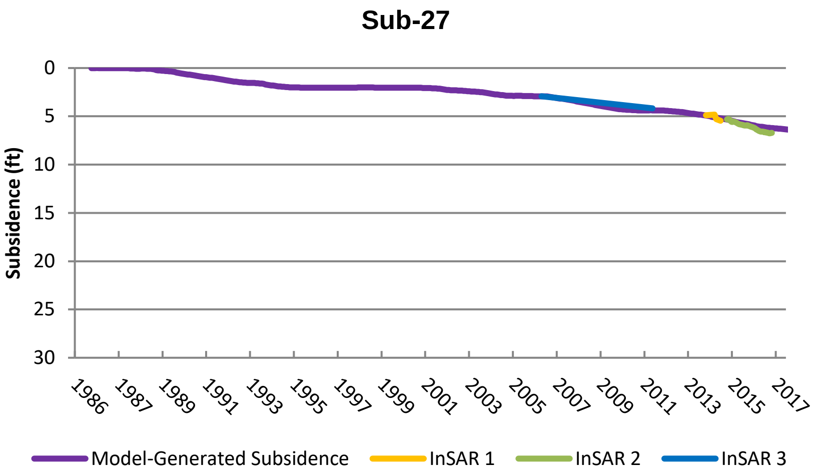
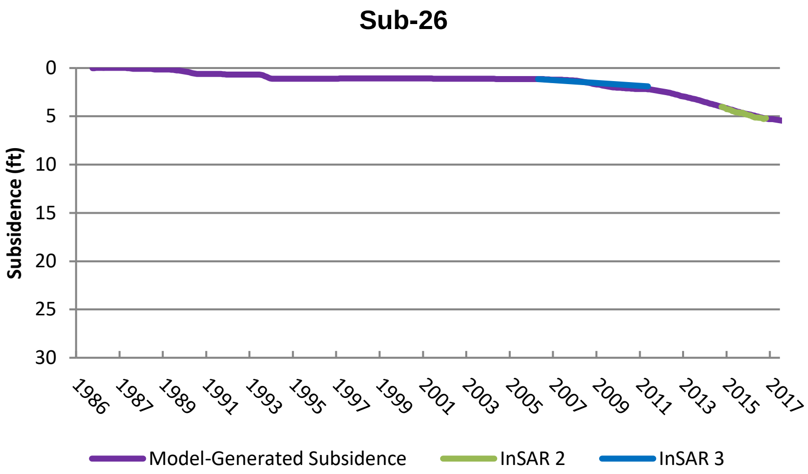
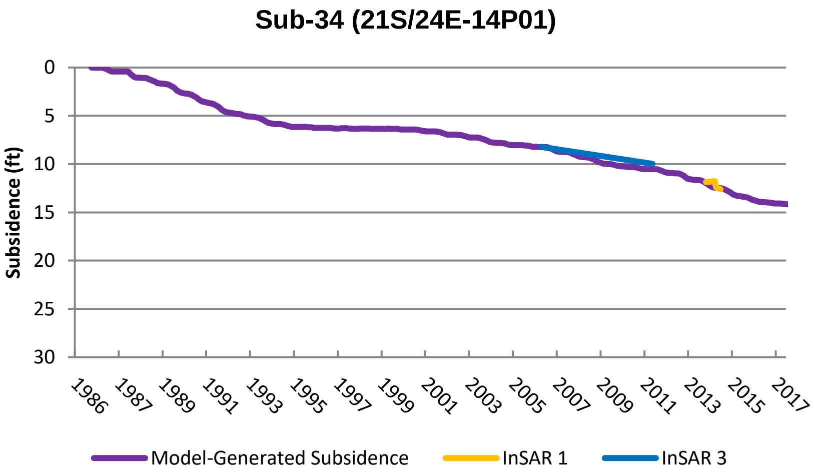
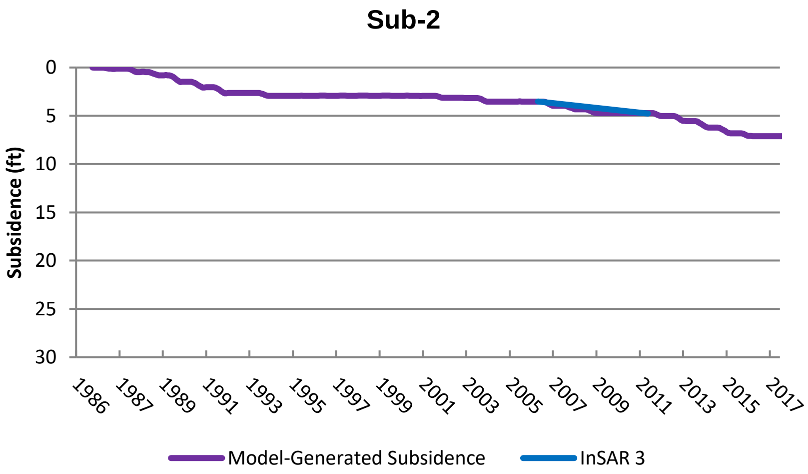
Land Subsidence Calibration Graphs

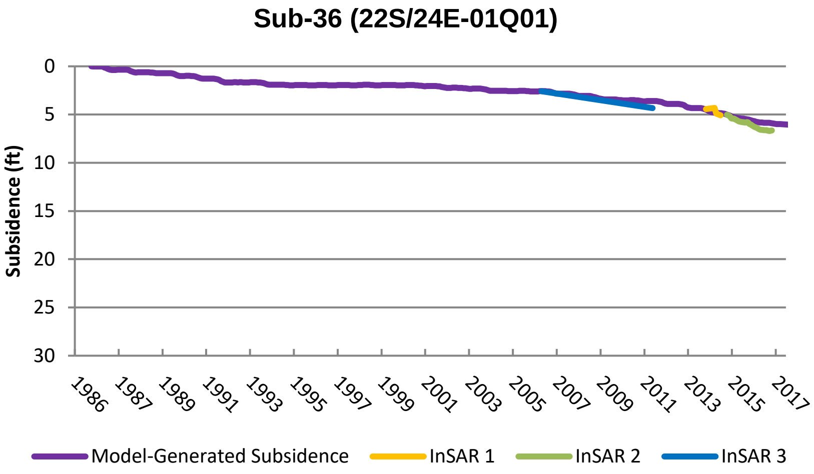


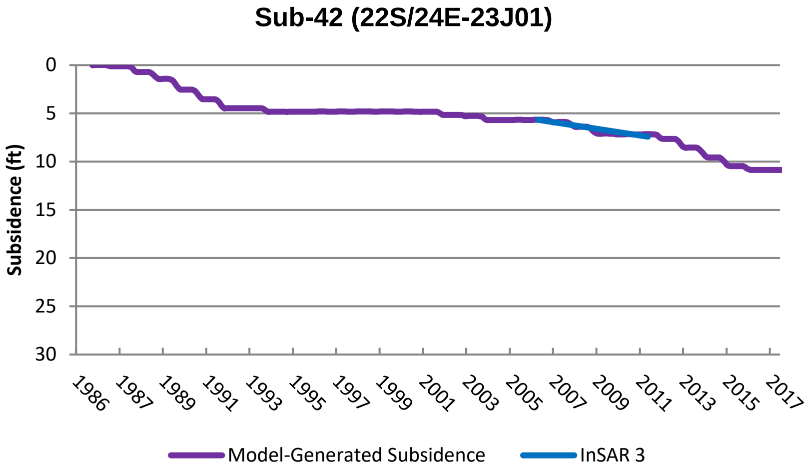


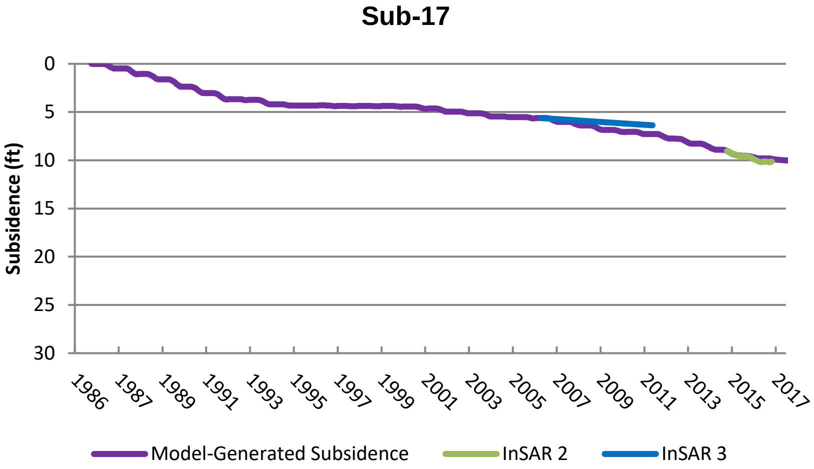


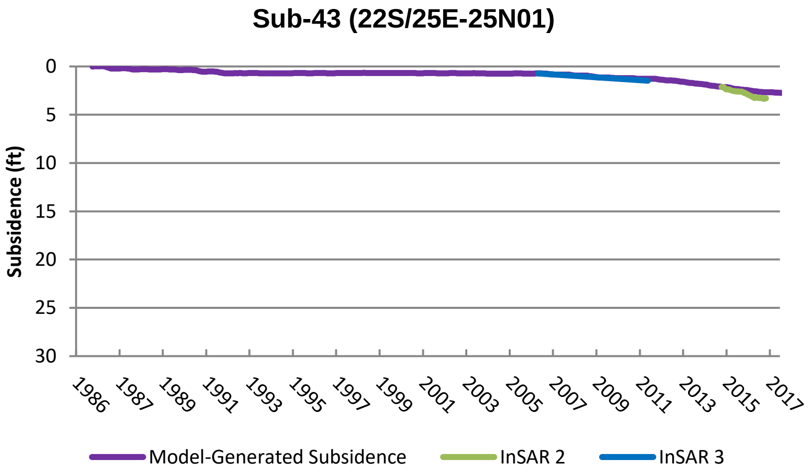


Land Subsidence Calibration Graphs

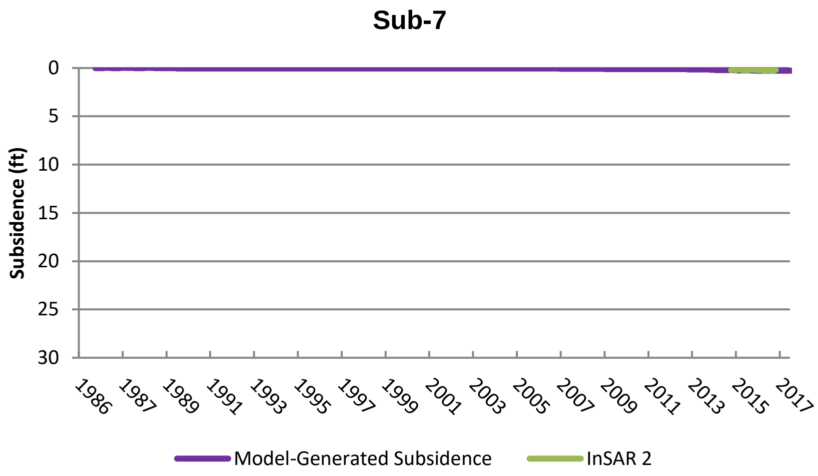


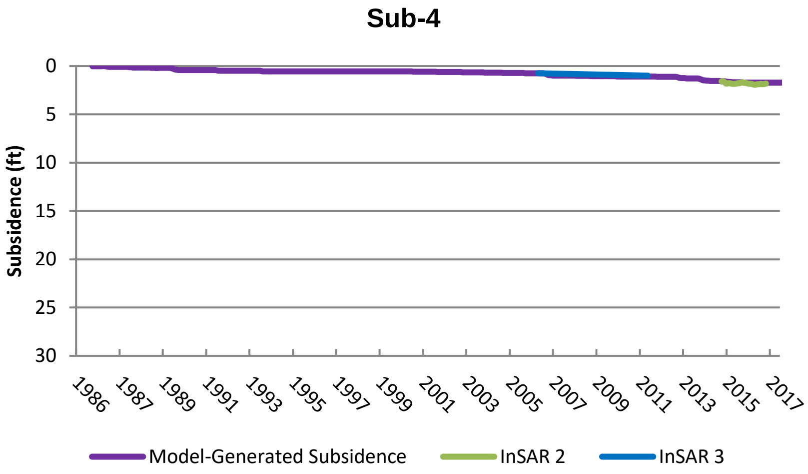


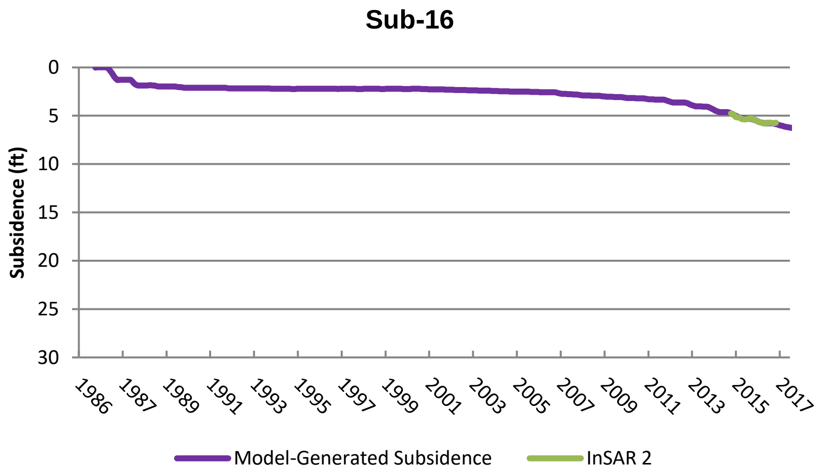


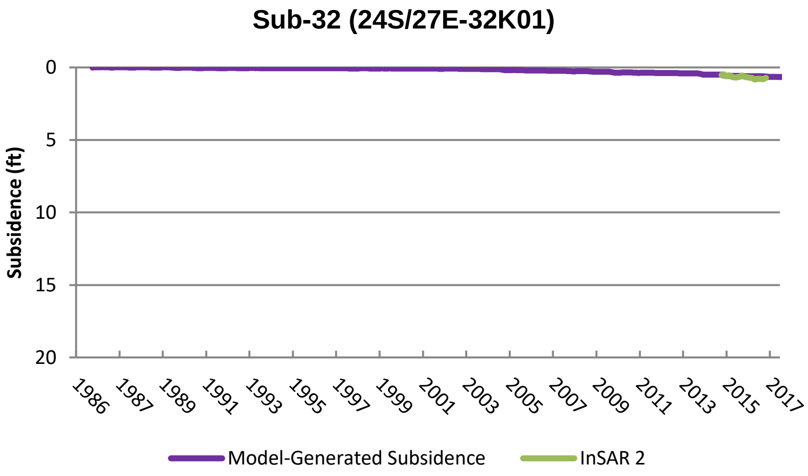


Land Subsidence Calibration Graphs



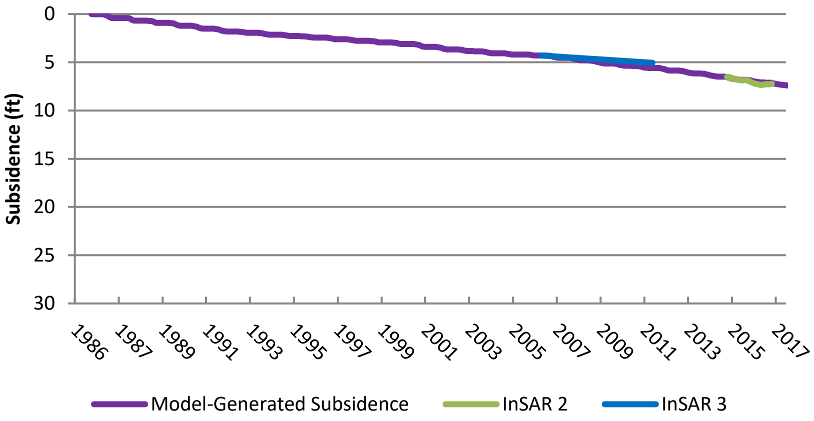




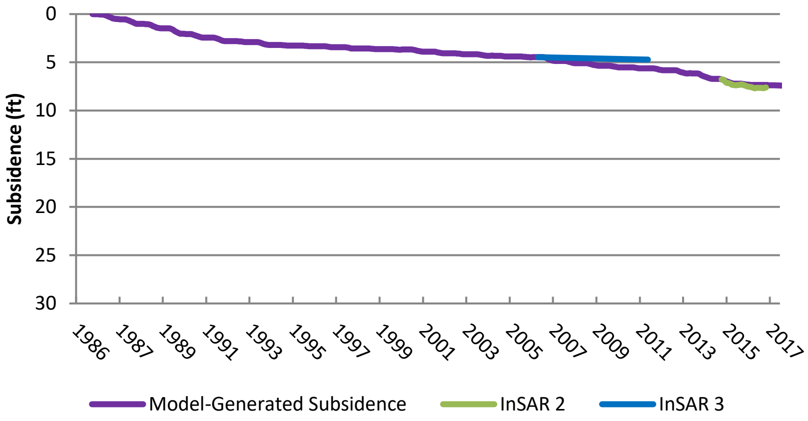


Land Subsidence Calibration Graphs

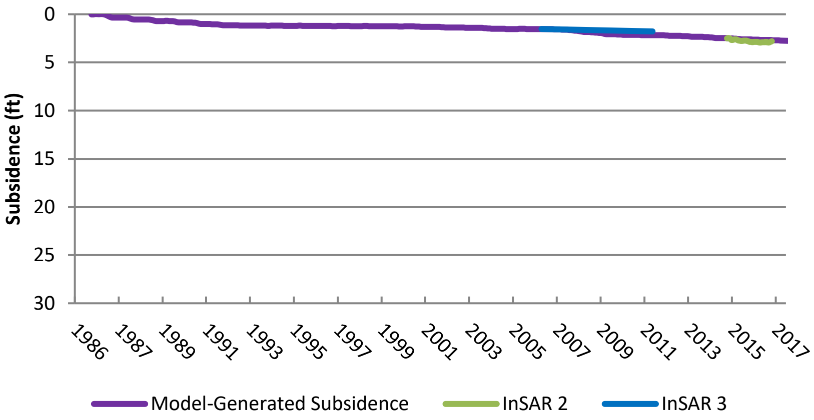
Sub-15



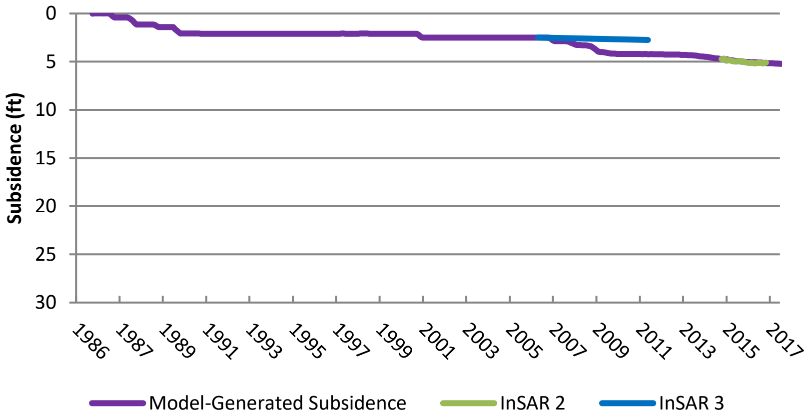
Sub-14



Sub-9

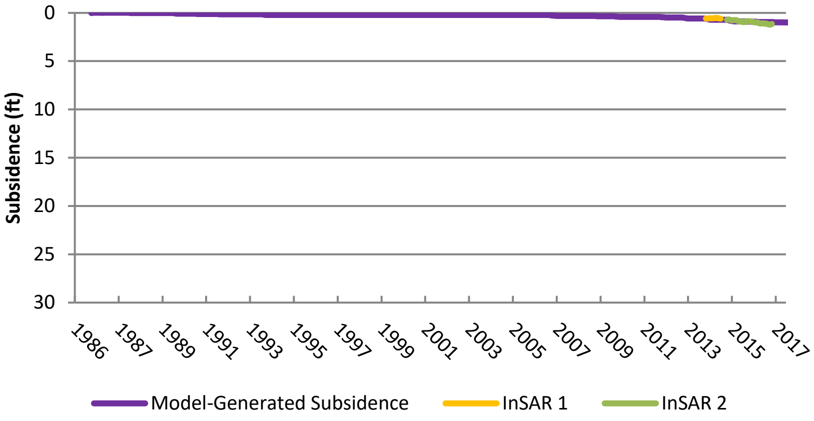


Sub-8

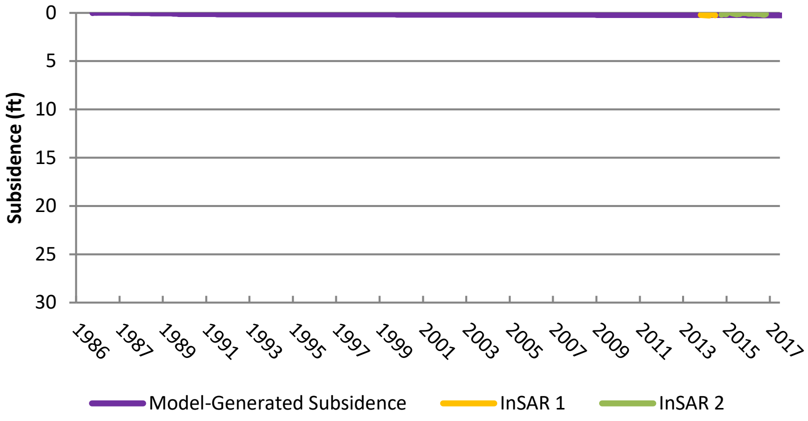


Land Subsidence Calibration Graphs

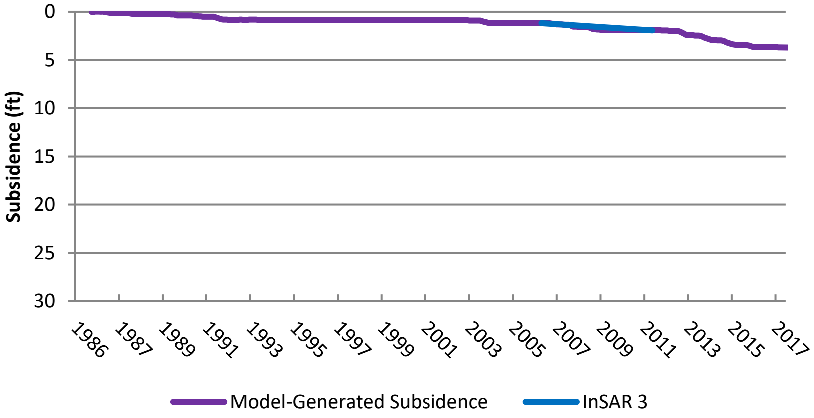
Sub-25



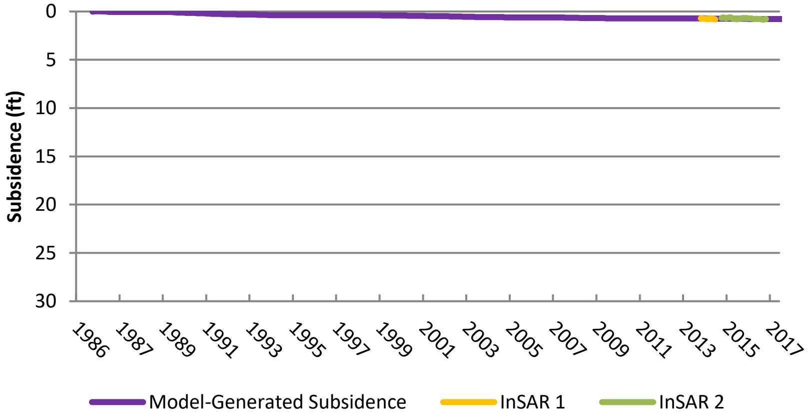
Sub-24



Sub-41 (21S/25E-01F01)

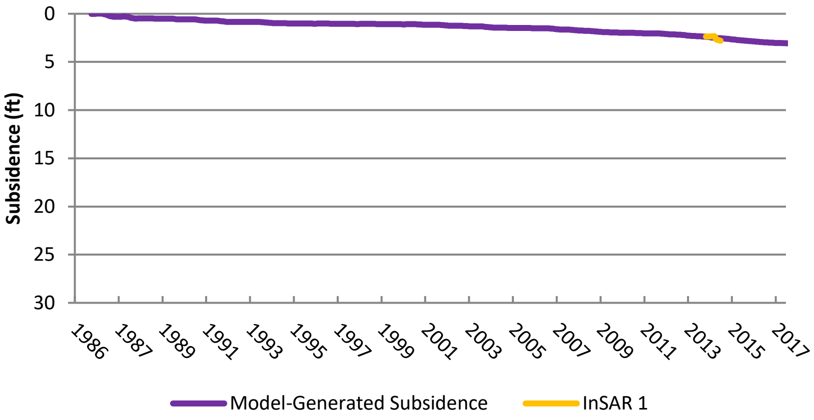


Sub-22

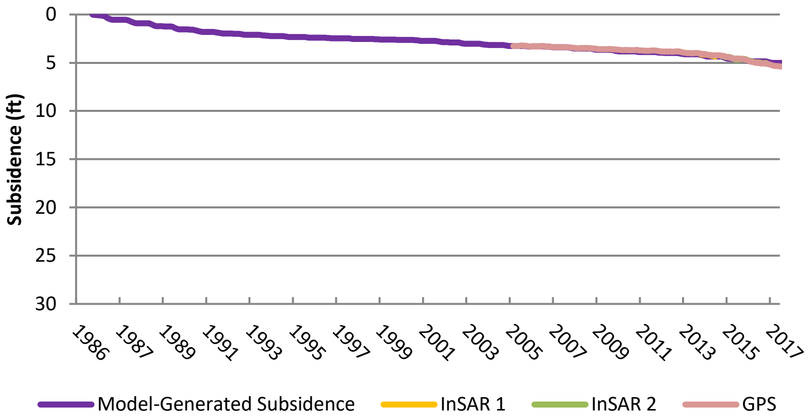


Land Subsidence Calibration Graphs

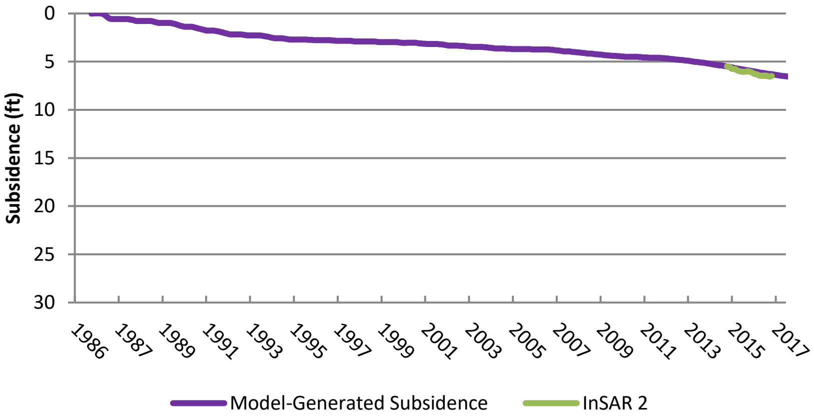
Sub-38 (21S/26E-32A01)



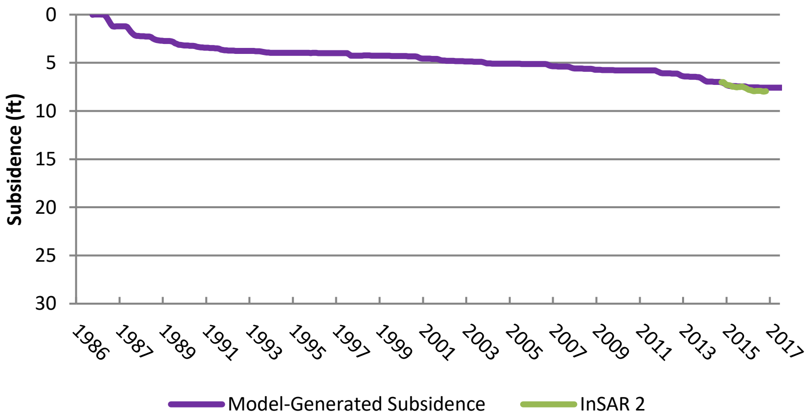
Sub-44 (Porterville GPS)



Sub-39 (22S/26E-10J01)

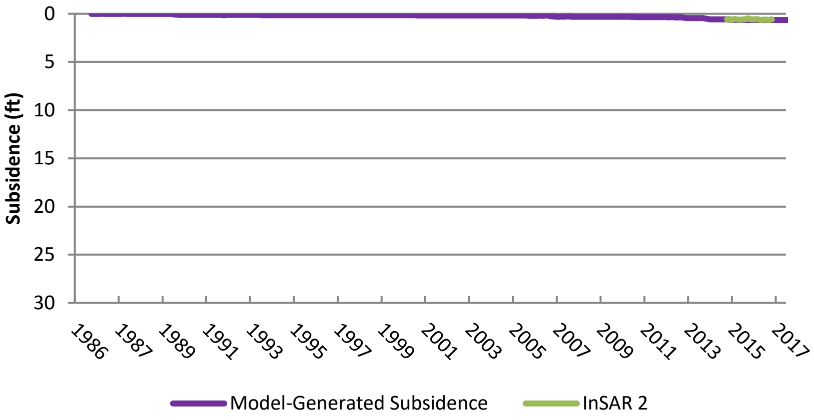


Sub-5

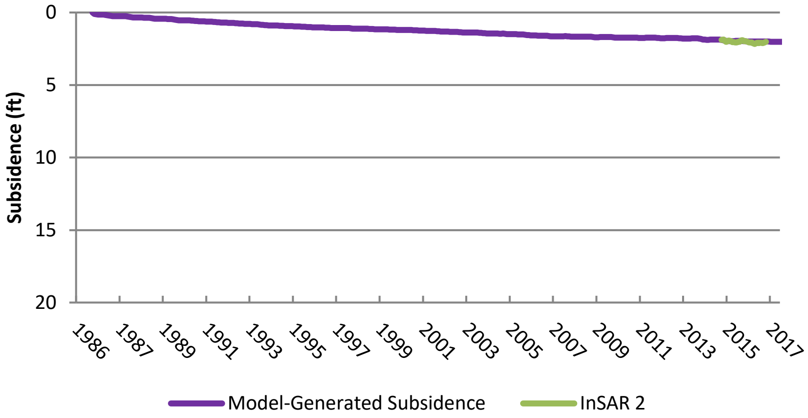


Land Subsidence Calibration Graphs

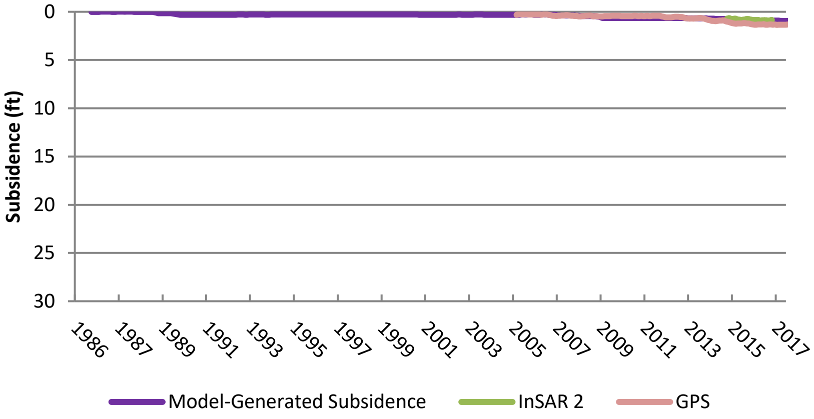
Sub-40 (24S/26E-32G01)



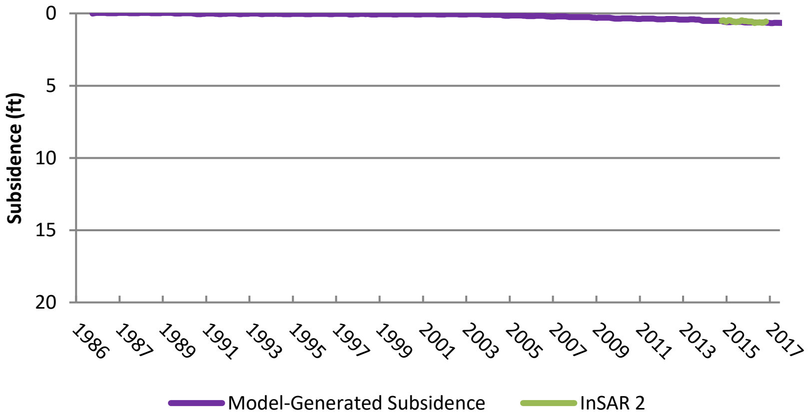
Sub-33 (24S/27E-08L01)



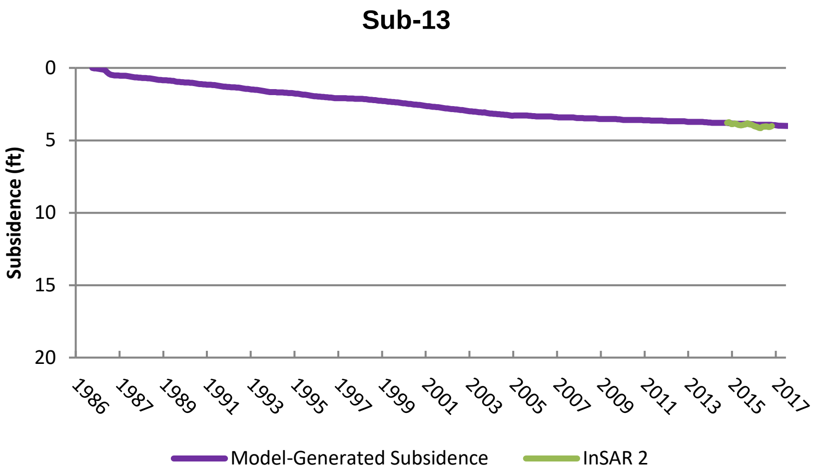
Sub-45 (Delano GPS)



Sub-6



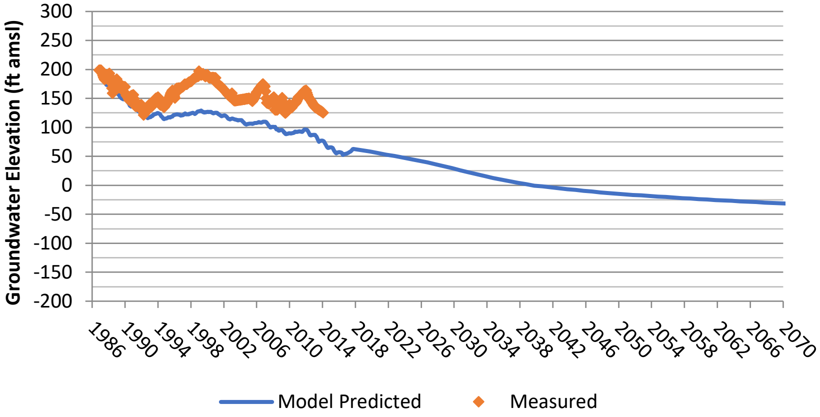
Land Subsidence Calibration Graphs

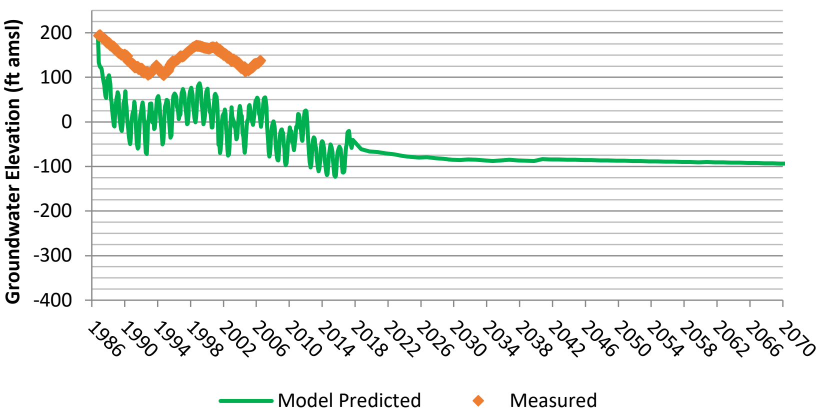


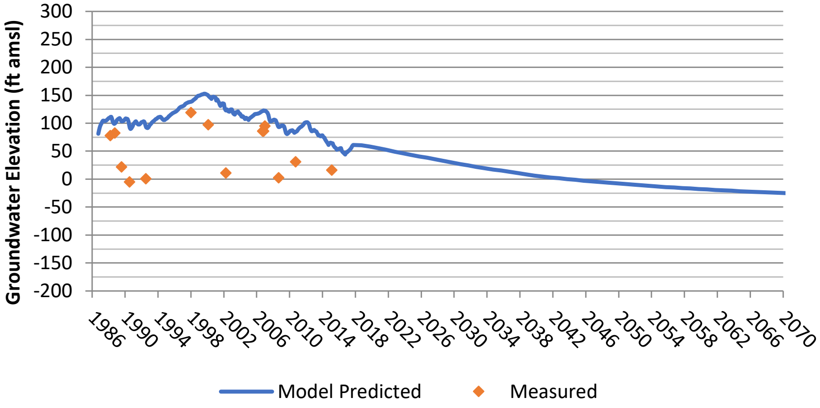
Appendix F

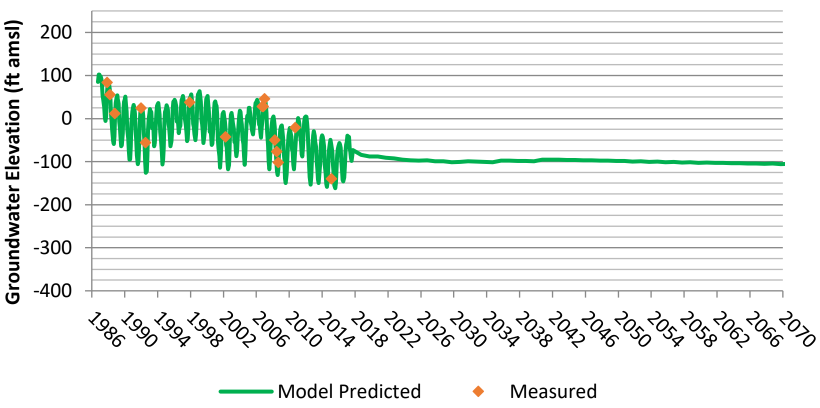
Model Simulated Hydrographs

Model Simulated Hydrographs


21S/23E-32K01 (L1)

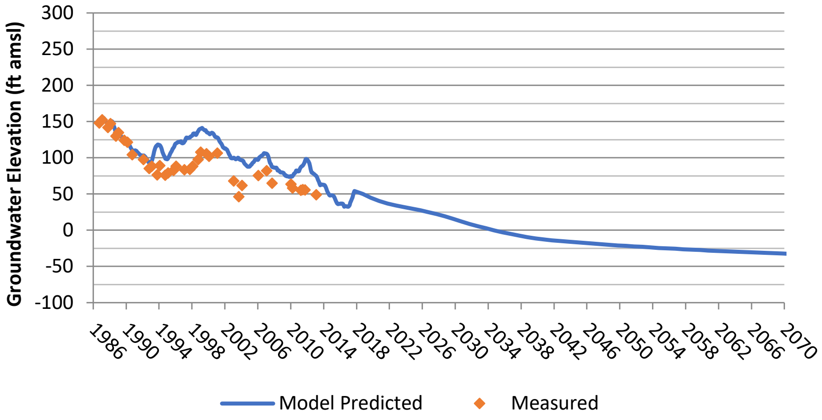

21S/23E-36R01 (L3)


Angiola G1 (L1)

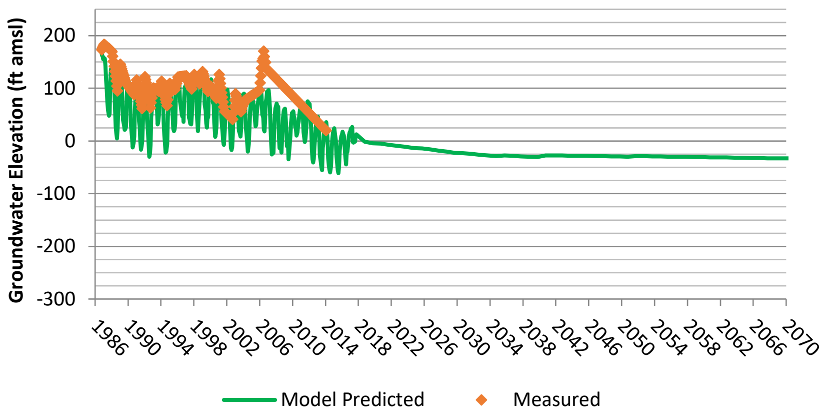

Angiola E10 (L3)

Model Simulated Hydrographs

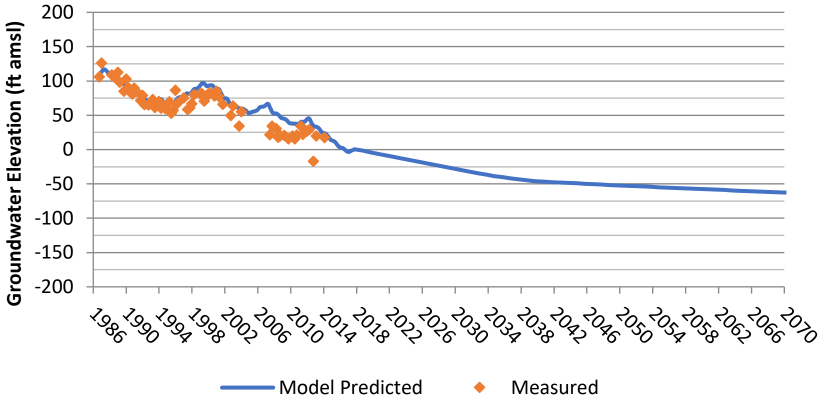
22S/24E-09A01 (L1)



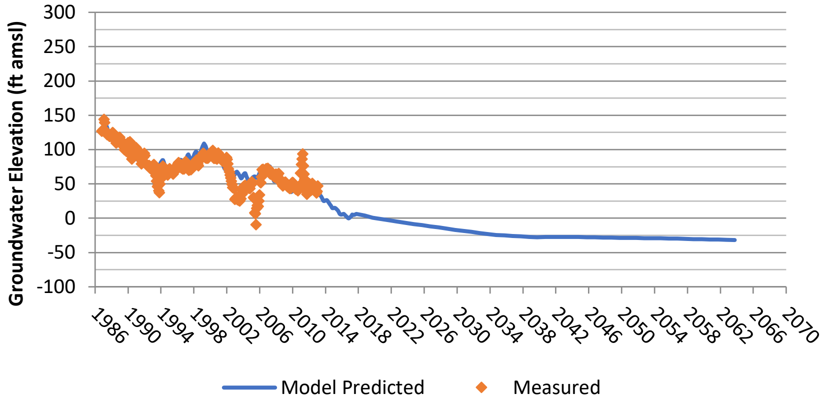
22S/24E-01Q01 (L3)



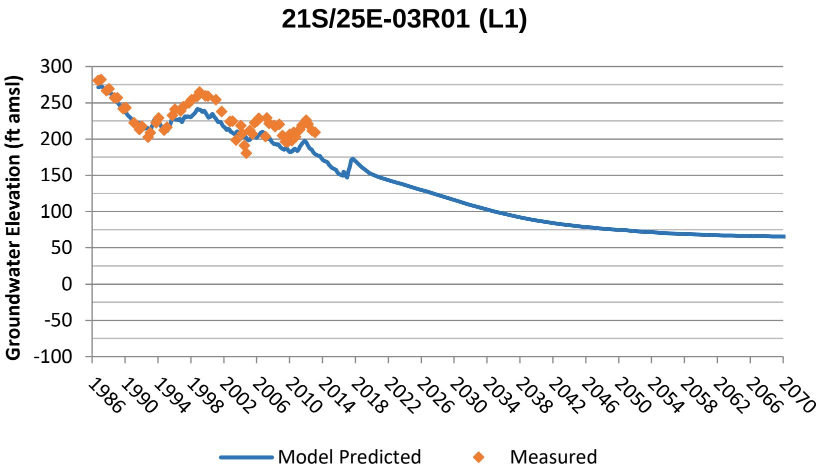
22S/24E-20A01 (L1)

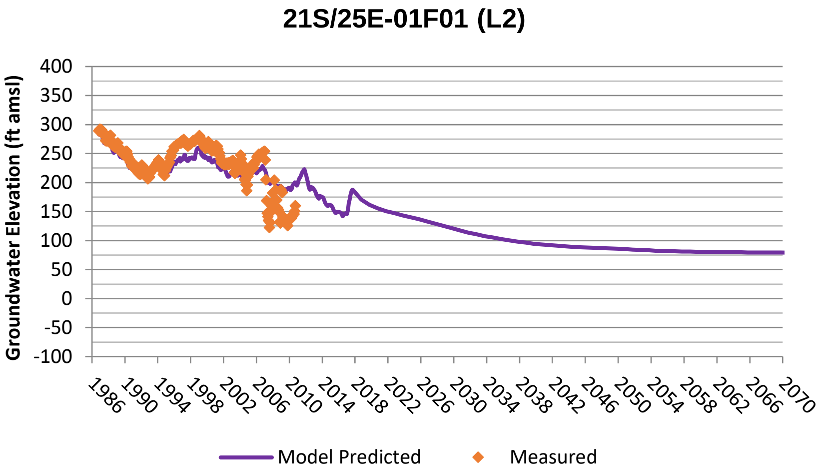


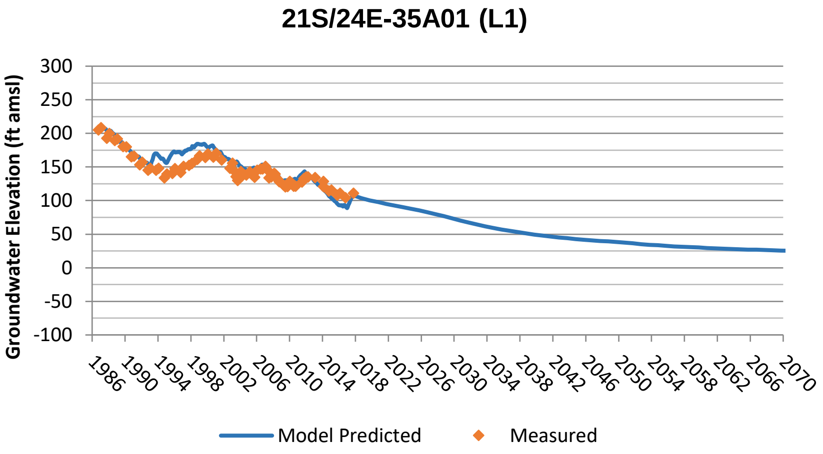
22S/24E-23J01 (L1)

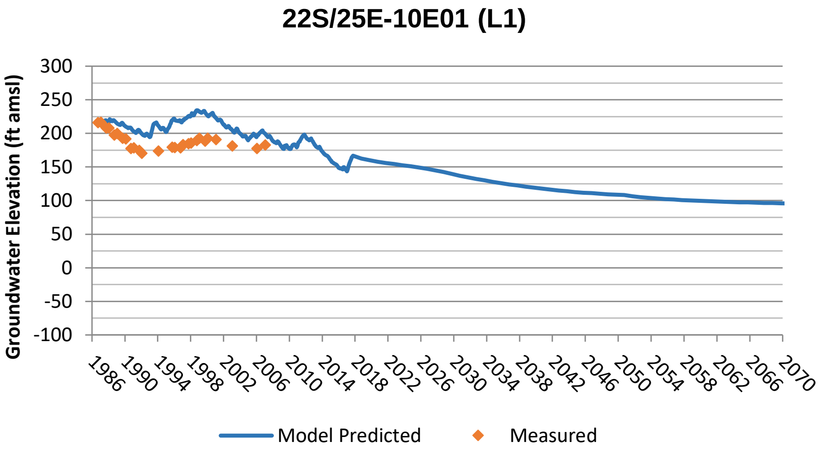


Model Simulated Hydrographs



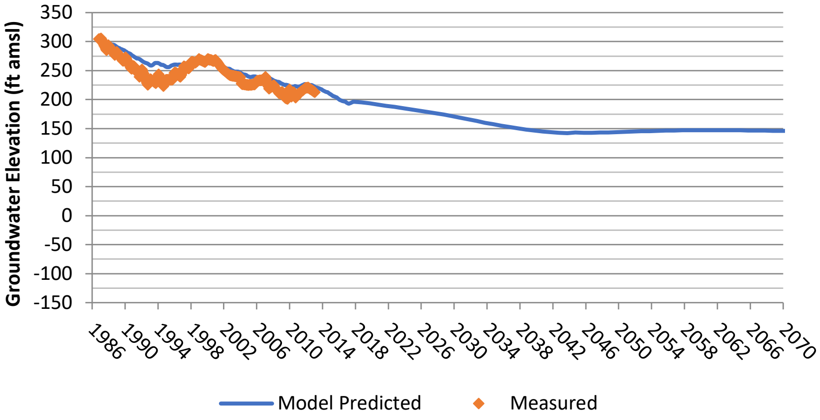




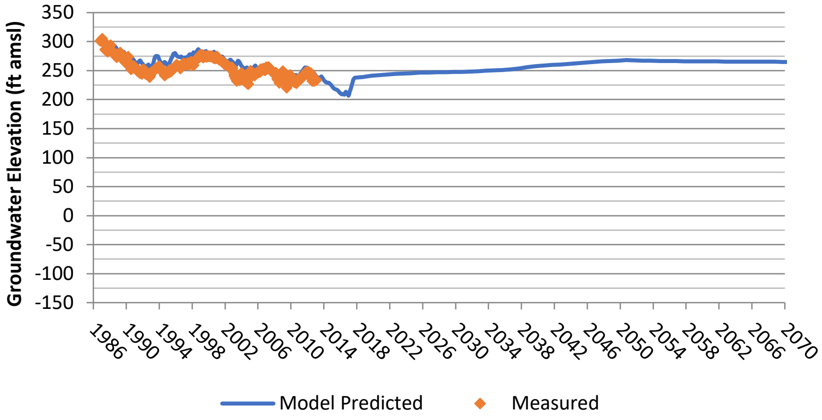


Model Simulated Hydrographs

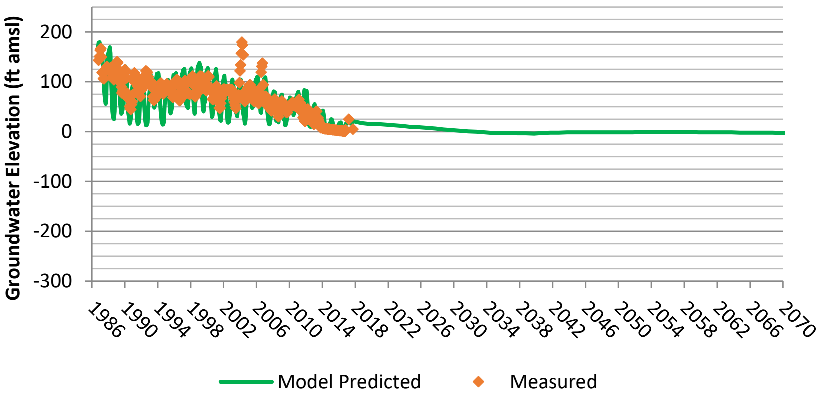
21S/26E-32A01 (L1)



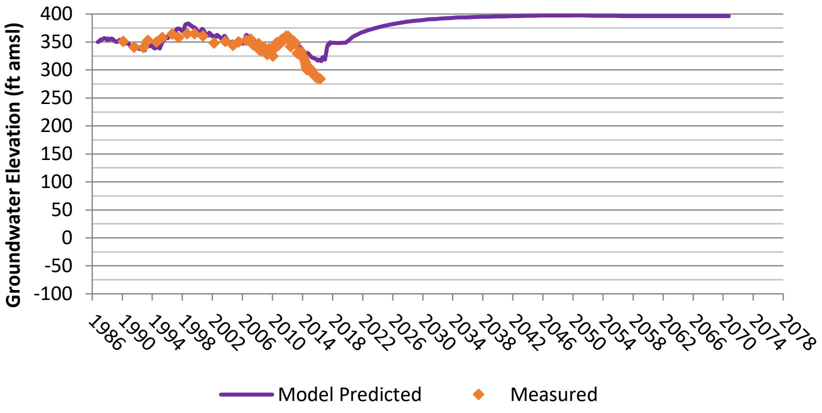
22S/26E-10J01 (L1)



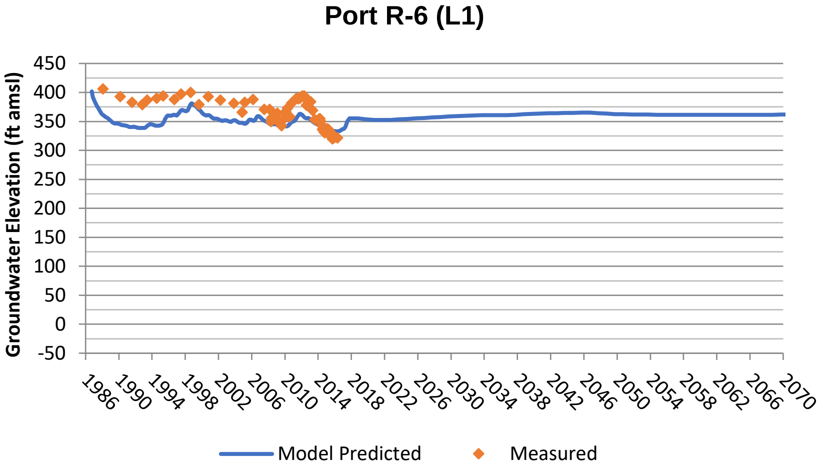
22S/25E-25N01 (L3)

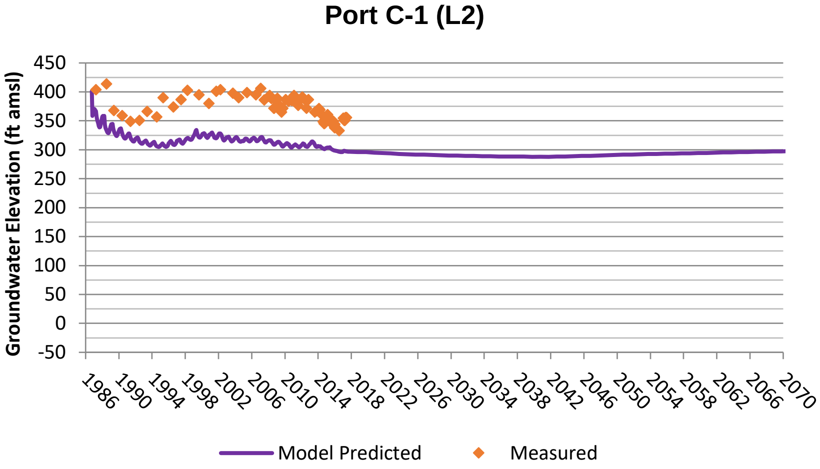


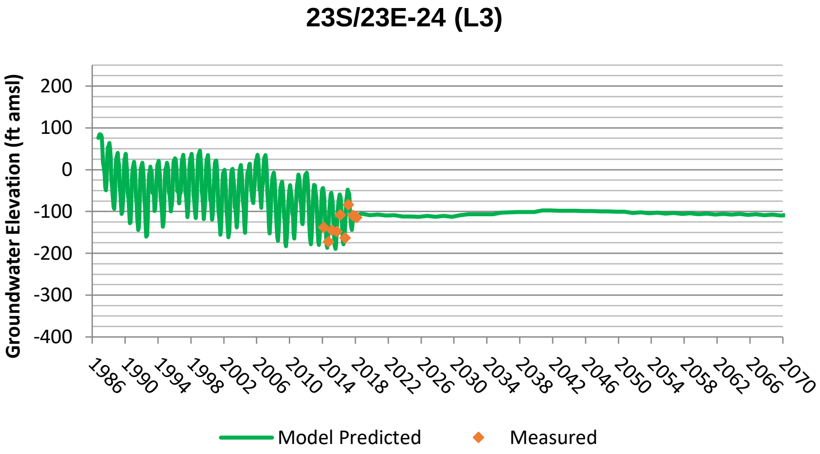
Port R-11 (L2)

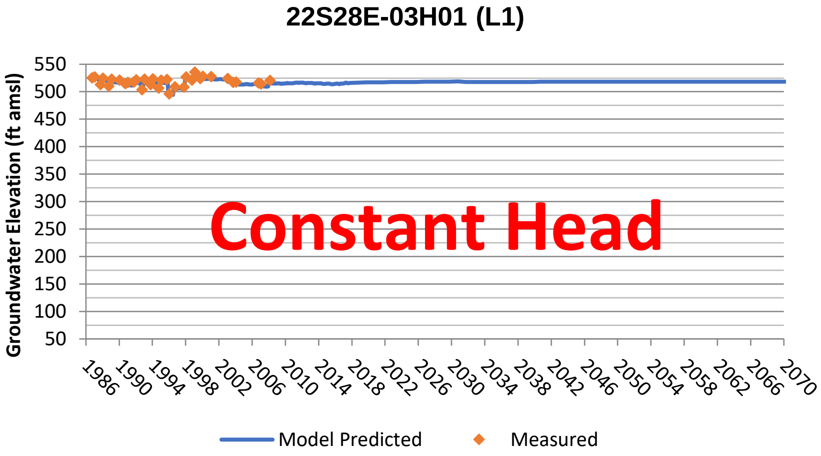


Model Simulated Hydrographs



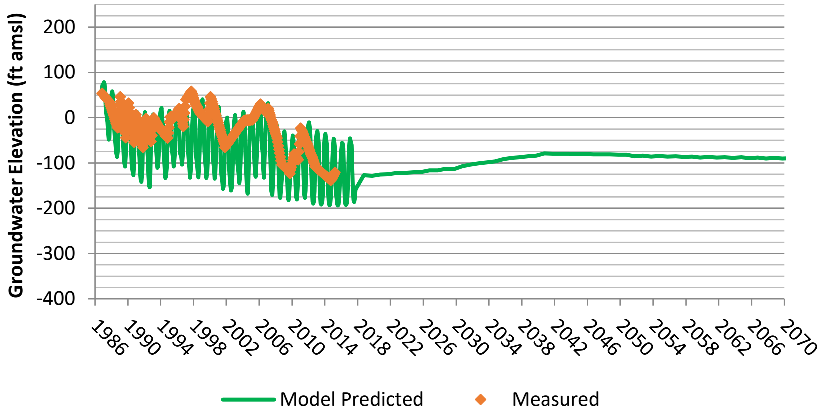




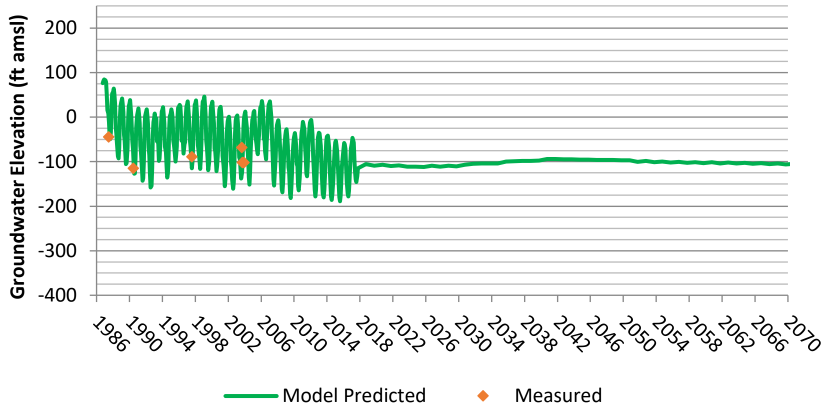


Model Simulated Hydrographs

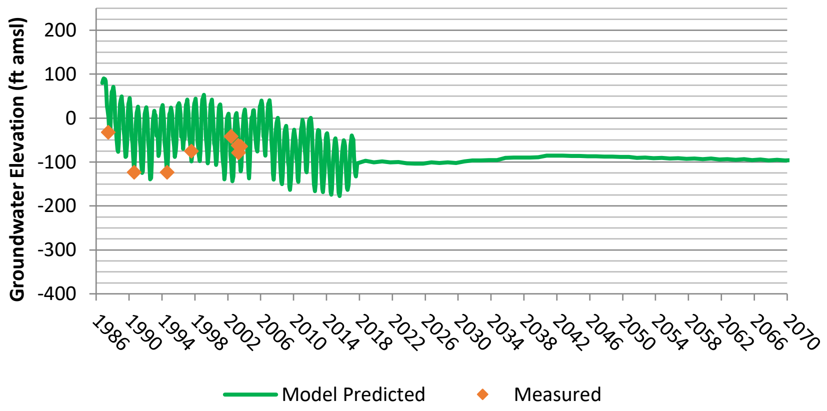
24S/23E-22R02 (L3)



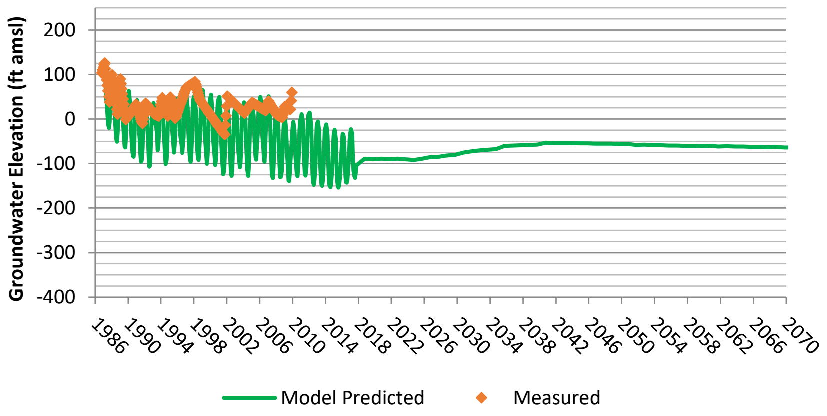
Well 51 (Alpaugh)



Well 53 (Alpaugh)

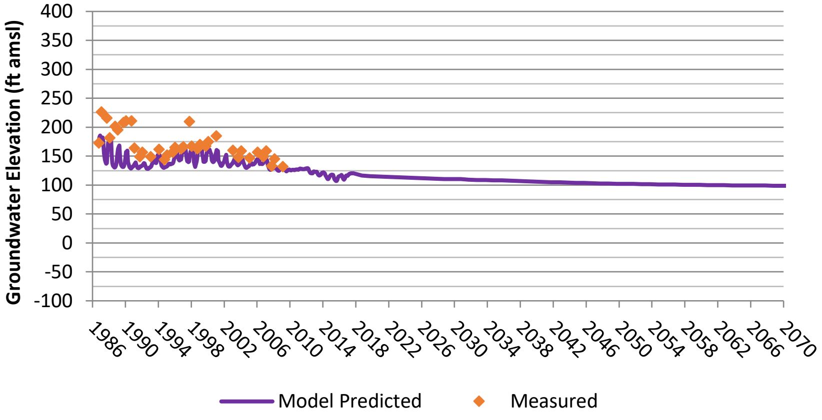


24S/24E-03A01 (L3)

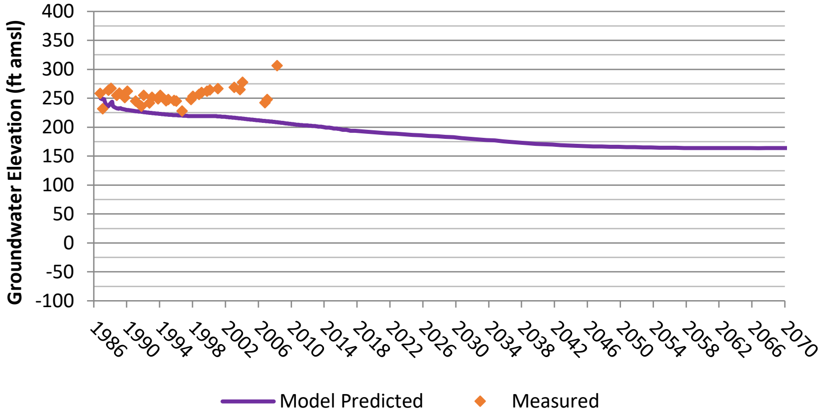


Model Simulated Hydrographs

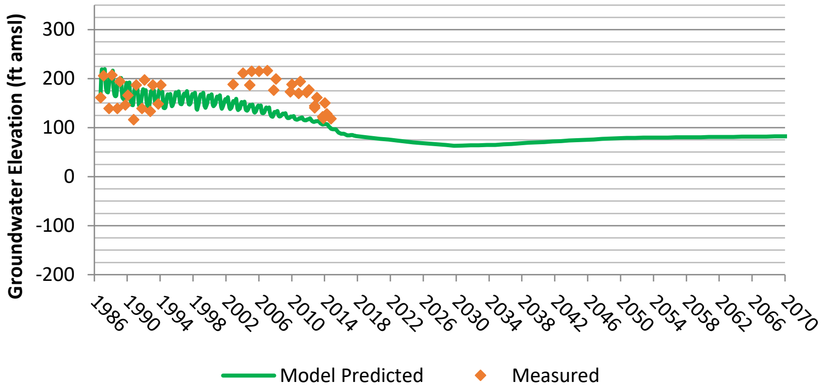
23S/26E-09C01 (L2)



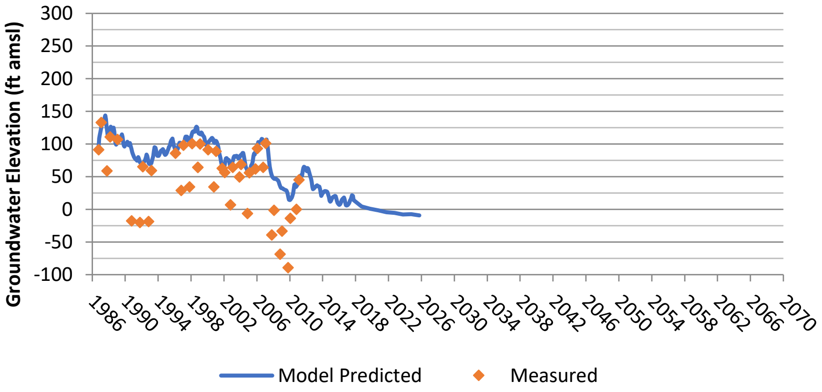
23S/26E-12J01 (L2)



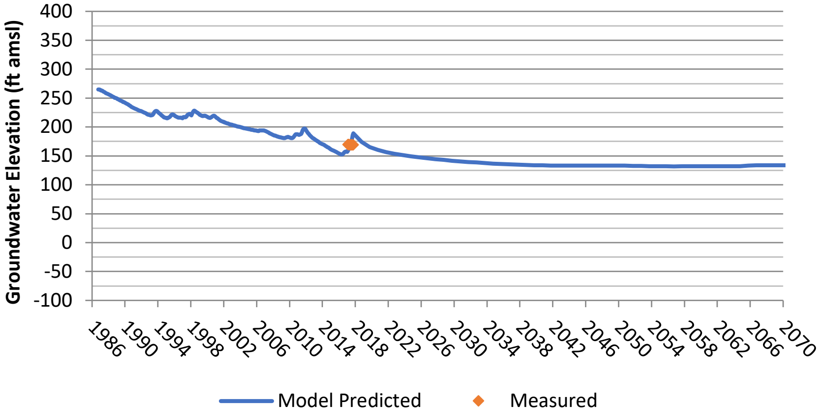
24S/26E-01R01 (L3)



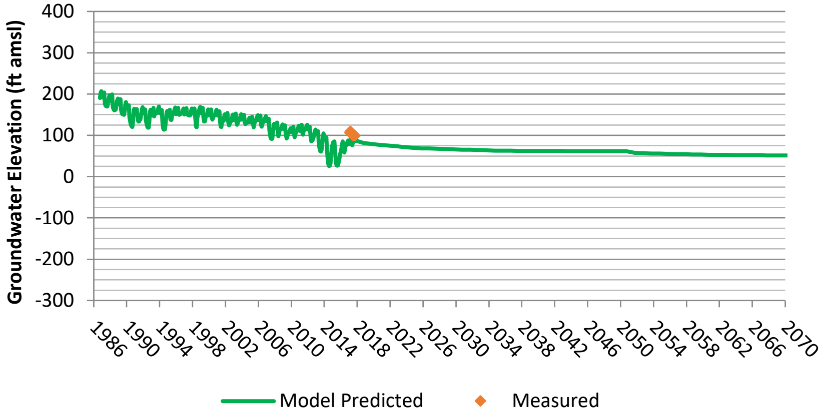
25S/24E-14R02 (L1)



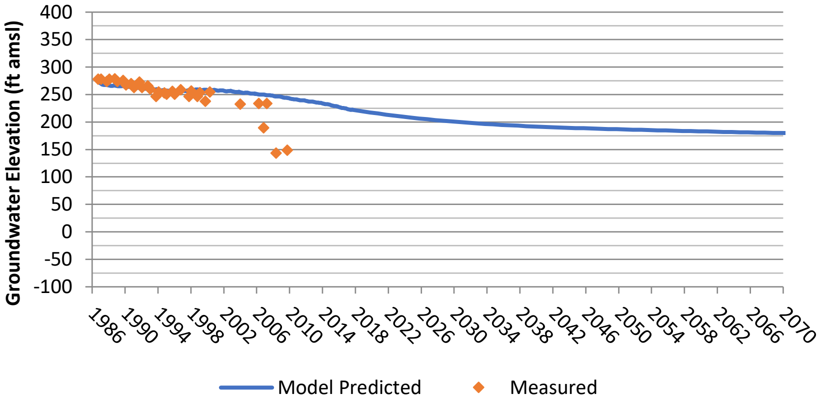
Model Simulated Hydrographs



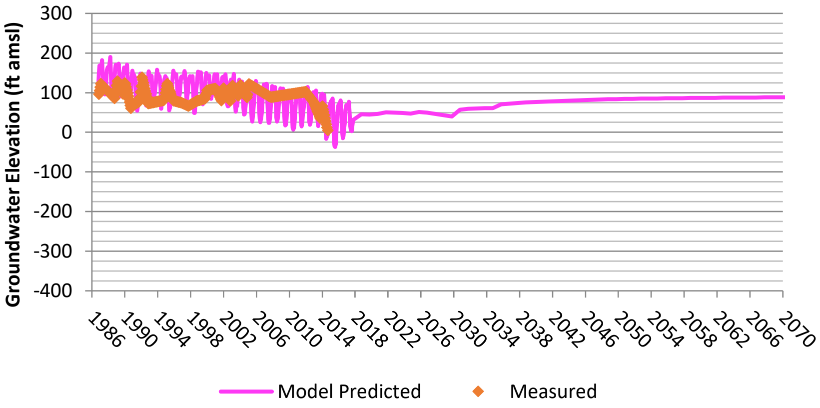
M19-L1 (DEID)



M19-L3 (DEID)

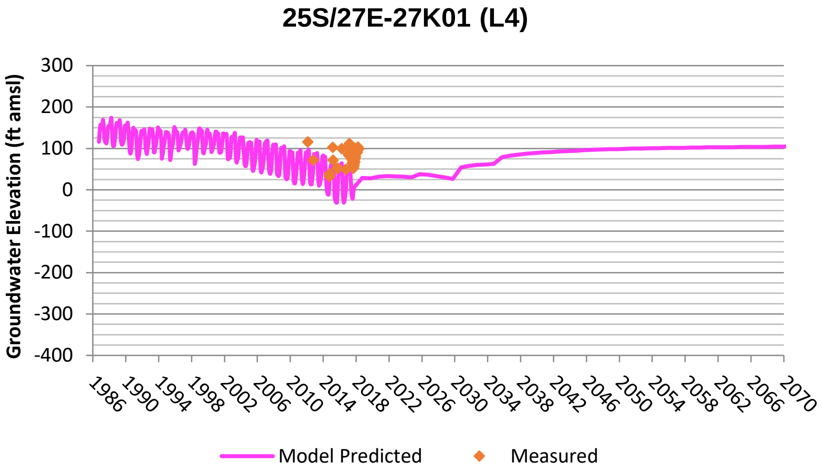


24S/25E-35P01 (L1)



24S/27E-32K01 (L4)

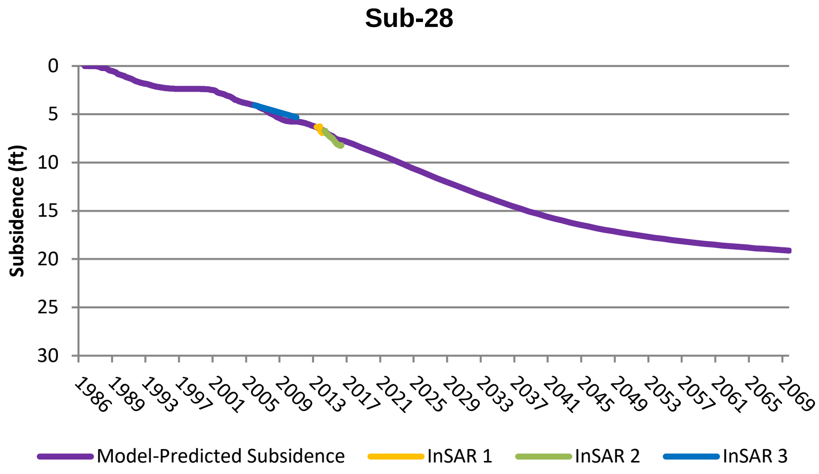
Model Simulated Hydrographs

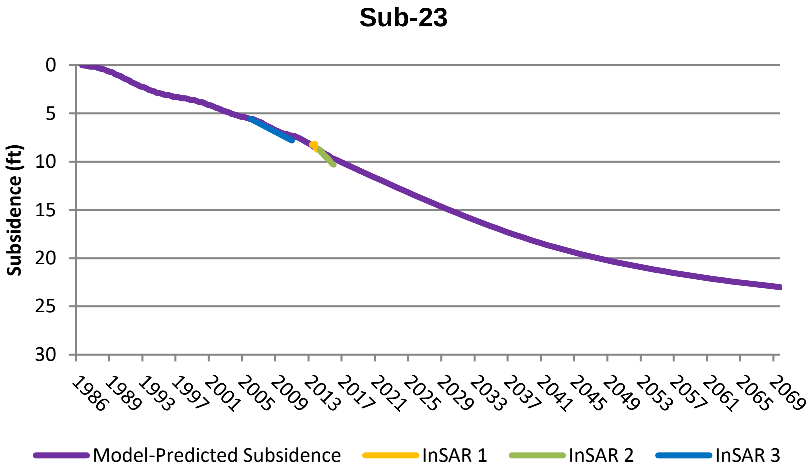


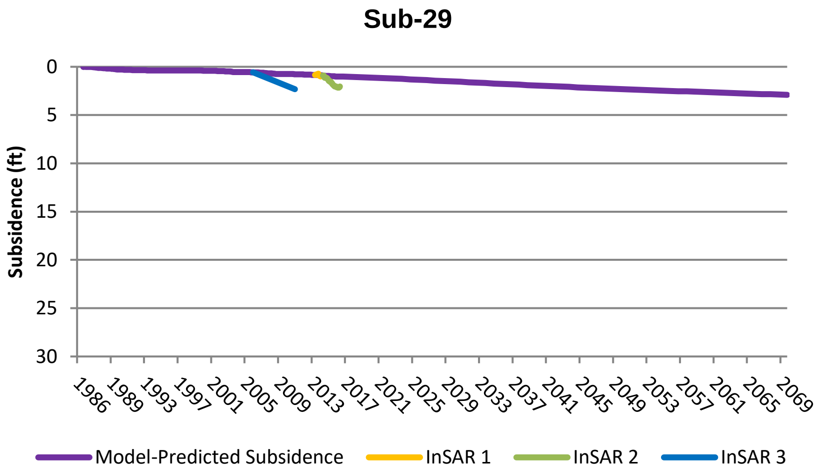
Appendix G

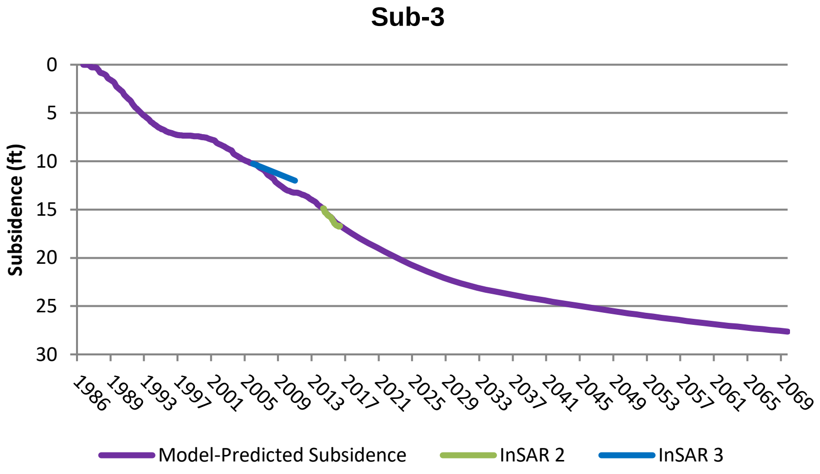
Model Simulation Land Subsidence Graphs

Model Simulation Land Subsidence Graphs


Sub-28

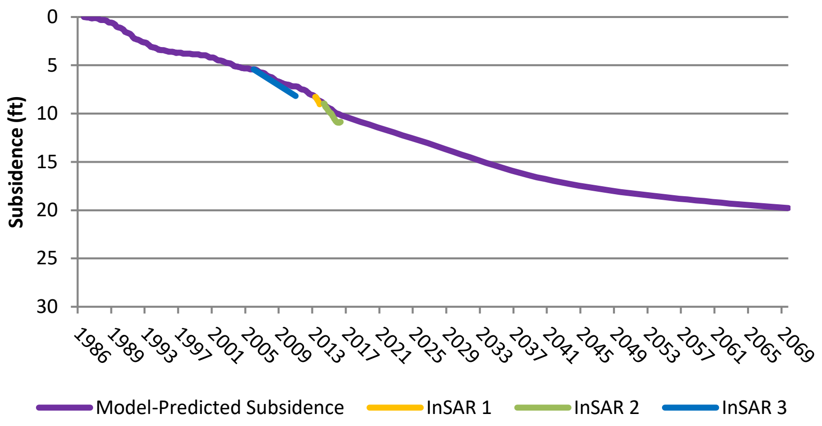

Sub-23


Sub-29

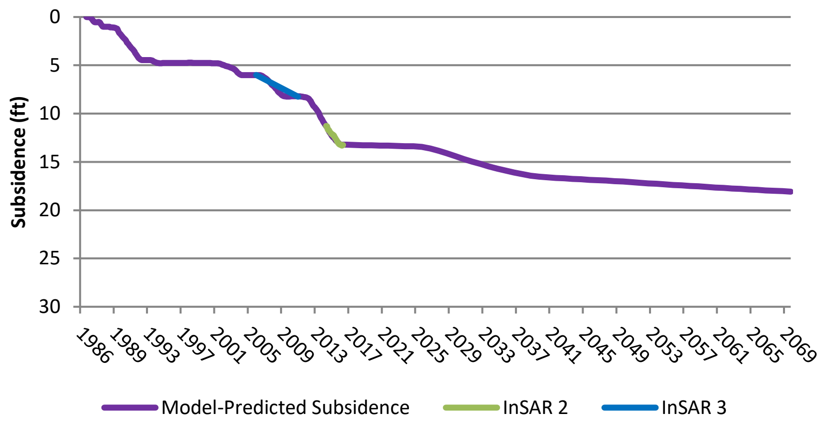

Sub-3

Model Simulation Land Subsidence Graphs

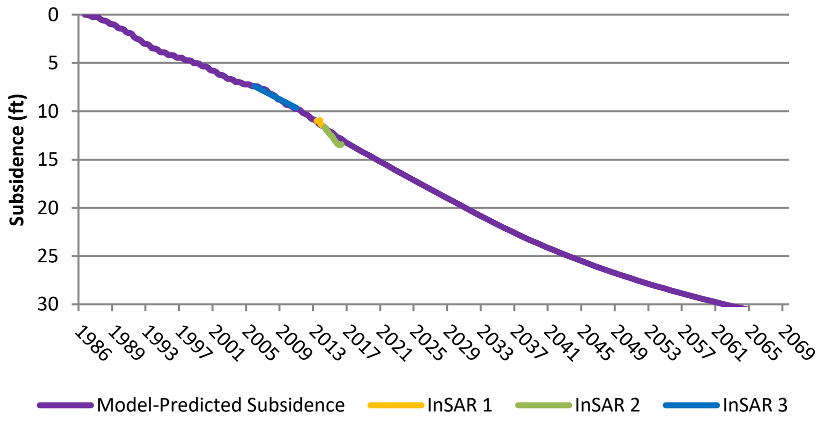
Sub-37 (21S/23E-32K01)



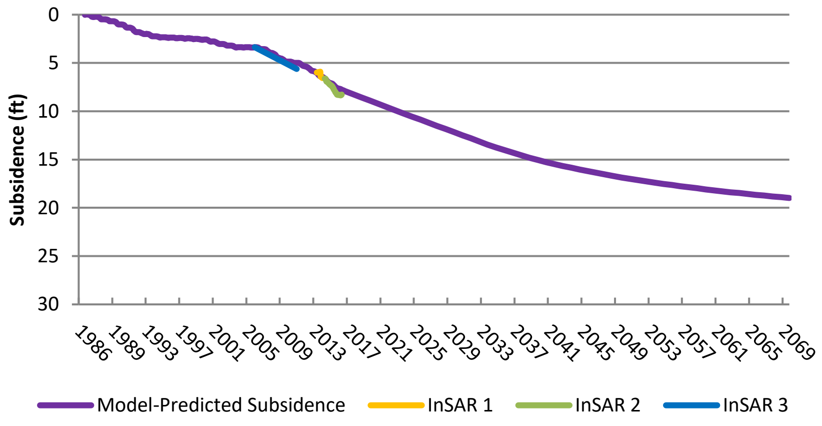
Sub-35 (21S/23E-36R01)



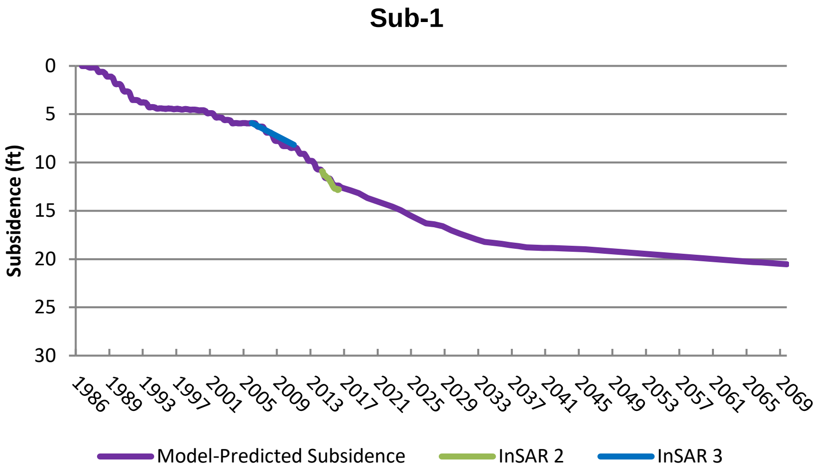
Sub-21

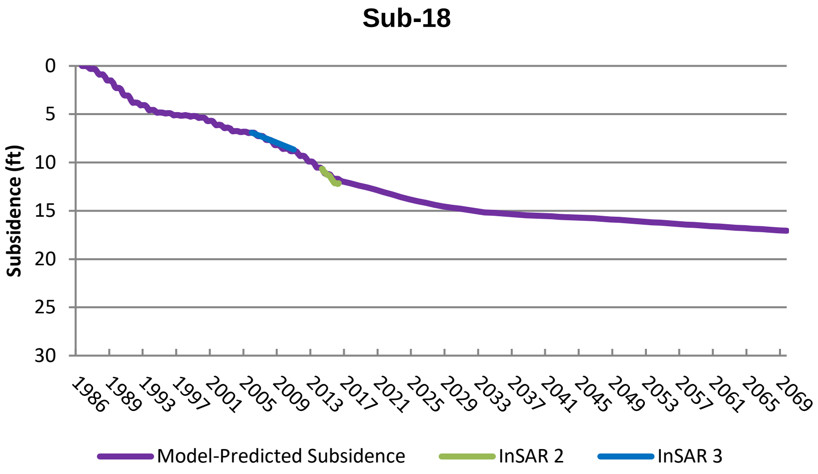


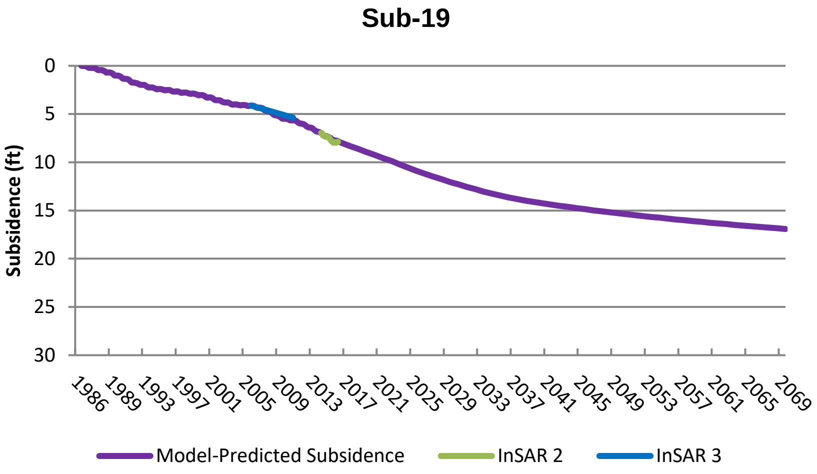
Sub-20

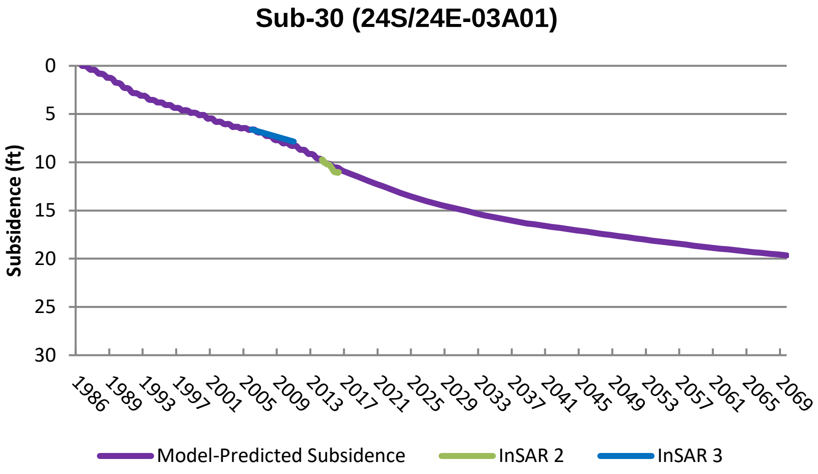


Model Simulation Land Subsidence Graphs

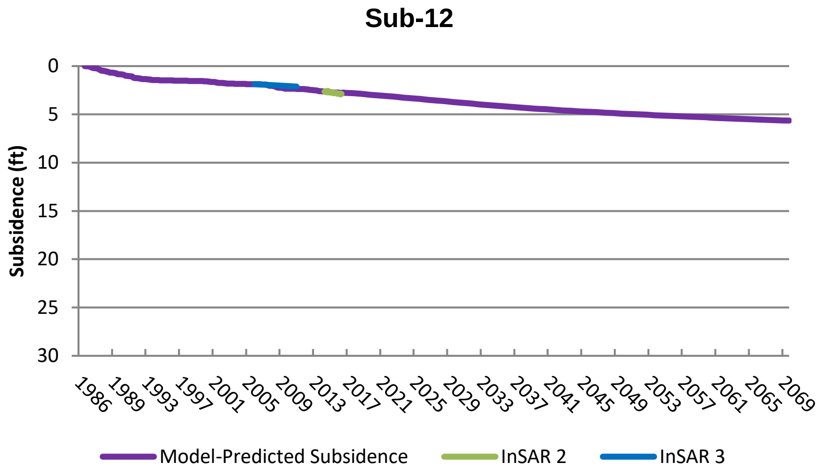


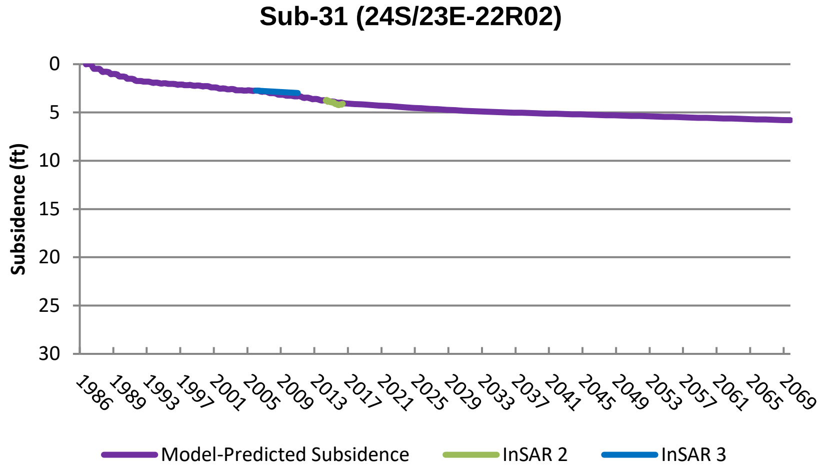


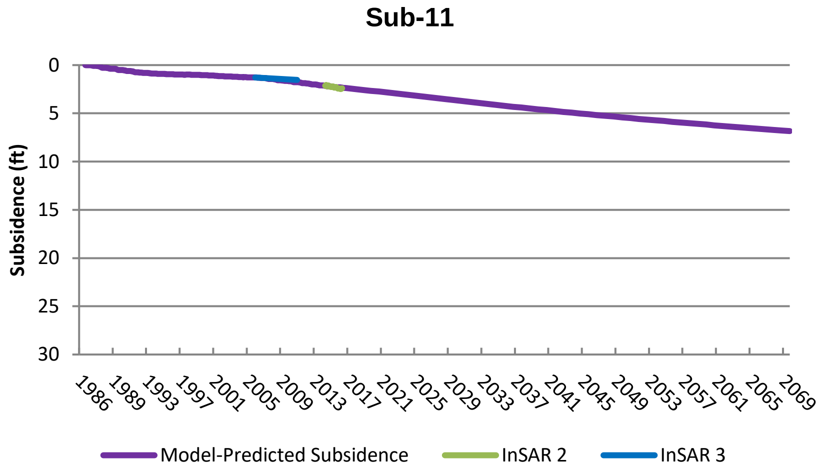


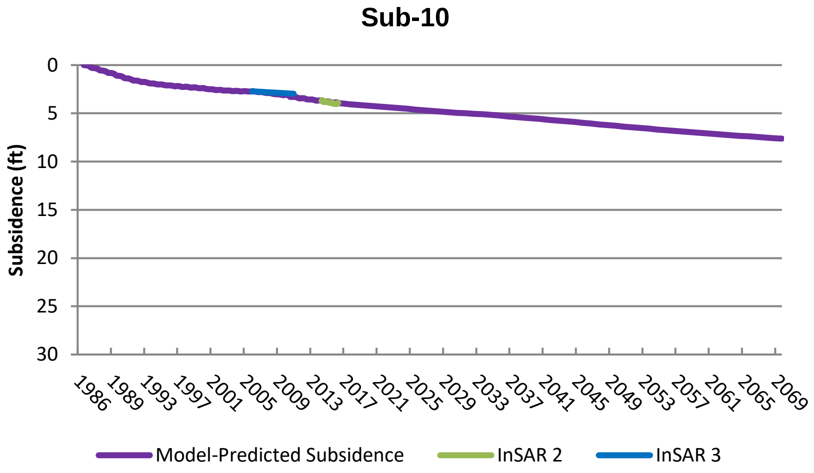


Model Simulation Land Subsidence Graphs

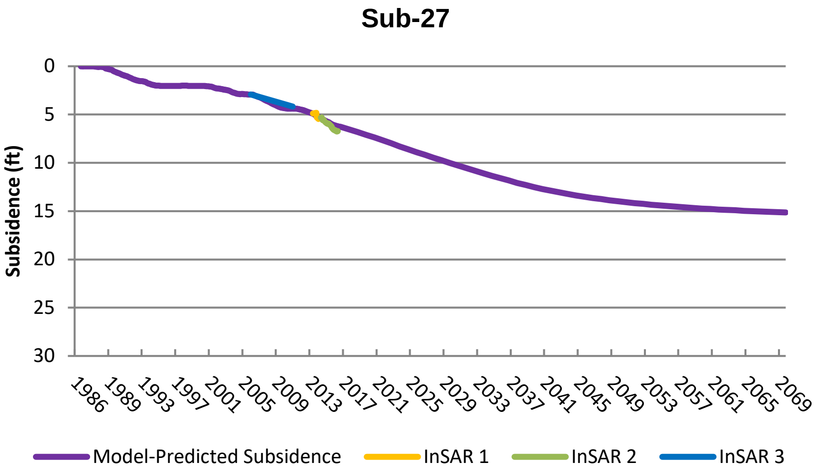


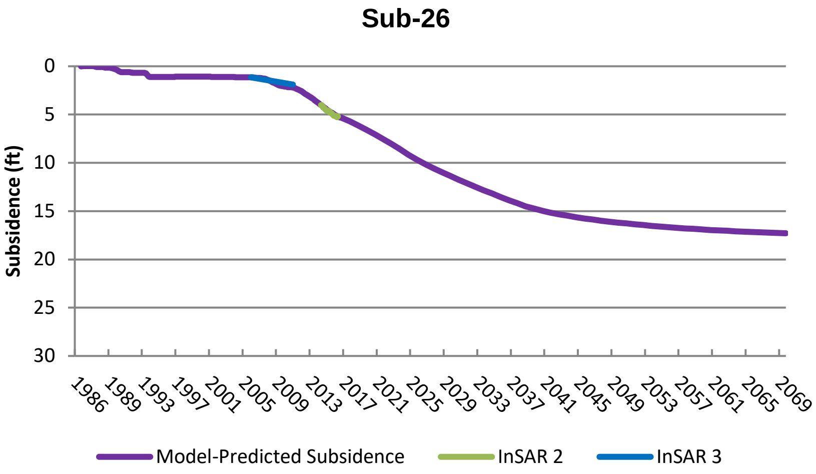


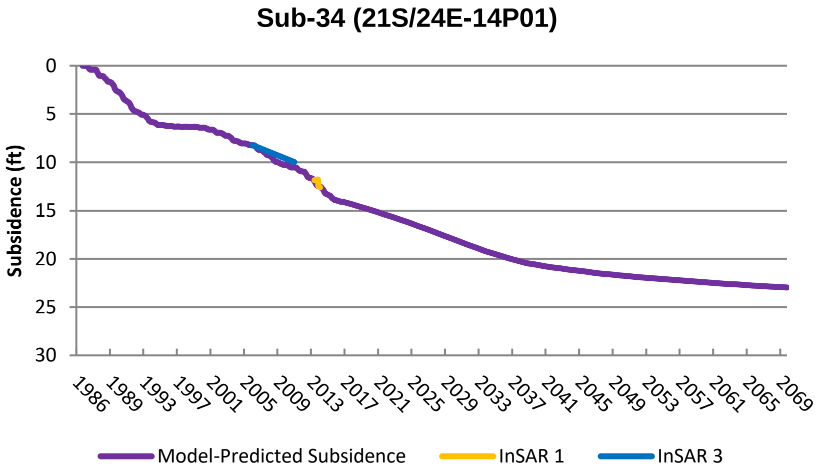


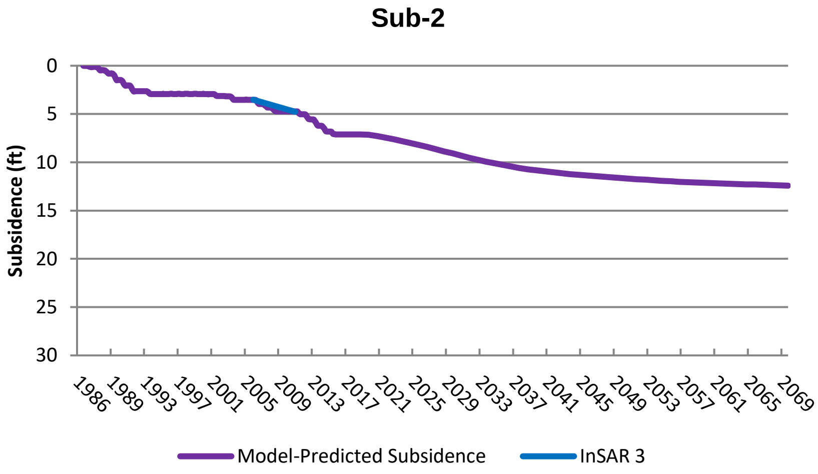


Model Simulation Land Subsidence Graphs

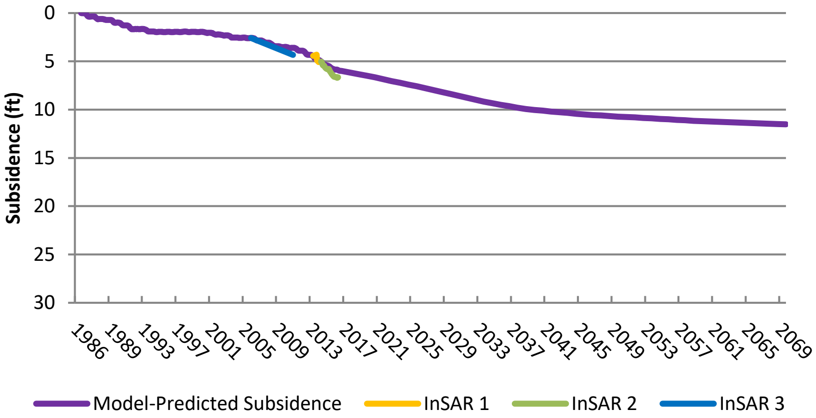


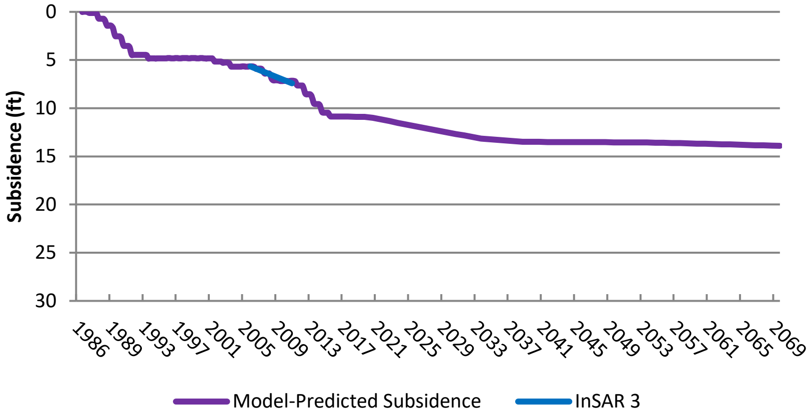


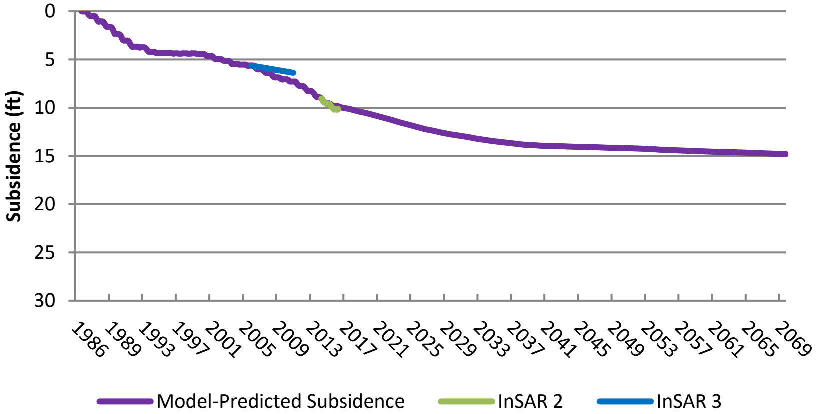


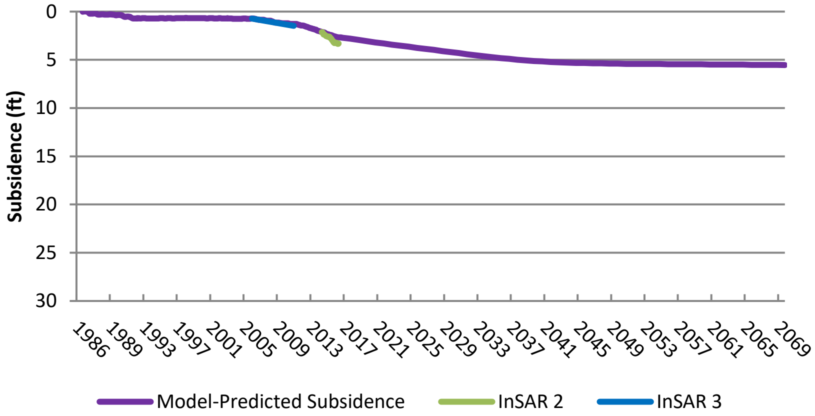


Model Simulation Land Subsidence Graphs


Sub-36 (22S/24E-01Q01)

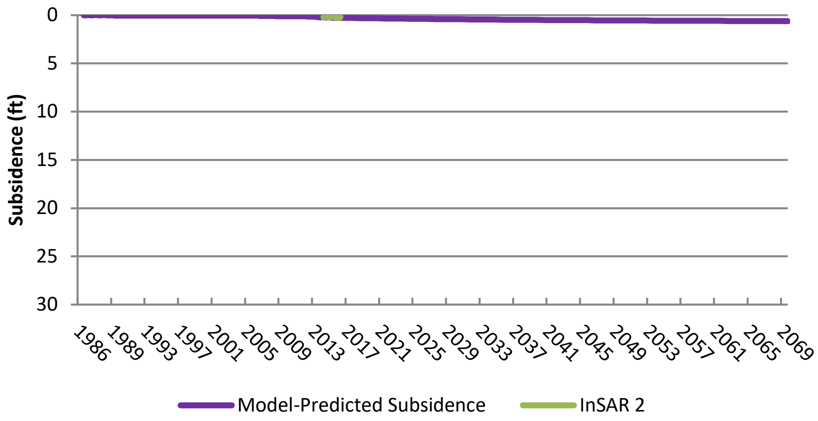

Sub-42 (22S/24E-23J01)


Sub-17

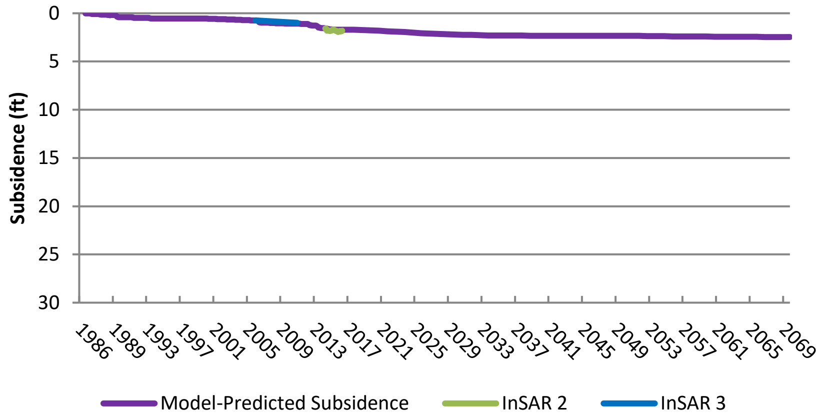

Sub-43 (22S/25E-25N01)

Model Simulation Land Subsidence Graphs

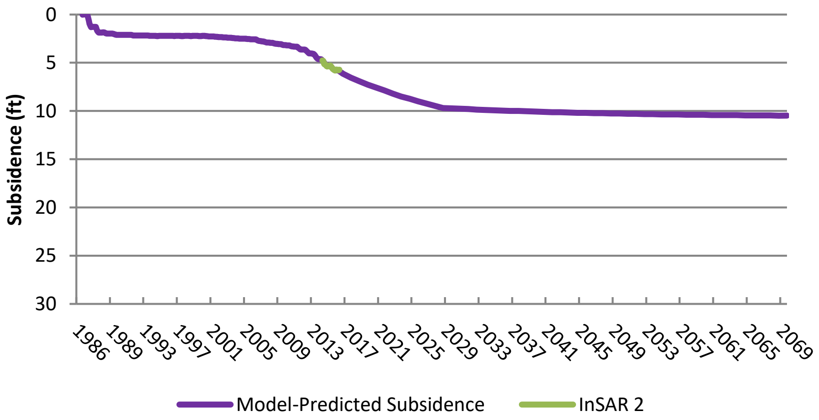
Sub-7



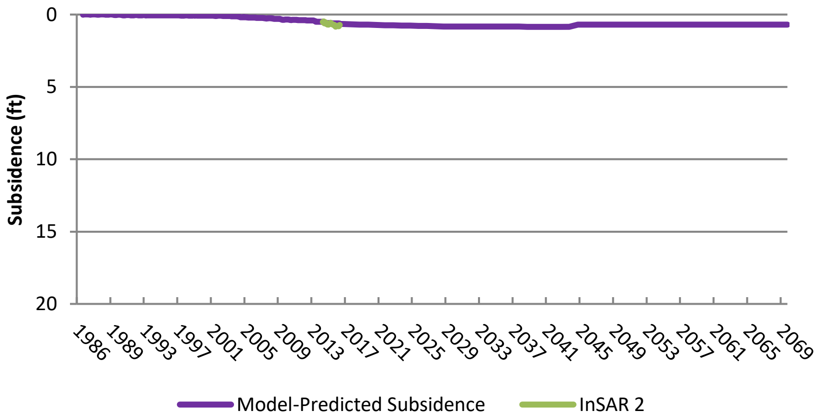
Sub-4



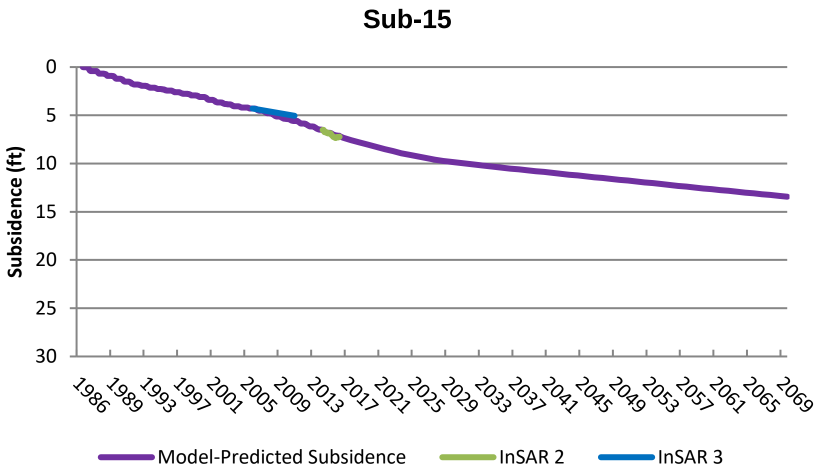
Sub-16

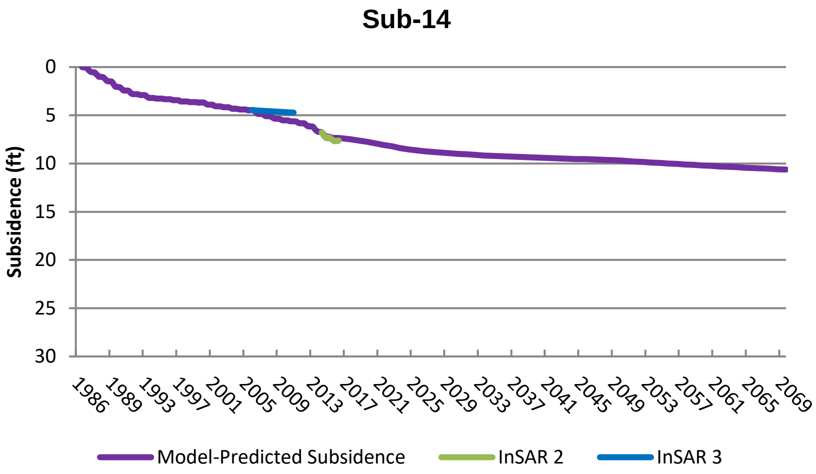


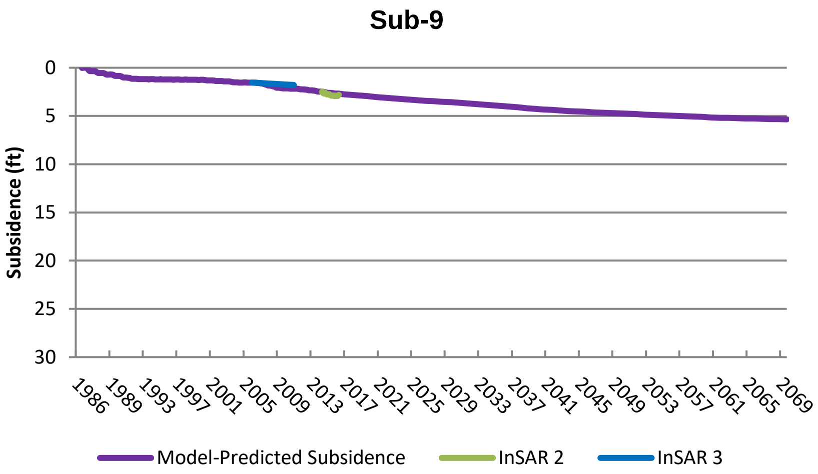
Sub-32 (24S/27E-32K01)

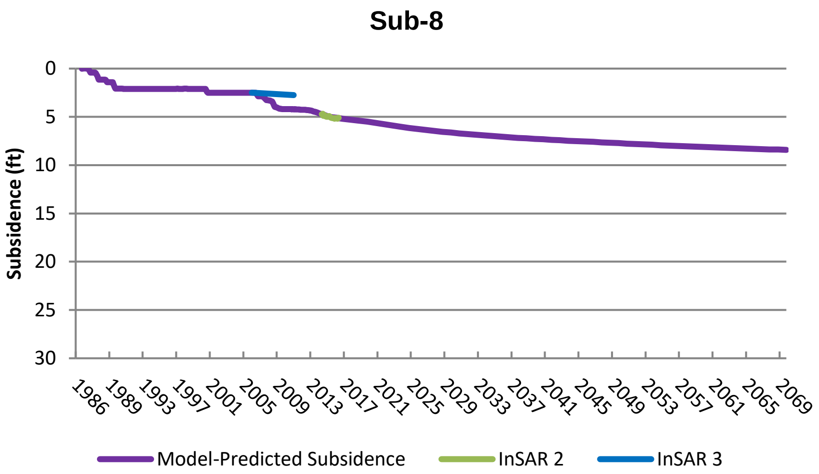


Model Simulation Land Subsidence Graphs

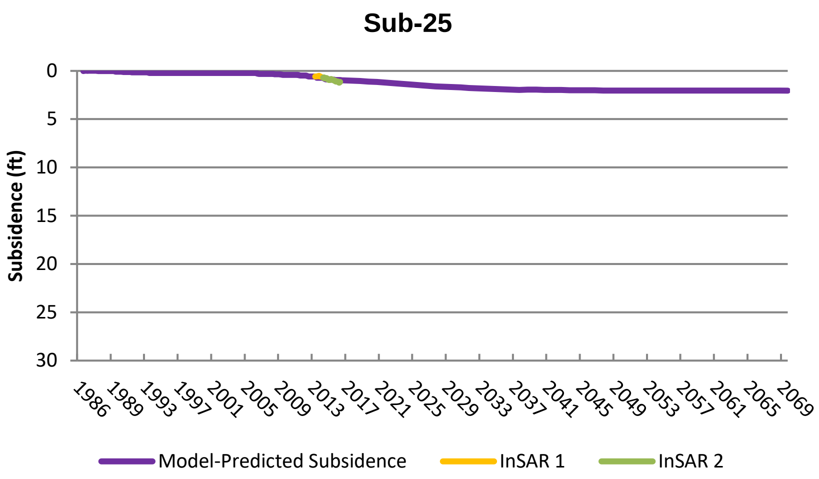


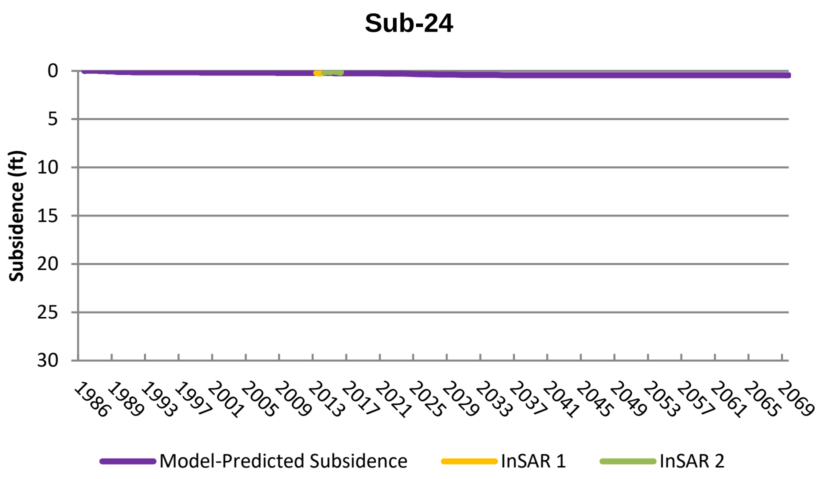


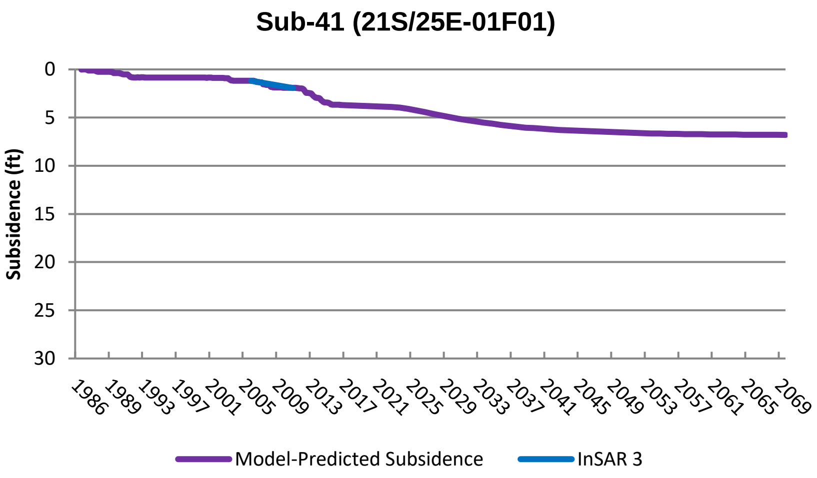


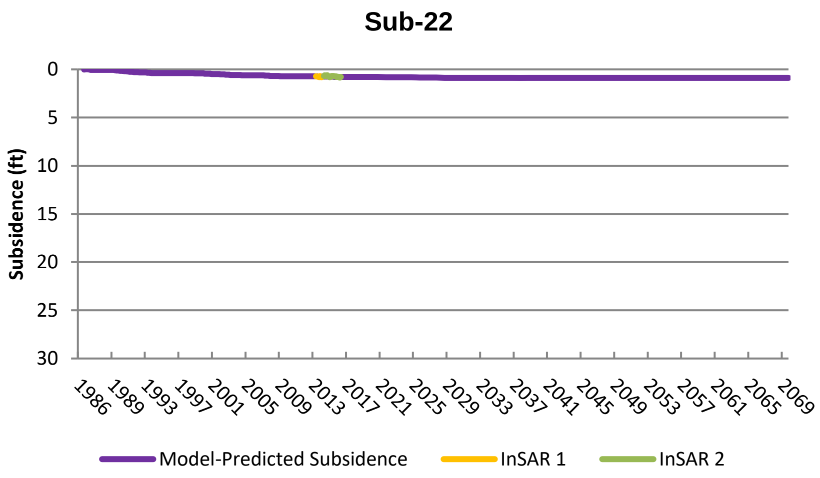


Model Simulation Land Subsidence Graphs

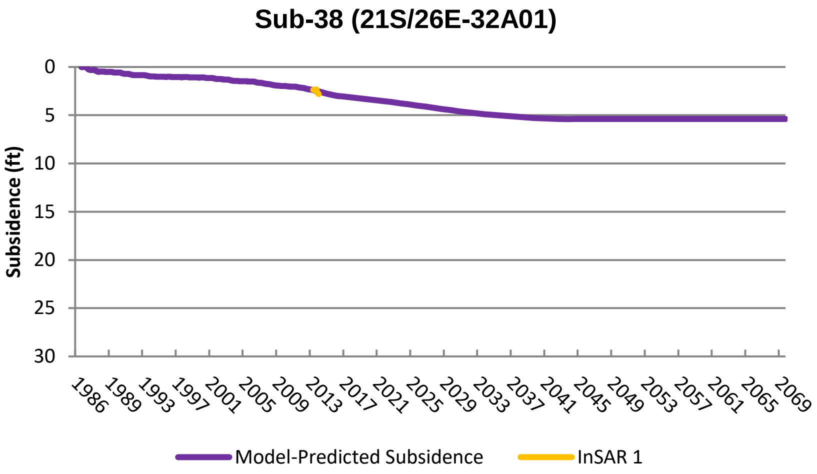

Sub-25

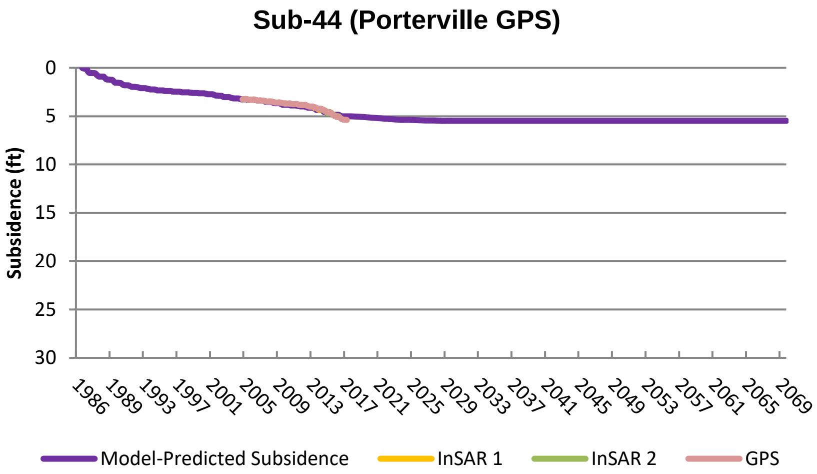

Sub-24

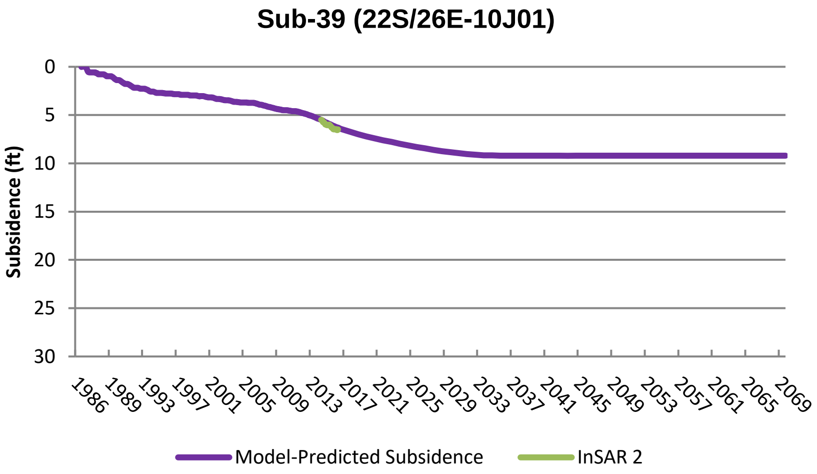

Sub-41 (21S/25E-01F01)

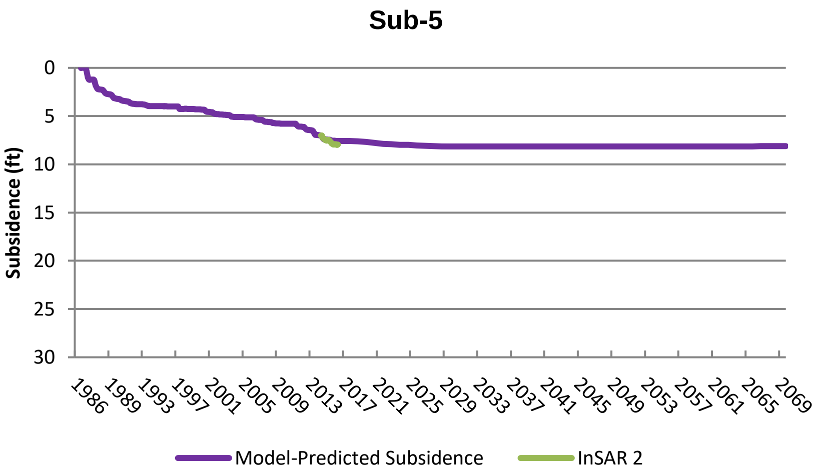

Sub-22

Model Simulation Land Subsidence Graphs

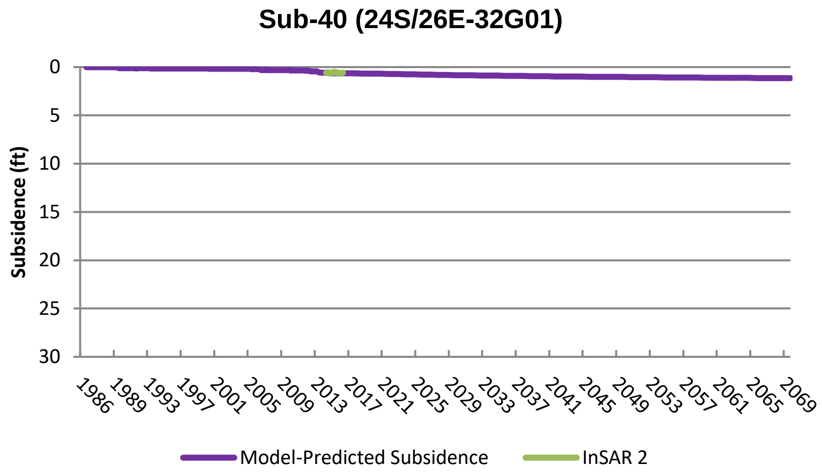


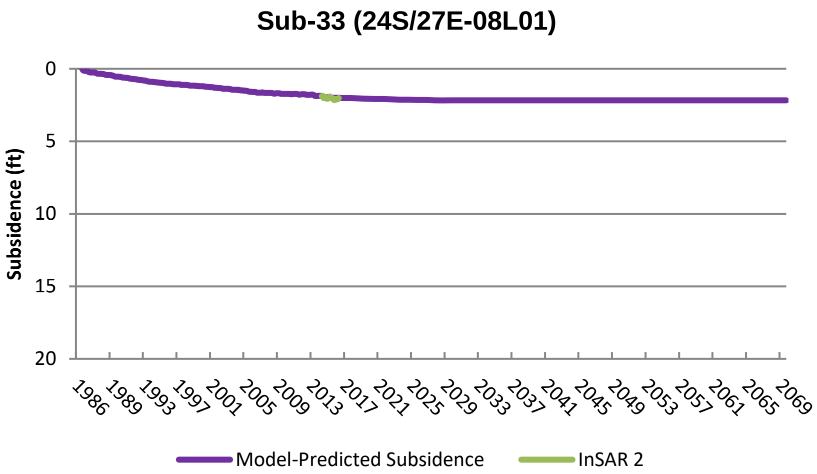


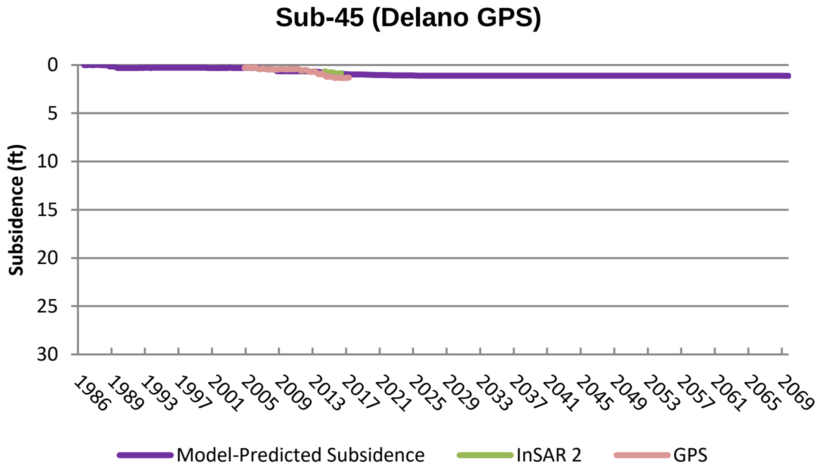


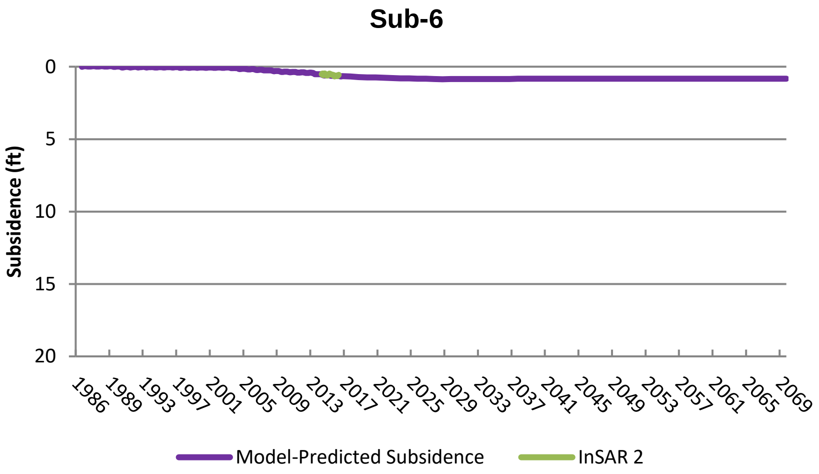


Model Simulation Land Subsidence Graphs

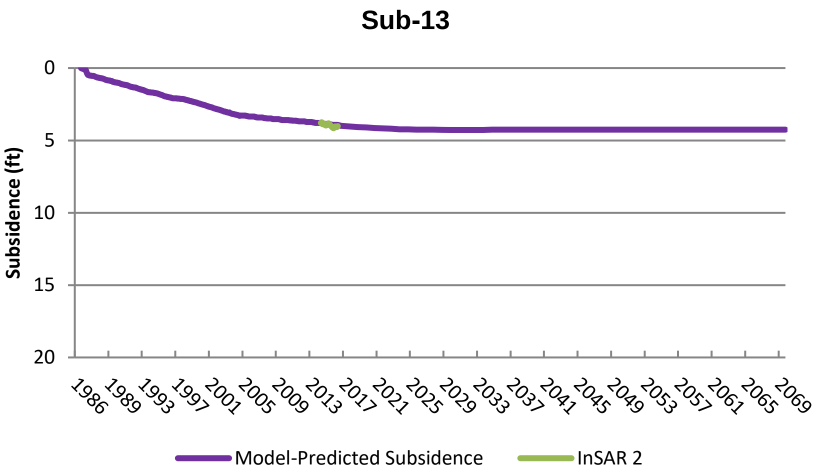








Model Simulation Land Subsidence Graphs



Attachment 4

Technical Memorandum

To:	Tule Subbasin Technical Advisory Committee
From:	Thomas Harder, P.G., C.HG. Thomas Harder & Co.
Date:	13-Jul-22
Re:	Technical Support for Addressing Department of Water Resources Comments Regarding Groundwater Levels in the Tule Subbasin

1 Introduction

This technical memorandum (TM) summarizes an analysis of currently established minimum thresholds and measurable objectives as they relate to potential impacts to beneficial uses and users of groundwater in the Tule Subbasin in Tulare County, California (see Figure 1). This TM was prepared to address comments from the California Department of Water Resources (CDWR) on groundwater sustainability plans (GSPs) prepared by each of the six Groundwater Sustainability Agencies (GSAs) within the Tule Subbasin. Specifically, this TM addresses comments related to groundwater levels.

1.1 Background

The Tule Subbasin Coordination Agreement formerly identified the criteria for undesirable results related to groundwater levels as the following: "*…the criteria for an undesirable result for the chronic lowering of groundwater levels is defined as the unreasonable lowering of the groundwater elevation below the minimum threshold for two consecutive years at greater than 50% of GSA Management Area RMS Sites, which results in significant impacts to groundwater supply.*"

The previous version of the Coordination Agreement further stated that "*…the avoidance of an undesirable result for the chronic lowering of groundwater levels is to protect unreasonable lowering of groundwater levels may effect groundwater users by causing well failures, additional operational costs for groundwater extraction from deeper pumping levels, and additional costs to lower pumps, deepen wells, or drill new wells.*"

In their review of the Tule Subbasin GSPs, each of which refer to the Coordination Agreement, the CDWR made the following general comments:

The GSPs do not define undesirable results or set minimum thresholds and measurable objectives for groundwater levels in a manner consistent with the GSP Regulations.

1. *The GSPs do not describe, with information specific to the Subbasin, the groundwater level conditions that are considered significant and unreasonable and would result in undesirable results. The GSPs do not explain or justify how the quantitative definition of undesirable results is consistent with avoiding effects the GSAs have identified as undesirable results.*

2. *The GSPs do not explain how minimum thresholds at the representative monitoring sites are consistent with the requirement to be based on a groundwater elevation indicating a depletion of supply at a given location. The GSPs do not demonstrate that the established sustainable management criteria are based on a commensurate level of understanding of the basin setting or whether the interests of beneficial uses and users have been considered.*

Based on the CDWR comments, the Tule Subbasin Coordination Agreement has been modified to reflect the analysis of potentially significant and unreasonable groundwater level conditions presented herein.

1.2 Purpose and Scope

The purpose of this TM is to provide the basis for determining significant and unreasonable groundwater level conditions in each of the six GSAs of the Tule Subbasin and to provide a basis for modifications to the Tule Subbasin Coordination Agreement and GSPs to address CDWR comments to the GSPs. Potentially significant and unreasonable groundwater level conditions was evaluated through an analysis of the number of wells that could be impacted if groundwater levels were drawn down to the minimum thresholds (MTs) identified by each GSA. The analysis of potentially impacted wells is based on readily available well data for the Tule Subbasin, as published in the CDWR driller’s log database. As this database does not contain information on well failures, operational costs for pumping groundwater, or pump settings for wells, the analysis to correlate MTs to significant and unreasonable conditions focuses on the total depth of wells and the number of those wells that would be rendered inoperable if groundwater levels are drawn down to the MTs.

1.3 Sources of Data

The sources of data used for this analysis include the following:

- CDWR's Online System for Well Completion Reports[1]
- Geographic Information System (GIS) shapefiles of the subbasin and GSA boundaries and wells,
- Minimum threshold groundwater level elevations for representative monitoring sites specific to both the Upper and Lower Aquifers in the Tule Subbasin,[2]
- Groundwater levels for January 2015 from the calibrated groundwater flow model of the Tule Subbasin,[3]
- Specific capacity data for wells in the Tule Subbasin.[4]

1.4 Beneficial Uses of Groundwater Addressed

As per Regional Water Quality Control Board – Central Valley Region Water Quality Control Plan for the Tulare Lake Basin,[5] the beneficial uses of water in the basin include:

- Agricultural Supply
- Domestic Supply
- Industrial Supply and
- Municipal Supply

---

[1] CDWR, 2022. https://data.ca.gov/dataset/well-completion-reports

[2] TH&Co, 2022. Tule Subbasin 2020/21 Annual Report. Prepared for the Tule Subbasin Technical Advisory Committee. Dated March 2022.

[3] TH&Co, 2021. Update to the Groundwater Flow Model of the Tule Subbasin. Technical Memorandum dated 7/30/21.

[4] TH&Co, 2020. Groundwater Flow Model of the Tule Subbasin. Report prepared for the Tule Subbasin MOU Group. Dated January 2020.

[5] RWQCB, 2018. Water Quality Control Plan for the Tulare Lake Basin, Section 2.

2 Analysis of Wells Potentially Impacted at the Minimum Thresholds in the Tule Subbasin GSPs

The premise behind the analysis presented herein is that wells rendered inoperable due to lowering of groundwater levels is a significant and unreasonable condition. While it is not possible to specifically identify, with accuracy, exactly how many wells in the Tule Subbasin would be impacted by lowering groundwater levels below the MTs, it is possible, using the CDWR database, to obtain an estimate of the number of wells that would be potentially impacted. Further, the database has been used, to the extent possible, to assess the beneficial uses served by the impacted wells, whether agricultural irrigation, domestic supply, industrial supply, or municipal supply.

The methodology to estimate the number of wells potentially impacted by lowering groundwater levels to the MTs included wells constructed in the Upper Aquifer, the Lower Aquifer, or both. While the reference MTs are different for each aquifer, the methodology to estimate potentially impacted wells was the same and included the following steps and assumptions:

- The MTs for each aquifer, as designated at representative monitoring sites, were contoured via kriging in Geographic Information System (GIS) to develop a MT surface across the subbasin (see Figures 2 and 3).
- Wells in the CDWR well database were sorted to include only those with total depth information.
- Non-pumping wells or wells documented for uses other than agricultural, private domestic, industrial, or municipal, (e.g. contaminant remediation, injection, monitoring) were also removed from the wells to be used in the analysis.
- The remaining wells were plotted on a map according to the location information in the CDWR database (see Figure 4). For wells with only township, range and section information, the well was plotted in the middle of the section. A total of 4,190 wells are shown on Figure 4.
- As per the Sustainable Groundwater Management Act (SGMA)[6] GSPs are not required to address undesirable results to wells associated with groundwater conditions prior to January 1, 2015. Thus, wells that would have been impacted prior to this time were removed from the analysis. To do this, a map was generated of the groundwater surface in January 2015 based on the calibrated groundwater flow model of the subbasin (see Figure 5).[7] The difference in groundwater level between January 2015 and the Upper Aquifer MTs across the Tule Subbasin is shown on Figure 6.

Wells at which the total depth or bottom of perforations were above the MT or where the total depth/bottom of perforations were below the MT but could not support pumping with a static

---

[6] California Water Code Part 2.74, Ch. 6, Section 10727.2 (b) (4)

[7] TH&Co, 2021. Update to the Groundwater Flow Model of the Tule Subbasin. Technical Memorandum prepare for the Tule Subbasin Technical Advisory Committee. Dated July 29, 2021.

groundwater level at the MT were considered "potentially impacted." Criteria for determining whether a well could support pumping when the static groundwater level was at the MT were the following:

- The pumps in all wells were assumed to be installed, or capable of being installed, within 10 feet of the bottom of the wells.
- It was assumed that the pumping groundwater level would need to be at least 20 feet above the pump intake to avoid cavitation or entrained air.
- Potential pumping drawdown was estimated based on specific capacity data from available wells and pumping rates reported on CDWR driller's logs.
- For each GSA, TH&Co used an average specific capacity from wells with specific capacity data in that GSA. Pumping rates were applied as an average rate for wells in each mile square section.
- The wells potentially impacted by lowering the groundwater level below the minimum thresholds, considering total well depth, adequate pump submergence, and drawdown, are summarized in Section 3.

3 Findings

Within the Tule Subbasin as a whole, 4,190 wells were identified from the CDWR database as having total depth information (see Figure 4). Of those wells, 1,692 were constructed completely within the Upper Aquifer and 2,498 wells were constructed either within the Lower Aquifer or as a composite well with perforations in both the Upper and Lower Aquifers.

Of the 4,190 wells, 568 wells would have already been impacted by January 2015 groundwater levels and were removed from consideration (see Figure 7). The remaining 3,622 wells were included in the analysis.

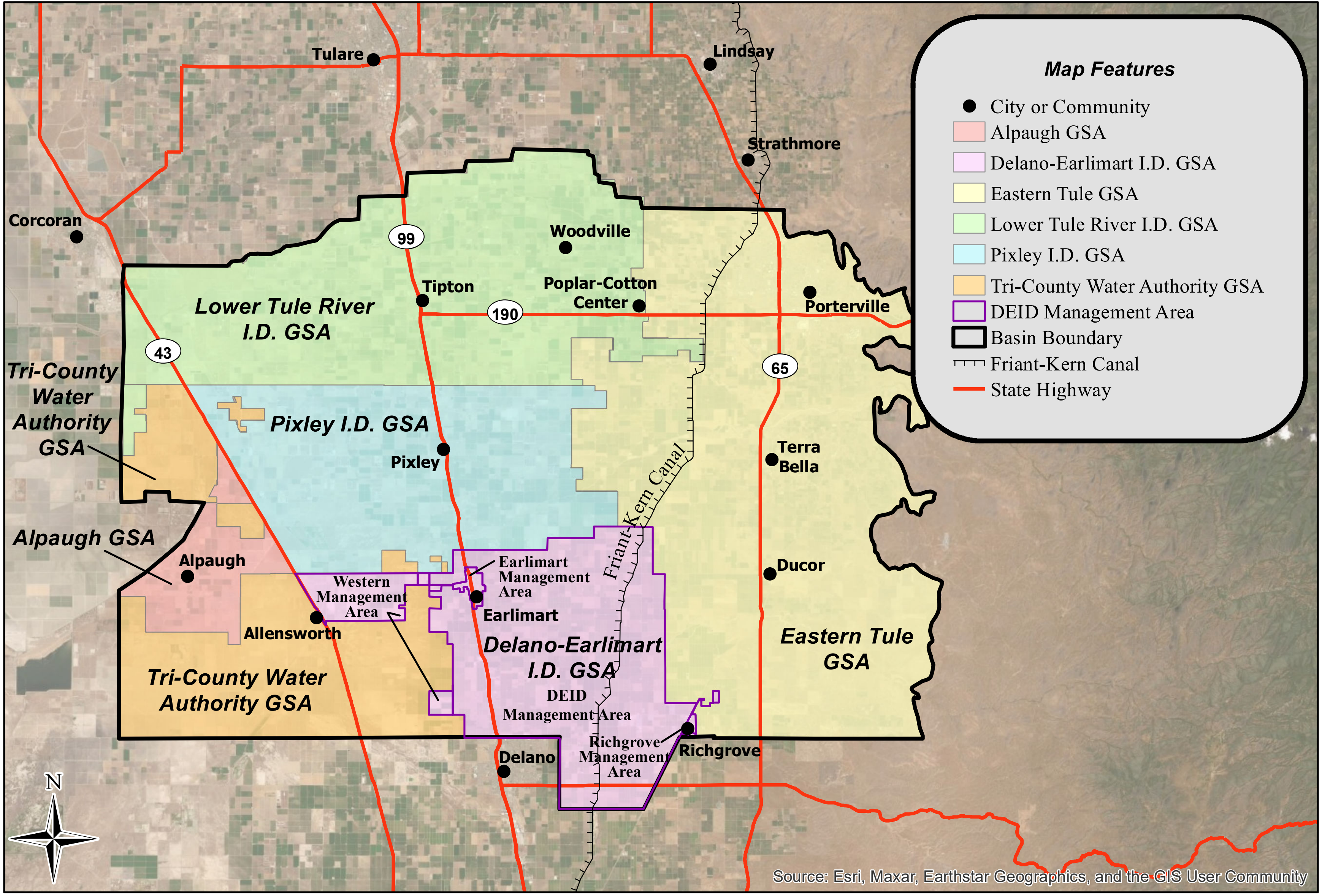
Of the 3,622 wells in the analysis, 776 wells would be impacted if groundwater levels were lowered to the MTs using the evaluation criteria described in Section 2 herein (see Figure 8). Some of these wells would be impacted before the MT groundwater levels were reached. Wells included in the analysis were completed in either the Upper Aquifer, the Lower Aquifer or both. The number of wells in each GSA predicted to be impacted if groundwater levels are lowered to the MTs, by beneficial use category, are as follows:

GSA	Number of Agricultural Irrigation Wells Potentially Impacted	Number of Domestic Wells Potentially Impacted	Number of Industrial Wells Potentially Impacted	Number of Municipal Wells Potentially Impacted	Number of Unknown Use Wells Potentially Impacted	Total Wells Potentially Impacted
Alpaugh ID GSA	1	0	0	0	0	1
DEID	1	6	0	0	1	8
ETGSA	91	428	15	8	19	561
LTRID GSA	49	92	5	0	4	150
Pixley ID GSA	6	38	1	0	6	51
Tri-County GSA	1	4	0	0	0	5
Total	149	568	21	8	30	776

DWR Comments - Groundwater Levels in the Tule Subbasin

July 2022

Tule Subbasin Technical Advisory Committee



Source: Esri, Maxar, Earthstar Geographics, and the GIS User Community

Thomas Harder & Co.
Groundwater Consulting

0 2.5 5 10 Miles
NAD 83 State Plane Zone 4

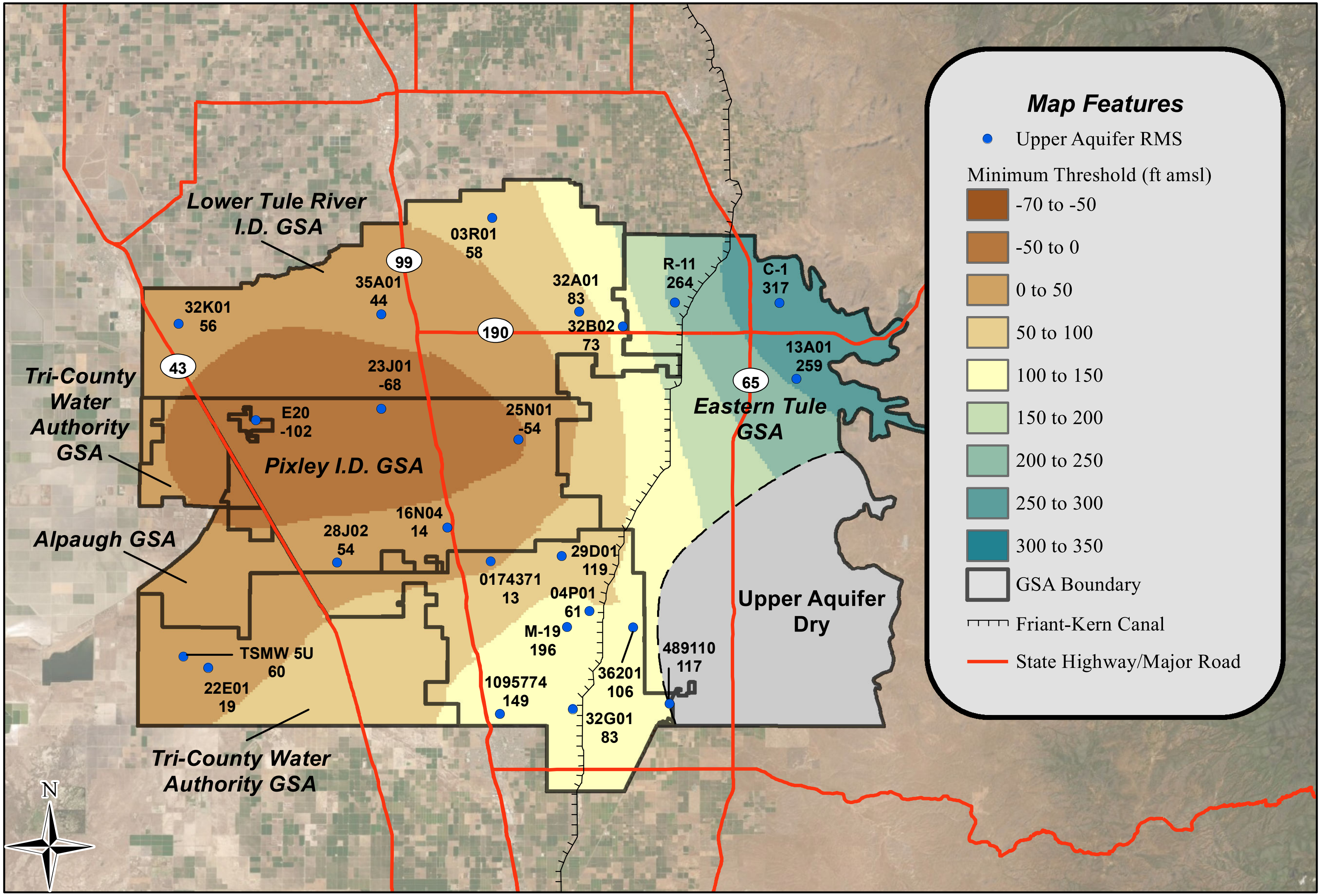
GSA Boundaries

Figure 1

DWR Comments - Groundwater Levels in the Tule Subbasin

July 2022

Tule Subbasin Technical Advisory Committee



Thomas Harder & Co.
Groundwater Consulting

0 2 4 8 Miles
NAD 83 State Plane Zone 4

Notes: ft amsl = feet above mean sea level
RMS = Representative Monitoring Site

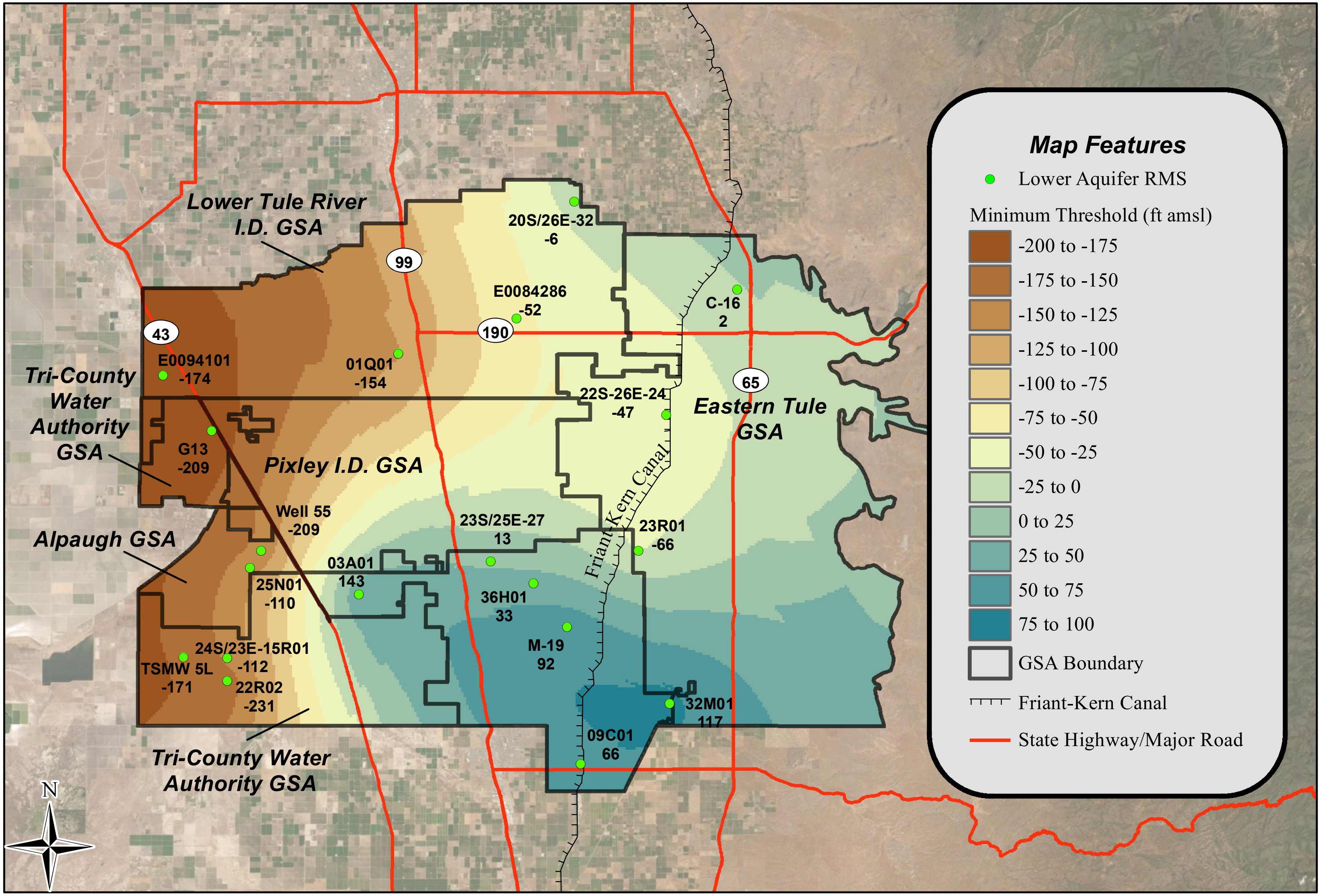
Minimum Thresholds - Upper Aquifer

Figure 2

DWR Comments - Groundwater Levels in the Tule Subbasin

July 2022

Tule Subbasin Technical Advisory Committee



Thomas Harder & Co.
Groundwater Consulting

0 2 4 8
Miles
NAD 83 State Plane Zone 4

Minimum Thresholds - Lower Aquifer

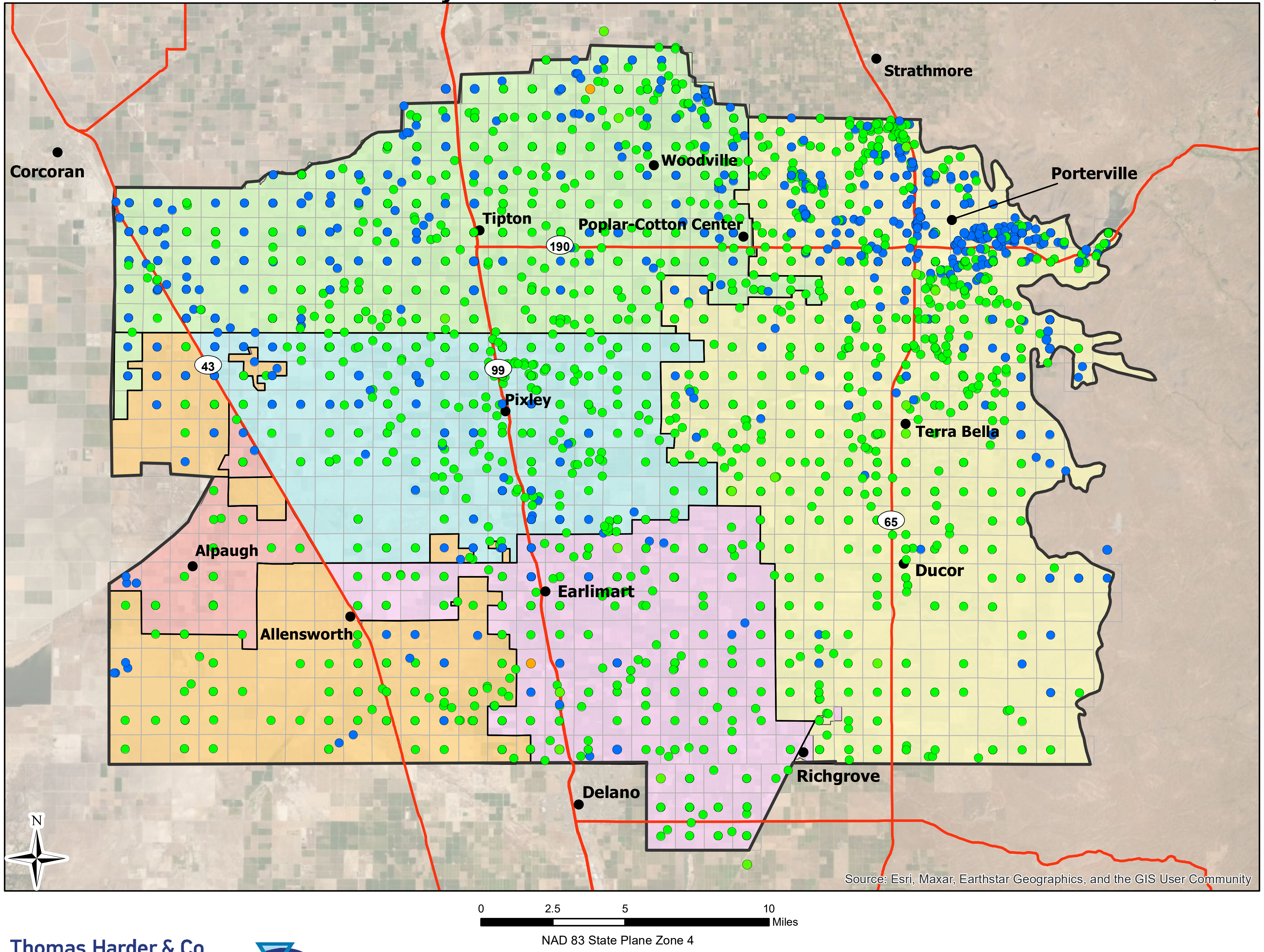
Figure 3

Notes: ft amsl = feet above mean sea level
RMS = Representative Monitoring Site

DWR Comments - Groundwater Levels in the Tule Subbasin

Tule Subbasin Technical Advisory Committee

July 2022



Map Features

DWR Well

- ● Upper Aquifer Well
- ● Lower Aquifer Well
- ● Composite Well
- ● City or Community
- ▢ Mile-Square Section
- 🟥 Alpaugh GSA
- 🟪 Delano-Earlimart I.D. GSA
- 🟨 Eastern Tule GSA
- 🟩 Lower Tule River I.D. GSA
- 🟦 Pixley I.D. GSA
- 🟧 Tri-County Water Authority GSA
- ▢ Basin Boundary
- — State Highway/Major Road

GSA	No. of Upper Aquifer Wells	No. of Lower Aquifer Wells
Alpaugh ID GSA	9	23
DEID	53	239
ETGSA	880	1,056
LTRID GSA	546	636
Pixley ID GSA	139	402
Tri-County GSA	65	142
Total	1,692	2,498

DWR Driller's Log Wells with Known Depth

Figure 4

Thomas Harder & Co.
Groundwater Consulting

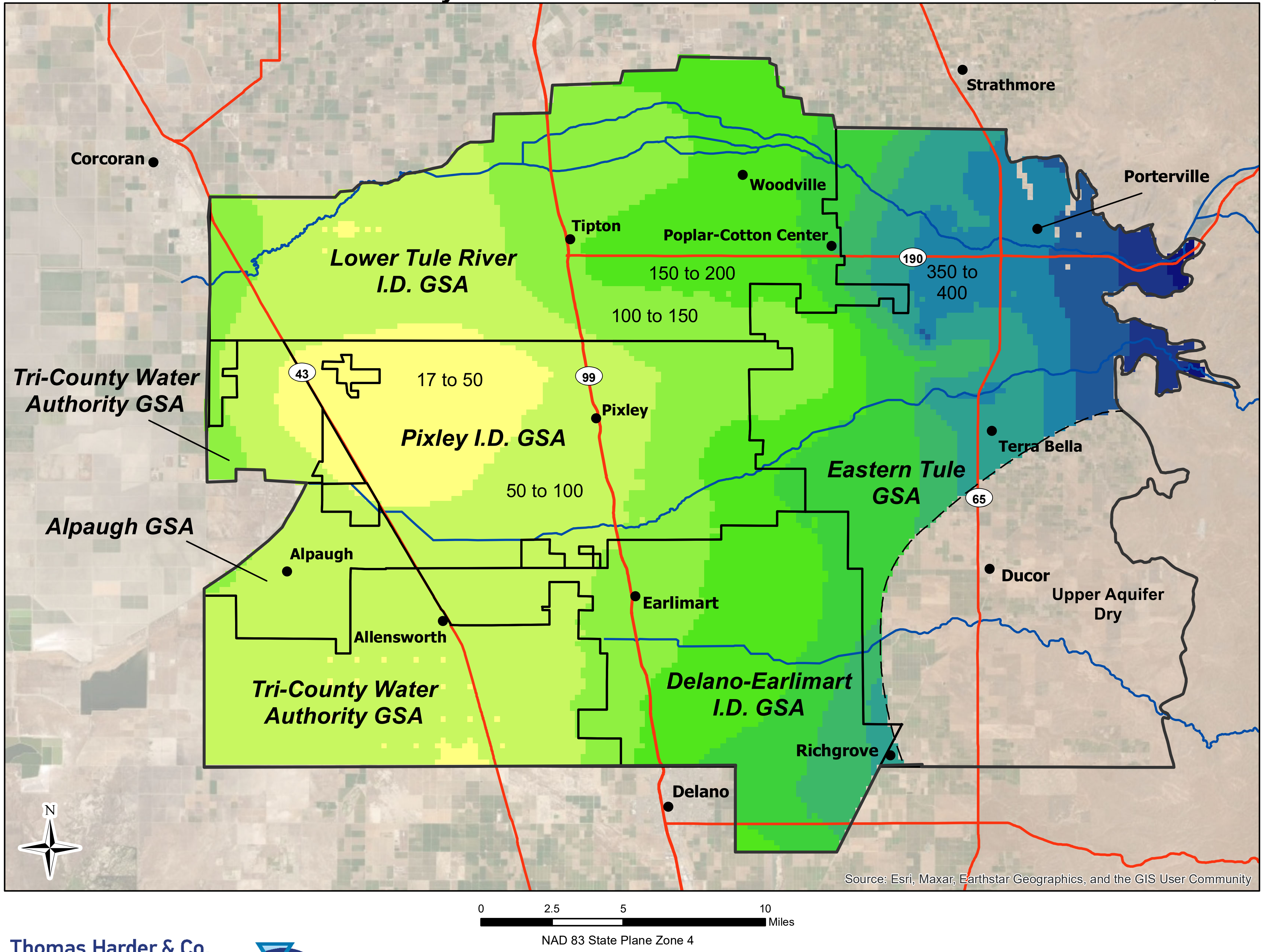
Note: The wells are plotted using coordinates provided by DWR. Many coordinates provided plot the well in the center of the section. Sections displaying only one well may actually have multiple wells plotted on top of one another.

Note: Wells include domestic, agricultural, industrial and public supply wells.

DWR Comments - Groundwater Levels in the Tule Subbasin

Tule Subbasin Technical Advisory Committee

July 2022



Map Features

Model Generated Groundwater Elevation (ft amsl)

- 🟨 17 to 50
- 🟩 50 to 100
- 🟩 100 to 150
- 🟩 150 to 200
- 🟩 200 to 250
- 🟩 250 to 300
- 🟦 300 to 350
- 🟦 350 to 400
- 🟦 400 to 450
- 🟦 450 to 500
- 🟦 500 to 550
- ☐ GSA Boundary
- ☐ Basin Boundary
- — State Highway/Major Road
- — Major Hydrologic Feature
- ● City or Community

Thomas Harder & Co.
Groundwater Consulting

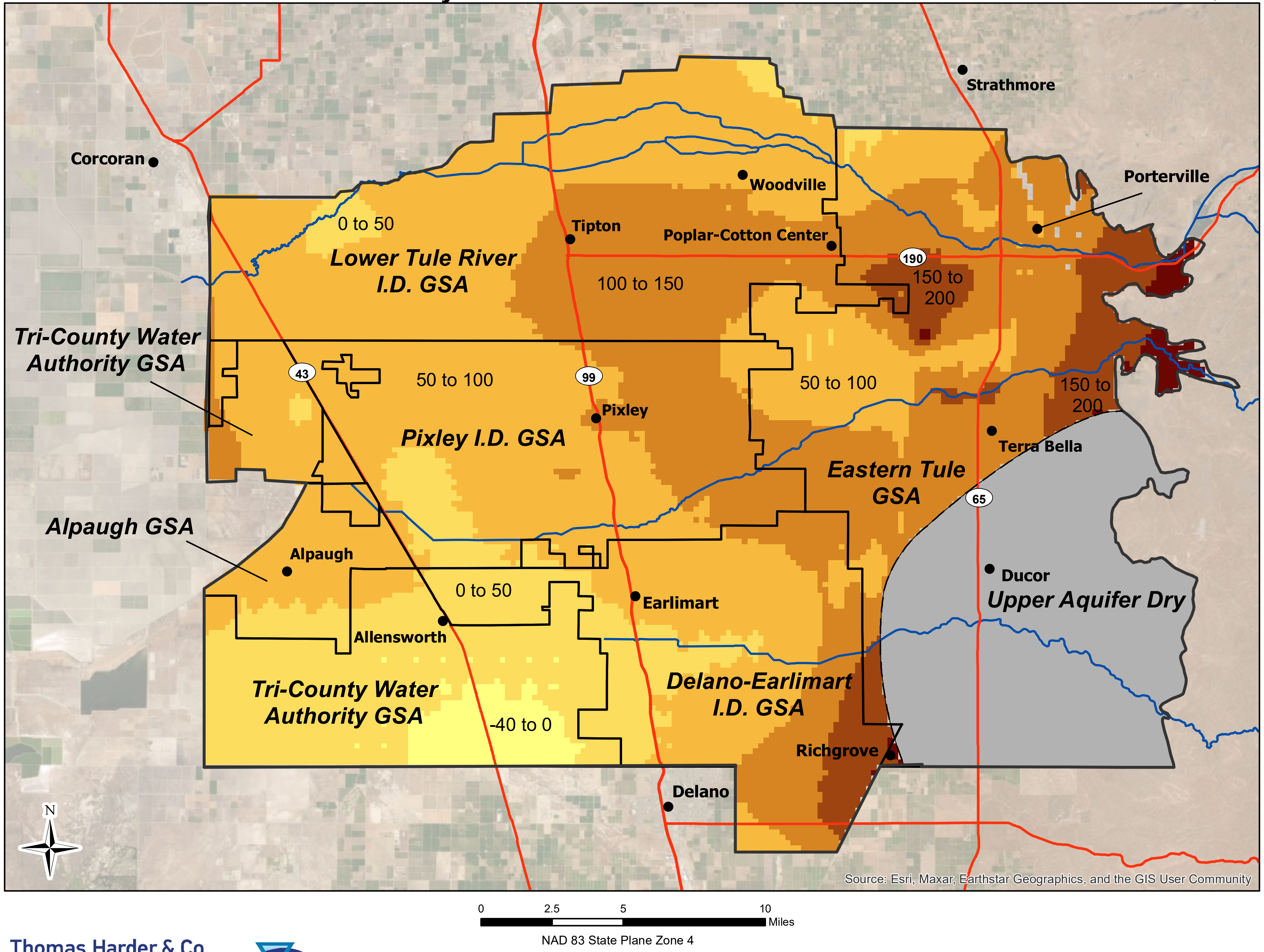
Model-Generated Upper Aquifer Groundwater Elevation - January 2015

Figure 5

DWR Comments - Groundwater Levels in the Tule Subbasin

Tule Subbasin Technical Advisory Committee

July 2022



Source: Esri, Maxar, Earthstar Geographics, and the GIS User Community

Map Features

Groundwater Elevation Difference (ft)

🟨	-40 to 0
🟨	0 to 50
🟧	50 to 100
🟧	100 to 150
🟫	150 to 200
🟥	200 to 260
☐	Tule Subbasin GSA
☐	Basin Boundary
—	State Highway/Major Road
—	Major Hydrologic Feature
●	City or Community

Thomas Harder & Co.
Groundwater Consulting

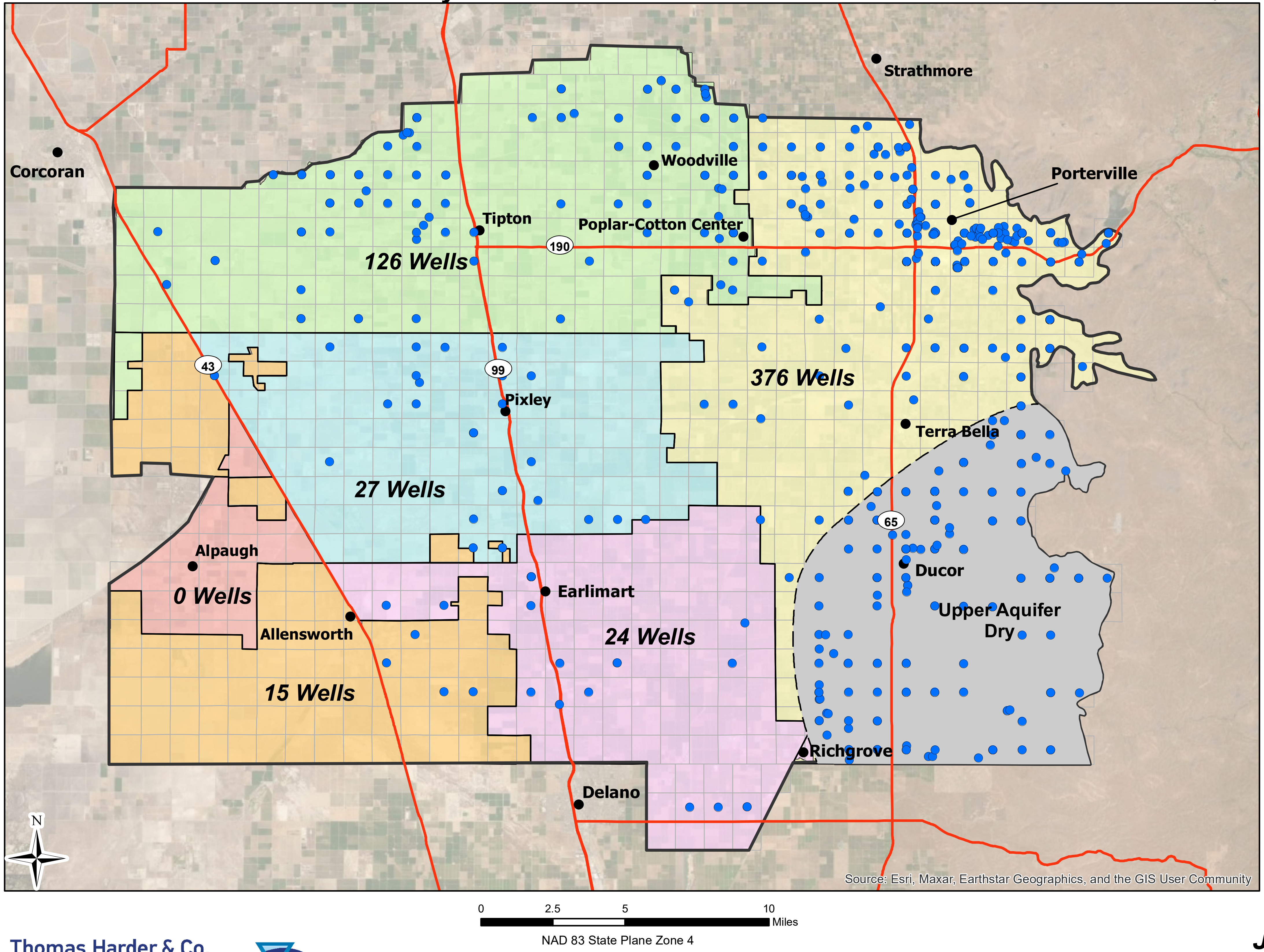
January 2015 to Minimum Thresholds Upper Aquifer Groundwater Elevation Difference

Figure 6

DWR Comments - Groundwater Levels in the Tule Subbasin

Tule Subbasin Technical Advisory Committee

July 2022



Source: Esri, Maxar, Earthstar Geographics, and the GIS User Community

Map Features

- ● Upper Aquifer Well
- ● City or Community
- ▭ Mile-Square Section
- 🟥 Alpaugh GSA
- 🟪 Delano-Earlimart I.D. GSA
- 🟨 Eastern Tule GSA
- 🟩 Lower Tule River I.D. GSA
- 🟦 Pixley I.D. GSA
- 🟧 Tri-County Water Authority GSA
- ▭ Basin Boundary
- — State Highway/Major Road

GSA	No. Dry Wells
Alpaugh ID GSA	0
DEID	24
ETGSA	376
LTRID GSA	126
Pixley ID GSA	27
Tri-County GSA	15
Total	568

Wells Shallower* than January 2015 Groundwater Levels

Figure 7

Thomas Harder & Co.
Groundwater Consulting

Note: The wells are plotted using coordinates provided by DWR. Many coordinates provided plot the well in the center of the section. Sections displaying only one well may actually have multiple wells plotted on top of one another.

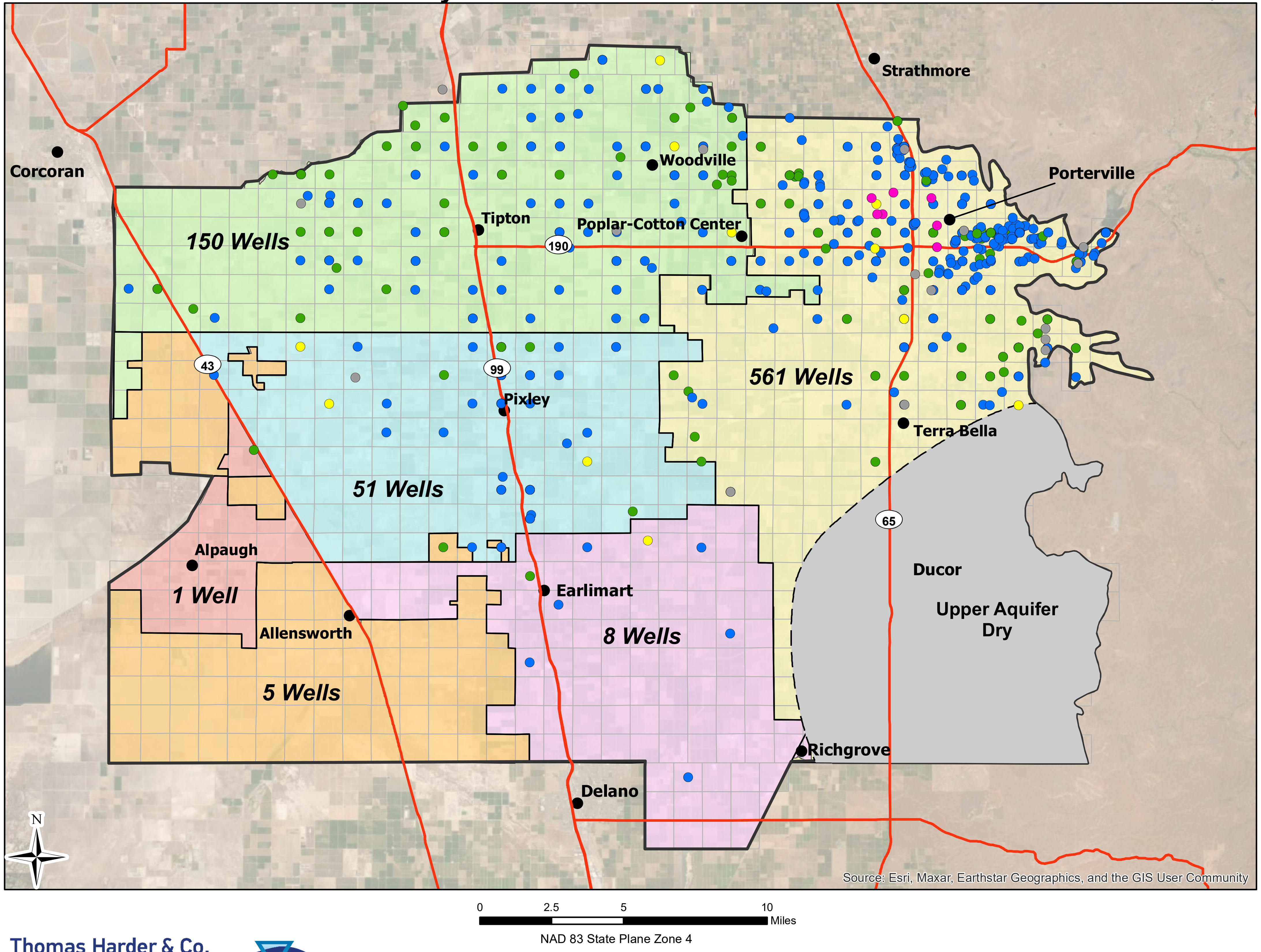
Note: Wells includes domestic, agricultural, industrial, and public supply wells.

*Includes drawdown and submegence assumptions.

DWR Comments - Groundwater Levels in the Tule Subbasin

Tule Subbasin Technical Advisory Committee

July 2022



Map Features

Affected Well

- ● Unknown
- ● Domestic
- ● Agricultural
- ● Municipal
- ● Industrial
- ● City or Community
- □ Mile-Square Section
- ■ Alpaugh GSA
- ■ Delano-Earlimart I.D. GSA
- ■ Eastern Tule GSA
- ■ Lower Tule River I.D. GSA
- ■ Pixley I.D. GSA
- ■ Tri-County Water Authority GSA
- □ Basin Boundary
- — State Highway/Major Road

GSA	No. of Affected Wells
Alpaugh ID GSA	1
DEID	8
ETGSA	561
LTRID GSA	150
Pixley ID GSA	51
Tri-County GSA	5
Total	776

Affected Wells* if Groundwater Levels Reach Minimum Thresholds

Figure 8

Thomas Harder & Co.
Groundwater Consulting

Note: The wells, with the exception of municipal wells, are plotted using coordinates provided by DWR. Many coordinates provided plot the well in the center of the section. Sections displaying only one well may actually have multiple wells plotted on top of one another.

*Includes drawdown and submegence assumptions.

TECHNICAL MEMORANDUM

To: Tule Subbasin SGMA Managers

From: Don Tucker – 4Creeks, Inc.

Date: June 29, 2022

Re: Technical Support for Addressing DWRs Comments Regarding Groundwater Quality Sustainable Management Criteria in the Tule Subbasin

1 Introduction

This technical memorandum (TM) was prepared to address the groundwater quality comments from the California Department of Water Resources (CDWR) on groundwater sustainability plans (GSPs) prepared by each of the six Groundwater Sustainability Agencies (GSAs) within the Tule Subbasin.

1.1 Background

The originally submitted Tule Subbasin Coordination Agreement addressed undesirable results related to groundwater quality as stated: "*…the criteria for an undesirable result for the degradation of groundwater quality is defined as the unreasonable long-term changes of groundwater quality above the minimum thresholds at greater than 50% of GSA Management Area RMS wells caused by groundwater pumping and/or groundwater recharge.*"

The original Coordination Agreement further stated that "*…the avoidance of an undesirable result for degraded groundwater quality is to protect the those using the groundwater, which varies depending on the use of the groundwater. The effects of degraded water quality caused by recharge or lowering of groundwater levels may impact crop growth or impact drinking water systems, both of which would cause additional expense of treatment to obtain suitable water.*"

Each of the Tule Subbasin GSA originally submitted GSPs further described the process/methodology used for setting Sustainable Management Criteria: "*The following four (4) steps detail the process for setting interim milestones and the measurable objective at individual RMS related to Groundwater Quality:*

Step 1: *Locate the RMS defined in the Tule Subbasin Monitoring Plan, identify which portion of the aquifer it represents, and the associated Constituents of Concern (COC) at the RMS based on groundwater suitability (Agriculture use, Domestic Use, Municipal Use).*

Step 2*:* *Prepare a table summarizing available historical groundwater quality data for each COC at the RMS well.*

Step 3*:* *Establish interim milestones and the measurable objective at each RMS well with calculating a change above the baseline groundwater quality to not exceed 10% of long term 10 year running average.*

Step 4: *Each year, during the Plan Implementation Period, re-calculate the long term 10 year running average. Evaluate changes to groundwater quality based on reduction of groundwater elevation or from recharge efforts.*"

Similar to the process described for interim milestones and measurable objectives, minimum thresholds at each RMS well were established to not exceed 15% change in the long-term 10-year running average.

Lastly, each of the Tule Subbasin GSA GSPs described the Constituent of Concerns (COC) that will be monitored at each RMS wells as follows: "*The COC vary depending on the suitability of the groundwater. Each of the COC to be monitored by the GSA at the RMS wells to serve as indicators for changes in groundwater quality are identified in the table below.*"

Municipal / Domestic	***Agricultural***
Arsenic	*pH*
Chromium (Total)	*Conductivity*
Nitrogen as N	*Nitrogen as N*
(any specific Title 22 MCL exceedance at baseline sampling event in Spring 2020)	

1.2 DWR Response

The CDWR made the following comments relating to addressing groundwater quality in the Coordination Agreement and individual GSPs within the Tule Subbasin:

"The GSPs do not provide sufficient information to justify the proposed sustainable management criteria for degraded water quality.

1. *The GSPs do not specify what groundwater conditions are considered suitable for agricultural irrigation and domestic use. The GSPs do not explain the choice of constituents (pH, conductivity, and nitrate) as a means of evaluating impacts to beneficial uses and users, especially agricultural irrigation.*

2. *The GSPs do not explain how the use of a 10-year running average to establish the sustainable management criteria will avoid undesirable results due to degraded groundwater quality and related potential effects of the undesirable results to existing regulatory standards. The GSPs do not explain how the criteria defining when undesirable results occur in the Subbasin was established, the rationale behind the approach, and why it is consistent with avoiding significant and unreasonable effects associated with groundwater pumping and other aspects of the GSAs' implementation of their GSPs.*

3. *The GSPs do not explain how the sustainable management criteria for degraded water quality relate to existing groundwater regulatory requirements in the Subbasin and how the GSAs will coordinate with existing agencies and programs to assess whether or not implementation of the GSPs is contributing to the degradation of water quality throughout the Subbasin."*

1.3 Purpose and Scope

The purpose of this TM is to provide the revised approach for re-establishing the sustainability management criteria (SMC) for groundwater quality as is relates to selection constituents of concerns for determining impacts to beneficial uses and users, the rationale used to quantify undesirable results as they relate to existing regulatory standards, and how impacts will be assessed to determine if GSA implementation efforts are a contributing factor to groundwater quality.

In general, the following items were prepared relating to DWRs comments for degradation of groundwater quality:

1. A detailed description of how the overlying beneficial uses and users were defined for determining constituent of concerns to monitor at each RMS groundwater quality well.
2. Redefined rationale for setting groundwater quality SMCs to align with existing regulatory requirements.
3. A detailed description of how ongoing coordination with existing groundwater regulatory agencies and programs will take place to evaluate if GSP implementation is contributing to degradation to groundwater quality.

1.4 Proposed Approach

1.4.1 Defining Beneficial Uses and Users at each RMS Well

Each groundwater quality RMS well will be designated as representative of agricultural or drinking water or both based on the beneficial use and users of groundwater within a representative area surrounding the well based on the following evaluation:

Drinking Water: The RMS well is within an urban MA or 1-mile of a public water system**.**

Agricultural: Greater than 50% of the pumping within the representative area is determined to be agricultural and there are no public water systems within a 1-mile radius.

An RMS well may be designated as representative of both agricultural and drinking water if it possesses a representative area with greater than 50% agricultural pumping and a public water system was within 1-mile.

The analysis used to determine the beneficial uses at each RMS well consisted of querying DWR well completion reports, public water systems, and schools using ArcGIS. The detailed breakdown of the steps to conduct analysis is described below.

1. Create a layer in ArcGIS by combining data from the following:
    - Well locations and well types from DWRs Well Completion Report Mapping Application
    - Boundaries of SWDIS Public Water Systems
    - Boundaries of Community/Urban areas from LAFCO
2. Overlay groundwater quality locations of RMS wells and create 1 mile buffer for analyzing.
3. Summarize the data identified in step 1 relative to each groundwater quality RMS well 1-mile buffer.
4. Define the groundwater quality RMS well as representative of drinking water and/or agricultural beneficial pumping beneficial use.

Wells types are categorized as drinking water, agricultural, or not applicable based on breakdown in **Table 1**.

Table 1: Categories of Well Types

Drinking Water	Agricultural	Not Applicable
Domestic	Irrigation - Agricultural	Cathodic Protection
Public	Other Irrigation	Destruction Monitoring
Water Supply	Water Supply Irrigation - Agricultural	Destruction Unknown Soil Boring
Water Supply Domestic	Water Supply Irrigation - Agriculture	Monitoring
Water Supply Public	Water Supply Stock or Animal Watering	Other Destruction
		Test Well
		Test Well Unknown
		Unknown
		Vapor Extraction
		Vapor Extraction n/a
		Water Supply Industrial
		Blanks

Results of this analysis are provided as part of the Monitoring Network Section of each GSP.

1.4.2 Rationale for Establishing Sustainable Management Criteria

Agricultural and drinking water constituents of concerns (COC) will be evaluated based on the established Maximum Contaminate Level (MCL) or Water Quality Objectives (WQO) by the responsible regulatory agency. In the case of drinking water, the following Title 22 constituents will be monitored and for agricultural the following Basin Plan Water Quality Objective (WQO) constituents of concern will be monitored:

Drinking Water Constituents of Concern

- Arsenic
- Nitrate as N
- Chromium-VI
- Dibromochloropropane (DBCP)
- 1,2,3- Trichloropropane (TCP)
- Tetrachloroethene (PCE)
- Chloride
- Total Dissolved Solids
- Perchlorate

Agricultural Constituents of Concern

- Chloride
- Sodium
- Total Dissolved Solids

Measurable objectives are proposed to be 75% of the regulatory limits for the COCs and the minimum thresholds are proposed to be the regulatory limits as identified in **Table 2**. For RMS wells that have historical exceedances of the MCLs or WQOs which were not caused by implementation of a GSP, minimum thresholds will not be set at the MCLs or WQOs, but rather the pre-SGMA implementation concentration. These RMS wells closely monitored to evaluate if further degradation is occurring at the RMS site as a result of GSP implementation into the future.

Table 2: Measurable Objectives and Minimum Thresholds for Groundwater Quality

Constituent	Units	Minimum Threshold		Measurable Objective	
		Drinking Water Limits (MCL/SMCL)	Agricultural Water Quality Objective	Drinking Water Limits (MCL/SMCL)	Agricultural Water Quality Objective
Arsenic	ppb	10	N/A	7.5	N/A
Nitrate as N	ppm	10	N/A	7.5	N/A
Hexavalent Chromium	ppb	10	N/A	7.5	N/A
Dibromochloropropane (DBCP)	ppb	0.2	N/A	0.15	N/A
1,2,3-Trichloropropane (TCP)	ppt	5	N/A	3.75	N/A
Tetrachloroethene (PCE)	ppb	5	N/A	3.75	N/A
Chloride	ppm	500	106	375	79.5
Sodium	ppm	N/A	69	N/A	51.75
Total Dissolved Solids	ppm	1,000	450	750	337.5
Perchlorate	ppb	6	N/A	4.5	N/A

Utilizing the criteria described above, the Tule Subbasin GSAs have revised the definition of undesirable results for degradation of groundwater quality in *Section 4.3.3.2 - Criteria to Define Undesirable Results (§354.26(b)(2))* in the Tule Subbasin Coordination Agreement as:

> *"..the exceedance of a minimum threshold at a groundwater quality RMS in any given GSA resulting from the implementation of a GSP. This condition would indicate that more aggressive management actions were needed to mitigate the overdraft."*

Additionally, the Tule Subbasin has developed a Mitigation Program Framework included as Attachment 7 of the Tule Subbasin Coordination Agreement, which describes the framework the Tule Subbasin GSAs would utilize to address impacts that occur from implementation of a GSP relative to degradation of groundwater quality due to GSA actions.

1.4.3 Coordination with Existing Groundwater Quality Regulatory Agencies and Programs

The monitoring and characterization of groundwater quality conditions has historically been conducted and reported by other public agencies and/or non-profits to meet requirements of other regulatory programs, which focus on the prevention of degradation of groundwater quality. The existing groundwater monitoring programs that the Tule Subbasin GSAs coordinate with are described in **Table 3**.

To prevent duplication of efforts and competing datasets for the ILRP, CV-Salts Nitrate Control Program, and SGMA GSAs, the Tule Subbasin utilizes a single group to manage the monitoring efforts within the Subbasin for collectively meeting the various requirements of these programs being implemented at the local level. This level of coordination between these agencies and groups ensures that the efforts performed under each program help provide a cohesive response to providing short term and long-term solutions to groundwater management.

The evaluation as to whether the implementation of a GSP may be contributing to the degradation of water quality will be completed as outlined in Attachment 7 of the Tule Subbasin Coordination Agreement. The types of mitigation for degradation of groundwater quality will vary by GSA and will be coordinated with the agencies listed in Table 2.

Other forms of mitigation may consist of joint ventures to secure grant funding to address GSA related impacts.

Table 3: Existing Groundwater Quality Monitoring Programs

Programs or Data Portals	Tule Subbasin Agency Coordinating with GSAs	Parameters	Monitoring Frequency	Program Objectives
AB-3030 and SB-1938 Groundwater Management Plans	Tule Subbasin GSAs, requirements incorporated into GSP Annual Reports	• Water levels are typically monitored annually. • Ag Suitability analysis (limited suite of general minerals) monitoring frequency between annual to once every 3 years.	Semiannual to Annual	
California SDWIS	Varies Public Water Systems	Database for all public water system wells and historical sample results. Data available includes all Title 22 regulated constituents.	• Title 22 General Minerals and Metals every 3 years. • Nitrate as N annually, if ≥ 5 ppm, sampled quarterly • VOCs and SOCs sampled every 3 years. • Uranium sampling depends on historical results but varies between 1 sample every 3 (when ≥ 10 pCi/L), 6 (when < 10 pCi/L) or 9 (when no historical detection) years.	Demonstrate compliance with Drinking Water Standards through monitoring and reporting water quality data.
CV-SALTS	Tule Basin Management Zone, Tule Basin Water Foundation	Sampling parameters required through Waste Discharge Requirements (WDR): typically include monthly sodium, chloride, electrical conductivity, nitrogen species (N, NO2, NO3, NH3), pH and other constituents of concern identified in the Report of Waste Discharge. A limited suite of general minerals is required quarterly from the source and annually from the wastewater.	Most constituents sampled monthly, quarterly general minerals from source water and annual general minerals from waste discharge.	To monitor degradation potential from wastewaters discharged to land application areas and provide interim replacement water when MCL for nitrate as N is exceeded while developing long term solutions for safe drinking water.
Department of Pesticide Regulation	County of Tulare	Pesticides	Annual	DPR samples groundwater to determine: (1) whether pesticides with the potential to pollute groundwater are present, (2) the extent and source of pesticide contamination, and (3) the effectiveness of regulatory mitigation measures.
GAMA (Collaboration with SWQCB, RWQCB, DWR, DPR, NWIS, LLNL)		• Constituents sampled vary by the Program Objectives. • Typically, USGS is the technical lead in conducting the studies and reporting data.	Varies	• Improve statewide comprehensive e groundwater monitoring. • Increase the availability of groundwater quality and contamination information to the public.
Geotracker and Envirostor Databases		Many contaminants of concern, organic and inorganic.	Depends on program. Monthly, Semiannually, Annually, etc.	Records database for cleanup program sites, permitted waste dischargers
ILRP	Tule Basin Water Quality Coalition	• Annually: static water level, temperature, pH, electrical conductivity, nitrate as nitrogen, and dissolved oxygen. • Once every five years: general minerals collection	Annual and Every 5 years	Monitor impacts of agricultural and fertilizer applications on first encountered groundwater
USGS California Water Science Center		Conducted multiple groundwater quality studies of the Tule Subbasin.	Reports, factsheet, and data publications range from 1994through 2017.	Special studies related to groundwater quality that provide comprehensive studies to characterize the basin.

Attachment 6

Technical Memorandum

To:	Tule Subbasin Technical Advisory Committee
From:	Thomas Harder, P.G., C.HG. Thomas Harder & Co.
Date:	13-Jul-22
Re:	Technical Support for Addressing Department of Water Resources Comments Regarding Land Subsidence in the Tule Subbasin

1 Introduction

This technical memorandum (TM) summarizes an analysis of currently established minimum thresholds and measurable objectives for land subsidence as they relate to potential impacts to land use, property interests, and critical infrastructure in the Tule Subbasin in Tulare County, California (see Figure 1). This TM was prepared to address comments from the California Department of Water Resources (CDWR) on groundwater sustainability plans (GSPs) prepared by each of the six Groundwater Sustainability Agencies (GSAs) within the Tule Subbasin.

1.1 Background

The Tule Subbasin Coordination Agreement formerly addressed undesirable results related to groundwater levels as the following: *"…the criteria for an undesirable result for land subsidence is defined as the unreasonable subsidence below minimum thresholds at greater than 50% of GSA Management Area RMS resulting in significant impacts to critical infrastructure."*

The previous version of the Coordination Agreement further stated that *"…the avoidance of an undesirable result of land subsidence is to protect critical infrastructure for the beneficial uses within the Tule Subbasin, including out of the ordinary costs to fix, repair, or otherwise retrofit such infrastructure beyond those which are expected or normal and may also result in an interim loss of benefits to the users of such infrastructure. An exceedance of minimum thresholds to the extent that the undesirable result for the Tule Subbasin is experienced could likely induce financial hardship on land and property interests, such as the redesign of previously planned construction projects and the fixing and retrofitting of existing infrastructure."*

In their review of the Tule Subbasin GSPs, each of which refer to the Coordination Agreement, the CDWR outlined the following Corrective Actions:[1]

1. *For areas defined as adjacent to the Canal in the Eastern Tule GSP, Delano-Earlimart Irrigation District GSP, and Lower Tule River Irrigation District GSP areas, the GSAs should identify, through analysis, the total amount of subsidence that can be tolerated by the Canal during implementation of the GSPs to maintain the ability to reasonably operate to meet contracted water supply deliveries. Eastern Tule GSA, Delano-Earlimart Irrigation District GSA, and Lower Tule River Irrigation District GSA should explain how implementation of the projects and management actions is consistent both with achieving the long-term avoidance or minimization of subsidence and with not exceeding the tolerable amount of cumulative subsidence adjacent to the Canal.*
    a. *GSPs adjacent to the Canal should provide an updated description of the Land Subsidence Management and Monitoring Plan and the associated subsidence management in the vicinity of the Canal. The GSPs should include details of any projects, management actions, or mitigation programs associated with the management of land subsidence in the Subbasin.*
2. *For areas not adjacent to the Canal, the GSAs should identify facilities and/or structures, land uses and property interests that may be susceptible to impacts from land subsidence and should quantify the amount of land subsidence that would result in undesirable results. The GSAs should describe the rationale and any analysis performed to inform the quantification of undesirable results in these areas.*
3. *Tule Subbasin GSAs should define the criteria for when undesirable results occur in the Subbasin based on the results of analyses completed in response to Corrective Actions 1 and 2, the rationale behind the approach, and why it is consistent with avoiding the significant and unreasonable effects identified by the GSAs.*
4. *The GSAs should revise their minimum thresholds and measurable objectives for land subsidence to be consistent with the intent of SGMA that subsidence be avoided or minimized once sustainability is achieved. In doing that, the GSAs should identify a cumulative amount of tolerable subsidence that, if exceeded, would substantially interfere with groundwater and land surface beneficial uses and users in the Subbasin. The GSPs should explain how the extent of any future subsidence permitted by the GSPs would not substantially interfere with surface land uses. The GSAs should explain how implementation of the projects and management actions is consistent both with achieving the long-term avoidance or minimization of subsidence and with not exceeding the tolerable amount of cumulative subsidence.*

---

[1] CDWR, 2022. Statement of Findings Regarding the Determination of Incomplete Status of the San Joaquin Valley – Tule Subbasin Groundwater Sustainability Plans; Letter Dated January 28, 2022. Section 3.2.

The updated Coordination Agreement has been modified to reflect the analysis of land subsidence in the Tule Subbasin, as presented herein.

1.2 Purpose and Scope

In general, the purpose of this TM is to provide a technical basis for addressing the four general CDWR comments on the sustainable management criteria for land subsidence in the Tule Subbasin, as quoted in Section 1.1. The technical analysis described herein provides the basis for defining significant and unreasonable land subsidence conditions in the Tule Subbasin.

1.3 Sources of Data

The analysis presented herein is based on the best available data and background reports at the time of preparation. Sources of data used for this analysis include the following:

- Geographic Information System (GIS) shapefiles of hydrologic and water infrastructure from local agencies (e.g. Lower Tule River Irrigation District, Saucelito Irrigation District, etc.)
- GIS shapefile of railroads from the California Department of Transportation (CalTrans).
- GIS shapefile of bridges from the United States Department of Transportation, National Bridge Inventory
- AMEC Foster Wheeler, 2017. Ground Subsidence Study Report, Corcoran Subsidence Bowl, San Joaquin Valley, California. Prepared for California High Speed Rail Authority
- GIS shapefiles of Flood Insurance Rate Maps (FIRMs) from the Federal Emergency Management Agency (FEMA), National Flood Insurance Program (NFIP).
- Pipeline locations from the National Pipeline Mapping System (NPMS)
- United States Geological Survey (USGS) Digital Elevation Model (DEM)
- Geographic Information System (GIS) shapefiles of the subbasin and GSA boundaries and wells
- Tule Subbasin survey benchmark data[2]
- Minimum threshold groundwater level elevations for representative monitoring sites in the Tule Subbasin[3]

---

[2] Thomas Harder & Co, 2022. Tule Subbasin 2020/21 Annual Report. Prepared for the Tule Subbasin Technical Advisory Committee.

[3] Thomas Harder & Co, 2022. Tule Subbasin 2020/21 Annual Report. Prepared for the Tule Subbasin Technical Advisory Committee.

2 Land Subsidence Conditions

2.1 Mechanisms of Land Subsidence

Land surface subsidence from groundwater withdrawal occurs in areas where the subsurface aquifer system includes relatively thick aquitards and the groundwater level is lowered from groundwater pumping. Aquitards are low permeability layers with relatively high silt and clay content. As the aquitards are compressible, the release of pore pressure caused by the lowering of groundwater levels results in compression of the low permeability layers. Within a limited range of groundwater level fluctuation, the compressed aquitards can accept water back into their structure when groundwater levels rise resulting in elastic rebound. However, if groundwater levels are maintained at these lower levels for long enough periods of time as a result of groundwater pumping, the compression of aquitards becomes permanent. This permanent compression of subsurface layers results in land surface subsidence.

2.2 Rate and Extent of Land Subsidence in the Tule Subbasin

As described in the Tule Subbasin Setting (Attachment 2 to the Coordination Agreement), the rate of land subsidence in the Tule Subbasin varies both spatially, according to the geology of the subsurface sediments, and temporally with changes in groundwater levels. In general, land subsidence rates are highest in the northwestern part of the subbasin (see Figure 2). The average rate of change in land surface elevation between 1987 and 2018 for the area of maximum subsidence in the western part of the subbasin was estimated to be approximately 12 feet over the 32-year period for a rate of 0.4 ft/yr. At the Porterville GPS station, the annual rate of subsidence between 2006 and 2013 was approximately 0.09 ft/yr but increased to approximately 0.29 ft/yr between 2013 and 2019.

Groundwater flow model analysis forecasts that land subsidence will continue during the transitional pumping period from 2020 to 2040 as groundwater levels continue to drop in parts of the Subbasin.[4] In general, the greatest amounts of land subsidence (up to eight feet) is forecasted to occur in the northwestern part of the subbasin during this time period, which represents an average rate of 0.4 ft/yr (see Figure 3). Land subsidence rates as high as 0.2 ft/yr are forecasted to occur in the vicinity of the Friant-Kern Canal between Deer Creek and White River.

---

[4] Thomas Harder & Co., 2020. Groundwater Flow Model of the Tule Subbasin. Prepared for the Tule Subbasin MOU Group. Dated January 2020.

2.3 Regional vs Differential Subsidence

Land subsidence can manifest itself as a regional phenomenon or at a local scale. Regional land subsidence results in a large area (e.g. 10’s to 100’s of square miles) subsiding at similar rates such that the effect of the lowered land elevation cannot be discerned except through periodic surveying of bench marks or information from satellites. Impacts to land uses, property interests, and critical infrastructure from this type of land subsidence are most likely to occur in the form of reduced surface carrying capacity of gravity-driven water conveyance, well damage, and flood control. Differential land subsidence results in localized adjoining areas subsiding at different rates relative to each other. This can result in land fissuring and often occurs along a fault or geologic boundary. Differential land subsidence has the most potential to cause damage to surface infrastructure such as roads, bridges, and buildings.

The best available information to date indicates that land subsidence in the Tule Subbasin has been regional in nature with little evidence of differential land subsidence and no reports of damage to infrastructure associated with differential land subsidence.

3 Land Subsidence Along the Friant-Kern Canal

Differential land subsidence rates along the portion of the Friant-Kern Canal that extends through the ETGSA has had a significant impact on the ability of the FWA to deliver surface water downstream of the impacted areas. Where the FKC crosses the northern and southern ETGSA boundaries, land subsidence rates have been relatively low and cumulative land subsidence in those areas have been on the order of 1 to 2 feet between 1959 and 2019. Land subsidence between the Tule River and White River, however, have resulted in up to approximately 9 feet of cumulative land subsidence at the FKC. This differential land subsidence has resulted in a low spot along the canal in the vicinity of Deer Creek that restricts flow in the canal. The original design flow capacity of the FKC was approximately 4,000 cubic feet per second (cfs). As of 2019, the flow capacity at the canal at Deer Creek had been reduced to approximately 1,900 cfs (United States Bureau of Reclamation, 2019). The FWA is currently pursuing repairs to the FKC to restore the original flow capacity. The long-term effectiveness of the repairs at maintaining flow capacity in the canal relies on limiting additional land subsidence during the SGMA transition period from 2020 to 2040 within the design of the repairs and minimizing land subsidence after 2040.

Groundwater flow model analysis forecasts as much as three feet of additional land subsidence at some locations of the FKC during the transition period from 2020 to 2040 (Figure 4). Through coordination with the Friant Water Authority staff and consultants, this value became the basis for engineering design modifications to restore canal flow capacity to its original condition. Land subsidence along the canal exceeding three feet was determined to be an undesirable result because it would be beyond what the engineering design could accommodate to restore the flow capacity to its original condition and what the parties to the FWA/ETGSA/Pixley GSA settlement agreement agreed to mitigate.

To address land subsidence along the FKC, the ETGSA developed a Land Subsidence Monitoring Plan[5] and Management Plan[6]. These plans are separate from, and in addition to, the monitoring plan established for the Tule Subbasin. The goal of the Land Subsidence Monitoring and Management Plans is to implement groundwater management measures necessary to minimize future non-recoverable land subsidence along the FKC in the SGMA transition period from 2020 – 2040 and to arrest nonrecoverable land subsidence along the FKC after 2040. The area encompassed by the plan is shown on Figure 5, along with Management Zones that have been identified where management actions may be implemented.

The ETGSA Land Subsidence Monitoring Plan includes:

- An enhanced benchmark and groundwater level monitoring network,

---

[5] TH&Co, 2021. Eastern Tule Groundwater Sustainability Agency Land Subsidence Monitoring Plan. Dated September 2021.

[6] ETGSA, 2022. Eastern Tule Groundwater Sustainability Agency Land Subsidence Management Plan. Dated February 2022.

- Establishment of a Land Subsidence Monitoring and Management Committee, and
- Annual Reporting

The Land Subsidence Management Plan establishes management action criteria for implementing enhanced management actions should land subsidence in any given Management Area reach certain thresholds. Four land subsidence thresholds, or "Tiers" have been established:

- Tier 1 – 0 to 1.49 ft of land subsidence
- Tier 2 – 1.5 to 1.99 ft of land subsidence
- Tier 3 – 2.0 to 2.49 ft of land subsidence
- Tier 4 – 2.5 to 2.99 ft of land subsidence.

Progressively aggressive management actions have been identified for each tier. Land subsidence in any given Management Area that exceeds the criteria, as measured semi-annually using InSAR data, triggers the management actions in the next higher tier.

4 Other Land Uses, Property Interests, and Critical Infrastructure Vulnerable to Land Subsidence in the Tule Subbasin

4.1 Gravity-Driven Water Conveyance Infrastructure

Gravity-driven water conveyance infrastructure includes canals, turnouts, recharge basins, stream channels used to convey water, pipelines, and field irrigation (see Figure 6). This infrastructure utilizes the land surface slope to maintain hydraulic head and velocity (and therefore flow capacity). Land subsidence results in changes in the slope of the land surface. Positive changes in slope (i.e. steepening of slope) may result in increased water velocities, increased pressure in pipelines, and lower hydraulic head (e.g. at turnouts). Negative changes in slope (i.e. flattening of slope) may result in decreased water velocities, lower pressure in pipelines, and higher hydraulic head (e.g. at turnouts and under bridges).

For completeness, below is a list of gravity-driven water conveyance infrastructure in the Tule Subbasin that may be vulnerable to changes in land surface slope due to subsidence:

- Regional canals including the following:
    - Friant-Kern Canal
    - Homeland Canal
- Local canals owned and operated by the following:
    - Lower Tule River Irrigation District
    - Pixley Irrigation District
    - Porterville Irrigation District
    - Various Tule River Association members (e.g. Porter Slough, Campbell-Moreland Ditch, etc.)
    - Angiola Water District
    - Alpaugh Irrigation District
- Turnouts to landowners
- Turnouts to recharge basins
- Tule River, Deer Creek, and White River channels used to convey native and imported water
- Pipelines owned and operated by the following
    - Porterville Irrigation District
    - Saucelito Irrigation District
    - Delano-Earlimart Irrigation District
    - Terra Bella Irrigation District
    - Kern-Tulare Irrigation District
    - Tea Pot Dome Irrigation District
- Field irrigation (e.g. field furrows, field flooding, etc.)

4.1.1 Analysis of Potential Impacts to Gravity Driven Water Conveyance from Land Subsidence

Changes in land surface slope or localized changes in land surface elevation have the potential to impact the flow capacity of gravity driven conveyance facilities. Groundwater flow modeling has shown that land subsidence is likely to continue through the 2020 to 2040 transition period (see Figure 3).[7] Minimum Thresholds (MTs) for land subsidence were developed based, in part, on land subsidence forecasts by the groundwater flow model for the 2020 to 2040 transition period. To assess the potential for undesirable results on gravity driven water conveyance in the Tule Subbasin if the land subsidence exceeds the minimum thresholds, TH&Co conducted the following analysis:

- The difference between the 2020 land surface elevations surveyed at the Representative Monitoring Sites (RMS; Benchmark Network) and the forecast maximum land subsidence (MTs) at the RMS was contoured in a Geographic Information System (GIS) using a kriging algorithm to produce a distribution of potential future land subsidence between 2020 and 2040 (see Figure 7).
- The 2020 land surface elevation and land surface elevation at maximum subsidence were discretized with square cells 1,650 ft on each side.
- Using the GIS slope tool, TH&Co calculated the land surface slopes for both the 2020 and MT land surface elevation conditions (see Figures 8 and 9).
- The forecast change in slope was estimated as the difference between the 2020 and MT slopes (see Figure 10).

Results of the analysis showed a projected flattening of the land surface slope along Deer Creek and west of the Friant-Kern Canal, along the Tule River west of State Highway 99, and north of Deer Creek along State Highway 43 (see Figure 10). However, changes in slope are not projected to change surface flow directions except for the area north of Deer Creek and State Highway 43, where the land surface is already relatively flat. Flattening of the surface slope at the west end of Deer Creek could change surface flow directions and flooding patterns in this area.

4.1.2 Potential for Undesirable Results on Gravity Driven Water Conveyance from Land Subsidence

The greatest potential for undesirable results related to changes in land surface slope from forecast land subsidence during the 2020 to 2040 transition period are water delivery capacity in the Homeland Canal, the ability to divert water from the western end of Deer Creek, and potential changes in the cost and ability to deliver water in conveyance pipelines. Except for the Friant-Kern Canal, no undesirable results on gravity driven conveyance have been documented from

---

[7] Thomas Harder & Co., 2020. Groundwater Flow Model of the Tule Subbasin. Prepared for the Tule Subbasin MOU Group. Dated January 2020.

historical land subsidence in the Tule Subbasin. Further, impacts associated from potential future changes in land surface slope are not anticipated.

4.2 Domestic, Agricultural, and Other Wells

Wells are susceptible to damage from land subsidence. Subsidence is the result of cumulative aquifer system (i.e. aquifers and aquitards) compaction at depth. As the aquifer system compacts, it causes vertical compression on the well casing, which may result in collapsing, bending, ripping, rupturing, or otherwise breaking. This can lead to a damaged and/or unusable well. Protrusion of the well casing at the land surface may also occur.

Casing compression is proportional to the thickness of compressing sediment, which varies in the Tule Subbasin spatially and with depth. In the Tule Subbasin, compression of the Lower Aquifer is greater than that of the Shallow Aquifer. Therefore, wells constructed in the Lower Aquifer are more susceptible to damage from land subsidence than wells constructed only in the Upper Aquifer.

While well casing damage from land subsidence is known to occur in wells constructed in the Tule Subbasin, details regarding the number of impacted wells and the amount of land subsidence that leads to casing damage/failure is not documented. Further, many new wells constructed in the last approximately 20 years have been designed with compression sections in their casing to accommodate the effects of land subsidence. For wells not equipped with compression sections, studies in other areas of the Central Valley of California suggest that casing damage is not common where land subsidence is less than approximately one foot.[8] Given that land subsidence has exceeded one foot throughout most of the Tule Subbasin since at least 2015 (see Figure 2), well damage from historical land subsidence is likely in wells not equipped with compression sections. Further, forecasted land subsidence for 2020 to 2040 is also estimated to exceed one foot throughout much of the subbasin, which may cause to wells not equipped to accommodate it. Potential undesirable results include the need to repair or replace damaged wells and difficulty or inability to remove pumps.

4.3 Flood Control

The historical tendency of any given area to flood during a precipitation event or prolonged period of above-normal precipitation is dependent on the land elevation of the area relative to other areas. Flooding occurs in low-lying areas. Changes in the land surface elevation and slope can impact the direction of surface water runoff and areas subject to flooding. Infrastructure built in areas protected from historical flooding or dependent on historical land/channel slopes to deliver surface water may be impacted if the slope of the land changes. The Federal Emergency Management

---

[8] Borchers, J.W., Gerber, M., Wiley, J., and Mitten, H., 1998. Using Down-Well Television Surveys to Evaluate Land Subsidence Damage to Water Wells in the Sacramento Valley, California.

Agency (FEMA) has published maps showing areas susceptible to flooding (see Figure 11). While these maps were updated in 2009, it is our understanding that they were based on topographic data that was outdated. As land subsidence continues to occur in the Tule Subbasin, it will be necessary to update the FEMA flood maps after land subsidence rates are minimized.

Potentially impacted flood control infrastructure includes berms/levees around the Tule River, Deer Creek, White River, smaller channels, and the Tulare Lakebed. The location and design capacity of this infrastructure are presently unknown. As described in Section 4.1.2 herein, changes in land elevation may affect some stakeholder's ability to divert water from the western end of Deer Creek. AMEC Foster Wheeler (2017) noted that potential flooding of the Tulare Lakebed is the primary concern for subsidence impacts to the California High Speed Rail (CSHR), more so than potential physical impacts to the track structure.[9]

4.4 State Highways, Railroads, Pipelines, and Bridges

State Highways, railroads, pipelines, and bridges may be susceptible to differential subsidence, should it occur. State highways in the Tule Subbasin include Highways 99, 43, 65, 190, and 155 (see Figure 12). In addition, there are 156 bridges from the National Bridge Inventory within the Tule Subbasin. Railroads in the Tule Subbasin include the Burlington-Northern Santa Fe (BNSF), Union Pacific, San Joaquin Valley Railroad, West Isle Line, and the planned California High Speed Rail (CHSR). Pipelines identified from the National Pipeline Mapping System (NPMS) include gas transmission pipelines and liquid petroleum pipelines.

Historically, there has been no reported impacts to state highways, railroads, pipelines and bridges in the Tule Subbasin attributed to land subsidence. Further, there has been no evidence of differential land subsidence that has impacted infrastructure in the subbasin.

The CHSR, which is currently under construction, is located on the western side of the Tule Subbasin (see Figure 12). AMEC (2017) conducted a detailed evaluation of potential subsidence-related impacts to the CHSR. The report identified the following potential concerns:

> Rapid and large-magnitude subsidence poses several potential concerns to the HSR, including (1) changes in slopes, vertical curvature, horizontal curvature, and twist; (2) development of fissures or compaction faults; and (3) changes in floodplains and site drainage.

AMEC Foster Wheeler (2017) noted that potential flooding of the Tulare Lakebed, which is associated with regional land subsidence, is the primary concern for subsidence impacts to the CSHR, more so than potential physical impacts to the track structure associated.

---

[9] AMEC Foster Wheeler, 2017. Ground Subsidence Study Report – Corcoran Subsidence Bowl, San Joaquin Valley, California. Prepared for the High Speed Rail Authority. Dated December 2017.

4.5 Wastewater Collection

Wastewater collection (i.e. sewer systems) relies on networks of gravity-driven sewers that may be susceptible to impacts from land subsidence (see Section 4.4). For completeness, cities and communities that operate wastewater collection include the following (see Figure 13):

- City of Porterville
- Terra Bella Sewer Maintenance District (SMD)
- Woodville Public Utilities District (PUD)
- Tipton Community Services District (CSD)
- Pixley PUD
- Earlimart PUD
- Richgrove CSD

Historically, there has been no reported impacts to wastewater collection systems in the Tule Subbasin attributed to land subsidence. Further, there has been no evidence or studies documenting differential land subsidence that has impacted wastewater infrastructure in the subbasin.

4.6 Other Potential Land Uses, Property Interests, and Critical Infrastructure

Other potential land uses, property interests, and critical infrastructure that could be impacted by differential land subsidence include buildings, utilities, and other facilities. Historically, there has been no reported impacts to infrastructure in the Tule Subbasin attributed to land subsidence. Further, there has been no evidence or studies documenting differential land subsidence that has impacted buildings, utilities, and other facilities in the subbasin.

5 Prioritization of Land Uses Vulnerable to Land Subsidence

The land uses, property interests, and critical infrastructure vulnerable to land subsidence were prioritized based on input from Tule Subbasin GSAs, a review of documented subsidence impacts in the Tule Subbasin, and historical and projected subsidence rates.

High priority land uses are those that are potentially impacted by regional land subsidence regardless of if there is differential land subsidence. High priority land uses include:

- Gravity-Driven Water Conveyance
    - Canals
    - Turnouts
    - Stream Channels
    - Water Delivery Pipelines
    - Basins
- Wells
- Flood Control Infrastructure

Low priority land uses are not typically impacted by regional land subsidence but are susceptible to differential land subsidence if it occurs. Based on the best available information, these land uses have not been impacted by the regional land subsidence that has historically occurred in the Tule Subbasin. The low priority land uses include:

- Highways and Bridges
- Railroads
- Other Pipelines
- Wastewater Collection
- Utilities
- Buildings

In the context of the discussion of infrastructure and land uses vulnerable to land subsidence (Sections 3 and 4 herein), undesirable results associated with the cumulative amount of land subsidence accommodated by the Minimum Thresholds, as published in each GSA’s GSP (see Figure 7), are not anticipated for most of the land uses in the Tule Subbasin. In those cases where an impact is reported, it is recommended that the Tule Subbasin GSAs establish a mitigation program to address such impacts.

6 Potential for Land Subsidence After 2040

Even with achievement of sustainable groundwater conditions by 2040, it is possible that ongoing land subsidence could occur in the Tule Subbasin after 2040. This additional land subsidence would take the form of:

- Elastic aquifer compaction and rebound whereby seasonal changes in groundwater levels result in lowering and raising of the land surface as the aquifer releases or takes in water. Changes in land elevation from elastic compaction (also known as "recoverable compaction") are typically on the order of tenths of feet or less.
- Residual compaction of clays after 2040 from the lowering of groundwater levels that occurred prior to 2040. Land subsidence associated with residual compaction is inelastic (i.e. permanent) and typically results in greater amounts of subsidence relative to recoverable compaction.

The greatest potential for undesirable results from land subsidence after 2040 is residual compaction associated with a groundwater condition that was established prior to 2040. Residual compaction rates and extents are hard to predict as they depend largely on the characteristics of the subsurface sediments at any given location. Recent studies by Smith and Knight (2019)[10] and Lees et al. (2022)[11] suggest that the duration and magnitude of residual land subsidence at any given location, assuming a stable groundwater level condition, is proportional to the thickness of subsurface clay at that location. Based on studies and modeling in the Kaweah Subbasin north of Tule Subbasin, residual subsidence rates could be on the order of 0.4 to 2 in/yr (1 to 5 cm/yr) (Lees et al., 2022) and last many years after groundwater levels have stabilized.

Given the uncertainty of residual compaction rates that could be expected at any given location in the Tule Subbasin after 2040, it is recommended to collect additional groundwater levels and land surface elevation data over time to establish more clearly the relationship between groundwater level changes and land subsidence in those areas of the Tule Subbasin where infrastructure and land uses are vulnerable to undesirable results. Further, construction of one or more extensometers in the areas of highest land subsidence rate is recommended to help establish the groundwater level at which land subsidence would be acceptably mitigated.

---

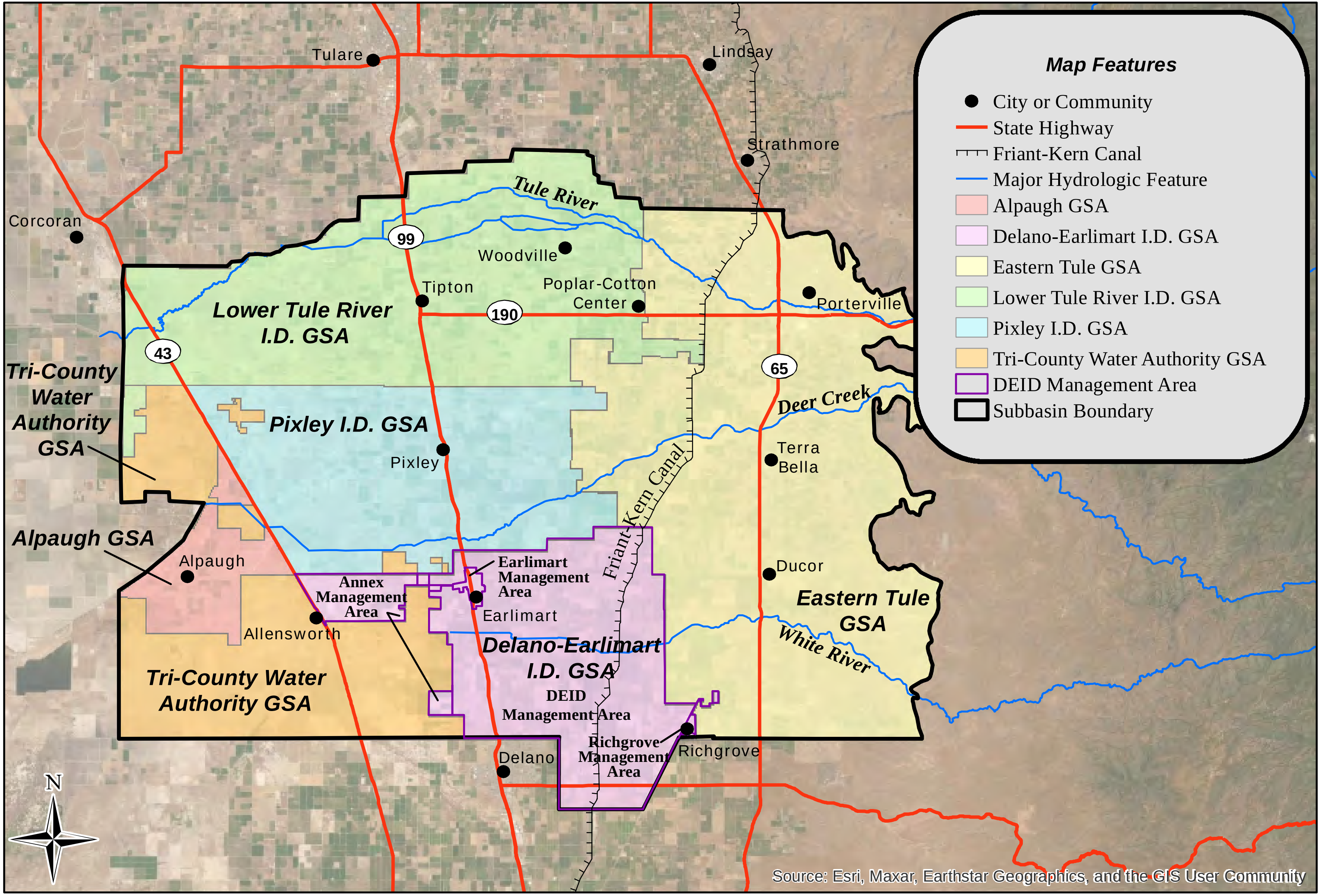
[10] Smith, R., and Knight, R., 2019. Modeling Land Subsidence Using InSAR and Airborne Electromagnetic Data. Water Resources Research, 55, 2801-2819.

[11] Lees, M., Knight, R., and Smith, R., 2022. Development and Application of a 1D Compaction Model to Understand 65 Years of Subsidence in the San Joaquin Valley. Water Resources Research, 58, e2021WR031390.

DWR Comments - Subsidence in the Tule Subbasin

July 2022

Tule Subbasin Technical Advisory Committee



Source: Esri, Maxar, Earthstar Geographics, and the GIS User Community

0 2.5 5 10
Miles
NAD 83 State Plane Zone 4

Thomas Harder & Co.
Groundwater Consulting

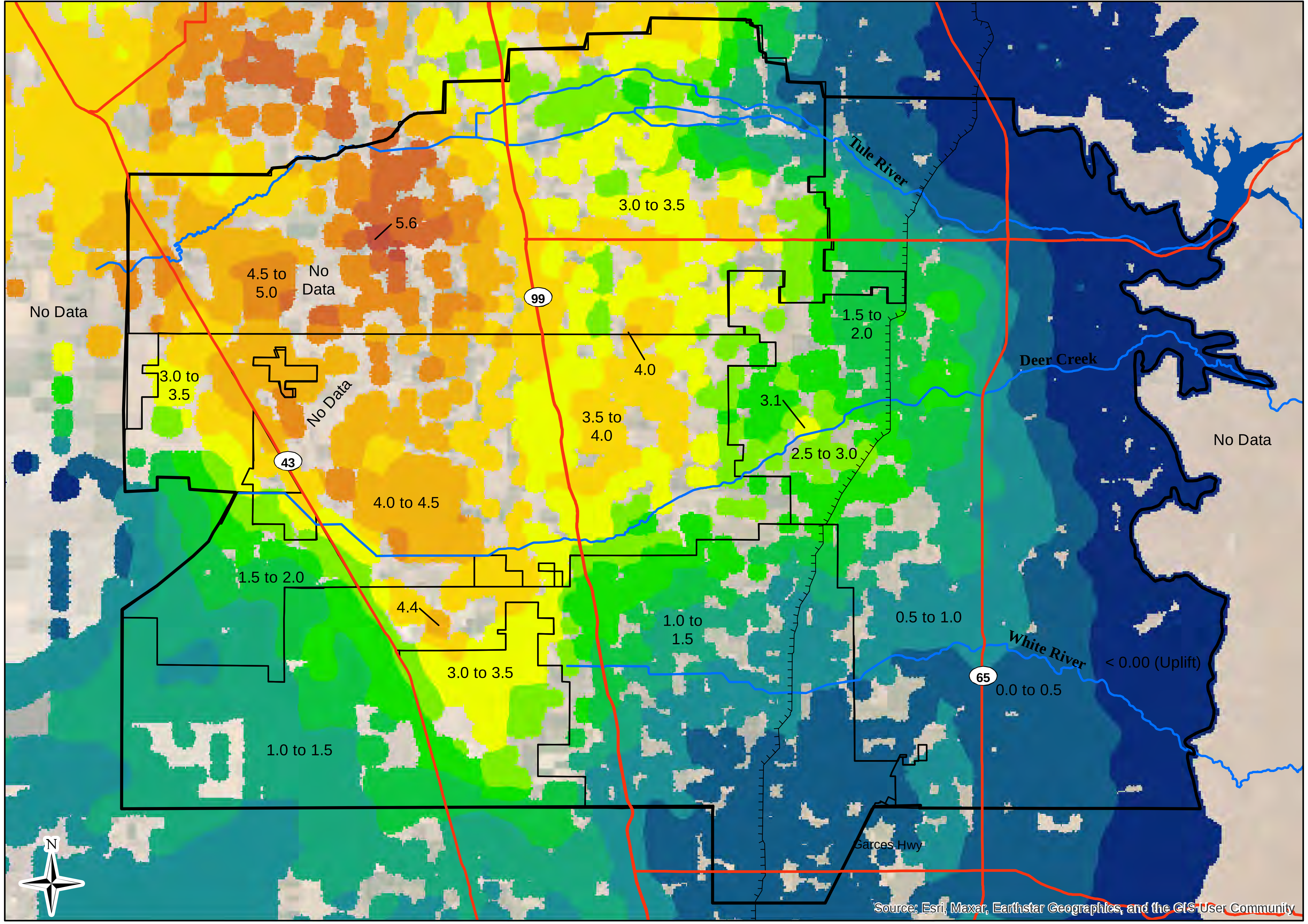
GSA Boundaries

Figure 1

DWR Comments - Subsidence in the Tule Subbasin

Tule Subbasin Technical Advisory Committee

July 2022



Source: Esri, Maxar, Earthstar Geographics, and the GIS User Community

Map Features

Subsidence (ft)	
🟥	5.5 to 6.0
🟧	5.0 to 5.5
🟧	4.5 to 5.0
🟧	4.0 to 4.5
🟨	3.5 to 4.0
🟨	3.0 to 3.5
🟩	2.5 to 3.0
🟩	2.0 to 2.5
🟩	1.5 to 2.0
🟩	1.0 to 1.5
🟦	0.5 to 1.0
🟦	0.0 to 0.5
🟦	< 0.0 (Uplift)
—	State Highway
┬┬┬┬┬	Friant-Kern Canal
—	Major Hydrologic Feature
☐	GSA Boundary
☐	Subbasin Boundary

0 2 4 8 Miles

NAD 83 State Plane Zone 4

InSAR data from:
https://gis.water.ca.gov/arcgisimg/rest/services/SAR/Vertical_Displacement_TRE_ALTAMIRA_Total_Since_20150613_20211001/ImageServer

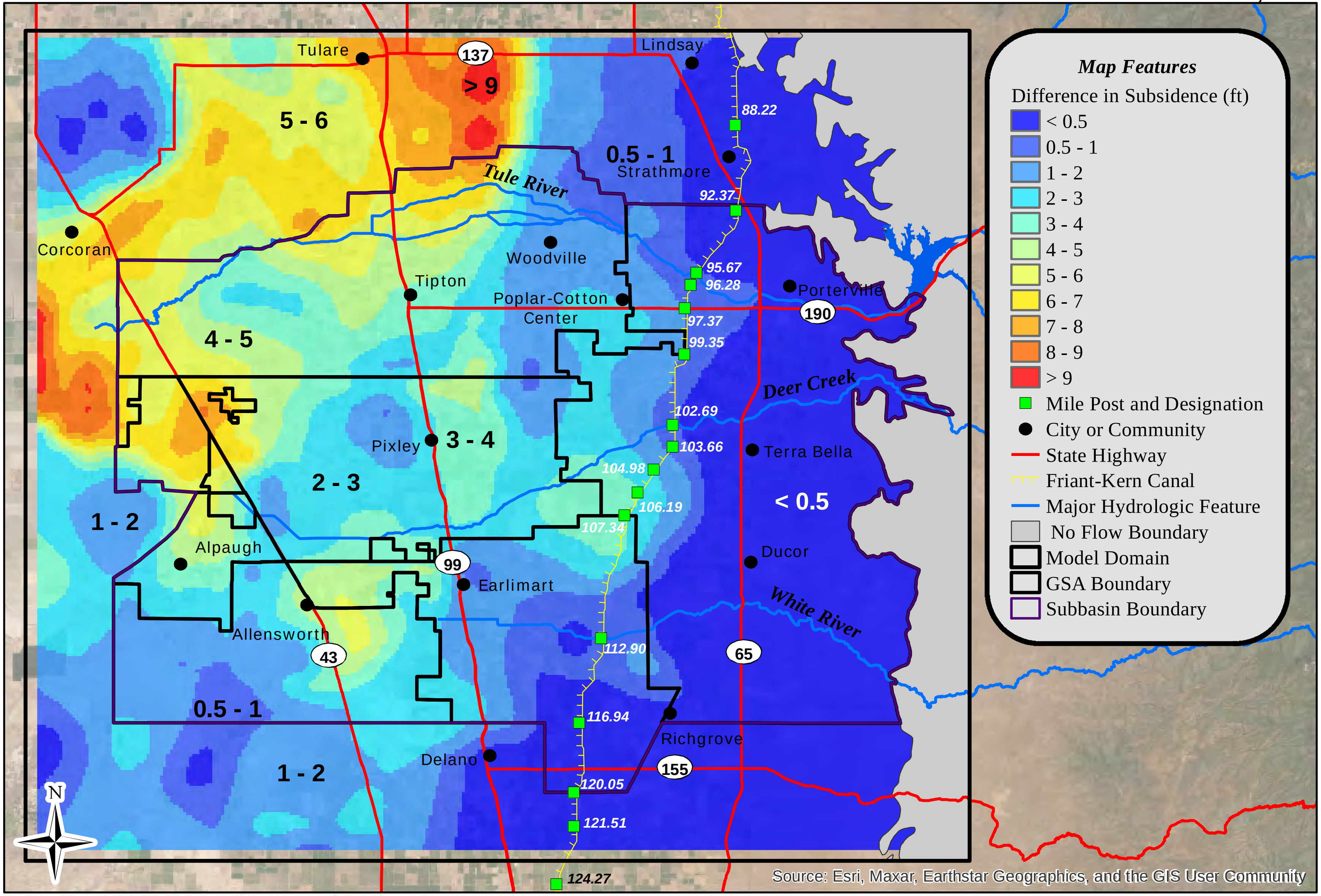
Thomas Harder & Co.
Groundwater Consulting

Land Subsidence
June 2015 to September 2021

Figure 2

DWR Comments -
Subsidence in the
Tule Subbasin
July 2022

Tule Subbasin Technical Advisory Committee



Source: Esri, Maxar, Earthstar Geographics, and the GIS User Community

Thomas Harder & Co.
Groundwater Consulting

NAD 83 State Plane Zone 4

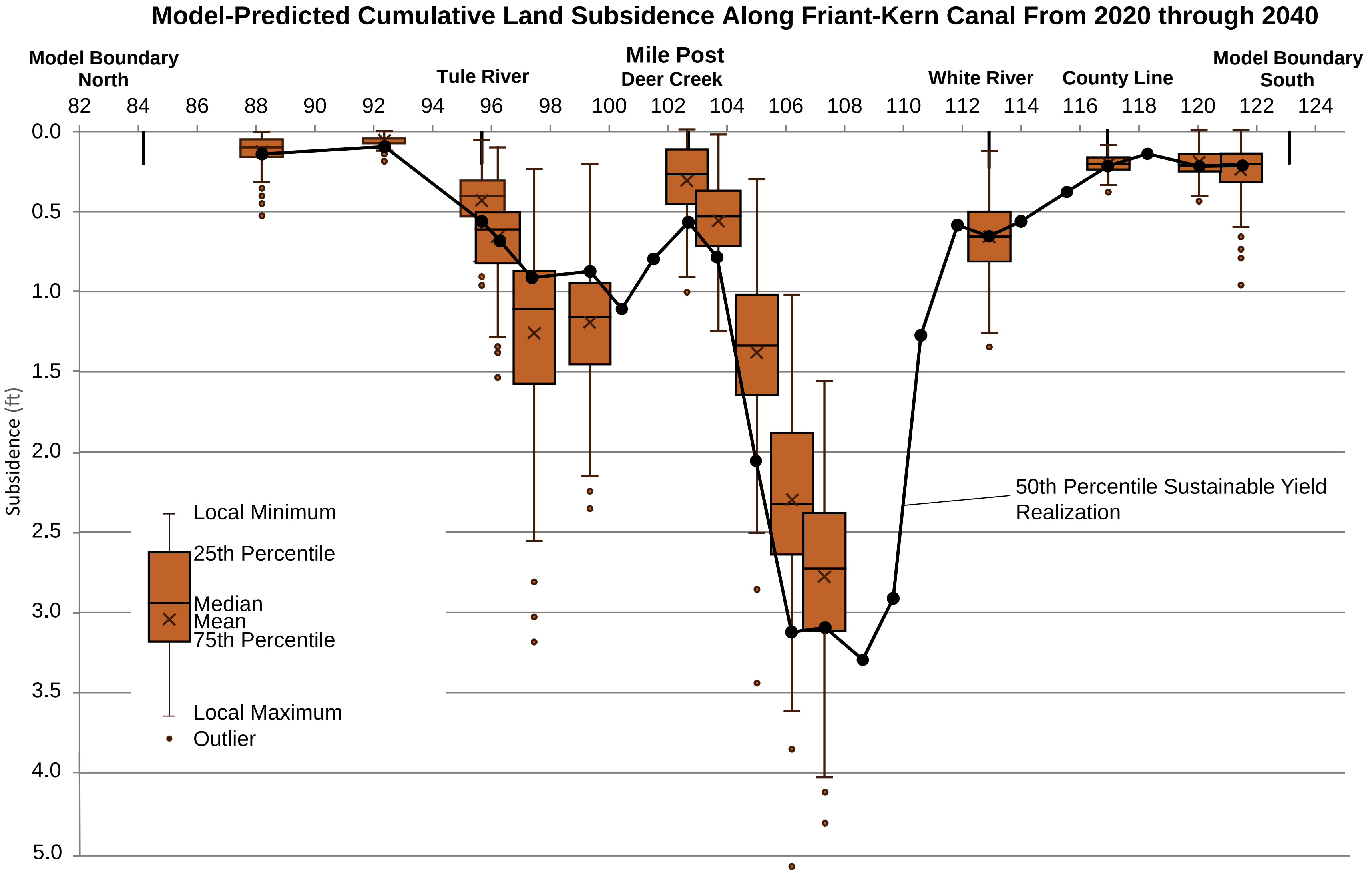
Note: This map shows the difference in subsidence from September 30, 2019 to September 30, 2039.

Cumulative Land Subsidence in the Tule Subbasin from 2020 to 2040

Figure 3

From Thomas Harder & Co., 2020. Groundwater Flow Model of the Tule Subbasin. Prepared for the Tule Subbasin MOU Group.

Figure 4



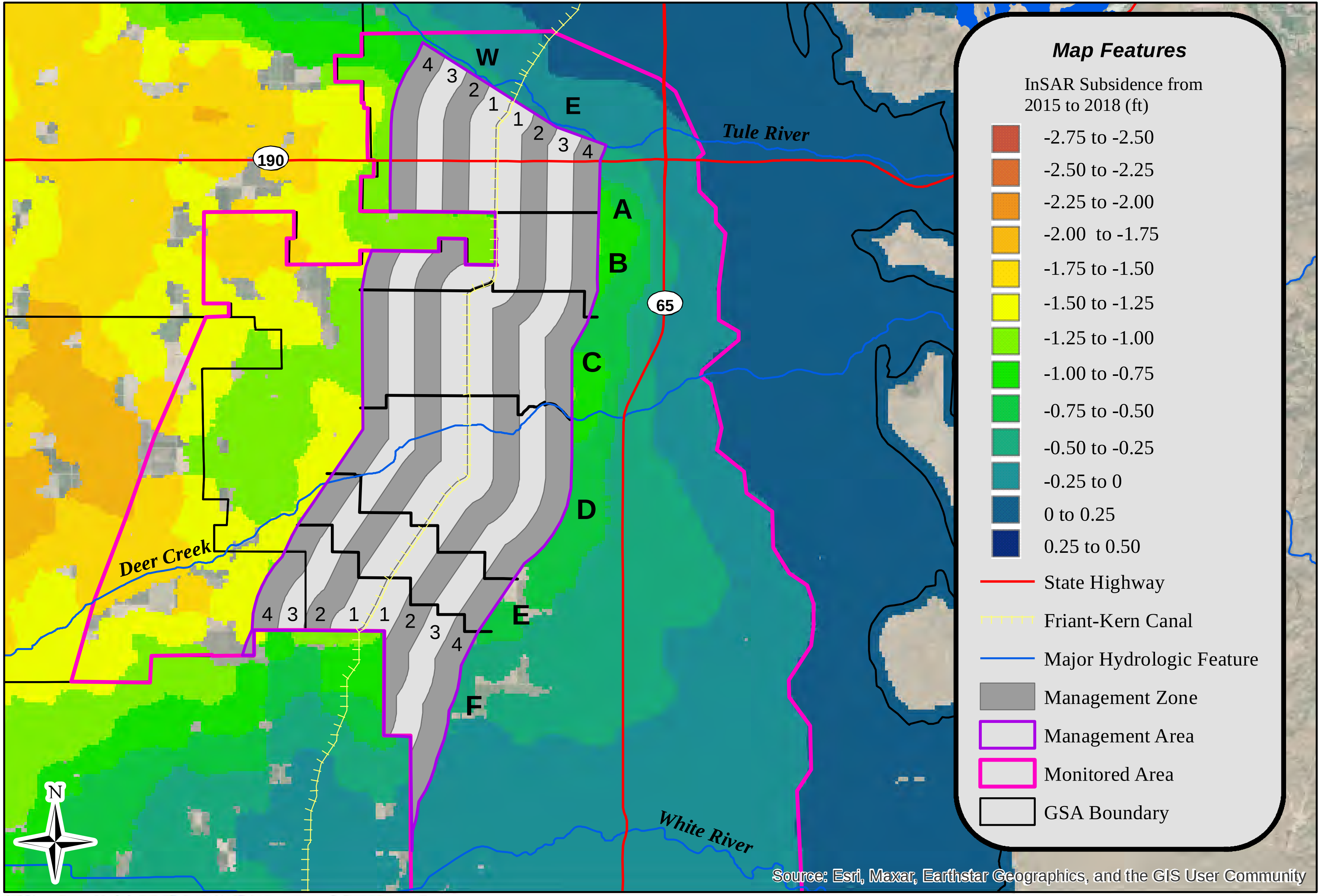
Note: From Thomas Harder & Co., 2020. Groundwater Flow Model of the Tule Subbasin. Prepared for the Tule Subbasin MOU Group.

July 2022

**DWR Comments -
Subsidence in the
Tule Subbasin**

July 2022

Tule Subbasin Technical Advisory Committee



Source: Esri, Maxar, Earthstar Geographics, and the GIS User Community

Thomas Harder & Co.
Groundwater Consulting

0 0.5 1 2 3 4 Miles

NAD 83 State Plane Zone 4

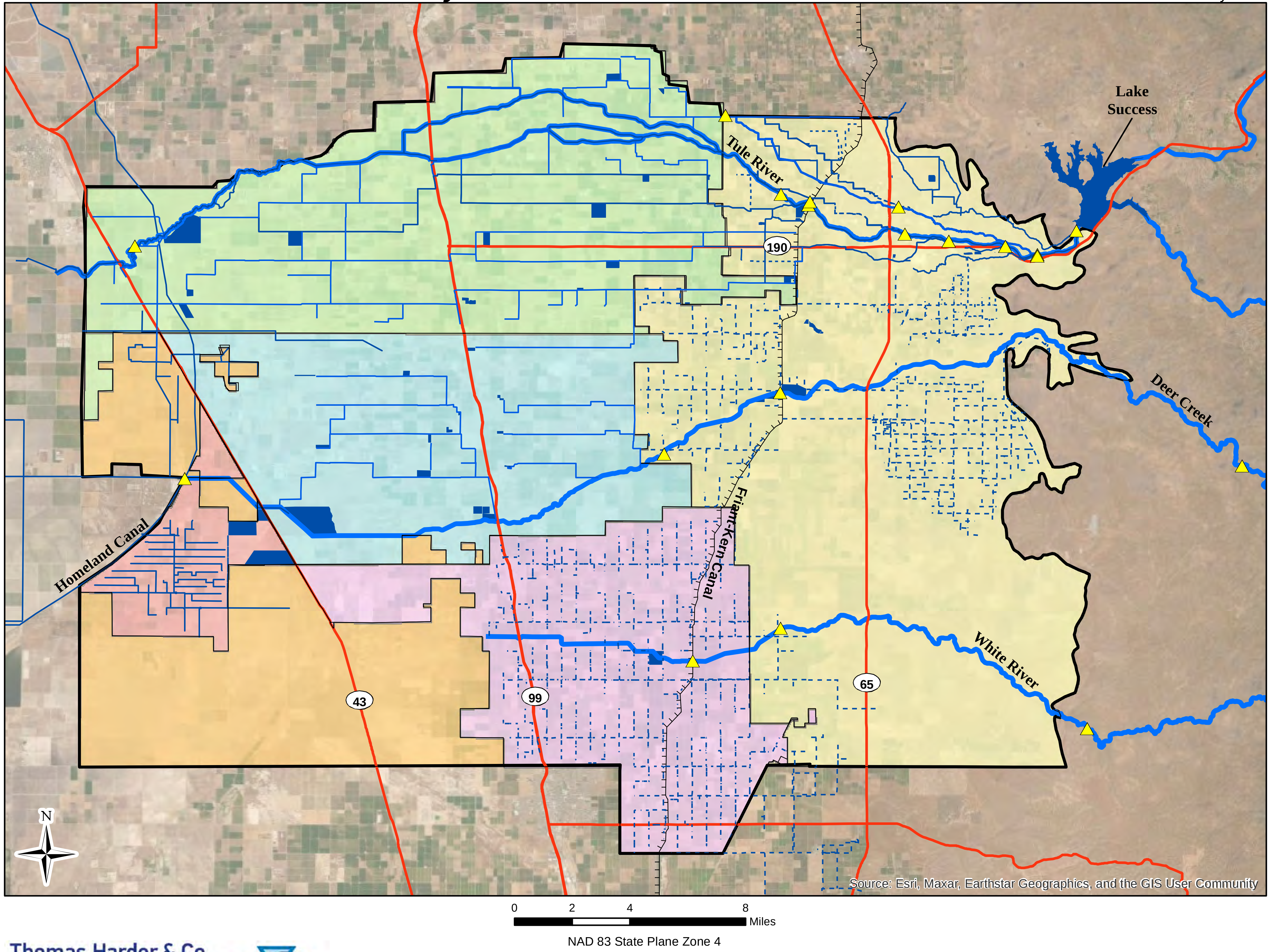
ETGSA Land Subsidence Managed Area with Management Subzones

Figure 5

DWR Comments -
Subsidence in the
Tule Subbasin

Tule Subbasin Technical Advisory Committee

July 2022



Source: Esri, Maxar, Earthstar Geographics, and the GIS User Community

Map Features

- △ Gaging Location/Surface Water Diversion
- — Canal
- - - - Pipe
- — State Highway
- ┬┬┬┬ Friant-Kern Canal
- — Major Hydrologic Feature
- ■ Artificial Recharge Basin
- ■ Alpaugh GSA
- ■ Delano-Earlimart I.D. GSA
- ■ Eastern Tule GSA
- ■ Lower Tule River I.D. GSA
- ■ Pixley I.D. GSA
- ■ Tri-County Water Authority GSA
- □ Subbasin Boundary

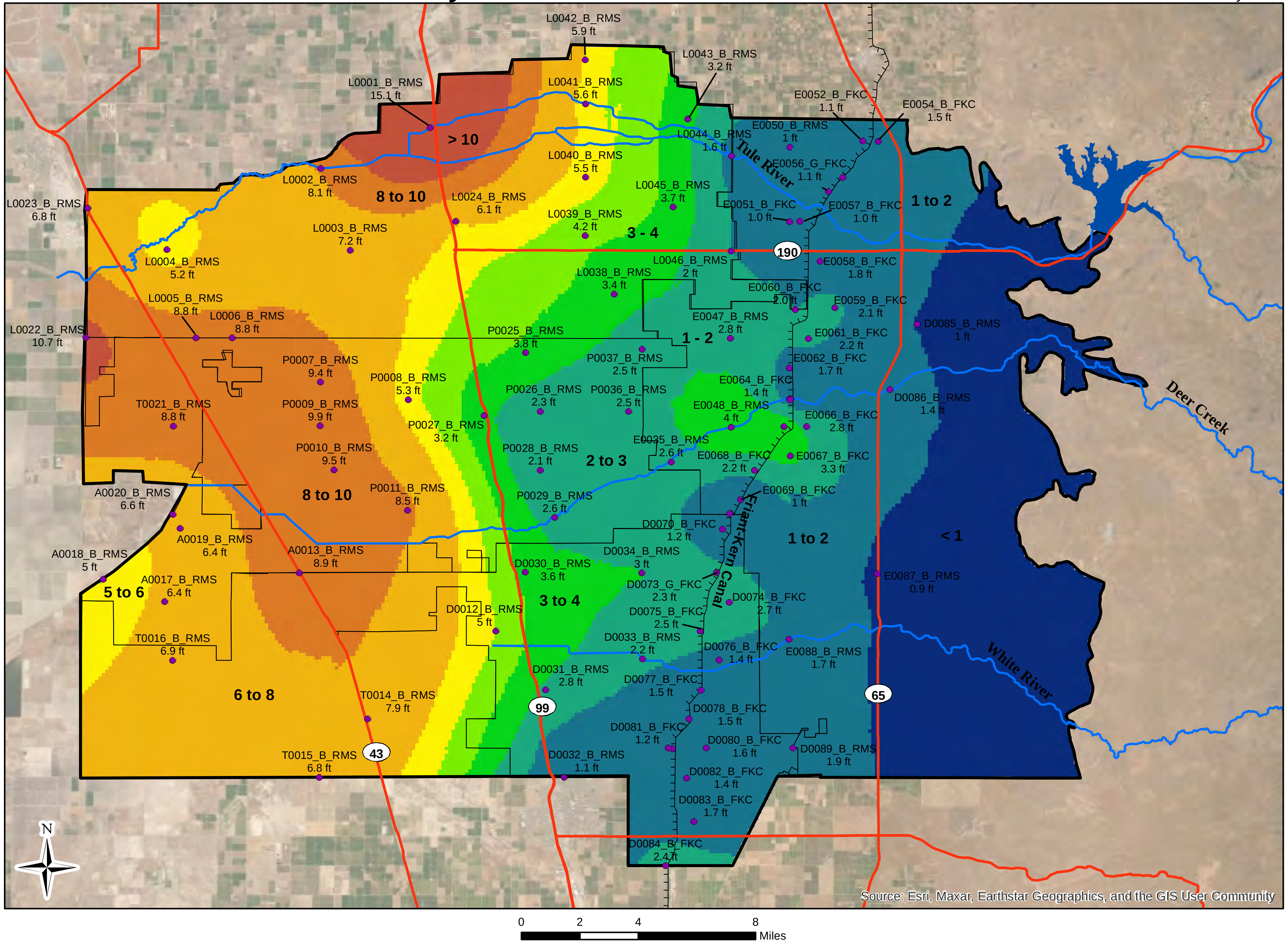
Thomas Harder & Co.
Groundwater Consulting

Gravity-Driven Water Conveyance Infrastructure

Figure 6

Tule Subbasin Technical Advisory Committee

July 2022



Source: Esri, Maxar, Earthstar Geographics, and the GIS User Community

NAD 83 State Plane Zone 4

Thomas Harder & Co.
Groundwater Consulting

DWR Comments - Subsidence in the Tule Subbasin

Map Features

Minimum Threshold (ft)

- 🟦 < 1
- 🟦 1 to 2
- 🟩 2 to 3
- 🟩 3 to 4
- 🟩 4 to 5
- 🟨 5 to 6
- 🟧 6 to 8
- 🟧 8 to 10
- 🟥 > 10
- ● Minimum Threshold at RMS (ft)
- State Highway
- Friant-Kern Canal
- Major Hydrologic Feature
- ☐ GSA Boundary
- ☐ Subbasin Boundary

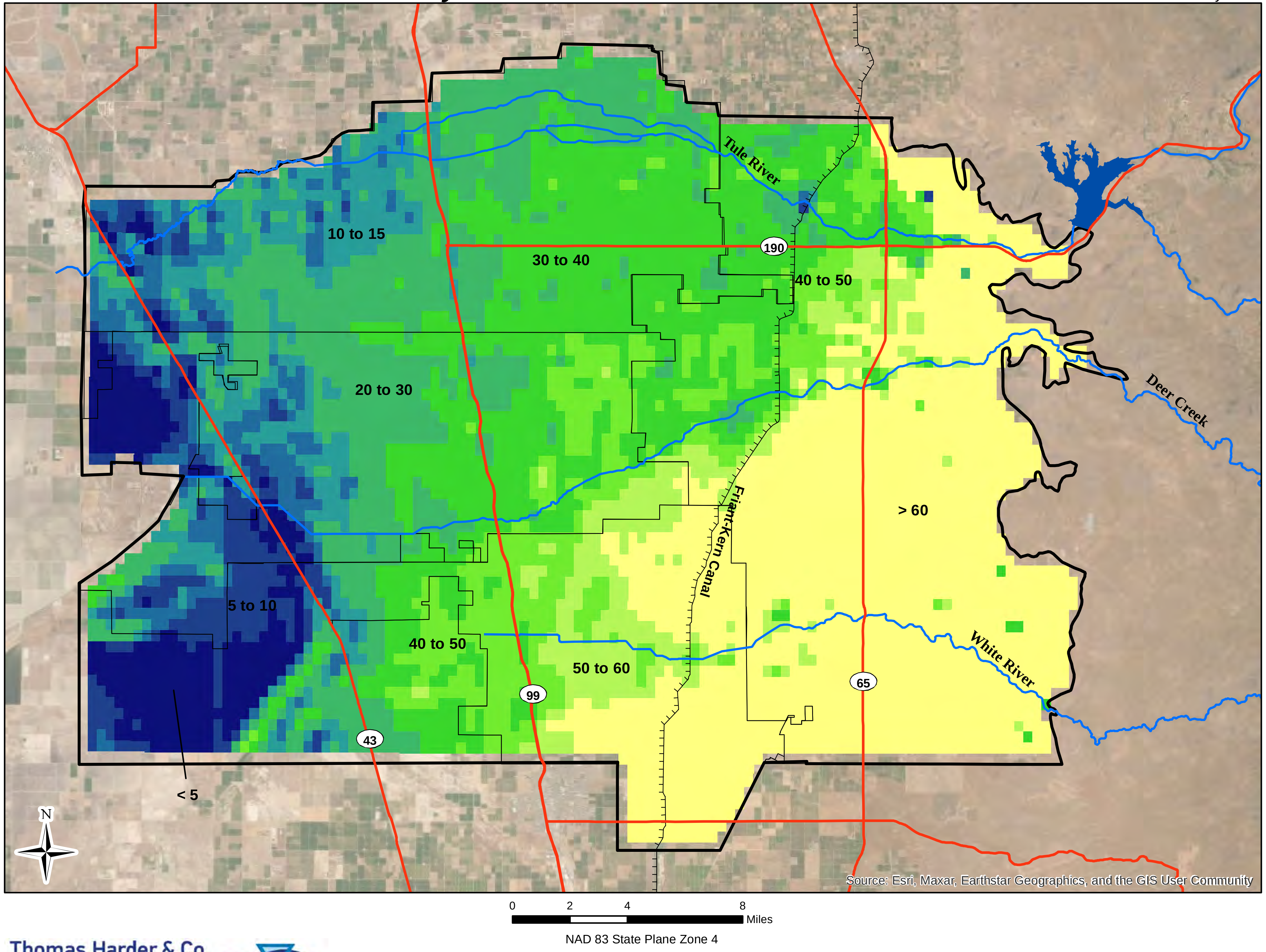
Minimum Threshold - Subsidence

Figure 7

DWR Comments - Subsidence in the Tule Subbasin

Tule Subbasin Technical Advisory Committee

July 2022



Source: Esri, Maxar, Earthstar Geographics, and the GIS User Community

Note: This map shows estimated land surface slope in 2020 based on the USGS DEM and 2020 benchmark elevations.

Thomas Harder & Co.
Groundwater Consulting

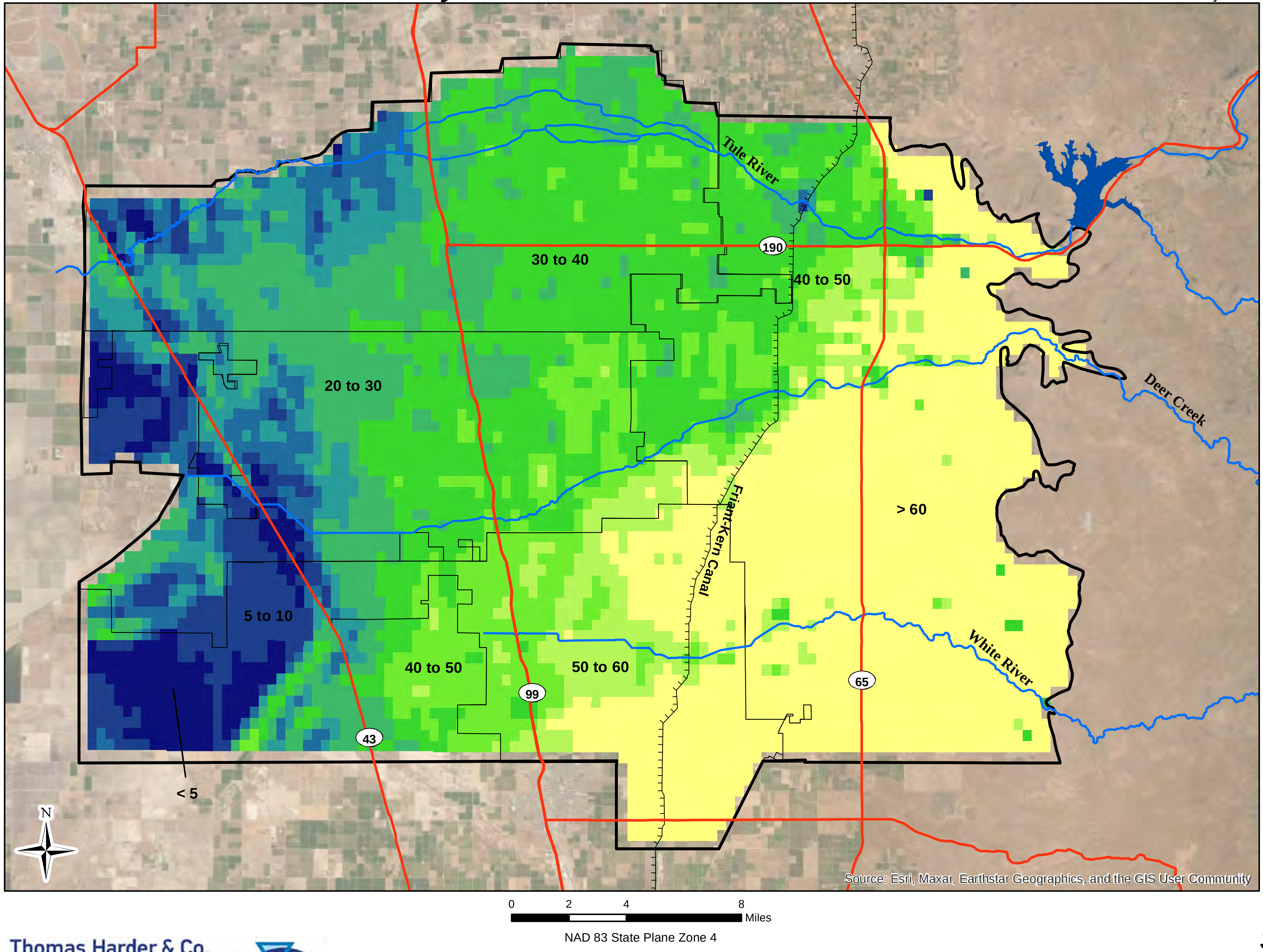
Estimated 2020 Land Surface Slope

Figure 8

DWR Comments -
Subsidence in the
Tule Subbasin

Tule Subbasin Technical Advisory Committee

July 2022



Source: Esri, Maxar, Earthstar Geographics, and the GIS User Community

Note: This map shows predicted land surface slope if subsidence reaches minimum thresholds.

Thomas Harder & Co.
Groundwater Consulting

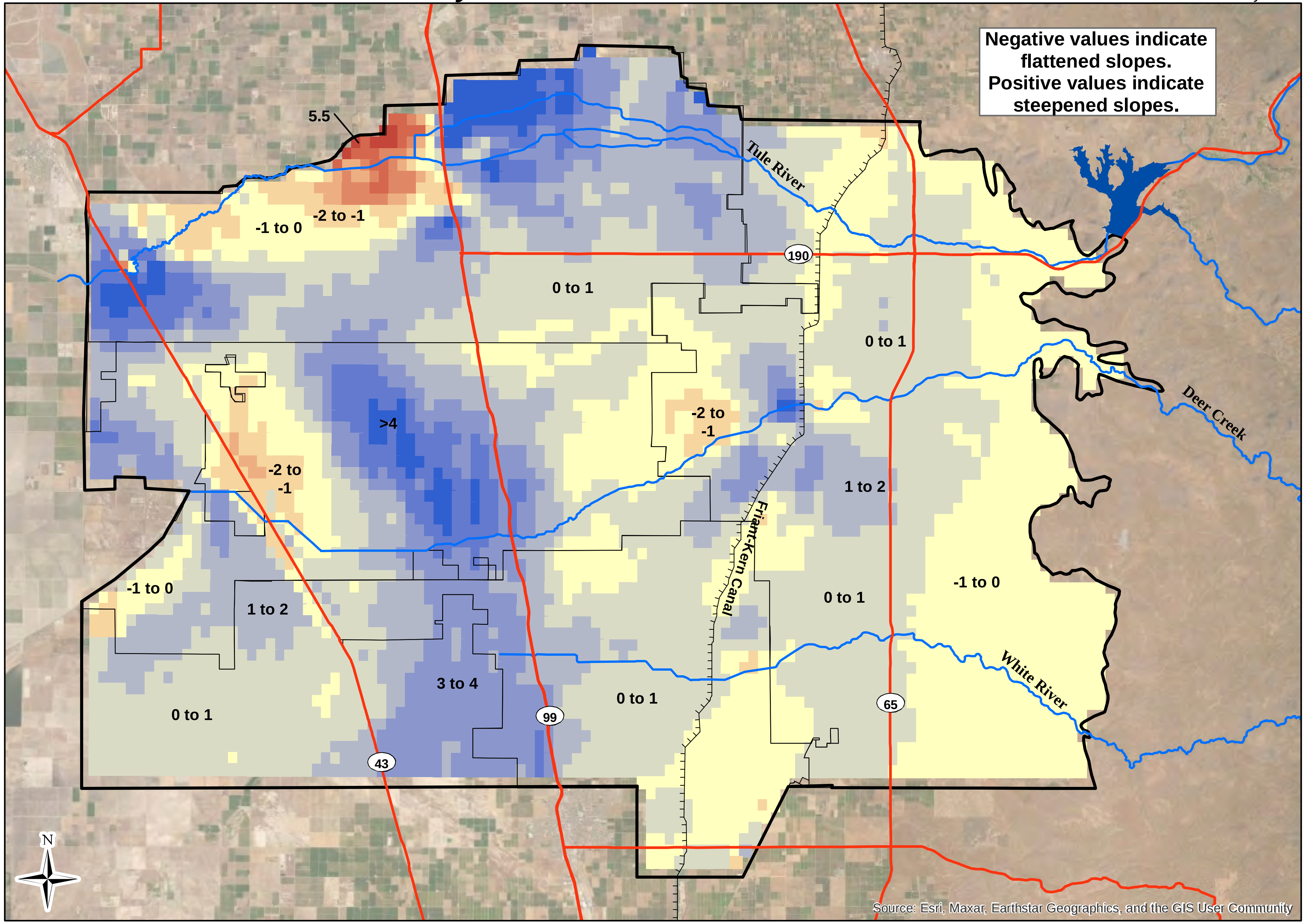
Estimated Land Surface Slope at Subsidence Minimum Thresholds

Figure 9

DWR Comments - Subsidence in the Tule Subbasin

Tule Subbasin Technical Advisory Committee

July 2022



Negative values indicate flattened slopes. Positive values indicate steepened slopes.

Source: Esri, Maxar, Earthstar Geographics, and the GIS User Community

0 2 4 8 Miles

NAD 83 State Plane Zone 4

Map Features

Change in Slope (ft per mile)

- 🟥 < -5
- 🟥 -5 to -4
- 🟧 -4 to -3
- 🟧 -3 to 2
- 🟧 -2 to -1
- 🟨 -1 to 0
- ⬜ 0 to 1
- 🟦 1 to 2
- 🟦 2 to 3
- 🟦 3 to 4
- 🟦 > 4
- — State Highway
- ┼┼┼ Friant-Kern Canal
- — Major Hydrologic Feature
- ☐ GSA Boundary
- ☐ Subbasin Boundary

Note: This map shows estimated change in land surface slope at the subsidence minimum thresholds relative to 2020 conditions.

Thomas Harder & Co.
Groundwater Consulting

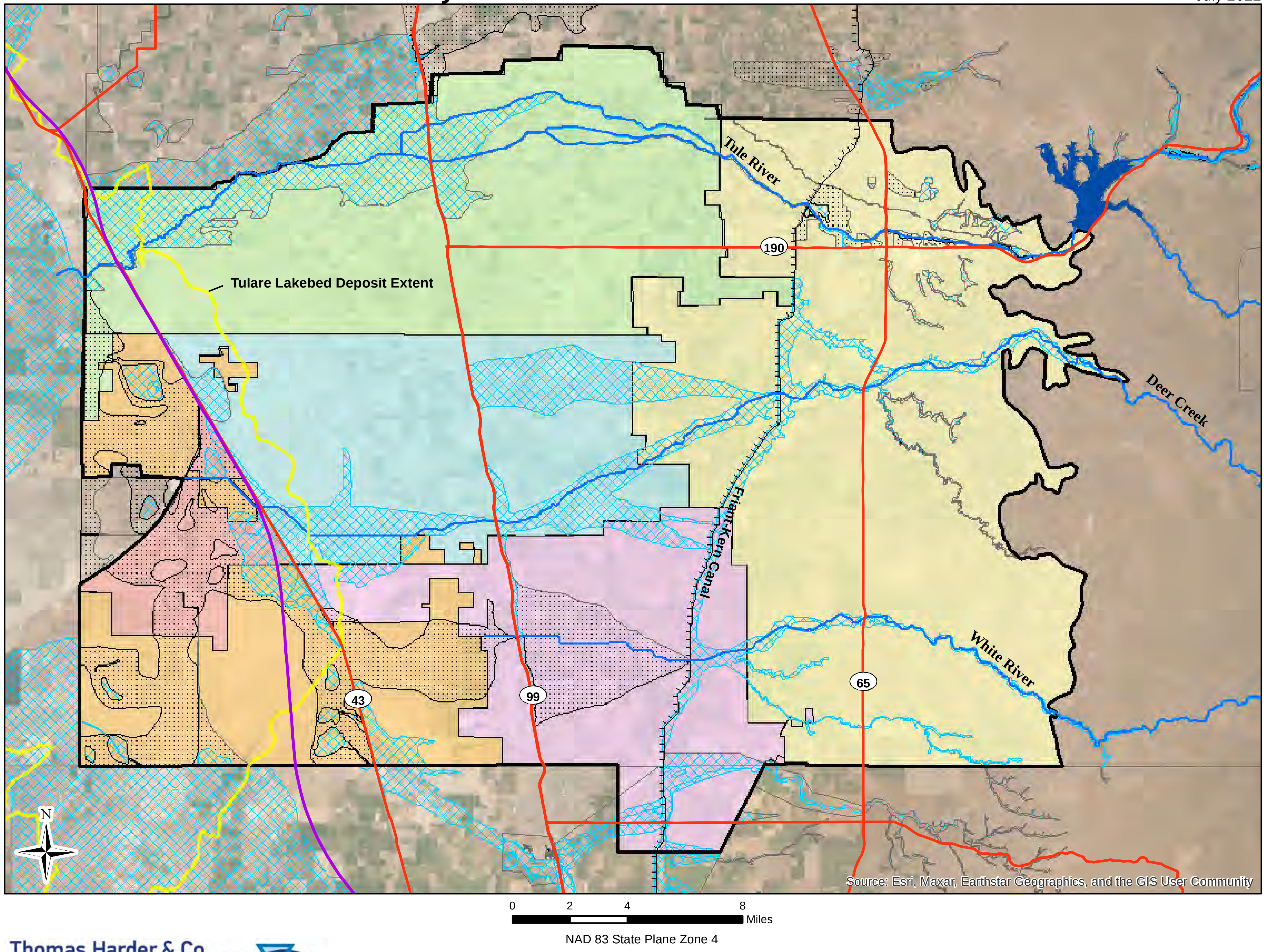
Estimated Change in Land Surface Slope

Figure 10

DWR Comments - Subsidence in the Tule Subbasin

Tule Subbasin Technical Advisory Committee

July 2022



Map Features

Simplified FEMA Flood Hazard Area*

- ▨ 1% Annual Chance Flood Area
- ░ 0.2% Annual Chance Flood Area
- ☐ Outside 0.2% Chance Flood Area
- ☐ Tulare Lakebed Deposit Extent
- — California High Speed Rail
- — State Highway
- ┬┬┬ Friant-Kern Canal
- — Major Hydrologic Feature
- 🟥 Alpaugh GSA
- 🟪 Delano-Earlimart I.D. GSA
- 🟨 Eastern Tule GSA
- 🟩 Lower Tule River I.D. GSA
- 🟦 Pixley I.D. GSA
- 🟧 Tri-County Water Authority GSA
- ☐ Subbasin Boundary

*Simplified data shown for illustrative purposes only. Not official National Flood Insurance Program (NFIP) reference.

Data modified from County Federal Emergency Management Agency (FEMA) maps.
https://www.fema.gov/flood-maps/national-flood-hazard-layer

Lake Deposits from California Geological Survey
Geologic Atlas of California Map No. 002
1:250,000 scale, Compiled by A.R. Smith, 1964
and Geologic Atlas of California Map No. 005,
1:250,000 scale, Compiled by: R.A. Matthews and J.L. Burnett

Thomas Harder & Co.
Groundwater Consulting

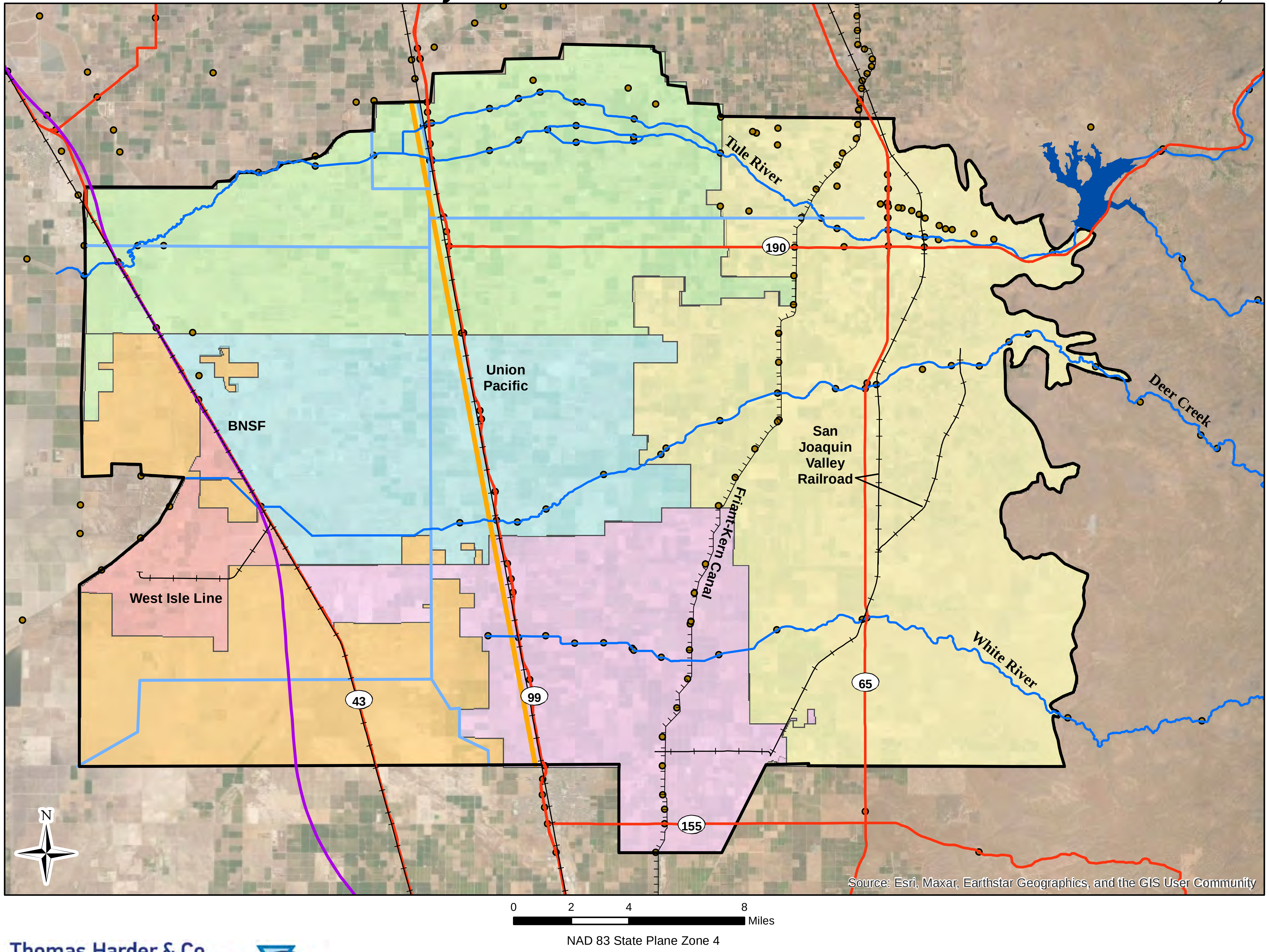
Simplified FEMA Flood Hazard Areas

Figure 11

DWR Comments - Subsidence in the Tule Subbasin

Tule Subbasin Technical Advisory Committee

July 2022



Map Features

- ● Local Bridge
- ┼ Railroad
- ━ California High Speed Rail
- ━ Gas Transmission Pipeline
- ━ Hazardous Liquid Pipeline
- ━ State Highway
- ┼┼┼ Friant-Kern Canal
- ━ Major Hydrologic Feature
- 🟥 Alpaugh GSA
- 🟪 Delano-Earlimart I.D. GSA
- 🟨 Eastern Tule GSA
- 🟩 Lower Tule River I.D. GSA
- 🟦 Pixley I.D. GSA
- 🟧 Tri-County Water Authority GSA
- ☐ Subbasin Boundary

Railroads from Caltrans.

Bridges from the US Department of Transportation, National Bridge Inventory.

Pipelines from the National Pipeline Mapping System (NPMS). Data shown for illustrative purposes only. https://pvnpms.phmsa.dot.gov/PublicViewer/

Thomas Harder & Co.
Groundwater Consulting

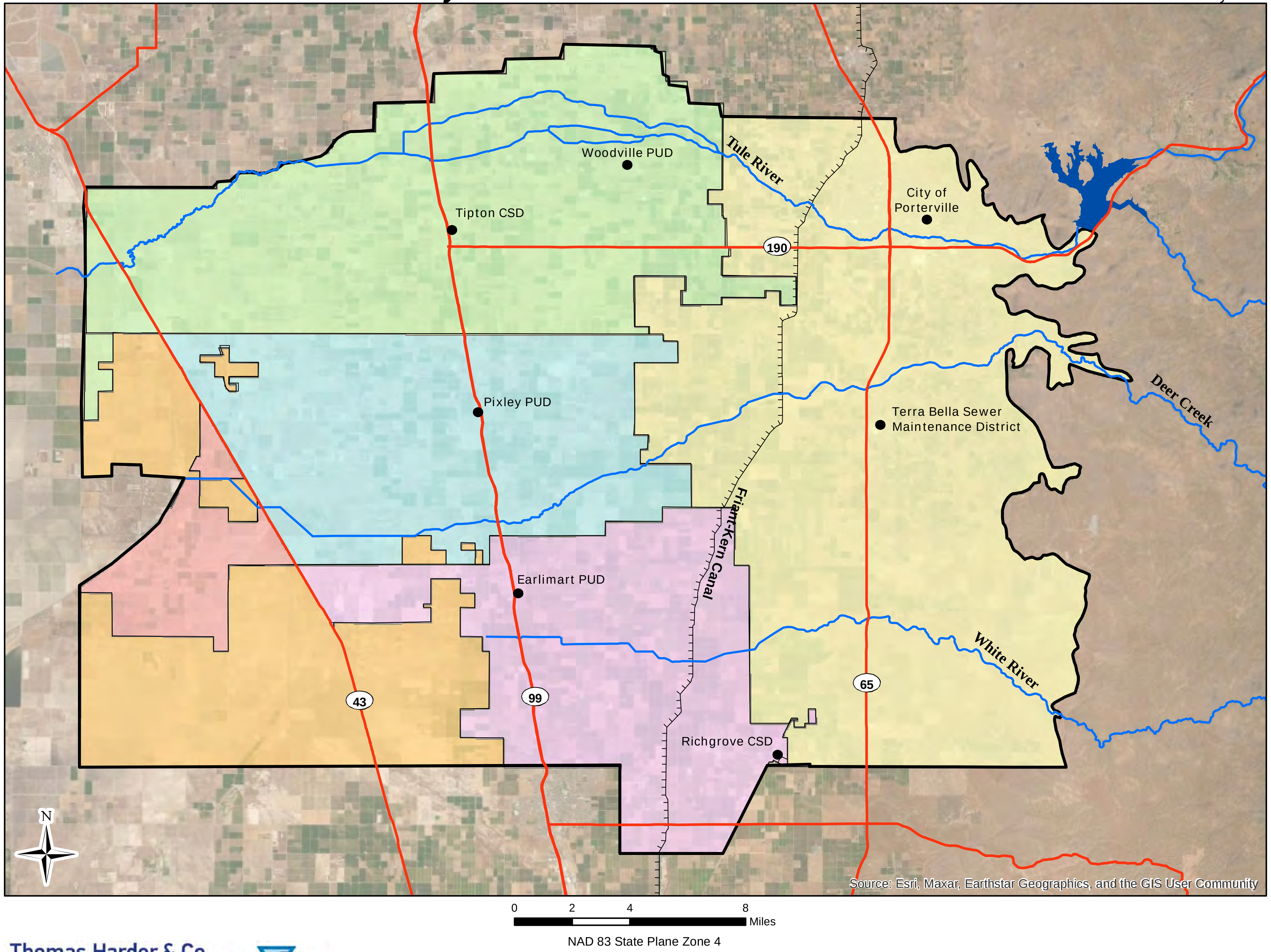
State Highways, Railroads, Pipelines, and Bridges

Figure 12

Tule Subbasin Technical Advisory Committee

July 2022

DWR Comments - Subsidence in the Tule Subbasin



Source: Esri, Maxar, Earthstar Geographics, and the GIS User Community

NAD 83 State Plane Zone 4

Map Features

- ● City or Community with Wastewater Collection
- — State Highway
- ┬┬┬┬ Friant-Kern Canal
- — Major Hydrologic Feature
- 🟥 Alpaugh GSA
- 🟪 Delano-Earlimart I.D. GSA
- 🟨 Eastern Tule GSA
- 🟩 Lower Tule River I.D. GSA
- 🟦 Pixley I.D. GSA
- 🟧 Tri-County Water Authority GSA
- ☐ Subbasin Boundary

Wastewater Collection

Thomas Harder & Co.
Groundwater Consulting

Figure 13

MITIGATION PROGRAM FRAMEWORK
COORDINATION AGREEMENT ATTACHMENT 7
Framework for GSA Mitigation Programs to Address Groundwater Levels, Land Subsidence and Groundwater Quality Impacts

Introduction

Sustainable management criteria identified in each of the Tule Subbasin Groundwater Sustainability Agencies' (GSAs) Groundwater Sustainability Plans (GSPs) have been developed to address significant and unreasonable impacts to agricultural, municipal, and industrial beneficial uses of groundwater. However, analysis based on available data suggests that numerous shallow domestic wells and potentially other wells may be impacted during the Sustainable Groundwater Management Act (SGMA) GSP implementation period between 2020 and 2040 as a result of continued lowering of groundwater levels during this period. Wells, land use, property, and infrastructure may also be impacted from land subsidence and changes in groundwater quality during this period.

The Tule Subbasin GSAs agree to each individually implement a Mitigation Program (Program) as needed to offset impacts associated with GSP-allowed activities, subject to the following framework and subject to the schedule provided herein. The goal of this framework is to establish a standard for mitigation programs to be implemented by each GSA for the purpose of mitigating anticipated impacts to beneficial uses to a level that avoids the occurrence of an Undesirable Result.

Each Mitigation Program may be extended or revised based on groundwater conditions in the future.

Mitigation Program Framework

The Subbasin has been in overdraft for many years, resulting in a significant lowering of regional and local groundwater levels. The GSPs are designed for the Subbasin to reach sustainability by 2040 and beyond. However, until sustainability is reached, some level of continued groundwater level decline and land subsidence is expected in areas of the Subbasin while the GSAs are in the process of implementing projects and management actions to achieve sustainability by 2040. The purpose of the GSAs' Mitigation Programs is to mitigate those wells, critical infrastructure, and land uses that are adversely affected by declining groundwater levels, land subsidence, and changes to groundwater quality while the GSAs reach sustainability.

Each GSA shall include a Program as a project or management action identified in that GSA's GSP, describing the following elements:

a) Identification of Impacts to be Addressed by Mitigation Program

Each Tule Subbasin GSA will adopt and implement a Mitigation Program to identify the specific needs for mitigation caused by pumping within the GSA's boundaries. Each GSA Mitigation

Program will separately identify the impacts to beneficial uses that the Program is intended to address. Each GSA Mitigation Program must provide a claim process to address impacts to (i) domestic and municipal wells, (ii) agricultural wells, and (iii) critical infrastructure. Decisions to include or exclude impacted users from participation in a GSA's Mitigation Program shall be supported by appropriate written technical data and analysis.

b) Process

For claims of impact to wells related to groundwater level declines, the process to be adopted by each GSA's Mitigation Program may include:

1) an application process by the well owner;
2) data collection by the GSA to verify the claim;
3) identification of suitable mitigation; and/or
4) response to said affected user.

For claims of impact to land uses from land subsidence, the process may include:

1) an application process by the affected party;
2) data collection by the GSA to verify the claim;
3) identification of suitable mitigation; and/or
4) coordination, as necessary, with said affected parties to implement the mitigation.

For claims of impact to groundwater quality that is attributable to pumping allowed by a GSA/GSP, the process may include:

1) an application process by the affected party;
2) data collection by the GSA to verify the claim;
3) identification of suitable mitigation; and/or
4) coordination, as necessary, with said affected parties to implement the mitigation.

SGMA requires GSAs and GSPs to measure sustainability from 2015 forward. As a result, GSAs do not necessarily need to provide mitigation for impacts that occurred prior to January 1, 2015.

For those claims that are shown not to be related to GSP-/GSA-approved or authorized activities, the GSA will, to the extent possible, provide assistance to the affected party to identify programs for addressing their issue.

c) *Investigation*

Once a claim of adverse impact has been made to a GSA, whether it be for well, specific land use, critical infrastructure or groundwater quality issue(s), the GSA will investigate the claim.

d) *Qualifications for Mitigation*

GSAs may determine whether to provide full or partial mitigation based on a user's compliance with the GSA's GSP, Rules & Regulations, and other laws or regulations. For example, a user whose own pumping has caused or contributed to overdraft or damage to their own well may not qualify for mitigation under the Program. Further, mitigation will be applied only to those claims that are shown to be attributable to GSP-/GSA-approved or authorized activities. Each GSA's Program will also address how claims that a GSA determines are caused by pumping outside the GSA's boundaries will be addressed.

e) *Mitigation*

Once a claim of impact has been confirmed to be due to GSP-/GSA-approved or authorized activities, the GSA will identify suitable mitigation to alleviate the impact.

For groundwater level impacts, this could be any of the following:

1) Deepening the well;
2) Constructing a new well;
3) Modifying pump equipment;
4) Providing temporary or permanent replacement water;
5) Coordinating consolidation of the domestic well owner with existing water systems; or
6) With the consent of the affected user, providing other acceptable means of mitigation.

For land use impacts, this could be any of the following:

1) Repair to canals, turnouts, stream channels, water delivery pipelines, and basins;
2) Repair to damaged wells;
3) Addressing flood control;
4) Addressing other damaged infrastructure; or
5) With the consent of the affected user, providing other acceptable means of mitigation.

For groundwater quality impacts (due to groundwater management/actions), this could be any of the following:

1) Adjusting groundwater pumping locations, rates, or schedules;
2) Modifying project operations;
3) Providing temporary or permanent replacement water;
4) Coordinating consolidation with existing water systems; or
5) With the consent of the affected user, providing other acceptable means of mitigation.

Various factors may reflect the proper mitigation methods for the specific issue. For example, age, location, financial impact to the beneficial user as a result of mitigation, and the beneficial user may reflect which mitigation measures are chosen by a particular GSA.

f) *Outreach*

Public outreach and education will be separately performed during development of the Mitigation Program and prior to implementation by each GSA.

Prior to implementation, extensive outreach will be needed to notify landowners of each GSA's Program requirements and how they can apply for assistance. Outreach may need to be performed in multiple languages as appropriate for each particular GSA. Outreach methods could include workshops, mailings, flyers, website postings, Board meeting announcements, etc.

g) Program Adoption Schedule

Each GSA will formulate and implement a mitigation claims process for domestic and municipal use impacts by December 31, 2022 and complete all other aspects of the Mitigation Program by June 30, 2023. During Program development, the GSAs will conduct community outreach and refer landowners and others to available local programs as well as other resources and funding programs from the County, State, or non-profit organizations, including the Tule Basin Water Foundation.

h) Mitigation Program Funding Source

Each GSA will develop a funding mechanism for the Program, which is dependent on the specific GSA needs for specific expected impacted wells, critical infrastructure, and land uses within each GSA. Funding is anticipated to be available for each GSA's Mitigation Program through implementation of assessments, fees, charges, and penalties. In addition, the GSAs will explore grant funding. The State has many existing grant programs for community water systems and well construction funding. County, state, and federal assistance will be needed to successfully implement the respective Mitigation Programs. Each GSA may, separately or in coordination with other GSAs, also work with local NGOs that may be able to provide assistance or seek grant monies to help fund the Program. GSAs may act individually or collectively to address and fund mitigation measures.

Appendix B: Kern – Tulare Water District Draft GSP

Amended

Groundwater Sustainability Plan

July 14, 2022

TABLE OF CONTENTS

CHAPTER 1. ADMINISTRATIVE INFORMATION

1.1 General Information *(Reg. § 354.4)*

1.1.1 Purpose of GSP

The 2014 Sustainable Groundwater Management Act (SGMA) requires prioritized California groundwater basins to be managed by a Groundwater Sustainability Agency (GSA) and for "critically overdrafted" basins (including Kern and Tule subbasins) to adopt a Groundwater Sustainability Plan (GSP) by January 31, 2020 and achieve sustainability by January 31, 2040.

SGMA requires the following list of "undesirable results" that are significant and unreasonable to be addressed in a GSP:

1. Chronic lowering of groundwater levels
2. Reduction of groundwater storage
3. Land subsidence that substantially interferes with land uses
4. Depletions of interconnected surface water
5. Seawater intrusion
6. Degradation of water quality

As part of SGMA, GSAs in the same subbasin must prepare a coordination agreement to ensure that all GSPs in the subbasin utilize the same methodologies for data collection and evaluation of the following:

1. Groundwater Elevation Data
2. Groundwater Extraction Data
3. Surface Water Supply
4. Total Water Use
5. Change in Groundwater Storage
6. Water Budget
7. Sustainable Yield

Kern-Tulare Water District (District or KTWD) has prepared this Groundwater Sustainability Plan (Plan) to assess the District's groundwater conditions and to provide monitoring and management actions to achieve sustainability that comply with SGMA. This Plan has been prepared using applicable regulations described in the California Code of Regulations, Title 23, Division 2, Chapter 1.5, Subchapter 2, Article 5 and the Best Management Practices provided by the California Department of Water Resources (DWR). As provided by Water Code Section 10720.5 (b), this report does not make any determination of water rights but is to document compliance by the District with SGMA[1]. The District understands that implementation of GSPs will require an initial period of significant data collection and confirmation of assumptions; therefore, the District will work collaboratively with adjacent agencies, including the

---

[1] Nothing in this Management Chapter or in the related Groundwater Sustainability Plan determines or alters surface water rights or groundwater rights under common law, any provision of law that determines or grants surface water rights, or otherwise. (See, California Water Code section 10720.5(b)). This Management Chapter and the related Groundwater Sustainability Plan shall be construed consistent with Section 2 of Article X of the California Constitution and nothing provided in this Chapter modifies rights or priorities to use or store groundwater except as expressly stated in California Water Code section 10720.5(a). The District reserves and retains all rights to the use of water to the extent provided by law.

Eastside Water Management Area, Cawelo Water District, Southern San Joaquin Municipal Utility District, and Eastern Tule GSA on changes to our GSPs as informed by the data.

1.1.2 Executive Summary

An executive summary of the Plan is included as Appendix 4.

1.2 Agency Information *(Reg. § 354.6)*

The District is located in both the Tule and Kern subbasins of the Tulare Lake Groundwater Basin. Landowners within the Tulare County portion of the District will be represented by the Eastern Tule GSA (ETGSA), of the Tule Subbasin, and governed by ETGSA's GSP. Landowners within the Kern County portion of the District will be represented by the Kern Groundwater Authority (KGA) GSA, of the Kern Subbasin and governed by KGA's GSP.

Agency Name: Kern Groundwater Authority GSA
Address: 1800 30th Street, Suite 280, Bakersfield, CA 93301
Plan Manager: Patty Poire
Phone: (661) 479-7171

Agency name: Eastern Tule GSA
Address: 881 W. Morton Avenue, Suite D, Porterville, CA
Plan Manager: Rogelio Caudillo
Phone: (559) 791-8880

1.2.1 Chapter Agency

The KGA has given each district within the KGA the responsibility to prepare an individual chapter to establish in-District management plans. The ETGSA has also defined KTWD as a separate management area within the ETGSA GSP. KTWD is a public agency organized in accordance with California Water District Law, Division 13 of the California Water Code (Commencing with Section 34000). The District was formed on March 5, 1974 to provide agricultural water within its service area. On January 1, 2009 the District consolidated with Rag Gulch Water District, which was formed in 1954. There is a board of five elected members that govern the District. It is operated by General Manger, Steven Dalke who is tasked with implementing the District's activities including implementation of this Plan.

Agency Name: Kern-Tulare Water District
Address: 5001 California Ave. Suite 102, Bakersfield, CA 93309
Plan Manager: Steven C. Dalke, General Manager
Phone: 661-327-3132

1.2.2 GSA Organization and Structure

The following describes the organization and management structure of the Tule and Kern subbasins.

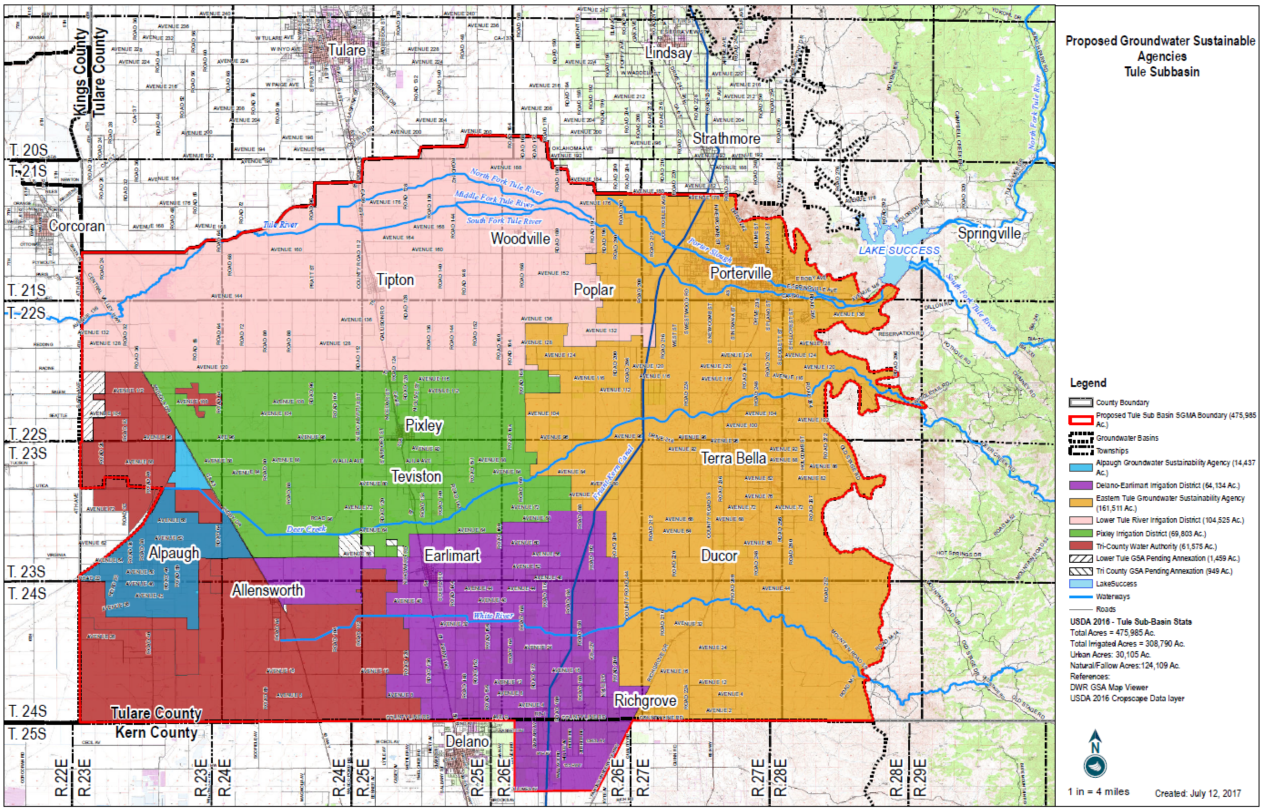
Tule Subbasin

The Tule Subbasin is divided into 6 GSAs, listed below, that have each developed individual GSPs:

1. Alpaugh GSA
2. Delano-Earlimart Irrigation District
3. Eastern Tule GSA
4. Lower Tule River Irrigation District
5. Pixley Irrigation District
6. Tri County Water Authority

Figure 1-1 identifies the locations of the GSAs and the extent of coverage throughout the Tule subbasin.

Figure 1-1 Tule Subbasin GSAs



An Agreement to develop and implement a Groundwater Sustainability Plan Coordination Agreement between GSAs within the Tule Subbasin was executed in September of 2015. The Agreement was amended in October of 2016 to include Kern-Tulare as part of the Eastern Tule GSA.

The GSAs agreed to form a Technical Advisory Committee (TAC) which meets monthly to facilitate the informational exchange within the subbasin (the District is represented by General Manager Steve Dalke). The meeting is attended by voting representatives from each GSA along with stakeholders from Tulare County and the general public. A coordination agreement is being prepared to coordinate the technical portions of GSPs required by SGMA.

Tom Harder from Thomas Harder and Co. was hired by the TAC to develop a hydrological conceptual model and water budget and to estimate the sustainable yield of the basin. Tom Harder and Co. also prepared the Tule Subbasin basin description and groundwater monitoring plan.

Eastern Tule GSA

KTWD is a participating district within the ETGSA which spans the entire eastern edge of the Tule Subbasin from the City of Porterville to the Kern/Tulare County line. A joint powers agreement was executed on December 6, 2016 forming the ETGSA and includes the 7 entities listed below:

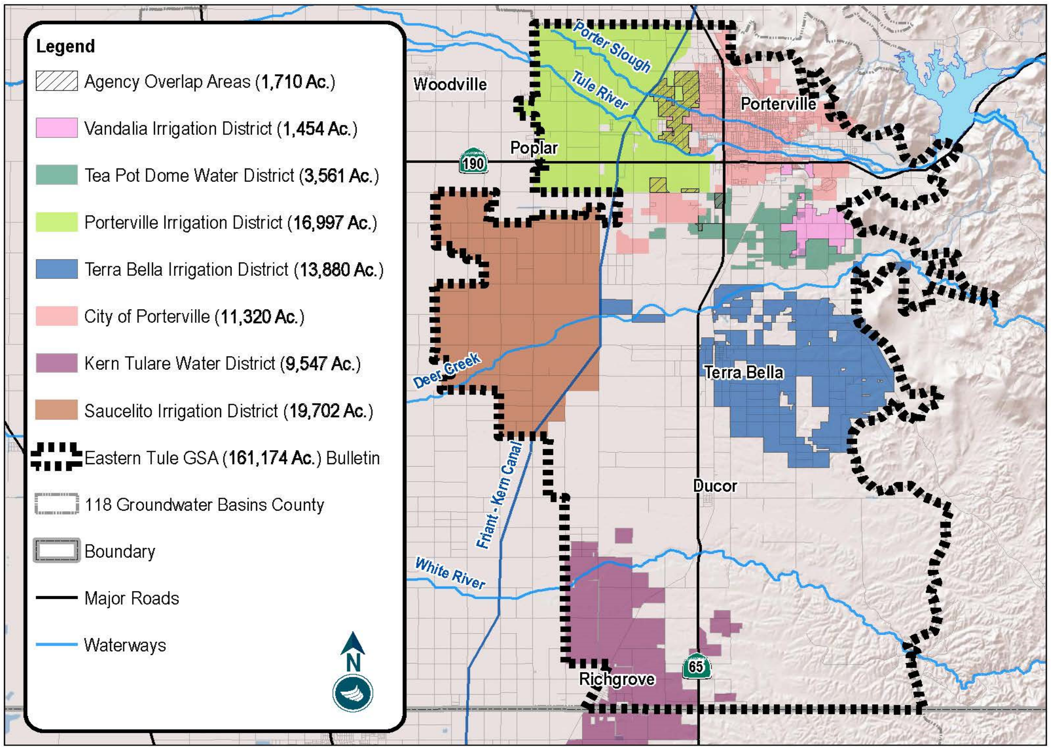
1. Porterville Irrigation District
2. Kern-Tulare Water District
3. Tea Pot Dome Irrigation District
4. Saucelito Irrigation District
5. Terra Bella Irrigation District
6. Vandalia Water District
7. City of Porterville

Figure 1-2 identifies the locations of each of the participating entities within the ETGSA. Within the ETGSA, KTWD is its own management area and will manage according to this Plan.

A Board of Directors has been established which meets every month. The Board of Directors consists of one member from each of the above entities (Director Curt Holmes is KTWD's representative on the Board) plus 2 representatives from the County of Tulare. Undistricted lands are represented by the County of Tulare.

An Executive Committee was formed of appointed staff members of each member agency. The District is represented by General Manager Steve Dalke for this committee. A Stakeholder Committee of groundwater users was formed to represent municipal, agricultural, and environmental interests. The committees meet at least once a month.

Figure 1-2 Eastern Tule GSA



Kern Subbasin

The Kern Subbasin includes 14 organized GSAs which have developed the following 6 independent GSPs:

1. Kern Groundwater Authority GSP (KGA GSP)
2. Buena Vista GSA GSP (BVGSA GSP)
3. Henry Miller Water District GSA GSP (HMWD GSA GSP)
4. Kern River GSA GSP (KRGSA GSP)
5. Olcese GSA GSP (OGSA GSP)
6. South of Kern River GSP (SOKR GSP)

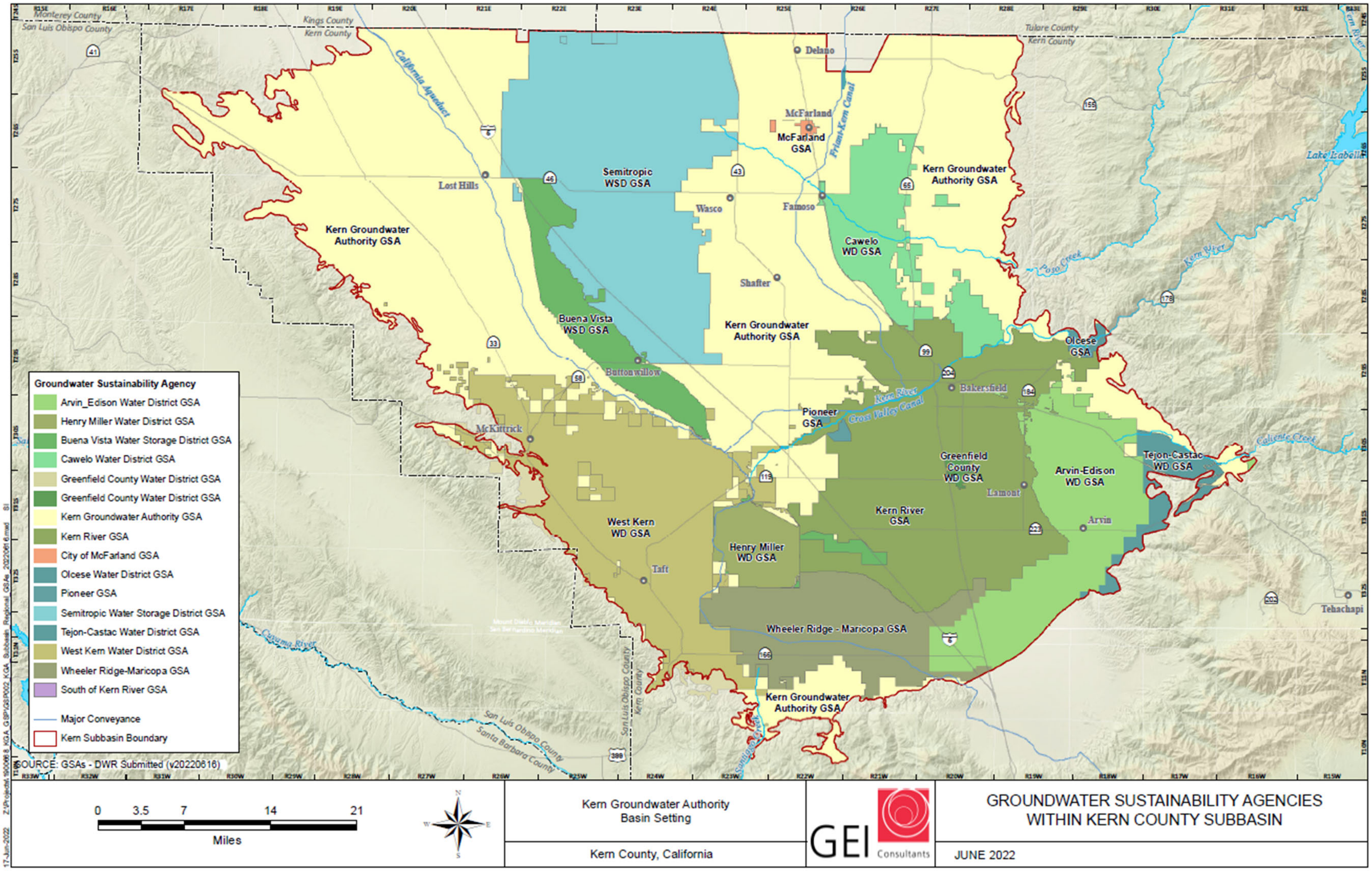
Table 1-1 indicates which GSAs have elected to prepare an independent GSP. The District is a participant in the Kern Groundwater Authority GSA.

Table 1-1: Groundwater Sustainability Agencies in Kern County Subbasin

GSA Name	*Independent GSP*	*GSP Name*
Buena Vista GSA	Yes	BVGSA GSP
Henry Miller Water District GSA	Yes	HMWD GSA GSP
Cawelo Water District GSA	No	KGA GSP
Kern Groundwater Authority GSA	Yes	KGA GSP
City of McFarland GSA	No	KGA GSP
Pioneer GSA	No	KGA GSP
Semitropic Water Storage District GSA	No	KGA GSP
West Kern Water District GSA	No	KGA GSP
Greenfield County Water District GSA	No	KRGSA GSP
Kern River GSA	Yes	KRGSA GSP
Olcese Water District GSA	Yes	OGSA GSP
Arvin-Edison Water Storage District GSA	Yes	SOKR GSP
Wheeler Ridge-Maricopa Water Storage District GSA	Yes	SOKR GSP
Tejon-Castac Water District GSA	Yes	SOKR GSP

Figure 1-3 identifies the locations of the GSAs and the extent of coverage throughout the Kern Subbasin.

Figure 1-3 Kern County Subbasin GSAs



Kern Groundwater Authority (KGA)

The Kern Groundwater Authority (KGA) provides local policy makers, stakeholders, and the public a forum to monitor, report and/or discuss groundwater activities and identify and address any local groundwater issues.

On April 26, 2017 the KGA (JPA) elected to become a GSA and was formed for the purpose of:

1. Coordinating groundwater management programs and activities;
2. Identifying and addressing issues pertaining to sustainable groundwater management; and
3. Estabishing a framework for local groundwater management

The 12 member agencies in the KGA are:

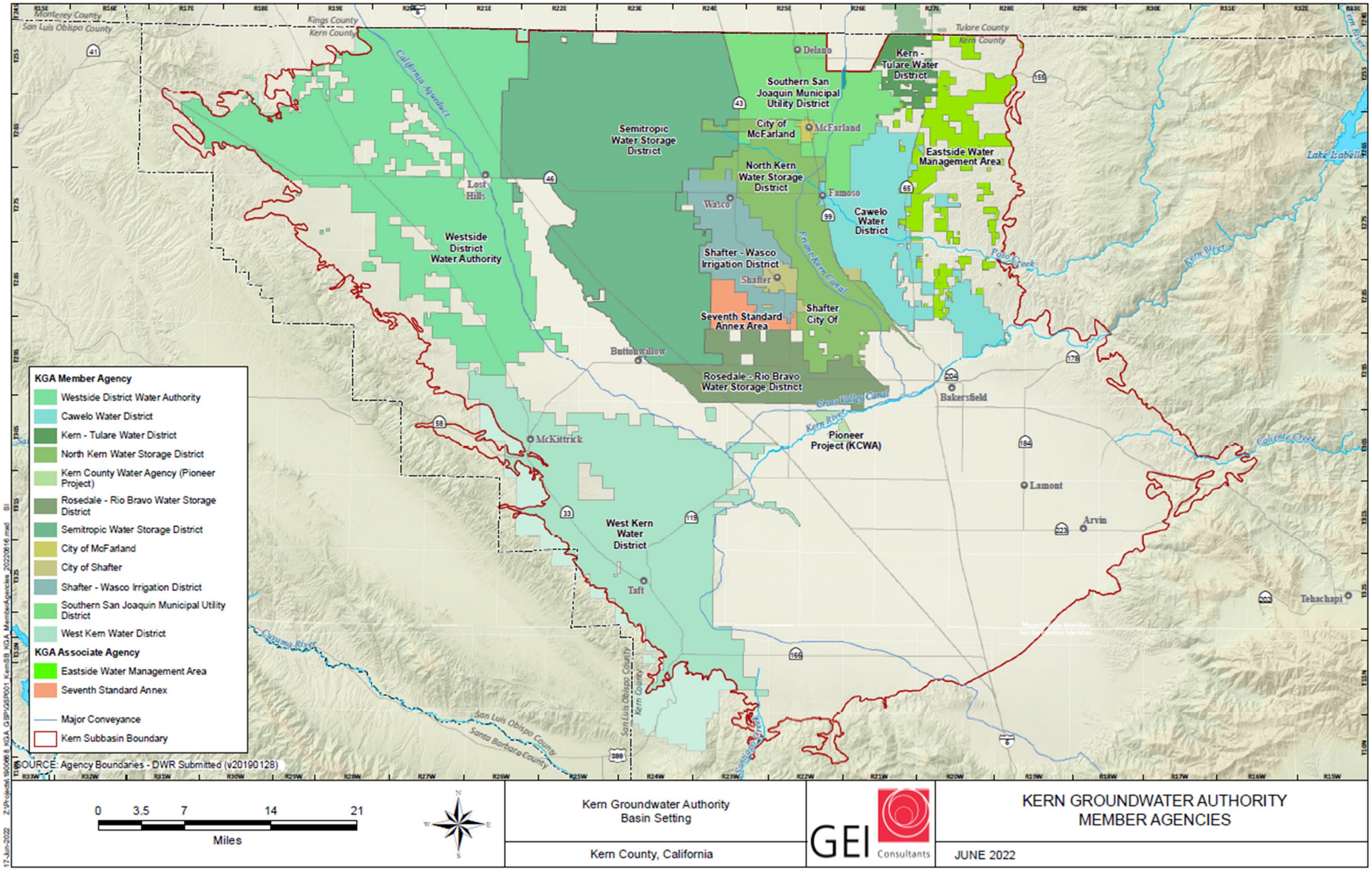
1. Cawelo Water District
2. City of Shafter
3. Kern County Water Agency – Pioneer Project
4. Kern-Tulare Water District
5. Kern Water Bank Authority
6. North Kern Water Storage District
7. Rosedale-Rio Bravo Water Storage District
8. Semitropic Water Storage District
9. Shafter-Wasco Irrigation District
10. Southern San Joaquin Municipal Utility District
11. West Kern Water District
12. Westside District Water Authority

The KGA is governed by a Board of Directors composed of directors from each of the General Members and meets monthly (Director Andrew Pandol is KTWD's representative on the Board). The KGA also includes a single associate member, the Eastside Water Management Area, who is a non-voting member of the KGA and represents non-districted lands outside of a KGA member agency boundary. Figure 1-4 identifies the locations of the member agencies and the associate member.

Special activity agreements have been executed to collect evapotranspiration data from Cal Poly Irrigation Training & Research Center; retain Todd Groundwater to prepare a Kern Subbasin groundwater model with peer review by Woodward & Curran; and for GEI Consultants, Inc. to develop overview components of a Groundwater Sustainability Plan for the KGA.

The evapotranspiration data will be used as part of the water budget required by DWR. The results of the groundwater model will be used to determine the sustainable yield and water balance. The data and model information will be a part of the required material for the GSP. The GSP will consist of an "Umbrella GSP," to describe the common sections for the subbasin, and a "Chapter GSP" for each of the participating members.

Figure 1-4 Kern Groundwater Authority Member Agencies



1.3 District Costs

In order to be a participating entity in the KGA GSA and ETGSA, the District shares the costs attributed to development of each of the GSPs. The District has also incurred in-house costs for District specific SGMA related efforts. Actual District costs from 2015 to 2018 and projected 2019 costs are shown in Table 1-2.

Table 1-2 District SGMA Costs

	J. Gillespie	*GEI*	*KGA GSA*	*ETGSA*	*Total*
2015	$0.00	$6,156.25	$0.00	$0.00	$6,156.25
2016	$3,600.00	$3,194.25	$0.00	$0.00	$6,794.25
2017	$1,650.00	$13,705.50	$15,294.89	$0.00	$30,650.39
2018	$0.00	$5,229.75	$31,797.85	$34,903.71	$71,931.31
***2019**	$0.00	$0.00	$69,970.99	$42,000.00	$111,970.99
	$5,250.00	$28,285.75	$117,063.73	$76,903.71	$227,503.19

*Based on GSA drafted budgets of projected 2019 costs.

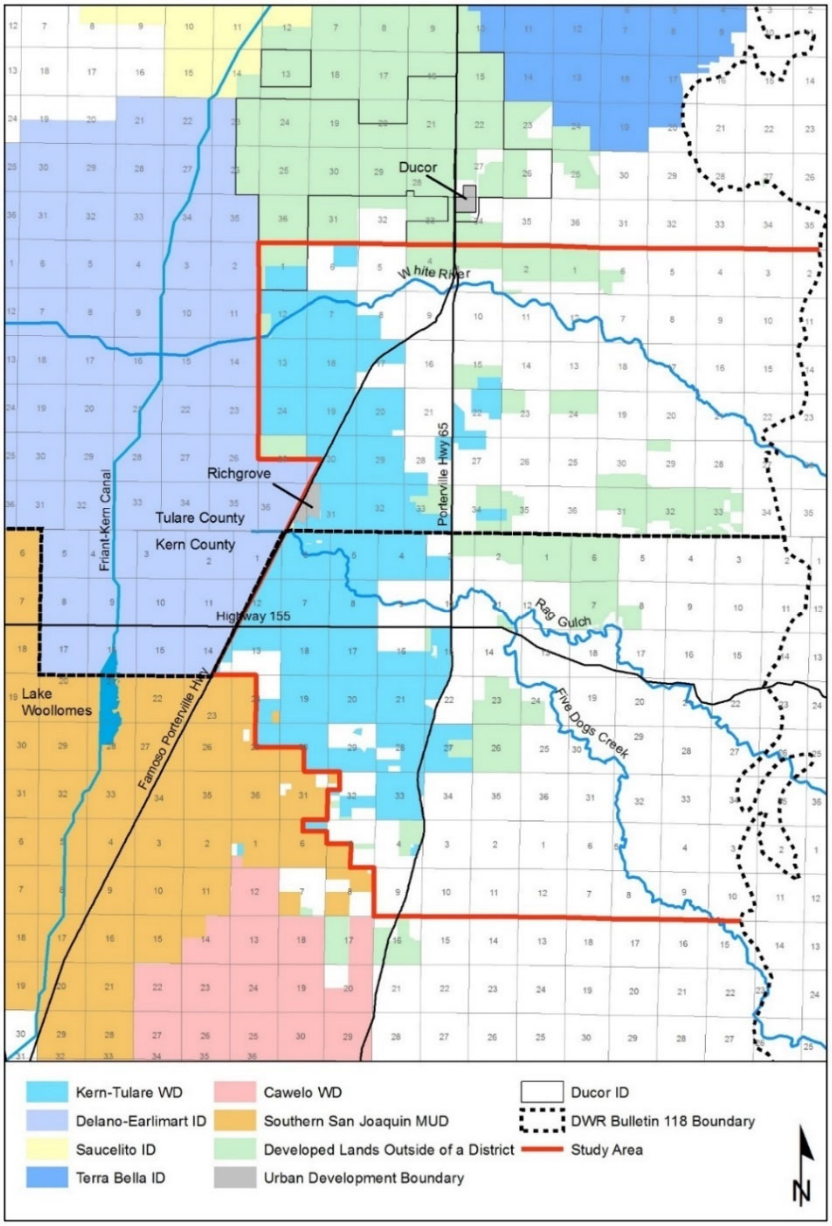
These direct expenses do not include extensive time spent by District staff in preparation of this plan. If the District were to implement all SGMA related projects, as described in Chapter 5, the total cost to the District would be approximately $26 million.

1.4 Description of Plan Area *(Reg. § 354.8)*

1.4.1 Geographic Areas Covered

The District is comprised of 20,140 acres located on the eastern side of the San Joaquin Valley in Kern and Tulare Counties, approximately 8 miles east of Delano and 27 miles north of Bakersfield. The study area as presented in Figure 1-5 indicates the location of the DWR Bulletin 118 boundaries, KTWD, neighboring water districts, and developed lands outside of a water district.

Figure 1-5 Study Area

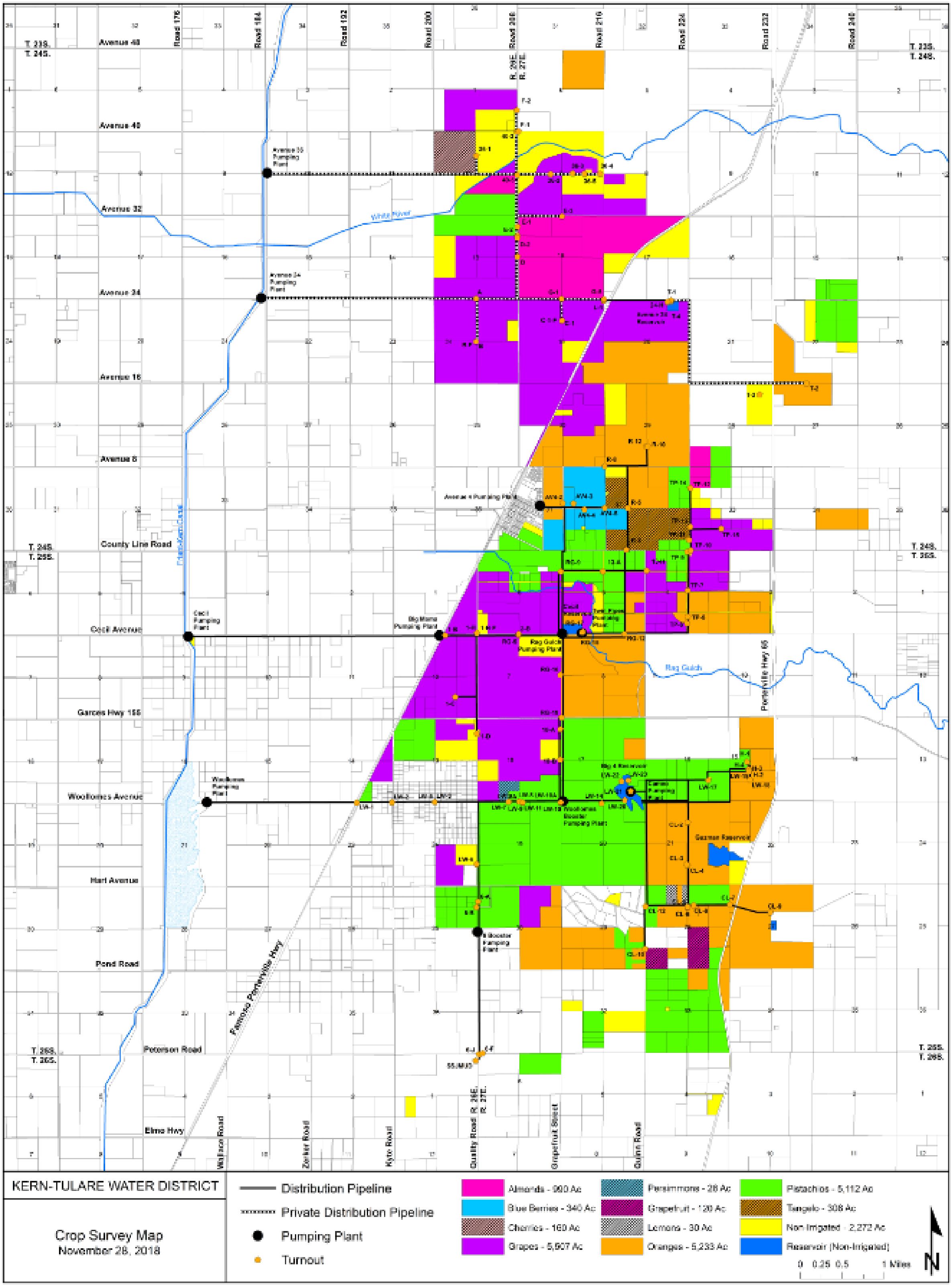


The study area was designated to include the undistricted lands immediately surrounding the District which may have an impact upon the District's groundwater levels. However, the Plan only provides monitoring and management actions to achieve sustainability within the District's management areas.

1.4.2 Plan Area Setting

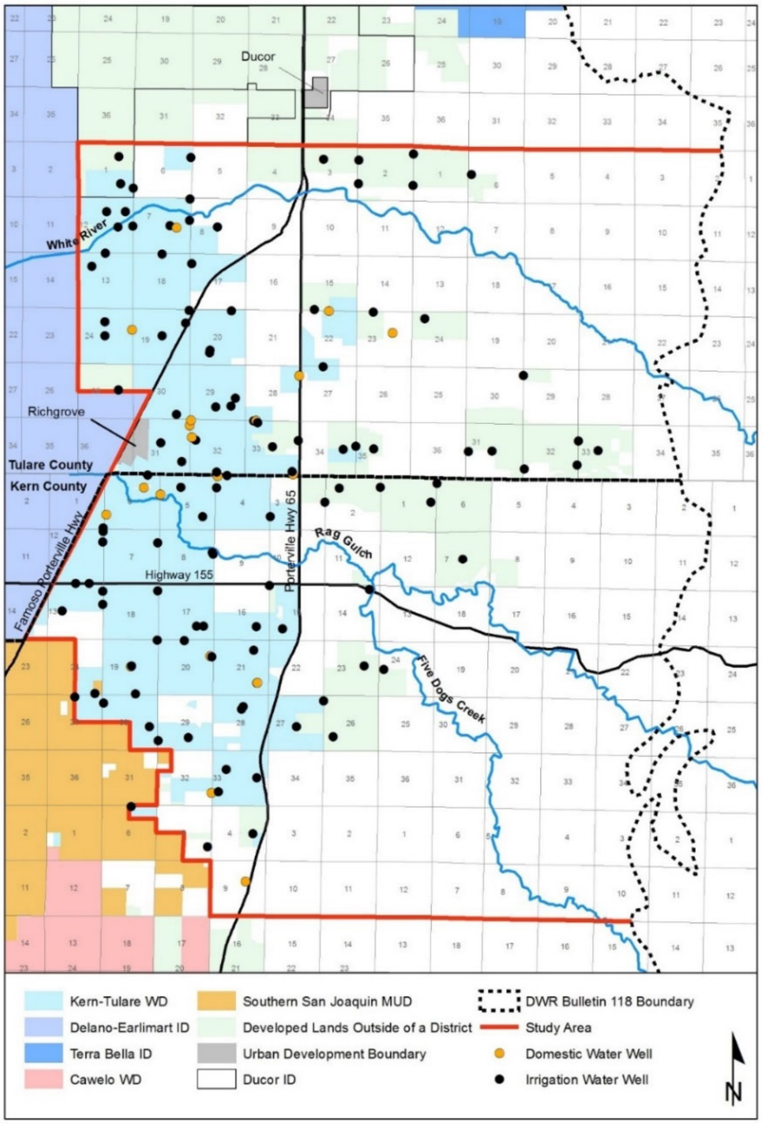
Existing land use within the District is predominately irrigated agriculture. The source of water within the District's service area is a combination of imported surface water and groundwater. A crop map indicating the agricultural land use within the District is presented as Figure 1-6. According to DWR's SGMA Data Viewer there are no tribal or Federal lands within the District's boundaries. There are about 50 acres within the District's non-service area owned by the County of Tulare as a solid waste disposal site that is exempt from District assessments and is currently undergoing detachment.

Figure 1-6 KTWD Crop Survey Map



A map indicating the location of all known active wells is presented in Figure 1-7. As shown in Figure 1-7, there are about 100 privately owned active wells within the District and 60 privately owned active wells adjacent to the District within the study area. The District is comprised of approximately 20,000 acres with a density of one well per 200 acres. There are approximately 10,000 developed acres to the east of the District within the study area with a density of one well per 160 developed acres.

Figure 1-7 Active Well Locations



1.4.3 Existing Monitoring and Management Programs

The California Legislature enacted Assembly Bill 3030 during the 1992 session, subsequently codified in Water Code section 10750, et seq. Water Code section 10753 states, in part, that: “Any local agency, whose service area includes a groundwater basin, or a portion of a groundwater basin, that is not subject to groundwater management pursuant to other provision of law or a court order, judgment, or decree, may, by ordinance, or by resolution if the local agency is not authorized to act by ordinance, adopt and implement a Groundwater Management Plan pursuant to this part within all or a portion of its service area." Water Code section 60224 empowers the District to take any action needed for protection and preservation of underlying groundwater supplies.

Since 2009, the California Statewide Groundwater Elevation Monitoring (CASGEM) Program, as developed and coordinated by the DWR, has tracked seasonal and long-term groundwater elevation trends in groundwater basins statewide in collaboration with local monitoring entities. The District has been a monitoring agency under this program since 2011.

In 2012, the District adopted an updated Groundwater Management Plan with the following objectives:

- Maintain or improve groundwater levels within the service territory;
- Control degradation of groundwater quality; and
- Limit land subsidence to the greatest extent possible.

Monitoring elements of the Groundwater Management Plan include:

- Semi-annual or semi-monthly monitoring of groundwater levels in wells within the service territory;
- Evaluation of available water quality data to assess areas of concern if necessary;
- Evaluation of available subsidence data to address areas of concern if necessary; and
- Preparation of monitoring reports once every 5 years to present the results of the monitoring program.

The District also implemented a DWR approved groundwater monitoring plan in 2015 and updated the plan in 2018 to better monitor the multiple aquifers that underlie the District. The District intends to use the existing management and monitoring programs to help carry out the efforts of this Plan and does not expect the programs to limit operational flexibility within the Plan area.

Conjunctive Use Programs

Water users within the District receive surface water imported by the District from various sources and supplement additional irrigation deliveries with groundwater. The District also participates in three banking programs within the Kern subbasin and has recharged over 300,000 acre-feet to be extracted when needed. Information about the District's source of imported water supplies and groundwater banking efforts can be found in Chapter 2 Section 2.2 and in Appendix 3.

1.4.4 General Plans in Plan Area

General plans and other land use plans governing the basin (including permitting for new or replacement wells) are developed and administered by the County of Kern and the County of Tulare. The Tulare County General Plan 2030 update was completed in August 2012. The Kern County General Plan is undergoing a 2040 update which is expected to be adopted in 2019. The implementation of the KTWD GSP is not anticipated to affect the Kern or Tulare County General Plan seeing as in both counties the land within the District is zoned as exclusive agriculture.

The Kern County Environmental Health Department issues permits for the construction and destruction or abandonment of wells within the Kern Subbasin. The ordinance has a number of components related to seals, water quality testing, destruction standards, proximity, and inspections that serve to protect groundwater quality. The Tulare County Environmental Health Division oversees the installation of water wells and distributes permits for the Tule Subbasin and contains similar regulations in the ordinance as Kern County.

1.4.5 Other Plan Elements from CWC *§ 10727.4*

- Control of saline water intrusion

Although seawater intrusion is not an issue for the District, migration of saline water in the Santa Margarita Formation (discussed in further detail in Chapter 2. Basin Setting) has the potential to degrade water quality beneath the District. The District will work together with the Eastside Water Management Area (EWMA), also users of the Santa Margarita Formation, to monitor and manage the potential movement of high-salinity water from the west which may entail additional sampling, analysis of electric log data, and implementation of appropriate management actions.

- Migration of contaminated groundwater

The District is actively monitoring groundwater through sampling and works with the Central Valley Regional Water Quality Control Board to specifically monitor groundwater contamination in the Kern portion of the District.

- Replenishment of groundwater extractions

The District imports on average 36,500 acre-feet per year of which an estimated 9,000 acre-feet is return flow to groundwater.

- Measures addressing groundwater contamination cleanup, recharge, diversions to storage, conservation, water recycling, conveyance, and extraction projects

The District participates in three groundwater banking projects, an in-District recycled produced water project, and is on committees that govern major regional conveyance facilities including the Friant Kern Canal and the Cross Valley Canal.

- Efficient water management practices

The District practices Best Management Practices (BMPs) including flow measurement devices throughout the District that are operated and maintained within +/- 5% accuracy; on-farm evaluations provided by the North Kern Resources Conservation District; demand based operation where growers can control their own turnout based on the need of the crops; and regular system evaluations to ensure high efficiencies throughout the District's distribution system.

- Relationships with state and federal regulatory agencies

The District holds contracts with the United States Bureau of Reclamation, permits with the Central Valley Regional Water Quality Control Board, and is currently working with the State Water Resources Control Board to administer funding granted to the District under the Clean Water State Revolving Fund.

1.5 Notice and Communication *(Reg. § 354.10)*

1.5.1 Participating Agencies

Notification and communication with other agencies and interested parties has predominately been handled by the ETGSA for the Tulare County portion of the District and by the KGA GSA for the Kern County portion of the District. The District has a representative on each of the Boards of Directors and the District's General Manager participates on various advisory committees for both GSAs. The District has also collaborated with the Eastside Water Management Area (EWMA) in Kern County and has had several meetings with the EWMA technical advisory committee.

1.5.2 Beneficial Uses and Users

As further discussed in Section 3.5.2, the beneficial users of the Santa Margarita Formation are agricultural users that drill irrigation wells to the depths of roughly 2,000 feet. All domestic wells within the District are drilled to depths of less than 700 feet and do not reach the Santa Margarita Formation. The District was formed for the purpose of providing agricultural water to land within its service area and agricultural users are directly represented by the District's elected five-member Board of Directors.

1.5.3 Public Meetings

ETGSA holds a Board meeting, a Stakeholder Committee meeting, and an Executive Committee meeting publicly every month. ETGSA maintains an Interested Parties list and sends regular notices regarding meeting announcements and materials as well as invitations to informational workshops hosted in the nearby communities. ETGSA has also made available a stakeholder survey on the ETGSA website.

KGA's Stakeholder meetings are held the first Monday of each month. KGA's Board meetings are held on the fourth Wednesday of every month. The KGA has hosted numerous informational workshops and solicited comments in a variety of forums including on-line stakeholder surveys in both English and Spanish. See Appendix C of KGA Umbrella GSP for KGA's comprehensive outreach effort.

KTWD holds a public Board meeting the second Thursday of every month. All District Board members are landowners within the District and are the elected representatives of the landowners within the District. The topic of "Sustainable Groundwater Management Act" was first put on the agenda on November 13, 2014 and has been discussed at nearly every board meeting since. The District held additional local outreach meetings on the following schedule:

- June 18th @ Elk's Lodge in Delano at 1pm
- July 9th @ Wyndham Hotel in Visalia at 8am
- July 9th @ GEI in Bakersfield at 1pm
- July 26th @ Elk's Lodge in Delano at 8am
- August 5th @ Elk's Lodge in Delano at 6pm

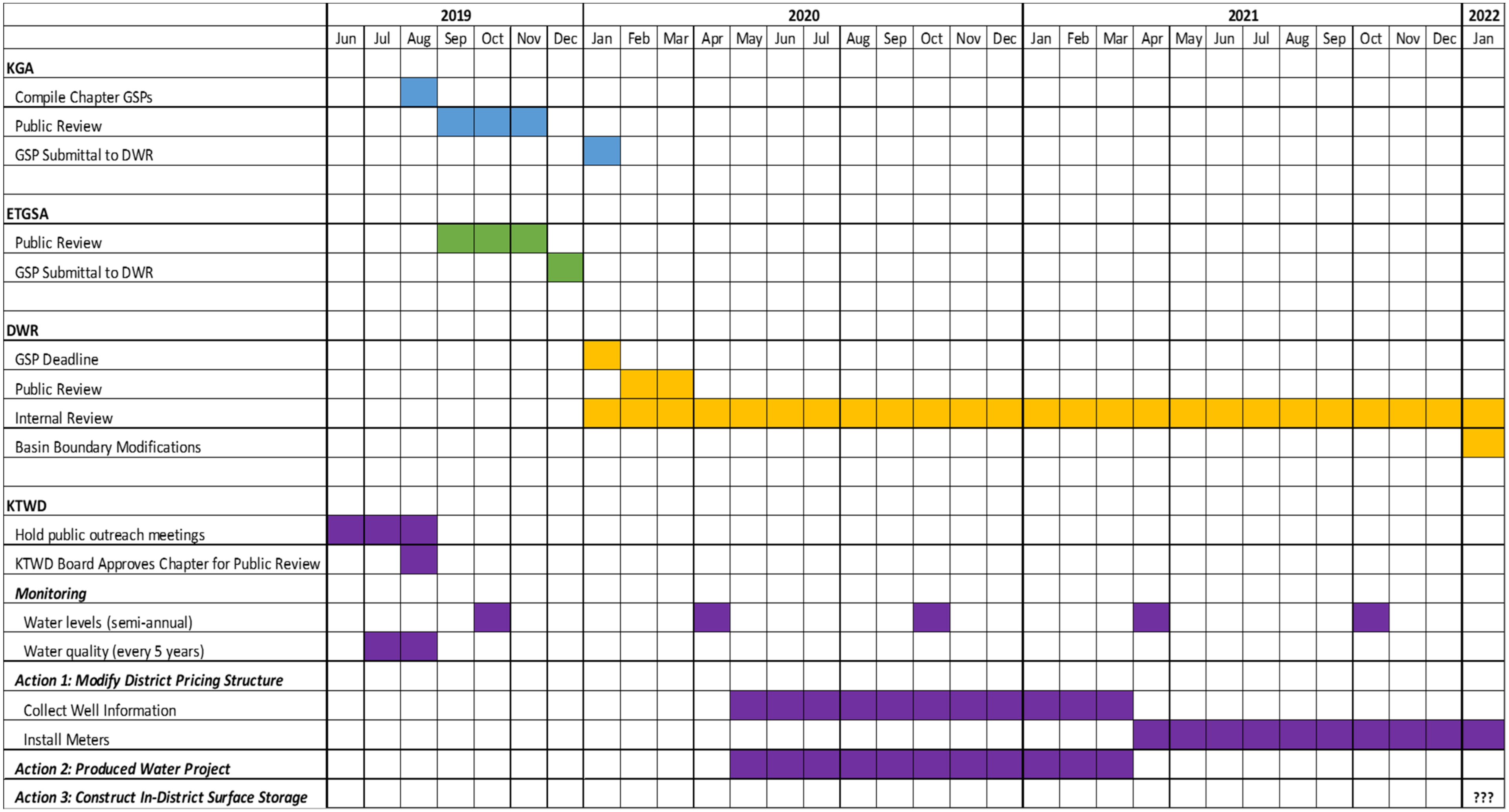
1.5.4 Comments Received

Wonderful Orchards LLC and Wonderful Citrus LLC collectively sent a comment on the KGA Umbrella GSP and the KTWD GSP. KGA responded on behalf of the GSA and all KGA comments received can be found in Appendix C of the Umbrella GSP. ETGSA comments received are found in the ETGSA GSP.

1.6 Implementation Schedule

Figure 1-8 provides the District's implementation schedule for this Plan as well as important dates for KGA GSA, ETGSA, and DWR.

Figure 1-8 Implementation Schedule



	2019							2020												2021												2022
	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Jan
KGA																																
Compile Chapter GSPs			🟦																													
Public Review				🟦	🟦	🟦																										
GSP Submittal to DWR								🟦																								
ETGSA																																
Public Review				🟩	🟩	🟩																										
GSP Submittal to DWR							🟩																									
DWR																																
GSP Deadline								🟨																								
Public Review									🟨	🟨																						
Internal Review								🟨	🟨	🟨	🟨	🟨	🟨	🟨	🟨	🟨	🟨	🟨	🟨	🟨	🟨	🟨	🟨	🟨	🟨	🟨	🟨	🟨	🟨	🟨	🟨	🟨
Basin Boundary Modifications																																🟨
KTWD																																
Hold public outreach meetings	🟪	🟪	🟪																													
KTWD Board Approves Chapter for Public Review			🟪																													
Monitoring																																
Water levels (semi-annual)					🟪						🟪						🟪						🟪						🟪			
Water quality (every 5 years)		🟪	🟪																													
Action 1: Modify District Pricing Structure																																
Collect Well Information												🟪	🟪	🟪	🟪	🟪	🟪	🟪	🟪	🟪	🟪	🟪										
Install Meters																							🟪	🟪	🟪	🟪	🟪	🟪	🟪	🟪	🟪	🟪
Action 2: Produced Water Project												🟪	🟪	🟪	🟪	🟪	🟪	🟪	🟪	🟪	🟪	🟪										
Action 3: Construct In-District Surface Storage																																???

CHAPTER 2. BASIN SETTING

2.1 Introduction (Reg. § 354.12)

This Chapter describes the information about the physical setting and characteristics of the study area and current conditions including the identification of data gaps and levels of uncertainty. The basin setting serves as the basis for defining and assessing reasonable sustainable management criteria and projects and management actions. Information provided in this Chapter pursuant to *Subarticle 2* was prepared by or under the direction of Steven C. Dalke (California Professional Engineer No. 41991).

2.2 Hydrogeologic Conceptual Model *(Reg. § 354.14)*

This Plan includes a descriptive hydrogeologic conceptual model of the study area based on technical studies and qualified maps that characterize the physical components and interaction of the surface water and groundwater systems in the study area.

The hydrogeologic conceptual model includes a description of the regional geologic and structural setting of the study area, a description of the principal aquifers and aquitards, five cross sections that display major stratigraphic and structural features, and maps displaying various physical characteristics of the study area.

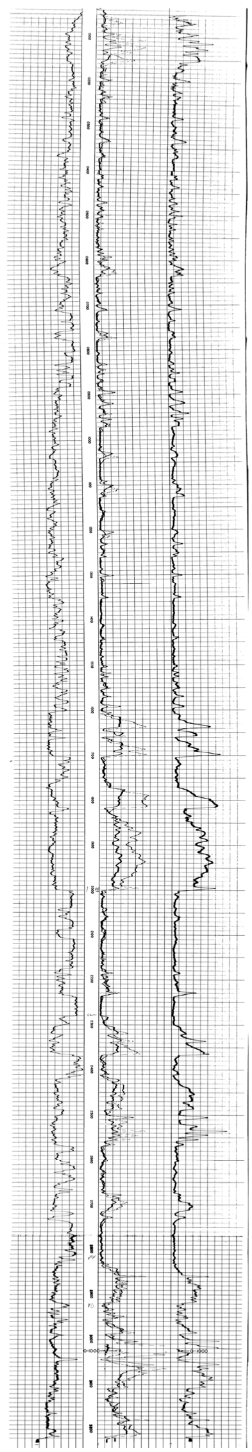
2.2.1 Regional Geologic and Structural Setting

Throughout Miocene and Pliocene time (approximately 25 to 2 million years ago), the southern San Joaquin Valley was a marine environment. Most of the valley's major oil reservoirs and some sands that currently act as local aquifers were deposited during this time. Overlying these marine sedimentary deposits are continental deposits of Pleistocene and Holocene age (2 million years ago to present). These continental deposits form the regional aquifer within the valley. All of these sedimentary deposits beneath the study area have been tilted westward along with the underlying Sierra Nevada basement complex (Gillespie, 2016).

Stratigraphy

Table 2-1 illustrates the sequence of geologic units beneath the study area, listed in order from youngest to oldest, and the correlation between the depositional environment, geophysical log, and general character of the strata. The geophysical log presented is from oil and gas well API no. 10700472 which is located one mile east of Richgrove, near the center of the District in the southwest corner of Section 29, T. 24 S., R. 27E. Each of the geologic units identified in Table 2-1 are further described in the sections which follow (Gillespie, 2016).

Table 2-1 Geologic Units Beneath the District

Dep. Environ.	Geophysical Log	Geologic Unit (depth)	General Character
Flood Plain		Tulare and Kern River continental deposits (0-200’)	Interbedded gravel, sand, silt, and clay that become more confined with depth.
Marine		San Joaquin and Etchegoin Pliocene marine deposits (200-1600’)	Siltstone, clayey, diatomaceous with thin lenticular sand beds. Minimal water production zone with water in thin sand layers. Clays within these sediments function as confining layers.
		Santa Margarita Formation (1,600-2,000’)	Fine to coarse greenish white sand, gravel, and sandstone. Major fresh water producing zone within and east of the District.
		Round Mountain Silt	Brown siltstone with diatomite member. Impervious water barrier.
		Olcese Sands (2,300-2,600’)	Light gray sandstone with a few pebble and siltstone beds. Fresh water producing zone within and east of District.
		Freeman-Jewett Silt	Brown siltstone with interbedded light-colored ashy beds. Impervious water barrier.
		Pyramid Hills and Vedder Sands	Interbedded sandstone and siltstone. Fresh water producing zone east of the District.
Non-marine		Walker Formation	Shaly silt with some lenticular sand stringers. Limited water production near the foothills.
		Basement (3,200’)	Granite or slate

Continental Deposits from the Sierra Nevada

The land surface of the study area is underlain by unconsolidated continental deposits (Tulare/Kern River formations) derived from the Sierra Nevada which make up most of the freshwater in the San Joaquin Valley (USGS, 2011). These deposits consist chiefly of alluvial, lacustrine, and flood-plain deposits which thicken from east to west (Lofgren and Klausing, 1969). The lacustrine Corcoran Clay is an important confining layer within these deposits. This clay layer occurs west of the District and is not present within the District.

This shallow aquifer system within the District can be separated into two units: (1) a shallow, highly permeable zone that occupies the uppermost 100 to 300 feet and forms a semi-confined aquifer; and (2) a deep zone that is hydraulically continuous with the shallow zone but in which confinement increases with depth. The deep zone ranges in thickness from 400 to 1,000 feet (Lofgren and Klausing, 1969).

During the early years of agricultural development, water for irrigation was pumped almost exclusively from the shallow, highly permeable zone. As water levels declined, deeper wells were drilled and many of the shallow wells were abandoned or restricted to domestic and stock use (Lofgren and Klausing, 1969).

Pliocene Marine Deposits

Underlying the unconsolidated continental deposits is a thick section of marine strata, chiefly siltstone, of Pliocene age (San Joaquin and Etchegoin formations). The partially cemented clayey siltstone contains thin, lenticular sand beds. This siltstone is differentiated from the overlying continental deposits by a marked change in lithology which is recognized in electric logs throughout the study area (Lofgren and Klausing, 1969).

The thin sandstone beds in this Pliocene marine siltstone sequence are tapped by a few wells, but the overall transmissibility of the siltstone unit is very low; thus it contributes little groundwater to wells and acts as a confining unit over most of the area. The thin sand beds may contain saline water that is unusable for ordinary purposes (Lofgren and Klausing, 1969). Only a few wells within the District produce low yields of fresh water from these thin sands.

In 2017 the District conducted a pump test on a 1,490 foot deep well located within the District that penetrates the Continental and Pliocene Marine Deposits. After pumping at a rate of 1,280 gpm for 24 hours the drawdown was 323 feet. This pump test demonstrates the low permeability of the Continental and Pliocene Marine Deposits beneath the District.

Santa Margarita Formation

Below the Pliocene marine deposits lay permeable sandstones of the Santa Margarita Formation. The average thickness of permeable sediments in the formation is 200 feet (Boyle, 1974). The Santa Margarita Formation is confined above and below by impervious silt and shale layers. The main Santa Margarita sand body lies beneath the District and can be fully penetrated by wells 2200-2400 feet deep which are predominantly used for irrigation purposes (Reynolds, 1955).

The sands in this formation were originally deposited in a nearshore marine environment and contained salt water. The observation that it is now filled with fresh water is evidence that groundwater recharge has occurred. Rainfall and stream seepage have fed fresh water into these sands east of the District where they crop out at the surface at a sufficient elevation to exert a westward hydraulic gradient in the sands. These waters have moved westward down-structure displacing the original saline waters westward into the deeper parts of the basin (Reynolds, 1955). Immediately west of the District, the Santa Margarita becomes saline. TDS values were estimated using the Humble variant of the Archie Equation of Winsauer et al. (1952) to determine that the salinity increases to over 2,000 mg/l just west of the District (Gillespie, 2016).

The first water well to produce agricultural water from the Santa Margarita Formation was the H. M. Holloway, Inc. Water Well #1 in Section 8, T.25S., R.27E. which was converted to a water well from an exploratory oil well drilled by the Western Gulf Oil Company in the early 1950's (Reynolds, 1955).

During the 1950's, wells drilled to depths of 1,800 to 2,400 feet in the vicinity of Richgrove first tapped artesian water-bearing sands of the Santa Margarita Formation; they proved to be a valuable source of groundwater supply. By 1957, about 20 large irrigation wells were taking water from the Santa Margarita. Most of these wells are perforated in overlying strata as well as in the Santa Margarita (Lofgren and Klausing, 1969).

In 2017 a District landowner conducted a pump test on a 1,860 foot deep well located within the District that is perforated to the Santa Margarita Formation. After pumping at a rate of 1,738 gpm for 24 hours the drawdown was 70 feet. This pump test demonstrates how much higher the permeability is in the Santa Margarita than the pump test conducted in the Continental and Pliocene Marine Deposits.

Round Mountain Silt

The Round Mountain Silt is an impervious siltstone and shale section approximately 200 feet thick that was deposited in an offshore marine environment. It is an effective groundwater flow barrier between the overlying Santa Margarita Formation and the underlying Olcese sands. This siltstone extends continuously over the entire area, but thins eastward (Reynolds, 1955).

Olcese Sands

The nearshore marine Olcese sands are present throughout the study area and have good porosity and permeability (Reynolds, 1955). The average thickness of permeable sediments in the formation is 180 feet (Boyle, 1974). Like the Santa Margarita Formation, this aquifer is recharged by rainfall and streamflow where the sands crop out east of the study area. The sands also originally contained salt water now displaced westward so that the freshwater interface lies primarily only in the eastern portion of the District and is used for irrigation purposes.

The confined aquifers of the Santa Margarita Formation and the Olcese Sands are shallow to the east and deepen to the west. These deposits contain useable groundwater and are located beneath fine-grained deposits that limit the natural recharge from the land surface. These formations outcrop at elevations of approximately 700 – 1,000 feet where they are replenished by surface waters at the mountain front that have displaced the original marine waters contained in the aquifers (Gillespie, 2016).

Wells within the District do not penetrate below the Olcese sands; therefore, for the purposes of this GSP, the bottom of the basin is defined as the bottom of the Olcese Sand Formation.

Freeman-Jewett Silt

Below the Olcese Sands is the offshore marine Freeman-Jewett silt which is about 350 feet thick in the west and thins to the east. It is primarily impervious silt although sands are locally present. It forms an effective groundwater flow barrier (Reynolds, 1955).

Pyramid Hills and Vedder Sands

The marine Pyramid Hill and Vedder Sands may be treated as a single unit varying in thickness from 100 feet to over 400 feet (Reynolds, 1955). Both are potential sources of groundwater, however, potable water from these sands is limited to a narrow belt east of the District (Lofgren and Klausing, 1969). These sands produce oil in the Jasmin field which is located near the eastern boundary of the District and are confined between the Freeman-Jewett and Walker formations.

Walker Formation

The Walker Formation is the non-marine equivalent of the Pyramid Hill and Vedder sands and lies below them and to the east. East of the District, the Walker Formation exists as a continental deposit composed principally of shaly silt with some lenticular sand stringers. The thickness of the Walker varies erratically through the area from 30 feet to nearly 200 feet (Reynolds, 1955). The non-marine sedimentary rocks generally are poorly permeable and yield only small quantities of water. Groundwater in and near the outcrop area generally is fresh, but further west and at moderate depths it becomes brackish to highly mineralized (Hilton et al., 1963).

Basement Complex

The basement complex is encountered directly below the Walker and gets increasingly deeper to the west, due to the westward tilting of the Sierra Nevada (Reynolds, 1955). The dominant rock types are igneous rocks ranging in composition from granite to gabbro and metamorphic rocks consisting largely of quartzite, schist, gneiss, and marble (Lofgren and Klausing, 1969). Although the rocks of the basement complex are relatively impermeable, they may yield sufficient water from fractures for domestic and stock use. They are present at great depth beneath the intensively cultivated area of the valley and are of no importance as a source of water except around the margins of the valley (Hilton et al., 1963).

2.2.2 Data Gaps and Uncertainty

The primary data gaps and uncertainty in the hydrogeologic conceptual model include:

- Hydraulic properties of the aquifers, including hydraulic conductivity and storativity.
- Aquifer-specific groundwater levels. Data for groundwater levels and quality have been obtained from wells screened in multiple aquifer zones.
- Underflow recharge from the Sierra Nevada.
- Well construction and pumping proportion between the shallow and deep aquifers.

The data gaps listed above create uncertainty on the impacts of different aquifer zones on the sustainability indicators. Additional monitoring points and dedicated monitoring wells perforated in the principal aquifers in the future would help reduce the uncertainty associated with these data gaps.

2.2.3 Geologic Cross Sections

The depths and thickness of the various aquifers were determined by evaluating e-logs obtained from DOGGR for 55 oil wells located within and around the study area as shown in Figure 2-1. The extent of freshwater in the Santa Margarita and Olcese formations was plotted using USGS Publication 63-47. Figure 2-2 through Figure 2-6 are the resulting cross sections that display the aquifers, the static water level of each aquifer, the extent of freshwater, and any active wells with total depth or perforated interval information. The locations of active wells within the study area were determined by conducting a physical well survey and utilizing satellite imagery. Wells were determined active if they either had a pump or were built after 1955. The number of well logs between 1955 to present closely matched the number of wells found. Figure 2-7 displays the deepest aquifer penetrated by the active wells as determined by the cross-sections.

Figure 2-1 DOGGR Oil Wells with E-logs

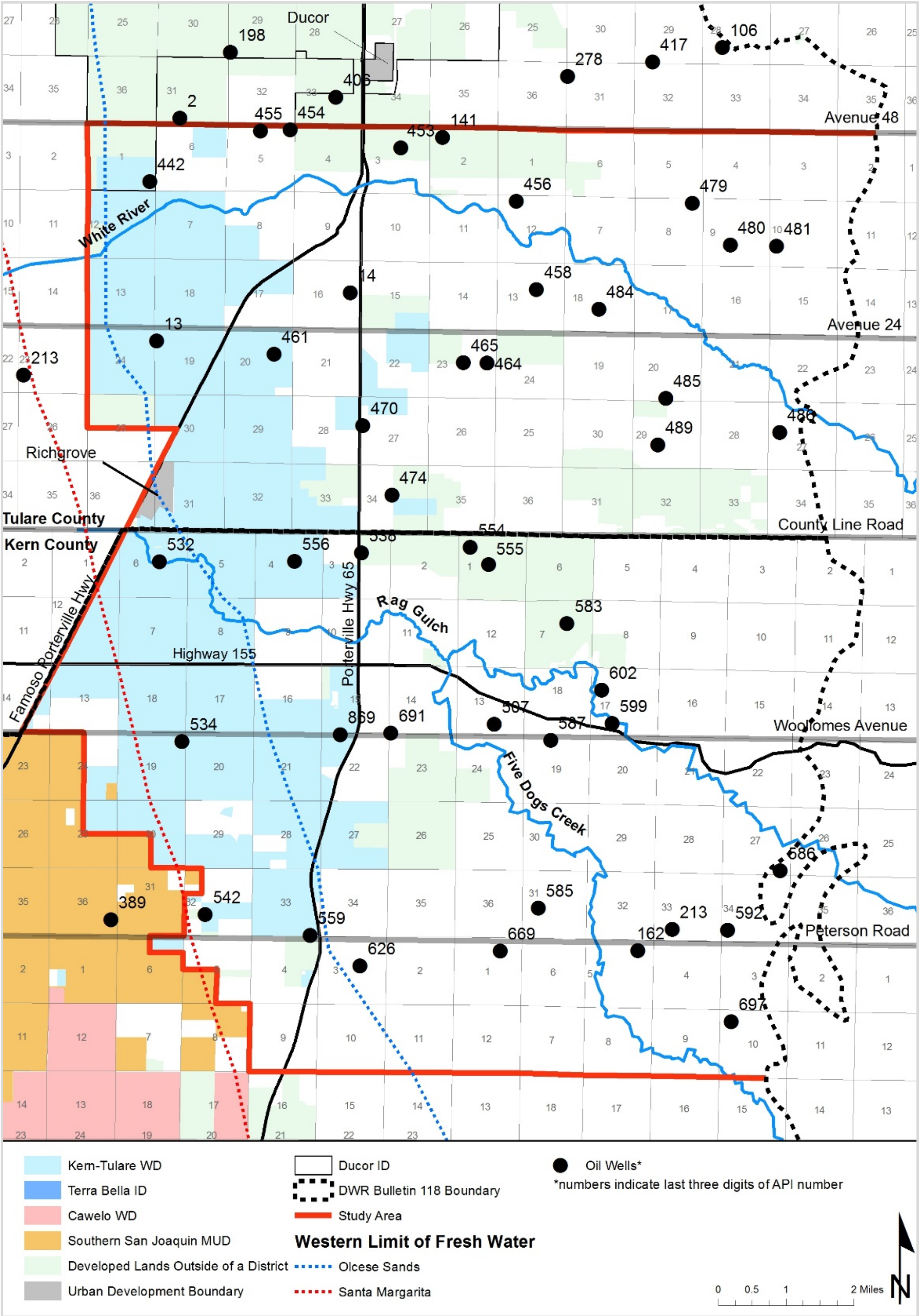


Figure 2-2 Cross Section along Avenue 48

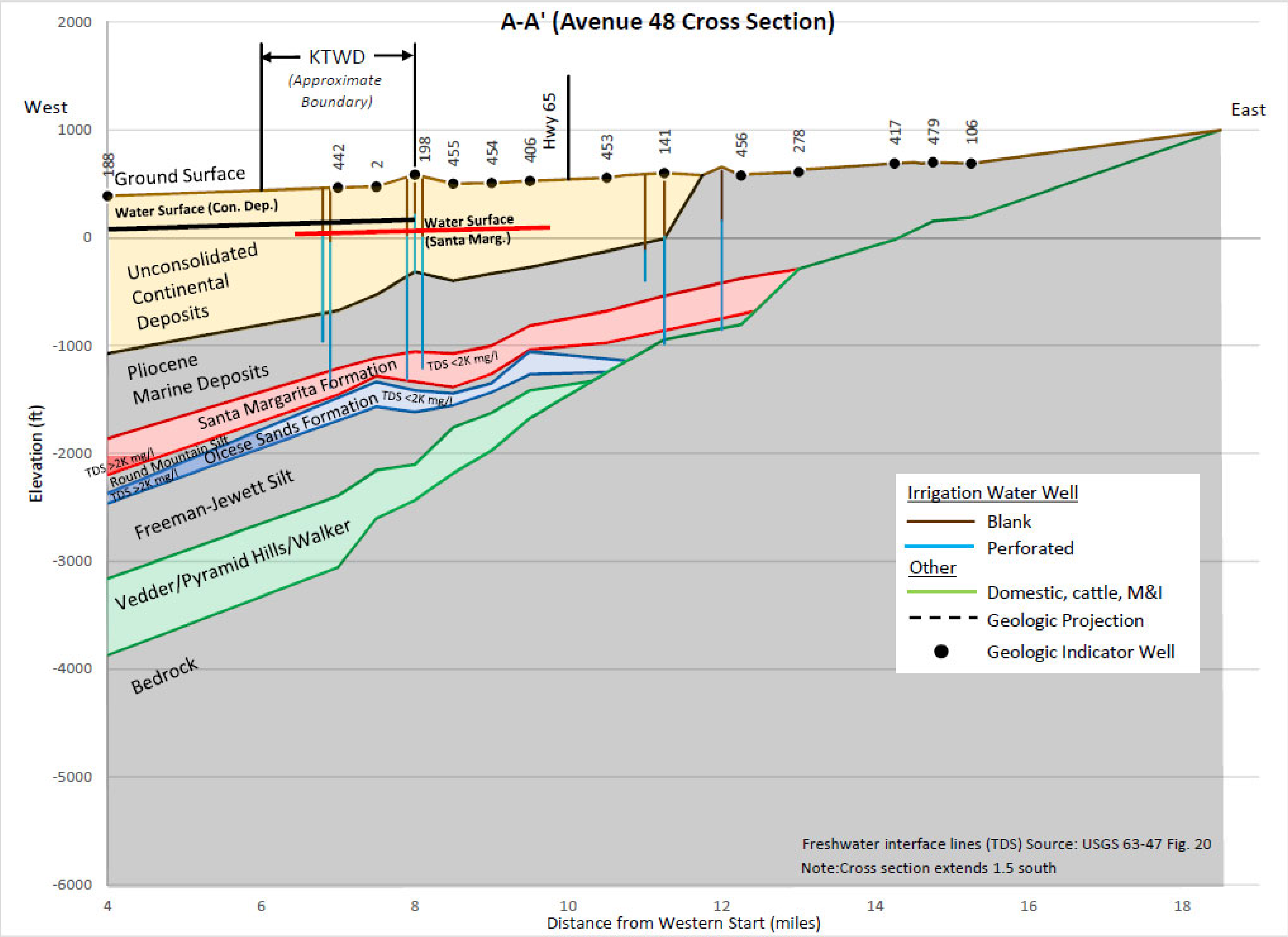
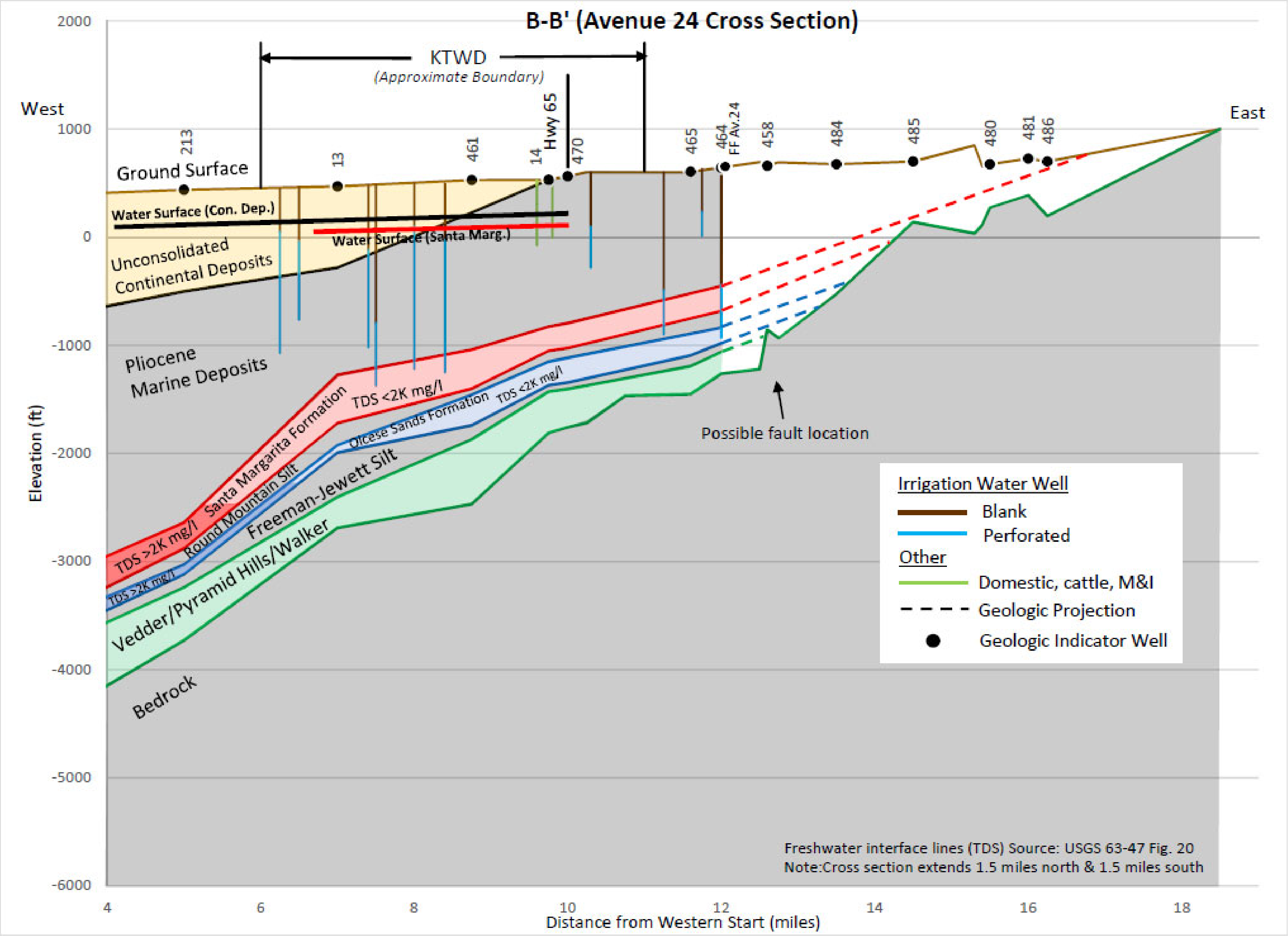


Figure 2-3 Cross Section along Avenue 24



B-B' (Avenue 24 Cross Section)

Freshwater interface lines (TDS) Source: USGS 63-47 Fig. 20
Note:Cross section extends 1.5 miles north & 1.5 miles south

Figure 2-4 Cross Section along County Line Road

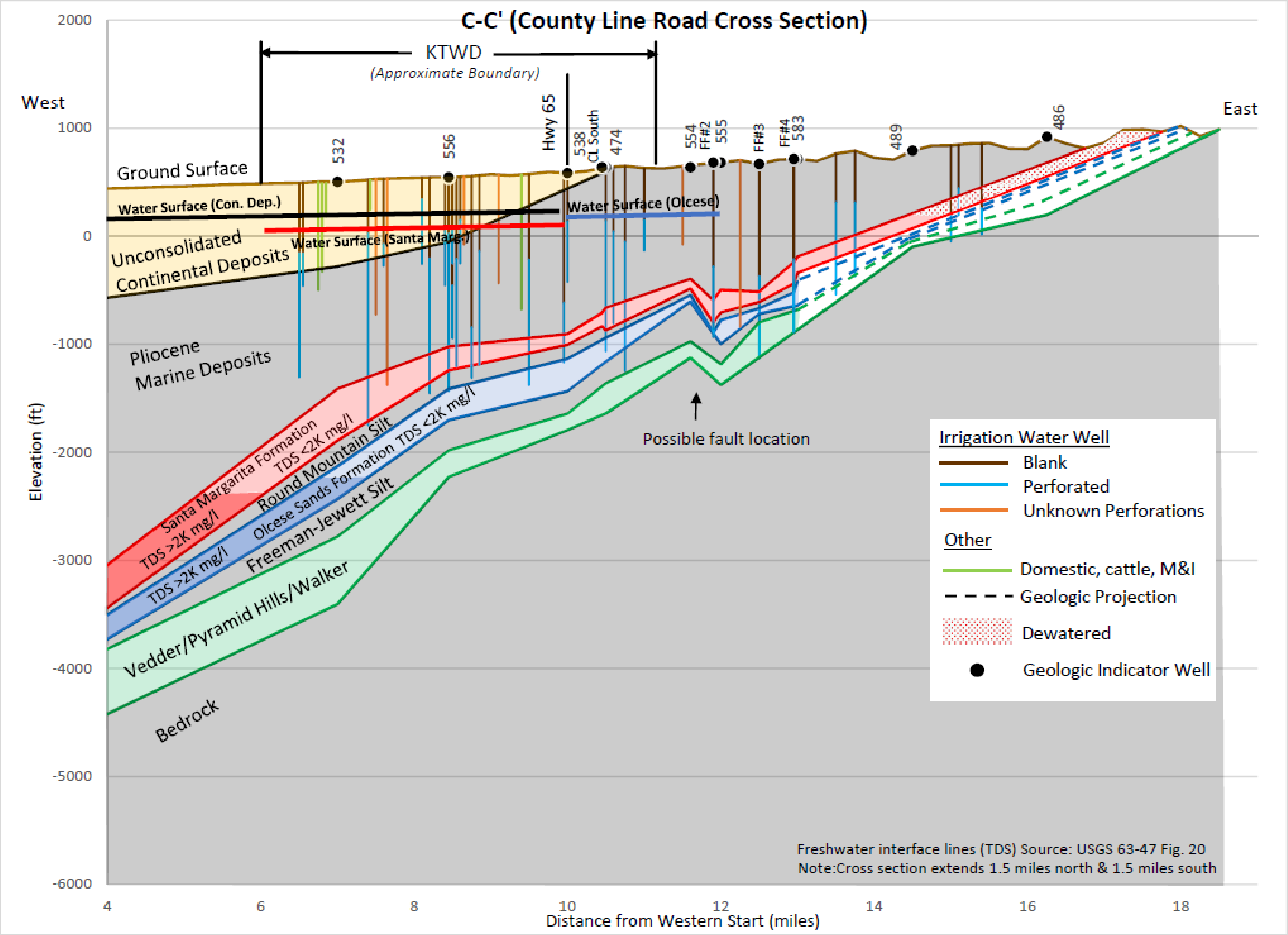


Figure 2-5 Cross Section along Woollomes Avenue

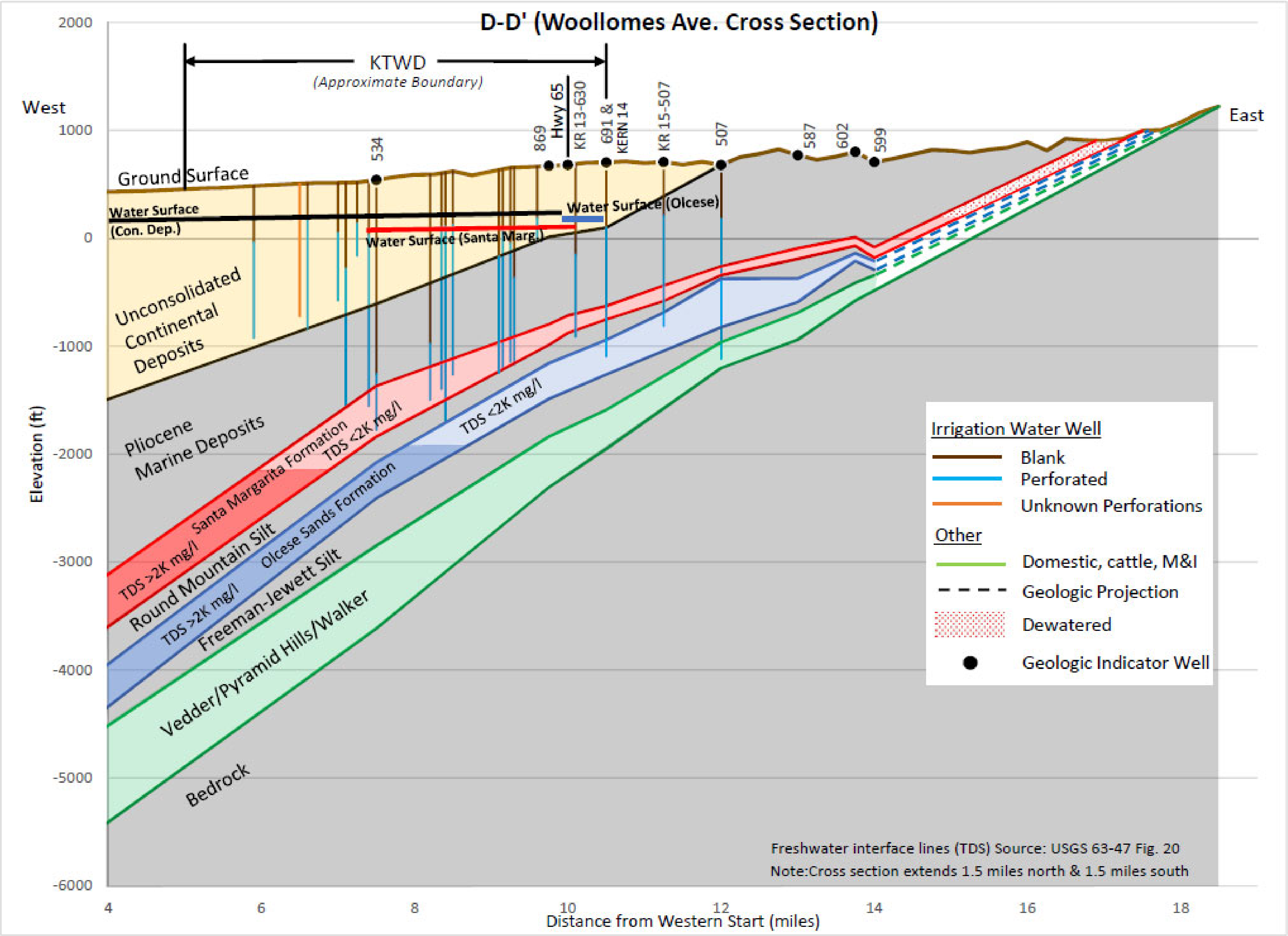


Figure 2-6 Cross Section along Peterson Road

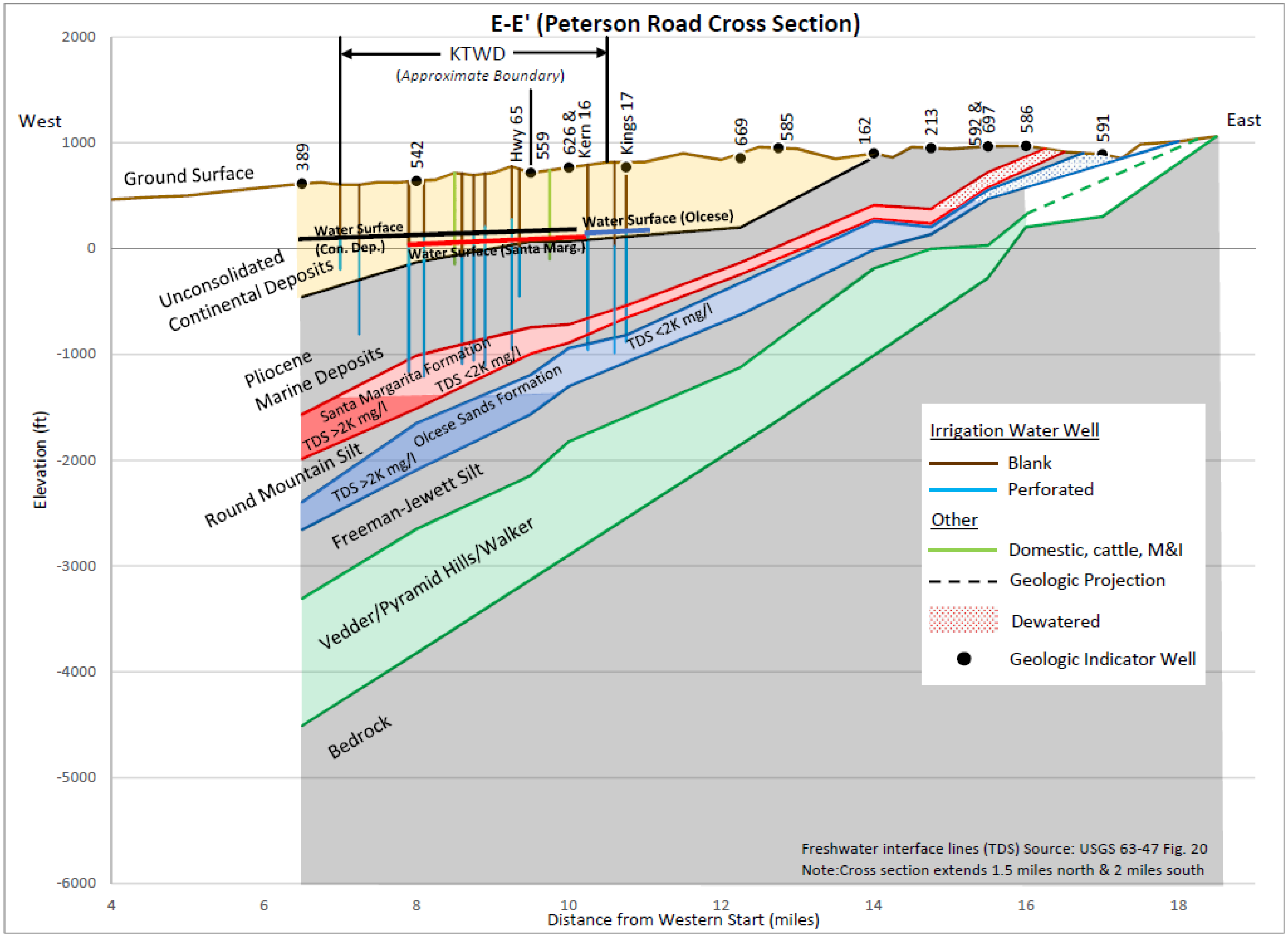
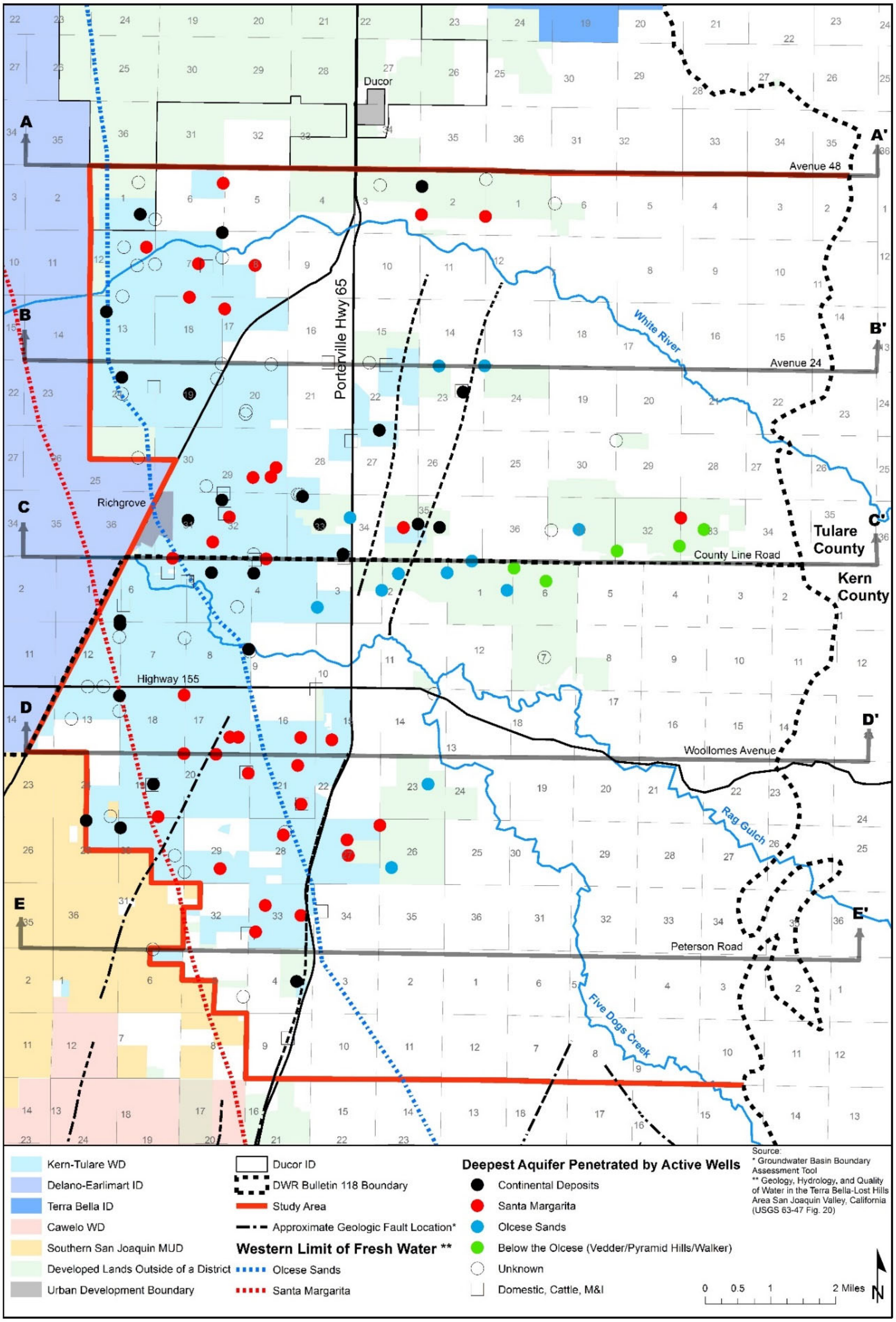


Figure 2-7 Deepest Aquifer Penetrated by Active Wells



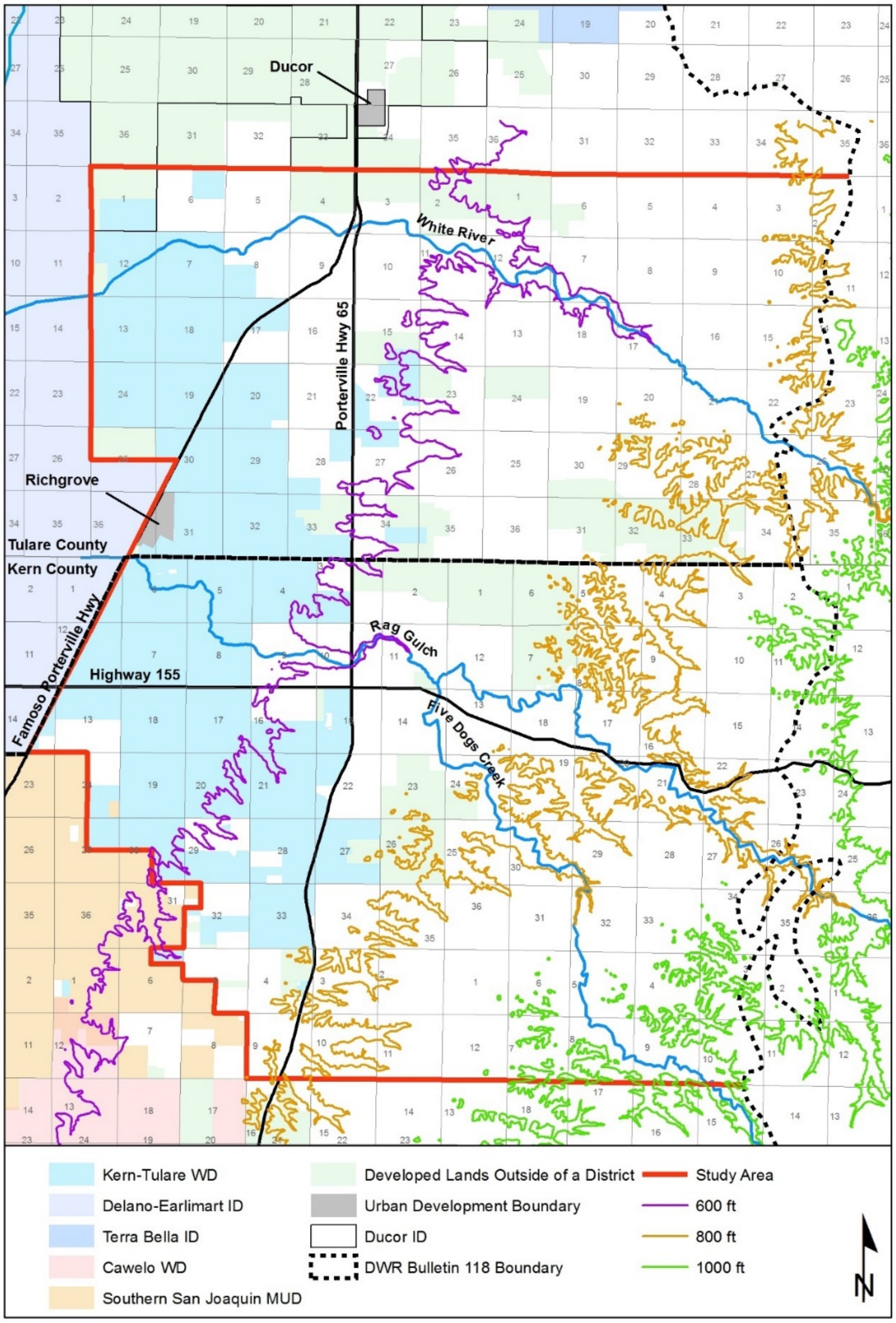
Source:
* Groundwater Basin Boundary Assessment Tool
** Geology, Hydrology, and Quality of Water in the Terra Bella-Lost Hills Area San Joaquin Valley, California (USGS 63-47 Fig. 20)

2.2.4 Maps of Physical Characteristics

Topographic information

Topographic information derived from the U.S. Geological Survey is presented in Figure 2-8.

Figure 2-8 Topography

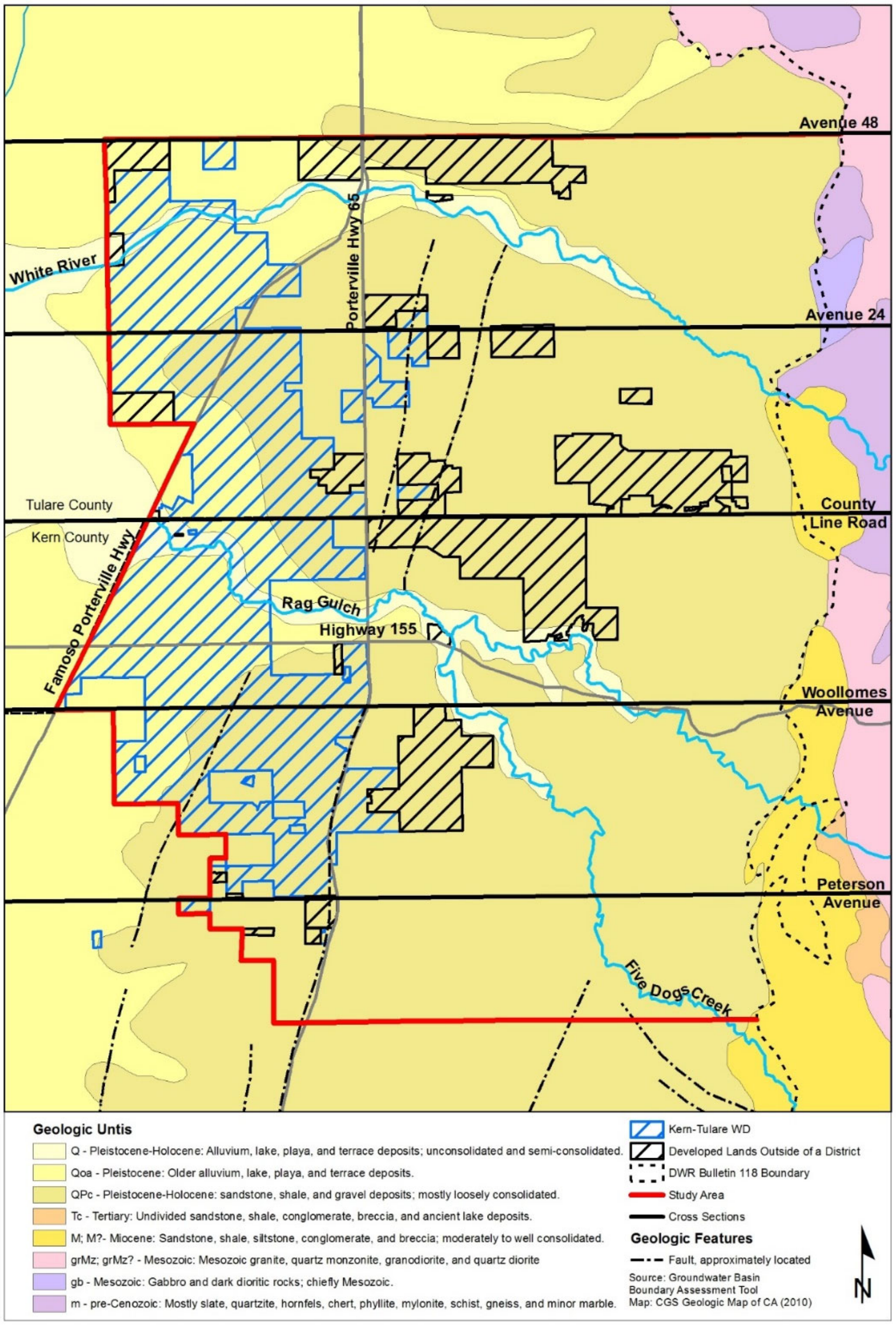


As shown in Figure 2-8 elevations vary from 1000 feet along the mountain front where the Santa Margarita Outcrops to 400 feet along the western limit of the District. The topography of the study area generally slopes to the northwest from the mountain front across the District.

Surficial geology

Surficial geology, according to CGS (2010) is presented in Figure 2-9.

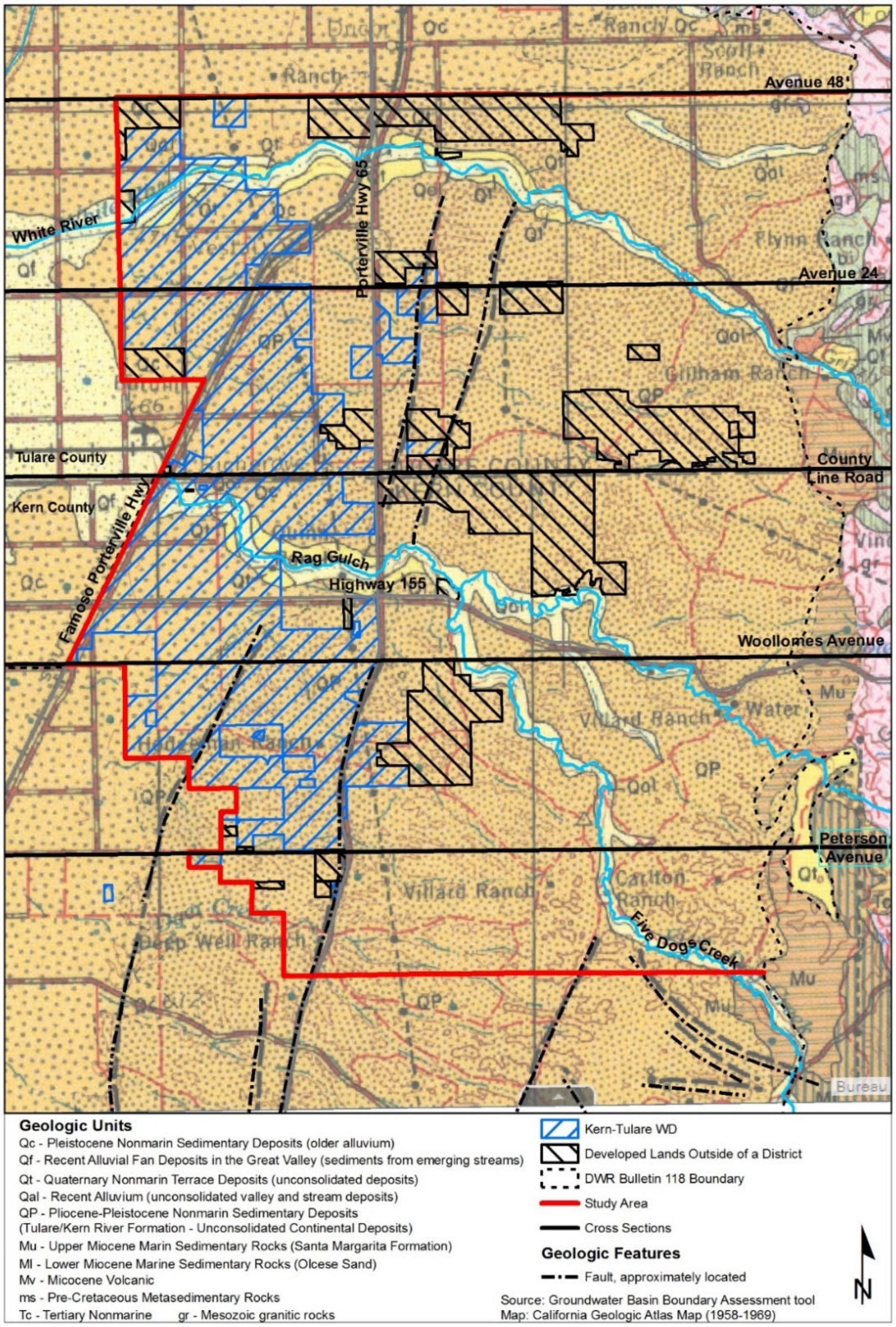
Figure 2-9 Surficial Geology



As shown in Figure 2-9, Quaternary: older alluvium, lake, playa, and terrace deposits (Qoa) are present in the western portion of the District and west of the District. Surficial geology within the District and east of the District consists of Pliocene-Pleistocene deposits (QPc) of sandstone, shale and gravely deposits.

Figure 2-9 also shows the location where the Santa Margarita and Olcese Sands outcrop, which is as Miocene. Surficial geology, according to Bartow (1991) is presented in Figure 2-10, which also includes outcropping of the Santa Margarita Formation (Mu), and the Olcese Sands (Ml).

Figure 2-10 Surficial Geology (CA Geologic Atlas Map)



Source: Groundwater Basin Boundary Assessment tool
Map: California Geologic Atlas Map (1958-1969)

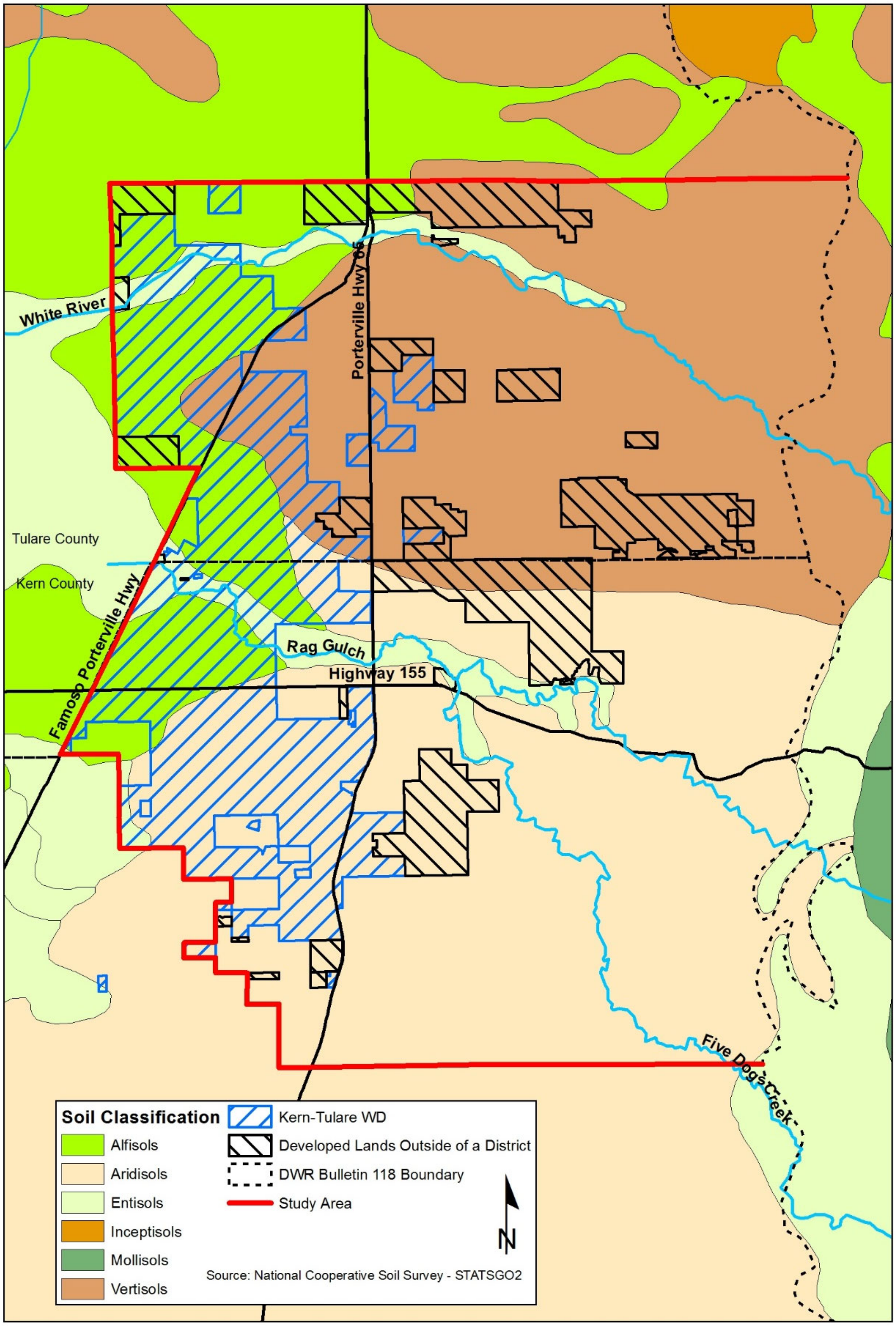
Localized faulting

The location of faults in the study area are also presented in Figure 2-9 and Figure 2-10 from the USGS U.S. Quaternary Faults and Folds Database (USGS, 2006). Tectonic activity in the area is expressed by moderate westward tilting and by minor displacement along two nearly vertical sub parallel north-northeast-trending faults that transect the District from north to south. The westernmost of the two northerly trending faults is believed to have had vertical displacement down to the west of 50 to 80 feet (Boyle, 1974). Displacement on the easternmost fault cannot be determined from available data. It is not known if these faults influence the continuity of aquifers in the subsurface. Long-term water level measurements and well-performance data will be necessary before the influence of faulting on subsurface conditions can be determined with certainty (Boyle, 1974).

Soil characteristics

Figure 2-11 presents the soil distribution within the study area as defined by the National Cooperative Soil Survey website (NRCS, 2018). Figure 2-11 shows that four soil orders are present in the study area: Alfisols, Aridisols, Entisols, and Vertisols. According to the online Encyclopedia Britannica (EB, 2018), Alfisols are characterized by well-developed soil horizons enriched with aluminum- and iron-bearing (Al/Fe) minerals but depleted of calcium carbonate. Ardisols are dry soils characterized by a low humus, light-colored surface horizon with a subsurface accumulation of soluble salts, silicate clays, and possibly a cemented layer of calcium carbonate, calcium sulfate (gypsum) or silica (EB, 2018). Entisols are characterized by the absence of soil horizons due to recent deposition or active erosion under extreme wet or dry conditions (EB, 2018). Vertisols are clay-rich soils (>30%) with significant cracking during the dry season due to the shrink-swell response of the clay minerals during the dry and wet seasons (EB, 2018). The shrink-swell action produces significant vertical mixing of the soil.

Figure 2-11 Soil Characteristics

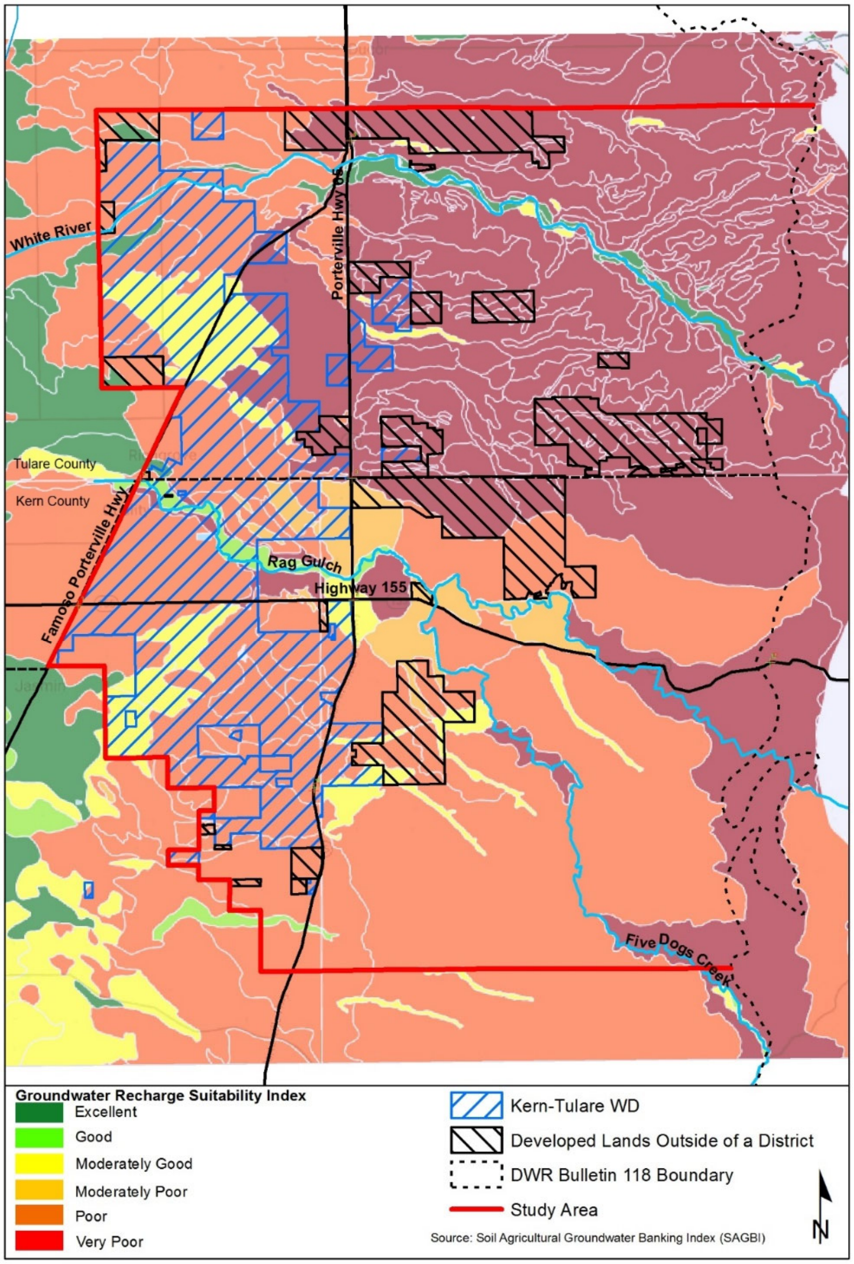


Source: National Cooperative Soil Survey - STATSGO2

Recharge

Figure 2-12 shows Hydrologic Soil Characteristics.

Figure 2-12 Hydrologic Soil Characteristics



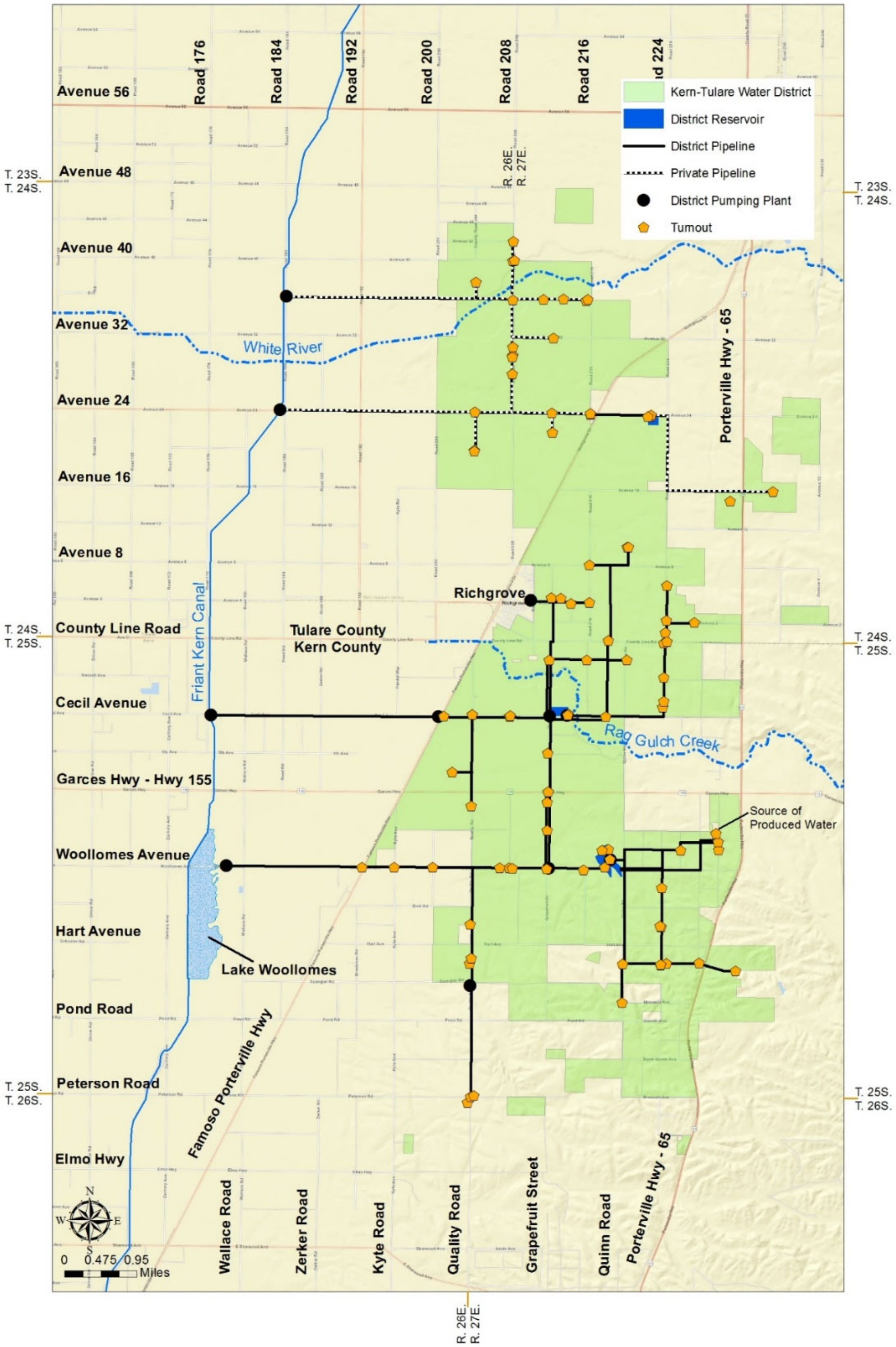
Source: Soil Agricultural Groundwater Banking Index (SAGBI)

As seen in Figure 2-12 the Soil Agricultural Groundwater Banking Index (SAGBI) shows the distribution of recharge within the study area as primarily poor to very poor soils which have slow to very slow infiltration rates. Poor soils have a low infiltration rate due to their fine texture or because of a layer that impedes downward movement of water. Very poor soils have a very slow infiltration rate due to the presence of clay and are located primarily in the northeast portion of the study area. Some soils also exist in the riparian areas of the District which are moderately well drained due to moderately fine to coarse textures.

Surface Water Bodies

A map of the District's distribution system which shows the location of surface water bodies in the study area, including the Friant-Kern Canal (FKC), Lake Woollomes, Rag Gulch and White River is presented in Figure 2-13.

Figure 2-13 Distribution System



The FKC is the primary source of water to the District which brings CVP water from the San Joaquin River. Lake Woollomes is a regulating reservoir and is part of the FKC. Ephemeral streams that flow through the basin from the mountains include Rag Gulch and White River.

2.2.5 Source of Imported Water Supplies

As shown in Figure 2-13, surface water is pumped upslope to the District from the FKC. The District's distribution system consists of 4 pumping plants from the FKC, 6 re-lift pumping plants, 60 miles of buried pipelines, and 3 regulatory reservoirs. The District has 54 Water Users served through 96 turnouts. All turnouts and District pumping plants are metered.

The District has two Cross Valley Contracts (14-06-200-8601A and 14-06-200-8367A) with the United States Bureau of Reclamation (Reclamation) for a combined total of up to 53,300 acre-feet per year of Central Valley Project (CVP) water and a Friant Class 2 Contract (I1R-1460A) for up to 5,000 acre-feet per year of CVP water. The District also enters into annual contracts for 215 water from Reclamation, purchases Class 1 and Class 2 water supplies from other Friant Contractors, purchases CVP water from other South of Delta contractors, and purchases Kern River Water from the City of Bakersfield.

A summary of historical monthly water deliveries to the District, by source, is presented in Appendix 2.

Groundwater Banking

The District has developed long-term groundwater banking programs with North Kern Water Storage District (North Kern), Rosedale-Rio Bravo Water Storage District (Rosedale-Rio Bravo), and West Kern Water Storage District (West Kern) to deliver excess water when surface supplies are available and to extract groundwater during years of inadequate supplies.

The North Kern project yields an annual dry year supply of up to 5,000 acre-feet. The agreement requires the District to bank water before it can be extracted and leave 10 percent of the water banked in North Kern to account for losses.

The Rosedale-Rio Bravo project yields an estimated dry year annual supply of up to 9,000 acre-feet. The agreement requires the District to bank 2.13 acre-feet for each acre-foot extracted and to bank water before it can be extracted.

The West Kern project yields an estimated dry year annual supply of up to 2,000 acre-feet. The agreement requires the District to bank 2 acre-feet for each acre-foot extracted and bank water before it can be extracted.

Supplies available to the District for banking include the District's CVP contract supplies, Section 215 water, flood flows conveyed in the Friant-Kern Canal, purchases from other CVP Contractors, Kern River water, and SWP water.

Produced Water

The District executed a 20-year contract with Hathaway, LLC in 2016 to receive produced water. The District currently receives about 2,400 acre-feet per year of water from this source on the east side of the District, which is delivered to the District's Big 4 reservoir to be blended with other water sources before being distributed. The source of oilfield produced water is from exempted aquifers beneath and hydrologically separated from the fresh-water bearing zones of the basin.

2.3 Groundwater Conditions *(Reg. § 354.16.)*

This Plan provides a description of current and historical groundwater conditions in the study area, including each of the following items which are required by SGMA:

- Groundwater elevations depicting the groundwater table or potentiometric surface associated with the current seasonal high for each principal aquifer within the basin.
- Hydrographs depicting long-term groundwater elevations, including historical highs and lows, for each of the principal aquifers.
- Semiannual hydrographs depicting changes in the volume of groundwater in storage between seasonal high groundwater conditions.
- Land subsidence.
- Groundwater quality data.

In accordance with Section § 354.26 of the Regulations the following are not described:

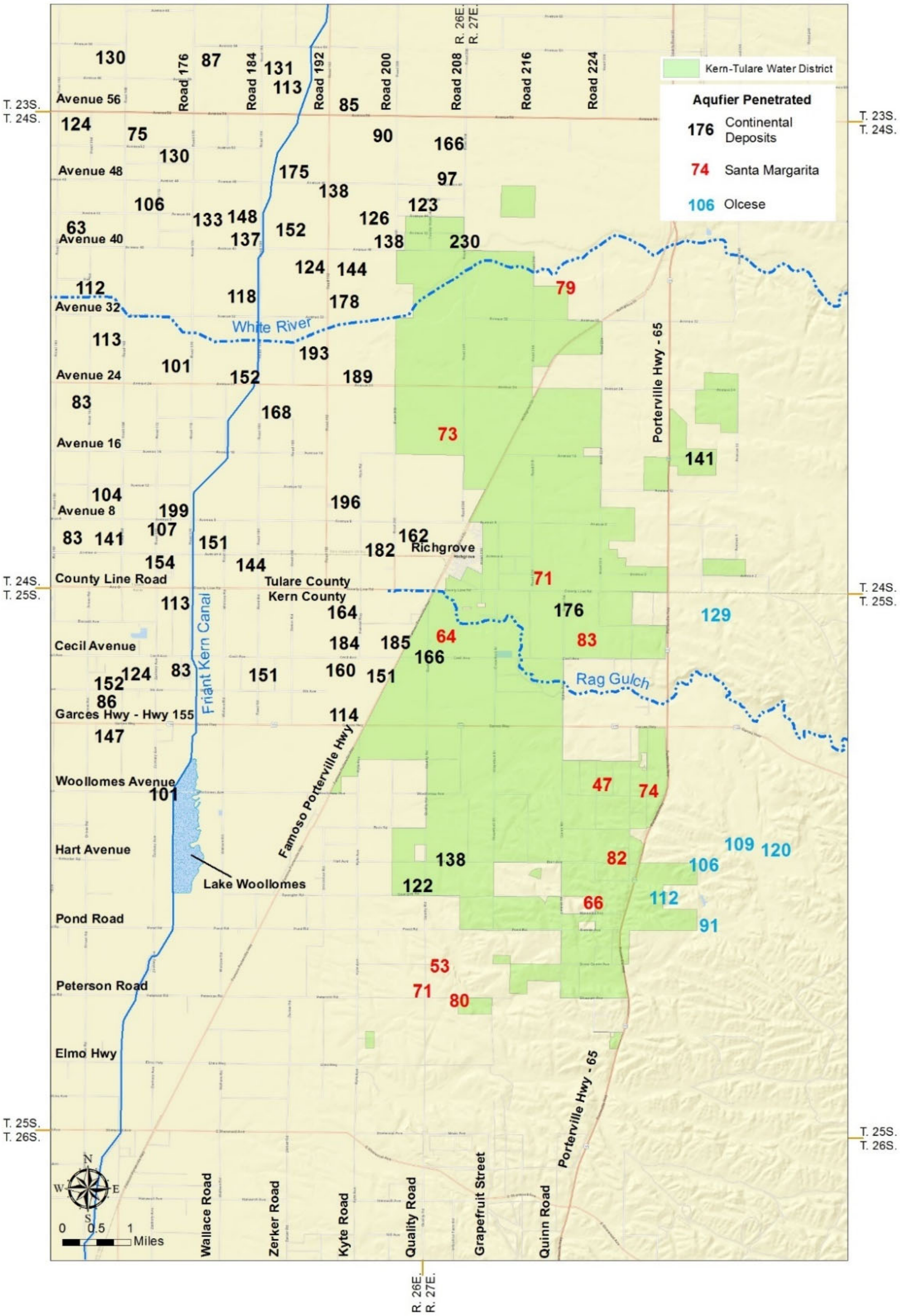
- Seawater intrusion – none within the study area. Seawater intrusion cannot occur within the District due to its location with respect to the Pacific Ocean. The District is approximately 120 miles inland of the Pacific Ocean and is separated from the ocean by approximately 90 miles of sedimentary rocks that make up the Coast Ranges.
- Interconnected surface water systems – none within the study area. According to DWR, "interconnected surface water" refers to surface water that is hydraulically connected by a continuous saturated zone to the underlying aquifer and the overlying surface water is not completely depleted. As described in Section 2.2, the only existing surface bodies within the District are reservoirs and two ephemeral streams; no interconnected surface waters.
- Groundwater dependent ecosystems – none within the study area. Groundwater dependent ecosystems require shallow groundwater or groundwater that discharges at the land surface; neither of which occur within the District. Throughout the District, the depth to groundwater is well below the level required to support ecosystems.

2.3.1 Groundwater Elevation Data

Groundwater elevations for all wells found in DWR's Well Data Library within and surrounding the District for Spring 2017 are presented in Figure 2-14. The general direction of groundwater flow is East to West.

As shown in Figure 2-14, groundwater elevations are highly variable and difficult to contour. In some cases, water levels in adjacent wells vary by over 100 feet. Wells that penetrate the Santa Margarita Formation show a lower groundwater elevation than wells completed only in the Continental Deposits. Contours cannot be drawn for the Continental Deposits because groundwater elevations are highly variable. Contours cannot be drawn for the Santa Margarita Formation because groundwater elevations are highly variable and data is sparse. Contours cannot be drawn for the Olcese Sands due to the lack of available data.

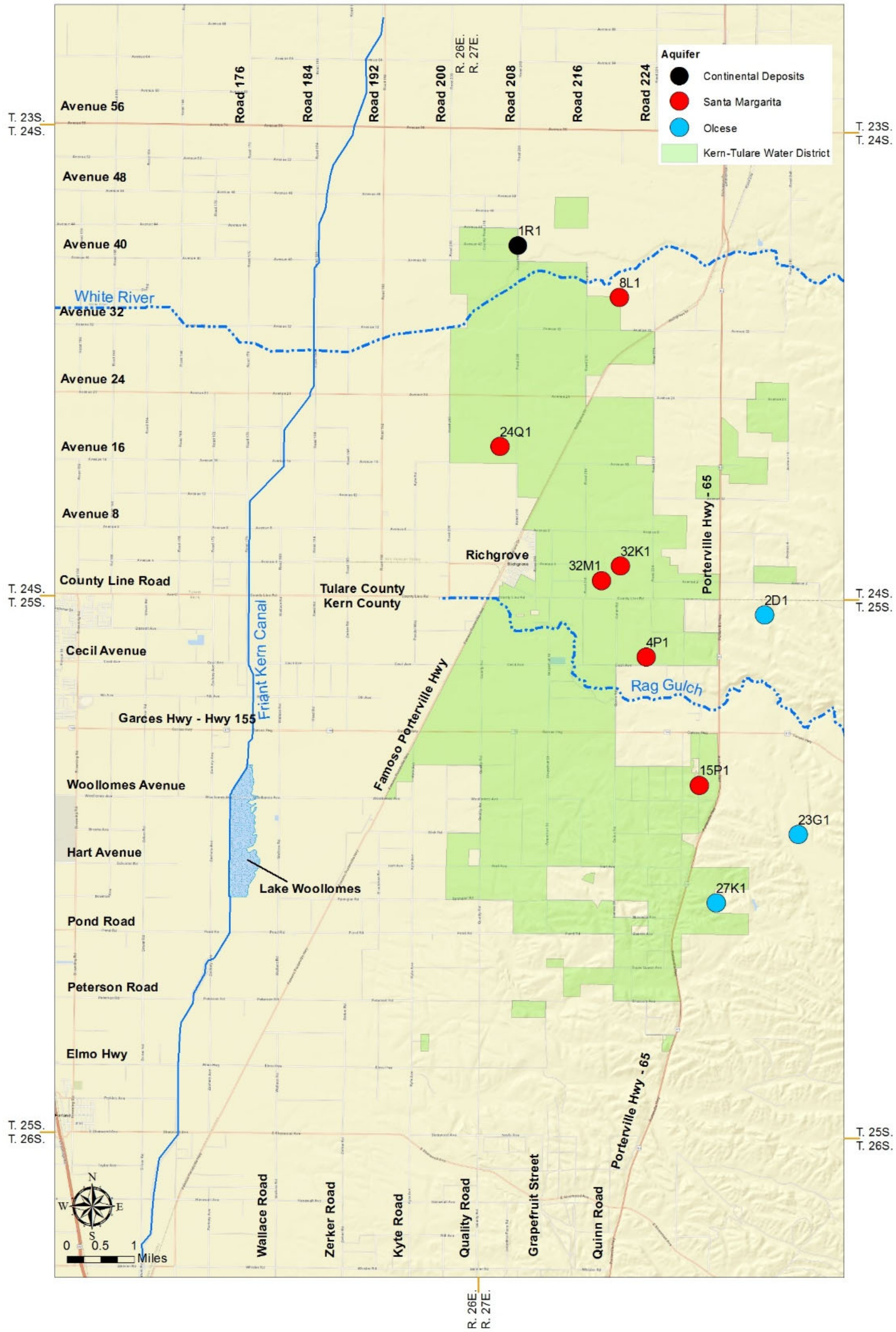
Figure 2-14 Spring 2017 Groundwater Elevations



Historical Hydrographs

The District performed a search of DWR records and prepared hydrographs for all wells that had long-standing periods of record and found six wells penetrated to the Santa Margarita, one well penetrated to the Continental Deposits, and three wells penetrated to the Olcese Sands. Figure 2-15 is a map that shows the location of these wells and the deepest aquifer they penetrate.

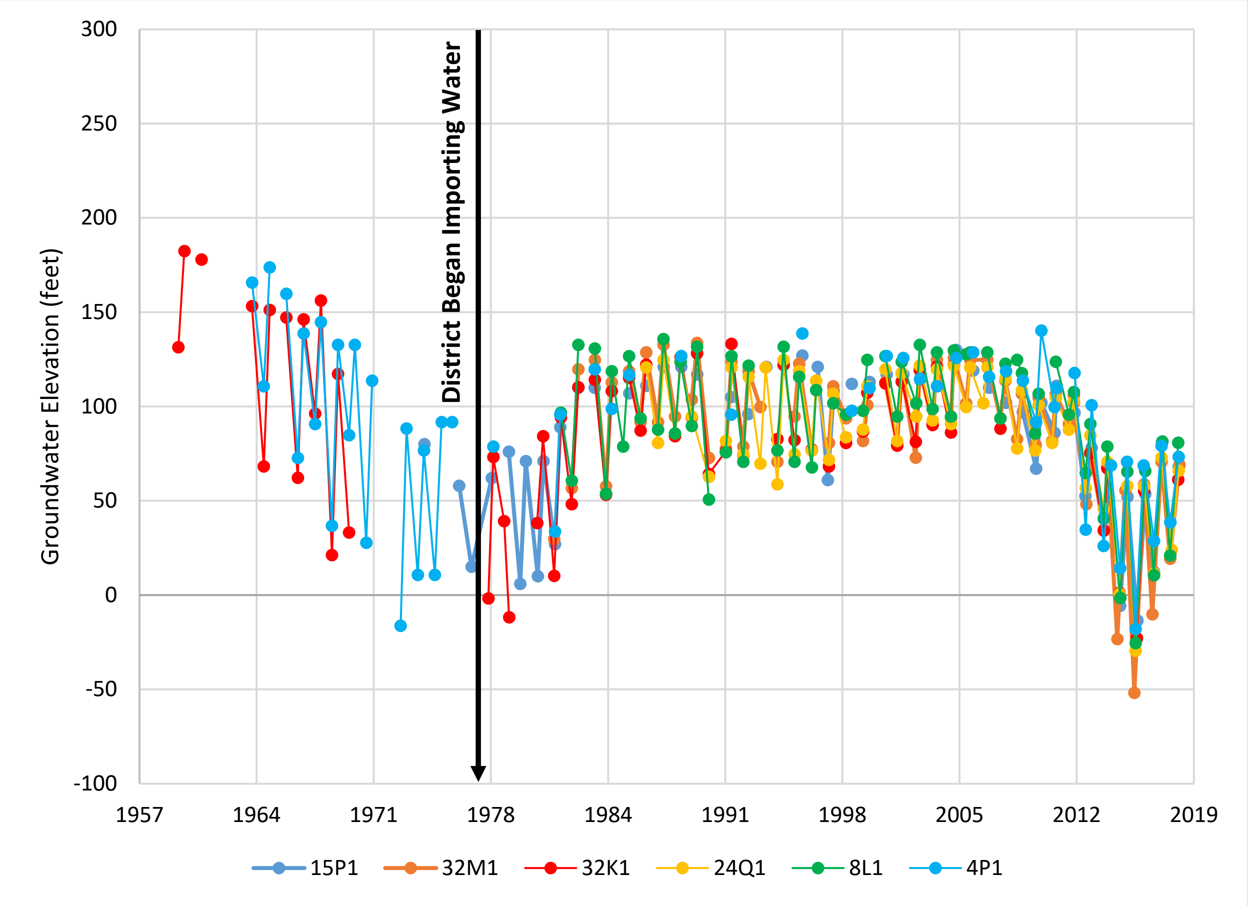
Figure 2-15 Hydrograph Location Map



Santa Margarita Formation

Figure 2-16 is a hydrograph of groundwater levels for six wells identified in Figure 2-14 that penetrate to the Santa Margarita Formation in the District.

Figure 2-16 Historical District Groundwater Levels in the Santa Margarita Formation



As shown in Figure 2-16, groundwater levels in the Santa Margarita Formation are consistent throughout the District regardless of location. All hydrographs show that prior to 1977 groundwater levels in the Santa Margarita Formation were falling at a rate of approximately 10 feet per year. Beginning in 1977, the District began importing water and, as a result, groundwater pumping reduced and groundwater levels rose significantly. From 1983 through 2009 groundwater levels remained stable, varying seasonally from elevations of 60 to 120 feet. The recent drought (2013 through 2016) caused groundwater pumping to increase resulting in spring groundwater levels declining by over 50 feet and fall levels declining by 100 feet. Groundwater levels are now recovering.

Continental Deposits

Figure 2-17 and Figure 2-18 are hydrographs of groundwater elevations in the Continental Deposits within the District and west of the District. Figure 2-17 shows groundwater levels for the only hydrograph available within the District and Figure 2-18 shows hydrographs for 3 wells west of the District.

Figure 2-17 Historical District Groundwater Levels in the Continental Deposits within the District

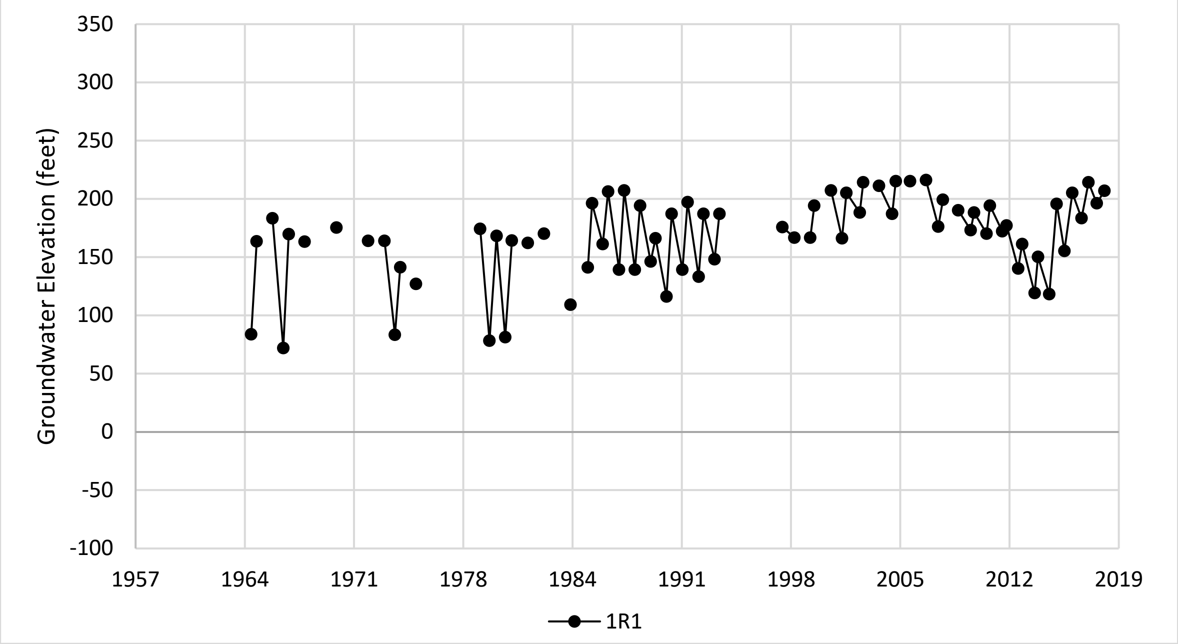
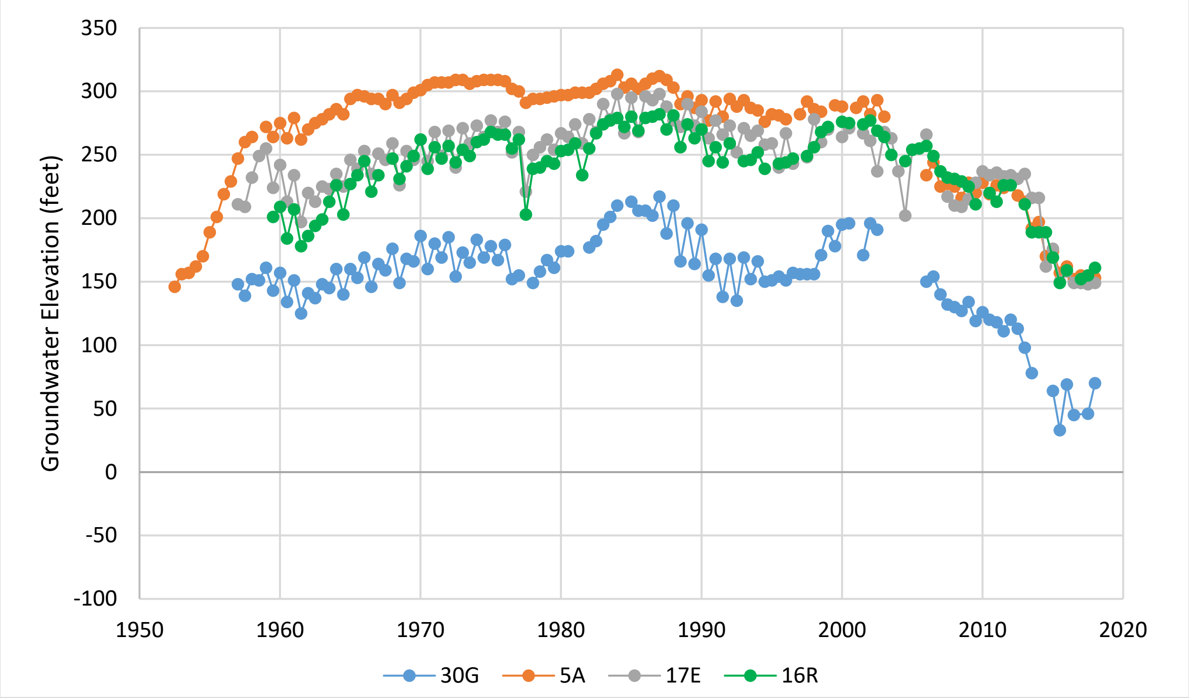


Figure 2-18 Historical Groundwater Levels in the Continental Deposits West of the District



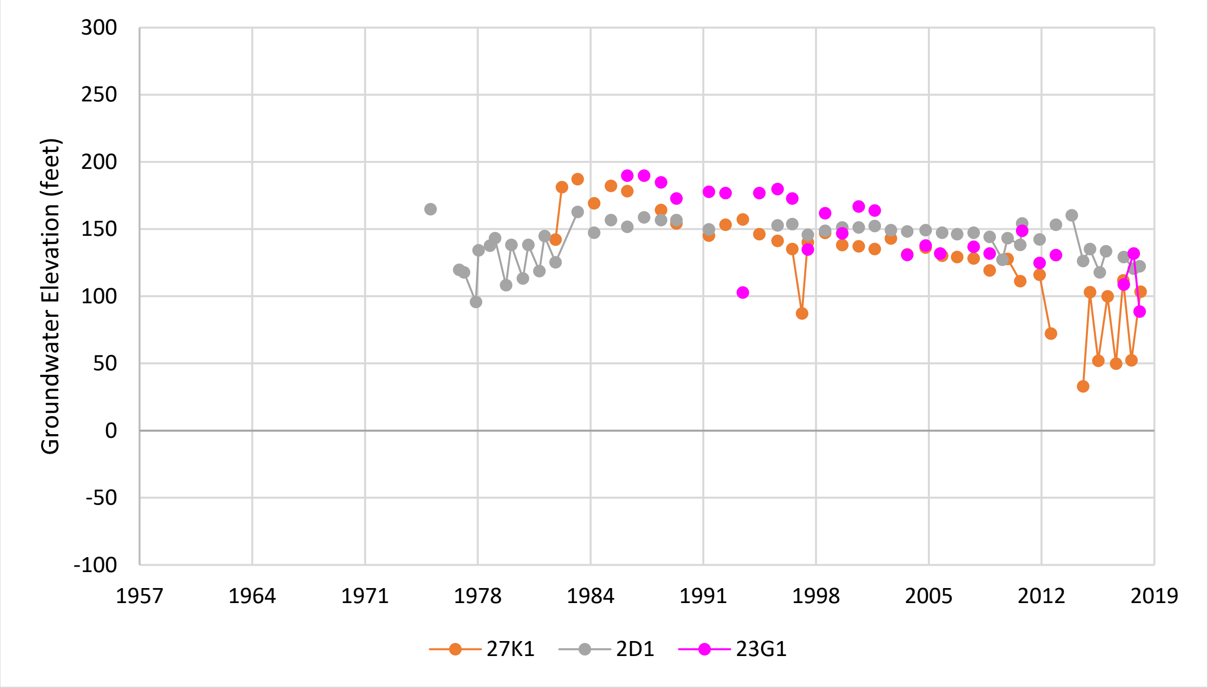
As shown in Figure 2-17, groundwater levels in the Continental Deposits in the northern portion of the District are increasing. The recent drought (2013-2016) caused spring groundwater levels to drop by 70 feet. Groundwater levels are recovering and have returned to pre-drought conditions.

As shown in Figure 2-18, groundwater levels in the Continental Deposits to the west of the District have been declining since 2005. Groundwater levels have dropped by 138 feet over the 12-year period from 2005 to 2017 and are continuing to decline.

Olcese Sands

Most wells to the east of the District penetrate the Santa Margarita Formation and the Olcese Sands. Figure 2-19 is a hydrograph of groundwater elevations for wells identified in Figure 2-15 that penetrate the Olcese Sands Formation with long-standing periods of record.

Figure 2-19 East of the District Historical Groundwater Levels in the Olcese Sands Formation

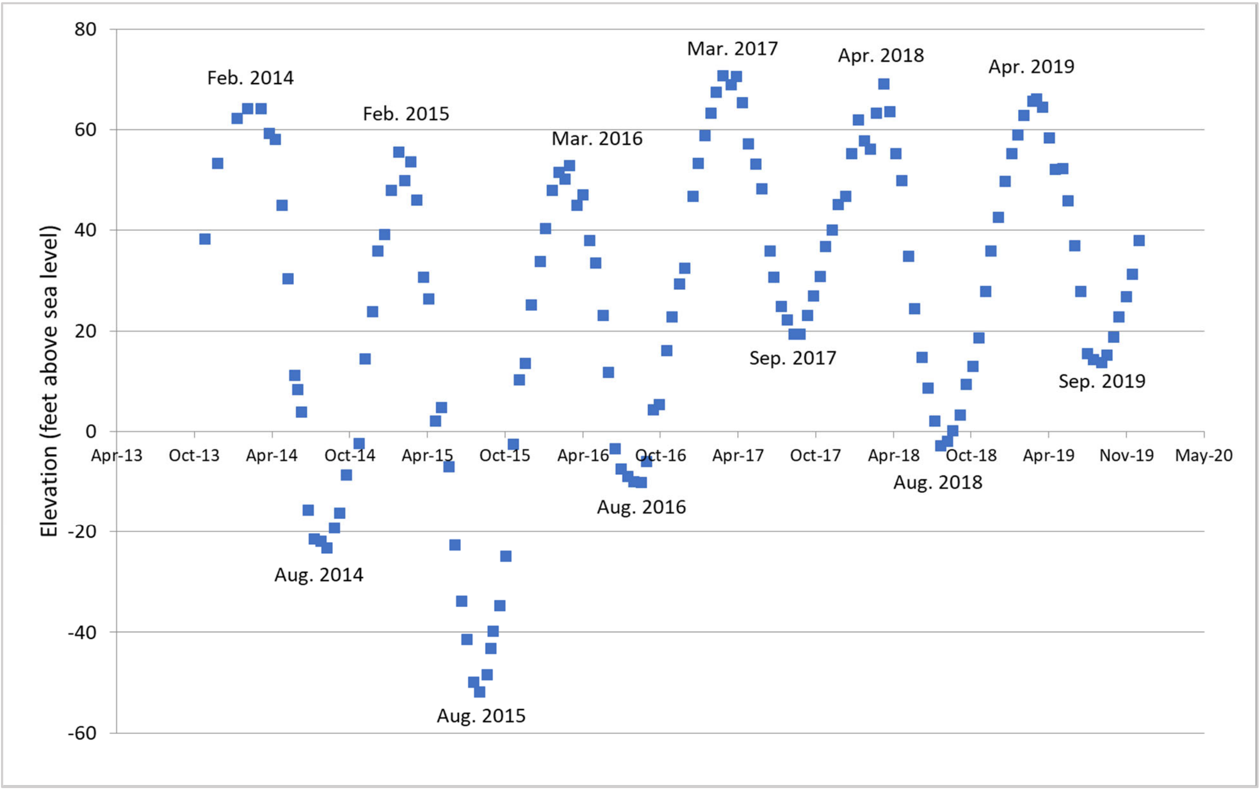


As shown in Figure 2-19, groundwater levels east of the District have dropped by 80 feet over the 30-year period from 1987 to 2016 and are continuing to decline. This is evidence that lands east of the District are pumping more from the basin than is replaced by recharge.

Semi-monthly Hydrographs

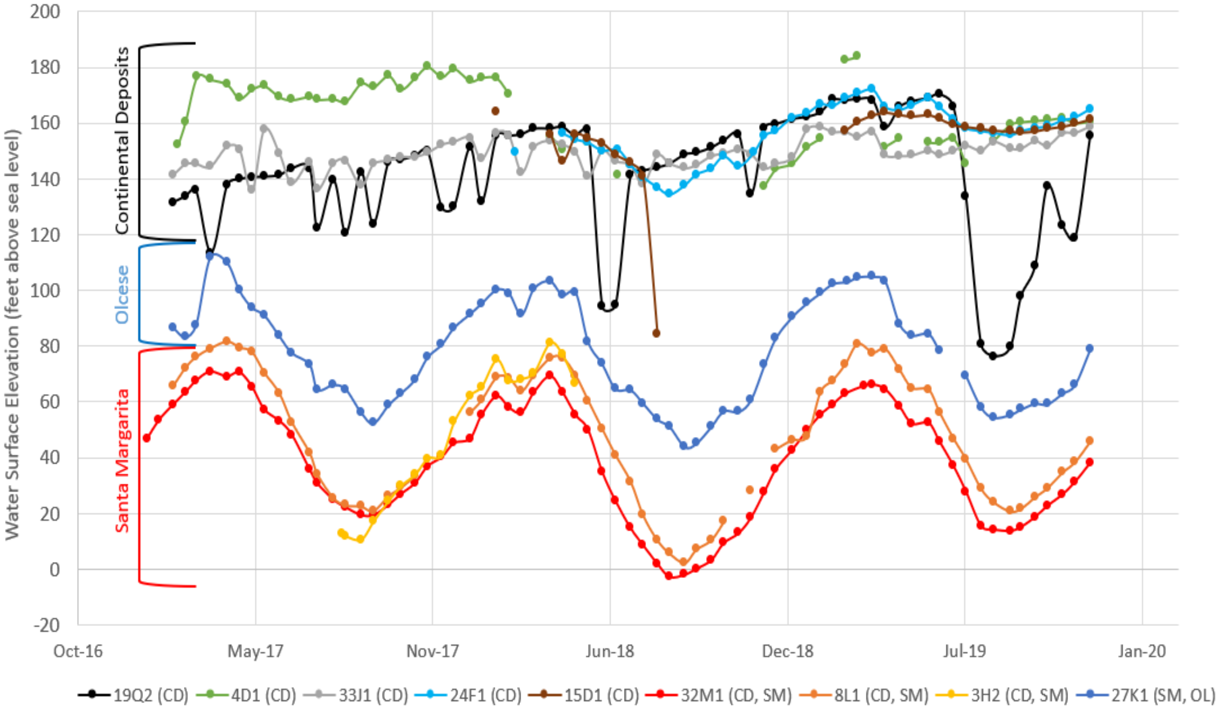
In 2013, the District began semi-monthly measurements on monitoring well 24S27E32M1M, located ¾ mile east of Richgrove near the center of the District. This well is an inactive irrigation well penetrated to the Santa Margarita Formation. Figure 2-20 is a hydrograph of these measurements from August 2013 to present which demonstrates the seasonal change in groundwater elevations. As shown in Figure 2-20, groundwater levels in the Santa Margarita Formation experience seasonal fluctuations of 50-110 feet.

Figure 2-20 In-District Groundwater Elevation Data for Well No. 24S27E32M1M (2013-2019)



In early 2017, the District began taking semi-monthly measurements on several additional wells. These wells represent groundwater levels from the wells that penetrate the Continental Deposits, Santa Margarita Formation, and Olcese Sands. Figure 2-21 is a hydrograph of the District's semi-monthly monitoring wells that distinguish the differences in groundwater level elevations and fluctuations between aquifers. Well numbers 24F1, 4D1, 15D1, 33J1, and 19Q2 penetrate only the Continental Deposits (CD). Well numbers 8L1, 32M1, and 3H2 penetrate to the Santa Margarita Formation (SM). Well number 27K1 penetrates to the Olcese Sands (OL) Formation.

Figure 2-21 Semi-monthly Well Measurement Comparison (2017-2019)



CD = Continental Deposits; SM = Santa Margarita Formation; OL = Olcese Sands

The following observations can be made from Figure 2-21:

1. Groundwater levels in the Continental Deposits are 60-140 feet higher than those in the Santa Margarita Formation and do not show the large seasonal fluctuations evidenced in the Santa Margarita Formation and Olcese Sands.
2. Wells that penetrate the Olcese Sands have water levels that are about 40 feet higher than those that only penetrate the Santa Margarita Formation.
3. Variations in the Continental Deposits may reflect recent or nearby pumping.
4. Wells penetrating the Santa Margarita and/or Olcese reflect seasonal fluctuations of about 60 feet.

2.3.2 Groundwater Quality

Table 2-2 is a summary of the sampling results conducted from 2014 through 2018 for wells in the groundwater monitoring network.

Table 2-2 Summary of Groundwater Quality Sampling Results

	Groundwater Well Concentrations (mg/L) (1)									
Well	4D1	19F1	33J1	12A	15D1	20C1	28G2	17D1	27K2	2D1
Date	12/22/17	6/12/14	2/4/15	1/3/18	2/22/18	8/5/15	8/5/15	5/16/17	4/6/18	4/6/18
Total Depth (ft)	800	N/A	820	884	680	2,000	2,030	1,870	1,650	1,650
Aquifer(s) Penetrated (2)	CD	CD	CD	CD	CD	CD, SM	CD, SM	CD, SM	CD, SM, OL	CD, SM, OL
Total Dissolved Solids (TDS)	680	400	380	290	380	460	360	-	410	360
Electrical Conductivity (EC)	620	696	632	450	521	760	570	436	528	443
Calcium (Ca)	50	41	30	29	43	25	2.8	5.8	30	25
Nitrate (NO3)	50	30	38	21	-	6.7	<2	-	<2	2
Nitrate (N)	-	6.7	8.5	5.0	7.5	-	-	0.17	-	-
Boron (B)	<0.10	0.20	0.07	0.05	0.04	0.19	0.32	0.32	0.10	0.10
Magnesium (Mg)	7.4	6.9	8.7	3.0	9.2	4.1	0.21	0.16	2.6	1.3
Sodium (Na)	46	81	100	59	46	88	100	101	61	50
Potassium (K)	3.4	4.7	4.0	3.0	4.4	3.7	1.8	1.4	4.3	4.2
Bicarbonate (HCO3)	110	130	210	116	130	99	110	185	134	127
Carbonate (CO3)	0	0	0	0	0	<10	12	0	0	0
Chloride (Cl)	50	43	30	28	42	63	63	44	48	28
Sulfate (SO4)	89	130	61	19	41	140	44	10	74	61

(1) Electrical conductivity units are umhos/cm

(2) CD = Continental Deposits, SM = Santa Margarita Formation, OL = Olcese Sands

As previously described, groundwater in the study area is produced from continental sedimentary formations derived from igneous and metamorphic rocks of the Sierra Nevada. Moreover, runoff from the Sierra Nevada contains a much lower TDS and this recharge contributes to the higher quality groundwater (Kennedy and Jenks, 2015). Fresh groundwater produced from sediments in the continental deposits is the calcium-sodium bicarbonate type with TDS concentrations ranging between 290-680 mg/L. Groundwater quality in wells that tap the Santa Margarita Formation is the sodium bicarbonate type with TDS concentrations ranging between 360-500 mg/L. Groundwater in wells that tap the Olcese Sands is the calcium-sodium type with a TDS range of 360-410 mg/L.

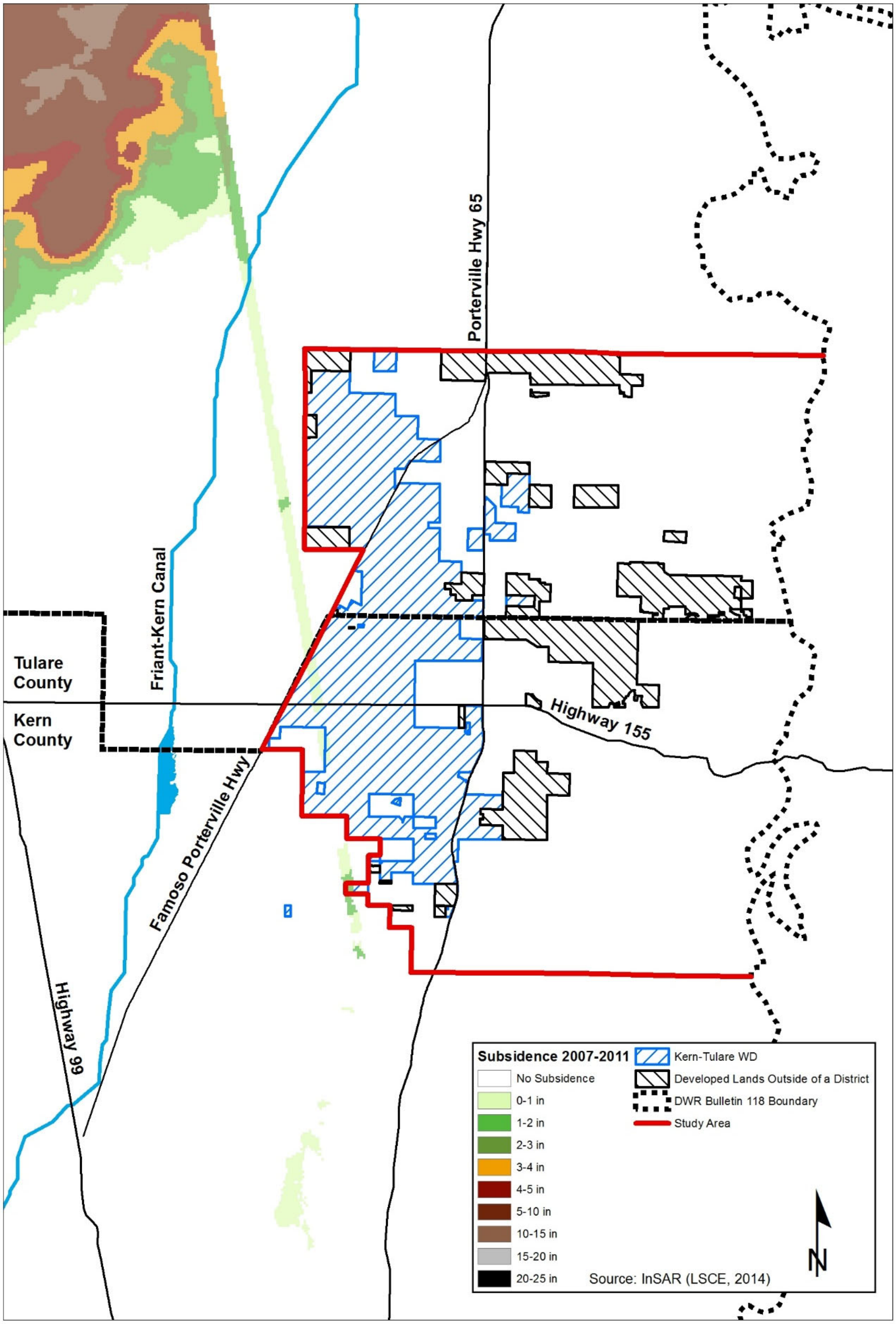
Based on available information on the SWRCB Geotracker website and the California Department of Toxic Substances Control (DTSC) EnviroStor website and ongoing communication with District water users, the District is unaware of any groundwater quality concerns or contaminant plumes within the study area which impact agriculture.

2.3.3 Subsidence

Historical documentation of subsidence has relied on various types of data, including ground surveys, borehole extensometers, and continuous GPS station information. Recent subsidence studies have utilized satellite- and aircraft-based Interferometric Synthetic Aperture Radar (InSAR) within the Central Valley and along the Friant-Kern Canal. Much of the InSAR work has been led by the National Aeronautics and Space Administration (NASA) Jet Propulsion Laboratory (JPL), as well as other international researchers. It should be noted that the JPL data is preliminary and has not been fully verified or calibrated with other sources. Subsidence within the study area measured by historical InSAR studies conducted from 2007 - 2011 is plotted on Figure 2-22. According to these studies, there was relatively no measurable subsidence within the study area during this period.

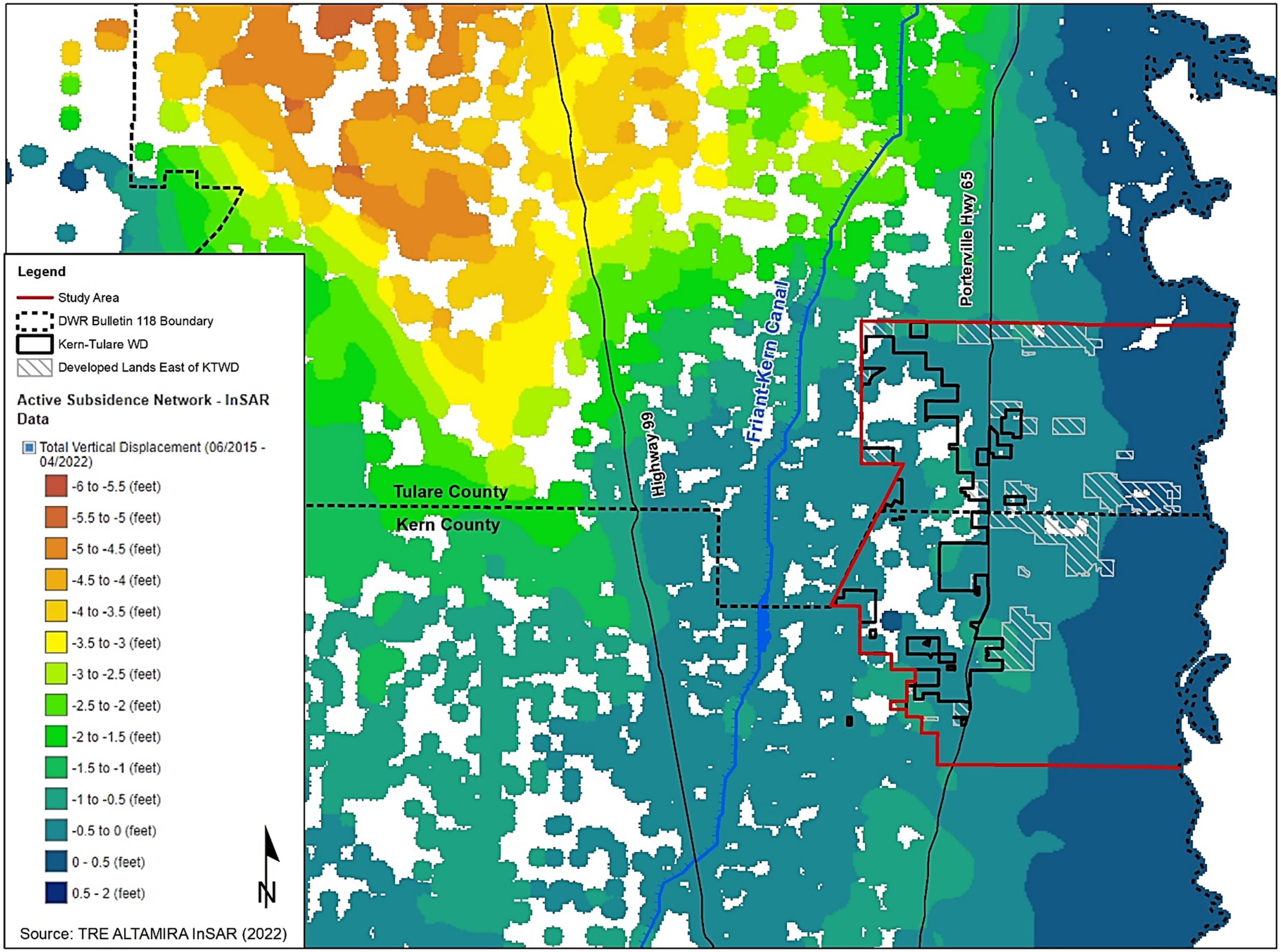
Subsidence as measured by recent InSAR studies provided by DWR (TRE ALTAMIRA, 2022) is plotted on Figure 2-23 and shows that from June 2015 – April 2022 approximately 0 to -0.7 ft of subsidence has occurred over the last 7 years. This equates to approximately 0 to 1.2-inches of average annual subsidence throughout the District. Concentrated areas of subsidence (total vertical displacement of -0.7 ft or 8.4 inches) occur within the study area along the eastern edge of the District. This is most likely caused by significant groundwater extraction for developed agriculture with no surface supply located outside the District's boundaries to the east.

Figure 2-22 Subsidence 2007-2011



Source: InSAR (LSCE, 2014)

Figure 2-23 Subsidence 2015 – 2022



Source: TRE ALTAMIRA InSAR (2022)

2.4 Water Budget (Reg. § 354.18.)

This section presents a water budget that provides an accounting and assessment of the total annual volume of groundwater and surface water entering and leaving the District, including historical, current and projected water budget conditions, and the change in the volume of water stored. For purposes of this Plan, some water budget components for the entire study area were evaluated to reflect the common aquifers shared by the area, however only a water budget for the District was developed. The water budget for the District was developed in coordination with KGA GSA and ETGSA.

2.4.1 Water Budget Coordination

Kern Subbasin

All GSAs in the Kern County subbasin (Subbasin) coordinated and collaborated on the development of a groundwater model (Model) to evaluate historical, baseline and projected groundwater conditions. The GSAs entered into a Cost Share Agreement with the Kern River GSA who took the lead and contracted with Todd Groundwater to develop the Model on behalf of the Subbasin. The contract required that Todd Groundwater use the C2VSim model provided by DWR. Considerable effort and resources were expended to update the C2VSim model with local data to better represent Subbasin conditions. The process Todd Groundwater used to update C2VSim is more fully described in the Historical and Projected Future Water Budget Development (see Attachment H in KGA Umbrella GSP). Basin-wide water budget results from the Model are provided in Attachment H and show the Subbasin, as a whole, has a total storage deficit of approximately 324,326 acre-feet per year (AFY) over the baseline period.

The Subbasin's dynamic conjunctive use programs, water banking operations, and water transfers/exchanges made it necessary to coordinate a GSA level water accounting system (Checkbook) using Subbasin specific values for supply, demand and net results. The Model results reflect Subbasin-wide conditions and do not allocate water shortages/surpluses, nor do the results allocate the "ownership" of water. As a result, the GSAs, through a coordinated effort, developed the Checkbook that estimates current conditions for each GSA that are generally consistent with the Model results under baseline condition. The Checkbook and Model budgets are based upon best available information, recognizing however, each estimate includes data gaps and has varying degrees of accuracy and/or reliability in the interest of developing a Subbasin coordinated approach.

The result of that effort indicates a current baseline shortage/deficit for KGA members of approximately -225,533 AFY. This reflects the difference between a total demand for KGA members of 1,475,358 AFY, and a total supply of 1,249,825AFY. Kern-Tulare Water Storage District's portion of the KGA shortage/deficit is 3,086 AF or a difference in demand of 30,031 and a water supply of 26,945.

As is mentioned above, each estimate includes data gaps and has varying degrees of accuracy and/or reliability. The Checkbook is complimentary to the Model and reflects the allocation of water supply benefits and obligations independent of geographic constraints within the Subbasin. This was important to recognize and ensure the coordination of the various groundwater banking projects and water management programs amongst the various GSA's within the groundwater basin.

KTWD Management Area

The KGA GSA adopted a water budget guidance document to ensure consistency within the respective chapters of the KGA GSP. The guidance document provides the estimate of native yield as 0.15 AF per acre in the Kern Subbasin. The ETGSA adopted a basin-wide water budget for the Tule Subbasin that is included in the ETGSA GSP. The native yield in accordance with the Tule Subbasin Setting is 0.18 AF per acre.

The District's total allowable groundwater pumping is a combination of native yield and return flows. Return flows for the District, explained later in more detail, were calculated as applied irrigation water and precipitation in excess of crop evapotranspiration, less runoff leaving the District. Average yearly return flows from 1993-2017 were 0.54 AF per acre.

	KGA GSA	ETGSA	KTWD
Native Yield (AF/ac)	0.15	0.18	-0.02
Return Flows (AF/ac)	0.54	0.54	0.54
Sustainable GW Pumping	0.69	0.72	0.52

As shown in the above table, the native yield used by the District is much more conservative than that used by the KGA GSA and ETGSA. The resulting -0.02 AF per acre indicates that with implementation of this GSP landowners within Kern-Tulare Water District will pump less than or equal to the return flows.

2.4.2 Historical Water Budget

A 25-year historical water budget was developed for the District from 1993 through 2017 to evaluate water demands, surface water deliveries, groundwater pumping, and aquifer response to water supply and demand. The historical water budget for the District includes the following along with a comparison to lands outside of the District:

1. A summary of land use within the study area.
2. A summary of historical water deliveries.
3. A quantitative assessment of the historical water budget which includes evapotranspiration (ET), effective precipitation, surface water deliveries, groundwater pumping and return flows to the groundwater basin.
4. A comparison of change in District groundwater storage from the water budget and measured groundwater levels to verify calibration of the historical water budget.
5. A description of how historical conditions concerning hydrology, water demand, and surface water supply availability or reliability have impacted the ability of the District to operate within the safe yield of the aquifers.

The water budget relies on the following fundamental relationship between inflows and outflows:

$$\text{Inflow} - \text{Outflow} = +/- \Delta \text{ Storage}$$

where inflows include precipitation, surface water deliveries, subsurface inflow, and return flow to groundwater (deep percolation); and outflows include ET, groundwater pumping, and subsurface outflow. Detailed documentation of the historical water budget, including assumptions and monthly calculations, is presented in Appendix 2. The presentation that follows is an annual summary of the detailed monthly analysis contained in Appendix 2.

Table 2-3 and Table 2-4 summarize the ET, effective precipitation, applied water, and surface water deliveries used to calculate groundwater pumping for both inside the District and outside the District within the study area. A discussion of each component and derivation of the values follows.

Table 2-3 Historical Groundwater Pumping within the District

Year	**Crop ET**	**Effective Precip**	**Total Applied Water**	**Surface Water Deliv.**	**Ground Water Pumping**
	(A)	***(B)***	***(C)***	***(D)***	***(E)***
1993	48,826	5,828	47,776	37,307	**10,470**
1994	50,872	8,072	47,556	40,721	**6,836**
1995	50,503	8,094	47,672	39,243	**8,428**
1996	51,107	7,341	48,832	41,718	**7,114**
1997	51,834	3,800	53,483	44,610	**8,873**
1998	53,738	12,981	45,328	35,110	**10,218**
1999	51,968	4,355	52,903	41,692	**11,211**
2000	50,607	6,173	50,037	44,509	**5,528**
2001	49,601	6,209	48,946	45,312	**3,635**
2002	47,405	4,746	47,409	38,337	**9,071**
2003	46,182	5,115	45,630	36,820	**8,810**
2004	47,000	5,264	46,374	38,633	**7,741**
2005	47,219	7,895	43,693	36,290	**7,403**
2006	51,528	9,075	47,169	35,371	**11,798**
2007	51,620	4,112	52,917	38,427	**14,490**
2008	52,747	3,414	54,815	40,233	**14,582**
2009	49,612	3,997	50,683	36,164	**14,518**
2010	52,003	6,826	50,197	32,840	**17,358**
2011	47,577	6,553	45,582	33,629	**11,953**
2012	48,435	5,379	47,840	35,853	**11,987**
2013	47,798	4,475	48,515	37,755	**10,760**
2014	48,366	4,962	48,227	21,409	**26,818**
2015	50,348	6,833	48,352	16,726	**31,627**
2016	50,161	5,414	49,719	29,879	**19,841**
2017	49,494	3,290	51,566	37,638	**13,929**
1993-2009 Average	*50,139*	6,263	*48,895*	*39,441*	***9,454***

(A) = Derived from ITRC data and land use.
(B) = Derived from Delano precipitation data and irrigated acreage.
(C) = Refer to Appendix 2.
(D) = From District turnout data.
(E) = Refer to Appendix 2.

Table 2-4 Historical Groundwater Pumping Outside of District

Year	Crop ET	Effective Precip	Total Applied Water	Surface Water Deliv.	Ground Water Pumping
	(A)	*(B)*	*(C)*	*(D)*	*(E)*
1993	15,758	2,626	14,591	0	**14,591**
1994	15,758	3,240	13,909	0	**13,909**
1995	16,146	3,411	14,149	0	**14,149**
1996	16,146	2,870	14,751	0	**14,751**
1997	16,146	1,733	16,014	0	**16,014**
1998	16,146	4,489	12,952	0	**12,952**
1999	16,146	1,390	16,395	0	**16,395**
2000	16,146	2,601	15,049	0	**15,049**
2001	16,146	2,839	14,785	0	**14,785**
2002	16,552	2,091	16,067	0	**16,067**
2003	17,468	2,161	17,008	0	**17,008**
2004	16,557	2,767	15,322	0	**15,322**
2005	16,557	3,445	14,570	0	**14,570**
2006	16,557	3,385	14,636	0	**14,636**
2007	16,557	2,021	16,151	0	**16,151**
2008	16,883	1,681	16,891	0	**16,891**
2009	19,345	1,985	19,289	0	**19,289**
2010	19,345	3,277	17,853	0	**17,853**
2011	19,475	3,459	17,796	0	**17,796**
2012	19,475	2,822	18,504	0	**18,504**
2013	19,475	2,150	19,250	0	**19,250**
2014	26,683	2,946	26,375	0	**26,375**
2015	29,958	4,386	28,413	0	**28,413**
2016	30,154	4,218	28,817	0	**28,817**
2017	31,026	2,825	31,334	0	**31,334**
1993-2009 Average	*16,530*	*2,632*	*15,443*	*0*	***15,443***

(A) = Derived from ITRC data and land use.

(B) = Derived from Delano precipitation data and irrigated acreage.

(C) = (A – B) ÷ 90% irrigation efficiency.

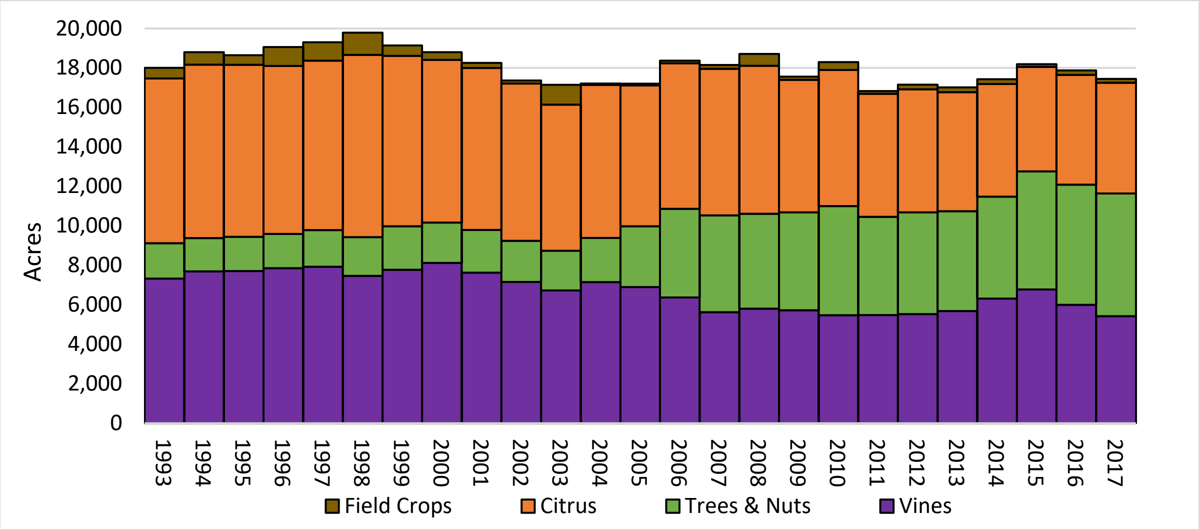
(D) = No surface water deliveries.

(E) = C – D

Land Use

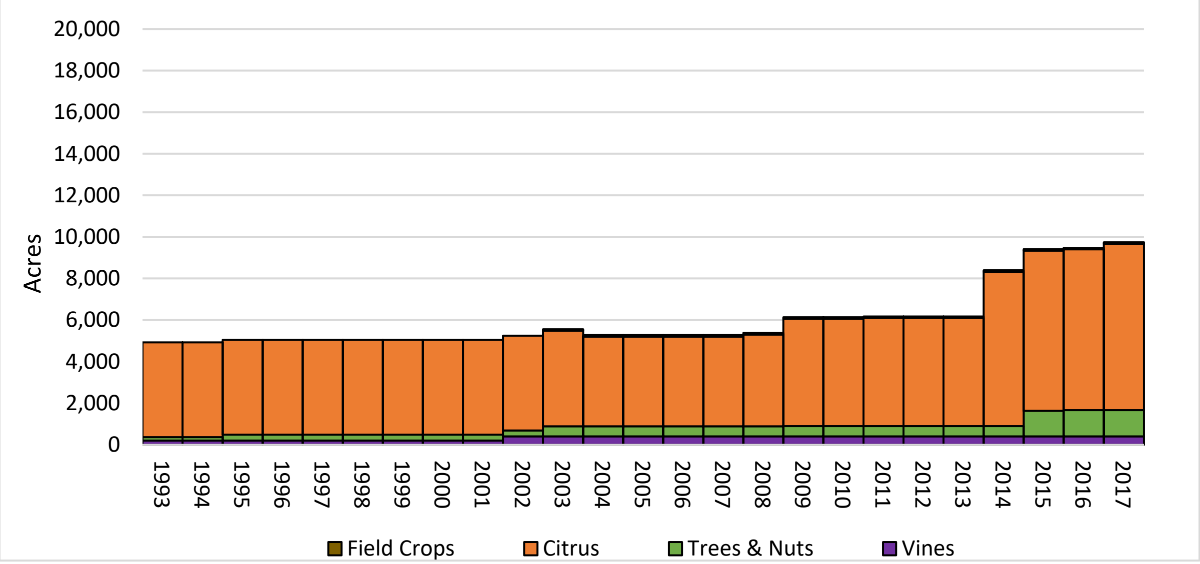
Historical land use for years 1993 through 2017 is summarized for the District in Figure 2-24 and summarized for lands within the study area but outside of the District in Figure 2-24. As shown in Figure 2-24, the total number of irrigated acres within the District has remained constant since 1993 and there has been a conversion from citrus and grapes to trees and nuts. The total number of irrigated acres for lands outside of the District has nearly doubled since 2008 as displayed in Figure 2-25.

Figure 2-24 Historical Land Use within the District (1993 - 2017)



(1) – Field Crops include blue berries, Sudan grass, and alfalfa.
(2) – Citrus include oranges, tangelo, kiwi, lemons, and grapefruit.
(3) – Trees and nuts include almonds, pistachios, cherries, persimmons, and pomegranates.
(4) – Vines include wine and table grapes.

Figure 2-25 Historical Land Use Outside of District (1993 - 2017)



(1) – Field Crops includes blue berries.
(2) – Citrus includes oranges, tangelo, kiwi, lemons, and grapefruit.
(3) – Trees and nuts include almonds, pistachios, cherries, persimmons, and pomegranates.
(4) – Vines includes wine and table grapes.

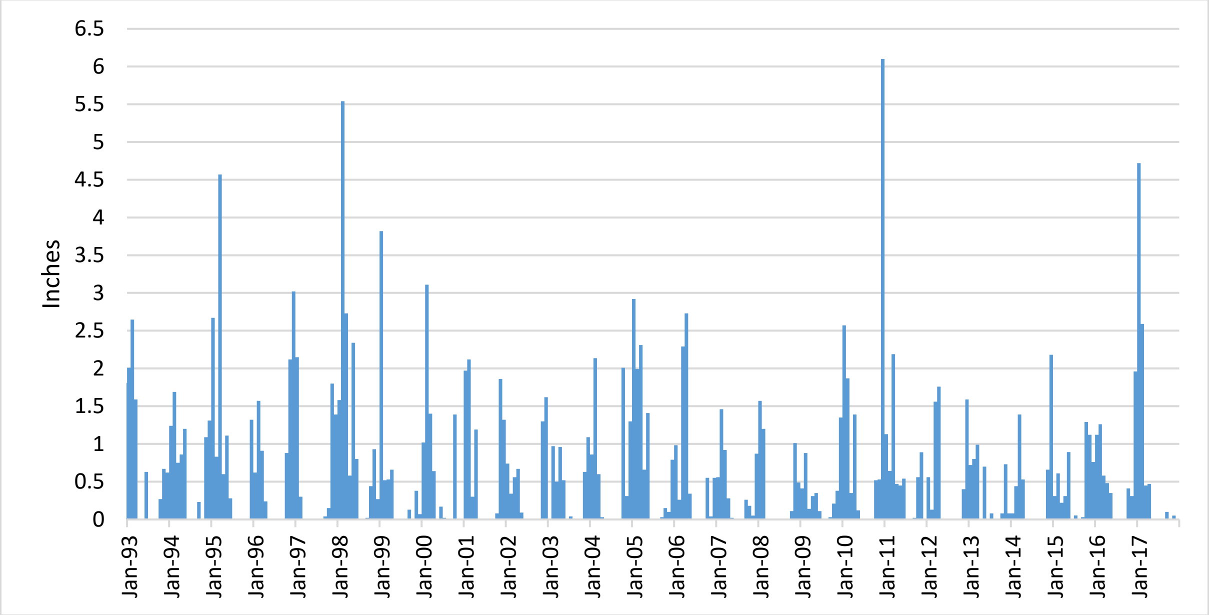
Evapotranspiration (ET)

The land use within and outside the District was used to determine the crop demand, or ET in acre-feet, which is an outflow of water from the study area. Table 2-3 and Table 2-4 display the ET values applied to land use for both inside and outside the District. ET was initially calculated using a table of monthly crop ET values from the Irrigation Training and Research Center (ITRC) that were then calibrated to ET values based on satellite imagery also determined by the ITRC. A detailed description of this analysis is provided in Appendix 2. Cropped acreage and calibrated ET values were used to evaluate ET in future years based on cropping patterns when ITRC satellite data is not available.

Precipitation

Precipitation is a source of inflow to the study area. Precipitation data for the study area was collected from the Western Regional Climate Center for the City of Delano, presented in Figure 2-26, and applied to the total irrigated acres.

Figure 2-26 Delano Precipitation (1993 – 2017)



Considering part of the rainfall can runoff or percolate to the groundwater, the District was interested in effective precipitation – the water that is stored in the root zone and can be used by the plants. Table 2-3 and Table 2-4 shows effective precipitation for within and outside the District. The values shown in Table 2-3 took into consideration monthly crop ET and known surface water deliveries (including an irrigation efficiency). A detailed description of this analysis is provided in Appendix 2.

Surface Supplies

Figure 2-27 and Table 2-3 show the amount of groundwater pumped compared to the amount of surface water delivered within the District. In most years, District growers have access to as much District water as they are willing to purchase. The District has concerns that when the cost to deliver surface water exceeds the cost of groundwater that some landowners may choose to use groundwater when surface water is available.

Limited District surface water supplies were available in 2014 and 2015 as shown in Figure 2-27. As a result, the District allocated water supplies to water users and growers pumped groundwater to meet the remaining irrigation demand.

Groundwater Pumping

Groundwater pumping within the District was calculated monthly as the difference between the applied water demand (crop evapotranspiration less effective precipitation divided by a 90% irrigation efficiency) and the surface water deliveries. Figure 2-27 and Table 2-3 summarize the annual volume of groundwater pumping and surface water deliveries within the District from 1993 through 2017.

Outside of the District, groundwater pumping and effective precipitation must meet all crop evapotranspiration requirements due to the fact that lands outside of the District do not receive surface supplies. Figure 2-28 and Table 2-4 summarize the volume of groundwater pumping outside of the District from 1993 through 2017.

Figure 2-27 District Water Supplies (1993 – 2017)

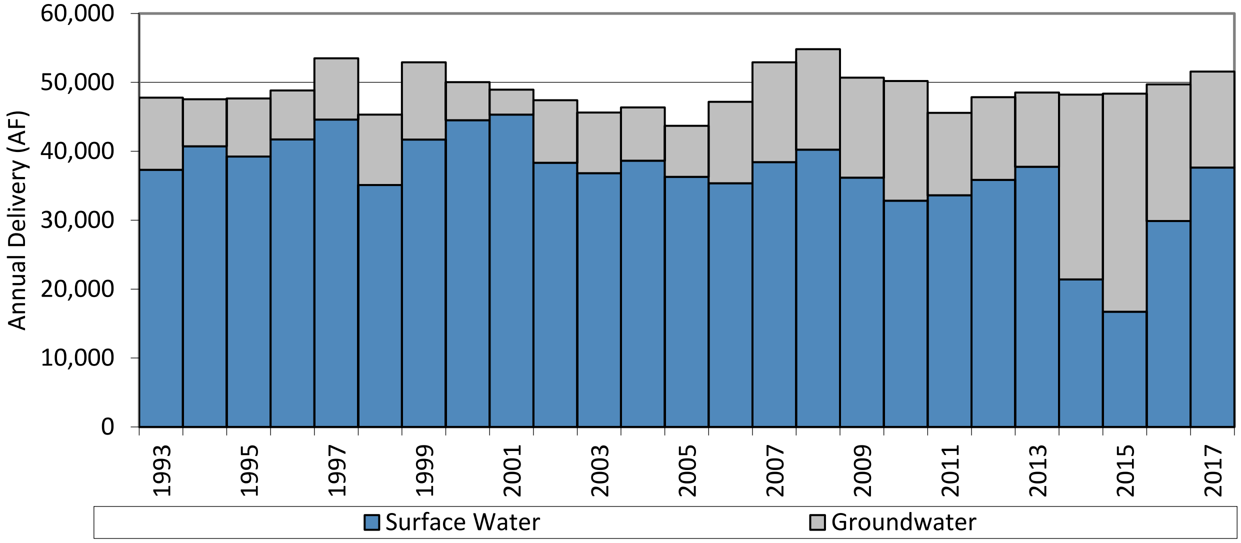
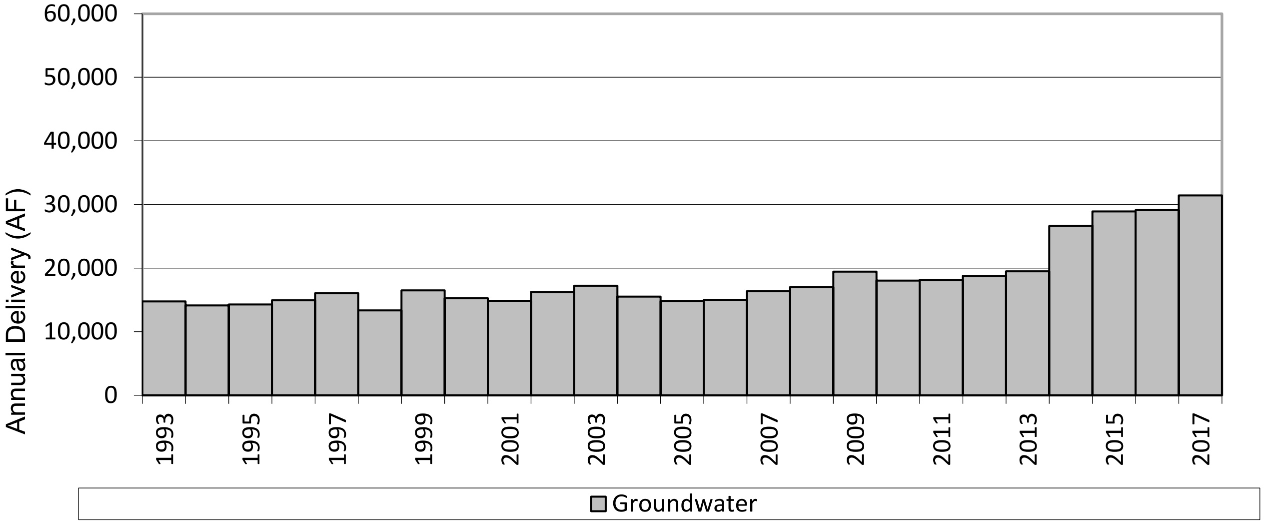


Figure 2-28 Water Supplies Outside of District (1993 – 2017)



Return Flow to Groundwater

The District considered any rain water in excess of the effective precipitation, that also did not runoff, as percolating below the root zone and attributed it as a return flow to groundwater. Table 2-5 calculates the return flow to groundwater based on the previously described inflows of total precipitation and applied water less the outflows of ET and runoff. The runoff leaving the District was calculated using a stream gauge in Rag Gulch, a creek that runs through the District and exits at Famoso Porterville Highway and County Line Road. The stream gauge located upstream of the Famoso-Porterville Highway has been measured continuously from 1976 to 2015. The annual runoff values for the water budget were estimated using the total Delano precipitation data and the observed annual peak flows in Rag Gulch.

Table 2-5 District Historical Return Flow

Year	Total Precip	Surface Water Deliv.	Ground Water Pumping	Crop ET	Runoff Leaving District	Return Flow to GW
	(A)	*(B)*	*(C)*	*(D)*	*(E)*	*(F)*
1993	12,668	37,307	10,470	48,826	0	**11,618**
1994	13,112	40,721	6,836	50,872	0	**9,796**
1995	17,675	39,243	8,428	50,503	2,498	**12,346**
1996	14,876	41,718	7,114	51,107	195	**12,406**
1997	9,377	44,610	8,873	51,834	0	**11,025**
1998	25,108	35,110	10,218	53,738	4,533	**12,166**
1999	9,745	41,692	11,211	51,968	1,493	**9,188**
2000	12,138	44,509	5,528	50,607	271	**11,297**
2001	13,445	45,312	3,635	49,601	0	**12,791**
2002	7,696	38,337	9,071	47,405	0	**7,700**
2003	6,727	36,820	8,810	46,182	0	**6,175**
2004	10,389	38,633	7,741	47,000	0	**9,763**
2005	14,853	36,290	7,403	47,219	0	**11,327**
2006	11,851	35,371	11,798	51,528	0	**7,492**
2007	6,970	38,427	14,490	51,620	0	**8,267**
2008	6,828	40,233	14,582	52,747	0	**8,896**
2009	6,100	36,164	14,518	49,612	0	**7,171**
2010	20,503	32,840	17,358	52,003	4,699	**13,998**
2011	9,663	33,629	11,953	47,577	0	**7,668**
2012	8,590	35,853	11,987	48,435	0	**7,995**
2013	5,926	37,755	10,760	47,798	0	**6,643**
2014	7,668	21,409	26,818	48,366	0	**7,528**
2015	8,464	16,726	31,627	50,348	0	**6,468**
2016	9,637	29,879	19,841	50,161	0	**9,195**
2017	12,181	37,638	13,929	49,494	2,261	**11,992**
1993-2009 Average	*11,739*	*39,441*	*9,454*	*50,139*	*529*	***9,966***

(A) = from Delano precipitation data.
(B) = from District turnout data.
(C) = from Table 2-4.
(D) = derived from ITRC data and land use.
(E) = derived from stream gauge data.
(F) = (A) + (B) + (C) – (D) – (E)

2.4.3 Water Budgets by Aquifer

The calculated groundwater pumping and return flows were used to create water budgets for the Continental Deposits and Santa Margarita Formation beneath the District. The District also determined sub-surface inflows and outflows from the aquifers to complete the water budgets, shown in Table 2-6. The values for sub-surface flows in Table 2-6 are constant due to the assumption that the hydrologic balance from 1993 to 2009 had no change in storage as explained below. A description of the sub-surface flow assumptions and calculation follows Table 2-6.

Table 2-6 District Historical Water Budgets by Aquifer

	Continental Deposits					**Santa Margarita**			
Year	**sub-surface Inflow**	**Return Flow to GW**	**Ground Water Pumping**	**sub-surface Outflow**	**Ground Water Balance**	**sub-surface Inflow**	**Ground Water Pumping**	**sub-surface Outflow**	**Ground Water Balance**
1993	0	11,618	2,617	7,602	1,398	7,091	7,852	0	-761
1994	0	9,796	1,709	7,602	1,882	7,091	5,127	0	1,202
1995	0	12,346	2,107	7,602	4,519	7,091	6,321	0	1,972
1996	0	12,406	1,778	7,602	7,544	7,091	5,335	0	3,727
1997	0	11,025	2,218	7,602	8,749	7,091	6,654	0	4,164
1998	0	12,166	2,555	7,602	10,757	7,091	7,664	0	3,591
1999	0	9,188	2,803	7,602	9,540	7,091	8,408	0	2,274
2000	0	11,297	1,382	7,602	11,852	7,091	4,146	0	5,218
2001	0	12,791	909	7,602	16,132	7,091	2,726	0	9,583
2002	0	7,700	2,268	7,602	13,962	7,091	6,803	0	9,870
2003	0	6,175	2,202	7,602	10,332	7,091	6,607	0	10,354
2004	0	9,763	1,935	7,602	10,557	7,091	5,806	0	11,639
2005	0	11,327	1,851	7,602	12,431	7,091	5,552	0	13,178
2006	0	7,492	2,949	7,602	9,371	7,091	8,848	0	11,420
2007	0	8,267	3,622	7,602	6,413	7,091	10,867	0	7,644
2008	0	8,896	3,646	7,602	4,061	7,091	10,937	0	3,798
2009	0	7,171	3,630	7,602	0	7,091	10,889	0	0
2010	0	13,998	4,339	7,602	2,056	7,091	13,018	0	-5,928
2011	0	7,668	2,988	7,602	-866	7,091	8,965	0	-7,802
2012	0	7,995	2,997	7,602	-3,470	7,091	8,990	0	-9,701
2013	0	6,643	2,690	7,602	-7,120	7,091	8,070	0	-10,680
2014	0	7,528	6,704	7,602	-13,898	7,091	20,113	0	-23,703
2015	0	6,468	7,907	7,602	-22,940	7,091	23,720	0	-40,332
2016	0	9,195	4,960	7,602	-26,307	7,091	14,880	0	-48,122
2017	0	11,992	3,482	7,602	-25,400	7,091	10,446	0	-51,477
1993-2009 Average	*0*	*9,966*	*2,364*	*7,602*		*7,091*	*7,091*	*0*	

As shown in Table 2-6, in most years the return flow to the Continental Deposits from applied Santa Margarita groundwater or surface water imports is greater than the amount of groundwater pumping from the Continental Deposits. The large amount of return flow contributes to the subsurface outflow to districts down gradient such as Delano-Earlimart Irrigation District and Southern San Joaquin Municipal Utility District who use the Continental Deposits as their primary aquifer.

Subsurface Flow

For the area beneath the District, subsurface inflow and outflow values were assumed using a water budget analysis for the period between 1993 through 2009 where no change in storage occurred as shown on the hydrograph in Section 2.3, Figure 2-16. Figure 2-29 provides an illustrative summary of the hydrologic balance calculated for this period with no change in storage. The proportion of groundwater pumped from each aquifer was assumed using the following information: 1) the large number of wells drilled to the Santa Margarita Formation in comparison to those drilled to the Continental Deposits (illustrated in Figure 2-2 through 2-6) and; 2) the observation that wells drilled to the Continental Deposits have significantly lower yields than those drilled to the Santa Margarita Formation. As a result, it was assumed that 25% of groundwater pumping occurs from the Continental Deposits and 75% from the Santa Margarita.

Continental Deposits

The subsurface inflow to the District for the Continental Deposits is currently unknown and therefore not given a value in the hydrologic model. The subsurface outflow from the District was estimated as 7,602 acre-feet per year based on the 1993 through 2009 water budget. This value was calculated as the difference between the average annual return flow (9,966 acre-feet) and the estimated average annual groundwater pumped from the Continental Deposits (25% of 9,454 = 2,364 acre-feet) during the 17-year period. This is a conservative (low) estimate which will increase by the amount of subsurface inflow to the Continental Deposits, currently assumed as zero.

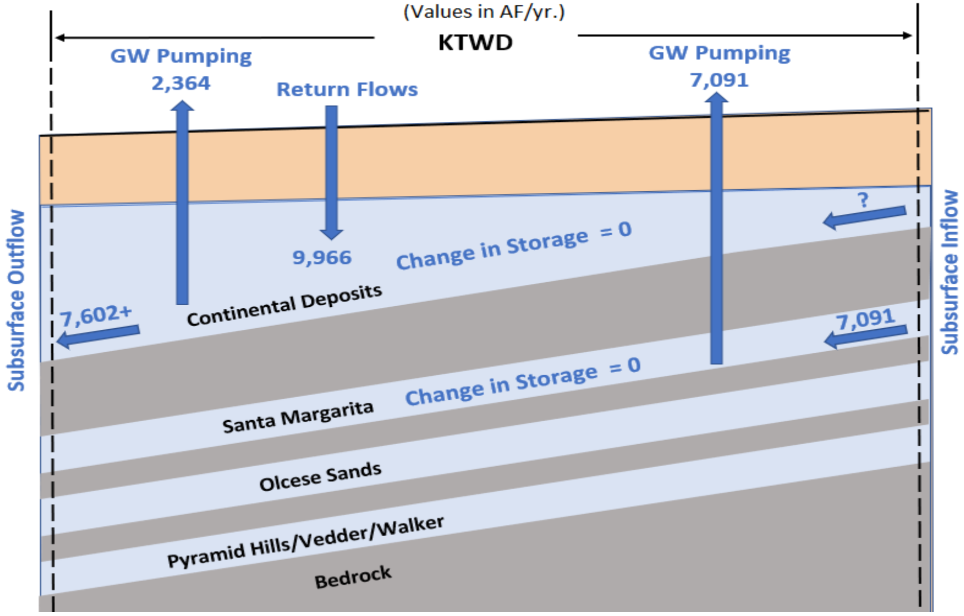
Santa Margarita

The subsurface inflow underneath the District in the Santa Margarita is assumed to equal the average groundwater pumping calculated from 1993 through 2009 (75% of 9,454 = 7,091 acre-feet). This assumption was made due to the constant water levels seen in the hydrograph during this period in section 2.3 on Figure 2-16.

Olcese Sands

For the most part, lands within the District do not currently pump out of the Olcese Sands; therefore, subsurface flow in this aquifer was not calculated.

Figure 2-29 Hydrologic Balance for 1993 – 2009



2.4.4 Change in Groundwater Storage

An estimated change in groundwater storage for the District was calculated using the historical water budget. The groundwater storage was evaluated using the monthly inflows and outflows to the aquifers beneath the District and was verified by measured groundwater levels. Figure 2-30 and Figure 2-31 provide a comparison of calculated groundwater storage from the water budget and measured groundwater levels to demonstrate calibration of the historical water budget.

Figure 2-30 Groundwater Levels in Continental Deposits beneath the District

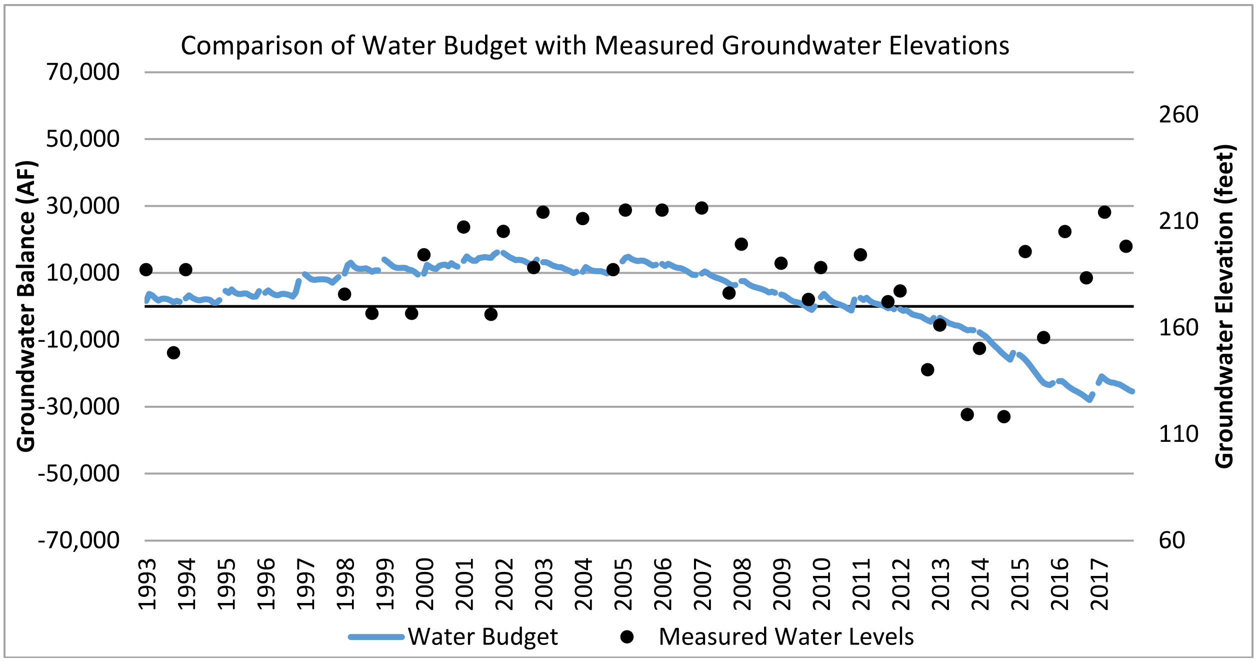
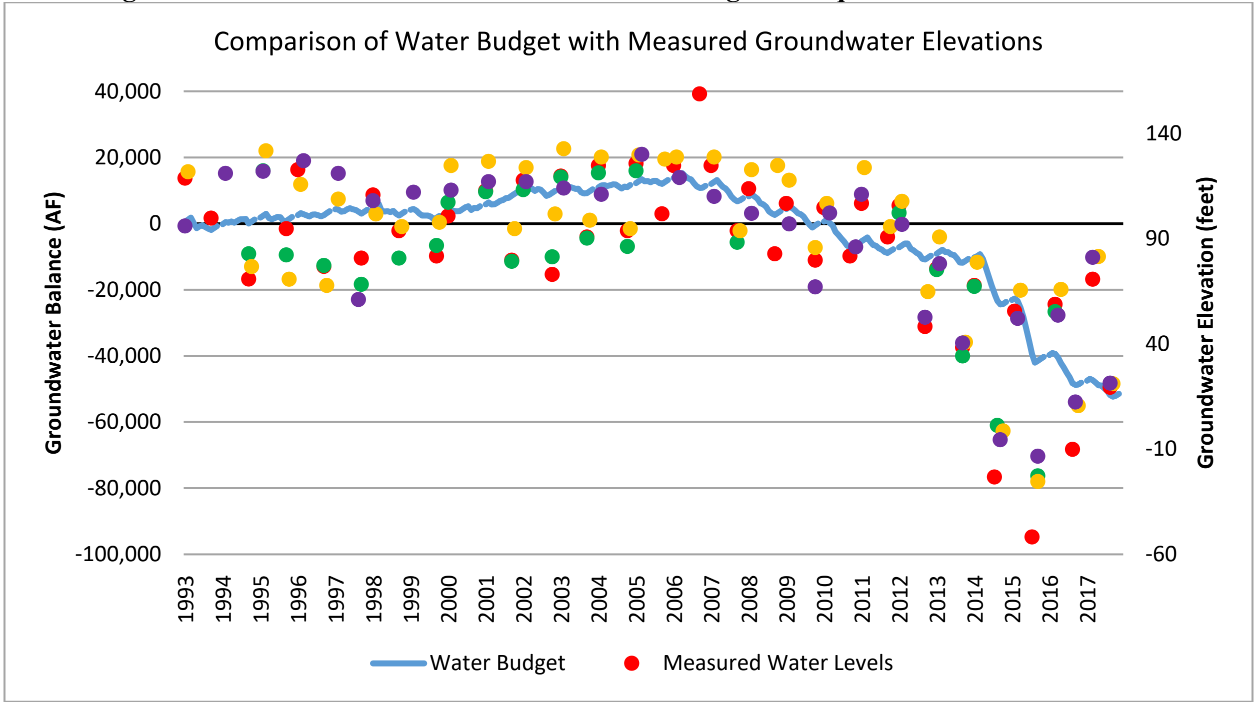


Figure 2-31 Groundwater Levels in the Santa Margarita Aquifer beneath the District



The blue line represents annual groundwater balances calculated in the water budget from Table 2-4. Historical groundwater elevations measured from monitoring wells are shown as colored dots. As demonstrated in Figure 2-30 and Figure 2-31:

- Measured groundwater levels have larger seasonal variations than the calculated groundwater balances from the water budget. This is because the water budget assumes constant subsurface inflow every month and does not reflect the seasonal variation of recharge from the mountain front.
- Calculated groundwater balances from the water budget calibrate very well with measured groundwater levels. However, during years 2016 and 2017, measured groundwater levels rise and calculated groundwater balances do not. This is because there is additional inflow to the area as a result of recovery from the drawdown that occurred in previous years. This movement of water within the basin does not present itself in the simple water budget approach. Another contributing factor is that the inflow is held constant at a calibrated level rather than varying annually with hydrology.
- The net impact of these discrepancies does not affect accuracy of the calibration of the hydrologic balance over the long run and the water budget approach is still a very good approximation of the safe yield of the aquifers beneath the District.

Figure 2-32 through Figure 2-35 show the results for the annual and cumulative change in storage for the Continental Deposits and Santa Margarita Formation.

Figure 2-32 Annual Change in Storage for Continental Deposits within the District

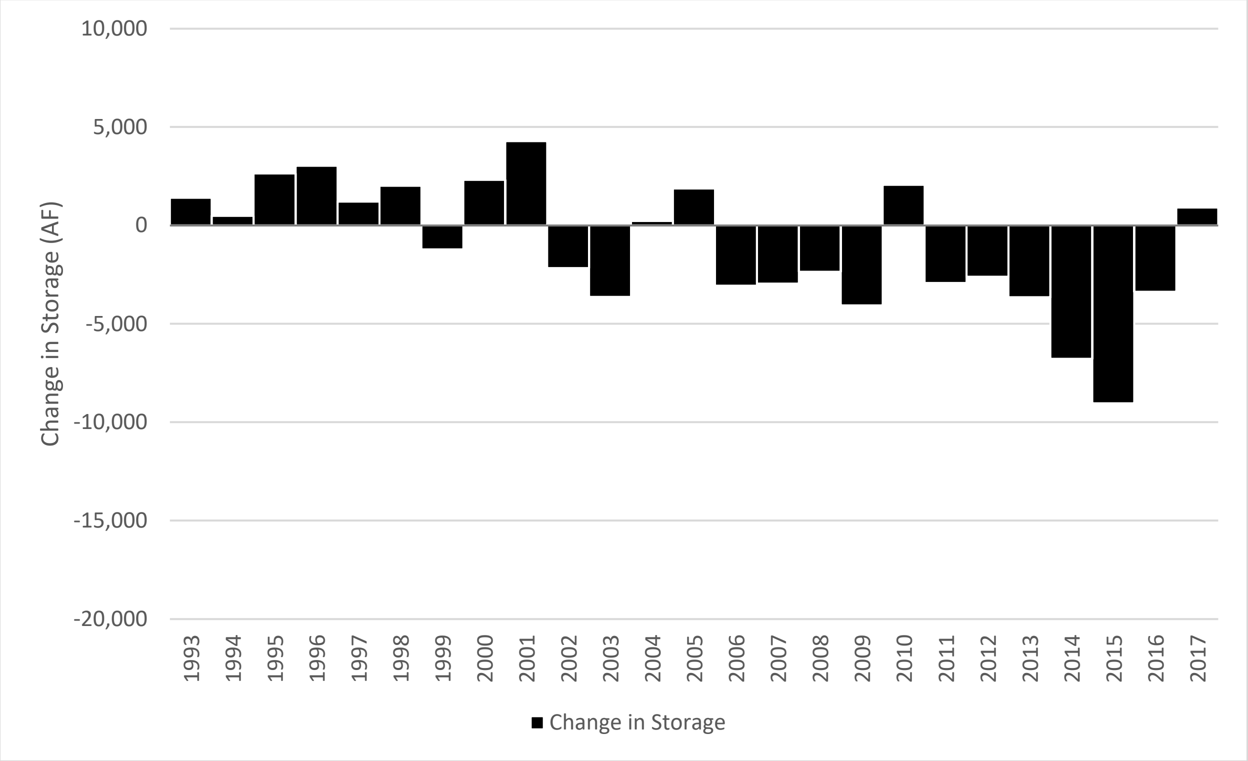


Figure 2-33 Cumulative Change in Storage for Continental Deposits within the District

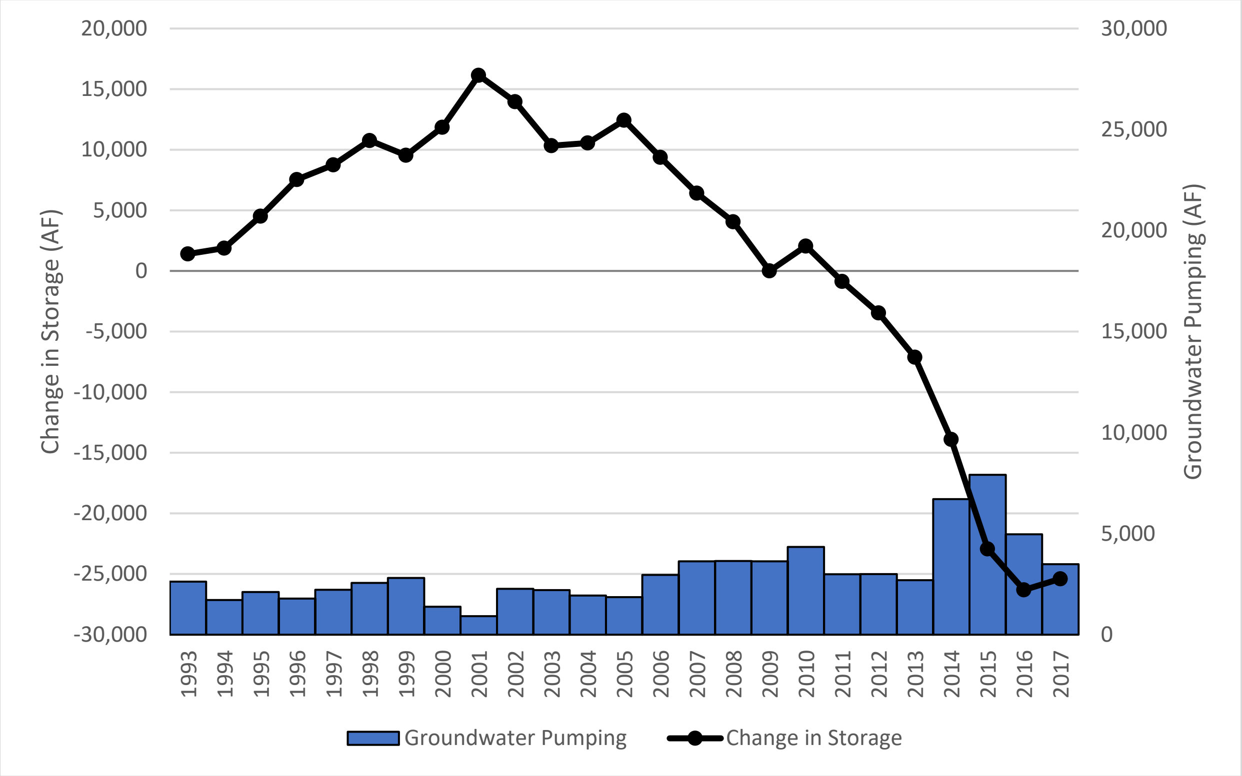


Figure 2-34 Annual Change in Storage for Santa Margarita Formation within the District

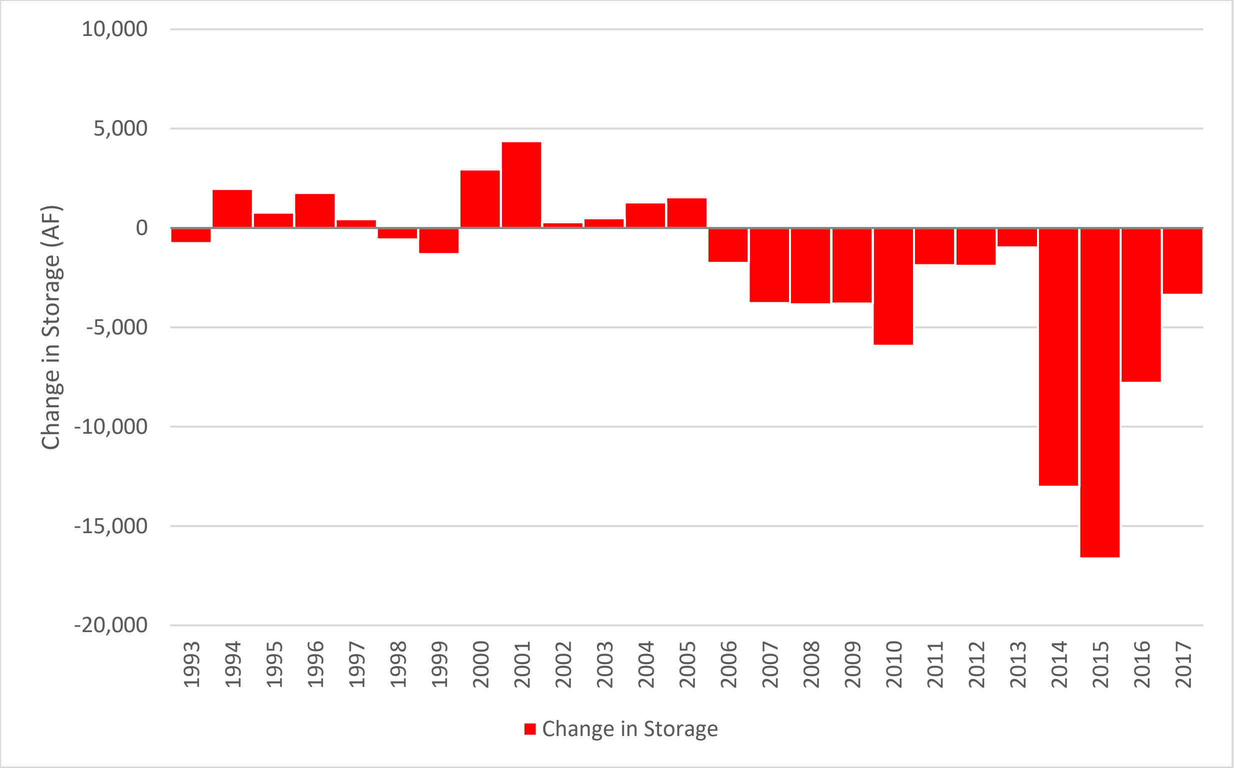
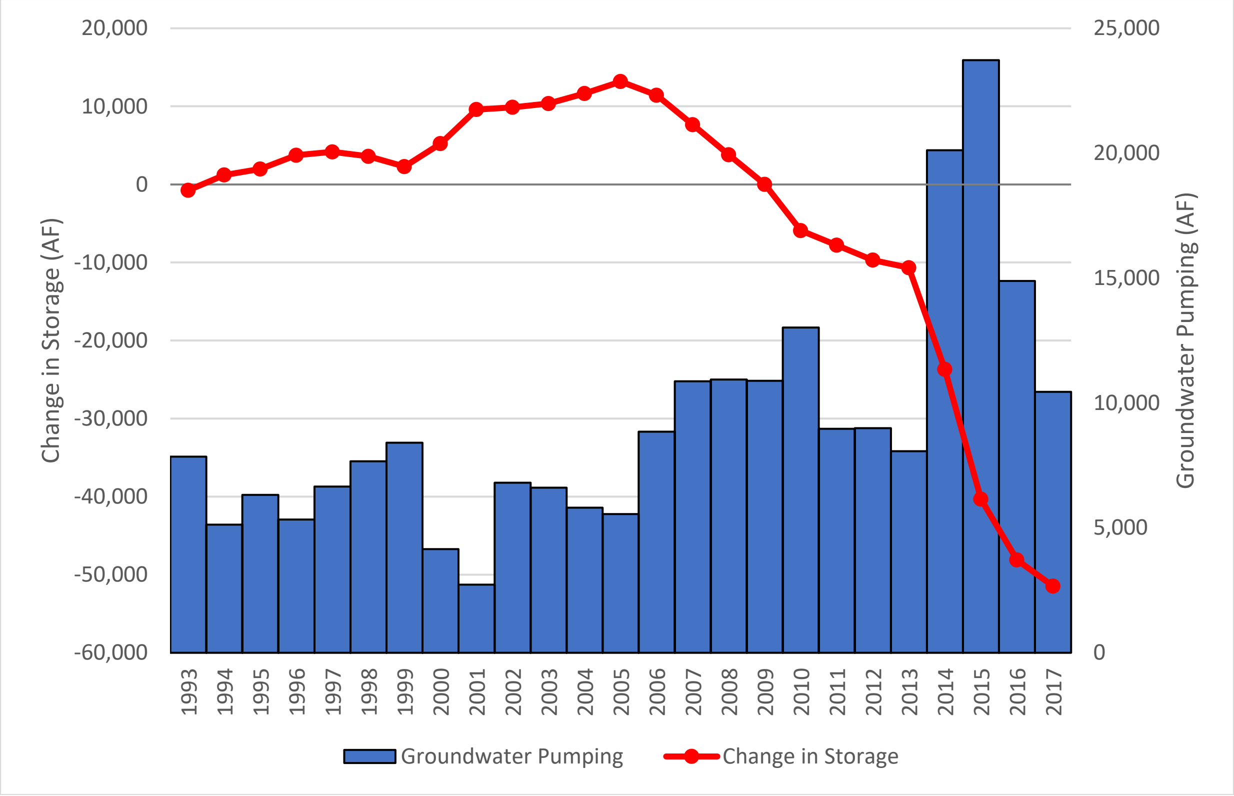


Figure 2-35 Cumulative Change in Storage for Santa Margarita Formation within the District



2.4.5 Evaluation of Safe Yield

The hydrographs presented in Section 2.3, Figure 2-16 and Figure 2-19 indicate that from 1993 to 2009 groundwater levels throughout the District were stable and groundwater levels East of the District were declining. Table 2-7 is a summary of the number of irrigated acres and quantities of groundwater pumping, based on crop demand, that occurred on a yearly average during that period both in the District and east of the District.

Table 2-7 Groundwater Pumping and Irrigated acres from 1993 to 2009

	Irrigated Acres	Groundwater Pumping	
		AF	AF/ac
District	18,319	9,454	0.52
East of District	5,210	15,443	2.96
Total	23,529	24,897	1.06

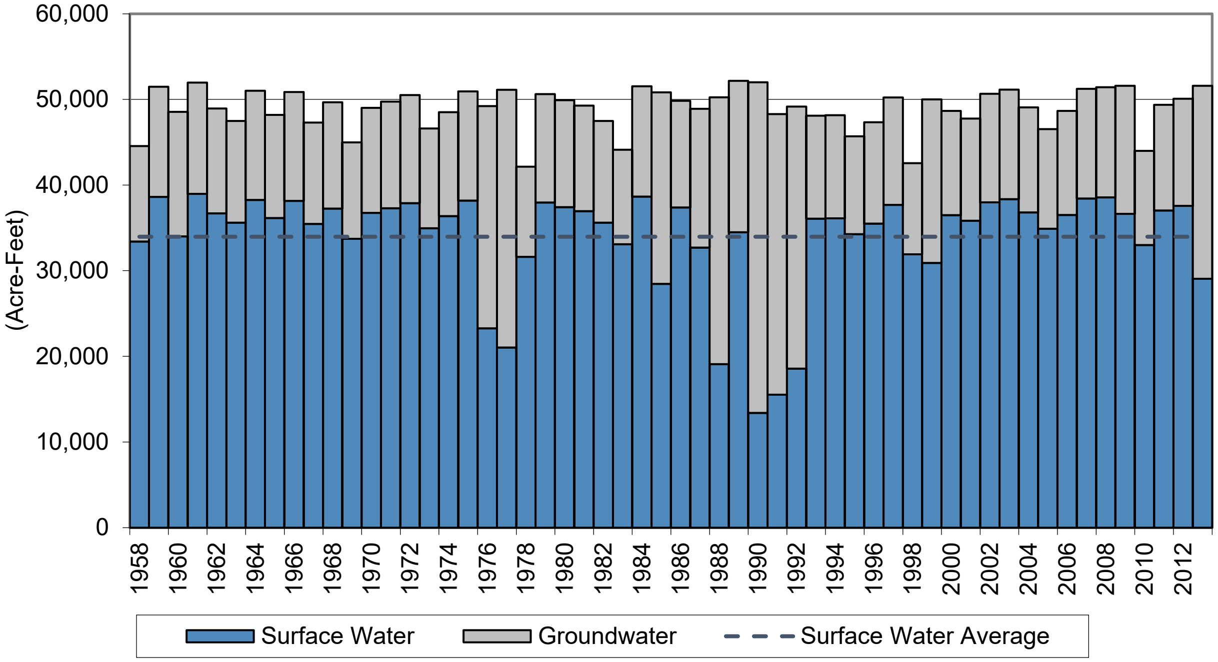
The District's zero change in storage during this period indicates that a combined groundwater extraction of approximately 9,450 acre-feet per year from the aquifers is a reasonable estimate of safe yield. If the approximate safe yield of the District was distributed amongst irrigated acreage within the District, the resulting allocation would equal 0.52 acre-feet per acre.

A safe yield was not estimated for the lands east of the District; however, as presented in Figure 2-19, groundwater levels fell each year during the 1993 to 2009 period when the historical average of groundwater pumping was 15,443 acre-feet. Further, as shown in Figure 2-25, the number of cropped acres east of the District has nearly doubled since 2009 resulting in groundwater pumping of over 30,000 acre-feet, as displayed in Figure 2-28 and Table 2-4. It is reasonable to assume that nearly doubling the pumping adjacent to the District will increase the rate of groundwater decline over the historical level. This decrease in groundwater levels immediately adjacent to the District has the potential to negatively impact groundwater levels and quality within the District. Management of adjacent lands is proposed to be conducted by the Eastside Water Management Area (EWMA) in Kern County and ETGSA in Tulare County to address this situation. Failure to limit groundwater pumping east of the District to their share of the safe yield will frustrate the District's ability to achieve sustainability.

2.4.6 Projected Water Budget

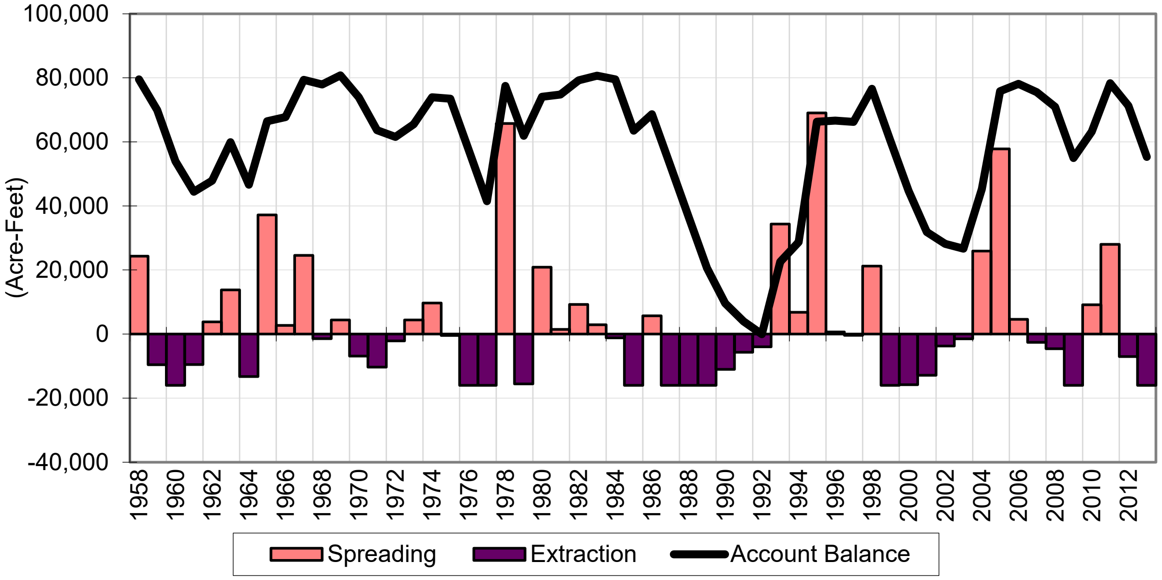
A projected water budget was prepared to estimate baseline future conditions of supply, demand, and aquifer response to Plan implementation within the District. Projected water demands utilized 2017 land use and crop coefficient information. Projected surface water supplies were based upon the most recent water supply estimates of future surface water supply. The projected water budget utilized the 56-year historical period from 1958 through 2013. This period was selected because it represented an average period of hydrology based upon Kern River natural flows. A detailed description of the projected water budget including results for baseline conditions is described in Appendix 3 and summarized in Figure 2-36 through Figure 2-39.

Figure 2-36 Source of water to District under future conditions



As shown in Figure 2-36, the baseline analysis resulted in an average annual District surface supply of about 33,706 acre-feet and average annual groundwater extraction of about 14,785 acre-feet. This anticipated increase in groundwater is attributable to the reduction of water supply availability due to increased environmental and regulatory conditions in the Delta, the settlement on the San Joaquin River, and implementation of SGMA. In years where available surface supplies are low, the District relies on the various banking programs to help supplement deliveries. Figure 2-37, is a summary of banking activities calculated as described in Appendix 3.

Figure 2-37 Water to District from banking supplies under future conditions



An estimated change in groundwater storage for the District was calculated using the projected water budget and the approximated safe yield. The difference between the projected groundwater pumping and the safe yield (assumed change in storage) is displayed annually in Figure 2-38 and cumulatively in Figure 2-39.

Figure 2-38 Projected Annual Change in Storage

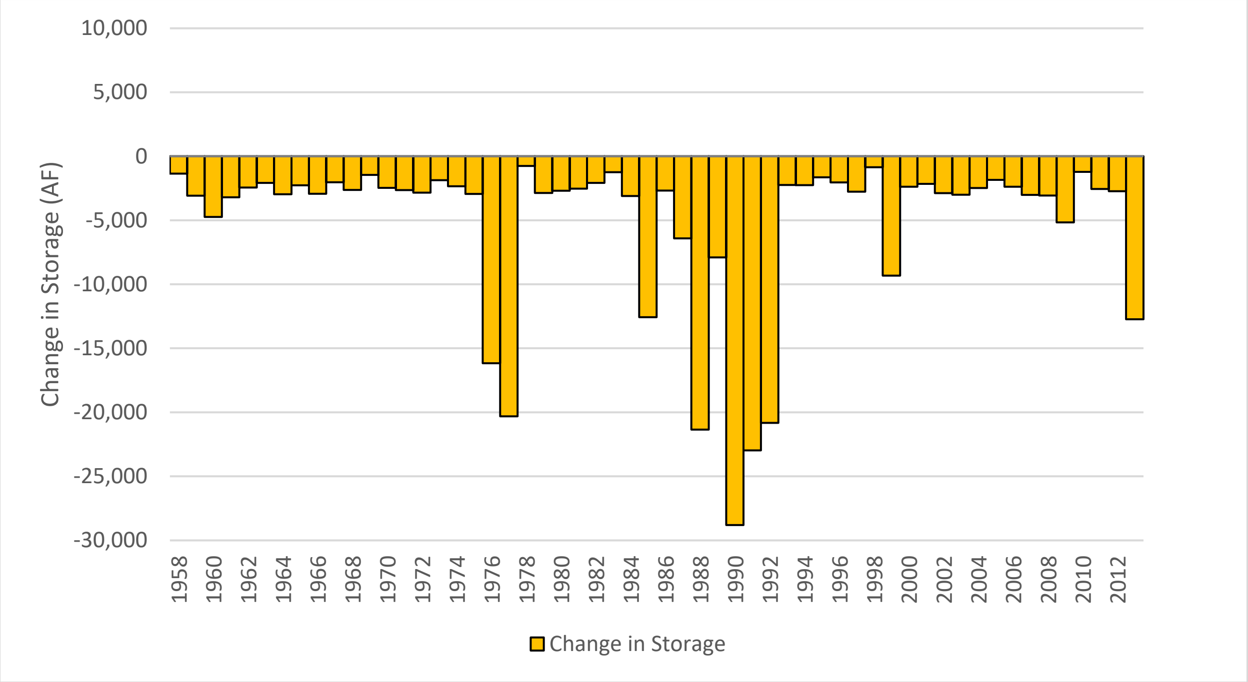


Figure 2-39 Projected Cumulative Change in Storage

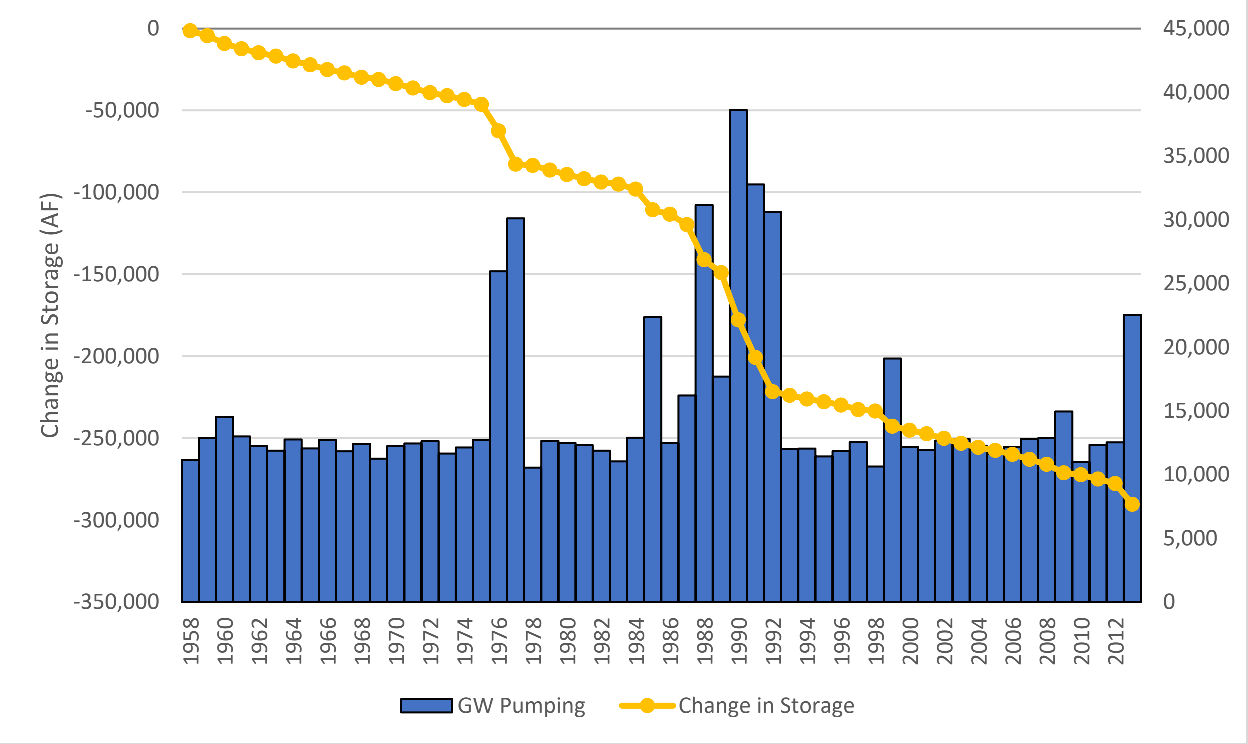


Figure 2-38 and Figure 2-39 demonstrate that given the projected future water supplies, the District will deplete the groundwater storage due to pumping that exceeds the safe yield. This supports the fact that the District's average groundwater pumping projection of 14,785 acre-feet per year will likely cause groundwater levels to decline and management actions or projects will be necessary to achieve sustainability.

Impacts of Climate Change

The scientific community is predicting that climate change will have the following impacts on water resources:

1. Precipitation occurring in wet years will be larger and droughts will be more severe.
2. Warmer temperatures will decrease snowpack as freezing level elevations rise and more precipitation falls as rain rather than snow. This will increase the magnitude of flood flows and cause runoff to occur earlier in the year.
3. Sea levels will rise as a result of melting polar ice caps causing salt-water intrusion and flooding.

These impacts will affect the District's water supply from both the Sierra Nevada and the Sacramento-San Joaquin Delta.

Larger wet years and more severe droughts will cause the District to rely more heavily upon existing banking programs and may cause a need for expansion of existing programs. Another likely scenario is that the District will adopt a program that incentivizes water users to over irrigate crops during wet years to recharge the groundwater basin using existing facilities. This can most effectively be accomplished by water users using flood irrigation to over irrigate in wet years and conserve water with drip and micro sprinklers in dry years.

Higher flood flows and earlier runoff will increase the opportunity for the District to purchase water on the open market to be stored in out-of-District banking programs. It should also cause a scenario where surface storage is used more often, increasing the benefit resulting from the District's proposed surface storage project in Chapter 5.

Rising sea levels will cause exports from the Delta to become less reliable and water quality to degrade. These impacts will eventually result in increased political pressure to configure a solution that improves water supplies and quality south of the Delta. The District remains hopeful that sound science will be used to better manage water supplies and the ecosystem which will result in increased water availability south of the Delta and improved habitat for fish and other species that rely upon the delta.

A climate change analysis that considers the above impacts to water resources has been conducted for both the ETGSA and KGA GSA.

2.5 Management Areas *(Reg. § 354.20)*

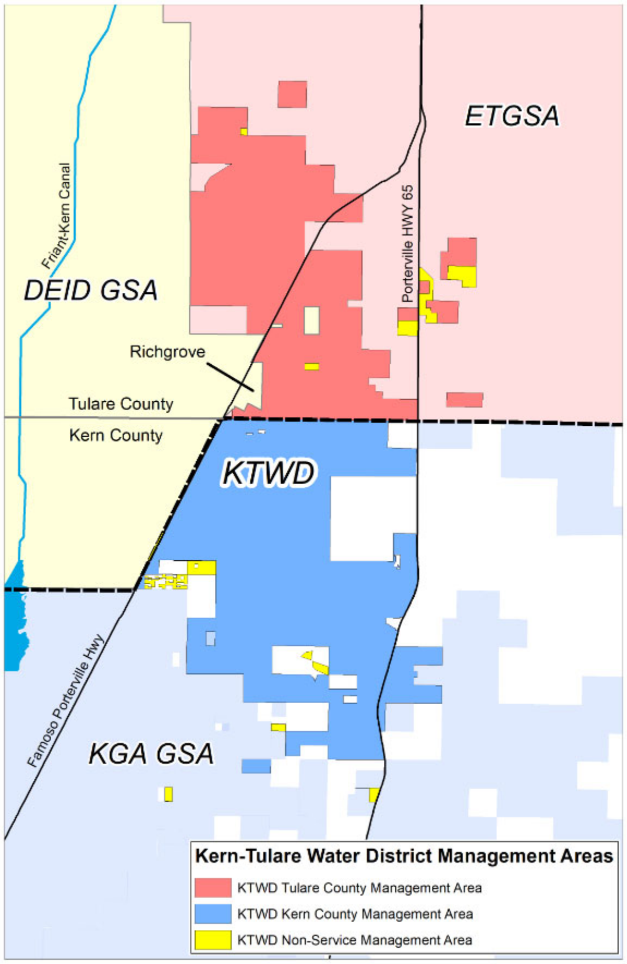
The District has determined three management areas as shown in Figure 2-40 that will be required based on the unique management structure within the District:

1. KTWD Kern County Management Area (KCMA)
2. KTWD Tulare County Management Area (TCMA)
3. KTWD Non-Service Management Area (NSMA)

The circumstances described in Chapter 1 illustrate the need for separate management areas to distinguish the District lands in Kern County and Tulare County. The KCMA will be managed under the KTWD Chapter Plan of the KGA GSA. The TCMA will be managed under the ETGSA as a separate management area in the ETGSA GSP. These management areas will have the same minimum thresholds, measurable objectives, and monitoring as established by this Plan.

The NSMA includes two types of land: 1) land within the District but outside the service area and 2) land outside of the District but covered by the District for SGMA purposes pursuant to an executed management agreement. There are 360 acres of non-service area land within the District that are assessed every year but do not receive any District water supplies and 180 acres of undistricted land that will be managed by the District also without surface water supplies. Since the water source of these lands is groundwater, the District will need to propose additional management actions to achieve sustainability for this management area. The NSMA must become sustainable without District water while being limited to the same safe yield (currently estimated at 0.52) as the rest of the District. The District will consider allowing some transitional pumping above the safe yield similar to the ETGSA and may develop a separate groundwater charge for the NSMA. Unlike the ETGSA, within the KTWD management areas there will not be a market structure to allow for the transfers of groundwater. Should lands within the NSMA prefer not to participate in the District's management outlined above, they may request for detachment from the District to ETGSA or EWMA, whichever is appropriate.

Figure 2-40 KTWD Management Areas



CHAPTER 3: SUSTAINABLE MANAGEMENT CRITERIA

3.1 Introduction (Reg. § 354.22)

This Chapter describes criteria that constitute sustainable groundwater management for the District, including the process to characterize undesirable results, and establish minimum thresholds and measurable objectives for each applicable sustainability indicator.

3.2 Sustainability Goal *(Reg. § 354.24)*

This Plan establishes a sustainability goal for the District that culminates in the absence of undesirable results by 2040. The Plan includes 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 District 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.

The primary sustainability goal for the District is to manage the groundwater resources of the Santa Margarita Formation for long-term use as a dry-year water supply for agriculture. Achieving this goal will require the District and other users of the Santa Margarita Formation to balance average annual inflows and outflows of water so that a negative change in storage does not occur over time. The sustainability goal inherently stabilizes groundwater elevations, which in turn inhibits water quality degradation, and avoids land subsidence. A combination of projects and management actions implemented by the District, as described later in Chapter 5, will ensure the District is operating within the safe yield described in Section 2.4 of the Basin Setting. The District's projected water supply analysis (Appendix 3) indicates that *Management Action 1: Modify District Pricing Structure* alone should achieve this sustainability goal. Under this management action the District will manage and maintain its groundwater resources by conserving groundwater when surface water supplies are available so that groundwater can be relied upon during times of drought.

3.3 General Process for Establishing Sustainable Management Criteria

Sustainable Management Criteria (SMC) for the District was developed in coordination with the KGA and the rest of the Kern Subbasin. The District used a combination of hydrogeologic analysis as presented in Chapter 2, Basin Setting, and landowner feedback from all users of the Santa Margarita Formation. The general process included:

- Developing geologic cross-sections using publicly available information to determine structural geology.
- Characterizing groundwater conditions within the Santa Margarita from groundwater hydrographs and groundwater quality analysis.
- Collecting landowner well data on location, depth, and construction information.
- Presenting SMC information to the District's Board of Directors and landowners.
- Receiving feedback at landowner workshops on the District's GSP including Minimum Thresholds and Measurable Objectives.
- Modifying Minimum Thresholds based on input from the Board of Directors and neighboring Management Areas.

3.4 Undesirable Results *(Reg. § 354.26)*

An Undesirable Result is a basin-wide definition of unreasonable impacts to beneficial uses and users of groundwater. The Kern Subbasin has defined the following terms to assist individual management areas with defining unreasonable impacts at the management area level:

- Minimum Threshold (MT) Exceedance: Where a single representative monitoring well exceeds its minimum threshold.
- MT Trigger: A criteria established at the management area level that signifies undesirable impacts within the management area. For groundwater levels this occurs when groundwater levels decline below established MTs in 40% or more of any representative monitoring wells within the management area over four consecutive bi-annual SGMA required monitoring events.
- Management Area Exceedance: Exceeding the MT Trigger within a management area is a "management area exceedance" and is now potentially contributing to a basin-wide Undesirable Result.

This Plan describes the processes and criteria relied upon to define the MT Trigger applicable to the District.

Seawater intrusion and depletion of interconnected surface water do not apply as indicators of sustainability as they are not likely to occur within the District. The District has established significant and unreasonable effects for the remaining sustainability indicators for the area within the District.

3.4.1 Chronic Lowering of Groundwater Levels (Reduction of groundwater storage)

The basin-wide definition for undesirable results for chronic lowering of groundwater levels is as follows:

The point at which significant and unreasonable impacts over the planning and implementation horizon, as determined by depth/elevation of water, affect the reasonable and beneficial use of, and access to, groundwater by overlying users. This is determined when the minimum threshold for groundwater levels are exceeded in at least three (3) adjacent management areas that represent at least 15% of the Subbasin or greater than 30% of the Subbasin (as measured by each management area). Minimum thresholds shall be set by each of the management areas through their respective management area plans or Groundwater Sustainability Plans.

The basin-wide definition for undesirable results for reduction of groundwater storage is as follows:

The point at which significant and unreasonable impacts as determined by the amount of groundwater in the basin, affect the reasonable and beneficial use of, and access to, groundwater by overlying users over an extended drought period. This is determined when the volume of storage (above the groundwater level minimum thresholds) is depleted to an elevation lower than the groundwater level minimum threshold in at least three (3) adjacent management areas that represent at least 15% of the subbasin or greater than 30% of the subbasin (as measured by the acreage of each Management Area). Minimum thresholds shall be set by each of the management areas through their respective management area plans or Groundwater Sustainability Plans.

KTWD Management Area Exceedance and MT Trigger

The primary sustainability goal for the District is to manage the groundwater resources of the Santa Margarita Formation for long-term use as a dry-year water supply for agricultural users. Achieving this goal will require the District and other users of the Santa Margarita Formation to balance average annual inflows and outflows of water so that a negative change in storage does not occur over time. A management area exceedance is triggered in the District when groundwater levels decline below established MTs in 40% or more of any representative monitoring wells within the District over four consecutive bi-annual SGMA required monitoring events. A management area exceedance in the District would signify significant and unreasonable groundwater elevations that have the potential to cause a loss of water supply for agricultural users of the Santa Margarita Formation.

Percent of wells: The District has selected a total of six representative monitoring wells (RMWs) with established minimum thresholds for groundwater levels in the Santa Margarita Formation. If one well reaches the minimum threshold (16% of RMWs), the District will follow the procedures as outlined by the KGA exceedance policy. An MT exceedance may indicate localized impacts are occurring that do not impact the overall groundwater supply within the District. The District will investigate the exceedance according to the KGA policy. If two wells reach the minimum threshold (40% of RMWs), this signifies that impacts to groundwater are occurring throughout the District. Given the uniform behavior of water levels in wells perforated to the Santa Margarita, having exceedances in two RMWs will most likely mean most of the RMWs are displaying the same downward trend.

Temporal: For the District, four bi-annual SGMA required monitoring events constitute significant and unreasonable effects to water supply because it indicates that groundwater levels are no longer recovering seasonally as they typically do in the Santa Margarita Formation. Two bi-annual measurements (1 year) will identify a change in seasonal fluctuations in the Santa Margarita Formation which has historically varied from 50 to 120 feet from Fall to Spring. Four bi-annual measurements (2 years) at the minimum threshold will identify a sustained depletion in the District's groundwater supply that is not recovering and may result in undesirable results for the subbasin.

3.4.2 Degraded Water Quality

The basin-wide definition for undesirable results for degraded water quality is as follows:

The point at which significant and unreasonable impacts over the planning and implementation horizon, as caused by water management actions, that affect the reasonable and beneficial use of, and access to, groundwater by overlying users. This is determined when the minimum threshold for a groundwater quality constituent of concern is exceeded in at least three (3) adjacent management areas that represent at least 15% of the Subbasin or greater than 30% of the Subbasin (as measured by each management area). Minimum thresholds shall be set by each of the management areas through their respective management area plans or Groundwater Sustainability Plans.

KTWD Management Area Exceedance and MT Trigger

As discussed in the Basin Setting, immediately west of the District, the Santa Margarita Formation becomes saline. Recharge has fed fresh water into these sands east of the District where they crop out at the surface at a sufficient elevation to exert a westward hydraulic gradient in the sands. These waters have moved westward displacing the original saline waters creating a fresh-saltwater interface along the western border of the District. As a result, over pumping of groundwater has the potential to reverse the gradient so that poor quality water begins to flow into the District from the west. Extreme caution should be exercised in pumping from these aquifers to avoid the eastward migration of the saline water and cause an undesirable result of degraded water quality.

A management area exceedance is triggered in the District when groundwater quality degrades below the established MT for TDS in 40% or more of any representative monitoring wells within the District.

Degradation of groundwater quality from increased concentrations of TDS has the potential to impact beneficial uses and users of groundwater by limiting the volume of groundwater available for use or requiring additional treatment or blending to remedy the higher salinity concentrations.

Groundwater quality data is collected for 5 wells perforated to the Santa Margarita Formation. If one well reaches the minimum threshold (20% of RMWs), the District will follow the procedures as outlined by the KGA exceedance policy. An MT exceedance may indicate localized impacts are occurring that do not impact the overall groundwater quality within the District. The District will investigate the exceedance according to the KGA policy. If two wells reach the minimum threshold (40% of RMWs), this signifies that impacts to groundwater quality are occurring throughout the District. As described in the Basin Setting, salinity increases to over 2,000 mg/l just west of the District (Gillespie, 2016). If the location of the fresh-saltwater interface were to move east, the two most westerly wells (one located in the northern most part of the District and one located in the southern most part) would most likely be the first to be impacted.

3.4.3 Land Subsidence

The basin-wide definition for undesirable results for subsidence is as follows:

The point at which significant and unreasonable impacts, as determined by a subsidence rate and extent in the basin, that affects the surface land uses or critical infrastructure. This is determined when subsidence results in significant and unreasonable impacts to critical infrastructure as indicated by monitoring points established by a basin wide coordinated GSP subsidence monitoring plan.

The Kern Subbasin has adopted two classifications for critical infrastructure: Regional Critical Infrastructure and Management Area Critical Infrastructure.

Regional Critical Infrastructure is defined as infrastructure located within the Subbasin that serves multiple areas of the Subbasin and whose loss of significant functionality due to inelastic subsidence, if caused by Subbasin groundwater extractions, would have significant impacts to beneficial users. The Subbasin has collectively determined that the only infrastructure that meets the definition for Regional Critical Infrastructure are the California Aqueduct and the Friant-Kern Canal. The California Aqueduct and the Friant-Kern Canal are not located within the District; however, both canals are critical for delivering water supplies to the District and the District will actively participate in the regional plan.

Management Area Critical Infrastructure is defined as infrastructure located within a particular Subbasin Management Area whose loss of significant functionality due to inelastic subsidence if caused by Subbasin groundwater extractions would have significant impacts to beneficial users within that Subbasin Management Area.

Land subsidence related to groundwater production has the potential to impact infrastructure within the District by creating additional costs to beneficial users. The only infrastructure on the land surface within the District are roads, pipelines, and wells. Within the District, groundwater elevations have declined historically without creating a loss of functionality due to subsidence. The District is unaware of any costs incurred to replace or repair infrastructure due to subsidence within the District. Even though significant impacts to infrastructure is not anticipated, the District's management actions aim to balance average annual inflows and outflows of water which reduces the potential for additional subsidence related to groundwater production.

3.5 Minimum Thresholds *(Reg. § 354.28)*

3.5.1 Chronic Lowering of Groundwater Levels (Reduction of groundwater storage)

According to *Subarticle 3. §354.28 (d),* an Agency may establish a representative minimum threshold for groundwater elevation to serve as the value for multiple sustainability indicators, where the Agency can demonstrate that the representative value is a reasonable proxy for multiple individual minimum thresholds as supported by adequate evidence. The District has selected a minimum groundwater elevation in the Santa Margarita to represent conditions that, if exceeded, may contribute to undesirable results. Groundwater elevation will be used as a proxy for reduction in groundwater storage due to the fact that a reduction in groundwater storage directly correlates to lowering of groundwater levels.

Significant and unreasonable groundwater elevations in the District are those that cause a loss of water supply for users of the Santa Margarita Formation. In particular, the minimum thresholds set by the District should avoid dewatering any agricultural groundwater production well that relies on the Santa Margarita Formation including those to the east of the District.

In order to develop the minimum threshold, the District initially started with the lowest water surface elevation experienced historically which occurred during the peak of the drought in August 2015 at -52 ft msl. The District received input from landowners regarding the water level conditions experienced during the drought and was informed that no wells had gone dry, but some landowners had to lower their pump settings. Since then, the District recently experienced a new historic low of -90 ft msl in September 2021 after two consecutive dry years and received the same feedback from landowners. As stated in the Basin Setting, wells that reach the Santa Margarita Formation are drilled to depths of 1800 to 2400 ft bgs, protecting them from the fluctuations of depth to water that have ranged from 600 to 800 ft bgs.

Next, the District discussed SMCs with the Eastside Water Management Area (EWMA) who are adjacent to the District and are comprised of beneficial users of the Santa Margarita in the northern portion of EWMA. EWMA established minimum thresholds at each individual well site based on the allowance of drawdown to 20% of the saturated water column height above the bottom of the well and was increased on a well-by-well basis to take into account the amount of head above the existing pump intake. EWMA had determined that the minimum threshold required in a representative monitoring well on the eastern border of the District (Well 04) that extracts groundwater out of the Santa Margarita Formation should be set at -133 ft msl.

Based on landowner feedback and coordination with the other beneficial users of the Santa Margarita Formation, the minimum threshold for groundwater elevation in wells perforated to the Santa Margarita Formation will be set at 150 feet below sea level (-150 ft) which ranges as a depth to water from about 600 to 830 feet throughout the District as shown in Table 3-1. At this elevation, no agricultural wells perforated to the Santa Margarita Formation will go dry. If the minimum threshold does occur and the District's groundwater supply is impacted, the District will reevaluate the threshold and coordinate with the other users of the Santa Margarita Formation.

Table 3-1 Minimum Threshold Depth for Monitoring Wells in Santa Margarita Formation

Well	**GS Elevation** (ft above mean sea level)	**WS Elevation** (ft above mean sea level)	**Depth to Water** (ft below ground surface)
24Q1	472	-150	622
8L1	504	-150	654
32M1	536	-150	686
4P1	581	-150	731
20C1	592	-150	742
15P1	680	-150	830

The uniform minimum threshold was selected based on the observation that wells perforated to the Santa Margarita Formation behave similarly, as shown in Figure 2-15 of the Basin Setting (Historical District Groundwater Levels in the Santa Margarita Formation from 1957 – 2018). Regardless of location within the District, these wells experience the same annual groundwater elevation changes although seasonal changes may vary. The groundwater elevation will be measured pursuant to the District's monitoring plan to be described in Chapter 4.

Minimum Threshold Impact on Beneficial Uses and Users

Agricultural land use and users**.** The beneficial users of the Santa Margarita Formation are agricultural users that drill irrigation wells to the depths of roughly 2000 feet to reach this highly permeable formation. There are 94 agricultural supply wells within the District (roughly 3 wells per square mile). The proposed minimum threshold does not protect agricultural users from economic impacts associated with lower water levels such as deeper pump settings or increased energy lift however agricultural users are willing to self-mitigate for these impacts. The minimum thresholds prevent continued lowering of groundwater elevations which may impact agricultural users by requiring an overall reduction in groundwater pumping for all users of the Santa Margarita Formation. This reduction could potentially impact users that do not have access to water supplies other than groundwater. Limiting the amount of groundwater pumping may limit the amount and type of crops that can be grown in areas without an imported water supply.

Domestic land use and users**.** There are only 18 domestic wells within the District. All domestic wells within the District are drilled to depths of less than 700 feet and do not reach the Santa Margarita Formation, which is 1800 to 2400 ft bgs. The upper aquifer supplying the domestic wells has a very low yield and results in an insignificant amount of pumping which is why the agricultural wells extend into the Santa Margarita. As shown in Figure 2-17 of the Basin Setting, groundwater levels in the upper aquifer that supplies the domestic wells are either stable or rising. Accordingly, the District's GSP and SMC focuses on the agricultural use of the Santa Margarita Formation. The District investigated if there were any impacts to domestic wells based off DWR's Dry Well Reporting System Data and confirmed that no domestic wells have experienced problems within the District. If impacts were to occur, extremely shallow domestic wells may become dry, requiring owners to drill deeper wells.

Relationship to Other Sustainability Indicators

Groundwater elevations can influence other sustainability indicators. The minimum threshold selected for groundwater elevation should avoid undesirable results for each of the other sustainability indicators.

- Reduction of groundwater storage: The District is using groundwater levels as a proxy for reduction in groundwater storage. The groundwater level minimum thresholds were selected to avoid dewatering the Santa Margarita Formation and the District's management actions are focused on pumping at or less than the sustainable yield. The minimum threshold selected ensures the District balances average annual inflows and outflows of groundwater so that a negative change in storage that results in lower groundwater levels does not occur.

- Degraded water quality: The District's main groundwater quality concern is that immediately west of the District the Santa Margarita Formation becomes saline. Recharge has fed fresh water from the east at a sufficient elevation to exert a westward hydraulic gradient in the Santa Margarita Formation maintaining the fresh-saltwater interface along the western border of the District. Over pumping of groundwater beneath the District has the potential to reverse the gradient so that saline water begins to move eastward. Since the groundwater level minimum threshold has been placed below what has historically been experienced and the District knows changes in groundwater elevation differences has the capability to change the groundwater gradient, the District has established a separate minimum threshold for groundwater quality as TDS of 750 mg/L as later discussed in Section 3.5.2. The District's management actions aim to balance average annual inflows and outflows of water which also reduces the potential for changing the groundwater gradient.

- Subsidence: Minimum thresholds for Regional Critical Infrastructure have been established at the subbasin level. The District has not proposed any additional local minimum threshold for management area critical infrastructure as later discussed in section 3.5.3. The only critical infrastructure on the land surface within the District are roads, pipelines, and wells. Within the District, groundwater elevations have declined historically without creating a loss of functionality due to subsidence. The District is unaware of any costs incurred to replace or repair infrastructure due to subsidence within the District. Even though significant impacts to infrastructure is not anticipated, the District's management actions aim to balance average annual inflows and outflows of water which reduces the potential for additional subsidence related to groundwater production.

3.5.2 Degraded Water Quality

The District believes that the main constituent of concern associated with the chronic lowering of groundwater levels is TDS. The District has established the minimum threshold for TDS as 750 mg/L for all representative monitoring wells within the District. Water quality degradation has not occurred even at the groundwater elevations experienced in 2015 and 2021; however, continued lowering of groundwater could move the salt-freshwater interface eastward which is why the District will evaluate water levels in conjunction with salinity measured as TDS to determine the adequacy of the selected elevation. Groundwater quality will be measured pursuant to the District's monitoring plan described in Chapter 4. The District will work closely with EWMA to monitor and manage the potential movement of the high-salinity water from the west.

3.5.3 Land Subsidence

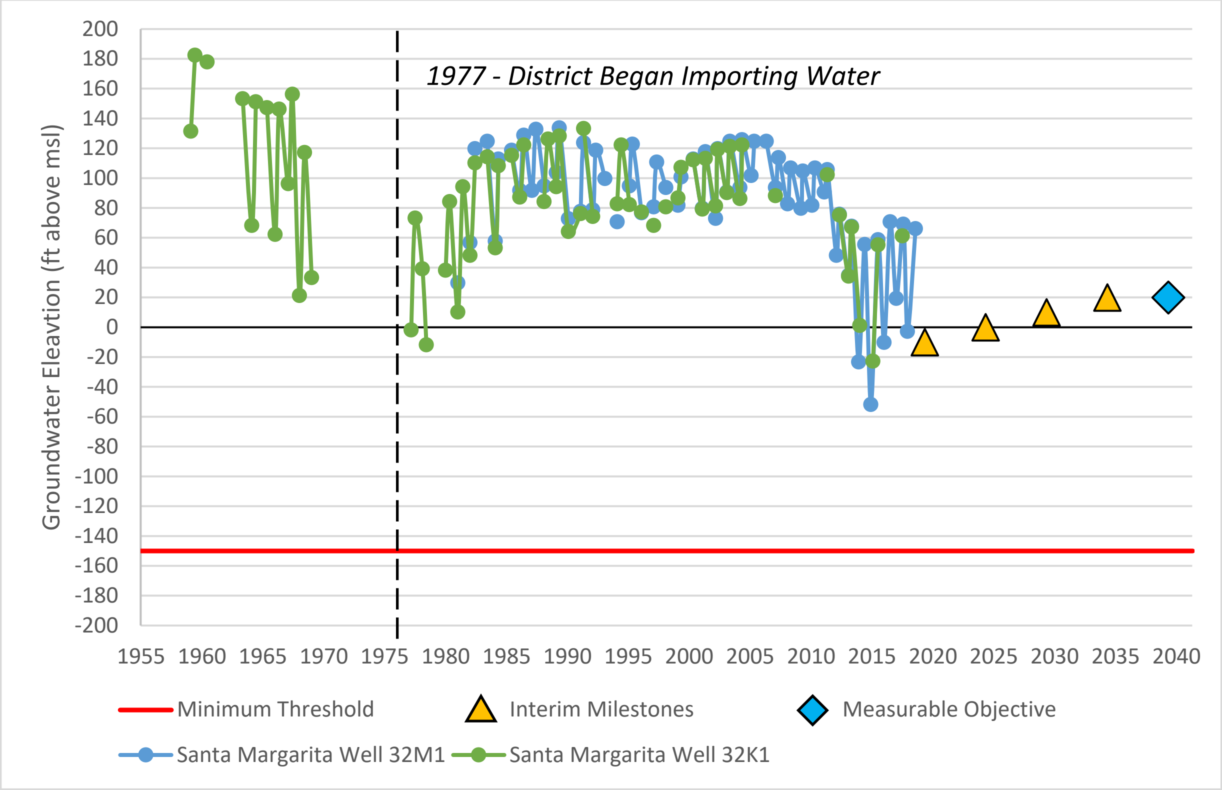
Land subsidence is being measured at the GSA level in both the Tule and Kern subbasins. Minimum thresholds for Regional Critical Infrastructure which includes the California Aqueduct and the Friant-Kern Canal have been established at the subbasin level. The District has not proposed any local minimum threshold for management area critical infrastructure. Land subsidence that interferes with surface land uses within the District has not occurred even at the groundwater elevations experienced in 2015 and 2021. As shown in Figure 2-23, current InSAR data provided by DWR shows that the total vertical displacement from June 2015 to April 2022 ranges from about 0 to -0.7 ft throughout the District. This equates to approximately 0 to 1.2-inches of average annual subsidence over the past 7 years. This amount of subsidence has not created any significant impacts to infrastructure within the District.

3.6 Measurable Objectives *(Reg. § 354.30)*

According to *Subarticle 3. §354.30 (d),* an Agency may establish a representative measurable objective for groundwater elevation to serve as the value for multiple sustainability indicators where the Agency can demonstrate that the representative value is a reasonable proxy for multiple individual measurable objectives as supported by adequate evidence. The District has selected to define a measurable objective of fall groundwater elevations in the Santa Margarita as 20 feet above sea level that will also represent the objective for groundwater storage. The seasonal range of elevations from 1993 through 2009, displayed in Figure 2-15 of the Basin Setting, is when the District was considered to be in balance; however, since the recent drought years (2013 through 2016) the District water elevations have not recovered to pre-drought levels. The elevations from the period of balance typically reached a fall low of 60 feet, and now the District has experienced new fall levels ranging from -20 to 20 feet. The District considers the path shown in Figure 3-1 to be a reasonable objective considering current conditions and the minimum threshold.

This measurable objective provides a reasonable margin of operational flexibility under adverse conditions and takes into consideration components such as historical water budgets, seasonal and long-term trends, and periods of drought. The measurable objective provides a margin of safety of 170 feet before reaching the minimum threshold.

Figure 3-1 Planning Horizon



The measurable objective for degraded groundwater quality indicated by TDS is the California state established MCL of 500 mg/L. The current water quality in the Santa Margarita formation ranges from

300 – 500 mg/L so a measurable objective of 500 mg/L to a minimum threshold of 750 mg/L provides an adequate range of operation.

Therefore, the District has established measurable objectives, including interim milestones in increments of five years, to achieve the sustainability goal for the basin within 20 years of Plan implementation and to continue to sustainably manage the groundwater basin over the planning and implementation horizon as shown in Figure 3-1. The District believes that implementation of the management actions described in Chapter 5 will result in groundwater levels fluctuating between the minimum threshold and the measurable objective for the foreseeable future, including 2040 and beyond.

CHAPTER 4. MONITORING NETWORKS

4.1 Introduction (Reg. § 354.32)

This Chapter describes the monitoring network developed, including monitoring objectives, monitoring protocols, and data reporting requirements. The monitoring network promotes the collection of data of sufficient quality, frequency, and distribution to characterize groundwater in the District and evaluate changing conditions that occur through implementation of the Plan. The existing monitoring networks protocols and standards in this Section are described to address the requirements of § 352.2, § 352.4, and § 354.32 to § 354.36 of the Regulations. Improvements to the monitoring networks will be addressed in accordance with § 354.38 and other sections listed herein.

4.2 Description of Monitoring Network *(Reg. § 354.34)*

The District implemented a DWR approved groundwater monitoring plan in 2015 and updated the plan in 2018 to better monitor the multiple aquifers that underlie the District. The District has developed groundwater level and groundwater quality monitoring networks capable of collecting sufficient data to monitor water levels and evaluate short-term, seasonal, and long-term trends in groundwater conditions. The monitoring networks consist of 25 wells specifically selected to represent the various aquifers throughout the study area. The networks provide sufficient spatial density to characterize groundwater conditions in the area and evaluate changing conditions that may occur through Plan implementation. The current networks are made up of agricultural production wells until dedicated monitoring wells can be installed. There is currently no local network for land subsidence monitoring.

The monitoring plans developed for the networks includes data collection protocols and temporal frequency that adhere to the requirements specified for monitoring networks. Monitoring networks will be implemented to accomplish objectives specified in the Emergency Regulations and to ensure the District is capable of collecting data related to the sustainability indicators.

4.2.1 Monitoring Network Objectives

The objectives of the monitoring networks are to: demonstrate progress toward achieving measurable objectives described in the Plan; monitor impacts to the beneficial uses of groundwater and stakeholders within the management areas; monitor changes in groundwater conditions relative to measurable objectives and minimum thresholds; quantify annual changes in water budget components; and monitor changes for the following pertinent sustainability indicators in the subbasins:

Sustainability Indicators

- Chronic Lowering of Groundwater Levels
- Reduction of Groundwater Storage
- Degraded Groundwater Quality
- Land Subsidence

In the District's study area of the Kern and Tule Subbasins, measuring indicators of seawater intrusion and depletion of interconnected surface water are not included in the monitoring network objectives due to the location of the subbasins and the lack of interconnected natural surface water systems associated with the pumping zone of the aquifers. In accordance with Section § 354.26 of the Regulations, any undesirable results related to sustainability indicators that are not present and are not likely to occur in a subbasin, shall not be required to establish criteria for undesirable results related to those sustainability indicators. As described in Section 2.3 of the Basin Setting of this plan, seawater intrusion and the depletion of interconnected surface waters are not a risk for causing undesirable results in the District's study area.

4.2.2 Data Quality and Assessment

The monitoring networks will obtain quality groundwater data to meet the measurable objectives of this GSP. The monitoring networks implemented with this GSP will include the analytical approaches to obtain acceptable data that can monitor the sustainability indicators (SIs) against minimum thresholds and interim milestones.

As described in DWR's *Groundwater Monitoring Protocols, Standards, and Sites BMP* (2016, Monitoring Protocols BMP), the processes for maintaining quality control and quality assurance are iterative, and, as such, will be evaluated every 5 years for effectiveness. Where necessary, improvements may be implemented to ensure each network continues to collect sufficient and representative information to demonstrate short-term, seasonal, and long-term trends in groundwater conditions and land subsidence to evaluate Plan implementation.

Monitoring Progress Toward Measurable Objectives

Groundwater levels in the subbasin are the key SIs to monitor undesirable results. Seasonal groundwater levels in the selected monitoring wells will be used to monitor the progress toward measurable objectives of the sustainable groundwater management in the subbasin. The seasonal groundwater levels will be compared against the 2017 baseline groundwater levels described in the Basin Setting and the minimum threshold groundwater levels in Section 3, to evaluate the achievement of interim milestones.

At five-year increments after GSP adoption, the progress toward reaching interim milestones for groundwater levels will be compared with monitoring data for storage, land subsidence, and water quality and their respective minimum thresholds, to evaluate the effectiveness of groundwater level milestones on these other SIs. Where needed, interim milestones for groundwater levels or other sustainability indicators may be adjusted in order to maintain the objectives of the GSP.

Monitoring Changes in Groundwater Conditions Relative to Measurable Objectives and Minimum Thresholds

The minimum thresholds and interim milestones for sustainability indicators have been established for respective management areas and are discussed in Section 3. Changes in the SIs observed from monitoring data for groundwater levels, groundwater storage, groundwater quality, and land subsidence will be monitored by the District.

Monitoring Impacts to Beneficial Uses and Stakeholders

The proposed monitoring networks will provide data used to monitor impacts of sustainable groundwater management to beneficial uses of groundwater and stakeholders. The proposed approach for monitoring impacts to beneficial uses and users of groundwater are described in Table 4-1 below.

Table 4-1 Impacts

Potential impacts on beneficial uses and users of groundwater	Monitoring Network	Notes
Groundwater elevation decline may result in increased pumping costs and or dry wells.	Groundwater Level Monitoring	Groundwater levels may be compared with well screen construction and pump depth settings.
Groundwater storage is reduced to less than minimum threshold affecting future supplies for use.	Groundwater Level Monitoring	Data will be incorporated into the subbasin model to quantify and monitor storage outlooks and minimum thresholds and interim milestones.
Groundwater quality is degraded and is not suitable for use without additional treatment costs.	Groundwater Quality Monitoring	Data from all water quality reporting sources will be evaluated to compare against minimum thresholds and objectives.
Land subsidence due to overdraft results in infrastructure damage and loss in aquifer storage.	Groundwater Level and Land Subsidence Monitoring	Groundwater levels and land subsidence data will be evaluated against minimum thresholds and interim milestones.

4.2.3 Existing Monitoring Network

Each sustainability indicator contains a different level of existing local monitoring networks. Descriptions of each network and regional programs, if applicable, outlining their capability to accomplish the objectives of groundwater management per this GSP are provided below.

Groundwater Levels and Change in Storage Monitoring

Since 2009, the California Statewide Groundwater Elevation Monitoring (CASGEM) Program, as developed and coordinated by the DWR, has tracked seasonal and long-term groundwater elevation trends in groundwater basins statewide in collaboration with local monitoring entities. The District has been a monitoring agency under this program since 2011. The monitoring networks established for CASGEM will serve as the base network to monitor groundwater levels within the District under SGMA.

Network: The network for monitoring changes in groundwater levels is consistent with the District's CASGEM network. From 2015 to 2018 the District increased the number of wells reported to CASGEM from 12 to 20 irrigation wells in the Kern and Tule Subbasins. The original wells continue to be monitored with the additional 8 wells comprised of 4 wells to represent water levels exclusively in the Continental Deposits and 4 wells that penetrate the Santa Margarita Formation and Olcese Sands.

Table 4-2 contains the list of network wells and provides the requested standard information regarding each well including: CASGEM well ID numbers, GPS coordinates, reference elevations, monitoring frequency, perforated intervals, and the monitored aquifer zone. The groundwater level monitoring network will also be used to monitor the change in groundwater storage.

Table 4-2 Groundwater Level Monitoring Network Wells

LOCAL WELL ID NUMBER	WELL NAME	CASGEM WELL NUMBER	SUB-BASIN	MONITORING FREQUENCY	SURVEY INFORMATION			RP ELEV	GS to RP	SCREENED INTERVAL	TOTAL DEPTH	AQUIFER
					LAT.	LONG.	GS ELEV					
24S26E24F1	24F1	357306N1191167W002	Tule	Semi-monthly	35.831	-119.117	461.92	464.57	2.65	504-1,224	1,224	CD
24S26E33J1M	33J1	357958N1191612W001	Tule	Semi-monthly	35.796	-119.161	436.83	438.93	2.10	400-820	820.0	CD
24S27E8L1M	8L1	358561N1190806W001	Tule	Semi-monthly	35.856	-119.081	503.74	516.74	13.00	522-1,747	1,747	CD, SM
24S27E32M1M	32M1	357944N1190845W001	Tule	Semi-monthly	35.795	-119.085	536.31	536.31	0.00	500-1,800	1800.0	CD, SM
25S27E15D1M	15D1	357617N1190628W002	Kern	Semi-monthly	35.762	-119.063	618.31	618.61	0.30	480-680	680.0	CD
25S27E19Q2M	19Q2	357331N1191055W001	Kern	Semi-monthly	35.733	-119.105	547.49	550.46	2.97	600-2,003	2,003	CD
25S27E4D1M	4D1	357873N1190801W001	Kern	Semi-monthly	35.787	-119.080	555.49	557.34	1.85	400-800	800	CD
25S27E27K1M	27K1	357250N1190506W001	Kern	Semi-monthly	35.725	-119.054	768.79	768.79	0.00	996-2,000	2,000	SM, OL
24S26E1R1M	1R1	358658N1191081W001	Tule	Semi-annual	35.866	-119.108	466.61	466.61	0.00	792-1,200	1,200	CD
24S26E24Q1	24Q1	358231N1191126W001	Tule	Semi-annual	35.823	-119.112	471.91	471.91	0.00	?	?	CD?, SM
24S27E22P1M	22P1	358200N1190473W001	Tule	Semi-annual	35.820	-119.046	593.32	593.32	0.00	503-884	884	CD
25S26E12A	12A	354635N1190659W001	Kern	Semi-annual	35.777	-119.116	513.68	517.18	3.50	660-960	960	CD
25S27E2D1M	2D1	357875N1190415W001	Kern	Semi-annual	35.788	-119.041	622.41	623.97	1.56	500-1,650	1,650	CD, SM, OL?
25S27E4P1M	4P1	357781N1190720W001	Kern	Semi-annual	35.778	-119.073	580.71	580.71	0.00	506-1,954	1,954	CD, SM
25S27E15P1M	15P1	357503N1190578W001	Kern	Semi-annual	35.751	-119.058	679.57	689.07	9.50	?	?	CD?, SM
25S27E20C1M	20C1	357464N1190898W001	Kern	Semi-annual	35.747	-119.090	592.36	594.28	1.92	500-2,000	2,000	CD, SM
25S27E24M2M	24M2	357403N1190256W001	Kern	Semi-annual	35.740	119.026	788.70	788.70	0.00	500-1,800	1,800	CD, SM, OL
25S27E30D	30D	354350N1190657W001	Kern	Semi-annual	35.731	-119.116	531.47	531.47	0.00	600-1,520	1,520	CD, SM?
25S28E6D	6D	357891N1190092W002	Kern	Semi-annual	35.789	-119.009	672.82	674.07	1.25	1,040-1,800	1,800	SM, OL

Rationale: The District's site selection process was based on the following characteristics: presence of an access port to measure water levels using an acoustic sounder or electric sounder; availability of a driller's log to determine well perforations; and adequate spatial distribution within the District.

Spatial Density: Figure 4-1 provides the current distribution of wells with available data as part of the District's CASGEM groundwater monitoring plan. Figure 4-1 also delineates between wells that penetrate only the Continental Deposits and deep wells that penetrate the Santa Margarita Formation and Olcese Sands. Based on the BMP for monitoring networks, the well density goal is to have between 4 to 10 wells per 100 square miles (DWR, 2017). The District is comprised of about 20,000 acres or 31 square miles equating to an average density of 1.5 monitoring wells per square mile (equivalent to 1500 wells per 100 square miles). Compared to the suggested BMP density, the District is well above the higher range of 10 wells per 100 square miles.

Frequency: The monitoring network is capable of collecting sufficient data to demonstrate short-term, seasonal, and long-term trends in groundwater conditions. The District monitors all 20 wells on the schedule established by DWR. At minimum, water level monitoring is conducted seasonally to evaluate groundwater elevations during spring time (seasonal high prior to summer irrigation demands) and fall (seasonal low after the summer irrigation demands). The District currently measures 9 of the monitoring wells semi-monthly and 11 wells semi-annually. Semi-monthly measurements are conducted on the 1st and 15th of each month. Semi-annual groundwater elevations measurements have been scheduled according to the 1-week period in spring and fall as recommended by DWR. All wells are also measured when the District observes a significant high or low water level to capture the seasonal peaks and declines.

Protocols: The District collects water level measurements using an acoustic sounder or electric sounder to determine the distance from a well's reference point to the water surface in the well. To establish the reference point, the District retained a professional land surveyor to provide horizontal and vertical locations of each monitoring well. The latitude and longitude of the wells are referenced to the North American Datum System of 1983 (NAD83) and the vertical elevation of the ground surface is referenced to the North American Vertical Datum of 1988 (NAVD88). The distance from the reference point (point of measurement) to the ground surface was either surveyed with reference to NAVD88 or measured by tape from the reference point to where the well casing intercepts the ground surface.

The District uses an acoustic sounder when possible because many depth-to-water distances beneath the District are over 500 feet deep. Steel tape is used on shallower wells (300 feet or less) or wells that do not have an access port for an acoustic sounder. To be consistent with DWR protocols for measuring groundwater levels, the District created forms to record water level measurements in the same format as those used by DWR, shown in Figure 4-2. Groundwater level trends since monitoring began are included in the Basin Setting and an example of recorded measurements from 2016 to the 0.1 foot are provided in Figure 4-2. The District also created well identification sheets, shown in Figure 4-3, to ensure data is taken from the correct well and to ensure accurate, reproducible measurement from the reference point.

Figure 4-1 Groundwater Level Monitoring Network

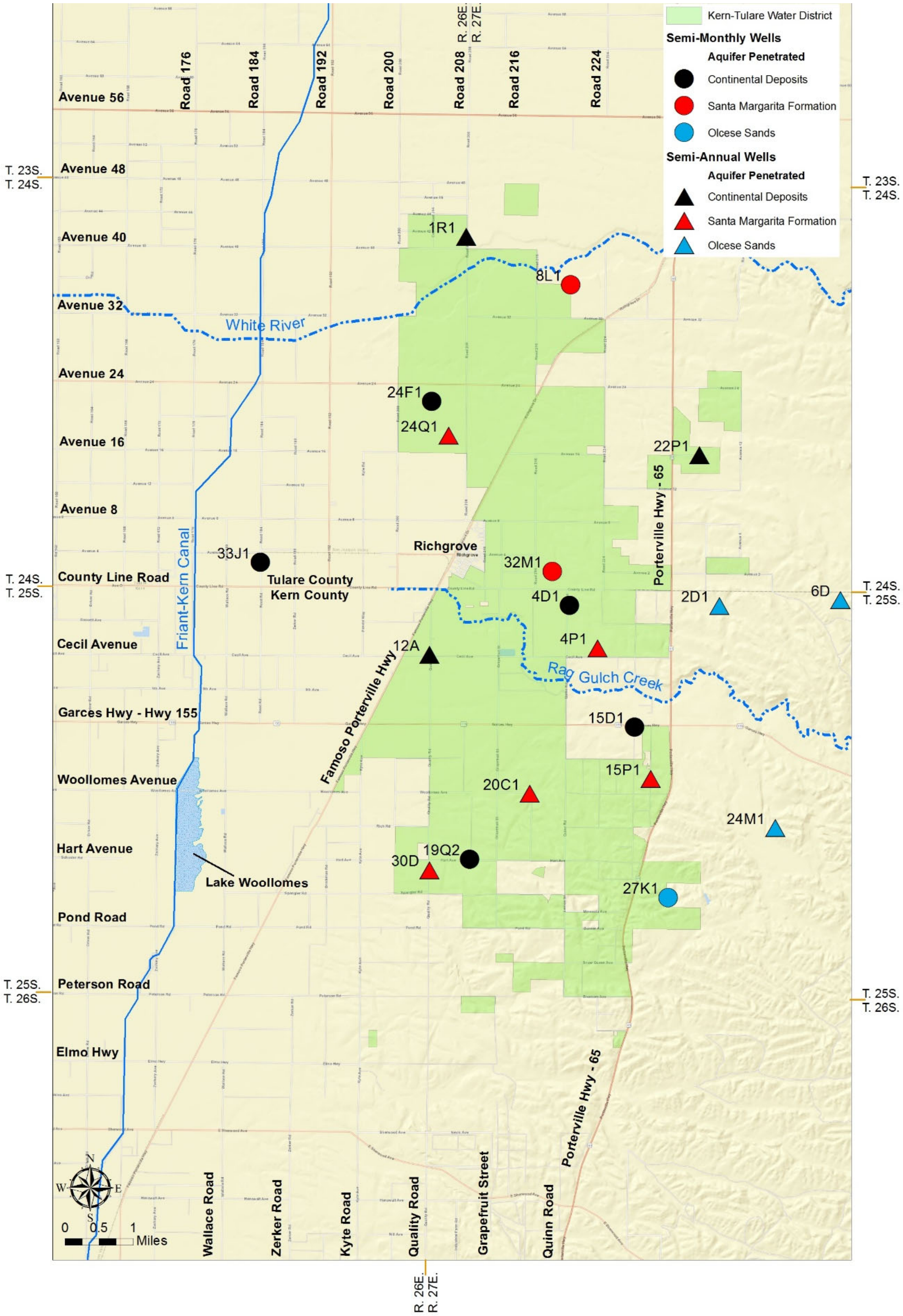


Figure 4-2 Example of recorded water level data (2016)

GROUNDWATER LEVEL MEASUREMENTS

Measured by

Groundwater Area **Kern-Tulare Water District**

Tabulated by

Measuring Agency **Kern-Tulare Water District**

Season/Year

STATE WELL NO.	RP ELEV	GS ELEV	DATE			TIME	WHY		REF. POINT TO WATER SURFACE	GROUND TO WATER SURFACE	WATER SURFACE ELEVATION
			MO	DA	YR	HR:MIN	NM	QM			
24S27E32M1	536.3	536.3	1	5	2016	7:30			502.5	502.5	33.8
24S27E32M1	536.3	536.3	1	15	2016	8:30			496.0	496.0	40.3
24S27E32M1	536.3	536.3	2	1	2016	10:30			488.4	488.4	47.9
24S27E32M1	536.3	536.3	2	16	2016	9:15			484.8	484.8	51.5
24S27E32M1	536.3	536.3	3	1	2016	12:40			486.2	486.2	50.1
24S27E32M1	536.3	536.3	3	15	2016	12:00			483.4	483.4	52.9
24S27E32M1	536.3	536.3	4	1	2016	10:38			491.4	491.4	44.9
24S27E32M1	536.3	536.3	4	15	2016	10:30			489.3	489.3	47.0
24S27E32M1	536.3	536.3	5	2	2016	11:30			498.4	498.4	37.9
24S27E32M1	536.3	536.3	5	16	2016	10:00			502.8	502.8	33.5
24S27E32M1	536.3	536.3	6	1	2016	11:15			513.2	513.2	23.1
24S27E32M1	536.3	536.3	6	15	2016	10:30			524.5	524.5	11.8
24S27E32M1	536.3	536.3	7	1	2016	12:25			539.8	539.8	-3.5
24S27E32M1	536.3	536.3	7	15	2016	12:05			543.7	543.7	-7.4
24S27E32M1	536.3	536.3	8	1	2016	12:00			545.3	545.3	-9.0
24S27E32M1	536.3	536.3	8	15	2016	10:20			546.3	546.3	-10.0
24S27E32M1	536.3	536.3	9	1	2016	9:45			546.5	546.5	-10.2
24S27E32M1	536.3	536.3	9	15	2016	10:00			542.3	542.3	-6.0
24S27E32M1	536.3	536.3	9	30	2016	10:30			532.0	532.0	4.3
24S27E32M1	536.3	536.3	10	14	2016	10:20			531.0	531	5.31
24S27E32M1	536.3	536.3	11	1	2016	12:05			520.3	520.3	16.0
24S27E32M1	536.3	536.3	11	14	2016	12:10			513.5	513.5	22.81
24S27E32M1	536.3	536.3	12	1	2016	9:30			507.0	507.0	29.3
24S27E32M1	536.3	536.3	12	15	2016	9:35			503.9	503.9	32.41

NO MEASUREMENT

0. Meas. Discontinued
1. Pumping
2. Pump house locked
3. Tape hung up
4. Can't get tape in
5. Unable to locate
6. Well Destroyed
7. Special
8. Casing leaking or wet
9. Temp. inaccessible

D. Dry

QUESTIONABLE MEASUREMENT

0. Caved or deepened
1. Pumping
2. Nearby pump operating
3. Casing leaking or wet
4. Pumped recently
5. Air gauge meas.
6. Other
7. Recharge operation nearby
8. Oil in casing
9. Acoustic sounder meas.

Figure 4-3 Sample well identification sheet

Well Number: 24S27E8L1M	Well Type: CASGEM
CASGEM Well Number: 358561N1190806W001	Well Completion Type: Single
Groundwater Basin: Tule	Total Depth: 1747feet
Date of Survey: 10/28/2013	Screened Intervals: 522-1747
Latitude: 35.855772 North	Well Completion Report: 337
Longitude: 119.080681 West	Use: Active irrigation well
Ground Surface (GS) Elevation: 503.74	Description of RP: End of discharge into stand pipe.
Reference Point (RP) Elevation: 516.74	Landowner: MZIRP, Inc.
RP to GS: 13.0 Feet	Water User: Sunview Vineyards
Location Description: ½ mile east of Turnout 36-4	
Well Location 	Reference Point Location 

Notes:

DWR also reads this well.

Groundwater Quality Monitoring

Water quality monitoring was implemented by the District as a part of AB-3030 and SB-1938 groundwater management planning. The District began collecting groundwater samples in 2015 and the current groundwater quality monitoring network was established in 2018. The monitoring wells used to collect groundwater quality information, identified in Table 4-3 and shown in Figure 4-4 are sufficient to characterize groundwater and will be used to fulfill the monitoring program requirements for SGMA. Data regarding drinking water is also available from 2 public water wells in Richgrove Community Services District (RCSD) with sampling results from 1987 to present. The public system monitoring results may be monitored by ETGSA and are not a part of the District's monitoring program. The District will work closely with EWMA to monitor the potential movement of the high-salinity water from the west.

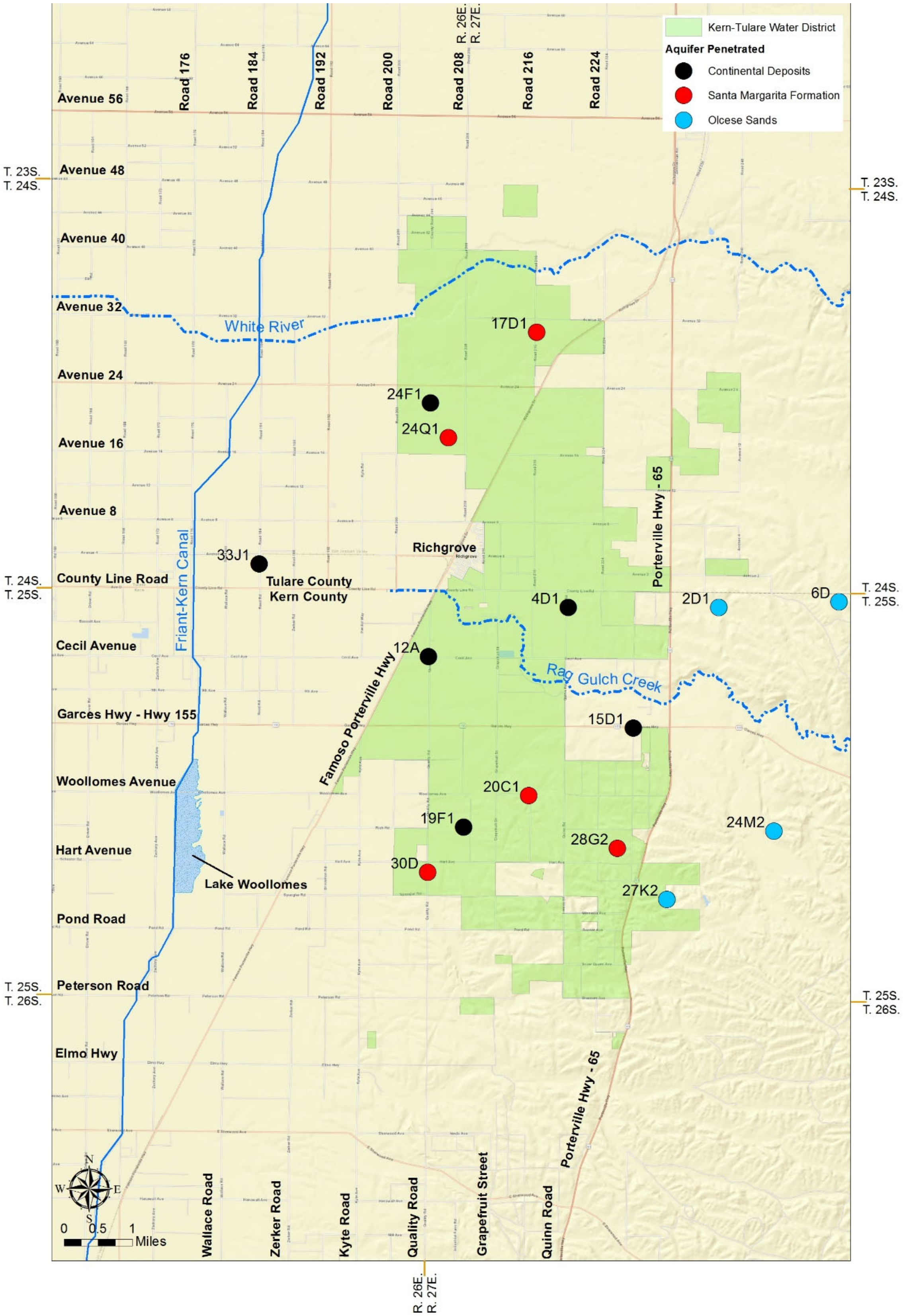
<u>Network:</u> Groundwater quality data is collected from 15 wells within and around the District. Table 4-3 provides a list of these wells including a local well ID number, GPS coordinates, perforated intervals, total depth, and aquifer penetration. Well driller's logs provided the information necessary to determine the screened intervals and aquifer penetration for each well.

Collection and evaluation of groundwater samples in the various aquifers within and around the District shows that groundwater from each aquifer has a different chemical composition. If a well does not have a driller's log then water quality alone may help determine which aquifer(s) is penetrated.

Table 4-3 Groundwater Quality Network Wells

LOCAL WELL ID NUMBER	WELL NAME	SUB-BASIN	LAT.	LONG.	GS ELEV.	SCREENED INTERVALS	TOTAL DEPTH	AQUIFER
24S26E24F1	24F1	Tule	35.831	-119.117	461.92	504-1,224	1,224	CD, SM
24S26E24Q1	24Q1	Tule	35.823	-119.112	471.91	?	?	CD?, SM
24S26E33J1M	33J1	Tule	35.796	-119.161	436.83	400-820	820	CD
24S27E17D1	17D1	Tule	35.841	-119.087	487.00	492-998 / 1,199-1,241 / 1281-1,323 / 1,364-1,860	1870	CD, SM
25S26E12A	12A	Kern	35.777	-119.116	513.68	660-960	960	CD
25S27E2D1M	2D1	Kern	35.788	-119.041	622.41	500-1,650	1,650	CD, SM, OL
25S27E4D1M	4D1	Kern	35.787	-119.080	555.49	400-800	800	CD
25S27E15D1M	15D1	Kern	35.762	-119.063	618.31	480-680	680	CD
25S27E19F1M	19F1	Kern	35.740	-119.108	532.72	464-?	?	CD
25S27E20C1M	20C1	Kern	35.747	-119.090	592.36	500-2,000	2,000	CD, SM
25S27E24M2M	24M2	Kern	35.740	-119.026	788.70	500-1,800	1,800	CD, SM, OL
25S27E27K2M	27K2	Kern	35.722	-119.521	768.79	900-1,650	1,650	CD, SM, OL
25S27E28G2M	28G2	Kern	35.728	-119.071	702.77	730-1,880	2,030	CD, SM
25S27E30D	30D	Kern	35.731	-119.116	531.47	600-1,520	1,520	CD, SM?
25S28E6D	6D	Kern	35.789	-119.009	672.82	1,040-1,800	1,800	SM, OL

Figure 4-4 Groundwater Quality Monitoring Network



Rationale: The District selected 15 wells to collect and analyze groundwater quality based on the following characteristics: 1) ability to collect representative samples from the Continental Deposits, Santa Margarita Formation, and Olcese Sands deposits; 2) coordination and consistency with the District's groundwater level monitoring well network; 3) ability to collect groundwater samples with the presence of a well pump; and 4) historical or recent water quality analysis results available from well owners.

Frequency: The District proposes to collect and evaluate groundwater quality samples every 5 years beginning in 2019 during the fall "low", typically in August, to provide data sufficient to address DWR's degraded water quality practices of the *Monitoring Networks and Identification of Data Gaps BMP (2016, Monitoring Networks BMP).* Given that the District only serves agricultural users; there are no known groundwater contamination plumes and; that groundwater quality does not quickly respond to surface contaminants due to slow deep percolation, a 5-year assessment is deemed adequate to assess groundwater quality impacts. Monitoring groundwater quality every 5 years is also adequate to evaluate that management activities avoid the significant and unreasonable degradation of water quality and will be included in each 5-year update.

Spatial Density: The spatial distribution of the network is adequate to map known regional water quality trends as identified in the Basin Setting. Figure 4-4 provides the current distribution of groundwater quality monitoring wells and also delineates between wells that penetrate the Continental Deposits and deep wells that penetrate the Santa Margarita Formation and Olcese Sands. As mentioned in Chapter 3, salinity is an important water quality characteristic to monitor as west of the District the Santa Margarita Formation becomes saline. Two indicator wells are present to monitor the western edge of the District (24Q1 and 30D) to pay particular attention to salinity as they will likely be the first affected.

Protocol: Groundwater quality samples are collected by District staff and analyzed by a laboratory. Landowners have signed coordination agreements with the District so that the District will directly collect groundwater samples from the monitoring wells. This process consists of pumping the well until 3 to 5 well volumes are removed then a sample is collected by District staff in a laboratory certified bottle and taken to a local laboratory for analysis.

An irrigation analysis is performed by the laboratory for all groundwater quality samples taken. A summary of typical groundwater quality sampling constituents included in an irrigation analysis is provided below:

- Total Dissolved Solids
- Electrical Conductivity
- Calcium
- Boron
- Sodium Bicarbonate
- Chloride
- Nitrate
- Magnesium
- Potassium
- Carbonate
- Sulfate

Land Subsidence Monitoring

Network: An in-district subsidence monitoring network has not yet been created. However, subsidence monitoring networks are available as a part of the ETGSA and KGA GSA GSP's. The most accessible data is from elevation monitoring along the Friant Kern Canal by the USBR. The closest subsidence measurement locations are at mile posts 120.05 and 124.27 along the Friant Kern Canal. Historical elevations are available from 1945 to 1959 and current elevations from 2017 to present.

InSAR data are also used as a regional land subsidence monitoring network; however, the availability of this data for district use depends on the availability of processed data from other sources. According to USGS, the ESA's Sentinel satellites collect InSAR data at an approximate weekly rate and are freely available for acquisition. This data has been available for download and use by the public after post-processing by technical professionals such as USGS and JPL (personal communication, USGS). The InSAR data is available as long as users continue to post process and distribute the data.

Frequency: The frequency of land subsidence data availability will be determined by the ETGSA and KGA GSA. Coordination with USGS and JPL for InSAR data, and coordination with USBR and Friant Water Authority for level survey data for Friant-Kern Canal will be necessary to finalize details of this monitoring network.

Spatial Density: The spatial distribution must be adequate to map land subsidence trends as identified in the Basin Setting, in the context of assessing land subsidence versus minimum thresholds and potential undesirable results.

4.3 Data Gaps and Planned Improvements *(Reg. § 354.38)*

The District has identified potential data gaps in the sustainability indicator monitoring networks. The data gaps and proposed improvements are described below to address how the District will satisfy minimum standards in the future.

4.3.1 Groundwater Levels

Existing monitoring wells are agricultural production wells; most of which are perforated through multiple aquifers making it difficult to distinguish individual aquifer groundwater characteristics. There is also a lack of subbasin monitoring data in the eastern lands of the study area that lie outside of the District, but have the potential to affect District groundwater levels.

Proposed Improvements

One of the District's planned network improvements is to drill dedicated monitoring wells that separately measure the distinct aquifers. In July 2020, two adjacent dedicated monitoring wells were completed on the eastern edge of the District within the Tule Subbasin that measure the distinct aquifers underneath the District: the Continental Deposits and the Santa Margarita Formation. The new dedicated monitoring wells enhance the quality of water level data by separately measuring water levels and water quality in the two aquifers. Dedicated monitoring wells in this location will help fill spatial data gaps by better characterizing the groundwater conditions to the East where much of the lands do not lie within a water district and therefore predominantly rely on groundwater. KTWD is also working with Eastside Water Management Area (EWMA) to pursue DWR Technical Support Services for monitoring wells in the Santa Margarita Formation and Olcese Sands on the eastern edge of the District within the Kern Subbasin.

The District will also consider installing data logging pressure transducers in the future to monitor groundwater levels in dedicated monitoring wells.

4.3.2 Groundwater Quality

The District's customers are agricultural landowners and thus the current sampling analysis does not include all drinking water related constituents of concern. The District acknowledges that the groundwater from the upper aquifer is shared by public and private water systems that may consume groundwater for drinking purposes.

Proposed Improvements

As described in the proposition above, installing dedicated monitoring wells may provide the ability to sample water quality from various aquifers.

4.3.3 Land Subsidence

Currently the District does not monitor land subsidence within the study area. Although there are several USBR elevation measurement locations along the Friant Kern Canal and InSAR data for the region, the collected data may not be representative of subsidence occurring within the study area.

Proposed Improvements

As discussed in the Basin Setting, land subsidence monitoring, via extensometers, that covers the study area is being developed by the KGA GSA and the Eastern Tule GSA which will include the District. The developed network will be implemented and discussed in future GSP updates.

4.4 Reporting Monitoring Data to the Department *(Reg. § 354.40)*

The monitoring data will be stored in the data management system developed pursuant to Section 352.6. A copy of the monitoring data will be included in the Annual Report and submitted electronically on forms provided by the Department.

CHAPTER 5. PROJECTS AND MANAGEMENT ACTIONS

5.1 Introduction (Reg. § 354.42)

This Chapter describes projects and management actions to meet the sustainability goal for the District in a manner that can be maintained over the planning and implementation horizon.

5.2 Projects and Management Actions *(Reg. § 354.44)*

Given the circumstances of unbalanced conditions as described in the Basin Setting, the District may begin implementation of projects and management actions (Actions) as shown on the implementation schedule in Section 1.6. The District has identified the following Actions as a means to accomplish groundwater sustainability:

1. Modify District Pricing Structure
2. Construct CRC Pipeline - Produced Water Project
3. Construct In-District Surface Storage

Each of the identified Actions will benefit groundwater levels beneath the District by increasing available surface water to decrease groundwater pumping. Following is a description of each of the Actions listed above which include:

- Description of the action
- Summary of the regulatory process and notice to the public
- Status and timeline for implementation
- Reduced groundwater pumping
- Capital cost estimate

5.2.1 Action 1: Modify District Pricing Structure

Each year the District's Board of Directors sets the surface water price for water users based on the blended water rates of the various sources of the District's water supply. This price is highly dependent upon hydrology and availability of water supplies. There are times when the cost of District water is more expensive than the cost to pump groundwater. During these times, some water users choose to pump groundwater instead of using surface water due to the cost difference.

The most affordable way to reduce groundwater pumping is to provide a pricing mechanism that causes groundwater to cost more than surface water. This could be accomplished by implementing a "groundwater charge" for every acre-foot pumped. Water Code §35533 provides the District the authority to collect groundwater charges. Revenue from the groundwater charge could be used to implement management actions or to reduce the cost to deliver surface water from the District.

Implementing a groundwater pumping charge would require the following to be accomplished:

1. Conduct a "Majority Protest" procedure under Proposition 218.
2. Install meters on all groundwater wells (or use an equivalent form of metering).
3. Set up procedures to read groundwater meters and charge for groundwater pumping.

Regulatory Process and Public Notice

The District has already begun the process of implementing Action 1. In 2021, the District focused on evaluating the best approach to implement a groundwater charge and has made significant progress. The District proposed a Groundwater Extraction Metering Plan and hosted a landowner workshop to receive input on the procedures of groundwater metering. The District elected to measure groundwater pumping by requiring meters on all groundwater wells. The District has amended the Rules and Regulations for the Sale and Distribution of Water to include the Groundwater Extraction Metering Plan and has retained a contractor to assist with meter installation requirements. The District published an Engineer's Report in June 2022 which determined what the upper limit of the groundwater extraction fee should be. The District will hold a Proposition 218 proceeding to establish the fee in August 2022.

Timeline

This project has been determined as the quickest, most effective way to benefit groundwater levels beneath the District and is already being implemented. A "Trial Period" began on January 1, 2022 to provide landowners with groundwater pumping information on their monthly statements through December 31, 2022 in anticipation of the new charge. If the groundwater extraction fees are approved by landowners, the District's ability to charge for groundwater will become effective January 2023.

Estimated Yield

5,580 AF/yr reduction in groundwater pumping.

Estimated Capital Cost

After receiving substantial landowner feedback, the District opted for landowners to own and maintain their groundwater well meters. Landowners are responsible for all costs associated with their meter. The initial cost of a new meter installation for the landowner ranges from $3,000 - $6,000.

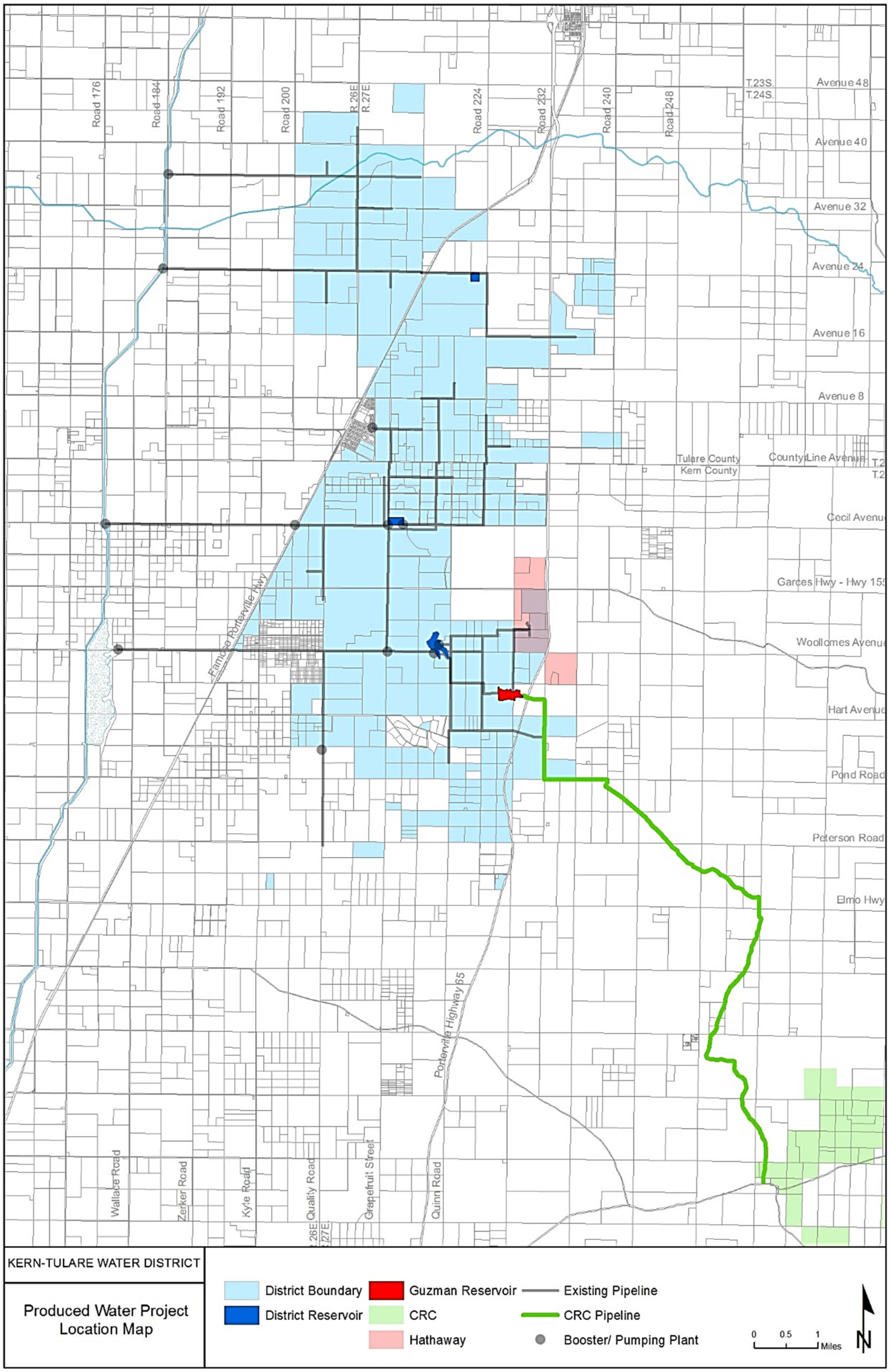
5.2.2 Action 2: CRC Pipeline Project - Produced Water Project

When oil companies pump oil from underground, a mixture of oil and water is extracted and needs to be processed for separation. For every barrel of oil produced, 20 to 140 barrels of water are also produced, referred to as "produced water", that the companies must dispose. Available produced water near the District is of good quality and can be used for irrigated agriculture with minimal treatment or blending.

The District has historically accepted produced water to provide surface water to the District and is in the process of obtaining an additional source of produced water from California Resources Corporation (CRC). Produced water from CRC will be transported through 12 miles of 15-inch pipeline to the Guzman Reservoir. From the Guzman Reservoir, water will be transported through 1.8 miles of 30-inch pipeline to the District's existing Big 4 Reservoir, from which it will be blended with water from the Friant-Kern Canal and distributed in existing facilities to existing irrigated agriculture located within the District.

Figure 5-1 is a Location Map showing the District and the relative location of the proposed project within the District.

Figure 5-1 Location Map



Regulatory Process and Public Notice

The District has made significant progress on implementation of the Project. Below is a summary of what has been completed:

- An updated Waste Discharge Requirements (WDR) Order No. R5-2019-0043 from the Regional Water Quality Control Board (Regional Board) that includes Guzman Reservoir was adopted in June 2019. The District received a construction permit by the Department of Water Resources, Division of Safety of Dams in September of 2019. Construction of the reservoir will begin in January 2020 and be completed in June 2020.
- An EIR for the Project was completed in 2016 to fulfill current CEQA requirements.
- A 401 permit from the State Water Resources Control Board, a 404 permit from the U.S. Corps of Engineers, and a 1600 permit from the California Department of Fish and Wildlife are required for the pipeline and were received in June 2019.
- A WDR will need to be acquired from the Regional Board and is projected to be obtained in late 2020.

Timeline

The District and CRC are in the process of acquiring permits, preparing an anti-degradation analysis and acquiring a WDR from the Regional Board. Project pipelines have been designed and plan and profile drawings have been prepared. The District is negotiating an agreement with CRC and obtaining rights-of-way. The pipeline construction is expected to be completed prior to 2025.

Estimated Yield

3,000 AF/yr of additional surface supplies (results in a reduction of 1,440 AF/yr in groundwater pumping).

Estimated Capital Cost

$5.9 million

5.2.3 Action 3: In-District Surface Storage

There are times when affordable water supplies are available, but the District has little to no irrigation demand and no available spreading capacity in its existing out-of-district banking programs. Construction of off-stream surface storage will allow the District to acquire water when it is available and store it to meet future irrigation demands.

The District has selected two potential reservoir sites with a total capacity of 8,000 AF to capture wet year water. The sites are located to the east of the District in both the north and south portions. A location map of facilities and detailed description is not provided due to the confidential nature of the property and rights of way acquisition.

Regulatory Process and Public Notice

- CEQA will be required for construction of facilities.
- NEPA will be required to annex the reservoir sites into the District.
- Construction permits will be required from the Division of Safety of Dams.
- Purchase of land and rights of ways will require negotiations with landowners.
- A proposition 218 election may be required to finance the project.

Timeline

The project is still in the preliminary design phase and will require additional steps before construction. The District has selected two potential reservoir sites, completed exploratory borings, and conducted a geotechnical evaluation of the two potential sites. The District has yet to acquire land and rights of way, permits, environmental documentation, or project financing. It is estimated that these facilities will be constructed between 2025 and 2030 if they are determined to be feasible and found to be necessary.

Estimated Yield

Based upon annual water supply modeling herein, the project yields only 530 AF/yr. However, a monthly analysis will need to be conducted to provide a better estimate of project yield, which could be as much as 2,000 AF/yr (assumes the reservoirs are used once every 4 years).

Estimated Capital Cost

$20 million

5.3 Evaluation of Cumulative Benefits

Benefits of the above Actions have been analyzed using a phased approach where actions are completed in sequence. Starting from this baseline, each Action was evaluated under the following phases to determine the cumulative benefits of implementation:

1. Phase 1: Implement Action 1
2. Phase 2: Implement Actions 1 & 2
3. Phase 3: Implement Actions 1, 2, & 3

A projected water supply analysis was prepared as part of Section 2.4 of the Basin Setting to estimate future irrigation demand, use of imported water supply, groundwater pumping, and related costs. Projected water demands utilized 2017 land use and crop coefficient information. Projected surface water supplies were based upon the most recent water supply estimates of future surface water supply. The projection was based on the 56-year historical hydrologic period from 1958 through 2013. The results of the projected future water supply conditions from Section 2.4 established a baseline for supplies. Table 5-1 presents a summary of the results for the baseline and each of the three phases.

Table 5-1 Projected future water supply under phased implementation

	Action 1: Modify Pricing Structure	**Action 2:** Construct CRC Pipeline Project	**Action 3:** Construct In-District Surface Storage	Avg. Surface Water Deliveries (AF/yr)	Avg. Groundwater Pumping (AF/yr)	District Cost of Surface Water ($/AF)
Base				33,706	14,785	$239
Phase 1	X			39,348	9,143	$250
Phase 2	X	X		40,726	7,764	$240
Phase 3	X	X	X	41,231	7,260	$232

A discussion of results for each of the Phases is presented in the sections that follow.

Base: No Action

Figure 5-2 and Figure 5-3 display the baseline conditions as presented in Section 2.4 of the Basin Setting.

Figure 5-2 Source of water to District under future baseline conditions

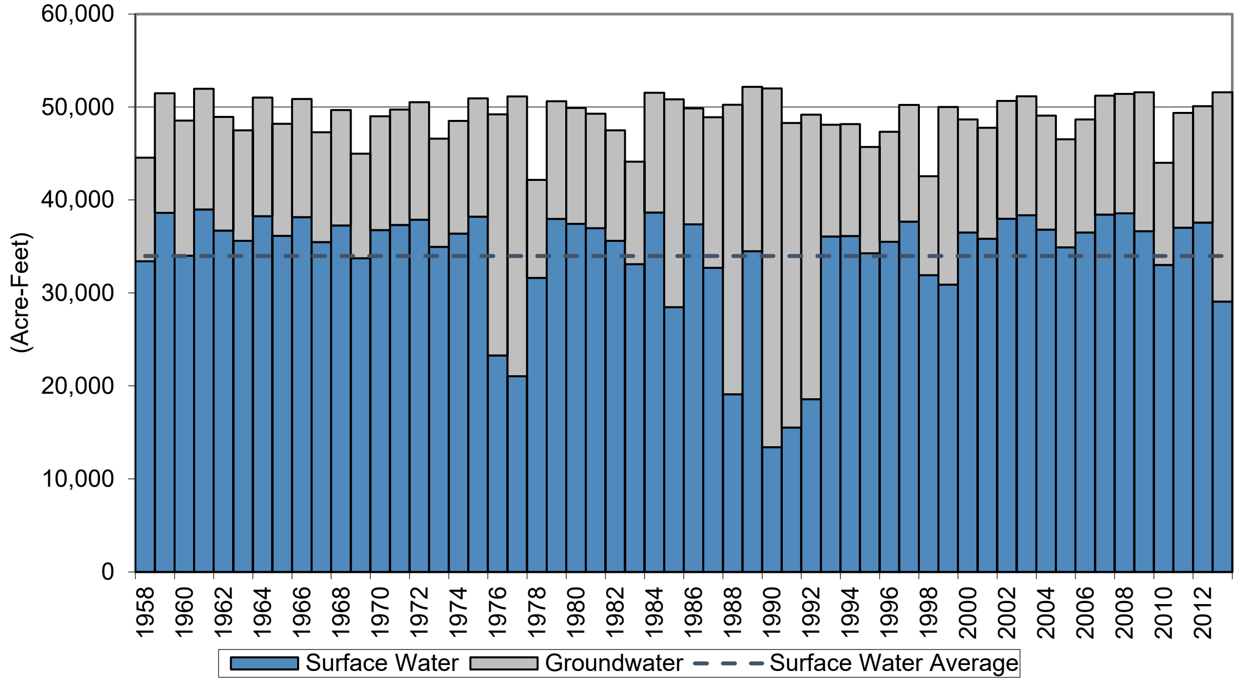
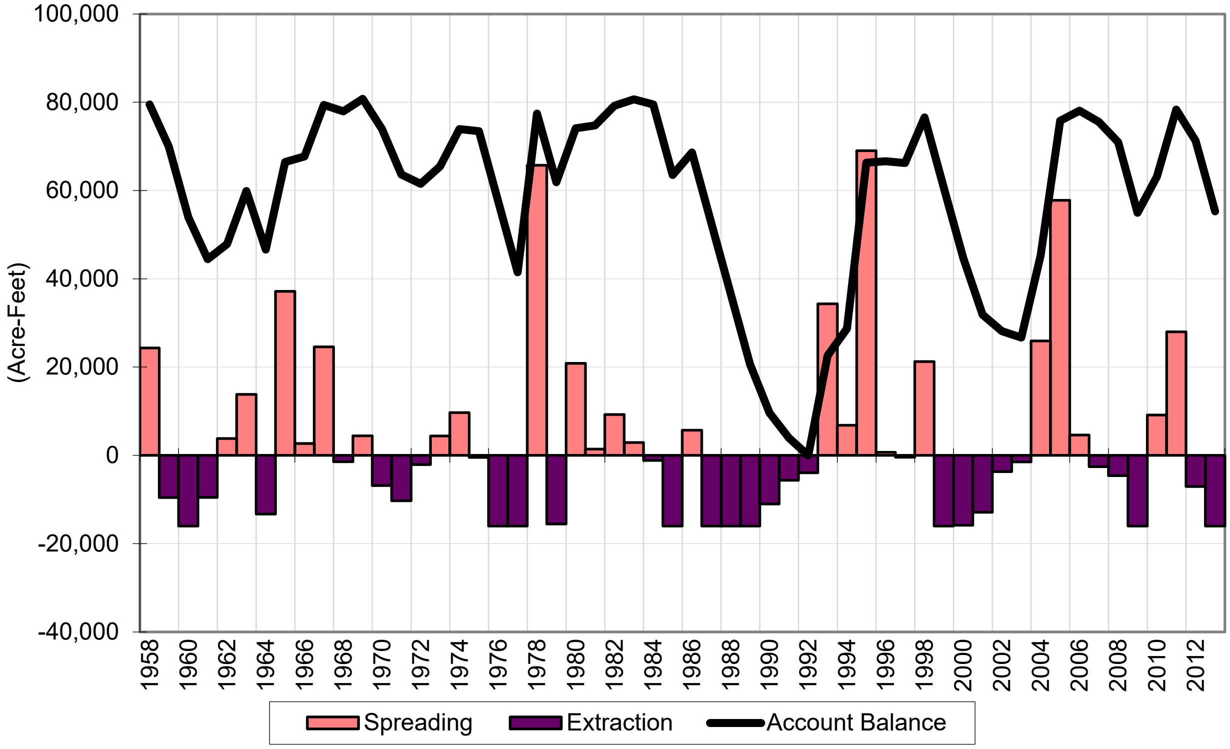


Figure 5-3 Banking supplies under baseline future conditions



Phase 1: Action 1 (Modify Pricing Structure)

Figure 5-4 is an illustrative example of incentivizing users to purchase more surface water by modifying the water pricing structure. In this example, a "groundwater charge" of $100/AF is implemented in order to reduce surface water prices to compete with groundwater prices. Figure 5-5 shows the resulting change in source of supply (surface water versus groundwater) and Figure 5-6 demonstrates the effect on the District's banking accounts caused by extracting banked water to provide these additional surface supplies.

Figure 5-4 Surface and groundwater rates in Phase 1

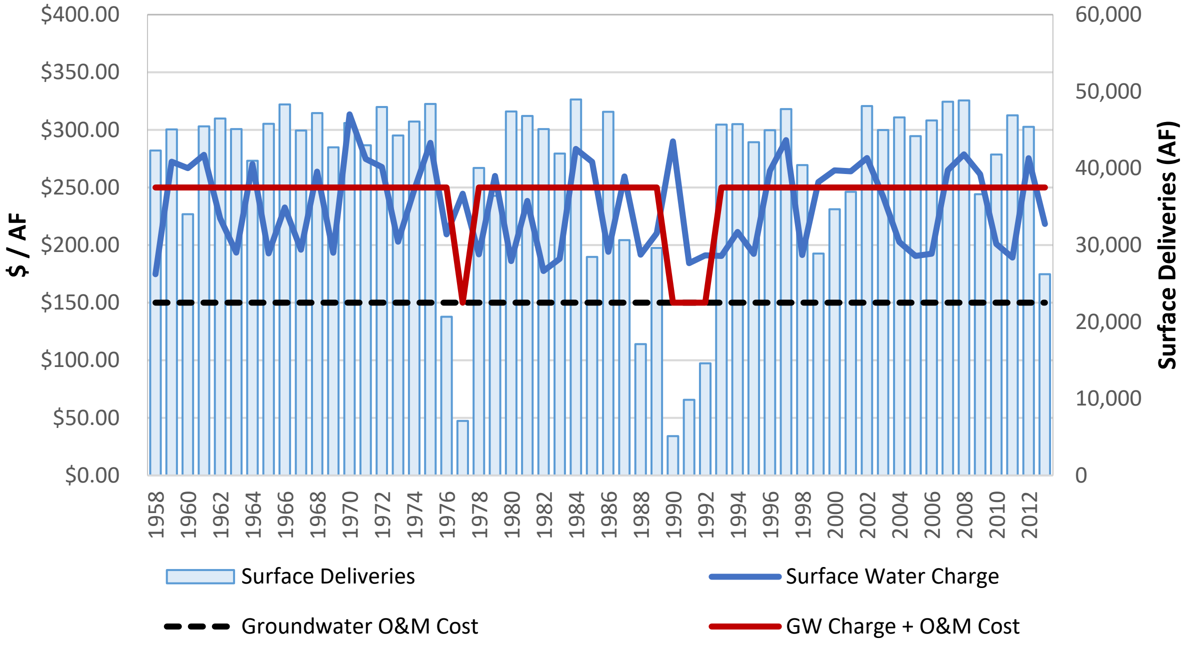


Figure 5-5 Source of water to District under Phase 1

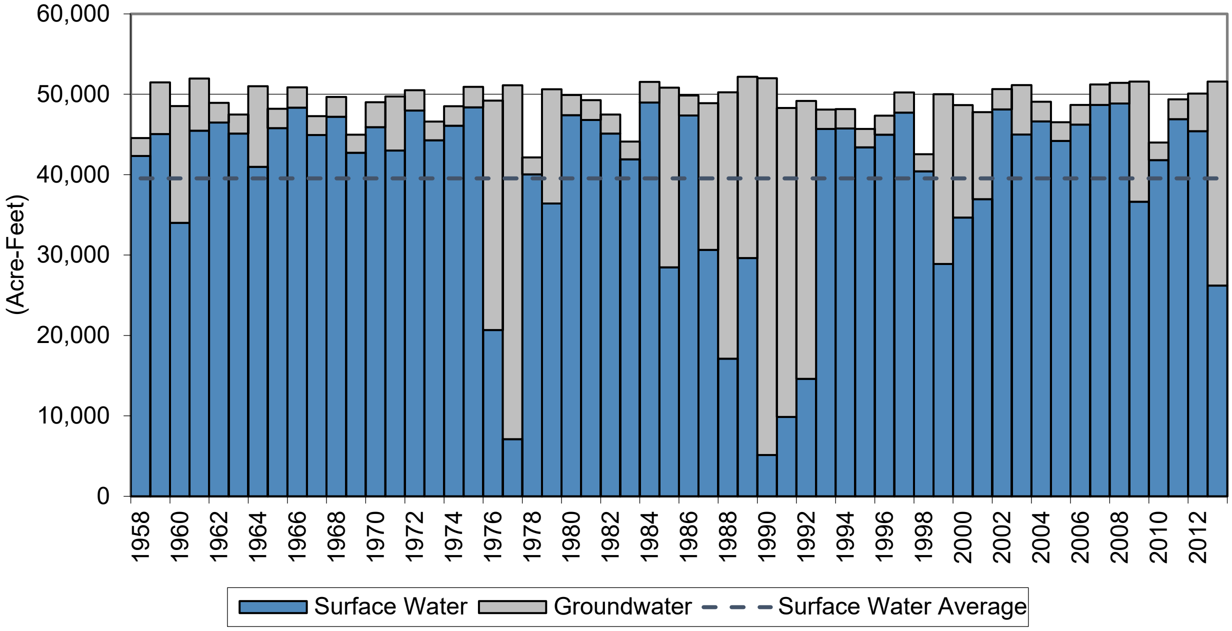
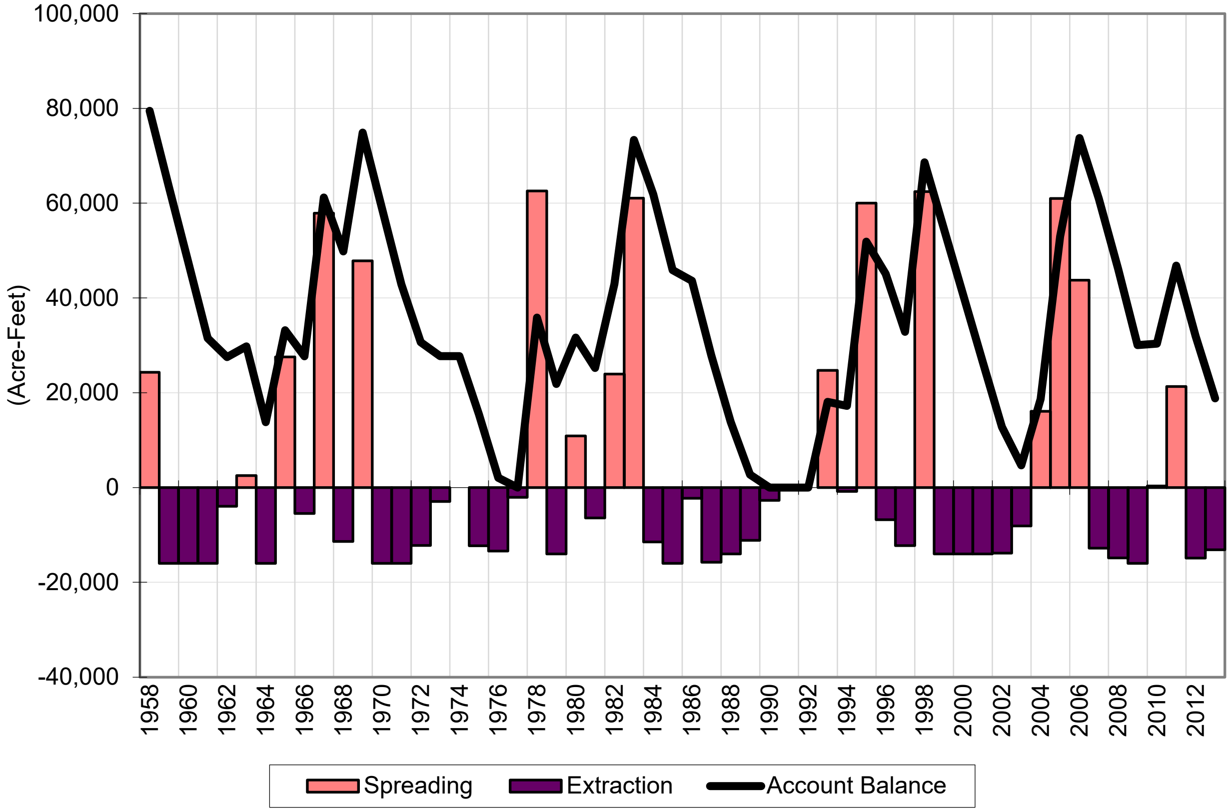


Figure 5-6 District banking supplies under Phase 1



As presented in Table 5-1, Phase 1 (Action 1) reduces the average annual groundwater pumping from 14,785 AF to 9,143 AF and increases the total District cost to purchase surface water from $239 to $250 per AF. Figure 5-5 demonstrates that by modifying the pricing structure, the District's surface water charge is similar and less than groundwater costs in most years. It is anticipated that during years of limited surface supply, which increases the cost of surface water, the groundwater pumping charge could be eliminated.

Figure 5-5 displays that surface water deliveries are increased in most years under Phase 1. However, as shown in Figure 5-6, in order to supply additional amounts of surface water the District's banking programs are used nearly every year and the storage accounts are exhausted during each drought period. With not enough banking supplies available in dry years, the cost of surface water increases and results in a reliance upon groundwater pumping.

Phase 2: Actions 1 & 2 (Modified Pricing + CRC Pipeline Project)

As presented in Table 5-1, Phase 2 creates additional surface supplies and reduces average annual groundwater pumping to 7,764 AF. Additional reasonably priced supplies also reduce the cost of surface water to $240 per AF; a similar cost as in the Base case. Figure 5-7 illustrates the additional surface water supplies provided by the produced water from CRC. Figure 5-8 demonstrates the small positive effect on the District's banking accounts as a result of obtaining additional surface supplies.

Figure 5-7 Source of water to District under Phase 2

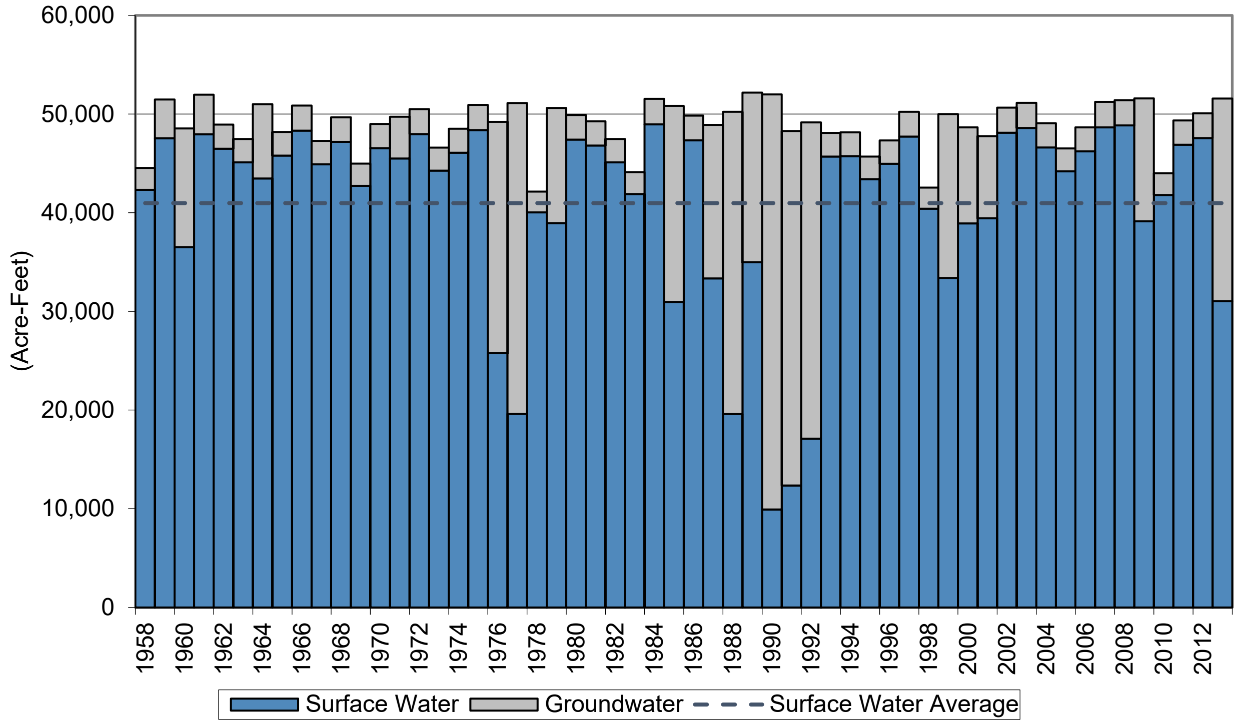
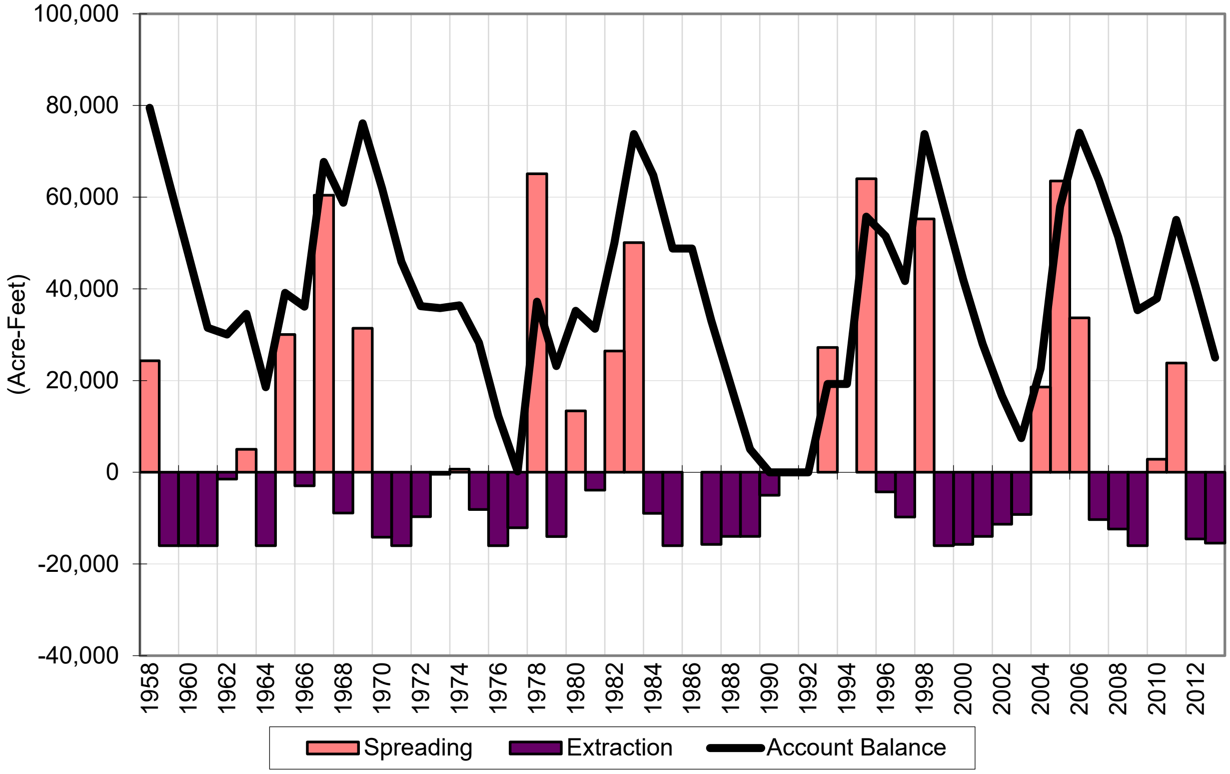


Figure 5-8 District banking supplies under Phase 2



As shown in Figure 5-7 surface water deliveries are increased in dry years. However, as shown in Figure 5-8, the District's banking programs are still used nearly every year and the storage accounts are exhausted during each drought period.

Phase 3: Action 1, 2, & 3 (Modified Pricing + CRC Pipeline Project + Surface Storage)

As presented in Table 5-1, Phase 3 reduces the average annual groundwater pumping to 7,260 AF and reduces the District's cost to purchase surface water to $232 per AF as a result of less expensive water available during wet years for delivery to storage. However, this alternative has a capital component which increases the user surface water fee by an estimated $36 per AF to a total of $268 per AF.

Figure 5-9 shows an increase in surface water supplies provided by the construction of surface storage. Figure 5-10 demonstrates the effect on the District's banking accounts as a result of having the capacity to capture more surface supplies.

Figure 5-9 Source of water to District under Phase 3

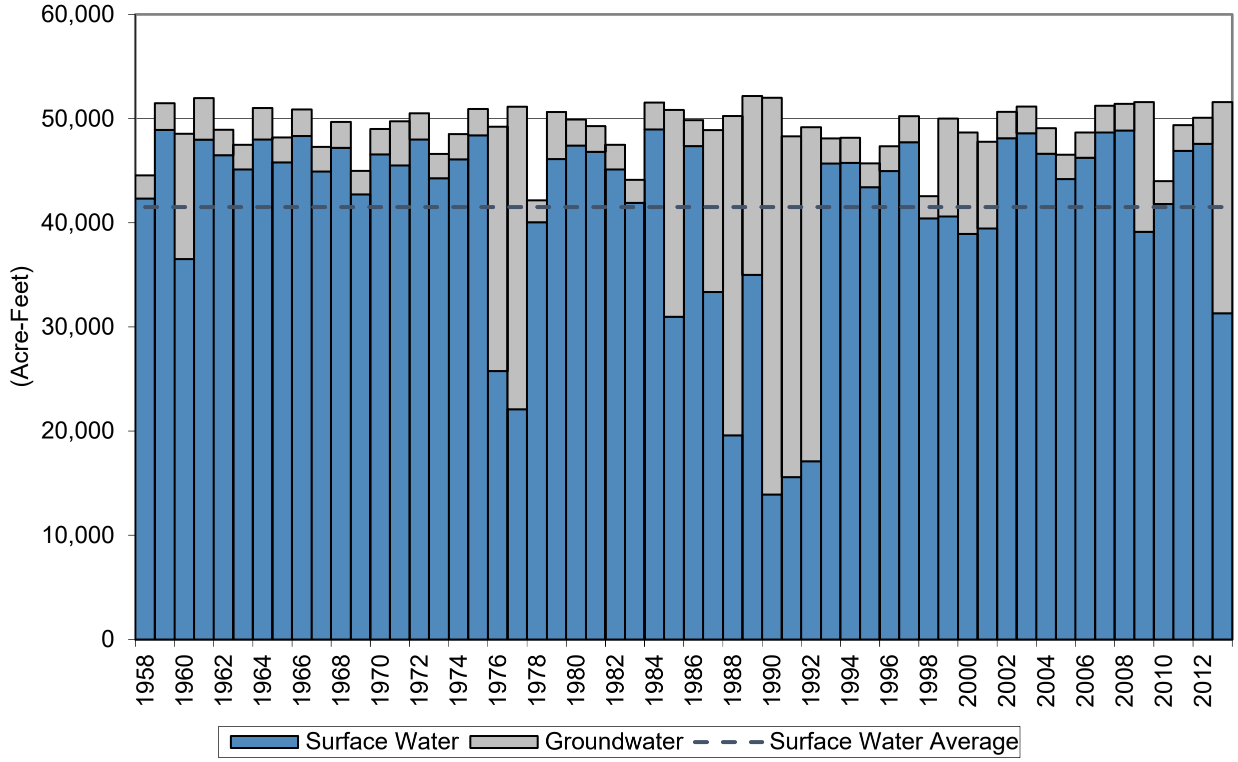
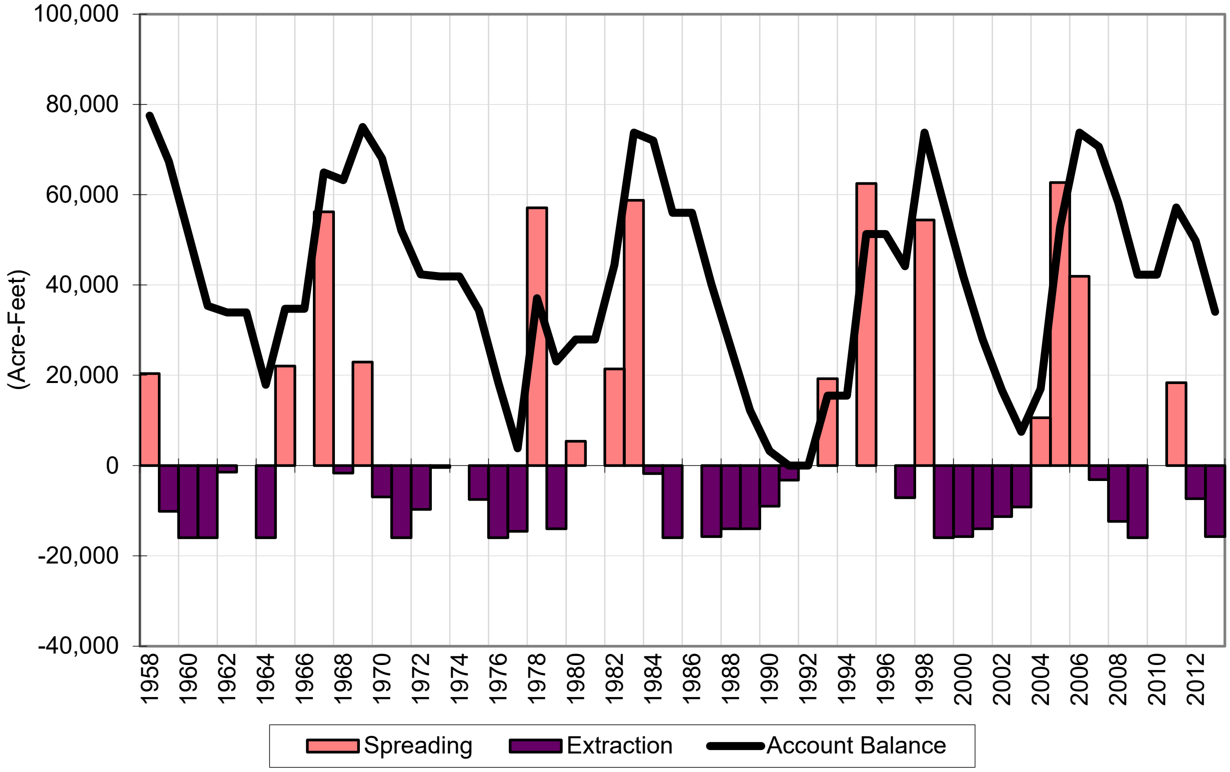


Figure 5-10 District banking supplies under Phase 3



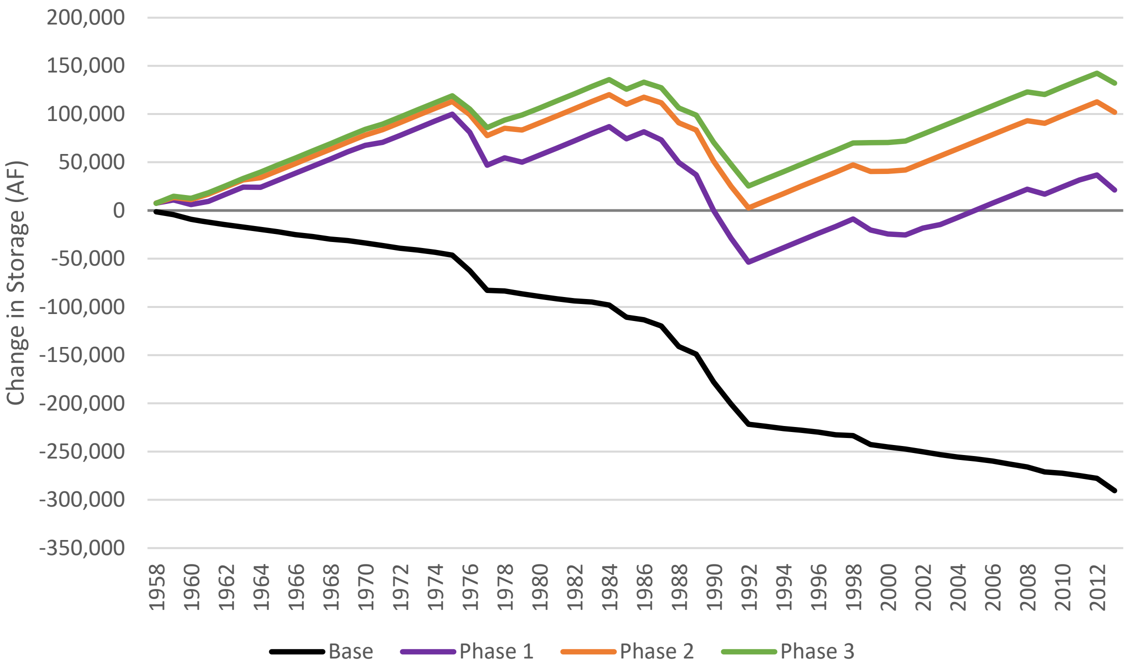
Similar to Phases 1 and 2, Figure 5-9 demonstrates that surface water deliveries are increased again in dry years; averaging 41,231 AF per year. Figure 5-10 illustrates that with additional capture of surface supplies, provided by Action 3, the District's banking programs are not used as often and the storage accounts are maintained at a greater level than in the previous phases.

Although the projected future water supply model resulted in an annual benefit of 530 AF/yr, the actual achieved benefit may be as much as 2,000 AF/yr (assuming 8,000 AF of storage is used once every four years). If the maximum benefit was achieved the average groundwater pumping could be reduced to 5,764 AF per year.

5.4 Evaluation of Groundwater Levels with Actions

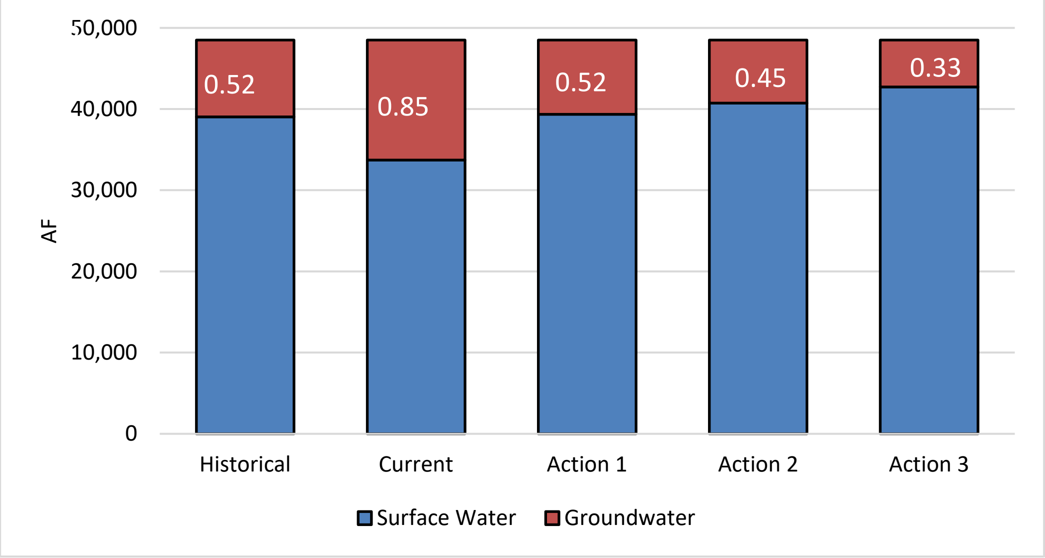
The District believes that with implementation of the described Actions, groundwater levels can be stabilized over the planning horizon. Figure 5-11 illustrates the positive change in storage as a result of the various Actions in comparison to the baseline as modeled over the projected 56-year period.

Figure 5-11 Projected Change in Groundwater Storage for Phases 1 - 3



Based upon the 1993 to 2009 historical conditions, the assumed safe yield is approximately 9,450 AF per year or 0.52 AF/acre. The projected model under current conditions indicates that water users within the District will pump an average of about 0.85 AF/acre of groundwater which will likely cause groundwater levels to lower. Implementing Action 1 would decrease groundwater pumping to about 0.52 AF/acre which meets the assumed safe yield for the District. Action 2 would continue to reduce groundwater pumping to approximately 0.45 AF/acre and increase groundwater levels and storage. Action 3 (assuming a yield of 2,000 AF/yr) would result in a reduction of groundwater pumping to about 0.33 AF/acre.

Figure 5-12 Summary of Groundwater Use (AF per acre) with Actions



APPENDIX 1: REFERENCES

Bartow, Alan J. 1991. *The Cenozoic Evolution of the San Joaquin Valley.* United States Geological Survey Professional Paper 1501.

Boyle Engineering Corporation. 1974. *Final Environmental Impact Report of Proposed Irrigation and Distributions System for Kern-Tulare Water District*.

California Geological Survery (CGS) 2010. *Geologic Map of California*. http://maps.conservation.ca.gov/cgs/DataViewer.html. Accessed March 12, 2018.

California Irrigation Management Information System (CIMIS). *Shafter Monthly Report (Station 5).* CA Department of Water Resources. Retrieved from https://cimis.water.ca.gov. Accessed October 25, 2018.

Cornerstone Engineering. 2015. *Engineering Report, Investigation of Rainfall Gauge Data Proximate to Groundwater Recharge Areas Impacting the Kern-Tulare Water District within Kern County.*

Encyclopedia Britannica (EB). 2018. Retrieved from https://www.britannica.com/. Accessed May 2018.

Farr, T.G., C. Jones, Z. Liu, 2016, *Progress report: Subsidence in the Central Valley, California.* Submitted to California Department of Water Resources.

Gillespie, J. M. and S.C. Dalke. 2016. *Analysis of Groundwater Resources for Kern-Tulare Water District.*

Hilton, G.S., R.L. Klausing, and F. Kunkel. 1963. *Geology, Hydrology and Quality of Water in the Terra Bella-Lost Hills Area.* U. S. Geological Survey: Open File Report 63-47.

Howes, D.J. 2018. *1993-2016 ITRC-METRIC ETc for Kern County.* Irrigation Training and Research Center (ITRC). California Polytechnic State University.

Irrigation Training and Research Center (ITRC). *California Evapotranspiration Data.* California Polytechnic State University. Retrieved from http://www.itrc.org/etdata/index.html. Accessed November 16, 2018.

Kennedy and Jenks Consultants. 2015. *Water Quality Assessment Report, Kern County 19.98 Zoning Ordinance EIR. In.* Draft Environmental Impact Report. Kern County Planning and Community Development Department.

Kern-Tulare Water District (KTWD). 2015. *Groundwater Monitoring Plan.*

Lofgren, B.E. and R.L. Klausing. 1969. *Land Subsidence due to Ground-Water Withdrawal Tulare-Wasco Area California.* U. S. Geological Survey: Professional Paper 437-B.

Luhdorff & Scalmanini Consulting Engineers (LSCE). 2014. *Land Subsidence from Groundwater Use in California.* Submitted to California Department of Water Resources.

Natural Resources Conservation Service (NRCS). *National Cooperative Soil Survey STATSGO2 Database - Web Soil Survey.* United States Department of Agriculture (USDA) Retrieved from http://websoilsurvey.nrcs.usda.gov/. Accessed October 25, 2018.

Provost & Pritchard Engineering Group. 2007. *Groundwater Management Plan Delano-Earlimart Irrigation District.*

Reynolds, H. W. Jr. 1955. *Geology Report, Ground Water Resources of the Richgrove Area.*

U.S. Bureau of Reclamation (USBR). 2012. EA-09-121: *Poso Creek Integrated Regional Water Management Plan: 25-Year Groundwater Banking, Transfer, and Exchange Program.*

U.S. Geological Survey (USGS). 2006. *Quaternary Fault and Fold Database for the United States.* Retrieved from https://earthquake.usgs.gov/hazards/qfaults/. Accessed October 17, 2018.

U.S. Geological Survey (USGS). 2011. *The San Joaquin-Tulare Basins NAWQA Study Unit Description.* Retrieved from USGS website: http://ca.water.usgs.gov/sanj_nawqa/sanj.html. Accessed October 25, 2018.

Western Regional Climate Center. *Cooperative Climatological Data Summaries*. Retrieved from https://wrcc.dri.edu/summary/Climsmsca.html. Accessed October 25, 2018.

Winsauer, W.O., H.M. Sherin, P.H. Masson, and M. Williams. 1952. *Resistivity of brine-saturated sands in relation to pore geometry.* American Association of Petroleum Geologists: Bulletin V. 36, p. 253-277.

WZI Inc., 2016. *Aquifer Exemption Study: Race Track Hill Area/Edison Field, Pyramid Hill Sands and Vedder Formations, Kern County, CA.* Division of Oil Gas and Geothermal Resources. Volume 1: Chapter 1.

APPENDIX 2 – HYDROLOGIC MODEL

A2.1 Introduction

A 25-year historical water budget was developed for the District from 1993 through 2017 to evaluate water demands, surface water deliveries, groundwater pumping, and aquifer response to water supply and demand. The historical water budget includes the following:

1. Land use for the study area.
2. Evapotranspiration (ET) for the study area.
3. Precipitation and runoff for the study area.
4. Surface water supplies for the District.
5. Deliveries to irrigation and banking for the District.

Using these water budget components, the District estimated the following:

- Groundwater pumping for the study area.
- Return flows to aquifers beneath the District.
- Subsurface flows to aquifers beneath the District.
- Change in groundwater storage for the aquifers beneath the District.

The water budget relies on the following fundamental relationship between inflows and outflows:

$$\text{Inflow} - \text{Outflow} = +/- \Delta \text{ Storage}$$

where inflows include precipitation, surface water deliveries, subsurface inflow, and return flow to groundwater (deep percolation); and outflows include ET, groundwater pumping, and subsurface outflow. Table A2-1 summarizes the ET, total precipitation, effective precipitation, total applied water, surface water deliveries, groundwater pumping, runoff, and return flow for within the District. A discussion of each component and derivation of the values follows.

Table A2-1 Historical Water Budget within the District

				Source of Applied Water					
Year	**Crop ET**	**Total Precip**	**Effective Precip**	**Applied Water Demand**	**Surface Water Deliv.**	**Ground Water Pumping**	**Total Applied Water**	**Runoff Leaving District**	**Return Flow to GW**
	(A)	***(B)***	***(C)***	***(D)***	***(E)***	***(F)***	***(G)***	***(H)***	***(I)***
1993	48,826	12,668	5,828	47,776	37,307	10,470	47,776	0	11,618
1994	50,872	13,112	8,072	47,556	40,721	6,836	47,556	0	9,796
1995	50,503	17,675	8,094	47,121	39,243	8,428	47,672	2,498	12,346
1996	51,107	14,876	7,341	48,629	41,718	7,114	48,832	195	12,406
1997	51,834	9,377	3,800	53,371	44,610	8,873	53,483	0	11,025
1998	53,738	25,108	12,981	45,285	35,110	10,218	45,328	4,533	12,166
1999	51,968	9,745	4,355	52,903	41,692	11,211	52,903	1,493	9,188
2000	50,607	12,138	6,173	49,371	44,509	5,528	50,037	271	11,297
2001	49,601	13,445	6,209	48,213	45,312	3,635	48,946	0	12,791
2002	47,405	7,696	4,746	47,399	38,337	9,071	47,409	0	7,700
2003	46,182	6,727	5,115	45,630	36,820	8,810	45,630	0	6,175
2004	47,000	10,389	5,264	46,374	38,633	7,741	46,374	0	9,763
2005	47,219	14,853	7,895	43,693	36,290	7,403	43,693	0	11,327
2006	51,528	11,851	9,075	47,169	35,371	11,798	47,169	0	7,492
2007	51,620	6,970	4,112	52,787	38,427	14,490	52,917	0	8,267
2008	52,747	6,828	3,414	54,815	40,233	14,582	54,815	0	8,896
2009	49,612	6,100	3,997	50,683	36,164	14,518	50,683	0	7,171
2010	52,003	20,503	6,826	50,197	32,840	17,358	50,197	4,699	13,998
2011	47,577	9,663	6,553	45,582	33,629	11,953	45,582	0	7,668
2012	48,435	8,590	5,379	47,840	35,853	11,987	47,840	0	7,995
2013	47,798	5,926	4,475	48,137	37,755	10,760	48,515	0	6,643
2014	48,366	7,668	4,962	48,227	21,409	26,818	48,227	0	7,528
2015	50,348	8,464	6,833	48,350	16,726	31,627	48,352	0	6,468
2016	50,161	9,637	5,414	49,719	29,879	19,841	49,719	0	9,195
2017	49,494	12,181	3,290	51,338	37,638	13,929	51,566	2,261	11,992
1993-2009 Average	*50,139*	*11,739*	*6,263*	*48,751*	*39,441*	*9,454*	*48,895*	*529*	*9,966*

(A) Annual values from Table A2-6.
(B) Annual values from Table A2-9.
(C) Annual values from Table A2-11.
(D) Calculated as (A – C) ÷ 90% irrigation efficiency.
(E) Annual values from Table A2-16.
(F) Annual values from Table A2-19.
(G) Calculated as (E + F).
(H) Annual values from Table A2-22.
(I) Calculated as (B + G – A – H)

A2.2 Hydrologic Balance Inputs

Land Use

The District annually performs a crop survey for lands within the District, and summarizes cropped acreage based upon APN acres. Crops are categorized as Grapevines, Trees & Nuts, Citrus, Field Crops or Non-Irrigated Acres. The sum of each of these categories and the non-irrigated acres make up the total acres for the District. The District has no control over what lands are put into production, or the type of crop that is produced. The decision to irrigate or not irrigate is entirely up to the landowner. Historical land use within the District is summarized for years 1993 through 2017 in Table A2-2.

Table A2-2 Annual Historical Land Use within the District

	Irrigated Acres						
Calendar Year	**Grape Vines**	**Trees & Nuts**	**Citrus**	**Field Crops**	**Total Irrigated Acres**	**Non-Irrigated Acres**	**Total Acres**
1993	7,327	1,785	8,356	529	17,997	9,478	27,475
1994	7,687	1,684	8,795	632	18,798	8,672	27,470
1995	7,708	1,730	8,716	484	18,638	7,527	26,165
1996	7,848	1,739	8,512	952	19,051	7,154	26,205
1997	7,926	1,851	8,587	936	19,300	6,935	26,235
1998	7,464	1,963	9,232	1,124	19,783	6,271	26,054
1999	7,771	2,200	8,635	533	19,139	6,834	25,973
2000	8,116	2,045	8,243	391	18,795	5,342	24,137
2001	7,622	2,166	8,208	255	18,251	5,884	24,135
2002	7,151	2,082	7,975	150	17,358	6,513	23,871
2003	6,723	2,013	7,396	1,007	17,139	6,753	23,892
2004	7,146	2,238	7,750	70	17,205	6,672	23,877
2005	6,897	3,081	7,134	89	17,201	5,869	23,069
2006	6,368	4,493	7,376	129	18,367	5,000	23,367
2007	5,622	4,906	7,427	189	18,144	5,298	23,441
2008	5,798	4,809	7,501	600	18,708	4,104	22,812
2009	5,722	4,956	6,717	159	17,554	4,606	22,160
2010	5,466	5,526	6,901	399	18,293	4,103	22,396
2011	5,474	4,977	6,238	139	16,828	3,890	20,718
2012	5,525	5,155	6,232	239	17,152	3,523	20,674
2013	5,678	5,062	6,032	240	17,012	3,301	20,313
2014	6,307	5,164	5,712	244	17,427	2,850	20,068
2015	6,770	5,989	5,288	140	18,157	2,071	20,228
2016	5,995	6,091	5,555	233	17,874	2,385	20,259
2017	5,422	6,211	5,610	200	17,443	2,639	20,082

(1) – Grapevines includes table grapes and wine grapes
(2) – Nuts and trees includes almonds, pistachios, cherries, persimmons, and pomegranates
(3) – Citrus includes oranges, tangelo, kiwi, lemons, and grapefruit
(4) – Field Crops includes blue berries, Sudan grass, and alfalfa

Since 1993, the District has removed (detached) some non-irrigated lands. As shown in Table A2-2, the total number of irrigated acres within the District has remained constant since 1993 and there has been a conversion from citrus and grapes to trees and nuts.

Historical land use outside the District is summarized for years 1993 through 2017 in Table A2-3. As shown in Table A2-3, the total number of irrigated acres for lands outside of the District has doubled since 1993. Since the District has detached lands over the years, the total acres outside of the District within the study area has also grown.

Table A2-3 Annual Historical Land Use Outside the District

Calendar Year	Irrigated Acres					Non-Irrigated Acres	Total Acres
	Grape Vines	Trees & Nuts	Citrus	Field Crops	Total Irrigated Acres		
1993	204	160	4,559	0	4,923	60,223	65,146
1994	204	160	4,559	0	4,923	60,228	65,151
1995	204	281	4,559	0	5,044	61,412	66,456
1996	204	281	4,559	0	5,044	61,372	66,416
1997	204	281	4,559	0	5,044	61,342	66,386
1998	204	281	4,559	0	5,044	61,523	66,567
1999	204	281	4,559	0	5,044	61,604	66,648
2000	204	281	4,559	0	5,044	63,440	68,484
2001	204	281	4,559	0	5,044	63,442	68,486
2002	404	281	4,559	0	5,244	63,506	68,750
2003	404	481	4,600	72	5,557	63,172	68,729
2004	404	481	4,320	72	5,277	63,468	68,744
2005	404	481	4,320	72	5,277	64,275	69,552
2006	404	481	4,320	72	5,277	63,977	69,254
2007	404	481	4,320	72	5,277	63,903	69,180
2008	404	481	4,420	72	5,377	64,432	69,809
2009	404	491	5,167	72	6,134	64,327	70,461
2010	404	491	5,167	72	6,134	64,092	70,226
2011	404	491	5,207	72	6,174	65,730	71,903
2012	404	491	5,207	72	6,174	65,773	71,947
2013	404	491	5,207	72	6,174	66,134	72,308
2014	404	491	7,422	72	8,389	64,164	72,553
2015	404	1,226	7,707	72	9,409	62,984	72,393
2016	404	1,259	7,735	72	9,470	62,892	72,362
2017	404	1,259	8,003	72	9,738	62,802	72,539

(1) – Nuts and trees includes almonds, pistachios, cherries, persimmons, and pomegranates
(2) – Citrus includes oranges, tangelo, kiwi, lemons, and grapefruit
(3) – Field Crops includes blue berries

Evapotranspiration

Evapotranspiration (ET) is the combination of evaporation and transpiration from plants and soil surfaces. To calculate the crop ET (ETc), the District used the crop coefficient approach where the ETc is calculated by multiplying the reference crop evapotranspiration (ETo) by the crop coefficient (Kc). The land use data was used to determine ETc for the crops grown in the study area.

The plant water use data used for this model was published by Cal Poly ITRC (ITRC, 2018) in a monthly ETc table reliant on assumptions of irrigation frequency, crop cover, planting and harvest dates, etc. The table selected was specific to Zone 15 for drip/micro irrigation in a typical year and used a grass reference ETo. The values in Table A2-4 below are monthly ETc values used in water balances for the crop types found within the study area. Values for water balances have been adjusted for bare spots and decreased vigor.

Table A2-4 Monthly Crop Evapotranspiration from ITRC

Monthly ETc (in.)				
	Grape Vines	Almonds	Citrus	Field Crop
Jan	-	-	0.97	1.02
Feb	-	1.06	2.22	0.85
Mar	0.48	1.19	2.86	1.10
Apr	1.77	4.15	4.33	1.70
May	3.97	6.62	5.10	2.54
Jun	5.95	6.97	5.29	7.42
Jul	5.82	6.79	5.16	7.53
Aug	4.62	5.98	4.54	2.72
Sep	2.42	4.24	3.56	0.02
Oct	0.34	2.07	2.67	0.31
Nov	0.76	0.75	1.38	0.79
Dec	-	-	1.13	1.05
Total	26.13	39.82	39.21	27.05

As shown in Table A2-4, ETc for grapes and almonds in the winter months were not calculated due to negligible rates outside of the growing season.

Calibrated Monthly Crop Evapotranspiration

In order to more accurately state the District's ETc values, the tabled monthly ETc values from the ITRC (Table A2-4) were compared and calibrated to ETc satellite data also provided by the ITRC (Howes, 2018). The satellite data determined total ETc in acre-feet using a modified Mapping of EvapoTranspiration with Internal Calibration (ITRC-METRIC) and LandSAT data for 1993 through 2015. ITRC-METRIC does not use land use/crop type information to calculate ET, therefore the District elected to calibrate the ITRC table values in order to calculate ET into the future when ITRC-METRIC values are not available.

An iterative process was used to calibrate the tabled monthly ETc values to the satellite data. The tabled values were converted to acre-feet by multiplying the District's land use data (acres) with the corresponding ETc value (converted to ft). The District applied a 3% reduction to the calculated acre-foot value to account for roads and reservoirs. The resulting acre-foot value was compared with the satellite acre-foot value and the original tabled ETc value was adjusted accordingly. The new calibrated table of ETc values are shown in Table A2-5.

Table A2-5 Monthly Calibrated Crop Evapotranspiration

Calibrated Monthly ETc (in.)				
	Grape Vines	Almonds	Citrus	Field Crop
Jan			1.16	1.22
Feb		0.82	1.72	0.66
Mar	0.58	1.45	3.48	1.34
Apr	1.62	3.80	3.97	1.56
May	3.39	5.65	4.35	2.17
Jun	4.67	5.47	4.15	5.82
Jul	5.38	6.27	4.77	6.95
Aug	4.90	6.34	4.81	2.88
Sep	3.11	5.44	4.57	0.03
Oct	0.56	3.40	4.39	0.51
Nov	0.88	0.87	1.60	0.92
Dec			1.29	1.19
Total	25.08	39.51	40.25	25.25

The calibration was performed by monthly ETc across all years. Figure A2-1 and Figure A2-2 show example comparisons from 1993 and 2013 of the monthly ETc values calculated using the Kc approach with land use and the ETc values from the ITRC-METRIC satellite data.

Figure A2-1 Example Calibration (1993)

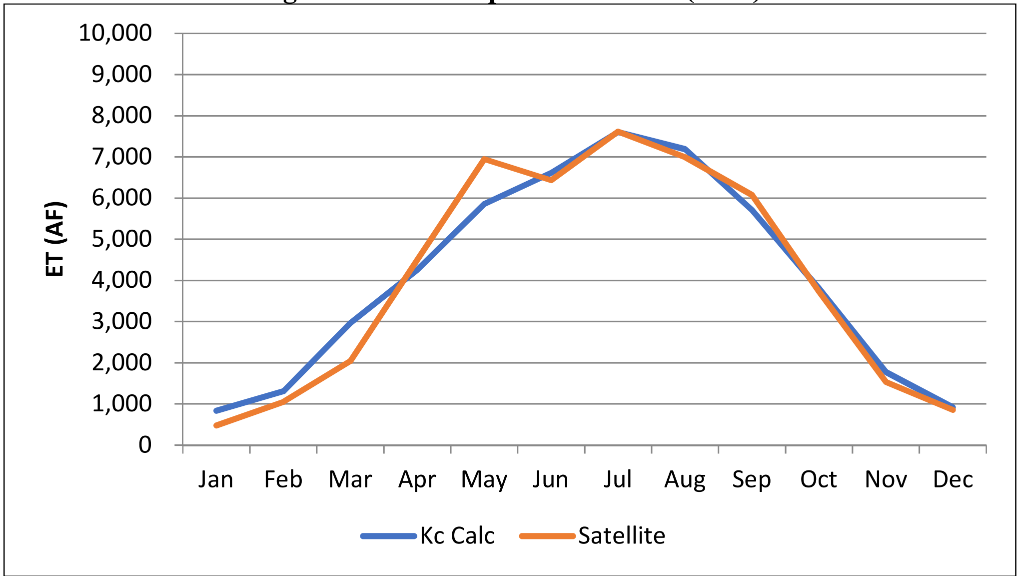


Figure A2-2 Example Calibration (2013)

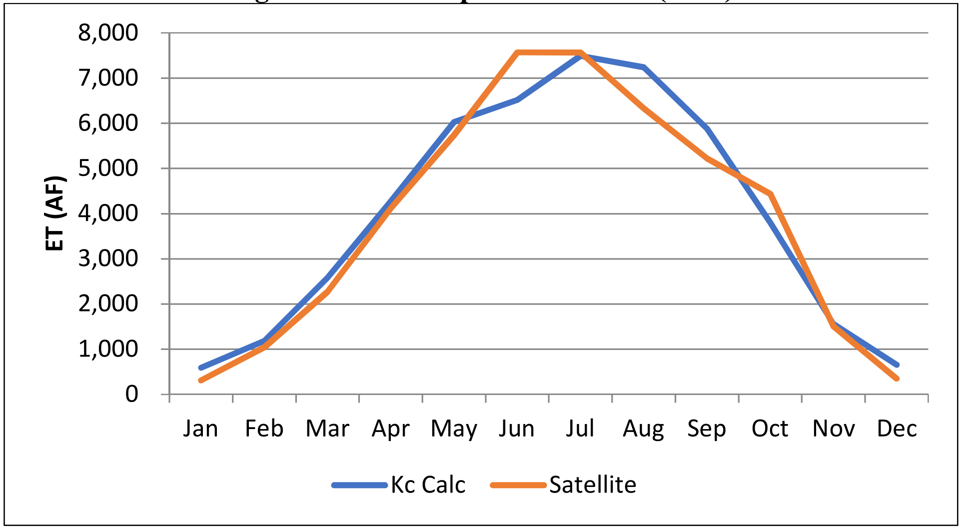
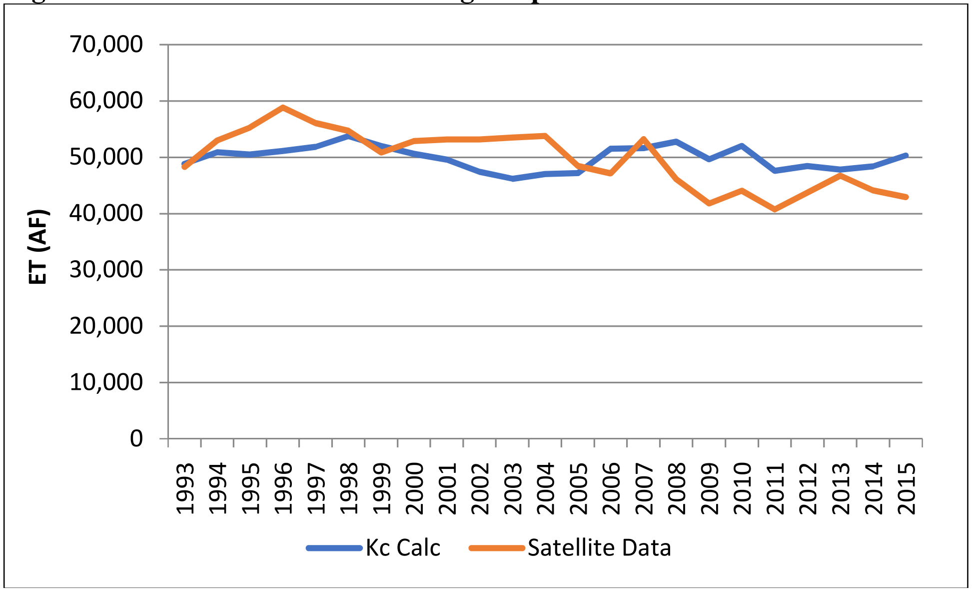


Figure A2-3 presents an annual summary of ETc from both methods showing the overall correlation between the two sets of data.

Figure A2-3 Annual ETc values using Crop Coefficients versus Satellite Data



The resulting calibrated ETc monthly values in acre-feet from 1993 – 2017 are shown in Table A2-6 and Table A2-7 for within and outside the District.

Table A2-6 Monthly District ETc values (AF)

	Jan	Feb	Mar	April	May	June	July	Aug	Sep	Oct	Nov	Dec	Total
1993	836	1,308	2,962	4,254	5,855	6,610	7,604	7,189	5,710	3,807	1,772	920	**48,826**
1994	887	1,368	3,102	4,424	6,080	6,897	7,937	7,474	5,919	3,955	1,855	975	**50,872**
1995	865	1,352	3,070	4,397	6,053	6,829	7,856	7,441	5,915	3,935	1,839	953	**50,503**
1996	892	1,349	3,071	4,411	6,106	7,038	8,105	7,531	5,879	3,890	1,858	977	**51,107**
1997	897	1,366	3,107	4,478	6,202	7,134	8,216	7,644	5,976	3,951	1,880	983	**51,834**
1998	976	1,473	3,300	4,682	6,386	7,315	8,426	7,813	6,148	4,197	1,952	1,068	**53,738**
1999	862	1,374	3,110	4,530	6,265	7,057	8,117	7,686	6,107	4,040	1,870	949	**51,968**
2000	811	1,302	2,983	4,384	6,126	6,920	7,958	7,558	5,981	3,868	1,822	895	**50,607**
2001	795	1,298	2,949	4,328	6,010	6,711	7,715	7,379	5,897	3,861	1,780	878	**49,601**
2002	763	1,254	2,840	4,152	5,742	6,368	7,319	7,035	5,655	3,730	1,703	843	**47,405**
2003	793	1,215	2,742	3,997	5,540	6,386	7,357	6,804	5,306	3,521	1,656	866	**46,182**
2004	734	1,229	2,787	4,118	5,719	6,323	7,264	7,007	5,640	3,690	1,678	812	**47,000**
2005	678	1,201	2,702	4,149	5,822	6,403	7,356	7,104	5,720	3,692	1,642	750	**47,219**
2006	704	1,330	2,915	4,596	6,414	6,929	7,958	7,722	6,298	4,144	1,738	779	**51,528**
2007	715	1,368	2,949	4,649	6,427	6,874	7,897	7,672	6,311	4,244	1,725	790	**51,620**
2008	762	1,394	3,011	4,718	6,529	7,116	8,183	7,817	6,341	4,269	1,770	838	**52,747**
2009	646	1,271	2,756	4,446	6,222	6,682	7,675	7,454	6,096	4,010	1,641	714	**49,612**
2010	686	1,347	2,889	4,677	6,519	7,013	8,059	7,773	6,351	4,230	1,705	756	**52,003**
2011	599	1,205	2,610	4,264	5,992	6,427	7,382	7,176	5,866	3,833	1,561	662	**47,577**
2012	608	1,221	2,643	4,336	6,103	6,571	7,549	7,308	5,955	3,887	1,584	671	**48,435**
2013	589	1,187	2,583	4,263	6,032	6,520	7,491	7,244	5,879	3,797	1,562	650	**47,798**
2014	560	1,149	2,535	4,275	6,139	6,698	7,695	7,421	5,963	3,740	1,573	617	**48,366**
2015	510	1,140	2,523	4,440	6,475	7,046	8,093	7,838	6,286	3,833	1,602	563	**50,348**
2016	544	1,189	2,583	4,467	6,419	6,932	7,963	7,709	6,235	3,925	1,595	600	**50,161**
2017	546	1,202	2,582	4,443	6,331	6,772	7,778	7,557	6,164	3,950	1,567	602	**49,494**

Table A2-7 Monthly Out of District ETc values (AF)

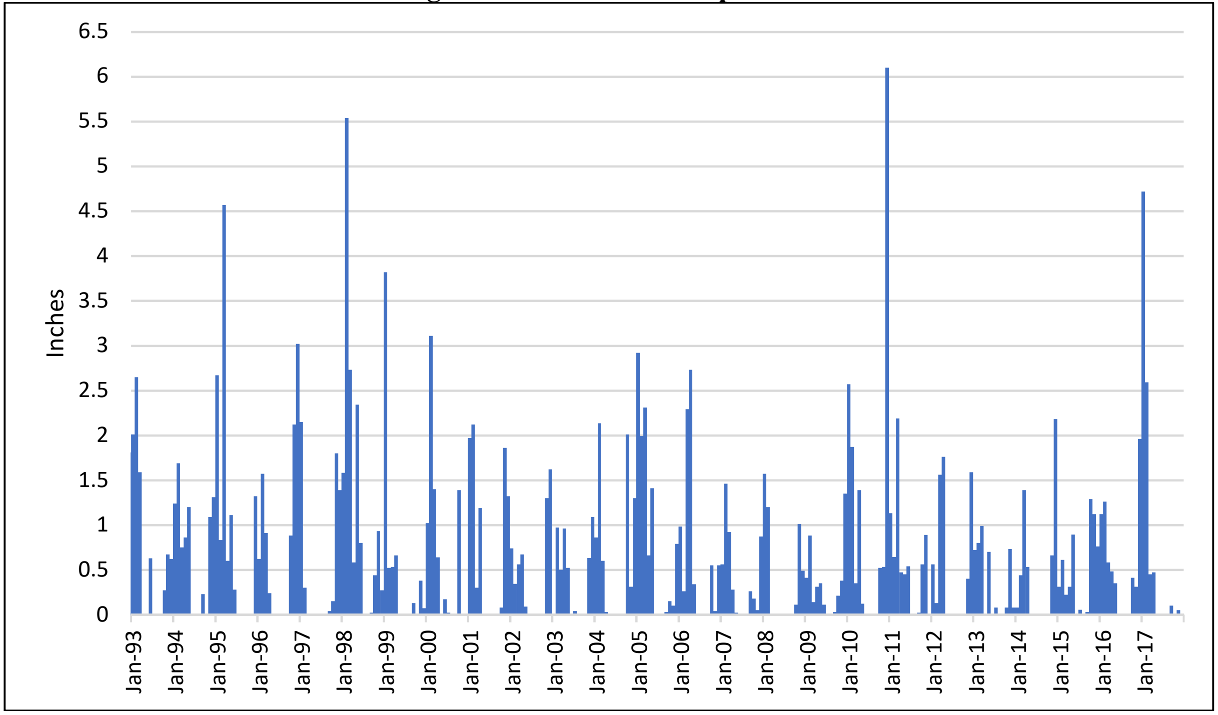
	Jan	Feb	Mar	April	May	June	July	Aug	Sep	Oct	Nov	Dec	Total
1993	427	644	1,311	1,537	1,733	1,678	1,926	1,936	1,805	1,670	617	474	**15,758**
1994	427	644	1,311	1,537	1,733	1,678	1,926	1,936	1,805	1,670	617	474	**15,758**
1995	427	652	1,325	1,575	1,788	1,732	1,987	1,998	1,858	1,703	626	474	**16,146**
1996	427	652	1,325	1,575	1,788	1,732	1,987	1,998	1,858	1,703	626	474	**16,146**
1997	427	652	1,325	1,575	1,788	1,732	1,987	1,998	1,858	1,703	626	474	**16,146**
1998	427	652	1,325	1,575	1,788	1,732	1,987	1,998	1,858	1,703	626	474	**16,146**
1999	427	652	1,325	1,575	1,788	1,732	1,987	1,998	1,858	1,703	626	474	**16,146**
2000	427	652	1,325	1,575	1,788	1,732	1,987	1,998	1,858	1,703	626	474	**16,146**
2001	427	652	1,325	1,575	1,788	1,732	1,987	1,998	1,858	1,703	626	474	**16,146**
2002	427	652	1,334	1,601	1,843	1,807	2,074	2,077	1,908	1,712	640	474	**16,552**
2003	438	675	1,377	1,684	1,961	1,943	2,232	2,212	2,011	1,785	665	485	**17,468**
2004	412	636	1,298	1,595	1,863	1,849	2,124	2,103	1,908	1,685	628	456	**16,557**
2005	412	636	1,298	1,595	1,863	1,849	2,124	2,103	1,908	1,685	628	456	**16,557**
2006	412	636	1,298	1,595	1,863	1,849	2,124	2,103	1,908	1,685	628	456	**16,557**
2007	412	636	1,298	1,595	1,863	1,849	2,124	2,103	1,908	1,685	628	456	**16,557**
2008	422	650	1,326	1,627	1,898	1,883	2,162	2,142	1,945	1,721	641	466	**16,883**
2009	492	754	1,537	1,869	2,165	2,138	2,455	2,438	2,225	1,988	739	544	**19,345**
2010	492	754	1,537	1,869	2,165	2,138	2,455	2,438	2,225	1,988	739	544	**19,345**
2011	495	760	1,549	1,882	2,179	2,151	2,470	2,453	2,240	2,003	744	548	**19,475**
2012	495	760	1,549	1,882	2,179	2,151	2,470	2,453	2,240	2,003	744	548	**19,475**
2013	495	760	1,549	1,882	2,179	2,151	2,470	2,453	2,240	2,003	744	548	**19,475**
2014	703	1,068	2,172	2,592	2,959	2,895	3,324	3,315	3,058	2,788	1,031	778	**26,683**
2015	730	1,156	2,338	2,909	3,395	3,316	3,806	3,803	3,486	3,091	1,120	808	**29,958**
2016	732	1,162	2,349	2,928	3,420	3,340	3,834	3,830	3,511	3,110	1,126	811	**30,154**
2017	757	1,200	2,425	3,014	3,514	3,430	3,937	3,935	3,610	3,205	1,161	839	**31,026**

Note that although ET was used to determine irrigation demand based on crop water use, ETc is not the only component of *applied water.* Applied water is the amount of irrigation water delivered to the field and is not the same as the plant water requirement. Applied water is greater than the ETc to account for irrigation inefficiencies. The District used an irrigation efficiency of 90% to calculate applied water.

Precipitation

Precipitation data for the City of Delano (to the west of the District) was collected from the Western Regional Climate Center. Figure A2-4 and Table A2-8 summarize the monthly precipitation data (total precipitation) in inches for the study area. Any data gaps were filled using calibrated precipitation data from the City of Bakersfield. A calibration value of 0.763 was determined using the data points between Delano and Bakersfield precipitation from 1958 to 2017.

Figure A2-4 Delano Precipitation



In Table A2-9 and Table A2-10 the precipitation data (converted to feet) was applied to the irrigated acreage within and outside the District to determine acre-feet of monthly rainfall over the two areas. It was assumed that the ET on non-irrigated crops and grasslands was equal to the precipitation; therefore, neither the precipitation nor the ET of non-irrigated acres was included in the analysis.

Table A2-8 Total Monthly Precipitation values (inches)

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Total
1993	2.01	2.65	1.59	0.01	0.00	0.63	0.00	0.00	0.00	0.27	0.67	0.62	**8.45**
1994	1.24	1.69	0.75	0.86	1.20	0.00	0.00	0.00	0.23	0.00	1.09	1.31	**8.37**
1995	2.67	0.83	4.57	0.60	1.11	0.28	0.00	0.00	0.00	0.00	0.00	1.32	**11.38**
1996	0.62	1.57	0.91	0.24	0.00	0.00	0.01	0.00	0.00	0.88	2.12	3.02	**9.37**
1997	2.15	0.30	0.00	0.00	0.00	0.00	0.00	0.00	0.04	0.15	1.80	1.39	**5.83**
1998	1.58	5.54	2.73	0.58	2.34	0.80	0.00	0.00	0.02	0.44	0.93	0.27	**15.23**
1999	3.82	0.52	0.53	0.66	0.00	0.00	0.00	0.00	0.13	0.00	0.38	0.07	**6.11**
2000	1.02	3.11	1.40	0.64	0.00	0.17	0.02	0.00	0.00	1.39	0.00	0.00	**7.75**
2001	1.97	2.12	0.30	1.19	0.00	0.00	0.00	0.00	0.00	0.08	1.86	1.32	**8.84**
2002	0.74	0.34	0.56	0.67	0.09	0.00	0.00	0.00	0.00	0.00	1.30	1.62	**5.32**
2003	0.00	0.97	0.50	0.96	0.52	0.00	0.04	0.00	0.00	0.00	0.63	1.09	**4.71**
2004	0.86	2.14	0.60	0.03	0.00	0.00	0.00	0.00	0.00	2.01	0.31	1.30	**7.25**
2005	2.92	1.99	2.31	0.66	1.41	0.00	0.00	0.00	0.03	0.15	0.10	0.79	**10.36**
2006	0.98	0.26	2.29	2.73	0.34	0.00	0.00	0.00	0.00	0.55	0.04	0.55	**7.74**
2007	0.56	1.46	0.92	0.28	0.02	0.00	0.01	0.00	0.26	0.18	0.05	0.87	**4.61**
2008	1.57	1.20	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.11	1.01	0.49	**4.38**
2009	0.41	0.88	0.14	0.31	0.35	0.11	0.00	0.00	0.03	0.21	0.38	1.35	**4.17**
2010	2.57	1.87	0.35	1.39	0.12	0.00	0.00	0.00	0.00	0.52	0.53	6.10	**13.45**
2011	1.13	0.64	2.19	0.47	0.45	0.54	0.00	0.00	0.02	0.56	0.89	0.00	**6.89**
2012	0.56	0.13	1.56	1.76	0.00	0.00	0.00	0.00	0.00	0.01	0.40	1.59	**6.01**
2013	0.72	0.80	0.99	0.00	0.70	0.00	0.08	0.00	0.00	0.08	0.73	0.08	**4.18**
2014	0.08	0.44	1.39	0.53	0.00	0.00	0.00	0.00	0.00	0.00	0.66	2.18	**5.28**
2015	0.31	0.61	0.22	0.31	0.89	0.00	0.05	0.00	0.03	1.29	1.12	0.76	**5.59**
2016	1.12	1.26	0.58	0.48	0.35	0.00	0.00	0.00	0.00	0.41	0.31	1.96	**6.47**
2017	4.72	2.59	0.45	0.47	0.00	0.00	0.00	0.00	0.10	0.00	0.05	0.00	**8.38**

Table A2-9 Total Monthly Precipitation values (AF) for the District

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Total
1993	3,014	3,971	2,385	15	0	943	0	0	0	405	1,005	930	**12,668**
1994	1,942	2,647	1,175	1,347	1,880	0	0	0	360	0	1,707	2,052	**13,112**
1995	4,147	1,289	7,098	932	1,724	435	0	0	0	0	0	2,050	**17,675**
1996	984	2,493	1,445	381	0	0	16	0	0	1,397	3,366	4,795	**14,876**
1997	3,458	483	0	0	0	0	0	0	64	241	2,895	2,236	**9,377**
1998	2,605	9,133	4,501	956	3,858	1,319	0	0	33	725	1,533	445	**25,108**
1999	6,093	829	845	1,053	0	0	0	0	207	0	606	112	**9,745**
2000	1,598	4,871	2,193	1,002	0	266	31	0	0	2,177	0	0	**12,138**
2001	2,996	3,224	456	1,810	0	0	0	0	0	122	2,829	2,008	**13,445**
2002	1,070	493	810	969	130	0	0	0	0	0	1,880	2,343	**7,696**
2003	0	1,385	714	1,371	743	0	57	0	0	0	900	1,557	**6,727**
2004	1,233	3,063	860	43	0	0	0	0	0	2,882	444	1,864	**10,389**
2005	4,186	2,856	3,311	946	2,021	0	0	0	43	215	143	1,132	**14,853**
2006	1,504	398	3,505	4,178	520	0	0	0	0	842	61	842	**11,851**
2007	847	2,207	1,391	423	30	0	15	0	393	272	76	1,315	**6,970**
2008	2,448	1,871	0	0	0	0	0	0	0	171	1,575	764	**6,828**
2009	600	1,287	205	453	512	161	0	0	44	307	556	1,975	**6,100**
2010	3,918	2,851	534	2,119	183	0	0	0	0	793	808	9,299	**20,503**
2011	1,585	901	3,069	659	631	757	0	0	28	785	1,248	0	**9,663**
2012	800	186	2,230	2,516	0	0	0	0	0	14	572	2,273	**8,590**
2013	1,021	1,134	1,403	0	992	0	113	0	0	113	1,035	113	**5,926**
2014	116	639	2,019	770	0	0	0	0	0	0	958	3,166	**7,668**
2015	469	923	333	469	1,348	0	79	0	45	1,952	1,695	1,150	**8,464**
2016	1,668	1,877	864	715	521	0	0	0	0	611	462	2,919	**9,637**
2017	6,861	3,765	654	683	0	0	0	0	145	0	73	0	**12,181**

Table A2-10 Total Monthly Precipitation values (AF) for Outside the District

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Total
1993	825	1,086	652	4	0	258	0	0	0	111	275	254	**3,465**
1994	509	693	308	353	492	0	0	0	94	0	447	537	**3,434**
1995	1,122	349	1,921	252	467	118	0	0	0	0	0	555	**4,783**
1996	261	660	383	101	0	0	4	0	0	370	891	1,269	**3,939**
1997	904	126	0	0	0	0	0	0	17	63	757	584	**2,451**
1998	664	2,329	1,148	244	984	336	0	0	8	185	391	113	**6,402**
1999	1,606	219	223	277	0	0	0	0	55	0	160	29	**2,568**
2000	429	1,307	588	269	0	71	8	0	0	584	0	0	**3,258**
2001	828	891	126	500	0	0	0	0	0	34	782	555	**3,716**
2002	323	149	245	293	39	0	0	0	0	0	568	708	**2,325**
2003	0	449	232	445	241	0	19	0	0	0	292	505	**2,181**
2004	378	939	264	13	0	0	0	0	0	884	136	572	**3,186**
2005	1,284	876	1,016	290	620	0	0	0	13	66	44	347	**4,556**
2006	432	114	1,007	1,200	150	0	0	0	0	242	18	242	**3,405**
2007	246	642	405	123	9	0	4	0	114	79	22	383	**2,027**
2008	703	538	0	0	0	0	0	0	0	49	453	220	**1,962**
2009	210	450	72	158	179	56	0	0	15	107	194	690	**2,131**
2010	1,314	956	179	710	61	0	0	0	0	266	271	3,118	**6,875**
2011	581	330	1,126	242	232	278	0	0	10	288	458	0	**3,545**
2012	288	67	803	905	0	0	0	0	0	5	206	818	**3,092**
2013	370	412	509	0	360	0	41	0	0	41	376	41	**2,150**
2014	56	308	972	370	0	0	0	0	0	0	461	1,524	**3,691**
2015	243	478	172	243	699	0	41	0	24	1,011	878	596	**4,386**
2016	884	994	458	379	276	0	0	0	0	324	245	1,547	**5,106**
2017	3,830	2,102	365	381	0	0	0	0	81	0	41	0	**6,800**

Effective Precipitation: Considering part of the rainfall can runoff or percolate to the groundwater, the District was interested in effective precipitation – the water that is stored in the root zone and can be used by the plants. The effective precipitation values for the District took into consideration crop ET and known surface water deliveries (including an irrigation efficiency). The effective precipitation for the District was calculated as the minimum between the total precipitation or the calculated ET less surface water deliveries divided by a 90% irrigation efficiency.

P = Precipitation; ET = Calculated Evapotranspiration; SW = Surface Water

*[Total P > ET – (SW * 90%)]*, then *[Effective P = ET – (SW * 90%)]*

*[Total P < ET – (SW * 90%)]*, then *[Effective P = Total P]*

This calculation assumes precipitation that meets the remaining ET demand after surface deliveries is effective.

The effective precipitation for outside the District was calculated as the minimum between the total precipitation or the calculated ET.

[Total P > ET], then *[Effective P = ET]*

[Total P < ET], then *[Effective P = Total P]*

This calculation uses precipitation that meets the monthly ET as the initial source of irrigation water. The remainder is met with groundwater because the lands outside of the District do not receive any surface water.

Monthly effective precipitation for the District and outside the District are shown in Table A2-11 and Table A2-12.

Table A2-11 Monthly Effective Precipitation values (AF) for the District

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Total
1993	777	1,250	2,219	15	0	474	0	0	0	405	104	584	**5,828**
1994	383	1,124	1,175	1,347	1,880	0	0	0	360	0	1,159	644	**8,072**
1995	782	1,281	2,940	932	1,724	435	0	0	0	0	0	0	**8,094**
1996	809	1,150	1,445	381	0	0	16	0	0	1,397	1,576	567	**7,341**
1997	771	483	0	0	0	0	0	0	64	241	1,447	794	**3,800**
1998	905	1,413	3,191	956	3,858	1,319	0	0	33	725	582	0	**12,981**
1999	703	829	845	1,053	0	0	0	0	207	0	606	112	**4,355**
2000	757	1,283	2,193	1,002	0	0	0	0	0	938	0	0	**6,173**
2001	657	1,252	456	1,810	0	0	0	0	0	37	1,212	785	**6,209**
2002	610	493	810	969	130	0	0	0	0	0	1,165	569	**4,746**
2003	0	779	706	1,371	743	0	57	0	0	0	900	559	**5,115**
2004	617	1,023	860	43	0	0	0	0	0	1,596	444	681	**5,264**
2005	660	1,132	2,410	946	2,021	0	0	0	43	215	143	325	**7,895**
2006	644	398	2,256	4,060	520	0	0	0	0	842	61	294	**9,075**
2007	0	996	1,391	423	30	0	15	0	393	272	76	516	**4,112**
2008	693	1,229	0	0	0	0	0	0	0	171	808	512	**3,414**
2009	507	975	205	453	512	161	0	0	44	307	493	340	**3,997**
2010	588	1,203	534	2,119	183	0	0	0	0	793	741	666	**6,826**
2011	496	901	1,860	659	631	757	0	0	28	785	436	0	**6,553**
2012	154	186	1,489	2,516	0	0	0	0	0	14	478	542	**5,379**
2013	364	1,077	1,387	0	992	0	113	0	0	113	427	0	**4,475**
2014	116	639	1,986	770	0	0	0	0	0	0	958	493	**4,962**
2015	401	923	333	469	1,348	0	79	0	45	1,952	1,282	0	**6,833**
2016	465	1,186	864	715	521	0	0	0	0	611	462	590	**5,414**
2017	546	1,189	654	683	0	0	0	0	145	0	73	0	**3,290**

Table A2-12 Monthly Effective Precipitation values (AF) for Outside the District

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Total
1993	427	644	652	4	0	258	0	0	0	111	275	254	**2,626**
1994	427	644	308	353	492	0	0	0	94	0	447	474	**3,240**
1995	427	349	1,325	252	467	118	0	0	0	0	0	474	**3,411**
1996	261	652	383	101	0	0	4	0	0	370	626	474	**2,870**
1997	427	126	0	0	0	0	0	0	17	63	626	474	**1,733**
1998	427	652	1,148	244	984	336	0	0	8	185	391	113	**4,489**
1999	427	219	223	277	0	0	0	0	55	0	160	29	**1,390**
2000	427	652	588	269	0	71	8	0	0	584	0	0	**2,601**
2001	427	652	126	500	0	0	0	0	0	34	626	474	**2,839**
2002	323	149	245	293	39	0	0	0	0	0	568	474	**2,091**
2003	0	449	232	445	241	0	19	0	0	0	292	485	**2,161**
2004	378	636	264	13	0	0	0	0	0	884	136	456	**2,767**
2005	412	636	1,016	290	620	0	0	0	13	66	44	347	**3,445**
2006	412	114	1,007	1,200	150	0	0	0	0	242	18	242	**3,385**
2007	246	636	405	123	9	0	4	0	114	79	22	383	**2,021**
2008	422	538	0	0	0	0	0	0	0	49	453	220	**1,681**
2009	210	450	72	158	179	56	0	0	15	107	194	544	**1,985**
2010	492	754	179	710	61	0	0	0	0	266	271	544	**3,277**
2011	495	330	1,126	242	232	278	0	0	10	288	458	0	**3,459**
2012	288	67	803	905	0	0	0	0	0	5	206	548	**2,822**
2013	370	412	509	0	360	0	41	0	0	41	376	41	**2,150**
2014	56	308	972	370	0	0	0	0	0	0	461	778	**2,946**
2015	243	478	172	243	699	0	41	0	24	1,011	878	596	**4,386**
2016	732	994	458	379	276	0	0	0	0	324	245	811	**4,218**
2017	757	1,200	365	381	0	0	0	0	81	0	41	0	**2,825**

Surface Supplies

The District has two Cross Valley Contracts (14-06-200-8601A and 14-06-200-8367A) with the United States Bureau of Reclamation (Reclamation) for a combined total of up to 53,300 acre-feet per year of Central Valley Project (CVP) water and a Friant Class 2 Contract (I1R-1460A) for up to 5,000 acre-feet per year of CVP water. The District also enters into annual contracts for 215 water from Reclamation, purchases Class 1 and Class 2 water supplies from other Friant Contractors, purchases CVP water from other South of Delta contractors, and purchases Kern River Water from the City of Bakersfield. Historical monthly surface deliveries were identified and summarized by the sources of the water based on District records. Below is a brief description of each source and the average percentage of total supply it accounts for:

KTWD XVC **(18%)**: The District's Cross Valley Contract (XVC), of 53,300 AF, began delivering water to the District in 1977. The water supply is from the Delta, in Northern California, and has suffered a loss of supply resulting from court-ordered actions, environmental regulations, increased urbanization and changes in weather patterns associated with climate change. The District has not had a full supply since 1998. When the water does become available it is typically exchanged with Kern County Water Agency for State Water Project water or the District's banking partners.

KTWD Class 2 **(<1%)**: The District has a 5,000 AF Class 2 Friant Contract that was purchased from Southern San Joaquin Municipal Utility District in 2012. This water becomes available after the Class 1 Friant Contractors supplies have been satisfied. The Class 1 total is 800,000 AF.

Friant Purchases **(21%)**: The District purchases additional Friant water from Friant Contractors in most years.

Friant Uncontrolled Season **(3%)**: Occasionally, Millerton Reservoir is unable to store the amount of water coming from the upper San Joaquin river and the Bureau of Reclamation must evacuate the reservoir as quickly as possible. One of the tools Reclamation uses, is called Uncontrolled Season; whereby all Class 2 contractors can take as much water as the canal can hold and the contractor can deliver, up to their contract amount. The District purchases uncontrolled season water from other Friant Contractors.

SOD/Other Purchases **(5%)**: The District purchases water from South of Delta (SOD) Bureau of Reclamation contractors and delivers the water either to Banking or to the District directly. The District also purchases water from other sources on occasion. This could include State Water Project supplies, local river supplies, or groundwater supplies from other Districts.

Kern River **(40%)**: The Kern River agreement with the City of Bakersfield consisted of an annual amount of 23,000 AF. This agreement began in 1977 and the current term expired in 2012. At the end of 2012 the City of Bakersfield still owed the District approximately 52,000 AF of water and is slowly paying the District back. The District and the City are now in the extension term and the City is obligated to sell the District up to 27,250 AF in years water demands within the City are met.

Produced Water **(2%)**: Water suitable for irrigated agriculture is produced as a by-product of oil production (produced water) and must be disposed. For the past 30 years, Hathaway LLC (Hathaway) and its predecessors, located adjacent to the District, have been delivering produced water to irrigate 400 acres of oranges within the District. Hathaway has expanded beyond the capabilities of its existing produced water delivery facilities and has partnered with the District for additional delivery to more service areas within the District since 2015.

From Banking **(11%)**: The District has several Reclamation approved water banking programs. In wet or average water years, after the District has met its in-District demands, excess water is delivered to banking programs. These programs provide water to the District in dry years. The "From Banking" is the amount that was extracted or removed from the banking programs to meet in-District demands.

Total historical water deliveries to both in-district and deliveries to banking are summarized by source of supply for years 1993 through 2017 in Table A2-13

Table A2-13 Total Annual Historical District Surface Supplies

Year	KTWD XVC	KTWD Class 2	Friant Purchase	Friant Unc.	SOD Purchase	Kern River	Produced Water	From Banking	Total
1993	4,672	0	0	0	0	33,726	386	0	38,784
1994	17,966	0	0	0	0	23,995	374	0	42,335
1995	0	0	2,692	0	0	37,726	380	0	40,798
1996	0	0	4,577	0	0	38,419	376	0	43,372
1997	0	0	5,199	0	0	40,836	346	0	46,381
1998	0	0	8,976	0	0	27,250	277	0	36,503
1999	0	0	7,081	0	0	37,132	248	0	44,461
2000	0	0	20,572	0	0	26,279	257	0	47,108
2001	22,920	0	8,119	0	6,321	13,862	240	0	51,462
2002	28,557	0	2,081	0	0	11,421	238	0	42,297
2003	2,188	0	19,088	2,131	0	15,779	208	0	39,394
2004	20,997	0	1,032	0	0	18,198	265	0	40,492
2005	0	0	66,130	44,356	0	30,460	216	0	141,162
2006	0	0	12,939	7,763	20,180	25,866	204	0	66,952
2007	17,833	0	1,147	282	8,419	5,569	356	6,426	40,032
2008	21,223	0	0	0	0	19,110	634	19	40,986
2009	0	0	25,701	0	0	16,139	691	5,285	47,816
2010	23,541	0	57,718	6,999	0	12,314	692	0	101,264
2011	0	0	63,616	1,379	0	16,432	878	0	82,305
2012	31,003	0	9,370	1,737	0	8,790	1,170	7,805	59,875
2013	13,719	0	217	0	3,003	3,706	1,324	17,689	39,658
2014	1,883	0	87	0	4,503	0	1,568	16,827	24,868
2015	0	0	500	0	562	0	1,580	14,225	16,867
2016	2,861	357	10,109	193	1,540	0	1,375	13,176	29,611
2017	0	4,309	18,347	6,303	22,758	30,736	2,098	0	84,551

As shown in Table A2-13:

- Use and availability of Cross Valley water varies significantly and is dependent upon conditions in the Delta.
- The District purchased a Class 2 contract in 2012. No water was available under this contract until 2016 and 2017.
- The District has historically relied upon purchases of Friant water. These purchases were large (over 60,000 AF/yr) in wet years and lesser in dry years.
- Friant uncontrolled season water was purchased during wet years; no water from this source was available in dry years.
- Historically, water from the Kern River was more reliable. Since 2012, Kern River water will only be available in wet years.
- Deliveries of produced water have increased in recent years.
- The District began operating its banking programs in 2001. Up to 16,000 AF is available from the Districts' banking programs.

Surface Supplies for Irrigation by Source

Historical District surface supplies for irrigation is summarized for years 1993 through 2017 in Table A2-14.

Table A2-14 Annual Historical District Surface Supplies to Meet Irrigation Demands

Year	KTWD XVC	KTWD Class 2	Friant Purchase	Friant Unc.	SOD Purchase	Kern River	Produced Water	From Banking	Total
1993	4,672	0	0	0	0	33,726	386	0	38,784
1994	17,966	0	0	0	0	23,995	374	0	42,335
1995	0	0	2,692	0	0	37,726	380	0	40,798
1996	0	0	4,577	0	0	38,419	376	0	43,372
1997	0	0	5,199	0	0	40,836	346	0	46,381
1998	0	0	8,976	0	0	27,250	277	0	36,503
1999	0	0	7,081	0	0	37,132	248	0	44,461
2000	0	0	20,572	0	0	26,279	257	0	47,108
2001	22,920	0	8,119	0	3,546	13,862	240	0	48,687
2002	28,557	0	2,081	0	0	11,421	238	0	42,297
2003	2,188	0	19,088	2,131	0	15,779	208	0	39,394
2004	20,997	0	1,032	0	0	18,198	265	0	40,492
2005	0	0	7,972	9,568	0	19,707	216	0	37,463
2006	0	0	12,939	7,763	0	15,866	204	0	36,772
2007	17,833	0	1,147	282	8,419	5,569	356	6,426	40,032
2008	21,223	0	0	0	0	19,110	634	19	40,986
2009	0	0	16,380	0	0	15,279	691	5,285	37,635
2010	0	0	26,129	359	0	6,316	692	0	33,496
2011	0	0	29,254	383	0	4,687	878	0	35,202
2012	14,585	0	5,108	0	0	8,790	1,170	7,805	37,458
2013	13,719	0	217	0	3,003	3,706	1,324	17,689	39,658
2014	1,883	0	87	0	4,503	0	1,568	16,827	24,868
2015	0	0	500	0	562	0	1,580	14,225	16,867
2016	2,861	357	10,109	193	1,540	0	1,375	13,176	29,611
2017	0	4,309	9,370	1,371	3,683	16,523	2,098	0	37,354

Surface Supplies for Groundwater Banking by Source

The District has banking programs with other districts including: Rosedale Rio Bravo Water Storage District, North Kern Water Storage District, West Kern Water District, Tulare Irrigation District, Semitropic Water Storage District, and Pixley Irrigation District. In wet or average water years, after the District has met its in-District demands, water is delivered to banking programs. These programs provide water to the District in dry years. Historical water deliveries to District Banking Projects are summarized by source of supply for years 1993 through 2017 in Table A2-15.

Table A2-15 Annual Historical District Surface Supplies to Banking Projects

Year	KTWD XVC	KTWD Class 2	Friant Purchase	Friant Unc.	SOD Purchase	Kern River	Total
1993	0	0	0	0	0	0	0
1994	0	0	0	0	0	0	0
1995	0	0	0	0	0	0	0
1996	0	0	0	0	0	0	0
1997	0	0	0	0	0	0	0
1998	0	0	0	0	0	0	0
1999	0	0	0	0	0	0	0
2000	0	0	0	0	0	0	0
2001	0	0	0	0	2,775	0	2,775
2002	0	0	0	0	0	0	0
2003	0	0	0	0	0	0	0
2004	0	0	0	0	0	0	0
2005	0	0	58,158	34,788	0	10,753	103,699
2006	0	0	0	0	20,180	10,000	30,180
2007	0	0	0	0	0	0	0
2008	0	0	0	0	0	0	0
2009	0	0	9,321	0	0	860	10,181
2010	23,541	0	31,589	6,640	0	5,998	67,768
2011	0	0	34,362	996	0	11,745	47,103
2012	16,418	0	4,262	1,737	0	0	22,417
2013	0	0	0	0	0	0	0
2014	0	0	0	0	0	0	0
2015	0	0	0	0	0	0	0
2016	0	0	0	0	0	0	0
2017	0	0	8,977	4,932	19,075	14,213	47,197

Summary of Deliveries

Table A2-16 summarizes annual surface water deliveries to user turnouts. The District experiences differences in water delivered to the District compared to water delivered to turnouts, shown as losses/reservoir storage. The District uses the deliveries to irrigation as the surface water delivery value for the water budget.

Table A2-16 Annual Historical District Deliveries to Irrigation

Year	Total Surface Water Supplies	Supplies for Banking	Supplies for Irrigation	Losses/ Reservoir Storage	Deliveries to Irrigation
1993	38,784	0	38,784	1,477	37,307
1994	42,335	0	42,335	1,614	40,721
1995	40,798	0	40,798	1,555	39,243
1996	43,372	0	43,372	1,654	41,718
1997	46,381	0	46,381	1,771	44,610
1998	36,503	0	36,503	1,393	35,110
1999	44,461	0	44,461	2,768	41,692
2000	47,108	0	47,108	2,599	44,509
2001	51,462	2,775	48,687	3,376	45,312
2002	42,297	0	42,297	3,960	38,337
2003	39,394	0	39,394	2,574	36,820
2004	40,492	0	40,492	1,859	38,633
2005	141,162	103,699	37,463	1,173	36,290
2006	66,952	30,180	36,772	1,401	35,371
2007	40,032	0	40,032	1,605	38,427
2008	40,986	0	40,986	753	40,233
2009	47,816	10,181	37,635	1,471	36,164
2010	101,264	67,768	33,496	657	32,840
2011	82,305	47,103	35,202	1,574	33,629
2012	59,875	22,417	37,458	1,605	35,853
2013	39,658	0	39,658	1,903	37,755
2014	24,868	0	24,868	3,459	21,409
2015	16,867	0	16,867	141	16,726
2016	29,611	0	29,611	-268	29,879
2017	84,551	47,197	37,354	-283	37,638

<u>Total Surface Water Supplies:</u> Includes all surface supplies for banking and irrigation.

<u>Losses/Reservoir Storage:</u> The District is a closed pipeline system with three regulating reservoirs. The reservoirs have both seepage and evaporation losses as well as a small amount of storage capacity to carry over supplies.

<u>Deliveries to Irrigation:</u> The District maintains historical records of all turnout deliveries within the District. The District uses flow meters to measure the volume of water at each turnout that have an accuracy of +/-5%. On average, the District observes about 4% difference from the metered supplies to the metered deliveries.

Groundwater Supplies

Groundwater pumping by landowners within the District were calculated as the difference between the applied water demand (ETc less effective precipitation divided by a 90% irrigation efficiency) and the surface water deliveries. In months where surface water deliveries were greater than the applied water demand, zero groundwater pumping is assumed. Outside of the District groundwater pumping is calculated as ETc less effective precipitation because those lands do not receive surface water supplies. Table A2-17 and Table A2-18 summarize the annual volume of groundwater pumping within and outside the District from 1993 through 2017.

Table A2-17 Annual Historical Groundwater Pumping within the District (AF)

			Source of Applied Water			
Year	**Crop ET**	**Effective Precip**	**Applied Water Demand**	**Surface Water Deliv.**	**Ground Water Pumping**	**Total Applied Water**
	(A)	***(B)***	***(C)***	***(D)***	***(E)***	***(F)***
1993	48,826	5,828	47,776	37,307	**10,470**	47,776
1994	50,872	8,072	47,556	40,721	**6,836**	47,556
1995	50,503	8,094	47,121	39,243	**8,428**	47,672
1996	51,107	7,341	48,629	41,718	**7,114**	48,832
1997	51,834	3,800	53,371	44,610	**8,873**	53,483
1998	53,738	12,981	45,285	35,110	**10,218**	45,328
1999	51,968	4,355	52,903	41,692	**11,211**	52,903
2000	50,607	6,173	49,371	44,509	**5,528**	50,037
2001	49,601	6,209	48,213	45,312	**3,635**	48,946
2002	47,405	4,746	47,399	38,337	**9,071**	47,409
2003	46,182	5,115	45,630	36,820	**8,810**	45,630
2004	47,000	5,264	46,374	38,633	**7,741**	46,374
2005	47,219	7,895	43,693	36,290	**7,403**	43,693
2006	51,528	9,075	47,169	35,371	**11,798**	47,169
2007	51,620	4,112	52,787	38,427	**14,490**	52,917
2008	52,747	3,414	54,815	40,233	**14,582**	54,815
2009	49,612	3,997	50,683	36,164	**14,518**	50,683
2010	52,003	6,826	50,197	32,840	**17,358**	50,197
2011	47,577	6,553	45,582	33,629	**11,953**	45,582
2012	48,435	5,379	47,840	35,853	**11,987**	47,840
2013	47,798	4,475	48,137	37,755	**10,760**	48,515
2014	48,366	4,962	48,227	21,409	**26,818**	48,227
2015	50,348	6,833	48,350	16,726	**31,627**	48,352
2016	50,161	5,414	49,719	29,879	**19,841**	49,719
2017	49,494	3,290	51,338	37,638	**13,929**	51,566
1993-2009 Average	*50,139*	*6,263*	*48,751*	*39,441*	***9,454***	*48,895*

(A) Annual values from Table A2-6.
(B) Annual values from Table A2-11.
(C) Calculated as (A – B) ÷ 90% irrigation efficiency.
(D) From District turnout data.
(E) Annual values from Table A2-19.
(F) Calculated as (E + F).

Table A2-18 Annual Historical Groundwater Pumping Outside of District (AF)

Year	Crop ET	Effective Precip	Applied Water Demand	Surface Water Deliv.	Ground Water Pumping
	(A)	*(B)*	*(C)*	*(D)*	*(E)*
1993	15,758	2,626	14,591	0	**14,591**
1994	15,758	3,240	13,909	0	**13,909**
1995	16,146	3,411	14,149	0	**14,149**
1996	16,146	2,870	14,751	0	**14,751**
1997	16,146	1,733	16,014	0	**16,014**
1998	16,146	4,489	12,952	0	**12,952**
1999	16,146	1,390	16,395	0	**16,395**
2000	16,146	2,601	15,049	0	**15,049**
2001	16,146	2,839	14,785	0	**14,785**
2002	16,552	2,091	16,067	0	**16,067**
2003	17,468	2,161	17,008	0	**17,008**
2004	16,557	2,767	15,322	0	**15,322**
2005	16,557	3,445	14,570	0	**14,570**
2006	16,557	3,385	14,636	0	**14,636**
2007	16,557	2,021	16,151	0	**16,151**
2008	16,883	1,681	16,891	0	**16,891**
2009	19,345	1,985	19,289	0	**19,289**
2010	19,345	3,277	17,853	0	**17,853**
2011	19,475	3,459	17,796	0	**17,796**
2012	19,475	2,822	18,504	0	**18,504**
2013	19,475	2,150	19,250	0	**19,250**
2014	26,683	2,946	26,375	0	**26,375**
2015	29,958	4,386	28,413	0	**28,413**
2016	30,154	4,218	28,817	0	**28,817**
2017	31,026	2,825	31,334	0	**31,334**
1993-2009 Average	*16,530*	*2,632*	*15,443*	*0*	***15,443***

(A) = derived from ITRC data and land use.
(B) = derived from Delano precipitation data and irrigated acreage.
(C) = (A – B) ÷ 90% irrigation efficiency.
(D) = No surface water deliveries.
(E) = C – D

Monthly groundwater pumping within and outside of the District are summarized in Table A2-19 and Table A2-20. Monthly groundwater pumping within the District was calculated as:

GW = Groundwater Pumping; AWD = Applied Water Demand; SW = Surface Water Deliveries; where,

AWD = (ET – Effective P) ÷ 90% irrigation efficiency; if,

$[AWD - SW > 0]$, then $[GW = AWD - SW]$; if,

$[AWD - SW < 0]$, then $[GW = 0]$.

Table A2-19 Monthly Groundwater Pumping within the District (AF)

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Total
1993	0	0	0	2,987	2,807	0	451	1,443	1,465	1,316	0	0	**10,470**
1994	0	0	986	311	1,308	57	137	731	687	2,619	0	0	**6,836**
1995	0	0	0	2,536	1,226	357	300	993	2,327	689	0	0	**8,428**
1996	0	0	1,265	1,248	1,216	0	732	1,095	1,243	316	0	0	**7,114**
1997	0	884	1,690	566	0	372	1,203	1,075	1,476	1,606	0	0	**8,873**
1998	0	0	0	3,578	1,058	653	1,120	371	1,903	1,534	0	0	**10,218**
1999	0	493	1,453	1,889	1,682	739	839	1,228	1,857	75	95	860	**11,211**
2000	0	0	226	1,064	669	0	0	403	2,246	0	920	0	**5,528**
2001	0	0	1,648	734	124	0	463	14	652	0	0	0	**3,635**
2002	0	376	850	601	1,718	0	1,073	1,958	2,126	370	0	0	**9,071**
2003	868	0	0	653	1,097	1,282	705	2,268	1,218	682	37	0	**8,810**
2004	0	0	696	1,111	510	419	821	1,628	1,589	0	966	0	**7,741**
2005	0	0	0	1,633	635	1,326	183	850	1,564	1,193	18	0	**7,403**
2006	0	345	0	0	2,023	1,702	1,231	2,317	2,086	1,372	721	0	**11,798**
2007	0	0	38	2,188	2,091	1,508	2,155	2,613	2,030	1,491	376	0	**14,490**
2008	0	0	1,634	1,718	2,554	1,273	1,728	2,667	1,665	1,342	0	0	**14,582**
2009	0	0	1,147	1,801	1,917	1,204	1,746	2,503	2,295	1,907	0	0	**14,518**
2010	0	0	2,174	1,713	3,426	1,972	2,201	2,101	2,374	1,396	0	0	**17,358**
2011	0	49	0	2,467	2,175	1,073	1,813	1,298	1,800	1,165	0	113	**11,953**
2012	0	17	0	757	2,942	1,421	1,785	1,403	2,536	1,126	0	0	**11,987**
2013	0	0	0	1,665	871	1,689	1,055	2,154	2,471	855	0	0	**10,760**
2014	176	324	0	2,664	4,457	4,116	4,108	4,621	3,560	2,235	557	0	**26,818**
2015	0	187	1,745	3,493	4,541	5,587	5,752	6,008	4,276	37	0	0	**31,627**
2016	0	0	1,146	2,222	3,043	2,613	2,851	2,587	3,280	1,430	668	0	**19,841**
2017	0	0	1,401	1,735	1,890	864	1,953	1,797	2,454	1,394	440	0	**13,929**

Table A2-20 Monthly Groundwater Pumping Outside the District (AF)

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Total
1993	0	0	731	1,704	1,926	1,578	2,140	2,151	2,005	1,732	380	244	**14,591**
1994	0	0	1,114	1,316	1,379	1,865	2,140	2,151	1,901	1,855	189	0	**13,909**
1995	0	337	0	1,469	1,469	1,793	2,208	2,220	2,065	1,893	695	0	**14,149**
1996	185	0	1,047	1,638	1,987	1,924	2,203	2,220	2,065	1,482	0	0	**14,751**
1997	0	585	1,472	1,750	1,987	1,924	2,208	2,220	2,046	1,822	0	0	**16,014**
1998	0	0	197	1,479	894	1,550	2,208	2,220	2,055	1,687	261	400	**12,952**
1999	0	482	1,224	1,441	1,987	1,924	2,208	2,220	2,004	1,893	518	494	**16,395**
2000	0	0	818	1,451	1,987	1,845	2,199	2,220	2,065	1,243	695	527	**15,049**
2001	0	0	1,332	1,194	1,987	1,924	2,208	2,220	2,065	1,855	0	0	**14,785**
2002	116	559	1,210	1,453	2,004	2,008	2,305	2,308	2,120	1,903	80	0	**16,067**
2003	487	251	1,273	1,378	1,912	2,159	2,459	2,458	2,235	1,983	414	0	**17,008**
2004	38	0	1,149	1,757	2,070	2,055	2,360	2,337	2,120	891	547	0	**15,322**
2005	0	0	314	1,449	1,381	2,055	2,360	2,337	2,105	1,799	649	121	**14,570**
2006	0	580	323	438	1,904	2,055	2,360	2,337	2,120	1,604	679	238	**14,636**
2007	184	0	993	1,635	2,060	2,055	2,355	2,337	1,993	1,785	674	82	**16,151**
2008	0	125	1,474	1,807	2,109	2,092	2,402	2,380	2,161	1,857	210	274	**16,891**
2009	313	339	1,629	1,901	2,207	2,313	2,728	2,709	2,455	2,090	605	0	**19,289**
2010	0	0	1,509	1,287	2,338	2,375	2,728	2,709	2,472	1,914	520	0	**17,853**
2011	0	477	470	1,822	2,164	2,082	2,745	2,726	2,477	1,905	318	609	**17,796**
2012	230	770	829	1,085	2,422	2,390	2,745	2,726	2,489	2,219	598	0	**18,504**
2013	139	387	1,155	2,091	2,022	2,390	2,699	2,726	2,489	2,179	409	563	**19,250**
2014	719	845	1,333	2,468	3,288	3,216	3,693	3,683	3,397	3,098	633	0	**26,375**
2015	541	753	2,406	2,963	2,996	3,684	4,183	4,225	3,847	2,311	269	236	**28,413**
2016	0	187	2,102	2,833	3,493	3,711	4,260	4,256	3,901	3,096	979	0	**28,817**
2017	0	0	2,289	2,926	3,905	3,811	4,374	4,372	3,921	3,561	1,245	932	**31,334**

Runoff

The runoff leaving the District was calculated based upon a stream gauge in Rag Gulch which estimates the peak annual flow. The stream gauge located upstream of the Famoso-Porterville Highway has been measured continuously from 1976 to 2014 and observed a maximum annual peak flow of 2,800 cfs in 1978. The gauge measurements from 1993 to 2014 are shown in Table A2-21.

Table A2-21 Rag Gulch Stream Gauge Measurements

Year	Peak Winter Flow (cfs) November – May
1993	0.0
1994	0.0
1995	53.0
1996	0.0
1997	0.1
1998	1450.0
1999	46.0
2000	40.0
2001	0.0
2002	0.0
2003	0.0
2004	0.0
2005	0.0
2006	0.0
2007	0.0
2008	0.0
2009	0.0
2010	0.0
2011	92.0
2012	0.1
2013	0.0
2014	0.0

To estimate the amount of runoff leaving the District, the stream gauge measurements from Table A2-21 were compared with monthly precipitation from Table A2-9. Based upon the comparison, it was assumed any precipitation in excess of 4600 acre-feet per month became runoff and left the District. Table A2-22 displays the calculated monthly runoff values in acre-feet from the District. By comparing Table A2-21 with Table A2-22, it is observed that the calculated frequency of runoff leaving the District, Table A2-22, is reasonably close to the frequency of runoff measured upstream of Famoso-Porterville Highway, Table A2-21.

Table A2-22 Calculated Monthly Runoff values (AF)

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Total
1993	0	0	0	0	0	0	0	0	0	0	0	0	0
1994	0	0	0	0	0	0	0	0	0	0	0	0	0
1995	0	0	2,498	0	0	0	0	0	0	0	0	0	2,498
1996	0	0	0	0	0	0	0	0	0	0	0	195	195
1997	0	0	0	0	0	0	0	0	0	0	0	0	0
1998	0	4,533	0	0	0	0	0	0	0	0	0	0	4,533
1999	1,493	0	0	0	0	0	0	0	0	0	0	0	1,493
2000	0	271	0	0	0	0	0	0	0	0	0	0	271
2001	0	0	0	0	0	0	0	0	0	0	0	0	0
2002	0	0	0	0	0	0	0	0	0	0	0	0	0
2003	0	0	0	0	0	0	0	0	0	0	0	0	0
2004	0	0	0	0	0	0	0	0	0	0	0	0	0
2005	0	0	0	0	0	0	0	0	0	0	0	0	0
2006	0	0	0	0	0	0	0	0	0	0	0	0	0
2007	0	0	0	0	0	0	0	0	0	0	0	0	0
2008	0	0	0	0	0	0	0	0	0	0	0	0	0
2009	0	0	0	0	0	0	0	0	0	0	0	0	0
2010	0	0	0	0	0	0	0	0	0	0	0	4,699	4,699
2011	0	0	0	0	0	0	0	0	0	0	0	0	0
2012	0	0	0	0	0	0	0	0	0	0	0	0	0
2013	0	0	0	0	0	0	0	0	0	0	0	0	0
2014	0	0	0	0	0	0	0	0	0	0	0	0	0
2015	0	0	0	0	0	0	0	0	0	0	0	0	0
2016	0	0	0	0	0	0	0	0	0	0	0	0	0
2017	2,261	0	0	0	0	0	0	0	0	0	0	0	2,261

Return Flow

The District considered any precipitation in excess of the effective precipitation, that also did not runoff, as percolating below the root zone and attributed it as a return flow to groundwater. The return flow is estimated as the excess water from precipitation after taking into account applied surface water, groundwater, evapotranspiration, and runoff as shown in Table A2-23.

P = Precipitation; SW = Applied Surface Water; GW = Applied Groundwater;
ET = Evapotranspiration; R = Runoff

[Total P + SW + GW – ET – R = Return Flow]

Table A2-23 District Annual Historical Return Flow

Year	Total Precip	Surface Water Deliv.	Ground Water Pumping	Crop ET	Runoff Leaving District	Return Flow to GW
	(A)	*(B)*	*(C)*	*(D)*	*(E)*	*(F)*
1993	12,668	37,307	10,470	48,826	0	**11,618**
1994	13,112	40,721	6,836	50,872	0	**9,796**
1995	17,675	39,243	8,428	50,503	2,498	**12,346**
1996	14,876	41,718	7,114	51,107	195	**12,406**
1997	9,377	44,610	8,873	51,834	0	**11,025**
1998	25,108	35,110	10,218	53,738	4,533	**12,166**
1999	9,745	41,692	11,211	51,968	1,493	**9,188**
2000	12,138	44,509	5,528	50,607	271	**11,297**
2001	13,445	45,312	3,635	49,601	0	**12,791**
2002	7,696	38,337	9,071	47,405	0	**7,700**
2003	6,727	36,820	8,810	46,182	0	**6,175**
2004	10,389	38,633	7,741	47,000	0	**9,763**
2005	14,853	36,290	7,403	47,219	0	**11,327**
2006	11,851	35,371	11,798	51,528	0	**7,492**
2007	6,970	38,427	14,490	51,620	0	**8,267**
2008	6,828	40,233	14,582	52,747	0	**8,896**
2009	6,100	36,164	14,518	49,612	0	**7,171**
2010	20,503	32,840	17,358	52,003	4,699	**13,998**
2011	9,663	33,629	11,953	47,577	0	**7,668**
2012	8,590	35,853	11,987	48,435	0	**7,995**
2013	5,926	37,755	10,760	47,798	0	**6,643**
2014	7,668	21,409	26,818	48,366	0	**7,528**
2015	8,464	16,726	31,627	50,348	0	**6,468**
2016	9,637	29,879	19,841	50,161	0	**9,195**
2017	12,181	37,638	13,929	49,494	2,261	**11,992**
1993-2009 Average	*11,739*	*39,441*	*9,454*	*50,139*	*529*	***9,966***

(A) = From Delano precipitation data.
(B) = From District turnout data.
(C) = Annual values from Table A2-19.
(D) = Derived from ITRC data and land use.
(E) = Derived from stream gauge data.
(F) = (A) + (B) + (C) – (D) – (E)

A2.3 Water Budgets by Aquifer

The District evaluated the aquifer hydrologic balance based upon the setting described in the Analysis of Groundwater Resources (Gillespie, 2016). Hydrographs of groundwater levels beneath the District in both the Continental Deposits and the Santa Margarita show stable groundwater levels for the period of 1993-2009, shown in Figure A2-5 and Figure A2-6. Using the stable groundwater levels, it is assumed that the change in storage in both aquifers during this period is equal to zero.

Figure A2-5 Historical District Groundwater Levels in the Continental Deposits

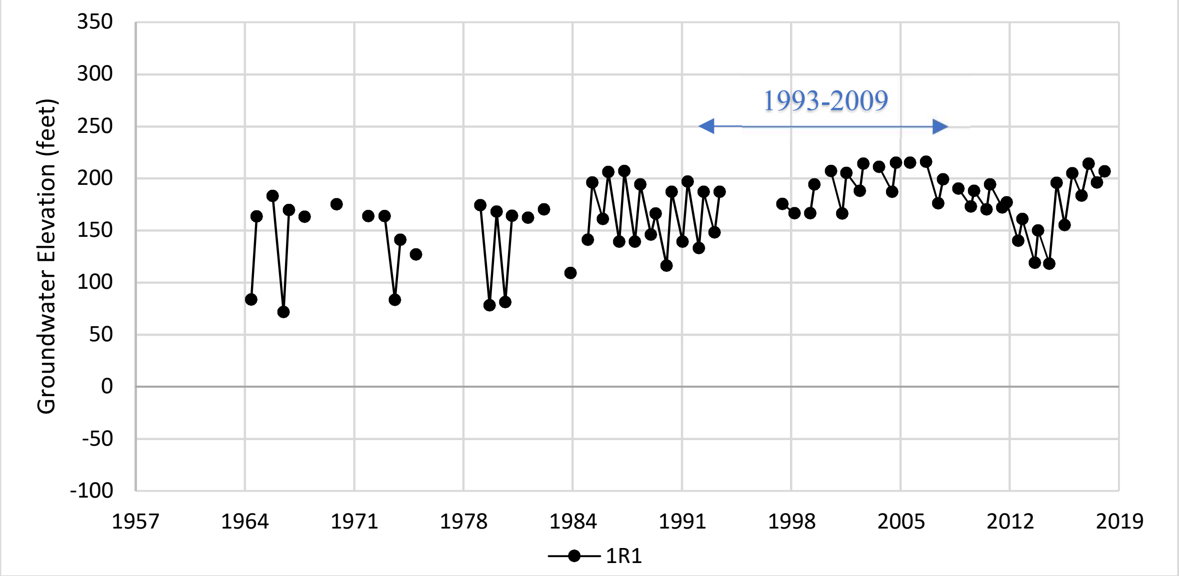
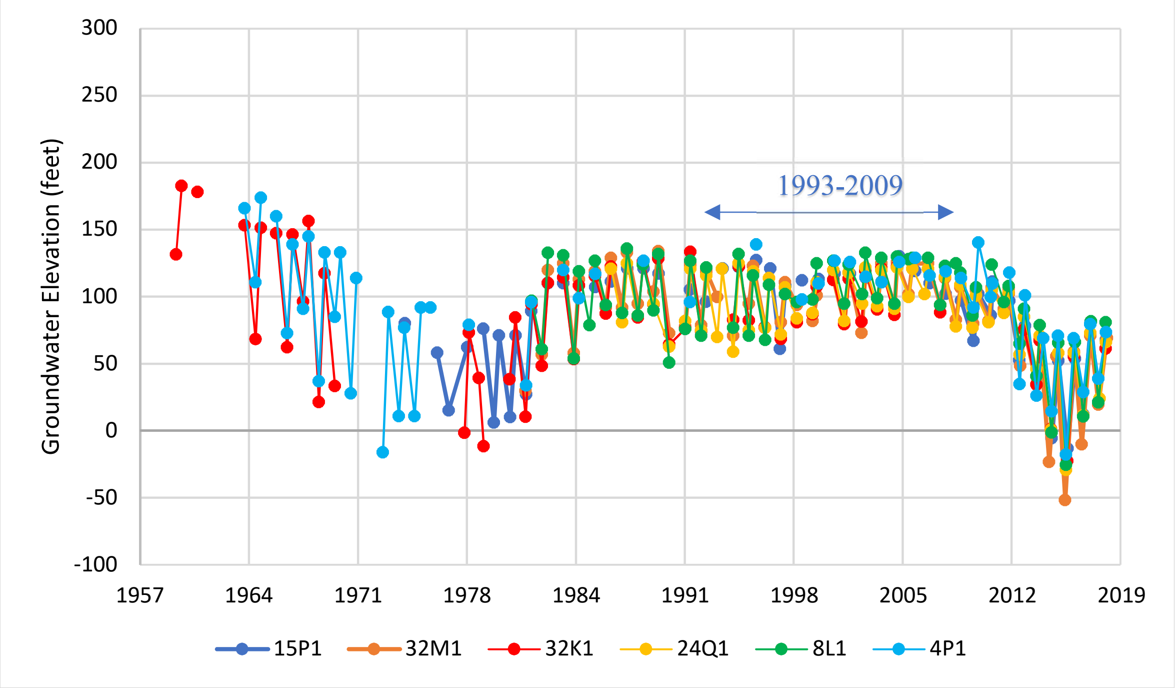


Figure A2-6 Historical District Groundwater Levels in the Santa Margarita Formation



Subsurface Flow

For the area beneath the District, subsurface inflow and outflow values were assumed using the averages from the period 1993 through 2009 where a "zero" change in storage was observed. For the purpose of this analysis, 25% of the groundwater pumping was assumed to be from the Continental Deposits and 75% from the Santa Margarita. The assigned percentages will need further study, but were based upon well depths, geology, and aquifer characteristics for the District. The following assumptions for each aquifer were used to calculate the historical water budget by aquifer for the District.

1993-2009 Averages (AF):

Calculated ET:	50,139
Effective Precipitation:	6,263
Surface Water Deliveries:	39,441
Groundwater Pumping:	9,454
Return Flow:	9,966

GW_{CD} = 9,454 AF * 25% = <u>2,364 AF</u>
GW_{SM} = 9,454 AF * 75% = <u>7,091 AF</u>

<u>Continental Deposit Analysis:</u> The inflows to the Continental Deposits beneath the District include subsurface inflow and surface return flows. The outflows are subsurface outflows and groundwater pumping. The subsurface inflow to the District for the Continental Deposits is currently unknown and therefore not given a value in the hydrologic model. The subsurface outflow from the District was estimated as 7,602 acre-feet per year based on the 1993 – 2009 water budget. This value was calculated as the difference between the average annual return flow (9,966 acre-feet) and the estimated average annual groundwater pumped from the Continental Deposits (25% of 9,454 = 2,364 acre-feet) during the 17-year period. This is a conservative (low) estimate which will increase by the amount of subsurface inflow to the Continental Deposits, currently assumed as zero.

Subsurface Inflow = 0 (Unknown)

Subsurface Outflow = Return Flow – GW_{CD}
Subsurface Outflow = 9,966 – 2,364 = <u>7,602 AF</u>

<u>Santa Margarita Analysis:</u> Since the Santa Margarita is a confined aquifer the only outflow is groundwater pumping and the only inflow is subsurface inflow generated in the foothills to the east of the District. Since the change in storage for this timeframe is equal to zero, the inflow from the east is assumed to be equal to the average amount of groundwater pumped during this time frame (75% of 9,454 = 7,091 acre-feet). This assumption was made due to the constant water levels seen in the hydrograph during this period in Figure A2-6.

Subsurface Inflow – $GW_{SM} = 0$
Subsurface Inflow = GW_{SM}
Subsurface Inflow = <u>7,091 AF</u>

Subsurface Outflow = 0

The calculated groundwater pumping, return flows, and subsurface flows were used to create water budgets for the Continental Deposits and Santa Margarita Formation beneath the District, summarized for years 1993 through 2017 in Table A2-24.

Table A2-24 District Annual Historical Water Budgets by Aquifer

	Continental Deposits					Santa Margarita			
Year	**sub-surface Inflow**	**Return Flow to GW**	**Ground Water Pumping**	**sub-surface Outflow**	**Ground Water Balance**	**sub-surface Inflow**	**Ground Water Pumping**	**sub-surface Outflow**	**Ground Water Balance**
1993	0	11,618	2,617	7,602	1,398	7,091	7,852	0	-761
1994	0	9,796	1,709	7,602	1,882	7,091	5,127	0	1,202
1995	0	12,346	2,107	7,602	4,519	7,091	6,321	0	1,972
1996	0	12,406	1,778	7,602	7,544	7,091	5,335	0	3,727
1997	0	11,025	2,218	7,602	8,749	7,091	6,654	0	4,164
1998	0	12,166	2,555	7,602	10,757	7,091	7,664	0	3,591
1999	0	9,188	2,803	7,602	9,540	7,091	8,408	0	2,274
2000	0	11,297	1,382	7,602	11,852	7,091	4,146	0	5,218
2001	0	12,791	909	7,602	16,132	7,091	2,726	0	9,583
2002	0	7,700	2,268	7,602	13,962	7,091	6,803	0	9,870
2003	0	6,175	2,202	7,602	10,332	7,091	6,607	0	10,354
2004	0	9,763	1,935	7,602	10,557	7,091	5,806	0	11,639
2005	0	11,327	1,851	7,602	12,431	7,091	5,552	0	13,178
2006	0	7,492	2,949	7,602	9,371	7,091	8,848	0	11,420
2007	0	8,267	3,622	7,602	6,413	7,091	10,867	0	7,644
2008	0	8,896	3,646	7,602	4,061	7,091	10,937	0	3,798
2009	0	7,171	3,630	7,602	0	7,091	10,889	0	0
2010	0	13,998	4,339	7,602	2,056	7,091	13,018	0	-5,928
2011	0	7,668	2,988	7,602	-866	7,091	8,965	0	-7,802
2012	0	7,995	2,997	7,602	-3,470	7,091	8,990	0	-9,701
2013	0	6,643	2,690	7,602	-7,120	7,091	8,070	0	-10,680
2014	0	7,528	6,704	7,602	-13,898	7,091	20,113	0	-23,703
2015	0	6,468	7,907	7,602	-22,940	7,091	23,720	0	-40,332
2016	0	9,195	4,960	7,602	-26,307	7,091	14,880	0	-48,122
2017	0	11,992	3,482	7,602	-25,400	7,091	10,446	0	-51,477
1993-2009 Average	*0*	*9,966*	*2,364*	*7,602*		*7,091*	*7,091*	*0*	

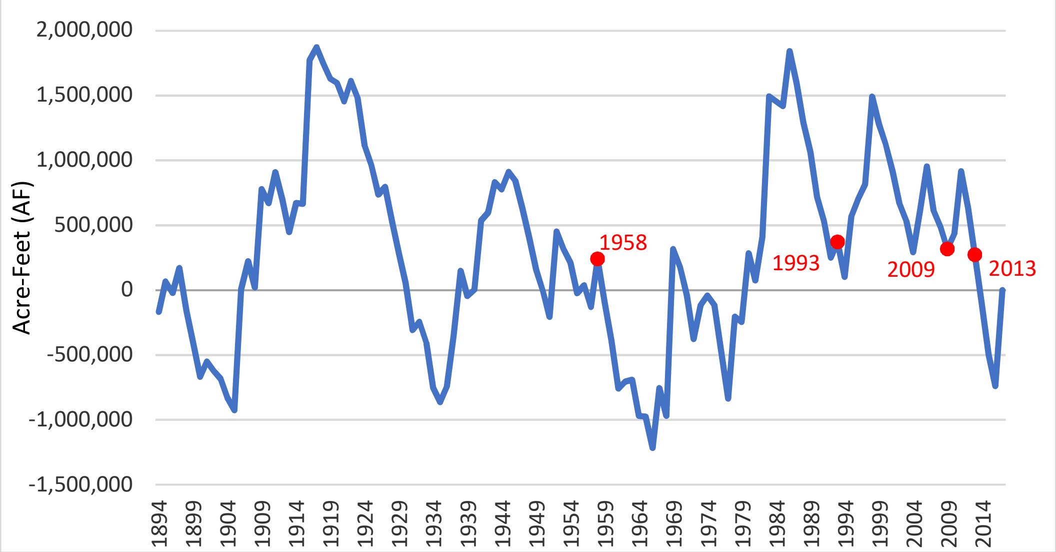
APPENDIX 3 – 50 YEAR MODEL

A3.1 Projected Hydrology

> *(A) Projected hydrology shall utilize 50 years of historical precipitation, evapotranspiration, and streamflow information as the baseline condition for estimating future hydrology. The projected hydrology information shall also be applied as the baseline condition used to evaluate future scenarios of hydrologic uncertainty associated with projections of climate change and sea level rise.*

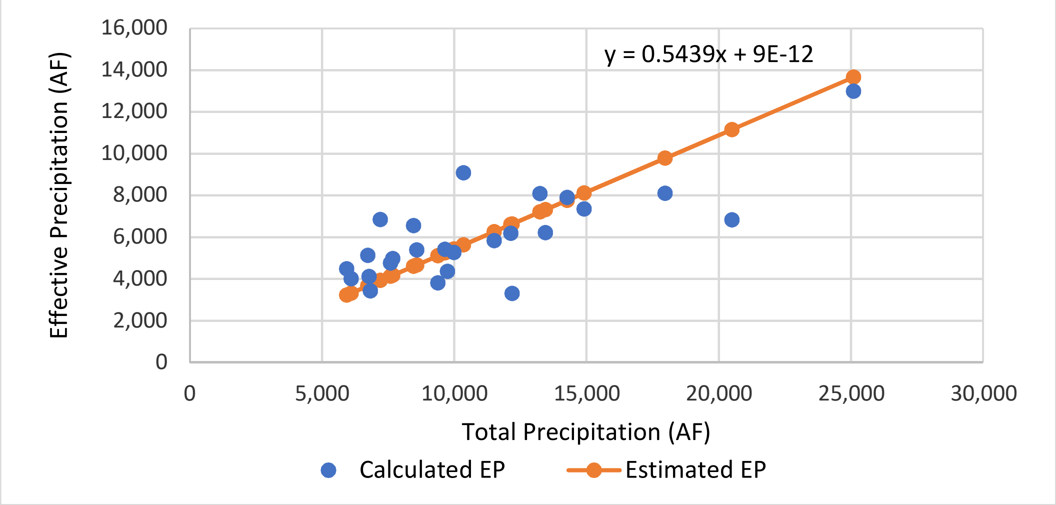
The projected water budget utilized the 56-year historical period from 1958 through 2013. This period was selected because it represented an average period of hydrology based upon Kern River natural flows, as shown in Figure A3-1.

Figure A3-1 Kern River at First Point of Measurement Accumulative Departure from Average



Historical precipitation data was gathered from 1958 through 2013 for the City of Delano. In order to estimate effective precipitation for the 56-year period, the District used the effective precipitation calculated from 1993 through 2017 in the Hydrologic Balance to determine a total precipitation to effective precipitation ratio of 0.5439. Figure A3-2 displays the calculated effective precipitation and the estimated effective precipitation from 1993 through 2017 versus the total precipitation for Delano.

Figure A3-2 Effective Precipitation Ratio (1993 – 2017)



The ratio was then used to estimate the effective precipitation for 1958 through 2013, shown in Table A3-1, using the total precipitation data for the City of Delano and the irrigated acres as of 2017 (17,443 acres).

*Total Precipitation (inches) ÷ 1 foot/12 inches * 17,443 acres * 0.5439 = Effective Precipitation (AF)*

Table A3-1 Projected Effective Precipitation

Year	Total Precip. (in)	Effective Precip. (AF)	Year	Total Precip. (in)	Effective Precip. (AF)
1958	12.78	10,103	**1986**	6.30	4,984
1959	4.30	3,399	**1987**	7.46	5,895
1960	7.90	6,245	**1988**	5.82	4,601
1961	3.71	2,933	**1989**	3.46	2,733
1962	7.42	5,866	**1990**	3.67	2,901
1963	9.19	7,265	**1991**	8.21	6,487
1964	4.88	3,858	**1992**	7.13	5,637
1965	8.32	6,577	**1993**	8.45	6,678
1966	5.05	3,992	**1994**	8.37	6,617
1967	9.43	7,455	**1995**	11.38	8,997
1968	6.51	5,147	**1996**	9.37	7,408
1969	12.26	9,692	**1997**	5.83	4,609
1970	7.33	5,795	**1998**	15.23	12,040
1971	6.44	5,091	**1999**	6.11	4,830
1972	5.49	4,340	**2000**	7.75	6,127
1973	10.27	8,119	**2001**	8.84	6,989
1974	7.94	6,277	**2002**	5.32	4,206
1975	4.98	3,936	**2003**	4.71	3,724
1976	7.07	5,589	**2004**	7.25	5,729
1977	4.73	3,739	**2005**	10.36	8,192
1978	15.71	12,420	**2006**	7.74	6,121
1979	5.35	4,230	**2007**	4.61	3,644
1980	6.23	4,925	**2008**	4.38	3,463
1981	7.00	5,534	**2009**	4.17	3,297
1982	9.19	7,265	**2010**	13.45	10,633
1983	13.31	10,522	**2011**	6.89	5,448
1984	4.23	3,344	**2012**	6.01	4,751
1985	5.10	4,032	**2013**	4.18	3,305

A3.2 Projected Water Demand

(B) Projected water demand shall utilize the most recent land use, evapotranspiration, and crop coefficient information as the baseline condition for estimating future water demand. The projected water demand information shall also be applied as the baseline condition used to evaluate future scenarios of water demand uncertainty associated with projected changes in local land use planning, population growth, and climate.

Projected water demands utilized 2017 land use and crop coefficient information. In 2017, the District recorded 5,422 acres of grape vines, 6,211 acres of trees and nuts, 5,610 acres of citrus, and 200 acres of field crops. The total irrigated acreage of 17,433 acres resulted in a calculated total evapotranspiration (ETc) of 49,494 acre-feet as displayed in Table A3-2.

Table A3-2 ETc calculated from crop coefficients (AF)

Month	Grape Vines (1)	Trees & Nuts (2)	Citrus (3)	Field Crops (4)	Total ETc (5)
Jan	0	0	542	20	**546**
Feb	0	425	804	11	**1,202**
Mar	264	749	1,626	22	**2,582**
Apr	733	1,968	1,854	26	**4,443**
May	1,531	2,925	2,035	36	**6,331**
Jun	2,110	2,832	1,941	97	**6,772**
Jul	2,429	3,246	2,228	116	**7,778**
Aug	2,213	3,281	2,250	48	**7,557**
Sep	1,403	2,816	2,135	0	**6,164**
Oct	252	1,761	2,051	8	**3,950**
Nov	399	451	750	15	**1,567**
Dec	0	0	601	20	**602**
Total	11,334	20,453	18,817	421	**49,494**

(1) – Vines include wine and table grapes.
(2) – Trees and nuts include almonds, pistachios, cherries, persimmons, and pomegranates.
(3) – Citrus include oranges, tangelo, kiwi, lemons, and grapefruit.
(4) – Field Crops include blue berries, Sudan grass, and alfalfa.

A3.3 Projected Surface Water Supply

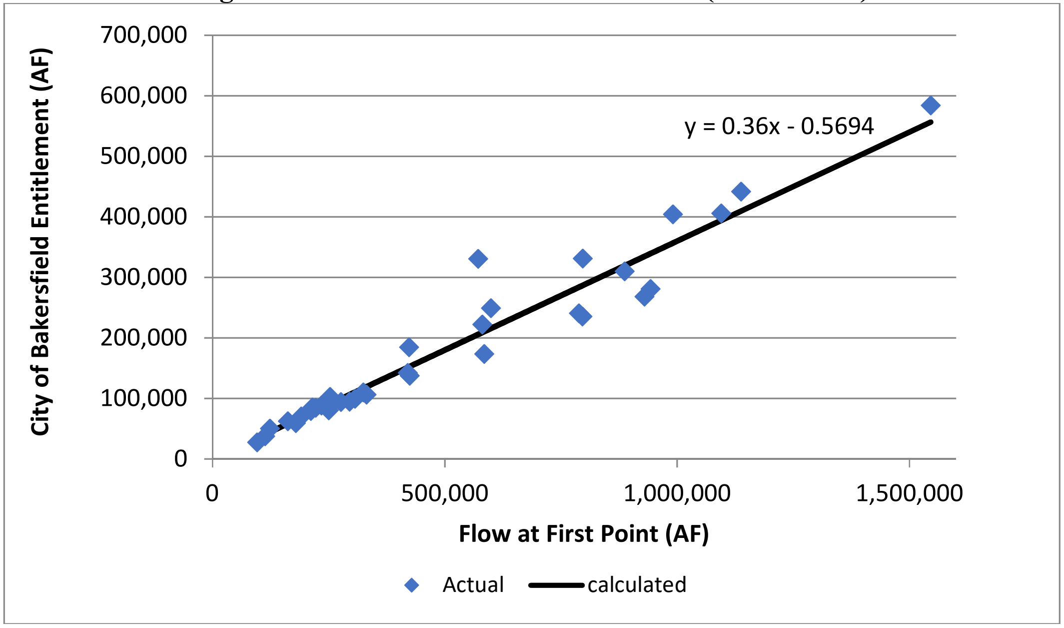
(C) Projected surface water supply shall utilize the most recent water supply information as the baseline condition for estimating future surface water supply. The projected surface water supply shall also be applied as the baseline condition used to evaluate future scenarios of surface water supply availability and reliability as a function of the historical surface water supply identified in Section 354.18(c)(2)(A), and the projected changes in local land use planning, population growth, and climate.

Projected surface water supplies were based upon the most recent water supply estimates of future surface water supply. There is no residential use within the District, therefore population projections are not included.

Kern River: The Kern River agreement with the City of Bakersfield (COB) consisted of an annual amount of 23,000 AF. This agreement began in 1977 and the current term expired in 2012. At the end of 2012 the COB still owed the District approximately 52,000 AF of water and paying the District back. The District and the COB are now in the extension term and the COB is obligated to sell the District up to 27,250 AF in years after water demands within the COB are met.

In order to estimate the projected Kern River supply available to the District, the COB Entitlement versus the flow measured at the Kern River's "first point of delivery" from 1977 through 2011 was plotted, shown in Figure A3-3.

Figure A3-3 Estimated Kern River Flow (1977 – 2011)



The estimated annual amount of Kern River water to the COB was 36% of 1st point as shown on Figure A3-3. This percentage was used to calculate the projected COB, shown in Table A3-3. In years where the COB is more than 240,000 AF (the COB demand), the District projects that up to 23,000 AF will be available. Table A3-3 includes all Kern River projections.

Table A3-3 Kern River Flows to COB and KTWD

Historic Year	Flow at First Pt. Apr.-Jul.	COB Entit. + or - Release	Calculated COB Entitlement	Historic Deliveries to KTWD	Future Estimated Available to KTWD
	(1)	(2)	(3)	(4)	(5)
1958	831,669		299,400		23,000
1959	130,585		47,010		0
1960	168,472		60,649		0
1961	87,374		31,454		0
1962	515,474		185,570		0
1963	476,579		171,568		0
1964	182,928		65,854		0
1965	456,668		164,400		0
1966	219,893		79,161		0
1967	924,005		332,641		23,000
1968	248,319		89,394		0
1969	1,747,874		629,234		23,000
1970	319,408		114,986		0
1971	244,475		88,011		0
1972	127,720		45,979		0
1973	723,768		260,556		20,556
1974	535,166		192,659		0
1975	386,180		139,024		0
1976	108,754		39,151		0
1977	95,649	27,255	34,433	7,673	0
1978	1,094,375	406,053	393,975	26,690	23,000
1979	419,859	142,291	151,149	27,122	0
1980	991,025	404,287	356,769	26,403	23,000
1981	252,681	88,983	90,965	26,700	0
1982	796,794	331,346	286,845	23,412	23,000
1983	1,545,810	583,919	556,491	7,587	23,000
1984	423,132	184,458	152,327	23,000	0
1985	424,293	137,624	152,745	23,000	0
1986	886,674	310,276	319,202	23,000	23,000
1987	211,408	79,370	76,106	23,000	0
1988	162,043	62,170	58,335	14,763	0
1989	234,430	88,436	84,394	19,635	0
1990	113,434	37,319	40,836	3,000	0
1991	276,543	94,394	99,555	23,000	0
1992	179,153	59,169	64,495	12,089	0
1993	584,691	173,763	210,488	33,726	0
1994	191,004	70,599	68,761	23,995	0
1995	929,221	268,357	334,519	37,726	23,000
1996	599,331	249,194	215,759	38,419	0
1997	571,476	330,737	205,731	40,836	0
1998	1,137,373	441,674	409,454	27,250	23,000
1999	252,627	102,621	90,945	37,132	0
2000	306,496	99,237	110,338	26,279	0
2001	250,292	80,594	90,105	13,862	0
2002	215,307	85,167	77,510	11,421	0
2003	324,508	110,159	116,822	15,779	0
2004	222,002	84,747	79,920	18,198	0
2005	788,500	240,496	283,860	30,460	23,000
2006	795,728	235,461	286,462	25,866	23,000
2007	123,410	50,036	44,427	5,569	0
2008	331,341	106,466	119,282	19,110	0
2009	295,161	94,763	106,257	16,139	0
2010	580,397	222,212	208,942	12,314	0
2011	942,858	280,694	339,428	16,432	23,000
2012	176,621		63,583	8,790	0
2013	102,915		37,049	3,706	0

(1) Flow at First Point Measuring Station on Kern River from April – July.
(2) City of Bakersfield Entitlement from historic records
(3) Calculated City of Bakersfield Entitlement (*Flow at First Pt (2) multiplied by 0.36*)
(4) Historical deliveries to KTWD based on District records.
(5) If City of Bakersfield Entitlement (4) is more than 240,000 AF then the value is the minimum of COB Entitilement (4) less 23,000 AF or 23,000 AF. If the COB Entitlement is less than 240,000 AF then value equals 0.

KTWD Class 2: The District has a 5,000 AF Class 2 Friant Contract that was purchased from Southern San Joaquin Municipal Utility District in 2012. This water becomes available after the Class 1 Friant Contractors supplies have been satisfied.

Friant Uncontrolled Season: Occasionally, Millerton Reservoir is unable to store the amount of water coming from the upper San Joaquin River and the Bureau of Reclamation (Reclamation) must evacuate the reservoir as quickly as possible. One of the tools Reclamation uses, is called Uncontrolled Season; whereby all contractors can take as much water as the canal can hold and the contractor can deliver, up to their contract amount. The District receives up to 5,000 AF/yr of uncontrolled season water from its Class 2 contract and purchases additional uncontrolled season water from other Friant Contractors.

Friant Purchases: The District purchases additional Friant water from Friant Contractors in most years, depending upon available supply.

KTWD XVC: The District's Cross Valley Contract (XVC), of 53,300 AF, began delivering water to the District in 1977. The water supply is from the Sacramento/San Joaquin River Delta and has suffered a loss of supply resulting from court-ordered actions, environmental regulations, increased urbanization and changes in weather patterns associated with climate change. The District has not had a full supply since 1998. When the water does become available it is typically exchanged with Kern County Water Agency for State Water Project water or delivered to the District's banking partners.

SOD/Other Purchases: The District purchases water from South of Delta (SOD) Bureau of Reclamation contractors and delivers the water either to Banking or to the District directly. The District also purchases water from other sources on occasion. This could include State Water Project supplies, local river supplies, or groundwater supplies from other Districts.

Table A3-4 Historic and Projected Allocations

	Historic Allocations						**Projected Future Allocations**					
	Friant		**SWP**		**CVP**		**Friant**		**SWP**		**CVP**	
Year	**Class 1**	**Class 2**	**Table A**	**Art. 21**	**SOD**	**XVC**	**Class 1**	**Class 2**	**Table A**	**Art. 21**	**SOD**	**XVC**
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)
1958	100%	76%			100%		100%	56%	100%		99%	0%
1959	99%	0%			100%		93%	0%	56%		37%	37%
1960	80%	0%			100%		57%	0%	49%		29%	29%
1961	57%	0%			100%		41%	0%	42%		41%	41%
1962	100%	42%			100%		100%	30%	57%		41%	41%
1963	100%	51%			100%		100%	39%	67%		53%	53%
1964	100%	7%			100%		92%	0%	64%		30%	30%
1965	100%	51%			100%		100%	38%	67%		73%	73%
1966	100%	11%			100%		100%	6%	64%		53%	53%
1967	100%	100%			100%		100%	88%	100%		100%	0%
1968	97%	0%	93%		100%		82%	0%	54%		41%	41%
1969	100%	100%	100%		100%		100%	91%	100%		100%	0%
1970	100%	27%	100%		100%		100%	14%	76%		62%	0%
1971	100%	25%	100%		100%		100%	10%	69%		36%	36%
1972	100%	9%	100%		100%		89%	0%	53%		44%	44%
1973	100%	42%	100%		100%		100%	27%	79%		60%	0%
1974	100%	47%	100%		100%		100%	37%	85%		85%	0%
1975	100%	41%	100%		100%		100%	31%	72%		66%	0%
1976	76%	0%	100%		100%		64%	0%	42%		9%	9%
1977	23%	0%	40%		25%	25%	23%	0%	11%		5%	5%
1978	100%	100%	100%		100%	100%	100%	84%	81%		100%	0%
1979	100%	41%	100%		100%	100%	100%	24%	75%		42%	0%
1980	100%	80%	100%		100%	100%	100%	58%	100%		76%	0%
1981	100%	11%	100%		100%	100%	100%	7%	56%		49%	49%
1982	100%	90%	100%		100%	100%	100%	73%	100%		100%	0%
1983	100%	100%	100%		100%	100%	100%	100%	100%		100%	0%
1984	100%	35%	100%		100%	100%	100%	26%	79%		63%	0%
1985	100%	9%	100%		100%	100%	100%	1%	75%		50%	0%
1986	100%	68%	100%		100%	100%	100%	53%	89%		60%	0%
1987	66%	0%	100%		100%	100%	65%	0%	22%		23%	23%
1988	84%	0%	100%		100%	100%	61%	0%	22%		1%	1%
1989	92%	0%	100%		100%	100%	61%	0%	64%		30%	30%
1990	70%	0%	50%		50%	50%	47%	0%	24%		0%	0%
1991	98%	0%	0%		25%	25%	67%	0%	15%		14%	14%
1992	82%	0%	45%		25%	25%	60%	0%	24%		23%	23%
1993	100%	70%	100%		50%	50%	100%	53%	67%		66%	66%
1994	84%	0%	50%		35%	35%	83%	0%	46%		58%	58%
1995	100%	100%	100%		100%	100%	100%	100%	91%		91%	0%
1996	100%	48%	100%		95%	95%	100%	40%	78%		76%	0%
1997	100%	35%	100%		90%	90%	100%	21%	85%		75%	0%
1998	100%	100%	100%		100%	100%	100%	89%	88%		100%	0%
1999	100%	29%	100%		70%	51%	100%	14%	77%		55%	0%
2000	100%	35%	90%	9%	65%	51%	100%	25%	75%		58%	0%
2001	100%	7%	39%	2%	50%	40%	84%	0%	32%		29%	29%
2002	100%	12%	70%	2%	70%	39%	90%	0%	64%		41%	41%
2003	100%	29%	90%	2%	75%	0%	100%	4%	56%		46%	46%
2004	100%	8%	65%	7%	70%	31%	88%	0%	65%		70%	70%
2005	100%	100%	90%	20%	85%	4%	100%	100%	90%		85%	0%
2006	100%	100%	100%	17%	100%	0%	100%	100%	100%		100%	0%
2007	65%	0%	60%	10%	50%	38%	65%	0%	60%		50%	50%
2008	100%	5%	35%	0%	40%	0%	100%	5%	35%		40%	40%
2009	77%	18%	40%	0%	10%	10%	77%	18%	40%		10%	10%
2010	100%	15%	50%	0%	45%	34%	100%	15%	50%		45%	45%
2011	100%	20%	80%	12%	80%	0%	100%	20%	80%		80%	0%
2012	50%	0%	65%	0%	40%	24%	50%	0%	65%		40%	40%
2013	62%	0%	35%	0%	20%	15%	62%	0%	35%		20%	20%

(1) 1922-2004 from Stiner modeling for pre-settlement; 2005-2017 are actual allocations from USBR Water Allocations history: https://www.usbr.gov/mp/cvo/vungvari/water_allocations_historical.pdf

(2) 1922-2004 from Stiner modeling for pre-settlement; 2005-2017 are actual allocations from USBR Water Allocations history: https://www.usbr.gov/mp/cvo/vungvari/water_allocations_historical.pdf

(3) From Ron Eid & Paul Fujitani Data

(4) From Mavens Notebook https://mavensnotebook.com/2018/04/05/ca-water-commission-article-21-water-explained/#jp-carousel-7455

(5) 1922-1977 from Arvin-Edison/ Met Water Storage and exchange program EIR 1978-2017 from USBR Water Allocations history: https://www.usbr.gov/mp/cvo/vungvari/water_allocations_historical.pdf

(6) 1977-1998 assumed same as SOD; 1999-2017 are actual Cross Valley deliveries

(7) 1922-2004 from Stiner modeling for post-settlement; 2005-2017 are actual allocations from USBR Water Allocations history: https://www.usbr.gov/mp/cvo/vungvari/water_allocations_historical.pdf

(8) 1922-2004 from Stiner modeling for post-settlement; 2005-2017 are actual allocations from USBR Water Allocations history: https://www.usbr.gov/mp/cvo/vungvari/water_allocations_historical.pdf

(9) 1922-2003 from 2015 SWP Delivery Capability Report, no climate change study; 2004-2017 are actual allocations from Column (4)

(10) Not used in this analysis.

(11) 1922-2003 from 2015 SWP Delivery Capability Report, no climate change study; 2004-2017 are actual allocations from Column (4)

(12) Calculated as Column 11 if Column 9 is less than 70%

Produced Water: Water suitable for irrigated agriculture is produced as a by-product of oil production (produced water) and must be disposed of. For the past 30 years, Hathaway LLC (Hathaway) and its predecessors have been delivering produced water to irrigate 400 acres within the District. Hathaway has expanded beyond the capabilities of its existing produced water delivery facilities and has partnered with the District for additional delivery to more service areas within the District since 2015.

From Banking: The District has developed long-term groundwater banking programs with North Kern Water Storage District (North Kern), Rosedale-Rio Bravo Water Storage District (Rosedale-Rio Bravo), and West Kern Water Storage District (West Kern). In wet or average water years, after the District has met its in-District demands, excess water is delivered to the banking programs. These programs provide water to the District in dry years. The "From Banking" is the amount that was extracted or removed from the banking programs to meet in-District demands.

The North Kern project yields an annual dry year supply of up to 5,000 acre-feet. The agreement requires the District to bank water before it can be extracted and leave 10 percent of the water banked in North Kern to account for losses.

Extraction Capacity = 5,000 AF
Spreading Capacity = 15,000 AF
Maximum Account Balance = 30,000 AF
Current Account Balance (2018) = 29,923 AF

The Rosedale-Rio Bravo project yields an estimated dry year annual supply of up to 9,000 acre-feet. The agreement requires the District to bank 2.13 acre-feet for each acre-foot extracted and to bank water before it can be extracted.

Extraction Capacity = 9,000 AF
Spreading Capacity = 50,000 AF
Maximum Account Balance = 40,000 AF
Current Account Balance (2018) = 30,384 AF

The West Kern project yields an estimated dry year annual supply of up to 2,000 acre-feet. The agreement requires the District to bank 2 acre-feet for each acre-foot extracted and bank water before it can be extracted.

Extraction Capacity = 2,000 AF
Spreading Capacity = 10,000 AF
Maximum Account Balance = 15,000 AF
Current Account Balance (2018) = 7,666 AF

A3.4 Model Runs

The District has identified the following Actions as a means to accomplish groundwater sustainability:

1. Modify District Pricing Structure
2. Construct CRC Pipeline - Produced Water Project
3. Construct In-District Surface Storage

To evaluate the amount of applied water demand, surface water available, and impact upon groundwater storage with the District's future Actions, several model runs were made. Model Run 1 evaluates the baseline (no action) condition. Model Run 2 applies Action 1 which provides an incentive to reduce groundwater pumping and increase surface water deliveries from 75% to 95% by causing groundwater to cost more than surface water. Model Run 2 applies Action 1 and 2 which provides 2,500 AF of additional surface supplies from available produced water. Model Run 3 applies Action 1, 2, and 3 which includes the construction of 8,000 AF of off-stream surface storage to store water when it is available. The inputs of the various model runs are summarized in Table A3-5:

Table A3-5 Model Inputs

Model Run	% of Applied Water Demand met by Surf. Water	Produced Water (AF)	Available Storage (AF)
1	75%	2400	2000
2	95%	2400	2000
3	95%	4900	2000
4	95%	4900	10000

<u>Surface Water Percentage of Applied Water Demand</u>: The percent of applied water demand met by surface water for Model Run 1 is based off historical data from 1993 through 2017. During that period, measured surface water deliveries met an average of 75% of the applied water demand, shown in

The percent of demand met by surface water for Model Runs 2 through 4 is increased to 95% as the District implements actions that allow for more surface water deliveries.

Table A3-6 Historical Percent of Applied Water Demand met by Surface Water

Year	Surf. Deliveries	AW Demand	%
	(1)	(2)	(3)
1993	37,307	47,776	78%
1994	40,721	47,556	86%
1995	39,243	47,121	83%
1996	41,718	48,629	86%
1997	44,610	53,371	84%
1998	35,110	45,285	78%
1999	41,692	52,903	79%
2000	44,509	49,371	90%
2001	45,312	48,213	94%
2002	38,337	47,399	81%
2003	36,820	45,630	81%
2004	38,633	46,374	83%
2005	36,290	43,693	83%
2006	35,371	47,169	75%
2007	38,427	52,787	73%
2008	40,233	54,815	73%
2009	36,164	50,683	71%
2010	32,840	50,197	65%
2011	33,629	45,582	74%
2012	35,853	47,840	75%
2013	37,755	48,137	78%
2014	21,409	48,227	44%
2015	16,726	48,350	35%
2016	29,879	49,719	60%
2017	37,638	51,338	73%
Average			**75%**

(1) Based on historical delivery records.
(2) Calculated as [(ETc – Effective Precipitation) ÷ 90% Irrigation Efficiency]
(3) Calculated as (1) ÷ (2)

<u>Produced Water:</u> The baseline produced water input is 2,400 AF delivered by Hathaway annually. The input is increased in Model Run 3 and 4 to 4,900 AF due to the construction of the CRC pipeline that provides an additional 2,500 AF of water per year.

<u>Storage:</u> The baseline storage input of 2,000 AF is what the District has historically carried over in the Millerton and San Luis Reservoirs. The input is increased in Model Run 4 to 10,000 AF due to the construction of in-District surface storage facilities that provide an additional storage capacity of 8,000 AF.

Detailed results of the following components for each model run are shown in Table A3-8 through Table A3-23:

- Banking Program Accounts
- Surface Water Deliveries
- Projected Water Budget
- Projected Groundwater Change in Storage

A summary of results for each model run is shown below in Table A3-7.

Table A3-7 Model Run Results (AF)

Model Run	Avg. Surface Deliveries	Avg. GW Pumping	Total Deliveries
1	33,706	14,785	48,491
2	39,348	9,143	48,491
3	40,726	7,764	48,491
4	41,231	7,260	48,491

Model Run 1: Baseline

Table A3-8 Model Run 1: Banking Programs

Year	North Kern Banking Program				Rosedale Banking Program				West Kern Banking Program				Total of Banking Programs				
	Avail. (1)	Spreading (2)	Extraction (3)	Act. Balance (4)	Avail. (5)	Spreading (6)	Extraction (7)	Act. Balance (8)	Avail. (9)	Spreading (10)	Extraction (11)	Act. Balance (12)	Spreading (13)	Extraction (14)	Act. Balance (15)	From Banking (16)	Carryover (17)
				29,923				30,384				7,666			67,973		
1958	35,358	86	0	30,000	35,273	20,482	0	40,000	14,791	3,667	0	9,500	24,326	0	79,500	0	11,124
1959	0	0	-5,000	25,000	0	0	-4,358	35,642	0	0	0	9,500	0	-9,367	70,132	9,358	0
1960	0	0	-5,000	20,000	0	0	-9,000	26,642	0	0	-2,000	7,500	0	-16,000	54,132	16,000	0
1961	0	0	-5,000	15,000	0	0	-4,337	22,305	0	0	0	7,500	0	-9,307	44,825	9,337	0
1962	4,150	4,150	0	18,735	0	0	0	22,305	0	0	0	7,500	3,936	0	48,367	0	0
1963	14,230	12,516	0	30,000	1,714	1,714	0	23,110	0	0	0	7,500	13,899	0	60,373	0	0
1964	0	0	-5,000	25,000	0	0	-8,059	15,051	0	0	0	7,500	0	-13,106	47,267	13,059	0
1965	37,558	5,556	0	30,000	32,003	32,003	0	30,076	0	0	0	7,500	37,284	0	67,163	0	0
1966	2,930	0	0	30,000	2,930	2,930	0	31,451	0	0	0	7,500	2,871	0	68,511	0	0
1967	69,586	0	0	30,000	69,586	18,208	0	40,000	51,377	3,750	0	9,375	22,896	0	79,375	0	47,627
1968	0	0	-1,153	28,847	0	0	0	40,000	0	0	0	9,375	0	-1,308	78,066	1,153	0
1969	69,789	1,281	0	30,000	68,508	0	0	40,000	68,508	2,813	0	10,781	4,266	0	80,781	0	65,695
1970	0	0	-5,000	25,000	0	0	-1,520	38,480	0	0	0	10,781	0	-6,729	74,052	6,520	0
1971	0	0	-5,000	20,000	0	0	-5,007	33,473	0	0	0	10,781	0	-10,157	63,895	10,007	0
1972	0	0	-1,856	18,144	0	0	0	33,473	0	0	0	10,781	0	-1,943	61,951	1,856	0
1973	4,851	4,851	0	22,510	0	0	0	33,473	0	0	0	10,781	4,448	0	65,955	0	0
1974	10,045	8,322	0	30,000	1,723	1,723	0	34,282	0	0	0	10,781	9,796	0	74,352	0	0
1975	0	0	-227	29,773	0	0	0	34,282	0	0	0	10,781	0	-281	74,071	227	0
1976	0	0	-5,000	24,773	0	0	-9,000	25,282	0	0	-2,000	8,781	0	-16,000	58,071	16,000	0
1977	0	0	-5,000	19,773	0	0	-9,000	16,282	0	0	-2,000	6,781	0	-16,000	42,071	16,000	0
1978	71,727	11,363	0	30,000	60,364	50,000	0	39,756	10,364	4,110	0	8,836	65,533	0	77,881	0	6,254
1979	0	0	-5,000	25,000	0	0	-9,000	30,756	0	0	-1,303	7,532	0	-15,382	62,499	15,303	0
1980	21,154	5,556	0	30,000	15,598	15,598	0	38,079	0	0	0	7,532	21,017	0	74,758	0	0
1981	1,760	0	0	30,000	1,760	1,760	0	38,906	0	0	0	7,532	1,573	0	75,497	0	0
1982	35,667	0	0	30,000	35,667	2,331	0	40,000	33,336	3,734	0	9,399	7,942	0	79,340	0	29,602
1983	72,724	0	0	30,000	72,724	0	0	40,000	72,724	2,800	0	10,799	2,830	0	80,755	0	69,923
1984	0	0	-973	29,027	0	0	0	40,000	0	0	0	10,799	0	-978	79,777	973	0
1985	0	0	-5,000	24,027	0	0	-9,000	31,000	0	0	-2,000	8,799	0	-16,000	63,777	16,000	0
1986	5,978	5,978	0	29,407	0	0	0	31,000	0	0	0	8,799	5,837	0	69,030	0	0
1987	0	0	-5,000	24,407	0	0	-9,000	22,000	0	0	-2,000	6,799	0	-16,000	53,030	16,000	0
1988	0	0	-5,000	19,407	0	0	-9,000	13,000	0	0	-2,000	4,799	0	-16,000	37,030	16,000	0
1989	0	0	-5,000	14,407	0	0	-9,000	4,000	0	0	-2,000	2,799	0	-16,000	21,030	16,000	0
1990	0	0	-5,000	9,407	0	0	-4,000	0	0	0	-2,000	799	0	-11,000	10,030	11,000	0
1991	0	0	-5,000	4,407	0	0	0	0	0	0	-799	0	0	-5,755	4,275	5,799	0
1992	0	0	-4,407	0	0	0	0	0	0	0	0	0	0	-4,275	0	4,407	0
1993	34,728	15,000	0	13,500	19,728	19,728	0	9,262	0	0	0	0	34,445	0	22,629	0	0
1994	7,192	7,192	0	19,973	0	0	0	9,262	0	0	0	0	6,915	0	28,852	0	0
1995	71,452	11,141	0	30,000	60,311	50,000	0	32,736	10,311	7,500	0	3,750	68,919	0	66,353	0	2,811
1996	1,116	0	0	30,000	1,116	1,116	0	33,260	0	0	0	3,750	773	0	66,716	0	0
1997	0	0	-141	29,859	0	0	0	33,260	0	0	0	3,750	0	-251	66,465	141	0
1998	71,660	156	0	30,000	71,504	14,356	0	40,000	57,148	5,625	0	6,563	20,886	0	76,563	0	51,523
1999	0	0	-5,000	25,000	0	0	-9,000	31,000	0	0	-2,000	4,563	0	-16,000	60,563	16,000	0
2000	0	0	-5,000	20,000	0	0	-9,000	22,000	0	0	-1,472	3,090	0	-15,709	44,854	15,472	0
2001	0	0	-5,000	15,000	0	0	-7,478	14,522	0	0	0	3,090	0	-12,787	32,067	12,478	0
2002	0	0	-3,461	11,539	0	0	0	14,522	0	0	0	3,090	0	-3,537	28,530	3,461	0
2003	0	0	-1,262	10,277	0	0	0	14,522	0	0	0	3,090	0	-1,298	27,231	1,262	0
2004	26,239	15,000	0	23,777	11,239	11,239	0	19,798	0	0	0	3,090	26,035	0	45,912	0	0
2005	70,782	6,914	0	30,000	63,868	43,030	0	40,000	20,838	5,955	0	6,068	57,003	0	75,890	0	14,883
2006	69,056	0	0	30,000	69,056	0	0	40,000	69,056	4,466	0	8,301	4,555	0	78,168	0	64,590
2007	0	0	-2,358	27,642	0	0	0	40,000	0	0	0	8,301	0	-2,388	75,780	2,358	0
2008	0	0	-4,389	23,253	0	0	0	40,000	0	0	0	8,301	0	-4,404	71,376	4,389	0
2009	0	0	-5,000	18,253	0	0	-9,000	31,000	0	0	-2,000	6,301	0	-16,000	55,376	16,000	0
2010	9,751	9,751	0	27,028	0	0	0	31,000	0	0	0	6,301	9,139	0	63,601	0	0
2011	31,495	3,302	0	30,000	28,193	19,170	0	40,000	9,023	4,350	0	8,476	27,549	0	78,376	0	4,673
2012	0	0	-5,000	25,000	0	0	-1,766	38,234	0	0	0	8,476	0	-6,888	71,488	6,766	0
2013	0	0	-5,000	20,000	0	0	-9,000	29,234	0	0	-2,000	6,476	0	-16,000	55,488	16,000	0

(1) Table A3-9 total surface water available (9) less surface water demand (21) less stored in surface storage (24) or 0 if negative.
(2) Minimum selected between maximum spreading capacity, available water (1), or the maximum account balance less the previous year's account balance divided by 0.9 (banking rate = 10% to NKWSD).
(3) First determines maximum of: Table A3-10 (22) Surface Water Demand less all other surface water supplies available besides from banking, or 0. Then takes the minimum of: the amount needed to meet Surface Water Demand, the maximum extraction capacity, or the balance in the bank.
(4) Spreading (2) multiplied by 0.9 banking rate plus Extraction (3) plus previous years account balance (4).
(5) Available surface supplies (1) less North Kern spreading (2).
(6) Minimum selected between maximum spreading capacity, available water (5), or the maximum account balance less the previous year's account balance * 2.13 (banking rate = 53.1% to RRBWSD).
(7) First determines maximum of: Table A3-10 (22) Surface Water Demand less all other surface water supplies available besides from banking plus amount extracted from North Kern (3), or 0. Then takes the minimum of: the amount needed to meet Surface Water Demand, the maximum extraction capacity, or the balance in the bank.
(8) Spreading (7) divided by 2.13 "leave behind" plus Extraction (8) plus previous years account balance (9).
(9) Available surface supplies (6) less Rosedale spreading (7).
(10) Minimum selected between maximum spreading capacity, available water (11), or the maximum account balance less the previous year's account balance divided by 2 (banking rate = 50% to WKWD).
(11) First determines maximum of: Table A3-10 (22) Surface Water Demand less all other surface water supplies available besides from banking plus amount extracted from Rosedale (3) and North Kern (7), or 0. Then takes the minimum of: the amount needed to meet Surface Water Demand, the maximum extraction capacity, or the balance in the bank.
(12) Spreading (12) divided by 2 plus Extraction (13) plus previous years account balance (14)
(13) The total amount spread in North Kern, Rosedale and West Kern.
(14) The total amount extracted in North Kern, Rosedale and West Kern.
(15) The total amount in banking in North Kern, Rosedale and West Kern.
(16) Amount Extracted (16).
(17) Amount Available (1) less the amount of Spreading (15).

Table A3-9 Model Run 1: Surface Water

	Water Available									Surface Water Deliveries by Source									
Year	Produced Water	Friant Unc.	KTWD Class 2	From Storage	Friant Purchase	Kern River	KTWD XVC	SOD Purchase	Total	Produced Water	Friant Unc.	KTWD Class 2	From Storage	Friant Purchase	Kern River	KTWD XVC	SOD Purchase	From Banking	Total
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)	(13)	(14)	(15)	(16)	(17)	(18)	(19)
1958	2,400	2,000	2,784	0	10,000	23,000	0	30,000	70,184	2,400	2,000	2,784	0	10,000	15,642	0	0	0	32,826
1959	2,400	0	0	1,800	5,000	0	19,854	0	29,054	2,400	0	0	1,800	5,000	0	19,854	0	9,358	38,412
1960	2,400	0	0	0	0	0	15,611	0	18,011	2,400	0	0	0	0	0	15,611	0	16,000	34,011
1961	2,400	0	0	0	0	0	22,064	5,000	29,464	2,400	0	0	0	0	0	22,064	5,000	9,337	38,801
1962	2,400	2,000	1,492	0	10,000	0	21,615	5,000	42,507	2,400	2,000	1,492	0	10,000	0	20,465	0	0	36,357
1963	2,400	2,000	1,927	1,800	10,000	0	28,294	5,000	51,421	2,400	2,000	1,927	1,800	10,000	0	17,063	0	0	35,191
1964	2,400	0	0	1,800	5,000	0	15,771	0	24,971	2,400	0	0	1,800	5,000	0	15,771	0	13,059	38,030
1965	2,400	2,000	1,877	0	10,000	0	39,045	20,000	75,322	2,400	2,000	1,877	0	10,000	0	19,487	0	0	35,764
1966	2,400	0	289	1,800	5,000	0	28,359	5,000	42,848	2,400	0	289	1,800	5,000	0	28,359	70	0	37,918
1967	2,400	5,000	4,418	1,800	40,000	23,000	0	30,000	106,618	2,400	5,000	4,418	1,800	21,414	0	0	0	0	35,032
1968	2,400	0	0	1,800	5,000	0	21,603	5,000	35,803	2,400	0	0	1,800	5,000	0	21,603	5,000	1,153	36,956
1969	2,400	5,000	4,557	0	40,000	23,000	0	30,000	104,957	2,400	5,000	4,557	0	21,211	0	0	0	0	33,168
1970	2,400	0	696	1,800	5,000	0	0	20,000	29,896	2,400	0	696	1,800	5,000	0	0	20,000	6,520	36,416
1971	2,400	0	478	0	5,000	0	19,117	0	26,995	2,400	0	478	0	5,000	0	19,117	0	10,007	37,002
1972	2,400	0	0	0	5,000	0	23,372	5,000	35,772	2,400	0	0	0	5,000	0	23,372	5,000	1,856	37,628
1973	2,400	2,000	1,374	0	10,000	20,556	0	5,000	41,330	2,400	2,000	1,374	0	10,000	18,705	0	0	0	34,479
1974	2,400	2,000	1,859	1,800	10,000	0	0	30,000	48,059	2,400	2,000	1,859	1,800	10,000	0	0	17,955	0	36,014
1975	2,400	2,000	1,538	1,800	10,000	0	0	20,000	37,738	2,400	2,000	1,538	1,800	10,000	0	0	20,000	227	37,965
1976	2,400	0	0	0	0	0	4,866	0	7,266	2,400	0	0	0	0	0	4,866	0	16,000	23,266
1977	2,400	0	0	0	0	0	2,630	0	5,030	2,400	0	0	0	0	0	2,630	0	16,000	21,030
1978	2,400	5,000	4,222	0	40,000	23,000	0	30,000	104,622	2,400	5,000	4,222	0	19,273	0	0	0	0	30,895
1979	2,400	2,000	1,217	1,800	10,000	0	0	5,000	22,417	2,400	2,000	1,217	1,800	10,000	0	0	5,000	15,303	37,720
1980	2,400	2,000	2,894	0	10,000	23,000	0	20,000	60,294	2,400	2,000	2,894	0	10,000	19,846	0	0	0	37,141
1981	2,400	0	335	1,800	5,000	0	25,858	5,000	40,394	2,400	0	335	1,800	5,000	0	25,858	1,240	0	36,633
1982	2,400	2,000	3,658	1,800	10,000	23,000	0	30,000	72,858	2,400	2,000	3,658	1,800	10,000	15,333	0	0	0	35,191
1983	2,400	5,000	5,000	1,800	40,000	23,000	0	30,000	107,200	2,400	5,000	5,000	1,800	18,276	0	0	0	0	32,476
1984	2,400	2,000	1,285	1,800	10,000	0	0	20,000	37,485	2,400	2,000	1,285	1,800	10,000	0	0	20,000	973	38,458
1985	2,400	0	64	0	5,000	0	0	5,000	12,464	2,400	0	64	0	5,000	0	0	5,000	16,000	28,464
1986	2,400	2,000	2,670	0	10,000	23,000	0	5,000	45,070	2,400	2,000	2,670	0	10,000	20,022	0	0	0	37,092
1987	2,400	0	0	1,800	0	0	12,493	0	16,693	2,400	0	0	1,800	0	0	12,493	0	16,000	32,693
1988	2,400	0	0	0	0	0	695	0	3,095	2,400	0	0	0	0	0	695	0	16,000	19,095
1989	2,400	0	0	0	0	0	16,087	0	18,487	2,400	0	0	0	0	0	16,087	0	16,000	34,487
1990	2,400	0	0	0	0	0	0	0	2,400	2,400	0	0	0	0	0	0	0	11,000	13,400
1991	2,400	0	0	0	0	0	7,460	0	9,860	2,400	0	0	0	0	0	7,460	0	5,799	15,660
1992	2,400	0	0	0	0	0	12,205	0	14,605	2,400	0	0	0	0	0	12,205	0	4,407	19,011
1993	2,400	2,000	2,673	0	10,000	0	35,335	20,000	72,408	2,400	2,000	2,673	0	10,000	0	18,607	0	0	35,680
1994	2,400	0	0	1,800	5,000	0	30,723	5,000	44,923	2,400	0	0	1,800	5,000	0	26,531	0	0	35,731
1995	2,400	5,000	5,000	1,800	40,000	23,000	0	30,000	107,200	2,400	5,000	5,000	1,800	19,548	0	0	0	0	33,748
1996	2,400	2,000	1,988	1,800	10,000	0	0	20,000	38,188	2,400	2,000	1,988	1,800	10,000	0	0	16,884	0	35,072
1997	2,400	2,000	1,064	1,800	10,000	0	0	20,000	37,264	2,400	2,000	1,064	1,800	10,000	0	0	20,000	141	37,404
1998	2,400	5,000	4,472	0	40,000	23,000	0	30,000	104,872	2,400	5,000	4,472	0	19,340	0	0	0	0	31,211
1999	2,400	0	696	1,800	5,000	0	0	5,000	14,896	2,400	0	696	1,800	5,000	0	0	5,000	16,000	30,896
2000	2,400	2,000	1,267	0	10,000	0	0	5,000	20,667	2,400	2,000	1,267	0	10,000	0	0	5,000	15,472	36,139
2001	2,400	0	0	0	5,000	0	15,543	0	22,943	2,400	0	0	0	5,000	0	15,543	0	12,478	35,421
2002	2,400	0	0	0	5,000	0	21,879	5,000	34,279	2,400	0	0	0	5,000	0	21,879	5,000	3,461	37,740
2003	2,400	0	214	0	5,000	0	24,266	5,000	36,880	2,400	0	214	0	5,000	0	24,266	5,000	1,262	38,142
2004	2,400	0	0	0	5,000	0	37,310	20,000	64,710	2,400	0	0	0	5,000	0	29,071	0	0	36,471
2005	2,400	5,000	5,000	1,800	40,000	23,000	0	30,000	107,200	2,400	5,000	5,000	1,800	20,218	0	0	0	0	34,418
2006	2,400	5,000	5,000	1,800	40,000	23,000	0	30,000	107,200	2,400	5,000	5,000	1,800	21,944	0	0	0	0	36,144
2007	2,400	0	0	1,800	0	0	26,650	5,000	35,850	2,400	0	0	1,800	0	0	26,650	5,000	2,358	38,208
2008	2,400	0	250	0	5,000	0	21,320	5,000	33,970	2,400	0	250	0	5,000	0	21,320	5,000	4,389	38,359
2009	2,400	2,000	900	0	10,000	0	5,330	0	20,630	2,400	2,000	900	0	10,000	0	5,330	0	16,000	36,630
2010	2,400	2,000	750	0	10,000	0	23,985	5,000	44,135	2,400	2,000	750	0	10,000	0	17,234	0	0	32,384
2011	2,400	2,000	1,000	1,800	10,000	23,000	0	30,000	70,200	2,400	2,000	1,000	1,800	10,000	19,505	0	0	0	36,705
2012	2,400	0	0	1,800	0	0	21,320	5,000	30,520	2,400	0	0	1,800	0	0	21,320	5,000	6,766	37,286
2013	2,400	0	0	0	0	0	10,660	0	13,060	2,400	0	0	0	0	0	10,660	0	16,000	29,060

(1) Estimated amount of produced water from Hathaway (and CRC in MR3 and MR4).
(2) Friant Uncontrolled Season Based on Friant Projected Future Allocations in Table A3-4: If Class 2 (8) is 80% or above - 5,000 AF, If Class 2 (8) is 15% or above - 2,000 AF, otherwise 0.
(3) KTWD Class 2- Based on Friant Projected Future Allocations in Table A3-4: The Class 2 allocation (8) multiplied by KTWD contract of 5,000 AF.
(4) Amount from storage. This is the available amount from Table A3-10 To Storage (24) from the previous year multiplied by .90 (to account for a 10% loss.)
(5) Friant purchases based on Friant Projected Future Allocations Table A3-4: If Class 2 (8) is 80% or above - 40,000 AF, If Class 2 (8) is 15% or above - 10,000 AF, if Class 1 (7) is 75% or above- 5,000 AF, otherwise 0
(6) From Kern River Table A3-3: Estimated Available to KTWD (4)
(7) CVP XVC Allocations Table A3-4: XVC allocation (12) multiplied by KTWD contract of 53,300 AF.
(8) South of Delta purchases based on Allocations Table A3-4: If SOD (11) is 80% or above - 30,000 AF, If SOD (11) is 60% or above - 20,000 AF, if SOD (11) is 40% or above- 5,000 AF, otherwise 0.
(9) Sum of water available (1 through 8)
(10) Equal to Produced Water from Water Available (1)
(11) Takes the minimum of Table A3-10 Surface Water Demand (22) less Produced Water (10), compared to the amount of Friant Unc. Water (2) available.
(12) Takes the minimum of Table A3-10 Surface Water Demand (22) less Produced Water (10) less Friant Unc. Water (11), compared to the amount of KTWD Class 2 (3) available.
(13) Takes the minimum of Table A3-10 Surface Water Demand (22) less Produced Water (10) less Friant Unc. Water (11) less KTWD Class 2 (12), compared to the amount of From Storage (4) available.
(14) Takes the minimum of Table A3-10 Surface Water Demand (22) less Produced Water (10) less Friant Unc. Water (11) less KTWD Class 2 (12) less From Storage (13), compared to the amount of Friant Purchase (5) available.
(15) Takes the minimum of Table A3-10 Surface Water Demand (22) less Produced Water (10) less Friant Unc. Water (11) less KTWD Class 2 (12) less From Storage (13) less Friant Purchase (14), compared to the amount of Kern River (6) available.
(16) Takes the minimum of Table A3-10 Surface Water Demand (22) less Produced Water (10) less Friant Unc. Water (11) less KTWD Class 2 (12) less From Storage (13) less Friant Purchase (14) less Kern River (15), compared to the amount of KTWD XVC (7) available.
(17) Takes the minimum of Table A3-10 Surface Water Demand (22) less Produced Water (10) less Friant Unc. Water (11) less KTWD Class 2 (12) less From Storage (13) less Friant Purchase (14) less Kern River (15) less KTWD XVC (16), compared to the amount of SOD Purchase (8) available.
(18) From Banking Operations Table A3-8: From Banking (18)
(19) Sum of Surface water deliveries by source (10 through 18)

Table A3-10 Model Run 1: Projected Water Budget

Year	Effective Precip.	Applied Water Demand	Surface Water Demand	Surface Water Deliveries	Ground Water Pumping	To Storage
	(20)	(21)	(22)	(23)	(24)	(25)
1958	10,103	43,767	32,826	32,826	10,942	2,000
1959	3,399	51,216	38,412	38,412	12,804	0
1960	6,245	48,054	36,040	34,011	14,043	0
1961	2,933	51,734	38,801	38,801	12,934	0
1962	5,866	48,476	36,357	36,357	12,119	2,000
1963	7,265	46,921	35,191	35,191	11,730	2,000
1964	3,858	50,707	38,030	38,030	12,677	0
1965	6,577	47,685	35,764	35,764	11,921	2,000
1966	3,992	50,557	37,918	37,918	12,639	2,000
1967	7,455	46,710	35,032	35,032	11,677	2,000
1968	5,147	49,275	36,956	36,956	12,319	0
1969	9,692	44,224	33,168	33,168	11,056	2,000
1970	5,795	48,555	36,416	36,416	12,139	0
1971	5,091	49,336	37,002	37,002	12,334	0
1972	4,340	50,171	37,628	37,628	12,543	0
1973	8,119	45,972	34,479	34,479	11,493	2,000
1974	6,277	48,019	36,014	36,014	12,005	2,000
1975	3,936	50,620	37,965	37,965	12,655	0
1976	5,589	48,783	36,587	23,266	25,517	0
1977	3,739	50,838	38,129	21,030	29,809	0
1978	12,420	41,194	30,895	30,895	10,298	2,000
1979	4,230	50,294	37,720	37,720	12,573	0
1980	4,925	49,521	37,141	37,141	12,380	2,000
1981	5,534	48,845	36,633	36,633	12,211	2,000
1982	7,265	46,921	35,191	35,191	11,730	2,000
1983	10,522	43,302	32,476	32,476	10,825	2,000
1984	3,344	51,278	38,458	38,458	12,819	0
1985	4,032	50,513	37,885	28,464	22,049	0
1986	4,984	49,455	37,092	37,092	12,364	2,000
1987	5,895	48,444	36,333	32,693	15,751	0
1988	4,601	49,881	37,411	19,095	30,786	0
1989	2,733	51,957	38,967	34,487	17,470	0
1990	2,901	51,770	38,827	13,400	38,370	0
1991	6,487	47,785	35,839	15,660	32,125	0
1992	5,637	48,730	36,548	19,011	29,719	0
1993	6,678	47,574	35,680	35,680	11,893	2,000
1994	6,617	47,641	35,731	35,731	11,910	2,000
1995	8,997	44,997	33,748	33,748	11,249	2,000
1996	7,408	46,763	35,072	35,072	11,691	2,000
1997	4,609	49,872	37,404	37,404	12,468	0
1998	12,040	41,615	31,211	31,211	10,404	2,000
1999	4,830	49,626	37,220	30,896	18,730	0
2000	6,127	48,186	36,139	36,139	12,046	0
2001	6,989	47,228	35,421	35,421	11,807	0
2002	4,206	50,320	37,740	37,740	12,580	0
2003	3,724	50,856	38,142	38,142	12,714	0
2004	5,729	48,628	36,471	36,471	12,157	2,000
2005	8,192	45,891	34,418	34,418	11,473	2,000
2006	6,121	48,192	36,144	36,144	12,048	2,000
2007	3,644	50,944	38,208	38,208	12,736	0
2008	3,463	51,146	38,359	38,359	12,786	0
2009	3,297	51,330	38,498	36,630	14,700	0
2010	10,633	43,179	32,384	32,384	10,795	2,000
2011	5,448	48,940	36,705	36,705	12,235	2,000
2012	4,751	49,714	37,286	37,286	12,429	0
2013	3,305	51,322	38,491	29,060	22,262	0
Average	**5,852**	**48,491**	**36,368**	**33,706**	**14,785**	

(20) From Effective Precipitation Table A3-1: Effective Precipitation (AF).

(21) Total ETc (49,494 AF) less the Effective Precip (20) divided by an irrigation efficiency of 90%.

(22) Applied Water Demand (21) times the Surface Water Demand Percentage (MR1 = 75%; MR2, MR3, MR4 = 95%). Accounts for the fact that growers may not use 100% of surface water even when available and instead still choose to pump groundwater.

(23) Sum of Surface water deliveries by source from Table A3-9 (10 through 18).

(24) Applied Water Demand (21) less the Total Surface Water Deliveries (23).

(25) The minimum amount of Table A3-9 Total Water Available (9) less the Surface Water Demand (22), compared to the determined amount the District feels they can put into surface storage (MR1, MR2, MR3 = 2,000 AF; MR4 = 10,000 AF).

Table A3-11 Model Run 1: Projected Groundwater Storage

Year	GW Pumping	Sust. Yield	GW Balance annual	GW Balance cumul.
	(1)	(2)	(3)	(4)
1958	10,942	9,454	(1,488)	(1,488)
1959	12,804	9,454	(3,350)	(4,838)
1960	14,043	9,454	(4,589)	(9,427)
1961	12,934	9,454	(3,480)	(12,907)
1962	12,119	9,454	(2,665)	(15,572)
1963	11,730	9,454	(2,276)	(17,848)
1964	12,677	9,454	(3,223)	(21,070)
1965	11,921	9,454	(2,467)	(23,538)
1966	12,639	9,454	(3,185)	(26,723)
1967	11,677	9,454	(2,223)	(28,947)
1968	12,319	9,454	(2,865)	(31,811)
1969	11,056	9,454	(1,602)	(33,413)
1970	12,139	9,454	(2,685)	(36,098)
1971	12,334	9,454	(2,880)	(38,978)
1972	12,543	9,454	(3,089)	(42,067)
1973	11,493	9,454	(2,039)	(44,106)
1974	12,005	9,454	(2,551)	(46,656)
1975	12,655	9,454	(3,201)	(49,857)
1976	25,517	9,454	(16,063)	(65,920)
1977	29,809	9,454	(20,355)	(86,275)
1978	10,298	9,454	(844)	(87,119)
1979	12,573	9,454	(3,119)	(90,239)
1980	12,380	9,454	(2,926)	(93,165)
1981	12,211	9,454	(2,757)	(95,922)
1982	11,730	9,454	(2,276)	(98,198)
1983	10,825	9,454	(1,371)	(99,570)
1984	12,819	9,454	(3,365)	(102,935)
1985	22,049	9,454	(12,595)	(115,531)
1986	12,364	9,454	(2,910)	(118,440)
1987	15,751	9,454	(6,297)	(124,737)
1988	30,786	9,454	(21,332)	(146,069)
1989	17,470	9,454	(8,016)	(154,085)
1990	38,370	9,454	(28,916)	(183,000)
1991	32,125	9,454	(22,671)	(205,672)
1992	29,719	9,454	(20,265)	(225,937)
1993	11,893	9,454	(2,439)	(228,376)
1994	11,910	9,454	(2,456)	(230,832)
1995	11,249	9,454	(1,795)	(232,628)
1996	11,691	9,454	(2,237)	(234,864)
1997	12,468	9,454	(3,014)	(237,878)
1998	10,404	9,454	(950)	(238,828)
1999	18,730	9,454	(9,276)	(248,104)
2000	12,046	9,454	(2,592)	(250,697)
2001	11,807	9,454	(2,353)	(253,050)
2002	12,580	9,454	(3,126)	(256,176)
2003	12,714	9,454	(3,260)	(259,436)
2004	12,157	9,454	(2,703)	(262,139)
2005	11,473	9,454	(2,019)	(264,158)
2006	12,048	9,454	(2,594)	(266,752)
2007	12,736	9,454	(3,282)	(270,034)
2008	12,786	9,454	(3,332)	(273,366)
2009	14,700	9,454	(5,246)	(278,613)
2010	10,795	9,454	(1,341)	(279,953)
2011	12,235	9,454	(2,781)	(282,734)
2012	12,429	9,454	(2,975)	(285,709)
2013	22,262	9,454	(12,808)	(298,516)

(1) From Table A3-10 (22)
(2) Calculated in Appendix 2 – Hydrologic Model.
(3) Calculated as Sustainable Yield (2) minus Groundwater Pumping (1).
(4) Cumulative sum of annual Groundwater Balance (3).

Model Run 2: Action 1 (95% of Demand Met with Surface Water)

Table A3-12 Model Run 2: Banking Programs

	North Kern Banking Program				Rosedale Banking Program				West Kern Banking Program				Total of Banking Programs				
Year	**Avail.** (1)	**Spreading** (2)	**Extraction** (3)	**Act. Balance** (4)	**Avail.** (5)	**Spreading** (6)	**Extraction** (7)	**Act. Balance** (8)	**Avail.** (9)	**Spreading** (10)	**Extraction** (11)	**Act. Balance** (12)	**Spreading** (13)	**Extraction** (14)	**Act. Balance** (15)	**From Banking** (16)	**Carryover** (17)
				29,923				30,384				7,666			67,973		
1958	26,605	86	0	30,000	26,519	20,482	0	40,000	6,037	3,667	0	9,500	24,235	0	79,500	0	2,370
1959	0	0	-5,000	25,000	0	0	-9,000	31,000	0	0	-2,000	7,500	0	-16,000	63,500	16,000	0
1960	0	0	-5,000	20,000	0	0	-9,000	22,000	0	0	-2,000	5,500	0	-16,000	47,500	16,000	0
1961	0	0	-5,000	15,000	0	0	-9,000	13,000	0	0	-2,000	3,500	0	-16,000	31,500	16,000	0
1962	0	0	-3,545	11,455	0	0	0	13,000	0	0	0	3,500	0	-3,545	27,955	3,545	0
1963	3,046	3,046	0	14,197	0	0	0	13,000	0	0	0	3,500	3,046	0	30,696	0	0
1964	0	0	-5,000	9,197	0	0	-9,000	4,000	0	0	-2,000	1,500	0	-16,000	14,696	16,000	0
1965	28,021	15,000	0	22,697	13,021	13,021	0	10,113	0	0	0	1,500	28,021	0	34,310	0	0
1966	0	0	-5,000	17,697	0	0	-181	9,932	0	0	0	1,500	0	-5,181	29,128	5,181	0
1967	58,444	13,670	0	30,000	44,774	44,774	0	30,952	0	0	0	1,500	58,444	0	62,452	0	0
1968	0	0	-5,000	25,000	0	0	-6,008	24,944	0	0	0	1,500	0	-11,008	51,444	11,008	0
1969	60,945	5,556	0	30,000	55,389	32,069	0	40,000	23,320	6,750	0	4,875	44,375	0	74,875	0	16,570
1970	0	0	-5,000	25,000	0	0	-9,000	31,000	0	0	-2,000	2,875	0	-16,000	58,875	16,000	0
1971	0	0	-5,000	20,000	0	0	-9,000	22,000	0	0	-2,000	875	0	-16,000	42,875	16,000	0
1972	0	0	-5,000	15,000	0	0	-6,890	15,110	0	0	0	875	0	-11,890	30,985	11,890	0
1973	0	0	-2,344	12,656	0	0	0	15,110	0	0	0	875	0	-2,344	28,641	2,344	0
1974	0	0	0	12,656	0	0	0	15,110	0	0	0	875	0	0	28,641	0	0
1975	0	0	-5,000	7,656	0	0	-6,573	8,537	0	0	0	875	0	-11,573	17,068	11,573	0
1976	0	0	-5,000	2,656	0	0	-8,537	0	0	0	-875	0	0	-14,411	2,656	14,411	0
1977	0	0	-2,656	0	0	0	0	0	0	0	0	0	0	-2,656	0	2,656	0
1978	63,488	15,000	0	13,500	48,488	48,488	0	22,764	0	0	0	0	63,488	0	36,264	0	0
1979	0	0	-5,000	8,500	0	0	-9,000	13,764	0	0	0	0	0	-14,000	22,264	14,000	0
1980	11,250	11,250	0	18,625	0	0	0	13,764	0	0	0	0	11,250	0	32,389	0	0
1981	0	0	-5,000	13,625	0	0	-1,008	12,756	0	0	0	0	0	-6,008	26,380	6,008	0
1982	24,483	15,000	0	27,125	9,483	9,483	0	17,208	0	0	0	0	24,483	0	44,333	0	0
1983	64,063	3,195	0	30,000	60,868	48,547	0	40,000	12,322	7,500	0	3,750	59,242	0	73,750	0	4,822
1984	0	0	-5,000	25,000	0	0	-6,229	33,771	0	0	0	3,750	0	-11,229	62,521	11,229	0
1985	0	0	-5,000	20,000	0	0	-9,000	24,771	0	0	-2,000	1,750	0	-16,000	46,521	16,000	0
1986	0	0	-1,913	18,087	0	0	0	24,771	0	0	0	1,750	0	-1,913	44,608	1,913	0
1987	0	0	-5,000	13,087	0	0	-9,000	15,771	0	0	-1,750	0	0	-15,750	28,858	15,750	0
1988	0	0	-5,000	8,087	0	0	-9,000	6,771	0	0	0	0	0	-14,000	14,858	14,000	0
1989	0	0	-5,000	3,087	0	0	-6,771	0	0	0	0	0	0	-11,771	3,087	11,771	0
1990	0	0	-3,087	0	0	0	0	0	0	0	0	0	0	-3,087	0	3,087	0
1991	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
1992	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
1993	25,213	15,000	0	13,500	10,213	10,213	0	4,795	0	0	0	0	25,213	0	18,295	0	0
1994	0	0	-336	13,164	0	0	0	4,795	0	0	0	0	0	-336	17,959	336	0
1995	60,653	15,000	0	26,664	45,653	45,653	0	26,228	0	0	0	0	60,653	0	52,892	0	0
1996	0	0	-5,000	21,664	0	0	-1,237	24,991	0	0	0	0	0	-6,237	46,655	6,237	0
1997	0	0	-5,000	16,664	0	0	-6,915	18,076	0	0	0	0	0	-11,915	34,740	11,915	0
1998	63,337	14,818	0	30,000	48,519	46,698	0	40,000	1,822	1,822	0	911	63,337	0	70,911	0	0
1999	0	0	-5,000	25,000	0	0	-9,000	31,000	0	0	-911	0	0	-14,911	56,000	14,911	0
2000	0	0	-5,000	20,000	0	0	-9,000	22,000	0	0	0	0	0	-14,000	42,000	14,000	0
2001	0	0	-5,000	15,000	0	0	-9,000	13,000	0	0	0	0	0	-14,000	28,000	14,000	0
2002	0	0	-5,000	10,000	0	0	-8,525	4,475	0	0	0	0	0	-13,525	14,475	13,525	0
2003	0	0	-5,000	5,000	0	0	-4,475	0	0	0	0	0	0	-9,475	5,000	9,475	0
2004	16,513	15,000	0	18,500	1,513	1,513	0	710	0	0	0	0	16,513	0	19,210	0	0
2005	61,603	12,778	0	30,000	48,826	48,826	0	23,633	0	0	0	0	61,603	0	53,633	0	0
2006	59,418	0	0	30,000	59,418	34,861	0	40,000	24,557	7,500	0	3,750	42,361	0	73,750	0	17,057
2007	0	0	-5,000	25,000	0	0	-7,547	32,453	0	0	0	3,750	0	-12,547	61,203	12,547	0
2008	0	0	-5,000	20,000	0	0	-9,000	23,453	0	0	-619	3,131	0	-14,619	46,585	14,619	0
2009	0	0	-5,000	15,000	0	0	-9,000	14,453	0	0	-2,000	1,131	0	-16,000	30,585	16,000	0
2010	1,115	1,115	0	16,004	0	0	0	14,453	0	0	0	1,131	1,115	0	31,588	0	0
2011	21,707	15,000	0	29,504	6,707	6,707	0	17,602	0	0	0	1,131	21,707	0	48,237	0	0
2012	0	0	-5,000	24,504	0	0	-9,000	8,602	0	0	-1,131	0	0	-15,131	33,106	15,131	0
2013	0	0	-5,000	19,504	0	0	-8,602	0	0	0	0	0	0	-13,602	19,504	13,602	0

Table A3-13 Model Run 2: Surface Water

	Water Available									Surface Water Deliveries by Source									
Year	**Produced Water**	**Friant Unc.**	**KTWD Class 2**	**From Storage**	**Friant Purchase**	**Kern River**	**KTWD XVC**	**SOD Purchase**	**Total**	**Produced Water**	**Friant Unc.**	**KTWD Class 2**	**From Storage**	**Friant Purchase**	**Kern River**	**KTWD XVC**	**SOD Purchase**	**From Banking**	**Total**
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)	(13)	(14)	(15)	(16)	(17)	(18)	(19)
1958	2,400	2,000	2,784	0	10,000	23,000	0	30,000	70,184	2,400	2,000	2,784	0	10,000	23,000	0	1,395	0	41,579
1959	2,400	0	0	1,800	5,000	0	19,854	0	29,054	2,400	0	0	1,800	5,000	0	19,854	0	16,000	45,054
1960	2,400	0	0	0	0	0	15,611	0	18,011	2,400	0	0	0	0	0	15,611	0	16,000	34,011
1961	2,400	0	0	0	0	0	22,064	5,000	29,464	2,400	0	0	0	0	0	22,064	5,000	16,000	45,464
1962	2,400	2,000	1,492	0	10,000	0	21,615	5,000	42,507	2,400	2,000	1,492	0	10,000	0	21,615	5,000	3,545	46,052
1963	2,400	2,000	1,927	0	10,000	0	28,294	5,000	49,621	2,400	2,000	1,927	0	10,000	0	28,248	0	0	44,575
1964	2,400	0	0	1,800	5,000	0	15,771	0	24,971	2,400	0	0	1,800	5,000	0	15,771	0	16,000	40,971
1965	2,400	2,000	1,877	0	10,000	0	39,045	20,000	75,322	2,400	2,000	1,877	0	10,000	0	29,024	0	0	45,301
1966	2,400	0	289	1,800	5,000	0	28,359	5,000	42,848	2,400	0	289	1,800	5,000	0	28,359	5,000	5,181	48,030
1967	2,400	5,000	4,418	0	40,000	23,000	0	30,000	104,818	2,400	5,000	4,418	0	32,556	0	0	0	0	44,374
1968	2,400	0	0	1,800	5,000	0	21,603	5,000	35,803	2,400	0	0	1,800	5,000	0	21,603	5,000	11,008	46,811
1969	2,400	5,000	4,557	0	40,000	23,000	0	30,000	104,957	2,400	5,000	4,557	0	30,055	0	0	0	0	42,013
1970	2,400	0	696	1,800	5,000	0	0	20,000	29,896	2,400	0	696	1,800	5,000	0	0	20,000	16,000	45,896
1971	2,400	0	478	0	5,000	0	19,117	0	26,995	2,400	0	478	0	5,000	0	19,117	0	16,000	42,995
1972	2,400	0	0	0	5,000	0	23,372	5,000	35,772	2,400	0	0	0	5,000	0	23,372	5,000	11,890	47,662
1973	2,400	2,000	1,374	0	10,000	20,556	0	5,000	41,330	2,400	2,000	1,374	0	10,000	20,556	0	5,000	2,344	43,674
1974	2,400	2,000	1,859	0	10,000	0	0	30,000	46,259	2,400	2,000	1,859	0	10,000	0	0	29,358	0	45,618
1975	2,400	2,000	1,538	577	10,000	0	0	20,000	36,516	2,400	2,000	1,538	577	10,000	0	0	20,000	11,573	48,089
1976	2,400	0	0	0	0	0	4,866	0	7,266	2,400	0	0	0	0	0	4,866	0	14,411	21,678
1977	2,400	0	0	0	0	0	2,630	0	5,030	2,400	0	0	0	0	0	2,630	0	2,656	7,686
1978	2,400	5,000	4,222	0	40,000	23,000	0	30,000	104,622	2,400	5,000	4,222	0	27,512	0	0	0	0	39,134
1979	2,400	2,000	1,217	1,800	10,000	0	0	5,000	22,417	2,400	2,000	1,217	1,800	10,000	0	0	5,000	14,000	36,417
1980	2,400	2,000	2,894	0	10,000	23,000	0	20,000	60,294	2,400	2,000	2,894	0	10,000	23,000	0	6,750	0	47,045
1981	2,400	0	335	1,800	5,000	0	25,858	5,000	40,394	2,400	0	335	1,800	5,000	0	25,858	5,000	6,008	46,402
1982	2,400	2,000	3,658	0	10,000	23,000	0	30,000	71,058	2,400	2,000	3,658	0	10,000	23,000	0	3,517	0	44,575
1983	2,400	5,000	5,000	1,800	40,000	23,000	0	30,000	107,200	2,400	5,000	5,000	1,800	26,937	0	0	0	0	41,137
1984	2,400	2,000	1,285	1,800	10,000	0	0	20,000	37,485	2,400	2,000	1,285	1,800	10,000	0	0	20,000	11,229	48,714
1985	2,400	0	64	0	5,000	0	0	5,000	12,464	2,400	0	64	0	5,000	0	0	5,000	16,000	28,464
1986	2,400	2,000	2,670	0	10,000	23,000	0	5,000	45,070	2,400	2,000	2,670	0	10,000	23,000	0	5,000	1,913	46,983
1987	2,400	0	0	0	0	0	12,493	0	14,893	2,400	0	0	0	0	0	12,493	0	15,750	30,643
1988	2,400	0	0	0	0	0	695	0	3,095	2,400	0	0	0	0	0	695	0	14,000	17,095
1989	2,400	0	0	0	0	0	16,087	0	18,487	2,400	0	0	0	0	0	16,087	0	11,771	30,258
1990	2,400	0	0	0	0	0	0	0	2,400	2,400	0	0	0	0	0	0	0	3,087	5,487
1991	2,400	0	0	0	0	0	7,460	0	9,860	2,400	0	0	0	0	0	7,460	0	0	9,860
1992	2,400	0	0	0	0	0	12,205	0	14,605	2,400	0	0	0	0	0	12,205	0	0	14,605
1993	2,400	2,000	2,673	0	10,000	0	35,335	20,000	72,408	2,400	2,000	2,673	0	10,000	0	28,122	0	0	45,195
1994	2,400	0	0	1,800	5,000	0	30,723	5,000	44,923	2,400	0	0	1,800	5,000	0	30,723	5,000	336	45,259
1995	2,400	5,000	5,000	0	40,000	23,000	0	30,000	105,400	2,400	5,000	5,000	0	30,347	0	0	0	0	42,747
1996	2,400	2,000	1,988	1,800	10,000	0	0	20,000	38,188	2,400	2,000	1,988	1,800	10,000	0	0	20,000	6,237	44,425
1997	2,400	2,000	1,064	0	10,000	0	0	20,000	35,464	2,400	2,000	1,064	0	10,000	0	0	20,000	11,915	47,379
1998	2,400	5,000	4,472	0	40,000	23,000	0	30,000	104,872	2,400	5,000	4,472	0	27,663	0	0	0	0	39,534
1999	2,400	0	696	1,800	5,000	0	0	5,000	14,896	2,400	0	696	1,800	5,000	0	0	5,000	14,911	29,807
2000	2,400	2,000	1,267	0	10,000	0	0	5,000	20,667	2,400	2,000	1,267	0	10,000	0	0	5,000	14,000	34,667
2001	2,400	0	0	0	5,000	0	15,543	0	22,943	2,400	0	0	0	5,000	0	15,543	0	14,000	36,943
2002	2,400	0	0	0	5,000	0	21,879	5,000	34,279	2,400	0	0	0	5,000	0	21,879	5,000	13,525	47,804
2003	2,400	0	214	0	5,000	0	24,266	5,000	36,880	2,400	0	214	0	5,000	0	24,266	5,000	9,475	46,356
2004	2,400	0	0	0	5,000	0	37,310	20,000	64,710	2,400	0	0	0	5,000	0	37,310	1,487	0	46,197
2005	2,400	5,000	5,000	1,800	40,000	23,000	0	30,000	107,200	2,400	5,000	5,000	1,800	29,397	0	0	0	0	43,597
2006	2,400	5,000	5,000	1,800	40,000	23,000	0	30,000	107,200	2,400	5,000	5,000	1,800	31,582	0	0	0	0	45,782
2007	2,400	0	0	1,800	0	0	26,650	5,000	35,850	2,400	0	0	1,800	0	0	26,650	5,000	12,547	48,397
2008	2,400	0	250	0	5,000	0	21,320	5,000	33,970	2,400	0	250	0	5,000	0	21,320	5,000	14,619	48,589
2009	2,400	2,000	900	0	10,000	0	5,330	0	20,630	2,400	2,000	900	0	10,000	0	5,330	0	16,000	36,630
2010	2,400	2,000	750	0	10,000	0	23,985	5,000	44,135	2,400	2,000	750	0	10,000	0	23,985	1,885	0	41,020
2011	2,400	2,000	1,000	1,800	10,000	23,000	0	30,000	70,200	2,400	2,000	1,000	1,800	10,000	23,000	0	6,293	0	46,493
2012	2,400	0	0	1,800	0	0	21,320	5,000	30,520	2,400	0	0	1,800	0	0	21,320	5,000	15,131	45,651
2013	2,400	0	0	0	0	0	10,660	0	13,060	2,400	0	0	0	0	0	10,660	0	13,602	26,662

Table A3-14 Model Run 2: Projected Water Budget

Year	Effective Precip.	Applied Water Demand	Surface Water Demand	Surface Water Deliveries	Ground Water Pumping	To Storage
	(20)	(21)	(22)	(23)	(24)	(25)
1958	10,103	43,767	41,579	41,579	2,188	2,000
1959	3,399	51,216	48,655	45,054	6,162	0
1960	6,245	48,054	45,651	34,011	14,043	0
1961	2,933	51,734	49,148	45,464	6,270	0
1962	5,866	48,476	46,052	46,052	2,424	0
1963	7,265	46,921	44,575	44,575	2,346	2,000
1964	3,858	50,707	48,171	40,971	9,736	0
1965	6,577	47,685	45,301	45,301	2,384	2,000
1966	3,992	50,557	48,030	48,030	2,528	0
1967	7,455	46,710	44,374	44,374	2,335	2,000
1968	5,147	49,275	46,811	46,811	2,464	0
1969	9,692	44,224	42,013	42,013	2,211	2,000
1970	5,795	48,555	46,127	45,896	2,659	0
1971	5,091	49,336	46,870	42,995	6,341	0
1972	4,340	50,171	47,662	47,662	2,509	0
1973	8,119	45,972	43,674	43,674	2,299	0
1974	6,277	48,019	45,618	45,618	2,401	642
1975	3,936	50,620	48,089	48,089	2,531	0
1976	5,589	48,783	46,344	21,678	27,105	0
1977	3,739	50,838	48,297	7,686	43,152	0
1978	12,420	41,194	39,134	39,134	2,060	2,000
1979	4,230	50,294	47,779	36,417	13,877	0
1980	4,925	49,521	47,045	47,045	2,476	2,000
1981	5,534	48,845	46,402	46,402	2,442	0
1982	7,265	46,921	44,575	44,575	2,346	2,000
1983	10,522	43,302	41,137	41,137	2,165	2,000
1984	3,344	51,278	48,714	48,714	2,564	0
1985	4,032	50,513	47,988	28,464	22,049	0
1986	4,984	49,455	46,983	46,983	2,473	0
1987	5,895	48,444	46,022	30,643	17,801	0
1988	4,601	49,881	47,387	17,095	32,786	0
1989	2,733	51,957	49,359	30,258	21,699	0
1990	2,901	51,770	49,181	5,487	46,283	0
1991	6,487	47,785	45,396	9,860	37,925	0
1992	5,637	48,730	46,294	14,605	34,126	0
1993	6,678	47,574	45,195	45,195	2,379	2,000
1994	6,617	47,641	45,259	45,259	2,382	0
1995	8,997	44,997	42,747	42,747	2,250	2,000
1996	7,408	46,763	44,425	44,425	2,338	0
1997	4,609	49,872	47,379	47,379	2,494	0
1998	12,040	41,615	39,534	39,534	2,081	2,000
1999	4,830	49,626	47,145	29,807	19,819	0
2000	6,127	48,186	45,776	34,667	13,519	0
2001	6,989	47,228	44,867	36,943	10,285	0
2002	4,206	50,320	47,804	47,804	2,516	0
2003	3,724	50,856	48,313	46,356	4,501	0
2004	5,729	48,628	46,197	46,197	2,431	2,000
2005	8,192	45,891	43,597	43,597	2,295	2,000
2006	6,121	48,192	45,782	45,782	2,410	2,000
2007	3,644	50,944	48,397	48,397	2,547	0
2008	3,463	51,146	48,589	48,589	2,557	0
2009	3,297	51,330	48,764	36,630	14,700	0
2010	10,633	43,179	41,020	41,020	2,159	2,000
2011	5,448	48,940	46,493	46,493	2,447	2,000
2012	4,751	49,714	47,228	45,651	4,063	0
2013	3,305	51,322	48,756	26,662	24,660	0
Average	**5,852**	**48,491**	**46,066**	**39,348**	**9,143**	

Table A3-15 Model Run 2: Projected Groundwater Storage

Year	GW Pumping	Sust. Yield	GW Balance annual	GW Balance cumul.
	(1)	(2)	(3)	(4)
1958	2,188	9,454	7,266	7,266
1959	6,162	9,454	3,292	10,558
1960	14,043	9,454	(4,589)	5,968
1961	6,270	9,454	3,184	9,152
1962	2,424	9,454	7,030	16,182
1963	2,346	9,454	7,108	23,290
1964	9,736	9,454	(282)	23,009
1965	2,384	9,454	7,070	30,078
1966	2,528	9,454	6,926	37,005
1967	2,335	9,454	7,119	44,123
1968	2,464	9,454	6,990	51,113
1969	2,211	9,454	7,243	58,356
1970	2,659	9,454	6,795	65,151
1971	6,341	9,454	3,113	68,264
1972	2,509	9,454	6,945	75,210
1973	2,299	9,454	7,155	82,365
1974	2,401	9,454	7,053	89,418
1975	2,531	9,454	6,923	96,341
1976	27,105	9,454	(17,651)	78,690
1977	43,152	9,454	(33,698)	44,991
1978	2,060	9,454	7,394	52,386
1979	13,877	9,454	(4,423)	47,963
1980	2,476	9,454	6,978	54,941
1981	2,442	9,454	7,012	61,953
1982	2,346	9,454	7,108	69,061
1983	2,165	9,454	7,289	76,349
1984	2,564	9,454	6,890	83,240
1985	22,049	9,454	(12,595)	70,644
1986	2,473	9,454	6,981	77,626
1987	17,801	9,454	(8,347)	69,279
1988	32,786	9,454	(23,332)	45,947
1989	21,699	9,454	(12,245)	33,702
1990	46,283	9,454	(36,829)	(3,127)
1991	37,925	9,454	(28,471)	(31,597)
1992	34,126	9,454	(24,672)	(56,269)
1993	2,379	9,454	7,075	(49,194)
1994	2,382	9,454	7,072	(42,122)
1995	2,250	9,454	7,204	(34,918)
1996	2,338	9,454	7,116	(27,802)
1997	2,494	9,454	6,960	(20,841)
1998	2,081	9,454	7,373	(13,468)
1999	19,819	9,454	(10,365)	(23,833)
2000	13,519	9,454	(4,065)	(27,898)
2001	10,285	9,454	(831)	(28,730)
2002	2,516	9,454	6,938	(21,792)
2003	4,501	9,454	4,953	(16,838)
2004	2,431	9,454	7,023	(9,816)
2005	2,295	9,454	7,159	(2,656)
2006	2,410	9,454	7,044	4,388
2007	2,547	9,454	6,907	11,295
2008	2,557	9,454	6,897	18,192
2009	14,700	9,454	(5,246)	12,945
2010	2,159	9,454	7,295	20,240
2011	2,447	9,454	7,007	27,247
2012	4,063	9,454	5,391	32,639
2013	24,660	9,454	(15,206)	17,433

Model Run 3: Actions 1 & 2 (Additional Produced Water)

Table A3-16 Model Run 3: Banking Programs

Year	North Kern Banking Program				Rosedale Banking Program				West Kern Banking Program				Total of Banking Programs				
	Avail. (1)	Spreading (2)	Extraction (3)	Act. Balance (4)	Avail. (5)	Spreading (6)	Extraction (7)	Act. Balance (8)	Avail. (9)	Spreading (10)	Extraction (11)	Act. Balance (12)	Spreading (13)	Extraction (14)	Act. Balance (15)	From Banking (16)	Carryover (17)
				29,923				30,384				7,666			67,973		
1958	29,105	86	0	30,000	29,019	20,482	0	40,000	8,537	3,667	0	9,500	24,235	0	79,500	0	4,870
1959	0	0	-5,000	25,000	0	0	-9,000	31,000	0	0	-2,000	7,500	0	-16,000	63,500	16,000	0
1960	0	0	-5,000	20,000	0	0	-9,000	22,000	0	0	-2,000	5,500	0	-16,000	47,500	16,000	0
1961	0	0	-5,000	15,000	0	0	-9,000	13,000	0	0	-2,000	3,500	0	-16,000	31,500	16,000	0
1962	0	0	-1,045	13,955	0	0	0	13,000	0	0	0	3,500	0	-1,045	30,455	1,045	0
1963	5,546	5,546	0	18,947	0	0	0	13,000	0	0	0	3,500	5,546	0	35,446	0	0
1964	0	0	-5,000	13,947	0	0	-9,000	4,000	0	0	-2,000	1,500	0	-16,000	19,446	16,000	0
1965	30,521	15,000	0	27,447	15,521	15,521	0	11,287	0	0	0	1,500	30,521	0	40,233	0	0
1966	0	0	-2,681	24,766	0	0	0	11,287	0	0	0	1,500	0	-2,681	37,552	2,681	0
1967	60,944	5,816	0	30,000	55,128	50,000	0	34,761	5,128	5,128	0	4,063	60,944	0	68,824	0	0
1968	0	0	-5,000	25,000	0	0	-3,508	31,253	0	0	0	4,063	0	-8,508	60,316	8,508	0
1969	63,445	5,556	0	30,000	57,889	18,632	0	40,000	39,257	5,468	0	6,798	29,655	0	76,798	0	33,789
1970	0	0	-5,000	25,000	0	0	-8,731	31,269	0	0	0	6,798	0	-13,731	63,067	13,731	0
1971	0	0	-5,000	20,000	0	0	-9,000	22,269	0	0	-2,000	4,798	0	-16,000	47,067	16,000	0
1972	0	0	-5,000	15,000	0	0	-4,390	17,879	0	0	0	4,798	0	-9,390	37,677	9,390	0
1973	0	0	0	15,000	0	0	0	17,879	0	0	0	4,798	0	0	37,677	0	0
1974	1,282	1,282	0	16,154	0	0	0	17,879	0	0	0	4,798	1,282	0	38,831	0	0
1975	0	0	-5,000	11,154	0	0	-2,851	15,028	0	0	0	4,798	0	-7,851	30,980	7,851	0
1976	0	0	-5,000	6,154	0	0	-9,000	6,028	0	0	-2,000	2,798	0	-16,000	14,980	16,000	0
1977	0	0	-5,000	1,154	0	0	-6,028	0	0	0	-2,000	798	0	-13,028	1,952	13,028	0
1978	65,988	15,000	0	14,654	50,988	50,000	0	23,474	988	988	0	1,292	65,988	0	39,420	0	0
1979	0	0	-5,000	9,654	0	0	-9,000	14,474	0	0	-1,292	0	0	-15,292	24,128	15,292	0
1980	13,750	13,750	0	22,029	0	0	0	14,474	0	0	0	0	13,750	0	36,503	0	0
1981	0	0	-3,508	18,520	0	0	0	14,474	0	0	0	0	0	-3,508	32,994	3,508	0
1982	26,983	12,755	0	30,000	14,228	14,228	0	21,154	0	0	0	0	26,983	0	51,154	0	0
1983	66,563	0	0	30,000	66,563	40,142	0	40,000	26,421	7,500	0	3,750	47,642	0	73,750	0	18,921
1984	0	0	-5,000	25,000	0	0	-3,729	36,271	0	0	0	3,750	0	-8,729	65,021	8,729	0
1985	0	0	-5,000	20,000	0	0	-9,000	27,271	0	0	-2,000	1,750	0	-16,000	49,021	16,000	0
1986	0	0	0	20,000	0	0	0	27,271	0	0	0	1,750	0	0	49,021	0	0
1987	0	0	-5,000	15,000	0	0	-9,000	18,271	0	0	-1,750	0	0	-15,750	33,271	15,750	0
1988	0	0	-5,000	10,000	0	0	-9,000	9,271	0	0	0	0	0	-14,000	19,271	14,000	0
1989	0	0	-5,000	5,000	0	0	-9,000	271	0	0	0	0	0	-14,000	5,271	14,000	0
1990	0	0	-5,000	0	0	0	-271	0	0	0	0	0	0	-5,271	0	5,271	0
1991	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
1992	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
1993	27,713	15,000	0	13,500	12,713	12,713	0	5,969	0	0	0	0	27,713	0	19,469	0	0
1994	164	164	0	13,647	0	0	0	5,969	0	0	0	0	164	0	19,616	0	0
1995	64,953	15,000	0	27,147	49,953	49,953	0	29,421	0	0	0	0	64,953	0	56,568	0	0
1996	0	0	-3,737	23,411	0	0	0	29,421	0	0	0	0	0	-3,737	52,831	3,737	0
1997	0	0	-5,000	18,411	0	0	-4,415	25,005	0	0	0	0	0	-9,415	43,416	9,415	0
1998	65,837	12,877	0	30,000	52,960	31,938	0	40,000	21,022	7,500	0	3,750	52,315	0	73,750	0	13,522
1999	0	0	-5,000	25,000	0	0	-9,000	31,000	0	0	-2,000	1,750	0	-16,000	57,750	16,000	0
2000	0	0	-5,000	20,000	0	0	-9,000	22,000	0	0	-1,750	0	0	-15,750	42,000	15,750	0
2001	0	0	-5,000	15,000	0	0	-9,000	13,000	0	0	0	0	0	-14,000	28,000	14,000	0
2002	0	0	-5,000	10,000	0	0	-6,025	6,975	0	0	0	0	0	-11,025	16,975	11,025	0
2003	0	0	-5,000	5,000	0	0	-3,933	3,042	0	0	0	0	0	-8,933	8,042	8,933	0
2004	19,013	15,000	0	18,500	4,013	4,013	0	4,926	0	0	0	0	19,013	0	23,426	0	0
2005	64,103	12,778	0	30,000	51,326	50,000	0	28,401	1,326	1,326	0	663	64,103	0	59,063	0	0
2006	61,918	0	0	30,000	61,918	24,707	0	40,000	37,211	7,169	0	4,247	31,875	0	74,247	0	30,042
2007	0	0	-5,000	25,000	0	0	-5,047	34,953	0	0	0	4,247	0	-10,047	64,200	10,047	0
2008	0	0	-5,000	20,000	0	0	-7,119	27,835	0	0	0	4,247	0	-12,119	52,082	12,119	0
2009	0	0	-5,000	15,000	0	0	-9,000	18,835	0	0	-2,000	2,247	0	-16,000	36,082	16,000	0
2010	3,615	3,615	0	18,254	0	0	0	18,835	0	0	0	2,247	3,615	0	39,335	0	0
2011	24,207	13,052	0	30,000	11,155	11,155	0	24,072	0	0	0	2,247	24,207	0	56,319	0	0
2012	0	0	-5,000	25,000	0	0	-9,000	15,072	0	0	-208	2,039	0	-14,208	42,111	14,208	0
2013	0	0	-5,000	20,000	0	0	-9,000	6,072	0	0	-2,000	39	0	-16,000	26,111	16,000	0

Table A3-17 Model Run 3: Surface Water

	Water Available									Surface Water Deliveries by Source									
Year	Produced Water	Friant Unc.	KTWD Class 2	From Storage	Friant Purchase	Kern River	KTWD XVC	SOD Purchase	Total	Produced Water	Friant Unc.	KTWD Class 2	From Storage	Friant Purchase	Kern River	KTWD XVC	SOD Purchase	From Banking	Total
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)	(13)	(14)	(15)	(16)	(17)	(18)	(19)
1958	4,900	2,000	2,784	0	10,000	23,000	0	30,000	72,684	4,900	2,000	2,784	0	10,000	21,895	0	0	0	41,579
1959	4,900	0	0	1,800	5,000	0	19,854	0	31,554	4,900	0	0	1,800	5,000	0	19,854	0	16,000	47,554
1960	4,900	0	0	0	0	0	15,611	0	20,511	4,900	0	0	0	0	0	15,611	0	16,000	36,511
1961	4,900	0	0	0	0	0	22,064	5,000	31,964	4,900	0	0	0	0	0	22,064	5,000	16,000	47,964
1962	4,900	2,000	1,492	0	10,000	0	21,615	5,000	45,007	4,900	2,000	1,492	0	10,000	0	21,615	5,000	1,045	46,052
1963	4,900	2,000	1,927	0	10,000	0	28,294	5,000	52,121	4,900	2,000	1,927	0	10,000	0	25,748	0	0	44,575
1964	4,900	0	0	1,800	5,000	0	15,771	0	27,471	4,900	0	0	1,800	5,000	0	15,771	0	16,000	43,471
1965	4,900	2,000	1,877	0	10,000	0	39,045	20,000	77,822	4,900	2,000	1,877	0	10,000	0	26,524	0	0	45,301
1966	4,900	0	289	1,800	5,000	0	28,359	5,000	45,348	4,900	0	289	1,800	5,000	0	28,359	5,000	2,681	48,030
1967	4,900	5,000	4,418	0	40,000	23,000	0	30,000	107,318	4,900	5,000	4,418	0	30,056	0	0	0	0	44,374
1968	4,900	0	0	1,800	5,000	0	21,603	5,000	38,303	4,900	0	0	1,800	5,000	0	21,603	5,000	8,508	46,811
1969	4,900	5,000	4,557	0	40,000	23,000	0	30,000	107,457	4,900	5,000	4,557	0	27,555	0	0	0	0	42,013
1970	4,900	0	696	1,800	5,000	0	0	20,000	32,396	4,900	0	696	1,800	5,000	0	0	20,000	13,731	46,127
1971	4,900	0	478	0	5,000	0	19,117	0	29,495	4,900	0	478	0	5,000	0	19,117	0	16,000	45,495
1972	4,900	0	0	0	5,000	0	23,372	5,000	38,272	4,900	0	0	0	5,000	0	23,372	5,000	9,390	47,662
1973	4,900	2,000	1,374	0	10,000	20,556	0	5,000	43,830	4,900	2,000	1,374	0	10,000	20,556	0	4,844	0	43,674
1974	4,900	2,000	1,859	141	10,000	0	0	30,000	48,900	4,900	2,000	1,859	141	10,000	0	0	26,718	0	45,618
1975	4,900	2,000	1,538	1,800	10,000	0	0	20,000	40,238	4,900	2,000	1,538	1,800	10,000	0	0	20,000	7,851	48,089
1976	4,900	0	0	0	0	0	4,866	0	9,766	4,900	0	0	0	0	0	4,866	0	16,000	25,766
1977	4,900	0	0	0	0	0	2,630	0	7,530	4,900	0	0	0	0	0	2,630	0	13,028	20,558
1978	4,900	5,000	4,222	0	40,000	23,000	0	30,000	107,122	4,900	5,000	4,222	0	25,012	0	0	0	0	39,134
1979	4,900	2,000	1,217	1,800	10,000	0	0	5,000	24,917	4,900	2,000	1,217	1,800	10,000	0	0	5,000	15,292	40,209
1980	4,900	2,000	2,894	0	10,000	23,000	0	20,000	62,794	4,900	2,000	2,894	0	10,000	23,000	0	4,250	0	47,045
1981	4,900	0	335	1,800	5,000	0	25,858	5,000	42,894	4,900	0	335	1,800	5,000	0	25,858	5,000	3,508	46,402
1982	4,900	2,000	3,658	0	10,000	23,000	0	30,000	73,558	4,900	2,000	3,658	0	10,000	23,000	0	1,017	0	44,575
1983	4,900	5,000	5,000	1,800	40,000	23,000	0	30,000	109,700	4,900	5,000	5,000	1,800	24,437	0	0	0	0	41,137
1984	4,900	2,000	1,285	1,800	10,000	0	0	20,000	39,985	4,900	2,000	1,285	1,800	10,000	0	0	20,000	8,729	48,714
1985	4,900	0	64	0	5,000	0	0	5,000	14,964	4,900	0	64	0	5,000	0	0	5,000	16,000	30,964
1986	4,900	2,000	2,670	0	10,000	23,000	0	5,000	47,570	4,900	2,000	2,670	0	10,000	23,000	0	4,413	0	46,983
1987	4,900	0	0	528	0	0	12,493	0	17,921	4,900	0	0	528	0	0	12,493	0	15,750	33,671
1988	4,900	0	0	0	0	0	695	0	5,595	4,900	0	0	0	0	0	695	0	14,000	19,595
1989	4,900	0	0	0	0	0	16,087	0	20,987	4,900	0	0	0	0	0	16,087	0	14,000	34,987
1990	4,900	0	0	0	0	0	0	0	4,900	4,900	0	0	0	0	0	0	0	5,271	10,171
1991	4,900	0	0	0	0	0	7,460	0	12,360	4,900	0	0	0	0	0	7,460	0	0	12,360
1992	4,900	0	0	0	0	0	12,205	0	17,105	4,900	0	0	0	0	0	12,205	0	0	17,105
1993	4,900	2,000	2,673	0	10,000	0	35,335	20,000	74,908	4,900	2,000	2,673	0	10,000	0	25,622	0	0	45,195
1994	4,900	0	0	1,800	5,000	0	30,723	5,000	47,423	4,900	0	0	1,800	5,000	0	30,723	2,836	0	45,259
1995	4,900	5,000	5,000	1,800	40,000	23,000	0	30,000	109,700	4,900	5,000	5,000	1,800	26,047	0	0	0	0	42,747
1996	4,900	2,000	1,988	1,800	10,000	0	0	20,000	40,688	4,900	2,000	1,988	1,800	10,000	0	0	20,000	3,737	44,425
1997	4,900	2,000	1,064	0	10,000	0	0	20,000	37,964	4,900	2,000	1,064	0	10,000	0	0	20,000	9,415	47,379
1998	4,900	5,000	4,472	0	40,000	23,000	0	30,000	107,372	4,900	5,000	4,472	0	25,163	0	0	0	0	39,534
1999	4,900	0	696	1,800	5,000	0	0	5,000	17,396	4,900	0	696	1,800	5,000	0	0	5,000	16,000	33,396
2000	4,900	2,000	1,267	0	10,000	0	0	5,000	23,167	4,900	2,000	1,267	0	10,000	0	0	5,000	15,750	38,917
2001	4,900	0	0	0	5,000	0	15,543	0	25,443	4,900	0	0	0	5,000	0	15,543	0	14,000	39,443
2002	4,900	0	0	0	5,000	0	21,879	5,000	36,779	4,900	0	0	0	5,000	0	21,879	5,000	11,025	47,804
2003	4,900	0	214	0	5,000	0	24,266	5,000	39,380	4,900	0	214	0	5,000	0	24,266	5,000	8,933	48,313
2004	4,900	0	0	0	5,000	0	37,310	20,000	67,210	4,900	0	0	0	5,000	0	36,297	0	0	46,197
2005	4,900	5,000	5,000	1,800	40,000	23,000	0	30,000	109,700	4,900	5,000	5,000	1,800	26,897	0	0	0	0	43,597
2006	4,900	5,000	5,000	1,800	40,000	23,000	0	30,000	109,700	4,900	5,000	5,000	1,800	29,082	0	0	0	0	45,782
2007	4,900	0	0	1,800	0	0	26,650	5,000	38,350	4,900	0	0	1,800	0	0	26,650	5,000	10,047	48,397
2008	4,900	0	250	0	5,000	0	21,320	5,000	36,470	4,900	0	250	0	5,000	0	21,320	5,000	12,119	48,589
2009	4,900	2,000	900	0	10,000	0	5,330	0	23,130	4,900	2,000	900	0	10,000	0	5,330	0	16,000	39,130
2010	4,900	2,000	750	0	10,000	0	23,985	5,000	46,635	4,900	2,000	750	0	10,000	0	23,370	0	0	41,020
2011	4,900	2,000	1,000	1,800	10,000	23,000	0	30,000	72,700	4,900	2,000	1,000	1,800	10,000	23,000	0	3,793	0	46,493
2012	4,900	0	0	1,800	0	0	21,320	5,000	33,020	4,900	0	0	1,800	0	0	21,320	5,000	14,208	47,228
2013	4,900	0	0	0	0	0	10,660	0	15,560	4,900	0	0	0	0	0	10,660	0	16,000	31,560

Table A3-18 Model Run 3: Projected Water Budget

Year	Effective Precip.	Applied Water Demand	Surface Water Demand	Surface Water Deliveries	Ground Water Pumping	To Storage
	(20)	(21)	(22)	(23)	(24)	(25)
1958	10,103	43,767	41,579	41,579	2,188	2,000
1959	3,399	51,216	48,655	47,554	3,662	0
1960	6,245	48,054	45,651	36,511	11,543	0
1961	2,933	51,734	49,148	47,964	3,770	0
1962	5,866	48,476	46,052	46,052	2,424	0
1963	7,265	46,921	44,575	44,575	2,346	2,000
1964	3,858	50,707	48,171	43,471	7,236	0
1965	6,577	47,685	45,301	45,301	2,384	2,000
1966	3,992	50,557	48,030	48,030	2,528	0
1967	7,455	46,710	44,374	44,374	2,335	2,000
1968	5,147	49,275	46,811	46,811	2,464	0
1969	9,692	44,224	42,013	42,013	2,211	2,000
1970	5,795	48,555	46,127	46,127	2,428	0
1971	5,091	49,336	46,870	45,495	3,841	0
1972	4,340	50,171	47,662	47,662	2,509	0
1973	8,119	45,972	43,674	43,674	2,299	156
1974	6,277	48,019	45,618	45,618	2,401	2,000
1975	3,936	50,620	48,089	48,089	2,531	0
1976	5,589	48,783	46,344	25,766	23,017	0
1977	3,739	50,838	48,297	20,558	30,281	0
1978	12,420	41,194	39,134	39,134	2,060	2,000
1979	4,230	50,294	47,779	40,209	10,085	0
1980	4,925	49,521	47,045	47,045	2,476	2,000
1981	5,534	48,845	46,402	46,402	2,442	0
1982	7,265	46,921	44,575	44,575	2,346	2,000
1983	10,522	43,302	41,137	41,137	2,165	2,000
1984	3,344	51,278	48,714	48,714	2,564	0
1985	4,032	50,513	47,988	30,964	19,549	0
1986	4,984	49,455	46,983	46,983	2,473	587
1987	5,895	48,444	46,022	33,671	14,772	0
1988	4,601	49,881	47,387	19,595	30,286	0
1989	2,733	51,957	49,359	34,987	16,970	0
1990	2,901	51,770	49,181	10,171	41,599	0
1991	6,487	47,785	45,396	12,360	35,425	0
1992	5,637	48,730	46,294	17,105	31,626	0
1993	6,678	47,574	45,195	45,195	2,379	2,000
1994	6,617	47,641	45,259	45,259	2,382	2,000
1995	8,997	44,997	42,747	42,747	2,250	2,000
1996	7,408	46,763	44,425	44,425	2,338	0
1997	4,609	49,872	47,379	47,379	2,494	0
1998	12,040	41,615	39,534	39,534	2,081	2,000
1999	4,830	49,626	47,145	33,396	16,230	0
2000	6,127	48,186	45,776	38,917	9,269	0
2001	6,989	47,228	44,867	39,443	7,785	0
2002	4,206	50,320	47,804	47,804	2,516	0
2003	3,724	50,856	48,313	48,313	2,543	0
2004	5,729	48,628	46,197	46,197	2,431	2,000
2005	8,192	45,891	43,597	43,597	2,295	2,000
2006	6,121	48,192	45,782	45,782	2,410	2,000
2007	3,644	50,944	48,397	48,397	2,547	0
2008	3,463	51,146	48,589	48,589	2,557	0
2009	3,297	51,330	48,764	39,130	12,200	0
2010	10,633	43,179	41,020	41,020	2,159	2,000
2011	5,448	48,940	46,493	46,493	2,447	2,000
2012	4,751	49,714	47,228	47,228	2,486	0
2013	3,305	51,322	48,756	31,560	19,762	0
Average	**5,852**	**48,491**	**46,066**	**40,726**	**7,764**	

Table A3-19 Model Run 3: Projected Groundwater Storage

Year	GW Pumping	Sust. Yield	GW Balance annual	GW Balance cumul.
	(1)	(2)	(3)	(4)
1958	2,188	9,454	7,266	7,266
1959	3,662	9,454	5,792	13,058
1960	11,543	9,454	(2,089)	10,968
1961	3,770	9,454	5,684	16,652
1962	2,424	9,454	7,030	23,682
1963	2,346	9,454	7,108	30,790
1964	7,236	9,454	2,218	33,009
1965	2,384	9,454	7,070	40,078
1966	2,528	9,454	6,926	47,005
1967	2,335	9,454	7,119	54,123
1968	2,464	9,454	6,990	61,113
1969	2,211	9,454	7,243	68,356
1970	2,428	9,454	7,026	75,382
1971	3,841	9,454	5,613	80,995
1972	2,509	9,454	6,945	87,941
1973	2,299	9,454	7,155	95,096
1974	2,401	9,454	7,053	102,149
1975	2,531	9,454	6,923	109,072
1976	23,017	9,454	(13,563)	95,509
1977	30,281	9,454	(20,827)	74,683
1978	2,060	9,454	7,394	82,077
1979	10,085	9,454	(631)	81,446
1980	2,476	9,454	6,978	88,424
1981	2,442	9,454	7,012	95,436
1982	2,346	9,454	7,108	102,544
1983	2,165	9,454	7,289	109,832
1984	2,564	9,454	6,890	116,723
1985	19,549	9,454	(10,095)	106,627
1986	2,473	9,454	6,981	113,609
1987	14,772	9,454	(5,318)	108,290
1988	30,286	9,454	(20,832)	87,458
1989	16,970	9,454	(7,516)	79,942
1990	41,599	9,454	(32,145)	47,798
1991	35,425	9,454	(25,971)	21,827
1992	31,626	9,454	(22,172)	(345)
1993	2,379	9,454	7,075	6,731
1994	2,382	9,454	7,072	13,803
1995	2,250	9,454	7,204	21,007
1996	2,338	9,454	7,116	28,123
1997	2,494	9,454	6,960	35,083
1998	2,081	9,454	7,373	42,456
1999	16,230	9,454	(6,776)	35,680
2000	9,269	9,454	185	35,865
2001	7,785	9,454	1,669	37,534
2002	2,516	9,454	6,938	44,472
2003	2,543	9,454	6,911	51,383
2004	2,431	9,454	7,023	58,406
2005	2,295	9,454	7,159	65,565
2006	2,410	9,454	7,044	72,610
2007	2,547	9,454	6,907	79,516
2008	2,557	9,454	6,897	86,413
2009	12,200	9,454	(2,746)	83,667
2010	2,159	9,454	7,295	90,962
2011	2,447	9,454	7,007	97,969
2012	2,486	9,454	6,968	104,937
2013	19,762	9,454	(10,308)	94,629

Model Run 4: Actions 1, 2, & 3 (Additional Surface Storage)

Table A3-20 Model Run 4: Banking Programs

Year	North Kern Banking Program				Rosedale Banking Program				West Kern Banking Program				Total of Banking Programs				
	Avail. (1)	Spreading (2)	Extraction (3)	Act. Balance (4)	Avail. (5)	Spreading (6)	Extraction (7)	Act. Balance (8)	Avail. (9)	Spreading (10)	Extraction (11)	Act. Balance (12)	Spreading (13)	Extraction (14)	Act. Balance (15)	From Banking (16)	Carryover (17)
				29,923				30,384				7,666			67,973		
1958	21,105	86	0	30,000	21,019	20,482	0	40,000	537	537	0	7,935	21,105	0	77,935	0	0
1959	0	0	-5,000	25,000	0	0	-4,901	35,099	0	0	0	7,935	0	-9,901	68,033	9,901	0
1960	0	0	-5,000	20,000	0	0	-9,000	26,099	0	0	-2,000	5,935	0	-16,000	52,033	16,000	0
1961	0	0	-5,000	15,000	0	0	-9,000	17,099	0	0	-2,000	3,935	0	-16,000	36,033	16,000	0
1962	0	0	-1,045	13,955	0	0	0	17,099	0	0	0	3,935	0	-1,045	34,989	1,045	0
1963	0	0	0	13,955	0	0	0	17,099	0	0	0	3,935	0	0	34,989	0	0
1964	0	0	-5,000	8,955	0	0	-9,000	8,099	0	0	-1,709	2,226	0	-15,709	19,280	15,709	0
1965	22,521	15,000	0	22,455	7,521	7,521	0	11,630	0	0	0	2,226	22,521	0	36,311	0	0
1966	0	0	0	22,455	0	0	0	11,630	0	0	0	2,226	0	0	36,311	0	0
1967	57,011	8,383	0	30,000	48,628	48,628	0	34,460	0	0	0	2,226	57,011	0	66,685	0	0
1968	0	0	-1,308	28,692	0	0	0	34,460	0	0	0	2,226	0	-1,308	65,377	1,308	0
1969	55,445	1,454	0	30,000	53,991	11,801	0	40,000	42,190	6,387	0	5,419	19,642	0	75,419	0	35,803
1970	0	0	-5,000	25,000	0	0	-1,531	38,469	0	0	0	5,419	0	-6,531	68,888	6,531	0
1971	0	0	-5,000	20,000	0	0	-9,000	29,469	0	0	-2,000	3,419	0	-16,000	52,888	16,000	0
1972	0	0	-5,000	15,000	0	0	-4,390	25,079	0	0	0	3,419	0	-9,390	43,498	9,390	0
1973	0	0	0	15,000	0	0	0	25,079	0	0	0	3,419	0	0	43,498	0	0
1974	0	0	0	15,000	0	0	0	25,079	0	0	0	3,419	0	0	43,498	0	0
1975	0	0	-5,000	10,000	0	0	-1,697	23,383	0	0	0	3,419	0	-6,697	36,802	6,697	0
1976	0	0	-5,000	5,000	0	0	-9,000	14,383	0	0	-2,000	1,419	0	-16,000	20,802	16,000	0
1977	0	0	-5,000	0	0	0	-9,000	5,383	0	0	-1,419	0	0	-15,419	5,383	15,419	0
1978	57,988	15,000	0	13,500	42,988	42,988	0	25,565	0	0	0	0	57,988	0	39,065	0	0
1979	0	0	-5,000	8,500	0	0	-9,000	16,565	0	0	0	0	0	-14,000	25,065	14,000	0
1980	5,750	5,750	0	13,675	0	0	0	16,565	0	0	0	0	5,750	0	30,239	0	0
1981	0	0	0	13,675	0	0	0	16,565	0	0	0	0	0	0	30,239	0	0
1982	22,306	15,000	0	27,175	7,306	7,306	0	19,995	0	0	0	0	22,306	0	47,169	0	0
1983	65,763	3,139	0	30,000	62,624	42,611	0	40,000	20,013	7,500	0	3,750	53,251	0	73,750	0	12,513
1984	0	0	-1,529	28,471	0	0	0	40,000	0	0	0	3,750	0	-1,529	72,221	1,529	0
1985	0	0	-5,000	23,471	0	0	-9,000	31,000	0	0	-2,000	1,750	0	-16,000	56,221	16,000	0
1986	0	0	0	23,471	0	0	0	31,000	0	0	0	1,750	0	0	56,221	0	0
1987	0	0	-5,000	18,471	0	0	-9,000	22,000	0	0	-1,750	0	0	-15,750	40,471	15,750	0
1988	0	0	-5,000	13,471	0	0	-9,000	13,000	0	0	0	0	0	-14,000	26,471	14,000	0
1989	0	0	-5,000	8,471	0	0	-9,000	4,000	0	0	0	0	0	-14,000	12,471	14,000	0
1990	0	0	-5,000	3,471	0	0	-4,000	0	0	0	0	0	0	-9,000	3,471	9,000	0
1991	0	0	-3,471	0	0	0	0	0	0	0	0	0	0	-3,471	0	3,471	0
1992	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
1993	19,713	15,000	0	13,500	4,713	4,713	0	2,213	0	0	0	0	19,713	0	15,713	0	0
1994	0	0	0	13,500	0	0	0	2,213	0	0	0	0	0	0	15,713	0	0
1995	63,580	15,000	0	27,000	48,580	48,580	0	25,020	0	0	0	0	63,580	0	52,020	0	0
1996	0	0	0	27,000	0	0	0	25,020	0	0	0	0	0	0	52,020	0	0
1997	0	0	-5,000	22,000	0	0	-1,298	23,722	0	0	0	0	0	-6,298	45,722	6,298	0
1998	57,837	8,889	0	30,000	48,948	34,672	0	40,000	14,277	7,500	0	3,750	51,061	0	73,750	0	6,777
1999	0	0	-5,000	25,000	0	0	-9,000	31,000	0	0	-2,000	1,750	0	-16,000	57,750	16,000	0
2000	0	0	-5,000	20,000	0	0	-9,000	22,000	0	0	-1,750	0	0	-15,750	42,000	15,750	0
2001	0	0	-5,000	15,000	0	0	-9,000	13,000	0	0	0	0	0	-14,000	28,000	14,000	0
2002	0	0	-5,000	10,000	0	0	-6,025	6,975	0	0	0	0	0	-11,025	16,975	11,025	0
2003	0	0	-5,000	5,000	0	0	-3,933	3,042	0	0	0	0	0	-8,933	8,042	8,933	0
2004	11,013	11,013	0	14,912	0	0	0	3,042	0	0	0	0	11,013	0	17,954	0	0
2005	63,303	15,000	0	28,412	48,303	48,303	0	25,720	0	0	0	0	63,303	0	54,132	0	0
2006	61,118	1,765	0	30,000	59,353	30,417	0	40,000	28,937	7,500	0	3,750	39,681	0	73,750	0	21,437
2007	0	0	-2,847	27,153	0	0	0	40,000	0	0	0	3,750	0	-2,847	70,903	2,847	0
2008	0	0	-5,000	22,153	0	0	-7,119	32,881	0	0	0	3,750	0	-12,119	58,785	12,119	0
2009	0	0	-5,000	17,153	0	0	-9,000	23,881	0	0	-2,000	1,750	0	-16,000	42,785	16,000	0
2010	0	0	0	17,153	0	0	0	23,881	0	0	0	1,750	0	0	42,785	0	0
2011	19,460	14,274	0	30,000	5,186	5,186	0	26,316	0	0	0	1,750	19,460	0	58,066	0	0
2012	0	0	-5,000	25,000	0	0	-2,008	24,308	0	0	0	1,750	0	-7,008	51,058	7,008	0
2013	0	0	-5,000	20,000	0	0	-9,000	15,308	0	0	-1,750	0	0	-15,750	35,308	15,750	0

Table A3-21 Model Run 4: Surface Water

	Water Available									Surface Water Deliveries by Source									
Year	Produced Water	Friant Unc.	KTWD Class 2	From Storage	Friant Purchase	Kern River	KTWD XVC	SOD Purchase	Total	Produced Water	Friant Unc.	KTWD Class 2	From Storage	Friant Purchase	Kern River	KTWD XVC	SOD Purchase	From Banking	Total
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)	(13)	(14)	(15)	(16)	(17)	(18)	(19)
1958	4,900	2,000	2,784	0	10,000	23,000	0	30,000	72,684	4,900	2,000	2,784	0	10,000	21,895	0	0	0	41,579
1959	4,900	0	0	9,000	5,000	0	19,854	0	38,754	4,900	0	0	9,000	5,000	0	19,854	0	9,901	48,655
1960	4,900	0	0	0	0	0	15,611	0	20,511	4,900	0	0	0	0	0	15,611	0	16,000	36,511
1961	4,900	0	0	0	0	0	22,064	5,000	31,964	4,900	0	0	0	0	0	22,064	5,000	16,000	47,964
1962	4,900	2,000	1,492	0	10,000	0	21,615	5,000	45,007	4,900	2,000	1,492	0	10,000	0	21,615	5,000	1,045	46,052
1963	4,900	2,000	1,927	0	10,000	0	28,294	5,000	52,121	4,900	2,000	1,927	0	10,000	0	25,748	0	0	44,575
1964	4,900	0	0	6,791	5,000	0	15,771	0	32,463	4,900	0	0	6,791	5,000	0	15,771	0	15,709	48,171
1965	4,900	2,000	1,877	0	10,000	0	39,045	20,000	77,822	4,900	2,000	1,877	0	10,000	0	26,524	0	0	45,301
1966	4,900	0	289	9,000	5,000	0	28,359	5,000	52,548	4,900	0	289	9,000	5,000	0	28,359	481	0	48,030
1967	4,900	5,000	4,418	4,067	40,000	23,000	0	30,000	111,385	4,900	5,000	4,418	4,067	25,989	0	0	0	0	44,374
1968	4,900	0	0	9,000	5,000	0	21,603	5,000	45,503	4,900	0	0	9,000	5,000	0	21,603	5,000	1,308	46,811
1969	4,900	5,000	4,557	0	40,000	23,000	0	30,000	107,457	4,900	5,000	4,557	0	27,555	0	0	0	0	42,013
1970	4,900	0	696	9,000	5,000	0	0	20,000	39,596	4,900	0	696	9,000	5,000	0	0	20,000	6,531	46,127
1971	4,900	0	478	0	5,000	0	19,117	0	29,495	4,900	0	478	0	5,000	0	19,117	0	16,000	45,495
1972	4,900	0	0	0	5,000	0	23,372	5,000	38,272	4,900	0	0	0	5,000	0	23,372	5,000	9,390	47,662
1973	4,900	2,000	1,374	0	10,000	20,556	0	5,000	43,830	4,900	2,000	1,374	0	10,000	20,556	0	4,844	0	43,674
1974	4,900	2,000	1,859	141	10,000	0	0	30,000	48,900	4,900	2,000	1,859	141	10,000	0	0	26,718	0	45,618
1975	4,900	2,000	1,538	2,954	10,000	0	0	20,000	41,392	4,900	2,000	1,538	2,954	10,000	0	0	20,000	6,697	48,089
1976	4,900	0	0	0	0	0	4,866	0	9,766	4,900	0	0	0	0	0	4,866	0	16,000	25,766
1977	4,900	0	0	0	0	0	2,630	0	7,530	4,900	0	0	0	0	0	2,630	0	15,419	22,949
1978	4,900	5,000	4,222	0	40,000	23,000	0	30,000	107,122	4,900	5,000	4,222	0	25,012	0	0	0	0	39,134
1979	4,900	2,000	1,217	9,000	10,000	0	0	5,000	32,117	4,900	2,000	1,217	9,000	10,000	0	0	5,000	14,000	46,117
1980	4,900	2,000	2,894	0	10,000	23,000	0	20,000	62,794	4,900	2,000	2,894	0	10,000	23,000	0	4,250	0	47,045
1981	4,900	0	335	9,000	5,000	0	25,858	5,000	50,094	4,900	0	335	9,000	5,000	0	25,858	1,308	0	46,402
1982	4,900	2,000	3,658	3,322	10,000	23,000	0	30,000	76,880	4,900	2,000	3,658	3,322	10,000	20,694	0	0	0	44,575
1983	4,900	5,000	5,000	9,000	40,000	23,000	0	30,000	116,900	4,900	5,000	5,000	9,000	17,237	0	0	0	0	41,137
1984	4,900	2,000	1,285	9,000	10,000	0	0	20,000	47,185	4,900	2,000	1,285	9,000	10,000	0	0	20,000	1,529	48,714
1985	4,900	0	64	0	5,000	0	0	5,000	14,964	4,900	0	64	0	5,000	0	0	5,000	16,000	30,964
1986	4,900	2,000	2,670	0	10,000	23,000	0	5,000	47,570	4,900	2,000	2,670	0	10,000	23,000	0	4,413	0	46,983
1987	4,900	0	0	528	0	0	12,493	0	17,921	4,900	0	0	528	0	0	12,493	0	15,750	33,671
1988	4,900	0	0	0	0	0	695	0	5,595	4,900	0	0	0	0	0	695	0	14,000	19,595
1989	4,900	0	0	0	0	0	16,087	0	20,987	4,900	0	0	0	0	0	16,087	0	14,000	34,987
1990	4,900	0	0	0	0	0	0	0	4,900	4,900	0	0	0	0	0	0	0	9,000	13,900
1991	4,900	0	0	0	0	0	7,460	0	12,360	4,900	0	0	0	0	0	7,460	0	3,471	15,831
1992	4,900	0	0	0	0	0	12,205	0	17,105	4,900	0	0	0	0	0	12,205	0	0	17,105
1993	4,900	2,000	2,673	0	10,000	0	35,335	20,000	74,908	4,900	2,000	2,673	0	10,000	0	25,622	0	0	45,195
1994	4,900	0	0	9,000	5,000	0	30,723	5,000	54,623	4,900	0	0	9,000	5,000	0	26,359	0	0	45,259
1995	4,900	5,000	5,000	8,427	40,000	23,000	0	30,000	116,327	4,900	5,000	5,000	8,427	19,420	0	0	0	0	42,747
1996	4,900	2,000	1,988	9,000	10,000	0	0	20,000	47,888	4,900	2,000	1,988	9,000	10,000	0	0	16,537	0	44,425
1997	4,900	2,000	1,064	3,117	10,000	0	0	20,000	41,081	4,900	2,000	1,064	3,117	10,000	0	0	20,000	6,298	47,379
1998	4,900	5,000	4,472	0	40,000	23,000	0	30,000	107,372	4,900	5,000	4,472	0	25,163	0	0	0	0	39,534
1999	4,900	0	696	9,000	5,000	0	0	5,000	24,596	4,900	0	696	9,000	5,000	0	0	5,000	16,000	40,596
2000	4,900	2,000	1,267	0	10,000	0	0	5,000	23,167	4,900	2,000	1,267	0	10,000	0	0	5,000	15,750	38,917
2001	4,900	0	0	0	5,000	0	15,543	0	25,443	4,900	0	0	0	5,000	0	15,543	0	14,000	39,443
2002	4,900	0	0	0	5,000	0	21,879	5,000	36,779	4,900	0	0	0	5,000	0	21,879	5,000	11,025	47,804
2003	4,900	0	214	0	5,000	0	24,266	5,000	39,380	4,900	0	214	0	5,000	0	24,266	5,000	8,933	48,313
2004	4,900	0	0	0	5,000	0	37,310	20,000	67,210	4,900	0	0	0	5,000	0	36,297	0	0	46,197
2005	4,900	5,000	5,000	9,000	40,000	23,000	0	30,000	116,900	4,900	5,000	5,000	9,000	19,697	0	0	0	0	43,597
2006	4,900	5,000	5,000	9,000	40,000	23,000	0	30,000	116,900	4,900	5,000	5,000	9,000	21,882	0	0	0	0	45,782
2007	4,900	0	0	9,000	0	0	26,650	5,000	45,550	4,900	0	0	9,000	0	0	26,650	5,000	2,847	48,397
2008	4,900	0	250	0	5,000	0	21,320	5,000	36,470	4,900	0	250	0	5,000	0	21,320	5,000	12,119	48,589
2009	4,900	2,000	900	0	10,000	0	5,330	0	23,130	4,900	2,000	900	0	10,000	0	5,330	0	16,000	39,130
2010	4,900	2,000	750	0	10,000	0	23,985	5,000	46,635	4,900	2,000	750	0	10,000	0	23,370	0	0	41,020
2011	4,900	2,000	1,000	5,054	10,000	23,000	0	30,000	75,954	4,900	2,000	1,000	5,054	10,000	23,000	0	540	0	46,493
2012	4,900	0	0	9,000	0	0	21,320	5,000	40,220	4,900	0	0	9,000	0	0	21,320	5,000	7,008	47,228
2013	4,900	0	0	0	0	0	10,660	0	15,560	4,900	0	0	0	0	0	10,660	0	15,750	31,310

Table A3-22 Model Run 4: Projected Water Budget

Year	Effective Precip.	Applied Water Demand	Surface Water Demand	Surface Water Deliveries	Ground Water Pumping	To Storage
	(20)	(21)	(22)	(23)	(24)	(25)
1958	10,103	43,767	41,579	41,579	2,188	10,000
1959	3,399	51,216	48,655	48,655	2,561	0
1960	6,245	48,054	45,651	36,511	11,543	0
1961	2,933	51,734	49,148	47,964	3,770	0
1962	5,866	48,476	46,052	46,052	2,424	0
1963	7,265	46,921	44,575	44,575	2,346	7,546
1964	3,858	50,707	48,171	48,171	2,535	0
1965	6,577	47,685	45,301	45,301	2,384	10,000
1966	3,992	50,557	48,030	48,030	2,528	4,519
1967	7,455	46,710	44,374	44,374	2,335	10,000
1968	5,147	49,275	46,811	46,811	2,464	0
1969	9,692	44,224	42,013	42,013	2,211	10,000
1970	5,795	48,555	46,127	46,127	2,428	0
1971	5,091	49,336	46,870	45,495	3,841	0
1972	4,340	50,171	47,662	47,662	2,509	0
1973	8,119	45,972	43,674	43,674	2,299	156
1974	6,277	48,019	45,618	45,618	2,401	3,282
1975	3,936	50,620	48,089	48,089	2,531	0
1976	5,589	48,783	46,344	25,766	23,017	0
1977	3,739	50,838	48,297	22,949	27,890	0
1978	12,420	41,194	39,134	39,134	2,060	10,000
1979	4,230	50,294	47,779	46,117	4,177	0
1980	4,925	49,521	47,045	47,045	2,476	10,000
1981	5,534	48,845	46,402	46,402	2,442	3,692
1982	7,265	46,921	44,575	44,575	2,346	10,000
1983	10,522	43,302	41,137	41,137	2,165	10,000
1984	3,344	51,278	48,714	48,714	2,564	0
1985	4,032	50,513	47,988	30,964	19,549	0
1986	4,984	49,455	46,983	46,983	2,473	587
1987	5,895	48,444	46,022	33,671	14,772	0
1988	4,601	49,881	47,387	19,595	30,286	0
1989	2,733	51,957	49,359	34,987	16,970	0
1990	2,901	51,770	49,181	13,900	37,870	0
1991	6,487	47,785	45,396	15,831	31,954	0
1992	5,637	48,730	46,294	17,105	31,626	0
1993	6,678	47,574	45,195	45,195	2,379	10,000
1994	6,617	47,641	45,259	45,259	2,382	9,364
1995	8,997	44,997	42,747	42,747	2,250	10,000
1996	7,408	46,763	44,425	44,425	2,338	3,463
1997	4,609	49,872	47,379	47,379	2,494	0
1998	12,040	41,615	39,534	39,534	2,081	10,000
1999	4,830	49,626	47,145	40,596	9,030	0
2000	6,127	48,186	45,776	38,917	9,269	0
2001	6,989	47,228	44,867	39,443	7,785	0
2002	4,206	50,320	47,804	47,804	2,516	0
2003	3,724	50,856	48,313	48,313	2,543	0
2004	5,729	48,628	46,197	46,197	2,431	10,000
2005	8,192	45,891	43,597	43,597	2,295	10,000
2006	6,121	48,192	45,782	45,782	2,410	10,000
2007	3,644	50,944	48,397	48,397	2,547	0
2008	3,463	51,146	48,589	48,589	2,557	0
2009	3,297	51,330	48,764	39,130	12,200	0
2010	10,633	43,179	41,020	41,020	2,159	5,615
2011	5,448	48,940	46,493	46,493	2,447	10,000
2012	4,751	49,714	47,228	47,228	2,486	0
2013	3,305	51,322	48,756	31,310	20,012	0
Average	**5,852**	**48,491**	**46,066**	**41,231**	**7,260**	

Table A3-23 Model Run 4: Projected Groundwater Storage

Year	GW Pumping	Sust. Yield	GW Balance annual	GW Balance cumul.
	(1)	(2)	(3)	(4)
1959	2,561	9,454	6,893	14,159
1960	11,543	9,454	(2,089)	12,070
1961	3,770	9,454	5,684	17,753
1962	2,424	9,454	7,030	24,784
1963	2,346	9,454	7,108	31,892
1964	2,535	9,454	6,919	38,810
1965	2,384	9,454	7,070	45,880
1966	2,528	9,454	6,926	52,806
1967	2,335	9,454	7,119	59,925
1968	2,464	9,454	6,990	66,915
1969	2,211	9,454	7,243	74,158
1970	2,428	9,454	7,026	81,184
1971	3,841	9,454	5,613	86,797
1972	2,509	9,454	6,945	93,742
1973	2,299	9,454	7,155	100,897
1974	2,401	9,454	7,053	107,951
1975	2,531	9,454	6,923	114,874
1976	23,017	9,454	(13,563)	101,311
1977	27,890	9,454	(18,436)	82,875
1978	2,060	9,454	7,394	90,270
1979	4,177	9,454	5,277	95,547
1980	2,476	9,454	6,978	102,525
1981	2,442	9,454	7,012	109,537
1982	2,346	9,454	7,108	116,644
1983	2,165	9,454	7,289	123,933
1984	2,564	9,454	6,890	130,824
1985	19,549	9,454	(10,095)	120,728
1986	2,473	9,454	6,981	127,710
1987	14,772	9,454	(5,318)	122,391
1988	30,286	9,454	(20,832)	101,559
1989	16,970	9,454	(7,516)	94,043
1990	37,870	9,454	(28,416)	65,628
1991	31,954	9,454	(22,500)	43,128
1992	31,626	9,454	(22,172)	20,956
1993	2,379	9,454	7,075	28,032
1994	2,382	9,454	7,072	35,104
1995	2,250	9,454	7,204	42,308
1996	2,338	9,454	7,116	49,424
1997	2,494	9,454	6,960	56,384
1998	2,081	9,454	7,373	63,757
1999	9,030	9,454	424	64,181
2000	9,269	9,454	185	64,366
2001	7,785	9,454	1,669	66,035
2002	2,516	9,454	6,938	72,973
2003	2,543	9,454	6,911	79,884
2004	2,431	9,454	7,023	86,907
2005	2,295	9,454	7,159	94,066
2006	2,410	9,454	7,044	101,110
2007	2,547	9,454	6,907	108,017
2008	2,557	9,454	6,897	114,914
2009	12,200	9,454	(2,746)	112,168
2010	2,159	9,454	7,295	119,463
2011	2,447	9,454	7,007	126,470
2012	2,486	9,454	6,968	133,438
2013	20,012	9,454	(10,558)	122,880

APPENDIX 4 – EXECUTIVE SUMMARY *(REG. § 354.4)*

The 2014 Sustainable Groundwater Management Act (SGMA) requires prioritized California groundwater basins to be managed by a Groundwater Sustainability Agency (GSA) and for "critically overdrafted" basins (including Kern and Tule subbasins) to adopt a Groundwater Sustainability Plan (GSP) by January 31, 2020 and achieve sustainability by January 31, 2040.

Kern-Tulare Water District (District or KTWD) has prepared this Groundwater Sustainability Plan (Plan) to assess the District's groundwater conditions within KTWD and to provide monitoring and management actions to achieve sustainability that comply with SGMA. The District understands that implementation of GSPs will require an initial period of significant data collection and confirmation of assumptions; therefore, the District will work collaboratively with adjacent agencies, including the Eastside Water Management Area (EWMA), Cawelo Water District, Southern San Joaquin Municipal Utility District, and Eastern Tule GSA on changes to our GSPs as informed by the data.

A4.1 Description of Plan Coverage

The District has determined three management areas as shown in Figure A4-1 will be required to address unique management situations within the District. These management areas are described below:

KTWD Tulare County Management Area (TCMA)

The District is located in both the Tule and Kern subbasins of the Tulare Lake Groundwater Basin. Landowners within the Tulare County portion of the District will be represented by the Eastern Tule GSA (ETGSA), of the Tule Subbasin, and governed by ETGSA's GSP. The ETGSA is developing a GSP to cover all members' lands within the GSA and also includes a KTWD management area.

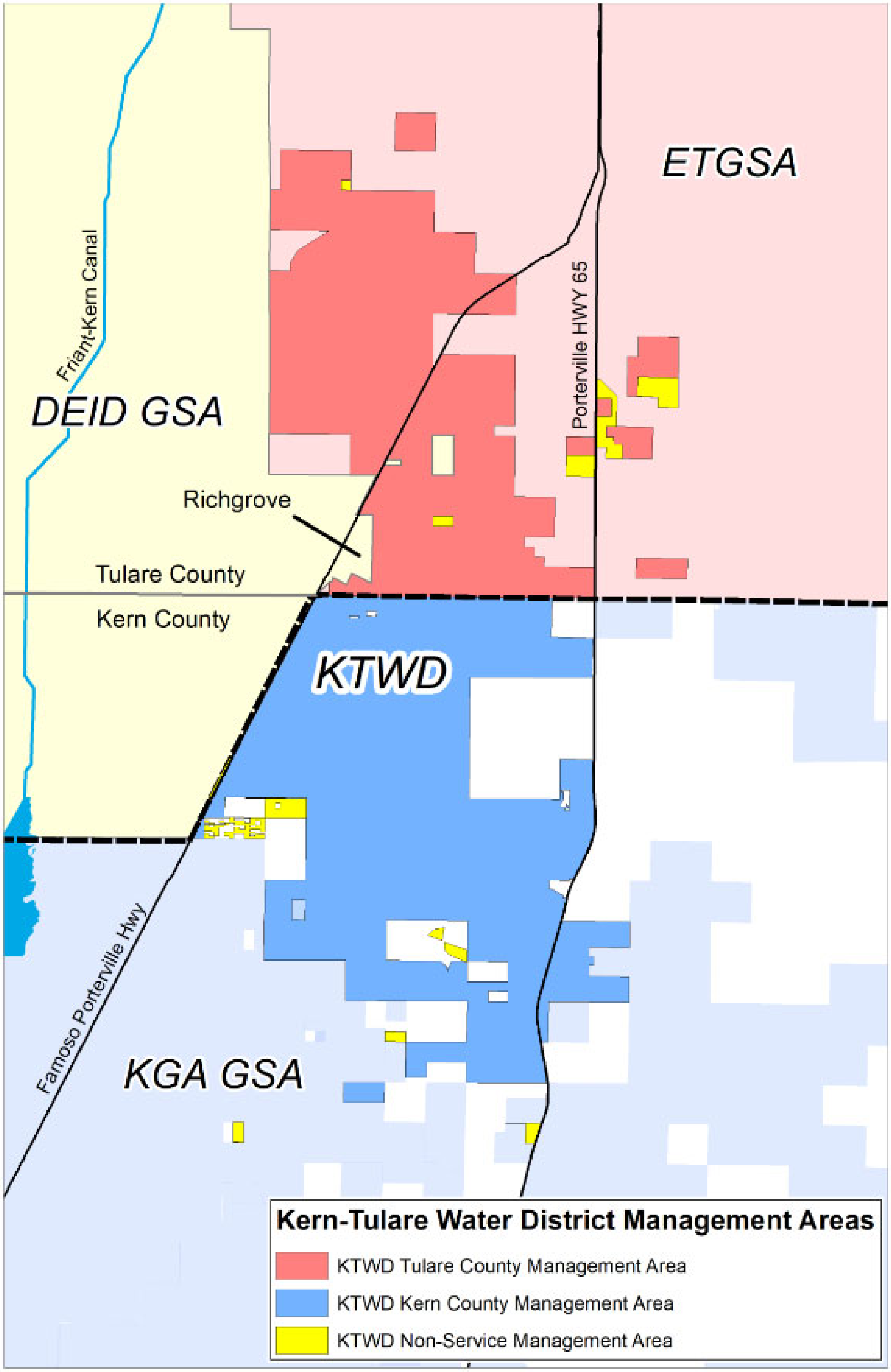
KTWD Kern County Management Area (KCMA)

Landowners within the Kern County portion of the District will be represented by the Kern Groundwater Authority (KGA) GSA, of the Kern Subbasin and governed by KGA's GSP. The KGA has given each District within the KGA the responsibility to prepare an individual chapter to establish in-District management plans.

KTWD Non-Service Management Area (NSMA)

The NSMA includes two types of land: 1) land within the District but outside the service area and 2) land outside of the District but covered by the District for SGMA purposes pursuant to an executed management agreement. There are 360 acres of non-service area land within the District that are assessed every year but do not receive any District water supplies and 180 acres of undistricted land that will be managed by the District also without surface water supplies. Since the water source of these lands is groundwater, the District will need to propose additional management actions to achieve sustainability for this management area. The NSMA must become sustainable without District water while being limited to the same safe yield (currently estimated at 0.52) as the rest of the District. The District will consider allowing some transitional pumping above the safe yield similar to the ETGSA and may develop a separate groundwater charge for the NSMA. Unlike the ETGSA, within the KTWD management areas there will not be a market structure to allow for the transfers of groundwater. Should lands within the NSMA prefer not to participate in the District's management outlined above, they may request for detachment from the District to ETGSA or EWMA, whichever is appropriate.

Figure A4-1 Plan Area



A4.2 Description of Sustainable Management Criteria

An Undesirable Result is a basin-wide definition of unreasonable impacts to beneficial uses and users of groundwater. The Kern Subbasin has defined the following terms to assist individual management areas with defining unreasonable impacts at the management area level:

- Minimum Threshold (MT) Trigger: A criteria established at the management area level that signifies undesirable impacts within the management area. For groundwater levels this occurs when groundwater levels decline below established MTs in 40% or more of any representative monitoring wells within the management area over four consecutive bi-annual SGMA required monitoring events.
- Management Area Exceedance: Exceeding the MT Trigger within a management area is a "management area exceedance" and is now potentially contributing to a basin-wide Undesirable Result.

The District has established minimum threshold triggers minimum thresholds and measurable objectives for the following sustainability indicators:

- Chronic lowering of groundwater levels indicating a depletion of supply
- Reduction of groundwater storage
- Degraded water quality

Chronic Lowering of Groundwater Levels (Reduction of groundwater storage)

The primary sustainability goal for the District is to manage the groundwater resources of the Santa Margarita Formation for long-term use as a dry-year water supply for agricultural users. Achieving this goal will require the District and other users of the Santa Margarita Formation to balance average annual inflows and outflows of water so that a negative change in storage does not occur over time.

A management area exceedance is triggered in the District when groundwater levels decline below established MTs in 40% or more of any representative monitoring wells within the District over four consecutive bi-annual SGMA required monitoring events. A management area exceedance in the District would signify significant and unreasonable groundwater elevations that have the potential to cause a loss of water supply for agricultural users of the Santa Margarita Formation. Based on landowner feedback and coordination with the other beneficial users of the Santa Margarita Formation, the minimum threshold for groundwater elevation in wells perforated to the Santa Margarita Formation will be set at 150 feet below sea level (-150 ft) which ranges as a depth to water from about 600 to 830 feet throughout the District as shown in Figure A4-2. At this elevation, no agricultural wells perforated to the Santa Margarita Formation will go dry. If the minimum threshold does occur and the District's groundwater supply is impacted, the District will reevaluate the threshold and coordinate with the other users of the Santa Margarita Formation.

According to *Subarticle 3. §354.28 (d),* an Agency may establish a representative minimum threshold for groundwater elevation to serve as the value for multiple sustainability indicators, where the Agency can demonstrate that the representative value is a reasonable proxy for multiple individual minimum thresholds as supported by adequate evidence. The District has selected a minimum groundwater elevation in the Santa Margarita to represent conditions that, if exceeded, may contribute to undesirable results. Groundwater elevation will be used as a proxy for reduction in groundwater storage due to the fact that a reduction in groundwater storage directly correlates to lowering of groundwater levels.

Degraded Water Quality

Immediately west of the District, the Santa Margarita Formation becomes saline. As a result, over pumping of groundwater has the potential to reverse the gradient so that poor quality water begins to flow into the District from the west. Extreme caution should be exercised in pumping from these aquifers to avoid the eastward migration of the saline water and cause an undesirable result of degraded water quality. The District believes that the main constituent of concern associated with the chronic lowering of groundwater levels is TDS.

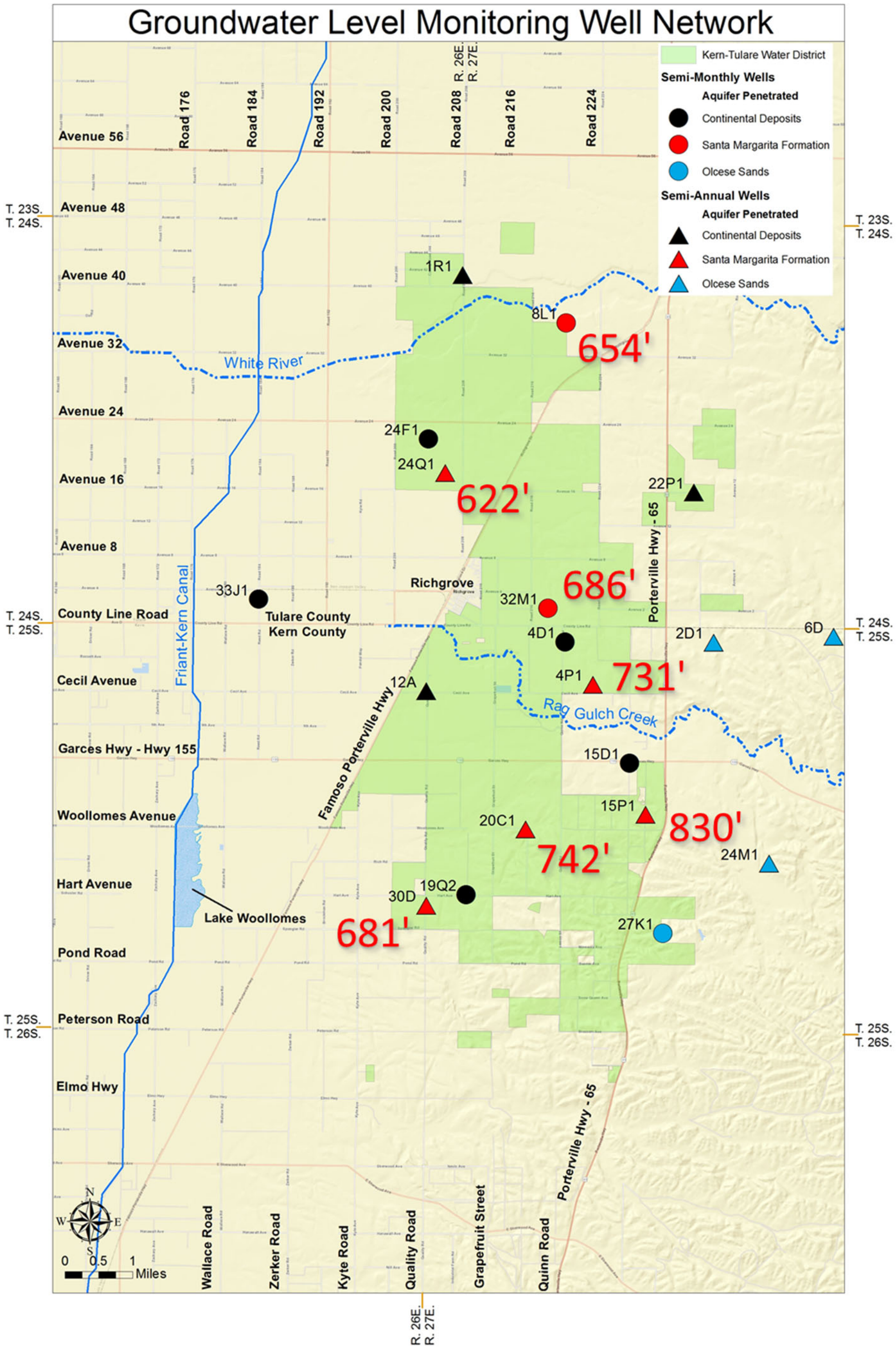
A management area exceedance is triggered in the District when groundwater quality degrades below the established MT for TDS in 40% or more of any representative monitoring wells within the District. Degradation of groundwater quality from increased concentrations of TDS has the potential to impact beneficial uses and users of groundwater by limiting the volume of groundwater available for use or requiring additional treatment or blending to remedy the higher salinity concentrations. The District has established the minimum threshold for TDS as 750 mg/L for all representative monitoring wells within the District. Water quality degradation has not occurred even at the groundwater elevations experienced in 2015 and 2021; however, continued lowering of groundwater could move the salt-freshwater interface eastward which is why the District will evaluate water levels in conjunction with salinity measured as TDS to determine the adequacy of the selected elevation.

The District will work together with the EWMA, also users of the Santa Margarita Formation, to monitor and manage the potential movement of high-salinity water from the west which may entail additional sampling, analysis of electric log data, and implementation of appropriate management actions.

Land Subsidence

Land subsidence is being measured at the GSA level in both the Tule and Kern subbasins. Minimum thresholds for Regional Critical Infrastructure which includes the California Aqueduct and the Friant-Kern Canal have been established at the subbasin level. The District has not proposed any local minimum threshold for management area critical infrastructure. Land subsidence that interferes with surface land uses within the District has not occurred even at the groundwater elevations experienced in 2015 and 2021. As shown in Figure 2-23 of the Basin Setting, current InSAR data provided by DWR shows that the total vertical displacement from June 2015 to April 2022 ranges from about 0 to -0.7 ft throughout the District. This equates to approximately 0 to 1.2-inches of average annual subsidence over the past 7 years. This amount of subsidence has not created any significant impacts to infrastructure within the District.

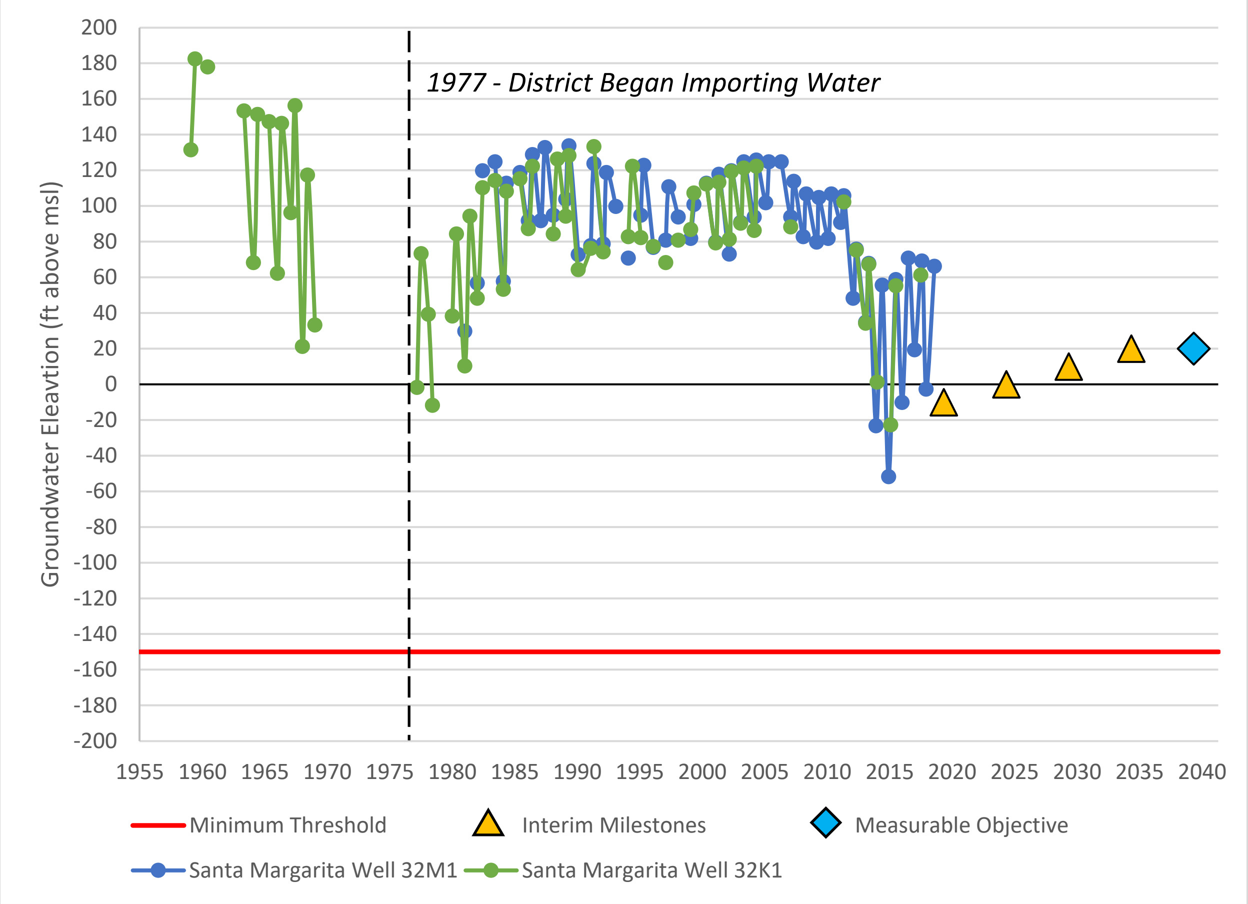
Figure A4-2 Groundwater Level Minimum Threshold as Depth to Water (-150 ft elevation)



Measurable Objective

The District has selected to define a measurable objective of fall groundwater elevations in the Santa Margarita as 20 feet above sea level, shown in Figure A4-3. This measurable objective provides a reasonable margin of operational flexibility under adverse conditions and takes into consideration components such as historical water budgets, seasonal and long-term trends, and periods of drought.

Figure A4-3 Planning Horizon



The measurable objective for degraded groundwater quality indicated by TDS is the California state established MCL of 500 mg/L. The current water quality in the Santa Margarita formation ranges from 300 – 500 mg/L so a measurable objective of 500 m/L to a minimum threshold of 750 mg/L provides an adequate range of operation.

A4.1 Description of Monitoring Network

The District implemented a DWR approved groundwater monitoring plan in 2015 and updated the plan in 2018 to better monitor the multiple aquifers that underlie the District. The District has developed groundwater level and groundwater quality monitoring networks capable of collecting sufficient data to monitor water levels and evaluate short-term, seasonal, and long-term trends in groundwater conditions.

Groundwater Level Monitoring

The District monitors 20 wells for water levels on the schedule established by DWR and reports the results under DWR's CASGEM program. The District currently measures 9 of the monitoring wells semi-monthly and 11 wells semi-annually. Semi-monthly measurements are conducted on the 1st and 15th of each month. Semi-annual groundwater elevations measurements have been scheduled according to a 1-week period in spring and fall as recommended by DWR. All wells are also measured when the District observes a significant high or low water level to capture the seasonal peaks and declines.

Groundwater Quality Monitoring

Water quality monitoring was implemented by the District as a part of AB-3030 and SB-1938 groundwater management planning. The District began collecting groundwater samples in 2015 and in 2018 established the current groundwater quality monitoring network which consists of 15 wells.

Land Subsidence Monitoring

Subsidence monitoring networks will be developed as a part of the ETGSA and Kern GSA GSP's.

A4.2 Description of Basin

Regional Geologic and Structural Setting

The geologic units penetrated by wells beneath the District, listed from youngest to oldest, include the following:

Continental Deposits from the Sierra Nevada

The unconsolidated continental deposits make up most of the freshwater in the San Joaquin Valley. Within the District, the lower continental deposits range from 400 to 1,000 feet below ground surface. This is the primary aquifer used by lands to the west of the District.

Pliocene Marine Deposits

Underlying the unconsolidated continental deposits is a thick section of partially cemented clayey siltstone. The overall transmissibility of the siltstone unit is very low; thus it contributes little groundwater to wells and acts as a confining unit over most of the area.

Santa Margarita Formation

Below the Pliocene marine deposits lay permeable sandstones of the Santa Margarita Formation. The Santa Margarita Formation is confined above and below by impervious silt and shale layers. The main Santa Margarita sand body lies beneath the District and can be fully penetrated by wells 2,200-2,400 feet deep which are predominantly used for irrigation purposes.

The sands in this formation originally contained salt water. Rainfall and stream seepage have fed fresh water into these sands east of the District displacing the original saline waters westward into the deeper parts of the basin. Immediately west of the District, the Santa Margarita remains saline with estimated TDS values of over 2,000 mg/l.

Round Mountain Silt

The Round Mountain Silt is an impervious siltstone and shale section and is an effective groundwater flow barrier between the overlying Santa Margarita Formation and the underlying Olcese sands. This siltstone extends continuously over the entire area, but thins eastward.

Olcese Sands

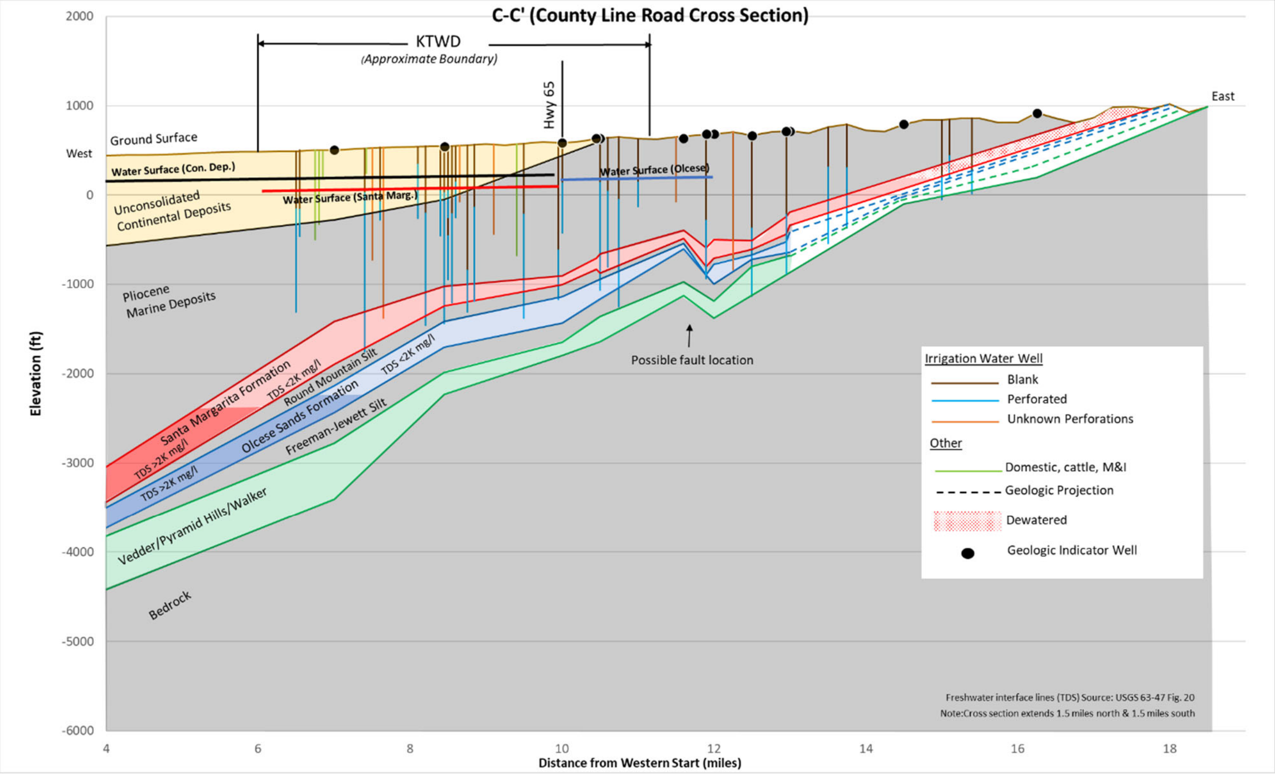
The Olcese sands are present throughout the District and have good porosity and permeability. Like the Santa Margarita Formation, this confined aquifer is recharged by rainfall and streamflow where the sands crop out east of the District. The sands also originally contained salt water now displaced westward so that the freshwater interface lies primarily only in the eastern portion of the District. These deposits contain useable groundwater and have been penetrated by District landowners in the proximity of Hwy 65.

Wells within the District do not penetrate below the Olcese sands; therefore, for the purposes of this GSP, the bottom of the basin is defined as the bottom of the Olcese Sand Formation.

Geologic Cross Section

A typical cross section is shown on Figure A4-4 along County Line Road. The depths and thickness of the various aquifers were determined by evaluating e-logs from oil wells obtained from DOGGR. In addition, the static water level of each aquifer, along with all active wells within 1½ miles on either side of County Line Road have been plotted on the cross section and include the total depth and perforated intervals of each well.

Figure A4-4 Cross Section along County Line Road



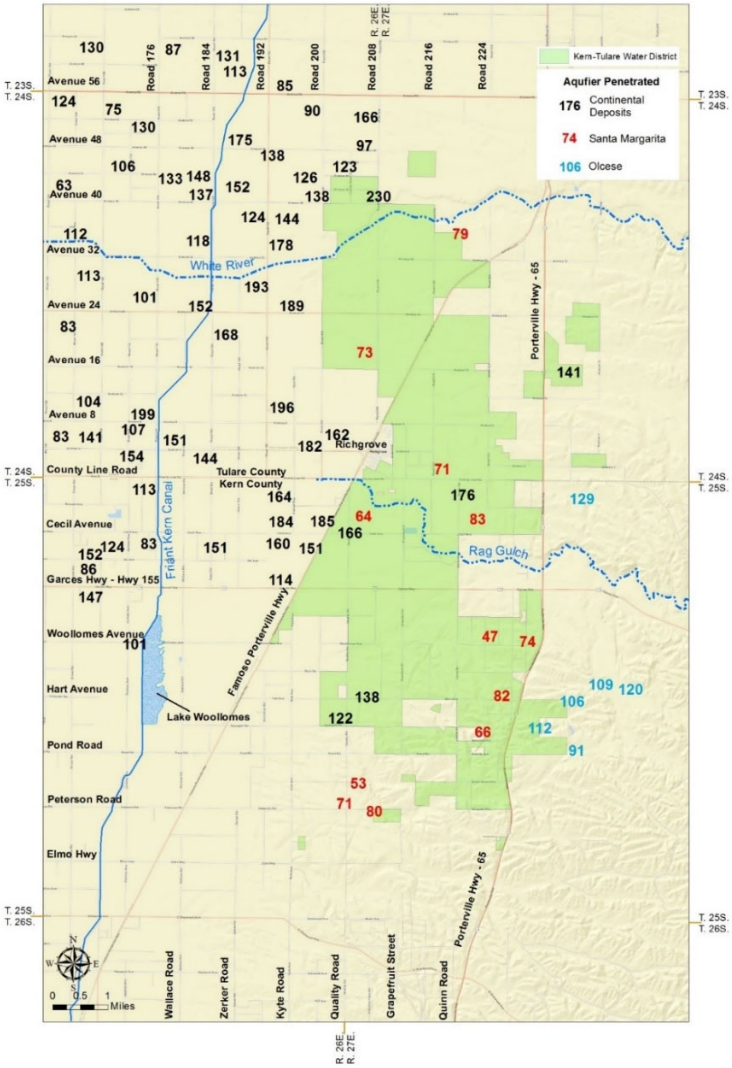
As shown in Figure A4-4: wells near the western border of the District penetrate the Continental Deposits; most of the wells within the District penetrate to the Santa Margarita Formation; and wells near the eastern border of the District extend to the Olcese Sands.

Groundwater Elevation Data

Groundwater elevations for all wells found in DWR's Well Data Library within and surrounding the District for Spring 2017 are presented in Figure A4-5. The general direction of groundwater flow is East to West.

As shown in Figure A4-5, groundwater elevations are highly variable and difficult to contour. In some cases, water levels in adjacent wells vary by over 100 feet. Wells that penetrate the Santa Margarita Formation show a lower groundwater elevation than wells completed only in the Continental Deposits. Contours cannot be drawn for the Continental Deposits because groundwater elevations are highly variable. Contours cannot be drawn for the Santa Margarita Formation because groundwater elevations are highly variable and data is sparse. Contours cannot be drawn for the Olcese Sands due to the lack of available data.

Figure A4-5 Spring 2017 Groundwater Elevations



Source of Imported Water Supplies

The District receives Central Valley Project (CVP) water through two Cross Valley Contracts (14-06-200-8601A and 14-06-200-8367A) with the United States Bureau of Reclamation (Reclamation) for a combined total of up to 53,300 acre-feet per year and a Friant Class 2 Contract (I1R-1460A) for up to 5,000 acre-feet per year. The District also enters into annual contracts for Section 215 water from Reclamation, purchases Class 1 and Class 2 water supplies from other Friant Contractors, purchases CVP water from other South of Delta contractors, purchases Kern River Water from the City of Bakersfield, and purchases SWP supplies when available.

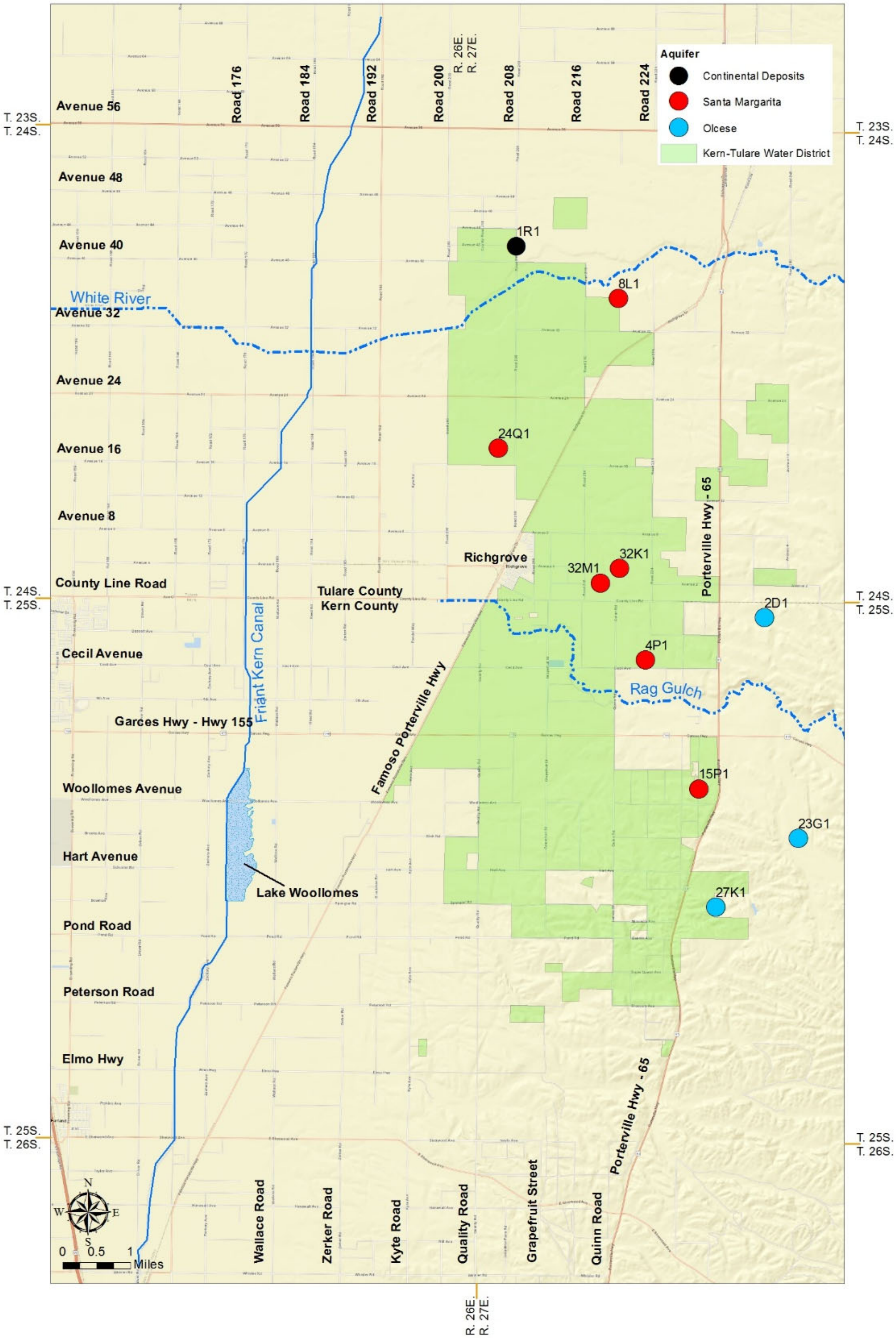
The District has developed long-term groundwater banking programs with North Kern Water Storage District (North Kern), Rosedale-Rio Bravo Water Storage District (Rosedale-Rio Bravo), and West Kern Water Storage District (West Kern) to deliver excess water when surface supplies are available and to extract groundwater during years of inadequate supplies. Supplies available to the District for banking include the District's CVP contract supplies, Section 215 water, flood flows conveyed in the Friant-Kern Canal, purchases from other CVP Contractors, Kern River water, and SWP water.

The District executed a 20-year contract with Hathaway, LLC in 2016 to receive produced water. The District currently receives about 2,400 acre-feet per year of water from this source on the east side of the District, which is delivered to the District's Big 4 reservoir to be blended with other water sources before being distributed. The source of oilfield produced water is from exempted aquifers beneath and hydrologically separated from the fresh-water bearing zones of the basin.

Historical Hydrographs

Figure A4-6 is a map that shows the location of all wells with long-standing periods of record and the deepest aquifer they penetrate.

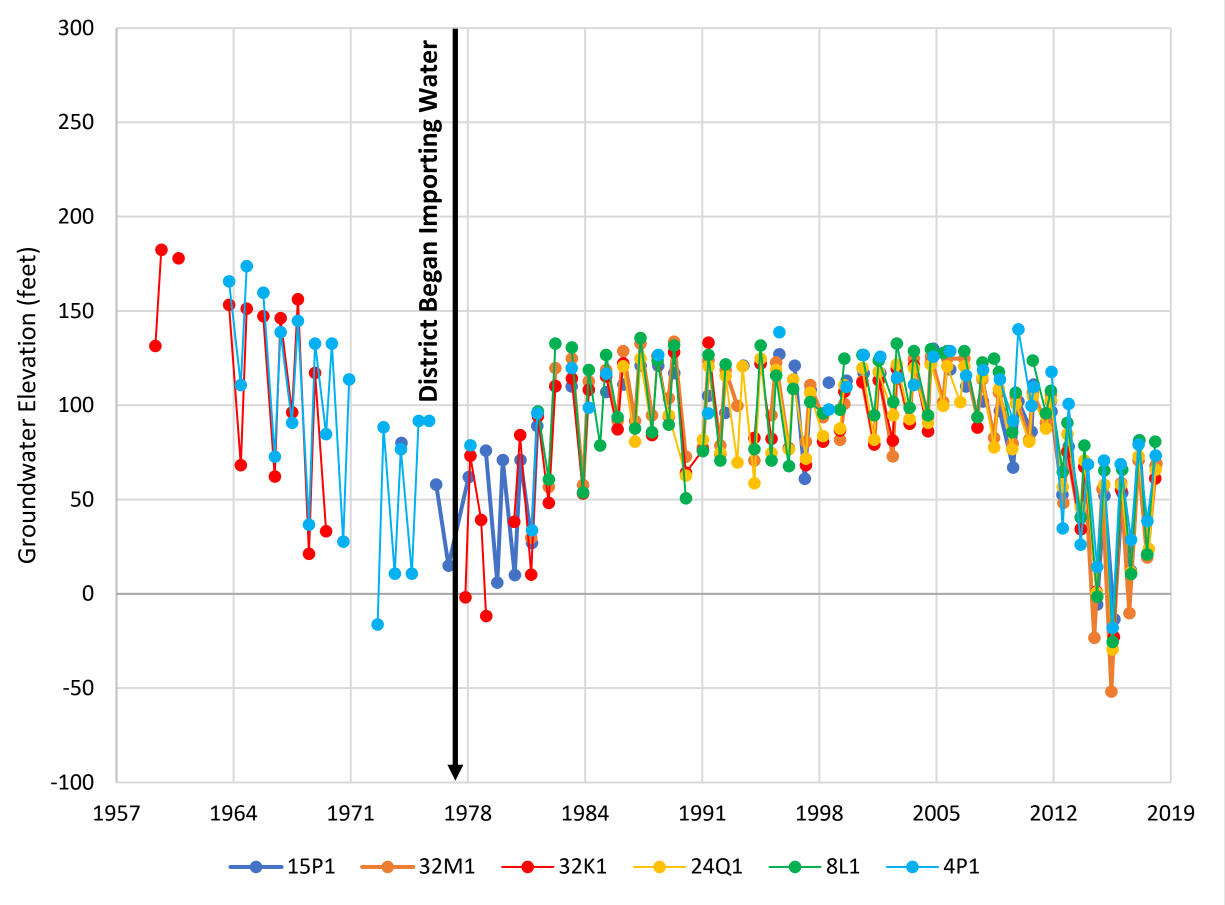
Figure A4-6 Hydrograph Location Map



Santa Margarita Formation

Figure A4-7 is a hydrograph of groundwater levels for wells identified in Figure A4-6 that penetrate the Santa Margarita Formation in the District.

Figure A4-7 Historical District Groundwater Levels in the Santa Margarita Formation

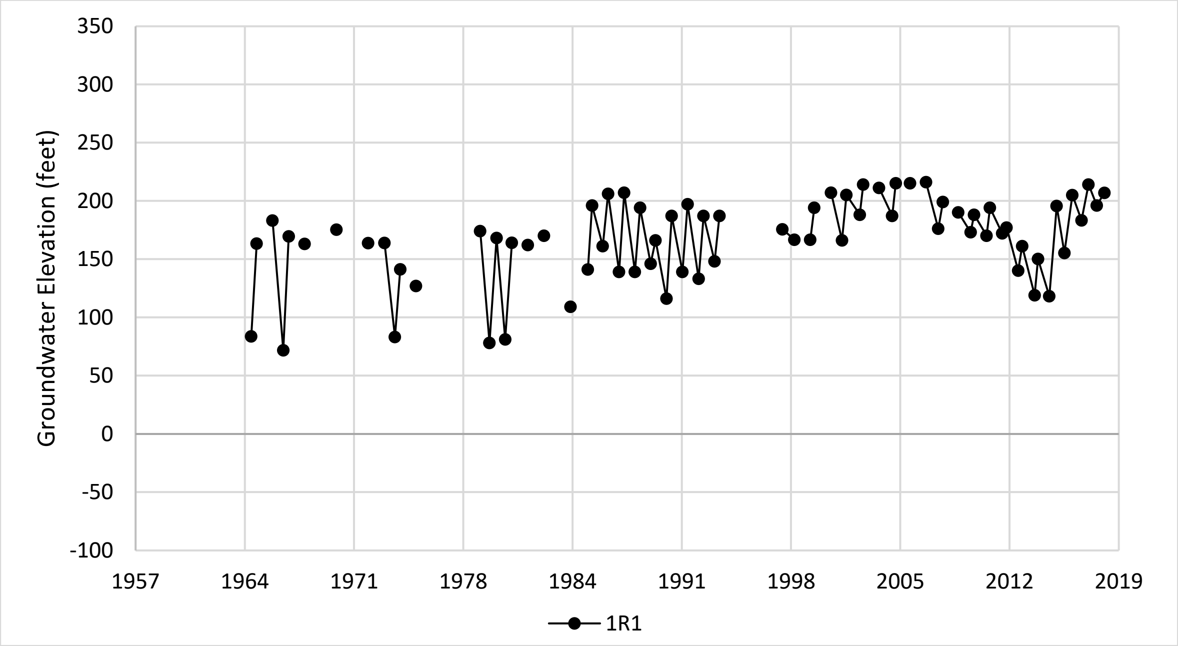


As shown in Figure A4-7, groundwater levels in the Santa Margarita Formation are consistent throughout the District regardless of location. All hydrographs show that prior to 1977 groundwater levels in the Santa Margarita Formation were falling at a rate of approximately 10 feet per year. Beginning in 1977, the District began importing water and, as a result, groundwater pumping reduced and groundwater levels rose significantly. From 1983 through 2009 groundwater levels remained stable, varying seasonally from elevations of 60 to 120 feet. The recent drought (2013 through 2016) caused groundwater pumping to increase resulting in spring groundwater levels declining by over 50 feet and fall levels declining by 100 feet. Groundwater levels are now recovering.

Continental Deposits

Figure A4-8 is the only available historical hydrograph of groundwater elevations within the District for the Continental Deposits. The well is relatively shallow and penetrates only the Continental Deposits.

Figure A4-8 Historical Groundwater Levels in the Continental Deposits within the District

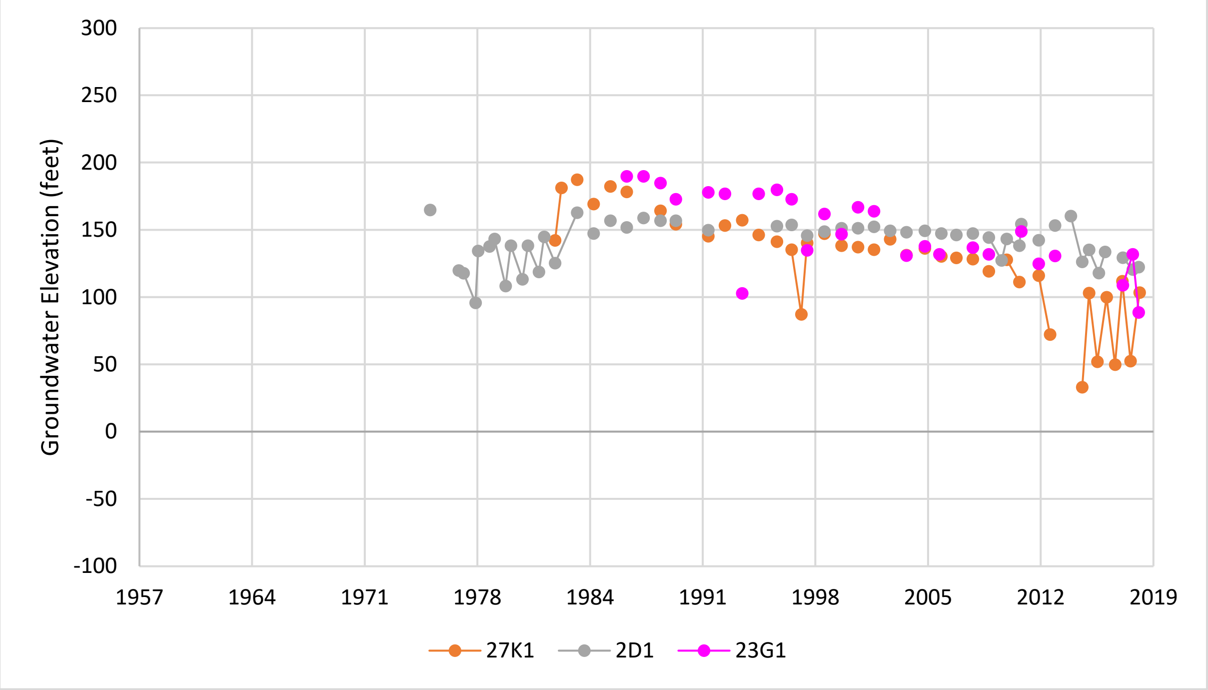


As shown in Figure A4-8, groundwater levels in the Continental Deposits in the northern portion of the District are increasing. The recent drought (2013-2016) caused spring groundwater levels to drop by 70 feet. Groundwater levels are recovering and have returned to pre-drought conditions.

Olcese Sands

Most wells to the east of the District penetrate the Santa Margarita Formation and the Olcese Sands. Figure A4-9 is a hydrograph of groundwater elevations for wells identified in Figure A4-6 that penetrate the Olcese Sands Formation with long-standing periods of record.

Figure A4-9 East of the District Historical Groundwater Levels in the Olcese Sands Formation

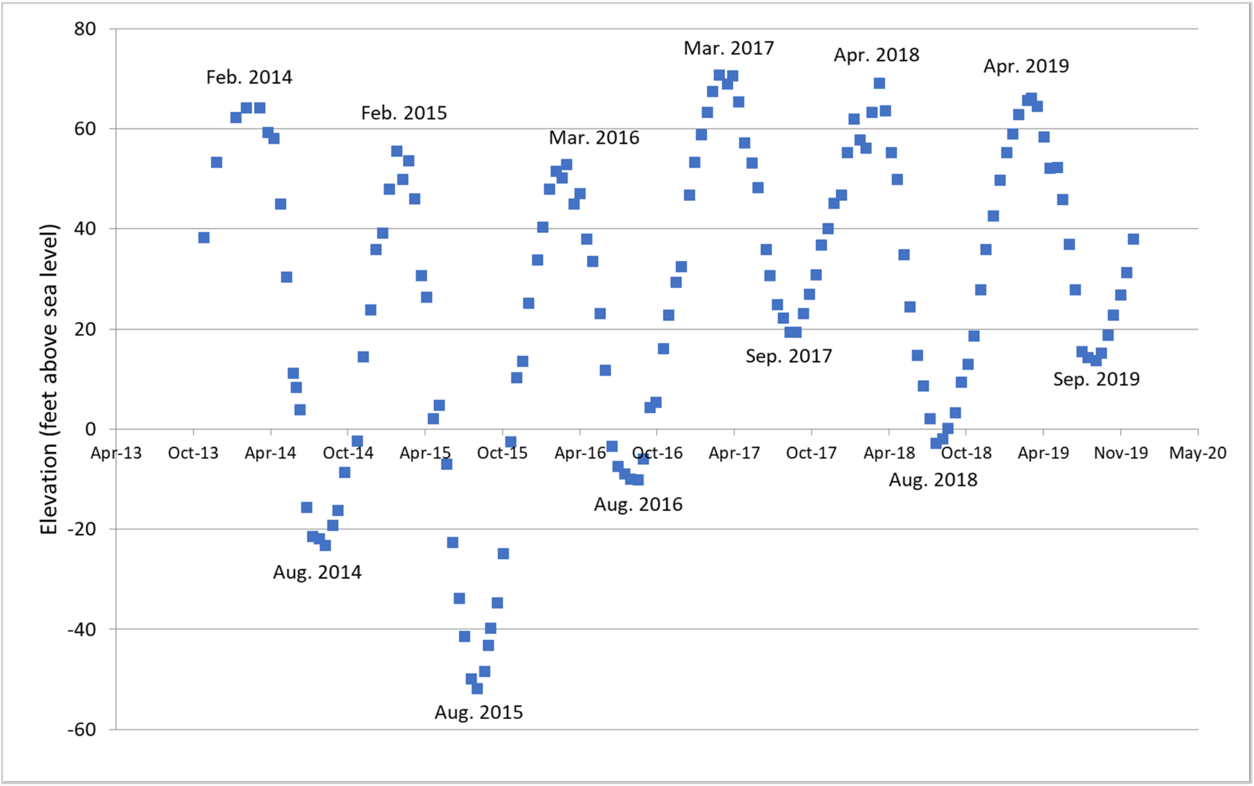


As shown in Figure A4-9, groundwater levels east of the District have dropped by 80 feet over the 30-year period from 1987 to 2016 and are continuing to decline. This is evidence that lands east of the District are pumping more from the basin than is replaced by recharge.

Semi-monthly Hydrographs

In 2013, the District began semi-monthly measurements on monitoring well 24S27E32M1M, located ¾ mile east of Richgrove near the center of the District. This well is an inactive irrigation well penetrated to the Santa Margarita Formation. Figure A4-10 is a hydrograph of these measurements from August 2013 to May 2019 which demonstrates the seasonal change in groundwater in elevations.

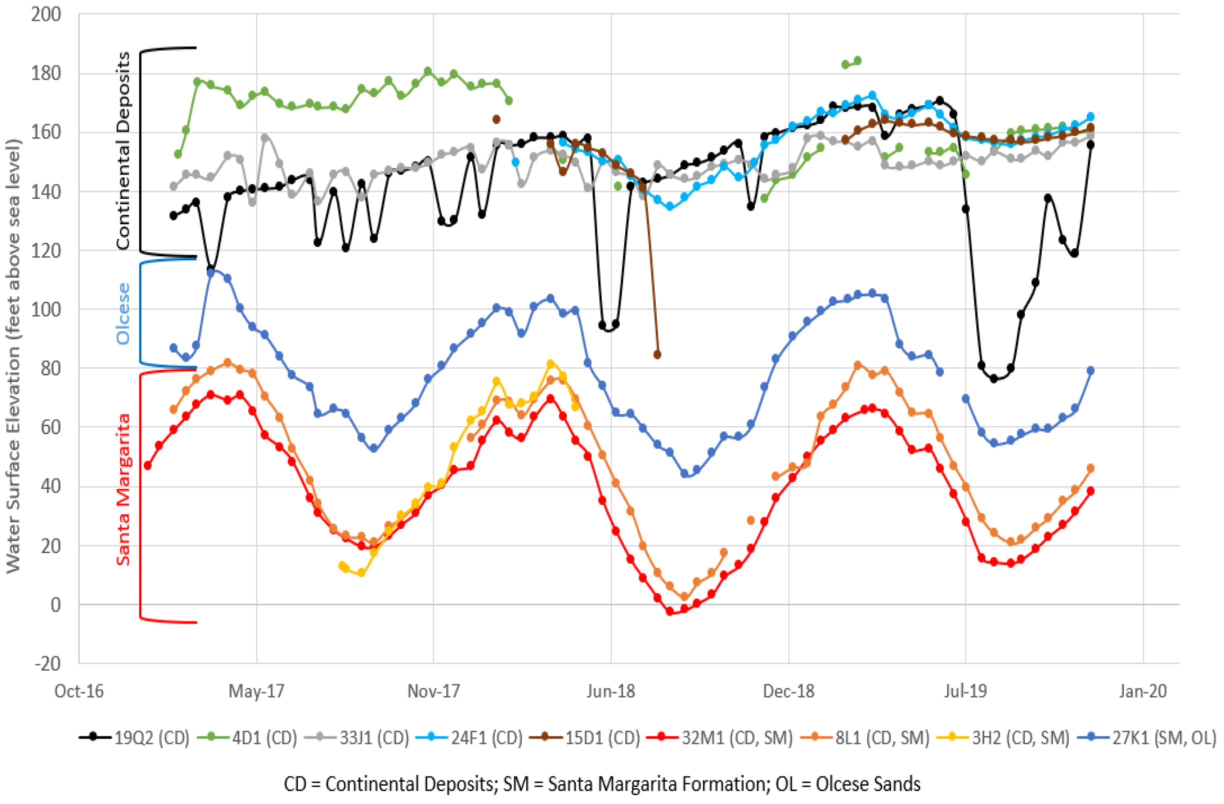
Figure A4-10 In-District Groundwater Elevation Data for Well No. 24S27E32M1M (2013-2019)



As shown in Figure A4-10, groundwater levels in the Santa Margarita Formation experience seasonal fluctuations of 50-110 feet.

In early 2017, the District began taking semi-monthly measurements on several additional wells. These wells represent groundwater levels from the wells that penetrate the Continental Deposits, Santa Margarita Formation, and Olcese Sands. Figure A4-11 is a hydrograph of the District's semi-monthly monitoring wells that distinguish the differences in groundwater level elevations and fluctuations between aquifers.

Figure A4-11 Semi-monthly Well Measurement Comparison (2017-2019)



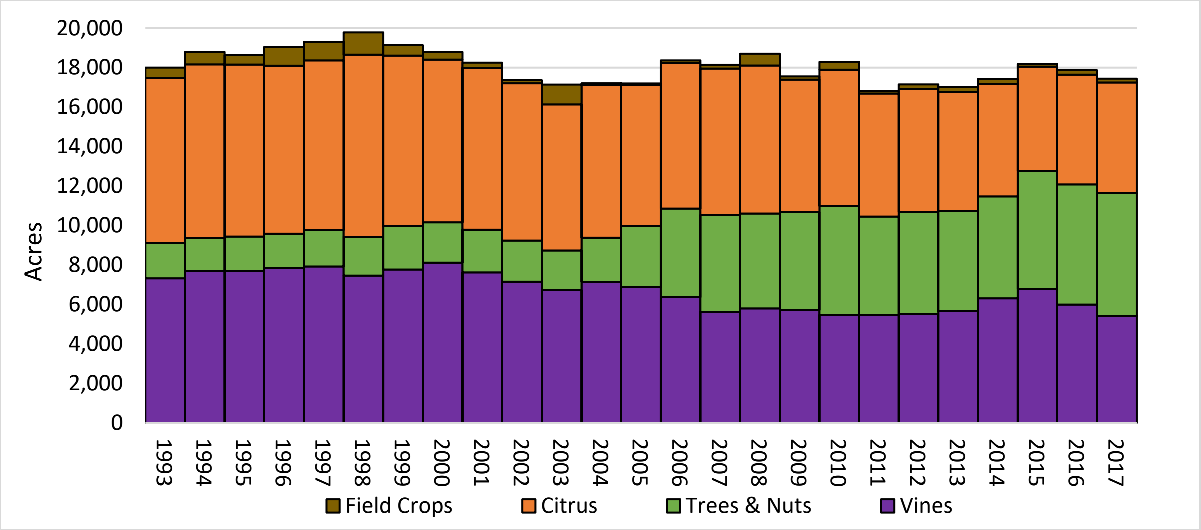
The following observations can be made from Figure A4-11:

1. Groundwater levels in the Continental Deposits are 60-140 feet higher than those in the Santa Margarita Formation and do not show the large seasonal fluctuations evidenced in the Santa Margarita Formation and Olcese Sands.
2. Wells that penetrate the Olcese Sands have water levels that are about 40 feet higher than those that only penetrate the Santa Margarita Formation.
3. Variations in the Continental Deposits may reflect recent or nearby pumping.
4. Wells penetrating the Santa Margarita and/or Olcese reflect seasonal fluctuations of about 60 feet.

Land Use

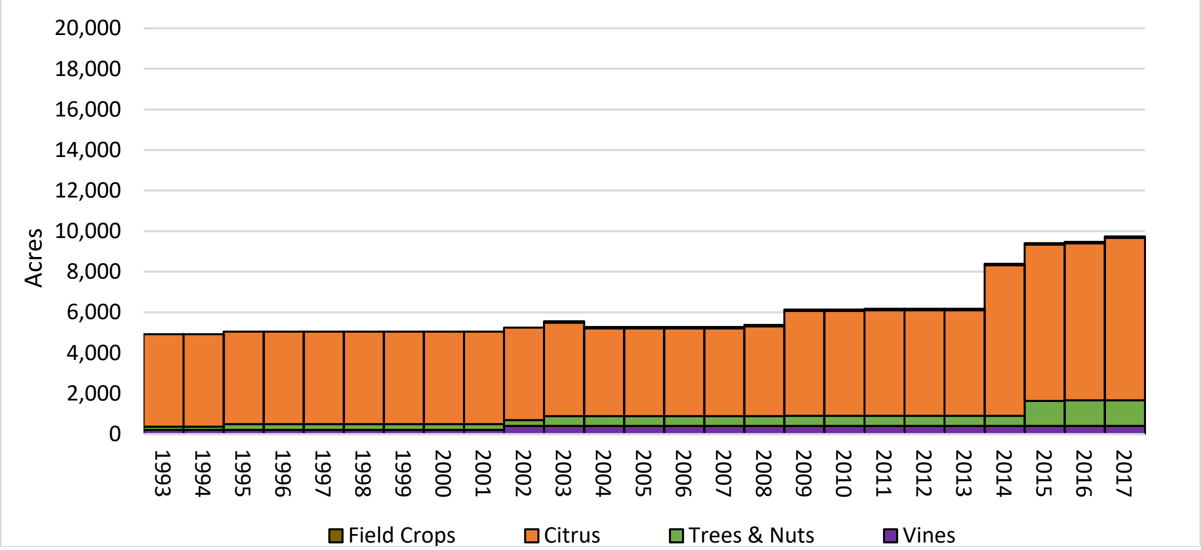
Historical land use for years 1993 through 2017 is summarized for the District in Figure A4-12 and summarized for lands adjacent to, primarily east of, the District in Figure A4-13. As shown in Figure A4-12, the total number of irrigated acres within the District has remained relatively constant since 1993 and there has been a conversion from citrus and grapes to trees and nuts. The total number of irrigated acres for lands outside of the District has nearly doubled since 2008 as displayed in Figure A4-13.

Figure A4-12 Historical Land Use within the District (1993 - 2017)



(1) – Field Crops include blue berries, Sudan grass, and alfalfa.
(2) – Citrus include oranges, tangelo, kiwi, lemons, and grapefruit.
(3) – Trees and nuts include almonds, pistachios, cherries, persimmons, and pomegranates.
(4) – Vines include wine and table grapes.

Figure A4-13 Historical Land Use Adjacent to theDistrict (1993 - 2017)

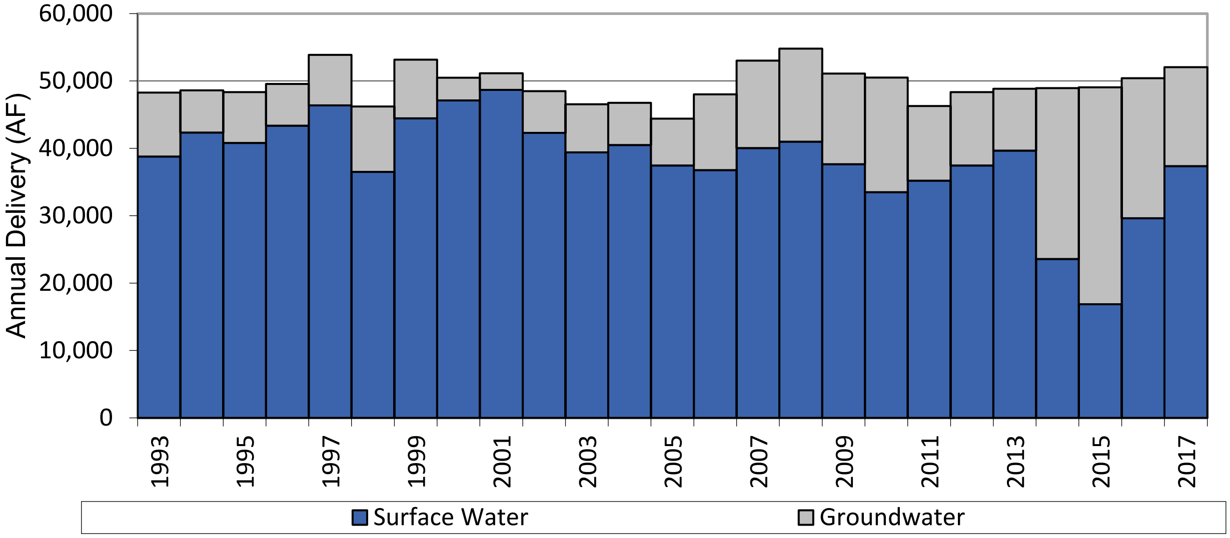


(1) – Field Crops includes blue berries.
(2) – Citrus includes oranges, tangelo, kiwi, lemons, and grapefruit.
(3) – Trees and nuts include almonds, pistachios, cherries, persimmons, and pomegranates.
(4) – Vines includes wine and table grapes.

Groundwater Pumping

Groundwater pumping within the District was calculated as the difference between the applied water demand and the surface water deliveries. Figure A4-14 summarizes the volume of groundwater pumping and surface water deliveries within the District from 1993 through 2017. In most years, District growers have access to as much District water as they are willing to purchase. However, when the cost to deliver surface water exceeds the cost of groundwater, some water users choose to pump groundwater when surface water is available.

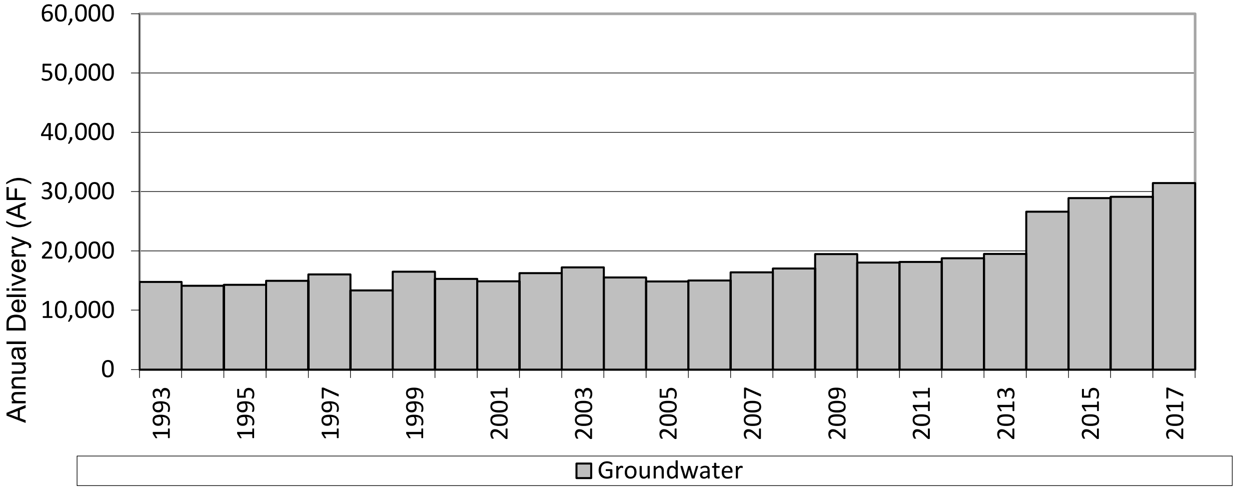
Figure A4-14 District Water Supplies (1993 – 2017)



Limited District surface water supplies were available in 2014 and 2015. As a result, the District allocated water supplies to water users and groundwater pumping increased to meet the remaining irrigation demand as shown in Figure A4-14.

Adjacent to the District, groundwater pumping and precipitation must meet all irrigation demand due to the fact that lands adjacent to the District do not receive surface supplies. Figure A4-15 summarizes the volume of groundwater pumping outside of the District from 1993 through 2017.

Figure A4-15 Water Supplies Adjacent to the District (1993 – 2017)



A4.3 Evaluation of Safe Yield

Water users within the District are reliant upon the Santa Margarita Formation for the District's program of conjunctively using surface water and groundwater. The District supplies surface water as it is available to conserve groundwater for use in times of drought. The District has significant concern with developed agriculture adjacent to the District which has no access to surface water and is entirely reliant upon groundwater. As these adjacent lands continue to extract the groundwater that the District has made available through it's conjunctive use program, the District's ability to maintain sustainability is severely compromised.

The hydrographs presented in Figure A4-7 through Figure A4-9 indicate that from 1993 to 2009 groundwater levels throughout the District were stable and groundwater levels east of the District were declining. Table A4-1 summarizes the average number of irrigated acres and annual groundwater pumping that occurred from 1993 to 2009 both in the District and adjacent to the District.

Table A4-1 Groundwater Pumping and Irrigated acres from 1993 to 2009

	Irrigated Acres	Groundwater Pumping	
		AF	AF/ac
District	18,319	9,454	0.52
Adjacent to the District	5,210	15,443	2.96
Total	23,529	24,897	1.06

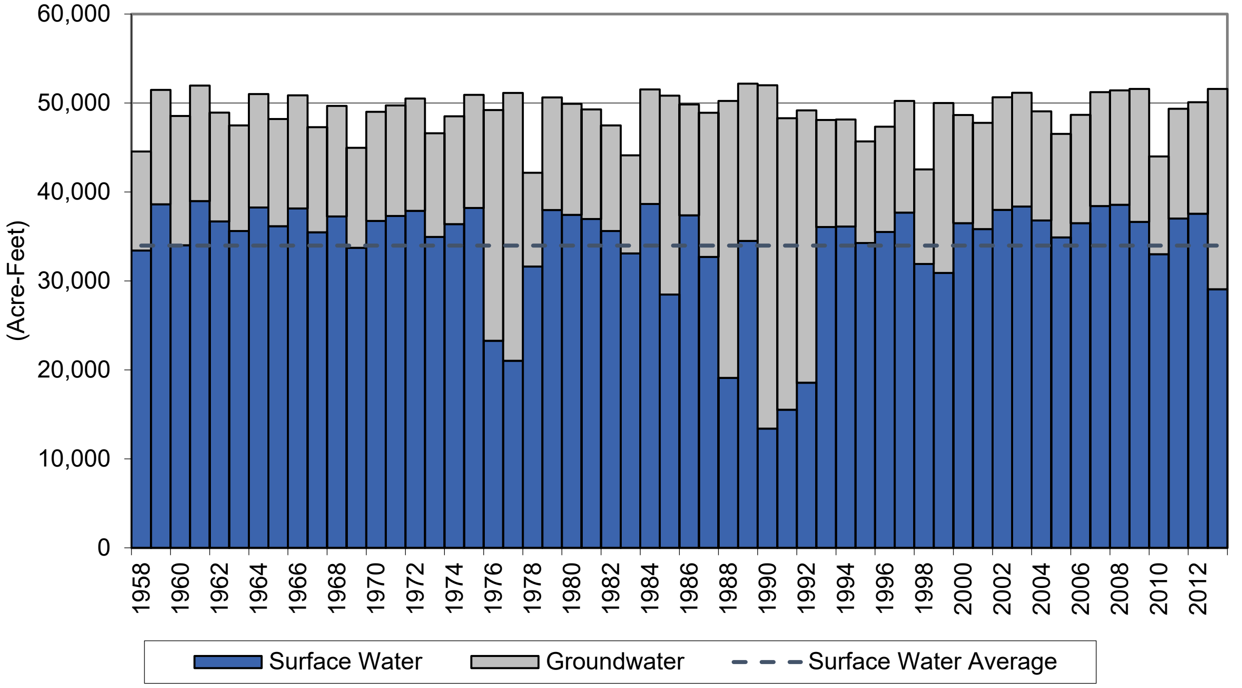
The fact that groundwater levels remained stable from 1993 to 2009 and an average of 9,454 AF/yr was pumped within the District during this period indicates that a groundwater extraction of approximately 9,450 acre-feet per year is a reasonable estimate of safe yield for the aquifers. If the approximate safe yield of the District was distributed amongst irrigated acreage within the District, the resulting allocation would equal 0.52 acre-feet per acre.

A safe yield was not estimated for the lands adjacent to the District; however, as presented in Figure A4-9, groundwater levels fell each year during the 1993 to 2009 period when the historical average of groundwater pumping was 15,443 acre-feet. Further, as shown in Figure A4-13, the number of cropped acres adjacent to the District has nearly doubled since 2009, resulting in groundwater pumping of over 30,000 acre-feet, as displayed in Figure A4-15. It is reasonable to assume that nearly doubling the pumping adjacent to the District will increase the rate of groundwater decline over the historical level. This decrease in groundwater levels immediately adjacent to the District has the potential to negatively impact groundwater levels and quality within the District. Management of adjacent lands is proposed to be conducted by the EWMA in Kern County and ETGSA in Tulare County to address this situation. Failure to limit groundwater pumping east of the District to their share of the safe yield will frustrate the District's ability to achieve sustainability.

A4.4 Projected Water Budget

A projected water budget was prepared to estimate baseline future conditions of supply, demand, and aquifer response to Plan implementation. Projected water demands utilized 2017 land use and ET estimates. Projected surface water supplies were based upon the most recent water supply estimates of future surface water supply. The projected water budget utilized the 56-year historical period from 1958 through 2013. This period was selected because it represented an average period of hydrology based upon Kern River natural flows. Figure A4-16 presents a summary of the results.

Figure A4-16 Source of water to District under future conditions



As shown in Figure A4-16, the baseline analysis resulted in an average annual District surface supply of about 33,700 acre-feet and average annual groundwater extraction of about 14,785 acre-feet. This anticipated increase in groundwater pumping over historic conditions is attributable to the reduction of water supply availability due to increased environmental and regulatory conditions in the Delta, the settlement on the San Joaquin River, and implementation of SGMA.

A4.5 Projects and Management Actions

Given the circumstances of potential overdraft conditions as described above, the District may begin implementation of projects and management actions (Actions) as soon as 2020. The District has identified the following Actions as a means to accomplish groundwater sustainability:

1. Modify District Pricing Structure
2. Construct CRC Pipeline - Produced Water Project
3. Construct In-District Surface Storage

Each of the identified Actions will benefit groundwater levels beneath the District by increasing use of available surface water to decrease groundwater pumping. Following is a description of each of the Actions listed above.

Action 1: Modify District Pricing Structure

Each year the District's Board of Directors sets the surface water price for water users based on the blended water rates of the various sources of the District's water supply. This price is highly dependent upon hydrology and availability of water supplies. There are times when the cost of District water is more expensive than the cost to pump groundwater. During these times, some water users choose to pump groundwater instead of using surface water due to the cost difference.

The most effective and timely way to reduce groundwater pumping is to provide a pricing mechanism that causes groundwater to cost more than surface water. This could be accomplished by implementing a "groundwater charge" for every acre-foot pumped. Revenue from the groundwater charge could be used to implement management actions or to reduce the cost to deliver surface water from the District.

Implementing a groundwater pumping charge would require the following to be accomplished:

1. Conduct a "Majority Protest" procedure under Proposition 218.
2. Install meters on all groundwater wells.
3. Set up procedures to read groundwater meters and charge for groundwater pumping.

This project has been determined as the quickest, most effective way to benefit groundwater levels beneath the District and the process of implementing Action 1 has already begun. Beginning in 2021, the District focused on evaluating the best approach to implement a groundwater charge and has made significant progress which includes the following:

- The District proposed a Groundwater Extraction Metering Plan and hosted a landowner workshop to receive input on the procedures of groundwater metering.
- After receiving substantial landowner feedback, the District determined to measure groundwater pumping by requiring meters on all groundwater wells and opted for landowners to own and maintain their groundwater well meters. Landowners are responsible for all costs associated with their meter. The initial cost of a new meter installation for the landowner ranges from $3,000 - $6,000.
- The District has amended the Rules and Regulations for the Sale and Distribution of Water to include the Groundwater Extraction Metering Plan and has retained a contractor to assist with meter installation requirements.
- The District began a "Trial Period" on January 1, 2022 to provide landowners with groundwater pumping information on their monthly statements through December 31, 2022 in anticipation of the new charge.
- The District published an Engineer's Report in June 2022 which determined what the upper limit of the groundwater extraction fee should be. The District will hold a Proposition 218 proceeding to establish the fee in August 2022. If the groundwater extraction fees are approved by landowners, the District's ability to charge for groundwater will become effective January 2023.

The project reduces groundwater pumping by an estimated 5,580 AF/yr.

Action 2: CRC Pipeline Project - Produced Water Project

The District has historically received produced water as a source of imported surface water to the District and is in the process of obtaining an additional source of produced water from California Resources Corporation (CRC). Produced water from CRC will be transported through 12 miles of 15-inch pipeline to the Guzman Reservoir. From the Guzman Reservoir, water will be transported through 1.8 miles of 30-inch pipeline to the District's existing Big 4 Reservoir, from which it will be blended with water from the Friant-Kern Canal and distributed in existing facilities to existing irrigated agriculture located within the District. If implemented, it is estimated that this pipeline construction can be completed prior to 2025.

The project yields a projected annual water supply of 3,000 AF/yr which reduces groundwater pumping by an estimated 1,440 AF/yr. The capital cost of this project is estimated at $5.9 million.

Action 3: In-District Surface Storage

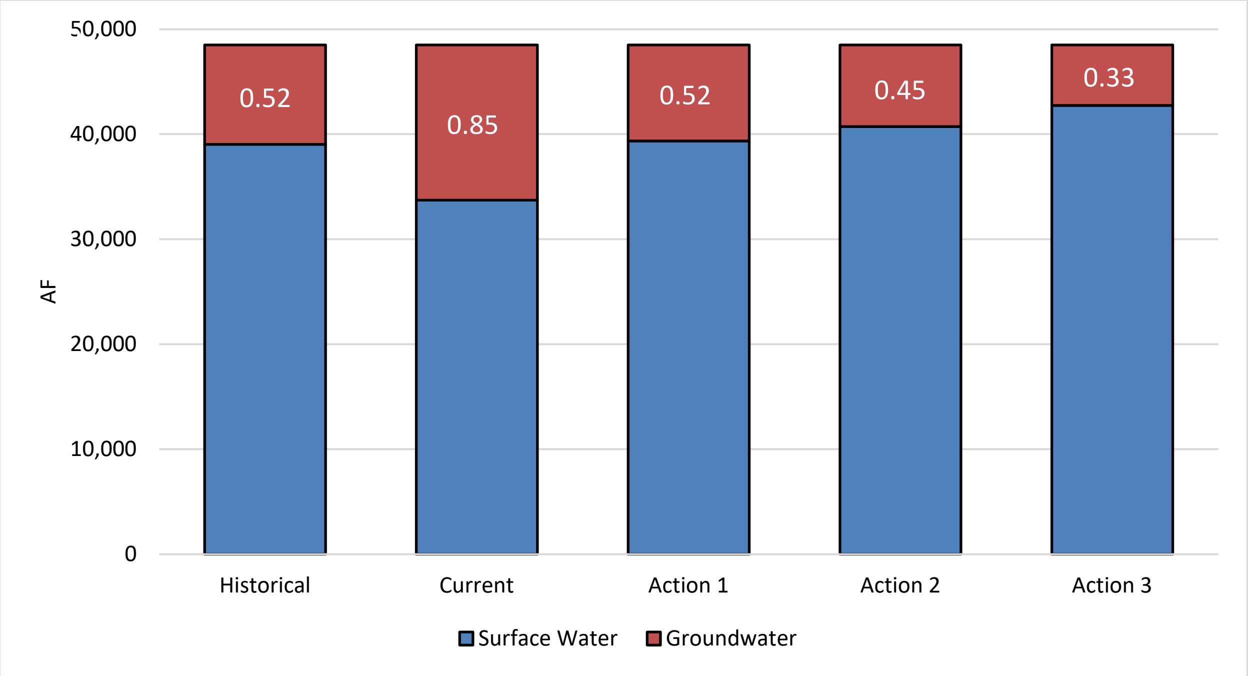
There are times when affordable water supplies are available, but the District has little to no irrigation demand and no available spreading capacity in its existing out-of-district banking programs. Construction of off-stream surface storage will allow the District to acquire water when it is available and store it to meet future irrigation demands. The District has selected two potential reservoir sites with a total capacity of 8,000 AF to capture wet year water. It is estimated that these facilities can be constructed between 2030 and 2035 if they are determined to be feasible and found to be necessary.

Based upon annual water supply modeling herein, the project yields only 530 AF/yr. However, a monthly analysis will need to be conducted to provide a better estimate of project yield, which could be as much as 2,000 AF/yr (assumes the reservoirs are used once every 4 years). The estimated capital cost for this project is $20 million.

Evaluation of Cumulative Benefits

Starting from the projected water budget conditions discussed in A4.4, benefits of the above Actions have been analyzed cumulatively where actions are completed in sequence. Figure A4-17 presents a summary of the results as the average groundwater pumping per acre-foot required under historical conditions (1993-2009), continuing current conditions into the future, and with implementation of the Actions under future conditions.

Figure A4-17 Summary of Groundwater Use (AF per acre) with Actions



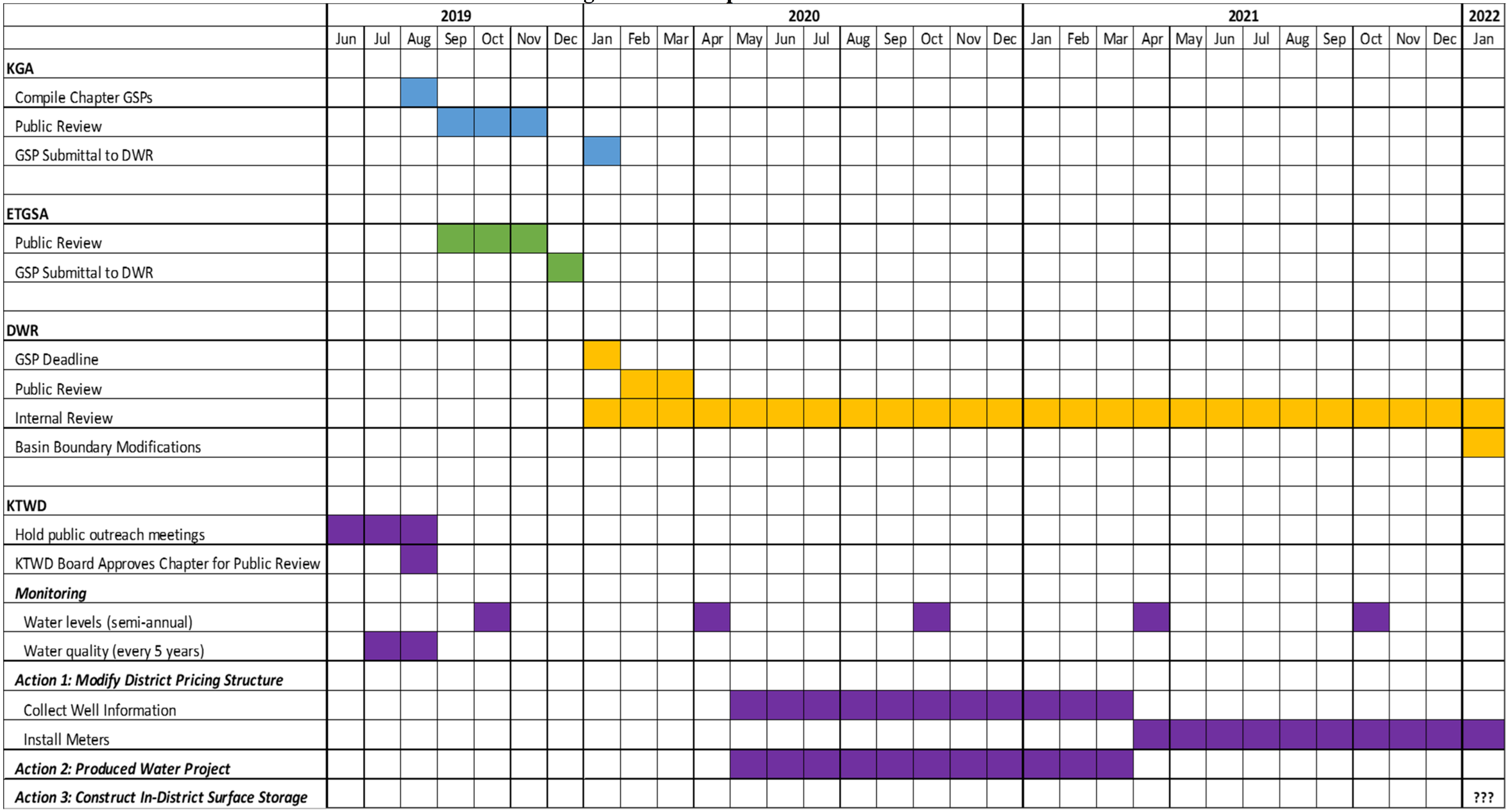
Evaluation of Groundwater Levels with Actions

The District believes that with implementation of the described Actions, groundwater levels can be stabilized over the planning horizon. Based upon the 1993 to 2009 historical conditions, the assumed safe yield is approximately 9,450 AF per year or 0.52 AF/acre. The projected model under current conditions indicates that water users within the District will pump an average of about 0.85 AF/acre of groundwater which will likely cause groundwater levels to lower. Implementing Action 1 would decrease groundwater pumping to about 0.52 AF/acre which meets the assumed safe yield for the District. Action 2 would continue to reduce groundwater pumping to approximately 0.45 AF/acre and increase groundwater levels and storage. Action 3 was evaluated assuming a yield of 2,000 AF/yr (8,000 AF used once every four years) resulting in a reduction of groundwater pumping to about 0.33 AF/acre.

A4.6 Implementation Schedule

Figure A4-18 provides the District's implementation schedule for this Plan as well as important dates for KGA GSA, ETGSA, and DWR.

Figure A4-18 Implementation Schedule



	2019							2020												2021												2022
	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Jan
KGA																																
Compile Chapter GSPs			🟦																													
Public Review				🟦	🟦	🟦																										
GSP Submittal to DWR								🟦																								
ETGSA																																
Public Review				🟩	🟩	🟩																										
GSP Submittal to DWR							🟩																									
DWR																																
GSP Deadline								🟨																								
Public Review									🟨	🟨																						
Internal Review								🟨	🟨	🟨	🟨	🟨	🟨	🟨	🟨	🟨	🟨	🟨	🟨	🟨	🟨	🟨	🟨	🟨	🟨	🟨	🟨	🟨	🟨	🟨	🟨	🟨
Basin Boundary Modifications																																🟨
KTWD																																
Hold public outreach meetings	🟪	🟪	🟪																													
KTWD Board Approves Chapter for Public Review			🟪																													
Monitoring																																
Water levels (semi-annual)					🟪						🟪						🟪						🟪						🟪			
Water quality (every 5 years)		🟪	🟪																													
Action 1: Modify District Pricing Structure																																
Collect Well Information												🟪	🟪	🟪	🟪	🟪	🟪	🟪	🟪	🟪	🟪	🟪										
Install Meters																							🟪	🟪	🟪	🟪	🟪	🟪	🟪	🟪	🟪	🟪
Action 2: Produced Water Project												🟪	🟪	🟪	🟪	🟪	🟪	🟪	🟪	🟪	🟪	🟪										
Action 3: Construct In-District Surface Storage																																???