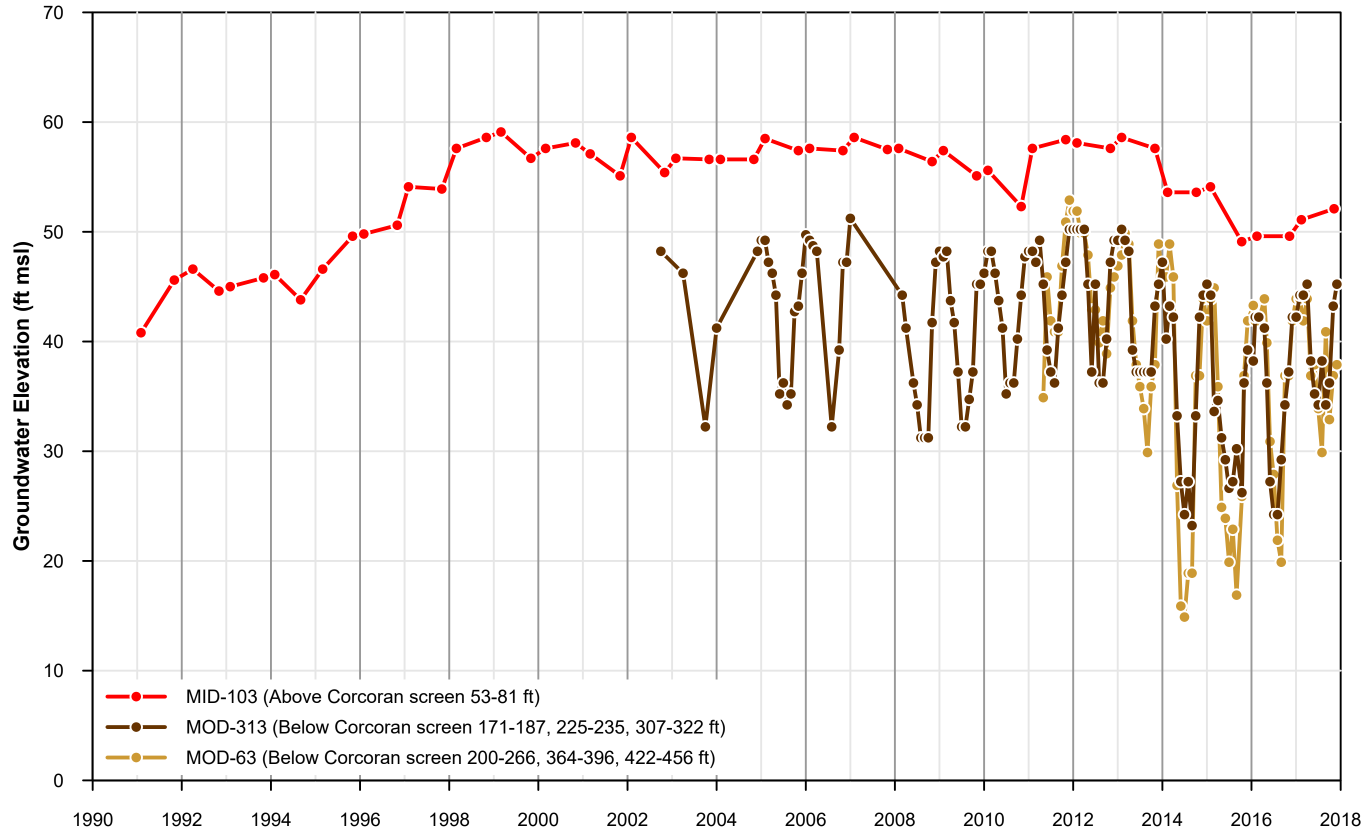
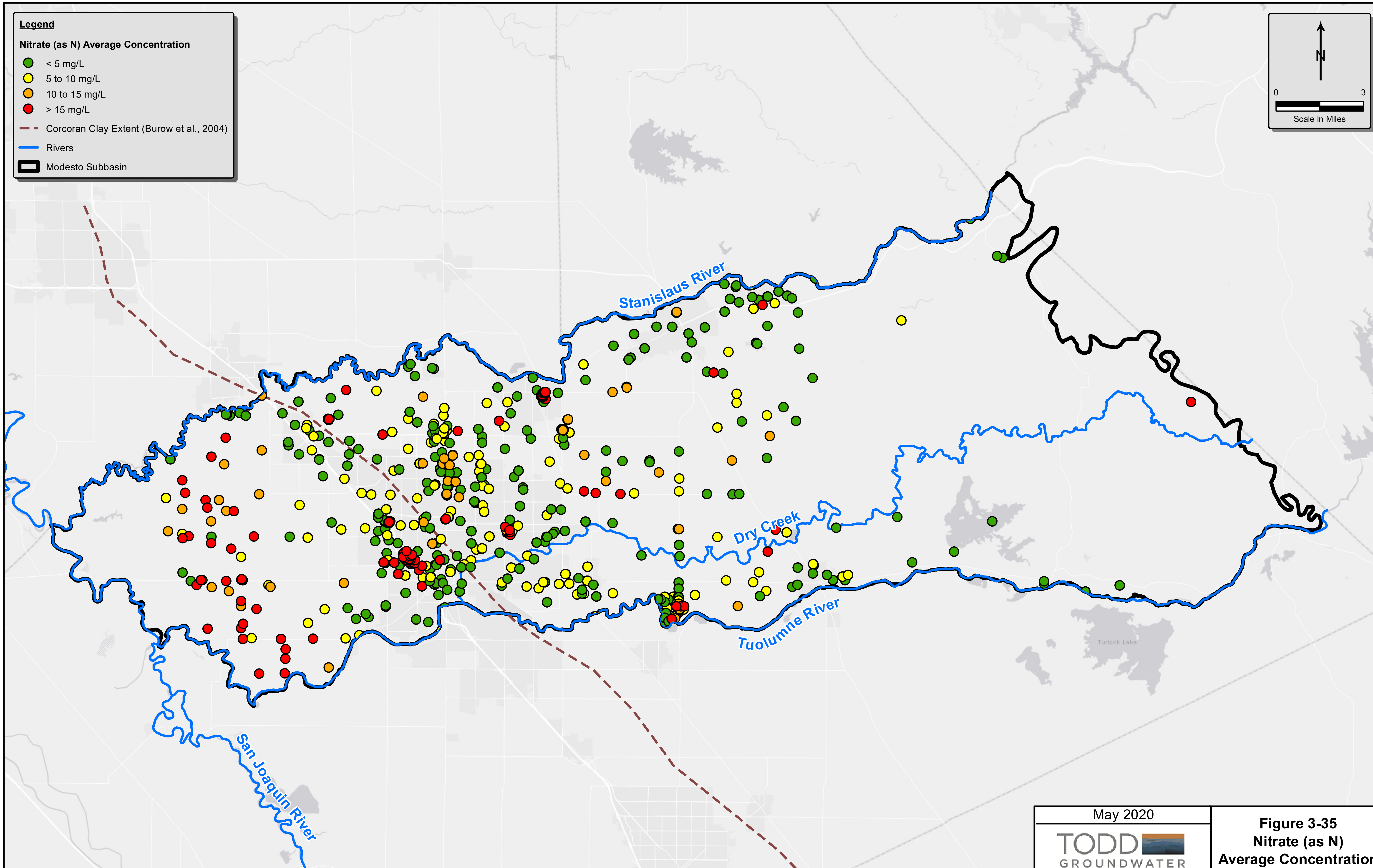


April 2020

TODD GROUNDWATER

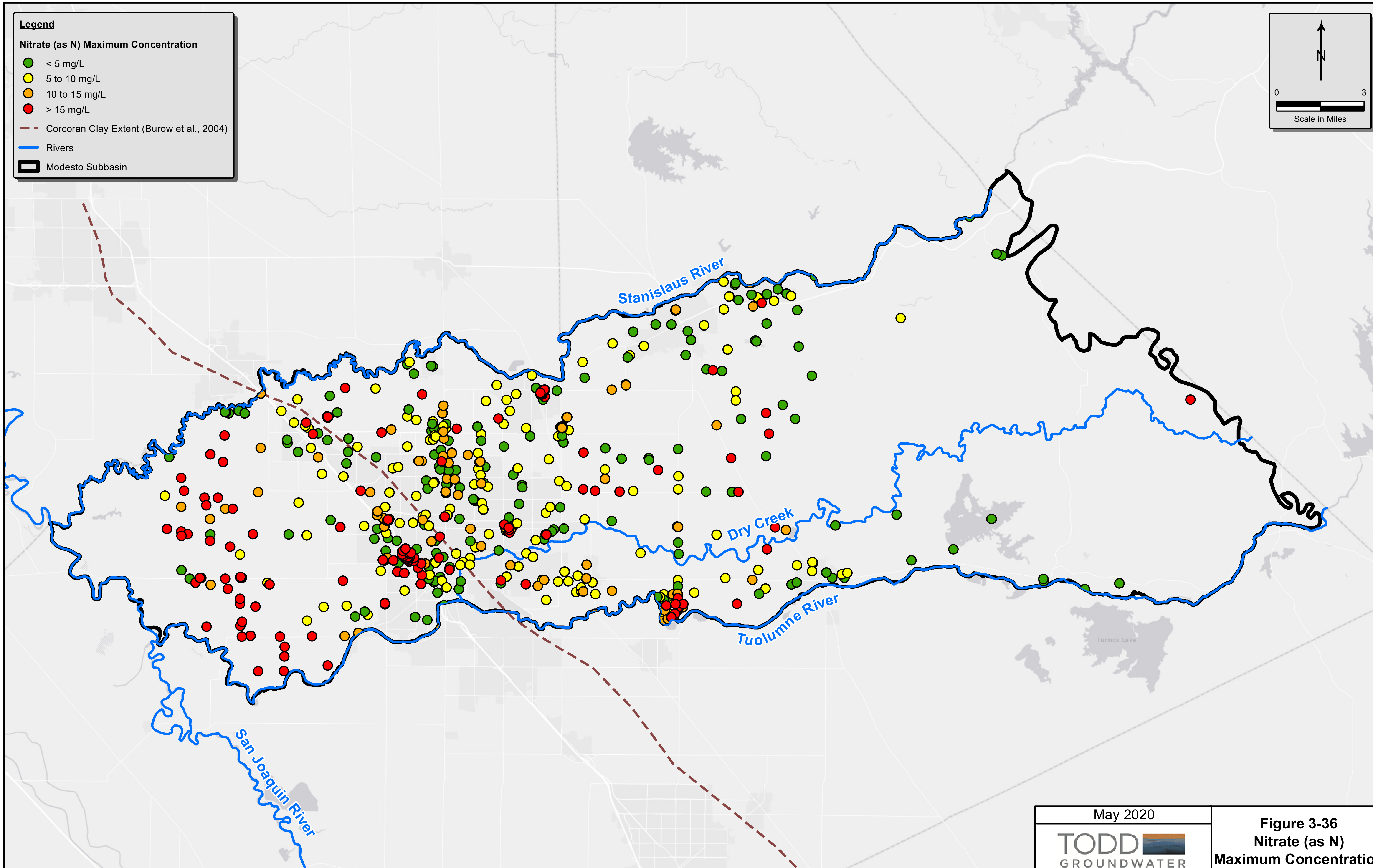
Figure 3-34
Vertical Flow Hydrographs, MID and City of Modesto Wells



May 2020

TODD GROUNDWATER

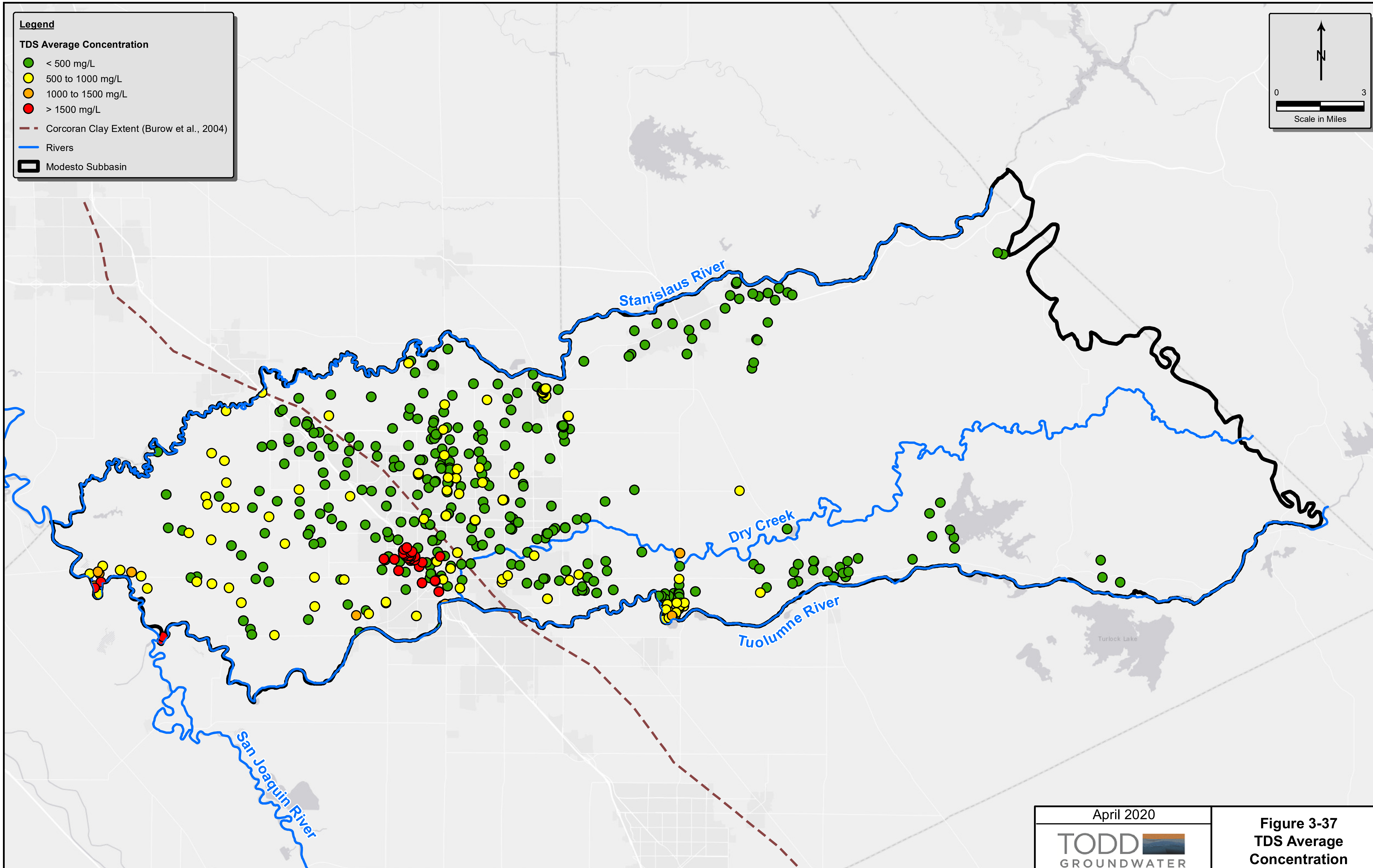
Figure 3-35
Nitrate (as N)
Average Concentration



May 2020

TODD GROUNDWATER

Figure 3-36
Nitrate (as N)
Maximum Concentration



April 2020

TODD GROUNDWATER

Figure 3-37
TDS Average Concentration

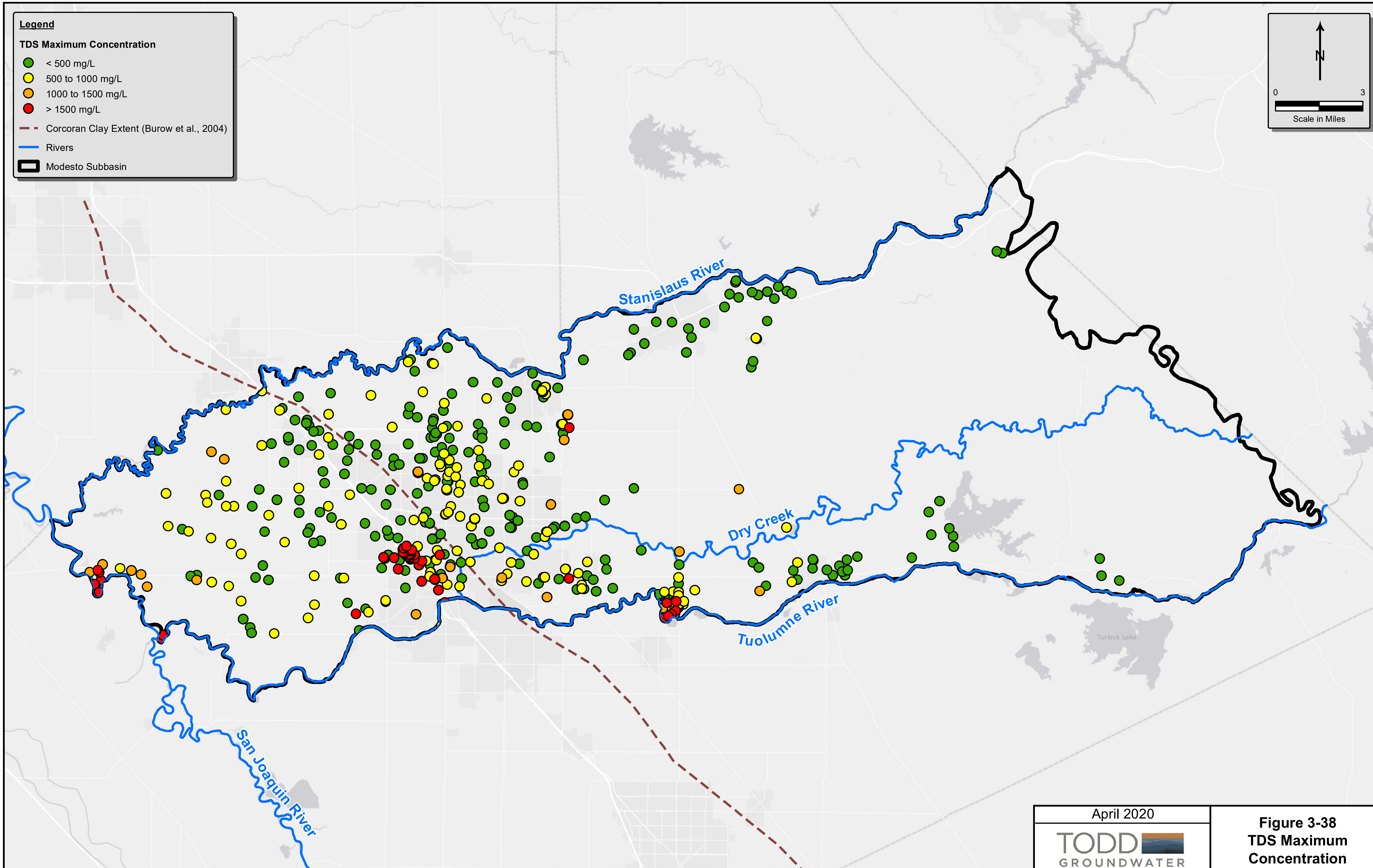
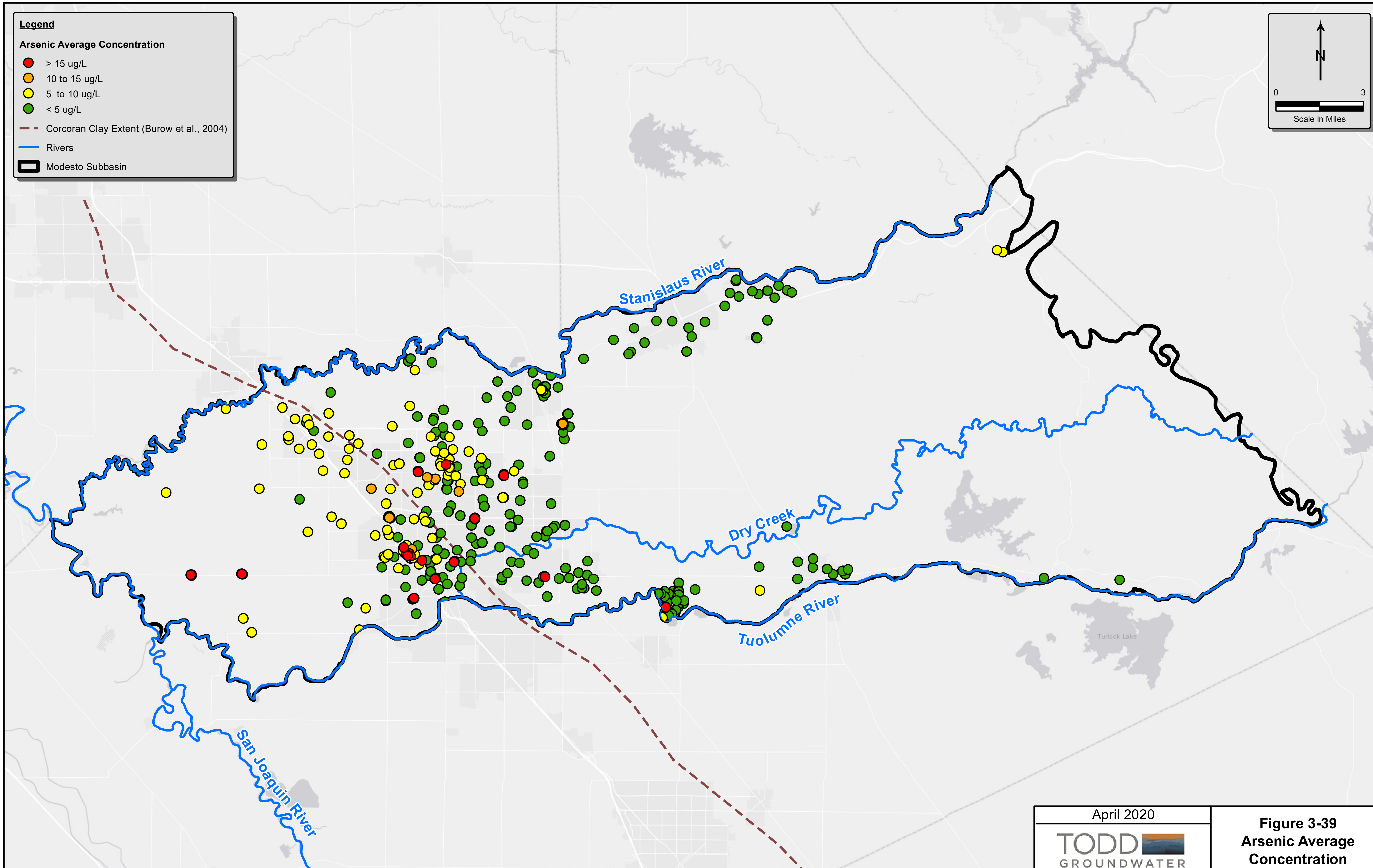


Figure 3-38
TDS Maximum Concentration



April 2020

TODD GROUNDWATER

Figure 3-39
Arsenic Average Concentration

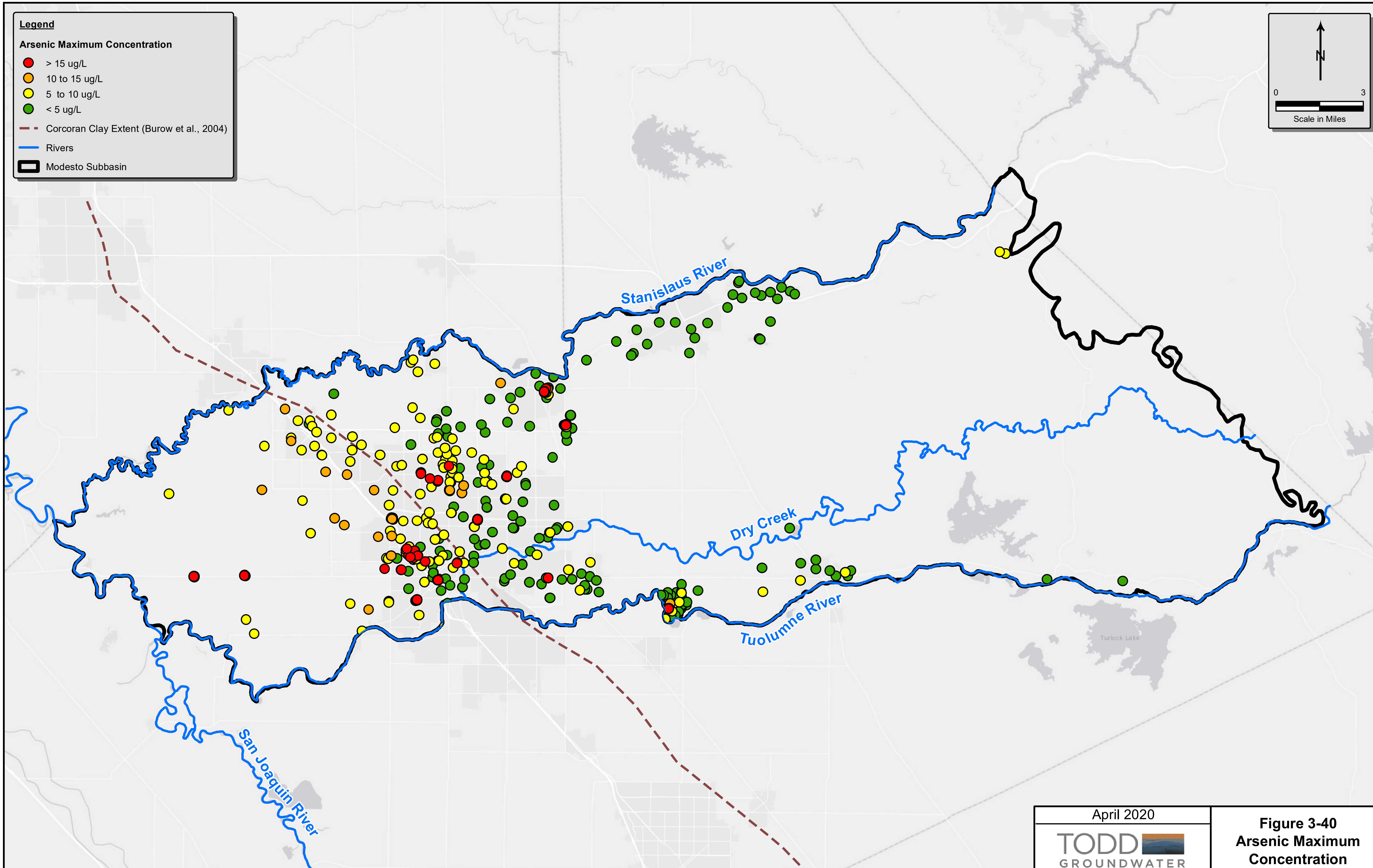


Figure 3-40
Arsenic Maximum Concentration

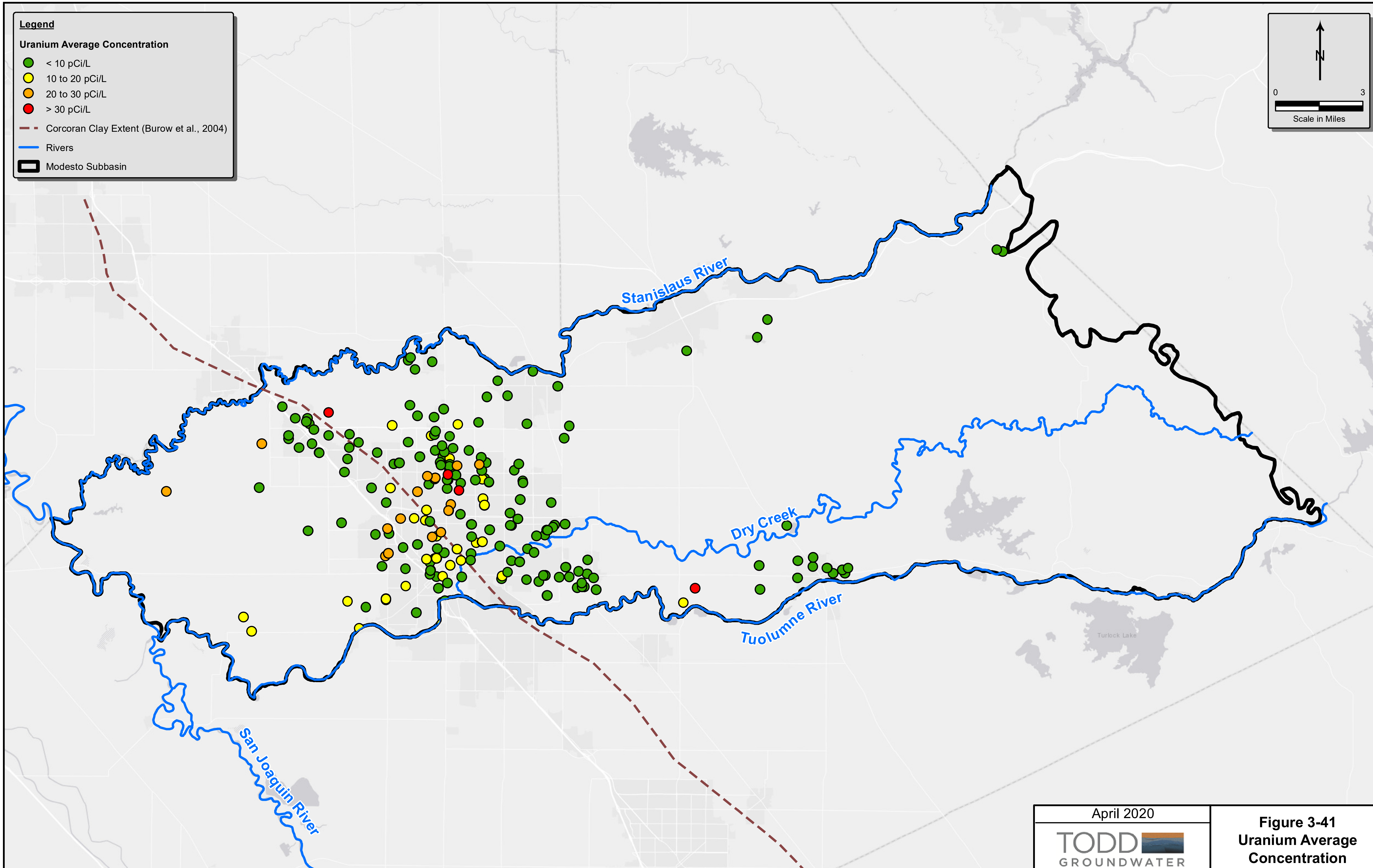
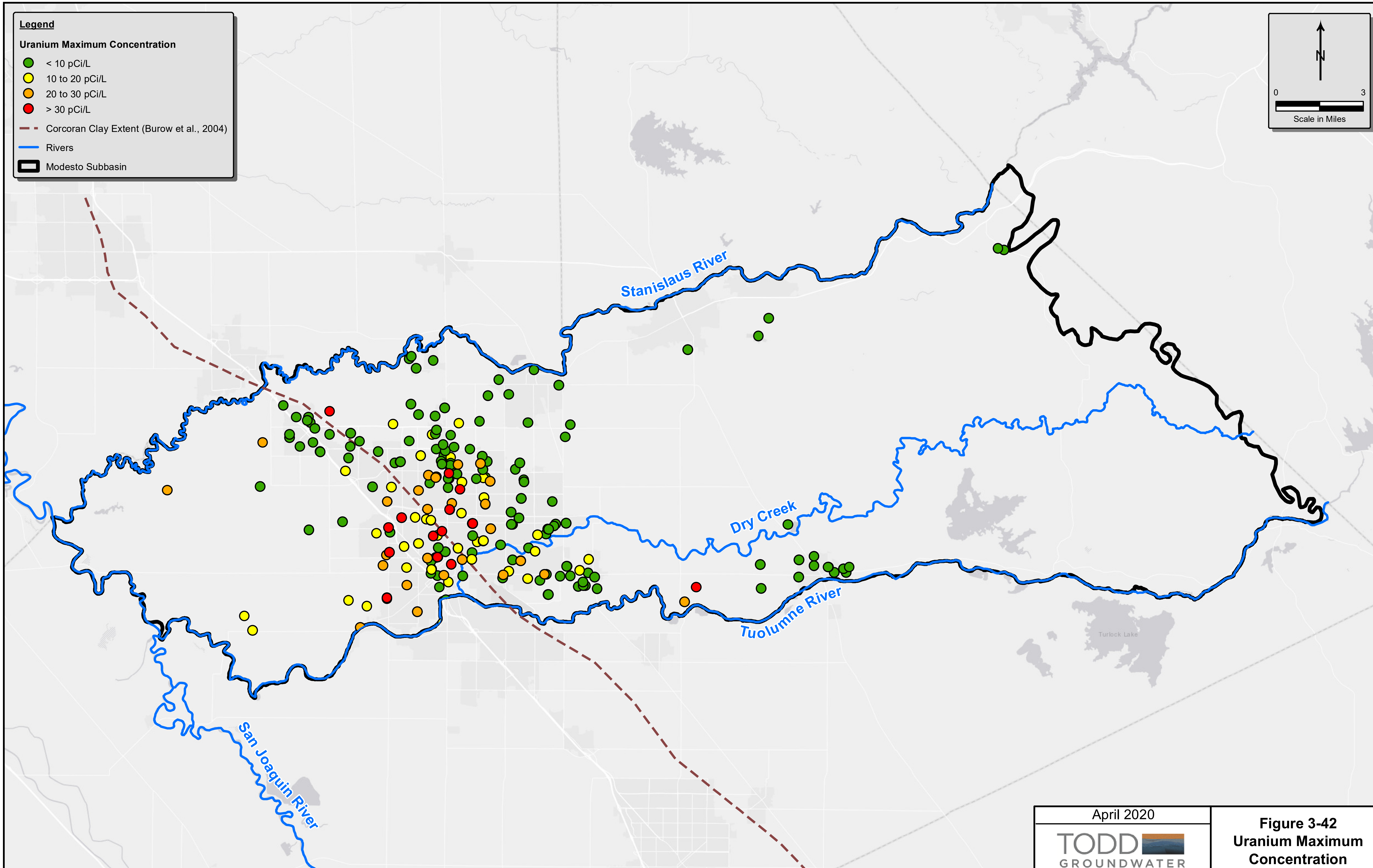


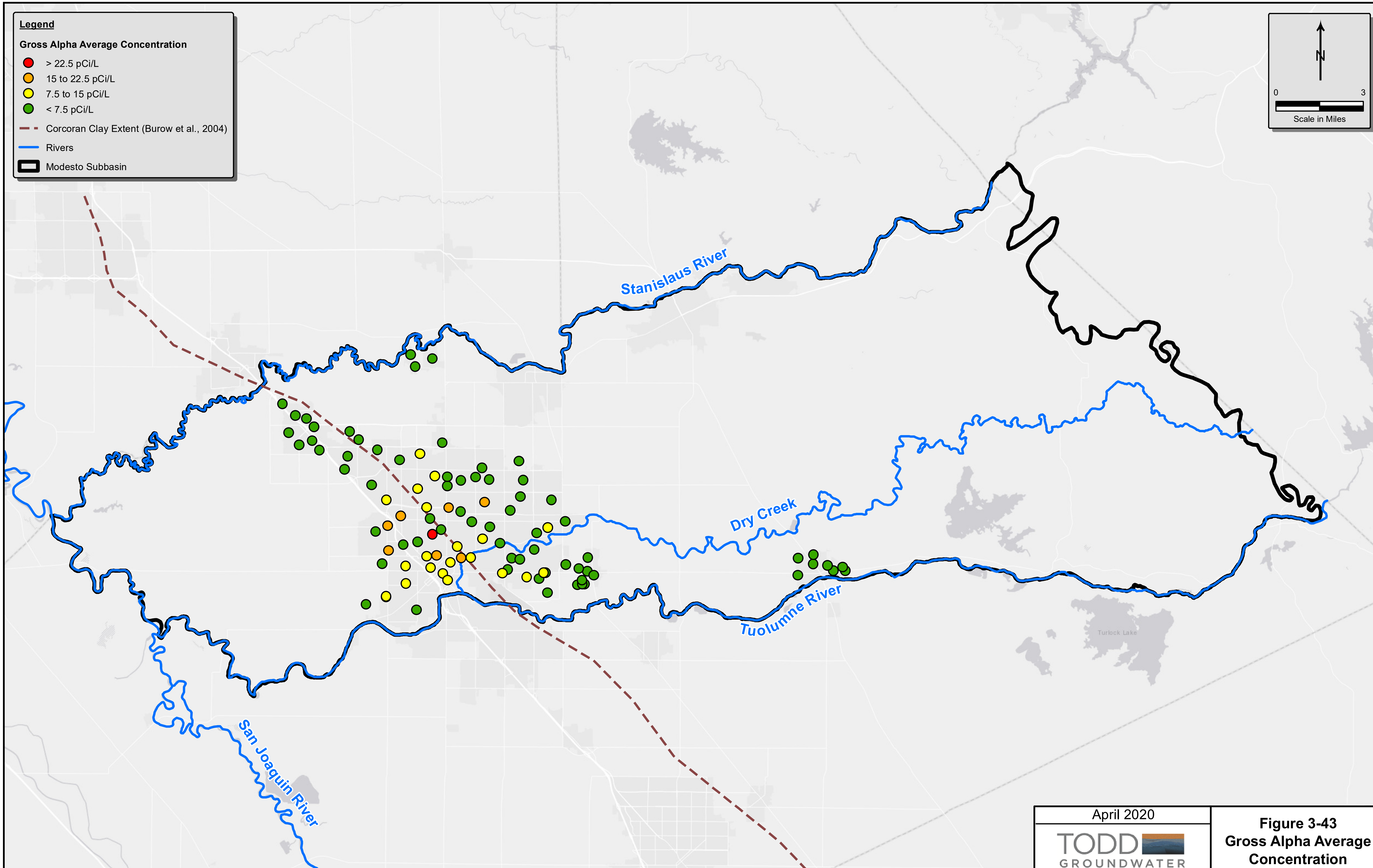
Figure 3-41
Uranium Average Concentration



April 2020

TODD GROUNDWATER

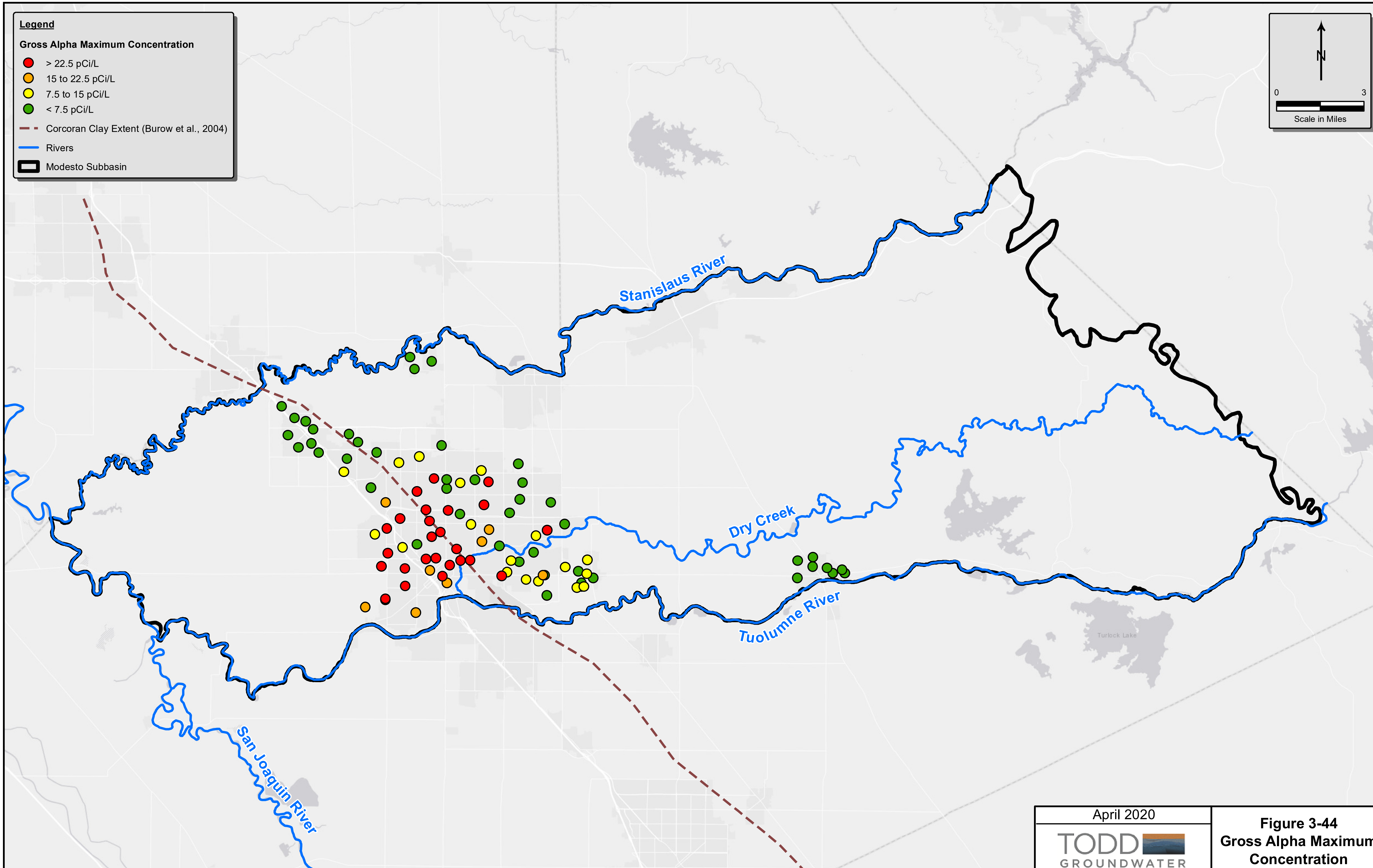
Figure 3-42
Uranium Maximum Concentration



April 2020

TODD GROUNDWATER

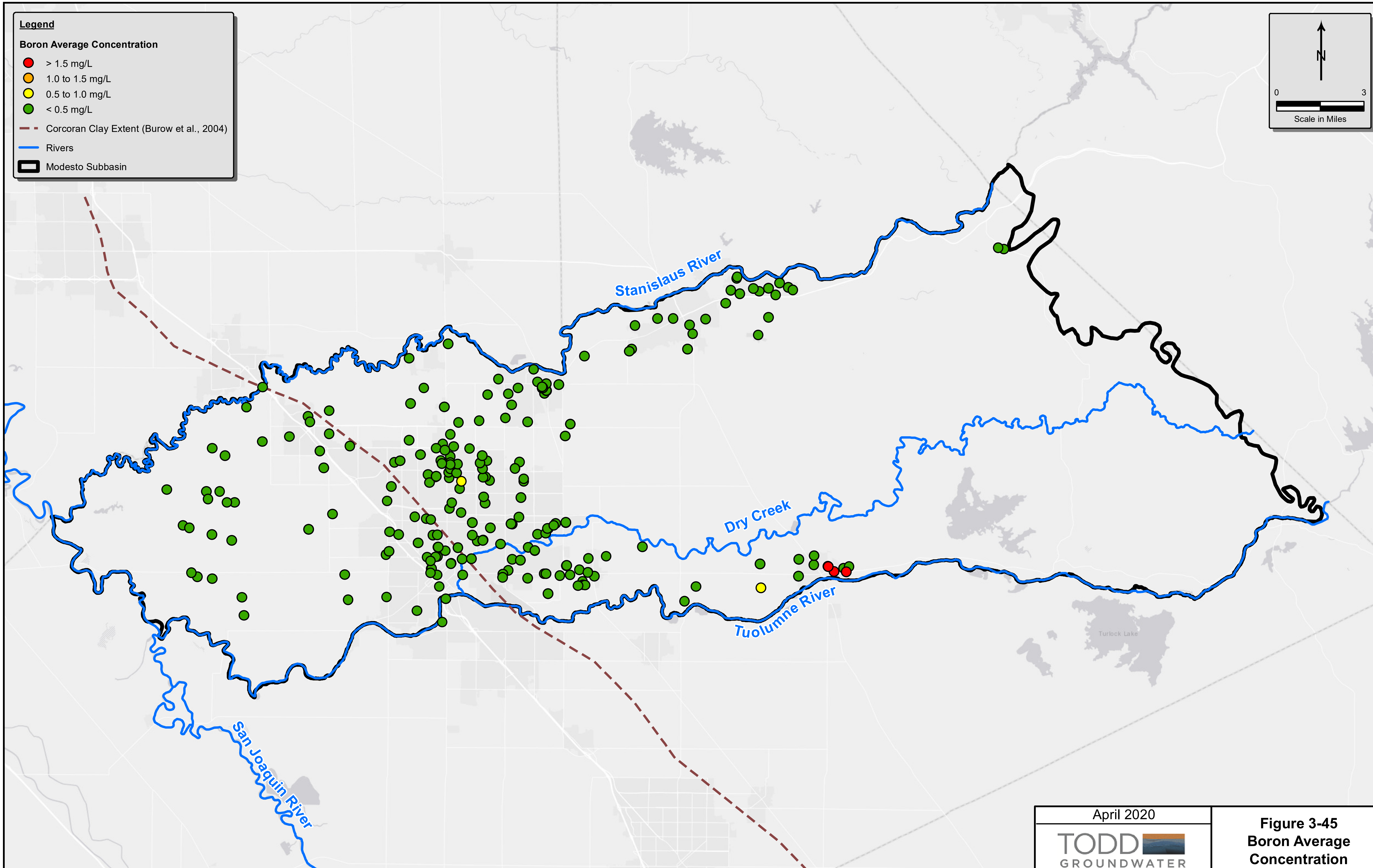
Figure 3-43
Gross Alpha Average Concentration



April 2020

TODD GROUNDWATER

Figure 3-44
Gross Alpha Maximum Concentration



April 2020

TODD GROUNDWATER

Figure 3-45
Boron Average Concentration

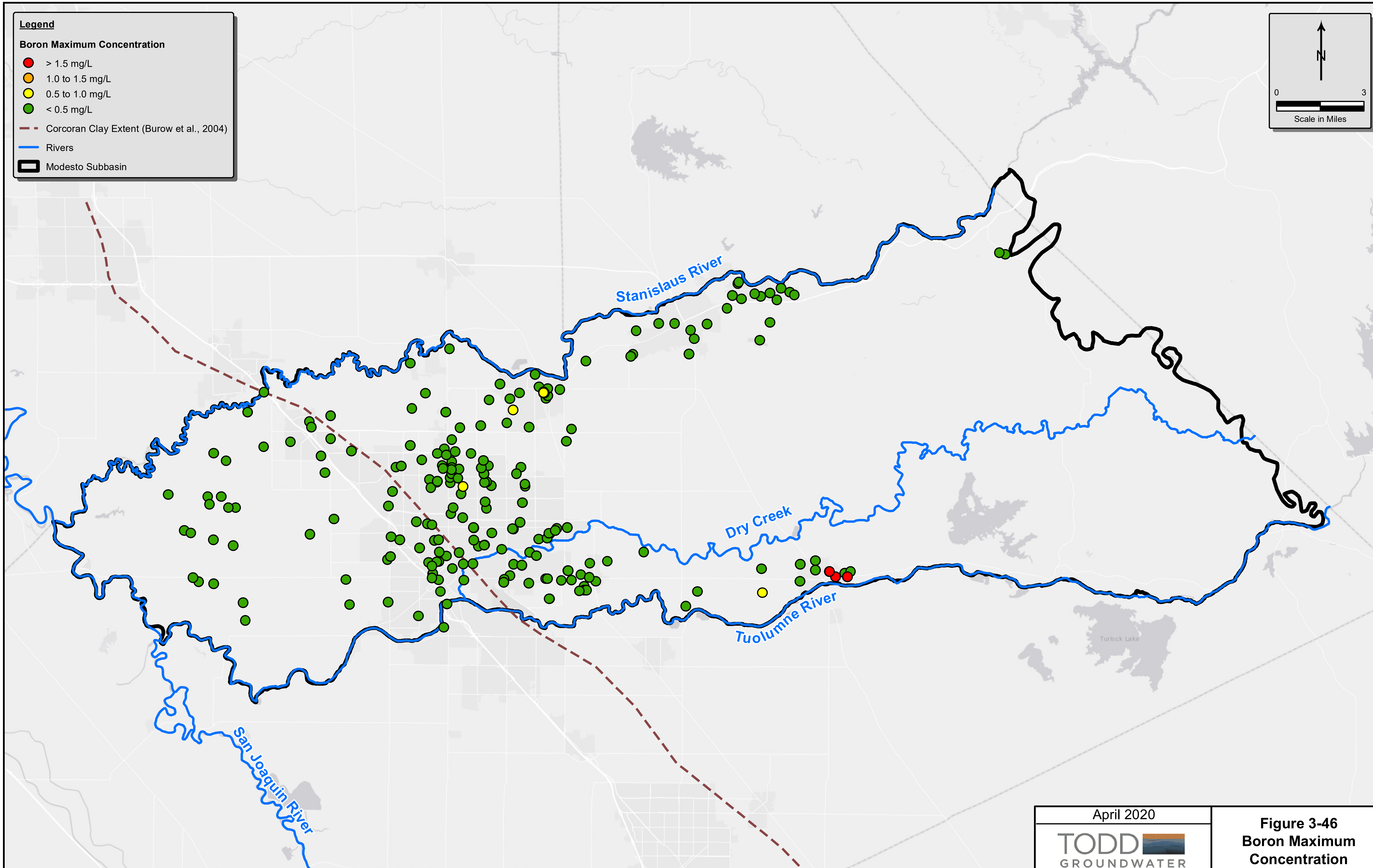


Figure 3-46
Boron Maximum Concentration

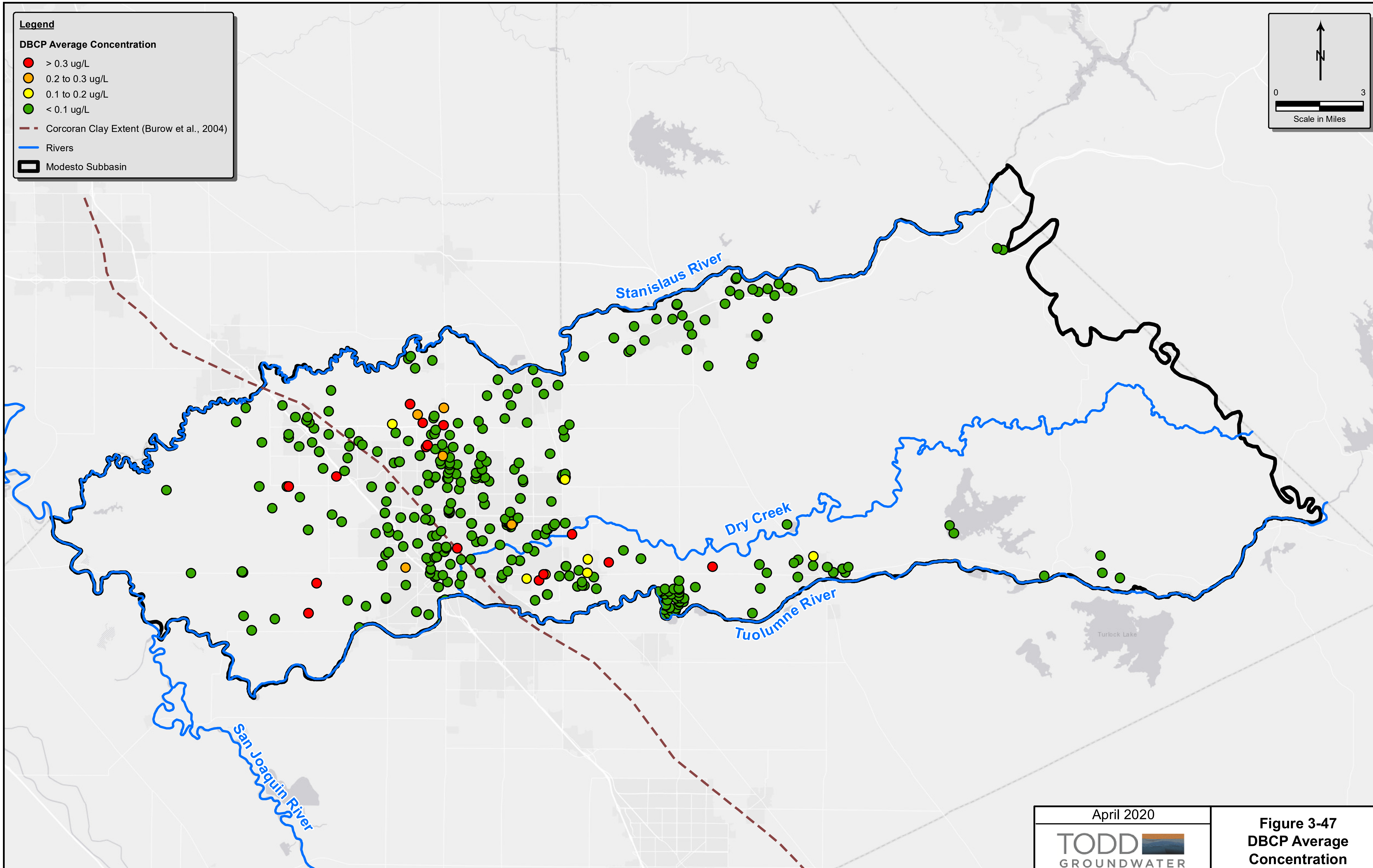
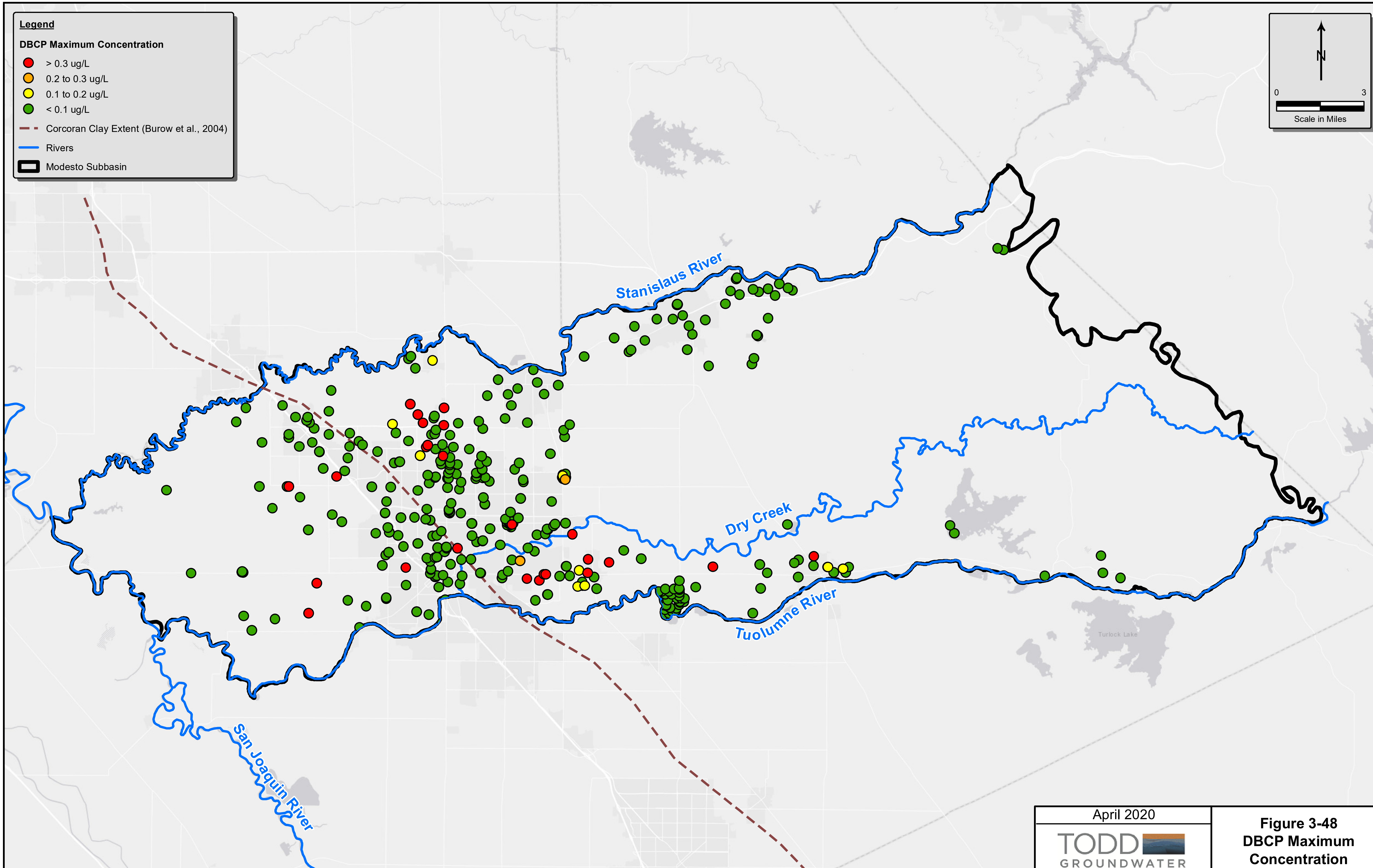


Figure 3-47
DBCP Average Concentration



April 2020

TODD GROUNDWATER

Figure 3-48
DBCP Maximum Concentration

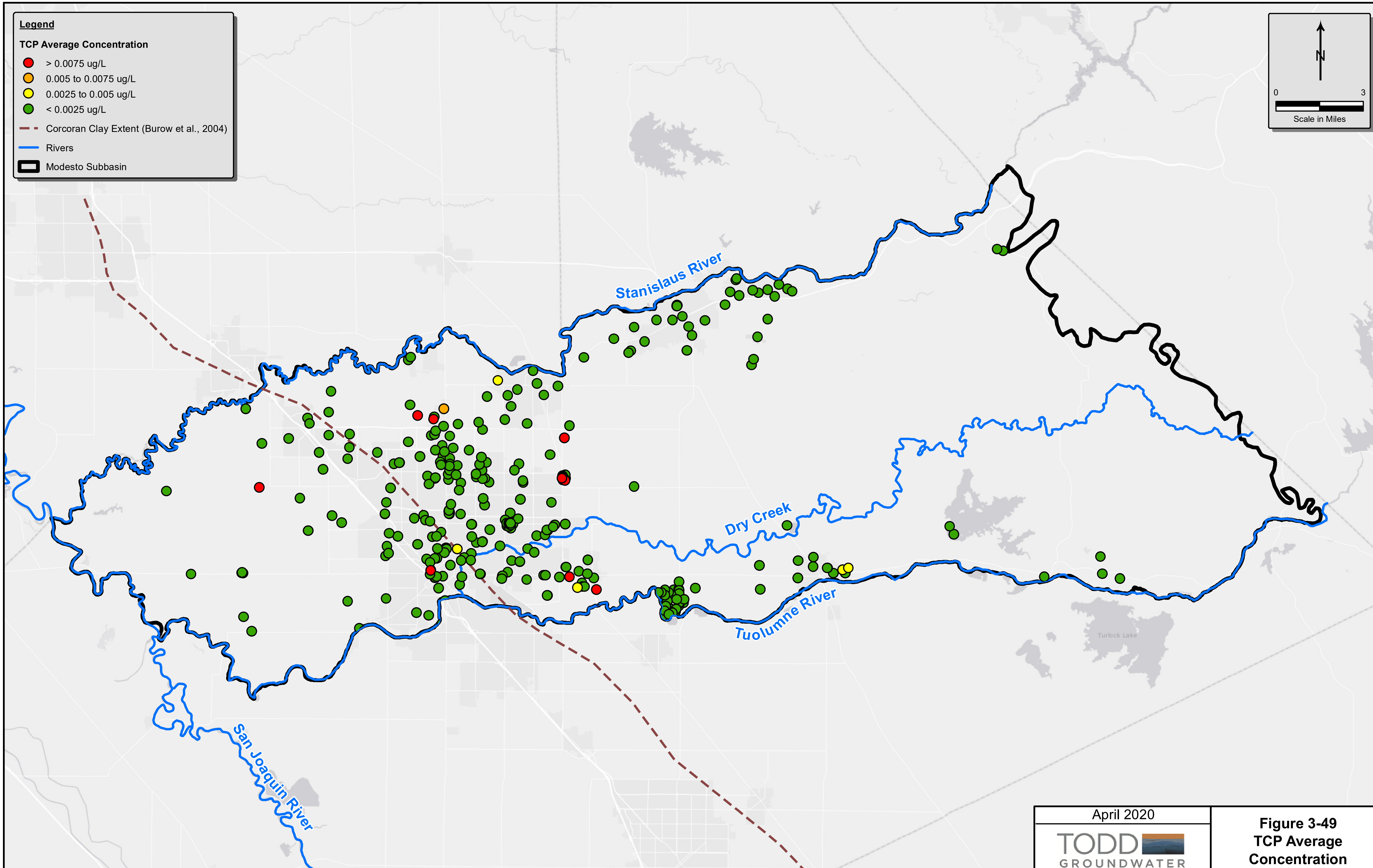


Figure 3-49
TCP Average Concentration

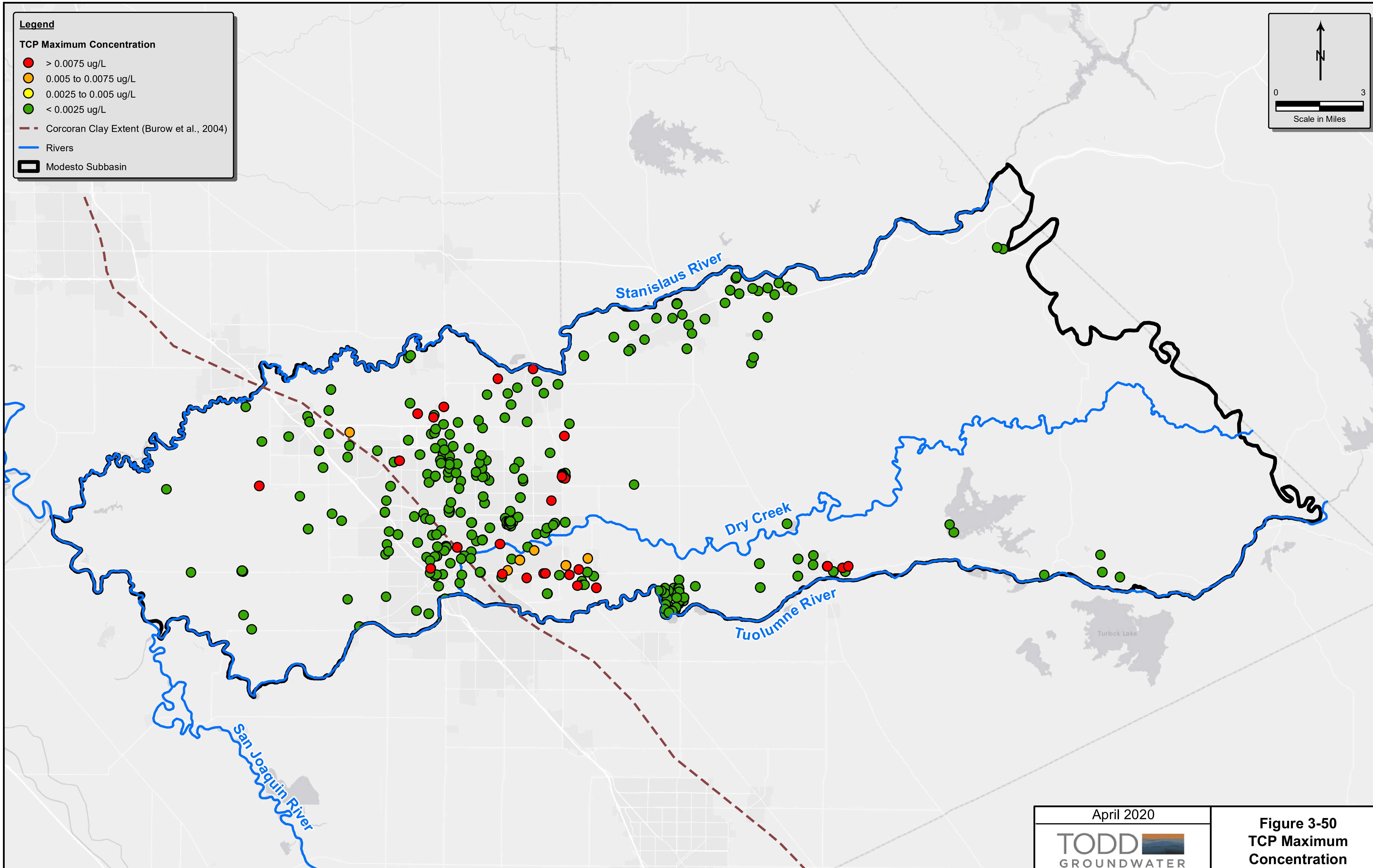
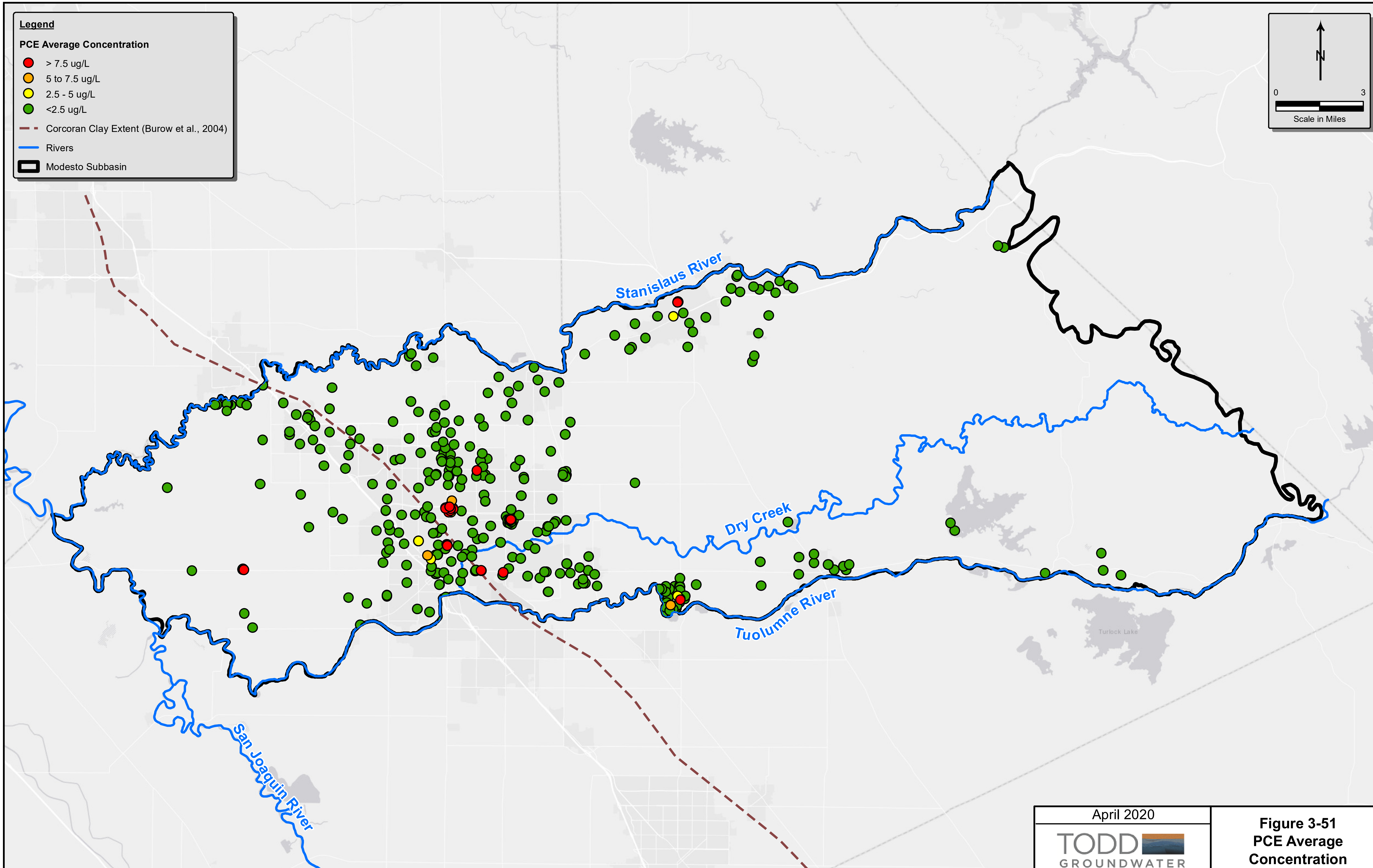


Figure 3-50
TCP Maximum Concentration



April 2020

TODD GROUNDWATER

Figure 3-51
PCE Average Concentration

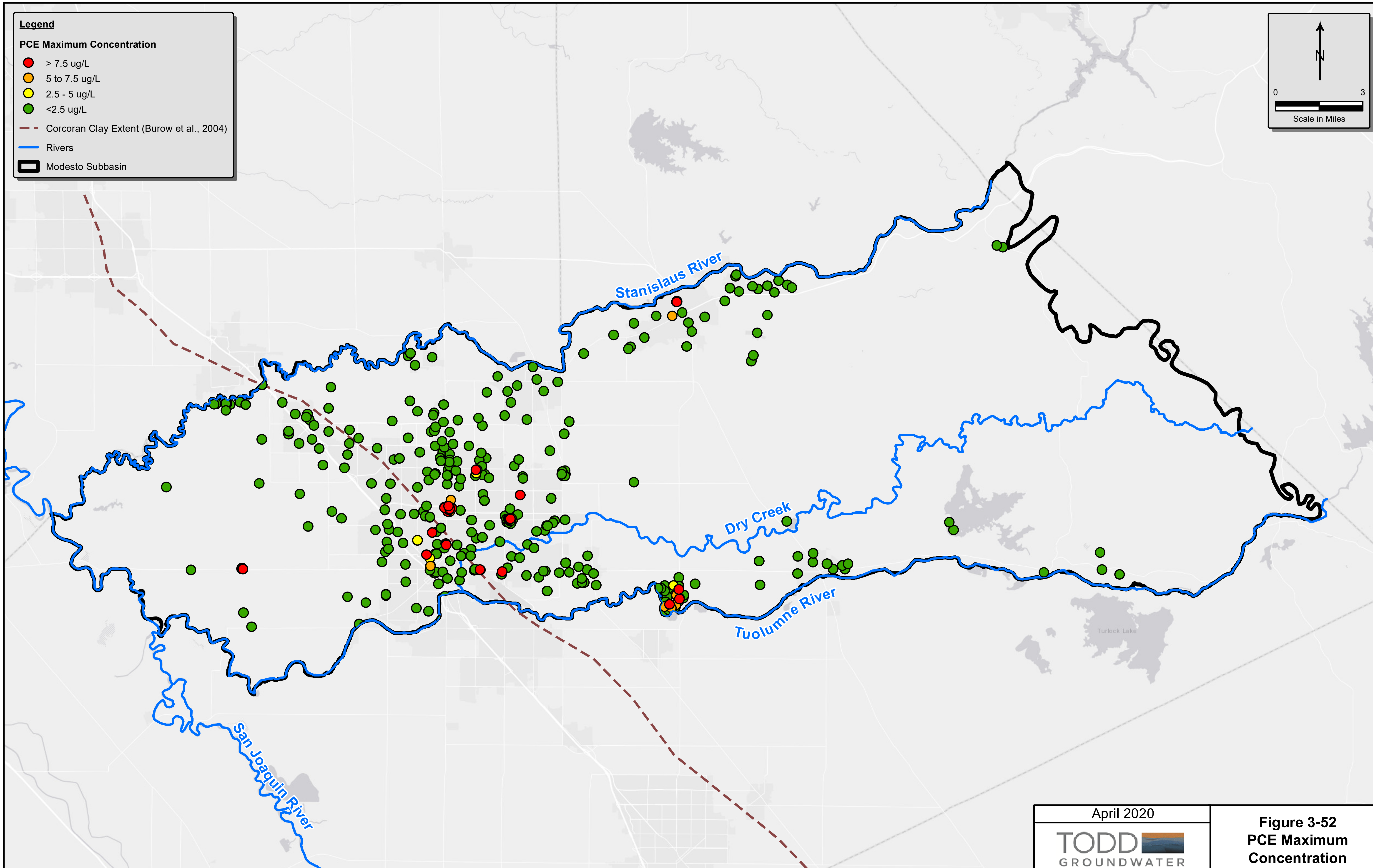
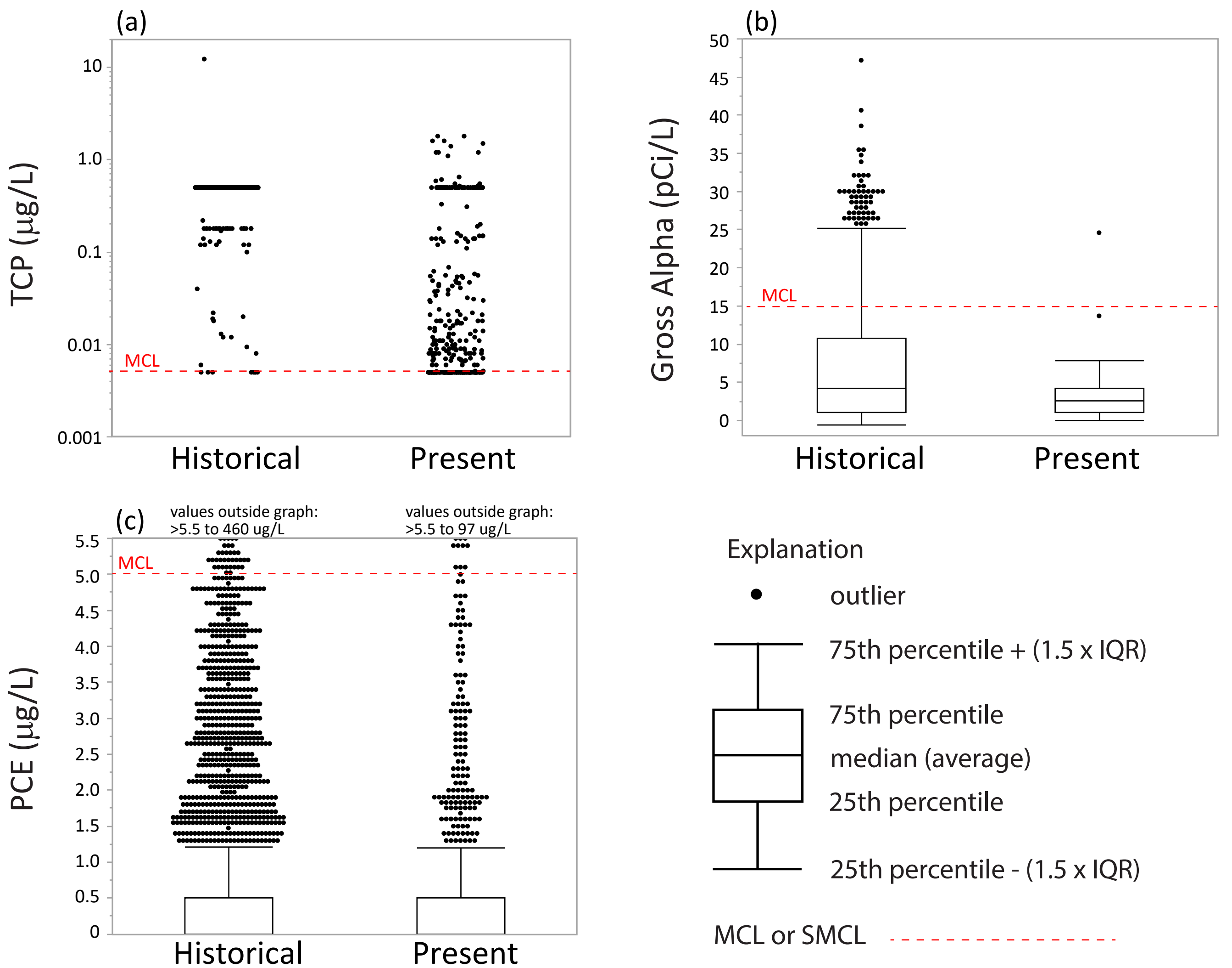


Figure 3-52
PCE Maximum Concentration

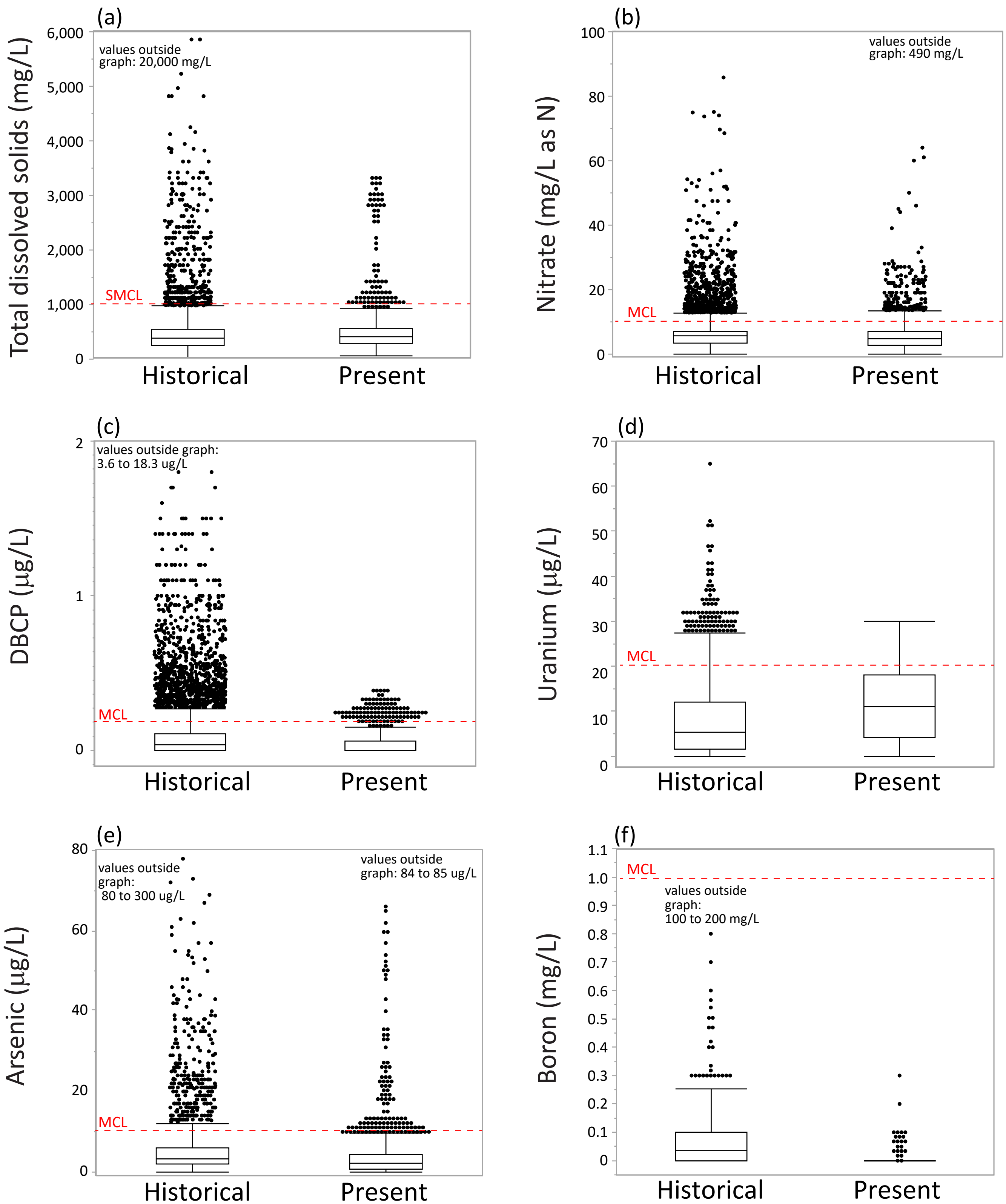


Note:
Concentrations of (a) TCP, (b) Gross Alpha, and (c) PCE under historical (water year 1995 to 2014) and present (2015 to 2019) periods, as compared to their respective Maximum Contaminant Level (MCL) or Secondary Maximum Contaminant Level (SMCL).

April 2020

TODD GROUNDWATER

Figure 3-53
Box Plots (1 of 2)

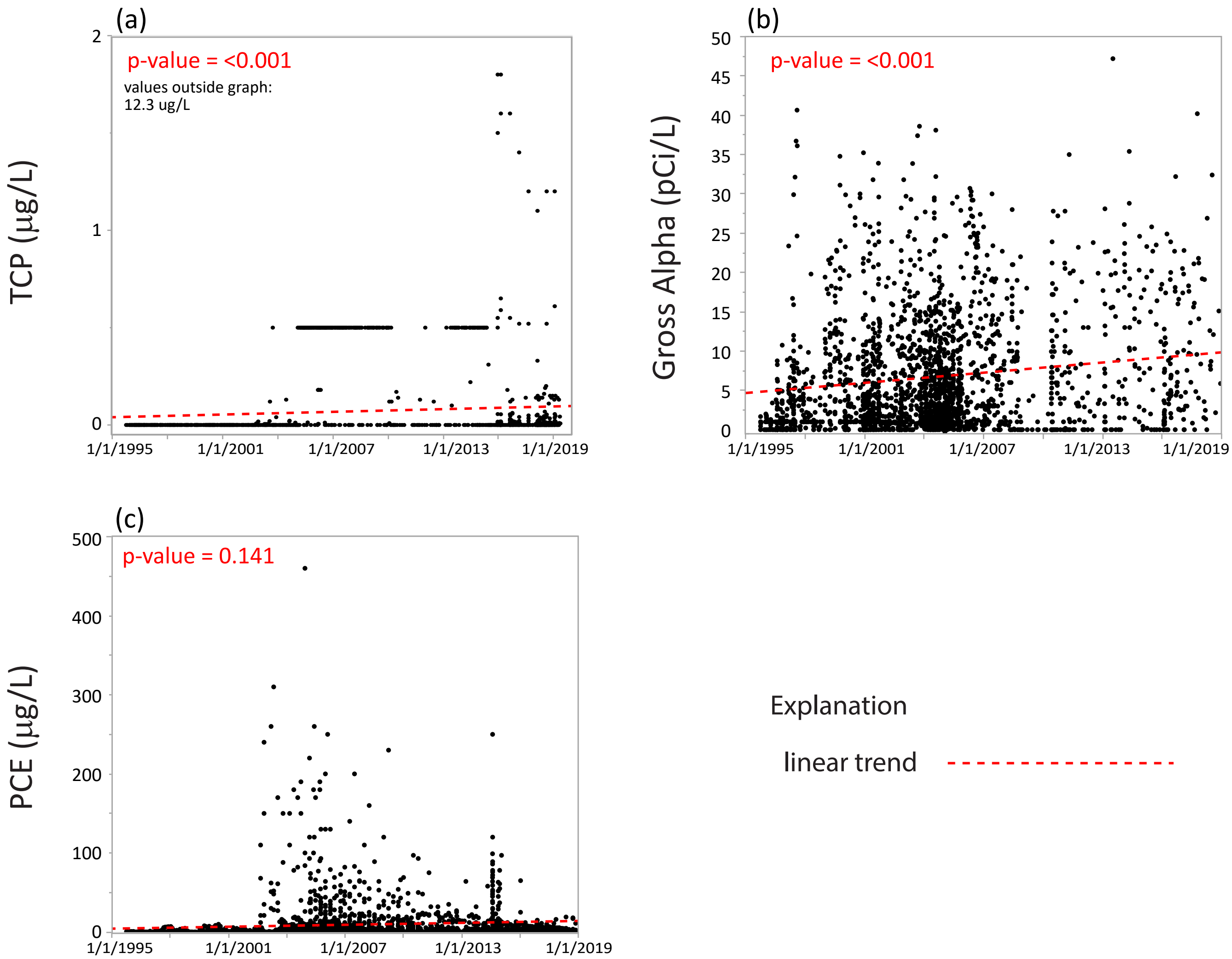


Note:
Concentrations of (a) total dissolved solids, (b) nitrate (as N), (c) DBCP, (d) uranium, (e) arsenic, and (f) boron under historical (water year 1995 to 2014) and present (2015 to 2019) periods, as compared to their respective Maximum Contaminant Level (MCL) or Secondary Maximum Contaminant Level (SMCL).

April 2020

TODD GROUNDWATER

Figure 3-54
Box Plots (2 of 2)

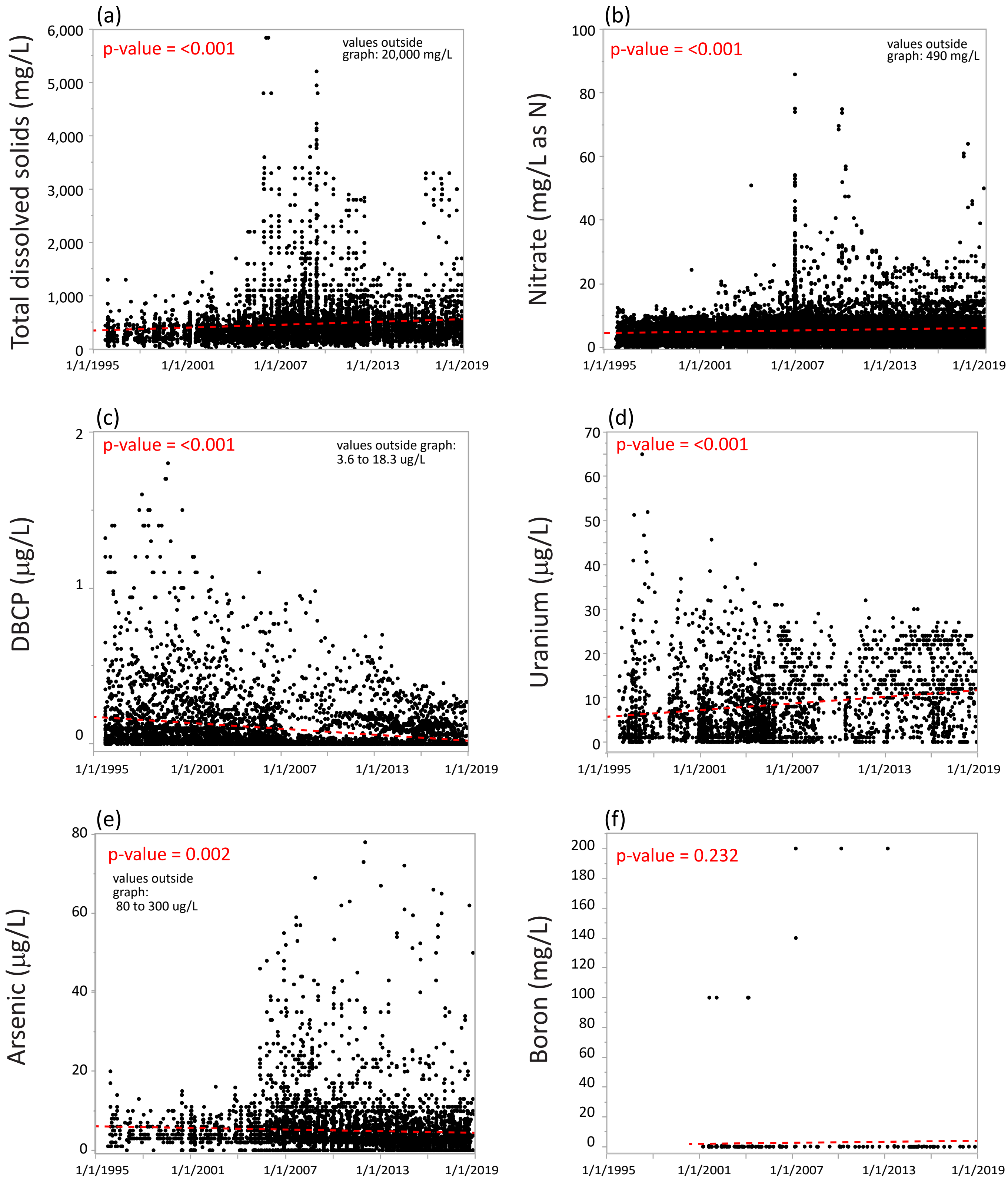


Note:
Linear temporal trends of (a) TCP, (b) Gross Alpha, and (c) PCE. The p-values less than the alpha-level of 0.05 are statistically significant trends.

April 2020

TODD GROUNDWATER

Figure 3-55
Linear Temporal Trends (1 of 2)

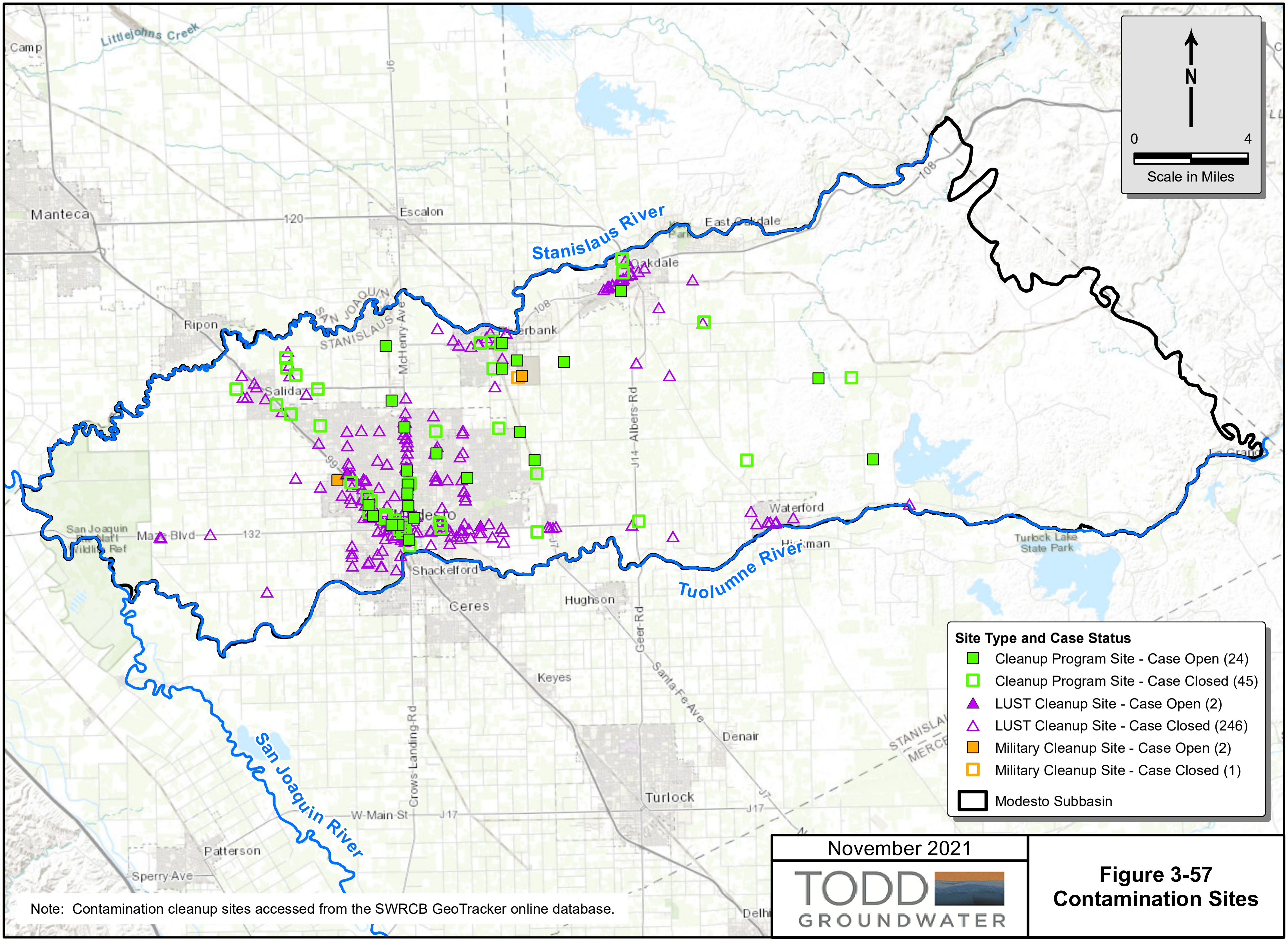


Note:
Linear temporal trends of (a) total dissolved solids, (b) nitrate (as N), (c) DBCP, (d) uranium, (e) arsenic, and (f) boron . The p-values less than the alpha-level of 0.05 are statistically significant trends.

April 2020

TODD GROUNDWATER

Figure 3-56
Linear Temporal Trends (2 of 2)

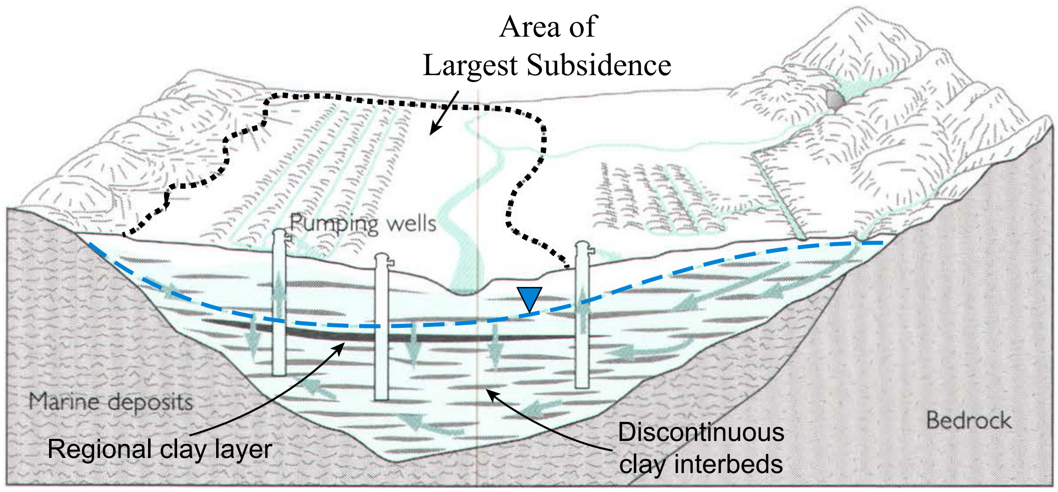


Note: Contamination cleanup sites accessed from the SWRCB GeoTracker online database.

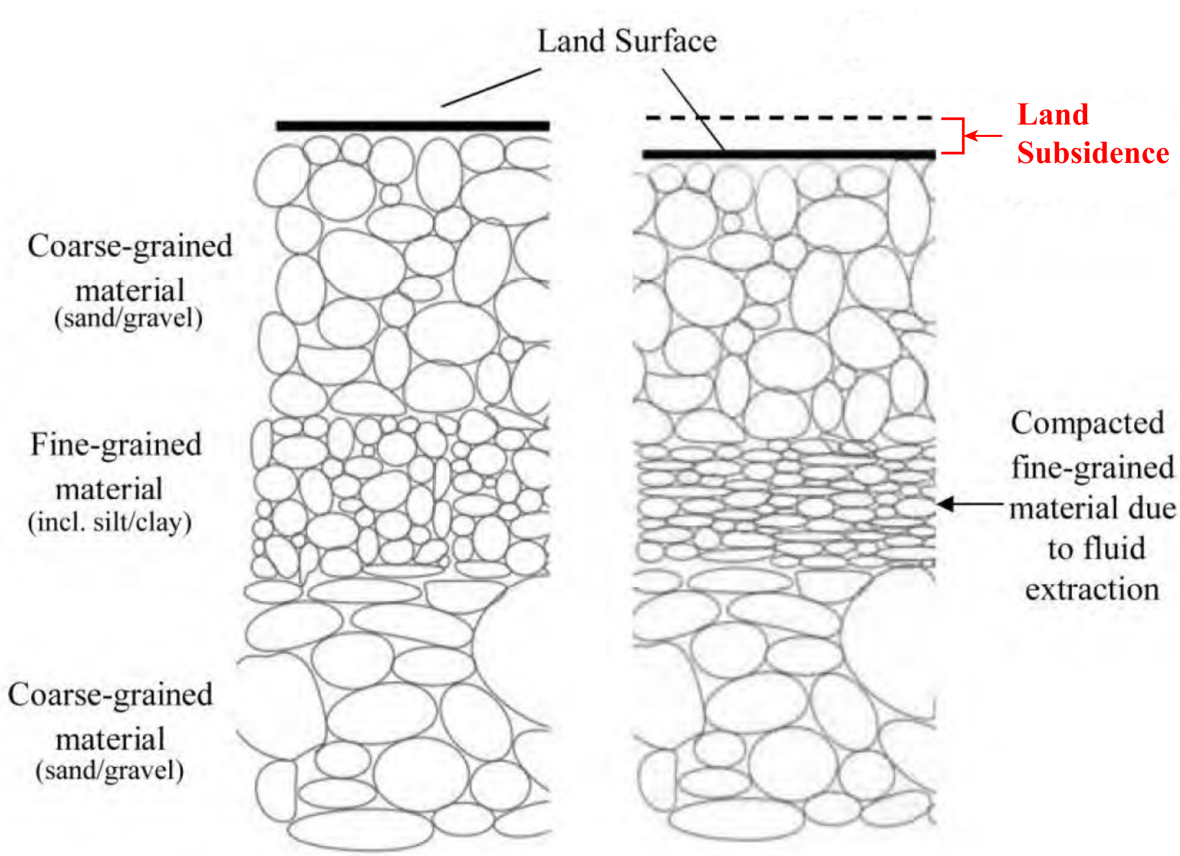
November 2021

TODD GROUNDWATER

Figure 3-57
Contamination Sites

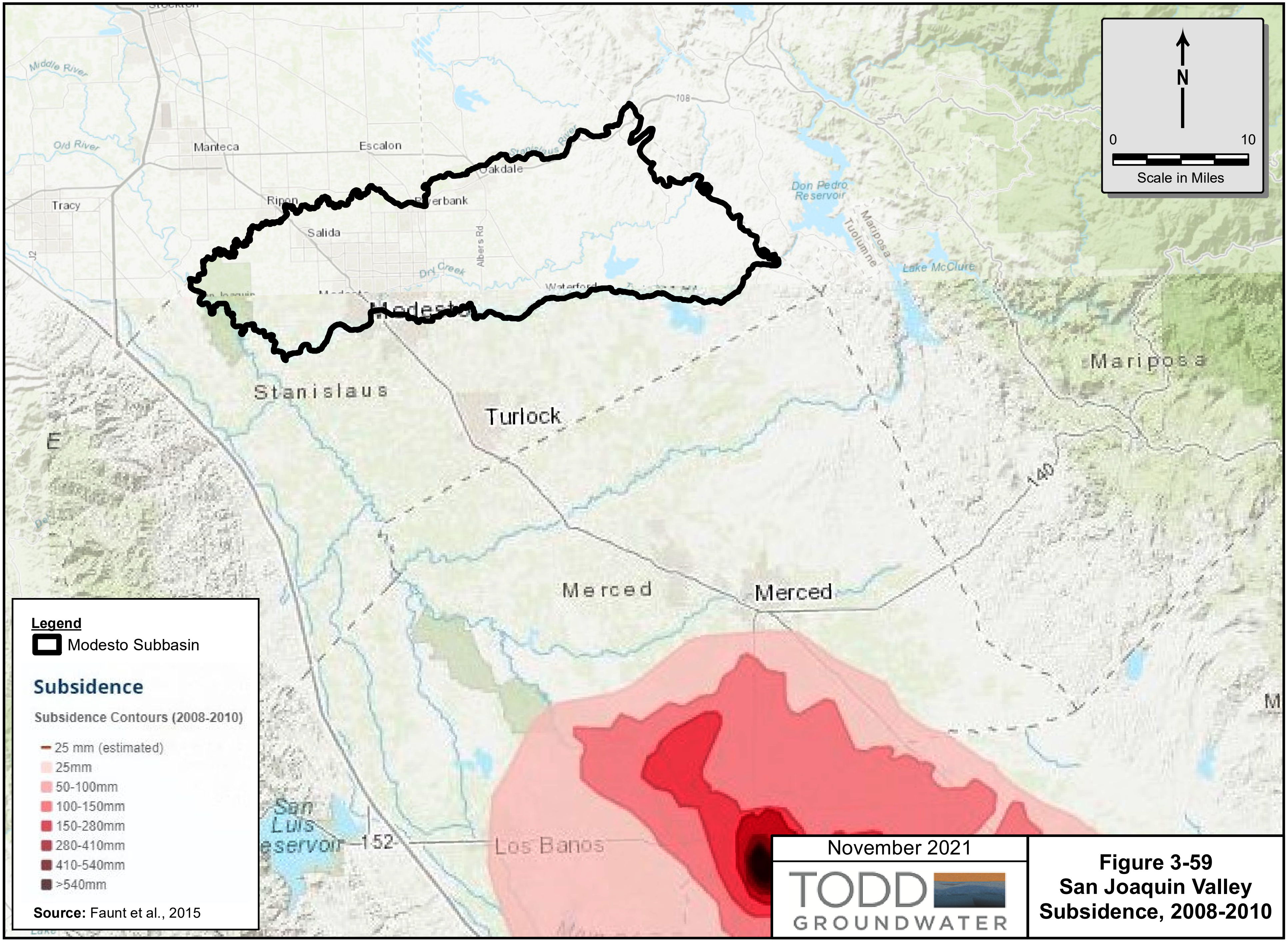


Source: Galloway et al., 1999.



After LSCE et al., 2014.

November 2021	**Figure 3-58 Concepts of Land Subsidence**
TODD GROUNDWATER	



November 2021

TODD GROUNDWATER

Figure 3-59
San Joaquin Valley Subsidence, 2008-2010

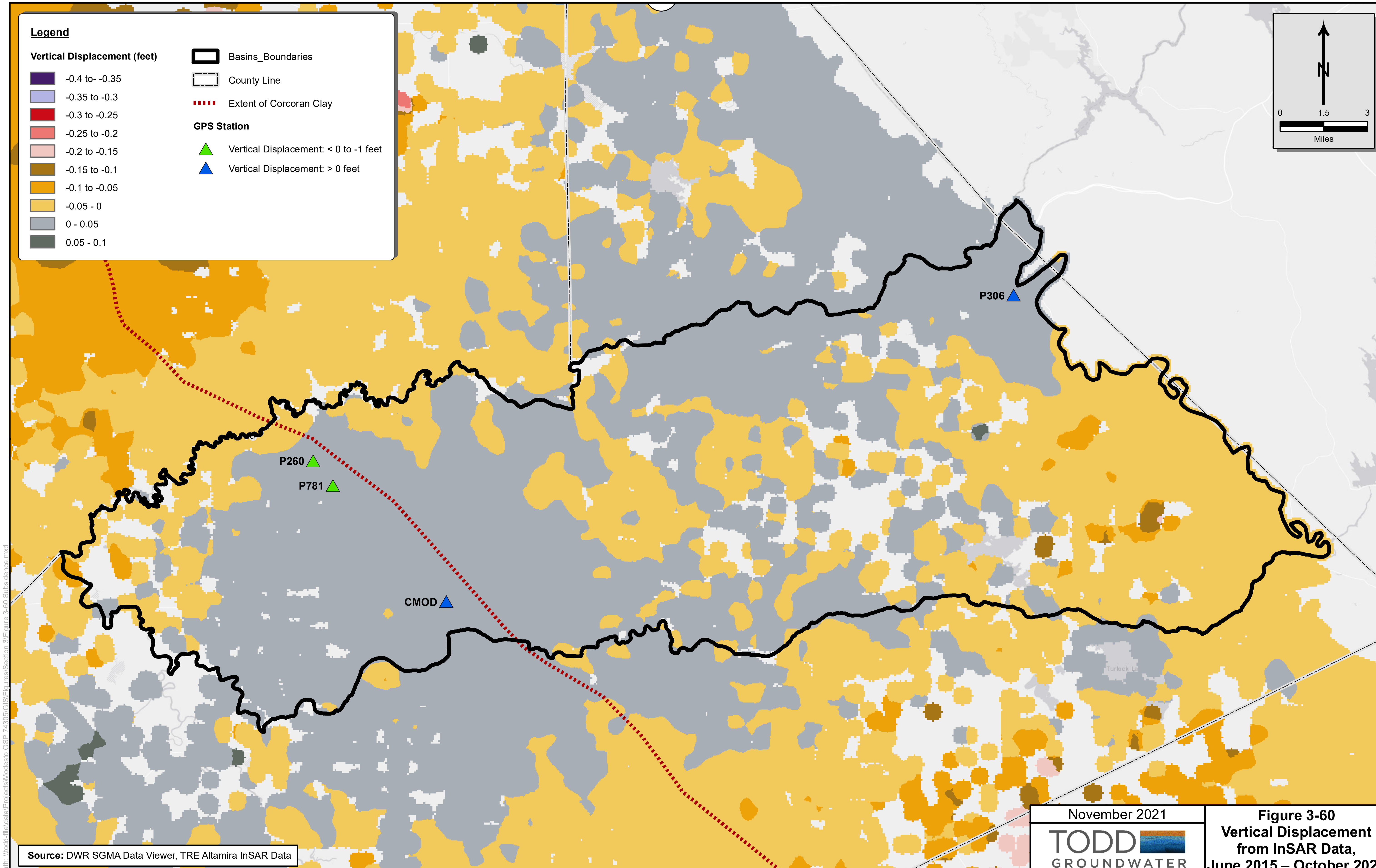
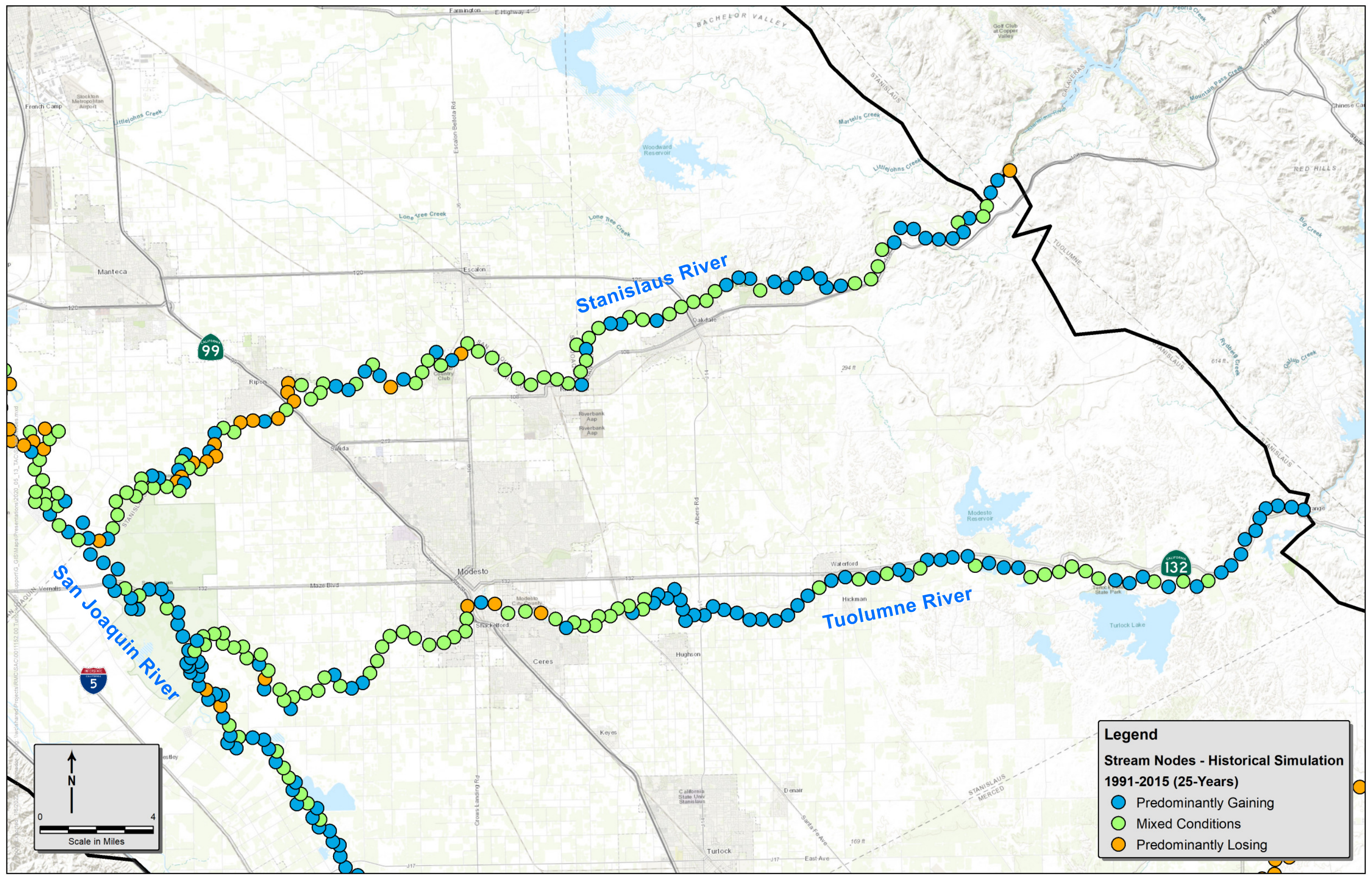
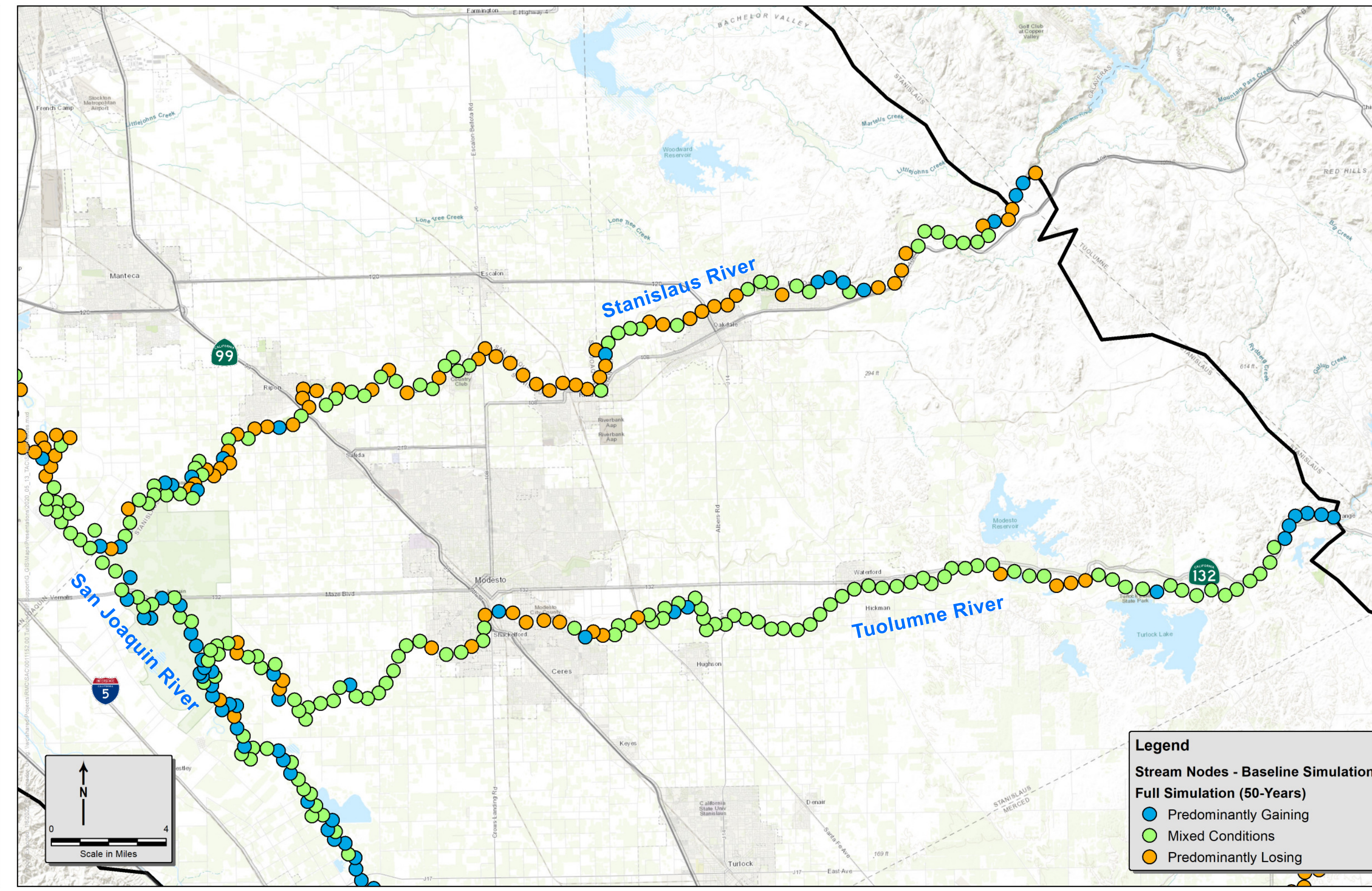


Figure 3-60
Vertical Displacement from InSAR Data, June 2015 – October 2020

Historical Conditions Simulation WY 1991-WY 2015



Projected Future Conditions Simulation Years 1-50



WOODARD & CURRAN

January 2022

Figure 3-61
Interconnected
Surface Water Conditions

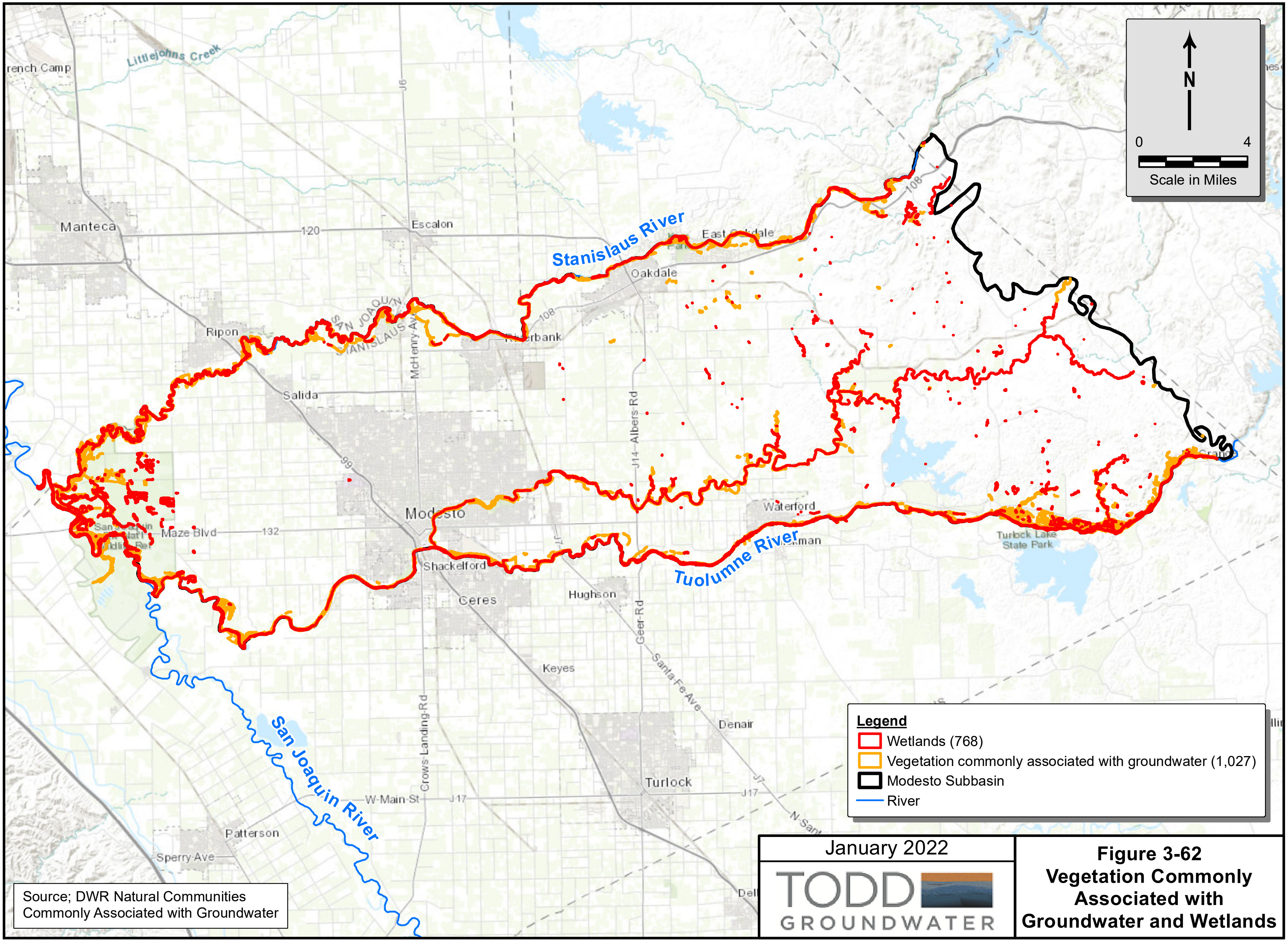
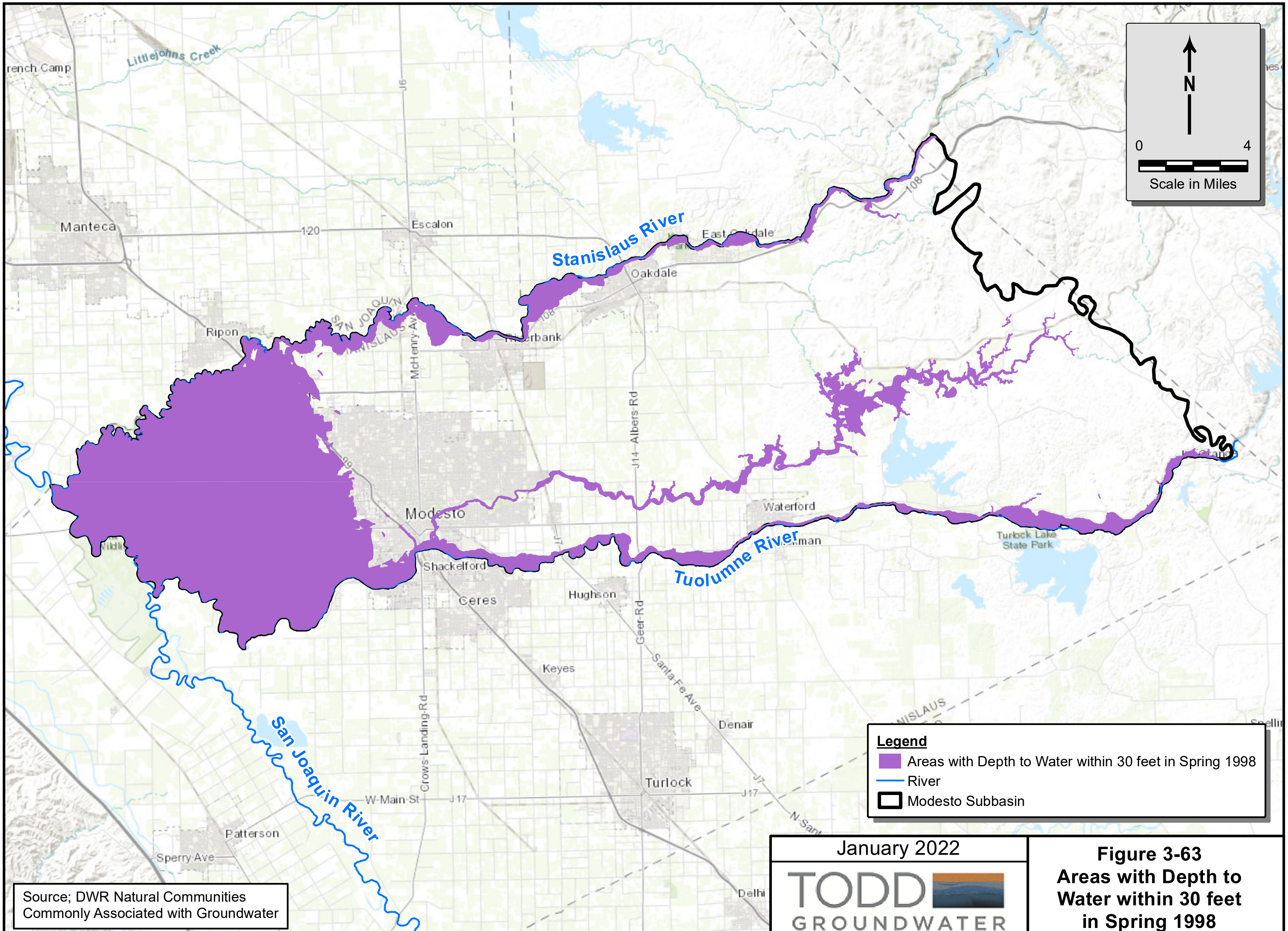


Figure 3-62
Vegetation Commonly Associated with Groundwater and Wetlands



January 2022

TODD GROUNDWATER

Figure 3-63
Areas with Depth to Water within 30 feet in Spring 1998

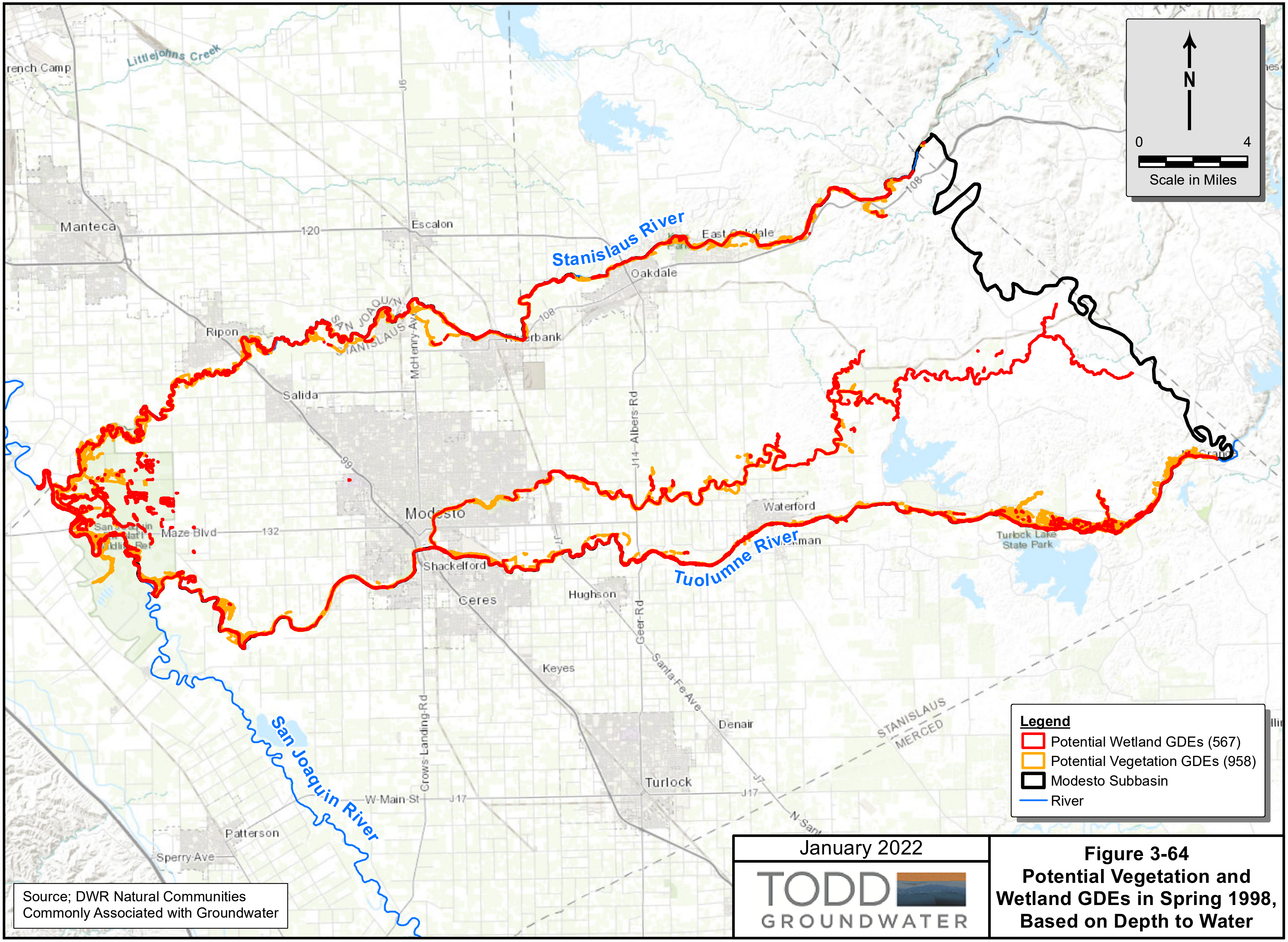
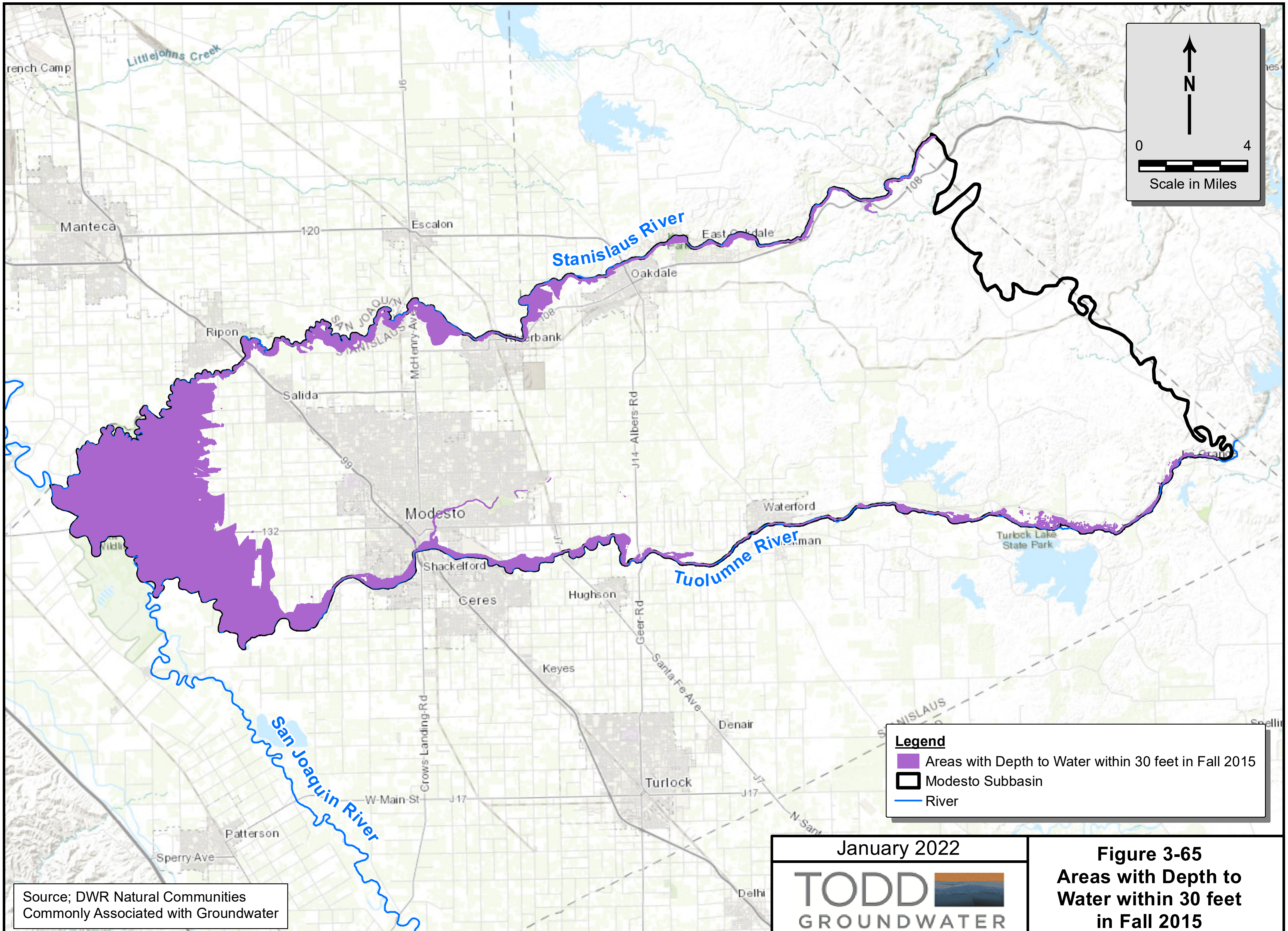


Figure 3-64
Potential Vegetation and Wetland GDEs in Spring 1998, Based on Depth to Water



January 2022

TODD GROUNDWATER

Figure 3-65
Areas with Depth to Water within 30 feet in Fall 2015

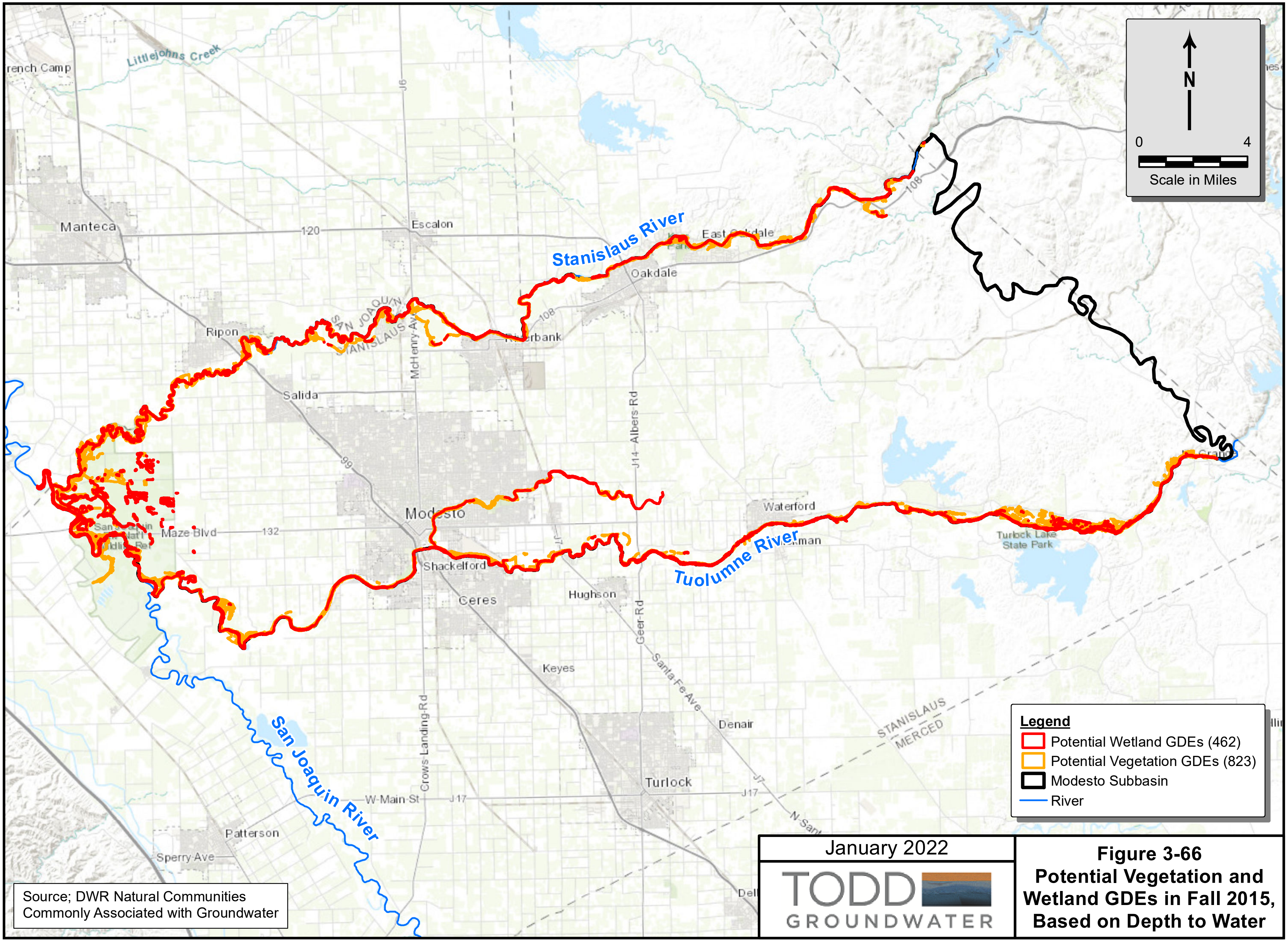
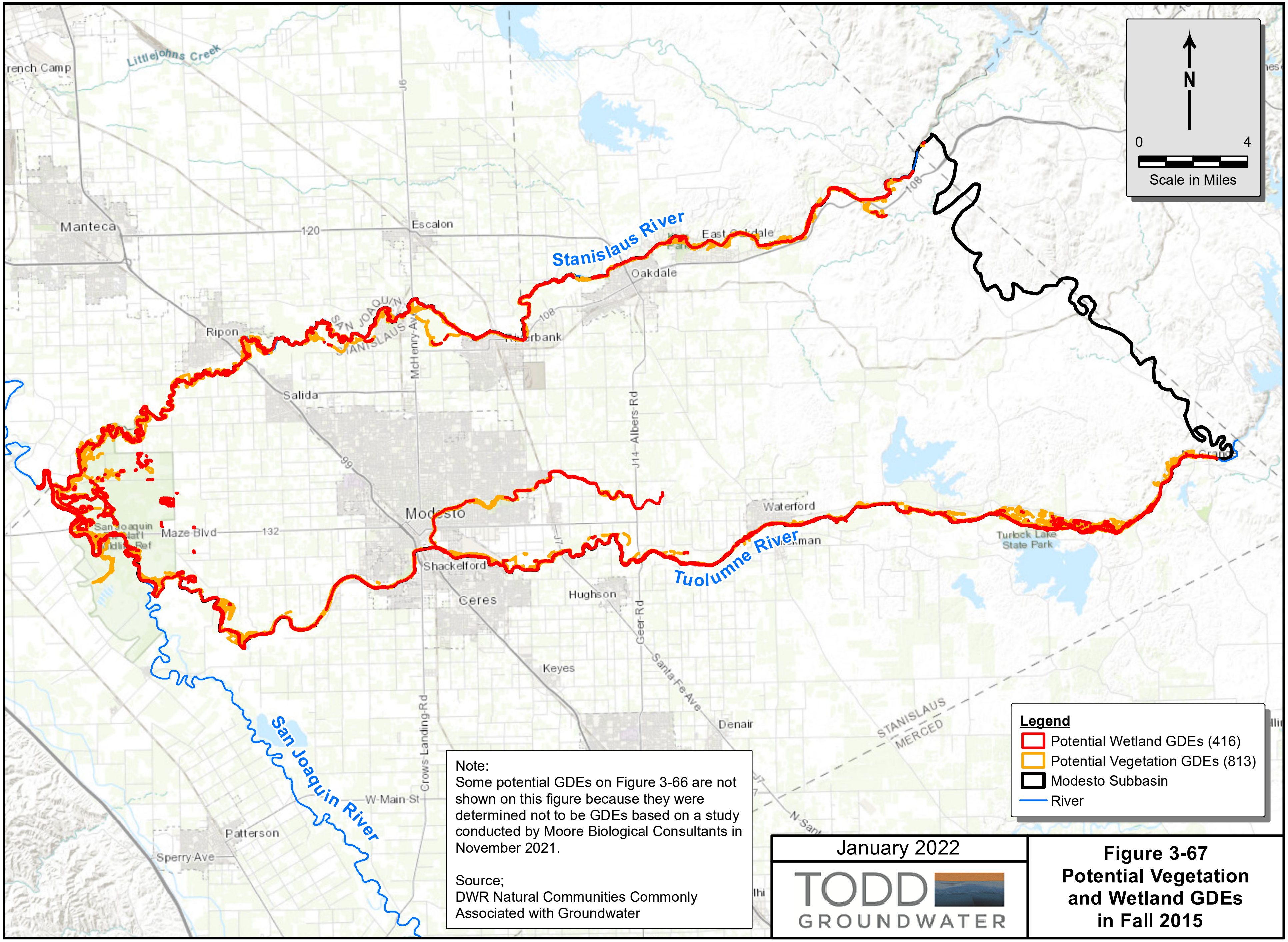


Figure 3-66
Potential Vegetation and Wetland GDEs in Fall 2015, Based on Depth to Water



Note:
Some potential GDEs on Figure 3-66 are not shown on this figure because they were determined not to be GDEs based on a study conducted by Moore Biological Consultants in November 2021.

Source;
DWR Natural Communities Commonly Associated with Groundwater

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Figure 3-67
Potential Vegetation and Wetland GDEs in Fall 2015

4. NOTICE AND COMMUNICATION

The GSAs in the Modesto Subbasin conducted a number of activities to engage beneficial users of groundwater, interested parties, and the general public in the development of the GSP. The STRGBA GSA and Tuolumne GSA were responsible for conducting outreach and engagement related to the SGMA for the portions of the Subbasin located within their respective service areas. The STRGBA GSA, which covers almost all of the Subbasin, took the lead in outreach with Tuolumne GSA coordinating through an agreement with Stanislaus County (**Appendix A**).

4.1. DECISION MAKING PROCESS

As described in **Chapter 1** of this GSP, the Stanislaus and Tuolumne Rivers Groundwater Basin Association (STRGBA) agencies entered into a Memorandum of Understanding (MOU) to form the STRGBA GSA in February 2017. The STRGBA GSA is governed by a committee tasked with overseeing activities to achieve the objectives of SGMA applicable within the Modesto Subbasin (Committee). Each member agency designates one staff person and one or more alternates to serve on the Committee. Stanislaus County participates in the Committee on behalf of the Tuolumne GSA.

Each calendar year, the Committee elects a chair and vice chair from its members. The chair is responsible for presiding over and notifying members of Committee meetings. Except for actions for which a different approval standard is set forth in the MOU, all actions of the Committee are approved by a majority vote carried by of the members present.

To provide a venue for discussion of technical topics related to the development of the GSP, the STRGBA GSA also formed a Technical Advisory Committee (TAC). TAC membership is not defined in the MOU, but it generally includes one participating representative from each of the STRGBA GSA member agencies. Stanislaus County, a STRGBA GSA member agency, represented both itself as well as the Tuolumne GSA in these TAC meetings.

Both Committee and TAC meetings are open to the public and held in accordance with the Ralph M. Brown Act (California Government Code section 5490 et sq.). These meetings are further described in **Section 3.4.1**.

4.2. GROUNDWATER BENEFICIAL USES AND USERS

Beneficial users and uses of groundwater were identified and engaged by the GSAs based on the place- and interest-based categories described in SGMA and codified in Water Code Section 10723.2:

(a) Holders of overlying groundwater rights, including:

(1) Agricultural users, including farmers, ranchers, and dairy professionals

(2) Domestic well owners

(b) Municipal well owners

(c) Public water systems

(d) Local land use planning agencies

(e) Environmental users of groundwater

(f) Surface water users, if there is a hydrologic connection between surface and groundwater bodies

(g) The federal government, including, but not limited to, the military and managers of federal lands

(h) California Native American tribes

(i) Disadvantaged communities, including, but not limited to, those served by private domestic wells or small community water systems

(j) Entities listed in Section 10927 that are monitoring and reporting groundwater elevations in all or a part of a groundwater basin managed by the groundwater sustainability agency

Beneficial users and uses representing these categories and nature of consultation with these users are further described below and identified in **Table 4-1**.

Table 4-1: Nature of Consultation with Beneficial Users

Beneficial User Category	Beneficial Users	Nature of Consultation: Participation in Stakeholder Assessment	Membership on STRGBA GSA and/or Technical Advisory Committee or Tuolumne County GSA	Interested Parties Database	Public Meetings, Workshops, and Subbasin Office Hours	Targeted Outreach to Representatives of Beneficial Users
Agricultural Users	Agricultural water providers - MID, OID	X	X	X	X	X
	Individual agricultural water users, including dairies, farmers, and ranchers	X		X	X	X
Domestic Well Owners	Domestic well owners	X		X	X	X
Municipal and Industrial Well Owners	City of Modesto	X	X	X	X	X
	City of Oakdale	X	X	X	X	X
	City of Riverbank	X	X	X	X	X
	City of Waterford	X	X	X	X	X
	Municipal supply wells owners	X	X	X	X	X
	MID	X	X	X	X	X
	OID	X	X	X	X	X
Public Water Systems	[See Section 2, Table 2-1 for the list of public water systems in the Subbasin]			X	X	
Local Land Use Planning Agencies	City of Modesto Planning Commission		X		X	
	City of Oakdale Planning Commission		X		X	
	City of Riverbank Planning Commission		X		X	
	City of Waterford Planning Commission		X		X	
	Stanislaus County Local Agency Formation Commission			X	X	
	Stanislaus County Planning Commission		X	X	X	
	Tuolumne County Local Agency Formation Commission				X	
	Tuolumne County Local Planning Commission		X	X	X	
Environmental Users of Groundwater	California Department of Fish and Wildlife			X	X	
	Tuolumne River Trust	X		X	X	
	U.S. Fish and Wildlife Service			X	X	
Surface Water Users	Individual landowners			X	X	
	MID	X	X	X	X	
	OID	X	X	X	X	
	Tuolumne River Trust	X		X	X	
Federal Government	U.S. Fish and Wildlife Service			X		
California Native American Tribes	[There are no tribal lands are documented in the DWR Water Management Planning Tool or are known to exist in the Modesto Subbasin.]					
Disadvantaged Communities (Census Designated Tracts)	Airport				X	X
	City of Oakdale	X	X	X	X	X
	City of Waterford	X	X	X	X	X
	Empire			X	X	X
	Rouse				X	X
	West Modesto				X	X
Groundwater Monitoring and Reporting Entities	STRGBA	X	X	X	X	X

KEY: GSA = Groundwater Sustainability Agency, MID = Modesto Irrigation District, OID = Oakdale Irrigation District, STRGBA = Stanislaus and Tuolumne Rivers Groundwater Basin Association

4.2.1. Agricultural Users (§10723.2(a)(1))

The Modesto Subbasin is largely agricultural. In 2017, approximately 64 percent of the Subbasin was defined as irrigated agriculture (Stanislaus Land Use dataset, 2017). Irrigated agriculture covers about 157,911 acres. Approximately 23 percent of the Subbasin (about 56,777 acres) consists of non-agriculture, non-irrigated agriculture (e.g., rangeland), undeveloped land, and surface water.

Agricultural groundwater users include growers, ranchers, and dairies. Water for agricultural purposes is primarily provided through groundwater extracted from the Subbasin, as well as surface water supplies provided by the Modesto Irrigation District (MID) and Oakdale Irrigation District (OID). MID and OID each operate groundwater wells to supplement surface water deliveries and manage the water table.

Agricultural interests are represented on the Committee by MID and OID; in addition, the elected boards and councils of the STRGBA GSA member agencies provide broad agricultural representation. Individuals representing agricultural water users were also part of the initial stakeholder assessment conducted to develop the Communication and Engagement Plan; and actively participated in monthly Committee and TAC meetings, public workshops, and GSP chapter public comment processes.

During development of the GSP, MID and OID conducted outreach on groundwater management practice and SGMA to their agricultural customers. Information was provided at MID and OID grower meetings, in newsletters, and during presentations to the MID and OID Boards of Directors. Agricultural groundwater users also participated in the Subbasin stakeholder assessment, which is described in the Communication and Engagement Plan.

4.2.2. Domestic Well Owners (§10723.2(a)(2))

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 the City of Modesto. OID also provides domestic water from District-owned wells for its rural water system and serves as the trustee of six improvement districts. A density of domestic wells is illustrated on **Figure 2-14** in **Chapter 2**.

Domestic well owners are represented on the Committee by OID and Stanislaus County and had the opportunity to consult in development of the GSP through monthly public meetings, workshops, and GSP public comment processes. An informational postcard was distributed to over 350 landowners in the eastern part of the Subbasin with a high density of domestic wells to inform them about development of the GSP. The STRGBA GSA also engaged the Municipal Advisory Councils for the communities of Airport, West Modesto, and Empire, located in unincorporated Stanislaus County, to inform them about development of the GSP and solicit input on locations for new groundwater monitoring wells.

4.2.3. Municipal & Industrial Well Owners (§10723.2(b))

There are approximately 150 municipal supply wells in the Subbasin, as shown in Chapter **2, Figure 2-13**. The highest concentration of municipal supply wells is located within the City of Modesto. There are also public supply wells located in the Cities of Oakdale, Riverbank, and Waterford; and unincorporated areas of Stanislaus County. The Cities of Modesto, Oakdale, Riverbank, and Waterford pump groundwater for municipal and industrial water supply. MID and OID also operate groundwater wells to supplement surface water supplies and manage the water table.

All four cities, Stanislaus County, MID, and OID are member agencies of the STRGBA GSA and represent municipal and industrial well owners. Member agency staff provided periodic updates to their respective governing bodies informing them about progress developing the GSP and consulting on key groundwater management decisions. STRGBA GSA staff also provided presentations on SGMA and the GSP at meetings of the Manufacturer's Council of Central Valley. In addition, municipal and industrial well owners participated in the stakeholder assessment.

4.2.4. Public Water Systems (§10723.2(c))

Public water systems in the Subbasin include the Cities of Modesto, Oakdale, Riverbank, and Waterford, as well as small community water supply systems operated by the respective community and regulated by Stanislaus County. There are approximately 77 water systems in the Subbasin that are not municipal or irrigation districts. A majority of these systems are very small. A summary of these non-municipal and non-irrigation systems is provided in **Chapter 2, Table 2-1** of the GSP.

The Cities of Modesto, Oakdale, Riverbank, and Waterford are all represented on the STRGBA Committee. Small community water systems were represented in development of the GSP by Stanislaus County.

4.2.5. Local Land Use Planning Agencies

Local land use planning agencies in the Modesto Subbasin include the planning commissions of the City of Modesto, City of Oakdale, City of Riverbank, City of Waterford, Stanislaus County, and Tuolumne County, as well the Stanislaus County and Tuolumne County Local Agency Formation Commissions. These agencies are represented on the Committee by their respective STRGBA GSA representative.

4.2.6. Environmental Users of Groundwater

The GSAs used the California Department of Water Resources' (DWR) Natural Communities Commonly Associated with Groundwater as a starting point to identify groundwater dependent ecosystems within the Modesto Subbasin. The mapping shows wetlands and vegetation along the three major rivers (Stanislaus, Tuolumne, and San Joaquin Rivers), along Dry Creek and areas between Dry Creek and the Tuolumne River, and within the San Joaquin River Natural Wildlife Refuge.

Environmental users of groundwater were invited to participate in monthly Committee and TAC meetings as well as public workshops. A representative from the Tuolumne River Trust also participated in the stakeholder assessment.

4.2.7. Surface Water Users (§10723.2(f))

The Tuolumne and Stanislaus Rivers provide the primary sources of water in the Modesto Subbasin. Surface water is used for agricultural, municipal, industrial, and environmental purposes. MID delivers surface water from the Tuolumne River for agricultural irrigation. MID also treats and delivers surface water from the Tuolumne River to the City of Modesto for municipal and industrial use. OID diverts water from the Stanislaus River to municipal and agricultural customers. Other surface water users include individual landowners with riparian water rights.

Surface water users are represented on the Committee and TAC by MID and OID. The STRGBA GSA also coordinated with GSAs in the Turlock Subbasin regarding management of flows in the Tuolumne River. In addition, Stanislaus County represents surface water users in non-district areas.

4.2.8. Federal Government (§10723.2(g))

Federal government agencies in the Modesto Subbasin include the U.S. Fish and Wildlife Service, which runs the San Joaquin River National Wildlife Refuge. The Local Redevelopment Authority oversees the transfers, reuse, and redevelopment of the former Riverbank Army Ammunition Plant, which was previously owned by the U.S. Army. Federal agencies were invited to participate in monthly Committee and TAC meetings and public workshops.

4.2.9. California Native American Tribes (§10723.2(h))

No tribal lands are documented in the DWR Water Management Planning Tool or are known to exist in the Modesto Subbasin.

4.2.10. Disadvantaged Communities (§10723.2(i))

Data published by the U.S. Census Bureau in 2018 show six Census Designated Places within the Modesto Subbasin that meet the annual Median Household Income (MHI) criteria to be considered a disadvantaged community or severely disadvantaged community by the State: Airport, Empire, Oakdale, Rouse, Waterford, and West Modesto. These communities are identified in **Figure 4-1**. The MHI for each is identified in **Table 4-2**.

Figure 4-1: Disadvantaged and Severely Disadvantaged Communities

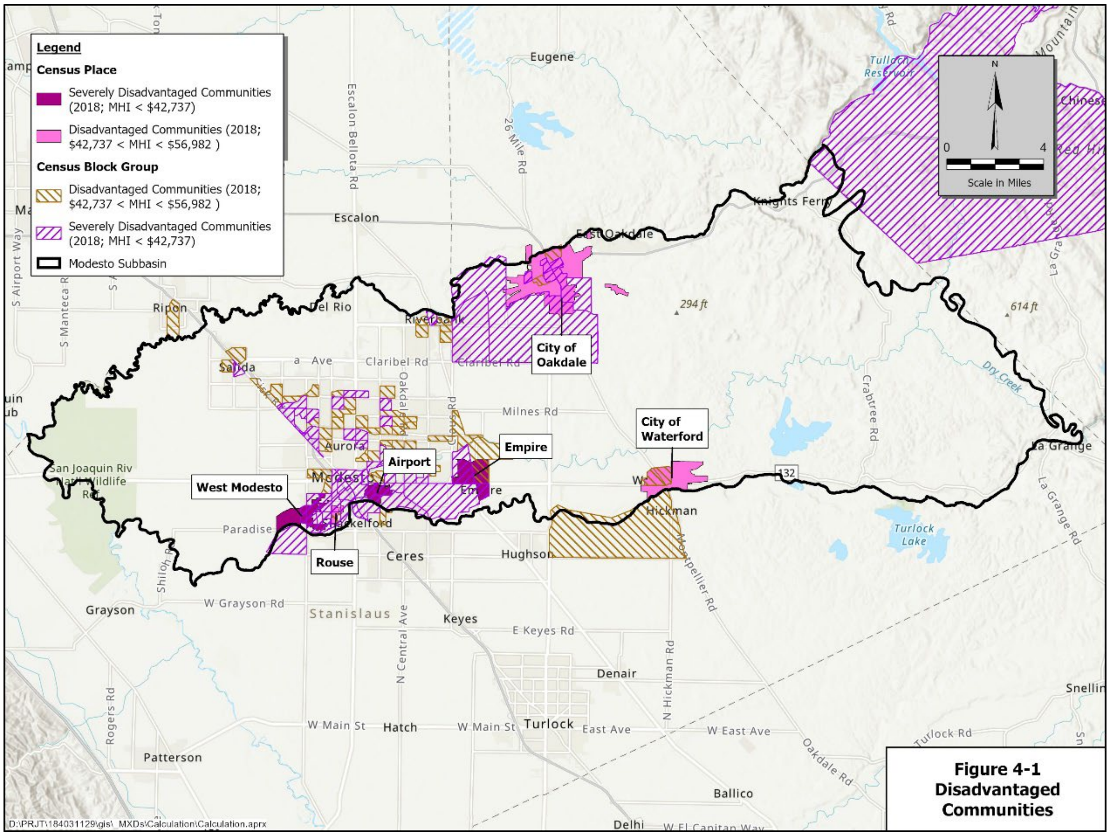

Table 4-2: Census-Designated Places Designated as Disadvantaged

Census-Designated Place	*Median Household Income[1]*	Population[2]
Airport	$28,352	1,389
City of Oakdale	$54,443	23,181
City of Waterford	$54,886	9,120
Empire	$36,774	4,202
Rouse	$46,300	1,913
West Modesto	$33,920	5,965

Notes;
[1] Median Household Income is based on 2014–2018 American Community Survey 5-Year Estimates
[2] Population is based on U.S. Census Bureau 2020 Decennial Census data

These communities are represented on the Committee and TAC by the City of Modesto, City of Oakdale, City of Waterford, and Stanislaus County. Water users in these communities were notified about development of the GSP through bilingual (English-Spanish) water bill inserts; notices and information distributed through the STRGBA GSA member agencies' existing communication platforms (e.g., websites, social media accounts, newsletters); and presentations provided at community advisory councils and other organizations.

The STRGBA GSA distributed a bilingual electronic survey in Spring and Summer 2019 to assess stakeholders' understanding and perspectives on key SGMA topics and gather input on preferred outreach strategies. The survey was promoted via utility bill inserts, postings on the STRGBA GSA and GSA member agencies' websites and social media pages, and a notice in the Stanislaus County Farm Bureau's Farm News. The survey went out to all water service customers, which included the communities of West Modesto, Rouse, Airport, Empire, and the City of Modesto. The survey results were posted on the STRGBA GSA website and used to develop the Modesto Subbasin Communication and Engagement Plan.

City of Modesto staff, on behalf of the STRGBA GSA, also attended various community meetings to discuss proposed locations for new groundwater monitoring wells and inform community members about development of the GSP. This included presentations at the Airport Neighborhood Collaborative, West Modesto Community Collaborative, and Empire Municipal Advisory Council in August and September 2019. In addition, informational materials were distributed through Stanislaus County Municipal Advisory Councils. Groundwater users in communities designated as disadvantaged also had the opportunity to participate in development of the GSP through monthly Committee and TAC meetings and public workshops.

4.2.11. Groundwater Elevation Monitoring and Reporting Entities (§10723.2(j))

STRGBA serves as the CASGEM Monitoring Entity for the Modesto Subbasin. Each municipality also monitors groundwater quality for its supply wells in compliance with state requirements.

4.3. PUBLIC ENGAGEMENT

The GSAs utilized a variety of tools and activities to encourage the active involvement of diverse social, cultural, and economic elements of the population within the Modesto Subbasin. These activities were guided by the Modesto Subbasin Communication and Engagement Plan, which is provided in **Appendix E**. The activities identified in the Communication and Engagement Plan were adapted in accordance with state and local social distancing requirements resulting from the COVID-19 pandemic.

To support execution of the activities identified in the plan and ensure a collaborative and inclusive GSP development process, the GSAs utilized DWR's Facilitation Support Services. Facilitation and outreach support was provided by Stantec Consulting Services Inc (Stantec).

4.3.1. Outreach Tools

The GSAs used several tools to support communication and engagement activities with stakeholders in the Modesto Subbasin. These tools include the following:

- **Project Website**: The STRGBA GSA member agencies have updated the STRGBA website (www.strgba.org) to provide information about SGMA and house GSA meeting and outreach materials. The Tuolumne GSA has added a SGMA-related page (https://www.tuolumnecounty.ca.gov/1292/Sustainable-Groundwater-Management-Act-S) to the Tuolumne County website.
- **Interested Parties Database**: Pursuant to the requirements of SGMA, the GSAs developed and maintain an Interested Party Database. The Database is used to notify stakeholders of pending meetings and workshops, opportunities for public comment, and notices of other GSA outreach actions.
- **Newsletter**: The STRGBA GSA distributes a semi-annual electronic newsletter to keep interested parties informed about progress in developing the GSP, opportunities for public engagement, and groundwater management issues or news of regional importance. Newsletters were distributed to the Interested Parties Database in Spring 2020, Fall 2020, and Spring 2021. Copies of the newsletter were also posted on the Subbasin website.
- **Informational Materials:** The Modesto Subbasin GSAs developed a suite of materials to inform beneficial users and interested parties about SGMA and topics pertaining to the GSP. This included fact sheets, frequently asked questions, presentation slides, and utility bill inserts. Many of these materials were translated into Spanish. To ensure consistent messaging across the basin, the GSAs also developed template presentation slides at different stages of GSP development to support presentations to member agency briefings and presentations to local industry and community groups.
- **Postcard:** The STRGBA GSA distributed an informational postcard to over 350 landowners in the non-districted area of the eastern portion of the Subbasin in September 2020 informing them about development of the GSP and inviting them to participate in the plan development process.

4.3.2. Outreach Activities

The GSAs conducted a variety of outreach activities to provide opportunities for beneficial users and other interested parties to stay informed and engaged in the development of the GSP. These activities were informed by the results of an electronic survey distributed by the

STRGBA GSA and stakeholder assessment conducted by Stantec staff in Spring 2019. Outreach activities included public STRGBA GSA and TAC meetings, GSP development workshops and office hours, member agency briefings, and presentations to organizations representing beneficial users of groundwater. Each of these activities is described in the Modesto Subbasin Communication and Engagement Plan, provided in **Appendix E**.

The GSAs utilized partnerships with trusted messengers in the Modesto Subbasin to broaden the dissemination of SGMA information and connect with hard-to-reach stakeholder groups. This included disseminating information through the Stanislaus County Farm Bureau, Manufacturers Council of the Central Valley, Empire Municipal Advisory Council, and local neighborhood collaboratives and community organizations. In addition, the STRGBA GSA conducted extensive public outreach to the communities of West Modesto, Rouse, Empire, Airport, and the City of Modesto regarding the locations and installation of new groundwater monitoring wells.

4.4. LIST OF PUBLIC MEETINGS

To consult beneficial users in development of the GSP and make decisions in a transparent and inclusive setting, the GSAs coordinated monthly public meetings, annual public workshops, and regular GSP office hours. In addition, the GSAs representatives provided presentations on the GSP at public meetings of their governing bodies and parties representing beneficial users. **Table 4-3** provides a list of the public meetings where the GSP was discussed or considered by the GSAs. A description of the committee meetings and public workshops is provided below.

Table 4-3: List of Public Meetings at Which the Groundwater Sustainability Plan Was Discussed

Type of Meeting	Format	Date(s)	
Community Presentations	Manufacturer's Council of Central Valley Meeting	04/18/2018	
	Airport Neighborhood Collaborative Meeting	09/09/2019	
	West Modesto Community Collaborative Meeting	09/11/2019	
	Empire Municipal Advisory Council Meeting	08/28/2019	
	Manufacturer's Council of Central Valley Meeting	07/15/2020	
	Modesto Chamber of Commerce, Government Relations Committee Meeting	11/20/2020	
	Mid San Joaquin RFMP Stakeholder Meeting	07/29/2021	
	Modesto Rotary	08/04/2021	
	Soroptimist International of Modesto	09/23/2021	
	Modesto Chamber of Commerce, Government Relations Committee Meeting	10/15/2021	
Public Workshop/ Groundwater Sustainability Plan Office Hours	Virtual	06/01/2020	
		03/25/2021	
		05/28/2021	
		08/25/2021	
Stanislaus and Tuolumne Rivers Groundwater Basin Association Groundwater Sustainability Agency Committee Meeting	In-Person and Virtual	01/18/2018	01/08/2020
		02/14/2018	02/12/2020
		05/09/2018	03/11/2020
		06/13/2018	04/08/2020
		07/11/2018	05/13/2020

Table 4-3: List of Public Meetings at Which the Groundwater Sustainability Plan Was Discussed (contd.)

Type of Meeting	Format	Date(s)	
Stanislaus and Tuolumne Rivers Groundwater Basin Association Groundwater Sustainability Agency Committee Meeting (contd.)	In-Person and Virtual (contd.)	08/08/2018	06/10/2020
		09/12/2018	07/08/2020
		10/10/2018	08/12/2020
		01/09/2019	09/09/2020
		02/13/2019	10/14/2020
		03/13/2019	12/09/2020
		04/10/2019	03/10/2021
		05/08/2019	04/14/2021
		06/12/2019	05/12/2021
		07/10/2019	06/09/2021
		08/14/2019	07/14/2021
		09/11/2019	08/11/2021
		10/09/2019	09/08/2021
		11/13/2019	10/13/2021
		12/11/2019	11/10/2021
			12/08/2021
Stanislaus and Tuolumne Rivers Groundwater Basin Association Groundwater Sustainability Agency Technical Advisory Committee Meeting	In-Person and Virtual	04/10/2019	01/13/2021
		07/10/2019	02/10/2021
		08/14/2019	06/23/2021
		11/13/2019	07/28/2021
		12/11/2019	08/11/2021
		05/13/2020	09/08/2021
		08/12/2020	09/22/2021
		10/27/2020	10/13/2021
		12/9/2020	11/20/2021

4.4.1. STRGBA Committee and Technical Advisory Committee Meetings

Monthly STRGBA GSA Committee and TAC meetings served as key opportunities for beneficial users and interested parties to track the process and consult in development of the GSP. Both meetings are held and noticed in accordance with the Brown Act and are open for members of the public to listen and provide comments. Comments on items on the agenda may be provided after STRGBA GSA discussion on the item. There is also time set aside for members of the public to provide comment on items not on the agenda. Public comments are recorded in the meeting minutes, which are posted on the STRGBA GSA website. Comments were recorded and considered by the planning team when developing and revising the GSP chapters.

The meetings were initially held in-person at MID's office at 1231 11th Street, Modesto, CA 95354 and by teleconferencing. In April 2020, the meetings were shifted to a virtual platform due to social distancing requirements and temporary changes in Brown Act requirements resulting from the COVID-19 pandemic. Members of the public were able to provide comment at the meetings via calling into the meeting or submitting comments in the virtual meeting platforms.

The GSAs noticed the meetings via a posting on the STRGBA GSA website and email distributed to the Interested Parties Database. A notice was also posted at the MID office for in-person meetings. Meeting agendas and materials were distributed to the Interested Parties Database and posted on the STRGBA GSA website prior to each meeting.

4.4.2. Public Workshops and GSP Office Hours

The GSAs held a public workshop and several Office Hours to inform beneficial users and interested parties about the GSP development process and collect input on topics central to the development of the GSP and groundwater management practices. The GSAs hosted a public workshop in June 2020 focused on SGMA and GSP development process.

The GSAs also hosted three Office Hours in March 2021, May 2021, and August 2021. The workshop topics included the draft sustainable management criteria, groundwater monitoring network, and management areas. The Office Hours are less formal than regular workshops and provide members of the public an opportunity to have a dialogue with STRGBA GSA representatives outside of the monthly meetings.

All workshops and Office Hours scheduled after April 2020 were held virtually due to local and state social distancing requirements resulting from the COVID-19 pandemic. Questions and comments submitted by members of the public was recorded by the planning and outreach staff. A summary of feedback provided by workshop participants was provided at GSP Coordination Committee and Technical Committee meetings and recorded in the workshop summaries, provided in **Appendix E**. Recordings of the May and August 2021 Office Hours were also made available on the STRGBA GSA website.

The GSAs noticed the workshops and GSP Office Hours via a bilingual (English-Spanish) flyer which was posted on the STRGBA GSA and member agencies' websites and member agencies' social media sites and was distributed to the Interested Parties Database.

4.4.3. Other Public Meetings

In addition to monthly public meetings and annual workshops, the STRGBA GSA member agency representatives also discussed the GSP at public meetings of the respective governing bodies and local community and civic organizations. **Table 4-3** provides a list of other public meetings during which the GSP was discussed or considered.

4.5. GSP COMMENTS AND RESPONSES

This section describes the process the GSAs used to solicit and respond to comments on the draft GSP. The draft GSP chapters were released for public review and comment as they were developed. Public comments were collected via email. In addition, interested parties could provide verbal comments during monthly Committee and TAC meetings and public workshops. Comments that raised substantive technical or policy issues resulted in revisions to the Draft GSP and are reflected in the draft plan.

4.5.1. Public Comment Process

The GSAs used a serial public comment process to provide beneficial users and members of the public multiple opportunities to review and provide comment on the draft GSP. Draft GSP chapters were released for public review and comment as they were completed. Members of the public were notified of the public comment period through an email distributed to the Interested Parties Database.

Comments were collected via an email to the STRGBA GSA and verbally during monthly Committee and TAC meetings. Comments provided at public meetings and workshops were recorded in the meeting minutes or workshop summary and reviewed by STRGBA GSA member agency staff. Copies of comments received on the draft GSP chapters were posted on the STRGBA GSA website.

At the close of each GSP chapter public comment period, comments received were reviewed by the STRGBA GSA member agency staff and summarized and discussed at monthly Committee and TAC meetings. Comments that raised credible technical or policy issues resulted in revisions to the draft GSP.

Pursuant to the requirements of California Water Code Section 10728.4, the GSAs also distributed a notice of intent to adopt the GSP to cities and counties within the GSP area. The notice was jointly distributed on August 10, 2021. A copy of the notice is provided in **Appendix E**.

4.6. PUBLIC INVOLVEMENT DURING GSP IMPLEMENTATION

The GSAs will keep members of the public and interested parties informed about progress implementing the GSP through emails to the Interested Parties Database, regularly scheduled public meetings, and annual workshops. The GSAs will continue to maintain the website and Interested Parties Database. Emails will be distributed to the Interested Parties Database on a regular basis to inform interested parties about upcoming meetings and public workshops, GSP implementation milestones, and the status of projects and management actions. The website will be updated on an as-needed basis to include information on and announcements pertaining to GSP implementation. The website will also serve as a repository for copies of the Modesto Subbasin Annual Reports and other materials developed during GSP implementation.

It is anticipated at that the STRGBA GSA will continue to meet on a monthly basis. Committee meetings will be noticed on the STRGBA GSA website and via an email to the Interested Parties Database. The GSAs will also hold public workshops as needed to keep members of the public and interested parties informed about progress implementing the GSP. The GSAs will notice the workshops via posting on the website, e-blast, and targeted outreach to organizations and agencies representing beneficial users in the Subbasin. The GSAs and GSA member agencies will also continue to conduct presentations to key stakeholder organizations on an as-needed basis to inform the about implementation of the GSP and groundwater conditions.

Additional public outreach activities may be conducted to support planning, design, and construction activities related to the groundwater management projects. Such activities will be noticed on the website and via an e-blast to the Interested Parties Database.

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5. WATER BUDGETS

Water budgets are a critical component of understanding and evaluating a groundwater basin's sustainability. This chapter discusses the:

- General background on water budgets, the basis of the selected water budgets (historical, current conditions, projected conditions), and their components
- Average annual Subbasin- and area[8]-wide stream, land and water use, and groundwater budgets summarized in tabular format
- Results and insights from the water budget for the historical, current conditions, and projected conditions budgets with supporting figures
- Projected water budget under climate change conditions, including climate change methodology and resulting impacts on the Subbasin
- Sustainable yield assumptions and resulting water budgets

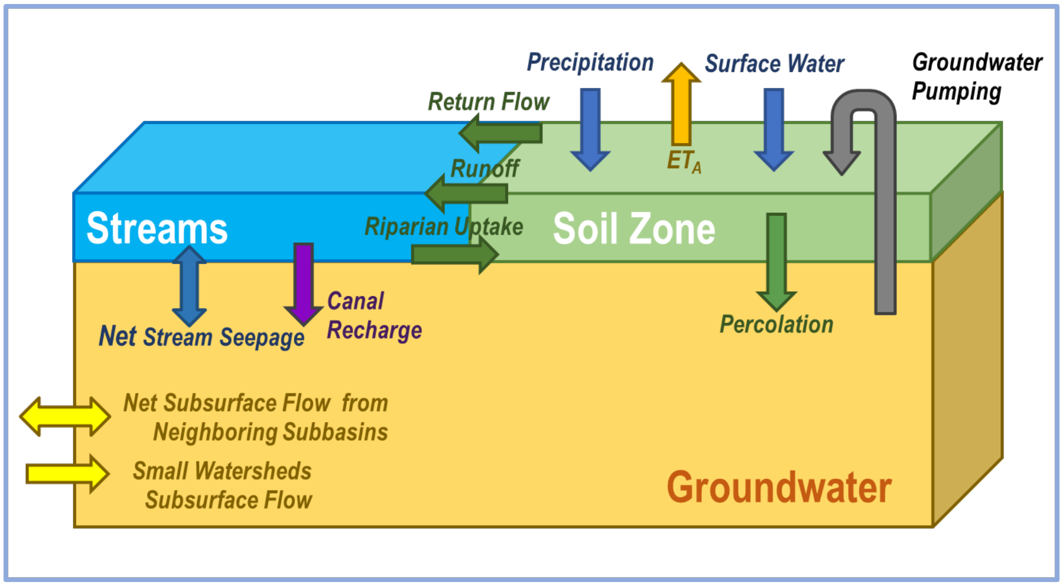
5.1. WATER BUDGET INFORMATION

Comprehensive hydrologic water budgets were developed to provide a quantitative understanding of water entering (inflows) and leaving (outflows) the Modesto Subbasin and are a requirement of the GSP regulations. Water budgets are provided for the three interconnected systems that define the overall hydrologic balance in the Modesto Subbasin - the land surface system, the stream and river system, and the groundwater system. Water entering and leaving each one of the physical systems, and water movement among the systems are a combination of natural processes and anthropogenic conditions. **Figure 5-1** highlights the main water budget components and interconnectivity of stream, surface, and groundwater components used in this analysis.

The values presented in the water budget provide hydrologic information on the historical, current, and projected conditions of the Modesto Subbasin relating to water demand, water supply, land use, population, climate change, groundwater and surface water interaction, and subsurface groundwater flow. An understanding of these impacts can assist in management of the Subbasin by identifying the scale of different water uses, highlighting potential risks presented by each condition, and identifying potential opportunities to improve water supply conditions and use of resources.

[8] The term "area" herein represents the four main subdivisions of the Modesto Subbasin discussed in this report – Modesto Irrigation District, Oakdale Irrigation District, Non-District East, and Non-District West. The establishment of these zones as Management Areas is discussed in **Section 6.2**.

Figure 5-1: Generalized Water Budget Diagram



The water budgets presented below reflect the interconnected movement of water through the land surface system (the soil zone), the stream system, and the groundwater system. Together, these systems and their interactions comprise the integrated water resources system which represents the comprehensive water cycle for the Subbasin. This comprehensive water budget is consistent with SGMA, GSP regulations, best management practices (BMPs), and recommendations in the Handbook for Water Budget Development published by the DWR (2020).

Water budgets can also be developed at different temporal scales. Daily water budgets can be used to demonstrate diurnal variation in the temperature and water use for agriculture and/or stream flows to assess implications on the fisheries and wildlife. Monthly water budgets are typically used to demonstrate variability in agricultural water demand during the irrigation season, or monthly and seasonal variability in surface water supply and/or groundwater pumping. The water budget for the Modesto Subbasin were developed on monthly intervals, though are presented on an annual basis in this report for presentation purposes and to facilitate their incorporation into policy decisions.

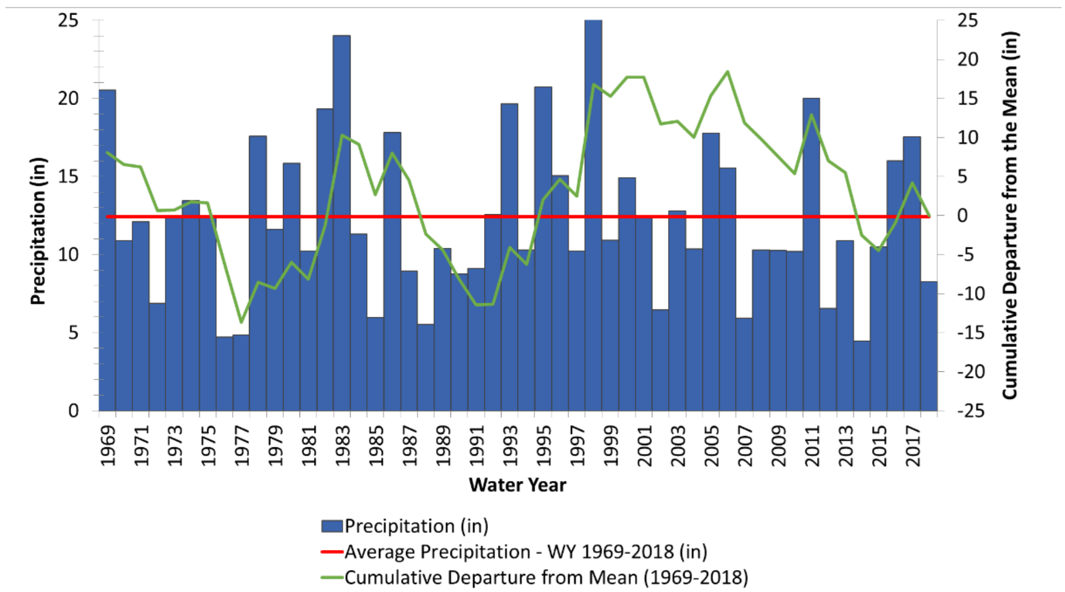
GSP regulations require that three sets of annual water budgets be developed, each reflecting the hydrology under historical, current, and projected levels of urban and agricultural development. Water budgets are developed to capture long-term conditions, which are assessed by averaging hydrologic conditions over several different timeframes. The historical water budgets reflect the average hydrology over a 25-year period (1991-2015), while current conditions are represented by a recent average year from the historical period (2010), and projected conditions are represented by the average of a 50-year hydrologic period. This provides opportunities to incorporate dry years and drought conditions, wet periods, and normal periods. By incorporating these varied conditions into the water budgets, the system can be analyzed in the short- and long-terms, allowing for assessment of the system response to certain hydrologic conditions (e.g., drought) and for assessment of broader system averages. The following subsection provides additional detail on identification of hydrologic periods.

5.1.1. Identification of Hydrologic Periods

Hydrologic periods were selected to meet the needs of developing historical, current, and projected water budgets. The GSP regulations require that the projected conditions are assessed over a 50-year hydrologic period to represent long-term hydrologic conditions. Precipitation data for the Modesto Subbasin were used to identify hydrologic periods that are representative of wet and dry periods and long-term average conditions needed for water budget analyses.

Rainfall data for the Subbasin is derived from the detailed database provided by the Precipitation-Elevation Regressions on Independent Slopes Model (PRISM) dataset. This data set is commonly used by DWR and other organizations for mapping the spatial and temporal distribution of precipitation throughout the state. DWR uses PRISM for the California Simulation of Evapotranspiration of Applied Water (CALSIMETAW) model, which is a major source of estimates of ET of applied water (ETAW) throughout the state. Periods with a balance of wet and dry intervals were identified by evaluating the cumulative departure from mean precipitation. **Figure 5-2** shows the annual precipitation and cumulative departure from the mean for the Modesto Subbasin. While the annual rainfall and precipitation data provides information on annual variability of rainfall over the course of the planning period, the cumulative departure from mean is indicative of long-term trends in Subbasin precipitation. In this context, the rising limbs of the cumulative departure line indicate short-term and long-term wet periods (e.g., 1978-83 and 1992-98), while falling limbs indicate short and long dry periods (e.g., 1976-77 and 2011-15). For the Modesto Subbasin water budget analysis, rainfall and water supply and demand conditions are available for the period October 1968 to September 2018 (WY 1969-2018), with an average annual rainfall of 12.4 inches. For the historical water budget analysis, the period WY 1991-2015 (average annual precipitation of 12.6 inches) is used, which coincides with the period for which the C2VSimTM model is calibrated, and for which the historical water demand and supplies have been confirmed. These periods of record meet the GSP regulatory requirement of at least 10 years for the historical water budget analysis. For the projected water budget purposes, the full period of WY 1969-2018 is used, which provides a 50-year record as required by GSP regulations.

Figure 5-2: 50-Year Historical Precipitation and Cumulative Departure from Mean Precipitation, Modesto Subbasin, California



5.1.2. Usage of C2VSimTM and Associated Data in Water Budget Development

Water budgets were developed utilizing C2VSimTM, a fully integrated surface and groundwater flow model covering the entire Central Valley. This version of C2VSim is based on the C2VSimFG-BETA2 model released by DWR. To support the GSP, C2VSimTM was developed and refined with a focus on land and water use operational data for both the Modesto and Turlock Subbasins. C2VSimTM, a quasi-three-dimensional finite element model, was developed using the Integrated Water Flow Model (IWFM) 2015 software package to simulate the relevant hydrologic processes prevailing in the model domain. The C2VSimTM integrates the groundwater aquifer with the surface hydrologic system and land surface processes and operations. Using data from federal, state, and local resources, the C2VSimTM was calibrated for the hydrologic period of October 1991 to September 2015 by comparing simulated evapotranspiration, groundwater levels, and streamflow records with historical observed records. Development of the model involved the study and analyses of hydrogeologic conditions, agricultural and urban water demands, agricultural and urban water supplies, and an evaluation of regional water quality conditions. Additional information on the data used to develop C2VSimTM is included in **Appendix C**.

All integrated hydrologic models contain assumptions and some level of uncertainty. They are decision support tools used to better understand complex interactive systems. Sources of model uncertainty include heterogeneity in hydrogeologic properties and stratigraphy, quality of historical data, projections of future land use, hydrology, operational data, and climatic conditions.

C2VSimTM has been calibrated and validated. The data and assumptions for Modesto and Turlock Subbasins were developed in a collaborative manner with the respective districts and are based on best available data and science. Projections of future land use and water demands were based on the most recent planning documents prepared by agencies in the Subbasin. In its current form, the model represents the best available data for the Subbasin. As additional information is collected during GSP implementation, the model will be updated to reflect the newly available resources. Efforts to address Subbasin data gaps will improve information available for the model.

With the C2VSimTM as the underlying framework, model simulations were developed to allow for the estimation of water budgets. Four model simulations were used to develop the water budgets for historical, current, projected, and climate change conditions, which are discussed in detail below:

The **historical water budget** is based on a simulation of historical conditions in the Modesto Subbasin (1991-2015).

The **current water budget** is based on an average year (2010) of the historical simulation that incorporates current irrigation and operational practices.

The **projected water budget** is based on a simulation of future land and water use over the historical hydrologic conditions.

The **climate change water budget** is based on the projected water budget under 2070 climate conditions and is discussed in **Section 5.2**.

The **sustainable yield water budget** is based on the projected water budget refined to meet SGMA sustainability criteria and is discussed in **Section 5.3**

5.1.3. Water Budget Definitions and Assumptions

Definitions and assumptions for the historical, current, and projected water budgets are provided below. These assumptions are summarized in **Table 5-1**.

5.1.3.1. Historical Water Budget

The historical water budget is intended to evaluate availability and reliability of past surface water supply deliveries, aquifer response to water supply, and demand trends relative to WY type. The historical calibration of the C2VSimTM reflects the historical conditions in the Modesto Subbasin through the 2015 water year. The hydrologic period of WY 1991 through 2015 is selected for the GSP historical water budget because it provides a period of representative hydrology while capturing recent operations within the Subbasin. The period WY 1991 through 2015 has an average annual precipitation of approximately 12.6 inches, slightly higher than the long-term average of 12.4 inches observed for the 50-year projected hydrologic period of WY 1969-2018. Both periods include the recent WY 2012-2015 drought, the wetter years of WY 1998 and 2010-2011, and periods of normal precipitation.

5.1.3.2. Current Water Budget

The current conditions water budget uses recent historical conditions. The 2010 water year was selected to represent current conditions because it was the last normal water year before the 2012-2015 drought. It represents the current level of development within the Subbasin and reflects current agricultural irrigation practices, land use patterns, surface water operations, and urban water usage under non-drought conditions.

5.1.3.3. Projected Water Budget

The projected water budget is intended to assess the hydrologic systems of the Subbasin under the projected agricultural and urban demand, water supply, and operational conditions over the next 50-years. The Projected Conditions Baseline scenario applies projected future land and water use conditions to the 50-year hydrologic period of WY 1969-2018. The Projected Condition Baseline assumes urban population and land use expansion based on each municipality's 2015 Urban Water Management Plan. Under projected conditions, agricultural land is held constant at 2015 cropping patters except where urban expansion pulls acreage out of production. Furthermore, under projected conditions, the consumptive use factor (CUF), or the ratio of evapotranspiration per unit of applied water, was increased relative to the historical to simulate modernization of irrigation management and technologies within the Subbasin.

The Projected Conditions Baseline includes the following conditions:

- Hydrologic period:
    - WY 1969-2018 (50-year hydrology)
- River flow is based on:
    - Tuolumne River: Tuolumne River System (TRS) operations model
    - Stanislaus River: Average monthly values by water year type
    - San Joaquin River: CalSim II baseline operations
- Land use is based on:
    - 2015 agricultural land use and cropping patterns held constant
    - Urban land use expansion based on 2015 UWMP
- Agricultural water demand is based on:
    - IWFM estimates based on current land use and refined CUF
- Surface water deliveries are based on data from:
    - Modesto ID – Tuolumne River System (TRS) operations model
    - Oakdale ID – Historical monthly average by water year type
    - Subbasin Riparian Users – Historical monthly average by water year type
- Urban water demand is based on:

- 2015 Urban Water Management Plans (UWMPs)
- Continuation of historical population trends, while meeting 2020 State of California GPCD goals.

- Urban water supply is based on:
  - Expanded surface water deliveries from MID to the City of Modesto
  - Projected urban groundwater production based on 2015 UWMPs distributed to existing wells

Table 5-1: Summary of Groundwater Budget Assumptions

Water Budget Type	Historical	Current	Projected
Tool	C2VSimTM	C2VSimTM	C2VSimTM
Scenario	Historical Simulation	Current Conditions Baseline	Projected Conditions Baseline
Hydrologic Years	WY 1991-2015	WY 2010	WY 1969-2018
Level of Development	Historical Records	WY 2010	General Plan buildout
Agricultural Demand	Historical Records	WY 2010	Projected based on refined 2015 land use and modern irrigation practices
Urban Demand	Historical Records	WY 2010	Projected based on local UWMP data and historical population growth
Water Supplies	Historical Records	WY 2010	Projected based on local operations modeling and historical trends

5.1.4. Water Budget Estimates

The primary components of the stream system, presented at the Subbasin scale, are:

- Inflows:
  - Stream inflows into the Tuolumne River and Stanislaus River at the boundary of the model and San Joaquin River inflows at upstream of the confluence of the Tuolumne and San Joaquin River (bounding the Modesto Subbasin)
  - Tributary inflows from surface water contributions from small watersheds

- Total stream gain from the groundwater system
- Surface runoff from precipitation to the stream system
- Return flow of applied water to the stream system

- Outflows:
  - San Joaquin River flow downstream of the Stanislaus River confluence
  - Surface water supplies diverted from the stream system to meet agricultural or urban demand downstream of La Grange Dam.
  - Stream seepage to the groundwater system
  - Uptake of river water from native or riparian vegetation along the stream bed

The primary components of the land surface system, presented for each water budget zone, include:

- Supplies:
  - Precipitation
  - Surface water supplies
  - Groundwater supplies
  - Uptake of river water from native or riparian vegetation along the stream bed
- Demands:
  - Evapotranspiration
  - Surface runoff of precipitation to the stream system
  - Return flow of applied water to the stream system
  - Percolation of water to the groundwater system
- Land surface system balance

The primary components of the groundwater system, presented at the Subbasin scale, are:

- Inflows:
  - Percolation of water from the land surface system
  - Groundwater gains from stream system
  - Subsurface inflow from neighboring subbasins and the foothills
- Outflows:
  - Groundwater discharge to the stream system
  - Groundwater production (pumping)
  - Subsurface outflow to neighboring subbasins

- Change in groundwater in storage - negative values represent a depletion of storage

The estimated water budgets are provided below in **Table 5-2** through **Table 5-8** for the historical, current, and projected water budgets. The land surface water budgets are presented for the entire Subbasin and for each water budget zone (Modesto Irrigation District managed zone (Modesto), Oakdale South, NDE, and Non-District West). Each of these zones represent the geographic area shown in **Figure 5-3** and include all sectors, including agricultural, industrial, municipal, and domestic water users. These zones have been used to develop *Management Areas* (as defined in the GSP regulations) based primarily on the availability of surface water sources. These Management Areas, along with the justification and rationale for each, are presented in **Section 6.2** on Sustainable Management Criteria.

Developing operational water budgets for the land surface system has allowed the GSAs to better quantify how varying anthropogenic processes have affected and will continue to affect the aquifer system. In contrast, the stream and groundwater system budgets are presented at the subbasin scale, to best target the GSA's sustainability goals and metrics.

Figure 5-3: Water Budget Zones

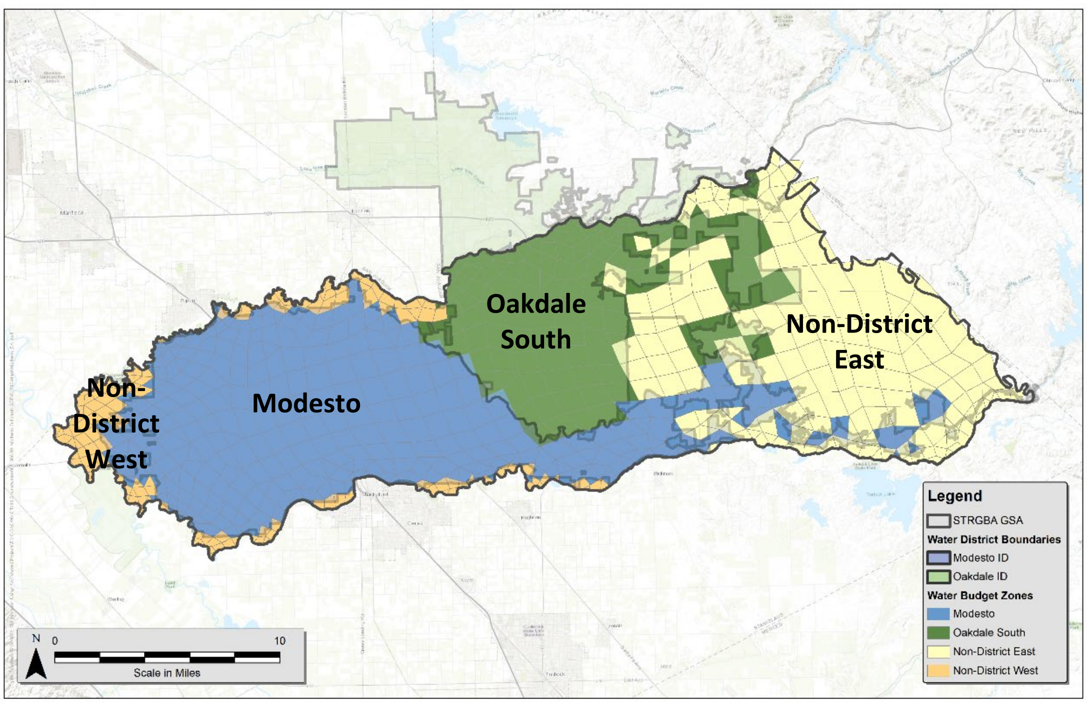


Table 5-2: Average Annual Water Budget – Stream Systems, Modesto Subbasin (AFY)

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
Stream Inflows	2,547,000	1,625,000	2,650,000
Stanislaus River	520,000	320,000	536,000
Tuolumne River	742,000	593,000	812,000
San Joaquin River	1,285,000	711,000	1,302,000
Tributary Inflow[1]	6,000	-	6,000
Stream Gain from Groundwater	207,000	167,000	104,000
Modesto Subbasin	100,000	80,000	50,000
Stanislaus River - South[2]	35,000	27,000	12,000
Tuolumne River - North	51,000	39,000	27,000
San Joaquin River - East	15,000	13,000	11,000
Other Subbasins	108,000	88,000	54,000
Stanislaus River – North	37,000	30,000	12,000
Tuolumne River - South	56,000	44,000	31,000
San Joaquin River - West	15,000	14,000	11,000
Surface Runoff to the Stream System[3]	57,000	35,000	60,000
Return Flow to Stream System[3]	104,000	97,000	113,000
Total Inflow	**2,922,000**	**1,923,000**	**2,934,000**
San Joaquin River Outflows	2,770,000	1,745,000	2,717,000
Diverted Surface Water[4]	43,000	47,000	33,000
Stream Seepage to Groundwater	74,000	95,000	146,000
Modesto Subbasin	40,000	51,000	76,000
Stanislaus River - South	19,000	20,000	36,000
Tuolumne River - North	20,000	30,000	38,000
San Joaquin River - East	1,000	-	2,000
Other Subbasins	34,000	44,000	71,000
Stanislaus River - North	13,000	14,000	31,000
Tuolumne River - South	20,000	30,000	38,000
San Joaquin River - West	1,000	-	2,000
Native & Riparian Uptake from Streams	35,000	37,000	37,000
Total Outflow	**2,922,000**	**1,923,000**	**2,934,000**

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

1 Tributary inflow includes surface water contributions from small watersheds

2 Represents the location of the Modesto Subbasin relative to the stream, i.e., "South" represents the gains/losses of that stream to the Modesto Subbasin where as "North" represents the gains/losses of that stream to the Eastern San Joaquin Subbasin.

3 Includes runoff/return flow from all subbasins adjacent to the stream system, not just the Modesto Subbasin.

4 Some surface water diversions are upstream of the Tuolumne River or Stanislaus River inflows and thus not included in this stream system (streams and canals) water budget.

Table 5-3: Average Annual Water Budget – Land Surface 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
Agricultural Areas Precipitation	147,000	122,000	139,000
Agricultural Water Supply	513,000	611,000	497,000
Agency Surface Water	264,000	250,000	241,000
Agency Groundwater	26,000	15,000	25,000
Private Groundwater	222,000	345,000	229,000
Urban Areas Precipitation	32,000	26,000	38,000
Urban Water Supply	89,000	88,000	111,000
Groundwater	63,000	56,000	60,000
Surface Water	26,000	32,000	51,000
Native Areas Precipitation	92,000	78,000	92,000
Native Uptake from Stream	20,000	20,000	22,000
Total Supplies	**892,000**	**945,000**	**900,000**
Agricultural ET	368,000	416,000	402,000
Agricultural ET of Precipitation	80,000	73,000	82,000
Agricultural ET of Surface Water	149,000	143,000	159,000
Agricultural ET of Agency Groundwater	14,000	8,000	16,000
Agricultural ET of Private Groundwater	125,000	192,000	146,000
Agricultural Percolation	246,000	236,000	201,000
Agricultural Percolation of Precipitation	57,000	39,000	45,000
Agricultural Percolation of Surface Water	99,000	83,000	75,000
Agricultural Percolation of Agency Groundwater	10,000	5,000	8,000
Agricultural Percolation of Private Groundwater	81,000	110,000	73,000
Agricultural Runoff & Return Flow	35,000	31,000	31,000
Urban Runoff & Return Flow	74,000	68,000	91,000
Urban ET	28,000	27,000	38,000
Urban Percolation	18,000	17,000	20,000
Native Runoff	12,000	5,000	12,000
Native ET	91,000	88,000	95,000
Native Percolation	8,000	3,000	7,000
Total Demands	**879,000**	**892,000**	**898,000**
Land Surface System Balance	13,000	53,000	2,000
Land Surface System Balance (% of supplies)	1.5%	5.6%	0.2%

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

Table 5-4: Average Annual Water Budget – Land Surface System, Modesto Area (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
Agricultural Areas Precipitation	73,000	58,000	65,000
Agricultural Water Supply	281,000	315,000	244,000
Agency Surface Water	125,000	121,000	106,000
Agency Groundwater	22,000	11,000	21,000
Private Groundwater	135,000	183,000	117,000
Urban Areas Precipitation	26,000	21,000	32,000
Urban Water Supply	73,000	72,000	96,000
Groundwater	47,000	40,000	45,000
Surface Water	26,000	32,000	51,000
Native Areas Precipitation	11,000	9,000	11,000
Native Uptake from Stream	5,000	5,000	5,000
Total Supplies	**468,000**	**481,000**	**453,000**
Agricultural ET	193,000	210,000	195,000
Agricultural ET of Precipitation	38,000	34,000	38,000
Agricultural ET of Surface Water	69,000	68,000	68,000
Agricultural ET of Agency Groundwater	12,000	6,000	14,000
Agricultural ET of Private Groundwater	74,000	103,000	75,000
Agricultural Percolation	136,000	137,000	97,000
Agricultural Percolation of Precipitation	29,000	21,000	21,000
Agricultural Percolation of Surface Water	48,000	44,000	33,000
Agricultural Percolation of Agency Groundwater	8,000	4,000	6,000
Agricultural Percolation of Private Groundwater	51,000	67,000	36,000
Agricultural Runoff & Return Flow	20,000	18,000	16,000
Urban Runoff & Return Flow	61,000	56,000	78,000
Urban ET	22,000	21,000	31,000
Urban Percolation	16,000	16,000	19,000
Native Runoff	1,000	-	1,000
Native ET	14,000	13,000	14,000
Native Percolation	1,000	1,000	1,000
Total Demands	**463,000**	**471,000**	**453,000**
Land Surface System Balance	6,000	10,000	1,000
Land Surface System Balance (% of supplies)	1.2%	2.1%	0.1%

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

Table 5-5: Average Annual Water Budget – Land Surface System, Oakdale South Area (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
Agricultural Areas Precipitation	46,000	40,000	45,000
Agricultural Water Supply	150,000	174,000	143,000
Agency Surface Water	120,000	109,000	121,000
Agency Groundwater	4,000	4,000	4,000
Private Groundwater	26,000	61,000	18,000
Urban Areas Precipitation	4,000	3,000	4,000
Urban Water Supply	11,000	12,000	9,000
Groundwater	11,000	12,000	9,000
Surface Water	-	-	-
Native Areas Precipitation	13,000	10,000	13,000
Native Uptake from Stream	2,000	2,000	2,000
Total Supplies	**225,000**	**241,000**	**217,000**
Agricultural ET	112,000	125,000	124,000
Agricultural ET of Precipitation	25,000	24,000	27,000
Agricultural ET of Surface Water	69,000	63,000	81,000
Agricultural ET of Agency Groundwater	2,000	2,000	3,000
Agricultural ET of Private Groundwater	15,000	36,000	12,000
Agricultural Percolation	72,000	59,000	57,000
Agricultural Percolation of Precipitation	17,000	11,000	14,000
Agricultural Percolation of Surface Water	45,000	30,000	37,000
Agricultural Percolation of Agency Groundwater	1,000	1,000	1,000
Agricultural Percolation of Private Groundwater	9,000	17,000	5,000
Agricultural Runoff & Return Flow	8,000	6,000	7,000
Urban Runoff & Return Flow	9,000	9,000	8,000
Urban ET	4,000	4,000	5,000
Urban Percolation	2,000	1,000	1,000
Native Runoff	2,000	1,000	2,000
Native ET	12,000	11,000	12,000
Native Percolation	1,000	1,000	1,000
Total Demands	**221,000**	**217,000**	**217,000**
Land Surface System Balance	4,000	24,000	-
Land Surface System Balance (% of supplies)	1.7%	9.8%	0.0%

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

Table 5-6: Average Annual Water Budget – Land Surface System, Non-District East (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
Agricultural Areas Precipitation	19,000	16,000	19,000
Agricultural Water Supply	48,000	84,000	81,000
Agency Surface Water	-	-	-
Agency Groundwater	-	-	-
Private Groundwater	48,000	84,000	81,000
Urban Areas Precipitation	-	-	-
Urban Water Supply	-	-	-
Groundwater	-	-	-
Surface Water	-	-	-
Native Areas Precipitation	65,000	57,000	65,000
Native Uptake from Stream	6,000	6,000	7,000
Total Supplies	**137,000**	**163,000**	**173,000**
Agricultural ET	37,000	54,000	60,000
Agricultural ET of Precipitation	11,000	11,000	10,000
Agricultural ET of Surface Water	-	-	-
Agricultural ET of Agency Groundwater	-	-	-
Agricultural ET of Private Groundwater	26,000	43,000	50,000
Agricultural Percolation	22,000	23,000	34,000
Agricultural Percolation of Precipitation	7,000	4,000	7,000
Agricultural Percolation of Surface Water	-	-	-
Agricultural Percolation of Agency Groundwater	-	-	-
Agricultural Percolation of Private Groundwater	16,000	19,000	27,000
Agricultural Runoff & Return Flow	5,000	5,000	6,000
Urban Runoff & Return Flow	-	-	-
Urban ET	-	-	-
Urban Percolation	-	-	-
Native Runoff	9,000	4,000	9,000
Native ET	56,000	54,000	58,000
Native Percolation	5,000	2,000	5,000
Total Demands	**134,000**	**142,000**	**171,000**
Land Surface System Balance	4,000	21,000	1,000
Land Surface System Balance (% of supplies)	2.6%	13.1%	0.8%

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

Table 5-7: Average Annual Water Budget – Land Surface System, Non-District West (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
Agricultural Areas Precipitation	10,000	8,000	10,000
Agricultural Water Supply	35,000	38,000	29,000
Agency Surface Water	19,000	20,000	15,000
Agency Groundwater	-	-	-
Private Groundwater	15,000	17,000	14,000
Urban Areas Precipitation	2,000	2,000	2,000
Urban Water Supply	5,000	4,000	6,000
Groundwater	5,000	4,000	6,000
Surface Water	-	-	-
Native Areas Precipitation	3,000	2,000	3,000
Native Uptake from Stream	7,000	7,000	8,000
Total Supplies	**61,000**	**61,000**	**57,000**
Agricultural ET	26,000	27,000	24,000
Agricultural ET of Precipitation	6,000	5,000	6,000
Agricultural ET of Surface Water	11,000	12,000	9,000
Agricultural ET of Agency Groundwater	-	-	-
Agricultural ET of Private Groundwater	9,000	10,000	9,000
Agricultural Percolation	16,000	18,000	13,000
Agricultural Percolation of Precipitation	4,000	3,000	3,000
Agricultural Percolation of Surface Water	7,000	8,000	5,000
Agricultural Percolation of Agency Groundwater	-	-	-
Agricultural Percolation of Private Groundwater	5,000	7,000	4,000
Agricultural Runoff & Return Flow	3,000	2,000	2,000
Urban Runoff & Return Flow	4,000	3,000	5,000
Urban ET	2,000	2,000	3,000
Urban Percolation	-	-	-
Native Runoff	-	-	-
Native ET	10,000	10,000	11,000
Native Percolation	-	-	-
Total Demands	**61,000**	**62,000**	**57,000**
Land Surface System Balance	-	(2,000)	-
Land Surface System Balance (% of supplies)	0.7%	-2.5%	-0.2%

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

Table 5-8: 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 in Storage	(43,000)	(125,000)	(11,000)

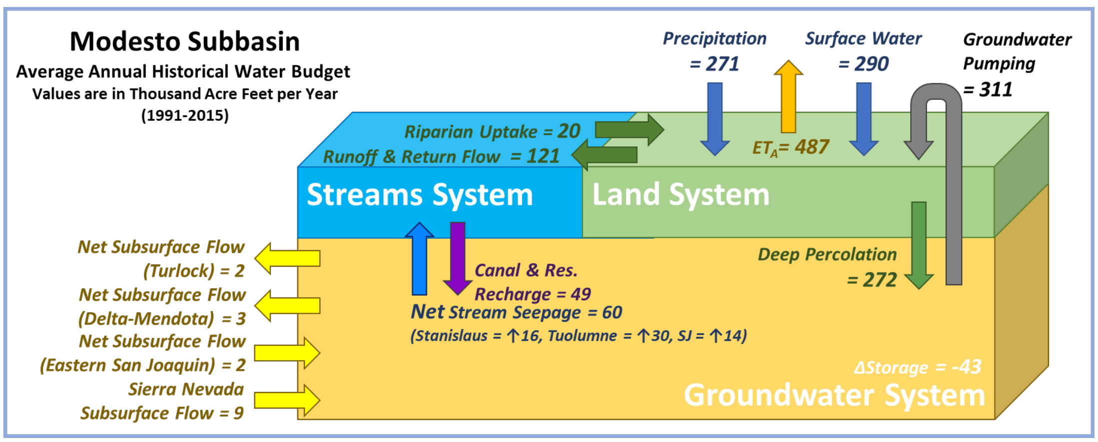
Note: sub-categories may not sum together due to rounding error

5.1.4.1. Historical Water Budget

The historical water budget is a quantitative evaluation of the historical surface and groundwater supply covering the 25-year period from WY 1991 to 2015. This period was selected as the representative hydrologic period as it reflects the most recent basin operations and has similar average precipitation compared to a longer historical period (WY 1969-2018). The goal of the water budget analysis is to characterize the water supply and demand, while summarizing the accounting of water demand and supply components and their changes within each area, and the Subbasin as a whole.

Figure 5-4 below shows the average annual water budget components for the entirety of the Modesto Subbasin and the interaction between the land surface, stream, and groundwater systems for the historical simulation.

Figure 5-4: Average Annual Historical Water Budget – Modesto Subbasin

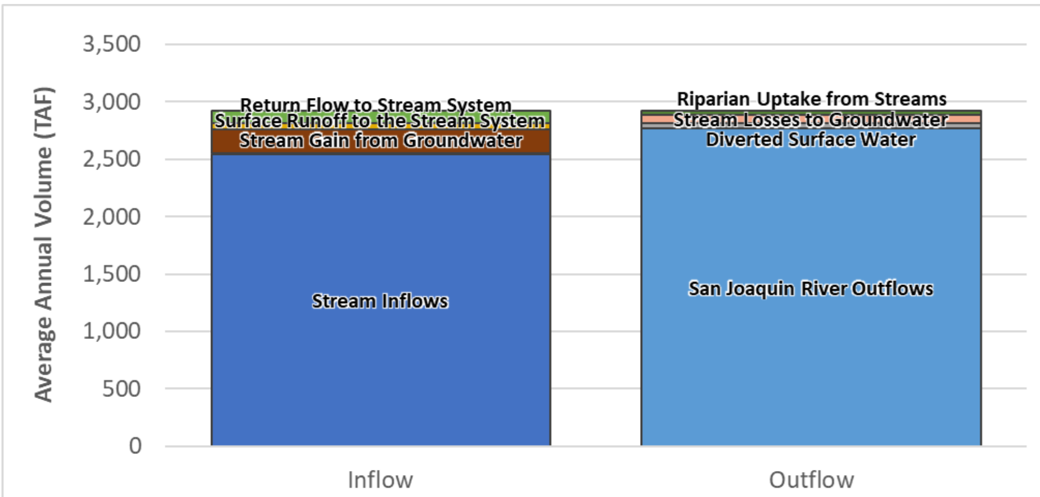


Note: sub-categories may not sum together due to rounding error

The existing stream system supplies multiple water users and agencies in the Modesto Subbasin, including Modesto ID, Oakdale ID, and riparian diverter along each of the major rivers. Analysis of the stream system accounts for potentially significant effects related to both natural interactions and managed operations of adjacent subbasins. Therefore, the water budget in **Table 5-2** above and **Figure 5-5**, shown below, provides average annual quantities of surface and canal system flows within the Modesto Subbasin, plus estimates of interactions with adjoining subbasins. Average annual surface water inflow to the streams adjacent to the Subbasin is estimated to be 2,921,000 AFY. Most of these flows enter the stream system through inflows from regulated reservoirs and river courses, with an average of 742,000 AFY from the Tuolumne, 520,000 AFY from the Stanislaus, and 1,285,000 AFY from the San Joaquin Rivers, respectively. Other stream system inflows include inflow from tributary watersheds (6,000 AFY), surface runoff from precipitation (57,000 AFY), return flow from applied water (104,000 AFY), and gain from groundwater (207,000 AFY).

Outflows from the Modesto Subbasin stream system total 2,922,000 AFY and include stream losses to the groundwater system (74,000 AFY), surface water diversions (43,000 AFY), and riparian uptake (35,000 AFY). Most outflows from the stream system are San Joaquin River flows, which discharge from the Modesto Subbasin downstream of its confluence with the Stanislaus River at an average of 2,770,000 AFY. Note that surface water diversions for Oakdale and Modesto Irrigation Districts occur from reservoirs upstream of the Subbasin boundaries and are not included in the stream-system budget.

Figure 5-5: Historical Average Annual Water Budget – Stream Systems, Modesto Subbasin



The land surface system of the Modesto Subbasin, shown in **Table 5-3** and in **Figure 5-6**, represents the demand and supplies in the Modesto Subbasin and in each zone. During the historical period, total average annual water supplies to the Modesto Subbasin is estimated at 892,000 AFY, consisting of precipitation (271,000 AFY), surface water deliveries (290,000 AFY), and groundwater supplies (312,000 AFY), as well as water uptake by riparian vegetation along the river courses (20,000 AFY). Surface water supplies are provided primarily through Modesto ID's and Oakdale ID's canal networks to growers in the districts, with some riparian surface water diversions in the Non-District West. Each of these areas supplement their surface water with some groundwater production to meet their agricultural and urban demand, whereas the NDE areas rely primarily on groundwater production for its agricultural supplies.

Average annual water demand in the Modesto Subbasin totals 879,000 AFY, and is comprised of agricultural crops, urban landscaping, and native evapotranspiration (487,000 AFY), surface runoff and return flow to the stream system (121,000 AFY), and deep percolation (272,000 AFY). **Figure 5-7** shows the annual volumes of major agricultural water demand and supply components throughout the historical water budget period. The surface water supply in this water budget is reflective of the applied water thus does not include operational return flow or canal seepage. **Figure 5-8** shows the annual supply and demand for municipal and private domestic water use in the Modesto Subbasin.

Figure 5-6: Historical Average Annual Water Budget – Land Surface System, Modesto Subbasin

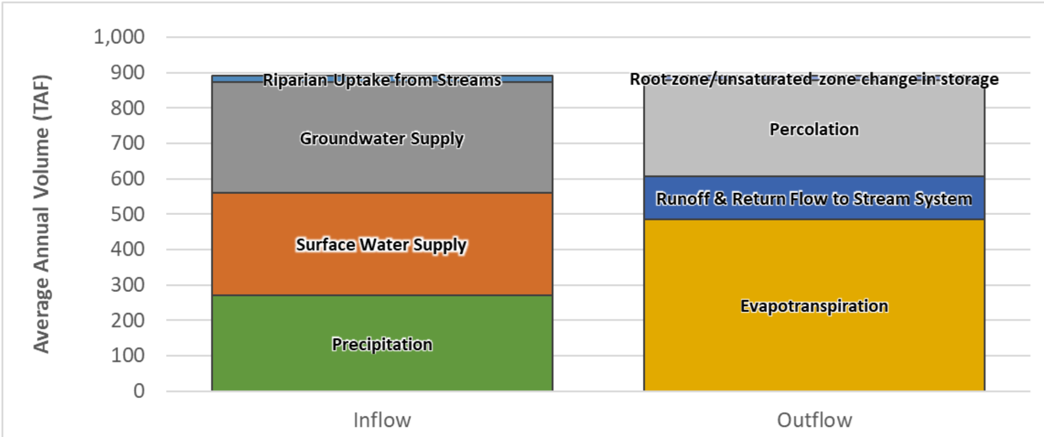


Figure 5-7: Historical Annual Water Budget – Agricultural Land Surface System, Modesto Subbasin

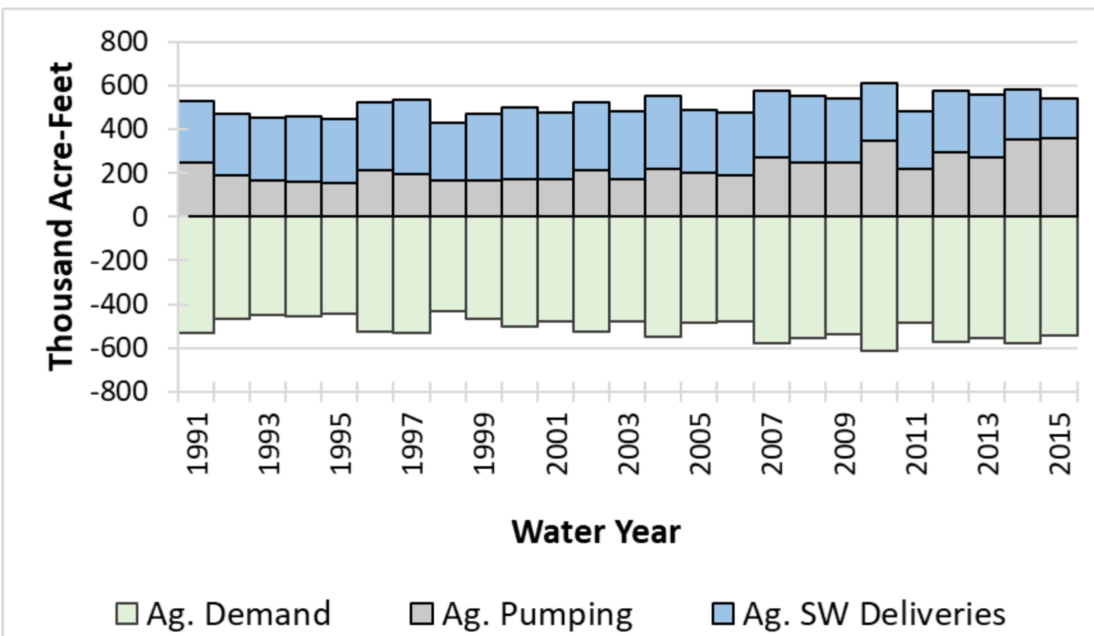


Figure 5-8: Historical Annual Water Budget – Urban Land Surface System, Modesto Subbasin

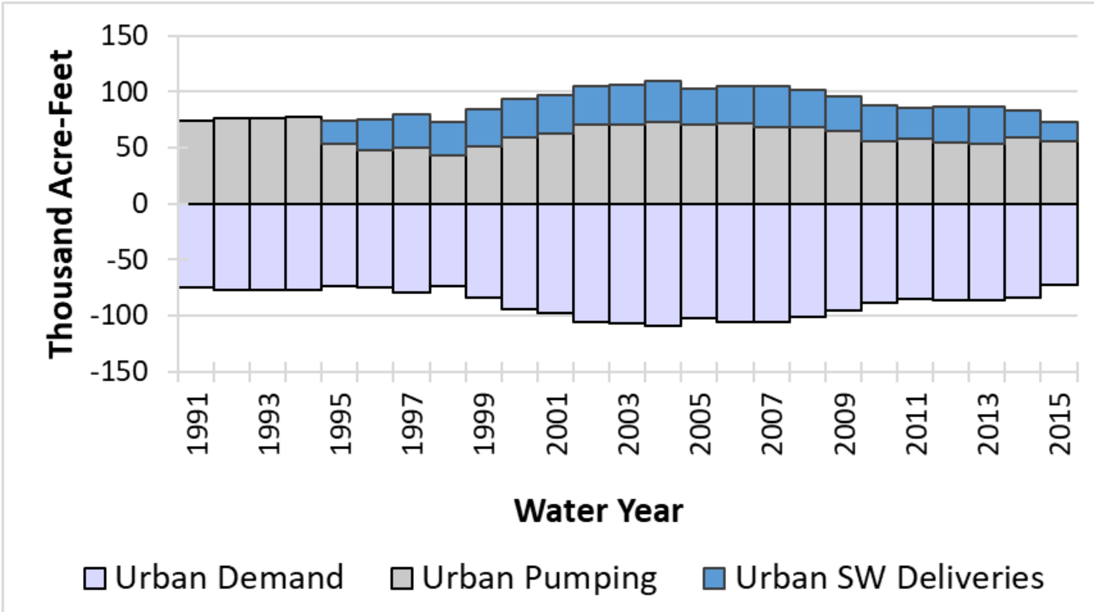


Table 5-8 highlights the major flow components of the Modesto Subbasin's groundwater system. As shown in this table, the aquifer receives approximately 440,000 AFY of inflows each year, which consist of recharge from streams (40,000 AFY), seepage from canals and reservoirs (49,000 AFY), deep percolation from precipitation and applied water (272,000 AFY), as well as subsurface inflows from the Sierra Nevada foothills and the neighboring subbasins of Eastern San Joaquin, Delta-Mendota, and Turlock (80,000 AFY combined).

Table 5-8 also shows the outflows from the Modesto Subbasin. On average, the outflows exceed the inflows in the Subbasin. The largest component of outflow from the groundwater system is groundwater pumping (311,000 AFY), followed by discharge to streams (100,000 AFY), and subsurface outflow to the neighboring subbasins (73,000 AFY).

In conjunction with the land surface budgets presented for each water budget area, a net-recharge analysis was preformed to better understand the relationship of water supply conditions and recharge to the groundwater system. This analysis is documented below, both at the Subbasin level and for each water budget area.

Figure 5-9 shows the total annual groundwater pumped from, and the subsequent recharge to the Modesto Subbasin. In this figure, groundwater pumping represents the combination of groundwater extracted for both agricultural and urban use for each year during the historical period. Recharge into the aquifer system includes both deep percolation from the land system and direct recharge from the canal and reservoir system. The deep percolation in this figure includes recharge from percolated precipitation, agricultural applied water, outdoor irrigation from municipal and rural domestic users.

Figure 5-10 shows the net-recharge in the Modesto Subbasin and is based on the annual balance from the previous figure. This figure indicates that during the historical period, the Subbasin has trended increasingly toward net extraction, but has on average experienced net recharge. This is both indicative of local hydrology and increasing demand on the aquifer system. Over the 25-year historical period, the Modesto Subbasin has seen a large increase in both urban demand and agricultural production. Over time, increases in groundwater production has further stressed the subbasin leading to more consistently negative values, or net extractions. Furthermore, through the 2012-2015 drought, the subbasin experienced a greater net-extraction from the aquifer system corresponding to reduced surface water supply, whereas in periods of wetter or normal operations, the Subbasin has historically been a net-contributor to the groundwater system.

Figure 5-11 through **Figure 5-18** show similar trends conditions for each water budget area. The Oakdale South water budget zone (**Figure 5-14**) has predominately experienced net recharge, while the NDE zone has predominately experienced net extraction (**Figure 5-16**). The Modesto water budget zone and the Non-District West zone experience more variable conditions trending in near-balance (**Figure 5-12** and **Figure 5-18**, respectively). Over the historical period, all zones have trended increasingly toward net extraction due to increased water demand from all sectors and drought conditions at the end of the period.

Overall, the Modesto Subbasin's groundwater system has experienced long term (25-year) decline in storage averaging 43,000 AFY as shown in **Figure 5-19**. This decline is more heavily weighted to the end of the study period due to increased stresses relating to both local hydrology, and water demand as shown in **Figure 20**. **Figure 20** also shows the temporal breakdown of the groundwater budget and highlights the intensifying decline of groundwater in storage in recent years, particularly under drought conditions where groundwater production has increased to a long-term high.

The historical inflows and outflows to the Modesto Subbasin change with hydrologic conditions. In wet years, precipitation and increased surface water availability reduces the need for groundwater use. However, in dry years, more groundwater is pumped to meet the demand not met by surface water or precipitation. This leads to an increase in groundwater in storage in wet years and a decrease in dry years. These trends are shown in **Table 5-9**, which provides average historical water supply and demand by water year type.

Figure 5-9: Groundwater Recharge and Extraction – Modesto Subbasin

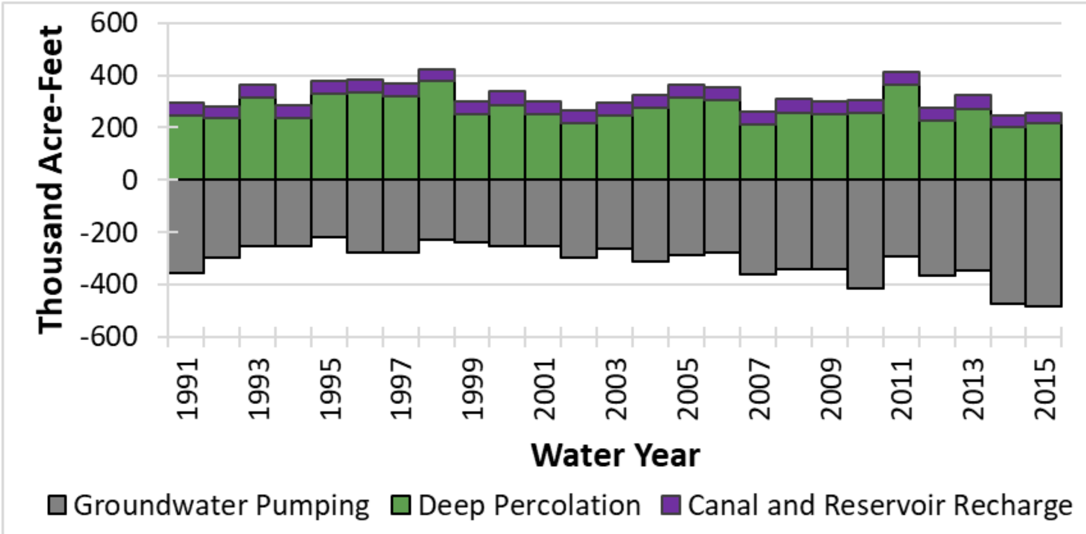


Figure 5-10: Net Recharge – Modesto Subbasin

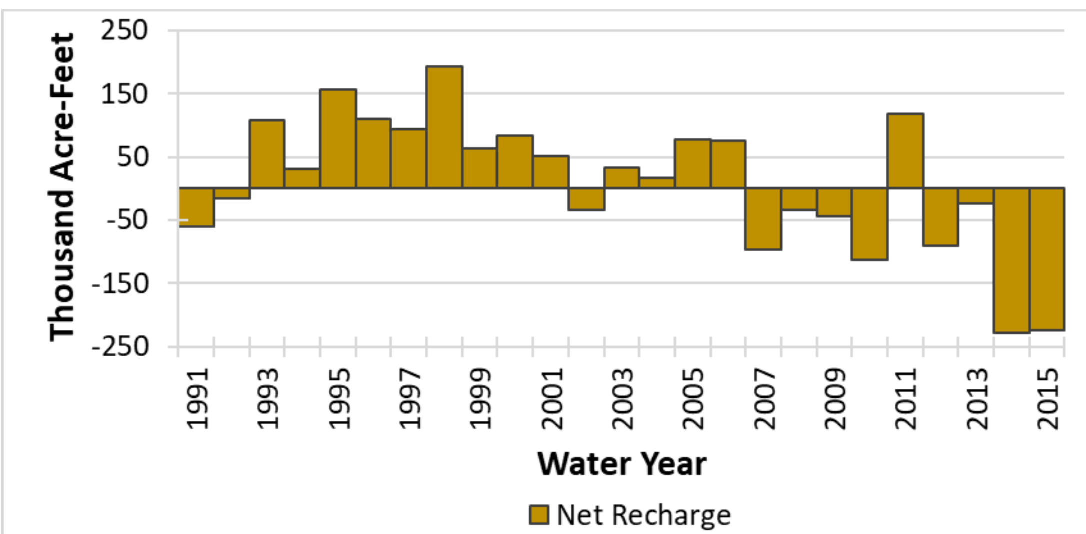


Figure 5-11: Groundwater Recharge and Extraction – Modesto Zone

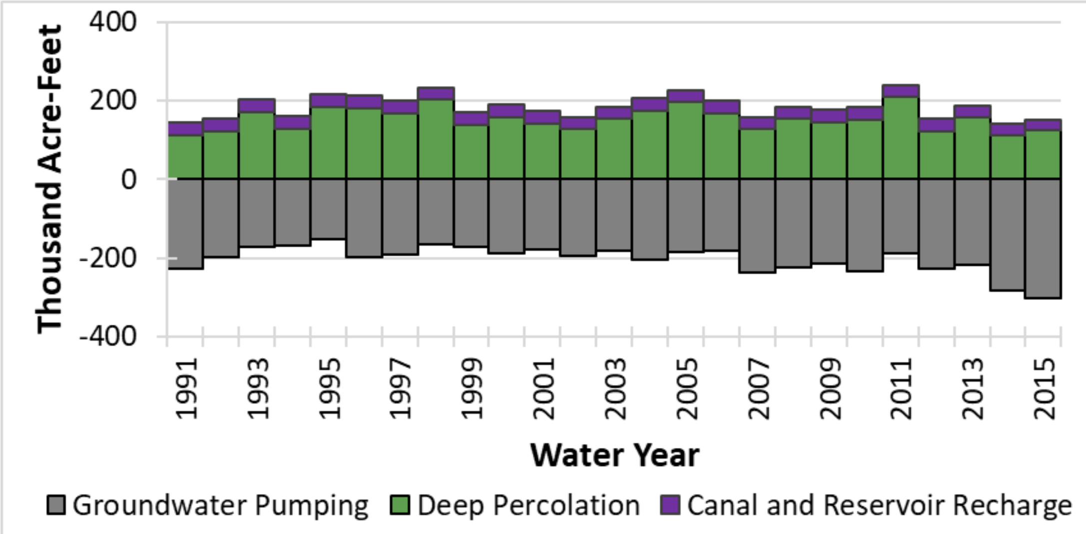


Figure 5-12: Net Recharge – Modesto Zone

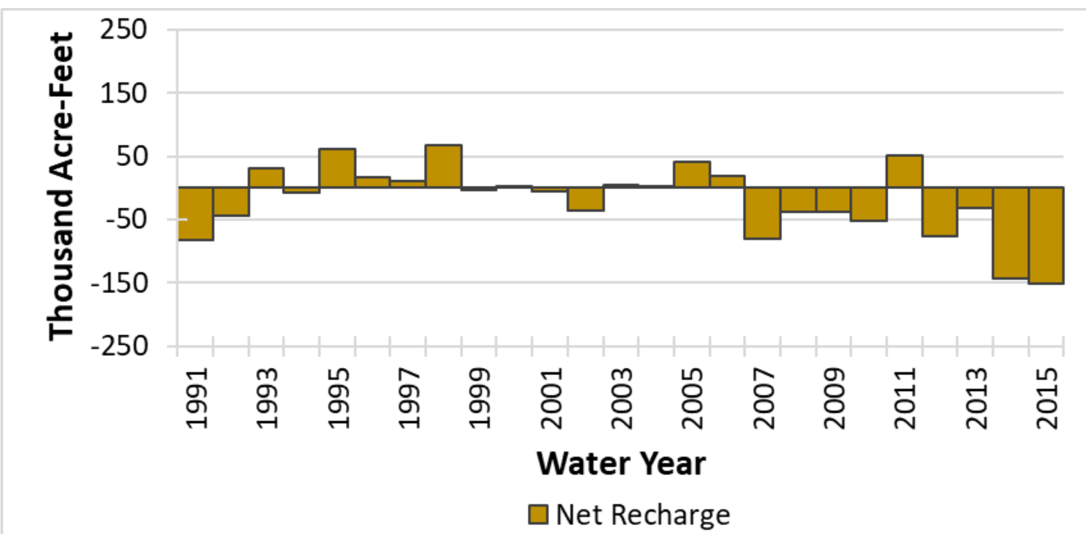


Figure 5-13: Groundwater Recharge and Extraction – Oakdale South Zone

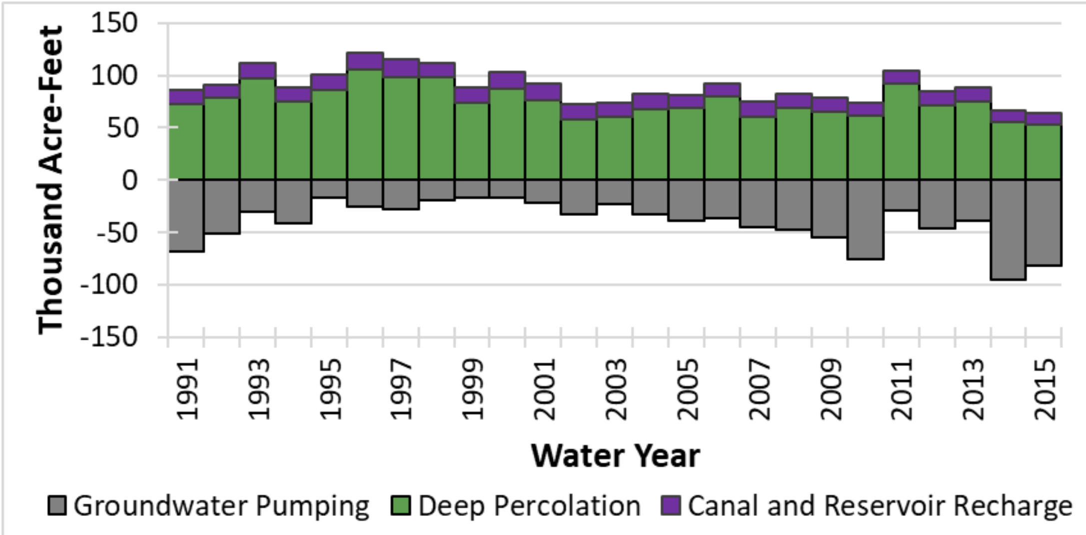


Figure 5-14: Net Recharge – Oakdale South Zone

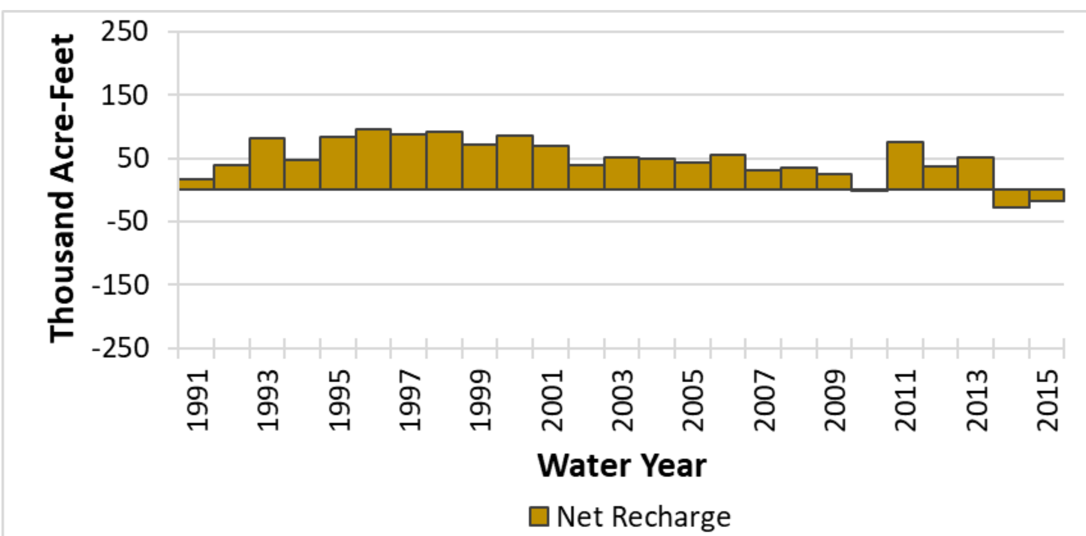


Figure 5-15: Groundwater Recharge and Extraction – Non-District East Zone

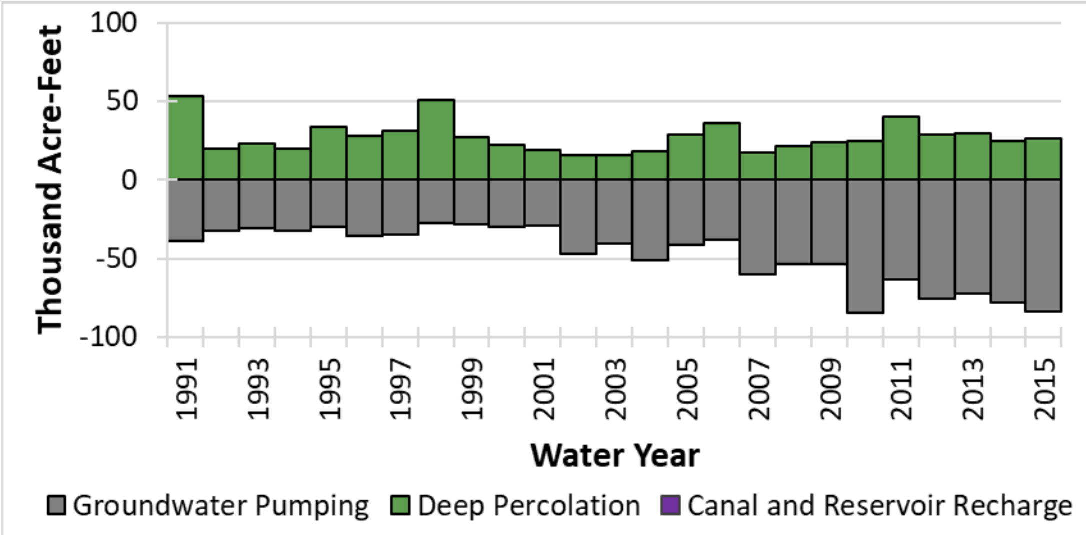


Figure 5-16: Net Recharge – Non-District East Zone

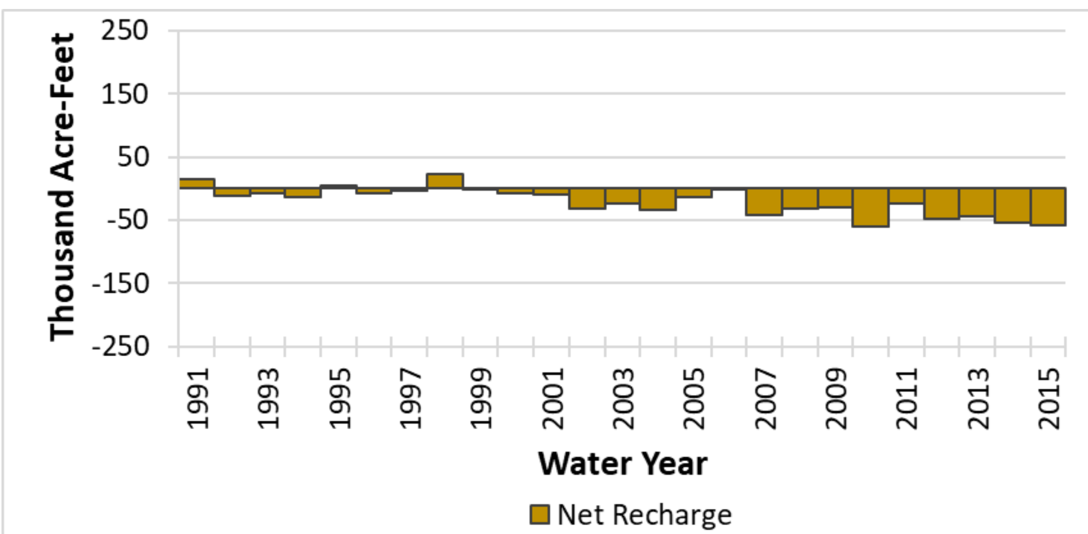


Figure 5-17: Groundwater Recharge and Extraction – Non-District West Area

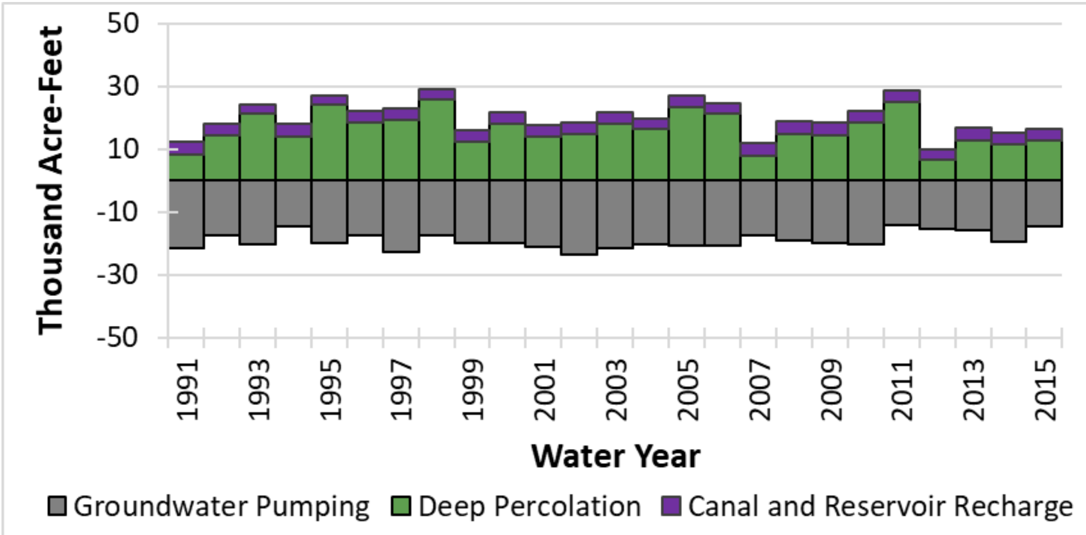


Figure 5-18: Net Recharge – Non-District West Area

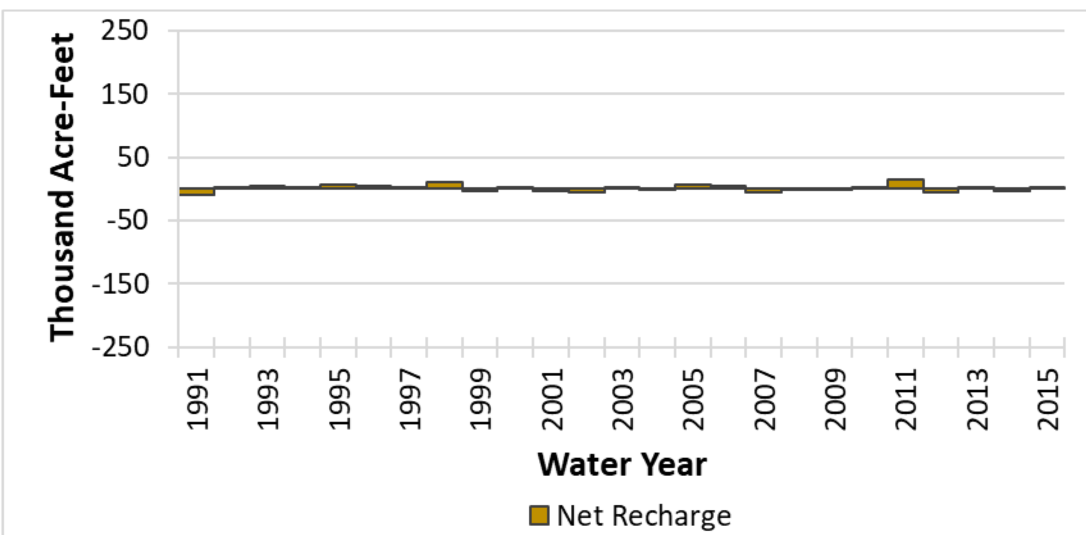


Figure 5-19: Historical Average Annual Water Budget – Groundwater System, Modesto Subbasin

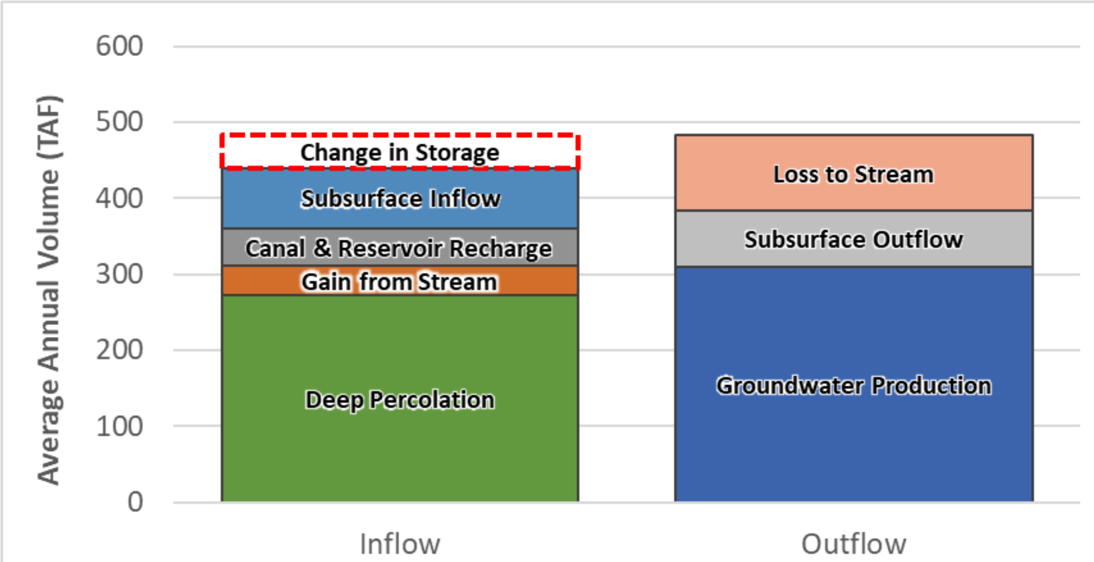
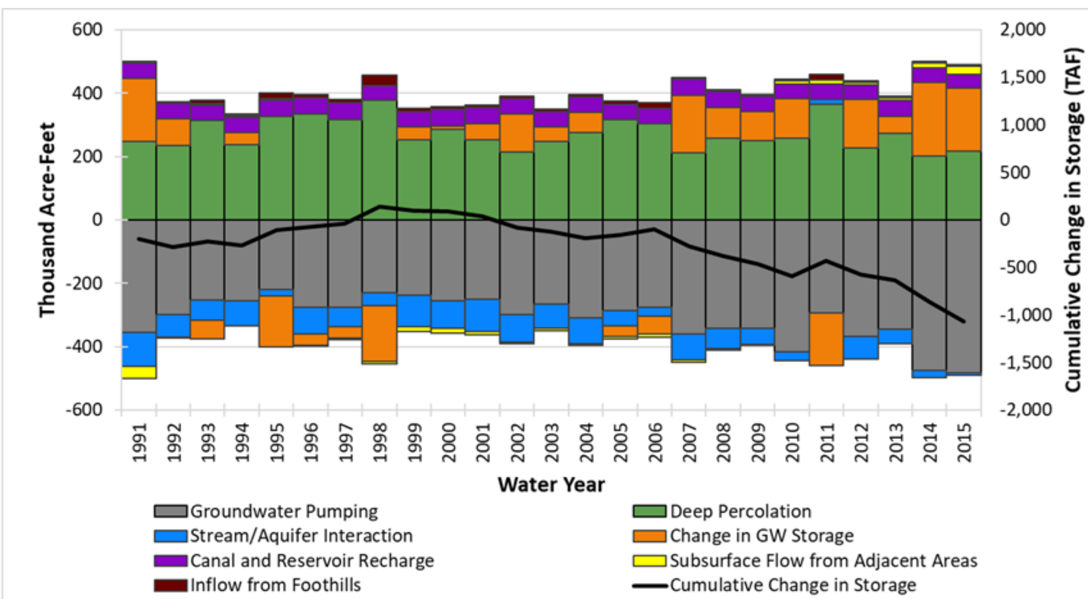


Figure 5-20: Historical Annual Water Budget – Groundwater System, Modesto Subbasin



*On **Figure 20**, positive numbers indicate inflows into the Subbasin aquifer, while negative numbers indicate outflows from the Subbasin aquifer.*

Table 5-9: Water Supply and Demand Budget by Year Type (AFY)

Component	Water Year Type (San Joaquin River Index)					
	Wet	Above Normal	Below Normal	Dry	Critical	Average
Agricultural Demand	479,000	526,000	511,000	532,000	533,000	516,000
Urban Demand	84,000	89,000	101,000	100,000	85,000	92,000
Total Water Demand	563,000	615,000	612,000	632,000	618,000	608,000
Total Surface Water Supply	317,000	332,000	335,000	342,000	289,000	323,000
Agricultural	292,000	299,000	302,000	308,000	271,000	294,000
Urban	25,000	33,000	33,000	34,000	18,000	29,000
Total Groundwater Supply	246,000	283,000	277,000	290,000	329,000	285,000
Agricultural	187,000	227,000	209,000	225,000	262,000	222,000
Urban	59,000	56,000	68,000	65,000	67,000	63,000
Total Water Supply	563,000	615,000	612,000	632,000	618,000	608,000
Change in GW Storage	90,000	-59,000	-69,000	-96,000	-136,000	-43,000

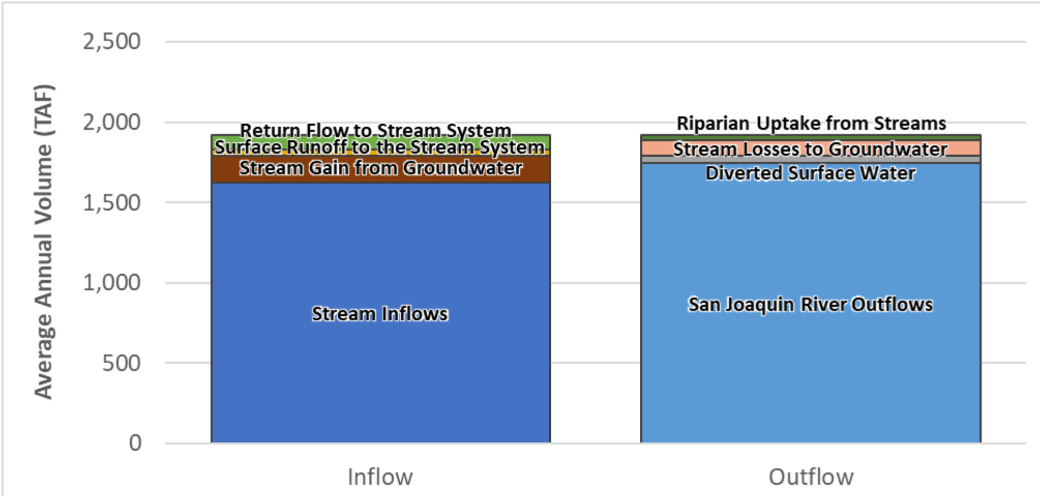
Notes: sub-categories may not sum together due to rounding error
All values in **Table 5-9** are from WYs 1991-2015

5.1.4.2. Current Water Budget

The current water budget quantifies inflows to and outflows from the basin under existing conditions. The 2010 water year was selected to represent current conditions because it reflects an average, non-drought water supply with existing land use and water demand.

Table 5-2 and **Figure 5-21** summarize the average annual inflows and outflows of the Current Conditions Baseline in the Modesto Subbasin stream system. Under current conditions, inflows to the stream system total 1,923,000 AFY with 1,625,000 AFY coming directly as inflow to the Stanislaus, Tuolumne, and San Joaquin Rivers, 35,000 AFY is the result of surface runoff from precipitation, 97,000 AFY of return flow from applied water, and 167,000 AFY of groundwater contributions. In contrast to stream inflow, stream system outflows under current conditions include an average of 47,000 AFY of surface water diversions for agricultural use, 95,000 AFY of discharge to the groundwater system, 37,000 AFY of direct uptake by riparian vegetation, and 1,745,000 AFY of downstream outflows in the San Joaquin River.

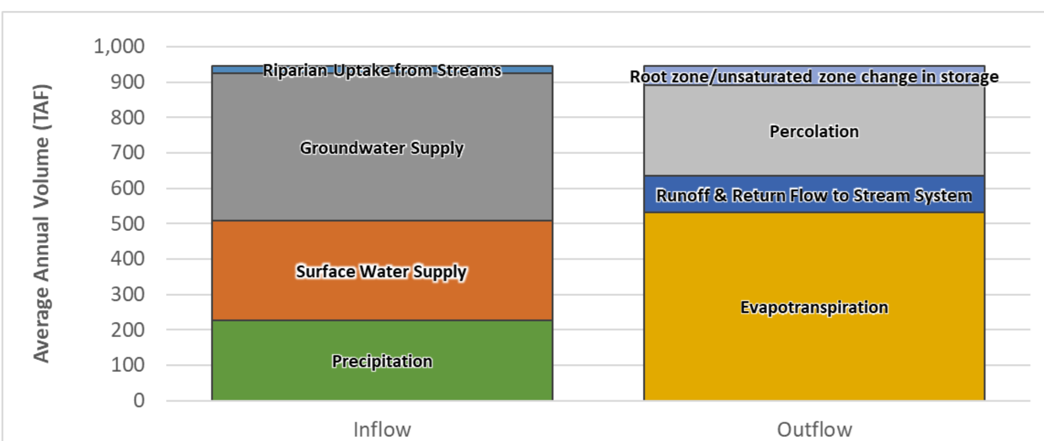
Figure 5-21: Current Conditions Annual Water Budget – Stream Systems, Modesto Subbasin



The land surface system water supply under Current Conditions, shown in **Table 5-3** and in **Figure 5-22**, is estimated using 2010 cropping patterns as the Subbasin experienced significant changes due to the 2012-2015 drought. Under the current Conditions Baseline the average annual water supply is estimated to be 945,000 AFY, including 226,000 AFY of precipitation, 699,000 AFY of surface and groundwater supply for irrigation and urban use (282,000 AFY of surface water and 417,000 AFY of groundwater), and 20,000 AFY of riparian uptake from the stream system.

The total water demand is estimated to be 892,000 AFY, which includes evapotranspiration (531,000 AFY), surface runoff and return flow to the stream system (105,000 AFY), and deep percolation (257,000 AFY). **Figure 5-22** summarizes the average annual current condition supplies and demands in the land surface budget for the Modesto Subbasin.

Figure 5-22: Current Conditions Average Annual Water Budget – Land Surface System, Modesto Subbasin

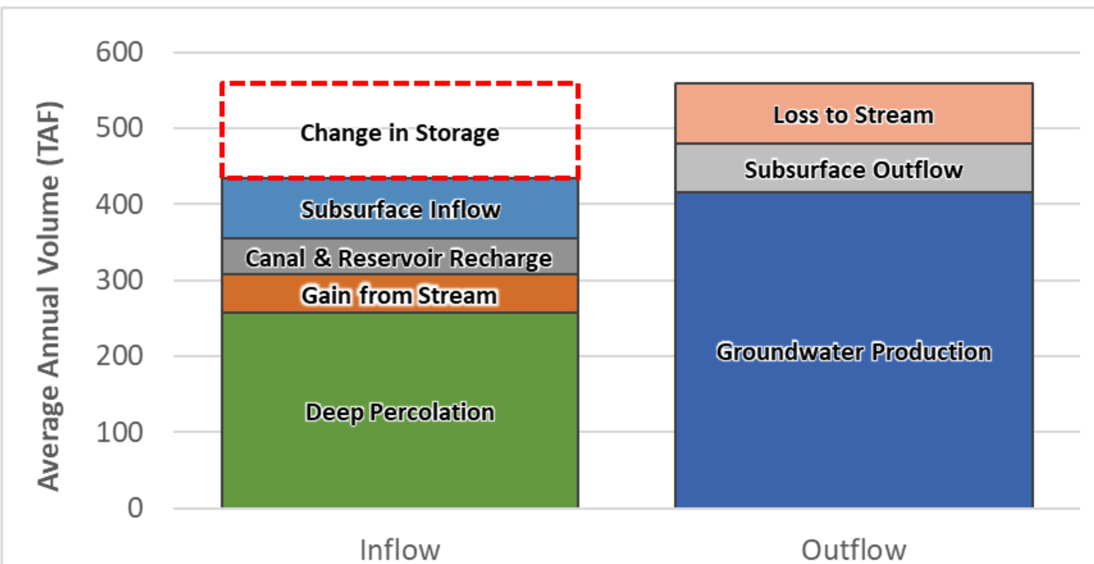


The groundwater system budget for current conditions baseline indicates an average annual inflow of 434,000 AFY, including 257,000 AFY of deep percolation, 47,000 AFY of canal and reservoir seepage, 51,000 AFY from stream seepage, and total subsurface inflows of 79,000 AFY.

Analysis of the groundwater system budget indicates that the system's average annual outflows exceed its inflows under current conditions, resulting in a net reduction in groundwater in storage. As under historical conditions, groundwater production (416,000 AFY) remains the largest component of groundwater discharge, with subsurface outflows (63,000 AFY) and discharge to the stream system (80,000 AFY) bringing the total system outflows to 559,000 AFY annually. Operational water budgets and net-groundwater interaction under current conditions remain like those of the historical period, based on the 2010 water year. On a Subbasin-wide scale, the groundwater in storage deficit under the current conditions baseline is approximately 125,000 AFY.

Figure 5-23 and **Table 5-8** summarize the average current conditions groundwater inflows and outflows in the Modesto Subbasin.

Figure 5-23: Current Conditions Average Annual Water Budget – Groundwater System, Modesto Subbasin



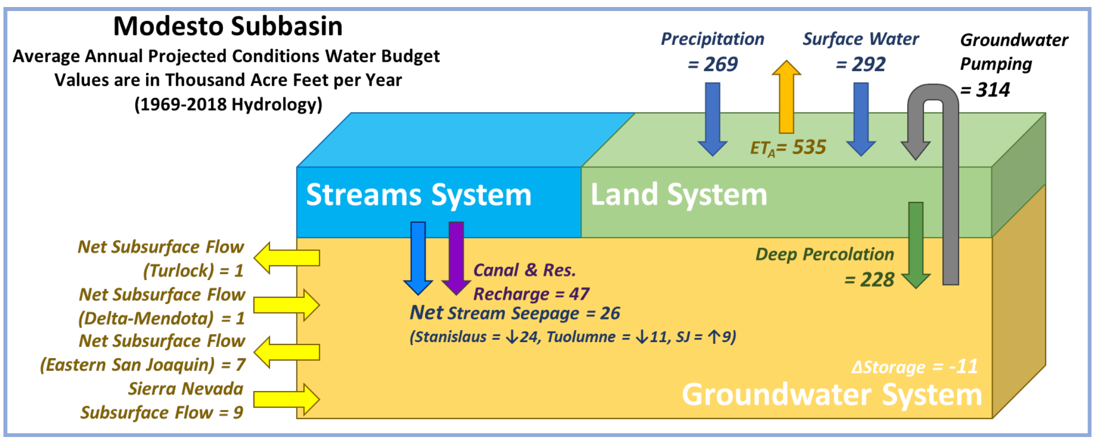
5.1.4.3. Projected Water Budget

The projected water budget provides an estimate of supplies and demands as defined under the projected conditions baseline listed above, including land use operations and their impact to the aquifer system. The projected conditions baseline is a version of C2VSimTM and was used to evaluate the water budget using projected operations in conjunction with the 50-year hydrologic period, 1969 to 2018.

Development of the projected water demand is based on the population growth trends reported in the 2015 UWMPs and the land use, evapotranspiration, and crop coefficient information from the Modesto ID and Oakdale ID 2015 AWMPs. Projected Tuolumne River inflows to the groundwater Subbasin and surface water supplies are determined through a combination of historical trends and the Tuolumne River System (TRS) operations model. Additional information about model development and inputs are detailed in the C2VSimTM Model Development Technical Memo in **Appendix C**.

Figure 5-24 shows the water budget schematic for the Modesto Subbasin with average annual projected values for each component.

Figure 5-24: Average Annual Projected Conditions Water Budget – Modesto Subbasin



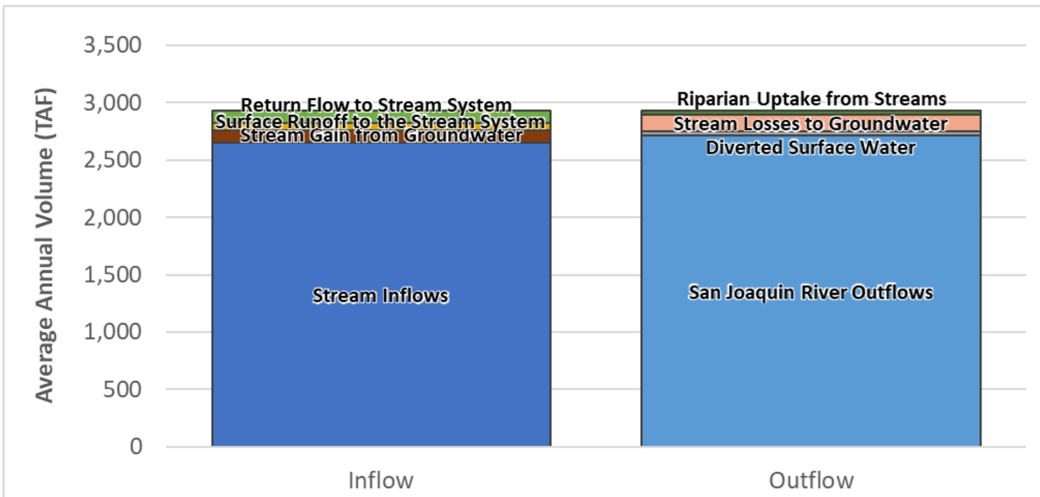
Note: sub-categories may not sum together due to rounding error

As shown in **Table 5-2**, average annual surface water inflows to the Modesto Subbasin's stream system total an average of 2,934,000 AFY. As with the historical and current conditions water budgets, stream inflows from the Stanislaus, Tuolumne, and San Joaquin Rivers comprise most of the inflows, averaging 2,650,000 AFY. Other inflows include contributions from tributaries (6,000 AY), gain from the aquifer (104,000 AFY), surface runoff from precipitation (60,000 AFY), and return flow from applied water to the stream system (113,000 AFY).

Under projected conditions, volumes of surface water diverted from Modesto Subbasin's stream system are lower than under historical conditions, down to 33,000 AFY from 43,000 AFY. Reduced diversion volumes under projected conditions are due to reduced demand by riparian users resulting from projected increases in irrigation efficiency. Other stream system outflows include seepage to the aquifer system (146,000 AFY), direct uptake by native vegetation (37,000 AFY), and San Joaquin River outflows downstream of the Tuolumne River confluence (2,717,000 AFY).

Groundwater levels are predicted to be further reduced under projected conditions than under historical conditions, and thus the 86,000 AFY reduction in net contribution from the aquifer[9] to the stream system matches the expected trend. Under such a decrease in aquifer contribution, streams in Modesto Subbasin transition from average net gaining streams to net losing streams. Therefore, under historical conditions, aquifers on average recharge streams, but under projected conditions, streams on average, recharge the aquifer. **Figure 5-25** summarizes the average projected inflows and outflows in the Modesto Subbasin surface water network.

Figure 5-25: Projected Conditions Average Annual Water Budget – Stream Systems, Modesto Subbasin



The land surface water budget for the Projected Conditions Baseline is shown on **Table 5-3** and has average annual supplies of 900,000 AFY. Supplies are comprised of precipitation (270,000 AFY), applied surface water (293,000 AFY), applied groundwater (315,000 AFY), and riparian uptake from streams (22,000 AFY). Demands total 898,000 AFY and are comprised of evapotranspiration (536,000 AFY), surface runoff and return flow (134,000 AFY) to the stream system, and deep percolation (228,000 AFY).

Urban supplies and demands increase relative to historical conditions due to forecasted population growth. Additionally, agricultural demand (evapotranspiration) is higher because agricultural land use is assumed to be at the historical high, reflecting more developed acres than average historical conditions. However, there is less percolation out of the root zone and agricultural return flow because of the projected improvements in irrigation efficiency (e.g., drip irrigation). The lower runoff in the projected conditions baseline compared to the historical scenario is driven by lower precipitation. There are no projected changes to soil

[9] Net contribution from the aquifer includes stream gains and losses within and outside of the Modesto Subbasin – any region adjacent to the Stanislaus River, Tuolumne River, and San Joaquin River.

characteristics (i.e., curve number or soil parameters) between the historical and projected conditions baseline scenarios.

A summary of these flows can be seen below in **Figure 5-26** though **Figure 5-28**. **Figure 5-27** and **Figure 5-28** show the annual change in the land surface water budget components through the simulation period.

Figure 5-26: Projected Conditions Average Annual Water Budget – Land Surface System, Modesto Subbasin

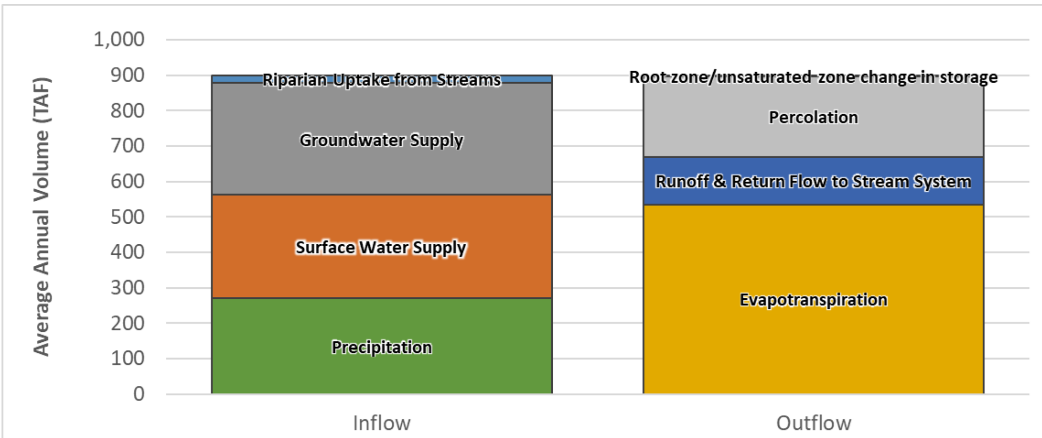


Figure 5-27: Projected Conditions Annual Water Budget – Agricultural Land Surface System, Modesto Subbasin

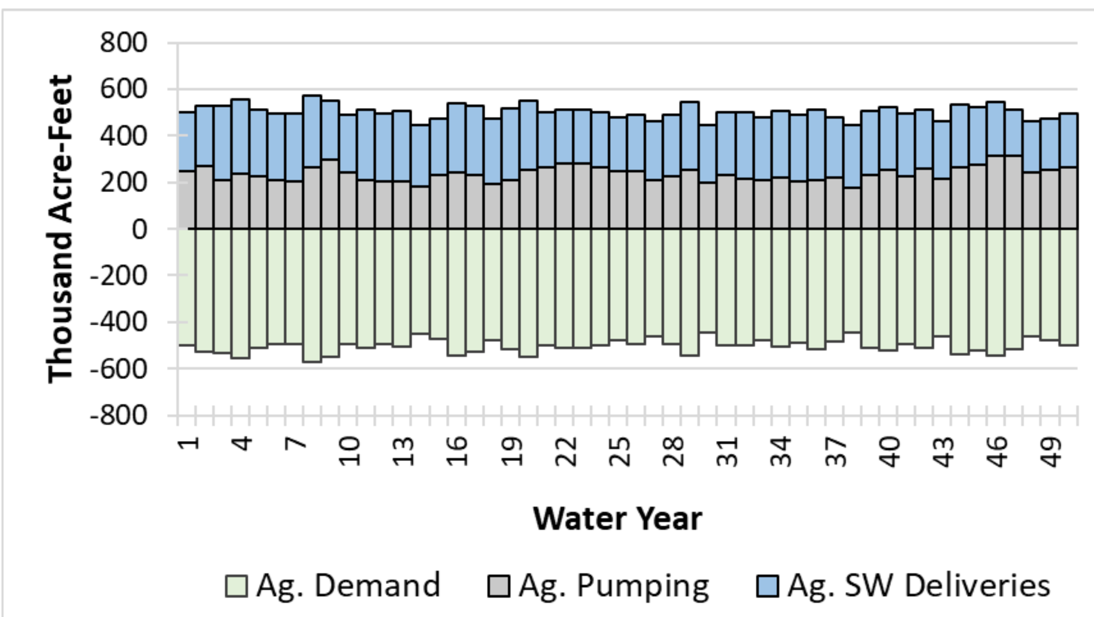
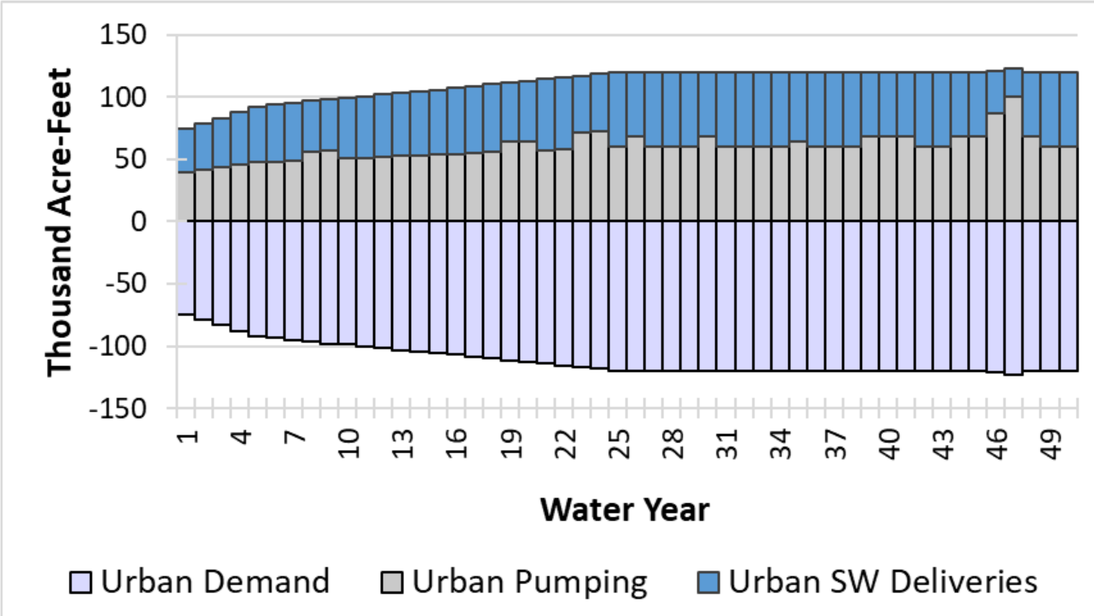


Figure 5-28: Projected Conditions Annual Water Budget – Urban Land Surface System, Modesto Subbasin



Anticipated growth in the Projected Conditions Baseline slightly increases groundwater production (314,000 AFY), compared to historical pumping. Subsurface outflows to neighboring subbasins (75,000 AF) and stream gain from groundwater (50,000 AFY) bring the total Subbasin discharges to 438,000 AFY.

Under projected conditions, the groundwater system of the Modesto Subbasin experiences an average of 428,000 AFY of inflows each year, of which 228,000 AFY is from deep percolation of rainfall and applied water. As previously mentioned, deep percolation from applied water is lower than under historical conditions because of projected increases in irrigation efficiency. Other inflows to the groundwater system consist of recharge from stream seepage (76,000 AFY), seepage from conveyance canals and reservoirs (47,000 AFY), and subsurface inflows from the Sierra Nevada foothills and neighboring subbasins of Eastern San Joaquin, Delta-Mendota, and Turlock (77,000 AFY combined). A summary of annual averages of the Modesto Subbasin groundwater system is provided on **Table 5-8**.

Under the projected conditions the groundwater system outflows are greater than the system inflows, resulting in an average annual groundwater in storage deficit of 11,000 AFY. While an average groundwater in storage decline of 11,000 AFY is significantly less than historical depletion (43,000 AFY), the decline is buffered by the net gain of 86,000 AFY of seepage from the stream system. This change in the projected groundwater conditions and stream-aquifer interactions are considered significant and unreasonable, which affects groundwater sustainability of the Subbasin.

An analysis of net recharge in the Projected Conditions model was performed for Modesto Subbasin and for each water budget area. **Figure 5-29** shows the total groundwater production and land-surface recharge each year under the projected conditions scenario. Additionally, the net-groundwater under projected conditions, shown in **Figure 5-30**, is predominantly negative, meaning that on average, the subbasin is a net-extractor. This continuation of historical trends reflects the relationship between the Subbasin's increased groundwater demand and declining storage.

Figure 5-31 through **Figure 5-38** show similar surface-to-groundwater operations and net-interaction to the historical water budgets. Under the projected conditions baseline, the Oakdale South water budget area maintains a constant net-contribution to the aquifer system while the Non-District West continues to be variable conditions and the NDE continues to be a net-extractor. The Modesto water budget area shows the greatest variance from the historical water budget, being predominantly a net-extractor under projected conditions. This is due to both changes in agricultural operations, combined with growing populations in the urban centers.

Figure 5-39 summarizes the average projected groundwater inflows and outflows in the Modesto Subbasin, while **Figure 5-40** shows the annual change in each component of the groundwater budget plus cumulative change in storage throughout the simulation period. Based on this figure, Modesto Subbasin is projected to experience approximately 11,000 AFY of storage decline under projected conditions, leading to cumulative reduction of approximately 530,000 AFY of groundwater in storage over the 50-year planning horizon.

Figure 5-29: Projected Conditions Groundwater Recharge and Extraction – Modesto Subbasin

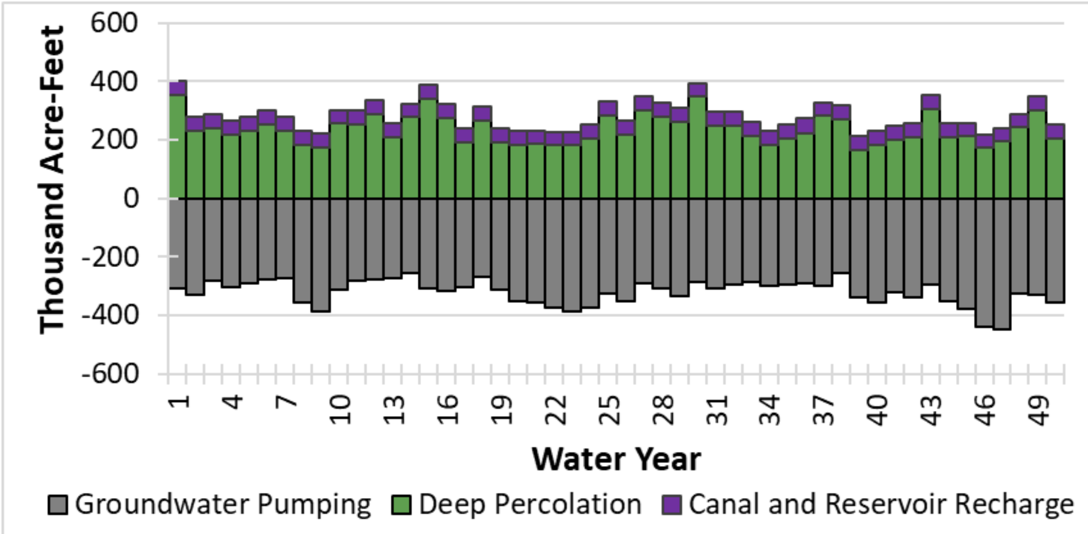


Figure 5-30: Projected Conditions Net Recharge – Modesto Subbasin

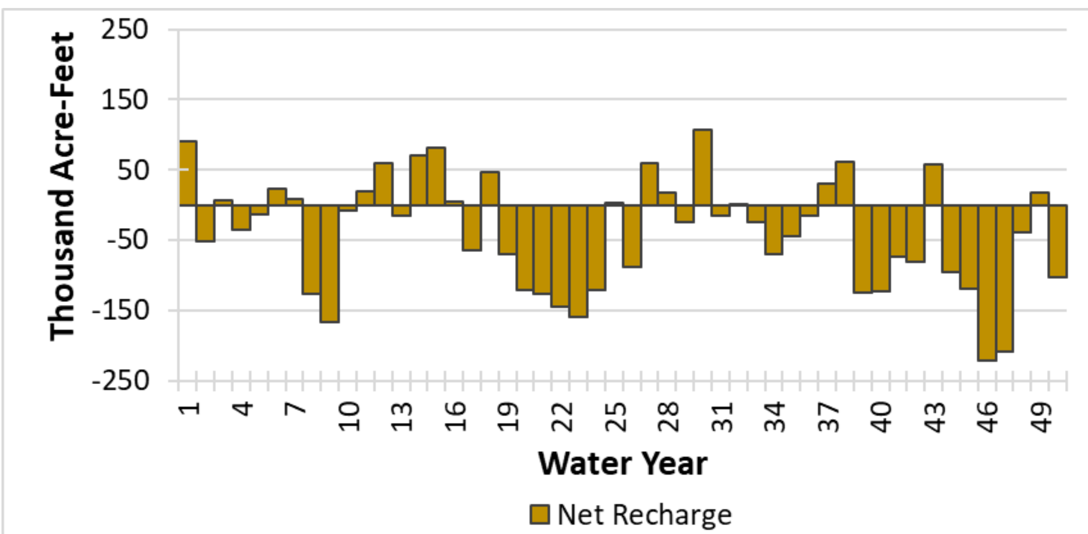


Figure 5-31: Projected Conditions Groundwater Recharge and Extraction – Modesto Zone

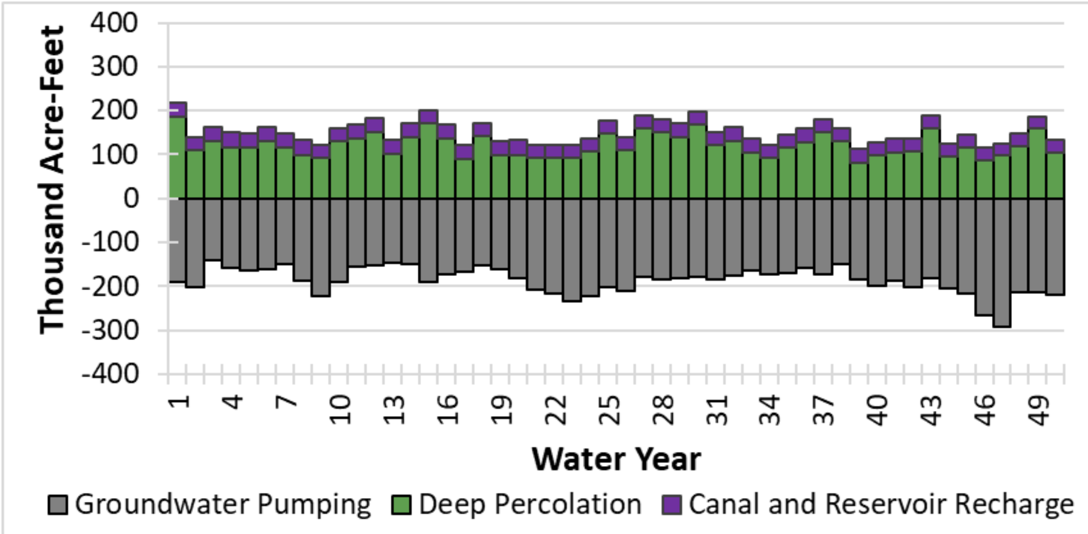


Figure 5-32: Projected Conditions Net Recharge – Modesto Zone

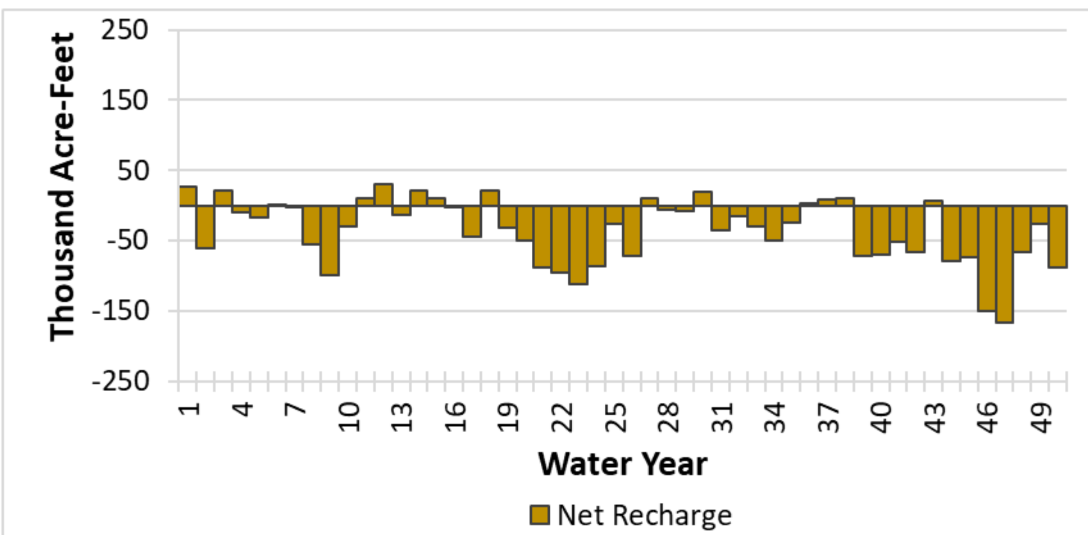


Figure 5-33: Projected Conditions Groundwater Recharge and Extraction – Oakdale South Zone

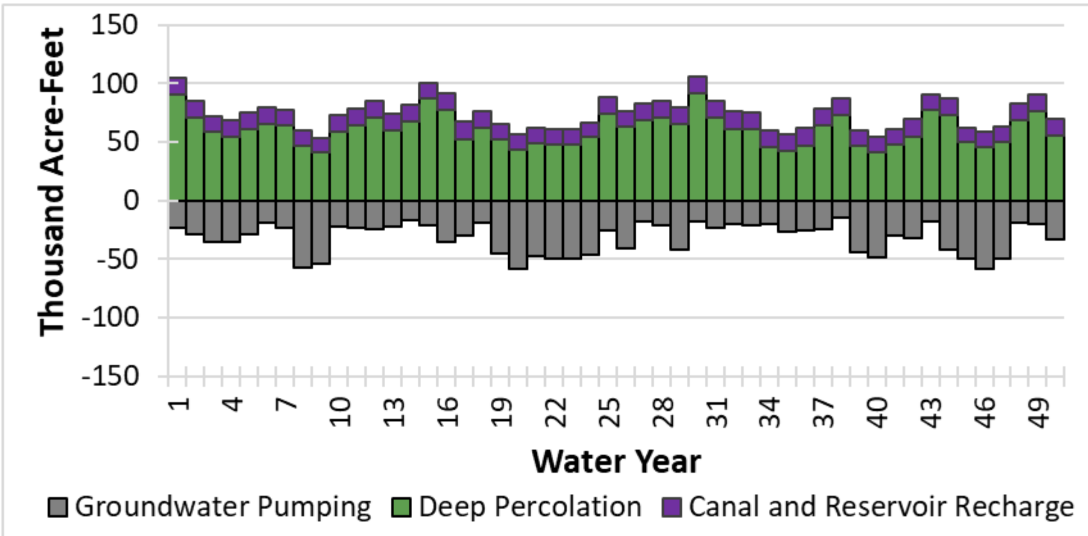


Figure 5-34: Projected Conditions Net Recharge – Oakdale South Zone

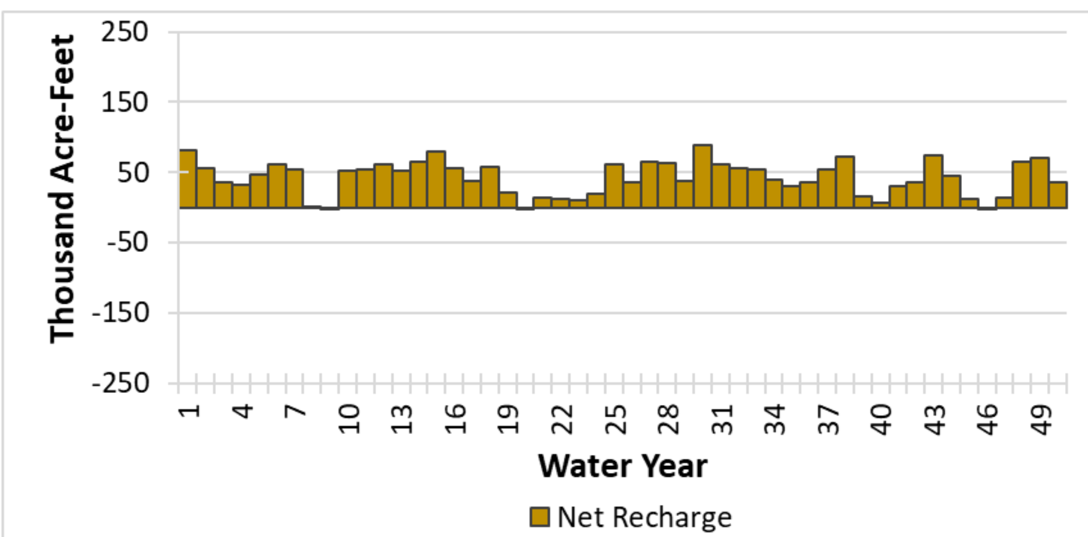


Figure 5-35: Groundwater Recharge and Extraction – Non-District East Area

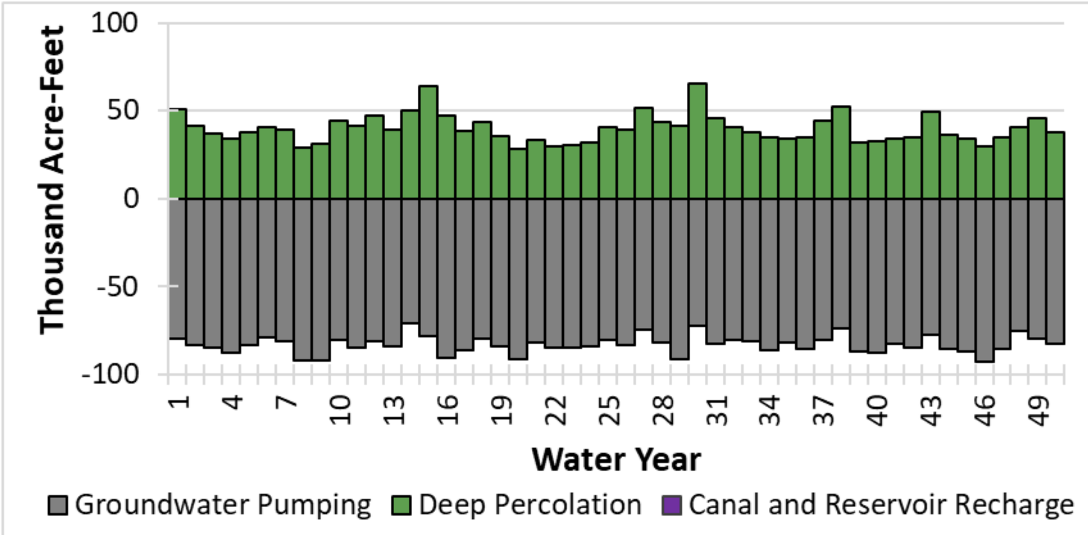


Figure 5-36: Net Recharge – Non-District East Area

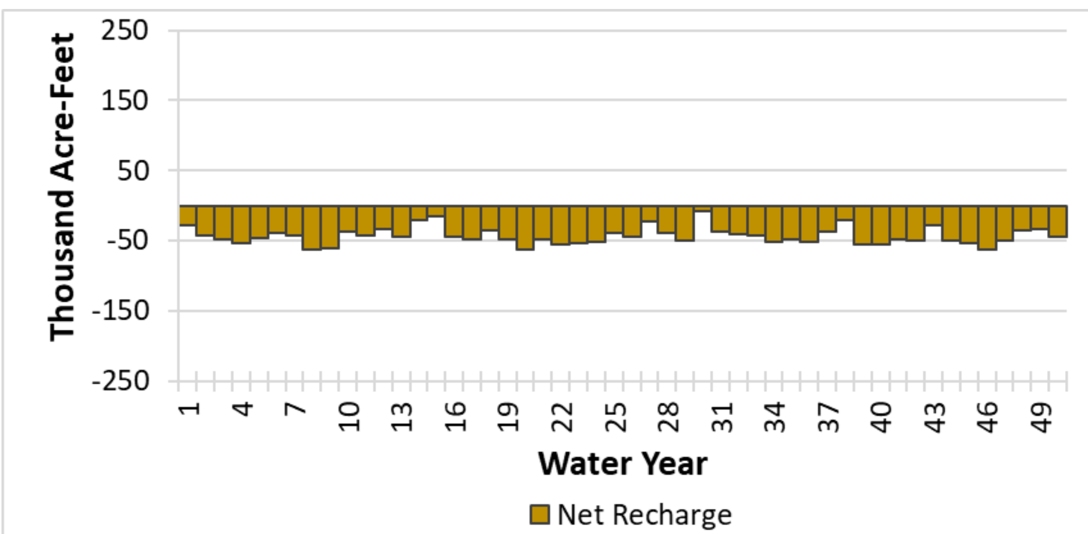


Figure 5-37: Groundwater Recharge and Extraction – Non-District West Zone

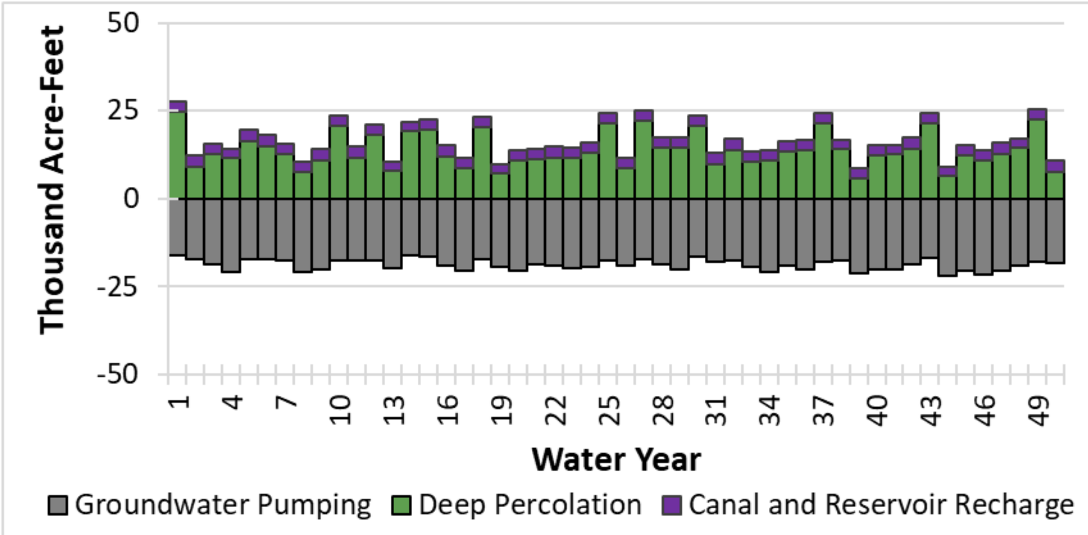


Figure 5-38: Net Recharge – Non-District West Zone

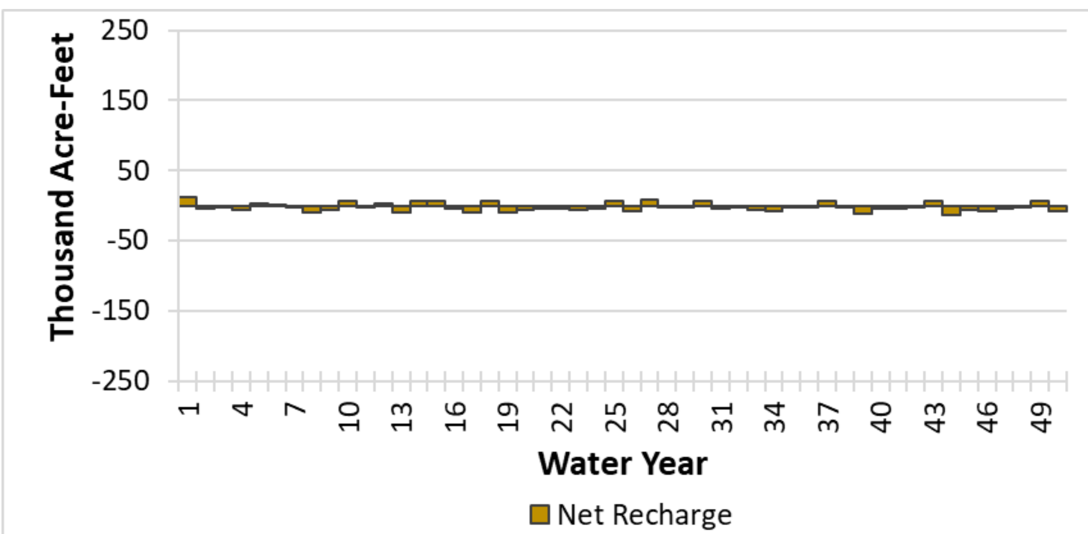


Figure 5-39: Projected Conditions Average Annual Water Budget – Groundwater System, Modesto Subbasin

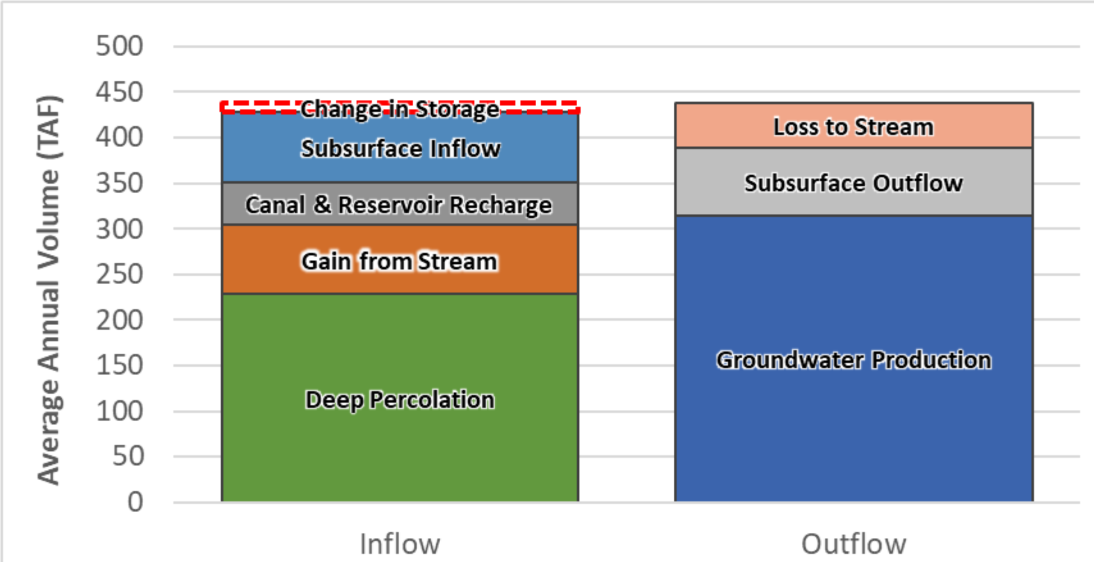
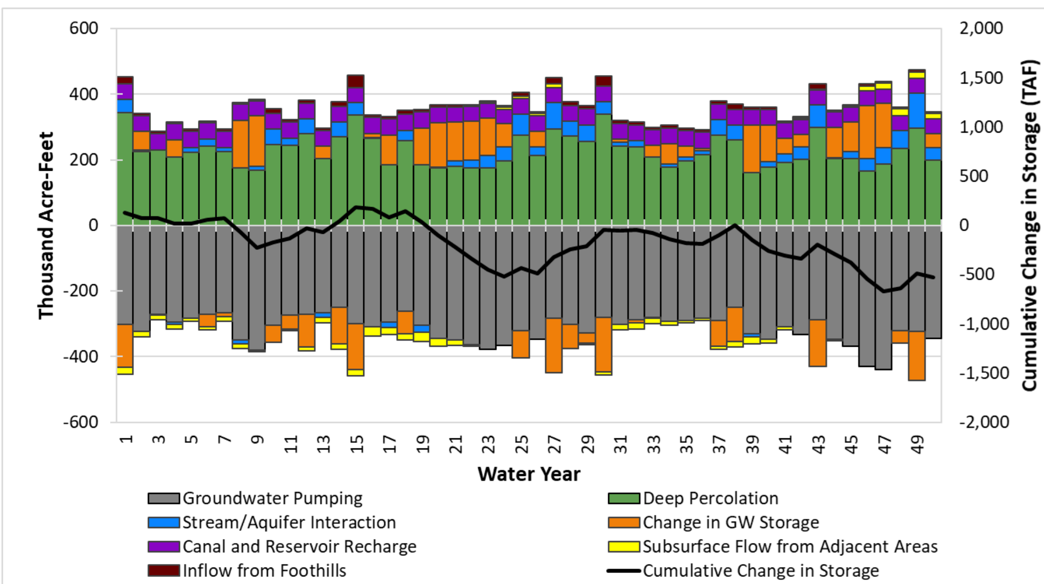


Figure 5-40: Projected Conditions Annual Water Budget – Groundwater System, Modesto Subbasin



5.2. CLIMATE CHANGE ANALYSIS

5.2.1. Regulatory Background

SGMA requires consideration of uncertainties associated with climate change in the development of GSPs. Consistent with §354.18(d)(3) and §354.18(e) of the SGMA Regulations, analyses for the Modesto GSP evaluated the projected water budget with and without climate change conditions.

5.2.2. DWR Guidance

Climate change analysis and the associated methods, tools, forecasted datasets, and the predictions of greenhouse gas concentrations in the atmosphere are continually evolving. The approach developed for this GSP is based on the methodology in DWR's guidance document (DWR, 2018b), which, in combination with Subbasin-specific modeling tools, was deemed to be the most appropriate information for evaluating climate change in the Modesto Subbasin GSP. The following resources from DWR were used in the climate change analysis:

- SGMA Data Viewer
- Guidance for Climate Change Data Use During Sustainability Plan Development and Appendices (Guidance Document)
- Water Budget BMP
- Desktop IWFM Tools

SGMA Data Viewer provides the location for which the climate change forecasts datasets[10] were downloaded for the Modesto Subbasin (DWR, 2019b). The guidance document details the approach, development, applications, and limitations of the datasets available from the SGMA Data Viewer (DWR, 2018b). The Water Budget BMP describes in greater detail how DWR recommends projected water budgets be computed (DWR, 2016a). The Desktop IWFM Tools (DWR, 2018c) are available to calculate the projected precipitation and evapotranspiration inputs under climate change conditions.

The methods suggested by DWR in the above resources were used, with modifications where appropriate, to ensure the resolution would be reasonable for the Modesto Subbasin and align with the assumptions of the C2VSimTM. **Figure 5-41** shows the overall process developed for the Modesto GSP consistent with the Climate Change Resource Guide (DWR, 2018b) and describes workflow beginning with baseline projected conditions to perturbed 2070 conditions for the projected model run. For this analysis, it is assumed that the projected climate change conditions for 2070 central tendency is used.

[10] In the industry, climate change impacted variable forecasts are sometimes referred to as "data" and their collections are called "datasets." Calling forecasted variable values "data" can be misleading, so this document tries to be explicit when referring to data (historical data) vs. forecasts or model outputs.

Figure 5-41: Modesto GSP Climate Change Analysis Process

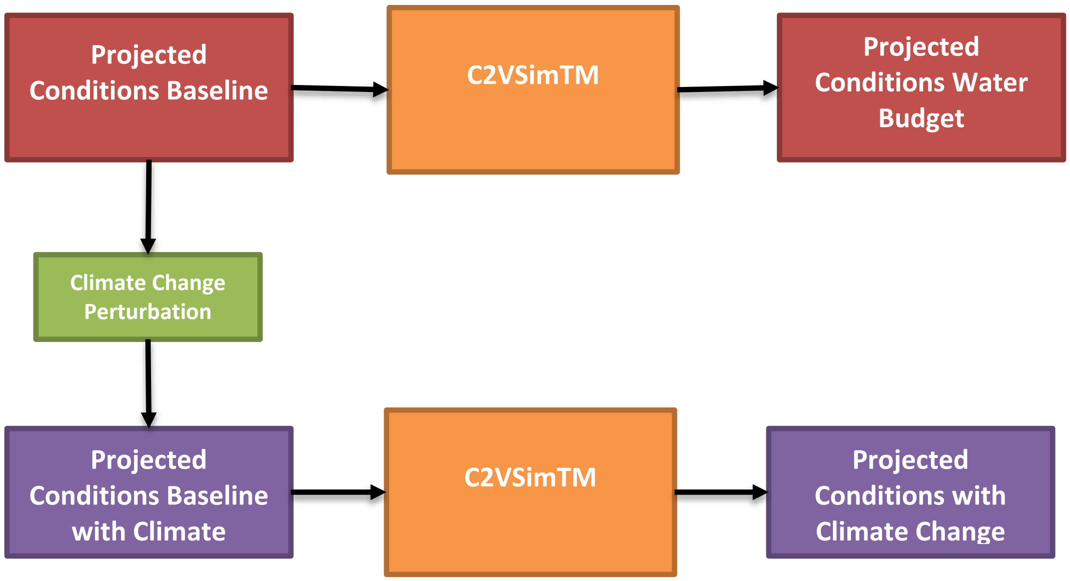


Table 5-10 summarizes the forecasted variable datasets provided by DWR that were used to carry out the climate change analysis. The "VIC" model (Variable Infiltration Capacity) referred to in **Table 5-10** is the hydrologic model used by DWR to estimate unimpaired flows in upper watersheds. "Unimpaired" streamflow refers to the natural streamflow produced by a watershed, without modifications to streamflow from reservoir regulations, diversions, and other operations. On the other hand, "impaired" streamflow referred to in **Table 5-10** is DWR's terminology for streams whose flow is impacted by ongoing water operations and upstream regulations, such as diversions, deliveries, and reservoir storage. Flows on these streams are simulated using the CalSim II model results from the DWR baseline model. For Modesto Subbasin GSP, stream inflow and surface water deliveries to MID and OID were utilized from the CalSim II baseline model results. The San Joaquin River flows were also based on the results of CalSim II baseline model from DWR. All timeseries shown in **Table 5-10** use a monthly timestep. **Section 5.2.3** includes further description of the methodology, datasets, and results.

Table 5-10: DWR-Provided Climate Change Datasets

Input Variable	DWR Provided Dataset
Unimpaired Streamflow	Combined VIC model runoff and baseflow to generate change factors, provided by HUC 8 watershed geometry
Impaired Streamflow (Ongoing Operations)	CalSim II time series outputs in .csv format
Precipitation	VIC model-generated GIS grid with associated change factor time series for each cell
Reference ET	VIC model-generated GIS grid with associated change factor time series for each cell

5.2.3. Climate Change Methodology

Climate change affects precipitation, streamflow, evapotranspiration and, for coastal aquifers, sea level rise, which in turn have impacts on the aquifer system. For the Modesto Subbasin, sea level rise is not relevant and not considered in this analysis. The method for perturbing the streamflow, precipitation, and evapotranspiration input files is described in the following sections. The late-century, 2070 central tendency climate scenario was evaluated in this analysis, consistent with DWR guidance (DWR, 2018b).

DWR combined 10 global climate models (GCMs) for two different representative climate pathways (RCPs) to generate the central tendency scenarios in the datasets used in this analysis. The "local analogs" method (LOCA) was used to downscale these 20 different climate projections to a scale usable for California (DWR, 2018b). DWR provides datasets for two future climate periods: 2030 and 2070. For 2030, there is one set of central tendency datasets available. For 2070, DWR has provided one central tendency scenario and two extreme scenarios: one that is drier with extreme warming and one that is wetter with moderate warming.

The 2070 central tendency projection serves to assess impacts of climate change over the long-term planning and implementation period and was therefore selected as the most appropriate scenario under which to assess in the Modesto GSP.

5.2.3.1. Streamflow under Climate Change

Hydrological forecasts for streamflow under various climate change scenarios are available from DWR as either a flow-based timeseries or a series of perturbation factors applicable to local data. DWR simulated volumetric flow in most regional surface water bodies by utilizing the Water Resource Integrated Modeling System (WRIMS, formally named CalSim II). While river flows and surface water diversions in the Tuolumne, Stanislaus, and San Joaquin Rivers are simulated in CalSim II, there are significant variations when compared to local historical data. Due to the uncertainty in CalSim II-simulated reservoir operations, flows from CalSim II provided by the state are not used directly in the Modesto GSP climate change analysis. Instead, relative perturbation factors were used to derive surface water inflows and diversions for analysis with the C2VSimTM.

The major streams entering the Modesto Subbasin are the Tuolumne River and Stanislaus River. All rivers are regulated and there are no unimpaired rivers or creeks that contribute significantly to the basin.

CalSim II estimated flows for point locations on the Tuolumne River and Stanislaus River were downloaded from DWR. The key flows obtained from CalSim II include:

- **Tuolumne River:** La Grange Outflow
- **Stanislaus River:** Goodwin Outflow

The San Joaquin River inflow was not adjusted in the climate change analysis because the Friant Dam is located far from the Modesto Subbasin and subbasins that are upstream of the Modesto Subbasin can have significant impacts on stream accretions/depletions, diversions, and operations. As these upstream impacts which are outside of the Modesto Subbasin cannot be captured without detailed analysis of projected flows under climate change conditions, the San Joaquin River flows are assumed to be same as the projected baseline conditions. This would not have a significant impact on the climate change analysis for the Modesto Subbasin, as majority of the surface water supplies, and interaction of surface and groundwater systems take place within Subbasins and along Tuolumne and Stanislaus Rivers.

The streamflow data extracted from CalSim II represent projected hydrology with climate change based on reservoir outflow, operational constraints, and diversions and deliveries of water for the State Water Project and the Central Valley Project. CalSim II data from WY 1965 to WY 2003 was available. For WY 2004 to WY 2018, streamflow data was synthesized based on similar year methodology, and used flows from WY 1965 to WY 2003 and the DWR San Joaquin Valley water year type (CDEC, 2018). (For example, the streamflow for October 2009 was calculated as the average of the October 1966 and October 1971 streamflow because these are all the Below Normal water years between WY 1965 and WY 2003.)

CalSim II outputs are considered more appropriate for regulated streams than streamflow derived using the unimpaired flow adjustment factors because CalSim II accounts for reservoir operations. As expected, streamflow simulated in CalSim II and those derived using the unimpaired flow adjustment factors did not present similar trends, particularly in dry years. DWR-provided unimpaired flow change factors do not account for variations in the operation of the reservoirs that would result from climate change conditions. The CalSim II flows, however, were also not considered completely appropriate for local conditions so a method was derived to compute change factors from CalSim II flows, as described below.

Using DWR's method of deriving the precipitation and evapotranspiration factors as a guide, a hybrid approach was derived to improve upon the discrepancy between the CalSim II and local models while accounting for some change in reservoir operations. In this approach, change factors are generated from the difference between each simulated future climate change CalSim II scenario (i.e., 2070) and the "without climate change" baseline CalSim II run. This "without climate change" baseline run is the CalSim II 1995 Historical Detrended simulation run provided through personal communication from DWR. The change perturbation factors are bounded by a maximum of 5 and minimum 0.2. For the purposes of simplicity, this method is referred to throughout the rest of the document as CalSim II Generated Perturbation Factors (CGPF). The generated change factors are then used to perturb the regulated baseline river inflows:

- Tuolumne River – CGPF multiplied by the projected conditions baseline for the Tuolumne River which is based on Tuolumne River System (TRS) operations model
- Stanislaus River – CGPF multiplied by the projected conditions baseline for the Stanislaus River which is based on historical trends and local hydrology

As previously discussed, the San Joaquin River flows were not perturbed due to the much larger tributary areas of the San Joaquin River that are outside the Modesto Subbasin. The CGPF method presents limitations given that the resulting flows are not directly obtained from an operations model. The actual mass balance on the reservoirs is not tracked in the estimates of the flows and, instead, the method relies on CalSim II tracking that storage and managing the reservoir based on the appropriate rule curves.

Figure 5-42 through **Figure 5-49** provide a comparison of projected conditions baseline and the CGPF method described above. Exceedance curves are included for each of the CGPF flows against the projected conditions baseline.

Figure 5-42: Tuolumne River Hydrograph

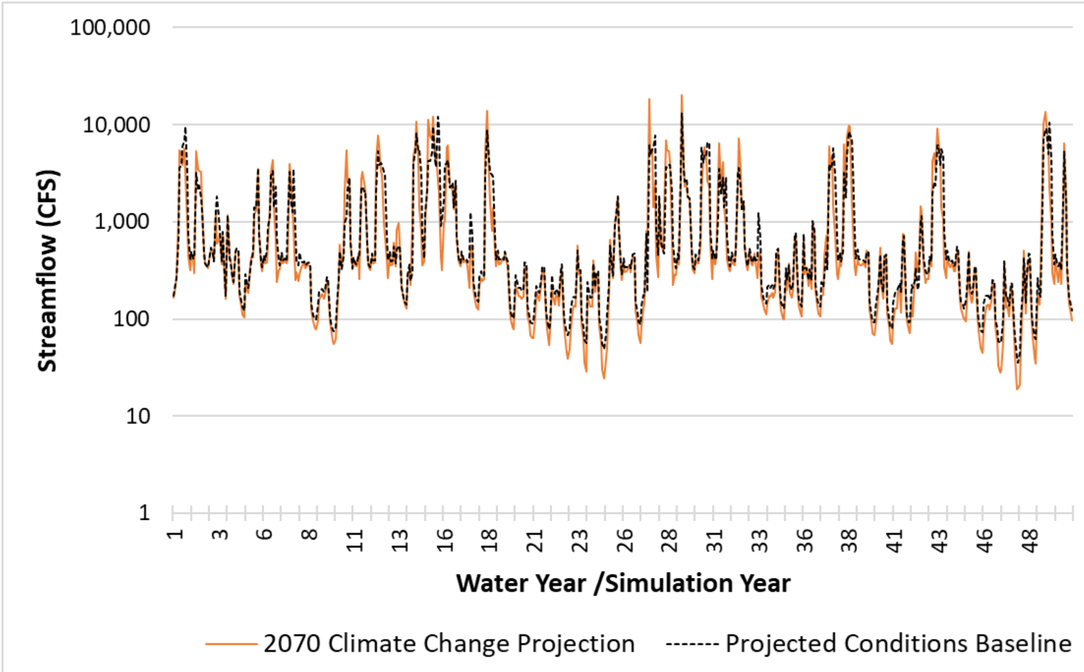


Figure 5-43: Tuolumne River Exceedance Curve

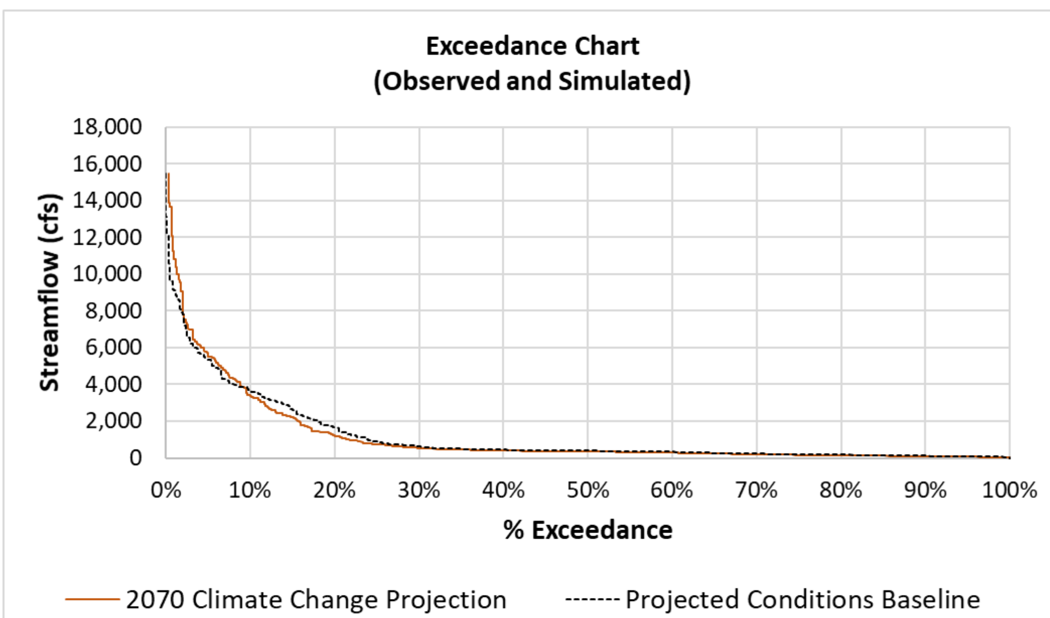


Figure 5-44: Stanislaus River Hydrograph

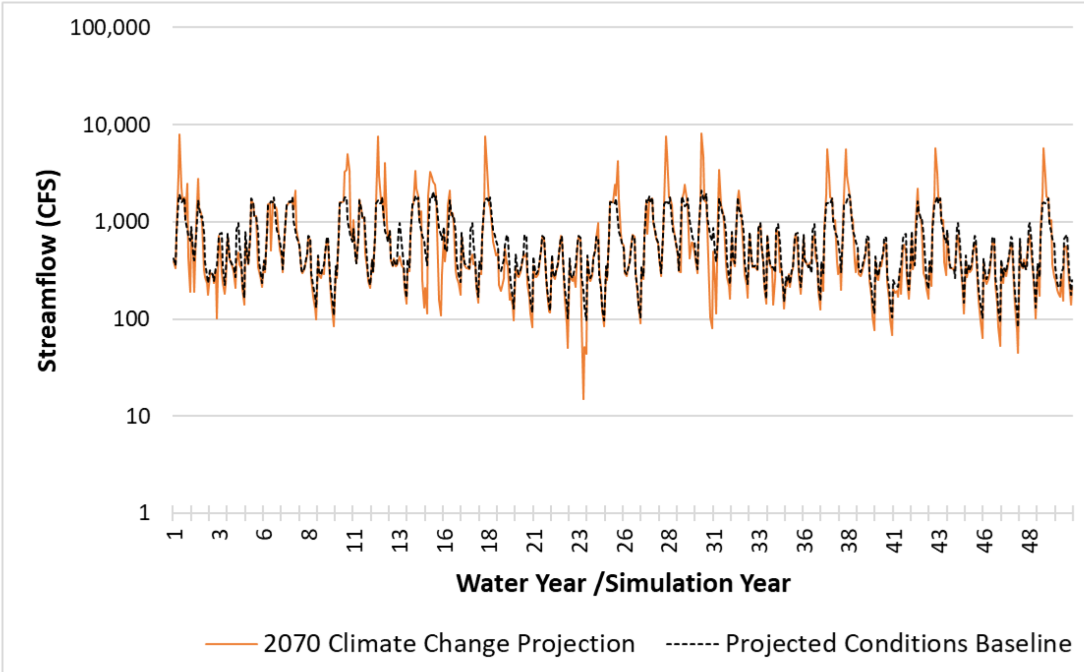
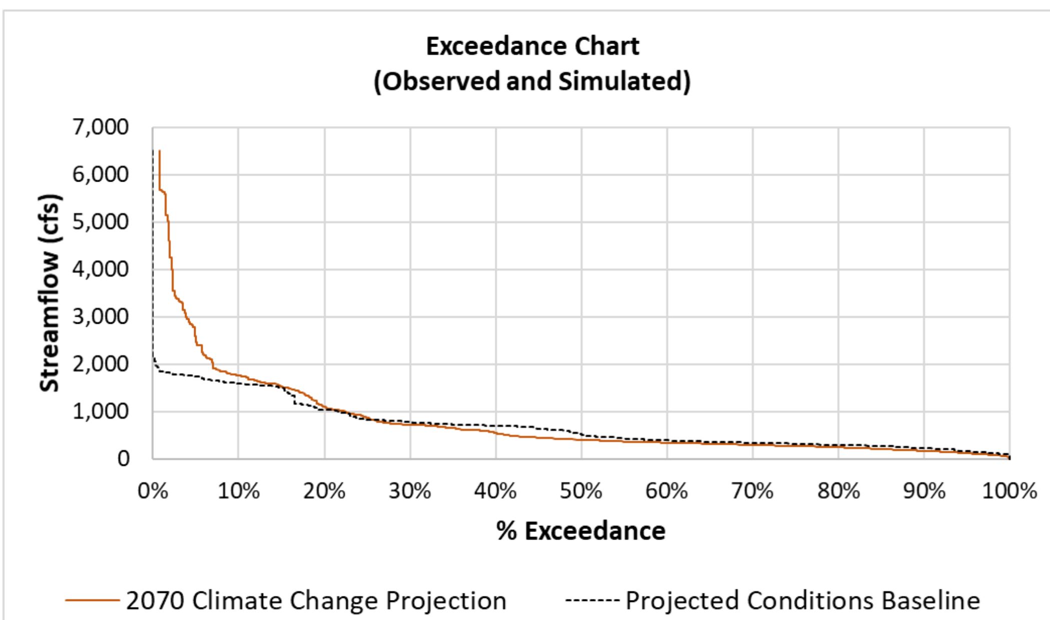


Figure 5-45: Stanislaus River Exceedance Curve



5.2.3.2. Precipitation and Evapotranspiration under Climate Change

Projected precipitation and evapotranspiration (ET) change factors provided by DWR were calculated using a climate period analysis based on historical precipitation and ET from January 1915 to December 2011 (DWR, 2018b). The Variable Infiltration Capacity (VIC) hydrologic model was used by DWR to simulate land-surface atmosphere exchanges of moisture and energy on a six-kilometer grid. Model output includes both precipitation and reference evapotranspiration change factors. The change factors provided by DWR were calculated as a ratio of a variable under a “future scenario” divided by a baseline. The baseline data is the 1995 Historical Template Detrended scenario by the VIC model through GCM downscaling. The “future scenario” corresponds to VIC outputs of the simulation of future conditions using GCM forecasted hydroclimatic variables as inputs. These change factors are thus a simple perturbation factor that corresponds to the ratio of a future with climate change divided by the past without it. Change factors are available on a monthly time step and spatially defined by the VIC model grid. Supplemental tables with the time series of perturbation factors are available by DWR for each grid cell. DWR has made accessible a Desktop GIS tool for both IWFM and MODFLOW to process these change factors (DWR, 2018c).

5.2.3.2.1. Applying Change Factors to Precipitation

DWR change factors were multiplied by projected conditions baseline precipitation to generate projected precipitation under the 2070 central tendency future scenario using the Desktop IWFM GIS tool (DWR, 2018c). The tool calculates an area weighted precipitation change factor for each model grid geometry. This model grid geometry was generated based on polygons built around the PRISM nodes that are within the model area.

However, the DWR tool only includes change factors through 2011. The remaining seven years of the time series were synthesized according to historically comparable water years (i.e., wet years were synthesized based on a wet year within the available time frame of the DWR tool). The perturbation factor from the corresponding month of the comparable year was applied to the baseline of the missing years (2012-2018) to generate projected values. Months with no precipitation in the baseline were assumed a monthly precipitation of 1 mm under climate change to account for increased precipitation that cannot be calculated from a baseline of 0 mm for these synthesized years. The comparable years that were used can be found in **Table 5-1101**.

Table 5-11: Comparable Water Years (Precipitation)

Missing Water Year	Comparable Water Year
2012	1968
2013	2007
2014	2002
2015	1971
2016	1981
2017	1993
2018	1987

The resulting perturbed precipitation values and the baseline precipitation values for the representative historical period can be found in **Figure 5-46** below. The exceedance plot for these two times series can be found in **Figure 5-47**.

Figure 5-46: Perturbed Precipitation Under Climate Change

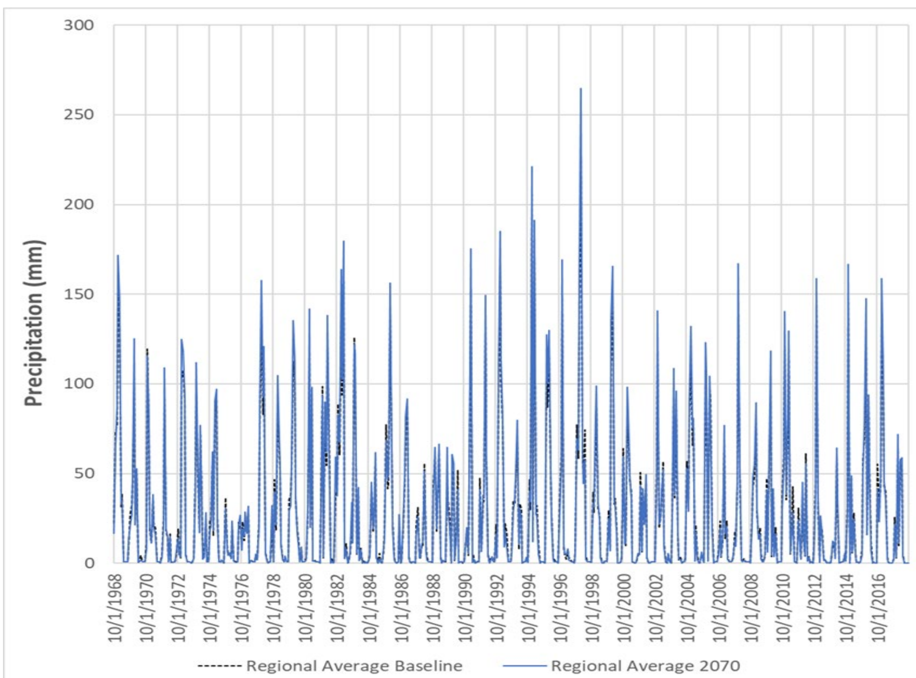


Figure 5-47: Perturbed Precipitation Exceedance Curve

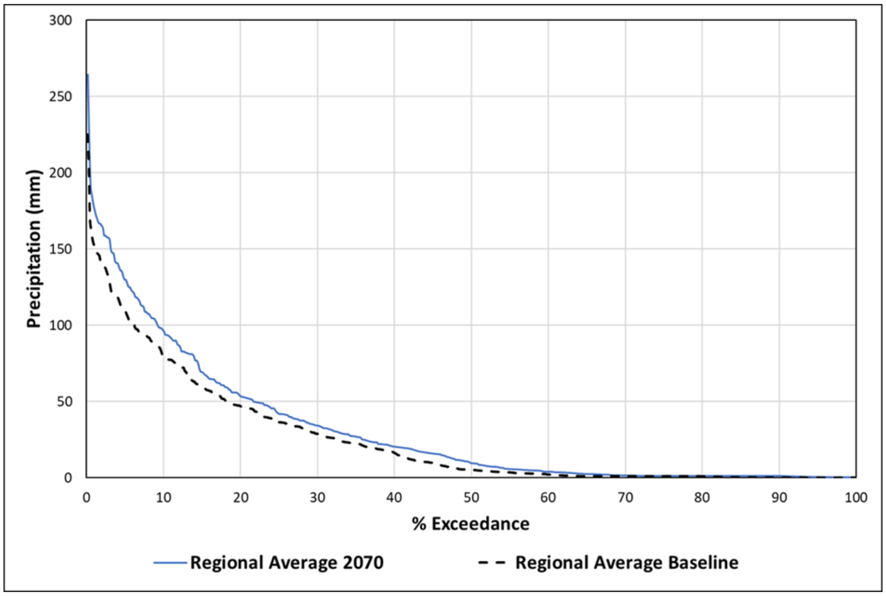


Figure 5-48 shows the difference between the regional average under 2070 climate change conditions and the regional average under projected conditions baseline plotted against different amounts of projected monthly precipitation. The average was taken across the area of the Modesto Subbasin.

Figure 5-48: Variation from Baseline of Perturbed Precipitation

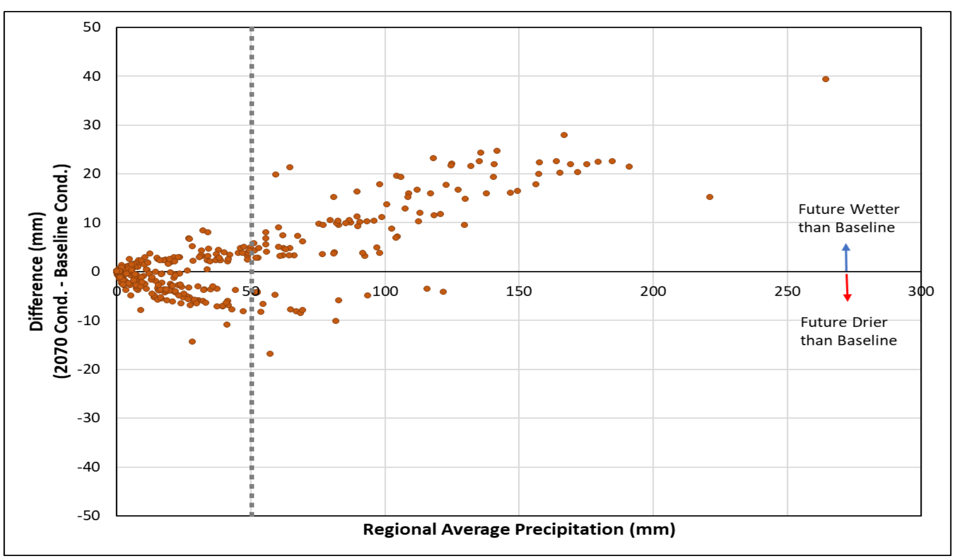
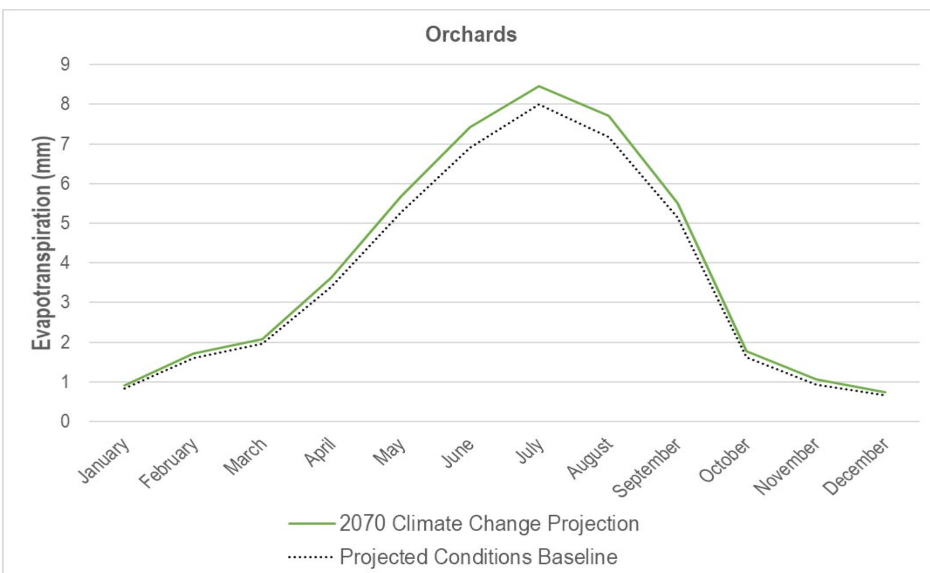


Figure 5-48 demonstrates that in 2070 with climate change added, in low precipitation months, there is approximately equal probability that the month will be wetter or drier than projected conditions baseline. However, under climate change, the 2070 conditions will be wetter in months with precipitation above approximately 50 mm, indicated by the vertical gray dashed line. Therefore, under climate change conditions (in the scenario selected for the GSP), we can see that the occurrence of low precipitation months will likely not change significantly, but the higher precipitation months are predicted to be wetter overall than the projected conditions baseline.

5.2.3.2.2. Applying Change Factors to Evapotranspiration

Potential ET in the Modesto Subbasin is aggregated to one of twenty-five land use categories but does not vary spatially. DWR provides change factors for ET in the same spatially distributed manner as precipitation, as described above. However, to match the level of discretization with the C2VSimTM, an average ET change factor was calculated across all VIC grid cells within the Modesto Subbasin boundary. Therefore, the tool to process ET provided by DWR was not needed or used. Change factors provided by DWR for November 1, 1964, through December 1, 2011, were averaged. This average ET change factor was then applied to the baseline ET time series for each crop type. Because the same ET change factor was applied over the entire baseline, no synthesis was required in this analysis. Refinement to the simulated evapotranspiration of orchards under 2070 climate conditions is shown in **Figure 5-49** below as an example. For 2070, the average change factor is 1.08.

Figure 5-49: Monthly ET for Sample Crops



5.2.3.3. Modesto Subbasin Water Budget Under Climate Change

A climate change scenario was developed for the C2VSimTM to evaluate the hydrological impacts under these conditions. The analysis was based on the projected conditions baseline with climate change perturbed inputs for streamflow, precipitation, and ET. Results are presented below in **Table 5-12** though **Table 5-14**.

Under the climate change scenario, the average annual volume of evapotranspiration is over six percent higher than the projected conditions baseline, increasing from 536,000 AFY to 568,000 AFY. Due to changes to local hydrology, the average annual surface water availability is projected to decrease by 1.6 percent from 293,000 AFY to 288,000 AFY.[11] As a result of less surface water and increased agricultural demands, private groundwater production is simulated to increase by approximately 14 percent, from 230,000 AFY to 262,000 AFY. Under climate change conditions, depletion in aquifer storage is expected to increase by more than half to an average annual rate of 17,000 AFY, from 11,000 AFY in the projected conditions baseline. This has an impact on the stream system and the net difference in stream-aquifer interactions, drawing 46,000 AFY on average from streamflow to the aquifer.

A graphical representation of simulated changes to evapotranspiration, surface deliveries, and groundwater pumping are presented in **Figure 5-50** though **Figure 5-52** below, and complete water budgets for the climate change scenario are shown in **Figure 5-53** though **Figure 5-55**.

[11] There are various approaches to estimating the effects of climate change on local hydrology. The 2070 Central Tendency used in this GSP according to DWR guidelines for GSP submittal may differ from local studies or certain Flood-MAR scenarios.

Figure 5-50: Simulated Changes in Evapotranspiration due to Climate Change (Scenario minus Baseline)

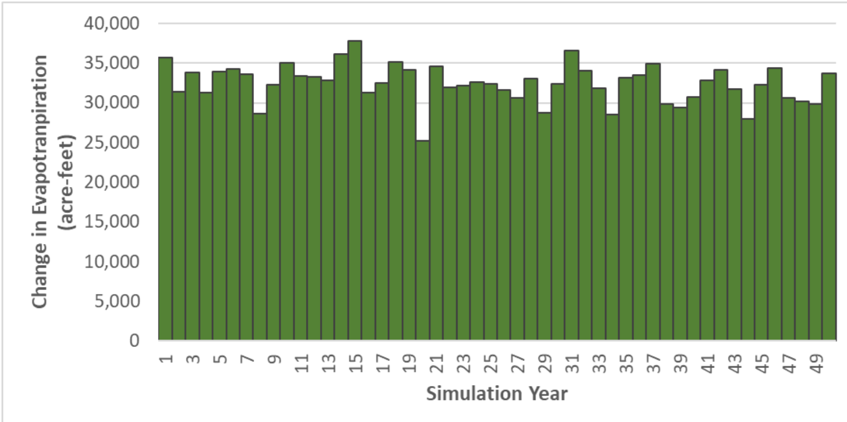


Figure 5-51: Simulated Changes in Surface Water Supplies due to Climate Change (Scenario minus Baseline)

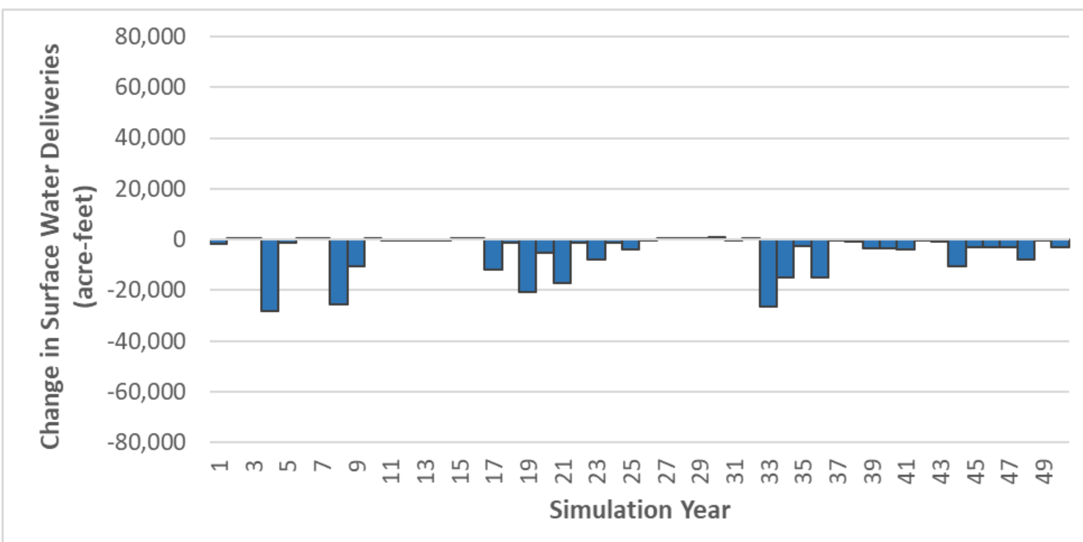


Figure 5-52: Simulated Changes in Groundwater Production due to Climate Change (Scenario minus Baseline)

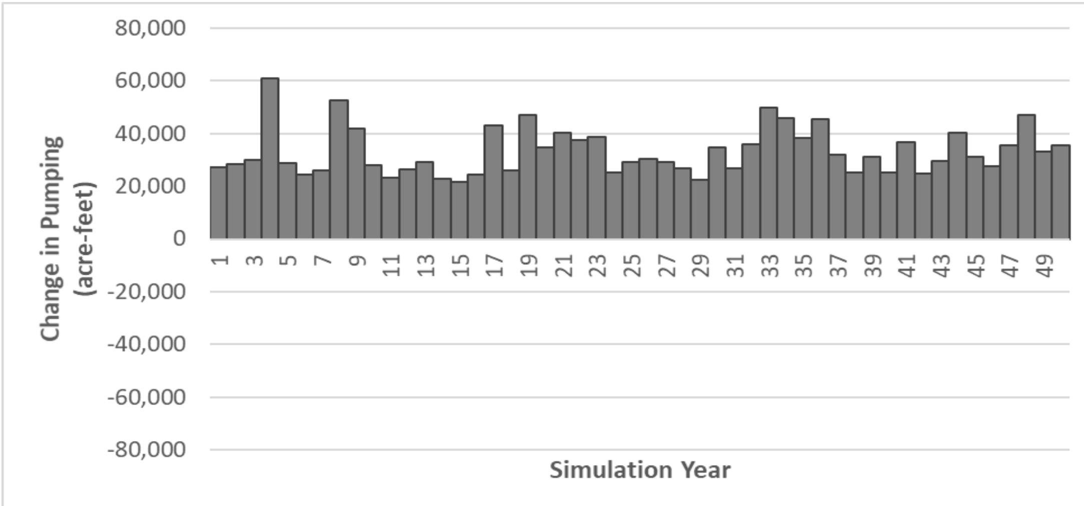


Figure 5-53: Agricultural Land and Water Use Budget – C2VSimTM Climate Change Scenario

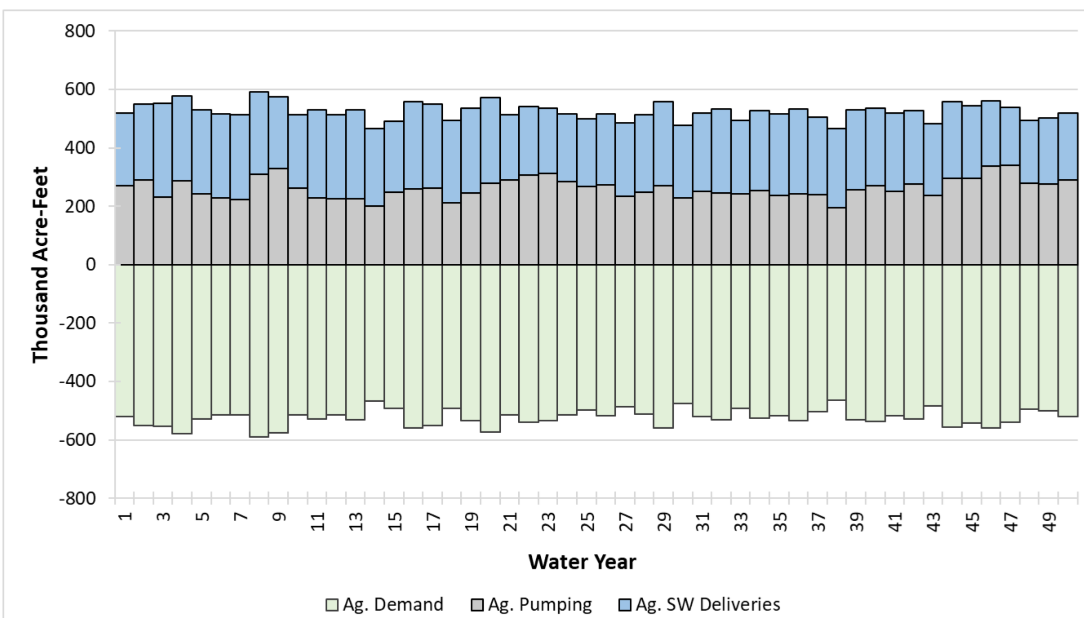


Figure 5-54: Urban Land and Water Use Budget – C2VSimTM Climate Change Scenario

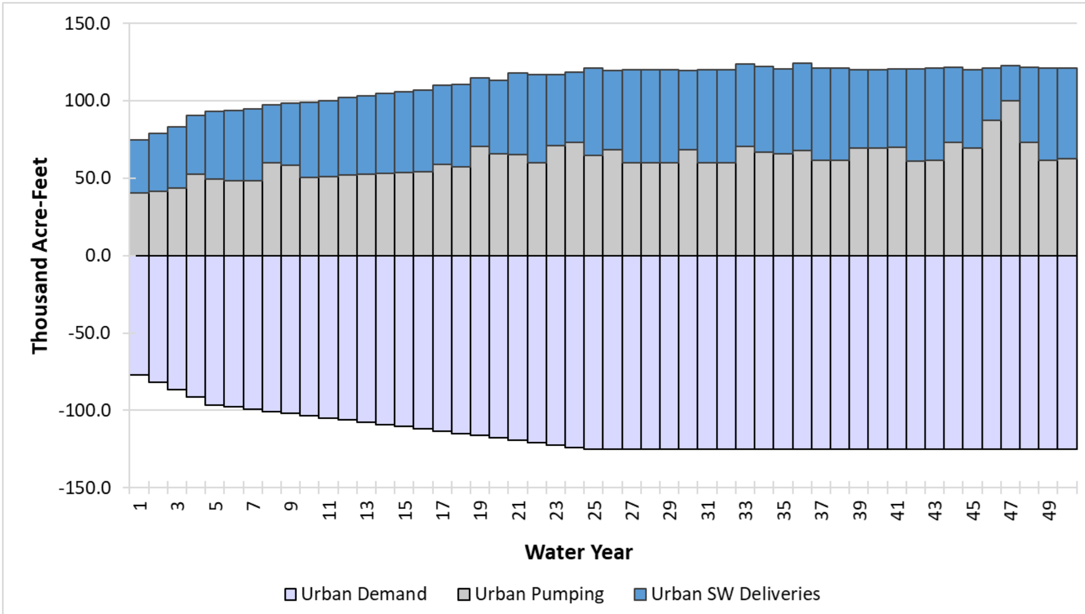


Figure 5-55: Groundwater Budget – C2VSimTM Climate Change Scenario

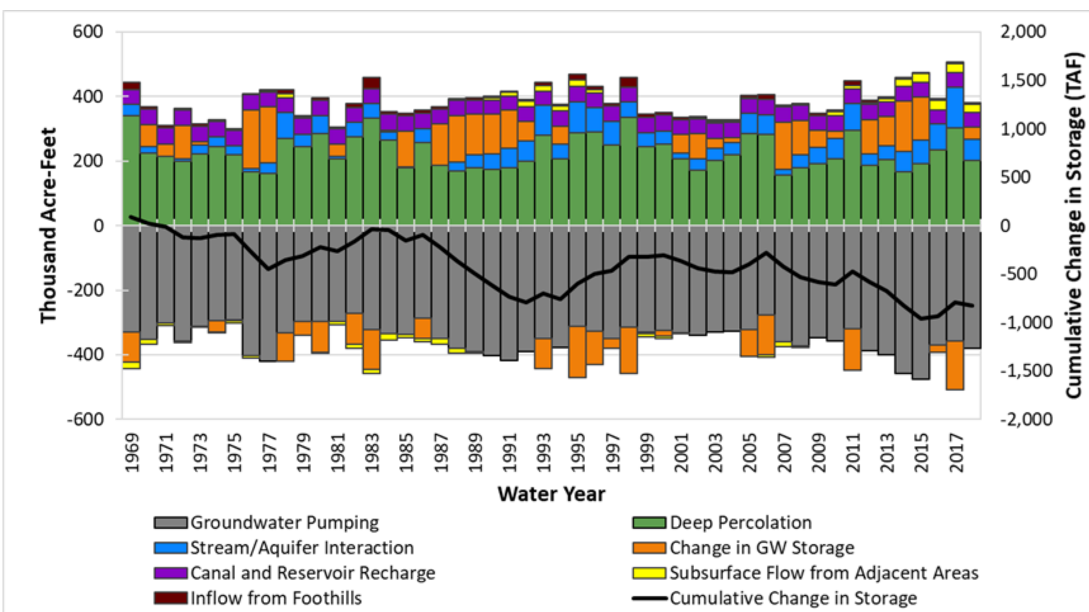


Table 5-12: Average Annual Water Budget Under Climate Change – Stream Systems, Modesto Subbasin (AFY)

Component	Projected Condition Water Budget	Climate Change Water Budget
Hydrologic Period	WY 1969 - 2018	WY 1969 - 2018
Stream Inflows	2,650,000	2,739,000
Stanislaus River	536,000	626,000
Tuolumne River	812,000	818,000
San Joaquin River	1,302,000	1,295,000
Tributary Inflow[1]	6,000	5,000
Stream Gain from Groundwater	104,000	96,000
Modesto Subbasin	50,000	45,000
Stanislaus River – South[2]	12,000	13,000
Tuolumne River - North	27,000	22,000
San Joaquin River - East	11,000	11,000
Other Subbasins	54,000	50,000
Stanislaus River - North	12,000	13,000
Tuolumne River - South	31,000	27,000
San Joaquin River - West	11,000	11,000
Surface Runoff to the Stream System[3]	60,000	72,000
Return Flow to Stream System[3]	113,000	114,000
Total Inflow	**2,934,000**	**3,025,000**
San Joaquin River Outflows	2,717,000	2,774,000
Diverted Surface Water[4]	33,000	33,000
Stream Seepage to Groundwater	146,000	177,000
Modesto Subbasin	76,000	91,000
Stanislaus River - South	36,000	44,000
Tuolumne River - North	38,000	45,000
San Joaquin River - East	2,000	2,000
Other Subbasins	71,000	86,000
Stanislaus River - North	31,000	39,000
Tuolumne River – South	38,000	45,000
San Joaquin River - West	2,000	2,000
Native & Riparian Uptake from Streams	37,000	41,000
Total Outflow	**2,934,000**	**3,025,000**

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

[1] Tributary inflow include surface water contributions from small watersheds

[2] Represents the location of the Modesto Subbasin relative to the stream, i.e., "North" represents the gains/losses of that stream to the Modesto Subbasin to the North.

[3] Includes runoff/return flow from all subbasins adjacent to the stream system, not just the Modesto Subbasin.

[4] Some surface water diversions are upstream of the Tuolumne River or Stanislaus River inflows and thus not included in this stream and canal water budget.

Table 5-13: Average Annual Water Budget Under Climate Change – Land Surface System, Modesto Subbasin (AFY)

Component	Projected Condition Water Budget	Climate Change Water Budget
Hydrologic Period	WY 1969 - 2018	WY 1969 - 2018
Agricultural Areas Precipitation	139,000	147,000
Agricultural Water Supply	497,000	525,000
Agency Surface Water	241,000	238,000
Agency Groundwater	25,000	25,000
Private Groundwater	230,000	262,000
Urban Areas Precipitation	38,000	40,000
Urban Water Supply	111,000	112,000
Groundwater	60,000	62,000
Surface Water	51,000	50,000
Native Areas Precipitation	92,000	97,000
Native & Riparian Uptake from Stream	22,000	24,000
Total Supplies	**900,000**	**945,000**
Agricultural ET	402,000	430,000
Agricultural ET of Precipitation	82,000	84,000
Agricultural ET of Surface Water	159,000	160,000
Agricultural ET of Agency Groundwater	16,000	17,000
Agricultural ET of Private Groundwater	146,000	170,000
Agricultural Percolation	201,000	202,000
Agricultural Percolation of Precipitation	45,000	46,000
Agricultural Percolation of Surface Water	75,000	70,000
Agricultural Percolation of Agency Groundwater	8,000	7,000
Agricultural Percolation of Private Groundwater	73,000	79,000
Agricultural Runoff & Return Flow	31,000	36,000
Urban Runoff & Return Flow	91,000	93,000
Urban ET	38,000	40,000
Urban Percolation	20,000	19,000
Native Runoff	12,000	15,000
Native ET	95,000	98,000
Native Percolation	7,000	8,000
Total Demands	**898,000**	**941,000**
Land Surface System Balance	2,000	4,000
Land Surface System Balance (% of supplies)	0.2%	0.4%

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

Table 5-14: Average Annual Water Budget Under Climate Change – Groundwater System, Modesto Subbasin (AFY)

Component	Projected Condition Water Budget	Climate Change Water Budget
Hydrologic Period	WY 1969 - 2018	WY 1969 - 2018
Gain from Stream	76,000	91,000
Gain from Stanislaus River	36,000	44,000
Gain from Tuolumne River	38,000	45,000
Gain from San Joaquin River	2,000	2,000
Canal & Reservoir Recharge	47,000	47,000
Deep Percolation	228,000	229,000
Subsurface Inflow	77,000	80,000
Flow from the Sierra Nevada Foothills	9,000	8,000
Eastern San Joaquin Subbasin Inflows	28,000	8,000
Turlock Subbasin Inflows	33,000	33,000
Delta Mendota Subbasin Inflows	7,000	32,000
Total Inflow	**428,000**	**446,000**
Discharge to Stream	50,000	45,000
Discharge to Stanislaus River	12,000	13,000
Discharge to Tuolumne River	27,000	22,000
Discharge to San Joaquin River	11,000	11,000
Subsurface Outflow	75,000	70,000
Eastern San Joaquin Subbasin Outflows	35,000	5,000
Turlock Subbasin Outflows	34,000	31,000
Delta Mendota Subbasin Outflows	6,000	35,000
Groundwater Production	314,000	347,000
Agency Ag. Groundwater Production	25,000	25,000
Private Ag. Groundwater Production	229,000	260,000
Urban Groundwater Production	60,000	62,000
Total Outflow	**438,000**	**463,000**
Change in Groundwater in Storage	(11,000)	(17,000)

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

5.2.3.4. Opportunities for Future Refinement

The climate change approach developed for this GSP is based on the methodology in DWR's guidance document (DWR, 2018b) and uses "best available information" related to climate change in the Modesto Subbasin. There are limitations and uncertainties associated with the analysis. One important limitation is that CalSim II does not fully simulate local surface water operations. Thus, the analysis conducted for this GSP may not fully reflect how surface and groundwater basin operations would respond to the changes in water demand and availability caused by climate change. For this first GSP iteration, use of a regional model and the perturbation factor approach were deemed appropriate given the uncertainties in the climate change analysis.

A recommendation for future refinements of this analysis is utilization of the local surface water operations model, the Tuolumne Reservoir Simulation (TRS) model. Use of this model would allow for greater resolution in the simulation of Tuolumne River flows and surface water supply based on local management. Additionally, utilization of TRS will allow for analysis of the localized climate conditions effecting snowpack and its implications on reservoir operations and streamflow. Further monitoring and adaptive management should be considered for the next update of the GSP along with improvements in DWR's climate change data.

5.3. SUSTAINABLE YIELD ESTIMATE

Sustainable yield is defined for SGMA purposes as "the maximum quantity of water, calculated over a base period representative of long-term conditions in the basin and including any temporary surplus, that can be withdrawn annually from a groundwater supply without causing an undesirable result." (CWC §10721(w)). Sustainable yield for the Modesto Subbasin was calculated through development of a C2VSimTM scenario in which the long-term (50-year) SGMA sustainability indicators are met either directly or by groundwater levels as a proxy as outlined in **Chapter 6: Sustainable Management Criteria**.

- **Reduction of Groundwater in Storage –** An Undesirable result is defined as significant and unreasonable reduction of groundwater in storage that would occur if the volume of groundwater supply is at risk of depletion and is not accessible for beneficial use, or if the Subbasin remains in a condition of long-term overdraft based on projected water use and average hydrologic conditions. in a manner that cannot be readily managed or mitigated.
- **Chronic Lowering of Groundwater Levels** – Undesirable results are defined as significant and unreasonable groundwater level declines – either due to multi-year droughts or due to chronic declines where groundwater is the sole supply – such that water supply wells are adversely impacted in a manner that cannot be readily managed or mitigated.
- **Depletion of Interconnected Surface Water –** An Undesirable Result is defined as significant and unreasonable adverse impacts to the beneficial uses of surface water caused by groundwater extraction.

The sustainable yield water budget is based on the Projected Conditions Baseline and is analyzed by reducing groundwater production through changes in the agricultural demand of the net groundwater extractors in Modesto Subbasin. Net-contributing and net-extracting users in the Subbasin are divided into the two groups shown in **Figure 5-56**. Group 1 users predominately rely on both surface and groundwater, while users in Group 2 predominantly rely on groundwater.

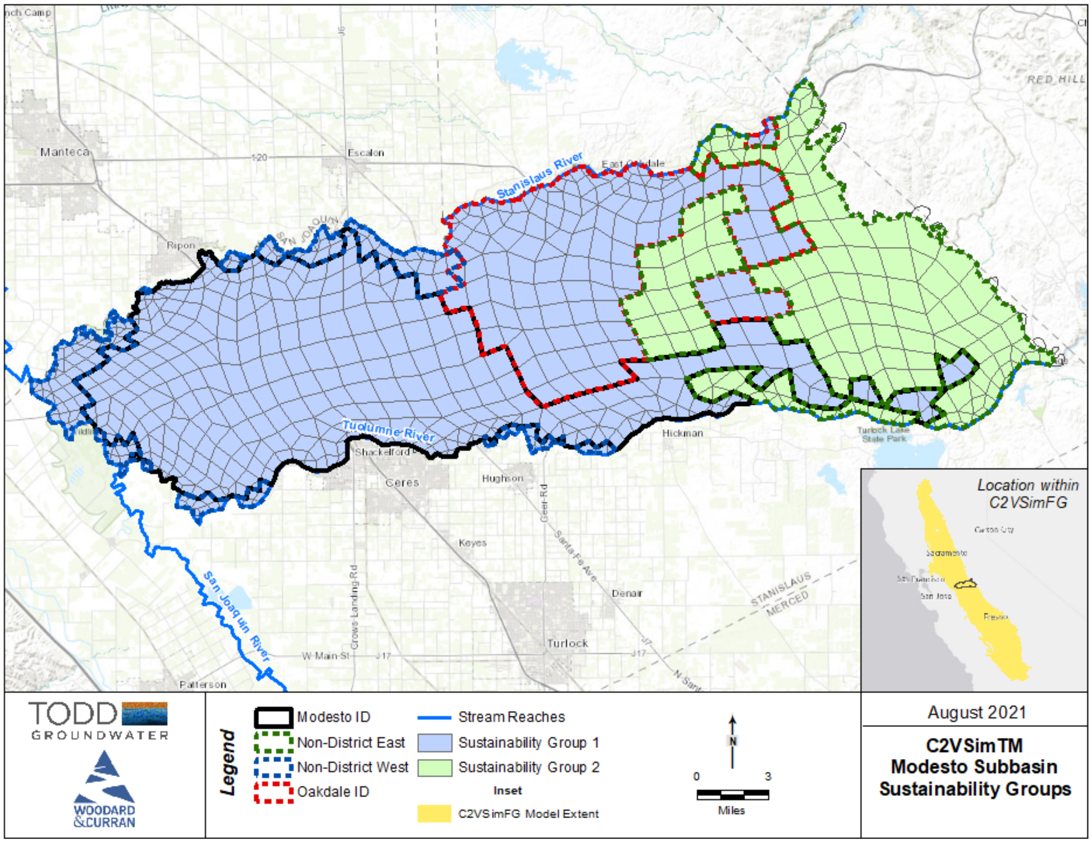
Group 1: Surface and Groundwater Users

- Modesto Irrigation District
- Oakdale Irrigation District
- Non-District West (riparian surface water users)

Group 2: Groundwater Only Users

- Non-District East

Figure 5-56: Modesto Subbasin Sustainability Groups



The Sustainable Yield Scenario varies from the Projected Conditions Baseline in its volume of agricultural water demand. These demands were reduced by decreasing agricultural land use via a global reduction in projected cropped acreage at the element level.

The sustainable yield water budget is intended to estimate future supply, demand, and aquifer response in the Modesto Subbasin under sustainable conditions achieved with a demand reduction scenario. To meet the goals set forth by the sustainability indicators listed above, Group 2 agricultural users would need to reduce demand by 58-percent from the projected baseline levels. This reduction in groundwater usage results in a sustainable yield of approximately 267,000 acre-feet per year for the Subbasin.

The methodology for reducing Subbasin-wide pumping to estimate sustainable yield is developed solely to estimate the subbasin's sustainable yield and is not intended to prescribe or describe how pumping would be reduced in the basin during GSP implementation to achieve sustainability. The reduction of groundwater demand to sustainable levels would be implemented in close coordination among the various Subbasin zones. The groundwater demand reduction is only one and/or part of the overall management actions that would result in groundwater sustainability within the Subbasin; factors such as water rights, beneficial uses, needs, and human right to water should also be considered. The status of plans for implementing management actions related to pumping reductions is further discussed in **Chapter 8 - Projects and Management Actions**.

Table 5-15 provides a detailed listing of the water flow components of the Modesto Subbasin's groundwater system for the historical, projected conditions baseline and sustainable yield conditions. To achieve sustainability and maintain minimum groundwater level thresholds, the Subbasin needs to experience an average annual net gain of groundwater in storage of 11,000 AFY. These conditions are met through 213,000 AFY of deep percolation, 47,000 AFY of canal and reservoir recharge, and 20,000 AFY of net subsurface inflow from the Sierra Nevada foothills and the neighboring Turlock, Delta-Mendota, and Eastern San Joaquin Subbasins. Outflows from the subbasin include 266,000 AFY of pumping and 14,000 AFY of net groundwater discharge to the surface water bodies. The major flow components are represented graphically in **Figure 5-57** and **Figure 5-58**, on an annual and average annual basis.

Figure 5-59 and **Figure 5-60** show the groundwater recharge and extraction and net recharge for the Modesto Subbasin. Under sustainable conditions, the Modesto Subbasin is expected to maintain an average net extraction of 7,000 AFY, compared to a net extraction of 39,000 AFY under projected conditions. This reduction in net extraction is attributed to the reduction of groundwater pumping, which is reduced from 314,000 AFY under the Baseline to 267,000 AFY under sustainable yield, combined with an overall reduction in percolation of agricultural applied water of 14,000 AFY between the two scenarios.

Table 5-15: Sustainable Yield Average Annual Water Budget Groundwater System – Modesto Subbasin

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 in Storage	(11,000)	-

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

Figure 5-57: Sustainable Yield Average Annual Water Budget Groundwater System – Modesto Subbasin

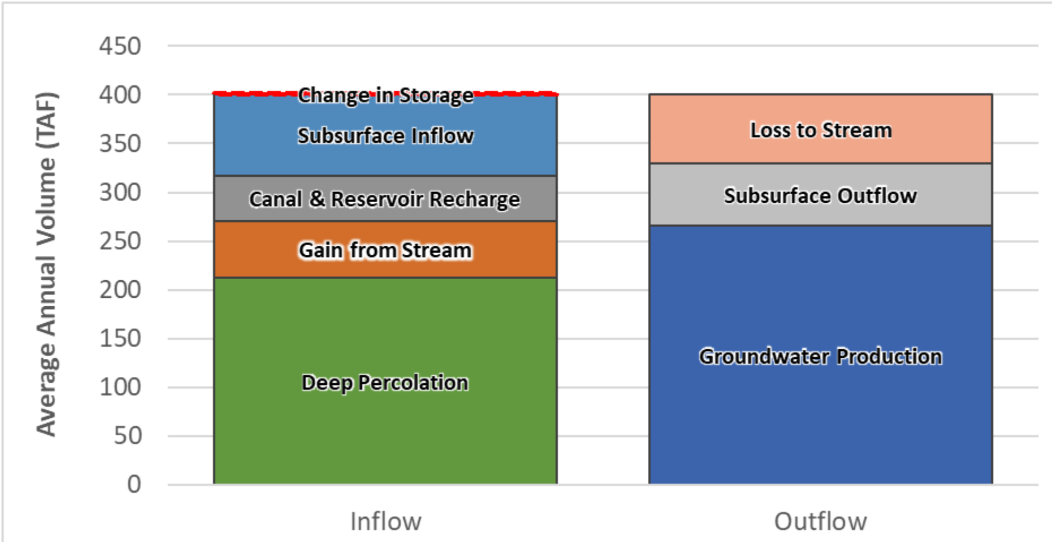


Figure 5-58: Sustainable Yield Water Budget Groundwater System – Modesto Subbasin

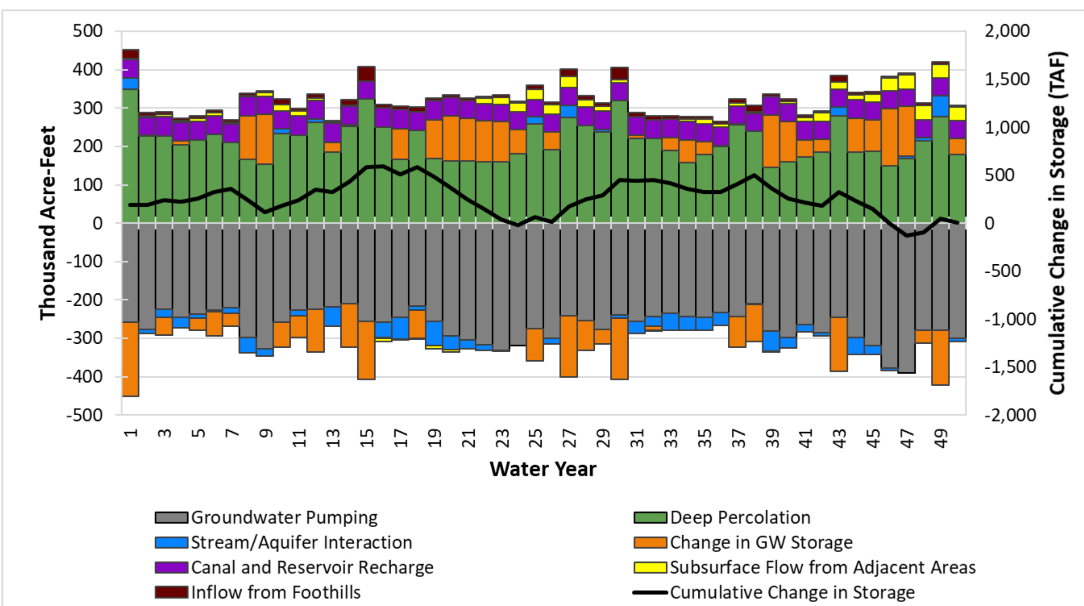


Figure 5-59: Sustainable Yield Water Budget Groundwater Recharge and Extraction – Modesto Subbasin

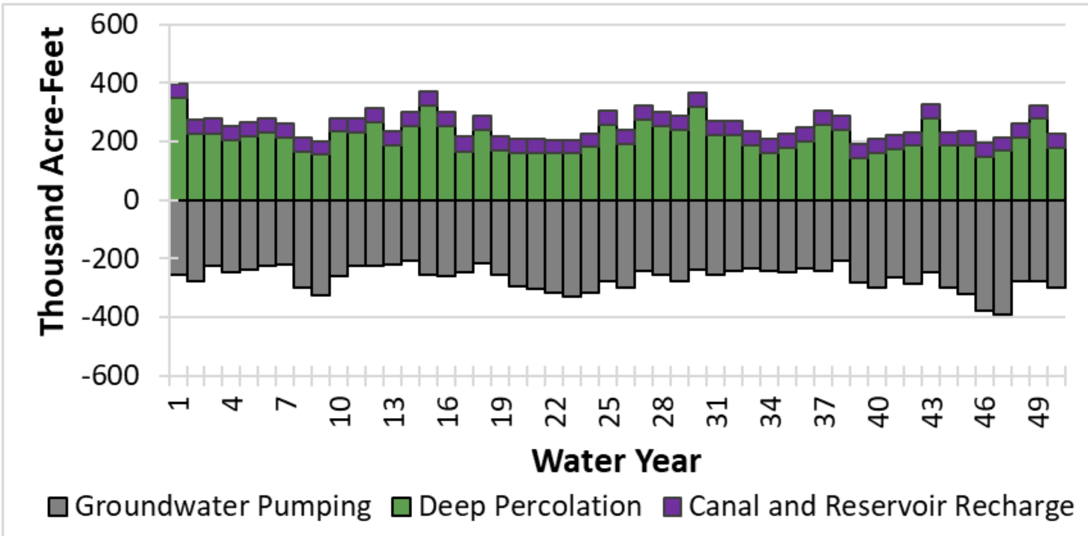
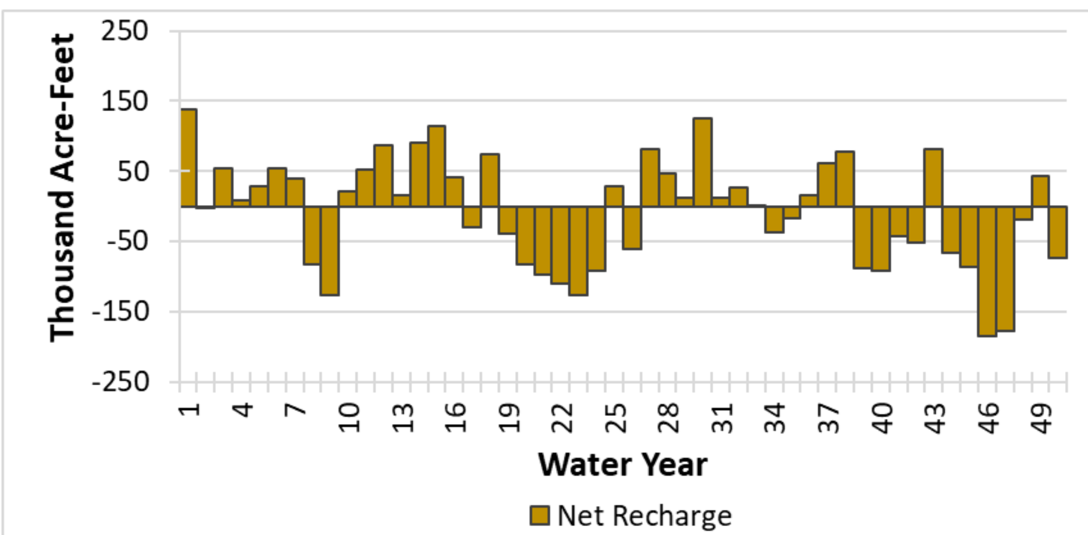


Figure 5-60: Sustainable Yield Water Budget Net Recharge – Modesto Subbasin



SUMMARY

The sustainable yield of the Modesto Subbasin is developed by methodically reducing groundwater demand for the net groundwater extractors (Sustainability Group 2) in the Subbasin. The goal of this groundwater demand reduction is to reduce groundwater pumping to a level that would result in no undesirable results if continued in the long-term. The presence of undesirable results is evaluated by analyzing sustainability indicators produced by the numerical model, including groundwater in storage, groundwater levels, and interconnected stream systems. It is assumed that by using groundwater levels as proxy for other applicable sustainability indicators (i.e., groundwater quality and land subsidence), the sustainable yield would address all applicable sustainability indicators in the Modesto Subbasin.

This analysis results in a sustainable yield of 267,000 AFY for the Modesto Subbasin.

The sustainable yield is based on the current and latest data and information for the subbasin. It is expected that the sustainable yield estimate would be updated for the next GSP update in 2027, as additional data and information become available on the operation of the Subbasin, implementation of projects and management actions, groundwater levels, storage, and quality, and as updates to the tools and technology, such as updates to the integrated numerical model are implemented.

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6. SUSTAINABLE MANAGEMENT CRITERIA

GSP regulations provide a framework for locally-defined and quantitative *sustainable management criteria*, which allows the GSAs to quantitatively measure and track ongoing sustainable management. These criteria include a sustainability goal, which has been developed as a mission statement for the GSP. Additional criteria include specific terminology from SGMA; a brief summary[12] of these terms – and the application of each – are provided below:

- Undesirable Results (URs[13]) – significant and unreasonable adverse conditions for any of the six sustainability indicators defined in the GSP regulations.
- Minimum Threshold (MT^2) – numeric value used to define undesirable results for each sustainability indicator at representative monitoring sites.
- Measurable Objective (MO^2) – numeric goal to track the performance of sustainable management at representative monitoring sites.
- Interim Milestone (IM^2) – target numeric value representing measurable groundwater conditions, in increments of five years, as set by the GSAs as part of the GSP.

Collectively, these criteria define sustainable groundwater management by:

- quantifying groundwater conditions to avoid, along with associated warning signs (URs and MTs);
- identifying favorable groundwater conditions and operational parameters (MOs); and
- providing targets for monitoring Subbasin progress toward achieving the sustainability goal (MTs, MOs, and IMs).

6.1. SUSTAINABILITY GOAL

A sustainability goal provides a mission statement for what the GSAs wish to achieve through sustainable management. GSP regulations provide requirements for a GSP Sustainability Goal, as follows:

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[12] Sustainable management criteria are more fully defined in SGMA (CWC 10721(a) – (ab) and GSP regulations (§351(a) – (an)).

[13] Because of the frequency of use, and to facilitate review of the text, the terms “undesirable results” “minimum threshold,” “measurable objective,” and “interim milestone” are abbreviated as “UR”, “MT”, “MO”, and “IM” respectively, throughout remaining sections of the GSP. However, the terms are spelled out in un-abbreviated form where helpful for context and clarity or when contained in a direct quotation.

> Each Agency shall establish in its Plan a sustainability goal for the basin that culminates in the absence of undesirable results within 20 years of the applicable statutory deadline. The Plan shall include a description of the sustainability goal, including information from the basin setting used to establish the sustainability goal, a discussion of the measures that will be implemented to ensure that the basin will be operated within its sustainable yield, and an explanation of how the sustainability goal is likely to be achieved within 20 years of Plan implementation and is likely to be maintained through the planning and implementation horizon. (§354.24).

In the Best Management Practices (BMPs) document on sustainable management criteria, DWR recommends that one succinct, common sustainability goal be developed for the entire Subbasin.

The requirements and guidance for a GSP sustainability goal were reviewed in a public meeting of the STRGBA GSA Technical Advisory Committee (TAC) in February 2021. That meeting was followed with a technical memorandum prepared by the technical team, in part, to assist TAC members with development of a goal. The memorandum summarized GSP requirements and how the sustainability goal fits within the overall sustainable management criteria process.

Based on TAC feedback, DWR guidance, and GSP requirements, the TAC Planning Group[14] developed a draft sustainability goal reviewed by the TAC at a public meeting on May 12, 2021. At that meeting, additional comments on the sustainability goal were received from stakeholders and TAC members. Those comments were incorporated into the draft sustainability goal presented below.

The Sustainability Goal of the Modesto Subbasin GSP *is to provide a sustainable groundwater supply for the local community and for the economic vitality of the region. Groundwater levels, storage volume, and quality will be actively managed by the STRGBA GSA to:*

- ***Operate the Subbasin within its sustainable yield to support beneficial uses including municipal, domestic, agricultural, industrial, and environmental;***
- ***Maintain a reliable, accessible, and high-quality groundwater supply, especially during droughts;***
- ***Manage groundwater levels such that beneficial uses of interconnected surface water are not adversely impacted by groundwater extractions;***
- ***Optimize conjunctive management of local surface water and groundwater resources;***
- ***Avoid adverse impacts from future potential land subsidence associated with groundwater level declines;***

[14] The TAC Planning Group is a small working group composed of representatives from the TAC to guide the GSP process and provide recommendations to the full TAC.

- ***Cooperate and coordinate with GSAs in neighboring subbasins to avoid undesirable results along the shared Subbasin boundaries.***

This goal will be achieved within the 20-year implementation period and maintained throughout the planning horizon through a robust monitoring program and a series of projects and management actions that involve groundwater recharge, in lieu surface water use, conservation, stormwater management, and other strategies to be developed and modified over time through adaptive management.

The sustainability goal is supported by information provided in GSP chapters on the plan area (**Chapter 2**) and basin setting (**Chapters 3** and **5**). Specific information used to inform the sustainability goal included the identification of land and water use in the Subbasin (**Chapter 2**), ongoing conjunctive management of surface water and groundwater (**Chapter 2.**), delineation of the base of fresh water and groundwater in storage (**Section 3.1.3**), the establishment of Principal Aquifers (**Section 3.1.4**), groundwater conditions (**Sections 3.2**), and historical and projected water budgets (**Chapter 5**). Additional considerations of basin conditions that support the sustainability goal are described in the following section.

6.2. SELECTION OF SUSTAINABLE MANAGEMENT CRITERIA

Six sustainability indicators are defined in the GSP regulations to represent groundwater conditions that, when determined to be significant and unreasonable, cause undesirable results. The avoidance of undesirable results is the foundation for sustainable groundwater management. Accordingly, these sustainability indicators are analyzed in the Modesto Subbasin to define undesirable results and other sustainability criteria, including MTs, MOs, and IMs. A representative monitoring network is established for each applicable indicator to track these conditions throughout the implementation and planning horizon.

Those six indicators and their associated icons developed by DWR are illustrated below.

Chronic Lowering of Water Levels	**Reduction of Groundwater in Storage**	**Seawater Intrusion**	**Degraded Water Quality**	**Inelastic Land Subsidence**	**Depletion of Inter-connected Surface Water**

6.2.1. Sustainability Considerations in the Modesto Subbasin

As explained in subsequent sections, this GSP analyzes conditions related to the six sustainability indicators that support definitions for undesirable results. SGMA legislation states that the GSAs are not required to address undesirable results that occurred before – and have not been corrected by – January 1, 2015 (§10727.2 (b)(4)). Accordingly, the focus for several indicators is to avoid future conditions that could lead to undesirable results.

Basin conditions as of 2015 and management considerations for each sustainability indicator are summarized in **Table 6-1**, along with the respective GSP section where each indicator is analyzed. General locations for the conditions described in the table are shown on **Figure 6-1** with certain areas highlighted by the sustainability indicator icons for reference.

Table 6-1: Sustainability Considerations for Modesto Subbasin

Basin Conditions	Undesirable Results in Modesto Subbasin as of 2015?	Management Considerations	GSP Sect.
Declining water levels are occurring, primarily in the eastern Subbasin. Other local areas experienced water level declines during drought.	Yes	Adverse impacts to public and domestic water supply wells caused by declining water levels. Water levels will be managed to avoid future impacts.	**6.3**
Overdraft conditions, primarily in areas where groundwater is the primary source of supply.	Yes	Over-pumping in certain areas has caused water level declines, which impact beneficial uses of both groundwater and surface water. GSP will arrest overdraft conditions.	**6.4**
Not applicable to this inland Subbasin.	No	None	**6.5**
Groundwater concentrations for certain constituents of concern are exceed drinking water standards over widespread areas of the Subbasin. Groundwater extractions, GSA projects, and GSA management actions may have the potential to degrade water quality in the future.	No	Historical water quality impacts have not been caused by GSA management activities, and therefore are not undesirable results as defined in this GSP. GSAs need to manage Subbasin groundwater so as not to further degrade groundwater quality.	**6.6**
No documented impacts from land subsidence in Subbasin; potential for compressible clays to cause land subsidence in the future.	No	If groundwater levels are managed at or near historic low levels, the potential for future undesirable results can be avoided.	**6.7**
Streamflow depletions have increased over time, especially on the Tuolumne and Stanislaus rivers. All 3 river boundaries remain interconnected, and no current impacts to surface water rights have been identified. Modeling predicts increased depletions in the future.	No	GSAs are not responsible for correcting conditions before 2015. However, modeling projects future streamflow depletions that may lead to undesirable results. GSAs will manage water levels to reduce future increases in streamflow depletions.	**6.8**

As indicated in **Table 6-1**, the Modesto Subbasin has experienced undesirable results associated with chronic lowering of water levels and reduction of groundwater in storage. These conditions have occurred primarily within and around the Non-District East Management Area (NDE MA) as shown on **Figure 6-1**. Over the historical study period, agricultural production has expanded in the eastern Subbasin where groundwater is the primary source of water supply. Over-pumping in this area has led to water level declines expanding into other areas, which exacerbated conditions during the 2014-2016 drought and caused impacts to both public and domestic water supply wells. During this time, more than 150 domestic wells failed (indicated on **Figure 6-1** by the small black dots). As explained in **Section 6.3**, most of the impacted wells appear to have been replaced with deeper wells. Nonetheless, some wells remain vulnerable to future multi-year droughts, including two areas highlighted on **Figure 6-1**.

As indicated in **Table 6-1**, the GSAs have determined that the seawater intrusion sustainability indicator, as described in GSP regulations, does not apply to the Modesto Subbasin; as such, no sustainable management criteria have been selected for this indicator (see **Section 6.5**).

As indicated in **Table 6-1**. undesirable results have not been experienced for the degraded water quality sustainability indicator even though numerous constituents of concern have been detected above drinking water standards over time. Undesirable results for this indicator refer to water quality impacts specifically *caused* by GSA management (see **Section 6.6.1**), which has not yet been initiated. The water quality icon on **Figure 6-1** is located in the City of Modesto where water quality is actively managed through groundwater extractions, wellhead treatment, and other operational strategies. Future GSA management will focus on protection against further degradation that could be caused by GSA activities.

As indicated in **Table 6-1**, no impacts from land subsidence have been observed in the Subbasin. However, basin conditions indicate that land subsidence could occur if water levels continue to decline. Compressible clay layers within and below the Corcoran Clay have been associated with land subsidence in other portions of the Central Valley. Areas within the extent of the Corcoran Clay are highlighted on **Figure 6-1** as most susceptible to land subsidence.

The Stanislaus, Tuolumne, and San Joaquin rivers are all interconnected surface water as defined by SGMA (see icons on **Figure 6-1**). Projected water budget analyses indicate increased streamflow depletion will occur in the future, which could lead to undesirable results unless water level declines are arrested (see **Section 6.8**).

The overall process for developing sustainable management criteria is discussed in the following section. Subsequent sections document the sustainable management criteria for each sustainability indicator (**Section 6.3** through **6.8**).

6.2.2. Public Process for Sustainable Management Criteria

An interactive and public process was established by the STRGBA GSA to develop sustainable management criteria for the Modesto Subbasin. The Tuolumne GSA participated through an agreement with Stanislaus County, a member agency of the STRGBA GSA. The STRGBA GSA formed a technical advisory committee (TAC) composed of GSA member agencies, who reviewed and commented on technical presentations throughout the GSP development process. The TAC formed a small planning group to guide development of technical analyses to support the process.

TAC meetings generally followed the monthly STRGBA GSA meetings (typically held on the 2nd Wednesday of each month at 1:30pm). The STRGBA GSA Chair led the TAC public meetings – with input from stakeholders – for development of recommended sustainable management criteria to be incorporated into the GSP. TAC meetings were held according to the Brown Act and technical presentations on sustainable management criteria were typically posted on the STRGBA GSA website prior to the meetings. In general, presentations provided information on the following topics relating to sustainable management criteria:

- requirements from the GSP regulations,
- relevant hydrogeological conditions in the Modesto Subbasin,
- recommendations from the DWR BMP on Sustainable Management Criteria, and
- examples from adjacent or other relevant subbasins.

Steps taken during this process were provided in a technical memorandum in February 2021 – information from which has been incorporated into this GSP chapter. The steps are summarized below:

1. Analyze the <u>six Sustainability Indicators,</u> applying conditions from the Basin Setting.
2. Define <u>Undesirable Results (URs)</u> as specific groundwater conditions to avoid.
3. Assign <u>minimum threshold (MTs)</u> for each indicator as a metric that can be used to define undesirable results.
4. Select <u>measurable objectives (MOs)</u> for each indicator as an operational target metric to avoid operating too close to the MT and to avoid undesirable results.
5. Develop i<u>nterim milestones (IMs)</u> that show progress toward each MO over the 20-year planning horizon.
6. Develop a <u>Sustainability Goal</u> that culminates in the absence of undesirable results (**Section 6.1**).

The sustainability indicators were introduced at the public GSP kickoff meeting on September 12, 2018 and were considered during development of the technical portions of the Plan Area (**Chapter 2**) and basin setting (**Chapters 3 and 5**). A TAC meeting focused solely on the sustainable management criteria was held on November 13, 2019, when the TAC considered examples of sustainable management criteria from neighboring subbasins.

Historical water budgets, zone budgets, and projected future water budgets were developed, presented, and discussed throughout 2020 (see details on the water budgets in **Chapter 5**).

More than 15 public TAC meetings were focused on sustainable management criteria, monitoring networks, and management areas. During these meetings, undesirable results were established, and MTs and MOs were selected. Sustainable management criteria, including undesirable results, MTs and MOs were quantified for each representative monitoring site for all three principal aquifers and the four management areas.

6.2.3. Management Areas

Regulations allow for the establishment of management areas within a Subbasin to facilitate implementation of the GSP. A management area can be operated differently from the others and can also define different sustainable management criteria. The GSP must explain the reason for creating each management area and provide rationale for the proposed operation of each; in particular, operation of one management area cannot cause undesirable results in other areas.

In the Modesto Subbasin management areas have been developed to facilitate GSP implementation of projects and are based on areas of similar water supplies and similar ongoing water management activities. Four management areas have been established in the Modesto Subbasin as shown on **Figure 6-2** and listed below (approximate acres as calculated in GIS):

- Modesto ID Management Area (101,914 acres)
- Oakdale ID Management Area (49,893 acres)
- Non-District East Management Area (77,218 acres)
- Non-District West Management Area (15,777 acres)

Boundaries of the first two management areas coincide with the current service area boundaries of Oakdale ID and Modesto ID (**Figure 6-2**). These areas also include most of the urban areas within the Subbasin including Modesto, Oakdale, most of Waterford, and parts of Riverbank. In these two management areas, surface water is available for conjunctive use and supplements groundwater supply for beneficial uses. Specifically, Oakdale ID conjunctively manages Stanislaus River water and groundwater within the Oakdale ID Management Area. Similarly, Modesto ID manages Tuolumne River water and groundwater conjunctively throughout the Modesto ID Management Area.

Surface water supply in these management areas was originally developed for agricultural uses but has been expanded over time to also provide drinking water supplies (e.g., City of Modesto) or non-potable urban uses. As a result, close coordination and partnerships already exist between STRGBA GSA member agencies within the Modesto ID and Oakdale ID management areas. Delineation of management areas coincident with current Modesto ID and Oakdale ID service area boundaries allow for seamless coordination of ongoing management activities with new management responsibilities under SGMA.

The Non-District East Management Area and Non-District West Management Area are located on lands outside of the two large irrigation district boundaries where management is currently coordinated through Stanislaus County[15] as a member agency of the STRGBA GSA. The Non-District West Management Area is the smaller of the two and contains lands between the rivers and Modesto ID and Oakdale ID management areas along the rim of the western Subbasin. Surface water is also available in this management area through riparian rights along the river boundaries. Delineation of these lands as a separate management area combines areas of similar water supply activities in the western Subbasin to facilitate GSA management.

The Non-District East Management Area is defined as lands in the eastern Subbasin outside of the Oakdale ID and Modesto ID management areas. Unlike the other management areas, surface water has not been widely available for water supply; groundwater has served as the primary water supply for the expanding agricultural production in the Non-District East Management Area.

As described above and explained in more detail in subsequent sections of **Chapter 6**, the Non-District East Management Area is the primary area with declining water levels in the Subbasin. Accordingly, projects and management actions are prioritized for this management area in order to achieve the Subbasin's Sustainability Goal.

Most of the infrastructure required for GSP projects will need to be developed in the Non-District East Management Area by local landowners. The Non-District East Management Area will need to develop agreements and partnerships with both the Modesto ID and the Oakdale ID management areas to bring additional water supply into the area.

As indicated by the information above, the delineation of management areas shown on **Figure 6-2** facilitates the future management activities anticipated by the GSP.

6.2.4. Organization of Sustainability Indicators

Each sustainability indicator is discussed separately in **Sections 6.3** through **6.8** below. Information within each of these sections is organized similarly and tracks the order of GSP requirements provided in *Subarticle 3. Sustainable Management Criteria*. Headings and subheadings in the subsequent sections are as follows:

- Introduction including regulatory definitions
- Definition of Undesirable Results along with quantitative criteria that are used to define when and where undesirable results would occur.
    - Causes of Undesirable Results

[15] As mentioned previously, Stanislaus County also represents the Tuolumne GSA by agreement.

    - Potential Effects on Beneficial Uses and Users of Groundwater
- Quantification of minimum thresholds (MTs) followed by the six requirements for MT analysis in the regulations
    - Justification and support for MTs
    - Relationship of MTs to other sustainability indicator MTs and how GSAs determined that undesirable results would be avoided
    - Impacts of MTs on adjacent subbasins
    - Effects of MTs on beneficial uses and users of groundwater
    - Consideration of State, Federal, or local standards in MT Selection
    - Quantitative measurement of MTs
- Quantification of measurable objectives (MOs)
- Quantification of interim milestones (IMs).

The description of the Plan Area (**Chapter 2**) was used to provide the context for groundwater wells and the overall water resources for the Subbasin. The hydrogeologic conceptual model and groundwater analyses (**Chapter 3**) were used to understand the basin conditions relevant to sustainability. The historical, current, and projected future water budgets (**Chapter 5**) were used to analyze overdraft conditions, streamflow depletions, and subsurface flows with adjacent subbasins. Water budgets were also used to establish a sustainable yield for the Subbasin that analyzed sustainable management criteria required to avoid undesirable results.

Collectively, these analyses informed and supported the selection of sustainable management criteria as discussed for each sustainability indicator below.

6.3. CHRONIC LOWERING OF GROUNDWATER LEVELS

SGMA defines an undesirable result for the chronic lowering of groundwater levels as a "significant and unreasonable depletion of supply if continued over the planning and implementation horizon" (§10721 (x)(1)). As described in **Section 3.2.4**, DWR estimated the amount of fresh groundwater supply beneath the Modesto Subbasin at about 14 million acre feet (MAF) in 1961. An analysis of the historical water budget (WY 1991 – WY 2015) estimates a depletion of about 1.1 MAF of this supply over the 25-year period (about 43,000 AFY, see **Figure 5-20** and **Table 5-8**), about 8 percent of the estimated total supply. Most of the deficit likely occurred in recent years with increases in agricultural water demand; this indicates that about 13 MAF of groundwater remains in storage.

Although significant amounts of fresh groundwater remain in the Subbasin, the chronic lowering of groundwater levels has created adverse impacts to numerous water supply wells. Because wells are the primary method for accessing groundwater for beneficial uses, adverse impacts to water supply wells can lead to undesirable results. As such, the emphasis of this sustainability indicator is depletion of *accessible* supply and focuses on adverse impacts to Subbasin supply wells. This emphasis is also consistent with GSP regulations, which note that depletion of supply should be considered "*at a given location*" (§354.28(c)(1)), such as at a well.

The SGMA definition of chronic lowering of groundwater levels also addresses water level declines within the context of overdraft and storage as shown below:

> Overdraft during a period of drought is not sufficient to establish a chronic lowering of groundwater levels if extractions and groundwater recharge are managed as necessary to ensure that reductions in groundwater levels or storage during a period of drought are offset by increases in groundwater levels or storage during other periods. (§10721 (x)(1)).

This definition allows for water level declines during drought as long as such declines do not result in undesirable results and as long as water levels recover to acceptable levels over average hydrologic conditions. Accordingly, the analysis of the chronic lowering of groundwater levels focuses on long-term trends of water level declines that do not recover during wet periods.

Undesirable results, including causes and impacts to beneficial uses, are described below in **Section 6.3.1**. The undesirable result definition, along with criteria to quantify where and when undesirable results will occur, is provided in **Table 6-3** at the end of **Section 6.3.1**. **Section 6.3.2** describes the quantification of minimum thresholds (MTs). **Section 6.3.3** provides the approach and selection of measurable objectives (MOs). Interim milestones that cover all of the applicable sustainability indicators are described in **Section 6.9**.

6.3.1. Undesirable Results for Chronic Lowering of Groundwater Levels

As summarized previously, groundwater level declines in the Modesto Subbasin are the combined results of overdraft and multi-year drought conditions. Over-pumping, primarily in the Non-District East Management Area (NDE MA) (**Figure 6-1**), has contributed to a historical Subbasin overdraft of about 43,000 AFY (**Section 5.1.4** and **Table 5-6**). Groundwater level declines associated with this overdraft have propagated outside of the NDE MA and affected water levels in adjacent areas to the west where additional water supply wells have been impacted (see estimated areas of vulnerable domestic wells on **Figure 6-1**).

Impacts to water supply wells are exacerbated during droughts. Chronic declines in groundwater levels are accelerated due to less availability of surface water for water supply, decreased recharge from decreases in precipitation and runoff, and/or increased irrigation demand due to higher temperatures. If groundwater declines are not arrested following a drought, future droughts will begin with even lower water levels, resulting in increased impacts to water supply wells and beneficial uses that worsen with each drought.

In addition to impacts to wells as described below, the lowering of groundwater levels may also lead to undesirable results for the other sustainability indicators such as reduction of groundwater in storage, land subsidence, depletions of interconnected surface water and adverse impacts to groundwater dependent ecosystems (GDEs). These impacts are summarized in **Section 6.3.2.2** and described separately for each indicator in remaining sections of this chapter.

6.3.1.1. Causes of Undesirable Results – Adverse Impacts to Wells

The combination of over-pumping and drought caused widespread adverse impacts to Subbasin water supply wells during drought conditions WY 2014 – WY 2017, resulting in undesirable results. Even though well owners appear to have mitigated most of these impacts, GSAs intend to arrest water level declines so that future widespread impacts to water supply wells can be avoided. Adverse impacts to water supply wells caused by chronic lowering of groundwater levels are discussed below.

In general, lower water levels increase pumping costs. If water levels fall below the pump intake, costs may be incurred for pump lowering and/or other well modifications. Further declines can result in water levels falling below the top of well screens, potentially decreasing capacity or well integrity due to geochemical changes, biological clogging, and/or air entrainment. Water level declines can also damage wellbore equipment, such as pumps or casing, from cavitation or other mechanisms. If water levels fall below the bottom of the well and do not sufficiently recover, the well is dewatered and would require replacement. Older wells, shallow wells, and/or wells with casing integrity issues typically have a higher risk of failure.

In the Modesto Subbasin, the STRGBA GSA member agencies responsible for public drinking water supplies documented numerous adverse impacts to public supply wells caused by declining water levels during drought (WY 2014 to WY 2017). During that period, declining water levels provided an opportunity to observe impacts associated with the historic low levels throughout much of the Subbasin. Most agencies observed a decrease in capacity and well efficiency. Some drinking water wells failed due to collapsed casing or other problems. More than 150 domestic wells were also adversely impacted (locations on **Figure 6-1**).

Significant adverse impacts to water supply wells in the Modesto Subbasin during this drought period are summarized in **Table 6-2** as follows.

Table 6-2: Adverse Impacts to Wells Associated with Declining Groundwater Levels

Adverse Impacts to Water Supply Wells from 2014 – 2017	Agencies Reporting Impacts
159 dry[1] or failed domestic wells (most were more than 50 years old and less than 100 feet deep)	Stanislaus County
Loss of capacity in municipal wells (pump replaced and lowered)	City of Waterford
Replace or deepen pumps in 3 agency wells; OID landowners also complained of well issues	Oakdale Irrigation District

[1]For purposes of this table, a "dry" domestic well does not necessarily mean that water levels in the aquifer have declined below the bottom of the well; well failures are also associated with water levels falling below a shallow pump intake or below the top of well screens such that capacity is adversely affected.

As indicated in **Table 6-2**, not all beneficial users of groundwater wells in the Modesto Subbasin experienced adverse impacts during the 2014 to 2017 drought. During this period, the cities of Riverbank and Oakdale were able to operate their deep drinking water supply wells without interruption. Similarly, Modesto ID did not experience well problems. The City of Modesto did not experience well impacts directly related to the drought but had water quality problems that could be exacerbated if groundwater levels continue to decline in the Subbasin. In the western Subbasin, groundwater levels experienced relatively small declines (less than 10 feet) and recovered quickly after 2016.

Most well impacts in **Table 6-2** occurred in the central-eastern Subbasin due to the presence of numerous water supply wells in areas of more significant water level declines (**Figure 6-1**; see also hydrographs on **Figure 3-25**). Although the 159 reported domestic well failures occurred throughout the Subbasin, most failures were concentrated in the eastern half of the Subbasin (**Figure 6-1**). Although most of these domestic wells appear to have been replaced, areas with vulnerable domestic wells have been identified along the Tuolumne and Stanislaus rivers (dashed areas on **Figure 6-1**). More details and analyses of failed and replacement domestic wells are provided in **Section 2.3.3**.

The City of Waterford is located within the vulnerable area along the Tuolumne River, where one of its primary water supply wells required replacing and lowering of a well pump during the 2015 drought (**Table 6-2**). Near the vulnerable area along the Stanislaus River, Oakdale ID reported water level declines of 20 feet to 50 feet from 2005 to 2020 in its deep water supply wells. Since 2016, water levels have continued to decline about 1.3 feet per year in the main service area and 2 to 4 feet per year in eastern OID. These declines caused adverse impacts to Oakdale ID deep agency wells. In addition, many landowners complained to Oakdale ID regarding private well issues.

Finally, the outreach team noted impacts to a few private wells as reported on the Modesto Subbasin Stakeholder Survey (see Chapter 4). Out of 12 responses from well owners, two reported either capacity or water quality issues with their well; the remaining 10 responders did not report well issues during the 2014-2017 drought.

6.3.1.2. Potential Effects on Beneficial Uses

Adverse impacts described above affect all beneficial uses of groundwater accessed through wells including municipal, domestic, industrial, and agricultural water supply. Any of these impacts can also affect property interests.

For agricultural users, impacts can increase costs, delay irrigation operations, and result in damage to crops. For industrial users, well issues can affect operational costs, delay goods and services, or adversely affect industrial processes relying on a specific groundwater quality. For public water suppliers, well impacts can increase wellfield operational costs, reduce pressure in distribution systems, cause water quality concerns, or even jeopardize the ability to provide a reliable and safe drinking water supply.

Impacted domestic well owners during the 2014-2017 drought reported the need for trucked water, use of temporary or permanent storage tanks, purchase of bottled water, lowering of well pumps, drilling of replacement wells, and other measures . A valley-wide shortage of drillers caused significant delay in the ability to lower a pump or otherwise modify/replace a well. In addition, domestic well owners in the Modesto Subbasin are often without financial resources necessary to replace their household water supply. Many domestic wells are located in underrepresented and economically-disadvantaged communities where wells are the only available drinking water source.

Although this sustainability indicator is focused on adverse impacts to wells, chronic lowering of groundwater levels can also adversely impact environmental uses of groundwater, including GDEs (**Section 3.2.8**). Given that GDEs in the Modesto Subbasin are primarily located along the three river boundaries, GDE impacts are also affected by the interconnected surface water sustainability indicator, as discussed in **Section 6.8**.

Many of these adverse well impacts that occurred during the 2014-2017 drought appear to have been mitigated. Public water suppliers have secured groundwater supply from new or modified wells. Proposed GSP projects will increase surface water deliveries for municipal supply in both Waterford and Modesto (see **Chapter 8**).

Most of the failed domestic wells appear to have been replaced. DWR well completion records indicate that about 236 new domestic wells have been drilled since 2015 – about 1.5 times the number of previously-reported failed wells. Although data are insufficient to provide a one-to-one match, most new wells are near the estimated location of a failed well and appear to be replacement wells[16].

Since 2016, only three domestic wells have been reported as being impacted from lower water levels. These domestic wells were reported to be dry as of August and September 2021 as indicated on the DWR Household Water Supply Shortage Reporting System (Household Water Supply Shortage Reporting System (ca.gov)). Of those three wells, the two in the City of Modesto were shallow wells with total depths of 29 feet and 79 feet. The reported failed well in the City of Oakdale had a total depth of 149 feet. `

SGMA does not require the protection of all groundwater wells or the correction of historical undesirable results. For this GSP, the widespread impacts to water supply wells during the 2014-2017 drought (which were caused by then-historic groundwater level declines) are considered to be undesirable results. Although impacts appear to be mostly mitigated at current groundwater levels, the GSP strives to avoid similar undesirable results in the future by arresting chronic groundwater level declines in the Subbasin.

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[16] The DWR database of domestic wells has been recognized to be incomplete, with uncertainty associated with numbers of wells, exact location, and well construction (including screen intervals, pump settings, or total depth. See analysis of domestic wells in **Section 2.3.2**.

6.3.1.3. Modesto Subbasin Definition of Undesirable Results

Based on the information summarized above and additional information presented in previous sections of this GSP (especially **Sections 2.3.2** and **3.2**), the definition of undesirable results focuses on maintaining access to groundwater supply through Subbasin wells.

Regulations also require that the undesirable result definition include quantitative criteria defining when and where groundwater conditions can cause an undesirable result (§354.26(b)(2)). These criteria include the number of monitoring sites/events where MT exceedances may create those conditions; criteria recognize that a single MT exceedance at one monitoring site during one monitoring event may not be sufficient to cause an undesirable result. This framework allows for clear identification as to when an undesirable result is triggered.

The undesirable result definition for the Modesto Subbasin, along with the criteria that may lead to an undesirable result, is summarized in the table below.

Table 6-3: Undesirable Results for Chronic Lowering of Groundwater Levels

	Undesirable Results Definition	Principal Aquifer(s)
Chronic Lowering of Groundwater Levels	Undesirable results are defined as significant and unreasonable groundwater level declines – either due to multi-year droughts or due to chronic declines where groundwater is the sole supply – such that water supply wells are adversely impacted in a manner that cannot be readily managed or mitigated. An undesirable result will occur when at least 33% of representative monitoring wells exceed the MT for a principal aquifer in 3 consecutive Fall monitoring events.	All

As indicated in the criteria above, an undesirable result is triggered when a third or more of the monitoring wells in each principal aquifer exceed the MT during three consecutive Fall monitoring events. To provide context for these criteria, additional Subbasin considerations are provided below.

At this time, the monitoring network for chronic lowering of water levels contains 61 wells distributed among the three principal aquifers. Maps of these representative monitoring well locations are provided in **Chapter 7** (**Figures 7-1**, **7-2**, and **7-3**). The number of wells in each principal aquifer are summarized below along with the number of wells that could trigger an undesirable result (i.e., 33 percent):

- Western Upper Principal Aquifer: 17 wells (33% - 6 wells)
- Western Lower Principal Aquifer: 5 wells (33% - 2 wells)
- Eastern Principal Aquifer: 39 wells (33% - 13 wells)

The number of representative monitoring wells that could trigger an undesirable result condition is relatively small (i.e., between 2 and 13 wells for each principal Aquifer), which provides protection for water supply wells in the Subbasin. The number of wells allowed to exceed the MTs are commensurate with the area of the aquifer being monitored. For example, the western aquifers cover about 56,000 acres while the Eastern Principal Aquifer is about three times as large (190,000 acres). Therefore, the number of wells associated with exceedances in the Eastern Principal Aquifer is much larger.

In addition, the areas that could cause undesirable results represent a relatively small percentage of the Subbasin – about 8 percent for exceedances in the western aquifers and about 25 percent of the Subbasin for exceedances in the Eastern Principal Aquifer. This indicates that undesirable results will be triggered when a relatively small area of the Subbasin exceeds the MT. In this manner, the undesirable results definition and criteria are protective against widespread exceedances of the MT.

Data gaps are recognized in the monitoring networks for both the Eastern Principal Aquifer and the Western Lower Principal Aquifer. Additional wells are planned for these networks in the initial years of GSP implementation (see Chapter 8). Accordingly, the number of wells with MT exceedances required to trigger undesirable results may need to be revised going forward.

The number of monitoring events with MT exceedances is also considered in the undesirable results definition in **Table 6-3**. This provides some flexibility for future drought conditions whereby wells are allowed to exceed the MT in drought as long as periods of decline are relatively short, and ongoing projects/management actions support subsequent water level recovery above the MTs. The use of three consecutive Fall semi-annual monitoring events is based on observation that three critically dry years (WY 2013 – WY 2015, see **Figure 3-2**) lead to previous undesirable results. Most of the adverse impacts to wells used to define undesirable results began at the end of this three-year period (i.e., Fall 2015) and extended throughout 2016. As described above, previous impacts to wells have been managed and mitigated for current (2021) groundwater elevations. The undesirable results criteria above are selected to avoid undesirable results during future multi-year droughts.

Even though monitoring will be conducted on a semi-annual basis (i.e., Spring and Fall), criteria limit the MT exceedances to Fall monitoring events. This focuses GSP management on long-term trends rather than seasonal fluctuations and is more protective against undesirable results. A partial Spring recovery above the MT may not indicate an improvement to an overall declining water level trend. When considered in the context of water year type, a comparison of Fall events allows for a better management tool for differentiating a short-term decline versus a longer term decline below the MT.

Collectively, these criteria provide a reasonable management approach for avoidance of undesirable results for chronic lowering of groundwater levels in the Modesto Subbasin.

6.3.2. Minimum Thresholds for Chronic Lowering of Groundwater Levels

Regulations require that the quantitative MT metric for this indicator be "the groundwater elevation indicating a depletion of supply at a given location that may lead to undesirable results" (§354.28 (c)(1). In the Modesto Subbasin, MTs are quantified as the low groundwater elevation from WY 1991 – WY 2020 at representative monitoring sites for all three Principal Aquifers.

While water levels have continued to decline in eastern portions of the Subbasin, the MT period contains the historic low water level for much of the Subbasin. Many of the selected MTs occurred in the 2015-2016 time period associated with drought conditions (**Figure 6-1**). However, some areas of the western Subbasin reached a historic low during the early to mid-1990s before surface water was available to the City of Modesto.

Table 6-5 states the selected approach for the MTs; the MT value at each representative monitoring well is presented in **Chapter 7**, which describes the GSP monitoring network (see **Section 7.1.1**). Hydrographs of all monitoring network wells with MTs and MOs are provided in **Appendix F**.

Table 6-4: Minimum Thresholds for Chronic Lowering of Groundwater Levels

	Minimum Thresholds	Principal Aquifer(s)
Chronic Lowering of Groundwater Levels	Minimum thresholds are set as the historic low groundwater elevation observed or estimated during WY 1991 – WY 2020 at each representative monitoring location, based on available data.	All

Information from the basin setting used to support these MTs are summarized in the following section.

6.3.2.1. Justification and Support for Minimum Thresholds

GSP regulations require that MTs for this indicator be supported by:

- The rate of groundwater elevation decline based on historical trends, water year type, and projected water use in the basin.
- Potential effects on other sustainability indicators. (§354.28 (c)(1)(A)(B)).

Historical declines in groundwater levels across the Subbasin are discussed throughout **Section 3.2** and specifically in **Section 3.2.2**; associated water year types are based on the detailed information in **Section 4.2.2.1** (also see **Figure 3-2**). **Figures 3-21** through **3-25** present hydrographs showing rates of decline in selected wells with relatively long water level records across the Subbasin. **Figure 6-1** provides locations of failed domestic wells from 2014 to 2017, representing undesirable results caused by groundwater level declines (also discussed in **Section 2.3.3** and shown on **Figure 2-15**). **Figure 2-17** shows the location of new and/or replacement domestic wells drilled since the 2015 drought.

As indicated by the hydrographs on **Figures 3-24 and 3-25**, water level declines become progressively larger from west to east in the Subbasin, especially since recent drought conditions began in WY 2013. Although wells with water level data are sparse in the NDE MA, groundwater levels in eastern-most wells have declined about 40 feet over the last seven years (decline rate of about 5.7 feet per year; see hydrograph 20 on **Figure 3-25**).

Rates of groundwater level declines are summarized briefly by principal aquifer below.

- <u>Western Upper Principal Aquifer (**Figures 3-21** and **3-22**)</u>: Water levels in this principal aquifer have been relatively shallow and stable throughout the study period with minimal – but observable – declines during drought. Water levels have recovered to near pre-drought levels in almost every well shown and no significant long-term water level declines have been observed. Depth to water ranges from less than 10 feet bgs to about 40 feet bgs. Most of historic low water levels occurred during 2015-2016 drought conditions. Some wells near the City of Modesto exhibit historic low water levels during the 1990s drought when groundwater was primarily the City's sole water supply (see hydrographs 7 and 8 on **Figure 3-22**). The availability of surface water to supplement the City's drinking water supply allowed water levels to recover. During more recent droughts, water levels in these wells have generally remained above the previous historic low levels.
- <u>Western Lower Principal Aquifer (**Figure 3-23**)</u>: Although water levels have been tracked in numerous wells in the western Subbasin, many wells are screened in both the Western Upper Principal Aquifer (unconfined) and the Western Lower Principal Aquifer (confined). Wells known to be screened only in the Western Lower Principal Aquifer are sparse; nonetheless, water levels appear to be relatively stable with small declines during drought (about 10 feet to 20 feet) followed by recovery in post-drought years. The decline and recovery for hydrograph 11 on **Figure 3-23** is due to the change in surface water availability for the City of Modesto as described above. Larger seasonal fluctuations are observed on the hydrographs due to the confined nature of the aquifer and its use by active pumping wells.

  <u>Eastern Principal Aquifer (**Figures 3-24** and **3-25**)</u>: Overall declines are observed in the Eastern Principal Aquifer, with increasing rates of decline and total declines from west to east. For wells in the western portion of the aquifer, long-term declines are relatively small (less than about 10 feet) over the study period (see hydrographs 12 and 13 on **Figure 3-24**). Wells slightly farther to the east exhibit

declines during the 2015 drought of about 20 feet with only partial recovery (hydrographs 14, 15, and 16 on **Figure 3-24**).

Wells in the eastern Subbasin have experienced the largest declines, both during drought and over the long term since at least the mid-2000s (**Figure 3-25**). As shown by hydrograph 20 on **Figure 3-25**, eastern wells have overall declines of about 40 feet during the recent drought and long-term declines since the mid-2000s. During that time, water demand in the eastern Subbasin increased due to the expansion of irrigated agriculture and changes in cropping patterns (see discussion in **Section 2.2** and **Figure 2-8**). In the eastern Subbasin, long-term rates of decline are up to about 2.7 feet/year; rates of decline during drought are up to about 6 feet/year (**Figure 3-25**).

Water level declines in the eastern Subbasin occur primarily in the NDE MA (**Figure 6-1**). However, local over-pumping in that area appears to have propagated westward, causing water level declines in other management areas – especially in eastern Oakdale ID MA. The area of water level declines also appears to be expanding to the north and south, intercepting groundwater that would typically be flowing toward the river boundaries.

The GSP intends to arrest these high rates of expanding water level declines by establishing MTs at the historic low water level observed (or estimated, if data are not available) during WY 1991 – WY 2020. Using this time period, MTs were selected for the 61 wells in the representative monitoring network for chronic lowering of groundwater levels; those MTs are discussed in **Section 7.1.1**, posted on **Figures 7-1**, **7-2**, and **7-3**, and listed in **Table 7-1**. Almost all of the selected MTs represent one of three time periods:

- Fall 2015 groundwater elevation (most western Subbasin wells)
- Fall 1991 groundwater elevation (a few wells near the City of Modesto)
- Fall 2020 groundwater elevations (most eastern Subbasin wells)

For most western wells, the MT was typically defined by 2015-2016 water levels. Even if water levels continue to decline in the eastern Subbasin while the GSP is being implemented, projects and management actions will have to be sufficient for water levels to recover back to the selected MT. The following conditions were considered when setting the MT at the historic low groundwater elevation:

- Replacement wells and other well improvements appear to have mitigated impacts from low water levels during the 2015-2016 drought conditions.
- The large number of new and deeper domestic wells drilled since 2015 can reasonably be assumed to accommodate current low water levels, with some tolerance for future droughts.
- The analysis in **Section 2.3.3** indicates that MTs will avoid the widespread failures of about five percent of the total domestic wells drilled in the Subbasin that occurred during the 2015 drought conditions. Uncertainties associated with data gaps

regarding domestic wells limit the ability to accurately identify the exact number of wells subject to impacts (see also **Section 9.5.3**).

- The Subbasin is not currently experiencing widespread adverse impacts to water supply wells that occurred in 2015-2016 and formed the basis for its undesirable result definition.
- Most of the MTs are commensurate with recent Fall 2020 water levels; no additional undesirable results were identified during that Fall period.
- As of Spring 2021, groundwater levels are within about 10 feet of the MT; several wells are below the MT.

Collectively, these considerations support the selection of the MTs for chronic lowering of groundwater levels.

6.3.2.2. Relationship between MTs of Each Sustainability Indicator

Regulations require a description of the relationship between the MTs for each sustainability indicator and how the GSAs have determined that basin conditions at each MT will avoid undesirable results (§354.28(b)(2)). To facilitate a comparison between MTs, a summary table of MTs for each sustainability indicator is provided below. Justification for the approach to the MTs for each indicator is provided in subsequent GSP sections, as indicated in the table.

Table 6-5: Summary of Minimum Thresholds by Sustainability Indicator

Sustainability Indicator	Minimum Threshold (MT)	GSP Section
Chronic Lowering of Groundwater Levels	Low groundwater elevation WY 1991 – WY 2020	**6.3.2**
Reduction of Groundwater in Storage	Low groundwater elevation WY 1991 – WY 2020	**6.4.2**
Seawater Intrusion	Not applicable	**6.5**
Degraded Water Quality	MCL of each Constituent of Concern	**6.6.2**
Land Subsidence	Low groundwater elevation WY 1991 – WY 2020	**6.7.2**
Interconnected Surface Water	Fall 2015 groundwater elevation	**6.8.2**

As indicated in the table above, the historic low groundwater elevation – as observed or estimated during the period WY 1991 – WY 2020 – has been selected as the MT for three of the six sustainability indicators (chronic lowering of groundwater levels, reduction of groundwater in storage, and land subsidence).

Groundwater elevations are also used as a proxy for interconnected surface water MTs but are set differently from other water level MTs. To be more protective of basin conditions along the three river boundaries, MTs for interconnected surface water are set as the Fall

2015 groundwater elevations. This approach is consistent with the need to guard against projected increases in streamflow depletion by the water budget modeling analyses (**Section 5.1.4.3**). In particular, projected increases in average streamflow depletions from the Stanislaus and Tuolumne rivers could lead to undesirable results. This approach is discussed in more detail in **Section 6.8**.

As discussed previously and indicated in the table above, the seawater intrusion indicator has been determined by the GSAs as not applicable to the inland Modesto Subbasin. Accordingly, no MTs have been set for seawater intrusion.

A different approach to MTs was used for the degraded water quality sustainability indicator. MTs for that indicator are set as the California drinking water standard for water quality constituents of concern most applicable to the Modesto Subbasin. This MT approach will not conflict with the other MTs for the Subbasin. Further, the MTs set for the other sustainability indicators are supportive of the MTs for degraded water quality, as described in more detail in **Section 6.6**.

The interrelatedness of the MTs among the four sustainability indicators with groundwater levels as a proxy are summarized below.

- MTs for chronic lowering of groundwater levels are used as a proxy for reduction of groundwater in storage and land subsidence for all three Principal Aquifers. Therefore, the MTs will not present conflicts between these three indicators.
- As explained in **Sections 6.4**, the use of groundwater elevations as a proxy for reduction of groundwater in storage is supported by the sustainable yield analysis (**Section 5.3**), whereby the historic low water levels are correlated directly to a sustainable yield <u>volume</u> for the Subbasin (267,000 AFY), which avoids undesirable results and also meets the requirement to use a volume as the metric for the reduction of groundwater in storage indicator (see **Section 6.4.2**).
- As explained in **Section 6.7**, the historic low water level is also an appropriate MT for land subsidence. By preventing significant groundwater level declines below the historic low level, the depressurization/dewatering of compressible subsurface clay layers can be avoided (see Section 6.7). Because this mechanism has been the primary cause of land subsidence in the Central Valley, the use of MTs for chronic lowering of groundwater levels as a proxy is supported (**Section 6.7.2**).
- The MTs for interconnected surface water are sufficiently close to the MTs for chronic lowering of water levels. Many of the MTs for chronic lowering of water levels are either the same or within only a few feet of the MTs for interconnected surface water. Accordingly, there are no conflicts between these two MT data sets. The use of water levels as a proxy for the interconnected surface water MTs is supported by the sustainable yield analysis in **Section 5.3** and demonstrates the ability of the aquifer to meet selected MTs for both sustainability indicators under the same basin conditions (see also **Section 6.8**).

Although presentation and review of technical information and selection of MTs by the TACs generally occurred one sustainability indicator at a time, basin conditions and sustainable yield analyses support the interrelatedness of the MTs. (Basin conditions that supported chronic lowering of water levels were discussed in **Section 6.3.2.1** above). Sustainable yield analyses were conducted interactively for future conditions and sustainable management criteria to determine how MTs could be achieved on a Subbasin-wide basis (**Section 5.3**). By first setting MTs to correct overdraft conditions and arrest future groundwater elevation declines, all of the other sustainability indicators in the Modesto Subbasin could be supported. The application of consistent methodologies in each principal aquifer and in each of the four management areas (**Figure 6-2**) allow the collective MTs to work well together to avoid undesirable results and support sustainable groundwater management.

Notwithstanding the protective MTs above, preventing all impacts to water supply wells may be difficult where large numbers of densely-spaced water supply wells are pumping at maximum capacities during drought conditions. Closely-spaced pumping wells can cause interference with other wells, even if basin-wide water levels are managed at reasonable levels. Well interference between two closely-spaced wells is not included in the undesirable results definition and will be managed locally, as needed. By setting MTs at historic low groundwater elevations across most of the Subbasin, regional long-term declines will be arrested and significant and unreasonable adverse impacts to water supply wells can be avoided.

6.3.2.3. Impacts of MTs on Adjacent Subbasins

Regulations require consideration of how Modesto Subbasin MTs impact the ability of an adjacent subbasin to achieve its sustainability goal. Significant technical similarities among the Modesto Subbasin and its three neighboring subbasins facilitate this process. For example, all of the subbasins have delineated principal aquifers in the same manner. In addition, all of the adjacent subbasins are linked to the Modesto Subbasin by a shared river boundary (i.e., Turlock Subbasin south of the Tuolumne River, Eastern San Joaquin Subbasin north of the Stanislaus River, and the Delta-Mendota Subbasin west of the San Joaquin River, see **Figure 6-1**). Due to the shared interconnected surface water along these rivers, MTs in each of the subbasins have been set in a similar manner.

There is also significant inter-basin coordination occurring among GSAs and member agencies across all of these subbasins. Multiple member agencies are actively involved in the GSP process in both the Modesto Subbasin and one of the adjacent subbasins.

For example, in the Eastern San Joaquin (ESJ) Subbasin to the north, both Oakdale ID and Stanislaus County are member agencies of ESJ GSAs and actively participated in GSP development for that subbasin. Oakdale ID has service areas and operations in both the Modesto and the ESJ subbasins, located along a large portion of the boundary between the two. Stanislaus County also provides consistent coordination in the Delta Mendota Subbasin to the west. In addition, members of the technical consulting team and outreach team in the Modesto Subbasin were also involved in GSP development in both the ESJ and Delta Mendota subbasins.

In the Turlock Subbasin to the south, several member agencies are represented in both the Turlock and Modesto subbasins, including Stanislaus County, City of Modesto (with pumping wells in the Turlock Subbasin), and the City of Waterford (which operates the water supply system for Hickman in the Turlock Subbasin). Also, Turlock ID and Modesto ID coordinate on diversions from the Tuolumne River to provide a large supply of Tuolumne River water to both subbasins. Finally, the GSP technical consulting team is the same in both Turlock and Modesto subbasins and has developed one integrated surface water-groundwater model for coordinated GSP analyses.

Through coordination activities by these member agencies, additional coordination meetings with adjacent subbasin representatives, and review of draft and completed GSPs, the MTs selected for chronic lowering of water levels in the three adjacent subbasins have been considered together. In brief, the Modesto Subbasin MTs are not expected to either cause undesirable results or adversely impact GSP implementation in adjacent subbasins, as summarized below.

6.3.2.3.1. Eastern San Joaquin Subbasin

The MTs for chronic lowering of water levels in the ESJ Subbasin are defined as the shallower groundwater elevation of the following (ESJGWA, 2019):

- the deeper of 1992 and 2015-2016 historical groundwater levels with a buffer of 100 percent of the historical range applied, or
- the 10th percentile domestic well total depth of wells within a 3-mile radius of the monitoring well.

MTs have been set for 20 representative monitoring wells in the ESJ Subbasin, four of which are within about three miles from the shared boundary with the Modesto Subbasin (02S07E31N001, 02S08E08A001, Burnett-OID4, and 01S10E26J001M; see Figure 3-2 in ESJGWA, 2019). All of the MTs set for the ESJ monitoring wells appear to be lower than the closest Modesto Subbasin MTs.

For example, the closest ESJ Subbasin well to the Modesto Subbasin is Burnett (OID4), located across the Stanislaus River from Modesto Subbasin monitoring wells Allen (OID1) and Birnbaum (OID3). The Burnett MT is 60.7 feet msl (Table 3-1 in ESJGWA, 2019) and the Birnbaum and Allen MTs are 74 and 75 feet msl, respectively (see **Figure 7-7**). MTs for all three wells are based on 2015 groundwater elevations, although the ESJ monitoring well has a buffer equal to the historical water level range (see first bullet above). As indicated by these values, MTs in the ESJ Subbasin are lower, but close to the MTs in the Modesto Subbasin. Accordingly, the MTs do not appear to conflict across the Subbasin boundary and MTs in the Modesto Subbasin are not expected to adversely impact GSP implementation in the ESJ Subbasin.

ESJ Subbasin MTs for chronic lowering of water levels are also used as a proxy for the reduction of groundwater in storage, land subsidence, and interconnected surface water. Therefore, these MTs represent the best MTs for evaluation of potential impacts across the shared Stanislaus River boundary. Finally, as noted above, Oakdale ID operates within its service areas on both sides of this boundary and has GSP monitoring and management responsibilities in both subbasins. This close coordination allows the tracking of potential impacts in each subbasin going forward.

6.3.2.3.2. Delta-Mendota Subbasin

Sustainable management criteria in the adjacent Delta-Mendota Subbasin are provided in the Northern & Central Delta-Mendota Regions GSP (W&C and P&P, 2019). In that GSP, the MTs for water levels are defined as the hydrologic low groundwater level for the Upper Principal Aquifer and 95 percent of the hydrologic low groundwater level for the Lower Principal Aquifer. Because these low groundwater levels generally occurred in WY 2015, and MTs along the San Joaquin River in the Modesto Subbasin are also set at WY 2015 levels (for interconnected surface water – see **Table 6-5**), there should be no conflict in MTs along this boundary.

Because the shared San Joaquin River boundary between the Delta-Mendota Subbasin and the Modesto Subbasin is relatively short, there are no representative monitoring wells in the Delta-Mendota Subbasin along that boundary. The two closest wells are 06-004 (Upper Aquifer) and 06-003 (Lower Aquifer), both located about three miles to the southwest from the southwestern corner of the Modesto Subbasin. MTs for those two wells are 14.8 feet msl and -8.6 feet msl, respectively.

In the Modesto Subbasin, the closest representative monitoring wells in equivalent principal aquifers are Canfield 90 (Western Upper Principal Aquifer) and MRWA-3 (Western Lower Principal Aquifer). MTs for chronic lowering of water levels in those wells are 32 feet msl and 28 feet msl, respectively. Given the higher elevations and distance from representative monitoring locations, the MTs in these two subbasins do not conflict and are not expected to adversely impact GSP implementation in either Subbasin.

6.3.2.3.3. Turlock Subbasin

By selecting MTs for the chronic lowering of groundwater levels at the historic low groundwater elevations, MTs in the inland portions of the Subbasin are slightly lower in some places than in the Turlock Subbasin. However, the methodology for selecting MTs along the shared Tuolumne River boundary is identical for both subbasins. Along that boundary MTs are set at the Fall 2015 groundwater elevations in the Modesto Subbasin for interconnected surface water (**Table 6-6**; see also **Section 6.8**). Sustainable yield analyses indicate very small subsurface flows between the two subbasins (within about 1,000 AFY) along the approximate 35-mile river boundary (see **Table 5-15** for the net subsurface flows between the two subbasins). These conditions suggest that there will be no adverse impacts on GSP implementation from MTs in the Modesto Subbasin on Turlock Subbasin MTs.

6.3.2.4. Effects of MTs on Beneficial Uses and Users of Groundwater

By arresting groundwater level declines in the Subbasin, long-term use of groundwater will become more sustainable and provide benefits to all beneficial uses of groundwater in the

Subbasin. However, there are consequences to maintaining these MTs for some current beneficial uses of groundwater.

In brief, the current level of groundwater use will not be able to be sustained without sufficient projects or management actions to replenish the Subbasin. This will require maintenance of water levels in deep wells that could otherwise accommodate additional declines. In the NDE MA, where growers are currently reliant on groundwater for agricultural beneficial uses, significant investment in projects and supplemental water will be required to support the current level of agricultural production. If projects cannot meet the sustainable yield, demand reduction will need to be considered, which could negatively affect property interests in the Subbasin.

Conversely, the beneficial uses of public water suppliers and domestic well owners will be supported by the MTs. Although water levels will be allowed to decline somewhat during drought conditions, the Subbasin will not be subject to the continual historic lows that would occur with deeper MTs. With improved long-term maintenance of water levels, municipal water suppliers will avoid the loss of expensive public drinking water supply wells as has been documented in public meetings (e.g., by the City of Waterford). The need for widespread domestic well replacements can also be avoided (see **Table 6-1**).

The prevention of further water level declines will also support the potential GDEs that have been identified in the Subbasin, most of which are located along the river boundaries (see **Section 3.2.8**). Even more protective MTs have been set along the rivers as described in more detail in **Section 6.8.2**.

6.3.2.5. Consideration of State, Federal, or Local Standards in MT Selection

GSP regulations require that GSAs consider how the selection of MTs might differ from other regulatory standards. For the chronic lowering of groundwater levels, the MT consists of quantified water levels in each representative monitoring well, which present no conflicts with regulatory standards.

6.3.2.6. Quantitative Measurement of Minimum Thresholds

As stated above, the MTs for the chronic lowering of groundwater levels will be monitored by quantitatively measuring water levels in representative monitoring well networks for each principal aquifer as described in **Chapter 7** (Monitoring Network) of this GSP (see **Section 7.1.1**, **Table 7-1**, and **Figures 7-1** through **7-3**. Monitoring will occur on a semi-annual basis, in Spring and Fall, to represent the seasonal high and low water level and to adhere to basin-wide water level sampling protocols (**Section 7.2.4**).

6.3.3. Measurable Objectives for Chronic Lowering of Groundwater Levels

GSP regulations define measurable objectives (MOs) as “specific, quantifiable goals for the maintenance or improvement of specified groundwater conditions that have been included in an adopted Plan to achieve the sustainability goal for the basin” (§351(s)). The MO is used to target desired groundwater conditions and provide a margin of operational flexibility above the MTs.

For chronic lowering of water levels, the MT represents a “floor” for maintenance of low water levels, with allowance for short-term exceedances by less than a third of representative monitoring wells during droughts (see **Table 6-5**). Accordingly, water levels will be managed generally between the MT and anticipated high water levels that occur during wet periods.

This operational range is represented by the midpoint between the MT and high water levels observed over average hydrologic conditions. Using the average hydrologic condition for the historical water budget study period of WY 1991 – WY 2015, the MO is defined as the midpoint between the selected MT and the high water level during that period (usually observed in 1998) for each representative monitoring location as summarized in the following table.

Table 6-6: Measurable Objectives for Chronic Lowering of Groundwater Levels

	Measurable Objectives	Principal Aquifer(s)
Chronic Lowering of Groundwater Levels	Measurable objectives are established as the midpoint between the historical high groundwater elevation and the MT at each representative monitoring location.	All

Each representative monitoring well is assigned a quantitative MO; these data are provided in **Chapter 7** (see **Table 7-1**).

Setting the MO at the midpoint between the MT and the high-water level results in a very small margin of operational flexibility for some western Subbasin wells screened in the Western Upper Principal Aquifer. In the far western areas of the Subbasin, water levels are shallow, and historical water levels have not fluctuated significantly. As a result, the MO is close to the MT; in some portions of the western Subbasin, there are only a few feet between the MO and the MT in representative monitoring wells. Setting the MO higher would not be consistent with the need to manage shallow groundwater such that existing agricultural land use can be preserved. MOs and MTs may require future adjustment to allow for more operational flexibility in the future.

It is also recognized that this methodology may be setting MOs higher than may be easily attained if ongoing drought conditions persist. At the time of preparation of this GSP, most years since the end of the historical study period (WY 2015) have been dry; these conditions may have reset the range of future expected high water levels in the Subbasin.

Nonetheless, this approach to MO selection provides a reasonable method to quantify desired groundwater conditions using best available data. Compliance with selected sustainable management criteria will be reported in GSP Annual Reports and revisited in the five-year GSP evaluation for possible adjustment as needed.

6.4. REDUCTION OF GROUNDWATER IN STORAGE

SGMA defines an undesirable result for the groundwater in storage sustainability indicator as "significant and unreasonable reduction of groundwater storage." (§10721 (x)(2)). GSP regulations require that the MT for the reduction of groundwater in storage be set as "a total volume of groundwater that can be withdrawn from the basin without causing conditions that may lead to undesirable results" (§354.28(c)(2)). This requirement contains almost identical language as the SGMA definition of sustainable yield.[17] In addition, regulations require the MT for this indicator to be supported specifically by the sustainable yield. The sustainable yield analysis for the Modesto Subbasin is presented in **Section 5.3** and discussed in the context of this indicator throughout the remaining subsections of **Section 6.4**, as well as throughout the remaining sections of **Chapter 6**.

Although the Modesto Subbasin is not at risk of depleting a large percentage of its total volume of groundwater supply, the ongoing depletion due to pumping larger volumes from the groundwater basin than can be reasonably replenished (overdraft conditions) requires mitigation to meet the Subbasin sustainability goal. As discussed in **Section 6.3**, the chronic lowering of groundwater levels in the Modesto Subbasin is caused primarily by overdraft conditions, illustrating the close relationship between these two indicators.

As explained in subsequent subsections, sustainable management criteria for chronic lowering of groundwater levels are used as a proxy for the reduction of groundwater in storage criteria. GSP regulations allow for use of groundwater elevations as a proxy metric when there is a significant correlation between groundwater levels and the metric for the other indicator (DWR, 2017). In this case, that metric is the volume of groundwater that can be extracted without causing undesirable results.

The definition of undesirable results for reduction of groundwater in storage, including causes and impacts to beneficial uses, is described in **Section 6.4.1** below, along with additional criteria to quantify where and when undesirable results occur. **Section 6.4.2** describes the selection and quantification of MTs, along with the justification and rationale. **Section 6.4.3** provides the approach and selection of MOs. Interim milestones that cover all of the applicable sustainability indicators are described in **Section 6.9**.

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[17] SGMA defines sustainable yield as "the maximum quantity of water, calculated over a base period representative of long-term conditions in the basin and including any temporary surplus, that can be withdrawn annually from a groundwater supply without causing an undesirable result." (§10721(w)).

6.4.1. Undesirable Results for Reduction of Groundwater in Storage

As described in **Chapter 5**, the historical reduction of groundwater in storage is estimated at about 43,000 AFY (see **Table 5-8**). This reduction is primarily related to overdraft[18], which is determined to be unsustainable and thereby an undesirable result in this GSP.

Modeling analyses of projected future conditions indicate that historical overdraft conditions could potentially improve to about 11,000 AFY but would do so at the expense of significant streamflow depletion of the rivers along the Subbasin boundaries (compare net gains/discharges to streams from historical to projected conditions in **Table 5-8**). These increases in projected streamflow depletions have also been determined to be an undesirable result.

The causes of groundwater conditions that lead to undesirable results for the reduction of groundwater in storage are described below. Impacts to beneficial uses are also discussed.

6.4.1.1. Cause of Undesirable Results

In the Modesto Subbasin, the reduction of groundwater in storage is caused by over-pumping primarily in the NDE MA in the eastern Subbasin (**Figure 6-1**). In this area, surface water is generally not available, and groundwater has provided the primary supply for the expansion of irrigated agriculture and conversion to crops with higher water demand. Over-pumping has caused lowering of water levels in this area.

Because overdraft conditions cause chronic lowering of groundwater levels, overdraft contributes to all of the undesirable results associated with that indicator (**Section 6.3.1.1** and **6.3.1.3**). Overdraft also contributes directly to undesirable results for each of the remaining applicable sustainability indicators.

Ongoing overdraft conditions are expected to expand the area of low groundwater levels to the north and south beneath the Stanislaus and Tuolumne rivers, resulting in significant and unreasonable streamflow depletions and impacts to surface water uses (see **Section 6.8.1.1** and **6.8.1.3**). Overdraft conditions can lower water levels in areas where poorer groundwater quality occurs at depth and contribute to undesirable results for the degradation of water quality (see **Section 6.6.1.1** and **6.6.1.3**). Finally, overdraft conditions can also contribute to undesirable results for land subsidence if the lowering of water levels depressurize or dewater subsurface compressible clays. Where this occurs, significant amounts of land subsidence could be triggered and ultimately cause significant and unreasonable impacts to land uses and/or critical infrastructure – defined in this GSP as undesirable results (see **Section 6.7.1.1** and **6.7.1.3**)

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[18] Other causes of reduction of groundwater in storage include net subsurface outflows or contributions to baseflow in rivers or streams.

6.4.1.2. Potential Effects on Beneficial Uses

The reduction of groundwater in storage causes lowering of water levels, which in turn, affects beneficial uses of groundwater and wells. As such potential effects on beneficial uses for reduction of groundwater in storage also includes the potential effects for chronic lowering of water levels as documented in **Sections 6.3.1.2** and **6.3.1.3**.

Recognizing that the volume of usable groundwater in the Modesto Subbasin is relatively large, and the base of freshwater is deep, a large groundwater supply would be accessible with sufficiently deep wells. However, the increased costs associated with installation and pumping lifts could ultimately place limits on beneficial uses of groundwater. With the large number of wells in the Subbasin, increased costs could be substantial and could also negatively impact land use and property interests.

Operating the Subbasin at significantly deeper levels also has the potential to pump groundwater with increased constituents of concern at depth. Deeper groundwater is often confined and subject to a geochemical environment that can impact the quality of drinking water supplies, increase public agency operational costs, and increase the potential for water quality impacts on water aesthetics such as odor or taste. Certain constituents, such as iron and manganese, can also cause impacts to groundwater conveyance pipes and fixtures. In addition, depth-related constituents can be associated with health effects if drinking water standards are exceeded (see also **Section 6.6.1.2**).

If overdraft contributes to land subsidence, beneficial users could experience adverse impacts to the physical ground surface, affecting surface operations, land uses, and potentially affecting property interests. Costs to repair or maintain infrastructure could increase; damage to roads or bridges may be associated with public safety concerns (see **Section 6.7.1.2**).

If overdraft results in inducing additional surface water from rivers, streamflow depletions could increase, potentially affecting all surface water beneficial uses including habitat, surface water rights holders, riparian vegetation, among others (see **Section 6.8.1.2**).

6.4.1.3. Modesto Subbasin Definition of Undesirable Results

Based on the information summarized above and supported in other chapters of this GSP, a definition of undesirable results has been developed for *Reduction of Groundwater in Storage* in the Modesto Subbasin.

Regulations require that the undesirable result definition include quantitative criteria used to define when and where groundwater conditions can cause an undesirable result (§354.26(b)(2)). These criteria address the number of monitoring sites and events that an MT can be exceeded before causing an undesirable result. These criteria recognize that a single MT exceedance at one monitoring site may not indicate an undesirable result. This framework also allows clear identification for when an undesirable result is triggered under the GSP. The undesirable result and associated criteria are provided in the following table.

Table 6-7: Undesirable Results for Reduction of Groundwater in Storage

	Undesirable Results Definition	Principal Aquifer(s)
Reduction of Groundwater in Storage	An undesirable result is defined as a significant and unreasonable reduction of groundwater in storage that would occur if the volume of groundwater supply is at risk of depletion and is not accessible for beneficial use, or if the Subbasin remains in a condition of long-term overdraft based on projected water use and average hydrologic conditions. An undesirable result will occur when at least 33% of representative monitoring wells exceed the MT for a principal aquifer in 3 consecutive Fall monitoring events.	All

The use of 33 percent of the representative monitoring wells is based on the chronic lowering of groundwater levels criteria as discussed in **Section 6.3.1.3**. The use of three Fall events for triggering undesirable results recognizes that short-term declines during drought are anticipated as long as reductions of groundwater in storage are eliminated over average hydrologic conditions. SGMA allows for reduction of groundwater in storage during droughts if water levels subsequently recover (see introductory paragraphs in **Section 6.3** above; see also **Section 6.3.1.3**).

The change in groundwater in storage is a required element for the GSP annual reports and will be documented annually in those reports over time. Over average hydrologic conditions, this element can be used to substantiate the correlation of overdraft conditions to the combination of MT exceedances for each principal aquifer as provided in the definition above.

The MTs selected for this indicator use MTs from the chronic lowering of water levels as a proxy, as presented in the following section.

6.4.2. Minimum Thresholds for Reduction of Groundwater in Storage

As indicated in the previous sections, reductions of groundwater in storage resulting from overdraft can be partially offset by inducing recharge from rivers (baseflow) or increasing subsurface inflows from other subbasins. Each of these can cause undesirable results relating to either streamflow depletions or adverse impacts to adjacent beneficial uses of groundwater. However, overdraft conditions can be corrected through projects and management actions such that undesirable results are avoided as demonstrated by an analysis of sustainable yield using the integrated surface water-groundwater model developed for the GSP (C2VSimFG-TM).

Under such an analysis – presented in **Section 5.3** – groundwater demand is reduced iteratively in areas of over-pumping until sustainable management criteria is met. The resulting sustainable yield for the Subbasin is used to inform and confirm the sustainable management criteria selected for the sustainability indicators. The sustainable yield is also used to guide locations and volumes required for projects and management actions.

For the Modesto Subbasin, the analysis estimated a sustainable yield of about 267,000 AFY (see the total volume of groundwater production in **Table 5-15**). Given that future projected groundwater production in the Subbasin has been estimated at 314,000, an increase in supply or reduction in demand that adds approximately 47,000 AFY is required to bring the Subbasin into sustainability.

The sustainable yield modeling analysis incorporated the sustainable management criteria for chronic lowering of water levels and was also shown to eliminate overdraft in the Subbasin over the 50-year implementation and planning horizon (**Section 5.3**; see **Figure 5-58**). Accordingly, both the chronic lowering of water levels criteria and elimination of overdraft are correlated to the sustainable yield of 267,000 AFY. This volume can be applied as a metric for reduction of groundwater in storage and linked directly to management criteria for the chronic lowering of groundwater levels indicator.

In this manner, the selection of a volume as the required metric for the reduction of groundwater in storage indicator is met (i.e., 267,000), and justification is provided by the sustainable yield modeling that the chronic lowering of water levels criteria can be applied as a proxy for the reduction of groundwater in storage sustainability indicator.

Table 6-8: Minimum Thresholds for Reduction of Groundwater in Storage

	Minimum Thresholds	Principal Aquifer(s)
Reduction of Groundwater in Storage	Minimum thresholds are defined as the historic low groundwater elevation observed or estimated during WY 1991 – WY 2020 at each representative monitoring location, based on available data. (Chronic Lowering of Groundwater Levels MT as a proxy.)	All

It is recognized that sustainable yield is not a fixed number and will vary over time with changes in land use, hydrologic conditions, and GSP implementation of projects and management actions. Nonetheless, this sustainable yield represents the current best available estimate to use as a required metric for the MT of this indicator.

6.4.2.1. Justification and Support for Minimum Thresholds

In the BMP on sustainable management criteria, DWR lists several technical topics to consider when selecting an MT for reduction of groundwater in storage. Those considerations, along with a summary of relevant information from the basin setting (and other related portions of the GSP), are provided below:

- Historical trends, water year types, and projected water use: In the Modesto Subbasin the historical conditions of overdraft were analyzed annually over a 25-year period and summarized for conditions in each of the management areas. As indicated on **Figure 5-3**, 17 of the 25 years experienced a net reduction of groundwater in storage, primarily due to overdraft. As indicated in **Table 5-9**, this imbalance even occurred in water year types of above normal precipitation. As indicated on **Figure 5-16**, much of this imbalance occurs in the NDE MA where annual water budgets indicated a new extraction from groundwater in storage in this area. Specifically, only 3 of the 25 years indicate more recharge than extraction in the NDE MA. Net extractions occurred in the NDE MA during every year since 1991. Water level declines described in **Section 6.3.2.1** support the water budget analysis in the NDE MA (see also **Figure 3-25**).

  Projected water budgets are shown annually for the 25-year period on **Figure 5-40** and confirm the continuation of overdraft conditions into the future. As indicated in the discussion on sustainable yield above, the avoidance of undesirable results estimated over-pumping of about 47,000 AFY, primarily in the NDE MA, as compared to the projected future water use in the Subbasin (see **Table 5-15**).

- Groundwater reserves needed to withstand future droughts: During recent drought conditions from WY 2013 through WY 2020, groundwater declines in the Subbasin were observed to range from less than 10 feet in the western Modesto ID MA to more than 40 feet in some areas of the NDE MA (see **Figures 3-21** through **3-25**). With about 13 MAF of fresh groundwater in storage to depths of more than 1,000 feet in some areas, groundwater reserves will be available to meet future demands under sustainable yield conditions.

- Whether production wells have ever gone dry: As described in **Section 2.3.2**, more than 150 domestic wells failed during the 2014 – 2016 drought of record. Additional adverse impacts to public supply wells related to water level declines were also documented (see **Section 6.3.1.1** and **Table 6-2** above). Since that time, well impacts appear to have been mitigated with the installation of more than 200 new and typically deeper domestic wells. Accordingly, the MTs are set at historical low groundwater levels and projects and management actions have been developed to avoid widespread well failures in the future (see **Chapter 8**).

- Effective storage of the basin: As mentioned previously, the Subbasin contains more than about 13 MAF of fresh groundwater in storage and overall depletion of groundwater supply is unlikely (**Section 3.2.4**. **Figure 3-18** illustrates the thickness of fresh groundwater in storage (between current groundwater level and the base of freshwater) across the Subbasin.

- Understanding of well construction and potential impacts to pumping costs: Well construction was considered in adverse impacts to public water supply wells summarized in **Section 6.3.1.3** above. Most of those wells were sufficiently deep for water supply during the 2015 drought; however, adverse impacts associated with declining water levels were documented (**Section 6.3.1.** and **Table 6-2**). By setting MTs close to current levels, existing Subbasin wells are supported.
- Adjacent Subbasin MTs: MTs for chronic lowering of groundwater levels are compared to and analyzed for each adjacent subbasin in **Sections 6.3.2.3.1** through **6.3.2.3.3** above. The Modesto Subbasin and all adjacent subbasins are using these MTs as a proxy for the reduction of groundwater in storage indicator; accordingly, those analyses apply to both indicators.

6.4.2.2. Relationship between MTs of Each Sustainability Indicator

Regulations require a description of the relationship between the MTs for each sustainability indicator and how the GSAs have determined that basin conditions for each MT will avoid undesirable results (§354.28(b)(2)). As previously discussed, the MTs for each sustainability indicator are summarized in **Table 6-5** and discussed in **Section 6.3.2.2**.

Section 6.3.2.2 also describes the relationship between the MT for chronic lowering of water levels and the MTs for each of the remaining sustainability indicators. Because the MTs for reduction of groundwater in storage are the same as the MTs for chronic lowering of water levels, that discussion would be identical for the reduction of groundwater in storage. As such, please refer to **Section 6.3.2.2** for this required component of the GSP.

6.4.2.3. Impacts of MTs on Adjacent Subbasins

Regulations require consideration of how Modesto Subbasin MTs impact the ability of an adjacent subbasin to achieve its sustainability goal. For the reduction of groundwater in storage sustainability indicator, all three adjacent subbasins – the ESJ Subbasin, the Delta-Mendota Subbasin and the Turlock Subbasin – are also using the MTs for the chronic lowering of groundwater levels as a proxy. Therefore, the considerations of how Modesto Subbasin MTs impact adjacent subbasin MTs are already analyzed for this sustainability indicator through the proxy. As such, please refer to **Section 6.3.2.3** for this required component of the GSP (see **Sections 6.3.2.3.1** through **6.3.2.3.3** on each of the three adjacent subbasins).

6.4.2.4. Effects of MTs on Beneficial Uses and Users of Groundwater

Benefits of these MTs on the beneficial uses and users of groundwater provide a balanced groundwater basin and eliminate overdraft conditions. As such, groundwater level declines are generally arrested. Long term benefits include a more sustainable groundwater supply for all beneficial uses, including municipal, industrial, domestic, agricultural, and environmental uses.

The effects of these conditions on beneficial uses and users of groundwater are similar to those stated for the chronic lowering of groundwater levels; as such, please refer to **Section 6.3.2.4** for this required component of the GSP.

6.4.2.5. Consideration of State, Federal, or Local Standards in MT Selection

GSP regulations require that GSAs consider how the selection of MTs might differ from other regulatory standards. For the reduction of groundwater in storage indicator, the MT consists of quantified water levels in each representative monitoring well. Accordingly, there are no conflicts with regard to other regulatory standards.

6.4.2.6. Quantitative Measurement of Minimum Thresholds

As stated above, the MTs for the chronic lowering of groundwater levels are used as a proxy for monitoring reduction of groundwater in storage. Accordingly, the representative monitoring network, along with individual MTs and MOs, for chronic lowering of water levels are also applied to the reduction of groundwater in storage indicator.

MTs will be monitored by quantitatively measuring water levels in representative monitoring wells for each principal aquifer as described in **Chapter 7** (Monitoring Network – see **Section 7.1.2**). Monitoring will occur on a semi-annual basis, in Spring and Fall, to represent the seasonal high and low water level and adhere to water level sampling protocols (**Section 7.2.4**). **Table 7-1** provides the quantitative MTs for each representative monitoring well used to monitor both chronic lowering of groundwater levels and reduction of groundwater in storage. Representative monitoring wells for both indicators are shown on **Figures 7-1** through **7-3**.

6.4.3. Measurable Objectives for Reduction of Groundwater in Storage

In the same manner that the MTs for chronic lowering of groundwater levels are used as a proxy for the reduction in groundwater in storage, the same MOs are also applied to this indicator, as provided in the following table.

Table 6-9: Measurable Objectives for Reduction of Groundwater in Storage

	Measurable Objectives	Principal Aquifer(s)
Reduction of Groundwater in Storage	Measurable objectives are established at the midpoint between the historical high groundwater elevation and the MT at each representative monitoring location. (Using Chronic Lowering of Groundwater Levels as a proxy).	All

Even though GSP regulations note that reduction in groundwater in storage is controlled by a single value for the Subbasin (in this case, 267,000 AFY), the management of that single value is manifested by applying chronic lowering of water levels criteria as a proxy for reduction of groundwater in storage including both the MTs and MOs at the same representative monitoring wells. MOs are listed for representative monitoring wells on **Table 7-1** for chronic lowering of groundwater levels, which are used as a proxy for reduction of groundwater in storage.

6.5. SEAWATER INTRUSION

GSP regulations define *Seawater Intrusion* as "the advancement of seawater into a groundwater supply that results in degradation of water quality in the basin and includes seawater from any source." The minimum threshold for the indicator "sh*all be defined by a chloride concentration isocontour*…where seawater intrusion may lead to undesirable results." Further, the seawater intrusion minimum threshold must consider the effects of "*current and projected sea levels*" (§354.28 (c)(3) *emphasis added*).

Typically, these conditions would occur in a coastal groundwater basin where aquifers are in hydraulic communication with the open ocean, either directly or indirectly by interconnected waterways such as bays, deltas, or inlets. As an inland basin, the Modesto Subbasin is not directly or indirectly connected to the open ocean. The Subbasin aquifers are separated from the Pacific Ocean by the bedrock units of the Coast Ranges; further Subbasin aquifers are more than 10 miles upgradient from the edge of the Sacramento-San Joaquin Delta and not influenced by deltaic seawater intrusion. GSAs in the Eastern San Joaquin Subbasin to the north have determined that seawater is not occurring nor is likely to occur in that subbasin, even though elevated salinity has been encountered in groundwater and the subbasin is closer the Sacramento-San Joaquin Delta. Elevated salinity conditions do not exist in the Modesto Subbasin such that a chloride concentration isocontour could be developed and used for the MT as required by the regulations.

GSP regulations state that if GSAs are "able to demonstrate that undesirable results related to one or more sustainability indicators are not present and are not likely to occur…" then sustainable management criteria are not required to be established (§354.26 (d)). To assess the applicability of the seawater intrusion indicator to the Modesto Subbasin, the technical team provided both a public presentation to the TAC (January 2021) as well as a technical memorandum on the issues (March 23, 2021). At a public meeting of the STRGBA GSA on April 14, 2021, the GSAs made the determination "that seawater intrusion does not exist and is not likely to occur in the future, and therefore a seawater intrusion sustainability indicator is not applicable in the Modesto Subbasin (Resolution 2021-2).

6.6. DEGRADATION OF WATER QUALITY

Degraded water quality is unique among the sustainability indicators in that other regulatory agencies have the primary responsibility for groundwater quality. SGMA does not authorize or mandate GSAs to duplicate these efforts. The GSAs are not responsible for enforcing drinking water requirements or for remediating groundwater quality problems caused by others (Moran and Belin, 2019). Similar to the other sustainability indicators, GSAs are not required to correct degraded water quality that occurred before January 1, 2015. Further, the existing regulatory framework does not require the GSAs to take affirmative actions to manage existing groundwater quality.

However, SGMA does give the GSAs the authority to regulate groundwater extractions and groundwater levels. In addition, GSAs are responsible for development and implementation of projects and management actions to bring the Subbasin into sustainable groundwater conditions. Given these authorities, GSA activities have the potential to impact groundwater quality; this GSP focuses on avoidance of these potential impacts.

To protect against GSA impacts to water quality in the future, the GSAs intend to:

- track water quality annually through existing monitoring programs,
- assess the potential for GSA impacts to water quality, and
- confer and coordinate with other regulatory water quality agencies and regulated water quality coalitions in the Subbasin to ensure ongoing protection groundwater quality in the Subbasin.

Because most of the public drinking water suppliers in the Modesto Subbasin are also member agencies of the GSAs, there is already close coordination between water quality regulators and GSA members including the cities of Modesto, Riverbank, Oakdale, and Waterford.

The undesirable results associated with degraded water quality, including causes and impacts to beneficial uses, are described in **Section 6.6.1** below. **Section 6.6.2** describes the quantification of minimum thresholds (MTS), along with justification on how MTs avoid undesirable results. **Section 6.6.3** provides the approach and selection of MOs. Interim milestones (IMs) are described in **Section 6.9** but are not set for this sustainability indicator.

6.6.1. Undesirable Results for Degraded Groundwater Quality

SGMA defines an undesirable result for the water quality sustainability indicator as "significant and unreasonable degraded water quality, including the migration of contaminant plumes that impair water supplies." (§10721 (x)(4)). GSP guidance clarifies that GSAs are only responsible for degraded water quality caused by GSA management activities including regulation of pumping and water levels, along with projects and management actions (Moran and Belin, 2019). Such GSA activities that could lead to undesirable results are described in more detail below.

6.6.1.1. Causes of Undesirable Results

GSA management could potentially affect groundwater quality in several ways. GSAs could allow groundwater level declines in areas where poorer quality groundwater occurs at depth. In those areas, groundwater quality in water supply wells could be adversely impacted. In addition, GSA-allowed groundwater extractions could alter hydraulic gradients and local groundwater flow directions such that degraded water quality could spread laterally into un-impacted areas. Groundwater pumping can also induce the vertical migration of constituents of concern into un-impacted deeper aquifers.

High salinity groundwater is inferred to exist in the Modesto Subbasin below the base of fresh water. Although the base of fresh water is designated as the bottom of the groundwater basin, deep pumping could induce groundwater with elevated total dissolved solids (TDS) to migrate vertically into a well and/or into the freshwater zone of the aquifer. These actions could locally impair water supply and potentially reduce the amount of freshwater in the Subbasin. Deep wells that pump elevated concentrations of constituents of concern may also need to be abandoned to prevent conduits for migration of low quality groundwater.

GSP-related projects and management actions also have the potential to impact groundwater quality. For example, recharge projects could introduce water with constituents of concern or affect the migration of existing constituents. GSP regulations specifically require consideration of whether projects or management actions could inadvertently exacerbate the migration of contaminant plumes.

In the Modesto Subbasin, public water suppliers have noted some deterioration in water quality during recent drought conditions, especially constituents of concern arsenic and TDS; these observations suggest that concentrations of these constituents may be elevated at depth. However, nitrate, which is sourced from the surface has also increased in many areas, perhaps in wells with deeper screens that now pull from shallower, nitrate-impacted groundwater. The City of Modesto has conducted numerous investigations of water quality issues in their wellfields and notes that correlations between constituent concentration and depth are complex.

Degraded water quality can impair groundwater supplies, causing restrictions and/or costs for operation of drinking water supply wells. Increasing costs to provide a reliable and safe drinking water supply could lead to undesirable results. Costs and impacts for domestic wells are also a concern because those wells often represent the sole water supply for the household. Impacts to other beneficial uses other than drinking water supply could also lead to undesirable results. Certain constituents can harm crops, limit water supply for certain industrial processes, harm pipes, cause accelerated corrosion or clogging of fixtures, cause staining on bathtubs and sinks, produce bad taste or odor, and cause acute or chronic health effects.

In the Modesto Subbasin, seven constituents of concern have been identified as having the most likely potential for causing undesirable results based on widespread exceedances of MCLs and adverse impacts on public water suppliers in the Subbasin. Those constituents have been of most concern to STRGBA GSA member agencies as documented in a July 2019 public workshop on Subbasin water quality.

The constituents of concern are associated with a variety of sources including both naturally-occurring (geogenic) conditions and human related (anthropogenic) activities. The naturally-occurring constituents of concern may be elevated at certain depths or in certain aquifer layers and may be of most use in tracking impacts from GSA management of groundwater levels.

The anthropogenic constituents of concern, including nitrate, TCP and PCE (and some sources of TDS), are likely sourced at or near the ground surface where human-related activities occur. This suggests that shallow aquifers are more often impacted from these constituents. However, pumping can cause downward migration of these constituents into deeper aquifers either through more permeable portions of an aquitard or in conduits such as wells.

GSA management activities that cause degraded water quality and lead to significant operations costs and impaired groundwater supply are incorporated into the GSP definition of undesirable results. Specific impacts on beneficial users of groundwater from these conditions are summarized below.

6.6.1.2. Potential Effects on Beneficial Uses

As summarized above, degraded water quality can impair water supply and create considerable operational costs or constraints on public water suppliers. Public water suppliers may need to inactivate or abandon impacted wells, re-distribute wellfield pumping, blend contaminants with clean wells or surface water, drill additional wells, install wellhead or regional treatment facilities, and/or make other operational changes. Immediate notifications to customers may also be required.

If constituents of concern impact domestic wells, residents may lose their water supply; if water quality is not well known in domestic wells, impacts to public health and safety could occur. Agricultural and industrial uses of groundwater could also be adversely impacted as summarized in the previous section. Finally, environmental beneficial uses of groundwater could be impacted; for example, if pumping caused the migration of high salinity groundwater into freshwater areas, GDEs could be affected.

For the Modesto Subbasin, six of the seven constituents of concern have primary maximum contaminant levels (MCLs) that are associated with health concerns such as toxicity (i.e., nitrate, uranium) or carcinogens (i.e., arsenic, TCP, DBCP, and PCE). Accordingly, elevated concentrations of these constituents in drinking water can cause deleterious health effects. Wellhead treatment has been installed on numerous drinking water supply wells to manage these constituents. In particular, the City of Modesto has removed numerous water supply wells from service over time to manage local water quality issues (as indicated by the water quality icon on **Figure 6-1**). Constituents with concentrations above the health-based MCLs significantly affect operations and costs for public water suppliers to ensure a safe drinking water supply.

The regulatory drinking water standard for TDS is not health based and is referred to as a secondary MCL, which is related to aesthetics of the water such as taste or odor. However, public water suppliers incur costs for managing TDS concentrations to provide low salinity groundwater for customer satisfaction. In addition, elevated TDS concentrations in groundwater can also impact agricultural beneficial users by limiting crop yields and causing other operational problems. TDS can also limit industrial beneficial uses for industrial processes requiring low salinity water.

6.6.1.3. Modesto Subbasin Definition of Undesirable Results

Based on the information summarized above and presented in the basin setting, a definition for undesirable results has been developed for degraded water quality in the Modesto Subbasin. Regulations also require that the undesirable result definition include quantitative criteria used to define when and where groundwater conditions can cause an undesirable result (§354.26(b)(2)). This framework allows clear identification for when an undesirable result is triggered under the GSP; definition and criteria are provided below.

Table 6-10: Undesirable Results for Degraded Water Quality

	Undesirable Results Definition	Principal Aquifer(s)
Degraded Water Quality	An Undesirable Result is defined as significant and unreasonable adverse impacts to groundwater quality as indicated by a new (first-time) exceedance of, or further exceedance from, an MCL for a constituent of concern that is caused by GSA projects, management actions, or management of groundwater levels or extractions such that beneficial uses are affected and well owners experience an increase in operational costs. An undesirable result will occur when a Subbasin potable water supply well in the defined monitoring network reports a new (first-time) exceedance of an MT or an increase in concentration above the MT for a Modesto Subbasin constituent of concern that results in increased operational costs and is caused by GSA management activities as listed above.	All

The undesirable result is highly protective in that it requires analysis of every first-time exceedance of an MT or an increase above the MCL of an MT for any of the seven constituents of concern in each potable supply well monitored for that constituent. These criteria ensure that all key data are analyzed with respect to GSA activities. The GSAs will conduct this analysis on an annual basis.

To accomplish this annual analysis, historical data for each potable water supply well in the network must be reviewed on an annual basis to determine if the constituent has been exceeded in that well in the past. Each new (i.e., first-time) exceedance or increase in concentration above the MT – occurring after GSP adoption – must be tracked and analyzed separately to determine if such a concentration could have been caused by GSA regulated groundwater levels, extractions, or projects/management actions, and if additional operational costs are incurred by the well owner. If so, the concentration represents an undesirable result by definition.

This analysis will consider the recent groundwater elevations and extractions near each impacted well. Data will be analyzed in the context of the historical record to establish correlations between groundwater levels, monitoring well locations and construction, and water quality analyses. Changes in water levels and water quality in nearby wells will be incorporated into the analysis. Each constituent of concern will be analyzed using information on sources, historical records of nearby and regional wells, and occurrence/concentrations with respect to the principal aquifer and well screens.

Increases in concentration will also be tracked to comply with the MO described in **Section 6.6.3** below. Hydrographs and chemographs will be used to support the analyses, as needed. Analyses will be coordinated with local public agencies providing drinking water supply including member agencies of the GSAs. Data and analyses will be summarized in annual reports and coordinated with the regulatory agencies responsible for water quality. Any undesirable results will be identified, and GSAs will coordinate with regulatory agencies on options and mitigation measures for water quality impacts.

The MTs are quantified in the following section. The MOs are quantified in subsequent **Section 6.6.3**.

6.6.2. Minimum Thresholds for Degraded Water Quality

GSP regulations require that the MT metric for degraded water quality be set at the water quality measurement that indicates degradation at the monitoring site (DWR, 2017). Regulations also require the consideration of state and federal standards and Basin Plan water quality objectives when setting the MT.

The seven constituents of concern have already exceeded MCLs over a relatively widespread area in Subbasin principal aquifers. Accordingly, MCLs (including primary and secondary MCLs) are set as the MTs and are expressed as follows.

Table 6-11: Minimum Thresholds for Degraded Water Quality

	Minimum Thresholds	Principal Aquifer(s)
Degraded Water Quality	Minimum thresholds are set as the primary or secondary California maximum contaminant level (MCL) for each of seven (7) constituents of concern: • Nitrate (as N) - 10 mg/L • Arsenic - 10 ug/L • Uranium - 20 pCi/L • Total dissolved solids (TDS) - 500 mg/L • Dibromochloropropane (DBCP) - 0.2 ug/L • 1,2,3-Trichloropropane (TCP) - 0.005 ug/L • Tetrachloroethene (PCE) - 5 ug/L.	All

6.6.2.1. Justification and Support for Minimum Thresholds

Analysis of existing groundwater quality conditions in the Modesto Subbasin is provided in **Section 3.2.5 as** part of the basin setting. As explained in the text, the analysis included potential constituents of concern based on a review of the water quality database, local knowledge of constituents of concern from previous studies, and identified by GSA member agencies and stakeholders at a public TAC meeting in July 2019. Public water suppliers, including the City of Modesto, shared information on constituents of concern that have been identified in their drinking water wells over the historical study period. Other GSA members identified other potential constituents of concern that had been the target of several ongoing water quality programs including the Irrigated Lands Regulatory Program (ILRP) and Central Valley Salinity Alternatives for Long-Term Sustainability (CV-SALTS).

As presented in **Section 3.2.5**, data for these potential constituents of concern were analyzed over a 25-year study period based on available data. Analyses included development and posting of average and recent water quality data on Subbasin maps, along with various statistical analyses for concentration distribution, temporal trends and occurrence by principal aquifers (when known) (see **Tables 3-4**, **3-5**, and **3-6**).

Based on these analyses seven constituents of concern were selected for assignment of an MT and further characterization on an annual basis based on elevated concentrations over a relatively widespread area of the Subbasin. These constituents have been the most difficult to manage according to public water suppliers. The constituents also include a variety of sources and occurrences across the Subbasin to provide a more comprehensive tracking of groundwater quality. Specifically, the constituents include:

- naturally-occurring constituents (arsenic, uranium, TDS)
- special constituents with widespread areas of multiple non-point sources (nitrate, TCP, DBCP)
- constituents associated with industrial point sources and environmental investigations (PCE).

Data were evaluated for all three principal aquifers in the Subbasin because all are used for drinking water supply. The City of Modesto is the largest drinking water supplier and has wells in all three principal aquifers. The cities of Riverbank, Oakdale, and Waterford have municipal supply wells in the Eastern Principal Aquifer (see **Figure 2-13**). In addition to these providers, more than 75 smaller water systems scattered throughout the Subbasin also have wells in each of the principal aquifers. Numerous domestic wells also occur in both western and eastern principal aquifers. However, very few wells or drinking water systems are located in the eastern third of the Subbasin, (i.e., generally east of Waterford and Oakdale. See **Figures 2-10, 2-13**, **2-14**, and **6-1**).

Summary information is provided below on the seven constituents of concern assigned an MT; more detailed information is provided in **Section 3.2.5.3** including statistical analyses and temporal trends over a 25-year study period (1995 through 2019) and numerous water quality distribution maps on **Figures 3-35** through **3-52**.

6.6.2.1.1. Nitrate

Nitrate is the most widespread constituent of concern in both the California Central Valley and the Modesto Subbasin (see **Section 3.2.5**). Because of its serious health effects, the MCL of 10 mg/L of nitrate as N is selected as the MT. Sources, median and maximum concentrations, and occurrence of nitrate in Modesto Subbasin groundwater are described in **Section 3.2.5.3** and shown on **Figures 3-35** and **3-36**. Elevated nitrate concentrations are detected in all principal aquifers, including the confined Western Lower Principal Aquifer below the Corcoran Clay. Nitrate concentrations have exhibited a slightly increasing trend over the 25-year study period.

The widespread occurrence of nitrogen in California's Central Valley is being regulated by the Central Valley RWQCB under several programs (in addition to individual site regulatory orders). Those programs include the General Dairy Order (Dairy Order), the ILRP, and CV-SALTS. Nitrate concentrations in domestic wells are being mitigated through the Nitrate Control Program, which involves management areas with mandates to provide safe drinking water to impacted well owners (**Section 2.4.4**).

6.6.2.1.2. Arsenic

Arsenic is a naturally-occurring trace element in the rocks, soils, and groundwater of the Modesto Subbasin. Given its toxicity, the MT has been set at the arsenic MCL of 10 micrograms per liter (µg/L). Other water quality investigations have indicated that arsenic concentrations are higher in older and deeper groundwater samples (see **Section 3.2.5.3**). Although elevated arsenic has been detected in all principal aquifers, average concentrations are much higher in the Western Upper Principal Aquifer and Wester Lower Principal Aquifer than in the Eastern Principal Aquifer. Arsenic concentrations appear to be decreasing in Subbasin wells over the 25-year study period. Additional information on the occurrence and concentrations of arsenic in Modesto Subbasin groundwater is included in **Section 3.2.5.3** and shown on **Figures 3-39** and **3-40**.

6.6.2.1.3. Uranium

Uranium is another naturally-occurring trace element largely derived from granitic rocks in the Sierra Nevada. It is toxic and associated with health effects; the MT is set at the MCL of 20 picocuries per liter (pCi/L). Uranium has been detected at or above the MCL in shallow and intermediate depth wells in the City of Modesto wellfield; about nine wells have been taken offline due to elevated uranium concentrations. In general, concentrations of uranium are higher in the Western Upper Principal Aquifer compared to the other two aquifers. This occurrence is consistent with the geochemical conditions that lead to mobilization of uranium in the aquifers (**Section 3.2.5.3**). Over the 25-year study period, uranium concentrations have exhibited an increasing trend in Modesto Subbasin groundwater. Additional information on the occurrence and concentrations of uranium is included in **Section 3.2.5.3** and shown on **Figures 3-41** and **3-42**.

6.6.2.1.4. Total Dissolved Solids

TDS represents the total concentration of anions and cations in groundwater and is a useful indicator of mineralization, salt content, and overall groundwater quality. TDS generally meets drinking water standards in the Subbasin with only 14 percent of the TDS samples exceeding the upper limit California Secondary MCL of 1,000 mg/L. Most samples also meet the MT recommended secondary MCL for drinking water of 500 mg/L. The lower secondary MCL is used as the MT to address recommended concentrations for both drinking water and irrigation of some Modesto Subbasin crops (see **Section 3.2.5.3**) and to provide for a more protective water quality analysis.

Average and recent concentrations of TDS in groundwater samples are provided on **Figures 3-37** and **3-38**, respectively. As indicated on the maps, TDS concentrations are generally lowest in the central Subbasin, especially in the urban areas around Modesto, Oakdale, Riverbank, and Waterford. Elevated concentrations occur in the western Subbasin (in the San Joaquin National Wildlife Refuge) and in southwest Modesto.

Even though elevated TDS is inferred to occur in deeper portions of the Subbasin (below the base of freshwater), the statistical analysis in **Section 3.2.5.3** indicates that the highest TDS concentrations have been observed in the Western Upper Principal Aquifer (i.e., in the western Subbasin as indicated above). However, these high concentrations were not necessarily widespread and may indicate local point sources of TDS, especially near the San Joaquin River.

Additional information on the occurrence and concentrations of TDS in Modesto Subbasin groundwater is included in **Section 3.2.5.3** and shown on **Figures 3-37** and **3-38**.

6.6.2.1.5. 1,2,3-Trichloropropane (TCP)

TCP is a manufactured chlorinated hydrocarbon used for degreasing and previously associated with soil fumigants, which were widely used in agriculture through most of the 1980s. The chemical was banned in the 1990s. The MT is set at the MCL of 0.005 µg/L, which was only recently established (effective 2018). As a result, historical data for TCP in groundwater are sparse.

Elevated TCP concentrations have been detected in mostly urban areas, including Modesto, Riverbank, and Waterford, likely due to the increased sampling in drinking water supply wells. Even though TCP has been associated with relatively widespread application throughout the Central Valley, elevated concentrations are relatively sparse and localized in the Modesto Subbasin. This may indicate a lack of historical use in the Subbasin with just a few local point sources indicated. Elevated concentrations have not been detected in the Western Lower Principal Aquifer, indicating a surficial source and local protection against vertical migration by the Corcoran Clay.

Additional information on the occurrence and concentrations of TCP in Modesto Subbasin groundwater is included in **Section 3.2.5.3** and shown on **Figures 3-49** and **3-50**.

6.6.2.1.6. Dibromochloropropane (DBCP)

DBCP was a widely used pesticide (nematocide and soil fumigant) in the Central Valley prior to being banned in the late 1970s.Due to its mobility and toxicity, the MT is set at the MCL of 0.2 ug/L.

Concentrations are relatively low in the Modesto Subbasin with about 14 percent of the samples from the historical database exceeding the MCL. Similar to TCP, DBCP has not been detected in the Western Lower Principal Aquifer. In addition, data indicate a declining trend of concentrations over time, likely due to its long-term ban. Additional information on the occurrence and concentrations of DBCP in Modesto Subbasin groundwater is included in **Section 3.2.5.3** and shown on **Figures 3-47** and **3-48**.

6.6.2.1.7. Tetrachloroethene (PCE)

PCE is a volatile organic compound (VOC) developed as an industrial solvent. PCE has been widely use in a variety of industrial applications including as a dry cleaning fluid. Discharges from a number of dry cleaners in the City of Modesto have resulted in local contaminant plumes of PCE, all of which are being managed by other local regulatory agencies responsible for water quality. PCE has also been detected at Modesto Subbasin landfills and other sites under regulatory investigations and remediation. At least seven City of Modesto wells have installed wellhead treatment systems for managing PCE impacts. The MT is set at the California and Federal MCL of 5 ug/L.

Elevated concentrations of PCE are generally associated with point sources of the contaminant including industrial and commercial sites. Similar to TCP and DBCP, PCE has not been detected in the Western Lower Principal Aquifer, indicating surficial sources and protection by the Corcoran Clay.

Additional information on the occurrence and concentrations of PCE in Modesto Subbasin groundwater is included in **Section 3.2.5.3** and shown on **Figures 3-51** and **3-52**.

6.6.2.2. Relationship between MTs of Each Sustainability Indicator

Regulations require a description of the relationship between the MTs for each sustainability indicator and how the GSAs have determined that basin conditions at each MT will avoid undesirable results (§354.28(b)(2)). To facilitate a comparison between MTs, a summary of MTs for each sustainability indicator was provided in **Table 6-5** and discussed previously in **Section 6.3.2.2**.

As provided in **Section 6.3.2.2**, the MCLs for each constituent of concern – selected as the MTs – would not interfere with the MTs for the other sustainability indicators. All other MTs consist of groundwater elevations that are at or above the historic low water in the Subbasin. As such, the groundwater level MTs are protective against increases in constituents of concern that occur primarily at depth. Further, because these groundwater level MTs are similar to recent water levels across the Subbasin, hydraulic gradients would not be altered substantially that might cause migration of constituents into previously un-impacted areas.

In this manner, the MTs for the other sustainability indicators are supportive of the MTs for degraded water quality and cause no conflicts for groundwater management. The constituents will be tracked on an annual basis and analyzed with respect to changes in groundwater levels and extractions to determine if GSA management activities might be impacting groundwater quality.

GSA member agencies have already been coordinating with regulatory agencies responsible for drinking water quality in the Subbasin. In addition, these agencies are actively engaged with regulated water quality coalitions that have ongoing monitoring programs for certain Modesto Subbasin constituents of concern including the Nitrate Control Program and CV-Salts. Representatives from the Valley Water Collaborative – a coalition responsible for implementing the Nitrate Control Program (NCP) – provided a presentation at a public TAC meeting in December 2020. Many Subbasin landowners are directly participating in the NCP, providing additional opportunities for coordination.

Finally, as previously stated, multiple GSA member agencies are responsible for drinking water quality and routinely coordinate with water quality regulatory agencies. Because the drinking water standard (MCLs) are the target for both the water quality coalitions mentioned above and the water quality regulatory agencies, the selection of the MCLs as the MTs is consistent with other water quality programs. In this manner, the GSAs have determined that the MTs will avoid undesirable results.

6.6.2.3. Impacts of MTs on Adjacent Subbasins

Regulations require consideration of how Modesto Subbasin MTs impact the ability of an adjacent subbasin to achieve its sustainability goal. As summarized in more detail in **Section 6.3.2.3**, similar principal aquifers, shared interconnected surface water boundaries, and multiple GSA member agencies that overlap both the Modesto Subbasin and adjacent subbasins have facilitated setting MTs in the Modesto Subbasin that will not adversely impact adjacent subbasins GSP implementation.

Additional water quality considerations for MTs in each adjacent subbasin are summarized below.

6.6.2.3.1. Eastern San Joaquin Subbasin

The MT for degraded water quality in the ESJ Subbasin is defined as a TDS concentration of 1,000 mg/L TDS in representative monitoring wells, none of which occur along the shared subbasin boundary with the Modesto Subbasin. Rather, water quality monitoring is focused along the western rim of the ESJ Subbasin where TDS concentrations are of most concern in the ESJ Subbasin. The closest water quality monitoring well more than six miles north of the Modesto Subbasin. In addition, MTs for interconnected surface water, set at 2015 groundwater elevations along the Stanislaus River, are set similarly in both subbasins. Finally, water budget analyses for sustainable yield conditions indicate that subsurface flow is relatively small and occurs from the ESJ Subbasin into the Modesto Subbasin. Therefore, MTs in the Modesto Subbasin are not expected to conflict or affect the MTs in the ESJ Subbasin.

6.6.2.3.2. Delta-Mendota Subbasin

The Delta-Mendota Northern & Central GSP focused on constituents that are linked to groundwater elevations or other groundwater-management activities. Undesirable results are to be triggered if TDS, nitrate, or boron exceed the MCL or water quality objectives (WQOs) in three consecutive sampling events in non-drought years or additional degradation where current groundwater quality already exceeds the MCLs or WQOs. An undesirable result would also occur if a recharge project exceeded 20 percent of the aquifer's assimilative capacity without justification of a greater public benefit.

MTs were set at each monitoring site based on these criteria. As indicated in the GSP, there are no representative monitoring sites adjacent to the shared river boundary with the Modesto Subbasin (see the Delta-Mendota representative monitoring wells for degraded water quality on Figures 6-4 and 6-5 in W&C and P&P, 2019). The closest monitoring wells are 06-004 in the Upper Aquifer and 0-003 in the Lower Aquifer, located about three miles to the southwest of the southwestern corner of the Modesto Subbasin.

At those wells, the MTs for TDS are 4,000 mg/L and 2,000 mg/L for the Upper Aquifer and Lower Aquifer, respectively. The MTs for nitrate (as N) are 80 mg/L and 50 mg/L for the Upper Aquifer and Lower Aquifer, respectively. These MTs are much higher than the MCLs established for the MTs in the Modesto Subbasin. In addition, the closest monitoring wells are upgradient and would not be impacted by any degraded groundwater quality in the Modesto Subbasin.

In addition, water budget analyses indicate a net subsurface inflow from the Delta Mendota Subbasin into the Modesto Subbasin for projected future and sustainable yield conditions (**Table 5-15**). Collectively, the 3-mile distance from the nearest monitoring well, the upgradient location of the Delta-Mendota wells, the higher MTs for TDS and nitrate in the Delta-Mendota Subbasin, and the indicated subsurface flow direction into the Modesto Subbasin indicate that MTs in the Modesto Subbasin will not impact MTs for degraded water quality or impact GSP implementation in the Delta-Mendota Subbasin.

6.6.2.3.3. Turlock Subbasin

The Turlock Subbasin has defined undesirable results for degraded water quality in a similar manner to the Modesto Subbasin, using MCLs for six of the seven Modesto Subbasin constituents of concern as the MTs. Both subbasins have similar water quality issues and will coordinate the tracking and analysis across the Tuolumne River boundary.

In addition to the coordination of sustainable management criteria, two member agencies in the Modesto Subbasin - the City of Modesto and the City of Waterford[19] – monitor for groundwater quality in both subbasins, allowing for close coordination of any water quality issues along the Tuolumne River boundary. Water quality data for both subbasins will be analyzed annually using similar data sources and methods, which will allow for close

[19] The City of Waterford operates drinking water supply wells for the community of Hickman in the Turlock Subbasin.

coordination of any degraded water quality across the two subbasins. Analyses in both subbasins will be conducted to determine if GSA management of groundwater extractions, levels, or GSP projects/management actions are impacting groundwater quality. These analyses will be presented in Annual Reports for each subbasin.

6.6.2.4. Effects of MTs on Beneficial Uses and Users of Groundwater

The setting of MCLs as the MTs is protective with respect to the avoidance of undesirable results. By protecting drinking water quality, the long-term quality and quantity of useable groundwater for all beneficial uses will be preserved.

The City of Modesto has been historically impacted by water quality problems in their wellfields. About 18 water supply wells had to be removed from service for impacts related to arsenic, nitrate, or uranium (see **Section 3.2.5.3**). Another 9 water supply wells have been taken offline due to TCP or PCE contamination. To address these issues, the City has conducted numerous water quality studies and is currently completing a wellfield investigation and feasibility study to identify remedial options for wellfield management. Those independent studies and Subbasin-wide annual tracking of groundwater quality will each inform the other, providing a better understanding of degraded water quality in the Subbasin.

The commitment to analyze a large groundwater quality dataset across the Subbasin on an annual basis will improve GSA understanding of water quality in each Principal Aquifer and lead to better management practices. Expanded and ongoing data collection and analysis will also support ongoing regulatory monitoring, allowing others to evaluate their local water quality monitoring data in the context of Subbasin-wide water quality. For example, an improved understanding of water quality with depth allows future wells to be sited and designed such that water quality is optimized. Overall, these improvements will support all beneficial uses of groundwater in the Subbasin.

6.6.2.5. Consideration of State, Federal, or Local Standards in MT Selection

In setting MTs for degraded water quality, GSP regulations require that GSAs consider local, state, and federal water quality standards applicable to the Subbasin (354.28(c)(4)). As provided above, the degraded water quality sustainability indicator relies on California MCLs for the MT; in this manner, the MT adheres to drinking water quality standards set by California, which are either as protective or more protective than federal standards. The MCLs are also consistent with the local standards and water quality objectives (WQO) in the Central Valley RWQCB Basin Plan for the San Joaquin River Basin (2018). Accordingly, there are no conflicts with regard to regulatory standards.

6.6.2.6. Quantitative Measurement of Minimum Thresholds

As stated above, the MTs for the degradation of water quality will be quantitatively monitored through existing monitoring programs that are being managed by the SWRCB and uploaded to the public GeoTracker website. These water quality data are monitored by public agencies, regulated coalitions, and others in representative monitoring wells for each Principal Aquifer using regulatory-approved sampling protocols. Data will be downloaded from the State GeoTracker water quality website and supplemented with data from the salt and nutrient regulatory programs in the Subbasin (see **Section 2.4.4**). Water quality data will be analyzed for constituents of concern in each Principal Aquifer as described in **Chapter 7** (Monitoring Network) of this GSP (see **Section 7.1.4**). Analyses will be included in the Subbasin GSP annual reports.

These data are considered comprehensive for characterization of water quality in the Subbasin. More than 300 wells with water quality data for Modesto Subbasin constituents of concern were available from GeoTracker from January 2020 to May 2021; these water quality monitoring sites are shown on **Figure 7-4** as part of the GSP monitoring network and tabulated in **Appendix G**. As shown on **Figure 7-4**, wells are distributed throughout the Subbasin but focused in areas of drinking water supply wells (see **Figure 2-10**). This is appropriate given the emphasis on drinking water supply impacts (i.e., MCL exceedances) in the definition of undesirable results.

Although monitored wells will change from year to year based on regulatory monitoring requirements, public water suppliers generally monitor and report water quality data for all active drinking water wells (see **Figure 2-13**). GeoTracker also includes water quality monitoring data from sites with contaminant plumes as a part of the RWQCB regulatory programs (see summary data on **Figure 4-57**). As indicated in **Appendix G**, monitoring sites consist of municipal supply wells, monitoring wells, and domestic wells. Although most domestic wells are currently sampled for nitrate only (**Appendix G**), the SWRCB is planning to expand water quality monitoring in those wells, adding additional constituents of concern including most of those in the Modesto Subbasin.

Additional wells from supplemental regulatory programs are also either included on GeoTracker or available for public download to allow for a broad analysis of water quality on an annual basis. Monitoring programs for TDS and nitrate are conducted by the Eastern San Joaquin Water Quality Coalition (ESJWQC) in coordination with the CV-SALTS program and the Nitrate Control Program, which requires growers in management zones to ensure safe drinking water supplies for well owners impacted by nitrate concentrations (see **Section 2.4.4**). As a result of this large dataset, the GSAs are not planning to develop a separate GSP water quality monitoring network, and no water quality sampling will be conducted by the GSAs.

However, GSAs will ensure that projects and management actions comply with regulatory water quality requirements. GSAs will consider appropriate constituents, MCLs, and water quality objectives (WQOs) as projects are initiated to avoid undesirable results. Potential water quality considerations for currently proposed projects will be evaluated through the CEQA process as projects are implemented.

6.6.3. Measurable Objectives for Degraded Water Quality

To avoid exacerbation of the nature and extent of current groundwater quality by management activities, the GSAs are using the MOs to establish a target water quality condition whereby GSA management does not cause an increase in historical concentrations of constituents of concern (i.e., further degradation of water quality). This target is managed by the definition of measurable objectives for degraded water quality as follows.

Table 6-12: Measurable Objectives for Degraded Water Quality

	Measurable Objectives	Principal Aquifer(s)
Degraded Water Quality	Measurable objectives are defined as the historical maximum concentration of each constituent of concern at each representative monitoring location.	All

The same monitoring data summarized in **Section 6.6.2.6** above will be used to analyze MOs for the constituents of concern (see also **Figure 7-4**).

6.7. Land Subsidence

SGMA defines an undesirable result for land subsidence as "significant and unreasonable land subsidence that substantially interferes with surface land uses" (§10721 (x)(5)). In general, land subsidence can interfere with land use by causing damage to either the natural land surface (e.g., surface fissures) or to structures on the land surface (e.g., roads or pipelines). Potential impacts from land subsidence are documented in **Section 3.2.6** and summarized in **Section 6.7.1.1** below.

As described in **Section 3.2.6**, there have been no known impacts from inelastic land subsidence in the Modesto Subbasin. Land subsidence associated with groundwater extraction has been documented across large segments of the San Joaquin Valley since the 1950s, but these areas are located significant distances to the south of the Modesto Subbasin (see **Figure 3-58**).

However, as explained in the remainder of **Section 6.7**, the potential for future land subsidence in the Subbasin cannot be dismissed, given the presence of the Corcoran Clay, the decline of groundwater levels in certain management areas, and the results of recent GPS station monitoring and remote sensing data. As a protective measure, sustainable management criteria for the land subsidence sustainability indicator have been selected for all principal aquifers in the Modesto Subbasin.

Because there have been no known impacts from land subsidence, it is difficult to determine what rates of subsidence would lead to undesirable results. For the Modesto Subbasin, the sustainable management criteria for chronic lowering of water levels were developed to arrest groundwater level declines caused by groundwater extraction (**Section 6.3**). As such, those criteria would protect against future land subsidence (see **Section 6.7.1.1**). Accordingly, the sustainable management criteria, including MTs set as the historical low groundwater levels for WY 1991 through WY 2020, are used as a proxy for land subsidence sustainable management criteria.

Potential undesirable results, including causes and impacts to beneficial uses, are described in **Section 6.7.1** below, with a definition of undesirable results provided at the end of the section. **Section 6.7.2** describes the quantification of minimum thresholds (MTs) and provides additional information on rationale and coordination of MTs in adjacent subbasins. **Section 6.7.3** provides the approach and selection of measurable objectives (MOs). Interim milestones that cover all of the applicable sustainability indicators are described in **Section 6.9**.

6.7.1. Undesirable Results for Land Subsidence

Vertical displacement of the land surface can be caused by a variety of mechanisms, including extraction of oil and gas, the wetting of collapsible soils, piping of sediment from underground pipeline or tank leaks, collapse from underground mining facilities, tectonic activity along geological faults, and other conditions. This GSP only focuses on land subsidence related to groundwater extraction. The following sections summarize the physical processes that could potentially cause future land subsidence in the Modesto Subbasin as well as the related causes and effects of potential undesirable results.

6.7.1.1. Causes of Undesirable Results for Land Subsidence

Areas of the San Joaquin Valley have had impacts from land subsidence related to groundwater pumping, which has lowered water levels within and below the thick and compressible Corcoran Clay. For example, land subsidence in the Merced Subbasin to the south occurred in this manner (W&C, 2019) (see **Figure 3-58**).

As pumping removes groundwater from storage, the pore pressure and support of the aquifer framework are reduced, and sediments can be realigned and compacted at depth. This compaction is typically associated with thick and compressible clay layers. Subsurface compaction reduces the volume of subsurface sediments, causing the ground surface to depress. The processes and mechanisms that result in land subsidence are more complex than summarized herein, but the concept of subsurface compaction is typically used to provide a general understanding of the process. Additional information is summarized in **Section 3.2.6** and illustrated on **Figure 3-57**.

The western Modesto Subbasin within the extent of the Corcoran Clay is thought to be the area most susceptible to future land subsidence (see red striped area on **Figure 6-1**). Recent processing of satellite data to analyze vertical displacement – referred to as InSAR[20] – suggests that no land subsidence has recently occurred in the western Subbasin (see **Figure 3-59**). However, data show some small amounts of vertical displacement in the eastern

[20] InSAR refers to Interferometric Synthetic Aperture Radar data.

Modesto Subbasin (see **Figure 3-59**). It is not known whether this vertical displacement is related to groundwater extraction or other mechanisms described in **Section 6.7.1** above.

Nonetheless, the hydrogeological conditions in the western Subbasin and the InSAR data in the eastern Subbasin highlight the need for monitoring and management. Because groundwater drains slowly from compacted clay layers, there is a time lag between the triggering mechanisms that cause land subsidence and the actual depression on the land surface. A slow and small rate of decline in the land surface can go unnoticed until disruption of infrastructure or other physical manifestation of the problem occurs.

The processes above describe the causes of potential land subsidence, but the causes of undesirable results are related to the adverse impacts that land subsidence could have on land uses. For example, the documented land subsidence in the California Central Valley has caused numerous adverse impacts that could lead to undesirable results if they occurred in the Modesto Subbasin. Land subsidence could interfere with land use through a physical alteration of the ground surface, such as fissures, cracks, or depressions or by damaging physical structures on the ground surface such as buildings or infrastructure.

Adverse impacts are likely to occur in urban areas where numerous buildings, utilities, and pipelines are present. In addition, areas of groundwater wells could experience casing or other wellbore damage. Impacts have also been documented along surface water canals and transportation corridors, with damage to canals, roads, freeways or bridges. These impacts could cause an interruption to vital services or increase risks to public health and safety. In addition to physical damage, land subsidence can also affect gravity drainage in sewers, pipelines, or water conveyance canals and can also increase the risk of flooding (LSCE, 2014; W&C, 2019; W&C and P&P, 2019).

In consideration of these adverse impacts, the Modesto Subbasin GSAs incorporated impacts to infrastructure into its undesirable result definition. Definitions from GSPs in adjacent subbasins, including the Delta-Mendota and the Eastern San Joaquin subbasins, were also reviewed (W&C and P&P, 2019; ESJGWA, 2019). The definition of undesirable results for the Modesto Subbasin is provided in **Section 6.7.1.3** below.

6.7.1.2. Effects on Beneficial Uses of Groundwater

Two commonly-cited effects on almost all beneficial users of groundwater in the Central Valley include damage to casings in water supply wells and interference with water canal capacity and conveyance (LSCE, 2014). Widespread collapse of well casings resulting from land subsidence have been well-documented in numerous areas. Near El Nido, California, well casings have been observed protruding above the land surface, in some cases with the connected concrete well pad suspended in the air (LSCE, 2014). Casing damage typically requires well replacement, resulting in significant costs to beneficial users of groundwater.

Given the close linkage between groundwater and surface water use in the Central Valley, land subsidence impacts on water conveyance facilities can have a negative impact on the beneficial uses and users of groundwater. Land subsidence has reduced freeboard and flow capacity in large water conveyance canals such as the Delta-Mendota Canal, the California Aqueduct, and the Friant-Kern Canal. Repairs to restore conveyance capacity along critical segments of the Friant-Kern Canal alone is estimated to cost as much as $200 million or more (FWA, 2018). In the Merced Subbasin GSP, undesirable results for land subsidence were related primarily to the viability of the Eastside Bypass Canal, where subsidence has caused a reduction in freeboard and capacity over the last 50 years. These impacts to surface water canals can result in an increase in groundwater pumping, often from groundwater basins already experiencing overdraft conditions, which can lead to a depletion in water supply.

Subsurface compaction of clay layers also causes permanent removal of groundwater from storage. Although the usable storage capacity of an aquifer is not substantially impacted by the dewatering and compaction of clay layers, there is some amount of groundwater that is permanently lost. Pumping an identical amount of groundwater after this loss can result in a lower water level than before the clay layer was drained. Lower groundwater levels can result in higher pumping lift costs and other negative effects on beneficial uses of groundwater (see **Section 6.3.1.2**) (LSCE, 2014).

Land subsidence could also disrupt activities on the land surface including agricultural production. Changes to the land surface, such as with fissures or depressions, could affect how both surface water and groundwater is conveyed onto and within productive agricultural parcels. These effects could create inefficiencies in beneficial groundwater use or interferences with agricultural land uses.

Finally, any of the above activities that lead to increased groundwater pumping would also have the potential to affect environmental users of groundwater including potential GDEs (**see Section 3.2.8** and **Figure 3-60**).

6.7.1.3. Modesto Subbasin Definition of Undesirable Results

In consideration of the land use and infrastructure impacts summarized above, an undesirable result has been developed for the Modesto Subbasin. Regulations require that the undesirable result definition include quantitative criteria used to define when and where groundwater conditions can cause an undesirable result (§354.26(b)(2)). These criteria address the number of monitoring sites and events that an MT can be exceeded before causing an undesirable result while recognizing that a single MT exceedance at one monitoring site may not indicate an undesirable result. Criteria also allow for a clear identification when an undesirable result is triggered.

The definition of undesirable results is provided as follows.

Table 6-13: Undesirable Results for Land Subsidence

	Undesirable Results Definition	Principal Aquifer(s)
Land Subsidence	An Undesirable Result is defined as significant and unreasonable inelastic land subsidence, caused by groundwater extraction and associated water level declines, that adversely affects land use or reduces the viability of the use of critical infrastructure. An undesirable result will occur when 33 percent of representative monitoring wells exceed the MT in three consecutive Fall monitoring events.	All

The criteria for triggering an undesirable result were developed for the chronic lowering of water levels indicator as discussed in **Section 6.3.1.3** and are applied as a proxy for the land subsidence sustainability indicator.

Accordingly, the monitoring networks for both land subsidence and chronic lowering of water levels are identical. As stated in **Section 6.3.1.3**, 33 percent is equivalent to 6 of 17 wells in the Western Upper Principal Aquifer, 2 of 5 wells in the Western Lower Principal Aquifer, and 13 of 39 wells in the Eastern Principal Aquifer.

MT exceedances are limited to 3 consecutive Fall monitoring events to avoid the potential seasonal component of elastic land subsidence. Elastic subsidence may occur in the fall, during low water level conditions, only to rebound during the spring, during high water level conditions. Data from a GPS station in the Subbasin illustrates this seasonal rebound (see **Section 3.2.6**, information on existing GPS stations). If groundwater elevations are managed at or above the MTs on a regional and multi-year basis, potential undesirable results for land subsidence should be avoided.

Water level monitoring will be supplemented by annual screening of InSAR data. These data will be re-evaluated with the water level monitoring network in the five-year GSP evaluation. If InSAR data indicate increasing rates of subsidence, the monitoring network will be bolstered by additional monitoring, such as the installation of GPS stations, in targeted areas of the Subbasin. In addition, the criteria could also be adjusted to be more protective.

6.7.2. Minimum Thresholds for Land Subsidence

As provided in the GSP regulations, the MT for land subsidence "shall be the rate and extent of subsidence that substantially interferes with surface land uses and may lead to undesirable results" (§354.28(c)(5)). Given the lack of undesirable results associated with land subsidence in the Modesto Subbasin, it is not possible to correlate a rate of subsidence to undesirable results. As explained in more detail below, available data sets indicate no land subsidence over most of the Subbasin. InSAR data indicate very low rates of vertical displacement in the central and eastern Subbasin, but this may also be due to irrigation on clay-rich soils or other land surface modifications associated with agricultural operations (see **Figure 3-6**). Additional supporting technical information on land subsidence in the Modesto Subbasin is provided in **Section 3.2.6** and summarized below in **Section 6.7.2.1**.

Because the greatest risk for land subsidence in the Modesto Subbasin is the dewatering/depressurization of clays, setting MTs at historic low groundwater levels (WY 2015 – WY 2020) was viewed as a reasonable strategy for minimizing future subsidence. In this manner, groundwater levels would be protective against worsening conditions that could lead to future undesirable results for land subsidence. Because the chronic lowering of water level MTs were developed to arrest water level declines in the Subbasin, they serve as reasonable MTs for avoidance of undesirable results for land subsidence. As such, chronic lowering of water levels MTs are used as a proxy for directly monitoring for land subsidence as follows.

Table 6-14: Minimum Thresholds for Land Subsidence

	Minimum Thresholds	Principal Aquifer(s)
Land Subsidence	Minimum thresholds are defined as the historic low groundwater elevation observed or estimated during WY 1991 – WY 2020 at each representative monitoring location, based on available data. (Using Chronic Lowering of Groundwater Levels as a proxy.)	All

Additional support and justifications for the MTs, along with the quantitative criteria for the combination of MT exceedances provided in the undesirable results definition, are discussed in the following section.

6.7.2.1. Justification and Support for Minimum Thresholds

GSP regulations require that the MTs for land subsidence be supported by:

- Identification of land uses and property interests that have been affected or are likely to be affected by land subsidence, including an explanation of how these uses and interests were determined.
- Rationale for establishing MTs in consideration of the above effects
- Maps and graphs showing the extent and a rate of land subsidence in the basin that defines the MT and MO.

With regards to the identification of land uses and property interests that are likely to be affected by land subsidence, potential effects of land subsidence on property interests are mentioned above in **Sections 6.7.1.1** and **6.7.1.2**. These effects on beneficial uses are general and hypothetical because no effects on beneficial uses caused by land subsidence have been identified in the Subbasin.

As mentioned previously, InSAR data published by DWR provides the best available vertical displacement data for the Subbasin. **Figure 3-60** illustrates cumulative vertical displacement over more than five years, from June 2015 through October 2020. As indicated by the dark gray areas, there is no negative vertical displacement (land subsidence) over most of the Subbasin. Only one small area of land subsidence is indicated within the extent of the Corcoran Clay. This area, located in the northwest corner of the Subbasin in the San Joaquin Wildlife Refuge, indicates a rate of land subsidence of up to 0.24 inches per year.

InSAR data indicate larger rates of vertical displacement in the central-southeastern Subbasin (orange and brown on **Figure 3-60**). Data in this area indicate a vertical displacement rate of about 0.12 inches per year with rates up to about 0.36 inches per year in two small, isolated areas (**Figure 3-60**). This area is outside of the Corcoran Clay and is characterized by relatively shallow, consolidated aquifers (i.e., Mehrten Formation) that would be less likely to experience significant land subsidence than areas with compressible clays.

In addition, there are clay-rich soils and multiple restrictive layers (e.g., duripan) in the eastern Subbasin that could be the cause of these small rates of vertical displacement (rather than groundwater extractions) (see **Figure 3-6**). For example, clay soils can be subject to swelling when wetted. In addition, the disruption of restrictive layers on agricultural lands could also result in small local differences in surface elevation, as can other agricultural operations. However, this area is also associated with increasing groundwater extractions over the historical study period, and the potential for land subsidence associated with these extractions cannot be ruled out at this time.

The map on **Figure 3-59** also shows the locations of three existing global positioning system (GPS) stations[21] along Highway 99, within the extent of the Corcoran Clay. The two northern stations are in Salida, and the southern station is in Modesto. These existing stations, monitored by other programs, provide highly-accurate ground surface elevation data. Data available from the northern (August 2006 to December 2007) and southern (November 2006 to July 2001) GPS stations indicate that there has been no inelastic land subsidence at those locations. The central station indicates a rate of land subsidence of about 0.048 inches per year (less than 5 inches over 100 years), for the period of August 2008 to June 2014 (see **Section 3.2.6** for more information).

Increased rates of subsidence are often triggered during drought conditions (LSCE, 2014); the available recent land subsidence data in the Modesto Subbasin were collected during the long-term (and ongoing) drought conditions that resulted in historic low water levels

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[21] Installed and operated by the U.S. Bureau of Reclamation in connection with the San Joaquin River Restoration Program.

throughout the Subbasin. It is not possible to know whether the current rates will continue beyond the drought.

Collectively, these data suggest that significant rates of land subsidence are not occurring in the Modesto Subbasin. Accordingly, MTs are selected to be protective against triggering significant rates of subsidence in the future. All of the information and data reviewed to date indicate that undesirable results from land subsidence could be avoided by arresting the ongoing water level declines in the Subbasin. By setting MTs at the historical low, water level declines are controlled, and any current land subsidence is not exacerbated. As indicated above, the MTs for chronic lowering of groundwater levels are being used as a proxy for land subsidence MTs because these MTs manage groundwater levels near or above historic low groundwater levels (WY 1991 – WY 2020).

As an additional protective measure, the GSAs intend to download and review DWR's InSAR data on an annual basis, for screening purposes. As illustrated on **Figure 3-59**, the InSAR data cover the entire extent of the Subbasin. Data will be used for ongoing evaluation of the rate and extent of land subsidence. The data will be re-evaluated for the five-year evaluation in 2027. If significant rates of subsidence have occurred between 2022 and 2027, additional monitoring, such as additional wells or GPS stations, will be installed in areas of concern.

In this manner, the GSAs will ensure that the potential for impacts to land uses from land subsidence is not missed. This approach is reasonable, based on the best available data in the Modesto Subbasin.

6.7.2.2. Relationship between MTs of Each Sustainability Indicator

Regulations require a description of the relationship between the MTs for each sustainability indicator and how the GSAs have determined that basin conditions at each MT will avoid undesirable results (§354.28(b)(2)). To facilitate this comparison, MTs for each sustainability indicator were summarized in **Table 6-5,** as discussed above in **Section 6.3.2.2**.

Because the MTs for chronic lowering of groundwater levels are being used as a proxy for land subsidence, the interaction between the MTs for land subsidence and the other MTs is the same as for chronic lowering of water levels. As such, please refer to **Section 6.3.2.2** above for meeting this regulatory requirement for the land subsidence sustainability indicator. These sustainability indicators are also analyzed separately in other subsections of **Chapter 6**, as referenced in **Table 6-4**.

6.7.2.3. Impacts of MTs on Adjacent Subbasins

Regulations require consideration of how Modesto Subbasin MTs impact the ability of an adjacent subbasin to achieve its sustainability goal. As summarized in more detail in **Section 6.3.2.3**, similar principal aquifers, shared interconnected surface water boundaries, and multiple GSA member agencies that overlap both the Modesto Subbasin and adjacent subbasins have facilitated setting MTs in the Modesto Subbasin that will not adversely impact adjacent subbasins GSP implementation. Additional details relevant to each adjacent subbasin are summarized below.

6.7.2.3.1. Eastern San Joaquin Subbasin

ESJ Subbasin MTs for chronic lowering of water levels are also used as a proxy for the reduction of groundwater in storage, land subsidence, and interconnected surface water. Therefore, the analysis presented for the chronic lowering of water levels in **Section 6.3.2.3.1** provides the technical rationale for concluding that MTs in the Modesto Subbasin for land subsidence will not adversely affect GSP implementation in the ESJ Subbasin.

6.7.2.3.2. Delta Mendota Subbasin

Land subsidence is a prevalent issue in the Delta-Mendota Subbasin, with impacts to infrastructure of statewide importance (such as the California Aqueduct and the Delta-Mendota Canal). However, no significant land subsidence has been documented near the Modesto Subbasin. Most of the subsidence maps in the Northern & Central Delta-Mendota GSP either do not contain data or do not indicate significant amounts of land subsidence along its shared San Joaquin River boundary with the Modesto Subbasin (see Figures 5-113, 5-114, and 5-116 in W&C and P&P, 2019). The closest UNAVCO GPS station (P255) along the Delta-Mendota Canal is located approximately nine miles to the west of the Modesto Subbasin, and data from 2007 to 2018 at that station did not indicate inelastic land subsidence.

For the Northern & Central Delta-Mendota GSP, land subsidence MTs in the management area adjacent to the Modesto Subbasin are based on an acceptable loss in distribution capacity in subbasin canals, to be determined in a future study (W&C and P&P, 2019). The closest subsidence monitoring station to the Modesto Subbasin is more than two miles to the southwest of the Modesto Subbasin boundary (04-002), and the MT had not yet been quantified. However, given that MTs are set at the historical low groundwater levels, no impacts on land subsidence in the Delta-Mendota Subbasin would be anticipated. In addition, MTs for interconnected surface water are the Fall 2015 groundwater elevations along the San Joaquin River, providing even more protection for the adjacent subbasin (see **Section 6.8.2.3.2**). Given these conditions, no impacts are expected on GSP implementation in the Delta-Mendota Subbasin.

6.7.2.3.3. Turlock Subbasin

Both the Turlock Subbasin and Modesto Subbasin have approved MTs for interconnected surface water that are based on Fall 2015 water levels along both sides of the Tuolumne River (see **Section 6.8.2.3.3**). In that manner, the two GSPs are coordinating on MTs and avoiding undesirable results for streamflow depletion. Accordingly, MTs in the Modesto Subbasin for land subsidence will not have an adverse impact on GSP implementation in the Turlock Subbasin.

6.7.2.4. Effects of MTs on Beneficial Uses and Users of Groundwater

The setting of MTs is protective with respect to the avoidance of undesirable results. However, the MTs place operational constraints on agricultural wells and other water supply wells, especially during long-term multi-year droughts. Because the MTs for chronic lowering of water levels are used as a proxy for land subsidence, all of the same effects on beneficial uses and users of groundwater discussed previously also apply to this indicator (see **Section 6.3.2.4**).

Shallow groundwater levels in the Western Upper Principal Aquifer create operational issues for agriculture and groundwater pumping is required in some areas to drain fields and allow access for farming. Given the small fluctuations in these wells, maintaining water levels at MTs may impose restrictions on these extractions and limit beneficial uses of groundwater. However, the definition of undesirable results allows for short-term declines and criteria for undesirable results focus on the lowest seasonal levels (Fall). These criteria will assist with the necessary operational pumping of shallow groundwater in the western Subbasin.

Notwithstanding the constraints placed on various well owners, groundwater users would benefit from the control and mitigation of potential impacts from land subsidence in the future. Those impacts could negatively affect agricultural or urban land uses or other beneficial uses of groundwater as explained in **Section 6.7.1** above.

6.7.2.5. Consideration of State, Federal, or Local Standards in MT Selection

GSP regulations require that GSAs consider how the selection of MTs might differ from other regulatory standards. For land subsidence, the MT consists of managing water levels in each representative monitoring well, which would not conflict with other regulatory standards.

6.7.2.6. Quantitative Measurement of Minimum Thresholds

As stated above, the MTs for land subsidence will be monitored by quantitatively measuring water levels as a proxy in representative monitoring well networks for each applicable Principal Aquifer as described in **Section 7.1.5** of this GSP. Monitoring will occur on a semi-annual basis, in Spring and Fall, to represent the seasonal high and low water level and adhere to water level sampling protocols (**Section 7.2**).

For land subsidence, supplemental monitoring is also planned. To provide a backstop for the uncertainties associated with future rates and extents of land subsidence, the GSAs also intend to use the annual DWR-published InSAR data as a screening tool. Those data cover the entire extent of the Subbasin and will provide a valuable tool for evaluating future vertical displacement. When combined with the annual data on groundwater extractions and groundwater elevations, the InSAR data can be used to identify areas where vertical displacement rates are changing and provide areas of the Subbasin where additional monitoring may be warranted. Data from existing GPS stations will be incorporated in the annual analysis, as available. Collectively, InSAR and GPS stations will serve as future land subsidence screening tools and, if necessary, will help identify optimal locations for either additional wells or future GPS stations.

6.7.3. Measurable Objectives for Land Subsidence

The MO for land subsidence is the midpoint between the MT and the historical high water level (WY 1991 – WY 2020). This is the same approach as for chronic lowering of water levels and is developed at the same representative monitoring sites.

Table 6-15: Measurable Objectives for Land Subsidence

	Measurable Objectives	Principal Aquifer(s)
Land Subsidence	Midpoint between the historical high groundwater elevation and the MT at each representative monitoring location. (Using Chronic Lowering of Groundwater Levels as a proxy)	All

6.8. Depletion of Interconnected Surface Water

SGMA defines an undesirable result for the interconnected water sustainability indicator as "depletions of interconnected surface water that have significant and unreasonable adverse impacts on beneficial uses of the surface water." (§10721 (x)(6)). In the Modesto Subbasin, the Tuolumne, Stanislaus, and San Joaquin rivers are all interconnected surface water. Along these boundary rivers, groundwater occurs above the channel invert elevation on an average basis, allowing groundwater to interact with surface water. All three rivers are interconnected during historical, current, and projected future conditions (**Figure 6-1**).

STRGBA GSA member agencies Modesto ID and Oakdale ID manage surface water supplies from the Tuolumne River and Stanislaus River, respectively. The districts provide local management of diversions and conveyance of surface water for municipal drinking water (City of Modesto), non-potable municipal uses, and agricultural supply. Agency experience was used to guide the analysis of streamflow depletions and undesirable results. Both agencies provided information and data to incorporate into the integrated surface water-groundwater model (C2VSim-TM) for streamflow depletion analyses under historical, current, and projected future water budgets (see **Chapter 5**). Agencies also provided expertise on potential undesirable results for surface water rights. Modesto ID and the consultant team also coordinated with TID on information along the Tuolumne River; TID operates New Don Pedro Dam for releases to the Tuolumne River for water supply.

The undesirable results, including causes and impacts to beneficial uses, are described in **Section 6.8.1** below, with a definition of undesirable results at the end of the section that includes criteria to quantify where and when undesirable results would occur. **Section 6.8.2** describes the quantification of MTs. **Section 6.8.3** provides the approach and selection of MOs. IMs that cover all of the applicable sustainability indicators (except degraded water quality) are described in **Section 6.9**.

6.8.1. Undesirable Results for Interconnected Surface Water

Analyses of groundwater conditions and water budget modeling in the Modesto Subbasin highlight the linkages between groundwater extractions, reduction of groundwater in storage, and interconnected surface water. In its Water Budget BMP, DWR notes that increases in groundwater extraction will initially result in a decline in groundwater in storage. However, over time, this decline in storage will be ultimately balanced by decreases in groundwater flow to streams (DWR, 2016a). This condition will induce groundwater recharge, removing water from the rivers (streamflow depletion). Although beneficial to water levels and storage, this streamflow depletion may impact beneficial uses of surface water including municipal, agricultural, and environmental uses.

Modeling shows that increased streamflow depletion (i.e., net groundwater recharge) along the Modesto Subbasin boundaries is associated with groundwater level declines. This observation indicates that water levels along the rivers can be used as a proxy for streamflow depletions if the water level declines can be shown to be protective against undesirable results.

Groundwater level monitoring for this purpose is best accomplished with a series of shallow monitoring wells adjacent to and transitioning away from the river. Although not ideal, current GSP monitoring wells are relatively close to the rivers and are screened in the unconfined aquifers that are connected to the rivers. When coupled with stream gage data and ongoing modeling, current wells are likely to be sufficient for monitoring surface water-groundwater conditions in the short term (see **Section 7.1.6**, **Table 7-2**, and **Figure 7-5**). Over time, additional monitoring wells will be added to the interconnected surface water monitoring network. A management action to improve the monitoring network provides for additional shallow monitoring wells to be installed along the rivers over time (**Chapter 8**).

6.8.1.1. Causes of Undesirable Results

In the Modesto Subbasin, groundwater extractions – primarily in the NDE MA – have lowered groundwater levels locally and in adjacent areas to the west. These extractions intercept groundwater that would have naturally flowed toward the river boundaries, depleting some amount of baseflow to the rivers. This streamflow depletion increases over time during the historical study period (note the declining amounts of stream/aquifer interaction as groundwater outflow, as shown in blue on **Figure 5-20**).

Modeling of projected future conditions suggests that the area of groundwater level declines will expand to the north and south toward the Stanislaus and Tuolumne rivers and cause increases in streamflow depletion (compare the net river gains/losses between historical and projected conditions in **Table 5-8)**. Groundwater extractions in other parts of the Subbasin also contribute to this depletion, especially along the rivers. In the projected conditions scenario, both the Tuolumne and Stanislaus rivers transition from net gaining streams to net losing streams, a continuation of a trend that began in recent years.

If depletion increased significantly more than indicated from the modeling, the groundwater system could become disconnected from the surface water system. At that point, groundwater would no longer contribute baseflow to the river. Lower groundwater levels would induce more recharge from the river, significantly depleting flows; these conditions would produce an undesirable result.

In the Modesto Subbasin, integrated surface water-groundwater modeling indicates that the groundwater system and river system remain connected through the 50-year implementation and planning horizon under future projected conditions. This indicates that even if future water levels declined to the extent estimated, connection between the two systems could be maintained. The projected streamflow depletions average about 26,000 AFY, only about one percent of the total river outflows from the Subbasin.

Nonetheless, these future projected increases in streamflow depletion result in a net loss of streamflow from the river systems compared to a net gain in streamflow over historical conditions. In addition, beneficial uses could be adversely impacted at these predicted levels of streamflow depletion even if the groundwater and surface water systems remain connected (see **Section 6.8.1.2** below). Accordingly, the projections for future streamflow depletions are considered undesirable results in this GSP.

GSAs are not required to correct undesirable results that occurred prior to January 1, 2015. Rather, the GSAs intend to protect against future projected increases in depletions and set a "floor" at 2015 conditions. In this manner, future projected declines in groundwater elevations will be managed, and future projections for streamflow depletion will be reduced.

6.8.1.2. Potential Effects on Beneficial Uses

Beneficial uses of the three Modesto Subbasin rivers are provided in the Basin Plan for the Sacramento River Basin and the San Joaquin River Basin (CVRWQCB, 2018). All three rivers are associated with almost all categories of beneficial uses including municipal (including potential uses), agricultural, and/or industrial supply; recreation; freshwater habitat, migration, and spawning; and wildlife habitat. The three rivers also support large riparian corridors. A preliminary evaluation of vegetative and wetland areas mapped by TNC as natural communities commonly associated with groundwater (NCCAG) indicates potential GDEs along most of the river reaches in the Modesto Subbasin (DWR, 2018d) (see **Section 3.2.8**).

Although predicted future streamflow over the 50-year baseline conditions are not precise, the predicted depletions result in lower streamflow during low flow conditions. These changes could exacerbate drought conditions on the rivers and adversely affect all beneficial uses that rely on surface water.

Both Modesto ID and Oakdale ID noted that more water would have to be released over time to meet current downstream flow requirements. This would make operation of the river more difficult, especially during low-flow conditions, and provide less water supply for municipal and agricultural beneficial uses during times when water demands are high.

In addition to adverse impacts to surface water rights holders, these conditions could also adversely impact flows needed to support fish and other wildlife. The large riparian corridors along the river could be adversely impacted. Lower groundwater levels adjacent to the rivers could impact GDEs and other environmental uses of groundwater that occur along the Subbasin river boundaries.

6.8.1.3. Modesto Subbasin Definition of Undesirable Results

The definition of undesirable results for interconnected surface water in the Modesto Subbasin is based on the causes and effects discussed above, along with additional information from the basin setting and water budgets (**Chapters 3** and **5**). Regulations also require that the undesirable result definition include quantitative criteria used to define when and where groundwater conditions can cause an undesirable result (§354.26(b)(2)). These criteria set the number of monitoring sites and events to determine where and when an MT can be exceeded before causing undesirable results. This framework recognizes that a single MT exceedance at one monitoring site may not indicate an undesirable result. The criteria also allow clear identification for when an undesirable result is triggered under the GSP.

The definition of undesirable results along with the quantitative combination of MT exceedances that cause undesirable results are provided below.

Table 6-16: Undesirable Results for Interconnected Surface Water

	Undesirable Results Definition	Principal Aquifer(s)
Interconnected Surface Water	An Undesirable Result is defined as significant and unreasonable adverse impacts to the beneficial uses of surface water caused by groundwater extraction. An undesirable result will occur on either the Tuolumne or Stanislaus rivers when 33% of representative monitoring wells for that river exceed the MT in three consecutive Fall monitoring events. An undesirable result will occur on the San Joaquin River when 50% of representative monitoring wells for that river exceed the MT in three consecutive Fall monitoring events.	All

The 50% criterion for the San Joaquin River is because there are only two representative monitoring wells along the San Joaquin River, and MT exceedances in both wells (100%) is difficult to justify. This criterion may change when additional wells are added to the monitoring network along the San Joaquin River. An exceedance in only one well may not lead to undesirable results as being set in this GSP, so incorporating additional wells is a priority for improvements to the monitoring network. This and other improvements are included as an implementation action in **Chapter 9**.

The total number of current wells and the number of MT exceedances allowed by the undesirable result definition are summarized below. The monitoring network is described in **Chapter 7** and shown on **Figure 7-5**.

- Tuolumne River: 10 wells (33% - 3 wells)
- Stanislaus River: 8 wells (33% - 3 wells)
- San Joaquin River: 2 wells (50% - 1 well)

The MT exceedance is limited to three consecutive Fall events (semi-annual monitoring). Spring events will be monitored but not used in the criterion because the increase in Spring water levels would not be representative of potential negative impacts during low flows on the rivers.

These criteria were incorporated into the sustainable yield modeling (**Section 5.3**), which demonstrated that these criteria could be met using simulated hydrographs at wells along the river. Sustainable yield conditions indicate significant decreases in streamflow depletion at each of the three rivers as discussed below.

6.8.2. Minimum Thresholds for Interconnected Surface Water

GSP regulations require the metric for interconnected surface water MTs to be “the rate or volume of surface water depletions caused by groundwater use that has adverse impacts on beneficial uses of the surface water and may lead to undesirable results” (§354.28(c)(6)) (emphasis added). As explained in **Section 6.8.1.1**, the modeling projections of future volumes of streamflow depletion have been determined by the GSAs to be undesirable results and is caused by lower groundwater levels. Therefore, specific groundwater levels can be directly correlated to these volumes of streamflow depletion and used as a proxy for interconnected surface water MTs.

The link between streamflow depletion volume and groundwater levels is confirmed by a sustainable yield modeling analysis described in **Section 5.3**. For this analysis, groundwater extractions were reduced to test aquifer response to groundwater level MTs, resulting in a reduction in projected surface water depletions and elimination of net depletions over the Subbasin. That is, there was a net contribution to streamflow from the groundwater system at the Subbasin outflow (i.e., the downstream point past the confluence of the Stanislaus and San Joaquin rivers). By managing water levels at or near the Fall 2015 groundwater elevations, modeling showed that the projected net depletions could be eliminated. Accordingly, MTs for this sustainability indicator are defined at the 2015 groundwater elevations as follows.

Table 6-17: Minimum Thresholds for Interconnected Surface Water

	Minimum Thresholds	Principal Aquifer(s)
Interconnected Surface Water	Minimum Thresholds are defined as the low groundwater elevation observed in Fall 2015 at each representative monitoring location.	Western Upper and Eastern Principal Aquifers

6.8.2.1. Justification and Support for Minimum Thresholds

GSP regulations require that the MTs be supported by:

- Location, quantity, and timing of depletions of interconnected surface water
- A description of the groundwater and surface water model used to quantify surface water depletion (§354.28(c)(6)(A)(B)).

Background information for the interconnected surface water analysis is provided in **Section 3.2.7**, followed by a preliminary analysis of potential GDEs, which occur along the river boundaries (**Section 3.2.8** and **Figure 3.60**). The historical, projected, and sustainable yield water budgets provide a detailed assessment of groundwater-surface water interaction and are presented in **Chapter 5**. As described above in **Section 6.8.2**, the sustainable yield analysis in **Section 5.3** was used to support the selection of MTs for this indicator. These collective analyses are summarized below.

In brief, the Tuolumne, Stanislaus, and San Joaquin rivers are interconnected surface water as defined by SGMA. The surface water-groundwater interaction is dynamic, with recharge and baseflow varying along segments of the river both seasonally and over time. This dynamic system of mixed gaining and losing segments along the Tuolumne and Stanislaus rivers is the result of both natural interactions and managed operations. As mentioned previously, both rivers are actively managed to provide critical water supplies for the Modesto, Turlock, and Eastern San Joaquin subbasins. The San Joaquin River has less variability and has the largest flows of the three Subbasin rivers. The segment of the San Joaquin River along the western Modesto Subbasin can be characterized as a net gaining reach during both historical and projected future conditions.

The location, quantity, and timing of deletions of these interconnected rivers were analyzed using the integrated surface water-groundwater model C2VSimTM. This local model is based on the DWR regional C2VSimFG-BETA2 model, which has been revised to include local water budget data for both the Turlock and Modesto subbasins in order to simulate the river boundary more accurately. Local surface water and groundwater data from the Eastern San Joaquin Subbasin to the north was also incorporated into the modeling analyses. These revisions provided increased ability and accuracy for modeling interconnected surface water across the northern and southern river boundaries. Documentation of the revised C2VSim-TM model is provided in **Appendix C** of this GSP.

Interconnected surface water was analyzed with C2VSimTM for historical, current, and future projected water budget conditions including separate average annual water budgets for the Modesto Subbasin surface water systems (see **Table 5-2**). Total surface water inflows into the Subbasin historically have averaged about 2,547,000 AFY[22] for all three river systems, with about one-half consisting of the San Joaquin River flows. Surface water outflows are estimated at 2,770,000 AFY under historical conditions as measured at the confluence of the Stanislaus River and the San Joaquin River at the northwest corner of the Modesto Subbasin (**Table 5-2**).

During historical conditions, all three rivers were net gaining on an average annual basis with baseflow contributions of about 61,000 AFY (see the net of the Modesto Subbasin total gains from groundwater (baseflow) and losses to groundwater (seepage/recharge) under historical conditions in **Table 5-2**). Under future conditions, streamflow seepage is projected to increase in all three rivers, resulting in net depletions on both the Tuolumne and Stanislaus rivers over the 50-year period of analysis. Smaller streamflow depletions are projected to occur along the San Joaquin River, but the river remains a net gaining stream overall.

Historical conditions represent an average over a 25-year period. During that time, streamflow depletions increased along each of the Subbasin rivers as groundwater extractions increased, especially after about 2005. **Figure 5-20** illustrates this increase by showing overall smaller groundwater outflows to the surface water system from WY 2005 to WY 2015 (see annual estimates represented by the stream/aquifer interaction shaded blue on **Figure 5-20**). **Figure 5-25** shows the relatively small amount of total streamflow that is affected by the groundwater system.

To reduce the potential for projected future depletions to cause undesirable results, groundwater level declines associated with groundwater extractions need to be arrested. By managing groundwater at or above 2015 groundwater levels, sustainable yield modeling predicts significant improvements in the future projections. A summary of these improvements is shown in the following table.

[22] As footnoted in **Table 5-2**, some diversions occur upstream of the inflow measurement point into the Subbasin and are not included in these totals.

Table 6-18: Improvements to Interconnected Surface Water under Sustainable Yield Conditions

Modesto Subbasin Surface Water	Projected Future Baseline Conditions (AFY)	Sustainable Yield Conditions (AFY)	Increase in Baseflow* under Sustainable Yield Conditions	
			(AFY)	(%)
Total GW-SW Interaction	26,000	-15,000	41,000	158%
San Joaquin River	-9,000	-13,000	4,000	44%
Tuolumne River	11,000	-11,000	22,000	200%
Stanislaus River	24,000	9,000	15,000	63%

Positive numbers represent net recharge from surface water to groundwater (i.e., streamflow depletion, also referred to as a net losing river) over average hydrologic conditions.
Negative numbers represent a net contribution to surface water (SW) from groundwater (GW) (i.e., net baseflow, also referred to as a net gaining river) over average hydrologic conditions.
**"Increase in baseflow" refers to the larger contributions to surface water from groundwater (i.e., lower amounts of streamflow depletion) under Sustainable Yield Conditions.*

As shown in the table above, net streamflow depletion in the Modesto Subbasin rivers is estimated at 26,000 AFY under the projected future baseline conditions. Under sustainable yield conditions, which incorporated the 2015 groundwater elevation MTs, the projected future streamflow depletion is eliminated, and the overall surface water system returns to a net gaining condition. Sustainable yield conditions indicate an increase of 41,000 AFY of baseflow over projected future conditions. Additional details of these data are provided in **Section 5.1.4.4** for projected conditions (see also **Table 5-2** and **Figure 5-24**); additional details on the sustainable yield analysis are provided in **Section 5.3** (see **Table 5-15** and **Figure 5-24**).

6.8.2.2. Relationship between MTs of Each Sustainability Indicator

Regulations require a description of the relationship between the MTs for each sustainability indicator and how the GSAs have determined that basin conditions at each MT will avoid undesirable results (§354.28(b)(2)). **Table 6-5** summarizes the MTs for the sustainability indicators.

The use of 2015 groundwater levels as a proxy for interconnected surface water coordinates well to the other sustainability indicators, most of which are also tied to similar or identical water levels. The relationship between the MTs for interconnected surface water and the other MTs are summarized below:

- MTs for interconnected surface water are either identical or a few feet higher than the MTs selected for chronic lowering of water levels to allow more protection against streamflow depletions along the rivers. For the 20 wells along the rivers that are included in the monitoring networks for both the chronic lowering of groundwater levels and interconnected surface water indicators, MTs vary by four feet or less (compare **Figures 7-1** and **7-3** with **Figure 7-5**). These differences are not sufficient to create a conflict for GSP implementation and management.
- MTs for reduction of groundwater in storage and land subsidence are the same as those for the chronic lowering of water levels. As such, interaction of those MTs with interconnected surface water MTs occurs in the same manner as discussed above (see also **Section 6.4.2** and **6.5.2**).
- MTs have not been selected for the Seawater Intrusion indicator because it is not applicable to the inland Turlock Subbasin (see **Section 6.5**).
- MTs for interconnected surface water will not affect water quality and, as such, will not conflict with degraded water quality MTs. In addition, by setting MTs at the Fall 2015 groundwater levels along the rivers, groundwater will continue to contribute fresh water to the rivers. (see also **Section 6.6**).

Although these MTs were considered and approved separately for each of the sustainability indicators separately, the TAC reviewed technical presentations on how the MTs for each indicator coordinates with the others. Technical information and modeling analyses were reviewed both by mangers and representatives in the TAC planning group as well as in public TAC meetings held in tandem with monthly STRGBA GSA meetings.

6.8.2.3. Impacts of MTs on Adjacent Subbasins

Regulations require consideration of how Modesto Subbasin MTs impact the ability of an adjacent subbasin to achieve its sustainability goal. As summarized in more detail in **Section 6.3.2.3**, similar principal aquifers, shared interconnected surface water boundaries, and multiple GSA member agencies that overlap both the Modesto Subbasin and adjacent subbasins have facilitated setting MTs in the Modesto Subbasin that will not adversely impact adjacent subbasins GSP implementation. Additional details relevant to each adjacent subbasin are summarized below.

6.8.2.3.1. Eastern San Joaquin Subbasin

ESJ Subbasin MTs for chronic lowering of water levels are also used as a proxy for the reduction of groundwater in storage, land subsidence, and interconnected surface water. Given that the MTs for interconnected surface water are either the same or only a few feet higher than the MTs for the chronic lowering of water levels, the previous analysis in **Section 6.3.2.3.1** is applicable to this indicator. Information in that section provides the technical rationale for concluding that MTs in the Modesto Subbasin for interconnected surface water will not adversely affect GSP implementation in the ESJ Subbasin.

6.8.2.3.2. Delta-Mendota Subbasin

The Delta-Mendota Northern & Central GSP defines undesirable results for interconnected surface water as a percentage increase in streamflow depletions that is to be determined within the first five years of GSP implementation. A quantitative MT is not set due to insufficient data. The data to be incorporated into the evaluation will be collected from two wells along the San Joaquin River south of the Modesto Subbasin (see wells 03-001 and 03-003 on GSP Figure 6-7 *in* W&C and P&P, 2019). In the interim, the GSP selects a narrative MO, which states "no increased depletions of surface water occur as a result of groundwater pumping." (W&C and P&P, 2019).

In the absence of a quantitative MT for interconnected surface water, the MT for the Modesto Subbasin seems sufficiently high to not interfere with the Delta-Mendota Subbasin achieving its sustainability goal. As mentioned previously, MTs for chronic lowering of water levels have been set similarly in both subbasins adjacent to the San Joaquin River. Sustainable yield modeling shows that MTs for the San Joaquin River in the Modesto Subbasin are correlated to conditions that contribute a net baseflow of 13,000 AFY (**Table 6-18**), an amount that differs from the average historical net baseflow of only 1,000 AFY (i.e., 14,000 AFY; subtract outflows from inflow for the San Joaquin River on **Table 5-8**). With this contribution to baseflow and MTs from 2015 conditions on both sides of the river, the MT for interconnected surface water in the Modesto Subbasin would not be expected to negatively impact implementation of the Delta-Mendota Northern & Central GSP.

6.8.2.3.3. Turlock Subbasin

MTs selected in both subbasins are Fall 2015 groundwater levels for the interconnected surface water sustainability indicator along the shared Tuolumne River boundary. Representatives from both subbasins have determined that future projected depletions of streamflow on the Tuolumne River may lead to undesirable results and have selected groundwater levels as a proxy for monitoring interconnected surface water and avoiding those future conditions (see **Table 6-18** above).

Further, GSAs in both subbasins have tested the MTs through similar sustainable yield modeling analyses (**Section 5.3**) to ensure that interconnected surface water conditions are protected. Results of the sustainable yield modeling indicate similar net contributions to baseflow on both sides of the river (16,200 AFY from Turlock Subbasin compared to 11,000 AFY from Modesto Subbasin).

6.8.2.4. Effects of MTs on Beneficial Uses and Users of Groundwater

The setting of MTs is protective with respect to the avoidance of undesirable results related to streamflow depletion. By arresting groundwater level declines along the river boundaries, the net future projected streamflow depletions can be substantially reduced or eliminated at each of the Modesto Subbasin rivers, and long-term use of groundwater can become more sustainable. Environmental uses of surface water and groundwater would also be supported.

However, there will be consequences on current uses of groundwater. The MTs will not be able to be achieved without sufficient projects or management actions to raise and maintain water levels along the Subbasin river boundaries. This will require significant investment in projects to replenish the Subbasin. Although projects identified in Chapter 8 of this GSP appear to provide sufficient supplemental water supply to achieve the MTs, a management action of demand reduction is included in the GSP as a backstop in the event that projects and associated aquifer response are not as expected. In that case, both agricultural beneficial uses and property interests could be negatively impacted if demand reduction is required to meet the Subbasin sustainability goal.

6.8.2.5. Consideration of State, Federal, or Local Standards in MT Selection

GSP regulations require that GSAs consider how the selection of MTs might differ from other regulatory standards. For interconnected surface water, the MT consists of water levels quantified at each representative monitoring well. Surface water rights holders on the Stanislaus and Tuolumne rivers estimate that the MTs will not adversely impact surface water rights and will allow for compliance with state and federal requirements. Accordingly, there are no conflicts with regard to other regulatory standards.

6.8.2.6. Quantitative Measurement of Minimum Thresholds

As stated above, the MTs for interconnected surface water will be monitored by quantitatively measuring water levels in representative monitoring wells along the river boundaries as described in **Chapter 7** (see **Section 7.1.6**, **Table 7-2,** and **Figure 7-5**). Monitoring will occur on a semi-annual basis, in Spring and Fall, to represent the seasonal high and low water level and will adhere to water level sampling protocols (**Section 7.2**).

6.8.3. Measurable Objectives for Interconnected Surface Water

Similar to the other sustainability indicators, the MO for interconnected surface water is set as the midpoint between the high groundwater elevation and the MT in each of the representative monitoring wells. As explained in **Section 6.3.3**, the MTs represents a "floor" for maintenance of low water levels, with allowance for short-term exceedances during droughts. Accordingly, water levels will be managed over an operational range generally occurring between the MT (with temporary exceedances) and anticipated high water levels that occur during wet periods.

Table 6-19: Measurable Objectives for Interconnected Surface Water

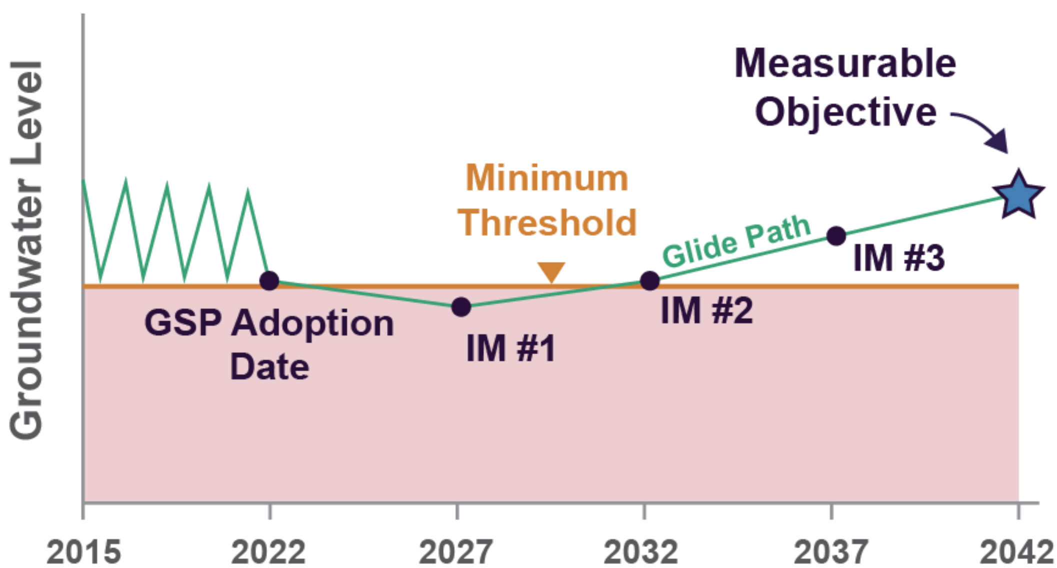
	Measurable Objectives	Principal Aquifer(s)
Interconnected Surface Water	Measurable objectives are established at the midpoint between the MT and the historical high groundwater elevation at each representative monitoring site.	Western Upper and Eastern Principal Aquifers

6.9. INTERIM MILESTONES

GSP regulations define an interim milestone (IM) as "a target value representing measurable groundwater conditions, in increments of five years, set by an Agency as part of a Plan." For the Modesto Subbasin, water levels are used as a metric for the IMs, consistent with the metric being used for MTs and MOs for all sustainability indicators except degraded water quality.

IMs provide a glide path for the Modesto Subbasin to reach its sustainability goal. The incremental approach recognizes that the path to sustainability is determined by the timing and effectiveness of GSP implementation, including projects and management actions designed to avoid undesirable results. For the Modesto Subbasin, a glide path provides needed flexibility for MAs of the Subbasin that will continue to decline – at rates dependent on future hydrologic conditions – until projects and management actions are implemented.

The following graphic prepared by DWR illustrates the concept of how IMs relate to the MT and MO. As shown, the IMs provide a glide path to sustainable management whereby MTs and MOs are maintained to avoid undesirable results.



In this conceptual graphic, the pink area represents water levels below the MT as designated in a representative monitoring well (i.e., an MT exceedance). In this example, water levels are expected to continue to decline after the GSP is adopted while projects are brought online. This concept acknowledges that the aquifer response to projects and management actions will take time. Interim milestones are illustrated in increments of five years following Plan adoption to define the glide path from undesirable results to the MO and achieving sustainable management by 2042.

In the Modesto Subbasin, long-term declines have occurred in NDE MA (**Figure 6-1**) and have expanded into the Oakdale ID MA (**Figure 6-2**). Accordingly, 2027 target values below the MT have been developed for representative monitoring wells in the management areas.

The amount of the anticipated declines between adoption and 2027 is dependent on future unknown hydrologic conditions. Since drought conditions began in WY 2013, dry hydrologic conditions have persisted in the Subbasin. Water year types as categorized by the DWR San Joaquin Valley indices since 2014 are summarized in the following table.

Table 6-20: Water Year Hydrologic Classification Indices Since 2014

Water Year	Water Year Type San Joaquin Valley Water Year Index
2014	Critically Dry
2015	Critically Dry
2016	Dry
2017	Wet
2018	Below Normal
2019	Wet
2020	Dry

Source : : https://cdec.water.ca.gov/reportapp/javareports?name=WSIHIST

As shown in the table, five out of seven water years between WY 2014 and WY 2020 have been categorized as below normal, dry, or critically dry. Water level declines associated with the last seven years may continue if hydrologic conditions do not improve, and/or if the aquifer response to GSP project implementation is delayed.

In order to plan for a worst-case scenario, a 2027 IM has been developed for declining wells based on the declines observed over the last seven years. By 2032, project implementation is expected to support water level recovery and the 2032 IM is set as the MT. If needed, the IM for 2037 is defined as the halfway point between the MT and MO. This trajectory is similar to the DWR conceptual diagram illustrated above. The 2027 IMs are provided in **Chapter 7** (see **Table 7-1** and **Table 7-3**) and shown on the hydrographs in **Appendix F**.

IMs have been designated conservatively for monitoring wells in the Oakdale ID MA and the NDE MA but will not be used to defer implementation of GSP projects or management actions. Other projects and/or management actions may also be needed during the first five years of GSP implementation to avoid undesirable results near wells if water levels reach the IMs.

To provide protection against IMs causing undesirable results, the following projects and management actions are being included in the GSP:

- A Group 2 project provides treated surface water to the City of Waterford to reduce pumping near interconnected surface water and in areas where domestic wells have previously failed (see **Figure 6-1**).
- Group 2 projects providing surface water as in lieu supply or for direct recharge are scheduled to begin immediately upon GSP adoption through coordination with, and actions by, landowners in the NDE MA to secure agreements and to plan for infrastructure with Oakdale ID and Modesto ID.

6.10. Summary of Sustainable Management Criteria and Adaptive Management

Collectively, the sustainable management criteria discussed in this GSP chapter provide a robust set of criteria to avoid undesirable results and achieve the Modesto Subbasin sustainability goal. Sustainable management criteria provided in multiple tables above are summarized in **Table 6-21**, including the definition of undesirable results, minimum thresholds (MTs), and measurable objectives (MOs) for all sustainability indicators applicable to the Modesto Subbasin GSP.

Modesto Subbasin GSAs note that this initial sustainable management criteria employs new SGMA terminology and represents reasonable estimates for sustainable management of groundwater through the planning horizon. Nonetheless, it is recognized that sustainable management criteria – including the definition of undesirable results – may require adjustment in the future.

Improvements to the GSP monitoring network including new installations of monitoring wells are incorporated into this GSP. As the GSAs implement the GSP and monitoring network, additional information will be routinely compiled and analyzed to evaluate aquifer response to the initial sustainable management criteria.

GSAs recognize that monitoring results may indicate that the initial undesirable results definition and MTs require adjustment in the future. Actual MTs that lead to undesirable results may be higher or lower than those selected in **Table 6-21** as projects and management actions are implemented. Consistent with the concept of adaptive management, the GSAs report compliance and GSP implementation in Annual Reports. The GSAs will also re-evaluate the criteria in the five-year GSP evaluation and make appropriate adjustments to ensure that the Subbasin meets its sustainability goal within the GSP implementation period as required.

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Table 6-21: Sustainable Management Criteria Summary

Sustainability Indicator	Undesirable Result Definition		Minimum Thresholds (MTs)	Measurable Objectives (MOs)	Principal Aquifers	GSP Section
	Narrative	Quantitative				
Chronic Lowering of Groundwater Levels	Undesirable results are defined as significant and unreasonable groundwater level declines – either due to multi-year droughts or due to chronic declines where groundwater is the sole supply – such that water supply wells are adversely impacted in a manner that cannot be readily managed or mitigated.	An undesirable result fwill occur when at least 33% of representative monitoring wells exceed the MT for a principal aquifer in 3 consecutive Fall monitoring events.	Historic low groundwater elevation observed or estimated during WY 1991 – WY 2020 at each representative monitoring location, based on available data.	Midpoint between the historical high groundwater elevation and the MT at each representative monitoring location.	All Principal Aquifers	6.3
Reduction of Groundwater in Storage	An Undesirable result is defined as significant and unreasonable reduction of groundwater in storage that would occur if the volume of groundwater supply is at risk of depletion and is not accessible for beneficial use, or if the Subbasin remains in a condition of long-term overdraft based on projected water use and average hydrologic conditions.	An undesirable result will occur for a principal aquifer when at least 33% of representative monitoring wells exceed the MT for for that principal aquifer in 3 consecutive Fall monitoring events.	Historic low groundwater elevation observed or estimated during WY 1991 – WY 2020 at each representative monitoring location, based on available data. (Chronic Lowering of Groundwater Levels as a proxy.)	Midpoint between the historical high groundwater elevation and the MT at each representative monitoring location. (Chronic Lowering of Groundwater Levels as a proxy.)	All Principal Aquifers	6.4
Seawater Intrusion	Not applicable in the Modesto Subbasin.	N/A	N/A	N/A	N/A	6.5
Degraded Water Quality	An Undesirable Result is defined as significant and unreasonable adverse impacts to groundwater quality as indicated by a new (first-time) exceedance of or further exceedance from an MCL of a constituent of concern (COC), that is caused by GSA projects, management actions, or management of groundwater levels or extractions such that beneficial uses are affected and well owners experience an increase in operational costs.	An undesirable result will occur when a Subbasin potable water supply well in the defined monitoring network reports a new (first-time) exceedance of an MT or an increase in concentration above the MT for a Modesto Subbasin constituent of concern (COC) that results in increased operational costs and is caused by GSA management activities as listed at left.	Minimum thresholds are set as the primary or secondary California maximum contaminant level (MCL) for each of seven (7) constituents of concern (COCs): Nitrate (as N) - 10 mg/L Arsenic - 10 ug/L Uranium - 20 pCi/L Total dissolved solids (TDS) - 500 mg/L Dibromochloropropane (DBCP) - 0.2 ug/L 1,2,3-Trichloropropane (TCP) - 0.005 ug/L Tetrachloroethene (PCE) - 5 ug/L.	Historical maximum concentration of each constituent of concern (COC) at each representative monitoring location.	All Principal Aquifers	6.6
Inelastic Land Subsidence	An Undesirable Result is defined as significant and unreasonable inelastic land subsidence, caused by groundwater extraction and associated water level declines, that adversely affects land use or reduces the viability of the use of critical infrastructure.	An undesirable result will occur when 33 percent of representative monitoring wells exceed the MT in three consecutive Spring monitoring events.	Historic low groundwater elevation observed or estimated during WY 1991 – WY 2020 at each representative monitoring location, based on available data. (Chronic Lowering of Groundwater Levels as a proxy.)	Midpoint between the historical high groundwater elevation and the MT at each representative monitoring location. (Chronic Lowering of Groundwater Levels as a proxy.)	All Principal Aquifers	6.7
Interconnected Surface Water	An Undesirable Result is defined as significant and unreasonable adverse impacts to the beneficial uses of surface water caused by groundwater extraction.	An undesirable result will occur on either the Tuolume or Stanislaus rivers when 33% of representative monitoring wells for that river exceed the MT in three consecutive Fall monitoring events. An undesirable result will occur on the San Joaquin River when 50% of representative monitoring wells for that river exceed the MT in three consecutive Fall monitoring events. The 50% criterion is based on the small number of representative montiroing wells currently avilable for the San Joaquin River and may change when additional wells are added to the monitoring network.	Low groundwater elevation observed in Fall 2015 at each representative monitoring location.	Midpoint between the historical high groundwater elevation and the MT at each representative monitoring site.	Western Upper Principal Aquifer and Eastern Principal Aquifer	6.8

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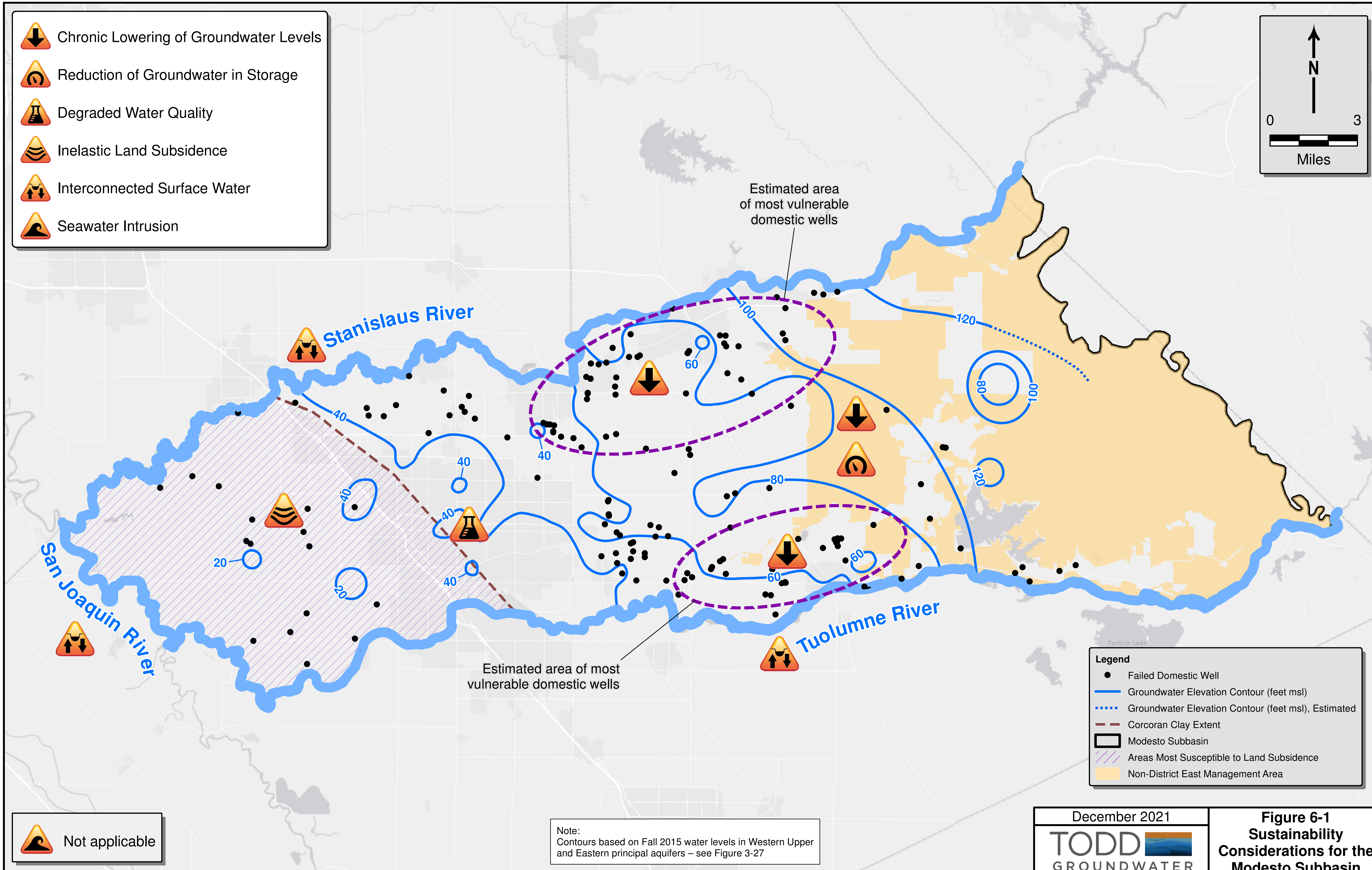

Figure 6-1
Sustainability Considerations for the Modesto Subbasin

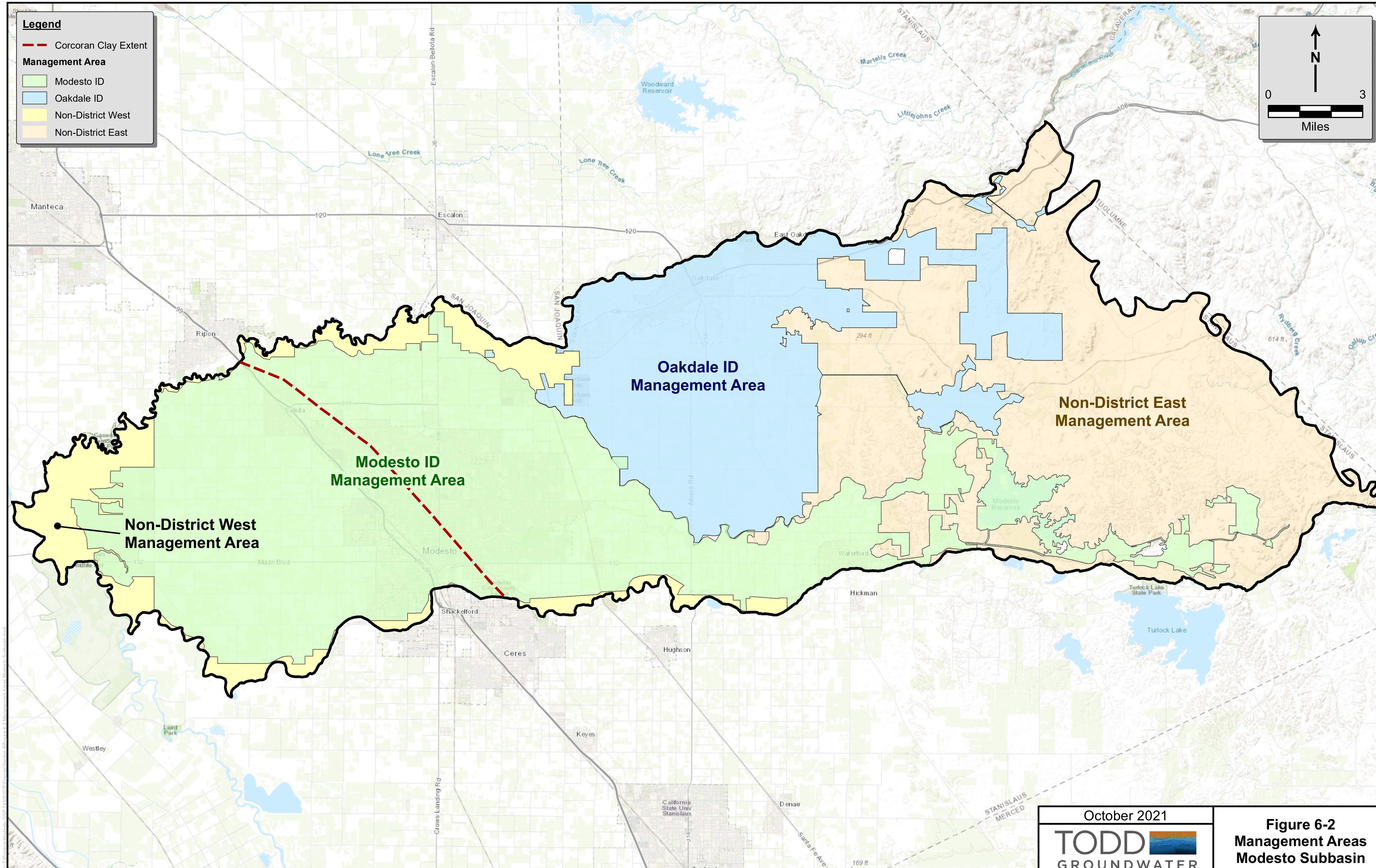

Figure 6-2
Management Areas
Modesto Subbasin

7. MONITORING NETWORK

The overall objective of the monitoring network for this Groundwater Sustainability Plan (GSP) is to yield representative information about groundwater conditions to guide and evaluate GSP implementation. Specifically, the GSP monitoring network is designed to:

- Evaluate groundwater conditions relative to sustainability indicators.
- Monitor for minimum thresholds to avoid undesirable results.
- Track interim milestones and measurable objectives to demonstrate progress on reaching sustainability goals for the Subbasin.
- Expand the existing monitoring network to better represent the entire Subbasin and address data gaps.
- Reduce uncertainty and provide better data to guide management actions, document the water budget, and improve understanding of the interconnection of surface water and groundwater.
- Identify and track potential impacts on beneficial uses and users of groundwater.

This GSP builds on existing monitoring programs with the intent to provide sufficient data for demonstrating short-term, seasonal, and long-term trends in groundwater levels. Existing monitoring programs include the CASGEM monitoring program, public water supplier groundwater monitoring programs in the municipalities, agricultural water supplier groundwater monitoring programs in Modesto Irrigation District (MID) and Oakdale Irrigation District (OID), and the Irrigated Lands Regulatory Program. These existing monitoring programs are described in **Section 2.4**.

The following summarizes the monitoring network. **Section 7.1** describes the monitoring network for each sustainability indicator. **Section 7.2** provides protocols for data collection and monitoring. **Section 7.3** describes how the monitoring network will be assessed and improved. **Section 7.4** summarizes the data management system (DMS) for data collected from the monitoring network. Figures for **Chapter 7** are provided at the end of the text to minimize interruption and facilitate multiple references to each figure.

7.1. DESCRIPTION OF MONITORING NETWORK

Groundwater level monitoring networks were developed to observe and document the chronic lowering of groundwater levels, reduction of groundwater in storage, land subsidence, and depletions of interconnected surface water. The applicability and rationale for using groundwater elevations to monitor each of these four sustainability indicators is discussed in **Chapter 6**, Sustainable Management Criteria. 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. Accordingly, groundwater elevations have been selected for a minimum threshold (MT) and measurable objective (MO) 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 networks are illustrated on **Figures 7-1** through **7-5.** The figures show locations of the wells in each monitoring network and the MT and MO for each well. Note that the current CASGEM program is being phased out and transitioned to the GSP monitoring network.

As described in **Chapter 6**, 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. This network consists of drinking water supply wells, regulated facilities, and regional water quality programs such as the Groundwater Ambient Monitoring and Assessment (GAMA) Program. When combined with additional data from regulated water quality coalitions, this collective dataset represents a comprehensive network for tracking and evaluation of water quality with respect to the sustainable management criteria. Additional information on this monitoring network is provided in **Section 7.1.4** below.

A monitoring network was not developed for the seawater intrusion sustainability indicator. As discussed in **Chapter 6**, the GSAs found that seawater intrusion, as defined by GSP regulations, is not applicable to the inland Modesto Subbasin. Specifically, GSAs determined that seawater intrusion is not present in the Subbasin and is not likely to occur in the future (see **Section 6.5**). In accordance with GSP regulations, no sustainable management criteria have been assigned to this indicator, and no monitoring network has been established (§354.34(j)).

As described in **Chapter 6**, 2027 Interim Milestones (IMs) were developed for monitoring network wells in the OID and Non-District East Management Areas. The first IM occurs in 2027 with target values set below the MTs to provide a buffer to allow water levels to drop below the MT, recognizing that water levels in these wells may continue to decline after the GSP is adopted as projects are being brought online. This concept acknowledges that the aquifer response to projects and management actions will take time. 2027 IM values assume that recent water level declines will continue at similar rates between 2022 and 2027. Additional IMs are at five-year increments: the 2032 IM is the MT, the 2037 IM is half-way between the MT and the MO, and the 2042 IM is the MO. IMs provide a glide path for the Modesto Subbasin to reach its sustainability goal.

Summaries of the monitoring networks are provided in **Tables 7-1** and **7-2**. Well information includes the well ID, State Well Number, CASGEM identification number where applicable, well type, and Principal Aquifer and Management Area in which the well is located, location coordinates, well depth, screen interval depth, the MT and MO, a brief summary of how the MT and MO were developed, and the 2027 IM where applicable.

Table 7-1: Summary of Monitoring Network, Chronic Lowering of Groundwater Levels

						Management Area														
Program	Well ID	State Well Number	CASGEM Identification Number	Well Use / Status	Principal Aquifer	MID	OID	Non-District East	Non-District West	Latitude (NAD 83)	Longitude (NAD 83)	Ground Surface Elevation (feet msl)	Reference Point Elevation (feet msl)	Total Well Depth (feet bgs)	Screen Interval Depths (feet bgs)	Minimum Threshold (MT) (feet msl)	Measurable Objective (MO) (feet msl)	MT/MO Note	Interim Milestone (2027) (feet msl)
CASGEM	Albers 232	03S10E26D001M	3559	Active Irrigation	Eastern	x				37.651020	-120.847696	145.4	145.7	460	196-288	60	76	based on measured data at the well	--
CASGEM	Allen OID-01	02S10E16M001M	4430	Active Irrigation	Eastern		x			37.759897	-120.885401	145.6	145.7	415	0-120	72	81	based on measured data at the well	61
CASGEM	American 208	02S08E25P001M	3723	Active Irrigation	Eastern	x				37.728064	-121.041430	99.9	99.9	320	79-272	48	55	based on measured data at the well	--
CASGEM	Bangs Ave 243	03S08E01K001M	3152	Active Irrigation	Eastern	x				37.703436	-121.038476	90.0	90.0	346	141-251	32	46	based on measured data at the well	--
CASGEM	Bentley OID-02	02S10E33J001M	4590	Active Irrigation	Eastern		x			37.715973	-120.866949	171.9	172.1	500	120-175	71	85	based on measured data at the well	56
CASGEM	Birnbaum OID-03	02S10E15N001M	4429	Active Irrigation	Eastern		x			37.755921	-120.863872	149.4	149.8	293	55-293	72	86	based on measured data at the well	61
CASGEM	Blossom 230	03S11E30K001M	3903	Active Irrigation	Eastern	x				37.645614	-120.801537	154.8	155.0	412	179-283	61	78	based on measured data at the well	--
CASGEM	Canfield 90	04S08E06L001M	26633	Active Irrigation	Western Upper	x				37.613113	-121.130799	52.0	52.3	151	40-75	32	36	based on measured data at the well	--
CASGEM	Cavil 214	03S10E06G001M	27057	Active Irrigation	Eastern	x				37.705044	-120.911296	135.6	135.6	480	107-275	53	73	based on measured data at the well	--
CASGEM	Claribel 206	03S09E03D001M	2093	Active Irrigation	Eastern	x				37.708526	-120.974280	114.1	114.5	650	96-550	49	62	based on measured data at the well	--
CASGEM	Crane OID-06	02S10E29E001M	29444	Active Irrigation	Eastern		x			37.733378	-120.899126	160.1	160.4	505	155-198	66	77	based on measured data at the well	55
CASGEM	Curtis #2 100	03S08E09P001M	3303	Active Irrigation	Western Upper	x				37.685351	-121.097462	63.6	63.6	124	79-100	34	41	based on measured data at the well	--
CASGEM	Furtado OID-07	02S11E32L001M	2529	Active Irrigation	Eastern		x			37.718381	-120.786289	212.0	212.5	590	200-580	69	81	based on measured data at the well	51
CASGEM	Gates Road 101	03S07E24M001M	3146	Active Irrigation	Western Upper	x				37.659699	-121.155215	44.2	44.2	64	--	24	33	based on measured data at the well	--
CASGEM	Hart Road 88	03S08E08D001M	3301	Active Irrigation	Western Upper	x				37.694807	-121.122902	54.9	55.2	130	73-85	35	40	based on measured data at the well	--
CASGEM	Head Lateral 3 215	03S10E17K001M	3552	Active Irrigation	Eastern	x				37.674398	-120.891430	135.8	135.6	476	116-400	56	73	based on measured data at the well	--
CASGEM	Head Lateral 8 194	02S08E27N001M	38870	Active Irrigation	Eastern	x				37.727189	-121.087002	79.5	79.8	302	148-211	40	47	based on measured data at the well	--
CASGEM	Jones WID 228	03S11E29J001M	38872	Active Irrigation	Eastern	x				37.641798	-120.776177	166.4	166.4	324	188-280	55	75	based on measured data at the well	--
CASGEM	Katen 69	03S07E25P001M	3147	Active Irrigation	Western Upper	x				37.637929	-121.149890	45.1	45.1	160	13-148	27	33	based on measured data at the well	--
CASGEM	Langdon Merle 241	02S09E28H001M	3876	Active Irrigation	Eastern	x				37.734908	-120.977526	128.4	128.5	595	160-300	50	62	based on measured data at the well	--
CASGEM	Lateral one 195	03S10E32G001M	3877	Active Irrigation	Eastern	x				37.632523	-120.889283	126.0	126.0	260	141-210	42	52	based on measured data at the well	--
CASGEM	Machado 23	03S08E17R001M	3864	Active Irrigation	Western Upper	x				37.668045	-121.105038	59.1	59.3	80	--	31	40	based on measured data at the well	--
CASGEM	Marquis OID-10	02S10E20C001M	29436	Active Irrigation	Eastern		x			37.753232	-120.896930	138.4	138.8	125	27-125	85	91	based on measured data at the well	78
CASGEM	North Ave 103	03S08E14B001M	3854	Active Irrigation	Western Upper	x				37.678393	-121.054335	73.9	74.6	130	53-81	41	50	based on measured data at the well	--
CASGEM	Paradise 235	04S08E02L001M	2151	Active Irrigation	Western Upper	x				37.614186	-121.057863	73.7	73.9	258	96-132	34	41	based on measured data at the well	--
CASGEM	Paulsell 1 OID-11	02S12E31K001M	26187	Active Irrigation	Eastern			x		37.717864	-120.691876	195.9	197.5	815	195-410	88	117	based on measured data at the well	53
CASGEM	Paulsell 2 OID-12	02S12E32P001M	38865	Active Irrigation	Eastern			x		37.710953	-120.676939	193.9	195.6	815	132-815	94	123	based on measured data at the well	58
CASGEM	Perley 202	03S09E14P001M	2109	Active Irrigation	Eastern	x				37.667719	-120.951955	104.9	105.4	255	76-204	36	45	based on measured data at the well	--
CASGEM	Philbrick 201	04S08E02H001M	26591	Active Irrigation	Western Upper	x				37.619159	-121.050003	73.1	73.5	88	58-74	34	41	based on measured data at the well	--
CASGEM	Quesenberry 223	03S12E19G001M	27424	Active Irrigation	Eastern			x		37.659773	-120.689681	197.0	197.0	380	168-208	89	110	based on measured data at the well	72
CASGEM	Riverbank OID-13	02S09E27G001M	49463	Active Irrigation	Eastern	x				37.735134	-120.964821	132.3	134.2	560	200-550	42	54	based on measured data at the well	--
CASGEM	Schmidt 227	03S11E27G003M	3897	Active Irrigation	Eastern	x				37.648671	-120.736000	192.3	192.2	248	113-153	59	78	based on measured data at the well	--
CASGEM	Van Buren 43	03S08E21Q001M	3873	Active Irrigation	Western Upper	x				37.654644	-121.094887	63.3	63.5	196	76-116	38	45	based on measured data at the well	--
CASGEM	Warnock 46	03S08E29K001M	4015	Active Irrigation	Western Upper	x				37.642900	-121.108575	55.1	55.1	240	--	35	42	based on measured data at the well	--

Table 7-1: Summary of Monitoring Network, Chronic Lowering of Groundwater Levels

						Management Area													
Program	Well ID	State Well Number	CASGEM Identification Number	Well Use / Status	Principal Aquifer	MID	OID	Non-District East	Non-District West	Latitude (NAD 83)	Longitude (NAD 83)	Ground Surface Elevation (feet msl)	Reference Point Elevation (feet msl)	Total Well Depth (feet bgs)	Screen Interval Depths (feet bgs)	Minimum Threshold (MT) (feet msl)	Measurable Objective (MO) (feet msl)	MT/MO Note	Interim Milestone (2027) (feet msl)
CASGEM	Wellsford 233	03S10E16K001M	3551	Active Irrigation	Eastern	x				37.673607	-120.875297	141.9	142.0	468	158-358	62	77	based on measured data at the well	--
CASGEM	Wood 210	03S10E18P001M	3553	Active Irrigation	Eastern	x				37.667487	-120.912168	121.3	121.3	606	87-547	52	66	based on measured data at the well	--
CASGEM	Young 76	04S08E04G001M	38078	Active Irrigation	Western Upper	x				37.618051	-121.094288	61.5	62.1	175	12-152	36	42	based on measured data at the well	--
City of Modesto	MOD-MWA-2	--	not applicable	Monitoring Well	Eastern	x				37.642986	-120.931770	--	103.8	175	150-170	30	36	MT: based on Oct 2015 contour map; MO: based on historic high, spring 1998 contour map	--
City of Modesto	MOD-MWB-1	--	not applicable	Monitoring Well	Western Upper	x				37.690559	-121.044299	--	78.8	177	152-172	40	49	MT: estimated from fall 2015 contour map; MO: historic high estimated from spring 1998 contour map	--
City of Modesto	MOD-MWB-2	--	not applicable	Monitoring Well	Western Lower	x				37.690559	-121.044245	--	78.7	250	225-245	26	34	MT: estimated from fall 2015 contour map; MO: historic high estimated from spring 1998 contour map	--
City of Modesto	MOD-MWC-3	--	not applicable	Monitoring Well	Eastern	x				37.672249	-120.940908	--	105.6	285	260-280	40	50	MT: based on October 2015 contour map, MO: based on spring 1998 contour map	--
City of Modesto	MOD-MWD-1	--	not applicable	Monitoring Well	Western Upper	x				37.649959	-121.048685	--	73.3	129	104-124	30	40	MT: estimated from fall 2015 contour map and MT at nearby CASGEM well (McDonald); MO: based on historic high from spring 1998 contour map	--
City of Modesto	MOD-MWD-3	--	not applicable	Monitoring Well	Western Lower	x				37.649958	-121.048649	--	73.2	243	218-238	30	37	MT: estimated from fall 2015 measured contour map and model contours (Layer 2); MO: historic high estimated from spring 1998 contour map	--
USGS	FPA-2	003S009E08K004M	not applicable	Monitoring Well	Eastern	x				37.686194	-121.000917	--	91.0	122.2	115-120	38	48	MT: based on October 2015 contour map; MO: based on maximum of measured data (higher than estimate from spring 1998 contour map)	--
USGS	OFPB-2	003S009E11F002M	not applicable	Monitoring Well	Eastern	x				37.690194	-120.951417	--	104.0	174.5	166-171	35	53	MT: based on fall 2015 contour map; MO: historic high based on spring 1998 contour map	--
USGS	MRWA-2	003S008E33R002M	not applicable	Monitoring Well	Western Upper	x				37.624121	-121.086103	--	64.0	183	174-179	36	43	MT: estimated from fall 2015 contour map and based on nearby CASGEM well (Young); MO: historic high estimated from spring 1998 contour map and CASGEM well (Young)	--
USGS	MRWA-3	003S008E33R001M	not applicable	Monitoring Well	Western Lower	x				37.624121	-121.086103	--	64.0	280	269-274	28	36	MT: estimated from model contours September 2015 (Layer 2); MO: historic high based on measured data	--
Prop 68	MW-1S	--	not applicable	Monitoring Well	Western Upper	x				37.707630	-121.087167	68.4	68.0	125	100-120	33	43	MT: based on fall 2015 contour map; MO: historic high based on spring 1998 contour map	--
Prop 68	MW-1D	--	not applicable	Monitoring Well	Western Lower	x				37.707631	-121.087136	68.5	67.9	250	225-245	14	27	MT: based on measured data in April 2021 (lower than fall 2015 contour map); MO: historic high based on spring 1998 contour map	--

Table 7-1: Summary of Monitoring Network, Chronic Lowering of Groundwater Levels

						Management Area														
Program	Well ID	State Well Number	CASGEM Identification Number	Well Use / Status	Principal Aquifer	MID	OID	Non-District East	Non-District West	Latitude (NAD 83)	Longitude (NAD 83)	Ground Surface Elevation (feet msl)	Reference Point Elevation (feet msl)	Total Well Depth (feet bgs)	Screen Interval Depths (feet bgs)	Minimum Threshold (MT) (feet msl)	Measurable Objective (MO) (feet msl)	MT/MO Note	Interim Milestone (2027) (feet msl)
Prop 68	MW-2S	--	not applicable	Monitoring Well	Western Upper	x				37.613886	-121.023442	71.1	70.7	135	110-130	34	41	MT/MO: based on nearby CASGEM well (Philbrick)	--
Prop 68	MW-2D	--	not applicable	Monitoring Well	Western Lower	x				37.613886	-121.023475	71.2	71.0	281	256-276	35	40	MT: based on fall 2015 model contour map (Lay 2); MO: based on historic high of measured data	--
Prop 68	MW-3S	--	not applicable	Monitoring Well	Eastern	x				37.630743	-120.967621	95.8	95.6	161	136-156	25	31	MT: based on historic low at nearby MOD-225; MO: based on max of measured data (slightly higher than historic high based on spring 1998 contour map)	--
Prop 68	MW-3D	--	not applicable	Monitoring Well	Eastern	x				37.630711	-120.967621	95.7	95.3	283	258-278	25	31	MT/MO: same as MW-3S (so far, measured water level data are similar)	--
Prop 68	MW-4S	--	not applicable	Monitoring Well	Eastern				x	37.728565	-120.941555	136.6	136.3	165	140-160	56	67	MT: based on fall 2015 contour map; MO: historic high based on spring 1998 contour map	--
Prop 68	MW-5S	--	not applicable	Monitoring Well	Eastern		x			37.763120	-120.825360	191.9	191.6	175	150-170	69	89	MT: based on historic low at nearby Oak-008; MO: based on historic high at nearby Oak-008	68
Prop 68	MW-6S	--	not applicable	Monitoring Well	Eastern	x				37.646100	-120.752540	171.3	170.9	179	154-174	65	83	MT: based on fall 2015 contour map; MO: historic high based on spring 1998 contour map	--
Prop 68	MW-7	--	not applicable	Monitoring Well	Eastern			x		37.743410	-120.704350	242.6	242.3	300	275-295	75	110	MT: based on minimum of available measured data at this well. There is a lack of water level data in this area of the Subbasin. MO: based on historic high at CASGEM well Paulsell-1 (~2 miles south).	40
Prop 68	MW-8	--	not applicable	Monitoring Well	Eastern			x		37.732370	-120.632880	292.9	292.3	290	265-285	75	110	MT: based on minimum of available measured data at this well. Similar value to nearby well on fall 2015 contour map. MO: based on historic high at CASGEM well Paulsell-1	49
Prop 68	MW-9	--	not applicable	Monitoring Well	Eastern			x		37.649510	-120.535140	244.5	247.6	365	340-360	150	180	MT: based on minimum of available measured data at this well. There is a lack of water level data in this area of the Subbasin. MO: Based on similar operational range as other eastern Subbasin wells (~30 ft)	138
Prop 68	MW-10	--	not applicable	Monitoring Well	Eastern			x		37.739630	-120.756490	265.1	264.7	265	240-260	72	101	MT: based on historic low at a nearby DWR WDL well - Dec 2013 (data from 1990 to 2014); MO: based on historic high at nearby DWR WDL well - Nov 1997	63
Prop 68	MW-11	--	not applicable	Monitoring Well	Eastern	x				37.643970	-120.900997	116.3	116.1	175	150-170	35	48	MT: based on historic low at nearby MOD-247; based on historic high at nearby MOD-247	--

Notes: IMs were developed for wells in the Non-District East Management Area and the OID Management Area, where water levels may continue to decline while projects are being brought online.
IMs were not assigned to wells in the Non-District West Management Area and the MID Management Area, where water levels are relatively stable and consistent with established MTs and MOs.
IMs provided on this table represent 5-year IMs (2027), as described in Section 7.1. The 10-year IMs (2032) are the MTs and the 15-year IMs (2037) are the midpoint between the MT and the MO (see Section 7.1).

Table 7-2: Summary of Monitoring Network, Interconnected Surface Water

Program	Well ID	State Well Number	CASGEM Identification Number	Well Use / Status	Principal Aquifer	Management Area				Latitude (NAD 83)	Longitude (NAD 83)	Ground Surface Elevation (feet msl)	Reference Point Elevation (feet msl)	Total Well Depth (feet bgs)	Screen Interval Depths (feet bgs)	Minimum Threshold (MT) (feet msl)	Measurable Objective (MO) (feet msl)	MT/MO Note	Interim Milestone (2027) (feet msl)
						MID	OID	Non-District East	Non-District West										
San Joaquin River																			
CASGEM	Canfield 90	04S08E06L001M	26633	Active Irrigation	Western Upper	x				37.613113	-121.130799	52.0	52.3	151	40-75	33	37	based on measured data at the well	--
CASGEM	Katen 69	03S07E25P001M	3147	Active Irrigation	Western Upper	x				37.637929	-121.149890	45.1	45.1	160	13-148	27	33	based on measured data at the well	--
Stanislaus River																			
CASGEM	Allen OID-01	02S10E16M001M	4430	Active Irrigation	Eastern		x			37.759897	-120.885401	145.6	145.7	415	0-120	75	83	based on measured data at the well	61
CASGEM	American 208	02S08E25P001M	3723	Active Irrigation	Eastern	x				37.728064	-121.041430	99.9	99.9	320	79-272	48	55	based on measured data at the well	--
CASGEM	Birnbaum OID-03	02S10E15N001M	4429	Active Irrigation	Eastern		x			37.755921	-120.863872	149.4	149.8	293	55-293	74	87	based on measured data at the well	61
CASGEM	Head Lateral 8 194	02S08E27N001M	38870	Active Irrigation	Eastern	x				37.727189	-121.087002	79.5	79.8	302	148-211	40	47	based on measured data at the well	--
CASGEM	Langdon Merle 241	02S09E28H001M	3876	Active Irrigation	Eastern	x				37.734908	-120.977526	128.4	128.5	595	160-300	50	62	based on measured data at the well	--
CASGEM	Marquis OID-10	02S10E20C001M	29436	Active Irrigation	Eastern		x			37.753232	-120.896930	138.4	138.8	125	27-125	86	92	based on measured data at the well	78
CASGEM	Riverbank OID-13	02S09E27G001M	49463	Active Irrigation	Eastern	x				37.735134	-120.964821	132.3	134.2	560	200-550	42	54	based on measured data at the well	--
Prop 68	MW-4S	--	not applicable	Monitoring Well	Eastern				x	37.728639	-120.941518	136.6	136.3	165	140-160	56	67	MT: based on fall 2015 contour map; MO: historic high based on spring 1998 contour map	--
Tuolumne River																			
CASGEM	Jones WID 228	03S11E29J001M	38872	Active Irrigation	Eastern	x				37.641798	-120.776177	166.4	166.4	324	188-280	55	75	based on measured data at the well	--
CASGEM	Lateral one 195	03S10E32G001M	3877	Active Irrigation	Eastern	x				37.632523	-120.889283	126.0	126.0	260	141-210	42	52	based on measured data at the well	--
CASGEM	Paradise 235	04S08E02L001M	2151	Active Irrigation	Western Upper	x				37.614186	-121.057863	73.7	73.9	258	96-132	34	41	based on measured data at the well	--
CASGEM	Philbrick 201	04S08E02H001M	26591	Active Irrigation	Western Upper	x				37.619159	-121.050003	73.1	73.5	88	58-74	38	43	based on measured data at the well	--
CASGEM	Quesenberry 223	03S12E19G001M	27424	Active Irrigation	Eastern			x		37.659773	-120.689681	197.0	197.0	380	168-208	89	110	based on measured data at the well	72
CASGEM	Schmidt 227	03S11E27G003M	3897	Active Irrigation	Eastern	x				37.648671	-120.736000	192.3	192.2	248	113-153	59	78	based on measured data at the well	--
Prop 68	MW-2S	--	not applicable	Monitoring Well	Western Upper	x				37.613886	-121.023442	71.1	70.7	135	110-130	38	43	MT/MO: based on nearby CASGEM well (Philbrick)	--
Prop 68	MW-3S	--	not applicable	Monitoring Well	Eastern	x				37.630743	-120.967621	95.8	95.6	161	136-156	26	32	MT: based on fall 2015 level at nearby MOD-225; MO: historic high based on spring 1998 contour map	--
Prop 68	MW-6S	--	not applicable	Monitoring Well	Eastern	x				37.646100	-120.752540	171.3	170.9	179	154-174	65	83	MT: based on fall 2015 contour map; MO: historic high based on spring 1998 contour map	--
Prop 68	MW-9	--	not applicable	Monitoring Well	Eastern			x		37.649510	-120.535140	244.5	247.6	365	340-360	150	180	MT: based on minimum of available measured data at this well. There is a lack of water level data in this area of the Subbasin. MO: Based on similar operational range as other eastern Subbasin wells (~30 ft)	138

Notes: IMs were developed for wells in the Non-District East Management Area and the OID Management Area, where water levels may continue to decline while projects are being brought online.
IMs were not assigned to wells in the Non-District West Management Area and the MID Management Area, where water levels are relatively stable and consistent with established MTs and MOs.
IMs provided on this table represent 5-year IMs (2027), as described in Section 7.1. The 10-year IMs (2032) are the MTs and the 15-year IMs (2037) are the midpoint between the MT and the MO (see Section 7.1).