January 2022

Modesto Subbasin

Groundwater Sustainability Plan

Stanislaus and Tuolumne Rivers Groundwater Basin Association (STRGBA) Groundwater Sustainability Agency

&

County of Tuolumne Groundwater Sustainability Agency

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Stanislaus & Tuolumne Rivers Groundwater Basin Association
Groundwater Sustainability Agency
1231 11th Street | Modesto, CA 95354
Email: www.strgba.org

January 31, 2022

Department of Water Resources (DWR)
Attention: Mr. Paul Gosselin
Deputy Director, Sustainable Groundwater Management
715 P Street
Sacramento, CA 95814

Re: Submittal of the Modesto Subbasin Groundwater Sustainability Plan

Dear Mr. Gosselin:

On behalf of the Stanislaus and Tuolumne Rivers Groundwater Basin Association Groundwater Sustainability Agency (STRGBA GSA) and the County of Tuolumne GSA, I am pleased to submit the Modesto Subbasin Groundwater Sustainability Plan (GSP). The GSP was adopted by the STRGBA GSA on January 31, 2022. In compliance with §353.4(b), this transmittal letter accompanies the GSP, which is being uploaded to the DWR SGMA portal.

We look forward to working with DWR during GSP implementation. If you or your staff have any questions regarding the GSP or submittal process, please feel free to contact me at (209) 840-5525 or at ethorburn@oakdaleirrigation.com.

Sincerely,

Eric Thorburn

Eric Thorburn, P.E.,
GSP Plan Manager
STRGBA GSA

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MODESTO SUBBASIN GROUNDWATER SUSTAINABILITY PLAN (GSP)

STANISLAUS AND TUOLUMNE RIVERS GROUNDWATER BASIN ASSOCIATION (STRGBA) GROUNDWATER SUSTAINABILITY AGENCY

COUNTY OF TUOLUMNE GROUNDWATER SUSTAINABILITY AGENCY

JANUARY 2022

Prepared by:
Todd Groundwater and
Woodard & Curran

In association with
Stantec

SIGNATURE PAGE

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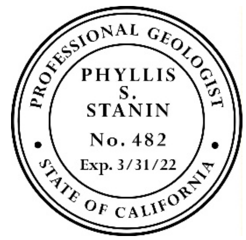
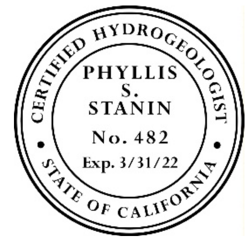
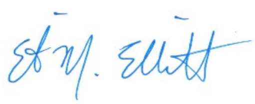
Todd Groundwater, Alameda, CA







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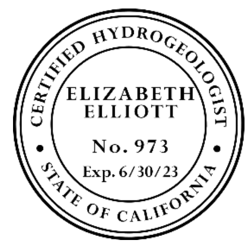

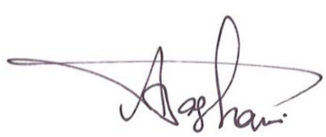

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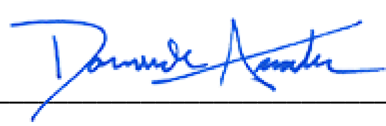

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ACKNOWLEDGMENTS

This Groundwater Sustainability Plan was prepared for the Stanislaus and Tuolumne Rivers Groundwater Basin Association Groundwater Sustainability Agency (STRGBA GSA) and the County of Tuolumne Groundwater Sustainability Agency (Tuolumne GSA) by a team of technical and outreach consultants under the guidance of a Technical Advisory Committee (TAC) that served as advisors to the GSAs. Technical consulting firms along with their general roles and responsibilities are summarized below:

Todd Groundwater led the technical team providing overall project management, hydrogeologic characterization, development of sustainable management criteria and the monitoring network, and primary responsibility for GSP development.

Woodard & Curran developed the local C2VSimTM integrated surface water-groundwater model, analyzed water budgets, and developed projects and management actions.

Stantec provided GSP outreach support including preparation of a Communications and Engagement Plan and the Notice and Communication GSP chapter, stakeholder engagement, and outreach support for public comments and GSP adoption.

In addition to GSP development activities summarized above, **Todd Groundwater** and **Ground Zero Analysis, Inc.** provided technical assistance and onsite field supervision for the installation of monitoring wells to support the GSP.

Funding for GSP development has been provided, in part, by a $1,000,000 Sustainable Groundwater Management (SGM) grant through an agreement with the State Department of Water Resources (DWR). Funding for this grant was provided by the Water Quality, Supply, and Infrastructure Improvement Act of 2014 (Proposition 1).

Additional funding to support GSP planning was provided by a second $1,000,000 SGM grant managed by DWR and funded by the California Drought, Water, Parks, Climate, Coastal Protection, and Outdoor Access for All Act of 2018 (Proposition 68). The provision of these State funds is through an amended agreement with the State of California Department of Water Resources. These funds were used for the installation of monitoring wells to support the GSP.

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Acronyms

AF	Acre-feet
AFY	Acre-feet per year
AWMP	Agricultural Water Management Plan
bgs	Below ground surface
BMP	Best Management Practices
Brown Act	Ralph M. Brown Act
BPA	Basin Plan Amendment
C2VSim	California Central Valley Groundwater-Surface Water Simulation Model
C2VSim-TM	C2VSim-Turlock/Modesto; revised regional C2VSim model for Turlock and Modesto subbasins
CALSIMETAW	California Simulation of Evapotranspiration of Applied Water
CARB	California Air Resources Board
CASGEM	California Statewide Groundwater Elevation Monitoring
CEQA	California Environmental Quality Act
CCR	California Code of Regulations
CDFW	California Department of Fish and Wildlife
cfs	Cubic feet per second
CGPF	CalSim II Generated Perturbation Factors
CPD	Comprehensive Planning District

CDPH	California Department of Public Health
CGPF	CalSim II Generated Perturbation Factors
CGPS	Continuously Operating Global Positioning System
COC	Constituent of Concern
Committee	STRGBA GSA representatives and/or alternates tasked with overseeing activities to achieve the objectives of SGMA as applicable within the Modesto Subbasin
CPD	Comprehensive Planning District
CUF	Consumptive Use Factor
CVRWQCB	Regional Water Quality Control Board, Central Valley Region
CV-SALTS	Central Valley Salinity Alternatives for Long-Term Sustainability
DAC	Disadvantaged Community
DBCP	Dibromochloropropane
DEM	Digital Elevation Map
DMMs	Demand Management Measures
DMS	Data Management System
DNAPL	Dense Non-Aqueous Phase Liquid
DO	Dissolved Oxygen
DOGGR	California Department of Oil, Gas and Geothermal Resources
DTSC	Department of Toxic Substances Control
DWR	Department of Water Resources, State of California
EDA	Economically Distressed Area
ESJ	Eastern San Joaquin
ESJWQC	East San Joaquin Water Quality Coalition
ETAW	Evapotranspiration of Applied Water
ET	Evapotranspiration
EWMP	Efficient Water Management Practices
FloodMAR	Flood Managed Aquifer Recharge
FMMP	Farmland Mapping and Monitoring Program
ft/day	Feet per day
GAMA	Groundwater Ambient Monitoring and Assessment
GDE	Groundwater dependent ecosystem

GPCD	Gallons per capita per day
gpd/ft	Gallons per day per foot
gpm	Gallons per minute
GPS	Global Positioning System
GSA	Groundwater Sustainability Agency
GSP	Groundwater Sustainability Plan
GWMP	Groundwater Management Plan
ILRP	Irrigated Lands Regulatory Program
IM	Interim Milestone
InSAR	Interferometric Synthetic Aperture Radar
IWFM	Integrated Water Flow Model
LAFCo	Local Agency Formation Commissions
LID	Low Impact Development
LUST	Leaking Underground Storage
MA	Management Area
MAF	Million Acre Feet
MCL	Maximum Contaminant Level
MG	Million Gallon
mg/L	milligrams per liter
mgd	Million Gallons per Day
MHI	Median Household Income
MID	Modesto Irrigation District
MO	Measurable Objective
MOU	Memorandum of Understanding
MRWTP	Modesto Regional Water Treatment Plant
msl	Mean Sea Level
MT	Minimum Threshold
NCCAG	Natural Communities Commonly Associated with Groundwater
NCP	Nitrate Control Program
NDE	Non-District East – areas in the eastern Subbasin outside of a water or irrigation district boundary
NED	National Elevation Dataset

NL	Notification Level
NMFS	National Marine Fisheries Service
NMP	Nitrogen Management Plan
NPDES	National Pollution Discharge Elimination System
NWIS	National Water Information System
OID	Oakdale Irrigation District
PCE	Tetrachloroethylene
pCi/L	Picocuries per Liter
PEIR	Programmatic Environmental Impact Report
PMAs	Projects and Management Actions
ppm	parts per million
PRISM	Parameter-elevation Relationships on Independent Slopes Model
QA/QC	Quality Assurance/Quality Control
RWQCB	Regional Water Quality Control Board
RWS	Rural Water System
SCADA	Supervisory Control and Data Acquisition
SCHM	Stanislaus County Hydrologic Model
SGMA	Sustainable Groundwater Management Act
SMC	Sustainable Management Criteria
SMCL	California Secondary Maximum Contaminant Level
SDAC	Severely Disadvantaged Community
SSJID	South San Joaquin Irrigation District
SSURGO	Soil Survey Geographic Database
STRGBA GSA	Stanislaus and Tuolumne Rivers Groundwater Basin Authority Groundwater Sustainability Agency
STRGBA	Stanislaus and Tuolumne Rivers Groundwater Basin Association
SWRCB	State Water Resources Control Board
T	Transmissivity
TAC	Technical Advisory Committee
TCP	1,2,3-Trichloropropane
TDS	Total Dissolved Solids
TNC	The Nature Conservancy

TRE	TRE ALTAMIRA Inc.
TRRP	Tuolumne River Regional Park
TRS	Tuolumne River System
umhos/cm	micromohs per centimeter
µg/L	Micrograms per liter
UR	Undesirable Result
USACE	United States Army Corps of Engineers
USBR	United States Bureau of Reclamation
USDA	United States Department of Agriculture
USGS	United States Geological Survey
UWMP	Urban Water Management Plan
VIC	Variable Infiltration Capacity
VOC	Volatile Organic Compound
WDR	Waste Discharge Requirements
WQO	Water Quality Objective
WRIMS	Water Resource Integrated Modeling System
WTSGSA	West Turlock Subbasin GSA
WY	Water Year

EXECUTIVE SUMMARY

This **Groundwater Sustainability Plan (GSP)** covers the entire Modesto Subbasin (5-22.02), designated a high-priority basin by the Department of Water Resources (DWR). The Modesto Subbasin covers about 245,253 acres in the northern San Joaquin Valley Groundwater Basin and is bounded by the Stanislaus River on the north, the Tuolumne River on the south, the San Joaquin River on the west and the crystalline basement rocks of the Sierra Nevada Foothills on the east. The Modesto Subbasin relies on two primary sources of water supply – surface water from the Stanislaus and Tuolumne rivers and groundwater pumped from the Subbasin.

This GSP is being prepared jointly by the **Stanislaus and Tuolumne Rivers Groundwater Basin Association (STRGBA) Groundwater Sustainability Agency (STRGBA GSA) and the County of Tuolumne Groundwater Sustainability Agency (Tuolumne GSA)**. The Subbasin GSAs are shown on Figure ES-1. The STRGBA GSA covers approximately 99.5 percent of the Modesto Subbasin, with the Tuolumne GSA covering approximately 1,000 acres that extends eastward into Tuolumne County. The Tuolumne GSA coordinated with the STRGBA GSA on the development of the Modesto Subbasin GSP through an agreement with Stanislaus County.

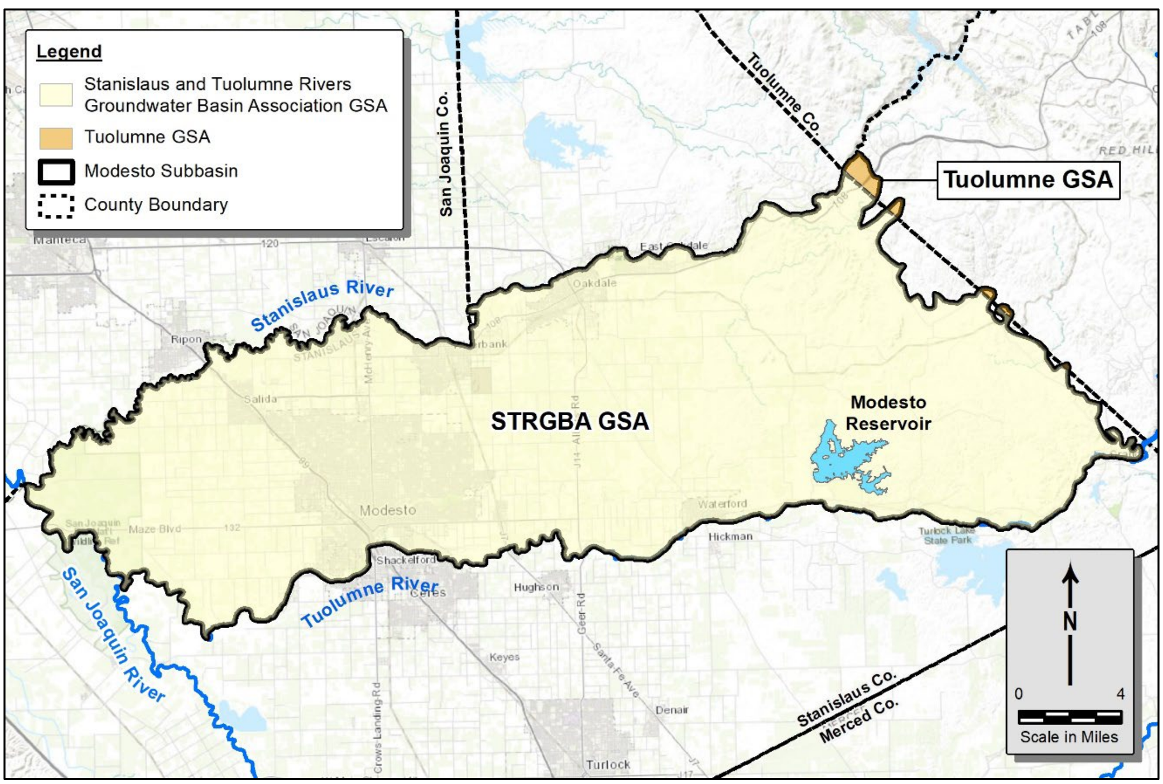

Figure ES-1 GSA Jurisdictional Boundaries

The STRGBA GSA is composed of seven member agencies that entered into a Memorandum of Understanding (MOU) to form a GSA and prepare a GSP. Member agencies of the STRGBA GSA include the City of Modesto, City of Oakdale, City of Riverbank, City of Waterford, Modesto Irrigation District

(MID), Oakdale Irrigation District (OID), and Stanislaus County. Service areas of these agencies in the Modesto Subbasin are shown on Figure ES-2. Many GSA member agencies have service areas in adjacent subbasins providing coordination for GSPs across the northern San Joaquin Valley.

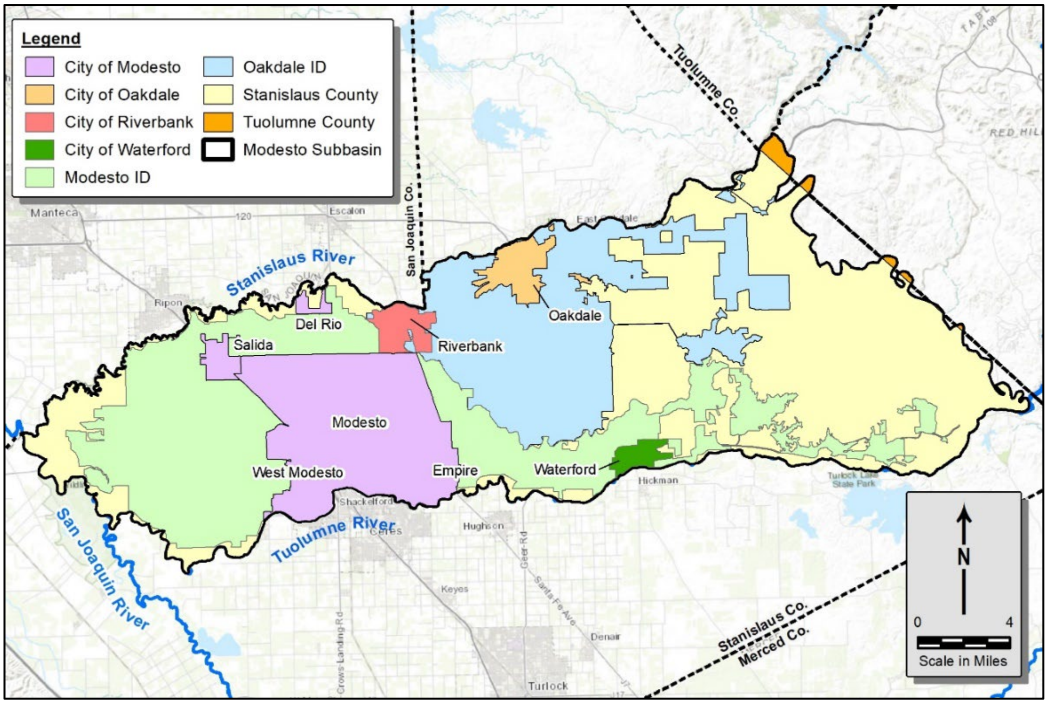

Figure ES-2 GSA Member Agency Jurisdictional Boundaries

GSA member agencies also represent stakeholders in disadvantaged areas in the Subbasin including the City of Modesto, City of Oakdale, City of Waterford, Stanislaus, and Tuolumne counties (Figure ES-3).

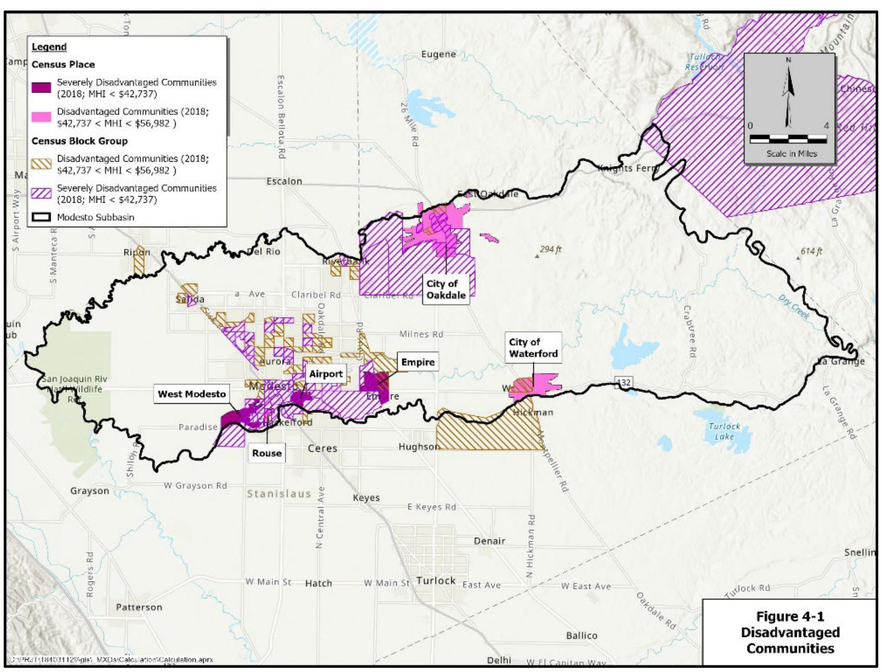

Figure ES-3 Disadvantaged Communities in the Modesto Subbasin

About 64 percent of the Modesto Subbasin is agricultural, with major crop types including almonds and other deciduous trees, corn, grains, pasture, vines, citrus and truck crops. Urban areas cover about 13 percent of the Subbasin. Remaining lands consist of non-agriculture, non-irrigated agriculture, undeveloped areas, and surface water (23 percent). Most of the undeveloped land is in the eastern portion of the Modesto Subbasin as shown by the 2017 land use map on Figure ES-4.

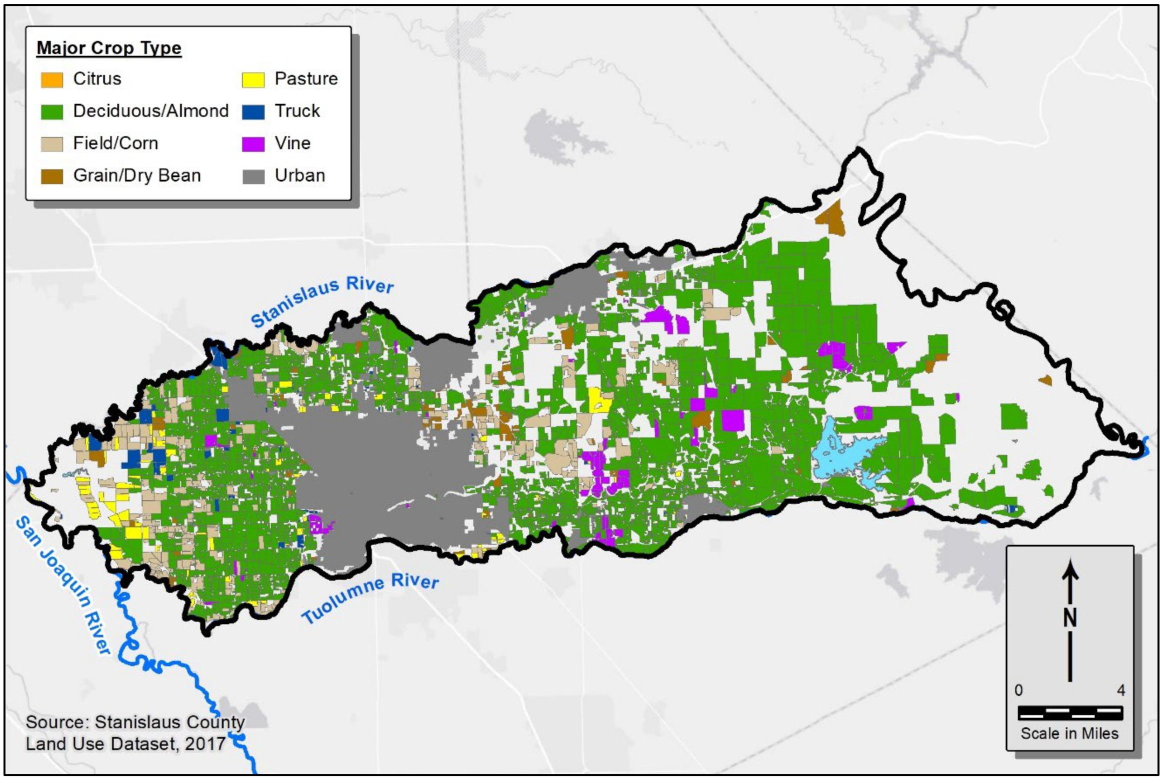

Figure ES-4 Existing Land Use

A significant expansion of irrigated agriculture occurred in the Subbasin during the GSP study period. In 1996, irrigated agriculture covered approximately 46 percent of the Subbasin (approximately 111,946 acres). Over the next 20 years, irrigated agriculture expanded by about 40 percent and by 2017 had added another 45,965 acres (total 157,911 acres, approximately 64 percent of the Subbasin). The increase in irrigated agriculture primarily resulted from a conversion of pasture to deciduous/almond orchards. Much of this expansion occurred in the eastern Subbasin – outside of Modesto ID and Oakdale ID service areas – where groundwater is the primary source of water supply.

Beneficial uses of groundwater in the Subbasin include municipal, small water system, and domestic drinking water, industrial and agricultural supply, and environmental uses. Environmental uses include interconnected surface water uses, aquatic habitat, and groundwater dependent ecosystems (GDEs).

Four separate Management Areas are delineated in the GSP to reflect areas of similar water supplies, streamlining coordination of water management and prioritizing areas for GSP project implementation. These management areas include Modesto ID Management Area, Oakdale ID Management Area, Non-District East Management Area, and Non-District West Management Area as shown on Figure ES-5.

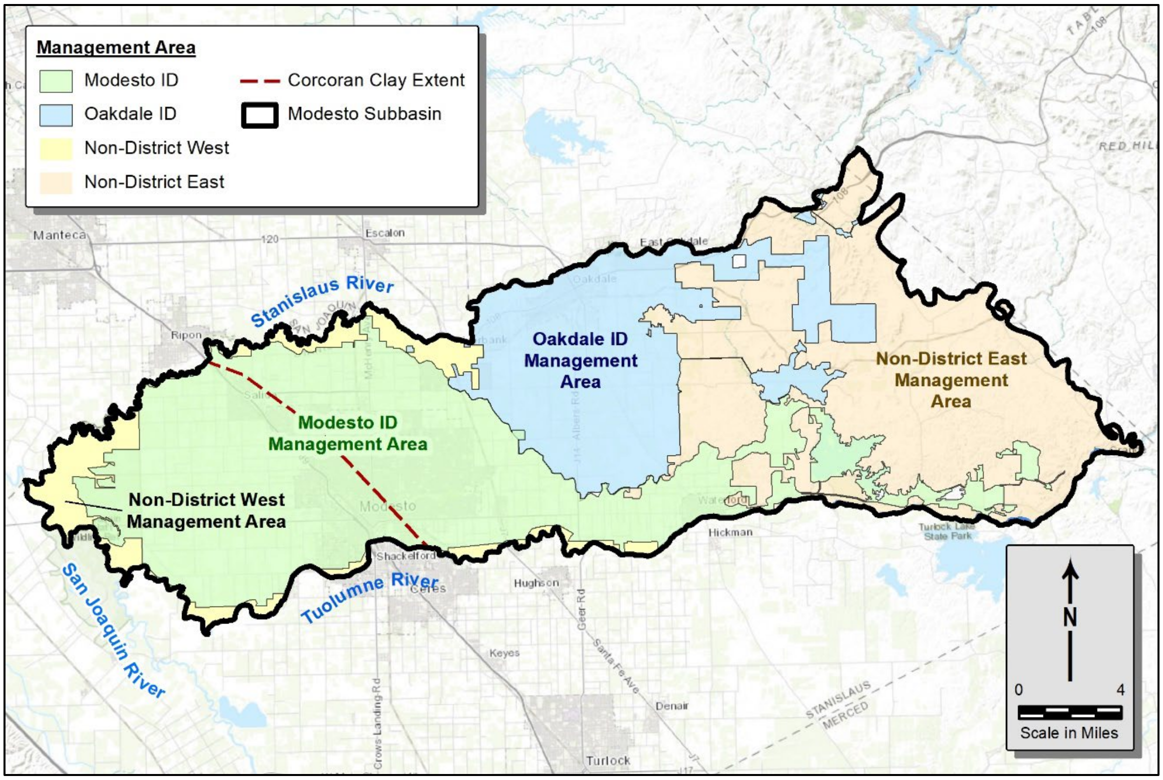

Figure ES-5 Modesto Subbasin Management Areas

The Non-District West Management Area contains lands along the western rim of the Subbasin, where both groundwater and surface water (riparian rights) are available for beneficial uses. The Non-District East Management Area includes lands outside of Modesto ID and Oakdale ID service areas in the eastern Subbasin, where groundwater is the primary water supply.

The Modesto ID and Oakdale ID Management Areas coincide with their service area boundaries, which facilitates ongoing water management responsibilities. Modesto ID manages Tuolumne River water and groundwater conjunctively, and Oakdale ID manages Stanislaus River water and groundwater conjunctively. The Non-District East and Non-District West Management Areas cover remaining lands outside of MID and OID jurisdiction, where Stanislaus County is the lead member agency.

The physical and water management setting of the Plan Area is contained in Chapter 2 and the hydrogeologic setting and groundwater conditions are provided in Chapter 3.

As summarized in the basin setting, the Modesto Subbasin extends from the Sierra Nevada foothills to the San Joaquin Valley floor, with ground surface elevations ranging from approximately 650 feet mean sea level (msl) in the eastern Subbasin to 20 feet msl along the San Joaquin River. The western Subbasin is relatively flat and the eastern Subbasin is hummocky, as the San Joaquin Valley floor transitions to the Sierra Nevada foothills. The eastern Subbasin boundary generally follows the contact of Subbasin sedimentary deposits with the crystalline basement rocks of the Sierra Nevada. This contact slopes steeply and the Modesto Subbasin is filled with sedimentary deposits that may extend thousands of feet below the surface. The base of fresh water, as mapped by USGS and incorporated into the C2VSimTM model used for this GSP, is used to define the bottom of the basin.

Three principal aquifers were defined in the Modesto Subbasin for future groundwater management under SGMA. The Corcoran Clay, underlying the western Subbasin, is the primary aquitard in the Subbasin and used to demarcate the three principal aquifers: the Western Upper Principal Aquifer is the unconfined aquifer above the Corcoran Clay, the Western Lower Principal Aquifer is the confined aquifer below the Corcoran Clay and the Eastern Principal Aquifer is the unconfined to semi-confined aquifer system east of the Corcoran Clay.

Cross sections were developed for the GSP based on geologic textures that illustrate the distribution of coarse- and fine-grained deposits within the Subbasin and the westerly dipping and thickening Corcoran Clay. Simplified cross sections were also developed to represent the geologic formations within the Subbasin. A conceptual cross section on Figure ES-6 is provided to illustrate subsurface conditions across the Subbasin including the principal aquifers, the Corcoran Clay, the westerly dipping formations, offsets caused by two interpreted geologic faults in the central and eastern Subbasin, and the base of fresh water which represents the bottom of the basin. The bottom of the basin is about -550 feet msl along the eastern Subbasin boundary, dips to about -1,000 feet msl in the center of the Subbasin and then rises to about -700 feet msl along the western Subbasin boundary.

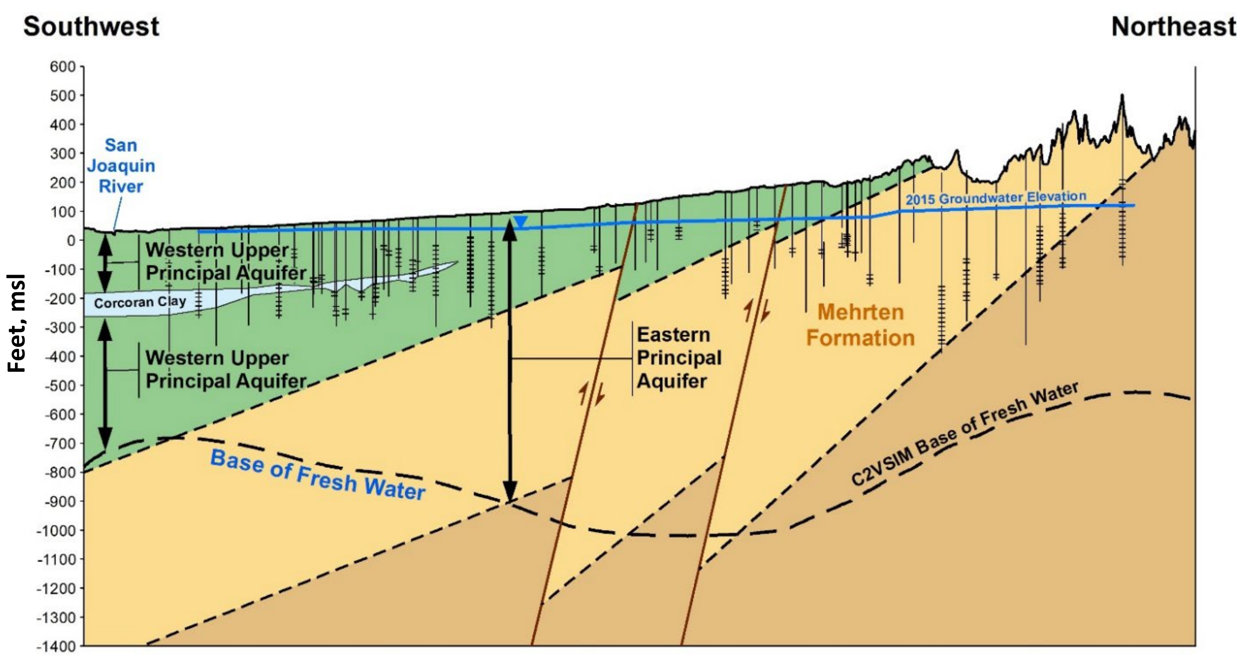

Figure ES-6 Cross Section of Hydrogeologic Framework

The cross section also depicts the shallow groundwater elevation across the Subbasin in Fall 2015 (blue line near top of section). As indicated on Figure ES-6, the water table is shallow in the western Subbasin and deepens to the east with the rising ground surface elevation. A small area of lowered water levels is indicated in the eastern Subbasin, reflecting an area with ongoing water level declines, although data in that area are sparse.

An analysis of **groundwater conditions** was conducted based on water levels measurements from approximately 450 wells during the study period. Most of the available water level measurements were from wells screened in the Western Upper Principal Aquifer and the Eastern Principal Aquifer; there are only a few wells screened solely in the Western Lower Principal Aquifer. Water level data were used to calibrate the C2VSimTM model, which was used to assist with groundwater flow analyses.

As indicated by the simulated contours in Figure ES-7, groundwater in the Subbasin flows generally to the southwest, with local water levels controlled by groundwater pumping. Water levels in the Western Upper Principal Aquifer were relatively low in the early 1990s and rose after 1995 when the City of Modesto began receiving water from the Modesto Regional Water Treatment Plant and began pumping less groundwater. Since then, water levels appear to be relatively stable, with small declines during drought (about 10 to 20 feet) followed by recovery in post-drought years. Water levels in the Eastern Principal Aquifer have declined since about 2000, with significant declines during the recent drought. In the eastern Subbasin, long-term rates of decline are up to about 2.7 feet per year, and rates of decline during drought are up to 6 feet per year. A generalized area is delineated in the eastern Subbasin on Figure ES-7 where water level declines have occurred (dashed blue line).

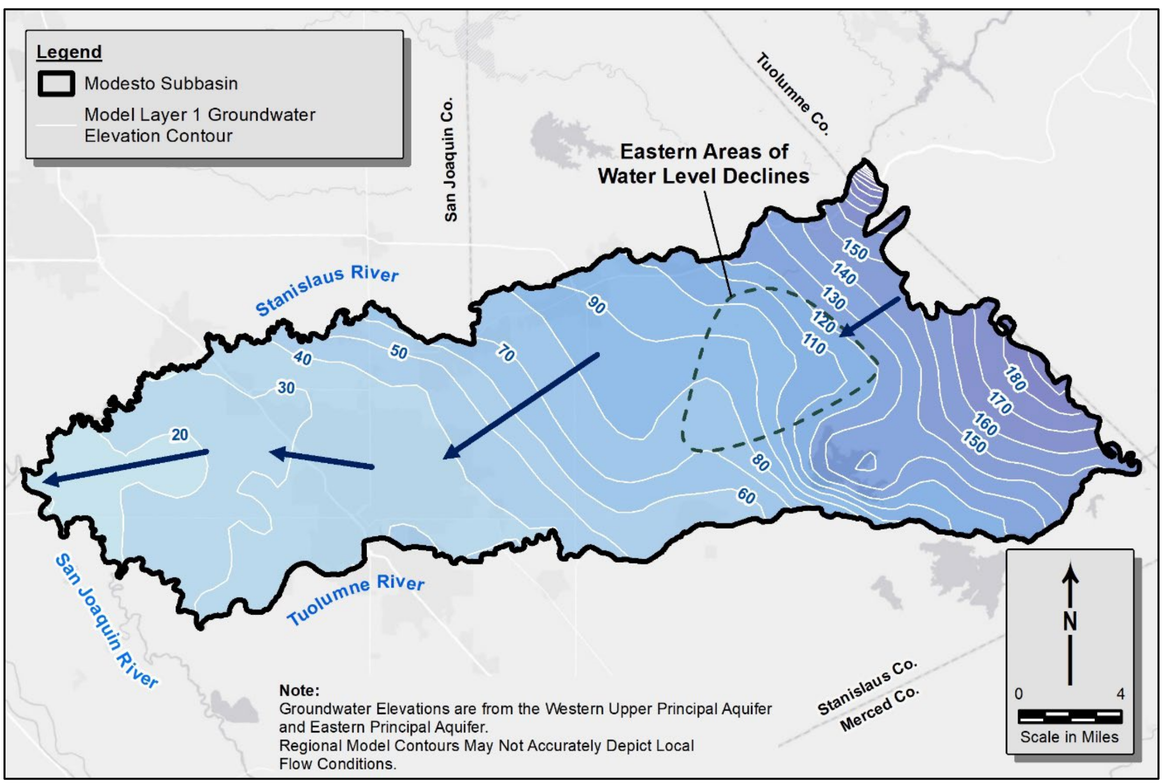

Figure ES-7 Simulated Groundwater Elevation Contours, September 2015, Unconfined Aquifer

The Tuolumne, Stanislaus and San Joaquin rivers flow for approximately 122 miles along three of the four Subbasin boundaries and are each **interconnected surface water as defined by SGMA**. The interconnectedness of the rivers was analyzed using the integrated surface water-groundwater model C2VSimTM, developed for the GSP. Model results show that the San Joaquin River along the Modesto Subbasin has been, and is projected to be, a net gaining reach. The Stanislaus and Tuolumne river systems are more dynamic, with recharge and baseflow varying along segments of the rivers both seasonally and over time. Total stream inflows into the Subbasin during the historical study period are approximately 2.5 million acre feet (MAF), more than one-half of which is from the San Joaquin River (1.3 MAF). The remaining inflows are from the Stanislaus River (0.5 MAF) and Tuolumne River (0.7 MAF). The Stanislaus and Tuolumne rivers drain into the San Joaquin River, which has an outflow from the Subbasin of approximately 2.8 MAF during the historical study period.

C2VSimTM was used to develop **water budgets** for the historical (1991 to 2015), current (2010) and projected conditions, which represents average hydrology and current land use over a 50-year future period. Inflows and outflows from the water budget analysis for these three conditions are summarized in Table ES-1.

Table ES-1 Average Annual Water Budget – Groundwater System, Modesto Subbasin (AFY)

Component	Historical Condition Water Budget	Current Condition Water Budget	Projected Condition Water Budget
Hydrologic Period	WY 1991- 2015	WY 2010	Hydrology from WY 1969 - 2018
Gain from Stream	40,000	51,000	76,000
Gain from Stanislaus River	19,000	20,000	36,000
Gain from Tuolumne River	20,000	30,000	38,000
Gain from San Joaquin River	1,000	-	2,000
Canal & Reservoir Recharge	49,000	47,000	47,000
Deep Percolation	272,000	257,000	228,000
Subsurface Inflow	80,000	79,000	77,000
Flow from the Sierra Nevada Foothills	9,000	5,000	9,000
Eastern San Joaquin Subbasin Inflows	8,000	9,000	28,000
Turlock Subbasin Inflows	30,000	34,000	33,000
Delta Mendota Subbasin Inflows	33,000	31,000	7,000
Total Inflow	**440,000**	**434,000**	**428,000**
Discharge to Stream	100,000	80,000	50,000
Discharge to Stanislaus River	35,000	27,000	12,000
Discharge to Tuolumne River	51,000	39,000	27,000
Discharge to San Joaquin River	15,000	13,000	11,000
Subsurface Outflow	73,000	63,000	75,000
Eastern San Joaquin Subbasin Outflows	6,000	5,000	35,000
Turlock Subbasin Outflows	32,000	24,000	34,000
Delta Mendota Subbasin Outflows	36,000	35,000	6,000
Groundwater Production	311,000	416,000	314,000
Agency Ag. Groundwater Production	26,000	15,000	25,000
Private Ag. Groundwater Production	222,000	345,000	229,000
Urban Groundwater Production	63,000	56,000	60,000
Total Outflow	**483,000**	**559,000**	**438,000**
Change in Groundwater Storage	(43,000)	(125,000)	(11,000)

Note: sub-categories may not sum together due to rounding error

As shown on Table ES-1, the Modesto Subbasin experienced a **decline of groundwater in storage** of 43,000 AFY during historical conditions, based on an inflow of 440,000 AFY and an outflow of 483,000 AFY. The historical water budget estimates groundwater production of 311,000 AFY; by subtracting the groundwater deficit from the groundwater production, a simplified sustainable yield of 268,000 AFY can be estimated for the historical study period. The average annual depletion in groundwater for the current and projected conditions are 125,000 AFY and 11,000 AFY, respectively.

The average decline of groundwater in storage of 11,000 AFY during projected conditions is significantly less than historical storage depletion of 43,000 AFY. However, this decline occurs at the expense of increased seepage of 86,000 AFY from primarily the Stanislaus and Tuolumne rivers in response to water level declines. This future increase in streamflow depletion as predicted by the model is considered significant and unreasonable.

Based on the basin setting and water budget analysis, **the GSP developed sustainable management criteria** to avoid undesirable results for the five sustainability indicators applicable to the Subbasin: chronic lowering of water levels, reduction of groundwater in storage, degraded water quality, inelastic land subsidence, and depletion of interconnected surface water. The seawater intrusion sustainability indicator is not applicable to the inland Modesto Subbasin. Subbasin conditions that were the primary considerations for sustainability were incorporated into the analysis. Those sustainability considerations are illustrated on Figure ES-8. DWR icons for each sustainability indicator are placed on the map to highlight the area and reference the discussion below.

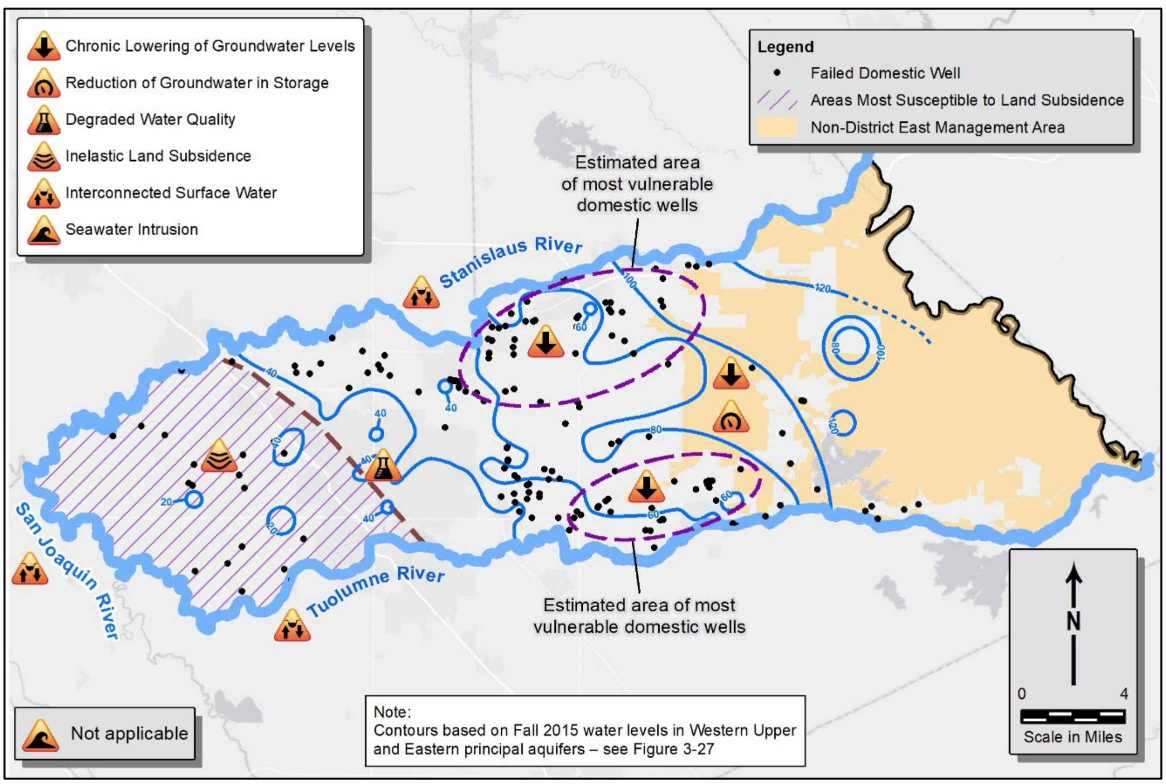

Figure ES-8 Sustainability Considerations for the Modesto Subbasin

As indicated on Figure ES-8, the Modesto Subbasin has experienced chronic lowering of water levels and reduction of groundwater in storage primarily within and around the Non-District East Management Area in the eastern Subbasin. The declining water levels in this area have propagated westward during drought conditions (2013-2017), lowering water levels in eastern Oakdale ID and in the vicinity of Waterford and causing impacts to domestic and public drinking water wells. A number of water quality constituents have been detected in excess of their maximum contaminant levels (MCLs) for drinking water, especially in the western Subbasin where most of the public drinking water wells occur. Although the City of Modesto and other public water suppliers manage their wellfield operations to control impacts to drinking water, the potential for degraded water quality in the future is also a consideration. No impacts from land subsidence have been observed in the Subbasin, but areas within the Corcoran Clay extent may be most susceptible to the potential for future land subsidence if water levels decline. Finally, the interconnected surface water sustainability indicator is a concern along the river boundaries, especially along the Tuolumne and Stanislaus rivers, where future increases in streamflow depletion are predicted unless water level declines and overdraft conditions are arrested.

To address these concerns, definitions of undesirable results, minimum thresholds, and other sustainable management criteria have been developed. A summary of the sustainable management criteria is provided in Table ES-3 below.

Table ES-3 Sustainable Management Criteria

Sustainability Indicator	Undesirable Results (narrative)	Minimum Thresholds
Chronic Lowering of Groundwater Levels	Adverse impacts to water supply wells from over-pumping	Historical low water level WY 1991–2020 (typically 2015, 1991, or current)
Reduction of GW in Storage	Long-term overdraft conditions based on projected water use and average hydrology	As above; linked to sustainable yield volume
Degraded Water Quality	Degradation caused by GSA projects/actions or management of water levels/extractions	MCLs of 7 constituents of concern
Seawater Intrusion	Not applicable	Not applicable
Inelastic Land Subsidence	Inelastic land subsidence that adversely impacts land use/infrastructure	Historical low water level WY 1991–2020 (typically 2015, 1991, or current)
Interconnected Surface Water	Adverse impacts on beneficial uses of surface water caused by groundwater extraction	Fall 2015 water levels (in coordination with adjacent subbasins)

These sustainable management criteria were tested with the C2VSimTM model to assist with evaluations of sustainability. This analysis, referred to as a **sustainable conditions analysis**, was conducted to determine how best to achieve the sustainability criteria and avoid undesirable results. The analysis modified the future projected conditions by reducing agricultural demand for groundwater users in the Non-District East Management Area (where groundwater is the primary water supply). This allowed the GSAs to optimize projects and management actions with respect to locations and quantities for future sustainable management.

Results from the sustainable conditions analysis are summarized in Table ES-2 and show that a 58 percent reduction in demand from the projected baseline levels would achieve a sustainable yield of approximately 266,000 for the Subbasin to avoid undesirable results. Since future projected groundwater production in the Subbasin is estimated at 314,000 AFY, an increase in supply or reduction in demand that adds approximately 47,000 AFY is required to bring the Subbasin into sustainability. Modeling suggests that the sustainable management criteria can be met under these conditions. It was recognized that these conditions could be met by increases in water supply as well as reductions in demand.

Table ES-2 Sustainable Yield Average Annual Water Budget, Modesto Subbasin (AFY)

Component	Projected Conditions	Sustainable Conditions
Hydrologic Period	Hydrology from WY 1969 - 2018	Hydrology from WY 1969 - 2018
Gain from Stream	76,000	58,000
Gain from Stanislaus River	36,000	27,000
Gain from Tuolumne River	38,000	29,000
Gain from San Joaquin River	2,000	1,000
Canal & Reservoir Recharge	47,000	47,000
Deep Percolation	228,000	213,000
Subsurface Inflow	77,000	83,000
Flow from the Sierra Nevada Foothills	9,000	9,000
Eastern San Joaquin Subbasin Inflows	28,000	9,000
Turlock Subbasin Inflows	33,000	29,000
Delta Mendota Subbasin Inflows	7,000	37,000
Total Inflow	**428,000**	**401,000**
Discharge to Stream	50,000	71,000
Discharge to Stanislaus River	12,000	18,000
Discharge to Tuolumne River	27,000	40,000
Discharge to San Joaquin River	11,000	14,000
Subsurface Outflow	75,000	63,000
Eastern San Joaquin Subbasin Outflows	35,000	4,000
Turlock Subbasin Outflows	34,000	30,000
Delta Mendota Subbasin Outflows	6,000	30,000
Groundwater Production	314,000	267,000
Agency Ag. Groundwater Production	25,000	25,000
Private Ag. Groundwater Production	229,000	181,000
Urban Groundwater Production	60,000	60,000
Total Outflow	**438,000**	**401,000**
Change in Groundwater Storage	(11,000)	-

Note: sub-categories may not sum together due to rounding error

Groundwater level monitoring networks were developed to track and document the achievement of sustainable management criteria for the chronic lowering of groundwater levels, reduction of groundwater in storage, land subsidence, and depletions of interconnected surface water. The monitoring networks are composed of representative monitoring wells that will be used to monitor sustainable management criteria for these sustainability indicators during the GSP implementation and planning horizon. Groundwater elevations were selected for a minimum threshold and measurable objective for each well in the monitoring network. The monitoring networks consist of CASGEM wells, City of Modesto monitoring wells, USGS monitoring wells and monitoring wells constructed in 2021 with Proposition 68 grant funding from DWR. The monitoring network for degradation of water quality will be based on wells monitored by others and available at the State Water Resources Control Board (SWRCB) GeoTracker website.

The water level monitoring network is shown on Figure ES-9. (The water quality monitoring network being implemented by others is shown on Figure 7-4).

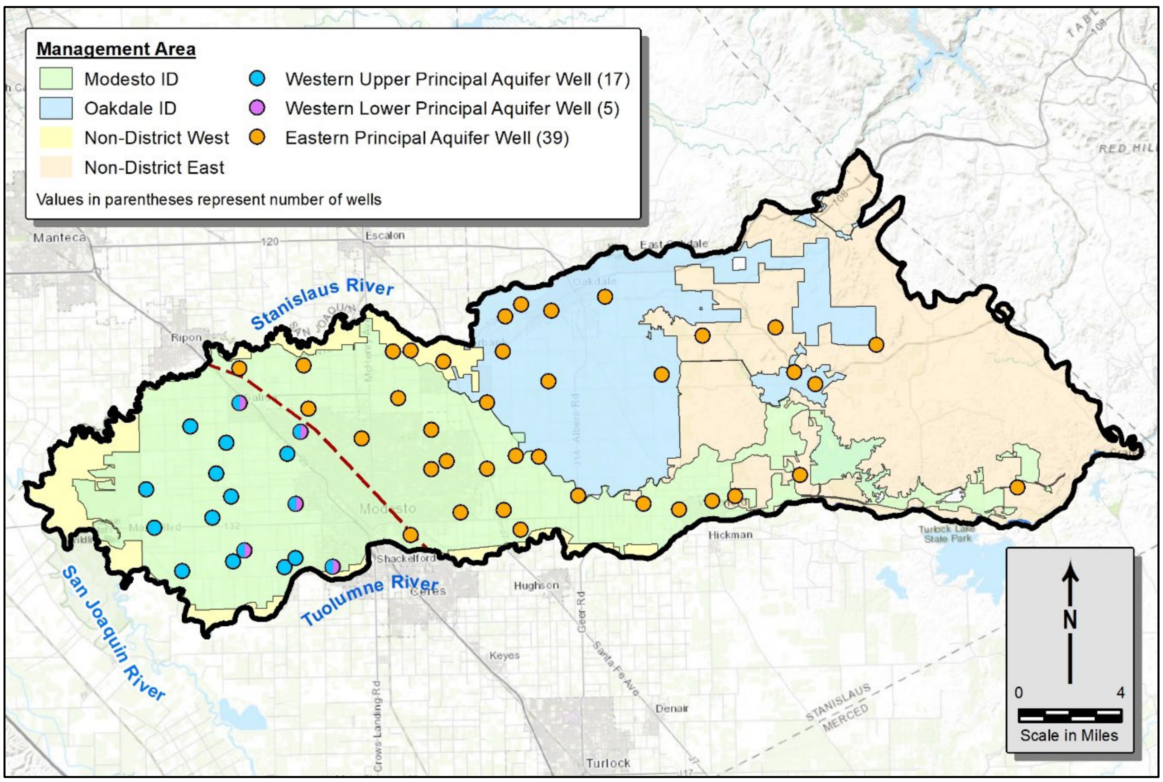

Figure ES-9 Summary of Monitoring Network

To achieve the sustainability goals for the Modesto Subbasin by 2042, and to avoid undesirable results over the remainder of a 50-year planning horizon, multiple **Projects and Management Actions** were identified by the GSAs. Three groups of projects were identified: Group 1 projects are in place and will continue to be implemented, Group 2 projects are still in the planning stages but are generally implementable, and Group 3 projects are being considered and are subject to feasibility. A summary of projects and management actions is provided in Table ES-4.

Table ES-4 GSP Projects for the Modesto Subbasin

Number	Proponent(s)	Project Name	Primary Mechanism(s)	Partner(s)	Group
1	City of Modesto	Growth Realization of Surface Water Treatment Plant Phase II	In-lieu Groundwater Recharge	N/A	1
2	City of Modesto	Advanced Metering Infrastructure Project (AMI)	Conservation	N/A	1
3	City of Modesto	Storm Drain Cross Connection Removal Project	Stormwater Capture	N/A	2
4	City of Waterford	Waterford/Hickman Surface Water Pump Station and Storage Tank	In-lieu Groundwater Recharge	City of Modesto, MID	2
5	Non-District East Areas	Modesto Irrigation District In-lieu and Direct Recharge Project	Direct or In-lieu Groundwater Recharge	Modesto ID	2
6	NDE Areas	Oakdale Irrigation District In-lieu and Direct Recharge Project	Direct or In-lieu Groundwater Recharge	OID	2
7	NDE Areas	Tuolumne River Flood Mitigation and Direct Recharge Project	Direct Groundwater Recharge	Modesto ID	2
8	NDE Areas	Dry Creek Flood Mitigation and Direct Recharge Project	Direct Groundwater Recharge	Stanislaus County	2
9	NDE Areas	Stanislaus River Flood Mitigation and Direct Recharge Project	Direct Groundwater Recharge	Stanislaus County	3
10	City of Modesto	Detention Basin Standards Specifications Update	Groundwater Recharge	N/A	3
11	NDE Areas	Recharge Ponds	Groundwater Recharge	N/A	3
12	City of Oakdale	OID Irrigation and Recharge to Benefit City of Oakdale	Direct or In-lieu Groundwater Recharge	N/A	3
13	MID	MID FloodMAR Projects	Direct Groundwater Recharge	N/A	3

Projects were coupled with additional management actions that are being developed for implementation with an adaptive management approach. Management actions generally refer to non-structural programs or policies designed to incentivize actions and strategies to support the sustainability of the groundwater Subbasin and include strategies for water conservation and demand reduction.

Table ES-65 List of Management Actions

Category	Number	Proponent[2]	Management Action	Primary Mechanism(s)[1]
Demand Reduction Strategies	1	Modesto Subbasin GSAs	Voluntary Conservation and/or Land Fallowing	Conservation/ Land Fallowing
	2	Modesto Subbasin GSAs	Conservation Practices	Conservation
Water Accounting framework	3	Modesto Subbasin GSAs	Groundwater Extraction and Surface Water Reporting Program	Pumping Reduction
	4	Modesto Subbasin GSAs	Groundwater Allocation and Pumping Management Program	Pumping Reduction
	5	Modesto Subbasin GSAs	Groundwater Extraction Fee	Pumping Reduction
	6	Modesto Subbasin GSAs	Groundwater Pumping Credit Market and Trading Program	Pumping Reduction

Group 1 and 2 projects were analyzed using the C2VSimTM model under the 50-year projected conditions. Two scenarios were simulated, Scenario 1 includes three urban and municipal projects and Scenario 2 adds agriculturally based in-lieu and direct recharge projects to Scenario 1. Scenario 1 projects are expected to reduce net groundwater pumping in the Subbasin by 13,700 AFY and will reduce the annual groundwater storage deficit by 1,500 AFY, from 11,000 AFY under Baseline conditions to 9,500 AFY under Scenario 1. Scenario 2 projects are expected to reduce groundwater pumping by 44,000 AFY and will reduce the annual groundwater storage deficit by 12,400 AFY, resulting in a net positive change in storage of 1,400 AFY.

Modeling analyses demonstrated the ability of Groups 1 and 2 GSP projects to meet the sustainable management criteria developed in Chapter 6 of the GSP. Modeling of representative monitoring sites indicate that undesirable results can be avoided over the 50-year implementation and planning horizon. **Results indicate that through regional cooperation and the commitment of project beneficiaries, groundwater sustainability can be achieved in the Modesto Subbasin without demand management**. Nonetheless, demand management is provided in the GSP as a backstop to avoid undesirable results in the future.

GSP implementation will begin immediately after the GSP is submitted in January 2022. Annual reports will be submitted by April 1 of each year following GSP adoption. Every five years, GSPs will be evaluated with respect to their progress in meeting sustainability goals. **Additional implementation activities are described in Chapter 9**.

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1. ADMINISTRATIVE INFORMATION

1.1. AGENCY INFORMATION

This Groundwater Sustainability Plan (GSP) covers the Modesto Subbasin (5-22.02) located in the northern San Joaquin Valley Groundwater Basin. The GSP is being prepared jointly by the Stanislaus and Tuolumne Rivers Groundwater Basin Association Groundwater Sustainability Agency (STRGBA GSA) and the County of Tuolumne Groundwater Sustainability Agency (Tuolumne GSA). Collectively, these two GSAs have been deemed exclusive GSAs and cover the entire Subbasin. The Modesto Subbasin boundaries and service areas of the STRGBA GSA and Tuolumne GSA are shown on **Figure 1-1**.

Service area boundaries for the two GSAs are aligned with Subbasin boundaries and are defined on the north and south by the Stanislaus River and the Tuolumne River, respectively. The STRGBA GSA is bounded on the west by the San Joaquin River. The eastern STRGBA GSA boundary is defined by the boundary between Stanislaus County and Tuolumne County, and also represents the western boundary of the Tuolumne GSA. The STRGBA GSA covers approximately 99.5 percent of the Modesto Subbasin. The Tuolumne GSA is composed of five areas covering approximately 1,000 acres (approximately 0.5 percent) of the Modesto Subbasin that extend into Tuolumne County (**Figure 1-1**).

The Modesto Subbasin has been designated as a High-Priority basin by the Department of Water Resources (DWR) with implications under the Sustainable Groundwater Management Act (SGMA). In compliance with SGMA deadlines, the Modesto Subbasin GSP is being completed, adopted, and submitted to DWR by January 31, 2022.

1.1.1. Stanislaus and Tuolumne Rivers Groundwater Basin Association Groundwater Sustainability Agency (STRGBA GSA)

In April 1994, six agencies in the Modesto Groundwater Subbasin executed a Memorandum of Understanding (MOU) to establish the Stanislaus and Tuolumne Rivers Groundwater Basin Association (STRGBA). In 2015, the MOU was revised to include the City of Waterford. STRGBA has historically been the primary entity responsible for coordinating, planning, and management of the shared groundwater resources in the Modesto Subbasin.

The STRGBA agencies entered into an MOU to form the STRGBA groundwater sustainability agency (GSA) and filed a Notice of Intent with DWR on February 16, 2017. Currently, STRGBA GSA is located at 1231 11th Street, Modesto, CA 95354, in the offices of Modesto Irrigation District; the GSA maintains an informational website at www.strgba.org.

The STRGBA GSA includes seven local agencies with service areas in the Subbasin:

- City of Modesto
- City of Oakdale
- City of Riverbank
- City of Waterford
- Modesto Irrigation District (MID)
- Oakdale Irrigation District (OID)
- Stanislaus County

Some STRGBA GSA members also serve areas outside of the Subbasin. Oakdale Irrigation District overlies portions of the Eastern San Joaquin Subbasin and participates in that subbasin GSP as the Oakdale Irrigation District Eastern San Joaquin Subbasin GSA. The City of Modesto provides water to communities within the Turlock Subbasin and participates as a member agency of the West Turlock Subbasin GSA (WTSGSA). The City of Waterford also has service areas in both the Modesto and Turlock subbasins and is an Associate Member of the WTSGSA. Stanislaus County spans portions of three subbasins in addition to the Modesto Subbasin including the Eastern San Joaquin Subbasin, the Turlock Subbasin, and the Delta-Mendota Subbasin; as such, the County is a member of multiple GSAs and participates in multiple GSPs. These cross-basin relationships provide a cooperative and coordinated approach to GSP development in the northern San Joaquin Valley.

Representatives of the STRGBA GSA member agencies have formed a Technical Advisory Committee (TAC) to assist the GSAs in preparation of the GSP. All TAC meetings are public meetings held in accordance with the Ralph M. Brown Act (California Government Code sections 54950 et seq.).

1.1.2. County of Tuolumne Groundwater Sustainability Agency

The Tuolumne GSA was formed on May 16, 2017, by adoption of County of Tuolumne Resolution No. 63-17 for the approximately 1,000-acre portion of the Modesto Subbasin that is within Tuolumne County. The Tuolumne GSA is cooperating with the STRGBA GSA on the development of one GSP for the entire Modesto Subbasin through a cooperation agreement with Stanislaus County (**Appendix A**). The Tuolumne GSA address is at the County of Tuolumne County Administrator's Office on 2 South Green Street, Sonora, CA 95370 (**Appendix A**).

1.2. ORGANIZATION AND MANAGEMENT STRUCTURE FOR PLAN DEVELOPMENT

On March 14, 2018, the STRGBA GSA notified DWR of their intent to prepare a GSP for the Modesto Subbasin (**Appendix A**). As noted above, the GSP is being developed by the STRGBA GSA and the Tuolumne GSA (through a Stanislaus County agreement). A TAC planning group was formed to provide oversight and direction to the technical consulting team assisting with plan preparation. Periodic public TAC meetings, typically held the second Tuesday of each month, allowed ongoing coordination with the TAC, local stakeholders, and the public.

TAC meetings also provided an opportunity to coordinate with SGMA activities in adjacent subbasins. Two of the adjacent subbasins, Delta-Mendota Subbasin and Eastern San Joaquin Subbasin, are designated as Critically-Overdrafted Basins and, as such, were required to submit GSPs to DWR in 2020. Accordingly, those two subbasins are progressing with GSP implementation. The Turlock Subbasin to the south is designated a High-Priority Basin, the same designation as the Modesto Subbasin and is on a similar schedule for plan development. The two subbasins coordinated the GSP technical approach and shared in the development of one integrated water resources model that covers both subbasins.

The City of Modesto, a STRGBA GSA member agency, has taken the lead on securing grant funding to cover a portion of the GSP preparation costs and is the administrator for a DWR grant under the Sustainable Groundwater Management (SGM) Planning Grant Program funded by Proposition 1. The Grant Agreement was executed on August 14, 2018. That grant was supplemented with a second SGM Planning Grant for the installation of monitoring wells in the Subbasin. That grant was funded by Proposition 68; the SGM grant agreement was amended to include the Proposition 68 grant on May 12, 2020.

Although GSP development occurred through a joint GSA effort, a Plan Manager has been authorized as the point of contact between the GSAs and DWR as required by SGMA. The Plan Manager is the authorized representative appointed through a coordination agreement or other agreement, who has been delegated authority for submitting the Plan to DWR. Contact information for the Plan Manager is provided in the transmittal letter and repeated below:

Eric C. Thorburn, P.E.
Water Operations Manager/District Engineer
Oakdale Irrigation District
1205 East F Street, Oakdale, CA 95361
(209) 840-5525
ethorburn@oakdaleirrigation.com

Following a public hearing, the STRGBA GSA adopted the GSP on January 31, 2022; the Resolution of Adoption is included in **Appendix B**. Prior to that date, member agencies also adopted the GSP separately in support of the process; see documentation in **Appendix B**.

1.3. IMPLEMENTATION OF THE GSP

The implementation of the GSP will be shared by the STRGBA GSA and the Tuolumne GSA, continuing their ongoing coordination developed during GSP preparation. The STRGBA GSA TAC will continue to serve as the advisory group for the GSA. Stakeholder outreach and communication of these activities will continue throughout the GSP implementation period.

The GSAs will oversee the development and implementation of GSP projects and management actions described in **Chapter 8**. The implementation plan for these projects and management actions, including schedule and funding sources, is described in **Chapter 9**.

1.3.1. GSP Implementation Costs

The operation of the Modesto Subbasin GSAs and GSP implementation will incur costs, which will require funding. There are five primary activities that will incur costs: implementing the GSP, implementing GSP-related projects and management actions, operation and administration of the GSAs, developing annual reports, and developing five-year evaluation reports. The total estimated annual budget for GSA operation and GSP implementation is anticipated to be between $250,000 and $350,000. Given the projects being proposed are anticipated to be funded by grants and/or the project proponent(s), this total estimated annual GSA budget figure excludes project related costs. However, it does provide flexibility for funding grant application preparation expenses for, or direct GSA funding of, more immediate development of management actions such that implementation of those actions could more readily occur if and when the need arose (i.e., fewer than anticipated projects were implemented, actual groundwater level decline exceeds projections, etc.). The total estimated cost of the proposed projects is approximately between $237,610,600 and $268,440,000. Costs for several additional projects and the management actions will be developed in the future contingent upon the need for implementation. The details of these estimated GSP implementation costs are provided **in Table 9-1**.

1.3.2. Financial Plan for Implementing the GSP

Costs associated with GSP implementation and operation of the GSAs could include GSA administration and legal support, stakeholder/Board engagement, outreach, GSP implementation program management, and monitoring. Operation of the GSAs is fully funded through contributions from GSA member agencies. Although ongoing operation of the GSAs is anticipated to include contributions from its member agencies, which are ultimately funded through customer fees or other public funds, additional funding may be required to implement the GSP. Funding through grants or loans has varying levels of certainty and as such, the GSAs may develop a financing plan that could include one or more of the following financing approaches: pumping fees, assessments based on irrigated acreage, or a combination of fees and assessments.

The STRGBA GSA member agencies intend to pursue grants and loans to help pay for project costs to the extent possible. If grants or loans are secured for project implementation, potential pumping fees and assessments may be adjusted to align with operating costs of the GSAs and ongoing GSP implementation activities. A potential hurdle to the utilization of state grant funding is that delays in payment by the State can cause hardships for disadvantaged communities. Therefore, it would be appropriate to expedite payments associated with grant funding by DWR.

Financing options for the projects and management actions are summarized on **Table 9-2** and may include grants, loans, funding from one or multiple GSA member agencies, GSA operating funds and/or funding from NDE landowners.

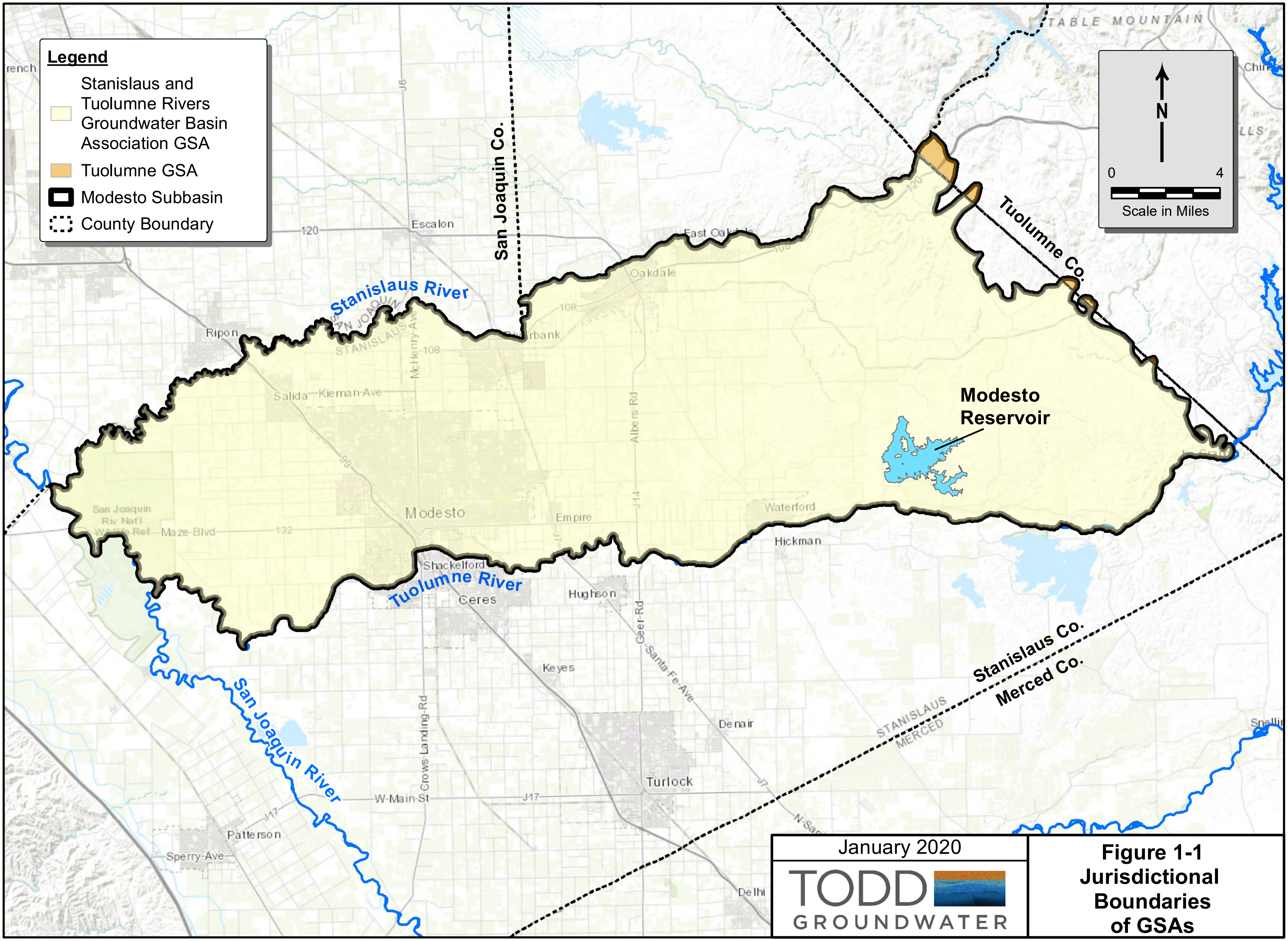

Figure 1-1 Jurisdictional Boundaries of GSAs

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2. PLAN AREA

The Modesto Subbasin covers 245,253 acres (about 383 square miles) of the larger San Joaquin Valley Groundwater Basin, as defined by DWR (5-22.02) in the 2019 basin prioritization. The San Joaquin Valley Groundwater Basin is defined on the west by the Coast Ranges, on the south by the San Emigdio and Tehachapi mountains, on the east by the Sierra Nevada, and on the north by the Sacramento-San Joaquin Delta and Sacramento Valley. The Modesto Subbasin is in the northern portion of the San Joaquin Valley and is bounded on the north by the Stanislaus River, on the south by the Tuolumne River, and on the west by the San Joaquin River (**Figure 2-1**). The eastern basin boundary is defined by crystalline basement rocks of the Sierra Nevada Foothills (DWR, 2006).

The Modesto Subbasin is hydraulically connected with surrounding subbasins along shared river boundaries (**Figure 2-1**). Adjacent subbasins include the Turlock Subbasin south of the Tuolumne River, the Delta-Mendota Subbasin west of the San Joaquin River, and the Eastern San Joaquin Subbasin north of the Stanislaus River. Of these subbasins, Delta-Mendota and Eastern San Joaquin are listed by DWR as being in critical overdraft. As such, these subbasins are required to prepare GSPs on an expedited schedule and to submit complete GSPs to DWR by January 31, 2020. Although the Modesto Subbasin GSP has a submittal date of January 31, 2022 – two years after the critically-overdrafted basins deadline – the Modesto Subbasin is coordinating with its neighbors through meetings and shared analyses.

2.1. AGENCIES AND JURISDICTIONAL BOUNDARIES

The Modesto Subbasin contains irrigation districts, municipalities, and portions of two counties. The jurisdictional boundaries of these agencies are shown on **Figure 2-2**. Note that these agencies are member agencies of one (or more) GSAs.

Two irrigation districts, Modesto Irrigation District (MID) and Oakdale Irrigation District (OID), provide surface water supply to the Modesto Subbasin, primarily for agricultural irrigation. MID also delivers surface water from the Tuolumne River to the Modesto Regional Water Treatment Plant for treatment and delivery to the City of Modesto. MID covers most of the western half of the Subbasin with its service areas bounded by the Stanislaus River to the north, the San Joaquin River to the west and the Tuolumne River to the south. The OID service area covers a portion of the central and eastern Subbasin (**Figure 2-2**). Approximately 60 percent of the OID service area is in the Modesto Subbasin with 40 percent in the Eastern San Joaquin Subbasin to the north (Bookman-Edmonston, 2005).

The Modesto Subbasin contains four municipalities and additional urban communities. Three municipalities are entirely within the boundaries of the Subbasin and include Oakdale, Riverbank, and Waterford. Most of the City of Modesto lies within the Modesto Subbasin, but the southern portion extends into the Turlock Subbasin. Waterford and Modesto are within the irrigation service area boundary of MID; Oakdale is within the service area boundary of OID. Riverbank straddles both irrigation districts. Additional urban communities include Del Rio, Salida, Empire and West Modesto (**Figure 2-2**). As described in

Chapter 4, and shown on **Figure 4-1**, there are six disadvantaged and severely disadvantaged communities in the Modesto Subbasin: Airport, Empire, Oakdale, Rouse, Waterford and West Modesto.

Portions of the Subbasin not located within an irrigation district are within the jurisdiction of Stanislaus County. As shown on **Figure 2-2**, these Stanislaus County areas occur mostly in the eastern Subbasin and along the Stanislaus, Tuolumne and San Joaquin rivers. These Stanislaus County areas represent approximately 22 percent of the Subbasin.

Approximately 1,000 acres of the Subbasin extends into Tuolumne County and is covered by the Tuolumne Groundwater Sustainability Agency (Tuolumne GSA). The Tuolumne GSA is cooperating in the Modesto Groundwater Subbasin GSP through a cooperation agreement with Stanislaus County; the County also represents the Tuolumne GSA during STRGBA GSA and TAC meetings.

Additional jurisdictional boundaries, including Federal or State land and/or other agencies with water management responsibilities were identified using the DWR Water Management Planning Tool (2018). As shown on **Figure 2-3**, the Subbasin contains California Department of Fish & Wildlife (CDFW) lands and easements, Federal Lands, and California Conservation Easements, as listed below:

- CDFW owned and operated lands and conservation easement: the Tuolumne River Restoration Center, adjacent to the Tuolumne River in the eastern Subbasin.
- Federal Land (data from the Bureau of Land Management) along the Tuolumne River, the San Joaquin River National Wildlife Refuge, and the Riverbank Army Ammunition Plant.
- California Conservation Easements, including San Joaquin River National Wildlife Refuge, Wetlands Reserve Program, Menghetti Farm, Ulm Farms Inc, and the Emergency Watershed Protection Program Floodplain Easement.

No other state or federal agencies with jurisdictional lands in the Subbasin are documented in the DWR Water Management Planning Tool. In addition, no tribal lands are documented in the DWR Water Management Planning Tool or are known to exist in the Modesto Subbasin.

2.2. EXISTING LAND USE

Figure 2-4 illustrates land use in the Modesto Subbasin based on a 2017 Stanislaus County land use map. As shown by the map, the Modesto Subbasin is largely agricultural, with the major crop types including almonds and other deciduous trees, corn, grains, pasture, vines, citrus, and truck crops. In 2017, approximately 64 percent of the Subbasin is defined as irrigated agriculture, covering about 157,911 acres. About 13 percent of the basin is classified as urban (approximately 30,564 acres), which includes the cities of Modesto, Oakdale, Riverbank and Waterford. The remaining 23 percent of the Subbasin (about 56,777 acres) consists of non-agriculture, non-irrigated agriculture (e.g., rangeland), undeveloped land, and surface water. Most of the undeveloped land is in the eastern portion of Modesto Subbasin (**Figure 2-4**).

Figure 2-5 illustrates the Prime Farmland in the Subbasin in 2016 as designated by the California Department of Conservation Farmland Mapping and Monitoring Program (FMMP). The FMMP map shows that most of the Subbasin is composed of Prime Irrigated Farmland and Unique Farmland. Unique Farmland consists of lesser quality soils used for the production of the State's leading agricultural crops. As described in **Section 2.6**, many of the land use planning agencies in the Subbasin have goals and policies for the preservation of these land uses. Other land uses identified by the FMMP in the Subbasin include urban, confined animal agriculture, non-irrigated grazing land, rural residential, vacant/disturbed land, nonagricultural/natural vegetation and semi-agricultural and rural commercial land.

Figure 2-6 illustrates previous land use from 1996, as mapped by DWR. In 1996, approximately 46 percent of the Subbasin is defined as irrigated agriculture, covering about 111,946 acres. A comparison of 1996 and 2017 land uses (**Figure 2-4**) shows that a significant amount of pasture has been converted to deciduous/almond and other crops over the last 20 years. In addition, irrigated acreage increased from 1996 to 2017 by approximately 45,965 acres, or 18.7 percent of the Subbasin. Most of this increase occurred in the eastern Subbasin outside of MID and OID jurisdiction, where groundwater is the primary source of water supply.

Figure 2-7 is a chart illustrating the number of wells drilled by year in the Modesto Subbasin based on information from the DWR Well Completion Report database. The database indicates approximately 6,360wells drilled in the Modesto Subbasin, about 4,540 of which have completion dates and were drilled from 1948 to August 2021. As shown on the figure, only a few wells were drilled each year before the mid-1950s and less than 40 wells per year were drilled before the 1970s. Well drilling increased significantly in the 1970s, with the number of wells fluctuating between about 50 to over 100 wells per year. A significant increase in well drilling occurred during the most recent drought, with 148 wells drilled in 2013 and 257 wells drilled in 2014. The number of wells drilled dropped significantly in 2015 through 2018. The timing of the Stanislaus County Groundwater Ordinance (discussed in **Section 2.6.1.3**) may also have influenced well drilling activity over the last several years.

Figure 2-8 shows the locations of the drilled wells. The upper panel of this figure shows the wells that were drilled before 2000 (i.e., from 1948 to 1999) and the lower panel shows the wells that were drilled from 2000 to August 2018. These figures illustrate an increase in the number of wells drilled in the eastern Subbasin since 2000, outside of MID or OID irrigation service areas.

2.3. WATER SOURCES AND USE

The two primary sources of water used in the Modesto Subbasin are surface water, from the Stanislaus and Tuolumne rivers, and Subbasin groundwater. No sources of imported water are available in the Subbasin.

Urban Water Management Plans (UWMPs) and Agricultural Water Management Plans (AWMPs), document surface water and groundwater use in the Subbasin. These plans include descriptions of local surface water and groundwater models, including the Stanislaus County Hydrologic Model (SCHM), and data provided by local agencies for the GSP. UWMPs are available for Modesto (2015), Modesto and Modesto Irrigation District (2010), Oakdale (2015), Riverbank (2015) and Waterford (2005). AWMPs are available for MID (2015) and OID (2015). A summary of the information on surface water and groundwater use from these planning documents is provided below.

2.3.1. Surface Water

Surface water facilities and conveyance infrastructure across the Subbasin are illustrated on **Figure 2-9**. As shown on the figure, the Subbasin contains a web of lined and unlined canals and pipelines to facilitate surface water conveyance. The Hetch Hetchy Aqueduct crosses the northern half of the Subbasin as part of a 167-mile project that conveys water from Hetch Hetchy Reservoir to the City and County of San Francisco and other municipalities.

OID diverts water from the Stanislaus River under pre-1914 water rights shared equally with the South San Joaquin Irrigation District (SSJID), located north of the Stanislaus River in the Eastern San Joaquin Subbasin. The adjudicated diversion rate from the Stanislaus River is 1,816.6 cubic feet per second (cfs). In 1988, after the construction of New Melones Dam upstream of Goodwin Dam, OID and SSJID entered into an operational agreement with United States Bureau of Reclamation (USBR) that provides the districts a combined supply of 600,000 acre-feet (AF) of water annually (Davids Engineering Inc., 2016).

OID diverts water at the Goodwin Dam into the South Main Canal, which serves agricultural irrigation water throughout OID south of the river in the Modesto Subbasin. OID also diverts water into the Joint Main Canal, for use north of the river in the Eastern San Joaquin Subbasin. Water flows from these canals through a system of unlined earthen ditches, concrete-lined canals, low-head pipelines and gates. Irrigation tailwater is reclaimed by OID using reclamation pumps or discharged to other landowners or irrigation districts via drainage canals.

MID diverts water from the Tuolumne River for agricultural irrigation and municipal supply. The mean annual MID diversion from the Tuolumne River is approximately 294,000 AF, based on the average hydrologic period from 2003 to 2012. Approximately twenty percent of this amount (67,000 AF) is currently delivered to the Modesto Regional Water Treatment Plant (MRWTP) for treatment and delivery to the City of Modesto (Provost and Pritchard, 2015).

New Don Pedro Reservoir, built in 1971 and located northeast of La Grange in the Sierra Nevada foothills, is jointly owned by MID and TID and has a maximum storage capacity of 2,030,000 AF. MID's share of water stored in New Don Pedro Reservoir is approximately 543,000 AF. La Grange Diversion Dam, constructed in 1893, is used to divert water from the Tuolumne River into the MID Upper Main Canal. Diversions flow through the Upper Main Canal to the Modesto Reservoir for temporary storage and irrigation deliveries and for delivery to the water treatment plant and then on to the City of Modesto. The Modesto Reservoir, owned and operated by MID, was built in 1911 and has a storage capacity of 28,000 AF.

MID distributes Tuolumne River water and groundwater via a network of facilities, including 15 miles of unlined canals, 147 miles of lined canals, 42 miles of pipelines and 39 miles of drains (Provost and Pritchard, 2015). In 2012, approximately 66,500 acres of land were irrigated within MID, 57,000 acres of which received surface water from MID (Provost and Pritchard, 2015).

2.3.2. Groundwater

Groundwater in the Modesto Subbasin is extracted primarily for agricultural irrigation, municipal, and domestic potable water supply. Based on the Stanislaus County Hydrologic Model (SCHM), groundwater pumping in the Subbasin for Water Year 2015 was estimated at 222,730 acre-feet per year (AFY). Approximately 77 percent was pumped for agricultural irrigation (170,892 AFY), 20.1 percent for municipal uses (45,968 AFY) and 2.6 percent for rural domestic use (5,870 AFY) (JJ&A, 2017).

Modesto ID pumps groundwater from approximately 100 production and drainage wells to supplement surface water supply and to help control the high water table in the western Subbasin. Groundwater pumping supplements reduced supply from the Tuolumne River during consecutive dry years and to serve areas where it is more difficult to deliver adequate amounts of surface water (Provost and Pritchard, 2015).

Oakdale ID pumps groundwater from 13 deep wells in the Modesto Subbasin to supplement surface water deliveries from the Stanislaus River. OID also provides domestic water from District owned wells for its rural water system (RWS) and serves as the trustee of six improvement districts that get water from deep wells that are individually owned by each improvement district.

Agricultural pumping by the districts is supplemented by numerous private agricultural wells throughout the Subbasin. In the western Subbasin, where groundwater levels are relatively shallow, drainage wells are used to maintain groundwater levels below the root zone to facilitate farming operations and manage salinity. Irrigation wells are used in areas of surface water availability to supplement supply, especially during droughts when surface water is insufficient to meet demands. In the eastern Subbasin, where surface water supplies are generally unavailable, irrigation wells provide the primary water supply for agricultural lands.

The cities of Modesto, Oakdale, Riverbank and Waterford pump groundwater for water supply. There are approximately 150 active supply wells in these four cities.

There are a number of small community water supply systems located throughout the Subbasin that are operated by the respective community and regulated by Stanislaus County. **Figure 2-10** illustrates the public water systems within Modesto Subbasin that are mapped by the California Environmental Health Tracking Program. The mapped systems include irrigation districts (MID and OID), municipal systems (Modesto, Oakdale, Riverbank and Waterford), and smaller, non-municipal and non-district systems. The municipal systems are outlined in black on **Figure 2-10**. There are approximately 77 systems within Modesto Subbasin that are not municipal or irrigation districts, illustrated by the burgundy shaded areas on **Figure 2-10** (some systems are so small that they appear as only a dot). A summary of these non-municipal and non-irrigation systems is provided on **Table 2-1**. Approximately 56 of these systems are very small, with 10 or less service connections, and almost all (71) have less than 50 service connections.

Groundwater extraction occurs throughout the Subbasin as indicated by the density of wells shown on **Figure 2-11**. This map, illustrating the number of production wells drilled per square mile, was developed from DWR's Well Completion Report Map Application. Production wells include water supply wells[1] designated as irrigation, public, municipal, and industrial on well completion reports. The highest density of production wells occurs in the western Subbasin, particularly north and west of Modesto. DWR's 2018 basin prioritization indicates that there+ are about 4,000 production wells in the Subbasin (DWR, 2018a).

Figure 2-12 illustrates the density of public supply wells in the Subbasin. Similar to **Figure 2-11**, this map was developed from DWR's Well Completion Report Application and includes water supply wells designated as public on well completion reports and is therefore a subset of the wells on **Figure 2-11**. The highest densities generally coincide within municipalities and urban centers. Public supply well densities associated with small community water systems are also indicated. Based on data received for the GSP, there are approximately 150 municipal public supply wells in the Subbasin; these are shown on **Figure 2-13**.

Information on domestic wells is provided in **Section 2.3.3**, following **Table 2-1** below.

[1] DWR's definitions of water supply wells are provided in DWR's *How to Fill Out a Well Completion Report* pamphlet, updated in March 2007.

Table 2-1: Public Water Systems in the Modesto Subbasin

Water System Name	Number of Service Connections
WATERFORD-RIVER POINTE	317
RIVERVIEW MOBILE HOME ESTATES	175
MODESTO MOBILE HOME PARK	150
PARK HEIGHTS MUTUAL WATER CO	95
DEL RIO EAST HOA WATER SYSTEM	55
OLIVE LANE MOBILEHOME PARK	51
LAZY B MOBILEHOME PARK	49
MORNINGSIDE MOBILEHOME PARK	49
MAZE BLVD MOBILEHOME PARK	40
WATERFORD SPORTSMEN'S CLUB	40
LONE PINE MHP	32
OASIS INVESTMENTS	31
STERLING INDUSTRIAL	30
A & M INDUSTRIES INC	25
RIVERBANK LRA	22
KIERNAN BUSINESS CENTER	20
TURLOCK STATE RECREATION AREA	19
LIBITZKY	15
MCHENRY BUSINESS PARK	15
TULLY MOBILE ESTATES	15
FEE WATER SYSTEM	12
CARDOZA WATER SYSTEM	10
CHARITY WAY WATER SYSTEM	10
GREGORI HIGH SCHOOL	9
HART- RANSOM UNION SCHOOL & DISTRICT	9
BLOOMINGCAMP WATER SYSTEM	7
FRAZIER NUT FARMS, INC.	7
SHILOH SCHOOL DISTRICT	7
COVENANT GROVE CHURCH	6
BURCHELL NURSERY, INC	5
MESA ELEMENTARY SCHOOL	5
STORER TRANSPORTATION	5
STRATOS WAY WATER COMPANY, INC	5
THE COUNTRY MARKET	5
LOS INDIOS WATER SYSTEM	4
MID VALLEY AG	4
THE FRUIT YARD RESTAURANT	4
JEHOVAH'S WITNESS SIERRA VISTA CONG	3
KIERNAN/MCHENRY WATER COMPANY, INC	3
LA GRANGE PARK-OHV	3

Table 2-1 (*continued*)

Water System Name	Number of Service Connections
ROBERTS FERRY NUT CO, INC (WS)	3
SALIDA HULLING ASSOCIATION WATER SYSTEI	3
5033 PENTECOST	2
AT&T WATER SYSTEM	2
BRETHREN HERITAGE SCHOOL, INC	2
EL RINCON & YOSEMITE HACIENDA MARKET	2
FISHER NUT	2
FOSTER FARMS-ELLENWOOD HATCHERY	2
GROVER LANDSCAPE WATER SYSTEM	2
LIBERTY BAPTIST CHURCH	2
OAKDALE GOLF & COUNTRY CLUB (EH)	2
ONE STOP WS	2
PARADISE SCHOOL	2
RATTO BROS, INC	2
ROBERTS FERRY SCHOOL CAFETERIA	2
STANISLAUS REGIONAL WATER AUTHORITY	2
WOOD COLONY CHRISTIAN SCHOOL	2
BECKLEY LYONS WATER SYSTEM	1
BEL PASSI BASEBALL	1
DEEVON WATER CO	1
ELKS LODGE 1282	1
FLOYD OVERHOLTZER WATER SYSTEM	1
FOX GROVE FISHING ACCESS	1
KNIGHTS FERRY RECREATION AREA	1
MABLE AVE BAPTIST CHURCH	1
MCHENRY GOLF CENTER	1
MODESTO CHRISTIAN CENTER (WATERSYSTEM	1
NINO'S PLACE WATER SYSTEM	1
OLIVEIRA WATER SYSTEM	1
PENTECOST PROPERTIES WATER SYSTEM	1
RAINBOW SPORTS COMPLEX	1
RAM NAAM MANDALI CHURCH OF MODESTO	1
SCONZA CANDY COMPANY	1
SHILOH-PARADISE BASEBALL FOR YOUTH	1
SMART STOP FOOD MART (EH)	1
STANISLAUS UNION SCHOOL DIST	1
SUNRISE ROCK & REDI-MIX	1

Notes:

1. Does not include municipal and irrigation district systems.

2. Source: California Environmental Health Tracking Program, Water System Map Viewer

2.3.3. Domestic Wells

Residents in the Modesto Subbasin that live outside of public water systems rely on domestic wells for their water supply. Based on DWR Well Completion Report records as of November 2020, approximately 3,190 domestic wells were constructed in the Modesto Subbasin. Of this number, about 210 new domestic wells were drilled since 2015; that was when many domestic wells began to fail during the drought as discussed below. An estimated 2,980 domestic wells were in place at the end of 2014. The density of domestic wells (number per square mile) is illustrated on **Figure 2-14**. Domestic wells are present throughout the Subbasin, but the highest density occurs in the central region of the Subbasin, along the Stanislaus and Tuolumne rivers, and west of Modesto. DWR records include many older wells dating back to the 1940s and do not indicate how many of these domestic wells are currently active.

During the recent drought, 159 domestic wells in the Subbasin were reported to be dry or suffered structural failure because of declining water levels, representing about five percent of the then-current number of domestic wells (2,980 total wells as stated above). **Figure 2-15** shows the domestic wells that were reported as dry or failed from 2014 through 2017 in Stanislaus County. According to Stanislaus County, most of these wells were less than 100 feet deep and more than 50 years old. As such, many of these wells likely had to be replaced. As part of their Dry Well Program, the County assisted well owners with storage tanks and new well installations.

An analysis was conducted to investigate the areas of the Subbasin with domestic wells that were most vulnerable to becoming dry during the recent drought. Based on the DWR Well Completion Report database, some construction data and completion dates were available for 2,356 domestic wells installed in the Subbasin between 1948 and November 2014. As stated previously, DWR records do not indicate how many of these domestic wells are currently active. The depths of these wells were compared to the groundwater depth in October 2015, based on groundwater elevation contours developed for the GSP (see **Figure 3-27a**). The difference between the bottom of the screen interval, or total depth if screen interval was not available, of each domestic well was subtracted from the depth to water to determine the water column thickness above the screen or base of the well. The estimated water column thickness at each domestic well is indicated by color on **Figure 2-16**. Domestic wells where the water level may be below the bottom of the screen or below the bottom of the well (i.e., dry) in October 2015 are shown as pink dots. There are 30 potentially dry wells, located primarily in the east-central region of the Subbasin near the river boundaries (about one percent of the wells with construction data and completion depths).

About 20 percent of the domestic wells have less than 50 feet of water above the bottom of their screen or base of the well as shown by yellow dots. These wells are considered to be vulnerable to becoming dry if water levels drop up to 50 feet below October 2015 levels. For context, analysis of water levels indicated that very few wells were observed to have declined up to 50 feet during the 2012-2016 time frame when rates of decline were generally the largest (see **Section 3.2.2** and **Figures 3-21** – **3-25**). In addition, those declines were observed in the eastern Subbasin where groundwater has been the primarily water supply. As shown on **Figure 2-16**, the more vulnerable wells are located primarily in the central region of the Subbasin along the river boundaries. These areas are consistent with the areas of reported dry wells between 2014 and 2017 (see **Figure 2-15**).

A similar analysis was conducted for domestic wells constructed since 2015 to investigate where and how many newer wells might be most vulnerable to dewatering if water levels declined significantly below 2015 levels. Between January 2015 and November 2020, approximately 210 domestic wells were constructed in the Subbasin. Many of these wells likely replaced the previously failed wells. In general, the wells were drilled to deeper depths – 75 percent were drilled to depths of over 200 feet.

The depths of the wells constructed since 2015 were compared to depth to water in October 2015 and color-coded in a similar manner as on **Figure 2-16**. The results, illustrated on **Figure 2-17**, indicate that most wells have 50 or more feet of water column thickness, and are not vulnerable to becoming dry. However, there are a small number (less than 10) of new domestic wells in areas that remain vulnerable if water levels decline significantly. These wells are in the east-central region of the Subbasin near the river boundaries; the same region identified as most vulnerable for domestic wells constructed before 2015 (**Figure 2-16**) and where most reports of dry wells occurred (**Figure 2-15**). These vulnerable areas are circled in red on **Figure 2-17**.

Based on reports of dry wells on DWR's Household Water Supply Shortage Reporting System (https://mydrywell.water.ca.gov/report/), as of November 2021, five wells were reported dry in the Modesto Subbasin between May and August 2021. These five wells are located in the east-central region of the Subbasin and generally correlate with the areas determined to be most the most vulnerable.

Note that the numbers in this domestic well analysis vary because not all wells contain complete information for construction or completion dates. And, as mentioned previously, it is unknown how many domestic wells are no longer in use or destroyed. However, the information above is based on the best available data at this time. The GSP implementation plan in Section 9 includes an activity to address these data gaps over time (see **Section 9.5.3**)

This analysis found that the percentage of vulnerable domestic wells is small. Approximately four percent (8 out of 210) of the new domestic wells constructed since 2015 are vulnerable to dewatering if water levels decline significantly below 2015 levels. As described in **Section 6.8** and shown in **Chapter 7**, minimum thresholds set for both interconnected surface water (Fall 2015 levels) and water levels (historic low levels) have been exceeded in recent years because of declining water levels, particularly in the eastern Subbasin. Yet, Stanislaus County reports that only a few wells have reported problems since 2017. In 2021, only five domestic wells were reported to be dry, representing less than one percent of the total domestic wells in the Subbasin. Given the consideration of data discussed above and MTs selected in Chapter 5, widespread failures of more than the five percent of total domestic wells drilled in the Subbasin (as occurred in 2014-2017) can likely be avoided under the selected sustainable management criteria. Data gaps for numbers of active domestic wells and construction information limit the ability to accurately predict the number of specific failures (addressed in **Section 9.5.3**).

2.4. WATER RESOURCES MONITORING PROGRAMS

Numerous monitoring programs that could support GSP development have been implemented in the Modesto Subbasin. These and other existing monitoring networks and protocols will be considered for improvements and/or adoption as part of the GSP monitoring network. GSP monitoring networks will be designed to:

- Evaluate sustainability indicators in each management area
- Address identified data gaps
- Monitor for minimum thresholds in each management area to avoid undesirable results
- Track interim milestones and measurable objectives to demonstrate progress on reaching sustainability goals for the Subbasin.

2.4.1. CASGEM Monitoring Program

The California Ambient Statewide Groundwater Elevation Monitoring (CASGEM) Program, administered by DWR, has compiled groundwater elevation data from designated monitoring entities since 2009. Data are used to track seasonal and long-term groundwater elevation trends in groundwater basins statewide. In addition to designated CASGEM wells, groundwater elevation data from other wells are also compiled into the system on a voluntary basis. Data are available for review online at the DWR CASGEM website (https://water.ca.gov/Programs/Groundwater-Management/Groundwater-Elevation-Monitoring--CASGEM).

The Stanislaus and Tuolumne Rivers Groundwater Basin Association (STRGBA) serves as the CASGEM Monitoring Entity for the Modesto Subbasin. Since 1994, STRGBA has coordinated groundwater planning and management in the Subbasin. As part of the CASGEM program, STRGBA measures water levels in 56 Subbasin wells. The monitoring network consists of wells owned by MID, OID, and the U. S. Geological Survey (USGS).

The current CASGEM online database contains approximately 2,400 unique water level measurements from the 56 Modesto Subbasin wells, spanning from November 1991 to October 2019. These wells are measured semi-annually to capture seasonal variation, typically once in February/March (seasonal high elevations) and once in October/November (seasonal low elevations) of each year. Information supplied by the CASGEM database includes local and state well numbers, latitude and longitude of the well, a unique CASGEM ID and station number, well use, ground surface elevation, depth to water, and calculated groundwater elevation.

Figure 2-18 illustrates the locations of the CASGEM monitoring wells and DWR Water Data Library wells that have been recently monitored (2015 to present). This figure includes 71 wells monitored by DWR and included in the DWR Water Data Library. The CASGEM wells are a subset of the DWR Water Data Library wells. As shown, the monitored wells are almost all located west of Modesto Reservoir.

2.4.2. Public Water Suppliers Groundwater Monitoring Programs

Public water suppliers in the Modesto Subbasin have implemented water level and water quality monitoring programs for their service areas. Water levels are monitored in production wells either monthly or quarterly. The City of Modesto is in the process of designing and constructing five sets of multi-completion monitoring wells for water quality and water level monitoring.

Each municipality also monitors groundwater quality for its supply wells in compliance with State requirements. Water quality monitoring requirements for public water systems are set by Title 22, Chapter 15, of the California Code of Regulations (CCR). Groundwater quality monitoring data are also compiled by local regulatory agencies for sites associated with groundwater contamination. Various municipalities have identified constituents of concern over time including nitrate, arsenic, uranium, trichloropropane (TCP), tetrachloroethylene (PCE), and dibromochloropropane (DBCP). Some of these data sets are maintained on the State Water Resources Control Board web-based database, referred to as GeoTracker.

A summary of the groundwater monitoring programs conducted by the public water suppliers is provided on the following table.

Table 2-2 : Groundwater Monitoring Programs by Public Water Suppliers

Agency	Monitoring Programs	
	Groundwater Levels	Groundwater Quality
City of Oakdale	Monthly water level monitoring conducted in most production wells.	State-required sampling in production wells.
City of Riverbank	Quarterly water level monitoring conducted in all production wells.	State-required sampling in production wells. Additional water quality sampling in production wells for local constituents of concern.
City of Waterford	Monthly water level monitoring conducted in production wells	State-required sampling in production wells.
City of Modesto	Ongoing water level monitoring program in monitoring wells (numbers and frequency vary with time).	State-required sampling in production wells. Additional water quality sampling in monitoring wells for local constituents of concern.

2.4.3. Agricultural Water Suppliers Monitoring Programs

Agricultural water suppliers conduct surface water and groundwater monitoring programs in the Subbasin. Such programs implemented by MID and OID are summarized below.

2.4.3.1. Modesto Irrigation District (MID)

MID measures water levels in approximately 50 deep irrigation wells and approximately 50 shallow drainage wells on a semi-annual basis, in February and November. On behalf of STRGBA, MID also measures water levels within their district as part of the CASGEM program.

MID monitors water quality as part of several programs:

- Modesto Reservoir: Daily monitoring of water quality in Modesto Reservoir for domestic water quality standards.
- Surface and Subsurface Drainage: Monitor surface water and groundwater in compliance with the aquatic herbicide general permit.
- NPDES permit: Monitoring program in compliance with a statewide general NPDES permit for discharge of aquatic herbicides.
- Irrigated Lands Regulatory Program: Water quality monitoring in compliance with the Irrigated Lands Regulatory Program as a member of the East San Joaquin Water Quality Coalition. Program is administered by the Central Valley Regional Water Quality Control Board (CVRWQCB). (see also **Section 2.4.4**).
- UC Davis Water Quality Study: The MID Domestic Water Treatment Plant, in conjunction with UC Davis, conducted water quality monitoring to identify constituents of greatest concern for water treatment.

2.4.3.2. Oakdale Irrigation District (OID)

OID measures water levels in a total of 12 OID and private wells within the district in the Modesto Subbasin on a semi-annual basis, in spring and fall. OID provides water levels to STRGBA, which serves as the CASGEM reporting agency.

- Irrigated Lands Regulatory Program: Water quality monitoring in compliance with the CVRWQCB Irrigated Lands Regulatory Program as a member of the East San Joaquin Water Quality Coalition (discussed in more detail below in **Section 2.4.4**).
- District water quality: OID measures electrical conductivity in 12 deep wells and 8 private wells as part of the groundwater monitoring program (GWMP) developed in the Integrated Regional Groundwater Management Plan (Bookman-Edmonston, 2005).
- NPDES permit: Monitoring program in compliance with a statewide general NPDES permit for discharge of aquatic herbicides.

2.4.4. Irrigated Lands Regulatory Programs

The Irrigated Lands Regulatory Program (ILRP) requires monitoring and reporting in compliance with the Conditional Waiver of Waste Discharge Requirements for Discharges from Irrigated Lands, a program administered by the CVRWQCB. It was initiated in 2003 to prevent impacts to surface water and groundwater from agricultural runoff, with a focus on nitrate.

The East San Joaquin Water Quality Coalition (ESJWQC) is a group of agricultural interests and growers that formed to represent dischargers who own or operate irrigated lands east of the San Joaquin River in Madera, Merced, Stanislaus, Tuolumne, and Mariposa counties. The ESJWQC files reports in compliance with Central Valley Water Board requirements (ESJWQC, 2019). The ESJWQC monitoring program samples for a wide array of constituents in drains and canals. The sampling program and monitoring stations are dynamic, with sampling stations and constituents changing frequently, as the program rotates throughout the watershed. In the Modesto Subbasin, both MID and OID are members of the coalition for the lands that they own.

The ESJWQC joined the Central Valley Salinity Coalition, a non-profit organization which manages funding for the Central Valley Salinity Alternatives for Long-Term Sustainability (CV-SALTS). CV-SALTS was formed in 2006 to address the salt problem in the Central Valley and prepared a Salt and Nutrient Management Plan for the entire Central Valley. Based on that plan, the SWRCB adopted a Basin Plan Amendment (BPA) in 2019 to guide nitrate and salt regulations. ESJWQC representatives participated in the framework development for regulatory requirements under the BPA (ESJWQC, 2020).

In December 2012, a new Waste Discharge Requirements (WDR) order for the ESJWQC was approved by the CVRWQCB that expanded the monitoring to include groundwater under the ILRP. The program ensured that surface water monitoring would continue but focused on a management approach rather than strict enforcement of water quality standards. A Nitrogen Management Plan (NMP) was implemented, which requires growers to document how much nitrogen is added and removed from irrigated lands. These numbers are reported to the CVRWQCB annually.

In January 2020, the Nitrate Control Program (NCP) was initiated, which requires growers to ensure safe drinking water supplies for well owners impacted by nitrate. Growers can elect to comply with these regulations cooperatively with other growers in designated Management Zones. Six priority groundwater subbasins were identified for Management Zones including Chowchilla, Kaweah, Kings, Turlock, Tule, and Modesto (ESJWQC, 2020).

The Valley Water Collaborative, which was funded by ESJWQC to implement the NCP, was formed to cover the Management Zones in the Turlock and Modesto subbasins. The Executive Director of the Valley Water Collaborative is in communication with the Subbasin GSAs about NCP program implementation in the Modesto Subbasin. The Executive Director provided an overview of the program at the December 2020 regular public meeting of the STRGBA GSA.

2.5. WATER RESOURCES MANAGEMENT PROGRAMS

As demonstrated from the monitoring programs described above, Modesto Subbasin agencies are actively managing surface water and groundwater conjunctively. Water management programs in the Modesto Subbasin have been documented in various planning documents prepared both separately by local water agencies and collaboratively through cooperative groups of agencies. Key water resources management programs in the Subbasin are summarized below.

2.5.1. Groundwater Management Plan

In April 1994, six agencies within the Modesto Subbasin formed the Stanislaus and Tuolumne Rivers Groundwater Basin Association (STRGBA) to manage groundwater. In 2003, STRGBA began preparing an Integrated Regional Groundwater Management Plan (GWMP) in compliance with the Groundwater Management Planning Act of 2002 (SB 1938) and the Integrated Regional Water Management Planning Act of 2002 (SB 1672) (Bookman-Edmonston, 2005). The GWMP describes several actions to protect groundwater resources that are implemented by STRGBA member agencies (Bookman-Edmonston, 2005). The following is a summary of these actions.

- Identification and Management of Wellhead Protection Areas: The purpose is to protect groundwater used for public supply, by protecting the area around a public supply well, or a recharge area that contributes water to a public supply well, to prevent water quality impacts.
- Regulation of the Migration of Contaminated Groundwater: STRGBA coordinates with responsible parties and regulatory agencies to keep STRGBA members informed of the status of known groundwater contamination.
- Identification of Well Construction Policies: Stanislaus County Department of Environmental Resources administers the well permitting program in the unincorporated areas of the Subbasin. STRGBA member agencies are required by State law to adopt the State Model Well Ordinance as a minimum standard for well construction.
- Administration of Well Abandonment and Destruction Programs: Unused wells must be properly abandoned to prevent the migration of contaminants.
- Mitigation of Overdraft Conditions: Reduce dependency on groundwater, by providing surface water to areas previously dependent on groundwater, and by encouraging growers to use surface water for irrigation, when available, instead of groundwater.
- Replenishment of Groundwater Extracted by Water Producers: Protect and manage the major recharge areas within the Subbasin.

- Construction and Operation of Recharge, Storage, Conservation, Water Recycling and Extraction Projects: Local agencies will encourage cooperation and sharing of information between the agencies to promote water management projects.
- Control of Saline Water Intrusion: STRGBA coordinates with member agencies to monitor groundwater quality to ensure that saline water from the San Joaquin River or the saline water associated with groundwater from the western San Joaquin Valley does not migrate into the Subbasin.

2.5.2. Urban Water Management Plans

The Urban Water Management Planning Act requires water suppliers that provide over 3,000 AFY or have over 3,000 connections to submit an Urban Water Management Plan (UWMP) to the State every five years. 2015 UWMPs are available for two cities in the Modesto Subbasin: Modesto (2015) and Riverbank (2015). The City of Modesto owned and operated Waterford's water system until July 1, 2015, and therefore Waterford's system is covered under the Modesto 2015 UWMP. Oakdale completed a 2010 UWMP Update (MCR Engineering, 2015) and has a Draft 2015 UWMP awaiting adoption. Modesto and MID completed a joint UWMP in 2010 (West Yost Associates, 2011)[2].

The 2015 UWMPs for the cities of Modesto (West Yost Associates, 2016a) and Riverbank (KSN Inc., 2016) are consistent with the Urban Water Management Planning Act as amended by SB X7-7 in 2009 and provide evaluations of water demand and water supply into the future. Each describes the service area, water system, historical and projected water use, and water supply sources, and provides a comparison of projected water supplies to water demands during normal, single-dry, and multiple-dry years in five-year increments from 2020 to 2035. Both cities indicate the availability of water supply to meet water demand into the future. Riverbank, which relies exclusively on groundwater, plans to meet future demands with groundwater. The City of Modesto, which relies on groundwater and treated surface water from MID, plans to continue to use these two sources of water to meet future demands. Each UWMP describes constraints (e.g., legal, environmental, water quality) on water supplies.

As required by SB X7-7, the UWMPs present each city's 2015 and 2020 water use targets, verify compliance with the interim 2015 water use target, and describe implementation plans for meeting the 2020 water use target. Recognizing the importance of water conservation, the UWMPs describe the six Demand Management Measures (DMMs) in compliance with SB X7-7. These DMMs include water waste prevention ordinances, metering, conservation pricing, public education and outreach, programs to assess and manage distribution system real loss, and water conservation program coordination and

[2] In June 2021, the City of Modesto and Modesto Irrigation District completed an updated joint UWMP for 2020. Data from these and other updated planning documents will be incorporated into future GSP analyses, such as in GSP Annual Reports.

staffing support. The cities each implement additional water conservation programs, as follows.

- Modesto has three additional DMMs, including residential conservation programs; commercial, industrial, institutional conservation programs; and large landscape irrigation conservation programs.
- Riverbank has several additional DMMs:
    - Water survey programs for single-family residential and multi-family residential customers
    - Large landscape conservation programs and incentives
    - High efficiency washing machine rebate program
    - High efficiency toilet replacement
    - Residential plumbing retrofit
    - Conservation programs for commercial, industrial and institutional accounts

Oakdale's 2010 UWMP (MCR Engineering, 2015) identifies fourteen similar demand management measures. As stated in the 2010 UWMP, Oakdale was implementing or partially implementing five of the demand management measures (MCR Engineering, 2015).

2.5.3. Agricultural Water Management Plans

Agricultural Water Management Plans (AWMPs) were prepared in 2015 in accordance with the Water Conservation Act of 2009 (SB X7-7) by two irrigation districts within the Modesto Subbasin: MID (Provost and Pritchard, 2015) and OID (Davids Engineering, 2016). The following is a summary of the water resources management programs described in these AWMPs.

The MID and OID 2015 AWMPs each describe the same Efficient Water Management Practices (EWMPs) in conformance with the California Code. These include two critical EWMPs that are mandatory for all agricultural water suppliers, and additional or conditional EWMPs, which are required if technically feasible and locally cost effective. The two mandatory EWMPs are to accurately measure the volume of water delivered to customers and to adopt a pricing structure based, at least partially, on the quantity of water delivered. MID and OID each describe the same thirteen additional EWMPs that are being implemented, as follows:

- Facilitate use of available recycled water that otherwise would not be used beneficially, meets all health and safety criteria, and does not harm crops or soils.
- Facilitate financing of capital improvements for on-farm irrigation systems.
- Implement an incentive pricing structure that promotes one or more of the following goals: (A) More efficient water use at farm level, (B) Conjunctive use of groundwater, (C) Appropriate increase of groundwater recharge, (D) Reduction in problem drainage, (E) Improved management of environmental resources, (F)

Effective management of all water sources throughout the year by adjusting seasonal pricing structures based on current conditions.

- Expand line or pipe distribution systems and construct regulatory reservoirs to increase distribution system flexibility and capacity, decrease maintenance and reduce seepage.
- Increase flexibility in water ordering by, and delivery to, water customers within operational limits.
- Construct and operate supplier spill and tailwater recovery systems
- Increase planned conjunctive use of surface water and groundwater within the supplier service area.
- Automate canal control structures.
- Facilitate or promote customer pump testing and evaluation.
- Designate a water conservation coordinator who will develop and implement the water management plan and prepare progress report.
- Provide for the availability of water management services to water users.
- Evaluate the policies of agencies that provide the supplier with water to identify the potential for institutional changes to allow more flexible water deliveries and storage.
- Evaluate and improve the efficiencies of the supplier’s pumps.

In addition to these, MID is implementing an EWMP to facilitate alternative land use for lands with exceptionally high water duties or whose irrigation contributes to significant problems, such as drainage problems.

2.5.4. Additional Plan Elements

The California Water Code contains a checklist for preparation of GSPs, which provide groundwater management elements that may be applicable for incorporation into the Modesto Subbasin GSP. Most management programs relevant to this checklist are described in the previous sections; programs are summarized below for each topic to ensure that the additional plan elements listed in the GSP regulations (Section 354.8 (g)) have been considered.

(a) *Control of saline water intrusion*: saline water intrusion is not applicable because this is not a coastal Subbasin. However, as summarized in **Section 2.5.1**, the Integrated Groundwater Management Plan (Bookman-Edmonston, 2005) describes STGRBA’s efforts to prevent saline groundwater from migrating into the Subbasin from the San Joaquin River and from the west side of the San Joaquin Valley.

(b) *Wellhead protection areas and recharge areas*: as described in **Section 2.5.1**.

(c) *Migration of contaminated groundwater*. As described in **Section 2.5.1**, STRGBA GSA will coordinate with responsible parties and regulatory agencies to keep STRGBA GSA member agencies informed of the status of known groundwater contamination. The oversight regulatory agencies may include the State Water Resources Control Board, the State Department of Toxic Substances Control (DTSC), or the County Department of Environmental Health.

(d) *A well abandonment and well destruction program*: As described in **Section 2.5.1**, the Integrated Regional Groundwater Management Plan (Bookman-Edmonston, 2005), states that the unused wells must be properly abandoned to prevent the migration of contaminants.

(e) *Replenishment of groundwater extractions*: As described in **Section 2.5.1**, the Integrated Regional Groundwater Management Plan (Bookman-Edmonston, 2005), the major recharge areas in the Subbasin will be protected and managed. In 2007, a recharge characterization for STRGBA was completed to define recharge areas by evaluating physical characteristics and anthropogenic conditions (WRIME, 2007).

(f) *Activities implementing, opportunities for, and removing impediments to, conjunctive use or underground storage*. Conjunctive use is an active groundwater management strategy being implemented by the City of Modesto, MID and OID. In addition, maximizing groundwater recharge is a goal or policy identified by many agencies with land use planning responsibility in the Subbasin (see **Section 2.6** below).

(g) *Well construction policies*. Stanislaus County has a well permitting program in accordance with the State Water Code that ensures proper well construction (see **Section 2.6.2** below).

(h) *Measures addressing groundwater contamination cleanup, groundwater recharge, in-lieu use, diversions to storage, conservation, water recycling, conveyance, and extraction projects*. As discussed above, most of these are addressed in the Integrated Regional GWMP (Bookman-Edmonston, 2005). Water conservation measures are provided in the UWMPs and AWMPs, as described in **Sections 2.5.2 and 2.5.3**.

(i) *Efficient water management practices, as defined in Section 10902, for the delivery of water and water conservation methods to improve the efficiency of water use*. Efficient water practices are provided in the UWMPs and AWMPs, as described in **Sections 2.5.2 and 2.5.3**.

(j) *Efforts to develop relationships with state and federal regulatory agencies*. These relationships are developed and coordinated in a variety of ways including coordination with CDFW on river issues, working with regulatory agencies regarding environmental sites within the City, oversight of the County for small community water system provision of water, among other activities (see also **Section 2.5.1**).

(k) *Processes to review land use plans and efforts to coordinate with land use planning agencies to assess activities that potentially create risks to groundwater quality or quantity.* As described in **Section 2.6** below, agencies within the Subbasin are conducting land use planning to ensure water supply availability and groundwater protection.

(l) *Impacts on groundwater dependent ecosystems (GDEs).* Groundwater elevation data collected as part of the groundwater level monitoring programs described in **Section 2.4** will be used to analyze the interconnectedness of surface water and groundwater and potential impacts on groundwater dependent ecosystems (GDEs). Additional analysis will incorporate results from the Modesto Subbasin integrated surface water- groundwater model, currently being revised.

The GSP will incorporate existing water resource management programs summarized above. In addition, goals, policies, and implementation measures in several General Plans in the Subbasin address aspects of water resource management programs, as discussed in the following section.

2.6. LAND USE PLANNING AND ELEMENTS

General Plans, Groundwater Ordinances, and information from other land use planning activities were compiled for review and consideration during GSP preparation and for coordination during GSP implementation. This section includes a summary of those plans and well permitting programs being implemented in the Modesto Subbasin.

2.6.1. Summary of General Plans and Groundwater Ordinances

Four cities and one county (including urban communities in the unincorporated areas) share land use planning responsibilities and authorities for the Modesto Subbasin. Most of the General Plans prepared by these entities contain goals and policies relating to water supplies, water use, and water resources. Land use designations, assumptions on growth, preservation of agricultural lands, or protection of environmental resources are examples of land use planning that could result in changes in water use over the planning horizon.

As part of GSP preparation, General Plans for Stanislaus County and the cities of Modesto, Oakdale, Riverbank and Waterford were reviewed. City and urban community boundaries and the Stanislaus County line are shown on **Figure 2-2**. Selected goals, policies, implementation measures, and issues from the General Plans are highlighted in the following sections with a focus on water resources and management.

2.6.1.1. Stanislaus County General Plan

In August 2016, Stanislaus County adopted its 2015 Comprehensive General Plan Update (County of Stanislaus, 2016). The General Plan area covers the entire County, which overlies portions of four groundwater subbasins, including the Modesto Subbasin as shown on **Figure 2-2**. Although the protection of natural resources in the County is a thread throughout the General Plan, a key goal with respect to water resources is contained in the Conservation/Open Space Element. That goal, along with associated policies and implementation measures are summarized in **Table 2-3**.

Although most of the County's population growth (96.8 percent) from 2000 to 2010 occurred in the incorporated areas, population increases in the 1990s created pressure to convert agricultural lands to non-agricultural use. In response to these conditions, county voters passed the *30-Year Land Use Restriction Initiative* (Measure E) in 2008. This measure requires that voters approve any future re-designation or re-zoning of agricultural or open space land use to residential use.

In addition, Stanislaus County has implemented a *Right-to-Farm Ordinance*. The County's ordinance establishes mechanisms designed to protect normal agricultural operations from pressures that can be created by urban neighbors. The County has also developed a *Farmland Mitigation Program* that requires any loss of farmland to residential development to be mitigated by the permanent protection of an equal amount of farmland. Agricultural Conservation easements granted in perpetuity are used as a means of minimizing farmland loss. Based on communications with the California Farmland Trust in October 2018, Agricultural Conservation easements continue to be granted and there are four parcels in Modesto, ranging from approximately 55 to 96 acres in size, with easements.

Notwithstanding the ongoing preservation of agricultural lands, the Stanislaus Council of Governments is projecting a population increase of 21.3 percent in the unincorporated areas by 2035 (from 110,236 to 133,753).

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Table 2-3: Selected Stanislaus County General Plan Goals and Policies

Table 2-3: Selected Stanislaus County General Plan Goals and Policies – Chapter Three: Conservation/Open Space Element		
Goal	**Policy**	**Implementation Measures**
Goal One. Encourage the protection and preservation of natural and scenic areas throughout the County	**Policy Three:** Areas of sensitive wildlife habitat and plant life (e.g., vernal pools, riparian habitats, flyways and other waterfowl habitats, etc.) including those habitats and plant species listed by state or federal agencies shall be protected from development and/or disturbance.	**1.** Review all development requests to ensure that sensitive areas (e.g., riparian habitats, vernal pools, rare plants, flyways, etc.) are left undisturbed or that mitigation measures acceptable to appropriate state and federal agencies are included in the project. **2.** In known sensitive areas, the State Department of Fish and Wildlife shall be notified as required by the California Native Plant Protection Act; the U.S. Fish and Wildlife Service also shall be notified. **3.** All discretionary projects that will potentially impact riparian habitat and/or vernal pools or other sensitive areas shall include mitigation measures for protecting that habitat. **4.** All discretionary projects within an adopted Airport Influence Area (AIA) that have the potential to create habitat, habitat conservation, or species protection shall be reviewed by the Airport Land Use Commission. **5.** Implementation of this policy shall not be extended to the level of an unconstitutional "taking" of property. **6.** Any ground disturbing activities on lands previously undisturbed that will potentially impact riparian habitat and/or vernal pools or other sensitive areas shall include mitigation measures for protecting that habitat, as required by the State Department of Fish and Wildlife.
Goal Two. Conserve water resources and protect water quality in the County	**Policy Five:** Protect groundwater aquifers and recharge areas, particularly those critical for the replenishment of reservoirs and aquifers.	**1**. Review proposals for urbanization in groundwater recharge areas to maximize recharge, prevent water quality degradation, and to not exacerbate groundwater overdraft. Areas susceptible to overdraft shall include a hydrogeological analysis and mitigation measures. Wastewater treatment may be required in areas susceptible to deterioration of groundwater quality. **2**. Department of Environmental Resources shall identify and require control of pollutants stored, handled, or disposed at the site. Groundwater monitoring programs will be adopted where hydrogeological assessment indicate the likely potential for groundwater deterioration. **3**. Stanislaus County shall discourage the use of dry wells for street drainage in urban areas to avoid contaminants reaching aquifers with beneficial uses. Storm water disposal systems shall be designed not to pollute receiving surface groundwater but integrated into an area-wide groundwater recharge program when feasible. **4**. Encourage new development to incorporate water conservation measures to minimize adverse impacts on water supplies. **5**. Continue to implement landscape provisions of the Zoning Ordinance, which encourage drought-tolerant landscaping and water-conserving irrigation methods. **6**. Encourage new urban development to be served by community wastewater treatment facilities and water systems rather than by package treatment plants or private septic tanks and wells.
	Policy Six: Preserve natural vegetation to protect waterways from bank erosion and siltation.	**1**. Development proposals and mining activities including, or in the vicinity of, waterways and/or wetlands shall be closely reviewed to minimize destruction of riparian habitat and vegetation. This includes referral to the US Army Corps of Engineers, US Fish and Wildlife Service, CA Depart. of Fish and Wildlife, and the CA Depart. of Conservation. **2**. Continue to encourage best management practices for agriculture and coordinate with soil and water conservation efforts of Stanislaus County Farm Bureau, Resource Conservation Districts, the US Soil Conservation Service, and local irrigation districts.
	Policy Seven: New development that does not derive domestic water from pre-existing domestic and public water supply systems shall be required to have a documented water supply that does not adversely impact Stanislaus County water resources.	**1**. Proposals for development to be served by new water supply systems shall be referred to appropriate water districts, irrigation district, community services district, the State Water Resources Board and any other appropriate agencies for review and comments. **2**. Review all development request to ensure a sufficient water supply to meet short and long-term water needs of the project without adversely impacting the quality and quantity of existing local water resources.
	Policy Eight: The county shall support efforts to develop and implement water management strategies.	**1**. The County will pursue state and federal funding options to improve water management resources in the County. **2.** The Department of Environmental Resources should continue to monitor groundwater quality for public water systems under the department's supervision and oversee investigations of soil and groundwater contamination. **3**. The County will coordinate with water purveyors, private landowners, and other water resource agencies in the region on data collection for groundwater conditions and in the development of a groundwater usage tracking system, including well location/construction mapping and groundwater level monitoring to guide future policy development. **4**. The County shall promote efforts to increase reliability of groundwater supplies through water resource management tools (surface water protection, conservation, public education, and expanded opportunities for conjunctive use of groundwater, surface water, and appropriately treated wastewater and stormwater reuse opportunities). **5.** The County will support and facilitate the formation of integrated, comprehensive county-wide regional water resources management plans, which incorporates existing water management plans and identifies and plans for management within the gaps between existing water management plans. **6**. The County will cooperate with other pertinent agencies, including cities and water district, in the preparation and adoption of a groundwater sustainability plan pursuant to SGMA and any subsequent legislation. The County will use its regulatory authority to implement the requirements of the groundwater sustainability plan. **7**. The County will obtain technical information and develop the planning/policies to improve groundwater recharge opportunities and groundwater conditions in the County. **8**. As information becomes available, the County will adopt General Plan changes to protect recharge areas and manage land use changes that have an impact on groundwater use and quality.

Table 2-3: Selected Stanislaus County General Plan Goals and Policies – Chapter Three: Conservation/Open Space Element (continued)		
Goal	**Policy**	**Implementation Measures**
	Policy Nine: The County will investigate additional sources of water for domestic use.	1. The County will work with irrigation and water districts, community services districts, municipal and private water providers in developing surface water and other potential water sources for domestic use.
Chapter Seven: Agricultural Element		
Goal One. Strengthen the agricultural sector of our economy.	**Policy 1.22:** The County shall encourage regional coordination of planning and development activities for the entire Central Valley.	**1.** The County shall participate in regional efforts to address long-range planning, infrastructure, conservation, and economic development issues facing the Central Valley.
Goal Two. Conserve our agricultural lands for agricultural uses.	**Policy 2.15:** In order to mitigate the conversion of agricultural land resulting from a discretionary project requiring a General Plan or Community Plan amendment from "Agriculture" to a residential land use designation, the County shall require the replacement of agricultural land at a 1:1 ratio with agricultural land of equal quality located in Stanislaus County.	**1.**Mitigation shall be applied consistent with the Farmland Mitigation Program Guidelines
Goal Three. Protect the natural resources that sustain our agricultural industry.	**Policy 3.4:** The County shall encourage the conservation of water for both agricultural, rural domestic, and urban uses.	**1.** The County shall encourage water conservation by farmers by providing information on irrigation methods and best management practices and coordinating with conservation efforts of the Farm Bureau, Resource Conservation Districts, Natural Resource Conservation Service, and irrigation districts. **2.** The County shall encourage urban water conservation and coordinate with conservation efforts of cities, local water districts and irrigation districts that deliver domestic water. **3.** The County shall continue to implement adopted landscape and irrigation standards designed to reduce water consumption in the landscape environment. **4.** The County shall work with local irrigation districts to preserve water rights and ensure that water saved through conservation may be stored and used locally, rather than "appropriated" and moved to metropolitan areas outside of Stanislaus County. **5.** The County shall encourage the development and use of appropriately treated water (reclaimed wastewater and stormwater) for both agricultural and urban irrigation.
	Policy 3.5: The County will continue to protect the quality of water necessary for crop production and marketing.	**1.** The County shall continue to require analysis of groundwater impacts in Environmental Impact Reports for proposed developments. **2.** The County shall investigate and adopt appropriate regulations to protect water quality.
	Policy 3.6: The County will continue to protect local groundwater for agricultural, rural domestic, and urban use in Stanislaus County.	**1**. The County shall implement the existing groundwater ordinance to ensure the sustainable supply and quality of local groundwater.

Table 2-3: Selected Stanislaus County General Plan Goals and Policies – Chapter One: Land Use Element (continued)		
Goal	**Policy**	**Implementation Measures**
Goal One. Provide for diverse land use needs by designating patterns which are responsive to the physical characteristics of the land as well as to environmental, economic, and social concerns of the residents of Stanislaus County**.**	**Policy 7:** Riparian habitat along the rivers and natural waterways of Stanislaus County shall, to the extent possible, be protected.	**1.** All requests for development which require discretionary approval and include lands adjacent to or within riparian habitat shall include measures for protecting that habitat to the extent that such protection does not pose threats to proposed site uses, such as airports.
Goal Four. Ensure that an effective level of public service is provided in unincorporated areas.	**Policy 24:** Future growth shall not exceed the capabilities/capacity of the provider of services such as sewer, water, public safety, solid waste management, road systems, schools, health care facilities, etc.	**2**. Development within a public water district and/or wastewater district shall connect to the public water system and/or the wastewater treatment facility; except where capacity is limited or connection to existing infrastructure is limiting, and an alternative is approved by the County's Department of Environmental Resources. For development outside a water and/or wastewater district, it shall meet the standards of the Stanislaus County Primary and Secondary Sewage Treatment Initiative (Measure X) and domestic water. **9**. The County will coordinate development with existing irrigation, water, utility, and transportation systems by referring projects to appropriate agencies and organizations for review and comment.
Goal Six. Promote and protect healthy living environments	**Policy 29**: Support the development of a built environment that is responsive to decreasing air and water pollution, reducing the consumption of natural resources and energy, increasing the reliability of local water supplies, and reduces vehicle miles traveled by facilitating alternative modes of transportation, and promoting active living (integration of physical activities, such as biking and walking, into everyday routines) opportunities.	**1**. County development standards shall be evaluated and revised, as necessary, to facilitate development incorporating the following (or similar) design features: • Alternative modes of transportation such as bicycle lanes, pedestrian paths, and facilities for public transit; • Alternative modes of storm water management (that mimic the functions of nature); and • Pedestrian friendly environments through appropriate setback, landscape, and wall/fencing standards.

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2.6.1.2. Stanislaus County Community Plans

The 2015 Update of the Stanislaus County General Plan includes Community Plans for two urban communities in the Modesto Subbasin including Del Rio and Salida (location on **Figure 2-2**).

Del Rio is a small community of approximately 2.1 square miles located north of the City of Modesto along the Stanislaus River. Del Rio is a mixed residential, recreational and agricultural community. Water is provided to portions of the community by the City of Modesto, while other areas are reliant on groundwater from private wells. Future development, which will require environmental review, would include low-density residential, natural open recreational space, and potential expansion of the Del Rio County Club golf course. Agricultural use would be confined to the southern portion of the community.

Salida is a small community of approximately 4,600 acres northwest of the City of Modesto along Highway 99. The community plan includes the existing community of Salida and an amendment area. The amendment area includes the Salida Area Planning, Road Improvement, Economic Development, and Farmland Protection Initiative approved by the Board of Supervisors in August 2007. Approximately one-third of the planned amended area is for industrial, one-third is for residential (low-density, medium density, and medium high-density), and one-third is for a business park, commercial and agriculture. Water is provided by the City of Modesto. Future development will require environmental review and an evaluation of water/sewer services.

2.6.1.3. Stanislaus County Groundwater Ordinance

In November 2014, Stanislaus County adopted a Groundwater Ordinance[3] to promote sustainable groundwater extraction in the unincorporated portions of Stanislaus County. The ordinance prohibits groundwater extractions that are unsustainable and prohibits exports of groundwater from the County. The ordinance references undesirable results as defined by SGMA and requires periodic reporting of groundwater information to the County Department of Environmental Resources that is "reasonably necessary to monitor the existing condition of groundwater resources within the County…". The ordinance allows for well permits to be issued on a discretionary basis; applications for non-exempt wells must include substantial evidence that they will not withdraw groundwater unsustainably as defined in the ordinance. To comply with the ordinance, the County has developed its Discretionary Well Permitting and Management Program, described below in **Section 2.6.2**.

2.6.1.4. City of Modesto General Plan

The City of Modesto adopted its Urban Area General Plan in October 2008 to provide a planning horizon through 2025 (City of Modesto, 2008). Most of the City is located in the Modesto Subbasin, but a small portion is located south of the Tuolumne River in the Turlock Subbasin. The City of Modesto has established 23 comprehensive planning districts (CPD). Two of these, Whitmore/Carpenter CPD and Fairview CPD, are in the Turlock Subbasin,

[3] Chapter 9.37, County Code.

while the remaining 21 CPDs are in the Modesto Subbasin. The CPDs in the Modesto Subbasin include residential, commercial, business park, mixed use, and open space land uses, with a total of approximately 42,000 acres, 174,000 dwelling units and 277,000 jobs.

The General Plan for the City of Modesto identifies water as the most critical natural resource in California. Water supply in Modesto is from City owned and operated wells and treated surface water purchased from MID. There are some private wells within City limits in parks and golf courses, and for industrial and agricultural uses. The General Plan has a water goal, wastewater goal and storm drainage goal. The policies to achieve these goals are summarized in **Table 2-4**. This table is based on the October 2008 General Plan and some items may be out-of-date and will be updated, if needed, in future GSP analyses.

Table 2-4: Selected City of Modesto General Plan Goals and Policies

Table 2-4: Selected City of Modesto General Plan Goals and Policies - Community Services and Facilities	
Goal	**Policy**
General Water Goal Ensure a consistent, reliable, high-quality water supply for the City of Modesto and its customers.	**Water Policies—Baseline Developed Area** a. During review of all proposed development, the City shall require, as a condition of approval, that all developments reduce their potable water demand. The City should refer to Table 5-1 in the Joint Urban Water Management Plan for potential techniques to reduce potable water demand, as well as those identified in the City's current UWMP. b. The City's Public Works Director may require water infrastructure master plans for the public infrastructure or when otherwise pertinent to provision of service at adopted service levels for the specific plan areas or other projects depending on site issues and location. c. Individual development projects, including lot splits, are subject to review by the City's Public Works Director for adequate water supply. d. According to state law (Senate Bill 1087 of 2005), no provider of water services may deny or condition the approval of an application for services, or reduce the amount of the services applied for, if the proposed development includes housing affordable to lower income households, except upon making specific findings in accordance with SB 1087. e. All new connections to the public water system shall have meters installed. In addition, on or before January 1, 2025, all existing municipal and industrial service connections shall have water meters installed. On or before January 1, 2010, the City shall charge all customers with water meters based on the volume of water delivered. f. The City of Modesto shall prepare and adopt an Urban Water Management Plan every five years in accordance with Water Code Section 10621. g. The City shall implement the Demand Measurement and Conservation Measures identified in the City's adopted Urban Water Management Plan. h. The City of Modesto shall prepare and maintain a Water Master Plan. The Water Master Plan shall be updated, as needed, to incorporate changes in growth projections, water supplies, and demands. i. The City of Modesto should continue to pursue additional potential water supply alternatives available to the City to accommodate growth and meet future demand in both normal and dry years. j. The City of Modesto will encourage the optimum beneficial use of water resources within the City. The City shall strive to maintain an adequate supply of high-quality water for urban uses. At a minimum, potable water supplies (including well water) delivered to water customers shall conform to the primary maximum contaminant levels as defined in the California Code of Regulations, Title 22, Section 64431-64444. k. The City of Modesto will strive to stabilize groundwater levels and eliminate groundwater overdraft, as part of a conjunctive groundwater–surface water management program. The City shall view regional water resources, such as groundwater, surface water, and recycled wastewater, as an integrated hydrologic system when developing water management programs. l. The City of Modesto will be the sole provider of municipal and industrial water services to the area within the City's Sphere of Influence, with the exception of private wells. The City will cooperate with the overlying agricultural water providers, MID and TID, and with adjacent municipal and industrial providers for the mutually beneficial management of the limited water resources. The City will also take into consideration its public trust duty with regard to environmental uses of water resources. m. The City will provide water service within the original Del Este service area. n. Water facilities will be constructed, operated, maintained, and replaced in a manner that will provide the best possible service to the public. The City shall ensure that infrastructure is installed before or concurrently with development. The City will take a comprehensive approach to financing, using a blend of special taxes, benefit assessments, and other methods to ensure that infrastructure installation occurs in a timely manner. o. The City will continue to establish guidelines, policies, and programs to implement water conservation to the maximum extent feasible. Funding for large conservation rebate or exchange programs should be in place. The City shall strive to maximize the utilization of water resources when developing and implementing its Economic Development Strategy. p. The City of Modesto shall participate in the development of a TID Surface Water Supply Project (SWSP). q. The City of Modesto shall implement Local Basin Management Objectives (BMOs) discussed in the Integrated Regional Groundwater Management Plan that relate to the specific approaches to water management goals including groundwater supply, groundwater quality, and protection against inelastic land surface subsidence. r. The City of Modesto shall support the Regional BMOs discussed in the Integrated Regional Groundwater Management Plan. s. The City of Modesto should develop and implement a water recycling program to reduce the demands for new water supplies in the City and basin. *This section addresses the requirements of Government Code Section 66455.3 for proposed residential subdivisions of over 500 dwellings.* t. For projects within the City's water service area, a copy of any project application shall be sent to the City Public Works Department within 5 days of the application being accepted as complete for processing by the City of Modesto. u. When approving a proposed residential subdivision of over 500 dwelling units, the City of Modesto must include a condition requiring a sufficient water supply to be available. Proof of availability of water supply depends upon several factors.

Table 2-4: Selected City of Modesto General Plan Goals and Policies - Community Services and Facilities (continued)	
Goal	**Policy**
	This section addresses the requirements of Senate Bills 221 and 610 of 2001 that establish the requirement for public water systems to prepare water supply assessments for projects as follows: v. A project means any of the following (consistent with Water Code Section 10912): a proposed residential development of more than 500 dwelling units; a proposed shopping center or business establishment employing more than 1,000 persons or having more than 250,000 square feet of floor space; a proposed hotel or motel, or both, having more than 500 rooms; a proposed industrial, manufacturing, or processing plant, or industrial park planned to house more than 1,000 persons, occupying more than 40 acres of land, or having more than 650,000 square feet of floor area; a mixed-use project that includes one or more of the projects identified above; or a project that would demand an amount of water equivalent to, or greater than, the amount of water required by a 500 dwelling unit project. w. The City shall consider adopting more specific or restrictive standards for the definition of a project within its water service area. x. For projects requiring an environmental impact report, negative declaration, or mitigated negative declaration under CEQA, the City, as the retail water supplier, shall prepare a Water Supply Assessment (WSA) that complies with the requirements of SB 610 and SB 221 in evaluating the sufficiency of water supply to serve the project, and include the findings of the WSA in the CEQA document. *This section addresses the requirements of Senate Bill 2095 of 2000 (Government Code Section 65601 et seq.) that relate to the mandated use of recycled water for landscaping purposes as follows:* y. Any local public or private entity that produces recycled water and determines that within 10 years it will provide recycled water within the boundaries of the City of Modesto must notify the City of that fact. Within 180 days of receipt of the notice, the City of Modesto shall adopt and enforce a specified recycled water ordinance. The recycled water ordinance must comply with the recycled water policies detailed in the City of Modesto's UWMP.
	Water Policies—Planned Urbanizing Area a. All of the Water Policies for the Baseline Developed Area apply within the Planned Urbanizing Area. b. The City of Modesto shall coordinate land development projects with the expansion of water treatment and supply facilities.
General Wastewater Goal The objective of the City's wastewater system is to meet increasingly strict wastewater regulations in a cost-effective manner. As demand for water increases in California, reclaiming wastewater could create opportunities to optimize the region's water resources. Similar opportunities exist for the beneficial reuse of biosolids and digester gas, and other residuals of wastewater treatment.	**Wastewater Policies—Baseline Developed Area** a. To protect public health and the environment, the City's wastewater treatment facilities will conform to standards for wastewater and biosolids treatment and disposal, as established by the Central Valley Regional Water Quality Control Board, in compliance with the Federal Clean Water Act, the State Porter-Cologne Act, and their implementing regulations, current and future. b. The City shall support the near-term expansion of the wastewater treatment and disposal capacity of the Jennings Road Secondary Treatment Plant. c. The City shall support both wastewater collection and treatment system improvements and associated costs needed to serve the City's existing and future customers. d. Wastewater facilities will be constructed, operated, maintained, and replaced in a manner that will provide the best possible service to the public as required by federal and state laws and regulations. In developing implementation plans, consideration shall be given to rehabilitation of essential existing facilities, expansion to meet current excess demand, and the timely expansion for future demand. e. If available, the City shall provide wastewater services within the sewer service agreement area. f. The City of Modesto shall continue to support, develop, and research future water reclamation opportunities as a water resource. g. The City's wastewater system capacity will be allocated to existing and future residential, commercial, and industrial customers. Discharges from environmental cleanup sites may be issued conditional discharge permits subject to the availability of excess treatment capacity. In accordance with federal and state regulations, all discharges to the wastewater system may not, or may not threaten to, upset, interfere, or pass through the wastewater system. h. The City Engineer may require wastewater infrastructure master plans for the specific public infrastructure or when otherwise pertinent to provision of service at adopted service levels for the specific plan areas or other projects depending on site issues and location. i. Individual development projects, including lot splits, are subject to review by the City's Public Works Director for adequate wastewater collection service. j. Within the entire General Plan boundary and sewer service areas, the City shall avoid increasing the burden on existing septic systems that results from the addition of new plumbing fixtures. k. Subject to the approval of the Stanislaus Local Agency Formation Commission, the City of Modesto will be the sole provider of wastewater services to the area within the City's Sphere of Influence and sewer service area. l. Prior to annexation, the City must find that adequate wastewater treatment and disposal capacity can be provided for the proposed annexation. m. The City will encourage the regional beneficial reuse of reclaimed water. The City is committed to development of a full reclamation program in the long term. The City will comply with Title 22 standards for use of reclaimed water and criteria contained in the California Department of Public Health (CDPH) "Purple Book." n. The City shall strive to use land application of biosolids as the most environmentally beneficial reuse of this resource, rather than the disposal options of landfilling or incineration. o. The City shall develop methods to discontinue the current practice of using the sanitary system to temporarily drain stormwater runoff. p. The City shall establish odor buffer zones around primary and secondary wastewater plants, thereby minimizing the likelihood of odors impacting new residential or commercial development. q. The City shall utilize source control and demand management among its tools for accomplishing the most cost-effective wastewater management, protective of public health and the environment. r. The City shall establish 10th percentile river flows as the baseline condition for design to minimize risks of exceeding Waste Discharge Requirements (WDR) and National Pollution Discharge Elimination System (NPDES) permit requirements. s. According to state law (Senate Bill 1087 of 2004), no provider of wastewater services may deny or condition the approval of an application for services, or reduce the amount of the services applied for, if the proposed development includes housing affordable to lower income households, except upon making specific findings in accordance with SB 1087.

Table 2-4: Selected City of Modesto General Plan Goals and Policies - Community Services and Facilities (continued)	
Goal	**Policy**
	Wastewater Policies—Planned Urbanizing Area a. All of the Wastewater policies for the Baseline Developed Area apply within the Planned Urbanizing Area. b. The City of Modesto will require each new development project to be served with public sanitary sewers. Utilities located in private streets shall be part of the public sewerage system and shall be connected to a sewer lateral. c. The City of Modesto will coordinate land development proposals with the expansion of wastewater facilities.
General Storm Drainage Goal The City should have an operating storm drainage system that protects people and property from flood damage and that protects the environment.	**Stormwater Drainage Policies—Baseline Developed Area** a. One-third of the Baseline Developed Area is served by "rock wells." New rock wells shall be allowed only under very limited circumstances. New storm drainage in the Baseline Developed Area shall be by means of positive storm drainage systems unless otherwise approved by the City Engineer. The new storm drainage facilities shall consider the drainage facility requirements presented in Table 9-1 of the Final Master Environmental Impact Report and the SDMP. This policy applies to both positive storm drainage systems and to new rock wells (which are generally discouraged) in the Baseline Developed Area. b. MID shall be consulted during the preparation of drainage studies required by this General Plan. c. The City shall prevent water pollution from urban storm runoff as established by the Central Valley Regional Water Quality Control Board Basin Plan for surface discharges and the Environmental Protection Agency for underground injection. d. Stormwater drainage facilities shall be constructed, operated, maintained, and replaced in a manner that will provide the best possible service to the public, as required by federal and state laws and regulations. In developing implementation plans, consideration shall be given to rehabilitation of existing facilities, remediation of developed areas with inadequate levels of drainage service, and the timely expansion of the system for future development. e. The City shall update and maintain its Storm Drainage Master Plan to cover the entire area within the City's Sphere of Influence. The City of Modesto shall adopt the Storm Drainage Master Plan, in consultation with Stanislaus County, MID, and TID, to address the projected cumulative flows that would be discharged to MID and TID facilities from the urbanized drainage areas. The master drainage program should include the procedures for planning, evaluation, and design of necessary stormwater drainage facilities to ensure that facilities are capable of accommodating the additional flows. The master drainage program should include capital improvement, operations, and maintenance-financing plans necessary to ensure that facilities are constructed in a timely fashion to reduce the impacts from potential flooding problems. f. New development shall comply with City requirements for conveyance, retention, and detention. New development shall include onsite storage of stormwater as necessary. Rock wells shall not be allowed for new development except at infill areas smaller than three acres where no other feasible alternative is available. g. The City Engineer may require stormwater drainage infrastructure master plans for the public infrastructure or when otherwise pertinent to provision of service at adopted service levels for the specific plan areas or other projects depending on site issues and location. h. Construction activities shall comply with the requirements of the City's Stormwater Management Plan under its municipal NPDES stormwater permit, and the State Water Resources Control Board's General Permit for Discharges of Storm Water Associated with Construction Activity. i. For developments within a mapped 100-year floodplain, studies shall be prepared that demonstrate how the development will comply with both the construction and postconstruction programs under the City's municipal NPDES permit. Developments in these areas shall not lead to increased erosion or releases of other contaminants that would cause violations of the City's municipal NPDES permit. j. The City shall ensure that new development complies with the City of Modesto's *Stormwater Management Program: Guidance Manual for New Development Stormwater Quality Control Measures*.
	Stormwater Drainage Policies—Planned Urbanizing Area a. All of the Stormwater Drainage policies for the Baseline Developed Area apply within the Planned Urbanizing Area. b. The City of Modesto shall require each new development area to be served with positive storm drainage systems. A positive storm drainage system may be comprised of catch basins, pipelines, channels, recharge/detention basins, and pumping facilities that discharge stormwater to surface waters. New detention basins must typically include new technologies in their design that allow for full, healthy, and sustainable landscaping. The City of Modesto *Design Standards for Dual Use Flood Control / Recreation Facilities* manual is the guiding document for the development of these facilities. The positive storm drainage facilities shall consider the requirements presented in Table 9-1 of the Final Master Environmental Impact Report and the SDMP. c. The City of Modesto shall require positive storm drainage facilities in the Planned Urbanizing Area. Recharge shall be typically accomplished at recharge/detention basins, designed to be in compliance with applicable federal and state water quality regulations for both groundwater and surface water. d. Where feasible, dual-use flood control/recreation facilities shall be developed (dual-use facilities) as part of the storm drainage system. Dual-use facilities maximize efficient use of land and funds by satisfying needs for water quality, flood control, recreation, and aesthetics within a single consolidated facility. e. Dual-use facilities shall be designed and constructed in accordance with the standards in the City of Modesto *Design Standards for Dual Use Flood Control/Recreation Facilities* manual and the Open Space and Parks/Planned Urbanizing Area Policy e. f. New developments shall be required to implement an appropriate selection of permanent pollution control measures in accordance with the City's implementation policies for the municipal NPDES stormwater permit. Permanent erosion control measures such as seeding and planting vegetation for new cut-and-fill slopes, directing runoff through vegetation, or otherwise reducing the off-site discharge of particulates and sediment are the most effective method of controlling off-site discharges of urban pollutants.

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2.6.1.5. City of Oakdale General Plan

The City of Oakdale is a small community spanning six square miles along the Stanislaus River in the northern region of the Modesto Subbasin (**Figure 2-2**). Oakdale adopted its 2030 General Plan (ESA, 2013) and anticipates an increase in population from approximately 21,000 in 2011 to 35,000 in 2030. This population growth is expected to require an increase in demand for residential, industrial, public/semi-public, retail and office development. Oakdale is completely reliant on groundwater for its water supply. The City is surrounded by agricultural lands consisting mostly of orchards. Water resource goals and policies from the Oakdale General Plan are summarized in **Table 2-5**.

Table 2-5: Selected City of Oakdale General Plan Goals and Policies

Goal	Policy
Goal PF-1 A sustainable supply of water delivered through an efficient infrastructure system to meet existing and future needs.	
Water Service Policies	
	PF-1.1 Reliable Supply and Distribution. Maintain a reliable supply of high quality water and a cost-effective distribution system to meet normal and emergency demands in both wet and dry years.
	PF-1.2 Urban Water Management Plan. Regularly review and update the City's Urban Water Management Plan and other water master planning and capital improvement tools to ensure adequate water supply, infrastructure, maintenance, rehabilitation, funding and conservation measures.
	PF 1.3 New Development. Require new development to demonstrate the availability of adequate water supply (either existing water supply or provision of new water sources) and infrastructure in accordance with city plans and standards. Ensure that new development constructs, dedicates and/or pays its fair share contribution to the water supply, treatment, storage, and distribution system necessary to serve the demands created by the development.
	PF 1.4 Existing OID Facilities. Coordinate with OID on the potential abandonment, relocation and/or reuse of existing facilities and easements within the City where appropriate.
	PF-1.5 Water Well Use. Discourage the use of private wells for domestic water use when connection to the City's water system is feasible.
	PF-1.6 Groundwater. Monitor and protect the quality and quantity of groundwater.
	PF-1.7 Groundwater Recharge. Preserve areas that provide important groundwater recharge capabilities such as undeveloped open space and natural drainage areas.
	PF-1.8 Regional Coordination. Continue to coordinate with other jurisdictions and agencies in preparing, and regularly reviewing and updating regional groundwater management plans to ensure acceptable groundwater quality and to minimize the potential for aquifer overdraft.
	PF-1.9 Surface Water. Work with the Oakdale Irrigation District to explore the potential use of surface water as future demands for groundwater increase.

Goal	Policy
	PF-1.10 Drinking Water Standards. Continue to provide domestic water that meets or exceeds state and federal drinking water standards by providing well water treatment, when necessary.
	PF-1.11 Energy Efficiency. Employ best practices to maintain the highest possible energy efficiency in the water infrastructure system to reduce costs and greenhouse gas emissions.
Water Conservation Policies	
	PF-1.12 Water Conservation Programs. Implement the City's water conservation program and amend the program as appropriate to reflect evolving technologies and best practices, consistent with the Oakdale Climate Action Plan.
	PF-1.13 Building and Site Design. Require new development to incorporate water saving techniques such as water efficient fixtures, drought-tolerant landscaping, on-site stormwater capture and re-use, and on-site commercial/industrial water reuse in accordance with state and other relevant standards.
	PF-1.14 Recycled Water. Explore opportunities to use recycled water in the city.
	PF-1.15 Water Education. Educate residents and businesses about the importance of water conservation and associated techniques and programs.
Goal NR-4: Water Resources and Quality	
Water Resource Protection Policies	
	NR-4.1 Stanislaus River. Protect surface water resources in Oakdale, including the Stanislaus River.
	NR-4.2 Groundwater Management Plan. Continue to work with applicable agencies to prepare, regularly review, update, and implement regional groundwater management plans to ensure the sustainability of groundwater quality and quantity.
	NR-4.3 Natural Open Space Areas. Preserve areas that provide important groundwater recharge, stormwater management, and water quality benefits such as undeveloped open spaces, natural habitat, riparian corridors, wetlands, and other drainage areas.
WATER QUALITY PROTECTION POLICIES	
	NR-4.4 National Pollution Discharge Elimination System. Regulate construction and operational activities to incorporate stormwater protection measures and best management practices in accordance with the City's National Pollution Discharge Elimination System (NPDES) permit.
	NR-4.5 Industrial, Agricultural, and Septic System Discharge. Regulate discharge from industrial users, use of agricultural chemicals (pesticides) and use of septic systems in accordance with local and State regulations to protect the City's natural water bodies.
	NR-4.6 Regulation of Runoff. Protect Oakdale's water resources from contamination by regulating stormwater collection and conveyance to ensure pollutants in runoff have been reduced to the maximum extent practicable.
	NR-4.7 New Development. Require new development to protect the quality of

Goal	Policy
	surface and groundwater bodies and natural drainage systems through site design, stormwater treatment, low impact development measures, and best management practices.
	NR-4.8 Regional Coordination. Coordinate and collaborate with agencies in the region and watershed to address water quality issues.
	NR-4.9 Education. Educate the public about practices and programs to minimize surface water and groundwater pollution.

2.6.1.6. City of Riverbank General Plan

The City of Riverbank updated its General Plan with a vision from 2005 to 2025 (City of Riverbank, 2009). Riverbank is small community located north of the City of Modesto along the Stanislaus River with a population of approximately 22,000 in 2008. The 2025 vision preserves the small-town character while anticipating population growth to approximately 52,500. Land use changes under the 2005-2025 Riverbank General Plan include residential, open space, commercial, industrial, multi-use recreation, mixed use, parks and civic. Water resources goals and policies from the Riverbank General Plan are summarized in **Table 2-6**.

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Table 2-6: Selected City of Riverbank General Plan Goals, Policies, and Implementation Strategies

Table 2-6: Selected City of Riverbank General Plan Goals, Policies, and Implementation Strategies		
Goal	**Policy**	**Implementation Strategies**
Goal DESIGN-19 Water Quality is Protected Throughout the Development Process and Occupation of the Site	**19.1** The City will establish site design criteria for allowing natural hydrological systems to function with minimum or no modification. **19.2** The City will promote the use of rain gardens, open ditches or swales, and pervious driveways and parking areas in site design to maximize infiltration of storm water and minimize runoff into environmentally critical areas. **19.3** The City will promote inclusion of passive rainwater collection systems in site and architectural design for non-potable water (gray-water) storage and use, thereby saving potable (drinking) water for ingestion.	
Goal CONS-4 Preserve Habitat Associated with the Stanislaus River While Increasing Public Access	**4.1** Approved projects, plans, and subdivisions shall avoid conversion of habitat within the existing Stanislaus River riparian corridor, including Great Valley Mixed Riparian Forest, Great Valley Willow Scrub, and Riparian Scrub areas, and shall preserve an open space buffer along the Stanislaus River and associated riparian areas. The open space buffer shall be designed to avoid impacts to habitat and special status species in the riparian corridor, as specified in Policy CONS 5.1, Policy CONS 5.2, Policy CONS 5.3, and Policy CONS 5.6, based on project specific biological resource assessment. The precise size of buffer from the river and associated riparian corridor is to be determined by site specific analysis. The riparian corridor preservation and open space buffer shall be provided through a permanent covenant, such as a conservation easement and shall also include an ongoing maintenance agreement with a land trust or other qualified nonprofit organization. The preservation of the riparian corridor and ongoing maintenance agreement is required prior to City approval of any subdivision of property or development project located in areas outside City limits as of January 1, 2007 (see Figure CONS-1). Low impact recreation could be allowed in this buffer area to the extent that impacts to these sensitive habitats are avoided or fully mitigated by demonstrating no net loss of habitat functions or value. Urban development shall not be allowed in this buffer area. **4.2** Approved projects, plans, and subdivisions shall provide for collection, conveyance, treatment, detention, and other stormwater management measures in a way that does not decrease water quality or alter hydrology in the Stanislaus River or associated groundwater recharge areas.	**1.** Development projects and subdivisions will be consistent with, and implement land use planning and greenhouse gas emission reduction measures developed pursuant to the regional Sustainable Community Strategy (per SB 375 of 2008), and consistent with Countywide and regional agricultural preservation planning, to the maximum extent feasible. In determining feasibility, there is a recognized need to balance the importance of agricultural resource conservation with other needs of Riverbank, such as State defined affordable housing, air quality, noise, water usage, and other public resources and services.
Goal CONS-6 Maintain or Increase Surface and Groundwater Quality Supply	**6.1** The City will require that waterways, floodplains, watersheds, and groundwater recharge areas are maintained in their natural condition, wherever feasible. **6.2** The City will coordinate with appropriate regional, state, and federal agencies to address local sources of groundwater and soil contamination, including underground storage tanks, septic tanks, agriculture, and industrial uses. **6.3** Approved projects, plans, and subdivisions in new growth areas shall incorporate natural drainage system design that emphasizes infiltration and decentralized treatment (rather than traditional piped approaches that quickly convey stormwater to large, centralized treatment facilities). **6.4** The City will encourage the use of permeable surfaces for hardscape. Impervious surfaces such as driveways, streets, and parking lots will be minimized so that land is available for a natural drainage system to absorb stormwater, reduce polluted urban runoff, recharge groundwater, and reduce flooding. **6.5** City street standards and parking requirements will balance the needs of transportation with the full range of community planning issues, including water quality, storm drainage, air quality, and other considerations. **6.6** The City will encourage the use of recycled water for appropriate use, including but not limited to outdoor irrigation, toilet flushing, fire hydrants, and commercial and industrial processes. **6.7** The City will require mitigation measures, in coordination with the Regional Water Quality Control Board, as a part of approved projects, plans, and subdivisions to address the quality and quantity of urban runoff, including that attributable to soil erosion.	**3.** The City will update the water, wastewater, and stormwater drainage master plans at least every five years to ensure the appropriate level of service is maintained as the City grows, and to ensure that appropriate projects are include in capital improvements planning and can be funded. The City will cooperate with local irrigation districts and public agencies to explore feasible surface water supplies or conjunctive use opportunities.

Table 2-6: Selected City of Riverbank General Plan Goals, Policies, and Implementation Strategies (continued)		
Goal	**Policy**	**Implementation Strategies**
Goal PUBLIC-2 Adequate Supply of Quality Water to Serve Existing and Future Project Development Needs	**2.1** The City will require that water supply, treatment, and delivery meet or exceed local, State, and federal standards. **2.2** The City will manage and enhance the City's water supply and facilities to accommodate existing and planned development, as identified in the City's Water Master Plan, Urban Water Management Plan, and Groundwater Source Efficiency Report. **2.3** New developments shall incorporate water conservation techniques to reduce water demand in new growth areas, including the use of reclaimed water for landscaping and irrigation. **2.4** The City will condition approval of new developments on demonstrating the availability of adequate water supply and infrastructure, including multiple dry years, as addressed in the City's Water Master Plan, Urban Water Management Plan, and Groundwater Source Efficiency Report. **2.5** The City will not induce urban development by providing provide water services in areas outside the Planning Area or areas not planned for urban development, such as areas designated for agriculture or open space.	**3.** The City will update the water, wastewater, and stormwater drainage master plans at least every five years to ensure the appropriate level of service is maintained as the City grows, and to ensure that appropriate projects are include in capital improvements planning and can be funded. The City will cooperate with local irrigation districts and public agencies to explore feasible surface water supplies or conjunctive use opportunities.
Goal PUBLIC-4 Storm Drainage Systems that Protect Public Safety, reserve Natural Resources, and Prevent Erosion and Flood Potential	**4.1** The City will maintain and improve, as necessary, existing public storm basins and flood control facilities, as identified in the Stormwater Master Plan. **4.2** The City will coordinate with County and Regional agencies, as well as the railroad, in the maintenance and improvement of storm drainage facilities to protect the City's residents, property, and structures from flood hazards. **4.3** The City will consider a variety of means for floodplain management, depending on the context, which may include development, improvement, and maintenance of structural flood control facilities; land use policy and zoning to prohibit incompatible urban development within the floodplain; erosion control techniques; setbacks from flood-prone areas; and other measures, as circumstances dictate. **4.4** The City will identify areas, such as wetlands, low-lying natural runoff areas, and pervious surfaces and percolation ponds, for natural storm water collection and filtration, in concert with the City's existing and future drainage infrastructure, to help reduce the amount of runoff and encourage groundwater recharge. **4.5** New development shall be designed to control surface runoff discharges to comply with the National Pollutant Discharge Elimination System Permit and the receiving water limitations assigned by the Regional Water Quality Control Board. **4.6** The City will establish that new development shall implement nonpoint source pollution control measures and programs designed to reduce and control the discharge of pollutants into the City's storm drains and river. **4.7** The City will require minimization of the amount of new impervious surfaces and directly connected impervious surfaces in areas of new development and redevelopment and, where feasible, maximize onsite infiltration of stormwater runoff. **4.8** The City will encourage pollution prevention methods, supplemented by pollutant source controls and treatment. Use small collection strategies located at, or as close to possible to the source (i.e., the point where water initially meets the ground) to minimize the transport or urban runoff and pollutants off-site. **4.9** The City will require the preservation and, where possible, will encourage that creation or restoration of areas that provide important water quality benefits, such as riparian corridors, wetlands, and buffer zones. **4.10** The City will limit disturbances of natural water bodies and natural drainage systems cause by development, including roads, highways, and bridges. **4.11** The City will require that new development avoid development in areas that are particularly susceptible to erosion and sediment loss; or will require that these areas are identified and protected from erosion and sediment loss. **4.12** The City will encourage and/or require the use of open, vegetated swales, stormwater cascades, and small wetland ponds instead of pipes and vaults, as a part of urban development proposed outside current City limits to mitigate stormwater impacts. **4.13** The City will enforce a no-net-runoff policy for areas proposed for development outside the current City limits.	**1.** The City will coordinate with area reclamation districts, Stanislaus County, the City of Modesto, and other agencies and jurisdictions for planning and coordinating drainage programs and policies on an areawide and regional basis.

2.6.1.7. City of Waterford General Plan

Waterford is a small community covering approximately 2.4 square miles along the Tuolumne River with a population of approximately 8,000 (**Figure 2-2**). In 2017, the City of Waterford updated its General Plan with a vision towards 2025, to plan for future growth that could double, triple or even quadruple its population over the next 20 to 30 years (Waterford Planning Department, 2007). The General Plan anticipates the need for future residential development and recognizes the need to accommodate business and industry.

Waterford is completely reliant on groundwater for water supply. Waterford currently owns and operates its water system, but before July 1, 2015, the City of Modesto provided water service to Waterford. Several policies in the General Plan address water, including Preserve and Enhance Water Quality, Promote Water Conservation Throughout the Planning Area and Use of Sustainable or "Green" Building Principals to Promote Water Conservation. Selected goals, policies and implementing actions in Waterford's General Plan are summarized on **Table 2-7**.

2.6.1.8. Tuolumne River Regional Park Master Plan

The Tuolumne River Regional Park (TRRP) Master Plan was developed in December 2001 for the Joint Powers Authority including the City of Modesto, City of Ceres and Stanislaus County (EDAW, Inc., 2001). The overall goals of the TRRP are to:

- Create a park where the recreational experience is oriented towards and compatible with the Tuolumne River, its water, natural resources, and processes.
- Provide a park that is a source of pride for the citizens of Stanislaus County and reflects and accommodates the County's diverse peoples and cultures.

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Table 2-7: Selected City of Waterford General Plan Goals, Policies, and Implementing Actions

Table 2-7: Selected City of Waterford General Plan Goals, Policies, and Implementing Actions		
Goal	**Policy**	**Implementing Actions**
Public Services and Facilities • Adequate Public Services and Facilities to Meet the Needs of the City's Residents • Cost-Effective Public Service Delivery Systems and Facilities • Public Services and Facilities Standards that are Applied Uniformly Throughout the City	**PF-1.3** Establish and Maintain a Program for Cost Effective Expansion of Municipal Services and Facilities to Meet Future Community Growth Needs. **PF-1.5** Assure that Expansion of the City Results in the Enhancement of Municipal Services and Facilities within Waterford Without Increasing Costs to The Existing City.	**PF-1.3.a** The City shall prepare and maintain master plans for the provision of sewer, water, storm drainage, streets and roadways and other public facilities and infrastructure for the service of the existing City and for the planned expansion of the City boundaries. **PF-1.5.j** Extension of infrastructure to newly annexed areas shall utilize the City's master plans for sewer, streets, storm drain, water and other infrastructure.
Urban Design • A Rural Community with a Unique Identity. • A Well Defined Urban Center. • An Integrated Community-Well Connected.	**UD-10** Maintain and Enhance the Unique Community Appearance of Waterford.	**UD-10d.** Encourage the development of methods to require acceptable levels of landscaping for new development and for landscaping maintenance in highly visible areas of the community. Landscape designs shall incorporate water conservation and low maintenance features.
Open Space for the Preservation of Natural Resources • OS-Maintain Waterford's Biological Resources. • OS-Maintain a High-Quality, Expanding Urban Forest • OS-Preserve Scenic Corridors and Resources • OS-Improve and Enhance Water Quality	**OS-A-1a** Identify, and recognize as significant, wetland habitats which meet the appropriate legal definition of federal and state law. **OS-A-2** Preserve and Enhance Tuolumne River and Dry Creek in Their Natural State Throughout the Planning Area. **OS-A-2c** Encourage alternatives to concrete channeling of existing natural drainage courses as part of any flood control project and support more natural flood control methods. **OS-A-5** Preserve and Enhance Water Quality.	**OS-A-5a.** Utilize storm water retention basins and other "Best Management Practices" to improve the quality of storm water discharged into the region's natural surface water system. **OS-A-5b** Monitor known sources of groundwater contamination within the City and its future expansion area. **OS-A-5c.** Periodically monitor the quality of surface water in the surface water system within the City and implement programs to minimize or eliminate sources of pollution. **OS-A-5d** Monitor ground water in areas in and around the City using septic system wastewater disposal systems.
Conservation of Resources • OS-Conserve Water Resources • OS-Preserve and Protect Soil Resources	**OS-E-1** Promote Water Conservation Throughout the Planning Area.	**OS-E-1a Develop and enforce water conservation policies and standards.** The City should consider adoption of a water conservation ordinance. **OS-E-1b Develop a Water Efficient Landscaping and Irrigation Ordinance.** Promote the conservation of water and the preservation of water quality by requiring drought tolerant plant material in landscaping and the retention of existing natural vegetation on new development projects. **OS-E-1c Provide leadership in conserving urban water resources.** City buildings and facilities should be equipped with water saving devices whenever practical. Municipal parks and playgrounds should employ water conservation techniques such as mulching, drip irrigation and other appropriate technologies. **OS-E-1d Encourage public water conservation efforts.** Through established public information systems in the community, the City should promote water conservation by providing information on water savings from low-flow fixtures and the value of insulating hot water lines in water re-circulating systems. Other conservation techniques can be addressed, such as the use of non-potable water for landscape irrigation purposes (water re-use, MID water, etc.).
Sustainable Design • SD-Sustainable "Green" Buildings City of Waterford. • SD- Application of "Green" or High Performance Building Technology	**SD-5.2** Use of Sustainable or "Green" Building Principals to promote Water Conservation.	**SD-5.2a. Manage Site Water** Create on-site small scale water features as part of landscape design that can serve as onsite storm water detention and minimize storm-water runoff during peak winter storm periods. **SD-5.2b. Use Gray Water Systems** Design landscape areas to make maximum use of treated wastewater or "purple pipe" systems. **SD-5.2c. Conserve Building Water Consumption** Use low flow water fixtures throughout the building.

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2.6.2. Stanislaus County Discretionary Well Permitting and Management Program

Well permitting processes have been established by Stanislaus County to implement county-wide groundwater ordinances that prevent export and overdraft and to ensure proper well construction and abandonment for the protection of groundwater resources. These processes are summarized below. Cities maintain control of well permitting within their city limits.

To implement the 2014 Stanislaus County Groundwater Ordinance (described above in **Section 2.6.1.3**), the County has developed its Discretionary Well Permitting and Management Program to prevent the unsustainable extraction from new wells subject to the Stanislaus County Groundwater Ordinance. The objectives of the Program, as stated in the County Programmatic Environmental Impact Report for the Program (PEIR), are as follows:

- Avoid or minimize potential adverse environmental impacts from the unsustainable extraction of groundwater resources, including, but not limited to, increased groundwater overdraft, land subsidence, uncontrolled movement of inferior quality groundwater, the lowering of groundwater levels, and increased groundwater degradation (Stanislaus County Code § 9.37.020 (4)); and

- Avoid or minimize potential adverse economic impacts from the unsustainable extraction of groundwater resources, including, but not limited to, loss of arable land, a decline in property values, increased pumping costs due to the lowering of groundwater levels, increased groundwater quality treatment costs, and replacement of wells due to declining groundwater levels, replacement of damaged wells, conveyance infrastructure, roads, bridges and other appurtenances, structures, or facilities due to land subsidence (Stanislaus County Code § 9.37.020 (5)). (Stanislaus County, March 2018).

The County program is designed to work cooperatively with SGMA and incorporates authorities and requirements provided under this GSP. In brief, the Program involves a discretionary well permitting process in non-exempt areas[4] of the County for all non-de minimis extraction in compliance with the Ordinance. After GSP adoption, the discretionary well permit program will apply to the installation of any new well or regulation of groundwater extraction from any existing well if the County reasonably concludes that a new or existing well is not in compliance with the GSP. The program includes a permit renewal process in five-year increments that coincides with the five-year GSP updates required by the GSP regulations.

[4] Exempt areas include incorporated areas and areas within the service area of a public water agency in compliance with a Groundwater Management Plan or GSP.

The Well Application review process, along with an application package and required mitigation measures, can be downloaded from the Stanislaus County website at: http://www.stancounty.com/er/pdf/application-packet.pdf.

2.6.3. How the General Plans and the GSP Affect the Other

In general, the General Plans reviewed in this section are accommodating population growth in the Subbasin, while preserving other beneficial uses of water by agriculture and the environment, which will result in increased water demands in the Subbasin. However, most of the plans recognize the need for water conservation, alternative supplies, and resource management. Many, especially the more recent plans, acknowledge the need for sustainable groundwater management. Ordinances for Stanislaus County incorporate the GSP planning process and SGMA requirements into specific programs, as described above.

All of the agencies with land use planning responsibilities and authorities are also STRGBA GSA member agencies. In addition, three member agencies (i.e., City of Modesto, OID, and Stanislaus County) are members of GSAs in neighboring subbasins which will help to ensure a high level of coordination in the GSP process. No conflicts between these land use plans and the Modesto Subbasin GSP have been identified.

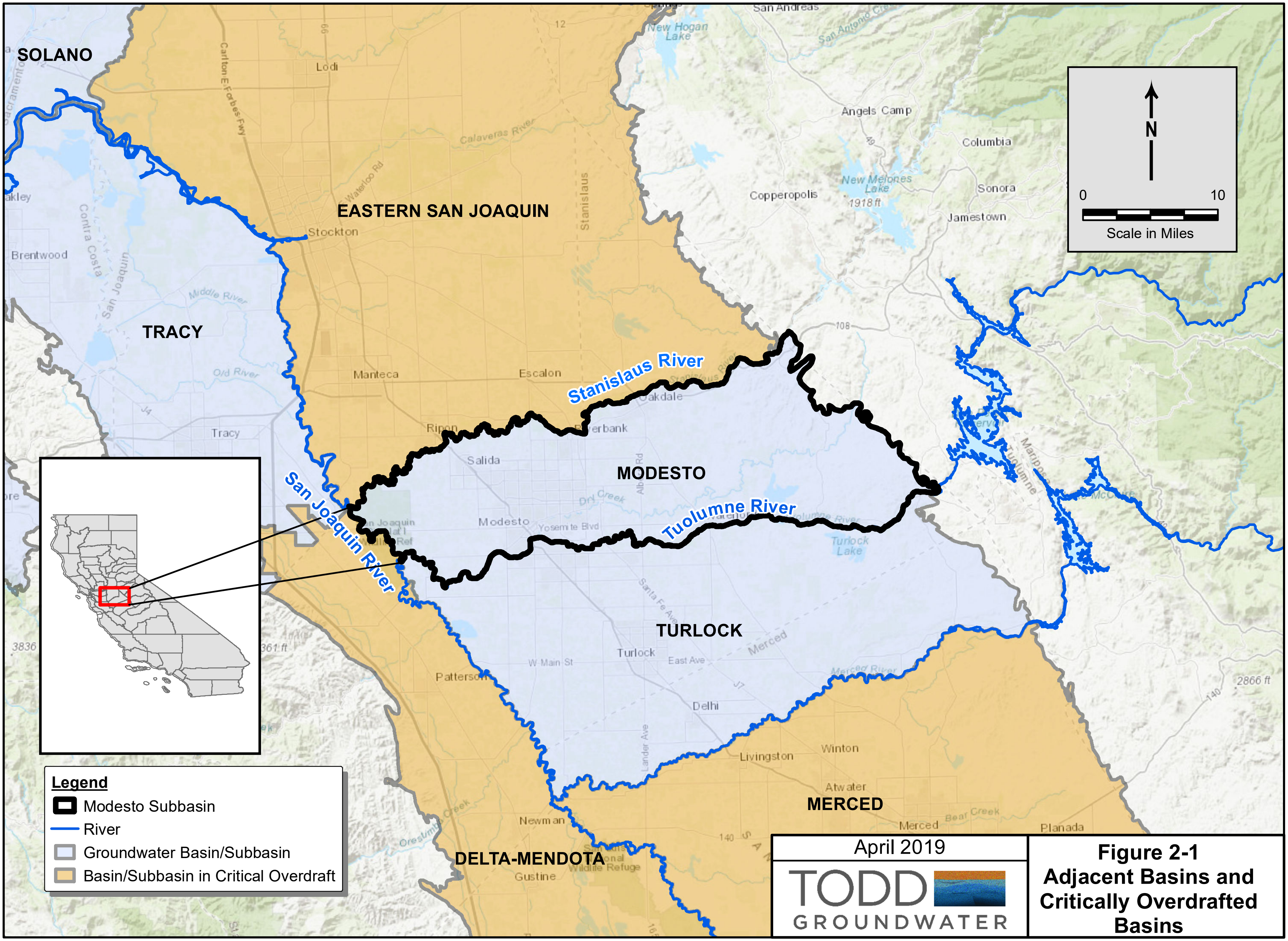


Figure 2-1
Adjacent Basins and Critically Overdrafted Basins

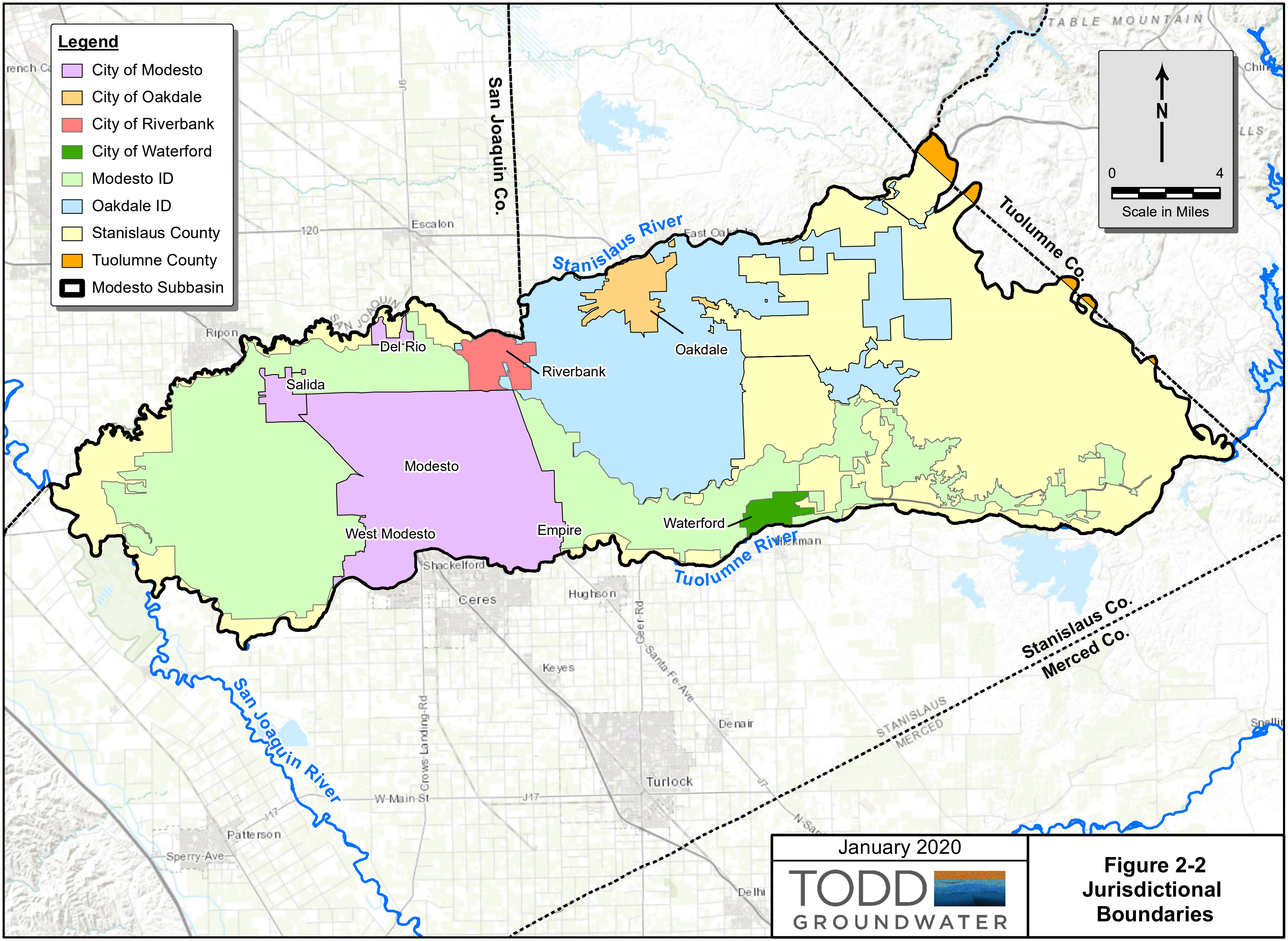


Figure 2-2 Jurisdictional Boundaries

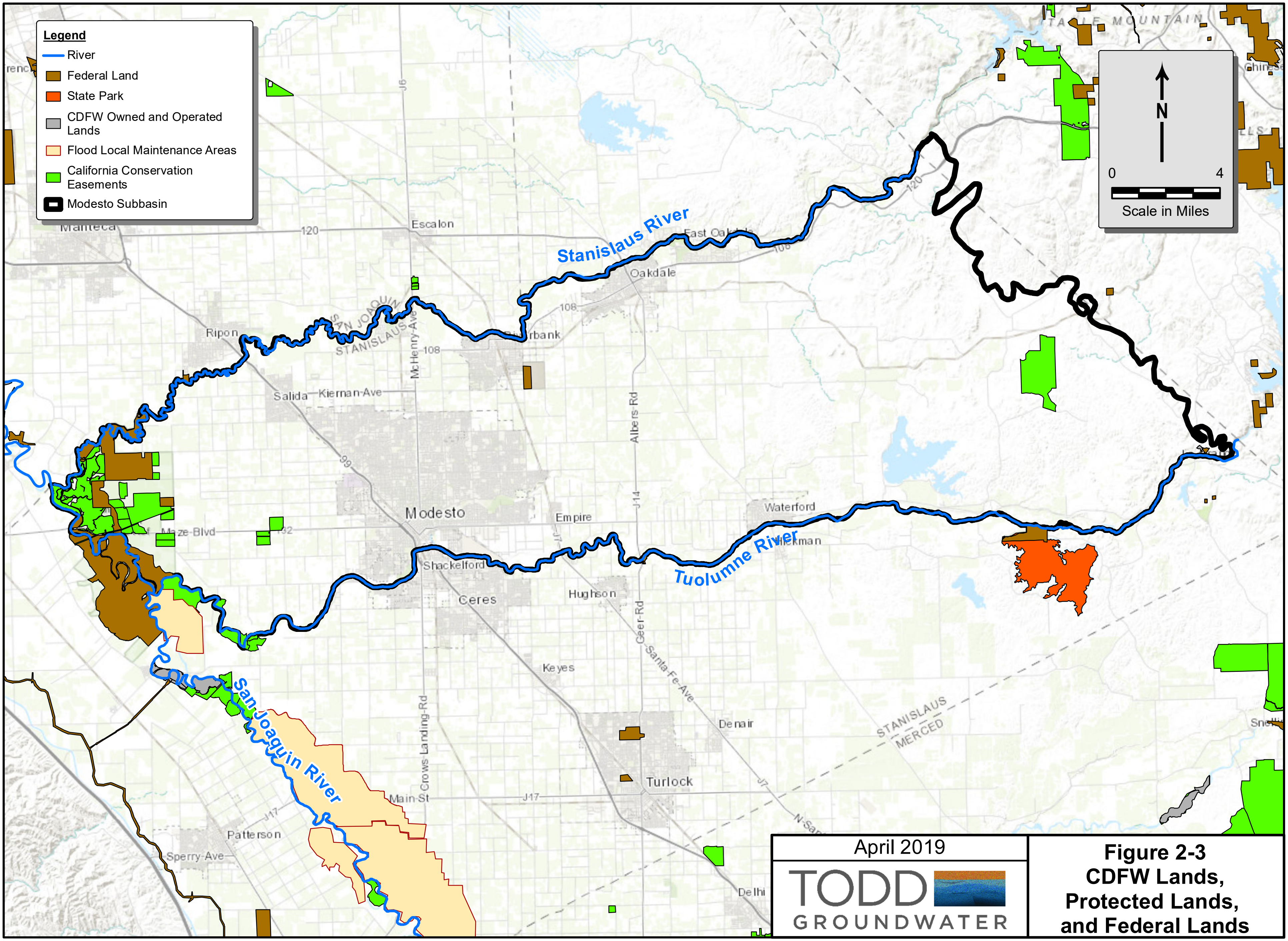
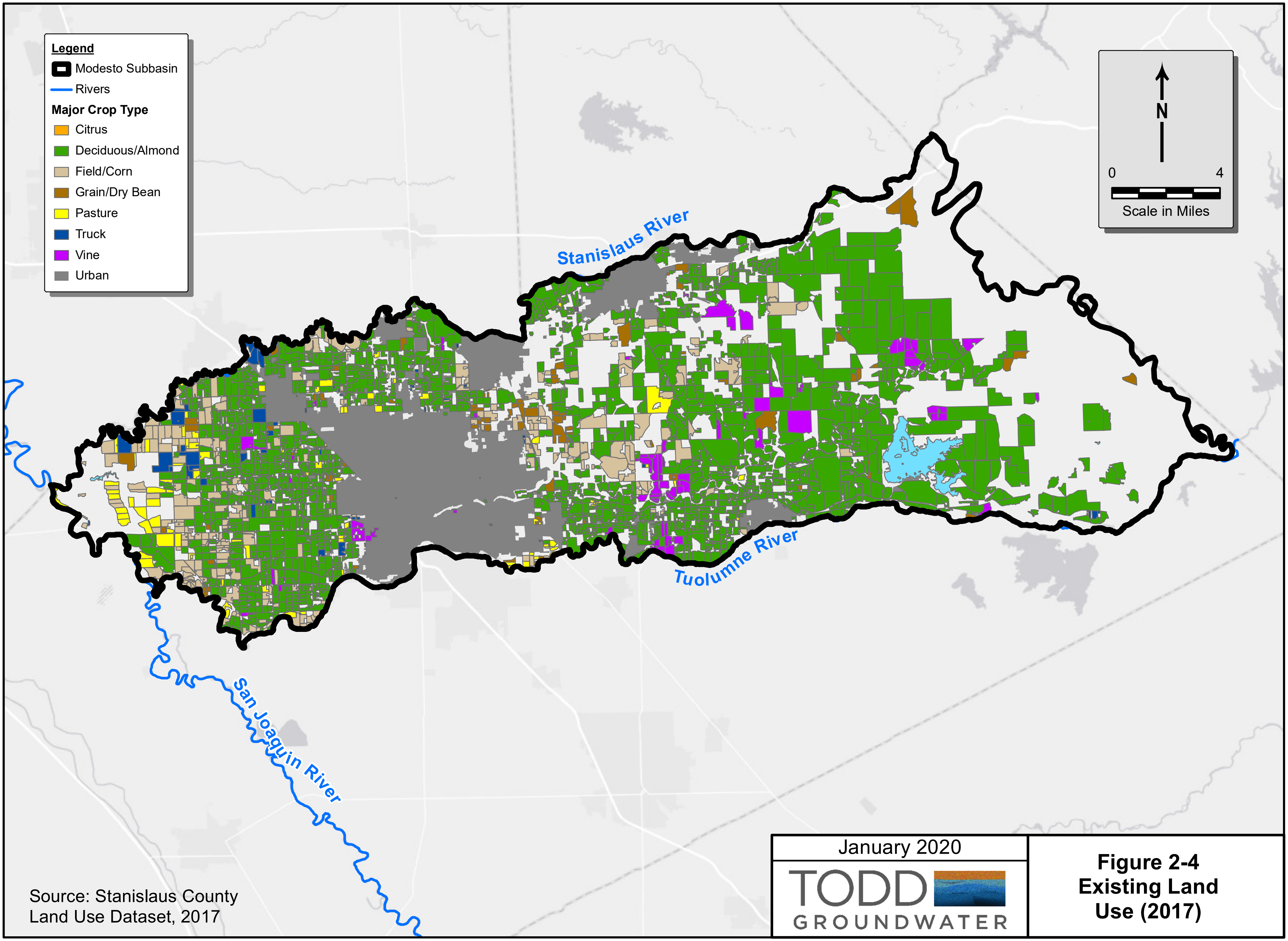


Figure 2-3
CDFW Lands, Protected Lands, and Federal Lands

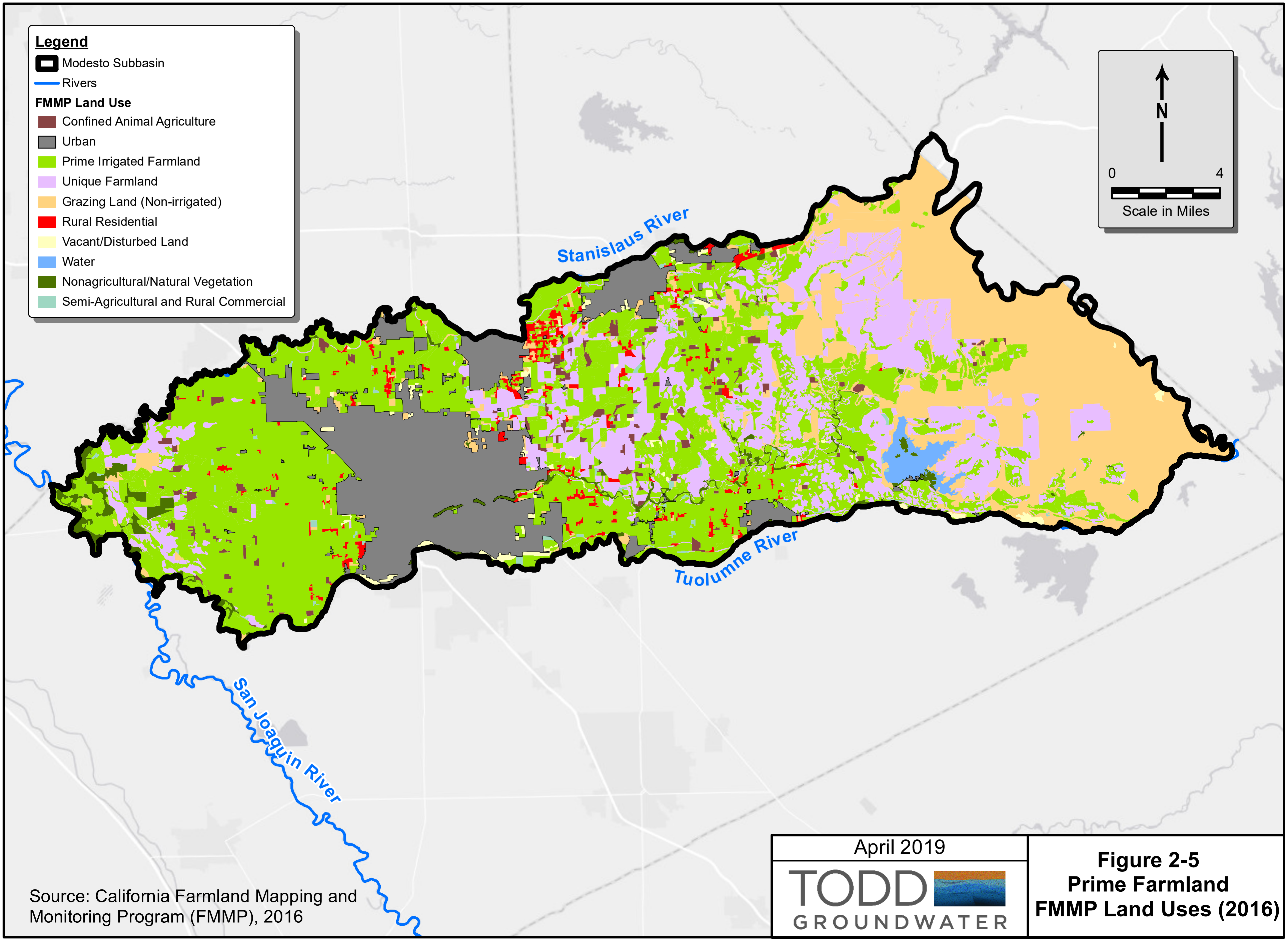


Source: Stanislaus County Land Use Dataset, 2017

January 2020

TODD GROUNDWATER

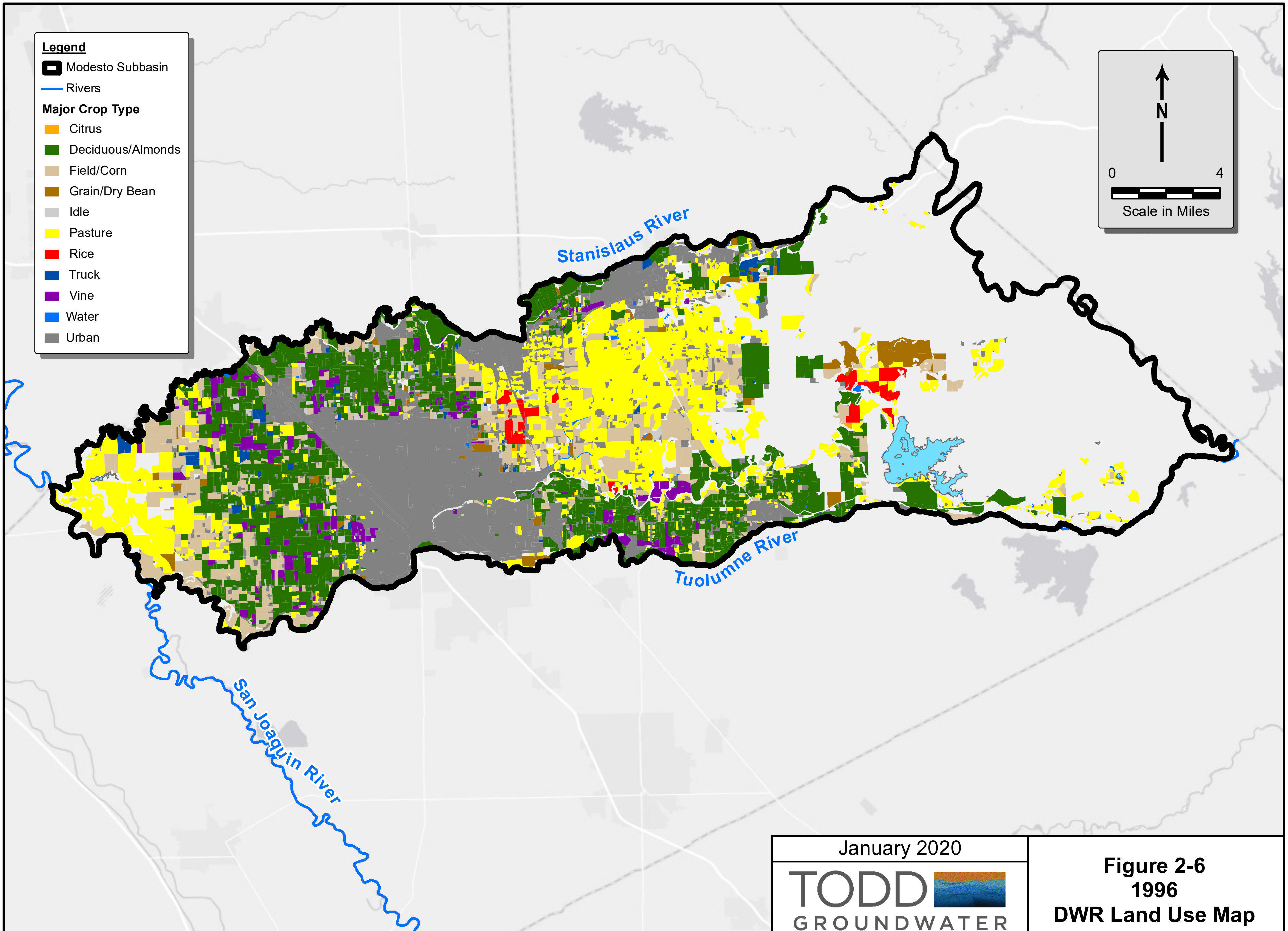
Figure 2-4
Existing Land Use (2017)



April 2019

TODD GROUNDWATER

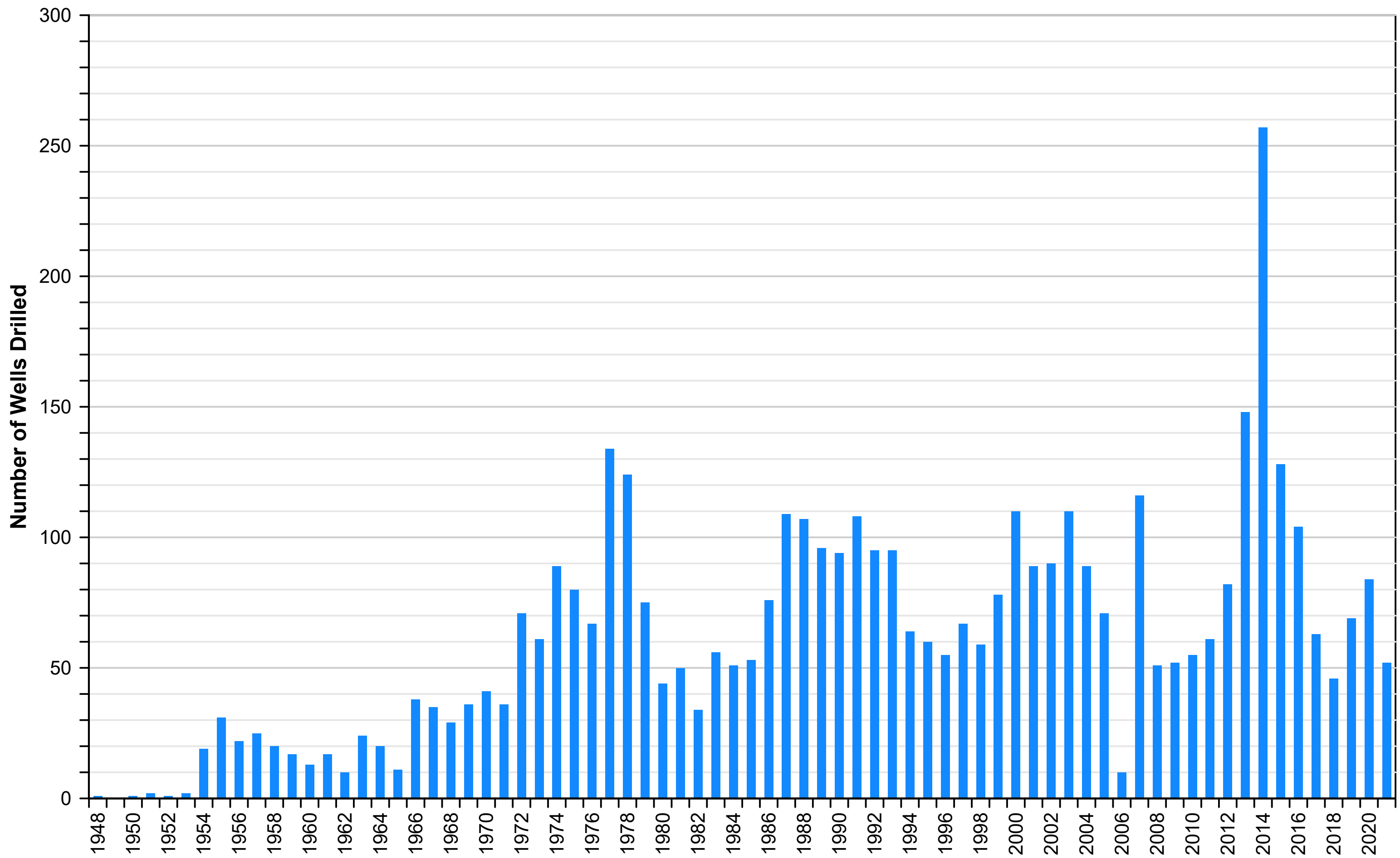
Figure 2-5
Prime Farmland
FMMP Land Uses (2016)



January 2020

TODD GROUNDWATER

Figure 2-6
1996
DWR Land Use Map

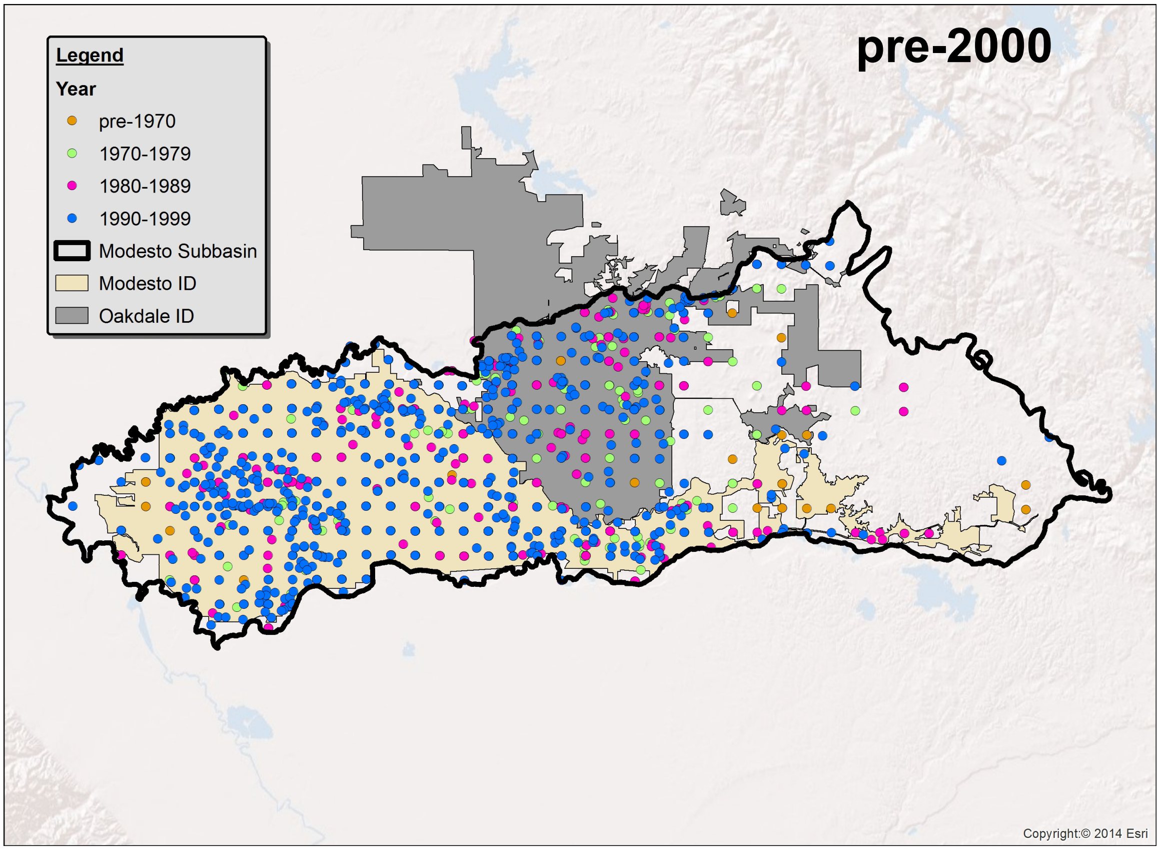


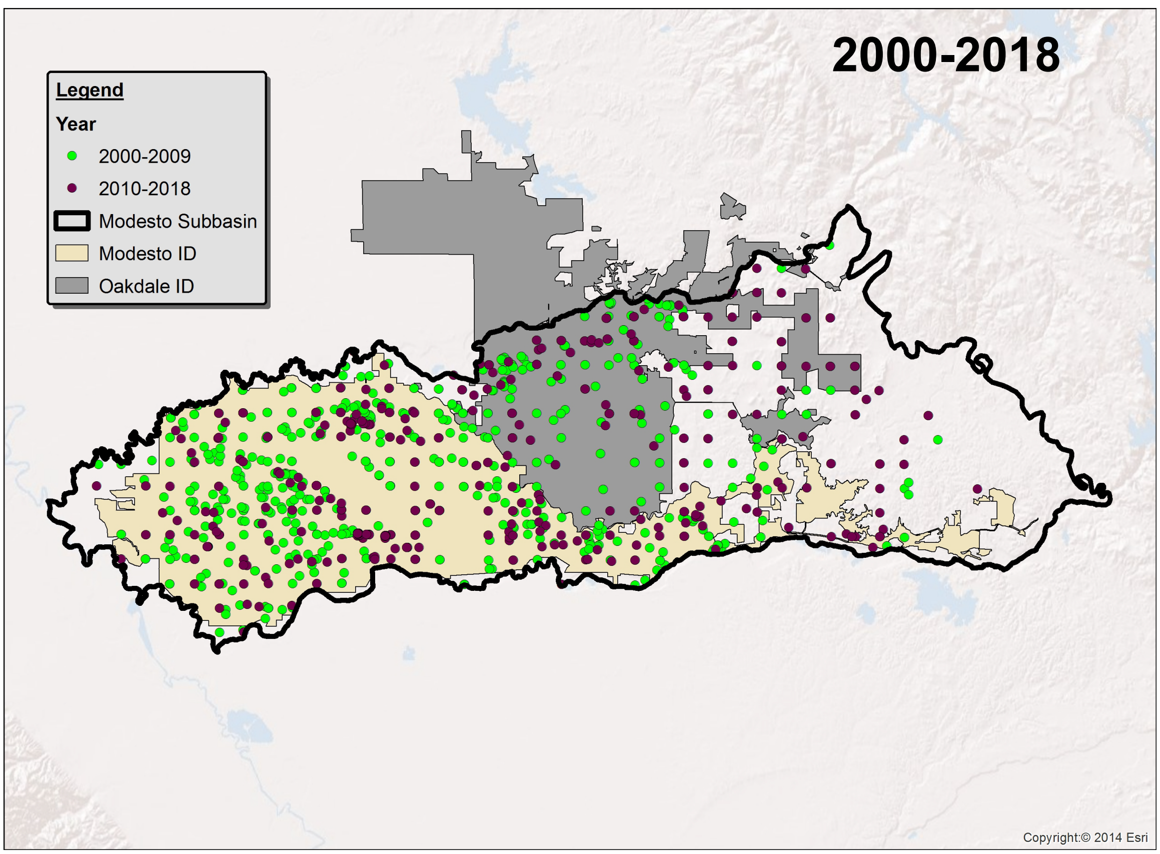
Source: DWR Well Completion Report Database.

November 2021

TODD GROUNDWATER

Figure 2-7
Number of Wells Drilled in Modesto Subbasin



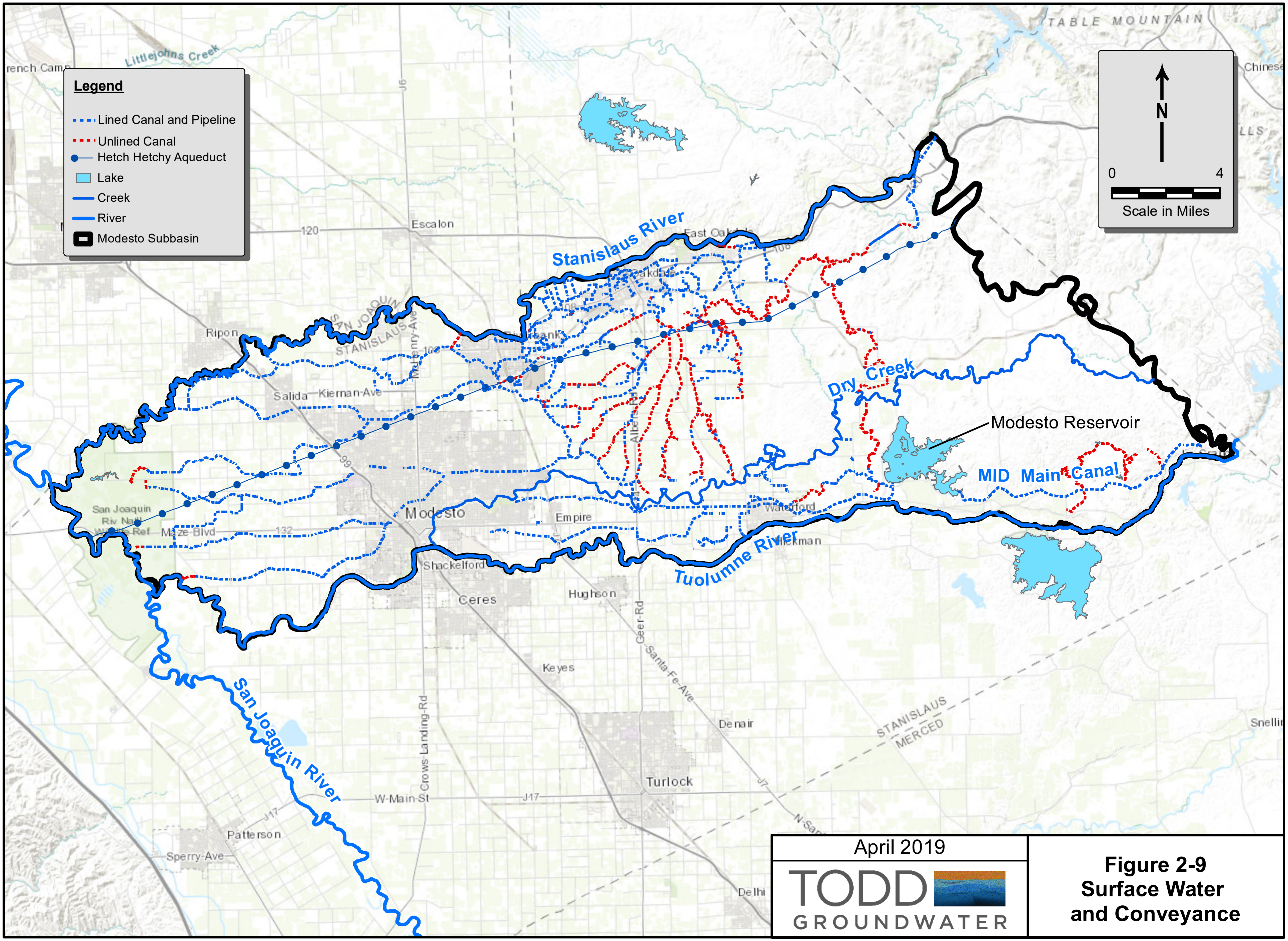


Source: DWR Well Completion Report Database

April 2019

TODD GROUNDWATER

Figure 2-8
Modesto Subbasin Wells



April 2019

TODD GROUNDWATER

Figure 2-9 Surface Water and Conveyance

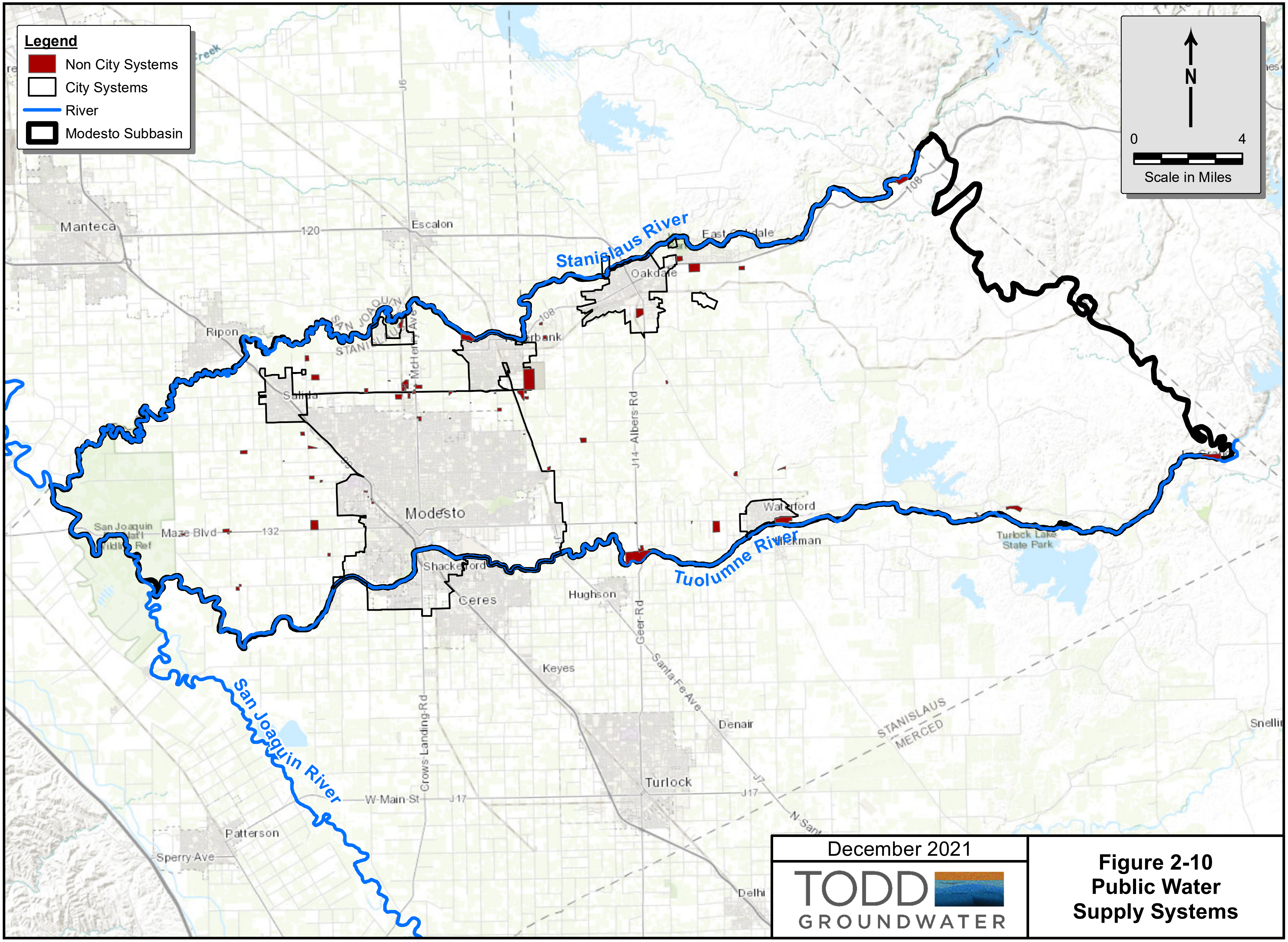


Figure 2-10
Public Water Supply Systems

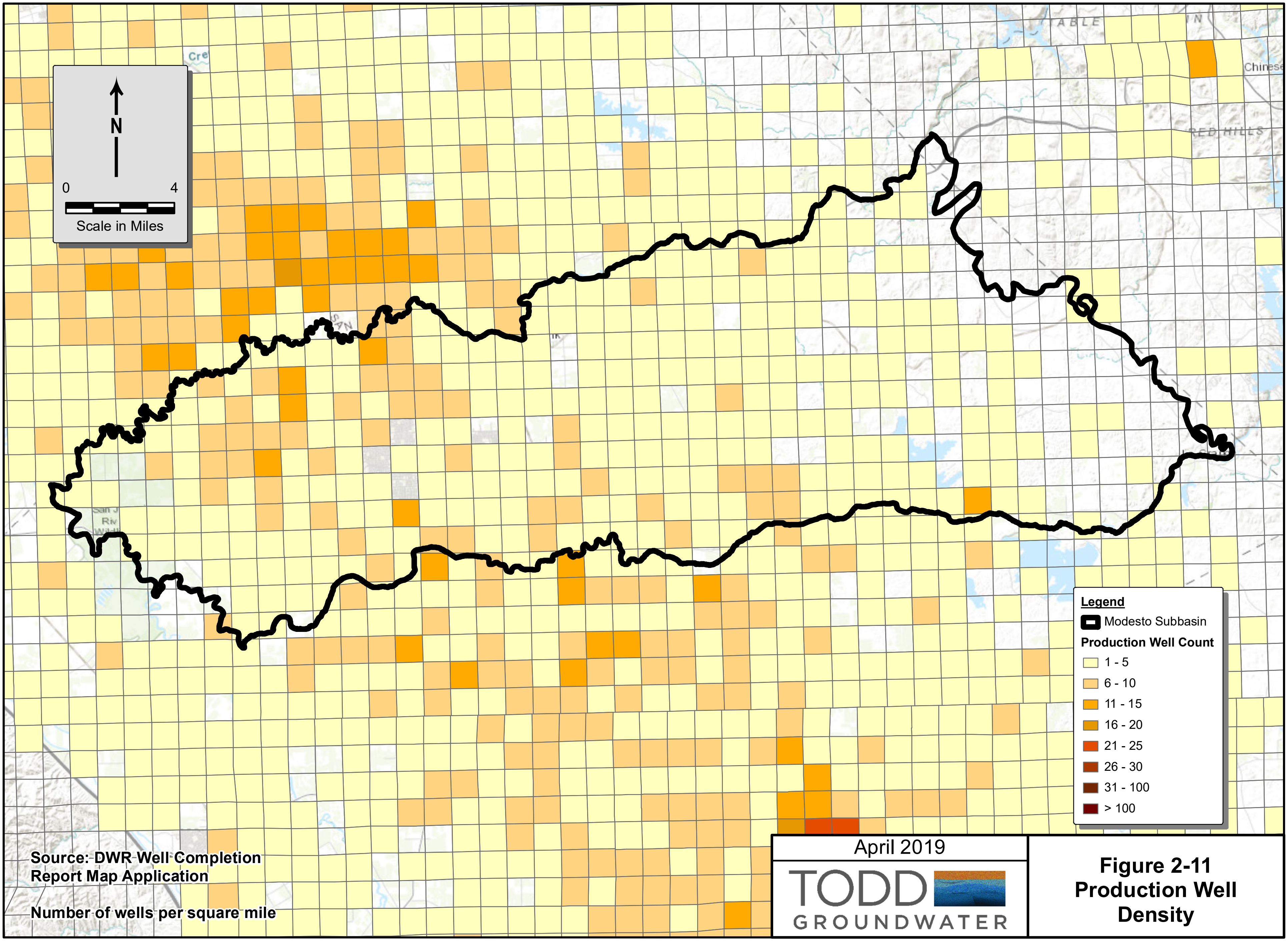
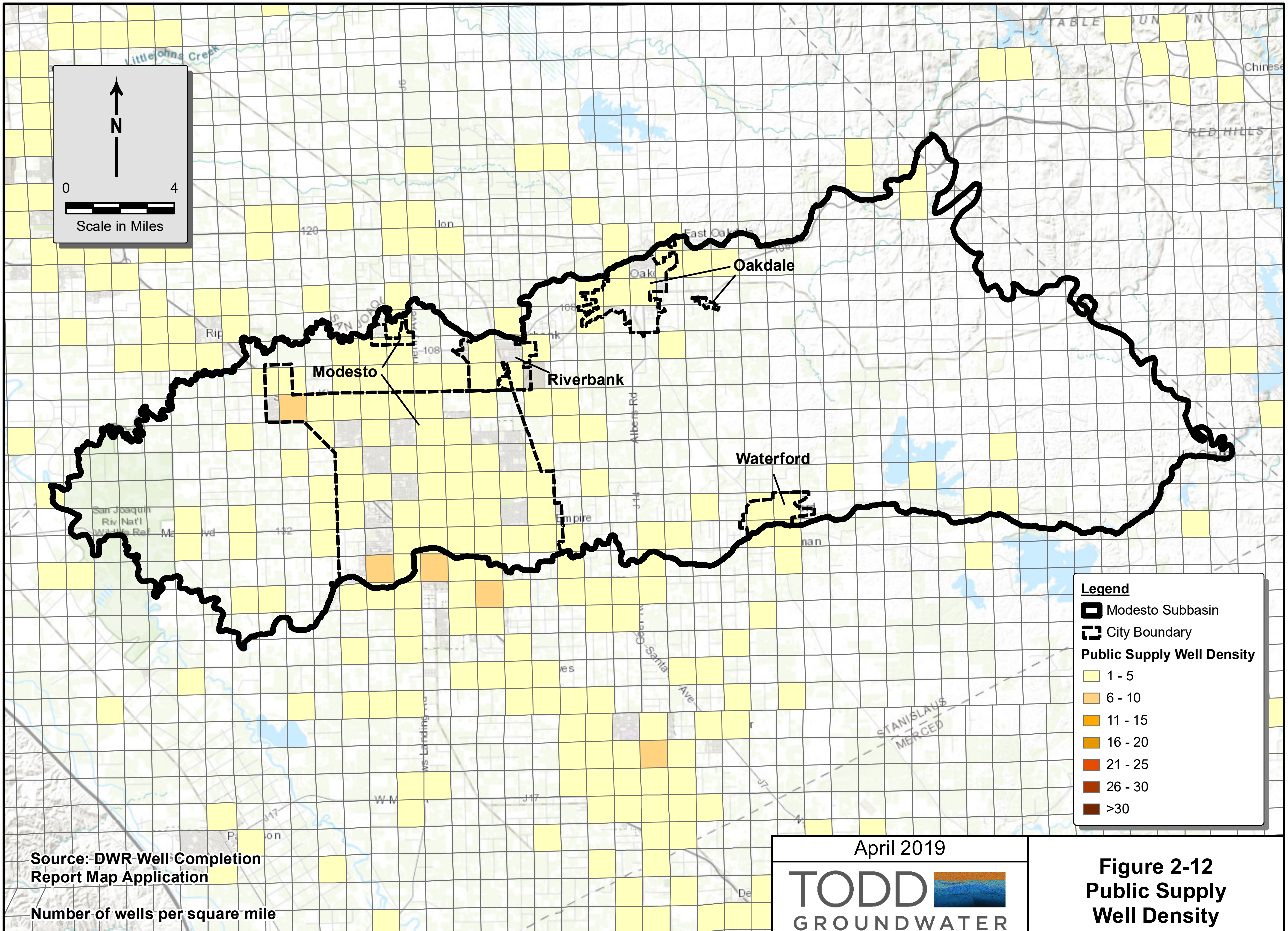


Figure 2-11
Production Well Density



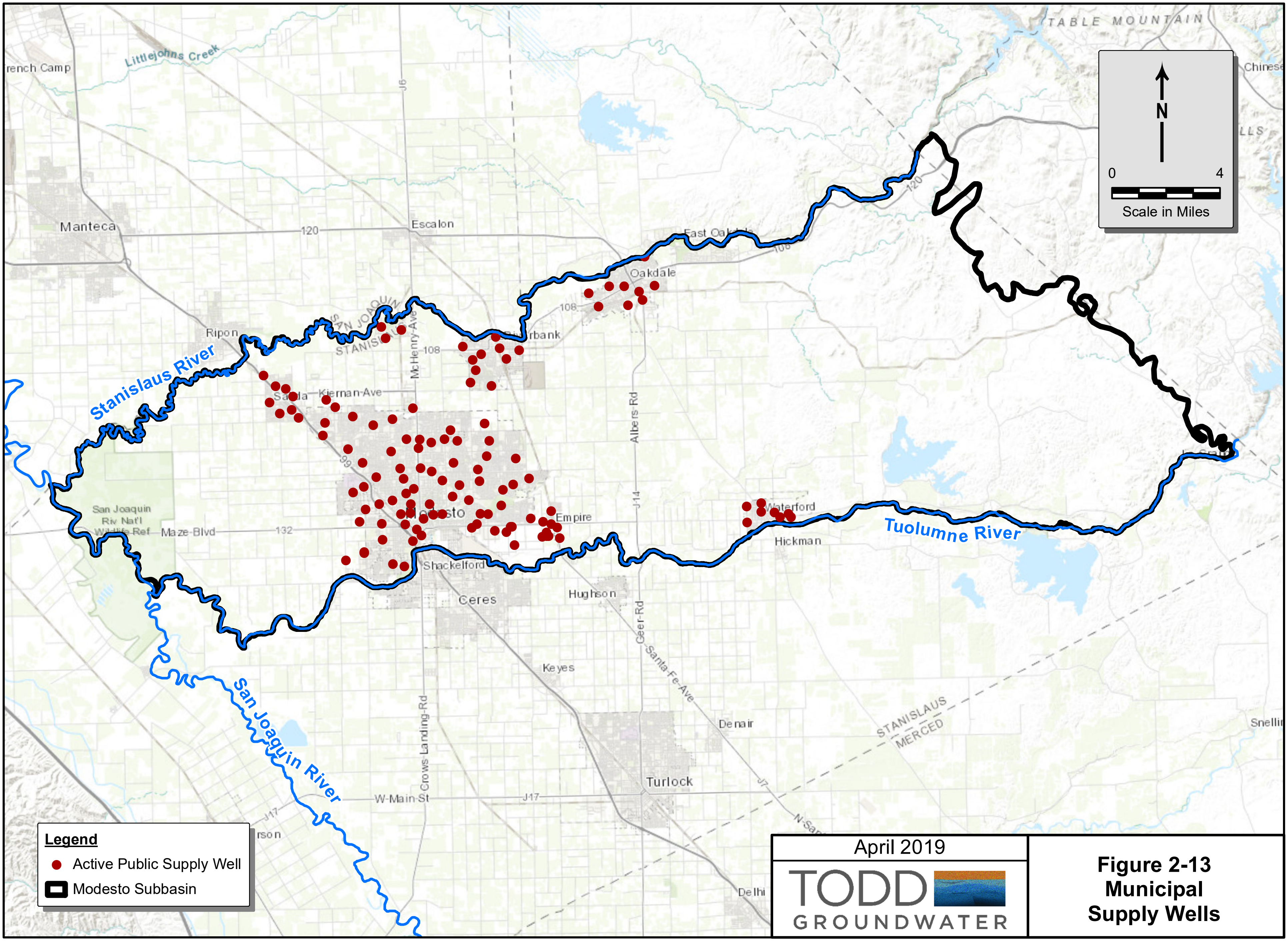
Source: DWR Well Completion Report Map Application

Number of wells per square mile

April 2019

TODD GROUNDWATER

Figure 2-12
Public Supply Well Density



TODD GROUNDWATER

Figure 2-13
Municipal Supply Wells

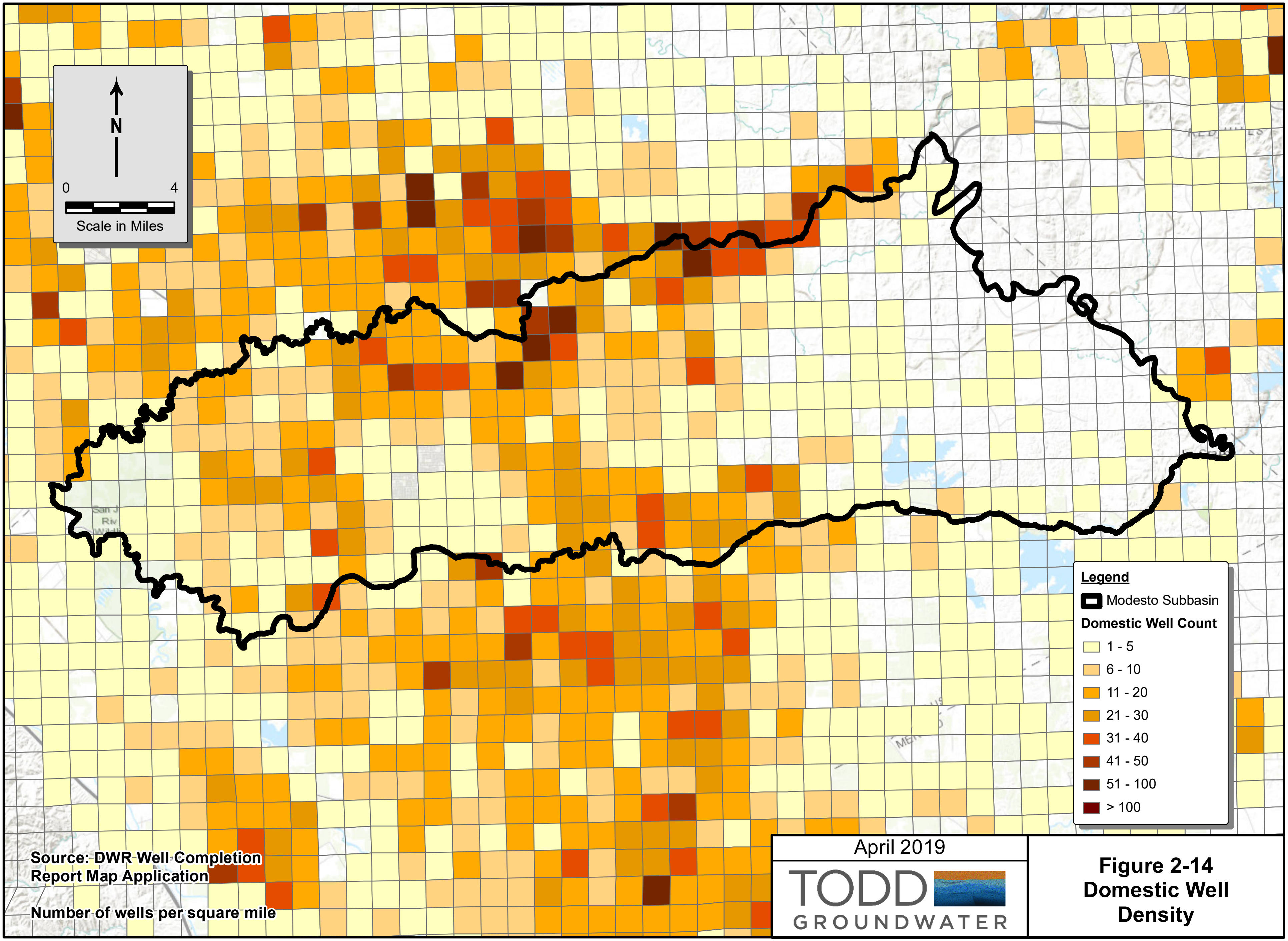
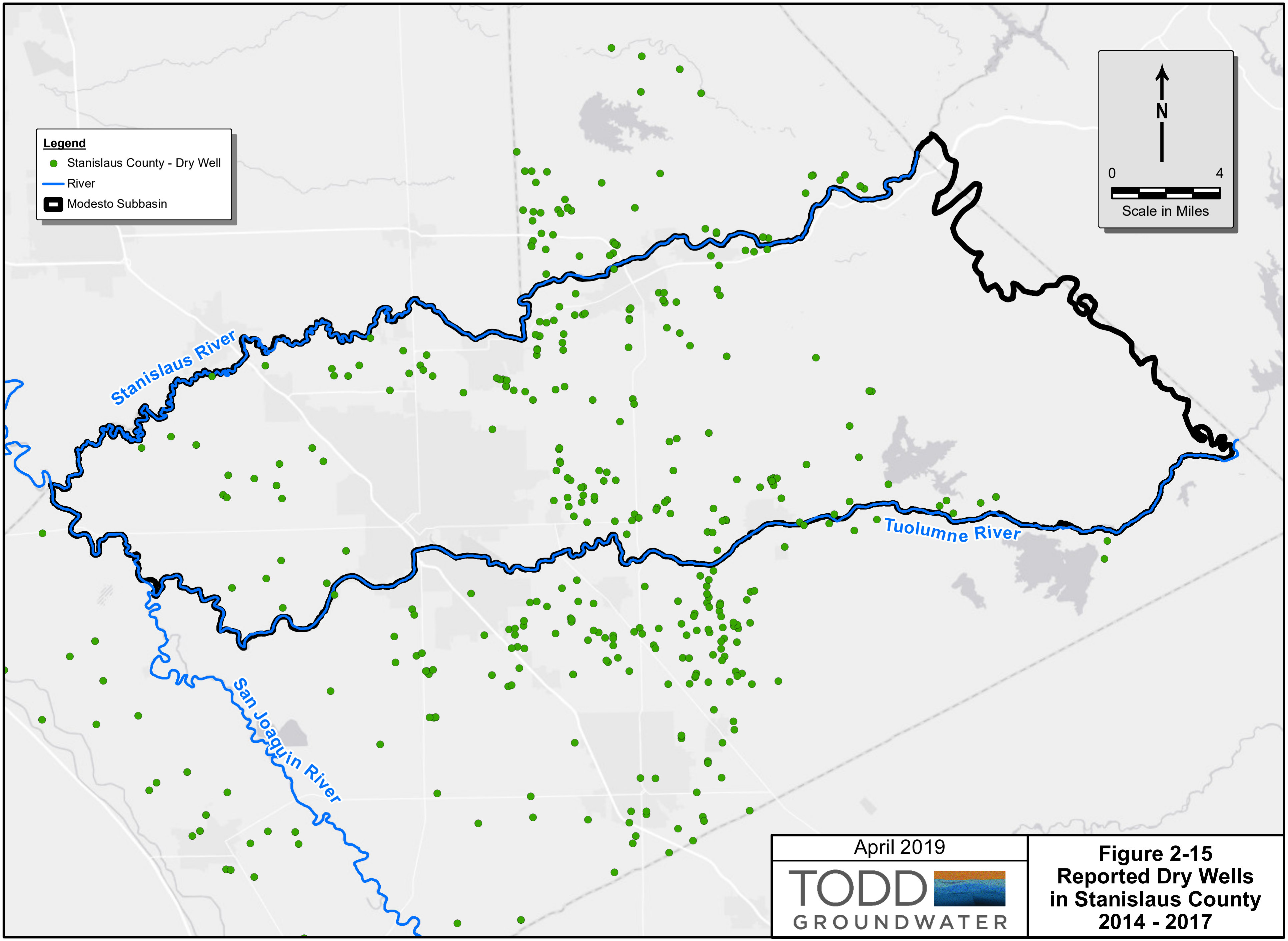


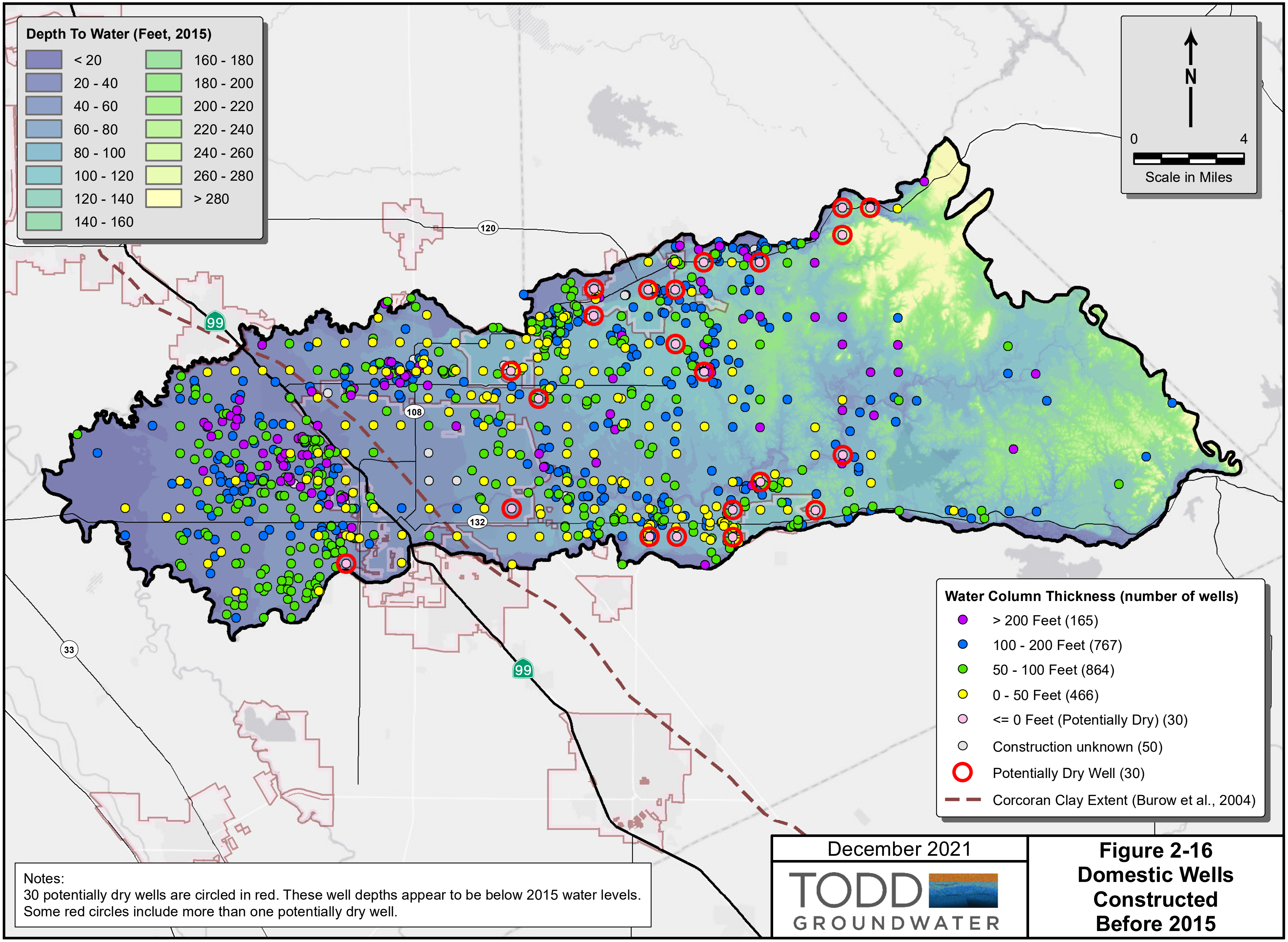
Figure 2-14 Domestic Well Density



April 2019

TODD GROUNDWATER

Figure 2-15
Reported Dry Wells in Stanislaus County 2014 - 2017

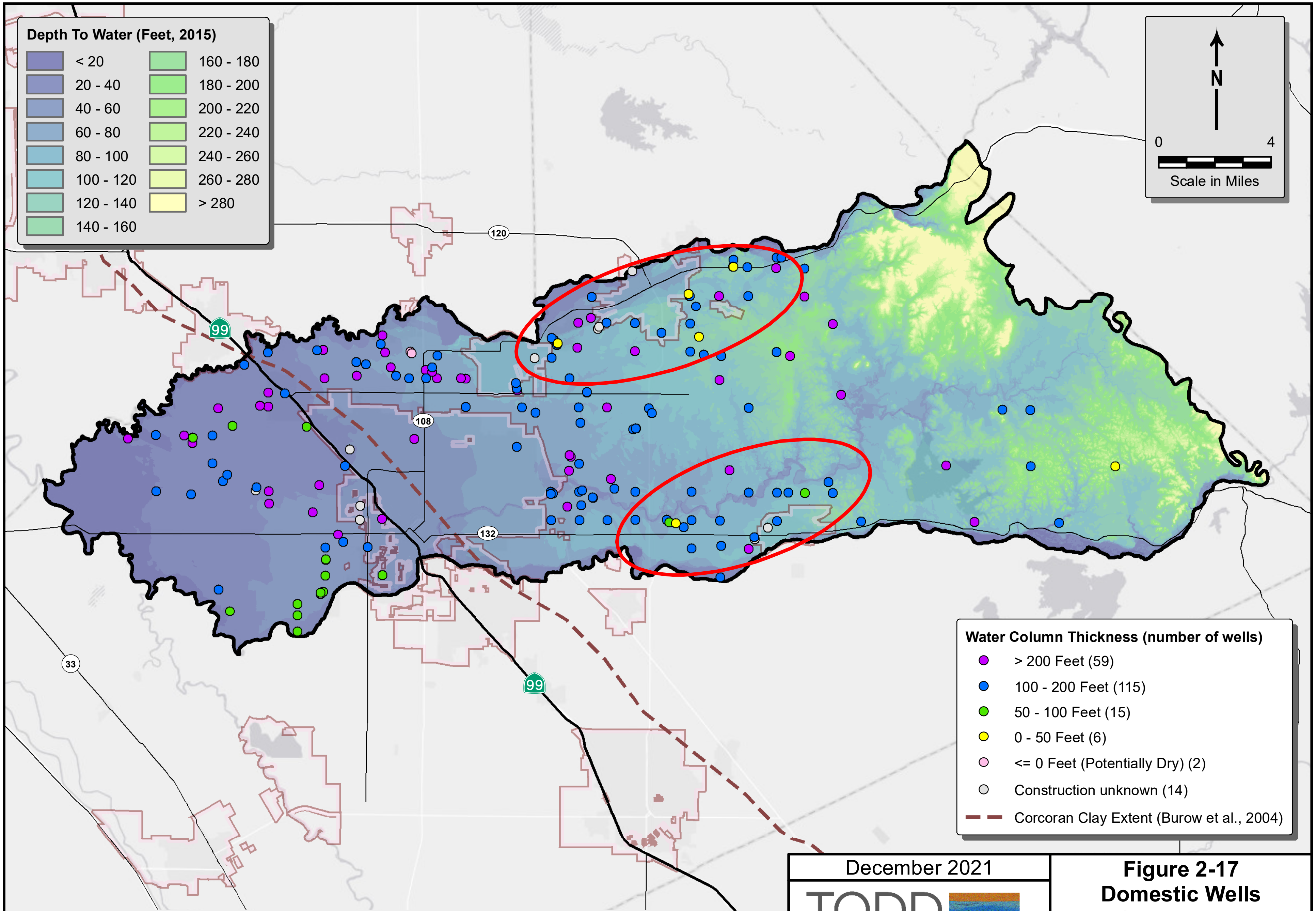


Notes:
30 potentially dry wells are circled in red. These well depths appear to be below 2015 water levels.
Some red circles include more than one potentially dry well.

December 2021

TODD GROUNDWATER

Figure 2-16
Domestic Wells Constructed Before 2015

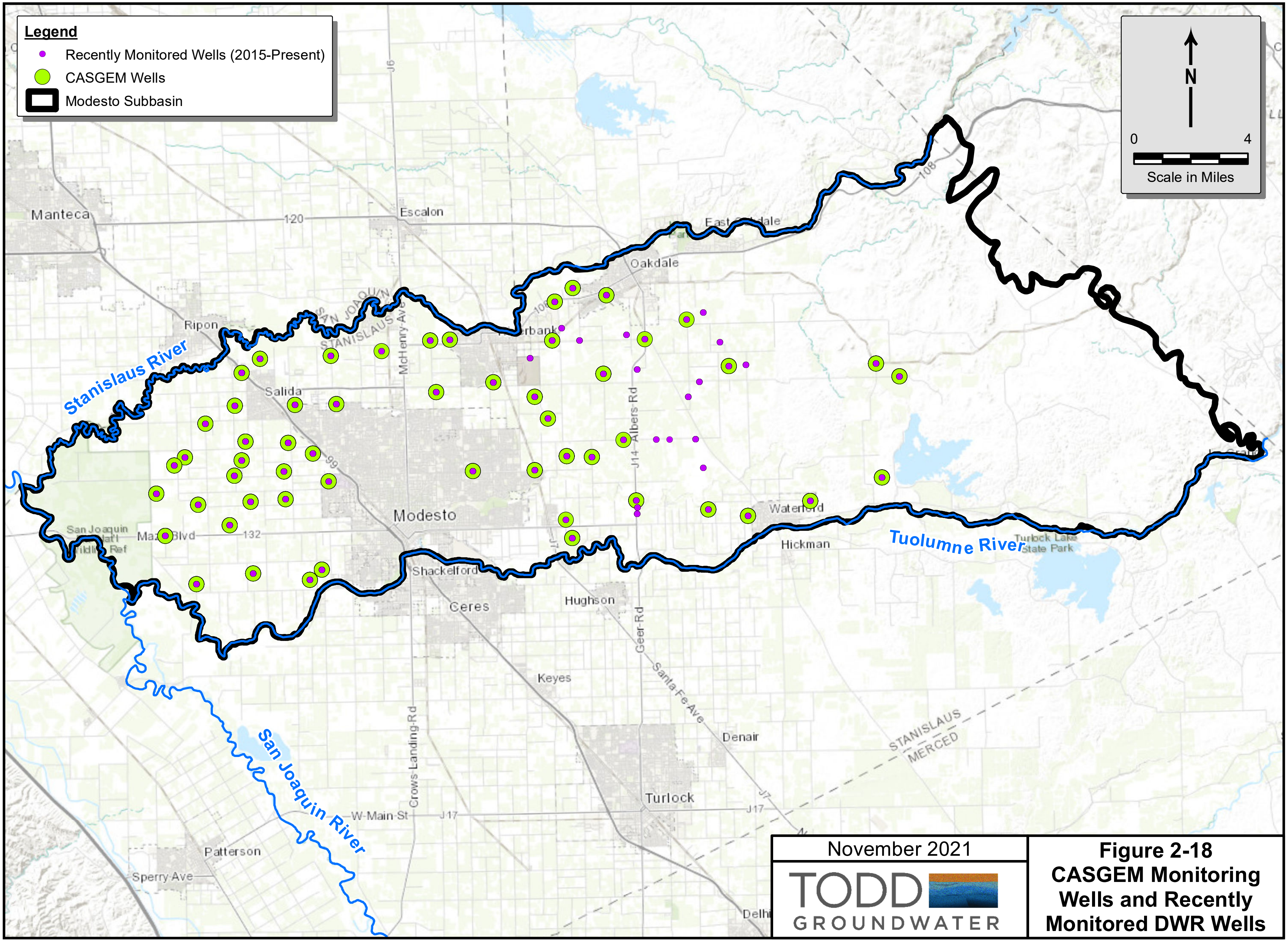


Note: Some newer wells remain vulnerable to significant declines in local areas (red circles).

December 2021

TODD GROUNDWATER

Figure 2-17
Domestic Wells Constructed Since 2015



November 2021

TODD GROUNDWATER

Figure 2-18
CASGEM Monitoring Wells and Recently Monitored DWR Wells

3. BASIN SETTING

The Modesto Subbasin of the San Joaquin Valley Groundwater Basin (DWR Basin 5-22.02) is approximately 247,000 acres (385 square miles) and located in the northern San Joaquin Valley in Stanislaus County. It is bordered by the Stanislaus River on the north, Tuolumne River on the south, San Joaquin River on the west and the foothills of the Sierra Nevada on the east. The Subbasin is categorized as high priority in DWR's 2019 Basin Prioritization (DWR, 2019a) based on its:

- number of public supply wells: 194 or 0.5 per square mile (DWR prioritization score of 4 out of 5);
- number of production wells: 4,009 or 10.5 per square mile (score of 4 out of 5);
- irrigated acreage: 119,066 acres or 311 acres per square mile, covering approximately 48 percent of the Subbasin (score of 4 out of 5);
- groundwater use: 216,522 AF or 0.88 AF per acre (score of 5 out of 5); and
- declining groundwater levels: long term hydrographs show groundwater level decline.

Although categorized as high priority, the Subbasin is not one of the 21 groundwater basins determined by DWR to be critically overdrafted[5]. To mitigate potential future overdraft and provide a foundation for sustainable groundwater management in this high priority Subbasin, the physical conditions associated with the groundwater system, referred to as the Basin Setting, are documented and described herein. The Basin Setting consists of three interrelated analyses:

1. Hydrogeologic Conceptual Model, which provides a physical description of the groundwater Subbasin including the geologic and hydrogeologic setting, basin geometry and principal aquifers.
2. Groundwater Conditions, which describes groundwater occurrence and flow, groundwater levels and quality, and interconnected surface water.
3. Water Budgets, which provide an accounting of inflows and outflows of the surface water and groundwater systems for historical, current, and future conditions.

Because the water budget analysis is relatively complex, water budgets are presented in a separate **Section 4** of this GSP. The hydrogeologic conceptual model and groundwater conditions are described in the following sections.

[5] Two adjacent subbasins, Delta-Mendota and Eastern San Joaquin, have been designated as critically overdrafted.

3.1. HYDROGEOLOGIC CONCEPTUAL MODEL

The development of the hydrogeologic conceptual model is based on an analysis of the regional geologic and structural setting, physical setting, basin boundaries, and principal aquifers and aquitards. Key building blocks of the hydrogeologic conceptual model include the development of new hydrogeologic cross sections and analyses conducted by others, including published technical studies, data, and maps, along with data provided by member agencies of the STRGBA GSA.

3.1.1. Regional Geologic and Structural Setting

The Modesto Subbasin is in the northeastern San Joaquin Valley where valley-fill sediments overlie consolidated, westward-dipping sedimentary units and basement rock of the Sierra Nevada. Older units crop out in the eastern subbasin and dip west-southwest into the San Joaquin Valley below younger units. The surface geology of the Modesto Subbasin, showing relatively older units in the east and younger units in the west, is shown on **Figure 3-1**.

The San Joaquin Valley is a large northwest-trending structural trough in the southern Central Valley, up to 200 miles long and 70 miles wide and filled with marine and continental sediments up to 6 miles thick (Burow et al., 2004). It evolved during the Cenozoic era from tectonic activity and changes in sea level and climate (Bartow, 1991). Tectonic processes included basin subsidence, uplift of the Sierra Nevada and Coast Ranges, and associated deformation (Burow et al., 2004).

Bartow (1991) divides the San Joaquin Valley into five regions based on structural style. The Modesto Subbasin is within the northern Sierran block, which extends from the Stockton arch on the north to Fresno on the south This region is the least deformed area of the San Joaquin Valley (Bartow, 1991). Deformation in this region consists mostly of a southwest tilt and minor late Cenozoic normal faulting (Bartow, 1991). The normal faulting is mostly within the foothills, a result of the valley side of the Sierra block subsiding faster than the Sierra Nevada was rising (Bartow, 1991). Faults in the foothills, east of the Subbasin, are shown on **Figure 3-1**.

Geologic units along the eastern subbasin boundary represent the oldest units in the Subbasin and include the Valley Springs Formation of Late Miocene age and the underlying Ione Formation of Middle Eocene age. These two formations are labeled Tvs and Ei on **Figure 3-1**, respectively. These consolidated units were formed from mostly non-marine sediments and represent both the eastern lateral extent and the local bottom of the groundwater basin. Jurassic-age metamorphic and volcanic rocks of the Sierra Nevada are in contact with these formations to the east and underlie them locally. In general, the eastern groundwater basin boundary is coincident with the base of the Ione Formation, which crops out along the eastern boundary (**Figure 3-1**).

The Mehrten Formation (late Miocene) crops out along a small portion of the northeastern Subbasin boundary, but primarily crops out as remnant hills in the eastern Subbasin (Tm on

Figure 3-1). This consolidated unit includes fluvial deposits (sandstone and conglomerates) consisting of eroded andesite and other rocks associated with volcanic eruptions in the adjacent Sierra Nevada. The re-working of andesite has produced distinctive black sands, which are locally well-sorted with relatively high permeability. These zones represent the primary aquifer system in the eastern Subbasin, especially in areas where the younger overlying sediments (discussed below) are unsaturated.

The younger geologic units in the Subbasin include alluvial sediments of Neogene (Pliocene) and Quaternary (Pleistocene and Holocene) age, including Quaternary alluvium deposited along the Stanislaus and Tuolumne rivers (shown in light yellow and labeled Q on **Figure 3-1**) and other alluvial/riverbank/terrace deposits. These additional deposits are also identified on **Figure 3-1** where they occur at the surface, and are listed below from oldest to youngest:

- Laguna Formation (Pl) of Pliocene age,
- Turlock Lake Formation (Qtl) of Early Pleistocene age,
- Riverbank Formation (Qr) of Middle Pleistocene age and
- Modesto Formation (Qm) of Late Pleistocene age.

The Corcoran Clay represents a regional aquitard in the upper part of the Turlock Lake Formation. The Corcoran Clay is a laterally-extensive clay unit deposited by an ancient lake that covers over 4,000 square miles in the San Joaquin Valley. It occurs beneath the western Subbasin and pinches out in the subsurface near Highway 99. The Corcoran Clay does not crop out and, as such, does not appear on **Figure 3-1**.

The Modesto Formation (Qm) is the primary surficial geologic unit in the western Subbasin. Younger alluvium (Q) is present along the Stanislaus and Tuolumne rivers and the Dos Palos Alluvium (Qdp) is present along the San Joaquin River.

The younger geologic units, including the Modesto Formation (Qm), Turlock Lake Formation (Qtl), Riverbank Formation (Qr), and Mehrten Formation (Tm) have been associated with high quality groundwater as characterized by total dissolved solids (TDS). The underlying older units of the Valley Springs Formation (Tvs) and the Ione Formation (Ei) have been associated with higher mineral and salt content. The hydrogeology and groundwater conditions in the Modesto Subbasin aquifer units are described in more detail in subsequent sections of the Basin Setting.

3.1.2. Physical Setting

3.1.2.1. Precipitation and Average Hydrologic Conditions

The Modesto Subbasin is characterized as a Mediterranean-type climate with hot, dry summers and cool, wet winters, with most of the precipitation occurring between November and March.

Figure 3-2 illustrates annual precipitation in the Modesto Subbasin on a water year (WY) basis from WY 1990 through 2017 as measured at the Modesto Irrigation District weather station in Modesto. The chart on **Figure 3-2** illustrates the variability in precipitation, from approximately 7.0 inches in WY 2014 to more than 24 inches in WY 1998. The long-term average rainfall in the Modesto Subbasin is about 12.6 inches per year based on data from 1961 – 2015. A Study Period from WY 1991 through WY 2015 has been selected for GSP analyses that is representative of average hydrologic conditions. The Study Period also overlaps the time period of a regional groundwater model being develop for the GSP and is associated with a relatively large amount of available data. As indicated on **Figure 3-2**, the average annual precipitation during the Study Period is 12.8 inches per year, which is within two percent of the long-term average.

Annual precipitation data on **Figure 3-2** is color-coded based on water year type using the San Joaquin Valley WY hydrologic classification indices (CDEC, 2018): wet (blue), above normal (green), below normal (brown), dry (yellow), and critically dry (red). The San Joaquin Valley WY indices do not always correlate directly with precipitation measured in the Modesto Subbasin because the indices are based on runoff from several rivers, including the Stanislaus, Tuolumne, Merced, and San Joaquin Rivers. However, the indices are a useful benchmark for establishing consistent water year types across numerous subbasins in the San Joaquin Valley.

Figure 3-2 shows that the wettest water years, with precipitation above 15 inches per year, occurred in water years 1993, 1995, 1996, 1998, 2000, 2005, 2010, 2011, 2016 and 2017 (all of which are designated as wet or above normal water year types, except water year 2016). The driest years, with precipitation less than 9 inches per year, occurred in water years 1990, 1991, 2004, 2007, 2009 and 2014 (all of which are designated as critically dry or dry water year types, except 2009).

Data from the PRISM Climate Group were compiled to evaluate spatial variability of precipitation across the Subbasin. These data are based on application of an interpolation model, *Parameter-elevation Relationships on Independent Slopes Model* (PRISM), to detailed datasets from 1895 to present as developed by Oregon State University and the U.S. Department of Agriculture. A PRISM isohyetal map showing 30-year average annual precipitation from 1981 – 2010 across the Subbasin is presented on **Figure 3-3**. This period is slightly wetter than the long-term average but provides the most complete data set for evaluation across the Subbasin.

As shown on **Figure 3-3**, the average annual precipitation varies across the Subbasin, increasing with topography from west to east. Average precipitation ranges from approximately 11 inches per year along the western Subbasin boundary to approximately 21 inches per year along the eastern boundary.

3.1.2.2. Topography

The Modesto Subbasin extends from the Sierra Nevada foothills to the San Joaquin Valley floor. Ground surface elevations dip to the west, from approximately 650 feet mean sea level (msl) in the foothills to less than 20 feet msl along the San Joaquin River. A Digital Elevation Map (DEM) of Subbasin topography based on the United States Geological Society

(USGS) National Elevation Dataset (NED) is provided on **Figure 3-4** and illustrates these ground surface elevations.

The western Subbasin is relatively flat. Ground surface elevations rise from about 20 feet msl along the San Joaquin River to about 200 feet msl near the center of the Subbasin. The topography in the eastern Subbasin is hilly and dissected by small drainages and by Dry Creek, a larger drainage and tributary of the Tuolumne River (**Figure 3-4**). The topography in the eastern Subbasin represents the transition from San Joaquin Valley floor to the Sierra Nevada foothills.

To better illustrate the ground surface elevations, four topographic profiles were generated from the NED. These profiles are illustrated on **Figure 3-5**. Profile 1-1' is along the center of the Subbasin from southwest to northeast and profiles 2-2', 3-3' and 4-4' extend from northwest to southeast across the Subbasin in the western, central and eastern Subbasin.

Profile 1-1' illustrates the rise in ground surface elevations from the San Joaquin River to the eastern Subbasin. Ground surface elevations range from about 20 to 500 feet msl along this profile. This profile illustrates the relatively gradual and uniform elevation gain in the western Subbasin and the hilly, dissected terrain in the east.

Profile 2-2' illustrates the Stanislaus and Tuolumne river channels and the flat topography between these channels in the western Subbasin. The ground surface elevations along this profile are relatively flat, sloping from approximately 100 feet msl near the Stanislaus River to approximately 90 feet msl along the Tuolumne River. On this profile, the Stanislaus River channel is wider and shallower than the Tuolumne River channel.

Profile 3-3' illustrates the ground surface elevations in the central Subbasin On this profile, the ground surface slopes from about 170 feet msl along the Stanislaus River to approximately 135 feet msl along Dry Creek. The ground surface between Dry Creek and the Tuolumne River is relatively flat. The topography along this profile is more variable, marking the transition from the flat western Subbasin to the hilly eastern Subbasin. On this profile, the Stanislaus River channel is wider and deeper than the Tuolumne River channel.

Profile 4-4' illustrates the higher elevations and more topographic relief in the eastern Subbasin. The dissected nature of the eastern hills is evident on the northern portion of the profile. Ground surface elevations along this profile vary from approximately 200 feet msl near the Stanislaus River to almost 500 feet msl between the Stanislaus River and Dry Creek. Ground surface elevations decline to about 200 feet msl at Dry Creek and remain relatively flat between Dry Creek and the Tuolumne River. On this profile, the Tuolumne River channel is wider and deeper than the Stanislaus River channel.

3.1.2.3. Soils

Soil textures from the Soil Survey Geographic (SSURGO) database for Stanislaus County, as developed by the U.S. Department of Agriculture Natural Resources Conservation Service (USDA), are illustrated on **Figure 3-6**. Soil textures are color-coded and listed in the legend by increasing grain size (texture). Most of the Subbasin is covered by silty sands (brown shading), clayey sands (dark blue shading), and clayey, silty sands (grayish blue shading). There are coarser-grained soils along the Stanislaus and Tuolumne rivers in the form of gravel and sand (red shading) along the upstream reaches and poorly graded sand and silt (yellow shading) along the middle reaches. The eastern Subbasin is dominated by clay (black shading), clay and silt (brown shading) and coarser-grained silty gravels (pink shading). Fine grained soils are present along the San Joaquin River in the form of clayey and silty sands (blue shading) and clay and silt (dark brown shading). The clay-rich soils in the west along the San Joaquin River limit infiltration and create localized perched conditions.

The USDA soil data shows that the eastern Subbasin is widely covered by low permeability surficial zones, generally referred to as "hardpan." These are considered restrictive layers in that they restrict or prevent surface water infiltration and serve to reduce groundwater recharge from precipitation or streamflow. The surficial occurrence of these materials is illustrated on **Figure 3-6** by cross hatching. Except for small areas near the Stanislaus and Tuolumne rivers and Dry Creek, most of the eastern Subbasin is covered by restrictive layers.

3.1.2.4. Surface Water Bodies and Water Conveyance

The Modesto Subbasin is bounded by rivers on three sides: the Stanislaus River on the north, the Tuolumne River on the south and the San Joaquin River on the west. The Modesto Subbasin is also internally drained by numerous small drainageways, the largest of which is Dry Creek. The Stanislaus and Tuolumne rivers originate in the Sierra Nevada and are tributaries of the San Joaquin River.

The Stanislaus River drains a watershed of about 1,051 square miles to the confluence of the San Joaquin River near Vernalis (Burow et al., 2004). Streamflow on the Stanislaus River ranges between 100 cubic feet per second (cfs) and 10,000 cfs (Phillips et al., 2015). The Tuolumne River drains a watershed of approximately 1,635 square miles and flows to the confluence of the San Joaquin River near Grayson (Burow et al., 2004). Typical average monthly streamflow in the Tuolumne River ranges from 100 to 400 cfs during low streamflow to more than 1,000 cfs, and sometimes more than 10,000 cfs, during high streamflow (Phillips et al., 2015).

The San Joaquin River is the primary drainage for the northern San Joaquin Valley and flows north into the Sacramento-San Joaquin River Delta and San Francisco Bay. Streamflow on the San Joaquin River from 1960 to 2004 ranged from less than 100 cfs upstream of the Merced River to more than 40,000 cfs downstream of the Stanislaus River (Phillips et al., 2015).

Water is diverted from both the Stanislaus and Tuolumne rivers for irrigation and municipal supply within the Subbasin. OID diverts water from the Stanislaus River at the Goodwin Dam into the South Main Canal, which serves agricultural irrigation water throughout OID within the Modesto Subbasin (Davids Engineering, Inc, 2016). Water flows from these canals through a system of unlined earthen ditches, concrete-lined canals, low-head pipelines and gates. Irrigation tailwater is reclaimed by OID using reclamation pumps or discharged to other landowners or irrigation districts via drainage canals. MID diverts water from the Tuolumne River at the La Grange Diversion Dam into the MID Upper Main Canal and onto the Modesto Reservoir (Provost & Pritchard, 2015). Most of the diverted water is used for irrigation, but approximately 20 percent is treated at the Modesto Regional Water Treatment Plan and delivered to the City of Modesto. MID delivers water through a network of lined and unlined canals, pipelines and drains.

3.1.3. Basin Boundaries

In order to define the subsurface lateral and bottom boundaries of the Modesto Subbasin, numerous features of the Subbasin are considered including the surficial river boundaries, the physical contact between the alluvial aquifers and basement rocks of the Sierra Nevada, and groundwater quality changes with depth. These considerations are discussed in the following sections.

3.1.3.1. Lateral Boundaries

Although the surficial river boundaries along the Stanislaus, Tuolumne, and San Joaquin rivers do not represent the extent of the Subbasin aquifers in the subsurface, they do represent important institutional boundaries and authorities for groundwater management. Accordingly, these boundaries are projected vertically in the subsurface to define the Subbasin lateral boundaries for groundwater management purposes.

The eastern Subbasin boundary generally follows the contact of Subbasin sedimentary deposits with the crystalline basement rocks of the Sierra Nevada, specifically the Jurassic-age Gopher Ridge Volcanics (Jgo) **Figure 3-1**. The eastern Subbasin boundary is primarily coincident with the base of the Ione Formation (Ei), which crops out along the boundary and overlies the crystalline basement rocks. The extent of this lateral boundary contact into the subsurface is not known with certainty but is assumed to be relatively steep. The northeastern Subbasin boundary is coincident with outcrops of both the Mehrten Formation (Tm) and the Table Mountain Latite (Mtm) volcanic rocks. Increasing salinity with depth may control the extent of this lateral boundary as discussed in more detail below.

3.1.3.2. Basin Bottom

The sedimentary units of the Modesto Subbasin likely extend several thousand feet into the subsurface. Therefore, using the contact between these units and crystalline basement rocks may not be appropriate for defining a basin bottom for management purposes. It has been well-documented by USGS (Page, 1973) and others that groundwater salinity in the San Joaquin Valley increases significantly with depth, often creating an operational bottom of the basin. The base of fresh water has been mapped by USGS and used in Central Valley subbasins to define the basin bottom. This map has been incorporated and extended by DWR in support of its regional central valley model C2VSim, the same model being revised and applied for the Modesto Subbasin GSP. Because the analysis for C2VSim provides a base of fresh water over the entire Subbasin, this model surface has been selected as a tentative basin bottom for GSP management purposes. Elevations defining that surface are reproduced on **Figure 3-7** and explained in more detail below.

A map on the base of fresh water was first developed on a San Joaquin Valley-wide basis by the USGS in 1973 (Page, 1973). The map was based on a specific conductance value of 3,000 micromohs per centimeter (umhos/cm), which is equivalent to a TDS range of about 2,000 to 2,880 milligrams per liter (mg/L), or parts per million (ppm), varying with temperature and differences in water chemistry. The map was highly detailed in some areas of the valley but only sparsely controlled in others, including the Modesto Subbasin. The few contours from the Page (1973) map that are near or within the Modesto Subbasin are reproduced in red on **Figure 3-7**. These contours are along the western Subbasin boundary and indicate that the elevation of the base of fresh water is between -400 and -600 feet mean sea level[6] (ft msl). The elevation of the base of fresh water continues to decline west of the western Subbasin boundary to an elevation of -800 feet msl.

Figure 3-8 illustrates the layers of the C2VSim model. As shown, the model is composed of five layers representing four aquifer layers and one aquitard: the unconfined aquifer (L1), Corcoran Clay (A2), primary shallow pumping layer (L2), deeper pumping layer (L3), and saline aquifer (L4). The base of the deeper pumping layer (L3) represents the base of fresh water. **Figure 3-7** shows elevation contours of the base of fresh water (base of L3) from C2VSim. The Page (1973) contours along the western Subbasin boundary are about 100 to 300 feet higher than in C2VSim. However, the elevation of the base of fresh water used in the C2VSim model represents the best available information for the base of fresh water and the operational bottom of the Subbasin.

As indicated on **Figure 3-7**, this Subbasin operational bottom is an undulating surface with the deepest portion occurring in the central Subbasin. Along the eastern Subbasin boundary, the bottom of the Subbasin is at approximately -600 feet msl. It rises slightly and then dips westward to an elevation of approximately -1,000 ft msl in the central Subbasin. The Subbasin bottom then gradually rises to an elevation of approximately -700 ft msl along the western Subbasin boundary.

3.1.3.3. Areas of Recharge and Discharge

Prior to groundwater use in the Modesto Subbasin, groundwater was recharged primarily in the eastern Subbasin where the Stanislaus and Tuolumne rivers entered the Subbasin. Groundwater flowed from these areas to the west (Burow et al., 2004). Artesian conditions occurred in the western Subbasin from upward movement of groundwater from the confined aquifer (Burow et al., 2004).

Since groundwater use began, deep percolation from irrigation is the primary source of recharge to the Subbasin and pumping (municipal, domestic, agricultural and drainage) is the primary source of discharge (Burow et al., 2004). Currently, there is apparent

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[6] Elevations represented as negative numbers in this GSP represent elevations below mean sea level and are denoted as -400 ft msl, for example.

downward flow of groundwater in the western Subbasin where artesian conditions were historically documented. Downward gradients are apparently created from pumping beneath the Corcoran Clay, including areas on the west side of the San Joaquin River (Burow et al., 2004).

Other sources of recharge include deep percolation of precipitation, underflow from the foothills, Modesto Reservoir leakage, leakage from unlined canals, and seepage from rivers and streams. Modesto Reservoir leakage was estimated by Modesto Irrigation District to be approximately 24,000 acre-feet per year (Phillips et al., 2015). Other sources of discharge include flow into the downstream (western) reaches of the Stanislaus and Tuolumne rivers, flow into the San Joaquin River, underflow beneath the western Subbasin boundary, flow out of subsurface drains and consumption by riparian vegetation.

3.1.4. Principal Aquifers and Aquitards

As mentioned previously, the Corcoran Clay represents the primary aquitard in the Subbasin and separates the alluvial aquifers above and below the clay, creating confined conditions at depth in the western Subbasin where the Corcoran Clay occurs. The Corcoran Clay does not extend into the eastern Subbasin, and no additional regional aquitard has been defined in this area. Accordingly, the Corcoran Clay defines two aquifer systems in the western Subbasin, but aquifers are more hydraulically connected in the eastern Subbasin where the regional clay is absent.

Recognizing these conditions, , three principal aquifers are defined in the Subbasin for the purposes of this GSP and future management of groundwater under SGMA. These three aquifers are defined as follows:

- Western Upper Principal Aquifer – unconfined aquifer above the Corcoran Clay.
- Western Lower Principal Aquifer – confined aquifer below the Corcoran Clay.
- Eastern Principal Aquifer – unconfined to semi-confined aquifer system east of the extent of the Corcoran Clay.

The definition of these three Principal Aquifers is consistent with the Principal Aquifer definitions for the Turlock Subbasin GSP, allowing for consistent interpretations along the shared Tuolumne River boundary. The Principal Aquifers in the Eastern San Joaquin Subbasin are different because the Corcoran Clay is only found in the southwest corner of the Subbasin. The Eastern San Joaquin GSP defines one principal aquifer the provides water from three production zones: a Shallow Zone, Intermediate Zone and Deep Zone.

The Western Upper Principal Aquifer and the Eastern Principal Aquifer are composed of Plio-Pleistocene- to Holocene- age alluvial sediments of the Modesto, Riverbank, Turlock Lake formations, and younger alluvium (where saturated). Not all of these alluvial sediments are present everywhere within the Eastern Principal Aquifer due to erosion or non-deposition. The base of the Western Principal Aquifer is the Corcoran Clay. The Eastern

Principal Aquifer (east of the Corcoran Clay) also includes the Laguna, Mehrten and older formations that extend to the operational bottom of the Subbasin (i.e., base of fresh water).

The Modesto, Riverbank and Turlock Lake formations form sequences of overlapping terrace and alluvial fan deposits in response to cycles of alluviation, soil formation and channel incision influenced by changes in climate and glacial stages in the Sierra Nevada (Jurgens et al., 2008). The Modesto Formation forms a thin veneer at the surface, approximately 20 feet thick (Jurgens et al., 2008) throughout most of the western Subbasin (Burow et al., 2004). The Modesto Formation is composed of fluvially-deposited arkosic sand, gravel and silt and its lithology is similar to the underlying Riverbank, Turlock Lake, and Laguna formations (Burow et al., 2004). Where saturated, the Modesto Formation yields moderate amounts of water (Burow et al., 2004).

The Riverbank Formation is also composed of fluvial arkosic sand, gravel and silt and varies in thickness from approximately 150 to 250 feet (Burow et al., 2004). Its depositional dip is slightly steeper than the Modesto Formation, resulting in westward thickening of the deposits. The formation yields moderate quantities of water.

The Turlock Lake Formation is the most developed aquifer in the western Subbasin, both within the Western Upper Principal Aquifer and the Eastern Principal Aquifer, yielding up to 2,000 gallons per minute (gpm) from gravel and sand units (Burow et al., 2004). Similar to the Modesto and Riverbank formations, the Turlock Lake Formation is composed of a coarsening-upward sequence of silt, arkosic sand, and gravel layers (Burow et al., 2004).

The Western Lower Principal Aquifer consists of the Turlock Lake Formation below the Corcoran Clay, the Laguna Formation and the underlying Mehrten Formation. Both the Western Lower Principal Aquifer and the Eastern Principal Aquifer extend to the base of fresh water, which is located within or below the Mehrten Formation, respectively.

The Laguna Formation is composed of alluvial deposits of gravel, sand, and silt in at least two coarsening-upwards sequences (Burow et al., 2004). Laguna Formation sediments are more consolidated than the younger overlying formations (Jurgens et al., 2008) and yield variable amounts of water (Burow et al., 2004). The Laguna Formation is commonly mapped as part of the Turlock Lake Formation in the Modesto area (Burow et al., 2004). The Laguna Formation is not clearly identifiable from adjacent units in areas to the east where it crops out at the surface (Burow et al., 2004).

USGS indicates that the Eastern Principal Aquifer is unconfined and becomes semi-confined with depth due to numerous discontinuous clay lenses and extensive paleosols (Burow et al., 2004). In addition, the Mehrten Formation is more consolidated than the overlying formations and the sand beds are generally thin, so the degree of hydraulic connection between the Mehrten and overlying deposits is not well understood (Burow et al., 2004). However, many wells in the Eastern Principal Aquifer are screened in both the Mehrten Formation and overlying younger formations, where present, providing for some hydraulic connection in wells. Further, these wells provide average water levels across these zones and would represent a combined aquifer system for managing water levels. In the absence of a defined aquitard, it is likely that there is hydraulic connection among the formations, especially where the shallow formations thin to the east.

The Corcoran Clay is defined in this GSP as the only principal aquitard, which delineates the base of the Western Upper Principal Aquifer and the top of the Western Lower Principal Aquifer. The eastern edge of the Corcoran Clay is oriented from northwest to southeast, approximately parallel to the axis of the Valley (Burow et al., 2004). Where present, the blue lacustrine Corcoran Clay is up to 100 feet thick and occurs at depths ranging from 80 to 210 feet (Burow et al., 2004). The Corcoran Clay is generally well sorted clay to silty clay but becomes siltier and grades into coarser textures along the edges (Burow et al., 2004).

The Corcoran Clay surface from the C2VSim Model within the Modesto Subbasin was replaced with the Corcoran Clay surface from the USGS MERSTAN model (Phillips et al., 2015). During analysis for this GSP, it was discovered that the top of the Corcoran Clay surface from C2VSim suggested a mounded area in the western Subbasin where the top of the clay was higher than anticipated and not supported by well logs or USGS texture data. This anomaly was discussed with DWR staff, who supported revision of the surface in the model. The Corcoran Clay surface used in the USGS MERSTAN model (Phillips et al., 2015) is based on USGS hydrogeologic characterization of the Modesto Area (Burow et al., 2004) and represents the most detailed mapping of the Corcoran Clay in the Modesto Subbasin.

The elevation contours of the top and base of the revised Corcoran Clay surface within the Modesto Subbasin is shown on **Figures 3-9 and 3-10**, respectively. The Corcoran Clay generally dips to the west, with some irregularities. The eastern edge of the top of the Corcoran Clay slopes from an elevation of approximately -70 ft msl along the southern Subbasin boundary to -110 ft msl along the northern Subbasin boundary. The top of the Corcoran Clay is deepest in the northwestern Subbasin, at an elevation of approximately -210 ft msl. The elevation contours of the base of the Corcoran Clay generally mimic the top surface, ranging in elevation from approximately -120 to -140 ft msl along its eastern boundary to -260 ft msl in the northwestern Subbasin.

3.1.4.1. Cross Section Development

Five hydrogeologic cross sections (A through E) were developed to illustrate the hydrostratigraphy of the principal aquifers in the Modesto Subbasin, with a focus on aquifer textures and geometry. Cross section locations are shown on **Figures 3-11**. Cross section A-A’ extends from southwest to northeast along the length of the Subbasin, cross sections B-B’, C-C’, and D-D’ are perpendicular to A-A’, oriented northwest to southeast. Cross section E-E’ is a local cross section parallel to A-A’ in the vicinity of Oakdale and along the Stanislaus River.

Cross sections were developed based on USGS texture data, DWR well completion reports, California Department of Oil, Gas and Geothermal Resources (DOGGR) geophysical logs, and localized cross sections in the City of Modesto as part of a previous study (Todd, 2016). Cross sections are presented on **Figures 3-12** through **3-18**.

The cross sections present generalized interpretations of coarse-grained (sands and gravels) and fine-grained (silts and clays) textures based on data from the USGS and DWR Well Completion Reports, along with interpretations of specific formations including the Corcoran Clay and Mehrten Formation. **Figure 3-11** shows the cross section locations, wells that were used to construct the cross sections (red dots), and the wells in the USGS texture database (black dots). Most of the cross section texture data are from wells in the USGS texture database (red dots with black dots). DWR Well Completion Reports were used in areas where USGS texture data were not available (red dots without black dots). In addition, geophysical logs from deep oil and gas wells used for cross section development are shown as green dots. **Figure 3-11** also shows the Corcoran Clay extent defined by the USGS (Burow et al., 2004). Ground surface elevations shown on the cross sections were generated from the National Elevation Dataset (NED, 10m) developed by the USGS, as illustrated on **Figure 3-4**.

The texture data were developed by the USGS for a hydrogeologic investigation (Burow et al., 2004) and incorporated into the USGS MERSTAN groundwater flow model (Phillips, et al., 2015). As part of the hydrogeologic investigation (Burow et al., 2004), the USGS reviewed over 10,000 well logs in the region and compiled a texture database using approximately 3,500 of these logs. There are approximately 900 wells in the Modesto Subbasin that are in the texture database. As illustrated on **Figure 3-11**, the USGS texture data does not extend into the eastern Subbasin because the MERSTAN model does not extend east of the Modesto Reservoir.

The USGS used a binary texture classification of either "coarse grained" (100 percent coarse) or "fine grained" (0 percent coarse) to categorize each interval on the well logs. Coarse-grained texture was defined as consisting primarily of sand or gravel while fine grained texture was defined as consisting primarily of silt or clay (Burow et al., 2004). Once this binary texture classification was complete, the coarse-grained percentage was averaged at 1-meter intervals along the depth of the well. This simplification of the lithology on a well basis allows identification of regions and/or depths of the groundwater basin that contain higher percentages of sand-rich zones, likely representing more permeable aquifers and large quantities of groundwater in storage.

The cross sections were created using the ESRI ArcHydro module for ArcGIS. The ArcHydro module allows import and three-dimensional plotting of geologic data from boreholes and topological surfaces. ArcHydro analysis tools include projection of borehole and surface data along cross-sections at selected orientations for analysis and geologic correlation.

DWR Well Completion Reports were available for most USGS texture database wells on the cross sections. The lithologic descriptions on the Well Completion Reports were used to define marker beds, such as black sands (Mehrten Formation) or blue clays (Corcoran Clay). The Well Completion Reports were also used to identify the screened intervals in the wells.

Where USGS texture data were not available, Well Completion Reports were used to interpret the lithology. Without the binary method used by USGS, the texture categories from the Well Completion Reports were defined on the cross sections at the same depth and thickness for which they were described on the Well Completion Reports. In this manner, the texture detail on each Well Completion Report is preserved. In areas with several closely-spaced wells, only higher-quality Well Completion Reports (i.e., most detailed data) were used.

The cross sections honor the texture information from the USGS and Well Completion Reports at well locations. Between well locations, the coarse-grained units were generally correlated based on elevation and thickness. Thick sand lenses were assumed to be more continuous and more likely to be interconnected than thinner sand lenses. The surficial geologic map (Wagner et al., 1991) presented as **Figure 3-1** was used to estimate surface contacts of the geologic formations on the cross sections when appropriate.

3.1.4.2. Cross Sections

Interpretations and observations for each of the five cross sections are described below.

Cross Section A-A'

Cross section A-A', shown on **Figure 3-12**, illustrates the lithology through the center of the Subbasin from southwest to northeast. The lithology is based on data from 61 wells and incorporates a local cross section (H-H') developed for the City of Modesto associated with a previous hydrogeologic study (Todd, 2016). The local cross section is incorporated into A-A' immediately east of cross section B-B' and extends for about 3 to 4 miles (see H-H' on **Figure 3-12**).

The Corcoran Clay extends from the western edge of A-A' and extends almost to the intersection of B-B'. Its extent agrees with that mapped by USGS (Burow et al., 2004). The top of the Corcoran Clay is approximately 150 feet below ground surface (bgs) at its eastern extent and dips to the west to a depth of approximately 220 feet bgs (equivalent to elevations of approximately -80 feet msl to -185 feet msl. The Corcoran Clay generally thickens to the west, ranging in thickness from about 10 feet in the east to about 70 feet in the west. The depth and thickness of the Corcoran Clay generally agrees with the Corcoran Clay in the USGS MERSTAN model (Phillips et al., 2015) and with the data incorporated into the Modesto Subbasin C2VSim model (**Figures 3-9** and **3-10**).

The top of the Mehrten Formation is estimated on the cross section based on the presence of black sands, which are colored orange on **Figure 3-12**. The Mehrten Formation crops out in the eastern Subbasin and is generally consistent with the geologic map illustrated on **Figure 3-1**. Black sands were not identified in the central and western Subbasin because not many wells extend deep enough to intersect the Mehrten Formation in that area. Based on the interpolated dip of the black sands, the top of the Mehrten Formation is approximately 400 feet below the City of Modesto (H-H' on **Figure 3-12**), east of where cross section B-B' crosses A-A' (**Figure 3-12**).

An offset in the top of the black sands was observed during construction of cross section E-E', located north of and parallel to cross section A-A'. As described in more detail for cross section E-E', this offset suggests vertical movement caused by a geologic fault. An offset in the black sands is also suggested by the data in a similar location on cross section A-A', east of the intersection with cross section C-C' (**Figure 3-12**). The vertical movement – down-dropped eastern block relative to the western block – is also consistent with offset observed on cross section E-E'. The estimated location of the fault plane is shown on cross section A-A'.

Cross section A'A' also illustrates the presence of thick coarse-grained units both above and below the Corcoran Clay, at the western edge of the Corcoran Clay. Thick sand units are also noted in the eastern Subbasin within the Mehrten Formation. Note that the lithology shown below the Corcoran Clay is only based on a few wells and is less certain than other areas with more wells. Wells in the western Subbasin are primarily screened either immediately above or immediately below the Corcoran Clay with some wells screened in both aquifers. Most of the wells in the eastern Subbasin are screened within the black sands of the Mehrten Formation.

Cross Section B-B'

Cross section B-B', shown on **Figure 3-13**, illustrates the lithology from the northern to the southern Subbasin boundary in the western Subbasin, through the City of Modesto. The lithology is based on texture information from 38 wells and incorporates a local cross section (D-D') developed in the City of Modesto from a previous study (Todd, 2016). The local cross section extends from north of the intersections with A-A' to the southern edge of the cross section (at B', **Figure 3-13**).

The Corcoran Clay extends from the southern edge of the cross section to slightly north of the Tuolumne River. At the Subbasin boundary, the top of the Corcoran Clay is at a depth of about 130 feet bgs (about -65 feet msl) and is about 65 feet thick. As shown on the cross section location map (**Figure 3-11**), the edge of the Corcoran Clay is oriented northwest to southeast and only intersects the southern portion of section B-B'. However, the Corcoran Clay does not extend as far east in this area as mapped by USGS (compare the edge of the Corcoran Clay on cross section B-B' to the Corcoran Clay extent mapped by USGS and shown on **Figure 3-11**). This could indicate that the extent is more irregular than previously mapped or extends farther than indicated by well data on this section. Because the cross section interpretation is based only on a few logs, the unit may have been too thin to be identified (or not recorded) on the Well Completion Reports.

Wells present in the southern region of the cross section are screened both above and below the Corcoran Clay. To the north of the Corcoran Clay, wells tend to have long screened intervals that intersect multiple coarse-grained units. The thickest coarse-grained units on cross section B-B' are present along the edge of the Corcoran Clay.

The wells on cross section B-B’ are not deep enough to penetrate the Mehrten Formation. Based on where B-B’ intersects A-A’, the Mehrten Formation is at an elevation of approximately -370 feet msl in this area of the Subbasin (near the bottom of B-B’ on **Figure 3-13**). The deepest wells on cross section B-B’ extend to about -300 feet msl.

Cross Section C-C’

Cross section C-C’, illustrated on **Figure 3-14**, depicts the lithology in the central Subbasin, east of the Corcoran Clay between Riverbank and Oakdale. The cross section is based on geologic information from 43 wells.

Most of the wells on cross section C-C’ section are too shallow to encounter the Mehrten Formation. However, a few wells are several hundred feet deep and have sufficiently long screens that intercept the Mehrten Formation black sands. These wells allow the top of the Mehrten Formation to be approximated on the cross section (**Figure 3-14**).

As shown on C’C’, the top of the Mehrten Formation is present at an elevation between -100 and -200 feet msl, shallower than in cross section B-B’ due to its westward dip. The elevation of the top of the Mehrten Formation dips gently to the south along this cross section, with elevations ranging from approximately -125 feet msl along the northern Subbasin boundary to approximately -220 feet msl at the southern Subbasin boundary. The depth to the Mehrten Formation from the edge of the river channels at the Subbasin boundaries range from about 285 feet bgs in the north to 325 feet in the south. The Mehrten is likely shallower in the northern section because it crops out over a larger area in the northern part of the Subbasin (see **Figure 3-14**).

The thickest and most continuous coarse-grained units on the section are in the center of the Subbasin. Coarse-grained units appear to be thicker and more continuous in the southern Subbasin near Dry Creek and the Tuolumne River than along the northern Subbasin boundary.

Cross Section D-D’

Cross section D-D’ (**Figure 3-15**) illustrates the lithology in the eastern Subbasin. The cross section extends from the Stanislaus River to the Tuolumne River and crosses Dry Creek and the Modesto Reservoir. The cross section is based on lithology from 27 wells. Due to the lack of USGS texture data in the eastern Subbasin, most of the lithologic information on this cross section is from DWR Well Completion Reports.

The cross section shows that the Mehrten Formation is shallow or crops out as remnant hills in the eastern Subbasin. The delineation of Mehrten Formation outcrop is based on the presence of black sands and the geologic map (**Figure 3-1**). The cross section is dominated by coarse-grained material and black sands. It should be noted that some Well Completion Reports do not indicate the color of the textures and much of the yellow color on the section may, in fact, also represent black sands.

The cross section shows that most of the wells are hundreds of feet deep and screened within or across the black sands. The black sands and coarse-grained material appear to be thicker and more extensive in the northern half of the Subbasin.

Cross Section E-E'

Cross section E-E', illustrated on **Figure 3-16**, is a local cross section in the northeast Subbasin oriented from southwest to northeast, parallel to cross section A-A'. The cross section is along the northern Subbasin boundary and extends from cross section C-C', through Oakdale, to east of cross section D-D'. The cross section approximately follows the Stanislaus River channel, crossing it in two places, and is based on lithology from 62 wells. Due to the high density of wells on the cross section, well numbers are shown on a separate expanded-scale version of this section, provided as **Figure 3-17**.

The Mehrten Formation is shallow throughout most of the cross section and crops out in the eastern region of the section. Similar to cross section D-D', the delineation of the Mehrten Formation outcrop is based on the presence of black sands and the geologic map (**Figure 3-1**). The Mehrten Formation crops out as remnant hills with the erosional surface roughly corresponding to the ground surface elevation on the cross section. The dip of the Mehrten Formation is visible because the transect is roughly parallel to the dip direction. The coarse-grained material and black sands appear to be the thickest and most continuous at depth, but this interpretation is based on only a few deep wells.

There was some irregularity in the elevation of the top of the black sands in wells in the western region of the section. It appears that the black sands on the western side of this fault are at a significantly higher elevation than on the east side of the fault, suggesting vertical movement possibly associated with a geologic fault as interpreted on E-E'. The eastern block is down-dropped relative to the western block.

The USGS (Marchand, 1980) mapped multiple surface lineaments (trending northwest to southeast) south of the Modesto Subbasin, within the Turlock Subbasin. This mapping included folds and faults with approximately northwest to southeast trends. The faulting, which occurred post-deposition, resulted in a down-dropped eastern block relative to the western block, showing reverse offset because of compressive stresses. The evidence of a fault in the Modesto Subbasin has a similar pattern of offset and trend as the faults mapped in the Turlock Subbasin.

Cross Section A-A' with Hydrogeologic Framework

Cross section A-A' is repeated on **Figure 3-18** with a focus on formations and the geometry of the Principal Aquifers rather than textures. The cross section depicts the formation boundaries and the base of fresh water from C2VSim through the center of the Subbasin from southwest to northeast (**Figure 3-11**). The boundary between the base of the undifferentiated Modesto, Riverbank, and Turlock Lake Formations and the top of the Mehrten Formation is the same as shown on cross section A-A' and is based on the geologic texture data. The base of the Mehrten Formation was approximated from geophysical logs at 13 deep oil and gas wells available from the California Department of Oil, Gas and Geothermal Resources (DOGGR). (The location of the DOGGR geophysical logs is shown on **Figure 3-11**).

The cross section shows the westward dip of the formations and offsets caused by two faults in the central and eastern Subbasin. The fault east of intersection with C-C' was identified based on offset of Mehrten Formation black sands. The fault identified west of intersection with C-C' is based on offset of the base of the Mehrten Formation identified from DOGGR geophysical logs. The fault west of C-C' is not shown on **Figure 3-12** because the wells in this area are not deep enough to intersect the black sands of the Mehrten Formation, and therefore offset could not be identified.

The base of fresh water surface from C2VSim, which represents the bottom of the Subbasin, is overlaid onto the conceptual cross section. The base of fresh water undulates throughout the Subbasin. It is highest in the eastern Subbasin, at an elevation of approximately -550 feet msl, and deepest in the central Subbasin, at an elevation of approximately -1,000 feet msl. In the eastern Subbasin, the base of fresh water is below the Mehrten Formation, within the undifferentiated continental and marine sediments. In the central Subbasin it rises into the base of the Mehrten Formation. The undulations approximately correspond with the locations of the faults.

The conceptual cross section also illustrates the three principal aquifers: the Western Upper Principal Aquifer above the Corcoran Clay, the Western Lower Principal Aquifer below the Corcoran Clay and above the base of fresh water, and the Eastern Principal Aquifer east of the Corcoran Clay and above the base of fresh water.

3.1.4.3. Aquifer Properties

The USGS compiled aquifer property data for the Modesto and Turlock subbasins (Burow et al., 2004). The USGS reported hydraulic conductivity above the Corcoran Clay, in the Western Upper Principal Aquifer, to range from 27 to 54 feet per day (ft/day) (Page, 1977 in Burow et al., 2004). The C2VSim Modesto Model has an average hydraulic conductivity above the Corcoran Clay of 42 ft/day, which is within this published range.

The hydraulic conductivities in the Mehrten Formation, at the base of both the Eastern Principal Aquifer and Western Lower Principal Aquifer, ranged from 0.01 to 67 ft/day (Page and Balding, 1973 in Burow et al., 2004). Average hydraulic conductivity in the lower aquifer of the C2VSIM Modesto Model, which includes the Mehrten Formation, is 25 ft/day, which is within this published range.

In the Eastern Principal Aquifer, the transmissivity (T) in the shallow unconsolidated sediments is estimated to be 9,100 ft^2/day (68,068 gpd/ft). The T in the deeper, partly consolidated sediments of both the Eastern Principal Aquifer and Western Lower Principal Aquifer was lower, approximately 8,000 ft^2/day (59,840 gpd/ft) (Page and Balding, 1973 in Burow et al., 2004).

3.1.5. Hydrogeologic Conceptual Model Representation in Modesto C2VSim Model

The hydrogeologic conceptual model was compared with the Modesto C2VSim Model to ensure that the hydrogeologic system is well represented in the model.

As discussed previously in Section 3.1.4, the original Corcoran Clay surface that was in the model was replaced with the Corcoran Clay surface from the USGS MERSTAN Model (Phillips et al., 2015). This was because an anomaly in the original surface was discovered while comparing the cross sections and well logs to the model. The Corcoran Clay surface in the USGS MERSTAN Model is the most detailed mapping of the Corcoran Clay in the Modesto Subbasin. The depth, thickness and extent of the Corcoran Clay shown on the cross sections generally agrees with the USGS MERSTAN Model, and consequently, with the revised surface in the Modesto C2VSim Model.

The model layers are a good representation of the Principal Aquifers. The primary shallow pumping layer of the model contains most of the pumping wells. As mentioned in the previous section, the average hydraulic conductivity in the model in the Western Upper Principal Aquifer and within the Mehrten Formation were within the range published in the literature.

The hydrogeologic conceptual model is well represented in the Modesto C2VSim Model. Because of this, the model is an effective tool for estimating water levels in areas lacking water level data, such as within the Western Lower Principal Aquifer and in the eastern Subbasin. The model is also an effective tool for developing water budgets, which will be presented in Section 4.

3.1.6. Data Gaps and Uncertainties in the Hydrogeologic Conceptual Model

This section will summarize hydrogeologic data gaps that affect implementation of the Plan and are related to the GSAs ability to sustainably manage groundwater. The Plan Implementation section, when developed, will describe how these data gaps will be addressed in future GSP actions. A summary of the data gaps for the Hydrogeologic Conceptual Model is summarized in the table below.

Table 3-1: Data Gaps for the Hydrogeologic Conceptual Model

Issue	Area	Impacts on Groundwater Management	Actions to Address
Eastern Subbasin Aquifers	East and Northeast of Modesto Reservoir	Sparse number of wells in this area of the Subbasin means more uncertainty regarding the Eastern Principal Aquifer.	• Collect relevant data from landowners, as available. • Install additional monitoring wells. • Examine lithologic logs and other well data when new wells are drilled in this area.
Mehrten Formation	Central and Western Subbasin	Depth to top of Mehrten Formation not well understood in central and western Subbasin due to shallow wells. Impacts understanding of aquifer properties and geometry.	• Examine lithologic logs and other well information as additional deep wells are drilled in central and western Subbasin. • Add testing program, such as geophysical logs, to proposed deep wells where needed.
Exact Base of Fresh Water	Entire Subbasin	Uncertainty in Subbasin geometry, fresh groundwater in storage, and water quality with depth.	Compile TDS data for wells with known screen intervals. Test water quality in all new Subbasin wells.

3.2. GROUNDWATER CONDITIONS

An evaluation of groundwater conditions in the Modesto Subbasin was conducted using water level data obtained from numerous sources, including the DWR Water Data Library (which includes CASGEM data), USGS, MID, OID, and the municipalities and urban communities. There are more than 600 wells in the Subbasin with measured water levels between 1918 and 2018, with most measurements occurring after 1970. The locations of these wells are shown on **Figure 3-19**. As shown on the figure, most water level data are from wells in the western and central Subbasin, with limited data in the eastern Subbasin.

The groundwater analysis focused on data from 1990 to 2018; this water level study period overlaps the water budget study period (WY 1991 – WY 2015, see **Section 3.1.2.1**) while including more recent data to examine current groundwater conditions. During this period, water levels were measured at approximately 450 of these wells.

3.2.1. Groundwater Occurrence

As summarized in **Section 3.1.4**, groundwater is present in unconfined to semi-confined aquifers above and east of the Corcoran Clay and in confined aquifers below the Corcoran Clay. Groundwater is also present in the shallow alluvial unconsolidated to semi-consolidated deposits as well as the underlying consolidated sediments; however, groundwater conditions are not well defined in the deeper aquifers due to a lack of data.

3.2.2. Water Levels and Trends

To examine water level trends over the study period, working hydrographs were constructed for each of the approximately 450 wells with water level measurements since 1990. Representative hydrographs were chosen for discussion from wells in each principal aquifer based on data availability and on levels, fluctuations, and trends consistent with other hydrographs in a certain area. The locations of selected wells with representative hydrographs are shown on **Figure 3-20** and are color-coded based on the principal aquifer in which they are screened.

Representative hydrographs are presented on **Figures 3-21** through **3-25**. These hydrographs have consistent horizontal scales (1990 to 2018) and vertical scales (0 to 160 feet msl) to facilitate comparisons across the Subbasin. The ground surface elevation is shown as a black line on the hydrographs unless it is greater than 160 ft msl, in which case it is noted at the top of the hydrograph. If known, the depth of the screened intervals for each well are noted on the hydrograph. Representative hydrographs include data measured at MID wells, City of Modesto wells, City of Oakdale wells, CASGEM wells and DWR Water Data Library wells.

Eight representative hydrographs from the Western Upper Principal Aquifer are illustrated on **Figures 3-21** and **3-22**. As shown on **Figure 3-21**, groundwater elevations in the western and central regions of the Western Upper principal aquifer are shallow. Depth to water in the northwest Subbasin (hydrograph 1) is within ten feet of ground surface and deepens to the south (hydrograph 2) and east (hydrographs 3, 4 and 5). Water levels are relatively stable, especially along the western Subbasin boundary near the San Joaquin River (hydrographs 1 and 2). Water levels fluctuate more to the east. Hydrographs 3, 4 and 5 show slightly more pronounced water level declines during the recent drought. The declines are greater in the center of the Subbasin (hydrograph 4, approximately 13 feet) than near the rivers (hydrographs 3 and 5, approximately 5 or less feet).

Three hydrographs from the eastern edge of the Western Upper Principal Aquifer are shown on **Figure 3-22** and illustrate a similar historical water level trend. Water levels between 1990 and 1995 are relatively low and rise after 1995 when the City of Modesto began receiving water from the Modesto Regional Water Treatment Plant (MRWTP) and pumping less groundwater. Water levels were relatively steady from 2000 to the recent drought, when declines up to 10 feet (hydrograph 7) and 15 feet (hydrograph 6) occurred. Water levels have recovered slightly since the end of the drought.

Hydrograph 8 illustrates water levels from a City of Modesto pumping well (Well 17). In 1994, shortly before the City of Modesto began receiving water from the MRWTP, water levels were the lowest of the study period. Between 1995 and 2000, after the City began receiving water from the MRWTP, water levels rose almost 50 feet. Since 2000, water levels indicate significant seasonal pumping variation, but overall have remained relatively steady.

Three hydrographs from the Western Lower Principal Aquifer are shown on **Figure 3-23**. Each of these hydrographs are from City of Modesto pumping wells (Well 290, Well 313 and Well 56). Each of these hydrographs illustrate significant seasonal pumping variations. When compared to Well 17, in the Wester Upper Principal Aquifer (hydrograph 8 on **Figure 3-22**), it appears that the water level variation below the Corcoran Clay is more significant than above the Corcoran Clay, consistent with pumping in a confined aquifer. Water levels in City of Modesto Well 56 (hydrograph 11) depict the historical trend of water level recovery between 1995 and 2000 followed by relatively stable water levels with seasonal pumping fluctuations. In general, water levels appear to be relatively stable, with small declines during drought (about 10 to 20 feet) followed by recovery in post-drought years.

Representative hydrographs from ten wells east of the edge of the Corcoran Clay in the Eastern Principal Aquifer are illustrated on **Figures 3-24** and **3-25**. Hydrographs from wells in the western side of the Eastern Principal Aquifer are shown on **Figure 3-24** and include three MID wells, one City of Modesto well and one well from the DWR WDL. These hydrographs indicate a deeper water table as ground surface elevations rise to the east. Hydrographs illustrate depths to water ranging from approximately 40 feet bgs in MID-208 to more than 80 feet bgs in MID-197 (**Figure 3-24**). The water levels in the MID wells are relatively steady until declines during the most recent drought. Those declines increase to the east, ranging from about 12 feet in MID-208 to 27 feet in MID-214. Some recovery occurred after the drought, but water levels remain approximately 20 feet below pre-drought levels in the two easternmost wells, MID-214 and MID-197.

The City of Modesto well 37 (hydrograph 13), located in the center of the Subbasin close to the edge of the Corcoran Clay, has a similar water level pattern to other City of Modesto wells in the western principal aquifers. The water level in City of Modesto Well 37 rose approximately 50 feet between 1995 and 2000 and remained relatively steady, with pumping cycles, since then. There is a slight downward water level trend since about 2005 that was less pronounced in the City of Modesto wells in the western principal aquifers.

Five hydrographs from the eastern region of the Eastern Principal Aquifer are illustrated on **Figure 3-25**. These hydrographs are from a City of Oakdale well (Well 5), two MID wells and two wells from the DWR WDL. Although the City of Oakdale Well 5 (hydrograph 17) has missing data between 1995 and 2009, the measured record illustrates up to 40 feet of seasonal pumping variations and an overall slightly declining trend. The other four hydrographs show historical declining trends since about the mid-2000s. For example, water levels in MID-228 (hydrograph 19, near the Tuolumne River), declined approximately 30 feet from the late 1990s to present. Most of the declines occur during the recent drought (2013 – 2016) and appear most significant in the eastern Subbasin. Water levels during the drought declined approximately 25 feet in MID-228 (hydrograph 19) and MID-223 (hydrograph 21) and about 40 feet in the DWR WDL well 02S12E32P01M (hydrograph 18), north of Modesto Reservoir. In that well, recent water levels have not recovered or stabilized substantially, even during the wet year of 2017.

In general, hydrographs in the Eastern Principal Aquifer indicate that water levels in the eastern Subbasin have declined since about 2000 and have significant declines during the most recent drought. The historical declining trends and the magnitude of decline during the recent drought are most pronounced in the eastern region of the Eastern Principal Aquifer. In the eastern Subbasin, long-term rates of decline are up to about 2.7 feet/year and rates of decline during drought are up to 6 feet/year. Due to a lack of data, water level trends east of the Modesto Reservoir and in the northeastern region of the Subbasin are not known.

3.2.3. Groundwater Flow

3.2.3.1. Groundwater Elevation Contour Maps

Groundwater elevation contour maps were developed at three different times within the study period: the wettest year (1998), a dry year during the recent drought (2015), and the most recent year with a sufficient set of measured data (2017). These contour maps are shown on **Figures 3-26, 3-27a, and 3-28**. Each groundwater elevation contour map includes water levels measured in the unconfined Western Upper Principal Aquifer and unconfined to semi-confined Eastern Principal Aquifer. Water levels from these two principal aquifers are shown and contoured on the same map as representative of water table conditions. In addition, simulated groundwater elevation contours from September 2015 in the Unconfined Aquifer are shown on **Figure 3-27b**.

Maps illustrating the available water level data in the Western Lower Principal Aquifer were developed for each time period and are shown on **Figures 3-29, 3-30a and 3-31**. Water levels in the Western Lower Principal Aquifer cannot be contoured due to limited data. Although many wells in the western Subbasin were drilled below the Corcoran Clay, most have screened intervals both above and below the clay. Wells shown on these figures are screened only below the Corcoran Clay. Simulated groundwater elevation contours from the groundwater model provide a more complete representation of water levels in the Western Lower Principal Aquifer than could be developed with current data. A simulated groundwater elevation contour map for the Confined Aquifer in September 2015 is shown on **Figure 3-30b**.

<u>Groundwater Flow in Spring 1998 (March and April)</u>

Groundwater elevations measured in spring 1998 are illustrated on **Figure 3-26**. As shown on **Figure 3-2**, water year 1998 is the wettest year between 1990 and 2017. With almost 25 inches of rain, precipitation during water year 1998 was almost double the long term average (12.6 inches) and study period average (12.8 inches). As shown on the hydrographs, water levels throughout most of the Subbasin rebounded between 1995 and

2000 in response to the reduction of groundwater pumping within the City of Modesto as a result of the delivery of water from the MRWTP. For this and other reasons, 1998 water levels do not always represent the highest water levels in all parts of the Subbasin.

Groundwater elevations in spring 1998 ranged from about 150 feet msl near the Modesto Reservoir to approximately 35 feet msl in the western Subbasin. The lowest groundwater elevations occurred along the western edge of the Subbasin and within the City of Modesto along the Tuolumne River. Groundwater flow is generally to the southwest with flatter hydraulic gradients in the west. There is a southerly component of flow towards the Tuolumne River in the western Subbasin caused by a pumping depression in the City of Modesto. Groundwater elevations in this region are between about 30 and 40 feet msl, which is similar to the groundwater elevations along the western edge of the Subbasin next to the San Joaquin River. There is a general area of higher groundwater elevations in the central Subbasin, with elevations slightly over 100 feet msl. Additional localized areas of higher or lower groundwater elevations also occur in the Subbasin. As illustrated on **Figure 3-26**, there is a lack of measured water level data in the eastern Subbasin.

Groundwater elevations in the Western Lower Principal Aquifer are available in only two wells during spring 1998 (**Figure 3-29**). The wells are along the eastern edge of the aquifer and have similar water levels (41 and 44 ft msl); levels are also similar to water levels in the Western Upper Principal Aquifer.

<u>Groundwater Flow in October 2015</u>

Figure 3-27a illustrates groundwater elevations measured in October 2015. Water year 2015 was the third consecutive critically dry year during the recent drought and water levels reached historical lows in many areas of the Subbasin. January 2015 is defined in the Water Code as the SGMA baseline, so this map generally represents baseline conditions for the Subbasin.

As shown on **Figure 3-27a**, groundwater elevations ranged from approximately 130 feet msl in the eastern Subbasin to 14 feet msl in the western Subbasin along the Tuolumne River in Modesto. In October 2015, more water level data are available in the eastern Subbasin than in spring 1998 and the highest water level (132 feet msl) was measured in the northeastern Subbasin.

Groundwater flow patterns in October 2015 are similar to spring 1998, with groundwater flow to the southwest, with a southerly component towards the Tuolumne River, especially within the City of Modesto. Hydraulic gradients are steeper in the eastern Subbasin and become flatter to the west. Even though flow directions are the same as 1998, groundwater levels in October 2015 are generally lower throughout the Subbasin.

Increased municipal pumping during the drought has created a pumping depression within the City of Modesto, with water levels approximately 20 feet lower than in spring 1998. Similarly, increased irrigation pumping has created a pumping depression east of the City of

Modesto in the central Subbasin, with water levels approximately 20 to 30 feet lower than in spring 1998. Water levels in the Western Upper Principal Aquifer appear to have the least amount of decline, on the order of 10 to 20 feet lower than in spring 1998. The magnitude of water level declines between these two time periods is larger in the east. For example, water levels in October 2015 near the Modesto Reservoir are approximately 30 to 40 feet lower than they were in spring 1998.

Simulated groundwater elevation contours in the unconfined aquifer from September 2015 are shown on **Figure 3-27b**. This figure shows that there is general agreement between simulated groundwater elevations from the model and measured groundwater elevations (see **Figure 3-27a**). Simulated groundwater elevations in the Western Upper Principal Aquifer range from approximately 20 to 40 feet msl, similar to measured data. Simulated groundwater elevations gradually increase to the east, with the 120 foot simulated contour in a similar location in the eastern Subbasin as depicted on the measured contour map. The simulated groundwater elevation contours in the central Subbasin are smoother than the contours based on measured data. This is because there is more well-by-well variability in the measured data based on localized pumping.

Groundwater elevations are available in four wells in the Western Lower Principal Aquifer for October 2015 (**Figure 3-30a**). The wells, located along the eastern edge of the aquifer, have elevations ranging from 26 to 41 feet msl; although there are more wells with 2015 data, elevations for the same wells are between 3 feet and 10 feet lower than in spring 1998. Simulated groundwater elevations in September 2015 provide a more complete representation of groundwater conditions in the Western Lower Principal Aquifer (**Figure 3-30b**). Simulated contours show flow to the northeast, with groundwater elevations ranging from over 30 to under 20. The simulated contours are in general agreement with the limited measured data shown on **Figure 3-30a**.

<u>Groundwater Flow in Spring 2017 (February through May)</u>

Groundwater elevations measured in spring 2017 are illustrated on **Figures 3-28 and 3-31**. Water year 2017 was a wet year with above average precipitation; as such, water levels are higher throughout the Subbasin than in October 2015.

As shown on **Figure 3-28**, groundwater elevations range from 110 feet msl north of the Modesto Reservoir to about 20 feet msl within the City of Modesto near the Tuolumne River. Groundwater flow patterns are similar to spring 1998 and October 2015. Flow is to the southwest with a southerly component towards the Tuolumne River, most notably in the vicinity of the City of Modesto, but also in other areas.

Groundwater elevations have recovered more in the western Subbasin than they have in the eastern Subbasin. For example, water levels within the City of Modesto are about 10 to 20 feet higher than in October 2015. Groundwater elevations in the central Eastern Principal Aquifer are less than 10 feet higher than in October 2015. Although data are limited, it appears that water levels have continued to decline further to the east. Two wells north of the Modesto Reservoir show water level declines of 13 feet (from 118 to 105 feet msl) and 3 feet (from 113 to 110 feet msl) since October 2015.

Water levels at four wells in the Western Lower Principal aquifer are shown on **Figure 3-31**. As in 1998 and 2015, the wells are along the eastern edge of the aquifer. Groundwater elevations are higher than they were in October 2015, ranging from 44 to 53 feet msl.

3.2.3.2. Vertical Groundwater Flow

The USGS has found that vertical groundwater movement within the extent of the Corcoran Clay is downward, from the Western Upper Principal Aquifer to the Western Lower Principal Aquifer (Burow et al., 2004). An analysis of groundwater elevation data in the Modesto Subbasin supports this.

The analysis of vertical gradients is based on water levels from a USGS well cluster and a group of nearby wells that are screened above and below the Corcoran Clay. The location of these wells is shown on **Figure 3-32** and hydrographs are shown on **Figures 3-33 and 3-34**. The extent of the Corcoran Clay, as defined by the USGS (Burow et al., 2004), is shown on **Figure 3-32**.

In 2004, USGS installed a cluster (MRWA) of three wells in the southwestern Subbasin. Two of the wells are screened above the Corcoran Clay (MRWA-1 and MRWA-2) and one is screened below the Corcoran Clay (MRWA-3). MRWA-1 is screened at a depth of 25 to 30 feet bgs (37 to 32 feet msl), in the shallow portion of the Western Upper Principal Aquifer. MRWA-2 is screened in the deeper portion of the Western Principal Aquifer just above the Corcoran Clay, at a depth of 174 to 179 feet bgs (-112 to -117 feet msl). MRWA-3 is screened in the Western Lower Principal Aquifer, at a depth of 269 to 274 feet bgs (-207 to -212 feet msl). According to data provided by the USGS, the Corcoran Clay was encountered from 195 to 240 feet bgs (-133 to -178 feet msl) at this location. The USGS collected water levels from these wells between 2004 and 2006 and again in 2009. These water levels are shown on **Figure 3-33**.

Water levels measured in the MRWA cluster show that groundwater elevations are higher in the Western Upper Principal Aquifer than the Western Lower Principal Aquifer. Groundwater elevations above the Corcoran Clay in MRWA-1 and MRWA-2 are similar to one another and are between about 1.5 and 6 feet higher than in MRWA-3, below the Corcoran Clay. Therefore, groundwater flow is downward from the Western Upper Principal Aquifer to the Western Lower Principal Aquifer (**Figure 3-33**).

Groundwater elevations in the shallow and deep regions of the Western Upper Principal Aquifer (MRWA-1 and MRWA-2) are similar except when steep declines occur below the Corcoran Clay. These declines are likely associated with pumping increases below the Corcoran Clay. The shallow unconfined aquifer does not appear to be affected (MRWA-1). The water levels show consistent downward groundwater flow from the Western Upper Principal Aquifer to the Western Lower Principal Aquifer, which is increased with pumping in the Western Lower Principal Aquifer (**Figure 3-33**).

The second set of wells used for the vertical groundwater flow analysis includes one MID well (MID-103), screened above the Corcoran Clay from 53 to 81 feet bgs, and two City of Modesto wells (MOD-63 and MOD-313), screened below the Corcoran Clay at multiple intervals ranging from 171 to 456 feet bgs. Well depths in relation to the Corcoran Clay were verified with the cross sections and the base elevation of the Corcoran Clay in the model. These wells, shown on **Figure 3-32**, are in close proximity to one another near the eastern edge of the Corcoran Clay.

Hydrographs for these three wells are shown on **Figure 3-34**. The City of Modesto wells show cyclic seasonal pumping fluctuations of up to 30 feet, while the MID well is relatively steady, with fluctuations of 10 or less feet. Groundwater elevations below the Corcoran Clay in the two City of Modesto wells are very similar to one another and consistently lower than the elevations in the MID well above the Corcoran Clay. Groundwater elevations above the Corcoran Clay are about 10 to 40 feet higher than below the Corcoran Clay. The biggest differences occurred during the recent drought (2014 to 2016) due to increased pumping. Water levels in this group of wells indicate consistent downward groundwater flow from the Western Upper Principal Aquifer to the Western Lower Principal Aquifer in this area of the Subbasin.

3.2.4. Changes of Groundwater in Storage

In Bulletin 118 (DWR, 2003), DWR estimates that there is 6.5 million acre feet (MAF) of fresh groundwater in storage to a depth of 300 feet in the Modesto Subbasin. However, as shown on the cross section on **Figure 3-18**, the depth to the base of fresh water is deeper than 300 feet, and therefore, the DWR estimate is likely too low. In 1961, it was estimated that 14 MAF of stored groundwater is present in the Subbasin to depths of up to 1,000 feet, a more reasonable estimate given the current understanding of subbasin geometry (DWR, 2003). Since 1961, based on declining water levels trends and fluctuations observed throughout the Subbasin, depletions in groundwater in storage has occurred in the Modesto Subbasin. Water level trends are described in **Section 3.2.2**.

One accepted method of estimating current groundwater in storage changes is to construct groundwater elevation contour maps during seasonal highs for various water years and develop change in water level maps between them. By applying storage parameters to these water level changes, a change in groundwater in storage can be estimated. However, these maps cannot be developed over the entire Modesto Subbasin with the desired level of certainty due to significant data gaps for water levels both within certain areas of the Subbasin as well as for one of the three Principal Aquifers. Consequently, the C2VSimTM model was used to develop GSP water budget analyses.

Results from the C2VSimTM model, which is well-calibrated and has reliable water budget data, provide an alternative method for estimating changes in groundwater in storage. The model also has the advantage of providing this information over the entire Subbasin, even where water level data are lacking. Selection, refinements, and calibration of the C2VSimTM model are provided in **Appendix C**. Water budgets, including change in groundwater in storage over a 25-year Study Period have been developed and are summarized in **Chapter 5** of this GSP. Those model results represent the best technical data available for determining changes in groundwater in storage over time.

The historical water budget is described in **Section 5.1.4.2**. As shown on **Table 5-8**, about 43,000 AFY has been depleted from groundwater in storage during the historical study period, from WY 1991 to 2015. This is equivalent to a cumulative depletion of approximately 1.07 MAF. The annual and cumulative change in storage is illustrated on **Figure 5-20**. Given that much of the groundwater level declines have occurred during the historical study period (primarily due to increased agricultural water demand), remaining groundwater in storage can be approximated at about 13 MAF.

As summarized on **Table 5-8**, the historical water budget estimates groundwater production of approximately 311,000 AFY. Given the average depletion of groundwater in storage is 43,000 AFY, a sustainable yield of approximately 268,000 AFY can be estimated for the historical study period. This is a simplistic estimate and does not take into account other important components of the water budget, such as interconnected surface water. Accordingly, this estimate cannot be projected for future conditions in the Subbasin. A more technically defensible sustainable yield estimate was developed for projected future conditions using the C2VSimTM as described in **Section 5.3**.

3.2.5. Groundwater Quality

Historical and current groundwater quality conditions of the Modesto Subbasin have been reviewed to characterize groundwater quality of the principal aquifers including an analysis of any constituents of concern. In particular, the analysis allows identification of groundwater quality issues that may affect the supply and beneficial uses of groundwater, including possible plumes of groundwater contamination. The compilation and analysis of historical and current data is described in the following sections, including the sources of data, screening procedures and quality assurance of the data, selection of constituents to analyze, and characteristics of the resulting data sets. Statistical summaries are also presented for select constituents.

3.2.5.1. Regional Groundwater Quality

Groundwater quality in the San Joaquin Valley is highly variable and reliant on the quality of the water recharging the aquifer, the chemical changes that occur as surface water percolates to groundwater, and chemical changes that occur within the aquifer (Dale et al., 1966). USGS has categorized regional groundwater quality in the San Joaquin Valley into three groups based on geography: east side, west side, and axial trough (Dale et al., 1966).

East side groundwater quality is of the bicarbonate type with low total dissolved solids (TDS). This groundwater is characteristic of the surface waters that drain the granitic Sierra Nevada Range to the east of the San Joaquin Valley groundwater basin (Dale et al., 1966). Groundwater quality in the east side reflects the quality of the quality of the local surface water including the Stanislaus and Tuolumne rivers, the primary sources of recharge to the Modesto Subbasin aquifers.

3.2.5.2. Local Groundwater Quality

Publicly available groundwater quality data for the Modesto Subbasin were used in this analysis. These data sources include STRGBA GSA member agencies (City of Modesto, City of Riverbank, City of Waterford, and Modesto Irrigation District), Eastern San Joaquin Water Quality Coalition, Central Valley Salinity Alternatives for Long-term Sustainability (CV-SALTS), and the California State Water Resources Control Board GeoTracker-GAMA and GAMA database. Water quality data from other STRGBA GSA member agencies, such as City of Oakdale, Oakdale Irrigation District, Stanislaus County, and Tuolumne County, were either not available or associated with constituents that were not included in this water quality analysis, such as total coliform and E. Coli coliform. The City of Modesto dataset includes >76,000 water quality records consisting of >30 different constituents collected between 1938 and 2018. The Eastern San Joaquin Water Quality Coalition dataset includes 50,696 records of nitrate analyses between 1902 and 2013, and 19,923 records of total dissolved solids (TDS) analyses between 1925 and 2013. The CV-SALTS database includes nitrate and TDS that were collected between 1934 to 2014 from the following five original collection agencies or sources: Regional Water Quality Control Board (RWQCB) Waste Discharge Requirements (WDR) data per the Dairy CARES program (Dairy); California Department of Public Health (CDPH); Department of Water Resources (DWR); the (USGS) National Water Information System (NWIS) program; and GeoTracker Groundwater Ambient Monitoring and Assessment (GAMA) program.

The data compiled here includes all well types, including domestic, public supply, industrial, monitoring, irrigation, and stock wells, and from all local groundwater quality monitoring programs in the Modesto Subbasin. Using these data, a Microsoft Access database was built that includes over 118,203 groundwater quality records that were collected from 1,339 wells between the start of water year 1995 (October 1, 1994) to 2019. The database includes 260 unique water quality constituents. However, only the most relevant water quality constituents for the Modesto Subbasin are analyzed here. Prior to analysis, quality assurance/quality control (QA/QC) steps were performed on the data, including the identification and removal of duplicate samples and cross-checking the correct well location.

3.2.5.3. Constituents of Concern

A list of potential constituents of concern was developed by the technical team based on a preliminary data review, and review of previous water quality analyses developed in the Subbasin. The constituent list was reviewed at two public STRGBA GSA TAC meetings – April and July 2019. Based on input from TAC members, nine potential constituents of concern were identified for the analysis as listed in the following table.

Table 3-2: Potential Constituents of Concern

Nitrate (as N)	**Boron**	**Dibromo-3-chloropropane (DBCP)**
Total Dissolved Solids (TDS)	**Uranium**	**Tetrachloroethene (PCE)**
Arsenic	**Gross Alpha, 1,2-**	**1,2,3-Trichloropropane (TCP)**

The following is a summary of groundwater quality conditions in the Modesto Subbasin during historical (water year 1995 to 2014) and present (2015 to 2019) periods, emphasizing these potential constituents of concern (COCs). Based on a review of water quality and input from the TAC, these COCs are the most likely to affect groundwater quality from irrigated agriculture (i.e., nitrate, TDS, and DBCP), which is the dominant land use across the Modesto Subbasin, from other human point sources (i.e., PCE) and from natural geogenic sources (i.e., arsenic, boron, uranium, and Gross Alpha) in the Subbasin. Nitrate is reported here as nitrate (as N); nitrate values reported in the original data sources as nitrate (as NO_3^-) were converted to nitrate (as N) prior to analysis.

Nitrate

Nitrate is the most common soluble form of nitrogen in natural groundwater and originates from natural and anthropogenic sources. In general, naturally occurring nitrate is found in low concentrations in groundwater and is derived from precipitation, atmospheric deposition, and natural biogeochemical cycling processes in soils, including the decomposition of organic matter. The most common anthropogenic source of nitrate is the application of nitrogen fertilizers, particularly on irrigated agricultural lands (Gurdak and Qi, 2012). As a result, nitrate is the most ubiquitous nonpoint-source COC of groundwater resources worldwide, including the Central Valley in California (Gurdak and Qi, 2012).

Point sources of nitrate in groundwater include feedlot and dairy drainage, leaching from septic systems, wastewater percolation, industrial wastewater, aerospace activities, and food processing waters (Viers et al., 2012). Denitrification is the only natural process that attenuates nitrate concentrations in groundwater. Previous studies have shown that denitrification is promoted in groundwater with anoxic conditions (dissolved oxygen (DO) < 0.5 mg/L) and large amounts of organic carbon (Gurdak and Qi, 2012). However, there are too few measurements of DO (N = 29) in the database to evaluate if oxic or anoxic conditions exist and the potential for denitrification. All of the DO samples except for two have concentrations in the oxic range (>0.5 milligrams per liter (mg/L)), which indicates a limited potential for denitrification. Future groundwater quality monitoring that includes measurements of DO could help characterize the potential for denitrification and explain the vulnerability of groundwater in the Modesto Subbasin to nitrate contamination.

Nitrate in groundwater from municipal wells in the Modesto Subbasin has been detected in concentrations that approach and, in some cases, exceed the MCL for drinking water (JJ&A and Formation Environmental, 2019). Currently, six municipal wells in the City of Modesto have been taken off-line due to elevated nitrate concentrations (JJ&A and Formation

Environmental, 2019). Blending of water is being used to reduce nitrate concentrations at other municipal wells. Nitrate is present in the City of Modesto's drinking water aquifers because of historical agricultural and wastewater management activities. Nitrate is often detected in the shallow aquifer system, but in some cases, can be drawn down into the deeper aquifer by pumping or through wells with long screened or perforated intervals (Jurgens et al., 2008). Nitrate migration is influenced by downward hydraulic gradients created by municipal pumping, and elevated nitrate concentrations are being drawn deeper in the aquifer near local cones of depression (JJ&A and Formation Environmental, 2019).

A total of 41,898 groundwater samples in the Modesto Subbasin have nitrate analyses and an average concentration of 5.3 mg/L (as N) and generally meet drinking water quality standards (**Table 3-3)**. The median value (5.0 mg/L) is approximately double of the range of nitrate concentrations (2 to 3 mg/L) that have been established by previous studies as representing relative background concentrations from natural processes (Gurdak and Qi, 2012). Although isotopic analysis on the nitrate is needed to identify the source, the median value of 5.0 mg/L indicates that more than half of the samples are above the relative background concentration and thus have a nitrogen input from mostly human sources, such as fertilizers. The majority (93%) of the nitrate analyses have concentrations that are below the MCL of 10 mg/L (as N) (**Table 3-3**). However, 7% of the nitrate samples have concentrations that exceed the MCL (**Table 3-3**).

The average and maximum concentrations of nitrate in groundwater from wells in the Modesto Subbasin during the period of water year 1995 to 2019 are shown in **Figures 3-35 and 3-36**. Nitrate concentrations are illustrated as green circles (less than 5 mg/L), yellow circles (between 5 mg/L and the MCL of 10 mg/L), orange circles (between 10 and 15 mg/L), and red circles (greater than 15 mg/L). Wells with average nitrate concentrations below the MCL of 10 mg/L (as N) tend to be located within the central part of the Subbasin, especially within the urban areas surrounding Modesto, Oakdale, Riverbank, and Waterford (**Figure 3-35**). The wells that have average nitrate concentrations that exceed the MCL of 10 mg/L (as N) are mostly located within the agricultural lands to the west and east of Modesto, but there are also clusters of exceedances within the City of Modesto (**Figure 3-35**). The spatial pattern of maximum nitrate concentrations is similar to the spatial pattern of average nitrate concentrations; most wells with maximum nitrate concentrations below the MCL tend to be in urban areas and the maximum nitrate concentrations above the MCL tend to be in the agricultural lands (**Figure 3-36).** However, there are several wells in Modesto and other urban areas of the Subbasin that have maximum nitrate concentrations above the MCL. The spatial patterns in the average and maximum nitrate concentrations are apparently influenced by the general land-use pattern of the Subbasin.

Table 3-3: Summary Statistics of Select Groundwater Quality Constituents

Water Quality Constituent	California MCL[1] or SMCL[2]	Number of Samples	Percentage of Samples			Concentrations			
			<0.5MCL	>0.5MCL to MCL	>MCL	Min.	Median	Avg.	Max.
Nutrients									
Nitrate (as N), mg/L	10 mg/L[1]	41,898	50%	42%	7%	0.0	5.0	5.3	490
Pesticides									
DBCP, µg/L	0.2 µg/L[1]	9,636	74%	12%	14%	0.0	0.0	0.1	18
TCP, µg/L	0.005 µg/L[1]	5,004	96%	0%	4%	0.000	0.000	0.008	12
Radionuclides									
Gross Alpha, pCi/L	15 pCi/L[1]	1,369	65%	20%	15%	-0.6	4.1	6.9	47
Uranium, pCi/L	20 pCi/L[1]	3,326	71%	20%	8%	0.0	4.9	7.4	65
Secondary Maxiumum Contaminant Level Constituents									
Total dissolved solids, mg/L	1,000 mg/L[2]	16,288	55%	30%	14%	0.0	450.0	703.2	20,000
Trace Elements									
Arsenic, µg/L	10 µg/L[1]	5,993	72%	20%	7%	0.0	2.9	4.8	300
Boron, mg/L	1 mg/L*	841	98%	1%	1%	0.0	0.0	1.9	200
Volatile Organic Compounds (VOC)									
PCE, µg/L	5 µg/L[1]	8,262	87%	4%	8%	0.0	0.0	10.4	8,860

Notes:

[1]**MCL**: California drinking water Maximum Contaminant Level

[2]**SMCL**: California drinking water Secondary Maximum Contaminant Level

<0.5MCL: percentage of samples with concentrations less than one-half the MCL.

>0.05MCL to MCL: percentage of samples with concentrations between one-half of the MCL to the MCL.

>MCL: percentage of samples with concentrations greater than the MCL.

*California State Notification Level (CA-NL). Boron does not have an MCL.

min.: minimum concentration

avg.: average concentration

max.: maximum concentration

Summary statistics of nitrate concentrations in groundwater from the Eastern Principal Aquifer, Western Upper Principal Aquifer, and Western Lower Principal Aquifer are shown in **Tables 3-4**, **3-5**, and **3-6**, respectively. The average nitrate concentrations are similar (5.6, 5.9, and 5.8 mg/L) in the Eastern, Western Upper, and Western Lower Principal Aquifers. The percentage of samples that exceed the 10 mg/L MCL in the Western Upper (13%) and Western Lower (22%) is greater than in the Eastern Principal Aquifer (3%). The data indicate that groundwater quality is relatively similar above and below the Corcoran Clay.

Table 3-4: Summary Statistics of Select Groundwater Quality Constituents for the Eastern Principal Aquifer

Water Quality Constituent	California MCL[1] or SMCL[2]	Number of Samples	Percentage of Samples			Concentrations			
			<0.5MCL	>0.5MCL to MCL	>MCL	Min.	Median	Avg.	Max.
Nutrients									
Nitrate (as N), mg/L	10 mg/L[1]	25,425	39%	58%	3%	0.0	5.7	5.6	490
Pesticides									
DBCP, µg/L	0.2 µg/L[1]	8,518	71%	14%	15%	0.0	0.0	0.1	18
TCP, µg/L	0.005 µg/L[1]	4,568	96%	0%	4%	0.000	0.000	0.008	12
Radionuclides									
Gross Alpha, pCi/L	15 pCi/L[1]	920	72%	17%	12%	-0.6	3.6	5.7	31
Uranium, pCi/L	20 pCi/L[1]	2,285	81%	14%	5%	0.0	4.0	5.9	52
Secondary Maxiumum Contaminant Level Constituents									
Total dissolved solids, mg/L	1,000 mg/L[2]	6,963	74%	25%	1%	0.0	380	389	3,000
Trace Elements									
Arsenic, µg/L	10 µg/L[1]	4,245	86%	11%	3%	0.0	2.2	3.1	130
Boron, mg/L	1 mg/L*	606	97%	1%	2%	0.0	0.0	2.6	200
Volatile Organic Compounds (VOC)									
PCE, µg/L	5 µg/L[1]	5,983	86%	5%	9%	0.0	0.0	6.3	8,860

Notes:

[1]**MCL**: California drinking water Maximum Contaminant Level

[2]**SMCL**: California drinking water Secondary Maximum Contaminant Level

<0.5MCL: percentage of samples with concentrations less than one-half the MCL.

>0.05MCL to MCL: percentage of samples with concentrations between one-half of the MCL to the MCL.

>MCL: percentage of samples with concentrations greater than the MCL.

*California State Notification Level (CA-NL). Boron does not have an MCL.

min.: minimum concentration

avg.: average concentration

max.: maximum concentration

Table 3-5: Summary Statistics of Select Groundwater Quality Constituents for the Western Upper Principal Aquifer

Water Quality Constituent	California MCL[1] or SMCL[2]	Number of Samples	Percentage of Samples			Concentrations			
			<0.5MCL	>0.5MCL to MCL	>MCL	Min.	Median	Avg.	Max.
Nutrients									
Nitrate (as NO3), mg/L	10 mg/L[1]	2,326	47%	40%	13%	0.0	5.3	5.9	52
Pesticides									
DBCP, µg/L	0.2 µg/L[1]	434	75%	2%	23%	0.0	0.0	0.1	1.5
TCP, µg/L	0.005 µg/L[1]	118	100%	0%	0%	0.0	0.000	0.000	0.000
Radionuclides									
Gross Alpha, pCi/L	15 pCi/L[1]	153	33%	33%	33%	0.0	11.4	12.4	47.2
Uranium, pCi/L	20 pCi/L[1]	433	29%	52%	20%	0.0	13.0	13.6	32
Secondary Maxiumum Contaminant Level Constituents									
Total dissolved solids, mg/L	1,000 mg/L[2]	1,215	46%	41%	13%	0.0	530	733	20,000
Trace Elements									
Arsenic, µg/L	10 µg/L[1]	1,108	42%	41%	17%	0.0	5.4	9.5	300
Boron, mg/L	1 mg/L*	139	100%	0%	0%	0.0	0.2	0.1	0.3
Volatile Organic Compounds (VOC)									
PCE, µg/L	5 µg/L[1]	1,014	93%	1%	7%	0.0	0.0	0.9	250

Notes:

[1]**MCL**: California drinking water Maximum Contaminant Level

[2]**SMCL**: California drinking water Secondary Maximum Contaminant Level

<0.5MCL: percentage of samples with concentrations less than one-half the MCL.

>0.05MCL to MCL: percentage of samples with concentrations between one-half of the MCL to the MCL.

>MCL: percentage of samples with concentrations greater than the MCL.

*California State Notification Level (CA-NL). Boron does not have an MCL.

min.: minimum concentration

avg.: average concentration

max.: maximum concentration

Table 3-6: Summary Statistics of Select Groundwater Quality Constituents for the Western Lower Principal Aquifer

Water Quality Constituent	California MCL[1] or SMCL[2]	Number of Samples	Percentage of Samples			Concentrations			
			<0.5MCL	>0.5MCL to MCL	>MCL	Min.	Median	Avg.	Max.
Nutrients									
Nitrate (as N), mg/L	10 mg/L[1]	445	50%	28%	22%	0.0	4.8	5.8	17
Pesticides									
DBCP, µg/L	0.2 µg/L[1]	110	100%	0%	0%	0.0	0.0	0.0	0
TCP, µg/L	0.005 µg/L[1]	133	95%	0%	5%	0.000	0.000	0.000	0
Radionuclides									
Gross Alpha, pCi/L	15 pCi/L[1]	30	93%	7%	0%	0.0	0.0	1.7	14
Uranium, pCi/L	20 pCi/L[1]	92	97%	3%	0%	0.0	1.0	1.4	13
Secondary Maxiumum Contaminant Level Constituents									
Total dissolved solids, mg/L	1,000 mg/L[2]	66	100%	0%	0%	45.0	188	192	468
Trace Elements									
Arsenic, µg/L	10 µg/L[1]	222	9%	74%	17%	0.0	9.0	8.3	14
Boron, mg/L	1 mg/L*	13	100%	0%	0%	0.0	0.1	0.1	0
Volatile Organic Compounds (VOC)									
PCE, µg/L	5 µg/L[1]	438	100%	0%	0%	0.0	0.0	0.0	1

Notes:

[1]**MCL**: California drinking water Maximum Contaminant Level

[2]**SMCL**: California drinking water Secondary Maximum Contaminant Level

<0.5MCL: percentage of samples with concentrations less than one-half the MCL.

>0.05MCL to MCL: percentage of samples with concentrations between one-half of the MCL to the MCL.

>MCL: percentage of samples with concentrations greater than the MCL.

***California State Notification Level (CA-NL). Boron does not have an MCL.

min.: minimum concentration

avg.: average concentration

max.: maximum concentration

Total Dissolved Solids

Total dissolved solids (TDS) represent the total concentration of anions and cations in water and is a useful indicator of mineralization, salt content, and overall groundwater quality. The TDS concentrations in groundwater of the Modesto Subbasin generally meet drinking water quality standards (**Table 3-3**) and some irrigation requirements. A total of 16,288 groundwater samples in the Modesto Subbasin have TDS analyses and only 14% of those samples exceed the California Secondary Maximum Contaminant Level (SMCL) of 1,000 mg/L (**Table 3-3**).

TDS can also be used to characterize the salinity of irrigation water, which can affect crop health and yield (Grattan, 2002). It is recommended that TDS concentrations should be below about 450 mg/L for irrigation of salt sensitive crops, and TDS concentrations between about 450 and 1,000 mg/L can represent a salinity hazard for plants if used as irrigation water (Bauder et al., 2014). About half (49%) of the samples have TDS concentrations less than 450 mg/L and would not cause plant stress. However, 36% of samples are between 450 and 1,000 mg/L and 14% of samples are greater than 1,000 mg/L. Therefore, about 51% of groundwater samples have TDS concentrations that could result in plant stress and salinity hazard as irrigation water.

To identify any areas of concern, the average and maximum TDS concentrations in groundwater from wells within the Modesto Subbasin during the period of water year 1995 to 2019 are shown in **Figures 3-37 and 3-38.** TDS concentrations are illustrated as green circles (below 500 mg/L), yellow circles (between 500 and 1,000 mg/L), orange circles (between 1,000 and 1,500 mg/L), and red circles (above 1,500 mg/L). The median and maximum TDS concentrations in groundwater throughout most of the Modesto are below 1,000 mg/L (**Figures 3-37 and 3-38**). Concentrations of TDS are generally lowest (less than 500 mg/L) in the central part of the Subbasin, especially within the urban areas surrounding Modesto, Oakdale, Riverbank, and Waterford (**Figure 3-37 and 3-38**). Concentrations of TDS above the MCL are generally found in wells located in the San Joaquin River National Wildlife Refuge on the western extent of the Subbasin, in southwest Modesto, and to the southeast of Modesto (**Figure 3-37 and 3-38**).

Summary statistics of TDS concentrations in groundwater from the Eastern Principal Aquifer, Western Upper Principal Aquifer, and Western Lower Principal Aquifer are shown in **Tables 3-4**, **3-5**, and **3-6**, respectively. The average TDS concentrations are similar (389 and 192 mg/L) in the Eastern and Western Lower Principal Aquifers. However, the average TDS in the Western Upper Principal Aquifer (733 mg/L) is much higher than in the other two Principal Aquifers. Similarly, 13% of TDS samples from the Western Upper Principal Aquifer exceed the MCL, while only 1 and 0% of the samples from the Eastern and Western Lower exceed the MCL. These results, along with the 20,000 mg/L maximum concentration may indicate a point source affecting TDS concentrations in the Western Upper Principal Aquifer (**Table 3-5**).

Arsenic

Arsenic is a naturally occurring trace element in rocks, soils, and groundwater in some areas of the Central Valley aquifer (Burton et al., 2012). In the Modesto Subbasin, arsenic in groundwater is generally naturally occurring and is largely derived from the Sierran sediments that were transported to the eastern San Joaquin Valley by glacial and fluvial processes (Jurgens et al., 2008). Previous studies of arsenic in the San Joaquin Valley (Belitz et al., 2003; Welch et al., 2006; Izbicki et al., 2008; and Burton et al., 2012) and a literature review of arsenic (Welch et al., 2000) have identified two dominant mechanisms for elevated arsenic in groundwater. The first mechanism is the reductive dissolution of arsenopyrite or other iron or manganese oxyhydroxides under iron- or manganese-reducing conditions. The second mechanism is the pH-dependent desorption of arsenic from aquifer sediments under oxic conditions, which tends to occur in groundwater with pH above 7.5 (Stollenwerk, 2003). Given the general oxic nature of groundwater in the Subbasin, sorption and desorption on iron oxyhydroxides at pH above 7.5 is expected to be the most significant control on arsenic groundwater mobility. Another mechanism that has been identified is the decreased resorption due to increasing pH, competing species, or lack of sorption sites (Jurgens et al., 2008; Jurgens et al., 2009). Arsenic can also be mobilized from aquitards by dewatering (Smith et al., 2018). The USGS (2008) indicate that migration of arsenic in groundwater in the study area can be facilitated by lateral and vertical gradients created by municipal pumping and by vertical movement through wells with long screened or perforated intervals. Additionally, it has been proposed that geochemical changes in modern recharge water, such as relatively high dissolved organic carbon concentrations could contribute to mobilization of arsenic in the aquifer (JJ&A and Formation Environmental, 2019). Anthropogenic sources of arsenic in groundwater can include the use of wood preservatives, paints and dyes, and from some mining and oilfield operations (Welch et al., 2000).

Groundwater arsenic concentrations in the Subbasin are generally higher in older and deeper groundwater samples (Jurgens et al., 2009). Arsenic in groundwater from municipal wells has been detected in concentrations that approach and, in some cases, exceed the MCL for drinking water (JJ&A and Formation Environmental, 2019). Several municipal wells from the City of Modesto have been taken off-line due to elevated arsenic concentrations (JJ&A and Formation Environmental, 2019).

The concentrations of arsenic are generally low in groundwater of the Modesto Subbasin as compared to the MCL (**Table 3-3**). A total of 5,993 groundwater samples have arsenic analyses and only 7% of those analyses exceed the California MCL of 10 µg/L (**Table 3-3**). The wells with average concentrations of arsenic that exceed the MCL are generally located in the urban area of Modesto and in wells on the western extent of the Subbasin (**Figures 3-39**). Wells with maximum concentrations of arsenic that exceed the MCL are also generally located in the urban areas of Modesto and Riverbank, and wells on the western extent of the Subbasin (**Figure 3-40**).

Summary statistics of arsenic concentrations in groundwater from the Eastern Principal Aquifer, Western Upper Principal Aquifer, and Western Lower Principal Aquifer are shown in **Tables 3-4**, **3-5**, and **3-6**, respectively. The average arsenic concentrations in the Western Upper (9.5 µg/L) and Western Lower (8.3 µg/L) Principal Aquifers are more than double the 3.1 µg/L average concentration in the Eastern Principal Aquifer. Similarly, 17% of the arsenic samples in both the Western Upper and Western Lower exceed the MCL, as compared to only 3% of samples in the Eastern Principal Aquifer. These data indicate important differences may exist in the source(s) and geochemical conditions that control arsenic in groundwater of the Western Upper and Lower Principal Aquifers as compared to the Eastern Principal Aquifer.

Uranium

Uranium in groundwater in the Modesto Subbasin is generally naturally occurring and is largely derived from granitic rocks in the Sierra Nevada rather than sources at land surface (Jurgens et al., 2008). The uranium was weathered from these rocks and oxidized and adsorbed to sediments that were transported to the eastern San Joaquin Valley by glacial and fluvial processes and deposited in the alluvial fans that now make up the Modesto Subbasin (Jurgens et al., 2008). Uranium is a relatively prevalent contaminant in shallow and intermediate depth aquifers in the study area, including beneath the City of Modesto (JJ&A and Formation Environmental, 2019). The mobilization of uranium in the shallow and intermediate aquifer is likely influenced by elevated bicarbonate concentrations in modern and oxic recharge water resulting from agricultural activities (Jurgens et al., 2009). Irrigation return flow that recharges the aquifer can be relatively elevated in bicarbonate concentrations because of the rich and active biomes of the agricultural soils that create elevated carbon dioxide and relatively high partial pressures of carbon dioxide that often result in bicarbonate water type of modern recharge. The uranium is mobilized from the natural sediments when the bicarbonate-rich water flow downward through the aquifer and replaces older groundwater that has relatively lower bicarbonate concentrations (Jurgens et al., 2009). Uranium concentrations have also been observed to be negatively correlated with pH (Burton et al., 2012). Therefore, uranium concentrations are generally higher near the water table and in shallow groundwater and decrease with depth (Jurgens et al., 2008).

Uranium has been detected in municipal wells at concentrations that approach and, in some cases, exceed the MCL for drinking water (JJ&A and Formation Environmental, 2019). Currently, nine municipal wells in the City of Modesto have been taken off-line due to elevated uranium concentrations (JJ&A and Formation Environmental, 2019).

The concentrations of uranium are generally low in groundwater across much of the Modesto Subbasin as compared to the MCL (**Table 3-3**). A total of 3,326 groundwater samples have uranium analyses and 8% of those analyses exceed the California MCL of 20 pCi/L (**Table 3-3**). Most of the uranium samples were collected from supply wells within the urban areas of Modesto, Oakdale, Riverbank, and Waterford. The wells with average (**Figure 3-41**) and maximum (**Figure 3-42**) uranium concentrations that exceed the MCL tend to be located in the City of Modesto.

Summary statistics of uranium concentrations in groundwater from the Eastern Principal Aquifer, Western Upper Principal Aquifer, and Western Lower Principal Aquifer are shown in **Tables 3-4**, **3-5**, and **3-6**, respectively. The uranium concentrations in groundwater are much greater in the Western Upper Principal Aquifer, as compared to the Eastern or Western Lower Principal Aquifers. A total of 20% of uranium samples in the Western Upper exceed the MCL, while only 5 and 0% in the Eastern and Western Lower, respectively, exceed the MCL. These differences in uranium concentration among groundwater of the Principal Aquifers are consistent with the processes of the oxic and bicarbonate rich irrigation return flow that mobilizes uranium in the shallow and intermediate aquifer.

Gross Alpha

Alpha particles (α-particles) are a type of radiation emitted by some radionuclides. The alpha particles consist of two protons and two neutrons. Their travel range is only a few centimeters. Once alpha particles lose energy, they pick up electrons and become helium.

Alpha emitting radionuclides are naturally occurring elements, and include radium-226, uranium-238, radium-226, and radon-222. Radium-226 and radon-222 are generally the alpha emitters of greatest interest to drinking water because they are groundwater contaminants widely distributed in the U.S. and associated with granitic rock, including the Sierra Nevada. The California MCL for gross alpha in drinking water is 15 pCi/L.

The concentrations of gross alpha are relatively low in groundwater across much of the Modesto Subbasin as compared to the MCL (**Table 3-3**). A total of 1,369 groundwater samples have gross alpha analyses and 85% of those analyses have concentrations that are less than the California MCL of 15 pCi/L. A total of 15% of the groundwater samples exceed the gross alpha MCL, which is a higher percentage than uranium samples exceeding the MCL (**Table 3-3**). Similar to the uranium samples, most of the gross alpha samples were collected from supply wells within the urban areas of Modesto, Oakdale, Riverbank, and Waterford. The wells with average (**Figure 3-43)** and maximum (**Figure 3-44**) uranium concentrations that exceed the MCL tend to be located in the City of Modesto, especially in the southwest part of Modesto.

Summary statistics of gross alpha in groundwater from the Eastern Principal Aquifer, Western Upper Principal Aquifer, and Western Lower Principal Aquifer are shown in **Tables 3-4**, **3-5**, and **3-6**, respectively. Similar to the pattern of uranium, the gross alpha in groundwater is much greater in the Western Upper Principal Aquifer, as compared to the Eastern or Western Lower Principal Aquifers. A total of 20% of uranium samples in the Western Upper exceed the MCL, while only 5 and 0% in the Eastern and Western Lower, respectively, exceed the MCL. Similar to uranium, these differences in gross alpha among groundwater of the Principal Aquifers are consistent with the processes of the oxic and bicarbonate rich irrigation return flow that mobilizes uranium in the shallow and intermediate aquifer.

Boron

Boron is a naturally occurring trace element in many minerals and rocks, including igneous rocks such as granite and pegmatite, and some evaporite minerals. Borax is a boron-containing evaporite mineral that is mined in California and is used as a cleaning agent and therefore may be present in sewage and industrial wastes (Burton et al., 2012). There is no MCL for boron. However, California has a Notification Level (NL) of 1 mg/L. Boron is an essential element for plant growth in relatively small concentrations. However, for many crops, boron concentrations greater than 1 to 2 mg/L may be toxic (Ayers and Westcot, 1994).

The concentrations of boron are generally very low in groundwater in the Modesto Subbasin as compared to the NL (**Table 3-3**). A total of 841 groundwater samples have boron analyses and 99% of those analyses have concentrations that are less than the California NL of 1.0 mg/L and 1% have concentrations that exceed the NL (**Table 3-3**). The average (**Figures 3-45**) and maximum (**Figures 3-46**) boron concentrations of groundwater in wells that exceed the NL are generally located in Waterford, which may indicate a potential point-source contamination issue. 98% of the boron analyses have concentrations below 0.5 mg/L (**Table 3-3**), and thus the boron concentrations in groundwater of the Modesto Subbasin are well below toxic levels for plants.

Summary statistics of boron concentrations in groundwater from the Eastern Principal Aquifer, Western Upper Principal Aquifer, and Western Lower Principal Aquifer are shown in **Tables 3-4**, **3-5**, and **3-6**, respectively. There are no major differences in boron concentration or percentage of samples that exceed the NL among the three Principal Aquifers.

Pesticides

Pesticides in groundwater can result from the over-application on agricultural lands or from point-source contamination and preferential flow down improperly constructed wells. While pesticides are typically soluble in water, many can be highly sorptive to soils, which can slow their transport to the water table. The analysis is focused on the two widely detected pesticides Dibromochloropropane (DBCP) and 1,2,3-Trichloropropane (TCP).

Dibromochloropropane (DBCP)

Dibromochloropropane (DBCP) was a widely used agricultural nematocide and soil fumigant in parts of the Central Valley that was first detected in California drinking water in 1979 and later banned in the late 1970s. In 1983, a statewide drinking water source monitoring program was initiated and found DBCP to be the most commonly detected pesticide in groundwater (CA Department of Health Services, 1999). DBCP is relatively mobile when dissolved in water and free DBCP may occur as a dense non-aqueous phase liquid (DNAPL). DBCP is toxic to humans at low concentrations, and thus has presented a local concern (JJ&A and Formation Environmental, 2019). The Federal and California MCL for DBCP is 0.2 µg/L. DBCP was detected in at least seven municipal wells in the City of Modesto at concentrations above the MCL that warranted the use of wellhead treatment using granular activated carbon (Jurgens et al., 2008). DBCP has also been detected at lower concentrations below the MCL in water from at least seven municipal wells from the City of Modesto (JJ&A and Formation Environmental, 2019).

The concentrations of DBCP are generally low in groundwater of the Modesto Subbasin as compared to the MCL (**Table 3-3**). A total of 9,636 groundwater samples have DBCP analyses and 86% of those analyses and below the California MCL of 0.2 µg/L (**Table 3-3**). The remaining 14% of samples with DBCP concentrations above the MCL are from wells that are generally located to the north, west, and southeast of the City of Modesto (**Figures 3-47 and 3-48**).

Summary statistics of DBCP concentrations in groundwater from the Eastern Principal Aquifer, Western Upper Principal Aquifer, and Western Lower Principal Aquifer are shown in **Tables 3-4**, **3-5**, and **3-6**, respectively. The percentage of DBCP samples that exceed the MCL are somewhat similar (15 and 23%) in the Eastern and Western Upper and greater than in the Western Lower (0%) Principal Aquifer. Unlike nitrate concentrations that were somewhat similar above and below the Corcoran Clay, relatively higher concentrations of DBCP appears to be more frequently detected in only the Western Upper Principal Aquifer. The relatively longer flow paths and travel times for groundwater below the Corcoran Clay may help to limit DBCP concentrations in the Western Lower Principal Aquifer.

1,2,3-Trichloropropane (TCP)

1,2,3-Trichloropropane (TCP) is a chlorinated hydrocarbon with high chemical stability that often occurs as an intermediate in chemical manufacturing. It is a manmade chemical that is often found at industrial or hazardous waste sites, used as a cleaning and degreasing solvent, and associated with pesticide products (SWRCB, 2019). TCP may be produced as a byproduct of processes used to produce soil fumigant chemicals. TCP is also a major and minor component of several soil fumigants that were used historically in California through most of the 1980s (Burton et al., 2012). Although TCP was banned from pesticides in the 1990s, it has been detected in groundwater beneath agricultural areas of the Central Valley as part of the GAMA sampling program (Shelton et al., 2008). TCP is an emerging contaminant of concern because it is widely detected and is a probable carcinogen to humans (SWRCB, 2019). In 2017, California adopted an MCL of 0.005 µg/L for drinking water, and now many water supply systems are being monitored for TCP. TCP has been detected in several wells throughout the Subbasin at concentrations above the MCL (JJ&A and Formation Environmental, 2019).

The concentrations of TCP in groundwater in the Modesto Subbasin as compared to the MCL are shown in **Table 3-3**. A total of 5,004 groundwater samples have TCP analyses and 4% of those analyses are above the California MCL of 0.005 µg/L (**Table 3-3**). The wells with average (**Figures 3-49**) and maximum (**Figures 3-50**) TCP concentrations that exceed the MCL are located primarily in the urban areas of Modesto, Riverbank and Waterford. As discussed below in the section on historical and present trends, the wells with elevated TCP tend to have concentrations that are sometimes two to three orders of magnitude greater than the MCL. Such high concentrations of TCP may indicate locations of point-source contamination.

Summary statistics of TCP concentrations in groundwater from the Eastern Principal Aquifer, Western Upper Principal Aquifer, and Western Lower Principal Aquifer are shown in **Tables 3-4**, **3-5**, and **3-6**, respectively. TCP exceedances of the MCL occur in 15% of Eastern Principal Aquifer samples, 23% of Western Upper Principal Aquifer samples, and 0% of Western Lower Principal Aquifer samples. These data suggest that relatively lower concentrations of TCP are below the Corcoran Clay.

Tetrachloroethylene (PCE)

Volatile organic compounds (VOCs) have been detected in several wells in and around the City of Modesto and in Oakdale (JJ&A and Formation Environmental, 2019). The source of the VOCs is largely attributed to historical dry-cleaning operations. At least seven City of

Modesto wells are currently receiving treatment to remove PCE, trichloroethylene, and (or) Freon-113 (JJ&A and Formation Environmental, 2019). There have been a number of response actions in the Modesto area to the PCE contamination, including site investigations, groundwater extraction to address shallow groundwater contamination, and soil vapor extraction to address source removal and potential vapor intrusion into buildings (JJ&A and Formation Environmental, 2019). Therefore, the VOC analysis here is focused on PCE.

Tetrachloroethylene (PCE) is a manufactured chemical and does not occur naturally in the environment. It is a regulated contaminant with a Federal and California MCL of 5 µg/L (SWRCB, 2017). Common sources of PCE include dry cleaning operations, textile operations, and metal degreasing processes. It was also widely used in the production of CFC-113 and other fluorocarbons. PCE is also used in rubber coatings, solvent soaps, printing inks, adhesives and glues, sealants, polishes, lubricants, and pesticides. PCE is a DNAPL and has moderate to high mobility.

The concentrations of PCE are generally low in groundwater in the Modesto Subbasin as compared to the MCL (**Table 3-3**). A total of 8,262 groundwater samples have PCE analyses and 92% of those analyses are below the California MCL of 5 µg/L (**Table 3-3**). Most PCE concentrations above the MCL are from wells located in Modesto and Oakdale, which are likely impacted by historical dry-cleaning operations (**Figures 3-51 and 3-52**).

Summary statistics of PCE concentrations in groundwater from the Eastern Principal Aquifer, Western Upper Principal Aquifer, and Western Lower Principal Aquifer are shown in **Tables 3-4**, **3-5**, and **3-6**, respectively. The percentage of PCE samples that exceed the MCL are somewhat similar (9% and 7%) in the Eastern and Western Upper and greater than in the Western Lower (0%) Principal Aquifer. Similar to patterns in DBCP and TCP concentrations, relatively lower concentrations of PCE appear to be detected below the Corcoran Clay in the Western Lower Principal Aquifer. The low permeability of the clay associated with relatively longer flow paths and travel times for groundwater below the Corcoran Clay may help to limit PCE concentrations in the Western Lower Principal Aquifer.

3.2.5.4. Trends in Historical and Present Groundwater Quality

Statistical tests were used to evaluate if the concentrations of groundwater quality constituents are statistically similar or different between historical (water year 1995 to 2014) and present (2015 to 2019) periods. This analysis will help identify processes that may affect the temporal trends in the groundwater quality of the Modesto Subbasin.

First, the Shapiro-Wilk test for normality was used to test the null hypothesis that the groundwater quality constituents come from a normal distribution. Results of the Shapiro-Wilk test support a rejection of the null hypothesis (α-level = 0.05) and indicate that nitrate, DBCP, TCP, Gross Alpha, Uranium, TDS, arsenic, boron, and PCE all have a non-normal distribution.

Based on the results of the Shapiro-Wilk tests, the nonparametric Wilcoxon rank-sum test was used to test the null hypothesis that the groundwater quality constituents sampled between the historical and present period come from populations that have the same distribution and thus are statistically similar. Results of the Wilcoxon rank-sum test support the decision to fail to reject the null hypothesis (α-level = 0.05) for TCP (p-value = 0.767), gross alpha (p-value = 0.212), and PCE (p-value = 0.981) (**Figure 3-53**), which indicates that these groundwater quality constituents have statistically similar median concentrations during the historical and present periods. However, the results of the Wilcoxon rank-sum test for nitrate (p-value = <0.001), DBCP (p-value = <0.001), uranium (p-value = <0.001), TDS (p-value = 0.001), arsenic (p-value = <0.001), and boron (p-value = <0.001) support the decision to reject the null hypothesis (**Figure 3-54**), which indicates that these groundwater quality constituents have statistically different median concentrations during the historical and present periods. The median concentrations of nitrate, DBCP, arsenic, and boron are statistically lower in the present period than the historical period (**Figure 3-54**). Conversely, the median concentrations for uranium and TDS are statistically higher in the present period than the historical period (**Figure 3-54**).

The temporal linear trends in groundwater quality constituents are evaluated in **Figures 3-55 and 3-56**. Results of the trend analysis indicate statistically significant (α-level = 0.05) increasing trends for TCP (p-value = <0.001) and gross alpha (p-value = <0.001) concentrations, but no statistically significant temporal trend for PCE (p-value = 0.141) (**Figure 3-55**). Results of the trend analysis indicate statistically significant (α-level = 0.05) increasing trends for TDS (p-value = <0.001), nitrate (p-value = <0.001), and uranium (p-value = <0.001) concentrations (**Figure 3-56**). Conversely, there are decreasing trends for DBCP (p-value = <0.001) and arsenic (p-value = 0.002), but no statistically significant trend for boron (p-value = 0.232) (**Figure 3-56**).

These findings indicate that TCP, gross alpha, TDS, nitrate, and uranium concentrations are increasing over time in the Modesto Subbasin, while DBCP and arsenic concentrations are decreasing over time in the Modesto Subbasin.

3.2.5.5. Contamination Sites from GeoTracker

The State Water Resources Control Board (SWRCB) GeoTracker online database was accessed to identify active and former contamination cleanup sites within the Subbasin. As of November 2021, 320 cleanup sites are documented on GeoTracker in the Modesto Subbasin. Less than 10 percent of these (28 sites) are open, and the remaining (292 sites) are closed. Active remediation or monitoring is still occurring at the open sites. The open cases include 2 Leaking Underground Storage (LUST) sites, 24 Cleanup Program sites, and 2 Military sites.

The contamination sites from GeoTracker are presented on **Figure 3-57**, and the number of each site (open and closed) is shown in the legend of this figure. Most of the sites are in the cities of Modesto, Riverbank, Oakdale and Waterford. Available data uploaded to GeoTracker from these sites will be considered in the annual analysis of groundwater quality to be conducted by the GSAs as part of GSP implementation (see **Section 6.6**).

3.2.6. Land Subsidence

The overdraft conditions exacerbated by the recent drought resulted in lowered groundwater levels – a condition that can contribute to subsidence of the ground surface. As water levels decline in the subsurface, dewatering and compaction of predominantly fine-grained deposits, such as clay and silt, can cause the overlying ground surface to subside.

This process is illustrated by two conceptual diagrams shown on **Figure 3-58**. The upper diagram depicts an alluvial groundwater basin with a regional clay layer and numerous smaller discontinuous clay layers. Water level declines associated with pumping cause a decrease in water pressure in the pore space (pore pressure) of the aquifer system (Galloway, et al., 1999). Because the water pressure in the pores helps support the weight of the overlying aquifer, the pore pressure decrease causes more weight of the overlying aquifer to be transferred to the grains within the structure of the sediment layer. The difference between the water pressure in the pores and the weight of the overlying aquifer is the effective stress. If the effective stress borne by the sediment grains exceeds the structural strength of the sediment layer, then the aquifer system begins to deform. This deformation consists of rearrangement and compaction of fine-grained units[7], as illustrated on the lower diagram of **Figure 3-58**. The tabular nature of the fine-grained sediments allows for preferred alignment and compaction. As the sediments compact, the ground surface can sink, as illustrated by the 2nd column on the lower diagram of **Figure 3-58**.

Land subsidence due to groundwater withdrawals can be temporary (elastic) or permanent (inelastic).

Elastic deformation occurs when sediments compress as pore pressures decrease but expand by an equal amount as pore pressures increase. A decrease in water levels from groundwater pumping causes a small elastic compaction in both coarse- and fine-grained sediments; however, this compaction recovers as the effective stress returns to its initial value. Because elastic deformation is relatively minor and fully recoverable, it is not considered an impact.

Inelastic deformation occurs when the magnitude of the greatest pressure that has acted on the clay layer since its deposition (preconsolidation stress) is exceeded. This occurs when groundwater levels in the aquifer reach a historically low level. During inelastic deformation, or compaction, the sediment grains rearrange into a tighter configuration as pore pressures are reduced. This causes the volume of the sediment layer to reduce, which causes the land surface to subside. Inelastic deformation is permanent because it does not recover as pore pressures increase. Clay particles are often planar in form and more subject to permanent realignment (and inelastic subsidence). In general, coarse-grained deposits (e.g., sand and gravels) have sufficient intergranular strength and do not undergo inelastic

[7] Although extraction of groundwater by pumping wells causes a more complex deformation of the aquifer system than discussed herein, the simplistic concept of vertical compaction is often used to illustrate the land subsidence process (Galloway, et al., 1999; LSCE et al., 2014).

deformation within the range of pore pressure changes encountered from groundwater pumping.

The volume of compaction is equal to the volume of groundwater that is expelled from the pore space, resulting in a loss of storage capacity. This loss of storage capacity is permanent but may not be substantial because clay layers do not typically store significant amounts of usable groundwater (LSCE, et al., 2014). Inelastic compaction, however, may decrease the vertical permeability of the clay resulting in minor changes in vertical flow.

The following potential impacts can be associated with land subsidence due to groundwater withdrawals (modified from LSCE, et al., 2014):

- Damage to infrastructure including foundations, roads, bridges, or pipelines;
- Loss of conveyance in canals, streams, or channels;
- Diminished effectiveness of levees;
- Collapsed or damaged well casings; and
- Land fissures.

Land subsidence in the San Joaquin Valley has been documented for more than 90 years and recent investigations using satellite imagery indicate continuing problems in some areas. However, subsidence is not a significant issue in Modesto Subbasin. **Figure 3-59** illustrates the results of a subsidence study conducted by the USGS (Faunt et al., 2015) in the San Joaquin Valley from 2008 to 2010. This study shows that subsidence did not occur within Modesto Subbasin during this time period.

Beginning in June 2015, vertical displacement was estimated throughout many California groundwater basins using Interferometric Synthetic Aperture Radar (InSAR) data. The InSAR data are collected by the European Space Agency (ESA) Sentinel-1A satellite and processed by TRE ALTAMIRA Inc. (TRE), under contract with DWR as part of DWR's SGMA technical assistance. **Figure 3-60** illustrates vertical displacement (in feet) for the Modesto Subbasin from June 2015 to October 2020, a period of approximately five years. Most of the Subbasin is shaded grey on this figure, indicating an absence of land subsidence. Negative vertical displacement (subsidence), shown by yellow to light brown colors, is indicated in the central and eastern Subbasin, within the Eastern Principal Aquifer (east of the Corcoran Clay), and also in the northwest corner of the Subbasin and in a thin strip along the lower reach of the Stanislaus River. Most of the eastern Subbasin indicates vertical displacement between 0 and 0.05 feet (0.6 inches), as shown by the yellow shading. This equates to a rate of approximately 0.12 inches per year over the five year period. There are two small areas in the eastern Subbasin where a larger rate of subsidence is indicated. The maximum measured subsidence, shown by the small brown shaded area, is 0.15 feet (1.8 inches). This is a minimal amount of measured subsidence and could possibly be due, in part, to the abundance of clay surficial soils (see black shading on **Figure 3-6**) that have the potential to shrink. Also, there are restrictive layers in the soil in the eastern part of the Subbasin that, if disturbed by agricultural operations, could alter the ground surface elevation. This type of vertical displacement is not likely related to groundwater extraction. This subsidence is not likely to impact critical infrastructure in this area. The measured subsidence in the northwest Subbasin is mostly between 0 and 0.5 feet (0.6 inches) over the five year period (yellow shading), with maximum measured subsidence on the order of 0.1 feet (1.2 inches, orange shading) over the five year period. There is a higher potential for subsidence in the western Modesto Subbasin if groundwater levels are lowered below the Corcoran Clay.

A recent study conducted by Towill, Inc. and TRE Altamira, Inc., under contract with DWR, showed that InSAR vertical displacement data is highly accurate in most areas. The study compared vertical displacement ground surface elevation data from InSAR to continuously operating global positioning system (CGPS) base stations (Towill, 2021). The study found that the two data sets had a high degree of correlation, with only a very small state-wide absolute difference of 8.86 mm. The study concludes that InSAR data accurately measured vertical displacement in California's ground surface to within 18 mm (0.7 inches) between January 1, 2015, and October 1, 2020. The InSAR data cover the full extent of the Subbasin and provide a reasonable dataset to use as a screening tool to evaluate subsidence in the Modesto Subbasin. The InSAR data will be updated annually and discussed in the GSP annual reports.

In addition to the InSAR data, there are four GPS stations in the Subbasin. As shown on **Figure 3-60**, three of these stations are along the Highway 99 corridor in Salida and Modesto, and one is in the northeastern corner of the Subbasin. These GPS stations indicate zero to low rates of vertical displacement. Stations P260, CMOD and P306 showed no subsidence, while P781 indicated land subsidence of about 0.048 inches per year. The data from these stations shows a cyclic pattern to ground surface elevation, demonstrating the effects of inelastic land subsidence.

3.2.7. Interconnected Surface Water

The Tuolumne, Stanislaus, and San Joaquin rivers are all interconnected surface water as defined by SGMA. These three rivers flow for approximately 122 miles along three of the four Subbasin boundaries. The Stanislaus River is approximately 59 miles long along the northern Subbasin boundary, the Tuolumne River approximately 47 miles along the southern boundary and the San Joaquin River approximately 16 miles along the western boundary.

The segment of the San Joaquin River along the Modesto Subbasin can be characterized as a net gaining reach, historically and also based on future projected conditions. The Tuolumne and Stanislaus river systems are more dynamic, with recharge and baseflow varying along segments of the rivers both seasonally and over time. This dynamic system is a result of both natural conditions and managed operations. Both rivers are actively managed to provide critical water supplies for the Modesto, Turlock, and Eastern San Joaquin subbasins.

As described in more detail in **Chapter 5** (see **Section 5.1.4**), total stream inflows into the Subbasin during the historical study period are approximately 2.5 MAF. Approximately half of this inflow (1.3 MAF) is from the San Joaquin River, with the other half split between the

Stanislaus River (0.5 MAF) and the Tuolumne River (0.7 MAF). The Stanislaus River and Tuolumne River drain into the San Joaquin River, and the outflow from the San Joaquin River out of the Subbasin is approximately 2.8 MAF during the historical study period.

The location, quantity, and timing of deletions of these interconnected rivers were analyzed using the integrated surface water-groundwater model C2VSimTM. Development of the model and model calibration is described in **Appendix C** (see **Appendix C Sections 2.1.2, 3.4,** and **4.3.2**). Analysis of interconnected surface water and surface water budgets under historical, current, and future projected conditions is provided in **Chapter 5**.

Data tables in **Chapter 5** provide details for estimating average gaining or losing conditions along each river. As shown on **Table 5-2**, during the historical period (WY 1991 – WY 2015), the Tuolumne, Stanislaus, and San Joaquin rivers were all net gaining rivers in the Modesto Subbasin. During that period, net gains from the groundwater system (baseflow) to the Tuolumne, Stanislaus, and San Joaquin rivers were 31,000 AFY, 16,000 AFY, and 14,000 AFY, respectively.

The model predicts that under the 50-year projected conditions the San Joaquin River will remain a net gaining river into the future with a net gain of 9,000 AFY. The Tuolumne and Stanislaus rivers are predicted to transition to overall net losing rivers, with average net losses of 11,000 and 24,000 AFY, respectively (**Table 5-2**). An increase in stream seepage to groundwater (streamflow depletion) was predicted for all rivers if current land and water use remain the same without additional water supplies.

To illustrate the variability of losing/gaining reaches along each river, the C2VSimTM was used to analyze each river node in the model as predominantly gaining, losing, or mixed conditions for both historical and projected future conditions. This nodal analysis is presented on **Figure 3-61**. Model nodes are represented as small circles along each of the rivers.

For illustration purposes, the model nodes are color coded with respect to net gaining or losing conditions for the two different simulation periods. Although conditions are highly dynamic at each node, the predominant condition (occurring in 85 percent of the model months represented) is highlighted. If conditions at the node are predominantly gaining, the node is blue; predominantly losing nodes are orange, and nodes that are not predominantly losing or gaining are labeled “mixed” and colored green. The node color does not represent quantity and does not account for seasonal or annualized volumes of water (**Figure 3-61**).

A comparison between the historical simulation and the projected future simulation shows locations where predominantly gaining reaches (blue) transition to predominantly losing reaches (orange) or mixed conditions (green) over time (**Figure 3-61**). On the Stanislaus River, this transition occurs over most of the river but is most pronounced downstream of Oakdale. On the Tuolumne River, most of the change occurs in the eastern two-thirds of the river, upstream of the City of Modesto. Along the short segment of the San Joaquin River that defines the Modesto Subbasin, conditions are either gaining or mixed with less change predicted from historical to future conditions (**Figure 3-61**).

Although the model indicates that all reaches of the rivers remain connected through historical and future projected conditions, increases in streamflow depletion over time are indicated by the model water budgets and illustrated by the nodal analysis. The nodal analysis correlated strongly with predicted changes in groundwater elevations. This correlation indicates that streamflow depletions are primarily associated with groundwater extractions. The correlation further suggests that if water level declines associated with local overdraft conditions are arrested, predicted increases in streamflow depletions can be reduced. Additional modeling supports this conclusion (**Sections 5.3 and 8.5.1**).This indication highlights the need for water level monitoring (**Chapter 7**). These conditions also guided the selection of sustainable management criteria (**Chapter 6**) for interconnected surface water and the development of GSP projects and management actions to arrest local water level declines (**Chapter 8**). Additional details on the water budget analysis of surface water are provided in **Chapter 5**.

3.2.8. Groundwater Dependent Ecosystems

A groundwater dependent ecosystem (GDE) is defined under SGMA as "ecological communities of species that depend on groundwater emerging from aquifers or on groundwater occurring near the ground surface" (23 CCR § 351(m)).

To support identification of groundwater dependent ecosystems (GDEs), DWR created the Natural Communities Commonly Associated with Groundwater (NCCAG) dataset. This Natural Communities dataset is a compilation of 48 publicly available State and federal agency datasets that map vegetation, wetlands, springs, and seeps in California. The resultant mapping of natural vegetation communities and wetlands commonly associated with groundwater has been reviewed by DWR, California Department of Fish and Wildlife (CDFW), and The Nature Conservancy (TNC) and provided online for California groundwater basins. The data included in the Natural Communities dataset do not necessarily represent GDEs but can be used as a starting point in identifying GDEs within a groundwater basin.

The NCCAG dataset includes two sets of polygons that represent different habitat classes. The first class is wetland features commonly associated with the surface expression of groundwater under natural, unmodified conditions. The second class is vegetation types that are commonly associated with the sub-surface presence of groundwater (phreatophytes) (DWR, 2018d). The presence of wetland or vegetation polygons in the NCCAG dataset, however, does not necessarily indicate the presence of a GDE. Rather, the NCCAG dataset provides a starting point for identifying potential GDEs.

The vegetation and wetlands polygons from the NCCAG dataset within the Modesto Subbasin are illustrated on **Figure 3-62.** There are approximately 1,800 NCCAG polygons (768 wetlands and 1,027 vegetative) in the Modesto Subbasin. Most of the wetlands and vegetation polygons are present along the three major rivers (Stanislaus, Tuolumne and San Joaquin rivers), along Dry Creek, between Dry Creek and the Tuolumne River, scattered in the eastern Subbasin, and along the western Subbasin boundary, within the San Joaquin River Natural Wildlife Refuge.

Given the large number of NCCAG polygons, it was not feasible to investigate the details of each polygon in the Subbasin. However, a depth to water analysis was conducted as a first approximation to identify wetlands and vegetation polygons in areas where depth to water exceeds rooting depths, in accordance with The Nature Conservancy's guidance (The Nature Conservancy, 2018).

Groundwater elevations were used to estimate depth to water during the wettest year of the GSP Study Period (Spring 1998) and at the end of the GSP Study Period, during a critically dry year (Fall 2015). These two years generally represent periods of high (1998) and low (2015) water levels over average hydrologic conditions. Using ArcGIS, a groundwater elevation surface was developed from simulated groundwater elevations from the C2VSim-TM model for each of the two years. This surface was subtracted from a digital elevation map (DEM) of ground surface elevations to develop depth to water maps.

The areas within the Modesto Subbasin with a depth to water within 30 feet in Spring 1998 are shown on **Figure 3-63**. In general, depth to water is within 30 feet along the river boundaries, along Dry Creek, and in the western Subbasin. The NCCAG polygons were then overlaid onto the depth to water map and polygons were removed from the map in areas where depth to water exceeded 30 feet. It is assumed that the vegetation and wetlands do not have access to groundwater when depth to water is deeper than 30 feet.

The map showing wetland and vegetation polygons in areas with depth to water within 30 feet in Spring 1998 is illustrated on **Figure 3-64**. This map has 1,525 polygons (567 wetland and 958 vegetative), an approximate 15 percent decrease from the original NCCAG dataset. Potential GDEs are present along the river boundaries, along Dry Creek and in the western Subbasin. Potential GDEs were eliminated in the eastern Subbasin, and away from the rivers and Dry Creek. **Figure 3-64** represents the potential GDEs that were present in Spring 1998. Since this was the wettest period within the GSP study period, with the highest water levels in many parts of the Subbasin, this map represents the potential GDEs that could have been present in the Modesto Subbasin during the GSP Study Period (WY 1990 – WY 2015).

A similar analysis was conducted for water levels in Fall 2015. The areas of the Modesto Subbasin with a depth to water within 30 feet are illustrated on **Figure 3-65**. Depth to water is within 30 feet within a thin band along the river boundaries, the western stretch of Dry Creek and along the western edge of the Subbasin. The wetland and vegetative polygons in areas where depth to water is within 30 feet are shown on **Figure 3-66**. As compared to the 1998 map (**Figure 3-64**), potential GDEs were eliminated along most of Dry Creek. This map has 1,285 polygons (462 wetland and 823 vegetative), an approximate 28 percent decrease from the original NCCAG dataset.

SGMA legislation requires the Subbasin GSAs to be responsible for GDEs that are present at the end of the GSP Study Period (WY 2015). Therefore, the polygons shown on **Figure 3-66** are potential GDEs that will be further evaluated following GSP adoption.

In 2021, Moore Biological Consultants reviewed the potential GDEs identified in Fall 2015 (**Figure 3-66**) within Mapes Ranch, a private property near the San Joaquin River. Moore Biological Consultants conducted a desktop study and a field survey and concluded that 56 potential GDE polygons (46 wetland and 10 vegetative) identified within the Mapes Ranch property are not GDEs. This study is provided in **Appendix D**. These polygons were removed from the Fall 2015 map of potential GDEs, as shown on **Figure 3-67**.

Based on the Fall 2015 depth to water analysis and the study conducted by Moore Biological Consultants, there are 1,229 potential GDE polygons (416 wetland and 813 vegetative) in the Modesto Subbasin (**Figure 3-67**). This is an approximate 31 percent decrease from the original NCCAG dataset. These potential GDEs occur along the river boundaries, the downstream reach of Dry Creek and along the western Subbasin boundary.

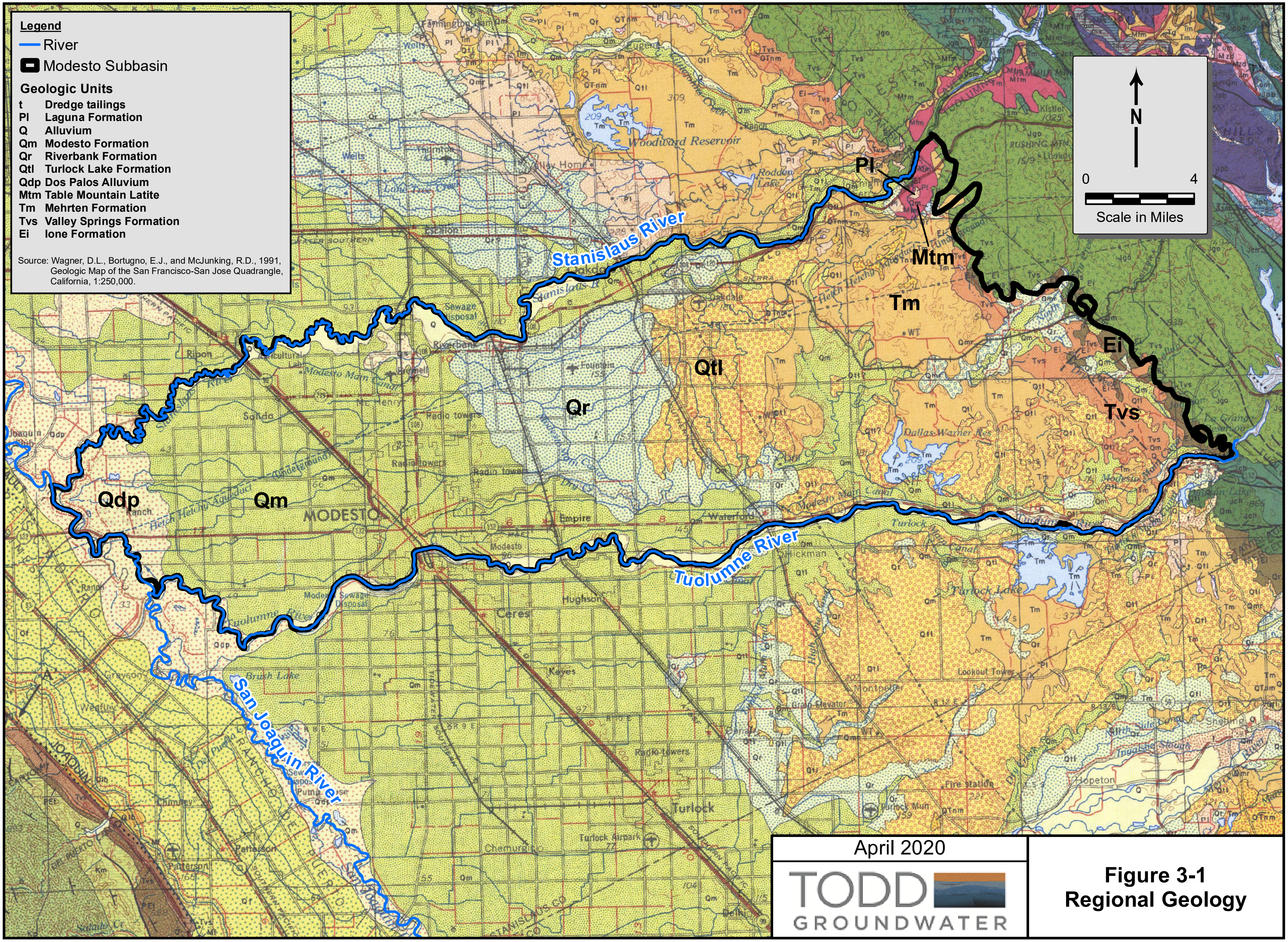
The GSAs plan to further investigate the potential GDEs during GSP implementation.

3.2.9. Data Gaps and Uncertainties for Groundwater Conditions

This section will summarize groundwater condition data gaps that affect implementation of the Plan and are related to the GSAs ability to sustainably manage groundwater. The Plan Implementation section, when developed, will describe how these data gaps will be addressed in future GSP actions. A summary of data gaps identified for the Groundwater Conditions analysis in the Modesto Subbasin is summarized in the following table.

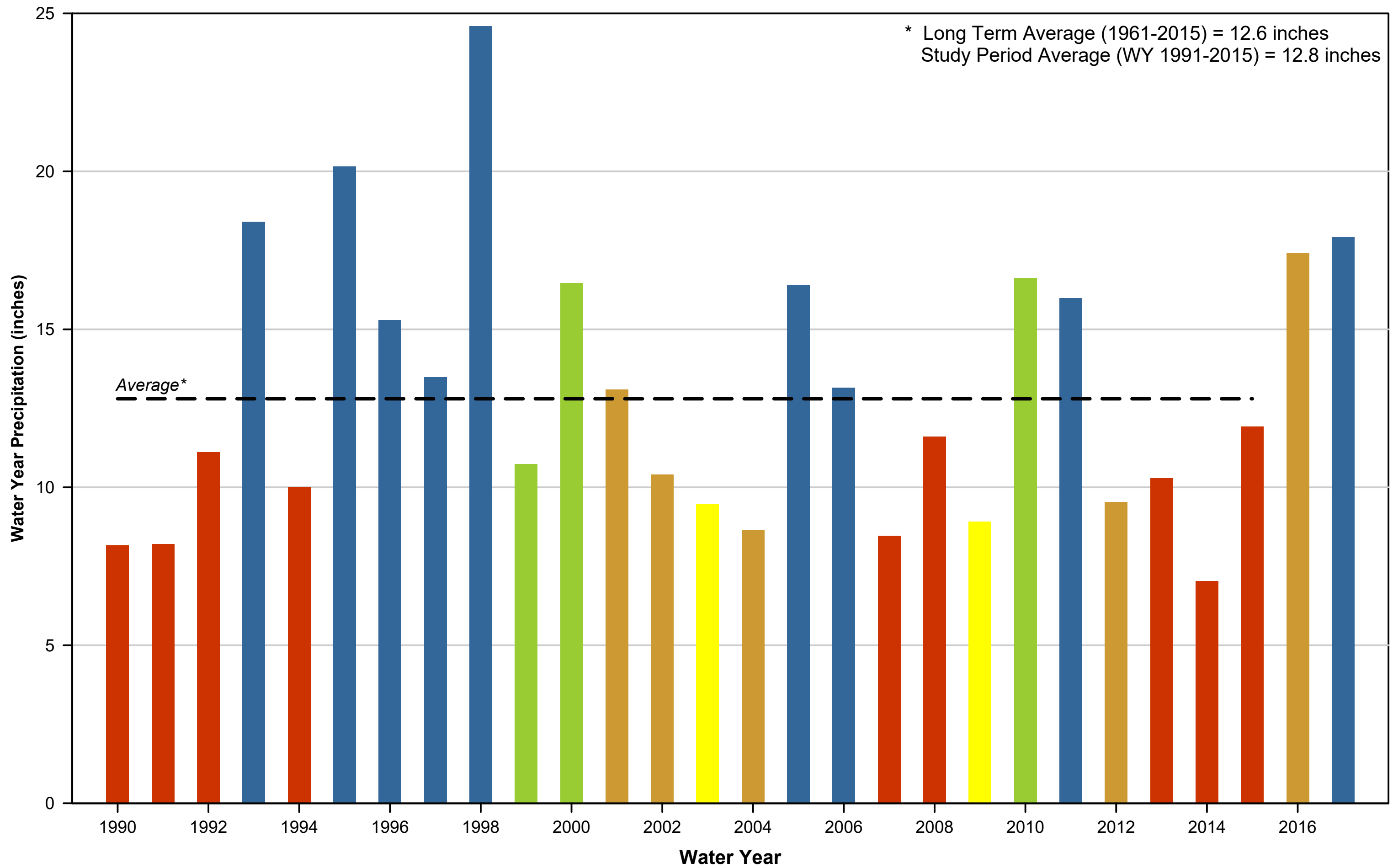
Table 3-7: Data Gaps for the Groundwater Conditions

Issue	Area	Impacts on Groundwater Management	Actions to Address
Water Levels in Western Lower Principal Aquifer	Western Lower Principal Aquifer	Groundwater levels and flow; vertical gradients; evaluation for potential future land subsidence; insufficient wells for groundwater elevation mapping.	• Install monitoring wells screened solely in the Western Lower Principal Aquifer. • Locate existing wells to incorporate into monitoring program, if available.
Groundwater Conditions in Eastern Subbasin	East of the Oakdale-Waterford Highway	Groundwater flow and quality of Eastern Principal Aquifer	• Install monitoring wells in eastern Subbasin. • Obtain water level data from landowners.
Interconnected Surface Water	River boundaries	Groundwater levels and flow, surface water availability, water budgets	• Continued analysis with C2VSimTM Model. • Improve monitoring.
GDEs	River boundaries	Groundwater levels and flow	Verify presence of GDEs based on NCCAG dataset.



April 2020

Figure 3-1
Regional Geology



Wet
Above Normal
Below Normal
Dry
Critically Dry

Notes:
Source - MID weather station (Modesto CA).
Water Year - October 1 through September.

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Figure 3-2
Annual Precipitation
Water Year

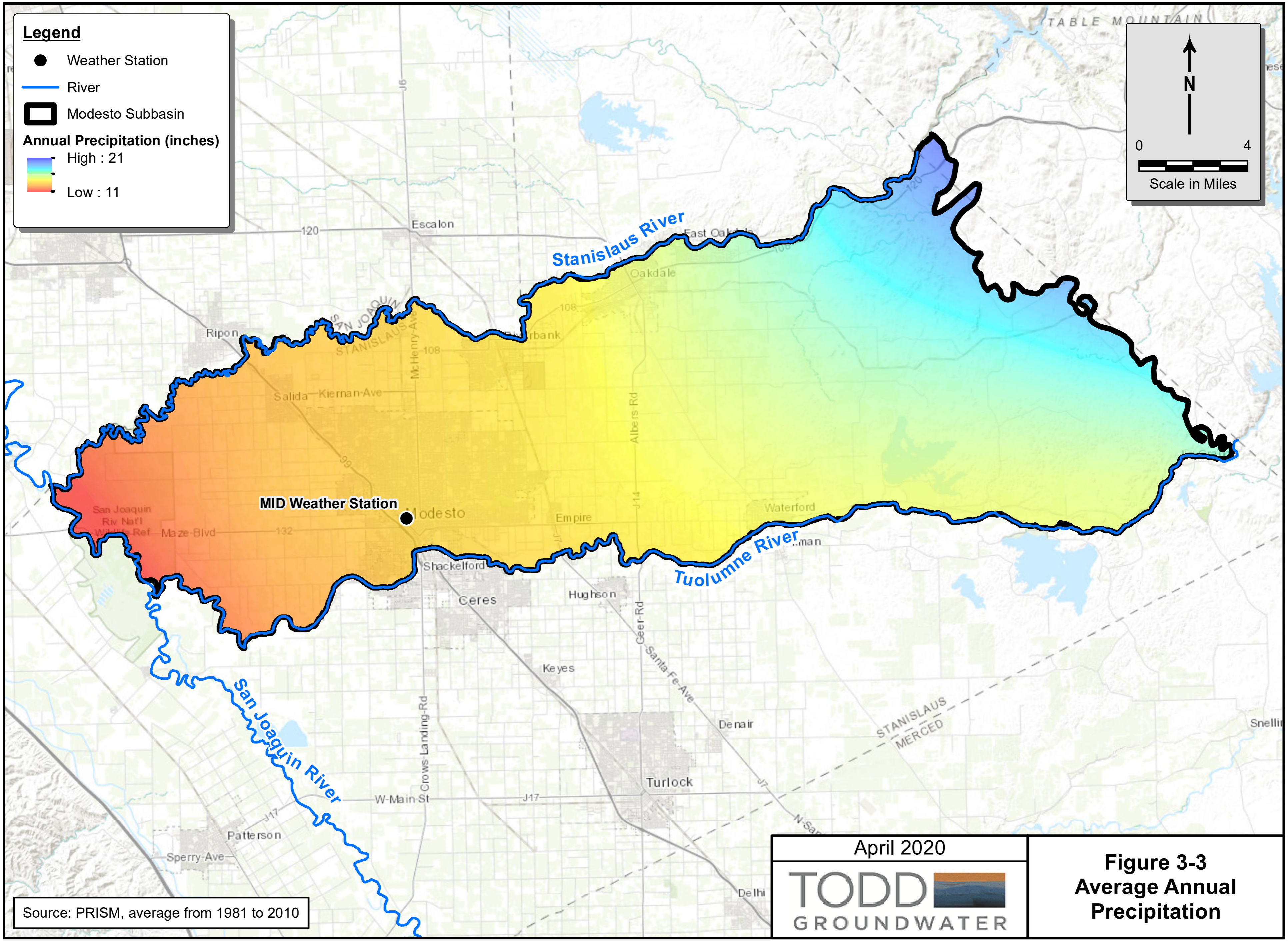
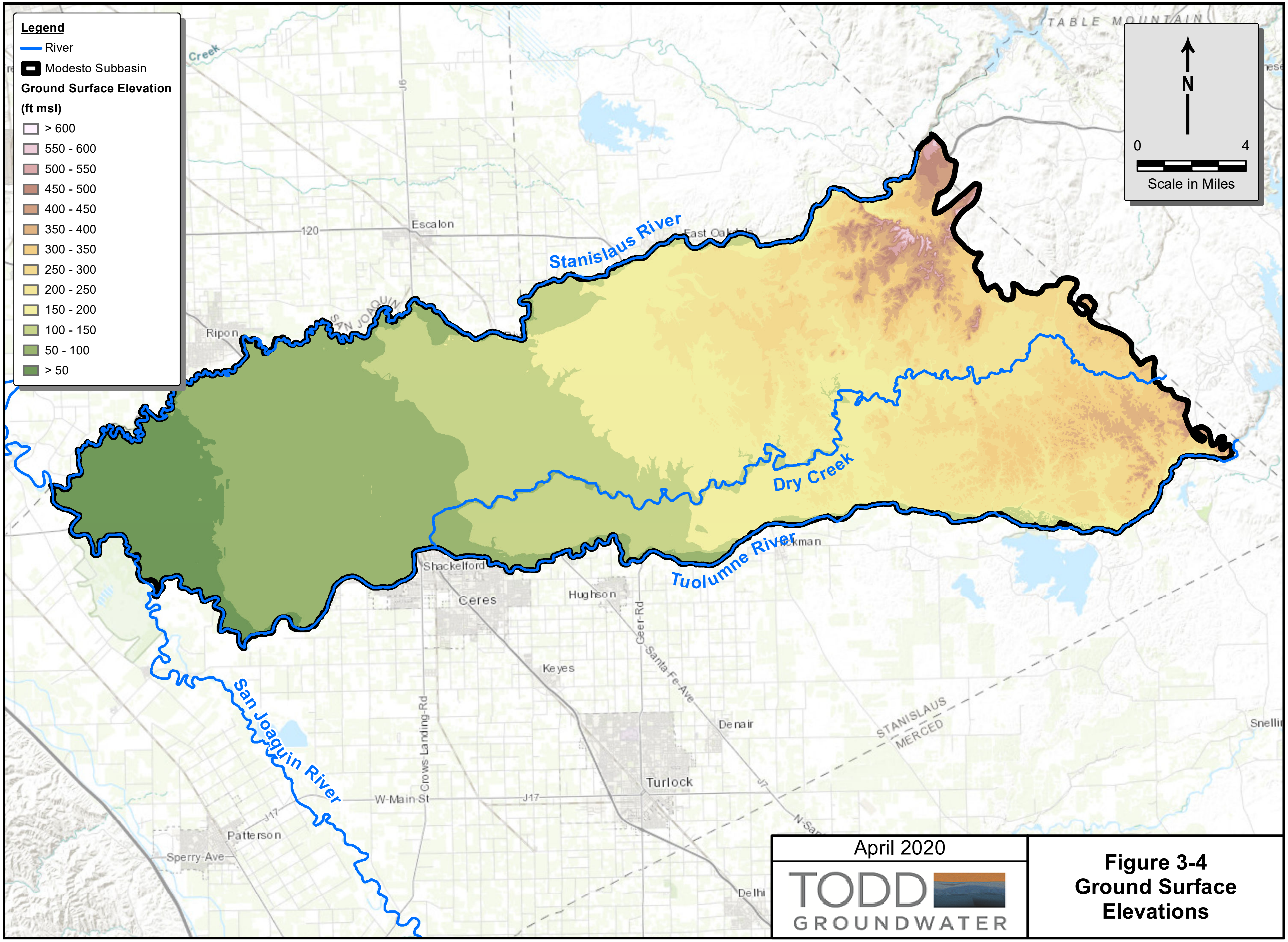


Figure 3-3
Average Annual Precipitation



April 2020

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Figure 3-4
Ground Surface Elevations

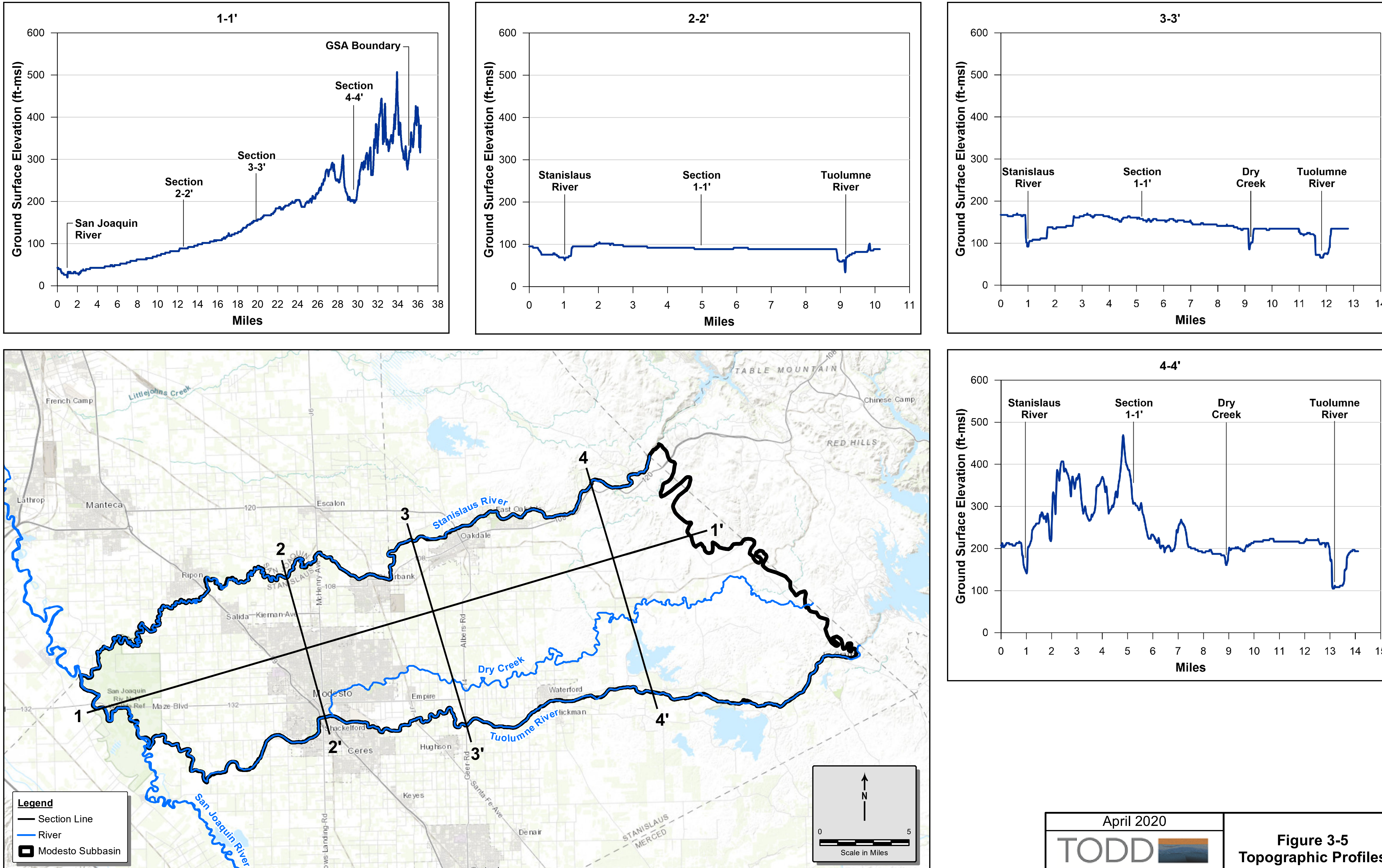

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Figure 3-5
Topographic Profiles

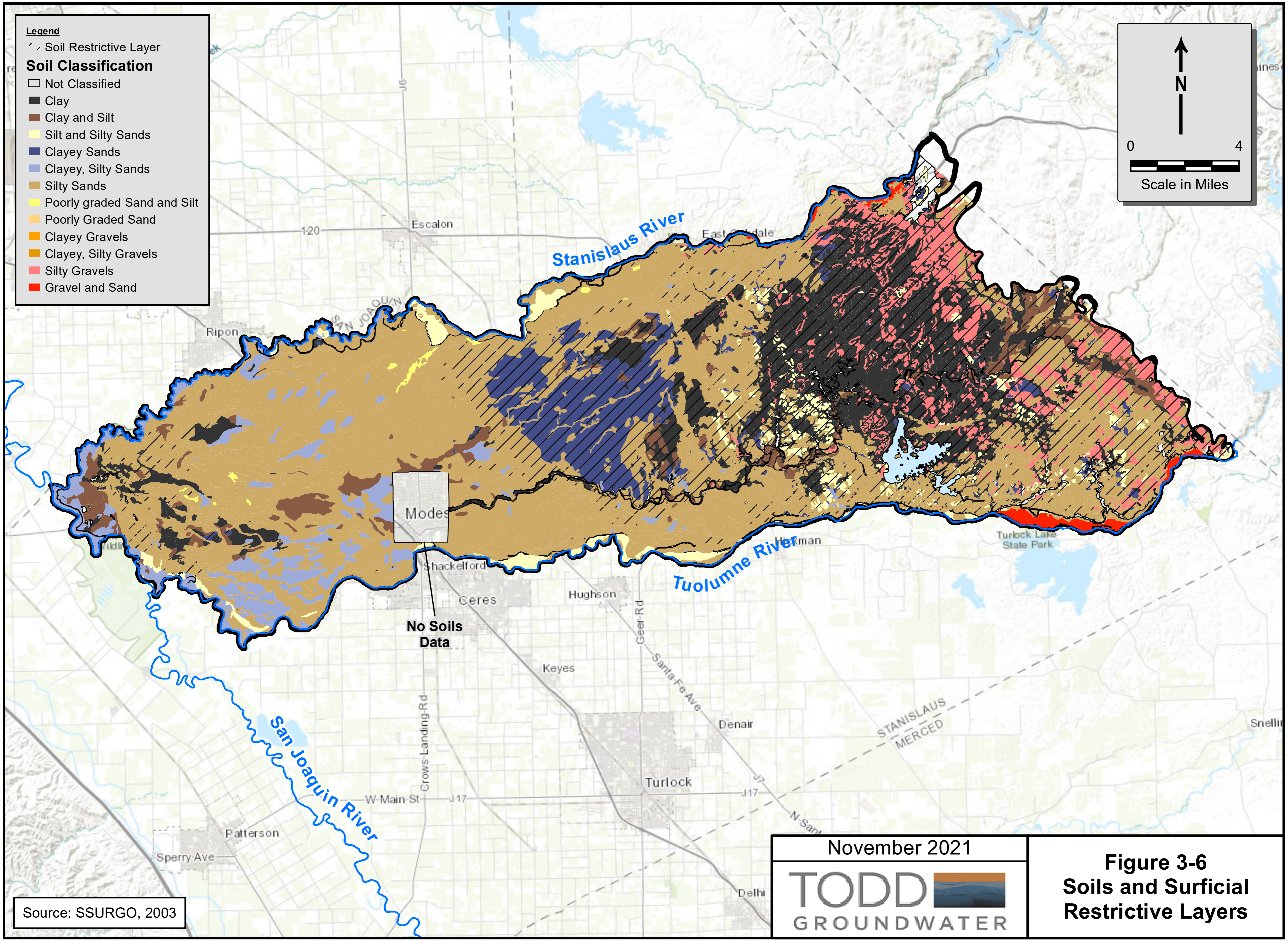


Figure 3-6
Soils and Surficial Restrictive Layers

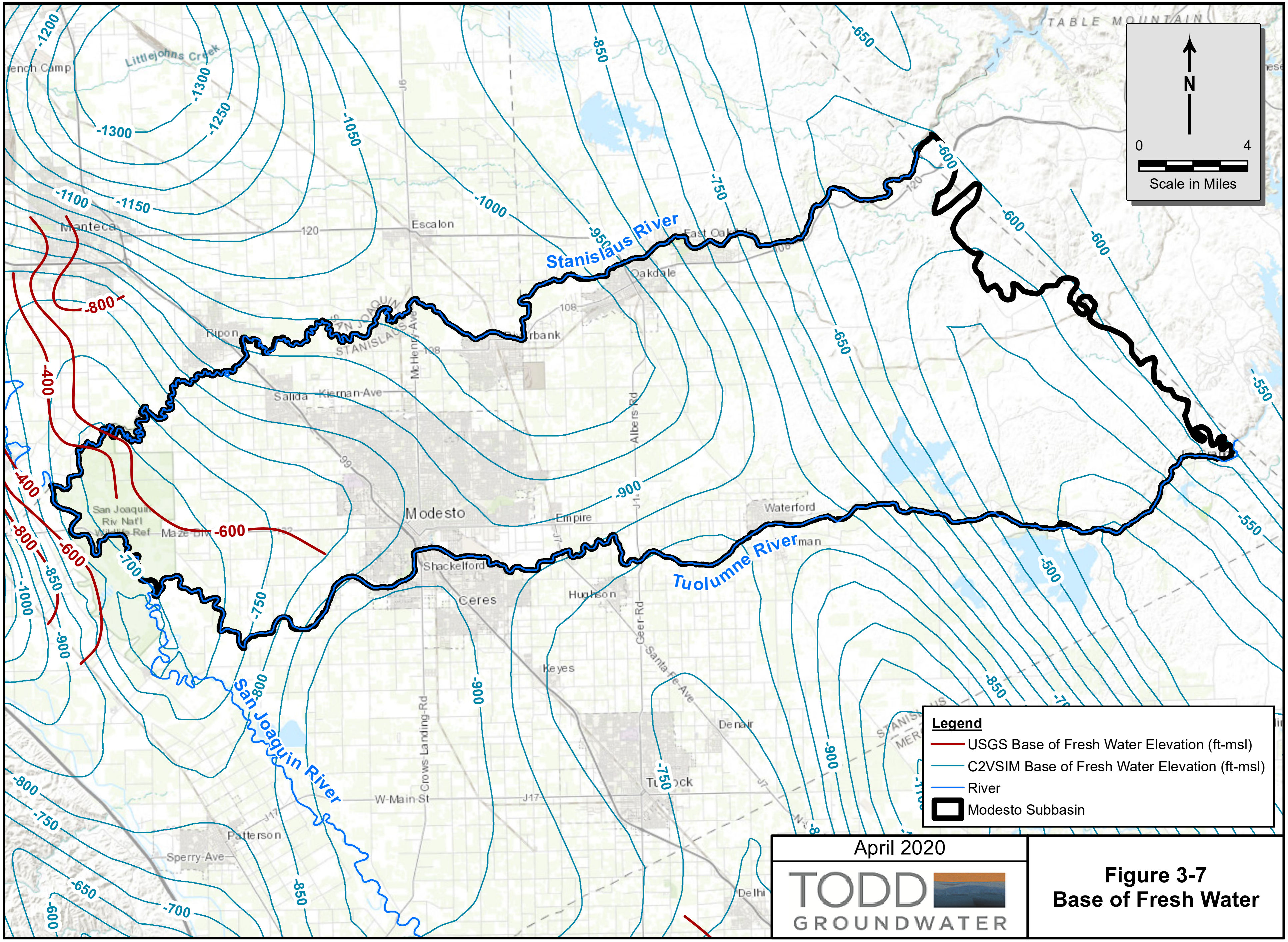
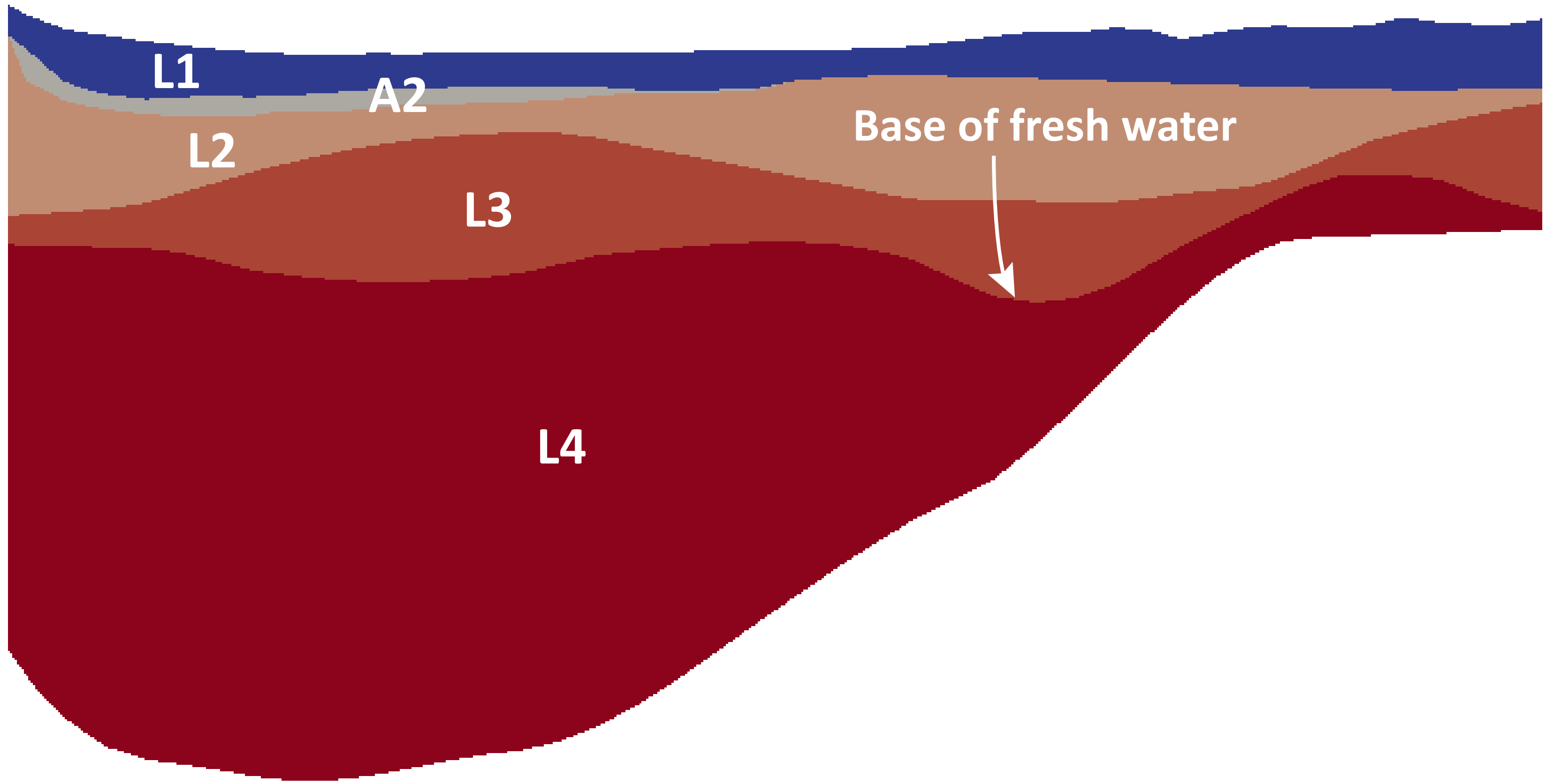


Figure 3-7
Base of Fresh Water



L1: Aquifer ranging from the ground surface to the top of the pumping layer

A2: Corcoran Clay

L2: Primary shallow pumping layer

L3: Deeper pumping layer (bottom of layer is the base of fresh water)

L4: Saline aquifer (bottom of layer is the base of continental deposits)

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Figure 3-8
C2VSIM
Model Layers

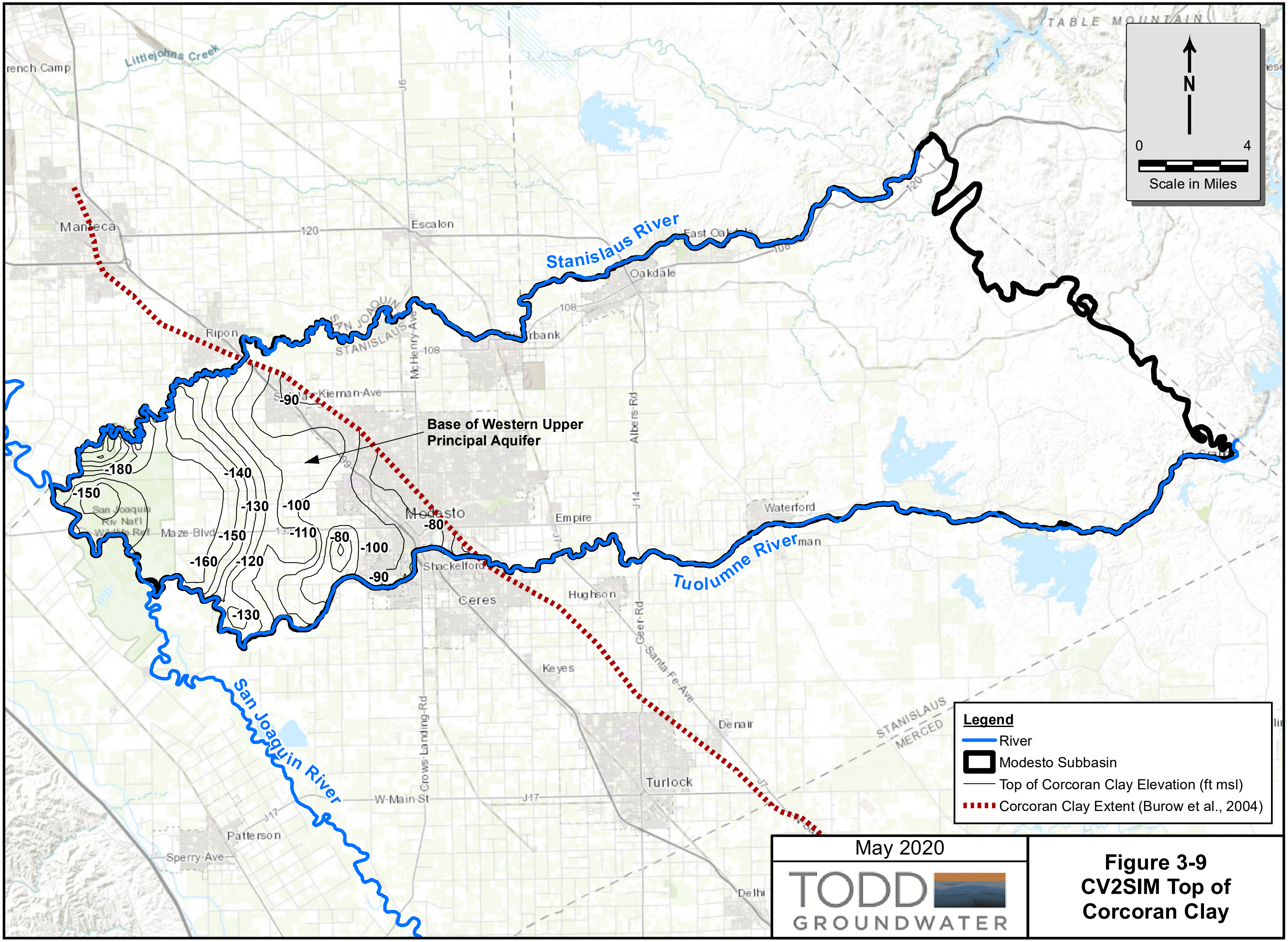

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Figure 3-9
CV2SIM Top of Corcoran Clay

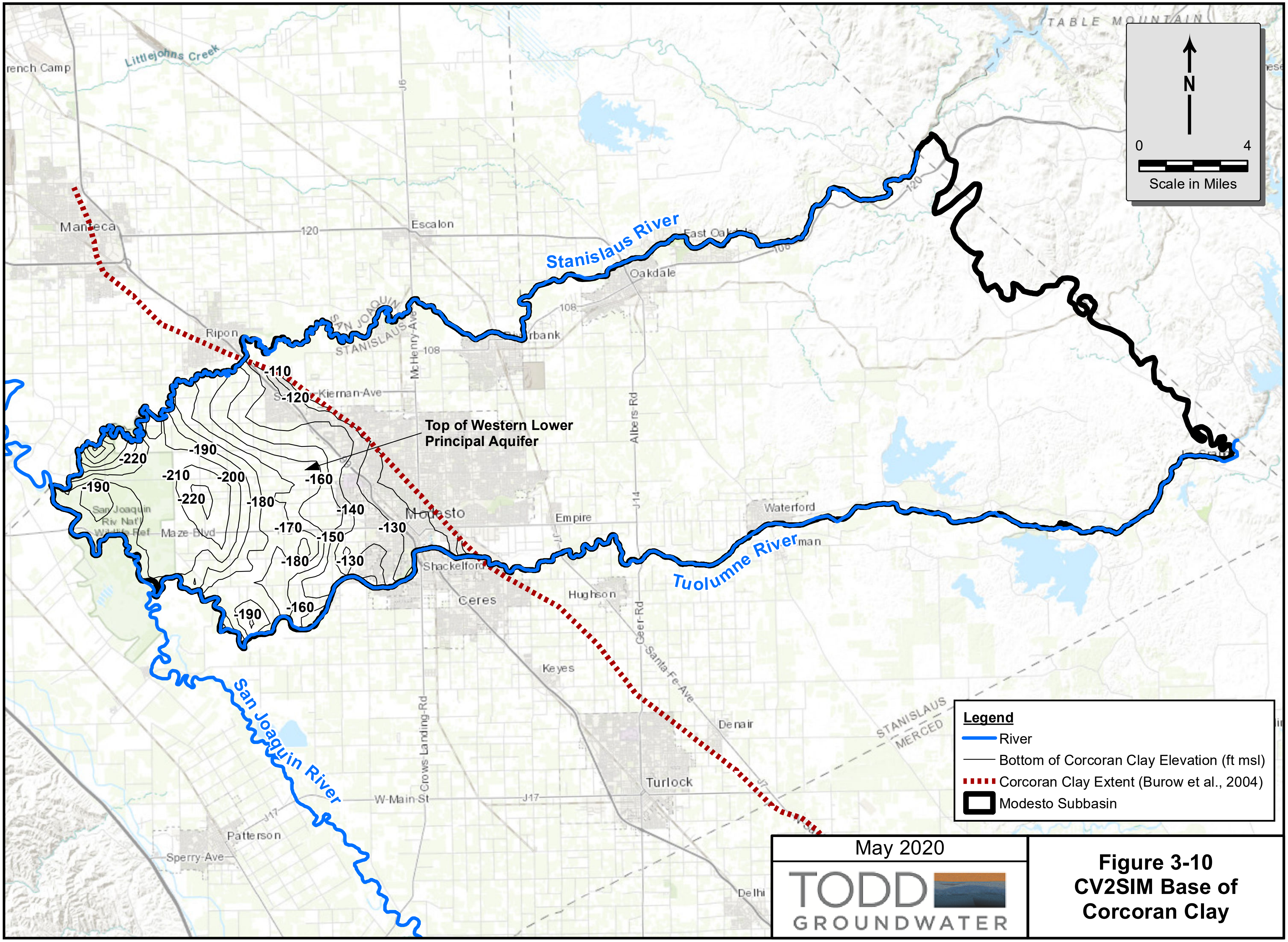

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Figure 3-10
CV2SIM Base of Corcoran Clay

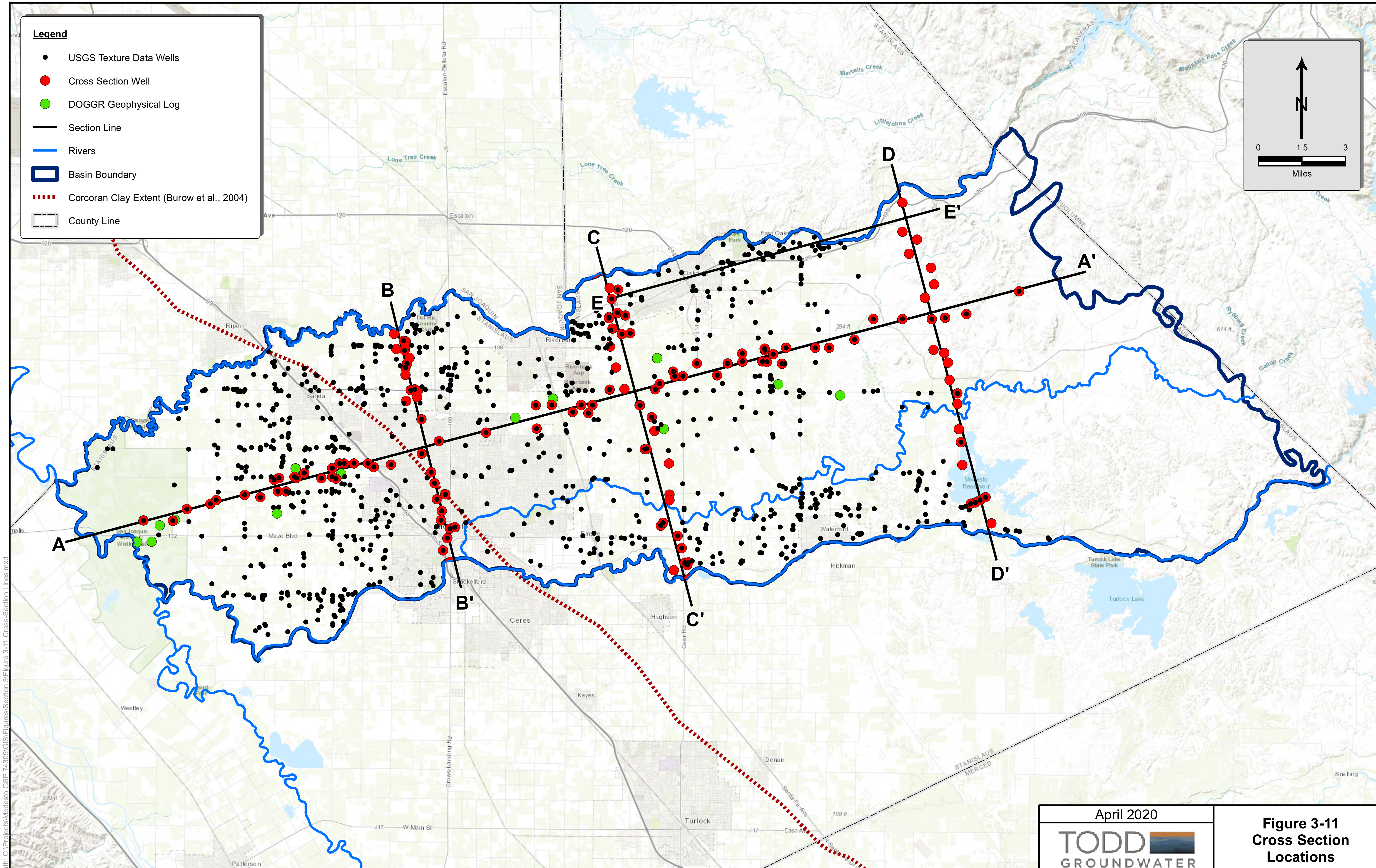

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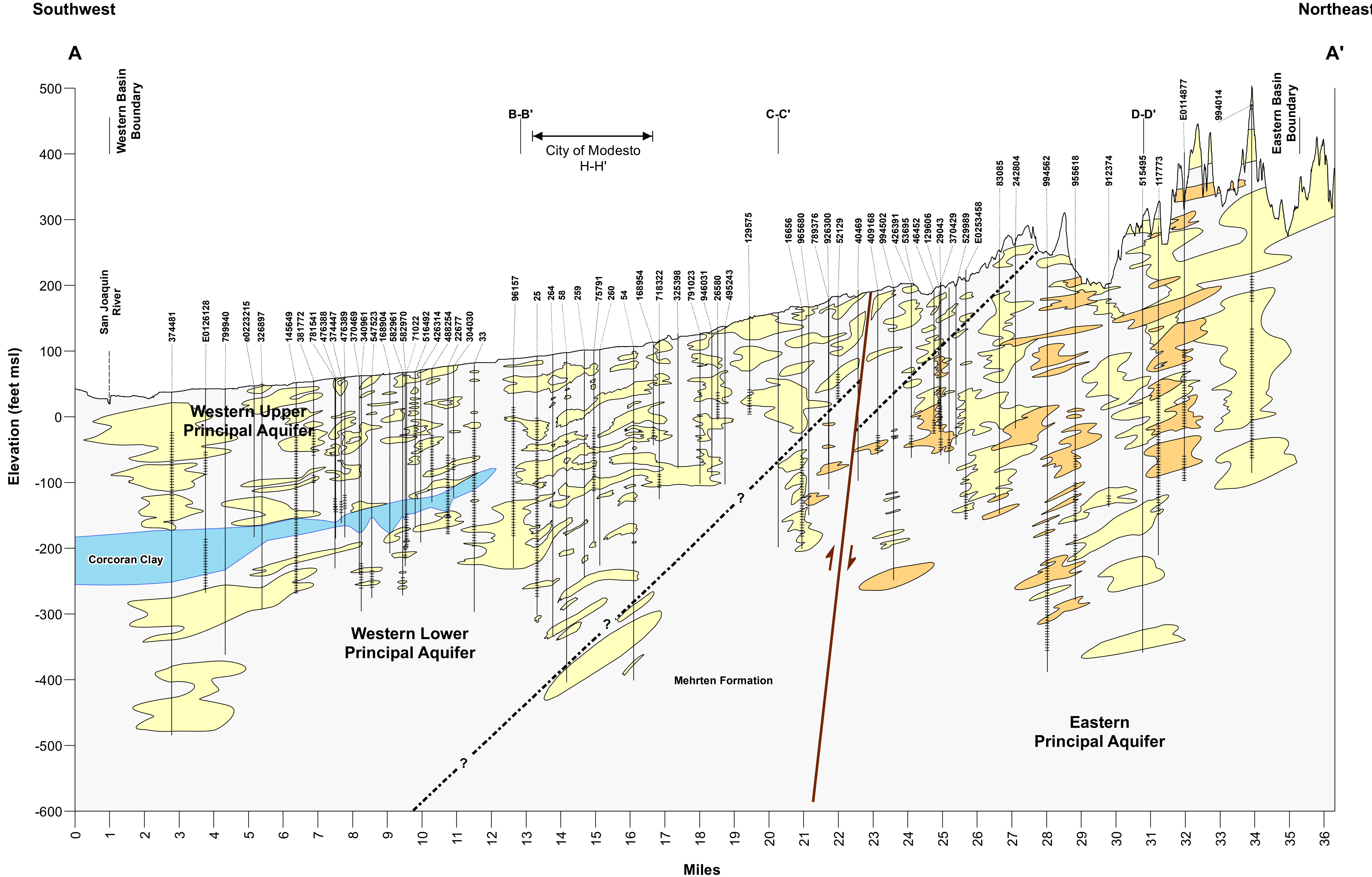
Figure 3-11
Cross Section Locations



Approximate Fault Location
Inferred Fault Motion
Estimated Top of Mehrten Formation
Coarse-Grained Material
Blue Clay
Black Sands
Fine-Grained Material

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Figure 3-12
Cross Section A-A'

Path: C:\Projects\Modesto GSP 74305\GIS\Figures\Section 3\Figure 3-12 Cross-Section A-A'.mxd

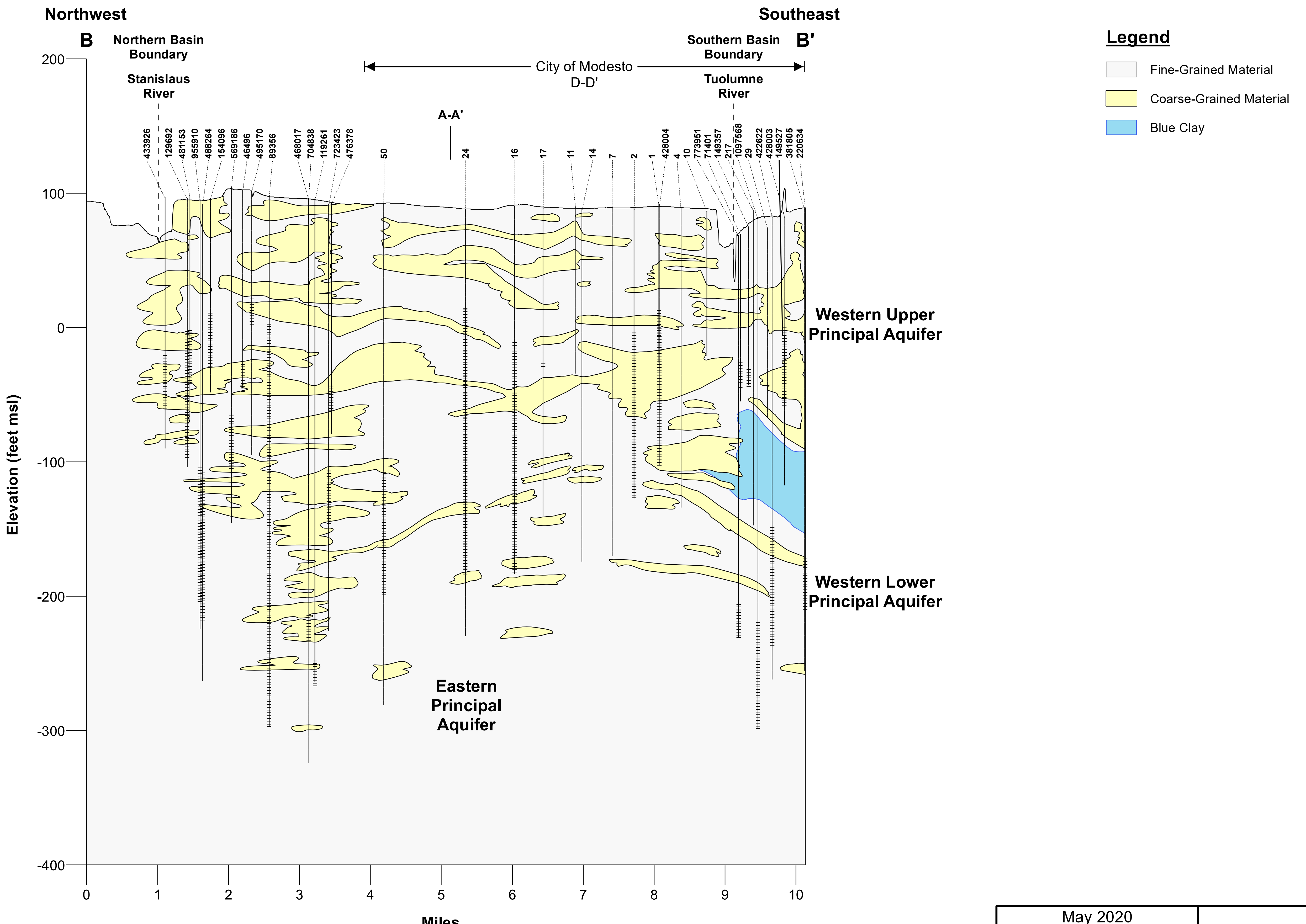

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Figure 3-13
Cross Section B-B'

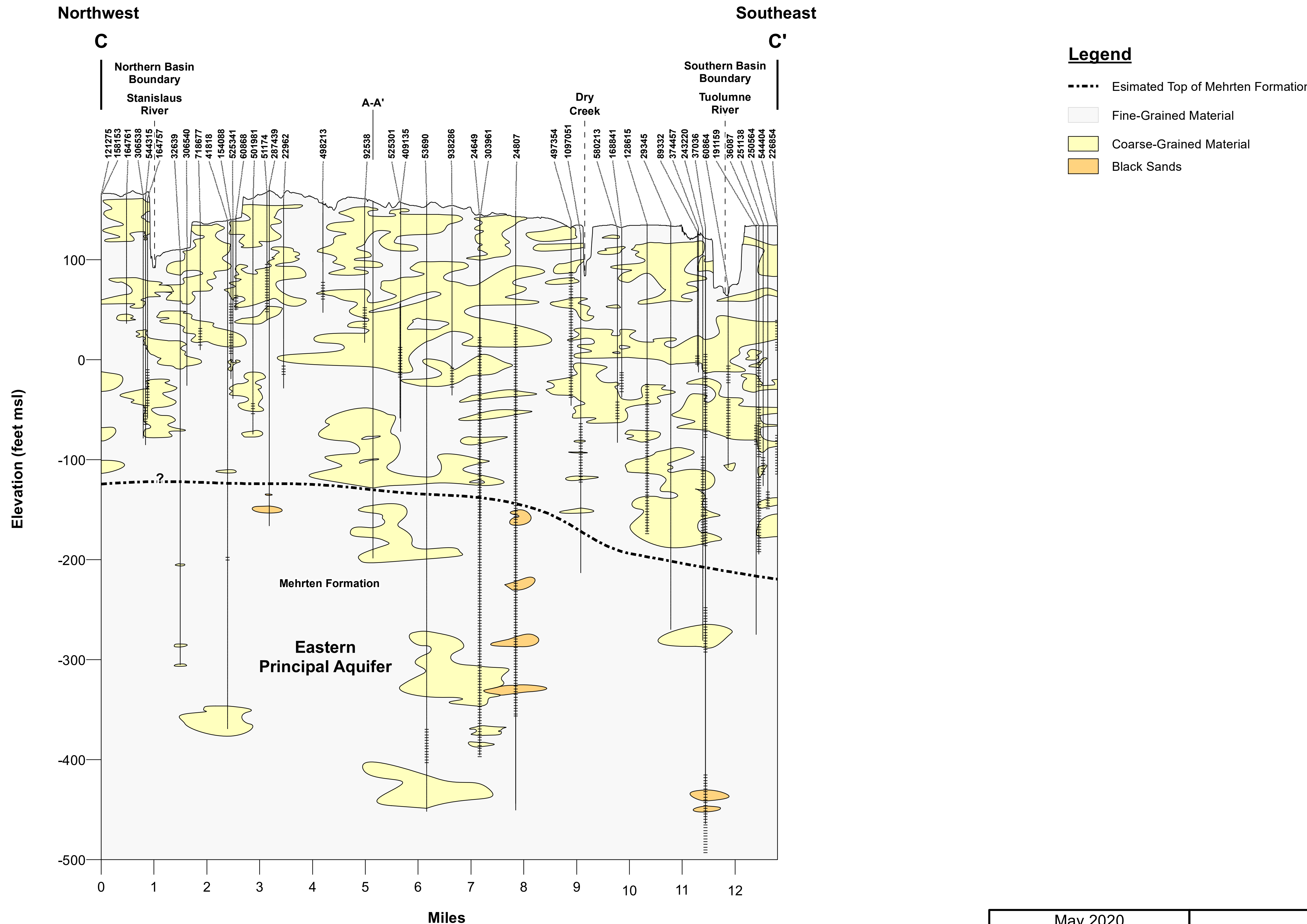

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Figure 3-14
Cross Section C-C'

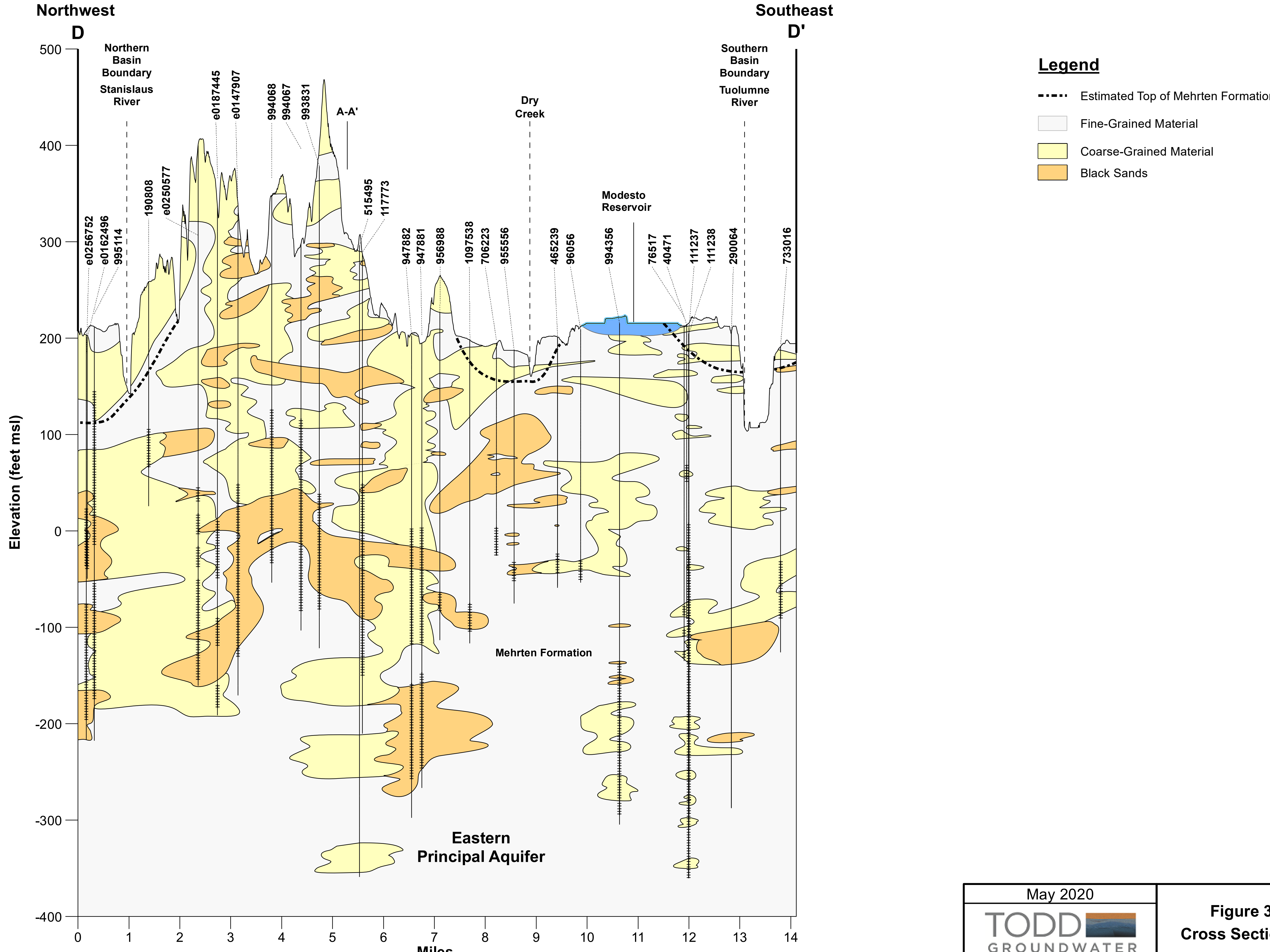

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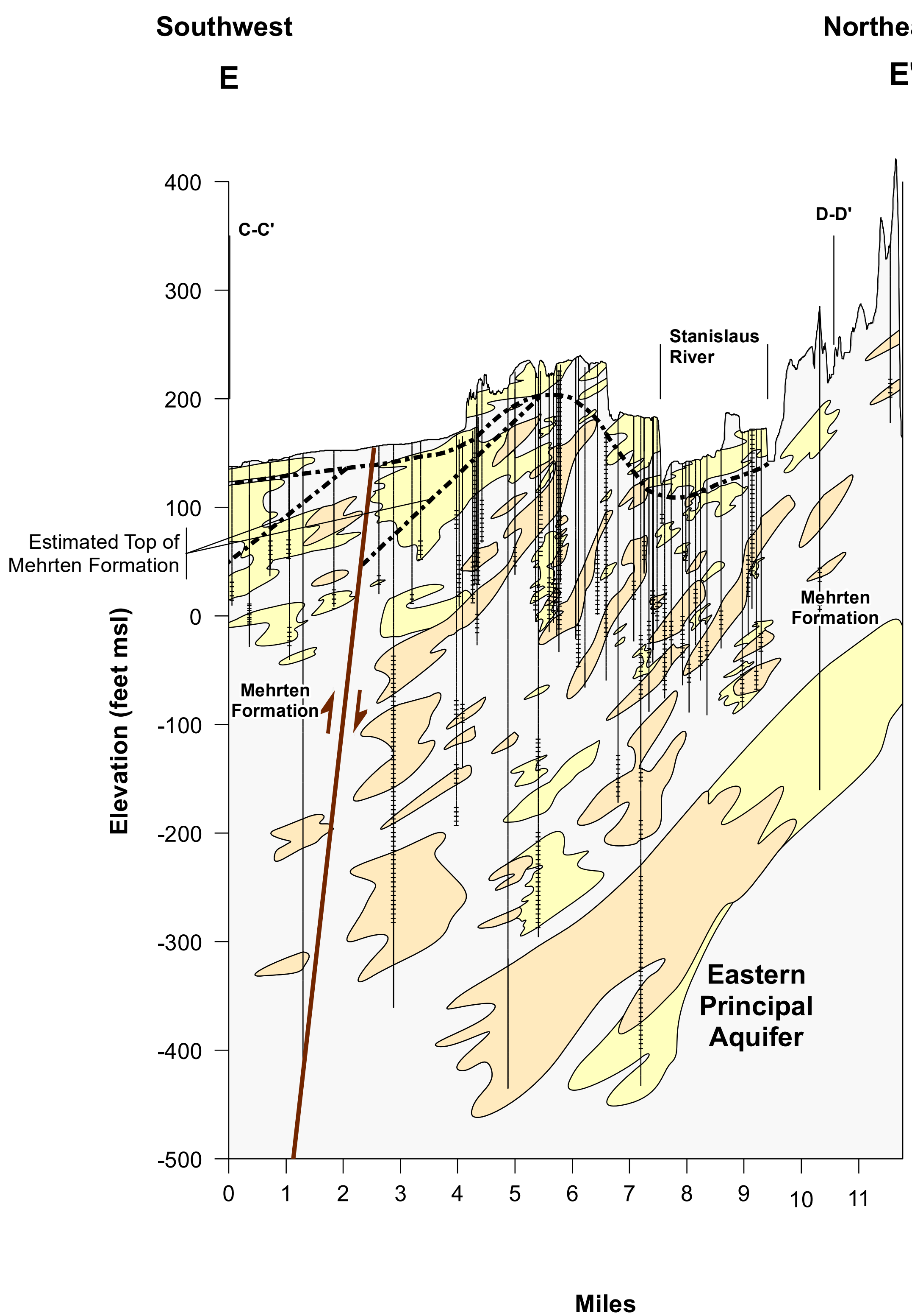
Figure 3-15
Cross Section D-D'



Legend

- Fine-Grained Material
- Coarse-Grained Material
- Black Sands
- Approximate Fault Location
- Inferred Fault Motion

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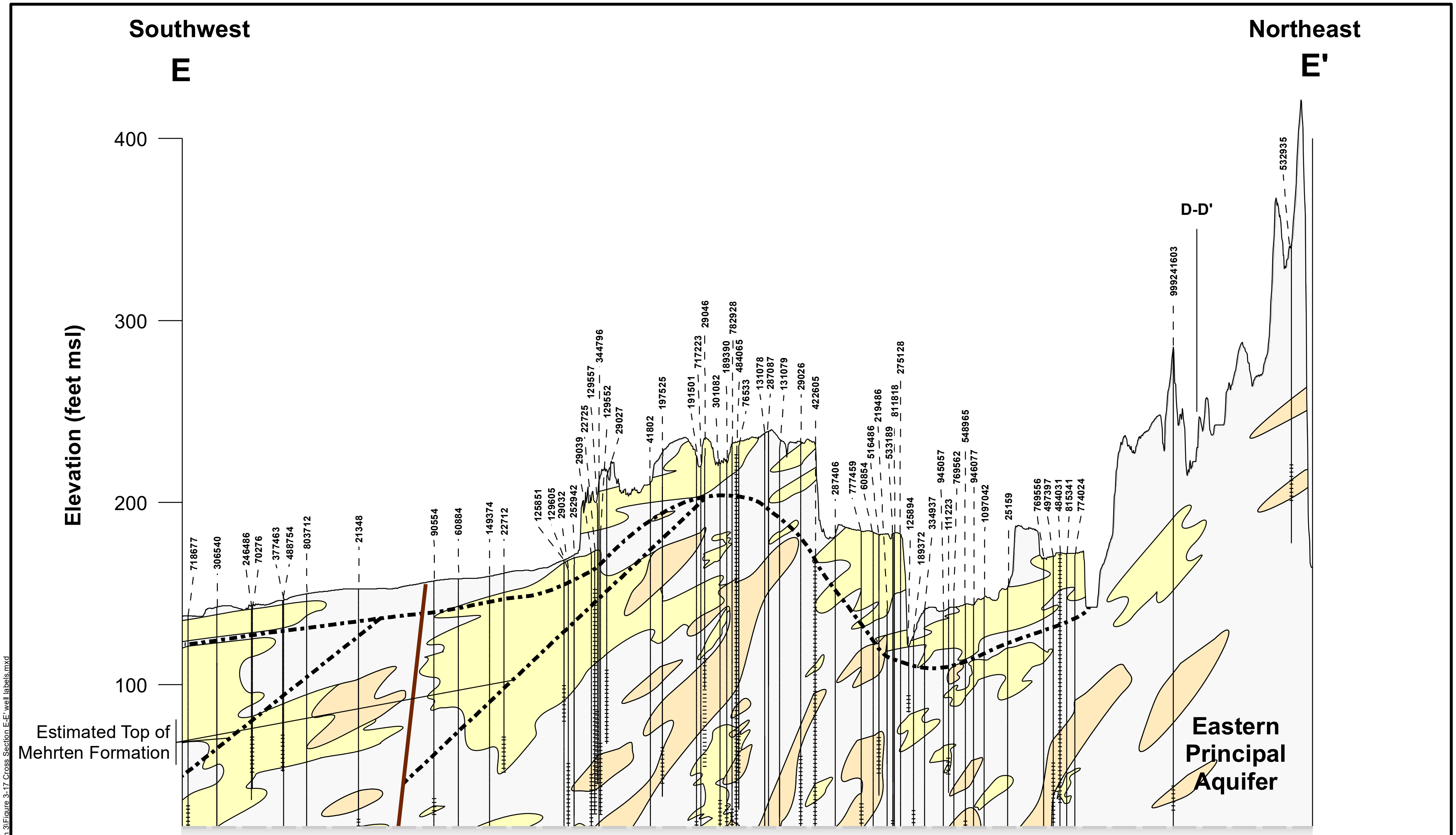
Figure 3-16
Cross Section E-E'

Path: C:\Projects\Modesto GSP 74305\GIS\Figures\Section 3\Figure 3-16 Cross-Section E-E'.mxd



Legend

Fine-Grained Material

Coarse-Grained Material

Black Sands

Approximate Fault Location

Inferred Fault Motion

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Figure 3-17
Cross Section E-E'
Alternative Scale

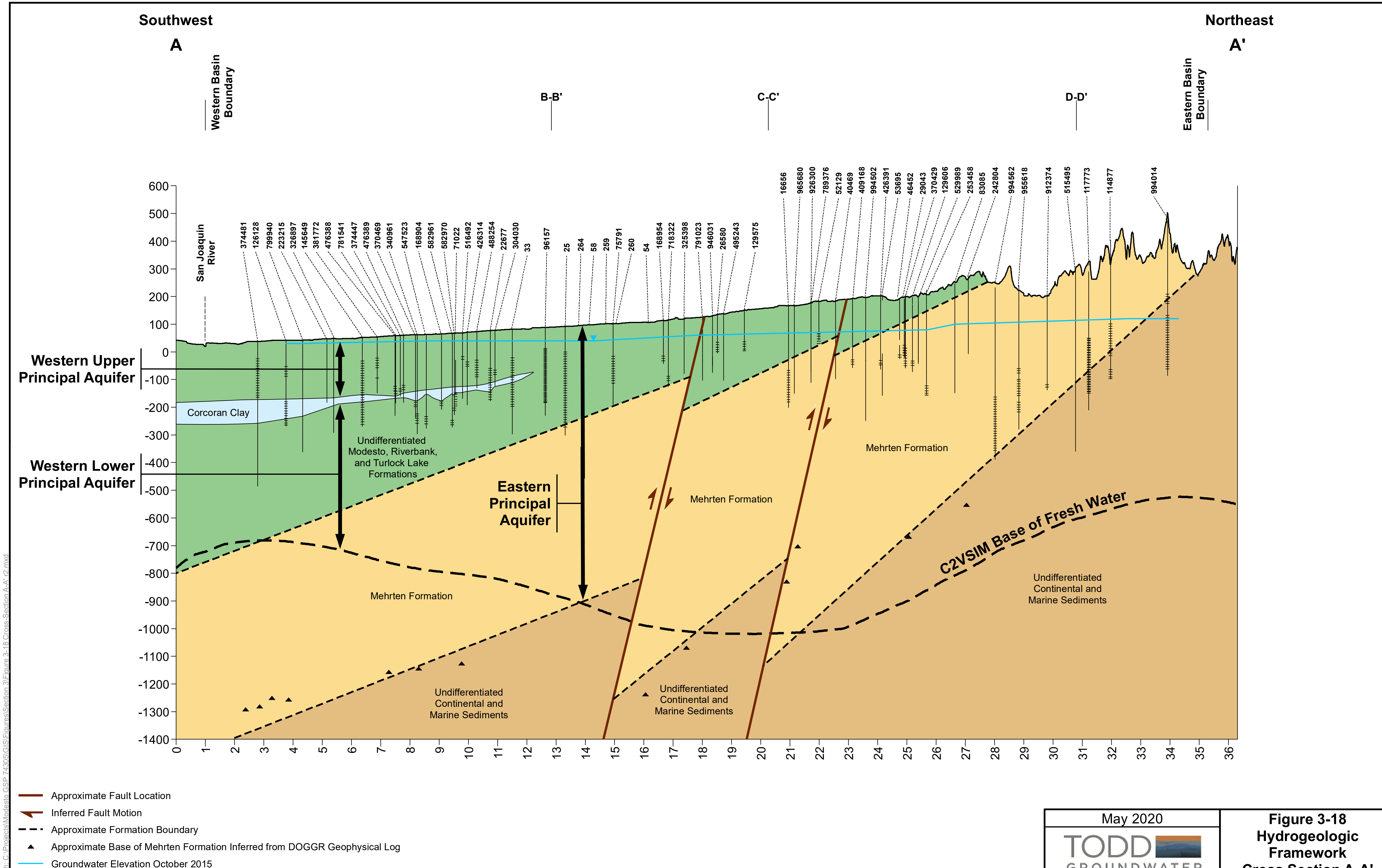

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Figure 3-18 Hydrogeologic Framework Cross Section A-A'

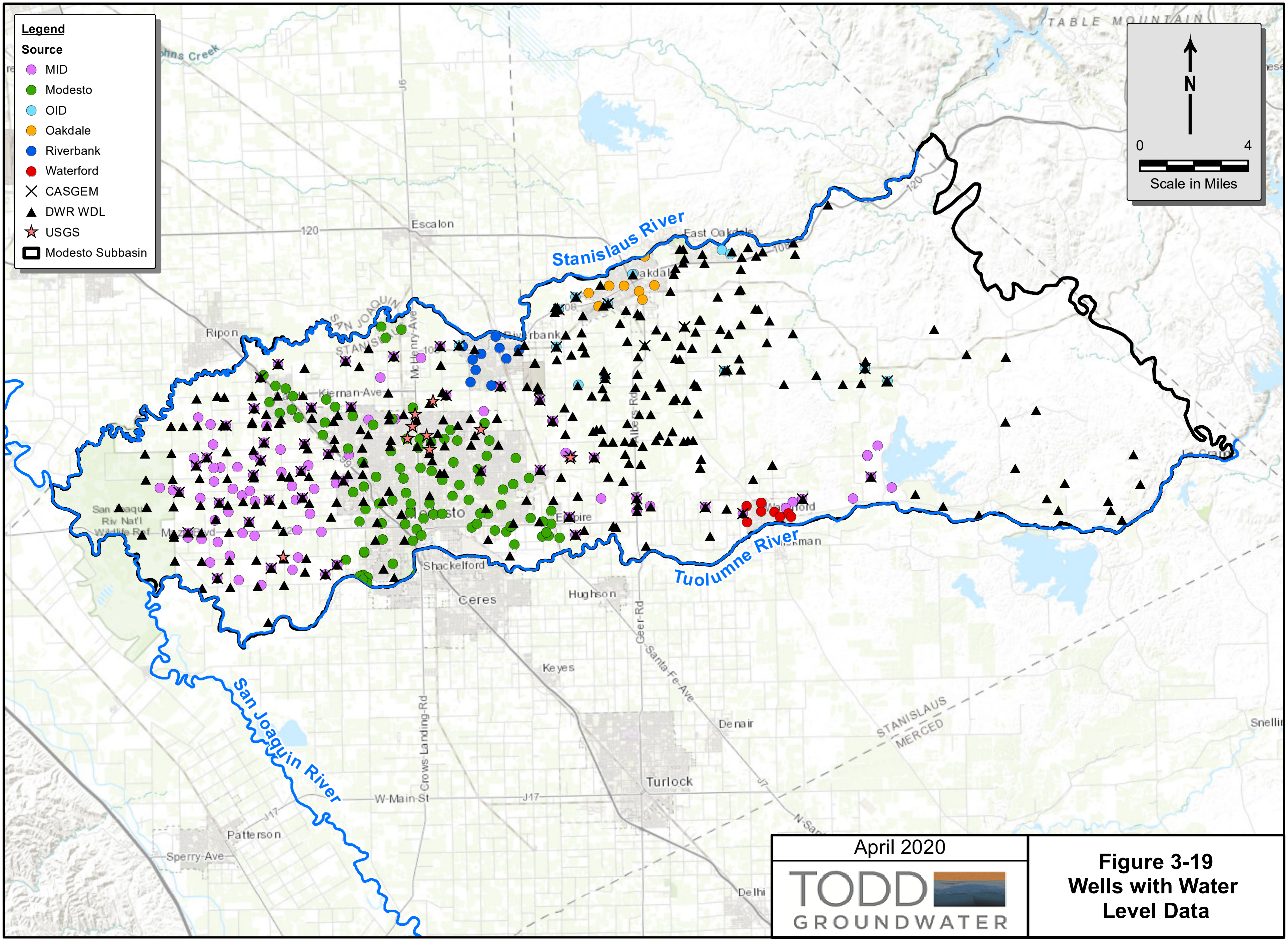

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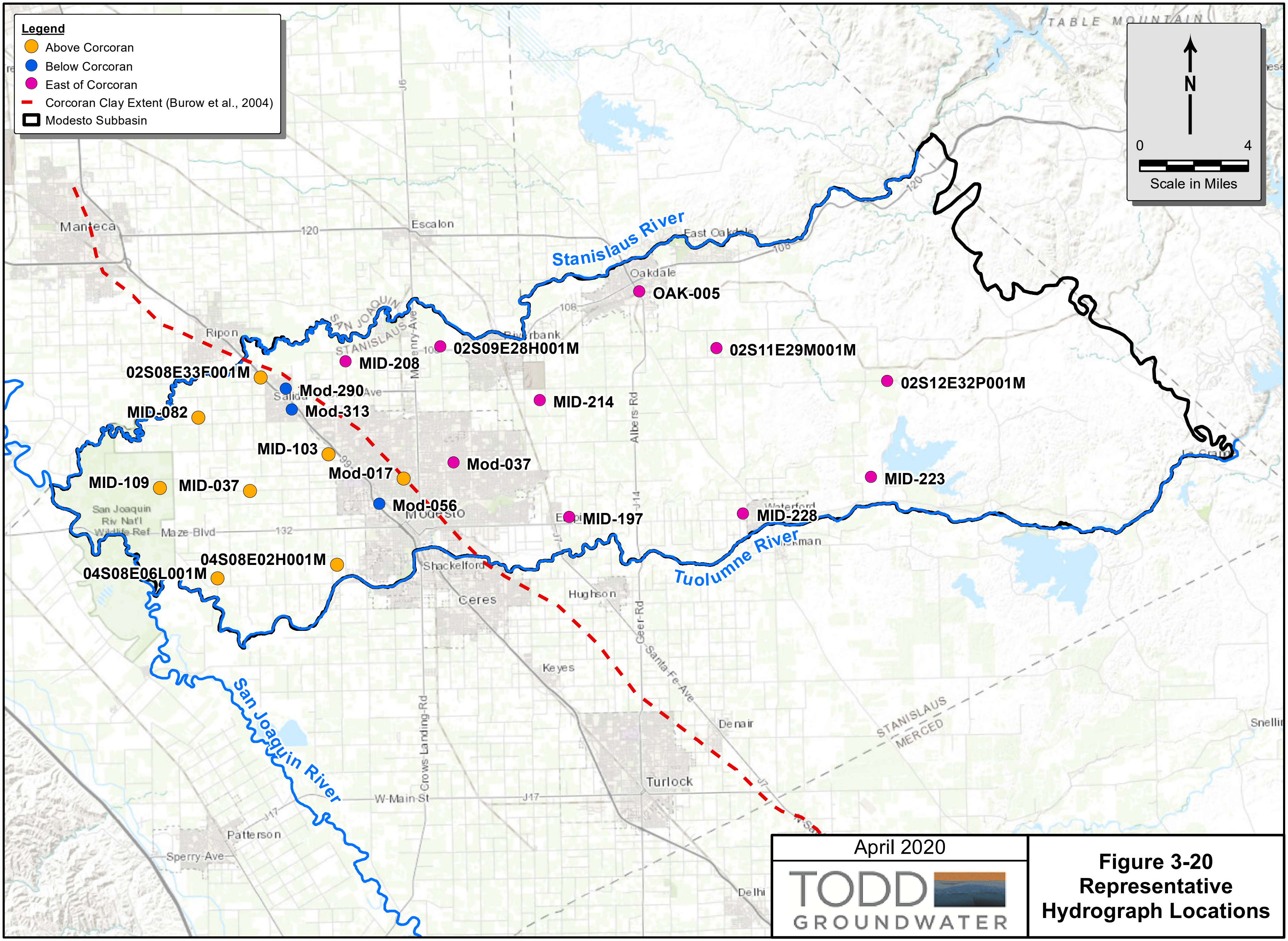
Figure 3-19
Wells with Water Level Data



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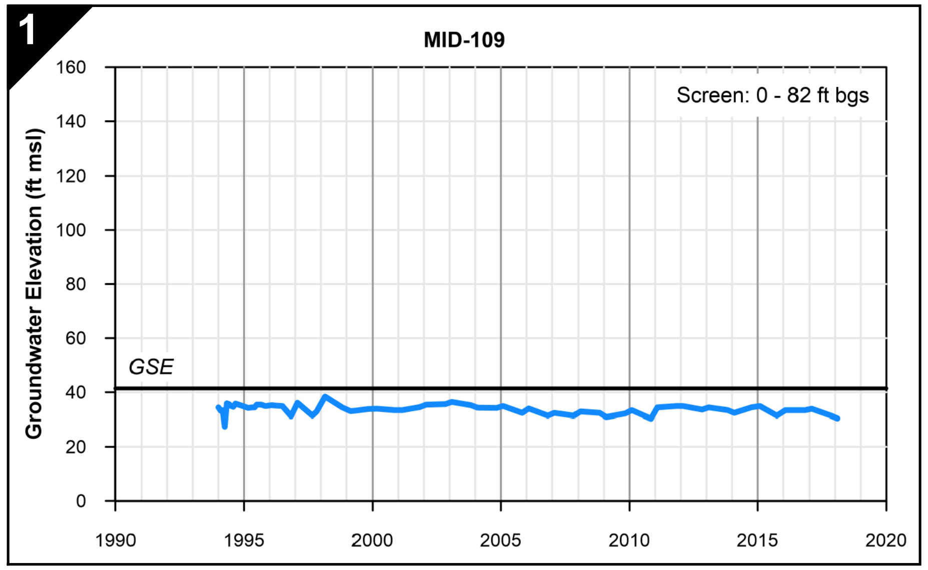
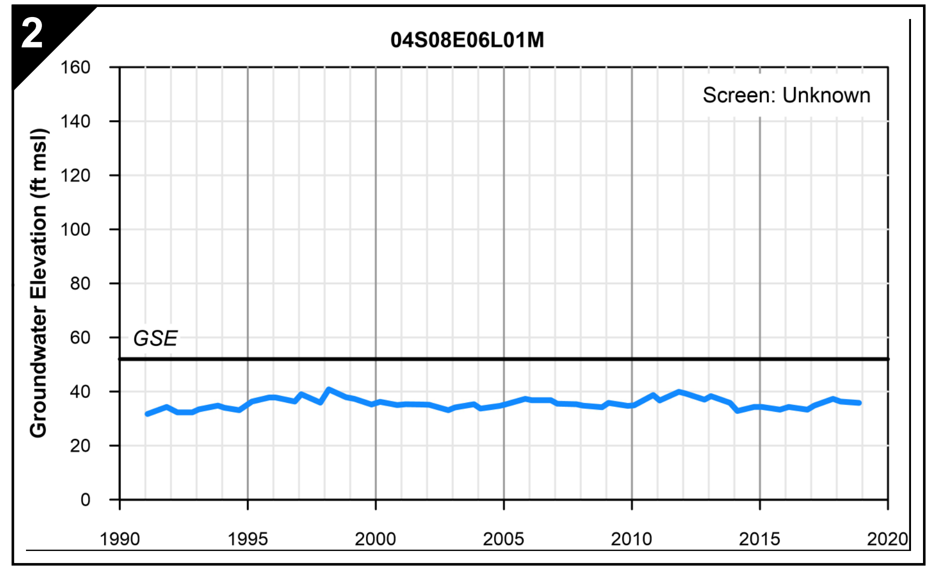
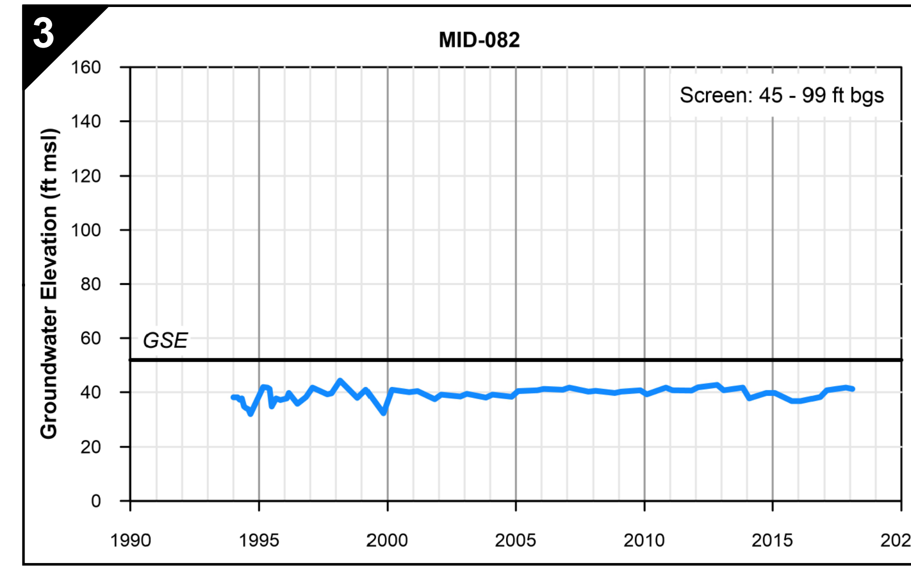
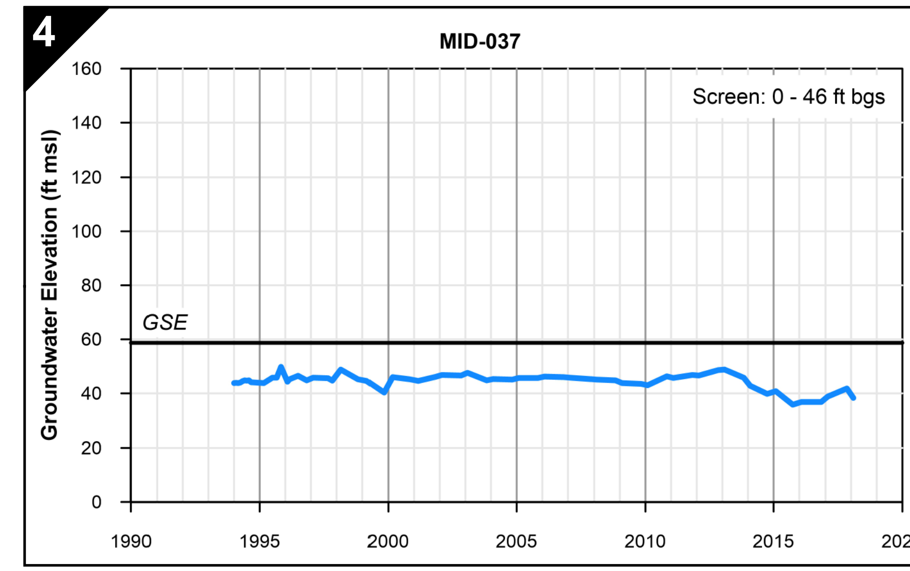
TODD GROUNDWATER

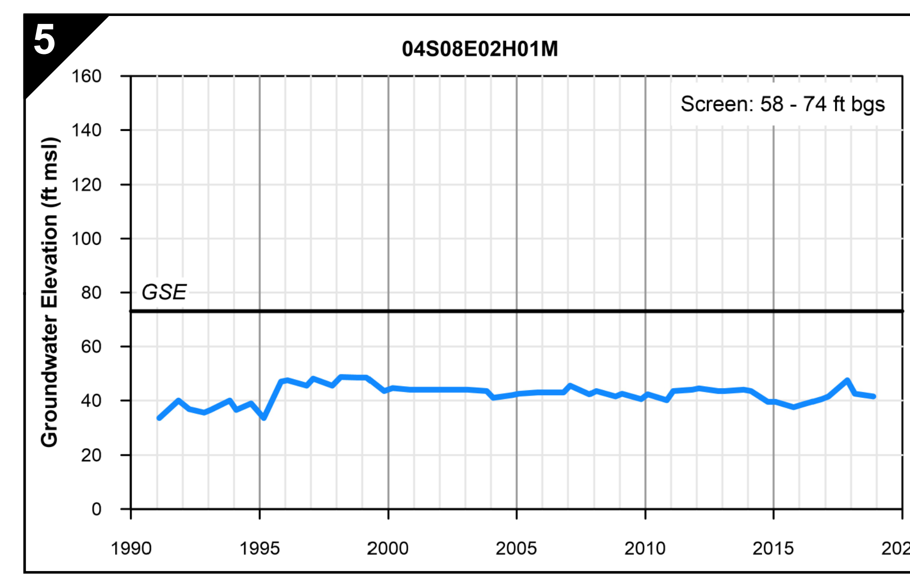
Figure 3-20
Representative Hydrograph Locations

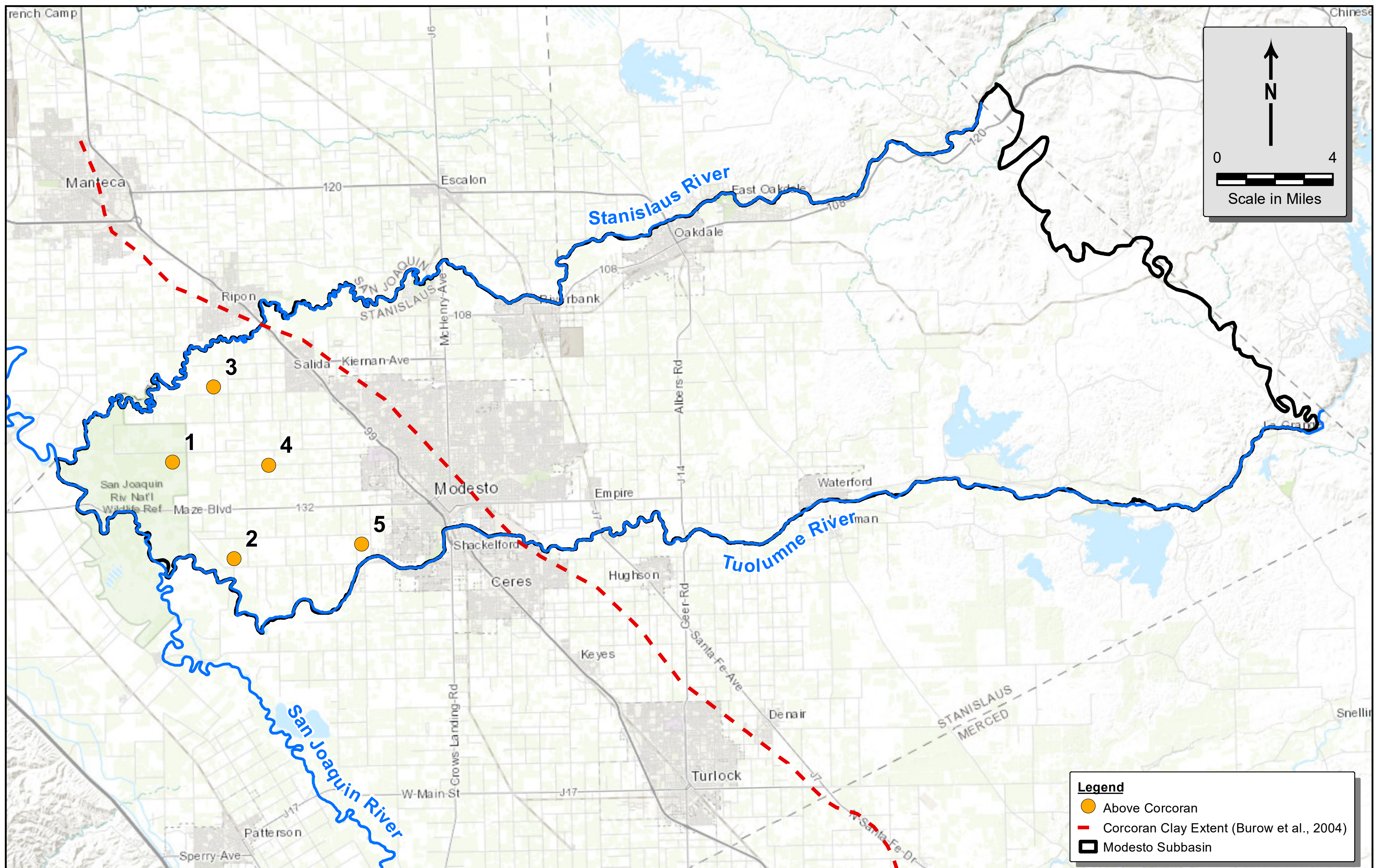








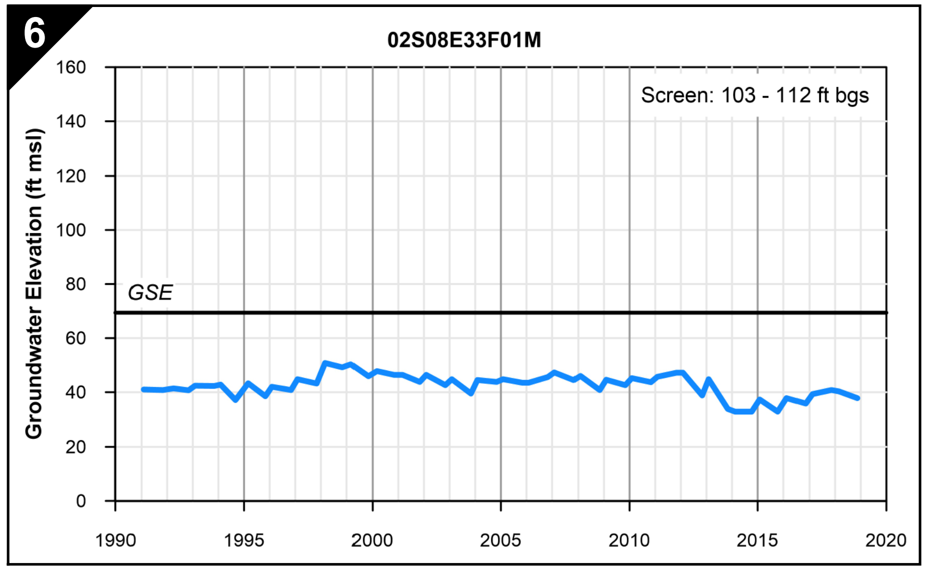


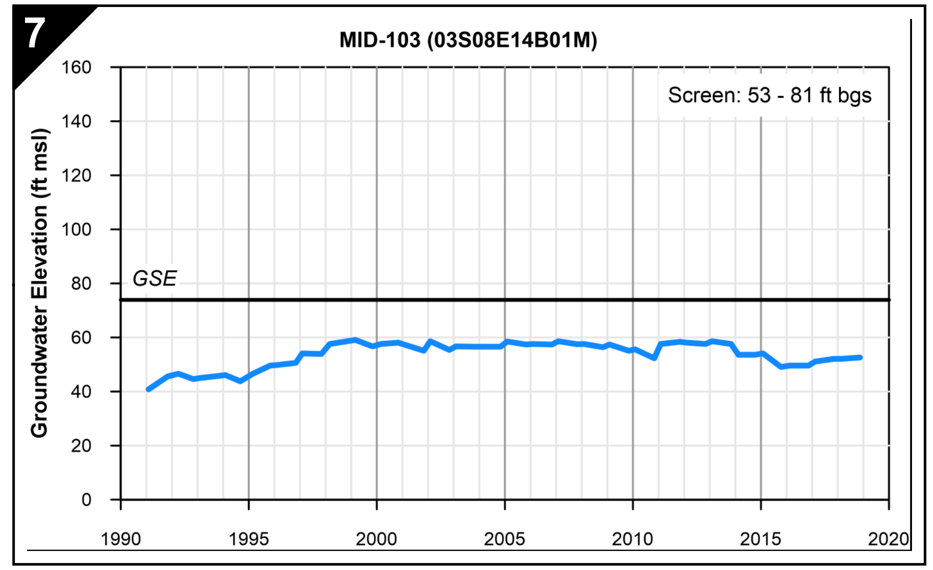


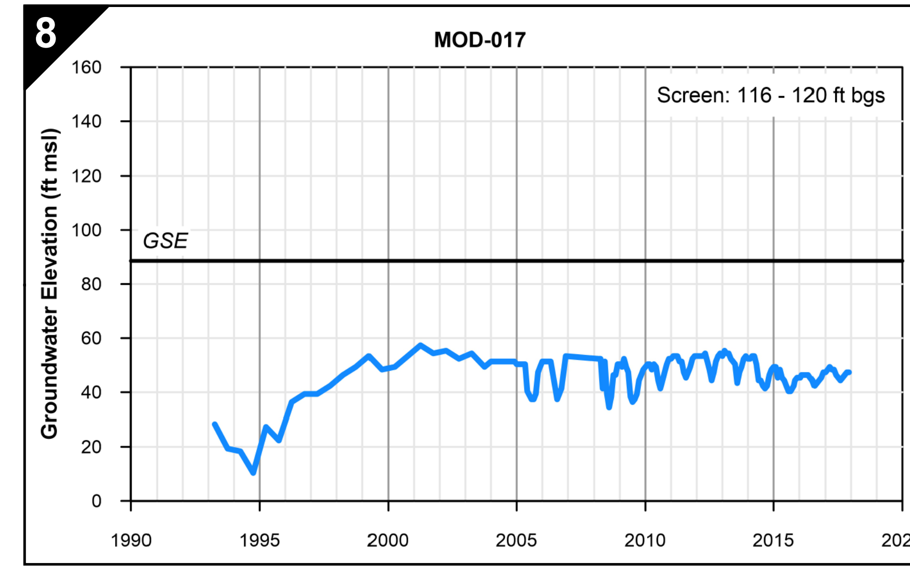
May 2020

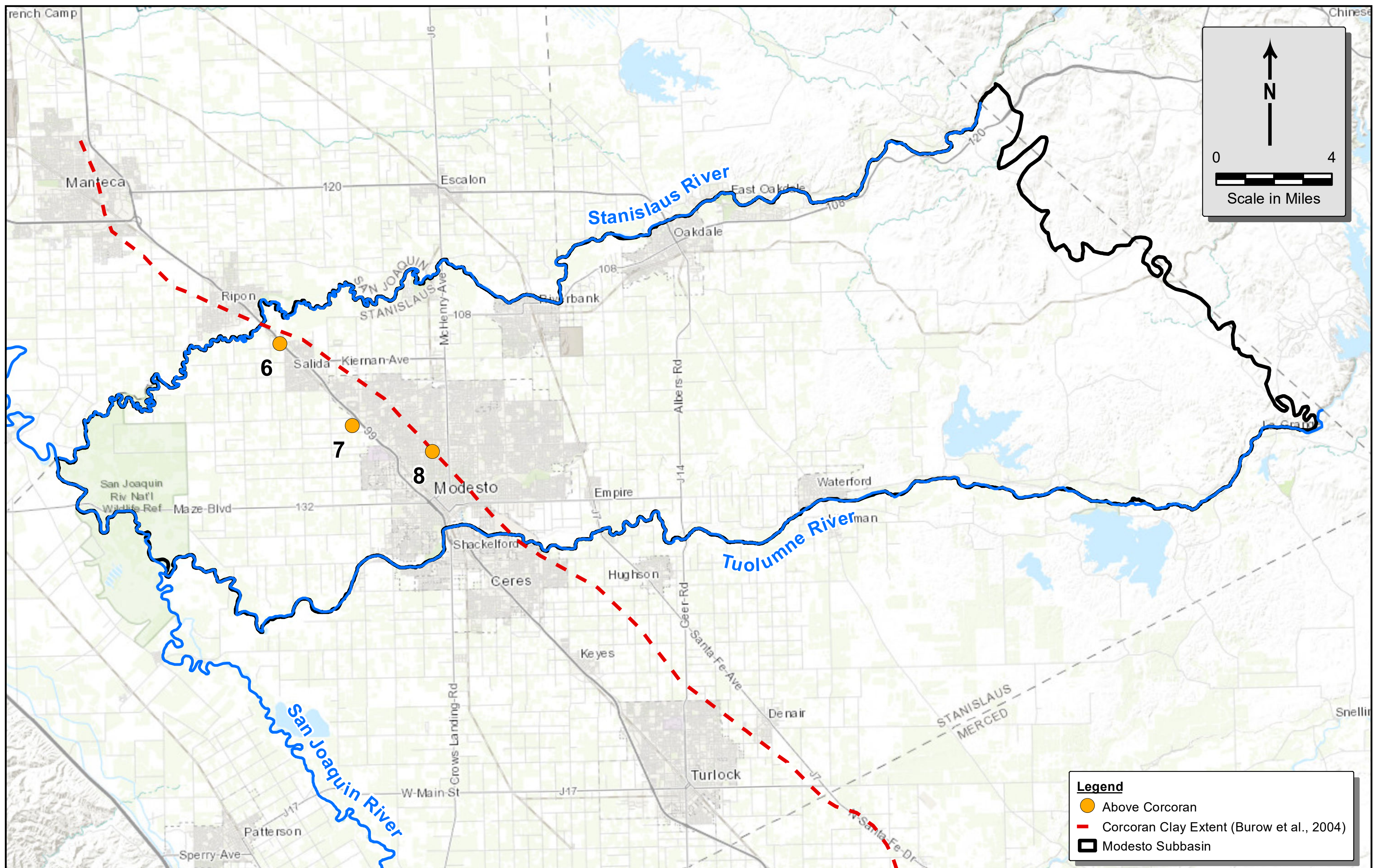
TODD GROUNDWATER

Figure 3-21
Representative Hydrographs
Western Upper
Principal Aquifer (1 of 2)





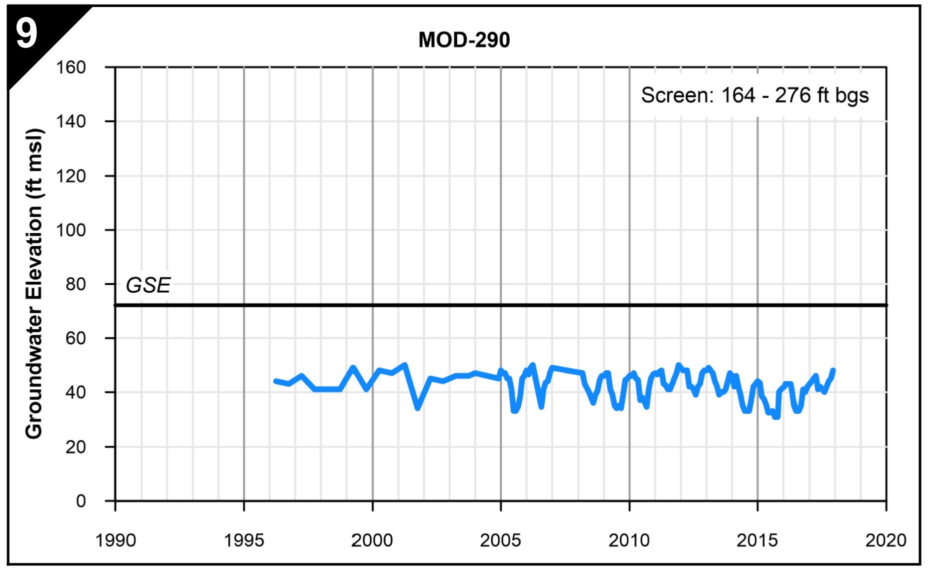


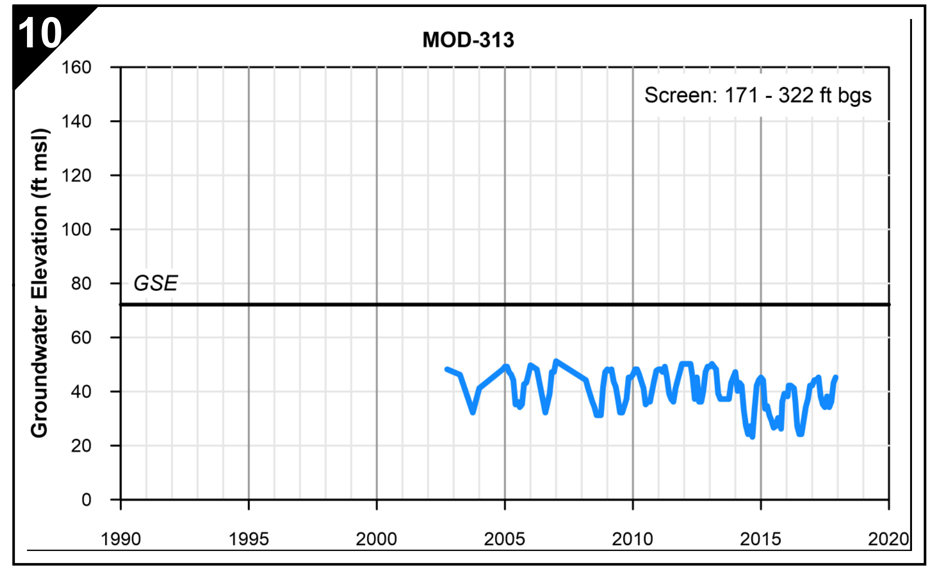


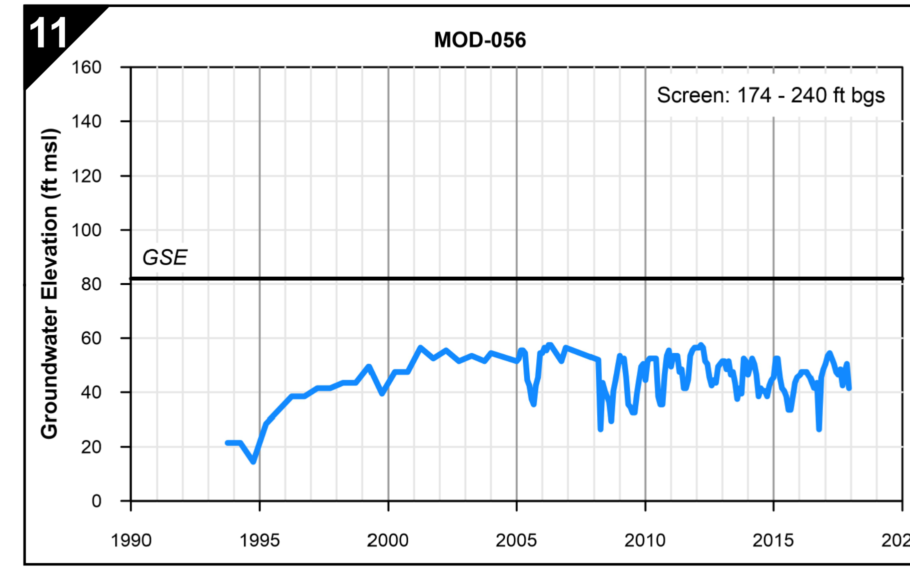
May 2020

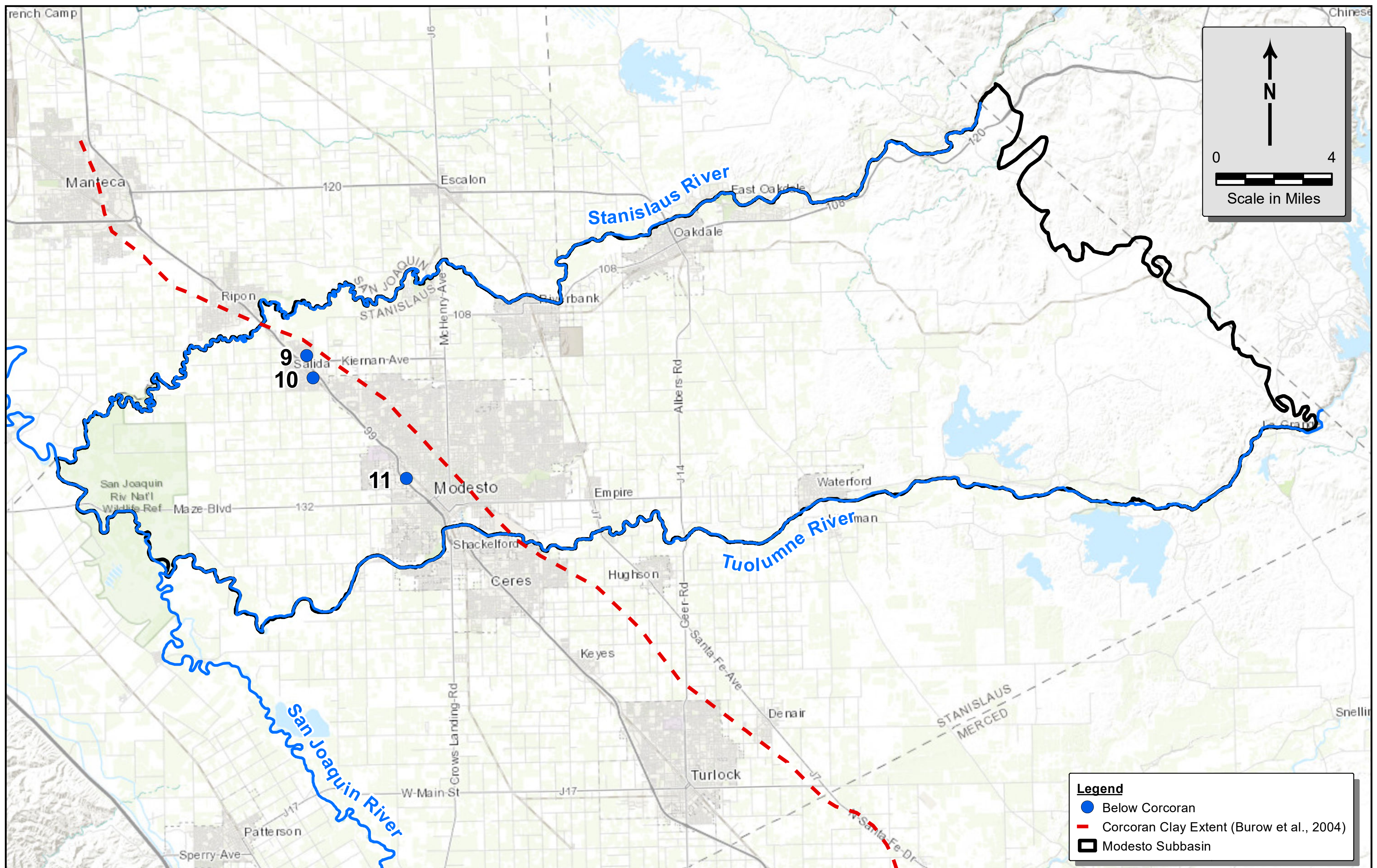
TODD GROUNDWATER

Figure 3-22
Representative Hydrographs
Western Upper
Principal Aquifer (2 of 2)





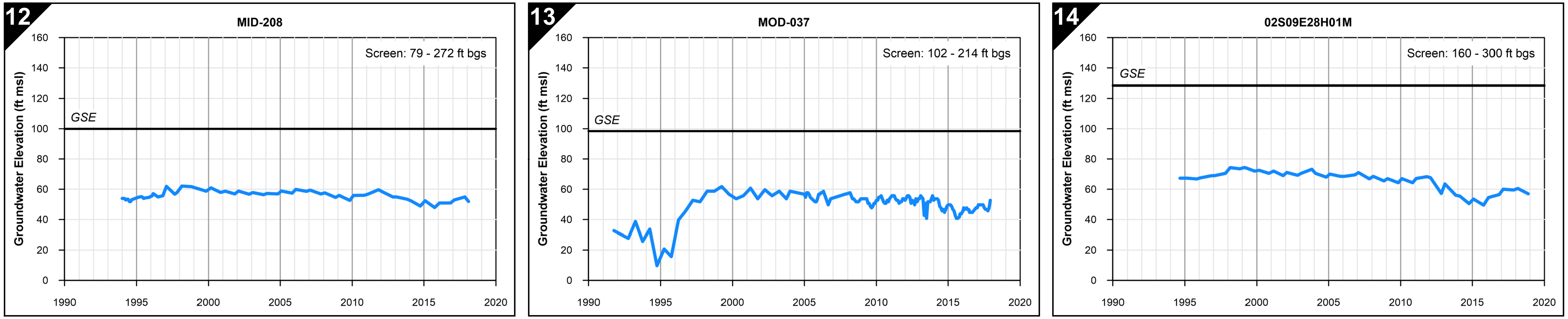


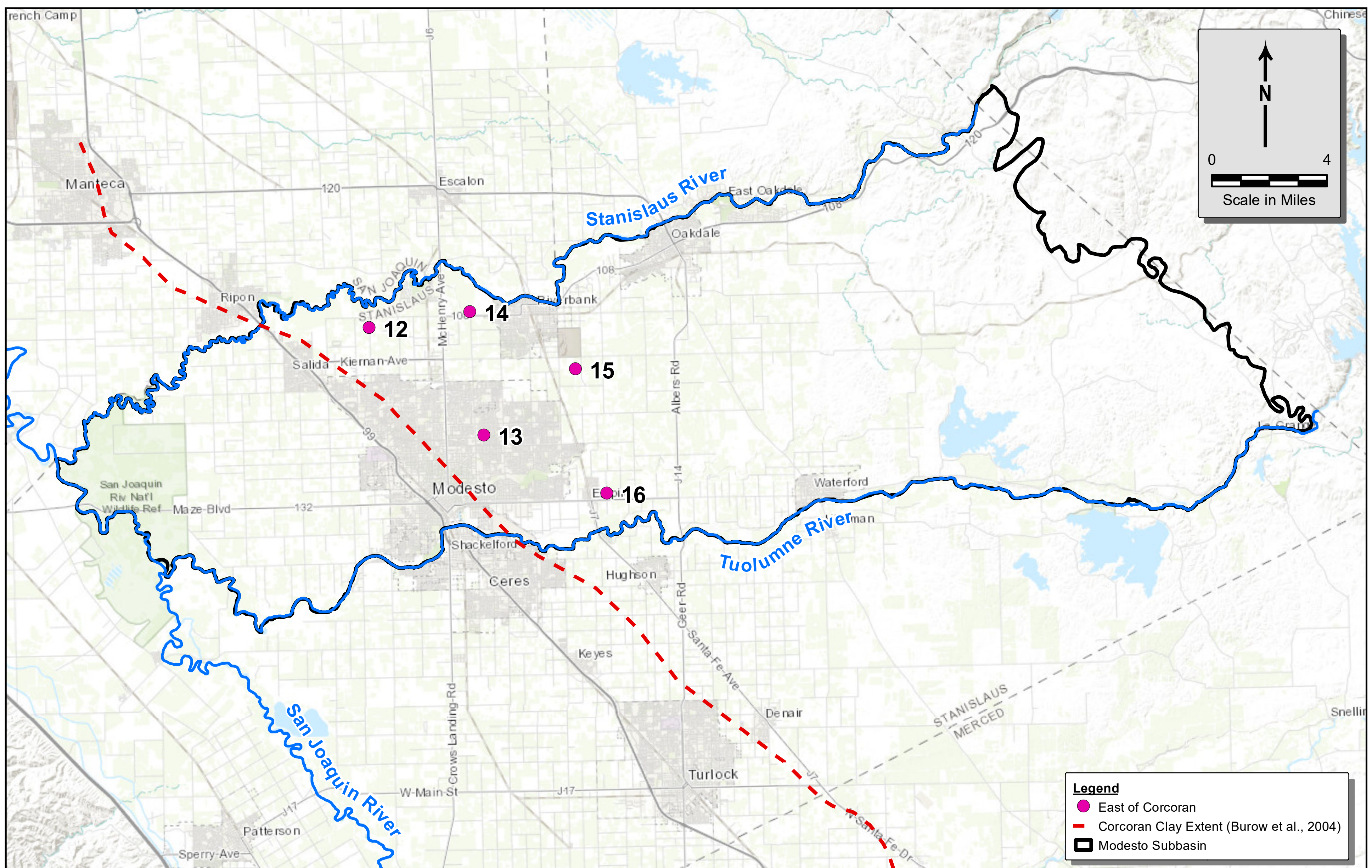


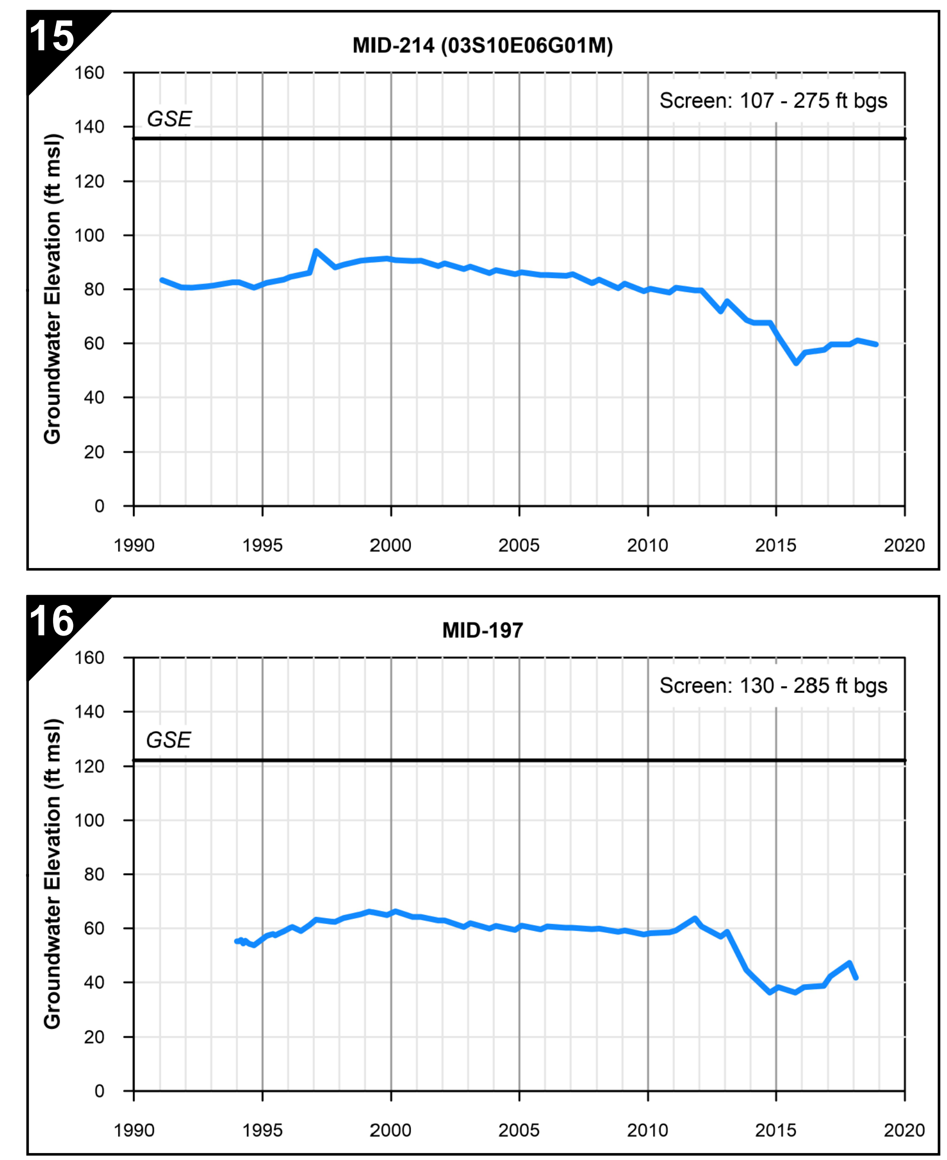
May 2020

TODD GROUNDWATER

Figure 3-23
Representative Hydrographs
Western Lower
Principal Aquifer



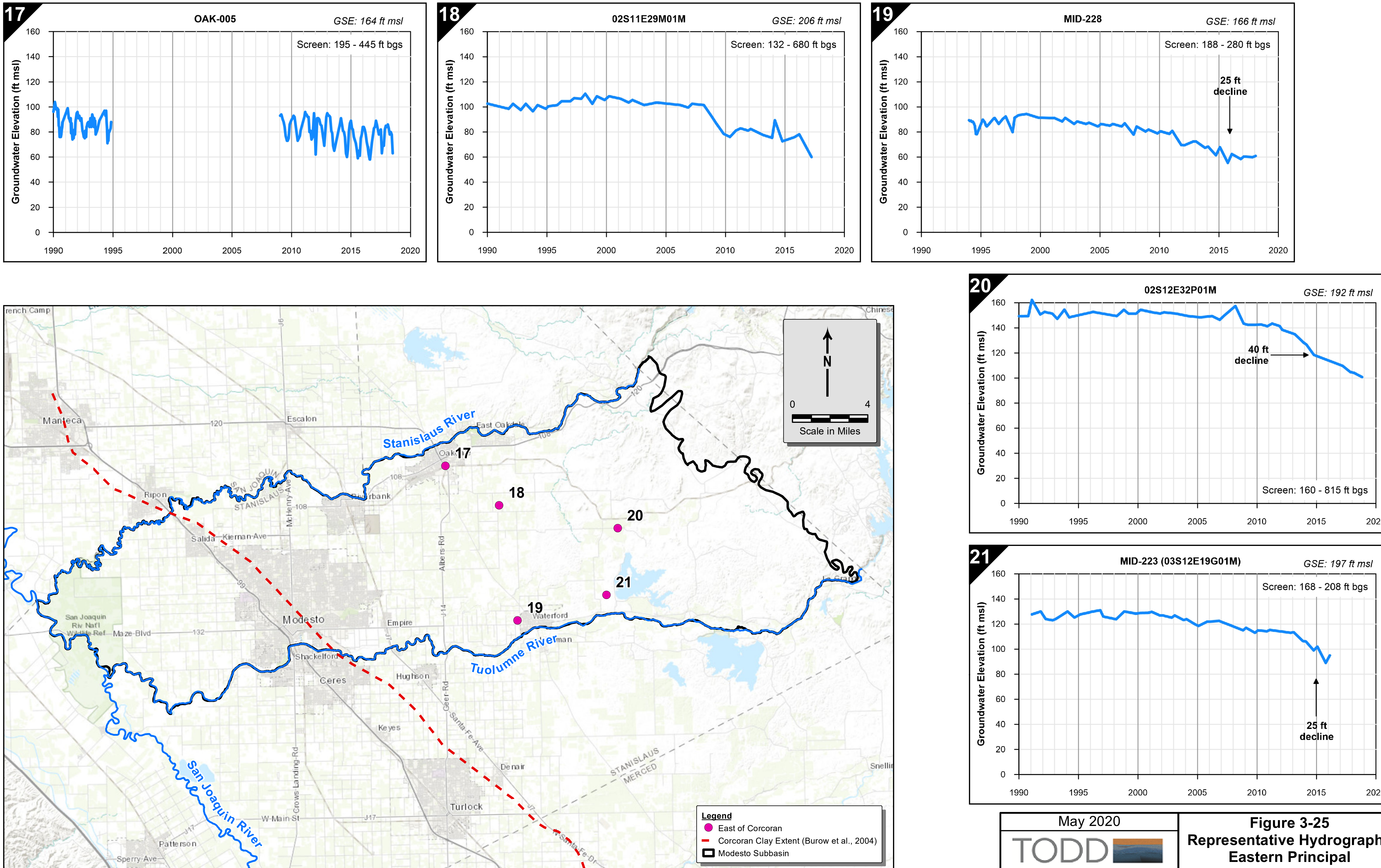




May 2020

TODD GROUNDWATER

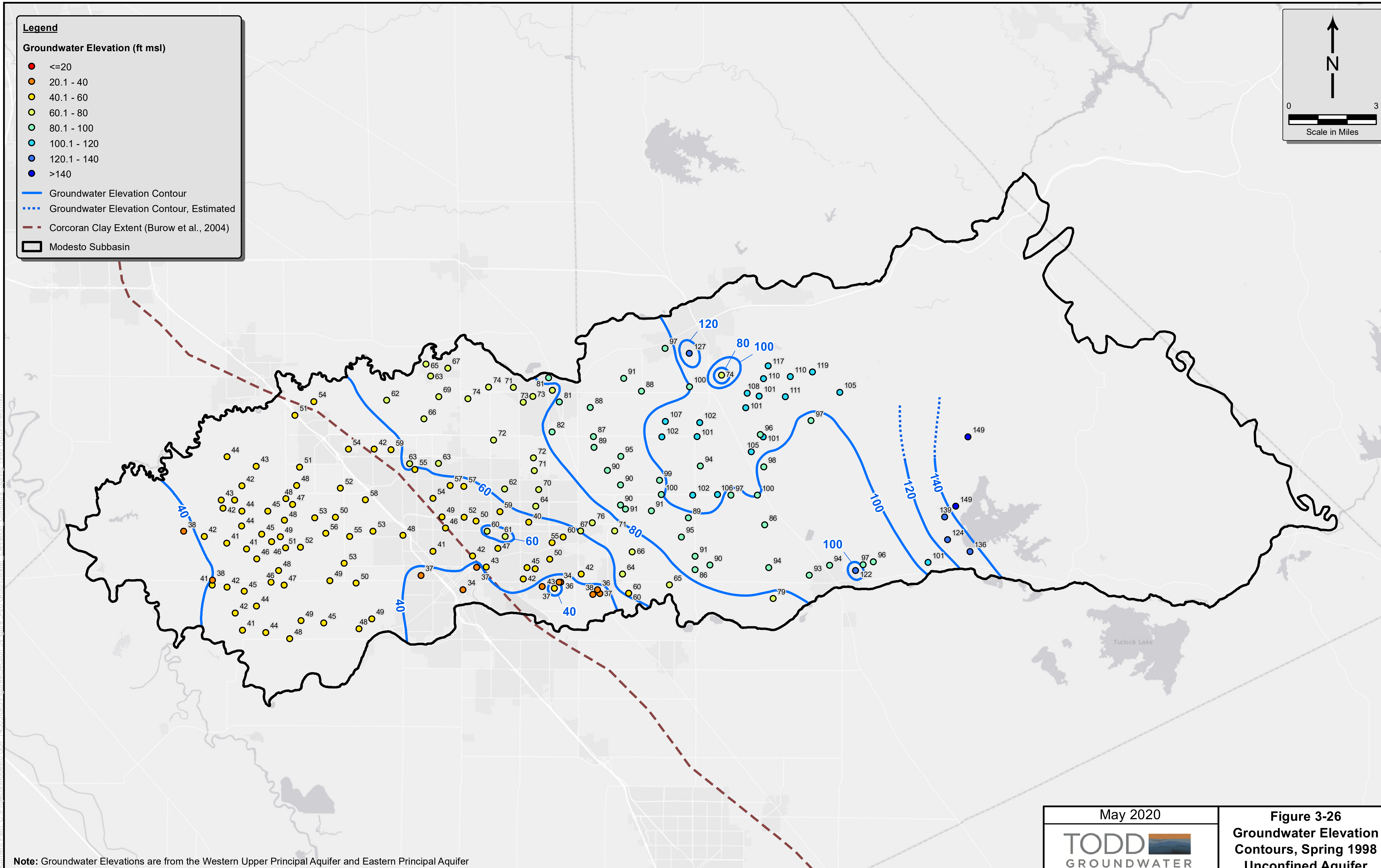
Figure 3-24
Representative Hydrographs
Eastern Principal
Aquifer (1 of 2)



May 2020

TODD GROUNDWATER

Figure 3-25
Representative Hydrographs
Eastern Principal Aquifer (2 of 2)



Legend
Groundwater Elevation (ft msl)
<=20
20.1 - 40
40.1 - 60
60.1 - 80
80.1 - 100
100.1 - 120
120.1 - 140
>140
Groundwater Elevation Contour
Groundwater Elevation Contour, Estimated
Corcoran Clay Extent (Burow et al., 2004)
Modesto Subbasin
N
0
3
Scale in Miles
Turlock Lake
Note: Groundwater Elevations are from the Western Upper Principal Aquifer and Eastern Principal Aquifer
May 2020
TODD
GROUNDWATER
Figure 3-26
Groundwater Elevation
Contours, Spring 1998
Unconfined Aquifer

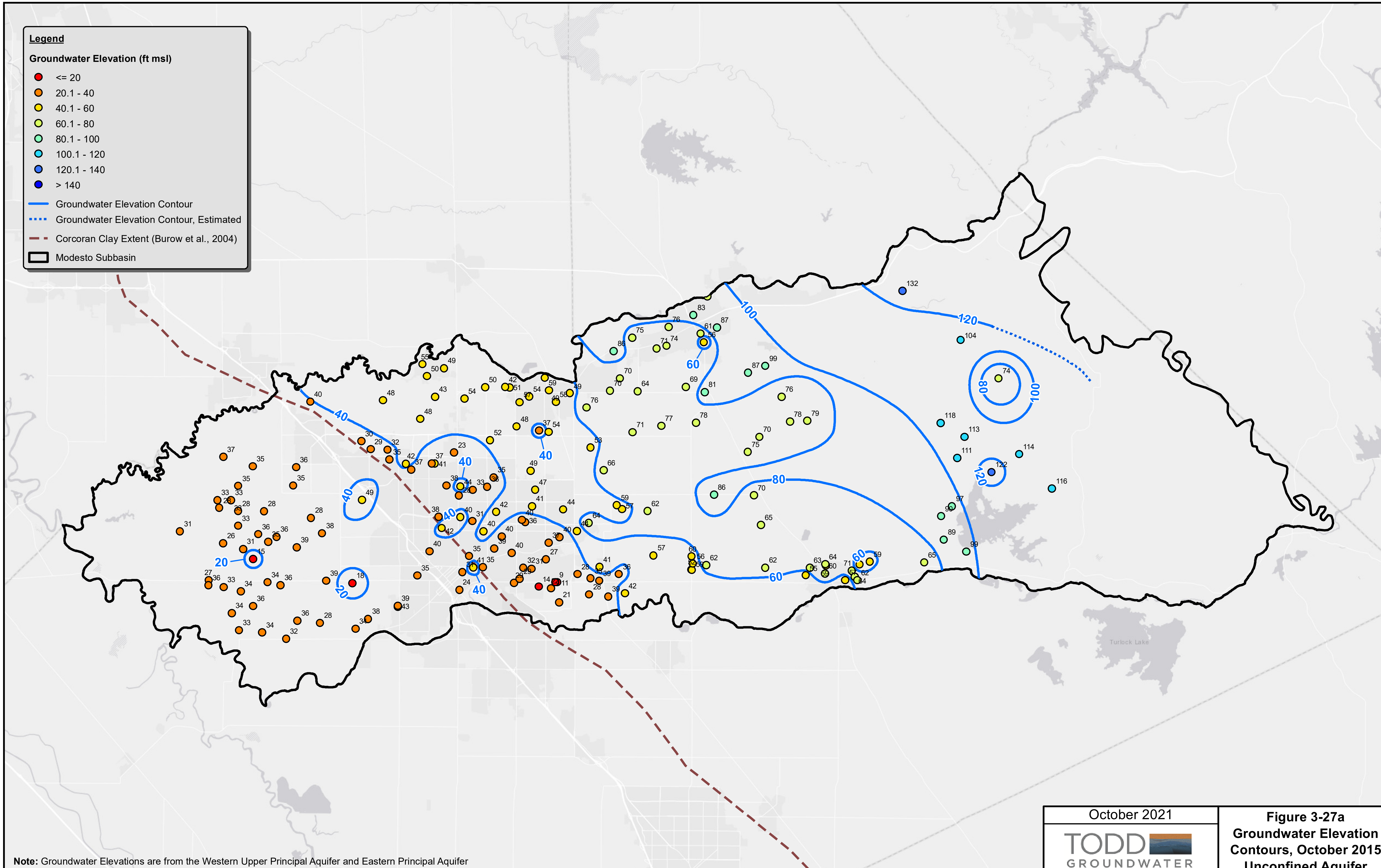
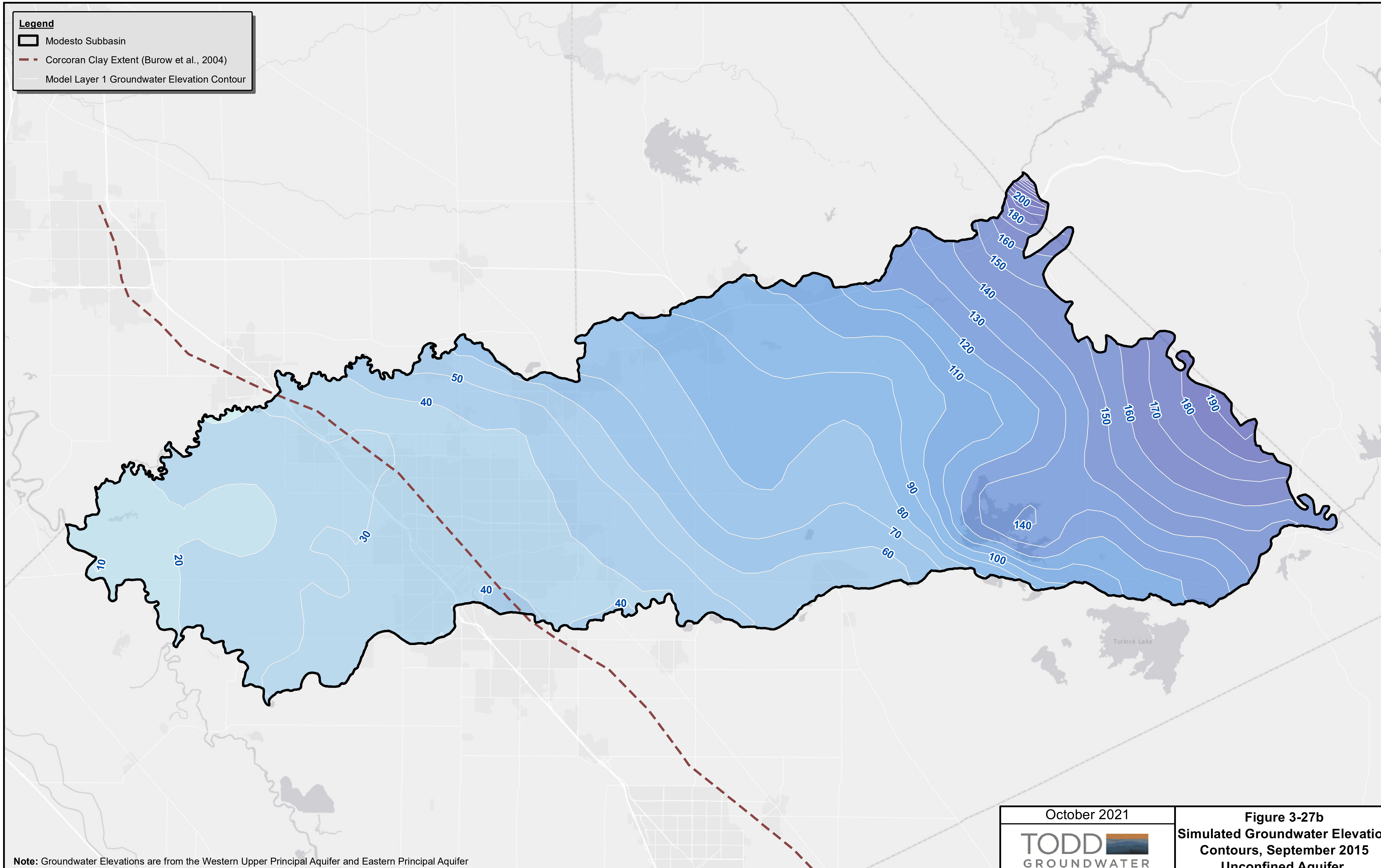


Figure 3-27a
Groundwater Elevation Contours, October 2015
Unconfined Aquifer

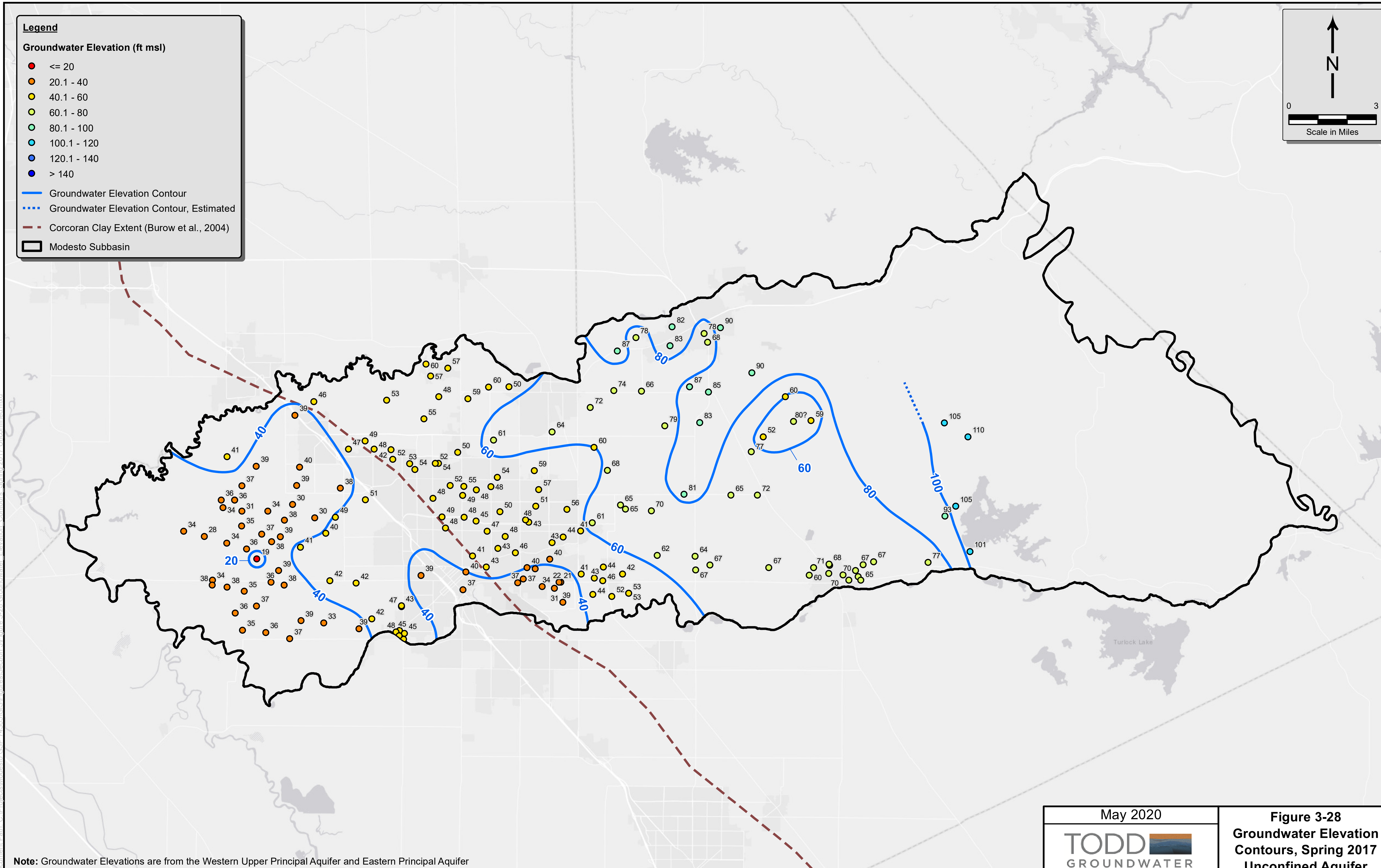


Note: Groundwater Elevations are from the Western Upper Principal Aquifer and Eastern Principal Aquifer

October 2021

TODD GROUNDWATER

Figure 3-27b
Simulated Groundwater Elevation Contours, September 2015
Unconfined Aquifer

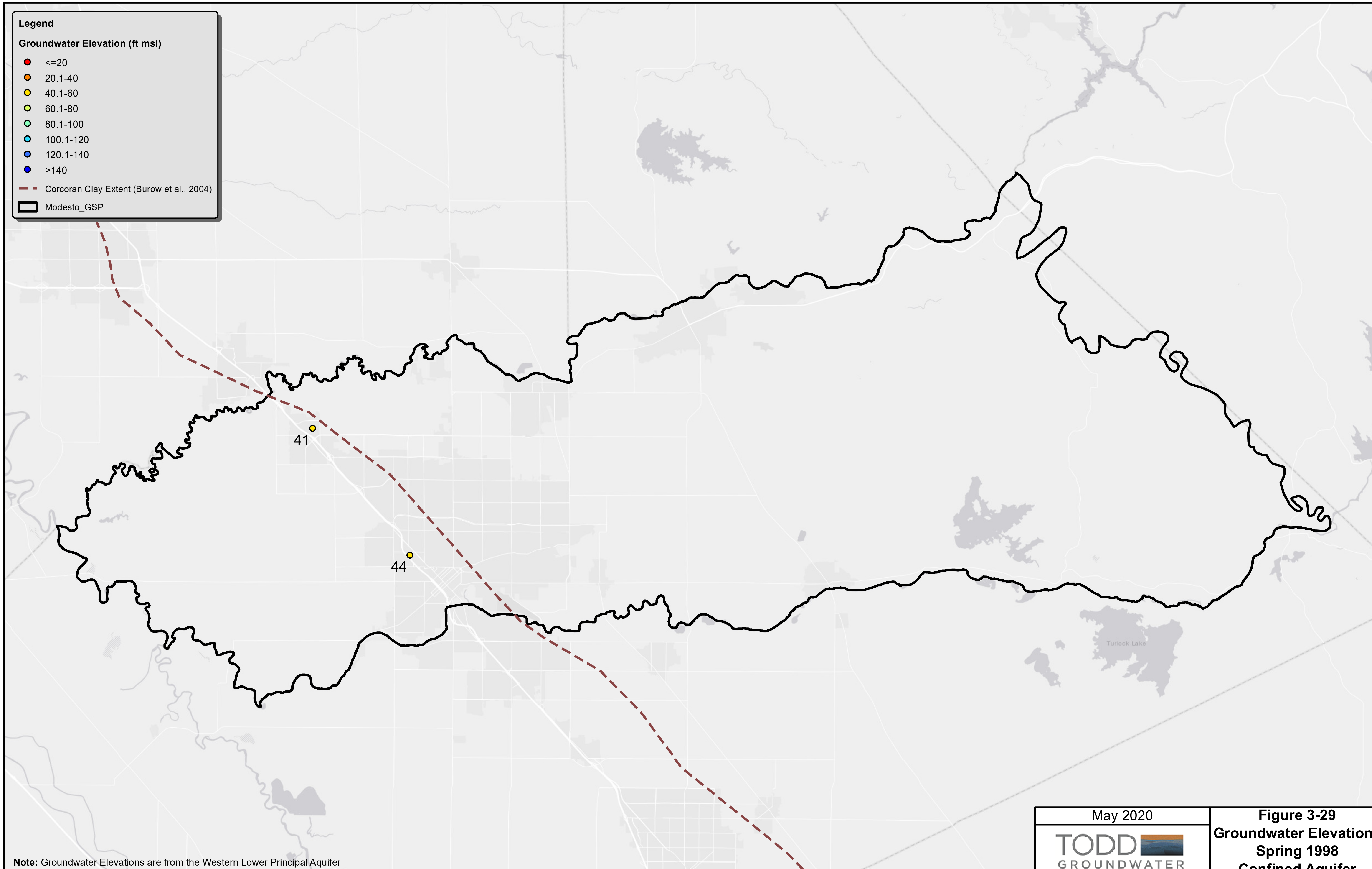


May 2020

TODD GROUNDWATER

Figure 3-28
Groundwater Elevation Contours, Spring 2017 Unconfined Aquifer

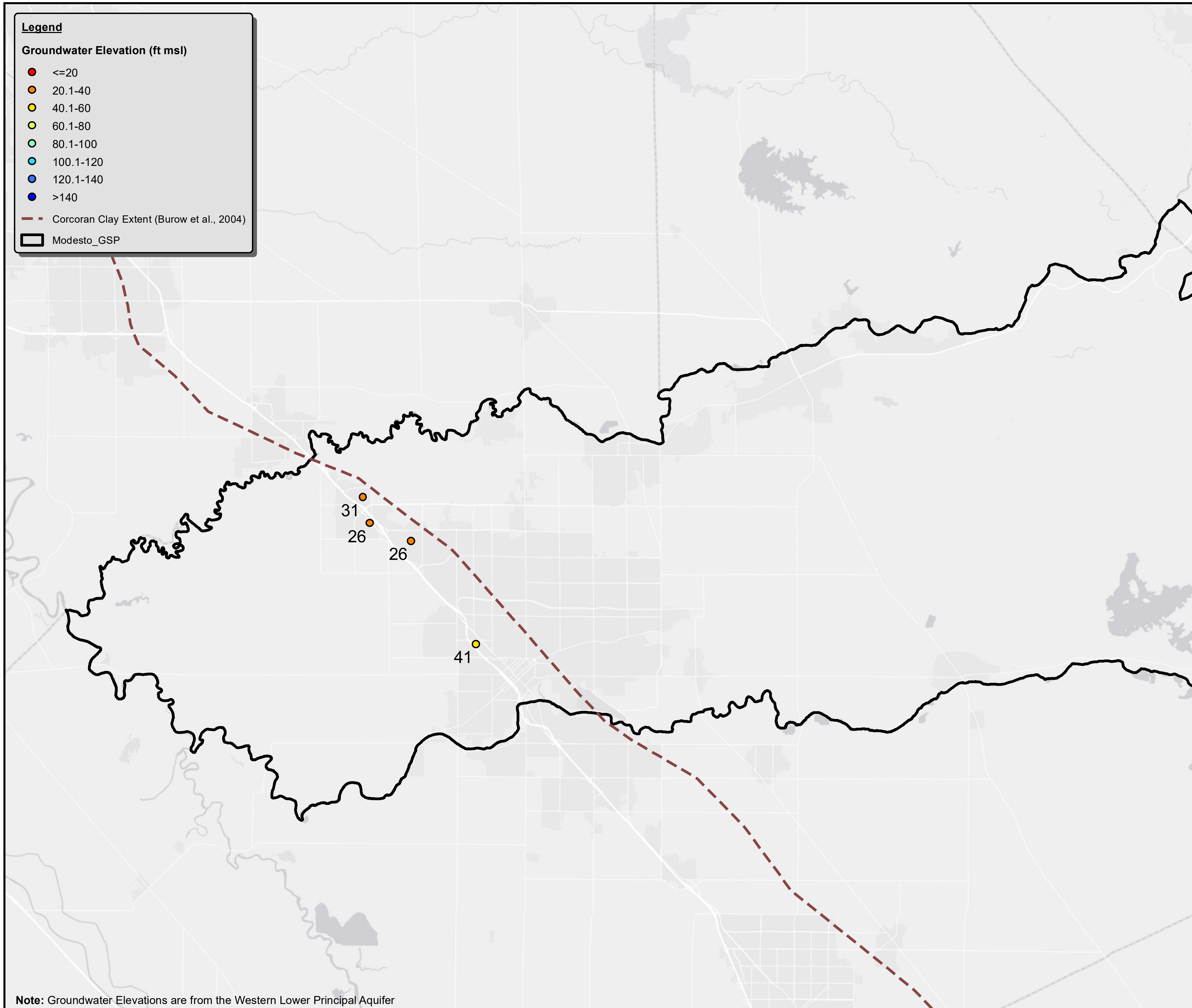
Note: Groundwater Elevations are from the Western Upper Principal Aquifer and Eastern Principal Aquifer



May 2020

TODD GROUNDWATER

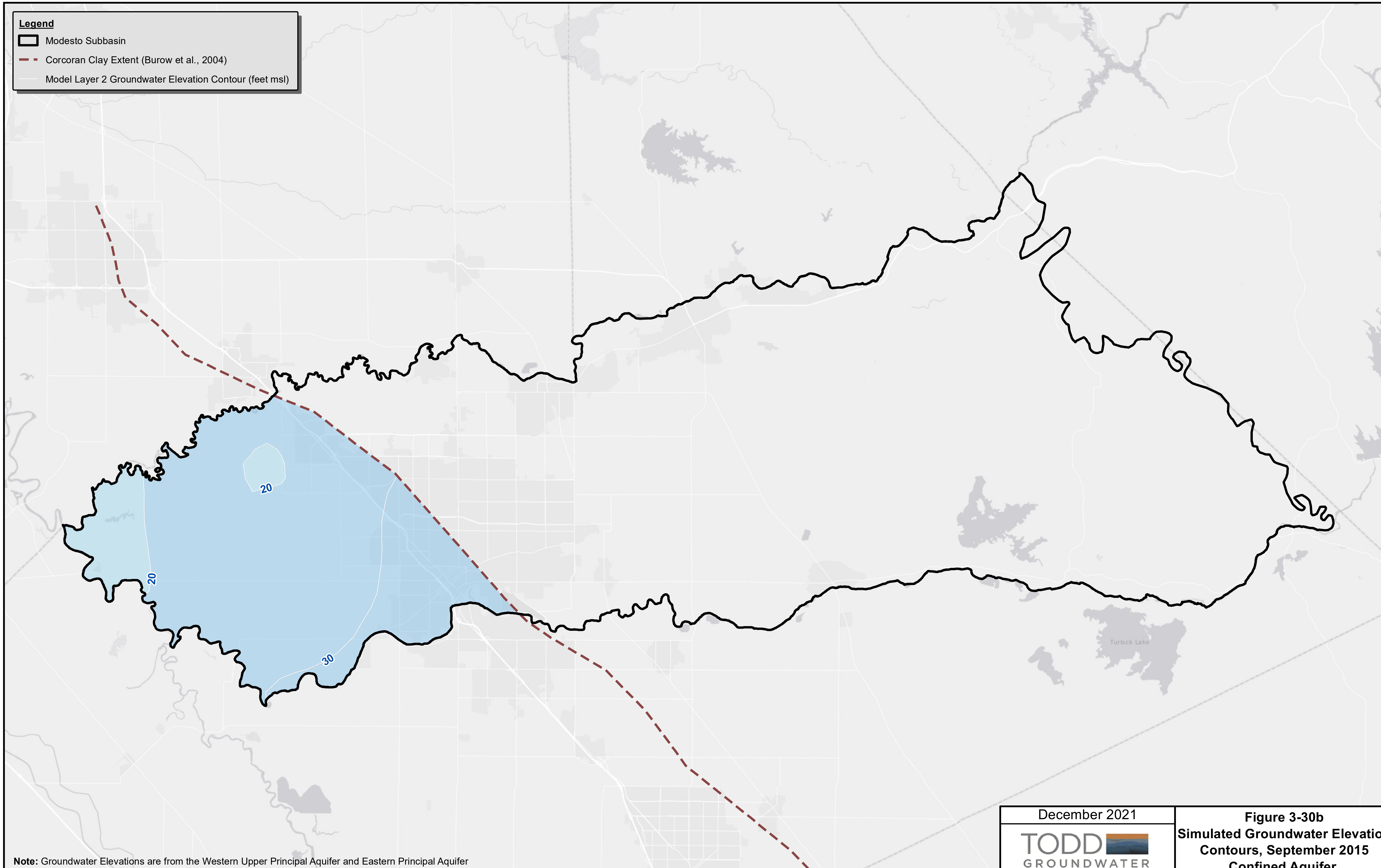
Figure 3-29
Groundwater Elevations
Spring 1998
Confined Aquifer



October 2021

TODD GROUNDWATER

Figure 3-30a
Groundwater Elevations
October 2015
Confined Aquifer

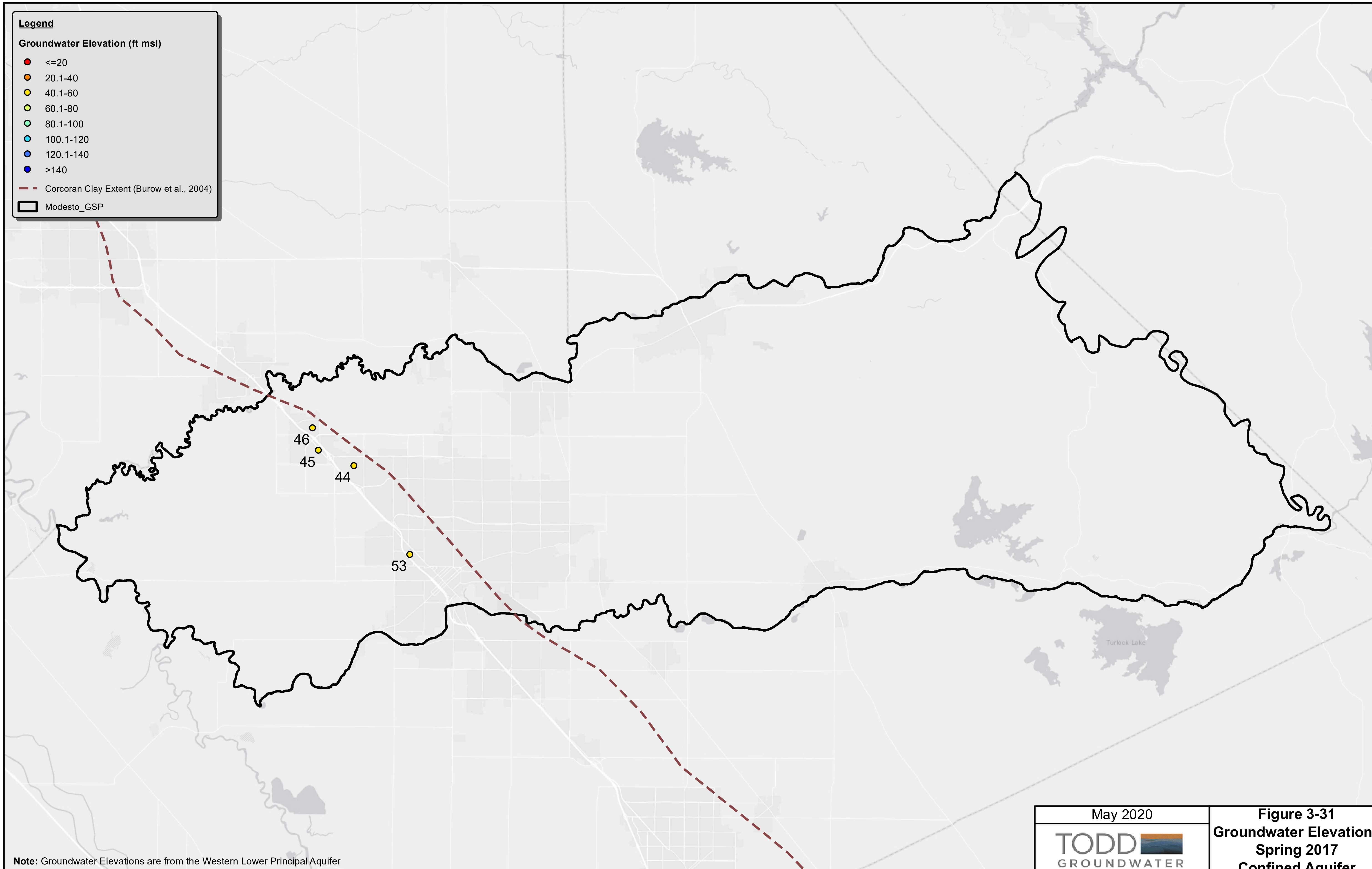


Note: Groundwater Elevations are from the Western Upper Principal Aquifer and Eastern Principal Aquifer

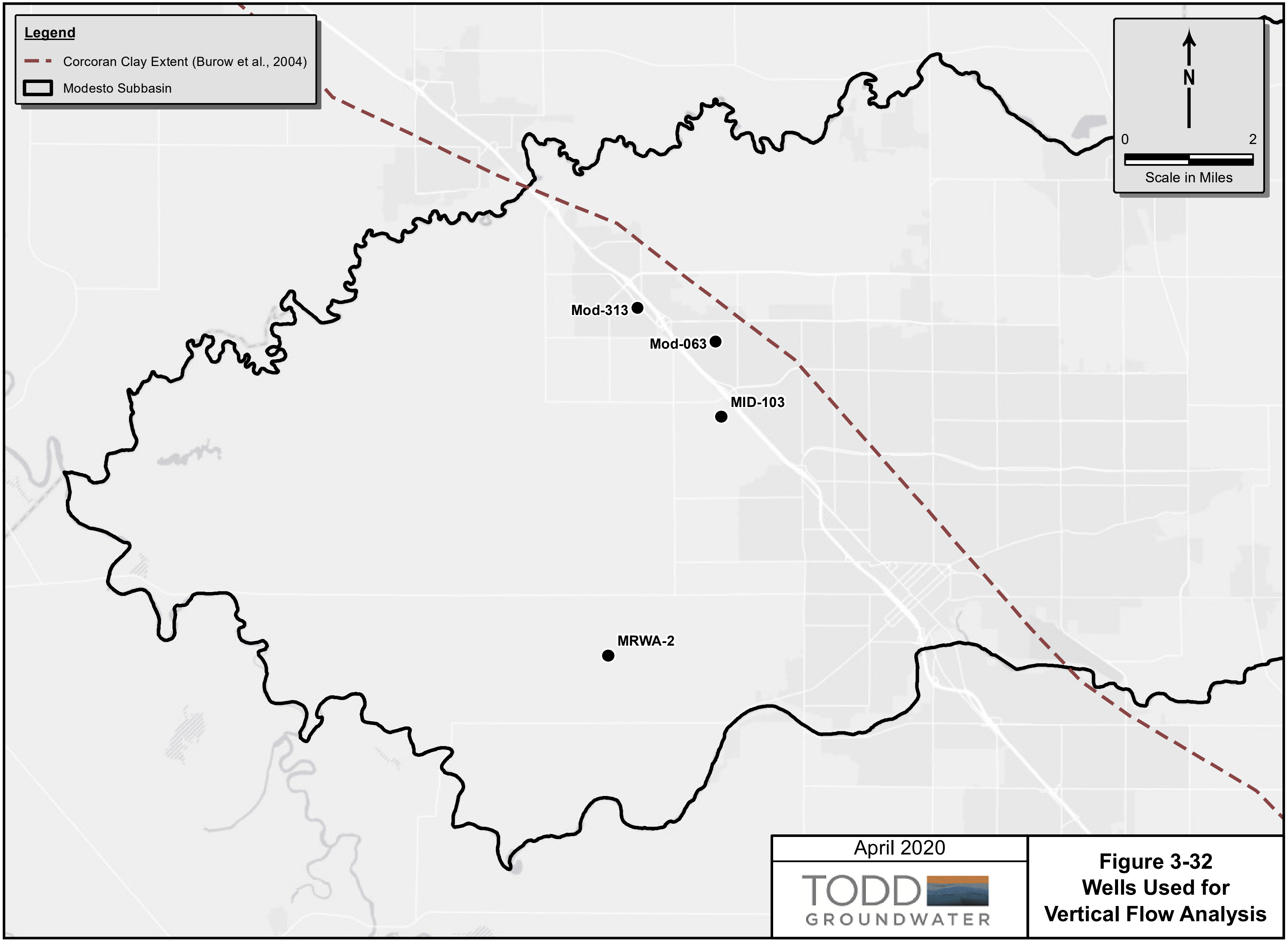
December 2021

TODD GROUNDWATER

Figure 3-30b
Simulated Groundwater Elevation Contours, September 2015
Confined Aquifer



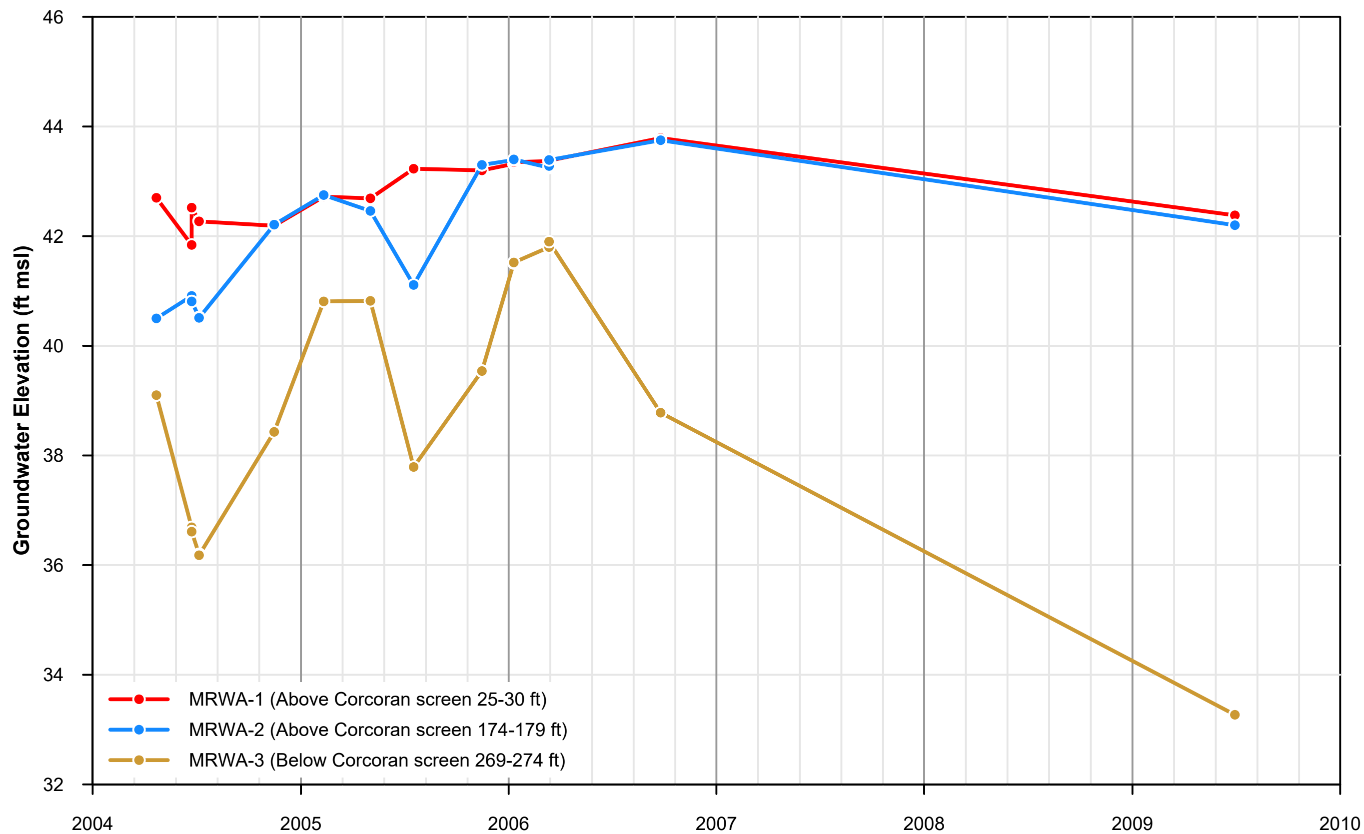
Legend
Groundwater Elevation (ft msl)
<=20
20.1-40
40.1-60
60.1-80
80.1-100
100.1-120
120.1-140
>140
Corcoran Clay Extent (Burow et al., 2004)
Modesto_GSP
46
45
44
53
Turlock Lake
Note: Groundwater Elevations are from the Western Lower Principal Aquifer
May 2020
TODD GROUNDWATER
Figure 3-31
Groundwater Elevations
Spring 2017
Confined Aquifer



April 2020

TODD GROUNDWATER

Figure 3-32
Wells Used for Vertical Flow Analysis



April 2020

TODD GROUNDWATER

Figure 3-33
Vertical Flow Hydrographs, USGS Well Cluster