Westside Subbasin

Groundwater Sustainability Plan

(Clarified and Amended GSP)

Prepared for

Westlands Water District GSA and County of Fresno GSA-Westside

Prepared by

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SIGNATURE PAGE OF PROFESSIONAL GEOLOGIST

Westside Subbasin
Groundwater Sustainability Plan

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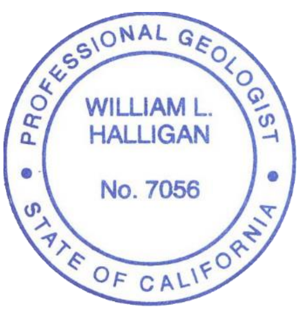

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LIST OF ACRONYMS AND ABREVIATIONS

Acronym	Meaning
§	Section
AB	Assembly Bill
AC	Advisory Committee
AF	acre-feet
AFY	acre-feet per year
ALOS	Advanced Land Observing Satellite ()
AMI	Automatic Meter Infrastructure
ASR	aquifer storage and recovery
bgs	below ground surface
BMP	best management practice
CASGEM	California Statewide Groundwater Elevation Monitoring
CASP	California Aqueduct Subsidence Program
CCR	California Code of Regulations
CEQA	California Environmental Quality Act
Coalition	Westlands Water Quality Coalition
CORS	Continuously Operating Reference Stations
CVHM	Central Valley Hydrologic Model
CVP	Central Valley Project
CVPIA	Central Valley Project Improvement Act
CV-SALTS	Central Valley Salinity Alternatives for Long-term Sustainability
DAC	disadvantaged community
District	Westlands Water District
DMS	data management system
dS/m	deciSiemens per meter (unit for measurement soil electrical conductivity)
DWR	California Department of Water Resources
EC	electrical conductivity
EISIP	Expanded Irrigation System Improvement Program
EIR	Environmental Impact Report
ENVISAT	Environmental Satellite
ESA	Endangered Species Act
ft	feet or foot
FTE	full time equivalent
GDE	groundwater dependent ecosystem
GDEi	groundwater dependent ecosystem indicators ()
GMAW	Groundwater Monitoring Advisory Workgroup
GMP	groundwater management plan
GQTM	Groundwater Quality Trend Monitoring Plan
GSA	groundwater sustainability agency

Acronym	Meaning
GSE	ground surface elevation
GSP	groundwater sustainability plan
GSP Reg	Groundwater Sustainability Plan Regulations
GWE	groundwater elevation
GWMP	groundwater management program
HPGN	High Precision Geodetic Network ()
InSAR	Interferometric Synthetic Aperture Radar
IRWM	Integrated Regional Water Management
IS	Initial Study
ISW	interconnected surface water
JPL	NASA Jet Propulsion Laboratory
LU	Land Use
MAF	million acre-feet
MCL	maximum contaminant level
mg/L	milligrams per liter
MO	measurable objective
MOU	Memorandum of Understanding
msl	mean sea level
MT	minimum threshold
my	million years
mya	Million years ago
mybp	million years before present
N	Nitrate or nitrogen
NASL	Naval Air Station Lemoore
ND	Negative Declaration
NEPA	National Environmental Policy Act
NOI	Notice of Intent
NRCS	Natural Resources Conservation Service
OS	Open Space
PBO	Plate Boundary Observatory
PLSS	Public Land Survey System
PMA	project and management action
QA/QC	quality assurance/quality control
RASA	Regional Aquifer System Analysis
RMS	representative monitoring site
SB	Senate Bill
SLC	San Luis Canal
SGMA	Sustainable Groundwater Management Act of 2014
SJRRP	San Joaquin River Restoration Program
SMC	Sustainable Management Criteria

Acronym	Meaning
SWRCB	State Water Resources Control Board
TAC	Technical Advisory Committee
TAF	thousand acre-feet
TDS	total dissolved solids
TNC	The Nature Conservancy
UAVSAR	Uninhabited Aerial Vehicle Synthetic Aperture
umhos/cm	micromhos per centimeter
UNAVCO	University NAVSTAR Consortium
USBR	U.S. Bureau of Reclamation
USDA	United States Department of Agriculture
USFWS	US Fish and Wildlife Service
USGS	U.S. Geological Survey
Wat. Code	California Water Code
WCR	well completion report
WSGM	Westside Groundwater Model
WSJ	Westside-San Joaquin
WSO	Well Standards Ordinance
WWD	Westlands Water District

EXECUTIVE SUMMARY

ES 1. INTRODUCTION

On September 16, 2014, Governor Jerry Brown signed into law three bills, Assembly Bill (AB) 1739 (Dickinson), Senate Bill (SB) 1168 (Pavley), and SB 1319 (Pavley), collectively known as the Sustainable Groundwater Management Act (SGMA). SGMA reflected the Legislature's declared policy that groundwater management is "best achieved" locally (California Water Code [Wat. Code § 113]). Towards that end, SGMA authorizes local sustainable management of groundwater resources under state oversight. Local sustainable management means management that maximizes the use of groundwater while avoiding undesirable results (Wat. Code § 10721(w)). SGMA requires that this sustainable management be maintained during the planning and implementation horizon (Wat. Code § 10721(v)).

SGMA requires qualified local agencies to establish a governance framework for the managed groundwater basin by forming local Groundwater Sustainability Agencies (GSAs) with the authority to develop, adopt, and implement a Groundwater Sustainability Plan (GSP). Under this GSP, the GSA must adequately define and monitor groundwater conditions in the managed area and establish criteria to maintain and/or achieve sustainability within 20 years of the GSP adoption. The GSA's failure to adopt a qualifying GSP could subject the basin or subbasin to the State's intervention and the exercise of its oversight authority and a loss of local control.

SGMA does not define groundwater overdraft *per se* for a basin or subbasin and instead identifies the "undesirable results" most commonly considered as evidence of overdraft and evidence that groundwater use is not sustainable:

1. Chronic Lowering of Groundwater Levels,
2. Significant and unreasonable reduction of groundwater storage,
3. Significant and unreasonable land subsidence,
4. Significant and unreasonable seawater intrusion,
5. Significant and unreasonable degradation of water quality, and
6. Depletion of interconnected surface water that cause significant and unreasonable adverse impacts on beneficial uses of surface water (Wat. Code § 10721(x)).

The Westside Subbasin (Subbasin) (**Figure ES-1**) has been identified by the California Department of Water Resources (DWR) as a critically overdrafted subbasin. Under SGMA, critically overdrafted subbasins are required to prepare and be managed under a GSP by January 31, 2020 (Wat. Code § 10720.7(a)(1)). This GSP has been prepared by Westlands Water District (WWD), acting as the GSA, in order to meet the statutory requirements, set forth in SGMA and the regulatory requirements developed by DWR for GSP development and implementation in California Code of Regulations (CCR) title 23, sections 350-358.4 (GSP Regulations) (DWR, 2016). The purpose of this GSP is to characterize groundwater conditions in the

Subbasin, to evaluate and report on conditions of overdraft, to establish sustainability goals and sustainability management criteria, and to describe projects and management actions the GSA intends to implement to achieve sustainability by 2040. While this GSP focuses on groundwater management actions by the GSA, actions are considered in the context of the entire basin setting and the actions of all water users in the Westside Subbasin to achieve subbasin-level sustainability.

The GSP was developed to comply with DWR's requirements to prepare, adopt and implement a GSP "consistent with the objective that a basin be sustainably managed within 20 years of GSP implementation without adversely affecting the ability of an adjacent basin to implement its GSP or achieve and maintain its sustainability goal over the planning and implementation horizon" as defined in the GSP Regulation section 350.4(f).

As mandated under GSP Regulation 354.24, the GSA has established a "sustainability goal for the basin that culminates in the absence of undesirable results within 20 years of the applicable statutory deadline." Specifically, the sustainability goal establishes that the Westside Subbasin will be operated within its sustainable yield by 2040 and maintain sustainability through the entire planning and implementation horizon through 2070. The GSP sets forth active management strategies that may be pursued by the GSA and stakeholders as authorized, as well as enforceable commitments to ensure its efficacy. These strategies include firming up access to more reliable surface water deliveries, conjunctive use, demand management through the adoption of an allocation system, improved efficiencies by transfer/trading, and surface water substitution within subsidence prone areas.

The Subbasin is not contiguous to the ocean and there is no potential risk of seawater intrusion. Consequently, the GSP is directed at avoiding chronic overdraft while avoiding significant and unreasonable reductions of groundwater storage, land subsidence, water quality degradation, and depletion of interconnected surface water.

The Fresno County GSA and Westlands Water District GSA adopted the Westside Subbasin GSP on January 7 and January 8, 2020, respectively, and submitted the GSP to the DWR SGMA Portal on January 23, 2020. In an effort to address comments by DWR, the GSAs clarified and amended Chapters 2, 3, 4 and 6 in July of 2022.

ES 2. SUMMARY OF PLAN AREA AND BASIN SETTING

The Westside Subbasin is in the western portion of the San Joaquin Valley Groundwater Basin, within Fresno and Kings counties. The Subbasin covers 972 square miles (622,215 acres) and spans approximately 17 miles east and west and 67 miles from Mendota to Kettleman City. The Subbasin lies within the western portion of the larger San Joaquin Groundwater Basin. The Subbasin is bordered by the Diablo Range to the west and other groundwater subbasins along its north, east and southern boundaries: the Pleasant Valley Subbasin (DWR Subbasin No. 5-22.10) lies to the southwest, the Tulare Lake Subbasin (DWR Subbasin No. 5-22.12) to the south, the Kings Subbasin (DWR Subbasin No. 5-22.08) to the east, and the Delta-Mendota Subbasin (DWR Subbasin No. 5-22.07) to the east and north (**Figure ES-1**).

WWD is the primary GSA responsible for the development of the GSP in the Subbasin. The Agency has entered into a Memorandum of Understanding with the Country of Fresno to adopt this GSP for the portions of the Subbasin that lie within its jurisdiction. The portion of the Subbasin that falls within Kings county but outside the Agencies boundaries is located on federal lands and therefore is exempt from SGMA.

Since the late 1960s, water demands within the Subbasin have been met by a combination of surface water and groundwater extractions. Historically, when surface supplies are curtailed, landowners turn to groundwater to off-set shortages in the surface supplies. The GSP establishes a sustainable basis to support agriculture and other beneficial users continued reliance upon groundwater and the economic interests of the landowners within the Subbasin, in a manner that both maximizes the efficient use of groundwater and avoids undesirable results.

The GSP does not alter or affect common law water rights of landowners. Instead, the GSP facilitates the maximum use of groundwater of common law right holders under a controlled management plan that provides opportunities, benefits and protections not otherwise available to overlying owners at common law. The GSP enables the establishment of clear rules for conjunctive use, banking, trading and ensures fair surface water substitution.

ES 2.1. Hydrogeologic Conceptual Model

The Subbasin is characterized by a relatively flat topographic setting along the west side of the Valley. Topography is highest along and just outside the western margins of the Subbasin with a gentle eastward slope toward the center of the San Joaquin Valley with less than a two percent slope. The topography ranges from about 1,000 feet elevation along the western margin of the Subbasin to about 170 feet elevation along the eastern boundary. There is little change in slope or elevation in the Subbasin in a north to south direction with elevations ranging from 150 to 200 feet.

Surficial geology in the Subbasin is primarily characterized by alluvial fan deposits of the Quaternary Great Valley Geologic Province with Pleistocene nonmarine deposits located in the southeastern portion of the Subbasin and along its eastern margins (**Figure ES-2**). Fresh groundwater bearing geologic deposits in the Subbasin are subdivided in previous studies into three units: the Upper Aquifer, the Lower Aquifer and the Corcoran Clay, which separates the aquifers. The Corcoran Clay underlies the entire Subbasin with the exception of a small area in the southwest, and the Upper and Lower Aquifer is a single aquifer unit. The depth to the Corcoran Clay generally increases to the west in the Subbasin and ranges from about 400 feet in the east to 800 feet or more at the western margins of the Subbasin. The thickness of the Corcoran Clay varies in the Subbasin from less than 20 feet to more than 100 feet. Generally, the Corcoran Clay is thinner in the southern portion of the Subbasin compared to the northern portion.

The shallow zone is a portion within the Upper Aquifer which has been defined as the upper most 100 feet. In the Subbasin, groundwater encountered in the upper 100 feet is not hydrologically connected to the rest of the Upper Aquifer showing no seasonal or long-term variation. Groundwater elevation in the upper most 100 feet are likely supported by recharge from irrigation, therefore, it is not defined as one of the primary aquifer units in the Subbasin.

Flow directions in the Upper and Lower Aquifers were derived from contours of equal groundwater elevation contours. In the Upper Aquifer, the flow direction in most years with sufficient data indicate an easterly flow direction. In the Lower Aquifer groundwater tends to flow eastward out of the Subbasin during wet years and flow into the Subbasin during extended drought periods. Generally, on a long term basis, flow directions in the Lower Aquifer are from east to west.

Historically, the shallow zone has exhibited relatively stable water levels since at least the 1990s in many wells and variations in groundwater levels are primarily influenced by recharge from agriculture and not from groundwater pumping from the Upper or Lower Aquifers. In the Upper Aquifer, wells with long-term water level data show temporal trends similar to those in the shallow zone. Rising groundwater levels in the Upper Aquifer are apparent prior to the early 2000s with more stable water levels after 2000 in many wells. Some wells in the Upper Aquifer exhibit considerable fluctuations in water levels although few consistent spatial patterns in these fluctuations and trends are evident.

Groundwater level data in the Lower Aquifer are available since the 1950s. Generally, groundwater conditions in the Lower Aquifer show the lowest groundwater levels occurred during the 1950s and 1960s with dramatic water level recoveries following the Central Valley Project surface water deliveries through the San Luis Canal (SLC) in 1968. Groundwater levels remained more stable from the late 1980s until the early 2000s, although notable short-term fluctuations are evident during this period in some wells.

For some wells, the impacts from curtailments in surface water deliveries, coupled with increases in groundwater pumping resulted in groundwater levels declining by as much as 200 feet in the five years between 2010 and 2015. Although recent declines in groundwater levels are dramatic, it is notable that declines largely occur in the Lower Aquifer (which is confined) as opposed to unconfined portions of the Upper Aquifer where most groundwater storage changes occur. However, these declines did result in an increase in subsidence in some areas of the Subbasin, particularly along portions of the SLC.

The groundwater quality in the Subbasin is primarily influenced by naturally occurring marine sediments that originated from the Coast Range. These marine sediments result in some areas of the Subbasin having elevated concentrations of total dissolved solids (TDS) and other trace elements. Evidence of groundwater quality degradation from manmade (anthropogenic) causes are limited due to data availability. Groundwater quality data was limited in geographic extent since 2000 when data was only available for small portions of the Subbasin. As a result, the lack of data (since 2000) limits the ability to characterize recent or current groundwater quality other than in small, localized areas along the eastern portions of the Subbasin. Beneficial uses of groundwater in the Subbasin are primarily agricultural in nature with some environmental, domestic and municipal uses. For agricultural beneficial uses, available groundwater quality data and outreach efforts indicate that TDS is the primary constituent of concern. Constituents of concern for domestic and urban beneficial users are those constituents that are regulated under the State of California's drinking water standards. Analysis of existing groundwater quality data indicates that TDS can be utilized as a proxy for other constituents of concern for domestic and urban beneficial users. Using TDS as a proxy for domestic and urban beneficial uses was justified from a correlation and spatial comparisons between TDS concentrations and other constituents of concern that occur in the Subbasin. In the Upper Aquifer, only two wells with recent data were available with TDS measurements, and they depicted increasing TDS concentrations. The available data in the Lower Aquifer showed a variation in trends throughout the Subbasin including increasing, decreasing, and stable TDS values.

Land subsidence is a major concern for the Subbasin, due to the use of groundwater to supplement variable surface water supplies. Subsidence has the potential to damage local, state, and federal infrastructure, including reducing the freeboard and flow capacity of the SLC and Coalinga Canal, and irrigation water-delivery canals, bridges, roads and flood control structures. Evidence suggests that the greatest amount of subsidence in the Subbasin is thought to occur within aquitards (or interbeds) below the Corcoran clay but may occur to a lesser extent in portions of the Upper Aquifer. Prior to the construction of the SLC, groundwater extraction led to large amounts of subsidence throughout the central portion of the Subbasin and led to the formation of three major subsidence bowls. More recently, high rates of subsidence occur locally in the north-central portion of the Subbasin near SLC checks 16 and 17 and in the south-central portion of the Subbasin near SLC check 20 have caused impacts to the conveyance capacity of the SLC. More recent Interferometric Synthetic Aperture Radar (InSAR) data also show high rates of subsidence in the southeastern portion of the Subbasin.

ES 2.2. Water Budget

A water budget is defined as a complete accounting of all water flowing into and out of a defined volume over a specified period of time. When the water budget encompasses the entire Subbasin, the water budget facilitates an assessment of the total volume of groundwater and surface water entering and leaving the Subbasin over time, capturing the change in the volume of water stored within the aquifer system. Water budgets were developed for the Subbasin during defined historical, current, and projected periods. A numerical integrated groundwater flow model referenced as the Westside Groundwater Model (WSGM) was developed and utilized to support development of the Subbasin water budgets.

The 1989 through 2015 water year period is representative of long-term annual average hydrologic conditions based on analysis of precipitation and Central Valley Project (CVP) supplies and selected as the historical water budget period. The current water budget year was selected as 2016 and the projected water budget period spanned from 2017 through 2070. The projected water budgets include the following:

- Utilization of historical hydrology and 2016 land use for the projected baseline budget,
- Incorporation of 2030 and 2070 climate change factors defined by DWR to evaluate climate uncertainty.

On the scale of the Subbasin, WSGM simulates a decline in groundwater storage averaging 19,000 acre-feet per year (AFY). Over the entire historical water budget period the cumulative decline in groundwater storage was nearly 517,000 acre-feet (AF). While this estimation of decline in groundwater storage suggests the Subbasin was experiencing overdraft, this estimation of groundwater storage decline represents less than 4% of total outflow and less than 6% of total groundwater pumping — suggesting that the Subbasin groundwater budget is relatively balanced over the historical water budget period. The groundwater model was used to estimate projected water budgets through 2070 under different climate scenarios and to evaluate the effects of projects and management actions. Projected water budget scenarios were developed for all the projects and management actions and compared to the three different baseline projections (baseline with no climate change, 2030 climate change baseline, and 2070 climate change baseline).

GSP Regulations require the water budget to quantify the sustainable yield for the Subbasin. (GSP Reg. § 354.18.) Sustainable yield is defined as "the maximum quantity of water, calculated over a base period representative of long-term conditions in the basin and including any temporary surplus, that can be withdrawn annually from a groundwater supply without causing an undesirable result" (Wat. Code § 10721(w)).

Consistent with GSP Regulations and DWR's Sustainable Management Criteria Best Management Practices (BMP) technical memorandum (DWR, 2017), sustainable yield has been calculated for the historical and projected water budget periods using the model (**Table ES-1**). The estimated sustainable yield for the historical period is 305,000 AFY. The estimated sustainable yield for the projected period (2020-2070) ranges from 270,000 to 294,000 AFY depending on the future climate specified. Model scenarios used to calculate the projected sustainable yield for the 2020-2070 reflect baseline conditions and exclude implementation of projects and management actions. Also assumed is that adjacent subbasins will set sustainable management criteria to maintain 2015 baseline conditions (Wat. Code §10727.2(b)(4)).

Table ES-1: Summary of Sustainable Yield Estimates from Historical and Projected Water Budgets

Description	Water Budget Period	Sustainable Yield (AFY)
Historical Groundwater Budget	1989 - 2015	305,000
Projected Groundwater Budget Baseline	2020 - 2070	270,000-294,000

Model projections suggest that assuming adjacent groundwater basins ensure sustainable management of groundwater conditions at 2015 baseline levels, the projected baseline with projects scenarios for the planning and implementation horizon results in sustainable groundwater conditions in the Subbasin by 2040 and through 2070. Implementation of sustainable management criteria that result in groundwater conditions in adjacent subbasins being worse than 2015 baseline conditions could impact Westlands' sustainability goals and effectiveness of planned projects and management actions. The failure of neighboring subbasins to implement timely GSP's may have a substantial and unreasonable impact on the Subbasin's goal to achieve sustainability.

The model scenarios include an anticipated implementation schedule for the projects and management actions planned through 2040. Given the schedule for project implementation provided by the GSA, the model results for the 2020 through 2040 period show that sustainability indicators avoid minimum thresholds (MTs) and associated undesirable results. Thus, the sustainable yield for this 2020-2040 projected period ensures this is a quantity of water "that can be withdrawn annually from a groundwater supply without causing an undesirable result" (Wat. Code § 10721(w)).

ES 3. SUSTAINABILITY MANAGEMENT CRITERIA

ES 3.1. Sustainability Indicators

The GSA's sustainability goal is to develop projects and management actions that result in the sustainable management of the groundwater resources of the Subbasin for long-term community, financial, and environmental benefits of residents and businesses in the Subbasin. The GSA's sustainability goal is to ensure that by 2040, and thereafter within the planning and implementation horizon of this GSP (50 years to 2070), the Subbasin is operated within its sustainable yield and does not exhibit undesirable results. The approach outlined in this GSP aims to meet this sustainability goal while maintaining the unique cultural, community, and agricultural business aspects of the Subbasin. In order to effectively meet this goal, the GSA has established minimum thresholds, measurable objectives, and interim milestones for the sustainability indicators listed in **Table ES-2**. The sustainability goals will be maintained through proactive monitoring and management by the GSA. **Table ES-2** presents a summary of the six sustainability indicators and whether each has occurred, is occurring, or is expected to occur in the future in the Subbasin without and with GSP implementation.

Table ES-2: Summary of Undesirable Results Applicable to the Plan Area

Sustainability Indicator	Historical Period	Current Conditions	Future Conditions without GSP Implementation	Future Conditions with GSP Implementation
Groundwater Level Declines	Yes	Yes	Yes	No
Reduction of Groundwater Storage	Yes	Yes	Yes	No
Land Subsidence	Yes	Yes	Yes	No
Seawater Intrusion	Not Applicable	Not Applicable	Not Applicable	Not Applicable
Degraded Water Quality	No	No	Not known	Not Known
Depletion of Interconnected Surface Water	Not Likely	Not Likely	Not Likely	No

The regulations define undesirable results as occurring when significant and unreasonable effects are caused by groundwater conditions occurring for a given sustainability indicator. Significant and unreasonable effects are defined for each sustainability indicator to avoid undesirable results and impacts to beneficial users. A summary of the sustainable management minimum thresholds (MT), measurable objectives (MO) and undesirable results is provided in **Table ES-3**. Locally defined undesirable results were based on discussion with GSA staff and technical representatives, review of available investigations on overdraft conditions, input received from interested parties and the public through public meetings.

Table ES-3: Summary of Minimum Thresholds, Measurable Objectives, and Undesirable Results

	Minimum Threshold	Measurable Objective	Undesirable Result
Chronic Lowering of Groundwater Levels	***Lower Aquifer Adjacent SLC:*** Lowest measured groundwater level encountered during 2012-2016 drought. ***Remainder of Subbasin:*** Lowest measured groundwater level encountered during 2012-2016 drought minus 40 feet.	Measured or estimated historical winter/spring groundwater level when pumping occurred within the range of sustainable yield	50% of any domestic well is dewatered in a hexagon with an exceeded MT; 10% of agricultural wells go dry in a hexagon with an exceeded MT
Reduction of Groundwater Storage	No long-term reduction in groundwater storage based on measured groundwater levels	Projected average future groundwater level from projected with projects model simulation (2040-2070	Exceedance of MT for two consecutive drought years
Land Subsidence	***Subsidence/Compaction Adjacent SLC:***		
	0.3 feet annually; 1.5 feet cumulative	0.0 feet annually; 0.0 feet cumulative	Annual MT is exceeded at three sites for two consecutive years; Exceedance of cumulative MT at any site
	Subsidence/Compaction Remainder of Subbasin:		
	0.3 feet annually; 2.5 feet cumulative	0.1 feet annually; 0.5 feet cumulative	Annual MT is exceeded at three sites for two consecutive years; Exceedance of cumulative MT at three sites
Seawater Intrusion	Not Applicable	Not Applicable	Not Applicable
Degraded Water Quality	TDS of 1,000 mg/L	***Areas with Agricultural Beneficial Users:*** TDS of 800 mg/L ***Areas with Drinking Water Beneficial Users:*** TDS of 500 mg/L	Two consecutive measurements exceed MT at any site
Depletion of Interconnected Surface Water	Not Currently Applicable	Not Currently Applicable	Not Currently Applicable

mg/L = milligrams per liter

ES 3.1.1. Groundwater Level Declines

The GSP Regulations provide that the “minimum thresholds for chronic lowering of groundwater levels shall be the groundwater level indicating a depletion of supply at a given location that may lead to undesirable results” (GSP Reg. § 354.28(c)(1)). Chronic lowering of groundwater levels in the Subbasin cause significant and unreasonable declines if they are below levels necessary to meet the minimum required to support overlying beneficial use(s) where alternative means of obtaining sufficient groundwater resources are not technically or financially feasible. In addition, groundwater levels will be managed with consideration of the minimum thresholds to ensure the primary water-producing aquifers in the Subbasin are not depleted in a manner to cause significant and unreasonable impacts to other sustainability indicators or beneficial users. Projections of groundwater levels in the Subbasin indicate that chronic lowering of groundwater levels below minimum thresholds are not expected to occur with the implementation of projects and management actions prior to 2040 and through the remainder of the planning and implementation horizon.

ES 3.1.2. Reduction of Groundwater Storage

The groundwater storage reduction sustainability indicator will be evaluated using groundwater levels as a proxy in conjunction with annual evaluations of monitored groundwater level changes. Based on considerations applied in developing the groundwater level minimum thresholds, reduction in groundwater storage minimum thresholds do not exceed any identified significant and unreasonable level of depleted groundwater storage volume.

ES 3.1.3. Land Subsidence

The sustainability goal for land subsidence is to limit subsidence at levels that do not lead to undesirable results. These undesirable results include impacts to the available freeboard and conveyance capacity of the SLC and other critical infrastructure including roads, bridges and pipelines. As a result, measurable objectives and minimum thresholds are specified at amounts which will significantly mitigate or eliminate impacts to beneficial users and critical infrastructure which will be achieved through implementation of projects and management actions (PMAs).

ES 3.1.4. Degradation of Groundwater Quality

The sustainability goal for groundwater quality is to prevent degradation of water quality from human activities related to groundwater extraction that adversely impact beneficial users to a significant and unreasonable degree. Where water quality is not impaired measurable objectives and minimum thresholds are specified at amounts that are protective of drinking water and agricultural uses. Significant and unreasonable degradation of water quality occurs when measured water quality exceeds the MT at any site. Where water quality is currently impaired, water quality monitoring will be conducted, but not assigned a measurable objective or minimum threshold as mitigation (blending, treatment, transition to salt tolerant crops) is already being implemented.

ES 3.1.5. Depletion of Interconnected Surface Water

Surface water streams that exist in the Subbasin are ephemeral in nature for short durations. Groundwater levels in the vicinity of existing ephemeral streams in the shallow zone are limited in the vicinity of the ephemeral streams, however, coupled with other data indicate that there may only be a few limited areas that have "potential groundwater dependent ecosystems" (GDE). For the most part, it appears that interconnected surface water (ISW) does not exist in the Subbasin, however, there are data gaps in the groundwater level data which need to be addressed in order to conduct a complete assessment. Additional monitoring of potential GDEs and ISWs will be conducted.

ES 3.1.6. Seawater Intrusion

The seawater intrusion sustainability criterium is not applicable to this Subbasin.

ES 3.2. Monitoring Network

The GSP monitoring network was developed to provide a robust measurement of Subbasin groundwater conditions and subsidence in order to evaluate Sustainable Management Criteria (SMC) and quantify progress towards sustainability goals. A representative monitoring network was developed to provide sufficient spatial and temporal coverage to achieve these objectives.

ES 3.2.1. Groundwater Monitoring Network

The groundwater monitoring network has been developed using existing wells in the Subbasin and will be supplemented (and/or some initial wells replaced) by new nested monitoring wells that are currently being constructed and will be fully installed by 2020. The database for existing wells was reviewed with preference given to the following criteria:

- CASGEM wells,
- Known construction (e.g., screen intervals, depth),
- Long histories of water level data (including recent data),
- Good spatial distribution,
- Relatively good match between observed and modeled water levels,
- Representation of both Upper and Lower Aquifers

The selected representative monitoring sites (RMS) for groundwater levels are distributed throughout the Subbasin to provide broad spatial coverage to the extent possible (**Figure ES-3 and ES-4**). Wells will be sampled bi-annually to characterize seasonal low and seasonal high groundwater levels.

ES 3.2.2. Subsidence Monitoring Network

Subsidence and aquifer system compaction is monitored through GPS, continuous GPS and extensometers. In some portions of the Subbasin, direct measurements of subsidence are unavailable, and measurements of Lower Aquifer groundwater levels are used as a proxy for subsidence. Representative sites rely on reported measurements from multiple entities including the United States

Geological Survey (USGS), University NAVSTAR Consortium (UNAVCO), DWR, United States Bureau of Reclamation (USBR), and WWD. The subsidence monitoring network provides robust spatial coverage of subsidence conditions within the Subbasin with enhanced monitoring located in key locations along the SLC where rates of subsidence impact the freeboard and conveyance capacity in the SLC (**Figure ES-5**). Measurements are taken continuously, bi-annually and annually depending on the monitoring agency.

ES 3.2.3. Groundwater Quality Monitoring Network

The groundwater quality indicator wells represent a subset of the water level indicator wells with additional wells included from other groundwater quality monitoring programs and is intended to provide sufficient spatial coverage to the extent possible (**Figure ES-6 and ES-7**). The monitoring network will be periodically reviewed and modified as needed. Sampling will be conducted annually and analyzed for TDS and Nitrate. Additionally, every five years the monitoring network will be sample for major anions and cations.

ES 4. Overview of Projects and Management Actions

To achieve the Subbasin sustainability goal by 2040 and avoid undesirable results through 2070 as required by SGMA, projects and management actions are being or will be developed and implemented by the GSA. Projects generally refer to structural programs whereas management actions are typically non-structural programs or policies that are intended to incentivize reductions in groundwater pumping.

The projects and management actions developed for the GSP are aimed at preventing and managing chronic lowering of groundwater levels, and significant and unreasonable reduction of groundwater storage, land subsidence, and degradation of groundwater quality. The GSP’s objective is to reduce potential socioeconomic impacts while improving groundwater conditions and avoid undesirable results typically associated with the lack of sustainable management and groundwater overdraft.

The cost, timing, and expected benefit to groundwater resources of the projects and management actions included in the GSP vary by type. **Table ES-4** lists and describes the proposed projects and management actions.

Table ES-4: Summary of Westside Subbasin Project and Management Actions

PMA	Description	Estimated Cost	Level of Project Development
1	Surface Water Imports	$0	Planning
2	Initial Allocation of Groundwater Extraction	$30,000	Planning and trading system development
3	Aquifer Storage and Recovery	$400,000	Program implementation
4	Targeted Pumping Reductions (reduce pumping near Check 16, 17 and 20)	$1,250,000	Planning and engineering
5	Percolation Basins	$100,000	Planning

ES 4.1. Project No. 1 – Surface Water Deliveries

The primary focus of the Surface Water Imports program is to increase surface water availability and reliability and to reduce the corresponding landowner reliance on groundwater within the Subbasin by fulfilling most of the agricultural, municipal, and industrial water demands within the Subbasin. Surface water deliveries will be obtained through existing CVP contracts and through water transfer and exchange projects. Increasing the supply of surface water will allow surface water to be used in lieu of groundwater leading to increased groundwater storage and levels. The increased delivery of surface water can further conjunctive use strategies.

ES 4.2. Project No. 2 – Initial Allocation of Groundwater Extraction

The GSA has prepared a groundwater allocation framework to manage demand by equally distributing the total annual pumping from the Subbasin on the basis of land acreage overlying the Subbasin. The groundwater allocation program includes a "transition period" from 2022-2030, in which a uniform annual allocation is established at 1.3 AF per acre and then subsequently reduced each year by 0.1 AF per acre until 2030. The groundwater will be distributed based on per-acre land ownership for all qualifying lands. Thus, every overlying landowner will have equal access to available groundwater subject to the sustainability requirements of the GSP and the avoidance of undesirable results. The allocation will not constitute a determination of common law water rights. Instead, the distribution will ensure there are no long-term imbalances in the Subbasin water budget, increase pumping transparency, and provide more flexibility to water users for resources management that provides benefits not traditionally available under common law — e.g., banking of unused water, trading.

ES 4.3. Project No. 3 – Aquifer Storage and Recovery

An aquifer storage and recovery (ASR) program involving the direct injection and subsurface storage of groundwater using agricultural wells has been proposed by the GSA to improve water supply reliability within the Subbasin. Landowners will voluntarily adopt the program in order to have the injected water contribute to the landowner's groundwater allocation.

ES 4.4. Project No. 4 – Targeted Pumping Reductions

It is possible that the combination of other measures will not be sufficient individually or collectively to avoid significant and unreasonable land subsidence. When combined with cumulative Subbasin pumping, groundwater withdrawals near Checks 16, 17, and 20 of the San Luis Canal/California Aqueduct, may require focused management efforts. Consequently, the GSP proposes to offer or, if necessary to avoid significant and unreasonable land subsidence, to require surface water substitution to reduce groundwater pumping near the SLC. In exchange for the reduction in pumping, the GSA may provide incentives to landowners included in this program. Participating landowners may be required to bear material unmitigated impacts in accepting the substitute surface water.

ES 4.5. Project No. 5 – Percolation Basins

The GSA is proposing engaging in managed aquifer recharge through percolation basins in selected areas of the Subbasin to increase groundwater in storage. These basins would be constructed on GSA-owned land where the Corcoran Clay is not present. The basins would be used to store excess water and recharge the Upper Aquifer and Lower Aquifer. Currently, the GSA is investigating the feasibility of this project at potential sites located in the Subbasin.

ES 5. PLAN IMPLEMENTATION

As required by SGMA, the GSP will be adopted and submitted to DWR by January 31, 2020 (Wat. Code § 10735.2(a)(2)). Implementation of the GSP will commence after the submittal date and DWR's approval of the GSP. In accordance with SGMA requirements, the GSA will prepare and submit annual reports to DWR by April 1st of each year along with GSP updates at least every five years. The GSA also will begin implementing the management actions following the submittal and approval of the GSP in 2020. Initial program development for all five projects will occur simultaneously. Projects will include the appropriate environmental analysis prior to implementation or construction, if required. These projects will be implemented as an augmentation strategy to increase aquifer storage with the goal of achieving sustainability within the Subbasin by 2040.

Development of this GSP was funded through a Proposition 1 Grant, and contributions from individual GSAs (e.g., through in-kind staff time, or separately contracted consulting services). WWD is funding additional projects, ancillary studies and implementation efforts. Administering the GSP and monitoring and reporting progress is projected to cost between $530,000 and $1,400,000 per year. Costs are expected to be higher during years in which a five-year periodic evaluation is due, and slightly lower during years in which an annual report is due. This cost estimate does not include the capital and annual operating cost of projects and management actions 3, 4 and 5.

The GSA evaluated the costs of GSP implementation and estimated the total projected cost of $16,600,000 during the 20-year implementation horizon. The projected total includes a 10% contingency amount and assumes a 3% inflation rate.

Implementing the GSP will be a costly endeavor and the GSA plans to utilize a combination of fees or assessments and outside funding sources to cover the costs. SGMA grants the GSA the authority to impose fees for the purpose of groundwater management under a GSP (Wat. Code §§ 10730, 10730.2).

To fund GSA operations and GSP implementation, the GSA is developing a financing plan that will include one or more of the following financing approaches:

- Grants and Low-Interest Loans: GSAs will continue to pursue grants and low interest loans to help fund planning studies and other GSA activities. However, grants and low-interest loans are not expected to cover all of GSA operating costs for GSP implementation.
- GSP Implementation Costs: Initial implementation costs not covered by grant funding will be assessed through a land-based charge on privately owned land in the Westside Subbasin. In the future, the GSA may adopt a volumetric charge on groundwater extracted from the Subbasin.
- Groundwater Metering Charge: Well owners will be directly charged for meters installed by the GSA under Wat. Code § 10725.8.
- Taxes: This could include general property related taxes that are not directly related to the benefits or costs of a service (ad valorem and parcel taxes), or special taxes imposed for specific purposes related to GSA activities.

The GSA is pursuing a combined approach, targeting available grants and low interest loans, and considering a combination of fees and assessments to cover operating and program-specific costs. The GSA will comply with statutory and California constitutional requirements to adopt any rate, fee, charge or assessment to fund implementation of the GSP.

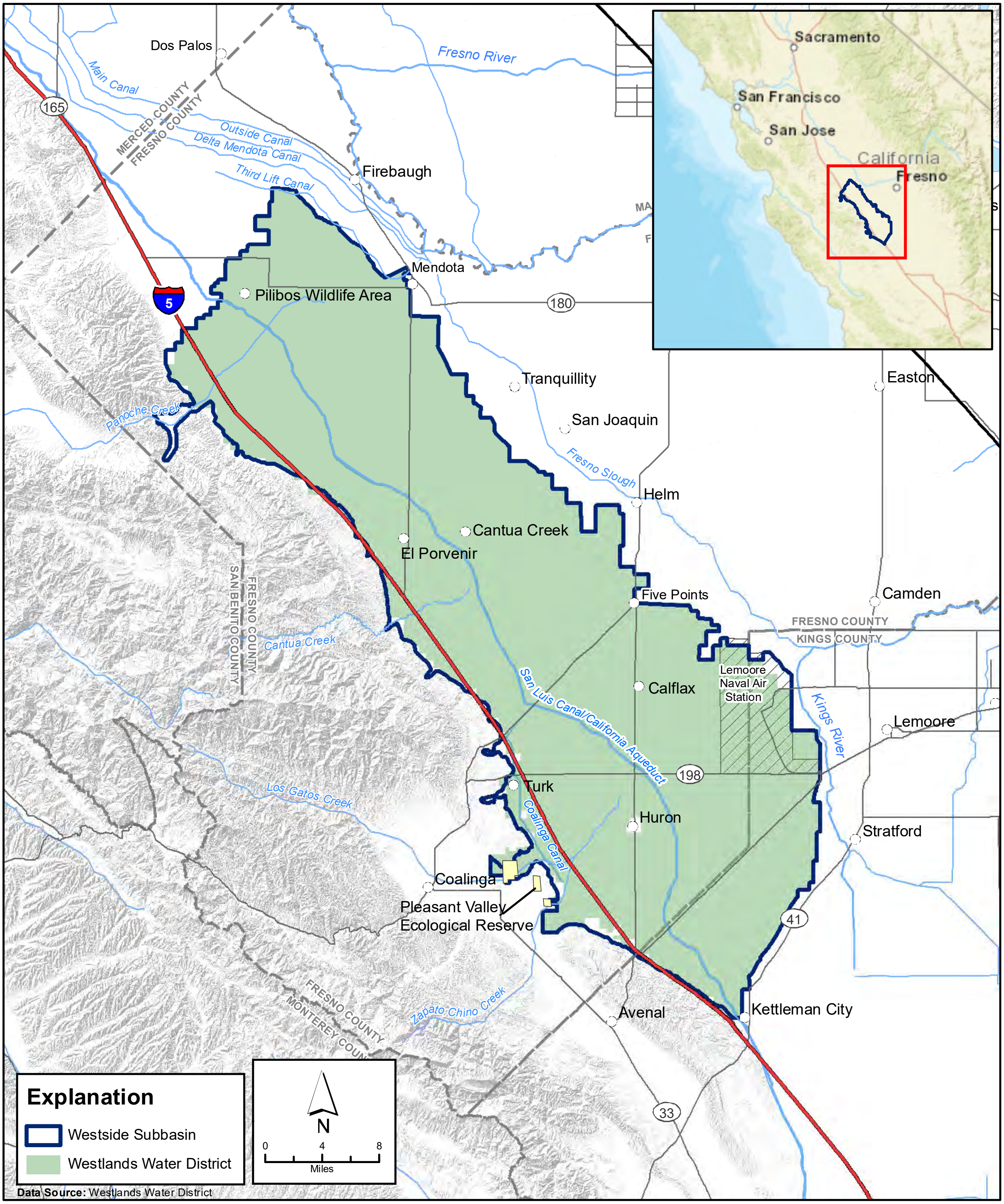
The GSP implementation schedule allows time for GSAs to develop and implement projects and management actions and meets all sustainability objectives by 2040. The GSA will begin implementing other GSP activities in 2020, with full implementation of projects and management actions to achieve sustainability by 2040.

The GSP uses the best available information and the best available science to provide a road map for the Westside Subbasin to meet its sustainability goal by 2040 and comply with the SGMA regulations. During each five-year update, progress will be assessed, and the GSP revised as necessary, to achieve the sustainability goal by 2040 and comply with the SGMA regulations.

ES 6. Overview of Governance

In adopting =SGMA, the Legislature made clear that nothing in SGMA "determines or alters surface water rights or groundwater rights under common law or any provision of law that determines or grants surface water rights" (Wat. Code § 10720.5(a)). In other words, the Legislature intended that actions undertaken in accordance with SGMA to respect common law water rights.

This GSP establishes the objective of maximizing the beneficial use of water within the Westside Subbasin, without causing undesirable results. The powers of the GSA are set forth in SGMA. This GSP meets the requirements of SGMA and vests the management authority in the GSA. Authorities include Powers of the Board, Rules and Regulations, Committees, Specific Powers, Variances and Appeals.



X:\2015 Job Files\15-104 Westlands WD\GIS\Map Files\Figure 1-1 Westlands Water District Location Map.mxd

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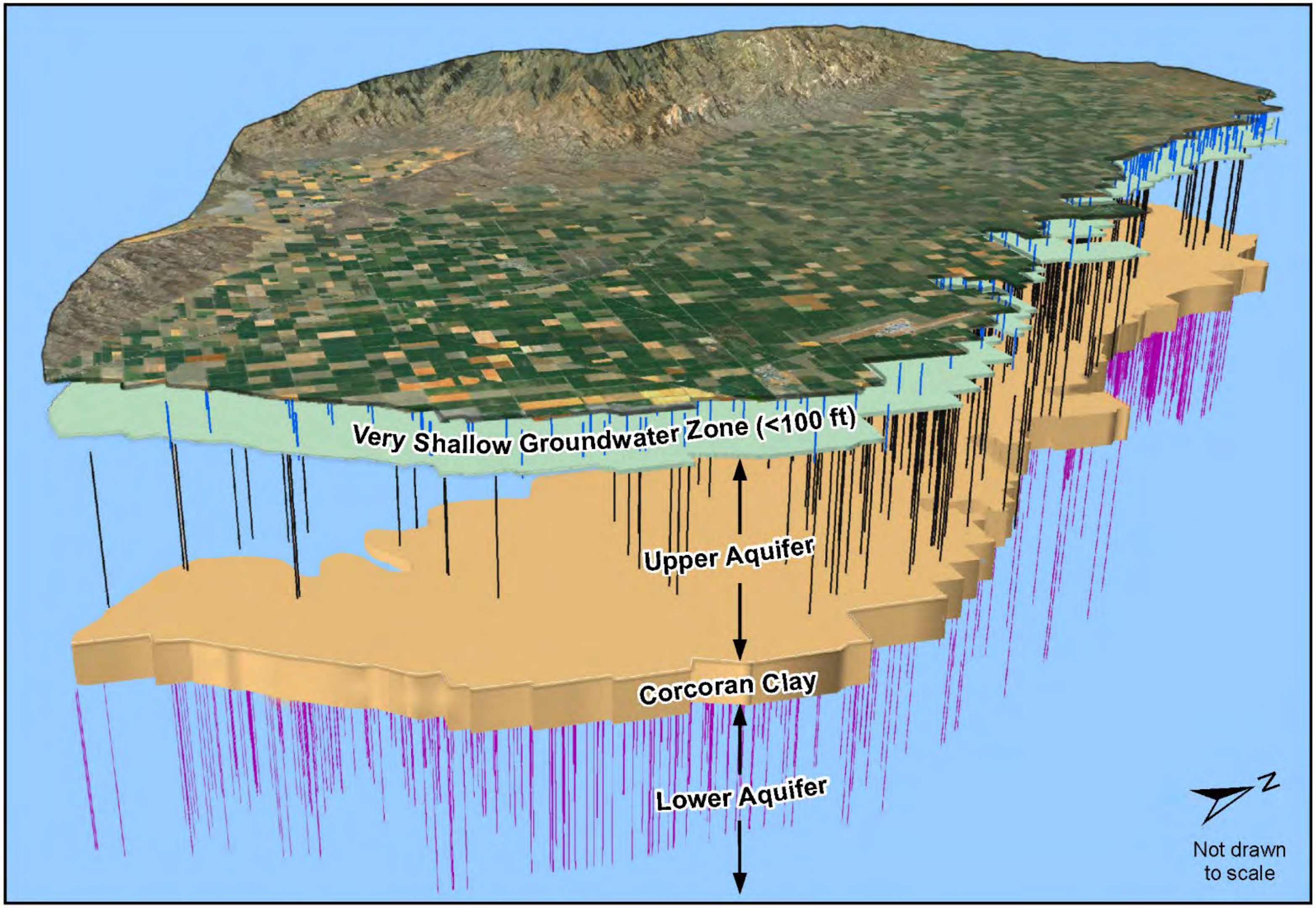
Consulting Engineers

FIGURE ES-1
Westside Subbasin Location Map

Hydrogeologic Conceptualization Report
Westside Subbasin



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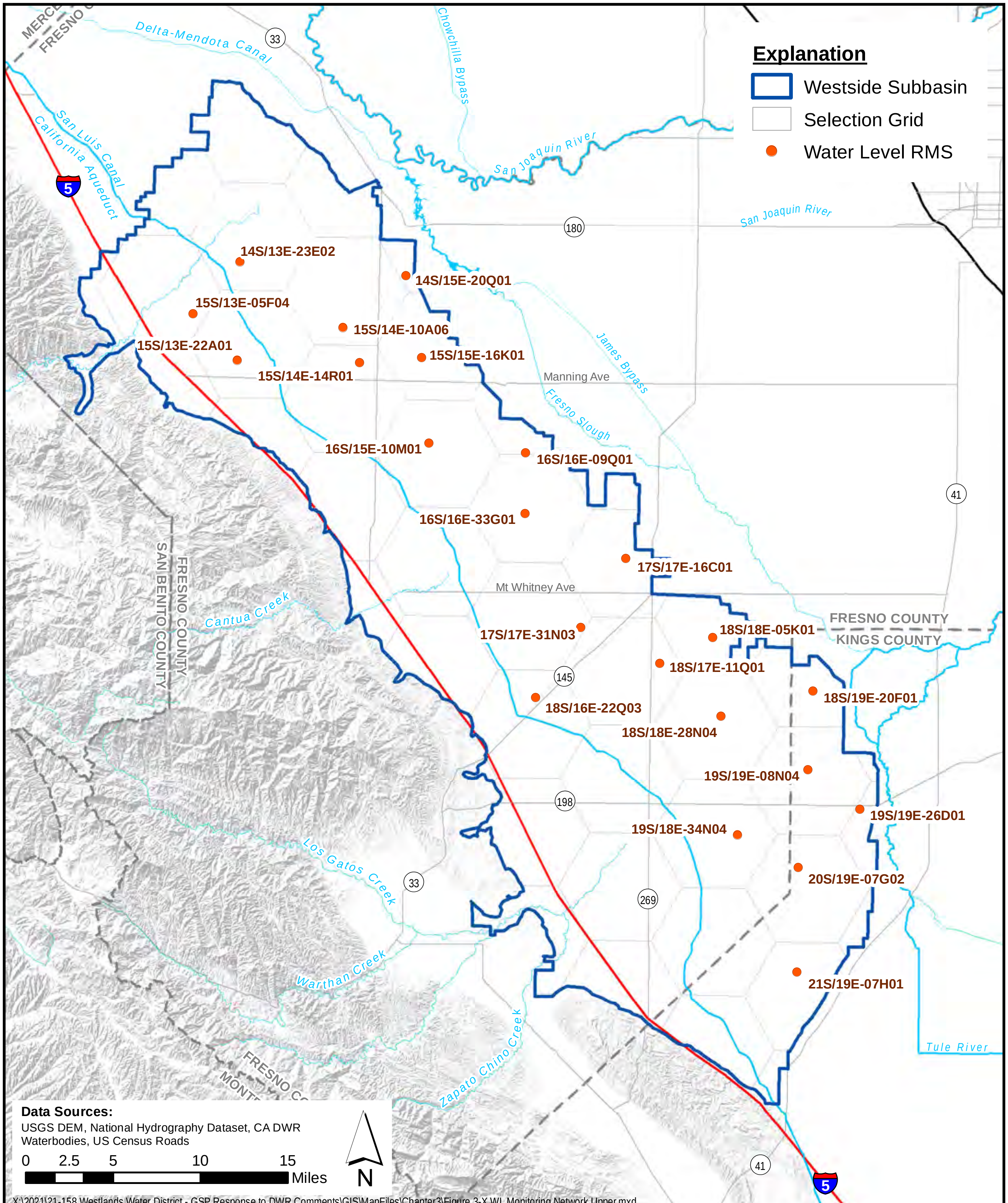
Westside Subbasin Hydrogeologic Conceptual Model

Groundwater Sustainability Plan – Westside Subbasin

Figure ES-2



Luhdorff & Scalmanini Consulting Engineers

Representative Monitoring Sites for Groundwater Levels (Upper Aquifer)

SGMA Sustainability Analyses
Westside Subbasin

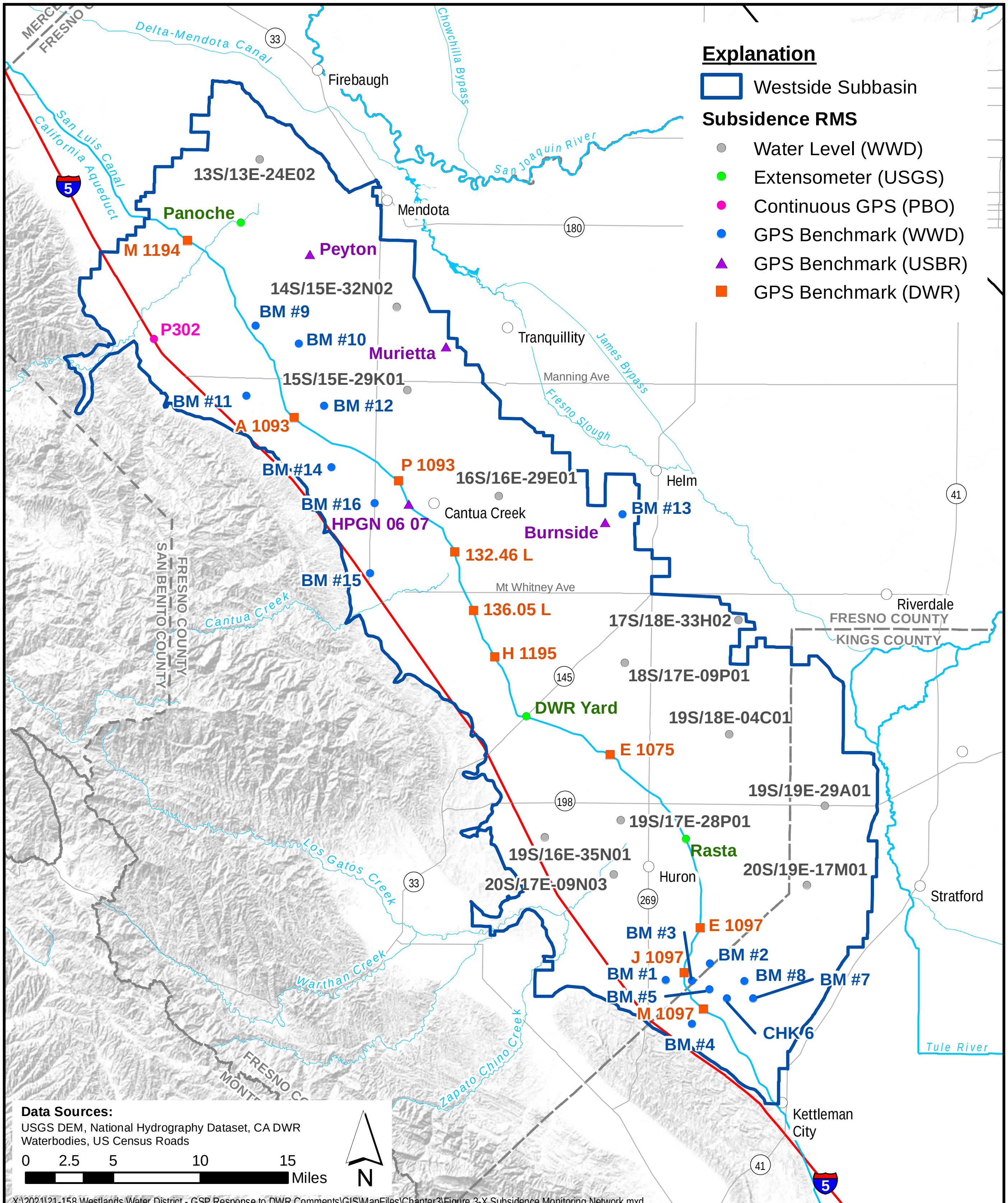
Figure ES-3

Luhdorff & Scalmanini Consulting Engineers

Representative Monitoring Sites for Groundwater Levels (Lower Aquifer)

SGMA Sustainability Analyses
Westside Subbasin

Figure ES-4



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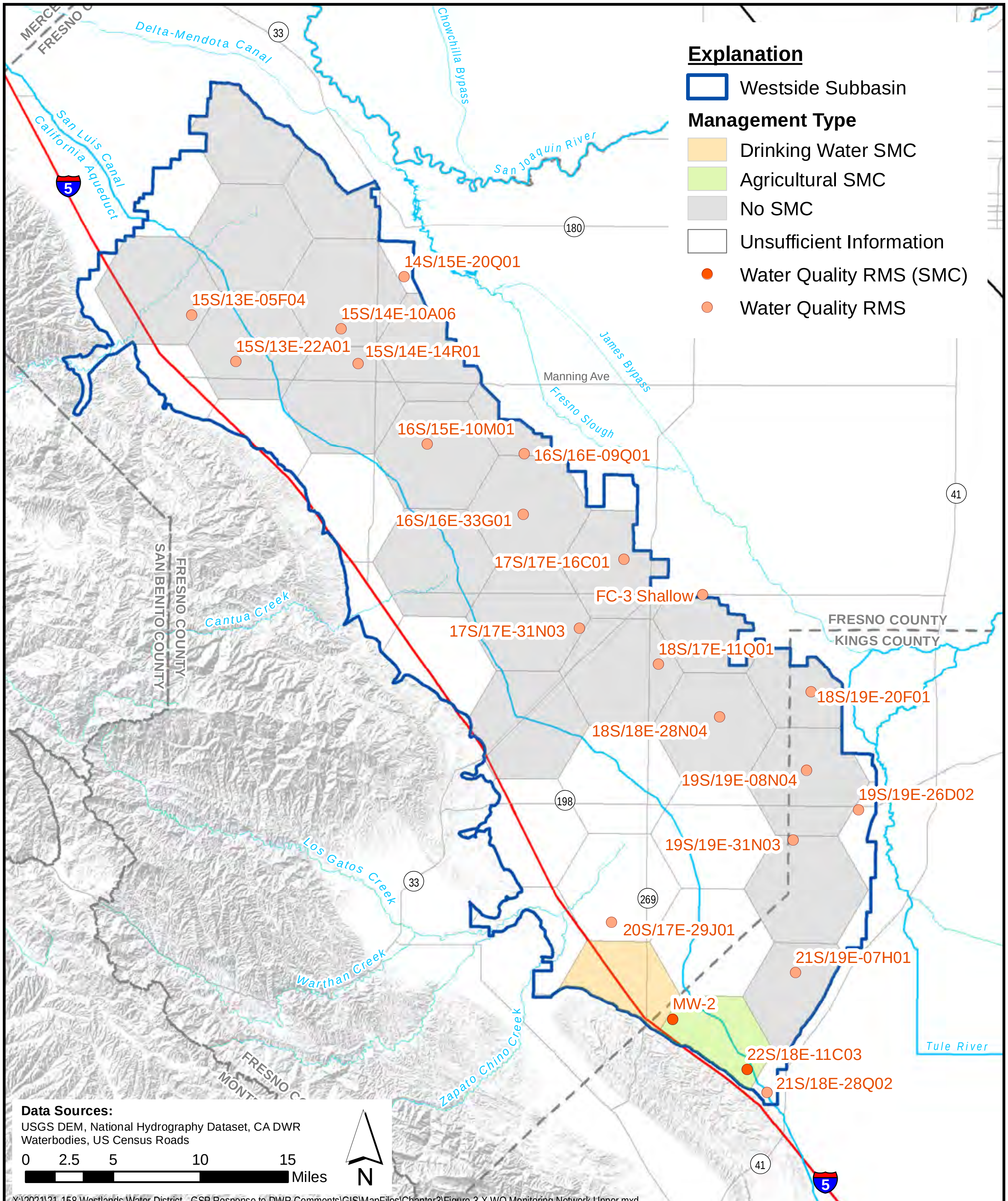
Representative Monitoring Sites for Land Surface Subsidence

SGMA Sustainability Analyses Westside Subbasin

Figure ES-5



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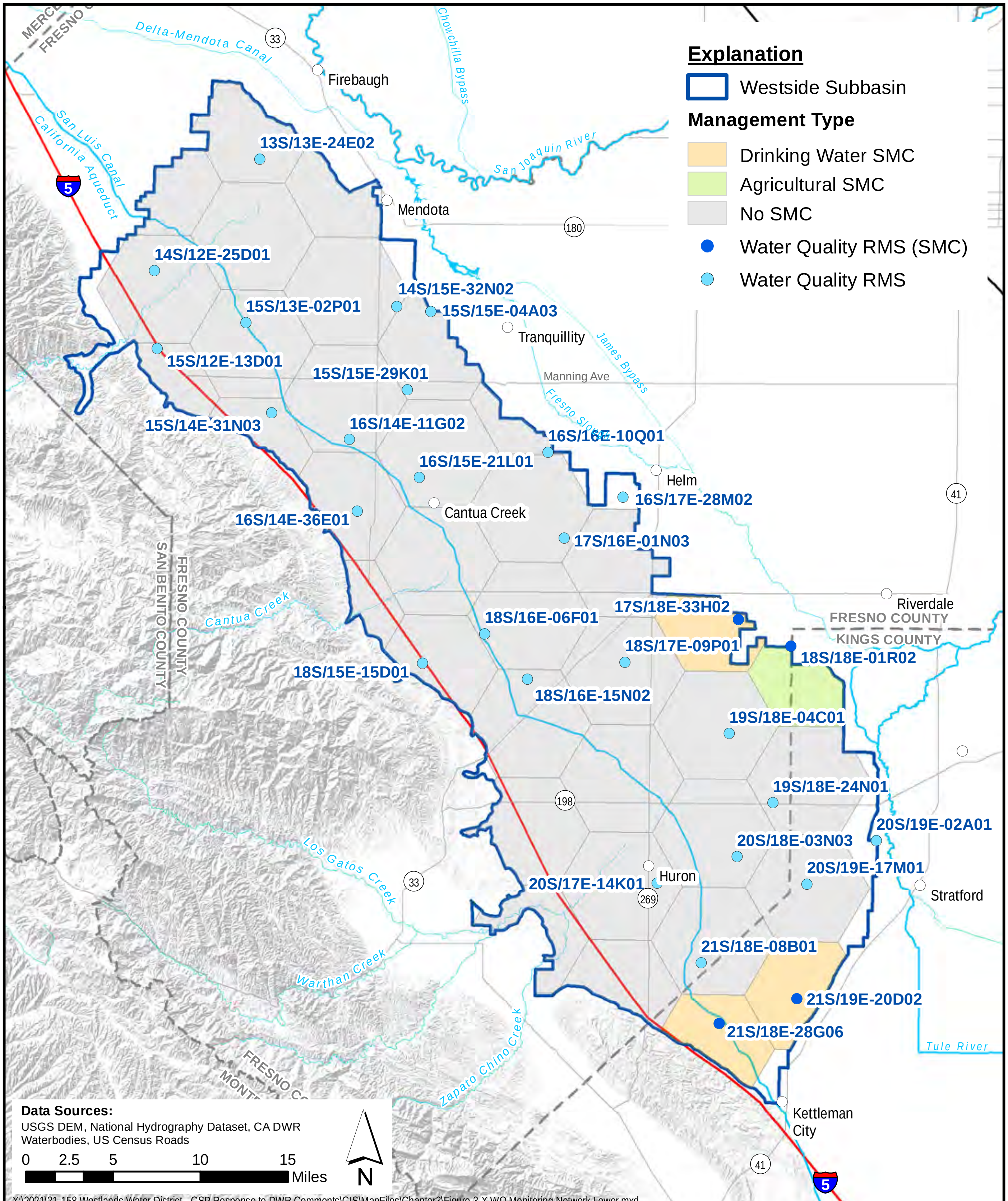
Representative Monitoring Sites for Groundwater Quality (Upper Aquifer)

SGMA Sustainability Analyses
Westside Subbasin

Figure ES-6



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Representative Monitoring Sites for Groundwater Quality (Lower Aquifer)

Figure ES-7

SGMA Sustainability Analyses
Westside Subbasin

1 INTRODUCTION

1.1 Purpose of the Groundwater Sustainability Plan

The purpose of this Groundwater Sustainability Plan (GSP) is to concurrently optimize groundwater use and groundwater storage in the Westside Subbasin and meet the regulatory requirements set forth in the three-bill legislative package, Assembly Bill (AB) 1739 (Dickinson), Senate Bill (SB) 1168 (Pavley), and SB 1319 (Pavley) collectively known as the Sustainable Groundwater Management Act (SGMA) (California Water Code (Wat. Code) §§ 10720 *et seq*.). Under SGMA, high priority basins or subbasins that are categorized as critically overdrafted must submit an adopted GSP to the California Department of Water Resources (DWR) by January 31, 2020. The Westside Subbasin (Subbasin No. 5-22.09 of the San Joaquin Valley (Valley) Groundwater Basin) (Westside Subbasin or Basin) is a high priority Subbasin designated by DWR as critically overdrafted. GSPs are prepared and implemented by Groundwater Sustainability Agencies (GSAs) are local and regional authorities. Westlands Water District (WWD or District) serves as the GSA for the Westside Subbasin. SGMA defines sustainable groundwater management as "management and use of groundwater in a manner that can be maintained during the planning and implementation horizon (50 years from 2020 through 2070) without causing undesirable results" (Wat. Code § 10721(v), which are any of the following effects caused by groundwater pumping occurring throughout the basin:

- Chronic lowering of groundwater levels indicating a significant and unreasonable depletion of supply,
- Significant and unreasonable reduction of groundwater storage,
- Significant and unreasonable seawater intrusion,
- Significant and unreasonable degraded water quality,
- Significant and unreasonable land subsidence, and
- Depletions of interconnected surface water that have significant and unreasonable adverse impacts on beneficial uses of the surface water. (Wat. Code § 10721(x)(1)-(6).)

The Westside Subbasin GSP describes the existing hydrogeologic conditions and current management practices in the Subbasin. It contains the steps that will be taken to achieve and maintain sustainability over the planning and implementation horizon and to prevent the undesirable results listed above.[1] Measurable objectives and minimum thresholds developed and described in this GSP for each sustainability indicator are based on projected hydrologic conditions. This GSP will result in sustainable groundwater management and the preservation of groundwater resources for maximum benefit by all beneficial users of groundwater in the Westside Subbasin.

1.2 Sustainability Goal

The District, acting as the GSA, will manage groundwater resources responsibly and sustainably in order to maintain acceptable standards of groundwater levels, groundwater quality, groundwater storage, and

[1] The Westside Subbasin is not a basin threatened by seawater intrusion.

subsidence. The sustainability is detailed in Chapter 3. The District's goal is to continue agriculture production while maintaining groundwater supplies and quality for all beneficial users of groundwater.

1.3 Agency Information

The Westside Subbasin is located in the western portion of the San Joaquin Valley Groundwater Basin in Fresno and Kings counties. The Subbasin is surrounded by the Pleasant Valley Subbasin (DWR Subbasin 5-22.10) that lies to the southwest, the Tulare Lake Subbasin (DWR Subbasin 5-22.12) to the south, the Kings Subbasin (DWR Subbasin 5-22.08) to the east, the Delta-Mendota Subbasin (DWR Subbasin 5-22.07) to the east and north, and the Coast Range resides along the western boundary.

The District was originally formed in 1952 under the California Water District Law (codified as Division 13 of the California Water Code). Upon formation, the District was composed of more than 400,000 acres. In 1962, the United States urged the District to merge with Westplains Water Storage District, which was located immediately to the west of the District, to optimize and support the federal government's delivery of surface water to the west side of the Valley. This merger extended the District's western service area boundary to the Interstate 5 corridor, expanded the District's acreage to approximately 600,000 acres, and increased the water supply contract amount from the United States Bureau of Reclamation (USBR) from 900,000 acre-feet (AF) per year in 1963 to a commitment of 1,150,000 acre-feet per year (AFY) in 1965. In March 2007, the lands within the Broadview Water District, located along the District's northern boundary, were annexed into the District to form the current District boundary.

As a result, today the District is the largest agricultural water district in the United States, encompassing approximately 1,000 square miles (approximately 614,000 acres) of farmland in western Fresno and Kings Counties (**Figure 1-1**). The District's federal water contracts provide water to approximately 700 family-owned farms that average 875 acres in size. These farms produce more than 60 different food and fiber crops for the fresh, dry, canned and frozen food markets in the United States and abroad. For over 100 years, this region has played a central role in the economies of both Fresno and Kings Counties.[2]

The District's water users rely on surface water and groundwater to irrigate their crops efficiently. The District receives its surface water supply from the Central Valley Project (CVP) through the C.W. "Bill" Jones Pumping Plant and takes delivery from the San Luis Canal (SLC). The District has contracts with USBR for 1.195 million acre-feet (MAF). However, the reliability of the District's CVP water supply has been reduced in large part due to regulatory requirements, preventing the delivery of its full contractual allocation in most years. Therefore, the District's water users have resorted to groundwater to help offset shortages in available surface water and to meet on-farm demands. To promote the efficient use of the District's water resources, farms within the District's jurisdiction utilize water-efficient irrigation techniques.

SGMA authorizes a "local public agency that has water supply, water management, or land use responsibilities within a groundwater subbasin or basin to elect to become a GSA and to develop, adopt, and implement a GSP. (Wat. Code § 10721(n).)" As a California Water District formed under the California

[2] Shires, Michael A., Ph.D., "The Economic Impact of the Westlands Water District on the Local and Regional Economy," (October 12, 2016), pp, iii, vi, x.

Water District Act (a copy of which is included in **Appendix A**), the District has the requisite water supply and water management authority to act as a GSA. (Wat. Code § 35401.) The District's Board elected to serve as the GSA of the Westside Subbasin on July 19, 2016, per Resolution Number 111-16 (a copy of which is included in **Appendix B**). DWR deemed the District as the exclusive GSA of the Westside Subbasin on November 1, 2016. Pursuant to this authority, the GSA notified the DWR of its intent to develop a Plan on December 22, 2016. A copy of the District's Notice of Intent (NOI) to serve as the GSA for the Subbasin and the NOI to Develop a Plan are included as **Appendix C**. The District's boundaries do not encompass the entirety of the Subbasin. The areas of the Subbasin that are not within the District's boundaries are limited in extent and the District entered into a Memorandum of Understanding with Fresno County (District-Fresno County MOU) on October 18, 2016 to include these non-District lands in the GSP for the Subbasin. The MOU is attached in **Appendix D**. However, following the ninety (90) day posting period of the Notice of Intent, DWR and the State Water Resources Control Board indicated that those Subbasin areas outside of the jurisdictional boundary of an agency that filed to be a GSA for those areas would be considered unmanaged. Subsequently, on May 2, 2017, the County of Fresno Board of Supervisors adopted a Resolution (#17-275) to authorize Department staff to submit a Notice of Intent to DWR indicating that the County intended to serve as a GSA for the unmanaged areas that are within the jurisdictional boundary of the County and outside the jurisdictional boundary of WWD.

This GSP covers the entire Westside Subbasin. The majority of the Westside Subbasin falls within the District's boundaries. Several small areas along the western and eastern edge of the Subbasin extend past the District's boundaries and fall within the jurisdiction of Fresno and Kings Counties. The County of Fresno serves as the GSA for the portions of the Westside Subbasin outside of the District's boundaries that lie within Fresno County. The Kings County portion of the Subbasin that falls outside the District's boundaries lies within Naval Air Station Lemoore (NASL), which is owned by the federal government and is exempt from the requirements of SGMA.

1.3.1 Organization and Management Structure of the GSA

The District's Board of Directors serve as the Subbasin's GSA Board. The GSA Board is comprised of nine members each of whom is (1) a holder of a title of land within the District, (2) the legal representative of a holder to a title of land within the District, or (3) a representative designated by the holder of title to land within the District. (See Wat. Code § 34700.) Board elections are held every two years, and Directors are elected to four-year terms of office.

The GSA Board manages and conducts the business and affairs of the Subbasin. The GSA Board meets on the third Tuesday of each month except on holidays and meetings are open to the general public. Agendas and Minutes are available on the District's website. The GSA Board's tasks include, but are not limited to, the following:

- Develop budget(s) and appropriate cost sharing for any project or program;
- Guidance and propose options for obtaining grant funding;
- Recommend the adoption of rules, regulations, policies, and procedures related to the MOU with Fresno County;

- Recommend the approval of any contracts with consultants or subcontractors that would undertake work on behalf of the Parties and/or relate to Basin-wide issues and, if applicable;
- Report to the Parties respective governing boards when dispute resolution is needed to resolve an impasse or inability to make a consensus recommendation;
- Recommend action and/or approval of a GSP.

Contact information for the District's GSP manager and the District itself, is provided below:

Agency:	Westlands Water District
Address:	3130 N Fresno Street, P.O. Box 6056 Fresno, CA 93703
GSP Manager:	Katarina Campbell, Supervisor of Resources
Phone Number:	559-224-1523
Electronic Mail Address:	kcampbell@wwd.ca.gov

Contact information for Fresno County, is provided below:

Agency:	The County of Fresno
Address:	2220 Tulare St. 6th Floor Fresno, CA 93721
GSP Manager:	Glenn Allen, Water and Natural Resources Manager
Phone Number:	559-600-4292
Electronic Mail Address:	glallen@co.fresno.ca.us

1.3.2 Legal Authority of the GSA

The following powers and authorities are granted to the District as the GSA (Wat. Code §§ 10725 *et seq*.):

- Adopt standards for measuring and reporting water use;
- Adopt rules, regulations, policies and procedures to govern the adoption and implementation of the GSP, as authorized by SGMA including funding of the GSA, and the collection of fees or charges as may be applicable;
- Develop and implement conservation best management practices;
- Develop and implement metering, monitoring and reporting related to groundwater pumping;
- Hire consultants as determined necessary or appropriate by the GSA; and
- Prepare a budget

Similarly, the County of Fresno has the authority to implement the GSP through its statutory land use and water management responsibilities pursuant to its constitutional police powers. Fresno County's Board of Supervisors adopted a resolution (No. 17-275) and was recognized as the GSA in the Westside Subbasin for approximately 10,183 acres west of the District's boundary, Appendix D.

1.3.3 Estimated Cost of Implementing GSP and the GSA's Approach to Meeting Costs

The majority of GSP development costs were funded through the District successfully obtaining a $2.5 million Proposition 1 grant for GSP development and monitoring facilities. In addition to the grant funds, the District expended approximately $500,000 on GSP development and related activities from revenues collected through the District's operations and maintenance water rate. The District is reimbursing this fund from SGMA land based charges, once adopted. Thus, the SGMA land-based charge will include a rate component to reimburse the District for those expenditures over a 5-year period.

The GSA Board is considering alternative funding methods to implement the GSP. Annual administration costs for the GSP are estimated to be $600,000 and are presented in Chapter 5 of the GSP. The ongoing costs of GSP implementation will be subject to further planning and GSA approvals for future actions, including but not limited to monitoring, metering, measurement, replenishment and storage of water.

1.4 GSP Organization

This GSP is organized according to DWR's "GSP Annotated Outline" for standardized reporting (CA DWR SGMP, 2016). The Preparation Checklist for GSP Submittal in DWR formatting can be found below in **Table 1-1** (CA DWR SGMP, 2016).

Table 1-1: DWR Preparation Checklist

GSP Regulations Section	Water Code Section	Requirement	Description	Section(s) or Page Number(s) in the GSP
352.2		Monitoring Protocols	• Monitoring protocols adopted by the GSA for data collection and management • Monitoring protocols that are designed to detect changes in groundwater levels, groundwater quality, inelastic surface subsidence for basins for which subsidence has been identified as a potential problem, and flow and quality of surface water that directly affect groundwater levels or quality or are caused by groundwater extraction in the basin	Ch. 3.5.2

GSP Regulations Section	Water Code Section	Requirement	Description	Section(s) or Page Number(s) in the GSP
354.4		General Information	• Executive Summary • List of references and technical studies	Ex. Summary and Ch. 7
354.6		Agency Information	• GSA mailing address • Organization and management structure • Contact information of Plan Manager • Legal authority of GSA • Estimate of implementation costs	Ch. 1.3
354.8(a)	10727.2(a)(4)	Map(s)	• Area covered by GSP • Adjudicated areas, other agencies within the basin, and areas covered by an Alternative • Jurisdictional boundaries of federal or State land • Existing land use designations • Density of wells per square mile	Ch. 2.1
354.8(b)		Description of the Plan Area	• Summary of jurisdictional areas and other features	Ch. 2.1
354.8(c) 354.8(d) 354.8(e)	10727.2(g)	Water Resource Monitoring and Management Programs	• Description of water resources monitoring and management programs • Description of how the monitoring networks of those plans will be incorporated into the GSP	Ch. 2.1.2

GSP Regulations Section	Water Code Section	Requirement	Description	Section(s) or Page Number(s) in the GSP
			• Description of how those plans may limit operational flexibility in the basin • Description of conjunctive use programs	
354.8(f)	10727.2(g)	Land Use Elements or Topic Categories of Applicable General Plans	• Summary of general plans and other land use plans • Description of how implementation of the GSP may change water demands or affect achievement of sustainability and how the GSP addresses those effects • Description of how implementation of the GSP may affect the water supply assumptions of relevant land use plans • Summary of the process for permitting new or replacement wells in the basin • Information regarding the implementation of land use plans outside the basin that could affect the ability of the Agency to achieve sustainable groundwater management	Ch. 2.1.3

GSP Regulations Section	Water Code Section	Requirement	Description	Section(s) or Page Number(s) in the GSP
354.8(g)	10727.4	Additional GSP Contents	**Description of Actions related to:** • Control of saline water intrusion • Wellhead protection • Migration of contaminated groundwater • Well abandonment and well destruction program • Replenishment of groundwater extractions • Conjunctive use and underground storage • Well construction policies • Addressing groundwater contamination cleanup, recharge, diversions to storage, conservation, water recycling, conveyance, and extraction projects • Efficient water management practices • Relationships with State and federal regulatory agencies • Review of land use plans and efforts to coordinate with land use planning agencies to assess activities that potentially create risks to groundwater quality or quantity	Ch. 2.1.4

GSP Regulations Section	Water Code Section	Requirement	Description	Section(s) or Page Number(s) in the GSP
			• Impacts on groundwater dependent ecosystems	
354.10		Notice and Communication	• Description of beneficial uses and users • List of public meetings • GSP comments and responses • Decision-making process • Public engagement • Encouraging active involvement • Informing the public on GSP implementation progress	Ch. 2.1.5
354.14		Hydrogeologic Conceptual Model	• Description of the Hydrogeologic Conceptual Model • Two scaled cross-sections • Map(s) of physical characteristics: topographic information, surficial geology, soil characteristics, surface water bodies, source and point of delivery for imported water supplies	Ch. 2.2
354.14(d)(4)	10727.2(a)(5)	Map of Recharge Areas	• Map delineating existing recharge areas that substantially contribute to the replenishment of the	Ch. 4.5

GSP Regulations Section	Water Code Section	Requirement	Description	Section(s) or Page Number(s) in the GSP
			basin, potential recharge areas, and discharge areas	
	10727.2(d)(4)	Recharge Areas	• Description of how recharge areas identified in the plan substantially contribute to the replenishment of the basin	Ch. 4.5
354.16	10727.2(a)(1) 10727.2(a)(2)	Current and Historical Groundwater Conditions	• Groundwater elevation data • Estimate of groundwater storage • Seawater intrusion conditions • Groundwater quality issues • Land subsidence conditions • Identification of interconnected surface water systems • Identification of groundwater-dependent ecosystems	Ch. 2.2.2
354.18	10727.2(a)(3)	Water Budget Information	• Description of inflows, outflows, and change in storage • Quantification of overdraft • Estimate of sustainable yield • Quantification of current, historical, and projected water budgets	Ch. 2.3

GSP Regulations Section	Water Code Section	Requirement	Description	Section(s) or Page Number(s) in the GSP
	10727.2(d)(5)	Surface Water Supply	• Description of surface water supply used or available for use for groundwater recharge or in-lieu use	Ch. 2.2.9
354.20		Management Areas	• Reason for creation of each management area • Minimum thresholds and measurable objectives for each management area • Level of monitoring and analysis • Explanation of how management of management areas will not cause undesirable results outside the management area • Description of management areas	Ch. 3.4.7
354.24		Sustainability Goal	• Description of the sustainability goal	Ch. 3.1
354.26		Undesirable Results	• Description of undesirable results • Cause of groundwater conditions that would lead to undesirable results • Criteria used to define undesirable results for each sustainability indicator • Potential effects of undesirable results on	Ch. 3.4

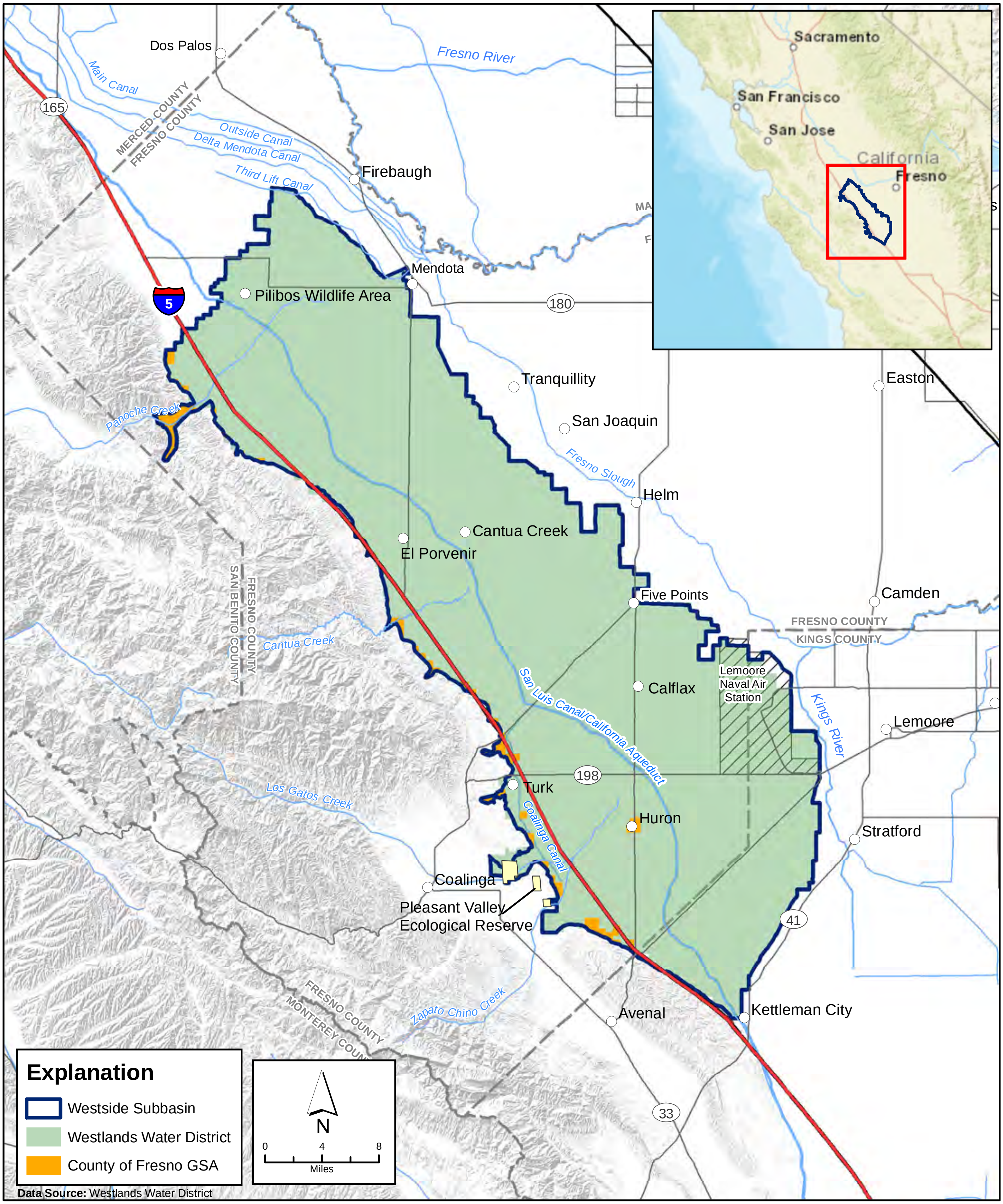
GSP Regulations Section	Water Code Section	Requirement	Description	Section(s) or Page Number(s) in the GSP
			beneficial uses and users of groundwater	
354.28	10727.2(d)(1) 10727.2(d)(2)	Minimum Thresholds	• Description of each minimum threshold and how they were established for each sustainability indicator • Relationship for each sustainability indicator • Description of how selection of the minimum threshold may affect beneficial uses and users of groundwater • Standards related to sustainability indicators • How each minimum threshold will be quantitatively measured	Ch. 3.3
354.30	10727.2(b)(1) 10727.2(b)(2) 10727.2(d)(1) 10727.2(d)(2)	Measurable Objectives	• Description of establishment of the measurable objectives for each sustainability indicator • Description of how a reasonable margin of safety was established for each measurable objective • Description of a reasonable path to achieve and maintain the	Ch. 3.2

GSP Regulations Section	Water Code Section	Requirement	Description	Section(s) or Page Number(s) in the GSP
			sustainability goal, including a description of interim milestones	
354.34	10727.2(d)(1) 10727.2(d)(2) 10727.2(e) 10727.2(f)	Monitoring Networks	• Description of monitoring network • Description of monitoring network objectives • Description of how the monitoring network is designed to: demonstrate groundwater occurrence, flow directions, and hydraulic gradients between principal aquifers and surface water features; estimate the change in annual groundwater in storage; monitor seawater intrusion; determine groundwater quality trends; identify the rate and extent of land subsidence; and calculate depletions of surface water caused by groundwater extractions • Description of how the monitoring network provides adequate coverage of Sustainability Indicators	Ch. 3.5

GSP Regulations Section	Water Code Section	Requirement	Description	Section(s) or Page Number(s) in the GSP
			• Density of monitoring sites and frequency of measurements required to demonstrate short-term, seasonal, and long-term trends • Scientific rationale (or reason) for site selection • Consistency with data and reporting standards • Corresponding sustainability indicator, minimum threshold, measurable objective, and interim milestone	
			(Monitoring Networks Continued) • Location and type of each monitoring site within the basin displayed on a map, and reported in tabular format, including information regarding the monitoring site type, frequency of measurement, and the purposes for which the monitoring site is being used • Description of technical standards, data collection methods, and other procedures or protocols to ensure comparable data and methodologies	Ch. 3.5

GSP Regulations Section	Water Code Section	Requirement	Description	Section(s) or Page Number(s) in the GSP
354.36		Representative Monitoring	• Description of representative sites • Demonstration of adequacy of using groundwater elevations as proxy for other sustainability indicators • Adequate evidence demonstrating site reflects general conditions in the area	Ch. 3.5.3
354.38		Assessment and Improvement of Monitoring Network	• Review and evaluation of the monitoring network • Identification and description of data gaps • Description of steps to fill data gaps • Description of monitoring frequency and density of sites	Ch. 3.5.4
354.44		Projects and Management Actions	• Description of projects and management actions that will help achieve the basin's sustainability goal • Measurable objective that is expected to benefit from each project and management action • Circumstances for implementation • Public noticing • Permitting and regulatory process	Ch. 4

GSP Regulations Section	Water Code Section	Requirement	Description	Section(s) or Page Number(s) in the GSP
			• Time-table for initiation and completion, and the accrual of expected benefits • Expected benefits and how they will be evaluated • How the project or management action will be accomplished. If the projects or management actions rely on water from outside the jurisdiction of the Agency, an explanation of the source and reliability of that water shall be included • Legal authority required • Estimated costs and plans to meet those costs • Management of groundwater extractions and recharge	
354.44(b)(2)	10727.2(d)(3)	Projects and Management Actions	• Overdraft mitigation projects and management actions	Ch. 4



X:\2017\17-082 Westlands WD - GSP Support Services\GIS\MapFiles\Figure 1-1 Westlands Water District Location Map.mxd

FIGURE 1-1
Westside Subbasin Location Map

Luhdorff & Scalmanini
Consulting Engineers

Hydrogeologic Conceptualization Report
Westside Subbasin

2 WESTSIDE SUBBASIN PLAN AREA AND SETTING

2.1 Description of Plan Area

2.1.1 Summary of Jurisdictional and Plan Area (GSP Reg. § 354.8 (b))

The Westside Subbasin (Subbasin, DWR Subbasin No. 5-22.09) covers 972 square miles (622,215 acres) and spans approximately 17 miles east and west and 67 miles north and south from Mendota to Kettleman City. The Subbasin lies within the western portion of the larger San Joaquin Valley Groundwater Basin (DWR Basin No. 5-22). The Subbasin is bordered by the Diablo Range to the west and other groundwater subbasins along its north, east and southern boundaries: the Pleasant Valley Subbasin (DWR Subbasin No. 5-22.10) lies to the southwest, the Tulare Lake Subbasin (DWR Subbasin No. 5-22.12) to the south, the Kings Subbasin (DWR Subbasin No. 5-22.08) to the east, and the Delta-Mendota Subbasin (DWR Subbasin No. 5-22.07) to the east and north (**Figure 2-1**).

This GSP covers the entire Subbasin, the majority of which falls within the District's boundaries. Several small areas along the western and eastern edge of the Subbasin extend past the District's boundaries and fall within the jurisdiction of Fresno and Kings Counties. The County of Fresno serves as the GSA for the portions of the Subbasin outside of the District's boundaries that lie within Fresno County. The Kings County portion of the Subbasin that falls outside the District's boundaries lies within Naval Air Station Lemoore (NASL), which is owned by the federal government and thus exempt from the requirements of SGMA.

There are no known adjudicated areas within or surrounding the Westside Subbasin.

Figure 2-2 titled, "Agencies in the GSP Area" depict all the known agencies in the Subbasin per GSP Regulations Section 354.8(a)(3). The agencies include Fresno County, Kings County, the City of Huron, the City of Avenal, NASL, Federal-Owned lands, and State-owned lands. Section 2.1.3 below includes additional information on the city and county agencies.

2.1.1.1 Summary of Existing Wells in Plan Area

Well types, well depth data, and well distribution data were obtained from internal records from the District. These data were compared to DWR's Well Completion Report (WCR) Map Application (DWR, 2018). Wells were categorized into three groups that include domestic, production (agricultural and industrial), and public supply wells. **Table 2-1** summarizes the types of wells by beneficial use.

Figures 2-3 through **2-5** show the density of wells in the Subbasin by their type of beneficial use. The well density is approximately 0.99 wells per square mile.

Table 2-1: Types of Wells

Type of Well	Total Wells
Domestic	38
Production (Agricultural & Industrial)	915
Public Supply & Municipal	6
TOTAL	**959**

The District records indicate that there are 38 active domestic well sites in the Subbasin as of 2022. The District visits all the well locations designated for domestic use on an annual basis and records whether the sites are inactive or active. The District also communicated with individual domestic wells owners to determine if the most recent drought impacted these domestic wells. The District noted that none of the domestic well owners reported their wells as having gone dry during that time period. Additionally, DWR's Dry Wells Reporting System has not reported dry wells in the Westside Subbasin. The District evaluated the screen intervals of all active domestic wells within the Westside Subbasin to determine the potential impact of selected Minimum Thresholds and this analysis is further discussed in Chapter 3. The domestic wells are considered de minimis extractors, pumping less than 2 Acre-Feet (AF) annually and collectively pumping up to 76 Acre-Feet/Year (AFY). The domestic wells identified and evaluated by the District are distributed throughout the District, rather than located in discrete areas.

2.1.2 Water Resource Monitoring and Management Programs (GSP Reg. § 354.8 (c, d, e))

For the last four decades, the District has actively managed the Subbasin's groundwater resources. The District monitors and manages the Subbasin through its Groundwater Management Plan (GMP), Water Management Plan, the California Statewide Groundwater Elevation Monitoring (CASGEM) program, Groundwater Quality Trend Monitoring Plan, and the Integrated Regional Water Management Plan. Implementing these programs, which are described below in detail, promote conjunctive use and preserve groundwater in the Westside Subbasin. The District does not believe any of these programs listed above limit the operation or implementation of the Subbasin's GSP. To the contrary, the existing water resources monitoring and management programs support the implementation of the GSP. The District utilized the existing programs detailed below to develop the monitoring network, described in Chapter 3, and added additional sites with sufficient historical data to fill in monitoring gaps.

2.1.2.1 Groundwater Management Plan (GMP)

The District developed and adopted its first GMP in 1996 pursuant to Assembly Bill 3030 (which was later codified under Part 2.75 of the Water Code). The main objective of the District's GMP is to preserve and enhance the long-term sustainability of the District's groundwater resources. The District's GMP outlined a comprehensive groundwater monitoring program which is described in this GSP.

"Pursuant to AB 3030, any local public agency which provides water service to all or a portion of its service area and whose service area includes all or a portion of a groundwater Subbasin, to adopt a groundwater management program. The law contains 12 components which may be included in a GMP. Each component may play some role in evaluating or operating a groundwater Subbasin so that groundwater can be managed to maximize the total water supply while protecting groundwater quality." (Westlands Water District, 1996).

Since 2012, the District has collected pumping data from all the accessible groundwater well meters on a quarterly basis. On average, this means collecting pumping data from 87 percent of groundwater well meters, since approximately 13 percent of the sites in the Subbasin are not accessible due to locked gates, have inoperable meters or are unmetered locations. Prior to 2012, the District estimated groundwater pumping in the Subbasin based on the amount of groundwater pumped in the Groundwater Management Program (GWMP). Through its GWMP, the District became the first water district in the state to integrate local groundwater resources into the District's water supply system. Through this program, the District acquires title to groundwater pumps, orders energy for the groundwater wells and integrates the groundwater pumped into the District's comprehensive water supply.

2.1.2.2 Water Management Plan

The District developed and implemented a Water Management Plan, which satisfies the requirements of the Agricultural Water Management Planning Act (Wat. Code, §§ 10800 et seq.), the Reclamation Reform Act of 1982 (P.L. 97-295-96, stat. 213), the Central Valley Project Improvement Act of 1992 (P.L. 102-575, 106 stat. 4713) and the Water Conservation Bill of 2009 (Wat. Code, § 10820). The Water Management Plan provides information about current water uses and charts a course for water efficiency improvements, conservation activities, and water-reduction goals. The District relies on the information collected pursuant to the Water Management Plan to establish funding priorities for the District's water-efficiency projects that will provide the largest impact. Water Management Plan objectives and goals:

- Conserve the available water supply
- Protect the integrity of water supply facilities
- Implement contingency plan in times of drought or water supply reduction
- Track Agricultural cropping patterns, changes in irrigated acres and anticipated land use changes within the District
- Measure the volume of water delivered to water users with accuracy
- Evaluate capital improvement projects with the potential to enhance reliable water supply
- Facilitate the financing of capital improvements for on-farm irrigation systems
- Pursues water transfers from other districts on an annual basis to supplement reduced contract deliveries to water users
- Facilitate individual water transfers between water users within the District or from other districts to supplement their water supply

- Promote and educate water users about water conservation and preventative measures to avoid wasteful use of water
- Participate in water quality monitoring practices
- Evaluate and improve efficiencies of District pumps

The Water Management Plan provides a framework of management practices, such as conjunctive use and conservation efforts, that help meet the water management goals and are consistent with the goals of the Westside Subbasin GSP.

2.1.2.2.1 Conjunctive Use

The Westside Subbasin is comprised of approximately 93 percent farmland. The primary land use of the Westside Subbasin is for agricultural beneficial uses producing more than 60 high quality commercial food and fiber crops. The Subbasin's water users rely on surface water and groundwater to irrigate their crops. The Subbasin receives surface water supplies from the CVP through the Delta facilities and takes delivery from the SLC. The District has water service contracts with the USBR for 1.197 MAF. However, the District does not often receive the full contractual allocation. **Table 2-2** titled "WWD Historical CVP Supply" summarizes the District's CVP allocation per Water Year.

The District's conjunctive use patterns fluctuate depending on available and utilized surface water supplies. Based on historical land use practices, the District's agricultural water users apply an average annual amount of approximately 960,000 AF to land overlying the Subbasin utilizing a combination of groundwater and imported surface water supplies. When surface water shortfalls exist, water users utilize groundwater to offset the deficit in surface water supplies. The District developed a Water Management Plan and Groundwater Management Plan to promote conjunctive use in the Westside Subbasin, located in **Appendices E and F**. The District developed the plans and set the following primary goals:

- Preserve and enhance the reliability of groundwater in the Westside Subbasin,
- Ensure the long-term availability of high-quality groundwater,
- Maintain local control of groundwater resources in the District, and
- Minimize the cost and impacts of groundwater use.

Additionally, the District Board of Directors has taken progressive actions to promote conjunctive use and discourage groundwater pumping when surface water supplies are adequate.

Table 2-2 titled, "WWD Historical CVP Supply", summarizes the historical allocation the District received since 1988 with the recent five- and ten-year averages yielding 45% and 40%, respectively.

Table 2-2: WWD Historical CVP Supply

Water Year	CVP Allocation	Water Year	CVP Allocation
1988	100%	**2004**	70%
1989	100%	**2005**	85%
1990	50%	**2006**	100%
1991	27%	**2007**	50%
1992	27%	**2008**	40%
1993	54%	**2009**	10%
1994	43%	**2010**	45%
1995	100%	**2011**	80%
1996	95%	**2012**	40%
1997	90%	**2013**	20%
1998	100%	**2014**	0%
1999	70%	**2015**	0%
2000	65%	**2016**	5%
2001	49%	**2017**	100%
2002	70%	**2018**	50%
2003	75%	**2019**	**75%**

2.1.2.2.2 Conservation Efforts

The District maintains its water distribution system by balancing meeting the water demand of thousands of turnouts simultaneously with adequate water pressure at all locations to address water quantity and peak flow rates. With its history of pervasive water shortages, the District and its growers work together to ensure that water delivered through its comprehensive water supply system is responsibly and sustainably managed. For example, most the District's distribution system is fully enclosed to eliminate losses from evaporation.

The District implemented the Expanded Irrigation System Improvement Program (EISIP) to provide funding assistance, through low interest equipment leases, to growers interested in installing high efficiency irrigation systems. Irrigation systems include drip, micro drip, center pivot sprinklers and aluminum pipes. The EISIP program was developed to support water conservation. Currently, more than 95 percent of District's land is irrigated with drip or sprinkler delivery systems. **Figure 2-13**, titled "Historical Change in Irrigation Practices", illustrates the shift in irrigation practices from 1985 to 2015. In 1985, less than 37 percent of landowners within the District employed efficient irrigation practices and over time that percentage has increased to 96 percent as of 2017. In addition to the changes in irrigation practices, the District also uses more than 3,300 water meters throughout the Subbasin to ensure conservation practices and that any losses due to leakage are immediately addressed.

2.1.2.3 California Statewide Groundwater Elevation Monitoring Program (CASGEM)

Since 2011, the District has participated in the CASGEM Program. In collaboration with DWR, the District developed a groundwater monitoring network which includes 151 wells. Under CASGEM, the District is required to measure and report groundwater levels annually. Since 2015, the District has monitored the CASGEM well sites twice a year to determine seasonal groundwater highs and lows. Some of the CASGEM monitoring wells were incorporated into the Plan's groundwater monitoring network. The Westside Subbasin GSP groundwater level monitoring network includes 20 wells from the CASGEM program. This includes 9 wells in the Upper Aquifer and 11 wells Lower Aquifer.

2.1.2.4 Groundwater Quality Trend Monitoring Plan

The Westlands Water Quality Coalition (Coalition) administers the Groundwater Quality Trend Monitoring Plan (GQTM) to determine groundwater quality conditions underlying irrigated agriculture and to develop long-term groundwater quality information that can be used to evaluate the regional effects (i.e., non-site-specific effects) of irrigated agriculture and its practices. The Coalition represents owners and operators of irrigated lands overlying the Subbasin, the Pleasant Valley Subbasin (DWR Subbasin No. 5-22.10), the Panoche Valley Subbasin (DWR Subbasin No. 5-23) and the Vallecitos Creek Valley Subbasin (DWR Subbasin No. 5-71) and assists members with the waste discharge requirements described in the Western Tulare Lake Subbasin General Order R5-2014-001. As part of the GQTM Program, the Coalition's primary objective is to develop a network of wells within both high and low vulnerable areas and to sample those wells for nitrate and nitrite as nitrogen and field parameters (including electrical conductivity (EC)) annually, and the above constituents, TDS, and general minerals every five years. The GQTM well network consists primarily of wells completed in the Upper Aquifer and is an evolving network based on consideration of data derived through the implementation of the GQTM Program. The District plans to incorporate these water quality results into the GSP's data management system. However, GQTM wells are not included in the Monitoring Network since the GQTM Program's objectives are different than those of SGMA. The District will reconsider incorporating the GQTM well into the Monitoring Network during each 5-year amendment. Incorporation of the GQTM into the Monitoring Network will likely be driven by the amount of pumping from the Upper Aquifer.

2.1.2.5 Integrated Regional Water Management Plan (IRWM)

The Integrated Regional Water Management (IRWM) is a collaborative effort to manage all aspects of water resources in a region. The IRWM Plan that encompasses the Westside Subbasin is the Westside-San Joaquin (WSJ) IRWM Region and is illustrated in **Figure 2-4a** (below). The 2019 WSJ IRWM Plan emphasizes multi-agency collaboration, stakeholder involvement, regional approaches to water management, water management involvement in land use decisions, and project monitoring to evaluate results of current practices. The WSJ IRWM Plan identifies projects that help achieve regional objectives and targets while working to address water-related challenges in the region. No single project identified in the IRWM Plan can meet all the objectives of the WSJ IRWM Region; therefore, the IRWM Plan identifies projects that can accrue regional benefits when implemented together and projects that provide coaction in specific benefit areas.

The Aquifer Storage and Recovery and Groundwater Recharge Projects were identified in the 2019 IRWM Plan and were also identified in the GSP as Project and Management Actions described in Chapter 4 to ensure the implementation of both plans were complementary. Implementation of the GSP is expected to support the regional water management goals of the WSJ IRWM Plan in the Westside Subbasin.

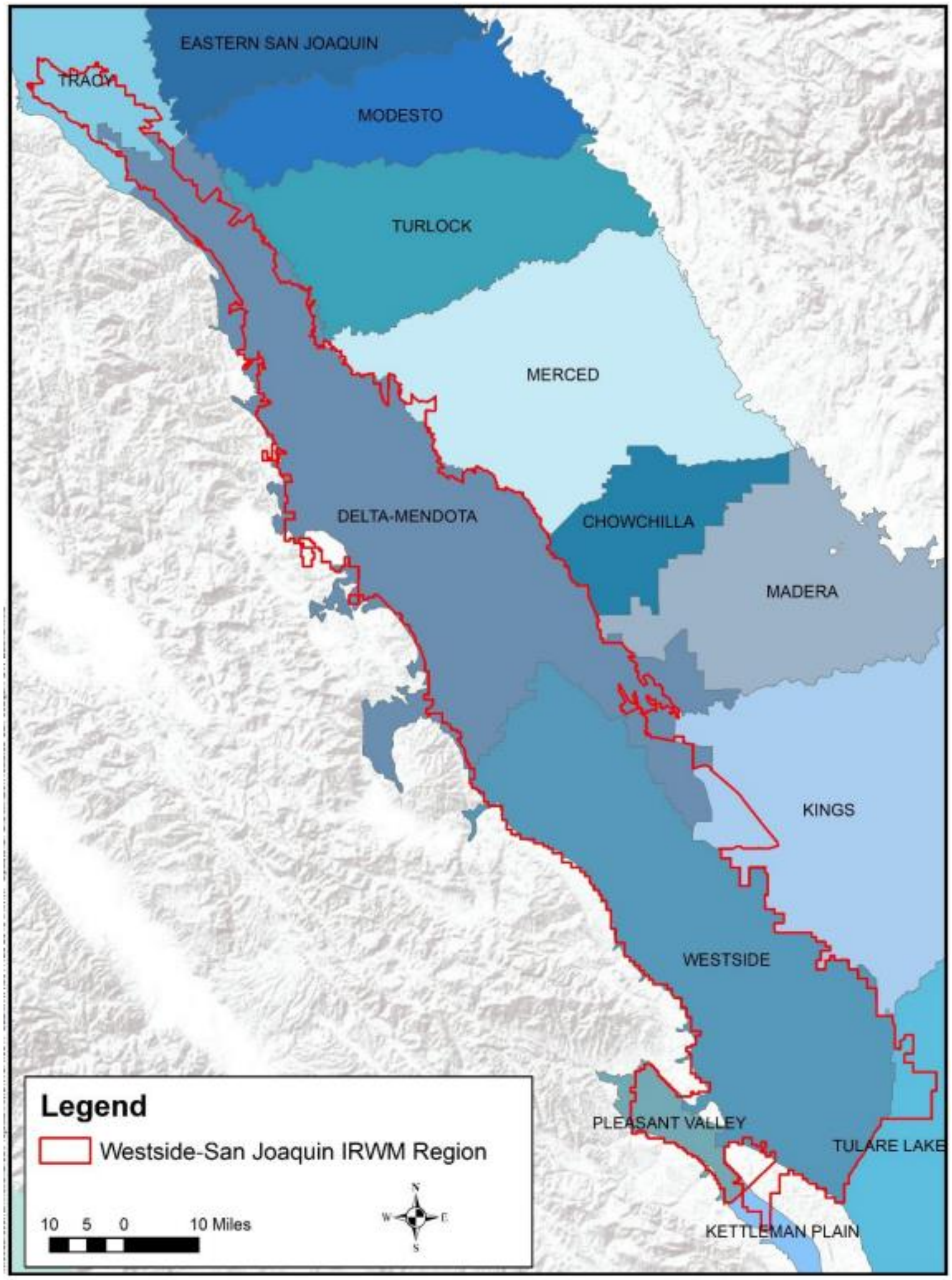


Figure 2-4a. Westside-San Joaquin IRWM Region
overlying Groundwater Basins.

2.1.3 Land Use Elements or Topic Categories of Applicable General Plans (§354.8 (f))

2.1.3.1 The Economic Role of Agriculture

The District provides water to support the economies of two Central Valley counties—Fresno County and Kings County. While most of its operations lie within Fresno County, significant acreage is located within Kings County. The agricultural industry in Fresno and Kings Counties is a major driver of employment and economic activity (Shires, 2016, Appendix J).

On the agricultural side, the District's provision of water resources and infrastructure results in the direct creation of economic value in the form of crops and the business of creating them. The District plays a central role in the creation of farm products with measurable and direct economic benefits through the following District provisions:

- Direct delivery of CVP contract water, transfers, or purchased water;
- Conveyance and distribution infrastructure; or
- Measuring, tracking, and pricing locally-derived water supplies.

As a major agricultural production area, the District's economic impact is not only on local markets but on regional and global markets. The District's almond production, for example, is one of the United States' major export successes.

Nationally, of the total domestic production, Westlands growers provide 3.5 percent of the fresh fruit and nuts and 5.4 percent of the vegetables and melons. Growers in the District contribute significantly to the state's supply of nine key commodities, including almonds, wine (by providing wine grapes), pistachios, table grapes, processed tomatoes, cotton, lettuce, and seeds for sowing. Additionally, hay, grain, and feed production from farms within the District contribute to the beef industry.

Crops produced within Westlands' boundaries accounted for an estimated 28.1 percent of the crop-related agricultural production in Fresno County in 2019 and 13.1 percent of the crop related agricultural production in Kings County in the same year. Given that Fresno County ranked first in the state in 2019 (Fresno County Ranking) for overall agricultural production and Kings County ranked eighth (Kings County Ranking), this is a significant contribution.

Within Fresno and Kings Counties, Westlands directly accounts for some $4.7 billion of economic output and over 35,000 jobs. This impact is through direct crop production and across the wide range of secondary and support activities that are possible because of the fruit and produce grown on farms within the District and Subbasin.

The communities within and adjacent to the District rely on the jobs and economic activity generated by agriculture in the District. School enrollment, tax base, and need for social services parallel the economic health and well-being of the industry.

2.1.3.2 Population Trends

Fresno and Kings Counties are expected to experience a small growth in population in the future. Fresno County is expected to grow by 606,200 people between 2015 and 2060, an annual average increase of approximately 1.1 percent (Fresno County 2040 General Plan Public Review Draft, 2017). Kings County is expected to grow from 149,702 people in 2015 to 204,649 people by 2050, an annual increase of approximately one percent as documented by the Department of Transportation (Dept. of Transportation, 2017). A population growth of approximately 1 percent during the GSP implementation horizon is incorporated into the analyses prepared for this Plan as well as the projects and management actions.

2.1.3.3 Land Use

Land use is a key factor influencing water demand, including the amount and distribution of groundwater pumping across the Subbasin. Changing land use conditions and irrigation practices can also greatly change water demand from year to year. Historical data on land uses within the Subbasin are available from both District records and from periodic land use surveys conducted by DWR and the United States Department of Agriculture (USDA). General Land use conditions based on DWR survey data of Kings and Fresno Counties are illustrated in **Figure 2-6.** Most of the Westside Subbasin is designated as agricultural. Data representing agricultural cropping is available in aggregate for the Subbasin on an annual basis starting in the mid-1960s. More recent annual land use data is available in spatially referenced GIS data formats that are helpful in understanding the spatial patterns in land use that exist across the Subbasin. The District also has spatial land use data for 1999 through 2015. This spatial data includes information on irrigation practices. Irrigation data aggregated to the total number of irrigated acres by irrigation method is available from 1985 to the present.

DWR conducted ground surveys in 1986 and 1991 and developed spatial data for those years. Subsequently, DWR surveys were conducted in the mid-1990s, early 2000s, and most recently in 2009 for parts of Fresno County and in 2011 for Kings County. The land use surveys conducted by DWR in the early 2000s also documented irrigation methods. Since 2007, the USDA published annual spatial land use data (CropScape) for the area. CropScape data is developed from remote sensing information. The reported accuracy of the USDA CropScape data is typically between 70 and 90 percent, although this varies by year, crop, and location. The USDA land use data do not include any information on irrigation method.

Available land use data from the District, DWR, and USDA represent crops and other land uses following detailed and specific designations. For the purposes of understanding land use patterns and trends across the Subbasin as it relates to the conceptual model, these specific land use designations are grouped into general categories for the purposes of this summary.

2.1.3.4 Current and Historical Land Use Conditions

Land uses within the Westside Subbasin have changed considerably over the years. During recent decades farmers in the Westside Subbasin have shifted from grains and cotton as the major crops towards nut trees. **Table 2-3** titled, "Summary of Historical Land Use for Select Years (1988, 2000, and 2015), summarizes the historical land use conditions for select years between 1988 and 2015 based on available data from the District, DWR, and USDA. In 1988, approximately 535,000 acres overlying the Subbasin were cultivated for agriculture; close to 61 percent (about 326,000 acres) of which was planted in grains and cotton. By 2000, the number of acres devoted to grains/cotton had declined to around 244,000 acres, although this still represented more than 45 percent of the cultivated area within the Subbasin. During this same period, vegetables were planted in about 184,000 acres and approximately 35,000 acres were planted with nut trees. In 2015, the total number of cultivated acres totaled around 339,000; of this amount, only 47,000 acres were planted in grains/cotton whereas nearly 142,000 acres were nut trees (42 percent). Between 1988 and 2015, the number of acres of vegetables being grown has remained considerably more stable than acres devoted to either grains/cotton or nut trees during this same period. A more modest increase in the cultivation of grapes and citrus/subtropics is also evident since 1988, and especially since 2000, with a corresponding decrease in acres of seeds/beans (**Table 2-3**). In 2015, more than 207,000 acres were temporarily fallowed due to drought, a considerable increase from the approximately 46,000 acres of fallow/non-agricultural land in 1988 and 2000.

Table 2-3: Summary of Historical Land Use for Select Years (1988, 2000, and 2015)

Land Use Category	1988 (acres)	2000 (acres)	2015 (acres)
Citrus/Subtropics	1,174	1,853	6,695
Fruit Trees	364	2,261	3,653
Grains/Cotton	325,827	243,736	50,219
Grapes	5,796	9,790	16,818
Grasses	10,673	14,858	7,410
Nut Trees	10,016	34,768	117,851
Seeds/Beans	37,331	31,755	3,746
Vegetables	139,237	183,750	114,284
Miscellaneous	4,075	7,927	36,739
Fallow/Non-Agricultural	45,632	46,748	212,846
Total Cultivated Land	**534,493**	**530,698**	**357,415**

The spatial distribution of land uses across the Subbasin in the mid-1990s, as mapped by DWR, is displayed in **Figure 2-7.** The prominence of grains/cotton and vegetable crops within the Subbasin during the 1990s is particularly evident in this map. As illustrated in **Figure 2-8,** the spatial distribution of land use in 2013 illustrates the trend of increasing acres of nut trees and fallowed land is apparent by 2013. By 2013, considerable parts of the western Subbasin converted to nut trees and large areas of agricultural land along the western edge of the Subbasin had been fallowed. An even greater number of acres were fallowed in 2014 and 2015 whereas the number of acres of nut trees continued to increase. **Figure 2-9** presents the historical changes in land use since the 1960s, including: (1) a notable decline in grains/cotton from its peak of more than 400,000 acres in the early 1980s; and (2) a steady increase of vegetables from the 1960s until early 2000s and the more recent increase in nut trees starting in the 1990s.

A small portion of land that is non-agricultural has been mapped as native vegetation or native riparian (**Figure 2-6).** Along the western edge of the Subbasin, the boundary intersects with the Southwest

San Joaquin Valley Habitat Conservation Plan & Natural Community Conservation Plan. This plan is being prepared by Aera Energy LLC and will serve as a basis for applications for incidental take permits from the U.S. Fish and Wildlife Service and California Department of Fish and Wildlife for threatened and endangered species. This conservation plan became available for public review in Spring 2020. The focus of the plan is related to active and future oil fields outside of the Subbasin, but the goals of this conservation plan will be reviewed and considered in the five-year GSP update.

2.1.3.5 Current and Historical Irrigation Practices

Similar to land use conditions, considerable changes in historical irrigation practices have also occurred within the Subbasin. Different methods for irrigating crops have different irrigation efficiencies. Irrigation efficiency is the percentage of applied irrigation water that is taken up by the plants with the remainder of applied water predominantly recharging groundwater.

Several main types of irrigation methods are used within the Subbasin. These irrigation methods include drip/micro, sprinkler, and gravity irrigation consisting of furrow and border methods. Some other irrigation methods are also used but only on very small scales. Drip irrigation is the most efficient irrigation method in part because the application of water is more precise and targeted so that evaporative and leaching losses below the root zone are more limited. Although drip irrigation is the most efficient method, it is also the most expensive to install and maintain. Sprinkler irrigation systems are less efficient than drip irrigation systems but more efficient than gravity irrigation methods. In sprinkler irrigation water is applied to the field from a pressurized piping system with nozzles that spray water over large areas. Sprinkler irrigation requires high pumping energy and typically requires filtration. Gravity irrigation systems are less efficient than both sprinkler and drip irrigation methods. In gravity irrigation, water is applied to the field by gravity with water moving across the field from high points to lower elevation areas. Although gravity irrigation requires little capital investment and maintenance of equipment, these methods are less efficient due to the irrigation losses resulting from uneven application of water. Less efficient irrigation practices also result in increased percolation of applied water below the root zone (Westlands 2013).

Figure 2-10 displays the spatial distribution of irrigation practices in 1999. In 1999, the majority of the Subbasin was being irrigated by sprinkler and furrow irrigation. At that time, a relatively small number of acres were using drip irrigation methods. In 2013, a majority of the Subbasin transitioned to drip irrigation, as shown on **Figure 2-11**. From 1985 to the early 2000s the predominate irrigation methods in the Subbasin were furrow and sprinkler irrigation. However, the current irrigation method in the Subbasin is predominately drip, as evident in the chart of historical irrigation practices presented as **Figure 2-12**.

In 1985, furrow irrigation methods were used on about 60 percent of the irrigated acres with about 40 percent being irrigated with sprinkler. An increasing number of acres relying on sprinkler irrigation occurred during the 1990s during which more than 50 percent of the irrigated acres were irrigated with sprinklers. Through the 1990s drip irrigation methods were used on a relatively small fraction of irrigated acres and it was not until after 2000 that the percentage of irrigated acres utilizing drip methods began to increase appreciably. By 2005, over 25 percent of crops used drip irrigation and the percent of crops using drip methods exceeded 65 percent by 2010. As of 2015, approximately 92 percent of irrigated acres were using drip irrigation methods. Trends in irrigation methods by percent of irrigated acres are displayed in **Figure 2-13**.

2.1.3.6 General Plan Considerations

The California Government Code (§§ 65350-65362) requires that each county and city in the state develop and adopt a General Plan. The General Plan consists of a statement of development policies and includes a diagram or diagrams and text setting forth objectives, principles, standards, and plan proposals. It is a comprehensive long-term plan for the physical development of the county or city. In this sense, it is a "blueprint" for development.

The Westside Subbasin is subject to Fresno and Kings Counties' General Plans along with the General Plans of the City of Huron and the City of Avenal. Implementation of this GSP will support all goals and policies established in the General Plans in the Subbasin consistent with SGMA and GSP Regulations. Development and implementation of this GSP has and will continue to consider the interests of all beneficial uses and users of groundwater, including agricultural water users, domestic, municipal water users, DACs, interconnected surface water habitats, groundwater dependent ecosystems, and other interested parties. The Fresno County General Plan is currently undergoing an update and it is not known how the updated General Plan may or may not affect water demands and/or ability to achieve sustainability in the Subbasin. Further discussion of each jurisdiction's plan is included below.

The portion of the Westside Subbasin within the District's jurisdictional boundary also is subject to the District's Rules and Regulations that cover the following:

- Regulations for Allocation and Use of Agricultural Water
- Terms and Conditions for Agricultural Water Service
- Regulations for Application and Use of Municipal and Industrial Water
- Terms and Conditions for Municipal and Industrial Water Service
- Allocation of Water When Lateral is at Maximum Design Capacity

These Rules and Regulations are referenced from https://wwd.ca.gov/about-westlands/additional-information/rules-and-regulations/.

The purpose of the District's Rules and Regulations is to establish rules and procedures for allocation and use of agricultural water. The Rules and Regulations consist of procedures regarding contract entitlements, water use, water transfers, payment for water/agreements, rescheduled water, and other guidelines that establish order within the District.

2.1.3.6.1 Fresno County

Land uses within the portion of the Subbasin located within the unincorporated area of Fresno County are governed by the Fresno County General Plan and Zoning Ordinance. The Fresno County General Plan provides policy direction for land use, development, open space protection, and environmental quality and sets out a vision reflected in goals, policies, programs and diagrams implemented primarily via the County's Zoning and Subdivision Ordinances. Fresno County's General Plan may be viewed here, https://www.co.fresno.ca.us/departments/public-works-planning/divisions-of-public-works-and-planning/development-services-division/planning-and-land-use/general-plan-maps.

The Fresno County General Plan is built on the following major themes:

- Land Use (LU) Element designates the general distribution and intensity of all uses of the land in the community. This includes residential uses, commercial uses, industrial uses, public facilities, and open space, among others.
- Circulation Element identifies the general location and extent of existing and proposed major transportation facilities, including major roadways, rail and transit, and airports.
- Housing Element assesses current and projected housing needs and sets out policies and proposals for the improvement of housing and the provision of adequate sites for housing to meet the needs of all economic segments of the community.
- Conservation Element addresses the conservation, development, and use of natural resources including water, forests, soils, rivers, and mineral deposits.
- Open Space (OS) Element details plans and measures for preserving open space for: protection of natural resources such as wildlife habitat; the managed production of resources such as agricultural and timber land; outdoor recreation such as parks, trails, and scenic vistas; and public health and safety such as areas subject to geologic hazards, flooding, and fires.
- Noise Element identifies and appraises noise problems and includes policies to protect the community from excessive noise.
- Safety Element establishes policies and programs to protect the community from risks associated with seismic, geologic, flood, and wildfire hazards.

Relating to resource protection, the Fresno County General Plan contains a host of policies and programs to protect and enhance the surface water and groundwater resources in the County as follows:

> **Policy LU-A.1:** Fresno County shall maintain agriculturally-designated areas for agriculture use and shall direct urban growth away from valuable agricultural lands to cities, unincorporated communities, and other areas planned for such development where public facilities and infrastructure are available.
>
> **Policy LU-A.2:** Fresno County shall allow by right in areas designated Agriculture activities related to the production of food and fiber and support uses incidental and secondary to the on-site agricultural operation. Uses listed in Table LU-3 are illustrative of the range of uses allowed in areas designated Agriculture.
>
> **Policy LU-A.6:** Fresno County shall maintain twenty (20) acres as the minimum permitted parcel size in areas designated Agriculture, except as provided in Policies LU-A.9, LU-A.10, and LU-A.11. Fresno County may require parcel sizes larger than twenty (20) acres based on zoning, local agricultural conditions, and to help ensure the viability of agricultural operations.

Policy OS-A.1: Fresno County shall develop, implement, and maintain a plan for achieving water resource sustainability, including a strategy to address overdraft and the needs of anticipated growth.

Policy OS-A.3: Fresno County shall provide active leadership in efforts to protect, enhance, monitor, and manage groundwater resources within its boundaries.

Policy OS-A.17: Fresno County shall directly and/or indirectly participate in the development, implementation, and maintenance of a program to recharge the aquifers underlying the County. The program shall make use of flood and other waters to offset existing and future groundwater pumping.

Lands within the Subbasin are predominately designated as Agriculture in the General Plan and zoned AE-20 and AE-40 (Exclusive Agriculture, 20- or 40-acre minimum parcel sizes). This designation provides for the production of food and fiber and the raising of livestock and poultry, agricultural processing facilities, and certain non-agricultural activities. In addition, there are small clusters of non-agricultural and rural settlement areas within the Subbasin. The land use designations are implemented largely through zoning which are deemed compatible, conditionally compatible, or incompatible with the various General Plan land use designations

2.1.3.6.2 Kings County

Land uses within the portion of the Subbasin located within the unincorporated area of Kings County are governed by the *2035 Kings County General Plan* which defines the goals, objectives, and polices that will guide the growth, use, and development of land under the jurisdiction authority of the Kings County through 2035. The priorities are to protect prime agricultural land and direct urban growth to existing cities and communities, and to increase economic and community sustainability. Similar to Fresno County, the General Plan contains information on: land use, resource conservation, open space, transportation, housing, health and safety, noise, air quality, dairies, and individual community plans. The portion of the Westside Subbasin within Kings County is subject to the County's authority with the exception of the NASL and the City of Avenal. Kings County's General Plan may be viewed here: https://www.countyofkings.com/departments/community-development-agency/information/2035-general-plan.

As it pertains to land use and resource conservation, the Kings County General Plan contains numerous policies to protect and enhance agricultural production and the surface water and groundwater resources in the County as follows:

Resource Conservation (RC) Policy A1.1.1: Cooperate with water purveyors and water management agencies to manage groundwater resources within the County to assure an adequate, safe and reliable groundwater supply for existing and future water users

RC Policy A1.1.6: Support expansion of joint management of surface water and groundwater supplies that contributes to the protection, reliability and sustainability of local and regional water supplies.

RC Policy A1.2.2: Require the use of low water consuming, drought-tolerant and native landscaping and other water conserving techniques, such as mulching, drip irrigation and moisture sensors, for new development.

RC Policy A1.3.1: Participate with and encourage all state, regional and local efforts to develop new or expanded water supplies that may serve Kings County.

LU Policy B1.1.1: Designate all agricultural and grazing land outside of planned urban areas as Limited Agriculture, General Agriculture, Exclusive Agriculture, or Natural Resource Conservation.

LU Policy B1.2.3: Land divisions involving Limited Agriculture designated land shall not result in the creation of a parcel(s) less than ten acres in size, or eleven acres in size when under a Williamson Act or Farmland Security Zone Contract. If land is classified as non-prime, the minimum shall be 41 acres except as provided in LU Policies B4.3.1, B4.3.2, and B4.3.3.

LU Policy B2.2.1: Apply the Limited Agriculture or Open Space land use designation around Community Districts and Urban Fringe areas to serve as a buffer between urban and intensive agricultural uses.

LU Policy B2.2.2: The designation of new residential land use designations in Agriculture OS areas shall be restricted in order to preserve productive agricultural land and discourage premature conversion to non-agricultural related land uses.

2.1.3.6.3 City of Huron

Land uses within the portion of the Subbasin located within the City of Huron are governed by the City of Huron General Plan that provides policy direction for land use, development, open space protection, and other policies. The General Plan may be viewed here:

http://cityofhuron.com/wp-content/uploads/2014/08/City-of-Huron-General-Plan-2025-Policies-Statement1.pdf.

The City of Huron General Plan is built on the following eight major elements:

1. Noise
2. Safety
3. Open Space, Conservation and Recreation
4. Air Quality
5. Circulation
6. Land Use
7. Public Services and Facilities
8. Housing

The City of Huron's public water supply is from imported water from the San Luis Canal/California Aqueduct with no municipal supply from groundwater.

2.1.3.6.4 City of Avenal

Land uses within the portion of the Subbasin located within the City of Avenal are governed by the City of Avenal General Plan and provides policy direction for land use, development, open space protection, and other policies. The General Plan may be viewed here: https://www.cityofavenal.com/370/General-Plan. The City of Avenal General Plan is built on the following seven major elements:

1. Land Use
2. Economic Development
3. Conservation, Natural Resources and Recreation
4. Circulation
5. Air Quality
6. Public Services
7. Safety

All the general plans identified above were reviewed and considered in the development of this GSP to ensure that the implementation of the GSP would not contradict any of the relevant general plan elements and polices. Land use plans for local agencies outside of the Subbasin were also determined not to significantly impact the Subbasin's ability to achieve sustainable management at this time.

2.1.4 Additional GSP Elements (§354.8 (g))

The additional GSP elements considered relevant for the Westside Subbasin are described below.

2.1.4.1 Well Permitting, Construction, Abandonment, Destruction and Permitting Process Updates Policies

2.1.4.1.1 Well Permitting

In order to obtain a permit to drill a well, a properly licensed contractor must submit a completed Well Permit Form with any applicable permit fees to Fresno County or Kings County (Fresno County Code Chapters 14.04 & 14.08 and Kings County Code Chapters, Chapter 14A). Contractors must possess an active C-57 Water Well Contractors License.

2.1.4.1.2 Well Construction

Well construction standards are consistent with the California Well Standards, Bulletin 74-81 and 74-90 (**Appendix G**). Bulletin 74-81 was published by DWR in December 1981 which sets the minimum standards for well construction throughout the State of California. These standards were supplemented by Bulletin 74-90 which was published by DWR in June 1991 to include additional information on the construction of monitoring and cathodic protection wells. The State of California is currently revising Bulletin 74 as a replacement for Bulletin 74-90. Below is a list of the topics covered in each of these bulletins regarding the construction standards used for well installation in the Subbasin.

- Well location with respect to pollutants and contaminants
- Sealing the upper annular space
- Surface construction features
- Disinfection
- Casing
- Sealing-off strata

- Well development
- Water quality sampling
- Special provisions for large diameter shallow wells
- Special provisions for driven wells
- Rehabilitation, repair and deepening of wells
- Temporary cover

2.1.4.1.3 Well Abandonment

In accordance with Section 115700 of the California Health and Safety Code, an inactive water well is considered abandoned if it has not been used for a period of one year and must be destroyed by a licensed C-57 water well contractor unless the owner demonstrates an intention to use the well again. The intention to use an inactive well again shall be demonstrated by the well owner by properly maintaining an inactive well for future use in such a way the following requirements are met:

- The well shall not impair the quality of water in the well and groundwater encountered by the well.
- The top of the well or well casing will be provided with a cover that is secured by a lock or by other means to prevent its removal without the use of equipment or tools, to prevent unauthorized access, to prevent a safety hazard to humans and animals, and to prevent illegal disposal of wastes in the well.
- The cover will be watertight where the top of the well casing or other surface openings to the well are below ground level, such as in a vault or below known levels of flooding. The cover will be watertight if the well is inactive for more than five consecutive years. A pump motor, angle drive, or other surface feature of a well, when in compliance with the above provisions, shall suffice as a cover.
- The well will be marked so it will be easily visible and located and labeled so it can easily be identified as a well.
- The area surrounding the well will be kept clear of brush, debris, and waste materials.

2.1.4.1.4 Well Destruction

These well destruction standards were based on California Well Standards Bulletins 74-82 and 74-90.

Only persons who possess an active C-57 Water Well Contractors License may perform well destructions. (Wat. Code § 13750.5; Well Standards § 2.4.3) Well destruction performed as an "incidental part" of a larger job by a contractor not possessing a C-57 license is **not** allowed.

No person shall destroy any well without first applying for and receiving a Permit issued by the Fresno County Department of Public Health. (Well Standards Ordinance (WSO) 14.04 and 14.08) All available well construction data shall be submitted with the application for a well destruction permit.

All well destructions shall be performed according to Part III, Sections 20-23, Bulletin 74-81 and 74-90 (WSO § 3).

- A hole shall be excavated around the well casing to a depth of 5 feet (ft) below the ground surface (bgs) and the well casing removed to the bottom of the excavation (a variance to not excavate the casing may be requested for special circumstances).
- The sealing material used for the upper portion of the well shall be allowed to spill over the casing into the excavation to form a cap.
- After the well has been properly filled, including sufficient time for the sealing material in the excavation to set, the excavation shall be filled with native soil.
- A State of California Well Completion Report ("Well Log") shall be submitted to the Fresno County Department of Public Health within 30 days of the completion of any well destruction. (Water Code § 13751; Well Standards § 7.1).

Materials used for sealing and filling are as follows:

- Impervious Sealing Materials. Approved imperious materials include neat cement, sand-cement grout, concrete, and bentonite clay.
- Filler Material. These include clay, silt, sand, gravel, crushed stone and clean native soils.

2.1.4.1.5 Permitting Process Updates

The District determined improving the well permitting process is one implementation measure that enhances the District's management of the Westside Subbasin. Thus, the GSP recommends Fresno and Kings County's permitting requirements include the following new construction standards for new wells drilled in the Westside Subbasin:

- Pump test results shall be submitted to the District within 60 days of completion. Pump testing results shall include the pump's capacity, well design, horsepower, efficiency, specifications and a copy of the well completion report that describes the characteristics of the geologic materials encountered during the drilling of the borehole.
- Installation of equipment to collect continuous flow data during the pumping test, depth to water level data before, during, and after the pumping test, and surveyed ground surface elevation data information (NAVD88 datum).
- Furnish and install a data logger and an Automatic Meter Infrastructure (AMI) technology upon well completion. The data logger should capture continuous water level data and transmit the data to the GSA monthly. The AMI must be approved by the District. The District will assume ownership of the meter upon well completion.

All new applicants are required to enter into an agreement to comply with the District's GSP.

2.1.4.2 Impacts on Groundwater Dependent Ecosystems

Potential groundwater dependent ecosystems (GDEs) identified by The Nature Conservancy (TNC) are shown in **Figure 2-14**. The potential for the existence of GDEs in the Westside Subbasin is limited due to the arid climatic conditions, presence of streams that only flow periodically and are ephemeral in nature, the location of groundwater pumping at vertical depth intervals in the Upper Aquifer that result in the lack of propagation of groundwater pumping to the land surface where the ephemeral streams are located, and the depth to groundwater. Based on depth to groundwater of the Upper Aquifer being deeper than 30 feet in the vicinity of the potential GDEs identified by TNC, the potential GDEs are not dependent on groundwater. Therefore, it is unlikely there are any GDEs in the Subbasin. The ecosystems that exist in the region are sustained by periodic rainfall events and ephemeral surface water. However, because existing data is not available in sufficient detail to definitively identify all potential GDEs, the District submitted a Technical Support Services request from DWR to install shallow wells on the western part of the Subbasin to address this data gap and to determine if there are any GDEs that could be impacted by groundwater pumping.

2.1.4.3 Control of Saline Water Intrusion

As described in Chapter 3, the location of the Subbasin in the San Joaquin Valley, which is physically separated from the Pacific Ocean, precludes the existence or presence of seawater intrusion.

2.1.4.4 Wellhead Protection and Recharge Areas

As described in Section 2.1.3, this GSP will follow the Counties' General Plans relevant to wellhead protection. Chapter 4 describes the recharge areas in the Westside Subbasin. Twice a year, the District conducts well monitoring. When the District comes across a well that has not been properly abandoned or capped, the water user is contacted via telephone and letter to address the issue in order to comply with Fresno and Kings Counties well standard ordinances.

2.1.4.5 Migration of contaminated groundwater

The GSAs are not aware of any known contaminant plumes in the Subbasin.

2.1.4.6 Relationships with State and Federal Regulatory Agencies

The GSA has developed relationships with the state and federal interests in the Westside Subbasin to ensure GSP information is communicated. Section 2.1.5.2, **Table 2-4** and **Figure 2-2**, details regulatory agencies in the Subbasin and the GSAs efforts to establish a relationship with the agencies.

2.1.4.7 Consideration of Land Use Existing Policies

The GSA considered the Land Use Policies on the cities and counties in the Subbasin. Detailed consideration is available in Section 2.1.3.

2.1.5 Notice and Communication (§354.10)

2.1.5.1 Identification of Groundwater Beneficial Uses/Interested Parties

Beneficial uses of groundwater in the Subbasin include domestic, urban and agricultural, consistent with California Code of Regulations, Title 23 Section 354.10. Agricultural water users are likely to be the most affected by implementing the GSP because those beneficial users utilize the most groundwater and cover the vast majority of the Subbasin. Many farmers are heavily dependent on groundwater for irrigation and will be adversely affected if and when pumping restrictions are put in place during an extended drought period.

The Pilibos Wildlife Area, Mendota Wildlife Area, and the Pleasant Valley Ecological Area were evaluated as potential environmental beneficial users of groundwater. However, the District determined that there was no groundwater extraction occurring in these areas. Furthermore, GDEs were also evaluated for the potential of passive groundwater use (e.g., root zone uptake) but as mentioned in Section 2.1.3.8., due to the depth to groundwater in these areas, they are not dependent on groundwater.

The Westside Subbasin's groundwater resources are primarily used for agricultural purposes and the beneficial users of groundwater include:[2]

- Agricultural Water Users. The largest group of interested parties within the Subbasin are water users that extract groundwater for agricultural uses.
- Domestic and Municipal & Industrial Well Users. The District identified approximately 38 active domestic wells and 13 active M&I wells within the Subbasin **(Table 2-1**).
- Public Water Systems. There are nine public water systems that deliver surface water within the Subbasin, including Avenal, Huron, El Porvenir (Three Rocks), Cantua Creek, Turk, Calfax, O'Neil Farms, NASL, and Five Points. There are three Public Water Systems that deliver groundwater with the surface water, **Figure 2-5** shows the Public Water Supply wells location. To the District's knowledge, NASL has a well that operates as a backup water supply, and Cantua Creek and El Porvenir drilled wells to extract groundwater. The City of Huron also drilled a groundwater well as a backup supply. Cantua Creek, El Porvenir and Huron's wells were constructed in 2021 but have not been furnished with above ground equipment and power. The aforementioned sites are expected to be active in 2024.
- Local Planning Agencies. Fresno and Kings Counties have local planning and land use authority on land overlying the Subbasin.
- Federal Government. NASL overlies approximately 11,500 acres, 8,500 of which are leased out to local farmers for agricultural purposes, along the Subbasin's eastern boundary. In addition to pumping groundwater for agricultural and domestic use, NASL also receives surface water from the District.
- Disadvantaged Communities (incorporated and unincorporated). According to the DWR Disadvantaged Community Mapping Tool, there are eight disadvantaged communities overlying the Subbasin, including Avenal, Huron, El Porvenir (Three Rocks), Cantua Creek, NASL, Calfax, O'Neil Farms, and Turk.

Table 2-4 identifies the interested parties in the Westside Subbasin and whether they extract groundwater. The jurisdictional boundaries for each of these entities are illustrated in **Figure 2-2**.

[2] There are no hydrologic surface water bodies or California tribes within the Subbasin.

Table 2-4: Agencies in the Westside Subbasin

Agency	Groundwater Extractor	Water Use Category
Counties		
Fresno County	No	Not Applicable
Kings County	No	Not Applicable
Cities		
City of Avenal	No	Not Applicable
City of Huron	Potentially	Not Applicable
Communities		
Calfax	No	Not Applicable
Cantua Creek	Potentially	Not Applicable*
Three Rocks	Potentially	Not Applicable*
Turk	No	Not Applicable
Westside (O'Neil Farms)	No	Not Applicable
Five Points	No	Not Applicable
Federal/ State Government		
Naval Air Station Lemoore (NASL)	Yes	Municipal and Agricultural
Untied State Bureau of Reclamation (USBR)	No	Not Applicable
Department of Water Resources (DWR)	No	Not Applicable
Wildlife User		
Pilibos Wildlife Area	No	Not Applicable
Pleasant Valley Ecological	No	Not Applicable
Mendota Wildlife Area	No	Not Applicable
Other Interested Parties		
Westlands' Water Users	Yes	Agricultural

*may change to a Public Supply well in the future.

2.1.5.2 Public Outreach

GSP Regulations Section 354.10 requires that the GSA consider the interest of all beneficial groundwater users. The GSA developed a Stakeholder Communication and Engagement Plan to ensure all interested parties were able to participate in GSP development. The Stakeholder Communication and Engagement Plan is posted on the District and GSA website, https://wwd.ca.gov/water-management/groundwater-management-program/sustainable-groundwater-management-act/ and is attached in **Appendix L**.

Additionally, in order to encourage active involvement of a diverse social, cultural and economic elements of the population within the Subbasin, the District held all GSP development meetings publicly, allowed for public comment, collaborated with counties, state and federal agencies in the Westside Subbasin, maintained close communication with organizations representing disadvantaged and severely disadvantaged communities, coordinated with neighboring GSAs, and provided monthly updates. The District held workshops during the development of this GSP, including bilingual (Spanish) workshops.

Appendix H includes a summary of the workshop activities, attendees and comments received. All the workshops were posted on the District's website, emailed to the District's water users and other interested parties, community centers such as schools and churches in the Subbasin, and when timing permitted mailed to communities. The workshops provided the beneficial groundwater users and interested parties affected by the implementation of the GSP to voice concerns, articulate questions, and provide ideas and feedback to staff. During the workshops, staff provided a presentation on SGMA components, potential impacts to current land use activity and allowed for public comment. The workshops were held about three-months apart, allowing the District time to incorporate the feedback provided at the previous workshop and present updates. **Table 2-5** titled "Public Outreach", lists the public meetings, workshops and outreach events hosted by the District.

Table 2-5: Public Outreach

Event	Date	Topic (s)
1	October 13, 2015	SGMA, Groundwater Rights, Groundwater Conditions, and Implementation
2	March 15, 2016	GSP Content, GSA Responsibilities, and SGMA Implementation
3	October 31, 2016	SGMA, GSP Regulations, and Content
4	December 21, 2016	GSP Development Schedule, Basin Settings, Management Area Potential, Undesirable Results, and Subbasin Projects
5	March 21, 2017	GSP Development and SGMA Implementation Schedule
6	June 22, 2017	GSP Outline, Groundwater Model Status, Subsidence, Water Budget, 10 Year Farm Plan, and Groundwater Credits Programs
7	September 22, 2017	Subsidence, Groundwater Model Status and Groundwater Credit Program
8	December 7, 2017	Groundwater Model Status, Sustainable Management Criteria, and Groundwater Credit Program
9	February 9, 2018	Groundwater Management Guiding Principles and GSP Conceptual Outline
10	April 6, 2018	Bilingual Workshop Introducing SGMA Requirements
11	May 3, 2018	Modeling Results Workshop
12	May 17, 2018	Bilingual Modeling Results Workshop
13	July 16, 2018	Westlands SGMA Groundwater Pumping Management and GSP Development
14	September 16, 2018	Bilingual Workshop the Westside Subbasin's Groundwater Model
15	April 3, 2019	Bilingual Forecast Scenarios and Augmentation Strategies Workshop

Event	Date	Topic (s)
District Board Meetings		
1	October 20, 2015	Basin Boundary and Groundwater Modeling Recommendations
2	November 17, 2015	Basin Boundary Modification and Draft GSP Regulations Dates
3	December 15, 2015	Neighboring Subbasins Communication and Retaining a Groundwater Modeler
4	January 19, 2016	Communication efforts with neighboring subbasins
5	February 16, 2016	Resolution Authorizing the District's staff to submit the Westside Subbasin Boundary Modification
6	March 15, 2016	Resolution Authorizing the District's staff to submit the Westside Subbasin Boundary Modification and release of draft GSP Regulations
7	April 19, 2016	Status of the Basin Boundary Modification, GSP Regulation comments and recommendation for the District to serve as the GSA
8	May 17, 2016	Status of the Basin Boundary Modification, Final GSP Regulations and GSA procedures
9	June 21, 2016	Status of the Basin Boundary Modification, GSP Regulations and GSA hearing dates
10	July 19, 2016	Resolution Authorizing District staff to file as the GSA of the Westside Subbasin, status of the Basin Boundary Modification and GSP development
11	August 17, 2016	MOUs with Fresno and Kings Counties, GSA filing status and concerns on the extraction limits of groundwater in the Westside Subbasin
12	September 20, 2016	Fresno and Kings Counties MOU recommendation
13	October 18, 2016	Executing the Fresno County MOU and Groundwater Model update
14	November 21, 2016	Exclusive GSA of the Westside Subbasin, Groundwater Model update and summary of the October 2016 GSP workshop
15	December 20, 2016	DWR BMPs and Groundwater Model update
16	January 17, 2017	Hydrogeological Conceptual Model and summary of the December 2016 Basin Settings workshop
17	February 28, 2017	Groundwater Model Update and DWR's Water Available for Replenishment report
18	April 18, 2017	Groundwater Model Update and DWR's Water Available for Replenishment report
19	May 16, 2017	Groundwater Modeling Update and SGMA implementation
20	July 18, 2017	Summary of the June 2017 workshop and DWR's GSP grant funding
21	October 17, 2017	Numeric Flow Modeling Calibration Update, Summary of the September 2017 workshop, and DWR's GSP grant funding
22	November 21, 2017	Numeric Flow Modeling Final Stages of Development and Summary of the October 2017 workshop
23	December 19, 2017	Groundwater Model Results update, and submission of DWR Grant Package for GSP Development, and summary of December 2017 workshop
24	January 17, 2018	Groundwater Model Results and SGMA implementation
25	March 20, 2018	Groundwater Model update and SGMA implementation
26	April 17, 2018	Summary of the April 2018 Bilingual workshop

Event	Date	Topic (s)
District Board Meetings		
27	May 15, 2018	GSP Project Status Report
28	June 19, 2018	GSP Project Status Report- Updated the Board on Outreach Activities
29	July 17, 2018	GSP Project Status Report and SGMA Groundwater Pumping Management Strategies
30	August 14, 2018	Groundwater Allocation (3-year rolling average)
31	September 18, 2018	Groundwater Allocation (5-year rolling average) and Alternative Groundwater Management Strategy (water levels)
32	October 16, 2018	Groundwater Management Strategy Example with Conceptual Minimum Threshold and GSA Actions
33	November 20, 2018	District's Groundwater Allocation Options and Tiered Pricing
34	December 18, 2018	Uniform Distribution of the District's Groundwater Allocation
35	January 15, 2019	Uniform Distribution of the District's Groundwater Allocation including District owned land
36	February 19, 2019	Management Areas Consolidation and Allocation by Aquifer
37	April 19, 2019	District's Augmentation Strategies Workshop Summary
38	May 21, 2019	Monitoring Network, Minimum Thresholds and Measurable
39	June 24, 2019	GSP Estimated Monitoring and Implementation Costs
40	July 16, 2019	GSP Annual and Implementation Cost Options
41	August 20, 2019	Chapter 5 on Implementation Cost Options
42	September 17, 2019	Chapter 5 on Implementation Cost Options
43	October 15, 2019	Draft GSP
44	October 30, 2019	Draft GSP Hearing
45	November 19, 2019	Summary of comments received and GSP finalization status
46	December 18,2019	Public Hearing to Consider adoption of the Final GSP; Board did not
47	January 8, 2020	Public Hearing to Consider Adoption of the Final GSP; Board

Comments that the District received regarding the Westside Subbasin GSP were compiled and considered in the preparation of the GSP by District staff and consultants. Items presented at public meetings that were ultimately eliminated from the GSP included: dividing the Subbasin into management areas and unique groundwater allocations by area. Based on public feedback the GSA offered translation services at the workshops.

The methodology described below was utilized in the review of comments received on the GSP.

- The comments comply with the GSP Regulations,
- The viability of implementing the comment in the GSP,
- Benefit to the beneficial users and interested parties in the Westside Subbasin, and
- Impacts on achieving Sustainability by 2040.
- Copies of the comment letters received, and the GSA's responses are found in **Appendix H.**

2.1.5.3 GSP Clarifications and Amendments Public Meetings

On January 21, 2022, the District received an incomplete determination on the Westside Subbasin GSP from the Department of Water Resources that provided the District 180 days, or until July 20, 2022, to resubmit the revised Westside Subbasin GSP to address the identified deficiencies for DWR's review. The letter highlights areas of the Westside Subbasin GSP that DWR has identified as deficient and is recommending corrective actions. DWR identified subsidence, groundwater levels and water quality sustainable management criteria as deficient areas in the GSP.

In order to encourage public participation of the District's strategy to address DWR's comments, the District hosted public meetings, discussed its approach and held a public hearing to clarify and amend Chapters 2, 3, 4 and 6. **Table 2-6** entitled "GSP Revision Meetings Summary", lists the public meetings, workshops and outreach events hosted by the District.

Table 2-6: GSP Revision Meetings Summary

Event	Date	Topic (s)
1	December 7, 2021	Joint Committee Meeting – AC and TAC Received an Update on the Department of Water Resource Staff's Initial Review
2	January 18, 2022	January Board Meeting SGMA Update – Westlands Water District GSA Discussion
3	February 15, 2022	February Meeting SGMA Update on February AC and TAC Meetings and GSP proposed GSP revisions
4	February 22, 2022	AC and TAC Receive an Update on Potential Revisions to the Subsidence Sections of the Groundwater Sustainability Plan
5	March 15, 2022	March Meeting SGMA Update – Westlands Water District GSA Discussion and Potential Revisions to the GSP
6	April 19, 2022	April Meeting SGMA Update – Westlands Water District GSA Meeting to Consider and Provide Input on the Rules and Regulations and Related GSP Revisions on Subsidence
7	June 21, 2022	Public Hearing to Adopt GSP Amendments

AC = Advisory Committee; TAC = Technical Advisory Committee

2.2 Hydrogeologic Conceptual Model (GSP Reg. § 354.14)

Section 2.2 describes the physical and geologic setting (Hydrogeologic Conceptual Model) of the Subbasin and groundwater conditions. This section provides information about the setting and characteristics of the Westside Subbasin and includes both historical and current conditions of the Subbasin. This section includes identification of data gaps and levels of uncertainty which affect a complete characterization of the Subbasin. The information in this section will be used to help assess and define sustainable management criteria and projects and management actions to address undesirable results during the planning and implementation horizon.

Pioneering studies were conducted by Mendenhall (1908) and Mendenhall and others (1916). In 1949, the State of California and the United States Geological Survey (USGS) agreed to an investigation of the western Fresno County area of the San Joaquin Valley. A reconnaissance study of the entire Valley was performed by Davis and others (1959), and a study of possible storage of water in the subsurface was presented by Davis and others (1964).

A series of reports covering sections of the Valley continued to be produced for 20 years by USGS authors. The first report was an initial effort in the Fresno County area by Davis and Poland (1957). Subsequent reports included: Wood and Davis (1959); Hilton and others (1963); Croft and Gordon (1968); Page and LeBlanc (1969); Mitten and others (1970); and Hotchkiss and Balding (1970). **Figure 2-15** depicts the cross-sections studied in each of these reports.

Another hydrogeologic study that focused on the Subbasin and the surrounding area was produced by Miller, Green, and Davis (1971) which focused on the geology of the compacting deposits within the Subbasin. That report was a compilation by Davis of earlier (circa 1963) unpublished reports by Miller and Green. Croft (1972) later presented a report summarizing the water-bearing deposits in the southern part of the Valley based on previous studies.

Page (1973) mapped the base of fresh water in the Valley. Page (1983) examined the nature of the Tulare Formation relationships in the Kettleman City area. Page (1986) compiled an opus of the water-bearing deposits, and Williamson and others (1989) examined groundwater flow of the entire Central Valley of California in the Regional Aquifer-Systems Analysis by the USGS. Bartow (1991) summarized the Cenozoic evolution of the Valley of California.

In 1954, the USGS began studying subsidence between Los Banos and Kettleman City, as well as in other areas throughout the Valley. A large number of historical reports on subsidence in this area were produced but were only cursorily reviewed for this section of the GSP. The most significant of these reports are Bull (1964), Bull and Miller (1975); Bull (1975), and Bull and Poland (1975).

In the northeastern Valley, east of the San Joaquin River (SJR) and largely north of the Fresno County line, detailed mapping of the younger alluvium deposits was summarized by Marchland and Allwardt (1981). The mapping was based on topographic position, stratigraphic relationships, and soil mapping. Lettis (1982) performed similar detailed mapping and analysis west of the SJR extending north of Mendota in Fresno County. Lettis presented a detailed cross-section of the stratigraphic units in northern Fresno County.

2.2.1 Topographic Information

The Subbasin is characterized by a relatively flat topographic setting along the west side of the Valley. Topography is highest along, and just outside, the western margins of the Subbasin and slopes gently eastward toward the center of the San Joaquin Valley with less than a two percent slope (**Figure 2-17**). The topography ranges from about 1,000 ft elevation along the western margin of the Subbasin to about 170 ft elevation along the Subbasin’s eastern boundary (**Figure 2-18**). There is little change in slope or elevation in the Subbasin from north to south with elevations ranging from between 150 to 200 ft.

2.2.2 Surficial Geology

Surficial geology in the Subbasin is illustrated in **Figure 2-16A** with an explanation of map symbols in **Figure 2-16B**. The information presented in these figures was compiled from several sources from the

California Geological Survey (Jennings and Strand, 1958; Jennings, 1958; and Matthews and Burnet, 1965) and the California Division of Mines and Geology (Smith, 1964). The Subbasin's surficial geology is primarily characterized by alluvial fan deposits of the Quaternary Great Valley Geologic Province with Pleistocene nonmarine deposits located in the southeastern portion of the Subbasin and along its western margins.

2.2.3 Regional Geologic Setting

The western portion of the central Valley where the Subbasin is located makes up the southern part of California's Great Valley Geologic Province. The Sierra Nevada Geologic Province begins to the east of the San Joaquin Groundwater Subbasin and the Coast Range Geologic Province sits to its west (**Figures 2-16A and 2-16B**).

2.2.3.1 Great Valley Geologic Province

The Valley is a broad, gentle, low relief, sediment-filled Subbasin between the mountainous terrains to the east and west (**Figure 2-16A**). The sedimentary deposits contain fresh groundwater, which is utilized along with surface water to support the extensive agricultural activities on the nutrient-rich soils of the valley floor. The Valley is comprised of four main geomorphic areas: the eastern and western alluvial plains, the central floodplain Subbasin, and the Tulare Lake Subbasin.

2.2.3.2 Eastern Alluvial Plains

These alluvial plains slope gently westward from the Sierra Nevada, which was formed by the coalescing alluvial fans from the major and minor drainages. Along the eastern margins of the Valley, older alluvial plains occur at higher elevation and with deep soil development. These older alluvial plains are partially dissected, incised and covered by deposits of younger alluvial plains. The SJR maintains a defined braided stream channel system to the center of the Valley and then flows northward, joined by tributary streams to the Sacramento/San Joaquin Delta.

The Kings River contains a broad alluvial plain area covered with a complex of distributary channels. The northern channels drain westward to the center of the Valley and flow northward through the Fresno Slough to join the SJR in the Mendota area. The southern distributaries flow southwestward into the Tulare Lakebed. The Kings River alluvial plain had been extensively modified by both man-made channelization of the distributary and by construction of ditches to route water for irrigation.

2.2.3.3 Western Alluvial Plains

A similar alluvial plain occurs along the west side of the Valley, formed by smaller streams draining the Diablo Range. The Western Alluvial Plains slope eastward toward the center of the Valley and become narrower and steeper near the Valley's outer edges. Distributary channels are less numerous, and not as well developed, as compared to the eastern alluvial plain. There are also areas of older alluvial fans, but these are smaller and less extensive than what occurs on the east side of the Valley.

To the south, the Valley has anticlinal structures in the Coalinga area and around Kettleman Hills. Here, small alluvial valleys are partially isolated as evidenced by the Pleasant Valley, Kettleman Plain, and Antelope Valley and Plain (**Figure 2-16A**). Drainage from the Pleasant Valley and the Kettleman Plain occurs to the main Valley by narrow stream channels across the Kettleman Hills trend. Further south, the Antelope Valley and Plain drain eastward to the main Valley across a broader alluvial plain.

2.2.3.4 Central Floodplain

The Central Floodplain geomorphic area occurs in the center of the Valley and separates the Western and Eastern Alluvial Plains. The floodplain is a very-low northward gradient flatland area of fine-grained deposits of floodplains, marshlands, and wetlands. In the north, beyond where the SJR enters the floodplain, numerous stream channels and sloughs meander northward. Along the SJR, stream channel and natural levee deposits occur surrounded by the floodplain deposits.

South of the SJR, the Central Floodplain area lacks the numerous stream channels and sloughs until the Kings River area and the southern distributary channels of the Kings River. As described previously, the southern distributary channels drain southward towards the Tulare Lakebed. Much of the floodplain area has been modified by man-made channels and ditches for drainage control, irrigation distribution, and channelization of flood flows to protect agricultural lands.

2.2.3.5 Tulare Lakebed

South of the Central Floodplain lies the Tulare Lakebed, which was historically the site of a perennial lake. Presently, however, the lake is dry except for during extremely wet periods. The floor of the lakebed is nearly flat with very low relief and is close to twenty feet lower than adjacent land surfaces. During previously high lake stands, the lake may have drained northward through the Central Floodplain to the north. Over the years, however, the lakebed has been modified by canals, ditches and levees to direct flood waters and distribute irrigation waters to the area’s extensive agricultural fields.

2.2.3.6 Sierra Nevada Geologic Province

The Sierra Nevada Geologic Province is a large fault-tilted mountain range rising to heights of over 10,000 ft at the crest. The Sierra Nevada is largely composed of granitic rocks with minor bodies of metamorphic rocks, such as along the western edge where the Sierra foothills are characterized by a band of strongly deformed metamorphosed formations. East of the Subbasin, these metamorphic rocks are largely covered by younger sedimentary deposits of the Valley.

The Sierra Nevada Geologic Province is drained by the major drainages of the Kings River, SJR, and Chowchilla River. During the Great Ice Age (Pleistocene 2.6 to 0.01 million years ago (mya)), the crest of the Sierra Nevada was much larger and huge volumes of sediment were produced from erosion by alpine glaciers and ice sheets. During this geologic time period, streams discharged eroded sediment into the Valley. The significance of this is that much of the younger sedimentary deposits in the Valley were sourced from rivers to the east of the Subbasin, as well as from a south-draining central river from further north of the Subbasin.

2.2.3.7 Coast Range Geologic Province

West of the San Joaquin Valley and the Subbasin lies the Diablo Range, which is part of the Coast Range Geologic Province. While rugged and steep topographically, the Diablo Range only rises to several thousand feet above sea level with its peaks topping out at around 4,000 ft. The western edge of the

Diablo Range, to the west of the Subbasin, marks the northwest trending San Andreas Fault system. (**Figure 2-19**).

The rocks in the Diablo Range are subdivided into three broad groups. To the northwest of the Subbasin the core of the Diablo Range is formed of complex, tectonically mixed and deformed, deep-sea marine sedimentary rocks (Franciscan Complex). Further south, only small areas of the Franciscan rocks are exposed and mixed with large to small blocks of ultra-basic volcanic rocks of sea floor crust (**Figure 2-16A**). Franciscan rocks are large to small blocks of ultra-basic volcanic rocks of sea floor crust.

As you move farther east, the Franciscan rocks of the Diablo Range are replaced by the Great Valley Sequence, characterized by consolidated marine sedimentary rocks (**Figure 2-16A**). Although these rocks retain some bedding characteristics, they are highly deformed by faulting and folding.

Younger marine and non-marine sedimentary rocks overlie the Great Valley Sequence. These rocks are faulted and folded similarly to the Great Valley Sequence. In the southwestern area, this rock group is exposed on the anticlinal features in the Coalinga and Kettleman Hills area (**Figure 2-16A and 2-19**). This area in the vicinity of Coalinga also separates the Westside Subbasin and the Pleasant Valley Subbasin to the west.

2.2.4 Identification/Differentiation of Hydrogeologic Units

With the late Pliocene isolation of the marine embayment in the southern Valley, the younger geologic history is dominated by non-marine sedimentary deposition. The depositional setting is similar to that seen in the Valley today with the eastern alluvial plain sourced from the Sierra Nevada and the western alluvial plain sourced from the Diablo Range. These two alluvial plains are separated by an axial fluvial/floodplain area which drained southward to the Tulare Lake area. It is from these younger geologic units that fresh groundwater is extracted by wells for beneficial uses.

Fresh groundwater bearing geologic deposits in the Subbasin have been subdivided by previous studies into two primary units: the Upper Aquifer and the Lower Aquifer, which are separated by the Corcoran Clay. **Figure 2-26** shows the map of the three geologic cross-sections prepared for this report, which depict the Upper Aquifer and Lower Aquifer units (**Figures 2-27, 2-28, and 2-29**). The Corcoran Clay was deposited in a widespread lake which inundated much of the Valley. The extent of the Corcoran Clay and depth to the top of this unit is presented in **Figure 2-30**. The Corcoran Clay underlies the entire Subbasin with the exception of a small area in the southwest. The depth to the Corcoran Clay generally increases in the western portion of the Subbasin and ranges from about 400 ft in the east to 800 ft or more at the Subbasin's western margins. The thickness of the Corcoran Clay varies in the Subbasin from less than 20 ft to more than 100 ft (**Figure 3-31**). Generally, the Corcoran Clay is thinner in the southern portion of the Subbasin compared to the northern portion.

The shallow zone is a zone within the Upper Aquifer which has been defined as the upper most 100 feet. In the Subbasin, groundwater production is not conducted in this zone, rather Upper Aquifer wells are commonly completed at deeper depths. Groundwater encountered in the Upper 100 feet does not have a direct hydraulic connection to the rest of the Upper Aquifer as evidenced by a lack of seasonal or long-term groundwater level variations. Groundwater elevation in the upper most 100 feet appear to be influenced by recharge from irrigation rather than groundwater pumping, therefore it is not defined as one of the primary aquifer units in the Subbasin. For the purpose of identifying groundwater dependent ecosystems and interconnected surface waters, the shallow zone of the Upper Aquifer was evaluated by analyzing first encountered groundwater. **Figure 2-33B** compares the seasonal fluctuation of water levels in the shallow zone to the water levels in the Upper Aquifer.

The hydrogeologic conceptual model defined the primary aquifer units in the Subbasin as the Upper and Lower Aquifer, separated by the Corcoran Clay.

2.2.4.1 Tulare Lake Beds

The lacustrine, fine-grained silt and clay deposits are termed informally in this report as the 'Tulare Lake Beds,' or simply 'Lake Beds'. The Tulare Lake Beds are a distinctive geologic unit composed of lake deposited silts and clays which extends over a period from late Pliocene (3-4 million years before present (mybp)) thru the Quaternary (2.6 million years (my) to present) and attains a net thickness of over 3,000 ft. In the Pleistocene, the upper Lake Beds expanded at least six times beyond the usual extent of the lower and middle Lake Beds. The most extensive high-level lake stand of the Corcoran or E-clay forms the main confining unit for the Lower Aquifers in much of the Valley. The importance of the Tulare Lake Beds to the sedimentologic, stratigraphic, and geologic history of the Valley should make them more commonly known, and possibly raised to formal named formational or, at least, member status. The extent of the Lake Beds below Tulare Lake is shown on cross-sections in Page (1986), Croft (1972), and Croft and Gordon (1968).

On geophysical logs, the Lake Beds are a monotonous thick (>3,000 ft) sequence of low resistivity units. Resistivity values are generally less than 10 ohms and mostly 5 ohms or less when viewed on geophysical logs of boreholes. Drillers' reports generally identify these clay beds as blue or gray clay. The beds appear to be largely composed of clay to silty clays, and clayey silts with some sandy clayey silts; there do not appear to be any sandy beds in the center of the lake.

At the northern edge, the Lake Beds interfinger and interbed with later Pliocene and younger sand units of stream origin. The relationship between the sand sequences and the Lake Beds has informally allowed the subdivisions of lower Lake Beds, middle Lake Beds and upper Lake Beds (Croft, 1972). The sand sequences are several hundred feet thick of either delta or beach deposition origin. The first and second sequences interfinger with the lower Lake Beds. The first sand sequence appears to be beach deposits of the Pliocene marine deposits. The third and fourth sand sequences interfinger with the middle Lake Beds and extend further south into the Lake Beds than the previous sand sequences.

During lower and middle Lake Beds deposition, the relationship between the lake margin sand deposits remained relatively stable, except as noted above. Bartow (1991) postulated that the Tulare Lake drained westward across the San Andreas Fault Zone to the Salinas Valley. This drainage pattern persisted, at least intermittently through the period of deposition of the lower and middle Lake Beds. Some climate changes related to the Pleistocene (2.6 to 0.01 mya) glaciation of wetter and cooler conditions may also factor into the variations of Lake Beds.

With the onset of upper Lake Bed deposition, the nature of the lake margin sand beds changed to thinner beds that interfingered with thin lake bed clays. The Lake Beds appear to expand northward and northeastward. The first significant Lake Bed expansion was mapped by Croft and Gordon (1968; Plate 8) as the F-clay. The culmination of the Lake Bed expansion followed as the Corcoran Clay covered nearly all the Valley from Stockton south (Page 1986; plates 4 and 5). The Corcoran Clay has been long recognized as the main confining bed in the Valley separating the primary upper and lower water bearing units.

Subsequent Lake Bed expansions (A, B, C, and D-Clays) of Croft and Gordon (1968) and Croft (1972) appear to be less extensive than the Corcoran Clay (E-Clay). The A and C-Clays are restricted to a narrow band below the Fresno Slough floodplain area (Croft, 1972). The northern extent of these upper Lake Beds is not well known.

The significance of the Tulare Lake Beds through the Quaternary (2.6 mya to present) is that the lake water level would be the base level to which the streams and alluvial fans/plains would be graded. As the lakes expanded, the streams would aggrade by lessening their slope and depositing sediment higher on the fluvial or alluvial plains. When the lakes contracted, the streams would incise by steepening their slope and carrying the sediment further down slope towards the existing lower lake level.

2.2.4.2 Lower Aquifer

North of the Tulare Lake Beds below the Corcoran Clay is the lower water-bearing zone (Lower Aquifer) (**Figure 2-27, Cross-section 1-1’**). With the isolation of the Pliocene marine embayment, deposition in the Valley became non-marine sediments as alluvial plains, fluvial floodplain systems, and lake beds. Below these sedimentary units are the older Paleogene and Neogene non-marine and marine units of the older geologic history.

The Lower Aquifer consists of late Pliocene and Pleistocene nonmarine deposits. These deposits overlie and may interfinger with the last marine deposits of the isolated marine embayment of the San Joaquin Formation. The depositional model for the Lower Aquifer is of two source areas: one from the Sierra Nevada to the east and the second from the Diablo Range to the west (**Figure 2-28, 2-29, Cross Sections 2-2’, 3-3’**).

The Sierra Nevada are dominated by granitic rocks, and the eroded sediments contain high percentages of quartz. The eroded sediments were deposited as alluvial fans, fluvial plains, and fluvial floodplains draining southward to the Tulare Lake Beds. Along the edge of the lake, four thick, massive sand sequences occur which appear to be deltaic, beach, and possibly dune deposits. To the north of the Tulare Lake Bed, these lake-margin sand sequences extend westward and span six to eight miles in width. They appear to consist of a massive lakeshore sand and a thick bedded sand zone, tapering to thin-bedded sands at the northern edge.

North of the lake-margin sand sequences, the Sierran-sourced deposits east of the Valley center appear to be alluvial/fluvial plain deposits. The Sierran-sourced deposits extend westward to near the western edge of the valley at depth and appear to be southward flowing fluvial/flood plain origins. Both of these areas have similar geologic character of numerous thin sand beds interbedded with thin silt and clay beds. Thick beds of either coarse or fine-grained materials appear to be lacking, and correlation of geologic units is relatively poor.

The relationship of Sierran-sourced units towards the Coast Range is not clear. The Pliocene and Pleistocene Sierran-sourced deposits in the Lower Aquifer have apparently not been named. Page (1986) related them to the similar-aged Laguna Formation to the north and the Kern River Formation of the southern Valley. In the Fresno, Kings, and Tulare County area these deposits are covered by younger deposits.

On the west side of the Valley, the deformation and uplift of the Diablo Range in the Pliocene appear to have increased the west-sourced sediment. The coarser upslope alluvial fans and plains appear to have been deposited west of the present edge of the Valley. Continued deformation and uplift caused the erosional removal of most of these late Pliocene sedimentary deposits. Small areas of older Paleogene and Neogene and Pliocene deposits are preserved in the Vallecitos syncline and erosional valleys of Little Panoche and Panoche Creeks. Davis & Poland (1959) and Miller and others (1971) noted that small, isolated exposures of late Pliocene alluvial deposits occur west of the edge of the present Valley but are too small to show on the maps.

The western-sourced alluvial deposits overlying the uppermost Pliocene marine unit (San Joaquin Formation) was named the Tulare Formation by Anderson (1905) in the Kettleman Hills area. Subsequent studies have extended the name Tulare Formation to similar deposits along the west side of the Valley. The Tulare Formation was also defined as the youngest deformed deposits along the west edge of the Valley. The age of the Tulare Formation is considered to be late Pliocene and Quaternary (Pleistocene). The Corcoran Clay is considered a member of the Tulare Formation and is age-dated between 700,000 to 600,000 years ago from volcanic ash beds.

The portion of the Tulare Formation below the Corcoran Clay has been intensively studied by the USGS as a result of deep groundwater level declines and subsidence in western Fresno County. The majority of these studies were based on collected geologic samples from boreholes drilled by governmental agencies. Detailed studies were made on the geologic character of the samples, petrology (rock type) of the sands, and mineralogy of the clays. Much of the information was summarized in Miller & others (1971), including thickness of Tulare Formation alluvial fan deposits.

The Diablo Range source rocks of Paleogene and older marine sedimentary units tend to yield fine-grained sediments from erosion. The alluvial fan/plain deposits beneath the Valley appear to be distal fan facies, fine-grained and thin bedded. These alluvial fan/plain deposits transition or interfinger with floodplain deposits eastward which are also largely fine-grained and thinly bedded.

Water wells drilled in western Fresno County are typically screened in the Lower Aquifer to achieve adequate yields; drilling by rotary drilling methods, coupled with normal driller’s techniques for describing subsurface lithology, were inadequate in describing the occurrence of the fine-grained and thin-bedded nature of the geologic materials. Due to these factors, geophysical logging of deep water wells began earlier (late 1930’s) than elsewhere in California.

All of the USGS geologic cross-sections covering the Subbasin used geophysical logs and borehole logs for correlations (Davis and Poland, 1957; Croft and Gordon, 1968; Miller and others, 1971; Croft, 1972). All of these cross-sections were reviewed for this report and selection of the most applicable cross-sections were modified for inclusion. Three cross-sections were selected from Miller and others (1971; A-A' B-B', & E-E'). Cross-section A-A' was selected to show the extent of the Corcoran clay north to south throughout the Subbasin (**Figure 2-27, Cross-section 1-1'**). Cross-sections B-B' and E-E' were selected to show the relationship of eastern versus western sourced units and depositional settings (**Figures 2-28 and 2-29, Cross-sections 2-2' and 3-3'**).

Selected geophysical logs from the Subbasin were also reviewed and were used to update the original cross-sections as needed. Generally, the published cross-sections represent the subsurface geologic conditions and validate the general interpretations made on the cross-sections.

2.2.4.3 Upper Aquifer

The upper water-bearing zone (Upper Aquifer) consists of the sedimentary deposits above the Corcoran Clay which are Quaternary to Holocene (late Pleistocene to present) in age. Throughout the Subbasin, these deposits consist of alluvial fan and lacustrine deposits with both Sierra and Costal sourced sediments. (**Figure 2-27, Cross-section 1-1'**). To the south and beneath the Tulare Lake Bed area, lacustrine clays and silts extend to the surface above the Corcoran Clay (Croft, 1972). Croft and Gordon (1968) also identified four additional upper lake bed clays (A, B, C, D) which extend further north. The A- and C-Clays are the most extensive of these clays; although they are limited to a narrow (6 to 8 mile) band along the center of the Valley, they extend to (and possibly past) Fresno County's northern boundary (Croft, 1972).

The sedimentary deposits in the Upper Aquifer are up to 800 ft thick with the thickest portions of the Upper Aquifer occurring near the Coast Range. The depositional setting is similar to the Lower Aquifer as it is composed of eastern-sourced fluvial/alluvial plain deposits, western-sourced alluvial plain deposits, and a central fluvial/floodplain zone with interbedded thin lacustrine clays of the uppermost Lake Beds (A-, B-, and C-Clays).

The Sierra Nevada eastern-sourced sedimentary deposits occur as a westward thinning wedge to about 10 miles west of the valley axis overlying the Corcoran Clay. The thickest deposits (500 ft or more) are under the valley axis beneath the Fresno Slough (Miller and others, 1971) (**Figure 2-28, Cross-section 2-2'**). To the south, these deposits are less thick (200-300 ft) where they inter-tongue and interbed with the upper Tulare Lake Beds. With the expansion of the uppermost Tulare Lake Beds northward starting with the C-clay, the eastern-sourced sediments shift to the east of the Lake Beds (Croft, 1972). As the Lakebed high strands of C, B, and A clays occur, the eastern sourced deposits receded eastward, and then expanded westward as the lake contracted. Further north where only the A- and C-Clays of the Lake Beds extend, these clays are interbedded with the fluvial and floodplain deposits along the axis of the valley. Croft (1972) shows a gap in the A- and C-Clays to the north; however, this may be due to lack of well control. The A-, B-, C-, and D- Clays are not shown in any of the cross-sections, but all the clays are present in the southern portion of the Subbasin along the Kings River, and the A- and C- Clays and in the northeastern portion of the Subbasin near the confluence of the Fresno Slough and San Joaquin River. The upper most zone of the Upper Aquifer, informally named the "shallow one" consists of wells that are above the A-Clay, where present, screened generally within the first 100 ft from ground surface. This area is not considered a principal aquifer or hydrologically connected to a principal aquifer. Groundwater production does not occur, and seasonal pumping from the Upper Aquifer does not affect water levels in the shallow zone. The Sierran-sourced sedimentary deposits in the Upper Aquifer have not consistently been termed much more than Quaternary alluvium. Similarly, sourced age deposits in the northern Valley have been mapped (in ascending order) as Turlock Lake, Riverbank and Modesto Formations (Marchland and Allwadt, 1981). Lettis (1982) has extended this terminology south into the northern Fresno County area. These units were based on detailed soil mapping and surficial mapping in the northern portion of the Valley. In general, it is difficult to identify these named units from drillers reports or geophysical logs and often require detailed geologic sampling from boreholes. For this reason, the term Quaternary alluvium eastern-sourced or Sierran-sourced will be used.

The Diablo Range western-sourced sedimentary deposits in the Upper Aquifer consist of an eastward thin/thinning wedge (Miller and others, 1971). The wedge is thickest (up to 800 ft) south of Panoche Creek along the edge of the Valley. The wedge thins (to 200 ft) as it moves north to the Fresno County Line. Eastward the wedge thins to pinch out west of the Fresno Slough. The western-sourced wedge interfingers with and overlies the eastern-sourced Sierran sedimentary deposits (**Figures 2-28 and 2-29, Cross Sections 2-2', and 3-3'**).

Older studies (Miller and others, 1971 and Croft 1972) reported an area where the Corcoran Clay did not extend to the western edge of the Valley. Subsequent studies by Page (1983; 1986) filled in some of this gap, but an area west of Huron remained. The cause of this is not clear. It may be that the Corcoran Clay pinches out or was possibly removed by erosion caused by the folding of the Kettleman Hills area. As a result, the Upper Aquifer lies directly on top of the Lower Aquifer without the confining bed of the Corcoran Clay being present (**Figure 2-29, Cross-section 3-3'**).

The western-sourced, alluvial fan deposits in the Upper Aquifer are considered the upper Tulare Formation. The deformed Tulare Formation is exposed as a narrow band along the eastern edge of the Diablo Range. Above the upper Tulare Formation are undeformed, younger alluvial fan deposits which can be readily differentiated and mapped at the surface. In northern Fresno County, Lettis (1982) subdivided the younger alluvial fan deposits into Los Banos alluvium and San Luis Ranch alluvium based on detailed mapping and detailed borehole information.

In the subsurface along the western boundary of the Valley floor, it is difficult to differentiate the upper Tulare Formation from overlying younger alluvium from water well driller's reports and geophysical logs. The cause of this is the similar age, source of sediments (Coast Range), and depositional setting of alluvial fans. The geophysical log character of the west-sourced alluvial fans is of low resistivity sand with gravel beds that occur immediately above the Corcoran Clay. These are believed to be fan delta or lake margin deposits. While geophysical logs tend to show more complex thinner interbedded units, borehole logs tend to show the sand units with silt and clay, and thick clayey units with sand. Contained gravel is generally reported in the uppermost younger alluvial fan deposits.

The western-sourced alluvial fans of the Upper Aquifer interfinger with eastern-sourced fluvial and delta sands which interfinger with upper Lake Beds further to the south (Croft, 1972). South of the Subbasin, the western-sourced alluvial fans interfinger directly with the upper Lake Beds (Bartow, 1972 C-C'). As the upper Lake Beds expanded northward as the C-, B- and A-Clays, the western alluvial fans extended or retreated as the Lake Beds varied.

Further north from the Lake Beds, the western-sourced alluvial fans initially spread eastward above the Corcoran Clay and then interfinger with the Sierran-sourced flood plain deposits (**Figures 2-29, Cross-sections 3-3'**). The western alluvial fans continue to extend eastward overlying the flood plain deposits. To the west, these alluvial fans appear to be locally slightly coarser by geophysical log, possibly representing the shift of the fans by uplift of the Diablo Range. Further east, the geophysical logs appear to show low resistivity in the thin bedding of distal alluvial fans blending into the flood plain deposits.

The northernmost cross-section (**Figure 2-28, Cross-section 2-2'**) shows a similar pattern of western-sourced alluvial fans extending eastward and interfingering and overlying the Sierran flood plain deposits. Geophysical logs tend to show low resistivity values and thin bedding character. Lettis (1982, cross-section B-B') shows about 200 ft of upper Tulare alluvial fan overlying the Corcoran Clay at the valley margin. From a thin edge to the west, the overlying younger alluvial deposits (Los Banos and San Luis alluvium) thicken eastward to about 500 ft and then begin to interfinger and thin eastward above the Sierran-sourced sedimentary deposits and uppermost Lake Bed clays (A- and C-Clays). As mentioned previously, it is difficult to separate the upper Tulare Formation from the overlying younger alluvium based in the subsurface by water well Drillers reports and geophysical logs.

2.2.4.4 Base of Fresh Water

The base of fresh water has been defined as the bottom of the Subbasin. The base of the freshwater in the Upper and Lower Aquifer system has been defined by the USGS (Page, 1971; 1973) using geophysical logs from oil and gas boreholes. Fresh water was defined as having a maximum specific conductance (EC) of 3,000 micromhos per centimeter (umhos/cm) which is equivalent to a total dissolved solids (TDS) concentration of about 2,000 milligrams per liter (mg/L). The map of the base of freshwater (Page, 1973) (**Figure 2-32**) indicates that in the northern portion of the Subbasin, the base is at elevations of -1,000 ft to less than -400 ft, mean sea level (msl). To the south, the base of freshwater extends to -2,000 ft in a trough parallel to the trend of the Diablo Range. As a result, the base of freshwater in the southern portion of the Subbasin is up to 1,600 ft lower than the elevation at which it occurs in the Subbasin's north.

2.2.5 Soils

Surficial soils data were obtained from the Natural Resources Conservation Service (NRCS). As part of the NRCS soil surveys, soil map units are defined to express similarities between soils within similar landform and landscape positions. Each soil map unit is assigned ranges of physical properties by aggregating data collected for each soil map unit.

Various soil types are present in the Subbasin (**Figure 2-20**). The dominant soil types within Subbasin include the Ciervo, Cerini, Tranquility, Lethnet, and Westhaven series. The Ciervo series is characterized by very deep, moderately well drained, clay soils and is found on the distal portions of alluvial fans along the center of the Subbasin but is absent in the southern portion of the Subbasin. The Cerini series is characterized by very deep, well drained, clay loam soils and is found on alluvial fans in the northwestern and south-central portions of the Subbasin. The Tranquility series is characterized by very deep, somewhat poorly draining clay soils and is found on distal portions of alluvial fans in the northeastern portion of the Subbasin. The Lethnet series is characterized by very deep, moderately well drained, clay loam soils and is found on unburied fan remnants in the southeastern portion of the Subbasin. The Westhaven series is characterized by very deep, well drained, loam or clay loam soils and is found on alluvial fans in the south central and southwestern portions of the Subbasin.

2.2.5.1 Physical Soil Properties

Figure 2-21 shows the texture of surficial soils within the Subbasin as mapped by the NRCS. Clay loam, clay, and sandy loam are the most dominant soil textures found within the Subbasin. Clay loam soils are present throughout the Subbasin, while clay soils are predominantly located in the northwestern portion of the Subbasin, and sandy loam soils are predominantly located along the western edge of the Subbasin. Loam is another notable texture present in the western portion of the Subbasin.

The saturated hydraulic conductivity of surficial soils as mapped by the NRCS is shown in **Figure 2-22** and ranges from less than 0.5 ft per day (ft/day) to over 4 ft/day. Hydraulic conductivity is highest along the western edge of the Subbasin corresponding to the sandy loam and loam soils and decreases towards the east where the soil contains more clay. The distribution of hydraulic conductivity throughout the Subbasin is related to the texture distribution of soils. Finer texture soils, such as clays, have low hydraulic conductivity while coarser texture soils, such as sandy loams, have higher hydraulic conductivity.

Figure 2-23 shows the spatial distribution of soil drainage characteristics throughout the Subbasin as mapped by NRCS. Similar in nature to saturated hydraulic conductivity properties, soils in the central and western portions of the Subbasin exhibit the highest drainage capability, while the soils occurring along the eastern portion of the Subbasin are generally poorly drained resulting in areas of low hydraulic conductivity. Poorly drained areas also correspond to fine clay zones. The soils with the poorest drainage properties are generally located near Highway 180 and the town of Helm (**Figure 2-23**).

2.2.5.2 Chemical Soil Properties

Chemical Soil Properties Soil salinity of surficial soils as mapped by the NRCS is shown in **Figure 2-24**. Salinity is a measurement of the amount of salt present in soil and is estimated by measuring EC of the soil. From an agricultural standpoint, the salinity of the soil is important because it can greatly impact the ability of the soil to support crops. While crops vary in their tolerance for elevated soil salinity, the productivity of most crops becomes impacted when EC levels are above 4 deciSiemens per meter (dS/m), although some more sensitive crops may have declining yields at lower salinity levels (Waskom et al., 2012).

In general, soil salinity increases from west to east within the Subbasin, with the southern portion having lower salinity than the northern portion. Salinity appears to be related to both hydraulic conductivity and drainage characteristics; however, soils with salinity greater than 4 dS/m appear more widespread than soil with poor drainage and hydraulic conductivity. Areas with the highest salinity are located in the eastern portion of the Subbasin where salinity commonly exceeds 4 dS/m.

Figure 2-25 shows the spatial distribution of soil pH as mapped by the NRCS. Soil pH is a measurement of the concentration of hydrogen ions present in soil. A pH in the range of 7 is considered neutral with increasing pH levels indicating more alkaline soil conditions and decreasing pH values indicating more acidic soil conditions. Crops vary in their ability to tolerate levels of soil pH; however, most crops grow best when the soil pH is slightly acidic at a value between 6 and 7. Highly alkaline soils (pH > 7.8) can affect plant health. Soil pH throughout the Subbasin is predominantly slightly alkaline, with the exceptions occurring in the southwesterly and southeasterly portions where soils are slightly acidic (southwesterly area) and more alkaline with pH in excess of 8.5 (southeasterly area).

2.2.6 Groundwater Levels

The characterization of groundwater levels is essential to understanding groundwater conditions including flow directions, trends in levels over the course of time, areas integral to recharge and those involved in discharge, and other hydrogeologic conditions. Groundwater level data that were analyzed were obtained from several sources including the District's records, and data available from USGS, DWR, and the State Water Resources Control Board (SWRCB) Geotracker database.

The compiled data underwent a quality assurance/quality control (QA/QC) process whereby data were evaluated for completeness and duplication. This process also identified any erroneous data. The accuracy of well location data is very important for analysis of groundwater levels. To assess well location accuracy, available well location coordinates were checked against the Public Land Survey System (PLSS) and, whenever possible, assigned a State Well Number.

All groundwater level data were classified by aquifer based on available well construction information. The perforated intervals for wells were compared to the elevation of the top and bottom of the Corcoran Clay within the Subbasin (**Figures 2-30 and 2-31**). As mentioned above, the Corcoran Clay is absent in the south-western area of the Subbasin. Through this comparison, well data was classified into five depth categories: shallow zone (upper 100 ft of the Upper Aquifer), Upper Aquifer, Lower Aquifer, composite (Upper and Lower Aquifer), and unknown (for those wells with no available well construction information). For wells located in areas where the Corcoran Clay is not present, wells with well construction information were designated as Upper Aquifer equivalent or Lower Aquifer equivalent, depending on the well perforated interval relative to the projected or nearby elevation of the Corcoran Clay. During the classification of wells by depth zone, wells with total depths or screen intervals at depths less than 100 ft were classified as the shallow zone. Wells with depths and intervals beyond 100 ft but above the Corcoran Clay layer were classified as Upper Aquifer and wells with depths and screen perforations below the Corcoran Clay were classified as being in the Lower Aquifer. Composite wells were classified as those with screen intervals spanning more than one aquifer. Wells lacking available well depth or screen perforation information were classified as unknown depth zone. For this GSP, the primary groundwater production aquifers are the upper and lower aquifers which will be the focus of the description of groundwater conditions. For contouring of groundwater elevations, only wells designated as Upper Aquifer or Lower Aquifer were utilized.

2.2.6.1 Historical Groundwater Levels

To gain a historical perspective of trends in groundwater levels in the Subbasin, groundwater level hydrographs were generated for wells with long-term data records. Panel maps presenting hydrographs of groundwater elevations through time in select wells are provided in **Figures 2-33 to 2-34**. These maps illustrate representative hydrographs of groundwater elevations and the locations of the specific wells used. Wells were selected based in part on their location within the Subbasin and the length of their data record.

Historical hydrographs of water level data for select wells in the Upper Aquifer are displayed in **Figure 2-33A**. Many of the wells with long-term water level data displayed on **Figure 2-33A** show increasing groundwater levels prior to the early 2000s, followed by stable water levels in some wells after 2000. Some wells in the Upper Aquifer, however, exhibit considerable fluctuations in water levels. Several hydrographs on **Figure 2-33A** illustrate water levels at specific depths within the Upper Aquifer. These data suggest that although temporal trends in groundwater levels may be similar at different depths within the Upper Aquifer, differences in groundwater elevations can exist within the Upper Aquifer. The reason for the different depths may be due to the well construction features of the wells and influences from groundwater pumping. Recent groundwater level data within the last ten years (2008-2018) indicate various degrees of groundwater elevation declines. The declines are indicative of many areas in the State that were impacted by the recent drought period and associated temporary increases in groundwater pumping, although a slight decreasing trend is observable in recent years, this trend is most evident in deeper wells within the Upper Aquifer. **Figure 2-33B** shows the relationship between the shallow zone and the rest of the Upper Aquifer. It is evident that groundwater elevations in the shallow zone generally do not strongly correlate with climatic conditions or seasonal pumping patterns. Of the eight examples presented, depths to water for seven of these shallow zone wells are within 40 feet of the ground surface. Each of these wells show little to no long-term decline or seasonal variation. The one shallow zone well with depths to water greater than 40 feet was screened between 80 and 90 feet below ground surface. In this example, the well also shows no seasonal variation, very little variation from climatic conditions, and no long-term decline. Many of the Upper Aquifer wells screened below the shallow zone show significant seasonal variations of groundwater elevation up to hundreds of feet.

Figure 2-34 presents hydrographs for selected wells in the Lower Aquifer. Historical groundwater conditions in the Lower Aquifer show historically low groundwater levels in the 1950s and 1960s with the dramatic rise of water levels after the onset of CVP surface water deliveries in 1968. Although notable short-term fluctuations in some Lower Aquifer wells are evident from the 1980s through the early 2000s, groundwater levels remained relatively stable during this period. Since 2010, however, groundwater levels in the Lower Aquifer have declined considerably (**Figure 2-34**). For some wells, groundwater levels have declined by as much as 200 ft in the five years between 2010 and 2015 and have continued to vary with climatic conditions. Although these recent declines in groundwater elevations are dramatic, it is notable that these values represent potentiometric elevation changes in a confined aquifer which are not necessarily equivalent in terms of change in aquifer storage to elevation changes in an unconfined or semi-confined system such as the Upper Aquifer.

2.2.6.2 Historical and Current Groundwater Elevation Contours and Flow Directions and Gradients by Aquifer (GSP Reg. § 354.16(a)(1))

All available data for wells with aquifer designations was also utilized to create groundwater elevation contours. Groundwater elevation contours were initially developed using spatial analysis tools available in ArcGIS followed by technical review and adjustment based on professional judgement. Contours were created during three different time periods to obtain an understanding of groundwater elevations during dry years, wet years, and current conditions. Years were chosen based on hydrographs generated for all wells in the two aquifers. Data from Winter/Spring 2006/2007 was used to represent a typical wet year, Summer/Fall 2009 represented a typical dry year, and Winter 2014/2015 was used for current conditions.

Figures 2-35 to 2-37 depict conditions in the Upper Aquifer zone during the three time periods. Groundwater level data was sparse in some areas of the Subbasin for the Upper Aquifer (**Figure 2-39**). The majority of the control points lay in the vicinity of the eastern boundary of the Subbasin. Furthermore, no conclusions can be drawn about groundwater conditions in the area to the south of Huron as no data was available for any of the time frames examined. An increase in data collection effort is evident in **Figure 2-37**, as it contains more control points than either of the preceding two figures. Although **Figure 2-36** represents a dry year, water levels in the northern region of the Subbasin are similar to those seen in 2006/2007, with the highest levels being 250 ft. Current conditions show a high of 200 ft in the same region. Groundwater levels along the SLC are higher than in other areas of the Subbasin (**Figure 2-37**). Although a concrete flow direction cannot be attributed to this aquifer zone due to the incompleteness of the dataset, a general trend of decreasing water levels toward the Subbasin's eastern boundary can be observed throughout each time frame. This indicates that the groundwater flow directions are influenced by groundwater development in the adjoining Subbasins located east of the Westside Subbasin.

The Lower Aquifer had a relatively large amount of data available for contouring for Winter/Spring 2006/2007 and winter 2014/2015, however, data was sparse for fall 2009 and primarily confined to the southern portion of the Subbasin. Although the data is sparse in some areas of the Subbasin for winter/spring 2006/2007, **Figure 2-38** suggests that groundwater levels tend to decrease from west to east across the Subbasin and in and around the city of Huron during this time. In Summer/Fall 2009, the limited groundwater data shows water levels decreasing to the east and southeast (**Figure 2-39**). In both winter/spring 2006/2007 and Summer/Fall 2009, water level elevations are generally 100 ft msl or less within the Subbasin. **Figure 2-40** shows a substantial increase in the amount of monitoring data available during this period which represents recent drought conditions. Generally, the groundwater elevation contours show a trough of low groundwater elevations along a north to south orientation in the central portion of the Subbasin with groundwater levels at around -160 ft below sea level. Groundwater levels increase with distance from the center of the Subbasin towards the western and eastern boundaries of the Subbasin. The two winter/spring contours of groundwater elevations indicate that groundwater flow directions in the Lower Aquifer flow eastward out of the Subbasin during wet years and flow into the Subbasin during extended drought periods. Additional contouring of Lower Aquifer groundwater levels is recommended in the future to assess the variability and frequency of subsurface inflows and outflows to and from the Subbasin in order to assess the influence of groundwater pumping within the Subbasin and in adjacent subbasins on groundwater flow directions and sustainable yield estimates.

2.2.7 Water Quality (GSP Reg. § 354.16(d))

The evaluation of groundwater quality in the Subbasin included a review of regional investigations (USGS, 2017; Carollo and LSCE, 2015; and USGS, 2013) and data collected from the same data sources as were used for groundwater level data. Groundwater quality data are available dating back to the 1930s and the collection of groundwater quality data, especially from the Upper Aquifer, has become more available since 2020 with the implementation of regional water quality regulatory programs such as the Irrigated Lands Regulatory Program (IRLP). The collection of groundwater quality data has been sporadic over time with little groundwater quality data collected between 2000 and 2020. The analysis of Subbasin-wide conditions relied on the period from 1950 to 2020. Groundwater quality in the Subbasin is primarily characterized by the occurrence of TDS, boron, selenium, arsenic, and sulfate that in some locations may exceed drinking water standards in the shallow zone of the Upper Aquifer (Carollo and LSCE, 2015). The elevated concentrations of these constituents are primarily naturally occurring as a result of the geologic composition of the aquifer materials (from the Coast Range) (USGS, 2017). The occurrence and cause of nitrate concentrations that exceed drinking water standards are currently being investigated under the ILRP to assess areas where nitrate concentrations are a result of natural sources such as geologic materials or from agricultural land use practices. The data collected by the Westlands Water Quality Coalition demonstrates that the concentration of nitrate in groundwater in the Westside Subbasin is generally at or below background concentrations meaning that it is not impacted by anthropogenic discharges. As result of the nitrate data and studies conducted by the Coalition, the Westside Subbasin is not prioritized under the Nitrate Control Program managed by the Central Valley Salinity Alternatives for Long-term Sustainability (CV-SALTS).

District farmers are currently implementing Best Management Practices (BMPs) such as switching to crops that can tolerate higher levels of salt, blending pumped groundwater with delivered surface water, and treatment, such as reverse osmosis, of groundwater. These BMPs allow farmers to continue to farm in areas where groundwater is affected by elevated TDS concentrations. **Figures 2-4 and 2-6** depict the implementation of the BMP and that groundwater is beneficially used across the Subbasin.

Beneficial uses of groundwater in the Subbasin include agriculture, domestic, and municipal uses. There are not any environmental beneficial users of groundwater in the Subbasin as described in **Section 2.1.5.1**. For agricultural beneficial uses, available groundwater quality data and outreach efforts indicate that TDS is the primary constituent of concern. Constituents of concern for domestic and urban beneficial users are those constituents that are regulated under the State of California’s drinking water standards. Analysis of existing groundwater quality data indicates that TDS can be utilized as a proxy for other constituents of concern for domestic and urban beneficial users. Using TDS as a proxy for domestic and urban beneficial uses was justified from a correlation and spatial comparisons between TDS concentrations and other constituents of concern that occur in the Subbasin. **Figures 2-41 and 2-42** show a correlation between TDS concentrations and two constituents of concern, nitrate and boron. **Figures 2-43 to 2-45** show that, although there is a lack of correlation between TDS and heavy metals of concern (selenium, arsenic, and chromium), high TDS (over 1000 mg/L) is present when heavy metals are present at elevated levels. These plots of TDS concentrations and concentrations of other constituents show that elevated TDS is a useful indicator of water quality impairment in the GSA as relates to agricultural and drinking water beneficial users.

The Subbasin includes 38 known active domestic wells. Available data on domestic well construction and monitoring is limited. Based on available data, most of these domestic wells are constructed in the Upper Aquifer or are composite wells that are constructed in the Upper Aquifer and Lower Aquifer with the shallow zone of the Upper Aquifer sealed to prevent downward percolation of poor-quality water. Groundwater quality constituents of most interest for the drinking water beneficial use can be represented by ambient TDS (monitored in available wells).

The District’s groundwater quality monitoring during GSP implementation will be augmented by monitoring from the GQTM program under the IRLP. This monitoring will provide data that will help characterize groundwater quality in the Subbasin, especially those areas of the Subbasin that have not experienced degradation of water quality due to the occurrence of marine sediments from the Coast Range and areas where domestic wells may be located. As stated in the IRLP General Order, "the trend monitoring program is designed to determine current water quality conditions of groundwater in the Third-Party area [e.g., the Subbasin], and to develop long-term groundwater quality information that can be used to evaluate the regional effects (not site-specific effects) of irrigated agriculture and its practices. Trend monitoring has been developed to answer Groundwater Monitoring Advisory Workgroup (GMAW) questions 1 and 4. At a minimum, trend monitoring must include annual monitoring for electrical conductivity, pH, dissolved oxygen, temperature, nitrate as nitrogen (N), and once every five-year monitoring for total dissolved solids, carbonate, bicarbonate, chloride, sulfate, boron, calcium, sodium, magnesium, and potassium."

Most municipal (community) water systems in the Subbasin rely on surface water from the California Aqueduct for urban supply and not on groundwater. The exception is Cantua Creek and El Porvenir which have historically used groundwater as a supplemental supply. However, currently their wells are inactive. Fresno County is in the process of installing a new well for Cantua Creek and El Porvenir. Water systems are regulated by the State Water Resources Control Board Division of Drinking Water and are required to report the water quality of the sources used for supply on an annual basis.

As discussed above, the groundwater quality data that was analyzed concluded that TDS (or salinity) can be used as a proxy for other constituents detected in the Subbasin. Prior to commencing any analysis on existing data, all EC data was converted to TDS (multiplied by a factor of 640 or 0.64 depending on the units of EC data) to create a uniform dataset. These records also underwent a QA/QC process during which duplicate records were deleted and all data was checked for accuracy and verified to the extent possible. These data were then used to develop the analysis below.

2.2.7.1 Historical Groundwater Quality by Aquifer with a Focus on Salinity

Maps of TDS concentrations and time series charts of TDS concentrations (salinity) of well locations were prepared using all available TDS and EC data. A select number of wells are depicted in **Figures 2-46 to 2-47** to present a historical overview of TDS concentrations in the Upper Aquifer and Lower Aquifer. Many of these wells lack continuous long-term data. However, the data likely represents local groundwater quality conditions because changes in groundwater quality that are caused by groundwater pumping and the migration of elevated TDS is dependent on horizontal groundwater flow and gradients. When using Darcy's Law and examining the flow of water, the velocity is often slow, with a likely range of between about 1 and 5,000 feet per year. The Upper Aquifer does not have many wells with continuous data with the exception of two wells which have data from the 2000s forward (19S/17E-11 and 18S/18e-34) (**Figure 2-46**).

These two wells both have measurements indicating increasing TDS concentration. The maps of TDS concentrations for the Upper Aquifer and Lower Aquifer were prepared to convey the areal extent of the aquifer system that has concentrations above 1,000 mg/L, which is the short-term maximum contaminant level for drinking water and is an important concentration level for domestic and urban beneficial users and also for agricultural beneficial uses for irrigation purposes on most crops (**Figures 2-48 through 2-53**).

Figures 2-48 through 2-50 show that the Upper Aquifer groundwater quality generally exceeds the drinking water standard of 1,000 mg/L with the exception of a few areas of the Subbasin.

The areas with elevated TDS concentrations above 1,000 mg/L represent baseline and historical conditions that are predominantly the result of the marine sediments of the Coast Range which compose many areas of the Upper Aquifer. The relatively poor water quality conditions of the Upper Aquifer are the primary reason why historical groundwater pumping has been less in the Upper Aquifer (approximately 15 percent of the total amount of Subbasin groundwater pumping) than in the Lower Aquifer.

The Lower Aquifer also has a lack of wells with continuous data (**Figure 2-47**). The available data showed a variation in trends throughout the Subbasin including increasing, decreasing, and stable salinity values. An assessment of trends in salinity concentrations is constrained due to the lack of data as well as the infrequent periods of data collection, similar to the Upper Aquifer data availability. However, when evaluating TDS concentrations spatially in the Lower Aquifer using all historical data (**Figures 2-51 through 2-53**), the occurrence of TDS in excess of 1,000 mg/L, representative of baseline conditions, reveals that many areas of the Lower Aquifer in the Subbasin have degraded water quality. However, the spatial distribution of degraded water quality in the Lower Aquifer is not as prevalent as in the Upper Aquifer and may be a primary reason why most groundwater pumping occurs from the Lower Aquifer in the Westside Subbasin.

All available data were also mapped to highlight areas with two or more exceedances of 1,000 mg/L for both the Upper and Lower Aquifers **(Figure 2-53a and 2-53b**). Areas with two or more exceedances are displayed in grey whereas areas with less than two (2) exceedances are shown in green. Areas with insufficient data are depicted in white. These maps further highlight areas with elevated TDS due to the marine sediments of the Coast Range (two (2) or more exceedances) and areas that can be managed for TDS (less than two (2) exceedances), as discussed further in Chapter 3.

2.2.7.2 Historical and Current Occurrence of Salinity

The maps presented above illustrate the occurrence of TDS spatially utilizing all the historical data available. This section describes the occurrence of water quality data in a series of time blocks beginning in 1990 to provide an understanding of the amount and occurrence of water quality data collection from 1990 to 2015 which generally corresponds to the GSP's historical water budget period. Over the past several years since 2020, the District has implemented the GSP monitoring program to collect groundwater quality data that also included the installation of 15 aquifer specific monitoring wells that enabled the collection of groundwater quality samples throughout the Subbasin. Currently, the available groundwater quality data collected over the past several years are being evaluated to compare recent data with historical data to identify time periods which would provide an indication of how salinity changes occurred spatially over time in each aquifer zone. Three time periods were selected for analysis (1990-1995, 2005-2009, 2010-2015) for which to display salinity data. Analysis of data collected since 2015 is currently in process and will be described fully in the 2025 GSP update.

Upper Aquifer TDS data is illustrated in **Figures 2-48 to 2-50**. The majority of the data available for the Upper Aquifer from 1990 to 1995 are concentrated along the eastern edge of the Subbasin. The majority of wells located north of Highway 198 and west of the Fresno-Kings county line have TDS concentrations below 1,000 mg/L. In contrast, wells along the eastern edge of the Subbasin, in the northern and central regions, have high densities of wells with TDS concentrations over 2,000 mg/L. The amount of data available for characterization decreases from 2005 to 2009 in the Upper Aquifer (**Figure 2-49**). However, a cluster of high TDS concentration wells is still observed in the central portion of the Subbasin, along the eastern boundary. Similar to **Figure 2-48**, the eastern boundary area intersecting with the Fresno-Kings county line shows that wells in that region have TDS concentrations below 1,000 mg/L**. Figure 2-50** has the fewest data points available for analysis. However, most of the wells with data available have TDS concentrations exceeding 1,000 mg/L. Most of this data is concentrated along the eastern boundary of the Subbasin in the central and southern regions of the boundary. Similar to the shallow zone, a lack of data is evident west of the California Aqueduct.

The majority of the wells providing TDS measurements in the Lower Aquifer are concentrated along the SLC and towards the Subbasin's western boundary. As seen in **Figure 2-51**, the majority of the wells have TDS concentrations below 2,000 mg/L. There is a small collection of wells in the vicinity of Huron which exhibit concentrations above 2,000 mg/L. The area along the Fresno-Kings county line in the southern portion of the Subbasin has a high concentration of wells with TDS levels below 1,000 mg/L. **Figure 2-52** continues the trends seen in **Figure 2-51** with wells in the southern half of the Subbasin generally having lower TDS concentrations than those in the northern region. These differences in groundwater quality in the Lower Aquifer are similar to the occurrence of groundwater pumping in the Lower Aquifer, with more pumping occurring in the southern half than the northern half of the Subbasin. The wells highlighted in **Figure 2-52** also show an area with higher TDS concentrations than those observed in the same region in **Figure 2-51**. Although a few wells to the west of Huron can be seen with concentration above 2,000 mg/L, recent conditions, as depicted in **Figure 2-53**, show more wells overall with TDS concentrations below 1,000 mg/L. Although there is less data in recent years, the available data suggests a slight improvement in TDS concentrations. The data gaps in the Lower Aquifer are not as apparent as in the Upper Aquifer. Although there is a decrease in the availability of data from the 1990s to the 2010s, a large amount of data across the Subbasin is still available. Future analyses, however, would benefit from an expansion of groundwater quality data from the northern and eastern parts of the Subbasin.

2.2.8 Subsurface Compaction and Land Subsidence

Land subsidence is a major concern for the Valley, and particularly for the Subbasin, due to the use of groundwater to supplement variable surface water supplies. Subsidence has the potential to damage local, state, and federal infrastructure, including reducing the freeboard and flow capacity of the SLC and Coalinga Canal, and irrigation water-delivery canals, bridges, roads and flood control structures. Subsidence in the Westside Subbasin is recognized to occur due to several factors including groundwater pumping, hydrocompaction, extraction from oil and gas fields, and tectonic plate movement (Ireland, 1984; Poland and Davis, 1969; **Figure 2-54**). While these contributing causes of subsidence are generally accepted, it is widely held that groundwater extraction is the primary cause of land subsidence in the Subbasin.

2.2.8.1 Physical Concepts

The mechanics of land subsidence due to groundwater extraction for irrigated agriculture is discussed below. The following summary is a brief description of the concepts that are used to quantify the physical relationship between groundwater extraction and subsidence.

2.2.8.1.1 Effective Stress

Land surface subsidence due groundwater pumping is attributable to the reduction in pore-water pressure predominantly in fine-grained materials within an aquifer system. This principle was initially developed by Terzaghi (1925), who related aquifer system compaction to pore-pressure and effective stress:

$$\sigma_e = \sigma_T - \rho \tag{1}$$

where: σ_e is the effective (intergranular) stress
σ_T is the total stress due to the geostatic load (downward force, as the weight of overlying sediments and water)
ρ is the pore-water pressure (buoyant upward force)

Under a constant geostatic load in a confined aquifer system, pumping induced deformation of the aquifer skeleton occurs due to a reduction in pore-water pressure, which causes an increase in the effective stress on the adjacent fine-grained interbeds leading to compaction of the skeletal framework of the interbeds. As water levels decline, the associated decrease in fluid pore-pressure transfers to a commensurate amount of the total (intergranular) stress between the contacts of the grains within the aquifer system. This increase in effective stress causes deformation (compaction) of the aquifer skeleton and especially fine-grained interbeds within or adjacent to the aquifers leading to land surface subsidence and possibly permanent loss of aquifer storage within fine-grained interbeds (**Figure 2-55**).

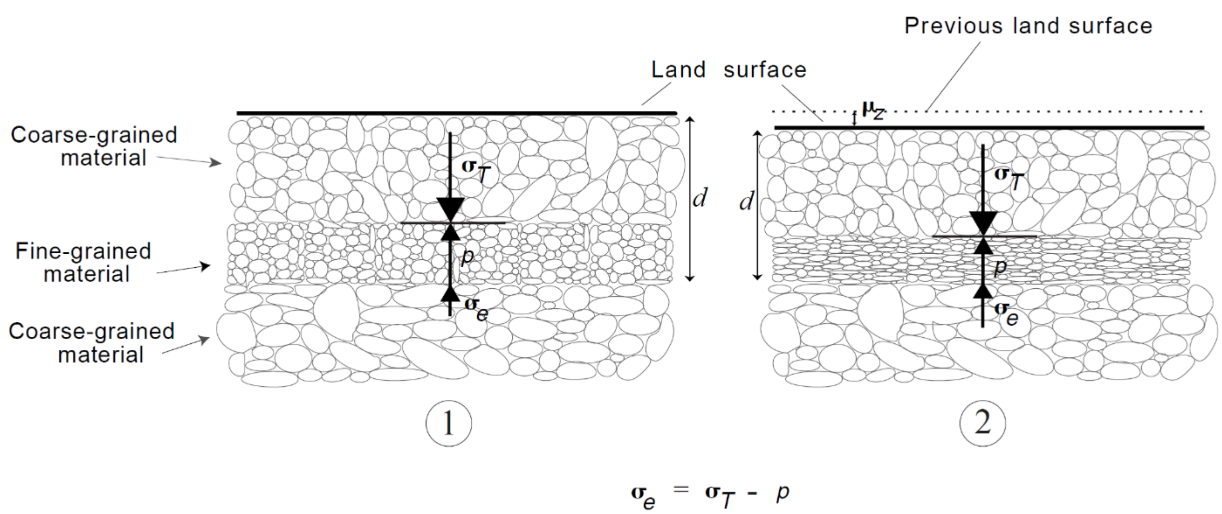


Figure 2-55. Increase in effective stress and vertical displacement (μ_z) of land surface (subsidence) as a result of a decrease in pore-water pressure for a confined aquifer layer (from Sneed and Galloway, 2000).

2.2.8.1.2 Elastic and Inelastic Deformation

In alluvial depositional environments, fine-grained materials are generally arranged in laterally extensive and/or discontinuous confining units referred to as "interbeds" within an aquifer system. For the purposes of evaluating subsidence, the term "aquifer" refers to the water bearing interconnected coarse-grained material within the aquifer system where (due to larger hydraulic diffusivity) the majority of initial water level and groundwater storage changes occur due to pumping.

Compaction and land subsidence are due to elastic and inelastic deformation of the aquifer skeleton (Terzaghi, 1925). Inelastic deformation occurs predominantly in the fine-grained materials within an aquifer system (Ireland, 1984; Hanson 1989). Inelastic deformation occurs in cases where the effective stress within the interbeds exceeds the greatest effective stress ever experienced within interbeds, which is referred to as "pre-consolidation stress" (Holzer, 1981). This is triggered when the hydraulic head in the interbeds drops below historic levels referred to as "pre-consolidation head" (Jorgensen, 1980; Leake and Prudic, 1991; Hoffman et al., 2003). The pre-consolidation stress threshold is a combination of previous low groundwater levels (buoyant force) and any past increases in geologic loading from sedimentary deposition plus any potential lithification or cementation of the sediments that comprise the aquifer system. Inelastic deformation and compaction results in the irreversible rearrangement of the grains within aquifer skeleton leading to a permanent reduction in aquifer storage and compaction.

Elastic deformation occurs in both fine and coarse-grained materials comprising the aquifer system in cases where the effective stress is less than the pre-consolidation stress. Elastic deformation manifests to varying degrees in both fine and coarse-grained sediments. Unlike inelastic compaction, elastic compaction is reversible and commensurate to the changes in effective stress in the aquifer system.

2.2.8.1.3 Skeletal Specific Storage

Land subsidence and changes in groundwater storage due to water level changes within a confined aquifer system are dependent on the physical properties of the aquifer materials. The amount of water stored or released within a unit thickness of aquifer material due to a unit change in hydraulic head is defined as the specific storage (S_s):

$$S_s = S_{sk} + n \times S_{sw} \text{ [ft}^{-1}\text{]} \tag{2}$$

where: S_{sk} is the component of specific storage due to the compressibility of the aquifer skeleton (skeletal specific storage)
S_{sw} is the component of specific storage due to the compressibility of water
n is the total porosity

The skeletal specific storage can be further refined to account for elastic (S_{ske}) and inelastic (S_{skv}) components, which are dependent on the hydraulic head (Leake and Prudic, 1991). Under conditions where the hydraulic head (h) is greater than the pre-consolidation head (H_c), the skeletal specific storage is equal to the elastic specific storage only. Under conditions where the hydraulic head is less than the pre-consolidation head, the skeletal specific storage is equal to the sum of the elastic and inelastic specific storage (modified from Leake and Prudic, 1991):

$$S_{sk} = S_{ske} + S_{skv}, h \leq H_c \text{ [ft}^{-1}\text{]} \quad (3)$$

Since inelastic compaction within interbeds is caused by permanent rearrangement of the grain structure, the inelastic skeletal specific storage is one to two orders of magnitude greater than the elastic skeletal specific storage (Riley, 1969; Helm, 1976; Riley, 1998).

2.2.8.1.4 Delayed Aquitard Drainage

Depending on the geometry (distribution and thickness) and hydraulic properties of the interbeds within an aquifer system, there may be a significant time-delay for hydraulic heads within interbeds to equilibrate with heads in adjacent aquifers (Terzaghi, 1925). As a result, so called “ultimate” amounts compaction may not be manifested until residual excess pore-pressure in the interbeds is released, which can occur much later than the initial decline in water levels within the adjacent aquifer. Recognition of this dynamic can be critical in slowly draining aquifer systems since the change in effective stress within interbeds (compaction) can continue to occur even when the measured hydraulic head within the aquifer does not exceed the pre-consolidation head as previous reductions of pore pressure from the adjacent aquifers are still propagating across the interior of the fine-grained beds (Sneed et al., 2018).

2.2.8.2 Subsidence Studies in the San Joaquin Valley

Early work from Mendenhall (1916) described in Bull and Miller (1975) indicates that the majority of the Westside Subbasin had flowing artesian wells prior to development of groundwater resources. By the early 1950s, groundwater extraction for irrigation in the west-central portion of the San Joaquin Valley encompassing the approximate boundary of the Westside Subbasin was estimated to exceed 1 MAF per-year – leading to considerable land subsidence in the Subbasin. Poland and others (1975) estimated total subsidence in the Subbasin between 1926 and 1972, which approached 30 feet in localized areas of the Subbasin.

While not initially considered in the initial development of the CVP, recognition of subsidence impacts on canal capacity led to the formation of the Inter-Agency Committee on Land Subsidence in 1954 prior to the construction of the San Luis Project. This led to a number of key studies spearheaded by the USGS and funded by DWR beginning in 1956. Key early studies are summarized in reports by Poland and Davis (1956) and Davis and others (1959). Concurrently, the USBR conducted subsidence studies in the 1960s which include estimates of the “ultimate” subsidence along the San Luis Canal (Propokovich, 1963; Propokovich 1969). Substantial efforts to characterize the rates and causes of subsidence are summarized in reports by Miller and others (1971), Bull and Miller (1975), Bull (1975) and Bull and Poland (1975), Poland and others (1975) and Ireland and others (1984) and Ireland (1986). A more detailed summary of these reports can be found in the USGS report on subsidence near the California Aqueduct (Sneed et al., 2018).

Notable studies aimed at analyzing stress and strain relationships and developing estimates of the material properties of the aquifer system in the San Joaquin Valley were conducted in studies listed above as well as Lofgren (1961), Riley (1969), Helm (1975, 1976, 1978) and Johnson (1984). Estimates of physical properties were also derived from laboratory consolidation tests by Johnson and others (1968). Additional consolidation tests from cores were analyzed by the USGS during the installation of newer monitoring wells in 2011-2012 (Hanson written commun., 2022). A detailed summary of results from these and other significant studies is provided in Sneed (2000).

Following the mid-1980s, there is a notable lack of significant subsidence-related studies in the San Joaquin Valley and abandonment of much of the subsidence monitoring network developed during planning and construction of the CVP. However, renewed interest in subsidence research and monitoring beginning in the early-2010s has led to several recent studies. Characterizations of subsidence near the Delta-Mendota Canal and California Aqueduct were conducted using measured subsidence and water level data in conjunction with InSAR by the USGS in 2013 and 2018 (Sneed et al., 2013; Sneed et al., 2018). In 2017, the California Dept. of Water Resources published the California Aqueduct Subsidence Study. More recently, a one-dimensional modeling study was released in 2021 reproducing historical land subsidence rates in the San Joaquin Valley (Lees et al., 2021).

Several regional numerical models have also been developed in the Central and San Joaquin Valley aimed at quantifying groundwater storage and land subsidence. These include models developed as part of the Regional Aquifer System Analysis (RASA) by the USGS (Williamson et al., 1989; Belitz et al., 1993), WESTSIM developed by the Berkeley Nation Laboratory (Quinn and Faghih; 2001) and the Central Valley Hydrologic Model (CVHM) developed by the USGS (Faunt et al., 2009).

2.2.8.3 Subsidence Monitoring

2.2.8.3.1 Geodesic Surveys

Characterization of the rates and spatial distribution of subsidence prior to CVP deliveries in the San Joaquin Valley were based on measurements from benchmarks constructed in the early-1900s by the USGS and subsequent geodesic surveys conducted between the 1940s through the mid-1970s. Results of these surveys were used to map total subsidence between 1926 and 1972 (Ireland et al., 1984). These maps show significant amounts of subsidence throughout the central-west portion of the Subbasin with pockets of more severe subsidence approaching 30 feet locally south of Firebaugh and east of Huron (**Figure 2-56**). Ireland and others (1984) also produced transects of land subsidence over time between 1943 and 1975 in the more severely affected areas (**Figure 2-57**).

Surveys conducted during highway leveling are another useful source of information. Sneed and others (2018) developed transects of estimated vertical displacement from highway leveling on 198 north of Huron between the 1960s and 2004. These transects show a maximum of 3000mm (9.8 feet) at Highway 198 (**Figure 2-58**).

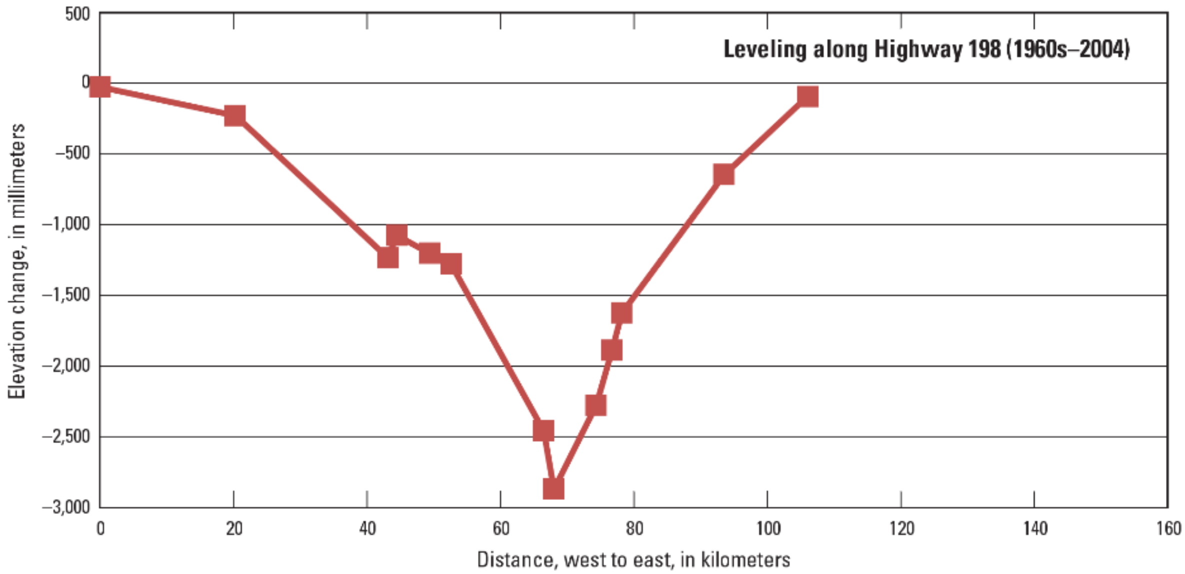


Figure 2-58. Vertical displacement estimated from highway leveling along 198 (1960s-2004) from Sneed and others (2018)

2.2.8.3.2 Extensometers

An extensometer measures the integrated vertical change in thickness (e.g., compaction and expansion) of a specified depth interval. In response to subsidence concerns in the west-central portion of the San Joaquin Valley, extensometers were constructed at eleven sites in vicinity of Westside Subbasin in the 1950s, 1960s, and 1970s by the USGS in cooperation with DWR (Ireland et al, 1984). An additional extensometer (Fordel) was constructed in the late-1990s (**Figure 2-59**). Timeseries of recorded water level, compaction and InSAR (where available) are presented from six key sites (**Figures 2-60 through 2-66**).

Of the twelve historical extensometer sites in the Westside Subbasin vicinity (**Table 2-7**), six sites are currently being measured for water-level changes and compaction (Oro Loma Deep, Panoche, Fordel, Yearout, DWR Yard, and Rasta), two are not operational (14S/12E-12H1 and 15S/16E-31N3), and four cannot be located (15S/13E-11D2, Cantua Creek, 17S/15E-14Q1, and 20S/18E-11Q1) as of 2016 (personal communication, M. Sneed, USGS, October 21, 2016). Four of the currently monitored extensometers target portions of the Lower Aquifer with depths that vary from about 1,000 to 2,000 feet (measuring only a percentage of the aquifer-system that is in places over 2,800 feet deep). Four extensometers were refurbished by the USGS in 2011- 2012 (Oro Loma, Panoche, DWR Yard and Rasta). Three extensometers (Oro Loma Shallow, Fordel and Yearout) target the Upper Aquifer with depths of about 450 feet and are outside the District's boundary to the north and west. Properly operated and installed extensometers can achieve high degrees of accuracy down to the part-per million level of change in displacement.

2.2.8.3.3 California Aqueduct Spirit Leveling and GPS

Measurements of vertical displacement from approximately 500 locations along the California Aqueduct (San Luis Canal) were provided to the District by DWR (**Figure 2-59**). Early measurements of vertical displacement were obtained through leveling (1967, 1993, 2000, 2006, 2009 and 2013). Spirit leveling is the oldest method of measuring subsidence and is a precise way to obtain local vertical displacement data relative to a stable survey location. Subsequent measurements (2015, 2016, 2017, 2018 and 2019) were obtained from static GPS measurements. Estimates of cumulative subsidence are presented from 2000 through 2015 (**Figure 2-67**) and from 2016 through 2019 (**Figure 2-68**). The accuracy of Spirit leveling can be first or second order (given as [4√(Survey Distance)]/1000, and [10√(Survey Distance)]/1000, respectively) depending on the devices used and length of survey intervals. GPS vertical displacement accuracy is dependent on the kinematic differences of the reference points used in the survey network.

2.2.8.3.4 UNAVCO GPS

Continuous GPS stations have been installed throughout the western United States since the early-2000s by the Plate Boundary Observatory (PBO), which is a division of UNAVCO. PBO's primary focus is monitoring plate tectonics from a network of mountain-based stations, but data from the high-precision GPS recorders are also useful for monitoring subsidence from stations located within alluvial sedimentary valleys like the Central Valley. The GPS stations monitor the vertical displacement of the ground surface, which shows how much total compaction is occurring from all depth zones and aquifers, including the Corcoran Clay and underlying clays in the Lower Aquifer. Two stations are in or adjacent to the Westside Subbasin in areas overlying compactable deposits. Of these, only P304 is located in an area experiencing significant rates of subsidence (**Figure 2-59**). Results from P304 are paired with water level and compaction data collected at the Fordel site (**Figure 2-60**). The other (P302), located near I-5 on Panoche Creek, has experienced less than 0.1 feet of subsidence since installation in December 2004. GPS accuracy of PBO sites is dependent on-site installation.

2.2.8.3.5 USBR (SJRRP) GPS Geodetic Control Network

The USBR established the San Joaquin River Restoration Program (SJRRP) Geodetic Control Network in 2011 to monitor subsidence within the SJRRP Restoration Area because subsidence affects infrastructure performance. USBR surveys over 70 control points in the San Joaquin Valley and the District overlaps the southern portion of this area (**Figure 2-59**). The USBR relies on static GPS methods to investigate subsidence within the SJRRP study area and collects and releases data biannually in July and December. Results from the four sites of the SJRRP Geodetic Network located within the Subbasin are presented in **Figure 2-69**. Reported vertical error from the survey in 2011 was estimated as 6.4 centimeters (0.21 feet) at static GPS sites within the USBR control points (USBR, 2011).

2.2.8.3.6 Westlands Water District Geodetic Control Network

A GPS Geodetic Control Network of 15 benchmark monuments and 1 checkpoint was established by the District in December of 2020 to enhance subsidence monitoring for GSP implementation. The sites were located in subsidence prone areas identified near SLC Checks 16, 17 and Check 20 (**Figure 2-59**). Thirteen of the 15 benchmark monuments were set on the concrete meter base of the District's water delivery turnouts. The remaining benchmark monuments were set in concrete within form tubes to a depth of three feet to avoid shallow thermal effects. GPS measurements are tied to Continuously Operating Reference Stations (CORS) to calculate precise location information. Subsequent GPS surveys were conducted in March and October of 2021 and March of 2022 (**Figure 2-70**). Estimated vertical accuracy ranges from 0.5 to 2 centimeters (0.02 to 0.07 ft) (Blair, Church & Flynn, 2021). In addition to the fifteen

(15) benchmark monuments, the District added ten (10) additional benchmark monuments to the subsidence monitoring network. The additional monuments were installed in June of 2022 in areas of the Subbasin where data gaps were present.

2.2.8.3.7 Interferometric Synthetic Aperture Radar (InSAR)

InSAR imagery is produced by reflecting radar signals off an area and measuring the travel time of the radar reflection back to the satellite. Two InSAR images of the same area acquired at different times are used to calculate the travel-time difference. The resulting maps are called interferograms that show ground-surface displacement between the two time periods calculated from the differences in reflection travel times. These can be used for broad regions of interest and can be used to position extensometers or GPS networks to precisely measure compaction or subsidence in a specific area. Generally speaking, the accuracy of most INSAR interferometric estimates of changes in land surface are on the order of 10mm (0.04 in), however, multiple factors can contribute to the accuracy of these differences, especially in agricultural setting where the land surface is displaced owing to cultivation and manual relevelling. This analysis relies on InSAR data has been processed by NASA Jet Propulsion Laboratory (JPL) and TRE Altamira produced for DWR. For presentation purposes, InSAR data have been paired with annual groundwater extraction data provided in **Figures 2-71 through 2-80**.

Data from the NASA JPL were collected by satellite from the Canadian Radarsat-2 mission (May 2014 – January 2015) and the airborne Uninhabited Aerial Vehicle Synthetic Aperture Radar (UAVSAR) mission launched by NASA (May 2013 – November 2018). UAVSAR is flown on a Gulfstream-III aircraft at 41,000 feet and has a higher ratio than satellite SARs (Farr et al., 2015). The NASA JPL also produced an InSAR imagery from Japanese PALSAR data (2006 – 2010), which were evaluated, but not used due to suspected issues with data accuracy and/or post-processing. Estimated vertical accuracy of the InSAR results were reported to be less than 1-inch (0.08 ft) for both Radarsat-2 and UAVSAR (Farr et al., 2015). Post-processed InSAR data were obtained through a Public Records Request to DWR made in March of 2022.

Data from TRE Altamira were collected from the Sentinel-1 satellite mission by the European Commission and European Space Agency (TRE Altamira, 2021). Data were post-processed using the proprietary SqueeSAR methodology to develop stable InSAR imagery at a 100-meter resolution and calibrated to Continuous GPS measurements collected UNAVCO and SOPAC with a reported vertical error of 18mm (0.06 ft) (Towhill, 2021). These data are publicly available and were downloaded through DWR (DWR, 2022).

2.2.8.4 Rates and Areas of Subsidence

2.2.8.4.1 Subsidence (1920's – 1989)

Groundwater withdrawal for irrigated agriculture in the Subbasin began in the mid-1920s and exceeded 960 thousand acre-feet (TAF) prior to CVP deliveries which began in 1968. By 1972, groundwater extraction led to large amounts of subsidence throughout the central portion of the Subbasin and led to the formation of three major subsidence bowls located southwest of Mendota (where subsidence exceeded 28 ft), in the Cantua Creek area and in the Huron area (**Figure 2-56**). Areas outside the Subbasin with high-rates of subsidence were located near Lemoore (up to 8 ft) and Pixley/Delano (up to 12 feet), which were also the subject of extensive study.

Following the start of CVP deliveries through the San Luis Canal in 1968, water levels began to stabilize and recover within the Subbasin until about 1989. During this period, rates of compaction measured at extensometers slowed considerably and generally ceased in about 1972 at the Rasta and Cantua Creek extensometers, about 1976 at the DWR Yard and Panoche extensometers and about 1980 at the Oro Loma Deep extensometer (**Figures 2-61 through 2-64**). An exception to this trend occurred in 1977 where surface water imports were reduced in response to the 1976-1977 drought resulting in increased rates of compaction recorded from extensometers. Inelastic subsidence of between roughly 0.1 and 1 feet continued to occur at these sites despite recovery in water levels due to delayed drainage of water from clayey aquitards resulting in a delay in equilibration of the pore-water pressure within compacting interbeds relative to pre-development conditions prior to the start of large-scale pumping. The variability in delay is likely a function of local groundwater conditions and the geometry and material properties of the fine-grained interbeds at each site.

2.2.8.4.2 Subsidence (1990-2011)

Beginning in 1990, cycles of drought have led to periodic reductions in CVP deliveries resulting in roughly proportionate increases in groundwater pumping. Droughts occurred from 1990-1994, 2007-2010 and 2012-2016. Since 2016, surface water deliveries have alternated between above average (2017, 2019) and below average (2018; 2020-2021). The statewide climate trend reflected in CVP deliveries can be considered as dry since 2007 with many experts more broadly characterizing recent hydrologic conditions as an extended drought. Unlike the period of groundwater level recovery following the start of surface water imports in 1968 when extensometers show delayed subsidence, more recent inelastic compaction and subsidence has generally only occurred during drought periods.

The extent and amount of subsidence that occurred during the drought between 1990 and 1994 is challenging to accurately characterize as measurements are limited to measured compaction from extensometers. Estimates of District groundwater extraction ranged from 225 to 600 TAF and averaged 410 TAF. Extensometers suggest that the greatest compaction during this period was observed in the central portion of the Subbasin at DWR Yard and 17S/15E-14Q1 extensometers (>1 ft) and Cantua Creek (~0.75 ft). Other extensometers in the northern and southern portions of the Subbasin were generally less than 0.5 feet.

The drought from 2007 through 2010 was less pronounced than the early-1990s drought. Estimated District groundwater pumping ranged from 140 to 480 TAF and averaged 347 TAF. Most extensometers were inactive or discontinued by this period. As a result, subsidence which occurred is estimated from readings at PBO continuous GPS stations and InSAR derived from Environmental Satellite (ENVISAT) and Advanced Land Observing Satellite (ALOS) data summarized in Sneed and others (2018). Most areas of the Subbasin experienced less than 0.3 feet of subsidence during this period. However, locally higher amounts of subsidence were measured near Helm (0.57 ft) and Kettleman City (0.41 feet). Surveys along the California Aqueduct between 2006 and 2009 by DWR also reveal up to about 0.4 feet of subsidence between Check 19 and 20 as well as in the vicinity of Check 17 (**Figure 2-67**).

2.2.8.4.3 Subsidence (2012-2016)

The drought period from 2012 through 2016 provides many insights regarding compaction and land subsidence both because of the extreme hydrologic conditions experienced during this time and the increase in availability of data with respect to rates and distribution of subsidence and groundwater pumping.

Maps of the distribution of groundwater pumping on a quarter-township (3x3 miles) were prepared for the 2013 through 2016 federal water contract year (March-February). Estimated total District groundwater pumping ranged from 321 TAF in 2012 to 671 TAF in in 2016 and averaged 543 TAF. Groundwater extraction maps show relatively consistent high volumes of groundwater pumping over a widespread area surrounding the greater Huron and near and northwest of Cantua Creek.

Groundwater pumping amounts correlate well with areas experiencing high rates of land subsidence shown by the InSAR derived from Radarsat-2 data (**Figure 2-71**) for 2015, cumulative subsidence from InSAR derived from UAVSAR data from May 2013 through April 2017 (**Figure 2-72 through 2-74**) and annual subsidence from InSAR derived from Sentinel-1 data from March 2016 through March 2017 (**Figure 2-76**). Maps of subsidence from InSAR derived from UAVSAR InSAR are limited to an approximately 13.5-mile wide area surrounding the California Aqueduct. These maps illustrate two primary subsidence bowls used in 2020 by the District to identify subsidence prone areas. Subsidence in the northern bowl, in the vicinity of Check 16 and 17, totals up to 1.5 feet over the drought period as measured at USBR High Precision Geodetic Network (HPGN) 06 07 near Cantua Creek (**Figure 2-69**). Subsidence in the southern bowl, located near Check 20, total up to approximately 3 feet. The greatest subsidence in the southern bowl correlates well with one township-quadrant where pumping regularly exceeded 2.5 acre-feet per acre. Subsidence captured by InSAR tends to correlate well with compaction measured at extensometers and with the DWR aqueduct surveys, although dates are not provided in the latter making it more challenging to differentiate inelastic and elastic subsidence.

As the area of interest focused on the SLC, InSAR derived from UAVSAR do not fully capture other notable areas which experienced large amounts of subsidence during the 2012-2016 drought. Subsidence in these areas is better illustrated through InSAR derived from Radarsat-2 and Sentinel-1 data and land surface measurements made by the USBR through the SJRRP static GPS benchmarks. These include a widespread area located on the Subbasin boundary west of Lemoore and Stratford. Up to 1.5 feet of subsidence also occurred in two localized areas in the vicinity of Helm and Tranquility as measured by the Burnside and Murrieta USBR static GPS benchmarks, respectively (**Figure 2-69**). Particularly near the Subbasin boundary, subsidence in these areas does not correspond as well with pumping within the District, suggesting pumping and groundwater level declines within adjacent Subbasins may contribute to subsidence in these areas.

2.2.8.4.4 Recent Subsidence (2017-2021)

Climate patterns were mixed between 2017 and 2021 and include three dry years with much lower than average surface-water deliveries (2018, 2020, 2021) and average to higher than average deliveries in 2017 and 2019. Total estimated groundwater extraction was 87 and 93 TAF during wet water contract years in

2017 and 2019, respectively. Total estimated groundwater pumping during dry years was 330 TAF in 2018, 485 TAF in 2020 and 631 TAF in 2021.

Wet years in 2017 and 2019 are notable in that reduced groundwater pumping resulted in the reversal of a portion of the subsidence experienced during the previous drought due to elastic expansion of clay interbeds and (to a lesser extent) coarse grained materials in the Subbasin as water levels increased. However, water levels measured at active extensometer sites indicate that groundwater conditions did not return fully to pre-drought conditions (i.e., conditions prior to 2012) (**Figures 2-61 through 2-64**). Notably, some areas outside the Subbasin (particularly in the Lemoore/Riverdale and El Nido) continued to experience relatively high rates of subsidence despite wetter than average statewide conditions (**Figures 2-76 and 2-78**). InSAR collected from Sentinel-1 suggests that the greatest increase in land surface elevation occurred in the middle of the central and southern portions of the Subbasin by as much as 0.3 to 0.5 feet from March 2017 to March 2018 roughly correlating with some areas which experienced the highest amounts of subsidence during the 2012-2016 drought (**Figure 2-76)**. Elastic recovery of subsidence at the USBR HPGN 06 07 totaled about 0.5 feet where other USBR sites show much smaller recovery (between 0.1 and 0.25 feet). Elastic recovery was less between March 2019 and March 2020 totaling 0.1 to 0.2 feet at most and likely within the range of the vertical accuracy of both InSAR and GPS benchmarks (**Figure 2-78**).

Dry conditions beginning in the 2020 Water Year have led to renewed subsidence within most of the Subbasin. Similar pumping patterns to the 2012-2016 drought have emerged leading to a decline in water levels measured at extensometers which approach lows experienced during the 2012-2016 period. Within numerous portions of the Subbasin, groundwater pumping exceeded 2 acre-feet per acre. InSAR indicates that land subsidence has approached 0.75 feet near the southwestern boundary of the Subbasin and approaches or exceeds 0.5 feet along portions of the San Luis Canal from 2020-2021 (**Figures 2-79 and 2-80**). Subsidence measured at USBR GPS benchmarks between December 2019 and December 2020 totals 0.7 feet at HPGN 06 07, 0.5 feet at Burnside and 0.4 feet at Murietta (**Figure 2-69**). Rates of subsidence measured at WWD benchmarks between March of 2021 and March of 2021 located near Check 20 exceeds 0.4 feet at 7 of 8 sites (**Figure 2-70**).

2.2.8.4.5 Vertical Distribution of Compaction and Planning Considerations

As described in Faunt and others (2009), the greatest amount of subsidence in the San Joaquin Basin is thought to occur within aquitards (or interbeds) below the Corcoran clay. This is due to several factors including the level of confinement, amounts of groundwater extraction and relatively greater total thickness of fine-grained interbeds in the Lower Aquifer. Ireland and others (1984) compared compaction measured at numerous extensometers to surveyed subsidence, to develop a relationship between depth and proportion of total subsidence (**Figure 2-81**). Results indicated that perhaps 80 percent of total subsidence occurs due to compaction at depths below 500 feet. This relationship can also be observed in **Figure 2-60** comparing measured compaction at the Fordel extensometer (depth: 450 ft bgs) and subsidence at the nearby UNAVCO P304 site near Mendota and at the Oro Loma Shallow (375 ft bgs) and Deep (1,000 ft bgs) extensometers shown in **Figure 2-61**, which show relatively small amounts of compaction in the Upper Aquifer.

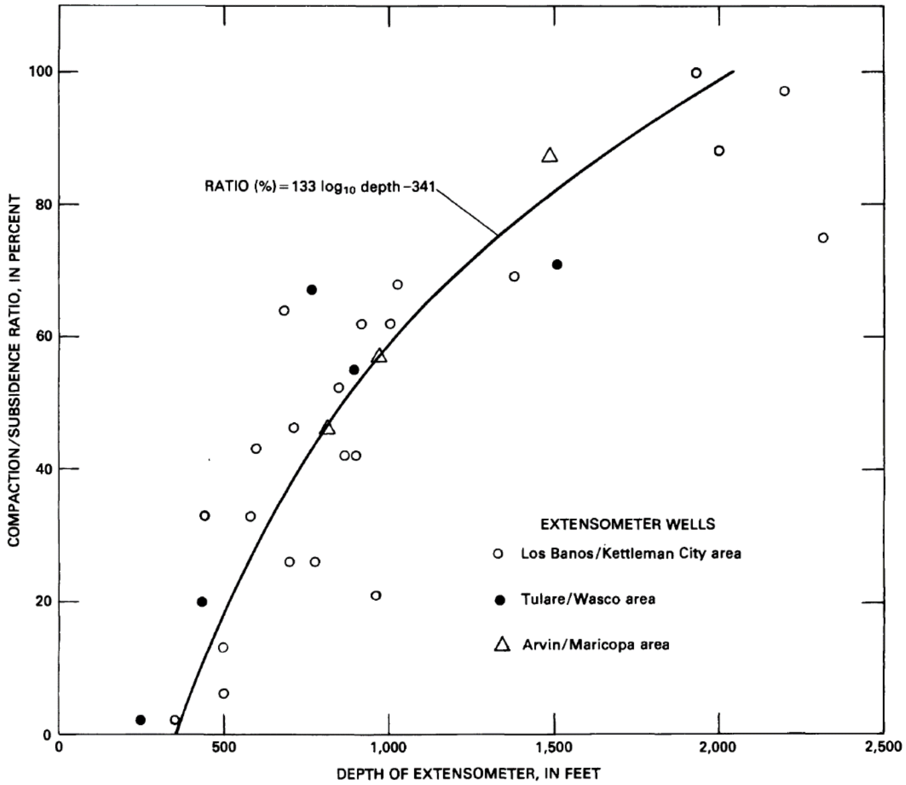


Figure 2-81. Relation of compaction/subsidence ratios to depth at extensometer wells in the San Joaquin Valley (from Ireland et al., 1984)

However, some portions of the Upper Aquifer may be susceptible to more significant amounts of compaction. Findings in Lees and others (2021) from modeling conducted near Hanford, CA suggest that that given "… significant head decline, it is possible for substantial subsidence to originate within the unconfined-to-semi-confined upper aquifer" (Lees et al., 2021). Areas of the Upper Aquifer may be locally prone to greater compaction where:

- The Upper Aquifer is appreciably thick (likely greater than 500 feet),
- The Upper Aquifer is composed of a significant fraction of fine-grained (compressible) interbeds that produce confined or semi-confined conditions,
- Groundwater withdrawal from the Upper Aquifer wells is great enough to reduce aquitard pore-pressure below the preconsolidation head. This can occur through long-term groundwater level declines (overdraft) or high rates of shorter-term (seasonal) pumping.

There is the potential that this risk may be mitigated through proper planning combined with measures to monitor compaction or subsidence where these conditions occur. The extent of subsidence as well as the potential efficacy of mitigation measures will be dependent upon both regional and site- specific information. Consequently, data pertinent to subsidence in the Upper Aquifer will continue to be collected and analyzed.

2.2.9 Water Supply

2.2.9.1 Imported Surface Water

Conjunctive use of surface and groundwater improves overall water supply reliability making more efficient use of water that is available. In wet periods, use of surface water is encouraged by WWD to preserve groundwater supplies (WWD, 2012). Imported surface water use within the Subbasin is derived largely from CVP water deliveries from the SLC and from other sources such as water transfers and exchanges. The District has an annual contract entitlement from Reclamation for 1,150,000 AF of water from the CVP; however, CVP allocations are often much lower (WWD, 2012). The District's surface water supply totals 1,197,000 AF which includes approximately 47,000 AF from CVP reassignment contracts.

2.2.9.1.1 Historical Surface Water Supplies

Surface water deliveries from the CVP began in 1968 with the goal to reduce groundwater pumping (WWD, 2016). Since 1990, however, CVP water supplies have been reduced annually due to drought and regulatory actions resulting from the Central Valley Project Improvement Act (CVPIA), the Endangered Species Act (ESA), Bay/Delta water quality requirements, and Court orders. The use of low salinity surface water for irrigation within the Subbasin has resulted in an increase in groundwater levels and decreasing trends in soil and shallow groundwater salinity in agricultural areas during the irrigation season (Carollo and LSCE, 2015). CVP water and other surface water supplies are carefully allocated, and all deliveries are metered. The annual imported water totals shown in **Figure 2-82** is the sum of water delivered within the District's boundaries (shown on **Figure 2-83**), including both CVP and other surface water supplies acquired by both landowners and the District (e.g., surplus water, supplemental supplies, and other adjustments). **Figure 2-82** shows the reduction of total surface water supplies in drought years (1991 to 1992, 2008 to 2009, and 2013 to 2015). Surface water deliveries have experienced a long-term declining trend since the mid-1990s, from a high of almost 1.4 MAF in 1984 to a low of about 200,000 AF in 2014 and 2015.

2.2.9.2 Conveyance System and Distribution

The District is in the San Luis Unit of the CVP and includes the SLC and the 12-mile concrete-lined Coalinga Canal facilities. The District has a permanent distribution system that consists of a closed, 1,034-mile buried pipeline network that conveys irrigation water from the SLC, Coalinga Canal, and a 7.4-mile unlined canal from the Mendota Pool to agricultural land. The distribution system was built between 1965 and 1979 (WWD, 2012) and serves about 88 percent of the irrigable land within the District's boundaries. The distribution system includes metered deliveries that allows optimum water management with virtually no losses to seepage, evaporation, and spills. Most of the irrigated land is east of the SLC and slopes from an elevation of about 320 ft to about 180 ft at the eastern edge and are fed by gravity laterals. Lands west of the SLC sit at a higher elevation and are served by pumping from both the SLC and by gravity from the Coalinga Canal. Lands not served by the distribution system use farmer-constructed temporary-diversions. **Figure 2-83** identifies the District's water conveyance system locations, the distribution system pipelines, and the delivery points.

2.2.10 Surface Water Bodies

Natural surface water bodies are limited by the arid climate and consist primarily of intermittent streams originating from the Coast Range. The main streams located in the Subbasin are the Little Panoche and Panoche Creeks, Arroyo Hondo, Cantua, Salt, Marinez, Domengine, and the Arroyo Pasajero (Los Gatos and Zapato Chino Creeks) which all flow eastward from the foothills. **Figure 2-84** shows the stream locations as well as the areas within the Subbasin with higher potential for groundwater recharge (Carollo and LSCE, 2015). Continuous flow measurements are only recorded at Panoche, Cantua, and Los Gatos Creeks. The remainder of creeks are either not gaged or are only measured for peak flows. Records indicate that flows are infrequent and are generally less than 100 cubic feet per second (cfs), with maximum peak flows of about 2,500 cfs (**Figure 2-84**). Results from the numerical model based on measured and estimates flow in natural surface water bodies show groundwater recharge from streams ranges from 0 AF in dry years to over 30,000 AF in wet years.

2.2.10.1 Groundwater Dependent Ecosystems

Groundwater dependent ecosystems (GDEs), as defined under SGMA, are ecological communities of species that depend on groundwater emerging from aquifers or on groundwater occurring near the surface. (GSP Regulation, § 351(m).) GDEs are considered a beneficial user of groundwater and must be identified and considered in a Subbasin's GSP. In the Subbasin, which is predominantly agricultural land use with an arid climate, GDEs are sparse and cover small areas, primarily occurring along ephemeral streams in the western portion of the Subbasin. The potential occurrence of GDEs were initially identified from datasets produced by TNC which contained mapped vegetation and wetlands representing groundwater dependent ecosystem indicators (GDEi) (**Figure 2-14**) (Rohde and others, 2018). The methodology used to identify GDEs was adapted from Rohde and others, 2018. The first recommended step to determine whether the TNC "potential" GDEs exist was to evaluate depth to water in the Shallow Zone using 30 ft bgs as a threshold. Using depth to water measurements in winter of 2014/2015, groundwater depths were generally less than 30 ft bgs (**Figure 2-85**).

As discussed in section 2.2.2.1.1 and displayed in **Figure 2-33B**, shallow zone groundwater elevations, in a few locations, are generally within 30 feet bgs. Unlike the rest of the Upper Aquifer, these groundwater elevations show very little variation over time in relation to seasonal pumping or climatic conditions. The most likely explanation for the consistent groundwater elevations in the shallow zone is the recharge from applied irrigation. For areas in the Subbasin where shallow groundwater wells are present, GDEs likely exist but are supported by irrigation, not naturally occurring groundwater. For this reason, where shallow wells are present near GDEs, these wells will monitor GDEs as part of the monitoring network. In the event of land fallowing, shallow groundwater elevations could decline. Incorporating these GDEs could potentially complicate the GSP implementation as land fallowing may be necessary to conserve resources and prevent undesirable results in the Upper and Lower Aquifers.

Potential GDEs are also present along the streams in the western side of the Subbasin where shallow wells are not present. These streams have been designated as a data gap for ISWs due to a lack of shallow groundwater elevation data. Once a period of record is established for shallow groundwater level elevations, the GSA will evaluate whether these potential GDEs rely on naturally occurring groundwater and take steps as needed to protect these beneficial uses of groundwater. If it is determined that naturally occurring groundwater supports GDEs along these streams, shallow wells and GDEs will be incorporated into the monitoring network for the existing data gap areas in future GSP updates.

2.2.10.2 Ecological Conditions

Ecological conditions were assessed to determine the conservation value of potential GDEs in the Westside Subbasin. Within the Subbasin, there are no critical habitats containing either threatened species or endangered species. Using publicly available datasets recommended by TNC (Rohde and others, 2018), **Figure 2-86** shows the mapped critical habitats around the Westside Subbasin obtained from the US Fish and Wildlife Service's (USFWS) Environmental Conservation Online System. As shown in **Figure 2-86**, there are no critical habitats identified in the Subbasin. While there are no critical habitats in the Subbasin, this does not exclude the possibility that endangered or threatened species may be present in the Subbasin.

2.3 Water Budget (GSP Reg. § 354.18)

The hydrologic budget summarizes the inflows and outflows to and from the Subbasin (GSP Regulation §354.18(b)). For GSP planning purposes, hydrologic budgets have been prepared for a historical water budget period, a current water budget year, and projected water budget period, which includes the 50-year GSP planning and implementation horizon. For the purposes of GSP preparation the Subbasin water budget was derived primarily from output generated by the Westside Groundwater Model (WSGM) developed as part of the GSP preparation and described in **Appendix I**. The WSGM is an integrated hydrologic model where land surface and groundwater processes are calculated simultaneously through a tightly coupled numerical model approach. The Subbasin water budgets and a summary of the GSP water budget periods are described below. The groundwater budget results for the historical, current, and projected periods are summarized below for the entire Subbasin. Aquifer specific groundwater budgets are presented in **Appendix I.**

2.3.1 Hydrologic Budget Terms

Water budgets are similar to a bank account in that there are inflows, outflows, and a change in the bank account balance or storage. Inflows and outflows in the hydrologic system are largely driven by processes occurring on the land surface. Within the Subbasin, these inflows and outflows are dominated by land use, especially irrigated agriculture. The water budgets are segregated into a land surface budget and a groundwater budget as shown on **Figure 2-87**. The primary inflows to the land surface budget include precipitation, imported surface water for farming operations and irrigation, and applied water for irrigation that is derived from groundwater pumping. Ephemeral streams which flow from the Coast Range in the west are also a part of the land surface system. These streams flow in wet years during the winter and spring and are an inflow to the land surface budget. Under other conditions, groundwater seepage from the streams is an outflow from the land surface into the groundwater budget. These streams terminate within the Subbasin and there is no natural surface water outflow from the Subbasin.

Outflows from the land surface budget include evapotranspiration and percolation of applied water to the groundwater system. Surface waters from streams and rivers do not flow out from the Subbasin. Water that flows in the San Luis Canal/California Aqueduct does enter and exit the Subbasin, however, this water is conveyed in a concrete-lined canal and is not separately accounted for in the land surface budget, only the amount from the canal that is conveyed to lands within the Subbasin. Groundwater and surface water imported for irrigation is used to satisfy crop demand and leaves the system due to plant transpiration and evaporation from the ground surface. A portion of the applied water is not used by the crops and instead percolates to the aquifer system as deep percolation. Similarly, precipitation is either consumed as evapotranspiration from crops and native vegetation or evaporates from bare soil. The portion of precipitation not consumed by evapotranspiration or evaporation percolates through the soil and recharges the groundwater system as deep percolation. During the water budget periods, any water that falls as precipitation or applied water that contributes to runoff or is collected by drains prior to recharging the aquifer system does not leave the Subbasin via the land surface. Diversion of agricultural tail water outside the Subbasin has been prohibited since the 1980's. As a result, the District has promoted efficient irrigation practices, reuse of tail water and has retired portions of the Subbasin impacted by historical drainage issues.

Direct uptake of groundwater for evapotranspiration acts as both an inflow and an outflow to the land surface budget. For simplicity, this is not directly reported in the land surface budget and is subtracted from the deep percolation term. As a result, deep percolation is reported as "Net Deep Percolation". Since streams act solely as a source of recharge to the groundwater system and terminate in the Subbasin, inflows and outflows of surface water are not reported in the land surface budget. The water exchanged between streams and the aquifer system is summarized in the "Stream Leakage" term in the groundwater budget.

The land surface system drives the stresses on the groundwater system. Inflows to the groundwater budget include areal recharge to the water table from deep percolation of applied water and precipitation described above, groundwater inflows into the Subbasin, and seepage from streams. The major outflows in the groundwater system are groundwater pumping to meet irrigation demand and lateral flow of groundwater to adjacent Subbasins.

2.3.2 Water Budget Estimation

The time period for calculating the historical water budget was selected to reflect overall average hydrologic conditions based on natural recharge through analysis of the cumulative departure from mean precipitation. The period selected for analysis spans from 1989 through 2015 water years. In order to evaluate the system response to hydrologic variability, this timeframe contains a series of wet and dry years. The historical water budget period and a listing of the hydrologic year types used to define the historical period is shown in **Table 2-8**. Local hydrologic conditions influencing streamflow, precipitation and reference evapotranspiration are best reflected by the San Joaquin Valley water year type. The availability of surface water imports (which are largely from the Sacramento Valley watershed) affect land use and consequently Sacramento Valley water year type is more representative of local hydrologic conditions than alternatives.

The 2016 water year was selected as the current water budget year. At the time of WSGM development, 2016 was the most current water budget year with complete data required for analysis. The water budget year was below normal in the Sacramento Valley and dry in the San Joaquin Valley.

The projected water budget period used for GSP analysis spans a total of 54 water years beginning in 2017 and ending in 2070 (October 2016 – September 2070). Data used to define the hydrology and datasets over this period corresponds to October 1965 through September 2018 (**Table 2-9**). Data from this period include wet and dry periods and are representative of overall average conditions based on water year type. Precipitation, reference evapotranspiration and streamflow assigned in the WSGM projected water budget period utilized historical data from the 1965 through 2018 period. In those months and/or years where historical data was not available, monthly and/or annual data from the most similar San Joaquin Water year type was used as a surrogate. Surface water data used in the projection were taken from the CalSim II 2030 Central Tendency Projection developed jointly by USBR and DWR for SGMA analysis (USBR, 2015). From the 2003 though 2018 historical period where CalSim data were not available, corresponding data from the nearest Sacramento Valley water year were used as a surrogate. Monthly CalSim II deliveries were aggregated by USBR contract water year and distributed in each month based on crop demand. CalSim II data deliveries were used in place of historical data because CalSim accounts for current factors such as the CVPIA that substantially reduced imports but are not included in the entire historical dataset.

The projected water budget must also consider the impacts of climate change and future projections of land use and population. For the purposes of the projected water budget analysis, climate change was the only factor that was considered to have a significant influence. The other variables, land use and population, are expected to remain relatively static over the projected water budget period.

Climate change influenced surface water deliveries, evapotranspiration, precipitation and natural streamflow. Variability due to climate change was incorporated into the WSGM using climate change factors and methodology outlined in the Climate Change Resource Guide and Guidance for Climate Change Data Use During Sustainability Plan Development prepared by DWR. (DWR, 2018). The 2030 and 2070 central tendency datasets were applied to WSGM data from March 2017 through October 2070. It is anticipated that SGMA and projected imported water supplies will have the largest influence on land use during the GSP 50-year planning and implementation horizon. Sustainable groundwater management will likely affect the amount of irrigated acreage within the Subbasin. For planning purposes, SGMA's impact on land use is evaluated in **Section 4.2**.

2.3.3 Historical Water Budget (GSP Reg. § 354.18(c)(2))

The water budget for the historical water budget period (1989 through 2015) is summarized by water year and presented below. The water budget includes inflows, outflows summarized with respect to the land surface system and groundwater system. This information is calculated from results simulated in WSGM based on hydrology, water supply and land use information from October 1989 through September 2015. Additional details with respect to modeling assumptions and simulated results are described in detail in **Appendix I**.

2.3.3.1 Land Surface System

Inflows of water into the land surface system budget in the Subbasin include precipitation, imported surface water and groundwater pumping. These are summarized annually in **Table 2-10** and **Figure 2-88**. Total simulated inflows over the historical period ranges from 982,000 AFY to 1,844,000 AFY and averages 1,502,000 AFY. Simulated precipitation ranges from 160,000 AFY to 847,000 AFY with an average of 389,000 AFY. Imported surface water ranges from 179,000 AFY to 1,373,000 AFY and averages 841,000 AFY. Throughout the historical period, the District maintained a CVP contract of 1,190,000 AF through the USBR. Groundwater pumping applied to the land surface system ranges from 79,000 AFY to 697,000 AFY and averages 325,000 AFY.

Outflows from the land surface system budget in the Subbasin include evaporation and deep percolation and are summarized annually in **Table 2-10** and **Figure 2-88**. Net deep percolation is equal to deep percolation to the aquifer system minus the direct groundwater uptake from plants and evaporation. Total simulated outflow ranges between 982,000 and 1,845,000 AFY and averages 1,503,000 AFY between 1989 through 2015. Total evapotranspiration ranges from 920,000 and 1,399,000 AFY and averages 1,185,000 AFY (**Table 2-10**). Net deep percolation ranges from 30,000 to 528,000 AFY and averages 317,000 AFY.

Throughout the historical period, the District maintained a CVP contract of 1,197,000 AF through the USBR. Over the most recent 10 years (2009 through 2018), the District received between 9,000 and 911,000 AFY of the District's total CVP contract. When summarized by USBR allocation water year (March through February) the average CVP delivery was 394,000 AFY (**Table 2-11**). During this same ten-year period, the District and individual water users have imported between 86,000 and 252,000 AFY of additional water averaging 166,000 AFY. As a result, total imported supplies have ranged from 168,000 to 1,129,000 AFY (**Table 2-11**). Generally, the reliability of surface water imports is a function of Sierra snowpack, runoff, reservoir levels and environmental constraints.

Table 2-11: Imported Surface Water to the Westside Subbasin (2009-2018)

Water Year	WY Index[1]	CVP Allocation (%)	Net CVP (AF)	Water User Acquired (AF)	Total Imported Surface Water (AF)
2009	D	10%	203,000	138,000	341,000
2010	BN	45%	590,000	151,000	741,000
2011	W	80%	877,000	252,000	1,129,000
2012	BN	40%	405,000	235,000	640,000
2013	D	20%	188,000	245,000	434,000
2014	C	0%	99,000	86,000	185,000
2015	C	0%	82,000	86,000	168,000
2016	BN	5%	9,000	247,000	256,000
2017	W	100%	911,000	124,000	1,036,000
2018	BN	50%	580,000	98,000	678,000
Average	**-**	**35%**	**394,000**	**166,000**	**560,000**

[1] C is Critical, D is Dry, BN is Below Normal, W is Wet

2.3.3.2 Groundwater System

Groundwater inflows include net deep percolation from precipitation and irrigation, seepage from streamflow to the aquifer system from ephemeral streams and lateral subsurface flow and are summarized for the historical water budget in **Table 2-12** and **Figure 2-89**. Total simulated inflow to the groundwater system ranges from 159,000 to 747,000 AFY and averages 477,000 AFY. Simulated net deep percolation averages 317,000 AFY and ranges from 28,000 to 530,000 AFY. Simulated seepage from streams ranges from nearly none to 33,000 AFY and averages about 10,000 AFY. Lateral subsurface inflow from adjacent subbasins ranges from 88,000 AFY to 245,000 AFY and averages 151,000 AFY.

Outflows from the groundwater system include groundwater pumping and lateral subsurface outflow to adjacent subbasins and are summarized in **Table 2-12** and **Figure 2-89**. Total simulated outflow from the groundwater system ranges from 240,000 to 865,000 AFY and averages 493,000 AFY. Groundwater pumping ranges from 91,000 AF in 2005 to nearly 700,000 AF in 1991 and averages 324,000 AFY. Lateral subsurface outflow to adjacent subbasins averages 169,000 AFY with a range from 144,000 to 192,000 AFY. Annual declines in groundwater storage range up to 568,000 AF and with annual increases in storage of up to 427,000 AF and varies depending on hydrologic year type.

2.3.3.3 Estimated Groundwater Overdraft

On the scale of the Subbasin, WSGM simulates a decline in groundwater storage averaging 19,000 AFY. Over the entire historical water budget period the cumulative decline in groundwater storage was nearly 517,000 AF (**Table 2-12**). While this measure of overdraft suggests the Subbasin was in an overdraft condition, this amount of groundwater storage decline represents less than 4% of total outflow and less than 6% of total groundwater pumping; suggesting that the Subbasin groundwater budget is relatively balanced over the historical water budget period.

The spatial distribution of the total accumulated change in groundwater storage from WSGM is shown in **Figure 2-90** to evaluate areas within the Subbasin that have experienced overdraft over the historical period. These results illustrate greater storage declines towards the central and southeastern portion of the Subbasin during the historical period and more stable groundwater levels to the west. This is consistent with the spatial distribution of subsidence, which is the primary indicator of overdraft in the Subbasin.

2.3.3.4 Estimated Sustainable Yield

Section 10721(w) of the California Water Code defines the sustainable yield as:

> "the maximum quantity of water, calculated over a base period representative of long-term conditions in the basin and including any temporary surplus, that can be withdrawn annually from a groundwater supply without causing an undesirable result."

Recognizing uncertainty resulting from data limitations and approach, multiple estimates of sustainable yield are provided. The sustainable yield provided includes previous estimates developed by the District and USBR, and an updated estimate derived from the WSGM.

- Previous estimates of sustainable yield (assuming "safe yield" or "perennial yield" are interchangeable) have varied to some degree. An internal estimate developed for the District's 1996 Groundwater Management Plan estimated a perennial yield of 200,000 AFY using a "best fit line" approach, however, this estimate was for the Lower Aquifer portion of the Subbasin. An estimate developed for the USBR Special Task Force Report on the San Luis Unit estimated safe yield as high as 312,000 AFY.
- The Subbasin sustainable yield for the historical period can be approximated by the relationship between long-term pumping and groundwater storage change by:

$$Sustainable\ Yield = Q_h + \Delta S_h \quad (4)$$

where: Q_h is the average annual gross pumping within the Subbasin simulated in the historical period

ΔS_h is the average annual gross change in groundwater storage in the Subbasin simulated in the historical period

This approach is based on the expectation that a reduction in long-term groundwater pumping will produce a roughly commensurate increase in long-term groundwater storage such that a reduction in pumping will effectively offset a decrease in storage. Given a long-term average pumping of 324,000 AFY and a decline in storage of 19,000 AFY, the approximate sustainable yield for the basin estimated from WSGM is 305,000 AFY.

2.3.4 Current Water Budget Assessment (GSP Reg. § 354.18(c)(1))

The water budget for the 2016 water year (October 2015 through September 2016) is presented in **Table 2-13** and **Table 2-14**. The water budget includes inflows, outflows summarized with respect to the land surface system and groundwater system. Streamflow occurs from relatively small ephemeral streams which enter the Subbasin from the Coast Range in the west. This information is calculated from results simulated in WSGM based on 2016 water year hydrology, water supply and land use. More detailed budget information is provided in **Appendix I**.

2.3.4.1 Land Surface System

Inflows to the land surface system include precipitation, imported surface water and groundwater pumping and summarized in **Table 2-13**. Precipitation contributes 467,000 AF to the Subbasin in the current water budget year. Imported surface water totals 255,000 AF. Of this total, WSGM utilizes 252,000 AF during the simulation. Approximately 0.3 percent of the total was not used for evapotranspiration was likely utilized for other farming practices that utilize water but are not well documented such as leaching, frost protection, etc. This small amount does not have a significant influence on model results when compared to the total amount of water utilized. Groundwater pumping contributes a total of 564,000 AF.

Outflows to the land surface system include evapotranspiration and net deep percolation and are summarized in **Table 2-13**. WSGM simulates a total outflow of 1,321,000 AF for the land surface system in the 2016 water year. Evapotranspiration totals 1,081,000 AF. Net deep percolation from irrigation and precipitation totals 201,000 AF.

Table 2-13: Current Year Land Surface Water Budget - Westside Subbasin (2016)

Water Budget Term	Volume (AF)
Precipitation	467,000
Imported Surface Water[1]	255,000
Utilized Surface Water[2]	252,000
Groundwater Pumping	564,000
Total Inflow	**1,321,000**
Evapotranspiration	1,081,000
Net Deep Percolation[3]	201,000
Total Outflow	**1,321,000**

1. Reported surface water imports from District records
2. Simulated surface water imports in WSGM (some water rejected)
3. Difference between deep percolation and direct groundwater uptake

2.3.4.2 Groundwater System

Groundwater inflows include net deep percolation from precipitation and irrigation, stream seepage from ephemeral streams and lateral subsurface flow and are summarized for the current water budget year in **Table 2-14**. Total inflow for the current water budget year is 404,000 AF. Simulated net deep percolation totals 165,000 AF. Seepage from streams totals less than 1,000 AF. Lateral subsurface inflow from adjacent subbasins is 239,000 AF for the year.

Groundwater outflows include groundwater pumping, stream leakage (stream gain) and lateral subsurface outflow and are summarized in **Table 2-14**. Total groundwater outflow totals 733,000 AF in the current water budget year. Outflow due to pumping totals 558,000 AF and occurs largely between May through August. Simulated flows from the aquifer to the stream system are negligible. Lateral subsurface outflow is 175,000 AF. The groundwater model simulates a groundwater storage decline of 330,000 AF for the current water budget year.

Table 2-14: Current Year Groundwater Budget - Westside Subbasin (2016)

Water Budget Term	Volume (AF)
Net Deep Percolation (af)	165,000
Stream Leakage (af)	0
Lateral Subsurface Inflow (af)	239,000
Total Inflow (af)	**404,000**
Groundwater Pumping (af)	558,000
Lateral Subsurface Outflow (af)	175,000
Total Outflow (af)	**733,000**
Change in Groundwater Storage (af)	**-330,000**

2.3.5 Projected Water Budget (GSP Reg. § 354.18(c)(3))

The water budget for the projected period from 2017 through 2070 is summarized by water year and presented below. Results for the 2017 through 2019 water budget years are included in the results to summarize water budget period between the current and projected periods but are not used in analysis of sustainability during the projected water budget period, rather the focus is on the 2020 through 2070 projected period. The water budget includes inflows, outflows summarized with respect to the land surface system and groundwater system. This information is calculated from results simulated in WSGM based on hydrology, water supply and land use information from October 2019 through September 2070. A detailed description of model assumptions, input, structure and results is provided in **Appendix I**.

2.3.5.1 Land Surface System

Inflows of water into the land surface system budget in the Subbasin include precipitation, imported surface water and groundwater pumping and are summarized annually in **Table 2-15** and **Figure 2-91**. Total simulated inflows over the projected water budget period ranges from 1,128,000 AFY to 1,666,000 AFY and averages 1,343,000 AFY.

Outflows from the land surface system budget in the Subbasin includes evaporation and deep percolation and are summarized annually in **Table 2-15** and **Figure 2-91**. Total simulated outflow ranges between 1,128,000 AFY to 1,666,000 AFY and averages 1,343,000 AFY.

2.3.5.2 Groundwater System

Groundwater inflows include net deep percolation from precipitation and irrigation, stream loss to the aquifer system from ephemeral streams and lateral subsurface flow and are summarized in **Table 2-16** and **Figure 2-92**. Total simulated inflow to the groundwater system ranges from 291,000 to 736,000 AFY and averages 451,000 AFY.

Outflows from the groundwater system include groundwater pumping and lateral subsurface outflow to adjacent subbasins and are summarized in **Table 2-16** and **Figure 2-92**. Total simulated outflow from the groundwater system ranges from 278,000 to 937,000 AFY and averages 501,000 AFY.

Projected subsurface inflow and outflow conditions are based on historical groundwater conditions in the adjacent basins. Projected subsurface inflows and outflows may, in the future amendments and interim updates to the GSP, need to be adjusted to account for sustainable management criteria in adjacent basins that permit groundwater conditions to fall below historical levels.

2.3.5.3 Projected Groundwater Overdraft

Given the conditions specified, the WSGM simulation projects a total decline in groundwater storage of 2,709,000 AF over the 50-year GSP planning horizon with an annual water balance deficit of 53,000 AFY **Table 2-16**. However, it should be recognized that simulated net lateral subsurface outflow from the Subbasin increases annually by an average of 6,000 AFY when compared to the historical period (**Table 2-12** and **Table 2-16**). This suggests that projected groundwater conditions in adjacent subbasins contribute to some extent to overdraft conditions within the Subbasin compared to the historical period.

2.3.5.4 Projected Sustainable Yield

The sustainable yield for the Subbasin under these baseline conditions was estimated using the following equation:

$$Sustainable\ Yield = Q_p + \Delta S_p + (L_h - L_p) \qquad (5)$$

where: Q_p is the average annual groundwater pumping within the Subbasin simulated in the projected model

ΔS_p is the average annual change in groundwater storage in the Subbasin simulated in the projected model.

L_h is the average annual lateral subsurface inflow into the Subbasin from adjacent subbasins simulated during the historical water budget period.

L_p is the average annual lateral subsurface inflow into the Subbasin from adjacent subbasins simulated during the 2020 through 2070 projected water budget period.

One of the benefits of this methodology is that the resultant sustainable yield estimate accounts for gross differences between historical and projected lateral subsurface flow between the Subbasin and adjacent GSAs as compared to historical methodologies of safe yield that accounts for total amount of subsurface inflows as a component of safe yield.

Based on this methodology, the projected sustainable yield is 269,000 AFY from the equation above. This is based on projected groundwater pumping of 322,000 AFY and decline in projected groundwater storage of 53,000 AFY. Simulated average historical net lateral subsurface flow from 1989 through 2015 is 18,000 AFY out of the Subbasin, while projected net lateral subsurface flow from 2020 through 2070 is 25,000 AFY out of the Subbasin resulting in a net difference of 6,000 AFY.

2.3.6 Projected Water Budget - 2030 Central Tendency Climate Scenario

The water budget for the projected water budget period (2020 through 2070) assuming 2030 climate change factors are summarized by water year and presented below.

2.3.6.1 Land Surface System

Inflows of water into the land surface system budget in the Subbasin include precipitation, imported surface water and groundwater pumping and are summarized annually in **Table 2-17** and **Figure 2-93**. Total simulated inflows over the projected water budget period ranges from 1,081,000 to 1,703,000 AFY and averages 1,330,000 AFY.

Outflows from the land surface system budget in the Subbasin includes evaporation and deep percolation and are summarized annually in **Table 2-17** and **Figure 2-93**. Total simulated outflow ranges between 1,081,000 to 1,703,000 AFY and averages 1,330,000 AFY.

2.3.6.2 Groundwater System

Groundwater inflows include net deep percolation from precipitation and irrigation, seepage to the aquifer system from ephemeral streams and lateral subsurface flow and are summarized for the current water budget year in **Table 2-18** and **Figure 2-94**. Total simulated inflow to the groundwater system ranges from 291,000 to 745,000 AFY and averages 451,000 AFY.

Outflows from the groundwater system include groundwater pumping, and lateral subsurface outflow to adjacent subbasins and are summarized in **Table 2-18** and **Figure 2-94**. Total simulated outflow from the groundwater system ranges from 269,000 to 943,000 AFY and averages 496,000 AFY.

2.3.6.3 Projected Groundwater Overdraft

Given the conditions specified, the WSGM simulation projects a total decline in groundwater storage of 2,413,000 AF over the 50-year GSP planning horizon with an annual water balance deficit of 47,000 AFY **Table 2-18**.

2.3.6.4 Projected Sustainable Yield

Based on the methodology presented in **Section 2.3.5.4**, the projected sustainable yield assuming 2030 climate change factors is 271,000 AFY. This assessment is based on projected groundwater pumping of 313,000 AF and decline in projected groundwater storage of 47,000 AFY. Simulated average historical net lateral subsurface flow from 1989-2015 was 18,000 AF out of the Subbasin while projected net lateral subsurface flow from 2020-2070 is 23,000 AFY out of the Subbasin resulting in a net difference of 5,000 AF.

2.3.7 Projected Water Budget - 2070 Central Tendency Climate Scenario

The water budget for the projected water budget period (2020 through 2070) assuming 2070 climate change factors are summarized by water year and presented below.

2.3.7.1 Land Surface System

Inflows of water into the land surface system budget in the Subbasin include precipitation, imported surface water and groundwater pumping and are summarized annually in **Table 2-19** and **Figure 2-95**. Total simulated inflows over the projected water budget period ranges from 1,188,000 to 1,801,000 AFY and averages 1,424,000 AFY.

Outflows from the land surface system budget in the Subbasin includes evaporation and deep percolation and are summarized annually in **Table 2-19** and **Figure 2-95**. Total simulated outflow ranges between 1,188,000 to 1,801,000 AFY and averages 1,424,000 AFY.

2.3.7.2 Groundwater System

Groundwater inflows include net deep percolation from precipitation and irrigation, stream loss to the aquifer system from ephemeral streams and lateral subsurface flow and are summarized for the projected water budget in **Table 2-20** and **Figure 2-96**. Total simulated inflow to the groundwater system ranges from 361,000 to 840,000 AFY and averages 547,000 AFY.

Outflows from the groundwater system include groundwater pumping and lateral subsurface outflow to adjacent subbasins and are summarized in **Table 2-20** and **Figure 2-96**. Total simulated outflow from the groundwater system ranges from 289,000 to 1,054,000 AFY and averages 656,000 AFY.

2.3.7.3 Projected Groundwater Overdraft

Given the conditions specified, the WSGM simulation projects a total decline in groundwater storage of 5,736,000 AF over the 50-year GSP planning horizon with an annual water balance deficit of 112,000 AFY **Table 2-20**.

2.3.7.4 Projected Sustainable Yield

Based on the methodology presented in **Section 2.3.5.4**, the projected sustainable yield assuming 2070 climate change factors is 294,000 AFY. This assessment is based on projected groundwater pumping of 467,000 AFY and decline in projected groundwater storage of 112,000 AFY. Simulated average historical net lateral subsurface flow from 1989-2015 was 18,000 AFY out of the Subbasin while projected net lateral subsurface flow from 2020-2070 is 42,000 AFY into the Subbasin resulting in a net difference of -61,000 AFY. However, it should be noted that this projection does not consider the implementation of project and management actions and was modeled consistent with GSP Regulation, Section 354.18(c)(3).

Table 2-7. Extensometer Construction and Operational Status (West-Central San Joaquin Valley)

<table>
<tr><th>Well No.</th><th>Nickname</th><th>Aquifer</th><th>Location</th><th>Type</th><th>Extenso-meter Depth (feet)</th><th>Perforated Interval (feet)</th><th>Operational Status</th><th>Record Dates</th></tr>
<tr><td colspan="9">Currently Operational</td></tr>
<tr><td>12S/12E-16H2</td><td rowspan="3">Oro Loma</td><td>Lower</td><td rowspan="3">North of WWD</td><td>cable</td><td>1,000</td><td></td><td>Yes</td><td>1958-2000, 2009-current</td></tr>
<tr><td>12S/12E-16H3</td><td>Upper</td><td>cable</td><td>350</td><td></td><td>No</td><td>1958-1982, 1997-2000, 2009-2011</td></tr>
<tr><td>12S/12E-16H5</td><td>Lower</td><td>well</td><td></td><td>670-712</td><td>Yes</td><td></td></tr>
<tr><td>13S/15E-31J17</td><td rowspan="2">Fordel</td><td>Upper</td><td rowspan="2">East of WWD</td><td>pipe</td><td>450</td><td></td><td>Yes</td><td rowspan="2">1999-2016</td></tr>
<tr><td>13S/15E-31J3</td><td>Upper</td><td>well</td><td></td><td>400-410</td><td>Yes</td></tr>
<tr><td>13/15-35D5</td><td>Yearout</td><td>Upper</td><td>East of WWD</td><td>cable</td><td>440</td><td>373-433</td><td>Yes</td><td>1965 to 1982, 1999 to present</td></tr>
<tr><td>14S/13E-11D6</td><td>Panoche</td><td>Lower</td><td>Northern WWD</td><td>cable</td><td>1,358</td><td>1,133-1,196</td><td>Yes</td><td>1961-1998, 2002-current</td></tr>
<tr><td>18S/16E-33A1</td><td>DWR Yard</td><td>Lower</td><td>Central WWD</td><td>cable</td><td>1,070</td><td>858-1,070</td><td>Yes</td><td>1965-1998, 2011-current</td></tr>
<tr><td>20S/18-6D1</td><td>Rasta</td><td>Lower</td><td>Southern WWD</td><td>cable</td><td>1,007</td><td>760-835, 851-872</td><td>Yes</td><td>1965-1998, 2002-current</td></tr>
<tr><td colspan="9">Not Operational or Not Found</td></tr>
<tr><td>14S/12E-12H1</td><td></td><td>Lower</td><td>Northern WWD</td><td>Unknown</td><td>936</td><td>740-936</td><td>No</td><td>1964-1998</td></tr>
<tr><td>15S/13E-11D2</td><td></td><td>Lower</td><td>Northern WWD</td><td>Unknown</td><td>960</td><td>900-960</td><td>Not Found</td><td>1964-1988</td></tr>
<tr><td>15S/16E-31N3</td><td></td><td>Upper</td><td>Central WWD</td><td>Unknown</td><td>595</td><td></td><td>No</td><td>1967-1983</td></tr>
<tr><td>16S/15E-34N1</td><td rowspan="5">Cantua Creek</td><td>Lower</td><td rowspan="5">Central WWD</td><td>Unknown</td><td>2,007</td><td></td><td rowspan="5">Not Found</td><td>1958-1998</td></tr>
<tr><td>16S/15E-34N2</td><td>Lower</td><td>Unknown</td><td>703</td><td></td><td></td></tr>
<tr><td>16S/15E-34N3</td><td>Upper</td><td>Unknown</td><td>503</td><td></td><td></td></tr>
<tr><td>16S/15E-34N4</td><td>Lower</td><td>well</td><td></td><td>1,052-1,112</td><td></td></tr>
<tr><td>16S/15E-34N5</td><td>Upper</td><td>well</td><td></td><td>240-300</td><td></td></tr>
<tr><td>17S/15E-14Q1</td><td></td><td>Lower</td><td>Central WWD</td><td>Unknown</td><td>2,315</td><td>1,064-1,094</td><td>Not Found</td><td>1969-1998</td></tr>
<tr><td>20S/18E-11Q1</td><td rowspan="3"></td><td></td><td rowspan="3">Southern WWD</td><td>Unknown</td><td>710</td><td>650-710</td><td>Not Found</td><td></td></tr>
<tr><td>20S/18E-11Q2</td><td></td><td>Unknown</td><td>845</td><td></td><td>Not Found</td><td></td></tr>
<tr><td>20S/18E-11Q3</td><td>Lower</td><td>Unknown</td><td>1,930</td><td>1,885-1,925</td><td>Not Found</td><td></td></tr>
</table>

Source: Ireland et al., 1984 and USGS website (http://ca.water.usgs.gov/land_subsidence/california-subsidence-measuring.html)

Table 2-8. Historic Water Budget San Joaquin Valley and Sacramento Valley Water Year Type

Water Year	Water Year Type San Joaquin Valley	Water Year Type Sacramento Valley
1989	C	D
1990	C	C
1991	C	C
1992	C	C
1993	W	AN
1994	C	C
1995	W	W
1996	W	W
1997	W	W
1998	W	W
1999	AN	W
2000	AN	AN
2001	D	D
2002	D	D
2003	BN	AN
2004	D	BN
2005	W	AN
2006	W	W
2007	C	D
2008	C	C
2009	BN	D
2010	AN	BN
2011	W	W
2012	D	BN
2013	C	D
2014	C	C
2015	C	C

Table 2-9. Projected Water Budget San Joaquin Valley and Sacramento Valley Water Year Type

Historic Water Year	Projected Water Year	Water Year Type San Joaquin Valley	Water Year Type Sacramento Valley
2017	2017[1]	W	W
1963	2018[2]	AN	W
1964	2019[2]	D	D
1965	2020	W	W
1966	2021	BN	BN
1967	2022	W	W
1968	2023	D	BN
1969	2024	W	W
1970	2025	AN	W
1971	2026	BN	W
1972	2027	D	BN
1973	2028	AN	AN
1974	2029	W	W
1975	2030	W	W
1976	2031	C	C
1977	2032	C	C
1978	2033	W	AN
1979	2034	AN	BN
1980	2035	W	AN
1981	2036	D	D
1982	2037	W	W
1983	2038	W	W
1984	2039	AN	W
1985	2040	D	D
1986	2041	W	W
1987	2042	C	D
1988	2043	C	C

Historic Water Year	Projected Water Year	Water Year Type San Joaquin Valley	Water Year Type Sacramento Valley
1989	2044	C	D
1990	2045	C	C
1991	2046	C	C
1992	2047	C	C
1993	2048	W	AN
1994	2049	C	C
1995	2050	W	W
1996	2051	W	W
1997	2052	W	W
1998	2053	W	W
1999	2054	AN	W
2000	2055	AN	AN
2001	2056	D	D
2002	2057	D	D
2003	2058	BN	AN
2004	2059	D	BN
2005	2060	W	AN
2006	2061	W	W
2007	2062	C	D
2008	2063	C	C
2009	2064	BN	D
2010	2065	AN	BN
2011	2066	W	W
2012	2067	D	BN
2013	2068	C	D
2014	2069	C	C
2015	2070	C	C

1. 2017 Climate and Streamflow. Reported Surface Water through February 2017.
2. Included in Numerical Model. Not Included in Analysis of Projected Period.

Table 2-10: Historic Land Surface Water Budget - Westside Subbasin (1989-2015)

Water Year	Water Year Type	Precipitation (af)	Imported Surface Water[1] (af)	Utilized Surface Water[2] (af)	Groundwater Pumping (af)	Total Inflow (af)	Evapo-transpiration (af)	Net Deep Percolation[3] (af)	Total Outflow (af)
1989	C	269,000	1,135,000	1,069,000	328,000	1,667,000	1,183,000	483,000	1,667,000
1990	C	243,000	924,000	902,000	484,000	1,629,000	1,200,000	429,000	1,629,000
1991	C	336,000	421,000	418,000	697,000	1,452,000	1,138,000	315,000	1,452,000
1992	C	402,000	457,000	455,000	665,000	1,521,000	1,221,000	300,000	1,521,000
1993	W	706,000	760,000	752,000	318,000	1,776,000	1,327,000	448,000	1,776,000
1994	C	362,000	891,000	881,000	439,000	1,682,000	1,286,000	396,000	1,682,000
1995	W	715,000	951,000	883,000	170,000	1,767,000	1,240,000	528,000	1,767,000
1996	W	364,000	1,373,000	1,227,000	177,000	1,769,000	1,269,000	500,000	1,769,000
1997	W	506,000	1,319,000	1,111,000	178,000	1,795,000	1,295,000	499,000	1,795,000
1998	W	847,000	993,000	881,000	116,000	1,845,000	1,370,000	474,000	1,845,000
1999	AN	290,000	1,279,000	1,158,000	208,000	1,655,000	1,304,000	351,000	1,655,000
2000	AN	388,000	949,000	902,000	304,000	1,595,000	1,319,000	275,000	1,595,000
2001	D	412,000	907,000	884,000	409,000	1,705,000	1,399,000	306,000	1,705,000
2002	D	265,000	892,000	864,000	412,000	1,541,000	1,254,000	287,000	1,541,000
2003	BN	380,000	997,000	963,000	227,000	1,571,000	1,254,000	317,000	1,571,000
2004	D	272,000	1,044,000	974,000	233,000	1,479,000	1,151,000	328,000	1,479,000
2005	W	633,000	992,000	909,000	79,000	1,621,000	1,266,000	356,000	1,621,000
2006	W	453,000	1,121,000	1,023,000	90,000	1,565,000	1,197,000	369,000	1,566,000
2007	C	163,000	1,025,000	963,000	241,000	1,368,000	1,126,000	242,000	1,368,000
2008	C	302,000	574,000	554,000	329,000	1,185,000	1,054,000	132,000	1,185,000
2009	BN	257,000	357,000	348,000	377,000	982,000	952,000	30,000	982,000
2010	AN	474,000	603,000	593,000	181,000	1,248,000	1,041,000	207,000	1,248,000
2011	W	587,000	1,011,000	928,000	93,000	1,609,000	1,160,000	449,000	1,609,000
2012	D	271,000	829,000	796,000	304,000	1,371,000	1,115,000	256,000	1,371,000
2013	C	196,000	508,000	493,000	454,000	1,143,000	1,021,000	121,000	1,143,000
2014	C	160,000	223,000	220,000	614,000	993,000	947,000	46,000	993,000
2015	C	250,000	179,000	178,000	608,000	1,035,000	920,000	115,000	1,035,000
Average		**389,000**	**841,000**	**790,000**	**324,000**	**1,503,000**	**1,185,000**	**317,000**	**1,503,000**

1. Reported surface water imports from WWD records
2. Simulated surface water imports (imports not utilized by model rejected and not included in FMP water budget)
3. Difference between deep percolation and groundwater uptake from plants and direct evaporation

Table 2-12: Historic Groundwater Budget - Westside Subbasin (1989-2015)

Water Year	Water Year Type	Net Deep Percolation (af)	Stream Leakage (af)	Lateral Subsurface Inflow (af)	Total Inflow (af)	Groundwater Pumping (af)	Lateral Subsurface Outflow (af)	Total Outflow (af)	Change In Groundwater Storage (af)
1989	C	485,000	0	205,000	691,000	326,000	178,000	503,000	182,000
1990	C	430,000	1,000	202,000	633,000	483,000	180,000	663,000	-36,000
1991	C	316,000	5,000	235,000	556,000	697,000	168,000	865,000	-315,000
1992	C	301,000	8,000	245,000	554,000	667,000	167,000	834,000	-286,000
1993	W	451,000	30,000	223,000	705,000	317,000	153,000	470,000	231,000
1994	C	398,000	3,000	206,000	607,000	436,000	162,000	598,000	2,000
1995	W	530,000	32,000	185,000	747,000	169,000	144,000	313,000	427,000
1996	W	500,000	10,000	141,000	651,000	176,000	152,000	329,000	320,000
1997	W	500,000	18,000	119,000	637,000	177,000	164,000	341,000	294,000
1998	W	476,000	33,000	102,000	611,000	116,000	163,000	279,000	329,000
1999	AN	349,000	6,000	98,000	453,000	209,000	171,000	380,000	73,000
2000	AN	275,000	6,000	114,000	394,000	304,000	163,000	467,000	-73,000
2001	D	306,000	10,000	142,000	458,000	408,000	170,000	578,000	-121,000
2002	D	287,000	1,000	167,000	455,000	413,000	173,000	587,000	-133,000
2003	BN	318,000	3,000	157,000	478,000	230,000	180,000	410,000	59,000
2004	D	328,000	2,000	133,000	462,000	236,000	192,000	428,000	31,000
2005	W	356,000	26,000	117,000	499,000	91,000	155,000	246,000	244,000
2006	W	368,000	14,000	88,000	470,000	101,000	153,000	254,000	211,000
2007	C	239,000	1,000	88,000	328,000	253,000	171,000	424,000	-98,000
2008	C	125,000	7,000	105,000	238,000	326,000	188,000	514,000	-281,000
2009	BN	28,000	1,000	130,000	159,000	373,000	186,000	559,000	-401,000
2010	AN	209,000	12,000	131,000	352,000	179,000	162,000	341,000	9,000
2011	W	451,000	24,000	96,000	572,000	92,000	148,000	240,000	327,000
2012	D	249,000	2,000	97,000	348,000	302,000	160,000	462,000	-112,000
2013	C	118,000	1,000	130,000	249,000	450,000	183,000	633,000	-383,000
2014	C	43,000	1,000	186,000	231,000	608,000	188,000	796,000	-568,000
2015	C	115,000	0	225,000	340,000	603,000	184,000	787,000	-449,000
Average		**317,000**	**10,000**	**151,000**	**477,000**	**324,000**	**169,000**	**493,000**	**-19,000**

Table 2-15: Projected Land Surface Water Budget - Westside Subbasin (2017-2070)

Water Year	Water Year Type	Precipitation (af)	Imported Surface Water[1] (af)	Utilized Surface Water[2] (af)	Groundwater Pumping (af)	Total (af)	Evapo-transpiration (af)	Net Deep Percolation[3] (af)	Total Outflow (af)
2017*	W	577,000	1,296,000	853,000	111,000	1,540,000	1,069,000	471,000	1,540,000
2018	AN	344,000	805,000	720,000	156,000	1,220,000	63,000	63,000	63,000
2019	D	255,000	457,000	456,000	498,000	1,209,000	57,000	57,000	57,000
2020	W	333,000	791,000	791,000	232,000	1,356,000	53,000	53,000	53,000
2021	BN	322,000	862,000	842,000	155,000	1,319,000	65,000	65,000	65,000
2022	W	462,000	1,282,000	689,000	143,000	1,295,000	71,000	71,000	71,000
2023	D	279,000	712,000	693,000	334,000	1,306,000	67,000	67,000	67,000
2024	W	775,000	1,310,000	716,000	131,000	1,622,000	133,000	133,000	133,000
2025	AN	297,000	755,000	742,000	206,000	1,245,000	91,000	91,000	91,000
2026	BN	328,000	626,000	626,000	293,000	1,247,000	81,000	81,000	81,000
2027	D	146,000	386,000	386,000	596,000	1,128,000	69,000	69,000	69,000
2028	AN	622,000	853,000	722,000	155,000	1,499,000	108,000	108,000	108,000
2029	W	391,000	981,000	878,000	144,000	1,413,000	91,000	91,000	91,000
2030	W	353,000	884,000	867,000	155,000	1,375,000	72,000	72,000	72,000
2031	C	402,000	665,000	665,000	235,000	1,301,000	64,000	64,000	64,000
2032	C	231,000	238,000	238,000	721,000	1,189,000	55,000	55,000	55,000
2033	W	851,000	822,000	642,000	173,000	1,666,000	123,000	123,000	123,000
2034	AN	424,000	753,000	749,000	279,000	1,452,000	98,000	98,000	98,000
2035	W	460,000	955,000	740,000	146,000	1,346,000	85,000	85,000	85,000
2036	D	338,000	772,000	766,000	178,000	1,282,000	80,000	80,000	80,000
2037	W	484,000	1,179,000	658,000	148,000	1,289,000	73,000	73,000	73,000
2038	W	757,000	1,325,000	741,000	148,000	1,645,000	125,000	125,000	125,000
2039	AN	214,000	897,000	886,000	165,000	1,265,000	93,000	93,000	93,000
2040	D	270,000	662,000	662,000	320,000	1,251,000	75,000	75,000	75,000
2041	W	503,000	740,000	740,000	210,000	1,453,000	78,000	78,000	78,000
2042	C	284,000	345,000	345,000	595,000	1,223,000	62,000	62,000	62,000
2043	C	338,000	227,000	227,000	694,000	1,260,000	51,000	51,000	51,000
2044	C	275,000	482,000	482,000	508,000	1,265,000	49,000	49,000	49,000
2045	C	249,000	235,000	235,000	747,000	1,231,000	41,000	41,000	41,000
2046	C	343,000	397,000	397,000	572,000	1,311,000	52,000	52,000	52,000
2047	C	409,000	511,000	511,000	457,000	1,377,000	54,000	54,000	54,000
2048	W	719,000	974,000	772,000	150,000	1,640,000	96,000	96,000	96,000
2049	C	369,000	602,000	597,000	336,000	1,302,000	60,000	60,000	60,000
2050	W	728,000	977,000	694,000	151,000	1,573,000	111,000	111,000	111,000
2051	W	374,000	1,194,000	826,000	138,000	1,338,000	94,000	94,000	94,000
2052	W	517,000	747,000	745,000	232,000	1,493,000	131,000	131,000	131,000
2053	W	865,000	1,304,000	592,000	147,000	1,604,000	158,000	158,000	158,000
2054	AN	296,000	906,000	795,000	144,000	1,234,000	110,000	110,000	110,000
2055	AN	397,000	722,000	720,000	199,000	1,315,000	106,000	106,000	106,000
2056	D	420,000	354,000	354,000	640,000	1,415,000	87,000	87,000	87,000
2057	D	271,000	603,000	603,000	423,000	1,298,000	71,000	71,000	71,000
2058	BN	388,000	760,000	758,000	171,000	1,318,000	63,000	63,000	63,000
2059	D	277,000	827,000	822,000	159,000	1,259,000	67,000	67,000	67,000
2060	W	645,000	657,000	657,000	189,000	1,491,000	92,000	92,000	92,000
2061	W	462,000	1,316,000	709,000	147,000	1,318,000	89,000	89,000	89,000
2062	C	167,000	513,000	498,000	466,000	1,131,000	68,000	68,000	68,000
2063	C	308,000	234,000	234,000	743,000	1,285,000	70,000	70,000	70,000
2064	BN	263,000	353,000	353,000	623,000	1,239,000	52,000	52,000	52,000
2065	AN	484,000	680,000	680,000	207,000	1,371,000	62,000	62,000	62,000
2066	W	599,000	735,000	686,000	156,000	1,441,000	89,000	89,000	89,000
2067	D	276,000	781,000	774,000	162,000	1,212,000	62,000	62,000	62,000
2068	C	200,000	342,000	341,000	659,000	1,201,000	54,000	54,000	54,000
2069	C	163,000	281,000	281,000	742,000	1,186,000	42,000	42,000	42,000
2070	C	254,000	505,000	505,000	482,000	1,241,000	43,000	43,000	43,000
Average (2020 - 2040)		416,000	843,000	700,000	241,000	1,357,000	84,000	84,000	1,357,000
Average (2020 - 2070)		404,000	726,000	620,000	320,000	1,343,000	79,000	79,000	1,343,000

* Actual water year type for 2017 (all other years derived from historic record)
1. Reported surface water imports from WWD records
2. Simulated surface water imports (imports not utilized by model rejected and not included in FMP water budget)
3. Difference between deep percolation and groundwater uptake from plants and direct evaporation

Table 2-16: Projected Groundwater Budget - Westside Subbasin (2017-2070)

Water Year	Water Year Type	Net Deep Percolation (af)	Stream Leakage (af)	Lateral Subsurface Inflow (af)	Total Inflow (af)	Pumping (af)	Lateral Subsurface Outflow (af)	Total Outflow (af)	Change In Groundwater Storage (af)
2017*	W	401,000	15,000	204,000	620,000	110,000	160,000	269,000	341,000
2018	AN	245,000	11,000	139,000	396,000	155,000	172,000	326,000	63,000
2019	D	210,000	1,000	152,000	363,000	494,000	188,000	681,000	-317,000
2020	W	218,000	12,000	173,000	403,000	230,000	194,000	424,000	-28,000
2021	BN	311,000	1,000	137,000	449,000	153,000	200,000	354,000	91,000
2022	W	288,000	23,000	111,000	421,000	142,000	155,000	297,000	120,000
2023	D	218,000	10,000	114,000	343,000	330,000	187,000	517,000	-172,000
2024	W	515,000	32,000	116,000	663,000	130,000	148,000	278,000	380,000
2025	AN	199,000	5,000	97,000	302,000	204,000	187,000	391,000	-92,000
2026	BN	246,000	2,000	110,000	359,000	290,000	201,000	491,000	-134,000
2027	D	226,000	1,000	172,000	399,000	591,000	198,000	789,000	-388,000
2028	AN	415,000	13,000	182,000	611,000	154,000	171,000	324,000	277,000
2029	W	236,000	11,000	124,000	372,000	143,000	190,000	332,000	35,000
2030	W	208,000	11,000	107,000	327,000	154,000	203,000	357,000	-35,000
2031	C	230,000	8,000	107,000	345,000	233,000	204,000	436,000	-91,000
2032	C	203,000	0	175,000	378,000	714,000	200,000	914,000	-532,000
2033	W	506,000	21,000	197,000	725,000	171,000	162,000	333,000	383,000
2034	AN	241,000	4,000	150,000	394,000	276,000	185,000	461,000	-69,000
2035	W	301,000	21,000	133,000	455,000	145,000	177,000	322,000	127,000
2036	D	222,000	1,000	110,000	333,000	176,000	200,000	376,000	-46,000
2037	W	236,000	23,000	99,000	358,000	146,000	162,000	308,000	48,000
2038	W	373,000	22,000	92,000	487,000	146,000	137,000	283,000	199,000
2039	AN	203,000	4,000	84,000	291,000	163,000	193,000	356,000	-68,000
2040	D	222,000	1,000	101,000	324,000	317,000	210,000	527,000	-200,000
2041	W	253,000	30,000	121,000	405,000	208,000	194,000	402,000	-2,000
2042	C	204,000	6,000	168,000	377,000	589,000	194,000	782,000	-402,000
2043	C	218,000	2,000	242,000	462,000	687,000	191,000	879,000	-417,000
2044	C	261,000	0	260,000	521,000	503,000	192,000	695,000	-177,000
2045	C	230,000	1,000	272,000	503,000	740,000	196,000	936,000	-433,000
2046	C	332,000	5,000	280,000	617,000	566,000	191,000	758,000	-146,000
2047	C	318,000	8,000	267,000	592,000	453,000	191,000	644,000	-58,000
2048	W	487,000	30,000	219,000	736,000	149,000	168,000	317,000	409,000
2049	C	211,000	3,000	170,000	383,000	333,000	185,000	518,000	-134,000
2050	W	493,000	31,000	155,000	679,000	150,000	162,000	312,000	362,000
2051	W	264,000	10,000	119,000	393,000	137,000	158,000	295,000	91,000
2052	W	380,000	17,000	110,000	507,000	229,000	178,000	407,000	96,000
2053	W	427,000	32,000	103,000	562,000	146,000	140,000	286,000	269,000
2054	AN	196,000	6,000	91,000	293,000	142,000	172,000	314,000	-23,000
2055	AN	241,000	5,000	92,000	338,000	197,000	190,000	387,000	-51,000
2056	D	216,000	10,000	161,000	387,000	634,000	195,000	829,000	-438,000
2057	D	244,000	1,000	215,000	460,000	419,000	198,000	617,000	-159,000
2058	BN	264,000	3,000	182,000	449,000	169,000	194,000	363,000	78,000
2059	D	268,000	1,000	138,000	406,000	158,000	201,000	359,000	43,000
2060	W	359,000	26,000	121,000	505,000	187,000	187,000	373,000	128,000
2061	W	292,000	12,000	114,000	418,000	146,000	150,000	296,000	118,000
2062	C	192,000	0	142,000	334,000	462,000	183,000	645,000	-304,000
2063	C	304,000	6,000	214,000	524,000	736,000	199,000	935,000	-411,000
2064	BN	224,000	0	266,000	491,000	617,000	195,000	812,000	-324,000
2065	AN	333,000	12,000	229,000	574,000	205,000	186,000	391,000	173,000
2066	W	361,000	23,000	170,000	554,000	154,000	171,000	325,000	221,000
2067	D	201,000	1,000	142,000	344,000	160,000	185,000	345,000	-2,000
2068	C	223,000	0	182,000	406,000	653,000	201,000	854,000	-442,000
2069	C	222,000	0	262,000	485,000	735,000	203,000	937,000	-456,000
2070	C	286,000	0	271,000	557,000	477,000	198,000	675,000	-123,000
Average (2020 - 2040)		277,000	11,000	128,000	416,000	238,000	184,000	422,000	-9,000
Average (2020 - 2070)		281,000	10,000	160,000	451,000	317,000	185,000	501,000	-53,000

* Actual water year type for 2017 (all other years derived from historic record)

Table 2-17: Projected Land Surface Water Budget (2030 Climate Change Factors)- Westside Subbasin (2017-2070)

Water Year	Water Year Type	Precipitation (af)	Imported Surface Water1 (af)	Utilized Surface Water2 (af)	Groundwater Pumping (af)	Total (af)	Evapo-transpiration (af)	Net Deep Percolation3 (af)	Total Outflow (af)
2017*	W	579,000	1,296,000	804,000	112,000	1,495,000	1,069,000	471,000	1,495,000
2018	AN	347,000	805,000	652,000	185,000	1,184,000	63,000	63,000	1,184,000
2019	D	267,000	457,000	456,000	460,000	1,183,000	57,000	57,000	1,183,000
2020	W	345,000	791,000	791,000	271,000	1,406,000	53,000	53,000	1,406,000
2021	BN	317,000	862,000	758,000	218,000	1,293,000	65,000	65,000	1,293,000
2022	W	471,000	1,282,000	614,000	144,000	1,229,000	71,000	71,000	1,229,000
2023	D	283,000	712,000	662,000	349,000	1,295,000	67,000	67,000	1,295,000
2024	W	810,000	1,310,000	641,000	134,000	1,585,000	133,000	133,000	1,585,000
2025	AN	306,000	755,000	726,000	213,000	1,246,000	91,000	91,000	1,246,000
2026	BN	333,000	626,000	625,000	287,000	1,245,000	81,000	81,000	1,245,000
2027	D	151,000	386,000	385,000	545,000	1,081,000	69,000	69,000	1,081,000
2028	AN	628,000	853,000	719,000	175,000	1,522,000	108,000	108,000	1,522,000
2029	W	401,000	981,000	886,000	151,000	1,438,000	91,000	91,000	1,438,000
2030	W	367,000	884,000	875,000	182,000	1,423,000	72,000	72,000	1,423,000
2031	C	442,000	665,000	636,000	301,000	1,379,000	64,000	64,000	1,379,000
2032	C	233,000	238,000	238,000	674,000	1,145,000	55,000	55,000	1,145,000
2033	W	895,000	822,000	642,000	166,000	1,703,000	123,000	123,000	1,703,000
2034	AN	436,000	753,000	706,000	267,000	1,409,000	98,000	98,000	1,409,000
2035	W	471,000	955,000	714,000	145,000	1,330,000	85,000	85,000	1,330,000
2036	D	342,000	772,000	715,000	167,000	1,224,000	80,000	80,000	1,224,000
2037	W	482,000	1,179,000	608,000	148,000	1,238,000	73,000	73,000	1,238,000
2038	W	779,000	1,325,000	742,000	148,000	1,669,000	125,000	125,000	1,669,000
2039	AN	222,000	897,000	853,000	186,000	1,261,000	93,000	93,000	1,261,000
2040	D	278,000	662,000	653,000	282,000	1,214,000	75,000	75,000	1,214,000
2041	W	515,000	740,000	690,000	199,000	1,404,000	78,000	78,000	1,404,000
2042	C	291,000	345,000	345,000	534,000	1,169,000	62,000	62,000	1,169,000
2043	C	348,000	227,000	227,000	614,000	1,189,000	51,000	51,000	1,189,000
2044	C	286,000	482,000	482,000	515,000	1,283,000	49,000	49,000	1,283,000
2045	C	266,000	235,000	235,000	751,000	1,252,000	41,000	41,000	1,252,000
2046	C	368,000	397,000	397,000	514,000	1,279,000	52,000	52,000	1,279,000
2047	C	425,000	511,000	511,000	483,000	1,419,000	54,000	54,000	1,419,000
2048	W	739,000	974,000	689,000	178,000	1,606,000	96,000	96,000	1,606,000
2049	C	380,000	602,000	593,000	335,000	1,307,000	60,000	60,000	1,307,000
2050	W	749,000	977,000	643,000	151,000	1,543,000	111,000	111,000	1,543,000
2051	W	389,000	1,194,000	765,000	138,000	1,292,000	94,000	94,000	1,292,000
2052	W	543,000	747,000	745,000	242,000	1,529,000	131,000	131,000	1,529,000
2053	W	879,000	1,304,000	543,000	146,000	1,568,000	158,000	158,000	1,568,000
2054	AN	302,000	906,000	769,000	142,000	1,214,000	110,000	110,000	1,214,000
2055	AN	407,000	722,000	644,000	179,000	1,230,000	106,000	106,000	1,230,000
2056	D	440,000	354,000	354,000	642,000	1,437,000	87,000	87,000	1,437,000
2057	D	281,000	603,000	599,000	367,000	1,247,000	71,000	71,000	1,247,000
2058	BN	399,000	760,000	758,000	190,000	1,347,000	63,000	63,000	1,347,000
2059	D	297,000	827,000	800,000	191,000	1,287,000	67,000	67,000	1,287,000
2060	W	675,000	657,000	641,000	195,000	1,510,000	92,000	92,000	1,510,000
2061	W	461,000	1,316,000	698,000	147,000	1,306,000	89,000	89,000	1,306,000
2062	C	174,000	513,000	495,000	491,000	1,160,000	68,000	68,000	1,160,000
2063	C	305,000	234,000	234,000	736,000	1,275,000	70,000	70,000	1,275,000
2064	BN	268,000	353,000	353,000	568,000	1,189,000	52,000	52,000	1,189,000
2065	AN	505,000	680,000	657,000	200,000	1,362,000	62,000	62,000	1,362,000
2066	W	606,000	735,000	612,000	166,000	1,383,000	89,000	89,000	1,383,000
2067	D	301,000	781,000	698,000	183,000	1,182,000	62,000	62,000	1,182,000
2068	C	212,000	342,000	342,000	664,000	1,217,000	54,000	54,000	1,217,000
2069	C	176,000	281,000	281,000	641,000	1,099,000	42,000	42,000	1,099,000
2070	C	250,000	505,000	505,000	448,000	1,204,000	43,000	43,000	1,204,000
Average (2020 - 2040)		428,000	843,000	676,000	245,000	1,349,000	84,000	84,000	1,349,000
Average (2020 - 2070)		416,000	726,000	598,000	316,000	1,330,000	79,000	79,000	1,330,000

* Actual water year type for 2017 (all other years derived from historic record)
1. Reported surface water imports from WWD records
2. Simulated surface water imports (imports not utilized by model rejected and not included in FMP water budget)
3. Difference between deep percolation and groundwater uptake from plants and direct evaporation

Table 2-18: Projected Groundwater Budget (2030 Climate Change Factors) - Westside Subbasin (2017-2070)

Water Year	Water Year Type	Net Deep Percolation (af)	Stream Leakage (af)	Lateral Subsurface Inflow (af)	Total Inflow (af)	Pumping (af)	Lateral Subsurface Outflow (af)	Total Outflow (af)	Change In Groundwater Storage (af)
2017*	W	398,000	15,000	204,000	618,000	111,000	158,000	269,000	338,000
2018	AN	246,000	12,000	141,000	399,000	184,000	169,000	353,000	42,000
2019	D	207,000	1,000	149,000	357,000	455,000	189,000	644,000	-286,000
2020	W	220,000	12,000	175,000	407,000	268,000	201,000	469,000	-67,000
2021	BN	305,000	1,000	152,000	458,000	216,000	193,000	409,000	46,000
2022	W	292,000	23,000	123,000	438,000	142,000	147,000	289,000	144,000
2023	D	219,000	10,000	118,000	348,000	346,000	186,000	532,000	-182,000
2024	W	528,000	32,000	126,000	685,000	132,000	149,000	281,000	398,000
2025	AN	200,000	5,000	103,000	308,000	211,000	185,000	396,000	-89,000
2026	BN	246,000	3,000	112,000	361,000	284,000	202,000	486,000	-126,000
2027	D	225,000	1,000	163,000	389,000	539,000	198,000	738,000	-347,000
2028	AN	419,000	13,000	180,000	613,000	173,000	169,000	343,000	259,000
2029	W	239,000	12,000	126,000	377,000	149,000	195,000	344,000	27,000
2030	W	212,000	11,000	111,000	334,000	180,000	206,000	386,000	-55,000
2031	C	237,000	8,000	118,000	363,000	298,000	202,000	499,000	-134,000
2032	C	201,000	0	187,000	388,000	667,000	198,000	866,000	-475,000
2033	W	524,000	22,000	196,000	742,000	165,000	159,000	323,000	410,000
2034	AN	240,000	4,000	149,000	393,000	264,000	189,000	453,000	-64,000
2035	W	305,000	22,000	132,000	458,000	143,000	176,000	319,000	132,000
2036	D	220,000	1,000	107,000	328,000	166,000	191,000	357,000	-32,000
2037	W	232,000	22,000	97,000	351,000	146,000	159,000	306,000	42,000
2038	W	376,000	22,000	91,000	489,000	146,000	141,000	288,000	196,000
2039	AN	201,000	4,000	87,000	292,000	185,000	195,000	379,000	-90,000
2040	D	220,000	1,000	100,000	321,000	280,000	211,000	491,000	-165,000
2041	W	249,000	30,000	115,000	395,000	197,000	191,000	388,000	1,000
2042	C	199,000	6,000	154,000	359,000	529,000	193,000	722,000	-358,000
2043	C	212,000	2,000	224,000	437,000	608,000	190,000	798,000	-360,000
2044	C	263,000	0	252,000	516,000	510,000	192,000	702,000	-190,000
2045	C	231,000	1,000	267,000	499,000	744,000	198,000	943,000	-443,000
2046	C	336,000	6,000	271,000	613,000	509,000	193,000	702,000	-96,000
2047	C	324,000	8,000	267,000	599,000	478,000	194,000	672,000	-78,000
2048	W	491,000	30,000	224,000	745,000	176,000	161,000	337,000	397,000
2049	C	209,000	3,000	174,000	386,000	331,000	183,000	514,000	-129,000
2050	W	500,000	31,000	156,000	687,000	149,000	159,000	308,000	370,000
2051	W	262,000	10,000	119,000	392,000	136,000	150,000	287,000	101,000
2052	W	383,000	18,000	111,000	512,000	240,000	175,000	415,000	93,000
2053	W	434,000	32,000	103,000	570,000	144,000	137,000	281,000	282,000
2054	AN	195,000	6,000	90,000	291,000	141,000	173,000	314,000	-23,000
2055	AN	237,000	6,000	88,000	331,000	177,000	185,000	362,000	-31,000
2056	D	213,000	10,000	157,000	380,000	636,000	196,000	832,000	-446,000
2057	D	239,000	1,000	203,000	442,000	363,000	196,000	559,000	-118,000
2058	BN	265,000	3,000	170,000	438,000	189,000	198,000	387,000	46,000
2059	D	271,000	1,000	142,000	414,000	189,000	199,000	388,000	22,000
2060	W	368,000	27,000	124,000	518,000	193,000	184,000	377,000	135,000
2061	W	288,000	13,000	117,000	418,000	145,000	149,000	294,000	119,000
2062	C	192,000	0	142,000	335,000	486,000	181,000	667,000	-325,000
2063	C	300,000	6,000	221,000	527,000	729,000	197,000	926,000	-399,000
2064	BN	220,000	0	260,000	480,000	562,000	193,000	756,000	-276,000
2065	AN	336,000	12,000	226,000	574,000	198,000	185,000	382,000	181,000
2066	W	360,000	24,000	168,000	552,000	164,000	166,000	330,000	213,000
2067	D	195,000	1,000	143,000	339,000	182,000	179,000	360,000	-24,000
2068	C	224,000	8,000	185,000	417,000	657,000	202,000	859,000	-437,000
2069	C	213,000	2,000	260,000	475,000	635,000	198,000	833,000	-360,000
2070	C	278,000	0	263,000	542,000	444,000	200,000	644,000	-108,000
Average (2020 - 2040)		279,000	11,000	131,000	421,000	243,000	183,000	426,000	-8,000
Average (2020 - 2070)		281,000	10,000	160,000	451,000	313,000	183,000	496,000	-47,000

* Actual water year type for 2017 (all other years derived from historic record)

Table 2-19: Projected Land Surface Water Budget (2070 Climate Change Factors) - Westside Subbasin (2017-2070)

Water Year	Water Year Type	Precipitation (af)	Imported Surface Water1 (af)	Utilized Surface Water2 (af)	Groundwater Pumping (af)	Total (af)	Evapo-transpiration (af)	Net Deep Percolation3 (af)	Total Outflow (af)
2017*	W	578,000	1,295,000	907,000	111,000	1,596,000	1,069,000	471,000	1,596,000
2018	AN	355,000	759,000	750,000	190,000	1,294,000	63,000	63,000	1,294,000
2019	D	248,000	210,000	210,000	804,000	1,262,000	57,000	57,000	1,262,000
2020	W	327,000	560,000	560,000	532,000	1,419,000	53,000	53,000	1,419,000
2021	BN	315,000	553,000	553,000	506,000	1,375,000	65,000	65,000	1,375,000
2022	W	472,000	1,105,000	731,000	162,000	1,365,000	71,000	71,000	1,365,000
2023	D	275,000	665,000	653,000	449,000	1,377,000	67,000	67,000	1,377,000
2024	W	840,000	1,057,000	763,000	141,000	1,744,000	133,000	133,000	1,744,000
2025	AN	320,000	606,000	601,000	404,000	1,325,000	91,000	91,000	1,325,000
2026	BN	313,000	525,000	525,000	469,000	1,308,000	81,000	81,000	1,308,000
2027	D	142,000	233,000	233,000	813,000	1,188,000	69,000	69,000	1,188,000
2028	AN	658,000	611,000	611,000	323,000	1,592,000	108,000	108,000	1,592,000
2029	W	405,000	691,000	691,000	402,000	1,497,000	91,000	91,000	1,497,000
2030	W	364,000	715,000	707,000	308,000	1,379,000	72,000	72,000	1,379,000
2031	C	458,000	380,000	380,000	570,000	1,408,000	64,000	64,000	1,408,000
2032	C	217,000	231,000	231,000	798,000	1,246,000	55,000	55,000	1,246,000
2033	W	942,000	665,000	659,000	200,000	1,801,000	123,000	123,000	1,801,000
2034	AN	461,000	651,000	651,000	439,000	1,551,000	98,000	98,000	1,551,000
2035	W	490,000	683,000	683,000	263,000	1,437,000	85,000	85,000	1,437,000
2036	D	358,000	690,000	690,000	318,000	1,366,000	80,000	80,000	1,366,000
2037	W	492,000	881,000	704,000	163,000	1,359,000	73,000	73,000	1,359,000
2038	W	810,000	1,320,000	803,000	148,000	1,760,000	125,000	125,000	1,760,000
2039	AN	206,000	692,000	683,000	435,000	1,324,000	93,000	93,000	1,324,000
2040	D	265,000	558,000	558,000	488,000	1,312,000	75,000	75,000	1,312,000
2041	W	531,000	569,000	569,000	444,000	1,544,000	78,000	78,000	1,544,000
2042	C	311,000	356,000	356,000	649,000	1,316,000	62,000	62,000	1,316,000
2043	C	334,000	227,000	227,000	761,000	1,322,000	51,000	51,000	1,322,000
2044	C	290,000	238,000	238,000	809,000	1,337,000	49,000	49,000	1,337,000
2045	C	271,000	227,000	227,000	816,000	1,315,000	41,000	41,000	1,315,000
2046	C	381,000	230,000	230,000	793,000	1,403,000	52,000	52,000	1,403,000
2047	C	446,000	230,000	230,000	793,000	1,469,000	54,000	54,000	1,469,000
2048	W	780,000	679,000	679,000	303,000	1,762,000	96,000	96,000	1,762,000
2049	C	389,000	506,000	506,000	486,000	1,382,000	60,000	60,000	1,382,000
2050	W	776,000	645,000	645,000	259,000	1,681,000	111,000	111,000	1,681,000
2051	W	406,000	1,109,000	882,000	144,000	1,432,000	94,000	94,000	1,432,000
2052	W	550,000	589,000	588,000	449,000	1,587,000	131,000	131,000	1,587,000
2053	W	914,000	1,301,000	649,000	153,000	1,717,000	158,000	158,000	1,717,000
2054	AN	306,000	714,000	695,000	310,000	1,312,000	110,000	110,000	1,312,000
2055	AN	430,000	710,000	710,000	276,000	1,416,000	106,000	106,000	1,416,000
2056	D	461,000	243,000	243,000	809,000	1,512,000	87,000	87,000	1,512,000
2057	D	267,000	507,000	507,000	586,000	1,360,000	71,000	71,000	1,360,000
2058	BN	385,000	655,000	655,000	345,000	1,385,000	63,000	63,000	1,385,000
2059	D	305,000	556,000	556,000	485,000	1,346,000	67,000	67,000	1,346,000
2060	W	677,000	656,000	656,000	258,000	1,590,000	92,000	92,000	1,590,000
2061	W	481,000	1,316,000	772,000	150,000	1,402,000	89,000	89,000	1,402,000
2062	C	178,000	510,000	497,000	526,000	1,201,000	68,000	68,000	1,201,000
2063	C	326,000	234,000	234,000	806,000	1,367,000	70,000	70,000	1,367,000
2064	BN	274,000	240,000	240,000	795,000	1,310,000	52,000	52,000	1,310,000
2065	AN	519,000	568,000	568,000	382,000	1,469,000	62,000	62,000	1,469,000
2066	W	618,000	590,000	590,000	318,000	1,526,000	89,000	89,000	1,526,000
2067	D	272,000	589,000	589,000	410,000	1,271,000	62,000	62,000	1,271,000
2068	C	181,000	353,000	353,000	711,000	1,245,000	54,000	54,000	1,245,000
2069	C	180,000	232,000	232,000	855,000	1,266,000	42,000	42,000	1,266,000
2070	C	218,000	229,000	229,000	824,000	1,270,000	43,000	43,000	1,270,000
Average (2020 - 2040)		435,000	670,000	603,000	397,000	1,435,000	84,000	84,000	1,435,000
Average (2020 - 2070)		423,000	586,000	530,000	471,000	1,424,000	79,000	79,000	1,424,000

* Actual water year type for 2017 (all other years derived from historic record)
1. Reported surface water imports from WWD records
2. Simulated surface water imports (imports not utilized by model rejected and not included in FMP water budget)
3. Difference between deep percolation and groundwater uptake from plants and direct evaporation

Table 2-20: Projected Groundwater Budget (2070 Climate Change Factors) - Westside Subbasin (2017-2070)

Water Year	Water Year Type	Net Deep Percolation (af)	Stream Leakage (af)	Lateral Subsurface Inflow (af)	Total Inflow (af)	Pumping (af)	Lateral Subsurface Outflow (af)	Total Outflow (af)	Change In Groundwater Storage (af)
2017	W	405,000	15,000	204,000	624,000	110,000	165,000	275,000	339,000
2018	AN	260,000	12,000	145,000	416,000	188,000	184,000	371,000	38,000
2019	D	209,000	1,000	195,000	405,000	797,000	191,000	988,000	-582,000
2020	W	223,000	11,000	256,000	491,000	527,000	190,000	717,000	-231,000
2021	BN	297,000	1,000	256,000	554,000	502,000	191,000	693,000	-140,000
2022	W	307,000	23,000	214,000	543,000	160,000	162,000	323,000	214,000
2023	D	225,000	10,000	183,000	418,000	444,000	191,000	635,000	-215,000
2024	W	579,000	32,000	175,000	786,000	140,000	162,000	302,000	477,000
2025	AN	231,000	6,000	155,000	392,000	400,000	191,000	591,000	-198,000
2026	BN	245,000	2,000	195,000	442,000	464,000	196,000	660,000	-220,000
2027	D	238,000	1,000	249,000	489,000	806,000	200,000	1,006,000	-518,000
2028	AN	449,000	14,000	248,000	711,000	320,000	181,000	501,000	199,000
2029	W	269,000	12,000	220,000	501,000	398,000	195,000	593,000	-94,000
2030	W	218,000	12,000	207,000	438,000	305,000	195,000	500,000	-65,000
2031	C	275,000	10,000	227,000	512,000	564,000	192,000	756,000	-244,000
2032	C	220,000	0	269,000	489,000	790,000	200,000	991,000	-504,000
2033	W	568,000	23,000	239,000	831,000	198,000	175,000	373,000	445,000
2034	AN	271,000	4,000	204,000	479,000	435,000	192,000	627,000	-147,000
2035	W	346,000	23,000	203,000	572,000	261,000	190,000	451,000	112,000
2036	D	253,000	1,000	180,000	434,000	315,000	199,000	514,000	-85,000
2037	W	244,000	22,000	161,000	427,000	161,000	176,000	337,000	83,000
2038	W	408,000	23,000	130,000	561,000	146,000	142,000	289,000	266,000
2039	AN	215,000	4,000	142,000	361,000	431,000	192,000	623,000	-261,000
2040	D	230,000	1,000	193,000	423,000	484,000	205,000	689,000	-264,000
2041	W	277,000	30,000	228,000	535,000	439,000	190,000	630,000	-99,000
2042	C	226,000	6,000	259,000	492,000	643,000	195,000	837,000	-346,000
2043	C	226,000	2,000	289,000	517,000	754,000	200,000	954,000	-440,000
2044	C	272,000	0	302,000	574,000	802,000	203,000	1,005,000	-434,000
2045	C	258,000	1,000	304,000	562,000	809,000	204,000	1,013,000	-451,000
2046	C	365,000	6,000	308,000	680,000	785,000	201,000	987,000	-313,000
2047	C	348,000	9,000	313,000	669,000	786,000	200,000	986,000	-322,000
2048	W	538,000	31,000	270,000	840,000	300,000	183,000	483,000	344,000
2049	C	227,000	3,000	243,000	473,000	482,000	193,000	675,000	-201,000
2050	W	563,000	32,000	232,000	828,000	257,000	175,000	432,000	383,000
2051	W	297,000	11,000	176,000	485,000	143,000	173,000	316,000	160,000
2052	W	413,000	18,000	175,000	606,000	445,000	184,000	629,000	-24,000
2053	W	479,000	32,000	171,000	682,000	152,000	141,000	293,000	380,000
2054	AN	223,000	6,000	147,000	376,000	307,000	177,000	484,000	-107,000
2055	AN	286,000	7,000	157,000	449,000	273,000	191,000	464,000	-20,000
2056	D	244,000	11,000	230,000	486,000	801,000	197,000	999,000	-511,000
2057	D	246,000	1,000	293,000	540,000	581,000	201,000	782,000	-246,000
2058	BN	270,000	3,000	263,000	536,000	342,000	198,000	540,000	-11,000
2059	D	294,000	1,000	251,000	546,000	480,000	201,000	681,000	-137,000
2060	W	393,000	27,000	237,000	657,000	255,000	183,000	439,000	206,000
2061	W	327,000	14,000	184,000	524,000	148,000	152,000	300,000	217,000
2062	C	209,000	0	194,000	403,000	521,000	186,000	707,000	-297,000
2063	C	332,000	7,000	264,000	604,000	799,000	203,000	1,002,000	-399,000
2064	BN	238,000	0	313,000	552,000	788,000	203,000	991,000	-443,000
2065	AN	367,000	13,000	281,000	662,000	379,000	190,000	568,000	87,000
2066	W	386,000	23,000	245,000	654,000	315,000	177,000	492,000	155,000
2067	D	217,000	1,000	238,000	457,000	406,000	190,000	596,000	-143,000
2068	C	230,000	10,000	274,000	514,000	704,000	204,000	908,000	-395,000
2069	C	236,000	2,000	318,000	556,000	847,000	207,000	1,054,000	-501,000
2070	C	265,000	0	324,000	589,000	816,000	208,000	1,024,000	-438,000
Average (2020 - 2040)		301,000	11,000	205,000	517,000	393,000	187,000	579,000	-66,000
Average (2020 - 2070)		305,000	11,000	231,000	547,000	467,000	189,000	656,000	-112,000

* Actual water year type for 2017 (all other years derived from historic record)

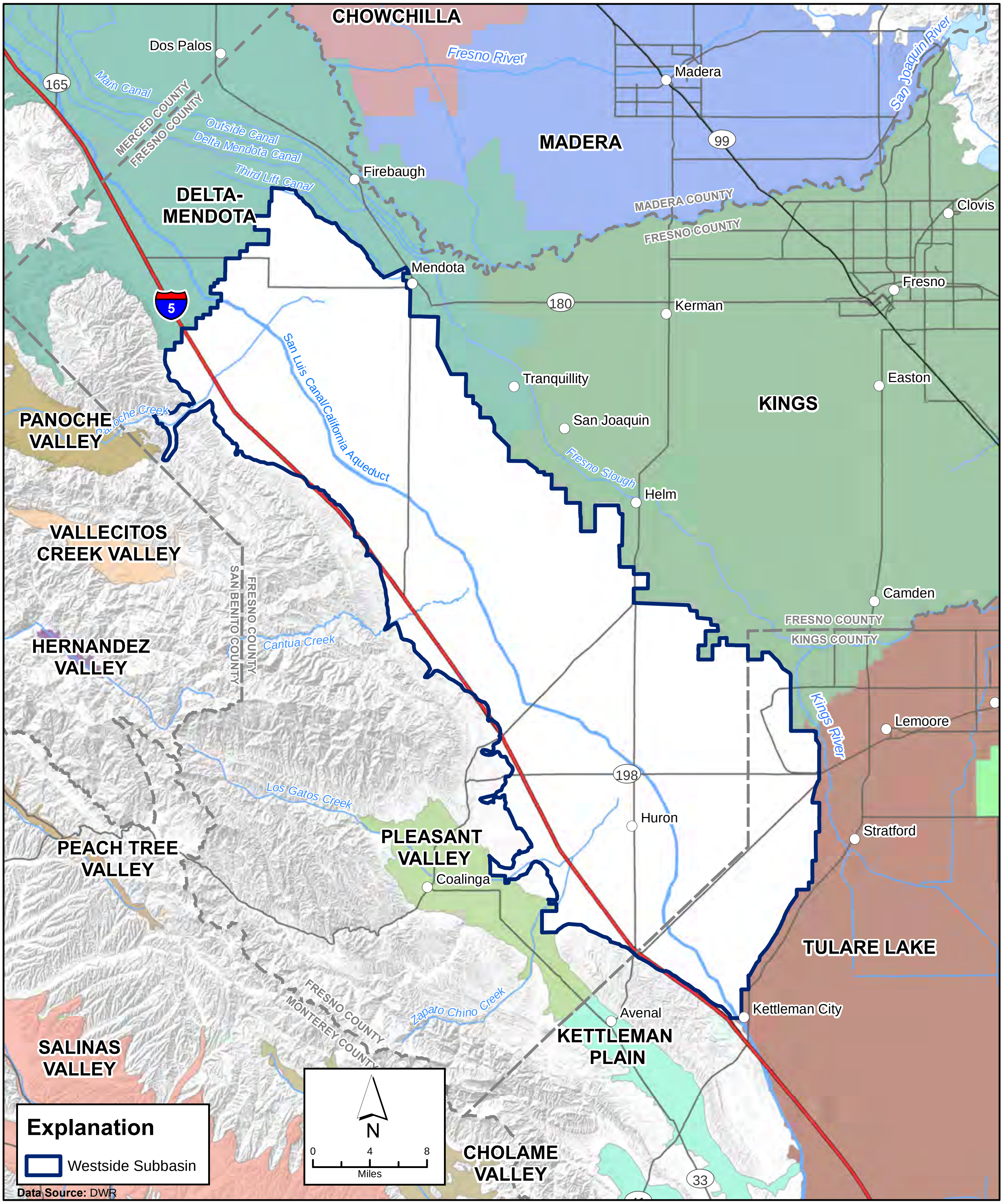


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FIGURE 2-1

Westside Subbasin and Surrounding Basins and Subbasins

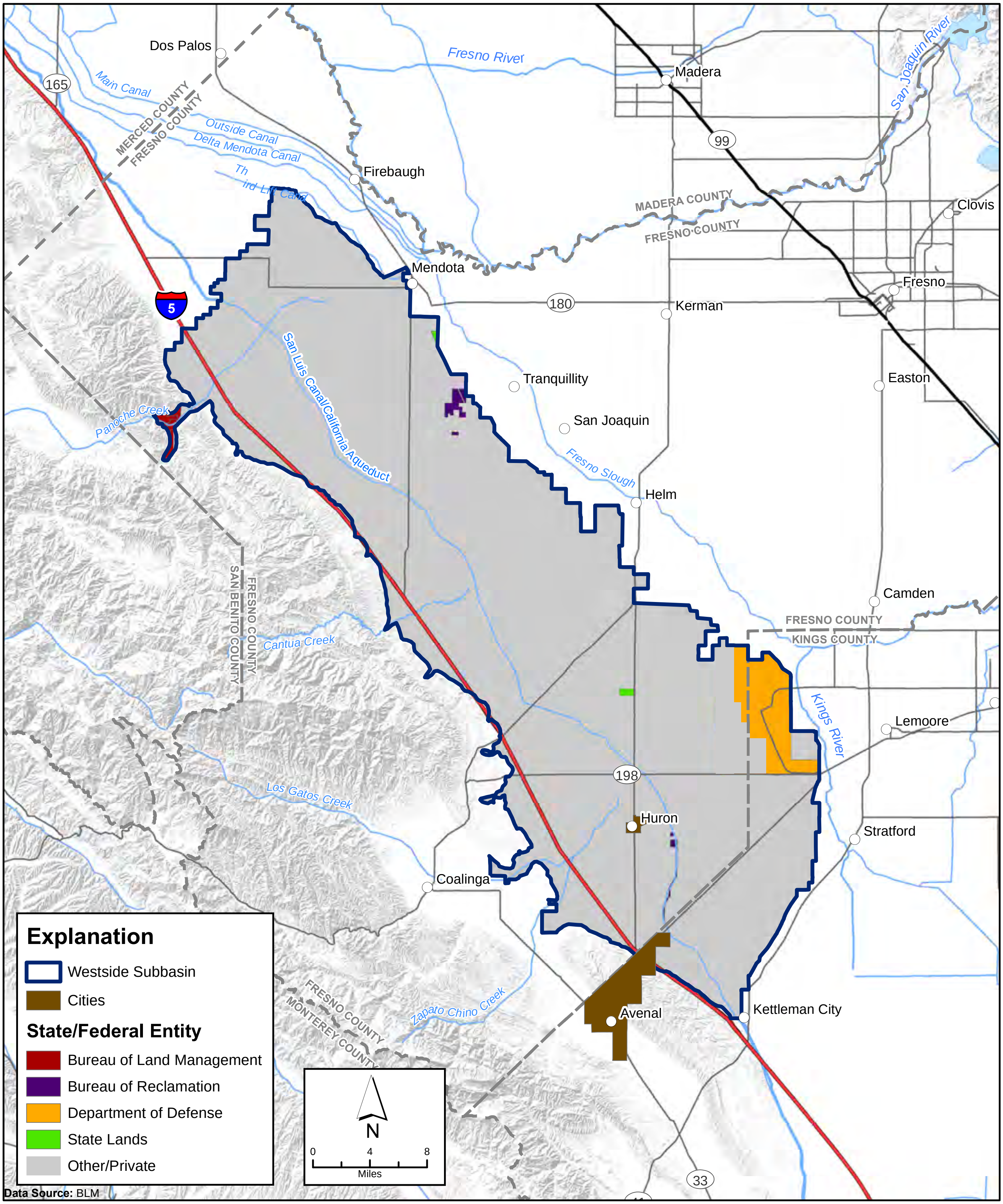

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FIGURE 2-2
Agencies in the GSP Area

Groundwater Sustainability Plan
Westside Subbasin

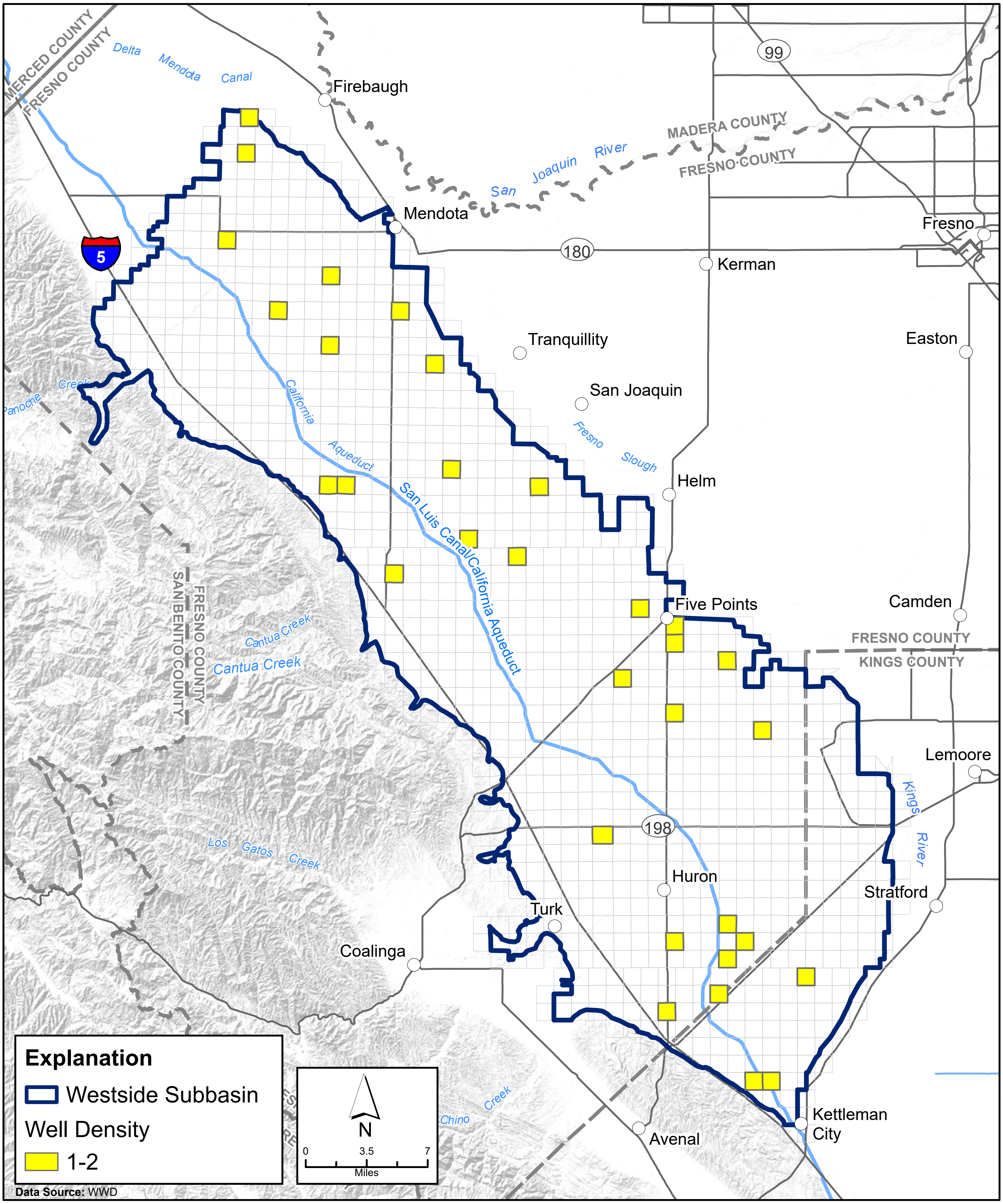

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FIGURE 2-3

Domestic Well Information from Westlands WD Field Survey

Groundwater Sustainability Plan
Westside Subbasin

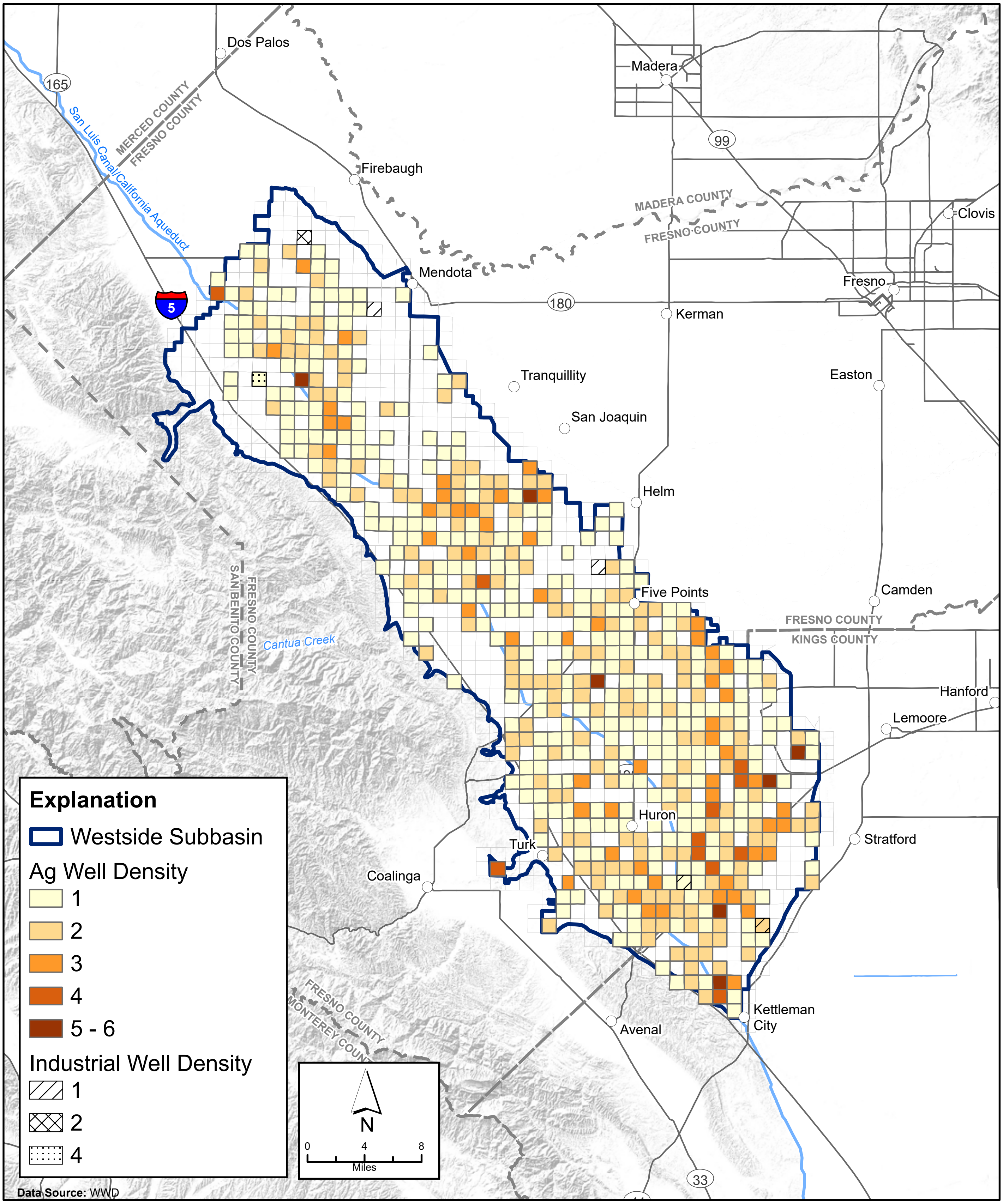

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FIGURE 2-4
Production Well Density (Agricultural & Industrial)

Groundwater Sustainability Plan
Westside Subbasin

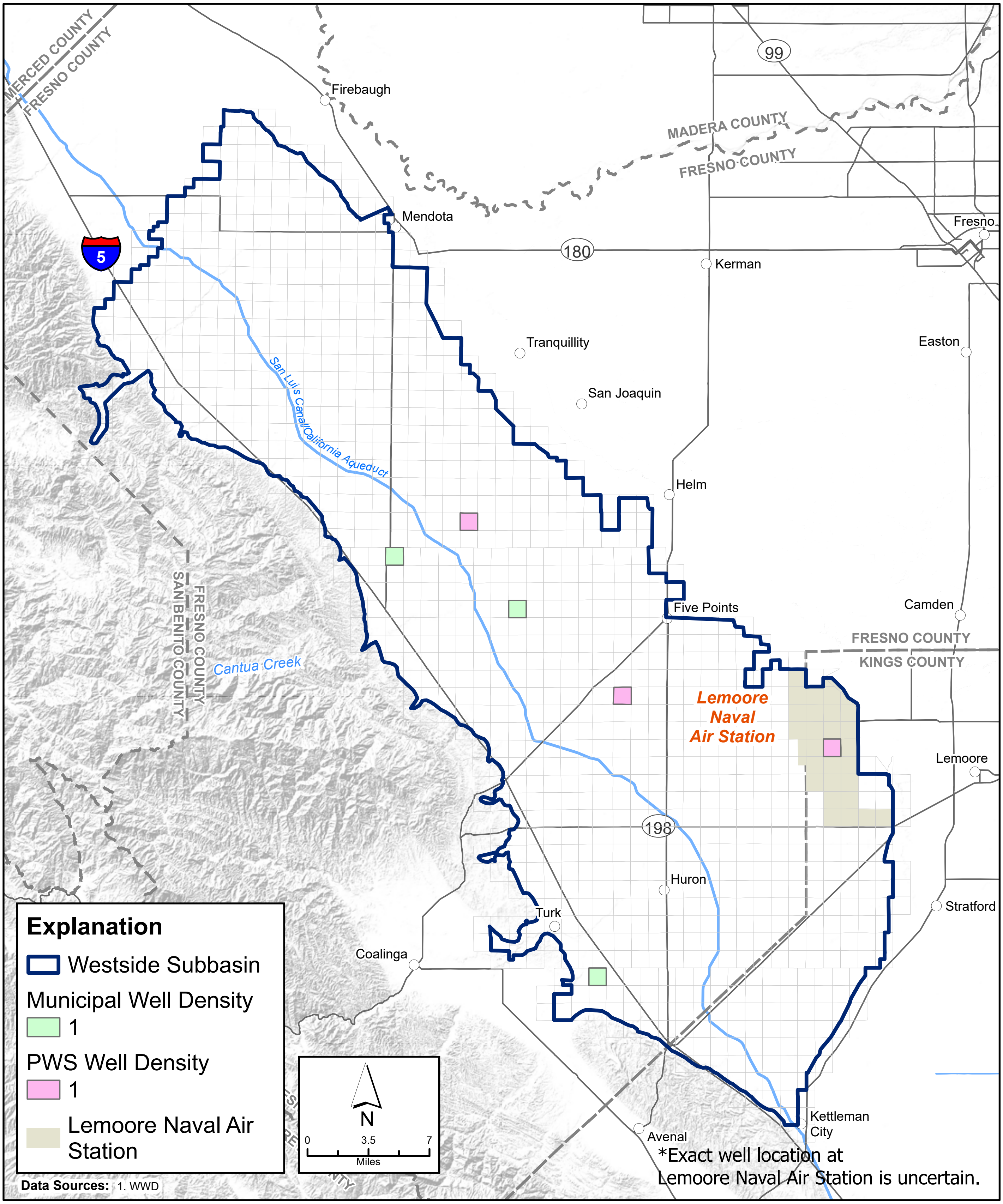

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FIGURE 2-5

Municipal and Public Water Supply Well Density

Groundwater Sustainability Plan
Westside Subbasin

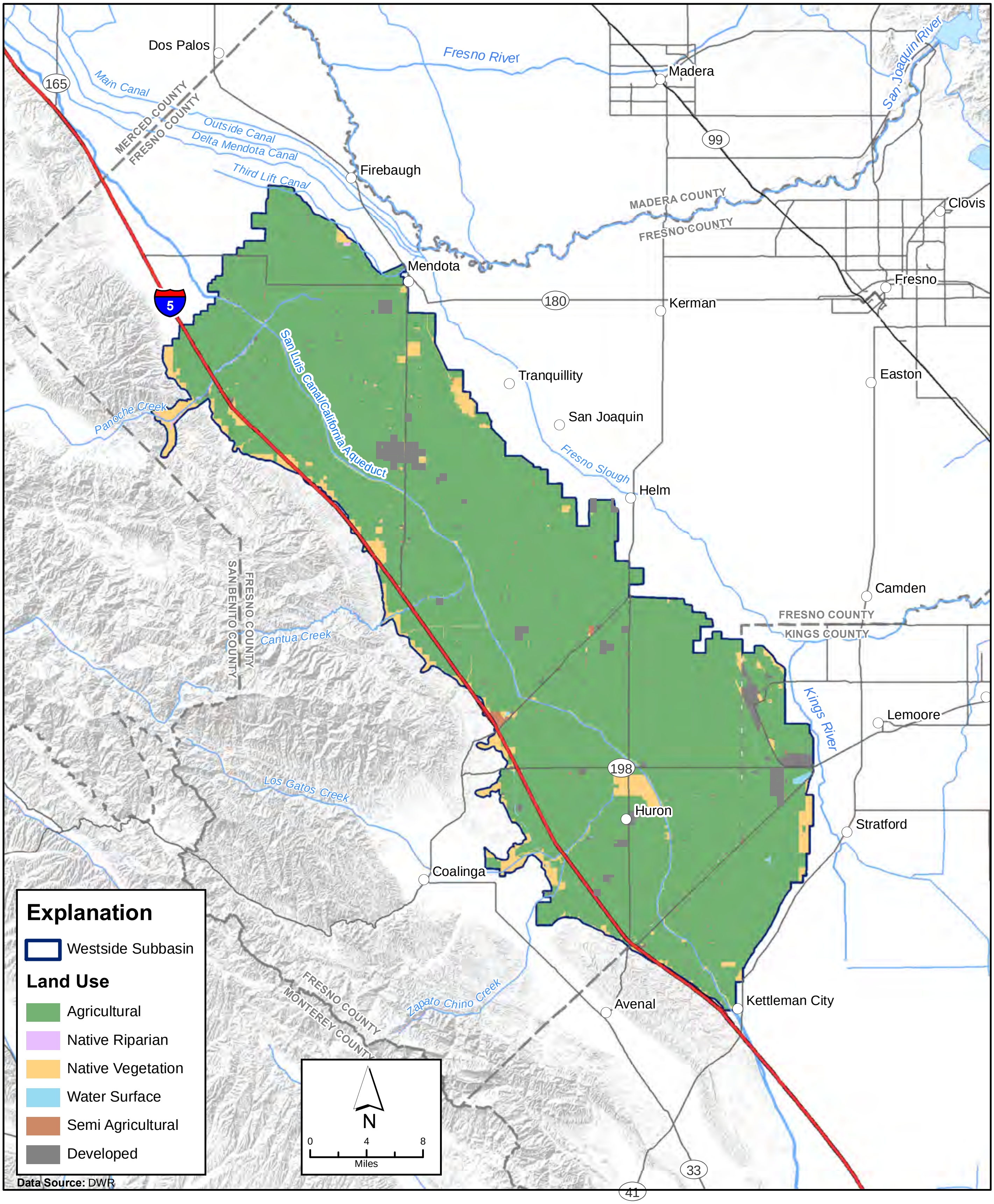

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FIGURE 2-6
General Land Use Designations

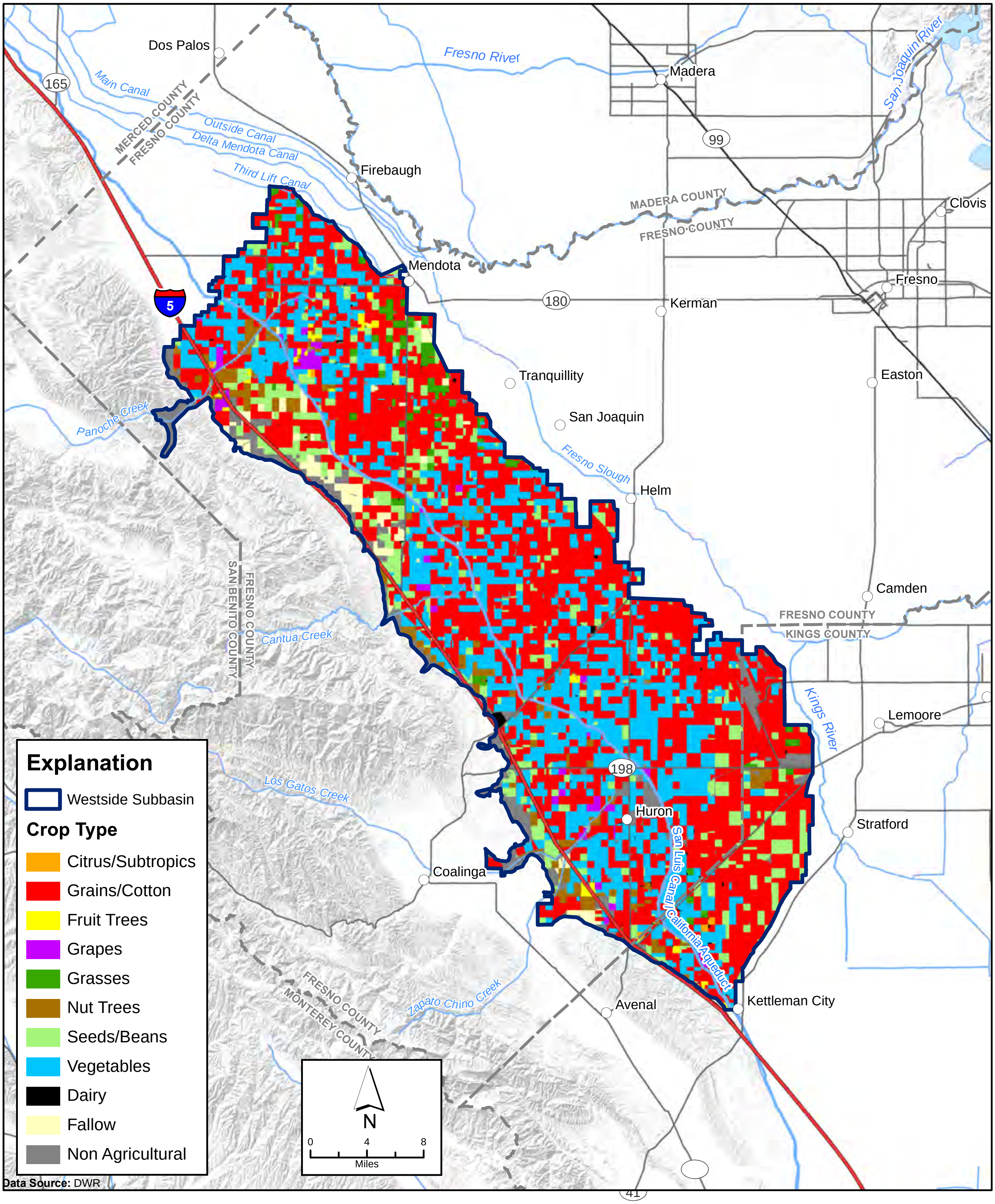

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FIGURE 2-7

Map of Land Use: Mid 1990s

Groundwater Sustainability Plan
Westside Subbasin

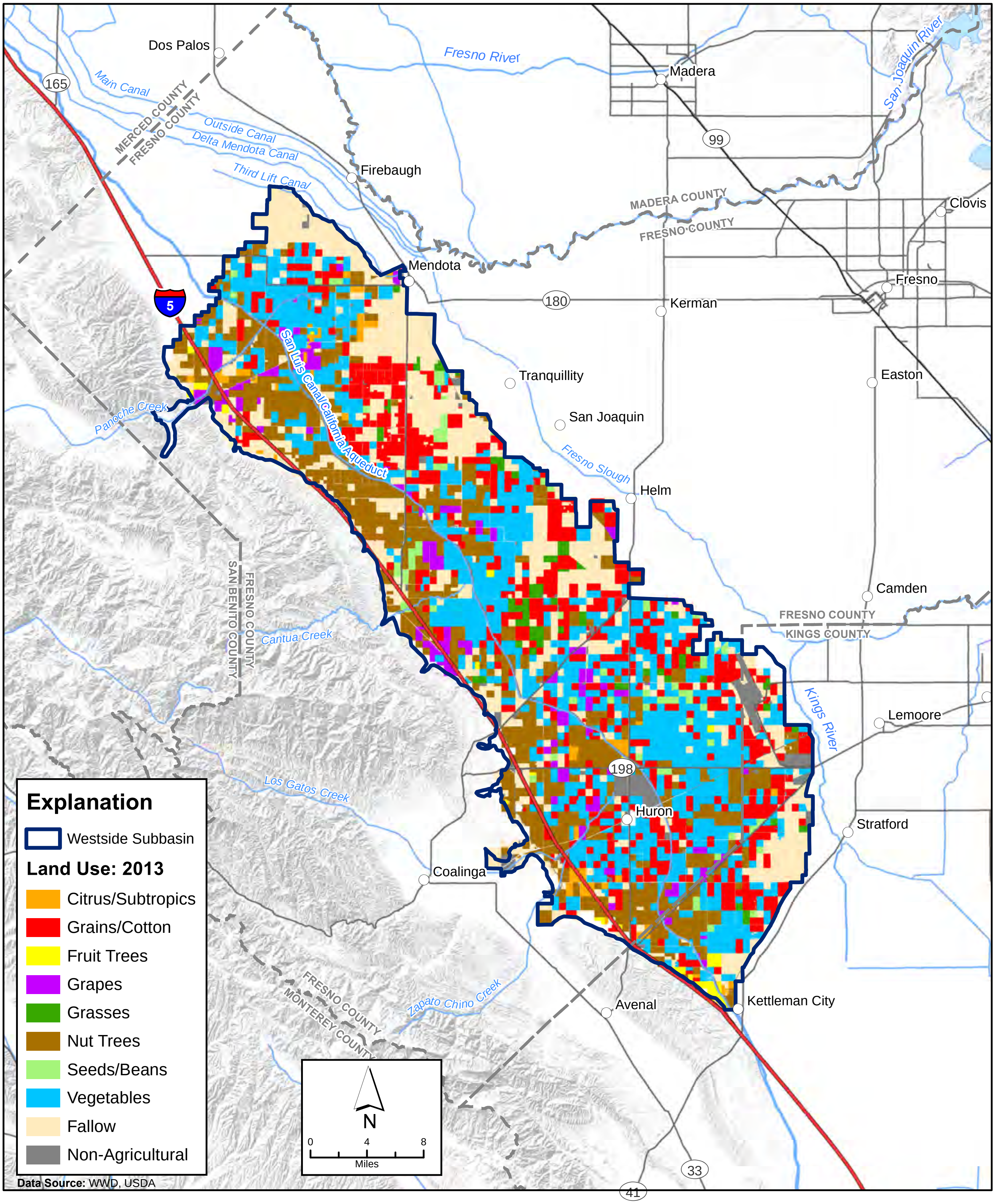

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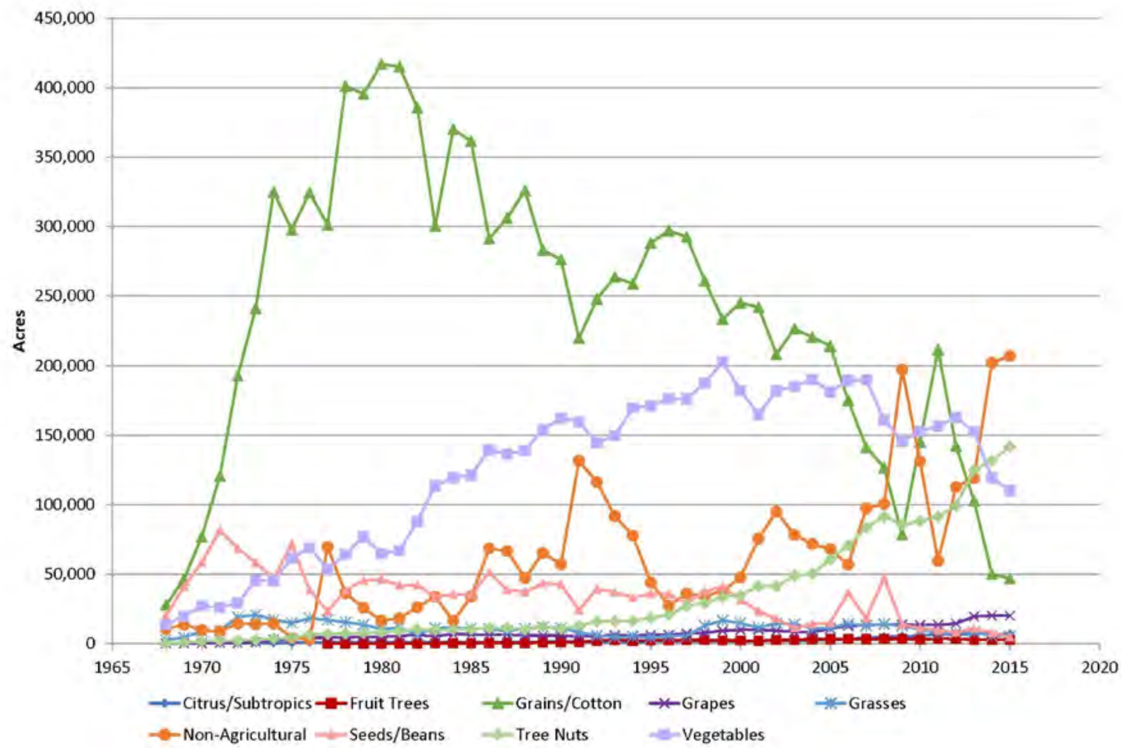
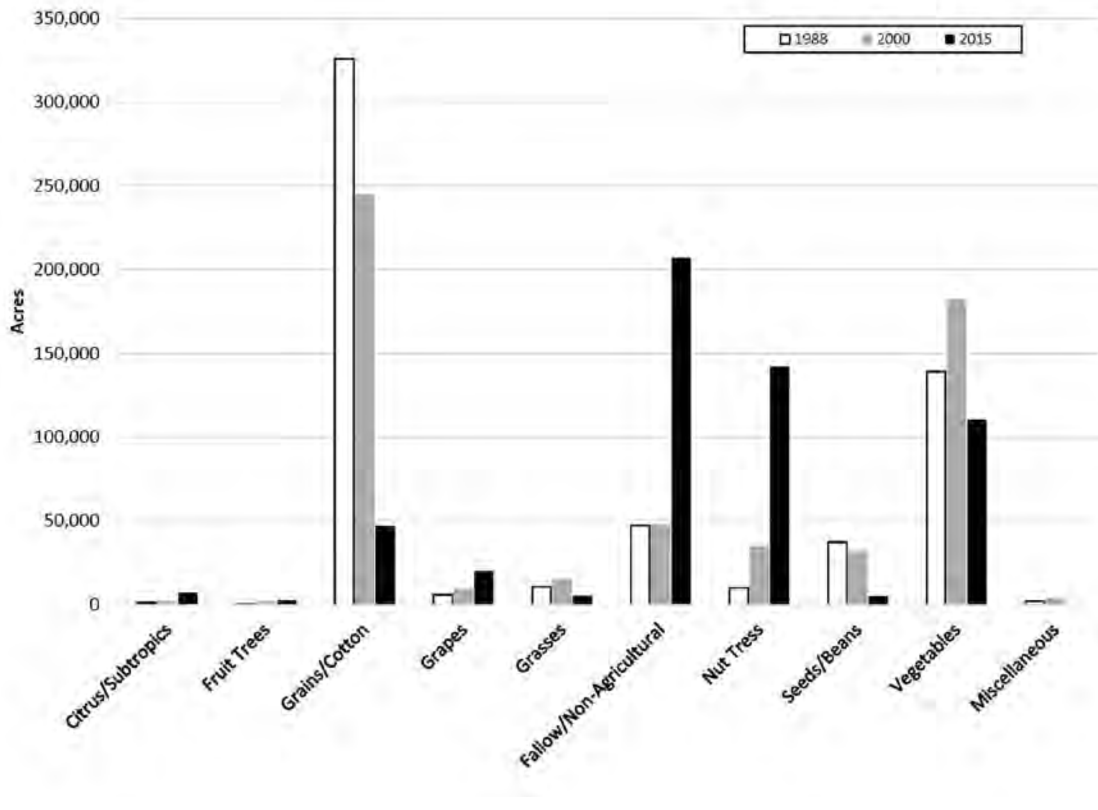
FIGURE 2-8
Map of Land Use: 2013





X:\2017\17-082 Westlands WD - GSP Support Services\GIS\MapFiles\20190417_edits\Figure 2-9 Historical Change in Land Uses.mxd

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FIGURE 2-9
Historical Change in Land Uses

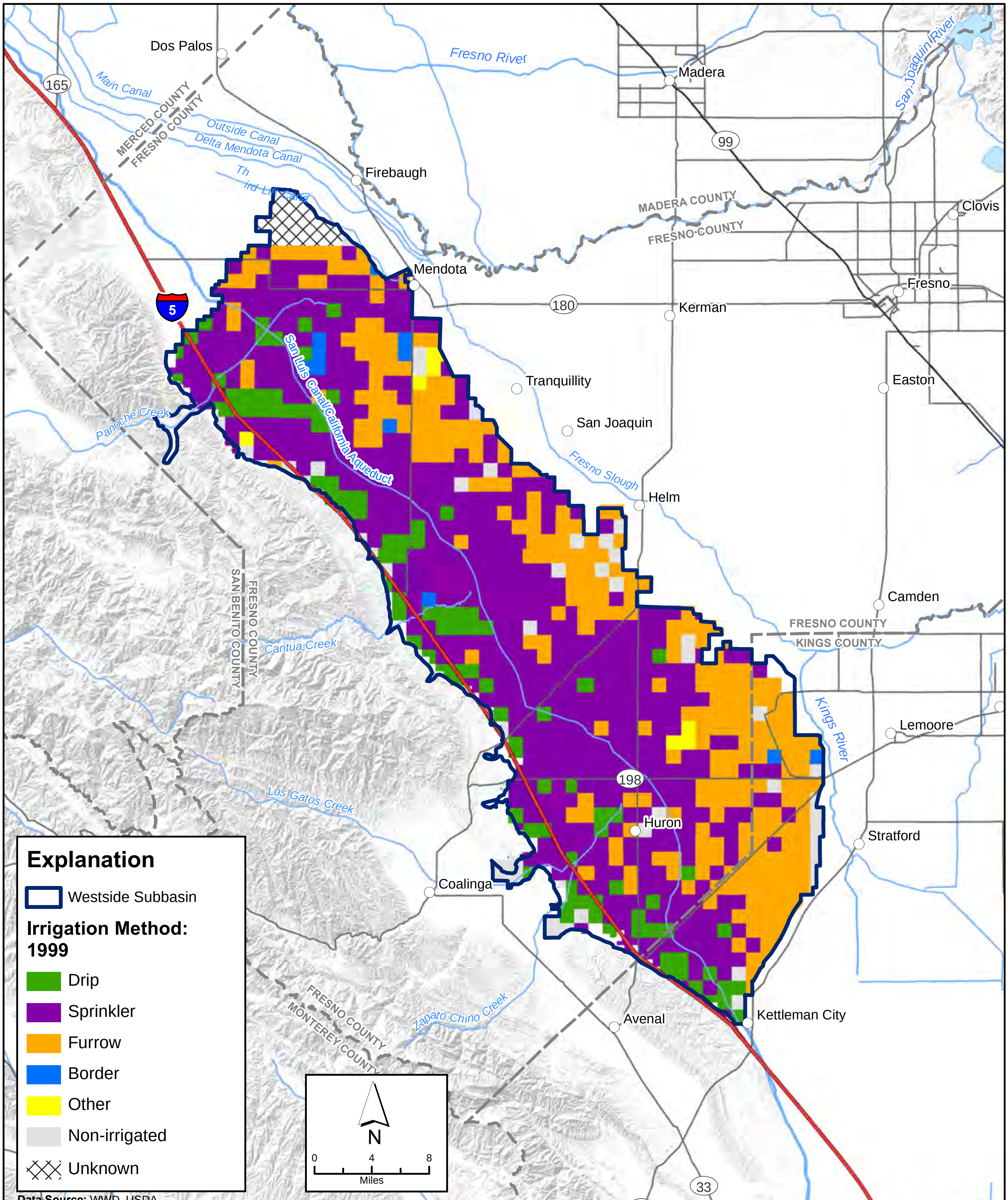

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FIGURE 2-10
Map of Irrigation Practices: 1999

Groundwater Sustainability Plan
Westside Subbasin

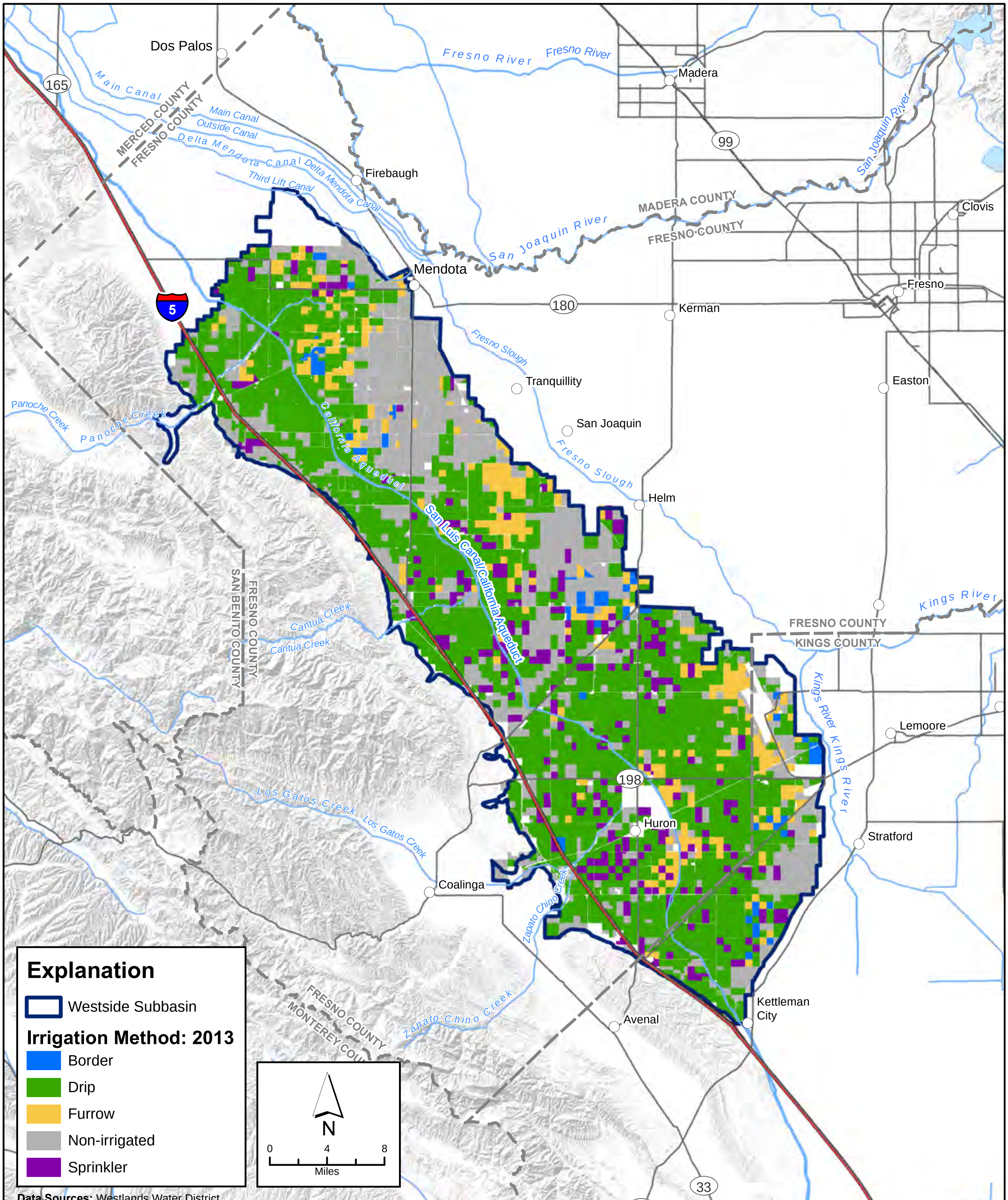

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FIGURE 2-11
Map of Irrigation Practices: 2013

Groundwater Sustainability Plan
Westside Subbasin

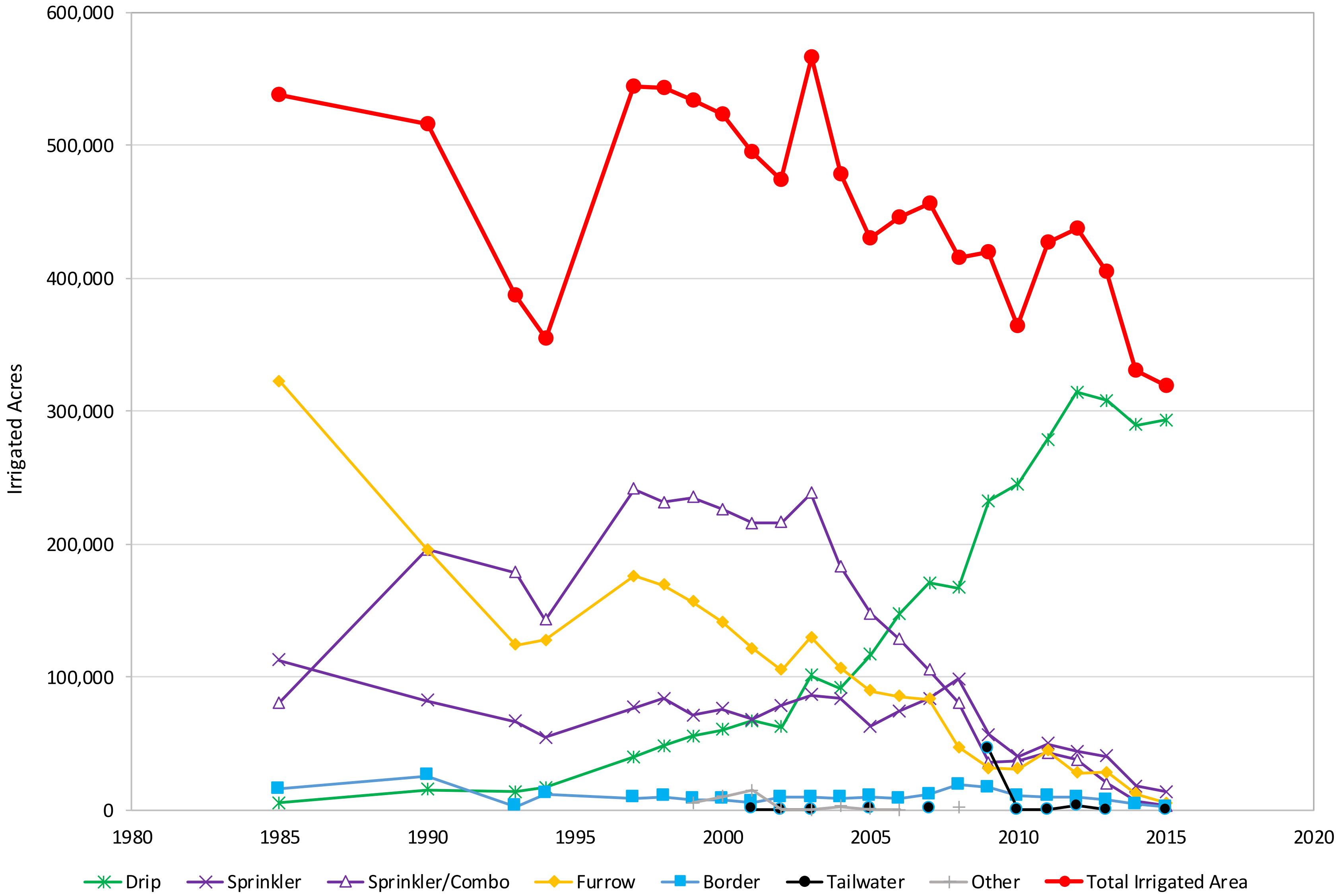

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FIGURE 2-12
Historical Irrigation Practices by Irrigated Acres

Groundwater Sustainability Plan
Westside Subbasin

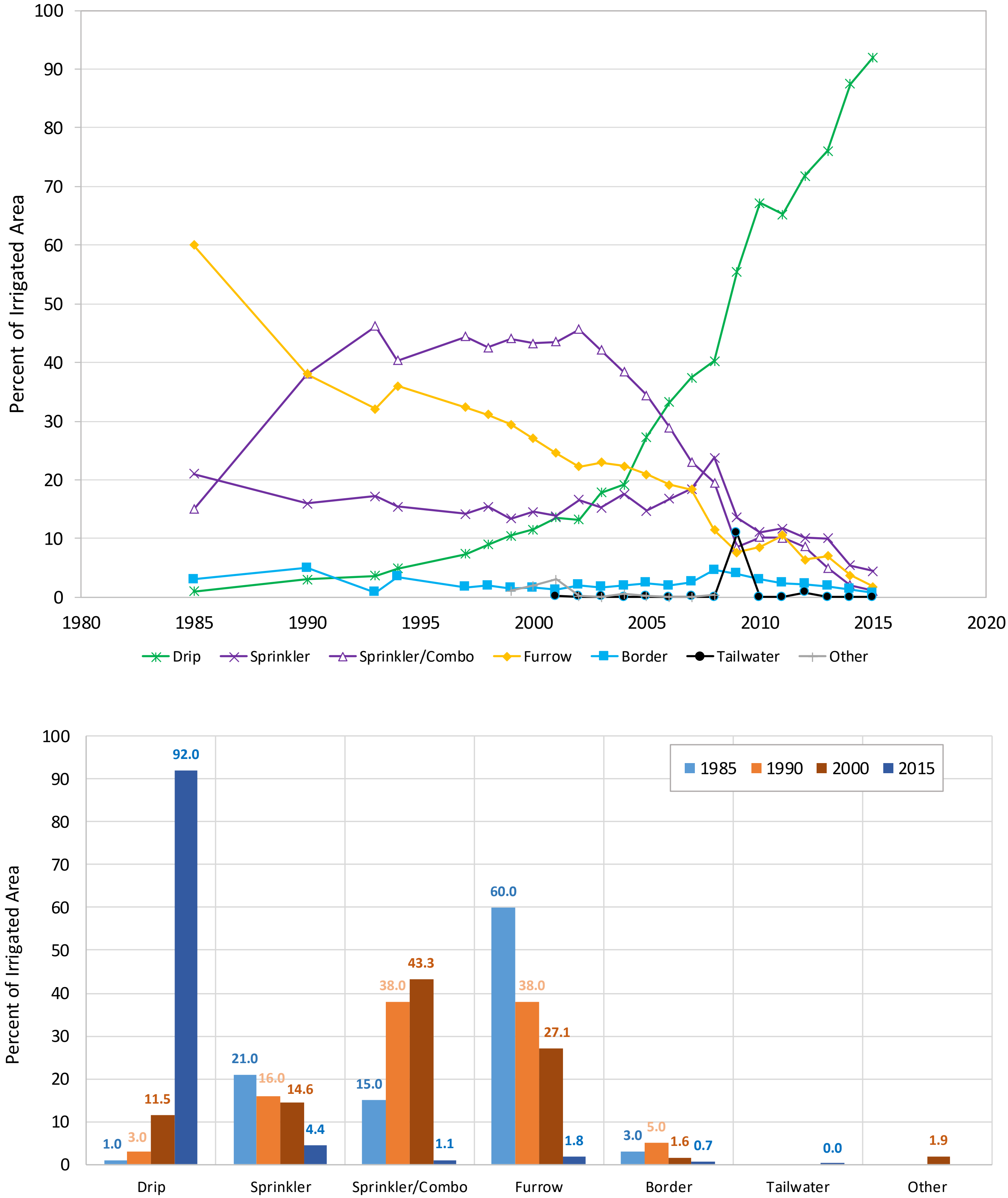

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FIGURE 2-13
Historical Change in Irrigation Practices

Groundwater Sustainability Plan
Westside Subbasin

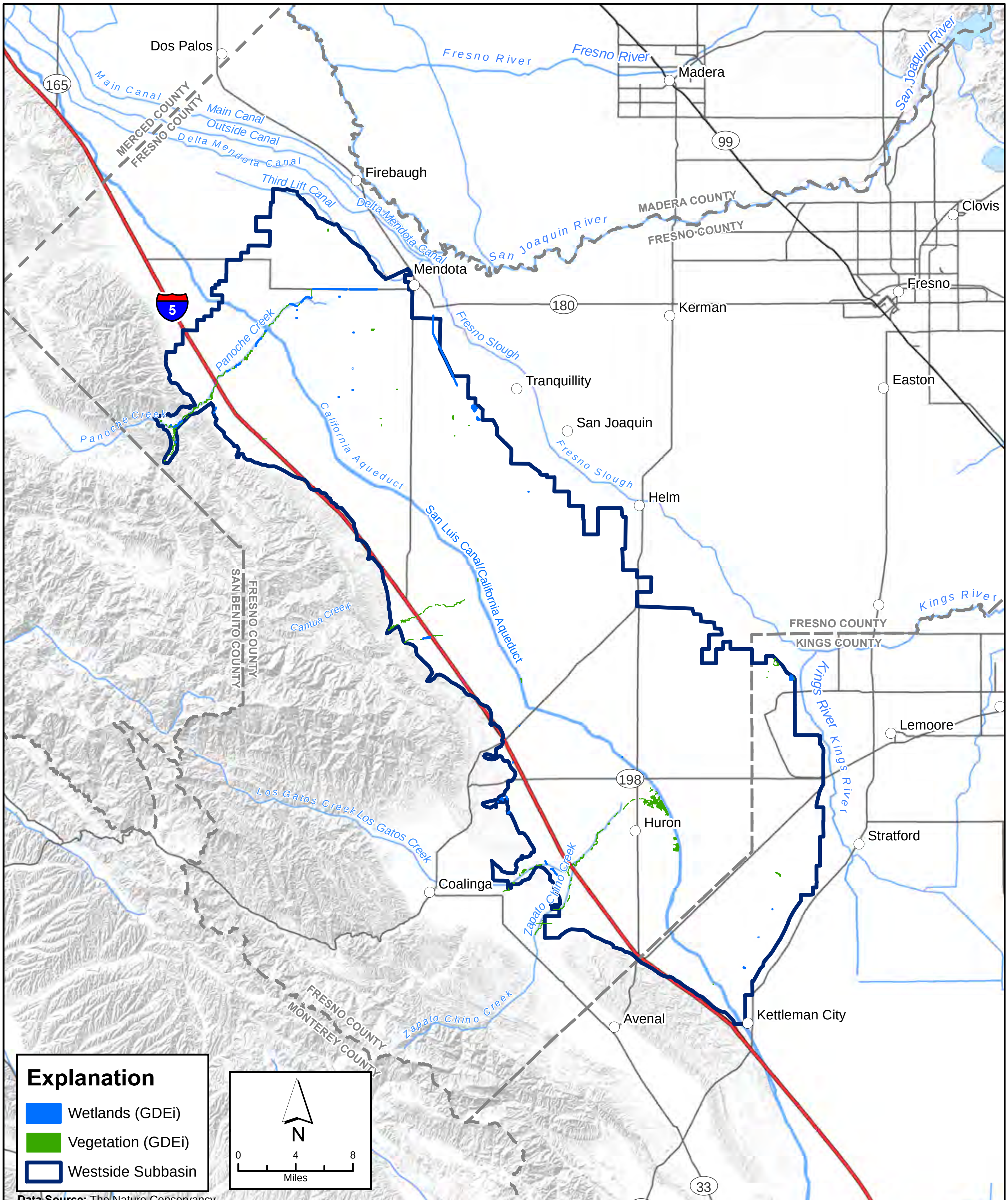

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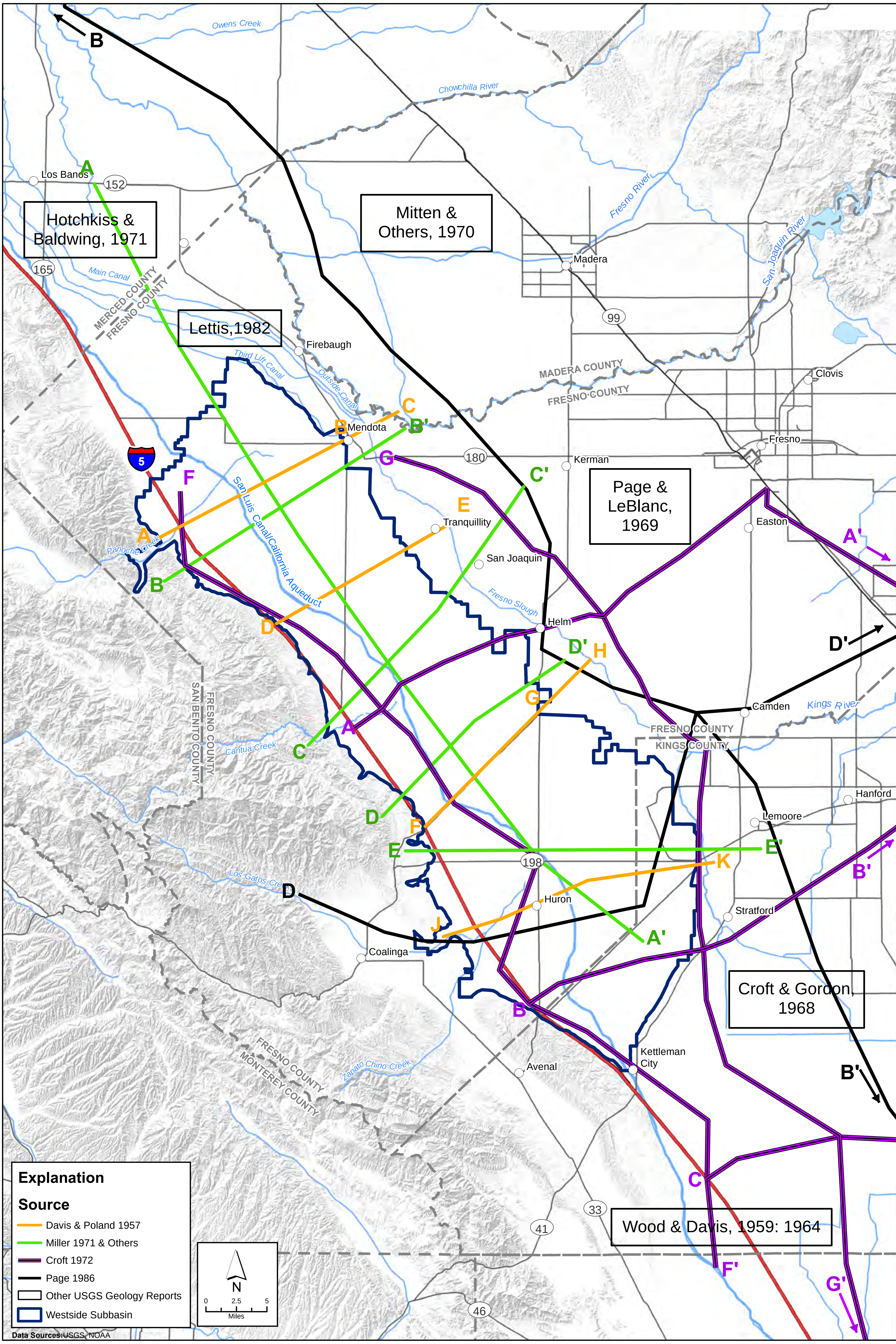
FIGURE 2-14
Potential Groundwater Dependent Ecosystems

Groundwater Sustainability Plan
Westside Subbasin



X:\2017\17-082 Westlands WD - GSP Support Services\GIS\MapFiles\Chapter_2\Figure 2-15 Locations of Cross Section update.mxd

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FIGURE 2-15
Location of Cross Section Traces from USGS References

Groundwater Sustainability Plan
Westside Subbasin

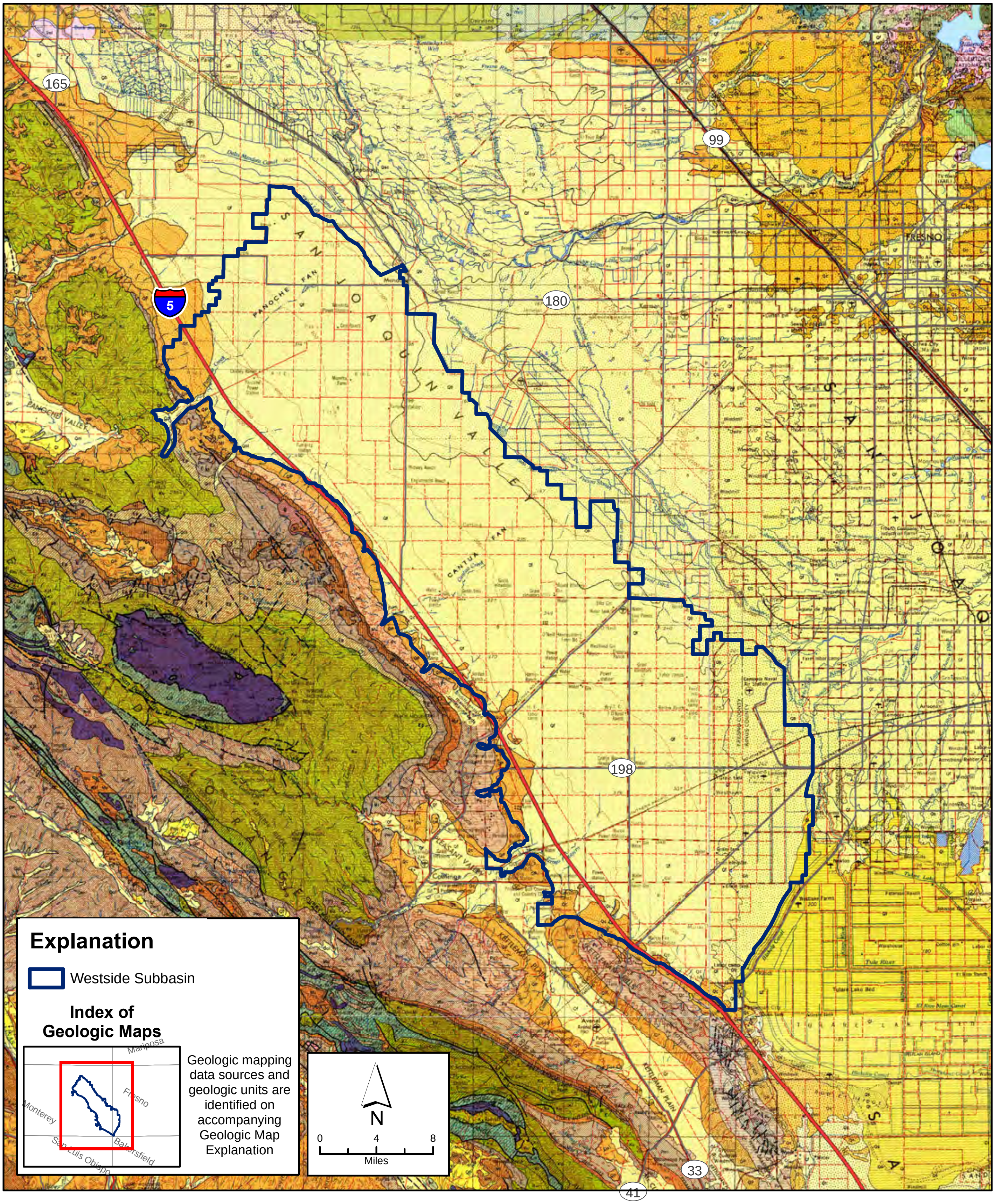

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FIGURE 2-16A
Geologic Map, Vicinity of Westlands Water District
Groundwater Sustainability Plan
Westside Subbasin

Compiled Geologic Map Explanation

Santa Cruz, San Luis Obispo, Bakersfield, and Fresno Quadrangles

Qal	Alluvium
Qsc	Stream channel deposits (GREAT VALLEY)
Qf	Fan deposits (GREAT VALLEY)
Qb	Basin deposits (GREAT VALLEY)
Ql	Quaternary lake deposits
Qt	Quaternary nonmarine terrace deposits
Qt	River terrace deposits
Qc	Pleistocene nonmarine
QP	Plio-Pleistocene nonmarine
Pc	Undivided Pliocene nonmarine
Pu	Upper Pliocene marine
Pmlc	Middle and/or lower Pliocene nonmarine
Pml	Middle and/or lower Pliocene marine
Mc	Undivided Miocene nonmarine
Muc	Upper Miocene nonmarine
Mu	Upper Miocene marine
Mv	Miocene volcanic: Mv^r —rhyolite; Mv^a —andesite; Mv^b —basalt; Mv^p —pyroclastic rocks
Mmc	Middle Miocene nonmarine
Mm	Middle Miocene marine
Ml	Lower Miocene marine
Φ	Oligocene marine
E	Eocene marine
Ep	Paleocene marine
Ku	Upper Cretaceous marine
Kl	Lower Cretaceous marine
KJf	Franciscan Group
KJfv	Franciscan volcanic and metavolcanic rocks
gr	Mesozoic granitic rocks
ub	Mesozoic ultrabasic intrusive rocks

Geologic Map compiled from:

1. Jennings, C.W. and Strand, R.G. , 1958, Geologic Atlas of California - Santa Cruz Quadrangle, California Geological Survey, Geologic Atlas of California Map No. 020, 1:250,000 scale.
2. Jennings, C.W., 1958, Geologic map of California - San Luis Obispo Quadrangle, California Division of Mines and Geology, 1:250,000 scale.
3. Smith, A.R., 1964, Geologic map of California - Bakersfield Quadrange, California Division of Mines and Geology, 1:250,000 scale.
4. Matthews, R.A. and Burnett, J.L. , 1965, Geologic Atlas of California - Fresno Quadrangle, California Geological Survey, Geologic Atlas of California Map No. 005, 1:250,000 scale.

X:\2015 Job Files\15-104 Westlands WD\GIS\Map Files\Figure 3-2B Geologic Map, (Explanation).mxd

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FIGURE 2-16B
Geologic Map, (Explanation)

Groundwater Sustainability Plan
Westside Subbasin

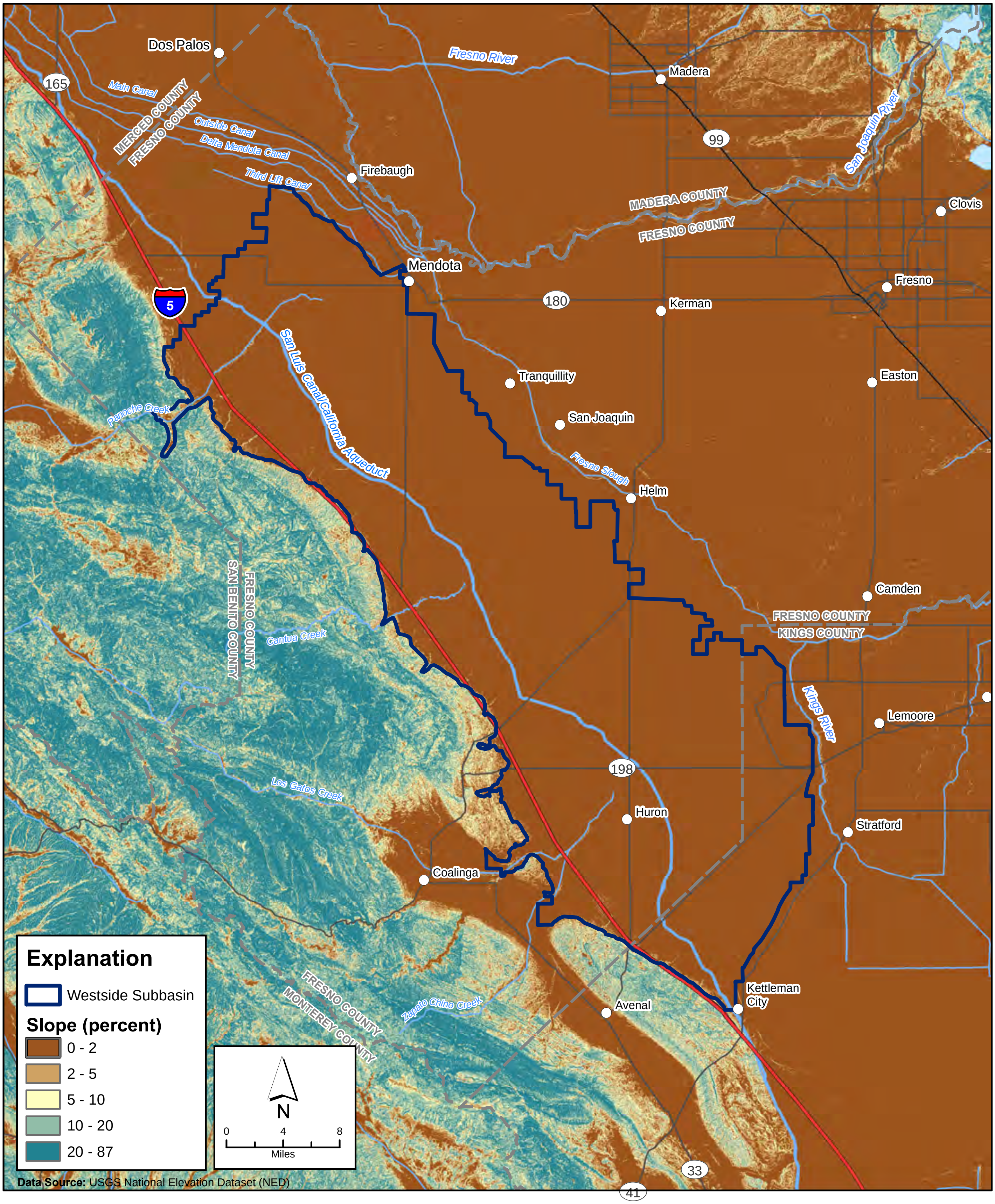

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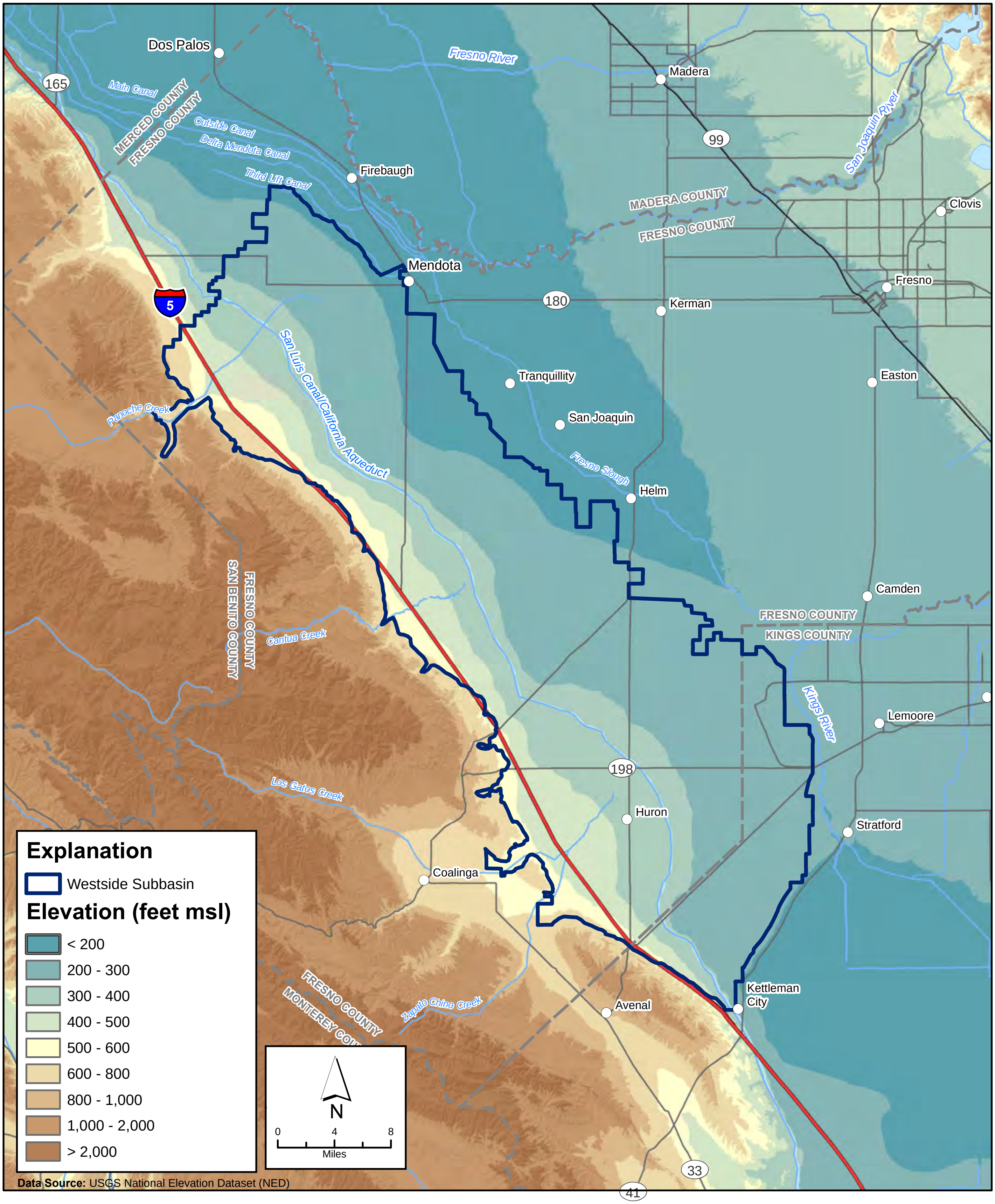
FIGURE 2-17
Map of Topographic Slope

Groundwater Sustainability Plan
Westside Subbasin



Data Source: USGS National Elevation Dataset (NED)

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FIGURE 2-18
Map of Ground Surface Elevation

Groundwater Sustainability Plan
Westside Subbasin

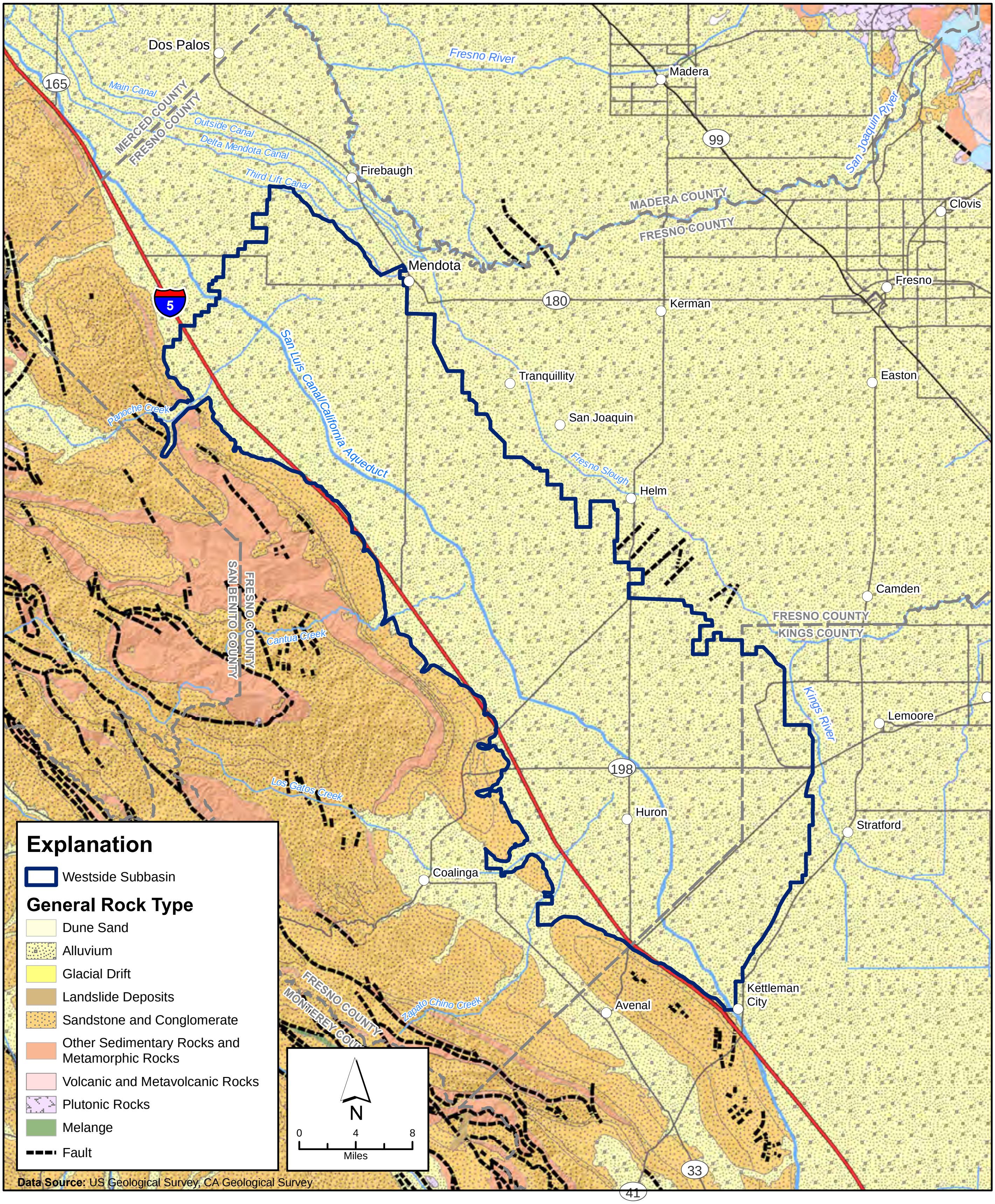

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FIGURE 2-19
Geologic Map with Faults, Vicinity of WWD

Groundwater Sustainability Plan
Westside Subbasin

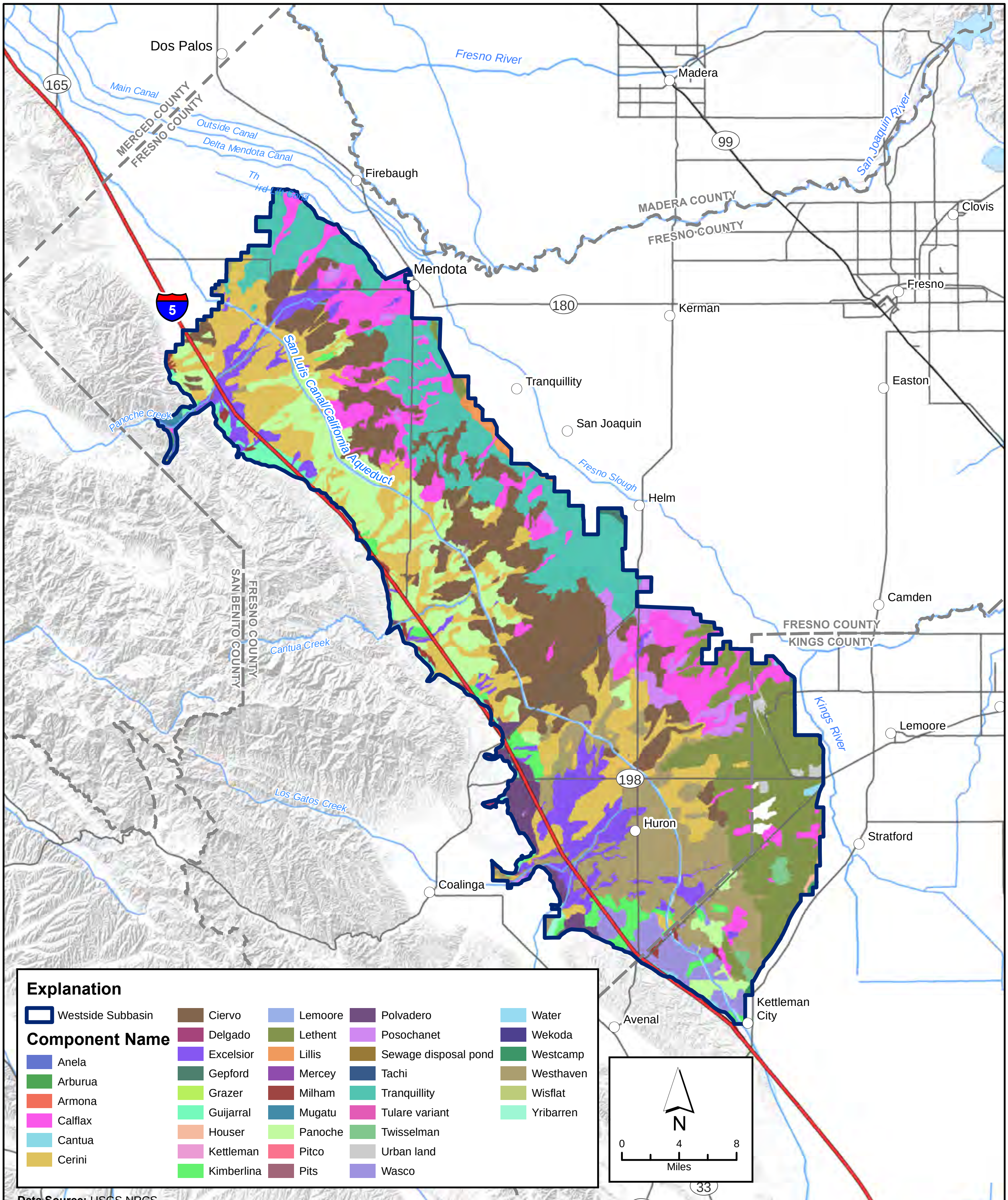

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FIGURE 2-20
Soils - Type

Groundwater Sustainability Plan
Westside Subbasin

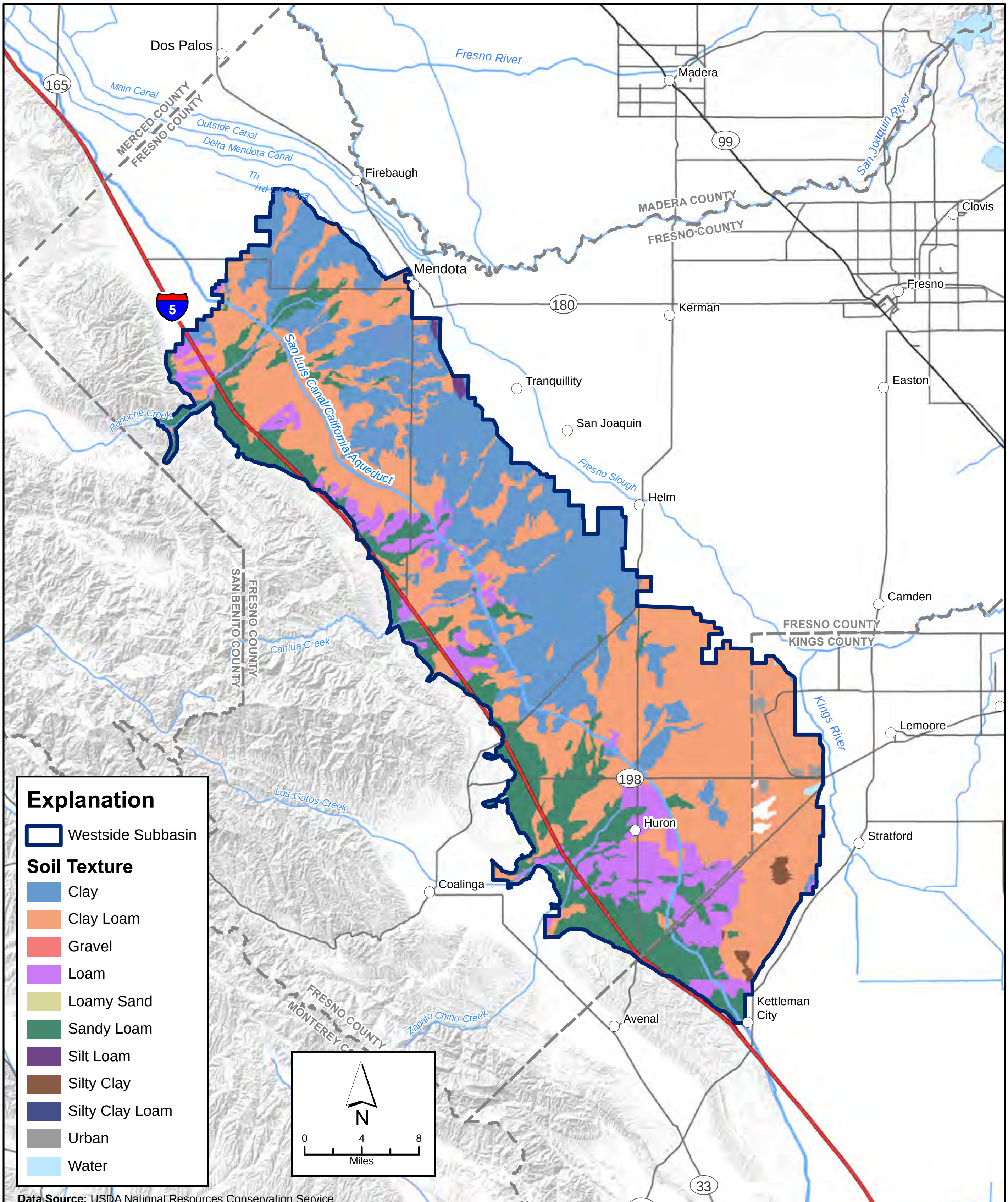

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FIGURE 2-21
Soils - Texture

Groundwater Sustainability Plan
Westside Subbasin

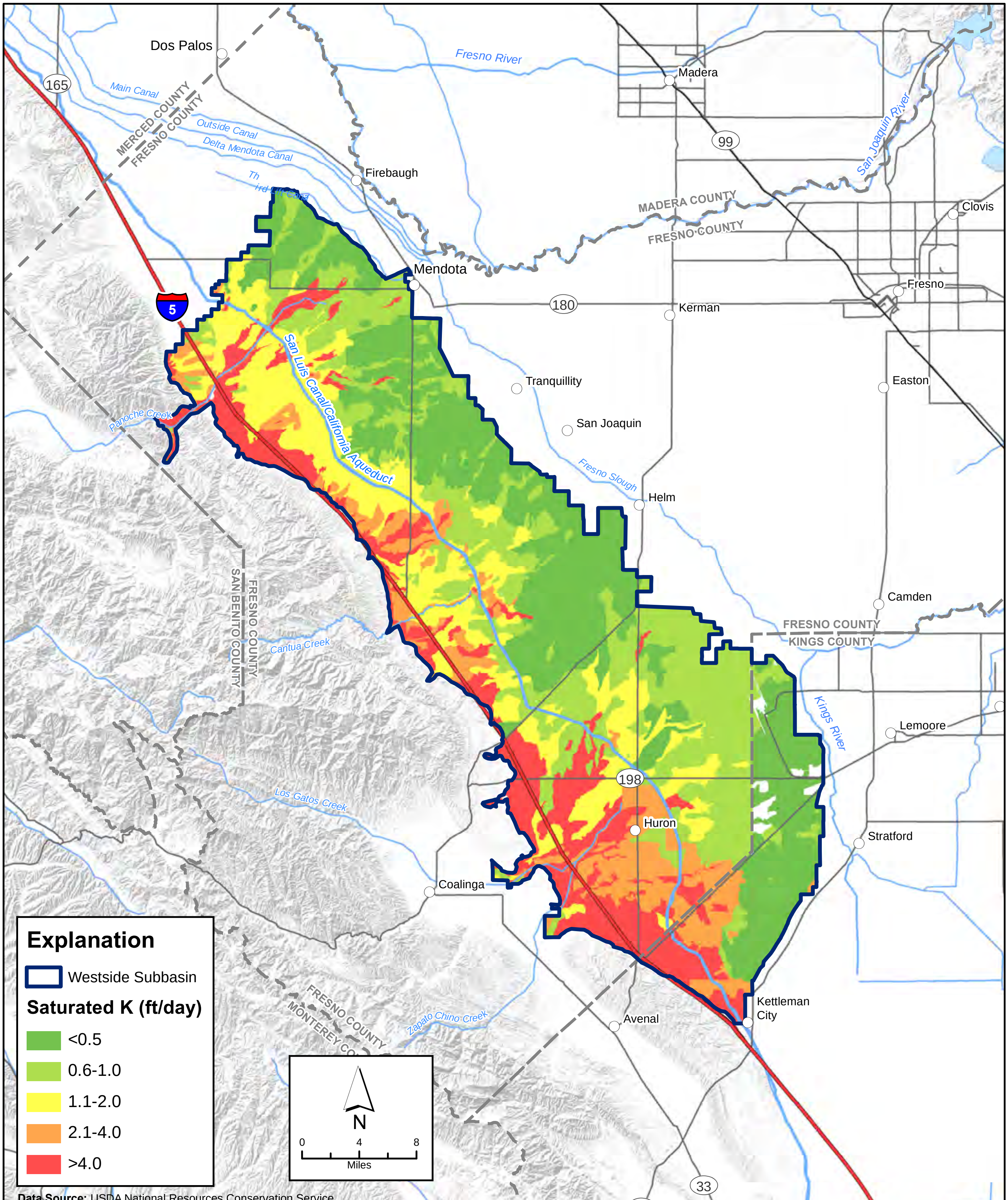

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FIGURE 2-22
Soils - Hydraulic Conductivity

Groundwater Sustainability Plan
Westside Subbasin

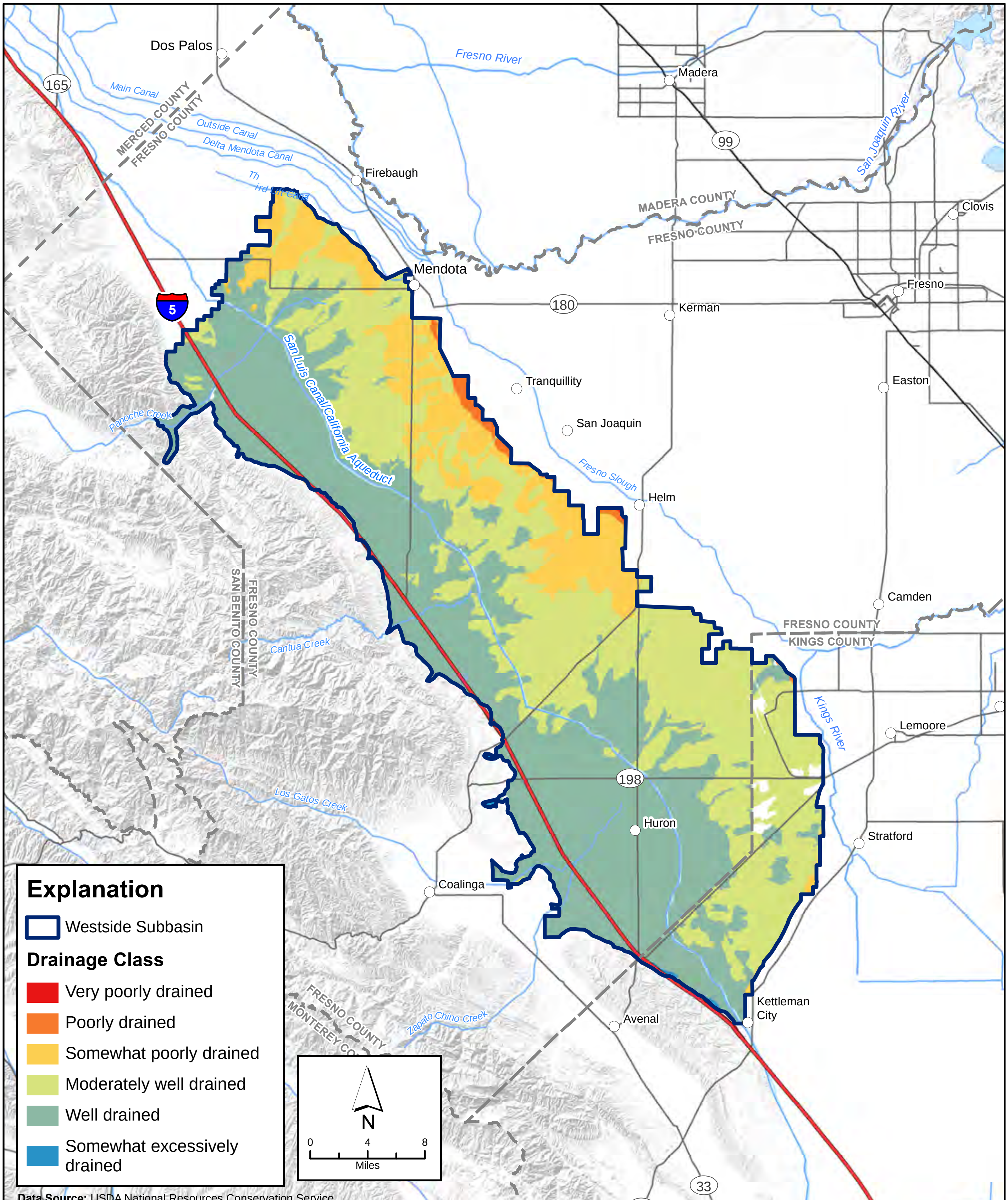

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FIGURE 2-23
Soils - Drainage

Groundwater Sustainability Plan
Westside Subbasin

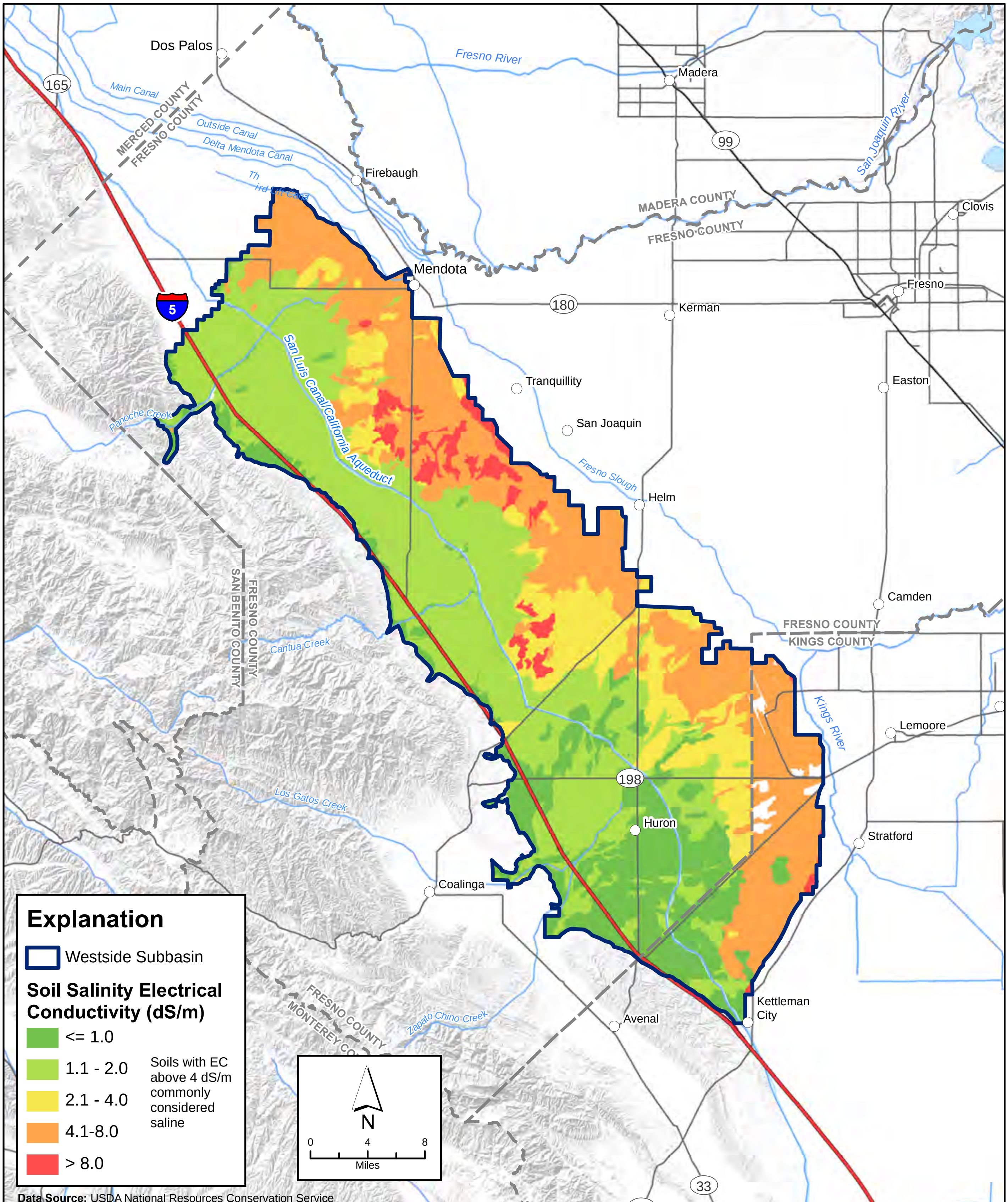

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FIGURE 2-24
Soils - Electrical Conductivity (EC)

Groundwater Sustainability Plan
Westside Subbasin

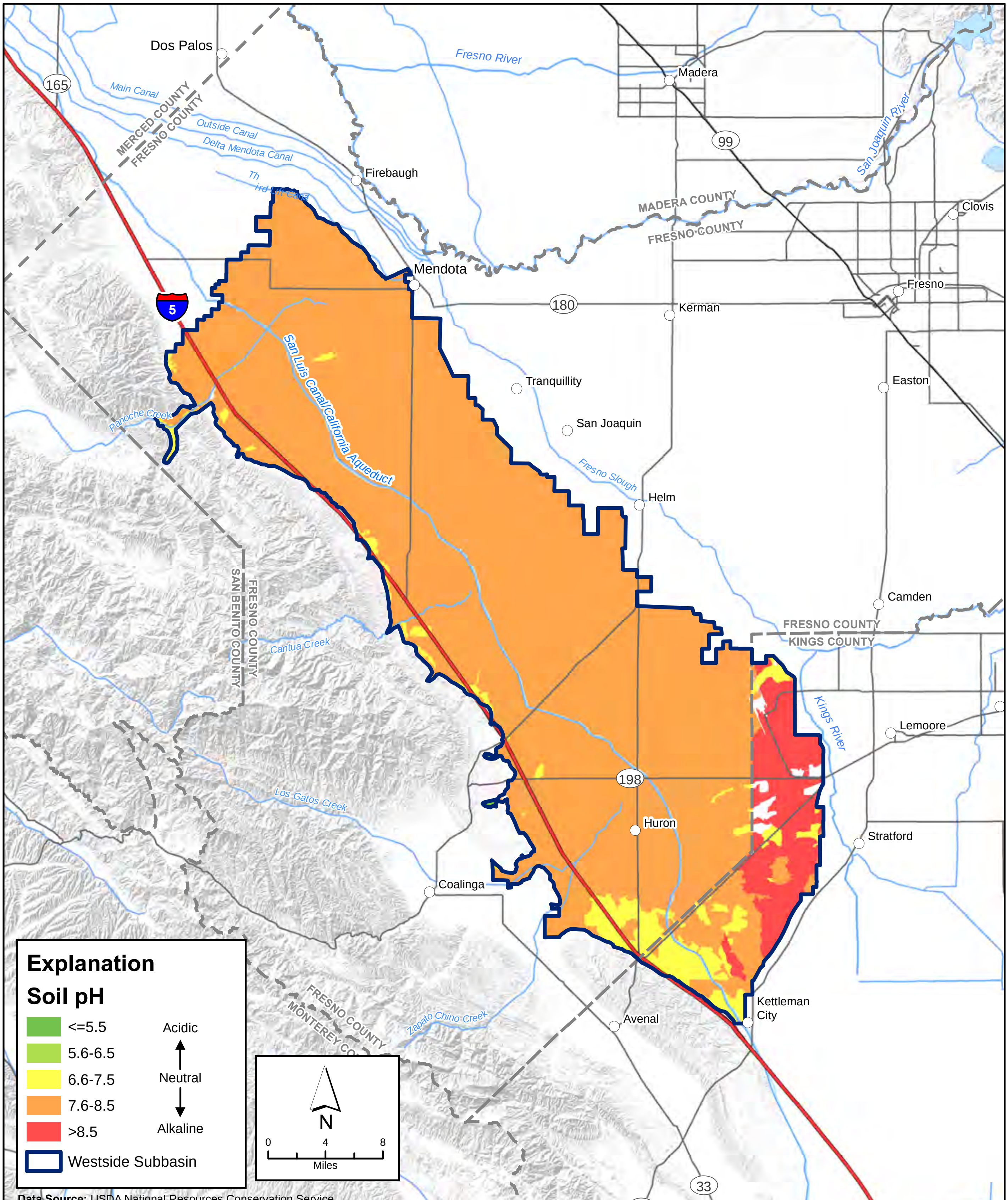

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FIGURE 2-25
Soils - pH

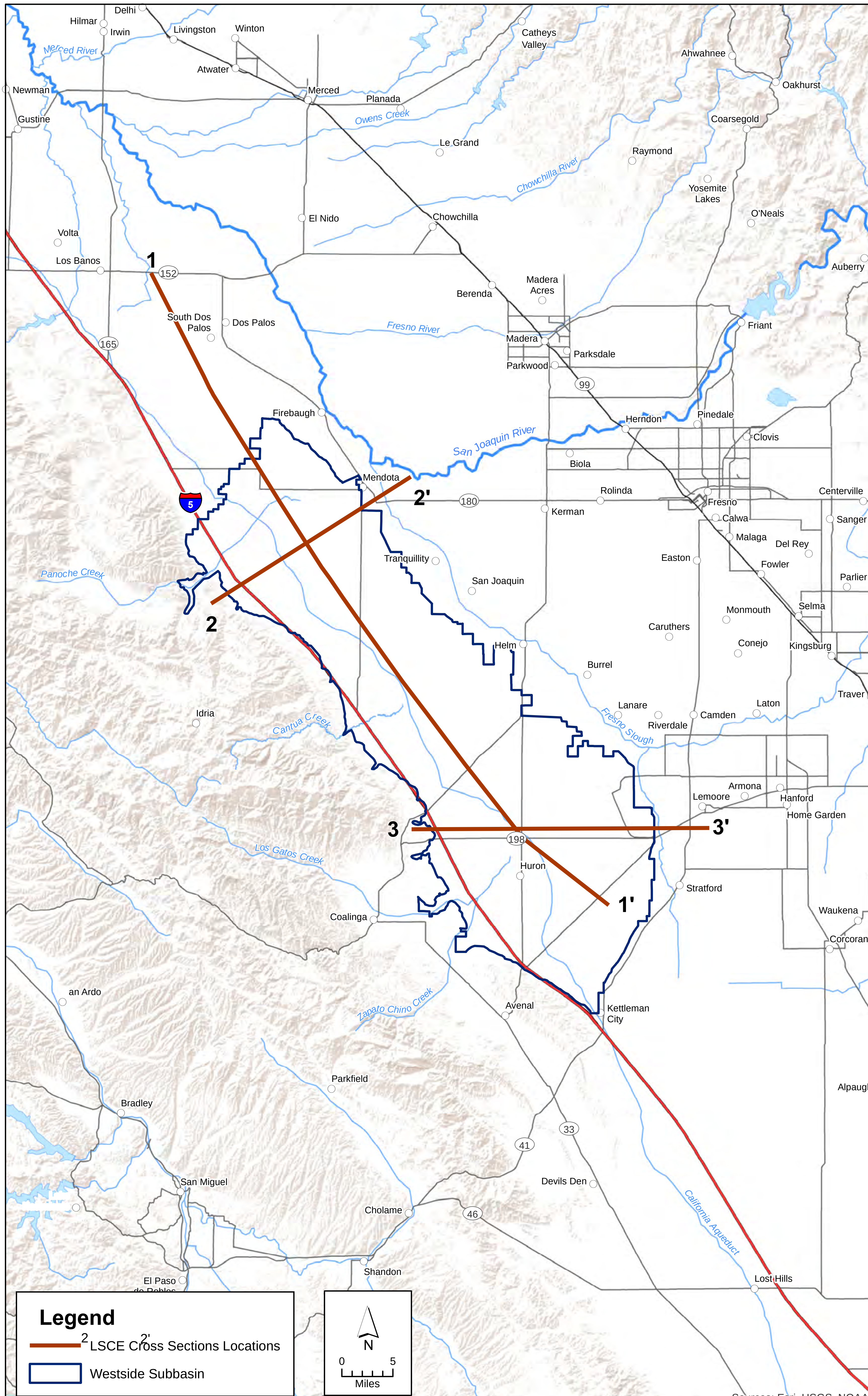

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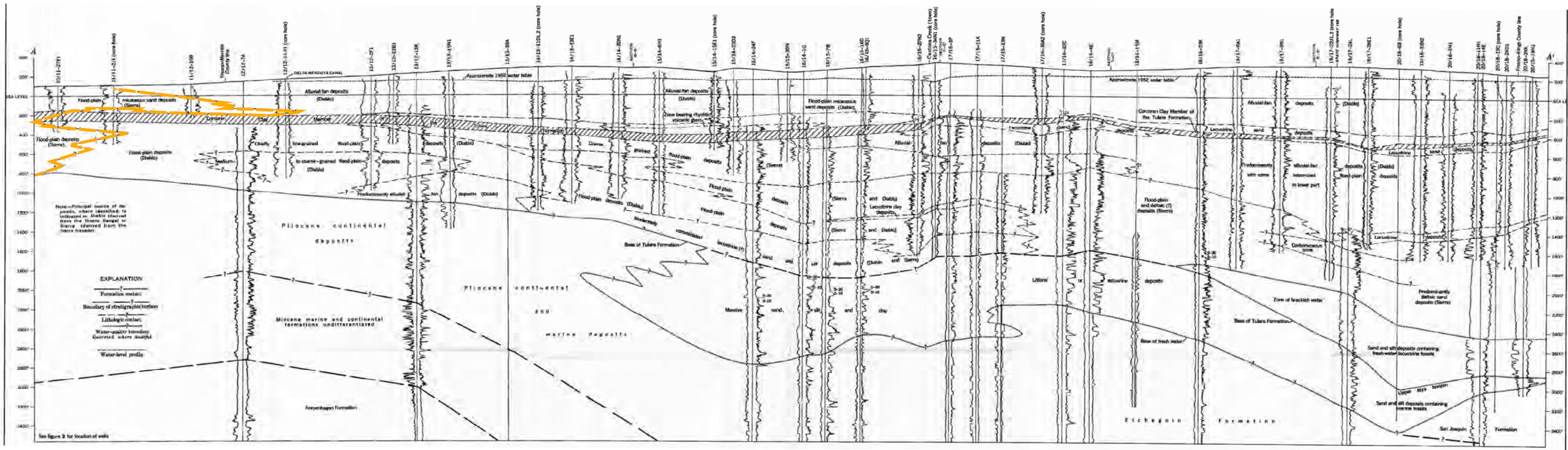
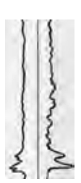
FIGURE 2-26
LSCE Geologic Cross Section Location Map

Groundwater Sustainability Plan
Westlands Water District





Geophysical Log
Left: Self-Potential
Right: Resistivity

EXPLANATION

——— ? ———
Formation contact

— — ? — —
Boundary of stratigraphic horizon

— — ? — —
Lithologic contact

······· ? ·······
Water-quality boundary
Queried where doubtful

— — — — — —
Water-level profile

Note — Principal source of deposits, where identified, is indicated as Diablo (derived from the Diablo Range) or Sierra (derived from the Sierra Nevada)

Edge of Coast Range Sourced Units

//// bfw *Base Fresh Water Page 1973*

Modified from:
Miller & Others, 1971 A-A'

0 1.5 3 6
Miles

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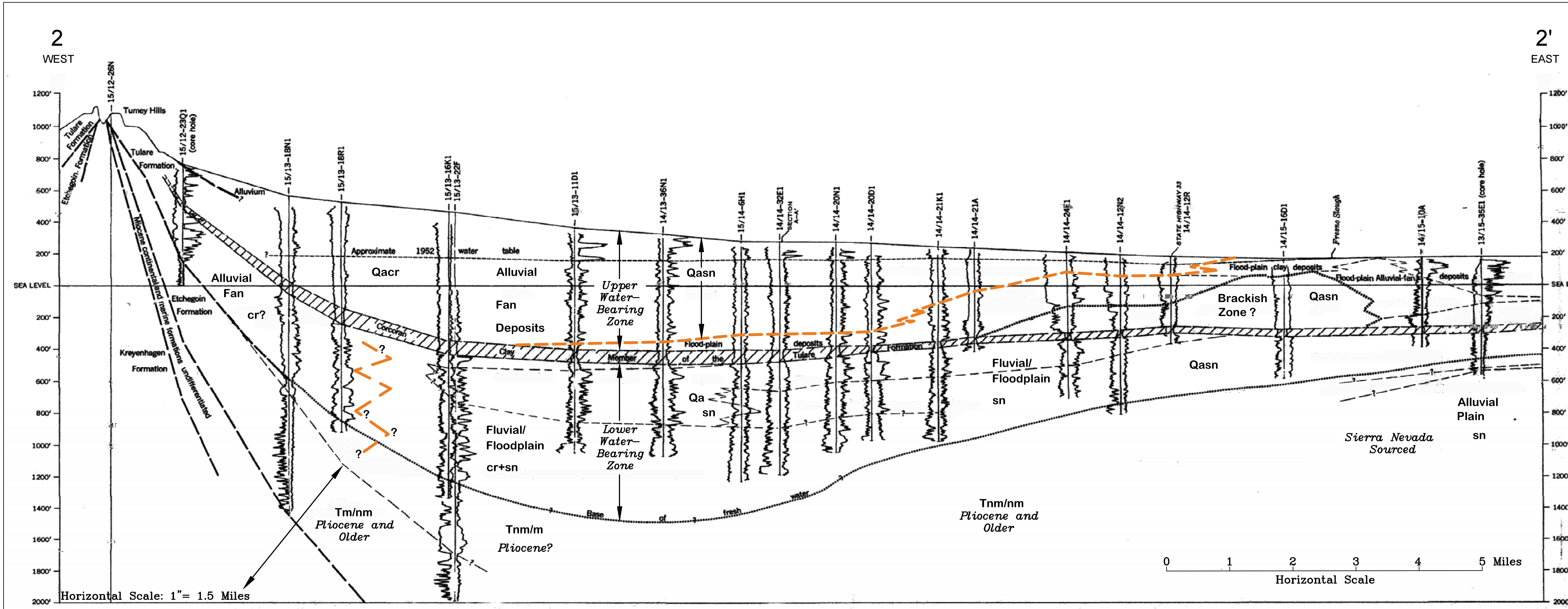
FIGURE 2-27
Geologic Cross Section 1-1'

Groundwater Sustainability Plan
Westlands Water District



EXPLANATION

——— ? ——— Formation contact

—— —— ? —— —— Boundary of stratigraphic horizon

— — — ? — — — Lithologic contact

······· ? ······· Water-quality boundary
Queried where doubtful

— — — — — — — Water-level profile

Note – Principal source of deposits, where identified, is indicated as Diablo (derived from the Diablo Range) or Sierra (derived from the Sierra Nevada)

Edge of Coast Range Sourced Units

s~ *Top Saline Water – LSCE*

//// bfw *Base Fresh Water Page 1973*

Modified From: Miller & Others, 1971, B–B'

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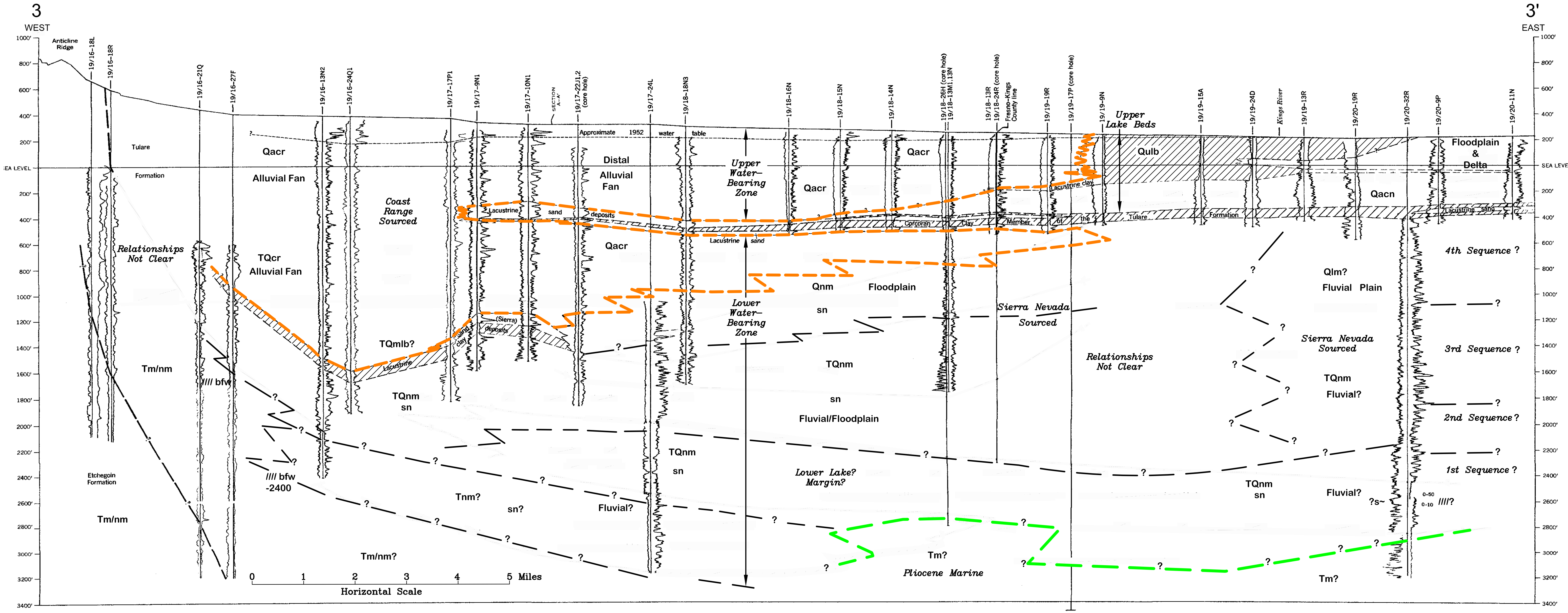
FIGURE 2-28
Geologic Cross Section 2-2'
Groundwater Sustainability Plan
Westside Subbasin



EXPLANATION

Formation contact

Boundary of stratigraphic horizon

Lithologic contact

Water-quality boundary
Queried where doubtful

Water-level profile

Edge of Coast Range Sourced Units

Edge of Marine Sediments

s~ *Top Saline Water – LSCE*

//// bfw *Base Fresh Water Page 1973*

Modified From: Miller & Others, 1971, E-E'

Note – Principal source of deposits, where identified, is indicated as Diablo (derived from the Diablo Range) or Sierra (derived from the Sierra Nevada)

CAD FILE: G:\Projects\Westlands Water\15-1-104\Geologic Cross Section 3-3' (R).dwg DATE: 4/18/2019 2:56 PM

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FIGURE 2-29
Geologic Cross Section 3-3'
Groundwater Sustainability Plan
Westside Subbasin

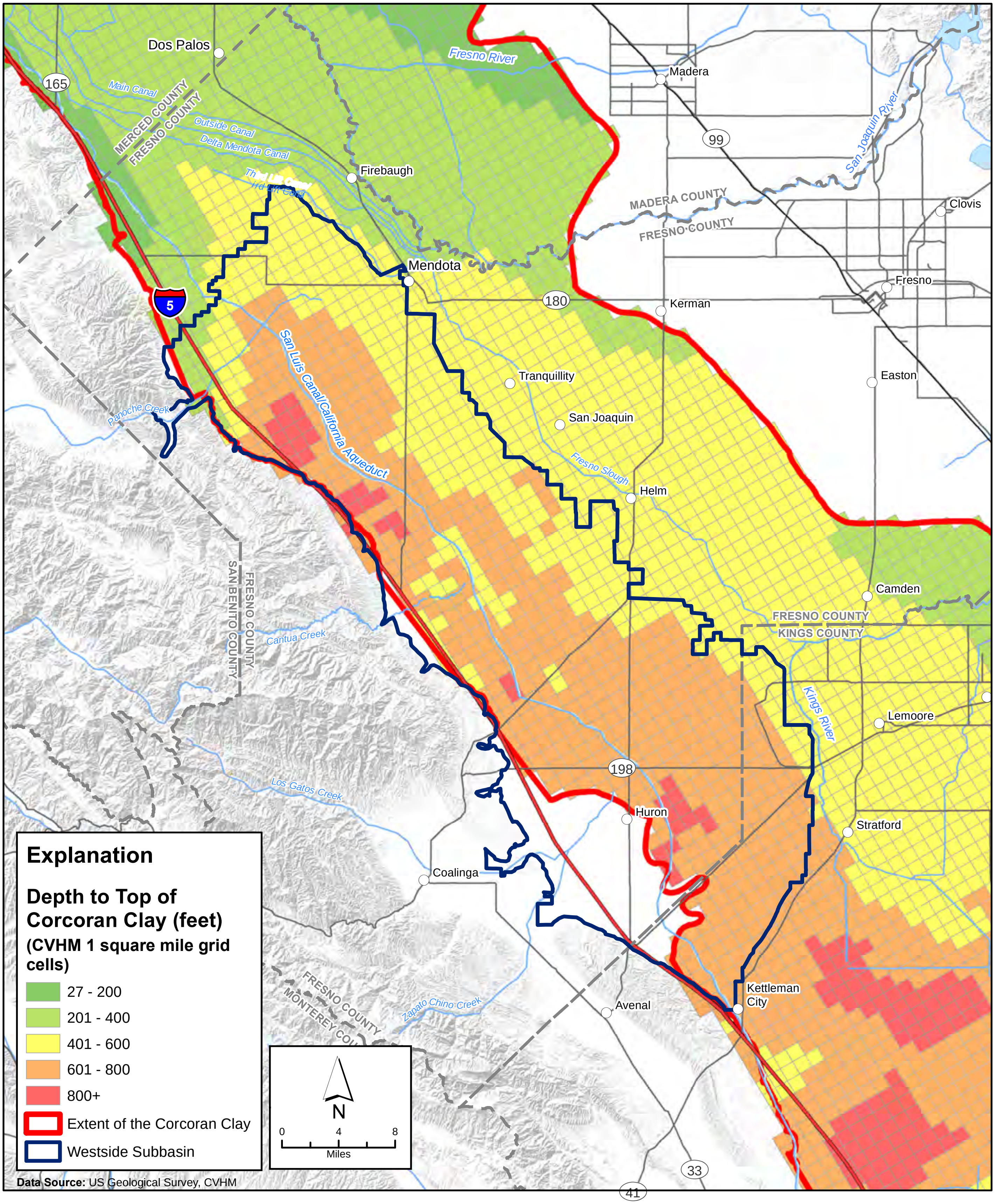

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FIGURE 2-30
Map of the Extent and Depth of Corcoran Clay

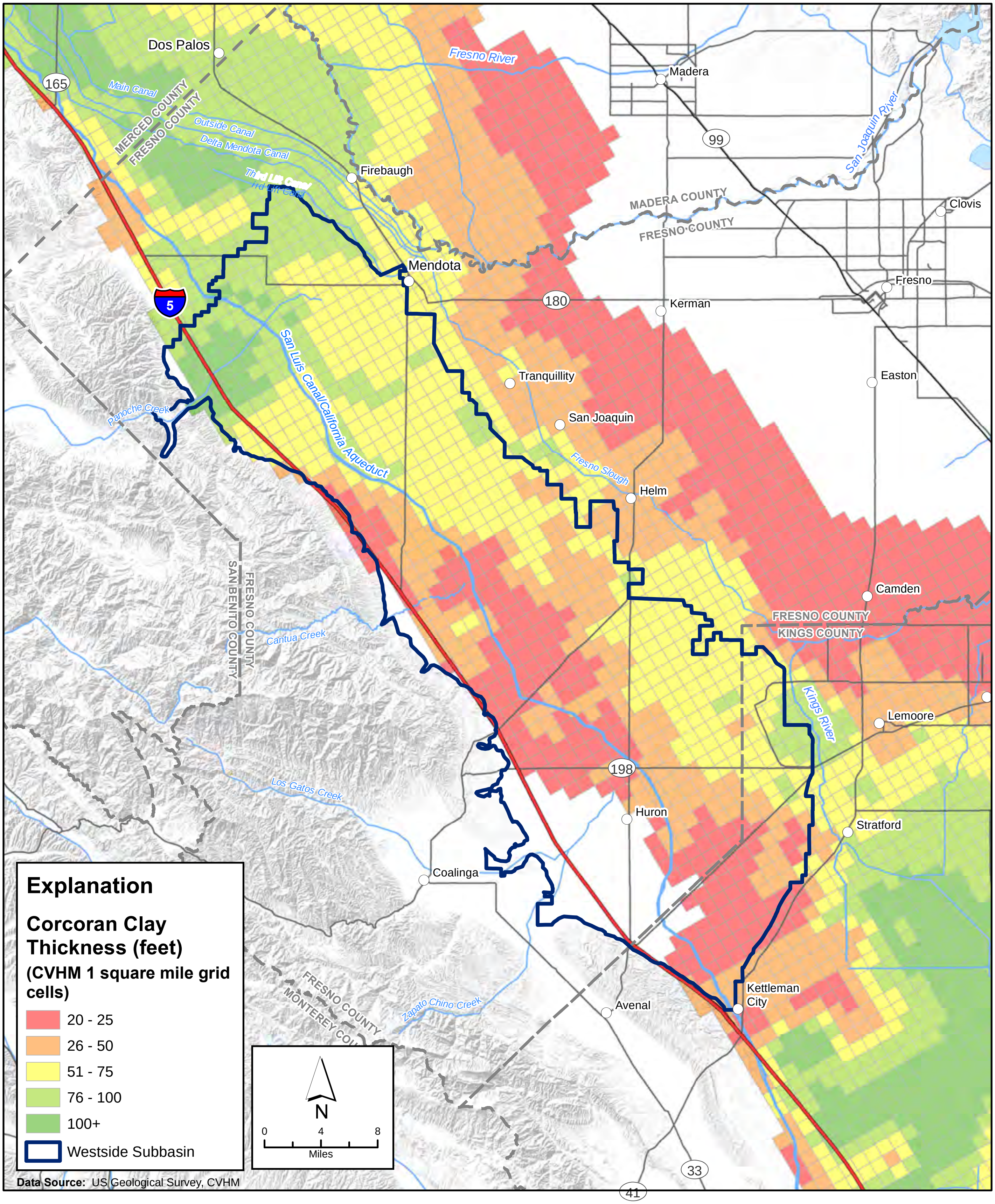

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FIGURE 2-31
Map of the Thickness of Corcoran Clay

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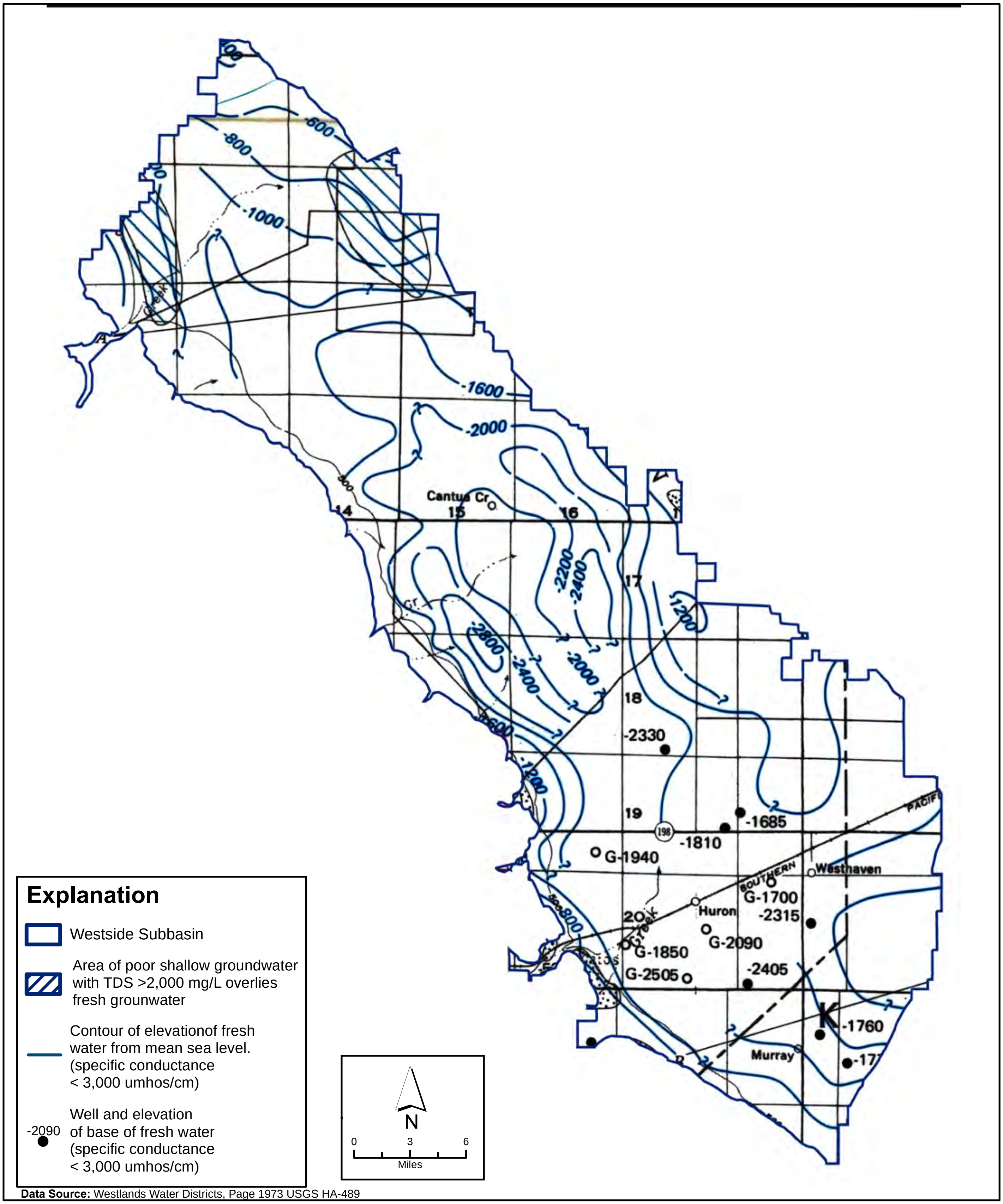
Groundwater Sustainability Plan
Westside Subbasin



Data Source: Westlands Water Districts, Page 1973 USGS HA-489

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FIGURE 2-32
Base of Fresh Water

Groundwater Sustainability Plan
Westside Subbasin

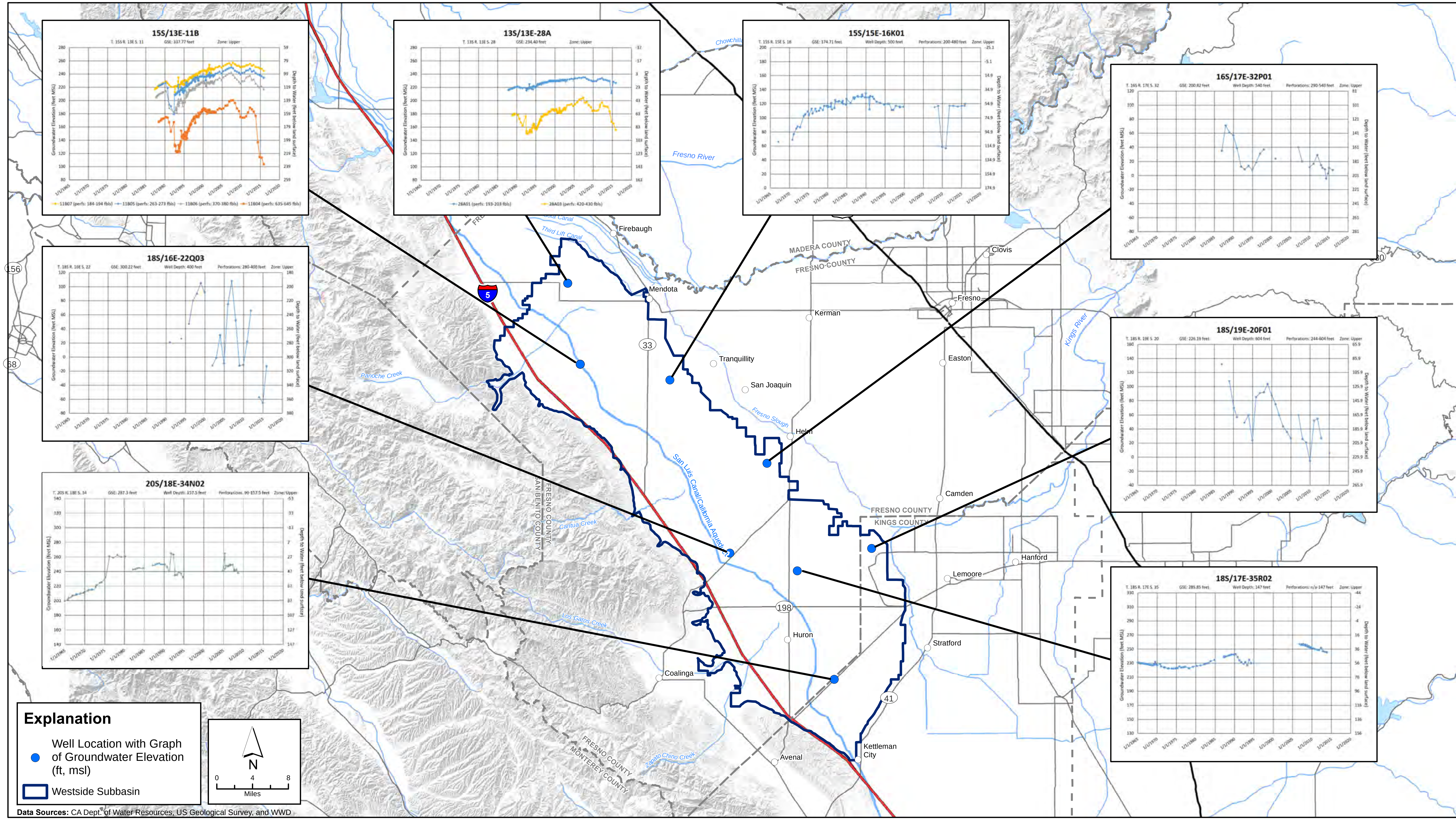

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FIGURE 2-33A
Panel Map of Selected Graphs of Groundwater Elevations
Upper Aquifer

Groundwater Sustainability Plan
Westside Subbasin

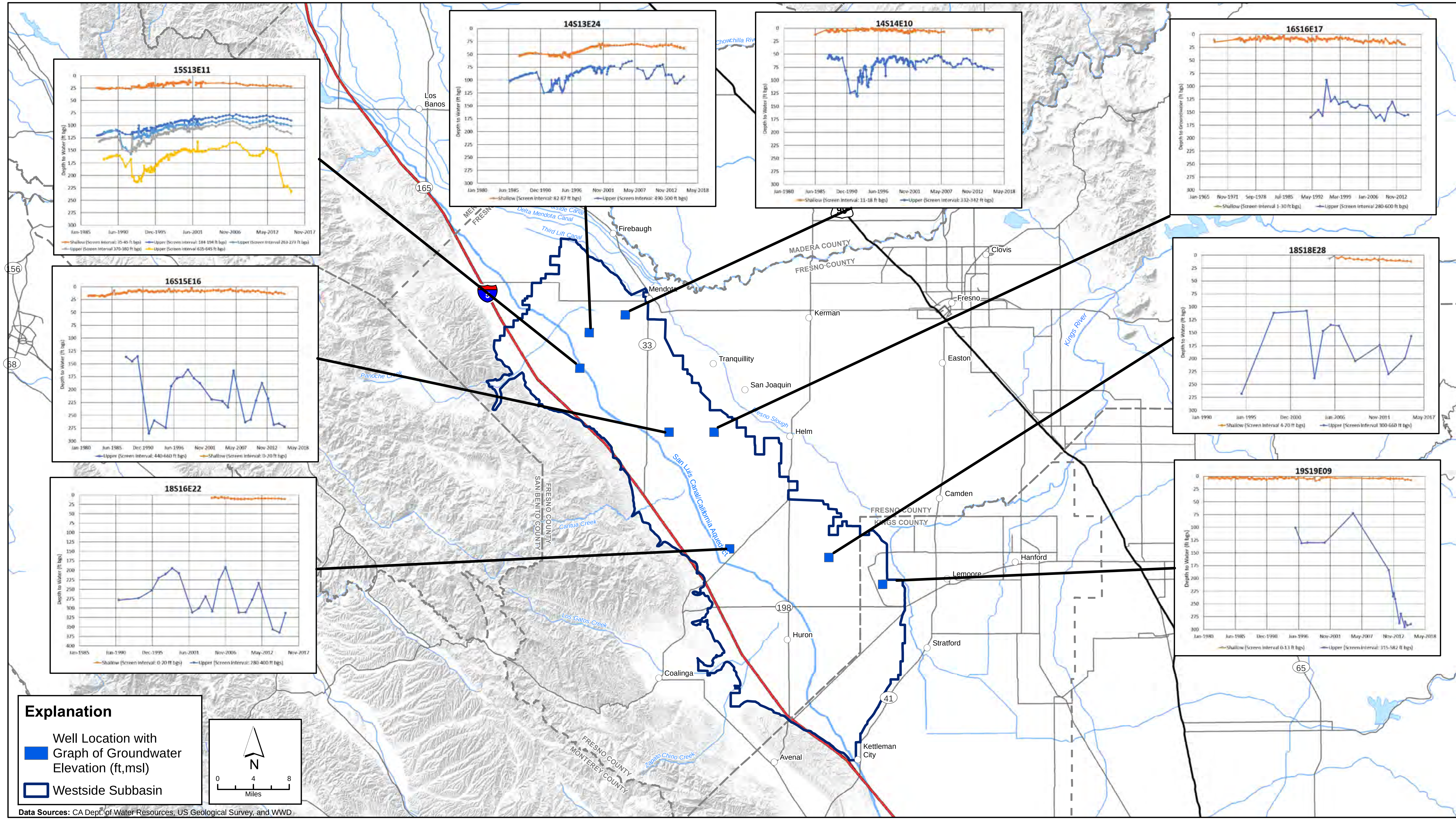

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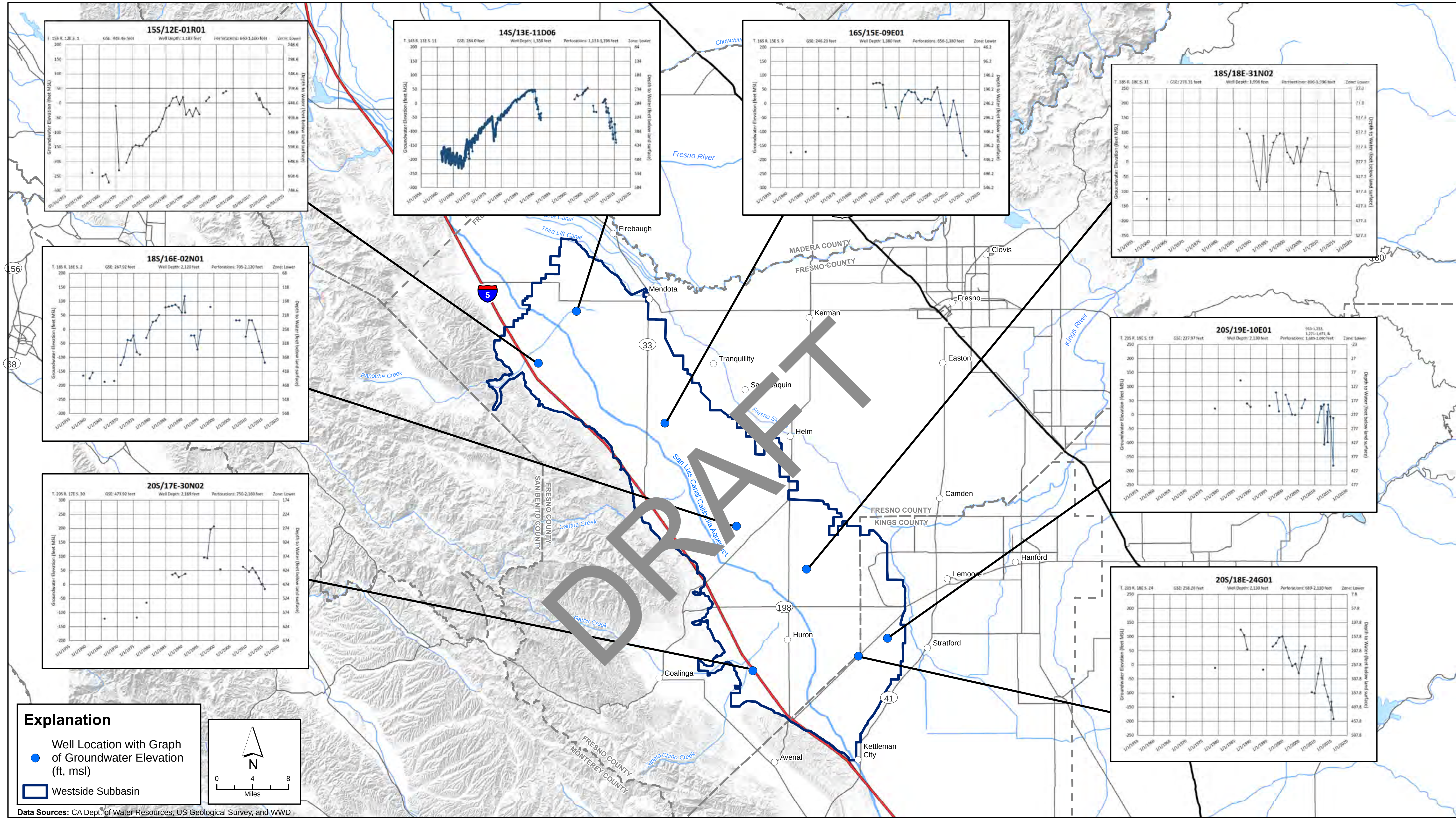
FIGURE 2-33B
Panel Map of Selected Graphs of Groundwater Elevations
Upper Aquifer & Shallow Zone

Groundwater Sustainability Plan
Westside Subbasin



Data Sources: CA Dept. of Water Resources, US Geological Survey, and WWD

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FIGURE 2-34
Panel Map of Selected Graphs of Groundwater Elevations
Lower Aquifer

Groundwater Sustainability Plan
Westside Subbasin

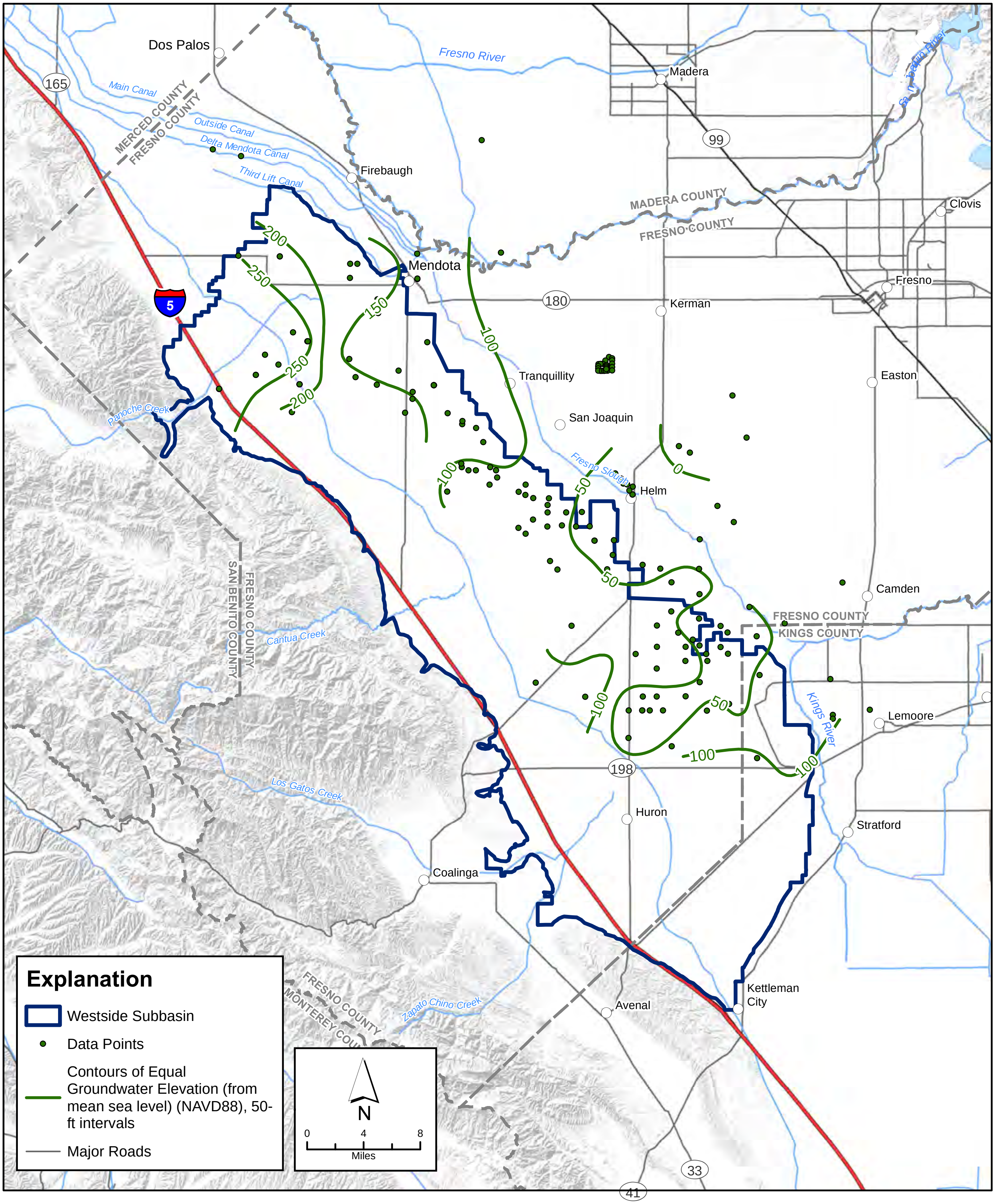

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FIGURE 2-35
Contours of Equal Groundwater Elevation Upper Aquifer, Winter/Spring 2006/2007

Groundwater Sustainability Plan
Westside Subbasin

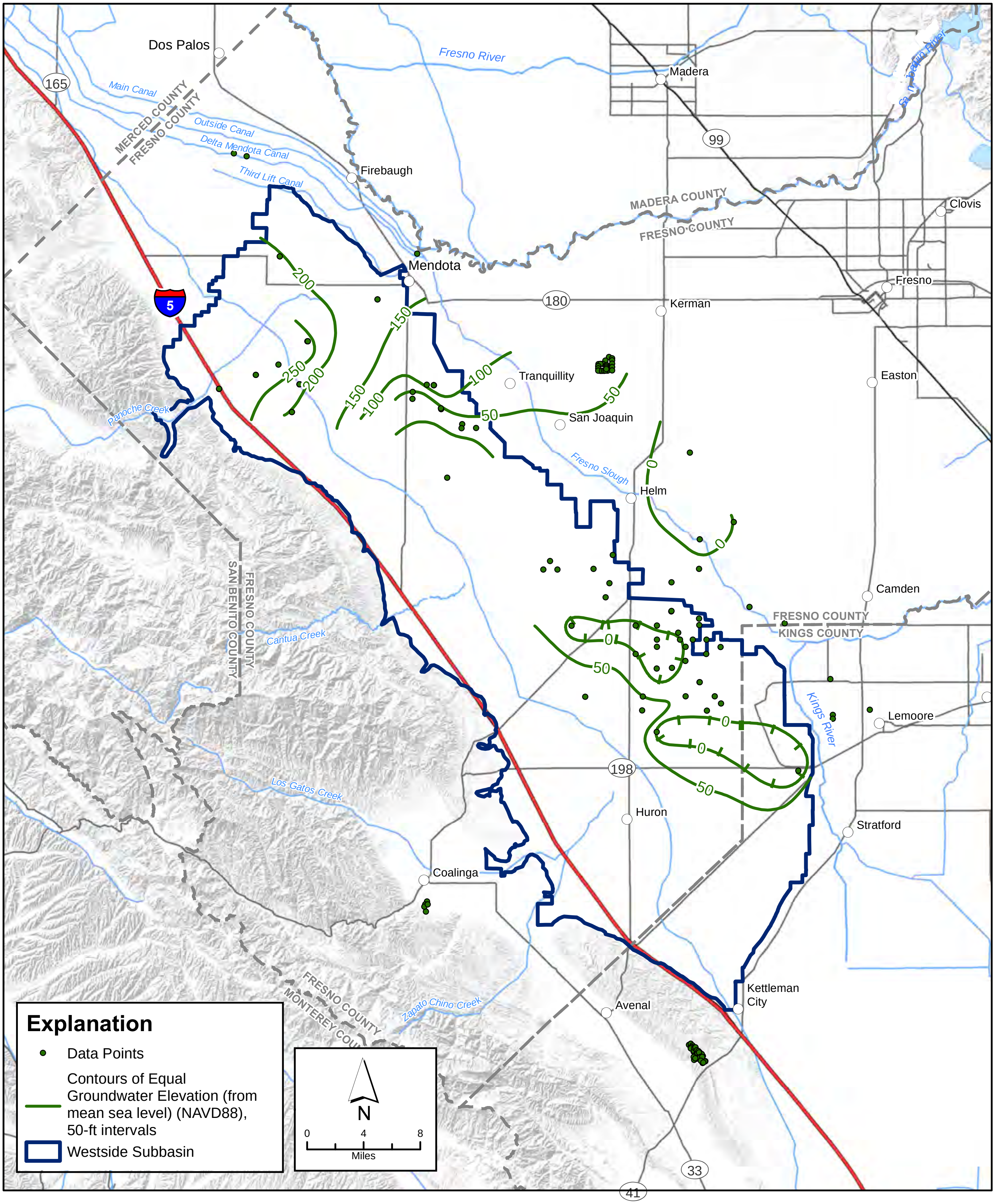

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FIGURE 2-36
Contours of Equal Groundwater Elevation
Upper Aquifer, Summer/Fall 2009

Groundwater Sustainability Plan
Westside Subbasin

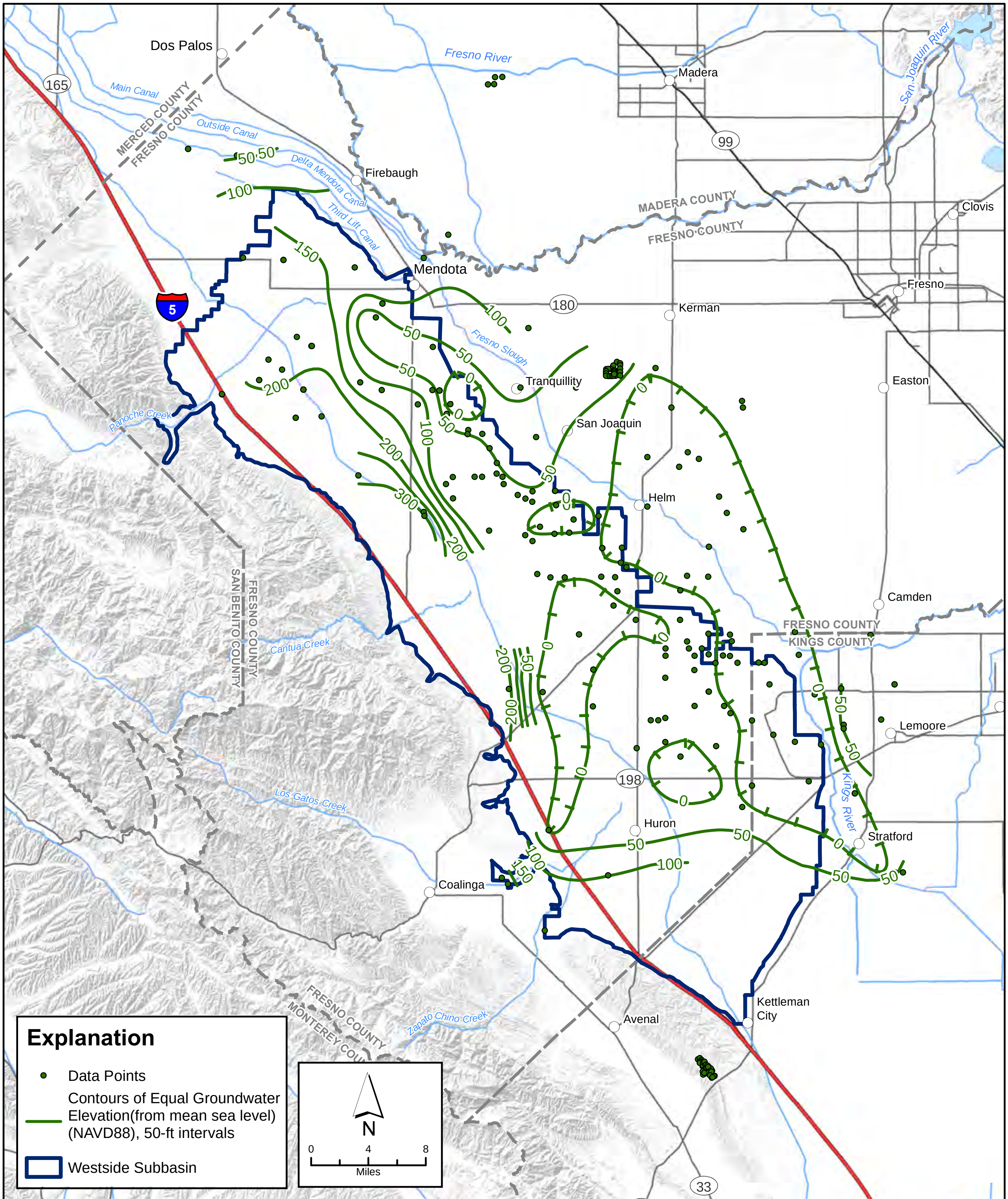

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FIGURE 2-37
Contours of Equal Groundwater Elevation
Upper Aquifer, Winter 2014/2015

Groundwater Sustainability Plan
Westside Subbasin

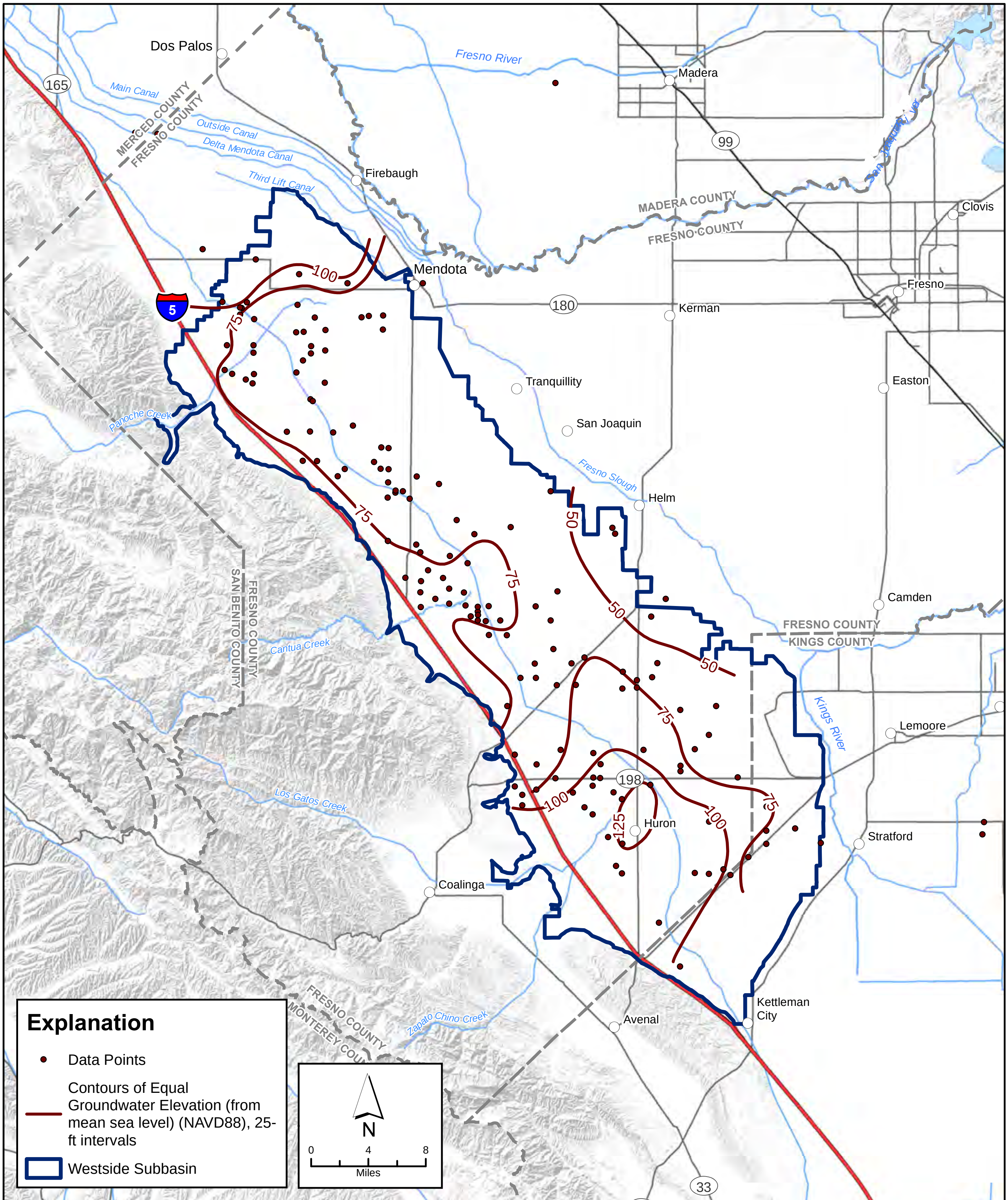

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FIGURE 2-38
Contours of Equal Groundwater Elevation Lower Aquifer, Winter/Spring 2006/2007

Groundwater Sustainability Plan
Westside Subbasin

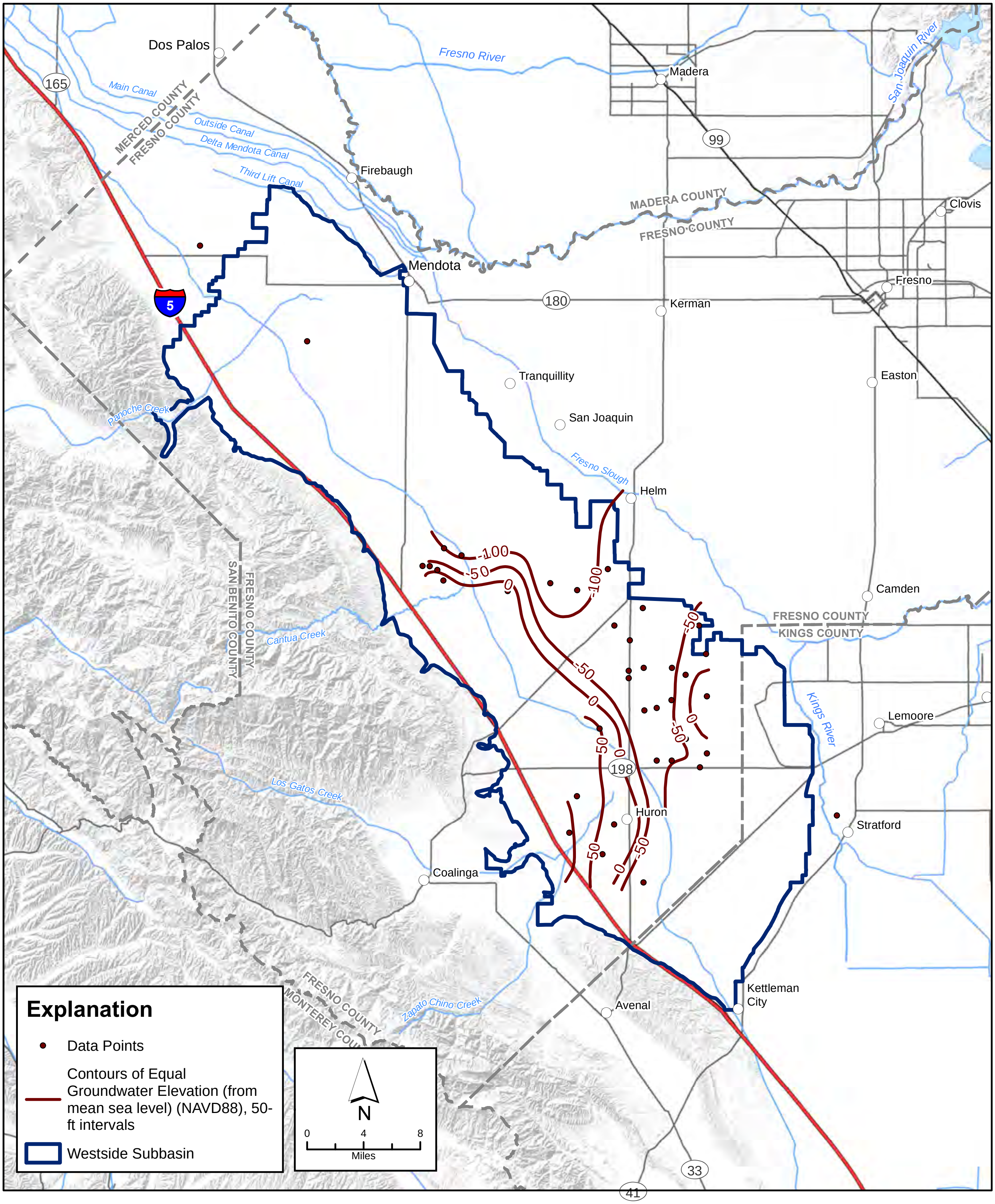

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FIGURE 2-39
Contours of Equal Groundwater Elevation
Lower Aquifer, Summer/Fall 2009

Groundwater Sustainability Plan
Westside Subbasin

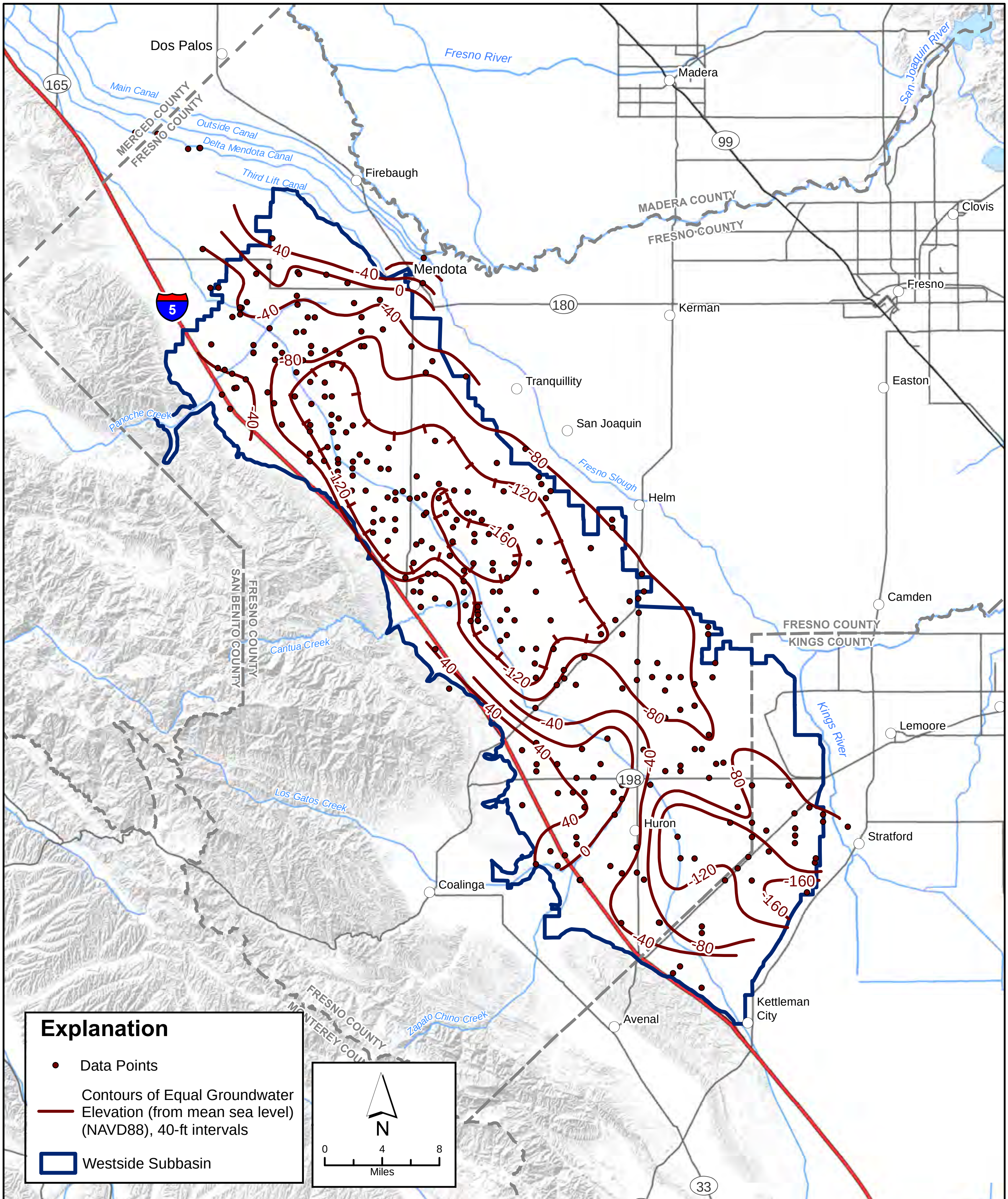

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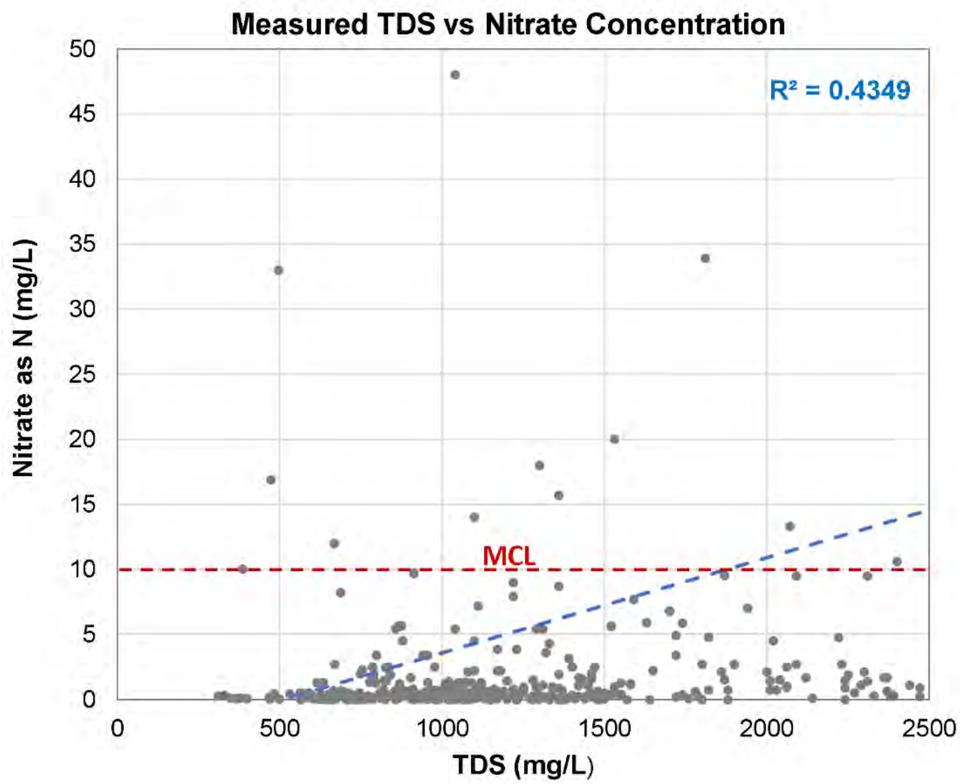
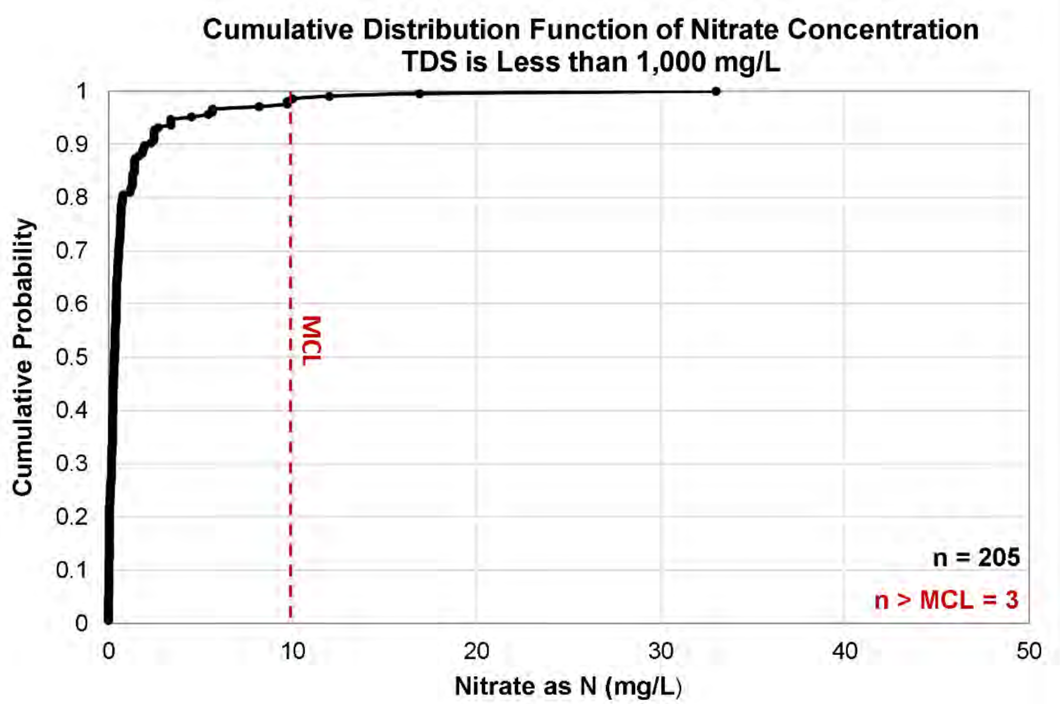
FIGURE 2-40
Contours of Equal Groundwater Elevation
Lower Aquifer, Winter 2014/2015

Groundwater Sustainability Plan
Westside Subbasin





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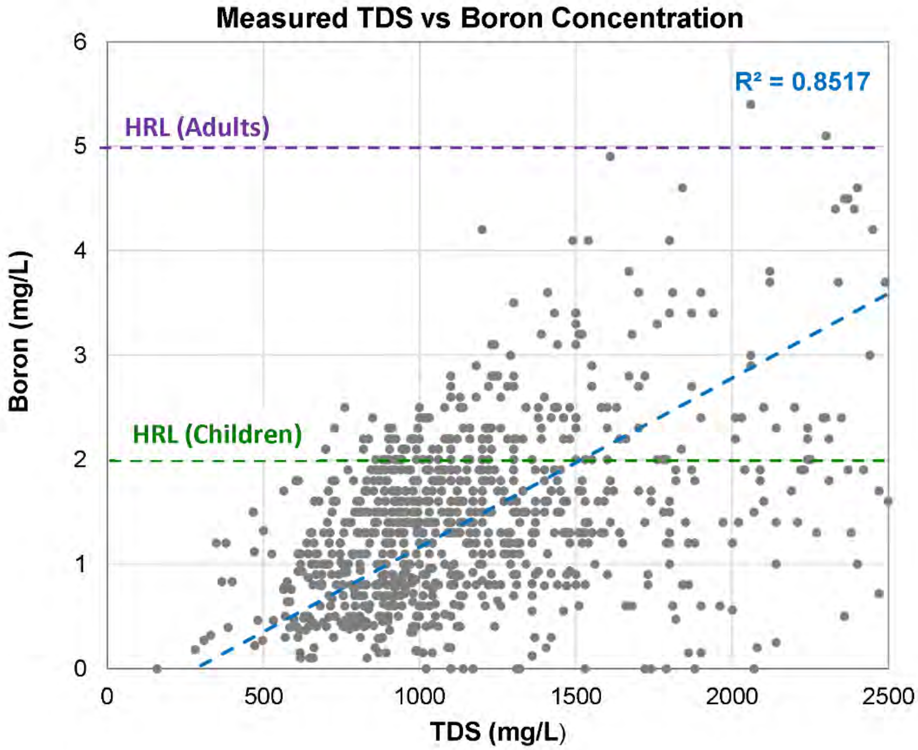
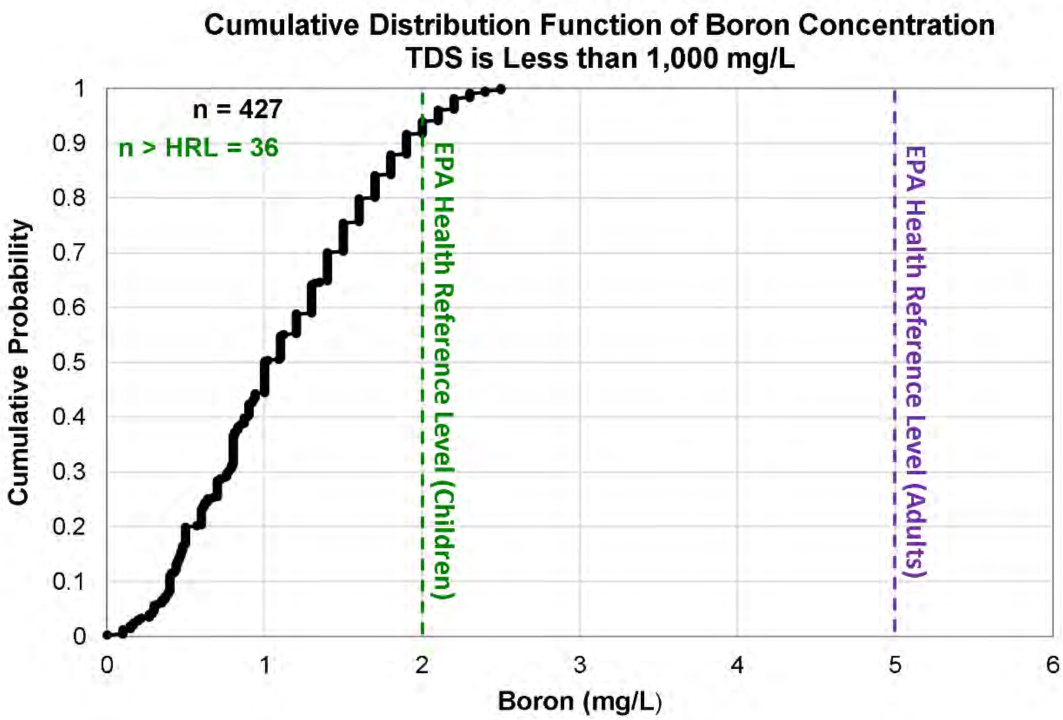
Relationship Between TDS and Nitrate

SGMA Sustainability Analysis
Westside Subbasin

Figure 2-41





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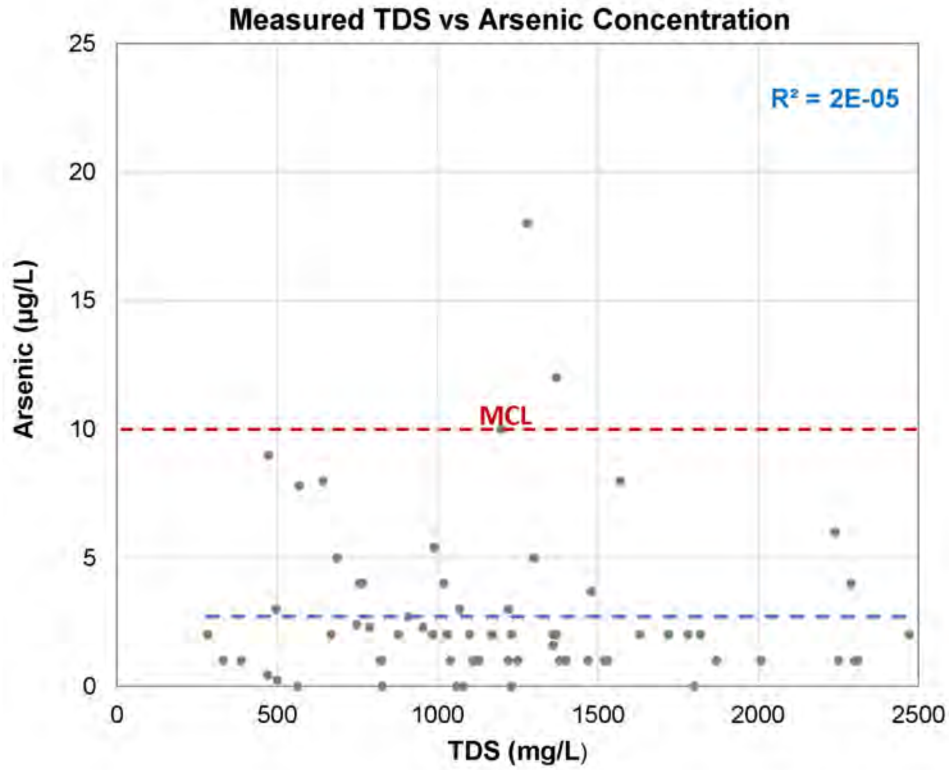
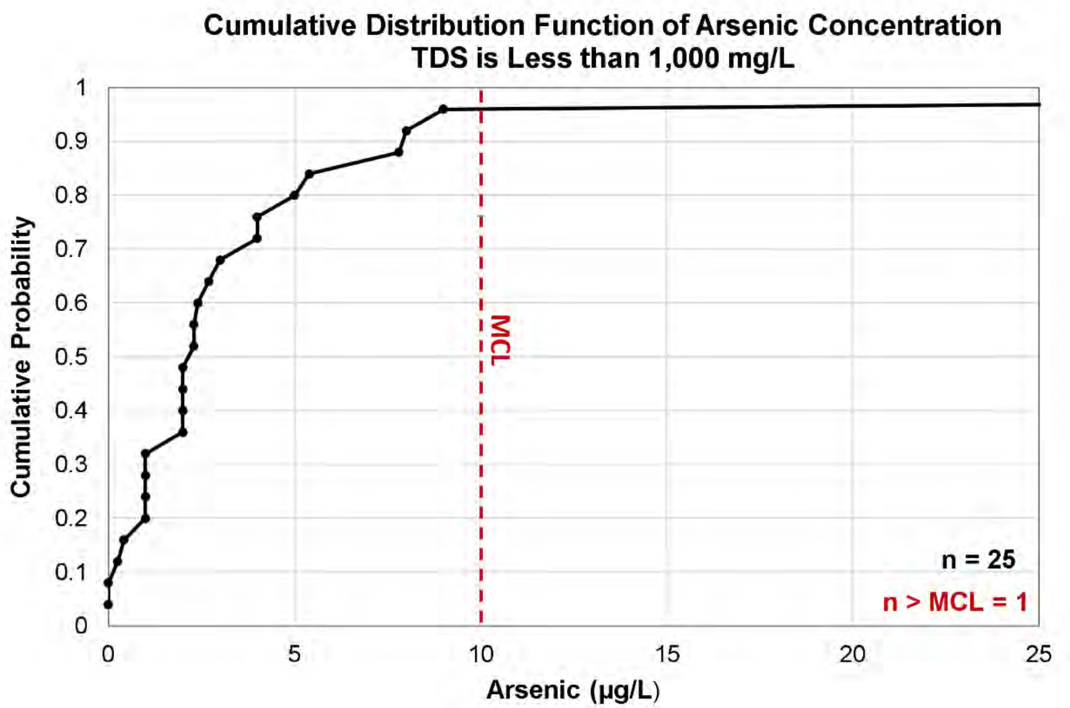
Relationship Between TDS and Boron

SGMA Sustainability Analysis
Westside Subbasin

Figure 2-42





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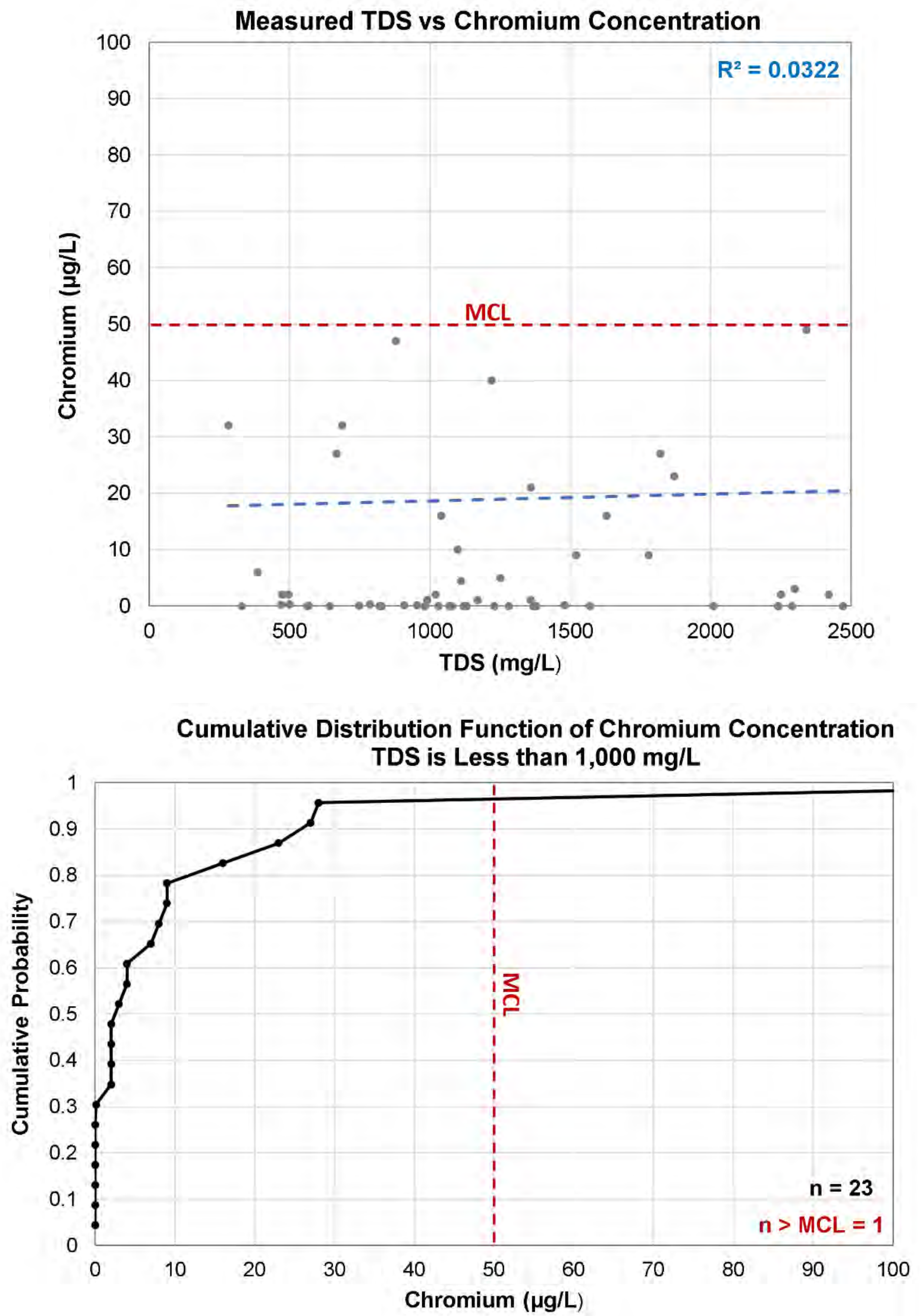
Relationship Between TDS and Arsenic

SGMA Sustainability Analysis
Westside Subbasin

Figure 2-43



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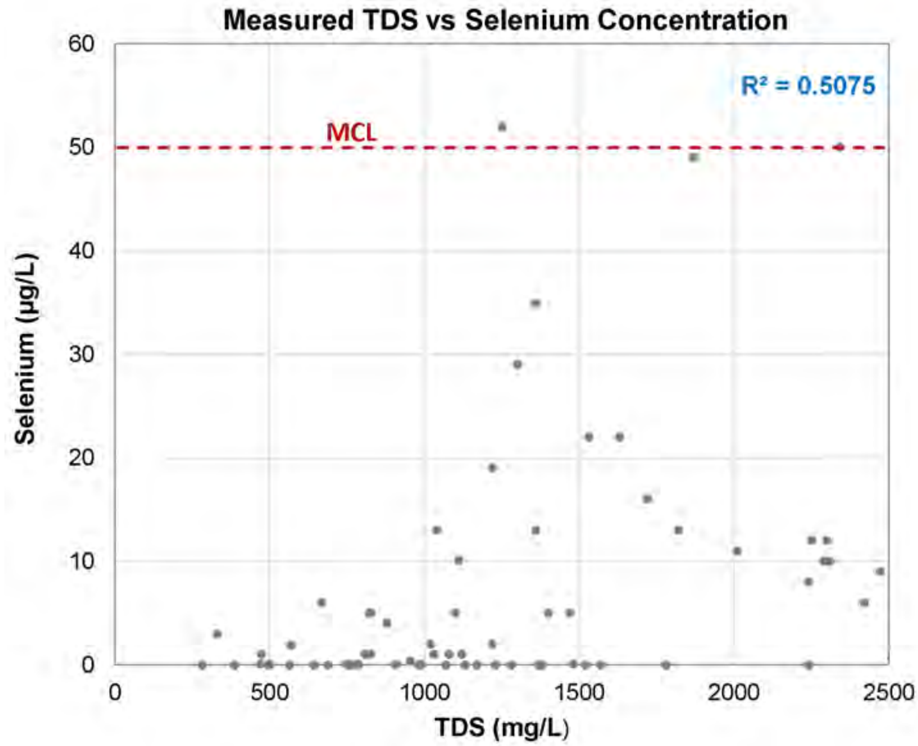
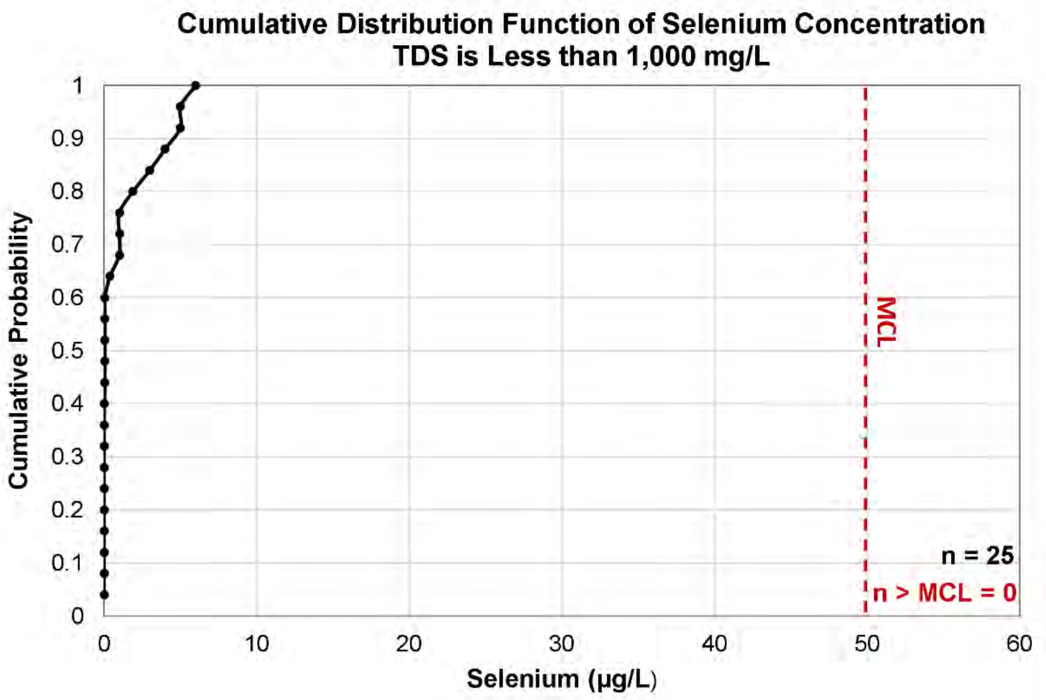
Relationship Between TDS and Chromium

SGMA Sustainability Analysis
Westside Subbasin

Figure 2-44





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Relationship Between TDS and Selenium

Figure 2-45

SGMA Sustainability Analysis
Westside Subbasin

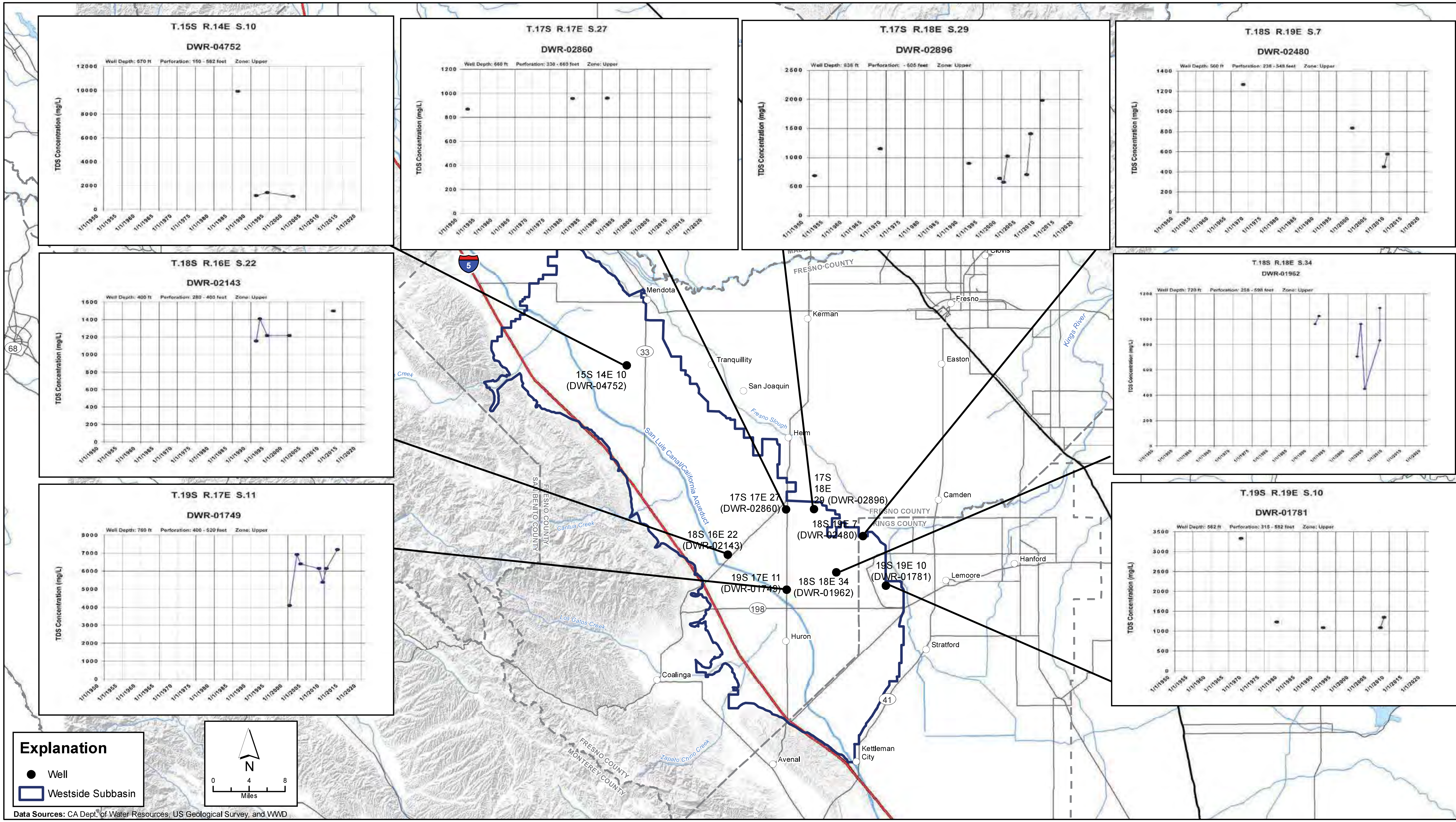

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FIGURE 2-46
SELECT GRAPHS OF TDS CONCENTRATION UPPER AQUIFER

Groundwater Sustainability Plan
Westside Subbasin

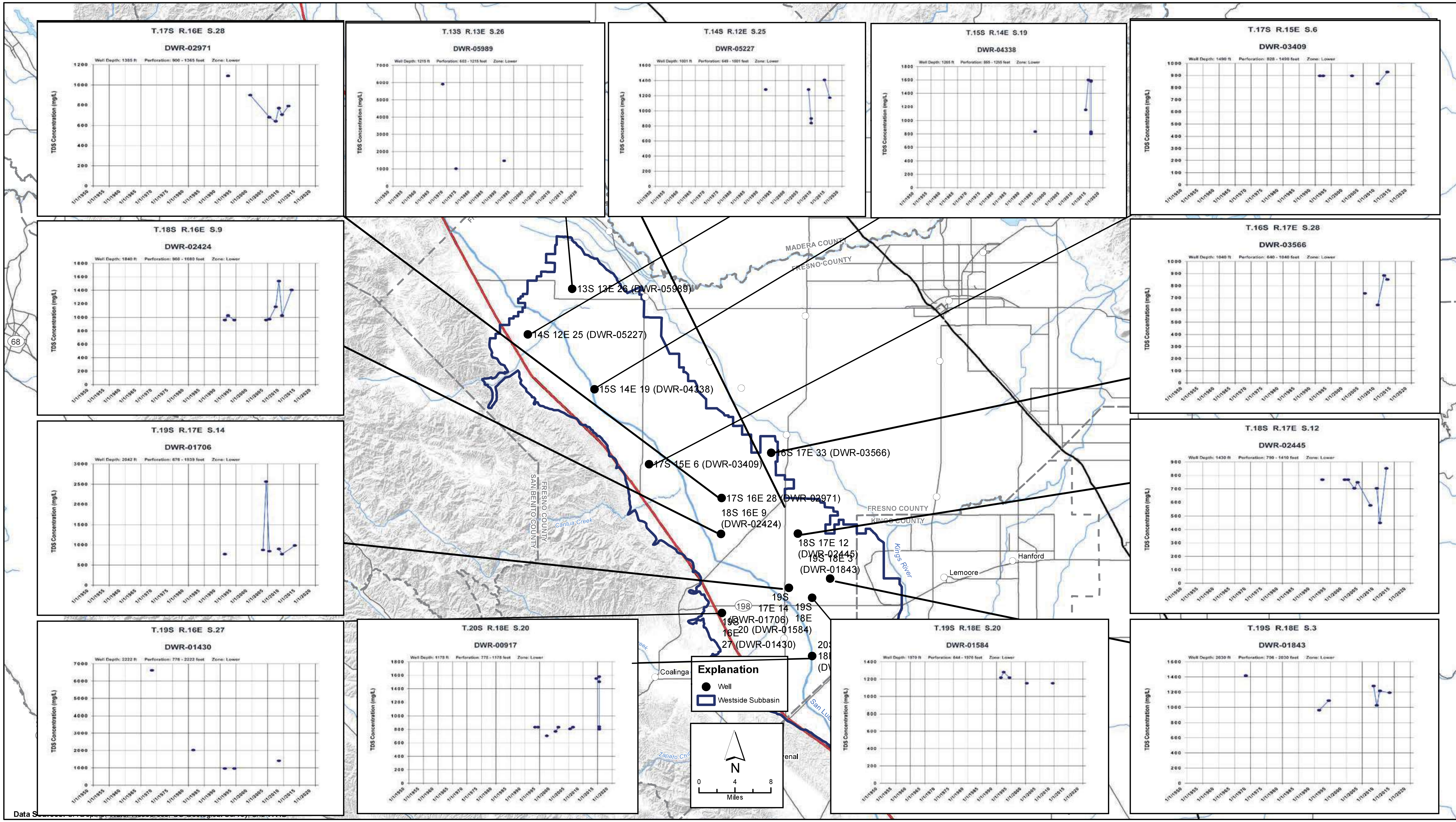

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FIGURE 2-47
SELECT GRAPHS OF TDS CONCENTRATION
LOWER AQUIFER

Groundwater Sustainability Plan
Westside Subbasin

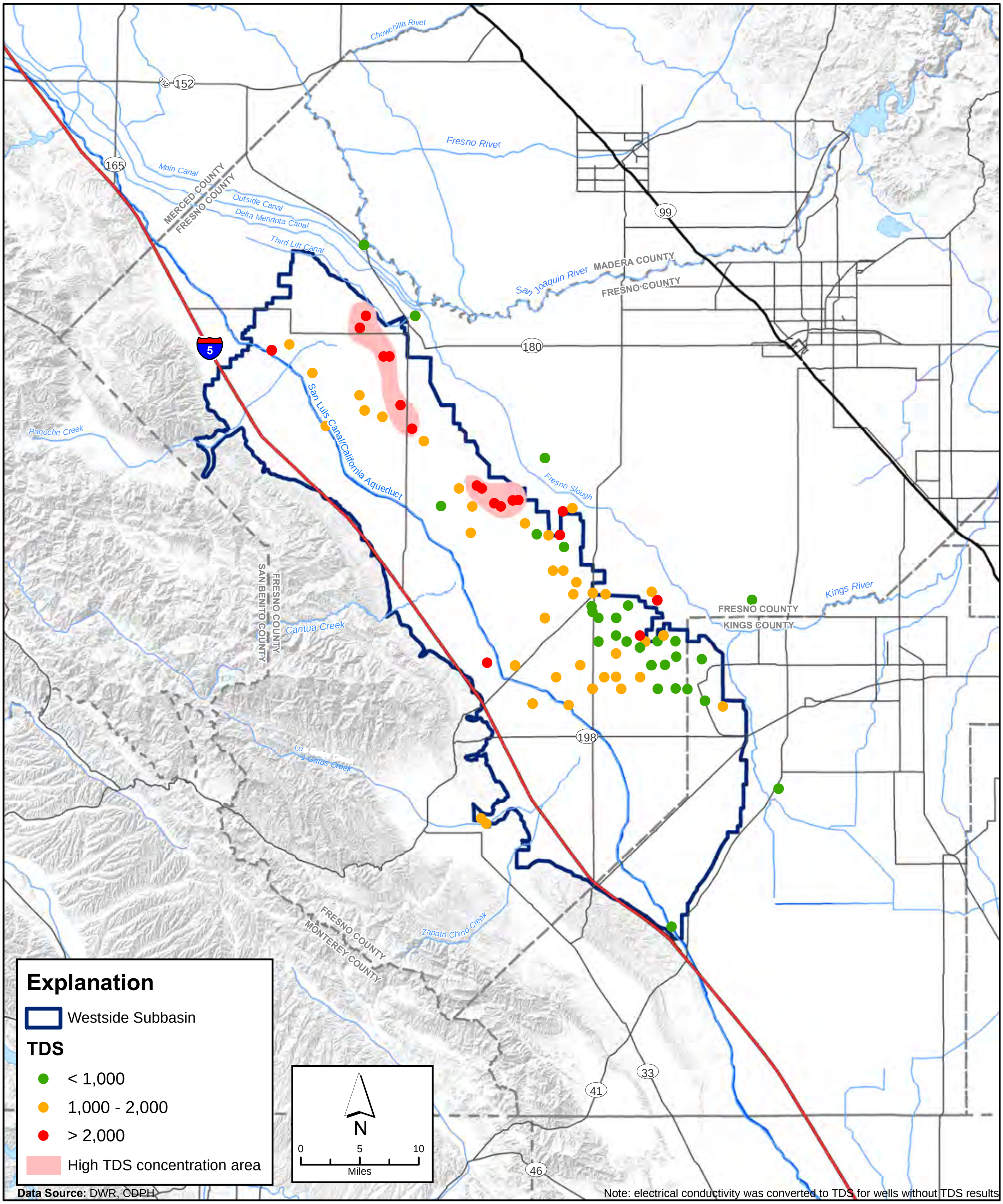

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FIGURE 2-48
1990 - 1995: TDS Concentrations Upper Aquifer

Groundwater Sustainability Plan
Westside Subbasin

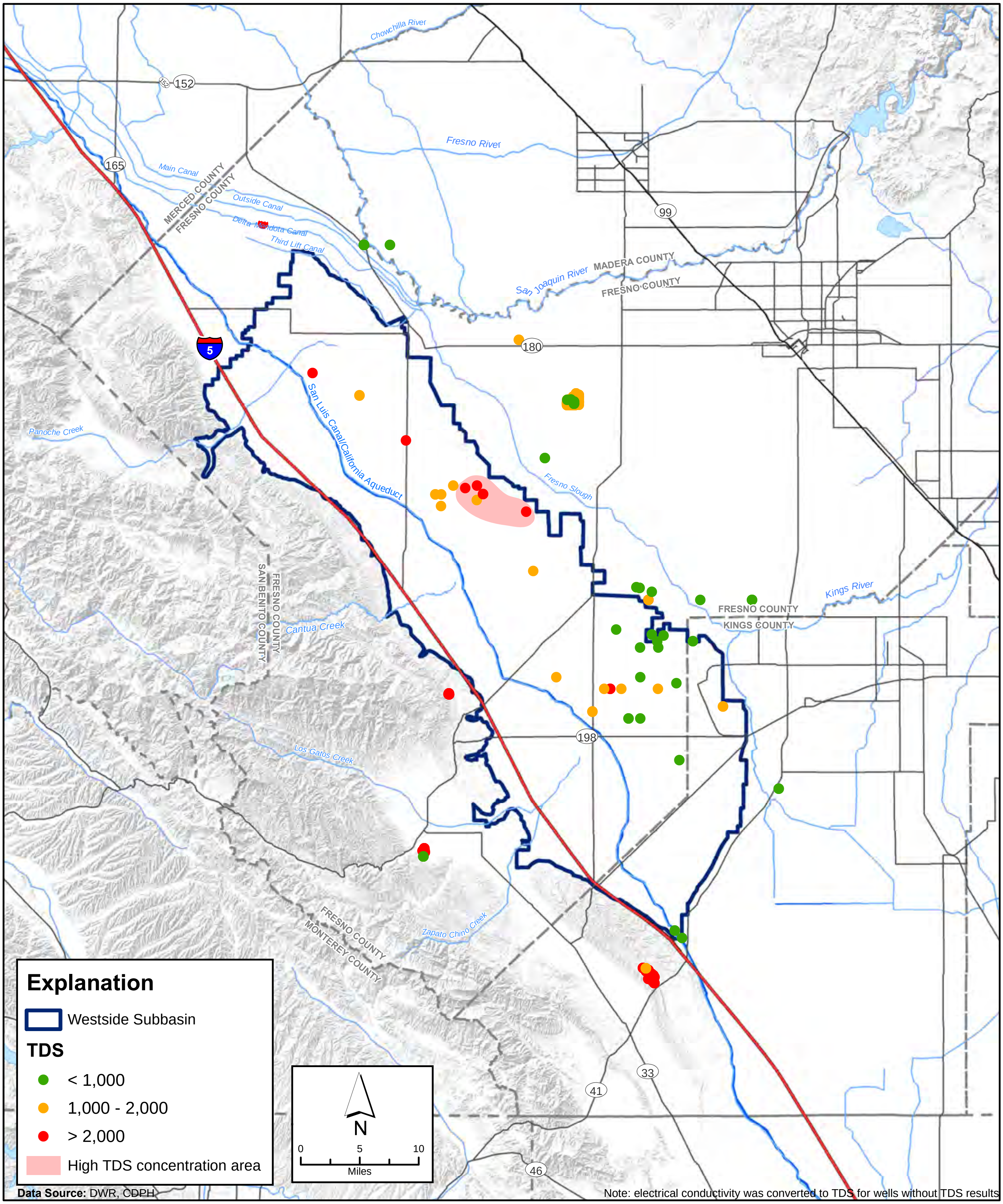

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FIGURE 2-49
2005 - 2009: TDS Concentrations
Upper Aquifer

Groundwater Sustainability Plan
Westside Subbasin

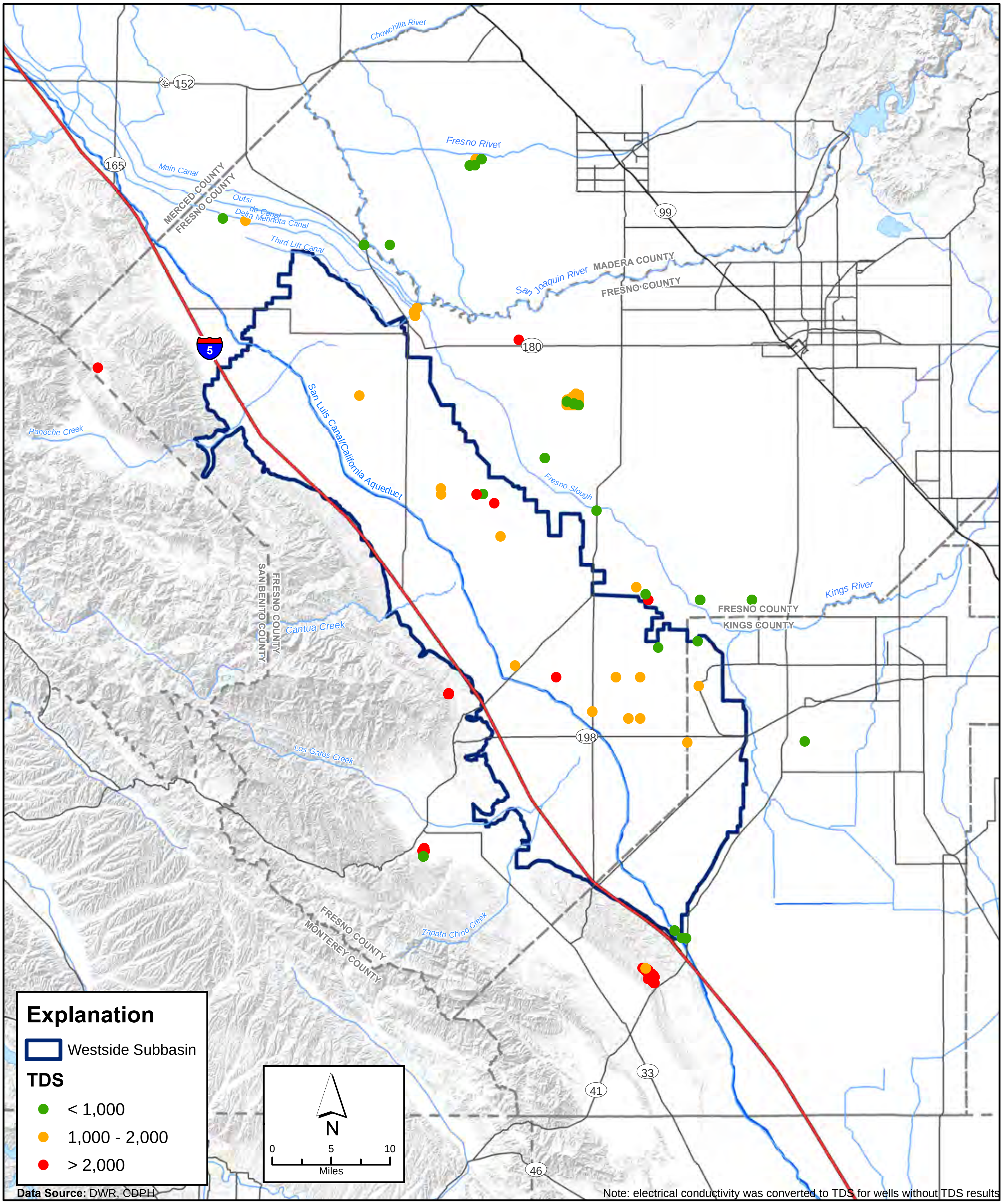

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FIGURE 2-50
2010 - 2015: TDS Concentrations Upper Aquifer

Groundwater Sustainability Plan
Westside Subbasin

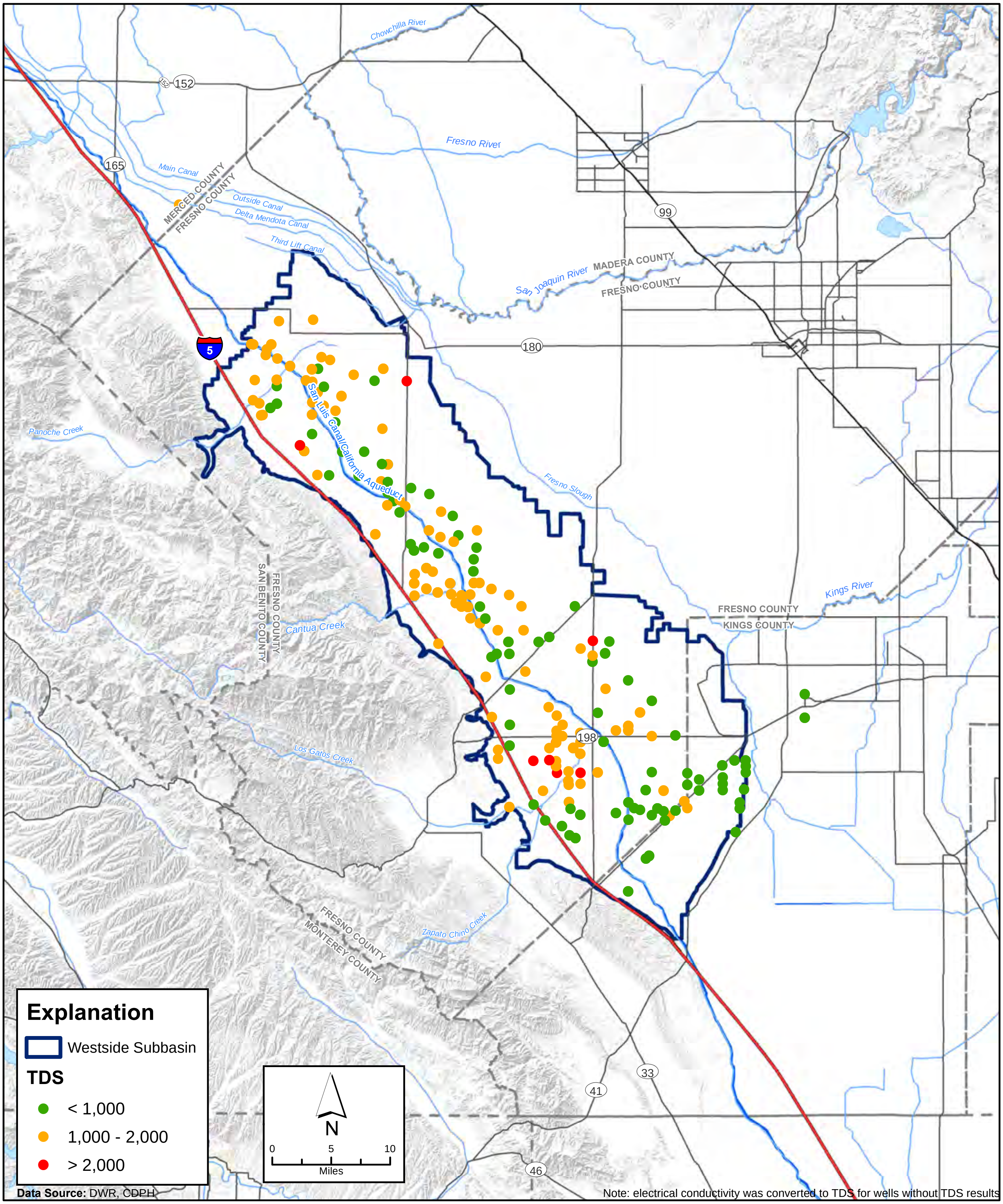

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FIGURE 2-51
1990 - 1995: TDS Concentrations
Lower Aquifer

Groundwater Sustainability Plan
Westside Subbasin

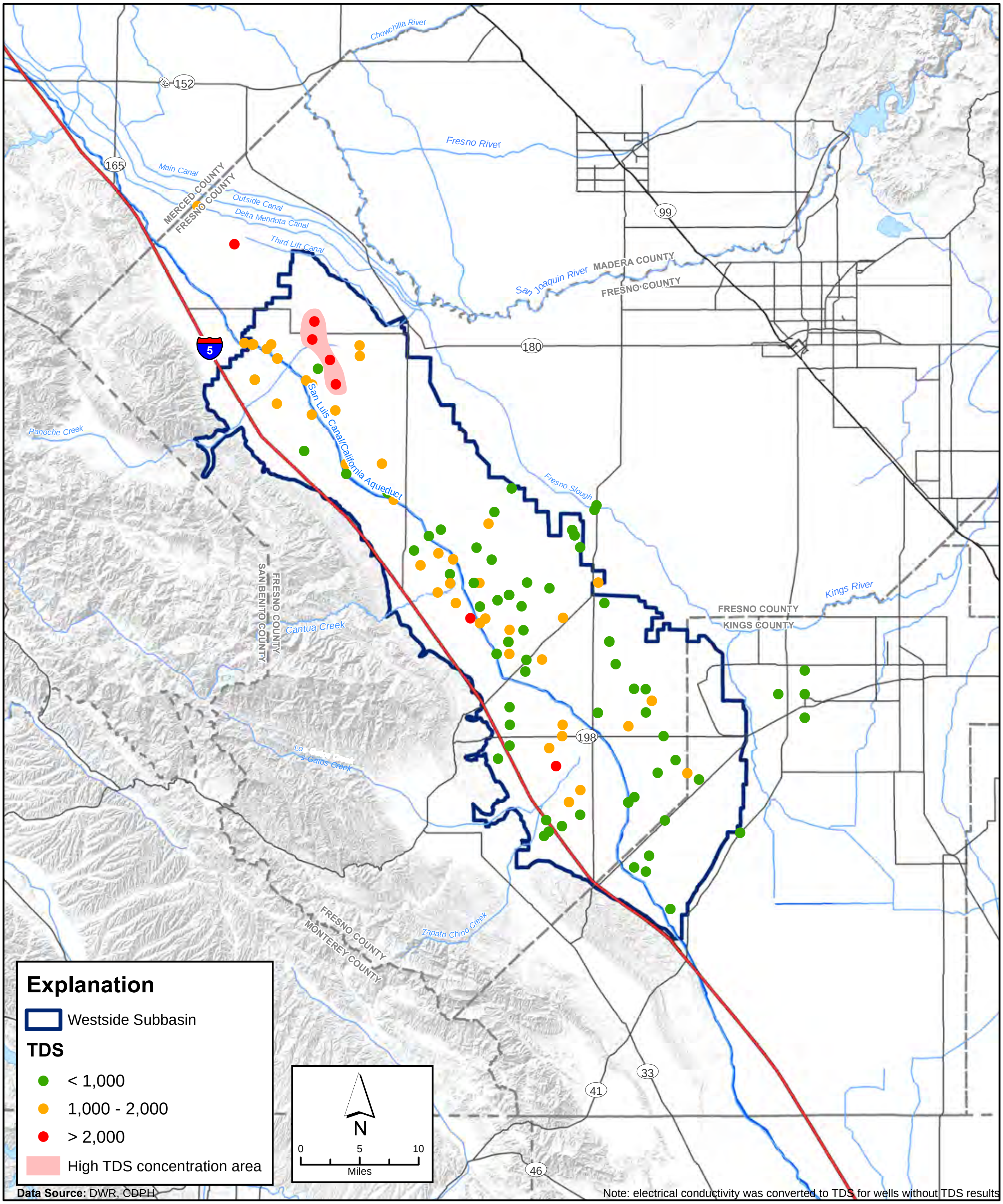

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FIGURE 2-52
2005 - 2009: TDS Concentrations Lower Aquifer

Groundwater Sustainability Plan
Westside Subbasin

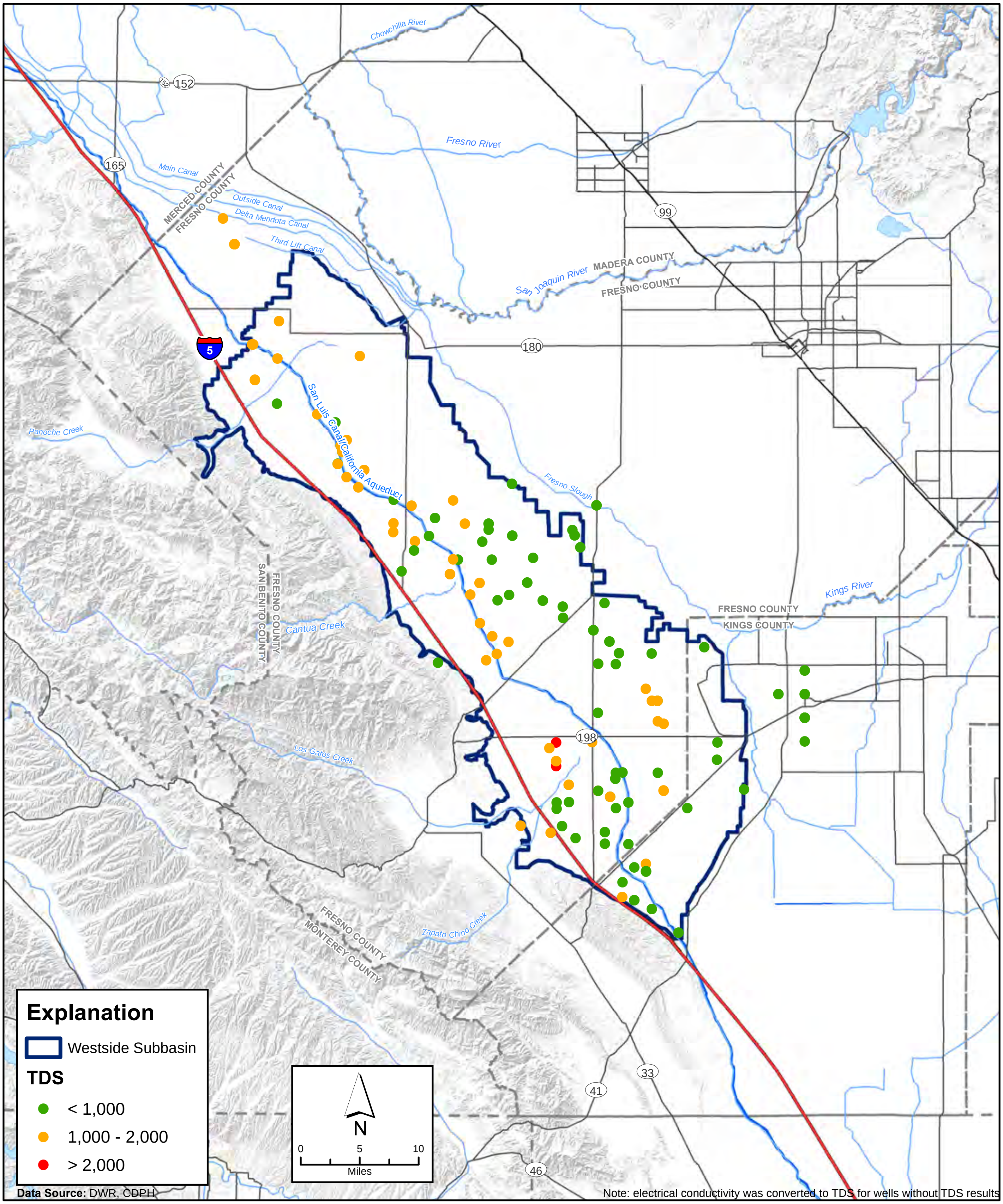

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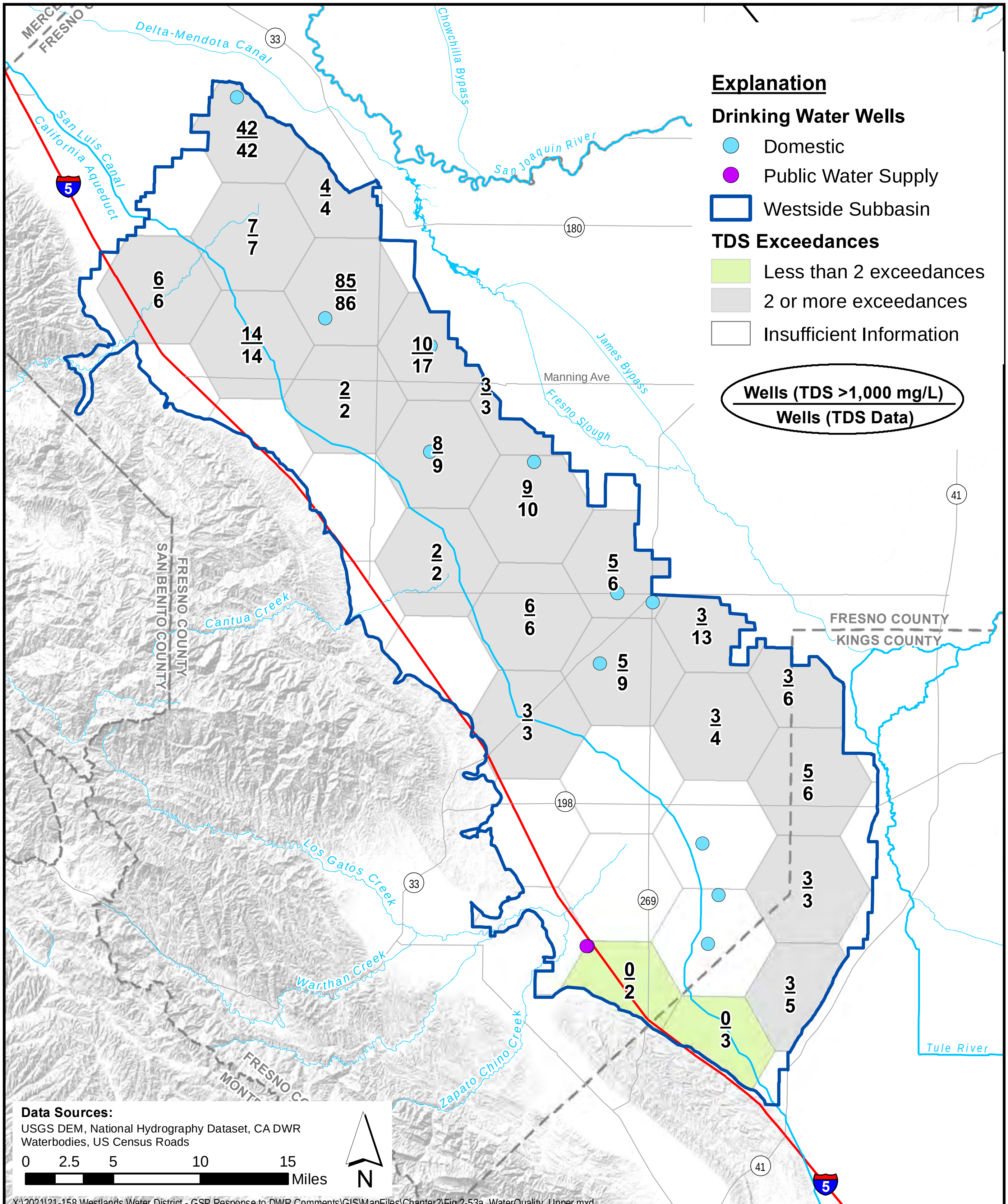
FIGURE 2-53
2010 - 2015: TDS Concentrations
Lower Aquifer

Groundwater Sustainability Plan
Westside Subbasin



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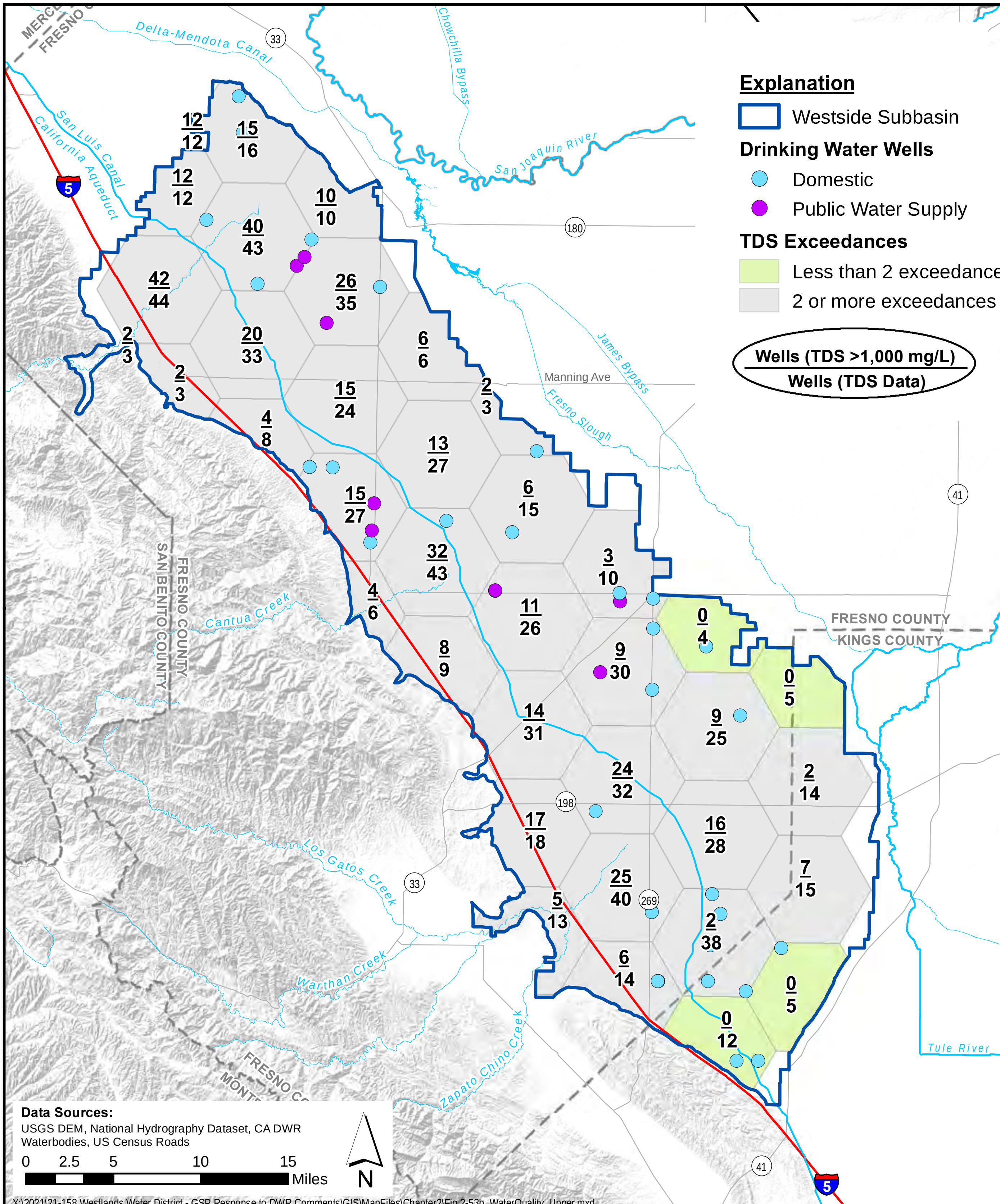
Summary of Measured TDS in Groundwater Wells (Upper Aquifer)

SGMA Sustainability Analyses
Westside Subbasin

Figure 2-53a



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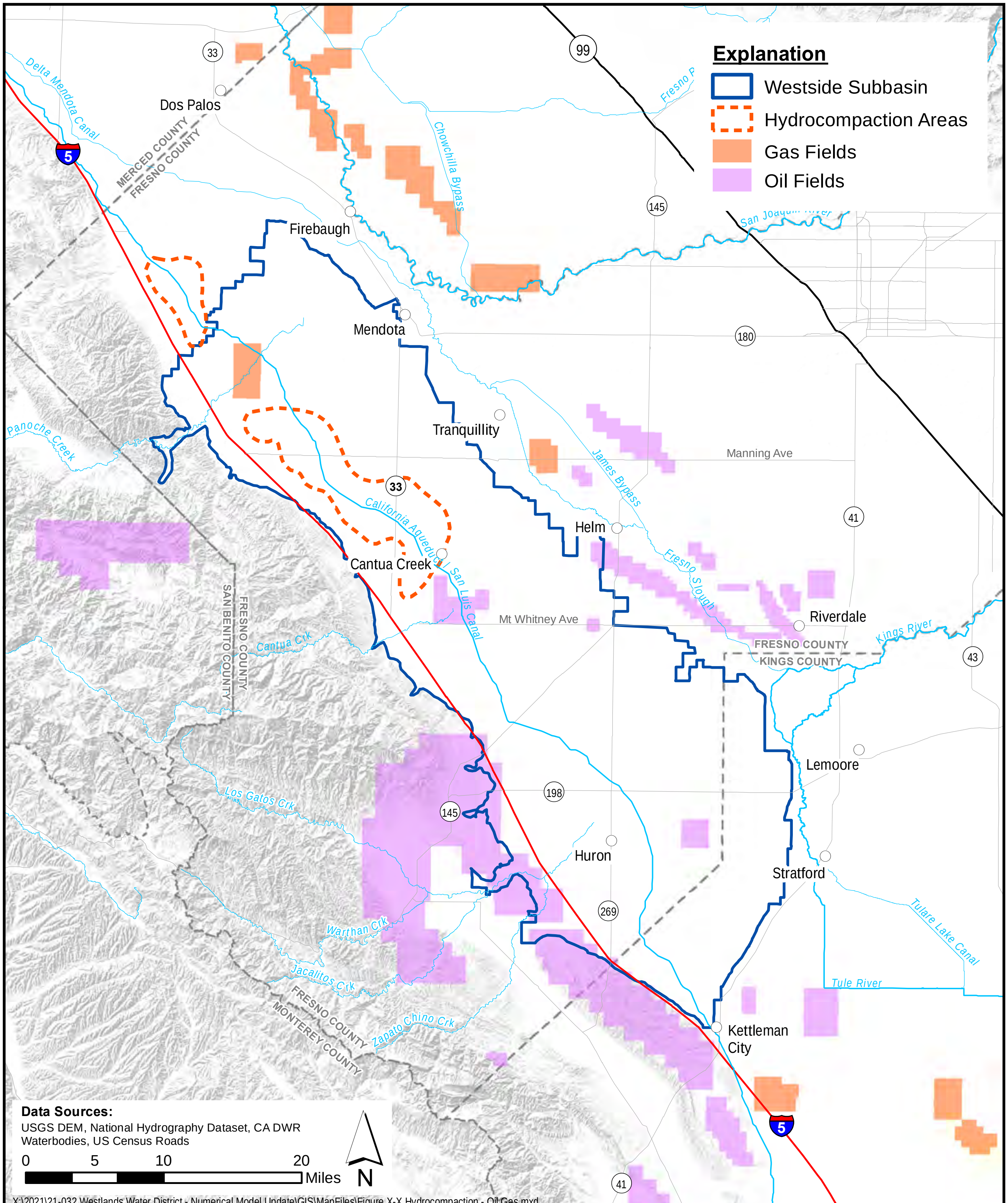
Summary of Measured TDS in Groundwater Wells (Lower Aquifer)

SGMA Sustainability Analyses
Westside Subbasin

Figure 2-53b



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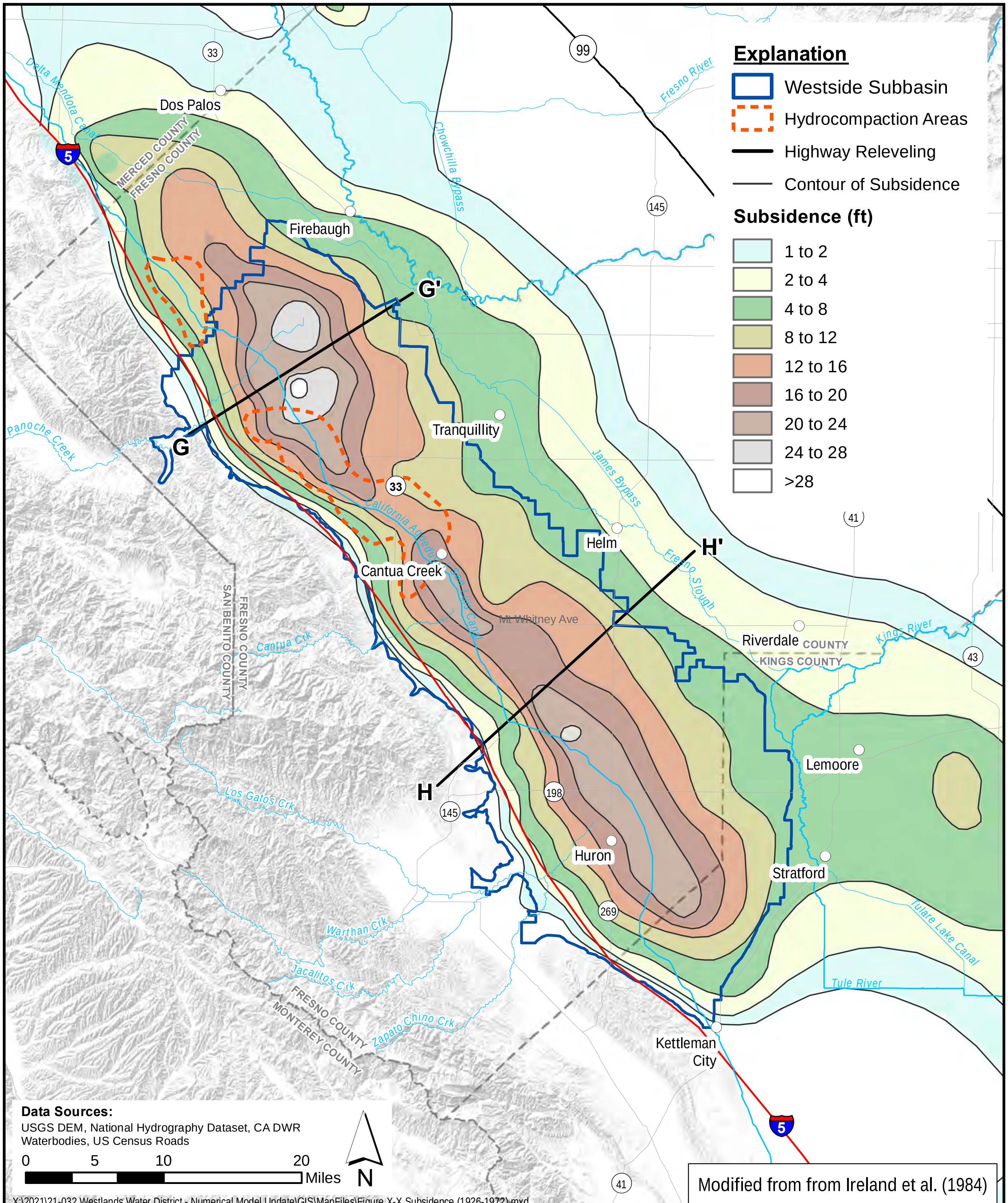
Oil and Gas Fields and Areas of Hydrocompaction

SGMA Sustainability Analyses Westside Subbasin

Figure 2-54



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Land Surface Subsidence (1926-1972)

SGMA Sustainability Analyses
Westside Subbasin

Figure 2-56

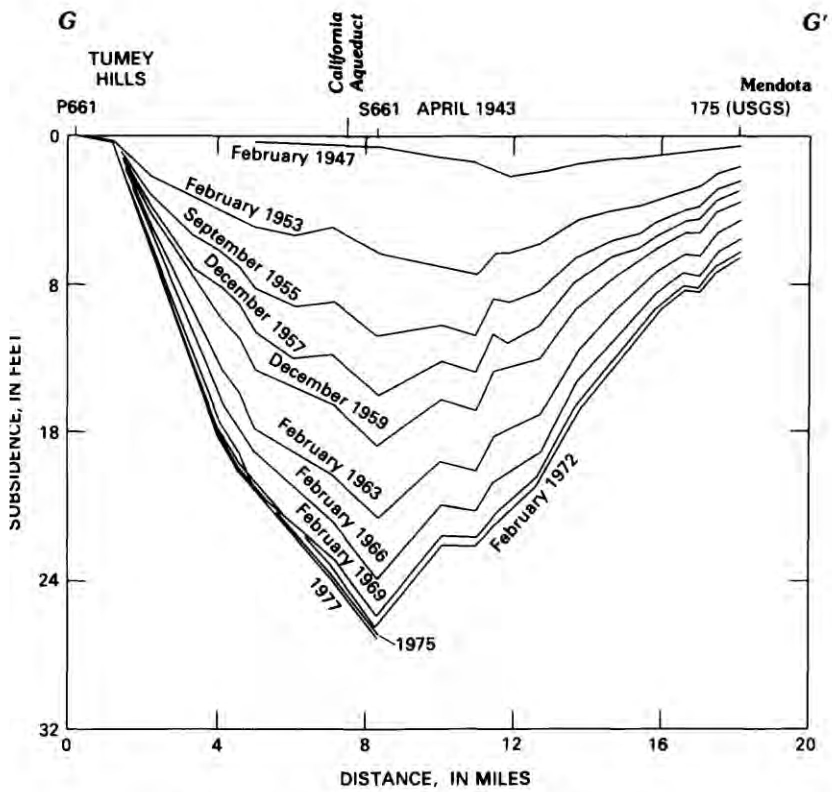

FIGURE 18.—Profiles of subsidence, 1943-77, Tumey Hills to Mendota.

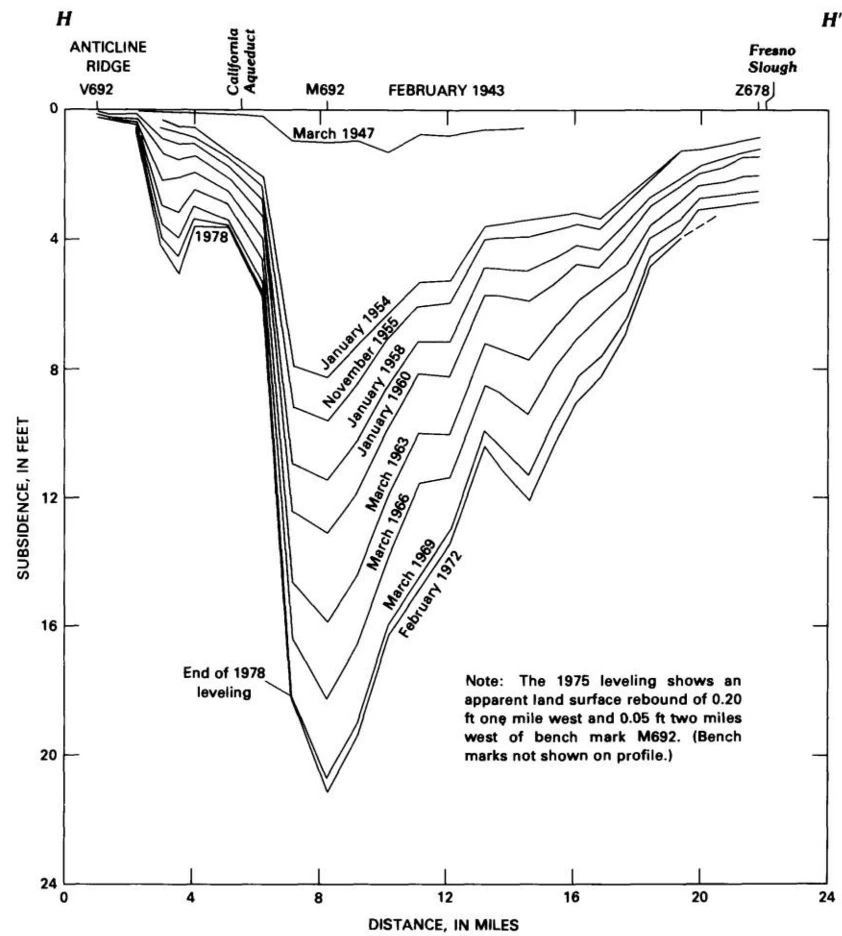

FIGURE 19.—Profiles of subsidence, 1943-78, Anticline Ridge to Fresno Slough.

From Ireland et. al (1984)

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Measured Subsidence G – G' and H – H' from Benchmarks (1943-1975)

Figure 2-57

SGMA Sustainability Analysis
Westside Subbasin