Appendix 2

2A Kaweah Subbasin Basin Setting Components

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Kaweah Subbasin
Basin Setting Components – Draft

March 2019 Revision

Submitted to:

East Kaweah Groundwater Sustainability Agency
Greater Kaweah Groundwater Sustainability Agency
Mid-Kaweah Groundwater Sustainability Agency

Submitted by:

GEI Consultants, Inc. and GSI Water Solutions

March 19, 2019

Prepared by: Chris Petersen and Tim Nicely

Reviewed by: Tim Thompson and Maria Pascoal

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AUTHOR INITIALS:TN, NP, BC, CP

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List of Abbreviations and Acronyms

AB	Assembly Bill
AF	Acre-feet
AF/WY	Acre-feet per Water Year
AFY	Acre-feet per Year
B-E	Bookman-Edmonston
bgs	Below Ground Surface
CalTrans	California Department of Transportation
Cal Water	California Water Service
CCTAG	Climate Change Technical Advisory Group
CIMIS	California Irrigation Management Information System
CVP	Central Valley Project
CRTN	California Real Time Network
CSRC	California Spatial Reference Center
CV-SALTS	Central Valley Salinity Alternatives for Long-term Sustainability
CWSC	U.S. Geological Survey California Water Science Center
DBCP	Dibromochloropropane
DDW	State Water Resources Control Board – Division of Drinking Water
DEM	Digital Elevation Model
DPR	Department of Pesticide Regulations
DTSC	Department of Toxic Substances Control
CDWR	California Department of Water Resources
EC	electrical conductivity
EKGSA	East Kaweah Groundwater Sustainability Agency
ESA	European Space Agency
ET	Evapotranspiration
FWA	Friant Water Authority
GAMA	Groundwater Ambient Monitoring and Assessment Program
GDE	Groundwater Dependent Ecosystem
GIS	Geographic Information System
GKGSA	Greater Kaweah Groundwater Sustainability Agency
GMP	Groundwater Management Plan
gpd	Gallons per Day
gpd/ft^2	Gallons per Day per Foot squared
GPS	Global Positioning System

GSA	Groundwater Sustainability Agency
GSP	Groundwater Sustainability Plan
HCM	Hydrogeologic Conceptual Model
HUC	Hydrologic Unit Code
ILRP	Irrigated Lands Regulatory Program
InSAR	Interferometric Synthetic Aperture Radar
IRWM	Integrated Regional Water Management
JPL	Jet Propulsion Laboratory
KDWCD	Kaweah Delta Water Conservation District
KSJRA	Kaweah & St. Johns River Association
LAS	Lower Aquifer System
LLNL	Lawrence Livermore National Laboratory
LUST	Leaking Underground Storage Tank
M&I	Municipal and Industrial
MCL	Maximum Contaminant Level
MKGSA	Mid-Kaweah Groundwater Sustainability Agency
NASA	National Aeronautics and Space Administration
NDVI	Normalized Difference Vegetation Index
NGS	National Geodetic Survey
NRCS	National Resource Conservation Service
NWIS	U.S. Geological Survey National Weather Information System
PBO	Plate Boundary Observation
PCE	Tetrachloroethylene
POTW	Publicly Owned Treatment Works
ppb	Parts per Billion
ppm	Parts per Million
RWQCB	Regional Water Quality Control Boards
SAGBI	Soil Agricultural Groundwater Banking Index
SAS	Single Aquifer System
SB	Senate Bill
SCE	Southern California Edison
SDWIS	State Drinking Water Information System
SGMA	Sustainable Groundwater Management Act
Sierra Nevada	Sierra Nevada Mountains
SJRRP	San Joaquin River Restoration Program
SMCL	Secondary Maximum Contaminant Level

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SNMP	Salt and Nitrate Management Plan
SOPAC	Scripps Orbit and Permanent Array Center
SR	California State Route
Subbasin	Kaweah Subbasin
SWRCB	State Water Resources Control Board
TAF	Trillion acre-feet
TCE	Trichloroethylene
TCP	1,2,3-Trichloropropane
TID	Tulare Irrigation District
UAS	Upper Aquifer System
UAVSAR	Uninhabited Aerial Vehicle Synthetic Aperture Radar
UC Davis	The University of California at Davis
USBR	U.S. Bureau of Reclamation
USGS	U.S. Geological Survey
UST	Underground Storage Tank
VIC	Variable Infiltration Capacity
VOC	Volatile Organic Compound
WDR	Waste Discharge Requirement
WRI	Water Resources Investigation
WSIP	Water Storage Investment Program
WWTP	Wastewater Treatment Plant

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Chapter 2. Basin Setting (§354.12)

This chapter provides a summary of the physical setting and geologic characteristics of the Kaweah Subbasin (Subbasin) that pertain to its groundwater conditions. Key aspects of this chapter include specific details related to the hydrogeologic conceptual model (HCM); current groundwater conditions and groundwater storage; the water budget including inflow and outflow details; the tools used to quantify the water budget, and, an overview of existing groundwater monitoring programs in the Subbasin.

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2.1 Overview of Plan Area

The Kaweah Subbasin, as defined in California's Department of Water Resources (CDWR) Bulletin 118 (2016), lies in the Tulare Lake Hydrologic Region of the San Joaquin Valley Groundwater Basin. The Subbasin is bounded by the Kings River Subbasin to the north, the Tulare Lake Subbasin to the west, the Tule Subbasin to the south, and the Sierra Nevada Mountains (Sierra Nevada) to the east. There are three groundwater sustainability agencies (GSAs) located in the Kaweah Subbasin: East Kaweah GSA (EKGSA), Greater Kaweah GSA (GKGSA), and Mid-Kaweah GSA (MKGSA). The GKGSA and MKGSA are roughly bisected by California State Route 99 (SR 99). The Kaweah and St. Johns Rivers, Cottonwood and Mill Creeks flow from the Sierra Nevada through the northern portion of the EKGSA and GKGSA jurisdictional areas, turning southwest and toward the Tulare Lake Basin. The Yokohl and Lewis Creeks also flow from the Sierra Nevada and appear along the eastern portion of the EKGSA.

The Kaweah Subbasin is mostly located in Tulare County, with western portions of the Subbasin in Kings County. The cities of Visalia and Tulare are located in the MKGSA jurisdictional area. The cities of Exeter, Farmersville, and Woodlake are in the GKGSA jurisdictional area, as well as a portion of the City of Hanford. The City of Lindsay is in the EKGSA jurisdictional area. The land use within the cities located in the Subbasin is classified as urban, while the majority of the Subbasin's acreage is classified as agricultural. This land use is further divided into field crops, grain and hay crops, pasture, or deciduous fruits and nuts.

2.1.1 Topographic Information

The topography of the Kaweah Subbasin area is characterized by a surface of low topographic relief, with variations rarely exceeding 10 feet except in stream channels. Elevations of the Kaweah Subbasin vary from about 800 feet above sea level near the easterly boundary to about 200 feet at the westerly boundary (***Figure 1***). The land generally slopes in a southwesterly direction at about 10 feet per mile, with this slope lessening near the westerly boundary.

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2.2 Hydrogeologic Conceptual Model §354.14

The purpose of a Hydrogeologic Conceptual Model (HCM) is to provide an easy to understand qualitative description of the physical characteristics of the regional hydrology; land use; geology; water quality; and principal aquifers and aquitards in the Subbasin. Once developed, an HCM is useful in providing the context to develop water budgets, monitoring networks, and identifying data gaps.

An HCM is neither a numerical groundwater model nor a water budget model. Rather, it is a written and graphical description of the hydrologic and hydrogeologic conditions that establish a foundation for development of a water budget. Refer to ***Section 2.5*** for information on the Subbasin water budget.

The narrative HCM description provided in this section is accompanied by graphical representations of physical characteristics of the Kaweah Subbasin to aid in the understanding of the geographic setting, regional geology, and basin geometry. This section describes the Subbasin HCM and includes an introduction and geologic context of the Subbasin within the overall Central Valley (CV) and San Joaquin Valley Groundwater Basin areas.

The HCM is primarily based on data compiled from two recent Water Resources Investigations (WRIs) within the Subbasin (Fugro West, 2007; Fugro Consultants, 2016), as well as additional data and analyses. Data include over 5,000 well completion reports for geologic data and water well design, geophysical electric logs and pumping test data from approximately 100 wells throughout the Kaweah Subbasin, as well as monitoring well data collected from DWR, Kaweah Delta Water Conservation District (KDWCD), and other GSA member agencies within the Subbasin.

The three reports cited below represent the key technical references used for this HCM. In addition to these reports, information to support the HCM was also collected from unpublished consultant reports and datasets related to work performed throughout the area, and personal communication with stakeholders and regulators.

- **Report on Investigation of the Water Resources of Kaweah Delta Water Conservation District (B-E, 1972).** An early, comprehensive study was conducted by Bookman-Edmonston (B-E) in the early 1970s, which integrated the conjunctive supply of both the surface and groundwater of the KDWCD. During the 32-year period between water years 1935 and 1966, land use and total consumptive use narrowly varied. The report presents historical elements of several water budget components including streamflow from as early as 1903 and precipitation dating back to 1877.

- **Water Resources Investigation of the Kaweah Delta Water Conservation District (Fugro West, 2003 [revised 2007]).** This WRI was prepared for the KDWCD in 2003 and presented a detailed geologic and hydrogeologic investigation and analysis that evaluated the quantity of groundwater in the KDWCD boundaries. The report included sources and volumes of natural recharge, water budgets, trends in water levels, and estimation of safe yield for the period of water years between 1981 and 1999. The 2003 report was revised in 2007 to account for adjustments to surface water delivery and crop water usage estimates used in the inventory method to determine changes of groundwater in storage. The overall conclusions of the 2007 report were consistent with the original 2003 investigation.

- **Water Resources Investigation Update, Kaweah Delta Water Conservation District (Fugro Consultants, 2016).** The 2016 WRI is an updated investigation that provides technical information regarding groundwater gradients, sources and volumes of natural recharge, the annual changes of the quantity of groundwater produced (based on estimated crop water uses), changes in groundwater storage, and the trends of groundwater levels throughout the study area. This report provided updates to the 2007 WRI including the conversion of calendar years to water years and extension of the analysis to the end of calendar year 2012. Additionally, the improved crop water use results (presented in the 2013 Davids Engineering report) were also incorporated into the study.

This HCM has been written by adhering to the requirements set forth in the California Code of Regulations, Title 23, Division 2, Chapter 1.5, Subchapter 2, Article 5, Subarticle 2 (§354.14).

2.2.1 Regional Setting

The Subbasin lies within the Tulare Lake Hydrologic Region of the Central Valley of California. The Central Valley covers approximately 20,000 square miles and extends from the Cascade Range to the north, the Sierra Nevada to the east, the Tehachapi Mountains to the south, and the Coast Ranges and San Francisco Bay to the west. The Central Valley is a vast agricultural region, drained by the Sacramento and San Joaquin rivers, averaging about 50 miles in width and extending about 400 miles northwest from the Tehachapi Mountains to Redding, CA. Generally, the land surface has low relief and is the result of millions of years of alluvial and fluvial deposition of sediments derived from the tectonic uplift of the surrounding mountain ranges. Most of the valley is near sea level but is higher along the valley margins. The Central Valley is divided into three groundwater basins according to CDWR's Bulletin 118 (2016). The northern one-third of the valley is within the Sacramento River Basin, the central one-third is within the San Joaquin River Basin, and the southern one-third is within the Tulare Lake Basin. The two southernmost basins, San Joaquin River and Tulare Lake, are generally referred to as the San Joaquin Valley region. The Kaweah Subbasin is located within the Tulare Lake Basin. In the vicinity of the Kaweah Subbasin, the Central Valley is approximately 65 miles wide and is bordered on the east by the Sierra Nevada and on the west by the Coast Range (***Figure 2***).

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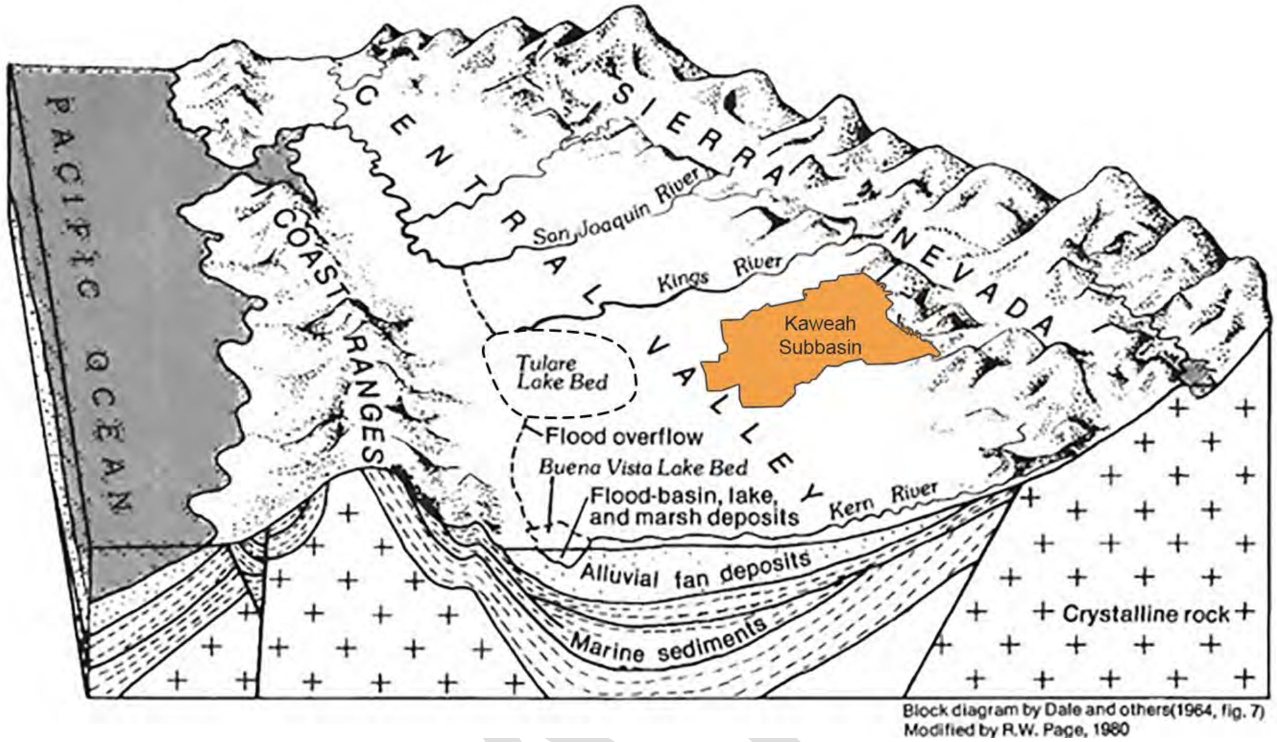

Figure 2: Isometric Block Diagram of Central San Joaquin Valley

The southern end of the Central Valley is a closed feature without external surface drainage. Tributary streams drain to depressions, the largest of which is the Tulare Lake bed located to the west of the Kaweah Subbasin boundary. The Kings, Kaweah, and Tule rivers and, on occasion, the Kern River, naturally discharge into Tulare Lake, but diversions by foothill reservoirs and irrigation activities commonly limit or prevent flows from reaching the lake (Fugro West, 2007).

2.2.1.1 Subbasin Features

The eastern portion of the Subbasin is a large alluvial deposit known as the Kaweah River fan. It is classified as a broad plain formed by a series of large coalescing alluvial deposits created by streams and rivers that drain the western slope of the Sierra Nevada.

The Kaweah River fan is characterized by a surface of low topographic relief, with variations rarely exceeding 10 feet except in stream channels. Elevations of the Kaweah Subbasin vary from about 800 feet above sea level near the easterly boundary to about 200 feet at the westerly boundary. The land generally slopes in a southwesterly direction at about 10 feet per mile, with this slope lessening near the westerly boundary.

The Kaweah River fan is separated from the larger Kings River fan to the north by Cross Creek. To the south, Elk Bayou separates the Kaweah River fan from the Tule River fan. Cottonwood Creek, an intermediate stream between Kings and Kaweah rivers, discharges onto the inter-fan area of these two systems (Davis et al, 1959; Fugro West, 2007).

In the easterly part of the Kaweah Subbasin, within and surrounding the principal rivers, surface soils are sandy and permeable, generally grading to finer materials to the west. In the inter-fan areas

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adjacent to Elk Bayou and Cross Creek, soils are alkaline and less fertile than in the remainder of the Kaweah Subbasin (Fugro West, 2007).

2.2.1.2 Regional Geology

This section provides a summary of the regional geologic history and rock types of the Subbasin.

Table 1, adapted from Page, 1986 and Bertoldi et. al., 1991, provides an overview of geologic deposits in the region within the context of regional hydrologic units. The following discussion provides a summary of the major geologic units present in the area, in sequence from oldest to youngest.

Table 1: Generalized Regional Geologic & Hydrologic Units of the San Joaquin Valley

	Generalized Regional Geology (adapted from Page, 1986, table 2 and Bertoldi et. al. 1991).	Generalized Regional Hydrologic Units
Quaternary	Flood basin deposits (0 to 100 ft thick) – Primarily clay, silt, and some sand; including muck, peat, and other organic soils in Delta area. These restrict yield to wells and impede vertical movement of water. River deposits (0 to 100 ft thick) – Primarily gravel, sand, and silt; include minor amounts of clay. Among the more permeable deposits in valley.	Undifferentiated upper water-bearing zone; unconfined to semiconfined. Principal confining unit (modified E Clay)
Tertiary and Quaternary	Lacustrine and marsh deposits (up to 3,600± ft thick) – Primarily clay and silt; include some sand. Thickest beneath Tulare Lake bed. Include three widespread clay units – A, C, and modified E clay. Modified E clay includes the Corcoran Clay Member of the Tulare Formation. These impede vertical movement of water. Continental rocks and deposits (15,000± ft thick) – Heterogeneous mix of poorly sorted clay, silt, sand, and gravel; includes some beds of mudstone, claystone, shale, siltstone, and conglomerate. They form the major aquifer system in the valley.	Undifferentiated lower water-bearing zone; semiconfined to confined. Extends to base of freshwater which is variable.
Tertiary	Marine rocks and deposits – Primarily sand, clay, silt, sandstone, shale, mudstone, and siltstone. Locally they yield fresh water to wells, mainly on the southeast side of the valley but also on the west side near Kettleman Hills.	Below the base of freshwater and depth of water wells. In many areas, post-Eocene deposits contain saline water.
Pre-Tertiary	Crystalline basement rocks – Non-water-bearing granitic and metamorphic rocks, except where fractured.	

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The oldest rocks in the area are Pre-Tertiary granitic and metamorphic rocks of the surrounding Sierra Nevada. These rocks crop out along the eastern flank of the Valley and form an almost impermeable boundary for groundwater in the Valley. In some areas, fractures and joints permit small yields of water to wells from these rocks (Page, 1986). For instance, in the eastern portion of the Kaweah Subbasin, water wells produce groundwater from fractures within the granitic bedrock.

Near the end of the Late Cretaceous period (approximately 65 million years ago), tectonic movements elevated the Coast Ranges to the west of the Central Valley and created a marine embayment. During the subsequent Tertiary period, sea levels rose and fell, periodically inundating this southern embayment. This resulted in deposition of both continental and marine sediments.

During the Pleistocene period (a period of time defined as from approximately 2.5 million to 12,000 years ago), the sea level fell, and continental sediments from alluvial and fluvial systems were deposited over the Tertiary-age deposits. These marine sediments are, in part, the source for some of the saline water that has migrated into adjacent and overlying continental deposits (Page, 1986). It is the overlying continental deposits and alluvium, however, that make up most of the regional aquifer system. During a portion of this period, brackish and freshwater lakes formed within the Central Valley and resulted in thick deposits of clay, as found throughout the upper Tulare Formation. The Corcoran Clay, specifically, has been mapped over much of the western and southwestern San Joaquin Valley. This clay layer constitutes a considerable impermeable to semipermeable zone that divides shallower upper zone water from lower zone groundwater of the regional aquifer system.

Since the Pleistocene period, the Central Valley has been dominated by sedimentary processes associated with stream channels, lakes, and rivers. Alluvial fans formed on both sides of the valley, especially on the eastern side. Deposition of fine-grained sediment carried by streams has progressively shifted toward the valley axis leaving the coarse-grained materials closer to the valley margins. The coarse-grained sediments in the fans typically are associated with stream channels. On the eastern side of the valley, these stream channels are large, laterally migrating distributary channels. Over time, shifting stream channels have created coalescing fans, forming broad sheets of interfingering, wedge-shaped lenses of gravel, sand, and fine-grained sediments, which make up the shallow continental water-bearing deposits of the regional aquifer system. Page (1986) identified various depositional environments for the continental sediments, including alluvial fan and deltaic conditions, primarily on the eastern side of the valley, and flood-plain, lake, and marsh conditions on the western side. Consequently, coarse-grained deposits are predominant on the eastern side while finer-grained deposits are predominant within the central and western areas of the Subbasin.

2.2.1.3 Kaweah Subbasin Geology

The geology underlying the Kaweah Subbasin is generally consistent with the regional geology as summarized in the preceding section. Details of the local geology, as it affects the occurrence and movement of groundwater, are provided below based on previous investigations in the area (Fugro West, 2007; Fugro Consultants, 2016). The following units are presented in sequence from the youngest (i.e., shallowest) to oldest:

- **Alluvium (Q), unconsolidated deposits:** Non-marine (i.e., continental), water-bearing material comprised of the Tulare Formation and equivalent units. Alluvium is generally mapped in the Subbasin except where the following specific units are provided.
    - Flood-basin deposits (Qb): Clay, silt, and some sand on the lateral edges of alluvial fan sediment distal from the Kaweah River.
    - Younger alluvium (Qya), oxidized older alluvium (Qoa[o]) and reduced older alluvium (Qoa[r]): Coarse-grained, water-bearing alluvial fan and stream deposits.

- o Lacustrine and Marsh Deposits (QTl): Fine-grained sediments representing a lake and marsh phase of equivalent continental and alluvial fan deposition. Includes the Tulare Formation and Corcoran Clay Member.

- **Continental Deposits – (QTc):** Heterogeneous mix of water-bearing poorly sorted clay, silt, sand, and gravel.

- **Marine Rocks – (Tmc):** Non-water-bearing marine sediments including the San Joaquin Formation. Historically, the top contact of Tmc marked the effective base of the Kaweah aquifer system because of the low permeability of Tmc and the general occurrence of brackish to saline water in Tmc (B-E, 1972).

- **Basement Rocks – (pT):** Insignificant water-bearing granitic and metamorphic rocks, except where highly fractured in the eastern portion of the Subbasin.

A correlation table of these geologic units within the context of the hydrogeology of the Subbasin is provided as ***Table 1***. ***Figure 3*** illustrates a location map of the geologic cross sections. These cross sections are included as ***Figure 4*** through ***Figure 13*** and demonstrate the distribution of units both laterally and with depth. A description of each geologic unit is presented below.

Unconsolidated Deposits – (Q)

The unconsolidated deposits include Alluvium (Q), younger alluvium (Qya), older alluvium (Qoa), lacustrine and marsh deposits (QTl) which include the Tulare Formation and Corcoran Clay Member, and unconsolidated continental deposits (QTc). The base of the unconsolidated deposits within the Kaweah Subbasin is projected by electric log correlation from the "upper Mya zone" (Tmc) beneath Tulare Lake Bed, eastward to the top of marine rocks (Woodring et al., 1940). The unconsolidated deposits are equivalent to the "continental deposits" from the Sierra Nevada shown on the cross sections by Klausing and Lohman (1964) and to the "unconsolidated deposits" as used by Hilton et al. (1963).

The unconsolidated deposits gradually thicken from along the western front of the Sierra Nevada to a maximum of about 10,000 feet at the western boundary of the Kaweah Subbasin. The unconsolidated deposits are divided into three stratigraphic units: younger alluvium, older alluvium, and lacustrine and continental deposits (Fugro West, 2007).

The younger alluvium interfingers and/or grades laterally into the flood basin deposits and into undifferentiated alluvium. The older alluvium and continental deposits interfinger and/or grade laterally into the lacustrine and marsh deposits or into alluvium. Furthermore, the older alluvium and continental deposits are further subdivided into "oxidized older alluvium" and "reduced older alluvium" based on depositional environment (Fugro West, 2007).

Unconsolidated deposits, which locally crop out east of the Kaweah Subbasin and extend beneath the Valley floor, were eroded from the adjacent mountains, then transported by streams and mudflows, and deposited in lakes, bogs, swamps, or on alluvial fans (Fugro West, 2007).

Oxidized deposits generally represent subaerial deposition, and reduced deposits generally represent subaqueous deposition (Davis et al., 1959). Oxidized deposits are red, yellow, and brown, consist of gravel, sand, silt and clay, and generally have well-developed soil profiles.

Flood-Basin Deposits – Qb

At the lateral edges of fanned sediment distal of the Kaweah River, there are flood-basin deposits that represent the final deposition of fine-grained sediments from periodic flooding. Clay, silt, and some sand were mapped by Page (1986).

Younger Alluvium – Qya

In the eastern portion of the Kaweah Subbasin, Qya is generally above the water table and does not constitute a major water-bearing unit. Younger alluvium consists of gravelly sand, silty sand, silt, and clay deposited along stream channels and laterally away from the channels in the westerly portion of the Kaweah Subbasin. Younger alluvium is relatively thin, reaching a maximum depth below ground surface of approximately 100 feet (Fugro West, 2007).

Oxidized Older Alluvium – Qoa(o)

The oxidized older alluvium may be unconfined in the eastern and central parts of the Subbasin. The Corcoran Clay and other lacustrine and marsh deposits (QTl) in the western part of the Subbasin divide water bearing zones of the Qoa(o) into both unconfined and confined conditions. The oxidized deposits that underlie the younger and older alluvium throughout most of the Subbasin are 200 to 500 feet thick (Croft, 1968). These consist mainly of deeply weathered, reddish brown, calcareous sandy silt and clay which can be readily identified when present. Beds of coarse sand and gravel are rare, but where present, they commonly contain significant silt and clay. The highly oxidized character of the deposits is the result of deep and prolonged weathering. Many of the easily weathered minerals presumably have altered to clay. Therefore, these deposits have low permeability (Fugro West, 2007).

The oxidized older alluvium unconformably overlies the continental deposits. The beds consist of fine to very coarse sand, gravel, silt and clay derived mainly from granitic rocks of the Sierra Nevada. Beneath the channels of the Kaweah, Tule and Kings rivers, electric logs indicate that the beds are very coarse. In the inter-fan areas in the eastern portions of the Kaweah Subbasin, metamorphic rocks and older sedimentary units contributed to the deposits. In those areas, the beds are not as coarse as the beds beneath the Kaweah, Tule, and Kings rivers. Fine grain deposits occur in the channel of Cross Creek (Fugro West, 2007).

East of SR 99, the contact of the older alluvium with the underlying oxidized continental deposits is well defined in electric logs. Structural contours, based on electric-log data, show the altitude above or below sea level of the base of the unit. The older alluvium thickens irregularly from east to west, most likely due to filling gorges cut by the ancient Tule River in the underlying oxidized continental deposits near Porterville. The base of the deposits occurs approximately 195 feet below land surface near Exeter and declines to 430 feet below land surface near Visalia and the unincorporated community of Goshen.

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Reduced Older Alluvium – Qoa(r)

These deposits are saturated with unconfined conditions in the eastern part of the Subbasin and confined in the western part of the Subbasin. Reduced deposits are blue, green, or gray, calcareous, and generally are finer grained than oxidized deposits. Commonly, these deposits have a higher organic content than the oxidized deposits. In some cases, the separation between the oxidized and reduced deposits are identified on well logs based on lithologic color, although such delineation is subjective. The coarsest grained reduced deposits were laid down in a flood plain or deltaic environment bordering lakes and swamps. Due to a high water table in parts of the eastern portion of the Kaweah Subbasin, the sediments have not been exposed to subaerial weathering conditions. The finest grained reduced sediments were mapped as flood basin, lacustrine, and marsh deposits.

The reduced older alluvium consists mainly of fine to coarse sand, silty sand, and clay that were deposited in a flood plain or deltaic environment. It overlies the continental deposits, interfingers with lacustrine and marsh deposits beneath the Tulare Lake Bed, and interfingers with alluvium, undifferentiated, north of the Tulare Lake Bed. Gravel that occurs in the oxidized older alluvium is generally absent. The deposits are sporadically cemented with calcium carbonate. Those descriptions imply, however, that the calcium carbonate is probably less abundant than in the underlying reduced continental deposits (Fugro West, 2007).

Lacustrine and Marsh Deposits – QTl

These fine-grained deposits generally do not provide reliable groundwater storage, but act as confining to semi-confining zones. The lacustrine and marsh deposits of Pliocene and Pleistocene age consist of blue-green or gray gypsiferous silt, clay, and fine sand that underlie the flood basin deposits and conformably overlie the marine rocks of late Pliocene age. In the subsurface beneath parts of Tulare Lake Bed, these beds extend to about 3,000 feet below land surface. Where the equivalent beds crop out in the Kettleman Hills on the west side of the Valley, they are named the Tulare Formation. Woodring et al. (1940) considered the top of the Tulare Formation to be the uppermost deformed bed. Therefore, by this definition, all the deformed unconsolidated deposits would form the Tulare Formation (Fugro West, 2007).

In the subsurface around the margins of the Tulare Lake Bed, lacustrine and marsh deposits form several clay zones that interfinger with more permeable beds of the continental deposits, alluvium, and older alluvium. Diagnostic fossils and stratigraphic relationships to adjacent deposits indicate these clays are principally of lacustrine origin. Clay zones are generally indicated by characteristic curves on electric logs and thereby facilitate some areal correlations between adjacent logs as shown on the hydrogeologic cross sections (***Figure 4*** through ***Figure 13).***

As many as six laterally continuous clay zones have locally been defined in the southern Valley. The most prominent of these clay zones is referred to as the Corcoran Clay. It is a member of the Tulare Formation within the Kaweah Subbasin. Clay deposits are nearly impermeable and do not yield significant water to wells (which is generally of poor water quality; Fugro West, 2007). The Corcoran Clay is the largest confining body in the area and underlies about 1,000 square miles west of SR 99. The beds were deposited in a pre-historic lake that occupied the Valley trough which varied from 10 to 40 miles in width and was more than 200 miles in length (Davis et al., 1959). The first wide-scale correlation of the Corcoran Clay was made by Frink and Kues (1954). The Corcoran Clay extends from Tulare Lake Bed to SR 99 and is vertically bifurcated near Goshen. It is about 75 feet thick on average but is approximately 140 feet thick near Corcoran (a city immediately southwest of the Kaweah Subbasin).

Continental Deposits – QTc

Represent the poorly sorted clay, silt, sand, gravel, claystone, shale, siltstone, and conglomerate that grade into the older alluvium and/or underlie older alluvium. These continental deposits are underlain by the Tertiary marine rocks (Tmc).

Marine Rocks (Non-water bearing) – Tmc

Along the eastern border of the Valley, Tertiary rocks, mainly of marine origin, underlie the unconsolidated deposits and overlap the basement complex. This unit may locally include beds of continental origin in the upper part (Croft, 1968). Outcrops of these marine rocks have not been identified in the Subbasin. The Tertiary marine rocks range in age from Eocene to late Pliocene and consist of consolidated to semi-consolidated sandstone, siltstone, and shale. They have traditionally been locally divided into several formations (Park and Weddle, 1959). Since they generally contain poor quality water (brackish and saline connate or dilute connate water) they are treated as one unit (Fugro West, 2007). Historically, the top of the Tmc is considered the effective base of the Subbasin because of the low permeability of Tmc and the general occurrence of brackish to saline water Tmc (B-E, 1972).

Basement Complex (non-water bearing) – pT

The basement complex of pre-Tertiary age consists of metamorphic and igneous rocks. These rocks occur as resistant inliers in the alluvium and as linear ridges in the foothills in the eastern-most portion of the Kaweah Subbasin. In the subsurface, they slope steeply westward from the Sierra Nevada beneath the deposits of Cretaceous age and younger rocks that compose the Central Valley fill. Escarpments interpreted as buried fault scarps are found along the eastern portion of Subbasin associated with the Rocky Hill fault. West of the escarpments, the slope of the basement complex steepens (Fugro West, 2007).

While the basement complex is considered to be non-water bearing in most areas, it is fractured and present at shallow depths in the eastern portion of the Kaweah Subbasin. Areas of Lindsay, Strathmore, and Ivanhoe and in the intermontane valleys are penetrated by many water wells. Near Farmersville and Exeter, the basement complex forms a broad, gently westward-sloping shelf overlain by 100 to 1,000 feet of unconsolidated deposits (Fugro West, 2007).

2.2.2 Geologic Features that Affect Groundwater Flow in the Kaweah Subbasin

According to CDWR's Bulletin 118 (2003), there are no reported groundwater barriers restricting horizontal flow in and out of the Kaweah Subbasin. However, the Rocky Hill fault zone as shown on ***Figure 3*** and ***Figure 5*** is not believed to affect groundwater flow within of the Subbasin. While, in the eastern portion of the Subbasin, the Rocky Hill fault offsets pre-Eocene deposits and may locally offset older alluvial deposits. These offsets are not known to disrupt groundwater flow. The linear alignment of ridges in this area generally define the fault line. Lithology data from boreholes along Cross Section B (***Figure 5***) suggest that older alluvium may be offset or vary in thickness across the Rocky Hill fault. While previous studies (Fugro West, 2007) suggested that the hydrologic connection of the oxidized alluvial aquifer may be restricted near the Rocky Hill fault, evidence of such restriction has not been noted by groundwater managers..

2.2.3 Lateral Boundaries of the Subbasin

The Kaweah Subbasin (Basin Number 5-022.11[1]) is situated within the Tulare Lake Hydrologic Region of the overall San Joaquin River Basin (Basin Number 5-022). The Kaweah Subbasin has a surface area of approximately 441,000 acres (696 square miles) (CDWR, 2003). The lateral boundaries of the Subbasin are defined by various jurisdictional and geographical segments as shown on ***Figure 14***. Crystalline bedrock of the Sierra Nevada foothills defines the eastern boundary of the Subbasin while the other three sides of the Subbasin are politically, but not geologically, bounded by the following Subbasins:

- Kings Groundwater Subbasin on the North
- Tule Groundwater Subbasin on the South
- Tulare Lake Groundwater Subbasin on the West

The political boundaries do not coincide with natural features that affect groundwater flow. Groundwater generally flows from natural recharge at higher elevations from the Sierra Nevada, west through the Subbasin to the Tulare Lake Groundwater Subbasin along the West boundary. Although groundwater flow is generally from northeast to southwest, there are some northern and southern areas where the flow direction is from east to west. These conditions indicate that there is a limited amount of underflow between Kaweah, Kings, and Tule Groundwater Subbasins.

2.2.4 Bottom of the Subbasin

The effective base of the Subbasin corresponds with the base of freshwater. This is generally defined as the elevation below which total dissolved solids are greater than 2,000 milligrams per liter (mg/l) (Bertoldi et al, 1991). The top of the Tmc has historically been used as the effective base of the Kaweah aquifer system because of its low permeability and general occurrence of brackish to saline water (B-E, 1972). However, based on abundant water quality data from wells throughout the area, the current designation of the base of freshwater is established as the base of the Tulare Formation, which is several hundred feet above the top of the Tmc in most places. This designation is based on two factors: (a) recent review of well completion reports for wells drilled within the last decade and (b) the opinions of groundwater managers and hydrogeologists working in this and adjacent basins.

The range of elevations of the effective base of the alluvial aquifer systems varies within the Subbasin from as deep as 1,100 feet below sea level in the western portion of the Subbasin near Corcoran, as indicated in B-E (1972) and Fugro West (2007), to as shallow as 50 feet below sea level east of the Rocky Hill fault (coinciding with the depth to crystalline bedrock) in the eastern portion of the Subbasin. The effective base of the aquifer system as shown on ***Figure 15*** and throughout

[1] As defined in CDWR Bulletin 118 2016

the geologic cross sections. The depth to crystalline bedrock to the east of Rocky Hill fault marks the eastern effective bottom of the basin (*Figure 4* through *Figure 13*).

2.2.5 Principal Aquifers and Aquitards of the Subbasin

Groundwater in the Kaweah Subbasin occurs primarily in an alluvial aquifer system that is present throughout the area. In the central and western parts of the Subbasin, the alluvial aquifer system consists of an upper unconfined zone (Upper Aquifer System [UAS]) above the Corcoran Clay and a lower confined zone (Lower Aquifer System [LAS]) below the Corcoran Clay. In the eastern portions of the Subbasin, the Corcoran Clay is not present, and the aquifer system consists of a single merged aquifer zone (Single Aquifer System [SAS]) that is unconfined or semi-confined. *Table 2* provides a summary of the Hydrostratigraphy of the Subbasin.

Table 2: Hydrostratigraphy of Kaweah Subbasin

Relative Depth	Kaweah Subbasin Hydrostratigraphy		Equivalent Geology	General Characteristics
	West	East	West / East	
Shallow	Upper Aquifer System (unconfined to semi-confined) (thickness 200 to 400 ft)	Principal Aquifer A/B (Merged Zone) (semiconfined with depth) (thickness 300 to 1000 ft)	Younger Alluvium – Qya Oxidized Older Alluvium – Qoa(o)	Qoa is the major aquifer of the Subbasin
	Principal confining unit (modified Corcoran “E” Clay) (thickness 60 to 200 ft)		Lacustrine and marsh deposits – QTl: Corcoran Clay Member	
Deep	Lower Aquifer System (confined) (thickness 500 to 1000 ft)		Oxidized Older Alluvium – Qoa(o) Reduced Older Alluvium – Qoa(r) Continental Deposits - QTc	

2.2.5.1 Formation Names

The primary aquifer system in the Subbasin is made up of unconsolidated deposits of Holocene, Pleistocene, and Pliocene age, younger and older alluvium, and continental deposits. The aquifer system is split in the western and central Subbasin by confining fine-grained beds of the Tulare lake bed or the Corcoran Clay member of the Tulare Formation. These confining beds may also include flood-basin and lacustrine deposits. The Corcoran Clay confining bed grades eastward until it effectively thins and becomes either absent or discontinuous. The split aquifer is merged as a single aquifer zone of alluvium and continental deposits made up of coarser material derived from the Sierra Nevada.

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Upper Aquifer System (UAS)

The UAS is present above the Corcoran Clay in the western and central portions of the Subbasin. It is made up of the following:

- Flood-basin deposits (Qb) consisting of poorly permeable silt, clay, and fine sand with groundwater of poor quality, and
- Younger alluvium (Qya) consisting of beds of moderately to highly permeable sand and silty sand, and
- Older alluvium (Qoa[o]) which is moderately to highly permeable and is the major productive aquifer horizon in the Subbasin.

Aquitard

The upper aquifer system is underlain by an aquitard (Corcoran Clay or lacustrine and marsh deposits [QTl]) consisting of blue, green, or gray silty clay and fine sand. The Corcoran Clay separates the upper aquifer from the lower confined aquifer and underlies the western half of the Subbasin at depths ranging from about 200 to 500 feet (Jennings, 2010). In the eastern portion of the Subbasin, where the Corcoran Clay becomes thin, discontinuous or absent, groundwater occurs in a merged Aquifer A/B under unconfined and semiconfined conditions.

The areas between the easterly edge of the Corcoran Clay and the Rocky Hill fault contain groundwater in the merged SAS in both unconfined and semi-confined continental deposits underlying the alluvium. East of the Rocky Hill Fault, the aquifer is considered merged and is semi-confined.

Lower Aquifer System (LAS)

The LAS, present in the western and central part of the Subbasin below the Corcoran Clay, is made up of the older alluvium (Qoa[o] and Qoa[r]) which is moderately to highly permeable. The LAS also includes the underlying continental deposits (QTc) where fresh water occurs; however, the majority of aquifer pumping occurs in the older alluvium. The bottom of the lower aquifer is the base of the Tulare Formation.

Single Aquifer System

In the eastern part of the Subbasin, where the Corcoran Clay thins, is discontinuous, or is absent, the upper and lower aquifers are merged into a single aquifer unit that is semiconfined. The merged zone is made up of younger alluvium (Qya), older alluvium (Qoa[o] and Qoa[r]), and continental deposits (QTc) (see ***Figure 4*** and ***Figure 5***).

2.2.5.2 Physical Characteristics

Hydrogeologic parameters of the aquifers and aquitards in the Kaweah Subbasin include average specific yield values for the upper 200 feet of sediments and numerical values of hydraulic conductivity, which are defined below. For the most part, reliable coefficients of storativity (aquifer storage) were documented in technical studies from controlled pumping tests with observation wells.

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The majority of these studies were carried out in the KDWCD portion, located in the GKGSA and MKGSA areas, of the Subbasin (Fugro West, 2007).

Specific Yield is defined as the volume of water that will drain by gravity from sediments within an aquifer if the regional water table were lowered. Within the Kaweah Subbasin, specific yield has been used to calculate changes of groundwater in storage for comparison to earlier time periods by the "specific yield method" (Fugro West, 2007; Fugro Consultants, 2016). Specific yield values ranged from about 6.5 percent to as high as 13.7 percent. The average specific yield of the deposits within the 10- to 200-foot-depth range is 9.9 percent, slightly below the Valley-wide average of 10.3 percent, but considerably above the average specific yield of any of the inter-stream storage units (Fugro Consultants, 2016). DWR estimated that the average specific yield for the Subbasin is 10.8 percent (DWR internal data; Davis, 1959). Sand and gravel together make up 25.6 percent of the total thickness, which is slightly below the Valley-wide average of 28 percent. Eighty percent of these coarse-grained deposits are reported as sand, twenty percent as gravel (Fugro West, 2007).

Hydraulic Conductivity is "a measure of the capacity for a rock or soil to transmit water" (Aqtesolv, 2016). Hydraulic conductivity values and storage coefficients for the entire Central Valley were compiled by Bertoldi et al. (1991). Efficiency tests for several hundred wells within the Tule and Kaweah Subbasins were converted to well-specific capacity data, from which a single horizontal hydraulic conductivity value was assigned to each section (KDWCD, 2012; Fugro West, 2007). A range of hydraulic conductivity values are present, reflecting the broad geographic area of the entire Valley. The broad range of values, which span several orders of magnitude within the Kaweah Subbasin, reflect a heterogeneous mixture of aquifers, aquitards, and aquicludes. The horizontal hydraulic conductivity values range from approximately 1 gallon per day per foot squared (gpd/ft^2) for the confined aquifer west of SR 99 to s high as 1,000 gpd/ft^2 in the semi-confined aquifer in the eastern half part of the Kaweah Subbasin (Fugro West, 2007).

Based upon SCE (Southern California Edison) pump test reports, which provide the "specific capacity" (i.e., the gallons per minute pumped per foot of drawdown) for tested wells, representative values of regional and local hydraulic conductivity were calculated. While these data are dependent on the manner of well drilling and development, age of the well, well design, and a variety of other factors, the results are considered representative for the purposes of this study. The hydraulic properties of the principal aquifers within the Kaweah Subbasin are presented on ***Table 3*** (based on Fugro West, 2007).

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Table 3: Aquifer Properties

Kaweah Subbasin Hydrostratigraphy	Associated Deposits	Average Thickness of Saturated Aquifer (feet)	Average Hydraulic Conductivity (gpd/ft²)
Western Side Upper Aquifer	Older alluvial deposits	150	250
Lower Aquifer	Younger continental deposits	150	150
	Older continental deposits	800	70
Corcoran Clay	Corcoran Clay and Lacustrine and Marsh Deposits	80 to 100	<1
Eastern Side Single Aquifer	Older alluvium (oxidized)	250	500
	Older alluvium (reduced)	250	250
	Younger continental deposits	150	150
	Older continental deposits	800	70

Source: Modified from Fugro West, 2007

2.2.5.3 Structural Properties that Restrict Groundwater Flow

The Corcoran Clay is the most significant subsurface feature in the Kaweah Subbasin affecting the occurrence and movement of groundwater. The Corcoran Clay is a relatively impervious stratum, the eastern edge of which follows generally a north-south line about two to three miles east of SR 99. The Corcoran Clay dips to the west and usable groundwater is found both above and below this stratum.

While there is significant uncertainty about the completion of most wells in the Subbasin, it is generally suspected that wells located within the Corcoran Clay area are, for the most part, perforated in and pump from the confined aquifer system (Fugro West, 2007). The heterogeneity of aquifer properties in the Subbasin and known presence of several interfingering aquitards in the west part of the Subbasin complicate the separation of water level data representative of the confined or unconfined aquifer systems. Through 1988, annual "pressure" system water level maps (prepared by DWR) suggested that the water levels in the unconfined system and the pressure system differed by no more than 20 feet and were both substantially above the Corcoran Clay. The water level data demonstrates similar water levels between the two aquifer systems, with considerable inter-aquifer groundwater flow occurring between the two systems (via wells with perforations in both systems).

The Rocky Hill Fault disrupts pre-Eocene deposits and may locally penetrate older alluvial deposits. The fault does not offset younger alluvium (based on water level data) and does not appear to constitute a horizontal barrier to groundwater flow (CDWR, 2003; Fugro Consultants, 2007).

2.2.5.4 General Water Quality of Principal Aquifers

The Subbasin aquifer system consists of unconsolidated marine and continental deposits of Pliocene, Pleistocene, and Holocene age. The eastern half of the Subbasin consists of three stratigraphic layers: continental deposits, older alluvium, and younger alluvium (Belitz and Burton, 2012). Continental deposits from the Pliocene and Pleistocene age are poorly permeable. The major aquifer of the Subbasin is the older alluvium. The older and younger alluvium are moderately to highly permeable. The western half of the Subbasin is less permeable, and the groundwater aquifer is confined by the Corcoran Clay layer. The remainder of this section provides a summary of several

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key constituents including: arsenic; nitrate; sodium; chloride; uranium1,2,3 – Trichloropropane (TCP); and Tetrachloroethylene (PCE). These constituents are known water quality concerns in the Subbasin.

In the Southeast San Joaquin Valley, arsenic is the constituent which most frequently occurs at concentrations above the drinking water standard (maximum contaminant level [MCL] = 10 ppb) in the primary aquifers (Burton and Belitz, 2012). Arsenic concentrations greater than 5 parts per billion (ppb) are primarily located within the the western part of the Subbasin (***Figure 68***). Wells evaluated in the eastern portion of the Subbasin rarely have arsenic detections. However, wells that do have detections are at concentrations less than 5 ppb. United States Geological Survey (USGS) reports indicate that wells constructed deeper than 250 feet tend to have higher arsenic levels; and these wells tend to be in the western portion of the Subbasin where wells are commonly deeper (***Figure 69***).

Nitrate is commonly detected throughout the Kaweah Subbasin with concentrations commonly higher than 8 parts per million (ppm). Wells in the eastern portion of the Subbasin have shown increasing trends over the past several years (***Figure 70***). Shallow wells have higher nitrate levels than wells deeper than 250 feet, because nitrate is a surface contaminant that primarily impacts shallower groundwater. Generalized water level contour maps were used to determine if changing water levels corresponds with increasing nitrate concentrations (***Figure72***). Sufficient data were not available to determine if nitrate is migrating into the deeper aquifer. Overall, nitrate detections are prevalent throughout the Subbasin, with highest concentrations in the eastern portion.

A total of 21 contaminated sites have been identified in the Subbasin. There is a large PCE plume located in the city of Visalia shown on ***Figure 76.*** A city-wide investigation, lead by California Department of Toxic Substances Control (DTSC), began in 2007 to determine the responsible party and the extent of the PCE plume. Nine sites are involved in this ongoing investigation (***Figure 77***). Management actions are currently in place through the DTSC agreement with California Water Service (Cal Water) to limit these surface contaminants from spreading further in the aquifer.

Sodium and chloride levels were detected in a small portion of the wells within the Subbasin (***Figure 81***). Sodium concentrations above the Agricultural Water Quality Goal of 69 ppm were detected in 13 wells. Chloride concentrations above the Agricultural Water Quality Goal of 106 ppm were detected in five wells. Without sufficient well construction reports or depth to water level data, it is difficult to determine if there is a correlation between the two. Overall, the common water quality issues for this Subbasin are arsenic, nitrate, TCP, PCE, sodium, uranium, and chloride. More data gathering such as through a monitoring program would be beneficial to gain a better understanding between these correlations.

2.2.5.5 Primary Use of Aquifers

The Kaweah Subbasin covers an area of 441,000 acres and has been highly developed with about 322,000 acres devoted to a variety of irrigated crops and approximately 53,000 acres of urbanized area (USDA, 2018).

At present, about 1,076,400 AF of water (surface and groundwater) per year are delivered for irrigation, municipal, and industrial uses. Water used for irrigated agriculture comprises more than 94 percent of the total water use, or 1,007,400 Acre-feet per year (AFY). Irrigation requirements are met from both surface and groundwater sources, while municipal and industrial supplies are obtained mostly from groundwater. Likewise, groundwater is the main source of water for small to large animal farms and residential dwellings in unincorporated parts of the Subbasin that are not served by municipal or small community water systems. This includes dairies and the non-agricultural ranchette properties throughout the Subbasin. The public water agencies and districts located within the Subbasin include the following:

- City of Woodlake
- City of Exeter
- City of Tulare
- Consolidated Peoples Ditch Company
- Ivanhoe Public Utilities District
- City of Lindsay
- Exeter Irrigation District
- Evans Ditch Company
- Ivanhoe Irrigation District
- Kaweah-Delta Water Conservation District
- Kings River Conservation District
- Kings County Water District
- Lakeside Irrigation Water District
- Lindmore Irrigation District
- Lindsay-Strathmore Irrigation District
- Strathmore Public Utilities District
- St. Johns Water District
- Tulare Irrigation District
- Stone Corral Water District
- Lewis Creek Water District

Private water agencies within the Subbasin include the following:

- California Water Service within Visalia, Goshen
- Goshen Ditch Company

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- Evans Ditch Company
- Modoc Ditch Company
- Melga Canal Company
- Settlers Ditch Company
- Corcoran Irrigation Company
- Wutchumna Water Company
- West Goshen Mutual Water Company
- Longs Canal Company
- Hamilton Ditch Company
- Sweeney Ditch Company
- Mathews Ditch Company
- Uphill Ditch Company
- Sentinel Butte Water Utilities Company
- Farmers Ditch Company
- Fleming Ditch Company
- Lemon Cove Ditch Company
- Oakes Ditch Company
- Persian Ditch Company
- Tulare Irrigation Company
- Elk Bayou Ditch Company
- Pratt Mutual Water Company

2.2.6 Geologic Cross Sections

Geologic cross sections depicting the structural geology and hydrologic units of the Subbasin were created based on historical reports and lithologic data from over 5,000 driller's logs and various existing geologic maps (Davis et al., 1957; Croft, 1968; B-E, 1972; Bertoldi et al, 1991; Page, 1986). Cross Sections A through J (***Figure 4*** through ***Figure 13***), provide the following information:

- Relative depths and screened intervals of production wells
- Lithology

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- Geophysical log profiles
- Topography from the USGS digital elevation model (DEM)
- Interpreted elevation of the top of the Corcoran clay surface
- Effective base of the alluvial aquifer system

The geologic cross sections were constructed by a professional geologist. The cross sections are presented with uniform vertical exaggeration to more clearly present the subsurface data. The locations of the cross sections are shown on the map in ***Figure 3***.

These cross sections are based on interpretations of Fugro West (2007; ***Figure 4*** through ***Figure 9***) with minor modifications to the elevation of the "Effective Base of Fresh Water System." The original Fugro West cross sections were extended to include the entire Subbasin based on newly acquired well log data. ***Figure 10*** through ***Figure 13*** in the EKGSA portion of the Subbasin are based on published cross sections (USBR, 1949; Davis et. al., 1959, and Croft and Gordon, 1968).

Cross sections demonstrate in the eastern portion of the Subbasin, the Rocky Hill fault disrupts pre-Eocene deposits and may locally penetrate older alluvial deposits. The linearity of the ridges in this area defines the fault line. The Rocky Hill fault does not offset younger alluvium based on water level data (Croft, 1968; Fugro West, 2007). The primary east-west geologic cross sections (***Figure 4*** through ***Figure 6***) indicate a thickening section of unconsolidated deposits to the west across the Subbasin. For the most part, regional folding has little effect on the patterns of groundwater flow within the Subbasin or at the political Subbasin boundary. The relative relationship between the "Effective Base of Fresh Water System" within the Continental Deposits (Qtc) and the marine rocks is evident in many of these cross sections. The several hundred feet between the marine rocks and the "Effective Base of Fresh Water System" is comprised of sedimentary deposits containing saline water.

The cross sections within the EKGSA's area (***Figure 10*** through ***Figure 13***) show the relative depth of the aquifer materials in the area, which are underlain by marine rocks and/or basement complex. These cross sections are relatively short to be presented at similar scales for easy comparison to ***Figure 4*** through ***Figure 9***.

2.2.7 Physical Characteristics

2.2.7.1 Surficial geology

As presented on ***Figure 2***, the rocks that outcrop in the Subbasin include a basement complex of pre-Tertiary age consisting of consolidated metamorphic and igneous rocks to the east and unconsolidated deposits of Holocene, Pliocene, and Pleistocene age throughout the remainder of the Subbasin. Consolidated marine rocks of Pliocene age and older do not crop out in this area but are penetrated by wells in the subsurface (Jennings, 2010; Croft, 1968; Fugro West, 2007).

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2.2.7.2 Soil recharge characteristics

Obtaining information on soil recharge characteristics in the Subbasin is important in understanding natural recharge to the groundwater system and for siting locations for artificial recharge projects. The University of California at Davis (UC Davis), in conjunction with the University of California Division of Agriculture and Natural Resources, developed the Soil Agricultural Groundwater Banking Index (SAGBI). The SAGBI is a composite evaluation of groundwater recharge feasibility on agricultural land (also called Irrigation Field Flooding). The following five parameters are incorporated into the Index:

1. Deep percolation is dependent upon the saturated hydraulic conductivity of the limiting layer.
2. Root zone residence time estimates drainage within the root zone shortly after water application.
3. Topography is scored according to slope classes based on ranges of slope percent.
4. Chemical limitations are quantified using the electrical conductivity (EC) of the soil.
5. Soil surface condition is identified by the soil erosion factor and the sodium adsorption ratio.

Proximity to a water conveyance system is not a factor considered in the SAGBI composite evaluation. Each factor was scored on a range, rather than discretely, and weighted according to significance. Adjustments were then made to reflect soil modification by deep tillage (i.e., shallow hard pan is assumed to have been removed by historic farming activities) to create a modified SAGBI. Ultimately, SAGBI seeks to categorize recharge potential according to risk of crop damage at the recharge site. Usefulness of the index is diminished when evaluating locations for dedicated recharge basins. In these cases, a soil profile illustrating deep percolation potential may prove to be more useful. As is the case with any model, the SAGBI is best applied in conjunction with other available data and on-site evaluation.

Figure 16 illustrates the modified SAGBI for the Subbasin which indicates that a majority of the land within the Subbasin is favorable for recharge. This model assumes that hardpans have been largely removed by previous farming practices. Hardpans are still extensive within the EKGSA, so this model should be considered in conjunction with the unmodified SAGBI. It is locally well known that surface recharge is ineffective in the EKGSA area, but water introduced deep enough into the strata infiltrates easily in those areas identified in the modified SAGBI as "good." Soils in the Subbasin were categorized by the National Resource Conservation Service (NRCS), which indicate that the soils are mostly of fine- to course-loamy in texture. As shown on the soils map in ***Figure 18***, the soils along the Lower Kaweah and St. Johns rivers, as well as those along Cottonwood, Yokohl, and Lewis creeks are the coarsest, whereas most of the remainder of the Subbasin is comprised mostly of fine to fine-loamy soil.

The presented data are based on a UC Davis study to identify potential areas favorable for enhanced groundwater recharge projects. Those projects are discussed below.

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2.2.7.3 Delineation of recharge areas, potential recharge areas, and discharge areas, including springs, seeps, and wetlands

Natural Recharge Areas

Natural recharge in the Subbasin is primarily derived from seepage from the Kaweah and St. Johns rivers, and intermittent streams. Seepage of water from rivers, streams, irrigation canals, and irrigation water applied in excess of plant and soil-moisture requirements constitute the principal sources of groundwater recharge to the aquifers. Direct precipitation contributes minor quantities of water to these aquifers (Croft and Gordon, 1968).

Potential recharge areas are presented in ***Figure 16*** as part of the soil map in support of potential future groundwater recharge projects. The data presented are the result of a study focused on the possibilities of using fallow agricultural land as (temporary) percolation basins during periods when excess surface water is available. The UC Davis study developed a methodology to determine and assign an index value to agricultural lands (i.e., SAGBI). The SAGBI analysis incorporates the following five important agricultural factors into the analysis: deep percolation, root zone residence time, topography, chemical limitations (salinity), and soil surface conditions. Notably, the data presented show the unmodified SAGBI data, which do not include areas that would benefit from the deep ripping of soils to a depth of 6 feet.

Potential Areas for Artificial Recharge

Potential artificial recharge areas can be identified using the soil data shown on ***Figure 16*** and ***Figure 18***. These maps provide a regional assessment of recharge potential and can be useful for initial screening. Local permeability, geologic structure, and an overall lack of suitable land limit the recharge potential in many areas of the Subbasin, particularly in the eastern portion (USBR, 1948). The map in ***Figure 16*** shows areas that are categorized as somewhat conducive to successful groundwater recharge projects including areas categorized as: Excellent, Good, Moderately Good and Moderately Poor. The map includes the existing recharge ponds for reference, many of which have been recharging groundwater for several decades. The results of the analysis in the Subbasin show that areas surrounding portions of the Lower Kaweah and St. Johns rivers, as well as portions of the Cottonwood Creek on the east side of the Subbasin are "Excellent" areas for agricultural recharge projects. "Good" and "Moderately Good" are present throughout all three GSAs in the Subbasin.

Existing groundwater recharge basins are locally present throughout the Subbasin for purposes of augmenting natural groundwater recharge. The supply to each recharge basin is variable from year to year. The northeast portion of the Subbasin is most suitable for artificial recharge, and the southwest portion is likewise fairly suitable. However, the northwest and southeast portion of the Subbasin are generally unfavorable, although there are some areas of moderate permeability in each (Provost and Pritchard, 2010).

Discharge Areas

East of McKay Point, the Kaweah River is a gaining stream, meaning that it derives some of its flow from groundwater that seeps upward into the riverbed. There are currently no other known groundwater discharges at ground surface (springs, seeps, etc.) originating in the area. Groundwater level maps will be presented in the Current and Historic Groundwater Conditions chapter of the

EKGSA Groundwater Sustainability Plan (GSP). Other groundwater discharges include groundwater pumping and subsurface fluxes across basin boundaries. These topics are addressed in ***Section 2.4***.

Seeps, Springs, and Wetlands

Areas indicated as being wetlands in the National Wetland Inventory are illustrated in ***Figure 17.*** Some areas of freshwater emergent wetlands are present in the eastern margins of the EKGSA, where small waterways come down from the foothills. Many small freshwater ponds are located within the EKGSA, the largest of which is located northwest of the junction of SR 137 and SR 65.

Areas identified as being potential Groundwater Dependent Ecosystems (GDEs) are presented in ***Figure 19***. The information presented originates from data compiled by the Nature Conservancy, which used vegetative cover and historic maps to develop a statewide map showing the locations of potential GDEs. The locations of these potential GDEs and hydrographs for the Subbasin indicate that the vegetation of these areas are dependent surface water flows, rather than shallow groundwater.

2.2.7.4 Surface water bodies

Figure 21 depicts the major surface water features within the Subbasin, such as natural channels, man-made channels (ditches), and lakes.

Natural Channels

The Kaweah River rises in the Sierra Nevada at an elevation of over 12,000 feet and drains a watershed area of about 630 square miles above the foothill line. Terminus Reservoir, located about 3-1/2 miles east of the easterly Subbasin boundary, has a tributary drainage area of about 560 square miles, which produces about 95 percent of the total runoff of the watershed. Seepage from the river contributes to recharge within the Subbasin.

Dry Creek and Yokohl Creek are tributaries entering the Kaweah River below Terminus Reservoir and produce significant quantities of water only during flood periods. Runoff in Kaweah River is largely retained within the Subbasin and only in infrequent years of exceptionally large runoff is there escape to Tulare Lake bed. Since completion of Terminus Dam and Reservoir in 1961, seasonal storage of Kaweah River flows has been provided, which assists in regulation to irrigation demand schedules. Other than maintenance of a minimum pool for recreation, no carryover storage is provided in the reservoir.

At McKay Point, the Kaweah River divides into the St. Johns River and Lower Kaweah River branches. Water is diverted from the St. Johns and Lower Kaweah rivers and distributed through a complex system of natural channels and canals owned or operated by numerous agencies and entitlement holders within the subbasin, all of which have established rights to the use of water from the Kaweah River.

The St. Johns River, from McKay Point, flows northwesterly through the northern part of the Subbasin to a point approximately 2 miles east of SR 99 where it changes course and flows in a southwesterly direction and is joined by Cottonwood Creek. Prior to reaching SR 99 at the confluence of Cottonwood Creek, the St. Johns River becomes Cross Creek. River flows at this

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point are diverted into Lakeside Ditch for irrigation use by Lakeside Irrigation Water District and Lakeside Ditch Company. Corcoran Irrigation District and other Tulare Lake water users divert flows from Cross Creek into Lakelands Canal No. 2. During periods of flooding, river flows continue in the Cross Creek channel into Tulare Lake bed.

A total of about 180,000 acres can receive irrigation water from the St. Johns River through the facilities of 15 entities. It is estimated that on the average about 142,000 AF/WY was diverted from the St. Johns River between 1981 and 1999.

The principal diversion works from the St. Johns River in downstream order are as follows:

- Longs Canal
- Ketchum Ditch
- Tulare Irrigation District Main Intake Canal
- Mathews Ditch
- Uphill Ditch
- Modoc Ditch
- St. Johns Ditch
- Goshen Ditch
- Lakeside Ditch
- Lakelands Canal No. 2

Water is diverted from the Friant-Kern Canal to Tulare Irrigation District (TID) at a large Parshall flume (a flow measurement device) and into the St. Johns River. In addition, there are several riparian users, with the principals being the Fisher & Harrell Ranch in the lower reach of the St. Johns River east of SR 99 and Basile Ranch, west of the highway.

The Lower Kaweah River, below McKay Point, conveys water to a series of distributary channels and canals throughout the central and southerly portions of the Subbasin. Outflow from the Subbasin occurs through Mill Creek to Cross Creek and from Elk Bayou to the Tule River in the southeasterly portion of the Subbasin.

About 126,000 acres can receive irrigation water from the Lower Kaweah River system through the facilities of 10 entities. The principal diversions from the Lower Kaweah River below McKay Point in downstream order are listed below.

- Hamilton Ditch
- Hanna Ranch

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- Consolidated Peoples Ditch
- Deep Creek
- Crocker Cut
- TIC Main Intake Canal
- Fleming Ditch
- Packwood Creek
- Oakes Ditch
- Evans Ditch
- Persian and Watson

A turnout on the Friant-Kern Canal provides for releases directly into the Lower Kaweah River. The Ketchum Ditch, which diverts water from the St. Johns River, discharges into the Lower Kaweah channel.

Man-made canals and ditches

Surface water is delivered from the natural rivers and imported sources through a combination of pipes as well as man-made canals and ditches. Within the East Kaweah GSA, all surface water deliveries are conveyed through piped systems with the single exception of the Wutchumna Ditch, which is the principal water course supplying supplies water to the Ivanhoe Irrigation District. The ditch, which flows parallel to and slightly north of the St. Johns River, diverts water from the Kaweah River about 1.5 miles above McKay Point and is operated by the Wutchumna Water Company. The Friant-Kern Canal, managed by the U.S. Bureau of Reclamation (USBR), runs the length of the EKGSA, generally following the eastern border. East of the City of Lindsay it turns south and runs through the interior of the EKGSA, skirting Strathmore and continuing to the south.

Within the remainder of the Kaweah Subbasin, principal man-made conveyance system is the Main Intake Canal of the TID, which delivers comingled Kaweah River and Central Valley Project (CVP) waters for use in the TID. TID also delivers water through the Cameron Creek and Packwood Creeks below the Tagus Evans Ditch. Within the Tulare Irrigation District, the largest entitlement holder within the Kaweah Subbasin, there are a total of approximately 300 miles of unlined canals and ditches, 30 miles of piped conveyances and ¼ mile of lined canals (TID, 2012).

The headgates (diversions) from the Kaweah and St. Johns Rivers discussed in the previous section are conveyed from the headgate to the crops within the entitlement holder service areas by hundreds of miles of ditches (***Figure 21***).

Several ditch companies divert water from the Lower Kaweah River, the principal ones are listed below:

- Consolidated Peoples, Farmers, and Elk Bayou Ditch Companies
- Mathews
- Jennings
- Uphill
- Modoc
- Goshen
- Lakeside Ditch Companies

TID, Fleming, Oakes, Evans, Watson, and Persian Ditch Companies receive water from both the Lower Kaweah and St. Johns Rivers. A schematic diagram of the Kaweah system is presented as **Figure 42**.

2.2.7.5 Source and point of delivery for imported water supplies

Imported water within the Kaweah Subbasin is delivered from both the CVP and Kings River systems, which have provide approximately 170,900 AFY on average over the historical period. These supplemental sources of water supply have been imported to the Subbasin to lands within the boundaries of the Subbasin from as early the late 1800s from the Kings River, which is currently delivered to the west portion of the Kaweah Subbasin into Lakeside Irrigation Water District. An additional source of supplemental supply to lands located within the Subbasin in the early 1950s was made available from the CVP, which is delivered through the Friant-Kern Canal (Fugro Consultants, 2016).

CVP water is diverted to the TID from three turnouts, which are located where Friant-Kern Canal crosses the Tulare Irrigation Main Canal, the St. Johns River channel, and the Lower Kaweah River channel, respectively. In addition, from time to time CVP water has been released into the Kings River channel and from there into canal systems traversing the western portion of the District towards the Lakeside Irrigation Water District. Imported water is delivered to the East Kaweah GSA through approximately 27 turnouts along the Friant-Kern Canal. The locations of the delivery points from the Friant-Kern Canal turnouts and headgates from the Kaweah, St. Johns and Lower Kaweah Rivers are presented on ***Figure 21***.

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2.3 Overview of Existing Monitoring Programs §354.8(c)

Groundwater monitoring and management has been underway for many decades in the Kaweah Subbasin. Currently, numerous local agencies are actively involved in the collection, review and evaluation of groundwater data for the purpose of groundwater management and protection. This section describes these monitoring programs. A groundwater management program (GMP) for TID was drafted in 1992 and 2010. The GMP focused on basin management; specifically, groundwater monitoring and sustainability, water quality, land subsidence, and surface water flow. These monitoring programs track the parameters listed below.

- Groundwater Levels
- Groundwater Quality
- Land Subsidence
- Surface Water Flow

2.3.1 Existing Groundwater Level Monitoring

The agencies located within the Kaweah Subbasin are involved in several long-term water level measurement program of wells throughout the Subbasin. Twenty-three-member agencies have collaborated and contributed data, which has been compiled and used for this Basin Setting effort. ***Table 4*** provides a summary of the groundwater level monitoring programs being conducted in each jurisdiction throughout the Subbasin. Groundwater level monitoring locations are shown on ***Figure 20***.

Within the Kaweah Subbasin, water level data were compiled using data from DWR's CASGEM program, the three GSAs within the Subbasin and the cooperating agencies are listed below.

- Several cities and communities within the Subbasin
- Kaweah Delta Water Conservation District
- Tulare Irrigation District
- Kings County Water District
- Cal Water (City of Visalia)
- City of Tulare
- Lindmore Irrigation District
- Exeter Irrigation District
- Ivanhoe Irrigation District
- Lindsay-Strathmore Irrigation District
- Stone Corral Irrigation District

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In total, more than 1,300 wells have been identified that have water level data. However, only a small percentage of these wells (on the order of 6 percent) have available well construction information (e.g., total depth, casing diameter, screened intervals, lithologic logs, e logs, etc.). Knowledge about the depth ranges of the screened intervals in the wells is important since there are significant water level differences in the various aquifers. The limited amount of information determining whether the wells are screened exclusively in the aquifers above or below the Corcoran Clay confining unit (i.e., the UAS or LAS, respectively) reduces the number of wells that can be used to create reliable water level contour maps. It is known that some wells are screened in the aquifers both above and below the Corcoran Clay.

Two agencies are known to have installed nested piezometers (i.e., monitoring wells with two or more separate, hydraulically-distinct casings that can measure water levels in different aquifers) in the Subbasin. KDWCD installed four such sets of wells on the west side of the Subbasin within Greater Kaweah GSA, each with separate casings that have screened intervals either above or below the Corcoran Clay. These wells show that water level difference above and below the clay can diverge by as much as 150 feet in this location. This illustrates the point that well construction information is needed to use water level monitoring data. Additionally, TID has installed four paired monitoring wells in the central part of the Subbasin within the Mid-Kaweah GSA.

2.3.1.1 Key Wells

A series of "key wells" have been identified to establish a consistent, long-term source of data to monitor the water levels in the various aquifers over the long-term. Approximately 118 wells have been preliminarily selected as key wells for the Subbasin (location shown on ***Figure 20***). The wells were selected based on the following criteria:

1. A long period of record of water level data, generally extending to the present;
2. Adequate information on well construction and aquifer of completion; and
3. Geographically distributed to be representative of all areas throughout the Subbasin to provide data that adequately tracks variations in groundwater levels throughout the area.

The key wells were chosen as a subset of the entire water level monitoring database to adequately represent the Subbasin both laterally and vertically. These key wells were used along with the other monitored wells for the creation of water level contour maps and water level hydrographs. Most of the known wells in the Subbasin are either missing or have limited well construction information. Therefore, the data gap will be addressed with the following the steps below.

1. Further review of acquired well logs;
2. Conducting down-hole video surveys of wells; and
3. Installing additional monitoring wells as funds become available.

While there are limitations associated with using water level data from wells without construction information, we have performed an initial assessment of many of the available wells with a long period of record. This process allowed for the selection of wells that were used for developing an initial understanding of groundwater level variations throughout the Subbasin. It is understood that

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this snapshot of groundwater conditions is limited based on the unknown completion information about the wells and may change as construction data is obtained in the future. *Table 4* provides a summary of groundwater level monitoring by agency.

Table 4: Existing Groundwater Level Monitoring Programs in the Kaweah Subbasin

Agency	GSA Monitored	Frequency of Monitoring	Period of Record of Monitoring	Types of Wells Monitored	Number of Wells (approximate)	Known Completion of Wells Monitored	Number of Dual Completion Wells	Auotomated Monitoring
Alta Irrigation District	EK, GK	Monthly to bi-annually	1921 - 2011	Ag / Domestic	5	None	None	Unknown
Bureau of Reclamation	All	Monthly to bi-annually	1924 - 2008	Unknown	118	15	Unknown	Unknown
Cal Water (City of Visalia)	MK, GK	monthly	1971 - 2018	Municipal	104	None	Unknown	Unknown
City of Lindsay	EK	bi-annually	2016 - 2017	Municipal	3	None	None	Unknown
City of Tulare	MK	Monthly to bi-annually	1992 - 2018	Municipal	30	11	None	Unknown
Deer Creek & Tule River Authority	None?	Bi-annually	2011 - 2018	Ag / Domestic	1	None	None	Unknown
Department of Water Resources	All	Bi-annually	1930 - 2016	Various	182	7	Unknown	Unknown
Exeter Irrigation District	EK, GK	Bi-annually	1963 - 2016	Agricultural	40	None	Unknown	Unknown
Ivanhoe Irrigation District	EK	Bi-annually	1961 - 2014	Agricultural	36	Few to none	Unknown	Unknown
Kaweah Delta Water Conservation District	GK, MK, (EK?)	Monthly to bi-annually	1919 - 2018	Agricultural	425	30	4	Unknown
Kings County Water District	GK, MK	Monthly to bi-annually	1963 - 2017	Agricultural	100	3	Unknown	Unknown
Kings River Conservation District	GK	Bi-annually	2011 - 2018	Agricultural	6	3	Unknown	Unknown
Lakeside Irrigation Water District	GK, MK	Bi-annually	2012 - 2017	Agricultural	33	2	Unknown	Unknown
Lewis Creek Water District	EK	Bi-annually	1971 - 2016	Agricultural	3	1	Unknown	Unknown
Lindmore Irrigation District	EK	Bi-annually	1945 - 2016	Agricultural	104	1	Unknown	Unknown
Lindsay-Strathmore Irrigation District	EK	Bi-annually	1955 - 2016	Agricultural	7	None	Unknown	Unknown
Porterville Irrigation District	EK	Rarely	1960 - 1978	Agricultural	1	None	Unknown	Unknown
Stone Corral Irrigation District	EK	Bi-annually	2006 - 2016	Agricultural	6	1	Unknown	Unknown
Tulare Irrigation District	MK	Bi-annually	1945 - 2018	Agricultural	128	5	4	Unknown
Tule River Lower Irrigation District	EK	Bi-annually	1953 - 2010	Agricultural	10	1	Unknown	Unknown

Since the early 1900's, TID has been observing declining groundwater levels in wells they monitor. TID began managing, supplying, and delivering water to growers within their district in 1889. Recorded monitoring of groundwater levels began in the 1940's and demonstrate seasonal fluctuations as well as periods of drought. During a seven-year drought from 1987 to 1995, groundwater levels dropped as much as 50 to 120 feet. Water level recovery was accomplished in 2000, five years after the drought ended. As of 2010, TID measures groundwater levels from approximately 100 wells each spring and fall and plans on installing dedicated monitoring wells to track groundwater levels in unconfined and confined aquifers. Likewise, KDWCD also measures the depths to groundwater in wells in the central KDWCD portion of the Subbasin.

2.3.2 Existing Groundwater Quality Monitoring

Groundwater quality monitoring and reporting is currently conducted through numerous public agencies. The following sections provide a summary of databases, programs, and agencies that actively collect groundwater data and information on where the data is stored and how it was used in this Basin Setting. A summary of these programs is provided in ***Section 2.3.2.3*** as ***Table 5***.

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2.3.2.1 Local Agency Groundwater Monitoring

Many existing, local water level monitoring programs were expanded by local water districts partly in response to Assembly Bill (AB)-3030 groundwater management planning in the mid-1990's, and subsequent Senate Bill (SB) 1938 compliant GMPs in the mid-2000s. Some district GMPs, such as those prepared by KDWCD and TID, are very detailed in providing subsurface hydrogeology, land use, and historical groundwater extents and fluctuations. Most plans provide a list of monitoring wells, associated well construction, a monitoring program, sampling plan, and an accompanying CASGEM monitoring plan.

In general, water levels and water quality in the Subbasin have been monitored annually, or twice a year where possible, and data reported biennially. Where viable, these monitoring networks will be incorporated into the defined monitoring networks for this Basin Setting and leveraged with monitoring network requirement for the Sustainable Groundwater Management Act (SGMA).

Water quality is monitored in many wells throughout the Subbasin. TID has a water quality sampling program which collects groundwater samples on a yearly basis from five private agricultural wells. However, this data is confidential to the owners and TID. Other agencies such as the Regional Water Quality Control Board, state and federal Environmental Protection Agency, USGS, SWRCB, City of Tulare, and various neighboring irrigation and water districts monitor groundwater quality in the region. TID collects and reviews data released from these agencies. The goal of the 2010 GMP was to maintain good water quality, specifically for agricultural irrigation, and to consolidate groundwater quality data into a single database (Provost & Pritchard, 2010).

TID water quality is generally excellent for both surface and groundwater supplies. Runoff from the Kaweah River and San Joaquin River is of very good to excellent quality and provides surface water supply and natural recharge for groundwater supply. The City of Tulare 2008 Consumer Confidence Report validates excellent water quality with parameters including: Total dissolved solids ranging from 86-220 ppm; specific conductance ranging from 130-340 uS/cm; and arsenic ranging from 2.1 -10 ppb.

2.3.2.2 California Drinking Water Information System Database (SDWIS)

All public drinking water systems (a system that has 15 or more service connections or regularly serves 25 individuals daily at least 60 days out of the year) are regulated by the State Water Resources Control Board (SWRCB) – Division of Drinking Water (DDW) and must demonstrate compliance with State and Federal drinking water standards through a rigorous monitoring and reporting program. Required monitoring for each well within each water system is uploaded to the DDW's database and subsequently available for the public through the State Drinking Water Information System (SDWIS). In addition to providing compliance monitoring data for each regulated water system, other information is available including monitoring frequency, basic facility descriptions, lead and copper sampling, violations and enforcement actions, and consumer confidence reports.

All drinking water systems are required to collect samples, that must include a comprehensive suite of constituents known as the "Title 22" list on a given frequency depending on the constituent and regional groundwater vulnerability. The following is a summary of the minimum sampling frequency for a public water supply well:

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- General minerals, metals and organics (Synthetic Organic Chemicals and Volatile Organic Compounds) sampling is required every 3 years. If any organics are detected, sampling frequency must be increased to quarterly.
- Nitrate is required annually. If nitrate is ≥5 ppm, then sampling is required quarterly.
- If arsenic is ≥5 ppb, sampling should be increased to quarterly.
- Radiological constituents (i.e., gross alpha and uranium) are sampled periodically, depending on historical results: once every 3 years (when initial monitoring is ≥ ½ the MCL); once every 6 years (when initial monitoring is ≤ ½ the MCL), or once every 9 years (when initial monitoring is non-detect).

Public water systems provide the most abundant source of data since the testing requirements are at frequent intervals and data collection began in 1974. All sample results are easily available from the SDWIS database. When using these data to characterize groundwater quality for the Basin Setting, only raw water quality data are considered. It is important to understand that this characterization is not intended to represent water supplied by purveyors because they may provide wellhead treatment to remove or reduce contamination.

2.3.2.3 Central Valley Salinity Alternatives for Long-term Sustainability (CV-SALTS)

CV-SALTS is a collaborative stakeholder driven and managed program to develop sustainable salinity and nitrate management planning for the Central Valley. The program objective is intended to facilitate the salt-reduction and nitrate-reduction implementation strategies recommended in the Salt and Nitrate Management Plan (SNMP) developed in 2017. The strategies are designed to address both legacy and ongoing salt and nitrate accumulation issues in surface and groundwater. The overarching management goals and priorities of the control efforts are: ensure safe drinking water supply; achieve balanced salt and nitrate loading; and implement long-term, managed restoration of impaired water bodies. The program is phased with the primary focus of early actions on nitrate impacts to groundwater drinking water supplies and established specific implementation activities. The Kaweah Subbasin is a Priority 1 basin for nitrate management. Consequently, the nitrate control program schedule is set to begin in 2019.

CV-SALTS will enact a nitrate control program as part of the SNMP which requires forming a management zone as a regulatory option to comply with the requirements of the nitrate program. The management zones will consist of a defined management area to manage nitrates, ensure safe drinking water, and meet applicable water quality objectives. Local management plans will be created to implement the long-term goals of the nitrate control program. As programs are implemented, there will be criteria established within each of the management areas to meet the objectives of their individual programs. While Irrigated Lands Regulatory Program (ILRP) allows for compliance of their regulatory program through coalitions that cover a broad, non-contiguous area based on similar land use, SGMA and CV-SALTS will both require management areas/zones to be contiguous areas regardless of land use.

Both the ILRP and CV-SALTS programs involve permittees and local stakeholders working towards water management objectives set forth by the State. In this regard, collaborative efforts should be

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made to maximize the resources of each program and provide a more integrated approach to developing local solutions for groundwater management.

2.3.2.4 Department of Pesticide Regulation

The Department of Pesticide Regulations (DPR) Ground Water Protection Program collects and evaluates samples for pesticides to (a) determine if there is a risk of groundwater contamination; (b) identify areas sensitive to pesticide contamination; and (c) develop mitigation measures to prevent that movement. DPR obtains groundwater sampling data from other public agencies, such as SDWIS, USGS, and Groundwater Ambient Monitoring and Assessment Program (GAMA), and through its own sampling program. Sampling locations and constituents are determined by pesticides used in a region, and from review of pesticide detections reported by other agencies.

Because of their sample selection methodology, DPR typically only collects one sample per well. Repeat sampling is not performed if there are positive detections. Rather, their focus is on validating contamination through their research and sampling program. These data are reported annually along with the actions taken by DPR and the SWRCB to protect groundwater from contamination by agricultural pesticides. Annual reports are reviewed, and contaminant detections are identified in the groundwater quality characterization. In the Kaweah Subbasin, only legacy pesticides (dibromochloropropane (DBCP) and 1,2,3-TCP) are detected in the public water system wells. No pesticides currently in use were identified.

2.3.2.5 GeoTracker and EnviroStor Databases

The SWRCB oversees the GeoTracker database. This database systems allows the SWRCB to house data related to sites that impact or have the potential to impact groundwater quality. Records available on GeoTracker include cleanup sites for Leaking Underground Storage Tank (LUST) sites, Department of Defense sites, and Cleanup Program sites. Other records for various unregulated projects and permitted facilities includes Irrigated Lands, Oil and Gas production, operating Permitted Underground Storage Tanks (USTs), and Land Disposal sites.

GeoTracker is a public and secure portal that can retrieve records and view data sets from multiple SWRCB programs and other agencies through a Google maps GIS interface. This database is useful for the public and can help other regulatory agencies monitor the progress of cases. It also provides a web application tool for secure reporting of lab data, field measurement data, documents, and reports.

The DTSC oversees the EnviroStor database. This data management system tracks cleanup, permitting, enforcement, and investigation efforts at hazardous waste facilities and sites with known contamination or sites where further investigation is warranted by the DTSC. This database only provides reports, inspection activities and enforcement actions completed on or after 2009. Like the GeoTracker database, this is useful for the public and other regulatory agencies to monitor progress of ongoing cases. The primary difference between the two databases is that EnviroStor only houses records for cases that DTSC is the lead regulatory agency, whereas the GeoTracker database houses records to cases from different regulatory agencies, such as at State and local levels. For the Basin Setting, both databases were searched to identify and report on any contamination sites that may have impacts to groundwater quality.

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2.3.2.6 Groundwater Ambient Monitoring and Assessment (GAMA) Program

The GAMA Program was created by the SWRCB in 2000. It was later expanded by the Groundwater Quality Monitoring Act of 2001 (AB 599). AB 599 required the State Water Board to integrate existing monitoring programs and design new program elements as necessary to monitor and assess groundwater quality. The GAMA Program is based on collaboration among agencies including the State and Regional Water Boards, CDWR, DPR, USGS, and USGS National Water Information System (NWIS), and Lawrence Livermore National Laboratory (LLNL). In addition to these state and federal agencies, local water agencies and well owners also participate in this program. The main goals of GAMA are to: improve statewide comprehensive groundwater monitoring; and increase the availability of groundwater quality and contamination information to the public. Monitoring projects in this program are described below.

- **GAMA Priority Basin Project**: This project provides a comprehensive groundwater quality assessment to help identify and understand the risks to groundwater. The project started assessing public system wells (deep groundwater resources) in 2002 and shifted focus to shallow aquifer assessments in 2012. Since 2002, the USGS, the project's technical lead, has performed baseline and trend assessments and sampled over 2,900 public and domestic water supply wells that represent 95% of the groundwater resources in California.

- **GAMA Domestic Well Project**: This project was conducted between 2002 and 2011 as part of the GAMA Program and sampled over 1,100 private wells in six California counties (Yuba, El Dorado, Tehama, Tulare, San Diego, and Monterey) for commonly detected chemicals. The voluntary participants received analytical test results and fact sheets, and the water quality data was included in the GeoTracker GAMA online database. The Domestic Well Project is currently on hiatus. Data from this project included nitrate concentrations and stable isotopic analysis for 29 domestic wells within the Kaweah Subbasin; these data have been incorporated into the Basin Setting.

- **GAMA Technical Hydrogeologic and Data Support**: These efforts have expanded to include several Divisions and Programs at both the SWRCB and the Regional Water Quality Control Boards, other state agencies, and non-governmental organizations. GAMA staff are providing support for the following activities:

  - Hydrogeologic analyses to evaluate drinking water sources
  - Development of geothermal well and water well standards
  - Technical support for state actions involving groundwater
  - Hydrogeologic analysis for desalination projects
  - Technical assistance for developing standard operating procedures for grant projects
  - High-level Geographic Information System (GIS) projects
  - Source water protection planning

- Antidegradation in groundwater planning

Although these GAMA activities were provided at a statewide level, Kaweah-specific groundwater information was used for this Basin Setting.

2.3.2.7 Irrigated Lands Regulatory Program (ILRP)

The ILRP was initiated in 2003 with a focus of protecting surface waters. Groundwater regulations were added in 2012. ILRP was implemented to protect receiving water bodies from impairment associated with agricultural runoff, tile drain flows, and storm water runoff from irrigated fields. Elements of this program that overlap with SGMA requirements are the monitoring programs focused on identifying groundwater impairment associated with irrigated agriculture.

Currently, the program has focused on sampling surface waters. Although groundwater regulations were implemented in 2012, data collection is not scheduled to begin until Fall 2018. Throughout the Central Valley, ILRP Coalitions and other participating water agencies are coordinating their efforts as the Central Valley Groundwater Monitoring Collaborative. The Kaweah Basin Water Quality Association (an ILRP Coalition) represents a large area of irrigated agriculture within the Kaweah Subbasin.

The Coalition's Comprehensive Groundwater Quality Management Plan identified areas where groundwater is vulnerable to degradation that is caused by agricultural irrigation practices. The Groundwater Trend Monitoring Work Plan, Phase II outlines the Coalition's compliance strategies which include continuing to educate their members on management practices that are protective of water quality; reporting on management practices that are actively used; and an annual sampling program to track nitrate level trends in groundwater.

The focus of ILRP's groundwater regulation is to track nitrate level trends and determine if current management practices are protecting groundwater from further degradation. The SWRCB's objective is to eventually restore nitrate concentrations to levels below the drinking water standard of 10 parts per million (mg/L, as nitrogen). Data collected and reported as a part of ILRP are provided to the SWRCB and are available in the GAMA database for download and use. Groundwater sampling will collect samples annually from shallow domestic wells (<600-ft deep). As the program progresses, the number of wells sampled may increase. Initially, the Regional Board recommended 0-3 wells per township, but the Coalitions were not able to gain landowner authorization for this number of wells. In compromise, the Regional Board approved sampling wells with landowner agreements and have suggested the Coalitions work along with as part of the SGMA process to develop a more comprehensive monitoring network.

Once established, the annual monitoring under this program will include static water level; temperature; pH; electrical conductivity; dissolved oxygen; and nitrate. Once every five years, a limited group of general minerals will also be collected.

2.3.2.8 United States Geological Survey

The USGS California Water Science Center (CWSC), provides California water data services by conducting data collection, processing, analysis, reporting, and archiving. Data types include surface water, groundwater, spring sites, and atmospheric sites, with data often available in real-time via satellite telemetry. The NWIS groundwater database consists of wide range of data on wells, springs,

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test holes, tunnels, drains, and excavations. Available groundwater-specific information includes groundwater level data, well depth, aquifer parameters, and more. USGS studies and reports that were specifically used for the Basin Setting and groundwater characterization include:

- Groundwater Quality in the Shallow Aquifers of the Tulare, Kaweah, and Tule Groundwater Basins and Adjacent Highlands areas, Southern San Joaquin Valley, California. USGS and SWRCB. Fact Sheet, January 2017.

- Groundwater Quality in the Southeast San Joaquin Valley, California. USGS and SWRCB. June 2012.

- Status and Understanding of Groundwater Quality in the Two Southern San Joaquin Valley Study Units, 2005-2006: California GAMA Priority. Scientific Investigations Report 2011-5218. 2012.

- Groundwater Quality Data in the Southeast San Joaquin Valley, 2005-2006: Results from the California GAMA Program. Data Series 351. USGS and SWRCB. 2008.

- Environmental Setting of the San Joaquin-Tulare Basins, California. Water Resources Investigations Report 97-4205. 1998.

2.3.2.9 Groundwater Quality Monitoring Programs Summary

Table 5 provides summary information relating to the programs described above. Each program summary includes monitoring parameters and frequency, program objectives, and items of note relating to the Kaweah Subbasin Basin Setting.

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Table 5: Existing Groundwater Quality Monitoring Programs

Programs or Data Portals	Parameters	Frequency	Program Objectives	Notes
AB-3030 and SB-1938	• Water levels are typically monitored annually. • Ag Suitability analysis (limited suite of general minerals) monitoring frequency between annual to once every 3 years.	Semiannual to Annual		Monitoring is recommended as a part of groundwater management planning. Data availability is inconsistent between Districts.
California SDWIS	Database for all public water system wells and historical sample results. Data available includes all Title 22 regulated constituents.	• Title 22 General Minerals and Metals every 3 years. • Nitrate as N annually, if ≥ 5 ppm, sampled quarterly • VOCs and SOCs sampled every 3 years. Uranium sampling depends on historical results but varies between 1 sample every 3 (when ≥ 10 pCi/L), 6 (when < 10 pCi/L) or 9 (when no historical detection) years.	Demonstrate compliance with Drinking Water Standards through monitoring and reporting water quality data.	An abundant source of data because of the required testing frequency and list of parameters.
CV-SALTS	Sampling parameters required through Waste Discharge Requirements (WDR): typically include monthly sodium, chloride, electrical conductivity, nitrogen species (N, NO_2, NO_3, NH_3), pH and other constituents of concern identified in the Report of Waste Discharge. A limited suite of general minerals is required quarterly from the source and annually from the wastewater.	Most constituents sampled monthly, quarterly general minerals from source water and annual general minerals from waste discharge. Kaweah is a Priority 1 Basin, meaning that management strategies will be initiated in 2019.	To monitor degradation potential from wastewaters discharged to land application areas.	Water quality monitoring required by CV-SALTS is consistent with the Regional Water Boards existing requirements through their WDR process. It is unlikely that additional monitoring will be required. The initial phases of the program are strongly focused on identifying sources of salinity and reducing salinity and nitrogen species in wastewaters discharged to land. By 2030, the program is expected to implement projects to aid with salt and nitrate management in the Central Valley.

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Programs or Data Portals	Parameters	Frequency	Program Objectives	Notes
Department of Pesticide Regulation	Pesticides	• Annual	DPR samples groundwater to determine (1) whether pesticides with the potential to pollute groundwater are present, (2) the extent and source of pesticide contamination, and (3) the effectiveness of regulatory mitigation measures.	Data available at: https://www.cdpr.ca.gov/docs/emon/grndwtr/index.htm
GAMA (Collaboration with SWQCB, RWQCB, DWR, DPR, NWIS, LLNL)	• Constituents sampled vary by the Program Objectives. • Typically, USGS is the technical lead in conducting the studies and reporting data.	• The Priority Basin Project performed baseline and trend assessments and sampled over 2,900 public and domestic wells that represent 95% of the groundwater resources in CA. • The Domestic Well Project sampled over 180 domestic wells in Tulare County: 29 Wells were within the Kaweah Subbasin.	• Improve statewide comprehensive groundwater monitoring. • Increase the availability of groundwater quality and contamination information to the public.	USGS reports prepared for the Priority Basin Project were used to identify constituents of concern in the basin and confirm water quality trends prepared for groundwater characterization.

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Programs or Data Portals	Parameters	Frequency	Program Objectives	Notes
Geotracker and Envirostor Databases	Many contaminants of concern, organic and inorganic.	Depends on program. Monthly, Semiannually, Annually, etc.	Records database for cleanup program sites, permitted waste dischargers	Records available on GeoTracker include: • Cleanup for Leaking Underground Storage Tank (LUST) sites • Department of Defense Sites • Cleanup Program Sites Other records for various unregulated projects and permitted facilities includes: • Irrigated Lands • Oil and Gas production • Operating Permitted Underground Storage Tanks (USTs) • Land Disposal Sites
ILRP	• Annually: static water level, temperature, pH, electrical conductivity, nitrate as nitrogen, and dissolved oxygen. • Once every five years: general minerals collection	Annual and Every 5 years	Monitor impacts of agricultural and fertilizer applications on first encountered groundwater	Sampling will begin in Fall 2018 with a limited number of wells sampled. The program will be expanded and may incorporate a shared sampling program with SGMA.
USGS California Water Science Center	Conducted multiple groundwater quality studies of the Kaweah Subbasin	Reports and fact sheet publications range from 1998 through 2017.	Special studies related to groundwater quality that provide comprehensive studies to characterize the basin.	Studies used for Basin Setting: • Groundwater Quality in the Shallow Aquifer (2017) • Status and Understanding (2012) • Groundwater Quality in SESJ (2012) • Groundwater Quality Data in the SESJ (2008) • Environmental Setting (1998)

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2.3.3 Existing Land Subsidence Monitoring

Past, recent, and potential future monitoring of land subsidence in the Kaweah Subbasin are briefly summarized below in ***Table 6***. Details and results of recent and historical subsidence monitoring are discussed in ***Section 2.8***. of this document.

Table 6: Summary of Land Subsidence Monitoring in the Kaweah Subbasin

Category	Monitoring Entity(s)	Period of Record
Historical Monitoring	• National Geodetic Survey of benchmarks (repeat level surveys)	• 1926-1970
Recent Monitoring	• National Geodetic Survey of benchmarks (repeat level surveys and installation and measurement of Deer Creek extensometer [8.5 miles south of subbasin]) • Local benchmark monitoring network (Kaweah Subbasin collaborators) • CGPS data from UNAVCO and CVSRN stations: P056, P566, CRCN, LEMA, and RAPT. • NASA including both InSAR and UAVSAR programs	• NGS – 1970 to Present • Tie into NGS and CGPS benchmarks • CGPS – ~2006 to Present (depending on station) • NASA – 2006 to 2017 (except from 2011-2014)
Future Data Availability	• National Geodetic Survey of benchmarks (repeat level surveys) • Deer Creek Extensometer to the South • CGPS data from UNAVCO and CVSRN stations: P056, P566, CRCN, LEMA, and RAPT • NASA including both InSAR and UAVSAR programs, potentially new extensometers in the Kaweah Subbasin	• 2018 through 2020 • 2018 to present • CGPS – continuous daily readings • Ongoing

Subsidence monitoring includes both land elevation surveying as well as groundwater level monitoring to consider the effects that the change in groundwater levels have on the rate and change of land subsidence over time. Land elevation survey monitoring includes National Geodetic Survey (NGS) benchmark repeat level surveys, remote sensing by Interferometric Synthetic Aperture Radar (InSAR), and in-situ compaction monitoring by an extensometer south of the Subbasin. Groundwater level monitoring, as briefly discussed in ***Section 2.3.1***, includes collecting data from representative monitoring wells throughout the Subbasin in all three aquifer systems: UAS, LAS, and SAS. In areas where the Corcoran Clay is present, preliminary monitoring results suggest that groundwater level decline in the lower aquifer system is contributing to increased land subsidence. The relationship between groundwater levels and land subsidence are discussed in ***Section 2.8.***

2.3.3.1 Future Data Availability

The effectiveness of future subsidence monitoring will require continued support by National Aeronautics and Space Administration/Jet Propulsion Laboratory (NASA/JPL), USGS, and Scripps Orbit and Permanent Array Center (SOPAC)/UNAVCO/California Department of Transportation (CalTrans) for InSAR and Global Positioning System (GPS) data processing and reporting. According to USGS, the European Space Agency's (ESA's) Sentinel satellites collect InSAR data at approximately weekly intervals, and data are available for download and use as necessary. These data require processing which has been performed by JPL at the request of DWR. Similarly, GPS data has been made available by UNAVCO, SOPAC/California Real Time Network (CRTN), and CalTrans. Although there are currently no extensometers within the Kaweah Subbasin, USGS has replaced extensometer 22S-27E-30D2 (Deer Creek south of Porterville and in the Tule Subbasin), and will provide data to interested parties (personal communication, USGS).

2.3.4 Existing Stream Flow Monitoring

At the upper reaches of the Kaweah River watershed, the U.S. Army Corps of Engineers measures and records inflow to Lake Kaweah. The Kaweah and St. Johns Rivers Association (KSJRA) measure data on a daily basis for the Kaweah River, Dry Creek, and Yokohl Creek. These data are summarized in annual reports and published by KSJRA.

The records of the stream groups impacting the facilities and stockholders of the ditch companies that they manage were acquired. Although data gaps exist, these may represent relatively small quantities of contributory flows. The records of the USGS are, for the most part, supplemental to the records of the Association and local agencies. The information that is published by the USGS, however, does fill some of the data gaps that exist in the information related to the local stream groups. ***Figure 20*** shows the locations of stream flow gauges monitored within the Subbasin.

Supplies made available from the Kings River impact the north, northwestern, and westerly areas of the Subbasin. Information as to the gross deliveries made available to these areas is available from the Kings River Water Association, as published in annual reports that contains the information necessary to document the gross delivery information. Specific information related to deliveries into areas in and adjacent to the Subbasin on the north, northwest, and westerly boundaries are available from records of the Corcoran Irrigation Company, the Corcoran Irrigation District, the Kings County Water District, the Lakeside Irrigation Water District, and the Melga Water District.

TID's main sources of surface water come from the San Joaquin and the Kaweah rivers. Surface water is provided from the San Joaquin River through a USBR contract which delivers water to TID from the Friant Dam via the Friant-Kern Canal. Kaweah River water is delivered to TID from KSJRA. TID can also obtain surface water from several small surface streams which pass through TID's service area.

Surface water quality is recorded by Friant Water Authority (FWA), USBR, and KSJRA to monitor long-term hydrology, water availability, and water quality changes. TID monitors published data from these agencies to ensure surface water quality does not affect groundwater quality.

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2.4 Groundwater Elevation and Flow Conditions §354.16

This section describes available information to document current and historical groundwater elevation data, flow directions, lateral and vertical gradients, and regional pumping patterns in the Subbasin.

2.4.1 Current and Historical Groundwater Trends

Current and historical groundwater level trends are provided below. This section provides an overview of groundwater flow conditions by describing groundwater elevation maps and key well hydrographs.

2.4.1.1 Elevation and flow directions

Water level measurements and groundwater elevation data from over 1,300 wells within and adjacent to the Subbasin were used to generate water level contour maps and water level hydrographs for individual water wells throughout the Subbasin. Water level contour maps for spring seasons of years 2015 through 2017 and earlier key years - 1981, 1999, and 2011 - during the representative base period are provided as ***Figure 23*** through ***Figure 28***. Water level contour maps for the fall season of the four most recent years - 2014 through 2017 - are provided as ***Figure 29*** through ***Figure 32***.

Groundwater flow direction was calculated for the spring of every year from 1981 to 2017 for the entire Kaweah subbasin. Groundwater flow directions were generally similar for the majority of the Subbasin during the subsequent years of 2013 through 2017. Flow directions are further quantified through numerical groundwater model development. The approach and methods used for numerical groundwater model development and described in the technical memorandum included as ***Appendix A***.

Groundwater within the Kaweah Subbasin flows from the Sierra Nevada towards the southwest. The presence of Corcoran Clay in the western portion of the Subbasin and lack of well construction information available for the measured water wells has resulted in meager determination of water level conditions in the confined aquifers of the region.

Inflow of groundwater into the Kaweah Subbasin occurs both from the north (Kings Subbasin), from mountain front recharge along the eastern edge of the basin, and in some years, from the south in response to pumping. Outflow of groundwater from the Kaweah Subbasin occurs to the west generally into the Tulare Lake Subbasin, but also occurs to the south into the Tule Lake Subbasin. Large areas of lowered groundwater levels were present in most years of the current drought in the west and southwestern portion of the Kaweah Subbasin, near the cities of Hanford and Corcoran. Groundwater levels are directly affected by the distribution of groundwater pumping in the basin which is further addressed in **Section 2.4.1.3**.

2.4.1.2 Lateral and vertical gradients

Due to the inherent variability in aquifer properties and the complexity of the gradients, estimates of subsurface flow within the Kaweah Subbasin are considered approximations.

Lateral Gradients

The rates of groundwater flow are a function of the slope of the groundwater surface and the permeability of the water-bearing materials. In the Subbasin, groundwater flow rates are on the order of a several feet per day. However, in materials of low permeability, such rates may be reduced to as little as a few feet per year. The gradients of the groundwater in this Subbasin vary but are typically between 10 vertical feet per mile (0.002 feet per foot) to 16 feet per mile (0.003 feet per foot) outside of significant groundwater pumping depressions.

Groundwater flow in underlying confined aquifers Lower Aquifer System (LAS), is analogous to the flow of water in a pressure conduit and moves in response to pressure differentials created by pumping extractions from the confined aquifer or by a buildup in the water table in the unconfined groundwater body supplying the aquifer (Fugro West, 2007). Along the western portion of the Subbasin, where dynamic pumping depressions are present, gradients steepen and groundwater flow rates increase by an order of magnitude. In these areas, groundwater levels can show vertical differences of 100 feet within less than a mile due to localized pumping stresses.

Vertical Gradients

Many wells in the Kaweah Subbasin west of SR 99 penetrate aquifers above and below the Corcoran Clay and provide significant vertical leakage and hydraulic communication, which affects the pattern of groundwater movement and rates of regional recharge and discharge (Malcolm Pirnie, 2001).

The water level analysis included an attempt to correlate 1,300 wells included in the monitoring network to well construction details. It was determined that very few well construction details were available for the monitored wells, making it difficult to determine whether measured water levels were representative of upper or lower aquifer systems. As early as 1972, "…it was found that many of the wells measured drew from more than one aquifer system and water level measurements therein reflected a composite of the water levels" (B-E, 1972).

Even without certainty about the specific completion of most wells, it is believed that wells located east of the Corcoran Clay extent reflect water level conditions representative of the SAS, while wells located within the area of the Corcoran Clay are, for the most part, perforated in the confined aquifer system below the Corcoran Clay (Fugro West, 2007). Furthermore, the heterogeneity of aquifer properties in the Subbasin and known presence of many interbedded aquitards in the west part of the Subbasin complicate the separation of water level data representative of the confined versus unconfined aquifer systems. According to Bertoldi (1991), the many fine-grained lenses of overlapping, discontinuous clay beds within the Valley have a combined effect that controls vertical flow to a greater degree than the Corcoran Clay.

There are currently eight paired (shallow and deep) monitoring wells within or in close proximity to the Kaweah Subbasin. Four are monitored by KDWCD and four are monitored by TID. The locations of these wells are shown on ***Figure 33*** and ***Figure 34***. Each monitoring location has two paired (shallow and deep) monitoring wells; one screened above the Corcoran Clay and the other screened below the Corcoran Clay. This enables water level monitoring agencies to measure vertical gradients distinctly without inaccuracies caused by hydraulic communication in wells screened in multiple aquifer zones. Several of these wells were installed recently; thus, only a limited amount of data is available. The KDWCD wells were installed between 2005 and 2006 and have consistent water level data to present, but the TID wells were installed in 2016 and only have one distinct water level measurement each.

As discussed previously, not all wells screened below the Corcoran Clay exhibit truly confined groundwater conditions. However, it is widely accepted that "the degree of confinement in the continental deposits generally increases in a westerly direction and becomes greater as depth to the aquifer increases" (B-E, 1972). This generality is corroborated by the paired hydrographs presented on ***Figure 33*** and ***Figure 34***. The TID wells, which are relatively close to the eastern extent of the Corcoran Clay, show relatively small vertical gradients. Water level differences in the shallow and deep wells vary between approximately 35 feet and 7 feet. The KDWCD wells, which are further west (three of the four wells are outside the basin), show much greater vertical gradients than the TID wells. Water elevations differences in the KDWCD nested wells average from about 50 feet to 200 feet. The two wells furthest to the southwest exhibit higher vertical gradients on average than the two northernmost wells, which are closer to the eastern extent of the Corcoran Clay.

2.4.1.3 Regional patterns

Figure 23 through ***Figure 32*** illustrate the groundwater elevation contour maps of the following periods: Spring 1981, Spring 1999, Spring 2011, Spring 2015 through 2017, and Fall 2014 through 2017. Review of the contour maps indicate that the principal direction of groundwater flow is to the southwest in the unconfined groundwater of the Kaweah River alluvial fan and continental deposits. Subsurface inflow occurs in the unconfined aquifer system above the Corcoran Clay, and from the Tule River system to the south. Outflow of confined groundwater occurs to the west in the confined aquifer system below the Corcoran Clay (Fugro West, 2007).

The influence of water extraction from the Kings River occurs to lands generally west of the Kaweah Subbasin and can be seen by contours that reflect replenishment from various tributaries in that area. The contours also show pumping depressions, which have been created in southwest corner of the Kaweah Subbasin north of Corcoran and west of Visalia.

The groundwater contours presented in this report were mapped as a single homogenous unit. Ideally, the contours would have been mapped by the principal aquifer units (SAS, LAS, and UAS); however, this wasn't feasible given the lack of well completion information for most wells in the Subbasin.

Wells located east of the Corcoran Clay boundary are all considered to be representative of the SAS. The SAS is generally unconfined to semi-confined aquifer system in the eastern half of the basin. All wells within the extent of the Corocan Clay could be representative of either the LAS or the UAS, depending on their depth and screened intervals. To contour the LAS and UAS separately, water level data would be needed in numerous wells of known completion that are dispersed throughout the basin. There are a small number of wells with known completion in the Corcoran Clay extent, but not enough to create reliable contour maps. Additionally, water level data from any wells with multiple screen zones that span both aquifer systems are not eligible for contour mapping. Until more well completion information for wells in the Corcoran Clay extent is acquired, it will remain infeasible to create contours for the separate principal aquifer units in the Kaweah Subbasin.

Water level hydrographs were selected from several of the wells with a long-term period of record. These are the key wells referenced throughout the Basin Setting. The selected hydrographs, presented as ***Figure 35***, provide a baseline of groundwater conditions throughout the Subbasin. The hydrographs selected demonstrate appropriate geographic distribution within the Subbasin and generally provide excellent records of both Spring and Fall water level conditions and long-term trends in water levels, some of which extend back to the 1940s.

2.4.1.4 Water Year Type

Discussion of water level trends must include context with regard to hydrologic variations in historical wet-dry cycles, referred to by DWR as "water year type". Water levels vary in response to the cyclical nature of precipitation, surface water flows, and diversions from the Kaweah River system. ***Figure 36*** illustrates the changing hydrologic conditions within the Subbasin for rainfall recorded in Visalia from water year 1878 through 2017. Average rainfall in the basin is 10.1 inches per year. The bottom half of the chart shows the annual precipitation. The upper portion of the chart shows the climactic variability by stacking subsequent years, such that upward trending portions (blue areas) represent wet periods and downward trending portions (yellow areas) represent drought periods.

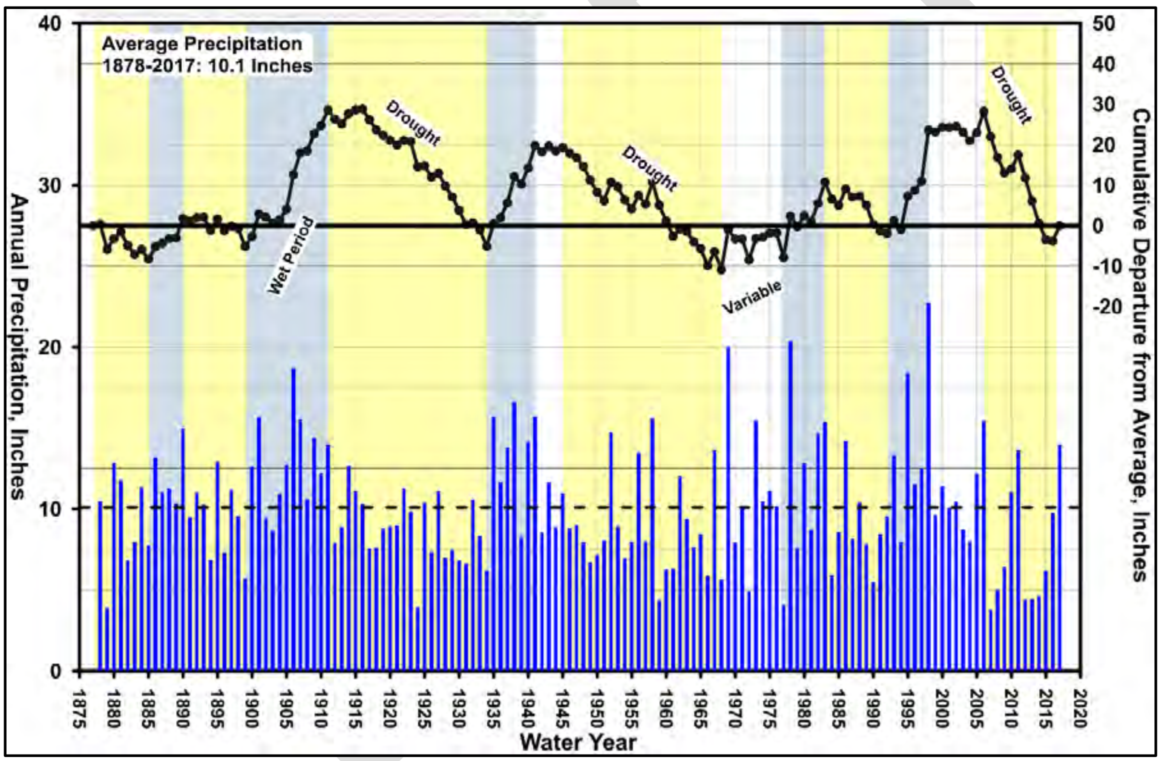

Figure 36: Cumulative Departure from Mean Precipitation – Visalia, California

Table 7: Historic Hydrologic Conditions (Water Year Types)

Period (Water Years)	Hydrologic Condition	Duration (No. of Years)	Precipitation Deviation (Inches)	Deviation Rate (Inches/year)
1878 to 1885	Drought	8	- 6	- 0.7
1886 to 1890	Wet	5	10	2.0
1891 to 1899	Drought	9	7	- 0.8
1900 to 1911	Wet	12	34	2.8
1912 to 1934	Drought	23	- 34	- 1.5
1935 to 1941	Wet	7	25	3.6
1942 to 1945	Variable	4	4	- 0.1
1946 to 1968	Drought	23	- 30	- 1.3
1969 to 1977	Variable	9	3	0.3
1978 to 1983	Wet	5	19	3.1
1984 to 1993	Drought	8	-10	-1.0
1994 to 1998	Wet	5	22	4.5
1999 to 2006	Variable	8	5	0.6
2007 to 2016	Drought	10	32	- 3.2

Precipitation data from Visalia California NOAA gauge.
Precipitation Deviation is the cumulative departure from average precipitation for the period
Deviation Rate provides a relative sense of the severity of the wet or dry periods.

Figure 36 and *Table 7* emphasize the highly variable climactic cycles common to the southern San Joaquin Valley consisting of prolonged periods of modest drought punctuated by short, intense wet periods. Notable aspects of this graph include:

- A 23-year drought including water years 1946 through 1968 received below-average precipitation, when an average of 1.5 inches below normal fell each year.
- A wet period from 1978 through 1983 received an annual average precipitation of 3.1 inches above normal each year.
- An eight-year drought period between 1984 and 1993 received an average of 1 inch below normal precipitation each year.
- A wet period from 1994 through 1998 which was recorded as wetter than the previous wet period. Annual rainfall averaged a full 4.5 inches above normal each year.

The most recent drought changed the long-term pattern of prolonged, but somewhat modest, droughts. During the period of ten years - water years 2007 to 2016 - the area received a total of 30 inches less rainfall than the long-term average, which is equal to an annual rainfall of 3 inches less than normal each year. During this decade, the Subbasin received 30 percent less rainfall than the long-term average; the most severe drought on record.

The water level hydrographs presented on ***Figure 35*** are color coded to show the varying climactic cycles (water year type) as above, where wet periods are shaded blue and dry periods (drought) are shaded yellow. White areas on the hydrographs represent variable conditions (alternating wet and dry years).

Throughout the Subbasin, water levels generally follow characteristic patterns following climactic cycles and availability of surface water to offset groundwater pumping. During wet periods water levels either remained relatively unchanged or rose moderately. During the wet periods between 1978 and 1983, and again during 1994 to 1998, water levels rose between 20 and 50 feet in most parts of the Subbasin.

During the eight-year drought of the late 1980s through mid-1990s, typical water levels declined by as much as 80 feet in the central and eastern portions of the basin. During this period, water levels in the southwestern portion of the basin declined more than 100 feet, within TID and near the Corcoran Irrigation District well field.

The most recent severe drought, which started in water year 2007, included an unprecedented multi-year period during between 2013 and 2015 when CVP deliveries were unavailable in the Subbasin. The combination of lack of precipitation and unavailability of CVP water reduced recharge and required local water demands to be met from groundwater pumping, collectively leading to lowered water levels throughout the basin. While in some areas, including north of Visalia, water level declines were limited to approximately 40 to 50 feet, other areas experienced water level declines of as much as 100 to 150 feet.

In many parts of the Subbasin, but particularly in the southern portion of EKGSA, west of the Cities of Lindsay and Strathmore and within MKGSA south of the city of Tulare, water levels in 2015 and 2016 declined to the lowest levels on record. Cumulatively, water levels declined since the record high levels of the (early 1940s or) early 1980s, by 50 to 150 feet. Notably, in one well south of the City of Tulare, the water level declined by more than 200 feet between the early 1980s through 2015. See ***Appendix B***.

Although the Subbasin experienced widespread water level declines, water levels in a few wells in the eastern portion of the basin along the Kaweah River experienced only limited declines. These wells are presumed to be both relatively shallow and to benefit from almost continual recharge from the flow of the Kaweah and St. Johns rivers. Since the 1960s, one well has experienced only 10 feet of decline with very limited seasonal fluctuations.

2.5 Kaweah Subbasin Water Budget §354.18

This section is provided for compliance with GSP Regulations § 354.18 which states that "Each Plan shall include a water budget for the basin that provides an accounting and assessment of the total annual volume of groundwater and surface water entering and leaving the basin, including historical, current and projected water budget conditions, and the change in the volume of water stored. Water budget information shall be reported in tabular and graphical form."

The GSP Regulations § 354.18(b) detail the required components for a water budget which are illustrated below in ***Figure 37.*** The Kaweah Subbasin water budget includes each of these required components and more.

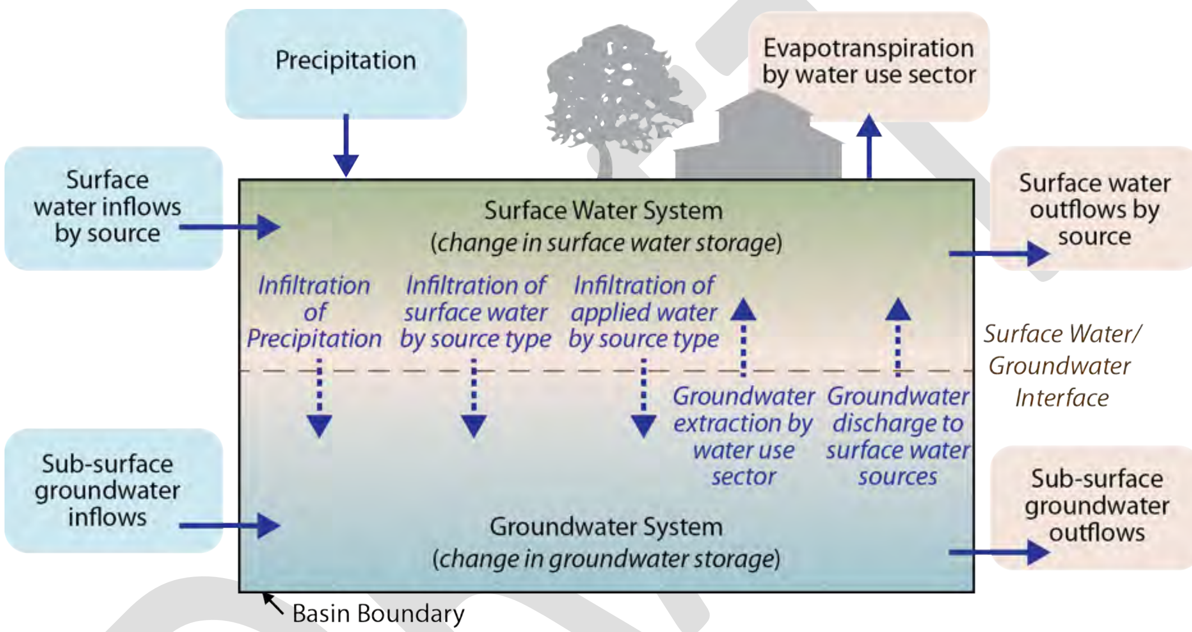

Figure 37: Water Budget Components (source, DWR)

The Kaweah Subbasin water budgets were created to quantify the inflows and outflows through the Subbasin based on a long period of hydrology, water supply availability, water demand, and land use information. The selected periods also include sufficient variability in these components to quantify and evaluate the aquifers' responses to these changes.

The historical and current water budgets for the Kaweah Subbasin are presented in ***Section 2.5.1*** below. The projected water budget is provided in ***Section 2.5.2***.

2.5.1 Historical and Current Water Budget

Water budget information was compiled for the three GSAs within the Subbasin to evaluate the historic availability and reliability of past surface water supply deliveries and the aquifer response to water supply and demand trends relative to water year type (or hydrologic condition). All readily available data were collected, and water budget compiled in accordance with a coordination agreement between the three GSAs, "to ensure that the three plans are developed and implemented utilizing the same data and methodologies, and that the elements of the Plans necessary to achieve

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the sustainability goal for the basin are based upon consistent interpretations of the basin setting." (§354.4 (a))

Within the Kaweah Subbasin, the historical water budget period (base period) was selected to be between water years 1981 and 2017. The current water budget period was between water years 1997 and 2017. The projected water budget extends to 2070 (***Figure 38***).

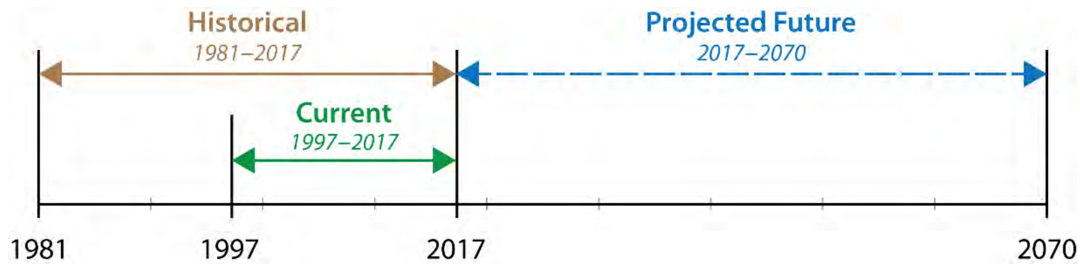

Figure 38: Historical, Current, and Projected Future Water Budget Periods for Kaweah Subbasin

2.5.1.1 Historical Water Budget Period Selection

The GSP Regulations describe the historical water budget as "A quantitative assessment of the historical water budget, starting with the most recently available information and extending back a minimum of 10 years, or as is sufficient to calibrate and reduce the uncertainty of the tools and methods used to estimate and project future water budget information and future aquifer response to proposed sustainable groundwater management practices over the planning and implementation horizon." The historical period selected also includes, "the most recently available information."

The selected representative period of the historical water budget for the Kaweah Subbasin, begins in water year 1981 and extends to the most-recent water year of 2017. The 37-year period selected for the historical water budget, includes two wet-dry hydrologic cycles; recent changes in water supply availability including an unprecedented lack of availability of imported water for several recent years; changes to water demand associated with new cropping patterns and associated land use.

The historical water budget (also referred to as the hydrologic base period) was used to define a specific time period over which elements of recharge and discharge to groundwater basin may be compared to the long-term average. This period allows the identification of long-term trends in groundwater basin supply and demand as well as water level trends, changes of groundwater in storage (both seasonal and long term), estimates of the annual components of inflow and outflow to the zone of saturation, safe yield estimates, and groundwater modeling.

The following summarizes the main considerations for base period selection:

> "The base period should be representative of long-term hydrologic conditions, encompassing dry, wet, and average years of precipitation. It must be contained within the historical record and should include recent cultural conditions to assist in determining projected basin operations. To minimize the amount of water in transit in the zone of aeration, the beginning and end of the base period should be preceded by comparatively similar rainfall quantities" (CDWR, 1962).

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Determination of an appropriate period included consideration of data availability, surface water reservoir management, and the historical development of water supplies imported from outside the Subbasin.

Furthermore, the GSP Regulations require that the historical water budget provide a "quantitative evaluation of the availability or reliability of historical surface water supply deliveries" and are to start "with the most recently available information … extending back a minimum of 10 years (§ 354.18 (c)(2)."

This base periods selection also helps inform the projected water budget which is to "utilize 50 years of historical precipitation, evapotranspiration, and streamflow information as the baseline condition for estimating future hydrology (§ 354.18 (c)(3)." Notably, the selection of both the historical water budget, described in this section, and current water budget, which is described in the subsequent section, are based on this requirement and both closely approximate long-term hydrologic conditions based up both precipitation and streamflow patterns, which are significant components of the overall supply. A strong correlation exists between Kaweah River flow and precipitation for the historical and current periods.

Precipitation records for 15 stations in and adjacent to the Subbasin were reviewed, six of which are shown on ***Table 8***. These six stations were selected as best representing the historical record of precipitation within and surrounding the Subbasin, based both on geographic distribution and period of record.

Table 8: Precipitation Stations Used for Base Period Analysis and Selection

Station Name	Elevation (feet, MSL)	Township/ Range/ Section	Start of Period*	Average for Period of Record (inches)	Average Precipitation 1945 to 2017 (inches)	Average Precipitation 1981 to 2017 (inches)	Average Precipitation 1999 to 2017 (inches)
Hanford 1 S	242	T18S/R21E-S31	1932	7.98	7.94	8.25	7.60
Corcoran Irrigation District	200	T21S/R22E-S15	1946	6.91	6.85	6.98	6.31
Visalia	325	T18S/R25E-S30	1878	10.14	10.21	10.08	8.90
Lindsay	420	T20S/R27E-S9	1932	11.65	11.53	11.67	10.68
Lemon Cove	513	T18S/R27E-S3	1932	13.77	13.68	14.07	13.00
Three Rivers Edison PH 1	1,140	T17S/R29E-S8	1949	21.69	21.69	22.47	18.46
Average				**12.02**	**11.98**	**12.25**	**10.83**

*Note: Period of Record extends through water year 2017

Generally, total precipitation is lower along the western portion of the Subbasin (Hanford and Corcoran Irrigation District stations), where at this lower elevation an average of less than 8 inches of precipitation per year are recorded. Along the eastern portion of Subbasin, at a relatively higher elevation (as represented by Lindsay and Lemon Cove), an average of 12 to 14 inches of precipitation is recorded. Outside of the Subbasin to the east, at a much higher elevation, greater precipitation occurs (as represented by the Three Rivers Edison gauge located in the foothills of the Sierra Nevada).

The key precipitation station for the Kaweah Subbasin is the Visalia station, because

- it has a long period of record between 1878 and current,
- is centrally located within the Subbasin, and
- approximates the average rainfall in the Subbasin.

A graph presenting the variability of rainfall recorded at the Visalia station is presented as ***Figure 39***. Average rainfall at this station is 10.1 inches per year. The bottom half of the chart shows the annual precipitation. The upper portion of the chart shows the climactic variability by stacking subsequent years, such that upward trending portions (blue areas) represent wet periods and downward trending portions (yellow areas) represent drought periods.

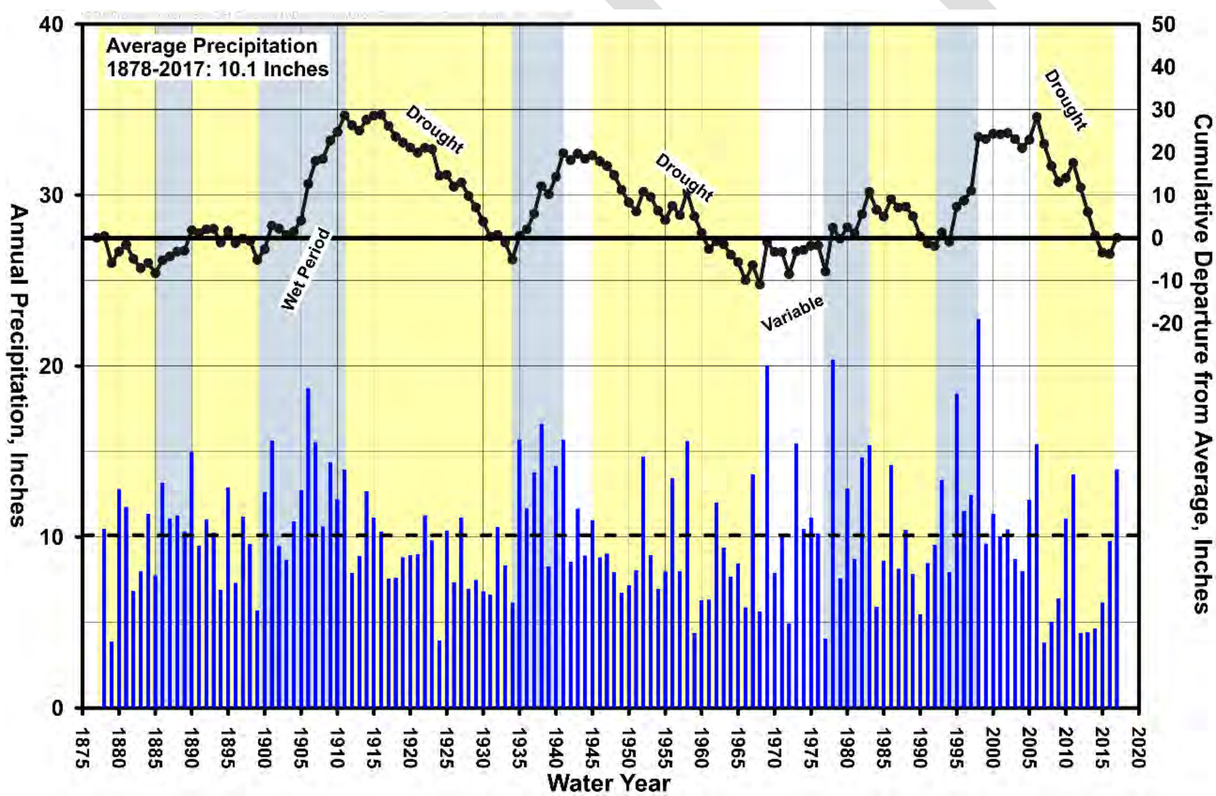

Figure 39: Cumulative Departure from Average Annual Precipitation, Visalia

Kaweah River flow records for the period of 1904 through 1989 were obtained from KDWCD staff and calculated as the summation of flow data from gauges at Kaweah River at Three Rivers and South Fork of Three Rivers. Flow records for the period of 1990 through 2017 were obtained from the U.S. Army Corps of Engineers' records of inflow to Lake Kaweah. Flow records at the Dry Creek gauging station and at the Kaweah River below McKay Point were similarly reviewed and are shown on ***Table 9***. As presented, Kaweah River flow as measured at Three Rivers (plus the South

Fork of Three Rivers) during the 37 year (inclusive) historical period of 1981 to 2017 closely approximates the long-term average during the period of record (within 3 percent).

Table 9: Surface Water Flow Stations Used for Base Period Analysis and Selection

Station Name	Elev. (feet, MSL)	Period of Record (Water Year)	Average for Period of Record (AFY)	Average for Historical Period 1981-2017 (AFY)	Range for Period of Record (AFY)
Kaweah River at Three Rivers + South Fork of Three Rivers (Full Natural Flow)	833	1904-Present	426,600	438,700	90,100 - 1,359,000
Dry Creek Near Lemon Cove	589	1962-Present	17,200	17,100	173 - 93,800
Kaweah River plus St. Johns River Below McKay Point	455	1962-Present	396,300	382,100	43,800 - 1,331,300

As presented on ***Figure 40***, variations in Kaweah River flow exhibit somewhat similar trends to climactic variations exhibited in the precipitation data.

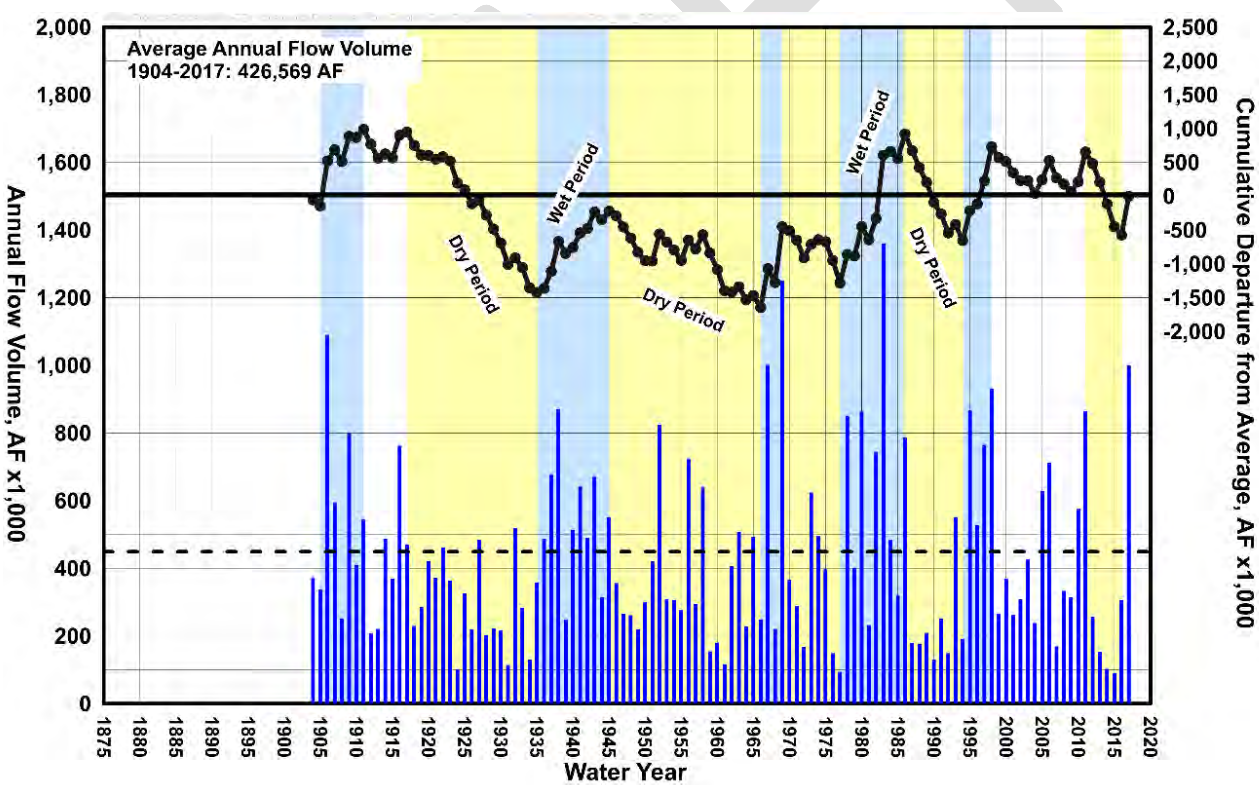

Figure 40: Cumulative Departure from Average Annual Flow, Kaweah River

An analysis of the statistical relationship between the composite precipitation and river flow data is presented as ***Figure 41***. The average composite precipitation and Kaweah River flow for the base period approximated the long-term average (within several percent).

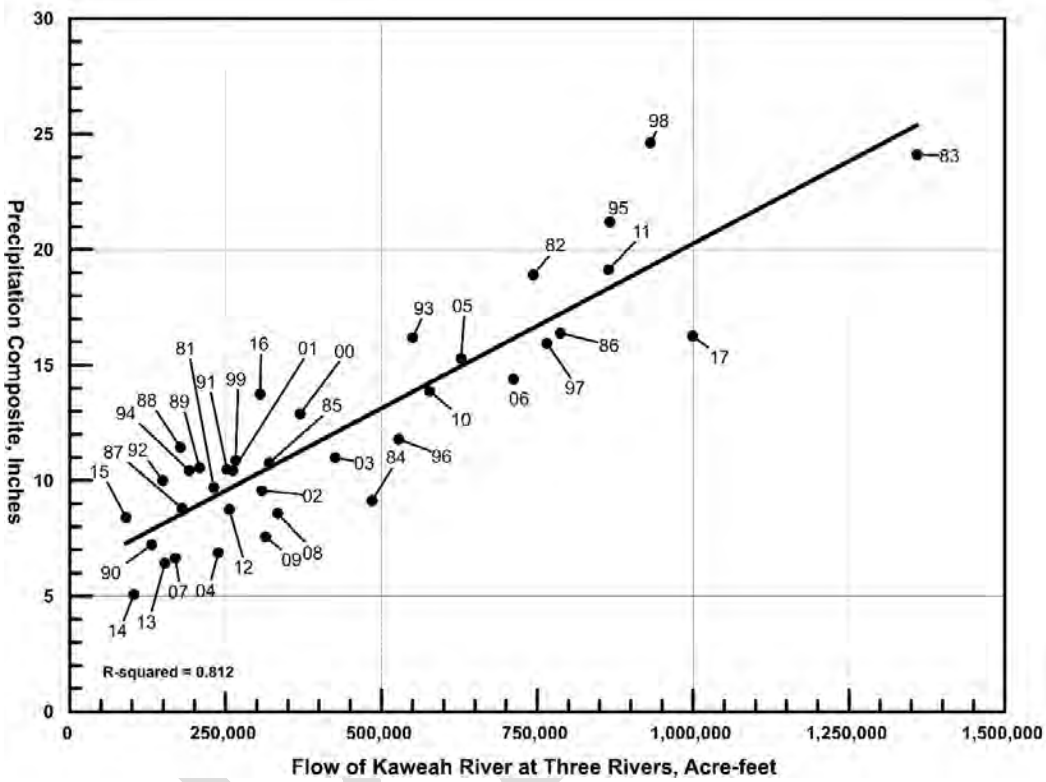

Figure 41: Kaweah River Runoff Versus Mean Precipitation

A review of the cumulative departure graphs for the precipitation station and Kaweah River flow identify candidate years for beginning the base period to include 1981, 1986, 1993 and 1999. The most recent water year (2017) was identified as a suitable year for ending the hydrologic base period. Importantly, 2017 is representative of current cultural conditions in the Subbasin relative to changes in land and water use. Precipitation totals in each year between 2012 and 2016 were below average, which would minimize significant amounts of water in transit through the unsaturated zone. A review of the differences in cumulative departure for these years is summarized in the following ***Table 10***.

Table 10: Historical Base Period Analysis (Relative to 1945 - 2017)

Station Number	Station Name	Difference in Cumulative Departure Between Base Period Years (inches)			
		1981-2017	1986-2017	1993-2017	1999-2017
43747	Hanford	0.38	0.38	0.57	-0.34
42012	Corcoran	0.06	0.06	0.38	-0.53
49367	Visalia	-0.22	-0.22	0.01	-1.31
44957	Lindsay	-0.14	-0.14	0.31	-0.85
44890	Lemon Cove	0.10	0.10	0.75	-0.68
48917	Three Rivers Edison	-0.70	-0.70	-0.52	-3.23
Average Cumulative Departure:		0.27	-0.09	0.25	-1.16

Based on comparison of precipitation averages, the most suitable candidates for a representative hydrologic base period are water years 1981 to 2017 and 1993 to 2017. Considering the availability of data, especially land use and California Irrigation Management Information System (CIMIS) data, the longer period of 1981 to 2017 is preferred. The relationship of surface water flow to precipitation was also considered in the selection of the base period by plotting flow at Three Rivers versus precipitation for various periods. For the most part, a strong correlation was obtained, showing a strong linear relationship, regardless of the period selected.

Based on the above, one appropriate base period was selected for use as the historical water budget: water years 1981 through 2017 (37 years inclusive). The average precipitation during both periods is within approximately 1 percent of each other and the long-term period. The position of the base period relative to historical wet-dry cycles is appropriate. If a smooth curve is fitted to the precipitation patterns, the base period includes two full cycles of wet and dry conditions. The base period ends in 2017, which incorporates recent cultural conditions, including an unprecedented lack of imported surface water availability between 2013 and 2015. The precipitation is similar for years leading into the beginning of the base period.

Compared to the long period of record from the Visalia station (130 years) average precipitation for the base period varies by less than 2 percent . Similarly, average flow for the base period varies by less than 3 percent compared to the long period of record of flow data from the Kaweah River at Three Rivers gauge (104 years), and by about 2 percent from the period of 1945 to 2017.

2.5.1.2 Current Water Budget

The GSP regulations state "current water budget information shall quantify current inflows and outflows for the basin using the most recent hydrology, water supply, water demand, and land use information."

The period 1997 to 2017 was selected for the current water budget in the Kaweah Subbasin. This period was selected because it represents current water supply conditions in the subbasin including

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surface water supply availability under average, extremely dry and extremely wet conditions. This period also represents the current crop and municipal water demands which have remained consistent throughout this period. The average annual overdraft during this period is 77,600 AFY. This overdraft value will be used as the starting point for the development of projects and management actions to bring the subbasin into balance and achieve Sustainable Yield by 2040. Groundwater modeling accounting for projected future supplies and demands, i.e., the projected water budget, will be used to evaluate the benefits of our planned projects and management actions at arresting the overdraft in the subbasin.

2.5.1.3 Summary of Water Budget Components

This section provides a description of each of the water budget components quantified as part of the historic budget evaluation.

Surface Water

Water from both locally derived and imported surface water sources are distributed in the natural and constructed channels in the Subbasin. The natural channels are the streams, rivers and creeks that flow from the catchments in the Sierra Nevada Mountains and foothill regions along the eastern side of the Subbasin. The constructed channels (ditches) are a system of hydraulically inter-connected canals and channels that deliver surface water from the natural channels to the entitlement holders, and ultimately to individual land units. Some natural channels receive diversions of imported surface water, comingled with native (local) sources, and divert it via ditches to entitlement holders.

The Kaweah River flows westward into the subbasin from the Sierra Nevada Mountains, beginning at an elevation of over 12,000 feet and drains a watershed area of about 630 square miles above the foothill line. Terminus Reservoir, located in the foothills of the Sierra Nevada, has a tributary drainage area of about 560 square miles, which produces about 95 percent of the total runoff of the watershed (Fugro Consultants, 2016).

During the period of record from water years 1901 through 2017, the average annual flow within the Kaweah River at Three Rivers (plus the South Fork of Three Rivers) was 426,600 AF/WY, ranging from a minimum of 90,100 AF/WY in 2015 to a maximum of 1,360,000 AF/WY in 1983. The average annual flow for the historical (1981 to 2017) period of 435,500 AF/WY was 104 percent of the long-term average since 1901.

The principal local source of water, the Kaweah River, is divided equally at McKay Point between the Lower Kaweah and St. Johns rivers, which occurs each year until the flow has diminished in the late summer months (Fugro West, 2007). Thereafter, the entire entitlement flow, regardless of the amount, is diverted into the Lower Kaweah River. A schematic diagram of the Kaweah River system is presented as ***Figure 42***. As presented on ***Table 11*** an average of 336,710 AF/WY of AF/WY Kaweah River water (through the entire Kaweah River system) was diverted through headgates for agricultural purposes.

Table 11: Surface Water in Kaweah Subbasin (AF/WY)

Water Year	CVP Water	Kings Water	Total Imported	Kaweah Water Diversions (Local Sources)	Total of Surface Water (Headgate Diversions)
1981	153,960	11,117	165,077	192,814	357,891
1982	324,038	3,217	327,255	594,413	921,668
1983	141,947	0	141,947	964,811	1,106,758
1984	224,960	42,685	267,645	446,364	714,009
1985	170,262	3,205	173,467	255,935	429,402
1986	273,525	18,068	291,593	568,236	859,829
1987	114,407	2,430	116,837	133,945	250,782
1988	141,865	1,996	143,861	140,009	283,870
1989	133,034	1,000	134,034	157,589	291,623
1990	69,224	0	69,224	96,294	165,518
1991	108,907	0	108,907	201,631	310,538
1992	108,785	1,226	110,011	105,851	215,862
1993	250,502	7,093	257,595	454,179	711,774
1994	106,309	1,392	107,701	136,046	243,747
1995	212,823	13,383	226,206	632,021	858,227
1996	255,721	33,753	289,474	401,832	691,306
1997	199,376	20,733	220,109	562,767	782,876
1998	169,292	13,919	183,211	698,203	881,414
1999	233,760	20,106	253,866	239,440	493,306
2000	224,684	2,575	227,259	297,865	525,124
2001	109,268	6,926	116,195	208,051	324,246
2002	133,824	2,341	136,165	230,074	366,238
2003	183,657	11,732	195,389	320,161	515,550
2004	123,718	5,562	129,279	175,451	304,730
2005	328,005	8,948	336,952	454,252	791,204
2006	239,266	15,723	254,990	531,308	786,298
2007	80,972	9,037	90,009	120,844	210,853
2008	107,908	0	107,908	264,142	372,050
2009	143,689	2,624	146,313	241,048	387,361
2010	240,826	3,223	244,050	440,838	684,887
2011	235,335	2,041	237,376	666,658	904,034
2012	98,102	2,688	100,789	198,608	299,397
2013	52,515	0	52,515	105,476	157,991
2014	24,169	0	24,169	72,652	96,821
2015	13,304	0	13,304	59,694	72,998
2016	97,606	0	97,606	231,650	329,256
2017	211,386	11,645	223,031	857,122	1,080,153
Maximum	**328,005**	**42,685**	**336,952**	**964,811**	**1,106,758**
Minimum	**13,304**	**0**	**13,304**	**59,694**	**72,998**
Average	**163,268**	**7,578**	**170,846**	**336,710**	**507,556**

During the historical period, an average of 170,846 AF/WY of water is imported annually, of which a majority (some 163,300 AF/WY) is imported from the CVP system. The remainder of the imported water, is directed into the Subbasin through the Kings River.

On average, for the historical base period, a total of 507,556 AF/WY of Kaweah River and imported water from both the CVP Friant Division system and Kings River system was diverted for irrigation within the Kaweah Subbasin. These local and imported water supplies are comingled during conveyance (**Table 11)**. The trend of deliveries of imported water is generally downward in recent years, with the exception of the wet years (e.g. 2005, 2011 and 2017). The gross irrigation demand is supplied by both surface and groundwater sources; of this an average of 685,400 AF/WY was extracted from the groundwater reservoir to satisfy crop demands (discussed later in this report). Conveyance losses related to the delivery of surface water is significant, and the estimated annual quantity of such a "loss" is discussed later in this section.

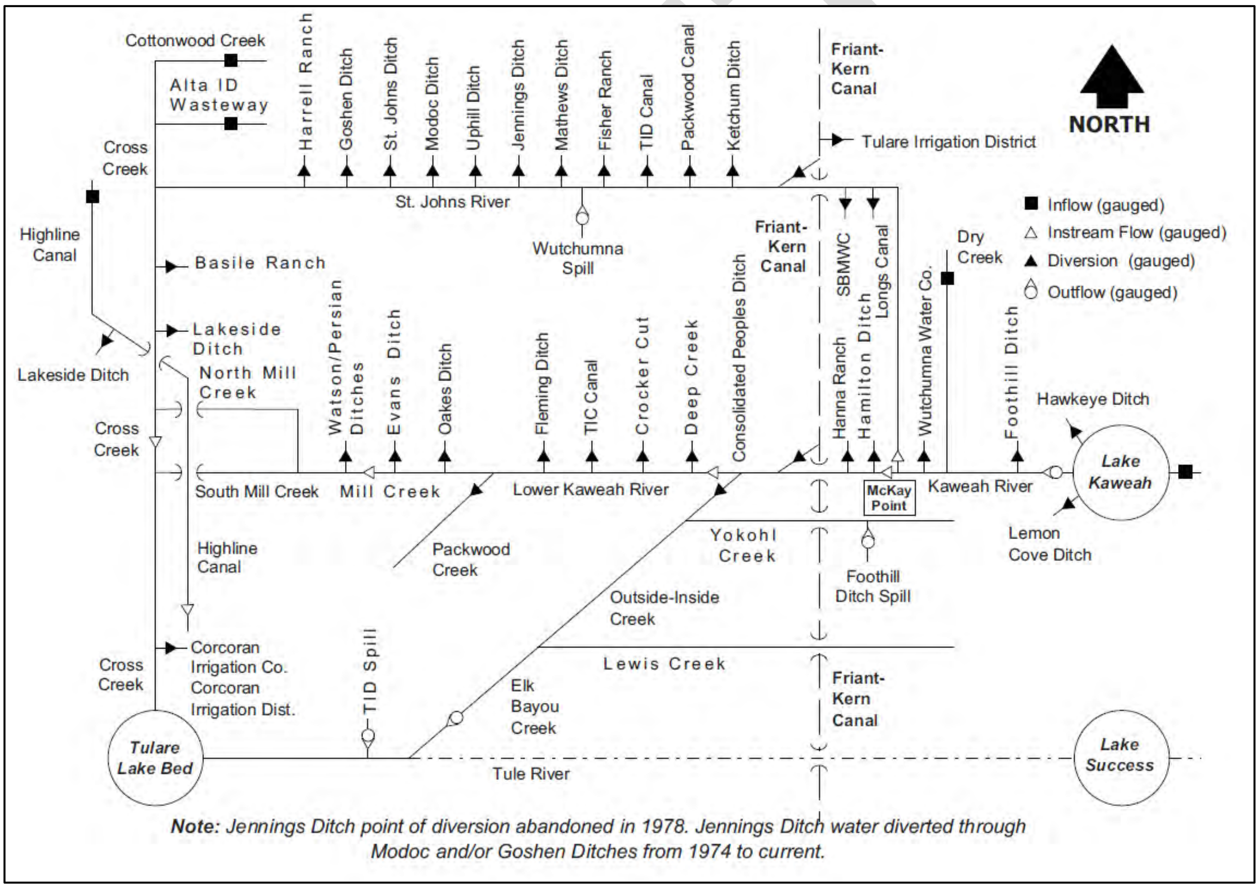

Figure 42: Schematic Diagram of Kaweah River System

Supplemental sources of water supply have been imported to the Subbasin for decades. Deliveries to lands within the boundaries of the Subbasin started in the late 1800s and were made available from the Kings River. An additional source of supplemental supply to lands located within the Subbasin in the early 1950s was made available from the CVP, with both long-term and short-term contract supplies. With the termination of short-term contracting procedures, supplemental supplies, in addition to the long-term CVP supplies, have been made available through temporary contracts.

The delivery of ample surface water by local and imported sources for agricultural irrigation is a key to avoiding several of the undesirable results in the Kaweah Subbasin. Within the historical base period, in the late 1980s, surplus water was available in the system beyond the needs of contractors. During the 1987 to 1992 drought, when imported water was available and no significant contract limitations were in place, no significant water level declines were noted.

Beginning in the 2010s, surplus water began to be partially allocated to the San Joaquin River Restoration Program. In the recent 2012 to 2015 drought, CVP contract deliveries were severely limited, such that in 2012 only 50% Class 1 water was delivered. In 2013 only 62% was delivered. In both 2014 and 2015, none of the contracted water was delivered. During these dry years, TID did not receive Class 2 contract water. Meanwhile, groundwater levels reached record lows.

Surface Water Crop Delivery

Crop water demands constitute the largest portion of groundwater and surface water demand in the Subbasin. Therefore, the complete understanding of how much of these two sources of water are applied to crops is central to the groundwater budget calculations. This section summarizes the methodology used to determine the volumes of surface water delivered to crops, which will in turn be used to estimate the additional crop water demand, which is provided through un-metered groundwater pumpage.

Surface water in the Kaweah Subbasin is used primarily to satisfy the irrigated agricultural demands, which constitutes the majority of water use. The irrigation of the agricultural lands is satisfied by a combination of diverted surface water and pumped groundwater. The calculation of the volume of surface water delivered to fields to meet agricultural crop demands is described using the following equation adapted from previous methods (Fugro West, 2007; Fugro Consultants, 2016):

$$SW_C = HG_{DIV} + R_{DIV} + RW - TotDS_P - RB_{DIV} - S$$

Where:

- SW_C = Surface water delivered to crops
- HG_{DIV} = Headgate diversions
- R_{DIV} = Riparian diversions
- RW = Recycled water
- $TotDS_P$ = Total ditch system percolation
- RB_{DIV} = Recharge basin diversions
- S = Spills

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The annual quantities of water associated with each of the components in the equation above are presented in subsequent sections with focus on "loss" of the water from the surface water system and subsequent inflow into the aquifer. The average volumes of water for each of the components of the above equation during the historical (base) period are:

$$SW_C = HG_{DIV} + R_{DIV} + RW - TotDS_P - RB_{DIV} - S$$

$$SW_C \cong 507{,}600 + 4{,}900 + 8{,}800 - 117{,}000 - 51{,}200 - 16{,}800$$

$$SW_C \cong 335{,}100$$

Based on the above calculation, the total volume of surface water delivered to crops averaged 335,100 AF/WY. This volume of surface water was used to offset groundwater pumpage for irrigated agriculture, the remainder of which was satisfied by groundwater pumpage. While this calculation was used for most areas of the Subbasin, in two limited cases the quantity of water delivered crops were reported directly and not calculated using this method.

These summaries of surface water flow components described in this section are provided to calculate the total amount of surface water delivered to crops. Several of these components will also be described further in a later section with regard to estimates of inflows to the groundwater system.

In general terms, the components of riparian diversions, recycled water applied to crops, total ditch system percolation, recharge basin diversions, and spills are presented in the following paragraphs.

Headgate Diversions (HG_{DIV})

Headgate diversions for each appropriator are an integral component into the water budget for the calculation of groundwater pumpage. Headgate diversions occur as surface water diverted from the natural channels into constructed canals and channels for delivery to entitlement holders for farm delivery. Data for these diversions were compiled from Kaweah and St. Johns Rivers Association records. Annual volumes of headgate diversions throughout the Subbasin are presented in ***Table 11***. Basin-wide, an average of 507,600 AF/WY was diverted through headgates from the surface water flow (from comingled local and imported sources). Such headgate diversions, in turn, experience seepage (ditch) losses, can be redistributed to artificial recharge basins, or in years of very high surface water flow, leave the District as "spill" or outflow.

Riparian Diversions (R_{DIV})

Annual quantities of surface water diverted by riparian users for agricultural use from the Lower Kaweah and St. Johns river systems were quantified in prior reports (Fugro West, 2007; Fugro Consultants, 2016). These riparian diversions were quantified in concert with the calculation of reach losses (natural channel percolation). The riparian diversions (located within GKGSA) are presented in ***Table 12***. On average, 4,922 AF/WY of surface water were diverted for riparian use.

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Table 12: Riparian Diversions (AF/WY)

Water Year	Riparian Diversions
1981	**3,046**
1982	**9,971**
1983	**12,054**
1984	**8,729**
1985	**4,899**
1986	**9,789**
1987	**2,677**
1988	**1,388**
1989	**2,032**
1990	**696**
1991	**1,843**
1992	**815**
1993	**5,640**
1994	**2,271**
1995	**9,031**
1996	**7,466**
1997	**7,553**
1998	**11,040**
1999	**5,806**
2000	**5,522**
2001	**2,162**
2002	**2,332**
2003	**3,260**
2004	**2,038**
2005	**8,418**
2006	**9,796**
2007	**2,381**
2008	**3,423**
2009	**2,080**
2010	**5,854**
2011	**10,346**
2012	**3,543**
2013	**1,521**
2014	**618**
2015	**242**
2016	**1,994**
2017	**9,825**
Maximum	**12,054**
Minimum	**242**
Average	**4,922**

Recycled Water (RW)

The cities of Visalia and Tulare both produce recycled water for crop irrigation as a portion of the effluent from their wastewater treatment plants (WWTPs). The managers of each WWTP provided Annual Use Monitoring Reports for this analysis. Based on these records, the WWTP effluent applied to nearby crops is estimated to be on average 20 percent of the effluent flow for Visalia and an average of 70 percent of the Tulare's effluent flow[2] over the period of record. The results of the recycled water applied to crops are presented in ***Table 13***. As presented, an average of 8,792 AF/WY of recycled water from the municipal wastewater treatment plants was delivered to crops on adjacent fields. There are no other applications of recycled water to crops within the Subbasin.

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[2] Based on Annual Use Reports

Table 13: Recycled Water Delivered to Crops (AF/WY)

Water Year	Recycled Water
1981	**5,019**
1982	**5,199**
1983	**5,379**
1984	**5,558**
1985	**5,739**
1986	**5,919**
1987	**6,099**
1988	**6,279**
1989	**6,459**
1990	**6,595**
1991	**6,786**
1992	**6,414**
1993	**6,942**
1994	**7,516**
1995	**7,749**
1996	**7,733**
1997	**7,879**
1998	**7,996**
1999	**8,590**
2000	**8,928**
2001	**9,077**
2002	**9,791**
2003	**10,671**
2004	**10,915**
2005	**11,359**
2006	**11,599**
2007	**11,781**
2008	**11,700**
2009	**11,350**
2010	**11,566**
2011	**11,548**
2012	**12,079**
2013	**11,825**
2014	**11,651**
2015	**11,092**
2016	**11,144**
2017	**11,374**
Maximum	**12,079**
Minimum	**5,019**
Average	**8,792**

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Total Ditch System Percolation ($TotDS_P$)

The volumes of total ditch system percolation are the portion of water that percolated through the bottom and sides of the ditch system between a headgate diversion point and a grower turnout for agricultural irrigation. These volumes are used to estimate how much of the water diverted at a headgate is ultimately delivered for agricultural irrigation. The results of the total ditch system percolation analysis are presented in ***Table 14***. Basin wide, the average annual volume of surface water that percolates through the ditch systems is 117,001 AF/WY.

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Table 14: Ditch Percolation (AF/WY)

Water Year	Ditch Percolation
1981	**70,745**
1982	**243,470**
1983	**257,593**
1984	**149,426**
1985	**85,151**
1986	**226,874**
1987	**35,502**
1988	**50,098**
1989	**50,355**
1990	**19,649**
1991	**61,780**
1992	**32,401**
1993	**177,784**
1994	**46,311**
1995	**215,126**
1996	**161,633**
1997	**189,363**
1998	**216,275**
1999	**104,433**
2000	**114,612**
2001	**65,837**
2002	**76,638**
2003	**120,560**
2004	**58,082**
2005	**206,240**
2006	**207,682**
2007	**38,028**
2008	**80,803**
2009	**90,254**
2010	**151,862**
2011	**196,378**
2012	**65,852**
2013	**29,293**
2014	**26,177**
2015	**17,698**
2016	**78,869**
2017	**310,206**
Maximum	**310,206**
Minimum	**17,698**
Average	**117,001**

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Recharge Basin Diversions (RB_{DIV})

The recharge basin diversions are the portions of water that percolate to groundwater via recharge basins subsequent to being diverted through a headgate. A summary of the recharge basin diversions is presented in ***Table 15***. Basin wide, an average of 51,191 AF/WY of the surface water is diverted to recharge basins. Total recharge basin inflow will be discussed below. There are no recharge basin diversions in EKGSA.

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Table 15: Recharge Basin Percolation (AF/WY)

Water Year	Basin Recharge
1981	**16,706**
1982	**103,579**
1983	**74,439**
1984	**43,474**
1985	**35,435**
1986	**99,137**
1987	**8,318**
1988	**20,892**
1989	**14,332**
1990	**4,687**
1991	**12,270**
1992	**9,032**
1993	**95,849**
1994	**9,582**
1995	**123,637**
1996	**71,069**
1997	**114,110**
1998	**115,638**
1999	**42,075**
2000	**37,608**
2001	**14,373**
2002	**14,790**
2003	**53,149**
2004	**16,701**
2005	**111,102**
2006	**83,625**
2007	**15,835**
2008	**16,943**
2009	**22,761**
2010	**94,110**
2011	**155,756**
2012	**26,090**
2013	**7,695**
2014	**349**
2015	**382**
2016	**22,073**
2017	**186,458**
Maximum	**186,458**
Minimum	**349**
Average	**51,191**

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Spills (S)

In years of significant surface water availability, the quantity of surface water can exceed the crop demands and recharge capacity of the conveyance systems and basins (Fugro Consultants, 2016). This occurred in 1983, 1995, 1997, 2006, 2011 and 2017. In such years, surface water flows out of the Subbasin in the form of surface water "spills"(***Figure 22***). Quantification of these spills is straightforward because these spill points are gauged and records are maintained by both KDWCD and TID. A summary of the surface water spills from the Subbasin is presented as ***Table 16***. Basin wide, an average of 16,767 AF/WY has been spilled from the Subbasin. Of these spills, only the Cross Creek spill occurs from the natural channels. There are no spills from the Subbasin from EKGSA.

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Table 16: Spills from the Subbasin (AF/WY)

Water Year	Spills
1981	**3,277**
1982	**56,246**
1983	**204,315**
1984	**37,993**
1985	**2,879**
1986	**51,784**
1987	**804**
1988	**757**
1989	**556**
1990	**0**
1991	**633**
1992	**74**
1993	**5,674**
1994	**152**
1995	**23,124**
1996	**6,730**
1997	**50,994**
1998	**38,904**
1999	**4,318**
2000	**10,567**
2001	**3,468**
2002	**3,321**
2003	**14,380**
2004	**2,382**
2005	**6,593**
2006	**24,675**
2007	**773**
2008	**1,651**
2009	**1,274**
2010	**7,263**
2011	**34,805**
2012	**1,541**
2013	**0**
2014	**0**
2015	**0**
2016	**177**
2017	**18,313**
Maximum	**204,315**
Minimum	**0**
Average	**16,767**

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Surface Water Delivered to Crops

The results of the calculations for the volume of surface water delivered to crops are summarized in ***Table 17***. As indicated, the average annual amount of surface water delivered to meet crop demand within the Subbasin is about 335,081 AF/WY over the base period (historical period). The deliveries show a clear correlation to the availability of surface water and ranged from about 65,799 AF/WY (2015) to 583,928 AF/WY (2017) just two years later. These values indicate that approximately two-thirds of the total water diverted through the headgates is ultimately delivered to the crops within the Subbasin.

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Table 17: Surface Water Delivered to Crops (AF/WY)

Water Year	SW Delivered to Crops
1981	**278,671**
1982	**530,403**
1983	**587,280**
1984	**497,124**
1985	**316,088**
1986	**495,387**
1987	**214,159**
1988	**219,328**
1989	**234,313**
1990	**147,874**
1991	**243,654**
1992	**180,900**
1993	**443,681**
1994	**196,360**
1995	**511,710**
1996	**465,774**
1997	**442,074**
1998	**527,890**
1999	**356,181**
2000	**375,275**
2001	**250,475**
2002	**282,037**
2003	**339,763**
2004	**239,493**
2005	**485,483**
2006	**488,422**
2007	**169,232**
2008	**286,352**
2009	**285,166**
2010	**446,511**
2011	**536,716**
2012	**220,069**
2013	**133,663**
2014	**80,923**
2015	**65,799**
2016	**239,854**
2017	**583,928**
Maximum	**587,280**
Minimum	**65,799**
Average	**335,081**

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Inflows to The Groundwater System

The inflow components to the groundwater system include the following:

- Subsurface inflow
- Percolation of precipitation
- Streambed percolation in the natural and man-made channels
- Artificial recharge
- Percolation of irrigation water
- Percolation of waste water

Each of these components and the method by which each was calculated is presented in this section.

Subsurface Inflow

Subsurface inflow is the flow of groundwater into and out of a groundwater basin. During the base period, subsurface inflow into the Kaweah Subbasin exceeded subsurface outflow from the Subbasin by 64,501 AF/WY (***Table 18***).

Annual estimates were prepared to determine the subsurface flow between the three GSAs within the Subbasin and both into and out of the Subbasin as a whole. These calculations were performed by two methods.

During the earlier period between 1981 and 1998, these calculations were performed using the Darcy flow equation, which requires input values of groundwater gradient and hydraulic conductivity. The gradient was calculated for every year of the base period using the groundwater contour maps prepared for this Basin Setting. Horizontal hydraulic conductivity values were used from the numerical groundwater model.

In this method, the rate of groundwater flow is expressed by the Darcy equation $Q = PiA$, where 'P' is the coefficient of aquifer permeability (horizontal hydraulic conductivity), 'i' is the average hydraulic gradient, and 'A' is the cross-sectional area of the saturated aquifer. Permeability data for the aquifers in the Kaweah Subbasin were discussed in **Section 2.2.5.2**, which were used in the numerical groundwater model. Hydraulic gradient data, derived from annual water level contour maps developed for this Basin Setting were analyzed on an annual basis over the base period. The cross-sectional areas of the aquifer at each groundwater flux line representing the boundaries of the Subbasin were estimated using GIS analysis. The general directions of which are presented in ***Figure 43***. From these, annual magnitudes of subsurface flow were tallied.

The second method used to compute groundwater flux along the Subbasin boundary was based on the numerical groundwater flow model. Groundwater flow into and out of the Subbasin were calculated as an output from the model. These estimates of groundwater flow are considered to be superior to the Darcian flux method.

These subsurface flow calculations include an estimate of mountain-front recharge, which is the contribution of water from the mountains to recharge the aquifers in the adjacent basins. For the Kaweah Subbasin, this flow enters the Subbasin from the Sierra Nevada on the east. Mountain front recharge is limited and most of the flow into the basin occurs principally as surface runoff, which subsequently percolates rapidly into alluvial valleys. Based on several sources, mountain-front recharge is estimated to contribute an average of 52,000 AF/WY to the Kaweah Subbasin. This volume of mountain-front recharge includes estimated percolation from minor streams along the eastern periphery of the Subbasin. For the purposes of this water budget, this estimation was varied based on water year type based on relative precipitation in any year.

A summary of the total estimated annual subsurface inflow and outflow is presented in ***Table 18***. The average total subsurface inflow into the Subbasin during the historical period was estimated to be 155,640 AF/WY. During this same period, average subsurface outflow was only 91,139 AF/WY, resulting in a net subsurface inflow into the basin of 64,501 AF/WY. A map of the typical subsurface flow within the Subbasin is presented as ***Figure 43***.

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Table 18: Subsurface Flow (AF/WY)

Water Year	Subsurface Inflows	Subsurface Outflows	Net Subsurface Flows
1981	7,416	113,057	**-105,641**
1982	102,364	108,566	**-6,202**
1983	193,509	113,190	**80,319**
1984	71,758	112,636	**-40,878**
1985	35,970	50,210	**-14,240**
1986	110,886	53,331	**57,555**
1987	43,989	95,673	**-51,685**
1988	81,490	125,284	**-43,795**
1989	(15,488)	74,850	**-90,338**
1990	(4,763)	32,566	**-37,329**
1991	36,014	54,523	**-18,509**
1992	87,139	123,629	**-36,490**
1993	171,393	112,885	**58,508**
1994	76,131	116,379	**-40,248**
1995	135,459	109,653	**25,806**
1996	229,839	83,117	**146,722**
1997	238,893	96,499	**142,395**
1998	208,409	93,089	**115,320**
1999	194,083	35,425	**158,659**
2000	197,904	57,725	**140,178**
2001	192,026	79,952	**112,073**
2002	192,215	89,440	**102,775**
2003	187,739	96,878	**90,861**
2004	164,507	93,392	**71,116**
2005	246,894	74,913	**171,981**
2006	247,302	61,294	**186,008**
2007	154,061	101,444	**52,617**
2008	180,795	166,204	**14,590**
2009	186,598	153,981	**32,617**
2010	246,030	117,451	**128,579**
2011	288,083	62,978	**225,106**
2012	199,932	68,294	**131,638**
2013	187,277	107,638	**79,639**
2014	193,692	93,867	**99,825**
2015	191,677	82,095	**109,582**
2016	200,844	93,551	**107,293**
2017	296,623	66,478	**230,145**
Maximum	**296,623**	**166,204**	**230,145**
Minimum	**-15,488**	**32,566**	**-105,641**
Average	**155,640**	**91,139**	**64,501**

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Percolation of Precipitation

The amount of rainfall that percolates deeply into the groundwater depends on many factors including the type and structure of the soil; density of the vegetation; the quantity, intensity and duration of rainfall; the vertical permeability of the soil; the relative saturation of the soil during rainfall episodes; and local topography. Deep percolation of rainfall does not occur until the initial soil moisture deficiency is exceeded. In most years, rainfall events do not produce sufficient quantities and timing of rainfall to penetrate beyond the root zone of native vegetation. However, in irrigated soils, because of the artificial application of water, the initial fall and winter moisture content is greater, and less annual rainfall is required to meet and exceed the soil moisture deficiency. Once the soil moisture deficiency within the root zone has been satisfied, continued precipitation (occurring prior to evapotranspiration) will percolate downward and eventually reach the groundwater reservoir.

Estimation of the deep percolation of precipitation was performed for the earlier period (prior to 2000) using an established method that incorporates the distribution of known crop types, rainfall distribution, reference evapotransporation (ET) data from the CIMIS, and soil data. From these data, the percolation of precipitation was calculated with the development of a monthly moisture model spreadsheet that accounted for immediate evaporation, effective rainfall, percolation of infiltrated rainfall, and percolation of rainfall runoff (Fugro West, 2007).

Since 2000, estimates of the percolation of precipitation were made by a different method, based on a combination of remote sensing (satellite) images and computer simulations, which relied on a daily root zone water balance model and crop ET. The method utilizes Davids Engineering's "Normalized Difference Vegetation Index" (NDVI) analysis methods, which were applied to the area of the KDWCD (Davids Engineering, 2013) and the entire Subbasin (Davids Engineering, 2018[***Appendix C***]).

The Davids Engineering analysis estimated percolation of precipitation applied to agricultural land. For the period of 2000 to 2017, the clipped irrigated fields GIS data was exported from GIS and imported into the Davids Engineering database model to develop an "irrigated fields" table. From this, the annual estimated percolation of precipitation on irrigated fields located within the Subbasin was calculated. The results were checked against previously calculated values (Fugro Consultants, 2016). Both the earlier DWR land use survey-based method and the Davids Engineering database-model method account for the agricultural land that has been converted to urban land use over time.

Percolation of precipitation on non-irrigated lands was estimated with published methods based on the distribution of annual precipitation with comparison parcel areas provided by Davids Engineering (Williamson et. al., 1989). Based on this method, an average of approximately 8 percent of the annual precipitation percolated into the groundwater during the base period. Within Visalia and Tulare, the principal urban areas, net percolation of precipitation directly on the urban areas is assumed to be negligible as these cities generally divert storm water into nearby channels that distribute it away from the city. However, the runoff amount from these areas is generally believed to be included in both the estimate of percolation into non-agricultural areas in the Kaweah Subbasin and streambed percolation.

Estimated percolation of precipitation is presented in ***Table 19***. These results indicate that the percolation of precipitation onto the irrigated lands within the Subbasin averaged 89,197 AF/WY.

On non-agricultural areas, an average of 18,428 AF/WY percolated to the groundwater reservoir. In total, an annual average of 107,625 AF/WY of precipitation percolated during the base period.

Table 19: Percolation of Precipitation (AF/WY)

Water Year	Precip on Ag Land	Precip on Non-Ag Land	Total Precip Percolation
1981	97,708	16,530	**114,238**
1982	107,397	25,860	**133,256**
1983	170,393	27,693	**198,086**
1984	26,301	12,071	**38,373**
1985	46,527	16,136	**62,664**
1986	133,058	25,011	**158,068**
1987	93,024	14,987	**108,011**
1988	78,888	18,779	**97,667**
1989	42,700	15,065	**57,765**
1990	65,033	11,440	**76,473**
1991	123,099	16,042	**139,140**
1992	67,582	17,417	**85,000**
1993	130,116	23,932	**154,049**
1994	73,708	15,729	**89,437**
1995	213,159	31,577	**244,736**
1996	100,127	20,371	**120,498**
1997	109,374	22,132	**131,507**
1998	258,852	29,960	**288,812**
1999	69,233	16,800	**86,034**
2000	82,482	19,653	**102,135**
2001	63,426	16,661	**80,087**
2002	67,840	16,451	**84,292**
2003	59,007	16,212	**75,220**
2004	48,927	12,831	**61,758**
2005	97,108	24,112	**121,220**
2006	129,634	25,387	**155,022**
2007	32,225	9,179	**41,404**
2008	52,943	13,801	**66,745**
2009	36,310	12,164	**48,474**
2010	72,084	19,666	**91,750**
2011	172,399	28,407	**200,807**
2012	50,752	13,618	**64,370**
2013	33,043	9,540	**42,583**
2014	25,505	8,047	**33,552**
2015	49,875	12,477	**62,352**
2016	88,100	20,329	**108,429**
2017	132,352	25,758	**158,111**
Maximum	**258,852**	**31,577**	**288,812**
Minimum	**25,505**	**8,047**	**33,552**
Average	**89,197**	**18,428**	**107,625**

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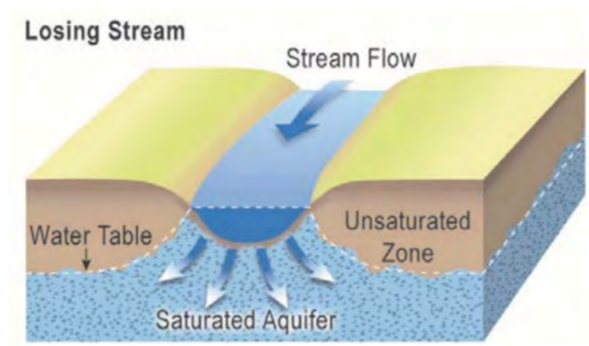
Streambed Percolation and Delivered Water Conveyance Losses

Natural Channels

Percolation of water from flows in natural channels has been estimated for the entire Subbasin. Within the GKGSA and MKGSA area, streambed percolation was based on comparison of flow between the Terminus Reservoir and the appropriators' headgates. This percolation is often referred to as "conveyance loss" (or seepage loss) (***Figure 44***). Percolation through the riverbeds of the St. Johns and Lower Kaweah rivers has been calculated for specific lengths of each river and is referred to as individual "reach losses." Percolation in these natural channels was estimated based on the number of days that water flowed in each reach and the difference between an adjusted reach loss and any known riparian diversion within the reach (Fugro West, 2007; Fugro Consultants, 2016).



Source: DWR

Figure 44: Losing Stream Diagram

Within the EKGSA, reliable, long-term streamflow gauges do not exist for the four major tributaries flowing into the area from the Sierra Nevada foothills. A single streamflow gauge exists on Yokohl Creek. The other three creeks, Cottonwood Creek, Lewis Creek, Fraiser Creeks, are ungauged. Therefore, in the absence of empirical data, the streambed percolation for all four creeks were assumed to be included within the mountain-front recharge estimate for the Subbasin. The natural channel reaches (portions) within the Subbasin are presented on ***Table 20***. In total, natural channel percolation within the Subbasin averaged 79,080 AF/WY as presented on ***Table 21***.

Table 20: Stream Reaches within the Kaweah Subbasin

Reach	Total Length (feet)
Lower Kaweah Reach #2	15,767
Lower Kaweah Reach #3	5,666
Lower Kaweah Reach #4	8,129
Lower Kaweah Reach #5	9,325
Lower Kaweah Reach #6	39,731
St. Johns Reach #1	18,168
St. Johns Reach #2	31,545
St. Johns Reach #3	8,318
St. Johns Reach #4	6,601
St. Johns Reach #5	10,331
St. Johns Reach #6	31,878
St. Johns Reach #7	61,066
St. Johns Reach #8	64,580

Table 21: Streambed Percolation (AF/WY)

Water Year	Streambed Percolation
1981	**54,231**
1982	**126,001**
1983	**188,773**
1984	**138,378**
1985	**69,467**
1986	**125,734**
1987	**45,507**
1988	**34,888**
1989	**38,409**
1990	**32,199**
1991	**47,071**
1992	**38,473**
1993	**98,293**
1994	**46,885**
1995	**135,990**
1996	**84,356**
1997	**102,699**
1998	**122,161**
1999	**64,052**
2000	**68,501**
2001	**40,490**
2002	**61,508**
2003	**73,346**
2004	**46,977**
2005	**126,312**
2006	**109,920**
2007	**35,725**
2008	**60,114**
2009	**60,710**
2010	**112,106**
2011	**144,354**
2012	**50,429**
2013	**46,119**
2014	**23,790**
2015	**19,552**
2016	**73,309**
2017	**179,122**
Maximum	**188,773**
Minimum	**19,552**
Average	**79,080**

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Ditches

Percolation of water from ditches within the Subbasin was estimated based on the best available data. Ditch system percolation was estimated by assigning a specified percentage of the water delivered to the appropriators' headgates as ditch percolation for each system for each year of the base period (Fugro West, 2007), which is described below.

The ditch system percolation analysis was calculated using a GIS analysis of the irrigated fields parcel data within each of the appropriators' service areas (Davids Engineering, 2018). The extents of the service areas were provided by agencies within the Subbasin including KDWCD and Lindsay-Strathmore Irrigation District, the areas of which are partially, or wholly, contained within Subbasin. A list of the names and irrigated field acreage within each of the service areas is presented in ***Table 22***, which cover a total of 259,059 acres within the approximately 443,000 acre Subbasin, or approximately 58 percent of the land area. Within the Subbasin the percolation within the ditches averaged 117,001 AF/WY, as presented on ***Table 23***.

Table 22: Appropriator Service Areas

Service Area	Acres
Consolidated Peoples D.C.	**15,770**
Evans D.C.	**4,369**
Exeter I.D.	**14,939**
Farmers D.C.	**13,202**
Fleming D.C.	**1,641**
Goshen D.C.	**5,586**
Hamilton D.C.	**350**
Ivanhoe I.D.	**10,466**
Lakeside Irrigation W.D.	**24,126**
Lemon Cove D.C.	**787**
Lewis Creek W.D.	**1,307**
Lindmore I.D.	**27,292**
Lindsay-Strathmore I.D.	**16,417**
Longs Canal Area	**952**
Mathews D.C.	**1,831**
Modoc D.C.	**6,486**
Oakes D.C.	**1,104**
Persian D.C.	**6,321**
Sentinel Butte	**815**
St. Johns W.D.	**13,355**
Stone Corral I.D.	**6,671**
Tulare I.D.	**70,446**
Tulare Irrigation Company	**7,887**
Uphill D.C.	**1,819**
Wutchumna W.C.	**5,218**
Total	**259,159**

Table 23: Total Ditch Percolation (AF/WY)

Water Year	All Conveyance Percolation
1981	70,745
1982	243,470
1983	257,593
1984	149,426
1985	85,151
1986	226,874
1987	35,502
1988	50,098
1989	50,355
1990	19,649
1991	61,780
1992	32,401
1993	177,784
1994	46,311
1995	215,126
1996	161,633
1997	189,363
1998	216,275
1999	104,433
2000	114,612
2001	65,837
2002	76,638
2003	120,560
2004	58,082
2005	206,240
2006	207,682
2007	38,028
2008	80,803
2009	90,254
2010	151,862
2011	196,378
2012	65,852
2013	29,293
2014	26,177
2015	17,698
2016	78,869
2017	310,206
Maximum	310,206
Minimum	17,698
Average	117,001
Total	**4,329,038**

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Artificial Recharge

Artificial recharge basins receive surface water, which percolates directly to groundwater, the volumes of which were estimated for the entire Subbasin. The method of estimating these volumes was developed as part of the WRIs for KDWCD, which involved multiplying the number of days each recharge basin received water by the basin's known percolation rate (recharge factor) (Fugro West, 2007). Artificial recharge occurs throughout the GKGSA and EKGSA. The basin recharge factors were refined for the entire period of the WRI (Fugro Consultants, 2016), and were utilized for this analysis for the entire base period.

There are 46 recharge basins completely within the Kaweah Subbasin (refer to ***Table 24***), over a total of 1,916 acres. Within these, the recharge inflows were determined for each recharge basin, using the methodology described in the previous reports (Fugro West, 2007; Fugro Consultants, 2016). The results of the recharge basin inflow analysis are presented as ***Table 15***. As indicated, an average of 51,191 AF/WY of surface water was recharged to the groundwater by recharge basins. The volume of water recharged by this method varies widely and episodic recharge occurs principally during times of excess flow associated with wet years.

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Table 24: Recharge Basins in the Kaweah Subbasin

Source	Basin ID	Source	Acres
Evans	Nelson Pit - 13	Evans	**25**
Farmers	Anderson - 24	Farmers	**130**
Farmers	Art Shannon - 1	Farmers	**27**
Farmers	Ellis - 27	Farmers	**9**
Farmers	Gary Shannon - 7	Farmers	**3**
Farmers	Gordon Shannon - 21	Farmers	**39**
Farmers	Nunes - 29	Farmers	**9**
Goshen Ditch	Doe-Goshen - 28	Goshen Ditch	**28**
Harrell No. 1	Harrell - 30	Harrell No. 1	**25**
Lakeside Ditch	Alcorn	Lakeside Ditch	**10**
Lakeside Ditch	Batti	Lakeside Ditch	**33**
Lakeside Ditch	Burr	Lakeside Ditch	**6**
Lakeside Ditch	Caeton	Lakeside Ditch	**4**
Lakeside Ditch	Green - 23	Lakeside Ditch	**4**
Lakeside Ditch	Guernsey	Lakeside Ditch	**4**
Lakeside Ditch	Howe - 15	Lakeside Ditch	**49**
Lakeside Ditch	Lakeside #2	Lakeside Ditch	**58**
Lakeside Ditch	Sousa	Lakeside Ditch	**6**
Lakeside Ditch	Youd	Lakeside Ditch	**6**
Modoc	Doe-Ritchie - 26	Modoc	**0**
Modoc	Goshen: Doe - 9	Modoc	**30**
Modoc	Shannon-Modoc - 22	Modoc	**8**
Modoc	Willow School - 5	Modoc	**14**
Peoples	Bill Clark - 32	Peoples	**1**
Peoples	Hammer - 31	Peoples	**1**
Peoples	Sunset - 95	Peoples	**95**
Persian	Packwood - 4	Persian	**147**
TID	Abercrombie - 14	TID	**17**
TID	Colpien - 3	TID	**144**
TID	Corcoran Hwy - 8	TID	**106**
TID	Creamline - 16	TID	**133**
TID	Doris - 25	TID	**26**
TID	Enterprise - 2	TID	**18**
TID	Franks - 17	TID	**33**
TID	Franks - 19	TID	**108**
TID	Guinn - 18	TID	**142**
TID	Liberty	TID	**29**
TID	Machado - 6	TID	**128**
TID	Martin	TID	**16**
TID	Swall	TID	**153**
TID	Tagus - 11	TID	**78**
TID	Watte - 20	TID	**14**
		Total	**1,916**

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Percolation of Irrigation Return Water

Estimates for percolation of irrigation return water are presented in *Table 25.*

Table 25: Percolation of Irrigation Water and Additional Recharge (AF/WY)

Water Year	Irrigation Return Flow	Additional Recharge
1981	**285,574**	**18,416**
1982	**276,604**	**36,740**
1983	**253,708**	**39,055**
1984	**344,152**	**51,797**
1985	**313,508**	**14,930**
1986	**251,295**	**8,565**
1987	**271,198**	**6,311**
1988	**274,740**	**10,130**
1989	**290,799**	**0**
1990	**285,874**	**219**
1991	**246,574**	**0**
1992	**246,249**	**0**
1993	**245,247**	**8,190**
1994	**247,267**	**0**
1995	**218,632**	**12,491**
1996	**226,064**	**8,161**
1997	**226,793**	**4,342**
1998	**173,211**	**23,281**
1999	**234,804**	**24,943**
2000	**237,762**	**19,190**
2001	**213,593**	**0**
2002	**226,064**	**5,482**
2003	**228,157**	**0**
2004	**219,653**	**2,342**
2005	**208,530**	**34,807**
2006	**230,550**	**18,983**
2007	**236,599**	**6,039**
2008	**229,848**	**1,812**
2009	**220,352**	**1,501**
2010	**216,833**	**15,107**
2011	**243,286**	**33,094**
2012	**236,186**	**0**
2013	**236,137**	**412**
2014	**242,824**	**0**
2015	**225,281**	**0**
2016	**208,859**	**3,142**
2017	**231,809**	**74,633**
Maximum	**344,152**	**74,633**
Minimum	**173,211**	**0**
Average	**243,368**	**13,084**

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Percolation of irrigation return water was estimated using two approaches, 1) the earlier (1981 to 1999) period, and 2) the later (2000 to 2017) period. Both approaches were based on the same analysis of "irrigated fields" used in the ditch system percolation analysis. A somewhat simplified version of this method was also utilized for the portion of the basin that are located outside of the KDWCD area.

Since 2000, GIS files of updated irrigated fields were acquired for the entire Subbasin. These were imported into the Davids Engineering database model for the calculation of the annual estimated percolation of irrigation return water for the irrigated fields as described by Davids Engineering (2013 and 2018).The Davids Engineering database model accounts for the agricultural land that has been converted to urban land use over time. The results of the analyses are presented in ***Table 25***. This principal form of groundwater recharge occurs within a relatively narrow range due to the continually-irrigated nature of the agricultural areas and near-constant recharge throughout the Subbasin. The average percolation of irrigation return water was 243,368 AF/WY during the historical (base) period ***Figures 45*** through ***49***, present the estimated distribution of groundwater pumping throughout the Subbasin.

In addition to the percolation calculated by the above method, some additional recharge occurs between the surface water headgate diversion and the fields calculated apart from ditch percolation. In some years, recharge occurs when excess water is delivered to the fields, which is beyond the requirements of the crop, either as additional ditch percolation or direct over-irrigation of the crops via on-farm recharge. On average, the volume of this recharge water is approximately 13,084 AF/WY, which occurs within the irrigated areas that receive surface water throughout the Subbasin.

Percolation of Wastewater

Several municipal WWTPs are operated within the Kaweah Subbasin, the principal ones of which are the cities of Visalia and Tulare, located entirely within MKGSA. Treated wastewater is discharged to holding ponds for percolation, evaporation, or agricultural reuse. Both WWTPs are regulated by Waste Discharge Requirements (WDRs) and Monitoring and Reporting Programs by the RWQCB (Fugro West, 2007). The managers of the two treatment plants were contacted by GSI and Annual Use Monitoring Reports for the City of Tulare were consulted during this analysis. Based on this research, on average, approximately 80 percent of the Visalia WWTP effluent percolates to groundwater while the other 20 percent is applied to adjacent crops. At the city of Tulare's WWTP, on average, 30 percent of the WWTP effluent percolates to groundwater while the other 70 percent is applied to nearby crops. The annual sums of wastewater that percolate to groundwater within MKGSA are presented in ***Table 26***. The table indicates that a total of 16,289 AF/WY of wastewater is recharged to the groundwater reservoir.

Table 26: Wastewater Percolation (AF/WY)

Water Year	Wastewater Percolation
1981	**11,082**
1982	**11,203**
1983	**11,588**
1984	**11,970**
1985	**12,375**
1986	**12,591**
1987	**13,159**
1988	**13,436**
1989	**13,874**
1990	**13,939**
1991	**14,231**
1992	**14,147**
1993	**14,519**
1994	**15,183**
1995	**15,655**
1996	**15,725**
1997	**16,133**
1998	**16,374**
1999	**16,982**
2000	**17,728**
2001	**18,063**
2002	**17,917**
2003	**18,645**
2004	**19,016**
2005	**19,172**
2006	**19,593**
2007	**19,440**
2008	**19,661**
2009	**19,434**
2010	**19,512**
2011	**19,409**
2012	**19,188**
2013	**18,975**
2014	**18,834**
2015	**18,025**
2016	**17,610**
2017	**18,299**
Maximum	**19,661**
Minimum	**11,082**
Average	**16,289**

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Outflows from the groundwater system

Outflow from the groundwater system occurs through the following components:

- Subsurface outflow,
- Agricultural and municipal groundwater pumpage,
- Phreatophyte evapotranspiration, and
- Evaporation.

Each of these components and the method used for each calculation is presented in this section.

Subsurface Outflow

Subsurface outflow is the flow of groundwater at depth that passes beyond the downgradient boundary of a groundwater basin. As presented on **Table 18**, during the historical base period, a total of 91,139 AF/WY of groundwater flowed out of the Subbasin, while subsurface inflow exceeded subsurface outflow by an average of 64,501 AF/WY.

Agricultural Water Demand and Consumptive Use

Agricultural water demand is the principal component of water use within the Kaweah Subbasin. Similar to and associated with the analysis for percolation of precipitation and percolation of irrigation water, the calculation of the agricultural water demand was calculated using two different methods, each of which are described below.

- For the earlier portion of the historical period prior to 2000, the agricultural water demand was based principally on periodic land surveys, which were separated by as many as 10 years (Fugro West, 2007). These methods were updated for the later (2000 to 2017) period, when remote sensing methods were adopted and which incorporated data from satellite images for the period from September 1998 to January 2011 (Davids Engineering, 2013) and again through the end of water year 2017 (Davids Engineering, 2018).
- For the later period since 2000, the irrigated fields were input into the Davids Engineering database model (2018) and then queried from the full Subbasin irrigated fields table to return annual estimated gross applied irrigation water for the irrigated fields. Because of the magnitude and importance of this component of water use in the area, considerable database model error checking was performed to verify the accuracy and reasonableness of the data. The Davids Engineering database model accounts for the agricultural land that has been converted to urban land use over time. The results of the gross applied irrigation water analyses indicated that an average of 1,007,363 AF/WY of water, from a combination of surface and groundwater sources, were delivered to the agricultural lands within the Subbasin (***Table 27*).**

Table 27: Gross Applied Water to Crops (Acre-Feet/WY)

Water Year	Crop Water Demand
1981	981,809
1982	933,059
1983	855,764
1984	1,160,572
1985	1,057,233
1986	909,899
1987	983,920
1988	997,082
1989	1,055,096
1990	1,037,574
1991	967,375
1992	968,204
1993	964,278
1994	971,984
1995	860,068
1996	965,166
1997	970,414
1998	741,888
1999	953,826
2000	1,013,101
2001	1,016,803
2002	1,072,721
2003	1,061,020
2004	1,087,721
2005	953,219
2006	981,903
2007	1,110,079
2008	1,101,383
2009	1,154,190
2010	1,022,157
2011	1,014,507
2012	1,103,581
2013	1,125,567
2014	1,146,453
2015	1,055,737
2016	964,415
2017	952,655
Maximum	**1,160,572**
Minimum	**741,888**
Average	**1,007,363**

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Municipal and Industrial Demand

Municipal and industrial (M&I) pumping from the Subbasin was estimated using a variety of methods. The categories of water users included in this summarized component include:

- Urban
- Small public water system
- Golf course
- Dairy
- Nursery
- Rural domestic

The total M&I groundwater pumping estimate within the Subbasin is the sum of the individual groundwater demands estimated for the components discussed in the following sections. Data used in the M&I groundwater pumping estimate were collected from a variety of sources. . Sources of these data include: metered municipal groundwater pumping records, demand estimates based on service connections and categories of facilities, population and dwelling unit density estimates, interviews with various industrial facility managers (nursery, food processing, and packing plants, etc.), and information provided by the County Agricultural Commissioner's Office and the Dairy Advisor. As presented on **Table 28,** M&I demand within the Subbasin averaged approximately 69,040 AF/WY, or 9 percent of the total groundwater pumpage.

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Table 28: Municipal and Industrial Demand (AF/WY)

Water Year	Urban Demand	Small Water System Demand	Rural Demand	Golf Course Demand	Dairy Demand	Nursery Demand	Total M&I Demand
1981	26,875	2,824	1,591	1,350	4,545	0	**37,185**
1982	26,425	2,898	1,591	1,350	5,300	0	**37,564**
1983	27,643	2,973	1,591	1,350	6,054	0	**39,611**
1984	31,285	3,046	1,591	1,350	6,808	0	**44,081**
1985	31,951	3,120	1,591	1,350	7,562	0	**45,574**
1986	34,399	3,194	1,591	1,350	8,316	0	**48,850**
1987	35,629	3,268	1,591	1,350	9,071	0	**50,910**
1988	36,110	3,342	1,591	1,350	8,983	0	**51,376**
1989	35,599	3,416	1,591	1,350	10,761	0	**52,717**
1990	37,506	3,490	1,591	1,350	11,222	0	**55,160**
1991	35,415	3,554	1,591	1,350	11,721	500	**54,130**
1992	38,153	3,615	1,591	1,350	12,433	500	**57,641**
1993	38,392	3,680	1,591	1,350	12,354	500	**57,868**
1994	41,359	3,742	1,591	1,350	13,590	500	**62,132**
1995	42,355	3,805	1,591	1,350	15,360	500	**64,961**
1996	44,876	3,863	1,591	1,485	14,581	500	**66,896**
1997	46,368	3,925	1,591	1,485	16,613	500	**70,483**
1998	39,285	3,989	1,591	1,620	16,623	500	**63,607**
1999	46,556	4,051	1,591	1,620	16,632	500	**70,950**
2000	47,129	4,113	1,591	1,620	16,641	500	**71,593**
2001	51,137	4,185	1,591	1,620	16,650	500	**75,683**
2002	54,474	4,266	1,591	1,755	17,550	500	**80,136**
2003	55,696	4,349	1,591	1,755	18,449	500	**82,341**
2004	59,623	4,431	1,591	1,755	19,349	500	**87,250**
2005	57,390	4,515	1,591	1,755	20,249	500	**85,999**
2006	57,932	4,597	1,591	1,485	21,148	500	**87,253**
2007	61,707	4,680	1,591	1,485	22,048	500	**92,010**
2008	62,340	4,763	1,591	1,485	22,947	500	**93,626**
2009	61,376	4,845	1,591	1,485	23,840	500	**93,637**
2010	57,918	4,927	1,591	1,485	24,740	500	**91,161**
2011	56,461	4,953	1,591	1,485	23,463	500	**88,451**
2012	57,977	4,979	1,591	1,485	19,338	500	**85,870**
2013	60,484	5,005	1,591	1,485	20,138	500	**89,203**
2014	54,963	5,031	1,591	1,485	20,138	500	**83,707**
2015	47,889	5,067	1,591	1,215	20,138	500	**76,400**
2016	49,143	5,104	1,591	1,215	20,888	500	**78,440**
2017	51,447	5,177	1,591	1,215	20,088	500	**80,018**
Maximum	**62,340**	**5,177**	**1,591**	**1,755**	**24,740**	**500**	**93,637**
Minimum	**26,425**	**2,824**	**1,591**	**1,215**	**4,545**	**0**	**37,185**
Average	**45,980**	**4,075**	**1,591**	**1,452**	**15,576**	**365**	**69,040**

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Urban Demand

Urban groundwater demand in the Subbasin is the demand occurs in the major cities:

- Visalia and Tulare (in the MKGSA),
- Exeter, Farmersville, Ivanhoe and Woodlake (within the GKGSA), and
- Lindsay in the EKGSA, which relies only partially on groundwater to meet demands.

All other water demand in the unincorporated areas are met by small public water systems regulated by the local environmental health departments or by private domestic wells. A summary of annual urban groundwater pumping is presented in **Table 28.** As indicated, urban demand increased from from about 26,875 (1981) to 60,484 (2013) AF/WY over the period. Since 2013, when statewide conservation measures were implemented, total urban water demand declined significantly through 2015 to 2017, by which time urban demands had declined to levels not seen since the late 1990s. Urban demand averaged about 45,980 AF/WY over the base period.

Small Water Systems Demand

Analysis of annual water demand for small, regulated public water systems in the Subbasin was accomplished based on data provided previous reports (Fugro West, 2007; Fugro Consultants, 2016) and an analysis of the types of water systems in the area available from the County of Tulare Health and Human Services Agency. The listings of water systems provided information such as the facility identification/name, general location within the respective counties, a code related to the approximate number of service connections for the facility, and a contact name and phone number for each facility. Typical groupings of facility types common to the lists included mutual water companies, schools, mobile home parks, county facilities (e.g. civic centers, road yards), motels, livestock sales yards, and miscellaneous industries such as nurseries, food processing facilities, packing houses, etc.

Approximately one-third of the groundwater pumped by small public water systems occurs in a rural setting. Of this groundwater pumping, approximately 70 percent of the pumped water is believed to return to groundwater via septic system percolation and landscape irrigation return flow, with the remainder being consumptively used (Dziegielewski and Kiefer, 2010). A summary of the net small water system groundwater pumping values is provided in ***Table 28.*** Although small in the context of the overall water use, the increase in small water system groundwater demand over the base period was noted and commensurate with population changes within the Subbasin.

Rural Domestic Demand

Rural domestic water demand in the Subbasin consists of the demand of residences not served by a municipal connection, mutual water company, or other small public water system. Rural residential units can be described as "ranchette" type homes of several acres in size with an average of population per dwelling unit of about three people. Net water demand for such dwelling units is on the order of 2 AF/WY.

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Unlike the small, public water system demand estimates that were indexed to population changes in Tulare County, the density of rural domestic dwellings has not changed significantly in the Subbasin over the base period, other than being replaced to a small degree by urban expansion. Similar to the rural small water system analysis above, a 70 percent portion of the pumped rural domestic water is assumed to return to groundwater via septic system percolation and irrigation return flows (Dziegielewski and Kiefer, 2010). Throughout the Subbasin, an annual total pumpage for rural users was 2,272 AF/WY on average, 30 percent of which returned to groundwater. Therefore, the net pumpage for rural users was 1,591 AF/WY. The rural domestic groundwater pumping calculations are included on ***Table 28***, and demonstrates demand from rural domestic users is very minor.

Golf Course Demand

Golf courses have operated within the Subbasin for the entire base period and the supply is believed to be groundwater pumping and recycled water from WWTPs. Based on this assumption, golf course demand was calculated using an estimated 300 AFY of demand per 18-holes water duty factor (Fugro West, 2007). It is estimated that 10 percent of the irrigation water applied on the golf courses returns to groundwater via deep percolation (Grismer, 1990; Cahn and Bali, 2015; Ayers and Westcot, 1985). A summary of the golf course groundwater pumping estimates is included in ***Table 28***. During the base period, between 1,215 and 1,755 AF/WY were pumped, of which between 140 and 200 AF/WY returned to the groundwater reservoir. An average of 1,452 AF/WY of net pumping occurred to satisfy golf course demand.

Dairy Pumping

The dairy industry and related processing and distribution facilities requires a significant amount of water. Estimates of net water consumed by the dairy industry (farms) were based on cow census records maintained by the County and a per-cow based water use factor. Conversations with County personnel indicate the gross daily water use per cow is on the order of 125 gallons per day (gpd). Net water use (after consideration for the recycling of the water for irrigation on adjacent agricultural lands) is on the order of 75 gpd (Fugro West, 2007). Groundwater pumping by dairies in the Subbasin is an average of 15,576 AF/WY (*Table 28*). This volume of net pumping has increased significantly since the beginning of the period when 4,545 AF/WY was pumped (net). Notably, the groundwater demand is influenced directly to dairy cow populations, which are in turn directly affected by the market price for milk. The highest groundwater demand for dairy use was during 2010 when a total of 24,740 AF/WY of (net) groundwater was pumped for dairy uses.

Nursery Demand

The Kaweah Subbasin has a single relatively minor nursery-based agricultural operation that has extracted an estimated average of 500 AF/WY since 1991, which is included in ***Table 28***.

Total M&I Groundwater Pumping

The total M&I groundwater pumping was estimated as the sum of the total pumping for each of the individual components described in the preceding paragraphs. For several of the M&I components, such as small water systems, rural domestic users, and golf courses, a portion of the pumped groundwater deep percolates and returns to the groundwater reservoir. A summary of the total M&I

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groundwater pumping calculations is included in *Table 28* which indicates that total M&I demand, satisfied mainly by groundwater sources, averaged 69,040 AF/WY.

Agricultural Pumping

The principal groundwater outflow from the Subbasin is pumping to satisfy irrigated agriculture. 91 percent of the total groundwater pumpage is used to fulfill this demand.

The distribution of groundwater pumping in the Subbasin for the irrigation of agriculture has been determined based on the spatial distribution of crop water demand and annual surface water delivery to individual surface water appropriator service areas (*Figures 50 through 54*). Crop water demand was calculated using two different methods for the 37-year period of record, as discussed earlier. Briefly, the analysis for water years prior to 2000 using estimated crop water use based on DWR land use surveys and irrigation efficiency factors (Fugro West, 2007). The analysis for water years from 2000 onward was completed by Davids Engineering (2018) using satellite data to calculate the NDVI. A detailed spatial distribution of crop water demand is available from the NDVI analysis method.

Surface water deliveries to crops from a combination of local Kaweah River and imported (CVP and Kings River) water sources for the 37-year period of record have been calculated by appropriator service area. Because the spatial distributions of surface water deliveries within each service area are unknown, it is assumed that surface water deliveries are distributed evenly across the irrigated fields within each service area. The current extent of irrigated agricultural land and the establishment of surface water appropriators in the Kaweah Subbasin was fully developed well before the beginning of the historical base period (B-E, 1972 and Fugro West, 2007). The appropriator service areas have remained essentially unchanged since that time. The only minor changes that have taken place are isolated conversions of agricultural lands to urban development (Davids Engineering, 2018) and conversion of land use within each service area. These minor changes to appropriator service areas have been accounted for in the surface water delivery analysis.

To determine distributions of groundwater pumping in the Subbasin for irrigated agriculture, the surface water volumes distributed among the known-irrigated fields within each service area were subtracted from the spatially precise NDVI crop water demand dataset, using the following equation:

$$AP = CD - SWc$$

where: AP = Agricultural Pumping

CD = Agricultural Crop Demand

SWc = Surface Water Crop Delivery

On average, a total of 685,375 AF/WY was pumped from the groundwater reservoir as shown on **Table 29**. This ranged from a low of 237,278 AF/WY in 1998, which was the wettest year of the period, and a high of over 1,065,530 AF/WY in 2014 during the recent drought and associated lack of imported surface water.

Table 29: Groundwater Pumping for Irrigated Agriculture (AF/WY)

Water Year	Ag Irrigation Pumping
1981	**721,553**
1982	**439,395**
1983	**307,540**
1984	**715,245**
1985	**756,074**
1986	**423,077**
1987	**776,072**
1988	**787,884**
1989	**820,783**
1990	**889,919**
1991	**723,721**
1992	**787,119**
1993	**528,788**
1994	**775,625**
1995	**360,849**
1996	**507,553**
1997	**532,683**
1998	**237,278**
1999	**622,587**
2000	**657,015**
2001	**766,328**
2002	**796,166**
2003	**721,257**
2004	**850,570**
2005	**502,543**
2006	**512,464**
2007	**946,886**
2008	**816,843**
2009	**870,526**
2010	**590,752**
2011	**511,468**
2012	**883,485**
2013	**992,285**
2014	**1,065,530**
2015	**989,938**
2016	**727,703**
2017	**443,360**
Maximum	**1,065,530**
Minimum	**237,278**
Average	**685,375**

The results of the analysis for water years 1999, 2001, 2006, 2015 and 2016 are presented on through **.** As expected, the results of this analysis show a pattern of increased agricultural pumping during drought periods to compensate for a reduction in surface water deliveries to irrigated lands from both local and imported sources and a commensurate increase in crop water demand.

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Pronounced increases in agricultural pumping occurred during extended periods of drought, such as the 2011 to 2015 period when imported water supplies were limited or non-existent.

During the following three periods, notable groundwater pumping increases occurred to satisfy agricultural demand:

- Between 1987 and 1992 when annual pumpage averaged 800,000 AF/WY;
- Between 2007 and 2009, when average pumpage for agriculture averaged 878,000 AF/WY; and
- Between 2012 and 2016 when average pumpage for agriculture exceeded 931,200 AF/WY.

Based upon this analysis and as shown on through , the following key observations regarding changes in water usage over the entire base period are noted:

- Groundwater pumping for agricultural uses has varied with surface water availability, but has increased at an average of 0.8% per year (5,500 AF/WY on average);
- crop water demand has increased modestly (at a rate of 0.3% or 2,800 AF/WY);
- surface water deliveries have declined at a rate of 1% or (-3,000 AF/WY on average); and
- since 1999, groundwater pumping has increased at a rate of 1.2% or 6,500 AF/WY.

Phreatophyte Extractions

Phreatophyte extraction consists of removing vegetation in riparian areas to prevent consumptive water use. Phreatophyte extractions within the Subbasin constitute a minor outflow component and were estimated in a manner constant with previous estimates (Fugro West, 2007). The results of phreatophyte extraction analysis are presented in **Table 30**, which indicate that this component constitutes a minor extraction from the groundwater reservoir (480 AF/WY).

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Table 30: Phreatophyte Extractions (Acre-Feet/WY)

Water Year	Phreatophyte Extractions
1981	**411**
1982	**692**
1983	**727**
1984	**280**
1985	**406**
1986	**672**
1987	**385**
1988	**491**
1989	**370**
1990	**258**
1991	**400**
1992	**451**
1993	**630**
1994	**376**
1995	**870**
1996	**545**
1997	**589**
1998	**1,075**
1999	**455**
2000	**537**
2001	**478**
2002	**493**
2003	**412**
2004	**377**
2005	**575**
2006	**730**
2007	**178**
2008	**237**
2009	**303**
2010	**523**
2011	**645**
2012	**207**
2013	**209**
2014	**219**
2015	**291**
2016	**462**
2017	**660**
Maximum	**1,075**
Minimum	**178**
Average	**476**

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2.5.1.4 Change in Storage §354.16 (b)

Annual variations in the volumes of groundwater in storage in the Subbasin were calculated for each year of the historical (base) period. The changes in storage for the 37-year period were used to evaluate conditions of water supply surplus and deficiency, and in identifying conditions of long-term overdraft.

As shown on **Table 31** and **Figure 55** below, there was an accumulated water supply deficiency of 2,428,487 AF over the 37-year study period, or an average deficit of 65,635 AF/WY.

Prior to 2000, a net surplus occurred throughout the Subbasin as calculated by this method, when inflows exceeded outflows by 323,000 AF, or an average of 17,900 AF/WY.

Between 1999 and 2017, when surface water supplies were occasionally unavailable and precipitation was low, the groundwater reservoir lost 2,176,000 AF, or an average of 143,000 AF/WY.

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Table 31: Change of Groundwater in Storage (Acre-Feet/WY)

Water Year	Total Inflow	Total Outflow	Inflow - Outflow	Cumulative Change in Storage
1981	578,407	875,019	(296,613)	**(296,613)**
1982	1,033,218	590,880	442,338	**145,725**
1983	1,216,750	464,621	752,129	**897,854**
1984	849,328	873,998	(24,670)	**873,184**
1985	629,499	854,223	(224,724)	**648,461**
1986	993,150	529,801	463,349	**1,111,809**
1987	531,995	925,272	(393,277)	**718,533**
1988	583,340	966,953	(383,613)	**334,919**
1989	450,046	950,735	(500,689)	**(165,770)**
1990	428,276	979,969	(551,692)	**(717,462)**
1991	557,081	835,059	(277,978)	**(995,440)**
1992	512,440	971,114	(458,674)	**(1,454,115)**
1993	965,324	702,939	262,385	**(1,191,730)**
1994	530,796	956,997	(426,201)	**(1,617,930)**
1995	1,101,727	539,252	562,475	**(1,055,455)**
1996	917,345	660,958	256,386	**(799,069)**
1997	1,023,840	703,536	320,304	**(478,765)**
1998	1,164,159	398,369	765,791	**287,026**
1999	767,406	731,503	35,903	**322,929**
2000	795,440	789,818	5,622	**328,550**
2001	624,469	925,262	(300,793)	**27,758**
2002	678,906	969,061	(290,155)	**(262,397)**
2003	756,815	903,916	(147,101)	**(409,498)**
2004	589,036	1,034,025	(444,990)	**(854,487)**
2005	1,074,278	667,099	407,179	**(447,309)**
2006	1,072,676	666,545	406,131	**(41,178)**
2007	547,132	1,143,054	(595,922)	**(637,100)**
2008	656,721	1,079,896	(423,174)	**(1,060,274)**
2009	650,083	1,121,433	(471,350)	**(1,531,624)**
2010	947,309	803,915	143,394	**(1,388,230)**
2011	1,281,167	667,375	613,792	**(774,438)**
2012	662,047	1,040,730	(378,682)	**(1,153,120)**
2013	568,489	1,191,559	(623,070)	**(1,776,190)**
2014	539,217	1,246,520	(707,303)	**(2,483,494)**
2015	534,967	1,150,819	(615,852)	**(3,099,346)**
2016	713,134	903,004	(189,870)	**(3,289,216)**
2017	1,455,261	594,532	860,729	**(2,428,487)**
Maximum	**1,455,261**	**1,246,520**	**860,729**	
Minimum	**428,276**	**398,369**	**-707,303**	
Average	**783,278**	**848,912**	**-65,635**	

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Figure 55: Kaweah Subbasin Hydrologic Budget Summary, Historical and Current Periods

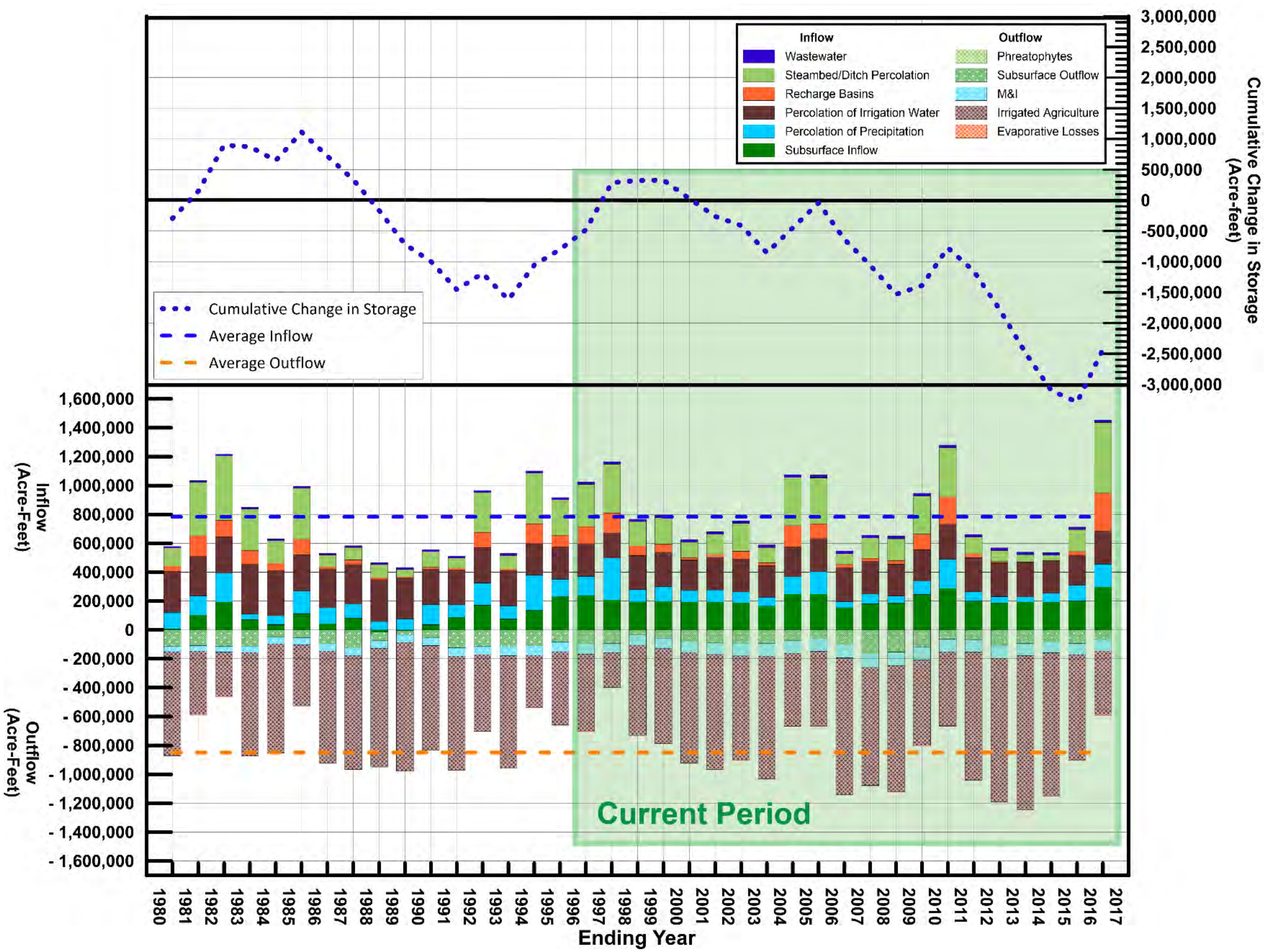

Figure 56: Kaweah Subbasin Hydrologic Budget Average, Historical Period

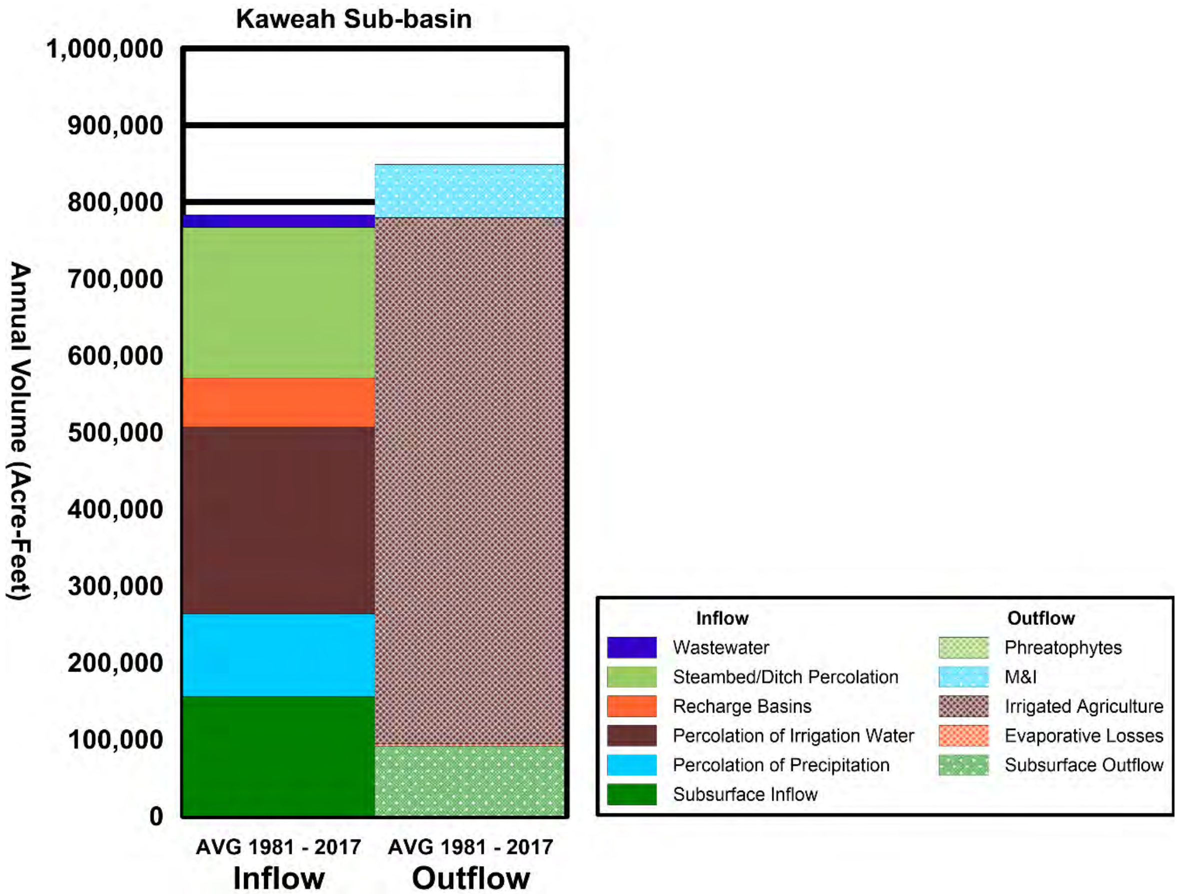

Figure 56 presents the annual amounts of each component of deep percolation and extractions within the Subbasin as computed using the hydrologic equilibrium equation (the "inventory method"). The results of the water budget show that the Kaweah Subbasin is in a severe overdraft during the historical period of water years 1981 to 2017. The magnitude of the overdraft for the Kaweah Subbasin during the overall base period was 65,600 AF/WY on average, which increased to 142,900 AF/WY since 1999.

Figure 57: Kaweah Subbasin Hydrologic Budget Average, Current Period

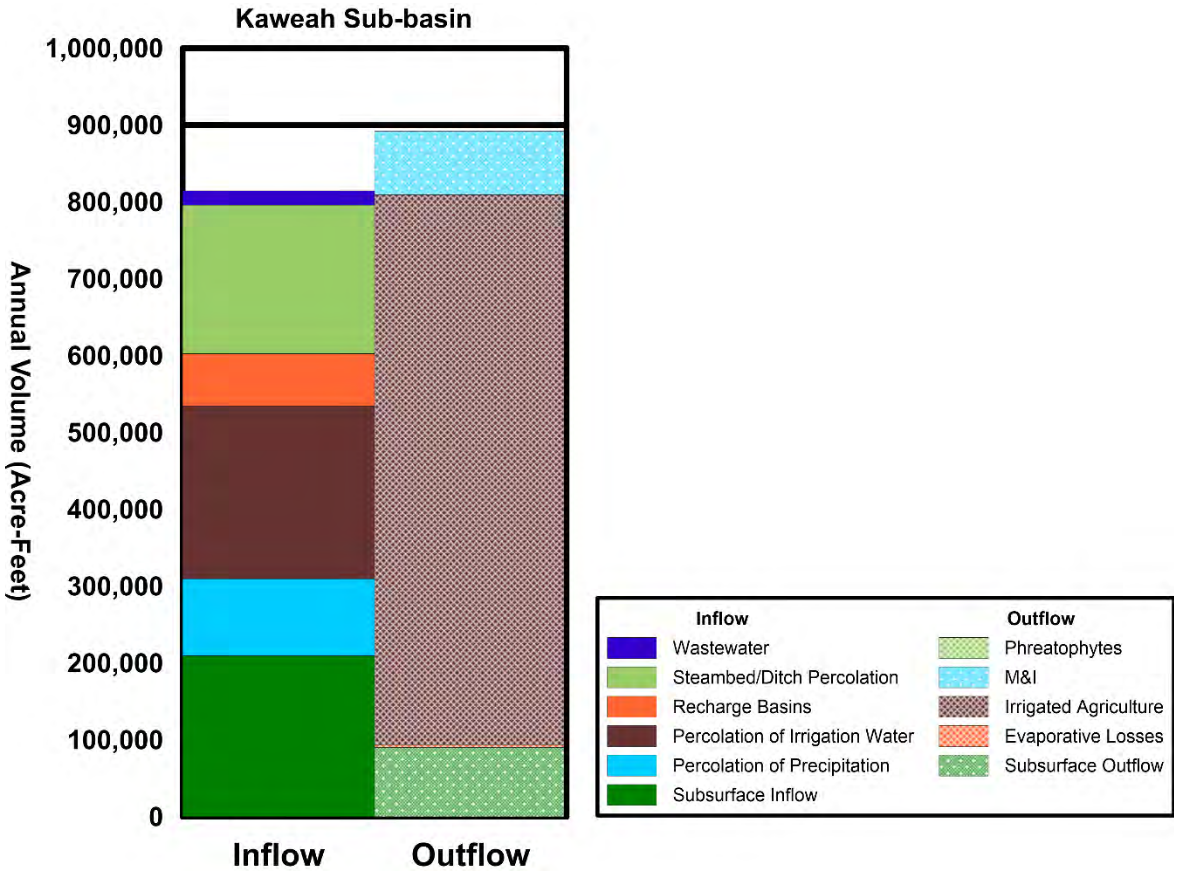

Figure 57 summarizes the current water budget components. The results of the water budget for the current water budget show the magnitude of the overdraft for the Kaweah Subbasin during the overall base period was is 77,600 AF/WY on average for the period 1997 to 2017. **Table 32** summarizes each component of the current water budget by year and shows a total decrease in storage during the period of 1.630 MAF.

Table 32: Current Period - Estimated Deep Percolation, Extractions and Change in Storage - Kaweah Subbasin (values in 1,000s AF)

Water Year	Rainfall		Components of Inflow						Components of Outflow										Change in Storage	Cumulative Change in Storage
									Groundwater Pumpage											
	Inches	% of Average	Subsurface Inflow	Wastewater Inflow	Steambed Percolation and Conveyance Losses	Percolation of Recharge Basins	Percolation of Irrigation Water	Percolation of Precipitation (Crop and Non-Ag Land)	M & I	Gross Applied Irrigation Water (Crop Water Demand)	Delivered Surface Water	*GW Pumping for Irrigated Agriculture*	*Total Net Extraction*	Extraction by Phreatophytes	Evaporative Losses	Subsurface Outflow	*Total Inflow*	*Total Outflow*	*Inventory Method*	*Inventory Method*
1997	12.5	128%	238.9	16.1	292.1	118.5	226.8	131.5	70.5	970.4	442.1	532.7	603.2	0.6	3.3	96.5	1,023.8	703.5	320.3	320.3
1998	22.8	234%	208.4	16.4	338.4	138.9	173.2	288.8	63.6	741.9	527.9	237.3	300.9	1.1	3.3	93.1	1,164.2	398.4	765.8	1,086.1
1999	9.6	99%	194.1	17.0	168.5	67.0	234.8	86.0	70.9	953.8	356.2	622.6	693.5	0.5	2.1	35.4	767.4	731.5	35.9	1,122.0
2000	11.4	117%	197.9	17.7	183.1	56.8	237.8	102.1	71.6	1,013.1	375.3	657.0	728.6	0.5	2.9	57.7	795.4	789.8	5.6	1,127.6
2001	10.1	103%	192.0	18.1	106.3	14.4	213.6	80.1	75.7	1,016.8	250.5	766.3	842.0	0.5	2.8	80.0	624.5	925.3	-300.8	826.8
2002	10.4	107%	192.2	17.9	138.1	20.3	226.1	84.3	80.1	1,072.7	282.0	796.2	876.3	0.5	2.8	89.4	678.9	969.1	-290.2	536.7
2003	8.7	90%	187.7	18.6	193.9	53.1	228.2	75.2	82.3	1,061.0	339.8	721.3	803.6	0.4	3.0	96.9	756.8	903.9	-147.1	389.6
2004	8.0	82%	164.5	19.0	105.1	19.0	219.7	61.8	87.3	1,087.7	239.5	850.6	937.8	0.4	2.4	93.4	589.0	1,034.0	-445.0	-55.4
2005	12.2	125%	246.9	19.2	332.6	145.9	208.5	121.2	86.0	953.2	485.5	502.5	588.5	0.6	3.1	74.9	1,074.3	667.1	407.2	351.8
2006	15.4	159%	247.3	19.6	317.6	102.6	230.5	155.0	87.3	981.9	488.4	512.5	599.7	0.7	4.8	61.3	1,072.7	666.5	406.1	757.9
2007	3.8	39%	154.1	19.4	73.8	21.9	236.6	41.4	92.0	1,110.1	169.2	946.9	1,038.9	0.2	2.5	101.4	547.1	1,143.1	-595.9	162.0
2008	5.0	52%	180.8	19.7	140.9	18.8	229.8	66.7	93.6	1,101.4	286.4	816.8	910.5	0.2	3.0	166.2	656.7	1,079.9	-423.2	-261.2
2009	6.4	66%	186.6	19.4	151.0	24.3	220.4	48.5	93.6	1,154.2	285.2	870.5	964.2	0.3	3.0	154.0	650.1	1,121.4	-471.4	-732.6
2010	11.1	114%	246.0	19.5	264.0	109.2	216.8	91.7	91.2	1,022.2	446.5	590.8	681.9	0.5	4.0	117.5	947.3	803.9	143.4	-589.2
2011	13.7	140%	288.1	19.4	340.7	188.9	243.3	200.8	88.5	1,014.5	536.7	511.5	599.9	0.6	3.8	63.0	1,281.2	667.4	613.8	24.6
2012	4.4	45%	199.9	19.2	116.3	26.1	236.2	64.4	85.9	1,103.6	220.1	883.5	969.4	0.2	2.9	68.3	662.0	1,040.7	-378.7	-354.1
2013	4.4	45%	187.3	19.0	75.4	8.1	236.1	42.6	89.2	1,125.6	133.7	992.3	1,081.5	0.2	2.2	107.6	568.5	1,191.6	-623.1	-977.1
2014	4.7	48%	193.7	18.8	50.0	0.3	242.8	33.6	83.7	1,146.5	80.9	1,065.5	1,149.2	0.2	3.2	93.9	539.2	1,246.5	-707.3	-1,684.4
2015	6.2	63%	191.7	18.0	37.2	0.4	225.3	62.4	76.4	1,055.7	65.8	989.9	1,066.3	0.3	2.1	82.1	535.0	1,150.8	-615.9	-2,300.3
2016	9.8	100%	200.8	17.6	152.2	25.2	208.9	108.4	78.4	964.4	239.9	727.7	806.1	0.5	2.8	93.6	713.1	903.0	-189.9	-2,490.1
2017	14.0	143%	296.6	18.3	489.3	261.1	231.8	158.1	80.0	952.7	583.9	443.4	523.4	0.7	4.0	66.5	1,455.3	594.5	860.7	-1,629.4
Maximum	22.8	234%	296.6	19.7	489.3	261.1	243.3	288.8	93.6	1,154.2	583.9	1,065.5	1,149.2	1.1	4.8	166.2	1,455.3	1,246.5	860.7	-81470.9
Minimum	3.8	39%	154.1	16.1	37.2	0.3	173.2	33.6	63.6	741.9	65.8	237.3	300.9	0.2	2.1	35.4	535.0	398.4	-707.3	
Average	**9.7**	**100%**	**209.3**	**18.5**	**193.6**	**67.7**	**225.1**	**100.2**	**82.3**	**1,028.7**	**325.5**	**716.1**	**798.4**	**0.5**	**3.1**	**90.1**	**814.4**	**892.0**	**-77.6**	
% of Total			26%	2%	24%	8%	28%	12%	9%			80%		0.05%	0.34%	10%				
			100%						100%											

Italic = Calculation
= Component of Inflow
= Component of Outflow

Specific Yield

One additional method of determining the annual change of groundwater in storage involves use of the specific yield method, which is based on water level contour maps created for key years throughout the Subbasin. To that end, groundwater contour maps were prepared for every year of the historical period by plotting water level data and accurately contouring the water surfaces. The contours of the water level surfaces represent spring conditions, based on as many as 655 wells evenly distributed throughout the Subbasin.

The storage calculations involved creating automated routines in GIS to develop a gridded surface, which were used to calculate the changes in water levels between the spring period of three key years of 1981, 1999 and 2017. The water surface changes were then integrated with the specific yield data available for the basin and described in Section 2.1.6.2 Physical Characteristics to calculate total change in basin storage.

Results of the analysis indicated that water levels declined by a total of 74 feet during the 37-year historic period on average throughout the Subbasin. During this period, a water supply deficiency of 3,127,300 AF has occurred, which is equal to an average rate of decline of 84,500 AF/WY. During the more recent (modeling) period since 2000, the water supply deficiency was approximately 2,948,600 AF, which is equal to a higher average rate of decline of 163,800 AF/WY. During this modeling period, water levels declined by a total of 70 feet on average throughout the subbasin.

The results indicate that the water budget and specific yield methods are in general agreement, indicating that water supply deficiency in the Subbasin during the historical period was between 2,430,000 AF (water budget method) and 3,127,000 AF (specific yield method). During the more-recent modeling period since 2000, when water budget (inventory method) data quality is higher and thought to be more reliable, the agreement between the two methods is much better. During this modeling period the total water supply deficit was between 2,660,000 and 2,950,000 AF, or roughly 148,000 to 155,000 AF/WY.

Safe Yield

The safe or perennial yield of a groundwater basin, when discussed in SGMA, is defined as the volume of groundwater that can be pumped on a long-term average basis without producing an undesirable result. Long-term withdrawals in excess of safe yield is considered overdraft. While the definition of "undesirable results" mentioned in the definition have changed in recent years and have now been codified in SGMA regulations, they are recognized to include not only the depletion of groundwater reserves, but also deterioration in water quality, unreasonable and uneconomic pumping lifts, creation of conflicts in water rights, land subsidence, and depletion of streamflow by induced infiltration (Freeze and Cherry, 1979). It should be recognized that the concepts of safe yield and overdraft imply conditions of water supply and use over a long-term period. Given the importance of the conjunctive use of both surface water and groundwater in the Subbasin, short-term water supply differences are satisfied by groundwater pumpage, which in any given year, often exceed the safe yield of the Subbasin. The Subbasin, however, has a very large amount of groundwater in storage that can be used as carryover storage during years when there is little natural recharge, and replaced in future years by reduced pumping (when surface water is available instead or from various types of projects, including, for instance, artificial recharge), or by groundwater recharge projects.

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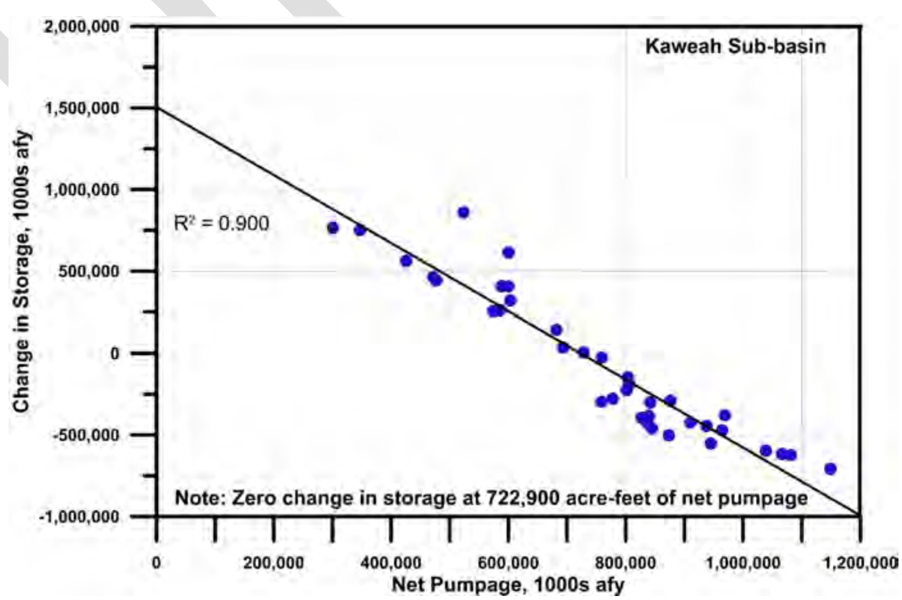
While safe yield of the Subbasin is difficult to estimate due to the inherent uncertainties in the estimates of recharge and discharge, there are several methods available to estimate the safe yield under the conditions of water supply and use that prevailed during the 37-year historical base period. Use of these methods requires acknowledgement of the inherent uncertainties in the estimates of recharge and discharge as well as the challenges associated with calculating the changes of groundwater in storage in the confined "pressure" area of the Subbasin.

The first methods assumes that the safe yield is equal to the long-term recharge inflow, calculated as the total inflow minus the annual overdraft. Although there are considerable assumptions used to estimate each component of inflow in the hydrologic equation, the results of this method suggest that the safe yield of the Subbasin would be approximately 717,800 AF/WY (summation of the components of inflow, that is 783,300 AF/WY, less the average annual overdraft, which is about 65,600 AF/WY). This average is approximate and does not encompass the non-uniformity in safe yield application across the entire basin. Based on the water budget for the historical period, discharge from the Subbasin exceeded recharge by some 65,600 AF/WY, resulting in a decline in water levels. Imbalances of pumping demand related to patterns of land use over the base period are apparent, which created a progressive lowering of water levels.

A second method to estimate the safe yield is to compare the annual extractions over the base period to the net changes of groundwater in storage. The resulting graphs provide the rate of extraction in which there is a zero-net change of groundwater in storage. This method, the so-called "practical rate of withdrawal," is a useful method so long as the coefficient of correlation between annual pumpage and storage changes is sufficiently robust and the calculated annual values of inflow and outflow are relatively accurate. Estimates compiled for this GSP are believed to be reasonably accurate in the estimates of annual groundwater extractions. Likewise, annual storage change estimates are also believed to be reasonably accurate, based on the distribution of wells and frequency of water level measurements. As presented on **Figure 58**, the intercept of zero storage change occurs at an annual pumpage of about 723,000 AFY, implying that net annual groundwater extractions at this approximate amount would produce no change of groundwater in storage.

Figure 58. Practical Rate of Withdrawal



A summary of the safe yield estimates is provided in **Table 33**, which indicates that the safe yield of the Kaweah Subbasin is approximately 720,000 AFY. Based on the above, under the current conditions of development and water supply, it is apparent that the Subbasin is in a condition of overdraft.

Table 33: Estimated Safe Yield, Historical Period (AFY)

Method	Safe Yield
Long-term Recharge	717,800
Practical Rate of Withdrawal	722,900

The estimates of safe yield will be refined with the forthcoming predictive numerical model runs with the Kaweah Subbasin groundwater model and will then will also be re-visited through the planning and implementation phase of the SGMA process. Furthermore, the safe yield estimate will likely be superseded by forthcoming sustainable yield values for the basins to avoid undesirable results and achieve measurable objectives.

2.5.2 Projected Water Budget

The GSP regulations require the following regarding Projected water budgets:

- "Projected water budgets shall be used to estimate future baseline conditions of supply, demand, and aquifer response to Plan implementation, and to identify the uncertainties of these projected water budget components."
- "Projected hydrology shall utilize 50 years of historical precipitation, evapotranspiration, and streamflow information as the baseline condition for estimating future hydrology…"
- "Projected water demand shall utilize the most recent land use, evapotranspiration, and crop coefficient information as the baseline condition for estimating future water demand…"
- "Projected surface water supply shall utilize the most recent water supply information as the baseline condition for estimating future surface water supply. The projected surface water supply shall also be applied as the baseline condition used to evaluate future scenarios of surface water supply availability and reliability as a function of the historical surface water supply identified in Section 354.18(c)(2)(A), and the projected changes in local land use planning, population growth, and climate."

The future water budget in the Kaweah Subbasin will be estimated through application of the numerical groundwater model. Alternative future water supply and demand scenarios will be developed in coordination with the GSA managers as input to the numerical groundwater model. This section briefly describes the estimated impact of climate change and legal/environmental water reallocations on supply availability and projected water demands.

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2.5.2.1 Climate Change Analysis and Results

SGMA requires local agencies developing and implementing GSPs to include water budgets which assess the current, historical, and projected water budgets for the basin, including the effects of climate change. Additional clarification can be found in DWR's Water Budget and Modeling BMPs which describe the use of climate change data to compute projected water budgets and simulate related actions in groundwater/surface water models. DWR has also provided SGMA Climate Change Data and published a Guidance for Climate Change Data Use During Groundwater Sustainability Plan Development (Guidance Document) as the primary source of technical guidance.

The DWR-provided climate change data are based on the California Water Commission's Water Storage Investment Program (WSIP) climate change analysis results which used global climate models and radiative forcing scenarios recommended for hydrologic studies in California by the Climate Change Technical Advisory Group (CCTAG). Climate data from the recommended GCM models and scenarios have also been downscaled and aggregated to generate an ensemble time series of change factors which describe the projected change in precipitation and evapotranspiration values for climate conditions that are expected to prevail at mid-century and late-century, centered around 2030 and 2070, respectively. The DWR dataset also includes two additional simulation results for extreme climate scenarios under 2070 conditions. Use of the extreme scenarios which represent Drier/Extreme Warming (2070DEW) and Wetter/Moderate Warming (2070WMW) conditions in GSPs is optional.

This section describes the retrieval, processing, and analysis of DWR-provided climate change data to project the impact of climate change on precipitation, evapotranspiration, upstream inflow, and imported flows in the Kaweah Subbasin under 2030 and 2070 conditions. The precipitation and evapotranspiration change projections are computed relative to a baseline period of 1981 to 2010 and are summarized for the EKGSA, GKGSA and MKGSA areas. For upstream inflow into Kaweah Lake and imported water from the Friant-Kern Canal, change projections are computed using a baseline period of 1981 to 2003. The choice of baseline periods was selected based on the baseline analysis period for the Basin Settings report (which includes water years from 1981 to 2017), and the available of concurrent climate projections (calendar years 1915 to 2011) and derived hydrologic simulations (water years 1922 to 2011) from the SGMA Data Viewer.

Data Processing

The 2030 and 2070 precipitation and ET data are available on 6 km resolution grids. The climate datasets have also been run through a soil moisture accounting model known as the Variable Infiltration Capacity (VIC) hydrology model and routed to the outlet of subbasins defined by 8-digit Hydrologic Unit Codes (HUCs). The resulting downscaled hydrologic time series are available also on the SGMA Data Viewer hosted by DWR. Precipitation and ET data used in this analysis were downloaded from the SGMA Data Viewer for 69 climate grid cells covering the Kaweah Subbasin. Separate monthly time series of change factors were developed for each of the three Kaweah Subbasin GSAs by averaging grid cell values covering each GSA area. Monthly time series of change factors for inflow into Kaweah Lake and flow diversions from the Friant-Kern Canal were similarly retrieved from the SGMA Data Viewer. Mean monthly and annual values were computed from the subbasin time series to show projected patterns of change under 2030 and 2070 conditions.

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Projected Changes in Evapotranspiration

Crops require more water to sustain growth in a warmer climate, and this increased water requirement is characterized in climate models using the rate of evapotranspiration. Under 2030 conditions, all three GSAs in the Kaweah Subbasin are projected to experience annual increases of 3.2% relative to the baseline period. ***Table 34; Figures 59 and 60*** signify the largest monthly changes would occur in Winter and early Summer with projected increases of 4.3% to 4.8% in January and 3.8% to 4% in June. Under 2070 conditions, annual evapotranspiration is projected to increase by 8.2% relative to the baseline period in all three GSA areas. The largest monthly changes would occur in December with projected increases of between 12.8% to 13.5%. Summer increases peak approximately 8% in May and June.

Table 34: Summary of Projected Changes in Evapotranspiration

	East Kaweah	Greater Kaweah	Mid-Kaweah	Largest Monthly Change	Month of Largest Change
Projected ET Change 2030	103.2%	103.2%	103.2%	4.6%	Jan
Projected ET Change 2070	108.2%	108.2%	108.2%	13.5%	Dec

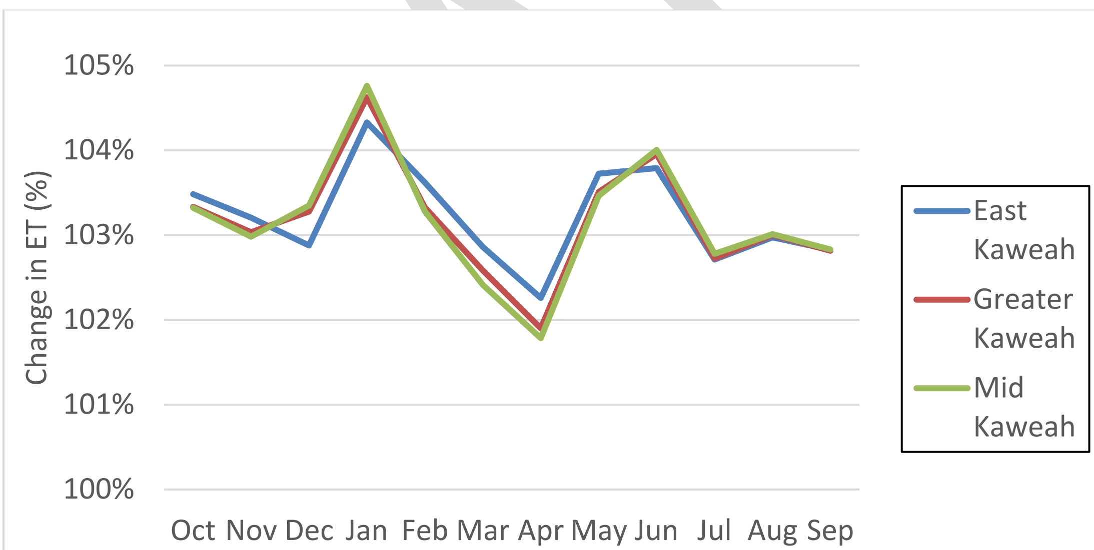

Figure 59: Evapotranspiration Projections under 2030 Conditions

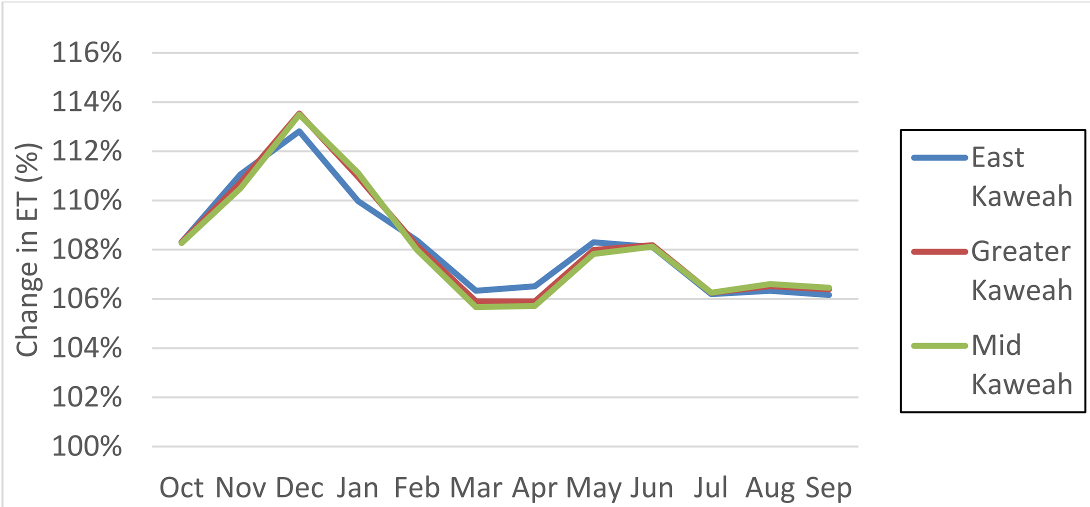

Figure 60: Evapotranspiration Projections under 2070 Conditions

Projected Changes in Precipitation

The seasonal timing of precipitation in the Kaweah Subbasin is projected to change. Sharp decreases are projected early Fall and late Spring precipitation accompanied by increases in Winter and Summer precipitation. ***Table 35; Figures 61 and 62*** display that under 2030 conditions, the largest monthly changes would occur in May with projected decreases of 14% while increases of approximately 9% and 10% are projected in March and August, respectively. Under 2070 conditions, decreases of up to 31% are projected in May while the largest increases are projected to occur in September (25%) and January (17%). All three GSA areas are projected to experience minimal changes in total annual precipitation. Annual increases in annual precipitation of 0.8% or less under 2030 conditions relative to the baseline period. Under 2070 conditions, small decreases in annual precipitation are projected with changes ranging from 0.6% in East Kaweah to 1.7% in Greater Kaweah and 1.9% in Mid-Kaweah.

Table 35: Summary of Projected Changes in Precipitation

	East Kaweah	Greater Kaweah	Mid-Kaweah	Largest Monthly Change	Month of Largest Change
Projected Precipitation Change 2030	100.4%	100.8%	100.8%	-14%	May
Projected Precipitation Change 2070	99.4%	98.3%	98.1%	25%	Sep

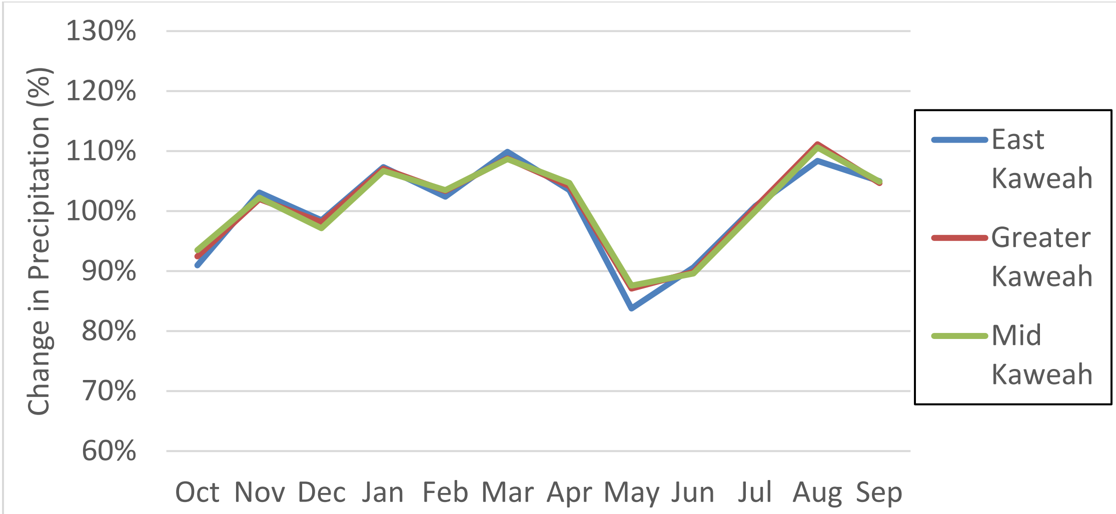

Figure 61: Precipitation Projections under 2030 Conditions

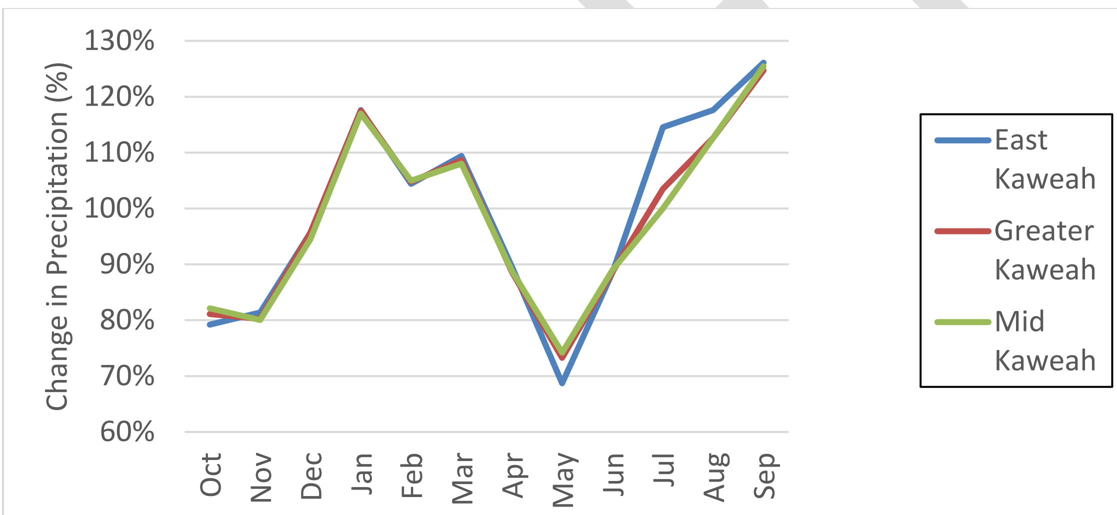

Figure 62: Precipitation Projections under 2070 Conditions

Projected Changes in Full Natural Flow

The quantity of inflows into Kaweah Lake, which is the main source of local water, are projected to decrease from 465 trillion acre-feet (TAF) per year under current climate conditions to 442 TAF under both 2030 and 2070 conditions. ***Figure 63*** shows peak flows are similarly projected to decrease from monthly peaks of 102 TAF under current climate conditions to 82 TAF by 2030 followed by a minimal decline to 81 TAF under 2070 conditions. However, significant changes in the seasonal timing of flows are expected. Under current and 2030 conditions, the monthly inflows into the reservoir are projected to peak in May. By 2070, inflows are projected to occur much earlier in the water year, with peak monthly inflows occurring in March.

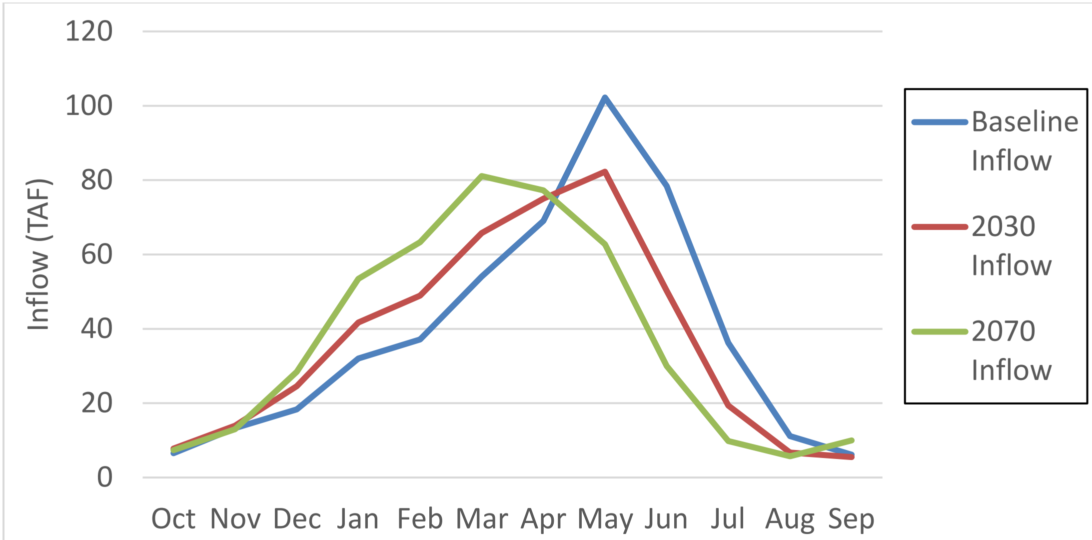

Figure 63: Projected Average Inflow into Kaweah Lake

Projected Changes in Imported Flow Diversions

Climate change could also impact the quantity and timing of imported water delivered to the Kaweah Subbasin from the CVP and the Kings River Basin. The Friant Water Authority has developed an analysis documented in a spreadsheet and a technical memorandum (***Appendix D***) showing the impact of climate change and the San Joaquin River Restoration Program (SJRRP) on water deliveries to the Friant-Kern Canal. The memorandum which is intended for use by water contractors preparing estimates of future Friant Division supplies in their groundwater sustainability plans summarizes results for five climate change conditions including:

- 2015 Conditions which represents a historical hydrology modified to match climate and sea level conditions for a thirty-year period centered at 1995 with a reference climate period of 1981 – 2010,

- Near-Future 2030 Central Tendency which represents a 2030 future hydrology with projected climate and sea level conditions for a thirty-year period centered at 2030 with a reference climate period of 2016 – 2045,

- Late-Future 2070 Central Tendency which represents a 2070 future condition with projected climate and sea level conditions for a thirty-year period centered at 2070 with a reference climate period of 2056 – 2085,

- Late-Future 2070 Drier/Extreme Warming Conditions (DEW) which represents a 2070 DEW future condition with projected climate and sea level conditions for a thirty-year period centered at 2070 with a reference climate period of 2056 – 2085, and

- Late-Future 2070 Wetter/Moderate Warming Conditions (WMW) which represents a 2070 WMW future condition with projected climate and sea level conditions for a thirty-year period centered at 2070 with a reference climate period of 2056 – 2085.

The five scenarios analyzed also reflect progressive changes in implementation of the SJRRS Restoration and Water Management Goals which also have a direct effect on Friant Division water supplies. Under the 2015 scenario, implementation of the SJRRS Restoration Goal is limited because of capacity restrictions in the San Joaquin River below Friant Dam, and the need for further buildout of groundwater infiltration facilities to take full advantage wet year supplies limits implementation of the SJRRS Water Management Goals. Restrictions on implementation are expected to remain in place until 2025. The 2030 and 2070 scenarios assume full implementation of the Reclamation's Funding Constrained Framework of the SJRRS.

Table 36 shows future projections of water deliveries to the Kaweah Subbasin from Friant with climate change and SJRRP implementation. The results indicate that relative to baseline conditions, the central tendency of water deliveries from the Friant-Kern system to the Kaweah Subbasin would decrease by 8.5% to 154.4 TAF under 2030 conditions and by 16.8% to 140.4 TAF under 2070 conditions. The two extreme climate conditions for 2070 would results in a 37.9% decrease to 104.7 TAF for the Drier/Extreme Warming Conditions and a 10.4% increase to 186.3 TAF for the Wetter/Moderate Warming Conditions, respectively. These projections suggest that the Kaweah subbasin needs to prepare for decreasing water deliveries from Friant in the Near-Future and under most scenarios in the Far-Future.

Table 36: Future Projections of Water Deliveries to the Kaweah Subbasin from Friant with Climate Change and SJRRP Implementation

Future Projections of Kaweah Imports from Friant with SJRRP					
Model Run	**Scenario Description**	**Class 1 (TAF/yr)**	**Class 2 / Other (TAF/yr)**	**16B and Recapture (TAF/yr)**	**Total Delivery (TAF/yr)**
2015.c	Applies 2015 Climate Conditions and assumes implementation of SJRRS is limited by downstream capacity limitations.	**105.5**	**37.5**	**25.6**	**168.7**
2030.c	Applies the Near-Future 2030 Central Tendency climate conditions and assumes Reclamation's Funding Constrained Framework for Implementing the SJRRS (SJRRP, 2018).	**101.6**	**22.6**	**30.1**	**154.4**
2070.c	Applies the Late-Future 2070 Central Tendency climate conditions and assumes Reclamation's Funding Constrained Framework for Implementing the SJRRS (SJRRP, 2018).	**95.9**	**13.7**	**30.8**	**140.4**
2070 DEW.c	Applies the Late-Future 2070 Drier/Extreme Warming climate conditions and assumes Reclamation's Funding Constrained Framework for Implementing the SJRRS (SJRRP, 2018).	**76.7**	**3.1**	**24.8**	**104.7**
2070 WMW.c	Applies the Late-Future 2070 Wetter/Moderate Warming climate conditions and assumes Reclamation's Funding Constrained Framework for Implementing the SJRRS (SJRRP, 2018).	**109.9**	**30.0**	**46.4**	**186.3**

Full natural flow of the Kings River at Pine Flat Dam is projected to decrease from 1,751 TAF under baseline conditions to 1,733 TAF under 2030 conditions and 1,731 TAF by 2070. The relative change in water supply is so small that Kings River water deliveries to Kaweah Subbasin would be assumed to remain unchanged at 13 TAF under both 2030 and 2070 conditions (*Table 37*).

Table 37. Summary of Projected Water Balance under 2030 and 2070 Conditions

	Annual Water Supply and Demand (TAF/yr)		
Changes in Primary Water Sources	Baseline	2030	2070
Upstream Inflow into Kaweah Lake	465	442	442
Total CVP Friant-Kern Canal Diversions	1200	1093	991
Total Kings River Full Natural Flow	1751	1733	1731
Surface Water Supply in Kaweah			
Rain Percolation (Cropland + Non-Ag)	118	119	116
Upstream Inflow Available for Kaweah	365	347	347
Imported Water CVP Friant-Kern Canal	169	154	140
Imported Water Kings River	13	13	13
Total Surface Water Supply in Kaweah	672	625	603
Water Demand in Kaweah			
Crop Water Demand	1004	1036	1086
Municipal & Industrial Demand	69	69	69
Total Water Demand in Kaweah	1073	1105	1155
Total Water Deficit in Kaweah	408	472	539

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2.5.2.2 Projected Demand Estimates

Based upon the historical and current water budget, the total water demands within the Subbasin were estimated for the future demand period extending 50 years into the future through 2070. To estimate total demand for this period, two components of demand were considered. These components include extraction from the groundwater reservoir and agriculture and M&I pumping.

Projected Agricultural Demand

For the base period, irrigated agriculture demand averaged 1,055,700 AF/WY, which was satisfied by a combination of surface water and groundwater. Recent crop survey data indicate that this demand is from a variety of crops including almonds, alfalfa, citrus, cotton, grapes, olives, truck crops, walnuts, wheat and several others (Davids Engineering, 2018). Crop ET was derived for each of these crops for each year during the recent period of 1999 to 2017, based upon trends in water use for each crop. During the period, total water demand related to the growing of almonds has increased by 14 percent, while total water demand to satisfy miscellaneous field crops has declined by 18 percent. By considering all of the trends for a total of 16 crop categories on a net basis, the average change in crop water ET demand has been relatively unchanged, increasing modestly each year between 1999 and 2018.

Future projection of crop demand to 2040 and 2070 indicates that agricultural demand will increase to 1,138,200 AF/WY in 2030 and 1,239,500 AF/WY in 2070, which includes projected climate change affects.

Projected M&I and Other Demands

This section briefly summarizes future M&I demands as well as other demands not included in M&I. These other demands include dairies, small water systems, rural domestic, golf courses and nursery users. To estimate future M&I demands, GEI reviewed the 2015 Urban Water Management Plans for the Cities of Visalia, Tulare, along with California Department of Finance population projections.

Table 38 demonstrates future M&I and other demands in the Kaweah Subbasin. As shown, 76,400 AF/WY in 2015 was met with groundwater pumping. M&I and other demand is projected to increase to 126,421 AF/WY in 2030 and 186,445 AF/WY in 2070.

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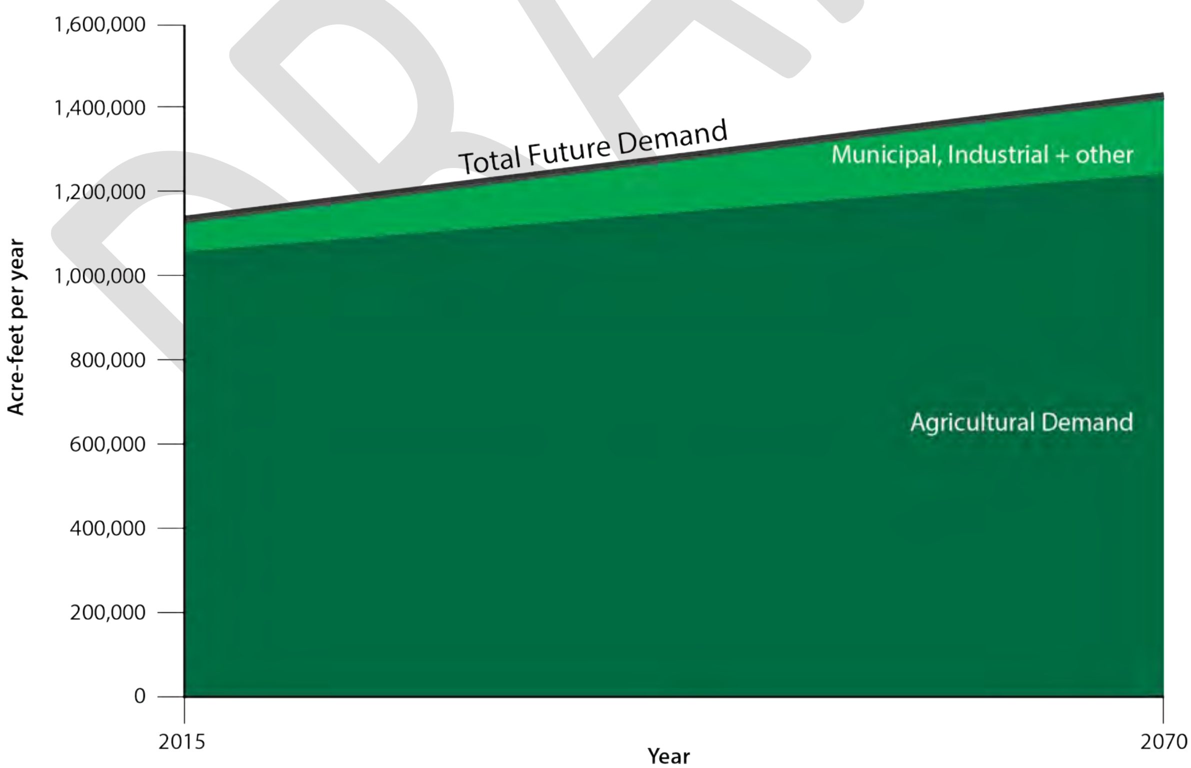
Table 38: Projected Water Demand (AF/WY)

	2015 Demand	Estimated 2040 Demand	Estimated 2070 Demand
Irrigation Demand	1,055,737	1,138,249	1,239,447
Tulare	9,055	20,372	33,952
Visalia	27,453	54,987	88,028
Exeter	1,825	2,336	2,949
Farmersville	822	1,052	1,328
Ivanhoe	694	888	1,122
Woodlake	1,688	2,161	2,728
Lindsay	518	663	837
Other Demand 2	34,345	43,961	55,501
Total M&I and Other	76,400	126,421	186,445
Total	**1,132,137**	**1,264,670**	**1,425,892**
Change	**--**	**132,533**	**293,755**

Notes: 1. This period selected for consistency with climate change datasets provided by DWR (DWR, 2018)
2. Other demand includes dairies, small water systems, rural domestic, golf courses, and nursery users

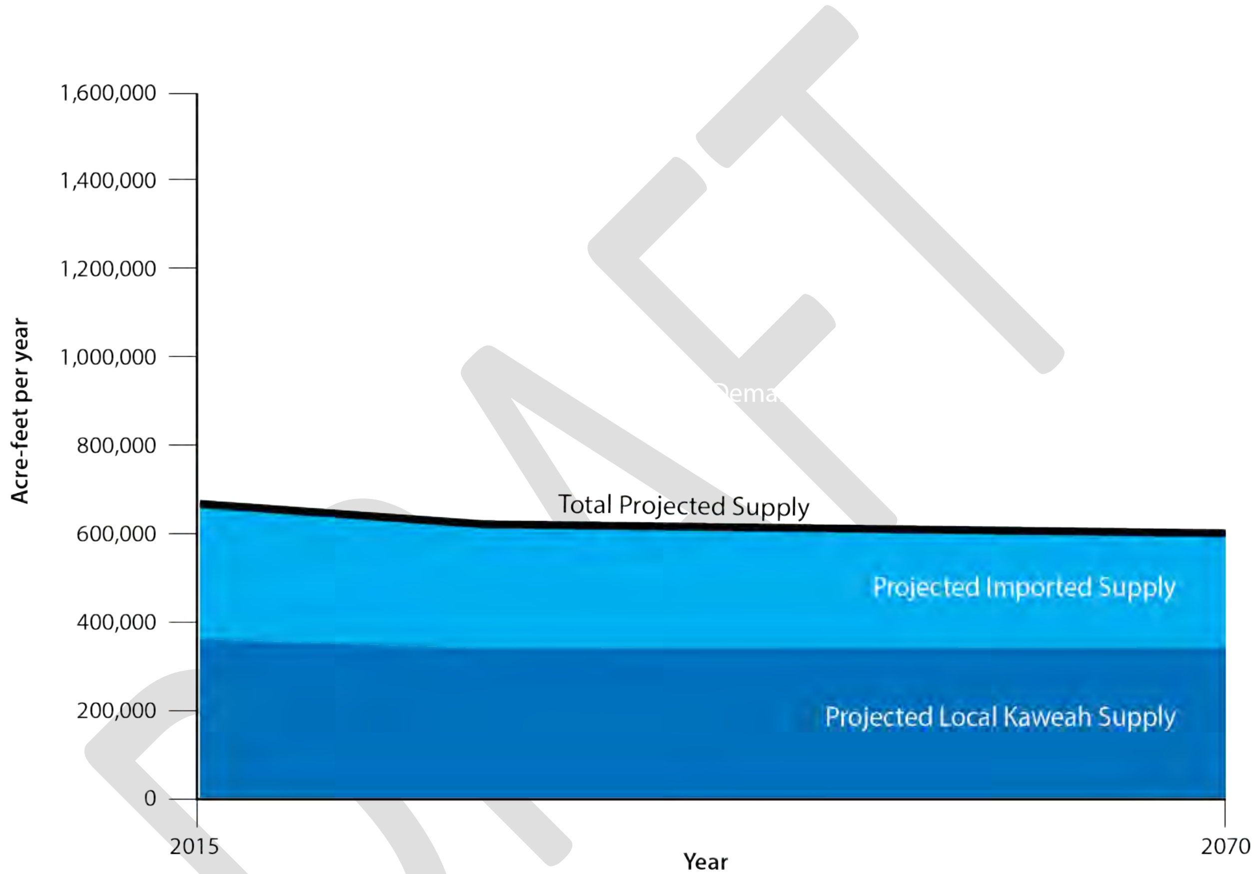
Figure 64 shows the increase in total Agricultural and M&I demand from 1,132,137 AF/WY in 2015, to 1,425,892 AF/WY in 2070, a 26% increase over the 50-year period. This increased demand results from increases in all three categories of users: agricultural, M&I and other demands.

Figure 64: Kaweah Subbasin Projected Water Demand



During the projected future period, water supply availability is projected to slightly decrease in response to climate change and because of restoration of flows on the San Joaquin River. ***Figures 65 and 66*** illustrate the gap between forecast water supply and forecast demand. This gap between future supply and demand will be met by groundwater supply produced at a sustainable yield that does not cause undesirable results. This sustainable yield will be established once measurable objectives are agreed upon throughout the basin. Groundwater modeling will be used to estimate the sustainable yield once initial thresholds and objectives are established.

Figure 65: Kaweah Subbasin Projected Water Supply



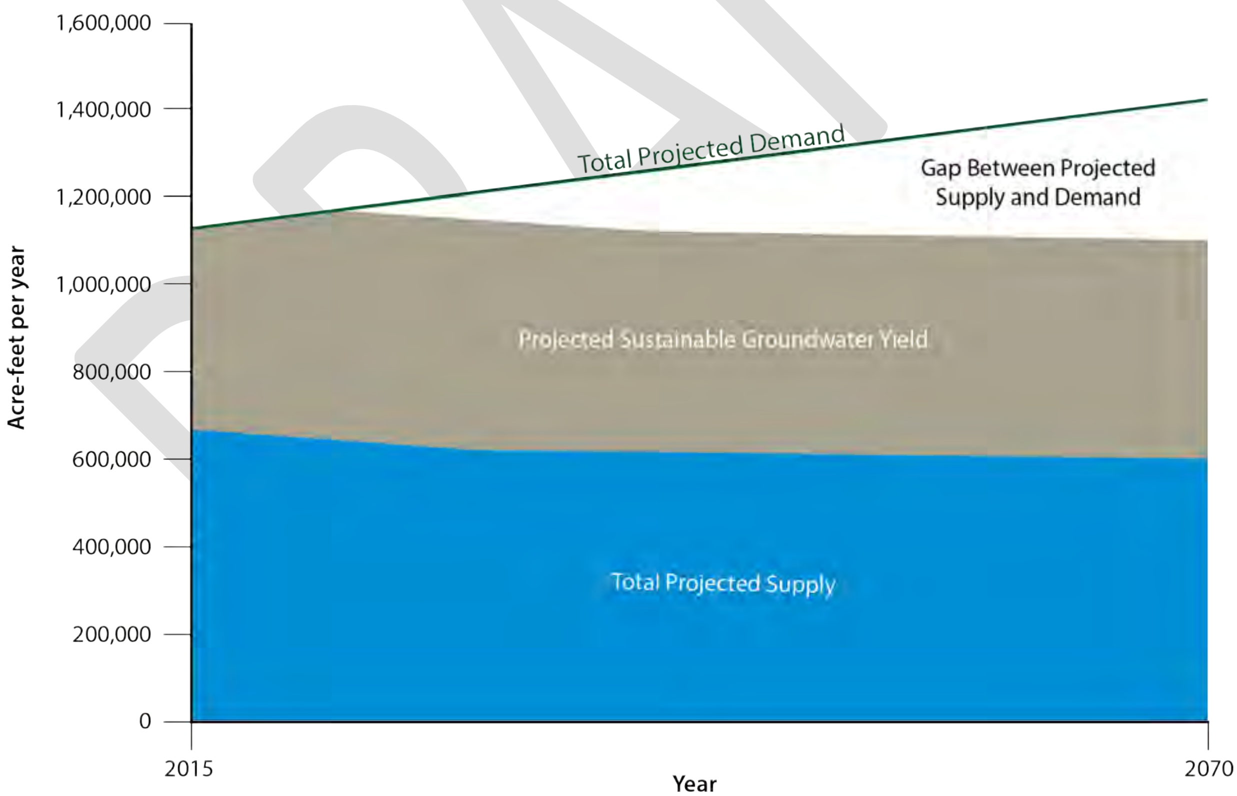
Impacts of Climate Change Projections on Water Balance

The impacts of climate change on the water balance of the Kaweah Subbasin is presented in ***Table 37***. The first section of the table shows baseline conditions and project changes under 2030 and 2070 conditions for the Subbasin's primary water sources including Kaweah Lake, CVP Friant-Kern Canal Diversions, and full natural flow of the Kings River. The second section of the table shows estimated impacts of changes at primary water sources on surface water supplies delivered to the Kaweah Subbasin. Rain percolation is assumed to change in direct proportion to projected changes in local precipitation. To estimate future changes in water deliveries from upstream inflows and imported sources, Kaweah Subbasin's share (expressed as a percentage) of source water available is assumed to remain unchanged. Imported water deliveries consequently change in direction proportion to projected changes at the respective sources. Annual crop water demands are projected to similarly change in direct proportion to changes in evapotranspiration.

Overall, total surface water supply in Kaweah Subbasin is projected to decrease from 665 TAF under baseline conditions to 633 TAF under 2030 conditions and 616 TAF by 2070, as shown on **Figure 66**. Conversely, total water demand is projected to increase from 1,073 TAF under baseline conditions to 1,105 TAF under 2030 conditions and 1,155 TAF under 2070 conditions. The combined effect of these changes is that total water deficit in the Subbasin will increase from 408 TAF under baseline conditions to 472 TAF under 2030 conditions and 539 TAF by 2070 unless measures are implemented to increase supply or reduce demand.

Figure 66 demonstrates that a widening future shortfall in supply is anticipated. Future projects and management actions will be developed and presented in subsequent chapters of this GSP. These projects and management actions will address the shortfall through either demand reduction (i.e. water use efficiency, reduction in crop acreage) or supply augmentation (i.e. increases in artificial recharge during wet periods, increased surface water delivery).

Figure 66: Kaweah Subbasin Projected Water Supply and Demand



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2.6 Seawater Intrusion §354.16 (c)

Seawater intrusion is not an issue in the Kaweah Subbasin because the subbasin does not have a coastal boundary. Seawater intrusion is an issue in coastal basins that may be induced by creating a landward gradient through lowering of the groundwater table. Once seawater reaches the area of groundwater production, the production wells will not be suitable for drinking or irrigation use and it will likely take decades and significant changes in water supply and use patterns to restore an aquifer's productivity. Maintaining a "wedge" of freshwater in coastal areas, between the ocean and the freshwater aquifers, may prevent undesirable results. Knowledge of the aquifer system, groundwater levels, and water gradients are needed to manage seawater intrusion.

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2.7 Groundwater Quality Conditions §354.16 (d)

This groundwater quality discussion is largely generalized, although constituents of concern are identified geographically. In 2007, Fugro conducted a Water Resources Investigation for the Kaweah Delta Water Conservation District. This report is referenced along with USGS studies and data collected from a wide variety of sources including state agencies, federal agencies, and county and city water departments. The Fugro study was limited by the volume of groundwater quality data that was available (Fugro West, 2007). At the time of this report, available groundwater quality data was confirmed to be insufficient to represent a large portion of the Subbasin. The primary source of data referenced for this characterization was obtained from the SDWIS which collects sample results from all State regulated public water systems.

2.7.1 Data Sources

There are 47 public water systems with data available in SDWIS. These systems are generally representative of the basin as they're located throughout the Subbasin. ***Figure 67*** shows the Kaweah Subbasin boundary, as well as the locations and density of wells with available water quality data. Between all 47 active public water systems, 174 wells were evaluated. In addition to SDWIS, GeoTracker and EnviroStor were searched to identify contaminant plumes, and the SWRCB's Human Right to Water Portal was searched to identify contaminants that commonly violate drinking water standards.

A limited amount of data are available for private domestic wells within the Subbasin; the State Water Board's GAMA Domestic Well Project provided insight to some private wells. Through their Groundwater Protection Section, the State Water Board offered voluntary groundwater monitoring to provide private well owners with information about their water quality. Groundwater samples were analyzed for bacteria, inorganic parameters, volatile organic compounds, and non-routine analytes. Select groundwater samples were also analyzed for stable isotopes of oxygen and hydrogen in water and stable isotopes of nitrogen and oxygen in nitrate. The State Board's GAMA report of the Domestic Well Project conducted for private well owners in Tulare County analyzed 29 of the 181 domestic well samples collected by the SWRCB for stable isotopes of nitrogen and oxygen in nitrate. The study found that nitrate isotopic composition varies with land use (dairies, agricultural/residential, and natural settings). Dairy site nitrate-N isotopic data are isotopically consistent with a manure source. While nitrate-O isotopic data are isotopically consistent with local nitrification of ammonium (from manure, septic effluent, or synthetic ammonium fertilizer).

The 29 samples that were analyzed for stable isotopes of nitrogen and oxygen were wells with higher nitrate concentration (median of 5 ppm and mean of 11 ppm nitrate as nitrogen). For a majority of the heavily impacted wells, the nitrate isotopic compositions indicate a dairy manure or septic effluent source, except for one well with a high nitrate concentration and an isotopic composition indicative of a synthetic fertilizer. Their study acknowledged that the data is under-represented by domestic wells with no potential anthropogenic sources within 500 meters of the well and that land uses were assigned on a high level.

2.7.2 Approach to Characterizing Groundwater Quality

Characterizing groundwater quality was conducted to comply with California Code of Regulations – Title 23 – Waters; Subarticle 2 §354.16(d) – Groundwater Conditions: groundwater quality issues that may affect the supply and beneficial uses of groundwater, including a description and map of the location of known groundwater contamination sites and plumes. Constituents evaluated and the methodology used were consistent with guidance provided in Assembly Bill 1249 (AB 1249) which states that "if the Integrated Regional Water Management (IRWM) region has areas of nitrate, arsenic, perchlorate, or hexavalent chromium contamination, the (IRWM) Plan must include a description of location, extent, and impacts of the contamination; actions undertaken to address the contamination, and a description of any additional actions needed to address the contamination" (Water Code §10541.(e)(14)). This approach of incorporating guidance from both programs was used to consider all major constituents of concern and characterize groundwater in a manner that is consistent with current water quality focused programs.

2.7.3 Results

While all regulated drinking water constituents were considered, findings from this evaluation show that the most common water quality issues within the Subbasin are: nitrate, arsenic, tetrachloroethylene (PCE), dibromochloropropane (DBCP), 1,2,3-trichloropropane (TCP), sodium, and chloride. This water quality discussion is divided by constituent to explain the drinking water standard, agricultural standard (sodium and chloride), and how these constituents impact beneficial uses in the different regions of the Subbasin. *Table 39* provides a summary of the range of these constituents within the Kaweah Subbasin referenced to the MCL.

Table 39: Summary of Water Quality Constituents in Kaweah Subbasin

Constituent	Units	Drinking Water Limits (MCL/SMCL)	Agricultural Water Quality Goal	Range in Kaweah Subbasin
Arsenic	ppb	10	100	ND - 20
Nitrate as N	ppm	10	n/a	ND - 27
Hexavalent Chromium	ppb	previously 10 ppb, currently under evaluation	n/a	ND - 14
Dibromochloropropane (DBCP)	ppb	0.2	n/a	ND - 0.31
1,2,3-Trichloropropane	ppt	5	n/a	ND - 230
Tetrachloroethylene (PCE)	ppb	5	n/a	ND - 270
Chloride	ppm	250	106	2 - 940
Sodium	ppm	n/a	69	1 - 270

2.7.3.1 Arsenic

Arsenic has a primary drinking water MCL of 10 ppb and an Agricultural Water Quality Goal of 100 ppb. Based on review of the Department of Pesticide Regulation studies and the hydrogeology of the Kaweah Subbasin, the major source of arsenic in this groundwater appears to be naturally occurring from erosion of natural deposits. Throughout the southern San Joaquin Valley, arsenic-rich minerals are present, including arsenopyrite, a common constituent of shales and apatite, a common constituent of phosphorites and the most common source of arsenic leaching materials in the aquifer (Burton, et. al., 2012). Data from public water systems shows that arsenic detections around 5-10 ppb are more prevalent in the western portion of the Subbasin, generally within the Corcoran clay. ***Figure 68*** shows the areas where arsenic is between 5- 10 ppb and/or shows an increasing trend to 10 ppb. The eastern boundary of the Corcoran clay generally follows the boundary of St. Johns River on the north till it crosses Highway 63 and extends south of Highway 63, where it continues south through the Subbasin and extends to the westerns portion of the Kaweah Subbasin.

USGS found that when arsenic is naturally occurring in the Kaweah Subbasin aquifer, concentrations tend to increase as pH increases due to desorption from aquifer sediments. Burton, et.al. (2012) report that almost all wells with moderate (5-10 ppb) or high (>10 ppb) arsenic concentrations were in samples with pH values greater than 7.6 units. This correlation between arsenic and pH is consistent in the public water wells evaluated. Wells with arsenic detections are located generally west of Highway 63 and Road 124.

When comparing the data from the municipal wells within the western portion of the Subbasin that have the Corcoran Clay present to the area east of Highway 63 where the aquifer is predominately alluvium, the pH levels were slightly lower than the western portion. This is further evidenced by the two wells located in the western portion of the Subbasin, west of Highway 63 and Road 124 that consistently have arsenic levels above 10 ppb, and pH levels that range from 9.1 – 9.6 units. Wells with arsenic levels less than 5 ppb typically have pH ranges from 7.0 – 8.6 units.

USGS also identified that arsenic concentrations were significantly higher in older and deeper groundwater. USGS assessed depth dependent arsenic concentrations by evaluating both the lateral and vertical extents of arsenic concentrations. Their conclusion is that higher arsenic concentrations directly correlate to well construction (completed depth and top of the perforations). Almost all detections with arsenic concentrations greater than 5 ppb were in wells deeper than 250-ft. These findings were compared with data obtained for this report. While the data is limited, there are two wells consistent with findings from the USGS Report. ***Figure 69*** shows that Well A with a total depth of 284 feet has historically had no arsenic detections. However, in Well B with a total depth of 760 feet also located in the same area has higher arsenic levels and at times exceeds 10 ppb.

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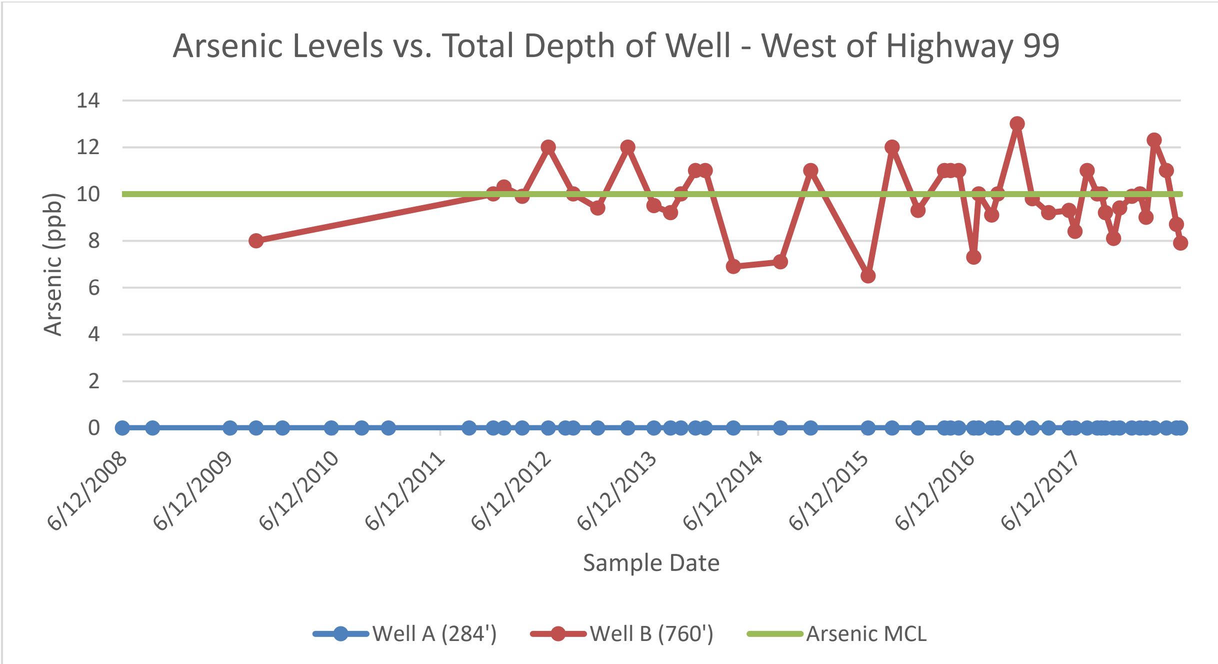

Figure 69: Hydrogeologic Zone 2 – Arsenic Levels vs. Total Depth of Well

2.7.3.2 Nitrate

Nitrate has an acute drinking water MCL of 10 ppm (as N). There is no Agricultural Water Quality Goal for nitrate. Nitrate predominately comes from runoff leaching from fertilizer use, leaching from septic systems and sewage, and small concentrations from erosion of natural deposits. Characterizing nitrate contamination in the Kaweah Subbasin includes identifying known and estimated sources of nitrate contamination, identifying public water system wells with nitrate concentrations above the MCL, and correlating the concentrations with land uses and water level trends.

Public water systems with high nitrate levels or increasing nitrate trends are common throughout the Subbasin. ***Figure 70*** provides a spatial observation of where the public water system wells with nitrate issues are generally located. Most nitrate concentrations greater than 5 ppm were detected in the eastern part of the studied area. In areas east of Highway 63 and Road 152 to the eastern extent of the Subbasin, nitrate tends to be higher than 5 ppm with increasing trends. All other areas of the Subbasin have nitrate levels ranging from non-detect to 5 ppm.

While Burton et. al. (2012) report that nitrate contaminations correlates to orchard and vineyard land uses, USGS finds that these regions also have medium to high density septic systems. ***Table 40*** shows the percentages of orchard and vineyard land uses and septic system density for each hydrogeologic zone (Tulare County 2007 land use data and Kings County 2003 land use data were used to create this table). Greater than 50 percent of the land use in this region are orchards or vineyards.

Septic-system density greater than the median value of 5 septic systems in a 500-meter radius around each selected GAMA well occurred throughout the Subbasin, with very high density of 9.4 septic systems within 500 meters of the selected well(s) between Highway 63 and Highways 245 and 65.

Figure 71 shows the location of wells selected by USGS to evaluate septic system density. Well locations are overlaid with land uses and public water system wells with high nitrate levels.

USGS data was used for this evaluation to develop a clearer understanding of potential sources of nitrate contamination. While previous reports point towards orchard and vineyard land uses, septic system density is an unquantified source of contamination. Data gathered by USGS was determined from housing characteristics data from the 1990 U.S. Census. The density of septic systems in each housing census block was calculated from the number of tanks and block area. The density of systems around each well was calculated from the area-weighted mean of the block densities for blocks within a 500-m buffer around the well location. To more precisely identify the nitrate sources, current data should be compiled and evaluated with proximity to domestic water wells. This effort is being made through the Disadvantaged Community Involvement Program to identify septic system density and condition in the Tulare-Kern Funding Area.

Table 40: Percentages of Nitrate Contributing Land Uses

Geographic Description	Orchard Percent	Vineyard Percent	Septic System Density (per 500 meters)
West of Hwy 63	8.91%	1.33%	5.5
Between Hwy 63 and Hwy 245 and Hwy 65	50.88%	3.19%	9.4
East of Friant-Kern Canal	45.64%	0.19%	5.5

It is well understood that nitrate is a surface contaminant and predominately impacts shallower wells, particularly wells with minimum sanitary features (i.e. the required 50-ft sanitary seal). Nitrate impacts based on well construction is demonstrated by the 3 wells with varied construction that are all located within the City of Tulare, Wells B and C are relatively close in proximity of each other but shows significantly different trends. While each of these wells are influenced by similar land uses and aquifer conditions, they each have varying levels of nitrate contamination. ***Table 41*** summarizes nitrate concentration and well construction for each of these wells. ***Figure 72*** graphically displays the nitrate trends.

Table 41: Comparison of Nitrate Concentrations and Well Construction

	Well A	Well B	Well C
Completed Depth	710	800	800
Sanitary Seal	280	260	370
Highest Perforations	320	280	400
Nitrate as N (ppm) current median value	8.2	14	3

While each of these wells show nitrate contamination related to land uses, vulnerability is substantially lower in Well C, which has a 370-ft sanitary seal. Both wells A and B have increasing trends, with the highest concentrations and steepest increasing trend found in Well B which has a sanitary seal of only 260-ft. Well B also shows significant variation in nitrate concentration that is likely associated with pumping duration at the time of sampling. Typically, shallow wells that are vulnerable to surface contamination will show the highest contaminant concentration with low pumping hours. Increased pumping hours will show lower contaminant concentrations. Regardless of contaminant/pumping correlations, this well has an increasing nitrate trend over time. Well A shows similar trends and pumping correlation, but the variation is less severe. Whereas Well C doesn't appear to be impacted by pumping or showing a significant increasing trend.

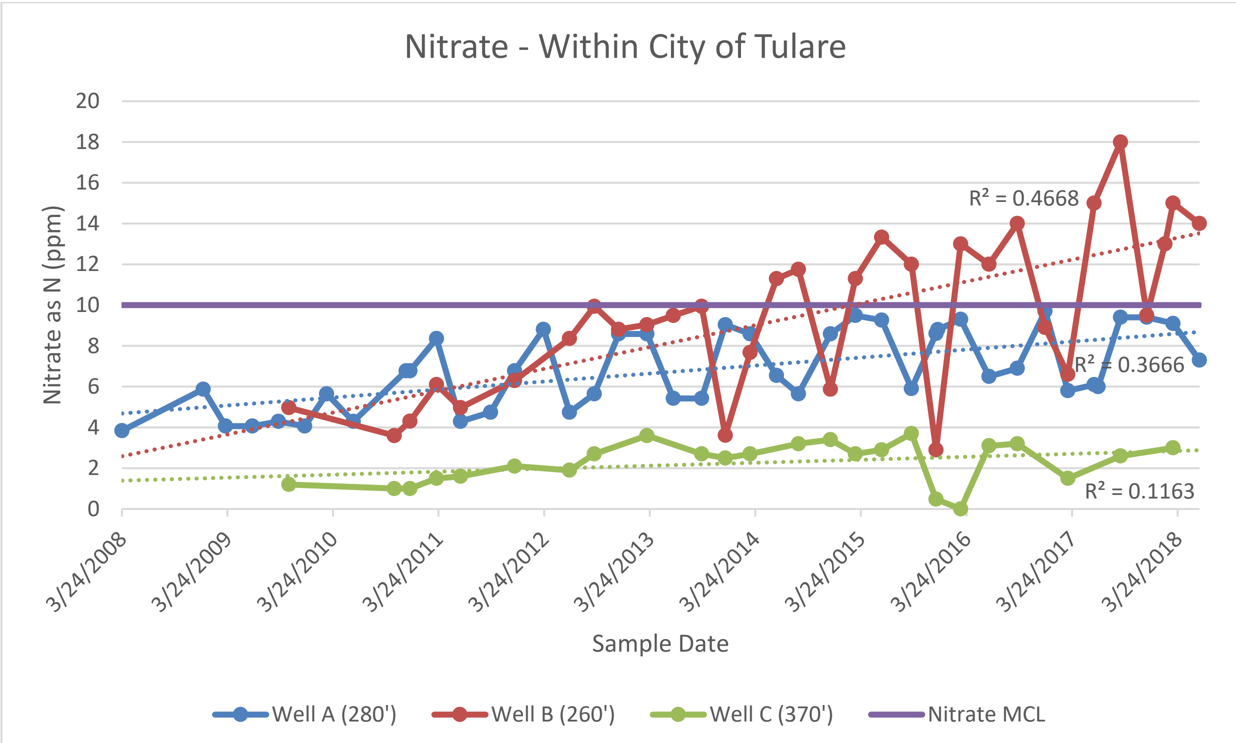

Figure 72: Nitrate Levels in Relation to Well Construction

In an effort to evaluate the extent of nitrate contamination basin-wide, a comparison was made between the general depth to water and nitrate concentrations. Since there was no well specific depth to water level data available, the use of the generalized depth to water levels of the Subbasin from DWR modeling database was used to determine if there is correlation between nitrate levels and changing water levels. In some of the wells located in the central portion of the Subbasin, there is no apparent correlation; however, in some wells located within the same area, it appears that nitrate levels are influenced by changing water levels. An evaluation of the wells between Highway 65 and Yokohl Creek shows that it does not appear that the declining water levels were causing nitrate to migrate deeper into the aquifer. See ***Figure 73*** as an example.

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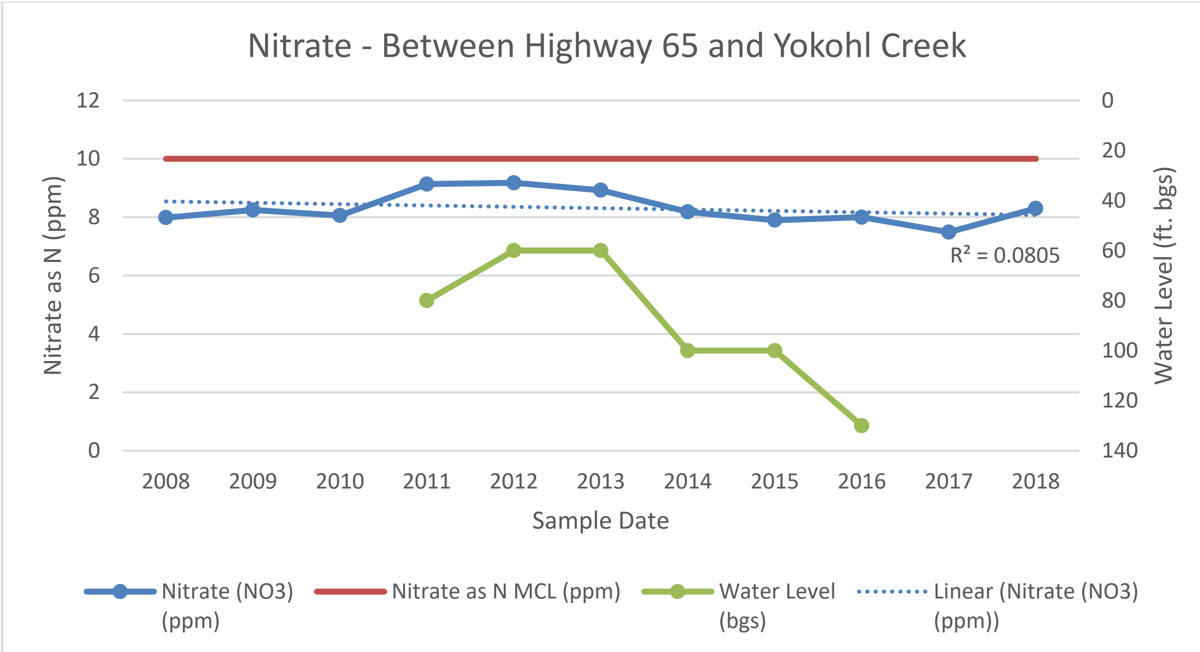

Figure 73: Nitrate Levels Remain Consistent Between Hwy 65 and Yokohl Creek

In contrast, the area south of Highway 137 between Roads 124 and 152, as shown in ***Figure 74***, there appears to be a correlation between declining water levels and increasing nitrate concentrations. This trend indicates that nitrate is migrating deeper into the aquifer and is within the pumping zone of the domestic wells evaluated in this region. This preliminary assessment is based on the limited amount of data available. To confirm accuracy of this trend, further studies are needed.

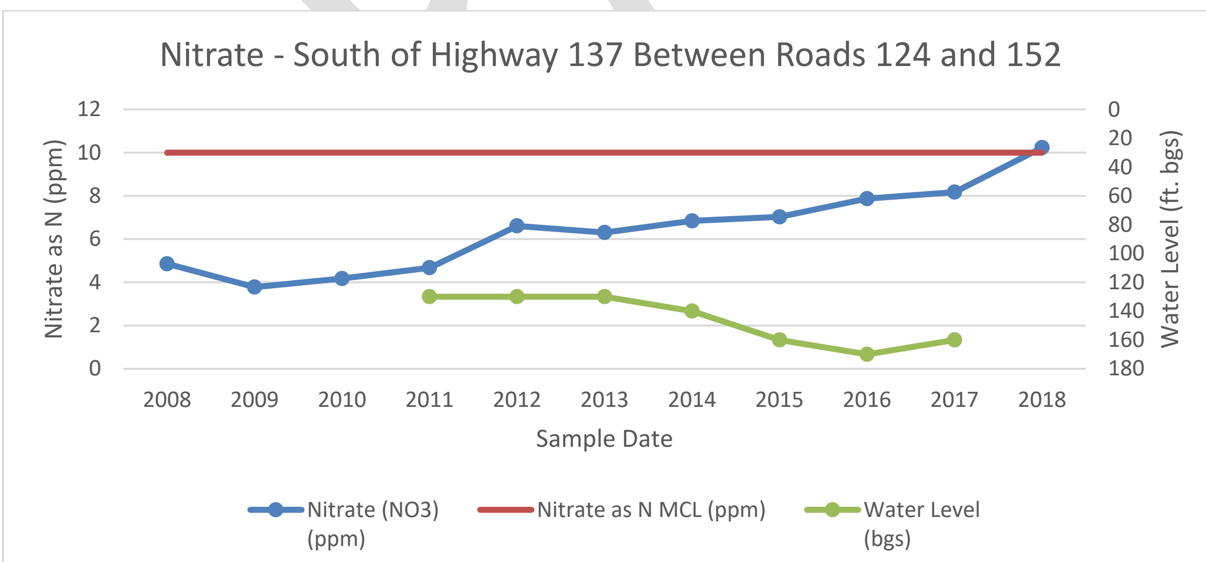

Figure 74: Nitrate levels increase south of Hwy 137

Figure 75 shows the nitrate trend that is representative of wells north of Highway 137 between Highway 99 and 63. The nitrate and water level trends that follow a parallel pattern indicate that nitrate is not migrating deeper into the aquifer. Nitrate in this well has decreased from its maximum concentration of 6 ppm to non-detect levels. This type of trend indicates that there are confining layers in the aquifer preventing nitrate from migrating with the water levels.

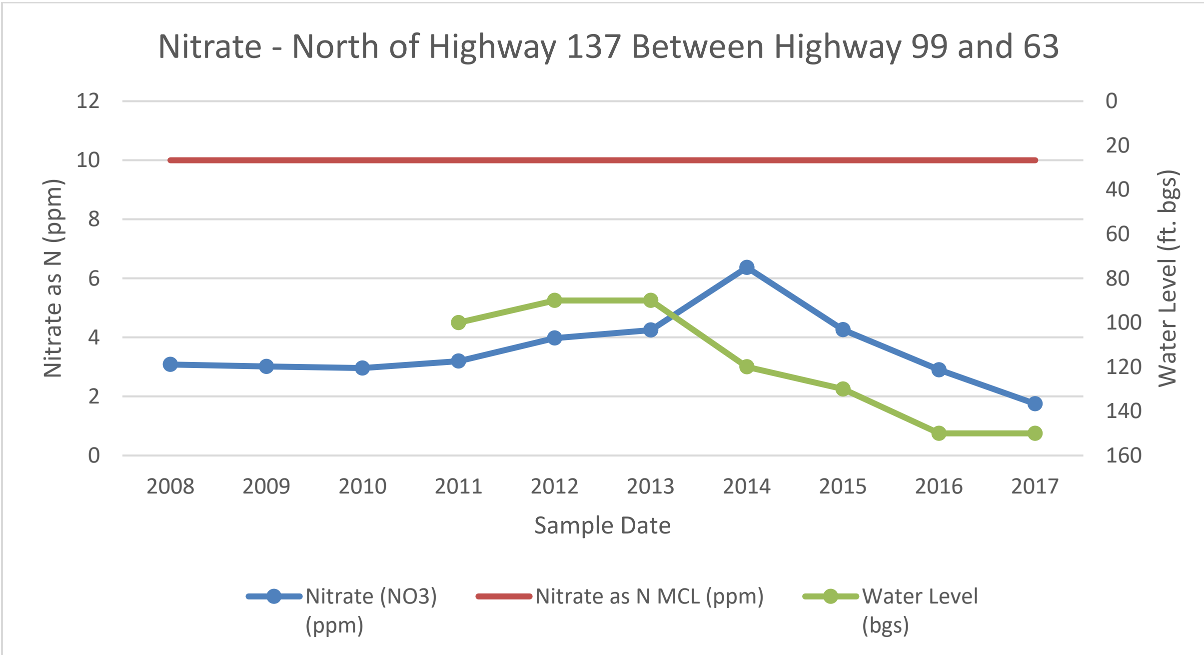

Figure 75: Nitrate levels decrease north of Hwy 137

2.7.3.3 Hexavalent Chromium

Hexavalent chromium is not commonly found in concentrations greater than 10 ppb in the Kaweah Subbasin. An evaluation of hexavalent chromium results indicates that only one well has historic levels with a maximum result of 14 ppb and an increasing trend. This well is located on the eastern border of the Subbasin, near the Friant-Kern Canal in hydrogeologic zone eight.

The federal MCL for total chromium (which includes chromium-3 and chromium -6) is 100 ppb, a specific federal MCL for chromium-6 has not been established. In California, the MCL for chromium-6 is currently 50 ppb. This MCL is a reversion from the July 2014 establishment of a primary MCL of 10 ppb. While DDW repeats the regulatory process for adopting the new MCL, the federal MCL of 50 ppb for total chromium applies. There is no Agricultural Water Quality Goal for hexavalent chromium.

2.7.3.4 Dibromochloropropane (DBCP)

Dibromochloropropane (DBCP) is a synthetic organic contaminant with a drinking water MCL of 0.2 ppb. There is no Agricultural Water Quality Goal. DBCP is a banned nematicide that is still present in soils and groundwater due to runoff or leaching from former use on soybeans, cotton, vineyards, tomatoes, and tree fruit.

Since the use of this pesticide was banned in 1977, concentrations of DBCP detected in the public water system wells have been either steady or decreasing trends. Presently, detections are found in 7 of the 47 public water systems, at concentrations below the MCL of 0.2 ppb.

Studies on the half-life of DBCP in groundwater estimate it will last from 3 to 400 years depending on ambient conditions. In 2008 the Department of Public Health (transferred to State Water Board as DDW in July 2014) estimated the median half-life of DBCP in the Central Valley is 20 years. This is consistent with the data that's been evaluated for this Subbasin since the levels are steady or decreasing.

2.7.3.5 1,2,3-Trichloropropane (TCP)

TCP is a semi-volatile organic compound with a primary drinking water MCL of 5 ppt. There is currently no federal MCL and no Agricultural Water Quality Goal. The majority of TCP in California's Central Valley is believed to be from an impurity in certain 1,3-D soil fumigants used to kill nematodes. When applied to land, TCP passes through soil and bonds to water, then sinks into the aquifer. It is a highly stable compound, meaning that it is resistant to degradation and has a half-life of hundreds of years[4].

Large public water systems began sampling their wells for TCP using a low-level analytical method around 2003, as a requirement of the Unregulated Chemical Monitoring Rule. From this data, DDW determined that the most impacted counties are Kern, Fresno, Tulare, Merced and Los Angeles. All water systems are required to test their wells quarterly beginning January 2018. Since only a few of the 47-public water system had data available in SDWIS at the time data was extracted for this report, the majority of detections were located in the central portion of the Subbasin. ***Figure 78*** shows wells with historical TCP detections in the Kaweah Subbasin.

2.7.3.6 Tetrachloroethylene (PCE) / Contamination Plumes

PCE is a volatile organic compound with a primary drinking water MCL of 5 ppb. There is no Agricultural Water Quality Goal for PCE. Sources of PCE include discharges related to dry cleaning operations and metal degreasing processes. An evaluation of contamination plumes in the Subbasin was identified through the SWRCB – GeoTracker and Department of Toxic Substances (DTSC) – EnviroStor databases. There is a total of 21 sites identified within the Kaweah Subbasin.

The largest PCE contamination plume involves nine sites in the city of Visalia, which are all dry cleaners. DTSC is leading this case and it's considered a city-wide investigation. According to the DTSC Fact Sheet dated January 2009, this investigation began after DTSC identified 25 public drinking water wells having detection of PCE. It is believed that the PCE plume is related to solvent releases from dry cleaning facilities in the city of Visalia. Soil and groundwater samples were first collected in 2007. Currently, the database indicates that from the nine sites identified there are three municipal drinking water wells that are within 1,500 feet of the plume vicinity. The three wells are located within the Cal Water area. One of the wells was shut down in 2000 due to PCE detection over the MCL. The well is now back online with PCE treatment.

Cal Water and DTSC entered into their first agreement in May 2007. One of the agreements identified between the two parties was for Cal Water to assist in preventing groundwater wells from spreading the PCE plume by early identification of problem areas or determination of appropriate

[4] Transformation and biodegradation of 1,2,3-trichloropropane (TCP) 2012. https://link.springer.com/content/pdf/10.1007%2Fs11356-012-0859-3.pdf

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remedial actions such as continued monitoring, pumping, not pumping, treatment, or well destruction. The agreement was amended in June 2009 and again in March 2013. The most recent agreement stated for Cal Water to evaluate the effects of pumping groundwater at two specific well locations. Subsequently the evaluation was focused to one well and based on a report completed in November 2015 of that well, it showed that the well resides in a dynamic geohydrologic environment. When the well is not pumping or under ambient condition, fresh water displaces PCE contaminated water from the shallow part of the aquifer near the well. When the well is pumping, it draws in the water from deep and shallow sources, including upper aquifer contaminated water. ***Figure 76*** shows the increasing PCE levels of the Cal Water well, with it peaking at 270 ppb in July 2014. Levels have significantly decreased but intermittently show increasing trends.

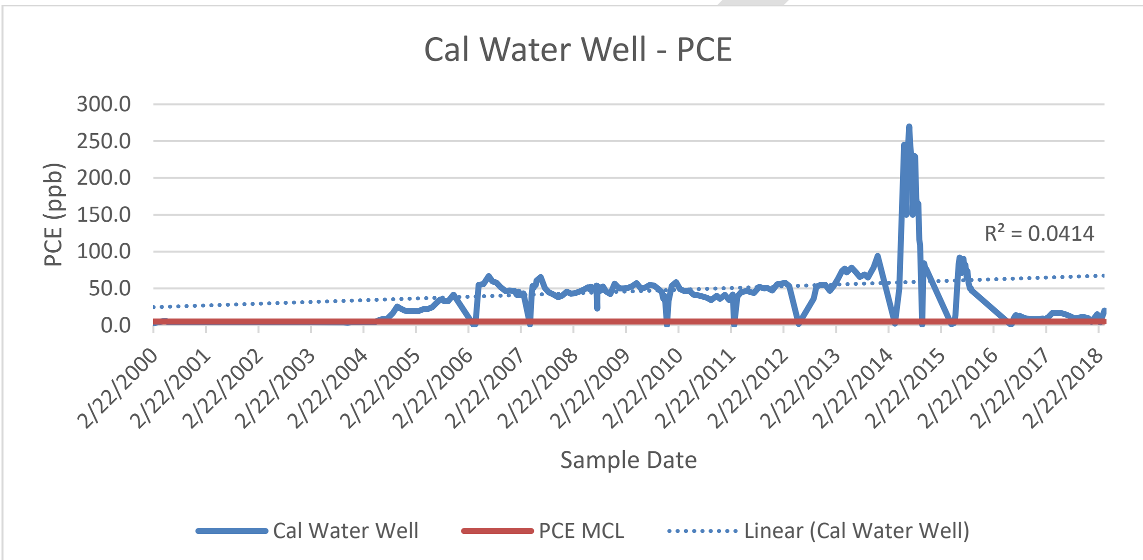

Figure 76: Historical PCE Levels of Cal Water Well Impacted by PCE Plume

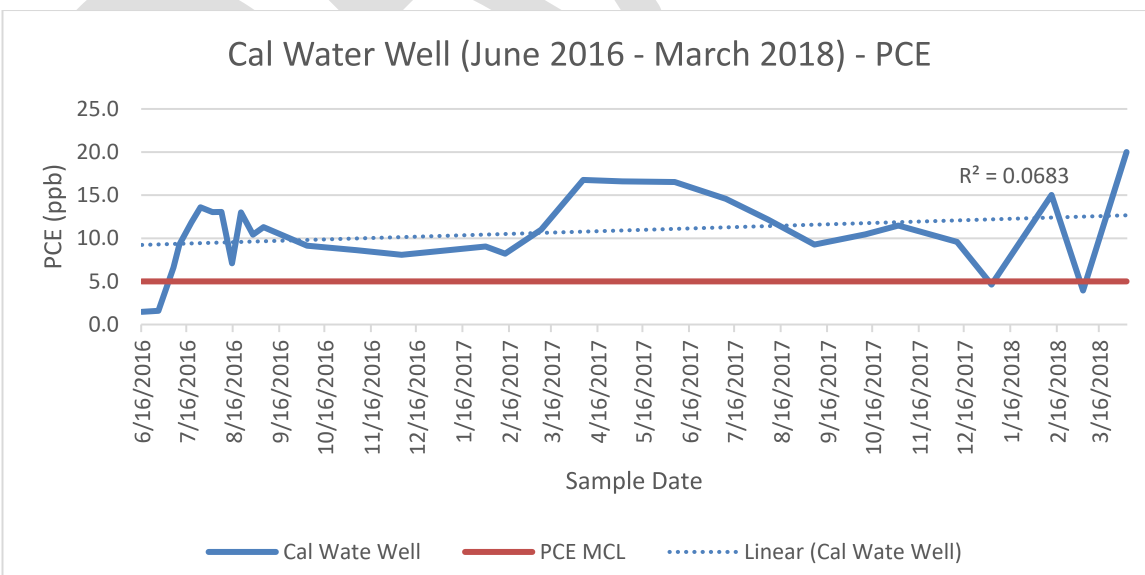

Figure 77: PCE Levels of Cal Water Well Impacted by PCE Plume from June 2016 – March 2018

This city-wide PCE investigation is still underway and each of the nine sites are in varying stages of investigation with work plans approved by DTSC. Monitoring wells that have been installed with screens about 100 feet below ground surface (bgs) have detected PCE levels above 5 ppb. The size of the plume has not been determined and is still under investigation. ***Figure 79*** shows the nine sites in relation to the municipal drinking water wells.

Other contamination sites were identified within the Subbasin. These other sites are summarized in ***Table 42*** An extensive summary for each of the contamination sites is not presented since most did not have more recent information or reports on the ongoing investigation of these sites. From reviewing the available reports, none of the sites listed have been determined to have an impact on the aquifer.

Table 42: Summary of Active Contamination Sites Not Part of PCE City-Wide Investigation

Global ID# / EnviroStor ID#	Lead Agency	Potential Contaminants of Concern	DDW Wells within 1500 Feet of Site	Status
SLT5FR184373 / 54270005	DTSC	VOC	No	Open – Remediation as of 5/12/10
SLT5FT344509	Regional Board	TCA, DCE, other inorganic/salt	Yes, but well inactivated in 2014	Open – Site Assessment as of 4/18/16
SL0610711757	Regional Board	Gasoline, MTBE, TBA, other fuel oxygenates, Diesel	Yes, but well was destroyed in 1995	Open – Inactive as of 4/28/16
T0610700032	Regional Board	Gasoline	No	Open – Eligible for closure as of 8/30/17
T0610700138	Regional Board	Gasoline	Yes	Open – Assessment & interim remedial action as of 1/29/17
T0610700075	Regional Board	Gasoline	Yes	Open – Site assessment as of 8/1/17
T10000011363	Regional Board	Polychlorinated biphenyls (PCBs), insecticides, pesticides, herbicides, arsenic, lead, mercury, total petroleum hydrocarbons (TPH) After testing, focus is arsenic	Yes – 4 total, but 3 have been inactivated in 1984 due to water system inactivation	Open – Site assessment as of 3/5/18
SL205194270	Regional Board	PCE, TCE, other chlorinated hydrocarbons	None identified, but reports indicate impacts to wells	Open – Verification monitoring as of 4/18/16

Global ID# / EnviroStor ID#	Lead Agency	Potential Contaminants of Concern	DDW Wells within 1500 Feet of Site	Status
SLT5FT424517	DTSC	Pesticides/ Herbicides	No	Open – Site assessment as of 1/22/87
SLT5S3483663	Regional Board	Pesticides, herbicides	No	Open – Inactive as of 5/21/09
80001396	DTSC	Soil - Lead, Sulfuric acid, TPH	No	Open – Active as of 1/1/08
80001510	DTSC	Cadmium, copper, lead, and zinc	Unknown	Open – Active as of 3/1/17

Out of all the contamination sites identified, there are 16 contamination sites that will need to be monitored to determine the extent of impact to the groundwater (***Figure 80***). Sites that have no information at all or eligible for closure is not counted towards the 16 contamination sites that needs further monitoring. The 9 PCE sites that are not listed in the table are also included in the count of 16 sites. In some of the sites, shallow monitoring wells went dry due to the water table levels dropping and deeper monitoring wells had to be drilled to continue the investigations. Currently, there is not enough information to determine if the contaminants are sinking with the groundwater levels. The main constituents of concern due to contamination plumes in this Subbasin are volatile organic compounds (VOCs), more specifically PCE and TCE, and gasoline related constituents. The two pesticide/herbicide plumes that were identified in the GeoTracker database have no information or data available.

2.7.3.7 Sodium and Chloride

Based on drinking water standards, the recommended secondary maximum contaminant level (SMCL) of chloride is 250 parts per million (ppm) with an upper limit of 500 ppm. There is no primary drinking water standard for sodium, however Water Quality Goals for Agriculture, published by the Food and Agriculture Organization of the United Nations in 1985, has set Agricultural Water Quality Goals for sodium and chloride at 69 ppm and 106 ppm, respectively. The criteria identified are protective of various agricultural uses of water, including irrigation of various types of crops and stock watering. These levels are used as a baseline to compare against and are not intended to represent an acceptable maximum value for the Subbasin. Since a majority of the land use in the Subbasin is irrigated lands, the Agricultural Water Quality Goals for sodium and chloride are used for this portion of the water quality evaluation.

There are four primary sources of sodium: agriculture, municipal, industrial, and natural. Agriculture practices result in evaporation of irrigation water which removes water and leaves the salts behind. Plants may also naturally increase soil salinity as they uptake water and exclude the salts. Application of synthetic fertilizers and manure from confined animal facilities are also other means by agriculture. A municipal source of sodium occurs through the use of detergents, water softeners, and industrial processes. Wastewater discharged to Publicly Owned Treatment Works (POTWs) and septic systems can increase salinity levels. An industrial source is by industrial processes such as cooling towers, power plants, food processors, and canning facilities. The last source is naturally from the groundwater, which contains naturally-occurring salts from dissolving rocks and organic material.

Only a few wells within the Kaweah Subbasin that have increasing or elevated sodium and chloride levels. However, there are small pockets within the Subbasin that have increasing or elevated sodium and chloride levels. ***Figure 81*** identifies where those wells are located. Sodium and chloride levels are increasing and, in some cases, already over the Agricultural Water Quality goals.

Figure 82 shows trends from two wells in a public water system located between Highway 65 and the Friant-Kern Canal with increasing chloride trends that have exceeded the Agricultural Water Quality goals and in one well, also exceeding the secondary drinking water standard. ***Figure 83*** also shows trends from wells within the City of Lindsay, where the chloride levels show a similar trend.

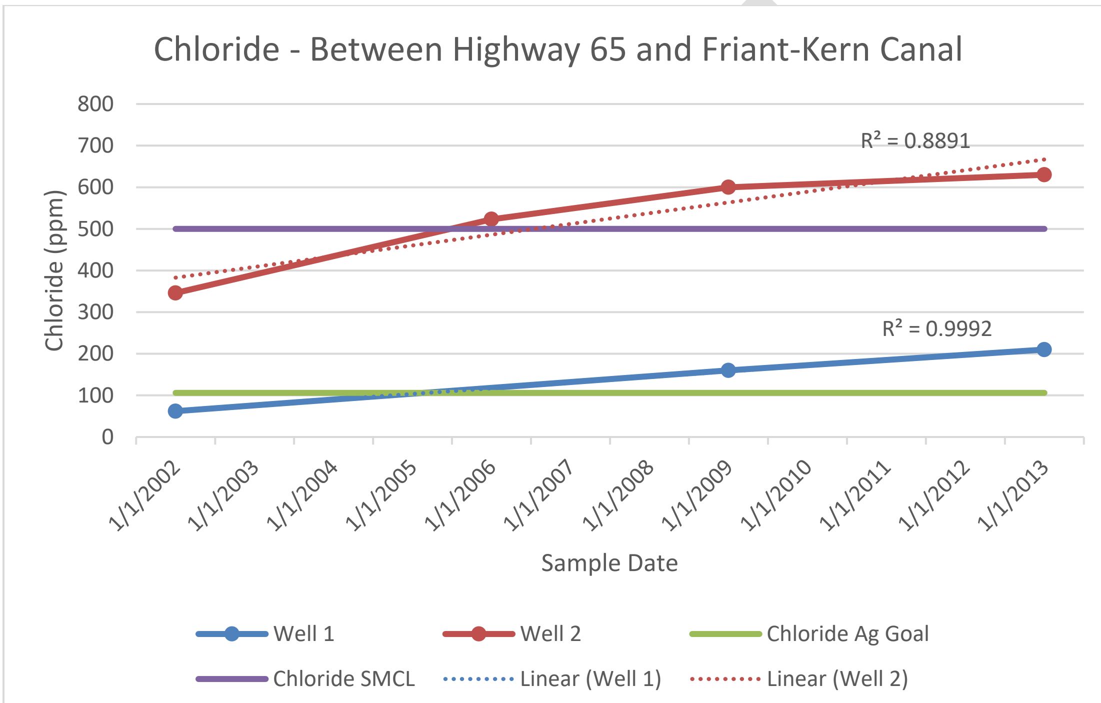

Figure 82: Chloride Trend of Two Wells Located Between Highway 65 and Friant-Kern Canal

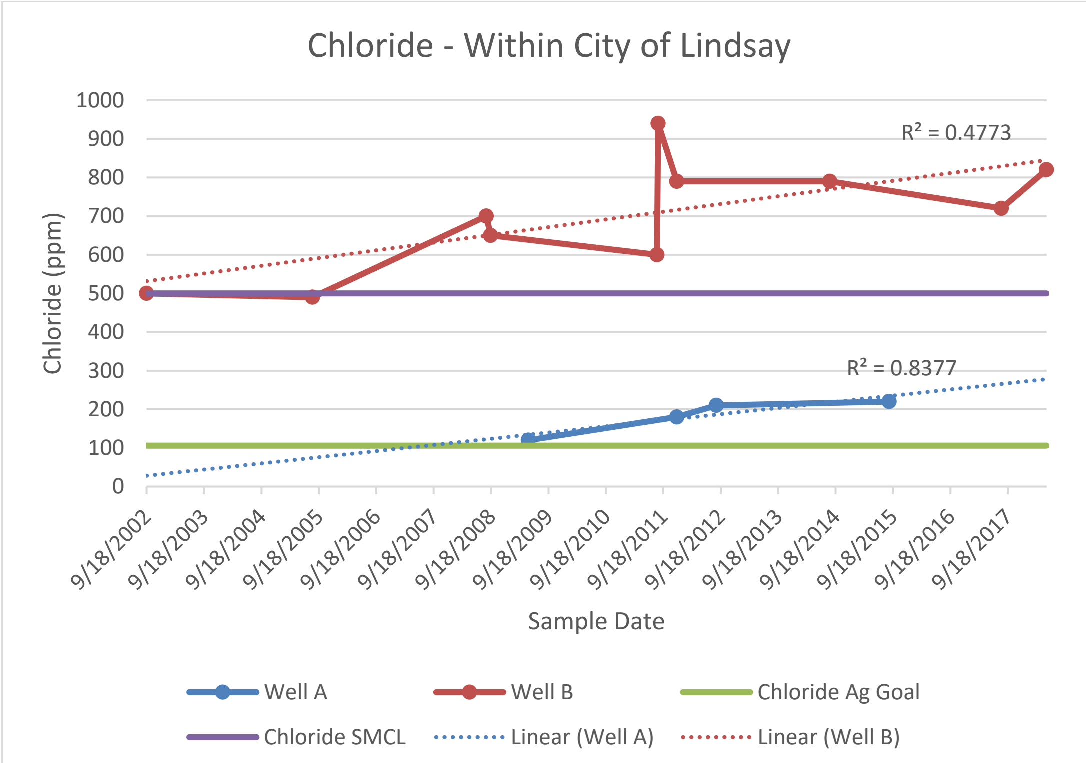

Figure 83: Chloride Trends of a Public Water System with Wells Within City of Lindsay

Findings from this evaluation show that the most common water quality issues within the Subbasin are: nitrate, arsenic, and PCE. Wells with high arsenic correlates with deeper, older water that is associated with the Corcoran Clay. The pH levels were also higher with wells having arsenic levels over 10 ppb. Nitrate is prevalent throughout the Subbasin with higher concentrations from east of Highway 63 to Highway 245 in the north and from Road 152 to the eastern extent of the Subbasin. These zones had greater than 50% of the land use as orchard and vineyards. Also, septic system density is greater in these areas compared to the rest of the Subbasin. Well construction also plays a factor in both elevated arsenic and nitrate levels. Deeper wells, greater than 250 ft., tend to have higher arsenic levels. On the other hand, shallow wells or wells with sanitary seals less than 250 ft. tend to have higher nitrate levels. The city-wide PCE plume in Visalia is something that needs to be monitored since it is an ongoing investigation. All other constituents that were evaluated are not a Subbasin-wide issue.

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2.8 Land Surface Subsidence §354.16 (e)

Inelastic (irrecoverable) land subsidence (subsidence) is a major concern in areas of active groundwater extraction due to increased flood risk in low lying areas; well casing, canal and infrastructure damage or collapse; and permanent reduction in the storage capacity of the aquifer.

2.8.1 Cause of Land Subsidence

Several processes contribute to land subsidence in the Subbasin and include, in order of decreasing magnitude: aquifer compaction by overdraft, hydrocompaction (shallow or near-surface subsidence) of moisture deficient deposits above the water table that are wetted for the first time since deposition, petroleum reservoir compaction due to oil and gas withdrawal, and subsidence caused by tectonic forces.

Inelastic compaction (subsidence) typically occurs in the fine-grained beds of the aquifers and in the aquitards due to the one-time release of water from the inelastic specific storage of clay layers caused by groundwater pumping. When long-term groundwater pumping and overdraft occurs, the aquifer system can become depressurized, and water originally deposited within the fine-grained units can be released from the clay layers. This depressurization allows for the permanent collapse and rearrangement of the structure, or matrix, of particles in fine-grained layers. Groundwater cannot re-enter the clay structure after it has inelastically collapsed. This condition represents a permanent loss of the water storage volume in fine-grained layers due to a reduction of porosity and specific storage in the clay layers. Although space within the overall aquifer is reduced by subsidence of the land surface and reduced thickness of the clay layers, this storage reduction does not substantially decrease usable storage for groundwater because the clay layers do not typically store significant amounts of recoverable, usable groundwater (LSCE, 2014). However, this one-time release of water from compaction has been substantial in some areas of the San Joaquin Valley. Although the largest regional clay unit in and adjacent to the Kaweah Subbasin is the Corcoran Clay, a relatively insignificant volume of water has been released from storage from it (Faunt et al., 2009). This is likely because of its large thickness and low permeability. However, the groundwater quality of the aquifers, however, could be impacted by the lower quality of groundwater emanating from the depressurized clay layers.

2.8.2 Regional Cause and Effect of Subsidence

Figure 84 through *Figure 88* of this section present land subsidence at a subbasin scale; however, the data also show that subsidence occurs regionally where the Corcoran Clay and other associated fine-grained units are present in the subsurface. Areas where greater groundwater pumping has occurred coupled with newly installed deeper well screen intervals below the Corcoran Clay may contribute to land subsidence from dewatered clays in previously unpumped depth intervals of the aquifer system. This topic is further discussed in the sustainable management criteria section of this report. These pumping intervals occur in the Kaweah Subbasin as well as in neighboring subbasins to the Northwest, West, Southwest, and South of the Subbasin. Additional data and coordination between subbasins are recommended to better understand the effects of groundwater management on the mitigation of land subsidence.

2.8.3 Past Land Subsidence

Historical documentation of subsidence within the Central Valley has relied on various types of data, including topographic mapping and ground surveys (including the remote sensing NASA JPL InSAR data), declining groundwater levels, borehole extensometers, and continuous GPS station information. Within the Subbasin, subsidence has been documented by the National Geodetic Survey at up to 8 feet from 1926 to 1970, as shown on ***Figure 84***. Groundwater overdraft (when there is a lack of surface water supply for irrigation) is considered to be the primary driver for historical land subsidence in the Central Valley (Faunt et. al., 2009). USGS estimates that about 75 percent of historical subsidence in the Central Valley occurred in the 1950s and 1960s, corresponding to extensive groundwater development. Time-series charts of historical water levels were compared with the DWR water year indices corresponding to above normal, below normal, and normal climatic conditions. In general, water levels declined during below normal water year indices (critical, dry, or below normal), while water levels were more stable or recovering during high water year indices (wet, above normal).

2.8.4 Recent Land Subsidence

Recent subsidence studies of the Central Valley, including the Subbasin, have utilized satellite-based, remote sensing data from the InSAR and aircraft-based L-band SAR or Unmanned Aerial Vehicle Synthetic Aperture Radar (UAVSAR) programs, led by NASA/JPL, as well as other international researchers. These datasets, shown on ***Figure 85*** and ***Figure 86***, provide a continuous estimate of subsidence over a large portion of the Subbasin. The annual rate of subsidence for these datasets are shown on ***Figure 87*** through ***Figure 88***.

Recent subsidence in the Subbasin and in the Tule Subbasin (immediately to the south) can also be observed at two continuous GPS (CGPS) stations, shown on ***Figure 85*** through ***Figure 88***. These monitoring points are located to the northwest of Farmersville (station P566), and southwest of Porterville (P056) and provide recent, localized subsidence data from November 2005 to present. These CGPS stations are monitored as a part of UNAVCO's Plate Boundary Observation (PBO), the California Real Time Network (CRTN) and California Spatial Reference Center (CSRC) of the Scripps Orbit and Permanent Array Center (SOPAC). Daily CGPS position time-series data with 6 month moving averages are plotted and displayed with InSAR data for comparative purposes on ***Figure 85*** through ***Figure 88***. The quality of these datasets is deemed "reproducible" by UNAVCO, and cumulative rates of subsidence were calculated by taking annual water year averages of the dataset. Annual averages of CGPS or future extensometer data may permit a more meaningful comparison with InSAR data in future calculations and analyses. Another dataset to be used in the future for comparing InSAR and CGPS data, are level surveying data from local subsidence monitoring benchmarks. These benchmarks represent a piece of the subsidence monitoring network as described in the monitoring section of this report.

Time-series charts of subsidence data are included on ***Figure 85*** and ***Figure 86***, and are compared with the DWR water year indices. Greater rates of compaction/subsidence generally correlate with below normal water year indices (critical, dry, or below normal), while lower rates of subsidence are observed during high water year indices (wet, above normal). The inserted hydrographs show that, in recent times, nearby water levels do not consistently correspond with DWR water year indices, likely due to changes in groundwater management practices and improved surface water supplies since the 1960's. Upon further examination of time-series data for the Corcoran Station, water levels

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in the lower aquifer (deep) better correlate with the water year indices and changes in subsidence rates, in contrast to the water levels in the upper aquifer (shallow), which do not correlate as readily with changes in subsidence rates.

Recent and historical subsidence data are summarized in ***Table 43***. It includes a summary of InSAR data published in a subsidence study commissioned by the California Water Foundation (LSCE, 2014), and by JPL. The InSAR data were collected from a group of satellites (Japanese PALSAR, Canadian Radarsat-2, and ESA's satellite-borne Sentinel-1A and -1B), from 2006 to 2017, with a data gap from 2011 to 2014 because there was a gap in satellite data collection until the ESA Sentinel satellites were launched in 2014.

According to the California Water Foundation study (LSCE, 2014), subsidence is on-going and leading to significant impairment of water deliveries from the Friant-Kern Canal south of the Kaweah Subbasin. According to DWR (2014), the Kaweah Subbasin was rated at a high risk for future subsidence due to 1) a significant number of wells with water levels at or below historical lows; 2) documented historical subsidence; and 3) documented current subsidence. Moreover, greater amounts of subsidence are occurring to the west, southwest, and south of Kaweah in adjacent subbasins. The amount of future subsidence will depend on whether future water level elevations decline below previous lows and remain at these levels for years. Maintaining water at a suitable water level elevation (threshold) may limit future subsidence caused by groundwater pumping within the Kaweah Subbasin.

2.8.5 Subsidence Locations

Historical subsidence within the Subbasin, as determined by the data sources discussed above, are presented on ***Figure 84*** through ***Figure 88***. Hydrographs for selected wells are plotted with subsidence data for comparison purposes. Although undesirable results due to subsidence are dependent up on declines in groundwater elevations and potentiometric surfaces for deeper aquifers, the presence of regional fine-grained stratigraphic units, such as the Corcoran Clay, and localized areas of substantial thicknesses of fine-grained layers is also a major factor. Likewise, key infrastructure that may be impacted by land subsidence should also be considered to determine areas that are sensitive to impacts from subsidence.

In general, groundwater levels lowered by pumping correspond with observed land subsidence, as seen on ***Figure 84***. The groundwater elevation declines shown on this figure can also be compared to the subsidence trends shown on other subsidence maps. The magnitude and annual rate of subsidence increases toward the west and southwest within the Kaweah Subbasin, and progressively increase to the south and west of the Subbasin boundaries, according to InSAR data as well as CGPS data and historical data from the Deer Creek Extensometer and surveying information along the Friant-Kern Canal.

Cumulative and annual rates of recent subsidence (Spring 2015 through 2017) are presented in ***Figure 86*** and ***Figure 88***, respectively. When compared to the cumulative and annual rates of subsidence shown for January 2007 through May 2011, shown on ***Figure 85*** and ***Figure 87***, it is apparent that land subsidence has increased in recent years, in response to drought conditions and increased groundwater demand. This trend is also reinforced by regional extensometer and CGPS data. Overall the limited CGPS data presented in the figures reasonably corresponds with the estimated magnitude of subsidence estimated by the InSAR data.

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2.8.6 Measured Subsidence

The following tabulated data includes cumulative inches of subsidence within Kaweah, and approximate annual rates for various data collection periods.

Table 43: Land Subsidence Data

Subbasin Area	Date Range	Cumulative Subsidence (inches)	Calculated Annual Rate of Subsidence (inches/year)	Source
Kaweah Subbasin	1926 - 1970	~0 - 96	0 – 2.2	Ireland, 1984. Topographic Maps and Leveling Data.
North of Farmersville	2007 - 2017	4.9	0.5	CGPS PBO (P566). Data are averaged by water year 2007 to 2017
South of Porterville (just outside of Subbasin)	2007 - 2017	21.3	2.1	CGPS PBO (P056 just south of Subbasin). Data are averaged by water year 2007 to 2017
Deer Creek. South of Porterville	1970 – 1982	15.8	1.3	Extensometer Data from USGS CA Water Science Center
Corcoran[5]	Sep. 2010 – May. 2017	76.35	11.4	Corcoran CGPS Station (CRCN). Central Valley Spatial Reference Network (CVSRN) Caltrans via California Real Time Network (CRTN) at SOPAC.
West and central Kaweah Subbasin *(Highest values in SW near Corcoran)*	Jan. 2007 – Mar. 2011	0 – 33.9	0 - 8	LSCE, 2014. Compiled from InSAR.
Kaweah Subbasin *(Highest values in SW near Corcoran)*	2015 - 2017	0 – 26.7	0 – 13.4	InSAR. Downloaded from DWR SGMA Viewer.
Mile Post 88. Friant-Kern Canal (FKC). Between Lindsay and Strathmore	1945/1951 to 2017	~4.6	~0.07	USBR FKC Subsidence Monitoring Surveys. NGVD29 to NAVD88
Mile Post 92 FKC. South of Subbasin	1945/1951 to 2017	~6.7	~0.1	

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[5] Cumulative Subsidence calculated from Annual Rate Value of 11.4 inches per year.

Subbasin Area	Date Range	Cumulative Subsidence (inches)	Calculated Annual Rate of Subsidence (inches/year)	Source
Mile Post 95 FKC. Tule River Siphon	1945/1951 to 2017	~21.6	~0.3	
	1959 to 2017	~20.3	~0.4	
Mile Post 96 FKC. South of Tule River.	1945/1951 to 2017	~27.4	~0.4	
	1959 to 2017	~25.2	~0.4	
Mile Post 99 FKC. West of CGPS P056	1945/1951 to 2017	~78.9	~1.1	

Although the highest rates of subsidence occur outside of the Kaweah Subbasin; to the west and south in the Tulare Lake and Tule subbasins, respectively; there has been significant subsidence within the Subbasin, largely focused in the western and southwest portions. It is apparent that this subsidence is coincident with both a decline in water levels from pumping near Corcoran, as well as pumping within the Kaweah and the Tule subbasins. Higher levels of subsidence have also been estimated southeast of Tulare and appear to correlate with neighboring subsidence in the Tule Subbasin. Overall, annual subsidence rates vary spatially but have increased in magnitude during the recent drought conditions, as groundwater supplied a higher percentage of agricultural demand.

2.8.7 Release of Water from Compression of Fine-Grained Units

Long-term overdraft conditions from groundwater pumping can lead to depressurization of the aquifer system and corresponding dewatering of fine-grained units (or dewatering of clays). The one-time release of water from dewatered clays may represent a one-time principle source of groundwater released from storage to the aquifer system, because fine-grained deposits constitute more than half of the unconsolidated sediments in the Central Valley (Faunt et. al., 2009). The 1989 USGS model (CV-RASA) and other studies attributed most of this one-time release of water to the aquifer system to dewatering of fine grained interbeds of clays and not from regional confining beds such as the Corcoran Clay (Ireland and others, 1984; Williamson and others, 1989; and Faunt et. al., 2009). It is further postulated that "a relatively significant volume of water has not yet been released from storage in the Corcoran Clay" (Faunt et. al., 2009).

2.8.7.1 Water Volume Calculation

The dewatering of clays may lead to measurable land subsidence, in which case, a rudimentary estimate of the volume of water contributing to the aquifer system by the dewatering of clays can be calculated. The land subsidence is a proxy for estimating one-time release of water from clays to aquifer system. A rough estimate of the volume water is calculated herein, by taking the land surface area multiplied by the measured change in vertical elevation of land surface, mostly attributed to land subsidence. Ideally, extensometers would provide depth-specific measurements of compaction of specific zones, instead of using changes in land surface; however, CGPS measuring points were used in the absence of extensometer data for this calculation. In addition, reliable InSAR data are not available for this time period, or for the entire Subbasin, to use as a control for this calculation. For a preliminary volume calculation of one-time water release from the clay layers to the aquifer system, the Subbasin was divided into relative zones of decreasing subsidence starting from the Southwest of the basin to the East-Northeast. These zones were approximated by using the 2015 to 2017 InSAR data as a qualitative tool to identify regimes or different zones of cumulative subsidence.

Figure 77, illustrates the zones which were chosen to correspond with nearby areas of subsidence that have a CGPS station. The Southwest zone corresponds with the 1. CRCN Corcoran station, the adjacent area to the Northeast corresponds with the 2. P056 Porterville station, the next adjacent area corresponds with the 3. P566 Visalia station which is situated in this zone, and the 4. Eastern-most area where negligible to zero subsidence has historically been recorded is not assigned to a CGPS station but is estimated as zero for this calculation. These areas or regimes of subsidence are base only on InSAR data and would require further refinement by additional data for better accuracy. It is likely that the Southwestern-most zone is overestimating the amount of water contributed to the system due to clay dewatering because the Corcoran station reports very high values of subsidence, which decreases rapidly toward the Northeast. The date range of analysis was chosen from September 30, 2011 to September 30, 2017, for the CGPS Stations as presented in *Table 44*.

Table 44: Preliminary Estimate of Volume of Water (AF) by Land Subsidence (2011 to 2017)

	1. CRCN	2. P056	3. P566	4. East
Year	**(Mean Vertical Change (inches))**			
2011	-0.8	-5.2	-2.4	--
2012	-3.7	-6.1	-2.7	--
2013	-15.5	-7.4	-3.1	--
2014	-27.2	-9.5	-3.5	--
2015	-38.9	-12.5	-4.0	--
2016	-52.4	-16.9	-4.6	--
2017	-62.1	-22.1	-5.3	--
Cumulative Total (inches) (9/30/11 to 9/30/17)	-61.3 (-5.1 ft)	-16.9 (-1.4 ft)	-2.9 (-0.2 ft)	-- (0 ft)
Rate (inches/year) (9/30/11 to 9/30/17)	-10	-2.8	-0.2	--
Acreage for each Subsidence Area	98,100	156,000	127,700	64,300
Preliminary Estimate of Volume of Water (AF) by Land Subsidence (2011 to 2017)	500,600	219,300	31,700	0

2.9 Interconnected Surface Water

Both the loss of streamflow to groundwater (losing streams) and the loss of groundwater to surface streams (gaining streams) are part of the natural hydrologic system. The direction of flow depends on the relative elevation of these inter-connected waters, and the rate of flow depends on the properties of the aquifer matrix and the gradients of the water sources. Many surface water-groundwater systems reverse the flow direction seasonally in response to either groundwater extraction or significant groundwater recharge related to spring and early summer runoff.

The flow rate between interconnected surface water-groundwater systems will generally increase as groundwater levels are pumped below the bottom of the surface channel and the flow gradient steepens. While not altogether common in the southern San Joaquin Valley, in many areas, the depth-to-groundwater results in a nearly vertical gradient from the surface stream, and depletion of streamflow becomes nearly constant, varying only with the wetted area of the stream channel.

Declining groundwater levels may decrease the discharge to surface streams and result in reduced instream flow and supply to wetland, estuary areas, and other groundwater dependent ecosystems. Loss of streamflow may reduce the supply available for downstream diverters or require additional releases to be made from surface water reservoirs to meet required instream and downstream needs.

An analysis of baseline conditions has been performed, which considered both local knowledge of natural streamflow within the Kaweah River system including timing and flow regimes (gaining and losing stretches) and gaged streamflow compared to groundwater-level information. Based on this, an estimate of streamflow contribution to the groundwater supply is included in the water budget for the period between water years 1981 and 2017.

Because the streamflow data has been compiled from continuous monitors (Parshall flumes) located throughout a majority of the Subbasin and compiled for every month of the base period, the cumulative effects of both wet year and drought year impacts are well-understood. Furthermore, semiannual groundwater-level measurements collected within Subbasin wells support the understanding of the variability of the relative proximity and/or separation of the surface water from the groundwater in both wet and drought conditions.

In general, the vast majority of the natural streams and manmade ditches (channels) throughout the Subbasin are considered losing channels throughout the year with considerable vertical separation between the channels and groundwater. This vertical separation and disconnection between surface and groundwater throughout much of the San Joaquin Valley floor is recognized by DWR and USGS in the conceptualizations for their regional numerical groundwater models CVHM and C2VSim. Streams located in the eastern portion of the Subbasin, generally between the Friant Kern Canal eastward to McKay Point (See ***Figure 20***), are more likely to be relatively neutral to gaining stream reaches during limited times of year.

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2.10 Groundwater Dependent Ecosystems

Where groundwater and surface water are separated by significant distances, as is the case with most of the Kaweah Subbasin, the groundwater does not interact with the natural streams or manmade ditches. In these areas, therefore, no possibility exists for the presence of Groundwater Dependent Ecosystems to exist. However, where the base of the aquifer is relatively shallow, as is the case along the eastern boundary of the Subbasin adjacent the Sierra Nevada, groundwater levels are closer to the surface.

As presented on ***Figure 19***, areas where groundwater is within 50 feet of the ground surface are located along the Kaweah River (Greater Kaweah GSA) and in two areas within the East Kaweah GSA. Notably, these represent areas where groundwater elevations as of the Spring of 2015 has risen to within 50 feet of the ground surface. The indicated areas are preliminary and subject to review of the local GSAs, who know better which areas can be considered Potential GDEs. This can be addressed as part of a further study.

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2.11 Conditions as of January 1, 2015

Groundwater levels measured in the spring and fall of each year by the DWR and member agencies provide the data required to document groundwater conditions January 1, 2015, as required. To document the groundwater conditions as of January 1, 2015 when SGMA was enacted, we are using the first round of groundwater level measurements that occurred after that date as the "baseline" condition against which future conditions will be compared. Groundwater levels at that time are presented as ***Figure 30***, along with the water level hydrographs presented as ***Figure 35***.

Review of the map and hydrograph indicate that water levels were near the lowest levels on record. In the spring of 2015 groundwater elevations varied from as low below sea level in the western portion of the basin near the cities of Hanford and Corcoran, to a high of over 400 feet above in the East Kaweah GSA area. As discussed, the exceptionally high pumpage was due in part to the severe drought coupled with a complete lack of delivery of imported CVP water for two years leading up to this period.

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Large Format Figures

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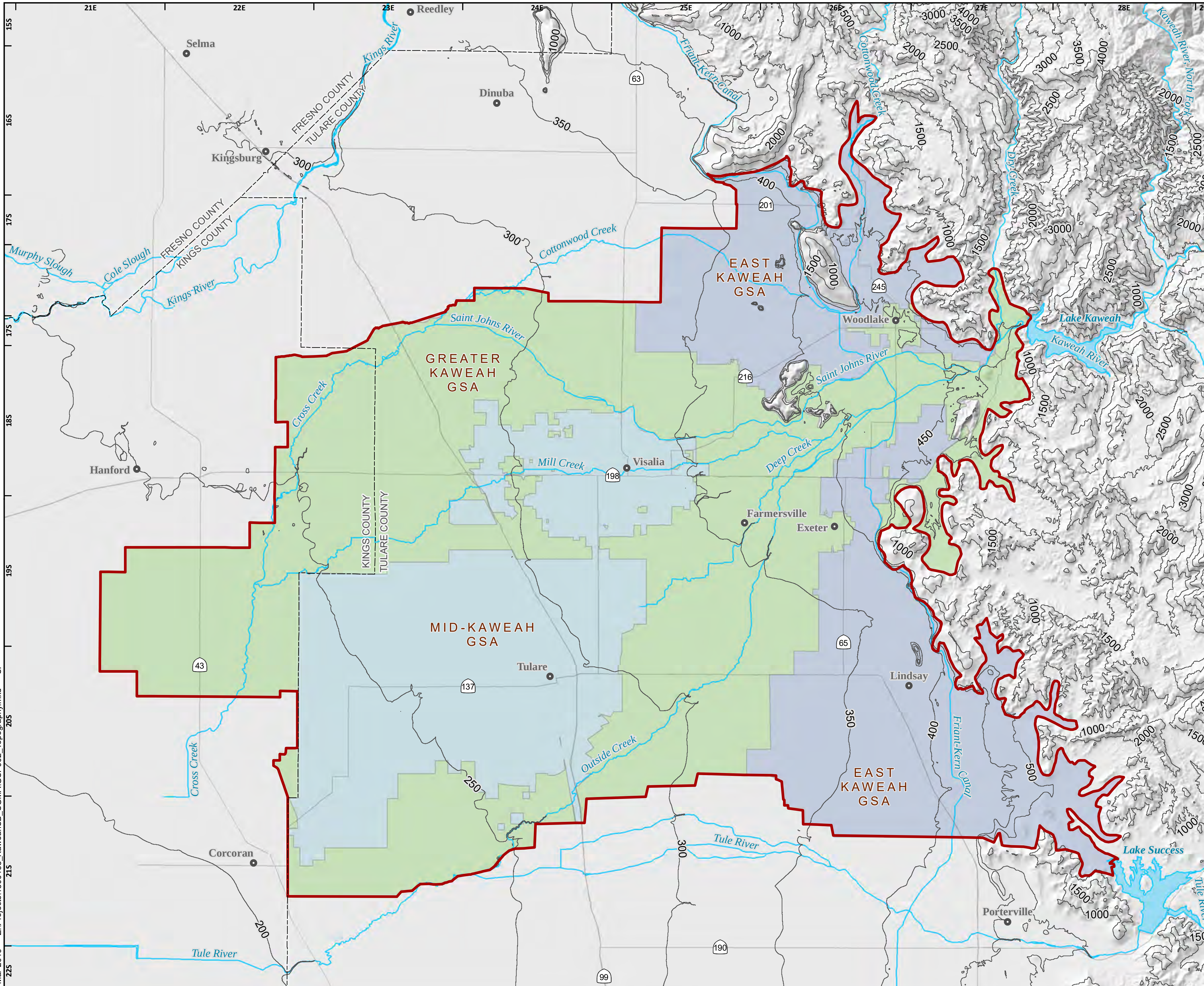

TOPOGRAPHIC MAP

Topographic Elevation Contours

Ground Surface Elevation Contours (500-ft interval at greater than 500 ft msl; 50-ft interval at less than 500 ft msl)

GSA Boundaries

East Kaweah GSA

Greater Kaweah GSA

Mid-Kaweah GSA

Kaweah Subbasin Boundary

All Other Features

Highway

Waterway

Lake

0 2 4 8

Miles

N

Kaweah Subbasin
Groundwater Sustainability Plan
Tulare County, California

Kaweah Subbasin

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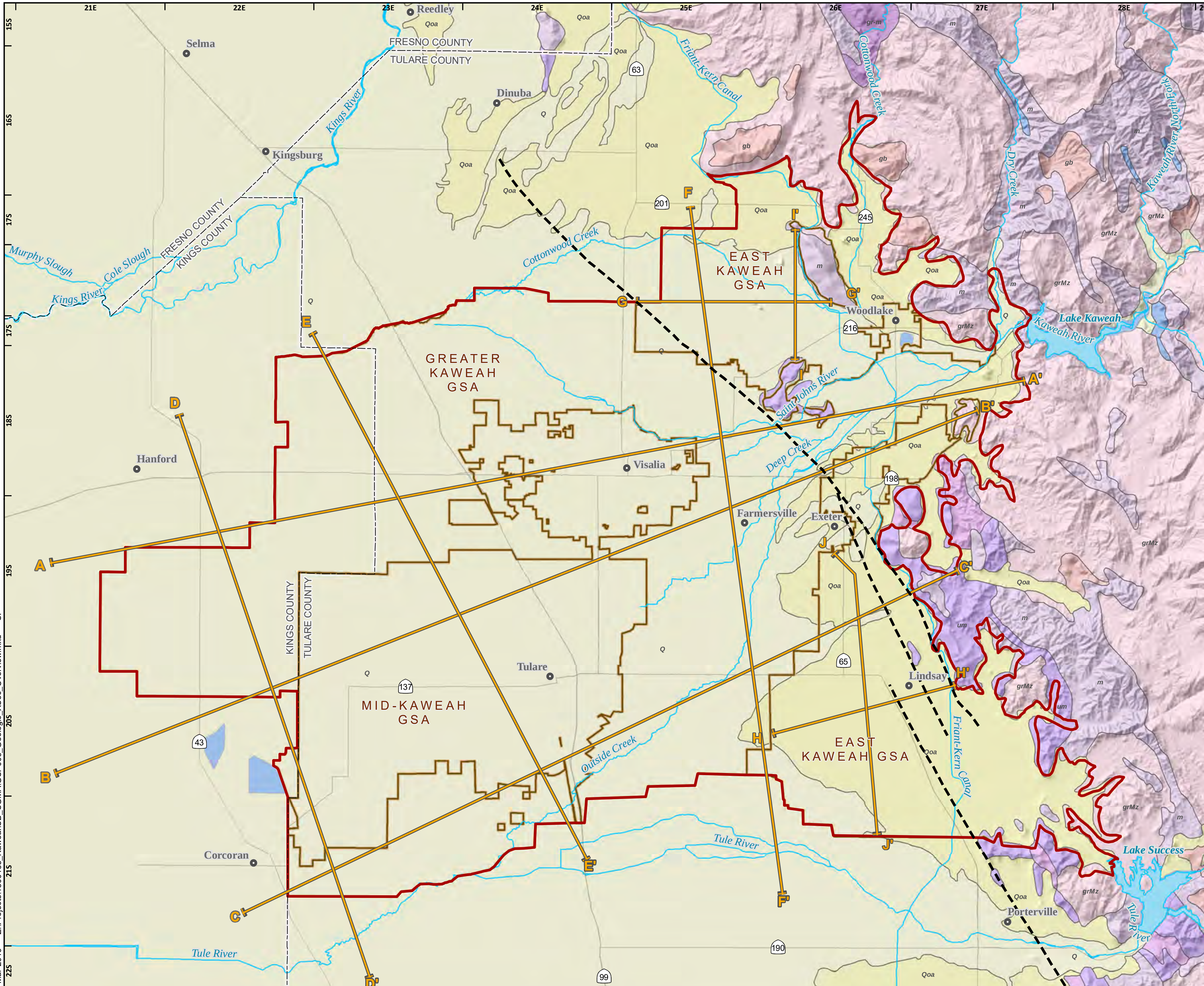
MARCH 2019 **DRAFT** FIGURE 1

11-Mar-2019 Z:\Projects\1800138_KaweahSB_SGMA\GSP002_Topography.mxd SI



GEOLOGIC AND CROSS SECTION LOCATION MAP

- Rocky Hill Fault Zone
- Cross Section Line

Surficial Geology

- Alluvium (Q)
- Older Alluvium (Qoa)
- Marine Sedimentary Rocks (ls)
- Mixed Granitic and Metamorphic Rocks (gr-m)
- Metavolcanic Rocks (mv)
- Granite (grMz)
- Ultramafic Plutonic Rocks (um)
- Gabbro (gb)
- Undated Granitic Rocks (gr)
- Mixed Rocks (m)
- Water
- Kaweah Subbasin Boundary
- Kaweah Subbasin GSA

All Other Features

- Highway
- Waterway
- Lakes

0 2 4 8
Miles

N

Kaweah Subbasin
Groundwater Sustainability Plan
Tulare County, California

Kaweah Subbasin

GEI Consultants

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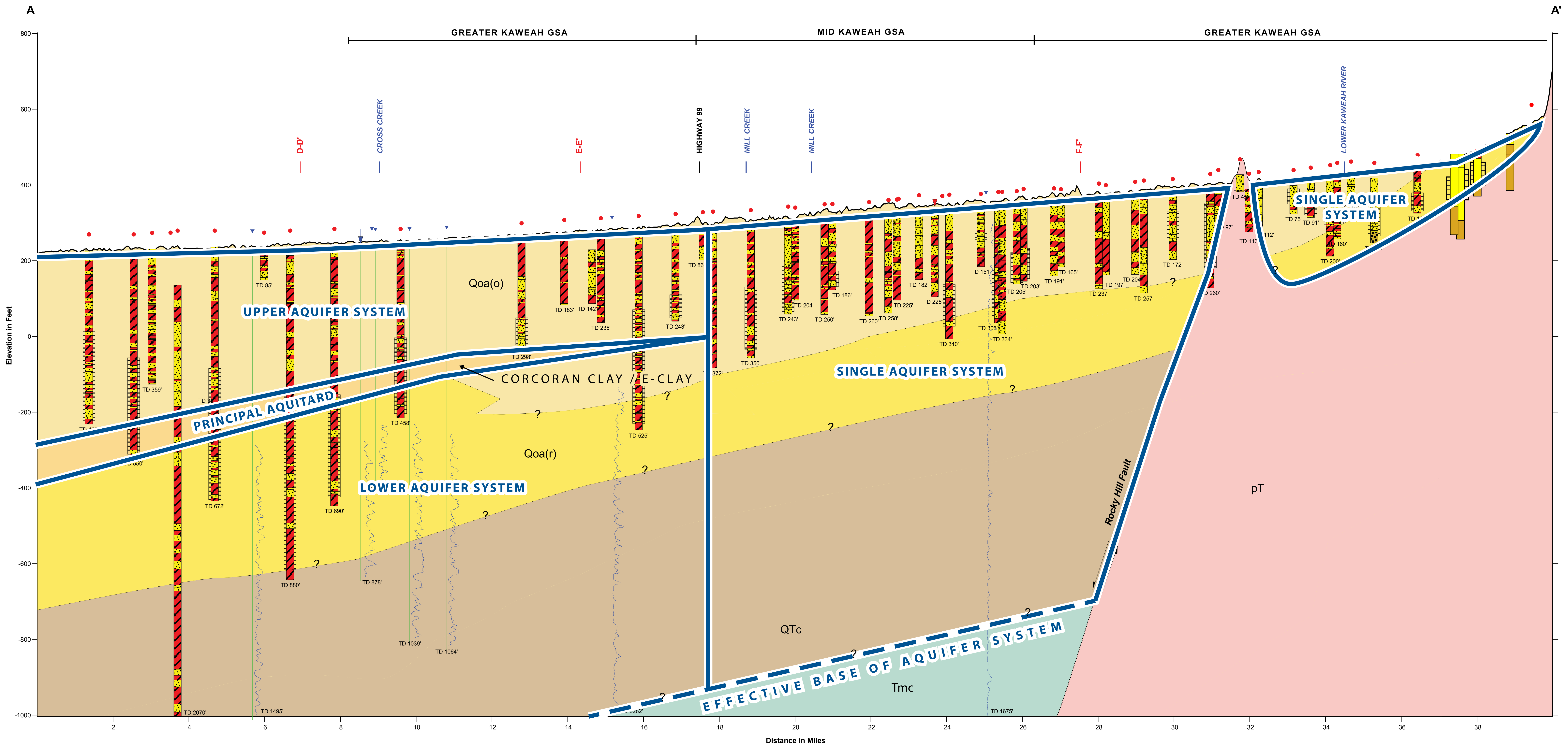
MARCH 2019 **DRAFT** FIGURE 3



DRAFT

FIGURE 4

Cross Section A

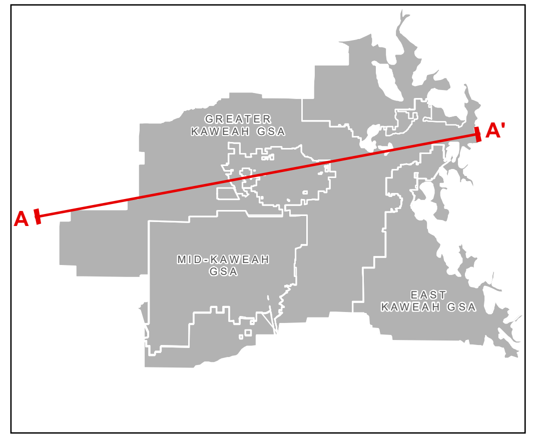
Kaweah Subbasin
Groundwater Sustainability Plan

LEGEND

- Qya - Younger Alluvium
- Qoa(o) - Older Alluvium (oxidized)
- QTl - Corcoran Clay (E-Clay, lacustrine)
- Qoa(r) - Older Alluvium (reduced)
- QTc - Continental Deposits
- Tmc - Marine and Continental Rocks
- pT - Basement Complex
- Generalized Boundaries of Aquifer System

Boring

- Clay
- Sand
- Sandstone/Rock



NOTES:

Cross section modified from Fugro, 2007, Plate 14, Geologic Cross Section A

1. Stratigraphic contacts are approximate and are interpreted from well and electric logs. Conditions vary both along and perpendicular to the section line.
2. Wells and electric logs are projected to a distance of one mile onto the lines of the cross sections. Therefore stratigraphic contacts may not exactly correspond to the contact indications (lithology, shear strength, etc.) in the logs.
3. Effective base of aquifer system is based on review of recent well logs, professional judgment based on collaboration with adjoining subbasins, and USGS base of fresh water contacts.

SCALE

200 ft

0 — 2 mi

VERTICAL EXAGGERATION: 52.8X

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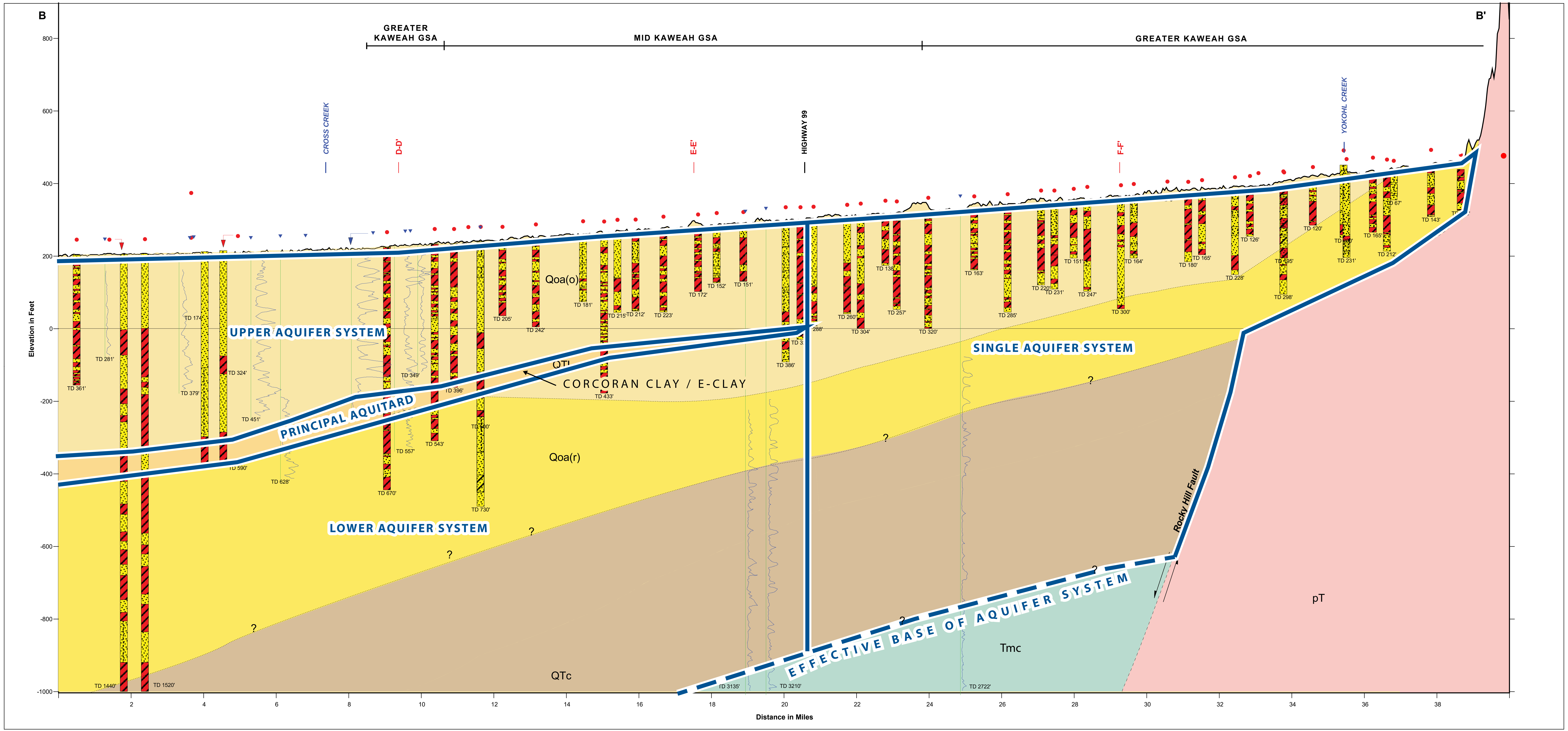


DRAFT **FIGURE 5**

Cross Section B

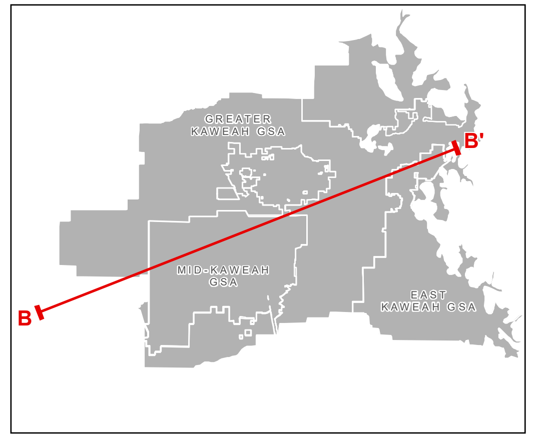
Kaweah Subbasin
Groundwater Sustainability Plan

LEGEND

- Qya - Younger Alluvium
- Qoa(o) - Older Alluvium (oxidized)
- QTl - Corcoran Clay (E-Clay, lacustrine)
- Qoa(r) - Older Alluvium (reduced)
- QTc - Continental Deposits
- Tmc - Marine and Continental Rocks
- pT - Basement Complex
- Generalized Boundaries of Aquifer System

Boring

- Clay
- Sand
- Sandstone/Rock



NOTES:

Cross section modified from Fugro, 2007, Plate 15,
Geologic Cross Section B

1. Stratigraphic contacts are approximate and are interpreted from well and electric logs. Conditions vary both along and perpendicular to the section line.
2. Wells and electric logs are projected to a distance of one mile onto the lines of the cross sections. Therefore stratigraphic contacts may not exactly correspond to the contact indications (lithology, shear strength, etc.) in the logs.
3. Effective base of aquifer system is based on review of recent well logs, professional judgment based on collaboration with adjoining subbasins, and USGS base of fresh water contacts.

SCALE

200 ft — 0 — 2 mi

VERTICAL EXAGGERATION: 52.8X

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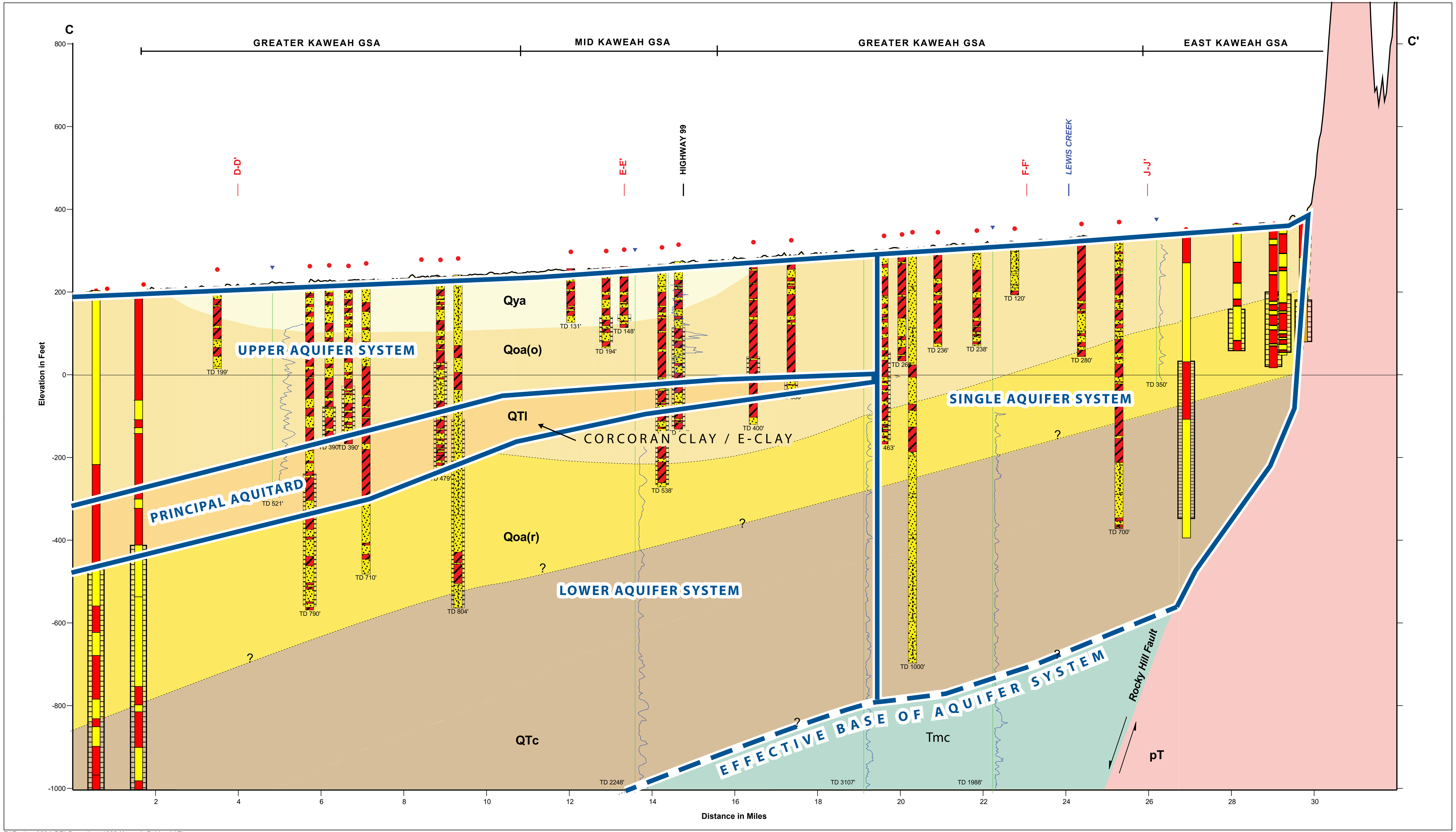
DRAFT

FIGURE 6

Cross Section C

Kaweah Subbasin
Groundwater Sustainability Plan

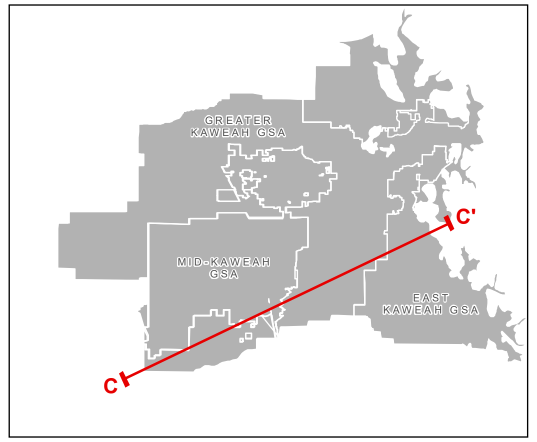


LEGEND

- Qya - Younger Alluvium
- Qoa(o) - Older Alluvium (oxidized)
- QTl - Corcoran Clay (E-Clay, lacustrine)
- Qoa(r) - Older Alluvium (reduced)
- QTc - Continental Deposits
- Tmc - Marine and Continental Rocks
- pT - Basement Complex
- Generalized Boundaries of Aquifer System

Boring

- Clay
- Sand
- Sandstone/Rock



NOTES:

Cross section modified from Fugro, 2007, Plate 16, Geologic Cross Section C

1. Stratigraphic contacts are approximate and are interpreted from well and electric logs. Conditions vary both along and perpendicular to the section line.
2. Wells and electric logs are projected to a distance of one mile onto the lines of the cross sections. Therefore stratigraphic contacts may not exactly correspond to the contact indications (lithology, shear strength, etc.) in the logs.
3. Effective base of aquifer system is based on review of recent well logs, professional judgment based on collaboration with adjoining subbasins, and USGS base of fresh water contacts.

SCALE

200 ft

0 — 2 mi

VERTICAL EXAGGERATION: 52.8X

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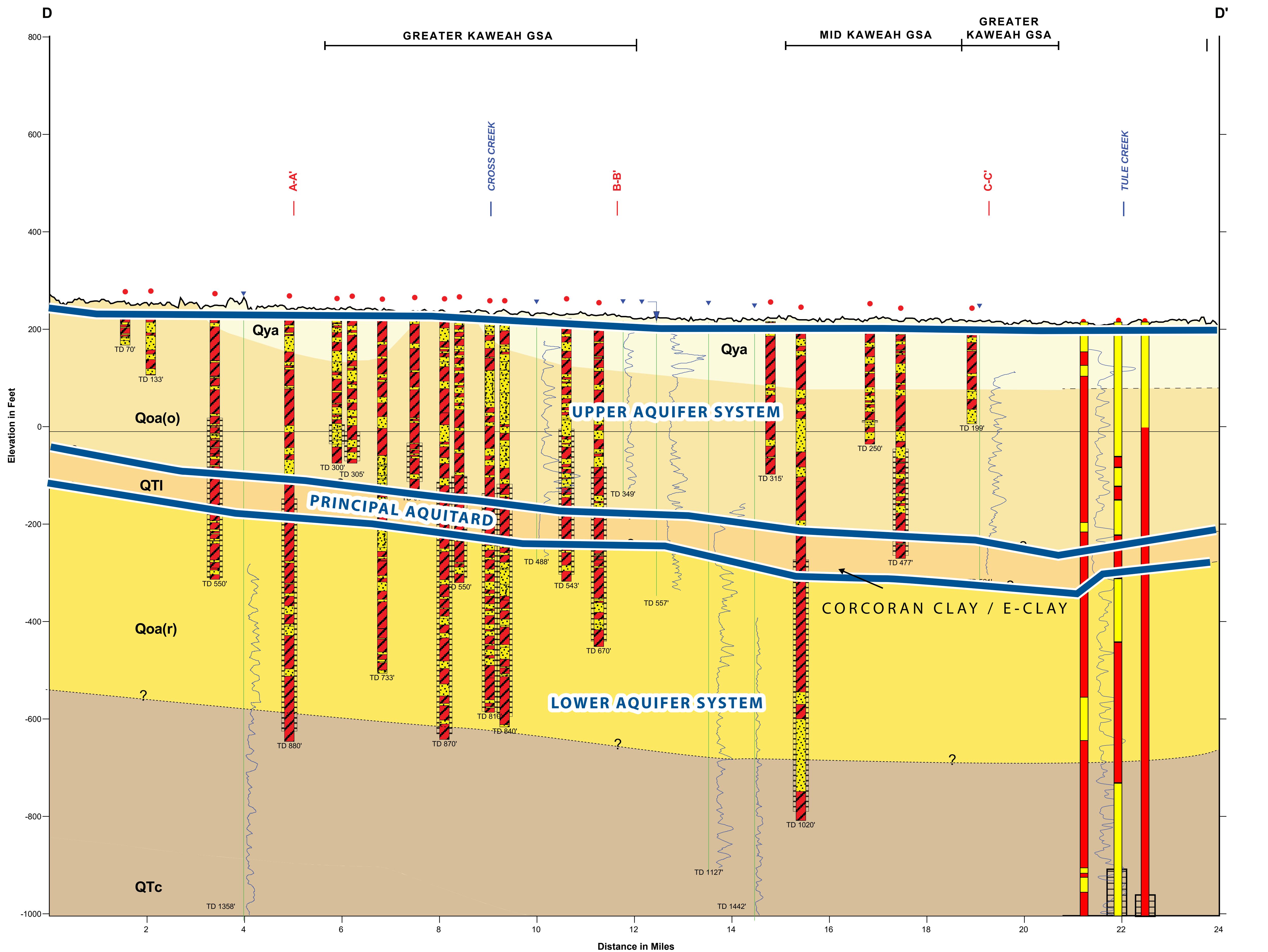


DRAFT **FIGURE 7**

Cross Section D

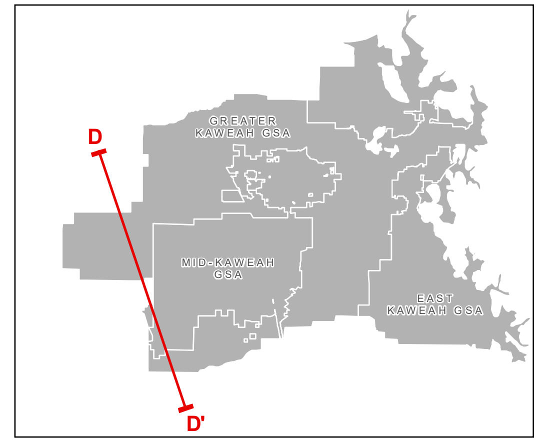
Kaweah Subbasin
Groundwater Sustainability Plan

LEGEND

- Qya - Younger Alluvium
- Qoa(o) - Older Alluvium (oxidized)
- QTl - Corcoran Clay (E-Clay, lacustrine)
- Qoa(r) - Older Alluvium (reduced)
- QTc - Continental Deposits
- Tmc - Marine and Continental Rocks
- pT - Basement Complex
- Generalized Boundaries of Aquifer System

Boring

- Clay
- Sand
- Sandstone/Rock



NOTES:

Cross section modified from Fugro, 2007, Plate 14, Geologic Cross Section D

1. Stratigraphic contacts are approximate and are interpreted from well and electric logs. Conditions vary both along and perpendicular to the section line.
2. Wells and electric logs are projected to a distance of one mile onto the lines of the cross sections. Therefore stratigraphic contacts may not exactly correspond to the contact indications (lithology, shear strength, etc.) in the logs.
3. Effective base of aquifer system is based on review of recent well logs, professional judgment based on collaboration with adjoining subbasins, and USGS base of fresh water contacts.
4. Effective Base of Aquifer System is base of continental deposits (Tulare Formation)

SCALE

200 ft

0 — 2 mi

VERTICAL EXAGGERATION: 52.8X

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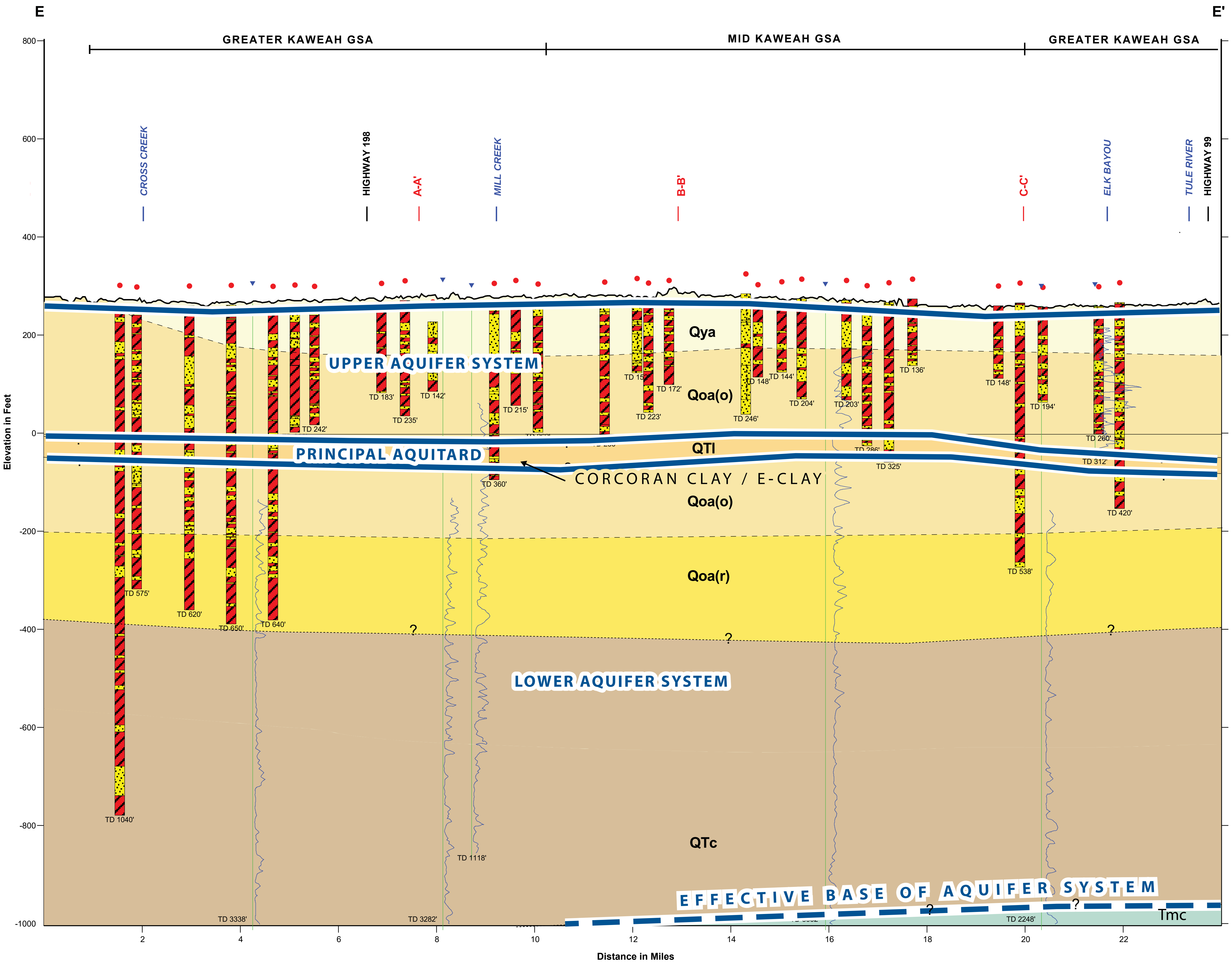

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DRAFT

FIGURE 8

Cross Section E

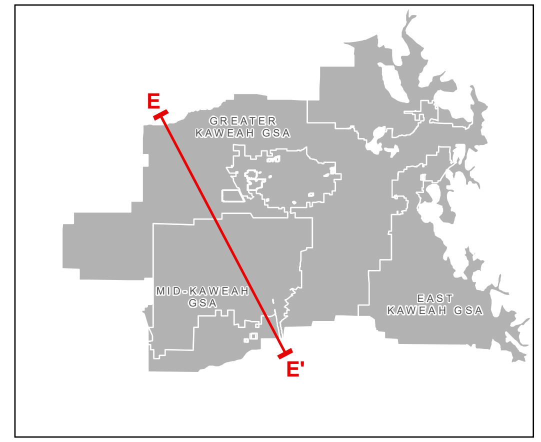
Kaweah Subbasin
Groundwater Sustainability Plan

LEGEND

- Qya - Younger Alluvium
- Qoa(o) - Older Alluvium (oxidized)
- QTl - Corcoran Clay (E-Clay, lacustrine)
- Qoa(r) - Older Alluvium (reduced)
- QTc - Continental Deposits
- Tmc - Marine and Continental Rocks
- pT - Basement Complex
- Generalized Boundaries of Aquifer System

Boring

- Clay
- Sand
- Sandstone/Rock



NOTES:

Cross section modified from Fugro, 2007, Plate 18, Geologic Cross Section E

1. Stratigraphic contacts are approximate and are interpreted from well and electric logs. Conditions vary both along and perpendicular to the section line.
2. Wells and electric logs are projected to a distance of one mile onto the lines of the cross sections. Therefore stratigraphic contacts may not exactly correspond to the contact indications (lithology, shear strength, etc.) in the logs.
3. Effective base of aquifer system is based on review of recent well logs, professional judgment based on collaboration with adjoining subbasins, and USGS base of fresh water contacts.

SCALE

200 ft

VERTICAL EXAGGERATION: 52.8X

0 — 2 mi

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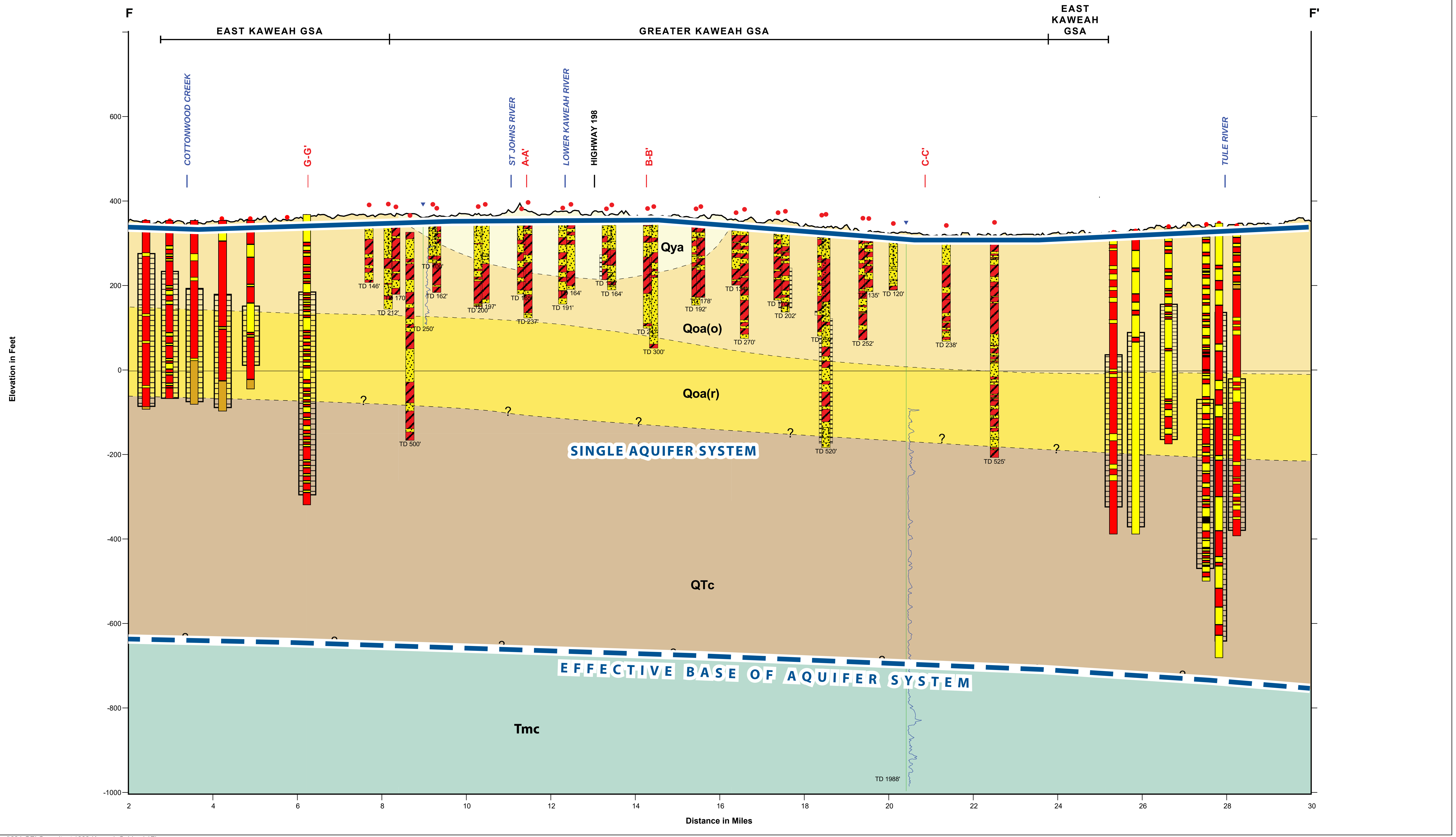


DRAFT **FIGURE 9**

Cross Section F

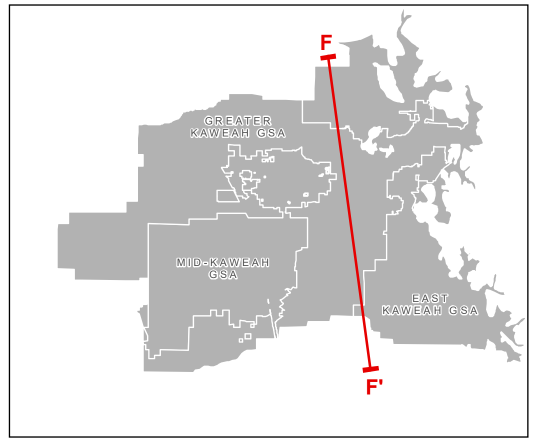
Kaweah Subbasin
Groundwater Sustainability Plan

LEGEND

- Qya - Younger Alluvium
- Qoa(o) - Older Alluvium (oxidized)
- QTl - Corcoran Clay (E-Clay, lacustrine)
- Qoa(r) - Older Alluvium (reduced)
- QTc - Continental Deposits
- Tmc - Marine and Continental Rocks
- pT - Basement Complex
- Generalized Boundaries of Aquifer System

Boring

- Clay
- Sand
- Sandstone/Rock



NOTES:

Cross section modified from Fugro, 2007, Plate 19,
Geologic Cross Section F

1. Stratigraphic contacts are approximate and are interpreted from well and electric logs. Conditions vary both along and perpendicular to the section line.
2. Wells and electric logs are projected to a distance of one mile onto the lines of the cross sections. Therefore stratigraphic contacts may not exactly correspond to the contact indications (lithology, shear strength, etc.) in the logs.
3. Effective base of aquifer system is based on review of recent well logs, professional judgment based on collaboration with adjoining subbasins, and USGS base of fresh water contacts.

SCALE

200 ft
0 2 mi

VERTICAL EXAGGERATION:
52.8X

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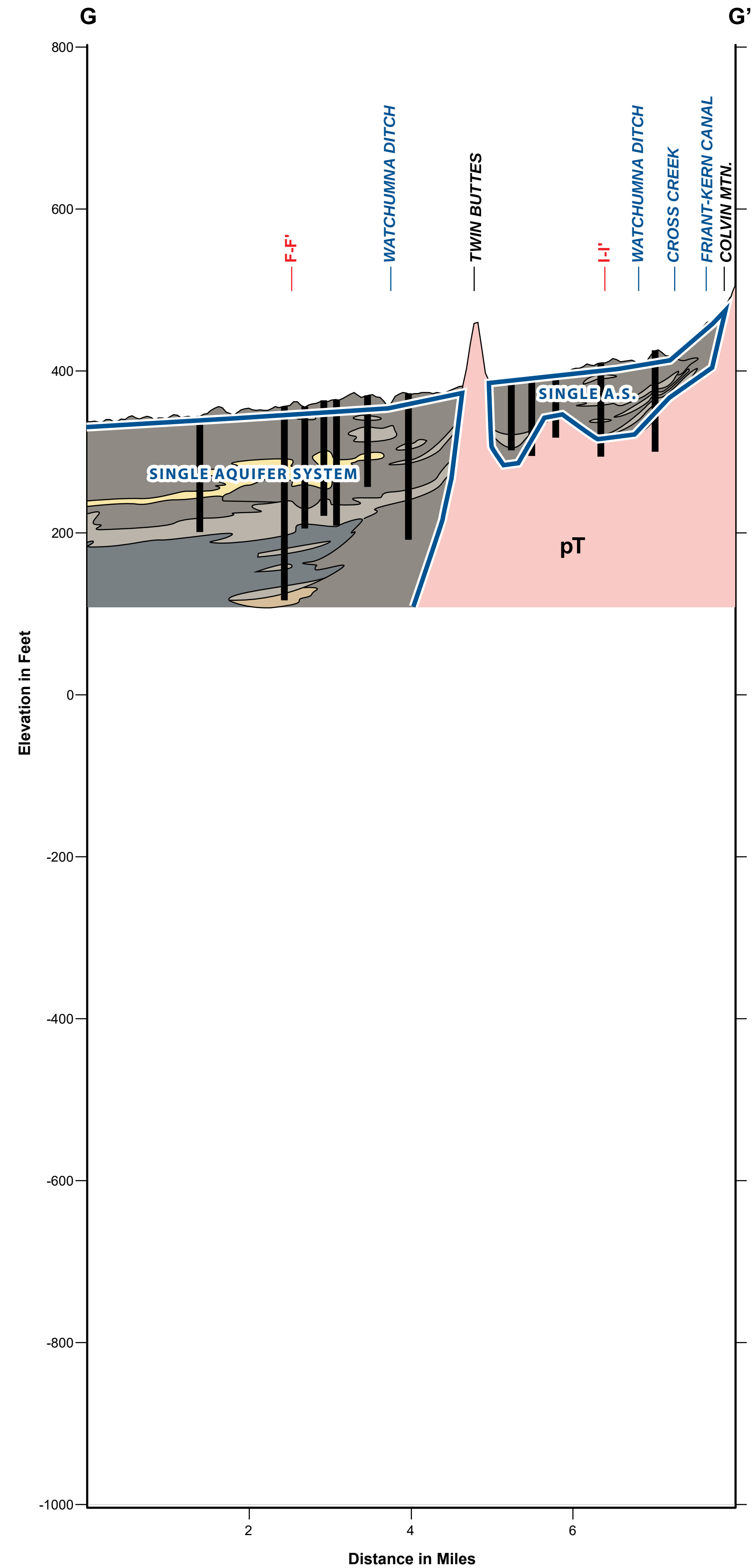


DRAFT

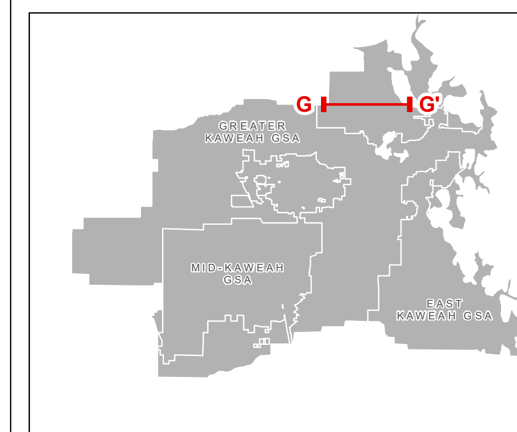
FIGURE 10

Cross Section G

Kaweah Subbasin
Groundwater Sustainability Plan

LEGEND

- Gravel
- Sand
- Silt
- Sandy Clay
- Clay
- pT - Basement Complex
- Generalized Boundaries of Aquifer System



NOTES:

Cross section modified from U.S. Bureau of Rec. (1949), Geologic Cross Section A

1. Stratigraphic contacts are approximate and are interpreted from well and electric logs. Conditions vary both along and perpendicular to the section line.
2. Wells and electric logs are projected to a distance of one mile onto the lines of the cross sections. Therefore stratigraphic contacts may not exactly correspond to the contact indications (lithology, shear strength, etc.) in the logs.
3. Effective base of aquifer system is based on review of recent well logs, professional judgment based on collaboration with adjoining subbasins, and USGS base of fresh water contacts.
4. Effective Base of Aquifer System is base of continental deposits (Tulare Formation)

SCALE

200 ft

0 — 2 mi

VERTICAL EXAGGERATION: 52.8X

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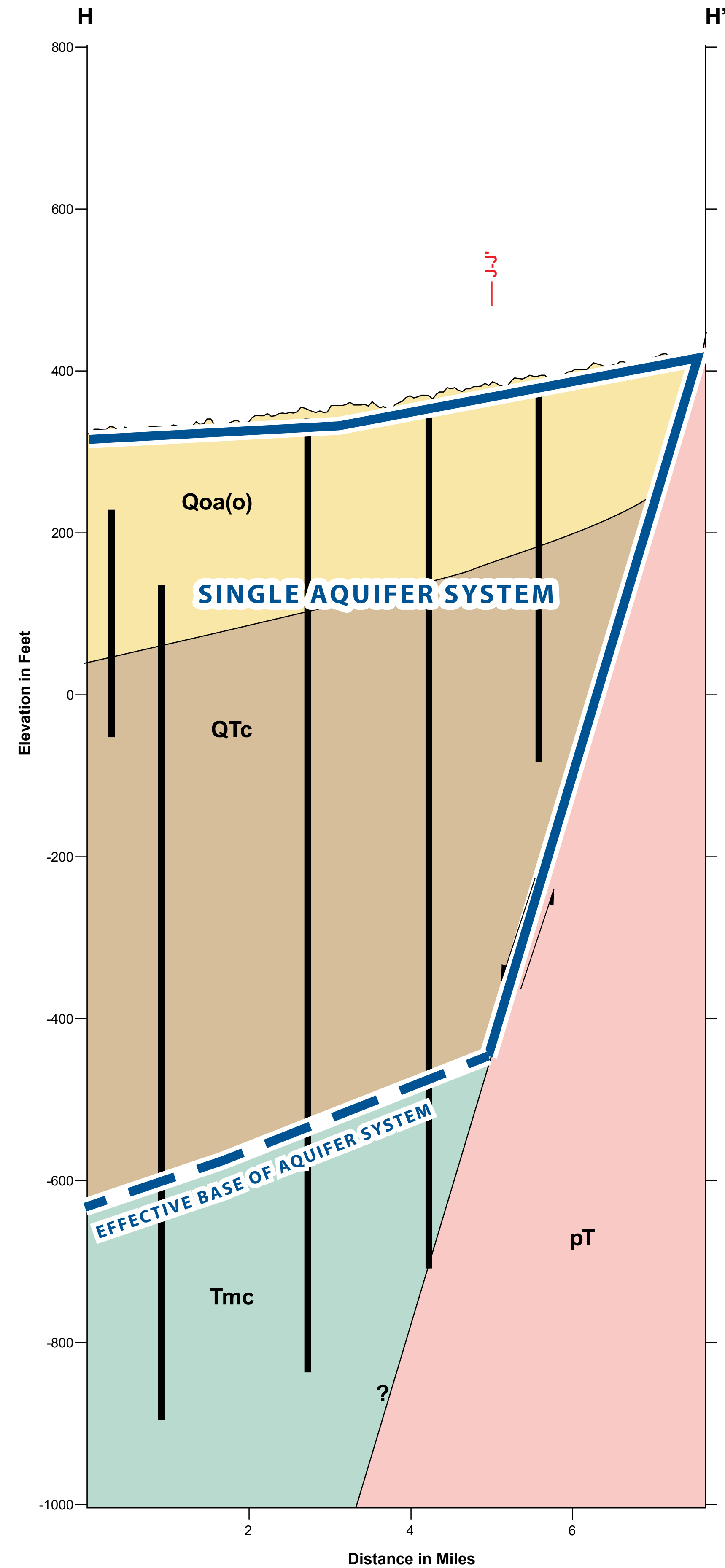


DRAFT

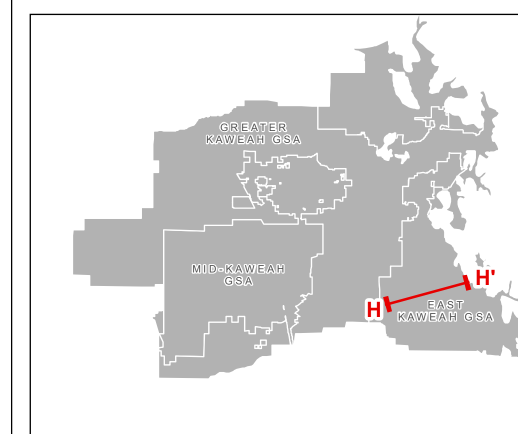
FIGURE 11

Cross Section H

Kaweah Subbasin
Groundwater Sustainability Plan

LEGEND

- Qya - Younger Alluvium
- Qoa(o) - Older Alluvium (oxidized)
- QTl - Corcoran Clay (E-Clay, lacustrine)
- Qoa(r) - Older Alluvium (reduced)
- QTc - Continental Deposits
- Tmc - Marine and Continental Rocks
- pT - Basement Complex
- Generalized Boundaries of Aquifer System



NOTES:

Cross section modified from Davis et al. (1959), Geologic Cross Section G

1. Stratigraphic contacts are approximate and are interpreted from well and electric logs. Conditions vary both along and perpendicular to the section line.
2. Wells and electric logs are projected to a distance of one mile onto the lines of the cross sections. Therefore stratigraphic contacts may not exactly correspond to the contact indications (lithology, shear strength, etc.) in the logs.
3. Effective base of aquifer system is based on review of recent well logs, professional judgment based on collaboration with adjoining subbasins, and USGS base of fresh water contacts.

SCALE

200 ft

VERTICAL EXAGGERATION:
52.8X

0 2 mi

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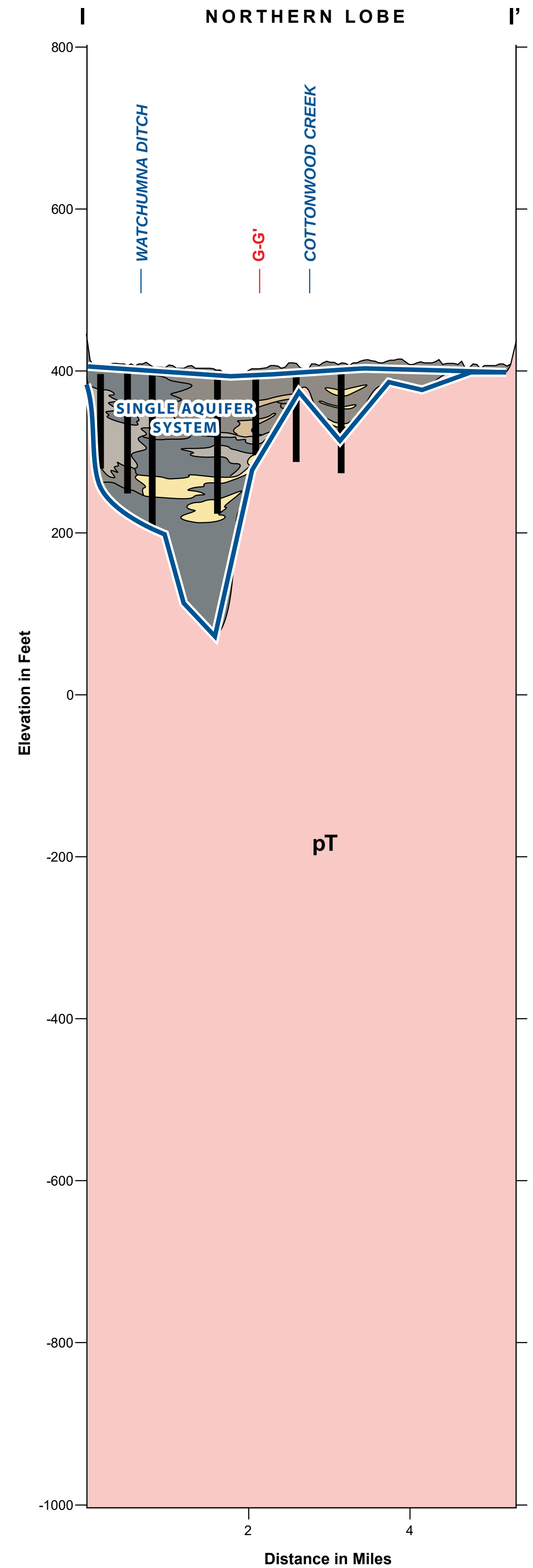


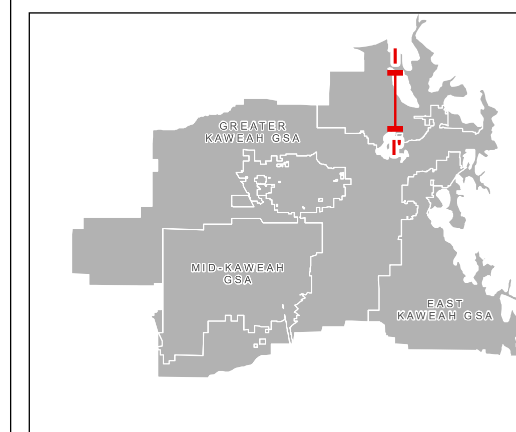
DRAFT **FIGURE 12**

Cross Section I

Kaweah Subbasin
Groundwater Sustainability Plan

LEGEND

- Gravel
- Sand
- Silt
- Sandy Clay
- Clay
- pT - Basement Complex
- Generalized Boundaries of Aquifer System



NOTES:

Cross section modified from U.S. Bureau of Rec. (1949), Geologic Cross Section D

1. Stratigraphic contacts are approximate and are interpreted from well and electric logs. Conditions vary both along and perpendicular to the section line.
2. Wells and electric logs are projected to a distance of one mile onto the lines of the cross sections. Therefore stratigraphic contacts may not exactly correspond to the contact indications (lithology, shear strength, etc.) in the logs.
3. Effective base of aquifer system is based on review of recent well logs, professional judgment based on collaboration with adjoining subbasins, and USGS base of fresh water contacts.
4. Effective Base of Aquifer System is base of continental deposits (Tulare Formation)

SCALE

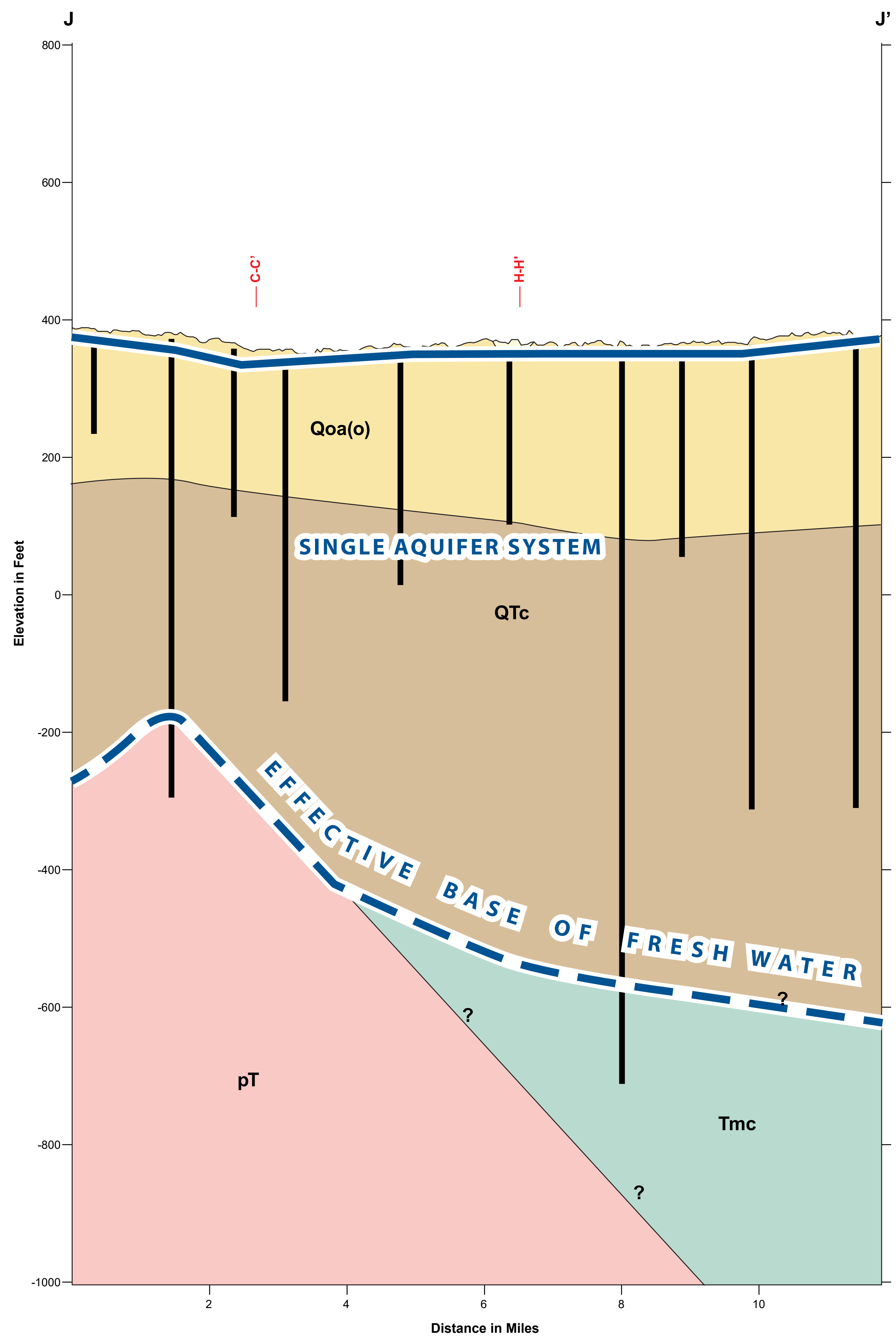
200 ft

0 2 mi

VERTICAL EXAGGERATION: 52.8X

GEI Consultants

GSI Water Solutions, Inc.



DRAFT

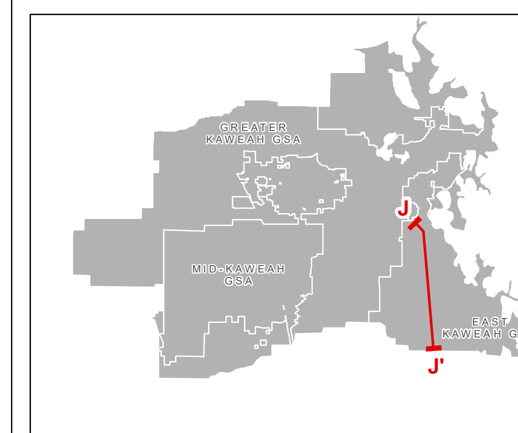
FIGURE 13

Cross Section J

Kaweah Subbasin
Groundwater Sustainability Plan

LEGEND

- Qya - Younger Alluvium
- Qoa(o) - Older Alluvium (oxidized)
- QTl - Corcoran Clay (E-Clay, lacustrine)
- Qoa(r) - Older Alluvium (reduced)
- QTc - Continental Deposits
- Tmc - Marine and Continental Rocks
- pT - Basement Complex
- Generalized Boundaries of Aquifer System



NOTES:

Cross section modified from Croft and Gordon (1968), Geologic Cross Section E

1. Stratigraphic contacts are approximate and are interpreted from well and electric logs. Conditions vary both along and perpendicular to the section line.
2. Wells and electric logs are projected to a distance of one mile onto the lines of the cross sections. Therefore stratigraphic contacts may not exactly correspond to the contact indications (lithology, shear strength, etc.) in the logs.
3. Effective base of aquifer system is based on review of recent well logs, professional judgment based on collaboration with adjoining subbasins, and USGS base of fresh water contacts.

SCALE

200 ft

VERTICAL EXAGGERATION: 52.8X

0 — 2 mi

GEI Consultants

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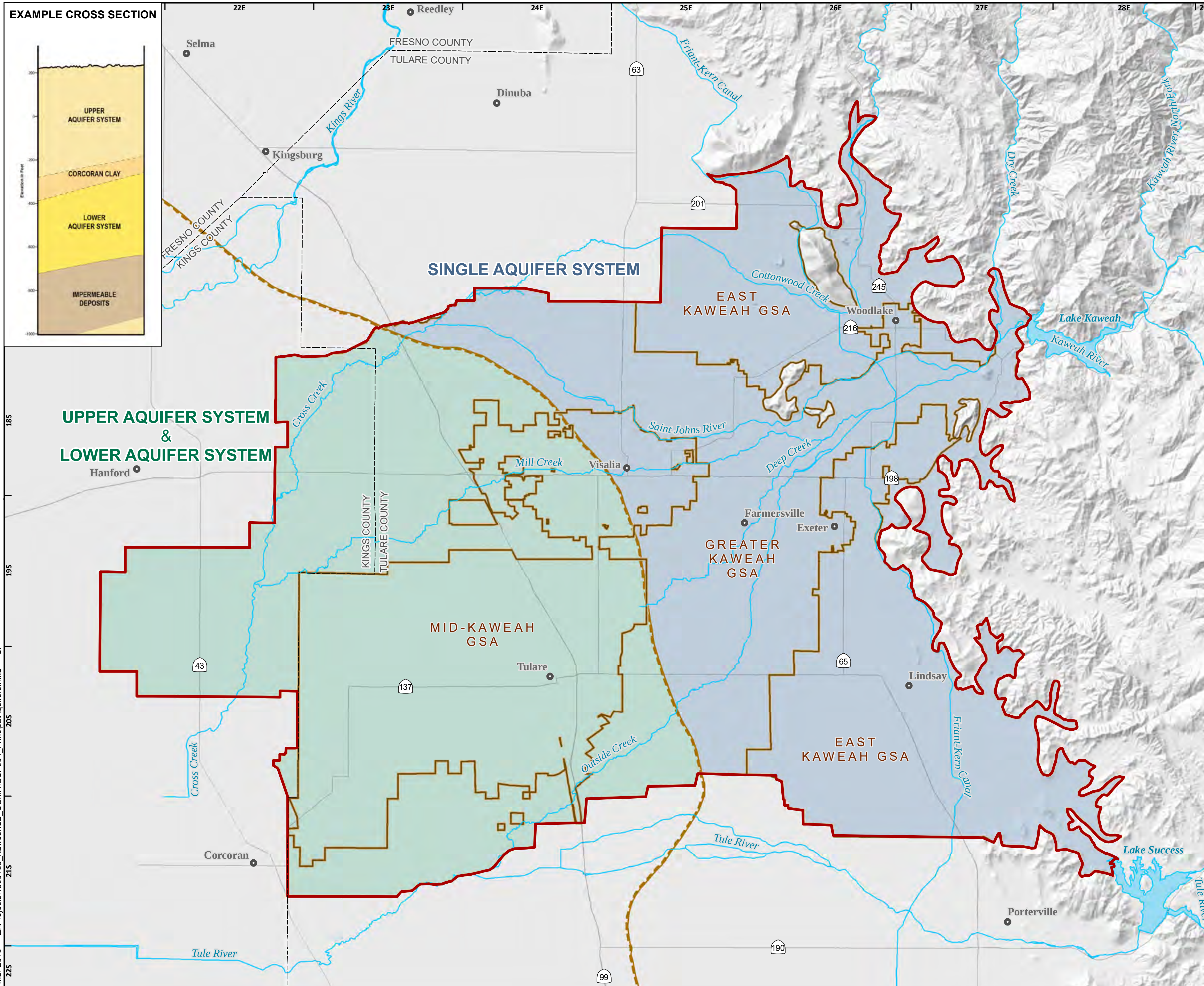

IDENTIFICATION OF PRINCIPAL AQUIFERS

- Approximate Extent of Corcoran Clay
- Upper/Lower Aquifer System
- Single Aquifer System
- Kaweah Subbasin Boundary
- Kaweah Subbasin GSA

All Other Features

- Highway
- Waterway
- Lake

0 2 4 8
Miles

N

Kaweah Subbasin
Groundwater Sustainability Plan
Tulare County, California

Kaweah Subbasin

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MARCH 2019 **DRAFT** FIGURE 14

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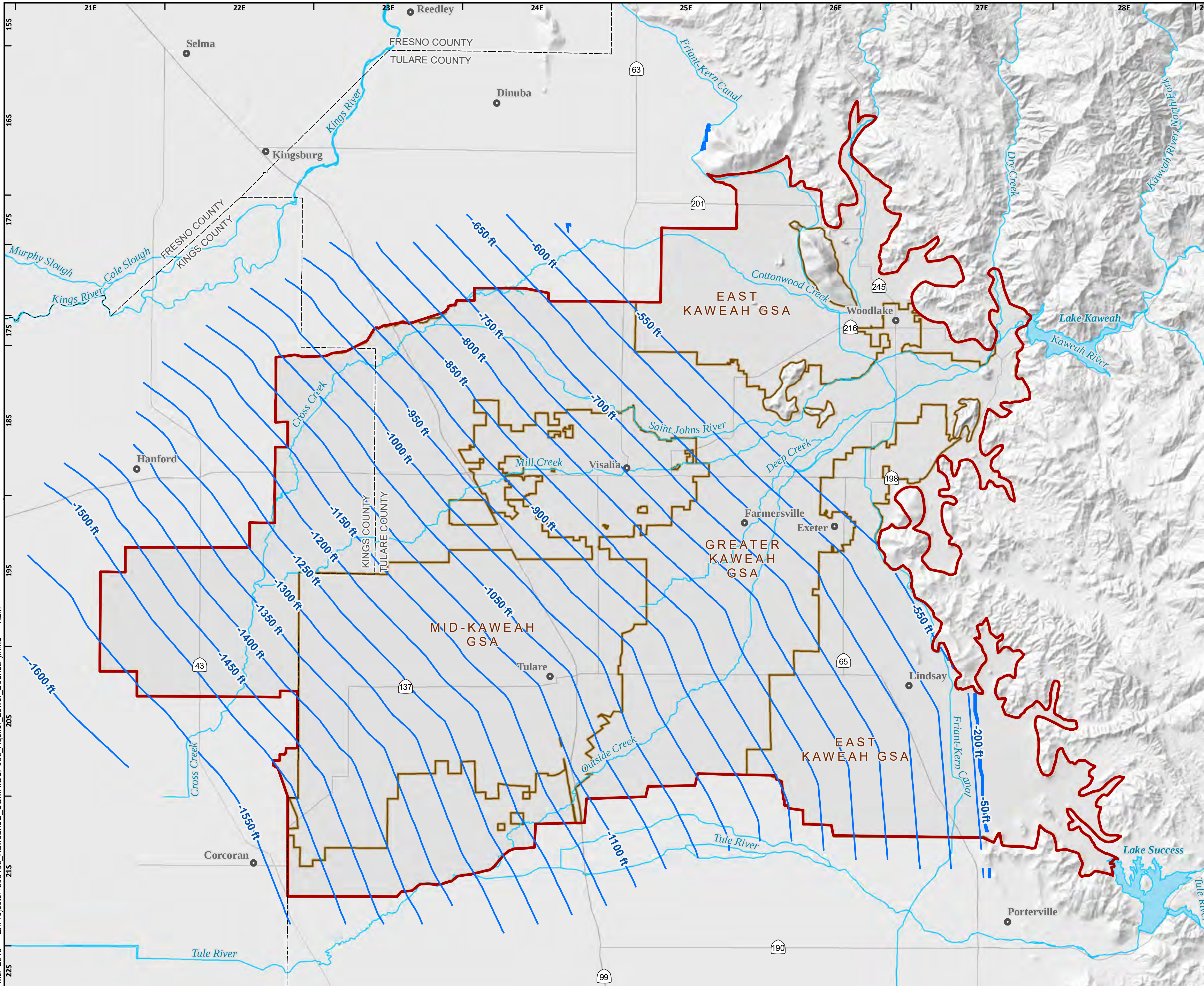
APPROXIMATE ELEVATION OF EFFECTIVE BASE OF FRESHWATER SYSTEM



Approx. Elevation of Effective Base of Freshwater System (ft MSL)

Kaweah Subbasin Boundary

Kaweah Subbasin GSA

All Other Features

Highway

Waterway

Lake

0 2 4 8

Miles

N

Kaweah Subbasin
Groundwater Sustainability Plan
Tulare County, California

Kaweah Subbasin

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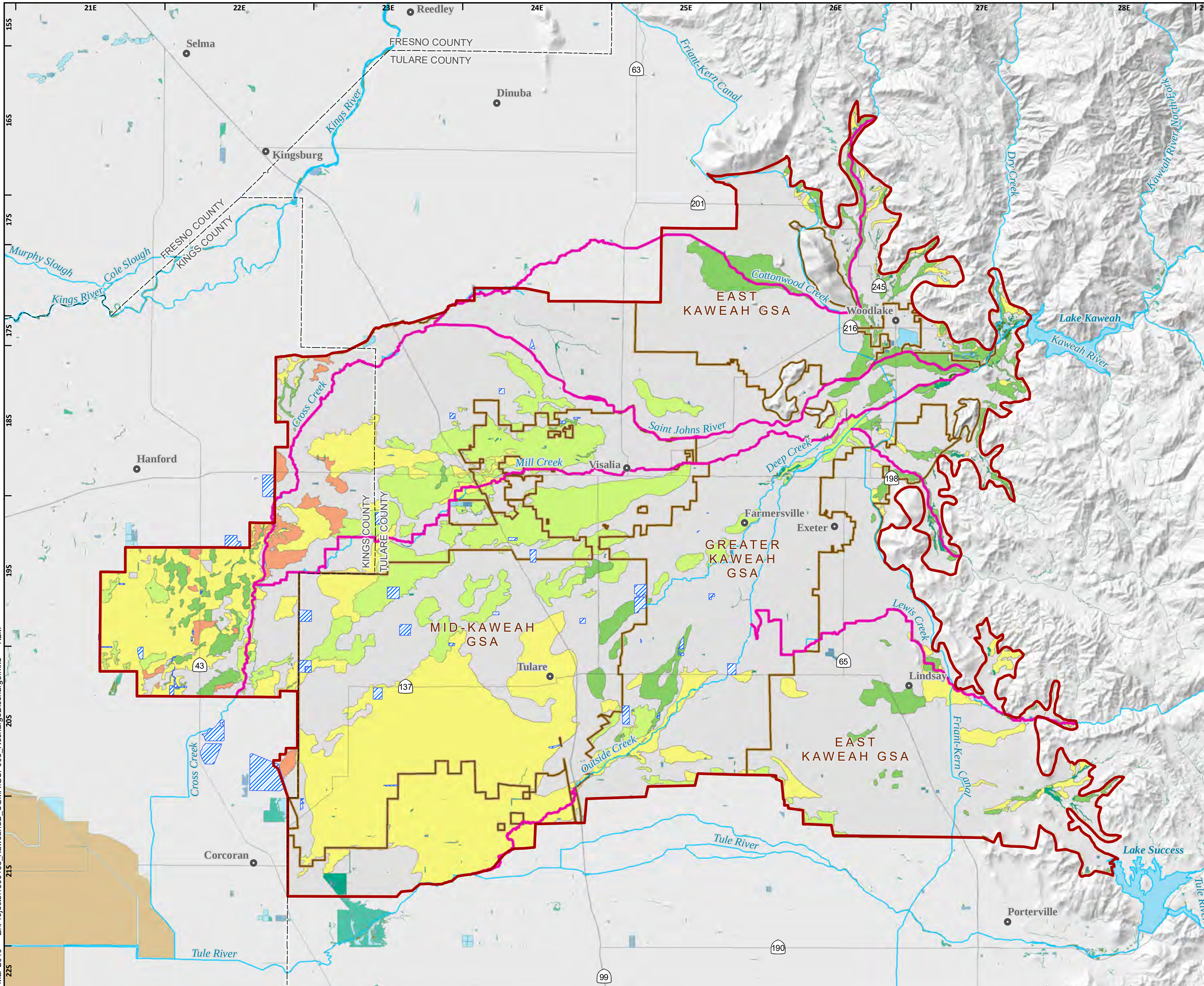
MARCH 2019 **DRAFT** FIGURE 15

18-Mar-2019 Z:\Projects\1800138_KaweahSB_SGMA\GSP005_Aquifer_Lower_Boundary.mxd KLM

GROUNDWATER RECHARGE AND DISCHARGE AREAS AND WETLANDS



Wetland Type (National Wetland Inventory, 2018)

- Freshwater Emergent Wetland
- Freshwater Forested/Shrub Wetland
- Freshwater/Recharge/Irrigation Pond
- Lake
- Farmed Wetland

Soil Agricultural Groundwater Banking Index (2015)

Rating Class

- Excellent
- Good
- Moderately Good
- Moderately Poor
- Recharge Basin
- Kaweah Subbasin Boundary
- Kaweah Subbasin GSA

All Other Features

- Highway
- Waterway
- Losing Stream Reach
- Lake

Note: Data is preliminary and subject to field verification for accuracy.

0 2 4 8
Miles

N

Kaweah Subbasin
Groundwater Sustainability Plan
Tulare County, California

Kaweah Subbasin

GEI Consultants

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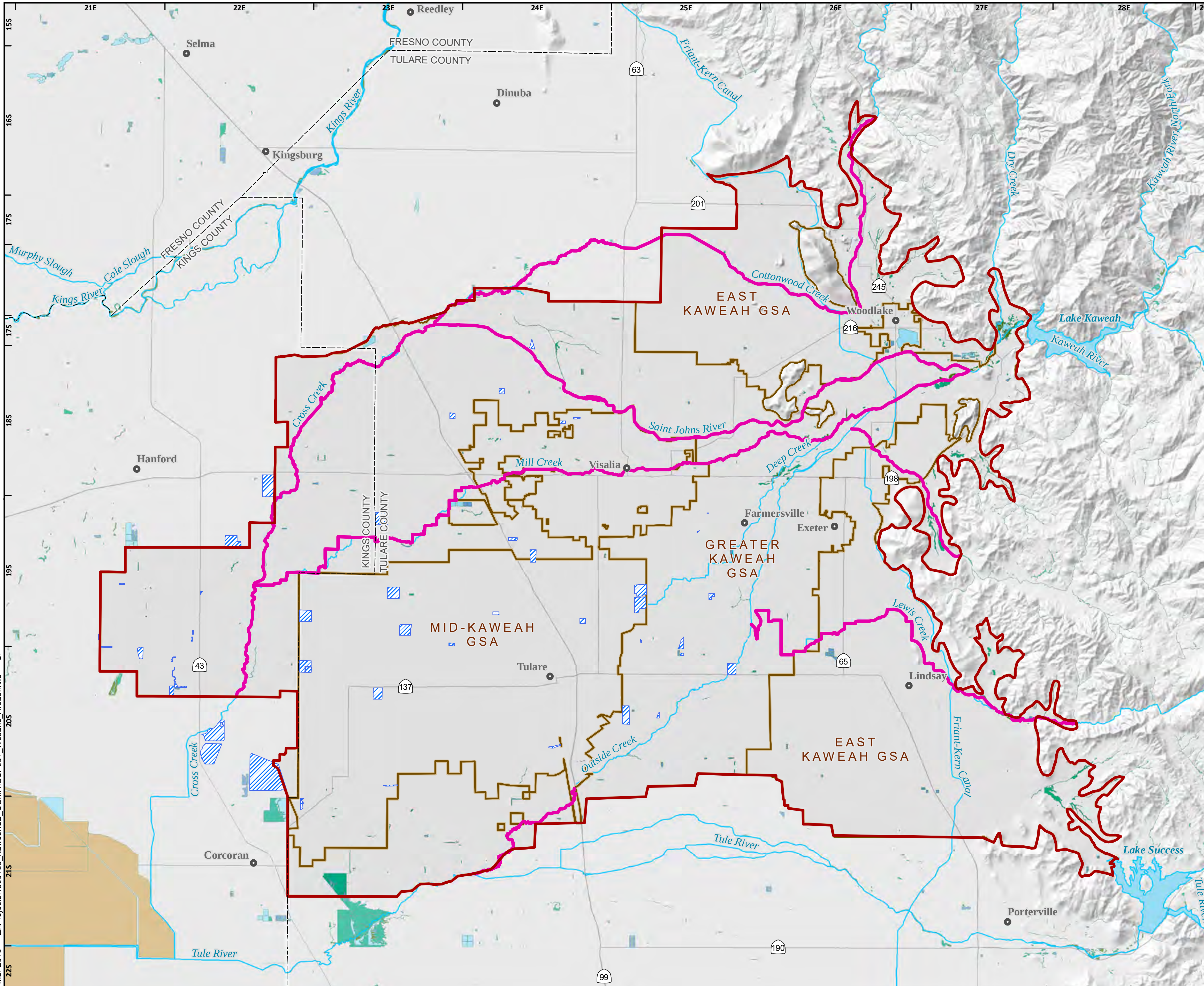
MARCH 2019 **DRAFT** FIGURE 16

11-Mar-2019 Z:\Projects\1800138_KaweahSB_SGMA\GSP006_RechargeDischarge.mxd KLM

WETLAND AREAS



Wetland Type (National Wetland Inventory, 2018)

- Freshwater Emergent Wetland
- Freshwater Forested/Shrub Wetland
- Freshwater/Recharge/Irrigation Pond
- Lake
- Farmed Wetland
- Recharge Basin
- Kaweah Subbasin Boundary
- Kaweah Subbasin GSA

All Other Features

- Highway
- Waterway
- Losing Stream Reach
- Lake

Note: Data is preliminary and subject to field verification for accuracy.

0 2 4 8
Miles

N

Kaweah Subbasin
Groundwater Sustainability Plan
Tulare County, California

Kaweah Subbasin

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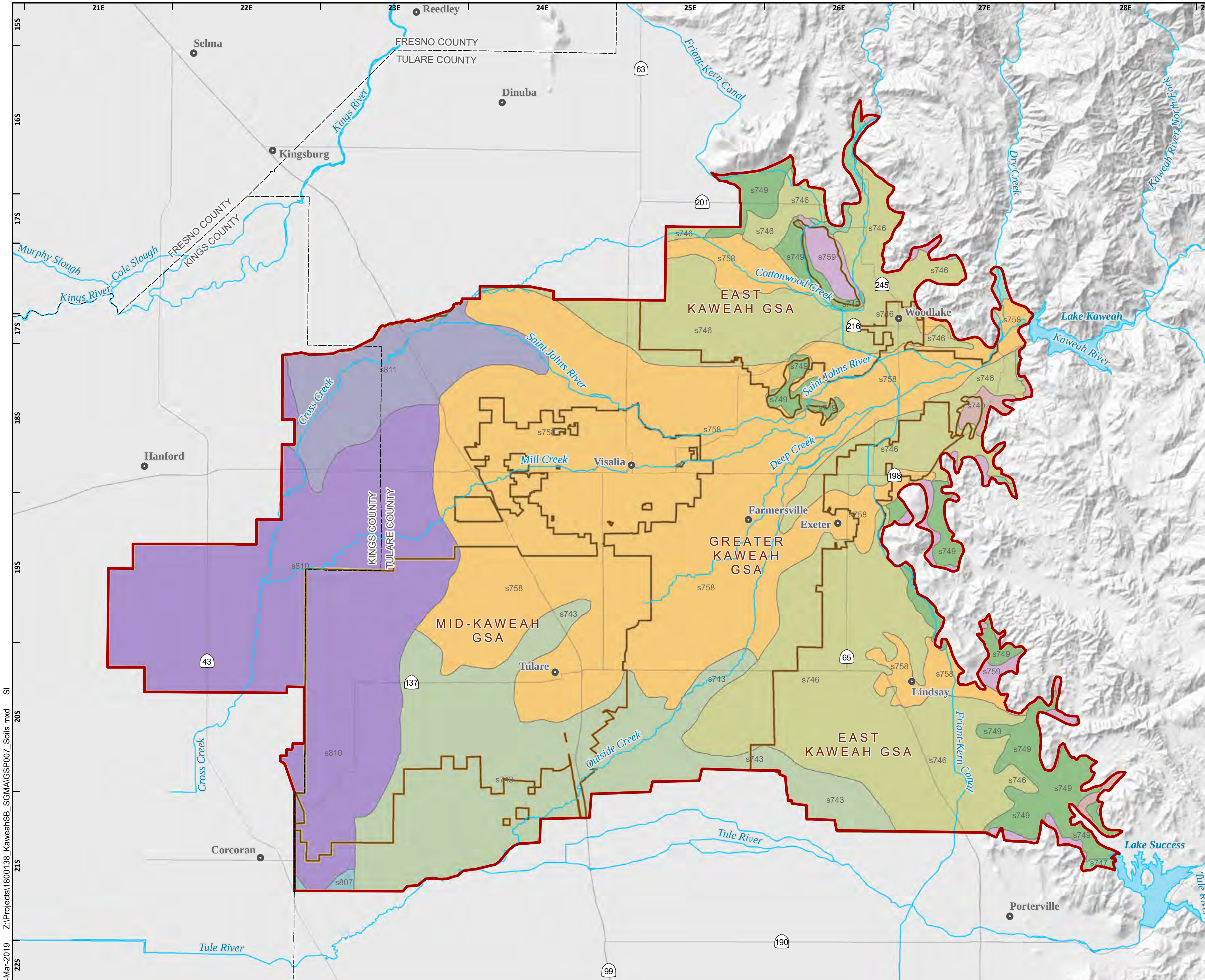
MARCH 2019 **DRAFT** FIGURE 17

11-Mar-2019 Z:\Projects\1800138_KaweahSB_SGMA\GSP051_Wetland_Areas.mxd SI



SOILS MAP

National Resource Conservation Service Soils Categories (STATSGO)

- Hanford-Delhi (s745)
- Lakeside-Kimberlina-Garces (s810)
- Lewis-Fresno-Dinuba (s742)
- Nord-Grangeville-Chino (s744)
- Porterville-Centerville (s749)
- Rock outcrop-Friant-Coarsegold (s751)
- Rock outcrop-Las Posas-Cibo (s759)
- San Joaquin-Madera-Cometa (s746)
- Sheephead-Rock outcrop-Holland-Crouch (s752)
- Tulare (s808)
- Vista-Rock outcrop-Auberry-Ahwahnee (s740)
- Vista-Rock outcrop-Cieneba (s747)
- Water (s8369)
- Waukena-Temple-Pond (s743)
- Westcamp-Houser-Gepford-Armona (s807)
- Woolstalf-Rock outcrop-Jocal-Hotaw-Chaix (s1072)
- Yettem-San Emigdio-Honcut (s758)
- Youd-Remnoy-Melga-Kimberlina (s811)
- Kaweah Subbasin Boundary
- Kaweah Subbasin GSA

All Other Features

- Highway
- Waterway
- Lake

0 2 4 8
Miles

N

Kaweah Subbasin
Groundwater Sustainability Plan
Tulare County, California

Kaweah Subbasin

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MARCH 2019 **DRAFT** FIGURE 18

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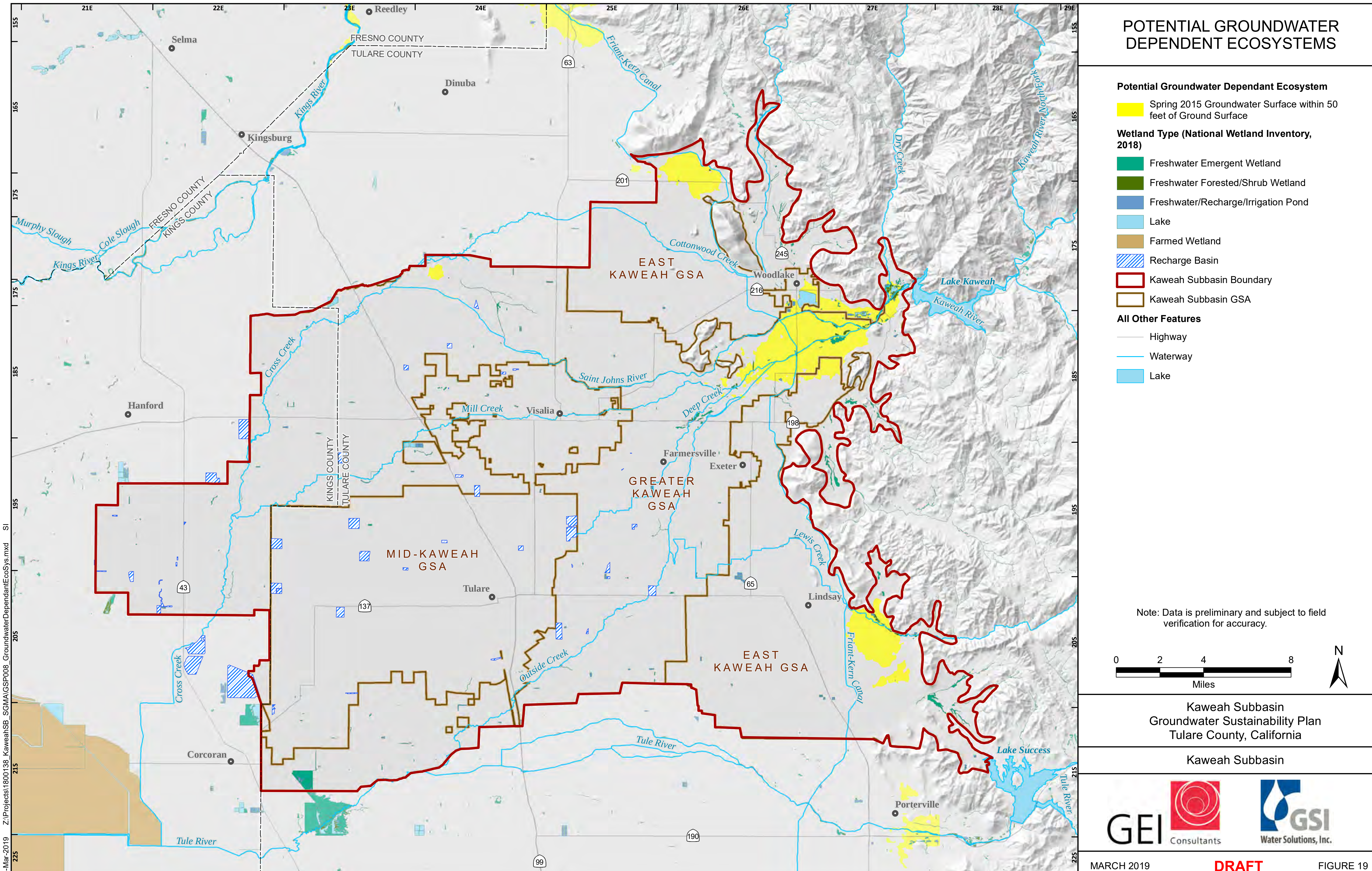
11-Mar-2019



POTENTIAL GROUNDWATER DEPENDENT ECOSYSTEMS
Potential Groundwater Dependant Ecosystem
Spring 2015 Groundwater Surface within 50 feet of Ground Surface
Wetland Type (National Wetland Inventory, 2018)
Freshwater Emergent Wetland
Freshwater Forested/Shrub Wetland
Freshwater/Recharge/Irrigation Pond
Lake
Farmed Wetland
Recharge Basin
Kaweah Subbasin Boundary
Kaweah Subbasin GSA
All Other Features
Highway
Waterway
Lake
Note: Data is preliminary and subject to field verification for accuracy.
0 2 4 8
Miles
N
Kaweah Subbasin
Groundwater Sustainability Plan
Tulare County, California
Kaweah Subbasin
GEI Consultants
GSI Water Solutions, Inc.
MARCH 2019
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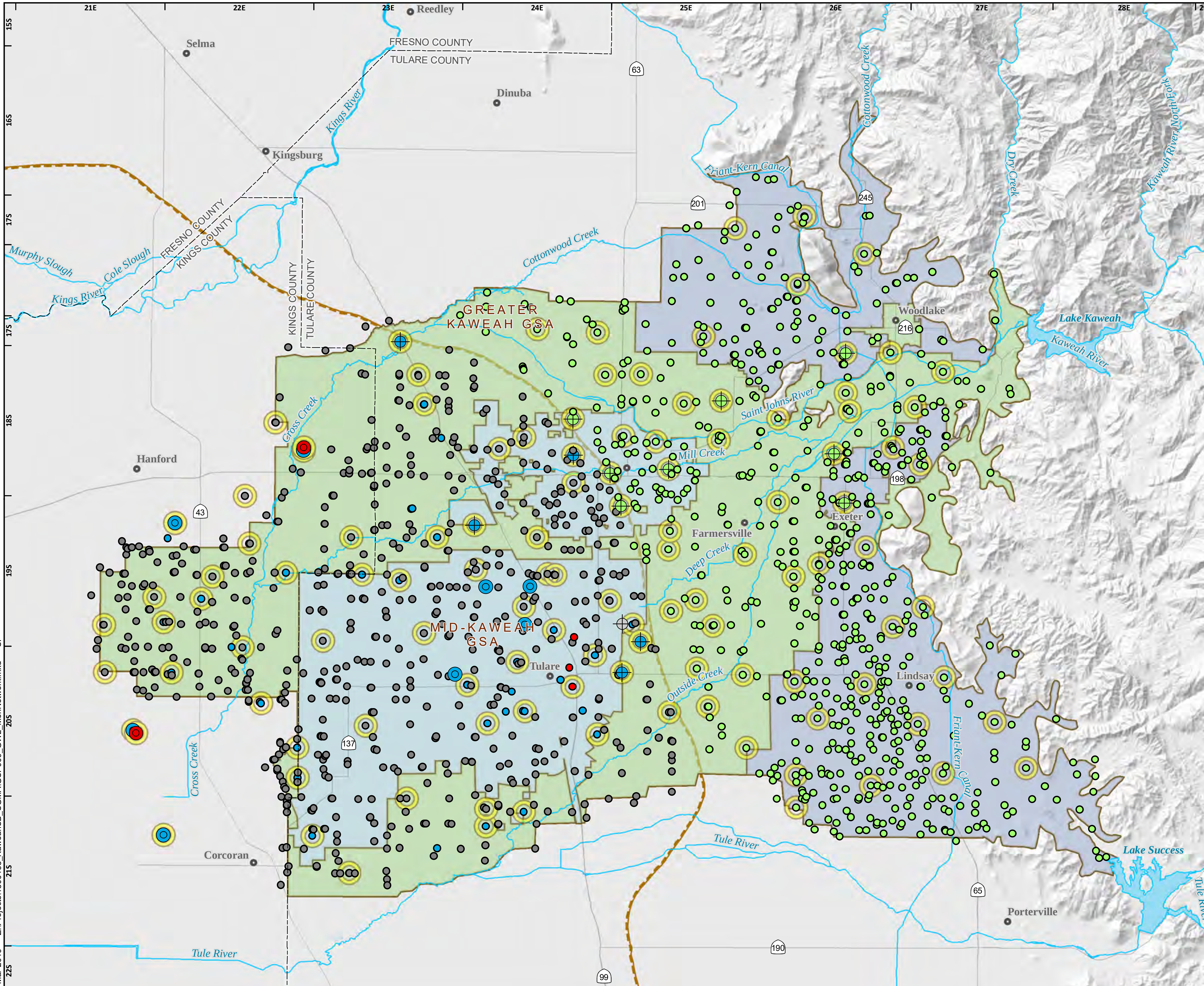
FIGURE 19
EAST KAWEAH GSA
GREATER KAWEAH GSA
MID-KAWEAH GSA
EAST KAWEAH GSA
Reedley
Selma
Dinuba
Kingsburg
Hanford
Visalia
Woodlake
Farmersville
Exeter
Tulare
Lindsay
Corcoran
Porterville
FRESNO COUNTY
TULARE COUNTY
KINGS COUNTY
Kings River
Murphy Slough
Cole Slough
Cross Creek
Friant-Kern Canal
Cottonwood Creek
Saint Johns River
Mill Creek
Deep Creek
Dry Creek
Kaweah River North Fork
Lake Kaweah
Kaweah River
Lewis Creek
Outside Creek
Tule River
Lake Success
11-Mar-2019 Z:\Projects\1800138_KaweahSB_SGMA\GSP008_GroundwaterDependantEcoSys.mxd SI

GROUNDWATER LEVEL MONITORING NETWORK



Well Types

- Lower Aquifer
- Upper Aquifer
- Single Aquifer
- Unknown
- Dedicated Monitoring Well
- Dual Completion Well
- Monitoring Well
- Key Well

Approximate Extent of Corcoran Clay

GSA Boundaries

- East Kaweah GSA
- Greater Kaweah GSA
- Mid-Kaweah GSA
- Kaweah Subbasin GSA

All Other Features

- Highway
- Waterway
- Lake

0 2 4 8
Miles

N

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Tulare County, California

Kaweah Subbasin

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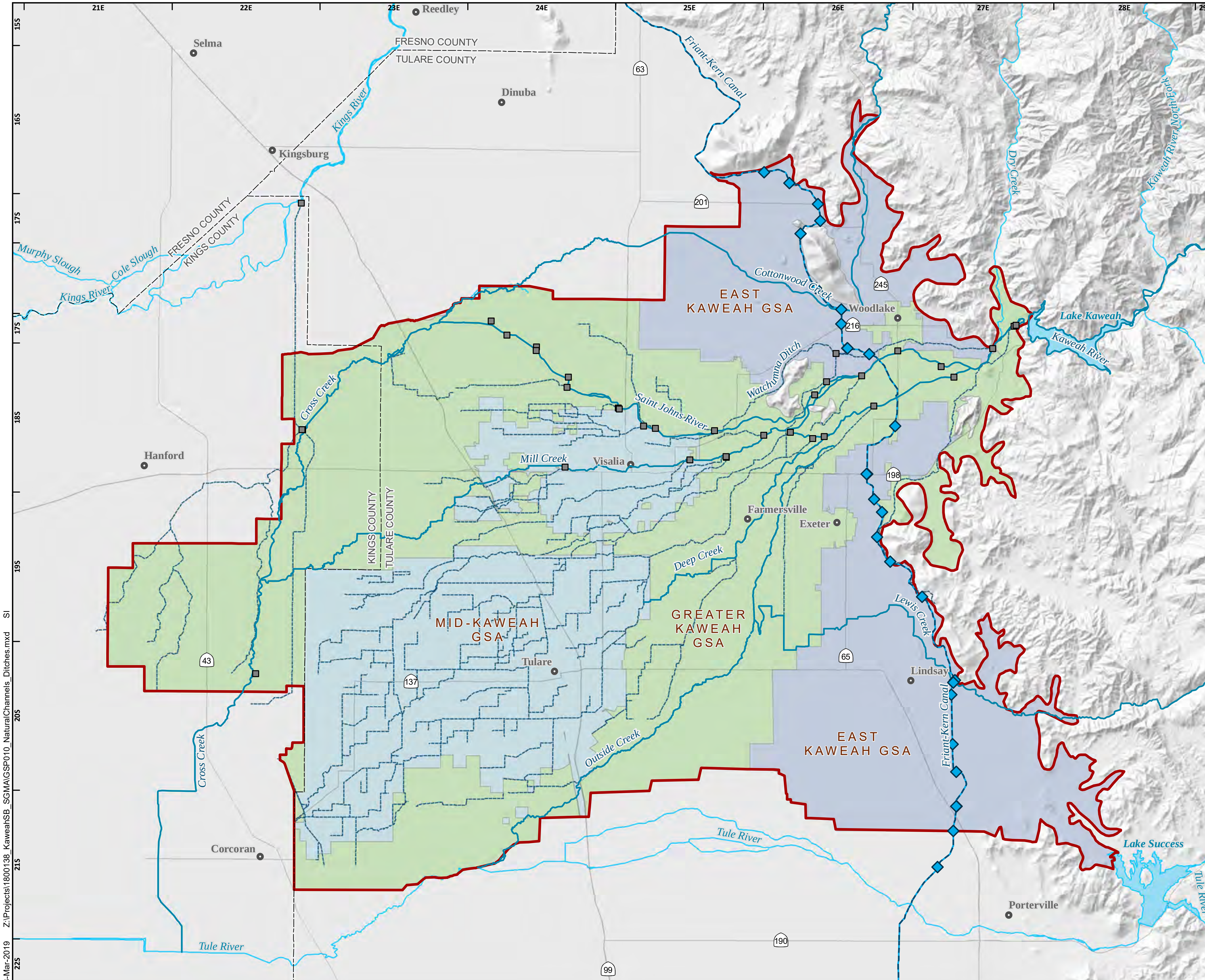
MARCH 2019 **DRAFT** FIGURE 20

Z:\Projects\1800138_KaweahSB_SGMA\GSP009_GWL_MonNetwork.mxd SI

11-Mar-2019

NATURAL AND MAN-MADE CHANNELS



- Friant-Kern Turnout
- Headgate
- Principal KSB Natural Channel
- Friant-Kern Canal
- Other Natural Channel
- Man-Made Channel

GSA Boundaries

- East Kaweah GSA
- Greater Kaweah GSA
- Mid-Kaweah GSA
- Kaweah Subbasin Boundary

All Other Features

- Highway
- Lake

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Tulare County, California

Kaweah Subbasin

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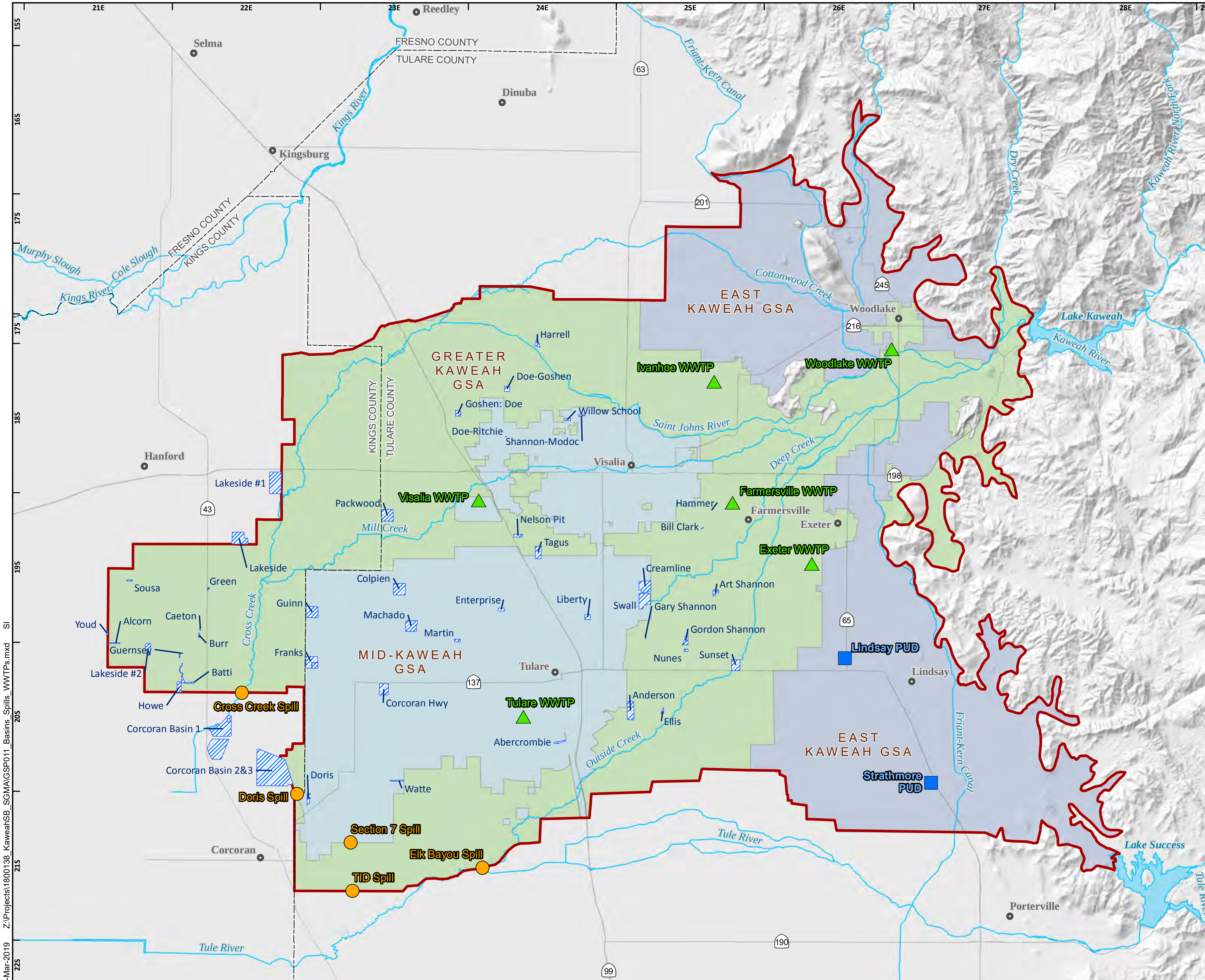
MARCH 2019 **DRAFT** FIGURE 21

RECHARGE BASINS, SPILLS AND WASTEWATER TREATMENT PLANTS



- Surface Water Spill Point
- Waste Water Treatment Plant (WWTP)
- PUD Treatment Plant
- Recharge Basin

GSA Boundaries

- East Kaweah GSA
- Greater Kaweah GSA
- Mid-Kaweah GSA
- Kaweah Subbasin Boundary

All Other Features

- Highway
- Waterway
- Lake

0 2 4 8

Miles

N

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Groundwater Sustainability Plan
Tulare County, California

Kaweah Subbasin

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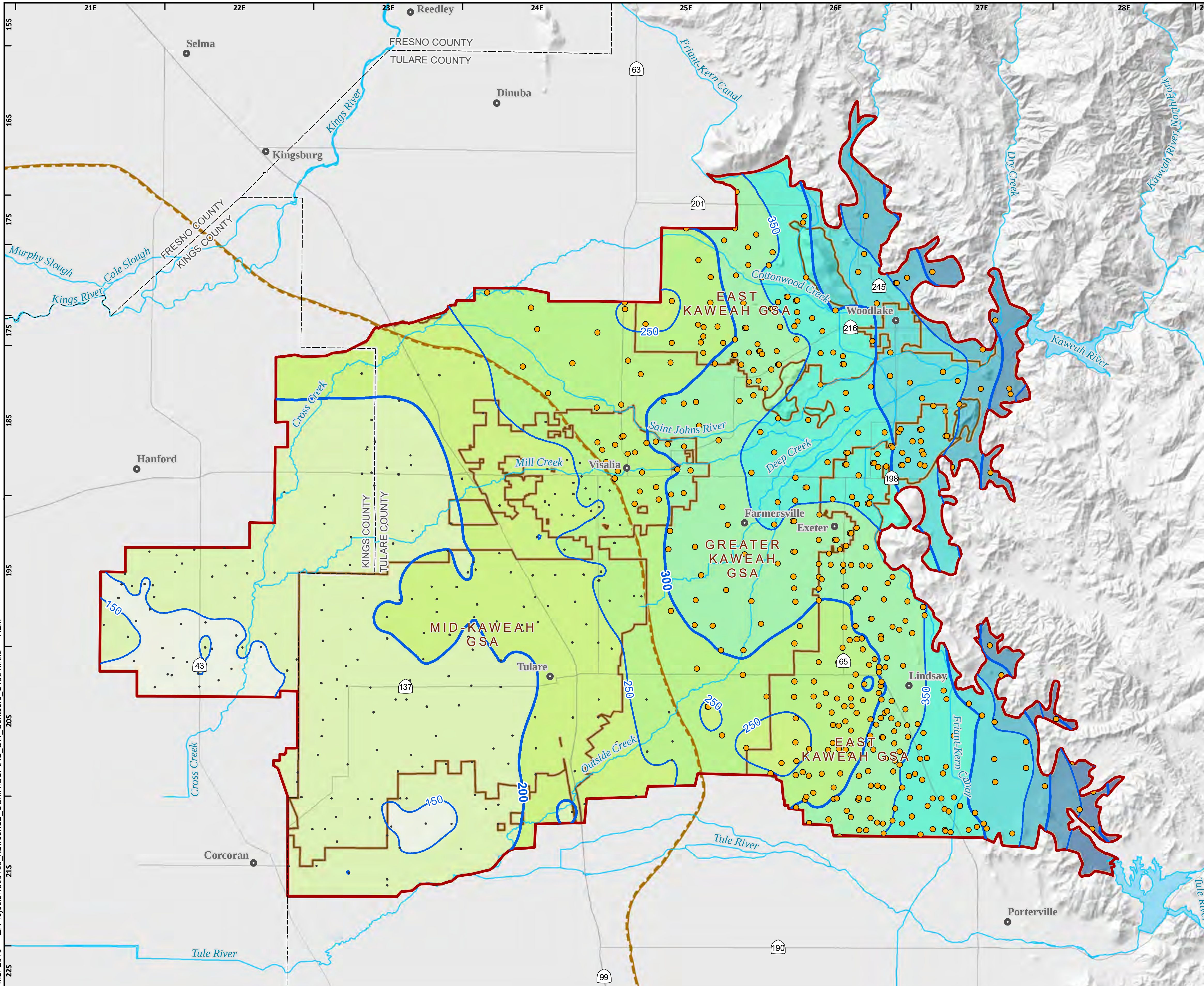
MARCH 2019 **DRAFT** FIGURE 22

Z:\Projects\1800138_KaweahSB_SGMA\GSP011_Basins_Spills_WWTPs.mxd SI

18-Mar-2019

SPRING 1981 GROUNDWATER ELEVATION CONTOURS



Legend

- Lower Aquifer System, Dedicated Monitoring Well
- Single Aquifer System, Dedicated Monitoring Well
- Lower Aquifer System Well
- Single Aquifer System Well
- Well Construction Details Unknown

Groundwater Elevation Contours, Spring 1981 (GWE ft msl)

- Major (100-foot interval)
- Minor (50-foot interval)
- 123 - 150
- 151 - 200
- 201 - 250
- 251 - 300
- 301 - 350
- 351 - 400
- 401 - 450
- 451 - 500
- 501 - 550
- 551 - 600
- 601 - 650
- Approximate Extent of Corcoran Clay
- Kaweah Subbasin Boundary
- Kaweah Subbasin GSA

All Other Features

- Highway
- Waterway
- Lake

0 2 4 8
Miles

N

Kaweah Subbasin
Groundwater Sustainability Plan
Tulare County, California

Kaweah Subbasin

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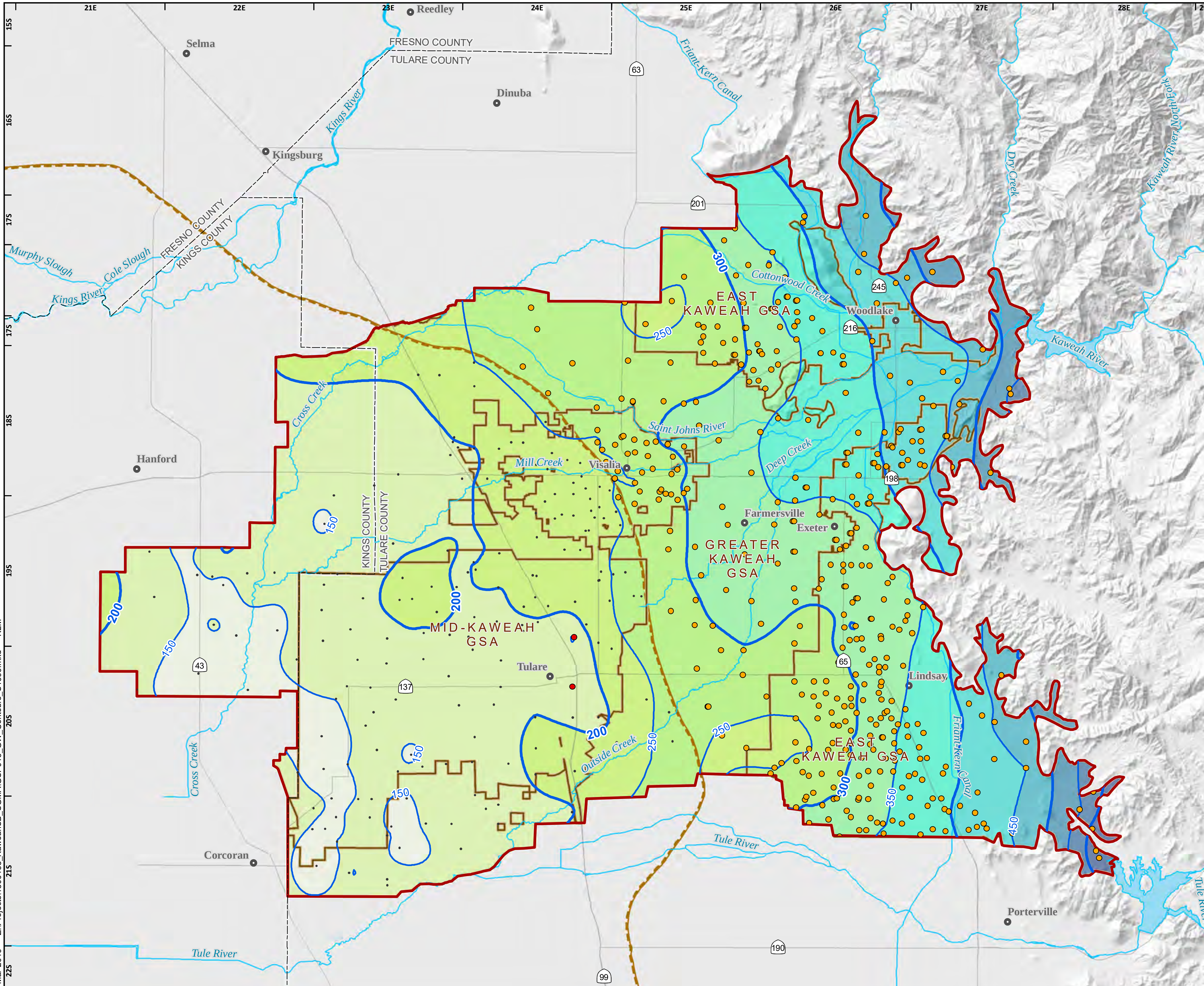
MARCH 2019 **DRAFT** FIGURE 23

Z:\Projects\1800138_KaweahSB_SGMA\GSP012_GW_Contours_S1981.mxd KLM
11-Mar-2019

SPRING 1999 GROUNDWATER ELEVATION CONTOURS



Lower Aquifer System, Dedicated Monitoring Well

Single Aquifer System, Dedicated Monitoring Well

Lower Aquifer System Well

Single Aquifer System Well

Well Construction Details Unknown

Groundwater Elevation Contours, Spring 1999 (GWE ft msl)

Major (100-foot interval)

Minor (50-foot interval)

120 - 150

151 - 200

201 - 250

251 - 300

301 - 350

351 - 400

401 - 450

451 - 500

501 - 550

551 - 600

601 - 650

Approximate Extent of Corcoran Clay

Kaweah Subbasin Boundary

Kaweah Subbasin GSA

All Other Features

Highway

Waterway

Lake

0 2 4 8
Miles

N

Kaweah Subbasin
Groundwater Sustainability Plan
Tulare County, California

Kaweah Subbasin

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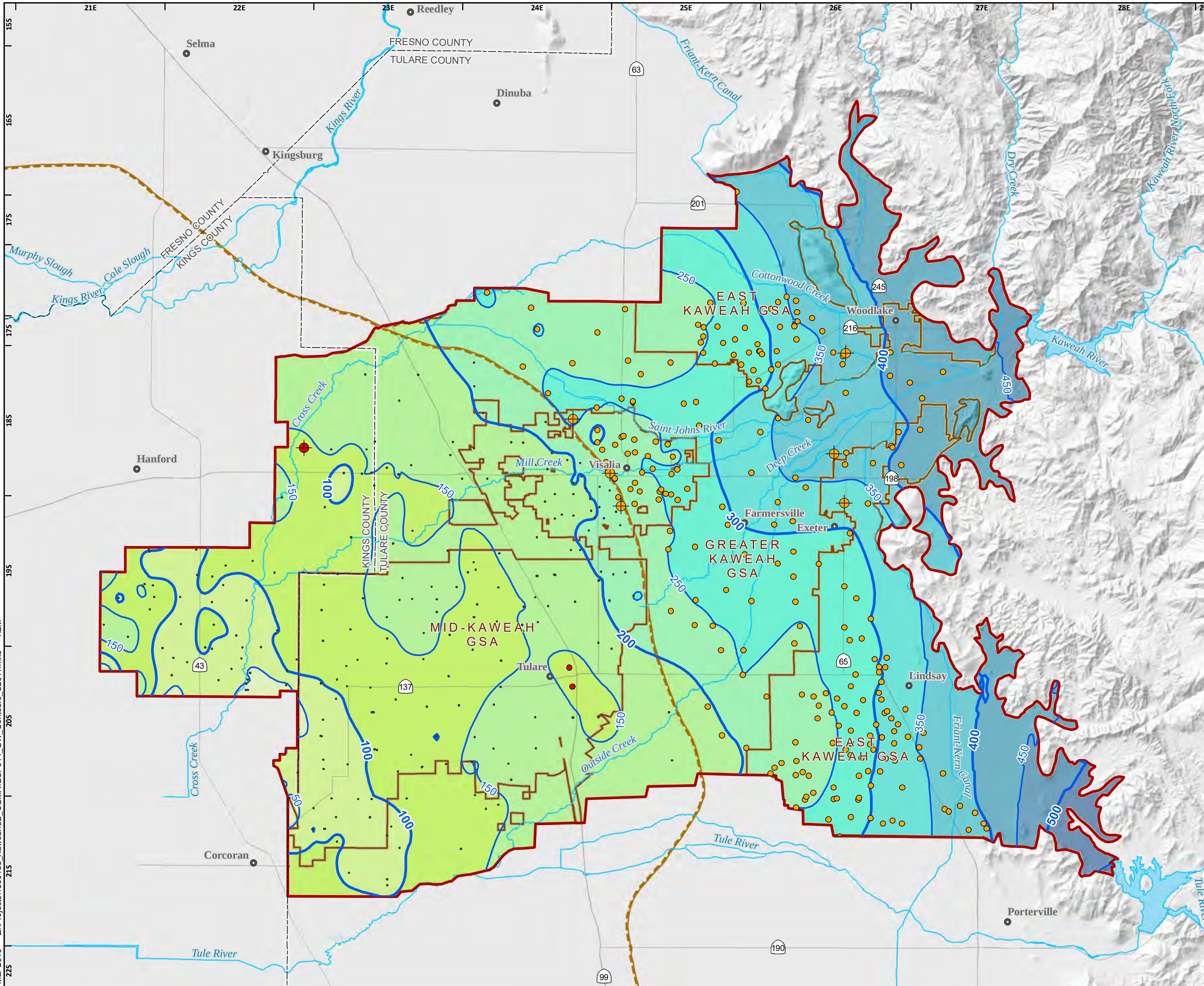
MARCH 2019 **DRAFT** FIGURE 24

11-Mar-2019 Z:\Projects\1800138_KaweahSB_SGMA\GSP013_GW_Contours_S1999.mxd KLM

SPRING 2011 GROUNDWATER ELEVATION CONTOURS



Lower Aquifer System, Dedicated Monitoring Well
Single Aquifer System, Dedicated Monitoring Well
Lower Aquifer System Well
Single Aquifer System Well
Well Construction Details Unknown

Groundwater Elevation Contours, Spring 2011 (GWE ft msl)

Major (100-foot interval)
Minor (50-foot interval)

-40 - 0
1 - 50
51 - 100
101 - 150
151 - 200
201 - 250
251 - 300
301 - 350
351 - 400
401 - 450
451 - 500
501 - 550
551 - 600

Approximate Extent of Corcoran Clay
Kaweah Subbasin Boundary
Kaweah Subbasin GSA

All Other Features

Highway
Waterway
Lake

0 2 4 8
Miles

N

Kaweah Subbasin
Groundwater Sustainability Plan
Tulare County, California

Kaweah Subbasin

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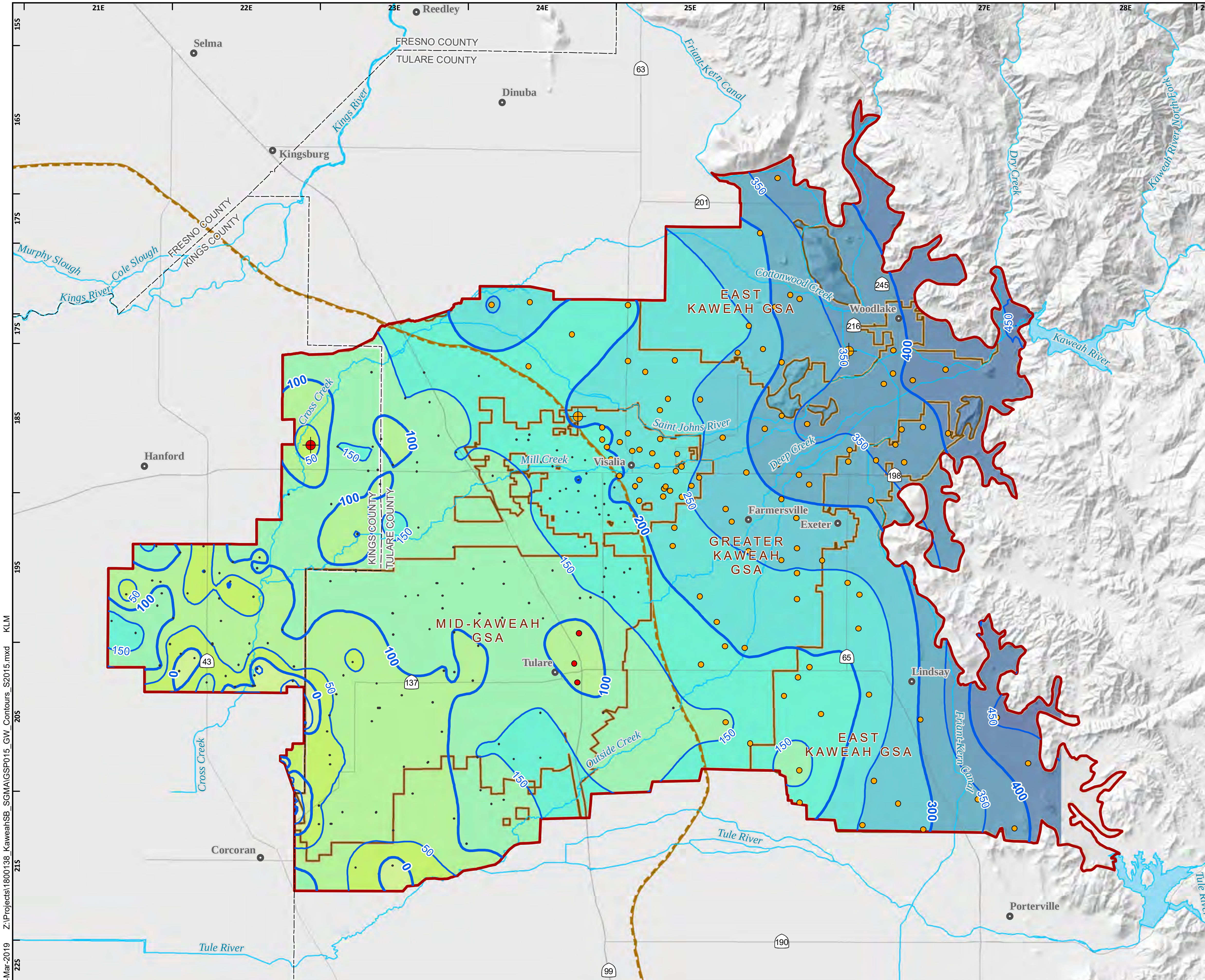
MARCH 2019 DRAFT FIGURE 25



Kaweah Subbasin
Groundwater Sustainability Plan
Tulare County, California

Kaweah Subbasin

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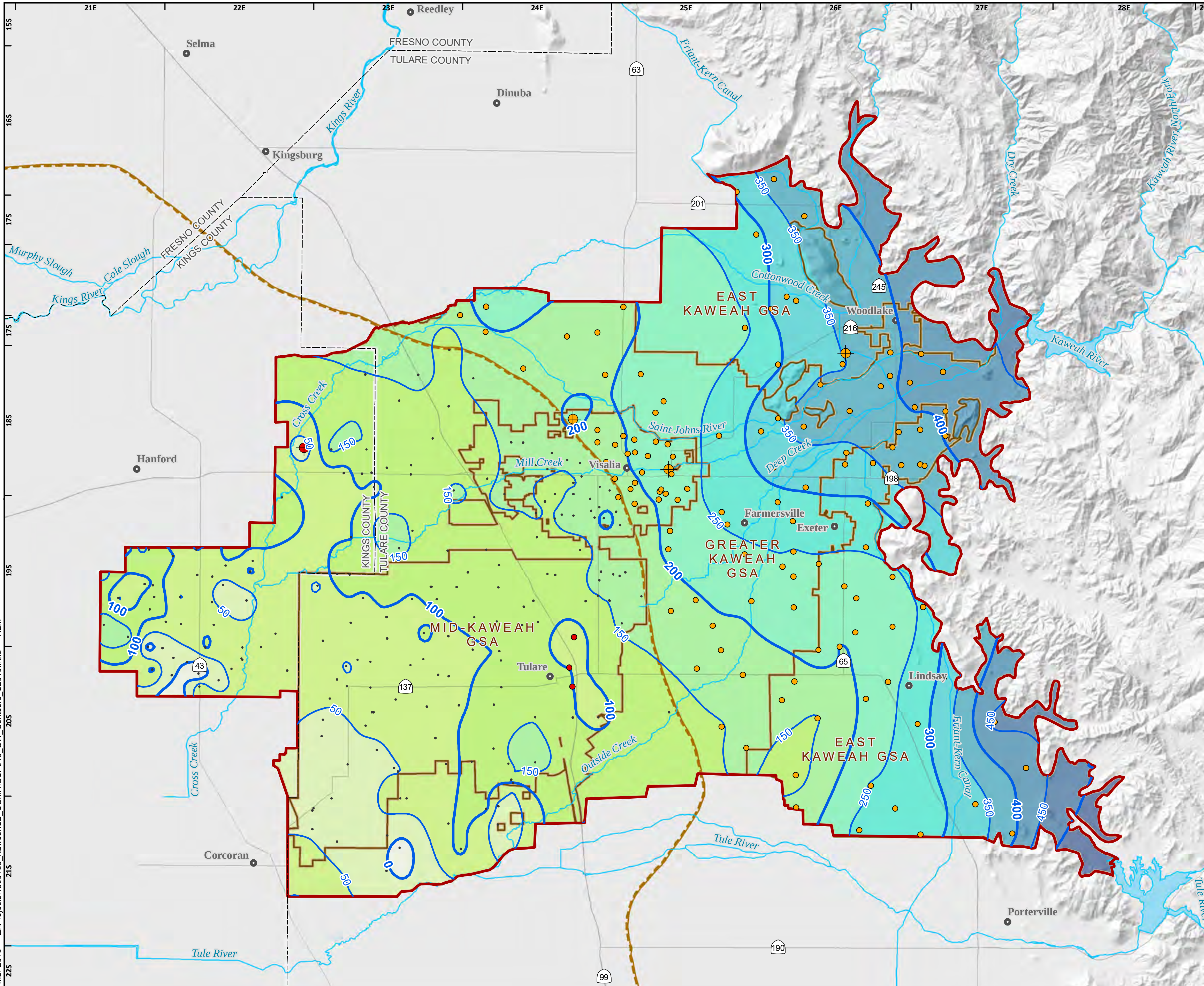
MARCH 2019 **DRAFT** FIGURE 26

SPRING 2016 GROUNDWATER ELEVATION CONTOURS



11-Mar-2019 Z:\Projects\1800138_KaweahSB_SGMA\GSP016_GW_Contours_S2016.mxd KLM

- Lower Aquifer System, Dedicated Monitoring Well
- Single Aquifer System, Dedicated Monitoring Well
- Lower Aquifer System Well
- Single Aquifer System Well
- Well Construction Details Unknown

Groundwater Elevation Contours, Spring 2016 (GWE ft msl)

- Major (100-foot interval)
- Minor (50-foot interval)
- -46 - 0
- 1 - 50
- 51 - 100
- 101 - 150
- 151 - 200
- 201 - 250
- 251 - 300
- 301 - 350
- 351 - 400
- 401 - 450
- 451 - 500
- 501 - 550
- Approximate Extent of Corcoran Clay
- Kaweah Subbasin Boundary
- Kaweah Subbasin GSA

All Other Features

- Highway
- Waterway
- Lake

0 2 4 8
Miles

N

Kaweah Subbasin
Groundwater Sustainability Plan
Tulare County, California

Kaweah Subbasin

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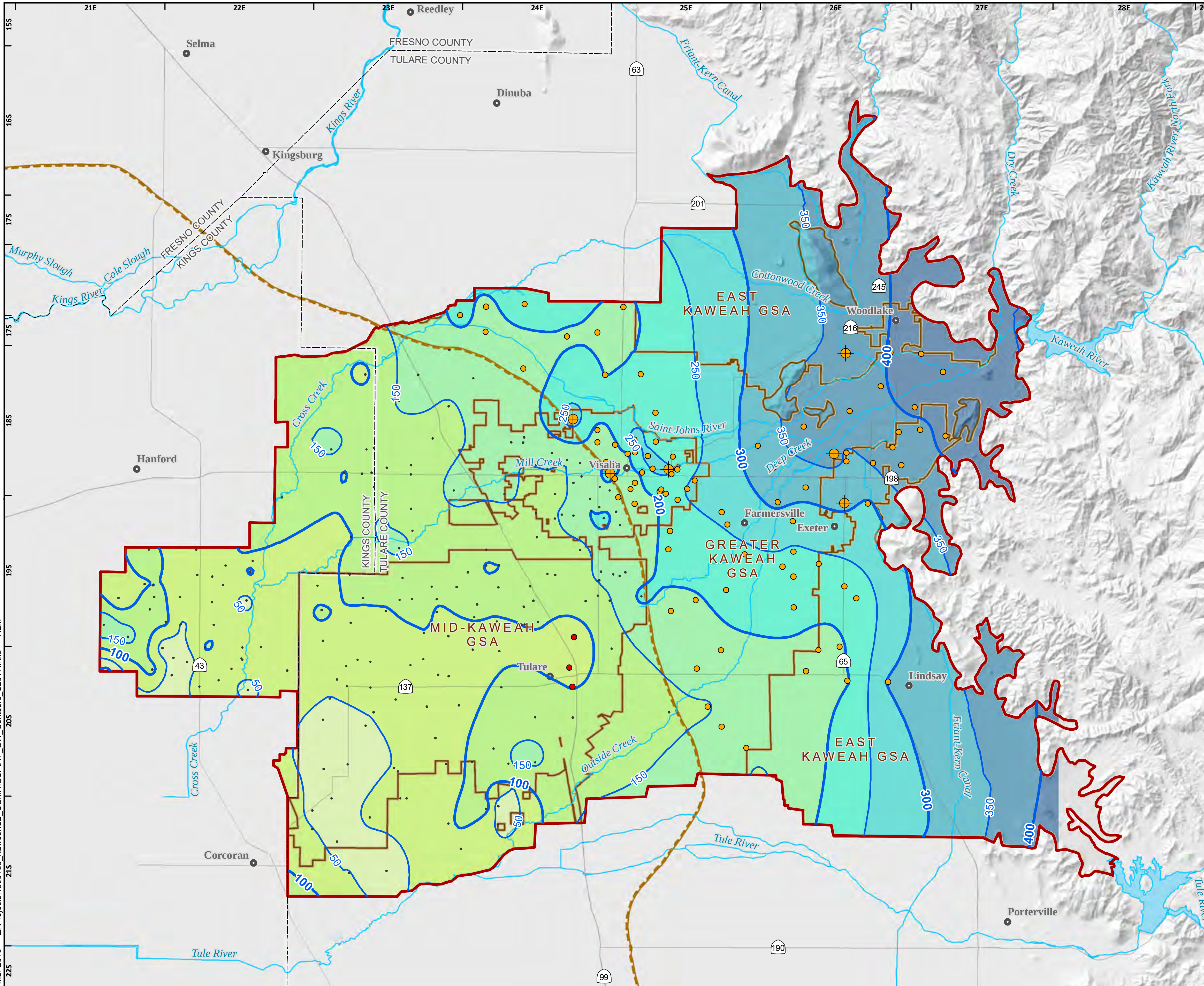
MARCH 2019 **DRAFT** FIGURE 27

SPRING 2017 GROUNDWATER ELEVATION CONTOURS



Lower Aquifer System, Dedicated Monitoring Well

Single Aquifer System, Dedicated Monitoring Well

Lower Aquifer System Well

Single Aquifer System Well

Well Construction Details Unknown

Groundwater Elevation Contours, Spring 2017 (GWE ft msl)

Major (100-foot interval)

Minor (50-foot interval)

-6 - 0

1 - 50

51 - 100

101 - 150

151 - 200

201 - 250

251 - 300

301 - 350

351 - 400

401 - 450

451 - 500

Approximate Extent of Corcoran Clay

Kaweah Subbasin Boundary

Kaweah Subbasin GSA

All Other Features

Highway

Waterway

Lake

0 2 4 8

Miles

N

Kaweah Subbasin
Groundwater Sustainability Plan
Tulare County, California

Kaweah Subbasin

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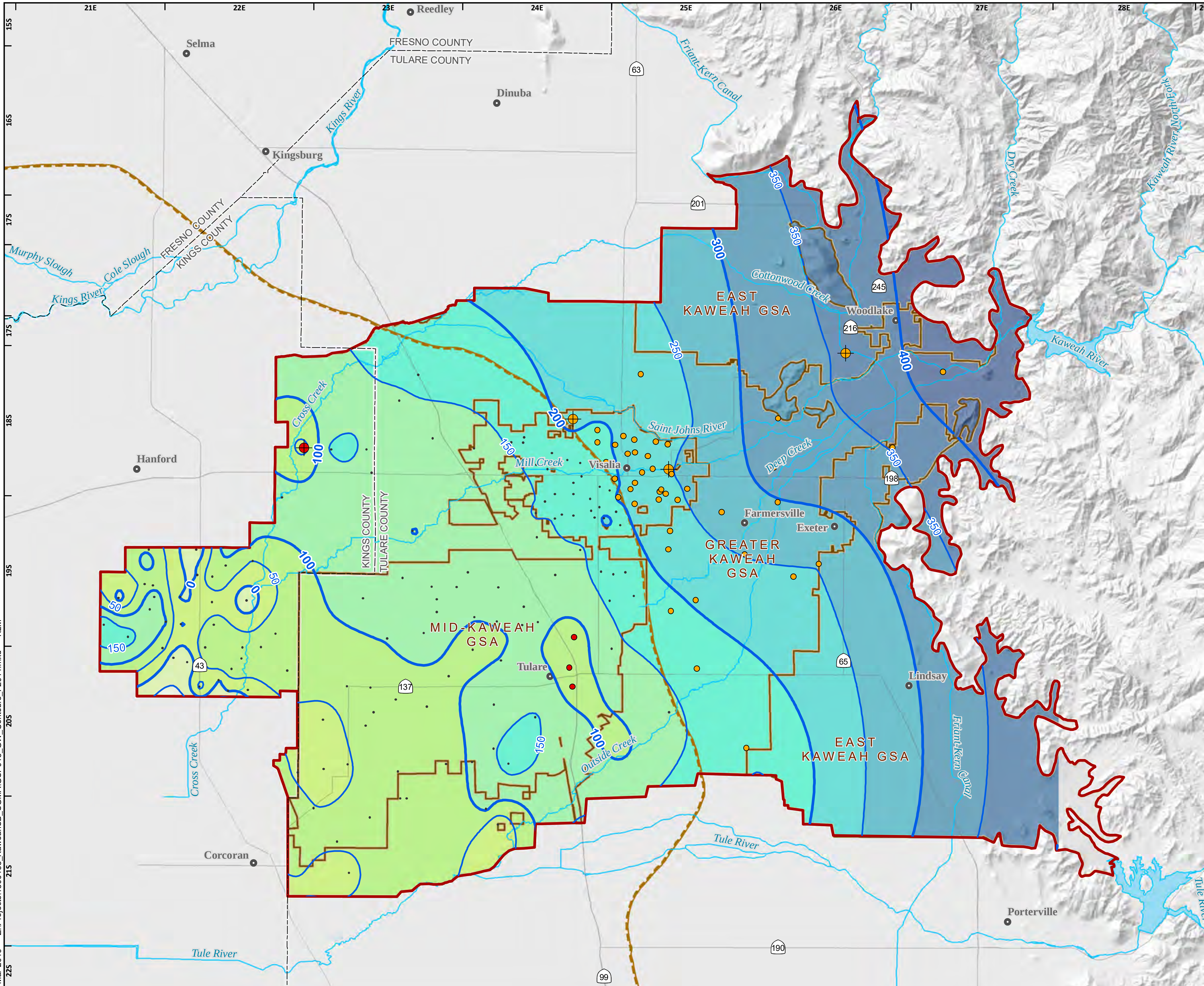
MARCH 2019 **DRAFT** FIGURE 28

FALL 2014 GROUNDWATER ELEVATION CONTOURS



- Lower Aquifer System, Dedicated Monitoring Well
- Single Aquifer System, Dedicated Monitoring Well
- Lower Aquifer System Well
- Single Aquifer System Well
- Well Construction Details Unknown

Groundwater Elevation Contours, Fall 2014 (GWE ft msl)

- Major (100-foot interval)
- Minor (50-foot interval)
- -75 - -50
- -49 - 0
- 1 - 50
- 51 - 100
- 101 - 150
- 151 - 200
- 201 - 250
- 251 - 300
- 301 - 350
- 351 - 400
- 401 - 450
- Approximate Extent of Corcoran Clay
- Kaweah Subbasin Boundary
- Kaweah Subbasin GSA

All Other Features

- Highway
- Waterway
- Lake

0 2 4 8
Miles

N

Kaweah Subbasin
Groundwater Sustainability Plan
Tulare County, California

Kaweah Subbasin

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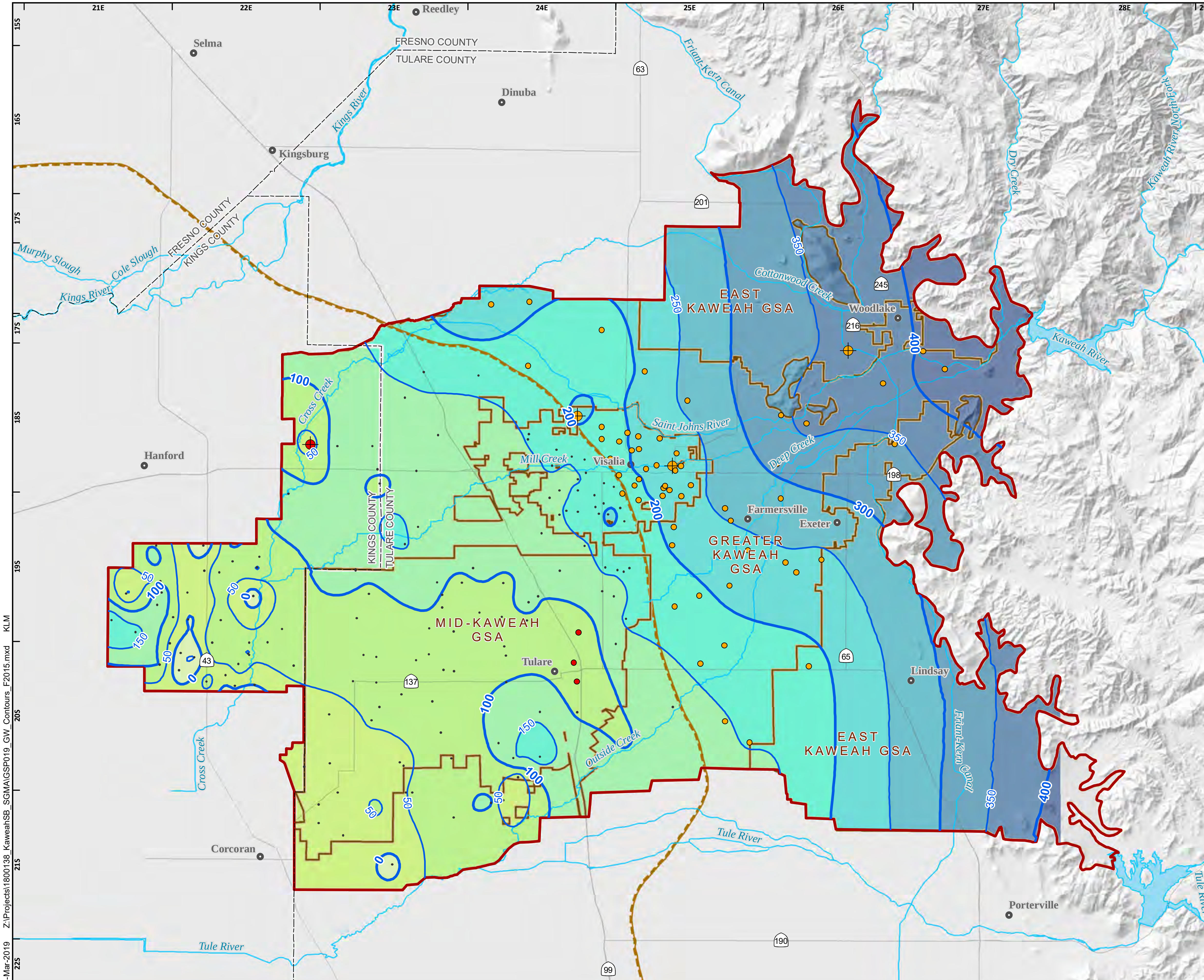
MARCH 2019 **DRAFT** FIGURE 29

FALL 2015 GROUNDWATER ELEVATION CONTOURS



- Lower Aquifer System, Dedicated Monitoring Well
- Single Aquifer System, Dedicated Monitoring Well
- Lower Aquifer System Well
- Single Aquifer System Well
- Well Construction Details Unknown

Groundwater Elevation Contours, Fall 2015 (GWE ft msl)

- Major (100-foot interval)
- Minor (50-foot interval)
- -52 - -50
- -49 - 0
- 1 - 50
- 51 - 100
- 101 - 150
- 151 - 200
- 201 - 250
- 251 - 300
- 301 - 350
- 351 - 400
- 401 - 450
- Approximate Extent of Corcoran Clay
- Kaweah Subbasin Boundary
- Kaweah Subbasin GSA

All Other Features

- Highway
- Waterway
- Lake

0 2 4 8
Miles

N

Kaweah Subbasin
Groundwater Sustainability Plan
Tulare County, California

Kaweah Subbasin

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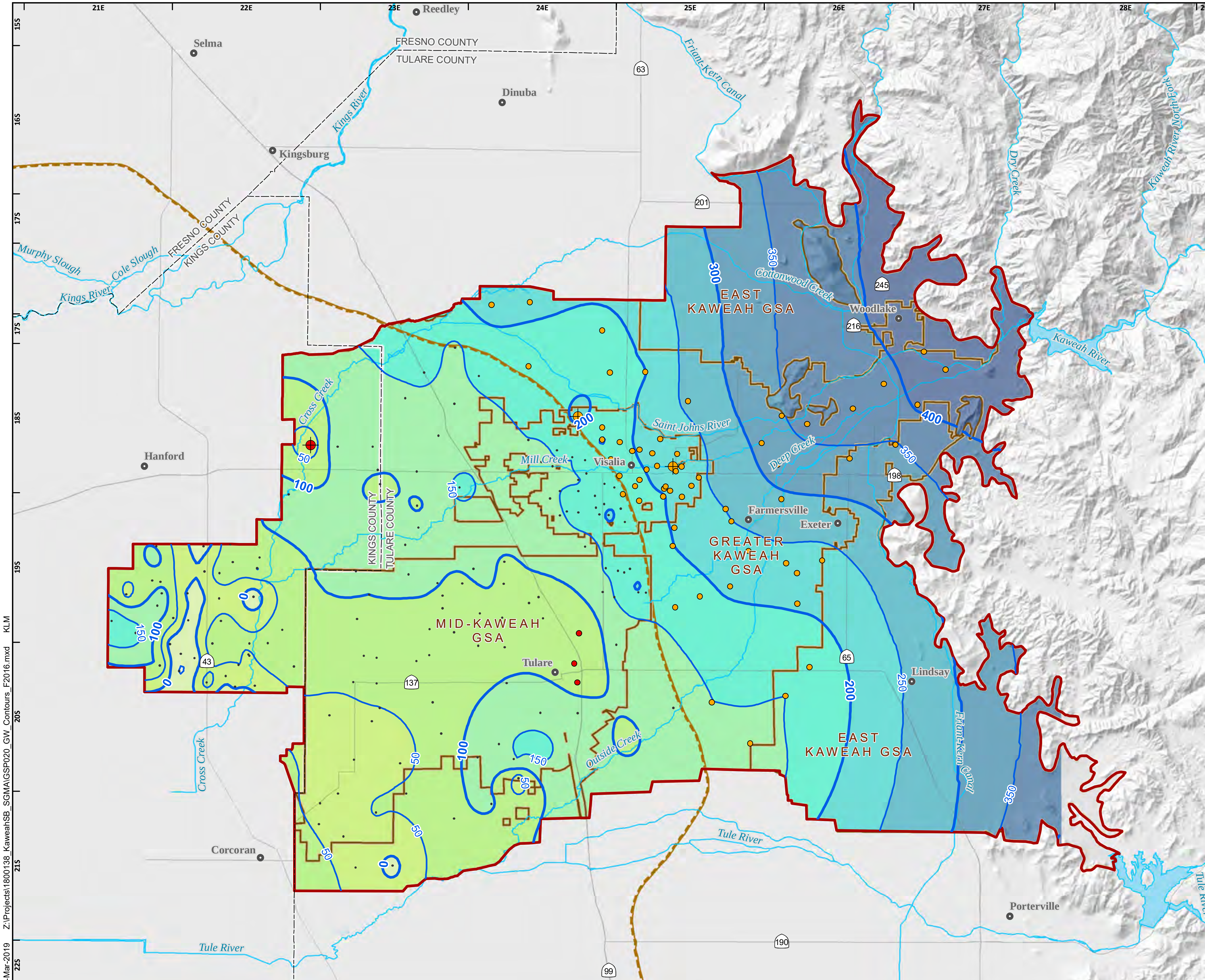
MARCH 2019 **DRAFT** FIGURE 30



FALL 2016 GROUNDWATER ELEVATION CONTOURS

- Lower Aquifer System, Dedicated Monitoring Well
- Single Aquifer System, Dedicated Monitoring Well
- Lower Aquifer System Well
- Single Aquifer System Well
- Well Construction Details Unknown

Groundwater Elevation Contours, Fall 2016 (GWE ft msl)

- Major (100-foot interval)
- Minor (50-foot interval)
- -56 - -50
- -49 - 0
- 1 - 50
- 51 - 100
- 101 - 150
- 151 - 200
- 201 - 250
- 251 - 300
- 301 - 350
- 351 - 400
- 401 - 450
- Approximate Extent of Corcoran Clay
- Kaweah Subbasin Boundary
- Kaweah Subbasin GSA

All Other Features

- Highway
- Waterway
- Lake

0 2 4 8
Miles
N

Kaweah Subbasin
Groundwater Sustainability Plan
Tulare County, California

Kaweah Subbasin

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MARCH 2019 **DRAFT** FIGURE 31

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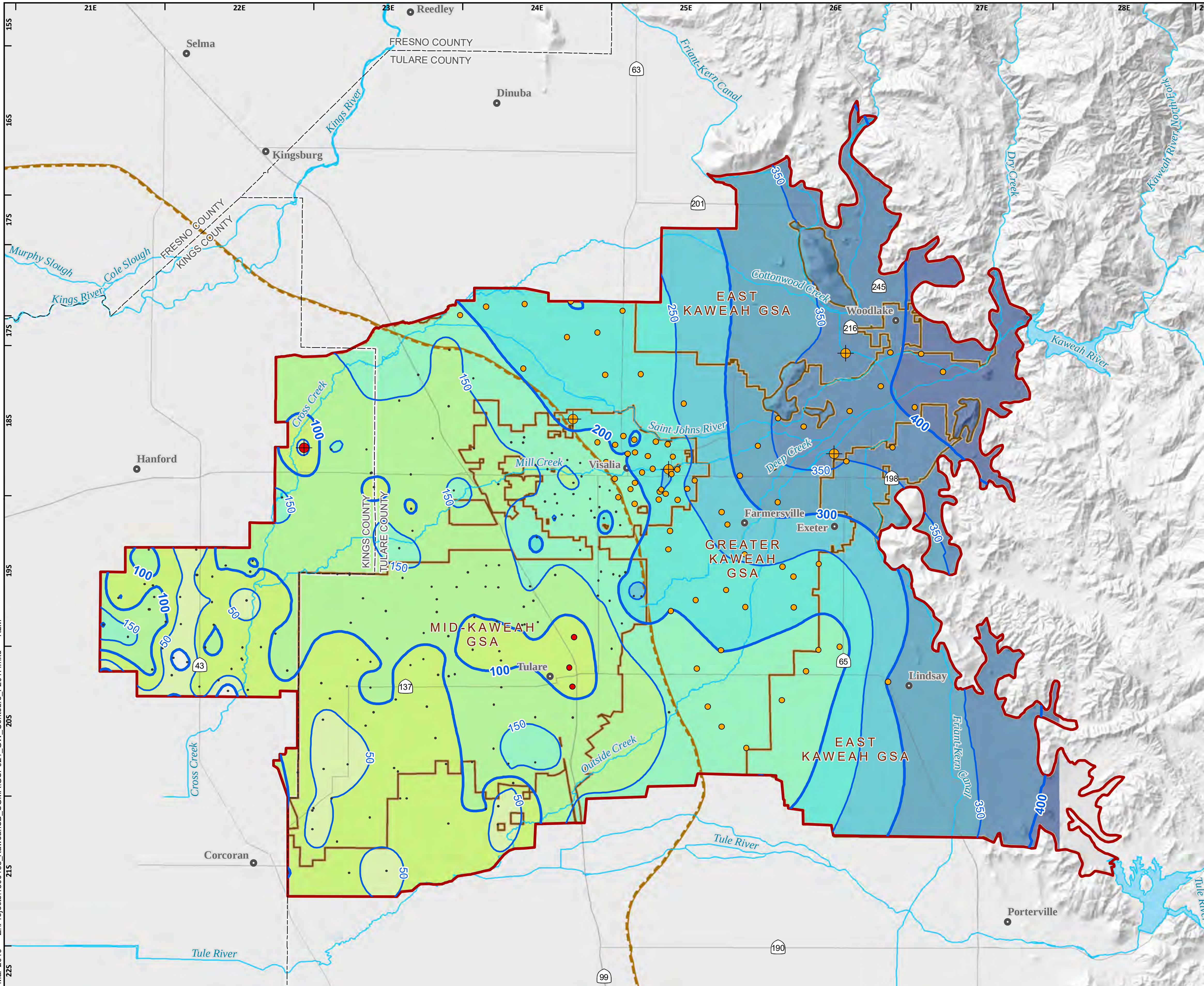
11-Mar-2019

FALL 2017 GROUNDWATER ELEVATION CONTOURS



Lower Aquifer System, Dedicated Monitoring Well

Single Aquifer System, Dedicated Monitoring Well

Lower Aquifer System Well

Single Aquifer System Well

Well Construction Details Unknown

Groundwater Elevation Contours, Fall 2017 (GWE ft msl)

Major (100-foot interval)

Minor (50-foot interval)

- -44 - 0
- 1 - 50
- 51 - 100
- 101 - 150
- 151 - 200
- 201 - 250
- 251 - 300
- 301 - 350
- 351 - 400
- 401 - 450

Approximate Extent of Corcoran Clay

Kaweah Subbasin Boundary

Kaweah Subbasin GSA

All Other Features

Highway

Waterway

Lake

0 2 4 8

Miles

N

Kaweah Subbasin
Groundwater Sustainability Plan
Tulare County, California

Kaweah Subbasin

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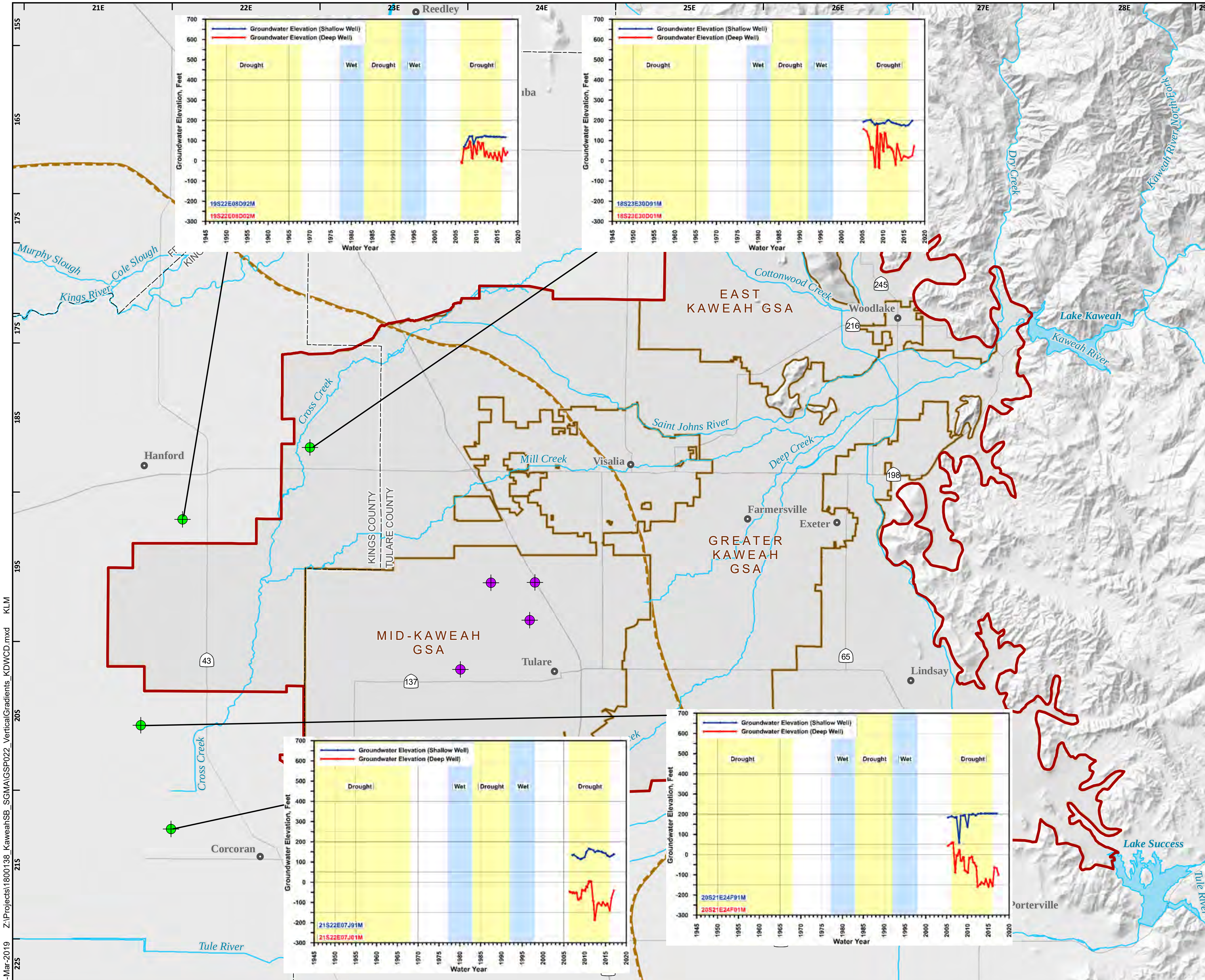
MARCH 2019 **DRAFT** FIGURE 32

Z:\Projects\1800138_KaweahSB_SGMA\GSP021_GW_Contours_F2017.mxd KLM

11-Mar-2019

VERTICAL GRADIENTS KAWEAH DELTA WATER CONSERVATION DISTRICT WELLS



Dual Completion Monitoring Wells

- KDWCD Dual Completion Wells
- TID Dual Completion Wells
- Approximate Extent of Corcoran Clay
- Kaweah Subbasin Boundary
- Kaweah Subbasin GSA

All Other Features

- Highway
- Waterway
- Lake

0 2 4 8
Miles

N

Kaweah Subbasin
Groundwater Sustainability Plan
Tulare County, California

Kaweah Subbasin

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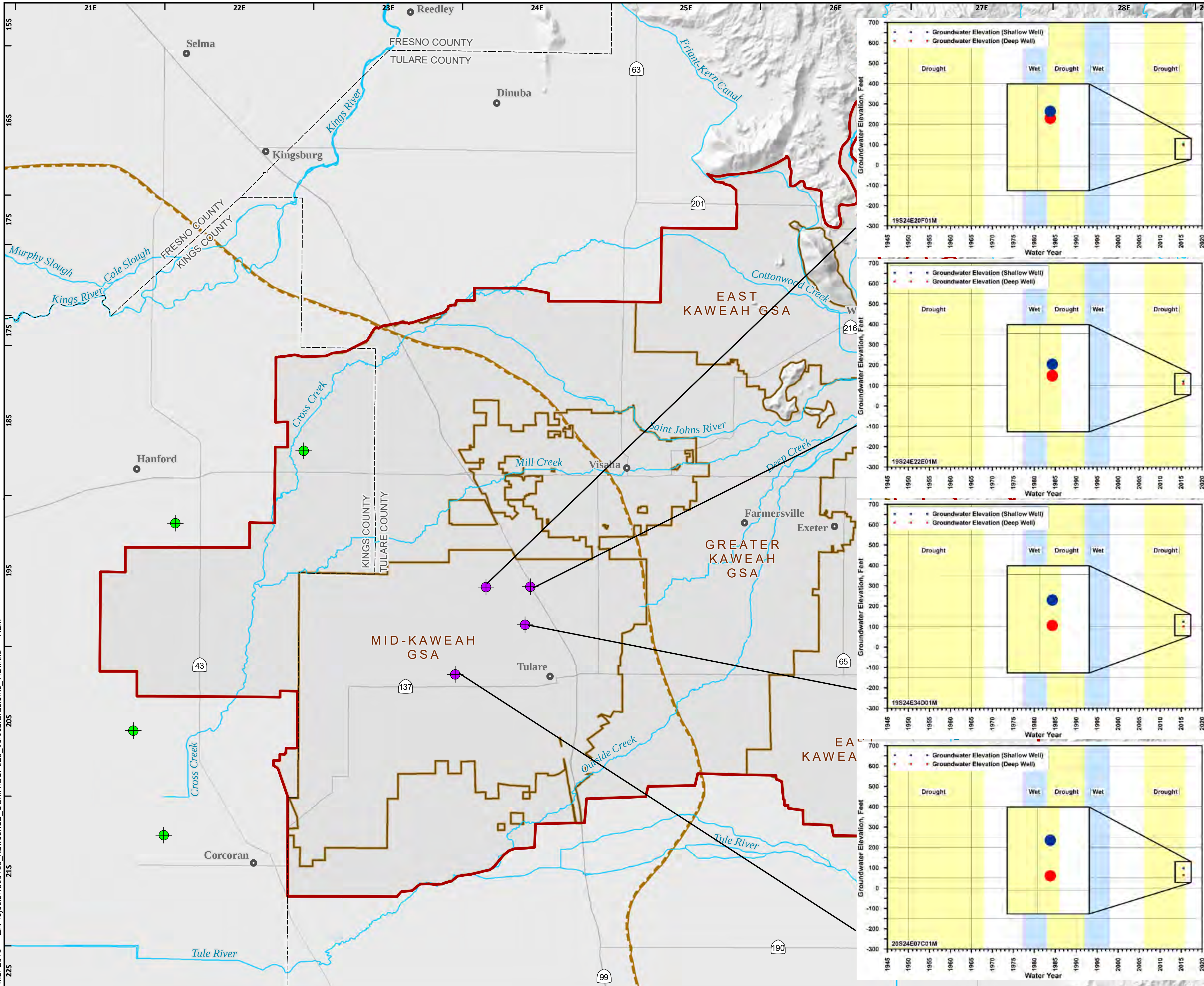
MARCH 2019 **DRAFT** FIGURE 33

11-Mar-2019 Z:\Projects\1800138_KaweahSB_SGMA\GSP022_VerticalGradients_KDWCD.mxd KLM



VERTICAL GRADIENTS TULARE IRRIGATION DISTRICTWELLS

Dual Completion Monitoring Wells

- KDWCD Dual Completion Wells
- TID Dual Completion Wells
- Approximate Extent of Corcoran Clay
- Kaweah Subbasin Boundary
- Kaweah Subbasin GSA

All Other Features

- Highway
- Waterway
- Lake

0 2 4 8
Miles

N

Kaweah Subbasin
Groundwater Sustainability Plan
Tulare County, California

Kaweah Subbasin

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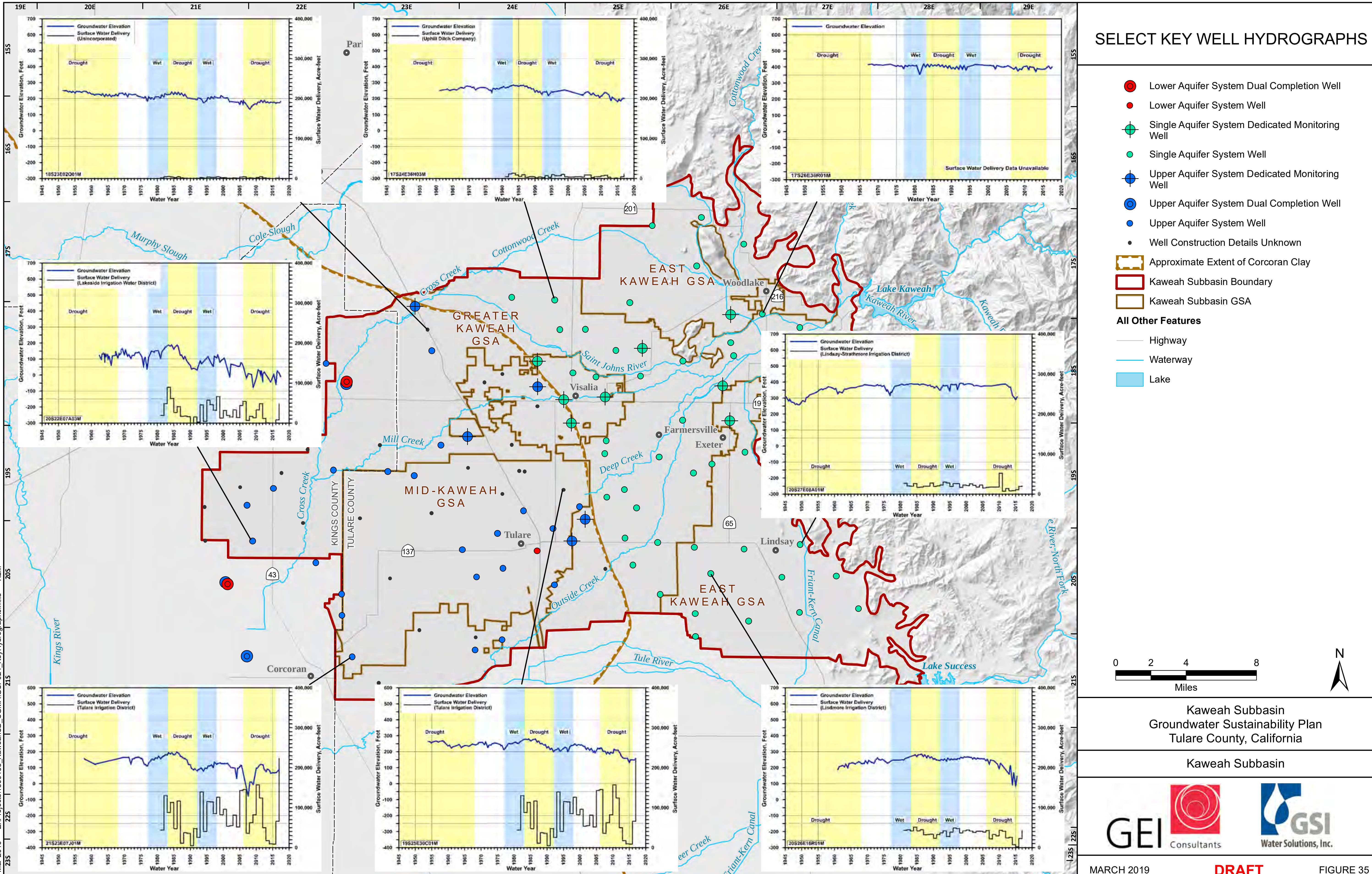
MARCH 2019 DRAFT FIGURE 34

11-Mar-2019 Z:\Projects\1800138_KaweahSB_SGMA\GSP023_VerticalGradients_TID.mxd KLM



SELECT KEY WELL HYDROGRAPHS

Kaweah Subbasin
Groundwater Sustainability Plan
Tulare County, California

Kaweah Subbasin

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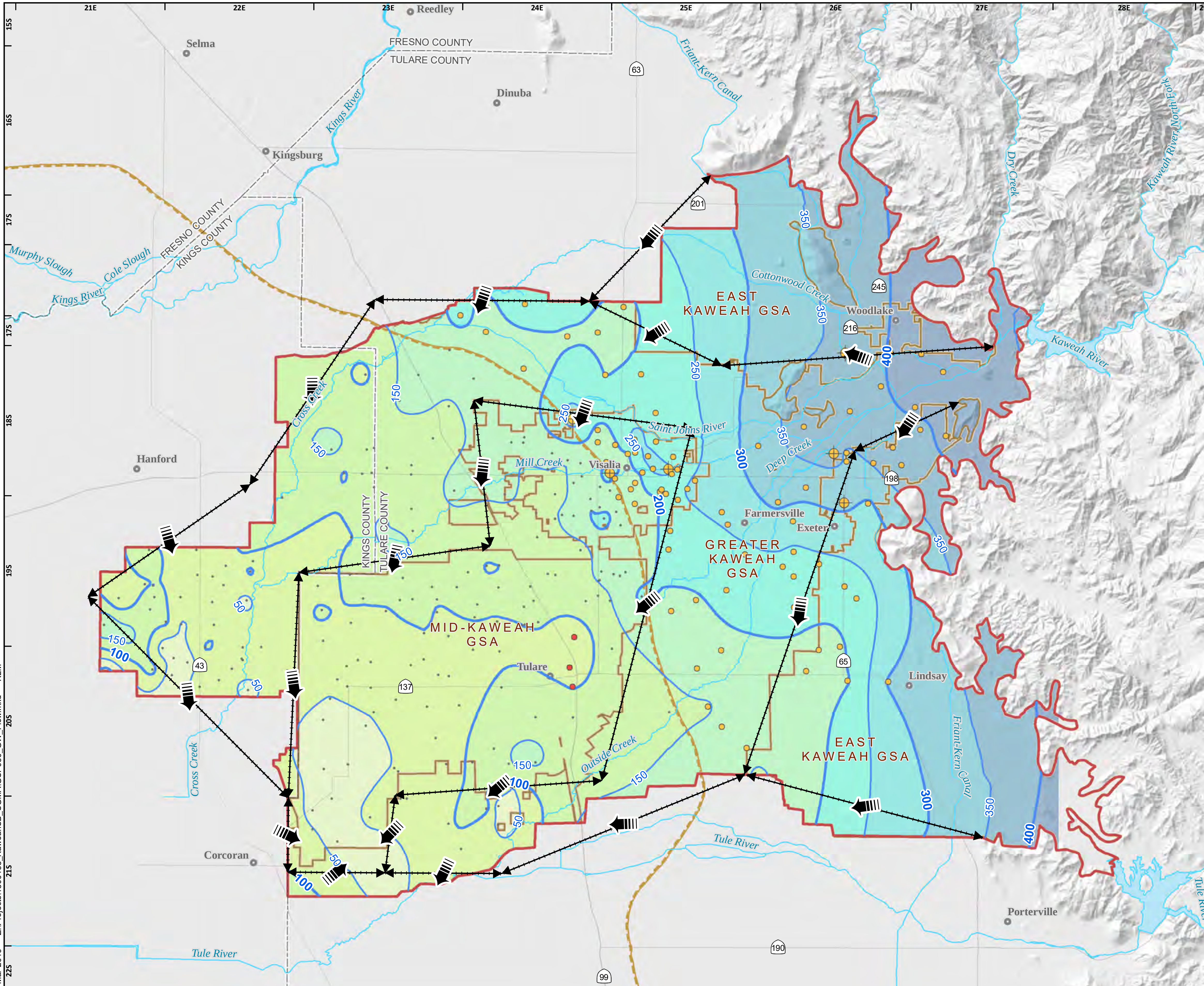
MARCH 2019 DRAFT FIGURE 35

TYPICAL GROUNDWATER FLOW SPRING 2017



Subsurface Flow Vector
Darcian Flux Line
Lower Aquifer System, Dedicated Monitoring Well
Single Aquifer System, Dedicated Monitoring Well
Lower Aquifer System Well
Single Aquifer System Well
Well Construction Details Unknown

Groundwater Elevation Contours, Spring 2017 (GWE ft msl)

Major (100-foot interval)
Minor (50-foot interval)
-6 - 0
1 - 50
51 - 100
101 - 150
151 - 200
201 - 250
251 - 300
301 - 350
351 - 400
401 - 450
451 - 500
Approximate Extent of Corcoran Clay
Kaweah Subbasin Boundary
Kaweah Subbasin GSA

All Other Features

Highway
Waterway
Lake

0 2 4 8
Miles
N

Kaweah Subbasin
Groundwater Sustainability Plan
Tulare County, California

Kaweah Subbasin

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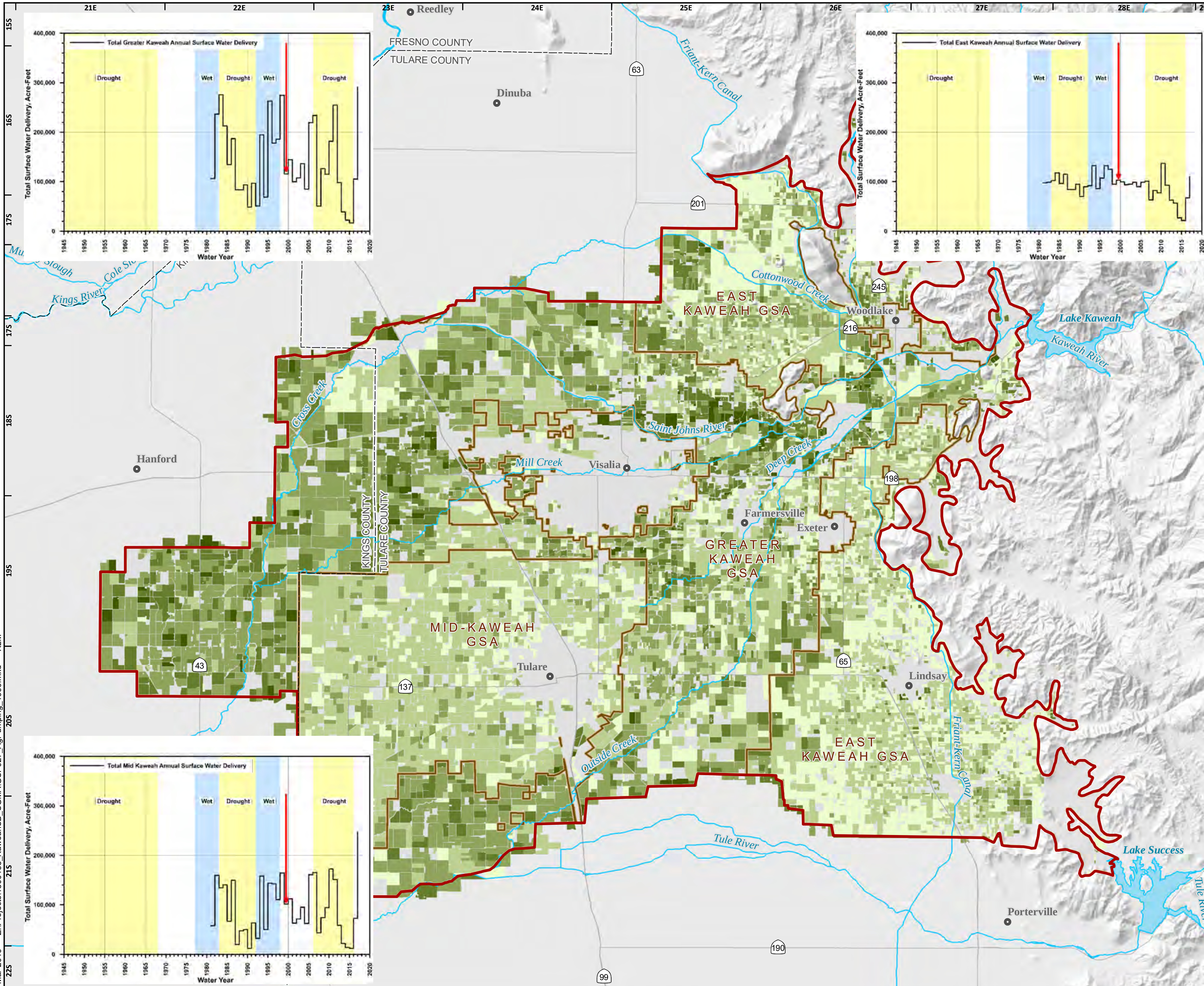
MARCH 2019 **DRAFT** FIGURE 43



ANNUAL AGRICULTURAL PUMPING WATER YEAR 1999

Agricultural Pumping, acre-feet/acre

- 0.0 - 1.0
- 1.1 - 2.0
- 2.1 - 3.0
- 3.1 - 4.0
- > 4.0
- Kaweah Subbasin Boundary
- Kaweah Subbasin GSA

All Other Features

- Highway
- Waterway
- Lake

0 2 4 8
Miles
N

Kaweah Subbasin
Groundwater Sustainability Plan
Tulare County, California

Kaweah Subbasin

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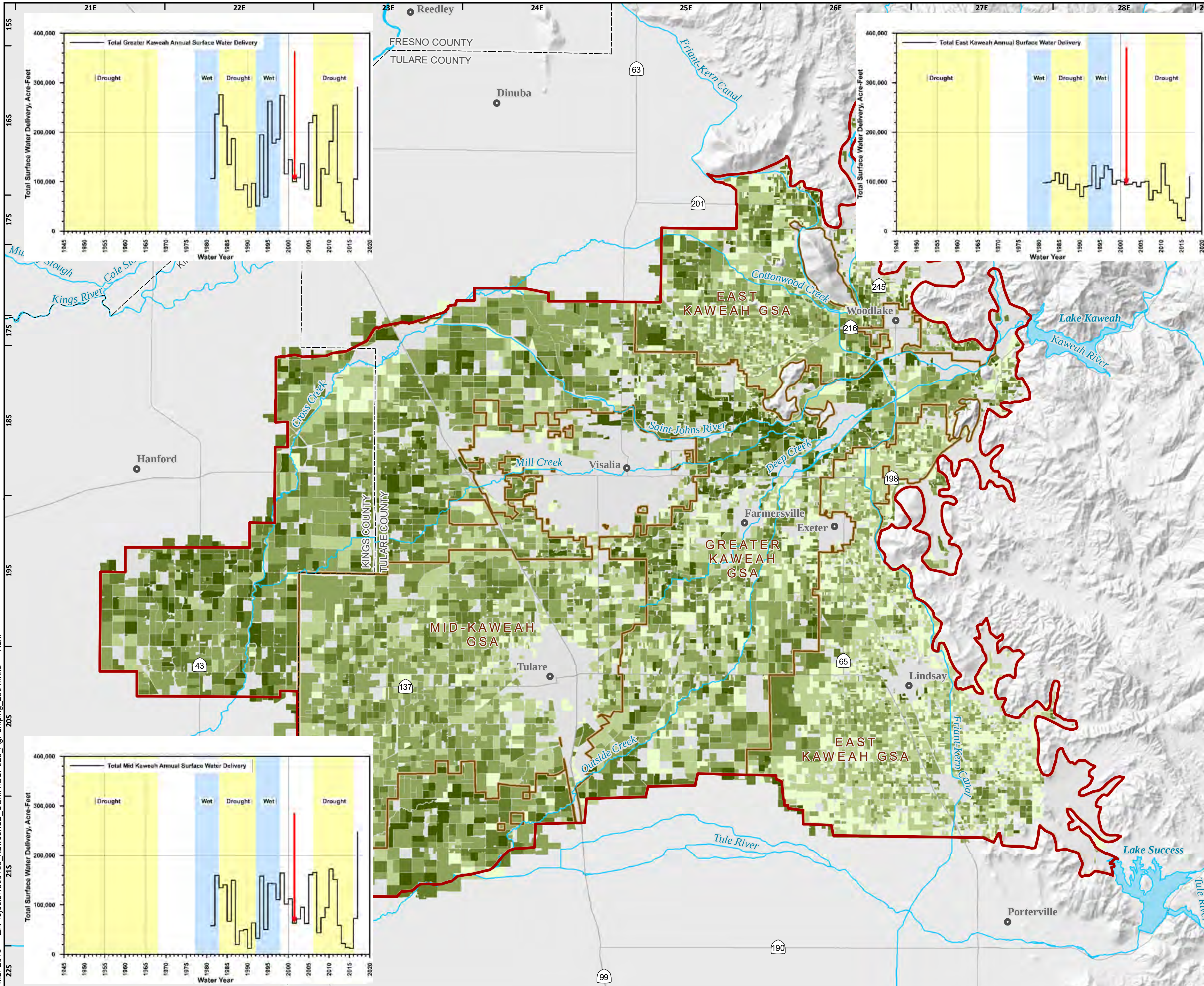
MARCH 2019 **DRAFT** FIGURE 45

11-Mar-2019 Z:\Projects\1800138_KaweahSB_SGMA\GSP027_AgPumping_1999.mxd KLM



ANNUAL AGRICULTURAL PUMPING WATER YEAR 2001

Agricultural Pumping, acre-feet/acre

- 0.0 - 1.0
- 1.1 - 2.0
- 2.1 - 3.0
- 3.1 - 4.0
- > 4.0
- Kaweah Subbasin Boundary
- Kaweah Subbasin GSA

All Other Features

- Highway
- Waterway
- Lake

0 2 4 8
Miles
N

Kaweah Subbasin
Groundwater Sustainability Plan
Tulare County, California

Kaweah Subbasin

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MARCH 2019 **DRAFT** FIGURE 46

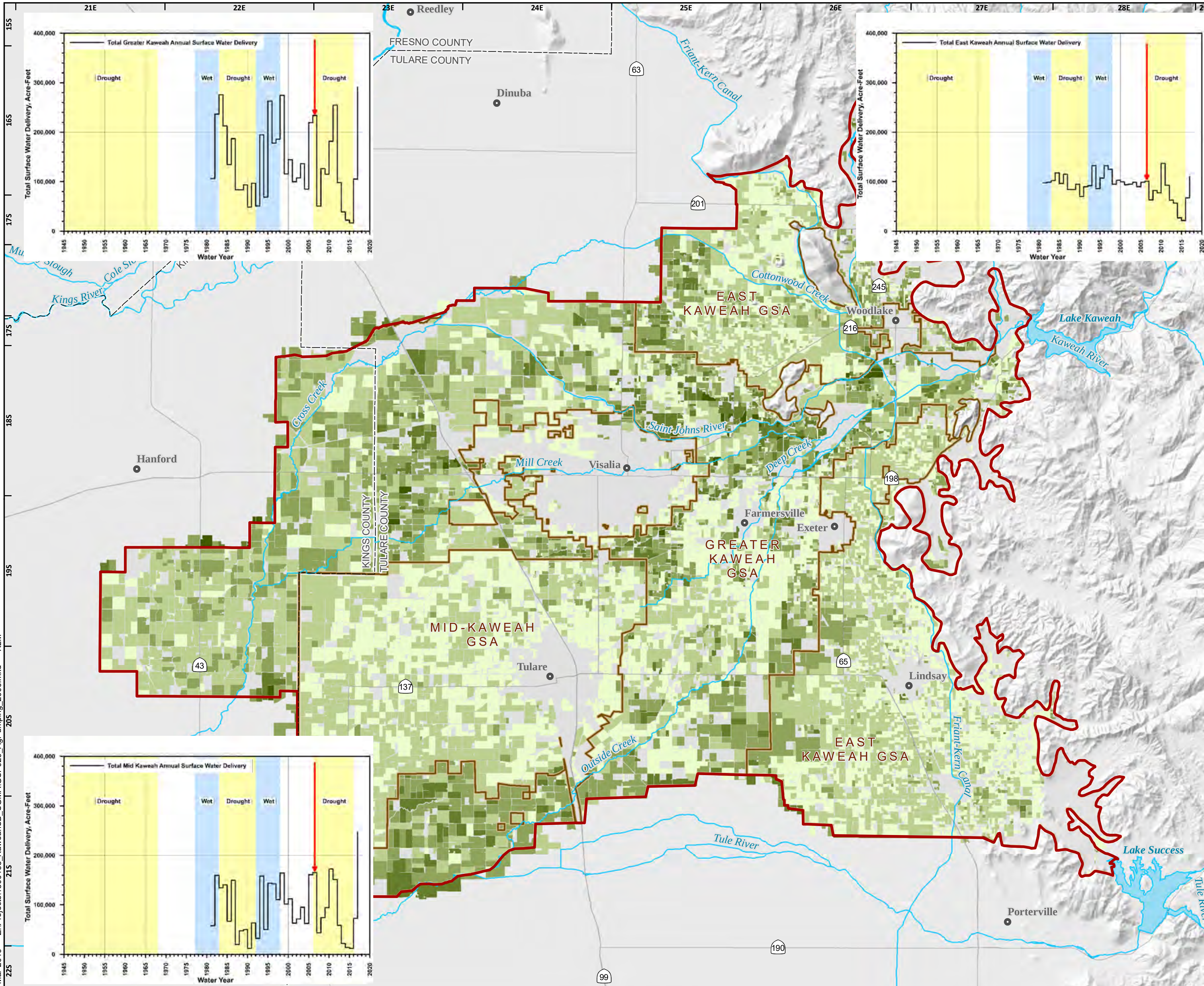
ANNUAL AGRICULTURAL PUMPING WATER YEAR 2006

Agricultural Pumping, acre-feet/acre

- 0.0 - 1.0
- 1.1 - 2.0
- 2.1 - 3.0
- 3.1 - 4.0
- > 4.0
- Kaweah Subbasin Boundary
- Kaweah Subbasin GSA

All Other Features

- Highway
- Waterway
- Lake



Kaweah Subbasin
Groundwater Sustainability Plan
Tulare County, California

Kaweah Subbasin

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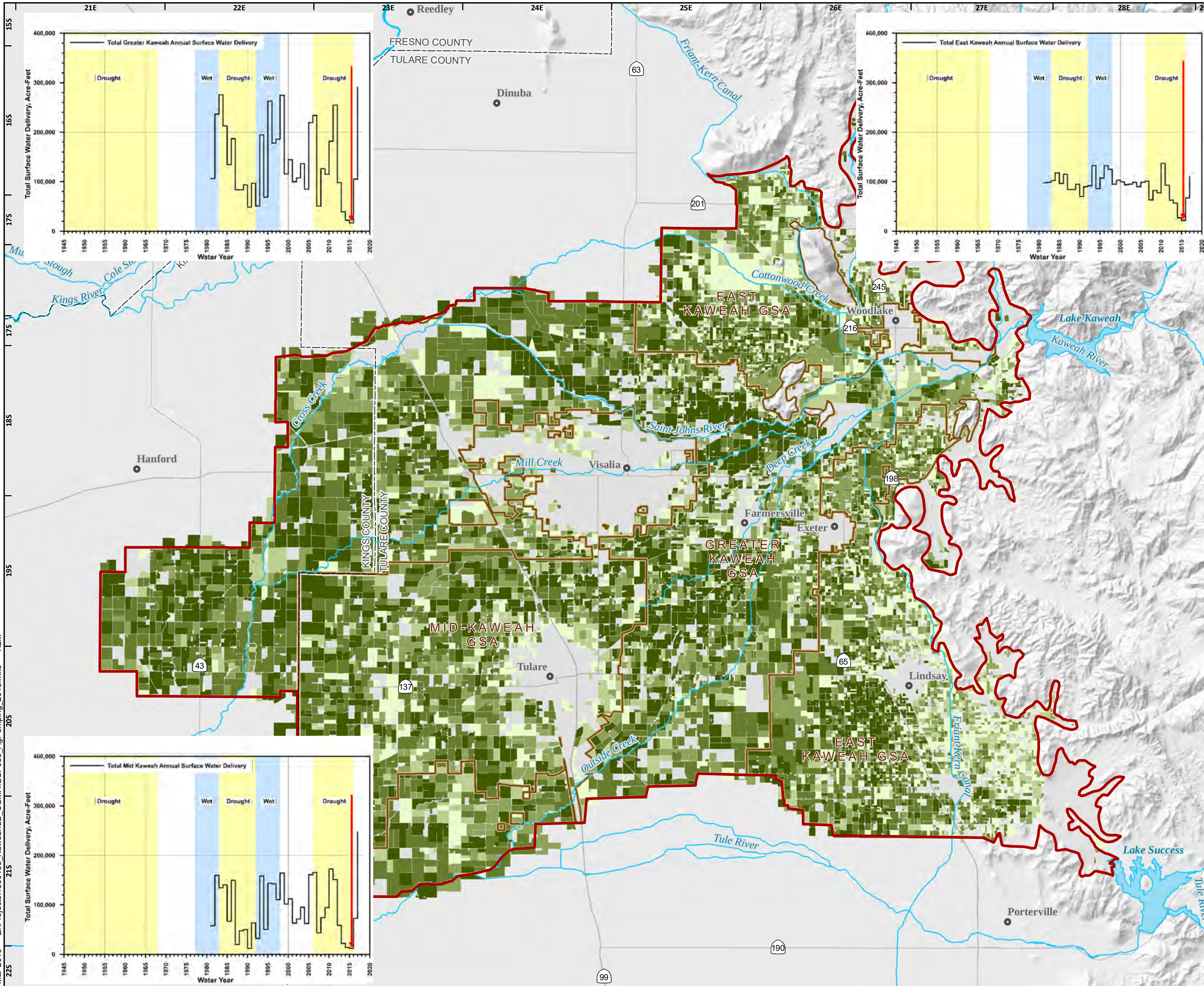
MARCH 2019 **DRAFT** FIGURE 47

11-Mar-2019 Z:\Projects\1800138_KaweahSB_SGMA\GSP029_AgPumping_2006.mxd KLM

ANNUAL AGRICULTURAL PUMPING WATER YEAR 2015



Agricultural Pumping, acre-feet/acre

- 0.0 - 1.0
- 1.1 - 2.0
- 2.1 - 3.0
- 3.1 - 4.0
- > 4.0
- Kaweah Subbasin Boundary
- Kaweah Subbasin GSA

All Other Features

- Highway
- Waterway
- Lake

0 2 4 8
Miles
N

Kaweah Subbasin
Groundwater Sustainability Plan
Tulare County, California

Kaweah Subbasin

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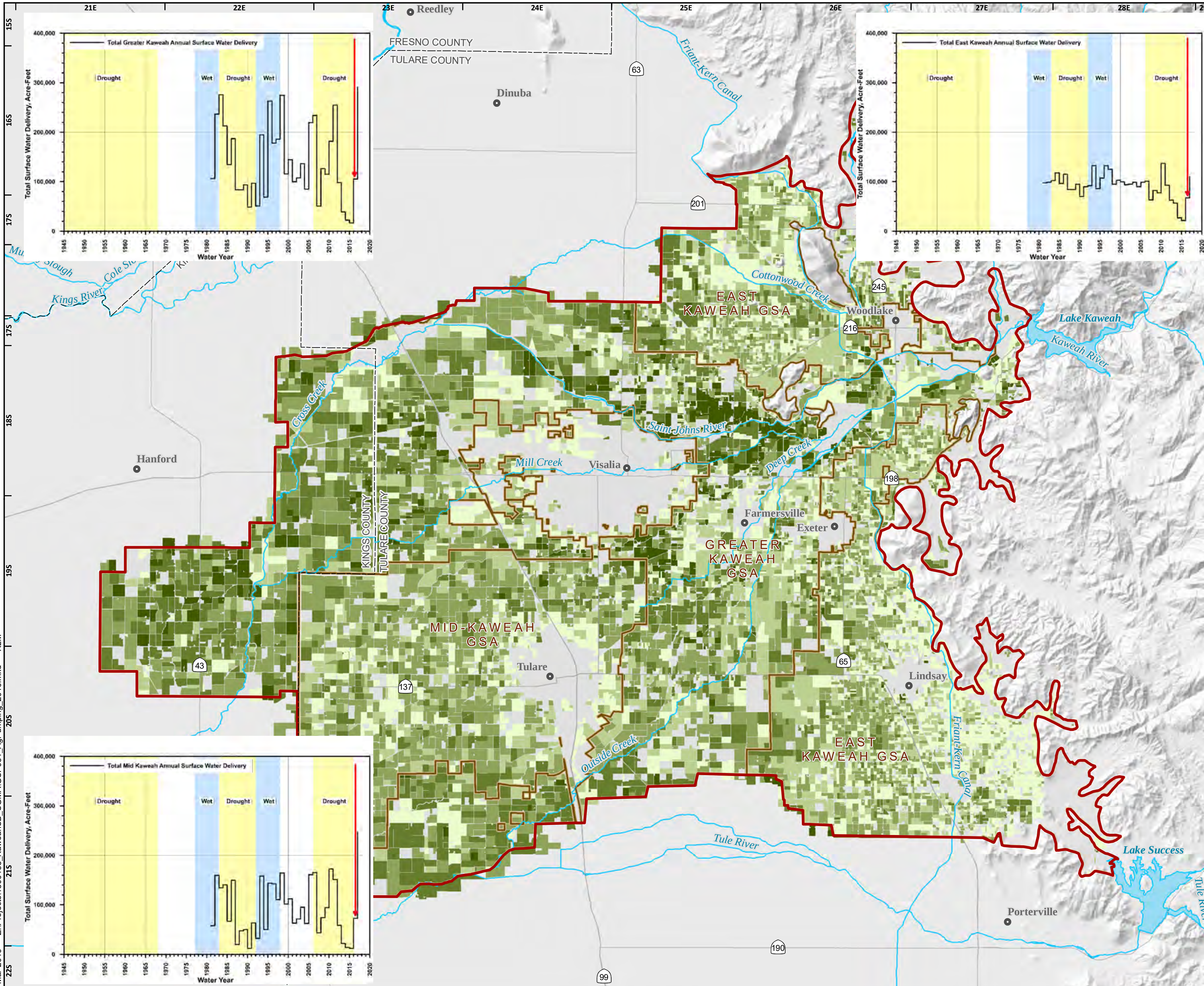
MARCH 2019 **DRAFT** FIGURE 48

11-Mar-2019 Z:\Projects\1800138_KaweahSB_SGMA\GSP030_AgPumping_2015.mxd KLM



ANNUAL AGRICULTURAL PUMPING WATER YEAR 2016

Agricultural Pumping, acre-feet/acre

- 0.0 - 1.0
- 1.1 - 2.0
- 2.1 - 3.0
- 3.1 - 4.0
- > 4.0
- Kaweah Subbasin Boundary
- Kaweah Subbasin GSA

All Other Features

- Highway
- Waterway
- Lake

0 2 4 8
Miles

N

Kaweah Subbasin
Groundwater Sustainability Plan
Tulare County, California

Kaweah Subbasin

GEI Consultants
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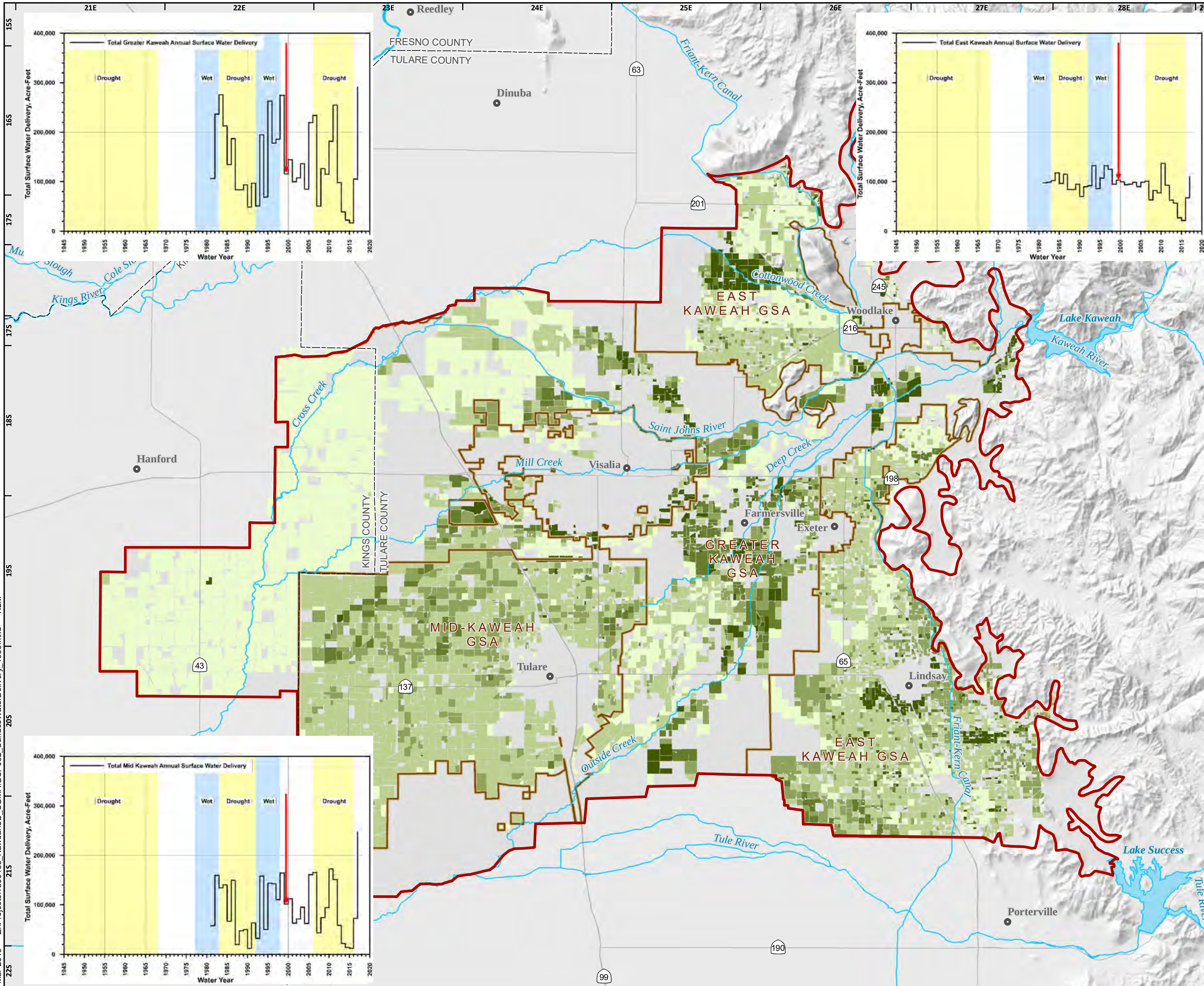
MARCH 2019 **DRAFT** FIGURE 49

ANNUAL SURFACE WATER DELIVERY WATER YEAR 1999



Surface Water Delivery, acre-feet/acre

- < 1.0
- 1.1 - 2.0
- 2.1 - 3.0
- 3.1 - 4.0
- > 4.0
- Kaweah Subbasin Boundary
- Kaweah Subbasin GSA

All Other Features

- Highway
- Waterway
- Lake

0 2 4 8 Miles

N

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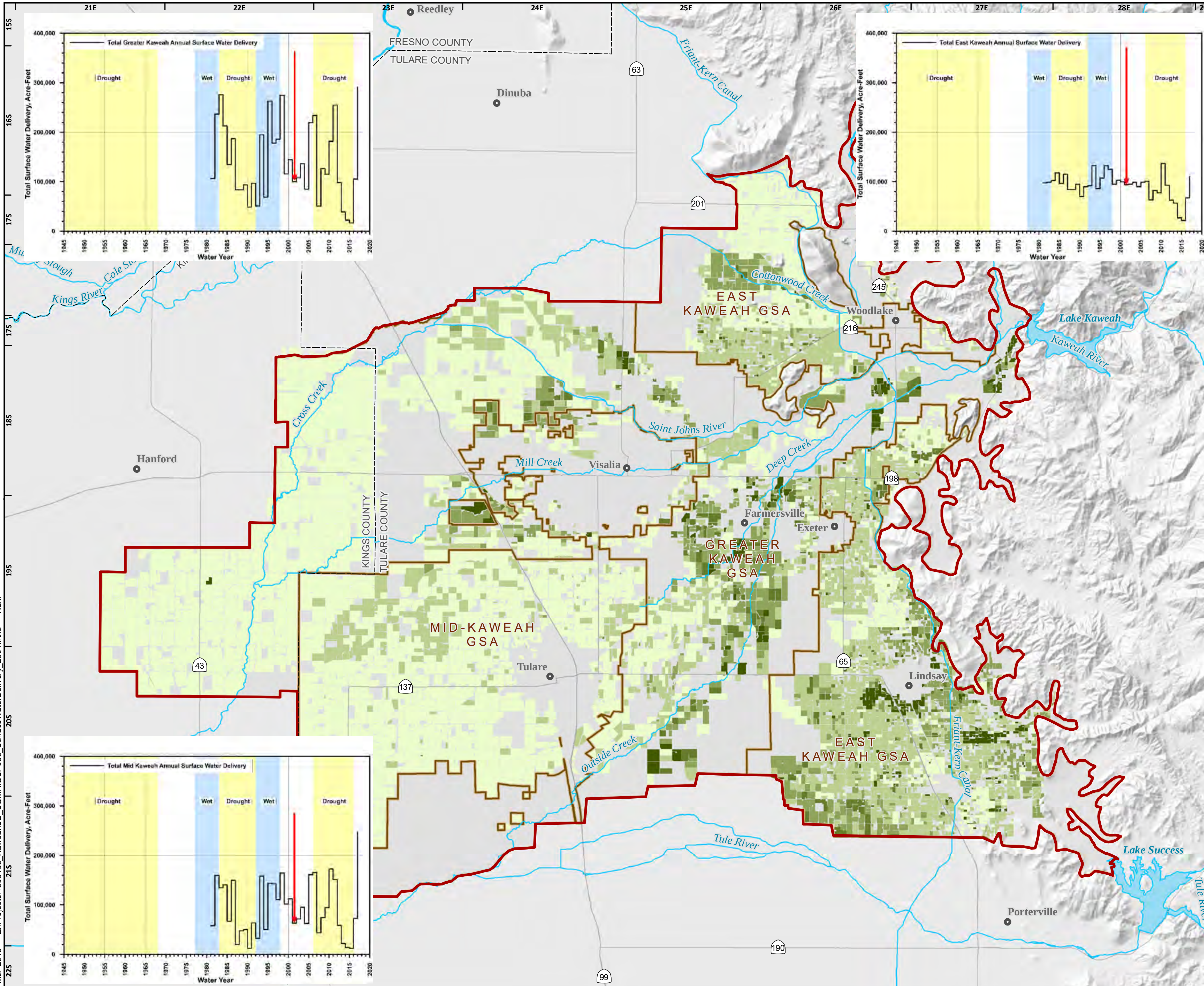
MARCH 2019 **DRAFT** FIGURE 50

Z:\Projects\1800138_KaweahSB_SGMA\GSP032_SurfaceWaterDelivery_1999.mxd KLM
12-Mar-2019

ANNUAL SURFACE WATER DELIVERY WATER YEAR 2001



Surface Water Delivery, acre-feet/acre

- < 1.0
- 1.1 - 2.0
- 2.1 - 3.0
- 3.1 - 4.0
- > 4.0
- Kaweah Subbasin Boundary
- Kaweah Subbasin GSA

All Other Features

- Highway
- Waterway
- Lake

0 2 4 8
Miles

N

Kaweah Subbasin
Groundwater Sustainability Plan
Tulare County, California

Kaweah Subbasin

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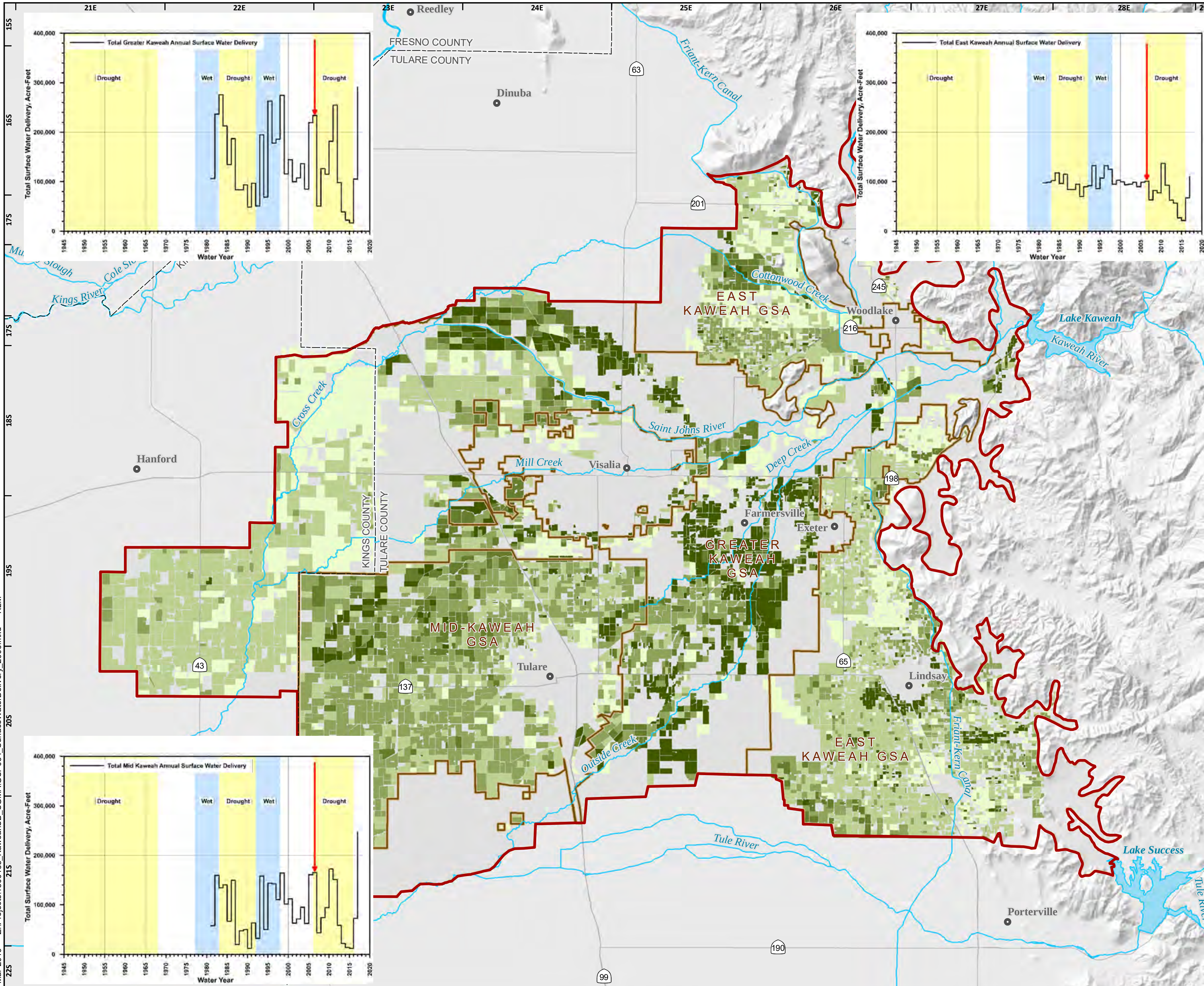
MARCH 2019 **DRAFT** FIGURE 51

Z:\Projects\1800138_KaweahSB_SGMA\GSP033_SurfaceWaterDelivery_2001.mxd KLM
12-Mar-2019



ANNUAL SURFACE WATER DELIVERY WATER YEAR 2006

Surface Water Delivery, acre-feet/acre

- < 1.0
- 1.1 - 2.0
- 2.1 - 3.0
- 3.1 - 4.0
- > 4.0
- Kaweah Subbasin Boundary
- Kaweah Subbasin GSA

All Other Features

- Highway
- Waterway
- Lake

0 2 4 8
Miles

N

Kaweah Subbasin
Groundwater Sustainability Plan
Tulare County, California

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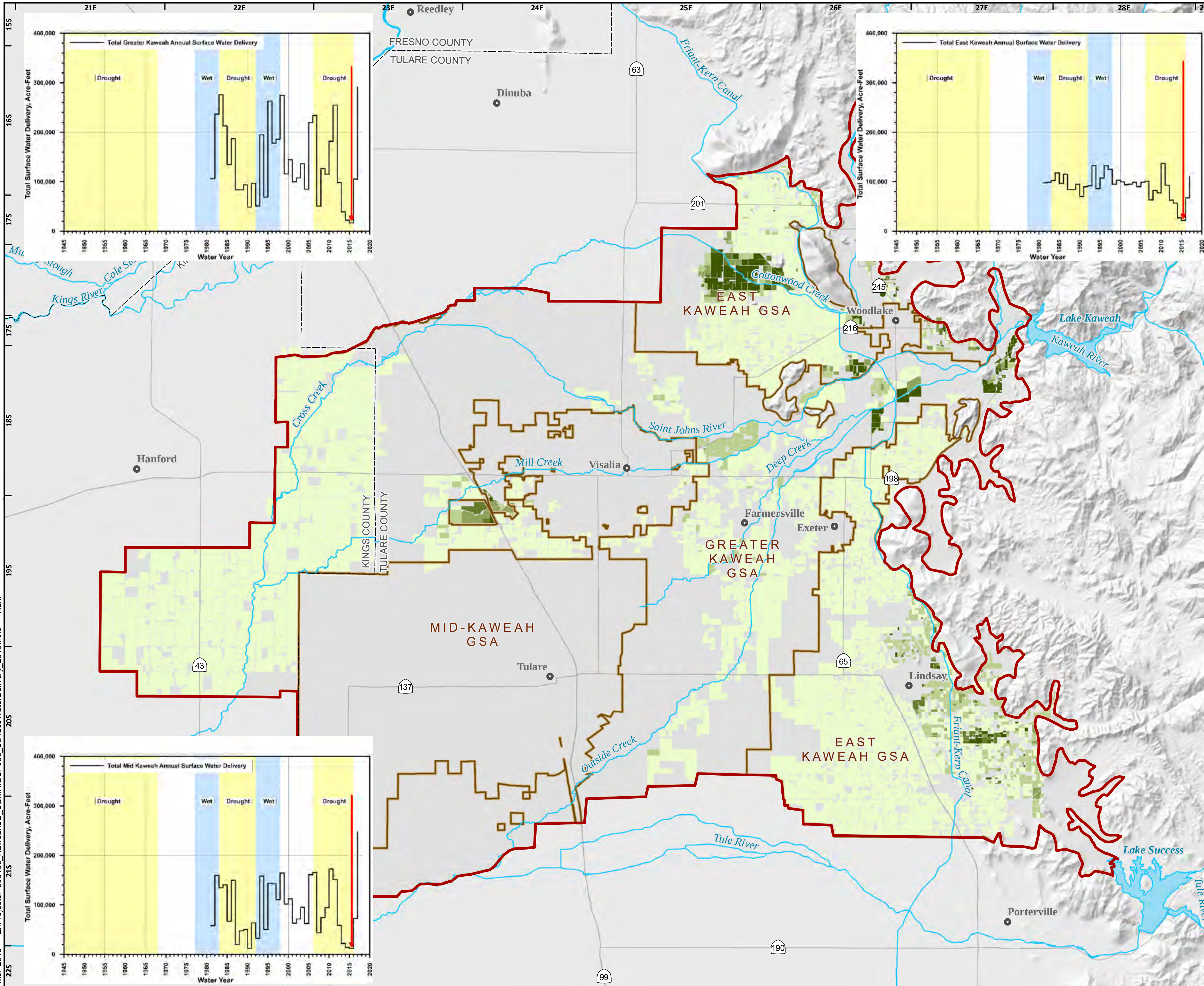
MARCH 2019 DRAFT FIGURE 52

Z:\Projects\1800138_KaweahSB_SGMA\GSP034_SurfaceWaterDelivery_2006.mxd KLM
12-Mar-2019

ANNUAL SURFACE WATER DELIVERY WATER YEAR 2015



Surface Water Delivery, acre-feet/acre

- < 1.0
- 1.1 - 2.0
- 2.1 - 3.0
- 3.1 - 4.0
- > 4.0
- Kaweah Subbasin Boundary
- Kaweah Subbasin GSA

All Other Features

- Highway
- Waterway
- Lake

0 2 4 8
Miles

N

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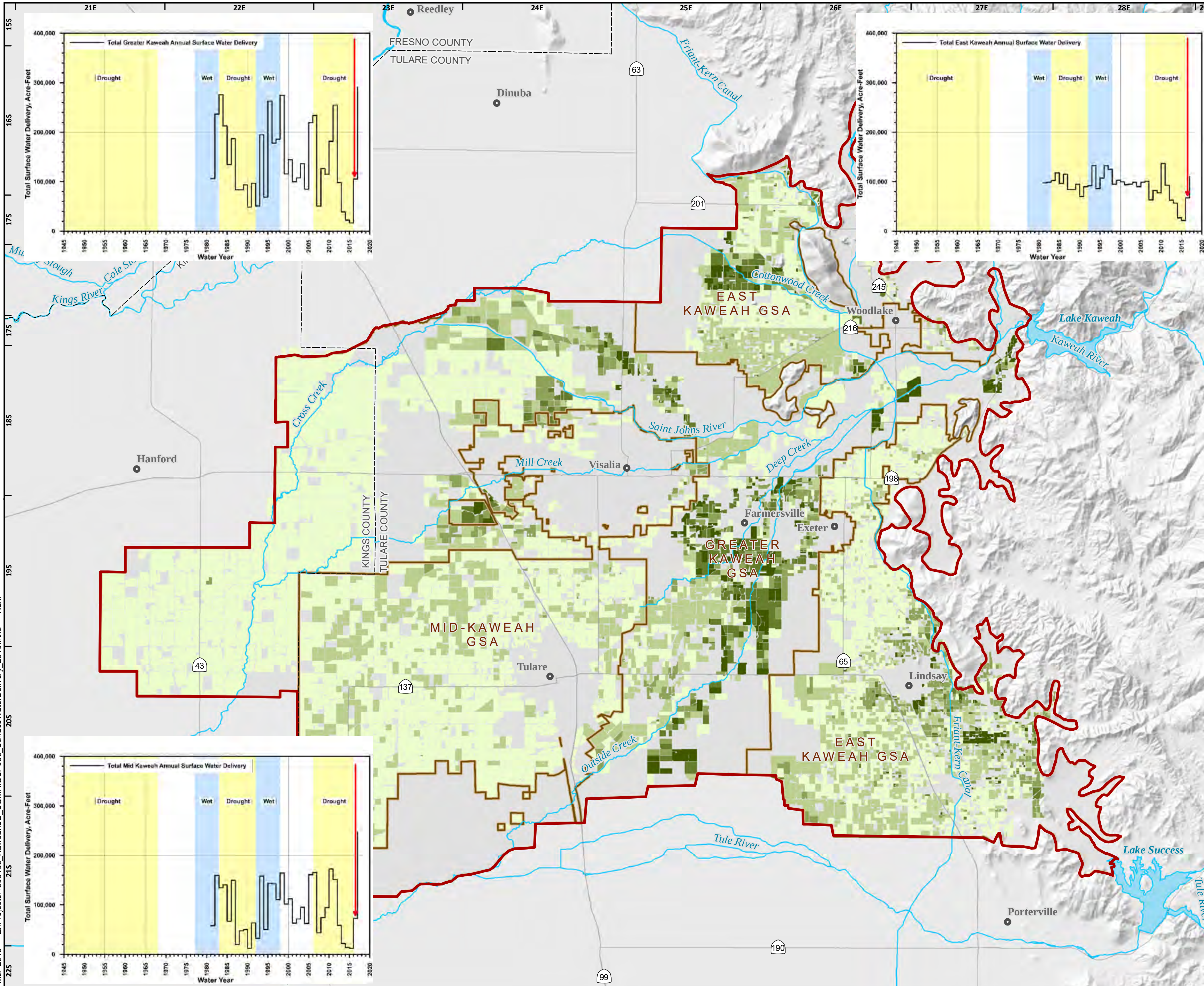
MARCH 2019 DRAFT FIGURE 53

12-Mar-2019 Z:\Projects\1800138_KaweahSB_SGMA\GSP035_SurfaceWaterDelivery_2015.mxd KLM



ANNUAL SURFACE WATER DELIVERY WATER YEAR 2016

Surface Water Delivery, acre-feet/acre

- < 1.0
- 1.1 - 2.0
- 2.1 - 3.0
- 3.1 - 4.0
- > 4.0
- Kaweah Subbasin Boundary
- Kaweah Subbasin GSA

All Other Features

- Highway
- Waterway
- Lake

0 2 4 8
Miles

N

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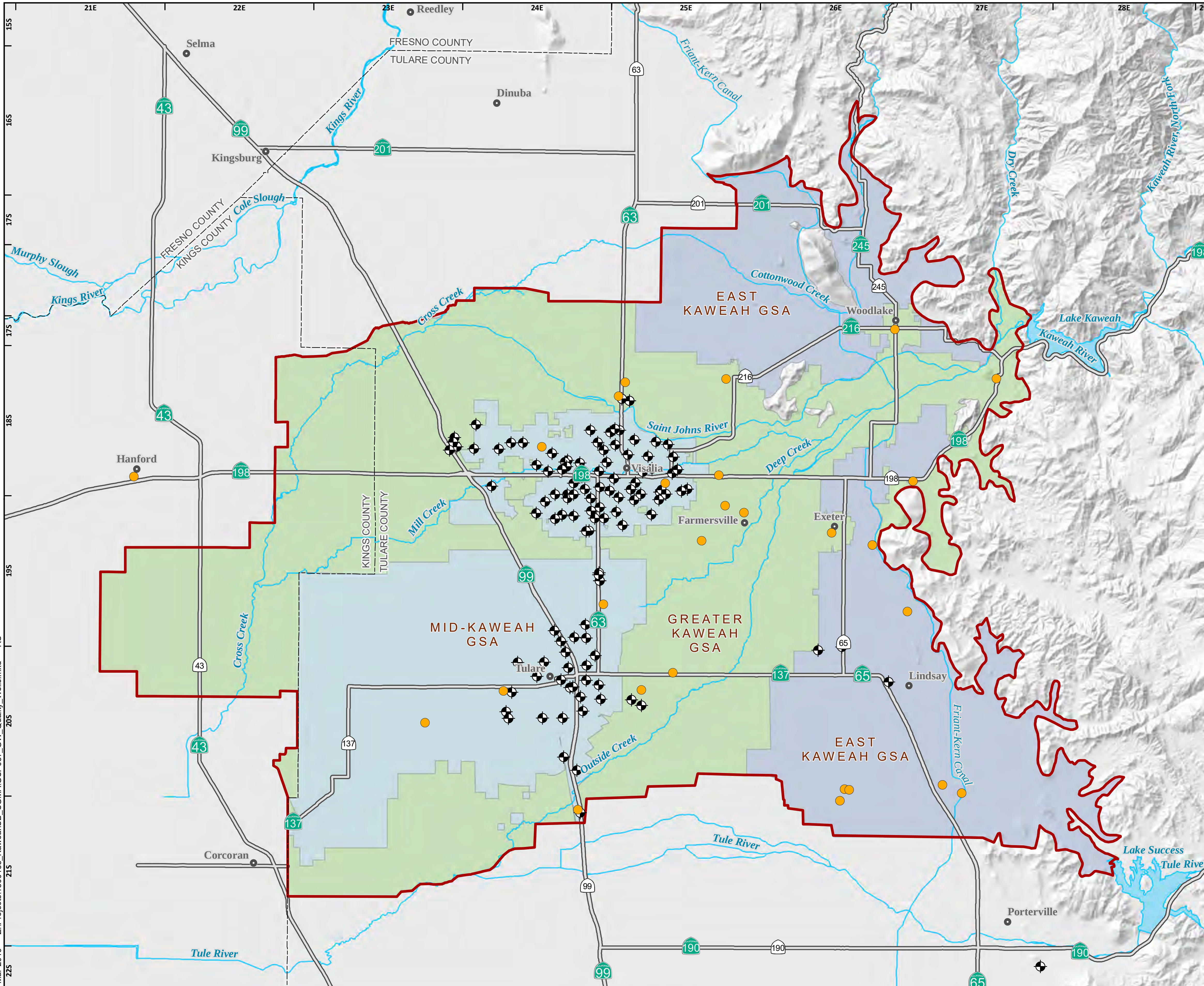
MARCH 2019 **DRAFT** FIGURE 54

12-Mar-2019 Z:\Projects\1800138_KaweahSB_SGMA\GSP036_SurfaceWaterDelivery_2016.mxd KLM

KAWEAH SUBBASIN GROUNDWATER QUALITY WELL LOCATIONS



- Representation of PWS with unknown Well Locations
- Approximate Well Location

GSA Boundaries

- East Kaweah GSA
- Greater Kaweah GSA
- Mid-Kaweah GSA
- Kaweah Subbasin Boundary

All Other Features

- Highway
- Waterway
- Lake

0 2 4 8
Miles

N

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MARCH 2019 **DRAFT** FIGURE 67