet of subsidence relative to 2019 levee elevations have been set as the measurable objective and minimum threshold, respectively, for each land subsidence representative monitoring site within the TRID MA. These values for additional subsidence tolerance were established based on professional judgement, local knowledge, and the 2017 emergency levee freeboard increase.

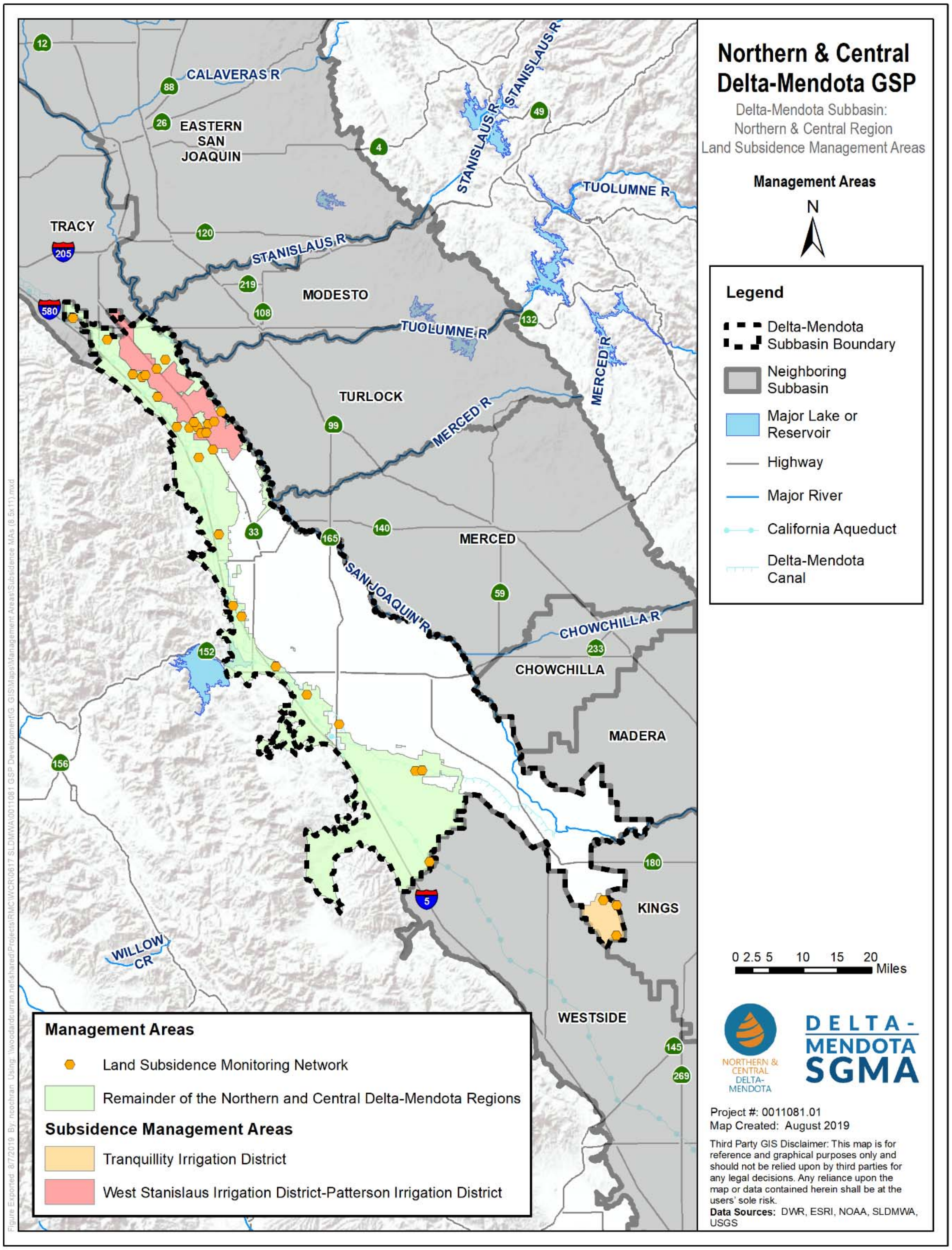

Figure 5-140. Subsidence Management Areas, Northern and Central Delta-Mendota Regions

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Table 5-35. Minimum Thresholds and Measurable Objectives for Subsidence Management Areas

Primary ID	Local ID	Agency	County	Management Area	Baseline Elevation [1]	Minimum Threshold	Measurable Objective
03-004	Locust Avenue Well	PID	Stanislaus	WSID-PID	TBD	TBD	TBD
03-005	Pumping Plant No. 2	PID	Stanislaus	WSID-PID	TBD	TBD	TBD
03-006	River Station	PID	Stanislaus	WSID-PID	TBD	TBD	TBD
04-002	WSID 1	WSID	Stanislaus	WSID-PID	TBD	TBD	TBD
04-003	WSID 11	WSID	Stanislaus	WSID-PID	TBD	TBD	TBD
04-004	WSID 21	WSID	Stanislaus	WSID-PID	TBD	TBD	TBD
07-019	AG-24	TRID	Fresno	TRID	157.77 ft GSE	153.77 ft GSE	155.77 ft GSE
07-025	TID A	TRID	Fresno	TRID	160.54 ft GSE	156.54 ft GSE	158.54 ft GSE
07-026	TID B	TRID	Fresno	TRID	169.22 ft GSE	165.22 ft GSE	167.22 ft GSE

TBD – To Be Determined

[1] Baseline elevation surveys will be performed for the monitoring sites in the WSID-PID MA by the end of calendar year 2019

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5.5.5.3 Monitoring and Analysis

GSP Emergency Regulations § 354.34(f) indicates: "If management areas are established, the quantity and density of monitoring sites in those areas shall be sufficient to evaluate conditions of the basin setting and sustainable management criteria specific to that area." For more information regarding the level of monitoring and analysis appropriate for each management area, refer to Section 7.2.5.5 *Land Subsidence Monitoring Network* of the *Sustainability Implementation* chapter.

The WSID-PID MA is approximately 58 square miles (mi^2) and the TRID MA is approximately 19 mi^2. The land subsidence monitoring network contains six (6) sites within the WSID-PID MA and three (3) sites within the TRID MA. Based on California Department of Water Resources' (DWR) recommendations as well as professional judgement, the selected number of monitoring sites within the WSID-PID and TRID MAs is sufficient to evaluate the land subsidence sustainability indicator relative to the sustainable management criteria established for each MA.

Each subsidence benchmark monitoring site will be surveyed and data will be analyzed and recorded annually within the TRID MA and during three (3) separate elevation surveys performed over the next five years within the WSID-PID MA. As there are no recorded issues related to conveyance capacity, stable groundwater levels, and substantial surface water supplies within this MA, subsidence is less of a concern in the WSID-PID MA compared to the remaining Plan Area. Baseline elevation measurements will be established in 2019 as reference for all representative monitoring sites within this MA, where subsequent elevation surveys at representative monitoring sites will be performed by the end of calendar year 2020 (in preparation for the 2021 Annual Report) and by the end of calendar year 2023 (in preparation for the 5-Year GSP Update in 2025). Measurements will be taken following seasonal high groundwater levels to capture the amount of inelastic subsidence occurring from the previous irrigation season(s). Monitoring frequency within the WSID-PID and TRID MAs will be reevaluated as part of the 5-Year GSP Update in 2025. For more detail regarding the level of monitoring and analysis appropriate for each management area, refer to Section 7.2.5.5 *Land Subsidence Monitoring Network* of the *Sustainability Implementation* chapter.

5.5.5.4 Operation and Outside Impacts

Due to ample surface water supplies available within the WSID-PID MA, it is unlikely that the minimal Lower Aquifer groundwater pumping currently occurring within this MA will significantly contribute to undesirable results related to inelastic land subsidence. The WSID-PID MA abuts the San Joaquin River Exchange Contractors (SJREC) GSP Group who, similarly, due to ample surface water supplies, is not currently experiencing significant levels of inelastic land subsidence from pumping within their Plan area. Due to the requirements that subbasins with multiple GSPs coordinate in the development and implementation of their GSPs, the Northern & Central Delta-Mendota Region and SJREC GSP Groups coordinated in the development of their land subsidence monitoring networks and data collection methodologies, as well as sustainable management criteria development, within and around the WSID-PID MA. The Northern & Central Delta-Mendota Region and SJREC GSP Groups will continue to coordinate as their respective GSPs are implemented to ensure land subsidence monitoring in the WSID-PID MA is adequate and necessary action is taken to prevent undesirable results outside the MA.

The TRID MA is geographically separate from the rest of the Northern & Central Delta-Mendota Region GSP Plan area. Therefore, based on professional judgement, it is unlikely that operation under different minimum thresholds and measurable objectives will cause undesirable results outside of the MA. The TRID MA abuts the Fresno County Management Area A & B (Fresno County) GSP Plan area. Due to the requirements that subbasins with multiple GSPs coordinate in the development and implementation of their GSPs, the Northern & Central Delta-Mendota Region and Fresno County GSP Groups coordinated in the development of their land subsidence monitoring networks and data collection methodologies, as well sustainable management criteria within and around the TRID MA. The Northern & Central Delta-Mendota Region and Fresno County GSP Groups will continue to coordinate as their respective GSPs are implemented to ensure land subsidence monitoring in the TRID MA is adequate and necessary actions are taken to prevent undesirable results outside the MA.

5.5.6 Depletion of Interconnected Surface Water

No management areas are delineated for the purposes of managing the depletions of interconnected surface water sustainability indicator.

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