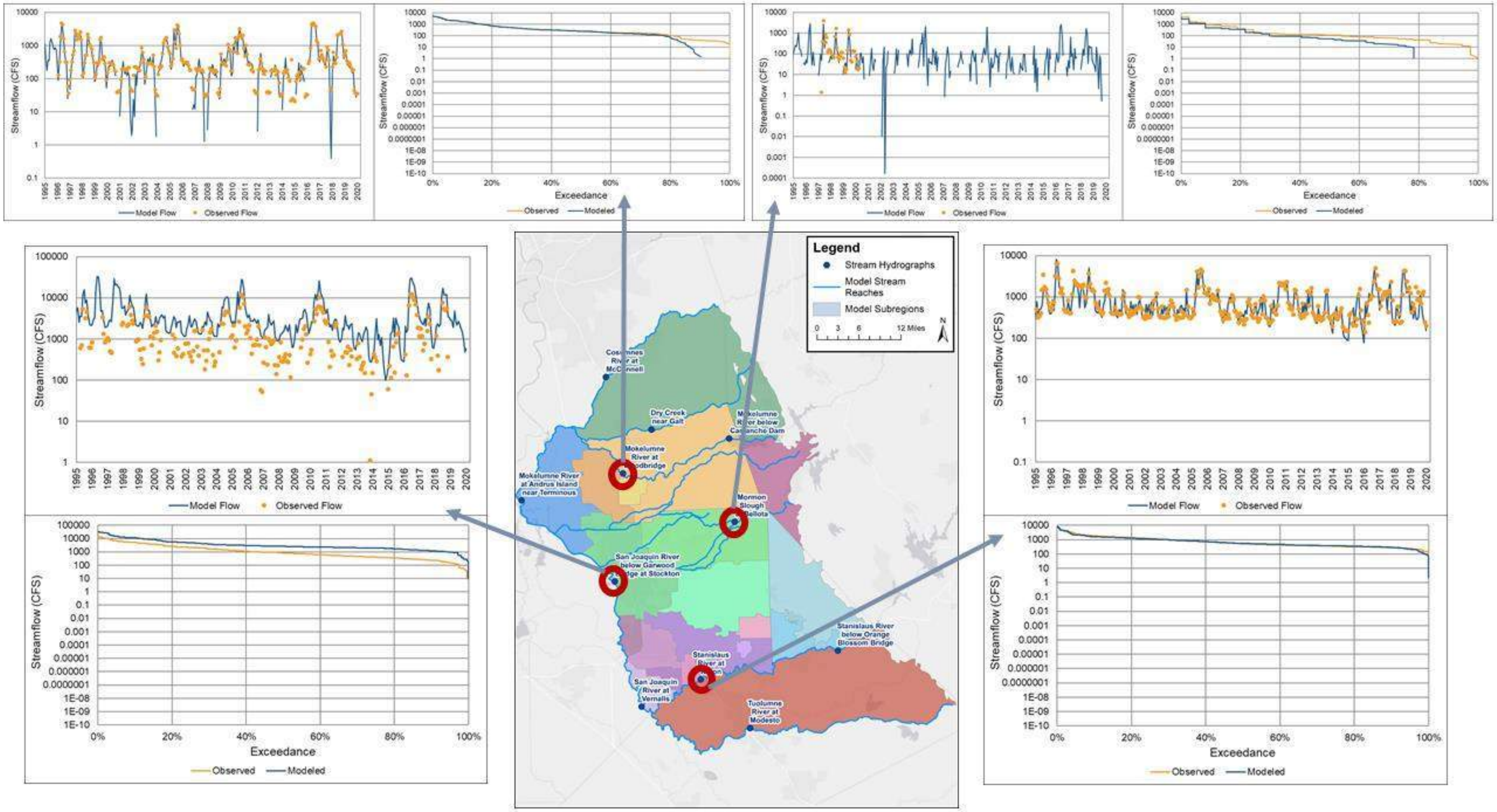
Dam and San Joaquin River near Vernalis) are duplicates of gages used to estimate stream inflow into the model area and were not referenced for streamflow calibration and only included as verification of the model setup.

Streambed hydraulic conductivity was adjusted during model calibration based on examination of stream flow hydrographs and stream reach water budgets. The portion of Mokelumne River through Camanche Reservoir (Reach 3) was assigned a streambed hydraulic conductivity of zero since all the surface water-groundwater interaction is already represented by the constrained general head boundary condition representing Camanche Reservoir. Additionally, streambed hydraulic conductivities were examined in the overlapping models of DWR's California Central Valley Groundwater-Surface Water Simulation Model with fine grid (C2VSimFG) and the Cosumnes-South American-North American Integrated Water Resources Model (CoSANA) and adjusted for some corresponding streams.

Simulated stream flows were compared with observed records and exceedance charts were also used to check the model performance when simulating high and low flows at each gage location. Calibration results for select stream gages are included in Figure 3.

Figure 3: Streamflow Calibration



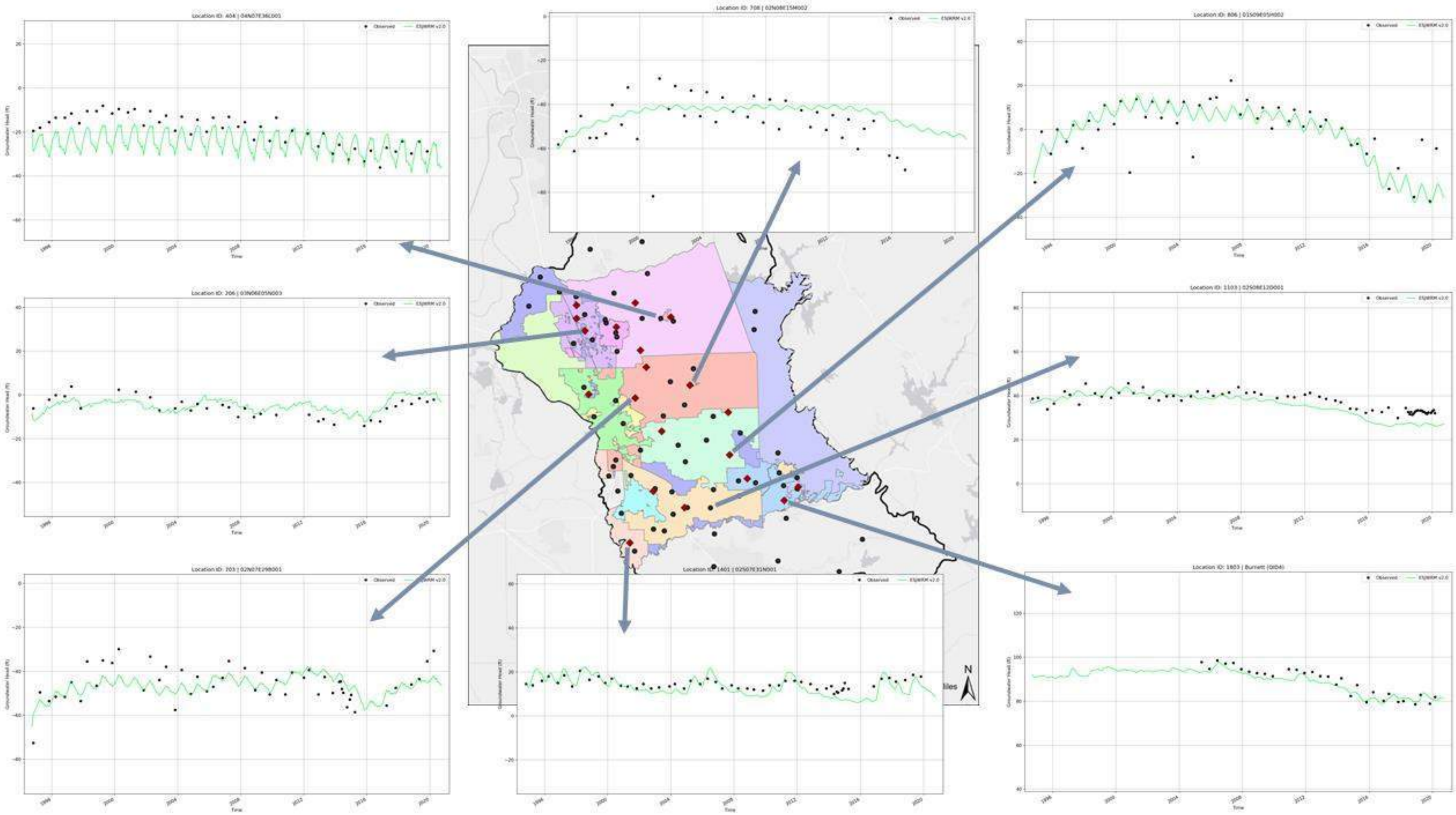
1.2.2.2 Groundwater Level Calibration

The goal of groundwater level calibration is to achieve the maximum agreement between simulated and observed groundwater elevations at calibration wells while maintaining reasonable values for aquifer parameters. During the calibration of ESJWRM Version 1.1, 70 wells were ultimately selected that were representative of the long-term conditions of groundwater levels both at a local and regional scale in ESJWRM. This same set of calibration points was kept for ESJWRM Version 2.0, with the addition of GSP Representative Monitoring Network wells if they were not already included.

Simulated groundwater levels are calibrated to observed levels through adjustments to hydrogeologic parameters or aquifer parameters including hydraulic conductivity, specific storage, and specific yield. The automated parameter estimation tool, PEST, was used to assist in refinement of aquifer parameters to improve model calibration. PEST-assisted calibration is performed to interact with ESJWRM via input and output files and iteratively modifies parameter values to reduce an objective function representative of the model residual error. These modifications are made within identified bounds of reasonable values for each parameter. PEST-assisted calibration focused on the aquifer parameters such as horizontal and vertical conductivities and storage parameters. Between PEST-assisted calibration iterations, the modeling team revisited the land system and small watershed budgets and made manual adjustments where needed, until calibration goals were met.

The results of the groundwater level calibration indicate that the ESJWRM reasonably simulates the long-term hydrologic responses under various hydrologic conditions. Figure 4 shows a selection of calibration wells with their resulting groundwater level hydrographs showing the updated calibration of ESJWRM Version 2.0. All ESJWRM Version 2.0 groundwater level hydrographs may be downloaded as a Google Earth KMZ file at (Link to be provided).

Figure 4: Groundwater Level Calibration



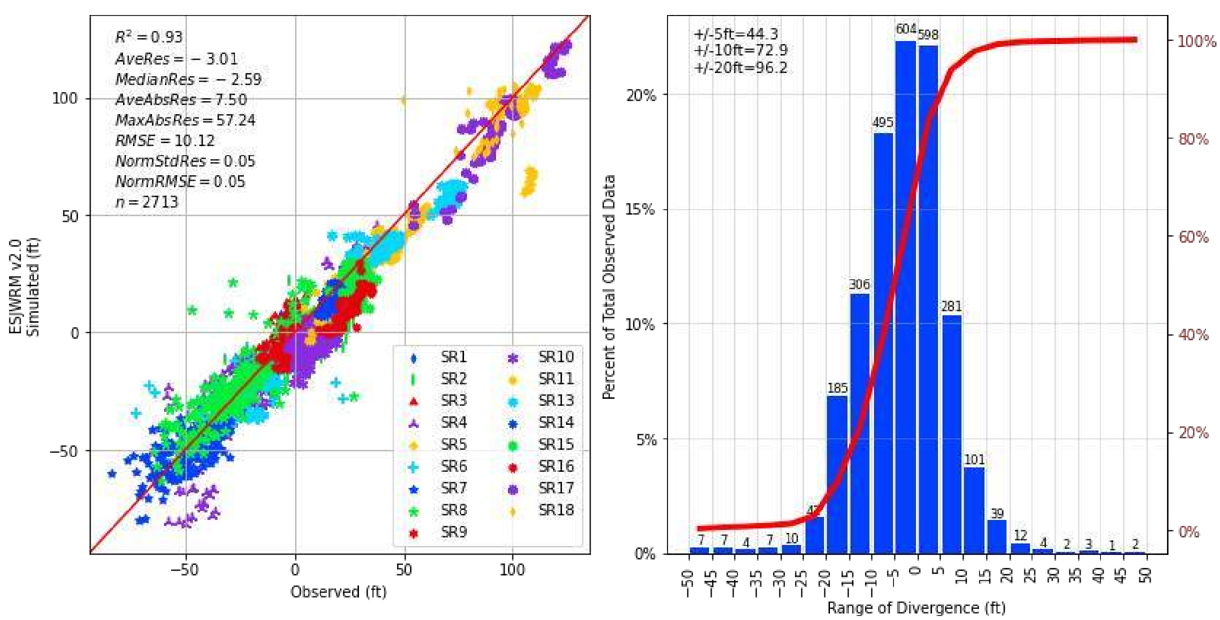
The ESJWRM calibration status was measured using two metrics: the groundwater level trend and the relationship between simulated and observed groundwater levels. The statistics were evaluated to meet the American Standard Testing Method (ASTM) standard. In addition to quantifiable metrics, the ESJWRM calibration was evaluated by generating reasonable regional groundwater flow directions and producing realistic water budgets.

The "Standard Guide for Calibrating a Groundwater Flow Model Application" (ASTM D5981) states that "the acceptable residual should be a small fraction of the head difference between the highest and lowest heads across the site." The residual is defined as the simulated head minus the observed head. An analysis of all calibration water levels within the model indicated the presence of 200+ feet of water level changes. Using 10 percent as the "small fraction", the acceptable residual level would be 20 feet. Calibration goals for the groundwater level residuals were set such that no more than 10 percent of the observed groundwater levels would exceed the acceptable residual level of 20 feet.

- 44% of observed groundwater levels are within +/- 5 feet of its respective simulated values
- 73% of observed groundwater levels are within +/- 10 feet of its respective simulated values
- 96% of observed groundwater levels are within +/- 20 feet of its respective simulated values

The residual histogram and scatter plot of simulated versus observed values for the ESJ Subbasin original calibration wells for the calibration period is shown in Figure 5. The scatter plot colors points by input data subregion. The highest elevations are seen in model subregions closer to the foothills (e.g., Subregion 5 and 17).

Figure 5: Calibration Statistics



1.2.3 Sensitivity Analysis

Sensitivity analysis is a way of investigating how sensitive certain model results are to changes in certain model parameters. A sensitive parameter is when the simulation results are greatly affected by changes in that parameter within its valid range. Conversely, an insensitive parameter means the changes in that parameter within its valid range do not affect the simulation results greatly.

Model parameters that are sensitive can be the largest sources of error and uncertainty when not precisely measured and well understood. For this reason, sensitivity analysis is an important step of the model calibration process. The sensitivity analysis serves the following purposes:

- To improve the understanding of input-output relationships
- To quantify the impact of inaccuracies in model parameters
- To evaluate the stability and robustness of the model
- To understand the overall range of accuracy of the model results

For these purposes, the following set of calibration parameters were selected for investigation under ESJWRM sensitivity analysis:

- Aquifer horizontal hydraulic conductivity (Kh) changed globally by factors of 0.5, 0.67, 1.5, 2.0
- Aquifer vertical hydraulic conductivity (Kv) changed globally by factors of 0.5, 0.67, 1.5, 2.0
- Aquitard vertical hydraulic conductivity (Kaqt) changed globally by factors of 0.5, 0.67, 1.5, 2.0
- Specific yield (Sy) changed globally by factors of 0.8, 1.2
- Specific storage (Ss) changed globally by factors of 0.1, 0.2, 5, 10
- Streambed hydraulic conductivity (Kstr) changed globally by factors of 0.2, 0.5, 2.0, 5.0
- Boundary condition conductance for both general and constrained general head (BC_Cond) changed globally by factors of 0.5, 0.67, 1.5, 2.0
- Saturated soil hydraulic conductivity (Ksoil) changed globally by factors of 0.2, 0.5, 2.0, 5.0
- Target soil moisture (TSM) changed globally by setting all values to 0.6 or 0.8

In the process of evaluating the sensitivity of model results to certain parameter changes, the results from the 32 sensitivity runs were analyzed for the ESJ Subbasin and model as a whole and compared to the calibrated model in terms of the groundwater residual statistics. As the changes to the input parameters for sensitivity analysis were made globally, the changes in the model performance were also considered on a global or subregional scale. An improvement in the model performance based on changes in one parameter at a global scale does not necessarily mean improvements in the overall model performance and/or calibration, as the model is calibrated to a number of target parameters, only some of which may be included in the performance assessment during the sensitivity analysis.

Figure 6 presents the relative change in the three groundwater level residual statistics used in the evaluation of model calibration performance for 10 parameters in the entire EJSWRM for the calibration period. These three groundwater level residual statistics are:

- Root mean square error (RMSE): This statistic is a measure of how spread out the residuals are.
- Average residual: This statistic measures how inaccurate simulation results are with respect to the corresponding observations on average.
- Correlation coefficient (R^2): This statistic is a measure of the strength of the linear relationship between the simulated and observed pairs.

In the calibrated model residual statistics shown in Figure 5, the RMSE is 10.12 feet, the average residual is -3.01 feet, and the R^2 is 0.93. In Figure 6, the impact of the parameter sensitivity on the average residual from the calibration value of -3.01 feet is always too much of an increase or almost no change. In all the runs, the R^2 of 0.93, which ideally would increase in a better calibrated model, either decreases or remains about the same as the calibrated model. Similarly, the RMSE of 10.12 feet would decrease in a better calibrated model; however, all the sensitivity runs either increase or have no impact on the RMSE.

Figure 7 and Figure 8 look at the change in calibration period average ESJ Subbasin change in storage and deep percolation (both parameters from the hydrologic groundwater budget). Both figures show how sensitive change in storage and deep percolation are to changes in parameters, notably aquifer horizontal hydraulic conductivity (Kh), streambed hydraulic conductivity (Kstr), saturated soil hydraulic conductivity (Ksoil), and target soil moisture (TSM). Even relatively minor changes to those parameters can have large impacts on the ultimate model results.

None of the sensitivity runs resulted in a significant improvement in statistics or results. This means that the model is stable and that the calibration is at or near an optimal point when global parameter changes are considered.

Figure 6: Sensitivity of Groundwater Level Residual Statistics in Entire ESJWRM

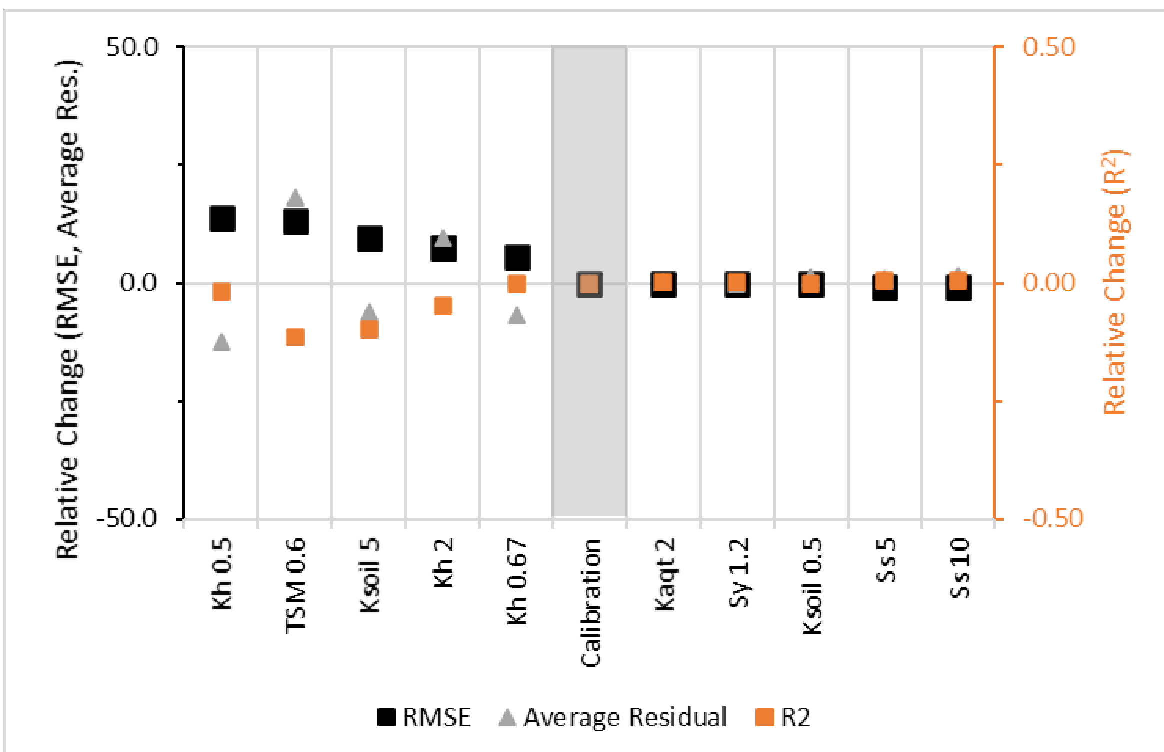


Figure 7: Sensitivity of Change in Groundwater Storage in ESJ Subbasin

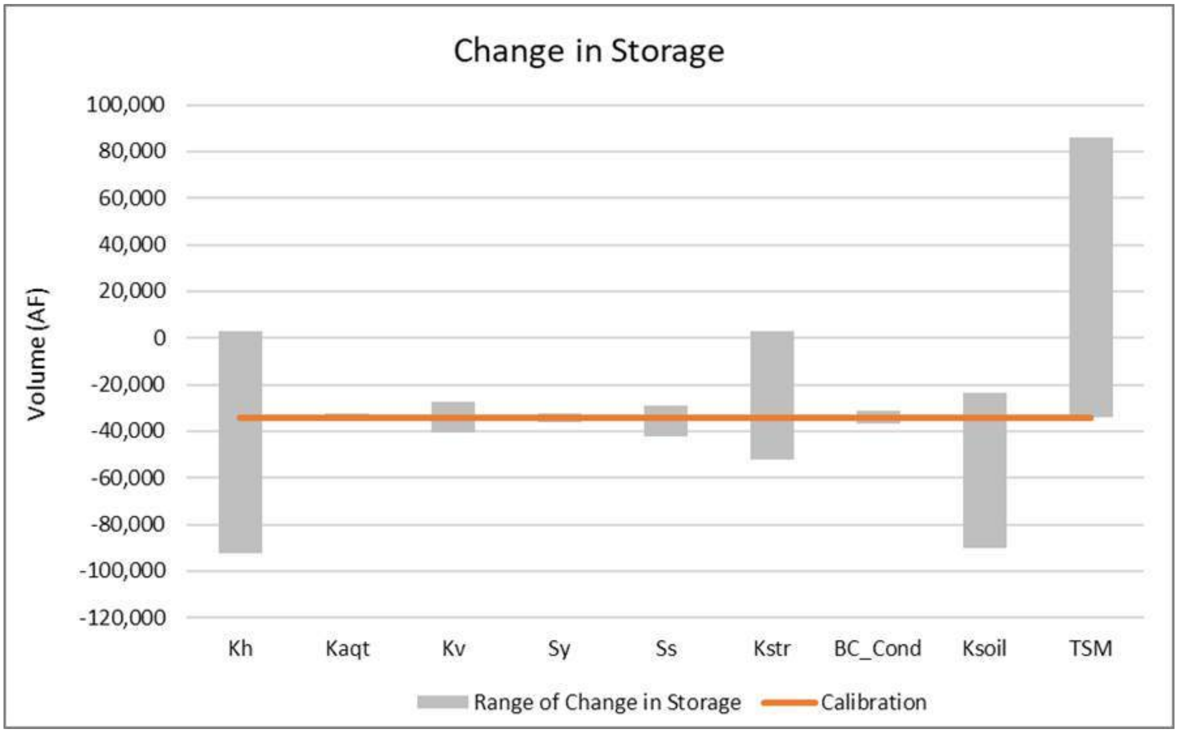
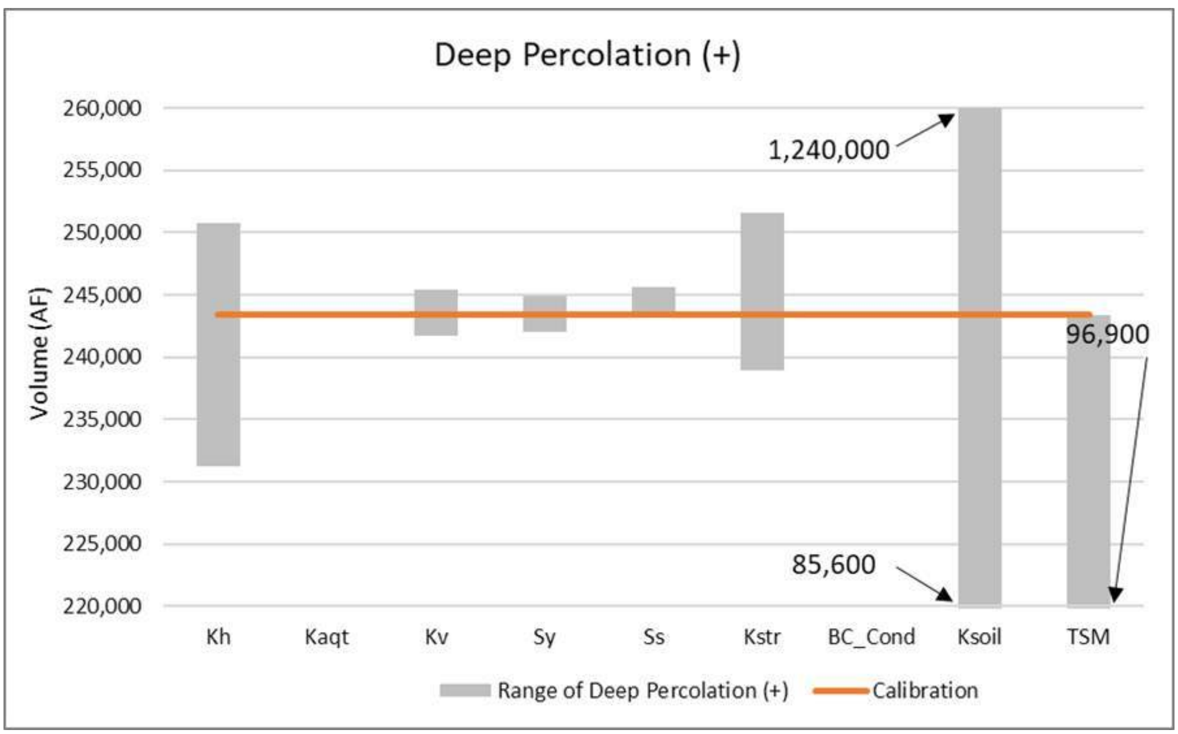


Figure 8: Sensitivity of Deep Percolation in ESJ Subbasin



1.3 Historical Model Results

A water budget balances supplies, demands, and any subsequent change in storage occurring within the specific portion of the hydrologic cycle. IWFM automatically outputs budgets at the subregion scale for processes involving groundwater, land surface, streams, root zone, small watersheds, and unsaturated zone. IWFM can output budgets down to a single element or any specific grouping of elements.

During this step of the calibration process, model results are reviewed and summarized into monthly and annual (by water year) budgets. The primary budgets reviewed for calibration are the land and water use budget and the groundwater budget. After extensive budget analysis, key model datasets and parameters are adjusted, particularly groundwater aquifer parameters, to better match local budgets from local agricultural water purveyors and local planning efforts. The ESJWRM Version 2.0 water budget results are summarized in the following sections.

1.3.1 Land and Water Use Budget

The land and water use budget includes two different versions, agricultural and urban, and represents the balance of the model-calculated water demands with the water supplied. Both the agricultural and urban versions include the same components that make up the water balance:

- Inflows:
  - Groundwater pumping
  - Surface water deliveries
  - Shortage (if applicable)
- Outflows:
  - Demand (either agricultural or urban)
  - Surplus (if applicable)

The average annual water demand for the Subbasin within the calibration period was 1,262 thousand acre-feet (TAF), consisting of 1,145 TAF agricultural demand and 117 TAF urban demand. This demand was met by an annual average of 567 TAF of surface water deliveries (512 TAF of agricultural and 55 TAF of urban deliveries) and was supplemented by 699 TAF of groundwater production (638 TAF of agricultural and 62 TAF of urban pumping). The average annual water shortage for the Subbasin within the calibration period was 5 TAF. Of this annual average, all of the surplus is from agricultural excess and the urban shortage is extremely minor at 0.15 TAF. Shortage and surplus represent a misalignment between the reported, estimated, or assumed water supply (groundwater pumping and surface water deliveries) and the calculated demands. In the historical model, this can occur when there are inaccuracies in the reported water supplies or uncertainties in the methodology and/or parameters used to calculate the demand. The small agricultural surplus indicates a minor misalignment of demands and supplies likely due to the timing, volume, or delivery location of the supplies. The annual simulated land and water use budgets for the calibration period are presented in Figure 9 and Figure 10 for the Subbasin as a whole, showing the agricultural and urban, respectively, demands and water supplies. If supply and demand do not balance, there is a surplus or shortage indicated on the land and water use budget.

Table 4 shows the annual averages described above for ESJWRM Version 2.0's calibration period. Compared to ESJWRM Version 1.1 ESJ Subbasin averages, which had a calibration period through 2015 instead of 2020, the biggest differences in ESJWRM Version 2.0 for the comparable calibration period are in the agricultural land and water use budget. Due to refinements to the agricultural surface water diversions (primarily due to OID, but also due to changes to SSJID, Delta, and riparian diversions), the surface water deliveries increased by 70 TAF compared to ESJWRM Version 1.1. Additional root zone calibration adjusted agricultural demand for several agencies (OID North, NSJWCD, and SSJID), resulting in ESJWRM Version 2.0 having more demand than ESJWRM Version 1.1. The refinement of delivery groups and estimated diversions reduced the surplus in ESJWRM Version 1.1 by 11 TAF, which resulted in less element pumping in ESJWRM Version 2.0. For the urban budget, the refinement of delivery groups (especially for Stockton area urban users), how demand was input into the model, and diversion amounts eliminated the surplus in ESJWRM Version 1.1.

The corresponding land and water use budgets for both agricultural and urban water demands are included for each GSA in Appendix A. OID is separated out into two separate water budgets: North and South. OID North is a GSA and OID South (not a GSA) is part of Modesto Subbasin. LCSD and LCWD do not have any agricultural demand and therefore a figure is not included.

Table 4: Eastern San Joaquin Subbasin Land and Water Use Budget Annual Averages

Land and Water Use Budget Component	ESJWRM Version 2.0 Annual Average for WY 1996-2020
Agricultural Area (thousand acres)	385
Agricultural Demand (TAF)	1,145
Agricultural Groundwater Pumping (TAF)	638
Agricultural Surface Water Deliveries (TAF)	512
Agricultural Surplus (TAF)[1]	5
Urban Area (thousand acres)	96
Urban Demand (TAF)	117
Urban Groundwater Pumping (TAF)	62
Urban Surface Water Deliveries (TAF)	55
Urban Shortage (TAF)[1]	0

[1] Shortage and surplus represent a misalignment between the reported, estimated or assumed water supply (groundwater pumping and surface water deliveries) and the calculated demands. In the historical model, this can occur when there are inaccuracies in the reported water supplies or uncertainties in the methodology and/or parameters used to calculate the demand. In the projected conditions, there are uncertainties in the assumptions and parameters used for both monthly supply and demand estimates and/or calculations, resulting in misalignments, which is reported as shortage or surplus.

Figure 9: Eastern San Joaquin Subbasin Agricultural Demand

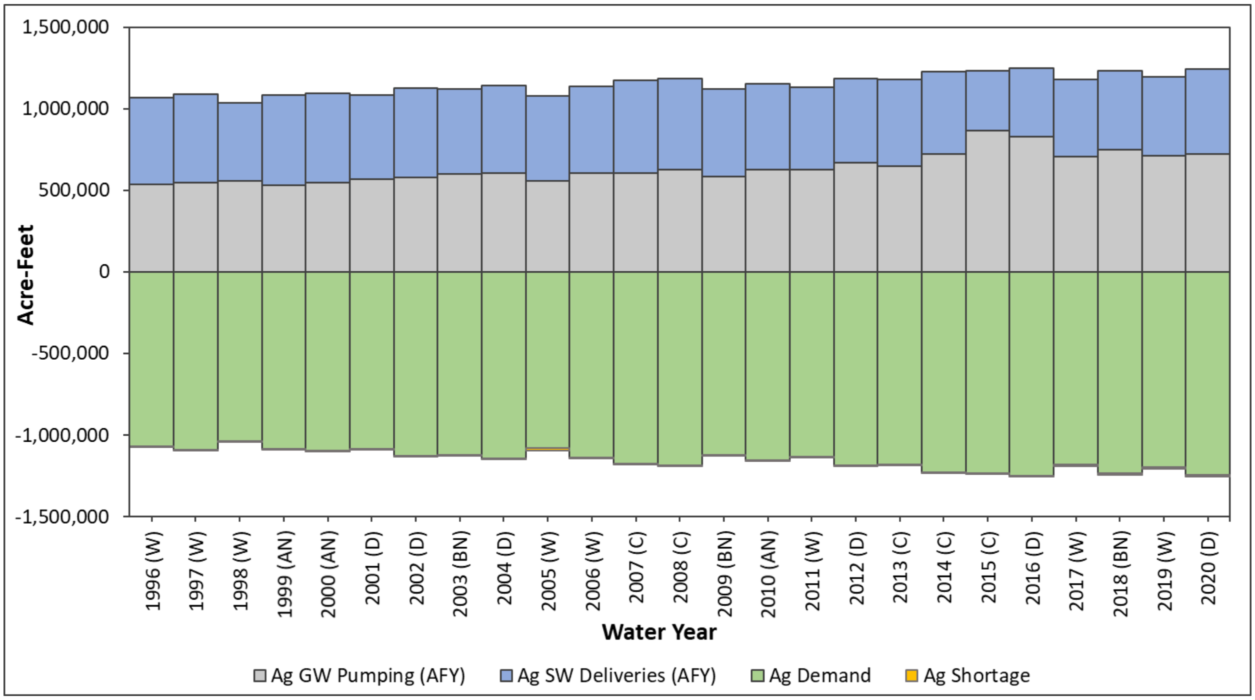
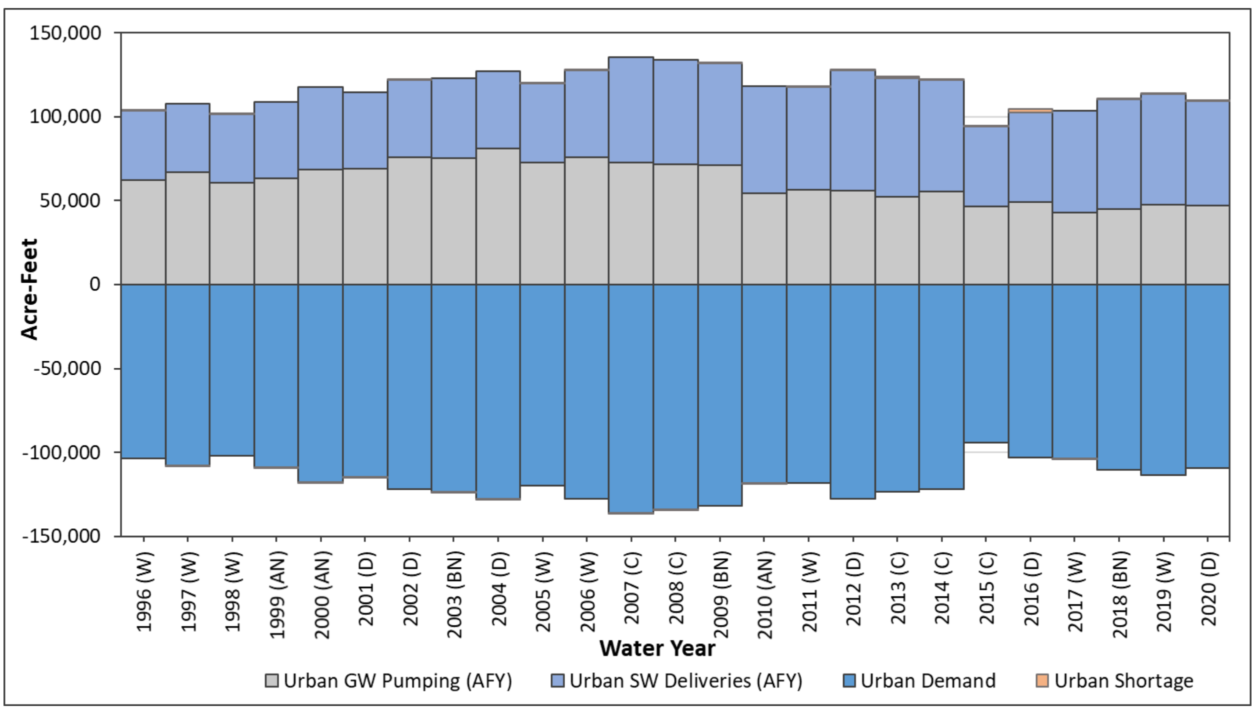


Figure 10: Eastern San Joaquin Subbasin Urban Demand



1.3.2 Hydrologic Groundwater Budget

The primary components of the groundwater budget, corresponding to the major hydrologic processes affecting groundwater flow in the ESJ Subbasin, are:

- Inflows:
  - Deep percolation (from rainfall and irrigation applied water)
  - Gain from stream (or recharge due to stream seepage)
  - Boundary inflow (from surrounding groundwater subbasins and the Sierra Nevada Mountains)
  - Other Recharge (from other sources such as irrigation canal seepage, managed aquifer recharge projects, and reservoir seepage)
- Outflows:
  - Groundwater pumping
  - Loss to stream (or outflow to streams and rivers)
  - Boundary outflow (to surrounding groundwater subbasins)
  - Change in groundwater storage (can be either an inflow or outflow)

The largest component in the groundwater budget is an average annual 709 TAF of pumping, offset by 262 TAF of deep percolation, a net gain from stream of 129 TAF, 169 TAF of other recharge, and a net boundary inflow of 113 TAF annually. The cumulative change in groundwater storage can be calculated from the change in groundwater storage. The groundwater storage in ESJ Subbasin during the calibration period was an average of 37 TAFY. These averages are shown in Table 5 and the Subbasin annual groundwater budget is shown in Figure 11.

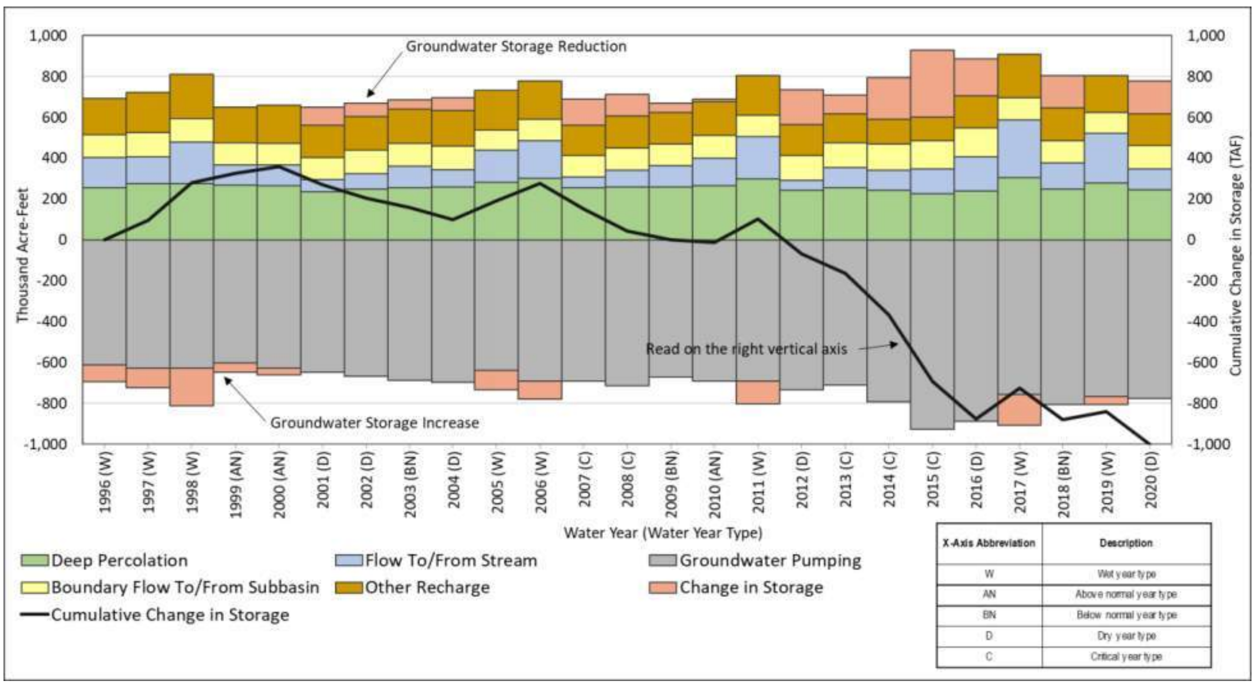
Table 5 shows the annual averages described above for ESJWRM Version 2.0's calibration period. The average annual change in storage estimation determined using ESJWRM Version 1.1 was 41 TAF. The latest update and calibration of the model to ESJWRM Version 2.0 has refined this estimate to an average annual change in storage of 37 TAF over the extended calibration period through 2020. The difference in these estimates is due in large part to the difference in the calibration period, as well as the overhaul of surface water data, especially with regards to OID, and the update to the overall model calibration. This difference in change in storage is well within the ranges observed in the sensitivity analysis discussed in Section 1.2.3.

Other differences observed in the groundwater budget between ESJWRM Version 2.0 and ESJWRM Version 1.1, using the comparable calibration period, are an increase in deep percolation in ESJWRM Version 2.0, most likely caused by increased applied surface water and changes to the root zone calibration, and a decrease in net stream seepage in ESJWRM Version 2.0 due to changes in groundwater levels near streams caused by other groundwater budget components.

Table 5: Eastern San Joaquin Subbasin Hydrologic Groundwater Budget Annual Averages

Hydrologic Groundwater Budget Component	ESJWRM Version 2.0 Annual Average for WY 1996-2020
Deep Percolation (TAF)	262
Other Recharge (TAF)	169
Net Stream Seepage (TAF)	129
Net Boundary Inflow (TAF)	113
Groundwater Pumping (TAF)	709
Change in Groundwater Storage (TAF)	37

Figure 11: Eastern San Joaquin Subbasin Hydrologic Groundwater Budget



2 Projected Conditions Baseline Update

The refinements and enhancements made to the historical data for the updated historical calibration ESJWRM (ESJWRM Version 2.0) required an update to the projected conditions baseline ESJWRM. The version of the Projected Conditions Baseline (PCBL) presented in the GSP finalized in November 2019 is called PCBL Version 1.0. The updated version of the PCBL using ESJWRM Version 2.0 extended dataset and calibration results is referred to as PCBL Version 2.0. This section presents the key data sources and assumptions used to develop the PCBL Version 2.0 and provides the model results.

The PCBL used to develop the projected water budgets represents estimated long-term hydrologic conditions of the Subbasin under the foreseeable future level of development. The future level of development represents approximately water year 2040 or the closest information available from planning documents.

2.1 Assumptions Used to Develop Projected Conditions Baseline Update

This section discusses the assumptions made in converting PCBL Version 1.0 to PCBL Version 2.0. The data and calibration parameters were updated to be consistent with the historical ESJWRM Version 2.0. Initial groundwater levels and soil conditions in the PCBL represent those at the end of the simulation period of the historical ESJWRM Version 2.0 (September 30, 2020).

2.1.1 Hydrology

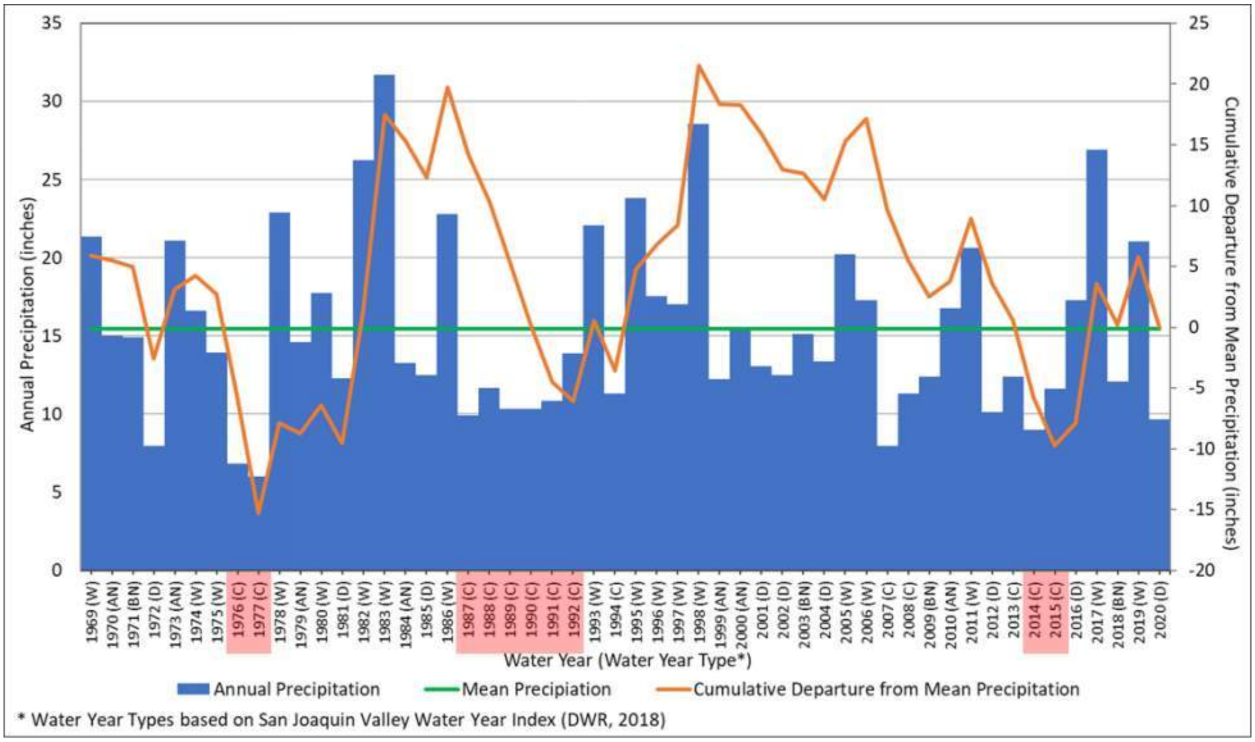
The GSP version of PCBL Version 1.0 included 50 years of hydrology data from water years 1969 through 2018 (October 1968 through September 30, 2018) and was documented in the ESJ Subbasin GSP (ESJGWA, 2019). The updated version PCBL Version 2.0 uses 52 years of hydrology data from water years 1969 through 2020 (October 1968 through September 30, 2020). The projected 52 years of hydrology used in PCBL Version 2.0 was maintained and extended to meet the SGMA requirements to evaluate how the Subbasin's surface and groundwater systems may react under representative hydrologic conditions.

2.1.1.1 Precipitation and Hydrologic Water Year Types

Historical precipitation or rainfall in the ESJ Subbasin was used to identify the hydrologic period that would provide a representation of wet, dry, and extreme periods needed for PCBL Version 2.0. Figure 12 shows the Subbasin annual precipitation (blue columns), average precipitation (green line) of approximately 15 inches, and cumulative departure from mean precipitation (orange line) for each water year from 1969 through 2020. This plot represents the spatially-averaged precipitation across ESJ Subbasin elements developed from PRISM precipitation data. The long-term average precipitation is subtracted from annual precipitation within each water year to develop the departure from average precipitation for each water year. Starting at the first year analyzed, the departures are added cumulatively for each subsequent year. Wet years have a positive departure and upward slopes, dry years have a negative departure and downward slopes, and a year with exactly average precipitation would have zero departure. More severe events are shown by steeper slopes and greater changes.

Each year on the x-axis in Figure 12 is indicated with the San Joaquin Valley Water Year Hydrologic Classification Index published by DWR. The 52 years of the PCBL, from WY 1969 through 2020, represent a range of hydrologic conditions, as identified by the water year types in the San Joaquin Valley Water Year Hydrologic Classification, which classifies water years 1901 through 2020 as Wet (W), Above Normal (AN), Below Normal (BN), Dry (D), and Critical (C) based on inflows to major reservoirs or lakes. A description of how this index is calculated and the specific data used to calculate this index is available online from CDEC at http://cdec.water.ca.gov/cgi-progs/iodir/WSIHIST. In the 52 years of hydrology used in the PCBL Version 2.0, there are 14 Critical years, 9 Dry years, 4 Below Normal years, 7 Above Normal years, and 18 Wet years.

Figure 12: Historical Precipitation in Eastern San Joaquin Subbasin



To facilitate assumptions for baseline water supplies and demands, the five San Joaquin Valley water year types were aggregated into three water year type groups. Critical and Dry years are combined into one category in the baseline water year types (called Dry years), Above Normal and Below Normal years are also combined into one category (Normal years), and Wet years remain in one category (called Wet years). With this breakdown, the three baseline water year types have a distribution of 23 Dry years, 11 Normal years, and 18 Wet years. These baseline water year types (Table 6) are used in the remainder of the PCBL data development and results discussion.

As evident in Figure 12, there are three periods of extreme drought in which there are sequences of critical years where the cumulative departure from mean precipitation drops significantly in a steep slope. To capture future extreme dry year periods that may occur in the PCBL, the following 10 water years were designated as Drought periods: 1976-1977, 1987-1992, and 2014-2015. Drought years are highlighted in red on the x-axis of Figure 12 and distinguished in Table 6. Though the most recent drought lasted from 2012 through 2015, the selected baseline drought years only included 2014 and 2015 as those were the most critical years in which supplies and demands were most impacted.

An 11-year period (WY 2010-2020) of historical hydrology was selected to form the basis of projected data developed by averaging recent historical data. This period was selected because of the reliability of the historical data in ESJWRM Version 2.0 during these years and because the distribution of water year types was relatively consistent with the overall PCBL hydrology.

Table 6: Baseline Hydrologic Water Year Types

Baseline Year	Water Year	San Joaquin Valley Water Year Hydrologic Classification	Baseline Year Type		Baseline Year	Water Year	San Joaquin Valley Water Year Hydrologic Classification	Baseline Year Type
1	1969	Wet	Wet		27	1995	Wet	Wet
2	1970	Above Normal	Normal		28	1996	Wet	Wet
3	1971	Below Normal	Normal		29	1997	Wet	Wet
4	1972	Dry	Dry		30	1998	Wet	Wet
5	1973	Above Normal	Normal		31	1999	Above Normal	Normal
6	1974	Wet	Wet		32	2000	Above Normal	Normal
7	1975	Wet	Wet		33	2001	Dry	Dry
8	1976	Critical	Drought		34	2002	Dry	Dry
9	1977	Critical	Drought		35	2003	Below Normal	Normal
10	1978	Wet	Wet		36	2004	Dry	Dry
11	1979	Above Normal	Normal		37	2005	Wet	Wet
12	1980	Wet	Wet		38	2006	Wet	Wet
13	1981	Dry	Dry		39	2007	Critical	Dry
14	1982	Wet	Wet		40	2008	Critical	Dry
15	1983	Wet	Wet		41	2009	Below Normal	Normal
16	1984	Above Normal	Normal		42	2010	Above Normal	Normal
17	1985	Dry	Dry		43	2011	Wet	Wet
18	1986	Wet	Wet		44	2012	Dry	Dry
19	1987	Critical	Drought		45	2013	Critical	Dry
20	1988	Critical	Drought		46	2014	Critical	Drought
21	1989	Critical	Drought		47	2015	Critical	Drought
22	1990	Critical	Drought		48	2016	Dry	Dry
23	1991	Critical	Drought		49	2017	Wet	Wet
24	1992	Critical	Drought		50	2018	Below Normal	Normal
25	1993	Wet	Wet		51	2019	Wet	Wet
26	1994	Critical	Dry		52	2020	Dry	Dry

2.1.1.2 Evapotranspiration

No changes to evapotranspiration in ESJ Subbasin were implemented in PCBL Version 2.0. ESJWM Version 2.0 evapotranspiration by land use type and by model subregion is assumed to be consistent into the future.

2.1.1.3 Streamflow

No change was assumed in PCBL Version 2.0 to all stream inflows. SSJID system outflows were calculated based on the 11-year aggregated water year type average of historical data for WY 2010-2020.

2.1.2 Land Use and Cropping Patterns

PCBL Version 2.0 used the latest land use dataset available and incorporated urban buildout to reflect the 2040 land use conditions. Land use and cropping patterns are based on the most recent, comprehensive, and model-wide land use survey from DWR (DWR, 2018d), with adjustments based on local information and input. This spatial land use data was mapped to ESJWRM model elements and is used as the basis of the PCBL as the latest source of reliable land use data covering the entire model domain. The same edits were made to elements representing LCSD and LCWD to remove agricultural land, as described above for ESJWRM Version 2.0 discussed in Section 1.1.5. The land use data for OID area is adjusted to reflect the information consistent with the OID AWMP.

To represent the extent of urban buildout in 2040, the urban areas in 2018 land use dataset were expanded to either the sphere of influence or general plan boundaries and are held constant during the simulation. The areas with urban buildout are shown in Figure 13 and include Lodi, Stockton, Lathrop, Manteca, Ripon, and Escalon. No growth was assumed for the Jenny Lind urban area. While there is agricultural growth anticipated in the eastern areas of the Subbasin and potential conversion of existing agricultural land to permanent irrigated crops, no reliable projections were available to include in the simulation; therefore, no additional agricultural land growth was added to the PCBL. Thus, cropping acreage is reduced only where urban expansion occurs. This means that due to projected urban growth of over 48,000 acres, agricultural acreage is expected to decrease by approximately 34,000 acres and undeveloped acreage decreases by under 15,000 acres. Table 7 shows the differences between the DWR 2018 data and the ultimate baseline acreage once urban buildout was incorporated. Figure 14 is a pie chart of the PCBL Version 2.0 cropping pattern.

Figure 13: 2018 Land Use with Urban Sphere of Influence Boundaries

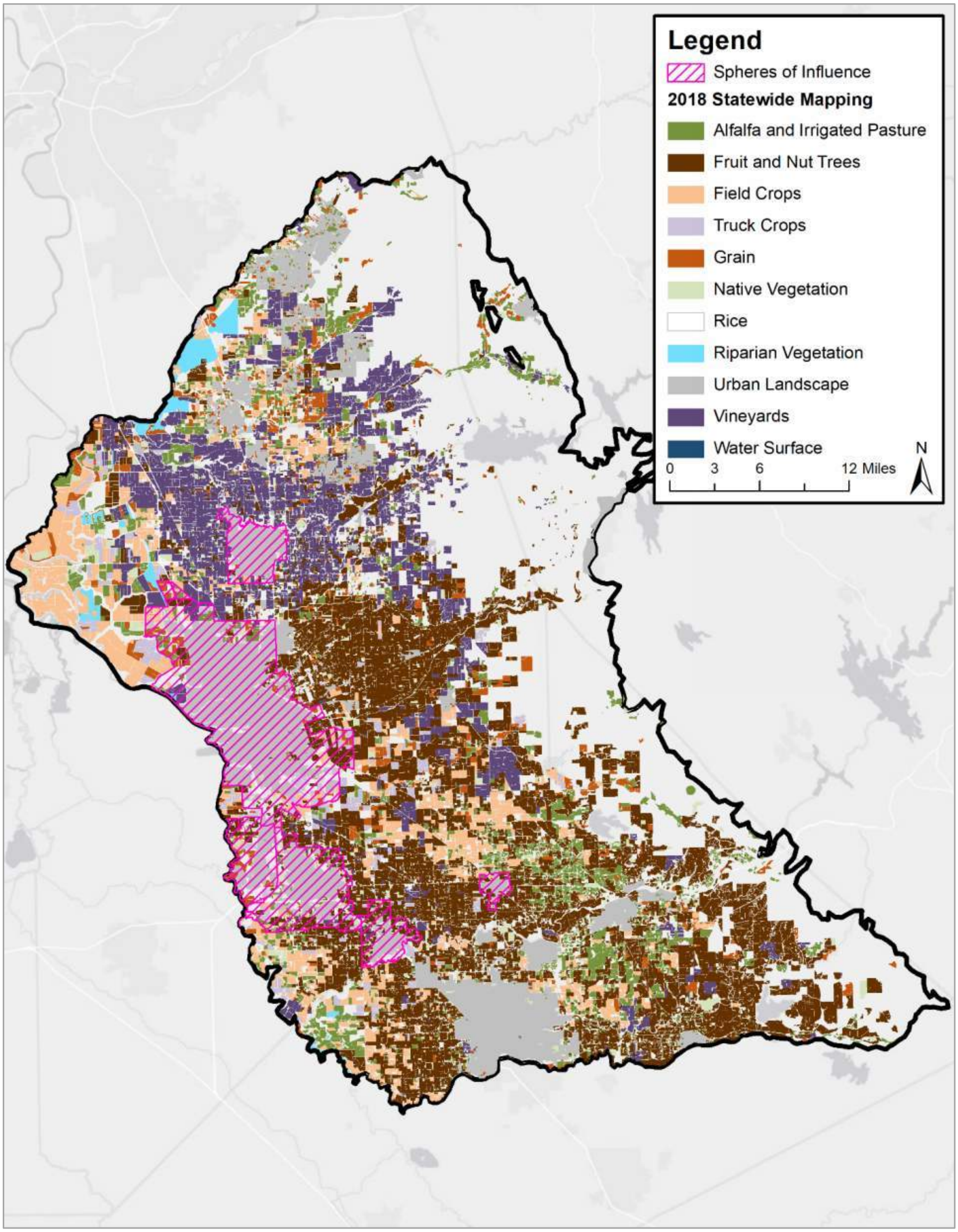
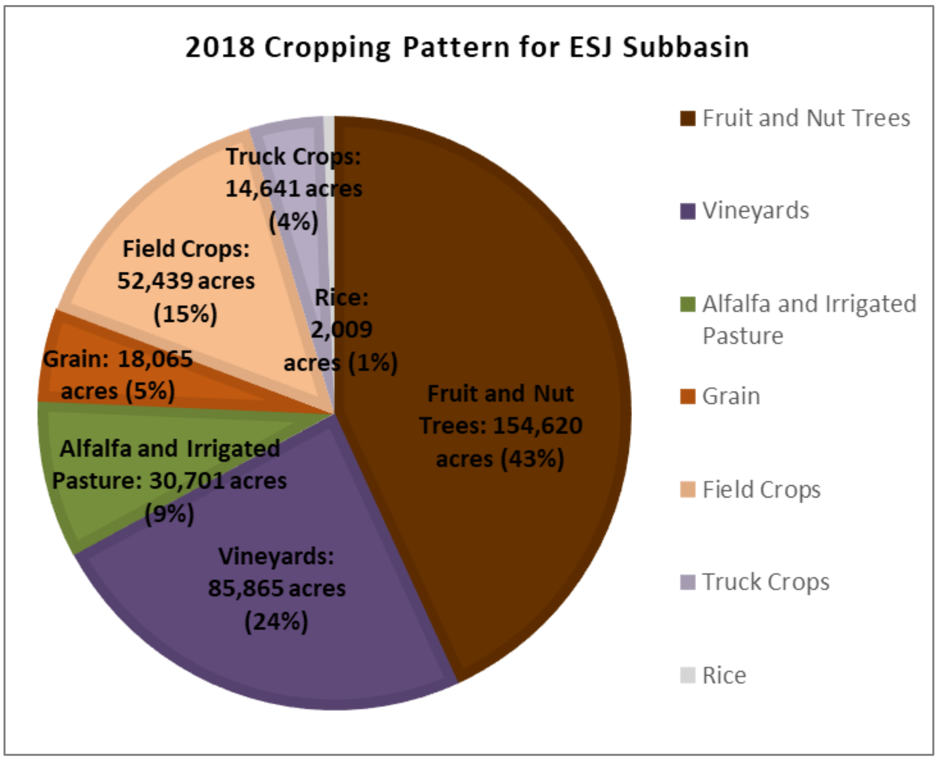


Table 7: ESJ Subbasin Land Use Acreages by Land Use Type

Land Use Type	DWR 2018 Survey	Baseline Model	Change from DWR 2018 Survey
Ag Acreage	392,112	358,340	-33,772
Urban Acreage	104,858	153,484	48,625
Undeveloped Acreage	255,143	240,289	-14,853
Riparian	12,579	12,579	0

Figure 14: 2018 Cropping Pattern for ESJ Subbasin



2.1.3 Water Supply and Demand

Urban water demand in the PCBL Version 2.0 is generally reflective of 2040 conditions. Demand and supply projections were generally available for 2040 or 2045 conditions from urban water management plans (UWMPs). Water demand and supply assumptions are based on the 2020 UWMPs, other planning documents, and the most current information provided by purveyors. Urban demand and supply projections were estimated for three water year types for wet, normal, and dry conditions, with drought periods assumed of critical water supply. Projections for wet years were assumed to be the same as normal conditions when wet year projections were unavailable. After the projected surface water supply and demand were pulled from the planning documents, the projected municipal pumping was calculated as the difference between surface water supply and demand. For the purpose of the modeling, supply was assumed to meet the demand with no surplus.

Agricultural water supply largely used the 11-year averages of grouped water year types from the recent historical data (WY 2010-2020). All PCBL annual average surface water diversion volumes are included in Table 2.

In each of the drought period years in the PCBL, it was assumed that the surface water supply delivered was at the 2015 level of supply, if lower than the dry year supply. Pumping was increased accordingly if not calculated within the model. In this way, the PCBL is based on the most recent critical year actual historical delivery data and simulates periods of extreme stress on the groundwater system.

2.2 Projected Conditions Baseline Results

This section provides a summary of the ESJWRM PCBL Version 2.0 results.

2.2.1 Land and Water Use Water Budget

The land and water use budget includes two different versions, agricultural and urban, and represents the balance of the model-calculated water demands with the water supplied. Both the agricultural and urban versions include the same components that make up the water balance:

- Inflows:
    - Groundwater pumping
    - Surface water deliveries
    - Shortage (if applicable)
- Outflows:
    - Demand (either agricultural or urban)
    - Surplus (if applicable)

The average annual projected water demand for the Subbasin within the 52-year simulation period is 1,258 thousand acre-feet (TAF), consisting of approximately 1,100 TAF expected agricultural demand and 158 TAF expected urban demand. This demand is met by an annual average of 528 TAF of surface water deliveries (453 TAF of agricultural and 76 TAF of urban deliveries) and is supplemented by 743 TAF of groundwater production (661 TAF of agricultural and 82 TAF of urban pumping). Due to uncertainties in the estimation of projected agricultural demand and historical supply records, there is 13 TAF of surplus in the Subbasin scale agricultural water use budget, which is insignificant relative to the total volume of water use. Shortage and surplus represent a misalignment between the reported, estimated, or assumed water supply (groundwater pumping and surface water deliveries) and the calculated demands. In the projected conditions, there are uncertainties in the assumptions and parameters used for both monthly supply and demand estimates and/or calculations, resulting in misalignments, which is reported as shortage or surplus. These annual averages are shown in Table 8. The annual land and water use budgets across the ESJ Subbasin are shown in Figure 15 and Figure 16 for the Subbasin as a whole, showing the agricultural and urban, respectively, demands plotted with water supplies.

The corresponding average annual agricultural and urban demand figures for the projected conditions baseline are included for each GSA in Appendix B. As in the historical model LCSD and LCWD do not have projected agricultural demand and therefore the figure is not included. At full buildout to the sphere of influence boundaries, City of Stockton GSA, San Joaquin County #2, and City of Manteca GSA do not have agricultural demand and therefore figures for those GSAs are also not included.

Table 8: Eastern San Joaquin Subbasin Land and Water Use Budget Annual Average

Land and Water Use Budget Component	PCBL Version 2.0 Annual Average
Agricultural Area (thousand acres)	359
Agricultural Demand (TAF)	1,100
Agricultural Groundwater Pumping (TAF)	661
Agricultural Surface Water Deliveries (TAF)	453
Agricultural Surplus (TAF)[1]	13
Urban Area (thousand acres)	153
Urban Demand (TAF)	158
Urban Groundwater Pumping (TAF)	82
Urban Surface Water Deliveries (TAF)	76
Urban Shortage (TAF)[1]	0

[1] Shortage and surplus represent a misalignment between the reported, estimated or assumed water supply (groundwater pumping and surface water deliveries) and the calculated demands. In the historical model, this can occur when there are inaccuracies in the reported water supplies or uncertainties in the methodology and/or parameters used to calculate the demand. In the projected conditions, there are uncertainties in the assumptions and parameters used for both monthly supply and demand estimates and/or calculations, resulting in misalignments, which is reported as shortage or surplus.

Figure 15: Eastern San Joaquin Subbasin Projected Agricultural Demand

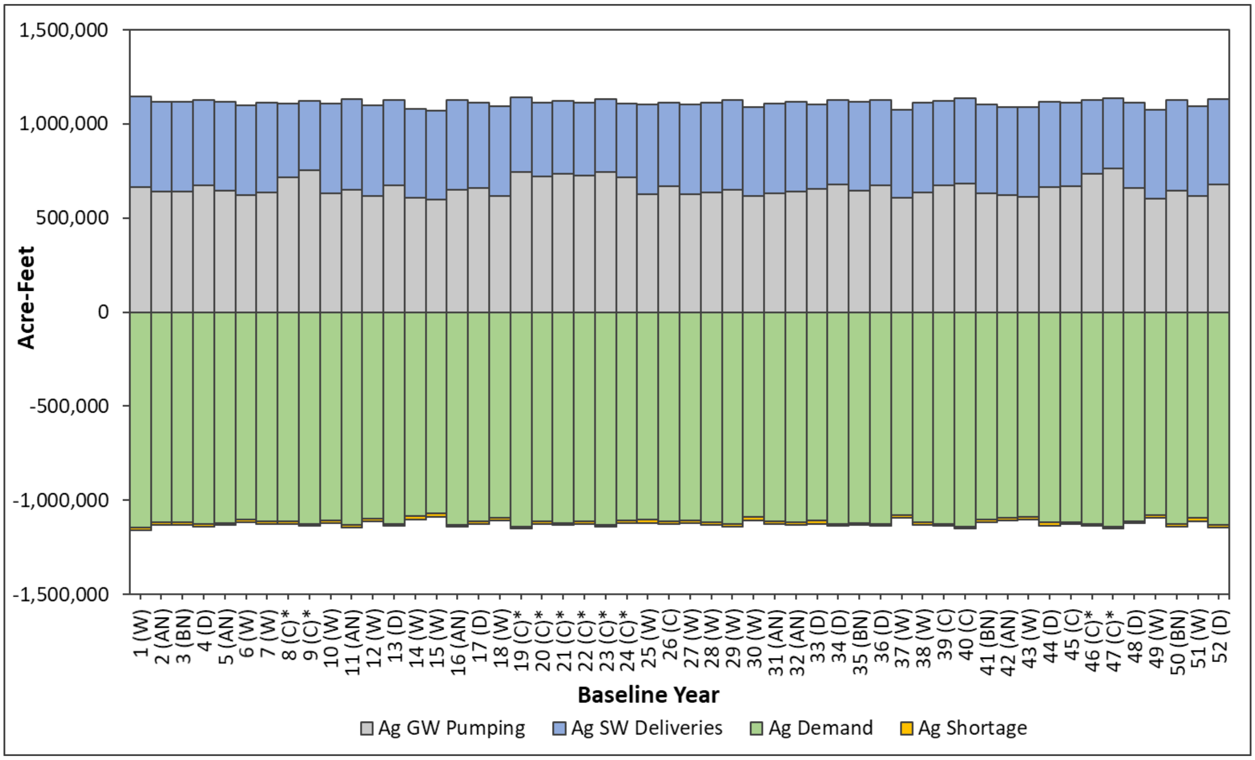
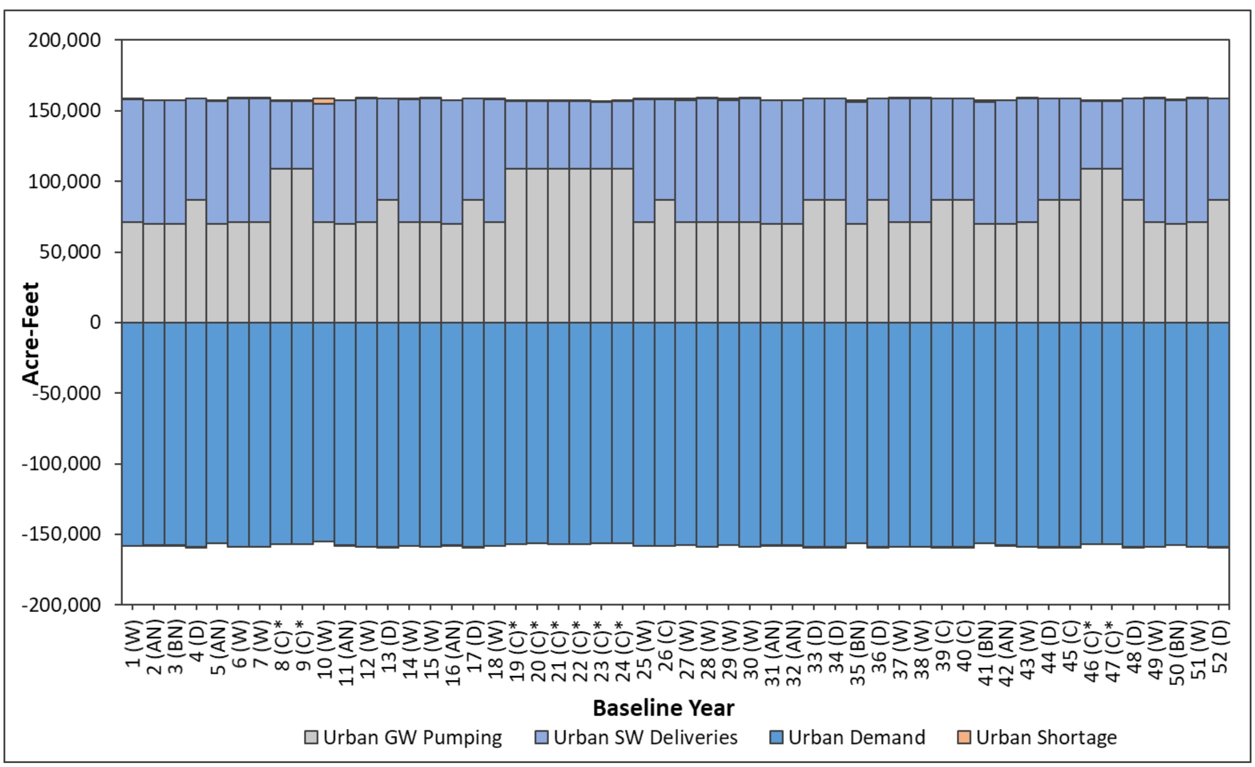


Figure 16: Eastern San Joaquin Subbasin Projected Urban Demand



2.2.2 Hydrologic Groundwater Budget

The primary components of the groundwater budget are the same as represented in the historical model. Corresponding to the major hydrologic processes affecting groundwater flow in the Subbasin, these are:

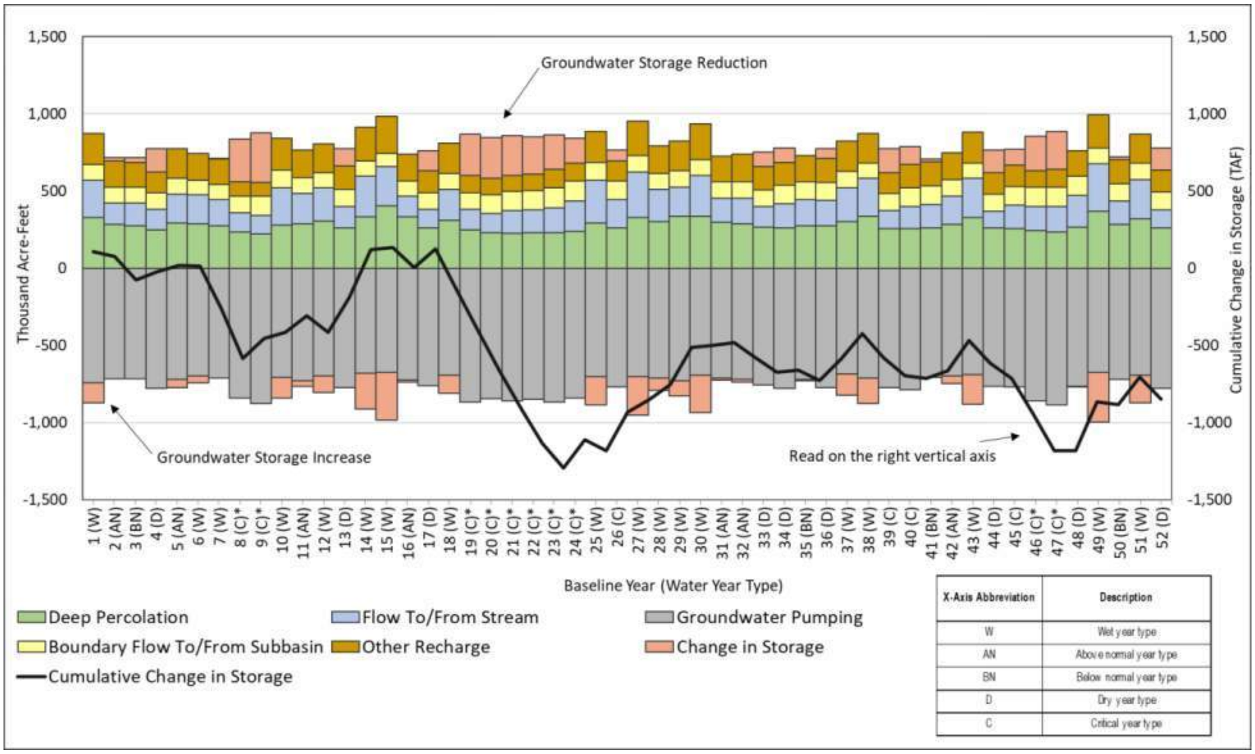
- Inflows:
    - Deep percolation (from rainfall and irrigation applied water)
    - Gain from stream (or recharge due to stream seepage)
    - Boundary inflow (from surrounding groundwater subbasins and the Sierra Nevada Mountains)
    - Other Recharge (from other sources such as irrigation canal seepage, managed aquifer recharge projects, and reservoir seepage)
- Outflows:
    - Groundwater pumping
    - Loss to stream (or outflow to streams and rivers)
    - Boundary outflow (to surrounding groundwater subbasins)
    - Change in groundwater storage (can be either an inflow or outflow)

Pumping in the PCBL Version 2.0 remains the largest component in the groundwater budget with an annual average 751 TAF. The PCBL offsets this pumping with 282 TAF of deep percolation, a net gain from stream of 181 TAF, 162 TAF of other recharge, and a total subsurface inflow of 110 TAF annually. The cumulative change in groundwater storage can be calculated from the annual change in groundwater storage. Due to inherent uncertainties in model input data, calculations, and calibration, all budget components have a degree of uncertainty. Given this uncertainty, the projected long-term average annual the groundwater storage deficit in ESJ Subbasin in the PCBL is 16 TAFY. These annual averages are shown in Table 9. The groundwater budgets, with average cumulative change in storage, are shown for the ESJ Subbasin in Figure 17.

Table 9: Eastern San Joaquin Subbasin Hydrologic Groundwater Budget Annual Average

Hydrologic Groundwater Budget Component	PCBL Version 2.0 Annual Average
Deep Percolation (TAF)	282
Other Recharge (TAF)	162
Net Stream Seepage (TAF)	181
Net Boundary Inflow (TAF)	110
Groundwater Pumping (TAF)	751
Change in Groundwater Storage (TAF)	16

Figure 17: Eastern San Joaquin Subbasin Projected Hydrologic Groundwater Budget



3 Projected Conditions Baseline Update with Climate Change

With the update of the PCBL Version 2.0, the potential impact of climate change on the Subbasin in the future was also updated. The version of the Projected Conditions Baseline with Climate Change (PCBL-CC) presented in the GSP finalized in November 2019 is called PCBL-CC Version 1.0. The updated version of the PCBL-CC using PCBL Version 2.0 with hydrology perturbation factors is referred to as PCBL-CC Version 2.0. Largely, PCBL-CC Version 1.0 and Version 2.0 use the same perturbation factors, but PCBL-CC Version 2.0 extends the simulation time period by two years. This section presents the climate change methodology, data sources, and assumptions used to develop the PCBL-CC Version 2.0 and provides the model results.

In PCBL-CC Version 1.0, the ESJGWA decided to use 2070 Central Tendency perturbation factors as a reasonable estimation of the impact of climate change. PCBL-CC Version 2.0 also used 2070 Central Tendency climate change conditions.

3.1 Climate Change Background and Methods

SGMA requires taking into consideration uncertainties associated with climate change in the development of GSPs.

Consistent with Section 354.18(d)(3) and Section 354.18(e) of the GSP Regulations, an analysis was performed for the Subbasin evaluating the projected water budget with and without climate change conditions.

Section 354.18(d)(3) of the GSP Regulations states:

"(d) The Agency shall utilize the following information provided, as available, by the Department pursuant to Section 353.2, or other data of comparable quality, to develop the water budget:

(1) Historical water budget information for mean annual temperature, mean annual precipitation, water year type, and land use.

(2) Current water budget information for temperature, water year type, evapotranspiration, and land use.

*(3) Projected water budget information for population, population growth, **climate change** [emphasis added], and sea level rise."*

Section 354.18(e) states:

*"(e) Each Plan shall rely on the best available information and best available science to quantify the water budget for the basin in order to provide an understanding of historical and projected hydrology, water demand, water supply, land use, population, **climate change** [emphasis added], sea level rise, groundwater and surface water interaction, and subsurface groundwater flow. If a numerical groundwater and surface water model is not used to quantify and evaluate the projected water budget conditions and the potential impacts to beneficial uses and users of groundwater, the Plan shall identify and describe an equally effective method, tool, or analytical model to evaluate projected water budget conditions."*

3.1.1 DWR Guidance

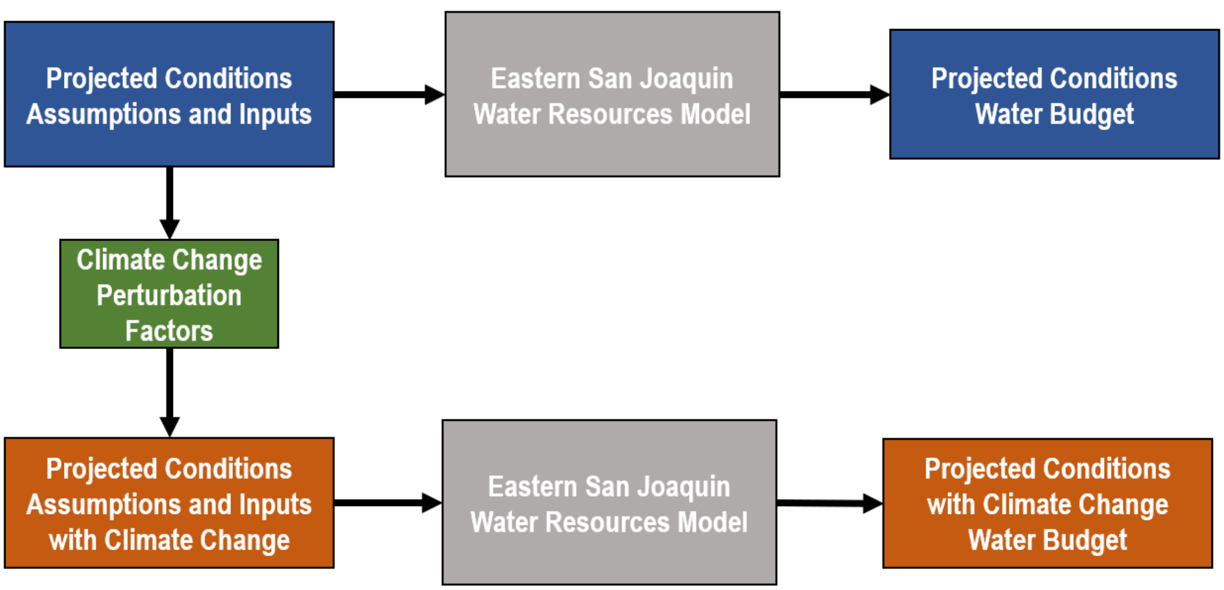
Climate change analysis is an area of continued evolution in terms of methods, tools, forecasted datasets, and the predictions of greenhouse gas concentrations in the atmosphere. The approach developed for this GSP is based on the methodology in DWR's guidance document (CA DWR, 2018b). The "best available information" related to climate change in the Eastern San Joaquin Subbasin was deemed to be the information provided by DWR combined with basin-specific modeling tools. The following resources from DWR were used in the climate change analysis:

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

The SGMA Data Viewer contains climate change forecast datasets for download (CA DWR, 2018c). The guidance document details the approach, development, applications, and limitations of the datasets available from the SGMA Data Viewer (CA DWR, 2018c). The Water Budget BMP describes in greater detail how DWR recommends projected water budgets with climate change be estimated (CA DWR, 2016). The Desktop IWFM Tools are available to estimate the projected precipitation and evapotranspiration inputs under climate change conditions (CA DWR, 2018b).

The methods suggested by DWR in the above resources were used, with modifications where needed, to ensure the results would be reasonable for the Eastern San Joaquin Subbasin and align with the assumptions of the ESJWRM. Figure 18 shows the overall process developed for the Subbasin consistent with the Climate Change Resource Guide (CA DWR, 2018b) and describes workflow beginning with projected conditions inputs and assumptions to perturbed 2070 conditions for the projected conditions.

Figure 18: Eastern San Joaquin Climate Change Analysis Process



The process described in Figure 18 of developing a projected water budget with and without climate change was discussed with DWR staff and is consistent with the regulations. Further, it enables the analysis to account for variability in demand and supply separate from the uncertainty associated with climate change forecasts.

Table 10: DWR-Provided DatasetsTable 10 summarizes the forecasted variable datasets provided by DWR that were used to carry out the climate change analysis (CA DWR, 2018b). The Variable Infiltration Capacity (VIC) model referred to in Table 10 is the fully mechanistic hydrologic model used by DWR to derive hydrographs under standard and climate change conditions.

Table 10: DWR-Provided Datasets

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

3.1.2 Climate Change Methodology

Accepted methods for estimating climate change impacts on groundwater are based on the assessment of impacts on the individual water resource system elements that directly link to groundwater. These elements include precipitation, streamflow, evapotranspiration and, for coastal aquifers, sea level rise as a boundary condition. For the Eastern San Joaquin Subbasin, sea level rise was not included.

The method for perturbing the streamflow, precipitation, and evapotranspiration input files is described in the following sections. A future scenario of 2070 climate forecasts was evaluated in this analysis, consistent with DWR guidance (CA DWR, 2018b). DWR combined 10 global climate models (GCMs) for two different representative climate pathways (RCPs) to generate the central tendency scenarios in the datasets used in this analysis. The "local analogs" method (LOCA) was used to downscale these 20 different climate projections to a scale usable for California (CA DWR, 2018b). The 2070 central tendency among these projections serves to assess impacts of climate change over the long-term planning and implementation period.

Model simulation results reported in the published GSP have been updated in this section using the updated PCBL Version 2.0 completed as part of the 2021 update of the historical and projected conditions model. This PCBL Version 2.0 has a 52-year simulation baseline period with hydrology from WY 2019 and WY 2020 incorporated. Updates to the PCBL are documented in Section 2. Model results from the updated PCBL-CC are reported in Section 3.3.

3.2 Projected Conditions Baseline with Climate Change Hydrology

This section provides a summary of the data sources, methodology, and summarized results of the updates to the hydrology under climate change conditions.

3.2.1 Streamflow under Climate Change

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

Local tributaries and smaller streams within Eastern San Joaquin Subbasin are not simulated in CalSim II and must be simulated using adjustment factors developed by DWR for unregulated stream systems. Dry Creek flows were perturbed using this method. The resolution of these perturbation factors is at the Hydrologic Unit Code 8 watershed scale. CalSim II model runs are not available for the Mokelumne River, according to Appendix B, Table B-2 of DWR's Climate Change Document (CA DWR, 2018b). Therefore, Mokelumne River flows used the perturbation factor method for consistency with the methodology applied to smaller streams. The remaining streams simulated in the ESJWRM utilize the IWFM small watershed package, whose climate change impacts are calculated internally dependent on both precipitation and evapotranspiration refinement. Table 11Table 11: Eastern San Joaquin Stream Inflows presents the impaired and unimpaired streams in the ESJWRM for the Eastern San Joaquin Subbasin.

Table 11: Eastern San Joaquin Stream Inflows

Modeled Stream	Impaired	Unimpaired
Within ESJ Subbasin		
Dry Creek		X
Mokelumne River		X
Calaveras River	X	
San Joaquin River	X	
Stanislaus River	X	
Within Model Area, Outside ESJ Subbasin		
Tuolumne River	x	
Cosumnes River	x	

3.2.1.1 Unimpaired Flows

Change factors for unimpaired streams (Dry Creek and Mokelumne River) were downloaded from SGMA Data Viewer and multiplied by the projected conditions input streamflow data to calculated perturbed flows. DWR change factors are available through 2011; however, the model hydrologic period runs from Water Year 1969-2018. Flows for the remaining model years beyond 2011 were synthesized using the change factor from the most recent matching water year type in the available dataset. Water Year types are designated for each year based on the San Joaquin Valley Runoff WY year type index (CA DWR, 2018a). DWR uses five designations ranging from driest to wettest conditions: Critical, Dry, Below Normal, Above Normal, and Wet. Table 12Table 12: San Joaquin Valley Water Year Type Designations below shows the year type designations used to synthesize the remaining years (2011-2018).

The PCBL with climate change scenario reported in the GSP only used hydrology baseline years through 2018. In the updated PCBL-CC reported in this TM, WY 2019 and WY 2020 are incorporated and added to Table 12 below. The climate change perturbation was carried out for the two additional years of simulation using methods consistent with how the rest of the synthesized years were calculated in the GSP for unimpaired streamflows.

As part of the update to the PCBL, South San Joaquin Irrigation District (SSJID) outflows were incorporated as a new stream inflow to the model. However because these are operationally dependent flows, they were not perturbed in this climate change scenario.

Table 12: San Joaquin Valley Water Year Type Designations

Water Year	Year Type
2003	Below Normal
2004	Dry
2005	Wet
2006	Wet
2007	Critical
2008	Critical
2009	Below Normal
2010	Above Normal
2011	Wet
2012	Dry

2013	Critical
2014	Critical
2015	Critical
2016	Dry
2017	Wet
2018	Below Normal
2019	Wet
2020	Dry

Figure 19 shows the perturbed time series against the projected conditions scenario time series for Dry Creek through the 52-year simulation period and Figure 20 presents the exceedance probability curve. Figure 21 and Figure 22 show the same perturbed time series and exceedance curves, but for Mokelumne River. The exceedance curves are provided because they more clearly show the differences between the projected conditions scenario and the with-climate-change scenario. Generally, flows under the climate change scenario are slightly higher.

Figure 19: Dry Creek Hydrograph

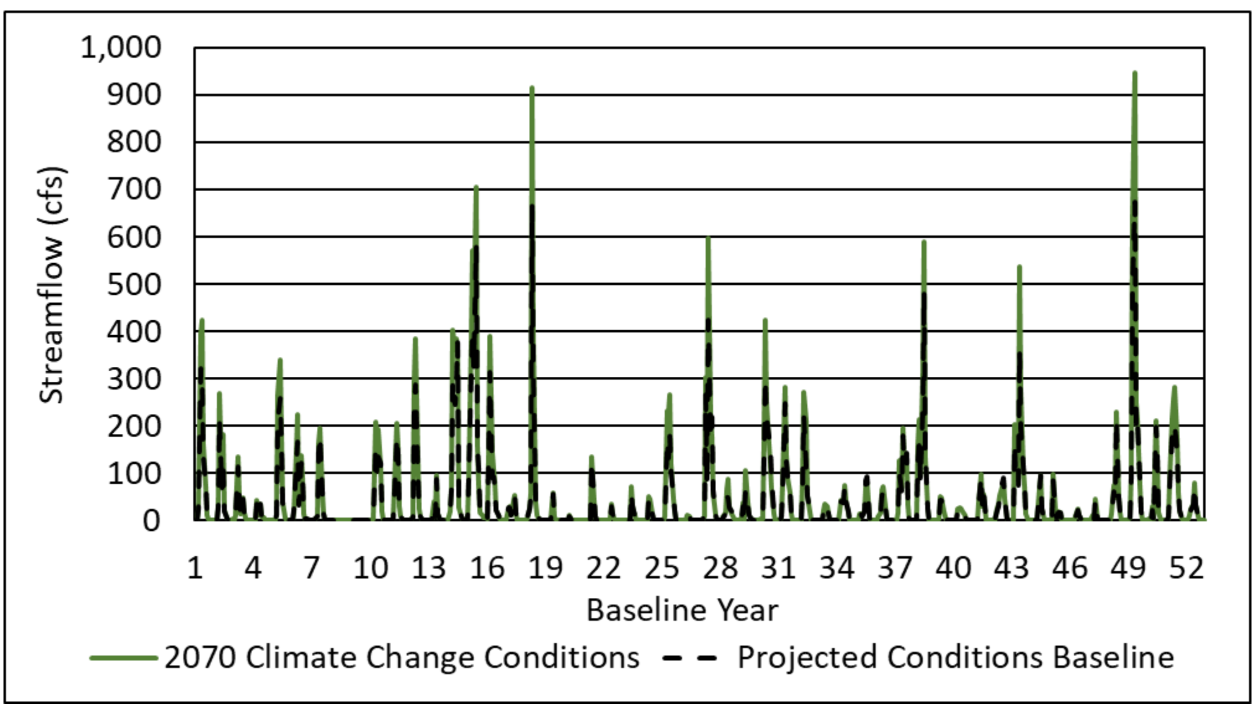


Figure 20: Dry Creek Exceedance Curve

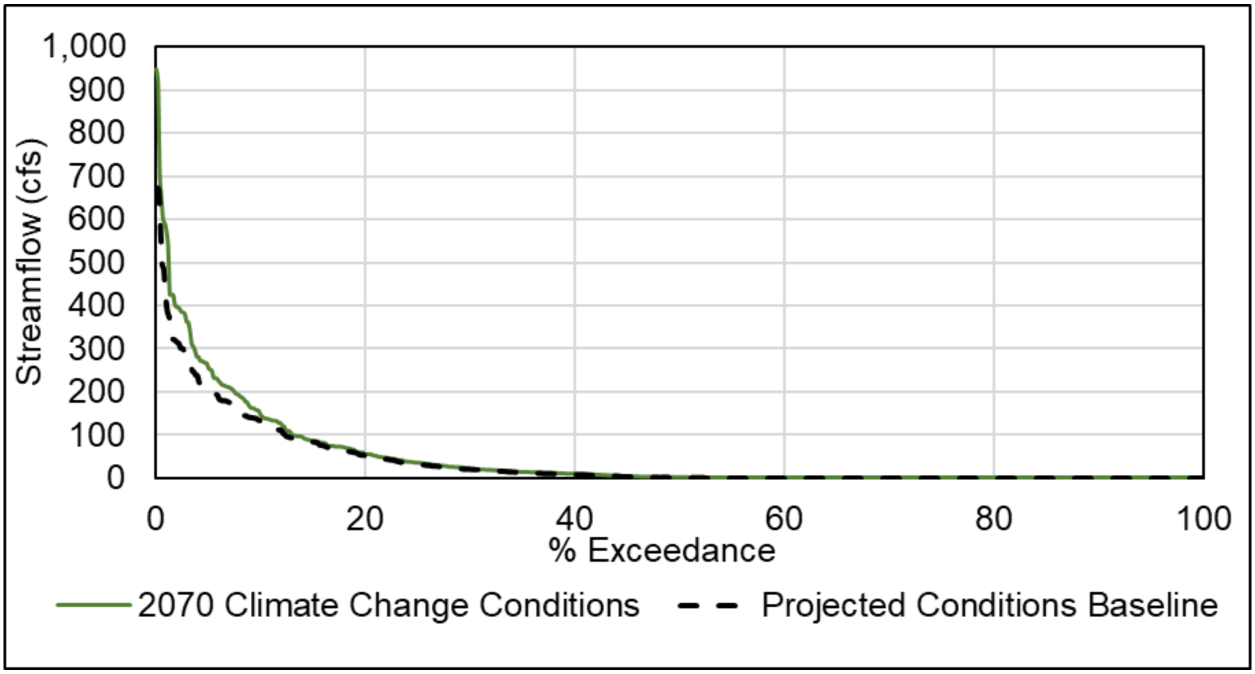


Figure 21: Mokelumne River Hydrograph

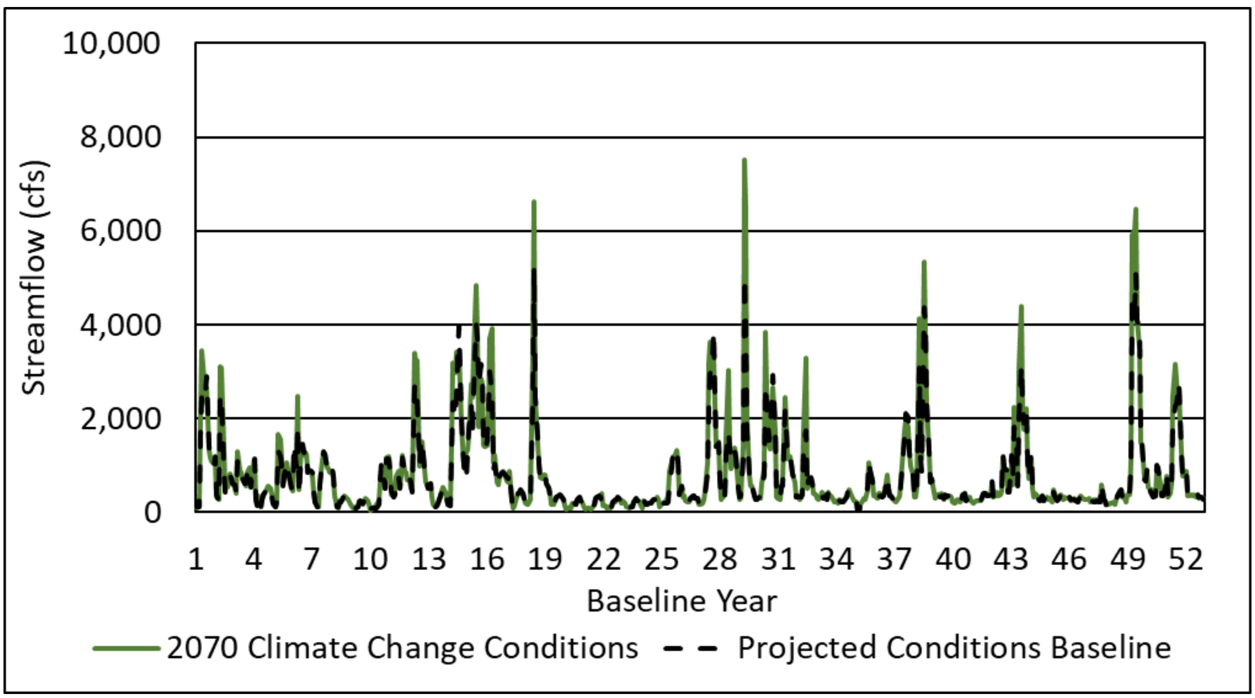
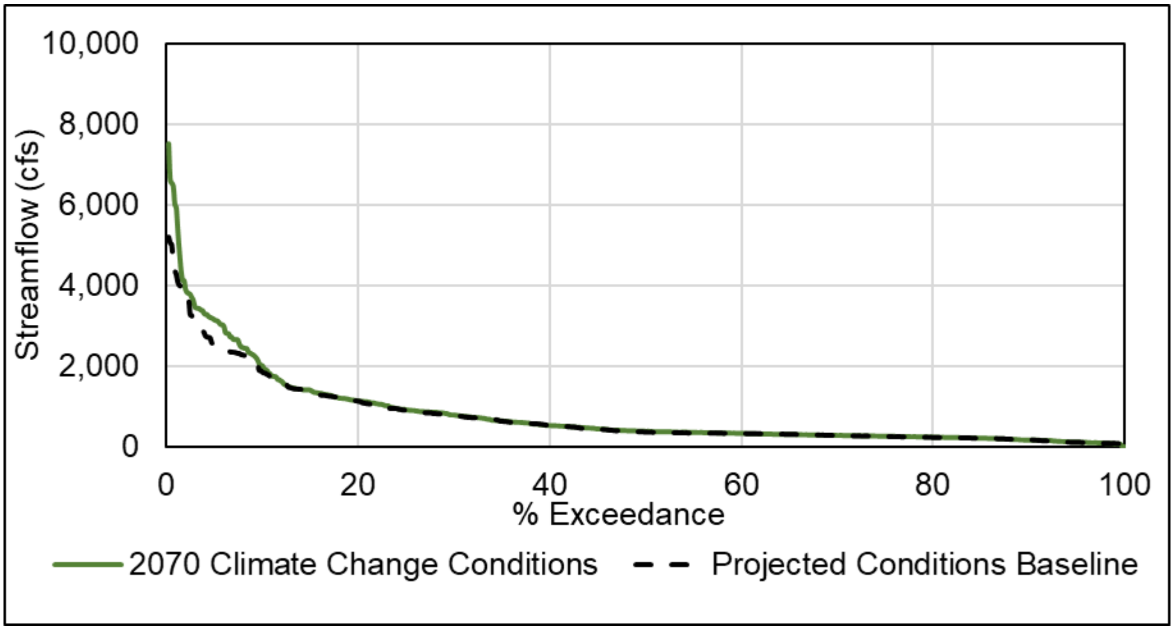


Figure 22: Mokelumne River Exceedance Curve



3.2.1.2 Impaired Flows

CalSim II-estimated flows for point locations on the Calaveras River, San Joaquin River, and Stanislaus River were downloaded from DWR. These points obtained from CalSim II include:

- Calaveras River: New Hogan Reservoir Outflow
- San Joaquin River: San Joaquin River at Vernalis
- Stanislaus River: New Melones Reservoir Outflow

These flows represent projected hydrology based on reservoir outflow, operational constraints, and diversions and deliveries of water for the State Water Project and the Central Valley Project. CalSim II data from WY 1969-2003 were available. For the years 2003-2018, streamflow was synthesized based on flows from WY 1969-2003 and the DWR year type index shown in Table 12 (CA DWR, 2018a). For example, the total monthly streamflow for October 2003 was calculated as the average of the monthly streamflows from October 1966 and October 1971 because they are the same water year type.

CalSim II simulated flows were compared with flows generated using the DWR-provided unimpaired perturbation factors. Streamflows simulated in CalSim II and those derived using the unimpaired adjustment factors did not present similar trends, particularly in dry years, due to CalSim II's simulation of reservoir operations. DWR-provided unimpaired change factors do not account for variations in the operation of the reservoirs that would result from climate change conditions. Therefore, CalSim II outputs were considered a more appropriate starting dataset for regulated streams given that downstream flow is driven by surface water demand rather than natural flow.

The team explored a hybrid approach to improve upon the discrepancy between flows produced using CalSim II and perturbation factors, while accounting for some change in reservoir operations. In this approach, change factors are generated from the difference between the simulated future climate change CalSim II scenario for 2070 climate conditions and a "without climate change" CalSim II run. This "without climate change" run is the CalSim II 1995 Historical Detrended simulation run. The generated change factors from these two runs were then used to perturb the regulated river inflows simulated in the ESJWRM projected conditions scenario. For the purposes of simplicity, this method is referred to throughout the rest of the document as CalSim II Generated Perturbation Factors (CGPF). The CGPF method presents limitations given that the resulting flows are not directly obtained from an operations model. The actual mass balance on the reservoirs is not tracked in the estimates of the flows and, instead, the method relies on CalSim II tracking storage and managing the reservoir based on the appropriate rule curves.

The climate change perturbation was carried out for the two additional years of simulation using methods consistent with how the rest of the synthesized years were calculated in the GSP for impaired streamflows.

Figure 23 through Figure 28 provide a comparison of project baseline condition and the results of the CGPF method described above for each stream within the ESJ Subbasin, updated for the 52-year simulation.

Figure 29 through Figure 32 show the same hydrographs for streams within the model area, but outside of the ESJ Subbasin. Exceedance curves are included for each of the CGPF flows against the project baseline flows.

Figure 23: Calaveras River Hydrograph

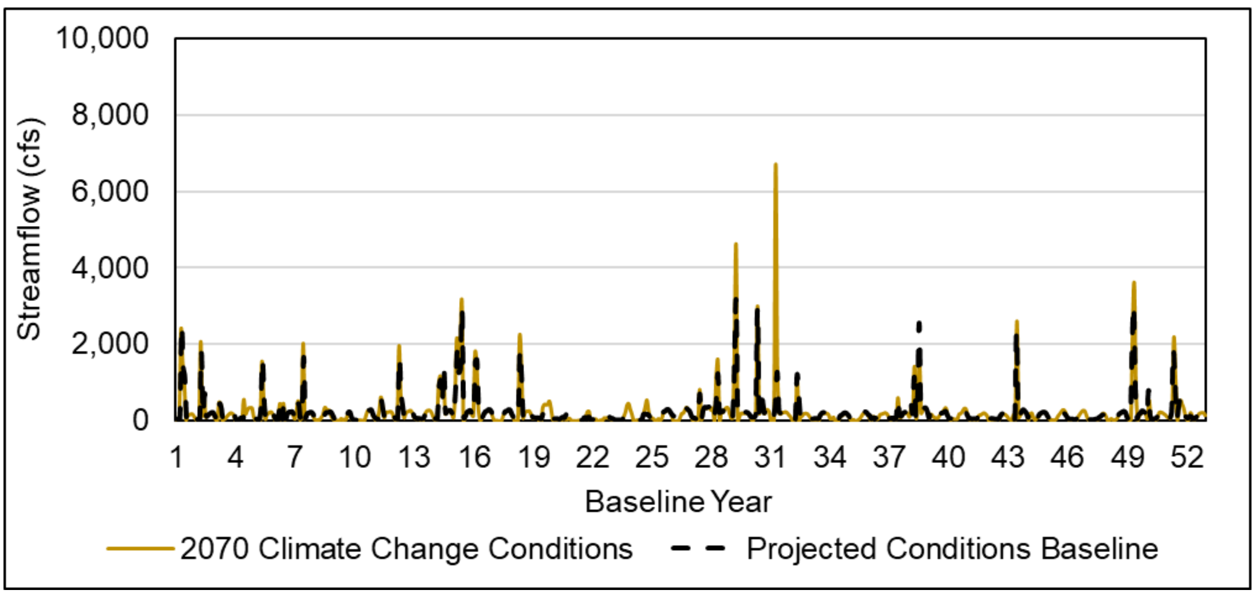


Figure 24: Calaveras River Exceedance Curve

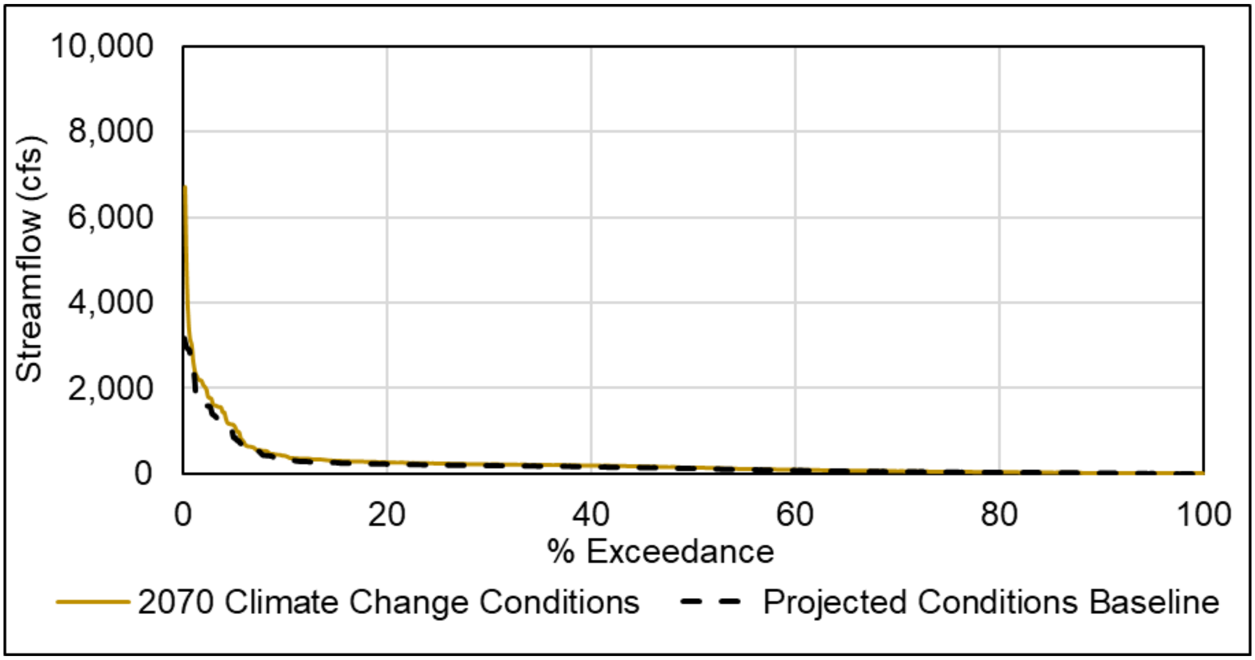


Figure 25: Stanislaus River Hydrograph

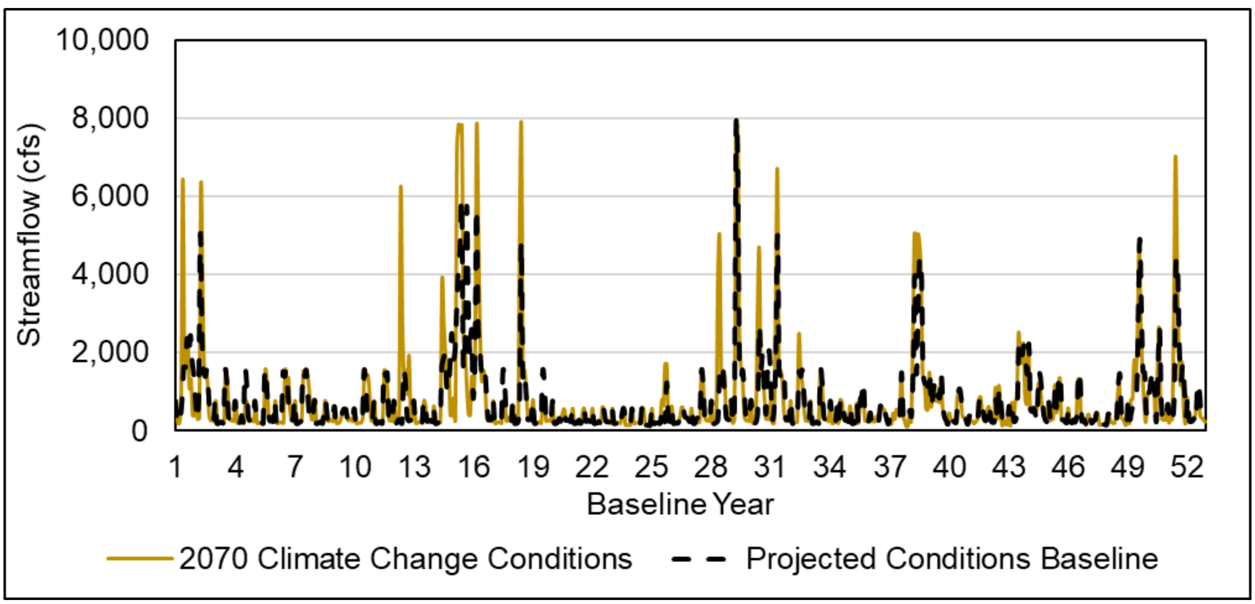


Figure 26: Stanislaus River Exceedance Curve

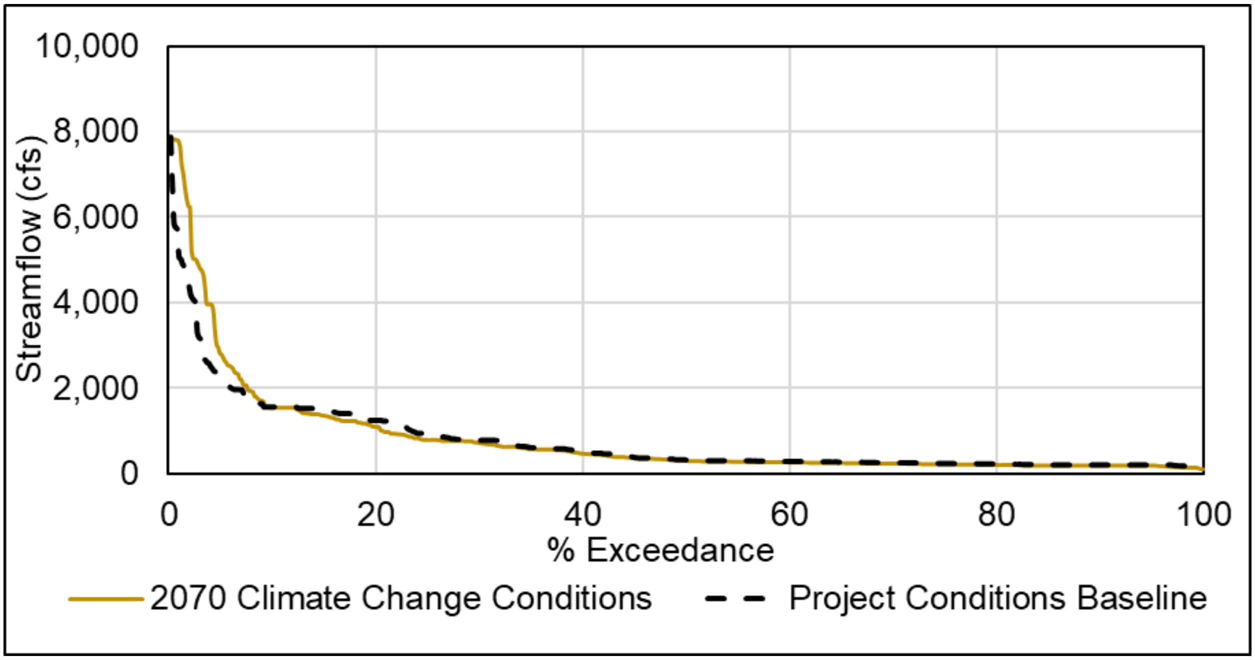


Figure 27: San Joaquin River Hydrograph

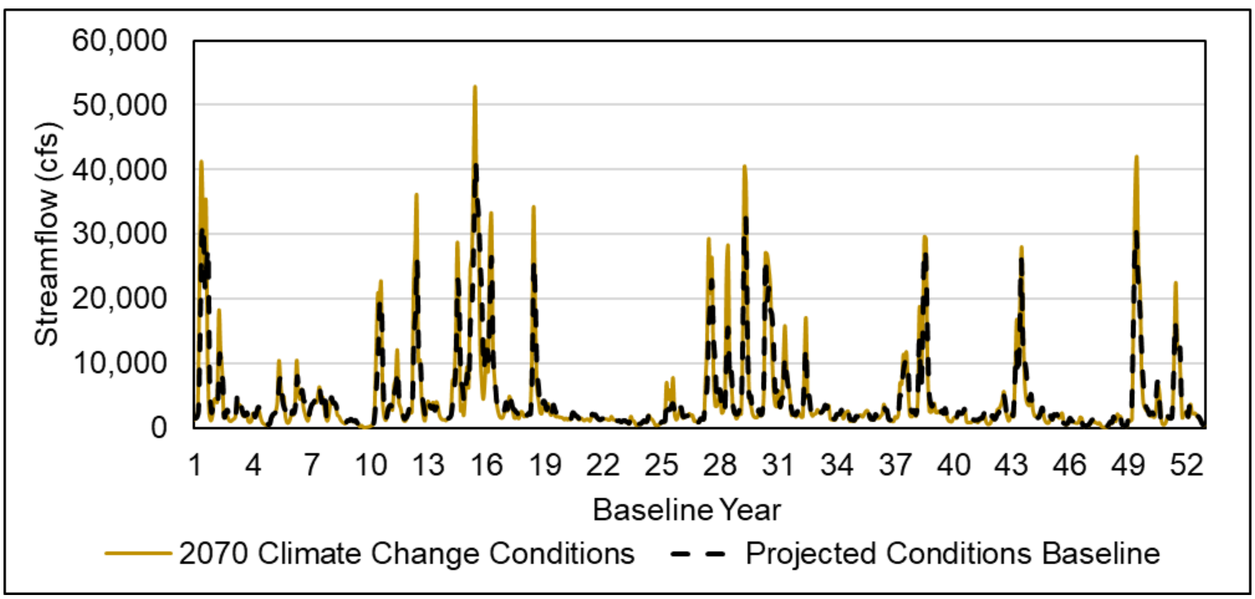


Figure 28: San Joaquin River Exceedance Curve

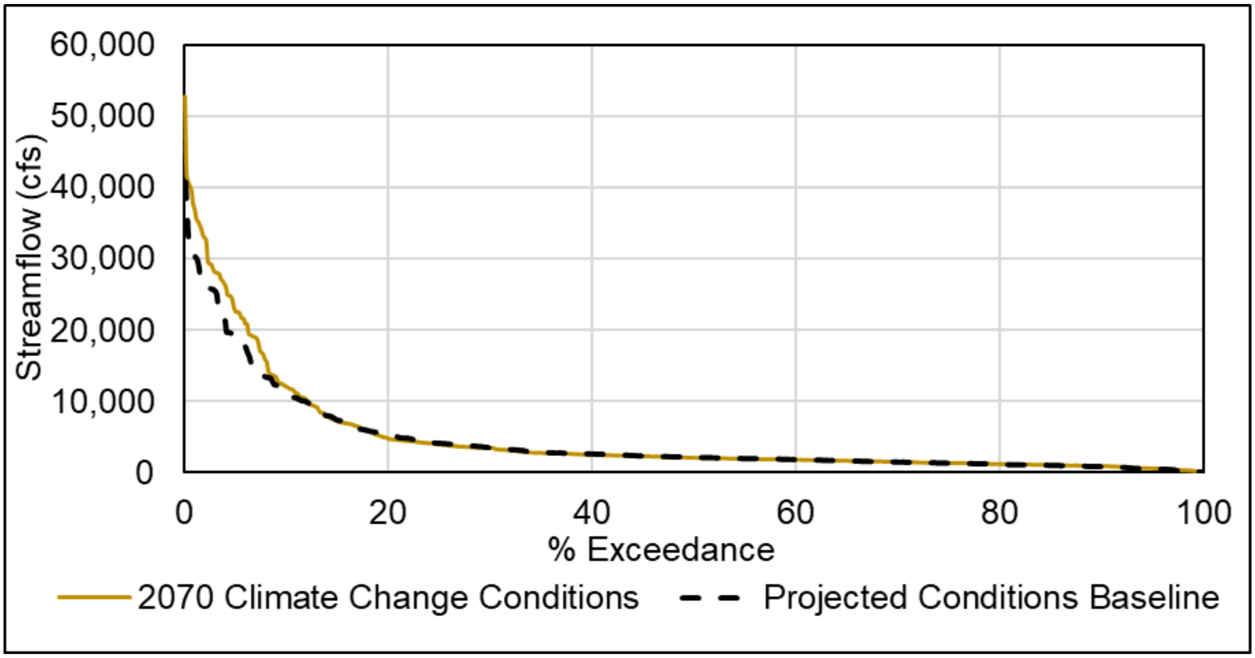


Figure 29: Tuolumne River Hydrograph

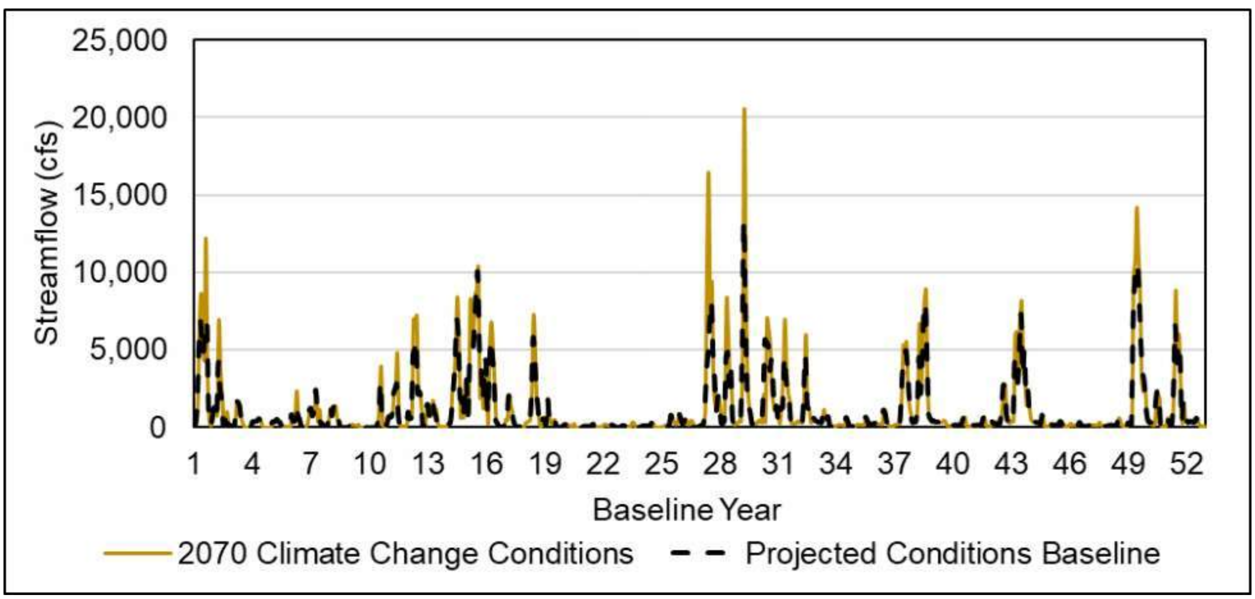


Figure 30: Tuolumne River Exceedance Curve

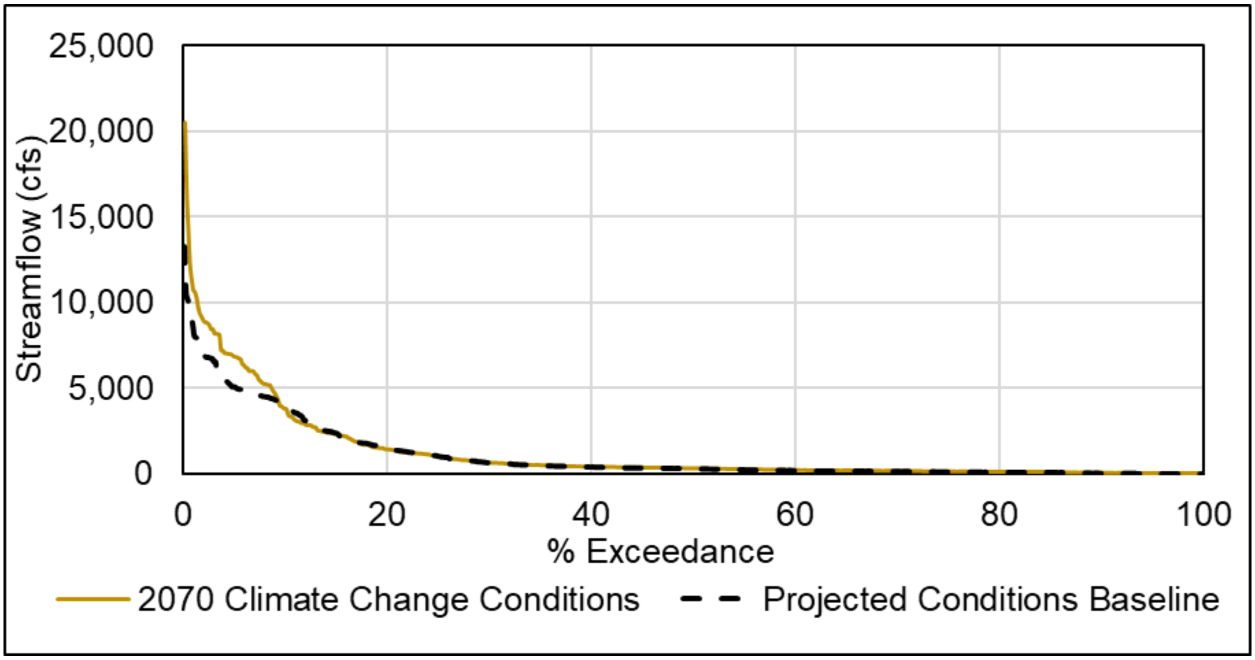


Figure 31: Cosumnes River Hydrograph

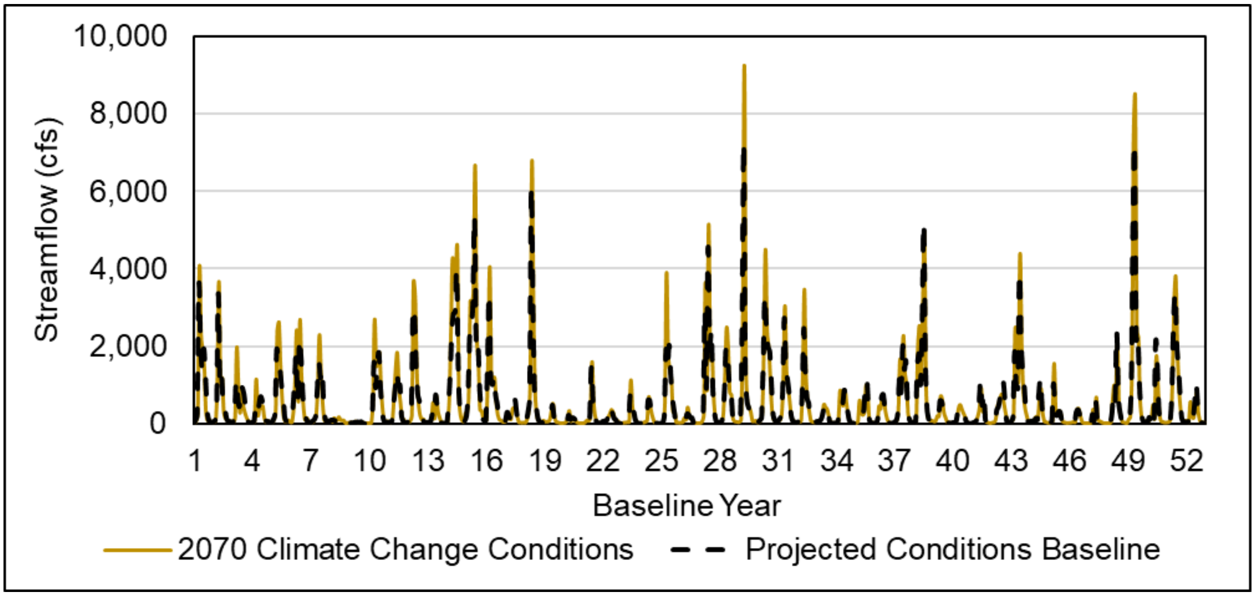
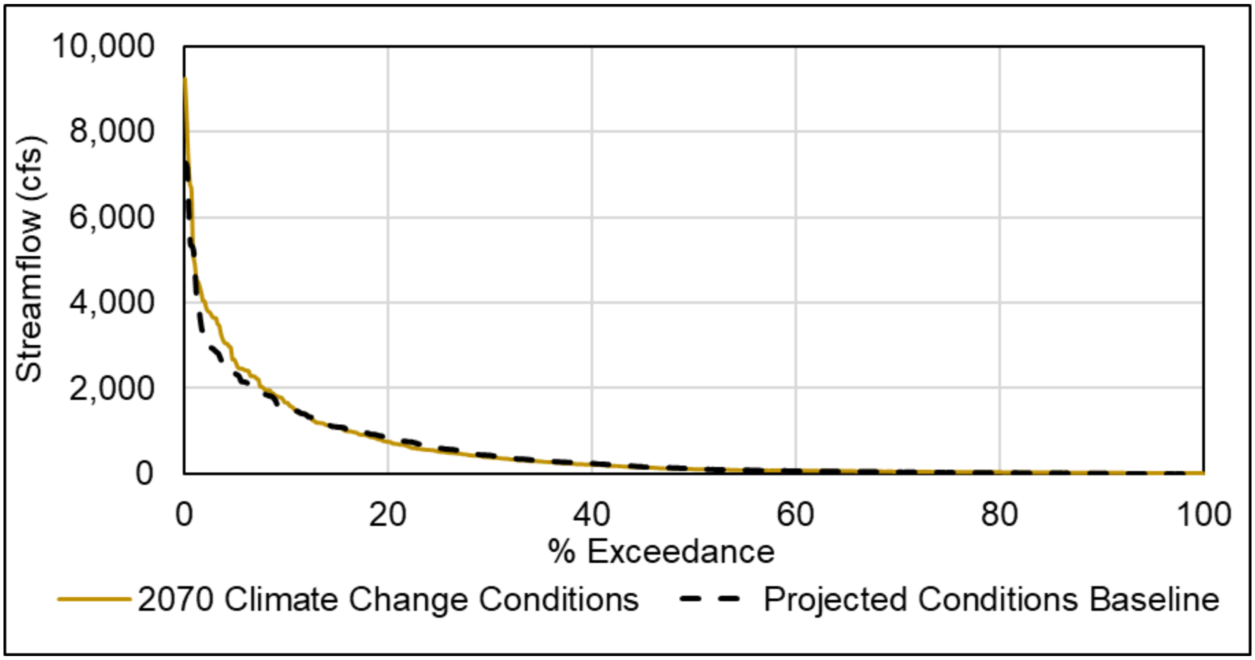


Figure 32: Cosumnes River Exceedance Curve



3.2.2 Precipitation and Evapotranspiration under Climate Change

Projected precipitation and evapotranspiration (ETo) change factors were calculated using a climate period analysis based on historical precipitation and ETo from January 1915 to December 2011 (CA DWR, 2018b). DWR used a macroscale hydrologic model that solves the water balance of a watershed, called the VIC Model. Change factors provided by DWR were calculated as a ratio of the value of a variable under a "future scenario" divided by a baseline. That baseline data is the 1995 Historical Temperature Detrended scenario downscaled from GCM climate data. The "future scenario" corresponds to VIC outputs of the simulation of future conditions using GCM forecasted hydroclimatic variables as inputs. These change factors are thus a simple perturbation factor that corresponds to the ratio of a future with climate change divided by the past without it. Change factors are available on a monthly time step and are spatially defined by the VIC model grid. Supplemental tables with the time series of perturbation factors are available from DWR for each grid cell. DWR has made accessible a Desktop GIS tool for both IWFM and MODFLOW to process these change factors (CA DWR, 2018c).

3.2.2.1 Applying Change Factors to Precipitation

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

However, the DWR tool only includes change factors through 2011. The remaining 6 years of the time series were synthesized according to historically comparable water years. The perturbation factor from the corresponding month of the comparable year was applied to the baseline of the missing years (2012-2018) to generate projected values. Months with no precipitation in the baseline were assumed to have a monthly precipitation of 1 mm under climate change to account for increased precipitation that cannot be calculated from a baseline of 0 mm for these synthesized years. The comparable years that were used can be found in Table 13. These comparable years were determined by comparing total San Joaquin Valley runoff, DWR year type index, and total annual Subbasin precipitation.

The same approach reported in the GSP to synthesizing years that are not included in the DWR dataset was used to extend the simulation for two additional years. The comparable water years used to represent WY 2019 and WY 2020 hydrology have been added to Table 13 below.

Table 13: Comparable Water Years (based on Precipitation)

Water Year Not Available in DWR Tool	Comparable Water Year
2012	2001
2013	1991
2014	1987
2015	1977
2016	2002
2017	1983
2018	1983
2019	2016
2020	2013

The resulting perturbed precipitation values and the baseline precipitation values for the representative historical period can be found in Figure 33. The exceedance plot for these two times series can be found in Figure 34, both updated for 52 years of projected conditions simulation. The absolute difference between the PCBL-CC and the PCBL are shown in Figure 35.

Figure 33: Perturbed Precipitation Under Climate Change

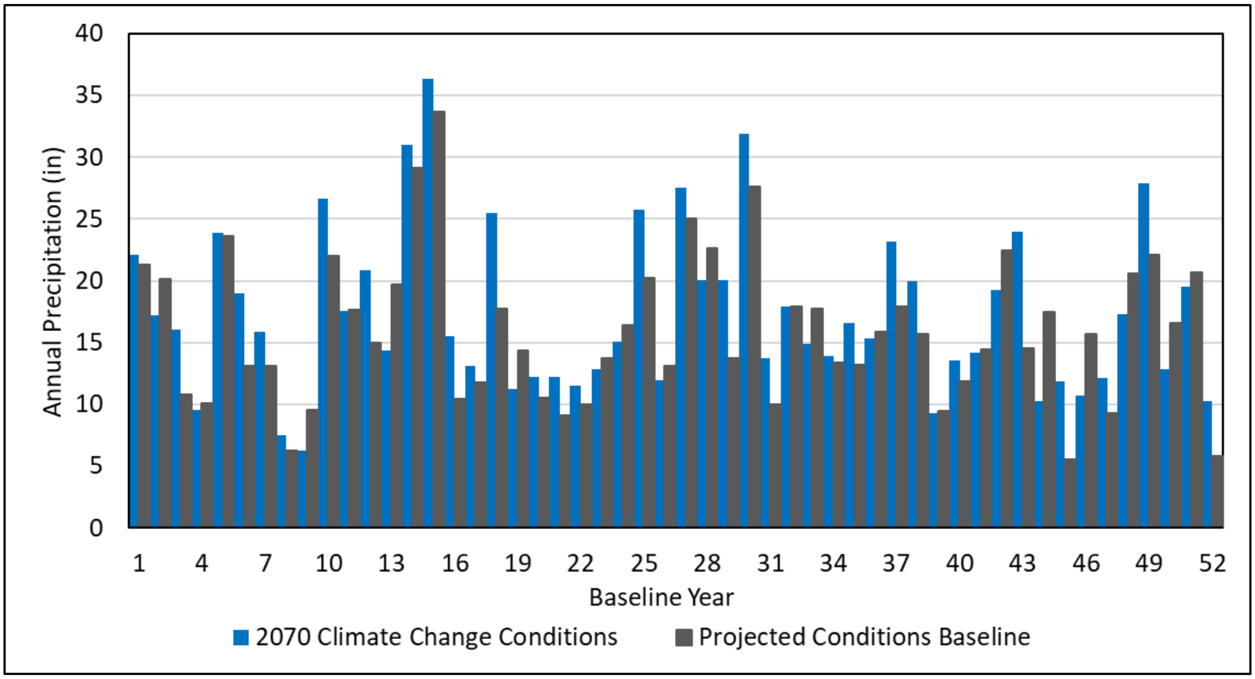


Figure 34: Perturbed Precipitation Exceedance Curve

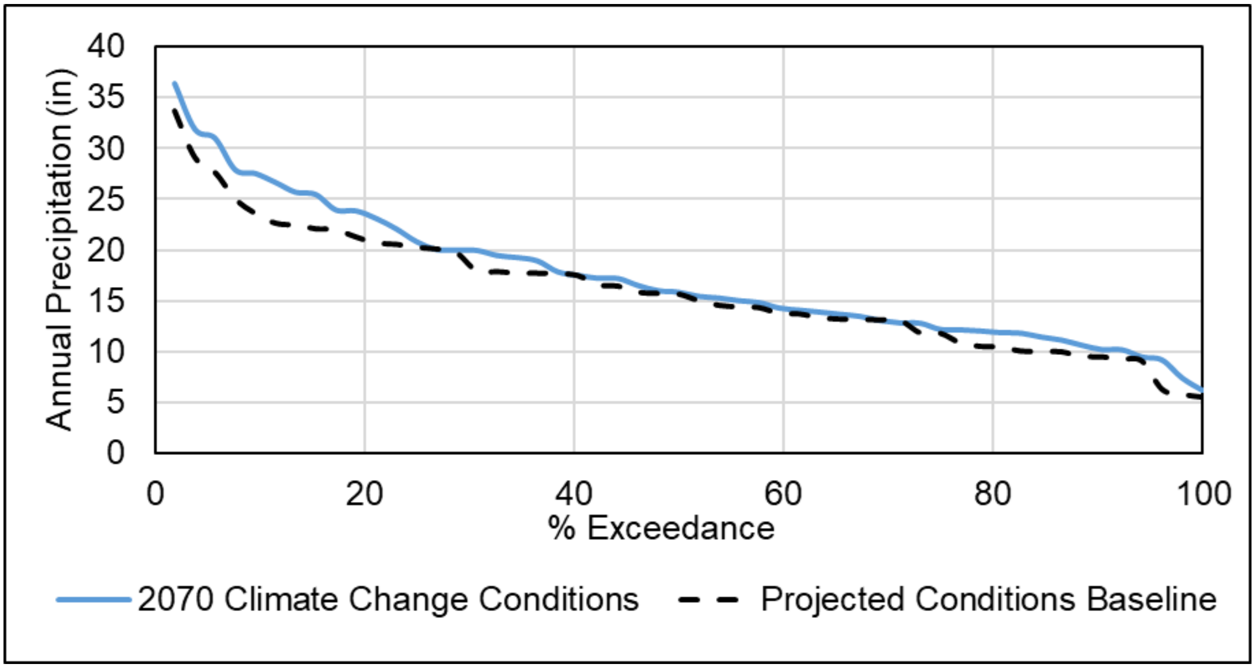
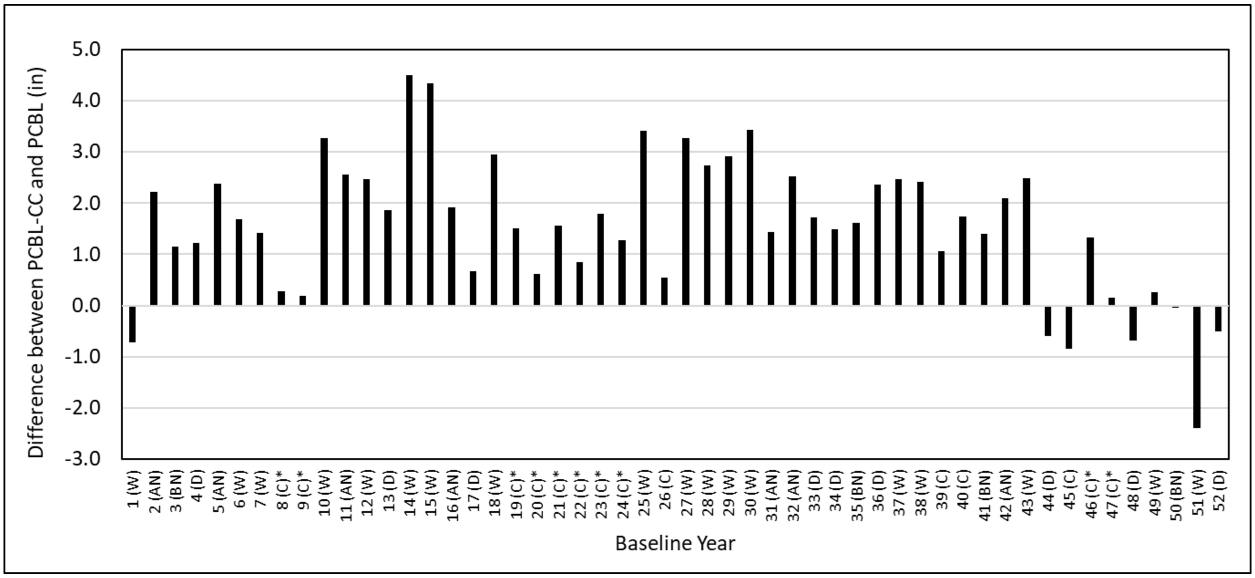


Figure 35: Subbasin Precipitation Difference with Climate Change Conditions



3.2.2.2 Applying Change Factors to Evapotranspiration

Potential ETo in the Subbasin varies geographically and by land use. The tool provided by DWR to process ETo was not used because of the minimal spatial variation in ETo in the Subbasin. DWR provides change factors for ETo that vary spatially based on the VIC model grid as described above. Change factors for November 1, 1964 through December 1, 2011 were averaged. For the purposes of this analysis, a localized averaged change factor of 1.082 or 1.084 was used depending on the crop type and where in the Subbasin that crop can be found. All ETo in the Subbasin is expected to increase. However, almonds, pistachios, walnuts, cherries, pasture, corn, and rice ETo are expected to increase more with climate change in the South of the Subbasin in comparison to the North. All land uses in the South and the remaining crops in the North are perturbed with a single average change factor of 1.084, as shown for vineyards in Error! Reference source not found..

This average ETo change factor was then applied to the historical ETo time series for each crop type. Because there is currently no interannual variability in ETo in ESJWRM, the same perturbed time series was applied across all simulation years. Refinement to the simulated evapotranspiration of almonds, walnuts, and cherries under 2070 climate conditions is shown in Figure 36 through Figure 38.

There were no changes made to the projected conditions simulation for evapotranspiration in the PCBL model update. Additionally, as is currently set up in the model, there is no variation by year, only by month. Therefore, there were no adjustments made to the evapotranspiration model input under the projected conditions with climate change scenario while extending the model through the 52 year simulation.

Figure 36: Monthly Evapotranspiration Variability for Almonds

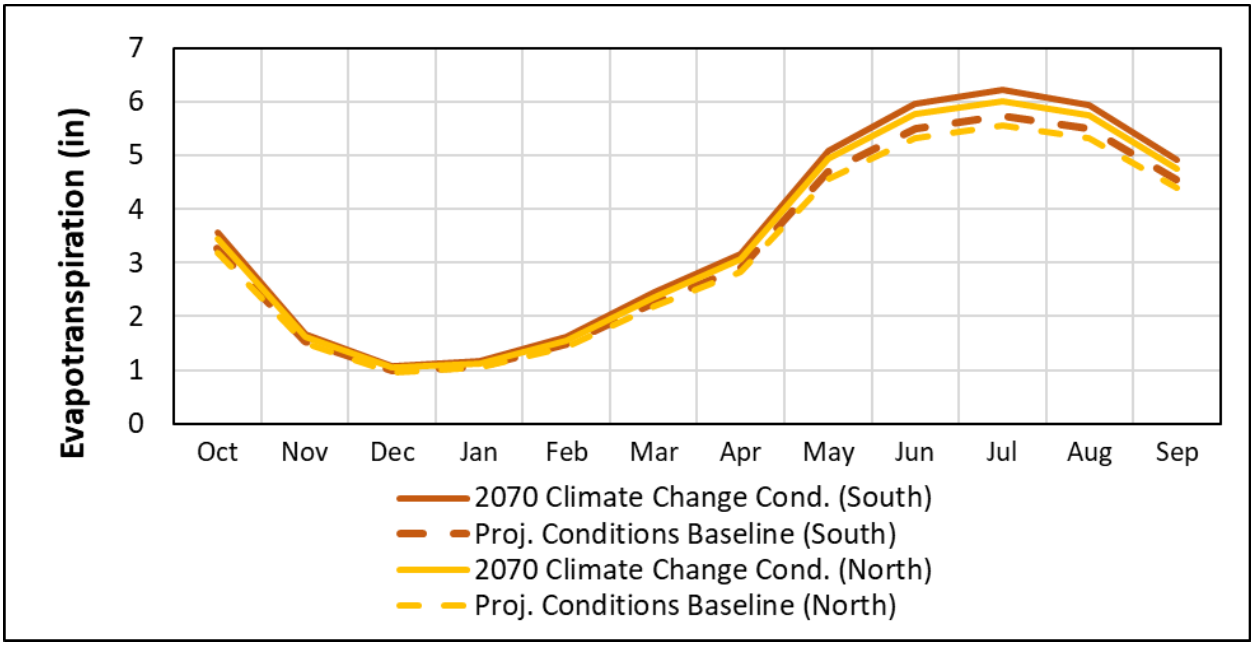


Figure 37: Monthly Evapotranspiration Variability for Walnuts

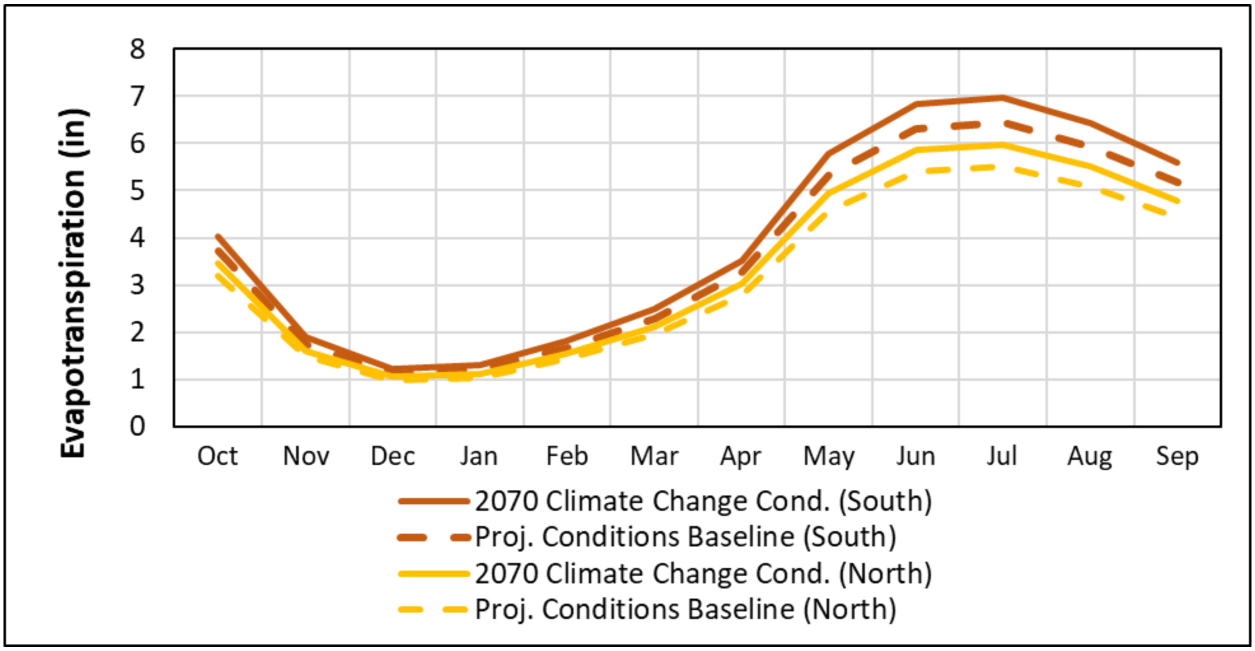


Figure 38: Monthly Evapotranspiration Variability for Cherries

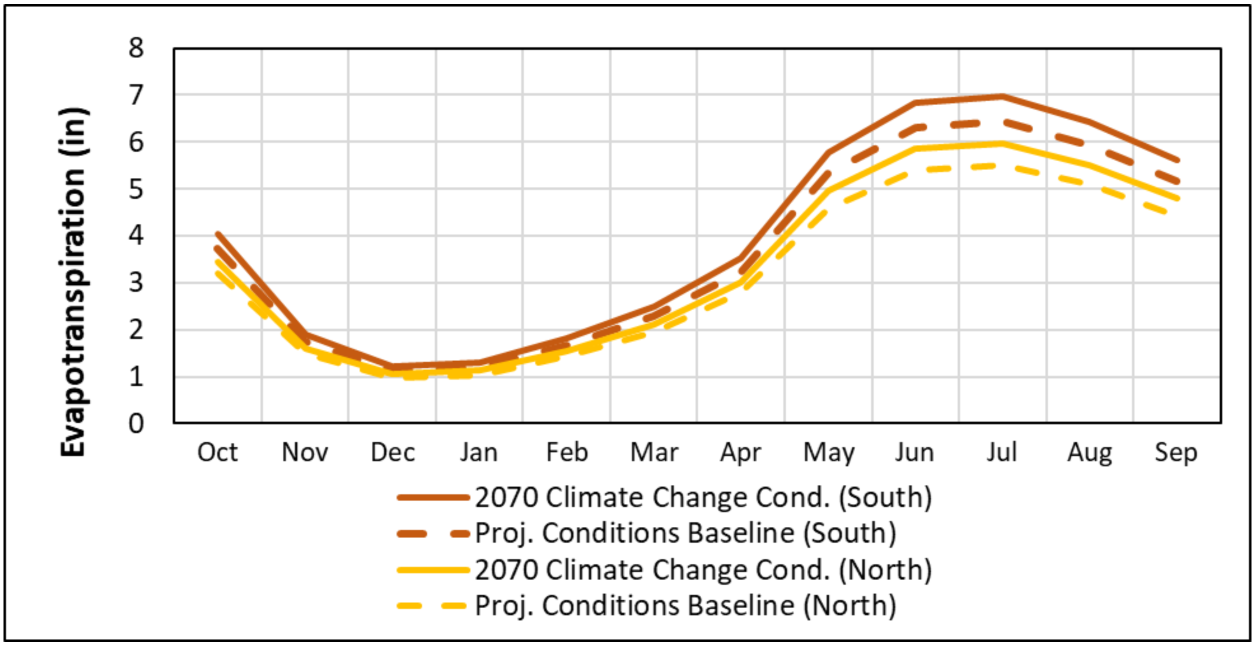
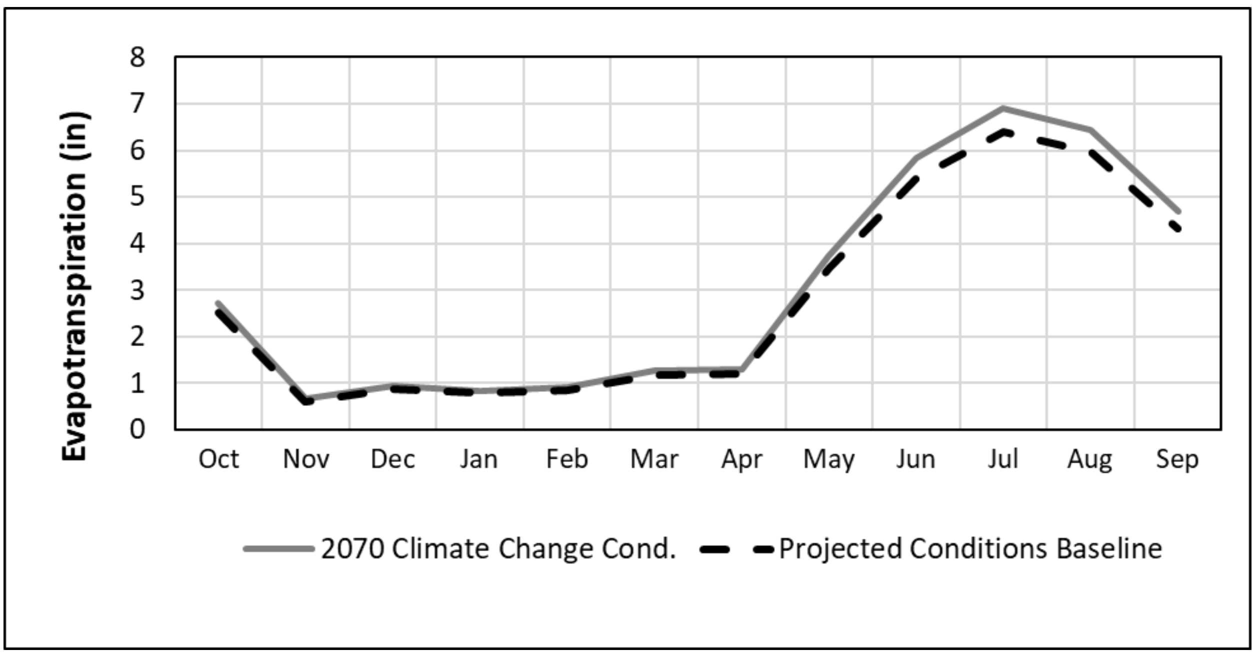


Figure 39: Monthly Evapotranspiration Variability for Vineyards



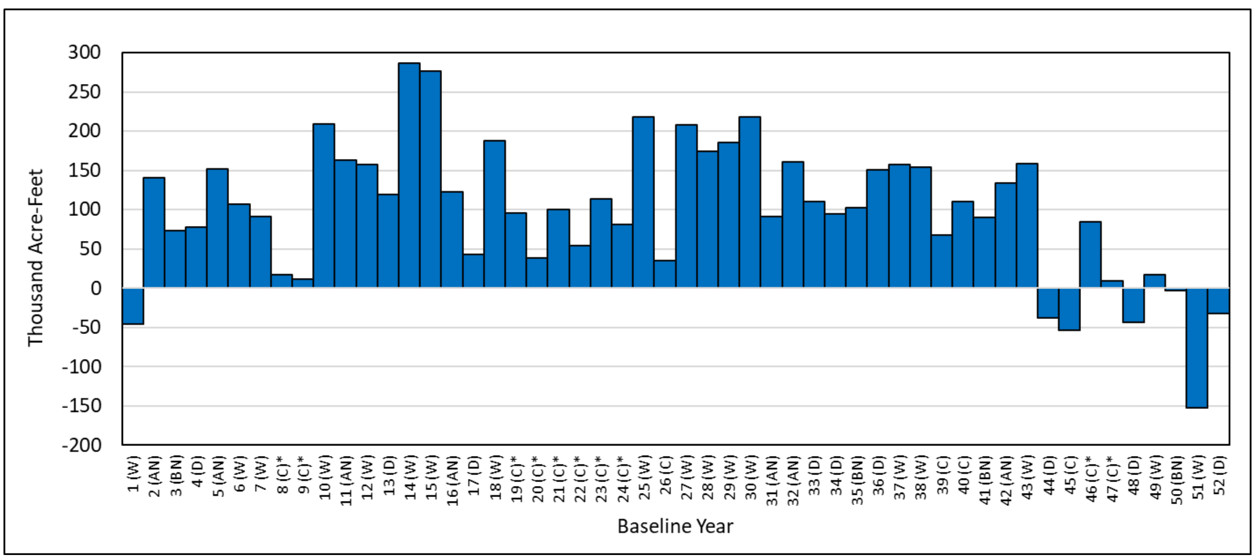
3.3 Projected Conditions Baseline with Climate Change Results

This section provides a summary of the ESJWRM PCBL-CC Version 2.0 results.

3.3.1 Differences in Precipitation, Evapotranspiration, and Streamflow under Climate Change

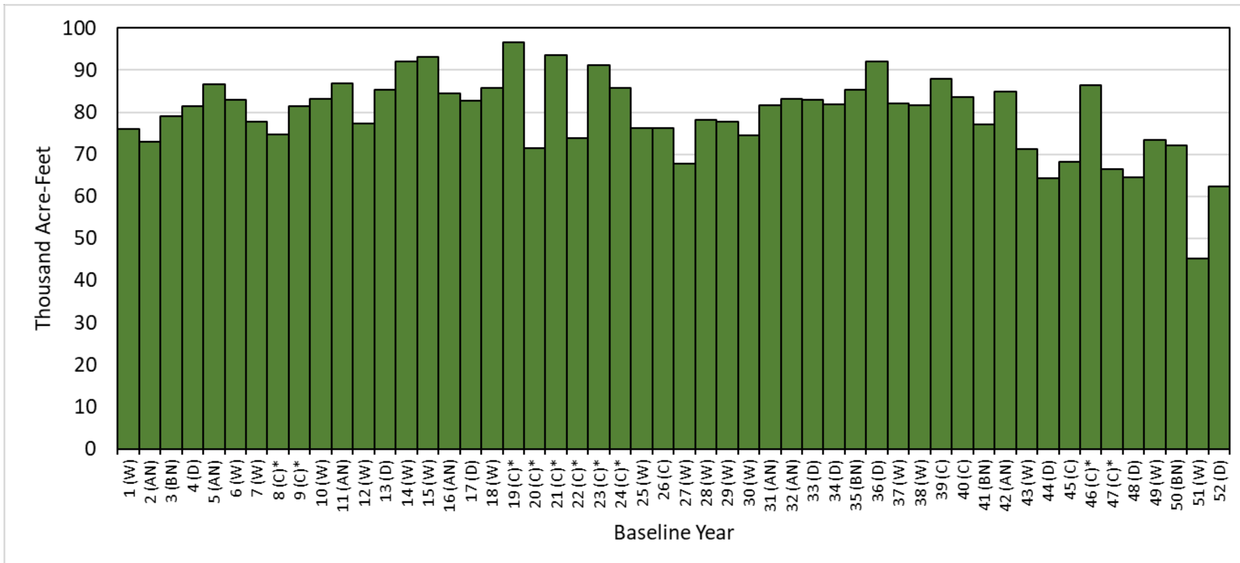
Under the climate change scenario (PCBL-CC), the average annual precipitation is overall 10 percent higher than the projected conditions scenario (PCBL), increasing from 985,000 AFY to 1,082,000 AFY or from about 15.5 in/year to 17.0 in/year. Similarly, the average annual volume of evapotranspiration in PCBL-CC is 8 percent higher than the PCBL, increasing to 1,441,000 AFY from 1,362,000 AFY. Despite there being higher flows in streams in PCBL-CC, the anticipated surface water diversions were not expected to change in PCBL-CC due to both availability of water in the stream and water rights agreements limiting diversion months. With a similar surface water supply and increased water demands under the PCBL-CC, private groundwater production is simulated to increase by approximately 10 percent, from 751,000 AFY to 833,000 AFY. Under climate change conditions, due to increased groundwater use driven by higher agricultural demands, the depletion in aquifer storage is expected to increase by about 134 percent to an average annual storage change of 38,000 AFY in the PCBL-CC, from 16,000 AFY in the PCBL. A graphical representation of simulated changes to precipitation, evapotranspiration, and groundwater pumping are presented in **Error! Reference source not found.** though **Error! Reference source not found.**. Full water budgets for the land surface and groundwater systems are discussed in Sections 3.3.2 and 3.3.3.

Figure 40: Simulated Changes in Precipitation due to Climate Change



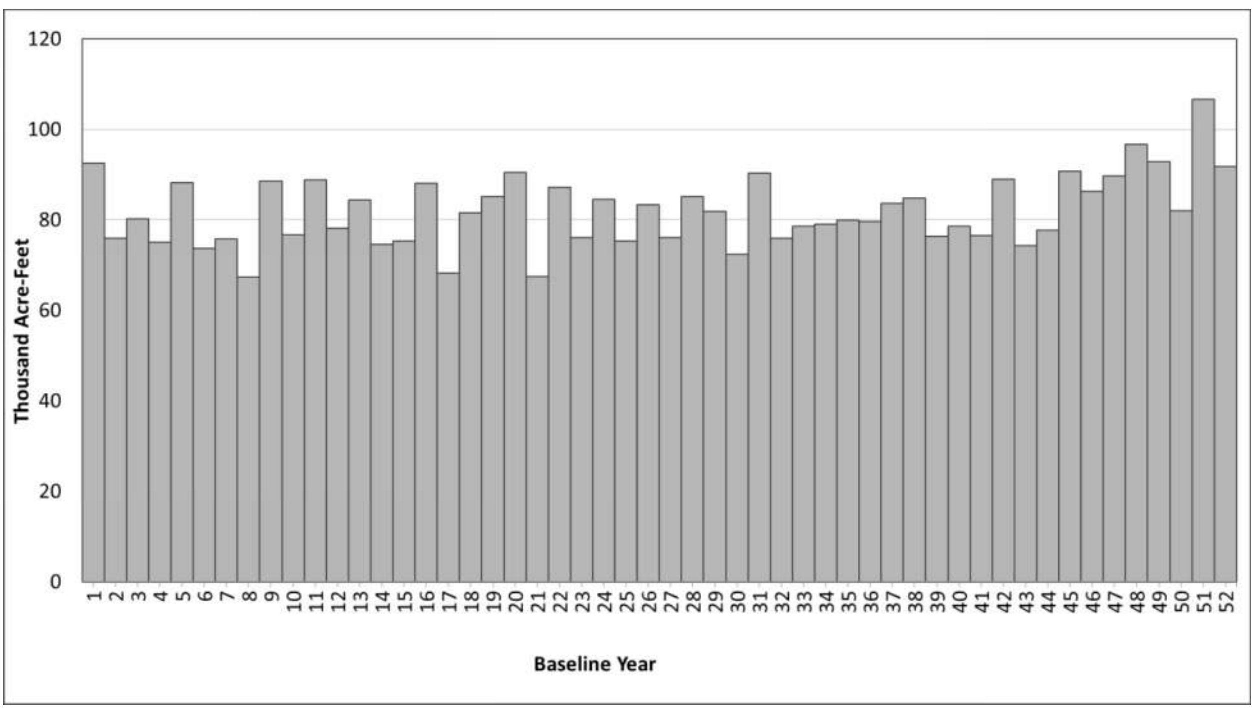
Note: Negative indicates PCBL value was larger and positive indicates PCBL-CC was larger. The climate change scenario largely has more precipitation than the projected conditions scenario.

Figure 41: Simulated Changes in Evapotranspiration due to Climate Change



Note: PCBL-CC evapotranspiration is always larger than the PCBL for all simulated years.

Figure 42: Simulated Changes in Groundwater Pumping due to Climate Change



Note: PCBL-CC groundwater pumping is always larger than the PCBL for all simulated years.

3.3.2 Land and Water Use Budget

The land and water use budget includes two different versions, agricultural and urban, and represents the balance of the model-calculated water demands with the water supplied. Both the agricultural and urban versions include the same components that make up the water balance:

- Inflows:
  - Groundwater pumping
  - Surface water deliveries
  - Shortage (if applicable)
- Outflows:
  - Demand (either agricultural or urban)
  - Surplus (if applicable)

The average annual projected water demand for the Subbasin within the 52-year simulation period is 1,339 thousand acre-feet (TAF), consisting of approximately 1,181 TAF expected agricultural demand and 158 TAF expected urban demand. This demand is met by an annual average of 528 TAF of surface water deliveries (452 TAF of agricultural and 76 TAF of urban deliveries) and is supplemented by 825 TAF of groundwater production (742 TAF of agricultural and 82 TAF of urban pumping). Due to uncertainties in the estimation of projected agricultural demand and historical supply records, there is 13 TAF of surplus in the Subbasin scale agricultural water use budget, which is insignificant relative to the total volume of water use. Shortage and surplus represent a misalignment between the reported, estimated, or assumed water supply (groundwater pumping and surface water deliveries) and the calculated demands. In the projected conditions, there are uncertainties in the assumptions and parameters used for both monthly supply and demand estimates and/or calculations, resulting in misalignments, which is reported as shortage or surplus. These annual averages are shown in Table 14. The annual land and water use budgets across the ESJ Subbasin are shown in Figure 43 and Figure 44 for the Subbasin as a whole, showing the agricultural and urban, respectively, demands plotted with water supplies.

A comparison between the PCBL and the PCBL-CC is included in

Table 15. As shown in Section 3.3.1 and Figure 41, evapotranspiration is higher in the PCBL-CC compared to the PCBL in every year of the simulation. This higher evapotranspiration translates to a higher agricultural demand in the PCBL-CC of 81,400 AFY, which must be met by increased groundwater pumping of 81,800 AFY. The slight difference between the demand increase and the groundwater pumping increase is due to a decrease in 400 AFY of agricultural surface water deliveries. Small changes in surface water availability in streams occurred in the PCBL-CC compared to the PCBL due to the impact of perturbation factors on monthly stream flows. On the urban demand side, there were no differences built into the assumptions for climate change for urban entities, so there were no changes to the urban areas in the PCBL-CC versus the PCBL, aside from a minor difference in surface water diversions that was balanced by a small increase in urban shortage.

Table 14: Eastern San Joaquin Subbasin Land and Water Use Budget Annual Average for PCBL-CC

Land and Water Use Budget Component	PCBL-CC Annual Average
Agricultural Area (thousand acres)	359
Agricultural Demand (TAF)	1,181
Agricultural Groundwater Pumping (TAF)	742
Agricultural Surface Water Deliveries (TAF)	452
Agricultural Surplus (TAF)	13
Urban Area (thousand acres)	153
Urban Demand (TAF)	158
Urban Groundwater Pumping (TAF)	82
Urban Surface Water Deliveries (TAF)	76
Urban Shortage (TAF)	0

Table 15: Eastern San Joaquin Subbasin Land and Water Use Budget Annual Average Comparison Between the PCBL and the PCBL-CC

	Annual Average		
Land and Water Use Budget Component	PCBL	PCBL-CC	Climate Change Impact (PCBL-CC minus PCBL)
Agricultural Area (acres)	358,600	358,600	0
Agricultural Demand (AF)	1,099,900	1,181,300	81,400
Agricultural Groundwater Pumping (AF)	660,600	742,400	81,800
Agricultural Surface Water Deliveries (AF)	452,800	452,400	-400
Agricultural Surplus (AF)	13,500	13,500	0
Urban Area (acres)	153,400	153,400	0
Urban Demand (AF)	158,100	158,100	0
Urban Groundwater Pumping (AF)	82,200	82,200	0
Urban Surface Water Deliveries (AF)	75,600	75,500	-100
Urban Shortage (AF)	300	400	100

Figure 43: Eastern San Joaquin Subbasin Projected Agricultural Demand in the PCBL-CC

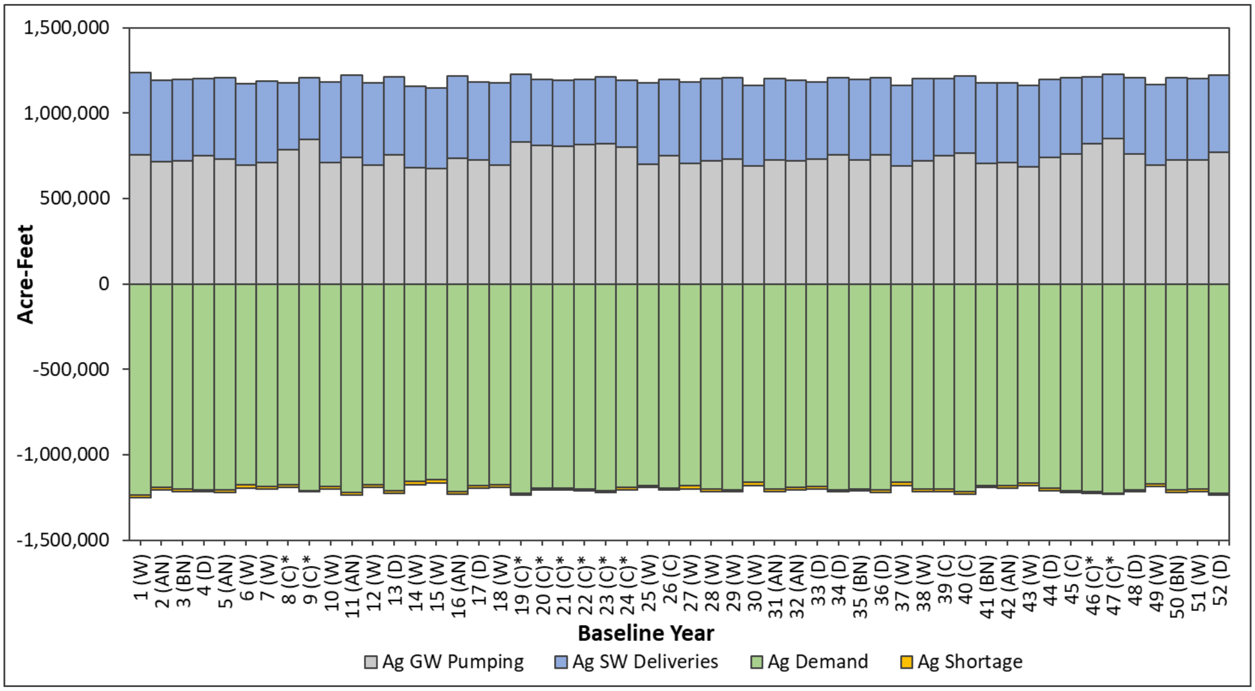
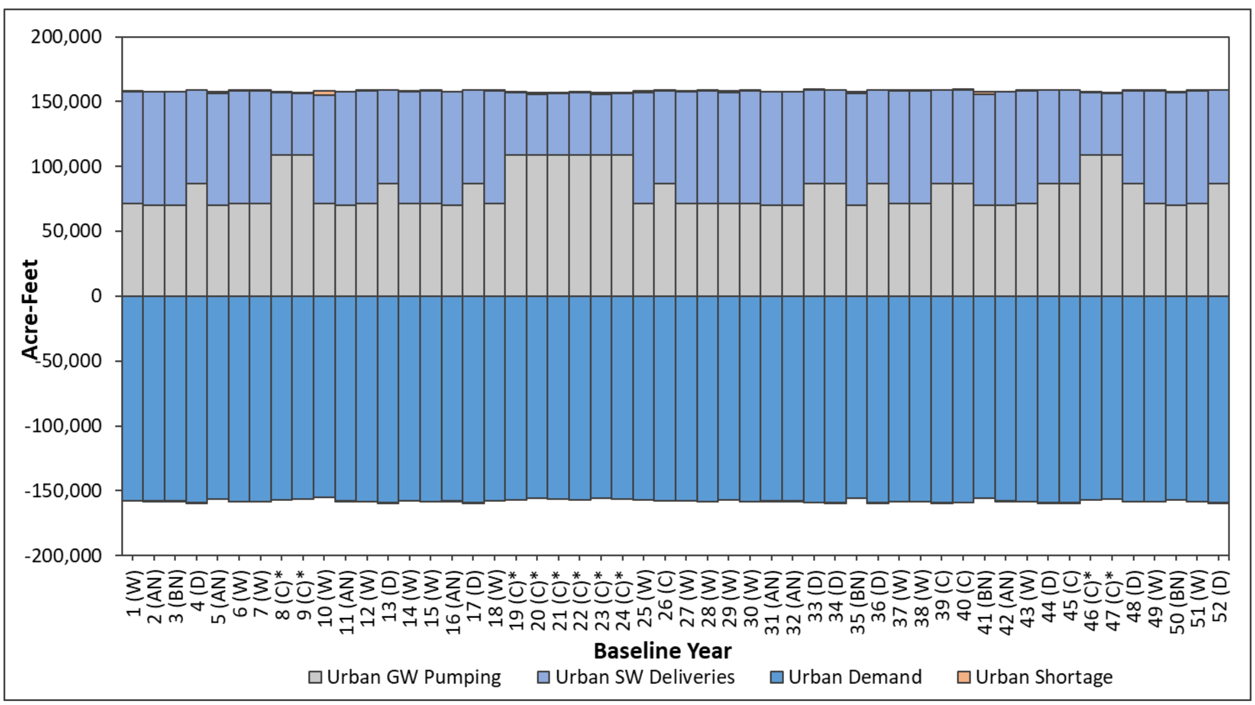


Figure 44: Eastern San Joaquin Subbasin Projected Urban Demand in the PCBL-CC



3.3.3 Groundwater Budget

The primary components of the groundwater budget are the same as represented in the historical model. Corresponding to the major hydrologic processes affecting groundwater flow in the Subbasin, these are:

- Inflows:
  - Deep percolation (from rainfall and irrigation applied water)
  - Gain from stream (or recharge due to stream seepage)
  - Boundary inflow (from surrounding groundwater subbasins and the Sierra Nevada Mountains)
  - Other Recharge (from other sources such as irrigation canal seepage, managed aquifer recharge projects, and reservoir seepage)
- Outflows:
  - Groundwater pumping
  - Loss to stream (or outflow to streams and rivers)
  - Boundary outflow (to surrounding groundwater subbasins)
  - Change in groundwater storage (can be either an inflow or outflow)

Pumping in the PCBL-CC remains the largest component in the groundwater budget with an annual average 833 TAF. The PCBL-CC offsets this pumping with 286 TAF of deep percolation, a net gain from stream of 218 TAF, 165 TAF of other recharge, and a total subsurface inflow of 126 TAF annually. Due to inherent uncertainties in model input data, calculations, and calibration, all budget components have a degree of uncertainty. Given this uncertainty, the projected long-term average annual the groundwater storage deficit in ESJ Subbasin in the PCBL-CC is 38 TAFY. These annual averages are shown in Table 16. The groundwater budget, with cumulative change in storage, is shown for the ESJ Subbasin in Figure 45.

A comparison of the PCBL and the PCBL-CC is shown in Table 17. The increase in groundwater pumping of 81,800 AFY is due to the increase in evapotranspiration and therefore increased agricultural demand as discussed above in Section 3.3.2 and

Table 15. Additionally, increased precipitation in most years as shown in **Error! Reference source not found.** and discussed in Section 3.3.1, leads to overall increased deep percolation from precipitation and other recharge (specifically the ungauged watershed drainage component). The increased groundwater pumping causes groundwater levels to be lower, which then causes increased stream seepage, boundary inflow, and change in groundwater storage. The streamflow is overall higher in the PCBL-CC, which may also allow for more stream seepage into the groundwater system.

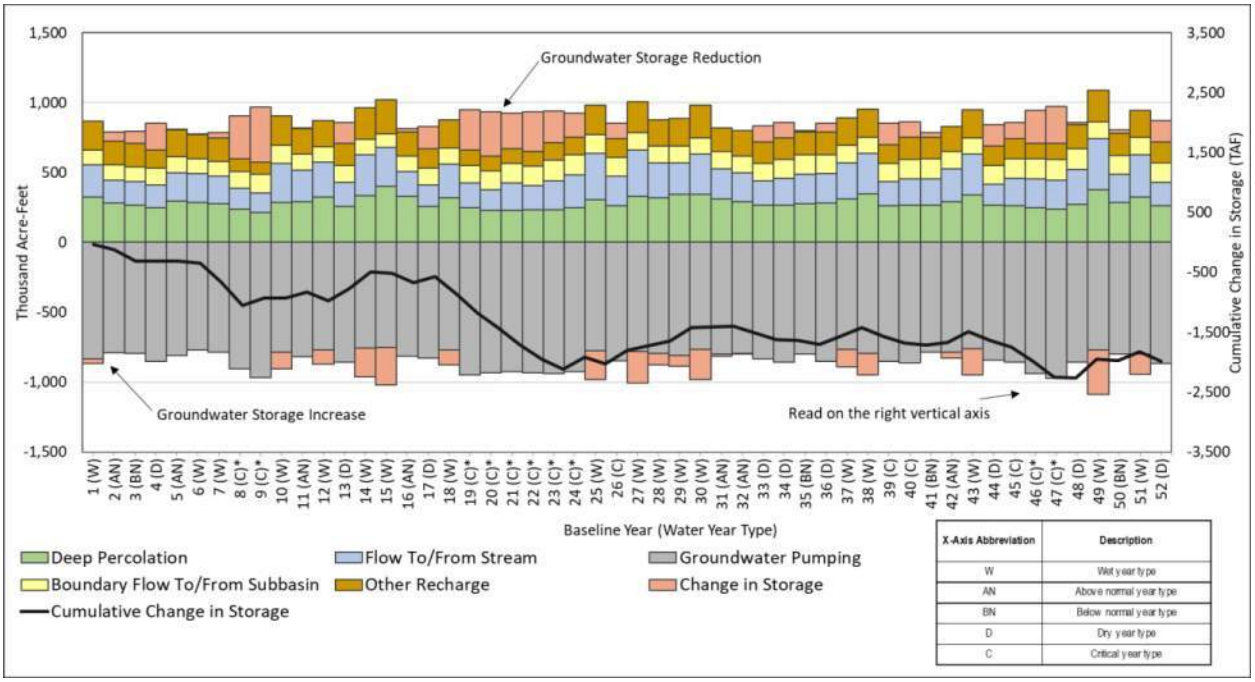
Table 16: Eastern San Joaquin Subbasin Hydrologic Groundwater Budget Annual Average

Hydrologic Groundwater Budget Component	PCBL-CC Annual Average
Deep Percolation (TAF)	286
Other Recharge (TAF)	165
Net Stream Seepage (TAF)	218
Net Boundary Inflow (TAF)	126
Groundwater Pumping (TAF)	833
Change in Groundwater Storage (TAF)	38

Table 17: Eastern San Joaquin Subbasin Hydrologic Groundwater Budget Annual Average Comparison Between the PCBL and the PCBL-CC

	Annual Average		
Hydrologic Groundwater Budget Component	PCBL	PCBL-CC	Climate Change Impact (PCBL-CC minus PCBL)
Deep Percolation (AF)	282,100	285,600	3,500
Other Recharge (AF)	161,700	165,300	3,600
Net Stream Seepage (AF)	180,700	218,100	37,400
Net Boundary Inflow (AF)	110,400	126,000	15,700
Groundwater Pumping (AF)	751,300	833,100	81,800
Change in Groundwater Storage (AF)	16,300	38,100	21,800

Figure 45: Eastern San Joaquin Subbasin Projected Hydrologic Groundwater Budget



4 Conclusions and Recommendations

The updated ESJWRM Version 2.0 is a robust, comprehensive, defensible, and well-established model for assessing the water resources in the ESJ Subbasin under historical and projected conditions using PCBL Version 2.0. The following recommendations are to be considered for further refinements and enhancements of the model:

- **Continue engagement with local groundwater users and managers**. Continue working with local agencies and groundwater users in ESJ Subbasin to further understand the local operations of the groundwater system and improve representation of groundwater users in the ESJWRM.
- **Enhance variability of potential evapotranspiration**. The current version of the IDC used for estimation of the consumptive use of crops in the ESJWRM uses monthly potential ET values that are the same for all years during the model period. Given that there may be annual variability in the potential ET data with possible effects on the annual estimation of crop water demand, it is recommended to use more detailed data with temporal variability to develop a full time series of ET values for use in the model.
- **Refine infiltration of precipitation**. The current version of the IDC is based on parameters from the DWR C2VSim model. Further refinements can be made to reflect the local soil conditions and rainfall runoff patterns.
- **Refine surface water deliveries in Cosumnes Subbasin.** The surface water deliveries in the Cosumnes Subbasin are currently at the subregion level and do not have the detailed spatial resolution of other areas within the ESJ Subbasin. This data may be verified and updated with modeling in that subbasin completed to meet the requirements of SGMA.
- **Update land use as needed.** As part of the statewide SGMA support, the DWR prepares statewide land use surveys every other year. It is recommended that the appropriate land use surveys be incorporated in the historical model, as well as the projected baseline as necessary and needed.
- **Integration with GRAT.** ESJGWA is in the process of developing a Groundwater Recharge Assessment Tool (GRAT). It is recommended to integrate the ESJWRM with the GRAT to better assess the implications of any water recharge on the state of the basin and distribution of benefits.
- **Climate change refinement.** The approach developed for the GSP and used in the PCBL-CC Version 2.0 update is based on the methodology in DWR's guidance document (CA DWR, 2018b) and uses "best available information" related to climate change in the Eastern San Joaquin Subbasin. There are limitations and uncertainties associated with the analysis. One important limitation is that CalSim II does not fully simulate local surface water operations. Thus, the analysis conducted for this GSP may not fully reflect how surface and groundwater basin operations would respond to the changes in water demand and availability caused by climate change. Mokelumne River flows are simulated in PCBL-CC as unimpaired despite the potential of changes to operations for Pardee and Camanche Reservoirs under climate change conditions. This presents an opportunity in future efforts to improve the analysis to better project streamflow. Use of a local model and the perturbation factor approach were deemed appropriate given the uncertainties in the climate change analysis.

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APPENDIX 3-A.
SUPPLEMENTAL DATA FOR CHRONIC LOWERING OF GROUNDWATER LEVEL MINIMUM THRESHOLDS

CASGEM ID	Local ID	GSA Well is Located In	Historical Drought Low (1992 or 2015-16) (ft bgs)	Historical Drought Low (1992 or 2015-16) (ft msl)	Year of Historical Drought Low	Total Well Depth (ft bgs)	Calculated Buffer (ft msl)	Depth of 10th Percentile Nearby Domestic Well (ft bgs)*	Depth of 10th Percentile Nearby Domestic Well (ft msl)*	Depth of 10th Percentile Nearby Municipal Well (if applicable) (ft msl)*	Historical Drought Low + Buffer (DTW) (ft bgs)	Historical Drought Low + Buffer (ft msl)	Minimum Threshold (ft msl)	Measurable Objectives (ft msl)	Average Groundwater Elevation (ft msl)	Most Recent Recorded Groundwater Elevation (ft msl)
378824N1210000W001	01S09E05H002	Central San Joaquin Water Conservation District	127.0	-19.6	1992	256.0	54.3	150.4	-49.8	N/A	181.3	-73.9	-49.8	-19.6	3.3	-17.6
379316N1211665W001	01N07E14J002	Central San Joaquin Water Conservation District	124.0	-70.4	1992	176.0	44.0	149.0	-129.0	N/A	168.0	-114.4	-114.4	-70.4	-43.5	-57.4
Not in CASGEM	Lodi City Well #2	City of Lodi	56.6	-3.5	1992	No Data	35.0	96.0	-56.3	-157.2	91.6	-38.5	-38.5	-3.5	13.8	0.6
Not in CASGEM	Manteca 18	City of Manteca	41.0	5.8	2016	No Data	21.8	100.0	-58.2	-120.1	62.8	-16.0	-16.0	5.8	8.2	4.8
380067N1213458W003	Swenson-3	City of Stockton	23.3	-19.3	2015	204.0	7.3	100.0	-97.4	-254.4	30.6	-26.6	-26.6	-19.3	-16.3	-15.2
378163N1208321W001	01S10E26J001M	Eastside San Joaquin GSA	100.9	81.7	2015	No Data	38.0	320.2	15.1	N/A	138.9	43.7	43.7	81.7	99.7	87.7
380206N1210943W001	02N08E15M002	Linden County Water District	153.5	-69.7	2016	403.0	74.5	205.0	-124.1	N/A	228.0	-144.2	-124.1	-69.7	-41.7	-69.7
Not in CASGEM	#3 Bear Creek	Lockeford Community Services District	152.0	-50.3	2016	No Data	22.0	168.0	-122.9	N/A	174.0	-72.3	-72.3	-50.3	-45.6	-46.3
381843N1212261W001	04N07E20H003M	North San Joaquin Water Conservation District	114.2	-36.7	2016	180.0	45.0	138.0	-110.3	N/A	159.2	-81.7	-81.7	-36.7	-15.6	-34.8
380909N1212153W001	03N07E21L003	North San Joaquin Water Conservation District	115.5	-57.5	1992	No Data	42.5	156.4	-109.4	N/A	158.0	-100.0	-100.0	-57.5	-35.0	-46.8
Not in CASGEM	Hirschfeld (OID-8)	Oakdale Irrigation District	100.5	31.5	2015	No Data	23.6	144.0	-11.5	N/A	124.1	8.0	8.0	31.5	44.2	31.8
377909N1208675W001	Burnett (OID-4)	Oakdale Irrigation District	108.2	79.7	2015	249.0	18.9	135.0	28.2	N/A	127.1	60.7	60.7	79.7	90.1	80.1
377136N1212508W001	02S07E31N001	South Delta Water Agency	11.0	13.0	1992	226.0	11.5	95.0	-62.5	N/A	22.5	1.5	1.5	13.0	14.6	16.0
377810N1211142W001	02S08E08A001	South San Joaquin GSA	49.4	24.0	2016	180.0	23.4	104.0	-42.2	N/A	72.8	0.6	0.6	24.0	29.1	23.0
380578N1212017W001	02N07E03D001	Stockton East Water District	137.0	-79.7	2016	484.0	52.0	170.0	-122.8	N/A	189.0	-131.7	-122.8	-79.7	-46.0	-71.7
379661N1210011W001	01N09E05J001	Stockton East Water District	207.0	-51.1	1992	750.0	120.2	198.0	-86.8	N/A	327.2	-171.3	-86.8	-51.1	-15.2	-16.3
379976N1212308W001	02N07E29B001	Stockton East Water District	122.5	-80.4	1992	202.0	60.6	165.0	-130.1	N/A	183.1	-141.0	-130.1	-80.4	-51.7	-47.4
381559N1213727W001	04N05E36H003	Woodbridge Irrigation District	30.0	-5.1	2015	112.0	26.0	83.0	-63.9	N/A	56.0	-31.1	-31.1	-5.1	5.6	6.4
381317N1213524W001	03N06E05N003	Woodbridge Irrigation District	42.0	-14.1	2015	292.0	21.0	77.4	-55.3	N/A	63.0	-35.1	-35.1	-14.1	-9.8	-7.0
381816N1213723W001	04N05E24J004	Woodbridge Irrigation District	30.0	-6.2	2015	190.0	25.0	75.5	-65.5	N/A	55.0	-31.2	-31.2	-6.2	3.5	5.3

*Data source for domestic and municipal well depths is the California DWR Online System for Well Completion Reports (OSWCR)
N/A = Not Applicable

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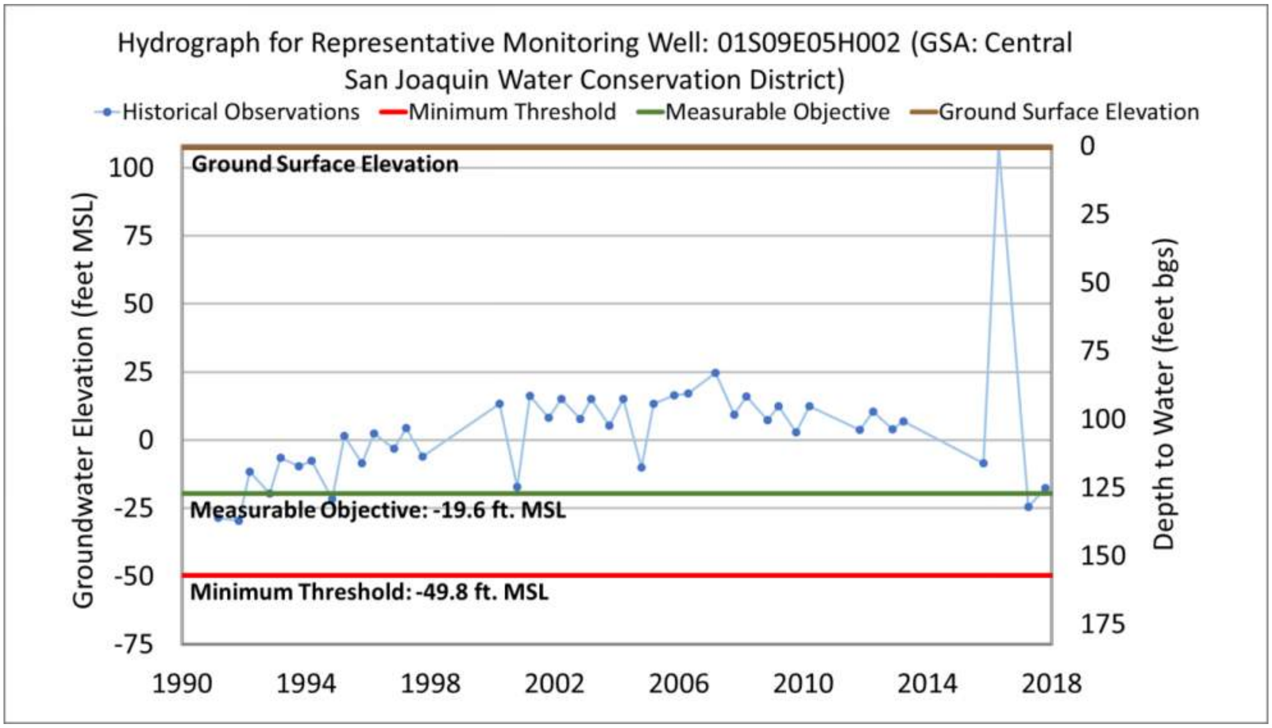
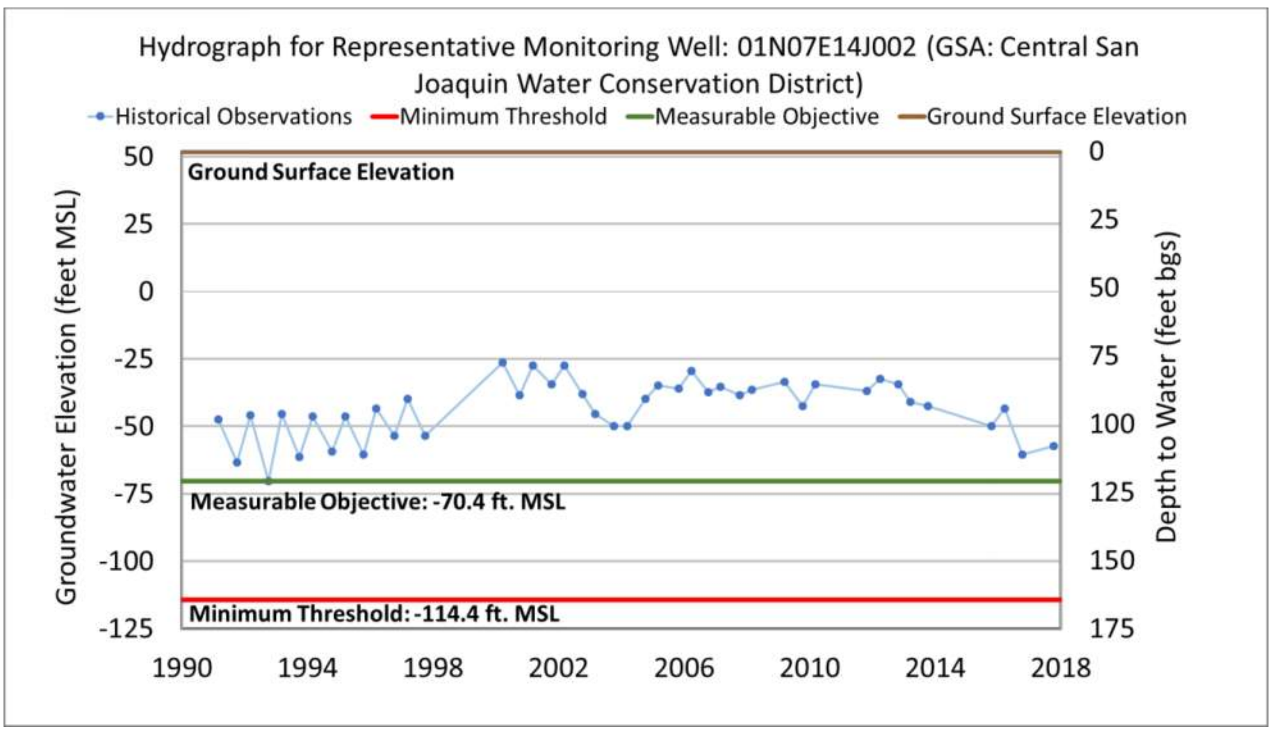
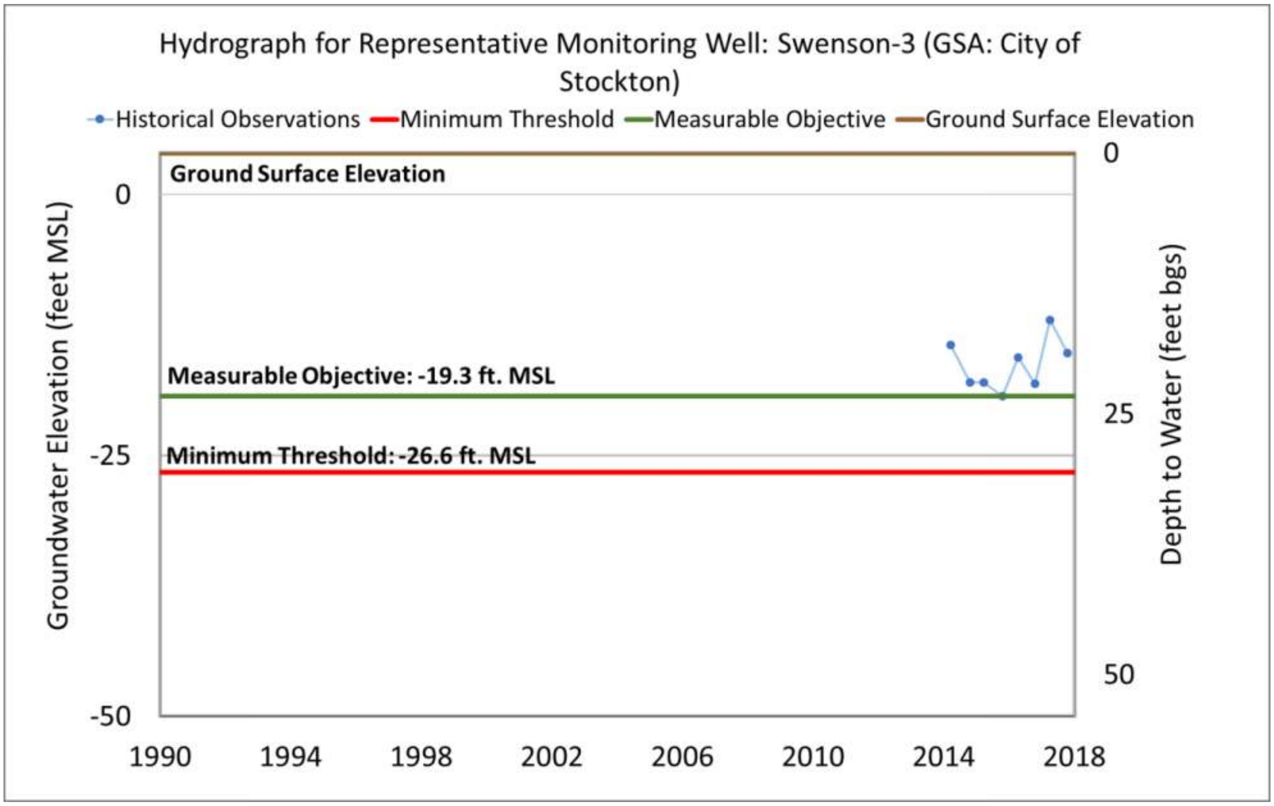
APPENDIX 3-B.
GROUNDWATER LEVEL REPRESENTATIVE MONITORING WELL HISTORICAL HYDROGRAPHS


Hydrograph for Representative Monitoring Well: 01S09E05H002 (GSA: Central San Joaquin Water Conservation District)
Historical Observations
Minimum Threshold
Measurable Objective
Ground Surface Elevation
Ground Surface Elevation
Measurable Objective: -19.6 ft. MSL
Minimum Threshold: -49.8 ft. MSL
Groundwater Elevation (feet MSL)
Depth to Water (feet bgs)
100
75
50
25
0
-25
-50
-75
0
25
50
75
100
125
150
175
1990
1994
1998
2002
2006
2010
2014
2018


Hydrograph for Representative Monitoring Well: 01N07E14J002 (GSA: Central San Joaquin Water Conservation District)
Historical Observations
Minimum Threshold
Measurable Objective
Ground Surface Elevation
Ground Surface Elevation
Measurable Objective: -70.4 ft. MSL
Minimum Threshold: -114.4 ft. MSL
Groundwater Elevation (feet MSL)
Depth to Water (feet bgs)
50
25
0
-25
-50
-75
-100
-125
0
25
50
75
100
125
150
175
1990
1994
1998
2002
2006
2010
2014
2018


Hydrograph for Representative Monitoring Well: Swenson-3 (GSA: City of Stockton)
Historical Observations
Minimum Threshold
Measurable Objective
Ground Surface Elevation
Ground Surface Elevation
Measurable Objective: -19.3 ft. MSL
Minimum Threshold: -26.6 ft. MSL
Groundwater Elevation (feet MSL)
Depth to Water (feet bgs)
0
-25
-50
0
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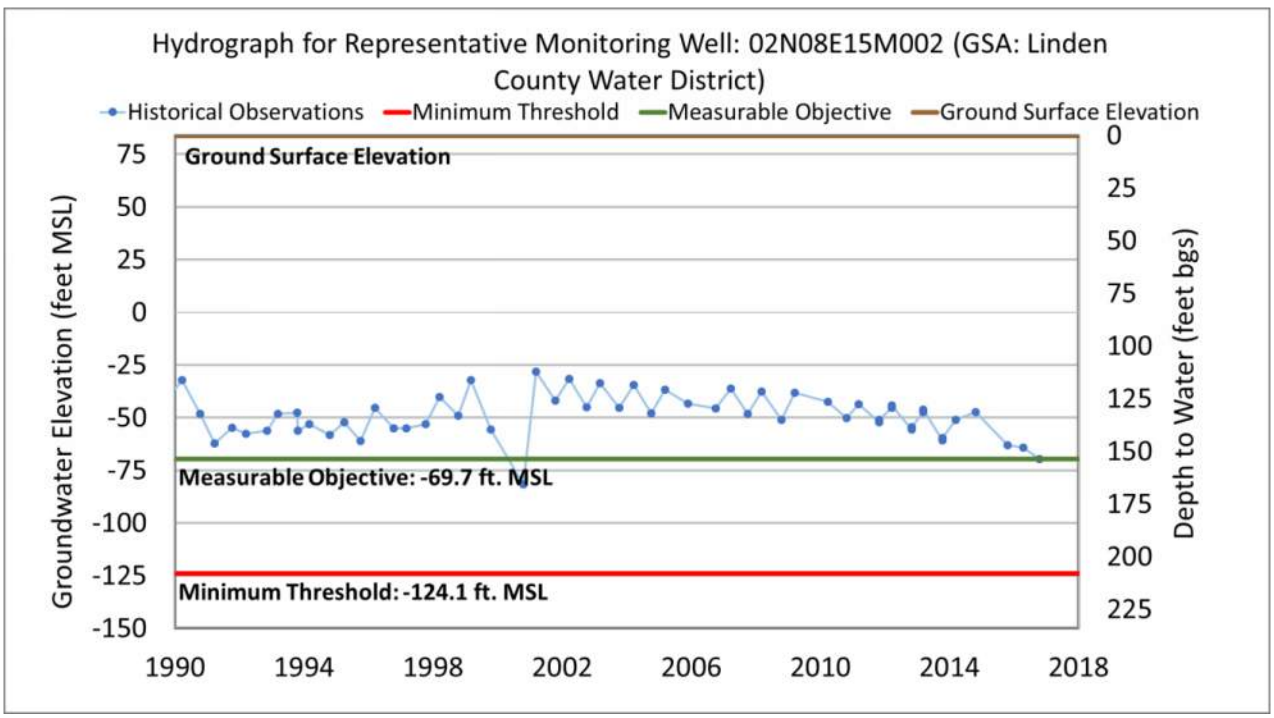
2014
2018


Hydrograph for Representative Monitoring Well: 02N08E15M002 (GSA: Linden County Water District)
Historical Observations
Minimum Threshold
Measurable Objective
Ground Surface Elevation
Ground Surface Elevation
Measurable Objective: -69.7 ft. MSL
Minimum Threshold: -124.1 ft. MSL
Groundwater Elevation (feet MSL)
Depth to Water (feet bgs)
75
50
25
0
-25
-50
-75
-100
-125
-150
0
25
50
75
100
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175
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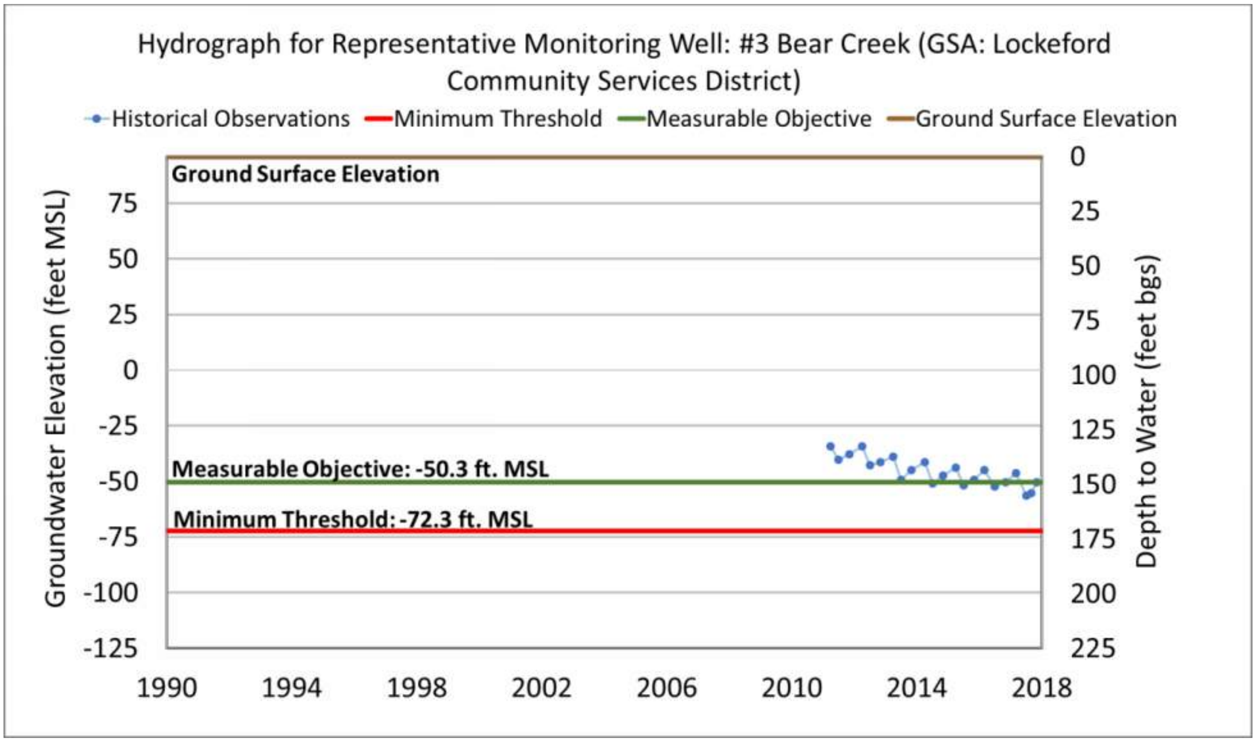
Hydrograph for Representative Monitoring Well: #3 Bear Creek (GSA: Lockeford Community Services District)
Historical Observations
Minimum Threshold
Measurable Objective
Ground Surface Elevation
Ground Surface Elevation
Measurable Objective: -50.3 ft. MSL
Minimum Threshold: -72.3 ft. MSL
Groundwater Elevation (feet MSL)
Depth to Water (feet bgs)
75
50
25
0
-25
-50
-75
-100
-125
0
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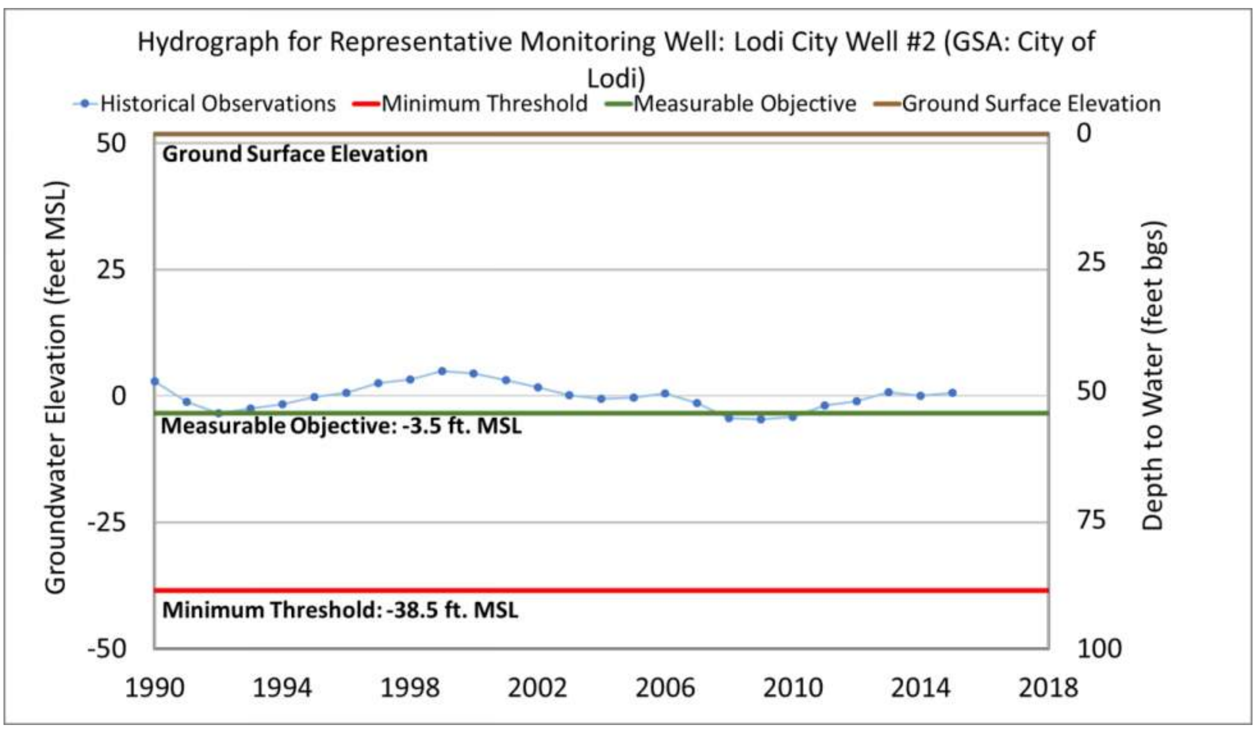
Hydrograph for Representative Monitoring Well: Lodi City Well #2 (GSA: City of Lodi)
Historical Observations
Minimum Threshold
Measurable Objective
Ground Surface Elevation
Ground Surface Elevation
Measurable Objective: -3.5 ft. MSL
Minimum Threshold: -38.5 ft. MSL
Groundwater Elevation (feet MSL)
Depth to Water (feet bgs)
50
25
0
-25
-50
0
25
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75
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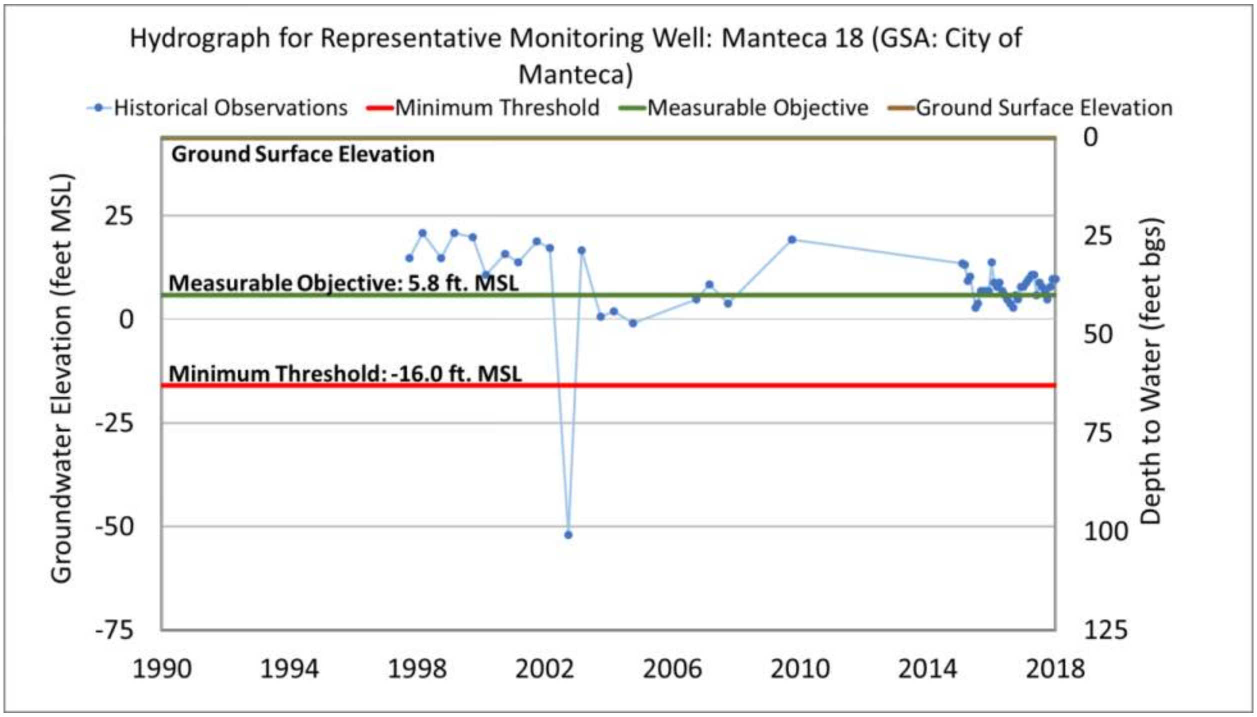

Hydrograph for Representative Monitoring Well: Manteca 18 (GSA: City of Manteca)
Historical Observations
Minimum Threshold
Measurable Objective
Ground Surface Elevation
Ground Surface Elevation
Measurable Objective: 5.8 ft. MSL
Minimum Threshold: -16.0 ft. MSL
Groundwater Elevation (feet MSL)
Depth to Water (feet bgs)
25
0
-25
-50
-75
0
25
50
75
100
125
1990
1994
1998
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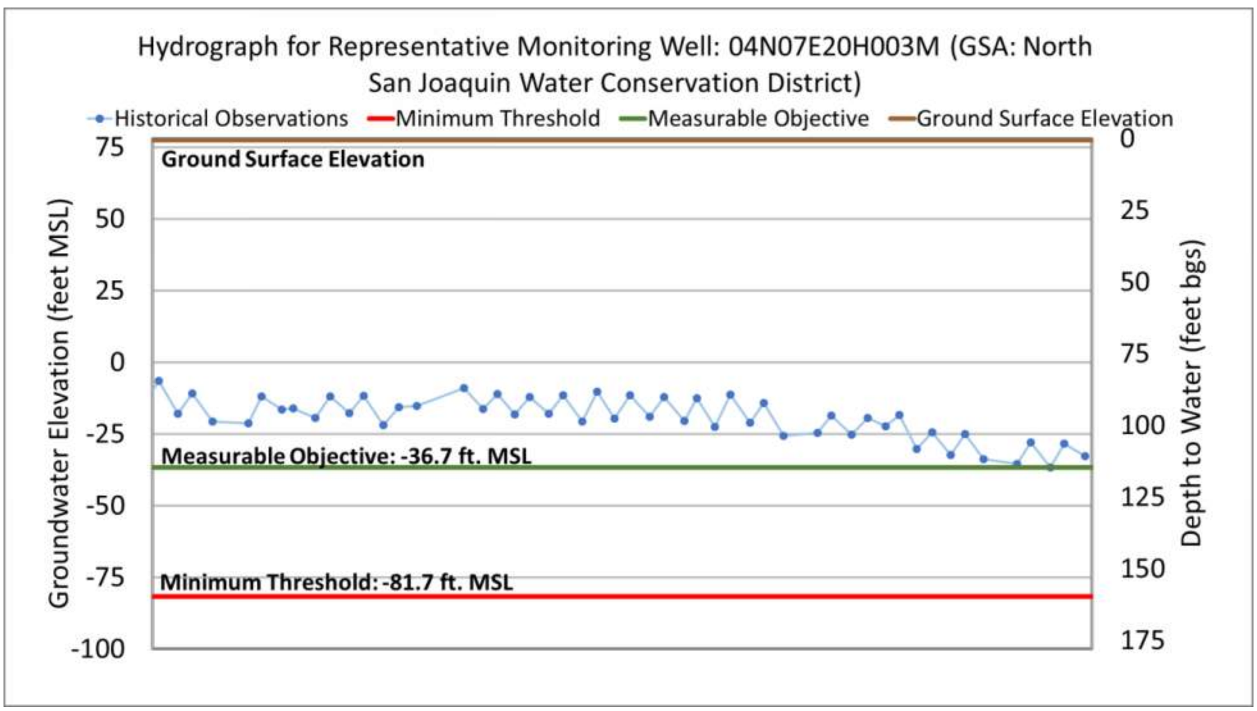
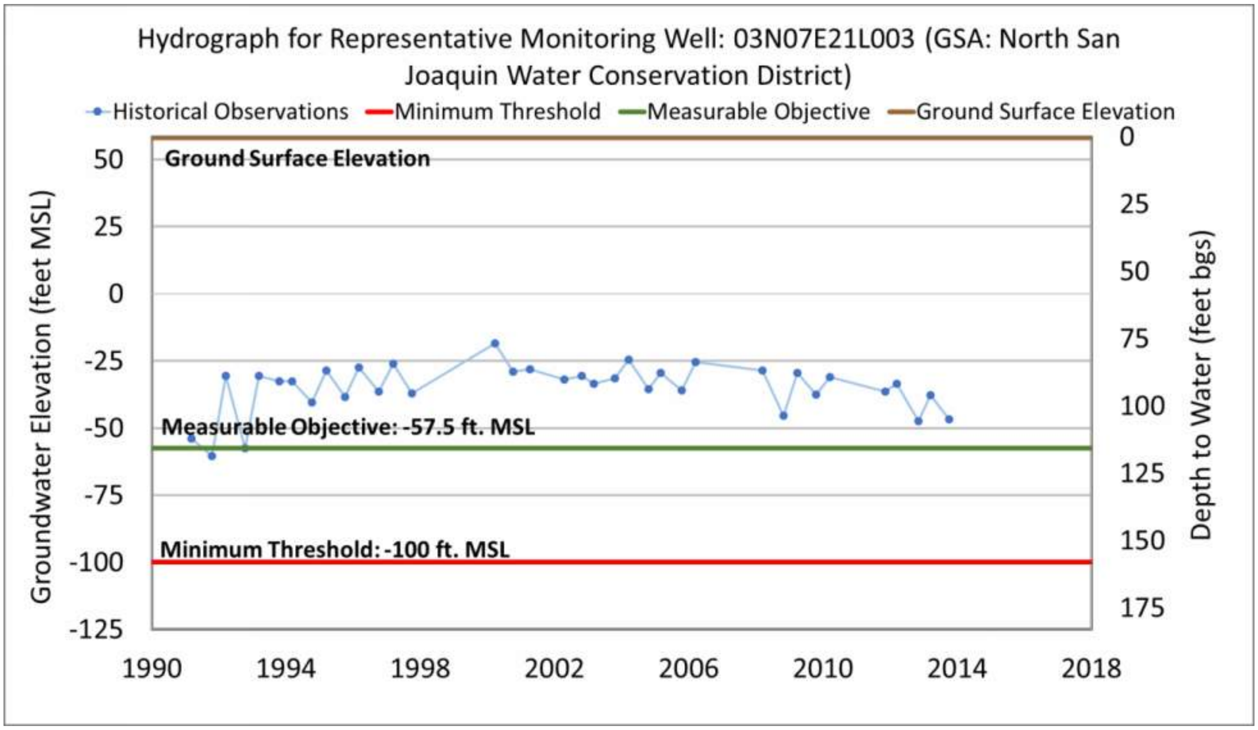
2018



Hydrograph for Representative Monitoring Well: 04N07E20H003M (GSA: North San Joaquin Water Conservation District)
Historical Observations
Minimum Threshold
Measurable Objective
Ground Surface Elevation
Ground Surface Elevation
Measurable Objective: -36.7 ft. MSL
Minimum Threshold: -81.7 ft. MSL
Groundwater Elevation (feet MSL)
Depth to Water (feet bgs)
75
50
25
0
-25
-50
-75
-100
0
25
50
75
100
125
150
175



Hydrograph for Representative Monitoring Well: 03N07E21L003 (GSA: North San Joaquin Water Conservation District)
Historical Observations
Minimum Threshold
Measurable Objective
Ground Surface Elevation
Ground Surface Elevation
Measurable Objective: -57.5 ft. MSL
Minimum Threshold: -100 ft. MSL
Groundwater Elevation (feet MSL)
Depth to Water (feet bgs)
50
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0
-25
-50
-75
-100
-125
0
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50
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125
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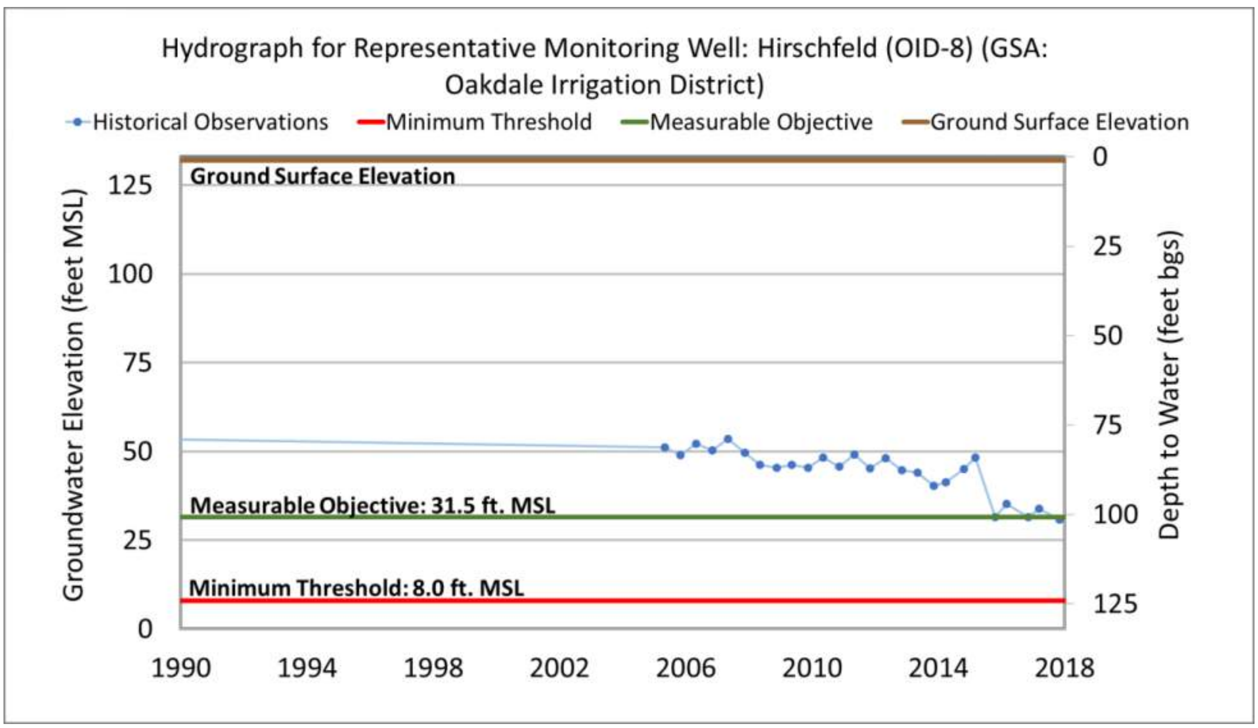

Hydrograph for Representative Monitoring Well: Hirschfeld (OID-8) (GSA: Oakdale Irrigation District)
Historical Observations
Minimum Threshold
Measurable Objective
Ground Surface Elevation
Ground Surface Elevation
Measurable Objective: 31.5 ft. MSL
Minimum Threshold: 8.0 ft. MSL
Groundwater Elevation (feet MSL)
Depth to Water (feet bgs)
125
100
75
50
25
0
0
25
50
75
100
125
1990
1994
1998
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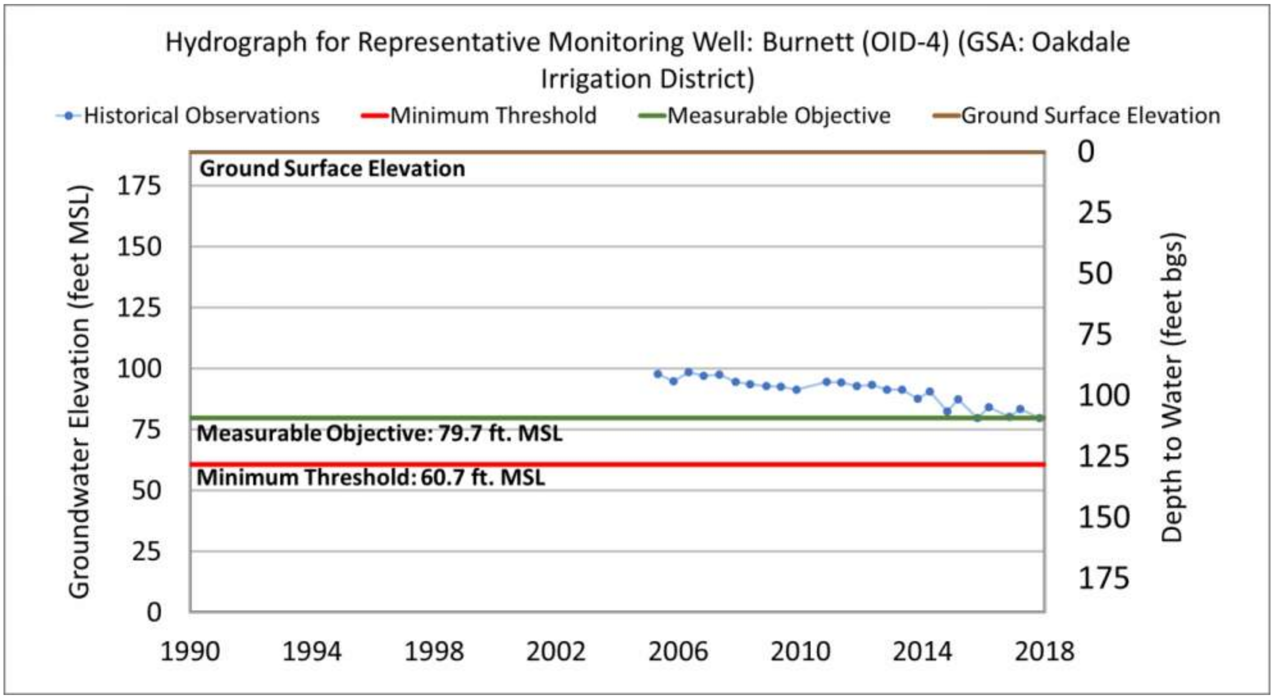
2018


Hydrograph for Representative Monitoring Well: Burnett (OID-4) (GSA: Oakdale Irrigation District)
Historical Observations
Minimum Threshold
Measurable Objective
Ground Surface Elevation
Ground Surface Elevation
Measurable Objective: 79.7 ft. MSL
Minimum Threshold: 60.7 ft. MSL
Groundwater Elevation (feet MSL)
Depth to Water (feet bgs)
0
25
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100
125
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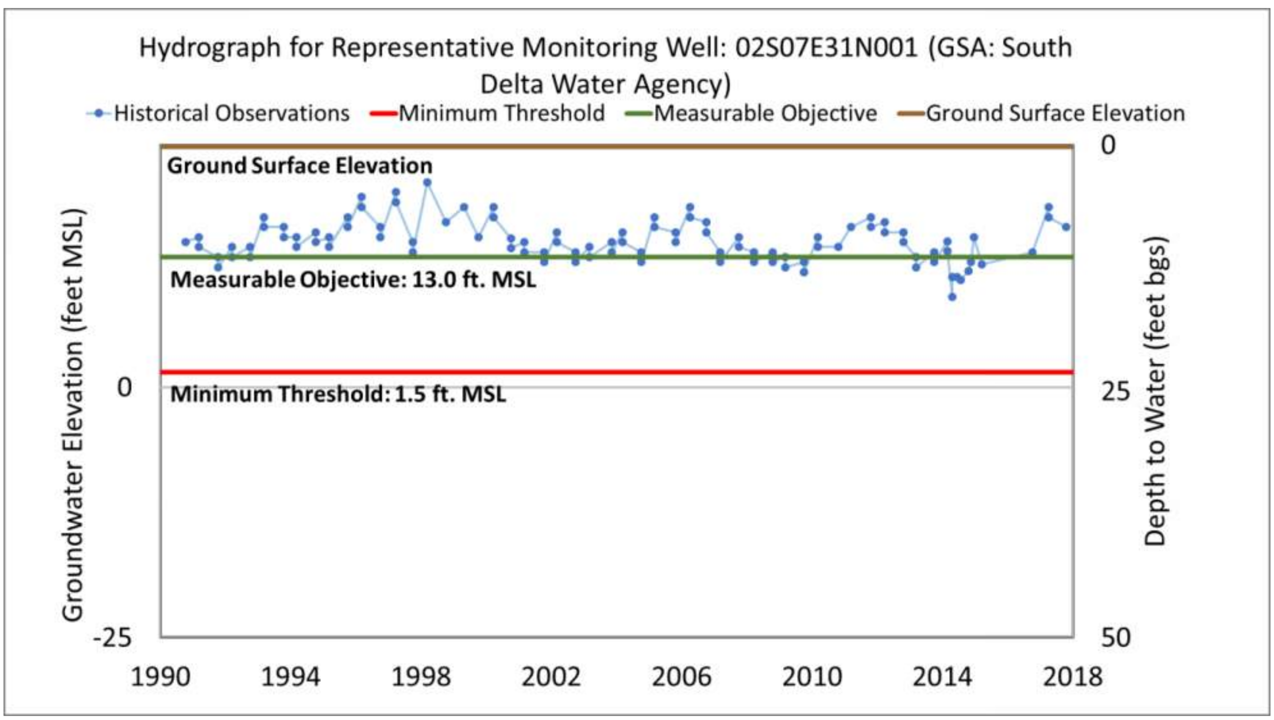
Hydrograph for Representative Monitoring Well: 02S07E31N001 (GSA: South Delta Water Agency)
Historical Observations
Minimum Threshold
Measurable Objective
Ground Surface Elevation
Ground Surface Elevation
Measurable Objective: 13.0 ft. MSL
Minimum Threshold: 1.5 ft. MSL
Groundwater Elevation (feet MSL)
Depth to Water (feet bgs)
0
-25
25
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1990
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2014
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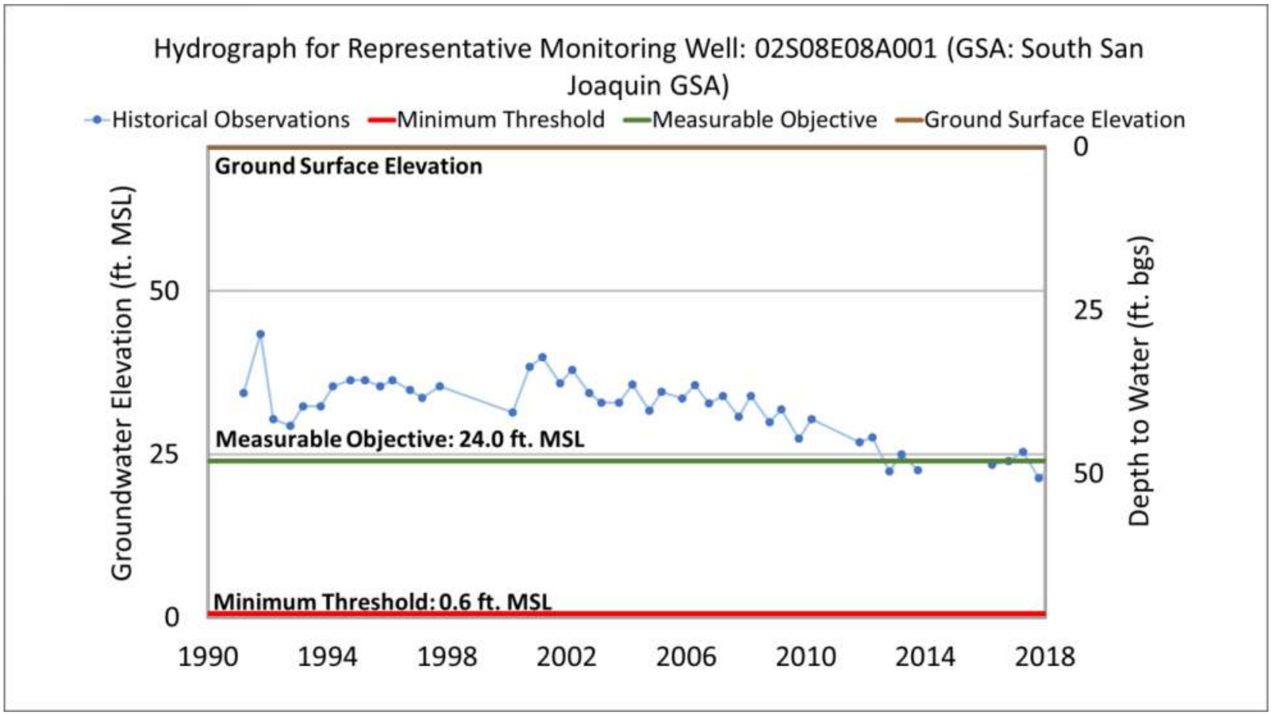

Hydrograph for Representative Monitoring Well: 02S08E08A001 (GSA: South San Joaquin GSA)
Historical Observations
Minimum Threshold
Measurable Objective
Ground Surface Elevation
Ground Surface Elevation
Measurable Objective: 24.0 ft. MSL
Minimum Threshold: 0.6 ft. MSL
Groundwater Elevation (ft. MSL)
Depth to Water (ft. bgs)
0
25
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1990
1994
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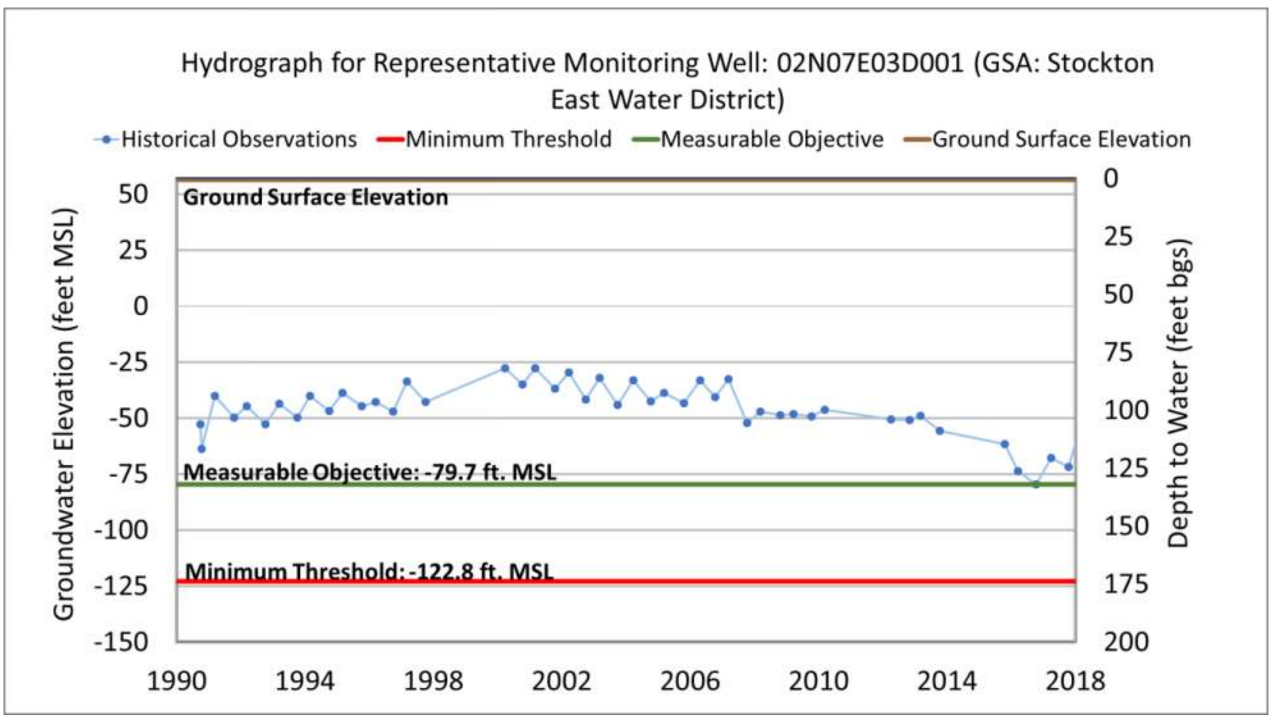
2014
2018



Hydrograph for Representative Monitoring Well: 02N07E03D001 (GSA: Stockton East Water District)
Historical Observations
Minimum Threshold
Measurable Objective
Ground Surface Elevation
Ground Surface Elevation
Measurable Objective: -79.7 ft. MSL
Minimum Threshold: -122.8 ft. MSL
Groundwater Elevation (feet MSL)
Depth to Water (feet bgs)
50
25
0
-25
-50
-75
-100
-125
-150
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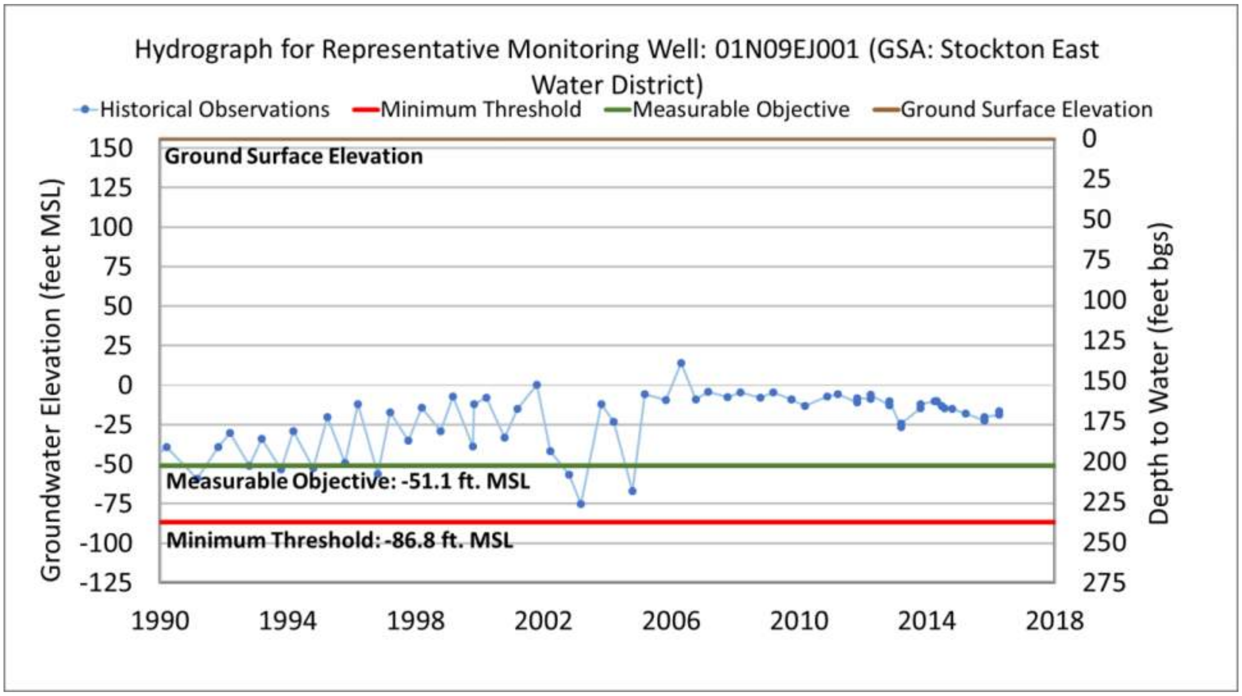
Hydrograph for Representative Monitoring Well: 01N09EJ001 (GSA: Stockton East Water District)
Historical Observations
Minimum Threshold
Measurable Objective
Ground Surface Elevation
Ground Surface Elevation
Measurable Objective: -51.1 ft. MSL
Minimum Threshold: -86.8 ft. MSL
Groundwater Elevation (feet MSL)
Depth to Water (feet bgs)
150
125
100
75
50
25
0
-25
-50
-75
-100
-125
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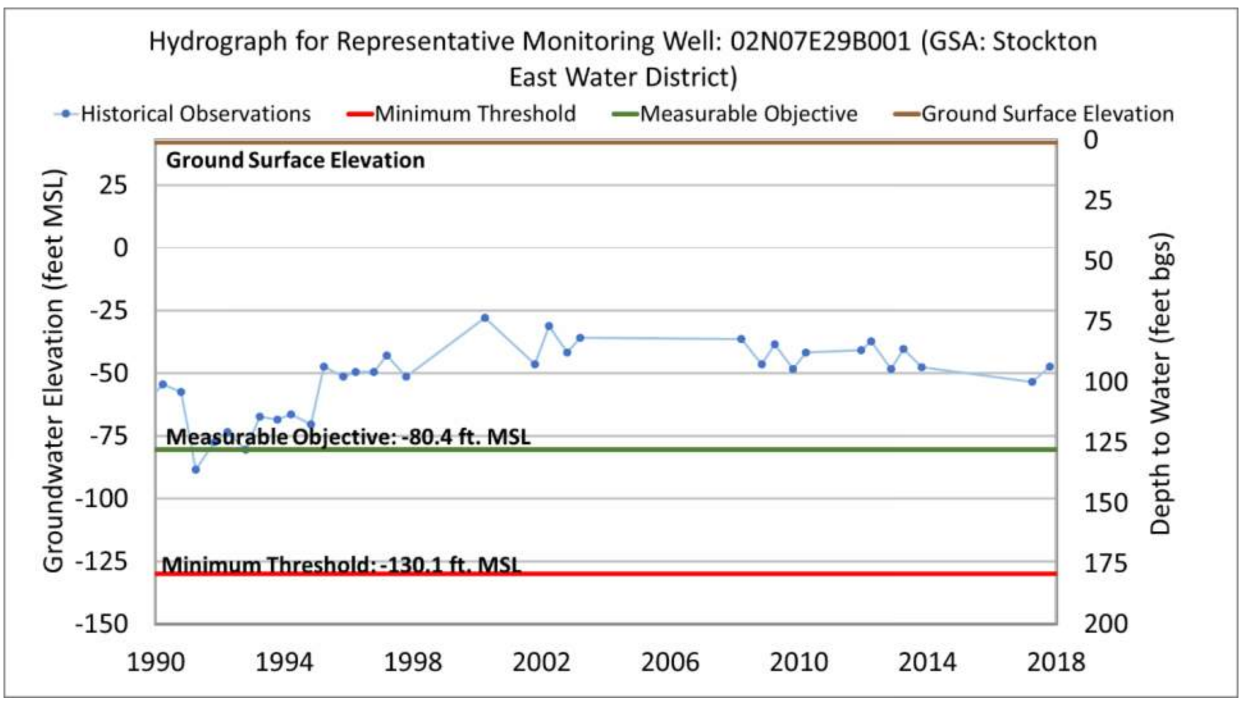
Hydrograph for Representative Monitoring Well: 02N07E29B001 (GSA: Stockton East Water District)
Historical Observations
Minimum Threshold
Measurable Objective
Ground Surface Elevation
Ground Surface Elevation
Measurable Objective: -80.4 ft. MSL
Minimum Threshold: -130.1 ft. MSL
Groundwater Elevation (feet MSL)
Depth to Water (feet bgs)
25
0
-25
-50
-75
-100
-125
-150
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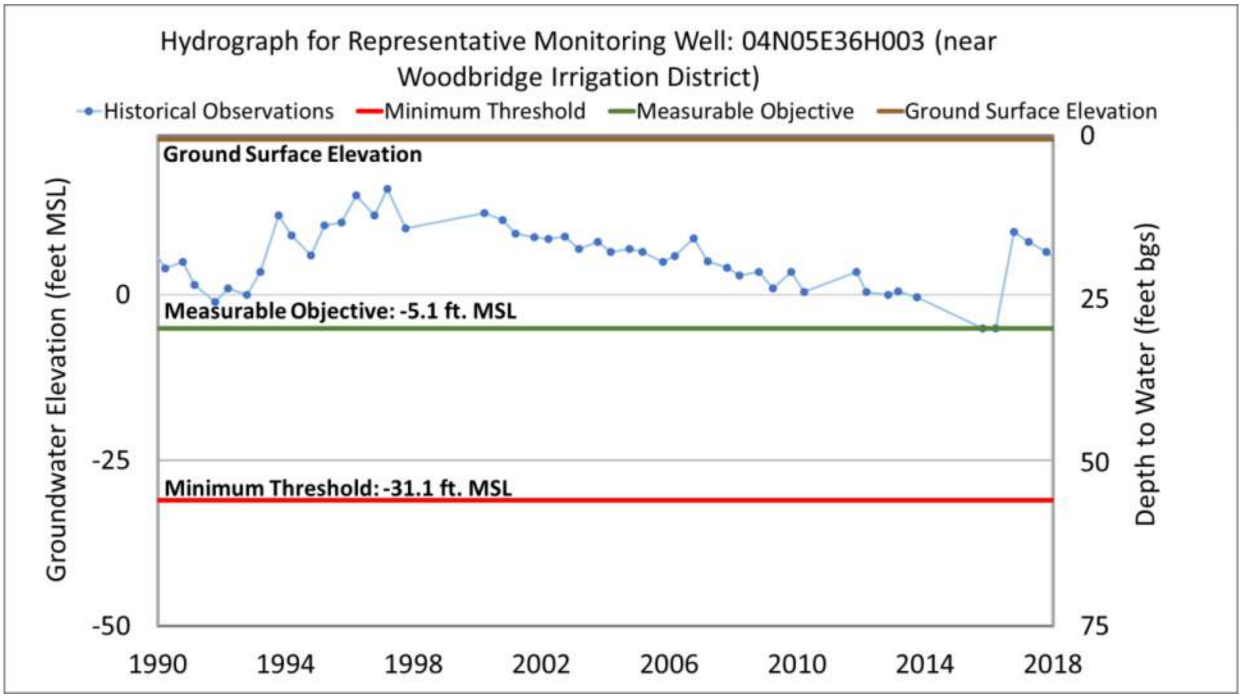
Hydrograph for Representative Monitoring Well: 04N05E36H003 (near Woodbridge Irrigation District)
Historical Observations
Minimum Threshold
Measurable Objective
Ground Surface Elevation
Ground Surface Elevation
Measurable Objective: -5.1 ft. MSL
Minimum Threshold: -31.1 ft. MSL
Groundwater Elevation (feet MSL)
Depth to Water (feet bgs)
0
-25
-50
0
25
50
75
1990
1994
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2006
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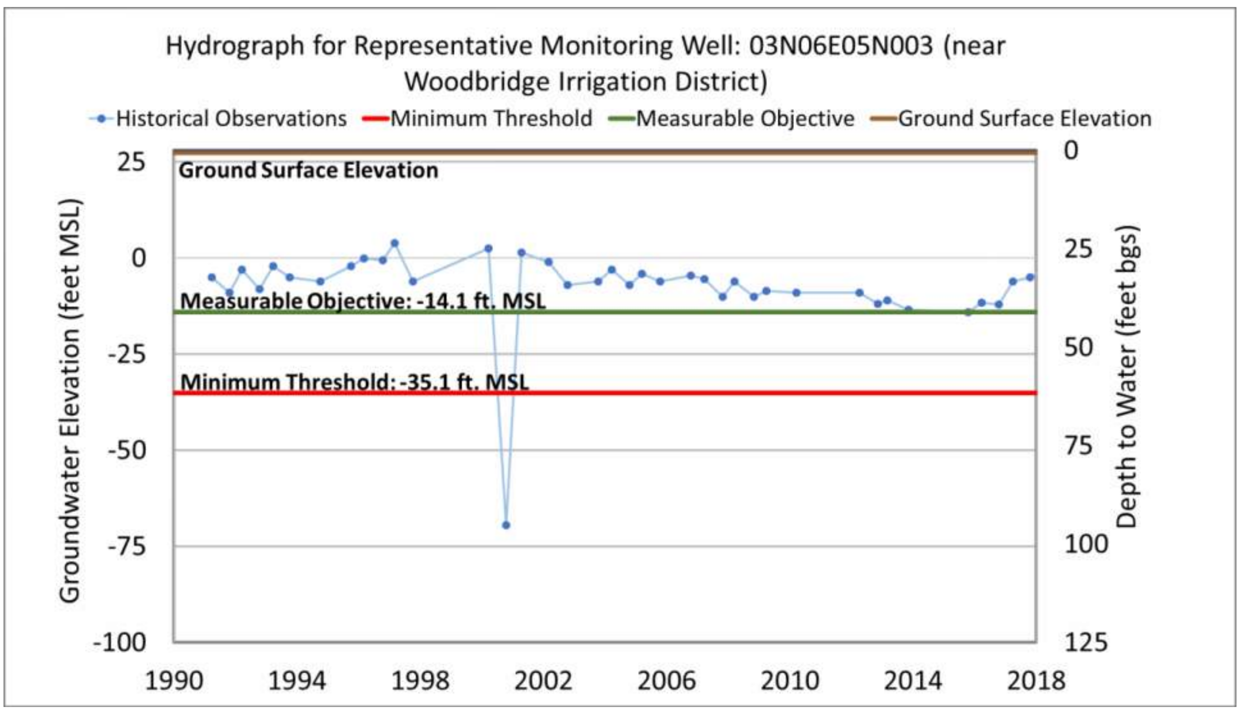
Hydrograph for Representative Monitoring Well: 03N06E05N003 (near Woodbridge Irrigation District)
Historical Observations
Minimum Threshold
Measurable Objective
Ground Surface Elevation
Ground Surface Elevation
Measurable Objective: -14.1 ft. MSL
Minimum Threshold: -35.1 ft. MSL
Groundwater Elevation (feet MSL)
Depth to Water (feet bgs)
25
0
-25
-50
-75
-100
0
25
50
75
100
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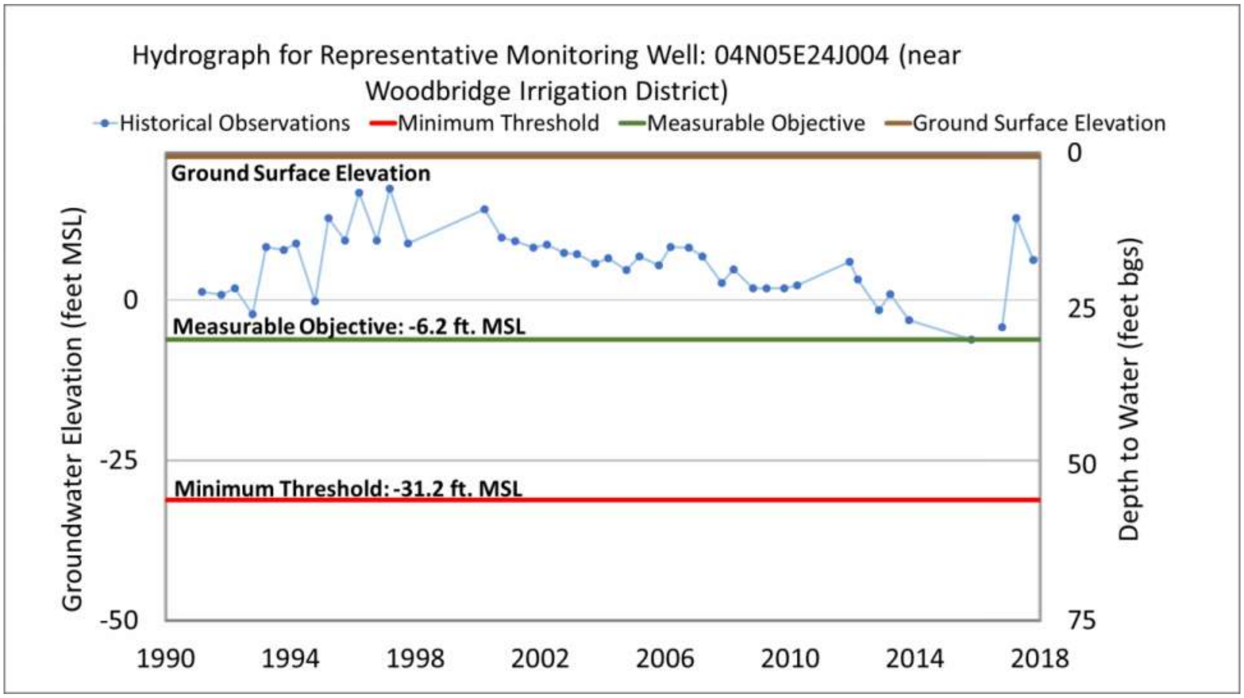
Hydrograph for Representative Monitoring Well: 04N05E24J004 (near Woodbridge Irrigation District)
Historical Observations
Minimum Threshold
Measurable Objective
Ground Surface Elevation
Ground Surface Elevation
Measurable Objective: -6.2 ft. MSL
Minimum Threshold: -31.2 ft. MSL
Groundwater Elevation (feet MSL)
Depth to Water (feet bgs)
0
-25
-50
0
25
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75
1990
1994
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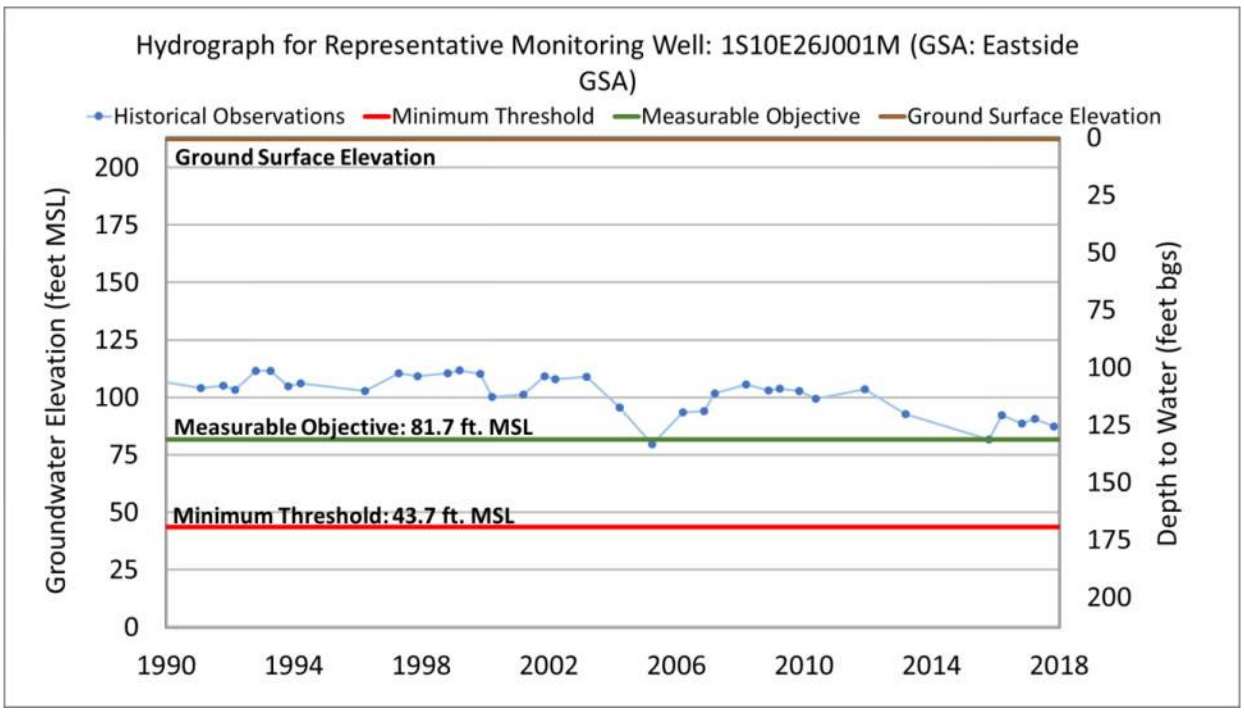
Hydrograph for Representative Monitoring Well: 1S10E26J001M (GSA: Eastside GSA)
Historical Observations
Minimum Threshold
Measurable Objective
Ground Surface Elevation
Ground Surface Elevation
Measurable Objective: 81.7 ft. MSL
Minimum Threshold: 43.7 ft. MSL
Groundwater Elevation (feet MSL)
Depth to Water (feet bgs)
200
175
150
125
100
75
50
25
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APPENDIX 3-C. CONSULTATION INITIATION LETTER FROM THE CALIFORNIA DEPARTMENT OF WATER RESOURCES TO THE EASTERN SAN JOAQUIN PLAN ADMINISTRATOR ENTITLED "EASTERN SAN JOAQUIN SUBBASIN – 2020 GROUNDWATER SUSTAINABILITY PLAN", DATED NOVEMBER 18, 2021

CALIFORNIA DEPARTMENT OF WATER RESOURCES
SUSTAINABLE GROUNDWATER MANAGEMENT OFFICE
901 P Street, Room 313-B | Sacramento, CA 95814 | P.O. Box 942836 | Sacramento, CA 94236-0001

November 18, 2021

Kris Balaji, PMP, P.E.
Eastern San Joaquin Subbasin Plan Administrator
1810 E. Hazelton Avenue, Stockton, CA 95201
kbalaji@sjgov.org

RE: Eastern San Joaquin Subbasin - 2020 Groundwater Sustainability Plan

Dear Kris Balaji,

The Eastern San Joaquin Groundwater Authority submitted the Eastern San Joaquin Groundwater Subbasin (Subbasin) Groundwater Sustainability Plan (GSP) to the Department of Water Resources (Department) for evaluation and assessment as required by the Sustainable Groundwater Management Act (SGMA).[1]

Department staff have substantially completed an initial review of the GSP and have identified potential deficiencies (see the enclosed document) which may preclude the Department's approval.[2] Department staff have also developed potential corrective actions[3] for each potential deficiency. The potential deficiencies do not necessarily represent all deficiencies or discrepancies that the Department may identify in the GSP but focus on those deficiencies that staff believe, if not addressed, could lead to a determination that the GSP is incomplete or inadequate.[4] This letter initiates consultation between the Department, the Plan Manager, and the Subbasin's 15 groundwater sustainability agencies (GSAs) regarding the amount of time needed to address the potential deficiencies and corrective actions. The Department will issue a final determination as described under the GSP Regulations[5] no later than January 29, 2022.

If the Department determines the GSP to be incomplete, the deficiencies precluding approval would need to be addressed within a period not to exceed 180 days from the

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[1] Water Code § 10720 et seq.
[2] 23 CCR § 355.2(e)(2).
[3] 23 CCR § 355.2(e)(2)(B).
[4] The Department recognizes that litigation regarding the GSP has been filed. The filing of litigation does not alter or affect the Department's mandate to issue its final assessment of the Agency's groundwater sustainability plan (GSP or Plan) for the basin within two years of its submission. (Water Code §10733.4(d).) Furthermore, the Department's assessment will consist of a technical review of the submitted Plan, as required by SGMA and the GSP Regulations, and the filing of the litigation did not in any way influence or affect the Department's evaluation of the Plan. The Department expresses no opinion on the claims of the parties in the pending litigation involving the GSP.
[5] 23 CCR Division 2, Chapter 1.5, Subchapter 2.

determination. A determination of incomplete would allow the GSAs to formally address identified deficiencies and submit a revised GSP to the Department for further review and evaluation. Department staff will contact you before making the final determination to discuss the potential deficiencies and the amount of time needed by the GSAs to address the potential corrective actions detailed in the enclosed document.

Materials submitted to the Department to address deficiencies must be part of the GSP. The GSAs must justify that any materials submitted are part of the revised GSP; this justification is also part of the submittal. To facilitate the Department's review of the revised GSP, the GSAs should also provide a companion document with tracked changes of modifications made to address deficiencies. The GSAs must submit the revised GSP through the DWR SGMA Portal where, as is currently available, interested parties may provide comments on submitted materials to the Department.

Department staff will work expeditiously to review materials submitted to address deficiencies and to evaluate compliance of the revised GSP. The Department will keep a GSP status designated as incomplete during its review of the submitted materials. The Department could subsequently approve an incomplete GSP if the GSAs have taken corrective actions to address deficiencies identified by the Department within a period not to exceed 180 days from the determination. The Department could also issue a determination of inadequate for an incomplete GSP if the Department, after consultation with the State Water Resources Control Board, determines the GSAs have not taken sufficient actions to correct the deficiencies identified by the Department.

If you have any questions, please do not hesitate to contact the Sustainable Groundwater Management Office staff by emailing sgmps@water.ca.gov.

Thank you,

Paul Gosselin

Paul Gosselin
Deputy Director for Sustainable Groundwater Management

Enclosure:

1. Potential Deficiencies and Corrective Actions

Potential Deficiencies and Corrective Actions

Department of Water Resources (Department) staff have identified deficiencies regarding the Eastern San Joaquin Subbasin (Subbasin) Groundwater Sustainability Plan (GSP) that may preclude the Department's approval. Therefore, consistent with the GSP Regulations, Department staff are considering corrective actions the Subbasin's groundwater sustainability agencies (GSAs) should review to determine whether and how the deficiencies can be addressed. The deficiencies and potential corrective actions are explained below, including the general regulatory background, the specific deficiencies identified in the GSP, and specific actions to address the deficiencies. The specific actions identified are potential corrective actions until the Department makes a final determination.

General Background

Potential deficiencies identified in the Eastern San Joaquin Subbasin GSP relate to the development and documentation of sustainable management criteria, including undesirable results and minimum thresholds that define when undesirable results may occur.

The Department's GSP Regulations describe several required elements of a GSP under the heading of "Sustainable Management Criteria"[6], including undesirable results, minimum thresholds, and measurable objectives. These components of sustainable management criteria must be quantified so that GSAs, the Department, and other interested parties can monitor progress towards sustainability in a basin consistently and objectively.

A GSA relies on local experience, public outreach and involvement, and information about the basin it has described in the GSP basin setting (i.e., the hydrogeologic conceptual model, the description of current and historical groundwater conditions, and the water budget), among other factors, to develop criteria for defining undesirable results and setting minimum thresholds and measurable objectives.[7]

The Sustainable Groundwater Management Act (SGMA) defines sustainable groundwater management as the management and use of groundwater in a manner that can be maintained during the planning and implementation horizon without causing undesirable results.[8] Avoidance of undesirable results is thus explicitly part of sustainable groundwater management as established by SGMA and critical to the success of a GSP.

The definition of undesirable results is critical to establishing an objective method to define and measure sustainability for a basin. As an initial matter, SGMA provides a

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[6] 23 CCR § Article 5, Subarticle 3.
[7] 23 CCR §§ 354.8, 354.10, 354.12 *et seq*.
[8] Water Code § 10721(v).

qualitative definition of undesirable results as "one or more" of six specific "effects caused by groundwater conditions occurring throughout the basin."[9]

GSAs define, in their GSPs, the specific significant and unreasonable effects that would constitute undesirable results and the groundwater conditions that would produce those results in their basins.[10] The GSAs' definition must include a description of the processes and criteria relied upon to define undesirable results and describe the effect of undesirable results on the beneficial uses and users of groundwater, surface land uses (for subsidence), and surface water (for interconnected surface water).[11]

SGMA leaves the task of establishing undesirable results and setting thresholds largely to the discretion of the GSAs, subject to review by the Department. In its review, the Department requires a thorough and reasonable analysis of the groundwater conditions and the associated effects the GSAs must manage the groundwater basin to avoid, and the GSAs' stated rationale for setting objective and quantitative sustainable management criteria to prevent those undesirable conditions from occurring.[12] If a GSP does not meet this requirement, the Department cannot evaluate the GSAs' likelihood of achieving their sustainability goal. That does not necessarily mean that the GSP or its objectives are inherently unreasonable; rather, the Department cannot evaluate whether the GSP's implementation would successfully achieve sustainable management if it is unclear what undesirable conditions the GSAs seek to avoid.

Potential Deficiency 1. The GSP lacks sufficient justification for identifying that undesirable results for chronic lowering of groundwater levels, subsidence, and depletion of interconnected surface waters can only occur in consecutive non-dry water year types. The GSP also lacks sufficient explanation for its chronic lowering of groundwater levels minimum thresholds and undesirable results.

The first potential deficiency relates to the GSP's requirement of two consecutive non-dry (i.e., below normal, above normal, or wet) water-year types and the exclusion of dry and critically dry water-year types in the identification of undesirable results for chronic lowering of groundwater levels, and, by proxy, land subsidence and depletions of interconnected surface water.

Background

Related to this potential deficiency, SGMA defines the term "Undesirable Result," in part, as one or more of the following effects caused by groundwater conditions occurring throughout the basin:[13]

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[9] Water Code § 10721(x).
[10] California Department of Water Resources, Best Management Practices for the Sustainable Management of Groundwater: Sustainable Management Criteria (Draft), November 2017.
[11] 23 CCR §§ 354.26(b), 354.28(c)(5), 354.28(c)(6).
[12] 23 CCR § 355.4(b)(1).
[13] Water Code § 10721(x).

- Chronic lowering of groundwater levels indicating a significant and unreasonable depletion of supply if continued over the planning and implementation horizon. Overdraft during a period of drought is not sufficient to establish a chronic lowering of groundwater levels if extractions and groundwater recharge are managed as necessary to ensure that reductions in groundwater levels or storage during a period of drought are offset by increases in groundwater levels or storage during other periods.
- Significant and unreasonable land subsidence that substantially interferes with surface land uses.
- Depletions of interconnected surface water that have significant and unreasonable adverse impacts on beneficial uses of the surface water.

Potential Deficiency Details

Department staff identified two areas of concern, described below, which, if not addressed, may preclude approval of the GSP. Regarding the first area of concern, the GSP identifies that an undesirable result occurs "when at least 25 percent of representative monitoring wells used to monitor groundwater levels (5 of 20 wells in the Subbasin) fall below their minimum level thresholds for two consecutive years that are categorized as non-dry years (below-normal, above-normal, or wet), according to the San Joaquin Valley Water Year Hydrologic Classification." The GSP further states that "the lowering of groundwater levels during consecutive dry or critically-dry years is not considered to be unreasonable, and would therefore not be considered an undesirable result, unless the levels do not rebound to above the thresholds following those consecutive non-dry years."[14]

Department staff find that the water-year type requirement in the definition of the undesirable result for chronic lowering of groundwater levels (i.e., two consecutive non-dry years) is not consistent with the intent of SGMA. The water-year type requirement could potentially allow for unmanaged and continued lowering of groundwater levels under certain hydrologic or climatic conditions that have occurred historically. A review of historical San Joaquin Valley water-year type classifications[15] indicates the potential for dry periods without the occurrence of a second consecutive non-dry year to persist for greater than ten years (see, e.g., the 11 years from water years 1985 through 1995). Department staff also note that concurrent below normal, above normal, or wet years occurred in only five of the last twenty water years from 2001 through 2020. Because of this definition, GSAs in the Subbasin could disregard potential impacts of groundwater level declines below the minimum thresholds during extended periods of dry years, even if interrupted by normal or wet years.

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[14] ESJ GSP, p. 253.
[15] Chronological Reconstructed Sacramento and San Joaquin Valley Water Year Hydrologic Classification Indices, Water Year 1901 through 2020. California Department of Water Resources, https://cdec.water.ca.gov/reportapp/javareports?name=WSIHIST.

Department staff also find this methodology inconsistent with other portions of the GSP. For example, while describing measurable objectives for groundwater levels, the GSP states, "the margin of operational flexibility is intended to accommodate droughts, climate change, conjunctive use operations, or other groundwater management activities. The margin of operational flexibility is defined as the difference between the minimum threshold and the measurable objective."[16] Based on these statements, it appears the minimum thresholds already accommodate drought conditions, so it is unclear why the GSP's definition of undesirable results further excludes minimum threshold exceedances during dry water years. (See Potential Corrective Action 1a.)

SGMA states that "overdraft during a period of drought is not sufficient to establish a chronic lowering of groundwater levels if extractions and groundwater recharge are managed as necessary to ensure that reductions in groundwater levels or storage during a period of drought are offset by increases in groundwater levels or storage during other periods."[17] If the GSAs intended to incorporate this concept into their definition of the undesirable result for chronic lowering of groundwater levels, the GSP fails to identify specific extraction and groundwater recharge management actions the GSAs would implement[18] or otherwise describe how the Subbasin would be managed to offset, by increases in groundwater levels or storage during other periods, dry year reductions of groundwater storage. The GSP identifies many projects that, once implemented, may lead to the elimination of long-term overdraft conditions in the Subbasin. However, the GSP does not sufficiently detail how projects and management actions, in conjunction with the proposed chronic lowering of groundwater levels sustainable management criteria, will offset drought-related groundwater reductions and avoid significant and unreasonable impacts when groundwater level minimum thresholds are potentially exceeded for an extended period in the absence of two consecutive non-dry years. (See Potential Corrective Action 1b.)

As noted above, the GSP states that minimum thresholds developed for chronic lowering of groundwater levels serve as proxies for subsidence[19] and depletion of interconnected surface waters.[20] Therefore, Department staff assume the GSAs intend to apply the same water-year type criteria to undesirable results for those sustainability indicators (i.e., land subsidence or depletion of interconnected surface water undesirable results do not occur until groundwater levels exceed the thresholds for two consecutive non-dry water years). However, where SGMA acknowledges that groundwater level declines during drought periods are not sufficient to cause an undesirable result for chronic lowering of groundwater levels, the statute does not similarly provide an exception for subsidence or stream depletion during periods of drought. (See Potential Corrective Action 1c.)

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[16] ESJ GSP, p. 259.
[17] Water Code § 10721(x)(1).
[18] 23 CCR § 354.44(b)(9).
[19] ESJ GSP, p. 270.
[20] ESJ GSP, p. 271.

Department staff's second area of concern is the GSP's evaluation of the effects of the proposed minimum thresholds and undesirable results on beneficial uses and users of groundwater. The GSP identifies that the chronic lowering of groundwater levels could cause undesirable results from wells going dry, reductions in pumping capacities, increased pumping costs, the need for deeper well installations or lowering of pumps, and adverse impacts to environmental uses and users.[21] The GSP builds an analysis of domestic wells going dry into its minimum thresholds, thereby considering the factors of wells going dry and the need for deeper well installations. However, it does not address how the management criteria address the other factors identified by the GSAs as potential undesirable results, including reductions in pumping capacity or increased pumping costs for shallow groundwater users, or adverse impacts to environmental uses and users.

The GSAs set minimum thresholds in the Subbasin at the shallower of the 10th percentile domestic [or municipal] well depth or the historical low groundwater levels with a subtracted buffer value, which the GSP states allows for operational flexibility.[22] These minimum threshold values generally allow groundwater levels to decline below historic lows; minimum thresholds defined using the buffer value approach allow twice the historical drawdown from the shallowest recorded groundwater levels.[23] Aside from the GSP's domestic well analysis, the only description of how minimum thresholds were evaluated to avoid undesirable results appears to be the statements that “for the majority of the Subbasin, GSA representatives identified no undesirable results, even if groundwater were to reach historical low groundwater levels” and that no GSA indicated undesirable results would occur “if the minimum threshold was set deeper than the [historic low] based on their understanding.”[24] The GSP provides no further explanation or description of how the individual GSAs concluded that there would be no undesirable results based on the minimum thresholds.

The GSP only considers an undesirable result to occur for groundwater levels in the Subbasin when at least 25 percent of representative monitoring wells (5 of 20 wells) fall below their minimum threshold value for two consecutive non-dry water years.[25] The GSP does not justify or discuss how the GSAs developed the 25 percent threshold, nor does it explain or disclose the potential impacts anticipated during extended drier climate conditions using this threshold. In other words, the proposed management program may lead to potential effects on domestic wells or other beneficial uses and users during prolonged dry- or below-normal periods, and that information should, at a minimum, be disclosed and considered in the GSP. (See Potential Corrective Action 1d.)

If, after considering this potential deficiency, the GSAs retain minimum thresholds that allow for continued lowering of groundwater levels, it is reasonable to assume that some

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[21] ESJ GSP, p. 253.
[22] ESJ GSP, p. 254.
[23] ESJ GSP, p. 258.
[24] ESJ GSP, p. 255.
[25] ESJ GSP, p. 253.

groundwater well impacts (e.g., loss of production capacity) will occur during the implementation of the GSP. SGMA requires GSAs to consider the interests of all groundwater uses and users and to implement their GSPs to mitigate overdraft conditions.[26] Implementing specific projects and management actions prevents undesirable results and achieves the sustainable yield of the basin. The GSAs should describe how projects and management actions would address drinking water impacts due to continued overdraft between the start of GSP implementation and the achievement of the sustainability goal. If the GSP does not include projects or management actions to address drinking water impacts, the GSP should contain a thorough discussion, with supporting facts and rationale, explaining how and why GSAs determined not to include actions to address those impacts from continued groundwater lowering below pre-SGMA levels. (See Potential Corrective Action 1e.)

Additionally, related to the groundwater level declines allowed for by the GSA's minimum thresholds, the GSAs have not explained how those groundwater level declines relate to the degradation of groundwater quality sustainability indicator. GSAs must describe, among other items, the relationship between minimum thresholds for a given sustainability indicator (in this case, chronic lowering of groundwater levels) and the other sustainability indicators.[27] The GSAs generally commit to monitoring a wide range of water quality constituents but they have only developed sustainable management criteria for total dissolved solids because they state they have not observed a causal nexus between groundwater management and degradation associated with the other constituents. While Department staff are not aware of evidence sufficient to conclude that the GSAs acted unreasonably by focusing on total dissolved solids, it is clear that the GSAs did not consider, or at least did not document, the potential for degradation to occur due to further lowering of groundwater levels beyond the historic lows. (See Potential Corrective Action 1f.)

Potential Corrective Action 1

a) Department staff believe the management approach described in the GSP, which couples minimum thresholds and measurable objectives that account for operational flexibility during dry periods with a definition of undesirable results that disregards minimum threshold exceedances in all years except consecutive below normal, above normal, or wet years, to be inconsistent with the objectives of SGMA. Therefore, the GSAs should remove the water-year type requirement from the GSP's undesirable result definition.
b) The GSP should be revised to include specific projects and management actions the GSAs would implement to offset drought-year groundwater level declines.
c) The GSAs should thoroughly explain how their approach avoids undesirable results for subsidence and depletion of interconnected surface waters, as SGMA does not

[26] 23 CCR § 355.4(b)(4), 355.4(b)(6).
[27] 23 CCR § 354.28(b)(2).

include an allowance or exemption for those conditions to continue in periods of drought.

d) Removing the water-year type requirement from the definition of an undesirable result (item a, above) would result in a GSP with groundwater level minimum thresholds designed to be generally protective of 90 percent of domestic wells regardless of regional hydrologic conditions. In that scenario, the GSAs should explain the rationale for determining that groundwater levels can exceed those thresholds at 25 percent of monitoring sites for two consecutive years before the effects would be considered significant and unreasonable. The GSAs should also explain how other factors they identified as "potential undesirable results" (e.g., adverse impacts to environmental uses and users) factored into selecting minimum thresholds and describe anticipated effects of the thresholds on beneficial uses and users of groundwater. Furthermore, the GSAs should explain whether other drinking water users that may rely on shallow wells, such as public water systems and state small water systems, were considered in the GSAs' site-specific thresholds. If not, the GSAs should conduct outreach with those users and incorporate their shallow wells, as applicable, into the site-specific minimum thresholds and measurable objectives.

e) The GSAs should revise the GSP to describe how they would address drinking water impacts caused by continued overdraft during the period between the start of GSP implementation and achieving the sustainability goal. If the GSP does not include projects or management actions to address those impacts, the GSP should contain a thorough discussion, with supporting facts and rationale, explaining how and why the GSAs determined not to include specific actions to address drinking water impacts from continued groundwater lowering below pre-SGMA levels.

f) The GSP should be revised to explain how the GSAs will assess groundwater quality degradation in areas where further groundwater level decline, below historic lows, is allowed via the minimum thresholds. The GSAs should further describe how they will coordinate with the appropriate groundwater users, including drinking water, environmental, and irrigation users as identified in the GSP. The GSAs should also discuss efforts to coordinate with water quality regulatory agencies and programs in the Subbasin to understand and develop a process for determining if continued lowering of groundwater levels is resulting in degraded water quality in the Subbasin during GSP implementation.

Potential Deficiency 2. The GSP does not provide enough information to support the use of the chronic lowering of groundwater level sustainable management criteria and representative monitoring network as a proxy for land subsidence.

Background

The GSP Regulations state that minimum thresholds for land subsidence should identify the rate and extent of subsidence that substantially interferes with surface land uses and may lead to undesirable results. These quantitative values should be supported by: [28]

- The identification of land uses or property interests potentially affected by land subsidence;
- An explanation of how impacts to those land uses or property interests were considered when establishing minimum thresholds;
- Maps or graphs showing the rates and extents of land subsidence defined by the minimum thresholds.

The GSP Regulations allow the use of groundwater elevations as a proxy for land subsidence. However, GSAs must demonstrate a significant correlation between groundwater levels and land subsidence and must demonstrate that groundwater level minimum thresholds represent a reasonable proxy for avoiding land subsidence undesirable results. Additionally, the GSAs must demonstrate how the monitoring network is adequate to identify undesirable results for both metrics.

Potential Deficiency Details

Department staff find that the GSP does not adequately identify or define minimum thresholds and undesirable results for land subsidence. The GSP also does not provide adequate justification and explanation for using the groundwater level minimum thresholds and representative monitoring network as a proxy for land subsidence.

Generally, the GSP identifies that irrecoverable loss of groundwater storage and damage to infrastructure, including water conveyance facilities and flood control facilities, are potential impacts of land subsidence.[29] However, the GSP does not identify specific infrastructure locations, particularly those associated with public safety, in the Subbasin and the rate and extent of subsidence that would substantially interfere with those land surface uses and may lead to undesirable results. Additionally, without identifying infrastructure considered at risk for interference from land subsidence, Department staff cannot evaluate whether the groundwater level representative monitoring network is adequate to detect potential subsidence-related impacts.

Department staff find the GSP does not provide adequate evidence to demonstrate a significant correlation between groundwater levels and land subsidence in the Subbasin.

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[28] 23 CCR § 354.28(c)(5).
[29] ESJ GSP, p. 269.

Without explaining this correlation, the Department cannot evaluate whether the groundwater level minimum thresholds and associated conditions required for identifying an undesirable result would protect against significant and unreasonable impacts related to land subsidence. The GSP states a significant correlation exists between groundwater levels and land subsidence, with lowering groundwater levels driving further land subsidence.[30] Department staff agree with this general statement. However, the GSP fails to provide adequate evidence to evaluate further this correlation, specifically concerning potential subsidence caused by groundwater levels falling below historic lows, as would be allowed by the groundwater level minimum thresholds set in the GSP.

The GSP's justification for using the proposed groundwater level minimum thresholds as a proxy for land subsidence appears to rely mainly on an incomplete analysis and a data set with significant data gaps. The GSP states there are no historical records of significant and unreasonable land subsidence in the Subbasin.[31] The GSP also states that there is a lack of direct land subsidence monitoring in the Subbasin.[32] The GSP uses this absence of historical records to assert that historically dewatered geologic units are not compressible and, therefore, not at risk for land subsidence. Although groundwater level minimum thresholds are below historic lows, the GSP states that the GSAs do not expect further declines in groundwater levels to dewater materials deeper than 205 feet below ground surface (the deepest groundwater level minimum threshold value in the Subbasin).[33] The GSP states that subsurface materials encountered up to this depth are the same [non-compressible] geologic units that have been historically dewatered.

Department staff find multiple aspects of this justification speculative and not supported by the best available science. First, the GSP presents no analysis of historic groundwater levels or historically dewatered subsurface materials to support the conclusion that the geologic units are not compressible. Second, the GSP does not provide an evaluation showing how additional declines in groundwater levels would only affect subsurface materials similar to those which have been historically dewatered. Third, the GSP is unclear on whether the conditions required to identify an undesirable result for chronic lowering of groundwater levels in the Subbasin are also required to identify an undesirable result for land subsidence. Management proposed in the GSP could allow groundwater level minimum thresholds to be exceeded in periods where two consecutive non-dry years do not occur, which does not support the claim that only materials up to the deepest groundwater level minimum threshold (205 feet below ground surface) will be dewatered.

Department staff note that the legislature intended that implementation of SGMA would avoid or minimize subsidence[34] once GSAs achieve the sustainability goal for a basin. Without analysis examining how allowable groundwater levels below those historically

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[30] ESJ GSP, p. 270.
[31] ESJ GSP, p. 269.
[32] ESJ GSP, p. 270.
[33] ESJ GSP, p. 270.
[34] Water Code § 10720.1(e).

experienced in the Subbasin may affect land subsidence, Department staff cannot determine if the GSP adequately avoids or minimizes land subsidence. While SGMA does not require prevention of all land subsidence, the GSP does not provide sufficient evidence to conclude that the proposed chronic lowering of groundwater level minimum thresholds are adequate to detect and avoid land subsidence undesirable results.

Potential Corrective Action 2

The GSAs must provide detailed information to demonstrate how the use of the chronic lowering of groundwater level minimum thresholds are sufficient as a proxy to detect and avoid significant and unreasonable land subsidence that substantially interferes with surface land uses. Alternatively, the GSAs could commit to utilizing direct monitoring for subsidence, e.g., with remotely sensed subsidence data provided by the Department. In that case, the GSAs should develop sustainable management criteria based on rates and extents of subsidence. Department staff suggest the GSAs consider and address the following issues:

1. The GSAs should revise the GSP to identify the total subsidence that critical infrastructure in the Subbasin can tolerate during GSP implementation. Support this identification with information on the effects of subsidence on land surface beneficial uses and users and the amount of subsidence that would substantially interfere with those uses and users.
2. The GSAs should revise the GSP to document a significant correlation between groundwater levels and specific amounts or rates of land subsidence. The analysis should account for potential subsidence related to groundwater level declines below historical lows and further declines that are allowed to exceed minimum thresholds (i.e., during non-consecutive non-dry years, if applicable based on the resolution to Potential Deficiency 1, above). This analysis should demonstrate that groundwater level declines allowed during GSP implementation are preventative of the rates and magnitudes of land subsidence considered significant and unreasonable based on the identified infrastructure of concern. If there is not sufficient data to establish a correlation, the GSAs should consider other options such as direct monitoring of land subsidence (e.g., remotely sensed data provided by the Department, extensometers, or GPS stations) until such time that the GSAs can establish a correlation.
3. The GSAs should explain how the groundwater level representative monitoring network is sufficient to detect significant and unreasonable subsidence that may substantially interfere with land uses, specifically any identified infrastructure of concern. If the groundwater level monitoring network alone is not adequate, based on specific infrastructure locations, Department staff suggest incorporating continued analysis of available InSAR data to cover areas with data gaps.

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APPENDIX 3-D.
TECHNICAL MEMORANDUM NO. 2 – DRINKING WATER & SHALLOW WELLS

TECHNICAL MEMORANDUM NO. 2 – Drinking Water & Shallow Wells

TO: Paul Gosselin, California Department of Water Resources Deputy Director

CC: Matt Zidar, on behalf of the Eastern San Joaquin Groundwater Authority

PREPARED BY: Leslie Dumas and Natalie Cochran/Woodard & Curran

DATE: June 24, 2022

RE: Eastern San Joaquin Groundwater Authority Response to DWR's November 18, 2021 Consultation Initiation Letter - Response to DWR Deficiency 1(d) and 1(e) and Corrective Actions

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The Eastern San Joaquin Groundwater Authority (ESJGWA or GWA) received a Consultation Initiation Letter (Letter) on November 18, 2021 (Attachment 1), from the California Department of Water Resources (DWR). The Letter identified two potential deficiencies with the Eastern San Joaquin Groundwater Subbasin (Subbasin) Groundwater Sustainability Plan (GSP) which may preclude DWR's approval, as well as potential corrective actions to address each potential deficiency. The Letter thus initiated consultation between DWR, the Plan Manager, and the Subbasin's groundwater sustainability agencies (GSAs) regarding the amount of time needed to address the potential deficiencies and corrective actions. A subsequent meeting with DWR was held on April 4, 2022 to discuss the Subbasin's proposed approach to addressing the identified deficiencies. The analysis presented in this memorandum was completed in response to the Letter, based on direction provided by the ESJGWA, the Subbasin GSAs and DWR. It is intended to supplement the Eastern San Joaquin GSP that was submitted in January 2020 and fill potential gaps identified in the Letter provided by DWR.

Deficiency 1, as described in the DWR November 18, 2021 letter, is summarized as follows:

Potential Deficiency 1: The GSP lacks sufficient justification for determining that undesirable results for chronic lowering of groundwater levels, subsidence, and depletion of interconnected surface waters can only occur in consecutive non-dry water year types. The GSP also lacks sufficient explanation for its minimum thresholds and undesirable results for chronic lowering of groundwater levels.

The letter then went on to identify six potential corrective actions that could address this deficiency. This Technical Memorandum (TM) was prepared to address the deficiency as described in Potential Correction Actions 1(d) and 1(e) which states the following:

"1(d) Removing the water-year type requirement from the definition of an undesirable result (item a, above) would result in a GSP with groundwater level minimum thresholds designed to be generally protective of 90 percent of domestic wells regardless of regional hydrologic conditions. In that scenario, the

GSAs should explain the rationale for determining that groundwater levels can exceed those thresholds at 25 percent of monitoring sites for two consecutive years before the effects would be considered significant and unreasonable. The GSAs should also explain how other factors they identified as "potential undesirable results" (e.g., adverse impacts to environmental uses and users) factored into selecting minimum thresholds and describe anticipated effects of the thresholds on beneficial uses and users of groundwater. Furthermore, the GSAs should explain whether other drinking water users that may rely on shallow wells, such as public water systems and state small water systems, were considered in the GSAs' site-specific thresholds. If not, the GSAs should conduct outreach with those users and incorporate their shallow wells, as applicable, into the site-specific minimum thresholds and measurable objectives.

1(e) The GSAs should revise the GSP to describe how they would address drinking water impacts caused by continued overdraft during the period between the start of GSP implementation and achieving the sustainability goal. If the GSP does not include projects or management actions to address those impacts, the GSP should contain a thorough discussion, with supporting facts and rationale, explaining how and why the GSAs determined not to include specific actions to address drinking water impacts from continued groundwater lowering below pre-SGMA levels."

The following subsections provide a response to each of the Potential Corrective Action subparts listed above, and include a discussion with supplemental information, analysis, justification, and data needed to support the GSP and address each issue identified.

Potential Corrective Action 1(d)-1: Explain the rationale for determining groundwater levels can exceed those thresholds at 25% of monitoring sites for two consecutive years before the effects would be considered significant and unreasonable.

Initial Review Provided by DWR

The Letter states the GSP "...identifies that the chronic lowering of groundwater levels could cause undesirable results from wells going dry, reductions in pumping capacities, increased pumping costs, the need for deeper well installations or lowering of pumps, and adverse impacts to environmental uses and users. The GSP builds an analysis of domestic wells going dry into its minimum thresholds, thereby considering the factors of wells going dry and the need for deeper well installations. However, it does not address how the management criteria address the other factors identified by the GSAs as potential undesirable results, including reductions in pumping capacity or increased pumping costs for shallow groundwater users, or adverse impacts to environmental uses and users."

As a Potential Corrective Action, the following is suggested: "Removing the water-year type requirement from the definition of an undesirable result (item a, above) would result in a GSP with groundwater level minimum thresholds designed to be generally protective of 90 percent of domestic wells regardless of regional hydrologic conditions. In that scenario, the GSAs should explain the rationale for determining that groundwater levels can exceed those thresholds at 25 percent of monitoring sites for two consecutive years before the effects would be considered significant and unreasonable."

Supplemental Information in Response to DWR Letter

Explanation of Rationale For Threshold Exceedance

Refer to "Response to DWR Deficiency 1(a) and 1(b)" technical memorandum for discussion regarding removal of the water-year type requirement from the definition of an undesirable result for the chronic lowering of groundwater levels minimum threshold. As noted in this TM, the revised definition of an undesirable result for the chronic lowering of groundwater levels is when at least 25 percent of representative monitoring wells used to monitor groundwater levels (5 of 20 representative monitoring wells in the Subbasin) fall below their minimum level thresholds for two consecutive years. Significant and unreasonable impacts that may occur when the minimum thresholds are exceeded for more than two consecutive years includes de-watering of a subset of the existing groundwater infrastructure, starting with the shallowest wells, which are generally domestic wells, and adverse effects on GDEs .

Two consecutive years of minimum threshold exceedances are used to determine if an undesirable result has occurred to establish a pattern rather than an isolated event. The lowering of groundwater levels during two consecutive dry or critically-dry years is not considered to be unreasonable unless the levels do not rebound to above the thresholds following wet conditions or are otherwise mitigated through adaptive management or implementation of projects and management actions. While statistically, three data points are required to establish a trend, three years of exceedances was felt to be too extreme, whereas a single exceedance was not sufficient to establish a trend. Therefore, the two consecutive years was selected as part of this definition.

At least 25 percent of representative monitoring wells used to monitor groundwater levels falling below their minimum thresholds for two consecutive years was presented to the Eastern San Joaquin Technical Advisory Committee (ESJ TAC) during the April 10, 2019 meeting and was approved by the Eastern San Joaquin Groundwater Authority (ESJGWA) Board during the May 8, 2019 meeting. Opportunity was available for public comment during the Public Draft GSP 45-day review period from July 10, 2019 to August 25, 2019. The Eastern San Joaquin Water Resources Model (ESJWRM) results under the projected conditions baseline scenario were used to evaluate minimum threshold exceedances, and the model results considered in determining that a 25 percent exceedance threshold was sufficient to determine that undesirable results would occur subbasin-wide (e.g., were not a localized event).

As the GSP is implemented, the definition of undesirable results for the chronic lowering of groundwater sustainability indicator, as well as all other applicable sustainability indicators, will continue to be evaluated to determine it supports the sustainability goal of the Subbasin.

Potential Corrective Action 1(d)-2: Explain how other factors they identified as "potential undesirable results" (e.g., adverse impacts to environmental uses and users) factored into

selecting minimum thresholds and describe anticipated effects of the thresholds on beneficial uses and users of groundwater

Initial Review Provided by DWR

The Letter states the GSP "…builds an analysis of domestic wells going dry into its minimum thresholds, thereby considering the factors of wells going dry and the need for deeper well installations. However, it does not address how the management criteria address the other factors identified by the GSAs as potential undesirable results, including reductions in pumping capacity or increased pumping costs for shallow groundwater users, or adverse impacts to environmental uses and users."

As a Potential Corrective Action, the following is suggested: "The GSAs should also explain how other factors they identified as "potential undesirable results" (e.g., adverse impacts to environmental uses and users) factored into selecting minimum thresholds and describe anticipated effects of the thresholds on beneficial uses and users of groundwater."

Supplemental Information in Response to DWR Letter

Explanation of Other Factors in Potential Undesirable Results

During GSP development (and as stated under Section 3.2.1.1.1 of the GSP), potential undesirable results identified by stakeholders included a significant and unreasonable:

- Number of wells going dry
- Reduction in the pumping capacity of existing wells
- Increase in pumping costs due to greater lift
- Need for deeper well installations or lowering of pumps
- Adverse impacts to environmental uses and users, including interconnected surface waters and groundwater-dependent ecosystems (GDEs)

As stated under Section 3.2.1.2 of the GSP, the minimum thresholds for chronic lowering of groundwater levels are the shallower at each representative monitoring well site of the following:

- The deeper of 1992 and 2015-2016 historical groundwater levels with a buffer of 100 percent of historical range applied, or

- The 10th percentile domestic well total depth of wells within a 3-mile radius of the monitoring well.[1,2]

To develop these thresholds, members of the ESJGWA Board, TAC, and Workgroup evaluated the potential for undesirable results based on past, present, and future conditions. In addition to anecdotal on-the-ground data, data from DWR and Subbasin GSAs, as well as information from reports and planning documents, were used to identify how a given area falls into any one of three general conditions: 1) Areas with significant and unreasonable existing issues, 2) Areas that previously had issues, and 3) Areas that have never had issues. Each of the three conditions correspond to a different pathway to setting minimum thresholds. Classification of the various areas were based on input from GSAs and stakeholders and review of prior planning documents.

- Areas with significant and unreasonable existing issues: these areas are considered to have undesirable results, and minimum thresholds are set to 2015 in accordance with Sustainable Groundwater Management Act (SGMA) legislation. No areas were identified by the ESJGWA Board or other stakeholders under this condition within the Subbasin.
- Areas that previously had significant and unreasonable issues: for areas with historical but not current significant and unreasonable results (as identified by GSAs, stakeholders, and prior planning documents), historical levels were considered in the development of minimum thresholds in addition to existing basin management criteria.
- Areas that have never had significant and unreasonable issues: in areas that have never had recognized issues (e.g., cones of depression), discussions on what the ESJGWA would consider to be significant and unreasonable drove identification of potential thresholds, and minimum thresholds were developed based on the preservation of future beneficial uses.

The ESJGWA Board and Advisory Committee reviewed previously adopted groundwater-related planning documents including the 2014 ESJ Integrated Regional Water Management Plan (IRWMP), the 2004 Groundwater Management Plan (GMP), Agricultural Water Management Plans (AWMPs), and the Mokelumne Watershed Interregional Sustainability Evaluation (MokeWISE) Water Program. These

[1] A radius of 2 miles was used for well 0307E21L003 to reflect domestic well depths in close proximity to the Mokelumne River.
[2] In municipalities with ordinances requiring the use of City water (water provided by the City's municipal wells), the 10th percentile municipal well depth is used in place of the 10th percentile domestic well depth criteria.

documents provided a starting point for setting minimum thresholds. The ESJ IRWMP indicates fall 1992 groundwater elevation levels as a historically low benchmark for the Subbasin, stating "The Eastern San Joaquin Groundwater Basin contour measured in 1992 is proposed as the basin management framework baseline. Groundwater fell to its lowest recorded elevation in 1992 following a significant drought period and it is considered undesirable to drop below this level" (Eastern San Joaquin County GBA, 2014). This language, although developed within the SGMA framework, has severed as a starting point for developing minimum thresholds under SGMA.

Fall 1992 groundwater levels were examined and compared to levels following the recent drought (fall 2015-2016) using groundwater elevation data from officially monitored California Statewide Groundwater Elevation Monitoring (CASGEM) wells, voluntarily monitored CASGEM wells, clustered and nested wells, and San Joaquin County database wells (described in further detail in Section 2.1.1.1 of the GSP). This examination showed that groundwater levels in some areas of the Subbasin have recovered since 1992, with much of the central portion of the Subbasin showing an increase of greater than 10 feet. However, groundwater levels in other portions of the Subbasin have further decreased below 1992 levels without undesirable effects being observed by the GSAs and other stakeholders. In many cases, areas that experienced undesirable effects in 1992 put mitigation measures in place, often deepening wells, meaning that 1992 groundwater levels would no longer trigger undesirable effects.

The deepest conditions between fourth quarter 1992 and 2015-2016 groundwater levels were examined to develop a greater understanding of potential impacts to beneficial uses experienced under historical low groundwater levels. These years were chosen based on the threshold language in the ESJ IRWMP and also to capture the end of the two most recent droughts. Fourth quarter 2014 data were used in the northwest corner of the Subbasin, where data are limited.

Individual GSAs confirmed understanding of the historical lows based on their experience and data, provided feedback on groundwater conditions for their GSAs, and indicated if undesirable results could occur if the minimum threshold was set deeper than the deeper of 1992 and 2015-2016 based on their understanding. GSAs then identified potential wells to be included in the representative monitoring network for the groundwater level sustainability indicator based on the adequate spatial coverage, availability of historical data, and reliability of the monitoring well. For the majority of the Subbasin, GSA representatives identified no undesirable results, even if groundwater were to reach historical low groundwater levels. As a starting point, a potential minimum threshold was considered for each representative monitoring well based on the lower of 1992 or 2015-2016 values unless otherwise indicated. A buffer was subtracted from the minimum 1992 or 2015 groundwater elevation. The buffer was calculated by finding the difference between the minimum and maximum groundwater level over the historical record for each representative monitoring well. The subtraction of the buffer provides a range in which groundwater levels may continue to decline during implementation of projects and management actions until sustainable yield is reached. The buffer allows for flexibility to account for natural fluctuations in groundwater levels but would avoid significant and unreasonable impacts to groundwater levels.

Information used to support development of well-specific minimum thresholds is included in Appendix 3-A and 3-B of the GSP.

Potential Corrective Action 1(d)-3: Explain whether other drinking water users that rely on shallow wells were considered or conduct outreach to shallow well users and incorporate their wells into consideration of site-specific MTs and MOs

Initial Review Provided by DWR

The Letter states "The GSAs set minimum thresholds in the Subbasin at the shallower of the 10th percentile domestic [or municipal] well depth or the historical low groundwater levels with a subtracted buffer value, which the GSP states allows for operational flexibility. These minimum threshold values generally allow groundwater levels to decline below historic lows; minimum thresholds defined using the buffer value approach allow twice the historical drawdown from the shallowest recorded groundwater levels. Aside from the GSP's domestic well analysis, the only description of how minimum thresholds were evaluated to avoid undesirable results appears to be the statements that "for the majority of the Subbasin, GSA representatives identified no undesirable results, even if groundwater were to reach historical low groundwater levels" and that no GSA indicated undesirable results would occur "if the minimum threshold was set deeper than the [historic low] based on their understanding." The GSP provides no further explanation or description of how the individual GSAs concluded that there would be no undesirable results based on the minimum thresholds.

As a Potential Corrective Action, the following is suggested: "The GSAs should explain whether other drinking water users that may rely on shallow wells, such as public water systems and state small water systems, were considered in the GSAs' site-specific thresholds. If not, the GSAs should conduct outreach with those users and incorporate their shallow wells, as applicable, into the site-specific minimum thresholds and measurable objectives."

Supplemental Information in Response to DWR Letter

Explanation of Drinking Water User Consideration

The ESJGWA Board determined that dewatering of domestic wells may be a potential undesirable result that could potentially be used to confirm the adequacy of the minimum threshold methodology. Domestic wells are generally shallower than agricultural and municipal wells and thus more sensitive to undesirable effects such as wells going dry. Additionally, the loss of a domestic well usually results in a loss of water for consumption, cooking, and sanitary purposes, which can often have substantial impacts on the users of the water and can be financially difficult for the well owner to replace. The 10^{th} percentile domestic well depth (i.e., the depth of the top 10^{th} percent most shallow well) was examined within a radius around the monitoring well representative of local conditions. A radius of three miles around each representative monitoring well was used to identify the 10^{th} percentile domestic well construction depth. For representative monitoring well 03N07E21L003, a 2-mile radius was used due to variations in groundwater levels due to its proximity to the Mokelumne River. The 3-mile radius of each representative monitoring well (including the 2-mile radius of monitoring well 03N07E21L003), includes an average of 400 domestic wells each, collectively capturing approximately 76 percent of the domestic wells in the Subbasin. In cases where the 10th percentile domestic well depth was shallower than the historical drought low with the buffer, that value was developed as the minimum threshold to prevent undesirable results associated with dewatering wells in the Subbasin.

Domestic well data were retrieved from the Online System for Well Completion Reports (OSWCR) database, which is sparsely populated with information on total casing depth, screening intervals, and the age of the well. The 10th percentile well depth was chosen due to the uncertainty in the database and to account for the fact that domestic wells may have been drilled to a very shallow depth prior to the current well drilling standards enforced by local jurisdictions and/or have reached the end of their lifecycle. The 10th percentile domestic well depth for groundwater levels is protective of approximately 90 percent of the domestic wells in the OSWCR dataset and is used as a criterion for determining if a decline in groundwater levels is significant and unreasonable under SGMA. In municipalities with ordinances requiring the use of City water (water provided by the City's municipal wells), the 10th percentile municipal well depth is used in place of the 10th percentile domestic well depth criteria. Furthermore, removal of the dry water year designation from the definition of identification of undesirable results ensures that groundwater levels will not decline below the established minimum thresholds (See Technical Memorandum No. 1 – *Undesirable Result Definition and Projects and Management Actions*).

Potential Corrective Action 1(e)-1: Describe how they [the GSAs] would address drinking water impacts caused by continued overdraft during the period between the start of GSP implementation and achieving the sustainability goal. If the GSP does not include projects or management actions to address those impacts, the GSP should contain a thorough discussion, with supporting facts and rationale, explaining how and why the GSAs determined not to include specific actions to address drinking water impacts from continued groundwater lowering below pre-SGMA levels.

Initial Review Provided by DWR

The Letter states "The GSAs should describe how projects and management actions would address drinking water impacts due to continued overdraft between the start of GSP implementation and the achievement of the sustainability goal. If the GSP does not include projects or management actions to address drinking water impacts, the GSP should contain a thorough discussion, with supporting facts and rationale, explaining how and why GSAs determined not to include actions to address those impacts from continued groundwater lowering below pre-SGMA levels."

As a Potential Corrective Action, the following is suggested: "The GSAs should revise the GSP to describe how they would address drinking water impacts caused by continued overdraft during the period between the start of GSP implementation and achieving the sustainability goal. If the GSP does not include projects or management actions to address those impacts, the GSP should contain a thorough discussion, with supporting facts and rationale, explaining how and why the GSAs determined not to include specific actions to address drinking water impacts from continued groundwater lowering below pre-SGMA levels."

Supplemental Information in Response to DWR Letter

Addressing Drinking Water Impacts

Refer to "Response to DWR Deficiency 1(a) and 1(b)" technical memorandum for discussion regarding removal of the water-year type requirement from the definition of an undesirable result for the chronic lowering of groundwater levels minimum threshold. As noted in this TM, the revised definition of an undesirable result for the chronic lowering of groundwater levels is when at least 25 percent of representative monitoring wells used to monitor groundwater levels (5 of 20 representative monitoring wells in the Subbasin) fall below their minimum level thresholds for two consecutive years.

The Eastern San Joaquin GSP contains 23 projects, where additional projects that support SGMA objectives have been identified since GSP adoption and submittal. Refer to "Response to DWR Deficiency 1(a) and 1(b)" technical memorandum for the latest project information and how the projects will mitigate overdraft conditions. The majority of projects in the GSP include groundwater recharge utilizing existing and pending surface water rights, which will elevate groundwater levels within the project benefitting areas throughout the Subbasin.

The basis for design and selection of the sustainable management criteria (SMCs) is the lowest drought-related groundwater conditions observed. The GWA and GSAs focused the GSP goals on the long-term sustainability of the Subbasin and implementation of projects that would help all beneficial users to have a reliable and resilient water supply, even in time of drought, and provide the ability to respond to climate change. The GWA and GSAs are supportive of ongoing agricultural, urban, and industrial water conservation efforts and to achieving the highest levels of water use efficiency technically achievable. It should be noted that water conservation programs have been successful in reducing urban and agricultural water demands such that those demands have become "hardened" and are less able to be reduced in time of drought without real impacts to the quality of life or economy. GSP projects and management actions are to reduce overdraft, and are designed to provide sustainable supplies through a drought without severe impacts to quality of life or the economy.

The GSP was not targeted toward emergency responses to drought or the short-term impacts associated with drought since this is the focus of the County Office of Emergency Services (OES) and a requirement for the water purveyors. In addition, the prevailing urban water management plans (UWMPs) and agricultural water management plans (AWMPs) identify water conservation goals and demand reduction targets, including water shortage contingency plans, and the GWA and GSAs are supportive of those plans (and the drought contingency responses) and will encourage the lead agencies for those plans to implement actions and programs consistent with local and state requirements. The GWA will work to better coordinate with the OES and urban purveyors to support emergency drought response efforts. The GWA and GSP development has included representatives from the urban suppliers and will continue to seek opportunities to engage with OES, the urban purveyors and to work to identify mutual goals, objectives and project opportunities.

With the removal of the water-year type requirement from the definition of an undesirable result for the chronic lowering of groundwater levels minimum threshold, established minimum thresholds will not allow for continued lowering of groundwater levels that will likely most severely impact shallow domestic well users. As noted in the prior explanation, the depth of shallow domestic wells and production wells was considered in establishing the numerical minimum thresholds at the representative monitoring sites, thereby considering the depths of and potential impacts to drinking water users relying on groundwater. If drinking water impacts are observed during GSP implementation as a result of the established minimum thresholds, the ESJGWA will evaluate the need to revise the minimum threshold methodology and/or implement additional projects or management actions to mitigate such impacts (as described in the "Response to DWR Deficiency 1(a) and 1(b)" technical memorandum). The GWA and GSAs will evaluate other programs as part of the adaptive management strategy, and annual program evaluation and reporting. Neither SGMA nor the California Water Code include requirements to mitigate for small and domestic systems or to include drought contingency plans in a GSP as this is the responsibility of other agencies or members of a GSA/GWA. If there is a statutory requirement included in the SGMA legislation at a future date, the GWA and GSAs will evaluate their programs and consider a well mitigation program. In the meantime, the following management actions will be included:

1. Outreach to domestic well owners and small water systems. This will include information related to forecasted water levels with and without projects to inform subsequent investments decisions for well improvement and replacement.

2. Production and distribution of current and forecasted groundwater level information to be provided to well permit applicants to inform the permitting process.

3. Review of well standards to evaluate opportunities to establish standards to better reflect current and forecasted groundwater level conditions.

4. The GWA and GSAs will actively promote small systems interties and/or consolidation of their systems to achieve supply reliability.

The future five-year update to the GSP will more closely evaluate and include information on UWMP water shortage contingency plans, and the GWA will coordinate with the County OES to support emergency drought responses and plans.

The GSAs recognize that domestic wells may be impacted by declining groundwater levels, as well as other factors, including but not limited to, end of useful life. The GSAs intentionally set the minimum thresholds in the GSP to avoid domestic well failures due to declining groundwater levels. However, the GSAs recognize the need for a back-up process to mitigate the impact of GSP management on domestic well failures, if necessary. As part of the five-year update to the GSP, the GSAs, through the GWA, will identify additional management actions that can be implemented to address this situation, including considering development of a domestic well mitigation policy and program ("DWMP").

REFERENCES

San Joaquin County Groundwater Basin Authority (Eastern San Joaquin County GBA). (2014). *Eastern San Joaquin Integrated Regional Water Management Plan Update*.

ATTACHMENT 1 – DWR Consultation Initiation Letter

CALIFORNIA DEPARTMENT OF WATER RESOURCES

SUSTAINABLE GROUNDWATER MANAGEMENT OFFICE

901 P Street, Room 313-B | Sacramento, CA 95814 | P.O. Box 942836 | Sacramento, CA 94236-0001

November 18, 2021

Kris Balaji, PMP, P.E.
Eastern San Joaquin Subbasin Plan Administrator
1810 E. Hazelton Avenue, Stockton, CA 95201
kbalaji@sjgov.org

RE: Eastern San Joaquin Subbasin - 2020 Groundwater Sustainability Plan

Dear Kris Balaji,

The Eastern San Joaquin Groundwater Authority submitted the Eastern San Joaquin Groundwater Subbasin (Subbasin) Groundwater Sustainability Plan (GSP) to the Department of Water Resources (Department) for evaluation and assessment as required by the Sustainable Groundwater Management Act (SGMA).[1]

Department staff have substantially completed an initial review of the GSP and have identified potential deficiencies (see the enclosed document) which may preclude the Department's approval.[2] Department staff have also developed potential corrective actions[3] for each potential deficiency. The potential deficiencies do not necessarily represent all deficiencies or discrepancies that the Department may identify in the GSP but focus on those deficiencies that staff believe, if not addressed, could lead to a determination that the GSP is incomplete or inadequate.[4] This letter initiates consultation between the Department, the Plan Manager, and the Subbasin's 15 groundwater sustainability agencies (GSAs) regarding the amount of time needed to address the potential deficiencies and corrective actions. The Department will issue a final determination as described under the GSP Regulations[5] no later than January 29, 2022.

If the Department determines the GSP to be incomplete, the deficiencies precluding approval would need to be addressed within a period not to exceed 180 days from the

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[1] Water Code § 10720 et seq.
[2] 23 CCR § 355.2(e)(2).
[3] 23 CCR § 355.2(e)(2)(B).
[4] The Department recognizes that litigation regarding the GSP has been filed. The filing of litigation does not alter or affect the Department's mandate to issue its final assessment of the Agency's groundwater sustainability plan (GSP or Plan) for the basin within two years of its submission. (Water Code §10733.4(d).) Furthermore, the Department's assessment will consist of a technical review of the submitted Plan, as required by SGMA and the GSP Regulations, and the filing of the litigation did not in any way influence or affect the Department's evaluation of the Plan. The Department expresses no opinion on the claims of the parties in the pending litigation involving the GSP.
[5] 23 CCR Division 2, Chapter 1.5, Subchapter 2.

determination. A determination of incomplete would allow the GSAs to formally address identified deficiencies and submit a revised GSP to the Department for further review and evaluation. Department staff will contact you before making the final determination to discuss the potential deficiencies and the amount of time needed by the GSAs to address the potential corrective actions detailed in the enclosed document.

Materials submitted to the Department to address deficiencies must be part of the GSP. The GSAs must justify that any materials submitted are part of the revised GSP; this justification is also part of the submittal. To facilitate the Department's review of the revised GSP, the GSAs should also provide a companion document with tracked changes of modifications made to address deficiencies. The GSAs must submit the revised GSP through the DWR SGMA Portal where, as is currently available, interested parties may provide comments on submitted materials to the Department.

Department staff will work expeditiously to review materials submitted to address deficiencies and to evaluate compliance of the revised GSP. The Department will keep a GSP status designated as incomplete during its review of the submitted materials. The Department could subsequently approve an incomplete GSP if the GSAs have taken corrective actions to address deficiencies identified by the Department within a period not to exceed 180 days from the determination. The Department could also issue a determination of inadequate for an incomplete GSP if the Department, after consultation with the State Water Resources Control Board, determines the GSAs have not taken sufficient actions to correct the deficiencies identified by the Department.

If you have any questions, please do not hesitate to contact the Sustainable Groundwater Management Office staff by emailing sgmps@water.ca.gov.

Thank you,

Paul Gosselin
Deputy Director for Sustainable Groundwater Management

Enclosure:

1. Potential Deficiencies and Corrective Actions

Potential Deficiencies and Corrective Actions

Department of Water Resources (Department) staff have identified deficiencies regarding the Eastern San Joaquin Subbasin (Subbasin) Groundwater Sustainability Plan (GSP) that may preclude the Department's approval. Therefore, consistent with the GSP Regulations, Department staff are considering corrective actions the Subbasin's groundwater sustainability agencies (GSAs) should review to determine whether and how the deficiencies can be addressed. The deficiencies and potential corrective actions are explained below, including the general regulatory background, the specific deficiencies identified in the GSP, and specific actions to address the deficiencies. The specific actions identified are potential corrective actions until the Department makes a final determination.

General Background

Potential deficiencies identified in the Eastern San Joaquin Subbasin GSP relate to the development and documentation of sustainable management criteria, including undesirable results and minimum thresholds that define when undesirable results may occur.

The Department's GSP Regulations describe several required elements of a GSP under the heading of "Sustainable Management Criteria"[6], including undesirable results, minimum thresholds, and measurable objectives. These components of sustainable management criteria must be quantified so that GSAs, the Department, and other interested parties can monitor progress towards sustainability in a basin consistently and objectively.

A GSA relies on local experience, public outreach and involvement, and information about the basin it has described in the GSP basin setting (i.e., the hydrogeologic conceptual model, the description of current and historical groundwater conditions, and the water budget), among other factors, to develop criteria for defining undesirable results and setting minimum thresholds and measurable objectives.[7]

The Sustainable Groundwater Management Act (SGMA) defines sustainable groundwater management as the management and use of groundwater in a manner that can be maintained during the planning and implementation horizon without causing undesirable results.[8] Avoidance of undesirable results is thus explicitly part of sustainable groundwater management as established by SGMA and critical to the success of a GSP.

The definition of undesirable results is critical to establishing an objective method to define and measure sustainability for a basin. As an initial matter, SGMA provides a

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[6] 23 CCR § Article 5, Subarticle 3.
[7] 23 CCR §§ 354.8, 354.10, 354.12 *et seq*.
[8] Water Code § 10721(v).

qualitative definition of undesirable results as "one or more" of six specific "effects caused by groundwater conditions occurring throughout the basin."[9]

GSAs define, in their GSPs, the specific significant and unreasonable effects that would constitute undesirable results and the groundwater conditions that would produce those results in their basins.[10] The GSAs' definition must include a description of the processes and criteria relied upon to define undesirable results and describe the effect of undesirable results on the beneficial uses and users of groundwater, surface land uses (for subsidence), and surface water (for interconnected surface water).[11]

SGMA leaves the task of establishing undesirable results and setting thresholds largely to the discretion of the GSAs, subject to review by the Department. In its review, the Department requires a thorough and reasonable analysis of the groundwater conditions and the associated effects the GSAs must manage the groundwater basin to avoid, and the GSAs' stated rationale for setting objective and quantitative sustainable management criteria to prevent those undesirable conditions from occurring.[12] If a GSP does not meet this requirement, the Department cannot evaluate the GSAs' likelihood of achieving their sustainability goal. That does not necessarily mean that the GSP or its objectives are inherently unreasonable; rather, the Department cannot evaluate whether the GSP's implementation would successfully achieve sustainable management if it is unclear what undesirable conditions the GSAs seek to avoid.

Potential Deficiency 1. The GSP lacks sufficient justification for identifying that undesirable results for chronic lowering of groundwater levels, subsidence, and depletion of interconnected surface waters can only occur in consecutive non-dry water year types. The GSP also lacks sufficient explanation for its chronic lowering of groundwater levels minimum thresholds and undesirable results.

1 The first potential deficiency relates to the GSP's requirement of two consecutive non-dry (i.e., below normal, above normal, or wet) water-year types and the exclusion of dry and critically dry water-year types in the identification of undesirable results for chronic lowering of groundwater levels, and, by proxy, land subsidence and depletions of interconnected surface water.

Background

Related to this potential deficiency, SGMA defines the term "Undesirable Result," in part, as one or more of the following effects caused by groundwater conditions occurring throughout the basin:[13]

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[9] Water Code § 10721(x).
[10] California Department of Water Resources, Best Management Practices for the Sustainable Management of Groundwater: Sustainable Management Criteria (Draft), November 2017.
[11] 23 CCR §§ 354.26(b), 354.28(c)(5), 354.28(c)(6).
[12] 23 CCR § 355.4(b)(1).
[13] Water Code § 10721(x).

- Chronic lowering of groundwater levels indicating a significant and unreasonable depletion of supply if continued over the planning and implementation horizon. Overdraft during a period of drought is not sufficient to establish a chronic lowering of groundwater levels if extractions and groundwater recharge are managed as necessary to ensure that reductions in groundwater levels or storage during a period of drought are offset by increases in groundwater levels or storage during other periods.
- Significant and unreasonable land subsidence that substantially interferes with surface land uses.
- Depletions of interconnected surface water that have significant and unreasonable adverse impacts on beneficial uses of the surface water.

Potential Deficiency Details

Department staff identified two areas of concern, described below, which, if not addressed, may preclude approval of the GSP. Regarding the first area of concern, the GSP identifies that an undesirable result occurs "when at least 25 percent of representative monitoring wells used to monitor groundwater levels (5 of 20 wells in the Subbasin) fall below their minimum level thresholds for two consecutive years that are categorized as non-dry years (below-normal, above-normal, or wet), according to the San Joaquin Valley Water Year Hydrologic Classification." The GSP further states that "the lowering of groundwater levels during consecutive dry or critically-dry years is not considered to be unreasonable, and would therefore not be considered an undesirable result, unless the levels do not rebound to above the thresholds following those consecutive non-dry years."[14]

1.1 Department staff find that the water-year type requirement in the definition of the undesirable result for chronic lowering of groundwater levels (i.e., two consecutive non-dry years) is not consistent with the intent of SGMA. The water-year type requirement could potentially allow for unmanaged and continued lowering of groundwater levels under certain hydrologic or climatic conditions that have occurred historically. A review of historical San Joaquin Valley water-year type classifications[15] indicates the potential for dry periods without the occurrence of a second consecutive non-dry year to persist for greater than ten years (see, e.g., the 11 years from water years 1985 through 1995). Department staff also note that concurrent below normal, above normal, or wet years occurred in only five of the last twenty water years from 2001 through 2020. Because of this definition, GSAs in the Subbasin could disregard potential impacts of groundwater level declines below the minimum thresholds during extended periods of dry years, even if interrupted by normal or wet years.

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[14] ESJ GSP, p. 253.
[15] Chronological Reconstructed Sacramento and San Joaquin Valley Water Year Hydrologic Classification Indices, Water Year 1901 through 2020. California Department of Water Resources, https://cdec.water.ca.gov/reportapp/javareports?name=WSIHIST.

Department staff also find this methodology inconsistent with other portions of the GSP. For example, while describing measurable objectives for groundwater levels, the GSP states, "the margin of operational flexibility is intended to accommodate droughts, climate change, conjunctive use operations, or other groundwater management activities. The margin of operational flexibility is defined as the difference between the minimum threshold and the measurable objective."[16] Based on these statements, it appears the
1.2 minimum thresholds already accommodate drought conditions, so it is unclear why the GSP's definition of undesirable results further excludes minimum threshold exceedances during dry water years. (See Potential Corrective Action 1a.)

SGMA states that "overdraft during a period of drought is not sufficient to establish a chronic lowering of groundwater levels if extractions and groundwater recharge are
1.3 managed as necessary to ensure that reductions in groundwater levels or storage during a period of drought are offset by increases in groundwater levels or storage during other periods."[17] If the GSAs intended to incorporate this concept into their definition of the undesirable result for chronic lowering of groundwater levels, the GSP fails to identify specific extraction and groundwater recharge management actions the GSAs would implement[18] or otherwise describe how the Subbasin would be managed to offset, by increases in groundwater levels or storage during other periods, dry year reductions of groundwater storage. The GSP identifies many projects that, once implemented, may lead to the elimination of long-term overdraft conditions in the Subbasin. However, the GSP does not sufficiently detail how projects and management actions, in conjunction with the proposed chronic lowering of groundwater levels sustainable management criteria, will offset drought-related groundwater reductions and avoid significant and unreasonable impacts when groundwater level minimum thresholds are potentially exceeded for an extended period in the absence of two consecutive non-dry years. (See Potential Corrective Action 1b.)

As noted above, the GSP states that minimum thresholds developed for chronic lowering of groundwater levels serve as proxies for subsidence[19] and depletion of interconnected surface waters.[20] Therefore, Department staff assume the GSAs intend to apply the same water-year type criteria to undesirable results for those sustainability indicators (i.e., land subsidence or depletion of interconnected surface water undesirable results do not occur until groundwater levels exceed the thresholds for two consecutive non-dry water years). However, where SGMA acknowledges that groundwater level declines during drought
1.4 periods are not sufficient to cause an undesirable result for chronic lowering of groundwater levels, the statute does not similarly provide an exception for subsidence or stream depletion during periods of drought. (See Potential Corrective Action 1c.)

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[16] ESJ GSP, p. 259.
[17] Water Code § 10721(x)(1).
[18] 23 CCR § 354.44(b)(9).
[19] ESJ GSP, p. 270.
[20] ESJ GSP, p. 271.

2 Department staff's second area of concern is the GSP's evaluation of the effects of the proposed minimum thresholds and undesirable results on beneficial uses and users of groundwater. The GSP identifies that the chronic lowering of groundwater levels could cause undesirable results from wells going dry, reductions in pumping capacities, increased pumping costs, the need for deeper well installations or lowering of pumps, and adverse impacts to environmental uses and users.[21] The GSP builds an analysis of domestic wells going dry into its minimum thresholds, thereby considering the factors of
2.1 wells going dry and the need for deeper well installations. However, it does not address how the management criteria address the other factors identified by the GSAs as potential undesirable results, including reductions in pumping capacity or increased pumping costs for shallow groundwater users, or adverse impacts to environmental uses and users.

The GSAs set minimum thresholds in the Subbasin at the shallower of the 10th percentile domestic [or municipal] well depth or the historical low groundwater levels with a subtracted buffer value, which the GSP states allows for operational flexibility.[22] These minimum threshold values generally allow groundwater levels to decline below historic lows; minimum thresholds defined using the buffer value approach allow twice the historical drawdown from the shallowest recorded groundwater levels.[23] Aside from the
2.2 GSP's domestic well analysis, the only description of how minimum thresholds were evaluated to avoid undesirable results appears to be the statements that “for the majority of the Subbasin, GSA representatives identified no undesirable results, even if groundwater were to reach historical low groundwater levels” and that no GSA indicated undesirable results would occur “if the minimum threshold was set deeper than the [historic low] based on their understanding.”[24] The GSP provides no further explanation or description of how the individual GSAs concluded that there would be no undesirable results based on the minimum thresholds.

The GSP only considers an undesirable result to occur for groundwater levels in the Subbasin when at least 25 percent of representative monitoring wells (5 of 20 wells) fall below their minimum threshold value for two consecutive non-dry water years.[25] The GSP
2.3 does not justify or discuss how the GSAs developed the 25 percent threshold, nor does it explain or disclose the potential impacts anticipated during extended drier climate conditions using this threshold. In other words, the proposed management program may lead to potential effects on domestic wells or other beneficial uses and users during prolonged dry- or below-normal periods, and that information should, at a minimum, be disclosed and considered in the GSP. (See Potential Corrective Action 1d.)

If, after considering this potential deficiency, the GSAs retain minimum thresholds that allow for continued lowering of groundwater levels, it is reasonable to assume that some

[21] ESJ GSP, p. 253.
[22] ESJ GSP, p. 254.
[23] ESJ GSP, p. 258.
[24] ESJ GSP, p. 255.
[25] ESJ GSP, p. 253.

groundwater well impacts (e.g., loss of production capacity) will occur during the implementation of the GSP. SGMA requires GSAs to consider the interests of all groundwater uses and users and to implement their GSPs to mitigate overdraft conditions.[26] Implementing specific projects and management actions prevents undesirable results and achieves the sustainable yield of the basin. The GSAs should
2.4 describe how projects and management actions would address drinking water impacts due to continued overdraft between the start of GSP implementation and the achievement of the sustainability goal. If the GSP does not include projects or management actions to address drinking water impacts, the GSP should contain a thorough discussion, with supporting facts and rationale, explaining how and why GSAs determined not to include actions to address those impacts from continued groundwater lowering below pre-SGMA levels. (See Potential Corrective Action 1e.)

Additionally, related to the groundwater level declines allowed for by the GSA's minimum
2.5 thresholds, the GSAs have not explained how those groundwater level declines relate to the degradation of groundwater quality sustainability indicator. GSAs must describe, among other items, the relationship between minimum thresholds for a given sustainability indicator (in this case, chronic lowering of groundwater levels) and the other sustainability indicators.[27] The GSAs generally commit to monitoring a wide range of water quality constituents but they have only developed sustainable management criteria for total dissolved solids because they state they have not observed a causal nexus between groundwater management and degradation associated with the other constituents. While Department staff are not aware of evidence sufficient to conclude that the GSAs acted unreasonably by focusing on total dissolved solids, it is clear that the GSAs did not consider, or at least did not document, the potential for degradation to occur due to further lowering of groundwater levels beyond the historic lows. (See Potential Corrective Action 1f.)

Potential Corrective Action 1

a) Department staff believe the management approach described in the GSP, which couples minimum thresholds and measurable objectives that account for operational flexibility during dry periods with a definition of undesirable results that disregards minimum threshold exceedances in all years except consecutive below normal, above normal, or wet years, to be inconsistent with the objectives of SGMA. Therefore, the GSAs should remove the water-year type requirement from the GSP's undesirable result definition.
b) The GSP should be revised to include specific projects and management actions the GSAs would implement to offset drought-year groundwater level declines.
c) The GSAs should thoroughly explain how their approach avoids undesirable results for subsidence and depletion of interconnected surface waters, as SGMA does not

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[26] 23 CCR § 355.4(b)(4), 355.4(b)(6).
[27] 23 CCR § 354.28(b)(2).

include an allowance or exemption for those conditions to continue in periods of drought.

d) Removing the water-year type requirement from the definition of an undesirable result (item a, above) would result in a GSP with groundwater level minimum thresholds designed to be generally protective of 90 percent of domestic wells regardless of regional hydrologic conditions. In that scenario, the GSAs should explain the rationale for determining that groundwater levels can exceed those thresholds at 25 percent of monitoring sites for two consecutive years before the effects would be considered significant and unreasonable. The GSAs should also explain how other factors they identified as "potential undesirable results" (e.g., adverse impacts to environmental uses and users) factored into selecting minimum thresholds and describe anticipated effects of the thresholds on beneficial uses and users of groundwater. Furthermore, the GSAs should explain whether other drinking water users that may rely on shallow wells, such as public water systems and state small water systems, were considered in the GSAs' site-specific thresholds. If not, the GSAs should conduct outreach with those users and incorporate their shallow wells, as applicable, into the site-specific minimum thresholds and measurable objectives.

e) The GSAs should revise the GSP to describe how they would address drinking water impacts caused by continued overdraft during the period between the start of GSP implementation and achieving the sustainability goal. If the GSP does not include projects or management actions to address those impacts, the GSP should contain a thorough discussion, with supporting facts and rationale, explaining how and why the GSAs determined not to include specific actions to address drinking water impacts from continued groundwater lowering below pre-SGMA levels.

f) The GSP should be revised to explain how the GSAs will assess groundwater quality degradation in areas where further groundwater level decline, below historic lows, is allowed via the minimum thresholds. The GSAs should further describe how they will coordinate with the appropriate groundwater users, including drinking water, environmental, and irrigation users as identified in the GSP. The GSAs should also discuss efforts to coordinate with water quality regulatory agencies and programs in the Subbasin to understand and develop a process for determining if continued lowering of groundwater levels is resulting in degraded water quality in the Subbasin during GSP implementation.

Potential Deficiency 2. The GSP does not provide enough information to support the use of the chronic lowering of groundwater level sustainable management criteria and representative monitoring network as a proxy for land subsidence.

Background

The GSP Regulations state that minimum thresholds for land subsidence should identify the rate and extent of subsidence that substantially interferes with surface land uses and may lead to undesirable results. These quantitative values should be supported by: [28]

- The identification of land uses or property interests potentially affected by land subsidence;
- An explanation of how impacts to those land uses or property interests were considered when establishing minimum thresholds;
- Maps or graphs showing the rates and extents of land subsidence defined by the minimum thresholds.

The GSP Regulations allow the use of groundwater elevations as a proxy for land subsidence. However, GSAs must demonstrate a significant correlation between groundwater levels and land subsidence and must demonstrate that groundwater level minimum thresholds represent a reasonable proxy for avoiding land subsidence undesirable results. Additionally, the GSAs must demonstrate how the monitoring network is adequate to identify undesirable results for both metrics.

Potential Deficiency Details

3.1 Department staff find that the GSP does not adequately identify or define minimum thresholds and undesirable results for land subsidence. The GSP also does not provide adequate justification and explanation for using the groundwater level minimum thresholds and representative monitoring network as a proxy for land subsidence.

3.2 Generally, the GSP identifies that irrecoverable loss of groundwater storage and damage to infrastructure, including water conveyance facilities and flood control facilities, are potential impacts of land subsidence.[29] However, the GSP does not identify specific infrastructure locations, particularly those associated with public safety, in the Subbasin and the rate and extent of subsidence that would substantially interfere with those land surface uses and may lead to undesirable results. Additionally, without identifying infrastructure considered at risk for interference from land subsidence, Department staff cannot evaluate whether the groundwater level representative monitoring network is adequate to detect potential subsidence-related impacts.

3.3 Department staff find the GSP does not provide adequate evidence to demonstrate a significant correlation between groundwater levels and land subsidence in the Subbasin.

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[28] 23 CCR § 354.28(c)(5).
[29] ESJ GSP, p. 269.

Without explaining this correlation, the Department cannot evaluate whether the groundwater level minimum thresholds and associated conditions required for identifying an undesirable result would protect against significant and unreasonable impacts related to land subsidence. The GSP states a significant correlation exists between groundwater levels and land subsidence, with lowering groundwater levels driving further land
3.4 subsidence.[30] Department staff agree with this general statement. However, the GSP fails to provide adequate evidence to evaluate further this correlation, specifically concerning potential subsidence caused by groundwater levels falling below historic lows, as would be allowed by the groundwater level minimum thresholds set in the GSP.

The GSP's justification for using the proposed groundwater level minimum thresholds as a proxy for land subsidence appears to rely mainly on an incomplete analysis and a data set with significant data gaps. The GSP states there are no historical records of significant and unreasonable land subsidence in the Subbasin.[31] The GSP also states that there is a lack of direct land subsidence monitoring in the Subbasin.[32] The GSP uses this absence of historical records to assert that historically dewatered geologic units are not compressible and, therefore, not at risk for land subsidence. Although groundwater level minimum thresholds are below historic lows, the GSP states that the GSAs do not expect further declines in groundwater levels to dewater materials deeper than 205 feet below ground surface (the deepest groundwater level minimum threshold value in the Subbasin).[33] The GSP states that subsurface materials encountered up to this depth are the same [non-compressible] geologic units that have been historically dewatered.

Department staff find multiple aspects of this justification speculative and not supported
3.5 by the best available science. First, the GSP presents no analysis of historic groundwater
levels or historically dewatered subsurface materials to support the conclusion that the
geologic units are not compressible. Second, the GSP does not provide an evaluation
3.6 showing how additional declines in groundwater levels would only affect subsurface
materials similar to those which have been historically dewatered. Third, the GSP is
3.7 unclear on whether the conditions required to identify an undesirable result for chronic lowering of groundwater levels in the Subbasin are also required to identify an undesirable result for land subsidence. Management proposed in the GSP could allow groundwater level minimum thresholds to be exceeded in periods where two consecutive non-dry years do not occur, which does not support the claim that only materials up to the deepest groundwater level minimum threshold (205 feet below ground surface) will be dewatered.

Department staff note that the legislature intended that implementation of SGMA would avoid or minimize subsidence[34] once GSAs achieve the sustainability goal for a basin. Without analysis examining how allowable groundwater levels below those historically

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[30] ESJ GSP, p. 270.
[31] ESJ GSP, p. 269.
[32] ESJ GSP, p. 270.
[33] ESJ GSP, p. 270.
[34] Water Code § 10720.1(e).

experienced in the Subbasin may affect land subsidence, Department staff cannot determine if the GSP adequately avoids or minimizes land subsidence. While SGMA does not require prevention of all land subsidence, the GSP does not provide sufficient evidence to conclude that the proposed chronic lowering of groundwater level minimum thresholds are adequate to detect and avoid land subsidence undesirable results.

Potential Corrective Action 2

The GSAs must provide detailed information to demonstrate how the use of the chronic lowering of groundwater level minimum thresholds are sufficient as a proxy to detect and avoid significant and unreasonable land subsidence that substantially interferes with surface land uses. Alternatively, the GSAs could commit to utilizing direct monitoring for subsidence, e.g., with remotely sensed subsidence data provided by the Department. In that case, the GSAs should develop sustainable management criteria based on rates and extents of subsidence. Department staff suggest the GSAs consider and address the following issues:

1. The GSAs should revise the GSP to identify the total subsidence that critical infrastructure in the Subbasin can tolerate during GSP implementation. Support this identification with information on the effects of subsidence on land surface beneficial uses and users and the amount of subsidence that would substantially interfere with those uses and users.
2. The GSAs should revise the GSP to document a significant correlation between groundwater levels and specific amounts or rates of land subsidence. The analysis should account for potential subsidence related to groundwater level declines below historical lows and further declines that are allowed to exceed minimum thresholds (i.e., during non-consecutive non-dry years, if applicable based on the resolution to Potential Deficiency 1, above). This analysis should demonstrate that groundwater level declines allowed during GSP implementation are preventative of the rates and magnitudes of land subsidence considered significant and unreasonable based on the identified infrastructure of concern. If there is not sufficient data to establish a correlation, the GSAs should consider other options such as direct monitoring of land subsidence (e.g., remotely sensed data provided by the Department, extensometers, or GPS stations) until such time that the GSAs can establish a correlation.
3. The GSAs should explain how the groundwater level representative monitoring network is sufficient to detect significant and unreasonable subsidence that may substantially interfere with land uses, specifically any identified infrastructure of concern. If the groundwater level monitoring network alone is not adequate, based on specific infrastructure locations, Department staff suggest incorporating continued analysis of available InSAR data to cover areas with data gaps.

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APPENDIX 3-E.
TECHNICAL MEMORANDUM NO. 3 – WATER QUALITY

TECHNICAL MEMORANDUM NO. 3 - Groundwater Quality Degradation in Areas where further Groundwater Level Decline is Allowed

TO: Paul Gosselin, California Department of Water Resources Deputy Director

CC: Kris Balaji, on behalf of the Eastern San Joaquin Groundwater Authority

PREPARED BY: Matt Zidar, San Joaquin County Public Works, Water Resources Division
Leslie Dumas and Natalie Cochran/Woodard & Curran

DATE: June 24, 2022

RE: Eastern San Joaquin Groundwater Authority Response to DWR's November 18, 2021 Consultation Initiation Letter - Response to DWR Deficiency 1(f) and Corrective Actions

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The Eastern San Joaquin Groundwater Authority (ESJGWA) received a Consultation Initiation Letter (Letter) on November 18, 2021 (Attachment 1), from the California Department of Water Resources (DWR). The Letter identified two potential deficiencies with the Eastern San Joaquin Groundwater Subbasin (Subbasin) Groundwater Sustainability Plan (GSP) which may preclude DWR's approval, as well as potential corrective actions to address each potential deficiency. The Letter thus initiated consultation between DWR, the Plan Manager, and the Subbasin's groundwater sustainability agencies (GSAs) regarding the amount of time needed to address the potential deficiencies and corrective actions. A subsequent meeting with DWR was held on April 4, 2022 to discuss the Subbasin's proposed approach to addressing the identified deficiencies. The analysis presented in this memorandum was completed in response to the Letter, based on direction provided by the ESJGWA, the Subbasin GSAs and DWR. It is intended to supplement the Eastern San Joaquin GSP that was submitted in January 2020 and fill potential gaps identified in the Letter provided by DWR.

Deficiency 1, as described in the DWR November 18, 2021 letter, is summarized as follows:

Potential Deficiency 1: The GSP lacks sufficient justification for determining that undesirable results for chronic lowering of groundwater levels, subsidence, and depletion of interconnected surface waters can only occur in consecutive non-dry water year types. The GSP also lacks sufficient explanation for its minimum thresholds and undesirable results for chronic lowering of groundwater levels.

The letter then went on to identify six potential corrective actions that could address this deficiency. This Technical Memorandum (TM) was prepared to address the deficiency as described in Potential Correction Actions 1(f), which states the following:

"1(f) The GSP should be revised to explain how the GSAs will assess groundwater quality degradation in areas where further groundwater level decline, below historic lows, is allowed via the minimum thresholds. The GSAs should further describe how they will coordinate with the appropriate groundwater users, including drinking water, environmental, and irrigation users as identified in the GSP. The GSAs should also discuss efforts to coordinate with water quality regulatory agencies and programs in the Subbasin to understand and develop a process for determining if continued lowering of groundwater levels is resulting in degraded water quality in the Subbasin during GSP implementation."

The following subsections provide a response to each of the Potential Corrective Action 1(f) subparts listed above, and include a discussion with supplemental information, analysis, justification, and data needed to support the GSP and to address each issue identified.

Potential Corrective Action 1(f)-1: Explain how the GSAs will assess groundwater quality degradation in areas where further groundwater level decline, below historic lows, is allowed via the minimum thresholds.

Initial Review Provided by DWR

The Letter states the GSAs "…have not explained how those groundwater level declines [allowed for by the GSP's minimum thresholds] relate to the degradation of groundwater quality sustainability indicator. GSAs must describe, among other items, the relationship between minimum thresholds for a given sustainability indicator (in this case, chronic lowering of groundwater levels) and the other sustainability indicators."

As a Potential Corrective Action, the following is suggested: "Explain how the GSAs will assess groundwater quality degradation in areas where further groundwater level decline, below historic lows, is allowed via the minimum thresholds."

Proposed Supplemental Information in Response to DWR Letter

Explanation of Groundwater Level Declines and Degradation of Water Quality

The only clear correlation between groundwater levels and water quality impairment from constituents of concern are related to the regional migration of poor-quality water from under the Delta to the groundwater pumping trough that is east of the City of Stockton. A gradient from the Delta toward the east causes the migration of poor-quality water into the Subbasin's principal aquifers which can be exacerbated by increased pumping east of the Delta. U.S. Geologic Survey (USGS) data and prior studies suggest that high chloride groundwater is the result of the eastern movement of brackish San Joaquin Delta water and the upward movement of saline water associated with older marine deposits underlying freshwater aquifer units (Izbicki, 2006). Chloride and total dissolved solids (TDS) have been the indicator constituents for this potential degradation mechanism.

Other than for the movement of poor-quality saline groundwater from the Delta eastward as a result changes in groundwater gradients (whether occurring naturally, induced by groundwater pumping, and/or as a result of some other hydrologically-related parameter), there is no simple correlation between groundwater levels and groundwater quality (as characterized by a large number of naturally-occurring constituents such as manganese, arsenic, boron, and manmade constituents such as 1,2,3-TCP and PFOS. Numerical modeling is one method of evaluating the hydraulic conditions which could cause migration and mixing of poor-quality water and the resultant degradation in groundwater quality; however, with the exception of simulating project-specific impacts, simulating long-term basin management would be difficult and speculative given the large number of potential constituents of concern and possible sources of those constituents.

This potential for regional migration of saline waters was one of the reasons for developing prior groundwater management plans and the Integrated Conjunctive Use Program, and for implementing related Project Management Actions (PMAs) over the past 20 years. Projects implemented to date include projects to reduce groundwater pumping by providing treated surface water in-lieu of groundwater use, such as the City of Stockton's Delta Diversion Project, which diverts Delta water for treatment and distribution in lieu of groundwater supplies. The Stockton East Water District (SEWD) Dr. Joe Waidhofer Water Treatment Plant also treats and purveys surface water to urban contractors, including the County of San Joaquin, City of Stockton, and California Water Service. These two in-lieu projects have helped decrease groundwater pumping and have allowed for recovery of groundwater levels on the order of 14 to 20 feet. This has reduced, but not eliminated, the eastern migration of poor-quality water from the Delta into the Subbasin by reducing the groundwater hydraulic gradient eastward from the Delta.

Implementation of the other PMAs included in the Eastern San Joaquin (ESJ) Groundwater Sustainability Plan (GSP) is intended to raise groundwater levels or, at minimum, keep levels in the operating zone defined as the elevations between the Measurable Objective (MO) and the Minimum Threshold (MT) established to avoid undesirable results. These sustainable management criteria were set specifically to help prevent the further migration of saline water. The relationship between the MOs and MTs for groundwater levels considered water quality and the afore-described saline water migration because there was a known potential and causality, even if no clear correlations.

There are dedicated monitoring wells that have been constructed in the past 20 years and a production well network which together serve as sentinels to track chloride and TDS as indicators of the saline water and potential migration (please see ESJ GSP Figure 2-58, pg. 2-84) and to monitor the sustainability indicators for this management problem. These wells are also part of the ESJ GSP representative monitoring well network.

California Code of Regulations (CCR) Title 22 establishes water quality standards for drinking water contaminants. A secondary MCL (SMCL) is defined for a variety of parameters, including chloride and TDS. Secondary MCLs are based on user acceptability of the quality of drinking water, as opposed to being established to protect human health. For the purposes of this GSP, comparing chloride and TDS concentrations to their respective SMCLs is the basis for monitoring the above-described groundwater quality concerns in the Eastern San Joaquin Subbasin. [should reference data for the water in or under the Delta that is of concern – do levels of chloride and/or TDS in these waters exceed SMCLs? i.e. do they pose a risk of causing exceedances in adjacent groundwater?]

Nexus Between GWL and WQ

Except for the potential for regional migration of saline water, there is no evidence or historical data to indicate that there is relationship between lowering of groundwater levels and groundwater quality degradation. We have not observed, nor can we anticipate, any causal connection between groundwater management actions that can be undertaken by GSAs, and lowering groundwater levels that would result in degradation associated with other constituents of concern.

There are, however, potential mechanisms for lowering groundwater levels to influence water quality. These include:

- Falling groundwater levels which may cause migration of already-contaminated groundwater from natural sources, nonpoint sources (salt, nitrate), or a plume from a point source where a potential responsible party is known.
- Rising groundwater levels creating changes in oxidation potential and mobilization of arsenic.
- Rising groundwater levels from recharge operations or reduce pumping that could mobilize nitrates or salts in the vadose zone.

The GSP reviews water quality issues regarding nitrates, arsenic, and salts, referencing Regional Water Quality Control Board (RWQCB) programs under the Central Valley Water Quality Control Plan, and those of the State Water Resources Control Board, including the Irrigated Lands Regulatory Program and the CVSALTS initiative, generally describing these programs and relationship to these efforts. The intent is to acknowledge those jurisdictions and authorities, create awareness of the areas of responsibility for management and regulation, and identify where there are known water quality issues and impairments to beneficial use being addressed through those authorities. The GSP acknowledges the Central Valley Regional Water Quality Control Board (RWQCB)/State Water Resources Control Board (SWRCB) responsibilities, including those of the Division of Drinking Water, and documents these programs and how they influence the GSAs PMAs and groundwater management in the region to be consistent and respectful of the authorities and programs of these related agencies. This includes local Environmental Health Department authorities to protect drinking water quality, health, and safety.

There may be a relationship between PMAs to be implemented by GSAs that merit review at the time such projects are proposed and subject to California Environmental Quality Act (CEQA), and if potential impacts are identified during scoping and the input of the responsible or trustee agencies. Any PMA that could result in violation of MCLs as a threshold of significance would require mitigation and monitoring to ensure there are no negative effects. For example, groundwater recharge has been observed to result in short term increases in nitrogen concentration in groundwater due to the flushing of nitrate from the soil and/or vadose zone to the water table. This known potential negative effect would require evaluation during project development and ongoing monitoring and mitigation during operation. The rising water table associated with a recharge project could also intersect with nitrogen entrained in the pore space in the vadose zone and mobilizing this constituent. Both effects have been observed to be short term in nature as more clean water is recharged over time and typically improves ambient water quality. Regardless, impacts would be evaluated and mitigated as required under CEQA.

Varying groundwater levels may also change geochemical conditions and result in oxidation and mobilization of some elements. This is one mechanism for mobilizing arsenic; however, there is not enough data to evaluate causal relationship or correlations with groundwater levels at this time. The GSP notes the monitoring well and drinking water well monitoring and reporting of arsenic levels.

Potential Corrective Action 1(f)-2: Describe how they will coordinate with the appropriate groundwater users, including drinking water, environmental, and irrigation users as identified in the GSP

Initial Review Provided by DWR

The Letter states "The GSAs generally commit to monitoring a wide range of water quality constituents, but they have only developed sustainable management criteria for total dissolved solids because they state they have not observed a causal nexus between groundwater management and degradation associated with the other constituents. While Department staff are not aware of evidence sufficient to conclude that the GSAs acted unreasonably by focusing on total dissolved solids, it is clear that the GSAs did not consider, or at least did not document, the potential for degradation to occur due to further lowering of groundwater levels beyond the historic low."

As a Potential Corrective Action, the following is suggested: "The GSAs should further describe how they will coordinate with the appropriate groundwater users, including drinking water, environmental, and irrigation users as identified in the GSP."

Supplemental Information in Response to DWR Letter

GSAs Assessment of Groundwater Quality Degradation

The ESJ GSP and PMAs are designed to prevent further groundwater level declines below the historic level and MTs established. The representative water quality monitoring well network in the area where lowering of groundwater levels may lead to degradation of water quality, along with tracking of other regional monitoring by the RWQCB, SWRCB and local water purveyors, will allow the GSAs to observe water quality conditions and identify when groundwater level MTs are exceeded to determine if water quality exceeds the SMCLs at the MT for the constituents of concern referenced in the GSP. If groundwater level MTs and groundwater quality SMCLs as MTs are exceeded, the GWA will convene a working group consisting of GSAs, regulators and local water purveyors to conduct and publish an assessment of the effect of groundwater management activities on the documented exceedance and propose timely corrective actions to manage groundwater differently, if needed, to avoid exacerbating the exceedance and to address the resultant undesirable results.

Through the ESJGWA, the GSAs will collaborate and share data with other programs monitoring water quality data to observe both ambient and regulated conditions.

Coordination with Groundwater Users

GSP implementation by the ESJGWA includes stakeholder coordination, outreach and engagement of groundwater users, and seeks to involve representatives of the different beneficial uses and users, including non-governmental organizations. The ESJGWA maintains a web site, is working to implement a data management system to provide transparent access to available groundwater level and quality data, and produces and distributes the required Annual Report which is a primary tool for communicating basin conditions and progress in achieving sustainability. The Annual Report includes documentation of efforts to coordinate with the other monitoring and regulatory programs to bring data and information into the

ESJGWA discussions and build awareness of how groundwater levels and quality may be managed together to achieve sustainability.

The Subbasin's Technical Advisory Committee will be used to review monitoring data from the GSP programs, and to integrate information from other monitoring programs into the Annual Report to identify where constituents of concern are degrading water quality and will seek to define if there is a relationship between groundwater levels and impacts to beneficial use.

Potential Corrective Action 1(f)-3: Discuss efforts to coordinate with water quality regulatory agencies and programs in the Subbasin to understand and develop a process for determining if continued lowering of groundwater levels is resulting in degraded water quality in the Subbasin during GSP implementation

Initial Review Provided by DWR

The Letter states "While Department staff are not aware of evidence sufficient to conclude that the GSAs acted unreasonably by focusing on total dissolved solids, it is clear that the GSAs did not consider, or at least did not document, the potential for degradation to occur due to further lowering of groundwater levels beyond the historic lows."

As a Potential Corrective Action, the following is suggested: "The GSAs should also discuss efforts to coordinate with water quality regulatory agencies and programs in the Subbasin to understand and develop a process for determining if continued lowering of groundwater levels is resulting in degraded water quality in the Subbasin during GSP implementation."

Supplemental Information in Response to DWR Letter

Coordination with Water Quality Regulatory Agencies and Programs

The primary state authority for protecting water quality under the Porter Cologne Water Act is the SWRCB and RWQCB via the *Water Quality Control Plans* (also known as Basin Plans) which define the beneficial uses of water (including groundwater), set water quality numeric and narrative objectives, establish priorities, and implement programs to manage both point and non- point sources of contamination. The Water Boards coordinate with the other state programs including, the Department of Pesticide Regulation.

Section 3.2.3.1.1 of the GSP discusses the Irrigated Lands Regulatory Program (ILRP) and Central Valley Salinity Alternatives for Long-Term Sustainability (CV-SALTS), two existing regulatory programs for the monitoring and regulation of nitrate and salts in the Central Valley. Under the ILRP, the San Joaquin County & Delta Water Quality Coalition (Coalition) is required to test and potentially mitigate for nitrate in domestic wells. The Coalition has 40 trend monitoring wells throughout San Joaquin County that are sampled yearly to determine the nitrate levels in the groundwater. They also hold grower meetings and conduct outreach to growers on best management practices that are protective of water quality for both surface water and groundwater. The Coalition completed its *Groundwater Assessment Report* in 2015 that identified areas that were highly susceptible to nitrate from agriculture leaching into groundwater (High Vulnerability Areas). The Coalition also analyzes monitoring data and grower-prepared nitrate management plan information to determine if the growers follow the requirements of the Irrigated Lands Regulatory Program. The Coalition then reports this analysis with required information to the Central Valley Regional Water Quality Board on an annual basis.

Additionally, the 2017 Salt and Nitrate Control Program, developed by CV-SALTS, identifies long-term nitrate management requirements (CVRWQCB, 2016). The Eastern San Joaquin Basin is Priority 2 Basin under the nitrate control program. The CV-SALTS Prioritization and Optimization (P&O) Study is a long-term effort to develop, plan and implement solutions for managing and controlling salt accumulation in the Valley.

In May 2018, because of CV-SALTS program efforts, a new Salt and Nitrate Management Plan (SNMP) was approved by the Central Valley Regional Water Quality Control Board as Amendments to the Basin Plans for the Sacramento River, San Joaquin River Basin and the Tulare Lake Basin. The State Water Resources Control Board then directed targeted revisions to the Amendments adopted by the Central Valley Water Board. The following Proposed Revisions were approved with an effective date of November 10, 2021.

- Salt and Nitrate Control Program Basin Plan Amendments – Proposed Revisions (2021)
- Salt and Nitrate Control Program – Basin Plan Amendment (2019)

The State Water Resources Control Board Division of Drinking Water and local health agencies monitor drinking water quality to protect public health and safety. Their programs and the proposed ESJ monitoring should share data to better diagnose and treat potential or known water quality impairments.

ESJGWA and GSA Project Management Actions

The ESJ GSP also proposes the following program management actions for the Subbasin GSAs to be coordinated through the ESJGWA. These include:

1. Regular Process for coordination

    a. The ESJGWA will hold an annual "groundwater water quality state of the basin" meeting or workshop in January and invite the members of the Coalitions to present the results of the monitoring program.

    b. The ESJ Technical Advisory Committee (TAC) will invite participation and *ex officio* representation from the RWQCB staff to receive regular information regarding ILRP, CV-SALTS and any planned updates or amendments to the San Joaquin Water Quality Control Plan.

2. Monitoring

    a. The ESJGWA will seek to develop monitoring and data sharing agreements with the Coalition.

    b. ESJGWA staff will work with the local Environmental Health Division and SWRCB Division of Drinking to identify drinking water wells which are nearing or have exceeded MCLs or SMCLs, noting the location, number of wells and the constituents of concern.

3. Data Management. Where possible, the ESJGWA will include the water quality data collected via other monitoring networks in their annual assessments, and will use this information to further evaluate trends and any correlations between groundwater levels, the groundwater level MTs, and observed water quality conditions.

4. Annual Report. Beyond the reporting of data from the GSP groundwater level and water quality monitoring network, the ESJ Annual Report will include expanded groundwater quality discussion to document:

    a. The annual results of the Coalitions monitoring program

    b. Known impairments identified by the RWQCB pursuant to the Water Quality Control Plans

    c. Wells and locations where MCLs have been exceeded as identified by the SWRCB Division of Drinking Water, consumer confidence reports, or the local Environmental Health Department

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APPENDIX 3-F.
TECHNICAL MEMORANDUM NO.4 – LAND SUBSIDENCE

TECHNICAL MEMORANDUM NO. 4 – LAND SUBSIDENCE

TO: Paul Gosselin, California Department of Water Resources Deputy Director

PREPARED BY: Kris Balaji, on behalf of the Eastern San Joaquin Groundwater Authority

DATE: June 24, 2022

RE: Eastern San Joaquin Groundwater Authority Response to DWR's November 18, 2021 Consultation Initiation Letter – Response to Potential Deficiency No. 2 and Corrective Actions

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1. Introduction

The Eastern San Joaquin Groundwater Authority (ESJGWA) received a Consultation Initiation Letter (Letter) on November 18, 2021 (Attachment 1), from the California Department of Water Resources (DWR). The Letter identified two potential deficiencies with the Eastern San Joaquin Groundwater Subbasin (Subbasin) Groundwater Sustainability Plan (GSP) which may preclude DWR's approval, as well as potential corrective actions to address each potential deficiency. The Letter thus initiated consultation between DWR, the Plan Manager, and the Subbasin's groundwater sustainability agencies (GSAs) regarding the amount of time needed to address the potential deficiencies and corrective actions. A subsequent meeting with DWR was held on April 4, 2022 to discuss the Subbasin's proposed approach to addressing the identified deficiencies. The analysis presented in this memorandum was completed in response to the Letter, based on direction provided by the ESJGWA, the Subbasin GSAs and DWR. It is intended to supplement the Eastern San Joaquin GSP that was submitted in January 2020 and fill potential gaps identified in the Letter provided by DWR.

The following sections provide a response to the Potential Corrective Actions identified under **Potential Deficiency 2**.

2. Potential Deficiency 2

<u>Potential Deficiency 2. The GSP does not provide enough information to support the use of the chronic lowering of groundwater levels sustainable management criteria and representative monitoring network as a proxy for land subsidence</u>

Under Potential Deficiency 2, DWR identified deficiencies related to the use of the chronic lowering of groundwater levels sustainable management criteria and representative monitoring network as a proxy for land subsidence. Specifically, DWR requests additional information demonstrating significant correlation between groundwater levels and land subsidence to demonstrate that groundwater level minimum thresholds represent a reasonable proxy for avoiding land subsidence undesirable results. The GSAs must additionally demonstrate how the monitoring network is adequate to identify undesirable results for land subsidence.

To address findings identified under Potential Deficiency 2, DWR has put forward Potential Corrective Action 2 for GSA consideration. Potential Corrective Action 2 contains three subparts, which are summarized below.

- **Potential Corrective Action 2-1:** Identify the total extent and rates of subsidence that critical infrastructure in the Subbasin can tolerate during GSP implementation.
- **Potential Corrective Action 2-2**: Document a significant correlation between groundwater levels and specific amounts or rates of land subsidence. Account for potential subsidence related to groundwater level declines below historic lows and further declines that would exceed minimum threshold levels. Demonstrate that

groundwater level declines allowed during GSP implementation are preventative of the rates and extent of land subsidence.

- **Potential Corrective Action 2-3:** Explain how the groundwater level representative monitoring network is sufficient to detect significant and unreasonable rates or extents of land subsidence that may substantially interfere with land uses.

The following subsections provide a response to each of the Potential Corrective Action subparts listed above, and include a discussion with supplemental information, analysis, justification, and data needed to support the GSP and address each issue identified.

Potential Corrective Action 2-1: Identify the total extent and rates of subsidence that critical infrastructure in the Subbasin can tolerate during GSP implementation

Initial Review Provided by DWR

The Letter states the GSP "does not adequately identify or define minimum thresholds and undesirable results for land subsidence… [and] does not identify specific infrastructure locations, particularly those associated with public safety, in the subbasin and the rate and extent of subsidence that would substantially interfere with those land surface uses and may lead to undesirable results". The Letter further clarifies that, "without identifying infrastructure considered at risk for interference from land subsidence, Department staff cannot evaluate whether the groundwater level representative monitoring network is adequate to detect potential subsidence-related impacts."

As a Potential Corrective Action, the following is suggested: "The GSA should revise the GSP to identify the total subsidence that critical infrastructure in the Subbasin can tolerate during GSP implementation. Support this identification with information on the effects of subsidence on land surface beneficial uses and users and the amount of subsidence that would substantially interfere with those uses and users."

Supplemental Information in Response to DWR Letter

Identification of Critical Infrastructure

The GSP describes an undesirable result for land subsidence in the Eastern San Joaquin Subbasin as occurring if land subsidence substantially interferes with beneficial uses of groundwater and infrastructure within the Subbasin over the planning and implementation horizon of the GSP. In coordination with the San Joaquin County Department of Public Works and the San Joaquin County Office of Emergency Services, the following infrastructure types have been identified as those potentially at risk for interference from land subsidence, if it were to occur in the Subbasin. Please note that, as discussed with DWR during the April 4th meeting, due to the sensitive nature of the critical infrastructure, specific infrastructure are not named and, rather, only the principal categories of these types of infrastructure are discussed below.

Critical infrastructure at risk for subsidence impacts:

- Major highways, roadways, and bridges
- Canals, pipelines, and levees
- Electrical transmission lines
- Schools
- Fire stations
- Hospitals and other medical facilities
- Law enforcement facilities (police stations, jails, correctional facilities)
- Water and wastewater treatment, distribution, and storage facilities
- Communication facilities

The Subbasin is served by an extensive road network, including major interstate highways. The San Joaquin County Department of Public Works maintains the County's 120-mile network of underground facilities, over 1,600 miles of roadway, 265 bridges, and 364 minor structures. In addition, San Joaquin County supports air service, a deep water port, transcontinental rail, and commuter trains. Major roadways located within the Subbasin boundary include Interstate 5 (I-5) and multiple State Routes (4, 12, 26, 88, 99, 120). Major bridges in the Subbasin serve both automobile and railroad transport. Major bridges in the subbasin include the San Joaquin River Bridge, Littlejohns Creek Bridge, Mormon Slough Bridge, and the Union Pacific Mossdale Bridge East.

Service buildings within the Subbasin include fire stations, hospitals, jails and correction facilities, police stations, and wastewater plants. The County also maintains 30 water systems with 52 wells, 3 sewage treatment plants, 9 sewage pumping stations, 68 storm drain pumping stations, and over 300 miles of levees and flood channels. In general, major pipelines that run through the County are in areas south of Lodi and southwest of Tracy along the foothills (outside of the Subbasin boundary).

In addition to identifying critical infrastructure at risk for subsidence impacts, the ESJGWA has worked with OES to identify the total subsidence load that critical infrastructure in the Subbasin can tolerate during GSP implementation, and what would be considered an undesirable result. Through input from OES, the critical infrastructure in the Subbasin can generally tolerate a significant amount of uniform settlement due to subsidence across the Subbasin, though the total amount of settlement that can be tolerated is dependent on the design of the specific infrastructure. Differential settlement across facilities in a locale, on the other hand, will result in more damage. However, it is worth noting that it is less common for subsidence to cause significant local differential sediment. In addition, the *San Joaquin County 2017 Local Hazard Mitigation Plan* identifies land subsidence as a potential cause for levee breakage; however, the hazard of subsidence is ranked "not likely" to occur.

Potential Corrective Action 2-2: Document a significant correlation between groundwater levels and specific amounts or rates of land subsidence. Account for potential subsidence related to groundwater level declines below historic lows and further declines that would exceed minimum threshold levels. Demonstrate that groundwater level declines allowed during GSP implementation are preventative of the rates and extent of land subsidence.

Initial Review Provided by DWR

The second part of this Potential Corrective Action seeks additional information to document a significant correlation between groundwater levels and land subsidence. The Letter states the GSP "fails to provide adequate evidence to evaluate further [the correlation between groundwater levels and land subsidence], specifically concerning potential subsidence caused by groundwater levels falling below historic lows, as would be allowed by the groundwater level minimum threshold set in the GSP. The Letter further states that the GSP "presents no analysis of historic groundwater levels or historically dewatered subsurface materials to support the conclusion that the geologic units are not compressible", "does not provide an evaluation showing how additional declines in groundwater levels would only affect subsurface materials similar to those which have been historically dewatered", and "is unclear on whether the conditions required to identify an undesirable result for chronic lowering of groundwater levels in the subbasin are also required to identify an undesirable result for land subsidence."

As a Potential Corrective Action, the following is suggested: "The GSAs should revise the GSP to document a significant correlation between groundwater levels and specific amounts or rates of land subsidence. The analysis should account for potential subsidence related to groundwater level declines below historical lows and further declines that are allowed to exceed minimum thresholds (i.e., during non-consecutive non-dry years, if applicable based on the resolution to Potential Deficiency 1, above). This analysis should demonstrate that groundwater level declines allowed during GSP implementation are preventative of the rates and magnitudes of land subsidence considered significant and unreasonable based on the identified infrastructure of concern. If there is not sufficient data to establish a correlation, the GSAs should consider other options such as direct monitoring of land subsidence (e.g., remotely sensed data provided by the Department, extensometers, or GPS stations) until such time that the GSAs can establish a correlation."

Supplemental Information in Response to DWR Letter

Areas Potentially At-Risk for Subsidence

As discussed in the GSP, despite long-term declining groundwater levels in the Subbasin, there are no historical records of impacts from land subsidence in the Eastern San Joaquin Subbasin. **Figure 1** shows regional subsidence produced from TRE Altamira Interferometric Synthetic Aperture Radar (InSAR) data, provided by DWR for SGMA application. This figure illustrates that subsidence has historically been minimal in the Subbasin and surrounding areas (ranging from -0.1 to 0.1 feet of vertical displacement annually). This corresponds with what San Joaquin County Public Works and San Joaquin County Office of Emergency Services staff have observed anecdotally, that the Subbasin has not historically experienced issues with land subsidence.

In the Subbasin, there are two potential mechanisms that could potentially contribute to inelastic land subsidence: 1) groundwater extraction resulting in dewatering and collapse of compressible clays in the subsurface, 2) and the oxidation of peaty soils.

Mechanism 1: Subsidence Caused by Dewatering and Collapse of Compressible Clays

The first mechanism for inelastic land subsidence involves the presence of compressible clays and strata in the subsurface, which are not known to be common in the Eastern San Joaquin Subbasin. The Corcoran Clay is one type of subsurface material that is potentially predisposed to compression, especially in the San Joaquin Valley. While dominant in basins to the south, the extent of Corcoran Clay within the Eastern San Joaquin Subbasin is limited to the extreme southwest corner of the Subbasin, near the City of Manteca. **Figure 2** shows the extent of Corcoran Clay within the Subbasin. This figure also includes hydrographs for two monitoring wells located in this area, one in the Representative monitoring network for chronic lowering of groundwater levels, and one in the Broad monitoring network for chronic lowering of groundwater levels. In addition, there are two other Broad groundwater level monitoring network wells that fall within the Corcoran Clay boundary but are outside of the boundary of the available Corcoran Clay depth raster dataset. As shown in the hydrographs provided, historical water levels have remained relatively constant in this area and are well above the Corcoran Clay elevation.

Well 02S07E31N001M (shown as well "A" in **Figure 1**) is in the Representative monitoring network for chronic lowering of groundwater levels. This well is located in the South Delta Water Agency (SDWA) GSA and has a minimum threshold set at 1.5 feet mean sea level (ft MSL), which while below the historical average, is still well above the Corcoran Clay elevation at that location (-176 ft MSL). The ESJGWA has identified a numeric trigger for groundwater levels at which subsidence would become a concern as -150 ft MSL in the portion of the Subbasin were Corcoran Clay is present. This numeric trigger was selected based on available Corcoran Clay elevation data and is intended to capture the shallowest Corcoran Clay in the Subbasin.

The Corcoran Clay layer in the Subbasin is not anticipated to become dewatered if groundwater levels do not drop below the elevation at which Corcoran Clay is present. Because the minimum thresholds for groundwater levels in the portion of the Subbasin where Corcoran Clay is present are higher in the aquifer than the elevation of the Corcoran Clay, groundwater levels are not anticipated to drop below the elevation at which Corcoran Clay is present. Therefore, if groundwater levels are maintained above their minimum thresholds, the Corcoran Clay layer, which is lower in elevation, would not become dewatered and therefore would not become compressed. Thus, the chronic lowering of groundwater levels minimum threshold is protective against dewatering of Corcoran Clay in the Subbasin.

Figure 3 (GSP Hydrogeologic Cross-Section E-E') shows the extent of Corcoran Clay in cross-section. As shown, the Corcoran Clay becomes interbedded with the sands and silt of the upper Turlock Lake Formation. Here, the clay is typically 20 to over 100 feet thick and is locally eroded and interfingered with coarser materials at its margin. It is not found in the central and northern portions of the Subbasin.

Mechanism 2: Subsidence Caused by the Oxidation of Peaty Soils

The second mechanism for inelastic land subsidence in the Subbasin area, the oxidation of peaty soils, does not appear to be directly related to groundwater pumping in the Subbasin (the management mechanism for Subbasin sustainability). As shown in **Figure 4**, the organic basin soils are restricted to the lower Sacramento-San Joaquin River Delta (Delta) portion of the Subbasin. Peat, muck, and clay loam are terms commonly applied to soils in this group. **Figure 5** shows the distribution of present-day modeled subsidence rates due to the oxidation of peaty soils in the Delta region, which ranges from 0 to 1.84 centimeters per year.

There are numerous factors that contribute to peat oxidation-related subsidence. Generally, these include (1) shrinkage due to dewatering, (2) consolidation due to loss of buoyant force and loading, (3) wind and water erosion, (4) oxidation of soil organic matter, and (5) burning. According to findings presented in *Present-day oxidative subsidence of organic soils and mitigation in the Sacramento-San Joaquin Delta, California, USA* (Deverel et al., 2016), subsidence rates in the Sacramento-San Joaquin Delta are primarily related to soil organic matter content, and secondarily to water- and land-management practices that determine depth to groundwater. This paper identifies rice cultivation and permanently flooded wetlands as the primary mitigation tools. As noted by Deverel *et. al*., depth to groundwater on Delta subsided islands is controlled primarily by networks of drainage ditches that feed to island drainage pumping stations that, in turn, continuously discharge drainage water to Delta channels. Drainage ditches collect water that seeps from adjacent channels and deep percolation of applied irrigation water. There are few depth-to-groundwater measurements in Delta organic soils and, in general, groundwater levels have been maintained at about 0.8–1.2 meters below land surface as the result of drainage system operation. Deverel also notes that based on his experience in working in the organic soils throughout the Delta since the early 1980s, depth to groundwater has not changed substantially over time in most places and prior research indicates a lack of change in Delta groundwater levels since the late 1980s (Deverel et al. 2016).

Figure 6 shows annual groundwater pumping in the Subbasin for Water Year 2021 and indicates that minimal groundwater extraction occurs in this area of the Subbasin.

Supplemental Land Subsidence Monitoring

To further supplement the land subsidence data collection efforts put forward in the GSP, continuous global positioning system (CGPS) data, InSAR data, and other subsidence data have been, and will continue to be, evaluated annually by the ESJGWA in coordination with the planned use of chronic lowering of groundwater level minimum thresholds as a proxy for land subsidence. The GSAs will monitor these data sets to better understand and report actual subsidence that occurs (if any) as groundwater levels decline. These data will be compiled and evaluated each year as part of the data assessment and production of the Annual Report, submitted to DWR each April 1. In addition, the ESJGWA will revisit the Hydrogeologic Conceptual Model (HCM) presented in the Subbasin's GSP after DWR's Airborne Electromagnetic (AEM) data become available.[1] At that time, the ESJGWA will adjust the representative monitoring network and methods as needed based on improved basin understanding to refine their methods for monitoring for inelastic land subsidence. This analysis and any subsequent revisions will be incorporated in the GSP five-year update. In time, the ESJGWA will endeavor to identify a correlation between groundwater levels and subsidence, as suggested by DWR. Below is a description of land subsidence datasets currently available for ESJGWA use and analysis.

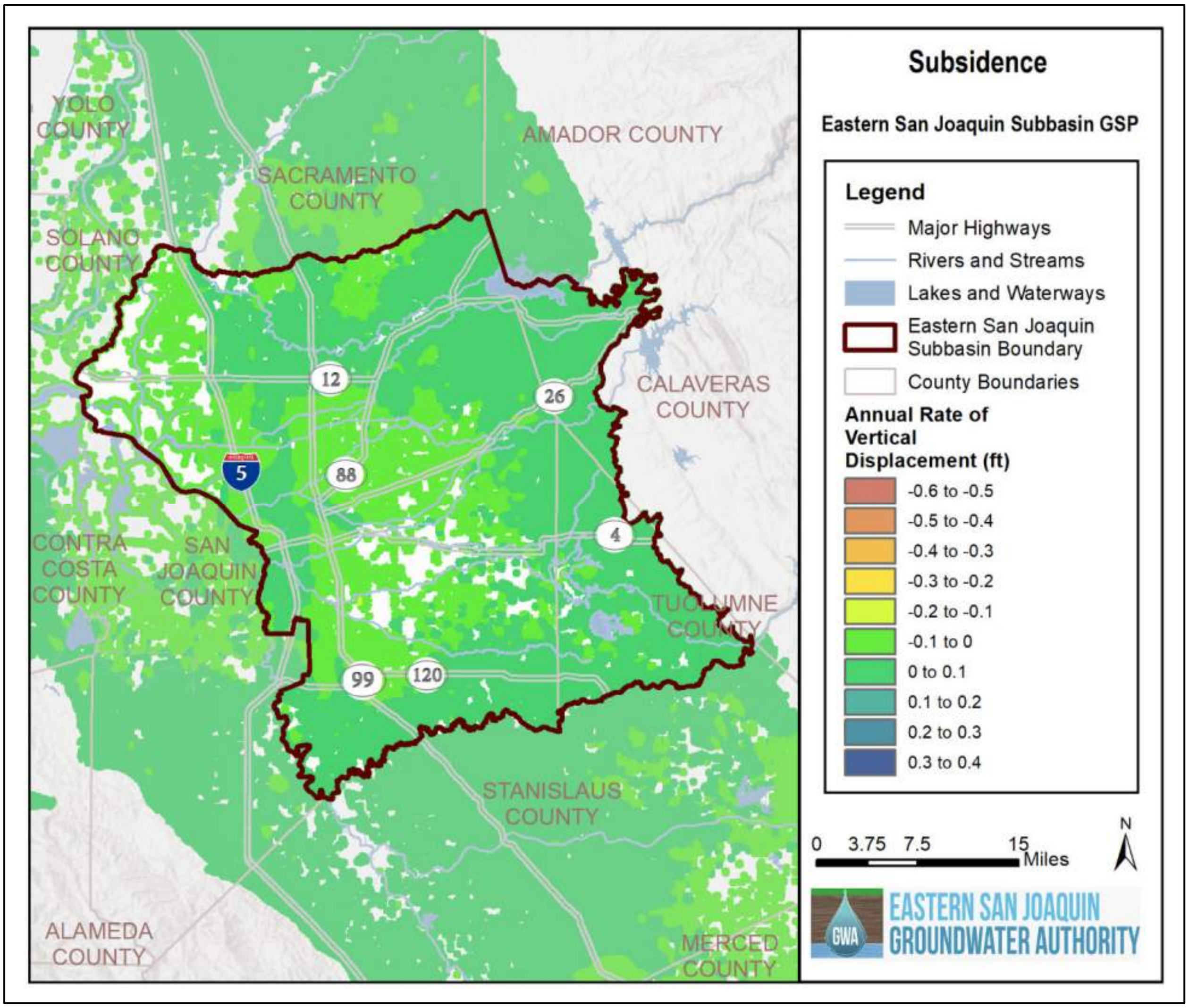
UNAVCO's Plate Boundary Observatory Program – Reporting since 2004, the UNAVCO (formerly University Navigation Satellite Timing and Ranging or NAVSTAR Consortium) Plate Boundary Observatory network consists of a

[1] DWR is conducting AEM surveys in California's high- and medium-priority groundwater basins, where data collection is feasible, to assist local water managers as they implement the Sustainable Groundwater Management Act (SGMA) to manage groundwater for long term sustainability. AEM surveys began in the summer of 2021 and will continue over the next several years. Eastern San Joaquin Subbasin is included in DWR's Survey Area 6, which is expected to be surveyed April 3-23, 2022, per the Tentative AEM Survey Schedule released by DWR. By this schedule, AEM data for the Subbasin is tentatively expected to be available in the first quarter of 2023.

network of about 1,100 CGPS and meteorology stations in the western United States to measure deformation resulting from the constant motion of the Pacific and North American tectonic plates in the western United States. Stations located within the Subbasin contain data from at least 2006 to current and include Station P309, located east of Linden, and Station P273, located west of Lodi. Other stations are also available in nearby Subbasins.

United States Geological Survey – The USGS report *Land Subsidence along the Delta-Mendota Canal in the Northern Part of the San Joaquin Valley, California*, *2003-10* (Sneed et al., 2013) presents land subsidence data in the southwestern portion of the Eastern San Joaquin Subbasin from 2007 to 2010. Data for about 100 square miles of the Subbasin were recorded using InSAR processing, a satellite-based remote sensing technique that can detect ground-surface deformation. Two InSAR techniques were used: conventional InSAR and persistent scatter (PS) InSAR. Both sources of data were collected from the Japanese Aerospace Exploration Agency's Advanced Land Observing Satellite.

Other -– DWR has made two InSAR datasets available for SGMA application: TRE Altamira InSAR point and raster data and NASA JPL raster data. Vertical displacement approximations in both datasets are collected by the European Space Agency's Sentinel-1A satellite. The two different datasets represent two different processing results, one by TRE Altamira Inc. and one by NASA JPL. The TRE Altamira data have coverage between January 2015 and October 2020. Both annual and total raster datasets from TRE Altamira are available and represent interpolations of the vertical displacement point features. The NASA JPL processed dataset spans Spring of 2015 to Summer of 2017.



Note: This dataset represents measurements of vertical ground surface displacement in between spring 2015 and summer 2017 (TRE Altamira, 2019).

Figure 1. Subsidence (Annual Rate of Vertical Displacement)

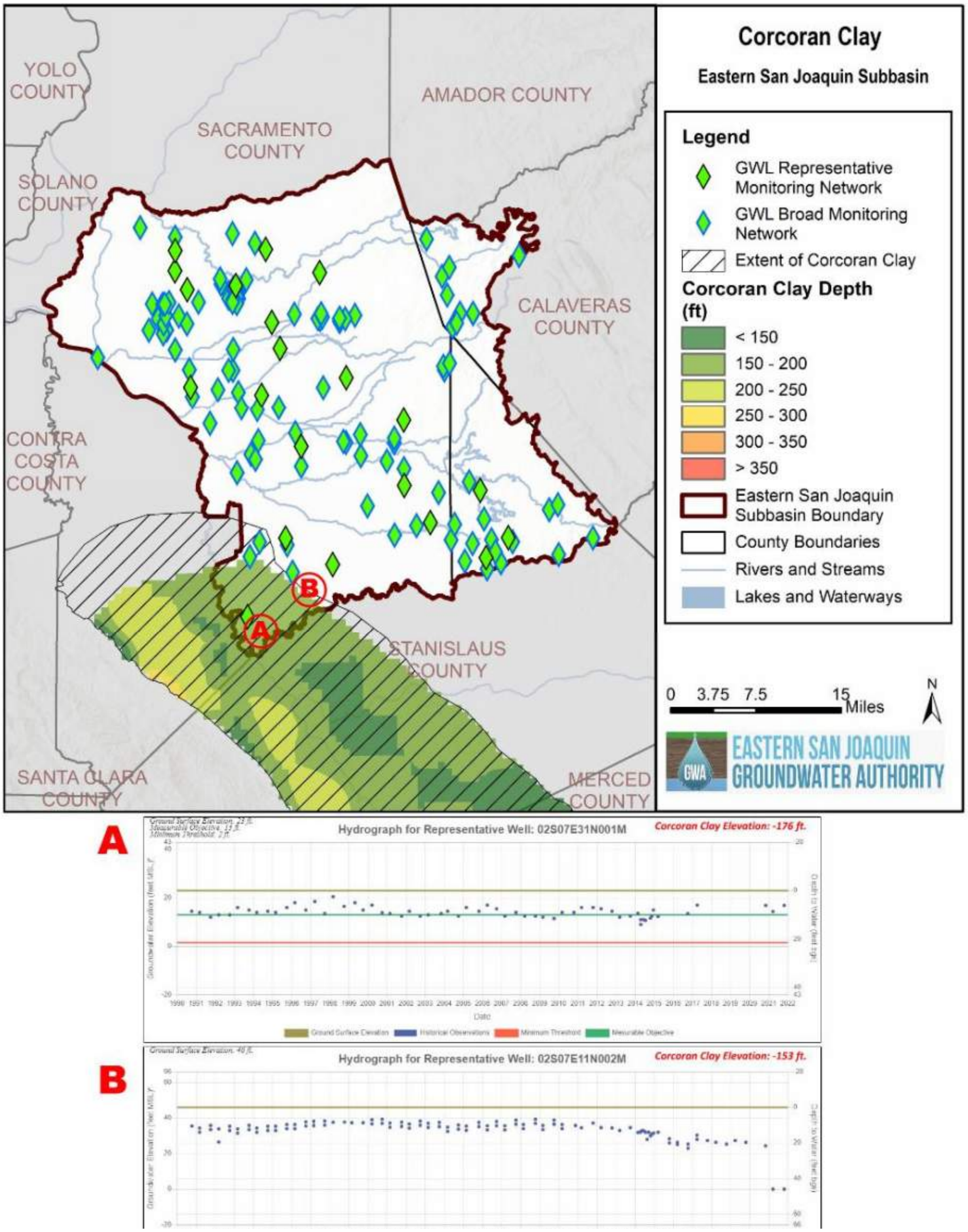


Figure 2. Extent of Corcoran Clay in the Eastern San Joaquin Subbasin with Select Representative Well Hydrographs

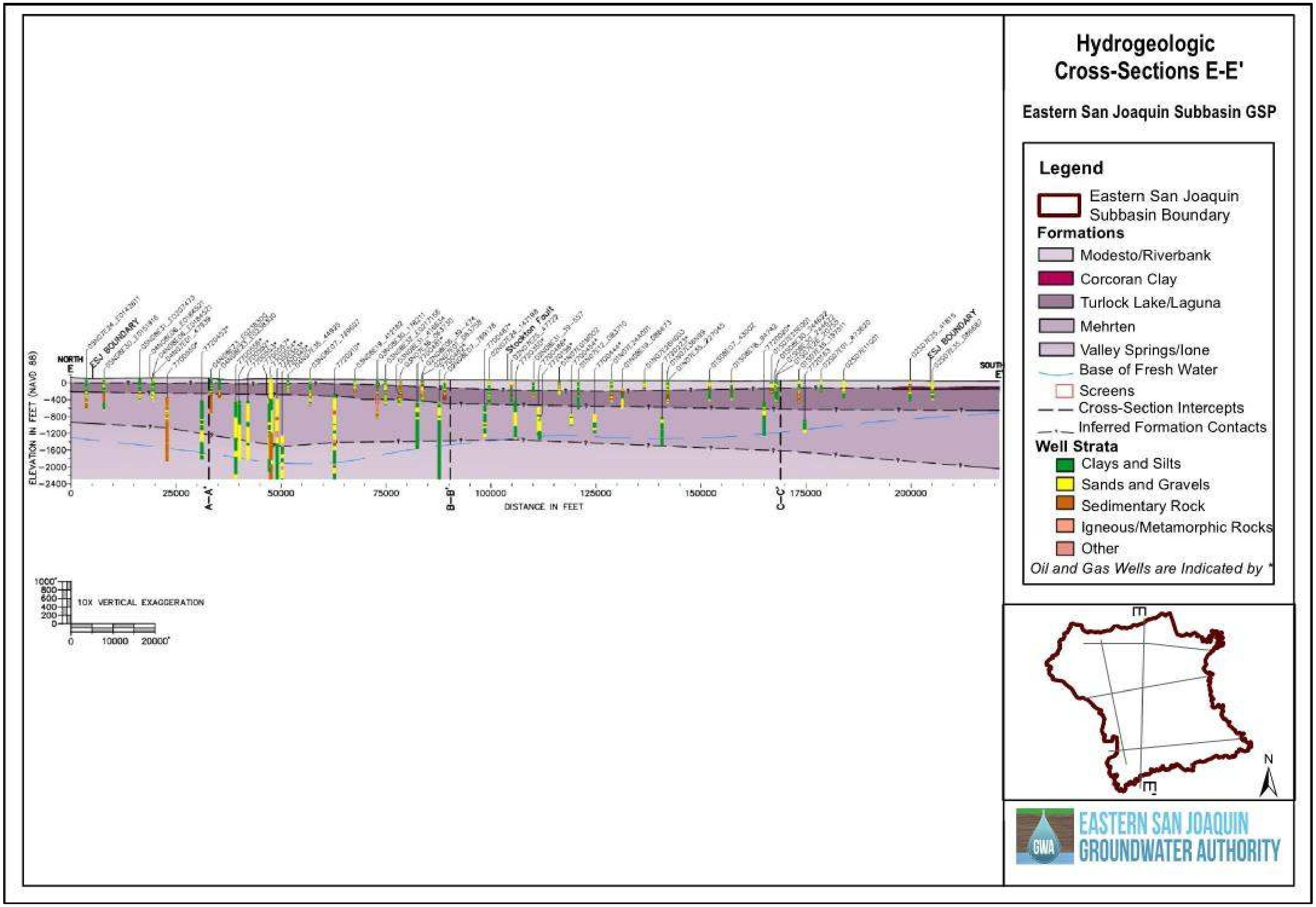


Figure 3. Hydrogeologic Cross-Section E-E'

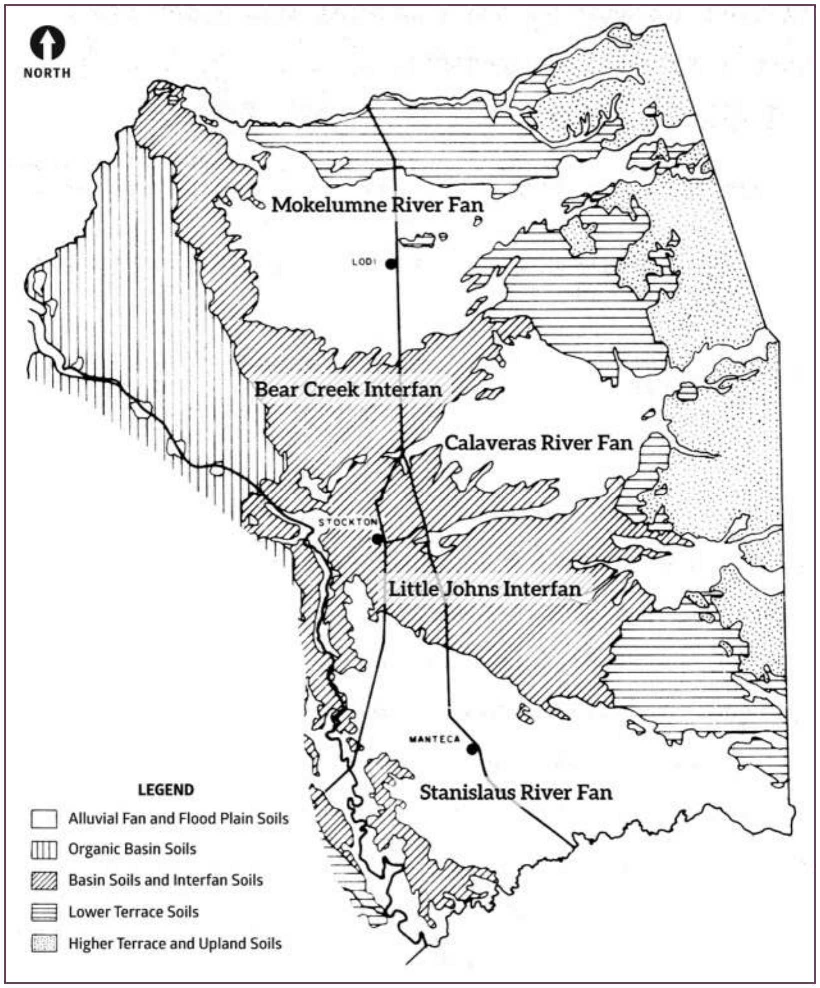
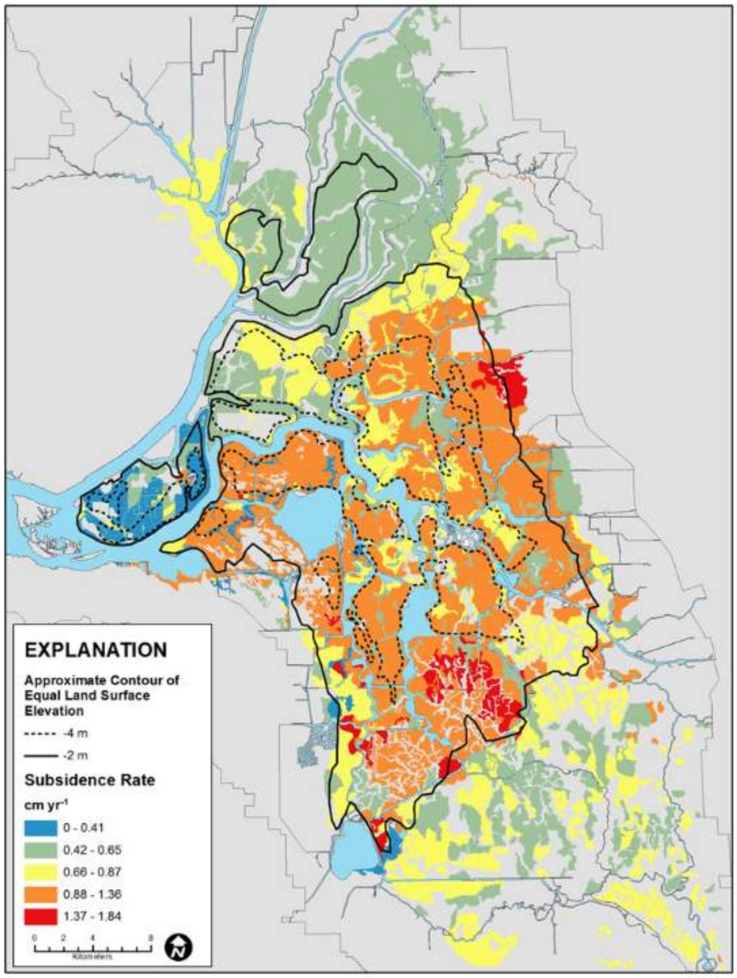


Figure 4. Soil Depositional Areas



Source: *Present-day oxidative subsidence of organic soils and mitigation in the Sacramento-San Joaquin Delta, California, USA* (Deverel et. al, 2016)

Figure 5. Oxidative Subsidence Rates in the Sacramento-San Joaquin Delta

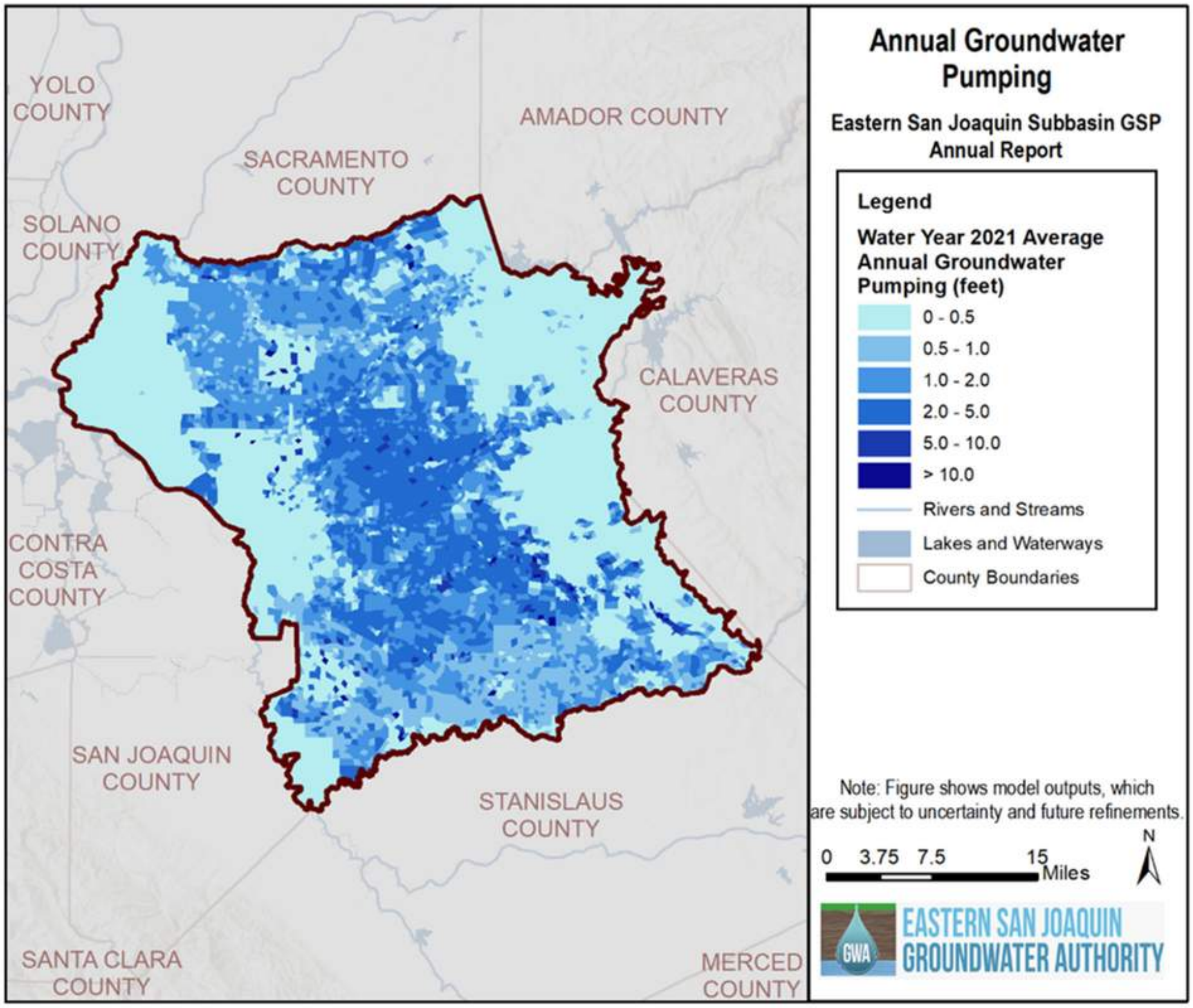


Figure 6. Average Annual Groundwater Pumping (Water Year 2021)

Potential Corrective Action 2-3: Explain how the groundwater level representative monitoring network is sufficient to detect significant and unreasonable rates or extents of land subsidence that may substantially interfere with land uses.

Initial Review Provided by DWR

The third part of the Potential Corrective Action under Deficiency 2 seeks additional information on how the chronic lowering of groundwater levels representative monitoring network is sufficient to detect significant and unreasonable subsidence that may substantially interfere with land uses, specifically any identified infrastructure of concern. The Letter states the GSP "is unclear on whether the conditions required to identify an undesirable result for chronic lowering of groundwater levels in the Subbasin are also required to identify an undesirable result for land subsidence." In addition, the Letter states, "While SGMA does not require prevention of all land subsidence, the GSP does not provide sufficient evidence to conclude that the proposed chronic lowering of groundwater level minimum thresholds are adequate to detect and avoid land subsidence undesirable results."

As a Potential Corrective Action, the following is suggested: "The GSAs should explain how the groundwater level representative monitoring network is sufficient to detect significant and unreasonable subsidence that may substantially interfere with land uses, specifically any identified infrastructure of concern. If the groundwater level monitoring network alone is not adequate, based on specific infrastructure locations, Department staff suggest incorporating continued analysis of available InSAR data to cover areas with data gaps."

Supplemental Information in Response to DWR Letter

The decision to use the groundwater levels representative monitoring network as a proxy for land subsidence was based on the information discussed in the prior section of this document. The GSAs recognize that additional land subsidence data collection and monitoring in the Subbasin over the first few years of GSP implementation will be an important indicator in assessing if the groundwater levels representative monitoring network alone will be sufficient to evaluate potential movement towards significant and unreasonable impacts to infrastructure due to inelastic land subsidence, particularly given that the Subbasin has not historically experienced issues related to land subsidence. For this reason, and in response to DWR's suggestion to incorporate continued analysis of available InSAR data to cover areas with data gaps, the GSAs have committed to annual collection and evaluation of land subsidence data from publicly available sources, including CGPS, InSAR, and other data sources, for assessment with data collected from its representative monitoring network. Data will be evaluated annually, and if subsidence is apparent, projects and management actions in that area will be triggered. The ESJGWA will establish a trigger value of 0.25 feet (annual rate of vertical displacement) at which point an analysis will occur to determine if the subsidence is directly related to groundwater management, and if deemed so, additional projects and management actions are triggered.

The ESJGWA has also determined that, following receipt of the DWR's AEM data, the GSAs will re-evaluate and update the representative monitoring network for land subsidence as part of GSP five-year update and in coordination with improvements and refinements to the GSP HCM through the use of the AEM survey data and new boring log data that becomes available.

REFERENCES

Deverel, Steven J., Timothy Ingrum, and David Leighton (2016), *Present-day oxidative subsidence of organic soils and mitigation in the Sacramento-San Joaquin Delta, California, USA*. Hydrogeology Journal (2016) 24:569-586.

Sneed, Michelle, Justin T. Brandt, and Mike Solt (2013), *Land Subsidence along the Delta-Mendota Canal in the Northern Part of the San Joaquin Valley, California*, *2003-10*. U.S. Geological Survey Scientific Investigations Report 2013-5142. As viewed at https://pubs.er.usgs.gov/publication/sir20135142.

ATTACHMENT 1 – DWR Consultation Initiation Letter

CALIFORNIA DEPARTMENT OF WATER RESOURCES

SUSTAINABLE GROUNDWATER MANAGEMENT OFFICE

901 P Street, Room 313-B | Sacramento, CA 95814 | P.O. Box 942836 | Sacramento, CA 94236-0001

November 18, 2021

Kris Balaji, PMP, P.E.
Eastern San Joaquin Subbasin Plan Administrator
1810 E. Hazelton Avenue, Stockton, CA 95201
kbalaji@sjgov.org

RE: Eastern San Joaquin Subbasin - 2020 Groundwater Sustainability Plan

Dear Kris Balaji,

The Eastern San Joaquin Groundwater Authority submitted the Eastern San Joaquin Groundwater Subbasin (Subbasin) Groundwater Sustainability Plan (GSP) to the Department of Water Resources (Department) for evaluation and assessment as required by the Sustainable Groundwater Management Act (SGMA).[1]

Department staff have substantially completed an initial review of the GSP and have identified potential deficiencies (see the enclosed document) which may preclude the Department's approval.[2] Department staff have also developed potential corrective actions[3] for each potential deficiency. The potential deficiencies do not necessarily represent all deficiencies or discrepancies that the Department may identify in the GSP but focus on those deficiencies that staff believe, if not addressed, could lead to a determination that the GSP is incomplete or inadequate.[4] This letter initiates consultation between the Department, the Plan Manager, and the Subbasin's 15 groundwater sustainability agencies (GSAs) regarding the amount of time needed to address the potential deficiencies and corrective actions. The Department will issue a final determination as described under the GSP Regulations[5] no later than January 29, 2022.

If the Department determines the GSP to be incomplete, the deficiencies precluding approval would need to be addressed within a period not to exceed 180 days from the

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[1] Water Code § 10720 et seq.
[2] 23 CCR § 355.2(e)(2).
[3] 23 CCR § 355.2(e)(2)(B).
[4] The Department recognizes that litigation regarding the GSP has been filed. The filing of litigation does not alter or affect the Department's mandate to issue its final assessment of the Agency's groundwater sustainability plan (GSP or Plan) for the basin within two years of its submission. (Water Code §10733.4(d).) Furthermore, the Department's assessment will consist of a technical review of the submitted Plan, as required by SGMA and the GSP Regulations, and the filing of the litigation did not in any way influence or affect the Department's evaluation of the Plan. The Department expresses no opinion on the claims of the parties in the pending litigation involving the GSP.
[5] 23 CCR Division 2, Chapter 1.5, Subchapter 2.

determination. A determination of incomplete would allow the GSAs to formally address identified deficiencies and submit a revised GSP to the Department for further review and evaluation. Department staff will contact you before making the final determination to discuss the potential deficiencies and the amount of time needed by the GSAs to address the potential corrective actions detailed in the enclosed document.

Materials submitted to the Department to address deficiencies must be part of the GSP. The GSAs must justify that any materials submitted are part of the revised GSP; this justification is also part of the submittal. To facilitate the Department's review of the revised GSP, the GSAs should also provide a companion document with tracked changes of modifications made to address deficiencies. The GSAs must submit the revised GSP through the DWR SGMA Portal where, as is currently available, interested parties may provide comments on submitted materials to the Department.

Department staff will work expeditiously to review materials submitted to address deficiencies and to evaluate compliance of the revised GSP. The Department will keep a GSP status designated as incomplete during its review of the submitted materials. The Department could subsequently approve an incomplete GSP if the GSAs have taken corrective actions to address deficiencies identified by the Department within a period not to exceed 180 days from the determination. The Department could also issue a determination of inadequate for an incomplete GSP if the Department, after consultation with the State Water Resources Control Board, determines the GSAs have not taken sufficient actions to correct the deficiencies identified by the Department.

If you have any questions, please do not hesitate to contact the Sustainable Groundwater Management Office staff by emailing sgmps@water.ca.gov.

Thank you,

Paul Gosselin
Deputy Director for Sustainable Groundwater Management

Enclosure:

1. Potential Deficiencies and Corrective Actions

Potential Deficiencies and Corrective Actions

Department of Water Resources (Department) staff have identified deficiencies regarding the Eastern San Joaquin Subbasin (Subbasin) Groundwater Sustainability Plan (GSP) that may preclude the Department's approval. Therefore, consistent with the GSP Regulations, Department staff are considering corrective actions the Subbasin's groundwater sustainability agencies (GSAs) should review to determine whether and how the deficiencies can be addressed. The deficiencies and potential corrective actions are explained below, including the general regulatory background, the specific deficiencies identified in the GSP, and specific actions to address the deficiencies. The specific actions identified are potential corrective actions until the Department makes a final determination.

General Background

Potential deficiencies identified in the Eastern San Joaquin Subbasin GSP relate to the development and documentation of sustainable management criteria, including undesirable results and minimum thresholds that define when undesirable results may occur.

The Department's GSP Regulations describe several required elements of a GSP under the heading of "Sustainable Management Criteria"[6], including undesirable results, minimum thresholds, and measurable objectives. These components of sustainable management criteria must be quantified so that GSAs, the Department, and other interested parties can monitor progress towards sustainability in a basin consistently and objectively.

A GSA relies on local experience, public outreach and involvement, and information about the basin it has described in the GSP basin setting (i.e., the hydrogeologic conceptual model, the description of current and historical groundwater conditions, and the water budget), among other factors, to develop criteria for defining undesirable results and setting minimum thresholds and measurable objectives.[7]

The Sustainable Groundwater Management Act (SGMA) defines sustainable groundwater management as the management and use of groundwater in a manner that can be maintained during the planning and implementation horizon without causing undesirable results.[8] Avoidance of undesirable results is thus explicitly part of sustainable groundwater management as established by SGMA and critical to the success of a GSP.

The definition of undesirable results is critical to establishing an objective method to define and measure sustainability for a basin. As an initial matter, SGMA provides a

[6] 23 CCR § Article 5, Subarticle 3.
[7] 23 CCR §§ 354.8, 354.10, 354.12 *et seq*.
[8] Water Code § 10721(v).

qualitative definition of undesirable results as “one or more” of six specific “effects caused by groundwater conditions occurring throughout the basin.”[9]

GSAs define, in their GSPs, the specific significant and unreasonable effects that would constitute undesirable results and the groundwater conditions that would produce those results in their basins.[10] The GSAs’ definition must include a description of the processes and criteria relied upon to define undesirable results and describe the effect of undesirable results on the beneficial uses and users of groundwater, surface land uses (for subsidence), and surface water (for interconnected surface water).[11]

SGMA leaves the task of establishing undesirable results and setting thresholds largely to the discretion of the GSAs, subject to review by the Department. In its review, the Department requires a thorough and reasonable analysis of the groundwater conditions and the associated effects the GSAs must manage the groundwater basin to avoid, and the GSAs’ stated rationale for setting objective and quantitative sustainable management criteria to prevent those undesirable conditions from occurring.[12] If a GSP does not meet this requirement, the Department cannot evaluate the GSAs’ likelihood of achieving their sustainability goal. That does not necessarily mean that the GSP or its objectives are inherently unreasonable; rather, the Department cannot evaluate whether the GSP's implementation would successfully achieve sustainable management if it is unclear what undesirable conditions the GSAs seek to avoid.

Potential Deficiency 1. The GSP lacks sufficient justification for identifying that undesirable results for chronic lowering of groundwater levels, subsidence, and depletion of interconnected surface waters can only occur in consecutive non-dry water year types. The GSP also lacks sufficient explanation for its chronic lowering of groundwater levels minimum thresholds and undesirable results.

1 The first potential deficiency relates to the GSP’s requirement of two consecutive non-dry (i.e., below normal, above normal, or wet) water-year types and the exclusion of dry and critically dry water-year types in the identification of undesirable results for chronic lowering of groundwater levels, and, by proxy, land subsidence and depletions of interconnected surface water.

Background

Related to this potential deficiency, SGMA defines the term “Undesirable Result,” in part, as one or more of the following effects caused by groundwater conditions occurring throughout the basin:[13]

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[9] Water Code § 10721(x).
[10] California Department of Water Resources, Best Management Practices for the Sustainable Management of Groundwater: Sustainable Management Criteria (Draft), November 2017.
[11] 23 CCR §§ 354.26(b), 354.28(c)(5), 354.28(c)(6).
[12] 23 CCR § 355.4(b)(1).
[13] Water Code § 10721(x).

- Chronic lowering of groundwater levels indicating a significant and unreasonable depletion of supply if continued over the planning and implementation horizon. Overdraft during a period of drought is not sufficient to establish a chronic lowering of groundwater levels if extractions and groundwater recharge are managed as necessary to ensure that reductions in groundwater levels or storage during a period of drought are offset by increases in groundwater levels or storage during other periods.
- Significant and unreasonable land subsidence that substantially interferes with surface land uses.
- Depletions of interconnected surface water that have significant and unreasonable adverse impacts on beneficial uses of the surface water.

Potential Deficiency Details

Department staff identified two areas of concern, described below, which, if not addressed, may preclude approval of the GSP. Regarding the first area of concern, the GSP identifies that an undesirable result occurs "when at least 25 percent of representative monitoring wells used to monitor groundwater levels (5 of 20 wells in the Subbasin) fall below their minimum level thresholds for two consecutive years that are categorized as non-dry years (below-normal, above-normal, or wet), according to the San Joaquin Valley Water Year Hydrologic Classification." The GSP further states that "the lowering of groundwater levels during consecutive dry or critically-dry years is not considered to be unreasonable, and would therefore not be considered an undesirable result, unless the levels do not rebound to above the thresholds following those consecutive non-dry years."[14]

1.1 Department staff find that the water-year type requirement in the definition of the undesirable result for chronic lowering of groundwater levels (i.e., two consecutive non-dry years) is not consistent with the intent of SGMA. The water-year type requirement could potentially allow for unmanaged and continued lowering of groundwater levels under certain hydrologic or climatic conditions that have occurred historically. A review of historical San Joaquin Valley water-year type classifications[15] indicates the potential for dry periods without the occurrence of a second consecutive non-dry year to persist for greater than ten years (see, e.g., the 11 years from water years 1985 through 1995). Department staff also note that concurrent below normal, above normal, or wet years occurred in only five of the last twenty water years from 2001 through 2020. Because of this definition, GSAs in the Subbasin could disregard potential impacts of groundwater level declines below the minimum thresholds during extended periods of dry years, even if interrupted by normal or wet years.

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[14] ESJ GSP, p. 253.
[15] Chronological Reconstructed Sacramento and San Joaquin Valley Water Year Hydrologic Classification Indices, Water Year 1901 through 2020. California Department of Water Resources, https://cdec.water.ca.gov/reportapp/javareports?name=WSIHIST.

Department staff also find this methodology inconsistent with other portions of the GSP. For example, while describing measurable objectives for groundwater levels, the GSP states, "the margin of operational flexibility is intended to accommodate droughts, climate change, conjunctive use operations, or other groundwater management activities. The margin of operational flexibility is defined as the difference between the minimum threshold and the measurable objective."[16] Based on these statements, it appears the
1.2 minimum thresholds already accommodate drought conditions, so it is unclear why the GSP's definition of undesirable results further excludes minimum threshold exceedances during dry water years. (See Potential Corrective Action 1a.)

SGMA states that "overdraft during a period of drought is not sufficient to establish a chronic lowering of groundwater levels if extractions and groundwater recharge are
1.3 managed as necessary to ensure that reductions in groundwater levels or storage during a period of drought are offset by increases in groundwater levels or storage during other periods."[17] If the GSAs intended to incorporate this concept into their definition of the undesirable result for chronic lowering of groundwater levels, the GSP fails to identify specific extraction and groundwater recharge management actions the GSAs would implement[18] or otherwise describe how the Subbasin would be managed to offset, by increases in groundwater levels or storage during other periods, dry year reductions of groundwater storage. The GSP identifies many projects that, once implemented, may lead to the elimination of long-term overdraft conditions in the Subbasin. However, the GSP does not sufficiently detail how projects and management actions, in conjunction with the proposed chronic lowering of groundwater levels sustainable management criteria, will offset drought-related groundwater reductions and avoid significant and unreasonable impacts when groundwater level minimum thresholds are potentially exceeded for an extended period in the absence of two consecutive non-dry years. (See Potential Corrective Action 1b.)

As noted above, the GSP states that minimum thresholds developed for chronic lowering of groundwater levels serve as proxies for subsidence[19] and depletion of interconnected surface waters.[20] Therefore, Department staff assume the GSAs intend to apply the same water-year type criteria to undesirable results for those sustainability indicators (i.e., land subsidence or depletion of interconnected surface water undesirable results do not occur until groundwater levels exceed the thresholds for two consecutive non-dry water years). However, where SGMA acknowledges that groundwater level declines during drought
1.4 periods are not sufficient to cause an undesirable result for chronic lowering of groundwater levels, the statute does not similarly provide an exception for subsidence or stream depletion during periods of drought. (See Potential Corrective Action 1c.)

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[16] ESJ GSP, p. 259.
[17] Water Code § 10721(x)(1).
[18] 23 CCR § 354.44(b)(9).
[19] ESJ GSP, p. 270.
[20] ESJ GSP, p. 271.

2 Department staff's second area of concern is the GSP's evaluation of the effects of the proposed minimum thresholds and undesirable results on beneficial uses and users of groundwater. The GSP identifies that the chronic lowering of groundwater levels could cause undesirable results from wells going dry, reductions in pumping capacities, increased pumping costs, the need for deeper well installations or lowering of pumps, and adverse impacts to environmental uses and users.[21] The GSP builds an analysis of
2.1 domestic wells going dry into its minimum thresholds, thereby considering the factors of wells going dry and the need for deeper well installations. However, it does not address how the management criteria address the other factors identified by the GSAs as potential undesirable results, including reductions in pumping capacity or increased pumping costs for shallow groundwater users, or adverse impacts to environmental uses and users.

The GSAs set minimum thresholds in the Subbasin at the shallower of the 10th percentile domestic [or municipal] well depth or the historical low groundwater levels with a subtracted buffer value, which the GSP states allows for operational flexibility.[22] These minimum threshold values generally allow groundwater levels to decline below historic lows; minimum thresholds defined using the buffer value approach allow twice the historical drawdown from the shallowest recorded groundwater levels.[23] Aside from the
2.2 GSP's domestic well analysis, the only description of how minimum thresholds were evaluated to avoid undesirable results appears to be the statements that “for the majority of the Subbasin, GSA representatives identified no undesirable results, even if groundwater were to reach historical low groundwater levels” and that no GSA indicated undesirable results would occur “if the minimum threshold was set deeper than the [historic low] based on their understanding.”[24] The GSP provides no further explanation or description of how the individual GSAs concluded that there would be no undesirable results based on the minimum thresholds.

The GSP only considers an undesirable result to occur for groundwater levels in the Subbasin when at least 25 percent of representative monitoring wells (5 of 20 wells) fall below their minimum threshold value for two consecutive non-dry water years.[25] The GSP
2.3 does not justify or discuss how the GSAs developed the 25 percent threshold, nor does it explain or disclose the potential impacts anticipated during extended drier climate conditions using this threshold. In other words, the proposed management program may lead to potential effects on domestic wells or other beneficial uses and users during prolonged dry- or below-normal periods, and that information should, at a minimum, be disclosed and considered in the GSP. (See Potential Corrective Action 1d.)

If, after considering this potential deficiency, the GSAs retain minimum thresholds that allow for continued lowering of groundwater levels, it is reasonable to assume that some

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[21] ESJ GSP, p. 253.
[22] ESJ GSP, p. 254.
[23] ESJ GSP, p. 258.
[24] ESJ GSP, p. 255.
[25] ESJ GSP, p. 253.

groundwater well impacts (e.g., loss of production capacity) will occur during the implementation of the GSP. SGMA requires GSAs to consider the interests of all groundwater uses and users and to implement their GSPs to mitigate overdraft conditions.[26] Implementing specific projects and management actions prevents undesirable results and achieves the sustainable yield of the basin. The GSAs should
2.4 describe how projects and management actions would address drinking water impacts due to continued overdraft between the start of GSP implementation and the achievement of the sustainability goal. If the GSP does not include projects or management actions to address drinking water impacts, the GSP should contain a thorough discussion, with supporting facts and rationale, explaining how and why GSAs determined not to include actions to address those impacts from continued groundwater lowering below pre-SGMA levels. (See Potential Corrective Action 1e.)

Additionally, related to the groundwater level declines allowed for by the GSA's minimum
2.5 thresholds, the GSAs have not explained how those groundwater level declines relate to the degradation of groundwater quality sustainability indicator. GSAs must describe, among other items, the relationship between minimum thresholds for a given sustainability indicator (in this case, chronic lowering of groundwater levels) and the other sustainability indicators.[27] The GSAs generally commit to monitoring a wide range of water quality constituents but they have only developed sustainable management criteria for total dissolved solids because they state they have not observed a causal nexus between groundwater management and degradation associated with the other constituents. While Department staff are not aware of evidence sufficient to conclude that the GSAs acted unreasonably by focusing on total dissolved solids, it is clear that the GSAs did not consider, or at least did not document, the potential for degradation to occur due to further lowering of groundwater levels beyond the historic lows. (See Potential Corrective Action 1f.)

Potential Corrective Action 1

a) Department staff believe the management approach described in the GSP, which couples minimum thresholds and measurable objectives that account for operational flexibility during dry periods with a definition of undesirable results that disregards minimum threshold exceedances in all years except consecutive below normal, above normal, or wet years, to be inconsistent with the objectives of SGMA. Therefore, the GSAs should remove the water-year type requirement from the GSP's undesirable result definition.
b) The GSP should be revised to include specific projects and management actions the GSAs would implement to offset drought-year groundwater level declines.
c) The GSAs should thoroughly explain how their approach avoids undesirable results for subsidence and depletion of interconnected surface waters, as SGMA does not

[26] 23 CCR § 355.4(b)(4), 355.4(b)(6).
[27] 23 CCR § 354.28(b)(2).

include an allowance or exemption for those conditions to continue in periods of drought.

d) Removing the water-year type requirement from the definition of an undesirable result (item a, above) would result in a GSP with groundwater level minimum thresholds designed to be generally protective of 90 percent of domestic wells regardless of regional hydrologic conditions. In that scenario, the GSAs should explain the rationale for determining that groundwater levels can exceed those thresholds at 25 percent of monitoring sites for two consecutive years before the effects would be considered significant and unreasonable. The GSAs should also explain how other factors they identified as "potential undesirable results" (e.g., adverse impacts to environmental uses and users) factored into selecting minimum thresholds and describe anticipated effects of the thresholds on beneficial uses and users of groundwater. Furthermore, the GSAs should explain whether other drinking water users that may rely on shallow wells, such as public water systems and state small water systems, were considered in the GSAs' site-specific thresholds. If not, the GSAs should conduct outreach with those users and incorporate their shallow wells, as applicable, into the site-specific minimum thresholds and measurable objectives.

e) The GSAs should revise the GSP to describe how they would address drinking water impacts caused by continued overdraft during the period between the start of GSP implementation and achieving the sustainability goal. If the GSP does not include projects or management actions to address those impacts, the GSP should contain a thorough discussion, with supporting facts and rationale, explaining how and why the GSAs determined not to include specific actions to address drinking water impacts from continued groundwater lowering below pre-SGMA levels.

f) The GSP should be revised to explain how the GSAs will assess groundwater quality degradation in areas where further groundwater level decline, below historic lows, is allowed via the minimum thresholds. The GSAs should further describe how they will coordinate with the appropriate groundwater users, including drinking water, environmental, and irrigation users as identified in the GSP. The GSAs should also discuss efforts to coordinate with water quality regulatory agencies and programs in the Subbasin to understand and develop a process for determining if continued lowering of groundwater levels is resulting in degraded water quality in the Subbasin during GSP implementation.

Potential Deficiency 2. The GSP does not provide enough information to support the use of the chronic lowering of groundwater level sustainable management criteria and representative monitoring network as a proxy for land subsidence.

Background

The GSP Regulations state that minimum thresholds for land subsidence should identify the rate and extent of subsidence that substantially interferes with surface land uses and may lead to undesirable results. These quantitative values should be supported by: [28]

- The identification of land uses or property interests potentially affected by land subsidence;
- An explanation of how impacts to those land uses or property interests were considered when establishing minimum thresholds;
- Maps or graphs showing the rates and extents of land subsidence defined by the minimum thresholds.

The GSP Regulations allow the use of groundwater elevations as a proxy for land subsidence. However, GSAs must demonstrate a significant correlation between groundwater levels and land subsidence and must demonstrate that groundwater level minimum thresholds represent a reasonable proxy for avoiding land subsidence undesirable results. Additionally, the GSAs must demonstrate how the monitoring network is adequate to identify undesirable results for both metrics.

Potential Deficiency Details

3.1 Department staff find that the GSP does not adequately identify or define minimum thresholds and undesirable results for land subsidence. The GSP also does not provide adequate justification and explanation for using the groundwater level minimum thresholds and representative monitoring network as a proxy for land subsidence.

3.2 Generally, the GSP identifies that irrecoverable loss of groundwater storage and damage to infrastructure, including water conveyance facilities and flood control facilities, are potential impacts of land subsidence.[29] However, the GSP does not identify specific infrastructure locations, particularly those associated with public safety, in the Subbasin and the rate and extent of subsidence that would substantially interfere with those land surface uses and may lead to undesirable results. Additionally, without identifying infrastructure considered at risk for interference from land subsidence, Department staff cannot evaluate whether the groundwater level representative monitoring network is adequate to detect potential subsidence-related impacts.

3.3 Department staff find the GSP does not provide adequate evidence to demonstrate a significant correlation between groundwater levels and land subsidence in the Subbasin.

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[28] 23 CCR § 354.28(c)(5).
[29] ESJ GSP, p. 269.

Without explaining this correlation, the Department cannot evaluate whether the
groundwater level minimum thresholds and associated conditions required for identifying
an undesirable result would protect against significant and unreasonable impacts related
to land subsidence. The GSP states a significant correlation exists between groundwater
levels and land subsidence, with lowering groundwater levels driving further land
3.4 subsidence.[30] Department staff agree with this general statement. However, the GSP fails
to provide adequate evidence to evaluate further this correlation, specifically concerning
potential subsidence caused by groundwater levels falling below historic lows, as would
be allowed by the groundwater level minimum thresholds set in the GSP.

The GSP's justification for using the proposed groundwater level minimum thresholds as a proxy for land subsidence appears to rely mainly on an incomplete analysis and a data set with significant data gaps. The GSP states there are no historical records of significant and unreasonable land subsidence in the Subbasin.[31] The GSP also states that there is a lack of direct land subsidence monitoring in the Subbasin.[32] The GSP uses this absence of historical records to assert that historically dewatered geologic units are not compressible and, therefore, not at risk for land subsidence. Although groundwater level minimum thresholds are below historic lows, the GSP states that the GSAs do not expect further declines in groundwater levels to dewater materials deeper than 205 feet below ground surface (the deepest groundwater level minimum threshold value in the Subbasin).[33] The GSP states that subsurface materials encountered up to this depth are the same [non-compressible] geologic units that have been historically dewatered.

Department staff find multiple aspects of this justification speculative and not supported
3.5 by the best available science. First, the GSP presents no analysis of historic groundwater
levels or historically dewatered subsurface materials to support the conclusion that the
geologic units are not compressible. Second, the GSP does not provide an evaluation
3.6 showing how additional declines in groundwater levels would only affect subsurface
materials similar to those which have been historically dewatered. Third, the GSP is
3.7 unclear on whether the conditions required to identify an undesirable result for chronic
lowering of groundwater levels in the Subbasin are also required to identify an undesirable
result for land subsidence. Management proposed in the GSP could allow groundwater
level minimum thresholds to be exceeded in periods where two consecutive non-dry years
do not occur, which does not support the claim that only materials up to the deepest
groundwater level minimum threshold (205 feet below ground surface) will be dewatered.

Department staff note that the legislature intended that implementation of SGMA would avoid or minimize subsidence[34] once GSAs achieve the sustainability goal for a basin. Without analysis examining how allowable groundwater levels below those historically

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[30] ESJ GSP, p. 270.
[31] ESJ GSP, p. 269.
[32] ESJ GSP, p. 270.
[33] ESJ GSP, p. 270.
[34] Water Code § 10720.1(e).

experienced in the Subbasin may affect land subsidence, Department staff cannot determine if the GSP adequately avoids or minimizes land subsidence. While SGMA does not require prevention of all land subsidence, the GSP does not provide sufficient evidence to conclude that the proposed chronic lowering of groundwater level minimum thresholds are adequate to detect and avoid land subsidence undesirable results.

Potential Corrective Action 2

The GSAs must provide detailed information to demonstrate how the use of the chronic lowering of groundwater level minimum thresholds are sufficient as a proxy to detect and avoid significant and unreasonable land subsidence that substantially interferes with surface land uses. Alternatively, the GSAs could commit to utilizing direct monitoring for subsidence, e.g., with remotely sensed subsidence data provided by the Department. In that case, the GSAs should develop sustainable management criteria based on rates and extents of subsidence. Department staff suggest the GSAs consider and address the following issues:

1. The GSAs should revise the GSP to identify the total subsidence that critical infrastructure in the Subbasin can tolerate during GSP implementation. Support this identification with information on the effects of subsidence on land surface beneficial uses and users and the amount of subsidence that would substantially interfere with those uses and users.
2. The GSAs should revise the GSP to document a significant correlation between groundwater levels and specific amounts or rates of land subsidence. The analysis should account for potential subsidence related to groundwater level declines below historical lows and further declines that are allowed to exceed minimum thresholds (i.e., during non-consecutive non-dry years, if applicable based on the resolution to Potential Deficiency 1, above). This analysis should demonstrate that groundwater level declines allowed during GSP implementation are preventative of the rates and magnitudes of land subsidence considered significant and unreasonable based on the identified infrastructure of concern. If there is not sufficient data to establish a correlation, the GSAs should consider other options such as direct monitoring of land subsidence (e.g., remotely sensed data provided by the Department, extensometers, or GPS stations) until such time that the GSAs can establish a correlation.
3. The GSAs should explain how the groundwater level representative monitoring network is sufficient to detect significant and unreasonable subsidence that may substantially interfere with land uses, specifically any identified infrastructure of concern. If the groundwater level monitoring network alone is not adequate, based on specific infrastructure locations, Department staff suggest incorporating continued analysis of available InSAR data to cover areas with data gaps.

APPENDIX 4-A.
BROAD MONITORING NETWORK FOR GROUNDWATER LEVELS WELL INFORMATION

Local Well ID	CASGEM Site Code	Monitoring Agency*	Well Depth (ft.)	Screen Interval (ft.)
CASGEM Wells				
02S10E02P001M	377843N1208435W001	Stanislaus County	Unknown	Unknown
01S10E27Q001M	378138N1208591W001	Stanislaus County	234	118–158
CCWD 008	380867N1209233W001	CCWD	Unknown	Unknown
CCWD 002	381036N1208903W001	CCWD	260	Unknown
CCWD 009	381042N1209111W001	CCWD	240	140–240
CCWD 014	381511N1209406W001	CCWD	360	275–355
CCWD 017	381783N1208162W001	CCWD	67	51.5–66.5
CCWD 015	381986N1209661W001	CCWD	340	150–340
02S10E05N001M	377860N1209016W001	Stanislaus County	475	98–232
OID-17	378112N1208251W001	Stanislaus County	720	190–310
Searway Dom	378164N1206958W001	Stanislaus County	Unknown	Unknown
01S10E21A001M	378402N1208710W001	Stanislaus County	400	Unknown
01N10E32Q001M	378874N1208954W001	Stanislaus County	Unknown	Unknown
01N07E19G001M	379209N1212476W001	SJCFCWCD	185	165–185
Sonora Rd #5	378521N1207663W001	Stanislaus County	220	60–220
02S07E11N002M	377708N1211790W001	SJCFCWCD	79	50–79
01S09E29M002M	378189N1210150W001	SJCFCWCD	132	120–132
01S09E21J002M	378312N1209797W001	SJCFCWCD	223	195–223
01S08E14B001M	378562N1210588W001	SJCFCWCD	396	244–396
01S09E02R001M	378734N1209447W001	SJCFCWCD	280	127–280
01N09E29R001M	379039N1210005W001	SJCFCWCD	700	100–700
01N07E26H003M	379061N1211661W001	SJCFCWCD	194	160–194
01N09E30C005M	379133N1210282W001	SJCFCWCD	376	340–376
01N08E22J001M	379200N1210700W001	SJCFCWCD	250	190–250
01N08E16H002M	379367N1210944W001	SJCFCWCD	420	120–180
01N09E17M001M	379370N1210162W001	SJCFCWCD	345	204–345
01N08E16G001M	379381N1210983W001	SJCFCWCD	296	112–120
01N09E17D001M	379428N1210162W001	SJCFCWCD	220	99–220
01N08E11L001M	379472N1210711W001	SJCFCWCD	372	168–372
01N07E11L001M	379487N1211759W001	SJCFCWCD	356	196–204
02N07E32M002M	379782N1212375W001	SJCFCWCD	270	164–175
03N08E22A001M	381008N1210810W001	SJCFCWCD	700	100–700
03N07E23C002M	381016N1211791W001	SJCFCWCD	248	152–248
04N07E17N001M	381919N1212436W001	SJCFCWCD	290	100–290
04N05E13H001M	381990N1213727W001	SJCFCWCD	190	50–190
04N06E12N002M	382041N1212799W001	SJCFCWCD	320	104–320
04N05E10K001M	382107N1214297W001	SJCFCWCD	115	90–115
Lodi WSM 05	380799N1213850W001	SJCFCWCD	20	5-20
CCWD 003	380914N1209167W001	CCWD	300	240–300
Lodi WSM 15	380943N1213991W001	SJCFCWCD	20	5-20
Lodi WSM 10	380982N1213658W001	SJCFCWCD	40	20–40
CCWD 001	381042N1208903W001	CCWD	240	176–180
Lodi WSM 17	381160N1213339W001	SJCFCWCD	59	34–54
Lodi MW-11	381287N1212851W001	SJCFCWCD	55	40–55
C-1	380078N1211315W001	SJCFCWCD	480	440–480
Foothill MW-2R	380313N1209362W001	SJCFCWCD	300	240–280

Local Well ID	CASGEM Site Code	Monitoring Agency*	Well Depth (ft.)	Screen Interval (ft.)
Foothill MW-3	380362N1209379W001	SJCFCWCD	295	270.96–289.89
Foothill MW-1	380402N1209279W001	SJCFCWCD	215	190–210
DWS-IPS	380438N1214959W001	SJCFCWCD	90	70–90
Lodi WSM 13	380751N1213908W001	SJCFCWCD	20	5-20
Lodi RMW2	380794N1214137W001	SJCFCWCD	17	16.82–16.83
Lodi WSM 02	380877N1213898W001	SJCFCWCD	20	5-20
Lodi WSM 11	380880N1213523W001	SJCFCWCD	50	25–50
North G-6	380926N1211057W001	SJCFCWCD	168	138–158
North G-4	380943N1211057W001	SJCFCWCD	170	129.5–169.5
Harney MW-3	380951N1211370W001	SJCFCWCD	148	95–145
North G-3D	380960N1211057W001	SJCFCWCD	167	127.5–166.5
North G-1	380962N1210966W001	SJCFCWCD	160	130–160
Harney MW-4	380964N1211407W001	SJCFCWCD	144	88–135
North G-5	380971N1211057W001	SJCFCWCD	170	129.5–169.5
Harney MW-2	380982N1211333W001	SJCFCWCD	147	93–143
Lodi WSM 01	380986N1213869W001	SJCFCWCD	20	5-20
Harney MW-1	381024N1211355W001	SJCFCWCD	159	100–150
Lodi WSM 19	381130N1214087W001	SJCFCWCD	31	6-26
Lodi MW-19	381181N1212736W001	SJCFCWCD	73	58–73
Lodi MW-16	381211N1212856W001	SJCFCWCD	60	45–60
Lodi MW-13	381291N1212688W001	SJCFCWCD	62	47–62
Lodi MW-08	381338N1212785W001	SJCFCWCD	55	40–55
02S10E10M002M	377766N1208657W001	Stanislaus County	225	Unknown
01S10E34R001M	377985N1208524W001	Stanislaus County	Unknown	Unknown
01S10E26J001M	378163N1208321W001	Stanislaus County	Unknown	Unknown
OID-16	378088N1208895W001	Stanislaus County	280	55–72
OID-5	378130N1209240W001	Stanislaus County	502	120–245
01S10E19L001M	378332N1209185W001	Stanislaus County	390	60–68
Sonora Rd #8	378589N1207522W001	Stanislaus County	155	90–155
Olive #2	377952N1207505W001	Stanislaus County	575	292–312
Local Wells				
Well 1	n/a	SJ County Flag City	170	120–170
Well 2	n/a	SJ County Flag City	180	130–180
Well 3	n/a	SJ County Flag City	Unknown	Unknown
Stockton 10R	n/a	City of Stockton	277	177–277
Stockton 28	n/a	City of Stockton	278	178–278
Stockton SSS8	n/a	City of Stockton	277	177–277
Manteca 15	n/a	City of Manteca	265	140–265
Manteca 16	n/a	City of Manteca	304	137–294
Manteca 17	n/a	City of Manteca	372	110–362
119-075-01	n/a	Cal Water	310	176–276
119-059-01	n/a	Cal Water	520	169–269
119-069-01	n/a	Cal Water	530	180–280
Lodi Well #5	n/a	City of Lodi	230	Unknown
Lodi Well #7	n/a	City of Lodi	422	Unknown
Lodi Well #11R	n/a	City of Lodi	465	140–462

Local Well ID	CASGEM Site Code	Monitoring Agency*	Well Depth (ft.)	Screen Interval (ft.)
Clustered and/or Nested Wells				
CCWD 004	381272N1209322W001	CCWD	435	415-435
CCWD 005	381272N1209322W002	CCWD	365	355-365
CCWD 006	381272N1209322W003	CCWD	230	210-230
CCWD 007	381272N1209322W004	CCWD	110	90-110
CCWD 010	381628N1209292W001	CCWD	390	370-390
CCWD 011	381628N1209292W002	CCWD	350	250-270
CCWD 012	381628N1209292W003	CCWD	135	115-135
Sperry-1	378972N1212936W001	SJCFCWCD	460	440-460
Sperry-2	378972N1212936W002	SJCFCWCD	282	262-282
Sperry-3	378972N1212936W003	SJCFCWCD	124	114-124
STK-7.1	379814N1212031W001	SJCFCWCD	665	545-565
STK-7.2	379814N1212031W002	SJCFCWCD	435	415-435
STK-7.3	379814N1212031W003	SJCFCWCD	305	270-295
STK-7.4	379814N1212031W004	SJCFCWCD	183	145-165
STK-4-1	379815N1212032W001	SJCFCWCD	560	540-560
STK-4-2	379815N1212032W002	SJCFCWCD	360	340-360
STK-4-3	379600N1213136W001	SJCFCWCD	220	200-220
STK6-1	379949N1213426W001	SJCFCWCD	618	540-560
STK6-2	379949N1213426W002	SJCFCWCD	470	450-470
STK6-3	379949N1213426W003	SJCFCWCD	260	240-260
STK2-1	380561N1212772W001	SJCFCWCD	635	615-635
STK2-2	380292N1212772W001	SJCFCWCD	540	520-540
STK2-3	380561N1212772W002	SJCFCWCD	300	280-300
STK2-4	380561N1212772W003	SJCFCWCD	220	200-220
Lodi SMW-1A	381147N1212722W001	SJCFCWCD	115	105-115
Lodi SMW-1B	381147N1212722W002	SJCFCWCD	210	200-210
Lodi WMW-2A	381164N1212792W001	SJCFCWCD	189	179-189
Lodi WMW-2B	381164N1212792W002	SJCFCWCD	214	204-214
Lodi WMW-2C	381164N1212792W003	SJCFCWCD	241	231-241
Lodi WMW-2D	381164N1212792W004	SJCFCWCD	293	283-293
Lodi WMW-1A	381203N1212787W001	SJCFCWCD	150	140-150
Lodi WMW-1B	381203N1212787W002	SJCFCWCD	205	195-205
Lodi WMW-1C	381203N1212787W003	SJCFCWCD	242	232-242
Lodi MW-21A	381227N1212718W001	SJCFCWCD	76	66-76
Lodi MW-21B	381227N1212718W002	SJCFCWCD	102	92-102
Lodi MW-21C	381227N1212718W003	SJCFCWCD	128	118-128
Lodi MW-24A	381269N1212711W001	SJCFCWCD	70	60-70
Lodi MW-24B	381269N1212711W002	SJCFCWCD	106	95.5-105.5
Lodi MW-24C	381269N1212711W003	SJCFCWCD	124	114-124
Lodi MW-25B	381292N1212757W001	SJCFCWCD	96	86-96
Lodi MW-25C	381292N1212757W002	SJCFCWCD	158	148-158
STK5-1	382476N1213481W001	SJCFCWCD	580	560-580
STK5-2	380292N1213481W001	SJCFCWCD	430	410-430
STK5-3	380292N1213481W002	SJCFCWCD	230	210-230
STK1-1	385330N1213710W001	SJCFCWCD	880	860-880
STK1-2	385330N1213710W003	SJCFCWCD	540	520-540

Local Well ID	CASGEM Site Code	Monitoring Agency*	Well Depth (ft.)	Screen Interval (ft.)
STK1-3	385330N1213710W004	SJCFCWCD	380	360-380
STK1-4	385330N1213710W005	SJCFCWCD	240	220-240
STK1-5	385330N1213710W002	SJCFCWCD	68	58-68
Swenson-1	380067N1213458W001	SJCFCWCD	502	482-502
Swenson-2	380067N1213458W002	SJCFCWCD	314	294-314
Swenson-3	380067N1213458W003	SJCFCWCD	204	194-204

* CCWD = Calaveras County Water District
SJ County Flag City = San Joaquin County Flag City
SJCFCWCD = San Joaquin County Flood Control and Water Conservation District

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APPENDIX 5-A.
LIST OF DMS DATA TYPES

Data Type	Parameter	Unit
Groundwater Level	Depth to Groundwater	feet
Groundwater Level	Groundwater Elevation	feet
Groundwater Quality	1,1,1-Trichloroethane (111-TCA)	micrograms per liter
Groundwater Quality	1,2,3-Trichloropropane (123-TCP)	micrograms per liter
Groundwater Quality	Aggressiveness Index	-
Groundwater Quality	Aluminum	micrograms per liter
Groundwater Quality	Antimony	micrograms per liter
Groundwater Quality	Apparent Color	-
Groundwater Quality	Arsenic	micrograms per liter
Groundwater Quality	Arsenic	micrograms per liter
Groundwater Quality	Arsenic	picocuries per liter
Groundwater Quality	Barium	parts per billion
Groundwater Quality	Barium	micrograms per liter
Groundwater Quality	Benzene	micrograms per liter
Groundwater Quality	Beryllium	micrograms per liter
Groundwater Quality	Bicarbonate (HCO3)	milligrams per liter
Groundwater Quality	Boron	micrograms per liter
Groundwater Quality	Cadmium	micrograms per liter
Groundwater Quality	Calcium	parts permillion
Groundwater Quality	Calcium	milligrams per liter
Groundwater Quality	Carbonate (CO3)	milligrams per liter
Groundwater Quality	Chloride	milligrams per liter
Groundwater Quality	Chloride	milligrams per liter
Groundwater Quality	Chloride	parts permillion
Groundwater Quality	Chlorine	milligrams per liter
Groundwater Quality	Chromium	parts per billion
Groundwater Quality	Chromium	micrograms per liter
Groundwater Quality	Conductivity @ 25C	micromhos per centimeter
Groundwater Quality	Copper	parts per billion
Groundwater Quality	Copper	micrograms per liter
Groundwater Quality	Corrosivity	-
Groundwater Quality	Cyanide	micrograms per liter
Groundwater Quality	Dibromochloropropane (DBCP)	micrograms per liter
Groundwater Quality	Fluoride	parts permillion
Groundwater Quality	Fluoride	milligrams per liter
Groundwater Quality	Gross Alpha Activity	picocuries per liter
Groundwater Quality	Hardness	parts permillion
Groundwater Quality	Hexavalaent Chromium (CR6)	micrograms per liter
Groundwater Quality	Hexavalaent Chromium(CR6)	micrograms per liter
Groundwater Quality	Hydroxide (OH)	milligrams per liter

Data Type	Parameter	Unit
Groundwater Quality	Iron	micrograms per liter
Groundwater Quality	Laboratory pH	-
Groundwater Quality	Laboratory Turbidity	nephelometric turbidity unit
Groundwater Quality	Lead	micrograms per liter
Groundwater Quality	Magensium	parts permillion
Groundwater Quality	Magnesium	milligrams per liter
Groundwater Quality	Manganese	micrograms per liter
Groundwater Quality	Mercury	micrograms per liter
Groundwater Quality	Methyl Tertiary Butyl Ether (MTBE)	micrograms per liter
Groundwater Quality	Methylene Active Blue Substances	milligrams per liter
Groundwater Quality	Nickel	micrograms per liter
Groundwater Quality	Nitrate (as N)	milligrams per liter
Groundwater Quality	Nitrate (as N)	parts permillion
Groundwater Quality	Nitrate (as N)	micrograms per liter
Groundwater Quality	Nitrate (as N)O4	milligrams per liter
Groundwater Quality	Nitrate (as N)O5	milligrams per liter
Groundwater Quality	Nitrate (as N)O6	milligrams per liter
Groundwater Quality	Nitrate (NO3)	milligrams per liter
Groundwater Quality	Odor Threshold (60'C)	-
Groundwater Quality	Perchlorate	micrograms per liter
Groundwater Quality	Perchlorate	micrograms per liter
Groundwater Quality	Potassium	parts permillion
Groundwater Quality	Potassium	milligrams per liter
Groundwater Quality	Selenium	micrograms per liter
Groundwater Quality	Silver	micrograms per liter
Groundwater Quality	Sodium	parts permillion
Groundwater Quality	Sodium	milligrams per liter
Groundwater Quality	Specific Conductance	microohmns
Groundwater Quality	Specific Conductance	micromhos per centimeter
Groundwater Quality	Specific Electrical Conductivity (SC)	UMHOS/CM
Groundwater Quality	Specific Electrical Conductivity (SC)	micromhos per centimeter
Groundwater Quality	Sulfate	parts permillion
Groundwater Quality	Sulfate	milligrams per liter
Groundwater Quality	Tetrachloroethylene (PCE)	micrograms per liter
Groundwater Quality	Thallium	micrograms per liter
Groundwater Quality	Total Alkalinity	parts permillion
Groundwater Quality	Total Alkalinity (CaCO3)	milligrams per liter
Groundwater Quality	Total ANIONS, meq/L	micromhos per centimeter

Data Type	Parameter	Unit
Groundwater Quality	Total ANIONS, meq/L	micromhos per centimeter
Groundwater Quality	Total ANIONS, meq/L	micromhos per centimeter
Groundwater Quality	Total CATIONS, meq/L	micromhos per centimeter
Groundwater Quality	Total CATIONS, meq/L	micromhos per centimeter
Groundwater Quality	Total Dissolved Solids (TDS)	milligrams per liter
Groundwater Quality	Total Dissolved Solids (TDS)	milligrams per liter
Groundwater Quality	Total Hardness (calc.)	milligrams per liter
Groundwater Quality	Total Trihalomethanes (TTHM)	parts per billion
Groundwater Quality	Trichloroethylene (TCE)	micrograms per liter
Groundwater Quality	Turbidity	-
Groundwater Quality	Uranium	picocuries per liter
Groundwater Quality	Vanadium	parts per billion
Groundwater Quality	Vanadium	micrograms per liter
Groundwater Quality	Zinc	micrograms per liter
Precipitation	Average Air Temperature	°F
Precipitation	Precipitation	inches
Precipitation	Reference Evapotranspiration (ETo)	Inches permonth
Streamflow	Streamflow	cubic feet per second
Surface Water Quality	(E)-Dimethomorph,water,filtered, recoverable	micrograms per liter
Surface Water Quality	(Z)-Dimethomorph,water,filtered, recoverable	micrograms per liter
Surface Water Quality	1,1,1-Trichloroethane,water,unfiltered,recoverable	micrograms per liter
Surface Water Quality	1,1,2,2-Tetrachloroethane,water,unfiltered,recoverable	micrograms per liter
Surface Water Quality	1,1,2-Trichloroethane,water,unfiltered,recoverable	micrograms per liter
Surface Water Quality	1,1-Dichloroethane,water,unfiltered,recoverable	micrograms per liter
Surface Water Quality	1,1-Dichloroethene,water,unfiltered,recoverable	micrograms per liter
Surface Water Quality	1,2,4-Trichlorobenzene,bed sediment smaller than 2 millimeters,wet sieved (native water),field,recoverable,dry weight	micrograms per kilogram
Surface Water Quality	1,2-Dibromoethene, water, unfiltered, recoverable	micrograms per liter
Surface Water Quality	1,2-Dichlorobenzene, water, unfiltered, recoverable	micrograms per liter
Surface Water Quality	1,2-Dichlorobenzene,bed sediment smaller than 2 millimeters,wet sieved (native water),field,recoverable,dry weight	micrograms per kilogram
Surface Water Quality	1,2-Dichloroethane,water,unfiltered,recoverable	micrograms per liter
Surface Water Quality	1,2-Dichloropropane,water,unfiltered,recoverable	micrograms per liter
Surface Water Quality	1,2-Dimethylnaphthalene,bed sediment smaller than 2 millimeters,wet sieved (native water),field,recoverable,dry weight	micrograms per kilogram
Surface Water Quality	1,3-Dichlorobenzene, water, unfiltered, recoverable, micrograms per liter	micrograms per liter
Surface Water Quality	1,3-Dichlorobenzene,bed sediment smaller than 2 millimeters,wet sieved (native water),field,recoverable,dry weight	micrograms per kilogram

Data Type	Parameter	Unit
Surface Water Quality	1,3-Dichloropropene,water,unfiltered,recoverable	micrograms per liter
Surface Water Quality	1,4-Dichlorobenzene, water, unfiltered, recoverable	micrograms per liter
Surface Water Quality	1,4-Dichlorobenzene,bed sediment smaller than 2 millimeters,wet sieved (native water),field,recoverable,dry weight	micrograms per kilogram
Surface Water Quality	1,4-Naphthoquinone,water,filtered,recoverable	micrograms per liter
Surface Water Quality	1,6-Dimethylnaphthalene,bed sediment smaller than 2 millimeters,wet sieved (native water),field,recoverable,dry weight	micrograms per kilogram
Surface Water Quality	1-Methyl-9H-fluorene,bed sediment smaller than 2 millimeters,wet sieved (native water),field,recoverable,dry weight	micrograms per kilogram
Surface Water Quality	1-Methylphenanthrene,bed sediment smaller than 2 millimeters,wet sieved (native water),field,recoverable,dry weight	micrograms per kilogram
Surface Water Quality	1-Methylpyrene,bed sediment smaller than 2 millimeters,wet sieved (native water),field,recoverable,dry weight	micrograms per kilogram
Surface Water Quality	1-Naphthol,water,filtered (0.7 micron glass fiber filter),recoverable	micrograms per liter
Surface Water Quality	2-(4-tert-Butylphenoxy)-cyclohexanol,water,filtered,recoverable	micrograms per liter
Surface Water Quality	2, 4-DB,water,filtered (0.7 micron glass fiber filter),recoverable	micrograms per liter
Surface Water Quality	2,2-Biquinoline,bed sediment smaller than 2 millimeters,wet sieved (native water),field,recoverable,dry weight	micrograms per kilogram
Surface Water Quality	2,3,6-Trimethylnaphthalene,bed sediment smaller than 2 millimeters,wet sieved (native water),field,recoverable,dry weight	micrograms per kilogram
Surface Water Quality	2,4,5-T,bed sediment,recoverable,dry weight	micrograms per kilogram
Surface Water Quality	2,4,5-T,surrogate,Schedule 9060/2060, water, filtered	percent recovery
Surface Water Quality	2,4,5-T,water,filtered,recoverable	micrograms per liter
Surface Water Quality	2,4,5-T,water,unfiltered,recoverable	micrograms per liter
Surface Water Quality	2,4-D,bed sediment,recoverable,dry weight	micrograms per kilogram
Surface Water Quality	2,4-D,water,filtered,recoverable	micrograms per liter
Surface Water Quality	2,4-D,water,unfiltered,recoverable	micrograms per liter
Surface Water Quality	2,4-Dinitrotoluene,bed sediment smaller than 2 millimeters,wet sieved (native water),field,recoverable,dry weight	micrograms per kilogram
Surface Water Quality	2,5-Dichloroaniline,water,filtered,recoverable	micrograms per liter
Surface Water Quality	2,6-Diethylaniline,water,filtered (0.7 micron glass fiber filter),recoverable	micrograms per liter
Surface Water Quality	2,6-Dimethylnaphthalene,bed sediment smaller than 2 millimeters,wet sieved (native water),field,recoverable,dry weight	micrograms per kilogram
Surface Water Quality	2,6-Dinitrotoluene,bed sediment smaller than 2 millimeters,wet sieved (native water),field,recoverable,dry weight	micrograms per kilogram
Surface Water Quality	2-[(2-Ethyl-6-methylphenyl)amino]-1-propanol,water,filtered,recoverable	micrograms per liter
Surface Water Quality	2-Amino-N-isopropylbenzamide,water,filtered,recoverable	micrograms per liter
Surface Water Quality	2-Chloro-2 6-diethylacetanilide,water,filtered,recoverable	micrograms per liter
Surface Water Quality	2-Chloro-4-isopropylamino-6-amino-s-triazine,water,filtered,recoverable	micrograms per liter
Surface Water Quality	2-Chloro-6-ethylamino-4-amino-s-triazine,water,filtered,recoverable	micrograms per liter

Data Type	Parameter	Unit
Surface Water Quality	2-Chloroethyl vinyl ether,water,unfiltered,recoverable	micrograms per liter
Surface Water Quality	2-Chloronaphthalene,bed sediment smaller than 2 millimeters,wet sieved (native water),field,recoverable,dry weight	micrograms per kilogram
Surface Water Quality	2-Chlorophenol,bed sediment smaller than 2 millimeters,wet sieved (native water),field,recoverable,dry weight	micrograms per kilogram
Surface Water Quality	2-Ethyl-6-methylaniline,water,filtered,recoverable	micrograms per liter
Surface Water Quality	2-Ethylnaphthalene,bed sediment smaller than 2 millimeters,wet sieved (native water),field,recoverable,dry weight	micrograms per kilogram
Surface Water Quality	2-Fluorobiphenyl,surrogate,bed sediment smaller than 2 millimeters, wet sieved (native water), field	percent recovery
Surface Water Quality	2-Hydroxy-4-isopropylamino-6-ethylamino-s-triazine,water,filtered,recoverable	micrograms per liter
Surface Water Quality	2-Methyl-4,6-dinitrophenol,water,filtered (0.7 micron glass fiber filter),recoverable	micrograms per liter
Surface Water Quality	2-Methylanthracene,bed sediment smaller than 2 millimeters,wet sieved (native water),field,recoverable,dry weight	micrograms per kilogram
Surface Water Quality	3-(Trifluoromethyl)aniline,water,filtered,recoverable	micrograms per liter
Surface Water Quality	3,4-Dichloroaniline,water,filtered,recoverable	micrograms per liter
Surface Water Quality	3,5-Dichloroaniline,water,filtered,recoverable	micrograms per liter
Surface Water Quality	3,5-Dimethylphenol,bed sediment smaller than 2 millimeters,wet sieved (native water),field,recoverable,dry weight	micrograms per kilogram
Surface Water Quality	3-Hydroxy carbofuran,water,filtered (0.7 micron glass fiber filter),recoverable	micrograms per liter
Surface Water Quality	3-Nitrotoluene,water,filtered (0.7 micron glass fiber filter),recoverable	micrograms per liter
Surface Water Quality	3-Phenoxybenzyl alcohol,water,filtered,recoverable	micrograms per liter
Surface Water Quality	4-(Hydroxymethyl) pendimethalin,water,filtered,recoverable	micrograms per liter
Surface Water Quality	4,4-Dichlorobenzophenone,water,filtered,recoverable	micrograms per liter
Surface Water Quality	4-Bromophenyl phenyl ether,bed sediment smaller than 2 millimeters,wet sieved (native water),field,recoverable,dry weight	micrograms per kilogram
Surface Water Quality	4-Chloro-2-methylphenol,water,filtered,recoverable	micrograms per liter
Surface Water Quality	4-Chloro-3-methylphenol,bed sediment smaller than 2 millimeters,wet sieved (native water),field,recoverable,dry weight	micrograms per kilogram
Surface Water Quality	4-Chlorophenyl methyl sulfone,water,filtered,recoverable	micrograms per liter
Surface Water Quality	4-Chlorophenyl phenyl ether,bed sediment smaller than 2 millimeters,wet sieved (native water),field,recoverable,dry weight	micrograms per kilogram
Surface Water Quality	4H-Cyclopenta[def]phenanthrene,bed sediment smaller than 2 millimeters,wet sieved (native water),field,recoverable,dry weight	micrograms per kilogram
Surface Water Quality	9,10-Anthraquinone,bed sediment smaller than 2 millimeters,wet sieved (native water),field,recoverable,dry weight	micrograms per kilogram
Surface Water Quality	9H-Fluorene,bed sediment smaller than 2 millimeters,wet sieved (native water),field,recoverable,dry weight	micrograms per kilogram
Surface Water Quality	Acenaphthene,bed sediment smaller than 2 millimeters,wet sieved (native water),field,recoverable,dry weight	micrograms per kilogram
Surface Water Quality	Acenaphthylene,bed sediment smaller than 2 millimeters,wet sieved (native water),field,recoverable,dry weight	micrograms per kilogram

Data Type	Parameter	Unit
Surface Water Quality	Acetochlor oxanilic acid,water,filtered (0.7 micron glass fiber filter),recoverable	micrograms per liter
Surface Water Quality	Acetochlor sulfonic acid,water,filtered (0.7 micron glass fiber filter),recoverable	micrograms per liter
Surface Water Quality	Acetochlor,water,filtered, recoverable	micrograms per liter
Surface Water Quality	Acid neutralizing capacity,water,unfiltered, inflection-point titration method (incremental titration method)	milligrams per liter as calcium carbonate
Surface Water Quality	Acid neutralizing capacity,water,unfiltered,fixed endpoint (pH 4.5) titration	milligrams per liter as calcium carbonate
Surface Water Quality	Acid neutralizing capacity,water,unfiltered,fixed endpoint (pH 4.5) titration, laboratory	milligrams per liter as calcium carbonate
Surface Water Quality	Acifluorfen,water,filtered (0.7 micron glass fiber filter),recoverable	micrograms per liter
Surface Water Quality	Acridine,bed sediment smaller than 2 millimeters,wet sieved (native water),field,recoverable,dry weight	micrograms per kilogram
Surface Water Quality	Agency analyzing sample	code
Surface Water Quality	Alachlor oxanilic acid,water,filtered (0.7 micron glass fiber filter),recoverable	micrograms per liter
Surface Water Quality	Alachlor sulfonic acid,water,filtered (0.7 micron glass fiber filter),recoverable	micrograms per liter
Surface Water Quality	Alachlor, water, unfiltered, recoverable	micrograms per liter
Surface Water Quality	Alachlor,water,filtered,recoverable	micrograms per liter
Surface Water Quality	Aldicarb sulfone,water,filtered (0.7 micron glass fiber filter),recoverable	micrograms per liter
Surface Water Quality	Aldicarb sulfoxide,water,filtered (0.7 micron glass fiber filter),recoverable	micrograms per liter
Surface Water Quality	Aldicarb,water,filtered (0.7 micron glass fiber filter),recoverable	micrograms per liter
Surface Water Quality	Aldrin,bed sediment smaller than 2 millimeters,wet sieved (native water),field,recoverable,dry weight	micrograms per kilogram
Surface Water Quality	Aldrin,bed sediment,recoverable,dry weight	micrograms per kilogram
Surface Water Quality	Aldrin,water,unfiltered,recoverable	micrograms per liter
Surface Water Quality	Alkalinity,water,filtered, inflection-point titration method (incremental titration method), field	milligrams per liter as calcium carbonate
Surface Water Quality	Alkalinity,water,filtered,Gran titration, field	milligrams per liter as calcium carbonate
Surface Water Quality	Allethrin,bed sediment,recoverable,dry weight	micrograms per kilogram
Surface Water Quality	Allethrin,suspended sediment,recoverable,dry weight	micrograms per kilogram
Surface Water Quality	alpha-Endosulfan, water, unfiltered, recoverable	micrograms per liter
Surface Water Quality	alpha-Endosulfan,bed sediment smaller than 2 millimeters,wet sieved (native water),field,recoverable,dry weight	micrograms per kilogram
Surface Water Quality	alpha-Endosulfan,bed sediment,recoverable,dry weight	micrograms per kilogram
Surface Water Quality	alpha-Endosulfan,water,filtered,recoverable	micrograms per liter
Surface Water Quality	alpha-HCH,bed sediment smaller than 2 millimeters,wet sieved (native water),field,recoverable,dry weight	micrograms per kilogram

Data Type	Parameter	Unit
Surface Water Quality	alpha-HCH,water,filtered,recoverable	micrograms per liter
Surface Water Quality	alpha-HCH-d6,surrogate,bed sediment smaller than 2 millimeters, wet sieved (native water), field	percent recovery
Surface Water Quality	alpha-HCH-d6,surrogate,Schedule 2002/9002,water,unfiltered	percent recovery
Surface Water Quality	alpha-HCH-d6,surrogate,Schedule 2003, water, filtered	percent recovery
Surface Water Quality	alpha-HCH-d6,surrogate,water,filtered (0.7 micron glass fiber filter)	percent recovery
Surface Water Quality	Aluminum,bed sediment smaller than 62.5 microns,wet sieved, filed, total digestion, dry weight	percent
Surface Water Quality	Aluminum,bed sediment,recoverable, dry weight	milligrams per kilogram
Surface Water Quality	Aluminum,suspended sediment,recoverable	micrograms per liter
Surface Water Quality	Aluminum,water,filtered	micrograms per liter
Surface Water Quality	Aluminum,water,recoverable, dry weight	micrograms per liter
Surface Water Quality	Ametryn,water,unfiltered,recoverable	micrograms per liter
Surface Water Quality	Aminomethylphosphonic acid,water,filtered (0.7 micron glass fiber filter),recoverable	micrograms per liter
Surface Water Quality	Ammonia plus organic nitrogen,water,filtered	milligrams per liter as nitrogen
Surface Water Quality	Ammonia plus organic nitrogen,water,unfiltered	milligrams per liter as nitrogen
Surface Water Quality	Ammonia,water,filtered	milligrams per liter as nitrogen
Surface Water Quality	Ammonia,water,filtered	milligrams per liter as NH4
Surface Water Quality	Ammonia,water,unfiltered	milligrams per liter as nitrogen
Surface Water Quality	Ammonia,water,unfiltered	milligrams per liter as NH4
Surface Water Quality	Analytical reference number,Schedule 2501	
Surface Water Quality	Anthracene,bed sediment smaller than 2 millimeters,wet sieved (native water),field,recoverable,dry weight	micrograms per kilogram
Surface Water Quality	Antimony,bed sediment smaller than 62.5 microns,wet sieved, filed, total digestion, dry weight	milligrams per kilogram
Surface Water Quality	Arsenic,bed sediment smaller than 62.5 microns,wet sieved, filed, total digestion, dry weight	milligrams per kilogram
Surface Water Quality	Arsenic,bed sediment,total digestion, dry weight	milligrams per kilogram
Surface Water Quality	Arsenic,suspended sediment,total	micrograms per liter
Surface Water Quality	Arsenic,water,filtered	micrograms per liter
Surface Water Quality	Arsenic,water,unfiltered	micrograms per liter
Surface Water Quality	Atrazine,water,filtered,recoverable	micrograms per liter
Surface Water Quality	Atrazine,water,unfiltered,recoverable	micrograms per liter
Surface Water Quality	Azinphos-methyl oxygen analog,water,filtered,recoverable	micrograms per liter
Surface Water Quality	Azinphos-methyl,water,filtered (0.7 micron glass fiber filter),recoverable	micrograms per liter
Surface Water Quality	Azobenzene,bed sediment smaller than 2 millimeters,wet sieved (native water),field,recoverable,dry weight	micrograms per kilogram

Data Type	Parameter	Unit
Surface Water Quality	Barban,surrogate,Schedules 2060/9060, water, filtered	percent recovery
Surface Water Quality	Barium,bed sediment smaller than 62.5 microns,wet sieved, filed, total digestion, dry weight	milligrams per kilogram
Surface Water Quality	Barium,bed sediment,recoverable, dry weight	milligrams per kilogram
Surface Water Quality	Barium,suspended sediment,recoverable	micrograms per liter
Surface Water Quality	Barium,water,filtered	micrograms per liter
Surface Water Quality	Barium,water,unfiltered,recoverable	micrograms per liter
Surface Water Quality	Barometric pressure	millimeters ofmercury
Surface Water Quality	BDMC,surrogate,water, unfiltered	percent recovery
Surface Water Quality	Bed sediment,sieve diameter	percent smaller than 0.0625millimeters
Surface Water Quality	Bed sediment,sieve diameter	percent smaller than 0.125millimeters
Surface Water Quality	Bed sediment,sieve diameter	percent smaller than 0.25millimeters
Surface Water Quality	Bed sediment,sieve diameter	percent smaller than 0.5millimeters
Surface Water Quality	Bed sediment,sieve diameter	percent smaller than 1millimeter
Surface Water Quality	Bed sediment,sieve diameter	percent smaller than 2millimeters
Surface Water Quality	Bed sediment,sieve diameter	percent smaller than 4millimeters
Surface Water Quality	Bed sediment,sieve diameter	percent smaller than 8millimeters
Surface Water Quality	Bendiocarb,water,filtered,recoverable	micrograms per liter
Surface Water Quality	Benfluralin,water,filtered (0.7 micron glass fiber filter),recoverable	micrograms per liter
Surface Water Quality	Benomyl,water,filtered,recoverable	micrograms per liter
Surface Water Quality	Bensulfuron-methyl,water,filtered,recoverable	micrograms per liter
Surface Water Quality	Bentazon,water,filtered (0.7 micron glass fiber filter),recoverable	micrograms per liter
Surface Water Quality	Benzene,water,unfiltered,recoverable	micrograms per liter
Surface Water Quality	Benzo[a]anthracene,bed sediment smaller than 2 millimeters,wet sieved (native water),field,recoverable,dry weight	micrograms per kilogram
Surface Water Quality	Benzo[a]pyrene,bed sediment smaller than 2 millimeters,wet sieved (native water),field,recoverable,dry weight	micrograms per kilogram
Surface Water Quality	Benzo[b]fluoranthene,bed sediment smaller than 2 millimeters,wet sieved (native water),field,recoverable,dry weight	micrograms per kilogram
Surface Water Quality	Benzo[c]cinnoline,bed sediment smaller than 2 millimeters,wet sieved (native water),field,recoverable,dry weight	micrograms per kilogram
Surface Water Quality	Benzo[ghi]perylene,bed sediment smaller than 2 millimeters,wet sieved (native water),field,recoverable,dry weight	micrograms per kilogram
Surface Water Quality	Benzo[k]fluoranthene,bed sediment smaller than 2 millimeters,wet sieved (native water),field,recoverable,dry weight	micrograms per kilogram
Surface Water Quality	Benzyl n-butyl phthalate,bed sediment smaller than 2 millimeters,wet sieved (native water),field,recoverable,dry weight	micrograms per kilogram

Data Type	Parameter	Unit
Surface Water Quality	Beryllium,bed sediment smaller than 62.5 microns,wet sieved, filed, total digestion, dry weight	milligrams per kilogram
Surface Water Quality	Beryllium,bed sediment,recoverable, dry weight	milligrams per kilogram
Surface Water Quality	Beryllium,water,filtered	micrograms per liter
Surface Water Quality	Beryllium,water,unfiltered,recoverable	micrograms per liter
Surface Water Quality	beta-Endosulfan,water,filtered,recoverable	micrograms per liter
Surface Water Quality	beta-HCH,bed sediment smaller than 2 millimeters,wet sieved (native water),field,recoverable,dry weight	micrograms per kilogram
Surface Water Quality	Bicarbonate,water,filtered,inflection-point titration method (incremental titration method)	milligrams per liter
Surface Water Quality	Bicarbonate,water,unfiltered,fixed endpoint (pH 4.5) titration,field	milligrams per liter
Surface Water Quality	Bicarbonate,water,unfiltered,inflection-point titration method (incremental titration method)	milligrams per liter
Surface Water Quality	Bifenthrin,bed sediment,recoverable,dry weight	micrograms per kilogram
Surface Water Quality	Bifenthrin,suspended sediment,recoverable	micrograms per liter
Surface Water Quality	Bifenthrin,water,filtered,recoverable	micrograms per liter
Surface Water Quality	Biochemical oxygen demand, water, unfiltered, 5 days at 20 degrees Celsius	milligrams per liter
Surface Water Quality	Biomass,periphyton,ash free dry mass	grams per squaremeter
Surface Water Quality	Biomass,periphyton,ash weight	grams per squaremeter
Surface Water Quality	Biomass,periphyton,dry weight	grams per squaremeter
Surface Water Quality	Biomass,plankton,ash weight	milligrams per liter
Surface Water Quality	Biomass,plankton,dry weight	milligrams per liter
Surface Water Quality	Biomass/chlorophyll ratio,periphyton	number
Surface Water Quality	Biomass/chlorophyll ratio,plankton	number
Surface Water Quality	Bis(2-chloroethoxy)methane,bed sediment smaller than 2 millimeters,wet sieved (native water),field,recoverable,dry weight	micrograms per kilogram
Surface Water Quality	Bis(2-ethylhexyl) phthalate,bed sediment smaller than 2 millimeters,wet sieved (native water),field,recoverable,dry weight	micrograms per kilogram
Surface Water Quality	Bismuth,bed sediment smaller than 177 microns,wet sieved, filed, total digestion, dry weight	milligrams per kilogram
Surface Water Quality	Bismuth,water,filtered	micrograms per liter
Surface Water Quality	Boron,bed sediment,recoverable, dry weight	milligrams per kilogram
Surface Water Quality	Boron,water,filtered	micrograms per liter
Surface Water Quality	Boron,water,unfiltered,recoverable	micrograms per liter
Surface Water Quality	Bromacil,water,filtered,recoverable	micrograms per liter
Surface Water Quality	Bromide, water, filtered	milligrams per liter
Surface Water Quality	Bromodichloromethane,water,unfiltered,recoverable	micrograms per liter
Surface Water Quality	Bromomethane,water,unfiltered,recoverable	micrograms per liter
Surface Water Quality	Bromoxynil,water,filtered (0.7 micron glass fiber filter),recoverable	micrograms per liter
Surface Water Quality	Butylate,water,filtered,recoverable	micrograms per liter
Surface Water Quality	C8-Alkylphenol,bed sediment smaller than 2 millimeters,wet sieved (native water),field,recoverable,dry weight	micrograms per kilogram

Data Type	Parameter	Unit
Surface Water Quality	Cadmium,bed sediment smaller than 62.5 microns,wet sieved, filed, total digestion, dry weight	milligrams per kilogram
Surface Water Quality	Cadmium,bed sediment,recoverable, dry weight	milligrams per kilogram
Surface Water Quality	Cadmium,suspended sediment,recoverable	micrograms per liter
Surface Water Quality	Cadmium,water,filtered	micrograms per liter
Surface Water Quality	Cadmium,water,unfiltered,recoverable	micrograms per liter
Surface Water Quality	Caffeine,water,filtered,recoverable	micrograms per liter
Surface Water Quality	Caffeine-13C,surrogate,Schedule 9060/2060, water, filtered	percent recovery
Surface Water Quality	Calcium,bed sediment smaller than 62.5 microns,wet sieved, filed, total digestion, dry weight	percent
Surface Water Quality	Calcium,water,filtered	milligrams per liter
Surface Water Quality	Carbaryl,water,filtered (0.7 micron glass fiber filter),recoverable	micrograms per liter
Surface Water Quality	Carbaryl,water,filtered (0.7 micron glass fiber filter),recoverable	micrograms per liter
Surface Water Quality	Carbaryl,water,unfiltered,recoverable	micrograms per liter
Surface Water Quality	Carbazole,bed sediment smaller than 2 millimeters,wet sieved (native water),field,recoverable,dry weight	micrograms per kilogram
Surface Water Quality	Carbofuran,water,filtered (0.7 micron glass fiber filter),recoverable	micrograms per liter
Surface Water Quality	Carbofuran,water,filtered (0.7 micron glass fiber filter),recoverable	micrograms per liter
Surface Water Quality	Carbon (inorganic plus organic), bed sediment, total, dry weight	grams per kilogram
Surface Water Quality	Carbon (inorganic plus organic),bed sediment smaller than 2 millimeters,wet sieved (native water),field,recoverable,dry weight	grams per kilogram
Surface Water Quality	Carbon (inorganic plus organic),bed sediment smaller than 62.5 microns,wet sieved (native water), field,recoverable,dry weight	percent
Surface Water Quality	Carbon (inorganic plus organic),suspended sediment,total	milligrams per liter
Surface Water Quality	Carbon dioxide,water,unfiltered	milligrams per liter
Surface Water Quality	Carbonate,water,filtered,inflection-point titration method (incremental titration method)	milligrams per liter
Surface Water Quality	Carbonate,water,unfiltered,fixed endpoint (pH 8.3) titration,field	milligrams per liter
Surface Water Quality	Carbonate,water,unfiltered,inflection-point titration method (incremental titration method)	milligrams per liter
Surface Water Quality	Carbonate,water,unfiltered,inflection-point titration method (incremental titration method),field	milligrams per liter as calcium carbonate
Surface Water Quality	Carbophenothion,bed sediment,recoverable,dry weight	micrograms per kilogram
Surface Water Quality	Carbophenothion,water,unfiltered,recoverable	micrograms per liter
Surface Water Quality	Cerium,bed sediment smaller than 62.5 microns,wet sieved, filed, total digestion, dry weight	milligrams per kilogram
Surface Water Quality	Chemical oxygen demand, low level, water, unfiltered	milligrams per liter
Surface Water Quality	Chloramben methyl ester,water,filtered,recoverable	micrograms per liter
Surface Water Quality	Chlordane (technical),bed sediment,recoverable,dry weight	micrograms per kilogram
Surface Water Quality	Chlordane (technical),water,unfiltered,recoverable	micrograms per liter
Surface Water Quality	Chlordane plus degradates,bed sediment,recoverable,maximum summation, dry weight	micrograms per kilogram

Data Type	Parameter	Unit
Surface Water Quality	Chloride,water,filtered	milligrams per liter
Surface Water Quality	Chlorimuron-ethyl,water,filtered,recoverable	micrograms per liter
Surface Water Quality	Chlorobenzene,water,unfiltered,recoverable	micrograms per liter
Surface Water Quality	Chloroethane,water,unfiltered,recoverable	micrograms per liter
Surface Water Quality	Chloromethane,water,unfiltered,recoverable	micrograms per liter
Surface Water Quality	Chloroneb,bed sediment smaller than 2 millimeters,wet sieved (native water),field,recoverable,dry weight	micrograms per kilogram
Surface Water Quality	Chlorophyll a,periphyton,chromatographic-fluorometric method	milligrams per squaremeter
Surface Water Quality	Chlorophyll a,phytoplankton,chromatographic-fluorometric method	micrograms per liter
Surface Water Quality	Chlorophyll b,phytoplankton,chromatographic-fluorometric method	micrograms per liter
Surface Water Quality	Chlorothalonil,water,filtered (0.7 micron glass fiber filter),recoverable	micrograms per liter
Surface Water Quality	Chlorpyrifos oxygen analog,water,filtered,recoverable	micrograms per liter
Surface Water Quality	Chlorpyrifos,water,filtered,recoverable	micrograms per liter
Surface Water Quality	Chlorpyrifos,water,unfiltered,recoverable	micrograms per liter
Surface Water Quality	Chromium(VI),water,filtered	micrograms per liter
Surface Water Quality	Chromium,bed sediment smaller than 62.5 microns,wet sieved, filed, total digestion, dry weight	milligrams per kilogram
Surface Water Quality	Chromium,bed sediment,recoverable	milligrams per kilogram
Surface Water Quality	Chromium,suspended sediment,recoverable	micrograms per liter
Surface Water Quality	Chromium,water,filtered	micrograms per liter
Surface Water Quality	Chromium,water,unfiltered,recoverable	micrograms per liter
Surface Water Quality	Chrysene,bed sediment smaller than 2 millimeters,wet sieved (native water),field,recoverable,dry weight	micrograms per kilogram
Surface Water Quality	cis-1,3-Dichloropropene, water, unfiltered, recoverable	micrograms per liter
Surface Water Quality	cis-Chlordane,bed sediment smaller than 2 millimeters,wet sieved (native water),field,recoverable,dry weight	micrograms per kilogram
Surface Water Quality	cis-Nonachlor,bed sediment smaller than 2 millimeters,wet sieved (native water),field,recoverable,dry weight	micrograms per kilogram
Surface Water Quality	cis-Permethrin,bed sediment smaller than 2 millimeters,wet sieved (native water),field,recoverable,dry weight	micrograms per kilogram
Surface Water Quality	cis-Permethrin,water,filtered (0.7 micron glass fiber filter),recoverable	micrograms per liter
Surface Water Quality	cis-Propiconazole,water,filtered, recoverable	micrograms per liter
Surface Water Quality	Clopyralid,water,filtered (0.7 micron glass fiber filter),recoverable	micrograms per liter
Surface Water Quality	Cobalt,bed sediment smaller than 62.5 microns,wet sieved, filed, total digestion, dry weight	milligrams per kilogram
Surface Water Quality	Cobalt,suspended sediment,recoverable	micrograms per liter
Surface Water Quality	Cobalt,water,filtered	micrograms per liter
Surface Water Quality	Cobalt,water,unfiltered, recoverable	micrograms per liter
Surface Water Quality	Copper,bed sediment smaller than 62.5 microns,wet sieved, filed, total digestion, dry weight	milligrams per kilogram
Surface Water Quality	Copper,bed sediment,recoverable, dry weight	milligrams per kilogram

Data Type	Parameter	Unit
Surface Water Quality	Copper,suspended sediment,recoverable	micrograms per liter
Surface Water Quality	Copper,water,filtered	micrograms per liter
Surface Water Quality	Copper,water,unfiltered,recoverable	micrograms per liter
Surface Water Quality	Cyanazine,water,filtered,recoverable	micrograms per liter
Surface Water Quality	Cyanazine,water,unfiltered,recoverable	micrograms per liter
Surface Water Quality	Cycloate,water,filtered,recoverable	micrograms per liter
Surface Water Quality	Cyfluthrin,bed sediment,recoverable,dry weight	micrograms per kilogram
Surface Water Quality	Cyfluthrin,suspended sediment,recoverable,dry weight	micrograms per kilogram
Surface Water Quality	Cyfluthrin,water,filtered,recoverable	micrograms per liter
Surface Water Quality	Cypermethrin,bed sediment,recoverable,dry weight	micrograms per kilogram
Surface Water Quality	Cypermethrin,suspended sediment,recoverable,dry weight	micrograms per kilogram
Surface Water Quality	Cypermethrin,water,filtered,recoverable	micrograms per liter
Surface Water Quality	DCPA monoacid,water,filtered (0.7 micron glass fiber filter),recoverable	micrograms per liter
Surface Water Quality	DCPA,bed sediment smaller than 2 millimeters,wet sieved (native water),field,recoverable,dry weight	micrograms per kilogram
Surface Water Quality	DCPA,water,filtered (0.7 micron glass fiber filter),recoverable	micrograms per liter
Surface Water Quality	DDT plus degradates,bed sediment smaller than 2 millimeters,wet sieved (native water),recoverable,minimum summation, dry weight	micrograms per kilogram
Surface Water Quality	DDT plus degradates,bed sediment smaller than 2 millimeters,wet sieved (native water),recoverable,minimum summation, dry weight	micrograms per kilogram
Surface Water Quality	Deltamethrin,bed sediment,recoverable,dry weight	micrograms per kilogram
Surface Water Quality	Deltamethrin,suspended sediment,recoverable,dry weight	micrograms per kilogram
Surface Water Quality	Desulfinylfipronil amide,water,filtered,recoverable	micrograms per liter
Surface Water Quality	Desulfinylfipronil,water,filtered,recoverable	micrograms per liter
Surface Water Quality	Diazinon,bed sediment,recoverable,dry weight	micrograms per kilogram
Surface Water Quality	Diazinon,water,filtered,recoverable	micrograms per liter
Surface Water Quality	Diazinon,water,unfiltered,recoverable	micrograms per liter
Surface Water Quality	Diazinon-d10,surrogate,Schedule 2002/9002,water,unfiltered	percent recovery
Surface Water Quality	Diazinon-d10,surrogate,Schedule 2003, water, filtered	percent recovery
Surface Water Quality	Diazinon-d10,surrogate,water,filtered (0.7 micron glass fiber filter)	percent recovery
Surface Water Quality	Diazoxon,water,filtered,recoverable	micrograms per liter
Surface Water Quality	Dibenzo[a,h]anthracene,bed sediment smaller than 2 millimeters,wet sieved (native water),field,recoverable,dry weight	micrograms per kilogram
Surface Water Quality	Dibenzothiophene,bed sediment smaller than 2 millimeters,wet sieved (native water),field,recoverable,dry weight	micrograms per kilogram
Surface Water Quality	Dibromochloromethane,water,unfiltered,recoverable	micrograms per liter
Surface Water Quality	Dicamba,water,filtered (0.7 micron glass fiber filter),recoverable	micrograms per liter

Data Type	Parameter	Unit
Surface Water Quality	Dicamba,water,unfiltered,recoverable	micrograms per liter
Surface Water Quality	Dichlobenil,water,filtered (0.7 micron glass fiber filter),recoverable	micrograms per liter
Surface Water Quality	Dichlorodifluoromethane,water,unfiltered,recoverable	micrograms per liter
Surface Water Quality	Dichloromethane,water,unfiltered,recoverable	micrograms per liter
Surface Water Quality	Dichlorprop,water,filtered (0.7 micron glass fiber filter),recoverable	micrograms per liter
Surface Water Quality	Dichlorprop,water,unfiltered,recoverable	micrograms per liter
Surface Water Quality	Dichlorvos,water,filtered,recoverable	micrograms per liter
Surface Water Quality	Dicrotophos,water,filtered,recoverable	micrograms per liter
Surface Water Quality	Dieldrin,bed sediment smaller than 2 millimeters,wet sieved (native water),field,recoverable,dry weight	micrograms per kilogram
Surface Water Quality	Dieldrin,bed sediment,recoverable,dry weight	micrograms per kilogram
Surface Water Quality	Dieldrin,water,filtered,recoverable	micrograms per liter
Surface Water Quality	Dieldrin,water,unfiltered,recoverable	micrograms per liter
Surface Water Quality	Diethyl phthalate,bed sediment smaller than 2 millimeters,wet sieved (native water),field,recoverable,dry weight	micrograms per kilogram
Surface Water Quality	Dimethenamid oxanilic acid,water,filtered,recoverable	micrograms per liter
Surface Water Quality	Dimethenamid sulfonic acid,water,filtered,recoverable	micrograms per liter
Surface Water Quality	Dimethoate,water,filtered (0.7 micron glass fiber filter),recoverable	micrograms per liter
Surface Water Quality	Dimethyl phthalate,bed sediment smaller than 2 millimeters,wet sieved (native water),field,recoverable,dry weight	micrograms per kilogram
Surface Water Quality	Di-n-butyl phthalate,bed sediment smaller than 2 millimeters,wet sieved (native water),field,recoverable,dry weight	micrograms per kilogram
Surface Water Quality	Di-n-octyl phthalate,bed sediment smaller than 2 millimeters,wet sieved (native water),field,recoverable,dry weight	micrograms per kilogram
Surface Water Quality	Dinoseb,water,filtered (0.7 micron glass fiber filter),recoverable	micrograms per liter
Surface Water Quality	Diphenamid,water,filtered,recoverable	micrograms per liter
Surface Water Quality	Discharge	cubic feet per second
Surface Water Quality	Discharge	cubicmeters per second
Surface Water Quality	Discharge,instantaneous	cubic feet per second
Surface Water Quality	Discharge,instantaneous	cubicmeters per second
Surface Water Quality	Dissolved oxygen,water,unfiltered	milligrams per liter
Surface Water Quality	Dissolved oxygen,water,unfiltered	percent of saturation
Surface Water Quality	Dissolved solids dried at 180 degrees Celsius,water,filtered	milligrams per liter
Surface Water Quality	Dissolved solids,water	tons per day
Surface Water Quality	Dissolved solids,water,filtered	tons per acre-foot
Surface Water Quality	Dissolved solids,water,filtered,sum of constituents	milligrams per liter
Surface Water Quality	Disulfoton sulfone,water,filtered,recoverable	micrograms per liter
Surface Water Quality	Disulfoton sulfoxide,water,filtered,recoverable	micrograms per liter
Surface Water Quality	Disulfoton,water,filtered (0.7 micron glass fiber filter),recoverable	micrograms per liter
Surface Water Quality	Diuron,water,filtered (0.7 micron glass fiber filter),recoverable	micrograms per liter
Surface Water Quality	Endosulfan ether,water,filtered,recoverable	micrograms per liter

Data Type	Parameter	Unit
Surface Water Quality	Endosulfan sulfate,water,filtered,recoverable	micrograms per liter
Surface Water Quality	Endrin,bed sediment smaller than 2 millimeters,wet sieved (native water),field,recoverable,dry weight	micrograms per kilogram
Surface Water Quality	Endrin,bed sediment,recoverable,dry weight	micrograms per kilogram
Surface Water Quality	Endrin,water,unfiltered,recoverable	micrograms per liter
Surface Water Quality	EPTC,water,filtered (0.7 micron glass fiber filter),recoverable	micrograms per liter
Surface Water Quality	Esfenvalerate,bed sediment,recoverable,dry weight	micrograms per kilogram
Surface Water Quality	Esfenvalerate,suspended sediment,recoverable,dry weight	micrograms per kilogram
Surface Water Quality	Esfenvalerate,water,filtered (0.7 micron glass fiber filter),recoverable	micrograms per liter
Surface Water Quality	Ethalfluralin,water,filtered (0.7 micron glass fiber filter),recoverable	micrograms per liter
Surface Water Quality	Ethion monoxon,water,filtered,recoverable	micrograms per liter
Surface Water Quality	Ethion,bed sediment,recoverable,dry weight	micrograms per kilogram
Surface Water Quality	Ethion,water,filtered,recoverable	micrograms per liter
Surface Water Quality	Ethion,water,unfiltered,recoverable	micrograms per liter
Surface Water Quality	Ethoprop,water,filtered (0.7 micron glass fiber filter),recoverable	micrograms per liter
Surface Water Quality	Ethylbenzene,water,unfiltered,recoverable	micrograms per liter
Surface Water Quality	Europium,bed sediment smaller than 62.5 microns,wet sieved, filed, total digestion, dry weight	milligrams per kilogram
Surface Water Quality	Fenamiphos sulfone,water,filtered,recoverable	micrograms per liter
Surface Water Quality	Fenamiphos sulfoxide,water,filtered,recoverable	micrograms per liter
Surface Water Quality	Fenamiphos,water,filtered,recoverable	micrograms per liter
Surface Water Quality	Fenpropathrin,bed sediment,recoverable,dry weight	micrograms per kilogram
Surface Water Quality	Fenpropathrin,suspended sediment,recoverable,dry weight	micrograms per kilogram
Surface Water Quality	Fenthion sulfoxide,water,filtered,recoverable	micrograms per liter
Surface Water Quality	Fenthion,water,filtered,recoverable	micrograms per liter
Surface Water Quality	Fenuron,water,filtered (0.7 micron glass fiber filter),recoverable	micrograms per liter
Surface Water Quality	Fipronil sulfide,water,filtered,recoverable	micrograms per liter
Surface Water Quality	Fipronil sulfone,water,filtered,recoverable	micrograms per liter
Surface Water Quality	Fipronil,water,filtered,recoverable	micrograms per liter
Surface Water Quality	Flufenacet oxanilic acid,water,filtered,recoverable	micrograms per liter
Surface Water Quality	Flufenacet sulfonic acid,water,filtered,recoverable	micrograms per liter
Surface Water Quality	Flumetralin,water,filtered,recoverable	micrograms per liter
Surface Water Quality	Flumetsulam,water,filtered,recoverable	micrograms per liter
Surface Water Quality	Fluometuron,water,filtered (0.7 micron glass fiber filter),recoverable	micrograms per liter
Surface Water Quality	Fluoranthene,bed sediment smaller than 2 millimeters,wet sieved (native water),field,recoverable,dry weight	micrograms per kilogram

Data Type	Parameter	Unit
Surface Water Quality	Fluoride,water,filtered	milligrams per liter
Surface Water Quality	Fonofos oxygen analog,water,filtered,recoverable	micrograms per liter
Surface Water Quality	Fonofos,water,filtered,recoverable	micrograms per liter
Surface Water Quality	Fonofos,water,unfiltered,recoverable	micrograms per liter
Surface Water Quality	Gage height	feet
Surface Water Quality	Gage height,above datum	meters
Surface Water Quality	Gallium,bed sediment smaller than 62.5 microns,wet sieved, filed, total digestion, dry weight	milligrams per kilogram
Surface Water Quality	Gallium,water,filtered	micrograms per liter
Surface Water Quality	Germanium,water,filtered	micrograms per liter
Surface Water Quality	Glufosinate,water,filtered (0.7 micron glass fiber filter),recoverable	micrograms per liter
Surface Water Quality	Glyphosate,water,filtered (0.7 micron glass fiber filter),recoverable	micrograms per liter
Surface Water Quality	Gold,bed sediment smaller than 62.5 microns,wet sieved, filed, total digestion, dry weight	milligrams per kilogram
Surface Water Quality	Hardness,water	milligrams per liter as calcium carbonate
Surface Water Quality	Heptachlor epoxide,bed sediment smaller than 2 millimeters,wet sieved (native water),field,recoverable,dry weight	micrograms per kilogram
Surface Water Quality	Heptachlor epoxide,bed sediment,recoverable,dry weight	micrograms per kilogram
Surface Water Quality	Heptachlor epoxide,water,unfiltered,recoverable	micrograms per liter
Surface Water Quality	Heptachlor,bed sediment smaller than 2 millimeters,wet sieved (native water),field,recoverable,dry weight	micrograms per kilogram
Surface Water Quality	Heptachlor,bed sediment,recoverable,dry weight	micrograms per kilogram
Surface Water Quality	Heptachlor,water,unfiltered,recoverable	micrograms per liter
Surface Water Quality	Hexachlorobenzene,bed sediment smaller than 2 millimeters,wet sieved (native water),field,recoverable,dry weight	micrograms per kilogram
Surface Water Quality	Hexazinone,water,filtered,recoverable	micrograms per liter
Surface Water Quality	Holmium,bed sediment smaller than 62.5 microns,wet sieved, filed, total digestion, dry weight	milligrams per kilogram
Surface Water Quality	Hydrogen ion,water,unfiltered	milligrams per liter
Surface Water Quality	Imazaquin,water,filtered,recoverable	micrograms per liter
Surface Water Quality	Imazethapyr,water,filtered,recoverable	micrograms per liter
Surface Water Quality	Imidacloprid,water,filtered,recoverable	micrograms per liter
Surface Water Quality	Indeno[1,2,3-cd]pyrene,bed sediment smaller than 2 millimeters,wet sieved (native water),field,recoverable,dry weight	micrograms per kilogram
Surface Water Quality	Inorganic carbon, bed sediment, total, dry weight	grams per kilogram
Surface Water Quality	Inorganic carbon,bed sediment smaller than 2 millimeters,wet sieved (native water),field,recoverable,dry weight	grams per kilogram
Surface Water Quality	Inorganic carbon,bed sediment smaller than 62.5 microns,wet sieved (native water), field,recoverable,dry weight	percent
Surface Water Quality	Inorganic carbon,suspended sediment,total	milligrams per liter
Surface Water Quality	Iprodione,water,filtered,recoverable	micrograms per liter

Data Type	Parameter	Unit
Surface Water Quality	Iron, water, unfiltered, micrograms per liter	micrograms per liter
Surface Water Quality	Iron,bed sediment smaller than 62.5 microns,wet sieved, filed, total digestion, dry weight	percent
Surface Water Quality	Iron,bed sediment,total digestion,dry weight	milligrams per kilogram
Surface Water Quality	Iron,suspended sediment,recoverable	micrograms per liter
Surface Water Quality	Iron,water,filtered	micrograms per liter
Surface Water Quality	Iron,water,unfiltered,recoverable	micrograms per liter
Surface Water Quality	Isodrin,bed sediment smaller than 2 millimeters,wet sieved (native water),field,recoverable,dry weight	micrograms per kilogram
Surface Water Quality	Isofenphos,surrogate,Schedule 1319, water, unfiltered	percent recovery
Surface Water Quality	Isofenphos,water,filtered,recoverable	micrograms per liter
Surface Water Quality	Isophorone,bed sediment smaller than 2 millimeters,wet sieved (native water),field,recoverable,dry weight	micrograms per kilogram
Surface Water Quality	Isoquinoline,bed sediment smaller than 2 millimeters,wet sieved (native water),field,recoverable,dry weight	micrograms per kilogram
Surface Water Quality	lambda-Cyhalothrin,bed sediment,recoverable,dry weight	micrograms per kilogram
Surface Water Quality	lambda-Cyhalothrin,suspended sediment,recoverable,dry weight	micrograms per kilogram
Surface Water Quality	lambda-Cyhalothrin,water,filtered,recoverable	micrograms per liter
Surface Water Quality	Lanthanum,bed sediment smaller than 62.5 microns,wet sieved, filed, total digestion, dry weight	milligrams per kilogram
Surface Water Quality	Lead,bed sediment smaller than 62.5 microns,wet sieved, filed, total digestion, dry weight	milligrams per kilogram
Surface Water Quality	Lead,bed sediment,recoverable, dry weight	milligrams per kilogram
Surface Water Quality	Lead,suspended sediment,recoverable	micrograms per liter
Surface Water Quality	Lead,water,filtered	micrograms per liter
Surface Water Quality	Lead,water,unfiltered,recoverable	micrograms per liter
Surface Water Quality	Lindane,bed sediment smaller than 2 millimeters,wet sieved (native water),field,recoverable,dry weight	micrograms per kilogram
Surface Water Quality	Lindane,bed sediment,recoverable,dry weight	micrograms per kilogram
Surface Water Quality	Lindane,water,filtered,recoverable	micrograms per liter
Surface Water Quality	Lindane,water,unfiltered,recoverable	micrograms per liter
Surface Water Quality	Linuron,water,filtered (0.7 micron glass fiber filter),recoverable	micrograms per liter
Surface Water Quality	Linuron,water,filtered (0.7 micron glass fiber filter),recoverable	micrograms per liter
Surface Water Quality	Lithium, suspended sediment, recoverable	micrograms per liter
Surface Water Quality	Lithium,bed sediment smaller than 62.5 microns,wet sieved, filed, total digestion, dry weight	milligrams per kilogram
Surface Water Quality	Lithium,bed sediment,dry weight	milligrams per kilogram
Surface Water Quality	Lithium,water,filtered	micrograms per liter
Surface Water Quality	Lithium,water,unfiltered,recoverable	micrograms per liter
Surface Water Quality	Loss on ignition of suspended solids, water, unfiltered	milligrams per liter

Data Type	Parameter	Unit
Surface Water Quality	Magnesium,bed sediment smaller than 62.5 microns,wet sieved, filed, total digestion, dry weight	percent
Surface Water Quality	Magnesium,water,filtered	milligrams per liter
Surface Water Quality	Malaoxon,water,filtered,recoverable	micrograms per liter
Surface Water Quality	Malathion,bed sediment,recoverable,dry weight	micrograms per kilogram
Surface Water Quality	Malathion,water,filtered,recoverable	micrograms per liter
Surface Water Quality	Malathion,water,unfiltered,recoverable	micrograms per liter
Surface Water Quality	Manganese,bed sediment smaller than 62.5 microns,wet sieved, filed, total digestion, dry weight	milligrams per kilogram
Surface Water Quality	Manganese,bed sediment,recoverable, dry weight	milligrams per kilogram
Surface Water Quality	Manganese,bulk atmospheric deposition,suspended,micrograms per liter	micrograms per liter
Surface Water Quality	Manganese,suspended sediment,recoverable	micrograms per liter
Surface Water Quality	Manganese,water,filtered	micrograms per liter
Surface Water Quality	Manganese,water,unfiltered,recoverable	micrograms per liter
Surface Water Quality	MCPA,water,filtered (0.7 micron glass fiber filter),recoverable	micrograms per liter
Surface Water Quality	MCPB,water,filtered (0.7 micron glass fiber filter),recoverable	micrograms per liter
Surface Water Quality	Mercury,bed sediment smaller than 62.5 microns,wet sieved, filed, total digestion, dry weight	milligrams per kilogram
Surface Water Quality	Mercury,bed sediment,recoverable, dry weight	milligrams per kilogram
Surface Water Quality	Mercury,biota,tissue,recoverable,dry weight	milligrams per kilogram
Surface Water Quality	Mercury,solids,total,dry weight	micrograms per kilogram
Surface Water Quality	Mercury,suspended sediment,recoverable	micrograms per liter
Surface Water Quality	Mercury,suspended sediment,total	nanograms per liter
Surface Water Quality	Mercury,water,filtered	nanograms per liter
Surface Water Quality	Mercury,water,filtered	micrograms per liter
Surface Water Quality	Mercury,water,unfiltered, recoverable	micrograms per liter
Surface Water Quality	Metalaxyl,water,filtered,recoverable	micrograms per liter
Surface Water Quality	Metalaxyl,water,filtered,recoverable	micrograms per liter
Surface Water Quality	Methidathion,water,filtered,recoverable	micrograms per liter
Surface Water Quality	Methiocarb,water,filtered (0.7 micron glass fiber filter),recoverable	micrograms per liter
Surface Water Quality	Methomyl,water,filtered (0.7 micron glass fiber filter),recoverable	micrograms per liter
Surface Water Quality	Methomyl,water,unfiltered,recoverable	micrograms per liter
Surface Water Quality	Methyl cis-3-(2,2-dichlorovinyl)-2,2-dimethylcyclopropane-1-carboxylate,water,filtered, recoverable	micrograms per liter
Surface Water Quality	Methyl paraoxon,water,filtered,recoverable	micrograms per liter
Surface Water Quality	Methyl parathion,bed sediment,recoverable,dry weight	micrograms per kilogram
Surface Water Quality	Methyl parathion,water,filtered (0.7 micron glass fiber filter),recoverable	micrograms per liter
Surface Water Quality	Methyl parathion,water,unfiltered,recoverable	micrograms per liter

Data Type	Parameter	Unit
Surface Water Quality	Methyl trans-3-(2,2-dichlorovinyl)-2,2-dimethylcyclopropane-1-carboxylate,water,filtered, recoverable	micrograms per liter
Surface Water Quality	Methyl trithion,bed sediment,dry weight,recoverable,dry weight	micrograms per kilogram
Surface Water Quality	Methyl trithion,water,unfiltered,recoverable	micrograms per liter
Surface Water Quality	Methylene blue active substances, water, unfiltered, recoverable	milligrams per liter
Surface Water Quality	Methylmercury,solids,total,dry weight	micrograms per kilogram
Surface Water Quality	Methylmercury,suspended sediment,total	nanograms per liter
Surface Water Quality	Methylmercury,water,filtered, recoverable	nanograms per liter
Surface Water Quality	Metolachlor oxanilic acid,water,filtered (0.7 micron glass fiber filter),recoverable	micrograms per liter
Surface Water Quality	Metolachlor sulfonic acid,water,filtered (0.7 micron glass fiber filter),recoverable	micrograms per liter
Surface Water Quality	Metolachlor, water, unfiltered, recoverable	micrograms per liter
Surface Water Quality	Metolachlor,water,filtered,recoverable	micrograms per liter
Surface Water Quality	Metribuzin, water, unfiltered, recoverable	micrograms per liter
Surface Water Quality	Metribuzin,water,filtered,recoverable	micrograms per liter
Surface Water Quality	Metsulfuron-methyl,water,filtered,recoverable	micrograms per liter
Surface Water Quality	Mirex,bed sediment smaller than 2 millimeters,wet sieved (native water),field,recoverable,dry weight	micrograms per kilogram
Surface Water Quality	Mirex,bed sediment,recoverable,dry weight	micrograms per kilogram
Surface Water Quality	Mirex,water,unfiltered,recoverable	micrograms per liter
Surface Water Quality	Molinate,water,filtered (0.7 micron glass fiber filter),recoverable	micrograms per liter
Surface Water Quality	Molybdenum,bed sediment smaller than 62.5 microns,wet sieved, filed, total digestion, dry weight	milligrams per kilogram
Surface Water Quality	Molybdenum,suspended sediment,unfiltered,recoverable	micrograms per liter
Surface Water Quality	Molybdenum,water,filtered	micrograms per liter
Surface Water Quality	Molybdenum,water,unfiltered	micrograms per liter
Surface Water Quality	Myclobutanil,water,filtered,recoverable	micrograms per liter
Surface Water Quality	N-(4-Chlorophenyl)-N-methylurea,water,filtered,recoverable	micrograms per liter
Surface Water Quality	Naphthalene,bed sediment smaller than 2 millimeters,wet sieved (native water),field,recoverable,dry weight	micrograms per kilogram
Surface Water Quality	Napropamide,water,filtered (0.7 micron glass fiber filter),recoverable	micrograms per liter
Surface Water Quality	Neburon,water,filtered (0.7 micron glass fiber filter),recoverable	micrograms per liter
Surface Water Quality	Neodymium,bed sediment smaller than 62.5 microns,wet sieved, filed, total digestion, dry weight	milligrams per kilogram
Surface Water Quality	Nickel,bed sediment smaller than 62.5 microns,wet sieved, filed, total digestion, dry weight	milligrams per kilogram
Surface Water Quality	Nickel,bed sediment,recoverable, dry weight	milligrams per kilogram
Surface Water Quality	Nickel,suspended sediment,recoverable	micrograms per liter
Surface Water Quality	Nickel,water,filtered	micrograms per liter

Data Type	Parameter	Unit
Surface Water Quality	Nickel,water,unfiltered,recoverable	micrograms per liter
Surface Water Quality	Nicosulfuron,water,filtered,recoverable	micrograms per liter
Surface Water Quality	Niobium,bed sediment smaller than 62.5 microns,wet sieved, filed, total digestion, dry weight	milligrams per kilogram
Surface Water Quality	Nitrate plus nitrite,water,filtered	milligrams per liter as nitrogen
Surface Water Quality	Nitrate plus nitrite,water,unfiltered	milligrams per liter as nitrogen
Surface Water Quality	Nitrate,water,filtered	milligrams per liter as nitrogen
Surface Water Quality	Nitrate,water,filtered	milligrams per liter
Surface Water Quality	Nitrite,water,filtered	milligrams per liter as nitrogen
Surface Water Quality	Nitrite,water,filtered	milligrams per liter
Surface Water Quality	Nitrobenzene,bed sediment smaller than 2 millimeters,wet sieved (native water),field,recoverable,dry weight	micrograms per kilogram
Surface Water Quality	Nitrobenzene-d5,surrogate,bed sediment smaller than 2 millimeters, wet sieved (native water), field	percent recovery
Surface Water Quality	N-Nitrosodi-n-propylamine,bed sediment smaller than 2 millimeters,wet sieved (native water),field,recoverable,dry weight	micrograms per kilogram
Surface Water Quality	N-Nitrosodiphenylamine,bed sediment smaller than 2 millimeters,wet sieved (native water),field,recoverable,dry weight	micrograms per kilogram
Surface Water Quality	Noncarbonate hardness,water,filtered	milligrams per liter as calcium carbonate
Surface Water Quality	Noncarbonate hardness,water,unfiltered	milligrams per liter as calcium carbonate
Surface Water Quality	Norflurazon,water,filtered (0.7 micron glass fiber filter),recoverable	micrograms per liter
Surface Water Quality	o, p-DDD,bed sediment smaller than 2 millimeters,wet sieved (native water),field,recoverable, dry weight	micrograms per kilogram
Surface Water Quality	o, p-DDE,bed sediment smaller than 2 millimeters,wet sieved (native water),field,recoverable, dry weight	micrograms per kilogram
Surface Water Quality	o, p-DDT,bed sediment smaller than 2 millimeters,wet sieved (native water),field,recoverable, dry weight	micrograms per kilogram
Surface Water Quality	o, p-Methoxychlor,wet sieved (native water),field,recoverable,dry weight	micrograms per kilogram
Surface Water Quality	O-Ethyl-O-methyl-S-propylphosphorothioate,water,filtered,recoverable	micrograms per liter
Surface Water Quality	Organic carbon, bed sediment, total, dry weight	grams per kilogram
Surface Water Quality	Organic carbon,bed sediment smaller than 2 millimeters,wet sieved (native water),field,recoverable,dry weight	grams per kilogram
Surface Water Quality	Organic carbon,bed sediment smaller than 62.5 microns,wet sieved (native water), field,recoverable,dry weight	percent
Surface Water Quality	Organic carbon,suspended sediment,total	milligrams per liter
Surface Water Quality	Organic carbon,water,filtered	milligrams per liter
Surface Water Quality	Organic carbon,water,unfiltered	milligrams per liter
Surface Water Quality	Organic nitrogen,water,filtered	milligrams per liter
Surface Water Quality	Organic nitrogen,water,unfiltered	milligrams per liter

Data Type	Parameter	Unit
Surface Water Quality	Orthophosphate,water,filtered	milligrams per liter
Surface Water Quality	Orthophosphate,water,filtered	milligrams per liter as phosphorus
Surface Water Quality	Oryzalin,water,filtered (0.7 micron glass fiber filter),recoverable	micrograms per liter
Surface Water Quality	Oxamyl,water,filtered (0.7 micron glass fiber filter),recoverable	micrograms per liter
Surface Water Quality	Oxychlordane,bed sediment smaller than 2 millimeters,wet sieved (native water),field,recoverable,dry weight	micrograms per kilogram
Surface Water Quality	Oxyfluorfen,water,filtered,recoverable	micrograms per liter
Surface Water Quality	p, p-DDD,bed sediment smaller than 2 millimeters,wet sieved (native water),field,recoverable, dry weight	micrograms per kilogram
Surface Water Quality	p, p-DDD,bed sediment,recoverable,dry weight	micrograms per kilogram
Surface Water Quality	p, p-DDD,water,unfiltered, recoverable	micrograms per liter
Surface Water Quality	p, p-DDE,bed sediment smaller than 2 millimeters,wet sieved (native water),field,recoverable, dry weight	micrograms per kilogram
Surface Water Quality	p, p-DDE,bed sediment,recoverable,dry weight	micrograms per kilogram
Surface Water Quality	p, p-DDE,water,filtered,recoverable	micrograms per liter
Surface Water Quality	p, p-DDE,water,unfiltered, recoverable	micrograms per liter
Surface Water Quality	p, p-DDT,bed sediment smaller than 2 millimeters,wet sieved (native water),field,recoverable, dry weight	micrograms per kilogram
Surface Water Quality	p, p-DDT,bed sediment,recoverable,dry weight	micrograms per kilogram
Surface Water Quality	p, p-DDT,water,unfiltered, recoverable	micrograms per liter
Surface Water Quality	p, p-Methoxychlor,bed sediment,recoverable,dry weight	micrograms per kilogram
Surface Water Quality	p, p-Methoxychlor,unfiltered,recoverable	micrograms per liter
Surface Water Quality	p, p-Methoxychlor,wet sieved (native water),field,recoverable,dry weight	micrograms per kilogram
Surface Water Quality	p,p-Ethyl-DDD, water, unfiltered, recoverable	micrograms per liter
Surface Water Quality	p,p-Ethyl-DDD,bed sediment,recoverable,dry weight	micrograms per kilogram
Surface Water Quality	Paraoxon,water,filtered,recoverable	micrograms per liter
Surface Water Quality	Parathion,bed sediment,recoverable,dry weight	micrograms per kilogram
Surface Water Quality	Parathion,water,filtered,recoverable	micrograms per liter
Surface Water Quality	Parathion,water,unfiltered,recoverable	micrograms per liter
Surface Water Quality	Particulate nitrogen,suspended in water	milligrams per liter
Surface Water Quality	PCB congener 14,surrogate,bed sediment smaller than 2 millimeters, wet sieved (native water), field	percent recovery
Surface Water Quality	PCB congener 204,surrogate,bed sediment smaller than 2 millimeters, wet sieved (native water), field	percent recovery
Surface Water Quality	PCBs,bed sediment smaller than 2 millimeters,wet sieved (native water),field,recoverable,dry weight	micrograms per kilogram
Surface Water Quality	PCBs,bed sediment,recoverable,dry weight	micrograms per kilogram

Data Type	Parameter	Unit
Surface Water Quality	PCBs,water,unfiltered,recoverable	micrograms per liter
Surface Water Quality	p-Cresol,bed sediment smaller than 2 millimeters,wet sieved (native water),field,recoverable,dry weight	micrograms per kilogram
Surface Water Quality	Pebulate,water,filtered (0.7 micron glass fiber filter),recoverable	micrograms per liter
Surface Water Quality	Pendimethalin,water,filtered (0.7 micron glass fiber filter),recoverable	micrograms per liter
Surface Water Quality	Pentachloroanisole,bed sediment smaller than 2 millimeters,wet sieved (native water),field,recoverable,dry weight	micrograms per kilogram
Surface Water Quality	Pentachloronitrobenzene,bed sediment smaller than 2 millimeters,wet sieved (native water),field,recoverable,dry weight	micrograms per kilogram
Surface Water Quality	Permethrin,bed sediment,recoverable,dry weight	micrograms per kilogram
Surface Water Quality	Permethrin,suspended sediment,recoverable,dry weight	micrograms per kilogram
Surface Water Quality	pH,water,unfiltered, field	standard units
Surface Water Quality	pH,water,unfiltered., laboratory	standard units
Surface Water Quality	Phenanthrene,bed sediment smaller than 2 millimeters,wet sieved (native water),field,recoverable,dry weight	micrograms per kilogram
Surface Water Quality	Phenanthridine,bed sediment smaller than 2 millimeters,wet sieved (native water),field,recoverable,dry weight	micrograms per kilogram
Surface Water Quality	Phenol,bed sediment smaller than 2 millimeters,wet sieved (native water),field,recoverable,dry weight	micrograms per kilogram
Surface Water Quality	Phenothrin,bed sediment,recoverable,dry weight	micrograms per kilogram
Surface Water Quality	Phenothrin,suspended sediment,recoverable,dry weight	micrograms per kilogram
Surface Water Quality	Pheophytin a,periphyton	milligrams per squaremeter
Surface Water Quality	Phorate oxygen analog,water,filtered,recoverable	micrograms per liter
Surface Water Quality	Phorate,water,filtered (0.7 micron glass fiber filter),recoverable	micrograms per liter
Surface Water Quality	Phorate,water,unfiltered,recoverable	micrograms per liter
Surface Water Quality	Phosmet oxygen analog,water,filtered,recoverable	micrograms per liter
Surface Water Quality	Phosmet,water,filtered,recoverable	micrograms per liter
Surface Water Quality	Phosphate,water,unfiltered	milligrams per liter
Surface Water Quality	Phosphorus,bed sediment smaller than 62.5 microns,wet sieved, filed, total digestion, dry weight	percent
Surface Water Quality	Phosphorus,water,filtered	milligrams per liter as phosphorus
Surface Water Quality	Phosphorus,water,unfiltered	milligrams per liter as phosphorus
Surface Water Quality	Phosphorus,water,unfiltered	milligrams per liter as phosphate
Surface Water Quality	Picloram,water,filtered (0.7 micron glass fiber filter),recoverable	micrograms per liter
Surface Water Quality	Picloram,water,unfiltered,recoverable	micrograms per liter
Surface Water Quality	Polychlorinated naphthalenes,bed sediment,recoverable,dry weight	micrograms per kilogram

Data Type	Parameter	Unit
Surface Water Quality	Polychlorinated naphthalenes,water,unfiltered,recoverable	micrograms per liter
Surface Water Quality	Potassium,bed sediment smaller than 62.5 microns,wet sieved, filed, total digestion, dry weight	percent
Surface Water Quality	Potassium,water,filtered	milligrams per liter
Surface Water Quality	Profenofos,water,filtered,recoverable	micrograms per liter
Surface Water Quality	Prometon,water,filtered,recoverable	micrograms per liter
Surface Water Quality	Prometon,water,unfiltered,recoverable	micrograms per liter
Surface Water Quality	Prometryn,water,filtered,recoverable	micrograms per liter
Surface Water Quality	Prometryn,water,unfiltered,recoverable	micrograms per liter
Surface Water Quality	Propachlor,water,filtered,recoverable	micrograms per liter
Surface Water Quality	Propanil,water,filtered (0.7 micron glass fiber filter),recoverable	micrograms per liter
Surface Water Quality	Propargite,water,filtered (0.7 micron glass fiber filter),recoverable	micrograms per liter
Surface Water Quality	Propazine,water,unfiltered,recoverable	micrograms per liter
Surface Water Quality	Propetamphos,water,filtered,recoverable	micrograms per liter
Surface Water Quality	Propham,water,filtered (0.7 micron glass fiber filter),recoverable	micrograms per liter
Surface Water Quality	Propham,water,unfiltered,recoverable	micrograms per liter
Surface Water Quality	Propiconazole,water,filtered,recoverable	micrograms per liter
Surface Water Quality	Propoxur,water,filtered (0.7 micron glass fiber filter),recoverable	micrograms per liter
Surface Water Quality	Propyzamide,water,filtered (0.7 micron glass fiber filter),recoverable	micrograms per liter
Surface Water Quality	p-Terphenyl-d14,surrogate,bed sediment smaller than 2 millimeters, wet sieved (native water), field	percent recovery
Surface Water Quality	Pyrene,bed sediment smaller than 2 millimeters,wet sieved (native water),field,recoverable,dry weight	micrograms per kilogram
Surface Water Quality	Quinoline,bed sediment smaller than 2 millimeters,wet sieved (native water),field,recoverable,dry weight	micrograms per kilogram
Surface Water Quality	Ratio of particulate nitrogen to particulate organic carbon	number
Surface Water Quality	Resmethrin,bed sediment,recoverable,dry weight	micrograms per kilogram
Surface Water Quality	Resmethrin,suspended sediment,recoverable,dry weight	micrograms per kilogram
Surface Water Quality	Sample purpose	code
Surface Water Quality	Sample source	code
Surface Water Quality	Sample volume,Schedule 1319	milliliters
Surface Water Quality	Sample volume,Schedule 2001	milliliters
Surface Water Quality	Sample volume,Schedule 2003	milliliters
Surface Water Quality	Sample volume,Schedule 2010	milliliters
Surface Water Quality	Sample volume,Schedule 2050	milliliters
Surface Water Quality	Sample volume,Schedule 2051	milliliters
Surface Water Quality	Sample volume,Schedules 2002 and 9002	milliliters
Surface Water Quality	Sample volume,Schedules 2060 and 9060	milliliters
Surface Water Quality	Sample weight,Schedule 2501	grams
Surface Water Quality	Sampler type	code

Data Type	Parameter	Unit
Surface Water Quality	Sampling condition	code
Surface Water Quality	Sampling method	code
Surface Water Quality	Scandium,bed sediment smaller than 62.5 microns,wet sieved, filed, total digestion, dry weight	milligrams per kilogram
Surface Water Quality	Selenium,bed sediment smaller than 62.5 microns,wet sieved, filed, total digestion, dry weight	milligrams per kilogram
Surface Water Quality	Selenium,bed sediment,total digestion,dry weight	milligrams per kilogram
Surface Water Quality	Selenium,suspended sediment,total	micrograms per liter
Surface Water Quality	Selenium,water,filtered	micrograms per liter
Surface Water Quality	Selenium,water,unfiltered	micrograms per liter
Surface Water Quality	Set number	lab code 0113
Surface Water Quality	Set number	lab code 0114
Surface Water Quality	Set number	Schedule 2001
Surface Water Quality	Set number	Schedule 2010
Surface Water Quality	Set number	Schedule 2050
Surface Water Quality	Set number	Schedule 2051
Surface Water Quality	Set number	Schedule 2002
Surface Water Quality	Set number,Schedule 1319	code
Surface Water Quality	Set number,Schedule 2060	lab code 9060
Surface Water Quality	Set number,Schedule 2502	
Surface Water Quality	Siduron,water,filtered,recoverable	micrograms per liter
Surface Water Quality	Silica,water,filtered	milligrams per liter as SiO2
Surface Water Quality	Silver,bed sediment smaller than 62.5 microns,wet sieved, filed, total digestion, dry weight	milligrams per kilogram
Surface Water Quality	Silver,suspended sediment,recoverable	micrograms per liter
Surface Water Quality	Silver,water,filtered	micrograms per liter
Surface Water Quality	Silver,water,unfiltered,recoverable	micrograms per liter
Surface Water Quality	Silvex,bed sediment,recoverable,dry weight	micrograms per kilogram
Surface Water Quality	Silvex,water,filtered,recoverable	micrograms per liter
Surface Water Quality	Silvex,water,unfiltered,recoverable	micrograms per liter
Surface Water Quality	Simazine,water,filtered,recoverable	micrograms per liter
Surface Water Quality	Simazine,water,unfiltered,recoverable	micrograms per liter
Surface Water Quality	Simetryn,water,unfiltered,recoverable	micrograms per liter
Surface Water Quality	Site visit purpose	code
Surface Water Quality	Sodium adsorption ratio,water	number
Surface Water Quality	Sodium fraction of cations,water	percent in equivalents ofmajor cations
Surface Water Quality	Sodium,bed sediment smaller than 62.5 microns,wet sieved, filed, total digestion, dry weight	percent
Surface Water Quality	Sodium,water,filtered	milligrams per liter

Data Type	Parameter	Unit
Surface Water Quality	Specific conductance,water,unfiltered	microsiemens per centimeter at 25 degrees Celsius
Surface Water Quality	Specific conductance,water,unfiltered, laboratory	microsiemens per centimeter at 25 degrees Celsius
Surface Water Quality	Strontium,bed sediment smaller than 62.5 microns,wet sieved, filed, total digestion, dry weight	milligrams per kilogram
Surface Water Quality	Styrene, water, unfiltered, recoverable	micrograms per liter
Surface Water Quality	Sulfate,water,filtered	milligrams per liter
Surface Water Quality	Sulfometuron-methyl,water,filtered,recoverable	micrograms per liter
Surface Water Quality	Sulfotepp,water,filtered,recoverable	micrograms per liter
Surface Water Quality	Sulfur,bed sediment smaller than 62.5 microns,wet sieved, filed, total digestion, dry weight	percent
Surface Water Quality	Sulprofos,water,filtered,recoverable	micrograms per liter
Surface Water Quality	Suspended sediment concentration	milligrams per liter
Surface Water Quality	Suspended sediment discharge	tons per day
Surface Water Quality	Suspended sediment,sieve diameter	percent smaller than 0.0625millimeters
Surface Water Quality	Suspended solids remaining after ignition, water, unfiltered	milligrams per liter
Surface Water Quality	Suspended solids, water, unfiltered	milligrams per liter
Surface Water Quality	Tantalum,bed sediment smaller than 62.5 microns,wet sieved, filed, total digestion, dry weight	milligrams per kilogram
Surface Water Quality	tau-Fluvalinate,bed sediment,recoverable,dry weight	micrograms per kilogram
Surface Water Quality	tau-Fluvalinate,suspended sediment,recoverable,dry weight	micrograms per kilogram
Surface Water Quality	Tebupirimfos,water,filtered,recoverable	micrograms per liter
Surface Water Quality	Tebupirimphos oxygen analog,water,filtered,recoverable	micrograms per liter
Surface Water Quality	Tebuthiuron,water,filtered (0.7 micron glass fiber filter),recoverable	micrograms per liter
Surface Water Quality	Tefluthrin acid benzyl ester,water,filtered,recoverable	micrograms per liter
Surface Water Quality	Tefluthrin acid pentafluorobenzyl ester,water,filtered,recoverable	micrograms per liter
Surface Water Quality	Tefluthrin,bed sediment,recoverable,dry weight	micrograms per kilogram
Surface Water Quality	Tefluthrin,suspended sediment,recoverable,dry weight	micrograms per kilogram
Surface Water Quality	Tefluthrin,water,filtered,recoverable	micrograms per liter
Surface Water Quality	Temephos,water,filtered,recoverable	micrograms per liter
Surface Water Quality	Temperature,air	degrees Celsius
Surface Water Quality	Temperature,water	degrees Celsius
Surface Water Quality	Terbacil,water,filtered (0.7 micron glass fiber filter),recoverable	micrograms per liter
Surface Water Quality	Terbacil,water,filtered,recoverable	micrograms per liter
Surface Water Quality	Terbufos oxygen analog sulfone,water,filtered,recoverable	micrograms per liter
Surface Water Quality	Terbufos,water,filtered (0.7 micron glass fiber filter),recoverable	micrograms per liter

Data Type	Parameter	Unit
Surface Water Quality	Terbuthylazine,surrogate,water,filtered (0.7 micron glass fiber filter)	percent recovery
Surface Water Quality	Terbuthylazine,water,filtered,recoverable	micrograms per liter
Surface Water Quality	Tetrachloroethene,water,unfiltered,recoverable	micrograms per liter
Surface Water Quality	Tetrachloromethane,water,unfiltered,recoverable	micrograms per liter
Surface Water Quality	Tetramethrin,bed sediment,recoverable,dry weight	micrograms per kilogram
Surface Water Quality	Tetramethrin,suspended sediment,recoverable,dry weight	micrograms per kilogram
Surface Water Quality	Thiobencarb,water,filtered (0.7 micron glass fiber filter),recoverable	micrograms per liter
Surface Water Quality	Thorium,bed sediment smaller than 62.5 microns,wet sieved, filed, total digestion, dry weight	milligrams per kilogram
Surface Water Quality	Tin,bed sediment smaller than 62.5 microns,wet sieved, filed, total digestion, dry weight	milligrams per kilogram
Surface Water Quality	Titanium,bed sediment smaller than 62.5 microns,wet sieved (native water), field,recoverable,dry weight	percent
Surface Water Quality	Titanium,water,filtered	micrograms per liter
Surface Water Quality	Toluene,water,unfiltered,recoverable	micrograms per liter
Surface Water Quality	Topical quality-control data purpose	code
Surface Water Quality	Total nitrogen (nitrate + nitrite + ammonia + organic-N),water,filtered,analytically determined	milligrams per liter
Surface Water Quality	Total nitrogen (nitrate + nitrite + ammonia + organic-N),water,unfiltered,analytically determined	milligrams per liter
Surface Water Quality	Total nitrogen,bed sediment,total, dry weight	milligrams per kilogram
Surface Water Quality	Total nitrogen,water,filtered	milligrams per liter
Surface Water Quality	Total nitrogen,water,unfiltered	milligrams per liter
Surface Water Quality	Total nitrogen,water,unfiltered	milligrams per liter as nitrate
Surface Water Quality	Toxaphene,bed sediment smaller than 2 millimeters,wet sieved (native water),field,recoverable,dry weight	micrograms per kilogram
Surface Water Quality	Toxaphene,bed sediment,recoverable,dry weight	micrograms per kilogram
Surface Water Quality	Toxaphene,water,unfiltered,recoverable	micrograms per liter
Surface Water Quality	trans-1,2-Dichloroethene,water,unfiltered,recoverable	micrograms per liter
Surface Water Quality	trans-1,3-Dichloropropene, water, unfiltered, recoverable	micrograms per liter
Surface Water Quality	trans-Chlordane,bed sediment smaller than 2 millimeters,wet sieved (native water),field,recoverable,dry weight	micrograms per kilogram
Surface Water Quality	trans-Nonachlor,bed sediment smaller than 2 millimeters,wet sieved (native water),field,recoverable,dry weight	micrograms per kilogram
Surface Water Quality	trans-Permethrin,bed sediment smaller than 2 millimeters,wet sieved (native water),field,recoverable,dry weight	micrograms per kilogram
Surface Water Quality	trans-Propiconazole,water,filtered, recoverable	micrograms per liter
Surface Water Quality	Triallate,water,filtered (0.7 micron glass fiber filter),recoverable	micrograms per liter
Surface Water Quality	Tribenuron-methyl,water,filtered,recoverable	micrograms per liter
Surface Water Quality	Tribromomethane,water,unfiltered,recoverable	micrograms per liter
Surface Water Quality	Tribuphos,water,filtered,recoverable	micrograms per liter

Data Type	Parameter	Unit
Surface Water Quality	Tribuphos,water,unfiltered,recoverable	micrograms per liter
Surface Water Quality	Trichloroethene,water,unfiltered,recoverable	micrograms per liter
Surface Water Quality	Trichlorofluoromethane,water,unfiltered,recoverable	micrograms per liter
Surface Water Quality	Trichloromethane,water,unfiltered,recoverable	micrograms per liter
Surface Water Quality	Triclopyr,water,filtered (0.7 micron glass fiber filter),recoverable	micrograms per liter
Surface Water Quality	Trifluralin, water, unfiltered, recoverable	micrograms per liter
Surface Water Quality	Trifluralin,water,filtered (0.7 micron glass fiber filter),recoverable	micrograms per liter
Surface Water Quality	Trihalomethanes,water,unfiltered,maximum summation	micrograms per liter
Surface Water Quality	Turbidity, water, unfiltered	nephelometric turbidity units
Surface Water Quality	Turbidity,water,unfiltered	Jackson Turbidity Units
Surface Water Quality	Type of quality assurance data associated with sample	code
Surface Water Quality	Type of replicate	code
Surface Water Quality	Uranium,bed sediment smaller than 62.5 microns,wet sieved, filed, total digestion, dry weight	milligrams per kilogram
Surface Water Quality	Vanadium,bed sediment smaller than 62.5 microns,wet sieved, filed, total digestion, dry weight	milligrams per kilogram
Surface Water Quality	Vanadium,water,filtered	micrograms per liter
Surface Water Quality	Vinyl chloride,water,unfiltered,recoverable	micrograms per liter
Surface Water Quality	Water present,biota,tissue, recoverable, dry weight	percent
Surface Water Quality	Xylene (all isomers), water, unfiltered, recoverable	micrograms per liter
Surface Water Quality	Ytterbium,bed sediment smaller than 62.5 microns,wet sieved, filed, total digestion, dry weight	milligrams per kilogram
Surface Water Quality	Yttrium,bed sediment smaller than 62.5 microns,wet sieved, filed, total digestion, dry weight	milligrams per kilogram
Surface Water Quality	Zinc,bed sediment smaller than 62.5 microns,wet sieved, filed, total digestion, dry weight	milligrams per kilogram
Surface Water Quality	Zinc,bed sediment,recoverable, dry weight	milligrams per kilogram
Surface Water Quality	Zinc,suspended sediment,recoverable	micrograms per liter
Surface Water Quality	Zinc,water,filtered	micrograms per liter
Surface Water Quality	Zinc,water,unfiltered,recoverable	micrograms per liter