materials (**Table 4-1**). This parameter should likely be further constrained during the parameter estimation process.

Porosity is assigned to represent the fraction of water within a sediment for the calculation of the portion of specific storage attributable to the compressibility of water (**Table 4-1**). Porosity ranges from 0.35 in gravel and sand to 0.45 in clay. Since the compressibility of water expressed as a specific storage (1.4 x 10^{-6} ft^{-1}) is substantially smaller than the elastic and inelastic skeletal specific storage values, the groundwater flow model is not significantly influenced by assigned porosity.

4.2 Farm Parameters

Calibrated farm parameters include multipliers which act on FMP input lists and arrays and irrigation efficiencies for the four irrigation types (**Table 4-1**). Changes during calibration for all parameters were constrained to keep parameter values within reasonable ranges. Parameters that were constrained include the multiplier for crop coefficients (*KCFACT*) and the capillary fringe height multiplier (*CAPFRINGEFACT*). Calibrated crop coefficients are higher than is expected for some crops (**Table 4-2**), but generally within a reasonable range for major crop types that are present within the model domain. In some instances, for some crops, the FTR and FEI sum to a value greater than one. In these instances, One-Water automatically scales these parameters to sum to 1 (**Table 4-2**). Results suggest that both the raw crop coefficient and consumptive use data for some specific crops may need to be reevaluated in order to improve model reliability.

4.3 Model Calibration

Calibration quality quantifies the ability of the groundwater model to simulate observed hydraulic heads (groundwater levels), subsidence and compaction, and pumping. These results are evaluated with respect to fit statistics outlined by Anderson and Woessner (2002) . More qualitative measures of model fit are also commonly used to evaluate model calibration quality and included in the model results.

4.3.1 Statistical Measures of Model Fit

Model calibration was evaluated through five common residual error statistics used to characterize model fit. These include the mean of residual error (ME), mean of absolute residual error (MAE), root mean of squared residual error ($RMSE$), Normalized RMSE ($NRMSE$), and linear correlation coefficient (R). The residual error here is calculated by subtracting the observed value from the modeled value at a specific physical location and time.

The mean of residual error (ME) is a measure of the general model tendency to overestimate (+) or underestimate (-) measured values. In general, it is a quantification of the model bias given by:

$$ME = \frac{1}{N}\sum_{i=1}^{N}(y_i - \hat{y}_i)$$

Where: N is the total number of observations
y_i is the i^{th} observed value

$\hat{y}_i$ is the ith simulated value of a model dependent variable

The mean absolute residual errors (MAE) is more robust to represent the goodness of fit as no individual errors will be canceled in the estimation as ME. The MAE estimates the average magnitude of the error between modeled and observed values and is defined as:

$$MAE = \frac{1}{N}\sum_{i=1}^{N}|(y_i - \hat{y}_i)|$$

The root mean of squared residual error ($RMSE$) is defined as the square root of the second moment of the differences between observed and simulated error. Since the error between each observed and simulated value is squared, larger errors tend to have a greater impact on the value of the $RMSE$, therefore RMSE is generally more sensitive to outliers than the MAE.

$$RMSE = \sqrt{\frac{1}{N}\sum_{i=1}^{N}(y_i - \hat{y}_i)^{\,2}}$$

The normalized root mean squared error ($NRMSE$) is calculated to account for the scale dependency of the $RMSE$ and is a measure of the $RMSE$ divided by the range of observations (Anderson and Woessner, 2002).

The linear correlation coefficient (R) is defined in the following equations:

$$R = \frac{COV(y, \hat{y})}{\sigma_y . \sigma_{\hat{y}}}$$

Where: $COV(y, \hat{y}_i)$ is the covariance between the observed (y) and simulated ($\hat{y}$) values
σ_y is the standard deviation of the observed values
$\sigma_{\hat{y}}$ is the standard deviation of the simulated values

The value of R lies between 1 (perfect linear correlation) and -1 (perfect linear correlation in the opposite direction). Usually, simulated and observed quantity is plotted in a scatter diagram to represent the model calibration results graphically with associated linear correlation coefficient R.

4.3.2 Hydraulic Head (Groundwater Levels)

Simulated and observed groundwater elevations were compared over the 1988 through 2015 calibration period (**Figure 4-4**, **Appendix A**). The calculated *RMSE* is 60.5 ft and the *MAE* is 40.3 ft. These values are small compared to the range of observed groundwater levels in the model domain (*NRMSE* = 6.3%) (**Figure 4-4**). The calculated *ME* (-6.6 ft) indicates that the model tends to simulate higher groundwater levels than observed (over-predict) by an average of about 7 feet. The plot of observed versus simulated heads indicate that lower observed groundwater levels between -300 ft below sea level and 0 ft sea level are generally overestimated by the model (model results are higher than observed) while groundwater levels above sea level to approximately 400 ft, mean sea level are generally simulated well by the model (**Figure 4-4**). Groundwater hydrographs of observed and simulated groundwater levels from wells used in model calibration are shown in **Appendix A**.

The spatial distribution of residual errors in the simulated groundwater levels are presented in **Figures 4-5** to **4-7**. Values in red depict where simulated hydraulic head is higher than observed, while blue represents where observed hydraulic head is higher than simulated values. Maps of the average residuals at the calibration wells show that the model overpredicts groundwater levels in wells in the southern portion of the domain while the average residual error suggests simulated heads are generally lower than observed in the northern portion of the Subbasin.

Color floods of groundwater elevation were prepared for the upper and lower aquifers from March of 2011 and September of 2015 (**Figures 4-8** to **4-13**). These years were selected to illustrate the spatial distribution of hydraulic head and model response to wet (Spring 2011) and dry periods (Fall 2015). Simulated groundwater levels in the upper aquifer show higher water levels along the Coast Range to the west with lower groundwater levels towards the San Joaquin Valley axis to the east (**Figures 4-7** and **4-9**). During the irrigation season in 2015, groundwater depressions form near Stratford, near the Fresno Slough, and toward the SLC west of San Joaquin (**Figure 4-12**). The lower aquifer shows groundwater depressions southwest of Mendota to the Coast Range to the west and more substantially in the Stratford area towards the southeastern extent of the model (**Figure 4-13**). These depressions are more exaggerated at the end of the irrigation season in 2015 as compared to Spring 2011 (**Figure 4-13**).

4.3.3 Subsidence

Simulated subsidence and aquifer system compaction were compared to measured values throughout the model domain (**Figure 4-14, Appendix B**). Emphasis was placed on simulated results near the SLC and observations are generally more concentrated in this area compared to other areas in the model domain. Simulated results show a *ME* of 0.11 ft meaning the simulated subsidence and compaction is on average slightly less than observed (**Figure 4-14**). *MAE* and *RMSE* are 0.29 feet and 0.50 ft, respectively. The *NRMSE* is 10.0%, meaning that the model error in subsidence and compaction is relatively small compared to the range of observations. However, the range of observations spans approximately 5 ft, with very few measured values exceeding 3 ft (**Figure 4-14**).

Simulated subsidence since the year 2000 along the SLC is compared in 2006, 2009, 2013 and 2015 (**Figure 4-15**). The model is able to capture areas of increased subsidence along the canal over the 15-year period to some extent. However, the model underestimates the magnitude of subsidence near mile post 130 and mile post 160 in 2015, which could be improved with additional calibration.

Model results for subsidence monitoring locations that are not along the SLC generally track observed trends and magnitude fairly well, however, when the magnitude of subsidence increased near the end of the calibration period, the model captures the trend in subsidence but not always the magnitude that was experienced. This could be due to the data limitations that influence the model's representation of groundwater pumping spatially and the reliance of groundwater pumping on the distribution of surface water supplies in the model domain on a field scale.

4.3.4 Groundwater Pumping

Simulated groundwater pumping was compared to measured pumping within each of the nine farms within WWD in years where reliable measurements were available (2012-2015). The model reliably captures both periods of high and low groundwater pumping (**Figure 4-16**). The *ME* is low (-538 acre-fee per year (AFY), suggesting little model bias. The *MAE* and *RMSE* are 11,336 AFY and 12,809 AFY, respectively. The *NRMSE* is 11.8%.

4.4 Model Water Budget

The water budget within the model domain was calculated for the 1989-2015 DWR water years (October through September). Water budgets are subdivided with respect to the land surface system and Groundwater Budget. The land surface system water budget summarizes annual inflows and outflows from the FMP including precipitation, surface water imports, water from groundwater pumping, evapotranspiration and net deep percolation. The groundwater budget summarizes annual inflows and outflows from the groundwater system including deep percolation, stream leakage, lateral subsurface flow and groundwater pumping. It should be noted that groundwater pumping acts as an inflow to the land surface system budget and an outflow in the groundwater budget. Conversely, net deep percolation acts as an outflow in the land surface system budget and an inflow to the groundwater budget.

4.4.1 Land Surface System

The simulated land surface system budget for the model domain is summarized by water year in **Table 4-4** and **Figure 4-17.** Inflows of water into the land surface system budget within the model domain include precipitation, imported surface water and groundwater pumping. Outflows from the land surface system budget within the model domain include evaporation and deep percolation. Total simulated inflows and outflows to the land surface system in the 1989 through 2015 water years range from 2,527,000 to 3,988,000 AFY and average 3,297,000 AFY.

4.4.2 Groundwater System

The simulated groundwater budget for the model domain is summarized by water year in **Table 4-5** and **Figure 4-18**. Inflows to the groundwater budget includes net deep percolation from irrigation and precipitation, losses from surface water bodied within the model domain and lateral subsurface flow from general head boundaries in the northern, eastern and southern portion of the model domain. Outflows from the groundwater budget include groundwater pumping, flow from the aquifer system to surface water boundaries and lateral subsurface flow to general head boundaries. Total simulated inflow in the 1989 through 2015 water years ranges from 718,000 to 1,562,000 AFY and averages 1,085,000 AFY. Total outflows range from 717,000 to 1,886,000 AFY and average 1,241,000 AFY. The simulated change in groundwater storage ranges from a 737,000 AFY increase in storage to a 1,081,000 AFY decrease in storage with an average annual decrease in groundwater storage of 157,000 AFY.

4.5 Westside Subbasin Water Budget

Water budgets for the Westside Subbasin were calculated using output from the MODFLOW FMP and the Zone Budget post-processing tool for evaluating local water budgets (Harbaugh, 1990).

4.5.1 Land Surface System

Inflows of water into the land surface system budget in the Subbasin include precipitation, imported surface water and groundwater pumping and are summarized annually in **Table 4-6** and **Figure 4-19**. Additional details regarding inflows from the land surface system are summarized by water year in **Table 4-7**. Total simulated inflows over the historic period ranges from 982,000 AFY to 1,844,000 AFY and averages 1,502,000 AFY. Simulated precipitation ranges from 160,000 AFY to 847,000 AFY with an average of 389,000 AFY. Imported surface water ranges from 179,000 AFY to 1,373,000 AFY and averages 841,000 AFY. Throughout the historic period, the District maintained a CVP contract of 1,190,000 AF through the USBR. Groundwater pumping applied to the land surface system ranges from 79,000 AFY to 697,000 AFY.

Outflows from the land surface system budget in the Subbasin includes evaporation and deep percolation and are summarized annually in **Table 4-6** and **Figure 4-19**. Additional details regarding outflows from the land surface system are summarized by water year in **Table 4-8**. Net deep percolation is equal to deep percolation to the aquifer system minus the direct groundwater uptake from plants and evaporation. Total simulated outflow ranges between 982,000 and 1,845,000 AFY and averages 1,503,000 AFY between 1989 through 2015. Total evapotranspiration ranges from 920,000 and 1,399,000 AFY and averages 1,185,000 AFY (**Table 4-6**). Net deep percolation ranges from 30,000 to 528,000 AFY and averages 317,000 AFY.

4.5.2 Groundwater System

Groundwater inflows include net deep percolation from precipitation and irrigation, seepage from streamflow to the aquifer system from ephemeral streams and lateral subsurface flow and are summarized for the historical water budget in **Table 4-9** and **Figure 4-20**. Total simulated inflow to the groundwater system ranges from 159,000 to 747,000 AFY and averages 477,000 AFY. Simulated net deep percolation averages 317,000 AFY and ranges from 28,000 in 2009 to 530,000 AFY in 1999 and is generally greater in wet years and less in dry years (**Figure 4-21**). Simulated seepage from streams ranges from nearly none to 33,000 AFY and averages about 10,000 AFY. Lateral subsurface inflow from adjacent subbasins ranges from 88,000 AFY to 245,000 AFY and averages 151,000 AFY (**Figure 4-22**).

Outflows from the groundwater system include groundwater pumping and lateral subsurface outflow to adjacent subbasins and are summarized in **Table 4-9** and **Figure 4-20**. Total simulated outflow from the groundwater system ranges from 241,000 to 865,000 AFY and averages 493,000 AFY. Groundwater pumping ranges from 91,000 AF in 2005 to nearly 700,000 AF in 1991 and averages 324,000 AFY (**Figure 4-23**). Lateral subsurface outflow to adjacent subbasins averages 169,000 AFY with a range from 144,000 to 192,000 AFY (**Figure 4-22**).

Annual change in groundwater storage ranges from a net decrease of up to 568,000 AF to a net increasing of up to 427,000 AF, in which the change in storage depends largely on the hydrologic year type and amount of imported surface water (**Table 4-9**). Groundwater storage generally increases between the late 1990's and decreases beginning in 2008. Other periods during the calibration period are relatively stable (**Figure 4-24**).

Groundwater budget results are segregated by aquifer type (Upper and Lower Aquifers) and provided in **Table 4-10** and **Table 4-11**. Simulated recharge in the Upper Aquifer is derived from precipitation and irrigation in combination with up to 10,000 AFY in stream recharge from creeks draining the Coast Range to the west of the Subbasin. Lateral subsurface flow from adjacent areas is generally small (**Table 4-11**). Outflows from the Upper Aquifer include lateral subsurface flow, groundwater pumping and vertical flow through the Corcoran clay and composite wells which act as a conduit for flow between the Upper and Lower Aquifers. Groundwater pumping totals 92,000 AFY or about 28% of total pumping (**Figure 4-25**). Simulated lateral subsurface flow out of the Upper Aquifer is substantially higher than lateral inflows into the Lower Aquifer such that the net lateral flow is approximately 100,000 AFY out of the Subbasin (**Figure 4-26**). Vertical flow between the Upper and Lower Aquifer is considerable and is generally a result of intraborehole flow through composite wells (**Figure 4-27**). Consequently, despite the majority of pumping occurring in the Lower Aquifer, the majority of the changes in groundwater storage are propagated to the water table in the Upper Aquifer over long enough time periods **(Table 4-11**).

The sources of recharge to the Lower Aquifer are lateral subsurface flow and vertical flow from the Upper Aquifer (**Table 4-11**) totaling an average of 271,000 AFY. Outflows include groundwater pumping and lateral subsurface outflow. Pumping in the Lower Aquifer accounts for approximately 71% of total pumping from the Subbasin (**Figure 4-25**). However, pumping is generally offset by recharge from the Upper Aquifer and lateral subsurface flow from adjacent areas (**Figure 4-26** and **Figure 4-27**). Changes in groundwater storage are generally smaller in the Lower Aquifer, but short-term changes can be substantial during periods of heavy pumping (**Figure 4-24**).

4.5.3 Groundwater Overdraft

On the scale of the Subbasin, the WSGM simulates a decline in groundwater storage averaging 19,000 AFY. Over the entire historical water budget period, the cumulative decline in groundwater storage was nearly 517,000 AF (**Table 4-9**). While this measure of overdraft (as represented by decline in groundwater storage) suggests that the Subbasin was in an overdraft condition, this amount of groundwater storage decline represents less than 4% of total outflow and less than 6% of total groundwater pumping. This suggests that the Subbasin groundwater budget is relatively balanced over the model calibration period.

While the decline in groundwater storage as an indicator of overdraft was relatively small compared to other water budget components, overdraft as represented by subsidence is considered the primary overdraft concern in the Subbasin due to impacts on selected areas of the SLC as described in the GSP. Overdraft from subsidence impacts on critical infrastructure has occurred in selected areas of the Subbasin along the SLC where the combination of groundwater pumping from the Lower Aquifer, occurrence of clay beds susceptible to compaction, and declines in Loser Aquifer groundwater levels have historically occurred.

4.5.4 Estimate of Sustainable Yield

The Subbasin sustainable yield for the historic period can be approximated by the relationship between long-term pumping and groundwater storage change by:

$$Sustainable\ Yield = Q_h + \Delta S_h$$

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

ΔS_h is the average annual gross change in groundwater storage in the Subbasin simulated from 1989 through 2015

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

4.6 Model Sensitivity

A model response or prediction depends on the governing equations it solves, the mechanisms and structure of the model, and the values of the model parameters. Sensitivity analysis is a means of evaluating model uncertainty due to parameter estimates by systematically altering one of the model parameters and examining the associated change in the model response. After the groundwater flow model was calibrated, quantitative sensitivity analyses were performed using the flow model parameters that were most uncertain and likely to affect the flow simulation results. The calibrated flow model was used as the baseline simulation and sensitivity simulations were compared with those of the baseline simulation at all observation points. Model sensitivity was evaluated for model parameters using UCODE-2014. The basis of a model parameters sensitivity was based on hydraulic head observations, groundwater pumping observations and subsidence, and compaction observations given a 2% parameter value perturbation. Sensitivity was evaluated through the Composite Scaled Sensitivity (CSS) statistic described by Hill and Tiedman (2007).

- Sensitivity of simulated hydraulic heads to parameter perturbation are presented in Figure 4-28. The CSS statistic shows the model is most sensitive to the FTR coefficient in the FMP, KVW1 and KHS3 parameters within the aquifer system defined in **Table 4-1**.
- Sensitivity of simulated land subsidence and compaction observations to parameter perturbation are presented in Figure 4-29. The CSS statistic shows the model is most sensitive to the FTR coefficient in the FMP and KHS3 and SSKVS1 parameters within the aquifer system defined in **Table 4-1**.
- Sensitivity of simulated groundwater pumping to parameter perturbation are presented in Figure 4-30. The CSS statistic shows the model is most sensitive to the OFE3 coefficient in the FMP and KVW1 parameter within the aquifer system defined in **Table 4-1**.

5 PREDICTIVE MODEL DEVELOPMENT

The numerical model was used to simulate projected groundwater conditions over the 50-year planning horizon used for GSP development. Predictive scenarios were developed to conduct the projected water budget assessment, develop measurable objectives and minimum thresholds and evaluate the efficacy of projects and management actions. Model results are used to inform planning and decision making during the development and adoption of the GSP. Accordingly, predictive model scenarios were developed using guidelines outlined in the DWR Modeling BMP (Joseph et. al., 2016).

5.1 Baseline Model

A baseline model was developed to serve as a comparative benchmark for predictive scenarios and analysis of climate change. The baseline model relies largely on historic data over a 50-year period to simulate future groundwater conditions. Results from the simulation are used to evaluate groundwater storage, groundwater levels and subsidence.

5.1.1 Model Period and Hydrology

The model period selected for the predictive scenario spans from the end of the historic water budget period used for model calibration (January 1988 – December 2015) through the 50-year GSP planning horizon ending in December of 2070.

Simulation of the 50-year planning and implementation horizon spanning from 2020 through 2070 relies on data from the historic period from 1965 through 2015 as outlined in Water Code §354.18(c)(3). This time frame includes a combination of wet and dry periods used to evaluate the basin water budget response to variable hydrologic stresses. During periods where no historic data is available (dependent on data source), values were assigned from surrogate water years using the closest DWR Water Year Hydrologic Classification Indices (Water Year Index). These values are derived from unimpaired runoff in the Sacramento and San Joaquin Valleys and published in DWR Bulletin 120.

Data used to assign model stresses within the period between the end of the calibration period and the start of the 50-year planning and implementation horizon (2016-2019) rely on a combination of 2016 through 2019 data and historic data from the 1961 through 1964. In instances where no historic data is available, values were assigned from similar DWR Water Year Indices.

5.1.2 Model Geometry

Temporally, the 55-year future scenario (2016 through 2070) was divided into 660 monthly stress periods. Each stress period was subdivided equally into 2 timesteps. Spatially, the model relied on the same discretization used in the historic period and outlined in **Section 3.1.1** and shown in **Figures 3-1** and **3-2**.

5.1.3 Aquifer Hydraulic Parameters

Hydraulic properties defined in the LPF package (horizontal and vertical hydraulic conductivity, specific yield and specific storage due to the compressibility of water) and SUB package (elastic and inelastic storativity) were unchanged from values used in the calibrated model and assigned to respective packages in the predictive model (**Table 4-2**).

5.1.4 Farm Process

The MODFLOW FMP define the water supply and demand functions used to calculate pumping and a majority of groundwater recharge to the system. As a result, decisions and datasets used to specify Farm Process inputs play a significant role in calculating the groundwater budget. A description of assumptions and inputs are described below.

5.1.4.1 Farm Delineation

The delineation of water balance sub-areas (farms) was updated for the predictive modeling period. Westlands was subdivided into 10 farms during the model calibration period in order to more accurately represent the spatial distribution of irrigation demand, surface water deliveries and groundwater pumping (**Figure 3-4**). The absence of this constraint coupled with the foreseeable need to shift supply and demand to different portions of the district required coarsening of the farm delineation within Westlands. Accordingly, the 10 farms used to represent the district during the historic period were reduced to one to simulate future conditions (**Figure 5-1**). No changes were made to the farm delineation outside of the Subbasin.

5.1.4.2 Climate

Climate inputs required for the MODFLOW FMP include the precipitation and reference evapotranspiration for each model cell stress period. Rainfall in the model domain was assigned from data developed by the Prism Climate Group (http://prism.oregonstate.edu/). Monthly historical PRISM data from 1963 through 2015 were used to assign precipitation in model cells for the predictive scenario in every stress period from 2018 through 2070. Values assigned in 2016 and 2017 were based on the monthly 4-km gridded PRISM mode data available for respective years. Average assigned precipitation over the predictive period is 8.4 inches per year over the active portion of the model domain. The distribution (minimum, maximum and mean) of precipitation assigned to cells within the active portion of the model domain summarized by calendar year is shown in **Figure 5-2**.

Reference evapotranspiration data are available from CIMIS weather stations beginning in 1982 and on a 2-km gridded format from the CIMIS spatial model of ET_o beginning in 2003. In order to develop the most accurate spatial dataset, the model relies predominantly on the gridded ET_o data from the spatial CIMIS database. For the historic period from 2003-2015 (corresponding to the predictive period from 2058-2070), the daily data provided in the spatial CIMIS model was incorporated directly into the groundwater model. During the period where only daily station data were available (1982-2003), daily ET_o from the station data were compared to daily gridded ET_o. For each day, the spatial model which most accurately represented the station data was selected and used in place of the station data for that day. These data were then combined with the 2003-2015 spatial CIMIS data to produce monthly gridded data from 1982 - 2015 (corresponding to the predictive period from 2038 -2070). Values in the remaining years (2018 – 2037) were assigned using available data from the most similar Water Year Index from the San Joaquin Valley. Values assigned in 2016 and 2017 are based on the monthly 2-km gridded spatial CIMIS model data available for those years. Assigned precipitation over the predictive period averages 5.9 ft per year (ft/yr) over the active portion of the model domain. The distribution (minimum, maximum and mean) of evapotranspiration assigned in the active portion of the model domain summarized by calendar year is shown in **Figure 5-3**.

5.1.4.3 Surface Water Deliveries

Surface water imports within the model domain were assigned using output from the California Water Resources Simulation Model II which provides monthly projected diversion amounts for CVP contractors (CalSim II). CalSim II is a water resources model developed jointly by DWR and USBR to simulate operations of the CVP and SWP (USBR, 2015). As part of the Water Storage Investment Program (WSIP) developed by the California Water Commission, CalSimII was run under 2030 and 2070 climate scenarios for future conditions which has subsequently been adopted for use in SGMA planning.

For the purposes of developing the baseline simulation of future conditions, output from the 2030 WSIP CalSim II run were used to assign surface water imports to entities within the model domain for the baseline scenario. These data were utilized in place of historic deliveries largely because they more closely match annual projected imports estimated by the district that are generally lower than historic amounts due to increased environmental flows and projected climate trends. CalSim II 2030 climate scenario projects WWD will receive an average of 517,000 AF per contract water year (March – February) – or about 43% of Westland’s original 1,190,000 AF CVP contract from 2020 through 2070 (**Figure 5-4**, **Table 5-1**). Within each year, surface water imports were distributed between stress periods based on irrigation demand as opposed to using the monthly deliveries provided by CalSim II.

The SLC/California Aqueduct is jointly managed by USBR and DWR under a Coordinated Use Agreement (USBR, 1986). Due to apportionment issues highlighted during the 2014-2015 drought, the Cooperated Use Agreement (COA) between DWR and USBR was updated and amended in 2018 (U.S. Department of the Interior (DOI), 2018, **Figure 5-5**). Based on the 2018 Addendum, it is expected that annual exports south of the delta through the CVP will be increased by an average of 95,000 AF, or about four percent. The COA will result in WWD receiving approximately 70 percent of the additional CVP exports south of the delta. This additional water ranges between 48,000 AF in wet water years to 85,000 AF in dry years (**Figure 5-6**). On average the total COA benefit is projected to contribute an additional 66,000 AF of water to the overall WWD supply, or approximately 6% of the original CVP contract amount of 1,190,000 AF (**Table 5-1**).

The third element of imported water is imported supplies from transfer and exchange projects. Historically, imported water from transfer and exchange projects have been acquired and imported annually by WWD and its water contractors in order to supplement CVP deliveries. These supplemental water deliveries have been obtained through a combination of transfers and exchanges between numerous entities within the Central Valley and delivered through the SLC. The additional water from transfers and exchanges are also delivered to the District through Laterals 6 and 7 in the Mendota Pool. From 1988 to 2017, supplemental district supply and water contractors acquired water on average approximately 180,000 AFY (**Table 5-2**).

Future projections of the total amount of additional imported water supplies are estimated based on the historical amounts with respect to the District's CVP allocation. This relationship results in supplemental water imports that are projected to average 90,000 acre-feet on an annual basis when the CVP allocation exceeds 1,000,000 to 218,000 AF when the WWD CVP allocation is between 750,000 and 1,000,000 AF (**Figure 5-7**). The annual projected amount of additional imported water is shown in **Table 5-1**. Supplemental water averages 154,000 AFY over the 50-year planning and implementation period. When added to projected CVP deliveries (including COA), the total annual surface water deliveries are projected to average 732,000 AFY (**Figure 5-8**).

Projected surface water imports to other entities holding CVP contracts were also assigned using modeling results provided by CalSim II. In most instances, each CalSim II diversion serves multiple water purveyors. Furthermore, the area served by each water purveyor may not fall entirely within the model domain. To account for this, water specified in each CalSim diversion was divided between purveyors proportionately based on their contract amount. This amount was reduced proportionately to the fraction of the entity within the model domain. Imports were aggregated annually (March – February) for each MODFLOW farm and distributed monthly based on irrigation demand.

Projected surface water allocations to entities in the southern Kings and Tulare Lake Subbasins (North Fork Kings GSA, South Fork Kings GSA, Mid-Kings GSA, Southwest Kings GSA, El Rico GSA) reliant on the Kings River could not be obtained. As a result, deliveries to these areas within the model domain were estimated based on a regression relationship. The linear regression model compares historic annual surface water imports to Westlands with respect to deliveries to the areas of North Fork Kings GSA, South Fork Kings GSA, Mid-Kings GSA, Southwest Kings GSA and El Rico GSA within the model domain. The regression model estimates the amount of water delivered to each of the unknown entities as some fraction of the amount imported to WWD. This relationship is then applied to the projected imports to WWD to estimate the projected surface water delivered to North Fork Kings GSA, South Fork Kings GSA, Mid-Kings GSA, Southwest Kings GSA and El Rico GSA.

5.1.4.4 Groundwater Pumping

Groundwater pumping is allocated dynamically for the baseline future condition scenario in timesteps when direct groundwater uptake from crops, precipitation, and surface water deliveries within a model stress period are not able to meet the consumptive demand within a farm. The number of wells and their construction did not change between the historic and future simulation. Groundwater pumping was distributed equally between all wells within each farm. The location of simulated wells is shown in **Figure 3-9**.

5.1.4.5 Land Use

A land use type was assigned to each model cell and held constant for the entire baseline scenario. Within WWD, land use provided by the district for 2016 was used to assign land use types (**Figure 5-9**). Outside of the district, the most recent land use survey available was used (**Table 3-2**). For the baseline case, neither land use dataset was modified prior to implementing in the predictive modeling period.

5.1.4.6 Farm Parameters

Crop and landscape parameters defined in the FMP (i.e. irrigation efficiency, crop coefficient, rooting depth) from the calibrated model period were used in the predictive modeling period.

5.1.5 Boundary Conditions

Boundary conditions specified outside of the MODFLOW FMP include the SFR package, the LAK package and GHB package.

5.1.5.1 General Head Boundary

Head dependent boundaries specified at the edge of the model domain using the GHB package are used to represent lateral subsurface groundwater flow into and out of the numerical model. The amount into or out of the model domain is dependent on the hydraulic head assigned to the boundary with respect to the hydraulic head inside the model domain. Significant bias can be introduced into the model projection if the hydraulic head assigned to the boundary is too high or low. It is often important to capture seasonal fluctuations due to groundwater pumping for irrigation which may propagate laterally to a significant extent in confined aquifers.

The hydraulic head in the GHB package was assigned based on repetition of simulated hydraulic heads in CVHM from 1963 to 2017 in CVHM cells corresponding to GHB cells in WSGM. Simulated hydraulic head from 2016 and 2017 were used for the 2016 and 2017 WSGM model years while hydraulic heads from 1963 through 2015 were used for the 2018 through 2070 projected period. Hydraulic heads from CVHM were adjusted in two significant ways to develop an appropriate distal head boundary for the projected period:

1) Hydraulic heads in the CVHM model were shifted vertically to provide a smooth transition between the historic and projected modeling periods.

2) At the time of preparing the GHB, it was assumed that hydraulic heads in adjacent subbasins outside the model domain will be sustainably managed to SGMA 2015 baseline levels during the projected period. Accordingly, long term average hydraulic heads were kept stable during the projected period but allowed to vary due to shorter term hydrologic stresses. This was achieved through adjusting the simulated water levels in CVHM such that the 5-year moving average did not change with time.

An example of these adjustments is shown for simulated water levels in one CVHM model cell in **Figure 5-10**.

5.1.5.2 Groundwater Surface Water Interaction

Boundary conditions used to simulate groundwater-surface water interaction are the SFR package for streams and the LAK package for the Mendota Pool. For the SJR and drainages in the coast ranges, gaged streamflow in 2016 and 2017 data were assigned over the corresponding model period. In the Kings River, which does not have public gage data available, historic data from 2002 and 2011 were used as a surrogate for these years. The period from 2018 through 2070 relied on historic data (where available) and data from similar DWR water year indexes where historic data were unavailable for the Kings River system and western drainages. For the SJR, flows were adjusted based on the methodology outlined in the San Joaquin River Restoration Program (SJRRP) flow requirements (SJRRP, 2013). These are based on historic unimpaired flow into Millerton Reservoir where available and data from surrogate years based on DWR water index where data are unavailable. The water budget for the Mendota Pool was based on historic data (where available) and surrogate years based on DWR water index where data is unavailable.

5.1.6 Initialization

Initial conditions for the predictive simulation include the initial hydraulic heads within each active model cell, initial preconsolidation head within each model cell and the initial stage in the Mendota Pool at the start of January 1st, 2016. These values were extracted from the simulated output at the end of the last timestep of the calibrated model and used to initialize the predictive model run.

5.2 Climate Change

Model uncertainty due to climate change was evaluated in accordance with Section 354.18(c)(3) of the GSP regulations. Model inputs for climate projections were developed using guidelines outlined in the DWR "Guidance for Climate Change Data Use During Groundwater Sustainability Plan Development" document (DWR, 2018). Analysis of climate change is based from data originally developed for the WSIP which provides 4 climate datasets centered around 2030 and 2070 climate conditions. Of these, datasets reflecting the central tendency of 2030 (near future) and 2070 (late future) of the ensemble of global circulation models were used to develop climate change factors used for two model projections which incorporate climate uncertainty. The projected run with no climate change perturbations, central tendency of 2030 (near future) and 2070 (late future) scenarios are hereafter referred to as the No Climate Change, 2030 Climate Change and 2070 Climate Change, respectively. Model inputs altered for projections influenced by climate change include surface water deliveries, streamflow, reference evapotranspiration and precipitation and are described below.

5.2.1 Surface Water Deliveries

Surface water deliveries to WWD and other areas within the model domain were assigned using results from the CalSim II model developed jointly by DWR and USBR. The process for developing input data for imported surface water are described in Section 5.1.4.3. Imported surface water data for baseline model with no climate change factors were used for the 2030 Climate Change scenario. The 2070 Climate Change scenario relied on data output from the 2070 central tendency CalSim scenario. CVP projected deliveries to WWD are shown in **Figure 5-11** and **Table 5-3**. Total imported surface water to WWD is shown in **Figure 5-12** and **Table 5-3**.

5.2.2 Streamflow

Climate adjusted streamflow can be derived using three methods outlined in the DWR Climate Change Document (DWR, 2018). Based on the nature of the input and location of the model domain, Method 1 and 3 were used to develop input for climate scenarios. Method 1 uses routed streamflow with bias correction generated through a Variable Infiltration Capacity (VIC) Model developed for the WSIP and is available as timeseries data at selected gage locations for several drainages within the state. Method 3 relies on monthly basin average change factors for hydrologic basins within the state which can be used to correct historic unimpaired flows to account for climate change. For the application of Method 1, DWR has developed a climate change tool used to correct existing monthly timeseries data that was utilized for stream inflow points in the model domain.

Method 1 was used to generate runoff input for the SJR. Timeseries data from the 2030 Climate Change and 2070 Climate Change VIC models are available for the Gravelly Ford gage through September 2003. Surrogate data from similar DWR hydrologic year types were used for the historic period from October 2003 through the end of the projected period.

For all other inflow locations, monthly flow for the 2030 Climate Change and 2070 Climate Change projections were derived using the climate change perturbation tool developed by DWR. A comparison of average unimpaired flow in Los Gatos Creek used in the No Climate Change, 2030 Climate Change and 2070 Climate Change projections are summarized by water year and shown in **Figure 5-13**. Discharge in the north and south branches of the Kings River are regulated by releases from the Pine Flat dam. However, there are no VIC output from these locations to specify flow into the model domain. Currently there are no publicly available sources of data to inform how these releases may be impacted by climate change within the SGMA framework. As a result, Method 3 was used to perturb model inputs at these locations.

5.2.3 Precipitation and Reference Evapotranspiration

DWR provides spatial and temporal perturbation factors to adjust precipitation and ET_o data to develop climate change projections based on the VIC model developed for the WSIP. Monthly VIC climate perturbation factors are available on 6-km by 6-km gridded cells (**Figure 5-14**). These data are applied as a multiplier to the monthly precipitation and ET_o data from the No Climate Change projection in each model cell for each climate projection beginning in March of 2017. Data are available for the historic period through December 2011. Perturbation factors for the period between January 2011 and December 2015 were derived from available data using similar DWR water year indices. Spatially each WSGM cell was mapped to each VIC model cell based on whether the centroid of the WSGM cell falls within a given VIC model cell. Average annual precipitation and ET_o for each climate projection is shown in **Figure 5-15** and **Figure 5-16**.

5.3 Projects and Management Actions

Model projections were used to evaluate Projects and Management Actions (PMAs) considered by WWD as part of GSP preparation and described in Chapter 4 of the GSP:

1. Project No. 1 – Surface Water Imports
2. Project No. 2 – Initial Allocation of Groundwater Extraction
3. Project No. 3 – Aquifer Storage and Recovery
4. Project No. 4 – Targeted Pumping Reductions
5. Project No. 5 – Percolation Basins

Of these, PMAs 2 through 4 were simulated using the groundwater model to evaluate impacts. PMA 1 is considered an existing management action which was included in the Baseline model projection. At the time of modeling, the District has not collected sufficient details with respect to PMA 5 to adequately constrain model inputs to develop a model scenario. As a result, this PMA is not currently evaluated using the numerical model.

5.3.1 Project No. 2 - Initial Allocation of Groundwater Extraction

A groundwater model scenario was used to determine groundwater pumping allocations for the GSP. It is expected that groundwater pumping allocations will serve as the primary PMA for the Subbasin to achieve sustainability. As a result, the simulation of PMA No. 2 is premised largely on determining the amount of groundwater that can be sustainably extracted from the aquifer system such that the long term change in storage over the 50-year projected water budget period from 2020 through 2070 is negligible. Operating under this premise, it is assumed that in order to stabilize groundwater storage the average groundwater pumping must be roughly equal to average groundwater recharge within the Subbasin over the model projection period. Under these conditions the water budget within the Subbasin is sustainable with respect to groundwater storage and the sustainable yield of the Subbasin can be roughly approximated to determine groundwater pumping allocations.

Given supply constrained demand concept driving One-Water, groundwater pumping is dynamically linked to irrigation demand which is driven largely by a combination climate inputs (ET and precipitation), surface water deliveries and land use. Given that climate inputs and surface water imports are fixed in the model projection, balancing groundwater pumping and recharge must be largely achieved through adjusting the amount of irrigated acreage.

Given these constraints, the projected model run used to inform pumping allocations for PMA No. 2 was developed by adjusting the amount of irrigated land in a given year such that pumping is equal to groundwater recharge. Within each USBR water contract year, the irrigated acreage was adjusted by changing the crop type in model cells from an irrigated crop type to a non-irrigated crop (wheat) in instances where groundwater pumping is greater than recharge and converting a non-irrigated crop to an irrigated crop (cotton) when recharge is greater than pumping. The land fallowing scheme was developed such that annual crops are fallowed first and permanent crops (trees, vineyards) are fallowed second. The land use footprint for making these adjustments is the 2016 land use array shown in **Figure 5-9**. Land use arrays from wet (2065) and dry (2043) years from the No Climate Change projection are shown in **Figure 5-17** and **Figure 5-18**, respectively.

The upper limit on irrigated acreage within the Subbasin was set as 450,000 acres based on the approximate maximum amount of irrigable land within the District. In wet years where recharge exceeds pumping and the upper limit of 450,000 acres is reached, the surplus water is banked and carried over for use in dry years. The lower limit on irrigated acreage was set as 300,000 acres in a given year. In instances where pumping exceeds recharge and there is no banked water, irrigated acreage is reduced below 300,000 acres. The resulting irrigated acreage for the No Climate Change, 2030 Climate Change and 2070 Climate Change projections are shown in **Figure 5-19**.

Within this framework it is also assumed that adjacent subbasins will each achieve sustainability as defined by 2015 baseline conditions. Though GSAs outside of the Subbasin will likely employ a variety of measures to achieve sustainability, for modeling purposes, land fallowing is the only management implemented to mitigate overdraft conditions during periods in the projected period where this is of concern. As a result, a similar approach was utilized within each water balance sub-area (farm) outside of the Subbasin.

5.3.2 Project No. 3 – Aquifer Storage and Recovery

Aquifer Storage and Recovery (ASR) is being investigated as a conjunctive use strategy to improve water supply reliability within the Subbasin. Due to the predominance of fine-grained soils combined with the occurrence of the Corcoran Clay throughout the majority of the Subbasin, there are limited opportunities for surface recharge within the Subbasin to benefit Lower Aquifer groundwater conditions (KDSA, 2009; Wood, 2019). As a result, the GSA has proposed implementing a large-scale agricultural ASR program, through artificial injection wells, as a more pragmatic alternative to enhance subsurface recharge in the Subbasin. The program feasibility was demonstrated in a 2018 pilot study on a retrofitted District-owned well (Brown and Caldwell, 2018). The report favored the development of a District-wide ASR program as an augmentation strategy for conjunctive use in the Subbasin. The District is currently pursuing programmatic compliance through a Report of Waste Discharge (ROWD) with the Central Valley Regional Water Quality Control Board (CVRWQCB or Regional Board) and California Division of Drinking Water (DDW) to inject water in up to 400 Ag-ASR wells within the Subbasin (Brown and Caldwell, 2019).

From the 932 WWD production wells included in the WSGM, 400 were selected randomly as ASR wells for PMA No. 3 model scenarios (**Figure 5-20**). Of these, 27 are completed in the Upper Aquifer, 204 are completed in the Lower Aquifer and 169 are composite wells completed in some portion of both aquifers.

Aquifer storage is anticipated to occur during periods where there is available water for injection. Sources of injected water are anticipated to be a combination of Section 215 non-storable water, at-risk carryover water from the San Luis Reservoir, flood flow dischargeand supplemental surface water imported by the District in wet years. The District expects an annual average of 28,000 AFY to be imported for injection by ASR wells during the projected period.

The total amount of water potentially available from flood flow discharge given implementation of ASR in 400 wells averages approximately 12,300 AFY in the No Climate Change and 2030 Climate Change models and 13,800 AFY in the 2070 Climate Change Scenarios (**Table 5-4** and **Table 5-5**). The total amount of water available for import in any given month was estimated based on the projected flow in the James Bypass. James Bypass flows were estimated based on specified inflow at the North Fork Kings River at Crescent Weir and adjusted for losses. This amount was further constrained to 50,000 AFY in any given year based on conveyance limits included in a 2017 Finding of No Significant Impact (FONSI) filed by the USBR in 2017 and also the total monthly injection capacity of the 400 ASR wells given a maximum of 650 gallons per minute (gpm) injection rate (USBR, 2017).

Supplemental water imported by the District and water users from other sources is specified in the model during wet years such that the total annual average amount of water imported for ASR totals 28,000 AFY.

In the No Climate Change and 2030 Climate Change projections, 50,000 AF of supplemental imports are specified as injection when projected CVP imports exceed 60% of the District's CVP contract. In the 2070 Climate Change projection, 50,000 AF supplemental imports are specified as injection when projected CVP imports exceed 42% of the District's CVP contract (**Table 5-4** and **Table 5-5**).

The total amount of water imported for injection in ASR wells is summarized by water contract year in **Figure 5-21** in the No Climate Change and 2030 Climate Change projection and **Figure 5-22** in the 2070 Climate Change projection. Injection within ASR wells were distributed equally between December and March of each year where water is supplied. During these stress periods, wells used for ASR are decoupled from the Farm Process and are not used to meet irrigation demand within the District. Accordingly, all groundwater pumping demand (if any) during these stress periods is met by the remaining 532 wells assigned in the District that are not used for injection.

5.3.3 Project No. 4 – Targeted Pumping Reductions

Land subsidence near Checks 16, 17 and 20 of the SLC/California Aqueduct during the 2013-2016 drought highlighted the necessity to develop a mechanism for the GSA to reduce groundwater pumping to avoid or mitigate undesirable results related to subsidence in these areas. With respect to the SLC at Checks 16, 17, and 20, any amount of additional land subsidence will significantly and adversely impact the ability for the USBR and DWR to convey water without implementing new design and construction measures to mitigate the impacts of aqueduct operations from subsidence. Accordingly, the GSA has developed a process to require groundwater pumping reductions in portions of the Subbasin and when necessary to immediately and directly relieve the groundwater pumping stress when continued pumping would produce significant undesirable results.

The numerical model is used to evaluate the efficacy of targeted pumping reductions in avoiding undesirable results. Given the immediate sensitivity regarding subsidence issues along the California Aqueduct at Checks 16, 17 and 20, modeling for PMA No. 4 focuses on pumping reductions in this area for a fixed number of wells during projected dry period. The model scenario was developed to evaluate an extreme case such that no pumping is simulated during the period considered and supplemental water provided by the District meets the entirety of pumping demand.

Wells in which pumping reductions were applied fall within subsidence prone areas are shown in **Figure 5-23**. A total number of 94 wells were included in the WSGM within these areas. Of these, 74 wells are completed in the Lower Aquifer and 20 are composite wells completed in the Upper and Lower Aquifers.

Pumping in these wells was disabled from the FMP from March 2042 through February 2047 (2042-2047 water contract years). This represents a long-term drought in the projected period where subsidence and other undesirable results are likely to occur (**Figure 5-8** and **5-12**). During this period, the amount of water pumped from wells located in the subsidence prone areas is substituted with surface water imports provided by the District and specified as a non-routed delivery in the FMP. The volume of simulated groundwater extracted by these wells was determined from the Baseline Model for each respective climate scenario (**Figure 5-24**).

6 CURRENT WATER BUDGET YEAR RESULTS

In order to maintain consistency with the GSP, model results are presented with respect to the Current Water Budget Year (2016) and projected water budget period (2017-2070). Results from the current water budget year include model output from October through December of the calibration period. As stated in **Section 5**, the current water budget year relies entirely on model data reported for the 2016 DWR water year.

6.1 Water Budget

Water budget results from the current water budget year are presented below. The simulated land surface water budget for the Subbasin shows a total inflow and outflow of 1,321,000 AFY (**Table 6-1)**. The simulated groundwater budget for the Subbasin shows a total inflow of 404,000 AF, total outflow of 733,000 AFY, and a decline in groundwater storage of 330,000 AF (**Table 6-2**). The change in groundwater storage from January 2016 to January 2017 is shown in (**Figure 6-1**). Results from the Upper Aquifer show total simulated inflow of 199,000 AF, outflow of 450,000 AF, and a decline in groundwater storage of 249,000 AF (**Table 6-3**). Results from the Upper Aquifer show a total simulated inflow of 382,000 AF, outflow of 460,000 AF, and a decline in groundwater storage of 81,000 AF (**Table 6-4**).

6.2 Groundwater Levels and Land Surface Subsidence

Simulated groundwater levels are provided for January 2016 for the Shallow Aquifer (**Figure 6-2**), Upper Aquifer (**Figure 6-3**), and Lower Aquifer (**Figure 6-4**). Groundwater levels are provided for January 2017 for the Shallow Aquifer (**Figure 6-5**), Upper Aquifer (**Figure 6-6**), and Lower Aquifer (**Figure 6-7**). The simulated change between January 2016 and January 2017 are shown for the Shallow Aquifer (**Figure 6-8**), Upper Aquifer (**Figure 6-9**), and Lower Aquifer (**Figure 6-10**). The amount of simulated land surface subsidence accrued from January 2016 to January 2017 is shown in **Figure 6-11**.

Table 6-1: Westside Subbasin Land Surface Budget for Current Water Budget Year

Water Budget Term	Volume (af)
Precipitation	467,000
Imported Surface Water[1]	255,000
Utilized Surface Water[2]	252,000
Groundwater Pumping	564,000
ET Groundwater	38,000
Total Inflow	**1,321,000**
Evaporation Irrigation	8,000
Evaporation Precipitation	215,000
Transpiration Irrigation	707,000
Transpiration Precipitation	151,000
Deep Percolation Irrigation and Precipitation	186,000
Deep Percolation Cultural Practices	16,000
ET Groundwater	38,000
Total Outflow	**1,321,000**

1. Reported surface water imports from District records (not included in total)
2. Simulated surface water imports in WSGM (some water rejected)
3. Difference between deep percolation and direct groundwater uptake

Table 6-2: Westside Subbasin Groundwater Budget for Current Water Budget Year

Water Budget Term	Volume (af)
Net Deep Percolation (af)	165,000
Stream Leakage (af)	<1,000
Lateral Subsurface Inflow (af)	239,000
Total Inflow (af)	**404,000**
Groundwater Pumping (af)	558,000
Lateral Subsurface Outflow (af)	175,000
Total Outflow (af)	**733,000**
Change in Groundwater Storage (af)	**-330,000**

Table 6-3: Westside Subbasin Upper Aquifer Groundwater Budget for Current Water Budget Year

Water Budget Term	Volume (af)
Net Deep Percolation(af)	165,000
Stream Leakage (af)	<1,000
Lateral Subsurface Inflow (af)	34,000
Total Inflow (af)	**199,000**
Groundwater Pumping (af)	161,000
Lateral Subsurface Outflow (af)	113,000
Vertical Flow	177,000
Total Outflow (af)	**450,000**
Change in Groundwater Storage (af)	**-249,000**

Table 6-4: Westside Subbasin Lower Aquifer Groundwater Budget for Current Water Budget Year

Water Budget Term	Volume (af)
Lateral Subsurface Inflow (af)	205,000
Vertical Flow	177,000
Total Inflow (af)	**382,000**
Groundwater Pumping (af)	397,000
Lateral Subsurface Outflow (af)	62,000
Total Outflow (af)	**460,000**
Change in Groundwater Storage (af)	**-81,000**

7 PREDICTIVE MODEL RESULTS

Results from the projected water budget period from 2017 through 2070 are presented below. Results are largely summarized with respect to the 20-year GSP planning horizon in 2040, and the 50-year GSP planning horizon in 2070. Results include land surface and groundwater budgets, groundwater levels, change in groundwater levels, and subsidence. Water budget output is summarized by water year (October – September) while spatial output (storage, groundwater levels and subsidence) is evaluated in January following each water year to assess groundwater conditions after water levels recover from irrigation. Output evaluating impacts of PMAs also include relative differences between the baseline and a given PMA with respect to storage, hydraulic head, and subsidence.

7.1 Baseline Model Results

Results from the Baseline model scenario are presented for the No Climate Change, 2030 Climate Change and 2070 Climate Change numerical model simulation from 2017 through 2070. Results include water budgets for the land surface system and groundwater system used in water budget analysis for the GSP are referenced in **Table 7-1** and **Table 7-2** and maps of groundwater levels, change in groundwater storage and land surface subsidence referenced in **Table 7-3**. Water budget results are presented on an annual basis based on DWR water year (October – September). Maps of simulated groundwater levels, change in groundwater levels, change in groundwater storage and land surface subsidence are presented for the 20 and 50-year planning horizons from January 1st, 2040 and January 1st, 2070.

Table 7-1: List of Water Budget Tables for the Baseline Scenario Projected Period

Climate Projection	Land Surface		Groundwater System		
	Inflows	Outlfows	Aggregate	Upper Aquifer	Lower Aquifer
No Climate	Table C-1	Table C-2	Table C-3	Table C-4	Table C-5
2030 Climate Change	Table C-6	Table C-7	Table C-8	Table C-9	Table C-10
2070 Climate Change	Table C-11	Table C-12	Table C-13	Table C-14	Table C-15

Table 7-2: List of Water Budget Figures for the Baseline Scenario Projected Period

Climate Projection	Land Surface Water Budget	Groundwater Budget
No Climate	Figure D-1	Figure D-2
2030 Climate Change	Figure D-3	Figure D-4
2070 Climate Change	Figure D-5	Figure D-6

Table 7-3: List of Groundwater Level, Groundwater Storage and Subsidence Maps for the Baseline Scenario Projected Period

Climate Projection	GW Level	Change in GW Level	Change in GW Storage	Subsidence
No Climate	Figure E-1 → E-6	Figure E-7 → E-12	Figure E-13 & E-14	Figure E-15 & E-16
2030 Climate Change	Figure F-1 → F-6	Figure F-7 → F-12	Figure F-13 & F-14	Figure F-15 & F-16
2070 Climate Change	Figure G-1 → G-6	Figure G-7 → G-12	Figure G-13 & G-14	Figure G-15 & G-16

7.1.1 Land Surface System Water Budget

Inflows and outflows to the land surface system in the Baseline scenario are summarized in **Figure 7-1** and **Figure 7-2**.

The largest source of water among the land surface system inflows is surface water applied to meet irrigation demand. The No Climate Change and 2030 Climate Change projections are developed using the 2030 CalSim surface water data while the 2070 Climate Change Scenario is based on the 2070 CalSim surface water data that are substantially lower (**Figure 7-1**). The difference in the amount of available surface water is reflected in the amount of surface water utilized in the No Climate Change projection (620,000 AFY) and 2030 Climate Change projection (598,000 AFY) compared to the 2070 Climate Change projection (530,000 AFY). The difference in applied surface water is reflected in the groundwater pumping required to meet irrigation demand. The No Climate Change and 2030 Climate change projection simulate average long-term groundwater pumping of 320,000 AFY and 316,000 AFY, respectively, while the pumping in the 2070 Climate Change projection averages 471,000 AFY (**Figure 7-1**).

Average surface water imports are smaller in the 50-year GSP planning horizon than the 20-year horizon in all climate projections. Imported surface water in the No Climate Change and 2030 Climate Change projections decline from 843,000 AFY in the 20-year planning horizon to 726,000 AFY in the 50-year planning horizon (**Table C-1** and **Table C-6**). Imported water in the 2070 projection and decline from 670,000 AFY to 586,000 AFY (**Table C-11**). Imported surface water is also substantially smaller than the average amount of 841,000 AFY assigned in the historic period (841,000 AFY) from 1989 through 2015 (**Table 4-6**). As a result, all models show a decline in surface water reliability as determined by the CalSim II model results provided by DWR.

Surface water deliveries vary substantially during the simulation period while land use is fixed as outlined in DWR's BMP for developing projected water budgets. As a result, imported surface water is not effectively utilized in the Baseline scenario because irrigation demand does not increase when more surface water is available. Of the total surface water in the model, 85% percent is used in the No Climate Change projection, 82% is utilized in 2030 Climate Change projection and 90% is utilized in the 2070 Climate Change projection.

The largest outflow from the land surface system is ET – of which ET from irrigation is the biggest term (**Figure 7-2**). Average annual ET from the No Climate Change and 2030 Climate Change Baseline projections are relatively similar (1,067,000 and 1,054,000 AFY, respectively), while ET from the 2070

Climate Change projection is slightly higher (1,124,000 AFY) due to the perturbation factors applied (**Figure 5-16**). Average annual ET in the projected period is lower than the historic period (1,186,000 AFY) and is largely a derivative of the fixed land use footprint used in the Baseline model scenario (**Table 4-8**).

The other major outflow from the land surface system is deep percolation which ranges from 356,000 to 372,000 AFY (**Figure 4-2**). The total deep percolation during the projected period is substantially less than the 516,000 AFY applied during the historic period (**Table 4-8**). This is likely due to a combination of crop type, which have gradually transitioned toward an increase in crops with higher irrigation efficiencies and improvements to irrigation efficiency within each crop type applied beginning in the latter portion of the historical period. Applied water for pre-irrigation and salt management is also lower leading to an overall decrease in deep percolation. The difference in deep percolation appears to be related to a commensurate decrease the amount of simulated ET directly from the water table. This water budget component decreased from 199,000 AFY in the historic period to between 71,000 and 81,000 AFY in the projected Baseline period (**Table 4-8** and **Figure 7-2**).

7.1.2 Groundwater System Water Budget

Inflows and outflows to groundwater system in the Baseline scenario are summarized in **Figure 7-3** and **Figure 7-4**.

Sources of inflow include net deep percolation (discussed in **Section 7.1.1**), lateral subsurface flow and leakage from stream channels from ephemeral creeks draining the coast ranges in the western portion of the model domain (**Figure 7-3**). Inflow from groundwater storage (representing a decrease in groundwater storage) is also contributes significantly to the Baseline groundwater budgets during the 50-year planning horizon and is discussed in **Section 7.1.2**. Average annual inflow from stream leakage is relatively small (~10,000 AFY). The bulk of the lateral subsurface inflow occurs in the Lower Aquifer where the majority of groundwater pumping occurs in all climate projections. The No Climate Change and 2030 Climate Change projections show an average annual inflow of 128,000 AFY to the Lower Aquifer, while the 2070 Climate Change projection shows 67,000 AFY more inflow (195,000 AFY) over the 50-year planning horizon (**Figure 7-3**).

Outflows include groundwater pumping and lateral subsurface flow. The majority of the lateral subsurface outflow occurs from the Upper Aquifer. With respect to net flow, lateral subsurface flow is generally out of the Upper Aquifer and to adjacent subbasins and into the Lower Aquifer from adjacent subbasins in the Baseline scenario. As mentioned in **Section 7.1.1**, groundwater pumping in the No Climate Change and 2030 Climate Change projections average 320,000 AFY and 316,000 AFY, respectively, while the pumping in the 2070 Climate Change projection averages 471,000 AFY **(Figure 7-4)**. Groundwater pumping is greater during the 50-year planning horizon, which is drier overall, than the 20-year horizon. Pumping in the 50-year planning horizon is between 70,000 and 79,000 AFY greater in the 2070 simulation.

Inter-aquifer flows between the Upper and Lower Aquifer are also substantial. Flow between aquifers occur through the wells completed in the Upper and Lower Aquifers and (to a lesser extent) through the

Corcoran clay. Average annual flows between aquifers total between 132,000 to 146,000 AFY in all scenarios. Flow, in aggregate, occurs from the Upper Aquifer to the Lower Aquifer (**Table X-X**).

7.1.3 Sustainability Indicators

The predictive model can be used to evaluate the projected groundwater conditions with respect to sustainability indicators. These are analyzed with respect to the 2040 and 2070 SGMA timelines in 2040 and 2070 These include groundwater levels, land surface subsidence and groundwater storage provided in (**Appendix E** - **G**).

7.1.3.1 Groundwater Levels

Groundwater levels are relatively stable through 2040 in the No Climate Change and 2030 Climate Change projections within the Subbasin (**Appendix E** and **F**). Some areas show moderate water level increases while others show increases. This is likely due to the differences in relative recharge and pumping rates as a result of reducing the number of farms within the Subbasin. Simulated results from the 2070 Climate Change 20-year projection show more substantial amounts of drawdown particularly in shallow groundwater zone and Upper Aquifer the southwestern portion of the Subbasin. All scenarios show considerable drawdown in the shallow groundwater zone and Upper and Lower Aquifers in the generally drier 50-year period. Water level changes in the 2070 Climate Change show severe drawdown occurring over the 50-year projection period (**Appendix G**).

7.1.3.2 Subsidence

Simulated subsidence is relatively minor and occurs largely in the southern portion of the Subbasin in 2040 in the No Climate Change and 2030 Climate Change projections but approaches 3 to 4 feet in the southern portion of the Subbasin in the 2070 Climate Change projection. Output at the end of the 2070 show substantial simulated subsidence in the southern portion of the Subbasin No Climate Change and 2030 Climate Change projections and severe subsidence over substantial portions of the Subbasin (**Appendix E** - **F**).

7.1.3.3 Groundwater Storage

The numerical model projects a substantial decrease in groundwater storage over the 50-year planning horizon under Baseline conditions (**Figure 7-3**). Projected overdraft in the 2070 Climate Change scenario is relatively severe by the end of 2070. The model shows projected groundwater storage over the 20-year planning horizon is relatively stable in the No Climate Change and 2030 Climate Change scenarios but simulates overdraft conditions in the 2070 Climate Change projection. Inspection of cumulative storage change with respect to time more clearly reveals the influence of climate and water year type on storage change (**Figure 7-5**). Prolonged dry periods where available surface water imports are curtailed lead to increased groundwater pumping to meet irrigation demand resulting in groundwater overdraft. This analysis highlights the need to reduce irrigation demand during extended dry periods to avoid undesirable results.

7.1.4 Estimated Sustainable Yield

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

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

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

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

L_h is the average annual lateral subsurface inflow into the Subbasin from adjacent GSAs simulated during the historic water budget period

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

One of the benefits of this methodology is that the resulting sustainable yield estimate accounts for gross differences between historic and projected lateral subsurface flow between the Subbasin and adjacent GSAs as compared to historic methodologies of safe yield that accounts for total amount of subsurface inflows as a component of safe yield. However, these projected differences in subsurface flows are also dependent on adjacent GSAs sustainably managing groundwater levels to 2015 baseline levels. IFollowing the completion of these model projections, it was learned that the neighboring GSAs in the Kings and Tulare Lake Subbasins are planning on sustainably managing groundwater levels to below 2015 baseline levels, thereby creating groundwater conditions that could impact sustainability goals in the Subbasin.

In addition, since the methodology is premised on Subbasin-wide simulated storage, the spatial and temporal distribution of groundwater pumping may need to be further augmented to avoid exceeding other sustainability indicators within the Subbasin that are not included in Baseline model scenarios. Similarly, the methodology assumes a linear relationship between groundwater pumping, groundwater storage and lateral subsurface inflows and outflows. While this is a useful approximation, this assumption may not adequately represent physical relationship in the aquifer system (i.e. a given change in groundwater pumping may not produce an equal change in groundwater storage in the actual system). Recognizing this, there is a need to develop a projection where simulated groundwater storage is stable to more appropriately estimate the sustainable yield for the Subbasin. This is largely addressed in PMA No. 2.

Based on this methodology, the estimated sustainable yield derived from the Baseline model run given the No Climate Change, 2030 Climate Change and the 2070 Climate Change projections are shown in **Table 7-4**. Simulated output from the No Climate Change and 2030 Climate Change model runs produce an estimated sustainable yield of between 267,000 AFY and 271,000 AFY for the 2040 and 2070 projected periods. Sustainable yield estimated from the 2070 Climate Change model run is higher; ranging from 290,000 AFY over the 2020-2040 period and 294,000 AFY over the 2020-2070 period.

Table 7-4: Baseline Estimated Sustainable Yield for the 2040 and 2070 GSP Planning Horizons

Groundwater Budget Term	No Climate Change		2030 Climate Change		2070 Climate Change	
	2040	2070	2040	2070	2040	2070
Pumping (af)	238,000	317,000	243,000	313,000	393,000	467,000
Change in GW Storage (af)	-9,000	-53,000	-8,000	-47,000	-66,000	-112,000
Difference in Lateral Subsurface Inflow (af)[1]	38,000	6,000	34,000	5,000	-37,000	-61,000
Sustainable Yield (af)	**267,000**	**270,000**	**269,000**	**271,000**	**290,000**	**294,000**

1. Difference between simulated historic and projected lateral subsurface flow

7.2 PMA No. 2 Model Results

Results from the PMA No.2 model scenario are presented for the No Climate Change, 2030 Climate Change and 2070 Climate Change numerical model simulation from 2017 through 2070. Results include water budgets for the land surface system and groundwater system used in water budget analysis for the GSP are referenced in **Table 7-5** and **Table 7-6** and maps of groundwater levels, change in groundwater storage and land surface subsidence referenced in **Table 7-7**. Maps illustrating the relative impacts of PMA No. 2 on water levels, groundwater storage and land surface subsidence are referenced in **Table 7-8**. Water budget results are presented on an annual basis based on DWR water year (October – September). Maps of simulated groundwater levels, change in groundwater levels, change in groundwater storage and land surface subsidence are presented for the 20 and 50-year planning horizons from January 1st, 2040 and January 1st, 2070.

Table 7-5: List of Water Budget Tables for the PMA No. 2 Projected Period

Climate Projection	Land Surface		Groundwater System		
	Inflows	Outlfows	Aggregate	Upper Aquifer	Lower Aquifer
No Climate	Table C-16	Table C-17	Table C-18	Table C-19	Table C-20
2030 Climate Change	Table C-21	Table C-22	Table C-23	Table C-24	Table C-25
2070 Climate Change	Table C-26	Table C-27	Table C-28	Table C-29	Table C-30

Table 7-6: List of Water Budget Figures for the PMA No. 2 Projected Period

Climate Projection	Land Surface Water Budget	Groundwater Budget
No Climate	Figure D-7	Figure D-8
2030 Climate Change	Figure D-9	Figure D-10
2070 Climate Change	Figure D-11	Figure D-12

Table 7-7: List of Groundwater Level, Groundwater Storage and Subsidence Maps for the PMA No. 2 Scenario Projected Period

Climate Projection	GW Level	Change in GW Level	Change in GW Storage	Subsidence
No Climate	Figure E-17 → E-22	Figure E-23 → E-28	Figure E-35 & E-36	Figure E-39 & E-40
2030 Climate Change	Figure F-17 → F-22	Figure F-23 → F-28	Figure F-35 & F-36	Figure F-39 & F-40
2070 Climate Change	Figure G-17 → G-22	Figure G-23 → G-28	Figure G-35 & G-36	Figure G-39 & G-40

Table 7-8: PMA No. 2 List of Figures of Project Impacts on Water Levels, Groundwater Storage & Subsidence

Climate Projection	Water Levels	Groundwater Storage	Subsidence
No Climate	Figure E-29 ⟶ E-34	Figure E-37 & E-38	Figure E-41 & E-42
2030 Climate Change	Figure F-29 ⟶ F-34	Figure F-37 & F-38	Figure F-41 & F-42
2070 Climate Change	Figure G-29 ⟶ G-34	Figure G-37 & G-38	Figure G-41 & G-42

7.2.1 Land Surface System Water Budget

Inflows and outflows to the land surface system in the Baseline scenario are summarized in **Figure 7-6** and **Figure 7-7**.

The largest source of inflow to the PMA No. 2 Land Surface System water budget is surface water imports utilized by the numerical model to satisfy irrigation demand (**Table 7-6**). The average utilization of surface water available for import is higher than the amount simulated in the Baseline. Of the available water, 93% is utilized in the No Climate Change projection, 92% is utilized in the 2030 Climate Change projection and 96% is utilized in the 2070 Climate Change projection. This increase is related to flexibility included in the PMA No. 2 scenario enabling irrigated acreage to increase when additional surface water Is available. Full utilization is not achieved for two reasons: 1) an upper limit on the amount of irrigable lands such that there is still a limit (although higher) on irrigation demand 2) irrigation demand can be met by direct ET from the water table and difficult to include in water budgets without running the model.

Total average simulated ET is greater in the No Climate Change and 2030 Climate Change projections and lower in the 2070 Climate Change projection (**Table 7-7**). ET is a function of crop type and reference ET and is scaled to the amount of available surface water in PMA No. 2. In PMA No. 2, the average amount of irrigated lands in the Subbasin in the No Climate Change and 2030 Climate Change projections is greater than the Baseline resulting in greater ET. Less water is available on average in the 2070 Climate Change resulting in fewer irrigated lands and lower average annual ET. The amount of water applied for irrigation is reflected in the amount of deep percolation which is greater than the Baseline in the No Climate Change and 2030 Climate Change projections and less in the 2070 Climate Change projection (**Table 7-7**).

7.2.2 Groundwater System Water Budget

Inflows and outflows to groundwater system in the Baseline scenario are summarized in **Figure 7-8** and **Figure 7-9**. The PMA No. 2 scenario simulates substantial differences in groundwater pumping, lateral subsurface flows and groundwater storage (discussed in **Section 7.2.3.3**) relative to the Baseline.

Total average groundwater pumping in the No Climate Change and 2030 Climate Change projections is similar to the Baseline (**Figure 7-4** and **Figure 7-9**). However, groundwater pumping in each given year can vary substantially particularly during dry years when irrigation demand is reduced to account for limits on available surface water supply. Conversely, pumping in wet years can be slightly higher in PMA No. 2 in order to increase the amount of irrigated land (this is not necessarily a management approach which is being promoted by the District but is a derivative of the land allocation and water budgeting approach developed for the PMA No. 2 simulation). Average annual groundwater pumping in the 2070 Climate Change projection is substantially less than in the Baseline due to reduction in demand commensurate to the quantity of available surface water. Similarly, groundwater pumping in the 2070 Climate Change projection is slightly less than in the No Climate Change and 2030 Climate Change projections because there is less surface water and (as a result) less deep percolation to recharge the aquifer system.

The dynamics of simulated lateral subsurface flow between the Subbasin and adjacent areas shifts considerably in the PMA No. 2 scenario output relative to the Baseline. This is due to a combination of simulated management activities inside and outside of the Subbasin. Gross lateral subsurface inflows are generally similar between model scenarios in the No Climate Change and 2030 Climate Change projections and decrease (particularly in the Lower Aquifer) likely due to a substantial reduction in groundwater pumping (**Figure 7-3** and **Figure 7-8**). Simulated lateral subsurface outflows are smaller in all PMA No. 2 results relative to the Baseline likely due (at least in part) to the decrease in groundwater pumping outside of the Subbasin and shifting the groundwater gradients near the Subbasin boundary.

7.2.3 Sustainability Indicators

Projected groundwater conditions with respect to sustainability indicators for the PMA No. 2 model scenario are analyzed in 2040 and 2070. These include groundwater levels, land surface subsidence and groundwater storage provided in (**Appendix E** - **G**).

7.2.3.1 Groundwater Levels

The water budgeting and land management framework included in PMA No. 2 provides substantial benefits to water levels within the Subbasin. Groundwater levels from the end of the 20-year planning horizon show some decline in the central and southwestern portion of the Subbasin in the Upper Aquifer and water table but are relatively stable throughout the remainder of the Subbasin. The model shows additional declines in similar areas at the end of the 50-year period but are otherwise stable in the remainder for the Subbasin.

7.2.3.2 Subsidence

Simulated results from PMA No. 2 also show substantial benefits to land surface subsidence. All climate projections show negligible amounts subsidence at the end of the 20-year planning horizon. The models simulate some subsidence in the southern portion of the district at the end of the 50-year planning horizon but does not exceed about 1.5 feet in total.

7.2.3.3 Groundwater Storage

The numerical model projects relatively stable gross groundwater storage and throughout the 50-year planning horizon. Results demonstrate effective conjunctive use management where groundwater is stored during wet periods and appropriate utilization of groundwater during dry periods (**Figure 7-10**). Spatially, storage declines show similar trends as those observed in water table groundwater levels. Generally, the western portion of the Subbasin (largely south of Cantua Creek) show decline in storage at the end of 2070.

7.2.4 Estimated Sustainable Yield

Based on the methodology provided in **Section 7.1.4**, the estimated sustainable yield derived from the PMA No. 2 model run given the No Climate Change, 2030 Climate Change and the 2070 Climate Change projections are shown in **Table 7-9**. Calculated sustainable yield from all climate change projections are relatively similar and range from 241,000 AFY to 277,000 AFY.

Table 7-9: PMA No. 2 Estimated Sustainable Yield for the 2040 and 2070 GSP Planning Horizons

Groundwater Budget Term	No Climate Change		2030 Climate Change		2070 Climate Change	
	2040	2070	2040	2070	2040	2070
Pumping (af)	287,000	322,000	286,000	328,000	292,000	297,000
Change in GW Storage (af)	22,000	-7,000	23,000	-8,000	7,000	-11,000
Difference in Lateral Subsurface Inflow (af)[1]	-33,000	-54,000	-32,000	-54,000	-41,000	-45,000
Sustainable Yield (af)	**276,000**	**261,000**	**277,000**	**266,000**	**258,000**	**241,000**

1. Difference between simulated historic and projected lateral subsurface flow

7.3 PMA No. 3 Model Results

Results from the PMA No.3 model scenario are presented for the No Climate Change, 2030 Climate Change and 2070 Climate Change numerical model simulation from 2017 through 2070. Results include water budgets for the land surface system and groundwater system used in water budget analysis for the GSP are referenced in **Table 7-10** and **Table 7-11** and maps of groundwater levels, change in groundwater storage and land surface subsidence referenced in **Table 7-12**. Maps illustrating the relative impacts of PMA No. 2 on water levels, groundwater storage and land surface subsidence are referenced in **Table 7-13**. Water budget results are presented on an annual basis based on DWR water year (October – September). Maps of simulated groundwater levels, change in groundwater levels, change in groundwater storage and land surface subsidence are presented for the 20 and 50-year planning horizons from January 1st, 2040 and January 1st, 2070.

Table 7-10: List of Water Budget Tables for the PMA No. 3 Projected Period

Climate Projection	Land Surface		Groundwater System		
	Inflows	Outflows	Aggregate	Upper Aquifer	Lower Aquifer
No Climate	Table C-31	Table C-32	Table C-33	Table C-34	Table C-35
2030 Climate Change	Table C-36	Table C-37	Table C-38	Table C-39	Table C-40
2070 Climate Change	Table C-41	Table C-42	Table C-43	Table C-44	Table C-45

Table 7-11: List of Water Budget Figures for the PMA No. 3 Projected Period

Climate Projection	Land Surface Water Budget	Groundwater Budget
No Climate	Figure D-13	Figure D-14
2030 Climate Change	Figure D-15	Figure D-16
2070 Climate Change	Figure D-17	Figure D-18

Table 7-12: List of Groundwater Level, Groundwater Storage and Subsidence Maps for the PMA No. 3 Scenario Projected Period

Climate Projection	GW Level	Change in GW Level	Change in GW Storage	Subsidence
No Climate	Figure E-43 → E-48	Figure E-49 → E-54	Figure E-60 & E-61	Figure E-64 & E-65
2030 Climate Change	Figure F-43 → F-48	Figure F-49 → F-54	Figure F-60 & F-61	Figure F-64 & F-65
2070 Climate Change	Figure G-43 → G-48	Figure G-49 → G-54	Figure G-60 & G-61	Figure G-64 & G-65

Table 7-13: PMA No. 3 List of Figures of Project Impacts on Water Levels, Groundwater Storage & Subsidence

Climate Projection	Water Levels	Groundwater Storage	Subsidence
No Climate	Figure E-55 ⟶ E-60	Figure E-62 & E-63	Figure E-66 & E-67
2030 Climate Change	Figure F-55 ⟶ F-60	Figure F-62 & F-63	Figure F-66 & F-67
2070 Climate Change	Figure G-55 ⟶ G-60	Figure G-62 & G-63	Figure G-66 & G-67

7.3.1 Land Surface System Water Budget

Inflows and outflows to the land surface system in the Baseline scenario are summarized in **Figure 7-11** and **Figure 7-12**. Differences in the land surface system budget between PMA No. 3 and the Baseline are negligible. Land surface system inflows and outflows change by less than 5 ,000 AFY.

7.3.2 Groundwater System Water Budget

Inflows and outflows to the land surface system in the Baseline scenario are summarized in **Figure 7-13** and **Figure 7-14**.

Total simulated inflows to the Subbasin groundwater system show an average annual increase of between 4,000 and 7,000 AFY due to simulated annual average injection of between 25,000 and 28,000 AFY. Total simulated outflows increase between 2 and 6 AFY.

Groundwater injection impacts on the Subbasin water budget are summarized in **Figure 7-15**. The model suggests that groundwater injection as part of the ASR program will predominantly lead to a decrease in lateral subsurface inflows into the Subbasin and an increase in lateral subsurface outflows. Lateral subsurface inflow decreases by between 13,000 and 18,000 AFY while lateral subsurface increases by between 5,000 and 9,000 AFY. The majority of the difference in lateral flows is simulated in the Lower Aquifer where the majority of injection occurs and perhaps due to higher Lower Aquifer diffusivity (T/S). In total, changes to lateral subsurface flow account for between 72% of the water injected for ASR.

Other water budget terms affected by injection include groundwater storage, groundwater pumping and groundwater ET. Groundwater storage increases by between 5,670 and 5,810 AFY or between 21% and 22% percent of injected water. Change in simulated groundwater pumping and groundwater ET are presented as a gross “Change Farm Flow” term for simplicity and accounts for between 4% and 8% of water injected.

7.3.3 Sustainability Indicators

Projected groundwater conditions with respect to sustainability indicators for the PMA No. 3 model scenario are analyzed in 2040 and 2070. These include groundwater levels, land surface subsidence and groundwater storage provided in (**Appendix E** - **G**).

7.3.3.1 Groundwater Levels

PMA No. 3 shows modest benefits to groundwater levels at the end of the 20 and 50-year planning horizons (**Appendix E** - **G**). Substantial impacts are observed in the Lower Aquifer in 2040, but not in 2070. This suggests that benefits are short-lived and dissipate quickly likely because injection occurs in a confined system with a relatively high diffusivity (T/S).

7.3.3.2 Subsidence

PMA No. 3 shows benefits to land surface subsidence in both the 20 and 50-year planning horizons (**Appendix E** - **G**). Accrual of benefits increase over time and are greater in 2070 than 2040. Benefits are largely simulated in the southern portion of the Subbasin where subsidence impacts are the greatest.

7.3.3.3 Groundwater Storage

Projected benefits to groundwater storage are discussed in **Section 7.3.2**. Storage benefits are modest relative to the amount of groundwater injected and small relative to the amount of storage decline simulated over the projected period. Total cumulative change in groundwater storage is shown in **Figure**

7-16. Cumulative storage benefits as a result of groundwater injection with respect to time are shown in **Figure 7-17** for the No Climate Change projection. In this plot total simulated cumulative injection is plotted in relation to the benefits to storage (storage increase) and increase in lateral subsurface flow during the model simulation period. These results suggest that the majority of storage benefits due to injection are lost to outflows to adjacent subareas relatively quickly.

7.3.4 Estimated Sustainable Yield

Based on the methodology provided in **Section 7.1.4**, the estimated sustainable yield derived from the PMA No. 3 model run given the No Climate Change, 2030 Climate Change and the 2070 Climate Change projections are shown in **Table 7-14**. Calculated sustainable yield from all climate change projections are increase substantially due to PMA No. 3. The calculation of sustainable yield accounts for both change in groundwater storage and lateral subsurface flow that are impacted by injection relative to the Baseline.

Table 7-14: PMA No. 3 Estimated Sustainable Yield for the 2040 and 2070 GSP Planning Horizons

Groundwater Budget Term	No Climate Change		2030 Climate Change		2070 Climate Change	
	2040	2070	2040	2070	2040	2070
Pumping (af)	237,000	315,000	242,000	311,000	391,000	465,000
Change in GW Storage (af)	4,000	-47,000	5,000	-42,000	-54,000	-107,000
Difference in Lateral Subsurface Inflow (af)[1]	62,000	26,000	59,000	25,000	-17,000	-41,000
Sustainable Yield (af)	**303,000**	**294,000**	**306,000**	**294,000**	**320,000**	**317,000**

1. Difference between simulated historic and projected lateral subsurface flow

7.4 PMA No. 4 Model Results

Results from the PMA No.4 model scenario are presented for the No Climate Change, 2030 Climate Change and 2070 Climate Change numerical model simulation from 2017 through 2070. Results include water budgets for the land surface system and groundwater system used in water budget analysis for the GSP are referenced in **Table 7-15** and **Table 7-16** and maps of groundwater levels, change in groundwater storage and land surface subsidence referenced in **Table 7-17**. Maps illustrating the relative impacts of PMA No. 2 on water levels, groundwater storage and land surface subsidence are referenced in **Table 7-18**. Water budget results are presented on an annual basis based on DWR water year (October – September). Maps of simulated groundwater levels, change in groundwater levels, change in groundwater storage and land surface subsidence are presented at the end of the pumping reduction period on April 1st, 2040 and 50-year planning horizons on January 1st, 2070.

Table 7-15: List of Water Budget Tables for the PMA No. 4 Projected Period

Climate Projection	Land Surface		Groundwater System		
	Inflows	Outflows	Aggregate	Upper Aquifer	Lower Aquifer
No Climate	Table C-46	Table C-47	Table C-48	Table C-49	Table C-50
2030 Climate Change	Table C-51	Table C-52	Table C-53	Table C-54	Table C-55
2070 Climate Change	Table C-56	Table C-57	Table C-58	Table C-59	Table C-60

Table 7-16: List of Water Budget Figures for the PMA No. 4 Projected Period

Climate Projection	Land Surface Water Budget	Groundwater Budget
No Climate	Figure D-19	Figure D-20
2030 Climate Change	Figure D-21	Figure D-22
2070 Climate Change	Figure D-23	Figure D-24

Table 7-17: List of Groundwater Level, Groundwater Storage and Subsidence Maps for the PMA No. 4 Scenario Projected Period

Climate Projection	GW Level	Change in GW Level	Change in GW Storage	Subsidence
No Climate	Figure E-69 → E-74	Figure E-75 → E-80	Figure E-87 & E-88	Figure E-91& E-92
2030 Climate Change	Figure F-69 → F-74	Figure F-75 → F-80	Figure F-87 & F-88	Figure F-91 & F-92
2070 Climate Change	Figure G-69 → G-74	Figure G-75 → G-80	Figure G-87 & G-88	Figure G-91 & G-92

Table 7-18: PMA No. 4 List of Figures of Project Impacts on Water Levels, Groundwater Storage & Subsidence

Climate Projection	Water Levels	Groundwater Storage	Subsidence
No Climate	Figure E-81 → E-86	Figure E-89 & E-90	Figure E-93 & E-94
2030 Climate Change	Figure F-81 → F-60	Figure F-89 & F-90	Figure F-93 & F-94
2070 Climate Change	Figure G-81 → G-60	Figure G-89 & G-90	Figure G-93 & G-94

7.4.1 Land Surface System Water Budget

Inflows and outflows to the land surface system in the Baseline scenario are summarized in **Figure 7-18** and **Figure 7-19**. Differences in the land surface system budget between PMA No. 4 and the Baseline are small over the 50-year planning period and largely constrained to pumping and surface water deliveries. Surface water deliveries are between 6,000 and 7,000 AFY greater on average in PMA No. 4 than simulated in the Baseline over the 50-year period. Conversely, groundwater pumping is between 6,000 and 7,000 AFY less on average than the Baseline over the 50-year period.

7.4.2 Groundwater System Water Budget

Inflows and outflows to the land surface system in the Baseline scenario are summarized in **Figure 7-20** and **Figure 7-21**.

Total simulated inflows to the Subbasin groundwater system show an average annual decrease of between 5,000 and 7,000 AFY in PMA No. 4 compared to the Baseline. The majority of the difference between the scenarios can be accounted for as an increase in groundwater storage in PMA No. 4 with a smaller amount attributed to a decrease in lateral subsurface flow and net deep percolation (**Figure 7-20**).

Simulated outflows in the groundwater system decrease by between 6,000 and 8,000 AFY in PMA No. 4 compared to the Baseline. Of this, the vast majority can be attributed to the decrease in pumping due to in lieu recharge from surface water deliveries (**Figure 7-21**).

7.4.3 Sustainability Indicators

Projected groundwater conditions with respect to sustainability indicators for the PMA No. 4 model scenario. Since PMA No. 4 does not begin until after the end of the 20-year planning period, results are instead analyzed at the end of the pumping reduction period in 2047 and at the end of the 50-year planning horizon. Sustainability indicators analyzed include groundwater levels, land surface subsidence and groundwater storage provided in (**Appendix E** - **G**).

7.4.3.1 Groundwater Levels

PMA No. 4 shows substantial localized benefits to groundwater levels with respect to the Baseline (**Appendix E** - **G**). Substantial impacts are observed in the Lower Aquifer in 2047 at the end of the pumping reduction period where the majority of pumping occurs. Water level benefits are also much greater north of Canuta Creek where there are more groundwater pumping wells. These impacts do not propagate significantly to the Upper Aquifer or shallow groundwater zone. Furthermore, benefits tend to be short-lived and dissipate quickly likely because injection occurs in a confined system with a relatively high diffusivity (T/S).

7.4.3.2 Subsidence

PMA No. 4 shows substantial localized benefits to land surface subsidence both in 2047 and at the end of the 50-year planning horizons (**Appendix E** - **G**). Subsidence in 2047 is reduced by nearly a foot near the SLC in the No Climate Change and 2030 Climate Change projections and exceeds one foot in the 2070 Climate Change projection. Reduced subsidence in PMA No. 4 relative to the Baseline decrease at the end of the 50-year planning horizon suggesting that subsequent dry periods may reverse accrued benefits.

7.4.3.3 Groundwater Storage

Projected benefits to groundwater storage are discussed in **Section 7.3.2**. Storage benefits are relatively large with respect to the amount of pumping reduction. Total cumulative change in groundwater storage is shown in **Figure 7-22**. Cumulative storage benefits as a result of pumping reductions with respect to time are shown in **Figure 7-23**. In this plot the cumulative difference in groundwater pumping is plotted in relation to the benefits to storage (storage increase) during the model simulation period. These results suggest that nearly one half of the simulated in lieu recharge benefit remains in groundwater storage even after over 20-years.

7.4.4 Estimated Sustainable Yield

Based on the methodology provided in **Section 7.1.4**, the estimated sustainable yield derived from the PMA No. 4 model run given the No Climate Change, 2030 Climate Change and the 2070 Climate Change projections are shown in **Table 7-19**. Calculated sustainable yield from all climate change projections are relatively similar to the Baseline in 2070 and identical to the Baseline in 2040 (prior to simulated PMA No. 4 implementation).

Table 7-19: PMA No. 4 Estimated Sustainable Yield for the 2040 and 2070 GSP Planning Horizons

Groundwater Budget Term	No Climate Change		2030 Climate Change		2070 Climate Change	
	2040	2070	2040	2070	2040	2070
Pumping (af)	238,000	310,000	243,000	307,000	393,000	459,000
Change in GW Storage (af)	-9,000	-51,000	-8,000	-45,000	-66,000	-107,000
Difference in Lateral Subsurface Inflow (af)[1]	38,000	9,000	34,000	9,000	-37,000	-58,000
Sustainable Yield (af)	**267,000**	**268,000**	**269,000**	**271,000**	**290,000**	**294,000**

1. Difference between simulated historic and projected lateral subsurface flow

8 MODEL UNCERTAINTY AND RECOMMENDATIONS

Numerical groundwater models are created based on simplified assumptions used to replicate complex natural systems. Consequently, results are generally subject to errors and limitations due to conceptual misunderstandings of the hydrologic system and uncertainties in estimating aquifer properties and boundary conditions. These uncertainties are due to both spatial and temporal limitations in observation data and the types of observation data available. Key limitations identified during model development include:

- Simulation of aquifer system compaction and land surface subsidence does not account for time delay that can substantially improve representation of compaction in model interbeds. This feature is available in the SUB package but adds numerical complexity that was considered prohibitive with respect to model runtime at the time of model development. Delay beds should be considered for future model updates.
- Direct evaporation and plant uptake of groundwater is poorly constrained. Simulated direct groundwater uptake can be substantial due to the proximity of the water table to the land surface, however, simulated amounts of groundwater evapotranspiration have not been compared to measured or estimated values. These estimates would be useful in further constraining consumptive use and dynamics between groundwater and surface processes.
- Estimates of water applied as part of cultural practices is poorly constrained. Water applied for cultural practices are known to include water used for pre-irrigation and as part of leaching salts in the soil. However, the amount and timing of water applied for these purposes is challenging to estimate, particularly in the projected model scenarios.
- Assumptions applied to areas adjacent to the Subbasin should be refined as information becomes available. Information such as land use, groundwater pumping estimates, surface water distribution and well construction can be readily incorporated to improve model performance in the historic period. Information regarding future land use and projects and management actions would be helpful in refining groundwater conditions at the Subbasin boundaries during the projected period.

9 SUMMARY AND CONCLUSIONS

An integrated hydrologic model (WSGM) was developed for the Westside Subbasin to support SGMA analysis and the preparation of a GSP. The model is based on an HCR developed for the Subbasin in conjunction with geologic and hydrologic data. The model dynamically links land surface and groundwater processes to simulate conjunctive use. The model was calibrated to historic groundwater levels, subsidence and compaction measurements and estimated groundwater pumping and provides insights into hydrologic responses in the Subbasin. A summary of model findings include:

- The model is able to reproduce groundwater levels and groundwater pumping relatively accurately. Simulation of land surface subsidence is adequate but may be improved through further model refinement.
- Major sources of recharge to the Subbasin include areal recharge from precipitation and irrigation and lateral subsurface flow (predominantly to the Lower Aquifer)
- Major sources of discharge from the Subbasin include groundwater pumping and lateral subsurface flow (largely in the Upper Aquifer)
- Though separated by the Corcoran clay, the Upper and Lower Aquifer are hydraulically connected through intraborehole flow through composite wells. Vertical flow is likely a substantial source of recharge to the Lower Aquifer.
- Groundwater storage (aggregated over the Subbasin) is relatively stable over the 1989 – 2015 historic period
- Simulated output from WSGM were used to develop an estimate of sustainable yield over the historic period of 305,000 AFY

WSGM was used to simulate projected groundwater conditions through the 50-year GSP planning horizon ending in 2070. Model inputs were developed based on GSP modeling BMPs published by DWR used to develop a Baseline scenario which includes:

- Over 50 years of historical data to develop projected hydrology
- Surface water imports from the CalSim II model developed jointly by USBR and DWR
- Projected land use based on 2016 cropping maps
- Analysis of climate uncertainty by perturbing model inputs using 2030 Climate Change and 2070 Climate Change multipliers

WSGM was also used to evaluate the efficacy of PMAs being proposed by the District to achieve sustainability. These include:

- Project No. 1 – Surface Water Imports (Included in Baseline)
- Project No. 2 – Initial Allocation of Groundwater Extraction
- Project No. 3 – Aquifer Storage and Recovery

- Project No. 4 – Targeted Pumping Reductions
- Project No. 5 – Percolation Basins (Not simulated in WSGM)

Results from the projected model were used to evaluate land surface water budgets, groundwater budgets and sustainability indicators (water levels, subsidence and groundwater storage). Output from the predictive model runs suggest:

- The Baseline model run results shows substantial declines in groundwater levels and groundwater storage and considerable amounts of land surface subsidence
- Simulated impacts are exacerbated in the 2070 Climate Change projection
- The model shows that implementation of PMA No. 2 substantially alleviates impacts on sustainability indicators through management of groundwater pumping and irrigated acreage.
- The model shows that groundwater injection simulated in PMA No. 3 results in moderate impacts to sustainability indicators
- The model shows that pumping reductions simulated near the SLC in PMA No. 4 leads to localized reduction in land surface subsidence and can substantially alleviate subsidence impacts near the canal
- Sustainable yield calculated from output from all scenarios ranges roughly between 250,000 and 300,000 AFY

10 REFERENCES

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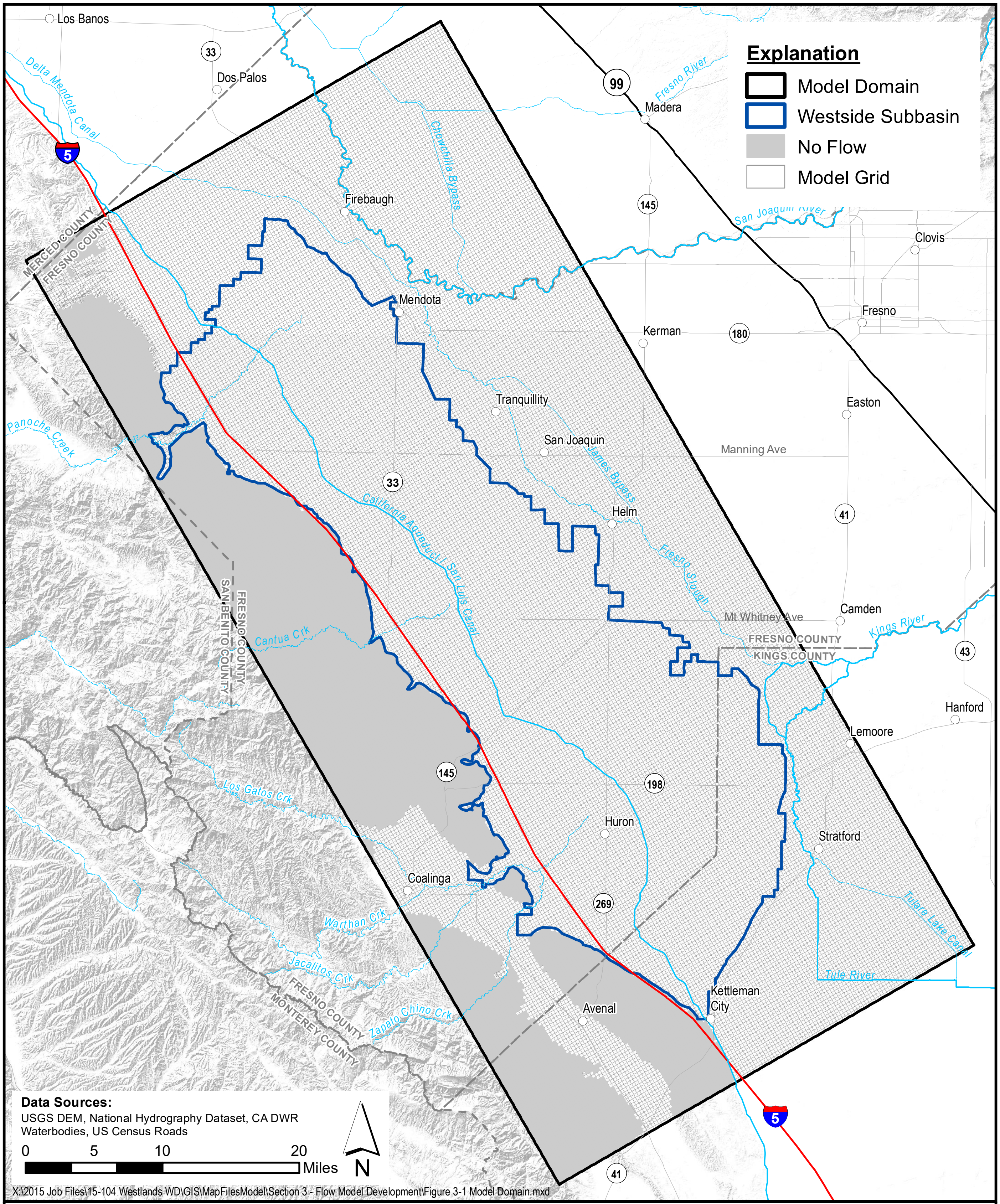

Data Sources:
USGS DEM, National Hydrography Dataset, CA DWR Waterbodies, US Census Roads

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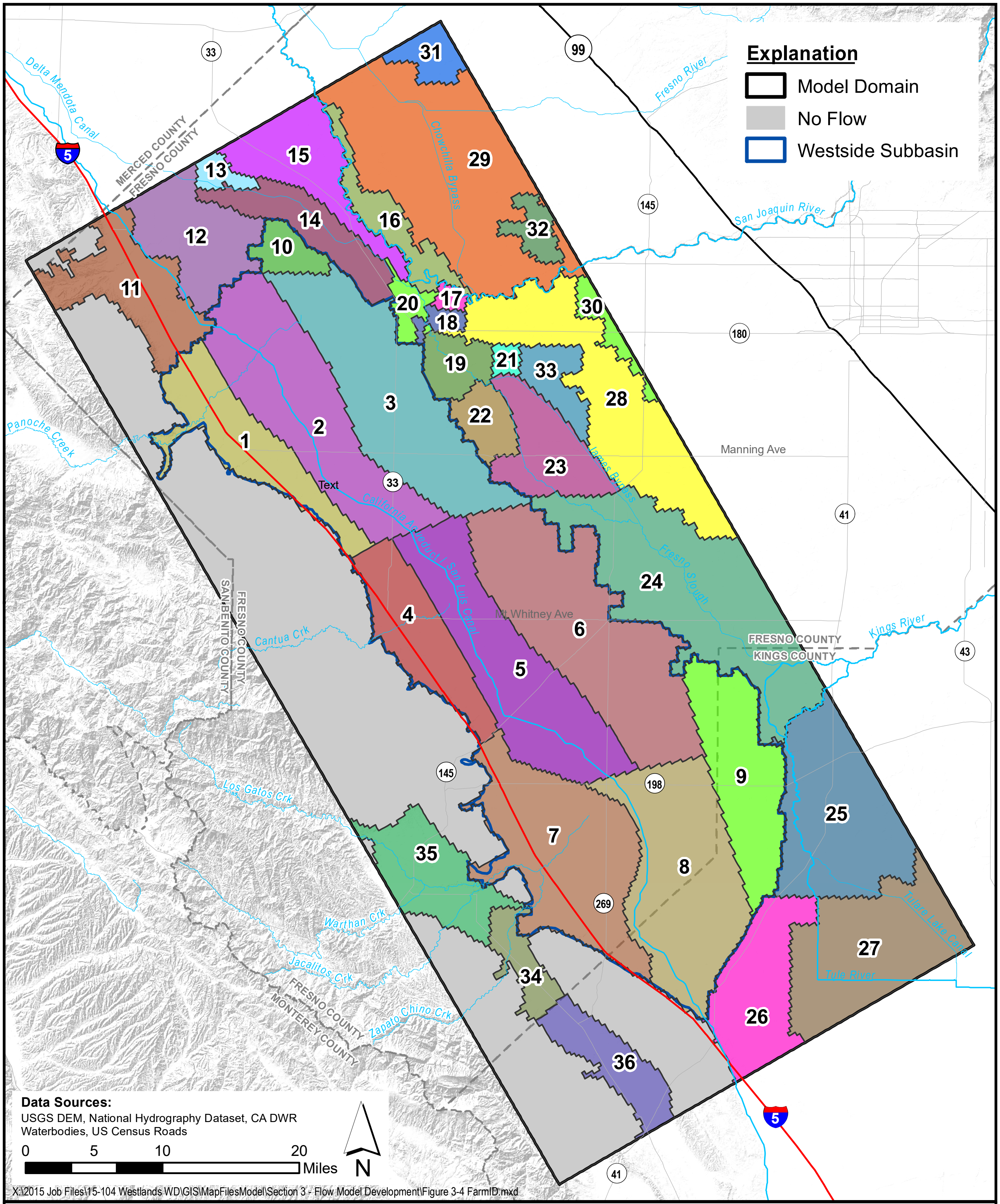
Luhdorff & Scalmanini
Consulting Engineers

Model Domain and Horizontal Descritization

SGMA Sustainability Analyses
Westside Subbasin

Figure ES-1



Data Sources:
USGS DEM, National Hydrography Dataset, CA DWR Waterbodies, US Census Roads

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Luhdorff & Scalmanini
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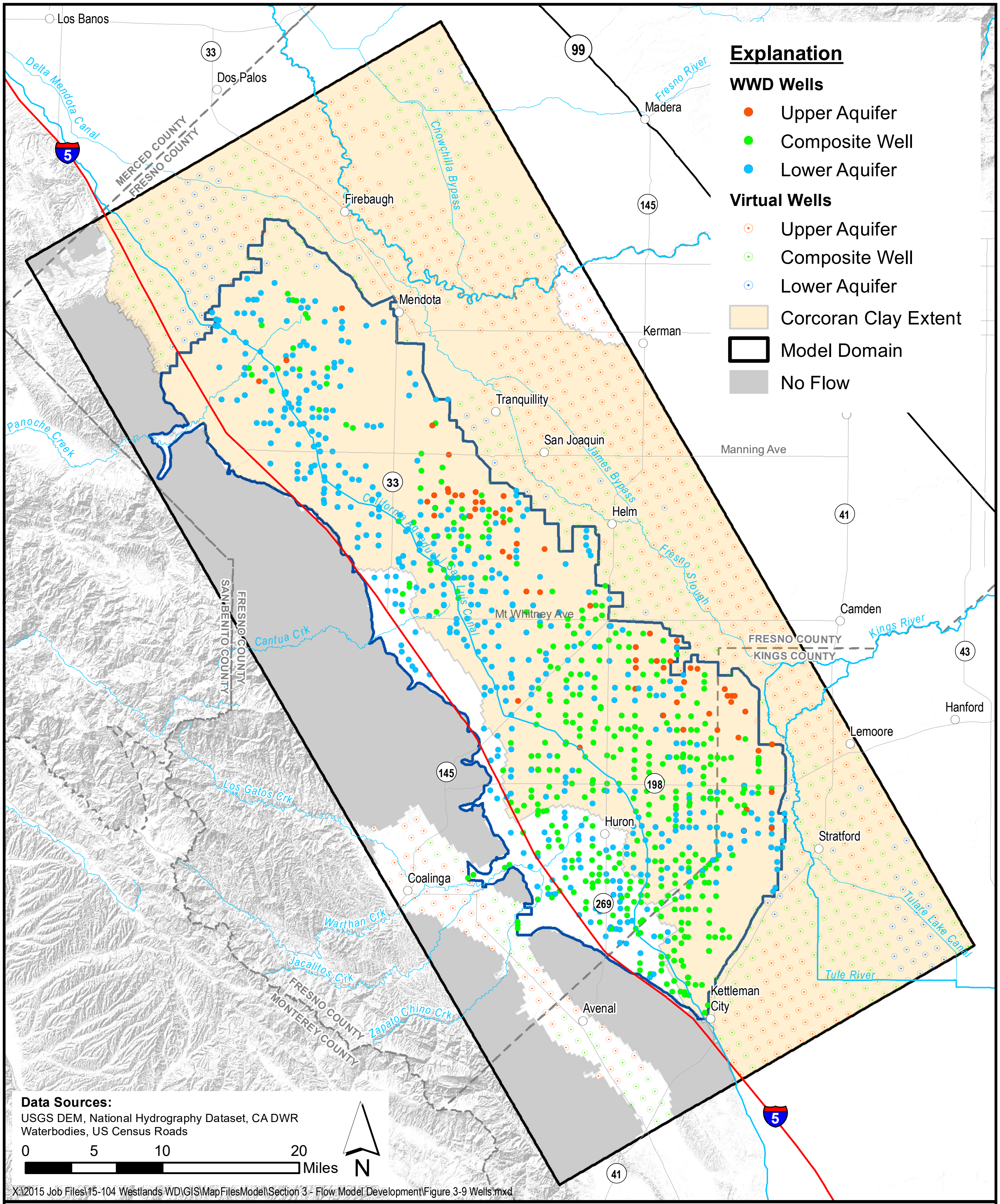
Farm Process - Farm ID Delineation

SGMA Sustainability Analyses
Westside Subbasin

Figure ES-2



Data Sources:
USGS DEM, National Hydrography Dataset, CA DWR
Waterbodies, US Census Roads

X:\2015 Job Files\15-104 Westlands WD\GIS\MapFilesModel\Section 3 - Flow Model Development\Figure 3-9 Wells.mxd

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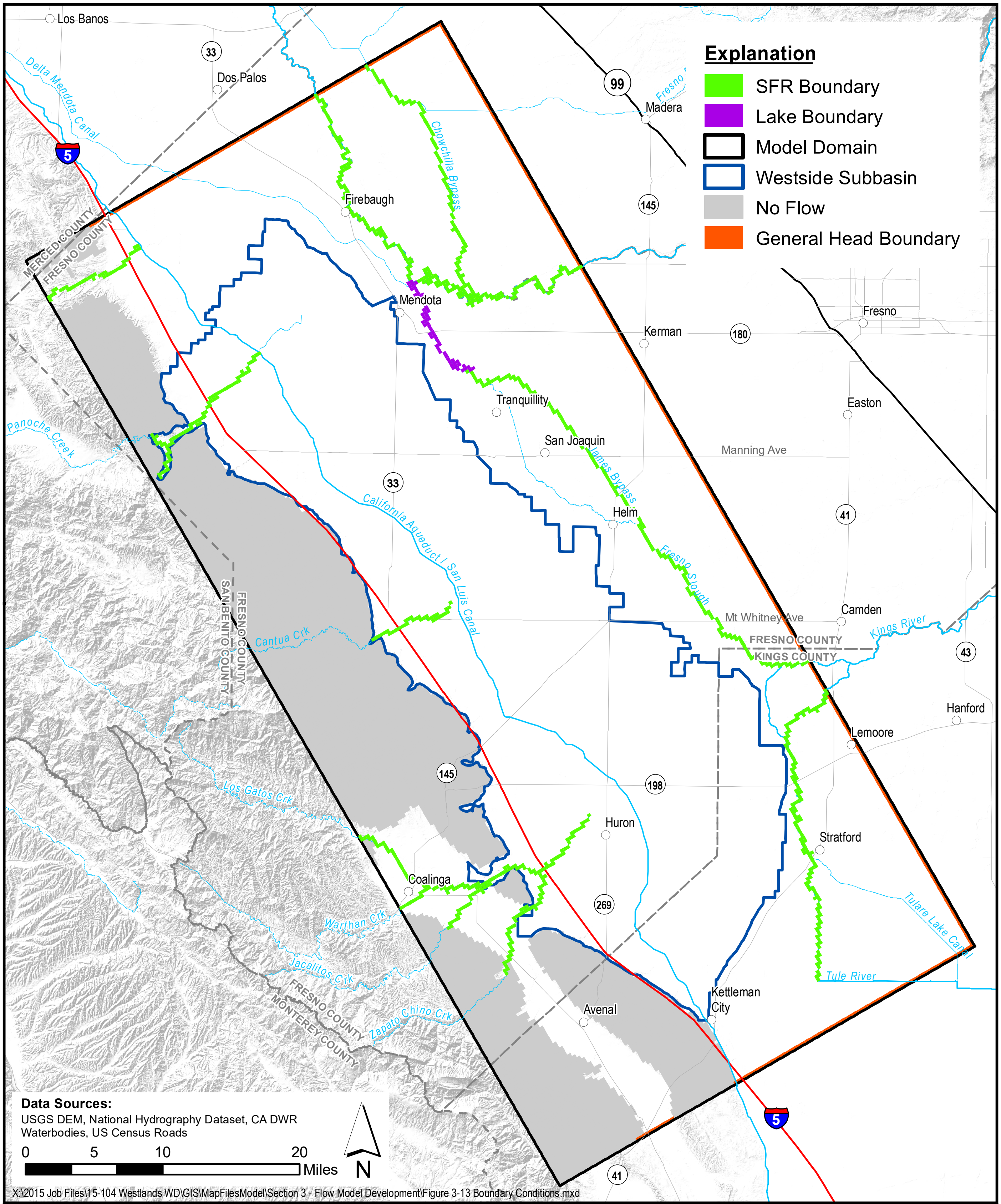
Location of WWD Production Wells and Non-WWD Virtual Production Wells

SGMA Sustainability Analyses
Westside Subbasin

Figure ES-3



Data Sources:
USGS DEM, National Hydrography Dataset, CA DWR Waterbodies, US Census Roads

X:\2015 Job Files\15-104 Westlands WD\GIS\MapFilesModel\Section 3 - Flow Model Development\Figure 3-13 Boundary Conditions.mxd

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Model Boundary Conditions

SGMA Sustainability Analyses
Westside Subbasin

Figure ES-4

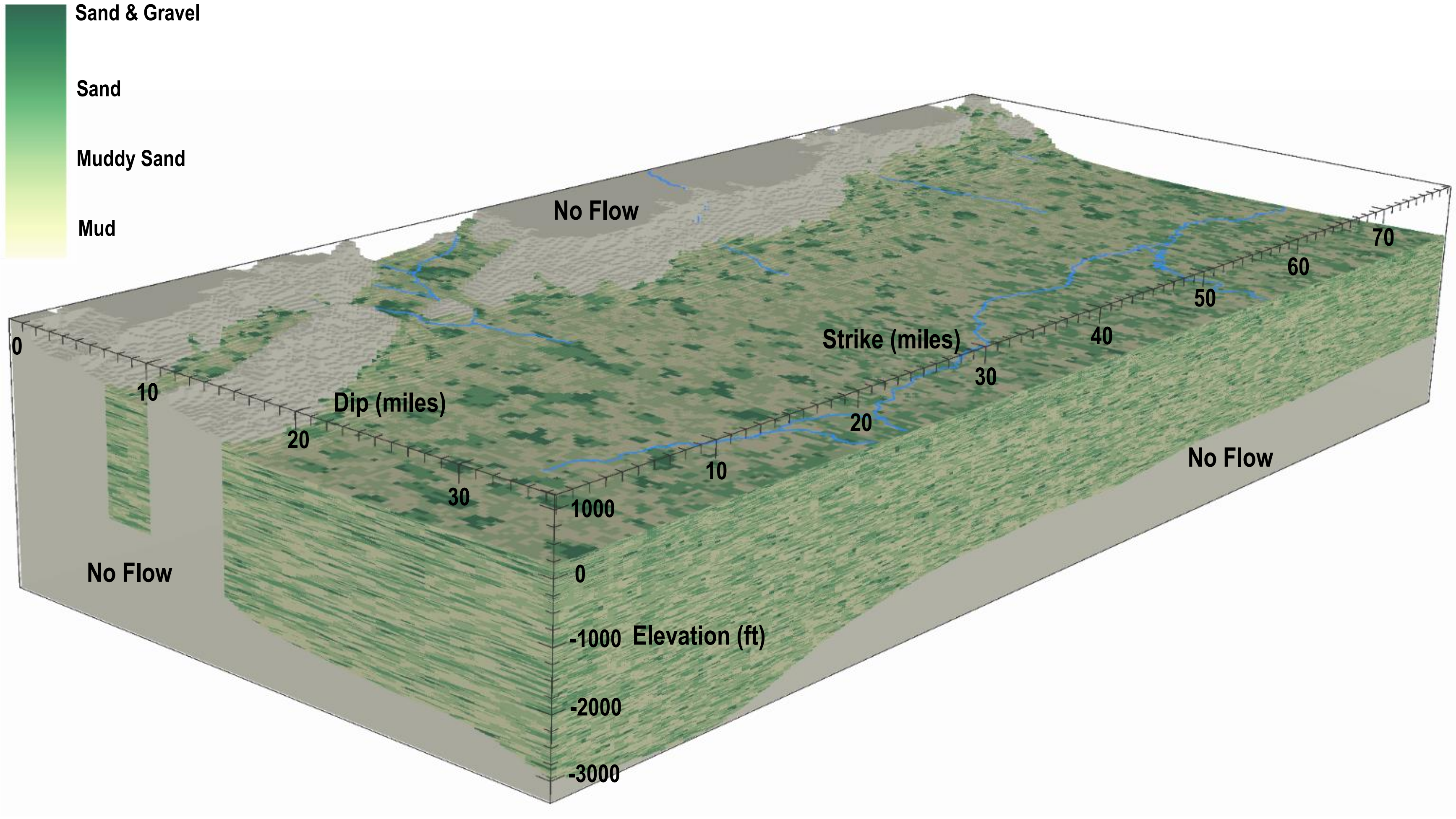

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Figure ES-5
Transition Probability Geostatistical Simulation Results

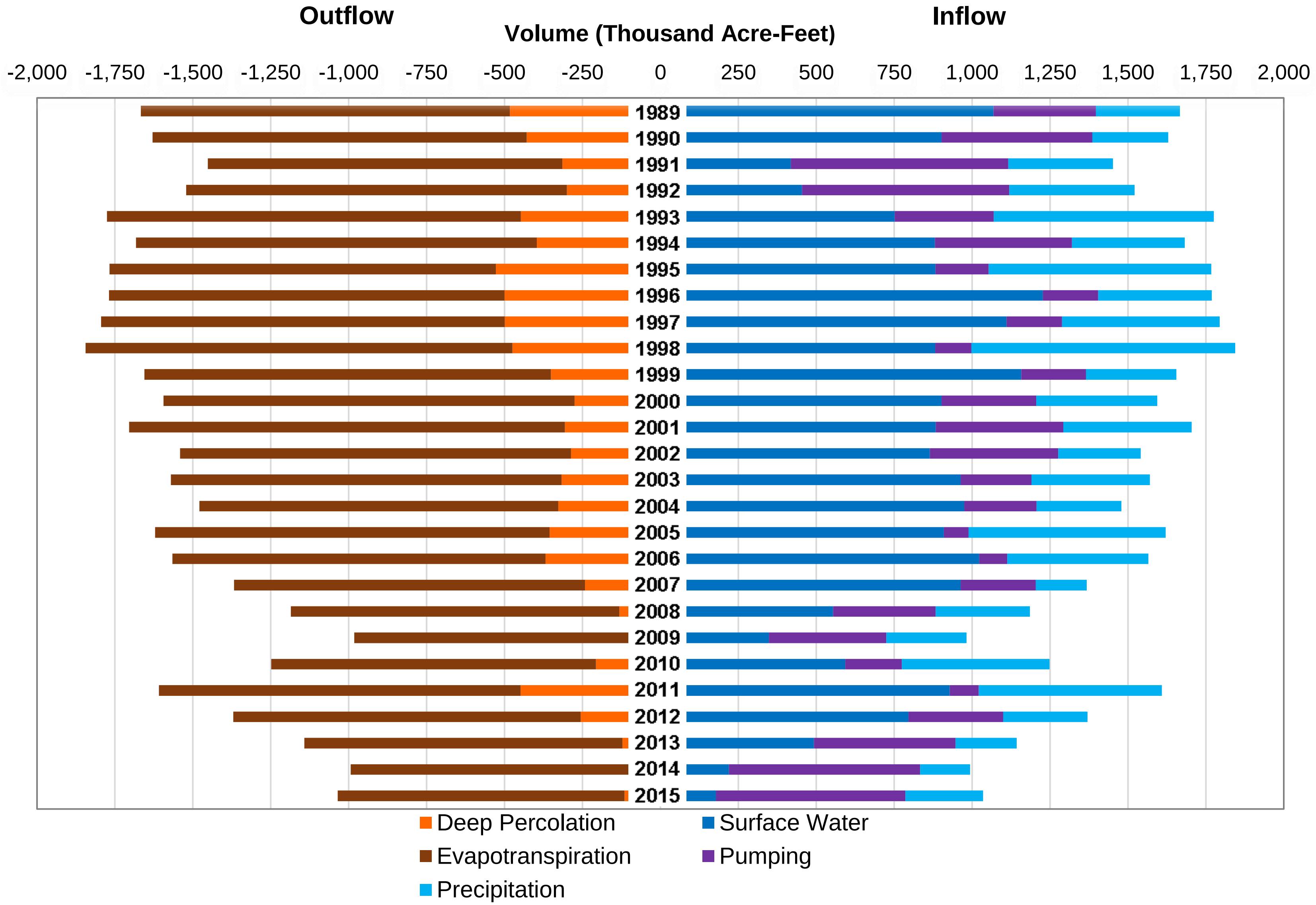

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Figure ES-6

Land Surface System Water Budget – Westside Subbasin

1989 - 2015

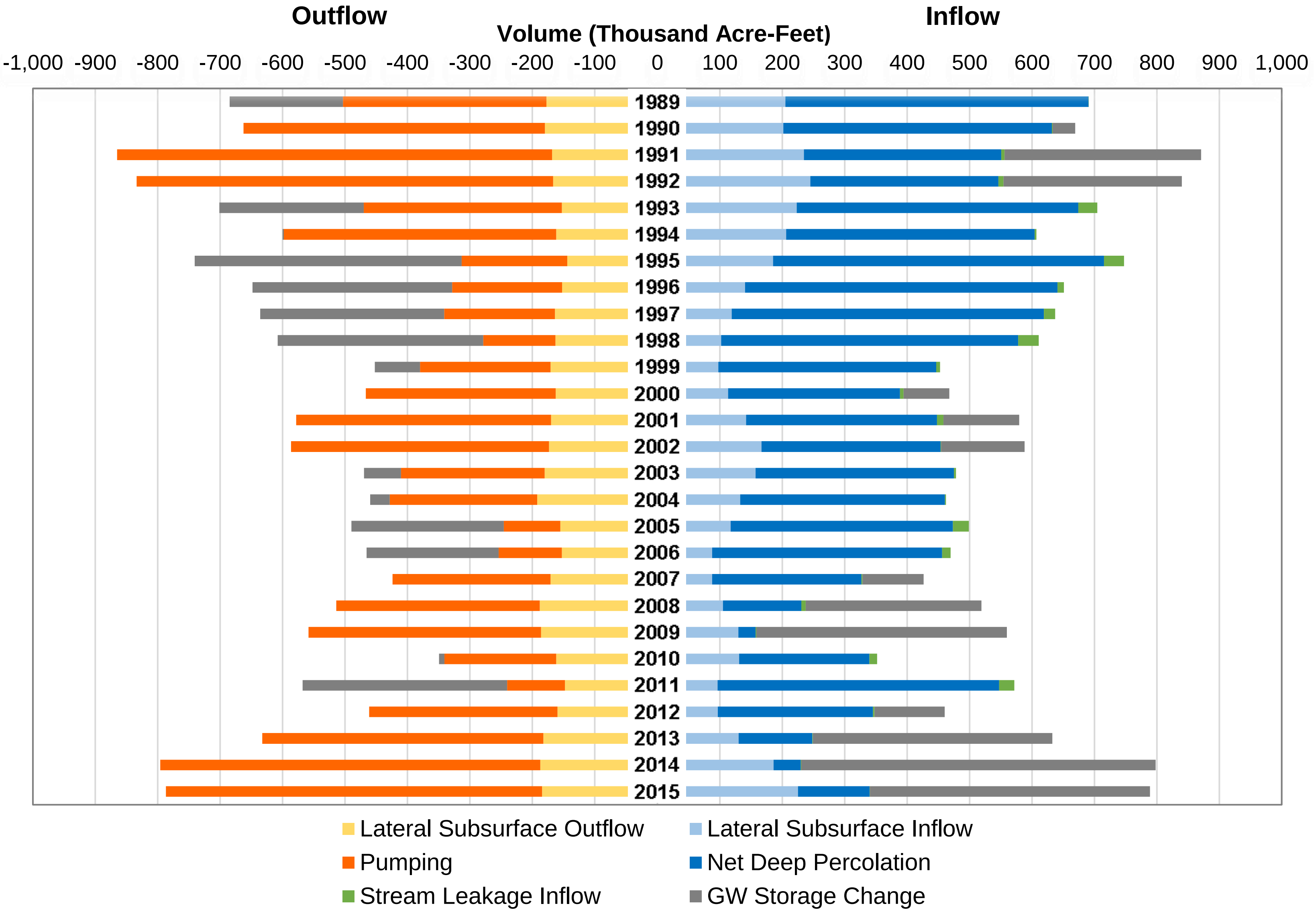

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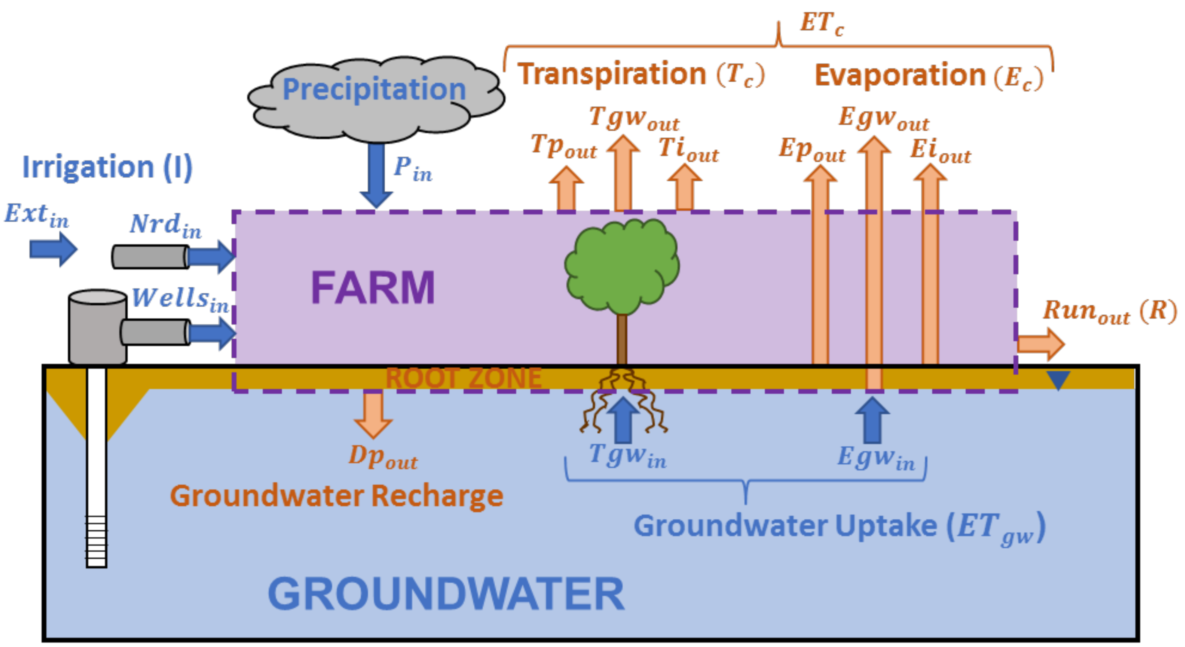
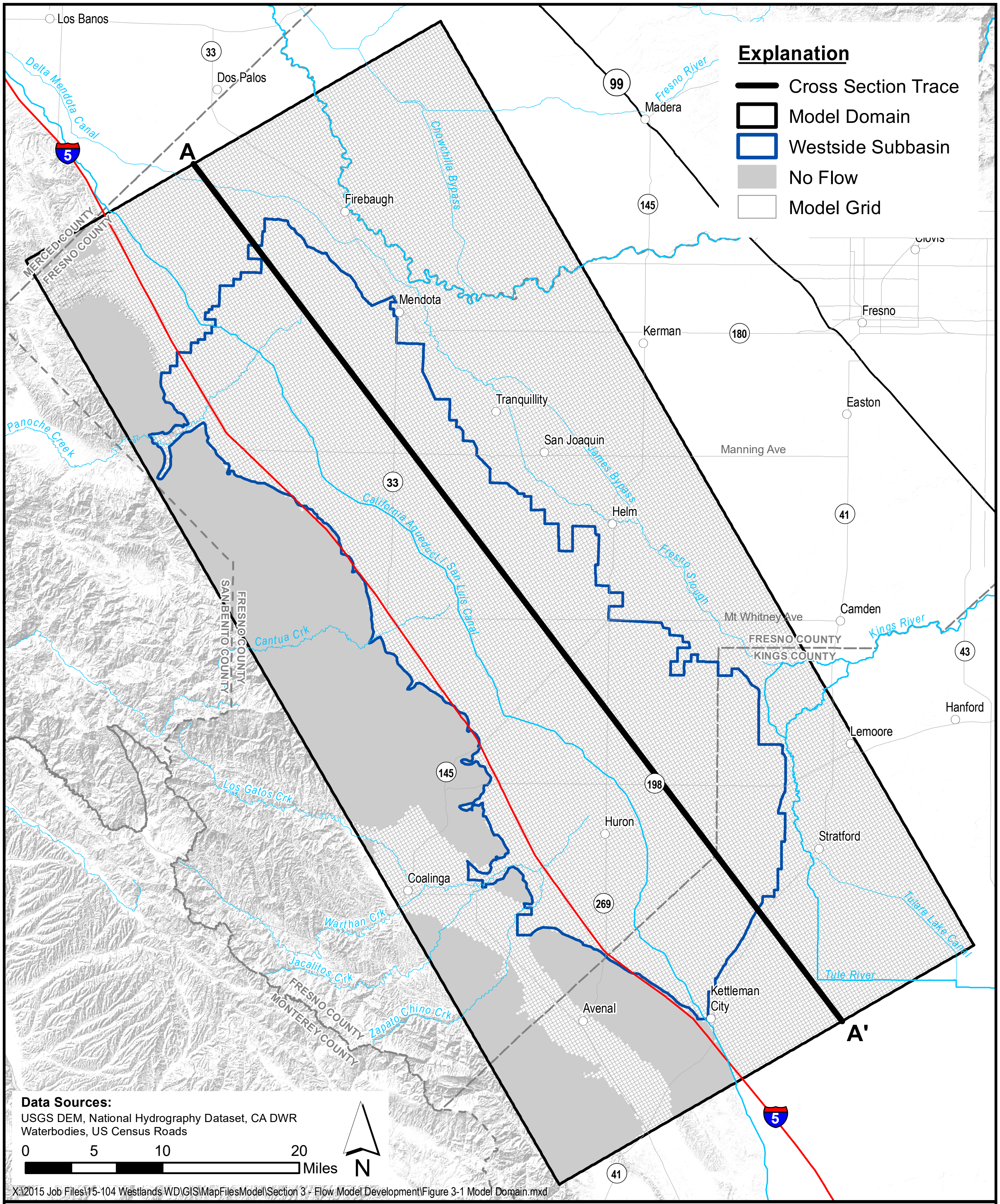
Figure ES-7
Groundwater Budget – Westside Subbasin
1989 - 2015



P_{in}	Precipitation into a farm
Nrd_{in}	Non-routed surface water delivery into a farm
$Wells_{in}$	Groundwater pumping delivery into a farm
Ext_{in}	External water delivery into a farm
Egw_{in}	Evaporation from groundwater into a farm
Tgw_{in}	Transpiration from groundwater into a farm
$ET_{gw} = Egw_{in} + Tgw_{in}$	Evapotranspiration from groundwater into a farm
Ei_{out}	Evaporation from irrigation (applied water) out of a farm
Ep_{out}	Evaporation from precipitation out of a farm
Egw_{out}	Evaporation from groundwater out of a farm
$E_C = Ei_{out} + Ep_{out} + Egw_{out}$	Evaporation from crop out of a farm
Ti_{out}	Transpiration from irrigation (applied water) out of a farm
Tp_{out}	Transpiration from precipitation out of a farm
Tgw_{out}	Transpiration from groundwater out of a farm
$T_C = Ti_{out} + Tp_{out} + Tgw_{out}$	Transpiration from crop out of a farm
$ET_C = E_C + T_C$	Evapotranspiration from crop out of a farm
Run_{out}	Overland runoff out of a farm
Dp_{out}	Deep percolation out of a farm into groundwater system

Figure 2-1. Conceptual model depicting hydrologic inputs and outputs in the Farm Process.



Data Sources:
USGS DEM, National Hydrography Dataset, CA DWR Waterbodies, US Census Roads

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Luhdorff & Scalmanini
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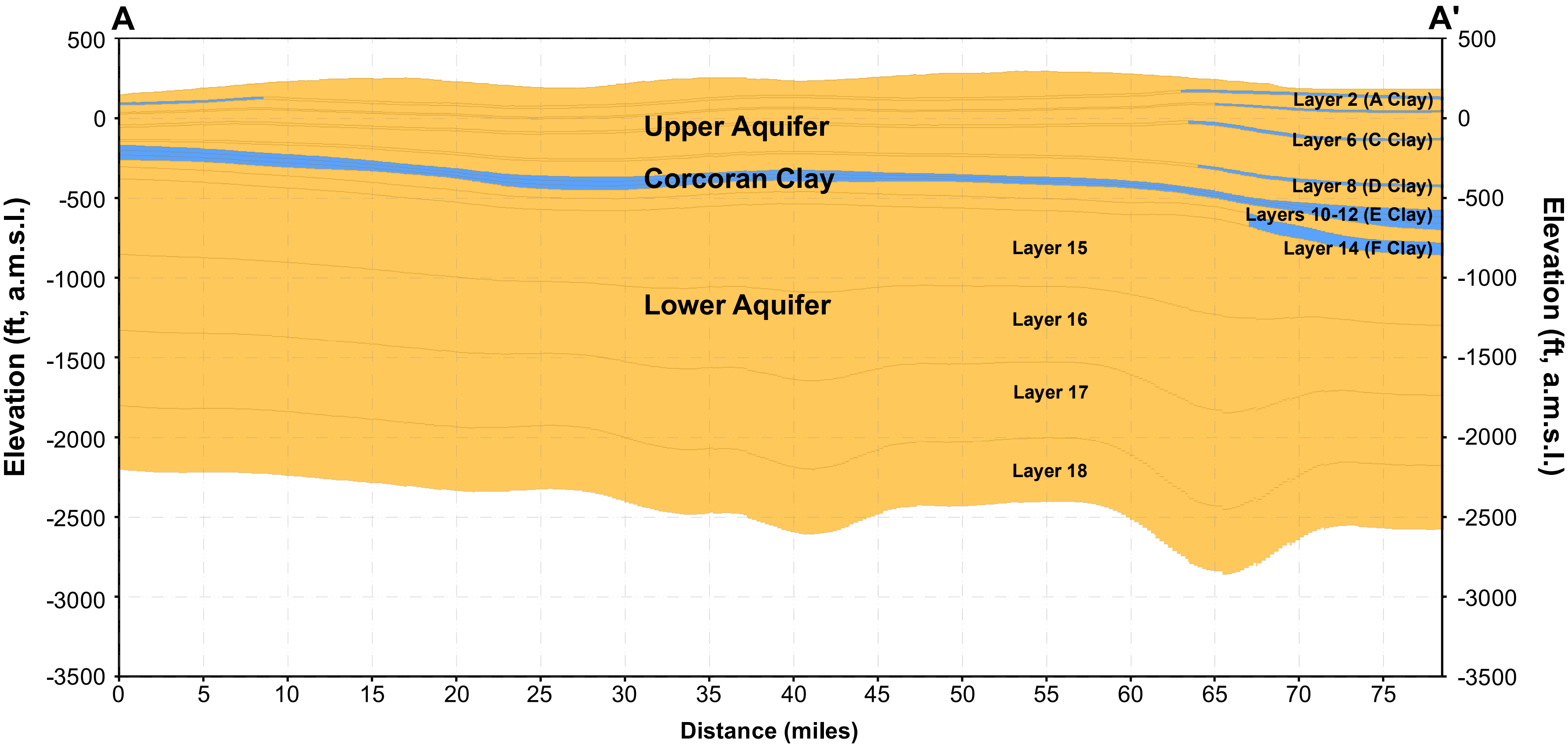
Model Domain and Horizontal Descritization

SGMA Sustainability Analyses
Westside Subbasin

Figure 3-1



X:\2015 Job Files\15-104 Westlands WD\GIS\MapFilesModel\Section 3 - Flow Model Development\Figure 3-2 Model Layering.mxd

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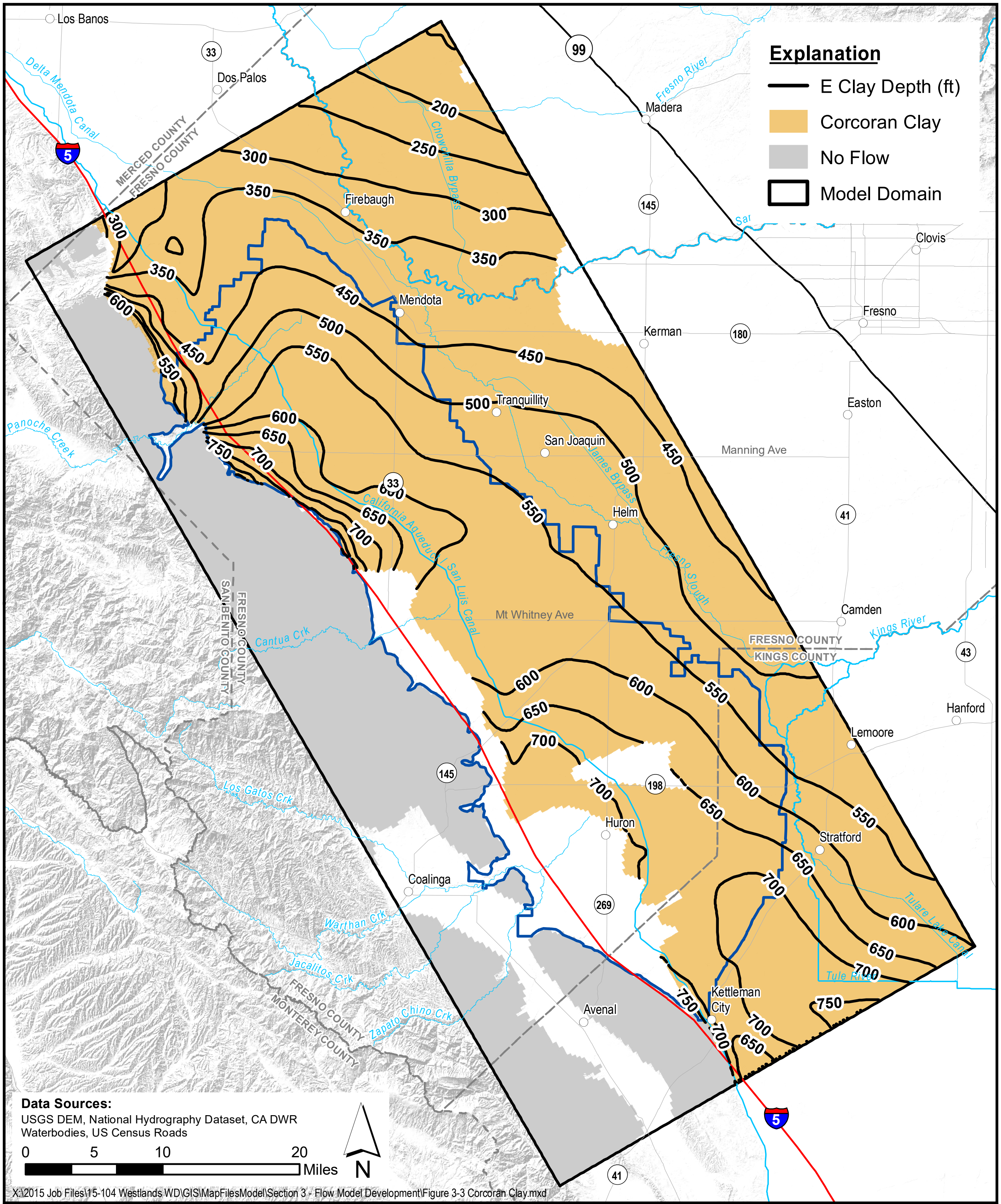
Model Vertical Discretization Through Model Cross Section A - A'

SGMA Sustainability Analyses
Westside Subbasin

Figure 3-2



Data Sources:
USGS DEM, National Hydrography Dataset, CA DWR Waterbodies, US Census Roads

X:\2015 Job Files\15-104 Westlands WD\GIS\MapFilesModel\Section 3 - Flow Model Development\Figure 3-3 Corcoran Clay.mxd

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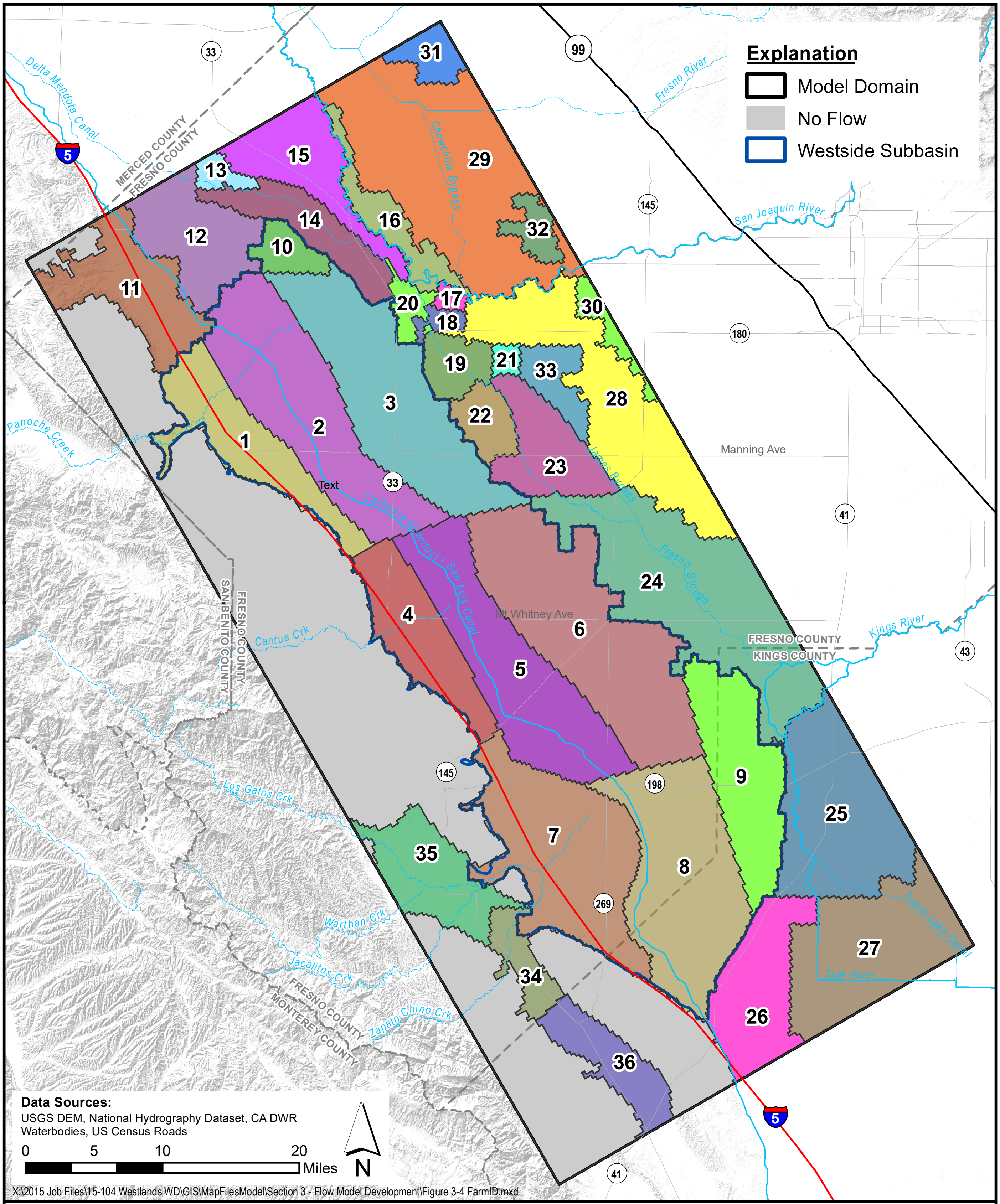
Depth and Extent of the Corcoran Clay

SGMA Sustainability Analyses
Westside Subbasin

Figure 3-3



Data Sources:
USGS DEM, National Hydrography Dataset, CA DWR Waterbodies, US Census Roads

X:\2015 Job Files\15-104 Westlands WD\GIS\MapFilesModel\Section 3 - Flow Model Development\Figure 3-4 FarmID.mxd

Luhdorff & Scalmanini
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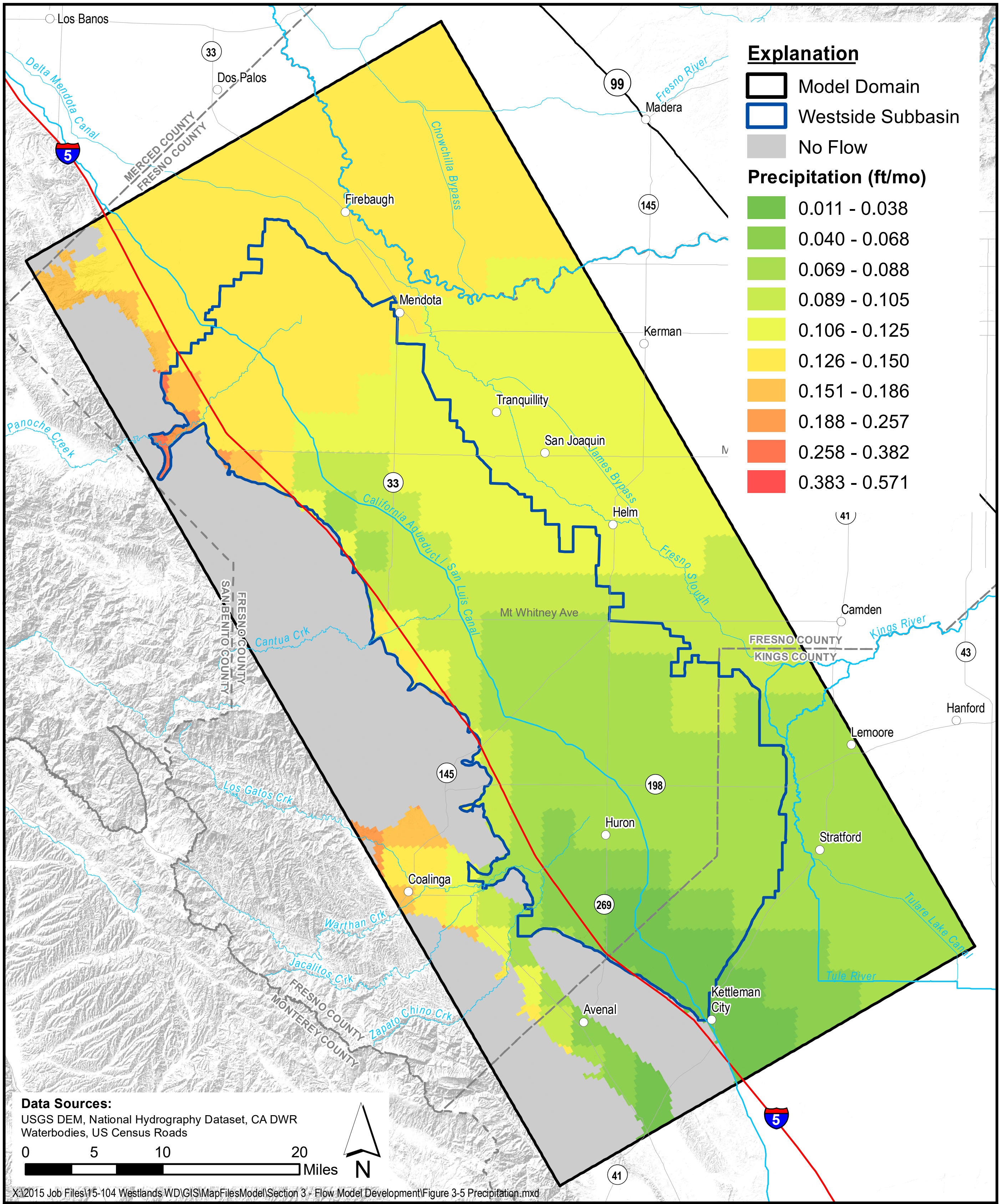
Farm Process - Farm ID Delineation

SGMA Sustainability Analyses
Westside Subbasin

Figure 3-4



Data Sources:
USGS DEM, National Hydrography Dataset, CA DWR Waterbodies, US Census Roads

X:\2015 Job Files\15-104 Westlands WD\GIS\MapFilesModel\Section 3 - Flow Model Development\Figure 3-5 Precipitation.mxd

Luhdorff & Scalmanini
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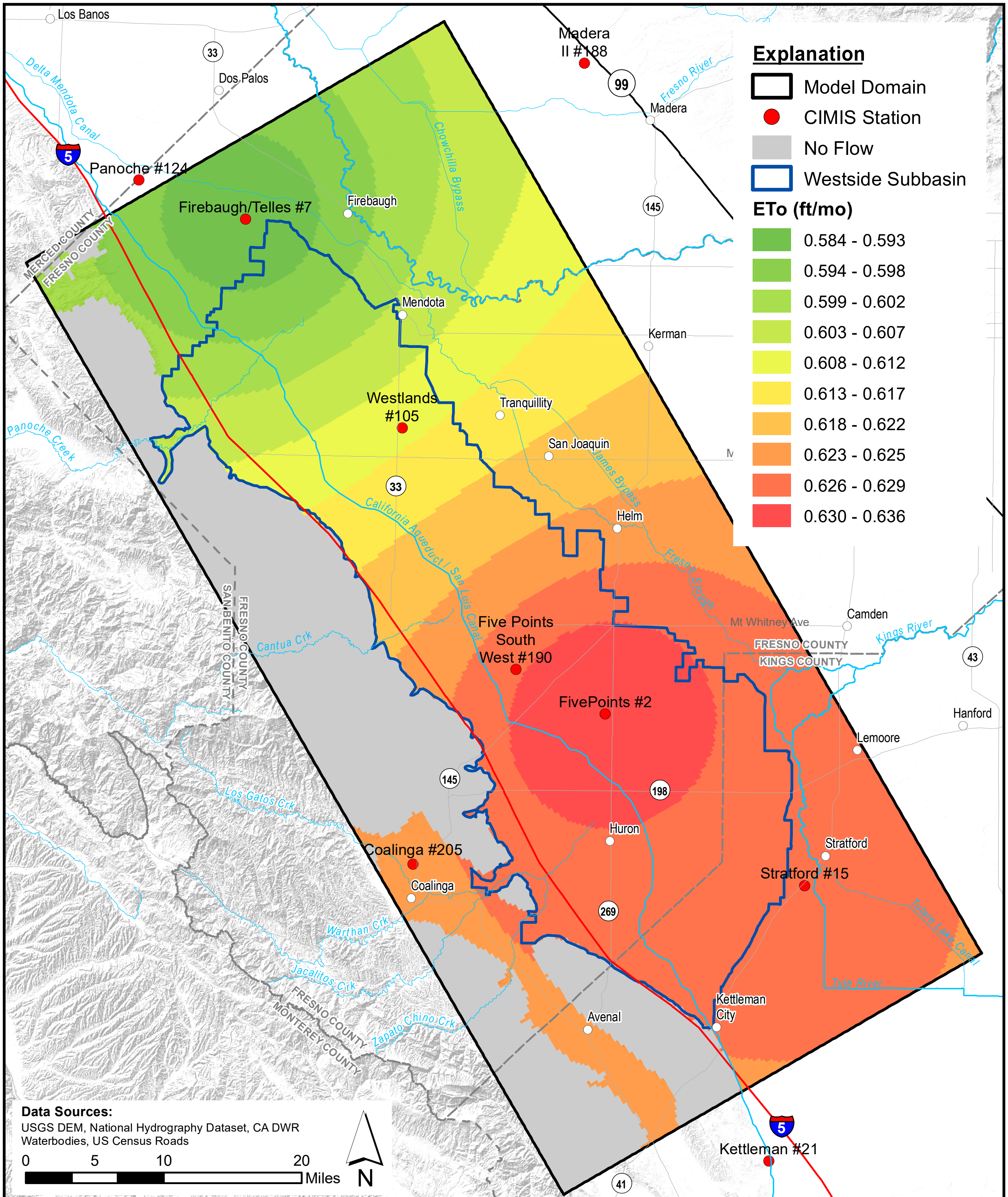
Assigned Precipitation from PRISM Data
February 2011

Figure 3-5

SGMA Sustainability Analyses
Westside Subbasin



Data Sources:
USGS DEM, National Hydrography Dataset, CA DWR
Waterbodies, US Census Roads

X:\2015 Job Files\15-104 Westlands WD\GIS\MapFilesModel\Section 3 - Flow Model Development\Figure 3-6 ETo Station Data.mxd

Luhdorff & Scalmanini
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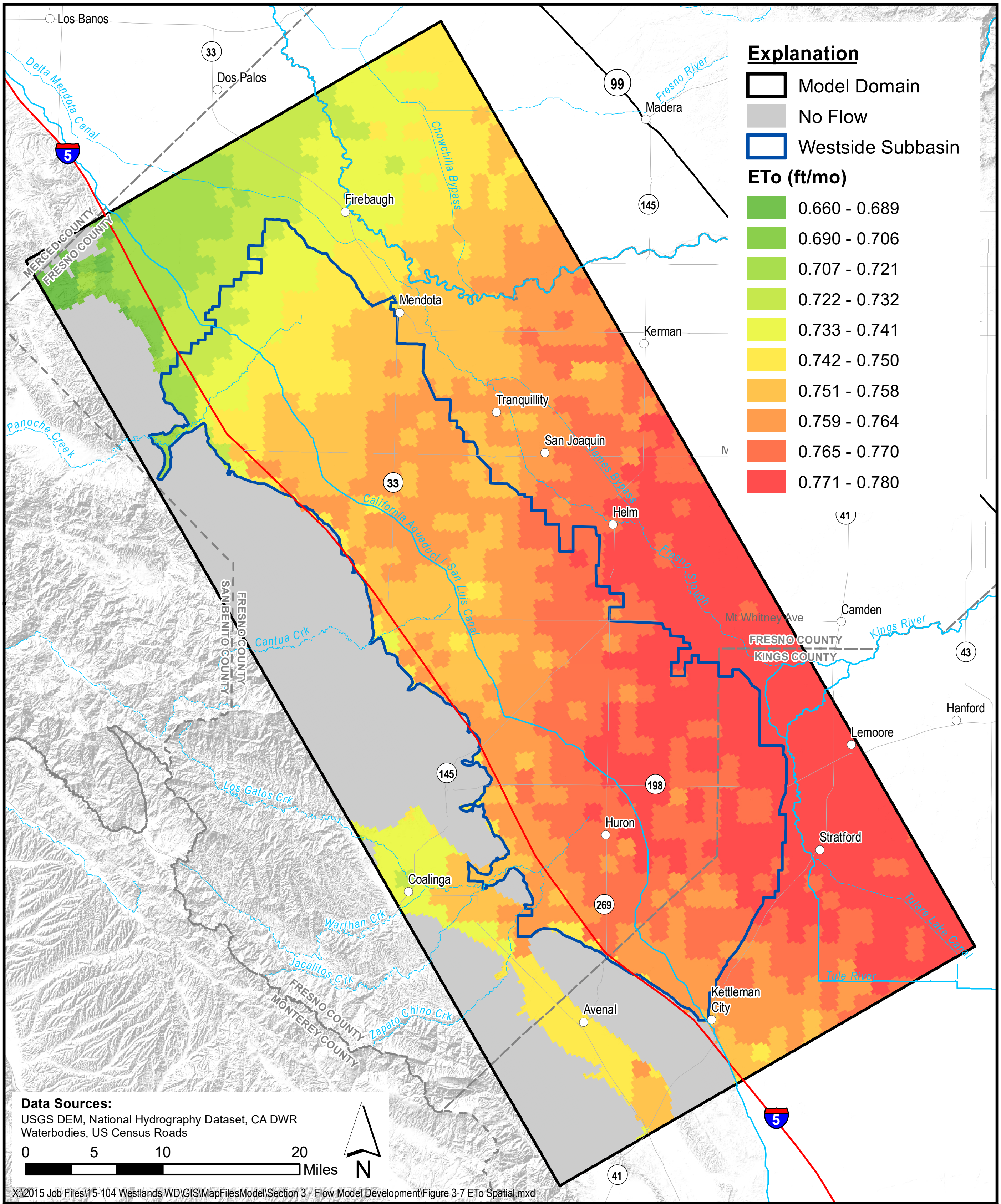
Reference ET Interpolated from CIMIS Stations
April 1990

Figure 3-6

SGMA Sustainability Analyses
Westside Subbasin



Data Sources:
USGS DEM, National Hydrography Dataset, CA DWR Waterbodies, US Census Roads

X:\2015 Job Files\15-104 Westlands WD\GIS\MapFilesModel\Section 3 - Flow Model Development\Figure 3-7 ETo Spatial.mxd

Luhdorff & Scalmanini
Consulting Engineers

Reference ET from CIMIS Spatial Model
June 2013

Figure 3-7

SGMA Sustainability Analyses
Westside Subbasin

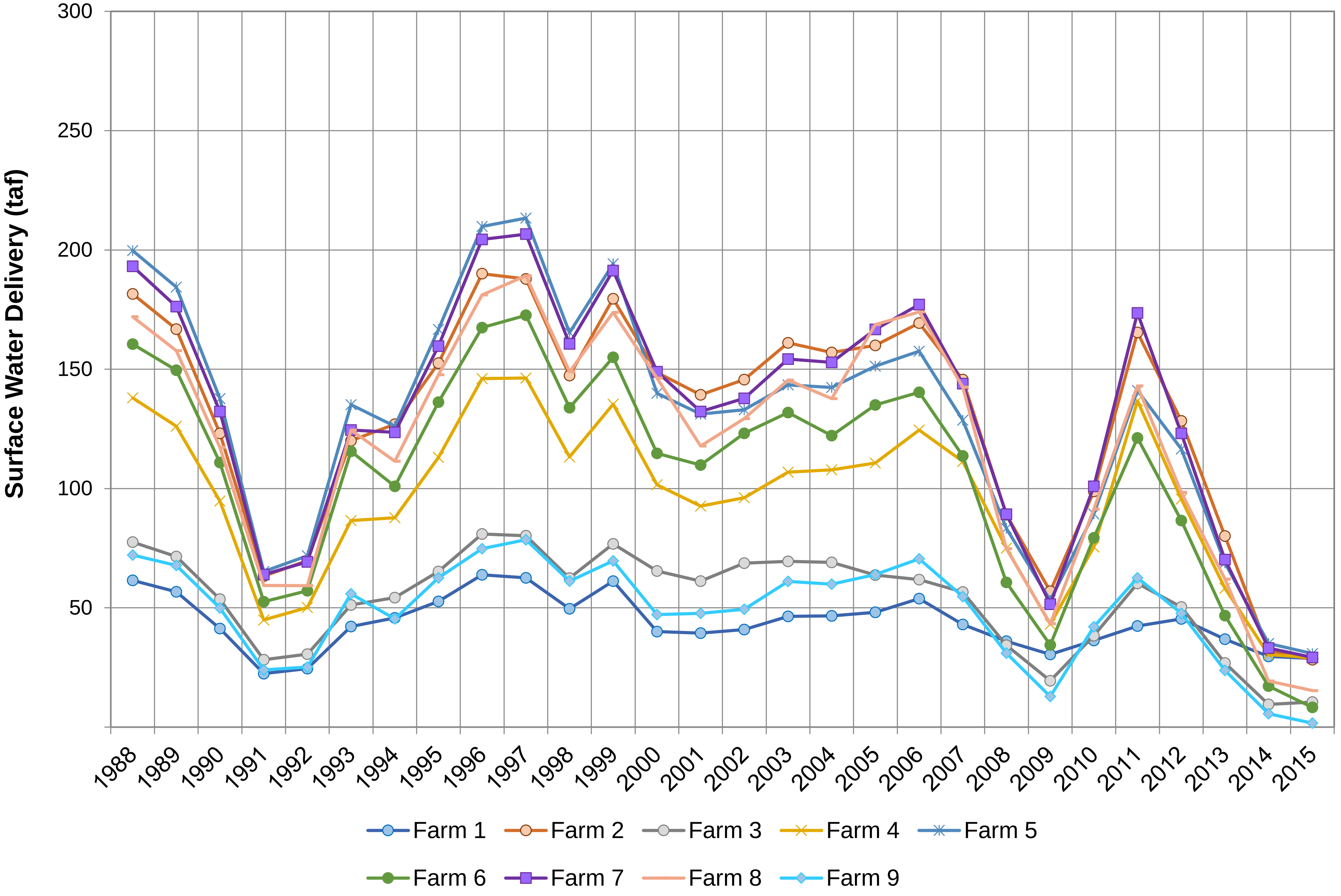


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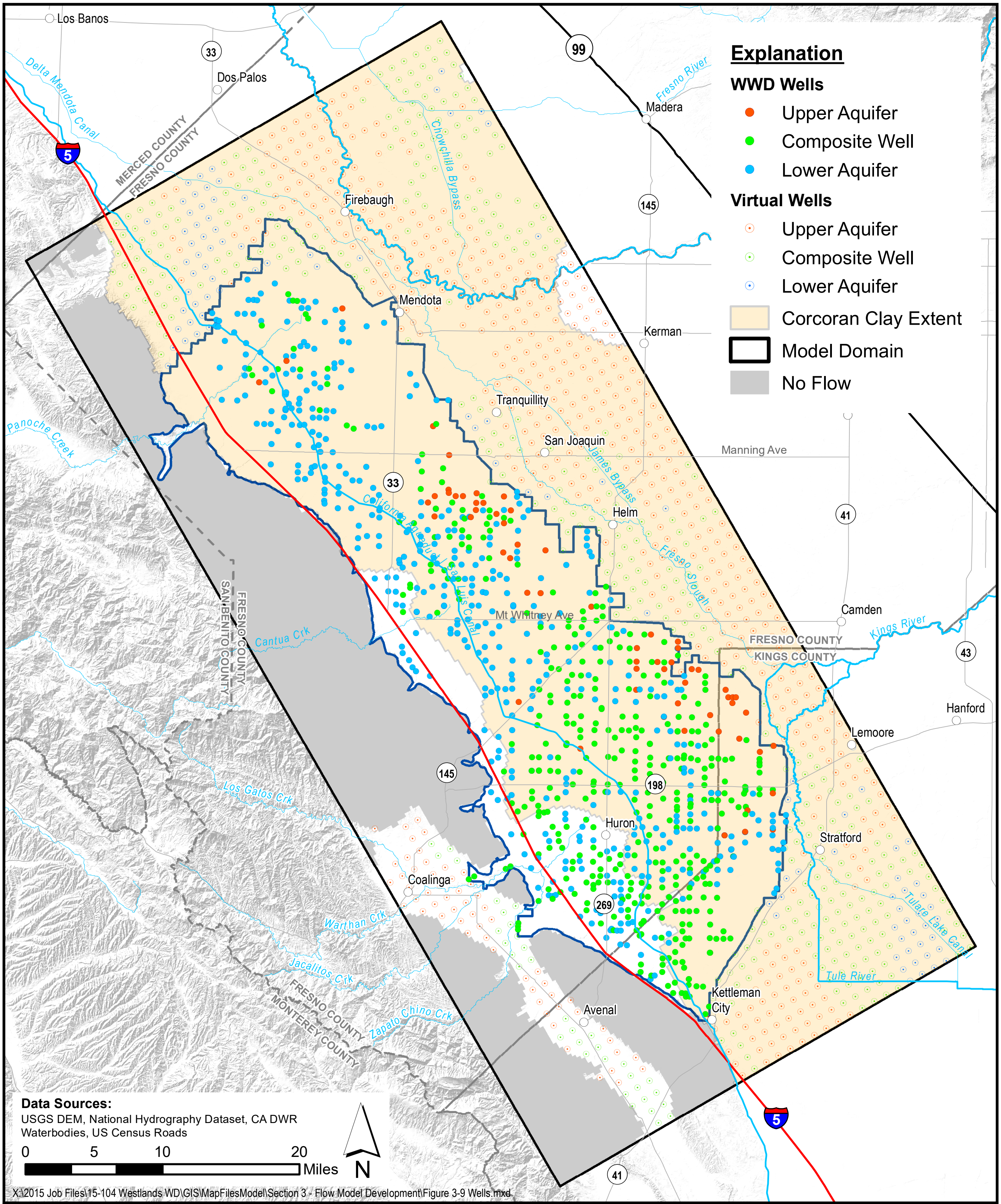
Figure 3-8
Surface Water Supplied to Farms (1988-2015)



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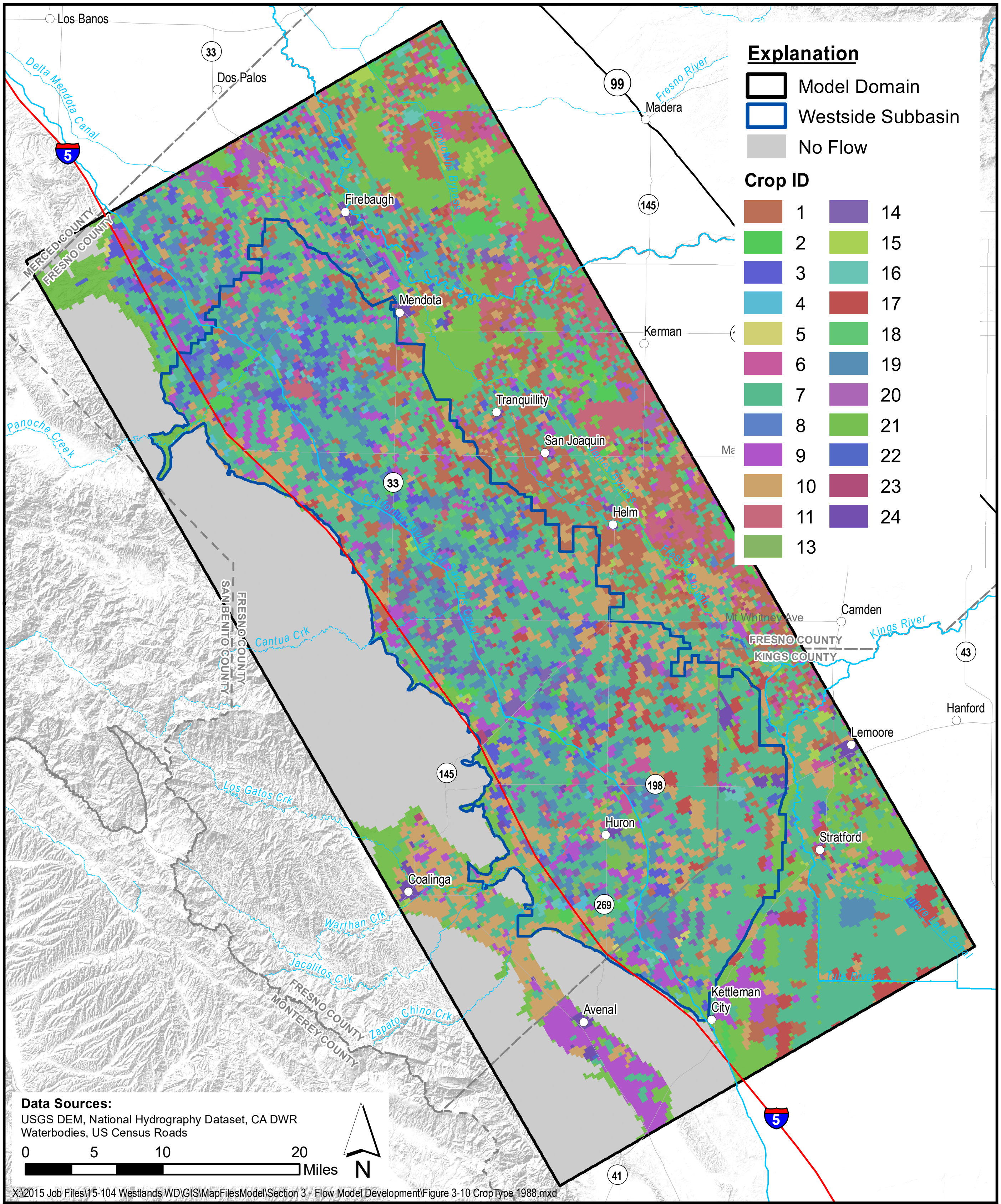
Location of WWD Production Wells and Non-WWD Virtual Production Wells

Figure 3-9

SGMA Sustainability Analyses
Westside Subbasin



Data Sources:
USGS DEM, National Hydrography Dataset, CA DWR Waterbodies, US Census Roads

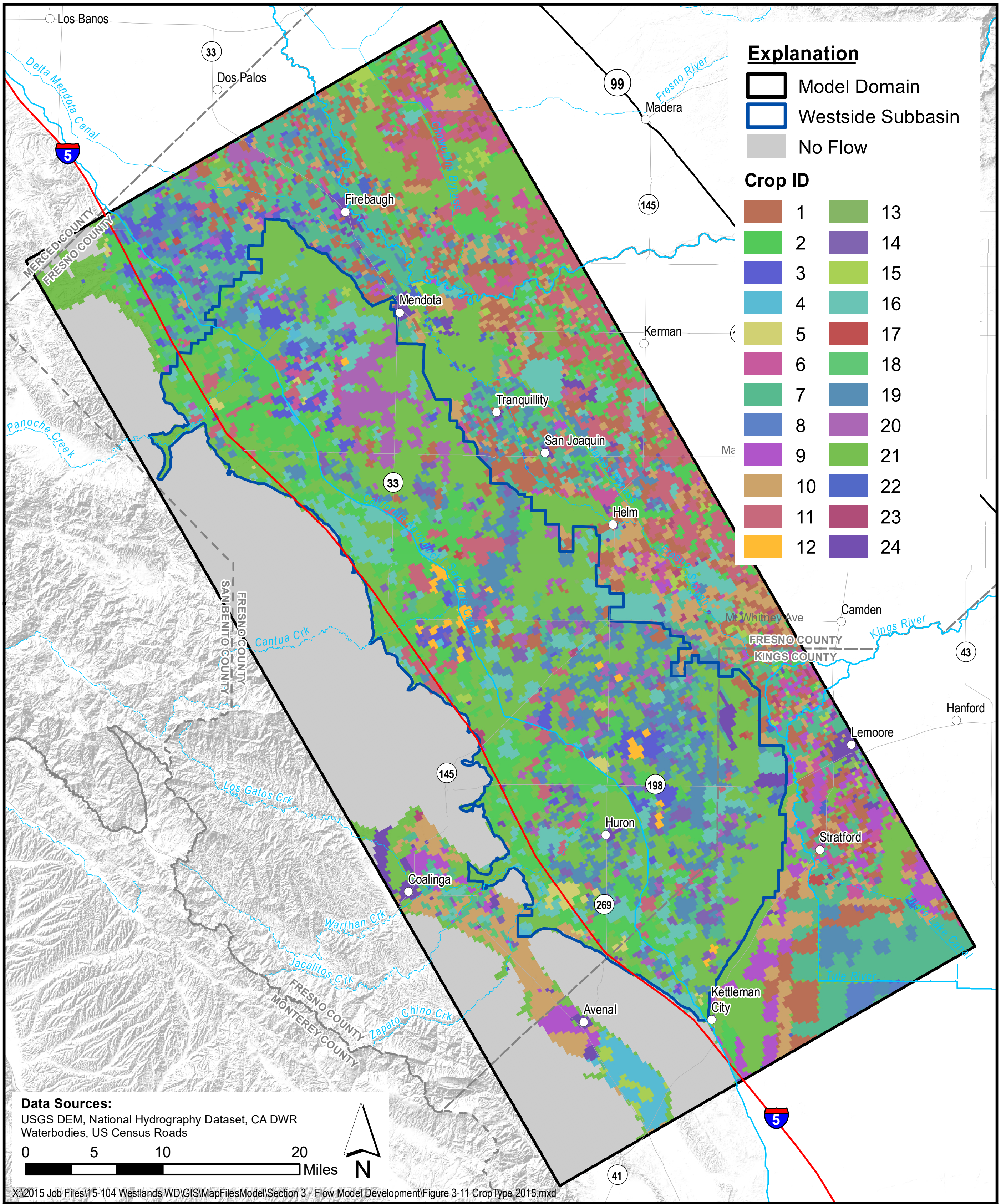
X:\2015 Job Files\15-104 Westlands WD\GIS\MapFilesModel\Section 3 - Flow Model Development\Figure 3-10 CropType 1988.mxd

Luhdorff & Scalmanini
Consulting Engineers

Assigned Crop Type 1988

SGMA Sustainability Analyses
Westside Subbasin

Figure 3-10



Data Sources:
USGS DEM, National Hydrography Dataset, CA DWR Waterbodies, US Census Roads

X:\2015 Job Files\15-104 Westlands WD\GIS\MapFilesModel\Section 3 - Flow Model Development\Figure 3-11 CropType 2015.mxd

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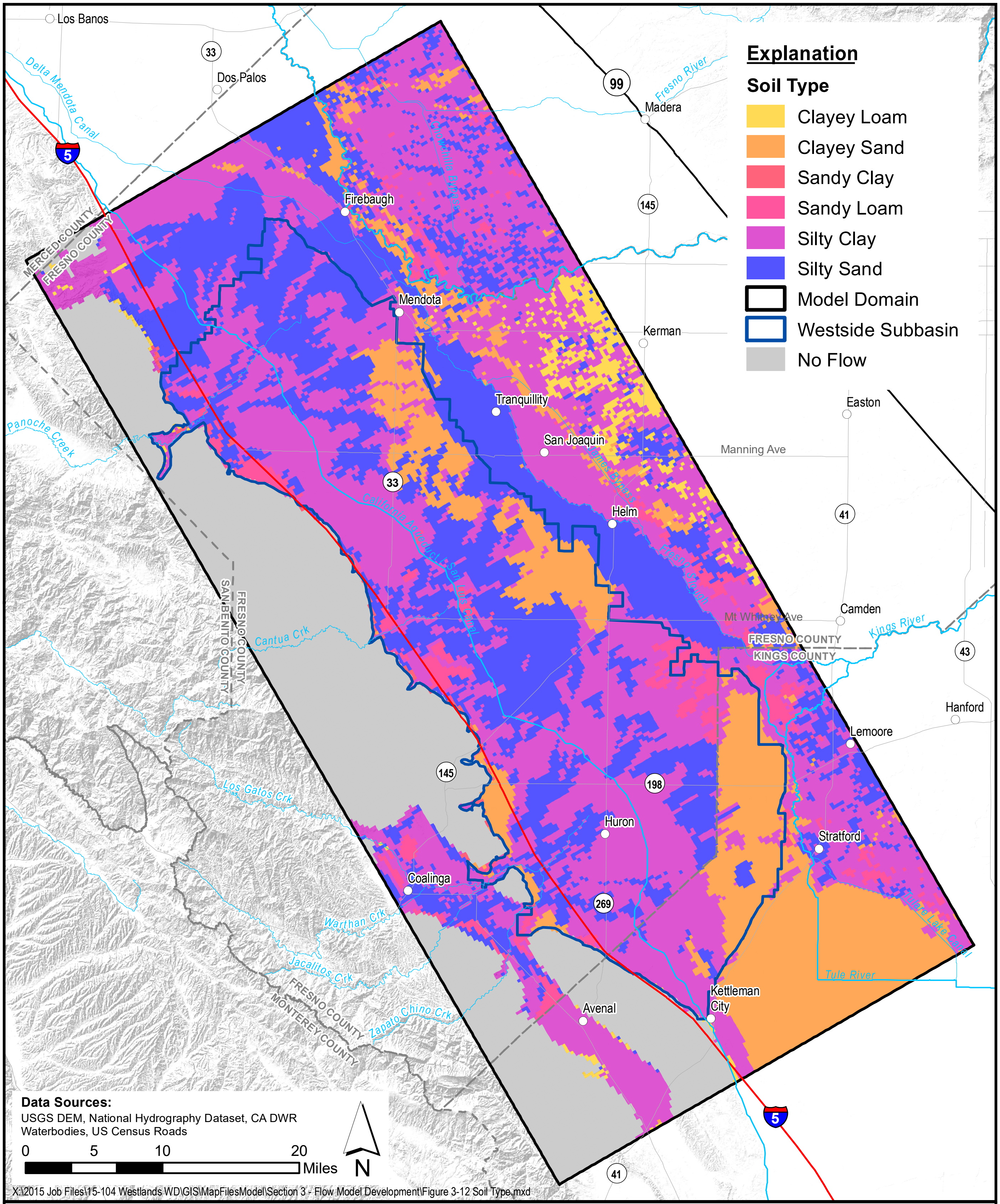
Assigned Crop Type 2015

SGMA Sustainability Analyses
Westside Subbasin

Figure 3-11



Data Sources:
USGS DEM, National Hydrography Dataset, CA DWR
Waterbodies, US Census Roads

X:\2015 Job Files\15-104 Westlands WD\GIS\MapFilesModel\Section 3 - Flow Model Development\Figure 3-12 Soil Type.mxd

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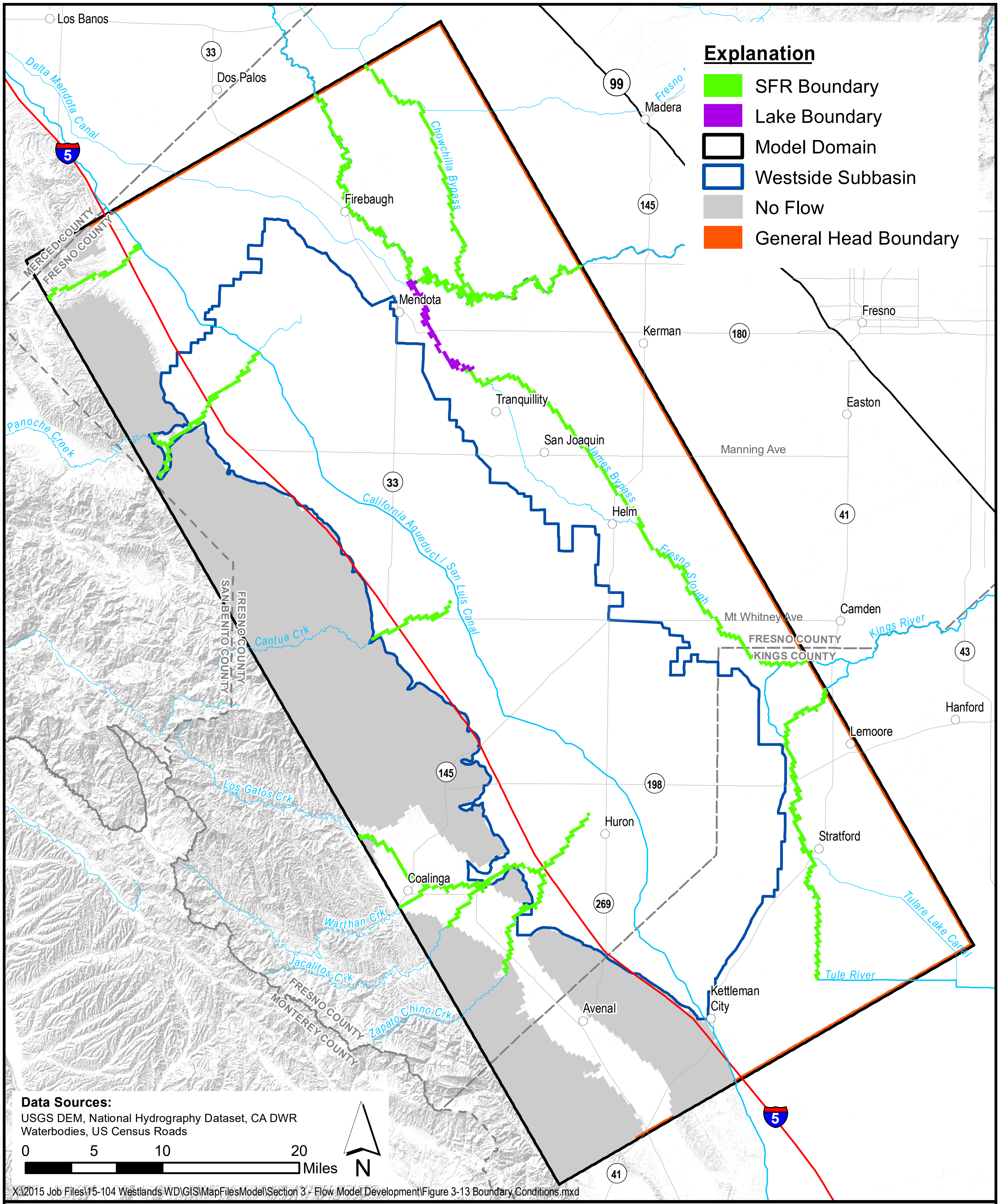
Assigned Soil Type from SSURGO Classification

SGMA Sustainability Analyses
Westside Subbasin

Figure 3-12



Data Sources:
USGS DEM, National Hydrography Dataset, CA DWR Waterbodies, US Census Roads

X:\2015 Job Files\15-104 Westlands WD\GIS\MapFilesModel\Section 3 - Flow Model Development\Figure 3-13 Boundary Conditions.mxd

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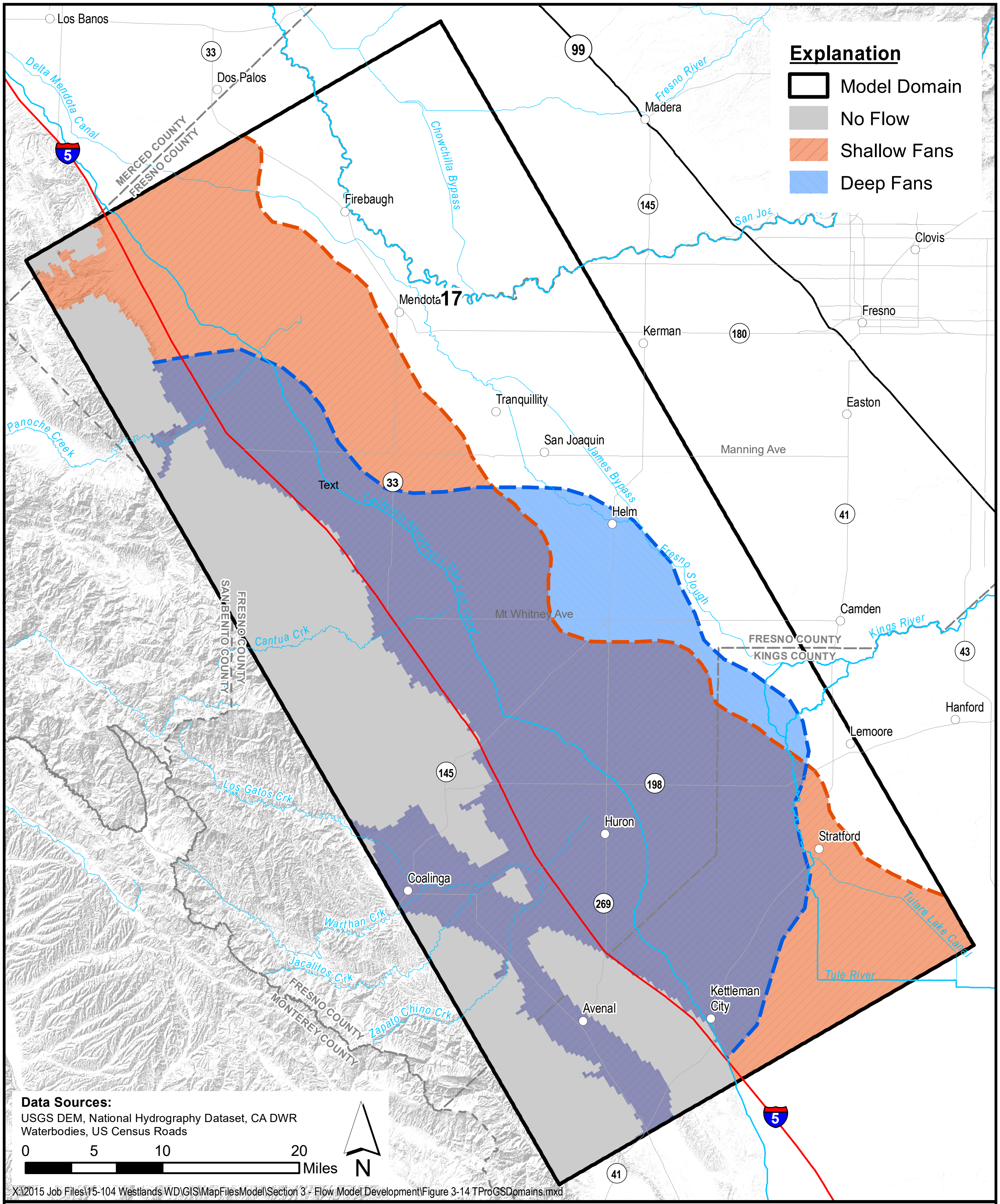
Model Boundary Conditions

SGMA Sustainability Analyses
Westside Subbasin

Figure 3-13



Data Sources:
USGS DEM, National Hydrography Dataset, CA DWR
Waterbodies, US Census Roads

X:\2015 Job Files\15-104 Westlands WD\GIS\MapFilesModel\Section 3 - Flow Model Development\Figure 3-14 TProGSDomains.mxd

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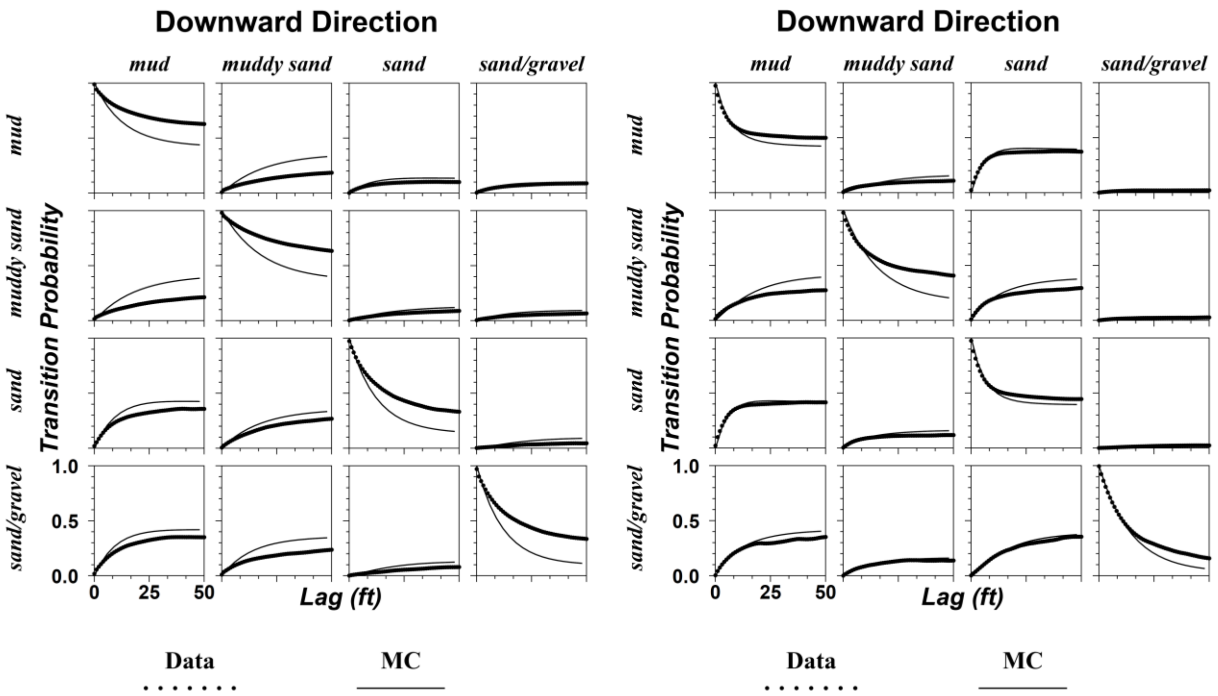
Extent of Shallow and Deep Westside Fans

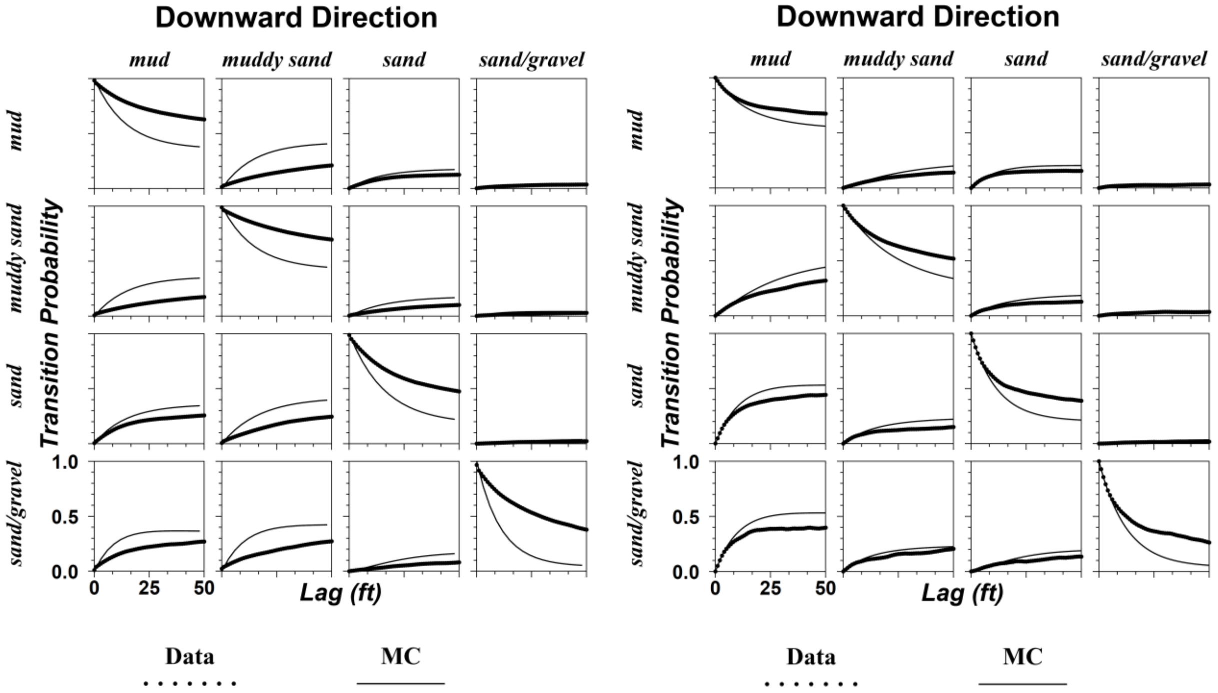
SGMA Sustainability Analyses
Westside Subbasin

Figure 3-14



(a) Shallow Coast Range Fans

(b) Shallow Sierran Fans



(c) Deep Coast Range Fans

(d) Deep Sierran Fans

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Figure 3-15
Vertical Markov Chain Models in Geostatistical Model Subdomains

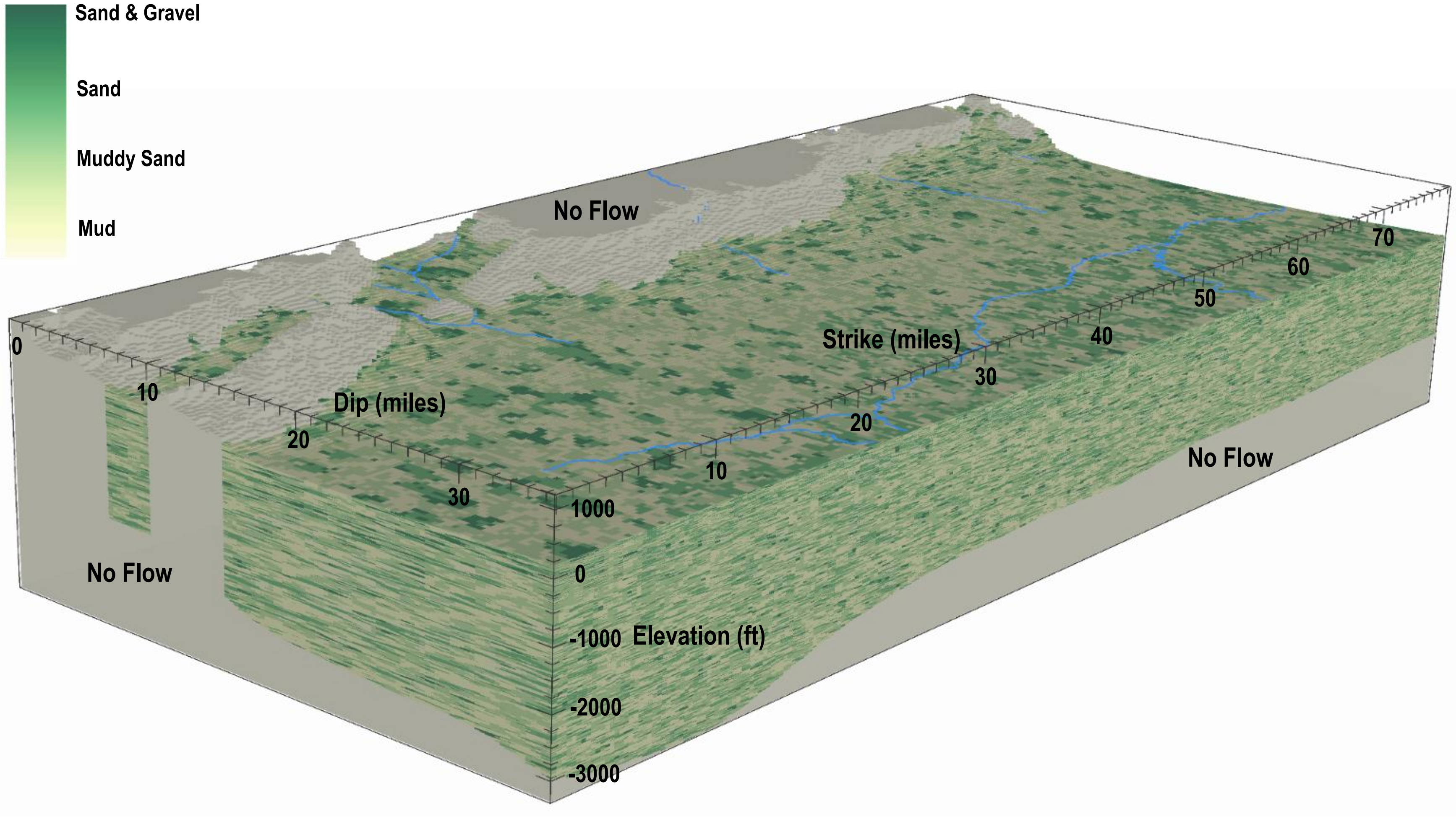

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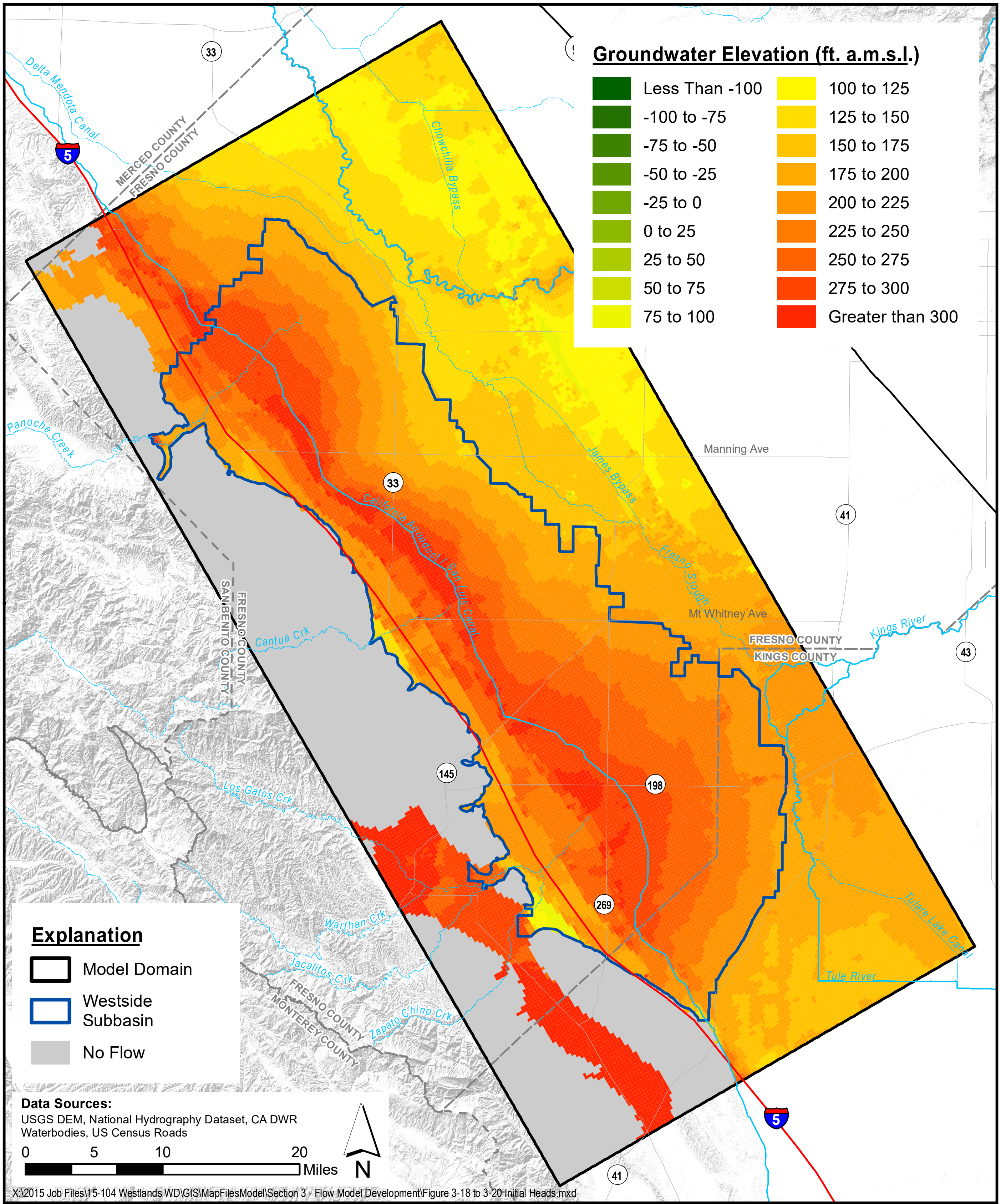
Figure 3-16
Transition Probability Geostatistical Simulation Results



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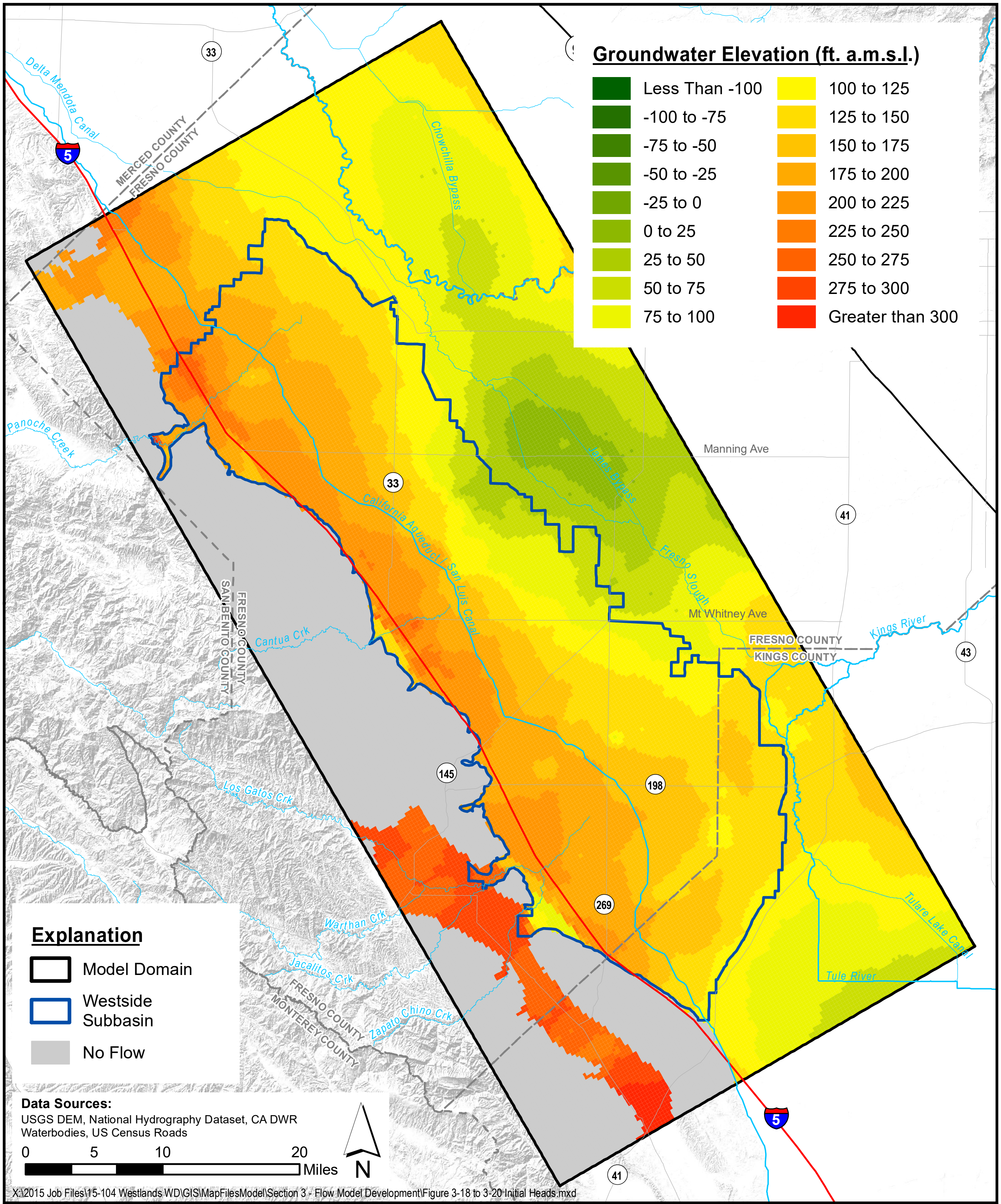
Initial Hydraulic Head in the Shallow Aquifer

SGMA Sustainability Analyses
Westside Subbasin

Figure 3-18



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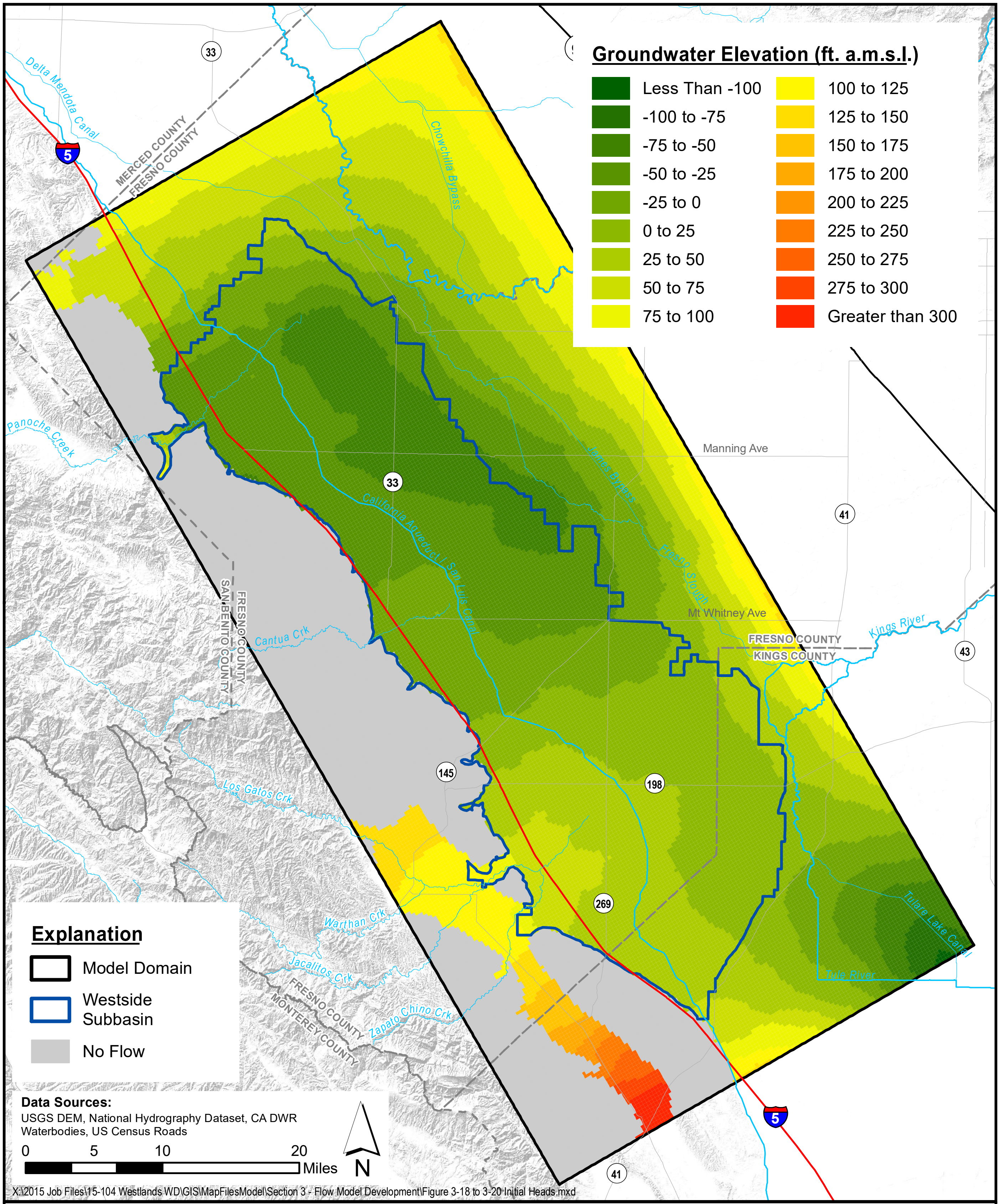
Initial Hydraulic Head in the Upper Aquifer

SGMA Sustainability Analyses
Westside Subbasin

Figure 3-19



Data Sources:
USGS DEM, National Hydrography Dataset, CA DWR Waterbodies, US Census Roads

X:\2015 Job Files\15-104 Westlands WD\GIS\MapFilesModel\Section 3 - Flow Model Development\Figure 3-18 to 3-20 Initial Heads.mxd

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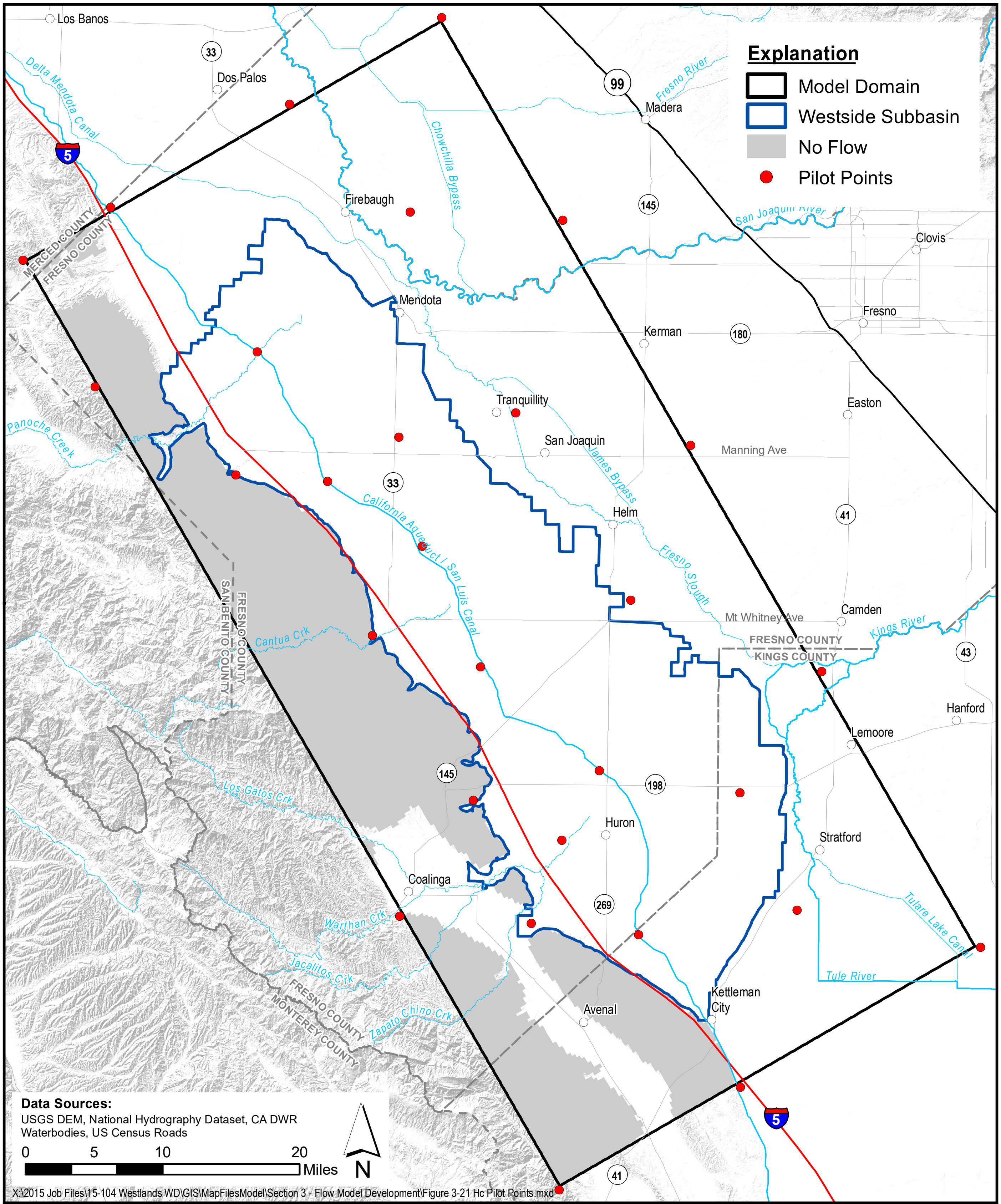
Initial Hydraulic Head in the Lower Aquifer

SGMA Sustainability Analyses
Westside Subbasin

Figure 3-20



Data Sources:
USGS DEM, National Hydrography Dataset, CA DWR Waterbodies, US Census Roads

X:\2015 Job Files\15-104 Westlands WD\GIS\MapFilesModel\Section 3 - Flow Model Development\Figure 3-21 Hc Pilot Points.mxd

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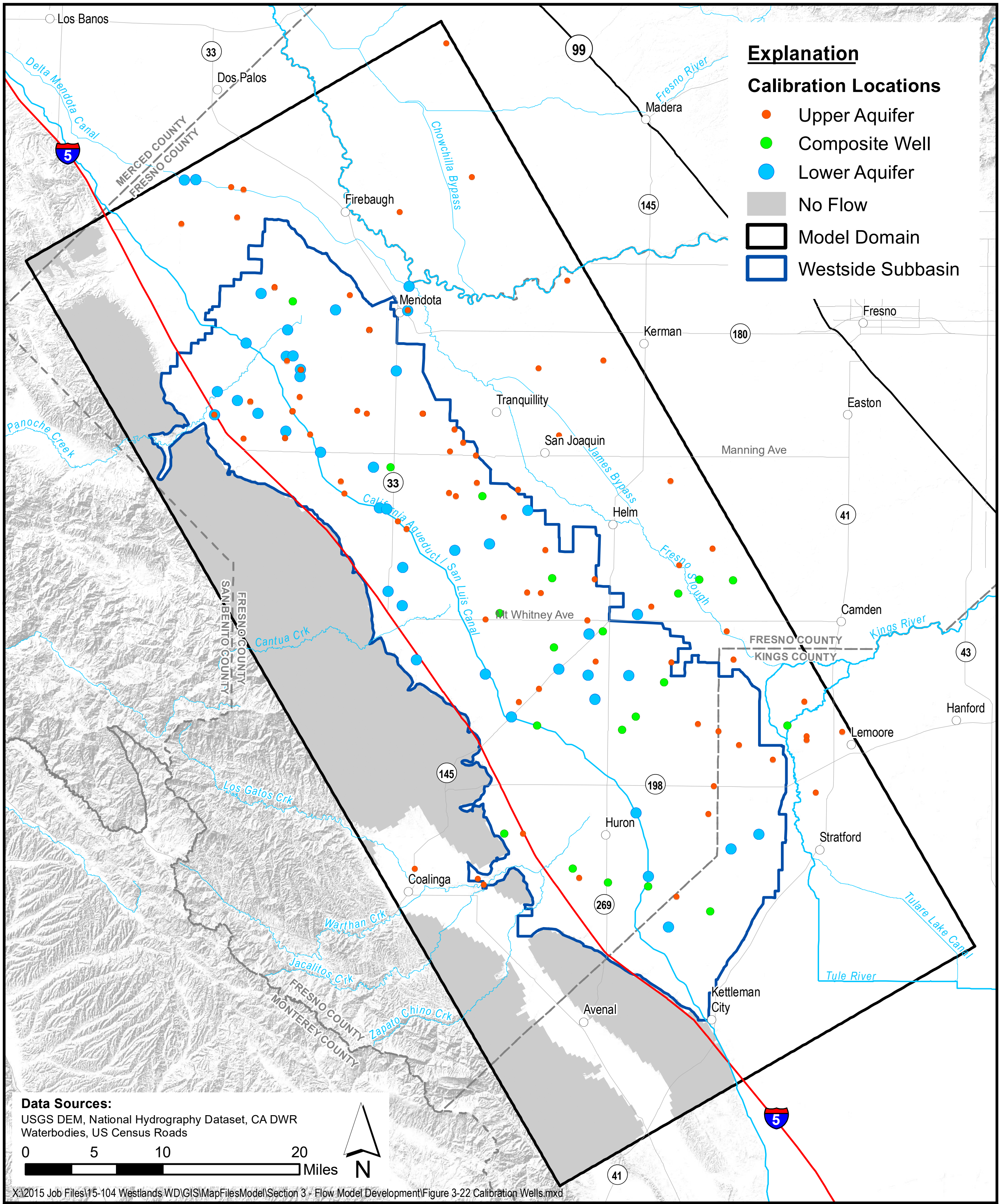
Pilot Points used to Assign Preconsolidation Head

SGMA Sustainability Analyses
Westside Subbasin

Figure 3-21



Data Sources:
USGS DEM, National Hydrography Dataset, CA DWR
Waterbodies, US Census Roads

X:\2015 Job Files\15-104 Westlands WD\GIS\MapFilesModel\Section 3 - Flow Model Development\Figure 3-22 Calibration Wells.mxd

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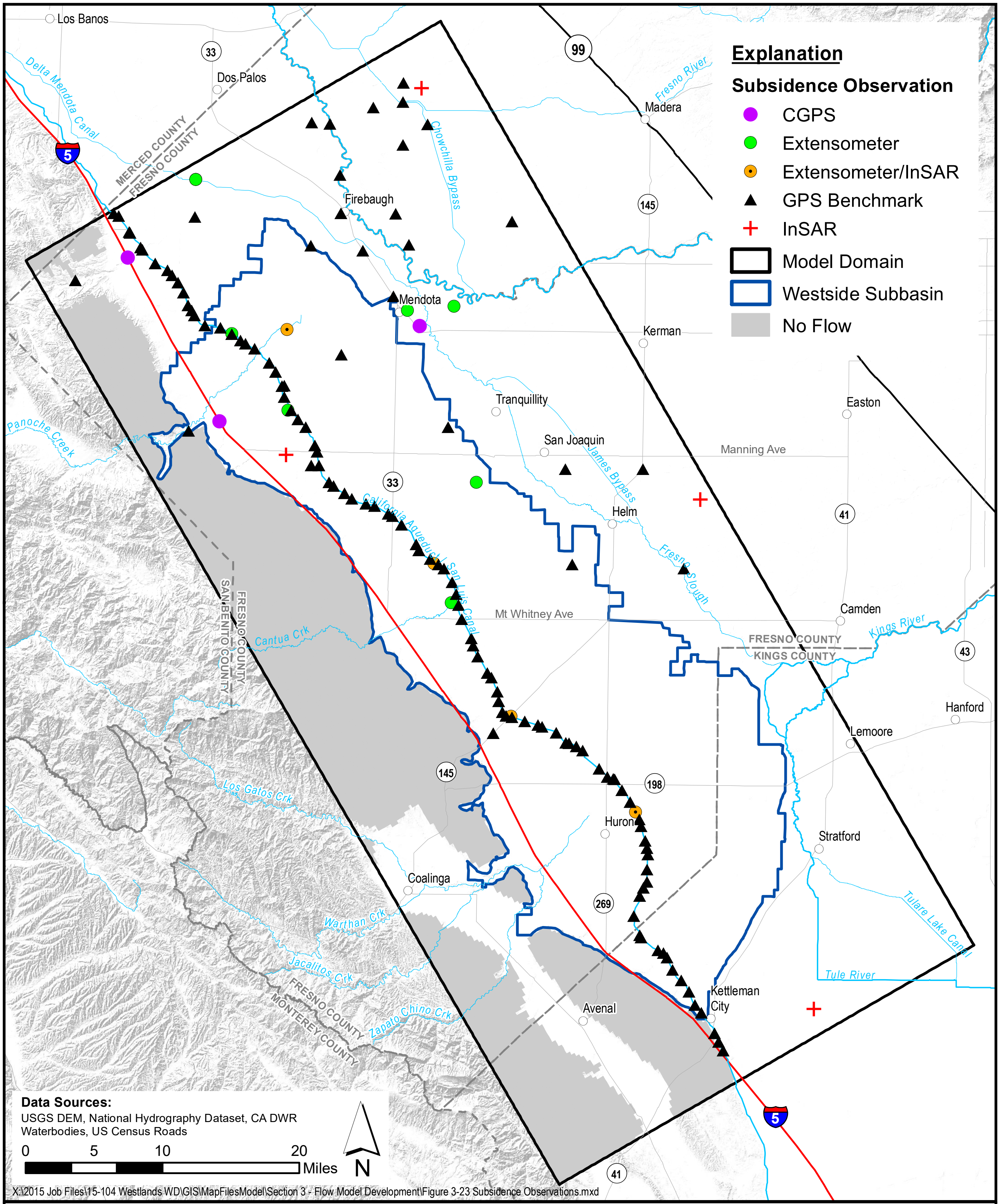
Location of Wells with Water Levels Used for Model Calibration

Figure 3-22

SGMA Sustainability Analyses
Westside Subbasin



Data Sources:
USGS DEM, National Hydrography Dataset, CA DWR Waterbodies, US Census Roads

X:\2015 Job Files\15-104 Westlands WD\GIS\MapFilesModel\Section 3 - Flow Model Development\Figure 3-23 Subsidence Observations.mxd

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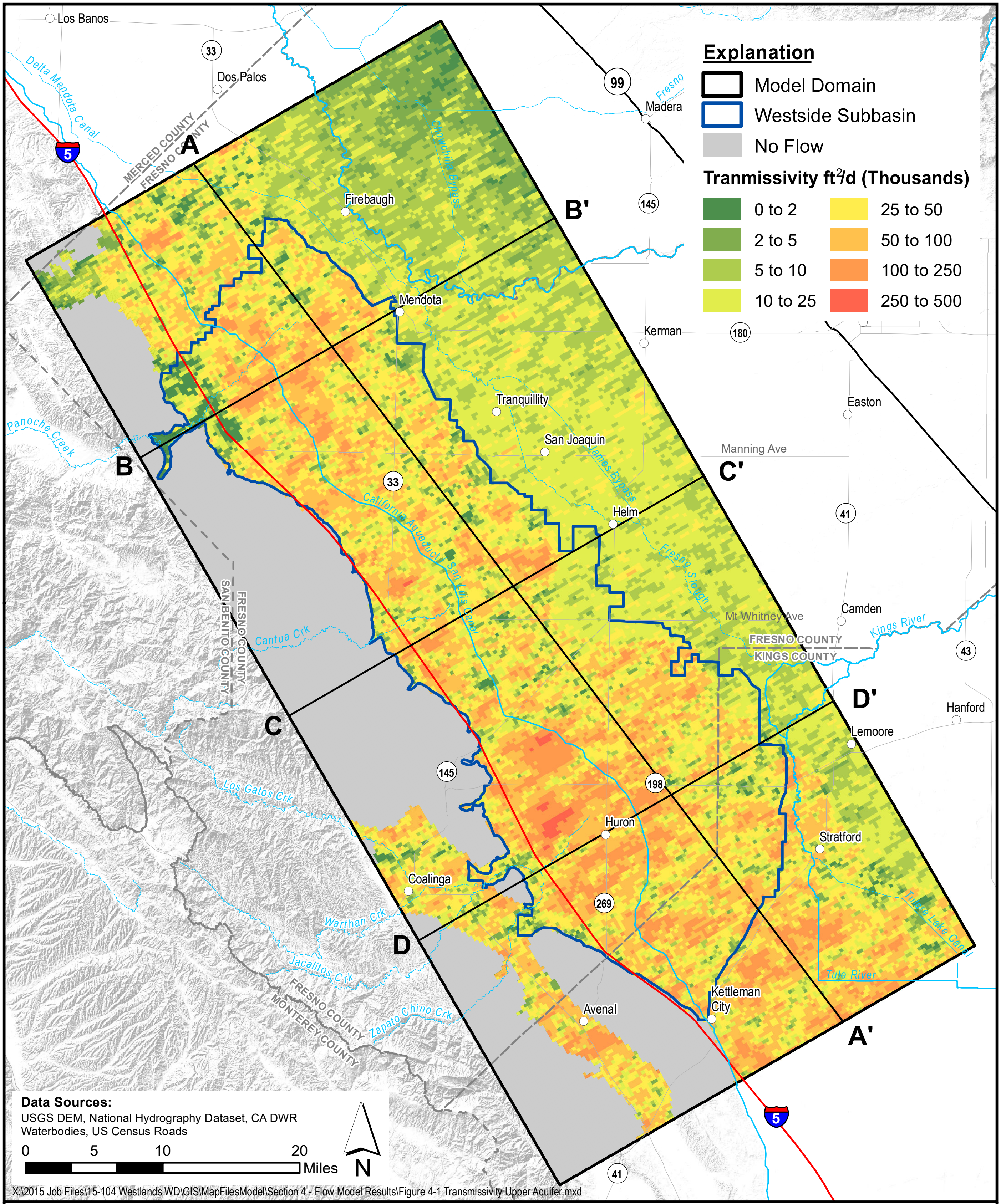
Location of Subsidence and Compaction Observations Used in Model Calibration

SGMA Sustainability Analyses
Westside Subbasin

Figure 3-23



Data Sources:
USGS DEM, National Hydrography Dataset, CA DWR Waterbodies, US Census Roads

X:\2015 Job Files\15-104 Westlands WD\GIS\MapFilesModel\Section 4 - Flow Model Results\Figure 4-1 Transmissivity Upper Aquifer.mxd

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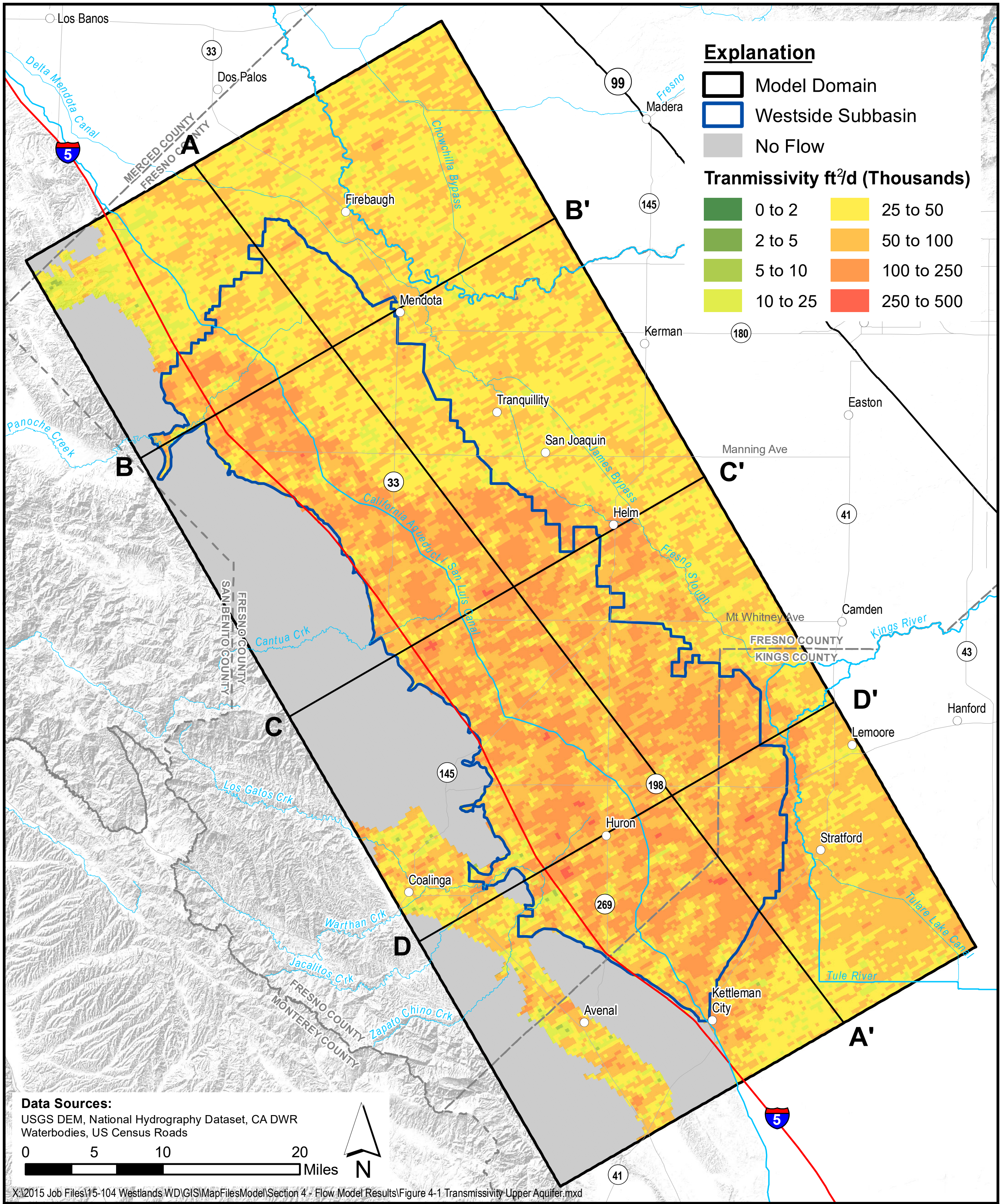
Transmissivity Assigned in the Upper Aquifer

SGMA Sustainability Analyses
Westside Subbasin

Figure 4-1



Data Sources:
USGS DEM, National Hydrography Dataset, CA DWR Waterbodies, US Census Roads

X:\2015 Job Files\15-104 Westlands WD\GIS\MapFilesModel\Section 4 - Flow Model Results\Figure 4-1 Transmissivity Upper Aquifer.mxd

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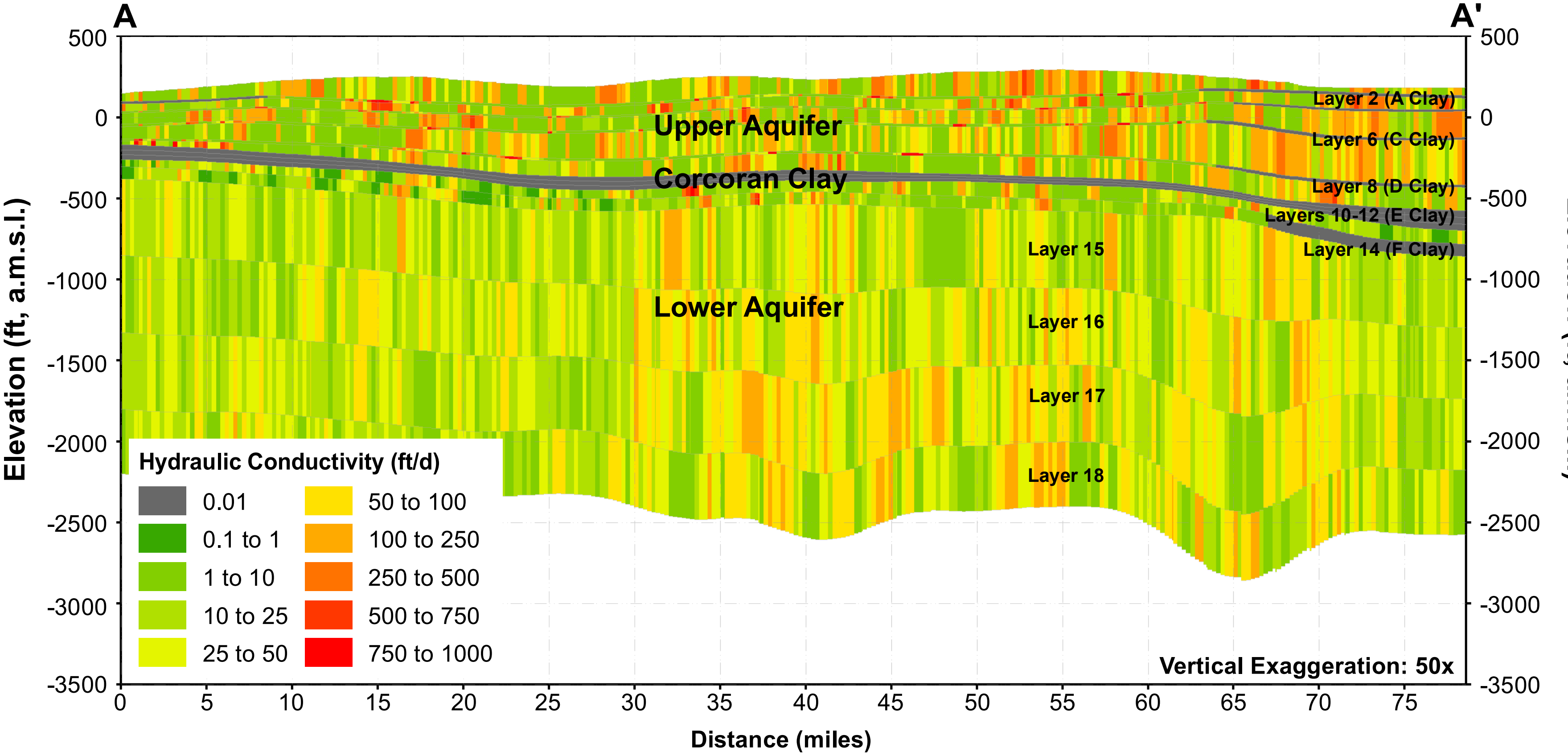
Transmissivity Assigned in the Lower Aquifer

SGMA Sustainability Analyses
Westside Subbasin

Figure 4-2



X:\2015 Job Files\15-104 Westlands WD\GIS\MapFilesModel\Section 4 - Flow Model Results\Figure 4-3a - Hydraulic Conductivity Section A.mxd

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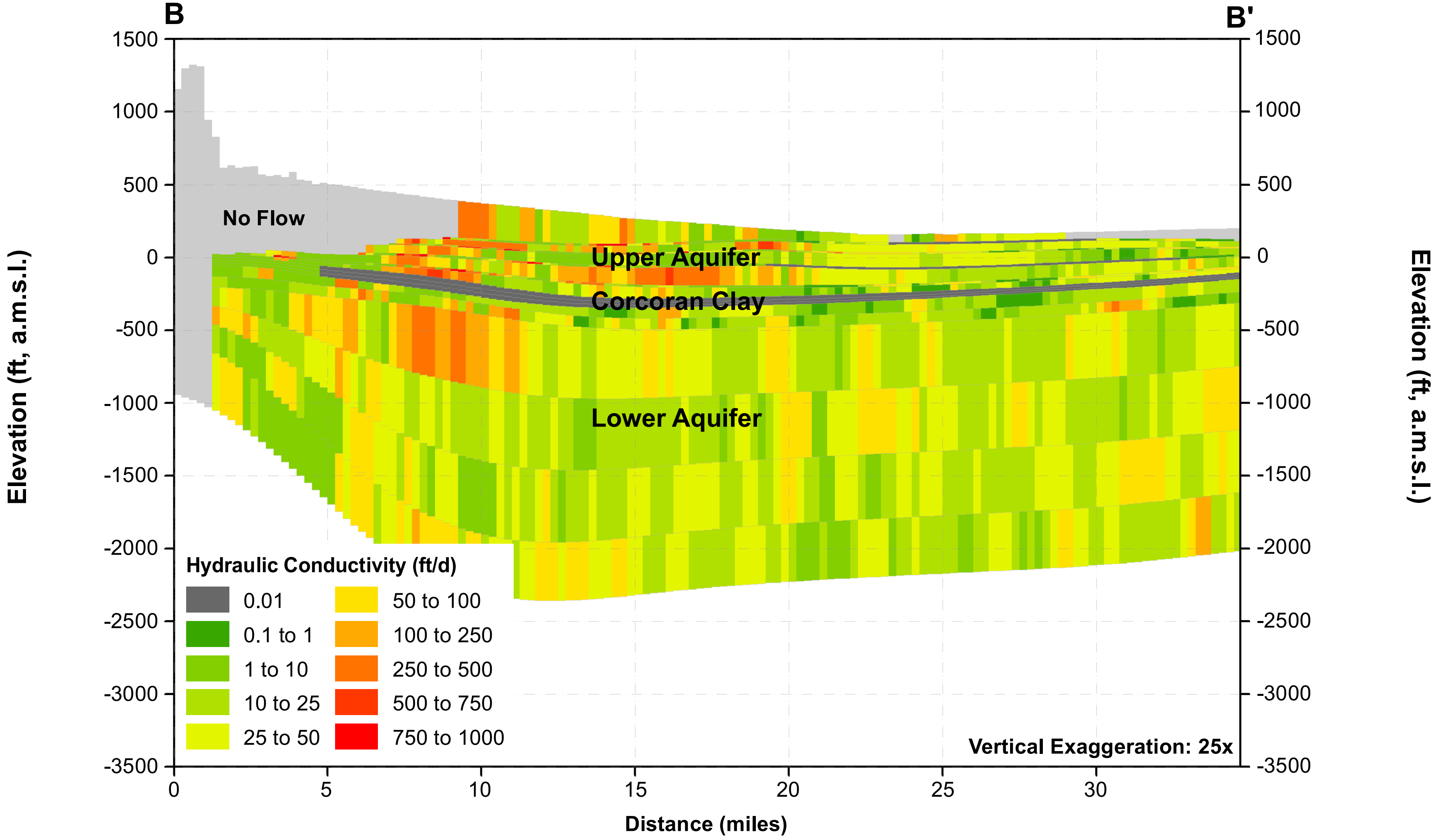
Assigned Hydraulic Conductivity Through Model Cross Section A - A'

SGMA Sustainability Analyses
Westside Subbasin

Figure 4-3a



X:\2015 Job Files\15-104 Westlands WD\GIS\MapFilesModel\Section 4 - Flow Model Results\Figure 4-3b - Hydraulic Conductivity Section B.mxd

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Assigned Hydraulic Conductivity Through Model Cross Section B - B'

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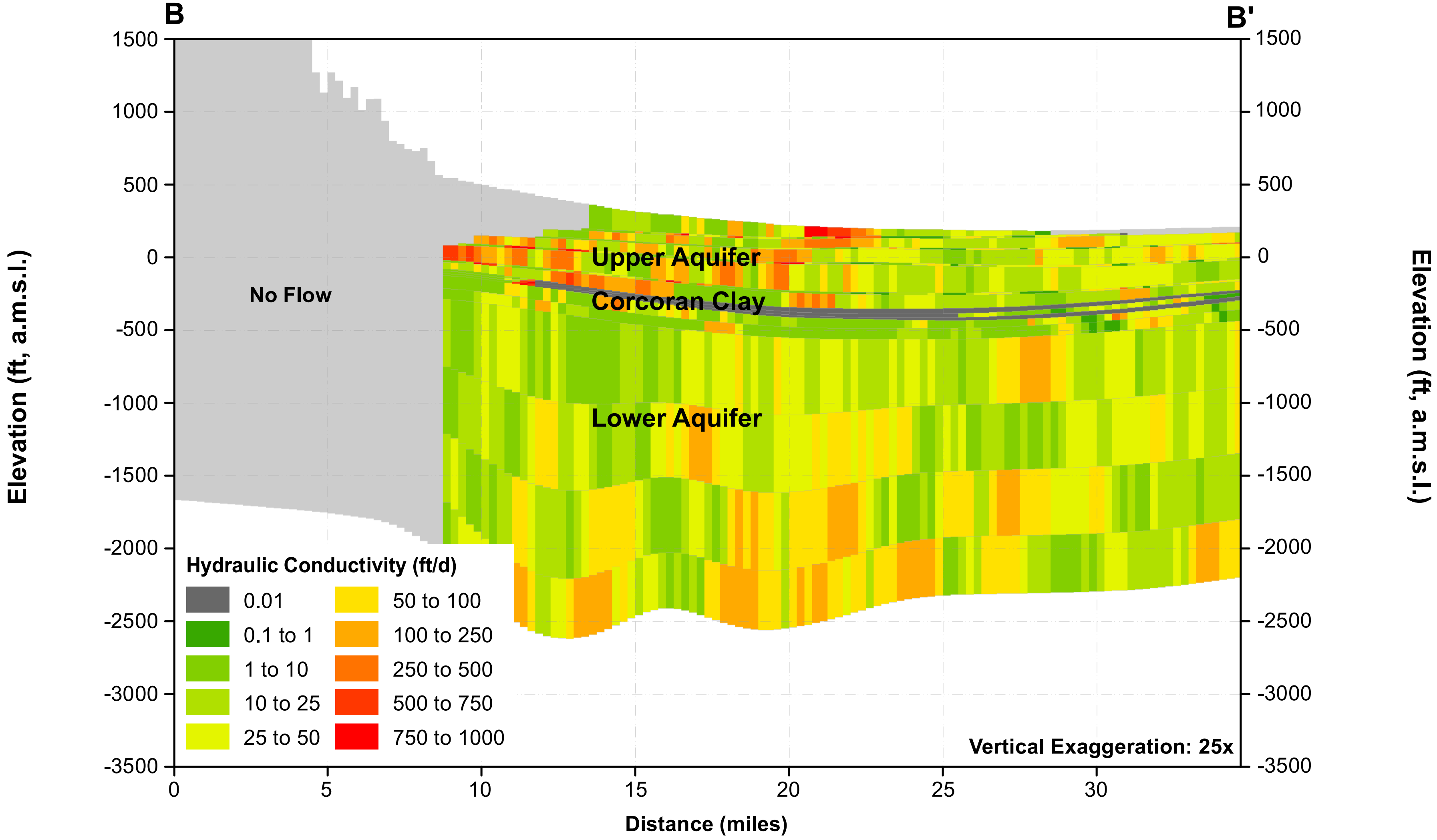
Westside Subbasin

Figure 4-3b



X:\2015 Job Files\15-104 Westlands WD\GIS\MapFilesModel\Section 4 - Flow Model Results\Figure 4-3c - Hydraulic Conductivity Section C.mxd

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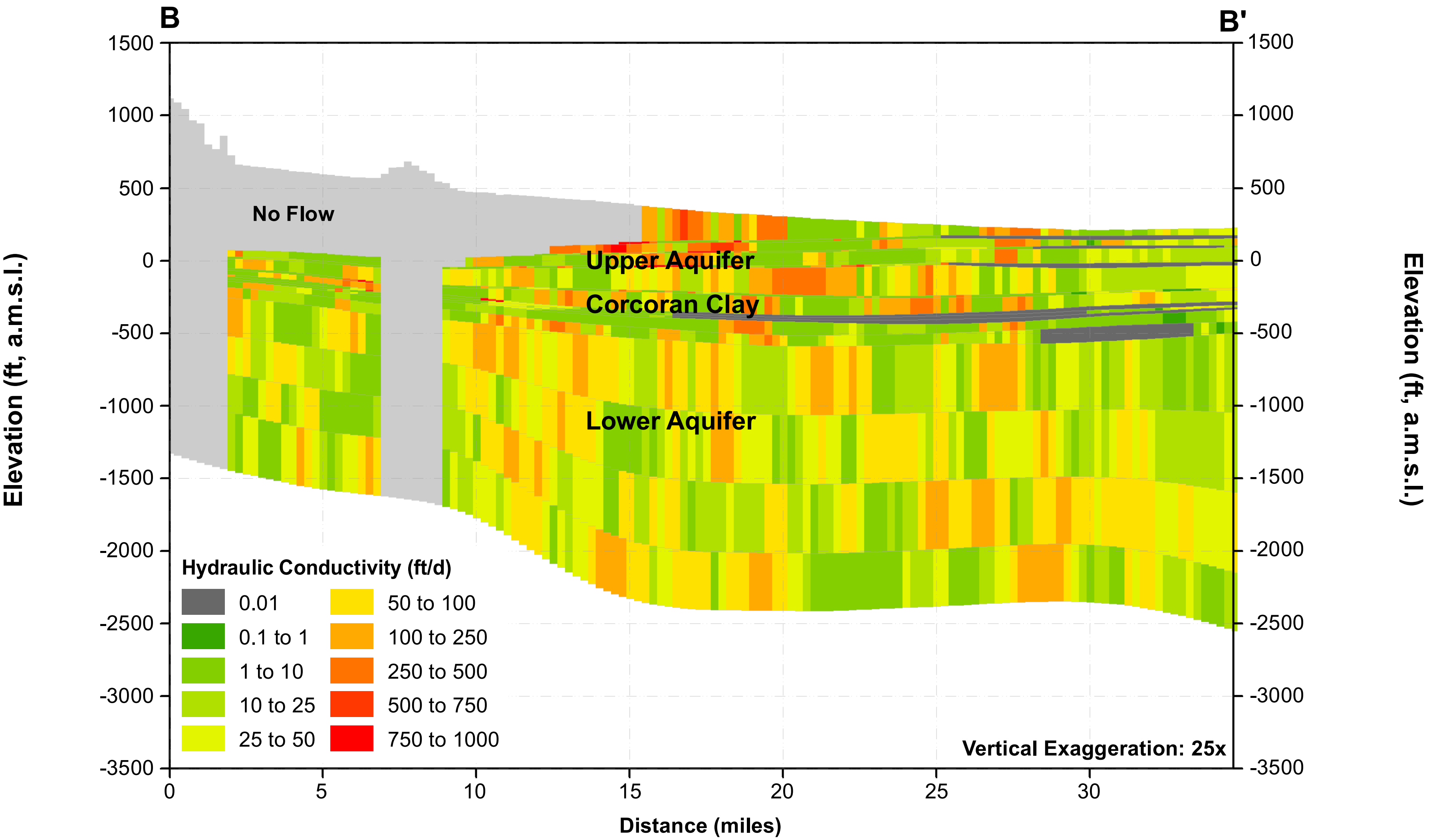
Assigned Hydraulic Conductivity Through Model Cross Section C - C'

SGMA Sustainability Analyses
Westside Subbasin

Figure 4-3c



X:\2015 Job Files\15-104 Westlands WD\GIS\MapFilesModel\Section 4 - Flow Model Results\Figure 4-3d - Hydraulic Conductivity Section D.mxd

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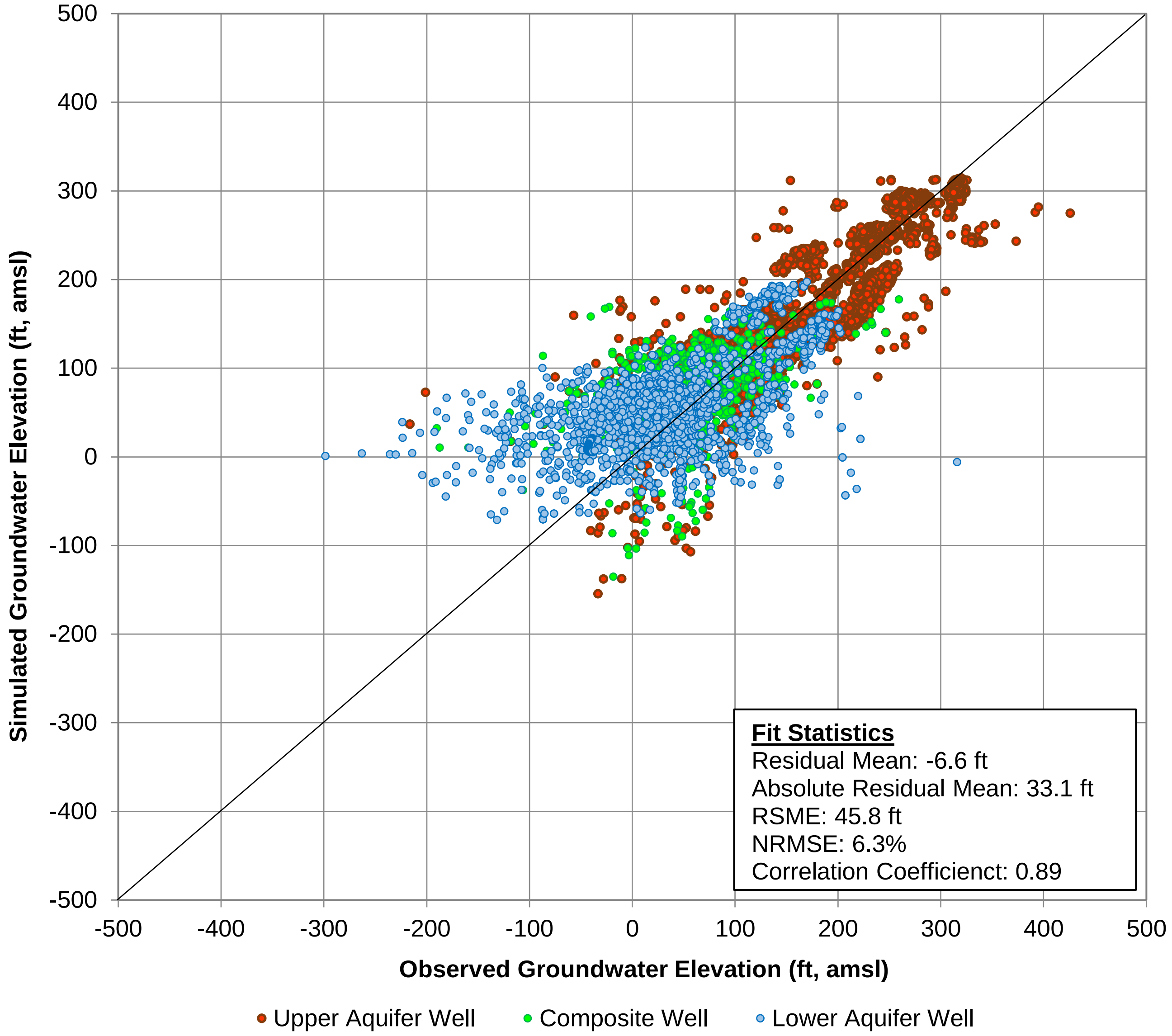
Assigned Hydraulic Conductivity Through Model Cross Section D - D'

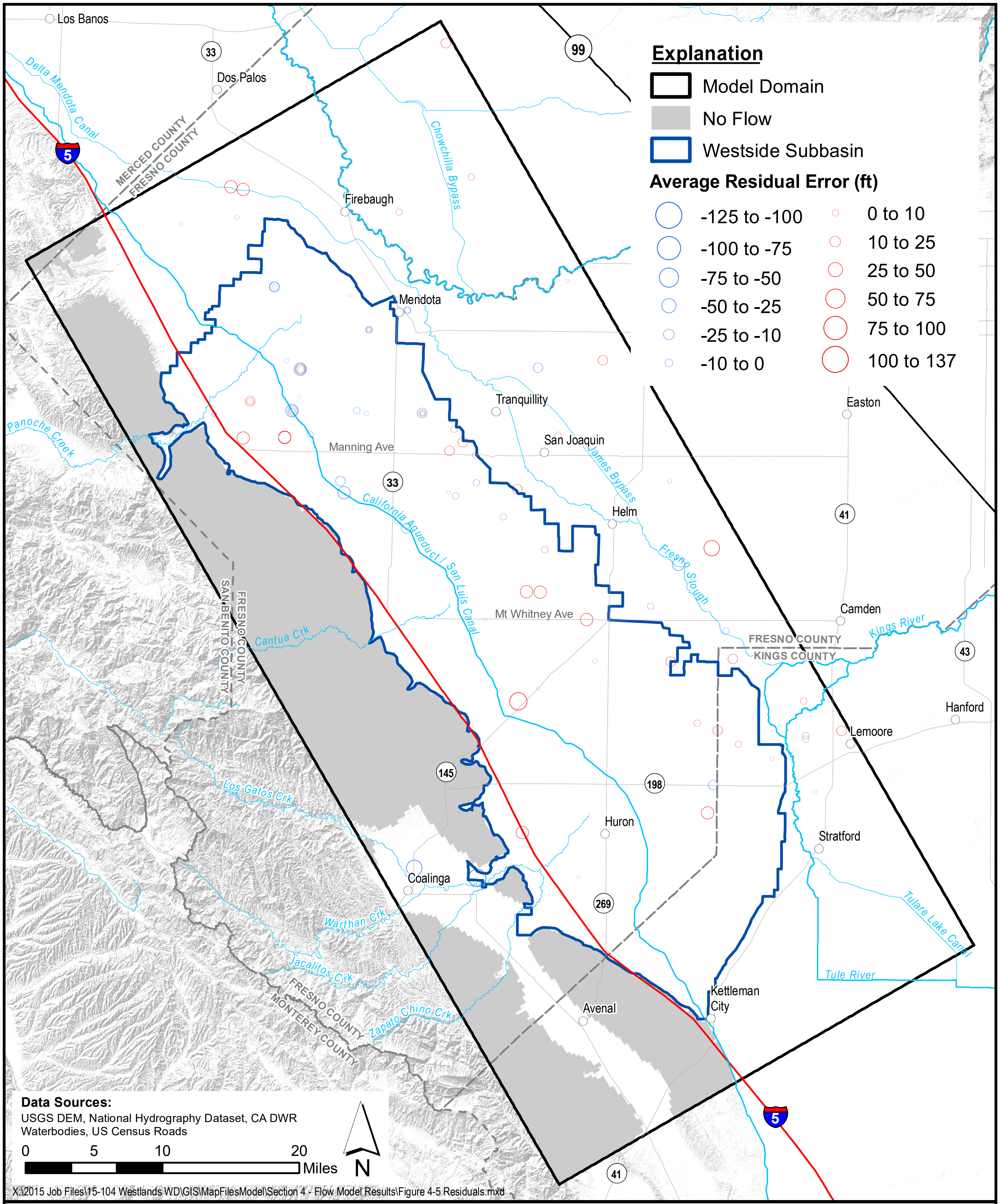
SGMA Sustainability Analyses
Westside Subbasin

Figure 4-3d



Fit Statistics
Residual Mean: -6.6 ft
Absolute Residual Mean: 33.1 ft
RSME: 45.8 ft
NRMSE: 6.3%
Correlation Coefficienct: 0.89

Figure 4-4
Observed vs. Simulated Hydraulic Head



Data Sources:
USGS DEM, National Hydrography Dataset, CA DWR Waterbodies, US Census Roads

X:\2015 Job Files\15-104 Westlands WD\GIS\MapFilesModel\Section 4 - Flow Model Results\Figure 4-5 Residuals.mxd

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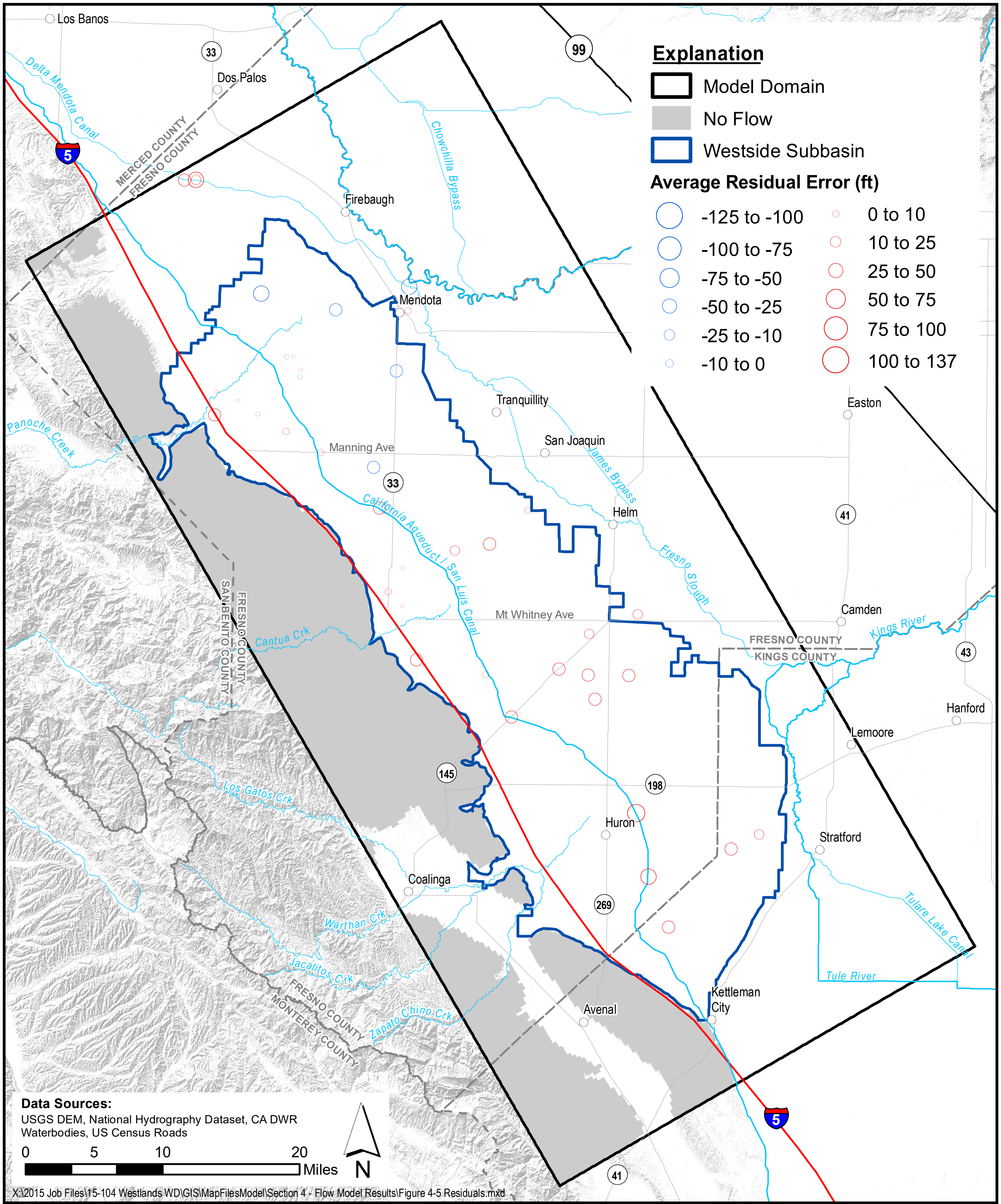
Residual Model Error in Hydraulic Heads Upper Aquifer Wells

Figure 4-5

SGMA Sustainability Analyses
Westside Subbasin



Data Sources:
USGS DEM, National Hydrography Dataset, CA DWR Waterbodies, US Census Roads

X:\2015 Job Files\15-104 Westlands WD\GIS\MapFilesModel\Section 4 - Flow Model Results\Figure 4-5 Residuals.mxd

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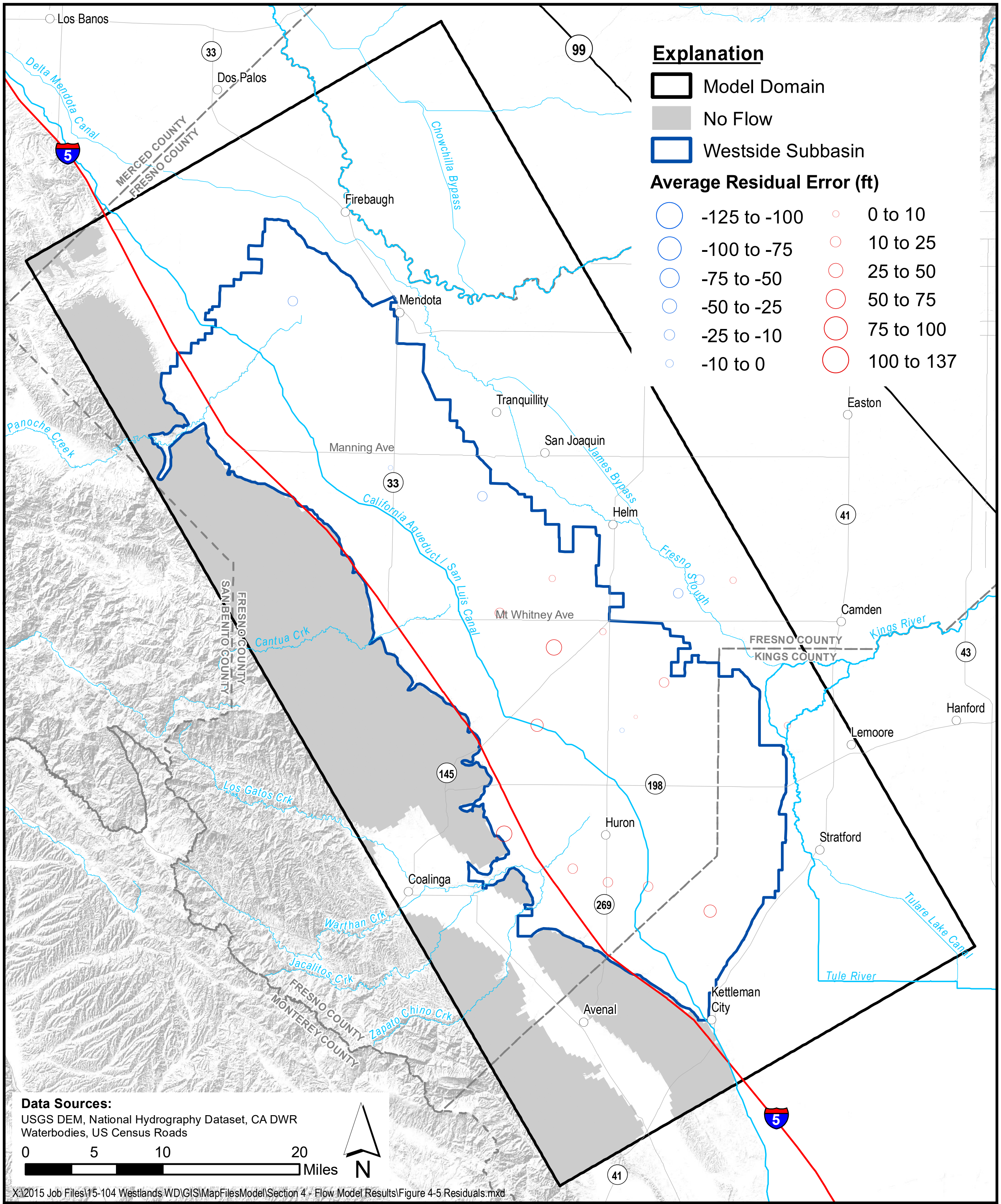
Residual Model Error in Hydraulic Heads Lower Aquifer Wells

Figure 4-6

SGMA Sustainability Analyses
Westside Subbasin



Data Sources:
USGS DEM, National Hydrography Dataset, CA DWR Waterbodies, US Census Roads

X:\2015 Job Files\15-104 Westlands WD\GIS\MapFilesModel\Section 4 - Flow Model Results\Figure 4-5 Residuals.mxd

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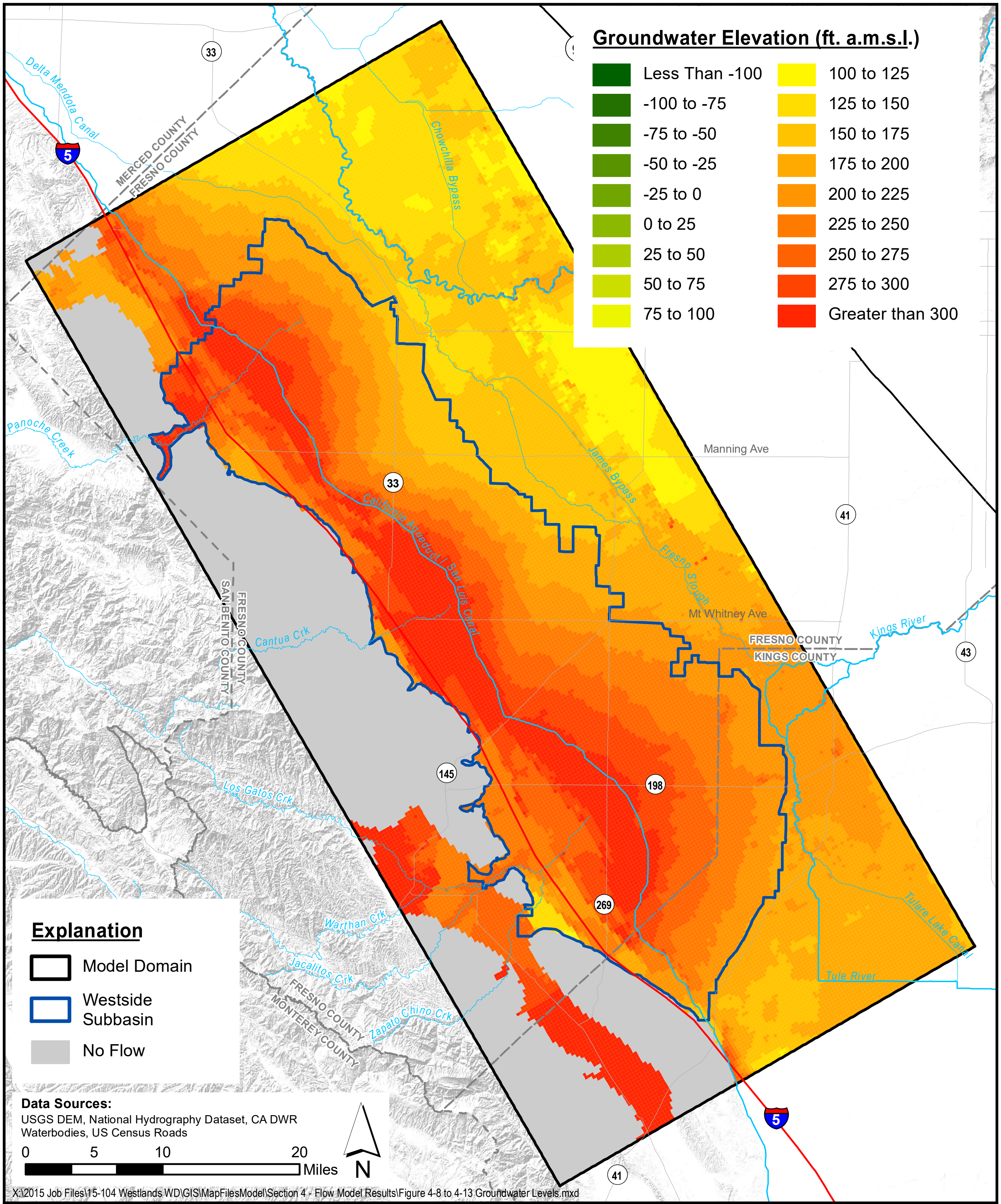
Residual Model Error in Hydraulic Heads Composite Wells

SGMA Sustainability Analyses
Westside Subbasin

Figure 4-7



Data Sources:
USGS DEM, National Hydrography Dataset, CA DWR Waterbodies, US Census Roads

X:\2015 Job Files\15-104 Westlands WD\GIS\MapFilesModel\Section 4 - Flow Model Results\Figure 4-8 to 4-13 Groundwater Levels.mxd

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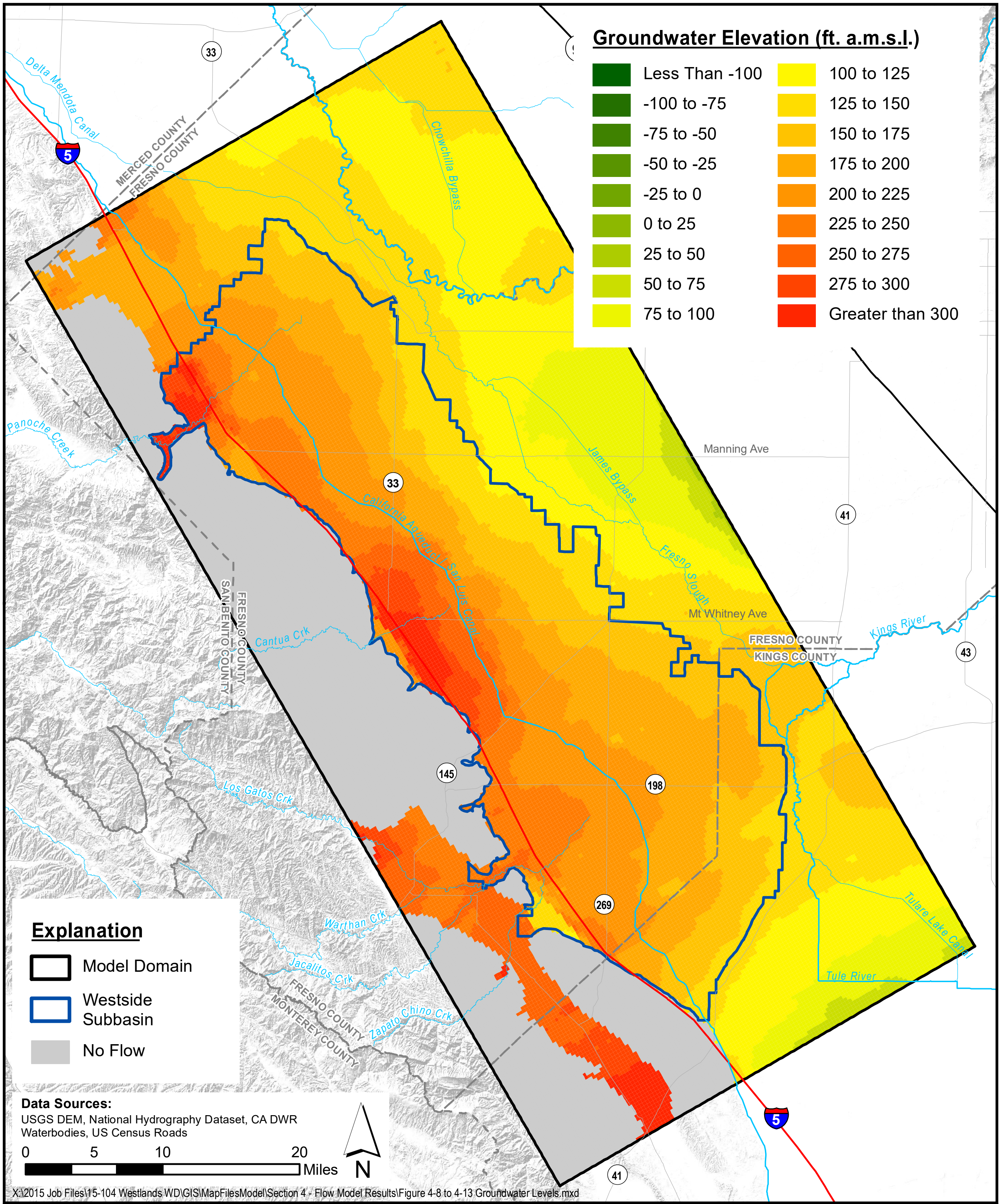
Simulated Hydraulic Head in the Shallow Aquifer March 2011

SGMA Sustainability Analyses
Westside Subbasin

Figure 4-8



X:\2015 Job Files\15-104 Westlands WD\GIS\MapFilesModel\Section 4 - Flow Model Results\Figure 4-8 to 4-13 Groundwater Levels.mxd

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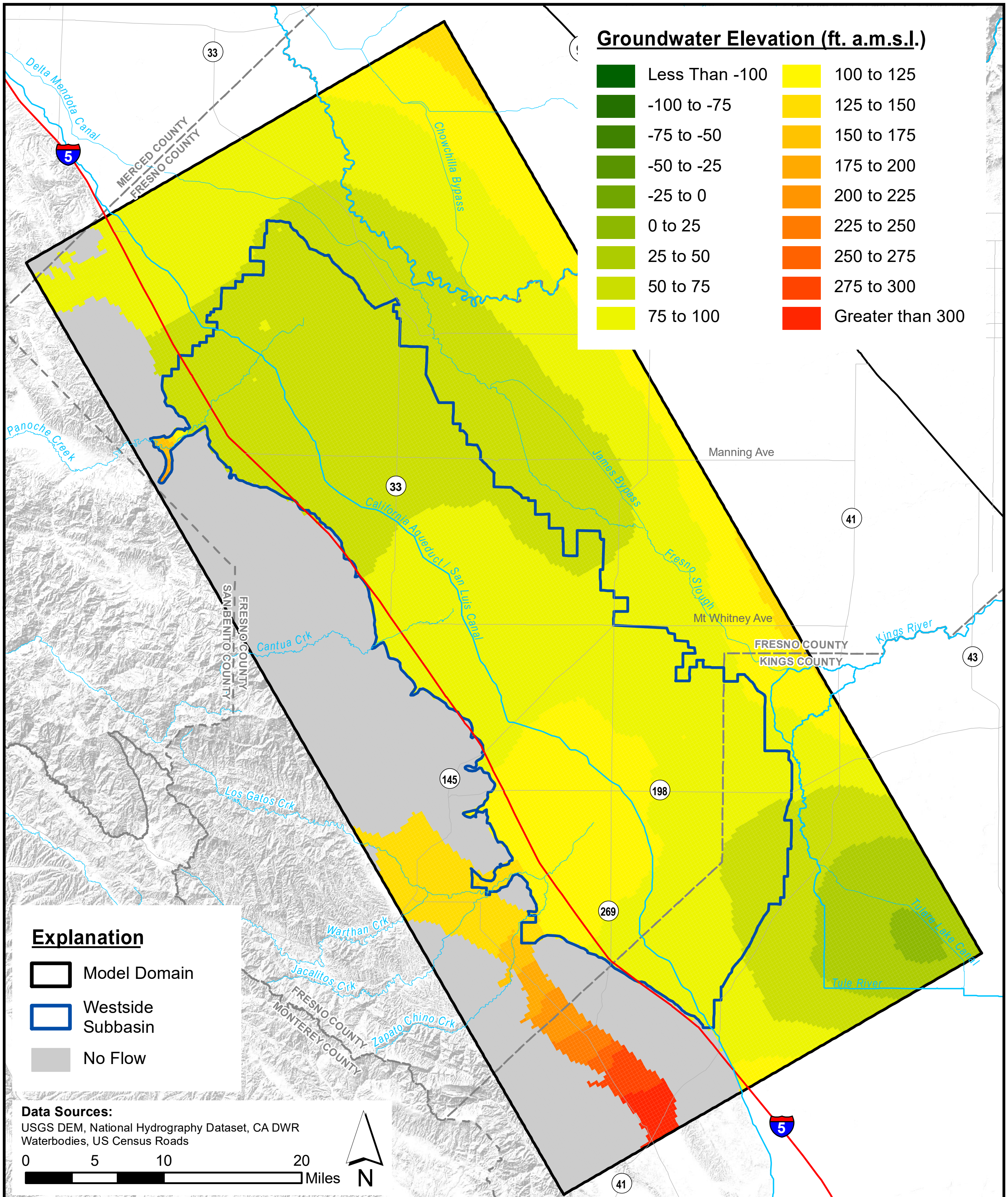
Simulated Hydraulic Head in the Upper Aquifer March 2011

SGMA Sustainability Analyses
Westside Subbasin

Figure 4-9



X:\2015 Job Files\15-104 Westlands WD\GIS\MapFilesModel\Section 4 - Flow Model Results\Figure 4-8 to 4-13 Groundwater Levels.mxd

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Simulated Hydraulic Head in the Lower Aquifer March 2011

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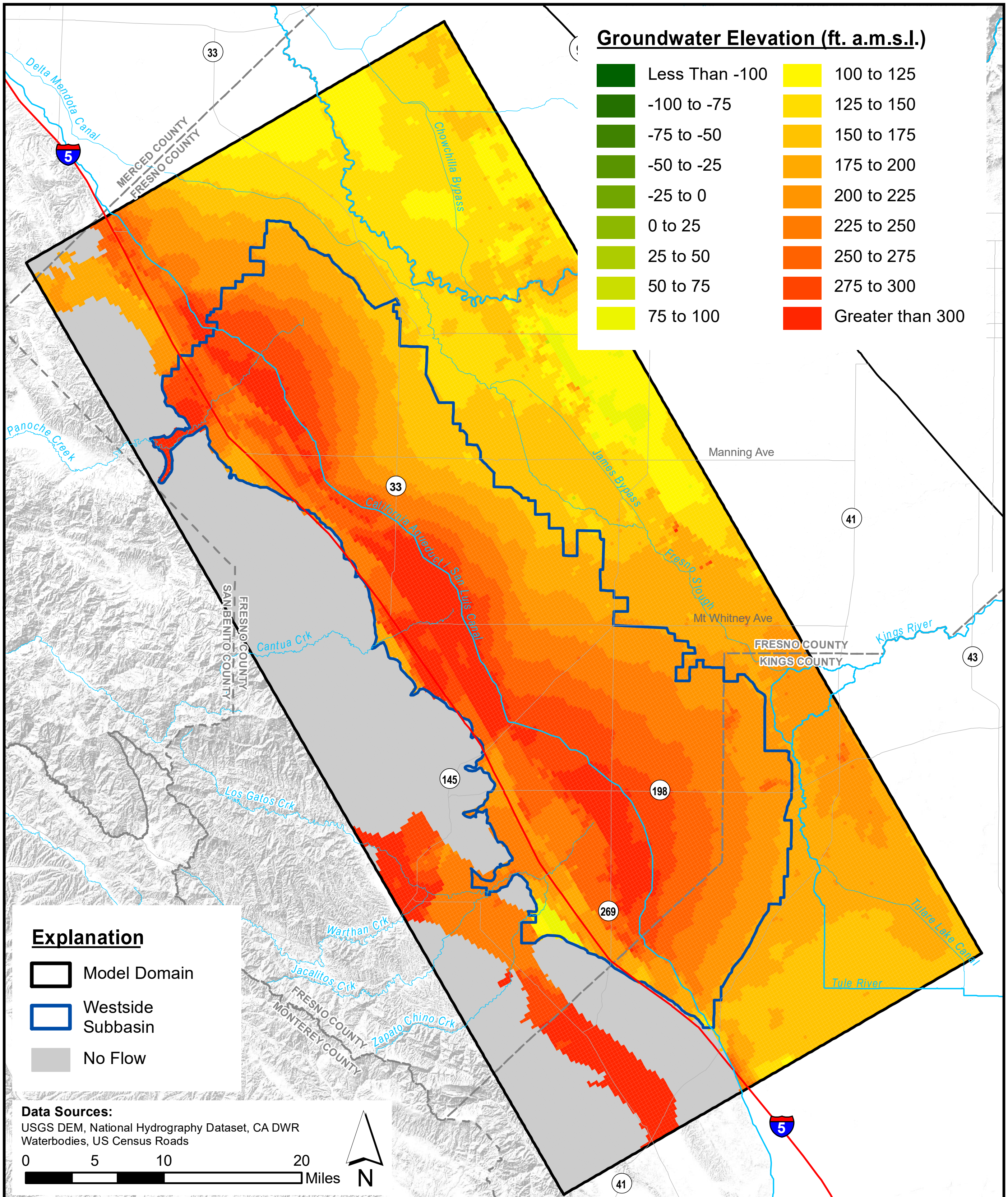
Westside Subbasin

Figure 4-10



X:\2015 Job Files\15-104 Westlands WD\GIS\MapFilesModel\Section 4 - Flow Model Results\Figure 4-8 to 4-13 Groundwater Levels.mxd

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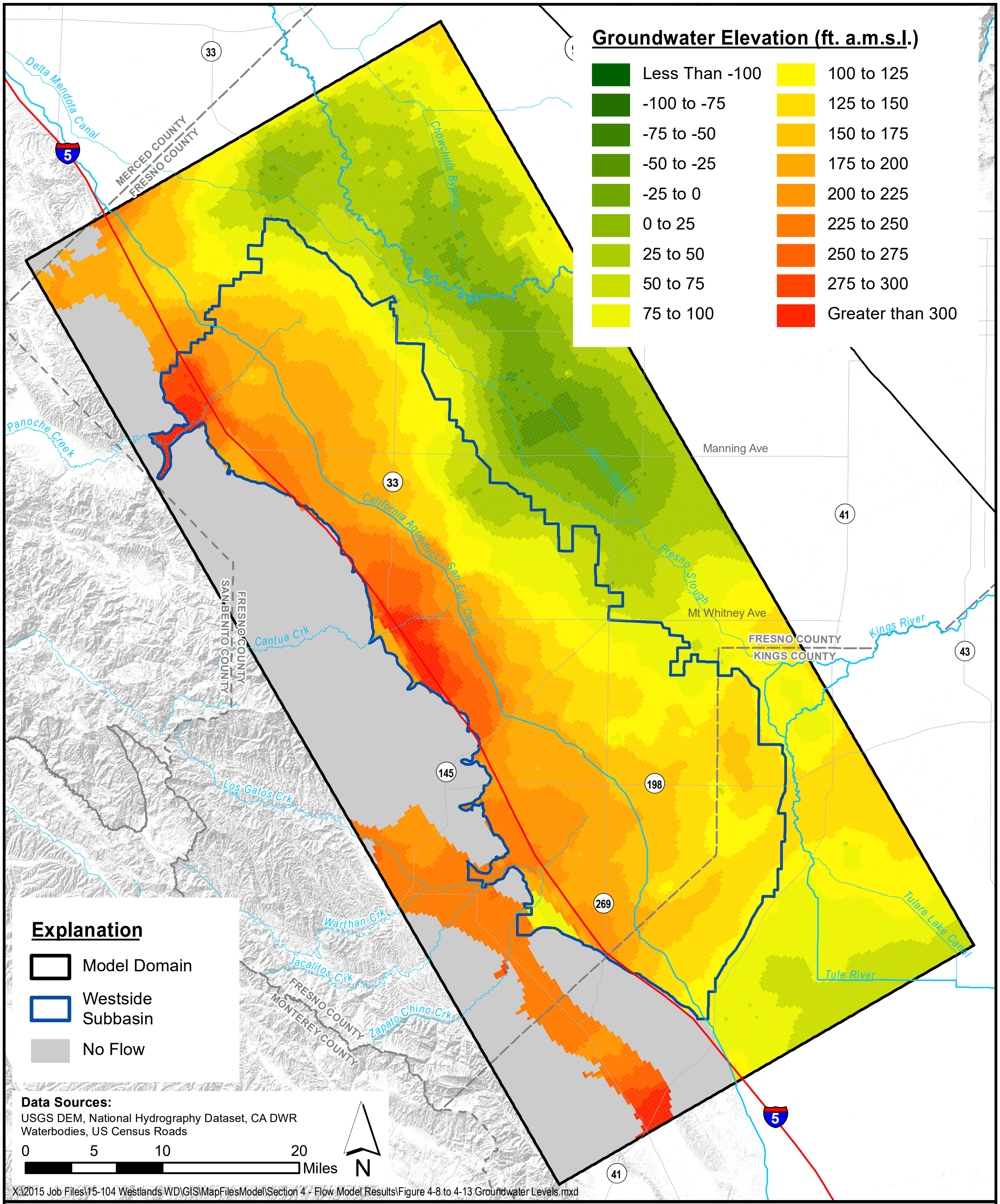
Simulated Hydraulic Head in the Shallow Aquifer October 2015

SGMA Sustainability Analyses
Westside Subbasin

Figure 4-11



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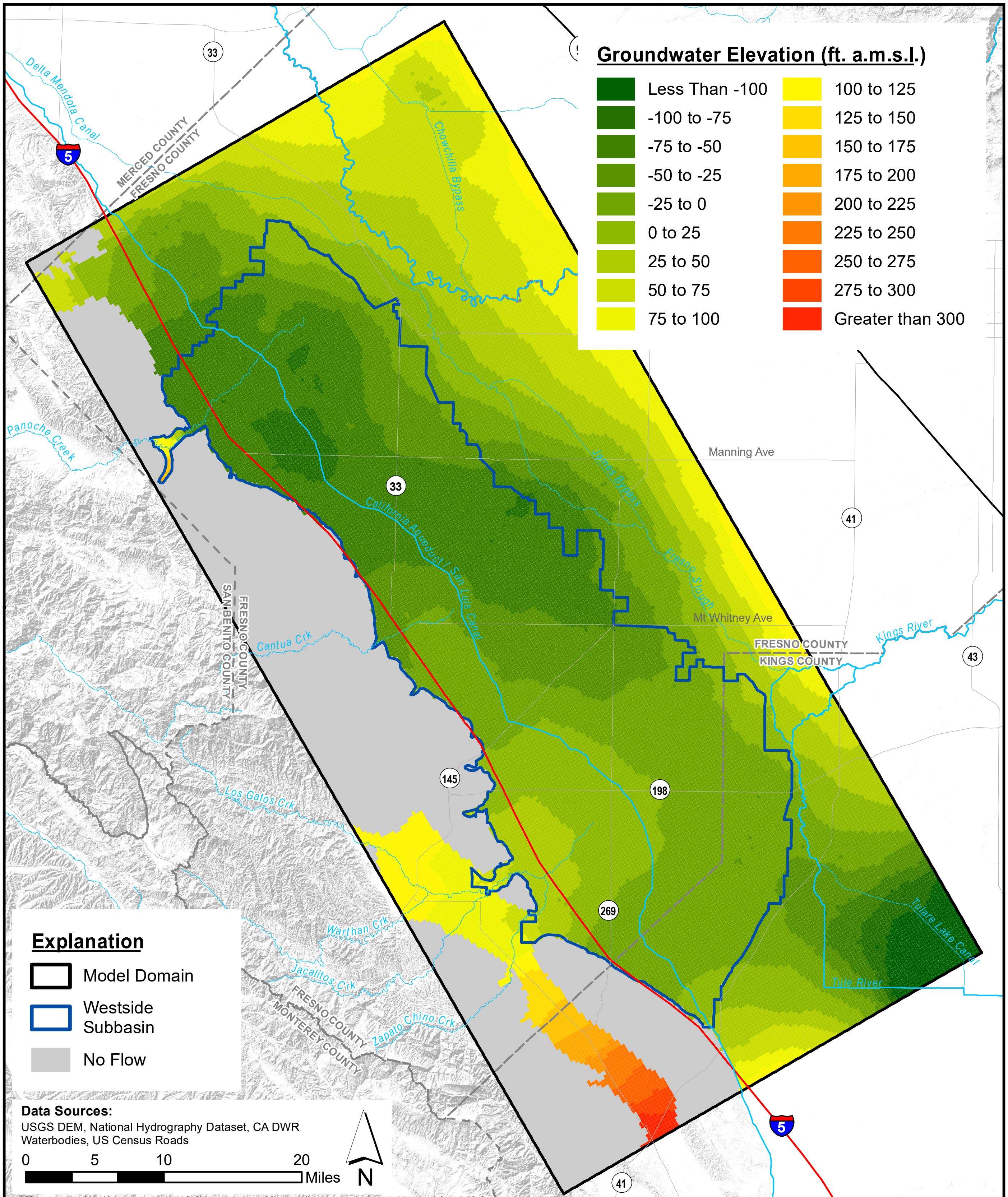
Simulated Hydraulic Head in the Upper Aquifer October 2015

SGMA Sustainability Analyses
Westside Subbasin

Figure 4-12



X:\2015 Job Files\15-104 Westlands WD\GIS\MapFilesModel\Section 4 - Flow Model Results\Figure 4-8 to 4-13 Groundwater Levels.mxd

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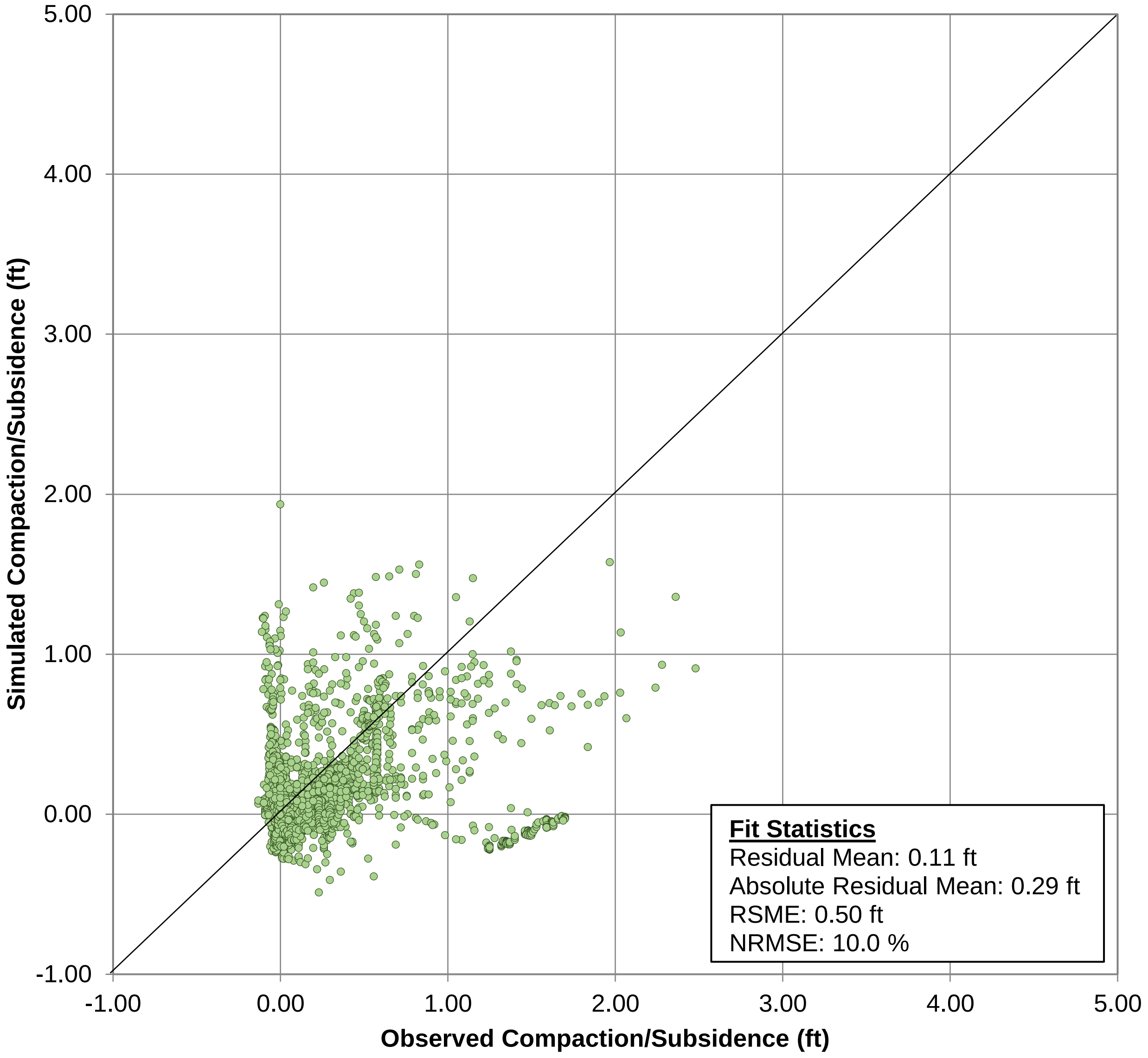
Simulated Hydraulic Head in the Lower Aquifer October 2015

Figure 4-13

SGMA Sustainability Analyses
Westside Subbasin



Fit Statistics
Residual Mean: 0.11 ft
Absolute Residual Mean: 0.29 ft
RSME: 0.50 ft
NRMSE: 10.0 %

Figure 4-14
Observed vs. Simulated Compaction and Land Subsidence

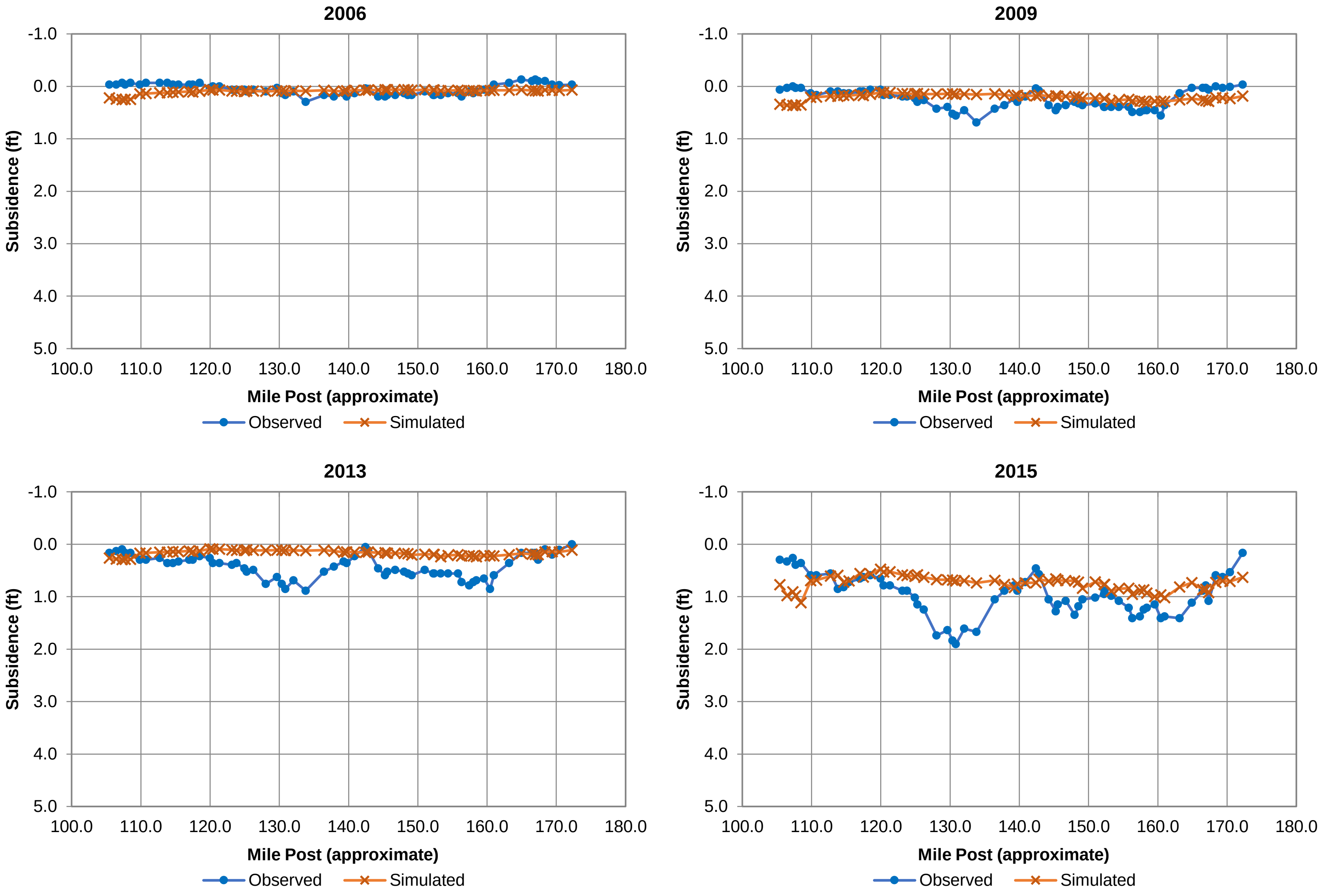
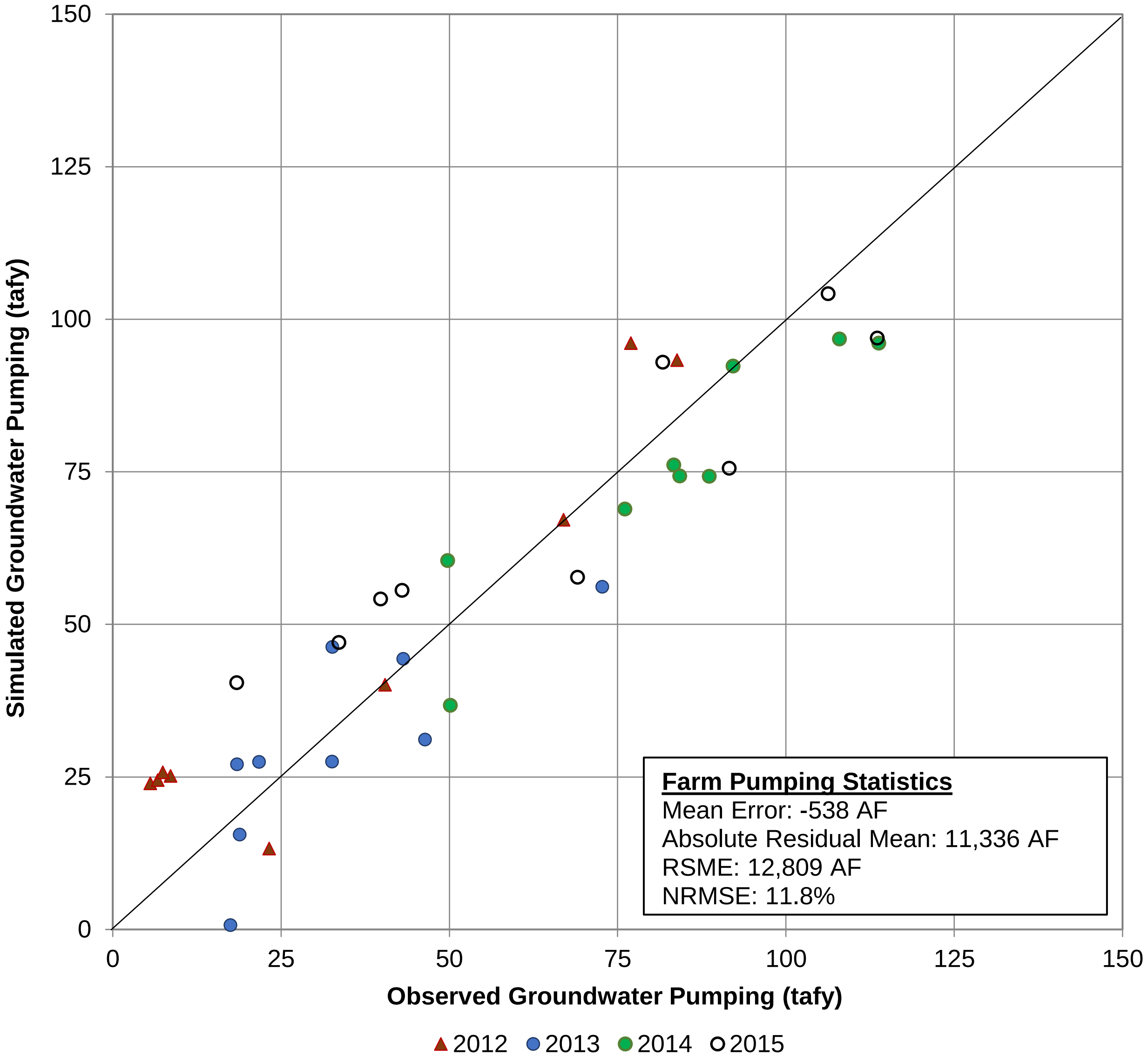


Figure 4-15
Observed vs. Simulated Land Subsidence Along the San Luis Canal



Farm Pumping Statistics
Mean Error: -538 AF
Absolute Residual Mean: 11,336 AF
RSME: 12,809 AF
NRMSE: 11.8%

Figure 4-16
Observed vs. Simulated Groundwater Pumping

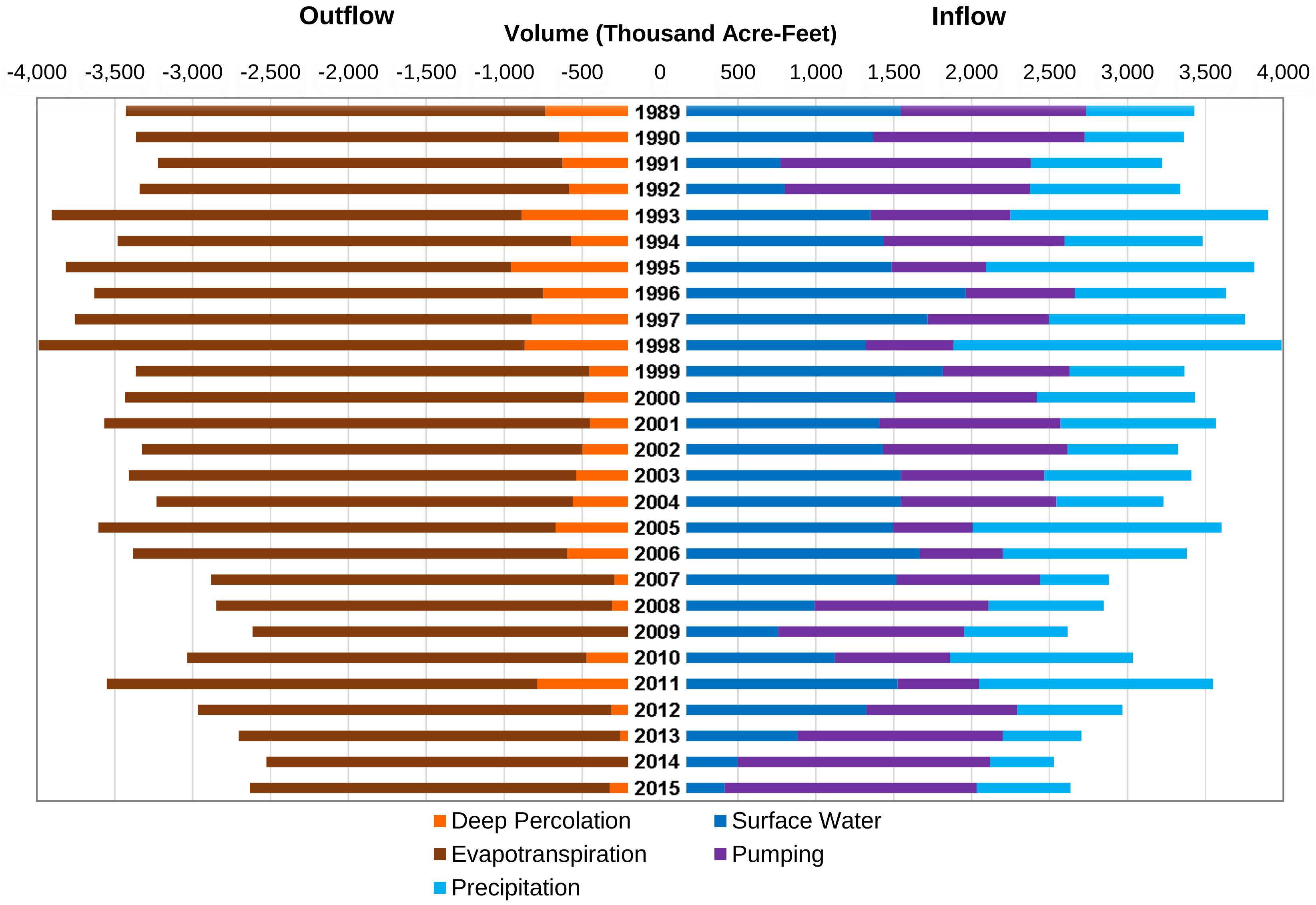


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Figure 4-17
Global Land Surface System Water Budget
1989 - 2015

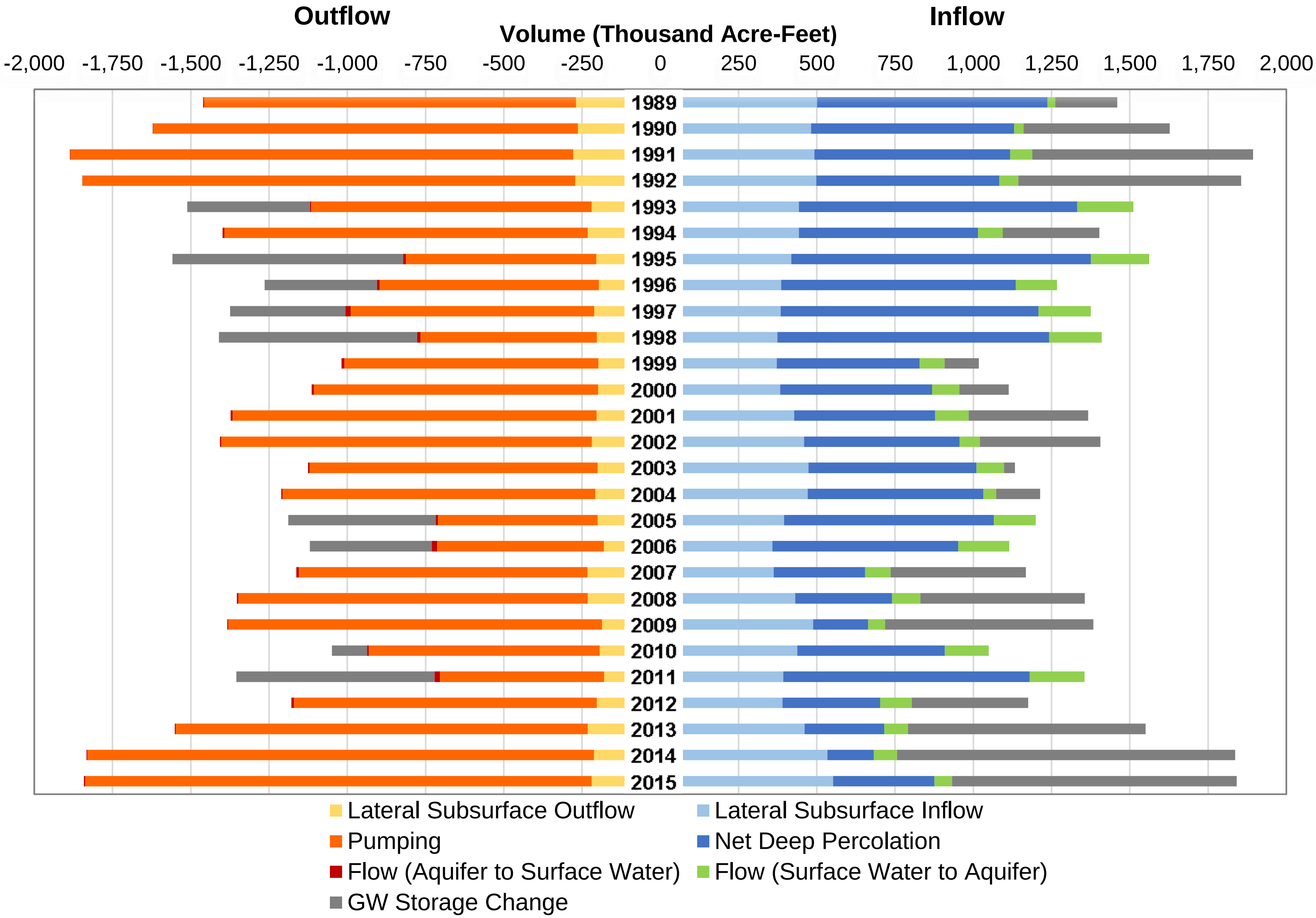

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Figure 4-18
Global Groundwater Budget
1989 - 2015

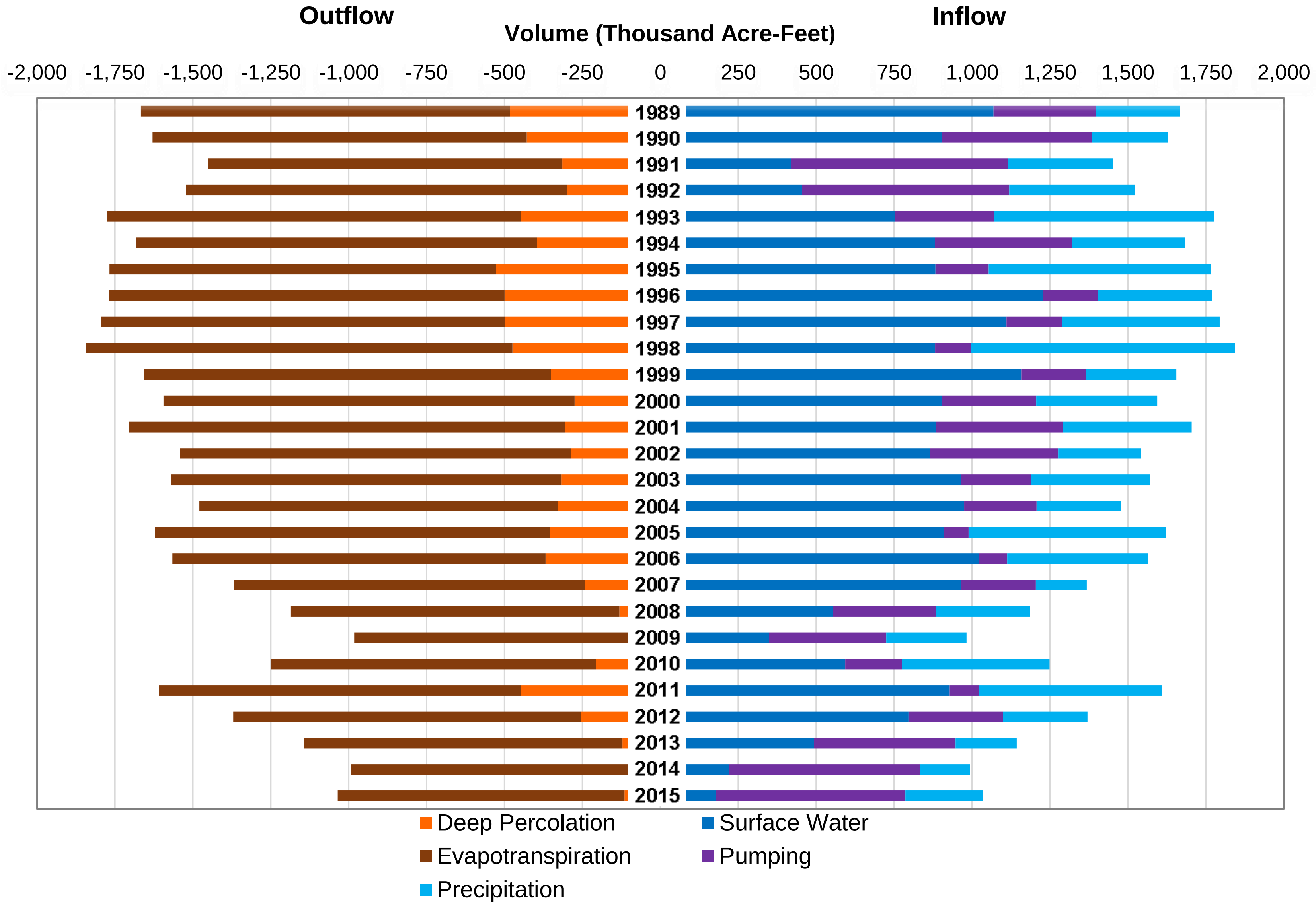

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Figure 4-19
Land Surface System Water Budget – Westside Subbasin
1989 - 2015

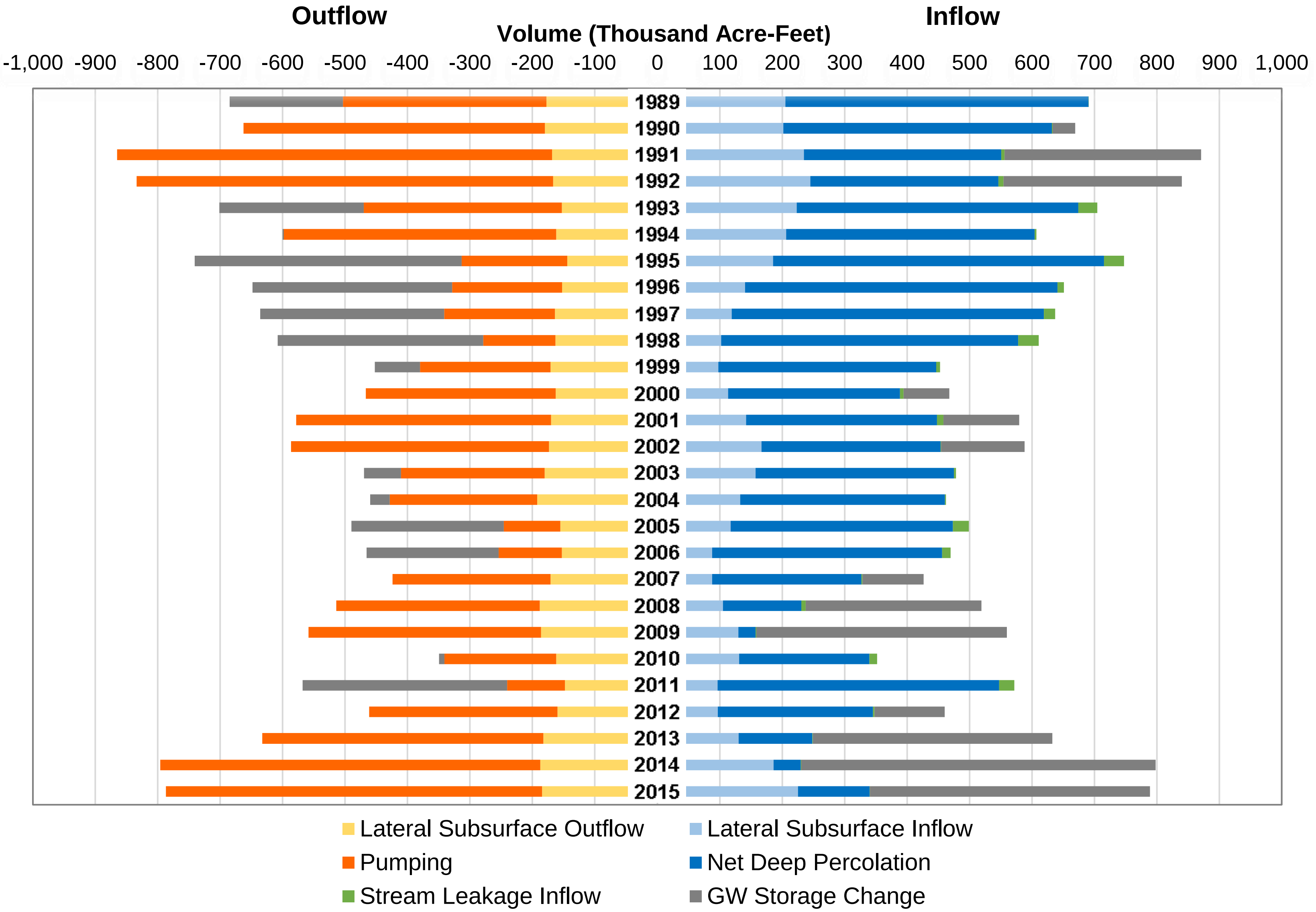

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Figure 4-20
Groundwater Budget – Westside Subbasin
1989 - 2015

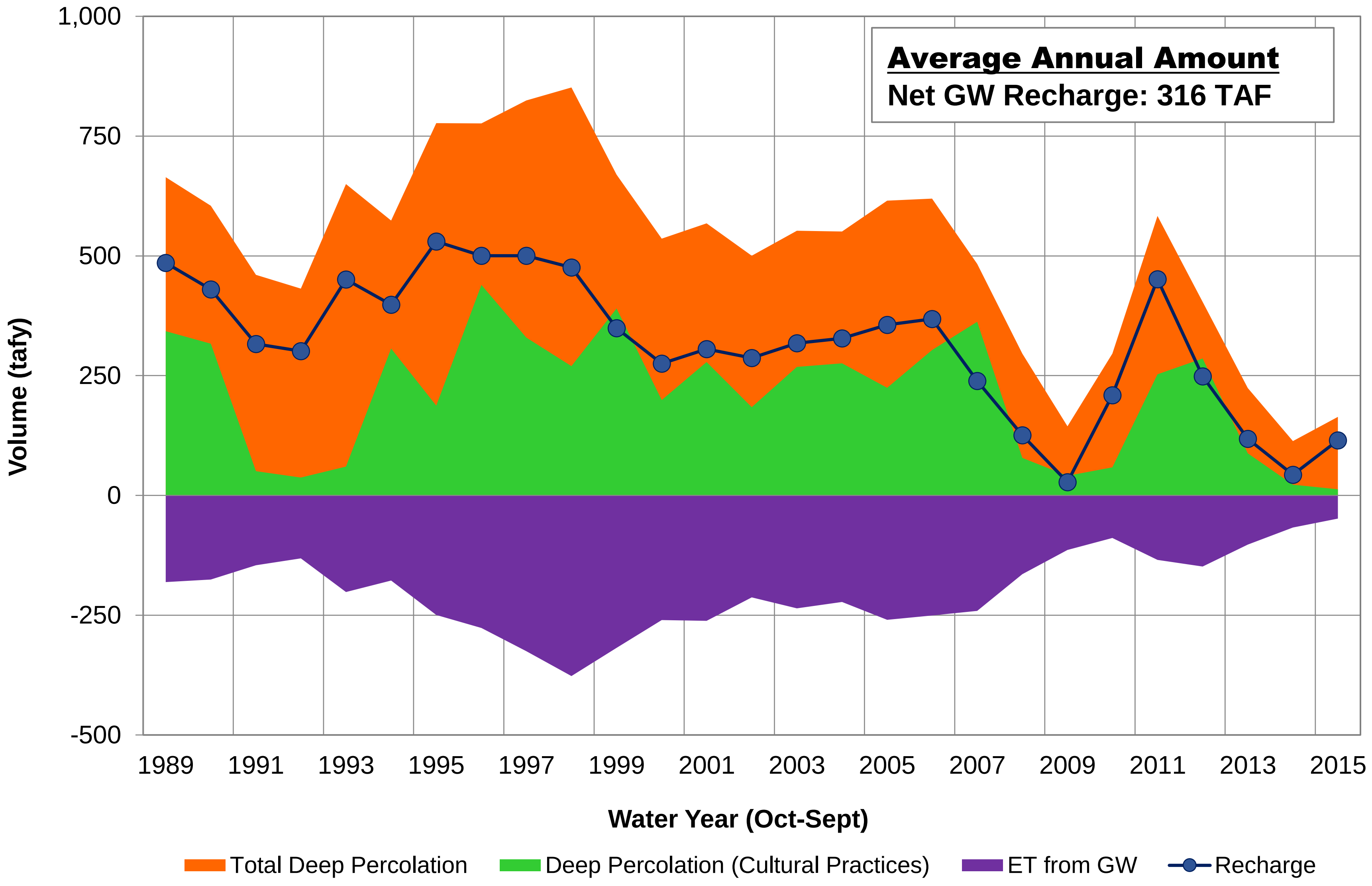

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Figure 4-21
Simulated Areal Groundwater Recharge – Westside Subbasin
1989 - 2015

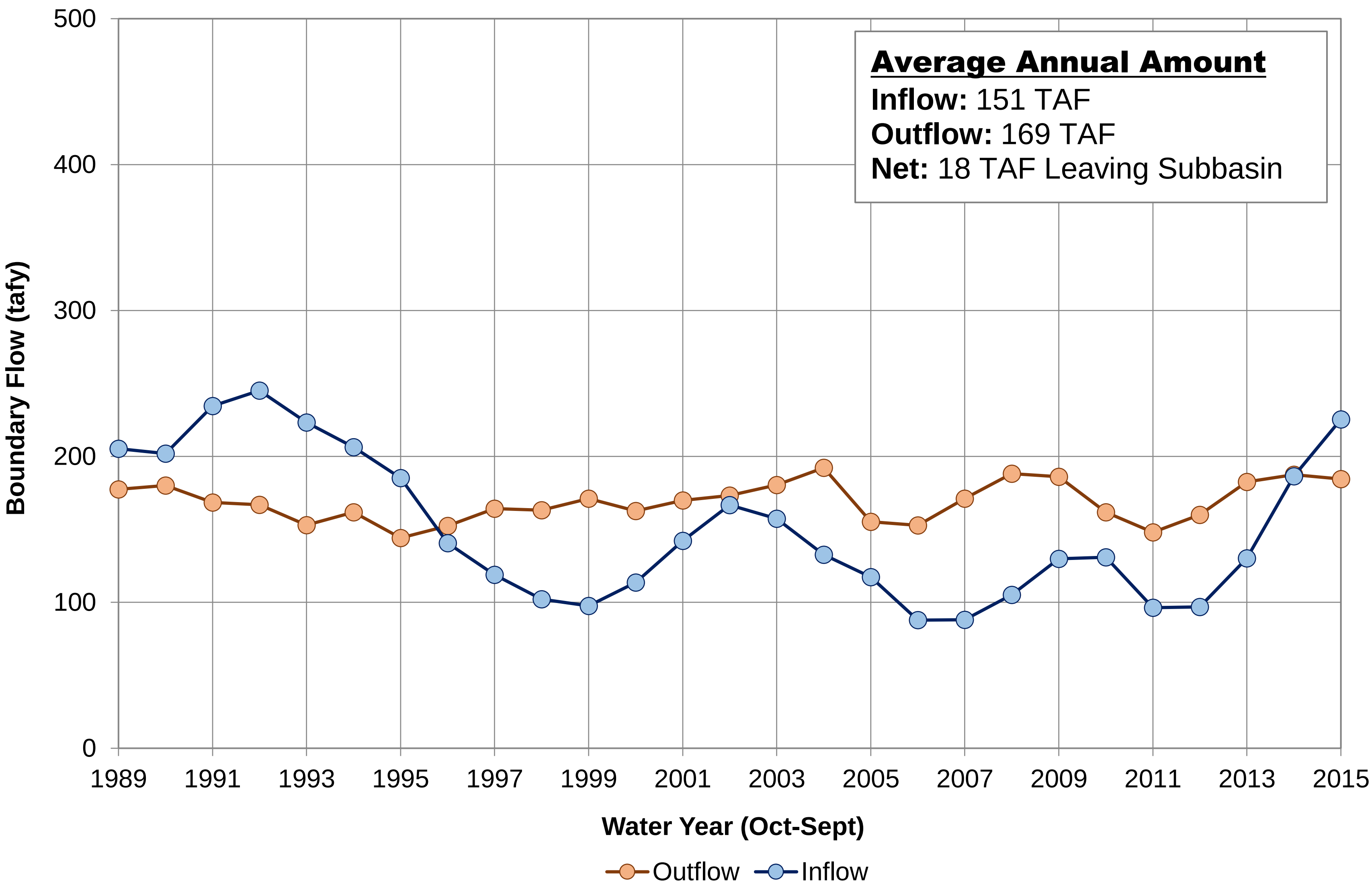

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Figure 4-22
Lateral Subsurface Groundwater Flow – Westside Subbasin
1989 - 2015

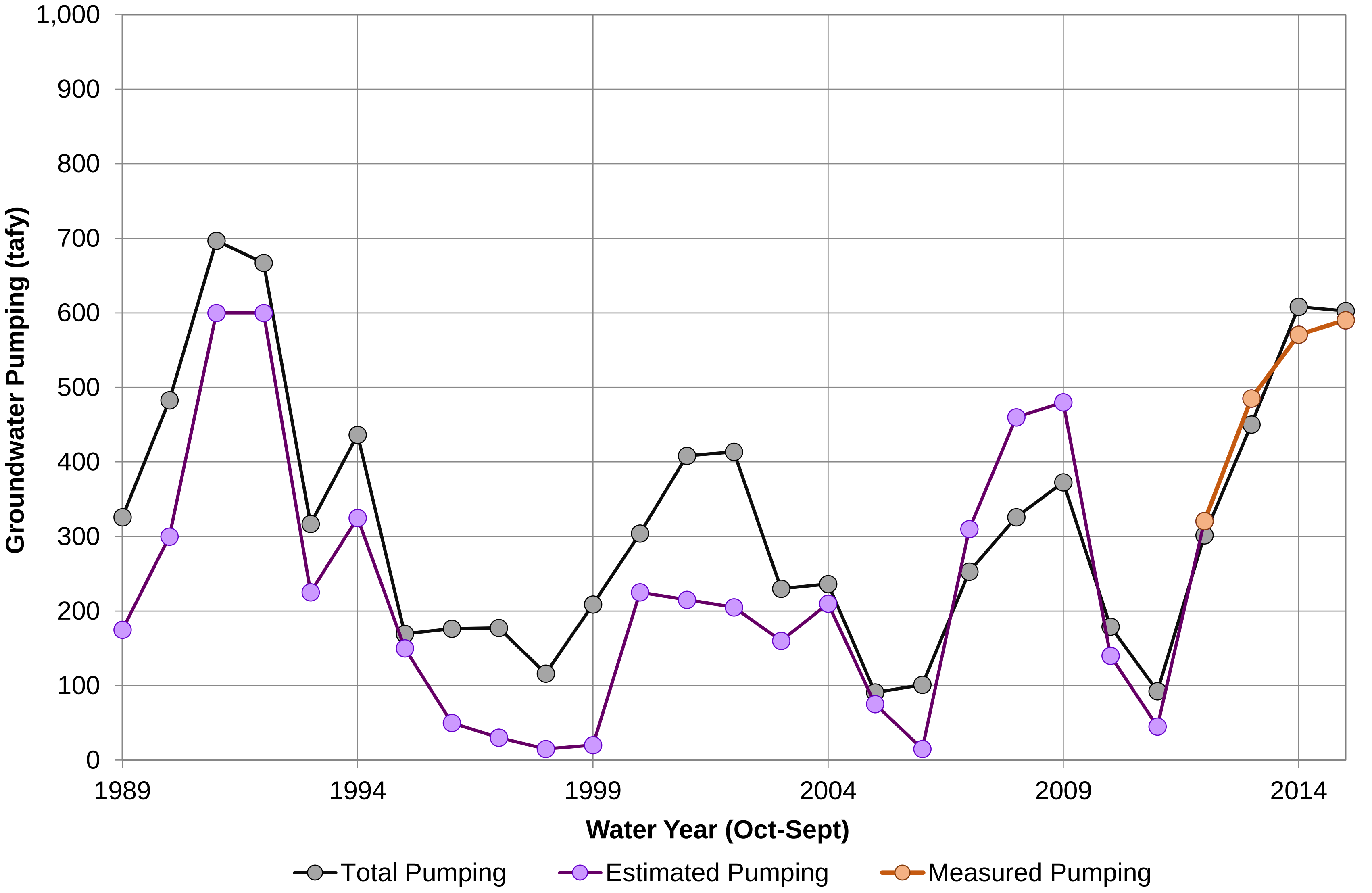

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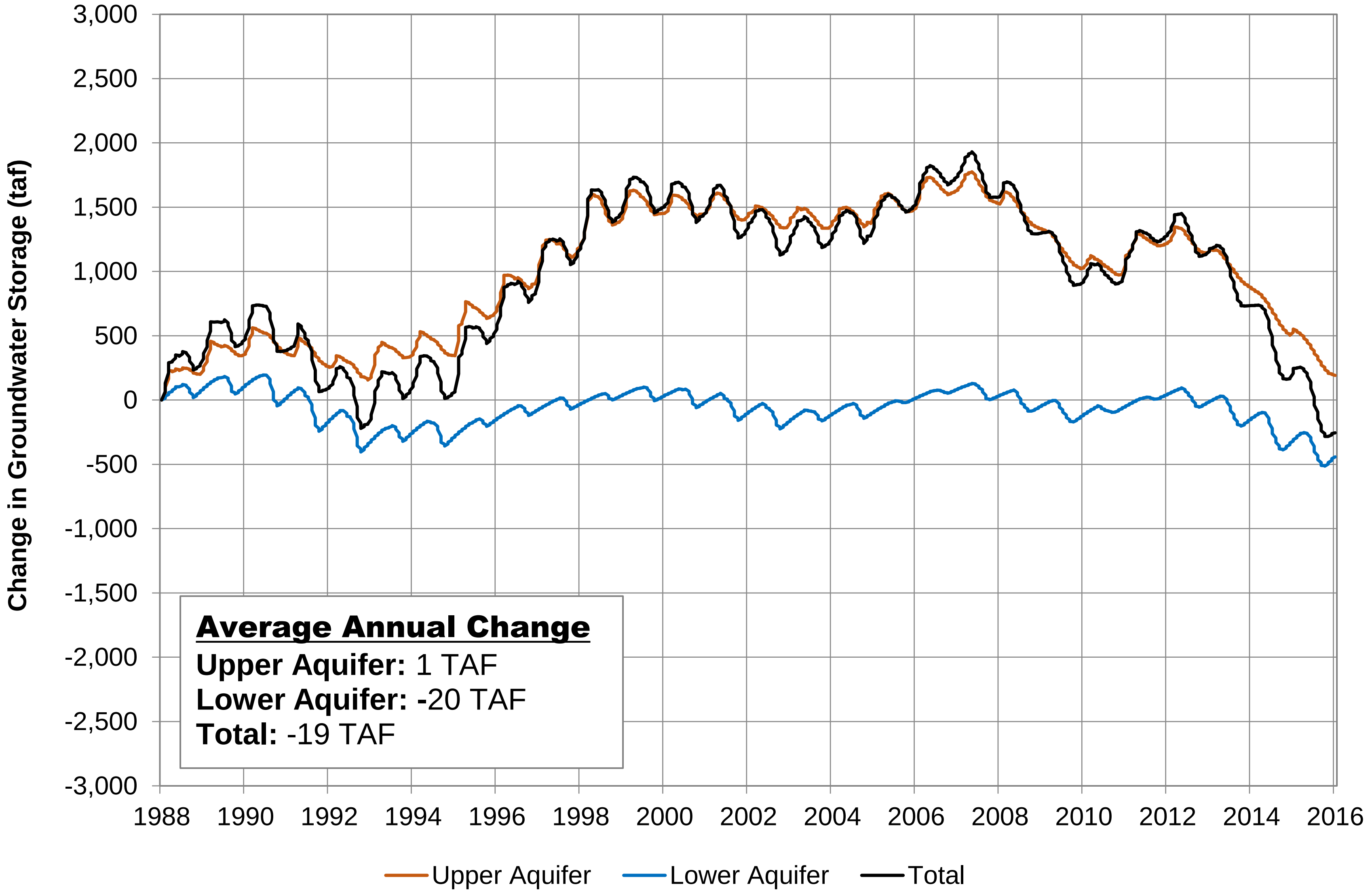
Figure 4-23
Simulated Groundwater Pumping – Westside Subbasin
1989 - 2015



Average Annual Change

Upper Aquifer: 1 TAF

Lower Aquifer: -20 TAF

Total: -19 TAF

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Figure 4-24
Change in Groundwater Storage – Westside Subbasin
1988 - 2015

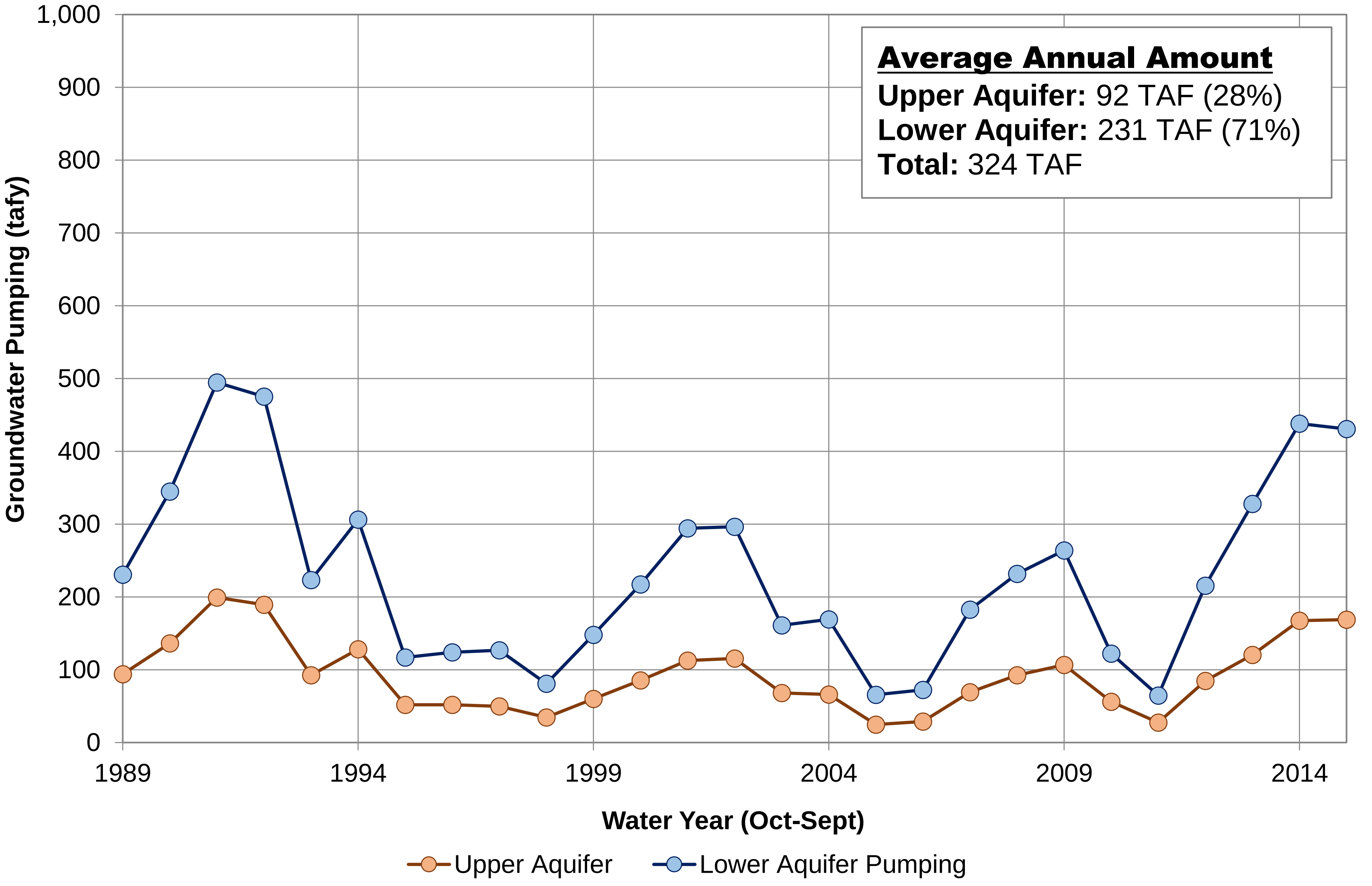

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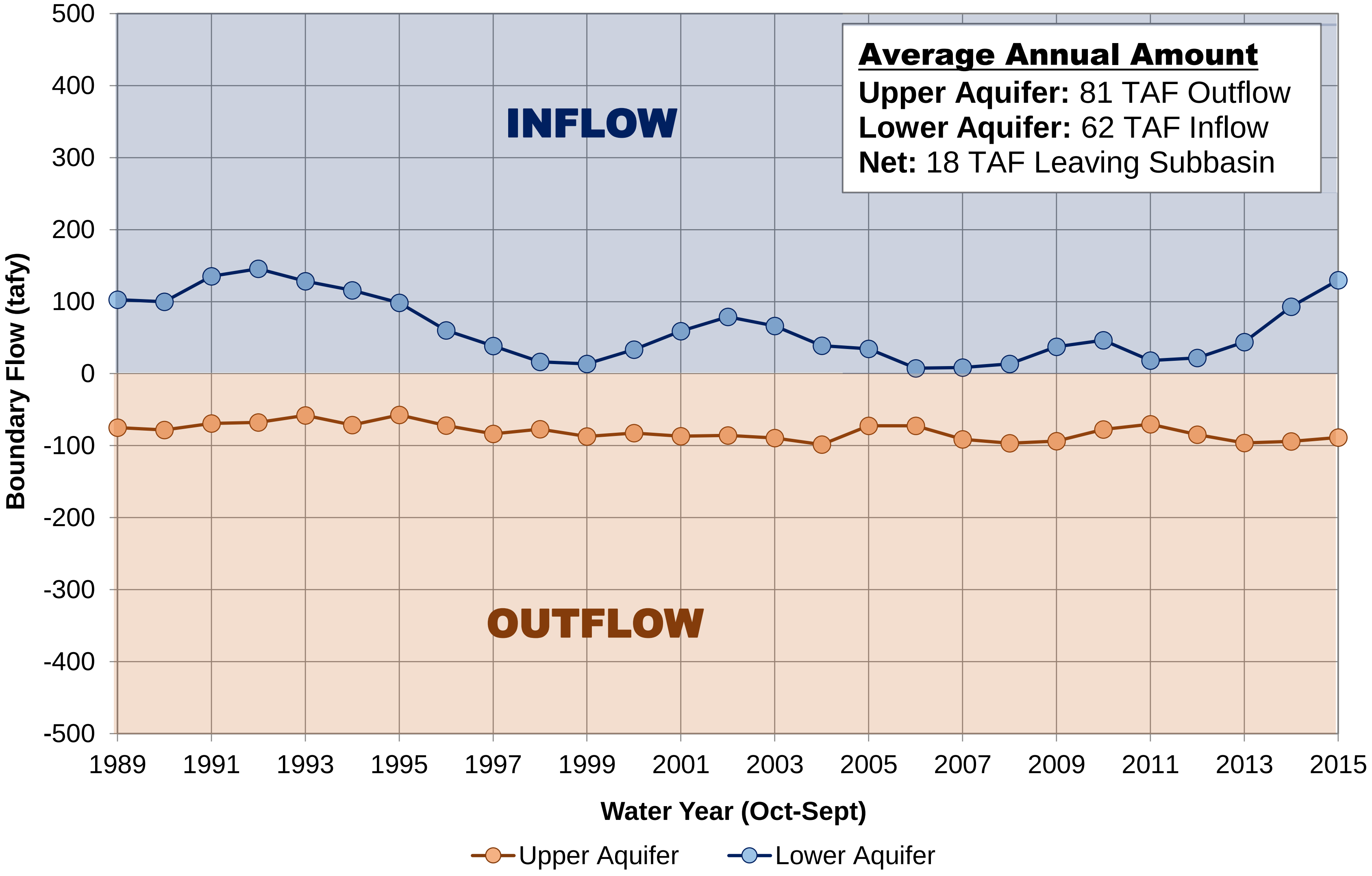
Figure 4-25
Upper and Lower Aquifer Groundwater Pumping – Westside Subbasin
1989 - 2015



Average Annual Amount
Upper Aquifer: 81 TAF Outflow
Lower Aquifer: 62 TAF Inflow
Net: 18 TAF Leaving Subbasin

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Figure 4-26
Net Lateral Subsurface Groundwater by Aquifer – Westside Subbasin
1989 - 2015

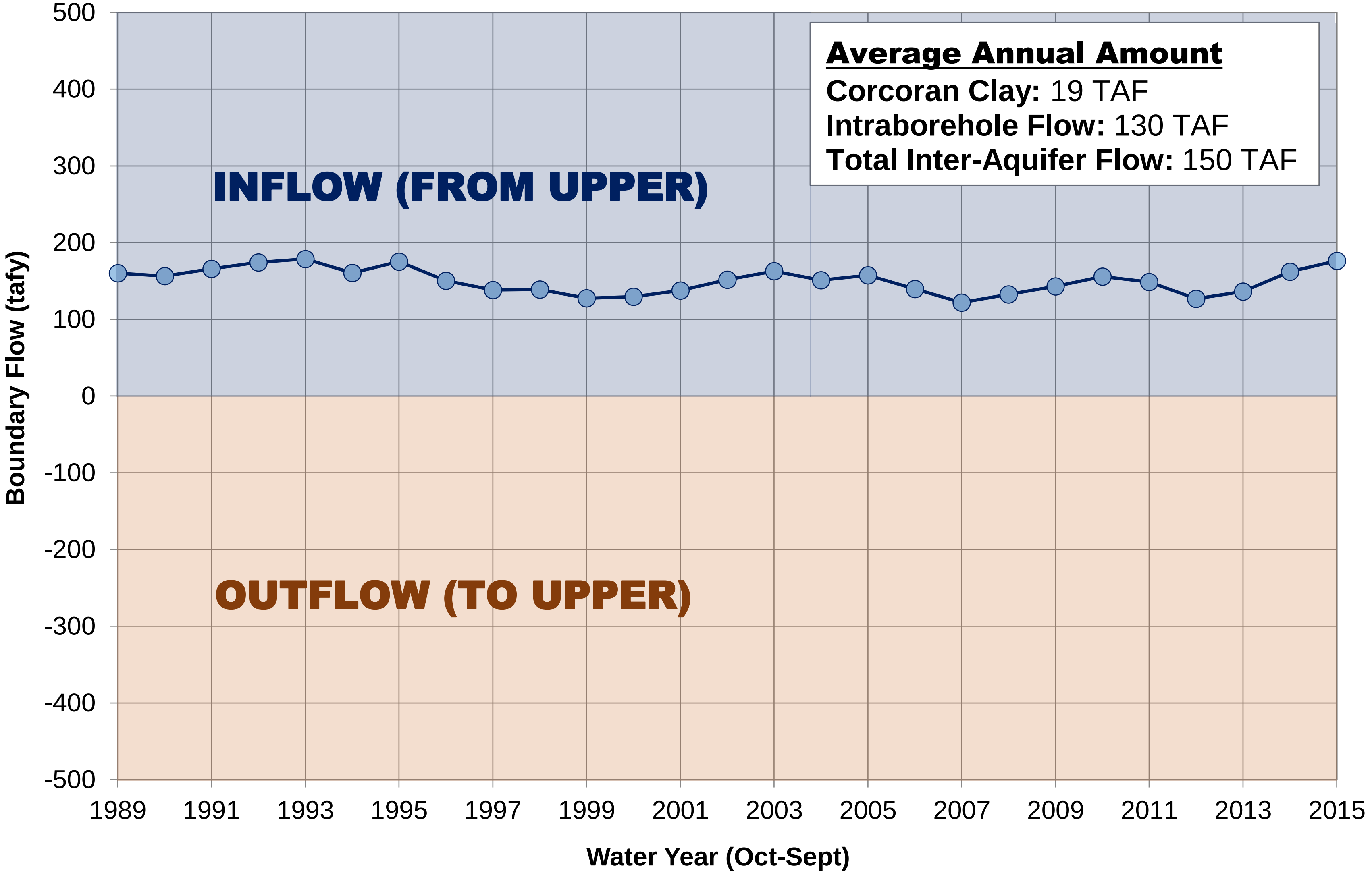

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Figure 4-27
Vertical Groundwater Flow Between Aquifers – Westside Subbasin
1989 - 2015

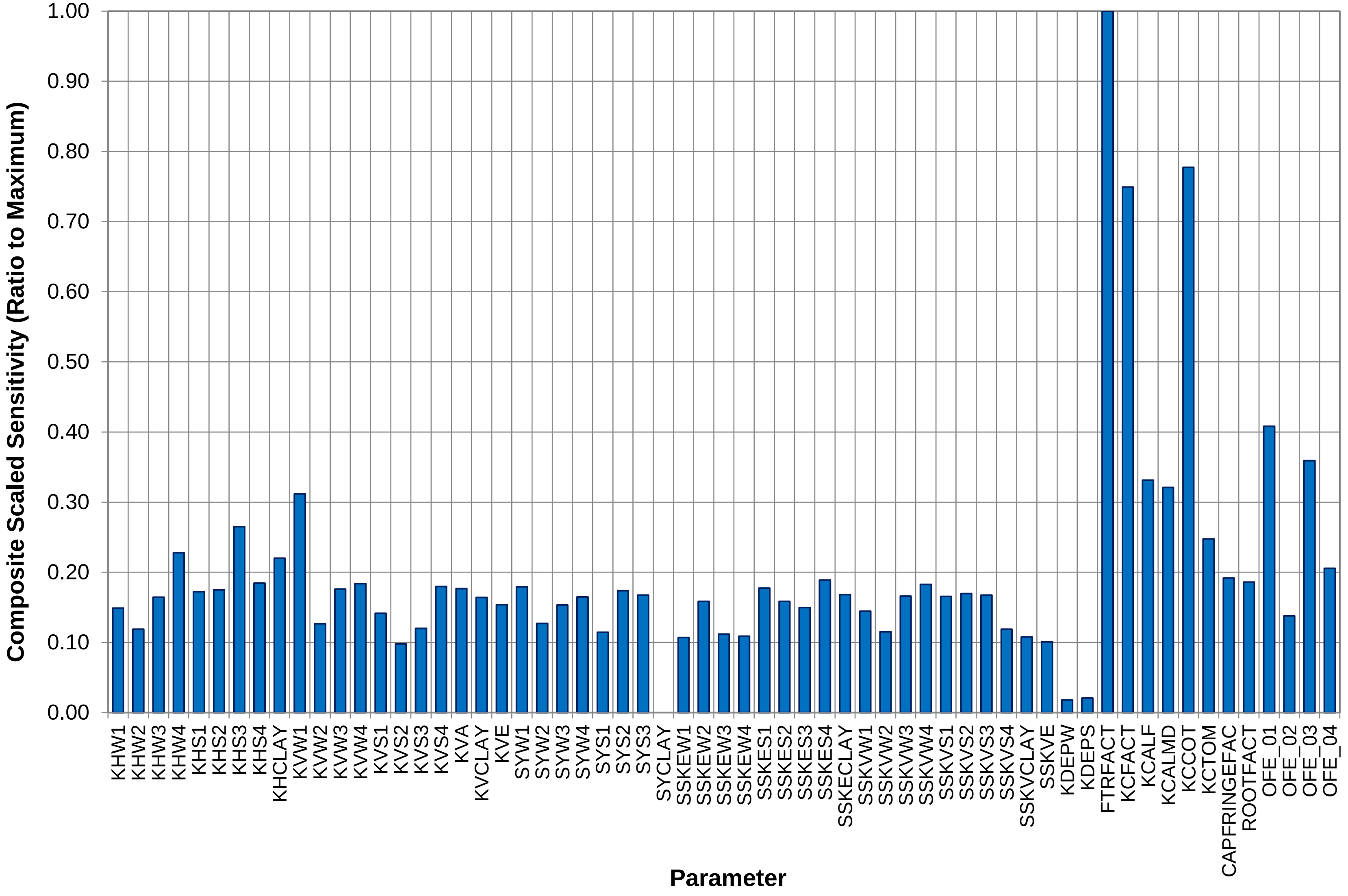

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Figure 4-28
Composite Scaled Sensitivity of Simulated Hydraulic Head to Model Parameter Values

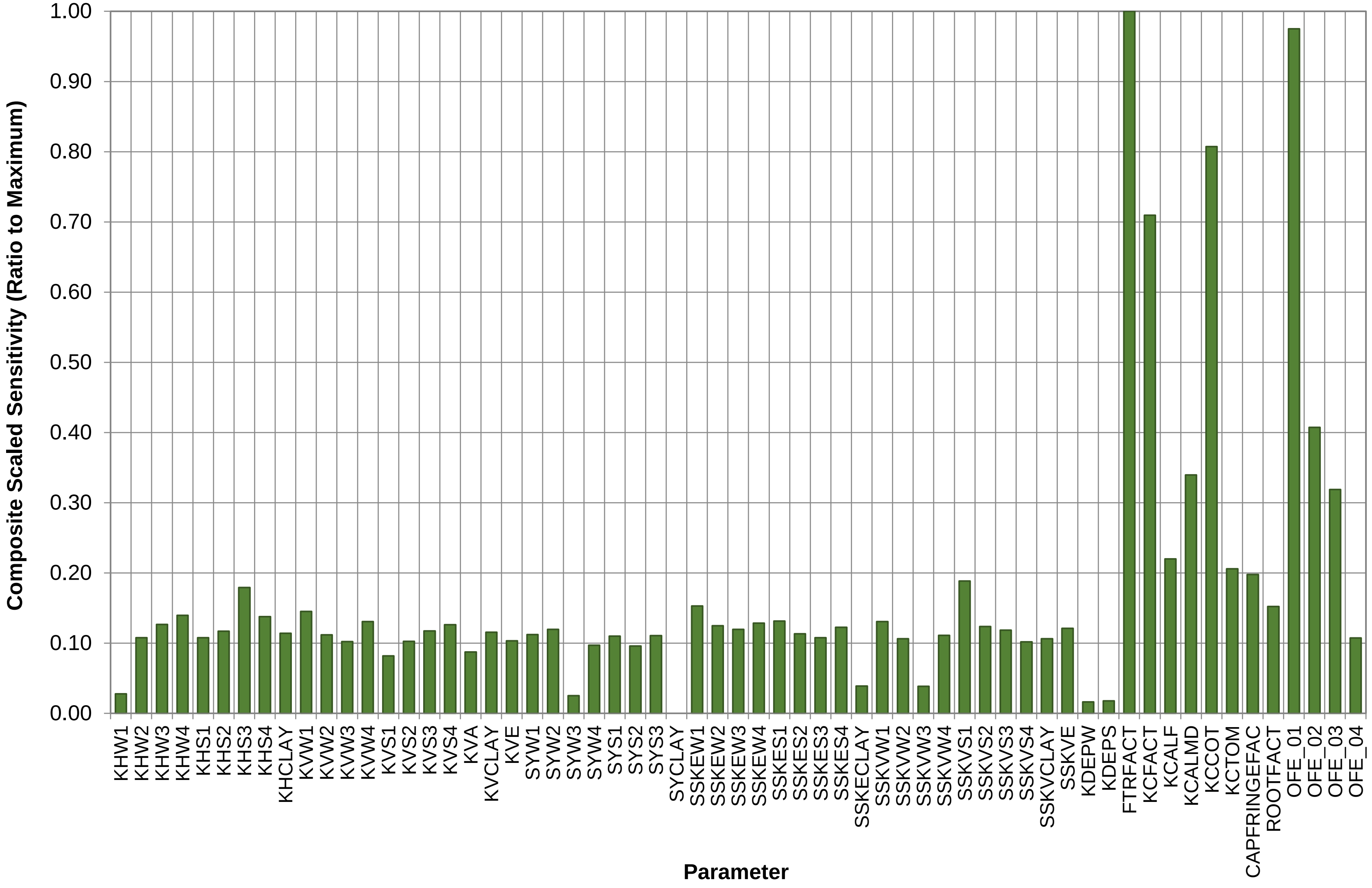

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Figure 4-29
Composite Scaled Sensitivity of Simulated Subsidence to Model Parameter Values

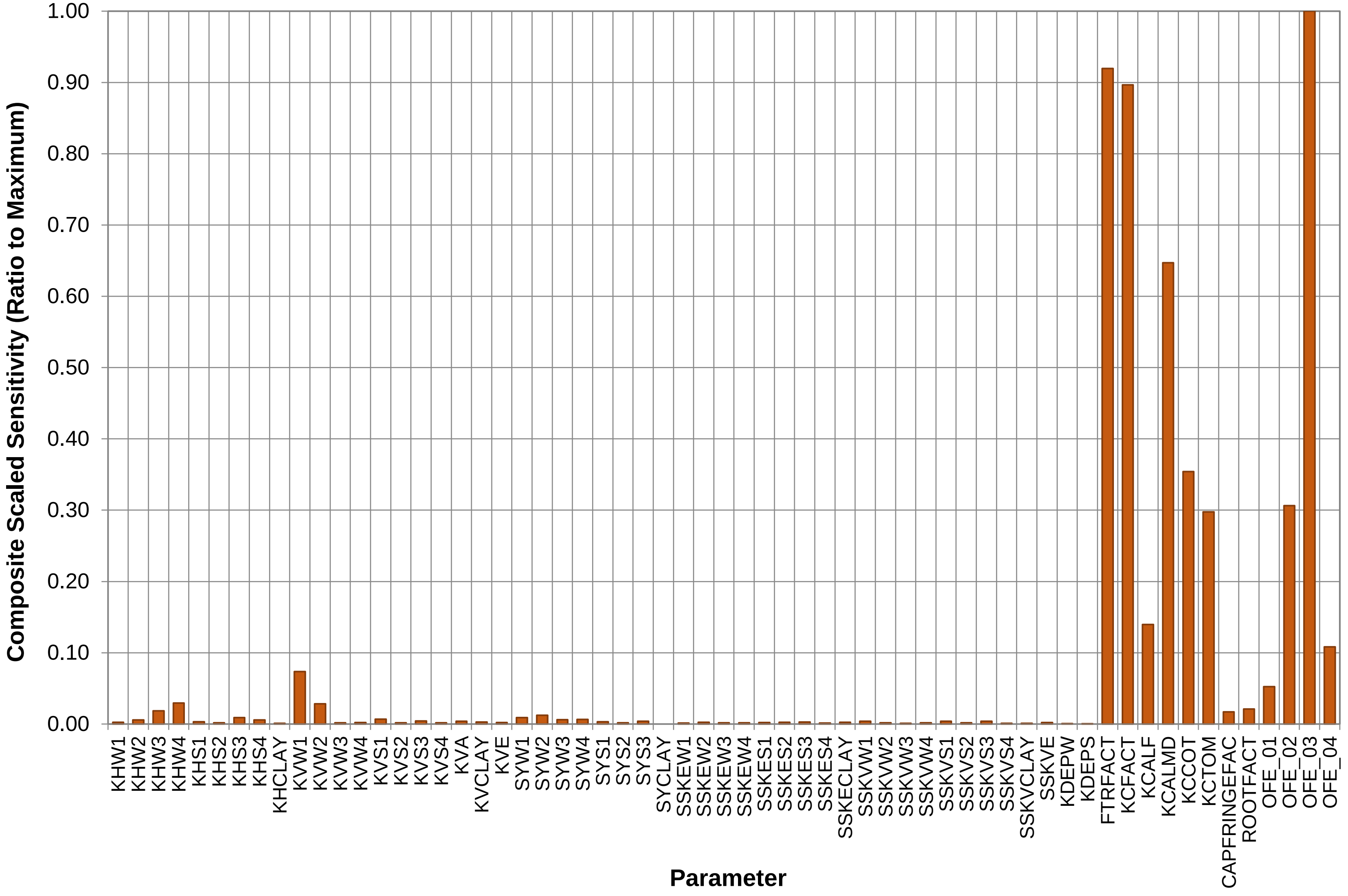


Figure 4-30
Composite Scaled Sensitivity of Simulated Groundwater Pumping to Model Parameter Values

Table 4-1: Calibrated Parameter Values from the Groundwater Flow Model

	Parameter Name	Calibrated Value (Coastal/Sierra)	Field and Laboratory Values
Kh Mud (ft/d)	KH1	1.07 / 0.65	2.8x10^{-6} - 2.8x10^{-3} ft/d[1]
Kh Muddy Sand (ft/d)	KH2	3.3 / 1.0	2.8x10^{-3} - 2.8x10^{-1} ft/d[1]
Kh Sand (ft/d)	KH3	36 / 52	2.8x10^{0} - 2.8x10^{2} ft/d[1]
Kh Sand & Gravel (ft/d)	KH4	1000 / 409	2.8x10^{1} - 2.8x10^{3} ft/d[1]; 8.2x10^{2} ft/d[3]
Kh A,B,C,D and F Clay (ft/d)	KHMUD	0.01	2.83x10^{-6} - 2.83x10^{-3} ft/d[1]
Kh Corcoran Clay (ft/d)	KHE	0.01	2.83x10^{-6} - 2.83x10^{-3} ft/d[1]
Kv Mud (ft/d)	KV1	1.11E-03 / 6.83E-04	2.0x10^{-5} - 3.0x10^{-3} ft/d[3]
Kv Muddy Sand (ft/d)	KV2	6.33E-03 / 0.10	-
Kv Sand (ft/d)	KV3	0.70 / 0.25	-
Kv Sand & Gravel (ft/d)	KV4	11.00 / 11.00	10 ft/d[3]
Kv A,B,C,D and F Clay (ft/d)	KVMUD	9.55E-04	2.0x10^{-6} - 2.0x10^{-3} ft/d[3]
Kv Corcoran Clay (ft/d)	KVE	2.96E-05	6.6x10^{-6} ft/d[4]
Sy Mud	SY1	0.10 / 0.10	0 - 0.35[3]
Sy Muddy Sand	SY2	0.20 / 0.17	0 - 0.35[3]
Sy Sand	SY3	0.27 / 0.23	0 - 0.35[3]
Sy Sand & Gravel	SY4	0.32 / 0.21	0 - 0.35[3]
Porosity Mud	PSTY1	0.45	0.33 - 0.60[1]; 0.25 - 0.65[3]
Porosity Muddy Sand	PSTY2	0.40	0.35 - 0.50[1]; 0.25 - 0.65[3]
Porosity Sand	PSTY3	0.35	0.25 - 0.65[3]
Porosity Sand & Gravel	PSTY4	0.35	0.25 - 0.50[1]; 0.25 - 0.65[3]
Porosity A,B,C,D and F Clay	PSTYMUD	0.45	0.33 - 0.60[1]; 0.25 - 0.65[3]
Porosity Corcoran Clay	PSTYE	0.45	0.33 - 0.60[1]; 0.25 - 0.65[3]
SS$_{ke}$ Mud (ft^{-1})	SSKE1	5.60E-06 / 6.02E-06	2.0x10^{-6} - 7.5x10^{-6} per ft[5-10]
SS$_{ke}$ Muddy Sand (ft^{-1})	SSKE2	2.25E-06 / 5.72E-06	-
SS$_{ke}$ Sand (ft^{-1})	SSKE3	2.00E-06 / 6.49E-06	-
SS$_{ke}$ Sand & Gravel (ft^{-1})	SSKE4	1.05E-06 / 1.10E-06	1.0x10^{-6} per ft[5-10]
SS$_{ke}$ A,B,C,D and F Clay (ft^{-1})	SSKEMUD	7.40E-06	2.0x10^{-6} - 7.5x10^{-6} per ft[5-10]
SS$_{ke}$ E Clay (ft^{-1})	SSKEE	7.40E-06	2.0x10^{-6} - 7.5x10^{-6} per ft[5-10]
SS$_{kv}$ Mud (ft^{-1})	SSKV1	1.40E-04 / 3.75E-04	1.4x10^{-4} - 6.7x10^{-4} per foot[10]
SS$_{kv}$ Muddy Sand (ft^{-1})	SSKV2	1.00E-04 / 1.00E-04	-
SS$_{kv}$ Sand (ft^{-1})	SSKV3	5.00E-05 / 2.84E-05	-
SS$_{kv}$ Sand & Gravel (ft^{-1})	SSKV4	1.10E-06 / 1.10E-05	-
SS$_{kv}$ A,B,C,D and F Clay (ft^{-1})	SSKVMUD	6.86E-04	1.4x10^{-4} - 6.7x10^{-4} per foot[10]
SS$_{kv}$ E Clay (ft^{-1})	SSKVE	7.40E-06	1.4x10^{-4} - 6.7x10^{-4} per foot[10]
Consumptive Use Fraction Multiplier	FTRFACT	1.10	-
Crop Coefficient Multipliers	KCFACT	1.00-1.34	-
Capillary Fringe Height Multiplier	CAPFRINGEFACT	0.81	-
Rooting Depth Multiplier	ROOTFACT	0.91	-
Irrigation Efficiency Furrow/Sprinkler	OFE_01	0.74	-
Irrigation Efficiency Sprinkler/Drip	OFE_02	0.81	-
Irrigation Efficiency Drip	OFE_03	0.93	-
Irrigation Efficiency Urban/Dairy	OFE_04	0.80	-

[1] Fetter (1988)

[2] Phillips et al (2007)

[3] Bertoldi et al (1991)

[4] Page (1977)

[5] Riley (1969)

[6] Riley (1984)

[7] Helm (1974)

[8] Helm (1975)

[9] Helm (1976)

[10] Helm (1977)

Table 4-2: Calibrated Monthly Crop Coefficients from the Groundwater Flow Model

Crop	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Alfalfa	0.45	0.61	0.88	0.56	0.73	0.68	0.68	0.70	0.63	0.87	0.56	0.32
Almonds	1.17	0.81	0.50	0.67	0.75	0.84	0.86	0.62	0.41	0.32	0.50	0.96
Melons	1.17	0.81	0.50	0.28	0.33	0.81	0.55	0.19	0.24	0.31	0.50	0.96
Carrots/Broccoli	1.17	1.00	1.08	1.09	0.56	0.19	0.18	0.19	0.24	0.31	0.50	0.96
Citrus	0.57	0.57	0.57	0.57	0.57	0.57	0.57	0.57	0.57	0.57	0.57	0.57
Corn	1.17	0.81	0.50	0.28	0.26	0.79	1.27	1.00	0.24	0.31	0.50	0.96
Cotton	1.17	0.81	0.50	0.28	0.22	0.32	1.12	1.35	0.80	0.31	0.50	0.96
Beans	1.17	0.81	0.50	0.28	0.22	0.21	0.54	1.03	0.87	0.31	0.50	0.96
Field Crops	1.17	0.81	0.74	0.71	0.48	0.19	0.33	0.54	0.47	0.31	0.50	0.96
Hay	1.17	1.26	1.26	1.09	0.48	0.19	0.18	0.19	0.24	0.31	0.50	0.96
Grapes	1.17	0.81	0.50	0.28	0.25	0.45	0.57	0.57	0.55	0.31	0.50	0.96
Lettuce-Fall	1.17	0.81	0.50	0.28	0.22	0.19	0.18	0.19	0.28	0.56	0.50	0.96
Lettuce-Spring	1.17	0.81	0.50	0.55	0.22	0.19	0.18	0.19	0.24	0.31	0.50	0.96
Onions	1.17	0.81	0.50	0.56	0.78	0.80	0.41	0.19	0.24	0.31	0.50	0.96
Pasture	1.17	0.81	0.63	0.83	1.02	1.18	1.20	1.20	1.20	1.20	1.09	0.96
Fruits/Nuts	1.17	0.81	0.50	0.45	0.66	0.74	0.74	0.74	0.66	0.45	0.50	0.96
Safflower/Canola	1.17	0.81	0.50	0.77	1.34	1.24	0.23	0.19	0.24	0.31	0.50	0.96
Beets	1.17	0.81	0.50	0.73	1.12	1.12	1.00	0.49	0.24	0.31	0.50	0.96
Tomatoes	1.17	0.81	0.50	0.32	0.93	1.28	0.46	0.19	0.24	0.31	0.50	0.96
Wheat	1.17	0.81	1.08	1.15	1.02	0.19	0.18	0.19	0.24	0.31	0.50	0.96
Fallow/Native Veg.	1.10	1.15	1.18	1.21	1.23	1.23	1.23	1.23	1.23	1.20	0.92	0.96
Water	1.26	1.26	1.26	1.26	1.26	1.26	1.26	1.26	1.26	1.26	1.26	1.26
Dairies	1.15	1.15	1.15	1.15	1.15	1.15	1.15	1.15	1.15	1.15	1.15	1.15
Urban	0.86	1.10	1.25	1.25	1.25	1.25	1.25	1.25	0.86	0.86	0.86	0.96

Table 4-3: Calibrated Monthly Consumptive Use Fractions from the Groundwater Flow Model

Crop	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Alfalfa	0.99	0.99	0.99	0.99	0.99	0.99	0.99	0.99	0.99	0.99	0.99	0.99
Almonds	0.00	0.00	0.22	0.94	0.99	1.00	1.00	1.00	1.00	0.22	0.00	0.00
Melons	0.00	0.00	0.00	0.00	0.44	0.88	0.88	0.00	0.00	0.00	0.00	0.00
Carrots/Broccoli	0.55	0.83	0.83	0.83	0.55	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Citrus	0.94	0.99	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
Corn	0.00	0.00	0.00	0.00	0.76	1.00	1.00	1.00	0.00	0.00	0.00	0.00
Cotton	0.00	0.00	0.00	0.00	0.00	0.55	0.99	0.99	0.83	0.00	0.00	0.00
Beans	0.00	0.00	0.00	0.00	0.00	0.28	0.99	0.99	0.83	0.00	0.00	0.00
Field Crops	0.68	0.86	1.00	1.00	0.69	0.00	0.00	0.78	0.67	0.00	0.37	0.42
Hay	0.87	1.00	1.00	1.00	1.00	0.00	0.00	0.00	0.00	0.00	0.00	0.56
Grapes	0.00	0.00	0.00	0.00	0.55	0.83	1.00	1.00	0.88	0.00	0.00	0.00
Lettuce-Fall	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.55	1.00	0.55	0.00
Lettuce-Spring	0.00	0.55	1.00	0.55	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Onions	0.00	0.00	0.55	0.83	0.99	0.99	0.55	0.00	0.00	0.00	0.00	0.00
Pasture	0.88	0.99	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
Fruits/Nuts	0.00	0.00	0.55	0.79	0.95	1.00	1.00	0.88	0.77	0.28	0.00	0.00
Safflower/Canola	0.00	0.28	0.55	0.99	0.94	0.22	0.00	0.00	0.00	0.00	0.00	0.00
Beets	0.00	0.00	0.22	0.72	0.99	0.99	0.99	0.72	0.00	0.00	0.00	0.00
Tomatoes	0.00	0.00	0.28	0.66	0.99	0.55	0.00	0.00	0.00	0.00	0.00	0.00
Wheat	0.22	0.55	0.99	0.99	0.33	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Fallow/Native Veg.	0.72	0.72	0.72	0.70	0.65	0.63	0.63	0.63	0.63	0.63	0.63	0.63
Water	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Dairies	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
Urban	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00

Table 4-4: Land Surface Water Budget for the Model Domain (1989-2015)

Water Year	Water Year Type	Precipitation (af)	Imported Surface Water[1] (af)	Utilized Surface Water[2] (af)	Groundwater Pumping (af)	Total Inflow (af)	Evapo-transpiration (af)	Net Deep Percolation[3] (af)	Total Outflow (af)
1989	C	696,000	1,746,000	1,545,000	1,189,000	3,430,000	2,694,000	736,000	3,430,000
1990	C	639,000	1,510,000	1,368,000	1,356,000	3,363,000	2,714,000	649,000	3,363,000
1991	C	843,000	859,000	773,000	1,606,000	3,223,000	2,597,000	626,000	3,223,000
1992	C	966,000	890,000	800,000	1,574,000	3,340,000	2,755,000	585,000	3,340,000
1993	W	1,656,000	1,586,000	1,351,000	896,000	3,904,000	3,015,000	889,000	3,904,000
1994	C	886,000	1,566,000	1,435,000	1,161,000	3,482,000	2,911,000	572,000	3,482,000
1995	W	1,720,000	1,833,000	1,485,000	609,000	3,814,000	2,857,000	957,000	3,814,000
1996	W	970,000	2,403,000	1,961,000	700,000	3,631,000	2,882,000	749,000	3,631,000
1997	W	1,260,000	2,163,000	1,717,000	779,000	3,756,000	2,933,000	823,000	3,756,000
1998	W	2,104,000	1,607,000	1,321,000	563,000	3,988,000	3,119,000	869,000	3,988,000
1999	AN	739,000	2,127,000	1,815,000	812,000	3,366,000	2,910,000	456,000	3,366,000
2000	AN	1,017,000	1,730,000	1,509,000	908,000	3,434,000	2,949,000	485,000	3,434,000
2001	D	997,000	1,532,000	1,408,000	1,163,000	3,567,000	3,117,000	451,000	3,567,000
2002	D	710,000	1,573,000	1,433,000	1,184,000	3,326,000	2,829,000	497,000	3,326,000
2003	BN	943,000	1,694,000	1,546,000	920,000	3,410,000	2,872,000	537,000	3,410,000
2004	D	688,000	1,738,000	1,545,000	999,000	3,232,000	2,671,000	561,000	3,232,000
2005	W	1,599,000	1,800,000	1,496,000	510,000	3,605,000	2,934,000	671,000	3,605,000
2006	W	1,181,000	2,036,000	1,667,000	533,000	3,381,000	2,787,000	594,000	3,381,000
2007	C	442,000	1,720,000	1,518,000	921,000	2,881,000	2,589,000	292,000	2,881,000
2008	C	741,000	1,126,000	991,000	1,116,000	2,848,000	2,539,000	309,000	2,848,000
2009	BN	663,000	863,000	758,000	1,194,000	2,616,000	2,440,000	176,000	2,616,000
2010	AN	1,175,000	1,290,000	1,122,000	738,000	3,035,000	2,563,000	472,000	3,035,000
2011	W	1,501,000	1,880,000	1,524,000	525,000	3,550,000	2,762,000	788,000	3,550,000
2012	D	675,000	1,490,000	1,325,000	967,000	2,967,000	2,655,000	312,000	2,967,000
2013	C	504,000	1,003,000	883,000	1,317,000	2,704,000	2,450,000	255,000	2,704,000
2014	C	410,000	537,000	498,000	1,619,000	2,527,000	2,379,000	148,000	2,527,000
2015	C	602,000	453,000	414,000	1,618,000	2,634,000	2,310,000	324,000	2,634,000
Average		**975,000**	**1,509,000**	**1,304,000**	**1,018,000**	**3,297,000**	**2,749,000**	**547,000**	**3,297,000**

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

Table 4-5: Aggregated Groundwater Budget for the Model Domain (1989-2015)

Water Year	Water Year Type	Net Deep Percolation (af)	Surface Water to Aquifer (af)	Lateral Subsurface Inflow (af)	Total Inflow (af)	Groundwater Pumping (af)	Aquifer to Surface Water (af)	Lateral Subsurface Outflow (af)	Total Outflow (af)	Change In Groundwater Storage (af)
1989	C	736,000	25,000	501,000	1,262,000	1,189,000	3,000	269,000	1,461,000	-198,000
1990	C	649,000	30,000	482,000	1,160,000	1,356,000	1,000	264,000	1,621,000	-467,000
1991	C	626,000	70,000	493,000	1,189,000	1,606,000	2,000	278,000	1,886,000	-705,000
1992	C	585,000	61,000	498,000	1,143,000	1,574,000	1,000	272,000	1,847,000	-712,000
1993	W	889,000	179,000	443,000	1,511,000	896,000	4,000	219,000	1,120,000	392,000
1994	C	572,000	79,000	443,000	1,094,000	1,161,000	6,000	232,000	1,399,000	-308,000
1995	W	957,000	187,000	418,000	1,562,000	609,000	8,000	204,000	821,000	737,000
1996	W	749,000	132,000	386,000	1,268,000	700,000	10,000	196,000	906,000	358,000
1997	W	823,000	167,000	385,000	1,375,000	779,000	16,000	211,000	1,006,000	368,000
1998	W	869,000	168,000	374,000	1,410,000	563,000	11,000	203,000	777,000	633,000
1999	AN	456,000	80,000	372,000	908,000	812,000	9,000	198,000	1,019,000	-110,000
2000	AN	485,000	87,000	383,000	955,000	908,000	7,000	199,000	1,114,000	-157,000
2001	D	451,000	107,000	428,000	985,000	1,163,000	6,000	204,000	1,373,000	-382,000
2002	D	497,000	64,000	459,000	1,021,000	1,184,000	5,000	219,000	1,407,000	-385,000
2003	BN	537,000	88,000	473,000	1,098,000	920,000	5,000	200,000	1,125,000	-35,000
2004	D	561,000	41,000	471,000	1,073,000	999,000	4,000	208,000	1,211,000	-141,000
2005	W	671,000	133,000	396,000	1,199,000	510,000	6,000	201,000	717,000	471,000
2006	W	594,000	163,000	358,000	1,115,000	533,000	17,000	181,000	731,000	389,000
2007	C	292,000	82,000	362,000	736,000	921,000	9,000	233,000	1,163,000	-432,000
2008	C	309,000	91,000	431,000	831,000	1,116,000	5,000	232,000	1,353,000	-525,000
2009	BN	176,000	54,000	488,000	718,000	1,194,000	4,000	186,000	1,384,000	-666,000
2010	AN	472,000	140,000	437,000	1,049,000	738,000	6,000	194,000	937,000	112,000
2011	W	788,000	175,000	393,000	1,356,000	525,000	17,000	179,000	722,000	633,000
2012	D	312,000	102,000	390,000	804,000	967,000	8,000	203,000	1,179,000	-371,000
2013	C	255,000	76,000	461,000	791,000	1,317,000	3,000	232,000	1,552,000	-759,000
2014	C	148,000	74,000	534,000	756,000	1,619,000	2,000	212,000	1,833,000	-1,081,000
2015	C	324,000	56,000	552,000	932,000	1,618,000	4,000	219,000	1,842,000	-909,000
Average		**547,000**	**100,000**	**437,000**	**1,085,000**	**1,018,000**	**7,000**	**217,000**	**1,241,000**	**-157,000**

Table 4-6: Land Surface Water Budget for the Westside Subbasin (1989-2015)

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

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

Table 4-7: Land Surface Inflows for the Westside Subbasin (1989-2015)

Water Year	Water Year Type	Precipitation (af)	Imported Surface Water[1] (af)	Utilized Surface Water[2] (af)	Groundwater Pumping (af)	ET Groundwater (af)	Total (af)
1989	C	269,000	1,135,000	1,069,000	328,000	181,000	1,848,000
1990	C	243,000	924,000	902,000	484,000	175,000	1,805,000
1991	C	336,000	421,000	418,000	697,000	146,000	1,598,000
1992	C	402,000	457,000	455,000	665,000	131,000	1,653,000
1993	W	706,000	760,000	752,000	318,000	202,000	1,977,000
1994	C	362,000	891,000	881,000	439,000	177,000	1,860,000
1995	W	715,000	951,000	883,000	170,000	249,000	2,017,000
1996	W	364,000	1,373,000	1,227,000	177,000	276,000	2,045,000
1997	W	506,000	1,319,000	1,111,000	178,000	325,000	2,120,000
1998	W	847,000	993,000	881,000	116,000	377,000	2,222,000
1999	AN	290,000	1,279,000	1,158,000	208,000	318,000	1,973,000
2000	AN	388,000	949,000	902,000	304,000	260,000	1,855,000
2001	D	412,000	907,000	884,000	409,000	262,000	1,966,000
2002	D	265,000	892,000	864,000	412,000	213,000	1,754,000
2003	BN	380,000	997,000	963,000	227,000	236,000	1,806,000
2004	D	272,000	1,044,000	974,000	233,000	223,000	1,701,000
2005	W	633,000	992,000	909,000	79,000	259,000	1,881,000
2006	W	453,000	1,121,000	1,023,000	90,000	251,000	1,816,000
2007	C	163,000	1,025,000	963,000	241,000	241,000	1,609,000
2008	C	302,000	574,000	554,000	329,000	164,000	1,350,000
2009	BN	257,000	357,000	348,000	377,000	114,000	1,096,000
2010	AN	474,000	603,000	593,000	181,000	89,000	1,337,000
2011	W	587,000	1,011,000	928,000	93,000	134,000	1,743,000
2012	D	271,000	829,000	796,000	304,000	149,000	1,519,000
2013	C	196,000	508,000	493,000	454,000	103,000	1,245,000
2014	C	160,000	223,000	220,000	614,000	67,000	1,061,000
2015	C	250,000	179,000	178,000	608,000	49,000	1,084,000
Average		389,000	841,000	790,000	324,000	199,000	1,702,000

1. Reported surface water imports from WWD records
2. Simulated surface water imports (imports not utilized by model rejected and not included in FMP water budget)

Table 4-8: Land Surface Outflows for the Westside Subbasin (1989-2015)

Water Year	Water Year Type	Evaporation (af)		Transpiration (af)		ET Groundwater (af)	Deep Percolation (af)		Total (af)
		Irrigation	Precipitation	Irrigation	Precipitation		Irrigation Demand	Cultural Practices	
1989	C	12,000	155,000	777,000	58,000	181,000	321,000	343,000	1,848,000
1990	C	14,000	158,000	786,000	67,000	175,000	288,000	317,000	1,805,000
1991	C	7,000	127,000	795,000	62,000	146,000	410,000	51,000	1,598,000
1992	C	6,000	211,000	809,000	63,000	131,000	394,000	37,000	1,653,000
1993	W	5,000	284,000	756,000	81,000	202,000	590,000	60,000	1,977,000
1994	C	9,000	249,000	755,000	95,000	177,000	267,000	307,000	1,860,000
1995	W	3,000	253,000	650,000	84,000	249,000	590,000	188,000	2,017,000
1996	W	7,000	205,000	722,000	59,000	276,000	337,000	439,000	2,045,000
1997	W	9,000	213,000	715,000	33,000	325,000	495,000	330,000	2,119,000
1998	W	2,000	315,000	558,000	118,000	377,000	581,000	270,000	2,222,000
1999	AN	10,000	189,000	740,000	48,000	318,000	279,000	390,000	1,973,000
2000	AN	12,000	203,000	762,000	82,000	260,000	337,000	199,000	1,855,000
2001	D	8,000	275,000	775,000	79,000	262,000	289,000	279,000	1,966,000
2002	D	13,000	160,000	829,000	39,000	213,000	316,000	184,000	1,754,000
2003	BN	11,000	225,000	704,000	78,000	236,000	284,000	268,000	1,806,000
2004	D	15,000	171,000	708,000	34,000	223,000	275,000	276,000	1,701,000
2005	W	4,000	293,000	598,000	112,000	259,000	390,000	225,000	1,881,000
2006	W	5,000	210,000	638,000	93,000	251,000	317,000	303,000	1,816,000
2007	C	15,000	114,000	712,000	44,000	241,000	121,000	362,000	1,609,000
2008	C	17,000	152,000	681,000	39,000	164,000	218,000	78,000	1,350,000
2009	BN	16,000	158,000	587,000	77,000	114,000	103,000	41,000	1,096,000
2010	AN	10,000	203,000	614,000	124,000	89,000	237,000	59,000	1,337,000
2011	W	5,000	244,000	660,000	116,000	134,000	331,000	253,000	1,743,000
2012	D	6,000	160,000	705,000	95,000	149,000	118,000	286,000	1,519,000
2013	C	15,000	117,000	743,000	43,000	103,000	136,000	88,000	1,245,000
2014	C	14,000	92,000	708,000	66,000	67,000	91,000	23,000	1,061,000
2015	C	19,000	107,000	674,000	72,000	49,000	151,000	13,000	1,084,000
Average		10,000	194,000	710,000	73,000	199,000	306,000	210,000	1,702,000

Table 4-9: Groundwater Budget for the Westside Subbasin (1989-2015)

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

Table 4-10: Upper Aquifer Groundwater Budget in the Westside Subbasin (1989-2015)

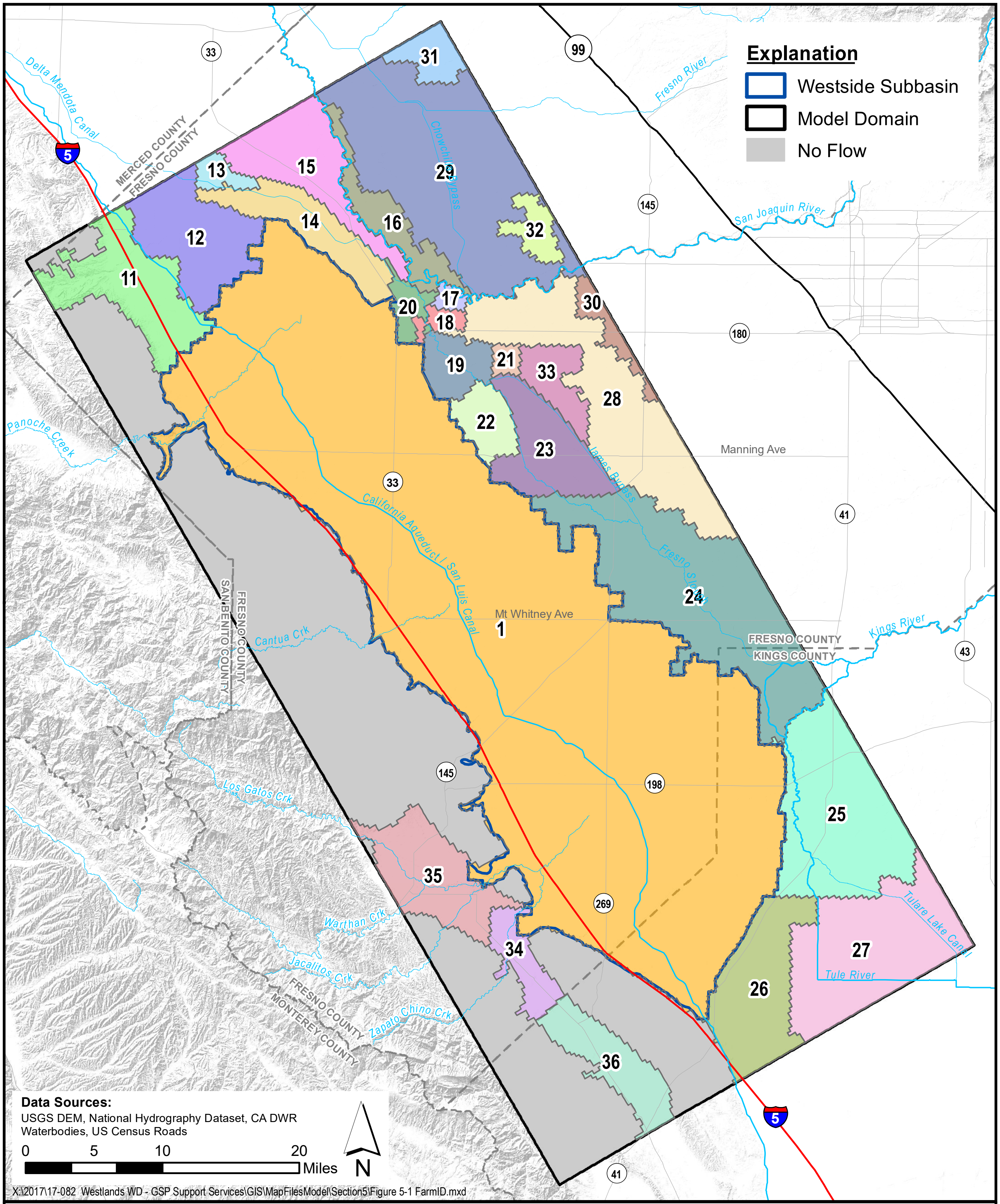
Water Year	Water Year Type	Net Deep Percolation (af)	Stream Leakage (af)	Lateral Subsurface Inflow (af)	Total Inflow (af)	Groundwater Pumping (af)	Lateral Subsurface Outflow (af)	Vertical Flow[1] (af)	Total Outflow (af)	Change In Groundwater Storage (af)
1989	C	485,000	0	33,000	519,000	94,000	108,000	160,000	363,000	150,000
1990	C	430,000	1,000	33,000	464,000	136,000	111,000	157,000	404,000	58,000
1991	C	316,000	5,000	36,000	357,000	199,000	105,000	166,000	470,000	-112,000
1992	C	301,000	8,000	36,000	345,000	189,000	104,000	174,000	467,000	-123,000
1993	W	451,000	30,000	36,000	517,000	93,000	94,000	179,000	365,000	146,000
1994	C	398,000	3,000	33,000	434,000	128,000	105,000	161,000	394,000	38,000
1995	W	530,000	32,000	33,000	595,000	52,000	91,000	175,000	318,000	269,000
1996	W	500,000	10,000	29,000	540,000	52,000	101,000	151,000	304,000	230,000
1997	W	500,000	18,000	28,000	546,000	50,000	111,000	138,000	299,000	243,000
1998	W	476,000	33,000	27,000	536,000	35,000	104,000	139,000	278,000	253,000
1999	AN	349,000	6,000	26,000	381,000	60,000	113,000	128,000	301,000	79,000
2000	AN	275,000	6,000	28,000	308,000	86,000	110,000	129,000	325,000	-16,000
2001	D	306,000	10,000	29,000	345,000	113,000	116,000	138,000	366,000	-18,000
2002	D	287,000	1,000	31,000	319,000	116,000	116,000	152,000	384,000	-64,000
2003	BN	318,000	3,000	30,000	351,000	68,000	120,000	163,000	351,000	-6,000
2004	D	328,000	2,000	30,000	359,000	66,000	128,000	151,000	345,000	9,000
2005	W	356,000	26,000	28,000	410,000	25,000	101,000	157,000	283,000	117,000
2006	W	368,000	14,000	25,000	407,000	29,000	97,000	140,000	266,000	134,000
2007	C	239,000	1,000	25,000	266,000	69,000	117,000	122,000	308,000	-44,000
2008	C	125,000	7,000	28,000	161,000	92,000	125,000	133,000	350,000	-189,000
2009	BN	28,000	1,000	30,000	59,000	107,000	124,000	143,000	374,000	-313,000
2010	AN	209,000	12,000	30,000	251,000	56,000	108,000	156,000	320,000	-73,000
2011	W	451,000	24,000	26,000	502,000	28,000	97,000	149,000	273,000	222,000
2012	D	249,000	2,000	25,000	276,000	85,000	110,000	127,000	322,000	-45,000
2013	C	118,000	1,000	28,000	147,000	120,000	124,000	136,000	381,000	-229,000
2014	C	43,000	1,000	31,000	75,000	167,000	125,000	162,000	454,000	-374,000
2015	C	115,000	0	33,000	148,000	169,000	122,000	176,000	467,000	-316,000
Average		**317,000**	**10,000**	**30,000**	**356,000**	**92,000**	**111,000**	**150,000**	**353,000**	**1,000**

[1] Flow from Upper to Lower Aquifer (Includes Flow through Corcoran Clay and Intraborehole Flow)

Table 4-11: Lower Aquifer Groundwater Budget in the Westside Subbasin (1989-2015)

Water Year	Water Year Type	Lateral Subsurface Inflow (af)	Vertical Flow[1] (af)	Total Inflow (af)	Groundwater Pumping (af)	Lateral Subsurface Outflow (af)	Total Outflow (af)	Change In Groundwater Storage (af)
1989	C	172,000	160,000	332,000	232,000	69,000	301,000	31,000
1990	C	169,000	157,000	326,000	346,000	69,000	415,000	-94,000
1991	C	199,000	166,000	365,000	497,000	64,000	561,000	-203,000
1992	C	209,000	174,000	383,000	478,000	63,000	541,000	-162,000
1993	W	187,000	179,000	366,000	224,000	59,000	283,000	86,000
1994	C	173,000	161,000	334,000	308,000	57,000	365,000	-36,000
1995	W	152,000	175,000	327,000	118,000	53,000	171,000	159,000
1996	W	111,000	151,000	262,000	124,000	51,000	175,000	89,000
1997	W	91,000	138,000	230,000	127,000	53,000	180,000	51,000
1998	W	75,000	139,000	214,000	81,000	59,000	140,000	76,000
1999	AN	72,000	128,000	199,000	149,000	58,000	207,000	-7,000
2000	AN	86,000	129,000	215,000	219,000	52,000	271,000	-58,000
2001	D	113,000	138,000	251,000	296,000	54,000	350,000	-103,000
2002	D	136,000	152,000	288,000	298,000	57,000	355,000	-70,000
2003	BN	127,000	163,000	290,000	162,000	61,000	222,000	65,000
2004	D	103,000	151,000	254,000	170,000	64,000	234,000	22,000
2005	W	89,000	157,000	247,000	66,000	54,000	120,000	127,000
2006	W	63,000	140,000	203,000	72,000	56,000	128,000	78,000
2007	C	63,000	122,000	185,000	184,000	54,000	238,000	-54,000
2008	C	77,000	133,000	210,000	233,000	63,000	297,000	-93,000
2009	BN	99,000	143,000	242,000	266,000	62,000	328,000	-88,000
2010	AN	101,000	156,000	256,000	123,000	54,000	177,000	82,000
2011	W	70,000	149,000	219,000	65,000	51,000	116,000	106,000
2012	D	72,000	127,000	199,000	217,000	50,000	267,000	-67,000
2013	C	102,000	136,000	238,000	330,000	58,000	388,000	-154,000
2014	C	156,000	162,000	318,000	441,000	62,000	503,000	-194,000
2015	C	192,000	176,000	369,000	434,000	62,000	496,000	-132,000
Average		**121,000**	**150,000**	**271,000**	**232,000**	**58,000**	**290,000**	**-20,000**

1. Flow from Upper to Lower Aquifer (Includes Flow through Corcoran Clay and Intraborehole Flow)



Data Sources:
USGS DEM, National Hydrography Dataset, CA DWR Waterbodies, US Census Roads

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Farm Delineation used to Simulate Projected Groundwater Conditions (2017 - 2070)

Figure 5-1

SGMA Sustainability Analyses
Westside Subbasin

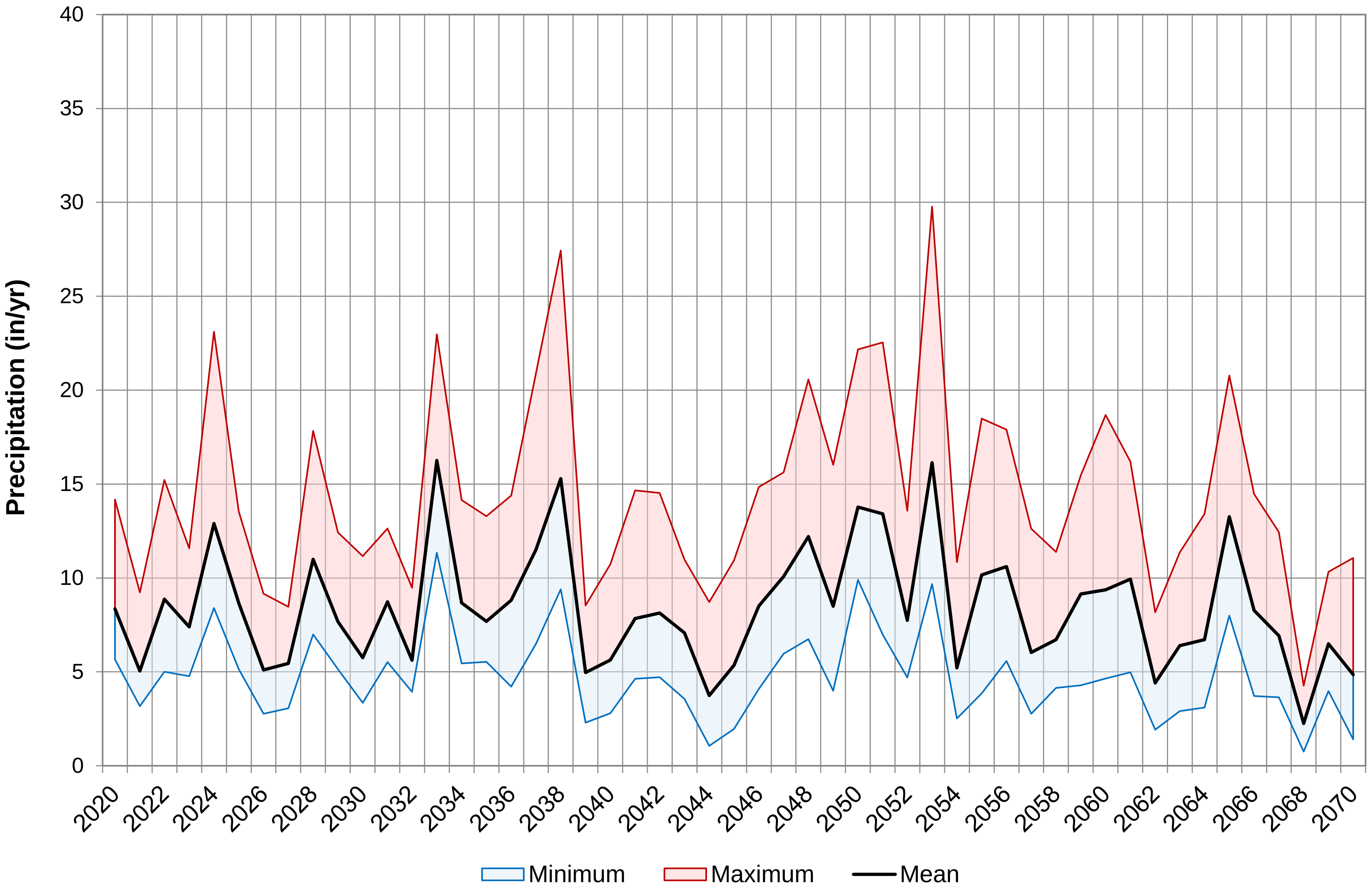

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Figure 5-2
Total Annual Precipitation Assigned to Model Cells
2020-2070

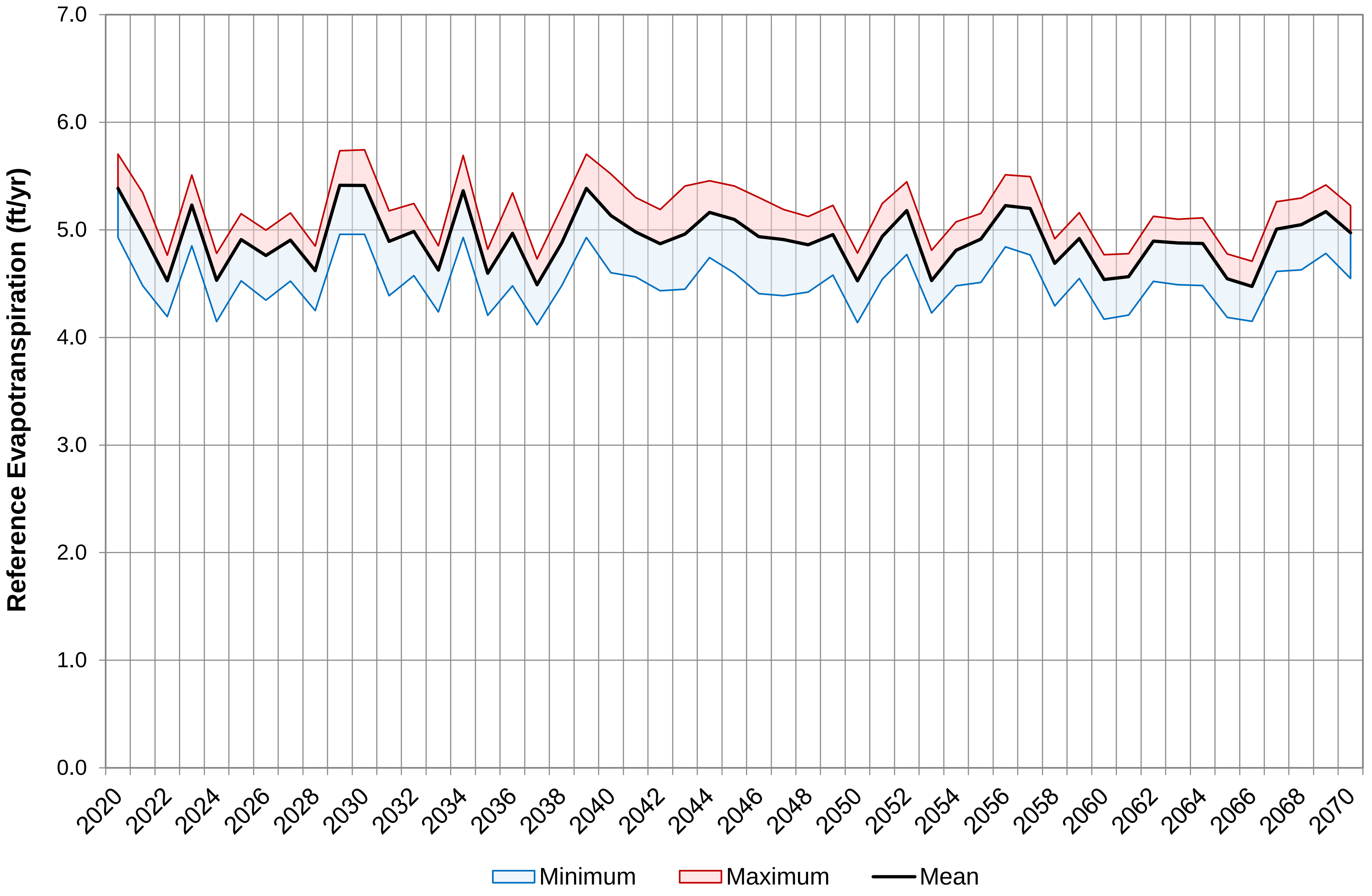

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Figure 5-3
Total Annual Reference Evapotranspiration Assigned to Model Cells
2020-2070

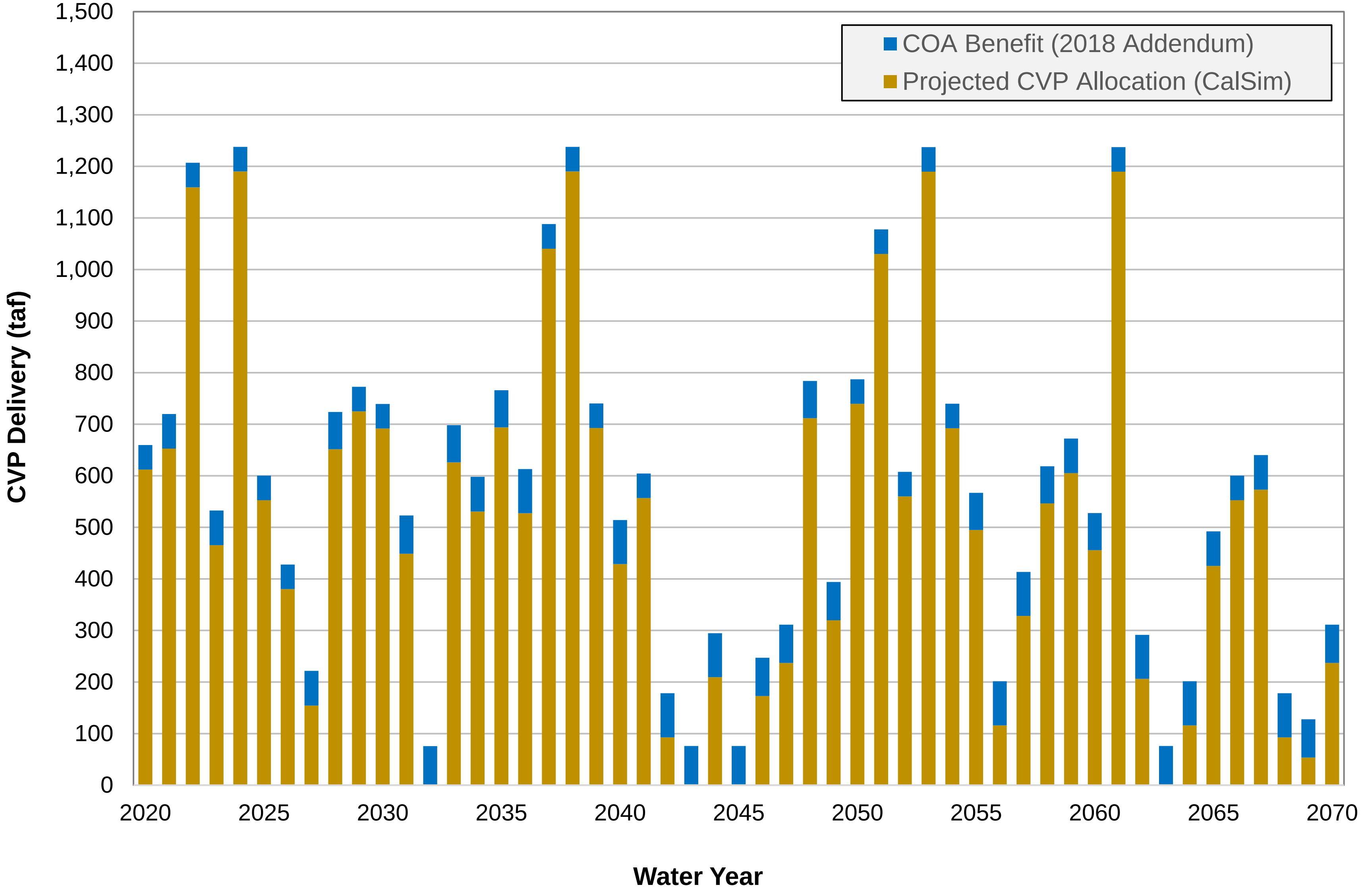

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Figure 5-4
Projected CVP Surface Water Imports to Westland Water District
2020-2070

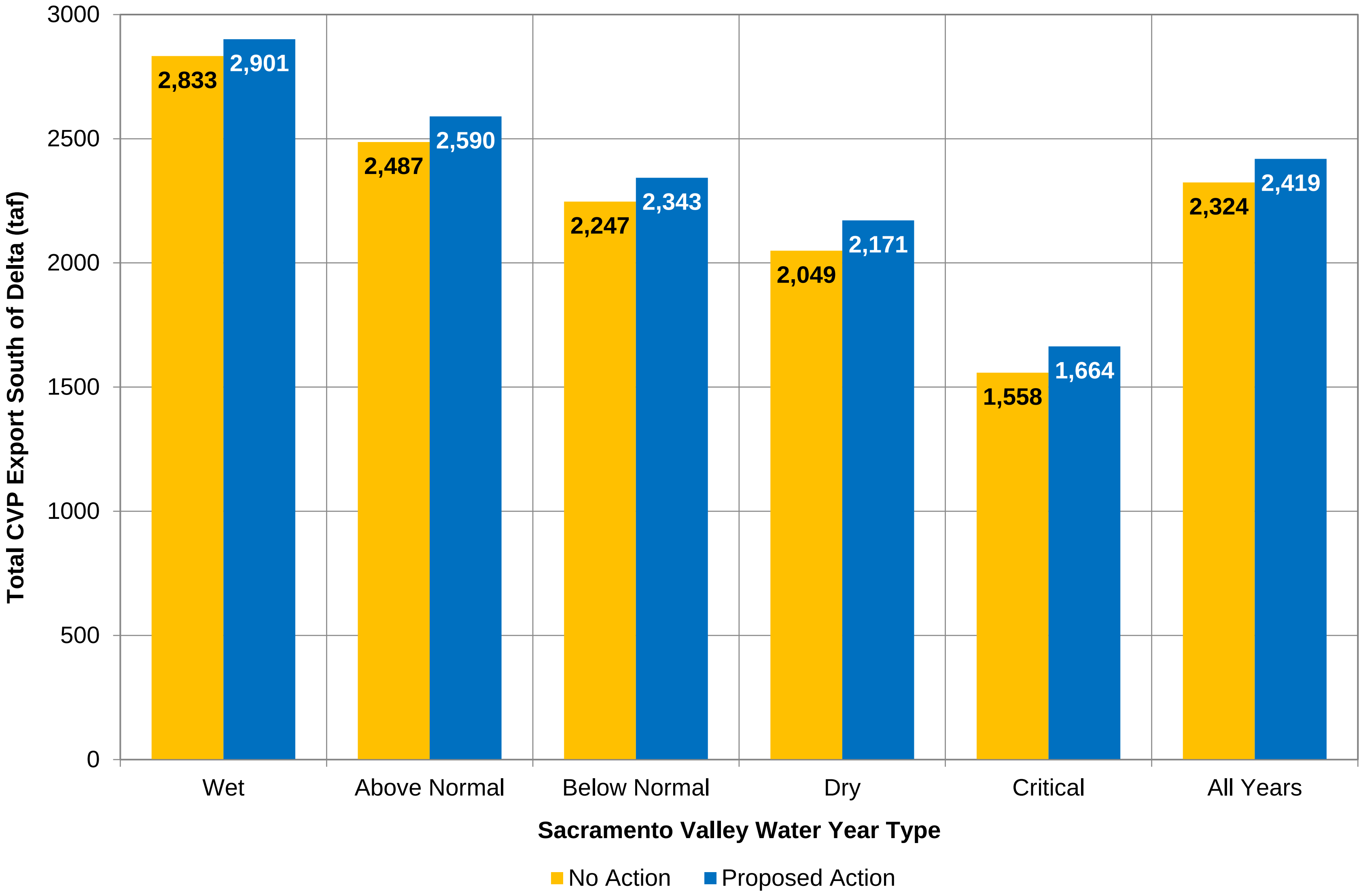

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Figure 5-5
Project vs No Project South of Delta CVP Exports
Cooperated Use Agreement Addendum

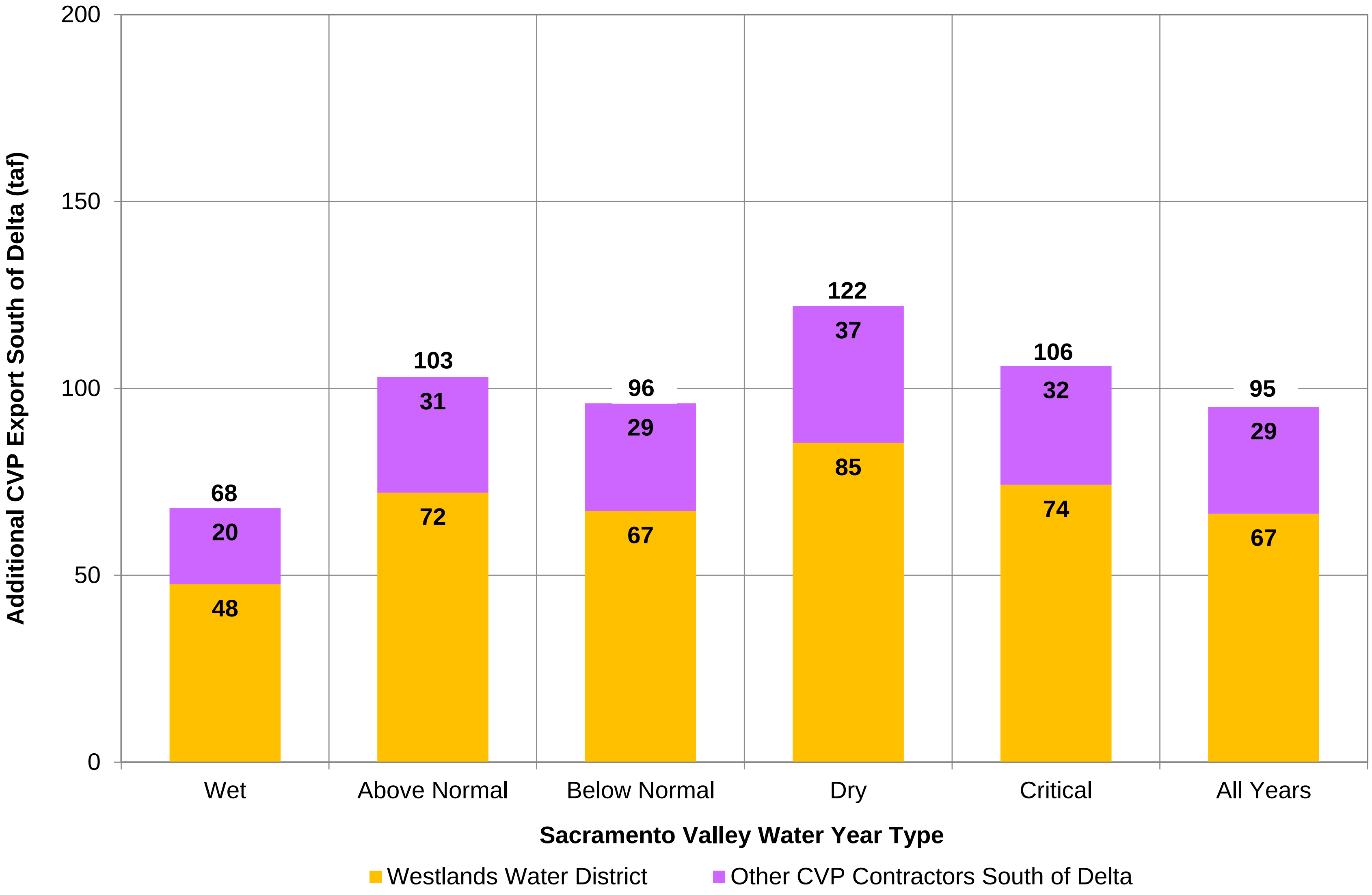

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Figure 5-6
Increase in South of Delta CVP Imports
Cooperated Use Agreement Addendum

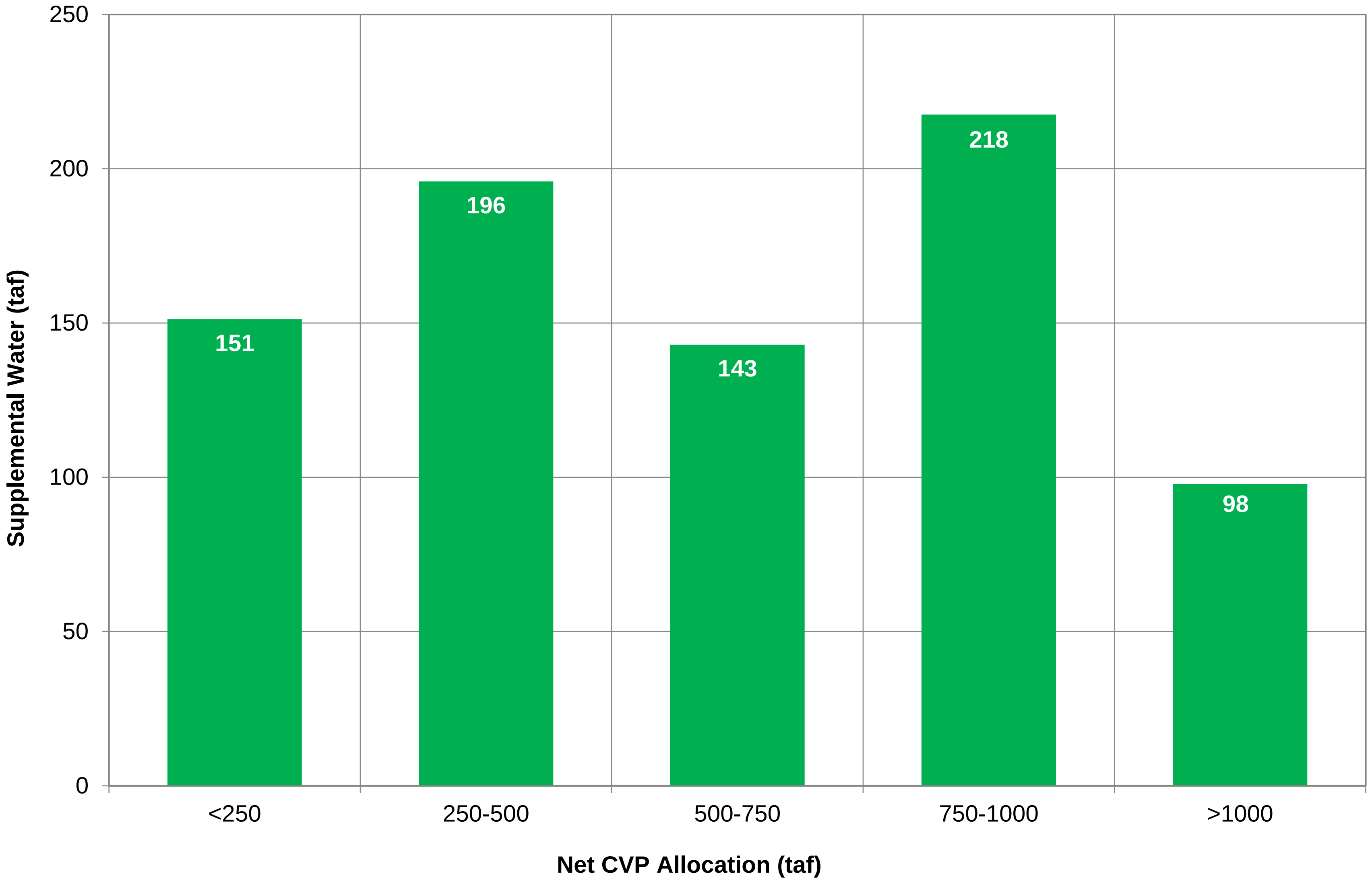

Figure 5-7
Supplemental District Supplied Water and Water User Transfers

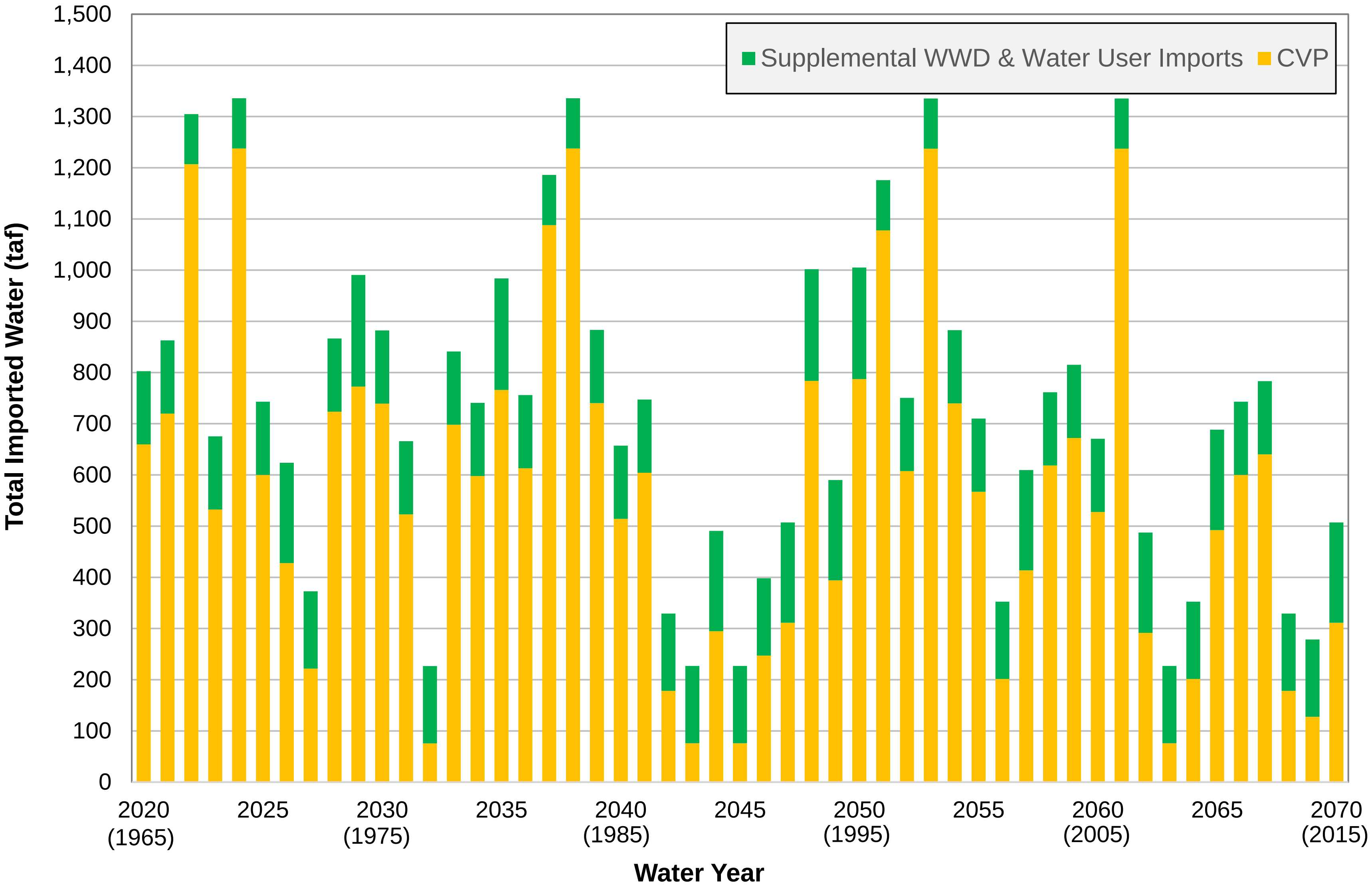

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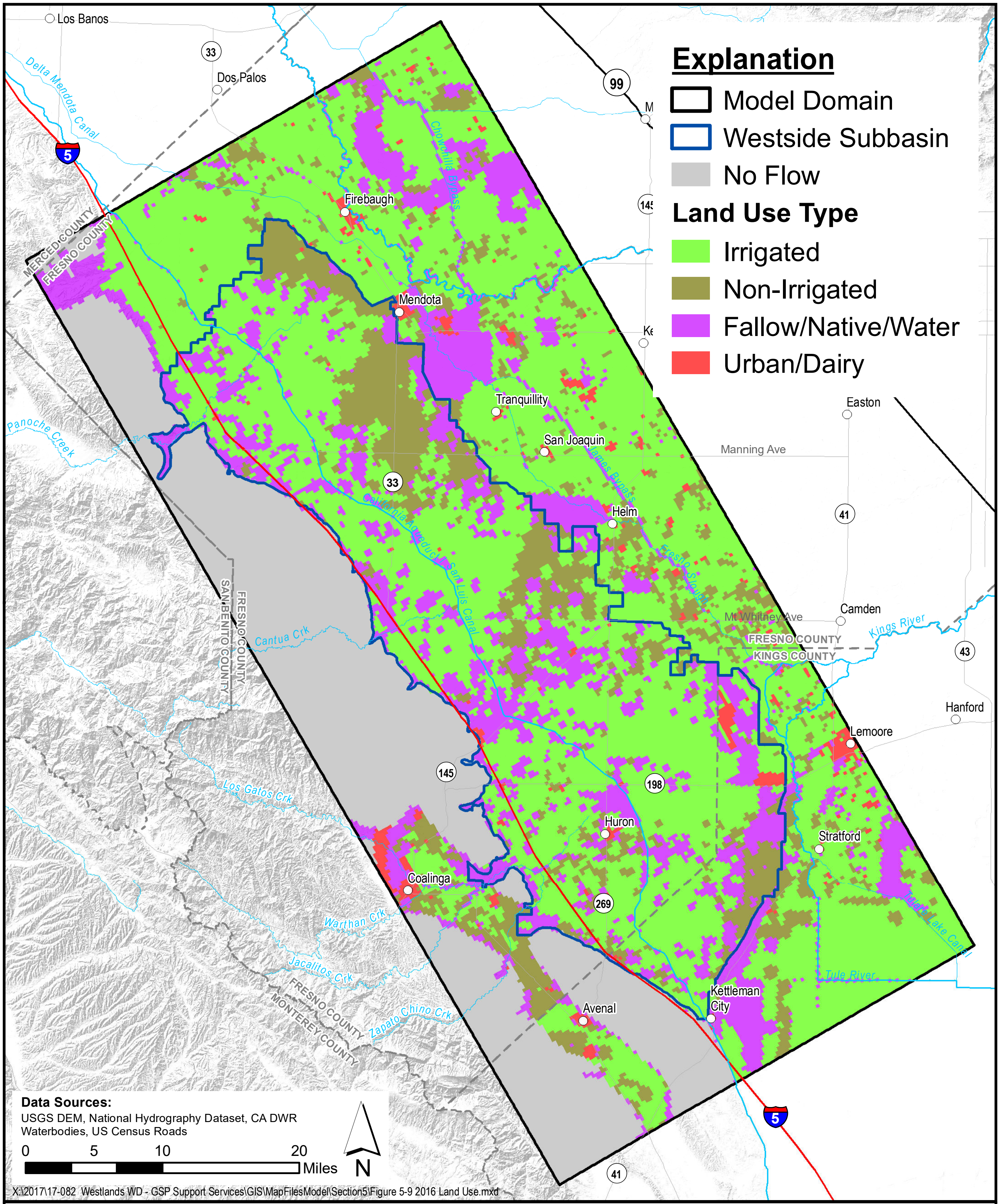
Figure 5-8
Total Projected Imports to Westlands Water District
Aggregated by CVP Contract Year



Data Sources:
USGS DEM, National Hydrography Dataset, CA DWR Waterbodies, US Census Roads

X:\2017\17-082 Westlands WD - GSP Support Services\GIS\MapFilesModel\Section5\Figure 5-9 2016 Land Use.mxd

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Assigned Land Use 2016

SGMA Sustainability Analyses
Westside Subbasin

Figure 5-9

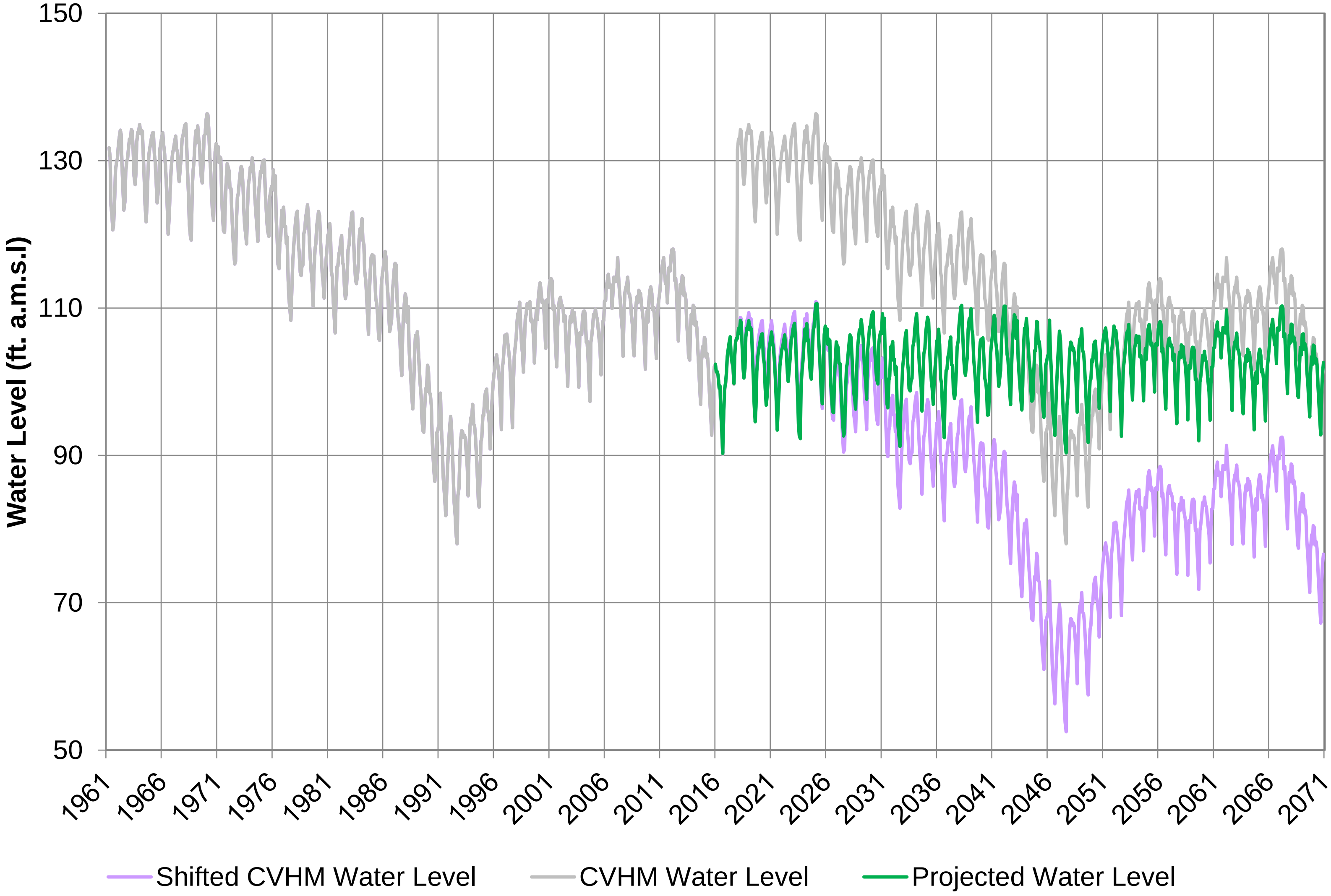

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Figure 5-10
Example of Projected General Head Boundary Water Level Adjustments

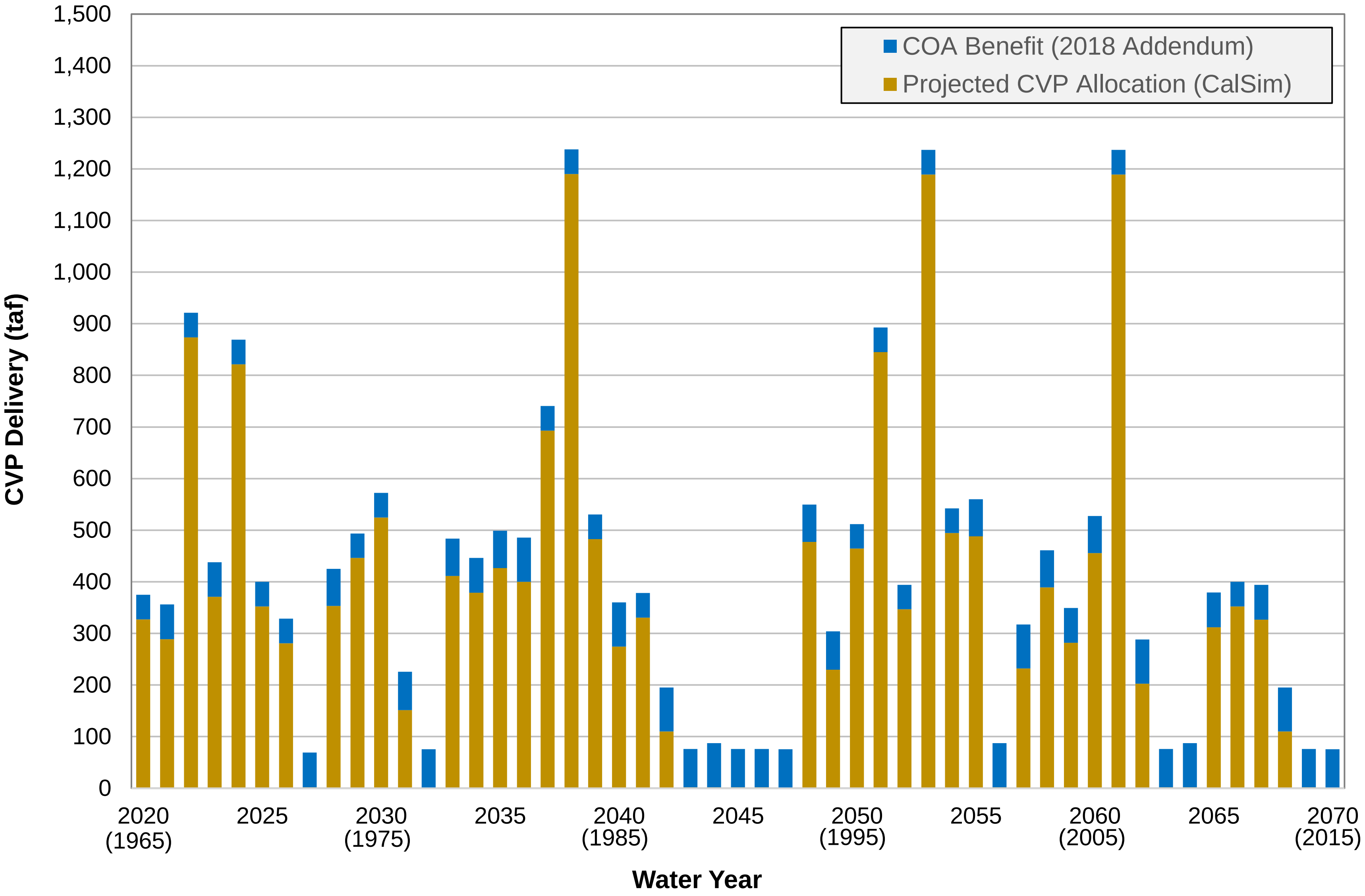

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Figure 5-11
Projected CVP Surface Water Imports to Westland Water District
2070 Climate Scenario 2020-2070

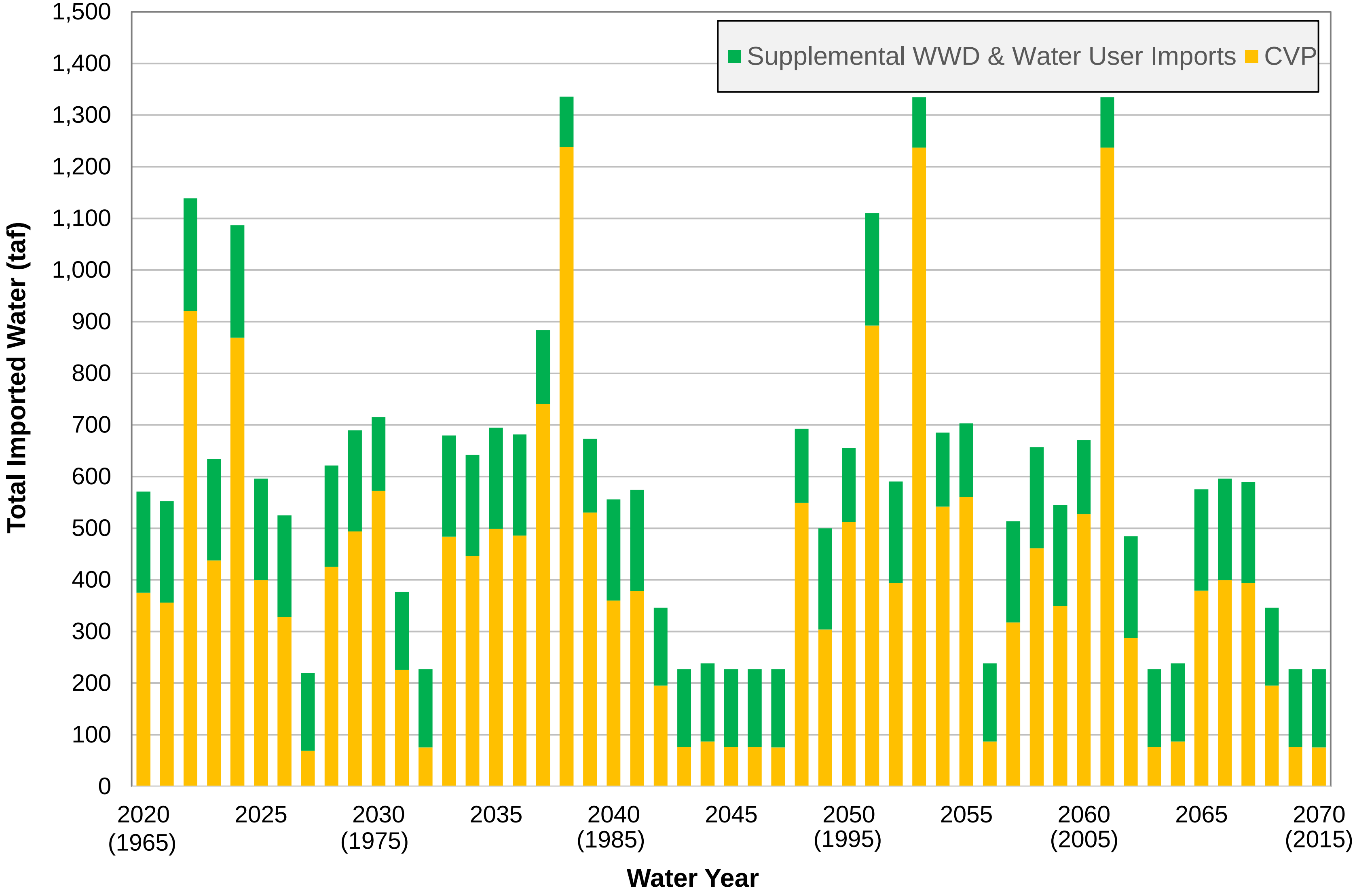

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Figure 5-12
Total Projected Imports to Westlands Water District
Aggregated by CVP Contract Year (2070 Climate Change)

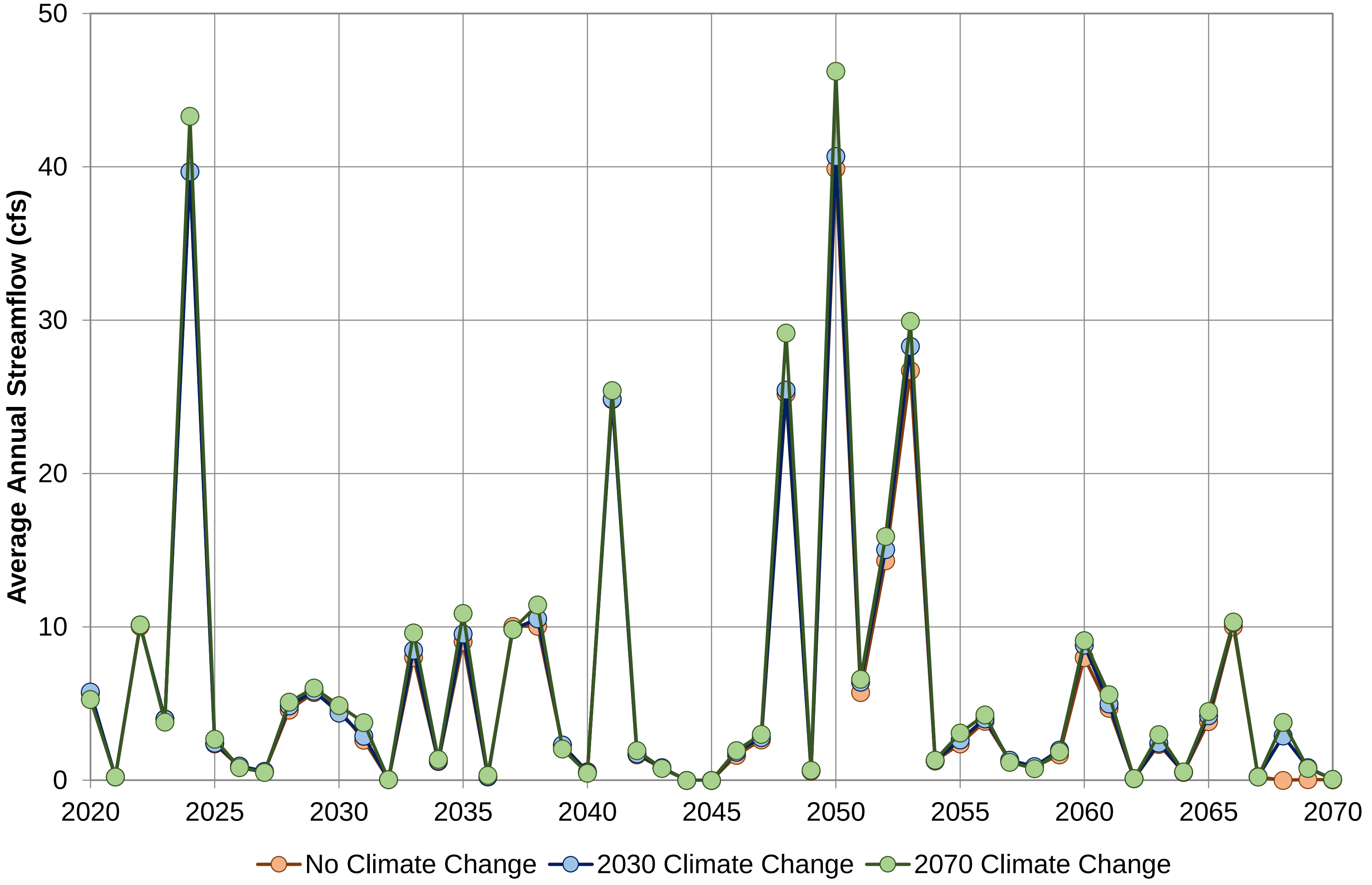

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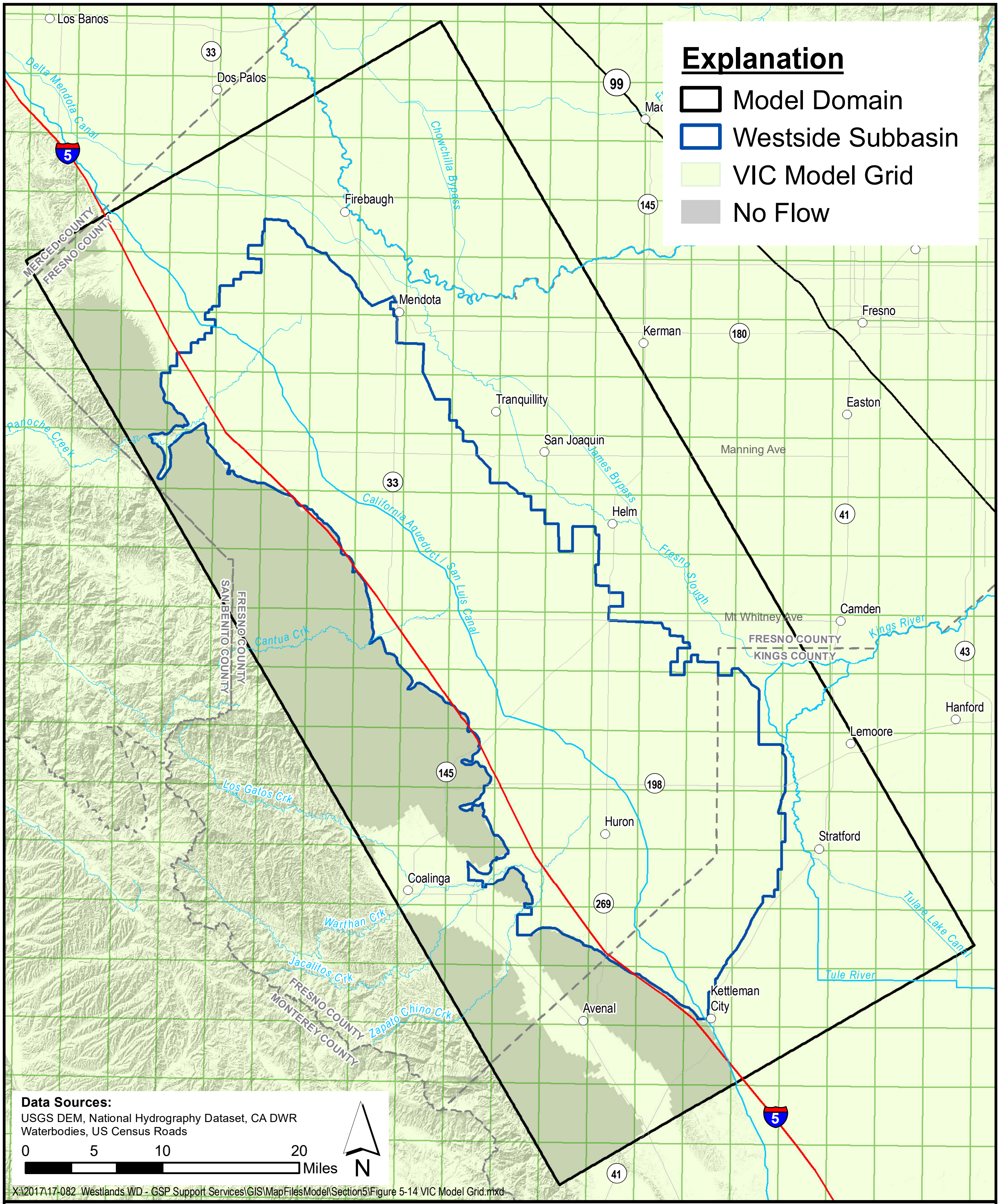
Figure 5-13
Assigned Flow in Los Gatos Creek in Model Projections
2020-2070



Data Sources:
USGS DEM, National Hydrography Dataset, CA DWR Waterbodies, US Census Roads

X:\2017\17-082_Westlands WD - GSP Support Services\GIS\MapFiles\Model\Section5\Figure 5-14 VIC Model Grid.mxd

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WSIP VIC Model Grid

SGMA Sustainability Analyses
Westside Subbasin

Figure 5-14

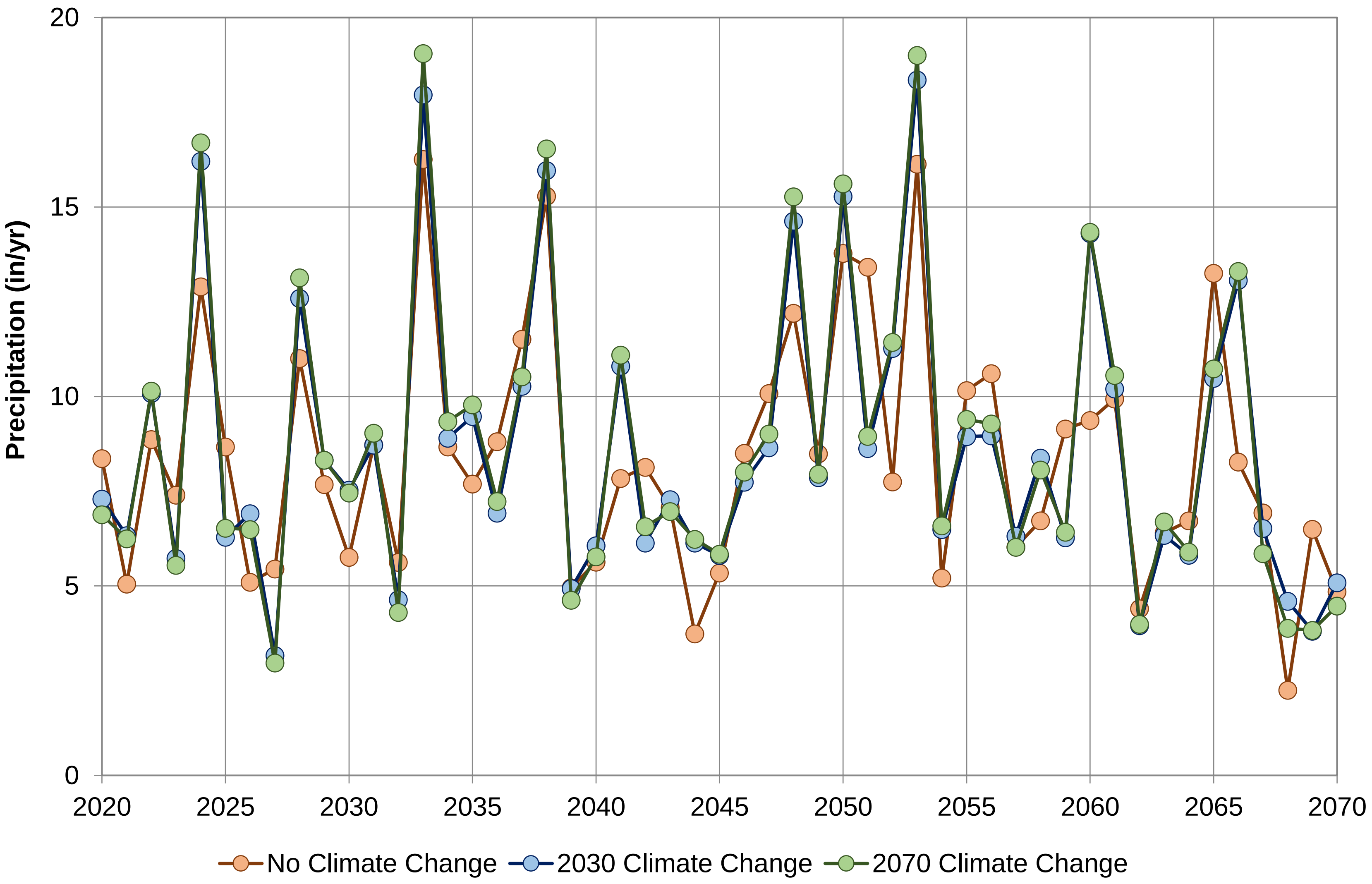

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Figure 5-15
Average Assigned Precipitation in Model Projections
2020-2070

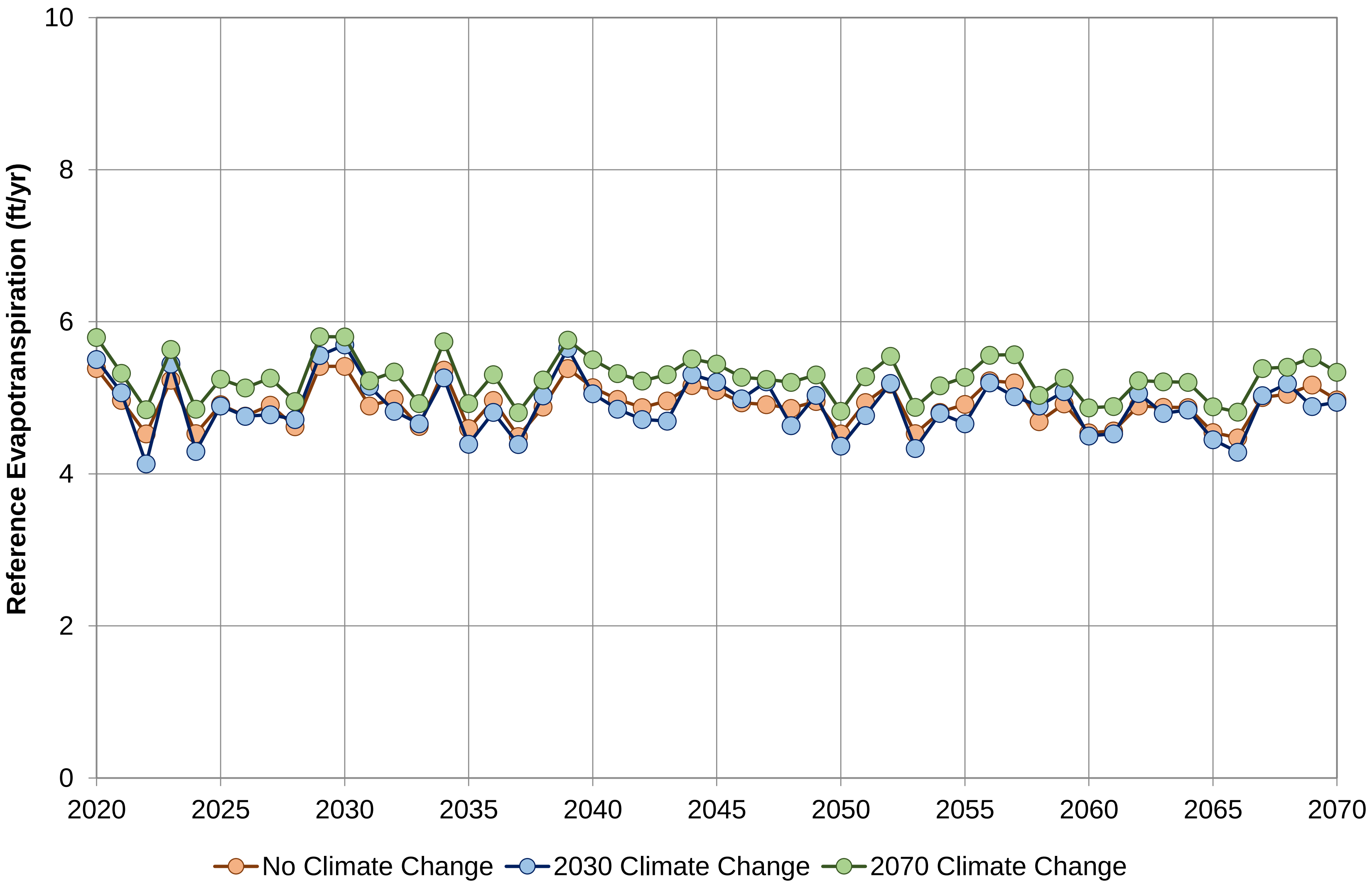

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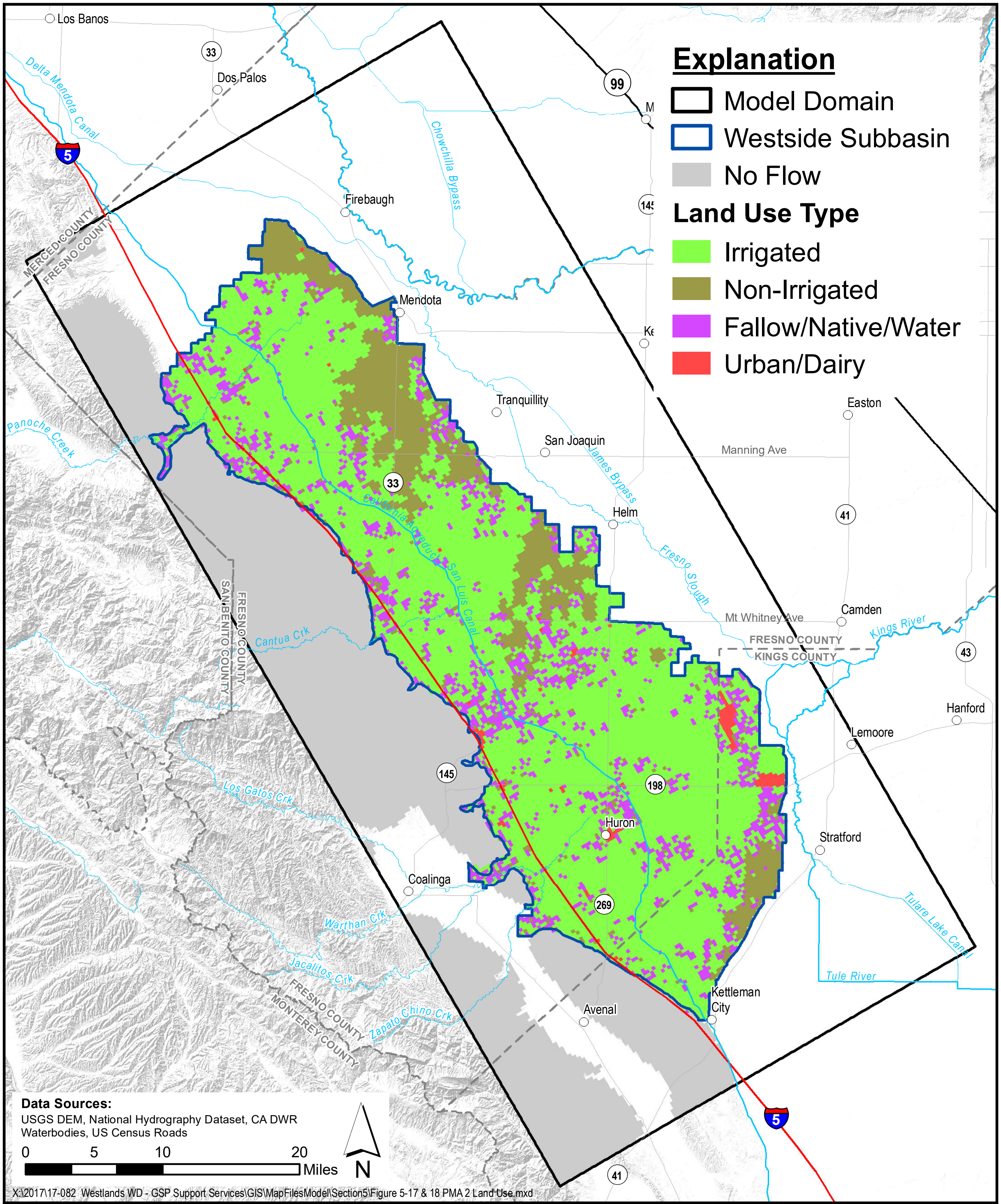
Figure 5-16
Average Assigned Reference Evapotranspiration in Model Projections
2020-2070



Data Sources:
USGS DEM, National Hydrography Dataset, CA DWR Waterbodies, US Census Roads

X:\2017\17-082 Westlands WD - GSP Support Services\GIS\MapFilesModel\Section5\Figure 5-17 & 18 PMA 2 Land Use.mxd

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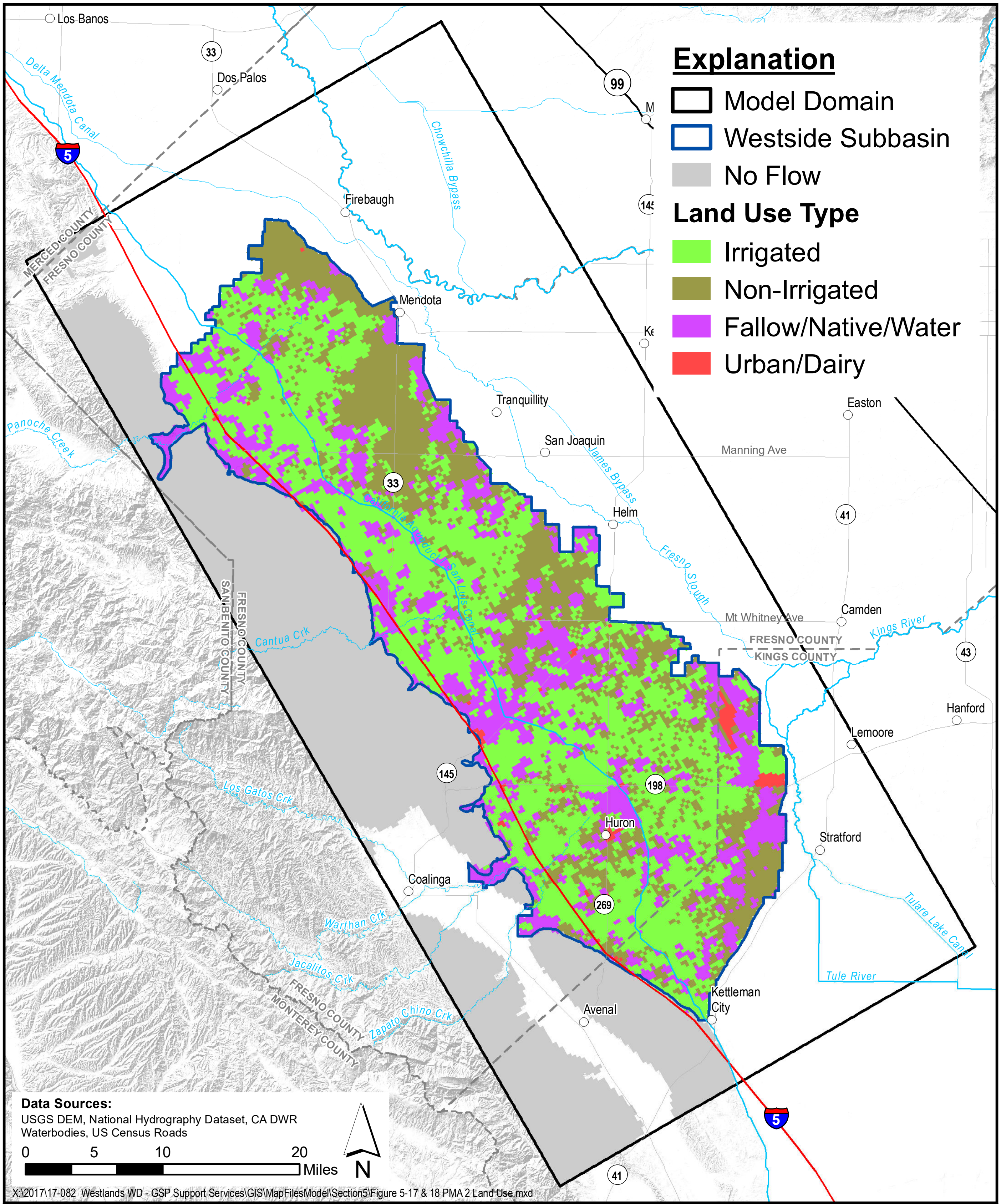
PMA No. 2 Assigned Crop Type 2065

SGMA Sustainability Analyses
Westside Subbasin

Figure 5-17



Data Sources:
USGS DEM, National Hydrography Dataset, CA DWR Waterbodies, US Census Roads

X:\2017\17-082 Westlands WD - GSP Support Services\GIS\MapFilesModel\Section5\Figure 5-17 & 18 PMA 2 Land Use.mxd

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PMA No. 2 Assigned Crop Type 2043

SGMA Sustainability Analyses
Westside Subbasin

Figure 5-18

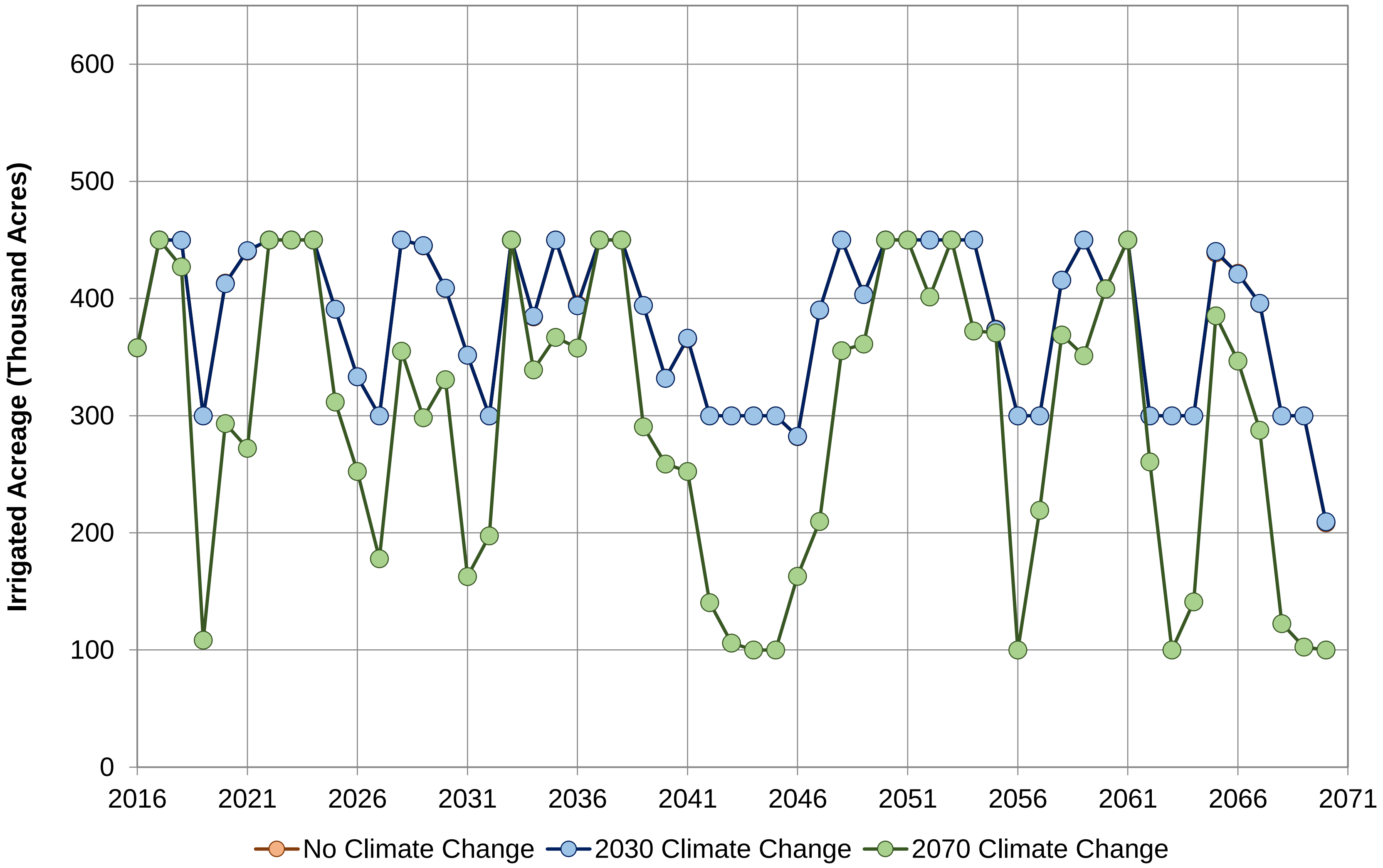

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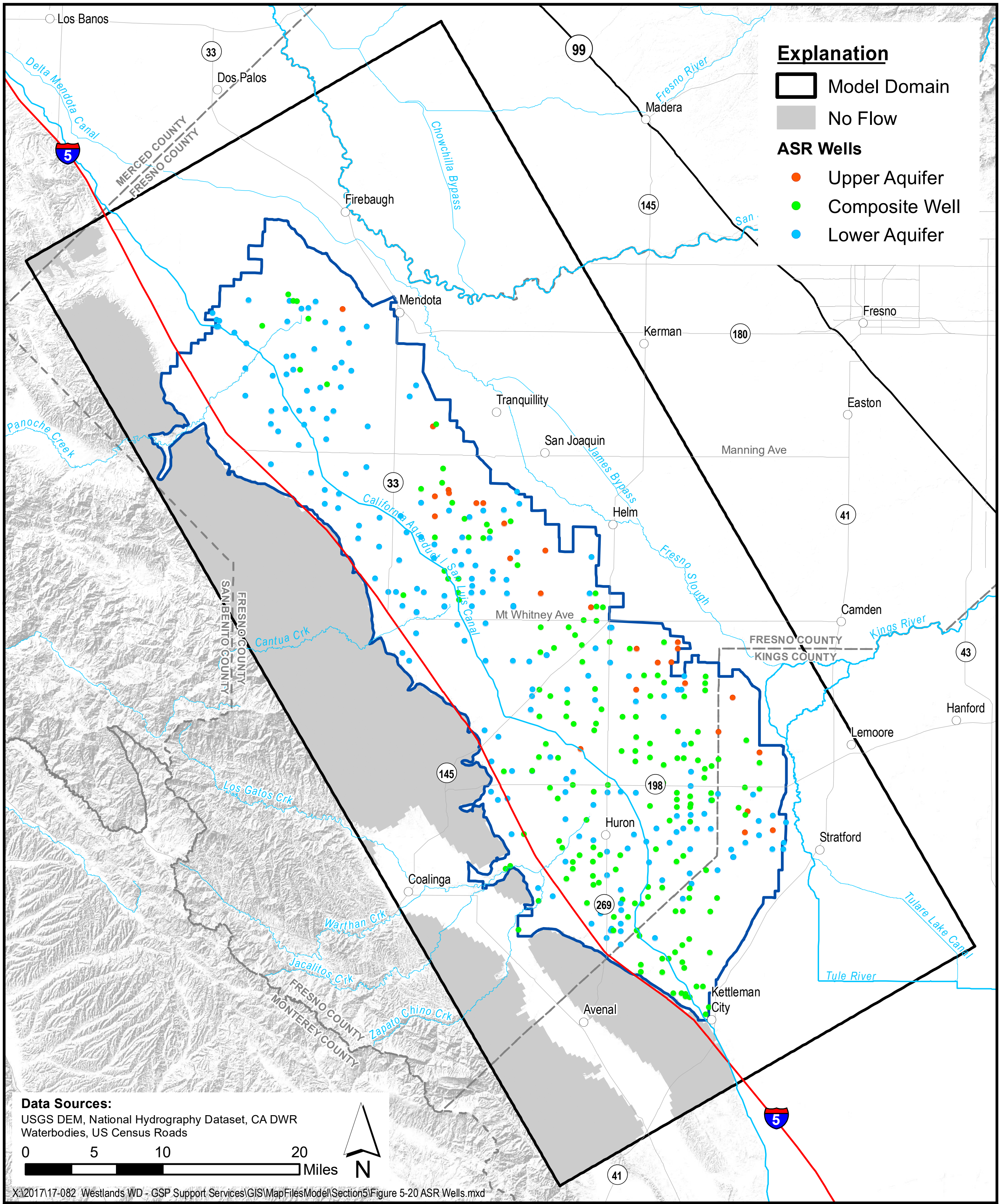
Figure 5-19
Average Assigned Irrigated Lands in PMA No. 2
2016-2070



Data Sources:
USGS DEM, National Hydrography Dataset, CA DWR
Waterbodies, US Census Roads

X:\2017\17-082 Westlands WD - GSP Support Services\GIS\MapFilesModel\Section5\Figure 5-20 ASR Wells.mxd

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Location of WWD Production Wells Used for Aquifer Storage and Recovery Simulation

SGMA Sustainability Analyses
Westside Subbasin

Figure 5-20

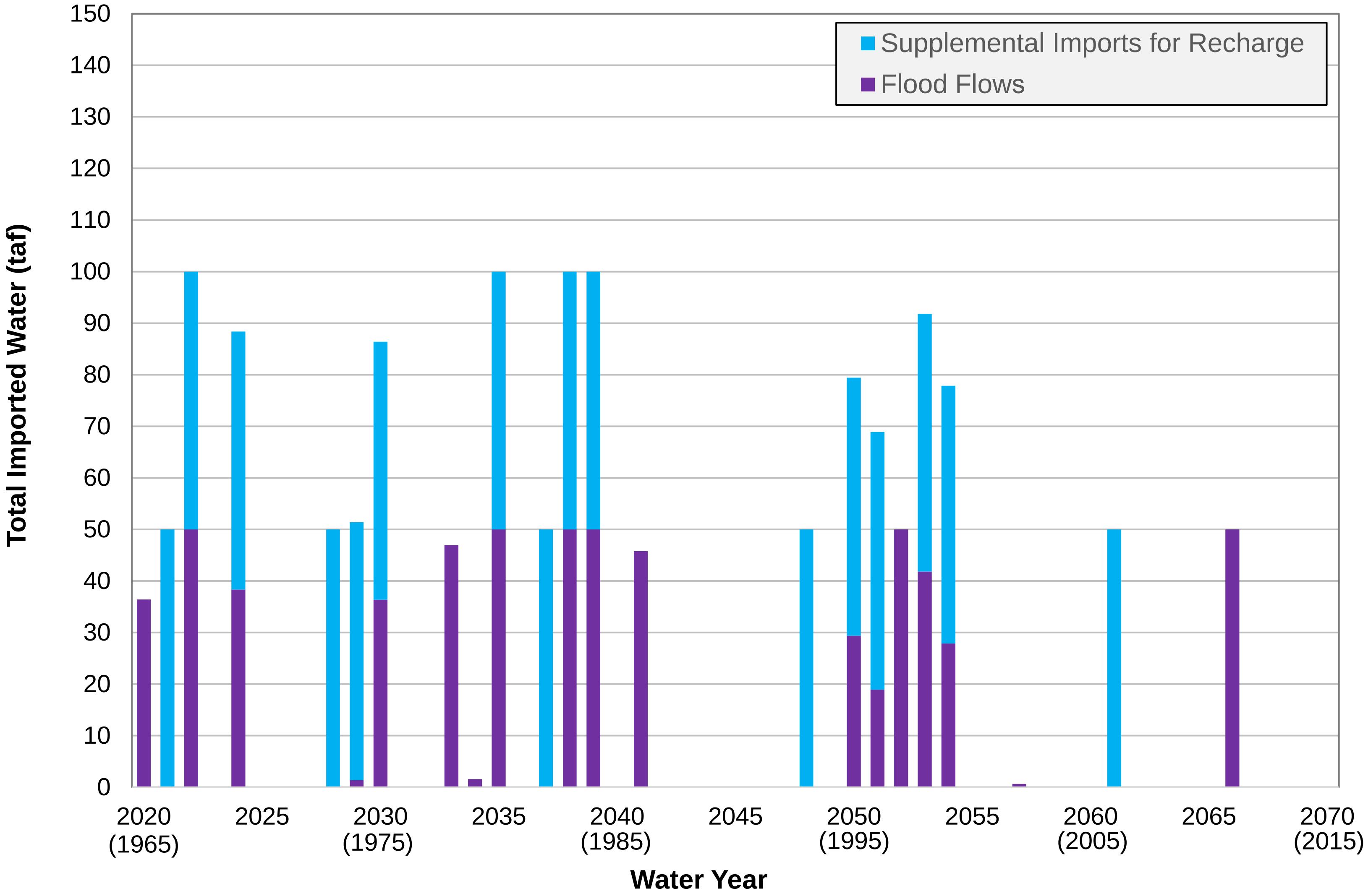

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Figure 5-21
Specified Injection in No Climate Change and 2030 Climate Change Projections

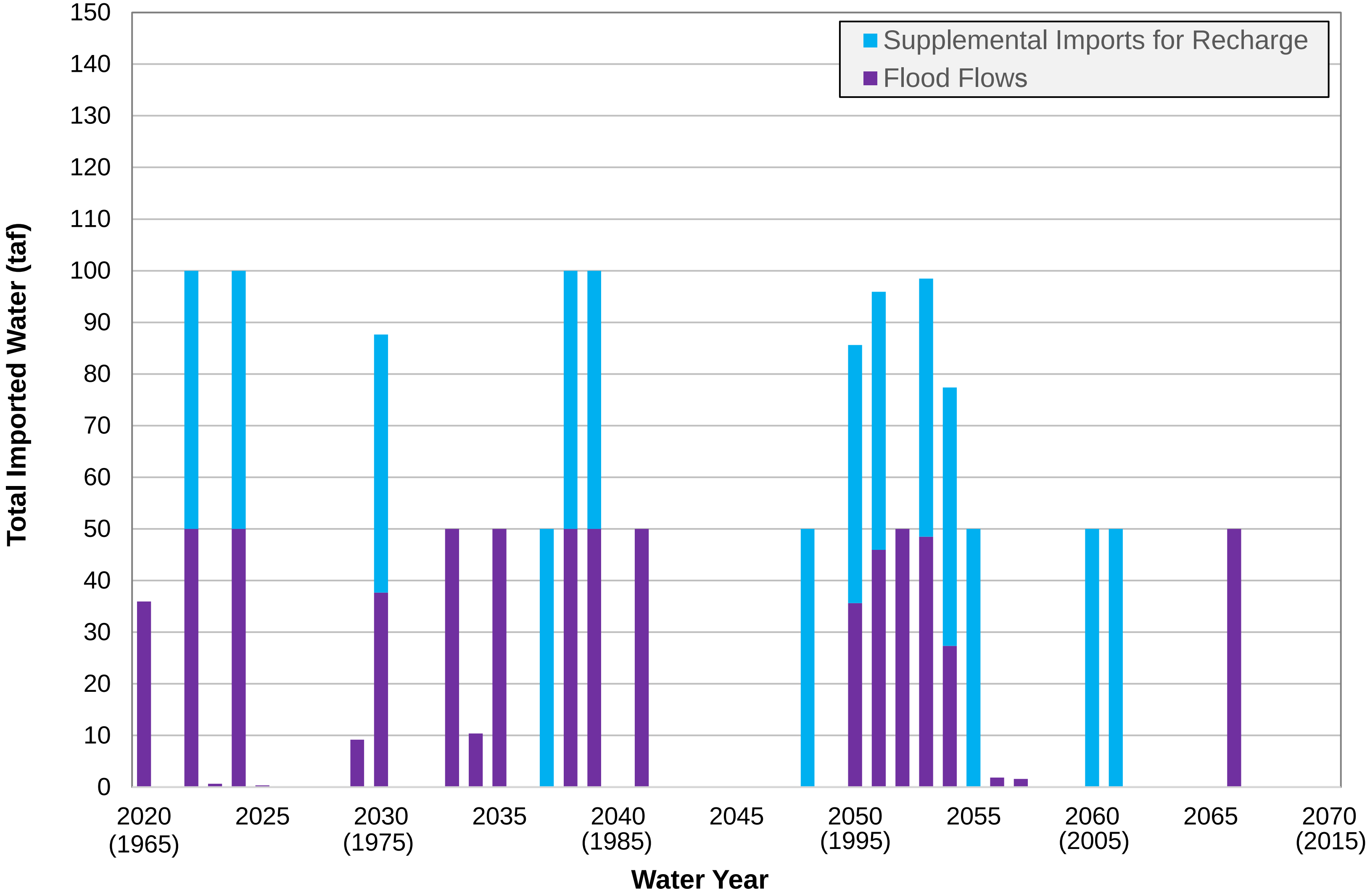

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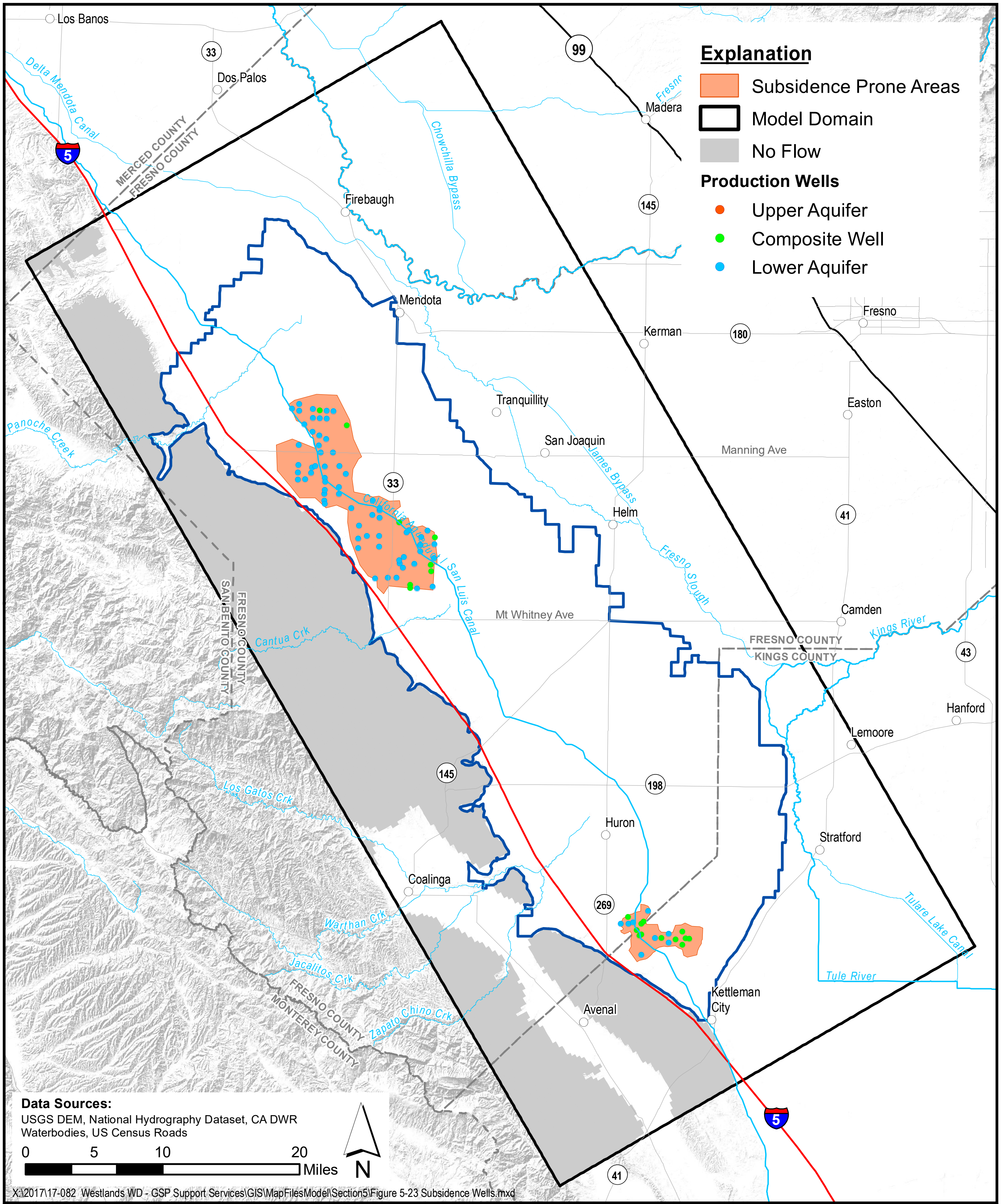
Figure 5-22
Specified Injection in 2070 Climate Change Projection



Data Sources:
USGS DEM, National Hydrography Dataset, CA DWR Waterbodies, US Census Roads

X:\2017\17-082 Westlands WD - GSP Support Services\GIS\MapFilesModel\Section5\Figure 5-23 Subsidence Wells.mxd

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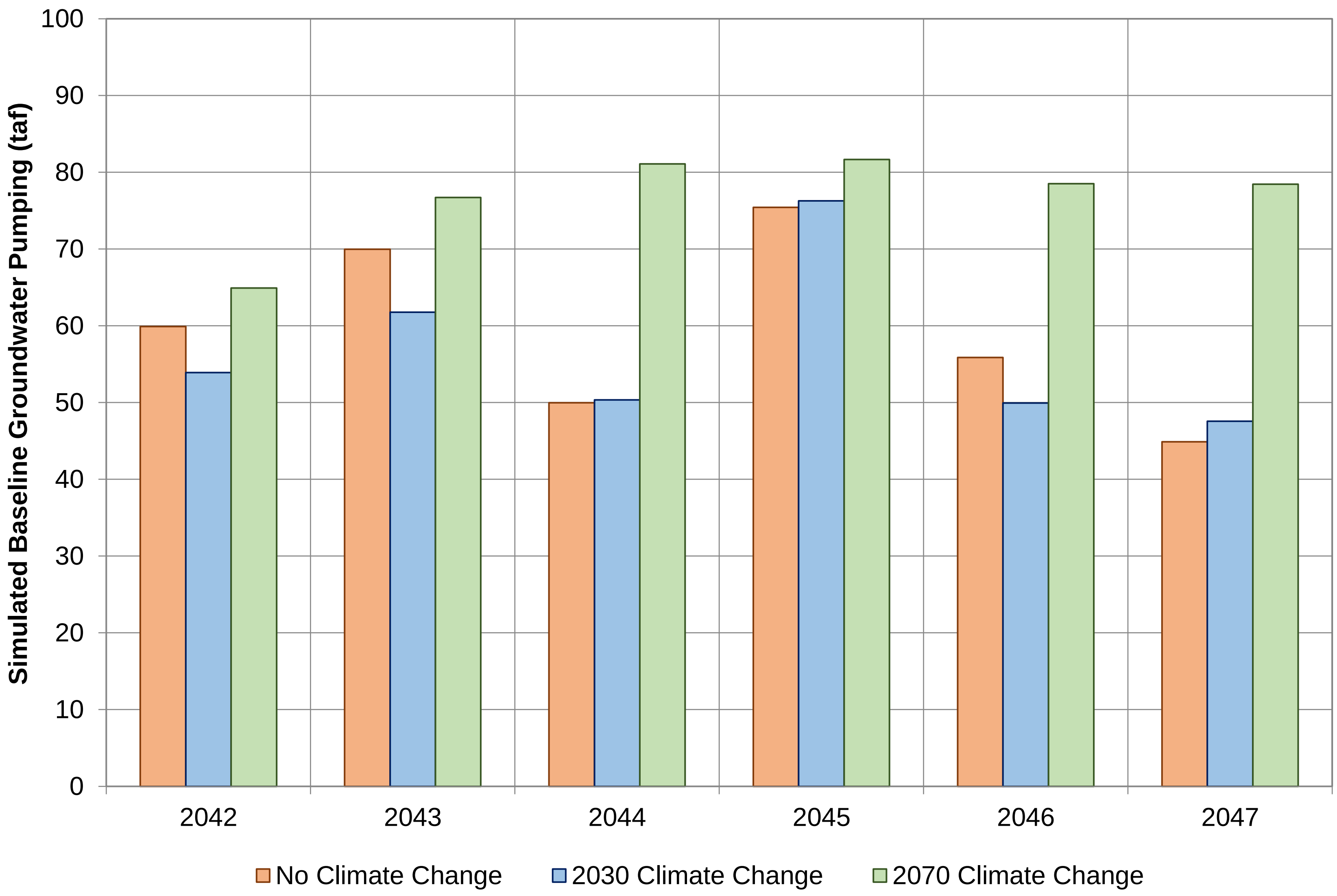
Subsidence Prone Areas and Production Wells Selected for Pumping Reduction

SGMA Sustainability Analyses
Westside Subbasin

Figure 5-23



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Consulting Engineers

Figure 5-24
Simulated Groundwater Pumping within Subsidence Prone Areas in Baseline Model Scenarios (2042 – 2047)

Table 5-1: Projected Surface Water Deliveries by USBR Water Contract Year (2020-2070)

Historic Water Year	Projected Water Year	Water Year Type[1]	CVP Allocation[2] (AF)	COA Benefit[3] (AF)	Total CVP Delivery (AF)	Supplemental WWD & W.U. Transfers[4] (AF)	Total Imported Water (AF)
-	2016	BN	9,000	-	9,000	247,000	256,000
-	2017	W	911,000	-	911,000	124,000	1,036,000
1963	2020	W	639,000	48,000	687,000	143,000	830,000
1964	2020	W	256,000	85,000	341,000	196,000	537,000
1965	2020	W	612,000	48,000	660,000	143,000	803,000
1966	2021	BN	653,000	67,000	720,000	143,000	863,000
1967	2022	W	1,159,000	48,000	1,207,000	98,000	1,305,000
1968	2023	BN	465,000	67,000	533,000	143,000	676,000
1969	2024	W	1,190,000	48,000	1,238,000	98,000	1,336,000
1970	2025	W	553,000	48,000	600,000	143,000	743,000
1971	2026	W	380,000	48,000	428,000	196,000	624,000
1972	2027	BN	154,000	67,000	222,000	151,000	373,000
1973	2028	AN	652,000	72,000	724,000	143,000	867,000
1974	2029	W	725,000	48,000	773,000	218,000	991,000
1975	2030	W	692,000	48,000	739,000	143,000	882,000
1976	2031	C	449,000	74,000	523,000	143,000	666,000
1977	2032	C	2,000	74,000	76,000	151,000	227,000
1978	2033	AN	626,000	72,000	698,000	143,000	841,000
1979	2034	BN	531,000	67,000	598,000	143,000	741,000
1980	2035	AN	694,000	72,000	766,000	218,000	984,000
1981	2036	D	528,000	85,000	613,000	143,000	756,000
1982	2037	W	1,040,000	48,000	1,088,000	98,000	1,186,000
1983	2038	W	1,190,000	48,000	1,238,000	98,000	1,336,000
1984	2039	W	693,000	48,000	740,000	143,000	883,000
1985	2040	D	429,000	85,000	514,000	143,000	657,000
1986	2041	W	557,000	48,000	604,000	143,000	747,000
1987	2042	D	93,000	85,000	178,000	151,000	329,000
1988	2043	C	2,000	74,000	76,000	151,000	227,000
1989	2044	D	209,000	85,000	295,000	196,000	491,000
1990	2045	C	2,000	74,000	76,000	151,000	227,000
1991	2046	C	173,000	74,000	247,000	151,000	398,000
1992	2047	C	237,000	74,000	311,000	196,000	507,000
1993	2048	AN	712,000	72,000	784,000	218,000	1,002,000
1994	2049	C	320,000	74,000	394,000	196,000	590,000
1995	2050	W	740,000	48,000	787,000	218,000	1,005,000
1996	2051	W	1,030,000	48,000	1,078,000	98,000	1,176,000
1997	2052	W	560,000	48,000	608,000	143,000	751,000
1998	2053	W	1,190,000	48,000	1,237,000	98,000	1,335,000
1999	2054	W	692,000	48,000	740,000	143,000	883,000
2000	2055	AN	495,000	72,000	567,000	143,000	710,000
2001	2056	D	116,000	85,000	201,000	151,000	352,000
2002	2057	D	328,000	85,000	414,000	196,000	610,000
2003	2058	AN	546,000	72,000	618,000	143,000	761,000
2004	2059	BN	605,000	67,000	672,000	143,000	815,000
2005	2060	AN	456,000	72,000	528,000	143,000	671,000
2006	2061	W	1,190,000	48,000	1,237,000	98,000	1,335,000
2007	2062	D	206,000	85,000	291,000	196,000	487,000
2008	2063	C	2,000	74,000	76,000	151,000	227,000
2009	2064	D	116,000	85,000	201,000	151,000	352,000
2010	2065	BN	425,000	67,000	492,000	196,000	688,000
2011	2066	W	553,000	48,000	600,000	143,000	743,000
2012	2067	BN	573,000	67,000	640,000	143,000	783,000
2013	2068	D	93,000	85,000	178,000	151,000	329,000
2014	2069	C	53,000	74,000	128,000	151,000	279,000
2015	2070	C	237,000	74,000	311,000	196,000	507,000
Annual Average			508,000	66,000	574,000	153,000	727,000
Percent of Allocation			43%	6%	48%	13%	61%

1. Sacramento Valley Water Year Type
2. Projected from Coordinated Long-Term Operation of the Central Valley Project and State Water Project
3. Estimated from 2018 Ammendment to Coordinated Operation Agreement
4. Estimated from Historic Supplemental Water Supply based on CVP Allocation

Table 5-2: Historic Surface Water Deliveries by USBR Water Contract Year (1989-2017)

WY	WY Index	CVP Allocation (%)	Net CVP (AF)	Water User Acquired (AF)	Supplemental District Supply (AF)	Total Supplemental Supply (AF)
1988	C	100%	1,150,000	7,657	97,712	105,369
1989	D	100%	1,035,369	20,530	99,549	120,079
1990	C	50%	625,196	18,502	-2,223	16,279
1991	C	27%	229,666	22,943	77,399	100,342
1992	C	27%	208,668	42,623	100,861	143,484
1993	AN	54%	682,833	152,520	82,511	235,031
1994	C	43%	458,281	56,541	108,083	164,624
1995	W	100%	1,021,719	57,840	121,747	179,587
1996	W	95%	994,935	92,953	172,609	265,562
1997	W	90%	968,408	94,908	261,085	355,993
1998	W	100%	945,115	54,205	162,684	216,889
1999	W	70%	806,040	178,632	111,144	289,776
2000	AN	65%	695,693	198,294	133,314	331,608
2001	D	49%	611,267	75,592	135,039	210,631
2002	D	70%	776,526	106,043	64,040	170,083
2003	AN	75%	863,150	107,958	32,518	140,476
2004	BN	70%	800,704	96,872	44,407	141,279
2005	AN	85%	996,147	20,776	98,347	119,123
2006	W	100%	1,076,461	45,936	38,079	84,015
2007	D	50%	647,864	87,554	61,466	149,020
2008	C	40%	347,222	85,421	102,862	188,283
2009	D	10%	202,991	68,070	70,149	138,219
2010	BN	45%	590,059	71,296	79,242	150,538
2011	W	80%	876,910	60,380	191,686	252,066
2012	BN	40%	405,451	111,154	123,636	234,790
2013	D	20%	188,448	101,413	143,962	245,375
2014	C	0%	98,573	59,714	26,382	86,096
2015	C	0%	82,429	51,134	34,600	85,734
2016	BN	5%	9,204	72,154	174,374	246,528
2017	W	100%	911,307	-50,009	174,490	124,481

Table 5-3: Projected 2070 Climate Change Surface Water Deliveries by USBR Water Contract Year (2020-2070)

Historic Water Year	Projected Water Year	Water Year Type[1]	CVP Allocation[2] (TAF)	COA Benefit[3] (TAF)	Total CVP Delivery (TAF)	Supplemental WWD & W.U. Transfers[4] (TAF)	Total Imported Water (TAF)
-	2016	BN	9,000	-	9,000	247,000	256,000
-	2017	W	911,000	-	911,000	124,000	1,036,000
1963	2018	W	592,000	48,000	640,000	143,000	783,000
1964	2019	D	50,000	85,000	135,000	151,000	286,000
1965	2020	W	327,000	48,000	375,000	196,000	571,000
1966	2021	BN	289,000	67,000	356,000	196,000	552,000
1967	2022	W	874,000	48,000	921,000	218,000	1,139,000
1968	2023	BN	371,000	67,000	438,000	196,000	634,000
1969	2024	W	821,000	48,000	869,000	218,000	1,087,000
1970	2025	W	352,000	48,000	400,000	196,000	596,000
1971	2026	W	281,000	48,000	329,000	196,000	525,000
1972	2027	BN	2,000	67,000	69,000	151,000	220,000
1973	2028	AN	353,000	72,000	425,000	196,000	621,000
1974	2029	W	446,000	48,000	494,000	196,000	690,000
1975	2030	W	525,000	48,000	572,000	143,000	715,000
1976	2031	C	151,000	74,000	226,000	151,000	377,000
1977	2032	C	1,000	74,000	76,000	151,000	227,000
1978	2033	AN	412,000	72,000	484,000	196,000	680,000
1979	2034	BN	379,000	67,000	446,000	196,000	642,000
1980	2035	AN	427,000	72,000	499,000	196,000	695,000
1981	2036	D	400,000	85,000	486,000	196,000	682,000
1982	2037	W	693,000	48,000	741,000	143,000	884,000
1983	2038	W	1,190,000	48,000	1,238,000	98,000	1,336,000
1984	2039	W	483,000	48,000	530,000	143,000	673,000
1985	2040	D	275,000	85,000	360,000	196,000	556,000
1986	2041	W	331,000	48,000	378,000	196,000	574,000
1987	2042	D	110,000	85,000	195,000	151,000	346,000
1988	2043	C	2,000	74,000	76,000	151,000	227,000
1989	2044	D	2,000	85,000	87,000	151,000	238,000
1990	2045	C	2,000	74,000	76,000	151,000	227,000
1991	2046	C	2,000	74,000	76,000	151,000	227,000
1992	2047	C	1,000	74,000	76,000	151,000	227,000
1993	2048	AN	477,000	72,000	549,000	143,000	692,000
1994	2049	C	230,000	74,000	304,000	196,000	500,000
1995	2050	W	464,000	48,000	512,000	143,000	655,000
1996	2051	W	845,000	48,000	893,000	218,000	1,111,000
1997	2052	W	347,000	48,000	394,000	196,000	590,000
1998	2053	W	1,189,000	48,000	1,237,000	98,000	1,335,000
1999	2054	W	494,000	48,000	542,000	143,000	685,000
2000	2055	AN	488,000	72,000	560,000	143,000	703,000
2001	2056	D	2,000	85,000	87,000	151,000	238,000
2002	2057	D	232,000	85,000	317,000	196,000	513,000
2003	2058	AN	389,000	72,000	461,000	196,000	657,000
2004	2059	BN	282,000	67,000	349,000	196,000	545,000
2005	2060	AN	455,000	72,000	528,000	143,000	671,000
2006	2061	W	1,189,000	48,000	1,237,000	98,000	1,335,000
2007	2062	D	203,000	85,000	288,000	196,000	484,000
2008	2063	C	2,000	74,000	76,000	151,000	227,000
2009	2064	D	2,000	85,000	87,000	151,000	238,000
2010	2065	BN	312,000	67,000	379,000	196,000	575,000
2011	2066	W	352,000	48,000	400,000	196,000	596,000
2012	2067	BN	327,000	67,000	394,000	196,000	590,000
2013	2068	D	110,000	85,000	195,000	151,000	346,000
2014	2069	C	2,000	74,000	76,000	151,000	227,000
2015	2070	C	1,000	74,000	76,000	151,000	227,000
Annual Average			351,000	66,000	416,000	170,000	586,000
Percent of Allocation			29%	6%	35%	14%	49%

1. Sacramento Valley Water Year Type
2. Projected from Coordinated Long-Term Operation of the Central Valley Project and State Water Project
3. Estimated from 2018 Ammendment to Coordinated Operation Agreement
4. Estimated from Historic Supplemental Water Supply based on CVP Allocation

Table 5-4: Amount of Injected Surface Water Specified in No Climate Change and 2030 Climate Change Projections (2020-2070)

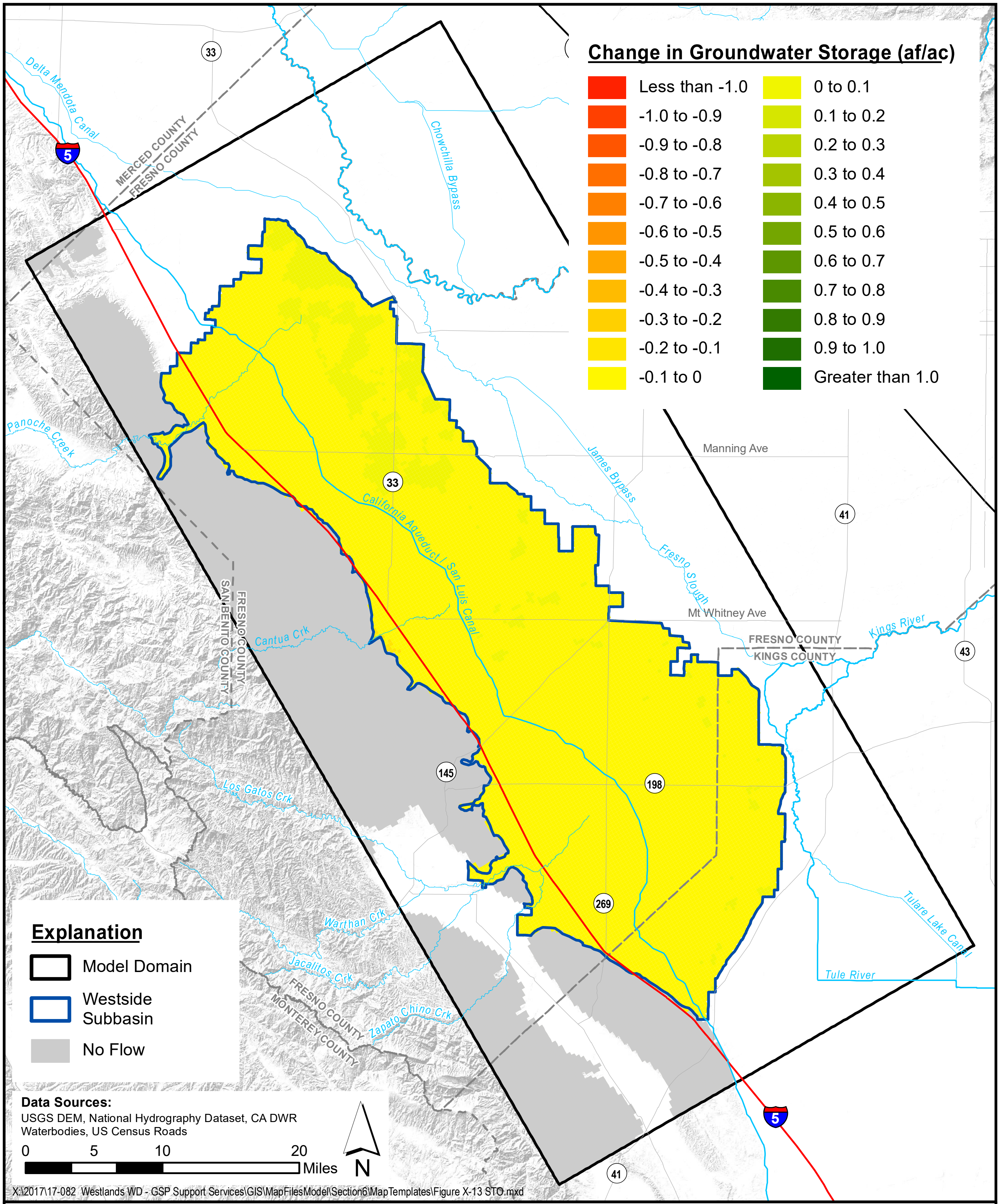
Historic Water Year	Projected Water Year	Water Year Type[1]	CVP Allocation[2] (AF)	Percent of CVP Contract	Supplemental Imports for Recharge[3] (af)	Flood Flows[4] (af)	Total Imports for Recharge Projects (af)
1965	2020	W	659,610	55%	0	36,407	36,407
1966	2021	BN	719,866	60%	50,000	0	50,000
1967	2022	W	1,206,971	101%	50,000	50,000	100,000
1968	2023	BN	532,524	45%	0	0	0
1969	2024	W	1,237,747	104%	50,000	38,357	88,357
1970	2025	W	600,147	50%	0	0	0
1971	2026	W	427,796	36%	0	0	0
1972	2027	BN	221,652	19%	0	0	0
1973	2028	AN	723,664	61%	50,000	0	50,000
1974	2029	W	772,602	65%	50,000	1,405	51,405
1975	2030	W	739,325	62%	50,000	36,379	86,379
1976	2031	C	522,907	44%	0	0	0
1977	2032	C	75,787	6%	0	0	0
1978	2033	AN	698,149	59%	0	47,002	47,002
1979	2034	BN	597,878	50%	0	1,583	1,583
1980	2035	AN	765,919	64%	50,000	50,000	100,000
1981	2036	D	612,916	52%	0	0	0
1982	2037	W	1,088,035	91%	50,000	0	50,000
1983	2038	W	1,237,755	104%	50,000	50,000	100,000
1984	2039	W	740,192	62%	50,000	50,000	100,000
1985	2040	D	514,264	43%	0	0	0
1986	2041	W	604,368	51%	0	45,765	45,765
1987	2042	D	178,255	15%	0	0	0
1988	2043	C	76,018	6%	0	0	0
1989	2044	D	294,805	25%	0	0	0
1990	2045	C	76,018	6%	0	0	0
1991	2046	C	247,039	21%	0	0	0
1992	2047	C	311,279	26%	0	0	0
1993	2048	AN	783,771	66%	50,000	0	50,000
1994	2049	C	394,138	33%	0	0	0
1995	2050	W	787,104	66%	50,000	29,405	79,405
1996	2051	W	1,077,821	91%	50,000	18,915	68,915
1997	2052	W	607,566	51%	0	50,000	50,000
1998	2053	W	1,237,316	104%	50,000	41,808	91,808
1999	2054	W	739,869	62%	50,000	27,872	77,872
2000	2055	AN	566,993	48%	0	0	0
2001	2056	D	201,435	17%	0	0	0
2002	2057	D	413,523	35%	0	627	627
2003	2058	AN	618,489	52%	0	0	0
2004	2059	BN	672,277	56%	0	0	0
2005	2060	AN	527,751	44%	0	0	0
2006	2061	W	1,237,316	104%	50,000	0	50,000
2007	2062	D	291,483	24%	0	0	0
2008	2063	C	76,018	6%	0	0	0
2009	2064	D	201,435	17%	0	0	0
2010	2065	BN	492,274	41%	0	0	0
2011	2066	W	600,147	50%	0	50,000	50,000
2012	2067	BN	640,249	54%	0	0	0
2013	2068	D	178,255	15%	0	0	0
2014	2069	C	127,664	11%	0	0	0
2015	2070	C	311,279	26%	0	0	0
Annual Average			573,876	48%	15,686	12,265	27,951

1. Sacramento Valley Water Year Type
2. Total CVP Allocation (Includes COA and Reassignment Contracts)
3. District Imports for Recharge Projects. Equals 50,000 AF When CVP Allocation Greater than 60% of Contract Amount (1,190,000 AFY)
4. Calculated from projected flows at the James Bypass. Flood flows cannot be stored so are limited to 35,600 AF per month based on max injection rate of 650 GPM in 400 wells in months when they are available. Conveyance through CVP facilities limited to 50,000 AF per year (FONSI 17-023).

Table 5-5: Amount of Injected Surface Water Specified in No Climate Change and 2070 Climate Change Projections (2020-2070)

Historic Water Year	Projected Water Year	Water Year Type[1]	CVP Allocation[2] (AF)	Percent of CVP Contract	Supplemental Imports for Recharge[3] (af)	Flood Flows[4] (af)	Total Imports for Recharge Projects (af)
1965	2020	W	374,871	32%	0	35,922	35,922
1966	2021	BN	356,173	30%	0	0	0
1967	2022	W	921,125	77%	50,000	50,000	100,000
1968	2023	BN	437,908	37%	0	631	631
1969	2024	W	868,955	73%	50,000	50,000	100,000
1970	2025	W	399,841	34%	0	337	337
1971	2026	W	328,661	28%	0	0	0
1972	2027	BN	69,018	6%	0	0	0
1973	2028	AN	425,316	36%	0	107	107
1974	2029	W	493,729	41%	0	9,166	9,166
1975	2030	W	572,340	48%	50,000	37,652	87,652
1976	2031	C	225,699	19%	0	0	0
1977	2032	C	75,549	6%	0	0	0
1978	2033	AN	483,631	41%	0	50,000	50,000
1979	2034	BN	446,102	37%	0	10,375	10,375
1980	2035	AN	498,718	42%	0	50,000	50,000
1981	2036	D	485,543	41%	0	0	0
1982	2037	W	740,697	62%	50,000	0	50,000
1983	2038	W	1,237,924	104%	50,000	50,000	100,000
1984	2039	W	530,338	45%	50,000	50,000	100,000
1985	2040	D	360,090	30%	0	0	0
1986	2041	W	378,374	32%	0	50,000	50,000
1987	2042	D	195,227	16%	0	0	0
1988	2043	C	76,018	6%	0	0	0
1989	2044	D	87,218	7%	0	0	0
1990	2045	C	75,837	6%	0	0	0
1991	2046	C	76,018	6%	0	0	0
1992	2047	C	75,570	6%	0	0	0
1993	2048	AN	549,462	46%	50,000	0	50,000
1994	2049	C	303,990	26%	0	0	0
1995	2050	W	511,901	43%	50,000	35,619	85,619
1996	2051	W	892,626	75%	50,000	45,935	95,935
1997	2052	W	394,269	33%	0	50,000	50,000
1998	2053	W	1,236,979	104%	50,000	48,496	98,496
1999	2054	W	542,049	46%	50,000	27,374	77,374
2000	2055	AN	560,147	47%	50,000	0	50,000
2001	2056	D	87,218	7%	0	1,871	1,871
2002	2057	D	317,321	27%	0	1,593	1,593
2003	2058	AN	461,180	39%	0	0	0
2004	2059	BN	349,094	29%	0	0	0
2005	2060	AN	527,540	44%	50,000	0	50,000
2006	2061	W	1,236,979	104%	50,000	0	50,000
2007	2062	D	288,069	24%	0	0	0
2008	2063	C	76,018	6%	0	0	0
2009	2064	D	87,218	7%	0	0	0
2010	2065	BN	379,241	32%	0	99	99
2011	2066	W	399,841	34%	0	50,000	50,000
2012	2067	BN	394,020	33%	0	0	0
2013	2068	D	195,227	16%	0	0	0
2014	2069	C	76,018	6%	0	0	0
2015	2070	C	75,570	6%	0	0	0
Annual Average			416,441	35%	13,725	13,827	27,552

1. Sacramento Valley Water Year Type
2. Total CVP Allocation (Includes COA and Reassignment Contracts)
3. District Imports for Recharge Projects. Equals 50,000 AF When CVP Allocation Greater than 60% of Contract Amount (1,190,000 AFY)
4. Calculated from projected flows at the James Bypass. Flood flows cannot be stored so are limited to 35,600 AF per month based on max injection rate of 650 GPM in 400 wells in months when they are available. Conveyance through CVP facilities limited to 50,000 AF per year (FONSI 17-023).



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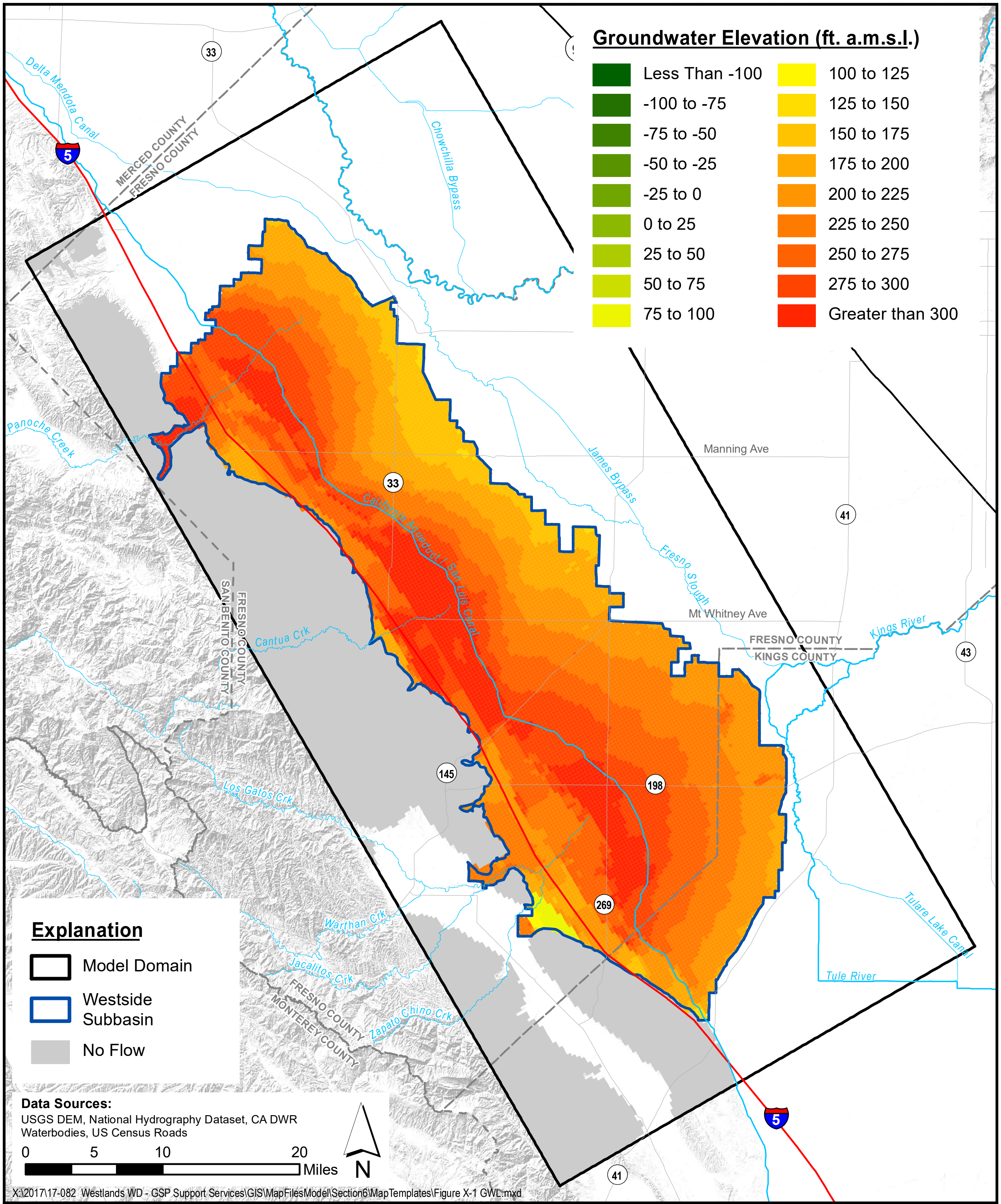
Simulated Change in Groundwater Storage
January 2016 to January 2017

SGMA Sustainability Analyses
Westside Subbasin

Figure 6-1



Data Sources:
USGS DEM, National Hydrography Dataset, CA DWR Waterbodies, US Census Roads

X:\2017\17-082 Westlands WD - GSP Support Services\GIS\MapFilesModel\Section6\MapTemplates\Figure X-1 GWL.mxd

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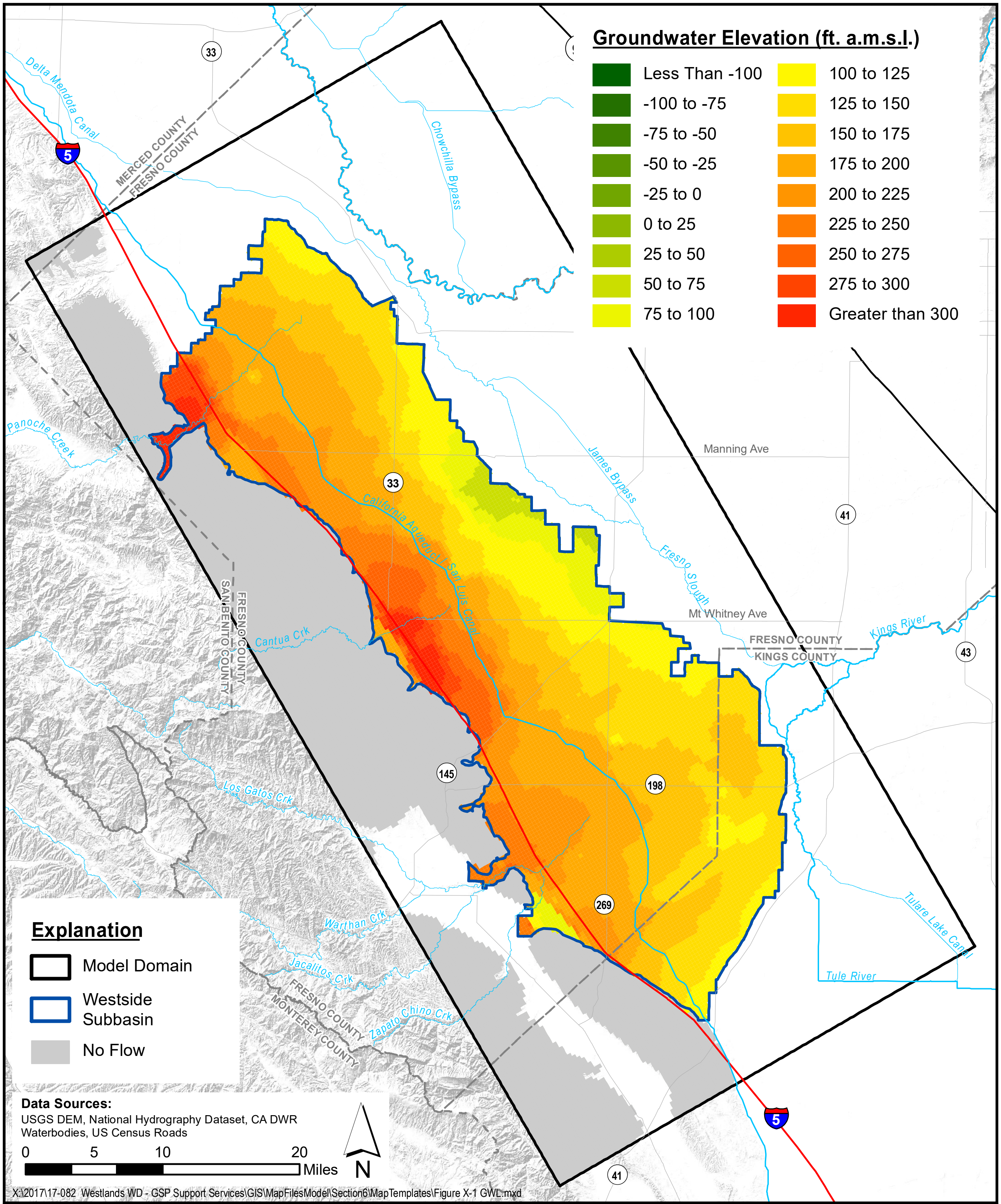
Simulated Groundwater Elevation - Shallow Aquifer January 2016

Figure 6-2

SGMA Sustainability Analyses
Westside Subbasin



Data Sources:
USGS DEM, National Hydrography Dataset, CA DWR Waterbodies, US Census Roads

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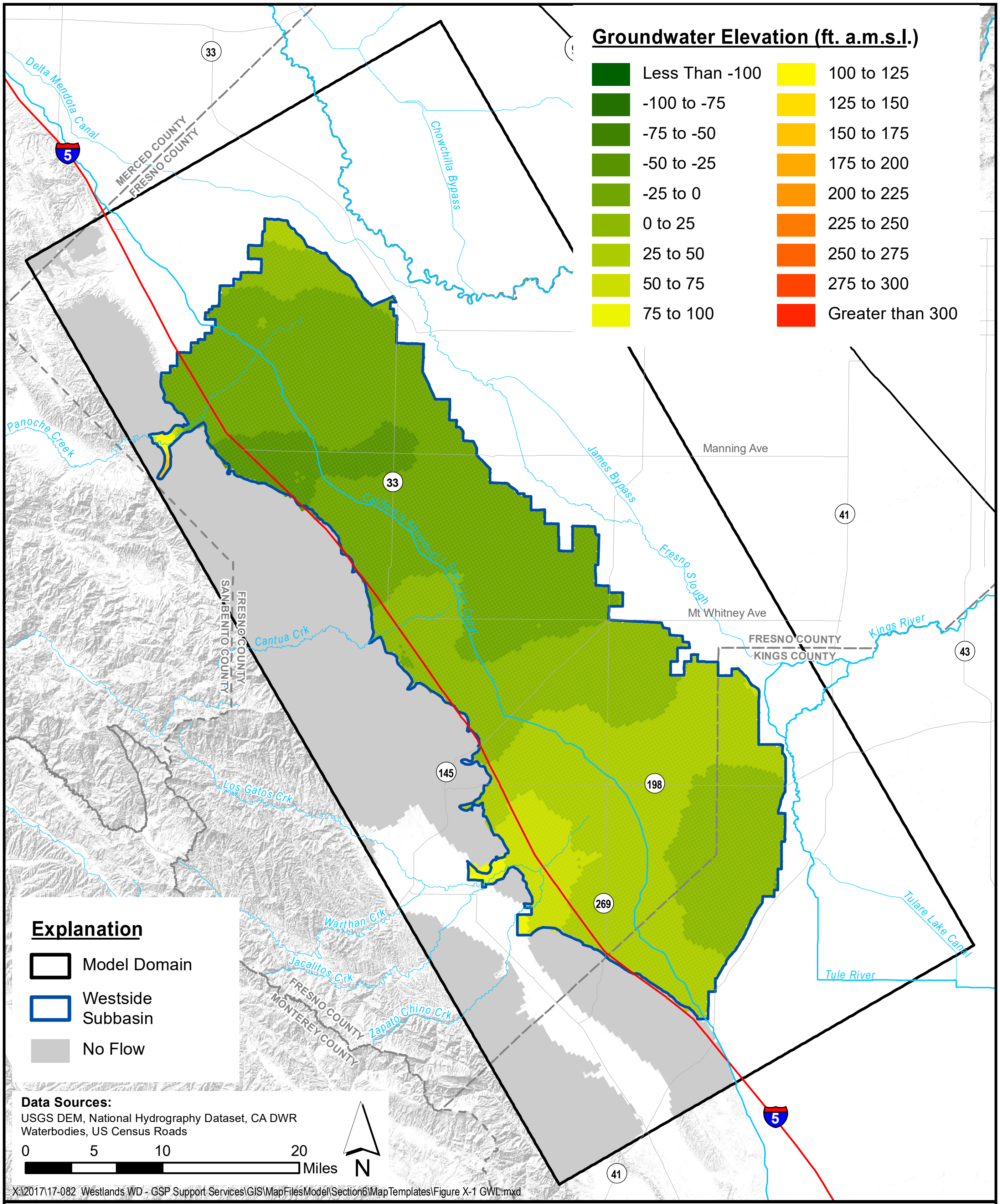
Simulated Groundwater Elevation - Upper Aquifer January 2016

SGMA Sustainability Analyses
Westside Subbasin

Figure 6-3



Data Sources:
USGS DEM, National Hydrography Dataset, CA DWR Waterbodies, US Census Roads

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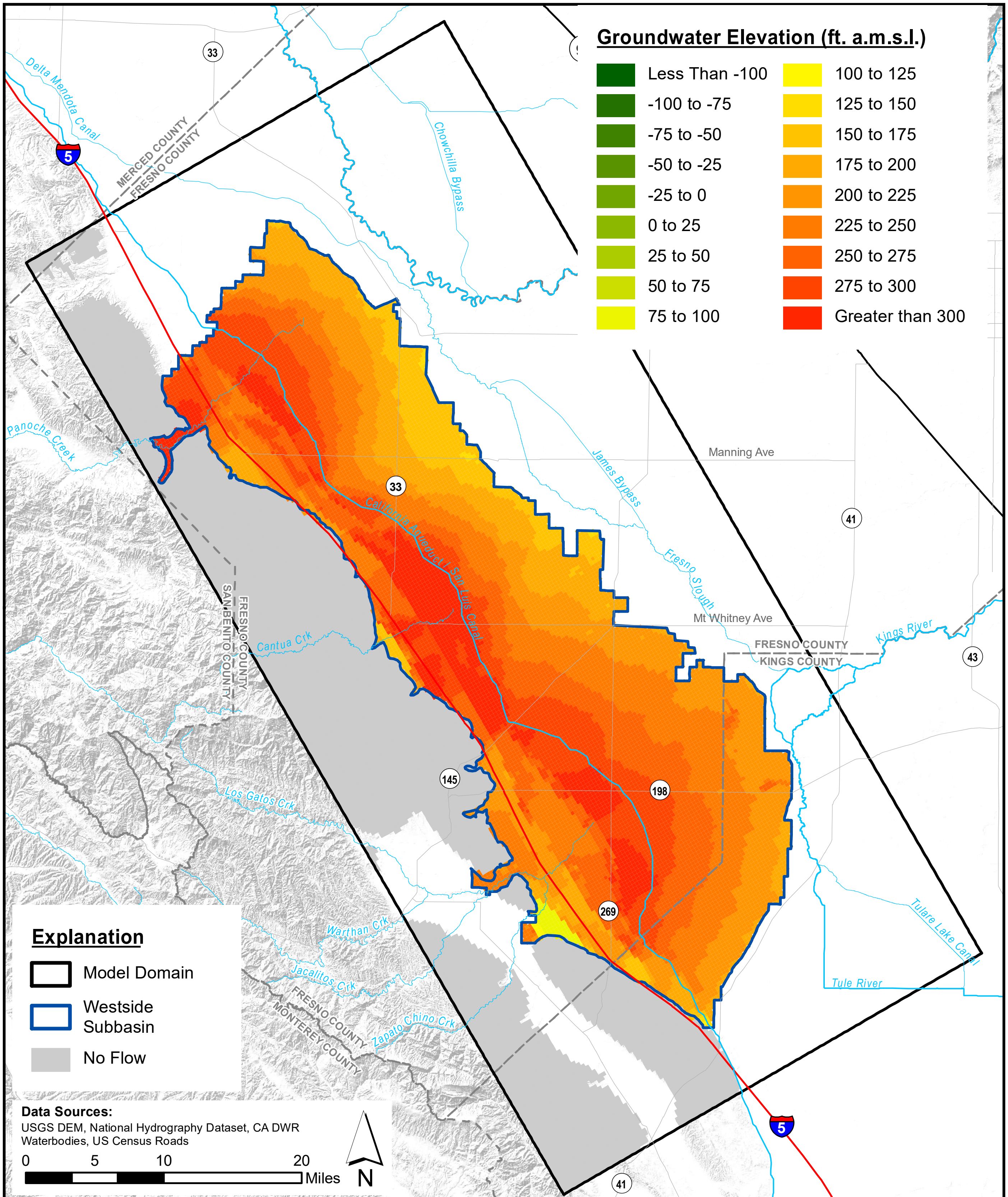
Simulated Groundwater Elevation - Lower Aquifer
January 2016

Figure 6-4

SGMA Sustainability Analyses
Westside Subbasin



Data Sources:
USGS DEM, National Hydrography Dataset, CA DWR Waterbodies, US Census Roads

X:\2017\17-082 Westlands WD - GSP Support Services\GIS\MapFilesModel\Section6\MapTemplates\Figure X-1 GWL.mxd

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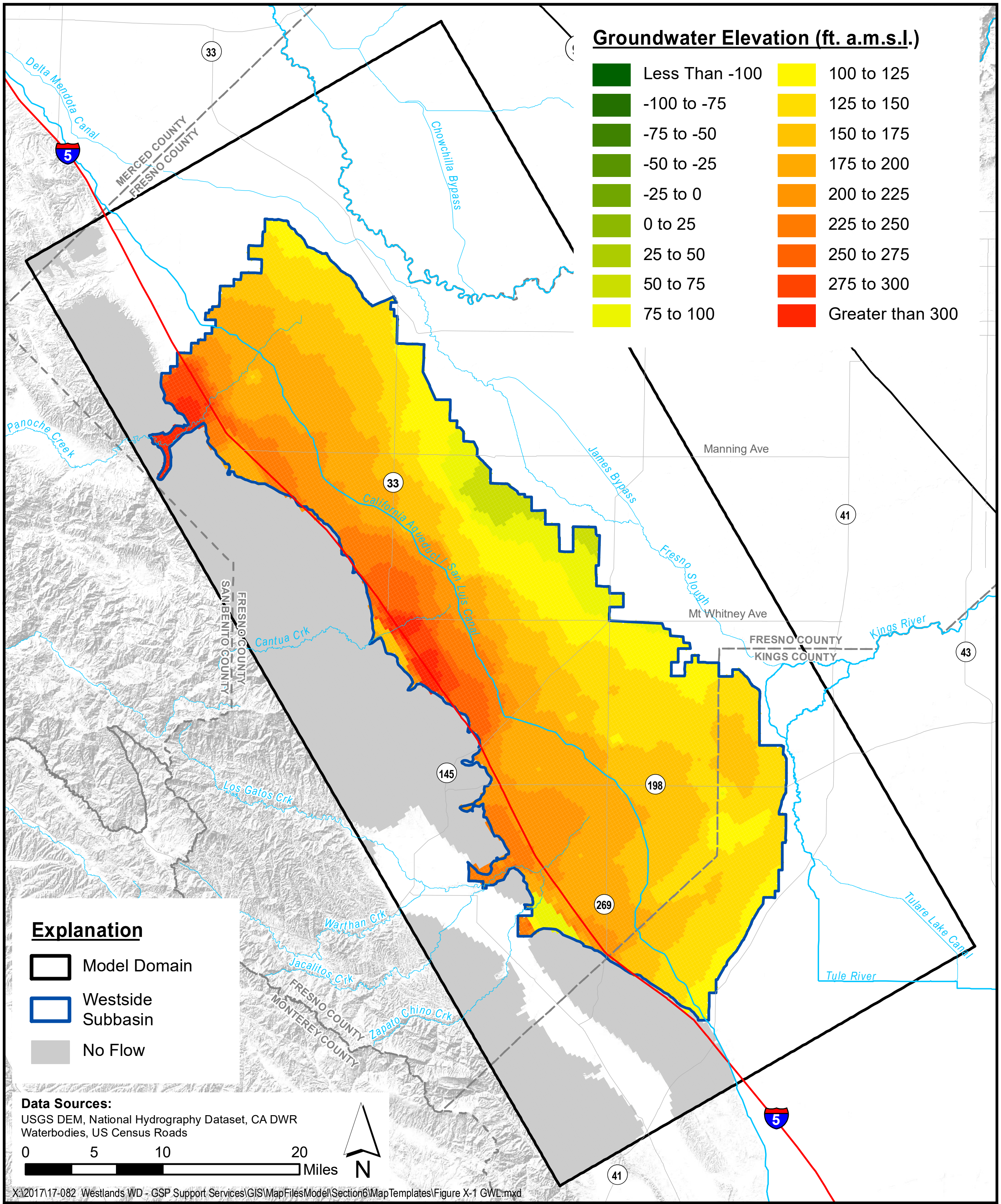
Simulated Groundwater Elevation - Shallow Aquifer
January 2017

Figure 6-5

SGMA Sustainability Analyses
Westside Subbasin



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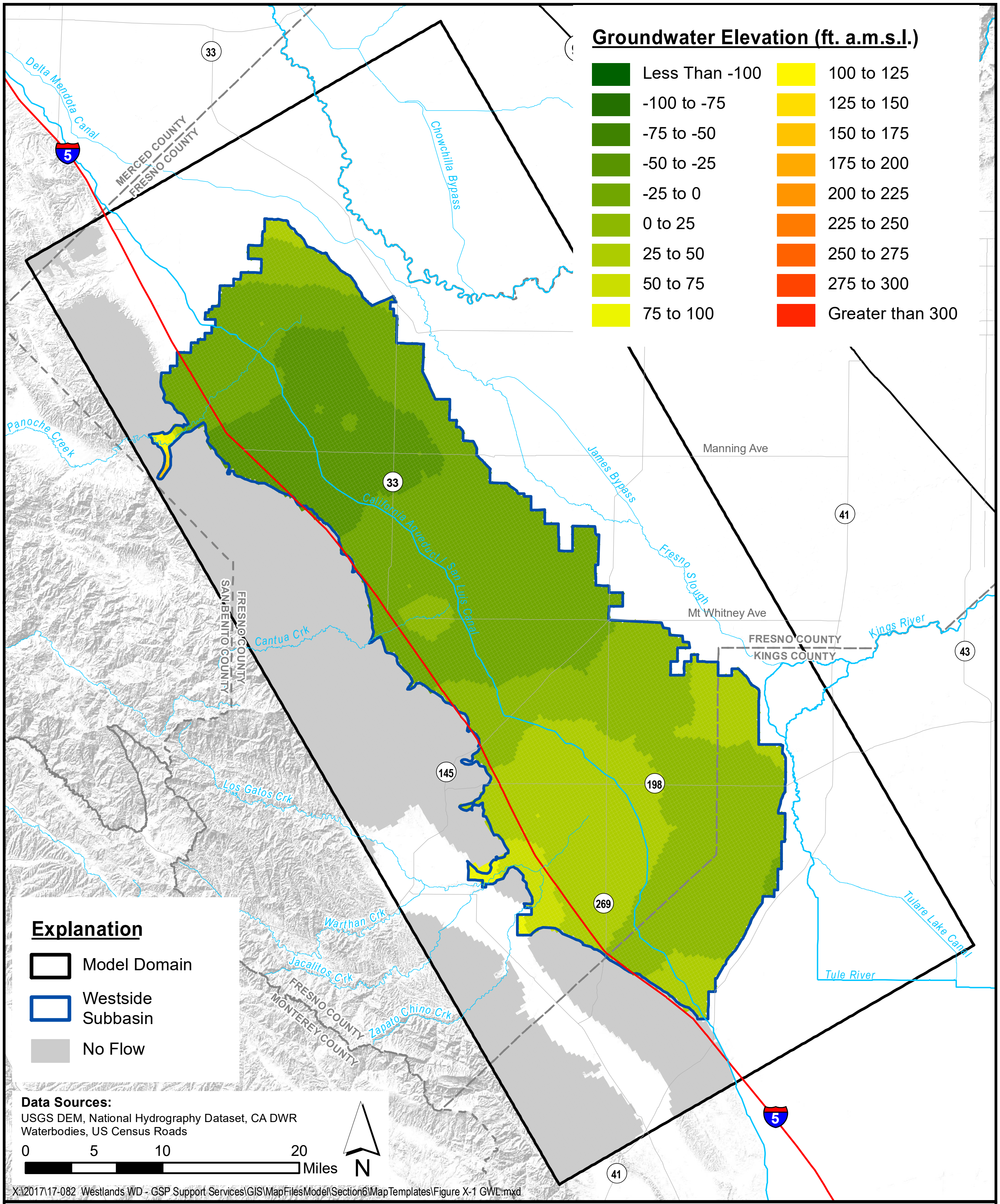
Simulated Groundwater Elevation - Upper Aquifer
January 2017

Figure 6-6

SGMA Sustainability Analyses
Westside Subbasin



Data Sources:
USGS DEM, National Hydrography Dataset, CA DWR Waterbodies, US Census Roads

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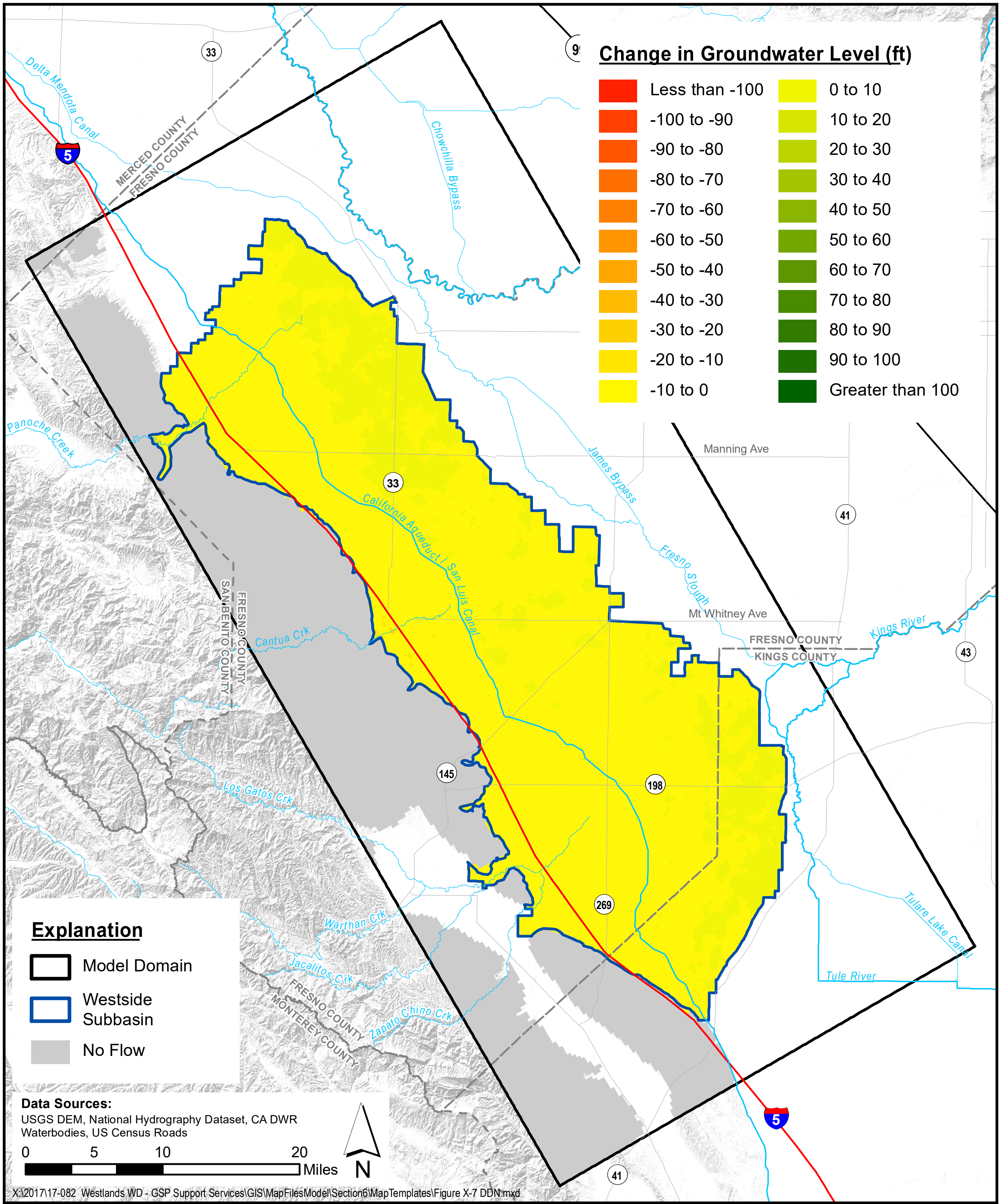
Simulated Groundwater Elevation - Lower Aquifer January 2017

SGMA Sustainability Analyses
Westside Subbasin

Figure 6-7



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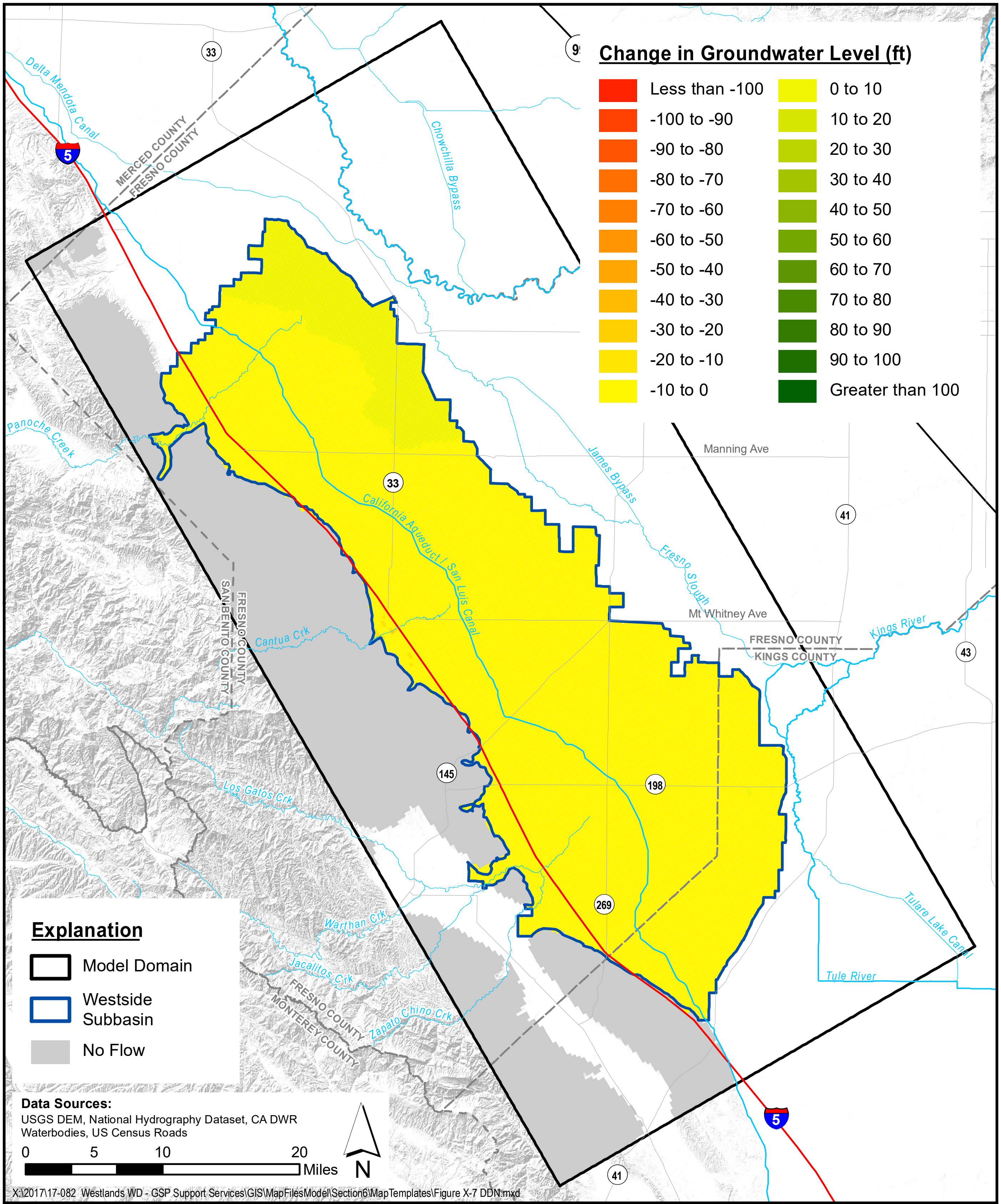
Simulated Change in Groundwater Elevation - Shallow Aquifer January 2016 to January 2017

Figure 6-8

SGMA Sustainability Analyses
Westside Subbasin



Data Sources:
USGS DEM, National Hydrography Dataset, CA DWR Waterbodies, US Census Roads

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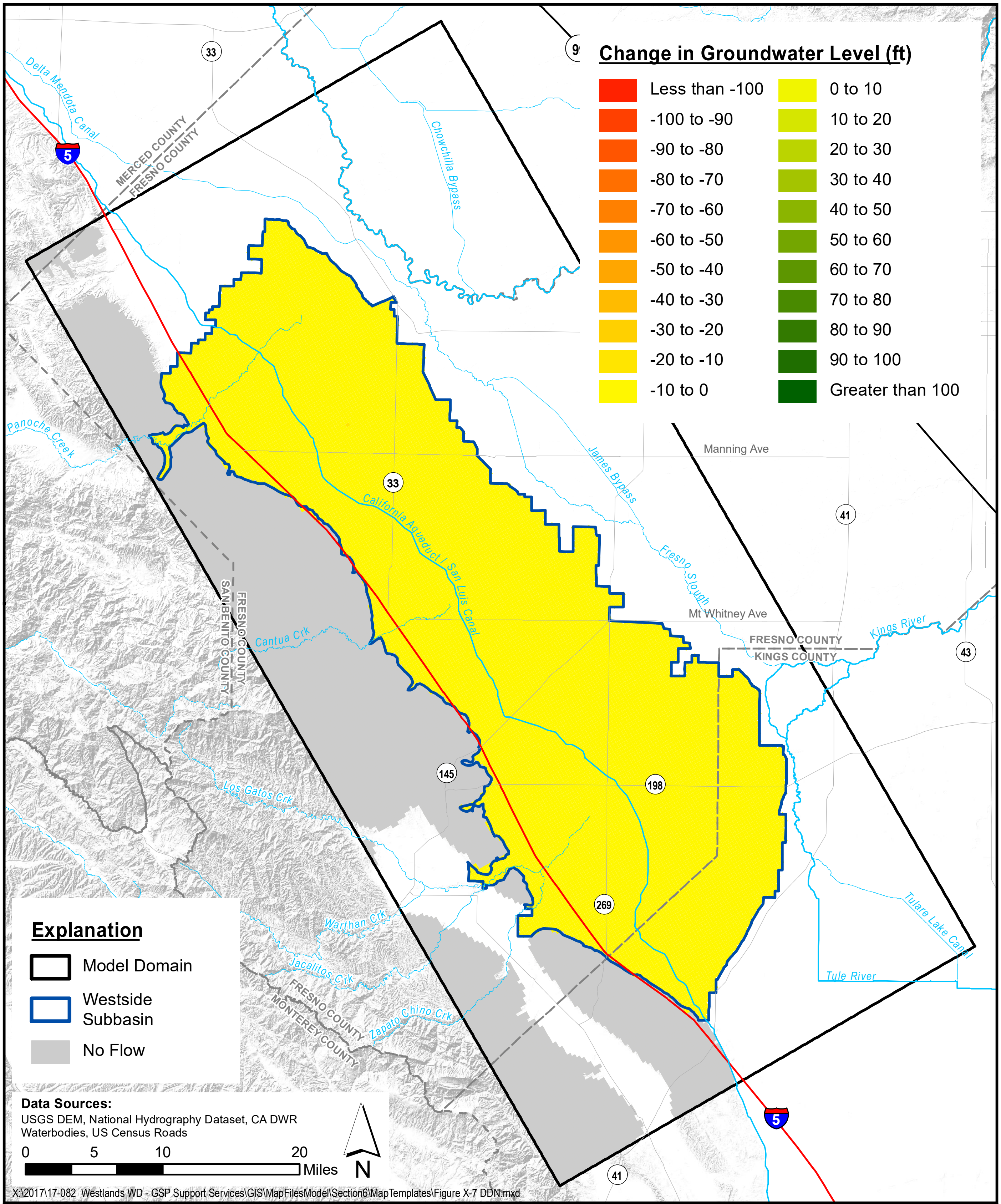
Simulated Change in Groundwater Elevation - Upper Aquifer January 2016 to January 2017

Figure 6-9

SGMA Sustainability Analyses
Westside Subbasin



Data Sources:
USGS DEM, National Hydrography Dataset, CA DWR Waterbodies, US Census Roads

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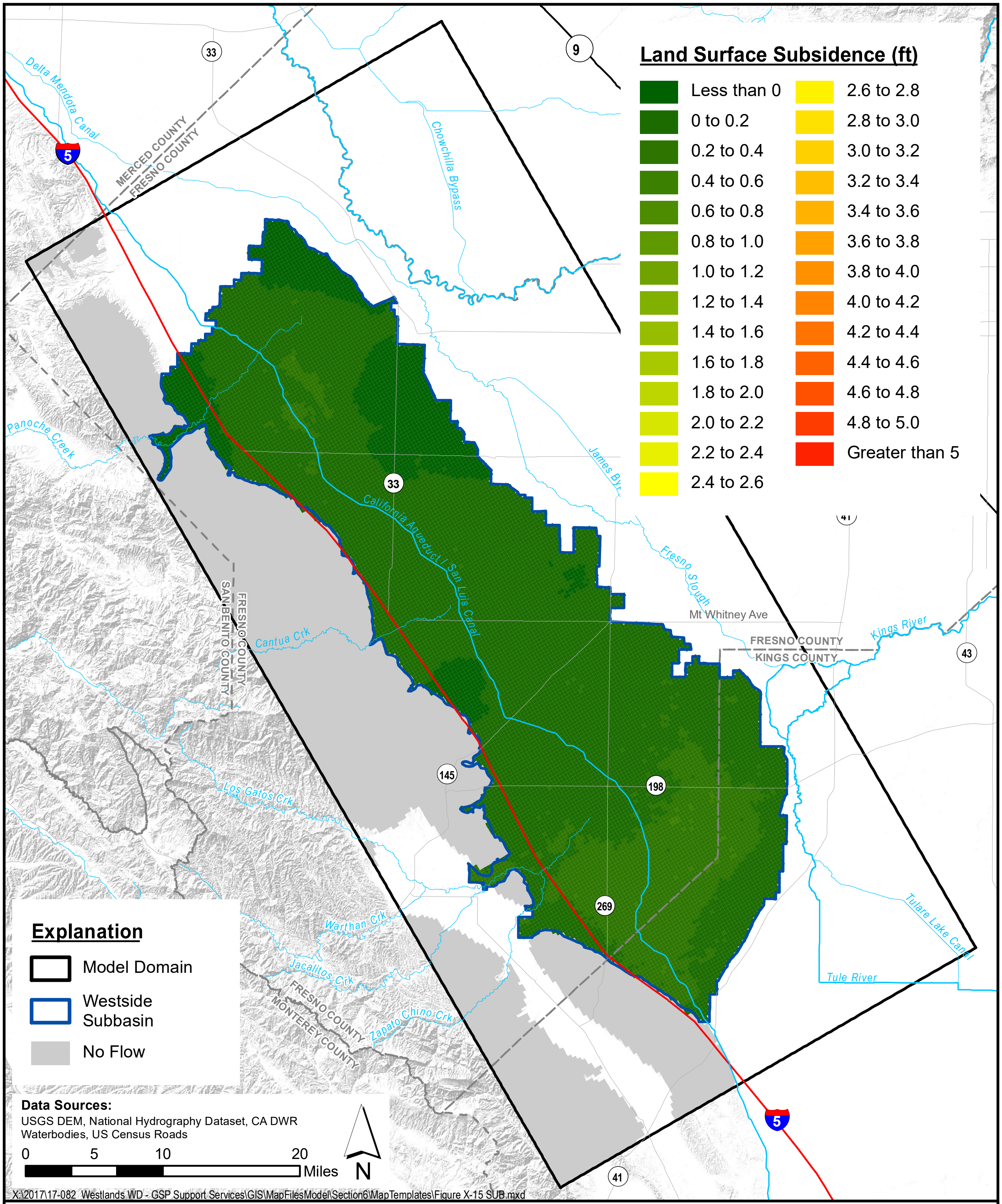
Simulated Change in Groundwater Elevation - Lower Aquifer
January 2016 to January 2017

Figure 6-10

SGMA Sustainability Analyses
Westside Subbasin



Data Sources:
USGS DEM, National Hydrography Dataset, CA DWR Waterbodies, US Census Roads

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Simulated Land Surface Subsidence
January 2016 to January 2017

SGMA Sustainability Analyses
Westside Subbasin

Figure 6-11

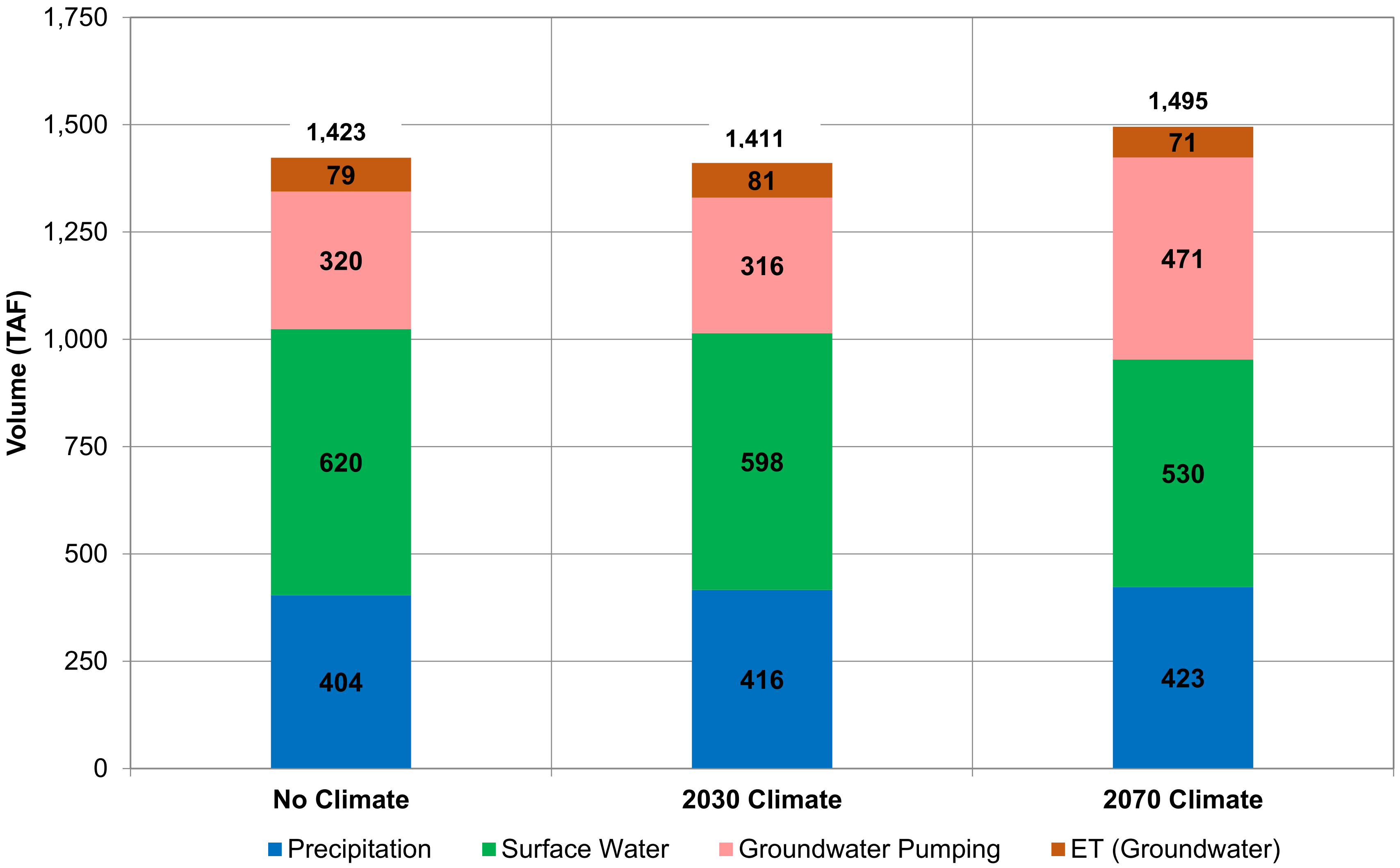

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Figure 7-1
Baseline Average Subbasin Land Surface System Inflows
2020-2070

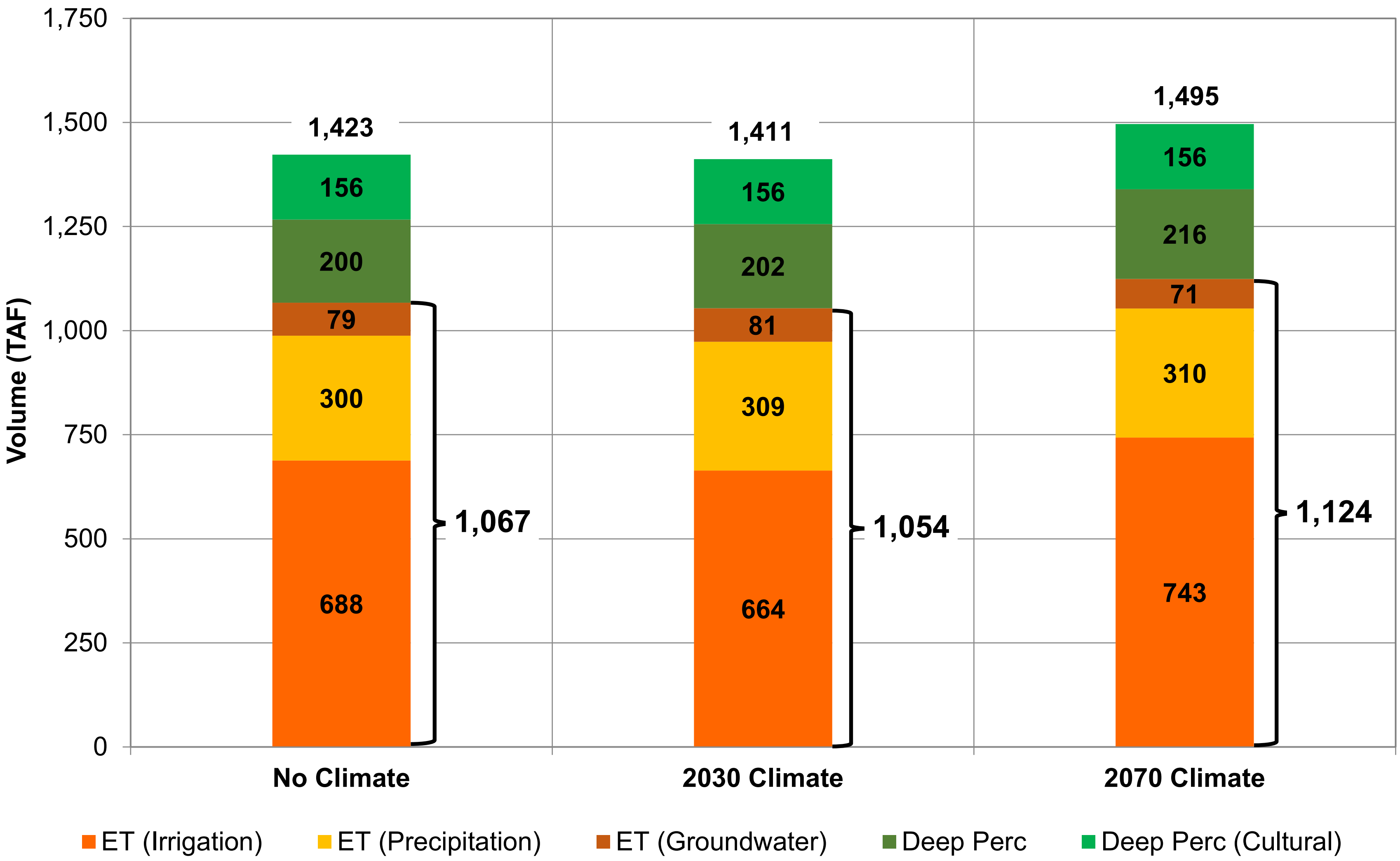

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Figure 7-2
Baseline Average Subbasin Land Surface System Outflows
2020-2070

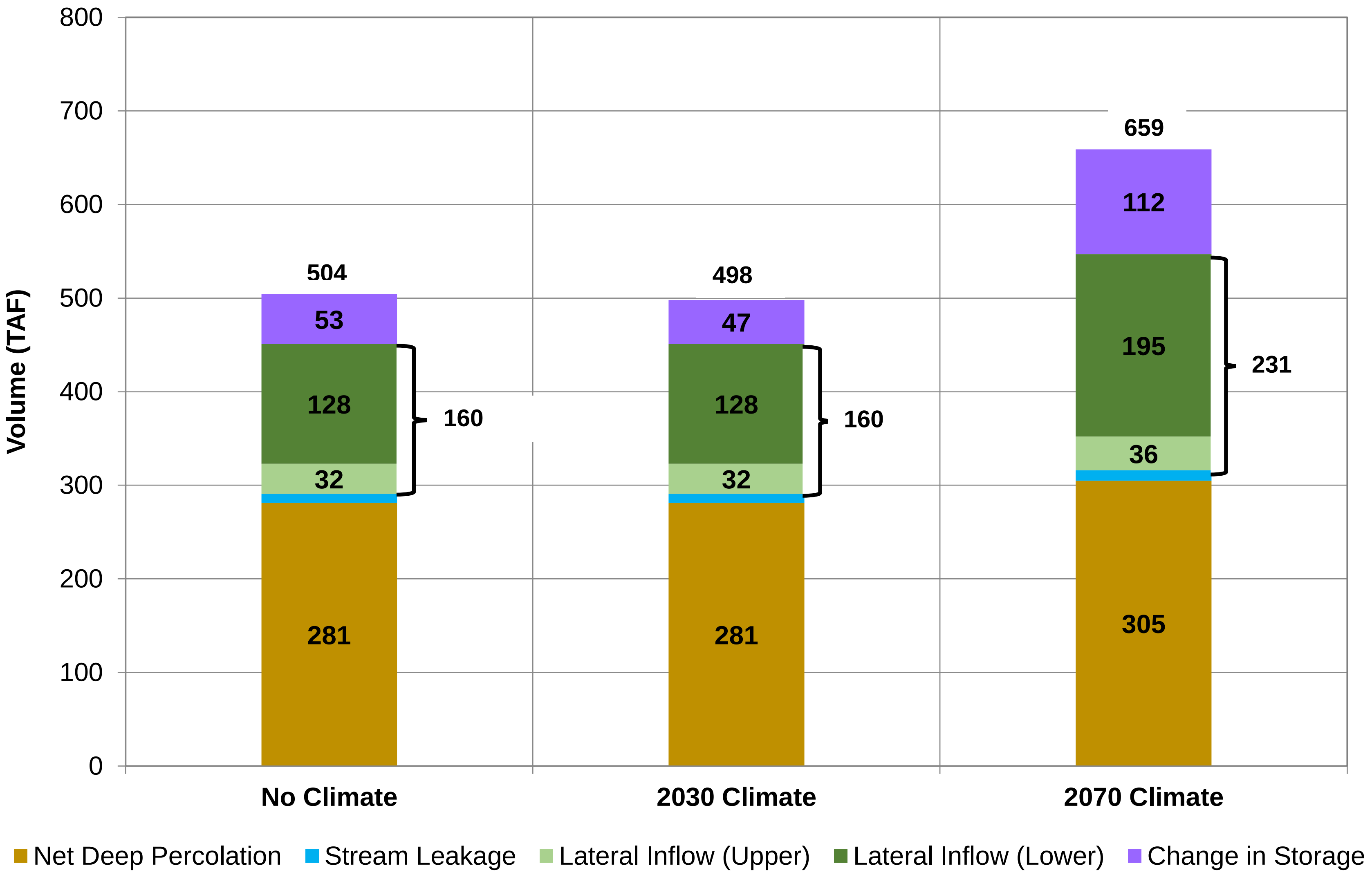

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Figure 7-3
Baseline Average Subbasin Groundwater Budget Inflows
2020-2070

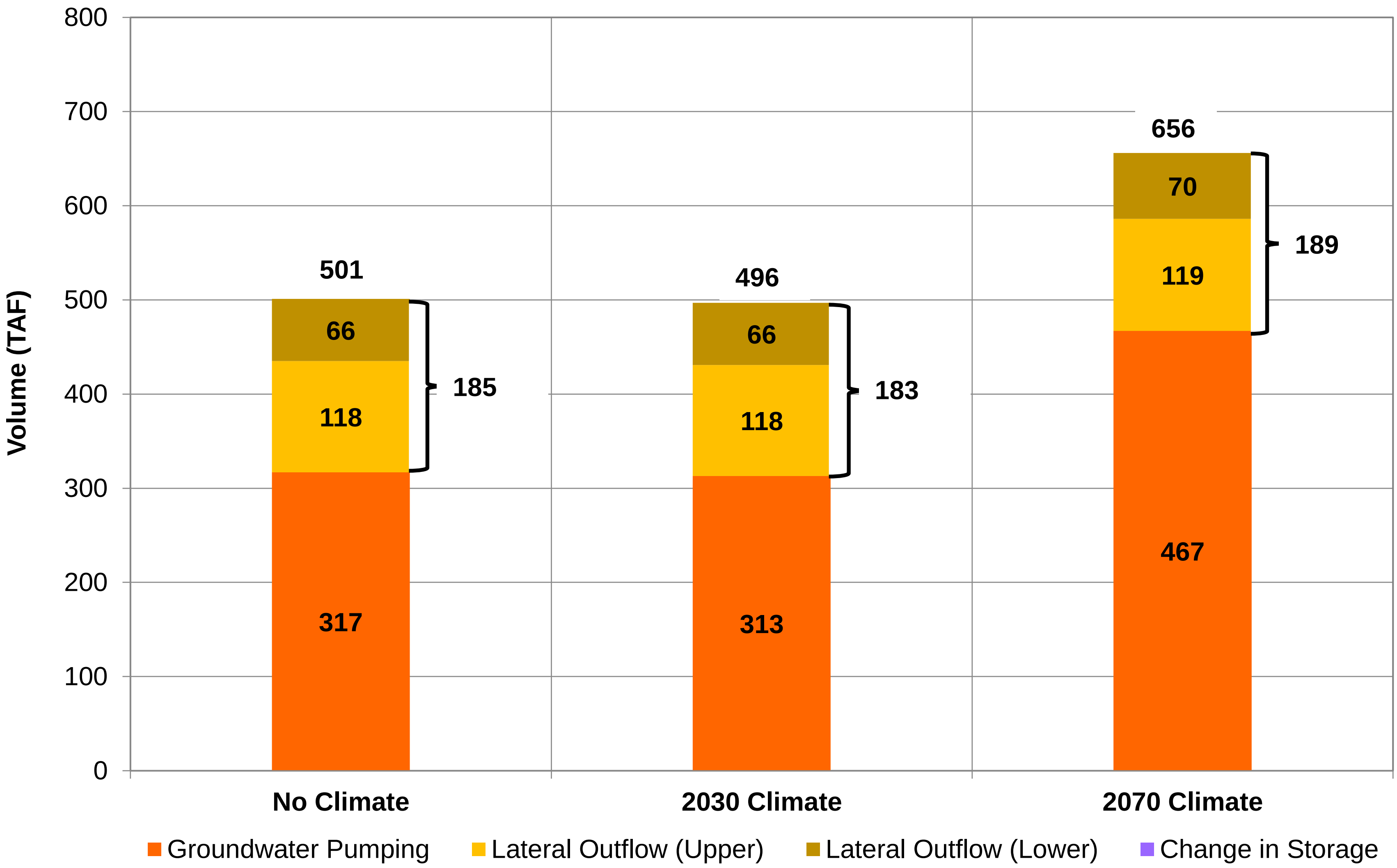

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Figure 7-4
Baseline Average Subbasin Groundwater Budget Outflows
2020-2070

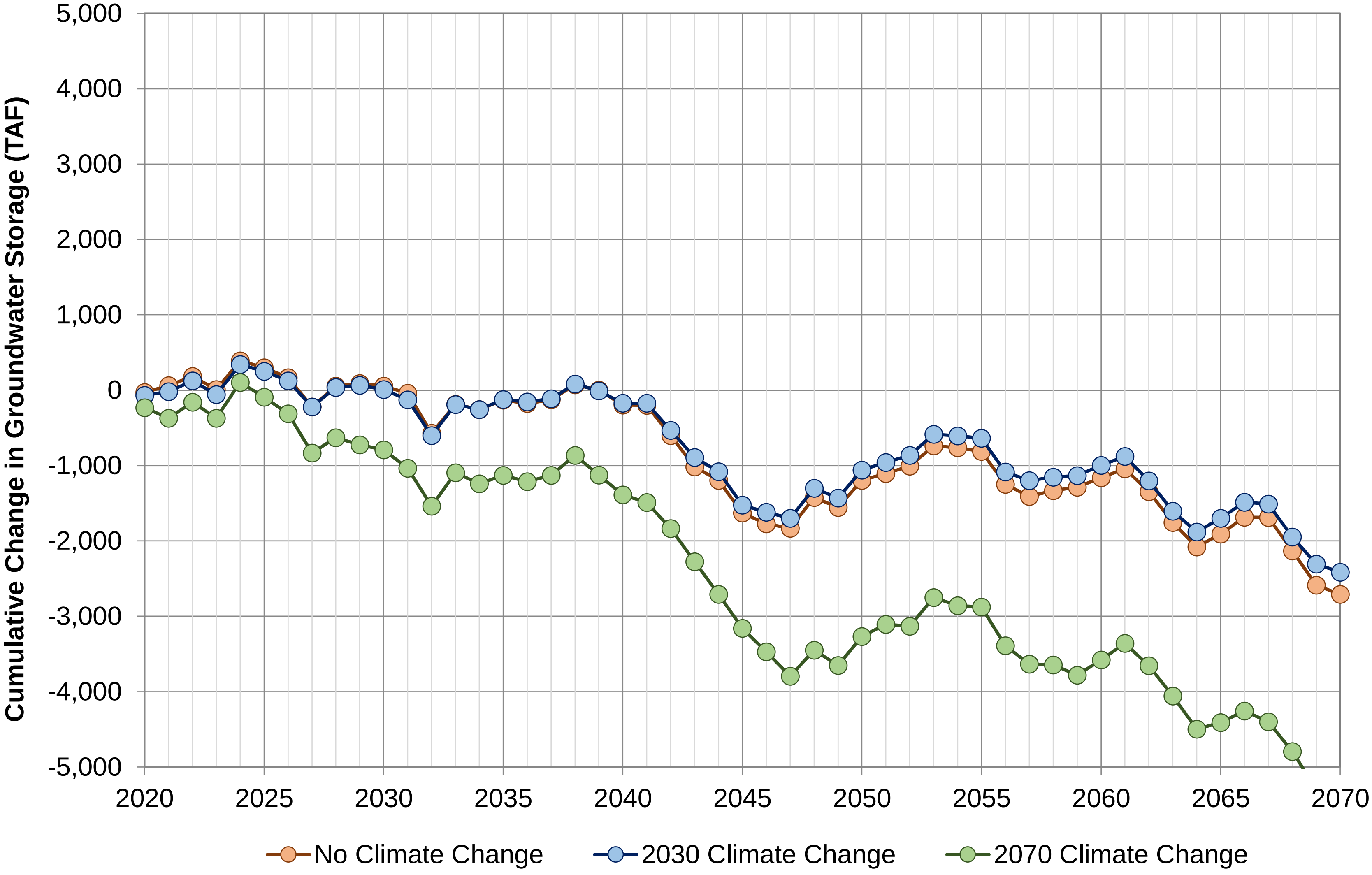

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Figure 7-5
Baseline Cumulative Change in Groundwater Storage
2020-2070

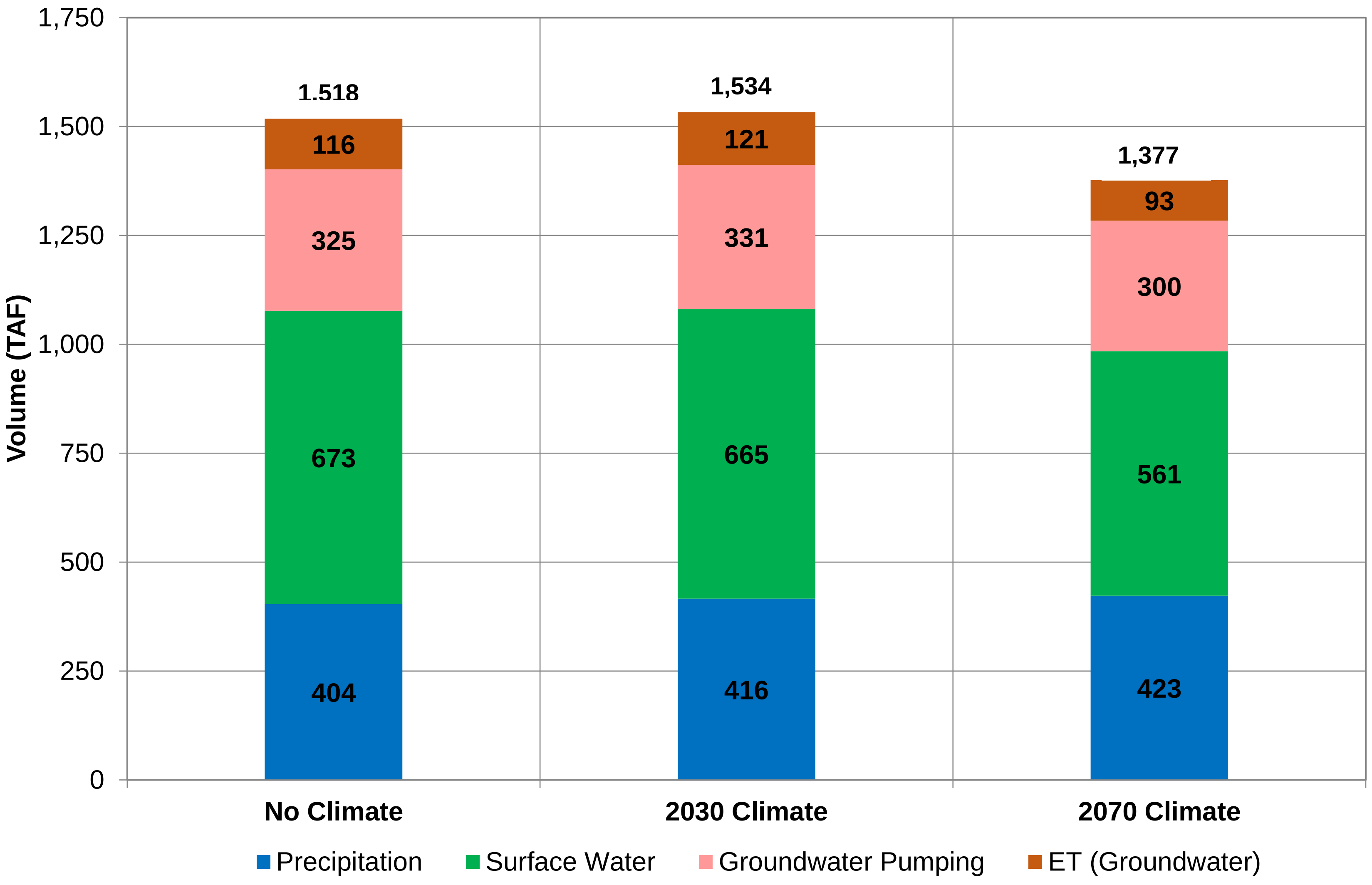

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Figure 7-6
PMA No. 2 Average Subbasin Land Surface System Inflows
2020-2070

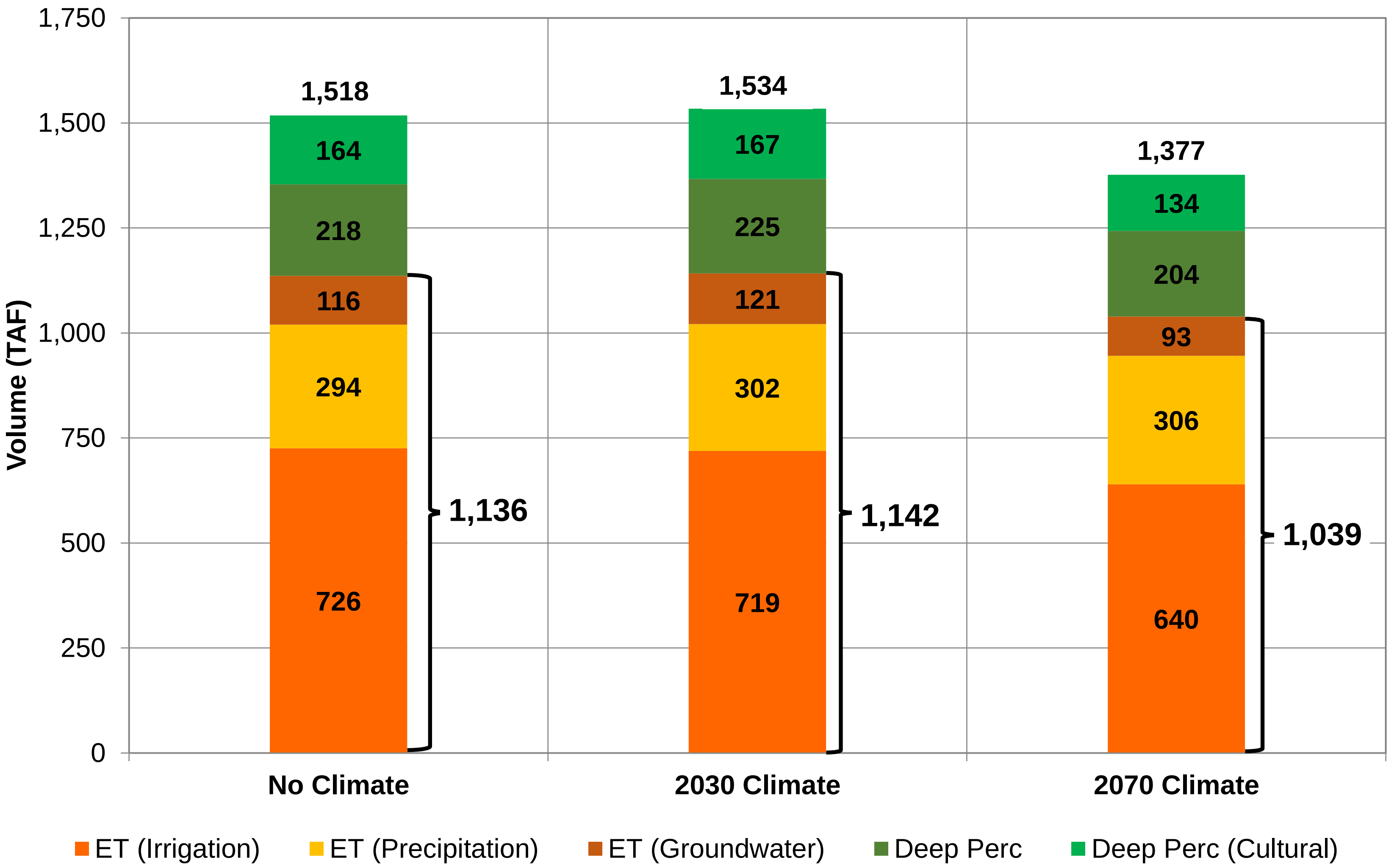

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Figure 7-7
PMA No. 2 Average Subbasin Land Surface System Outflows
2020-2070

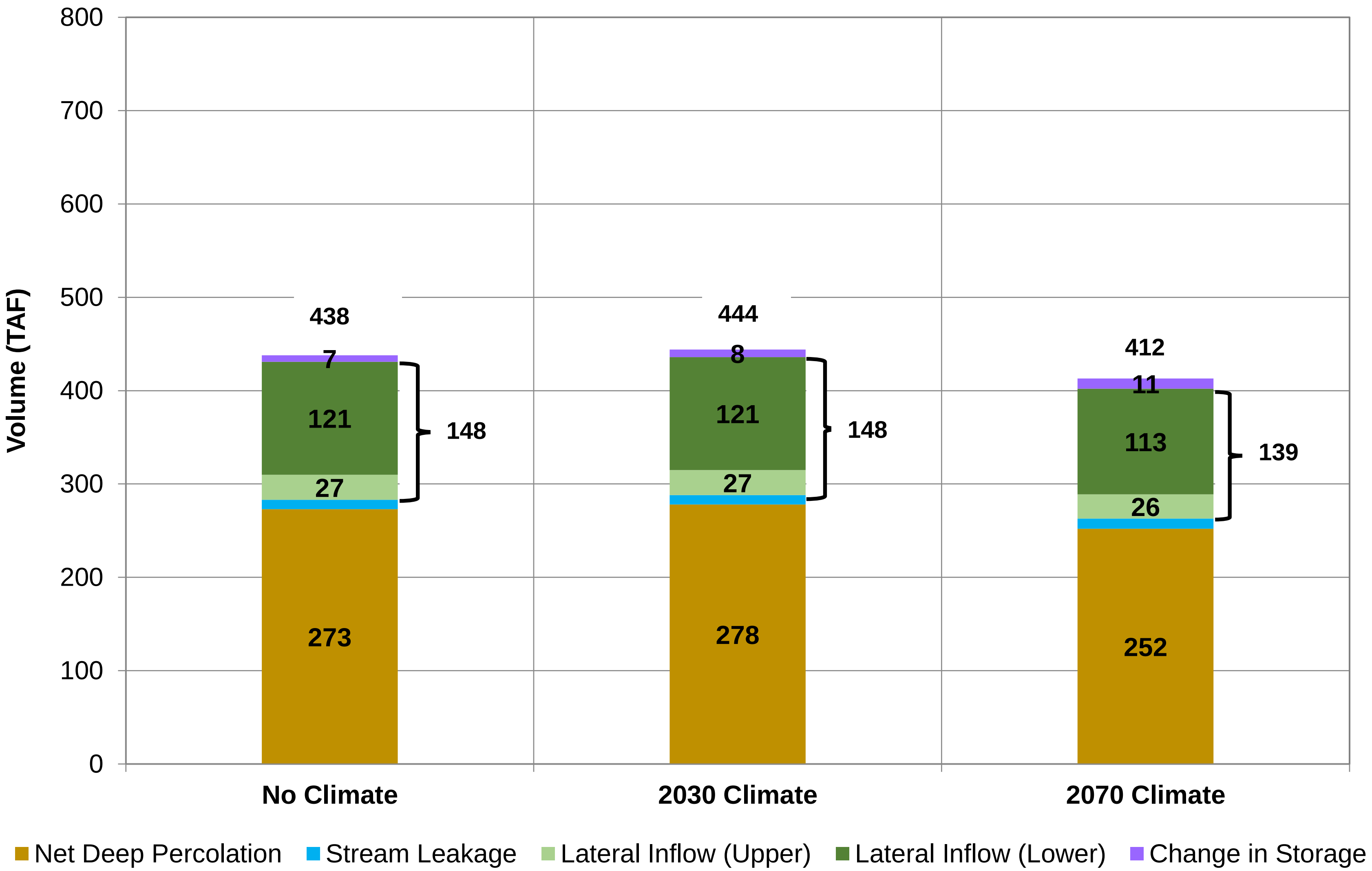

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Figure 7-8
PMA No. 2 Average Subbasin Groundwater Budget Inflows
2020-2070

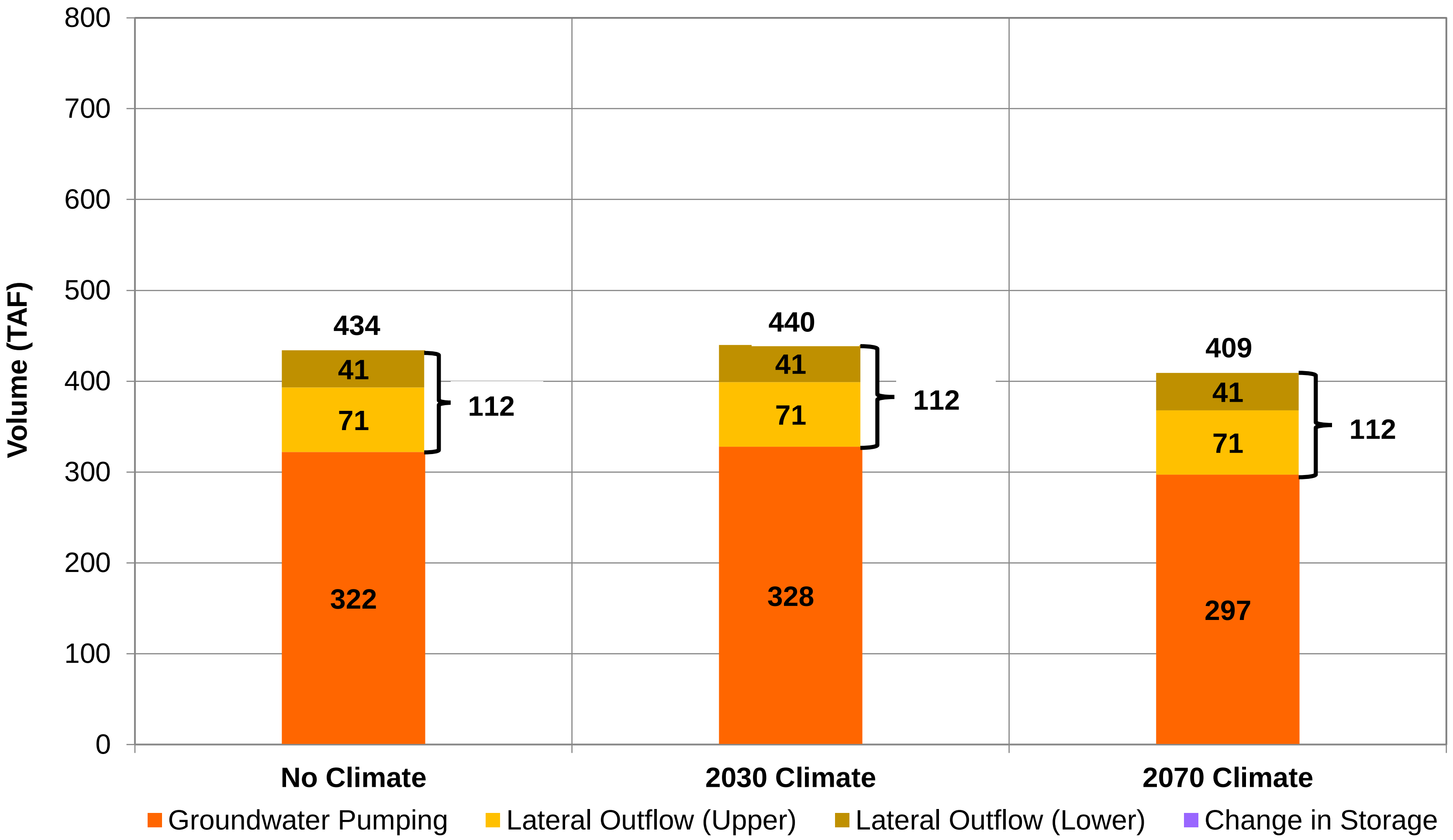

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Figure 7-9
PMA No. 2 Average Subbasin Groundwater Budget Outflows
2020-2070

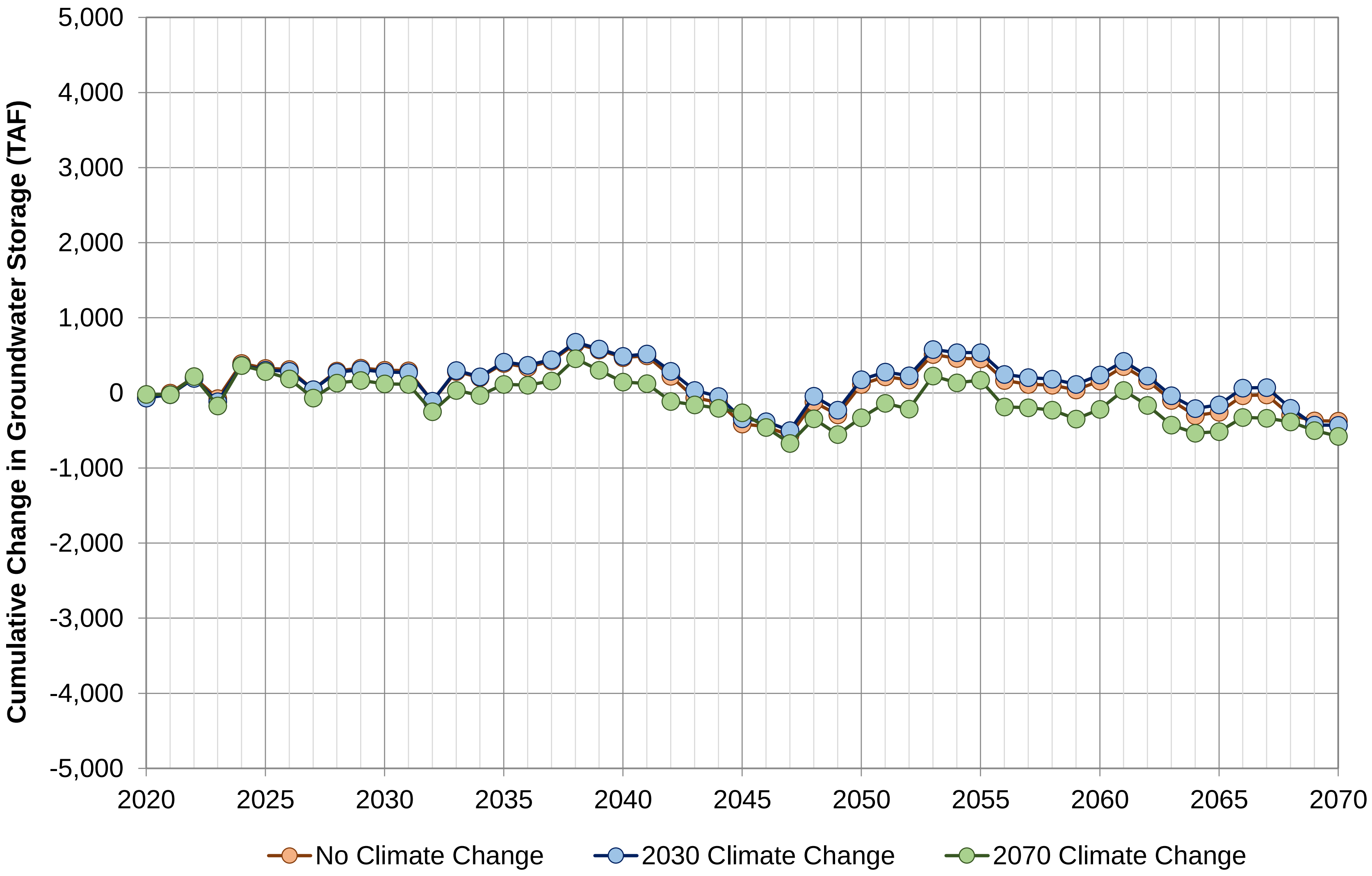

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Figure 7-10
PMA No. 2 Cumulative Change in Groundwater Storage
2020-2070

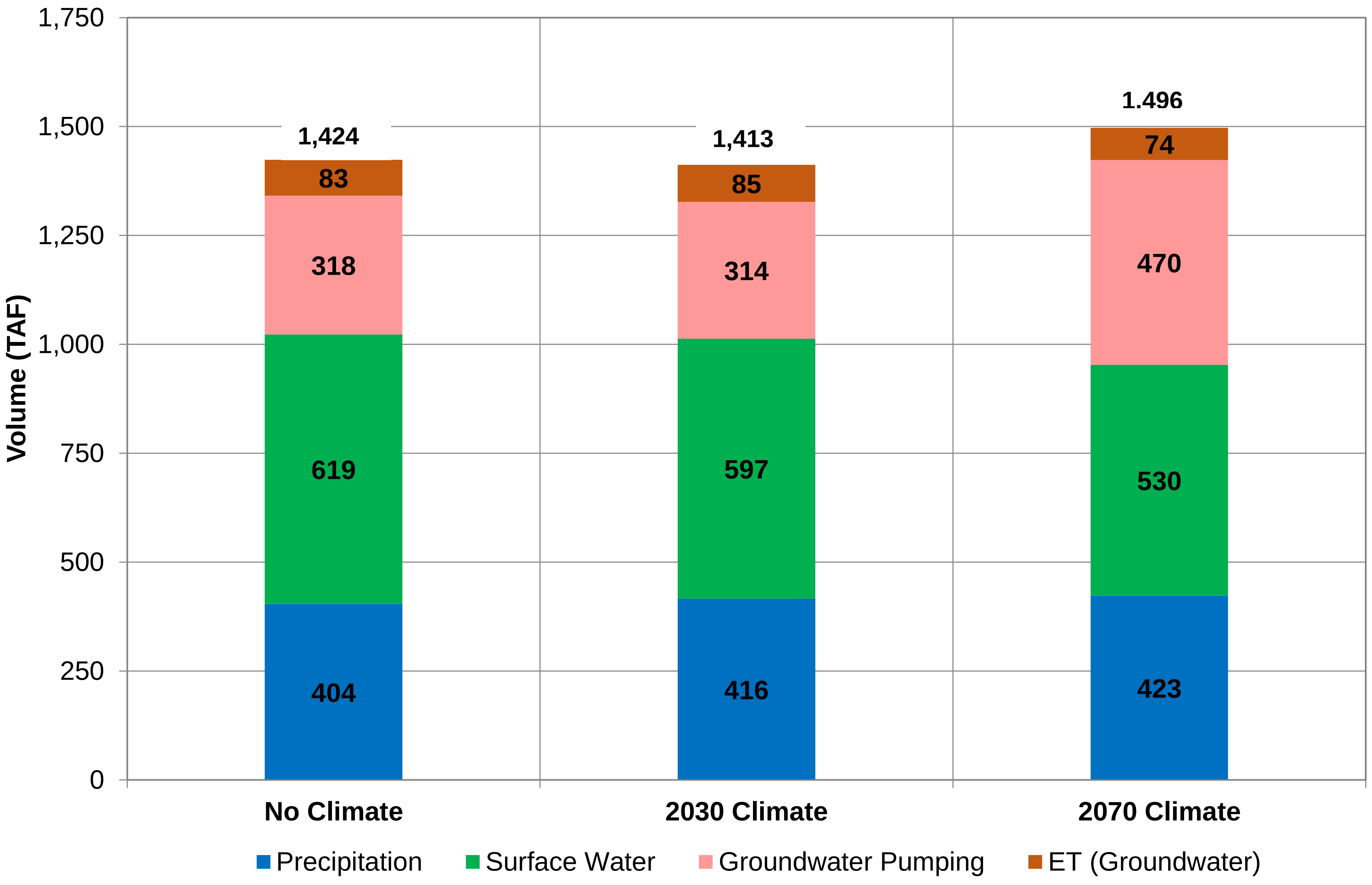

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Figure 7-11
PMA No. 3 Average Subbasin Land Surface System Inflows
2020-2070

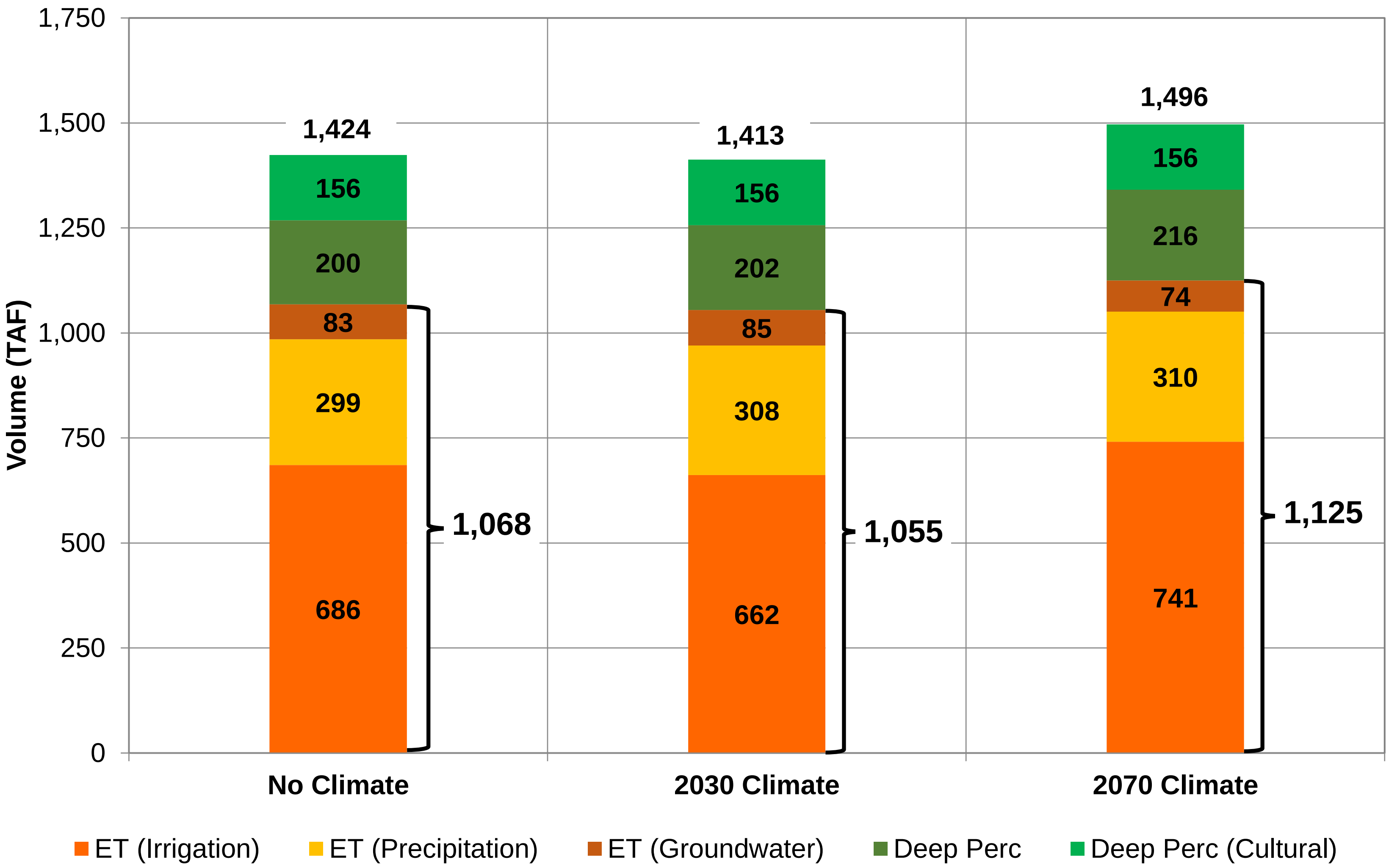

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Figure 7-12
PMA No. 3 Average Subbasin Land Surface System Outflows
2020-2070

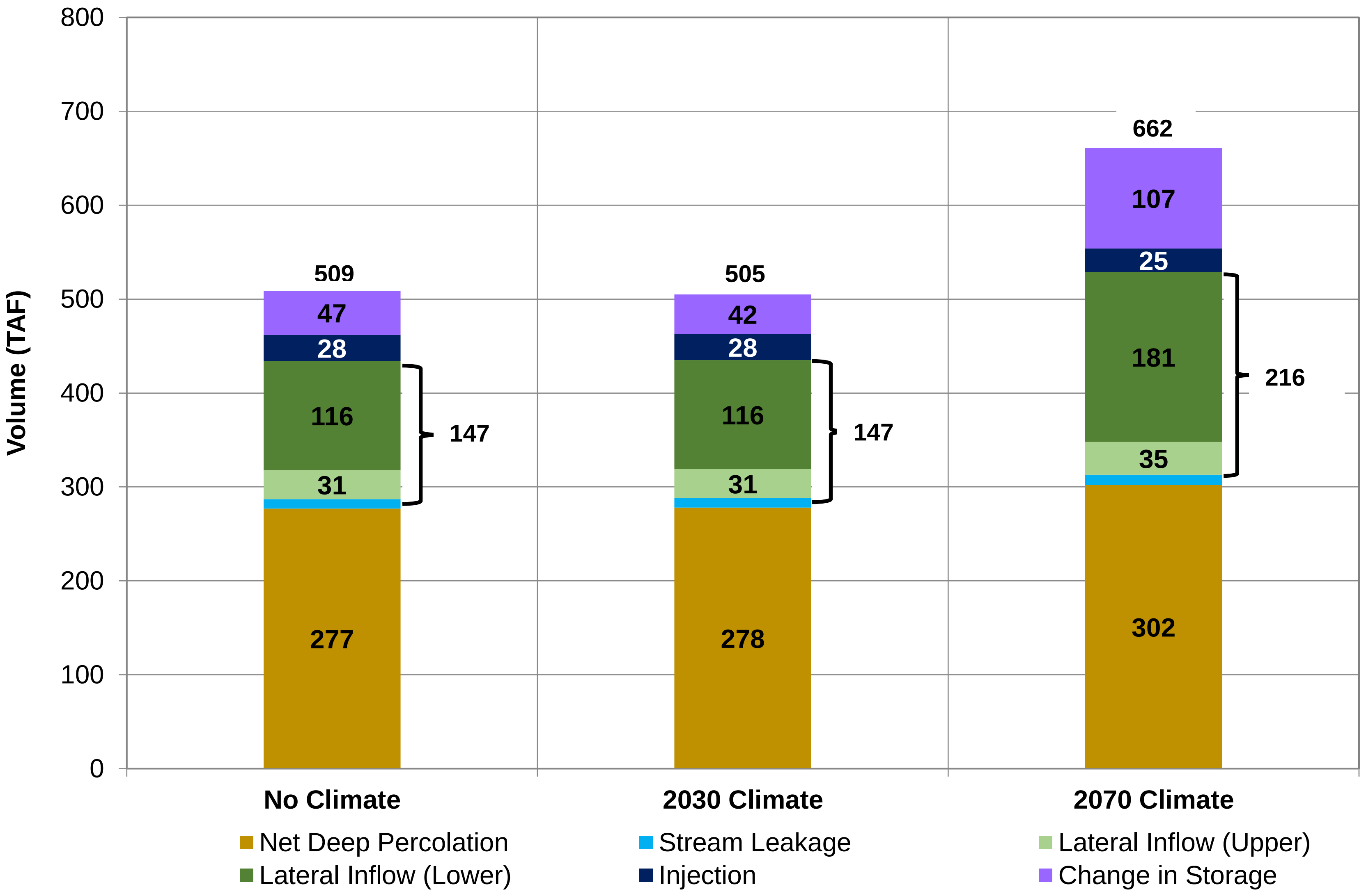

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Figure 7-13
PMA No. 3 Average Subbasin Groundwater Budget Inflows 2020-2070

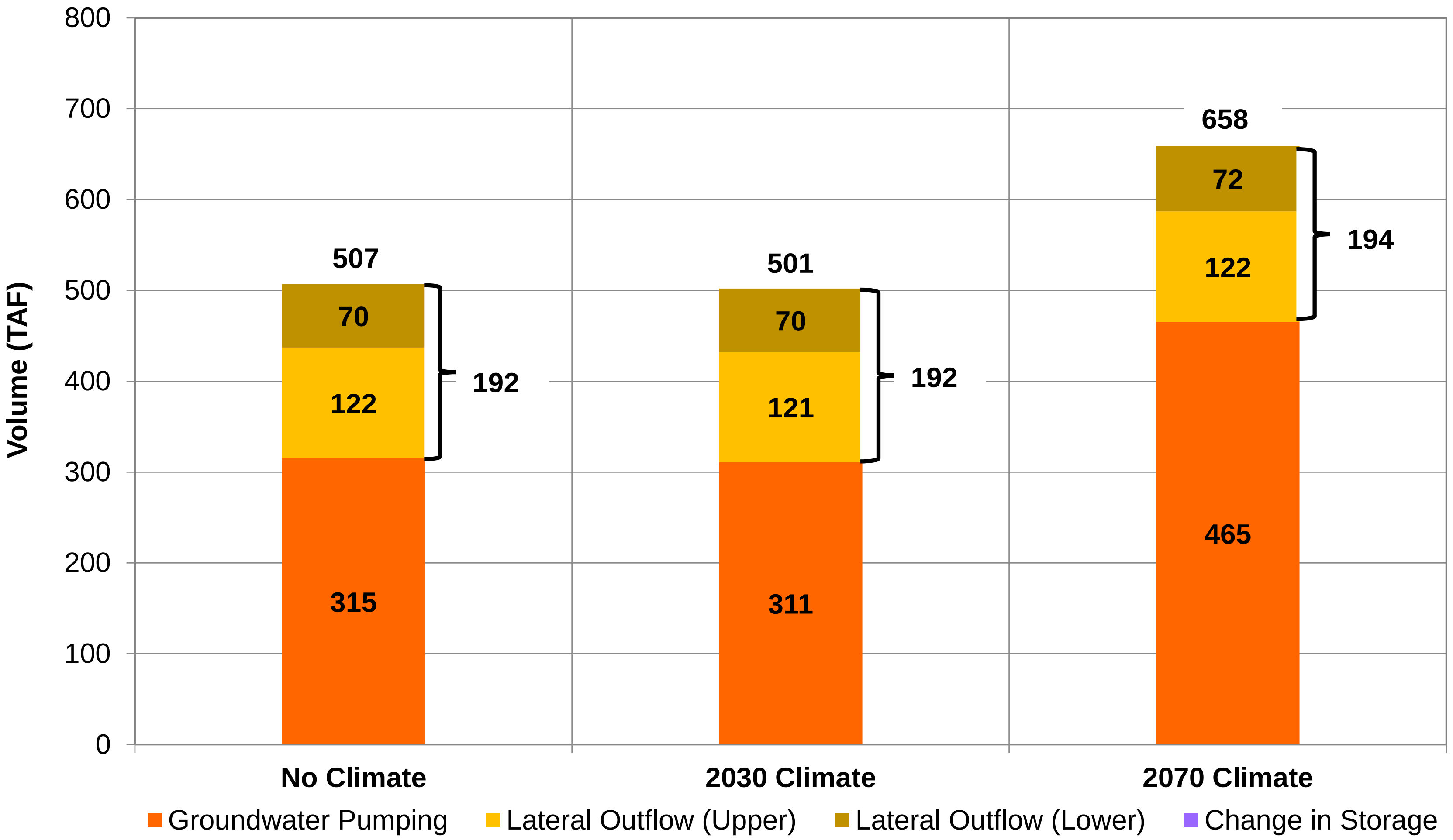

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Figure 7-14
PMA No. 3 Average Subbasin Groundwater Budget Outflows
2020-2070

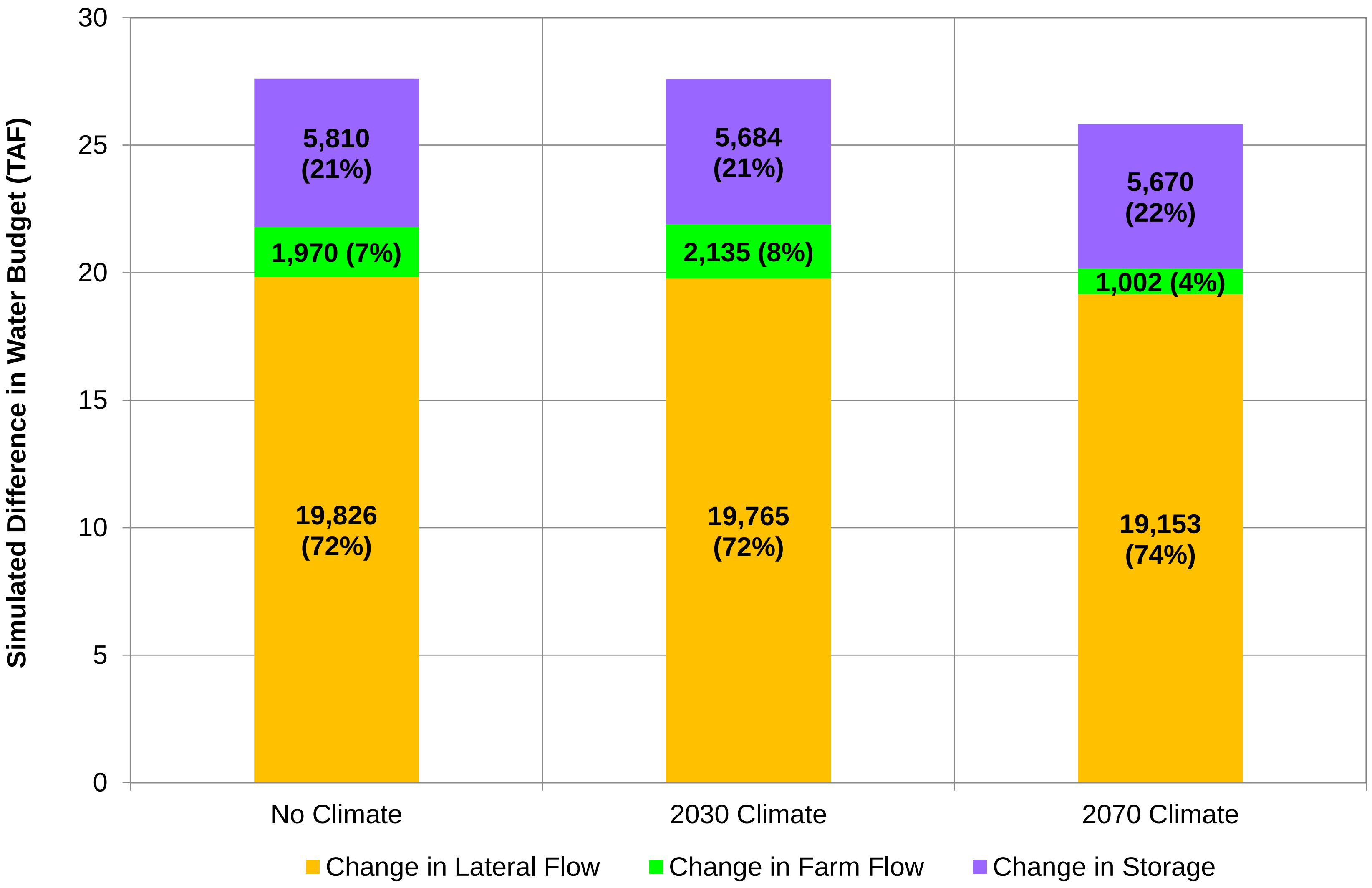

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Figure 7-15
PMA No. 3 Relative Difference in Simulated Water Budget Terms
2020-2070

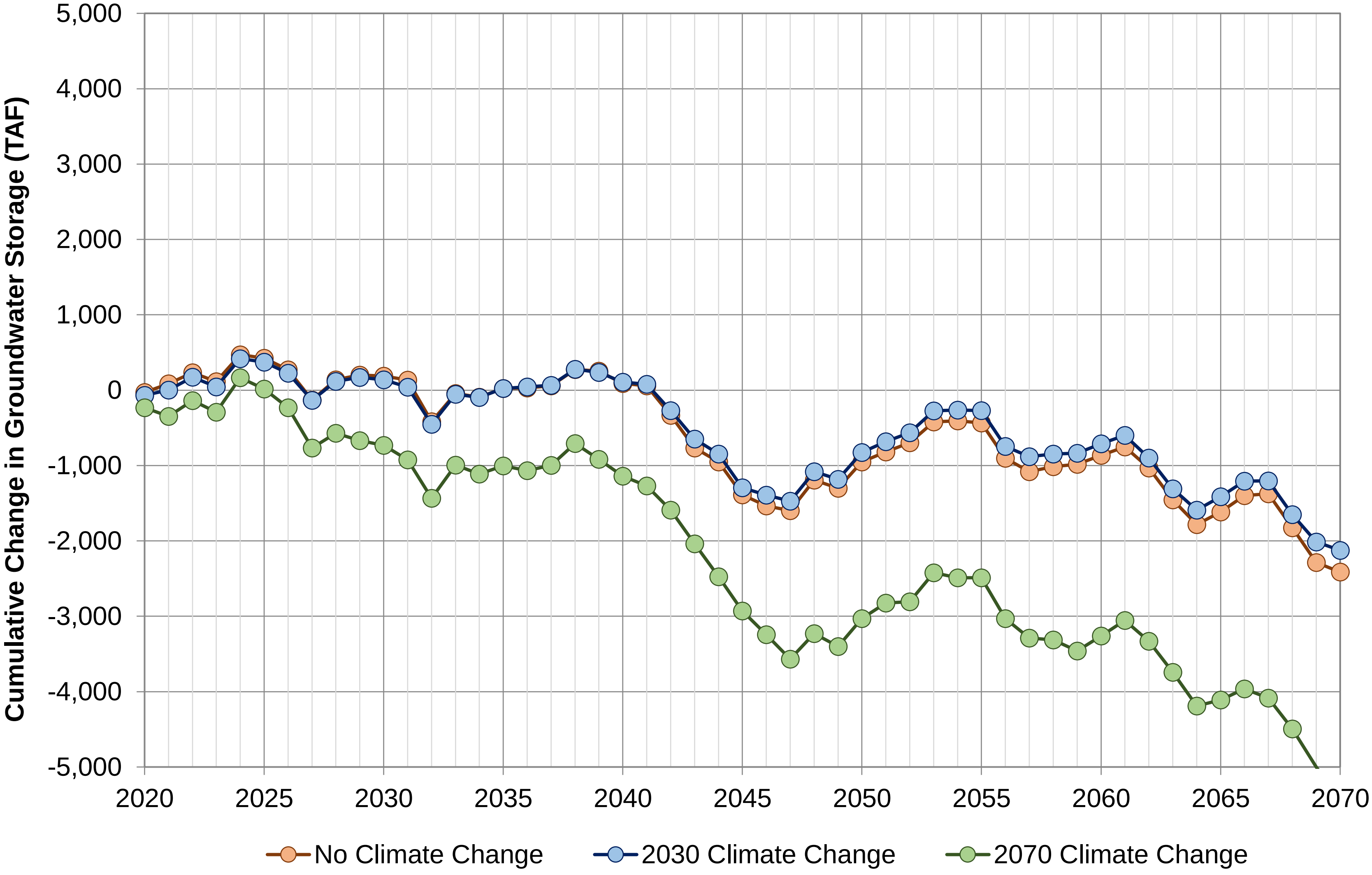

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Figure 7-16
PMA No. 3 Cumulative Change in Groundwater Storage
2020-2070

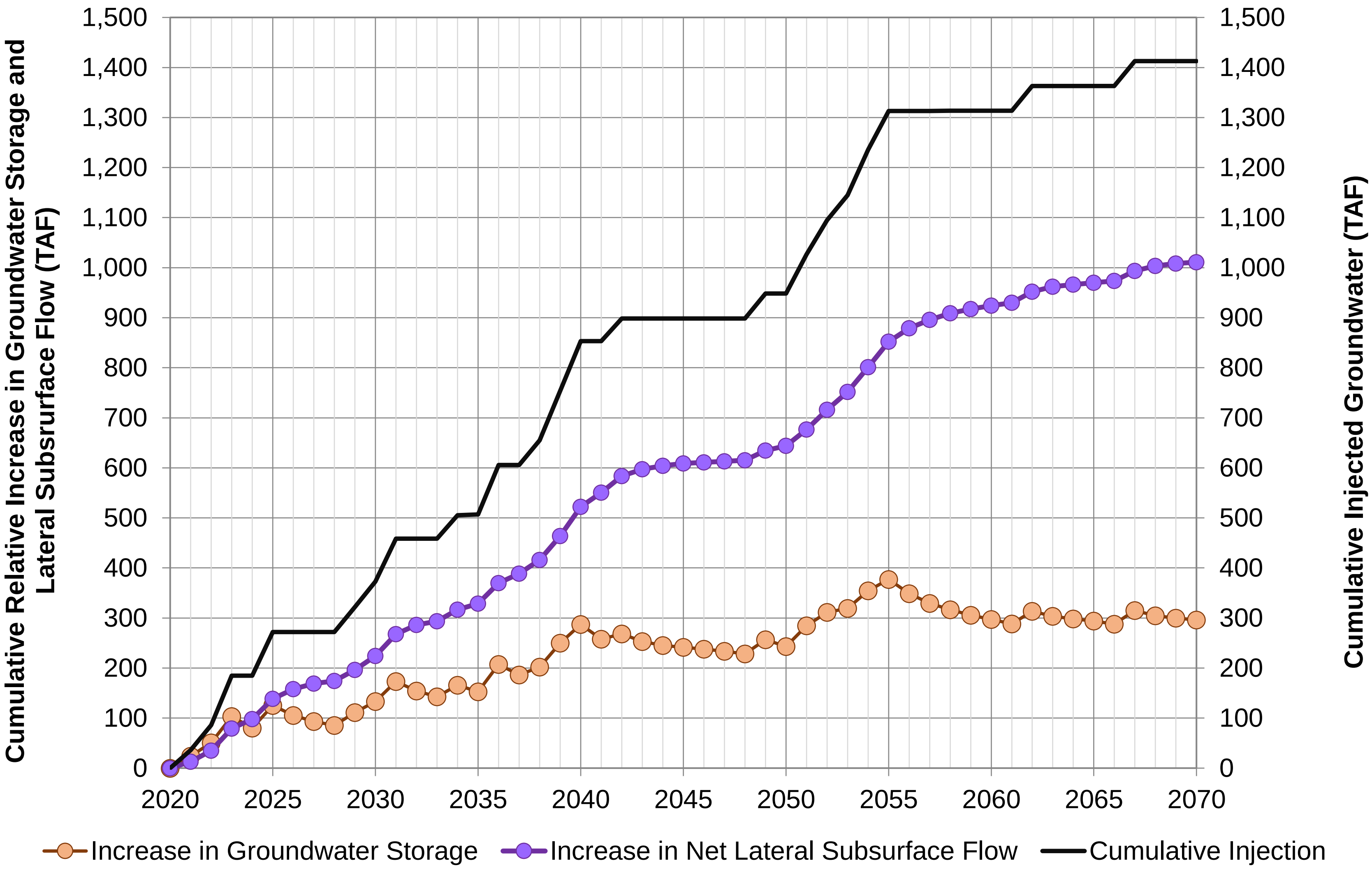

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Figure 7-17
Difference in Simulated Groundwater Storage and Net Lateral Flow in Relation to Groundwater Injection (2020-2070)

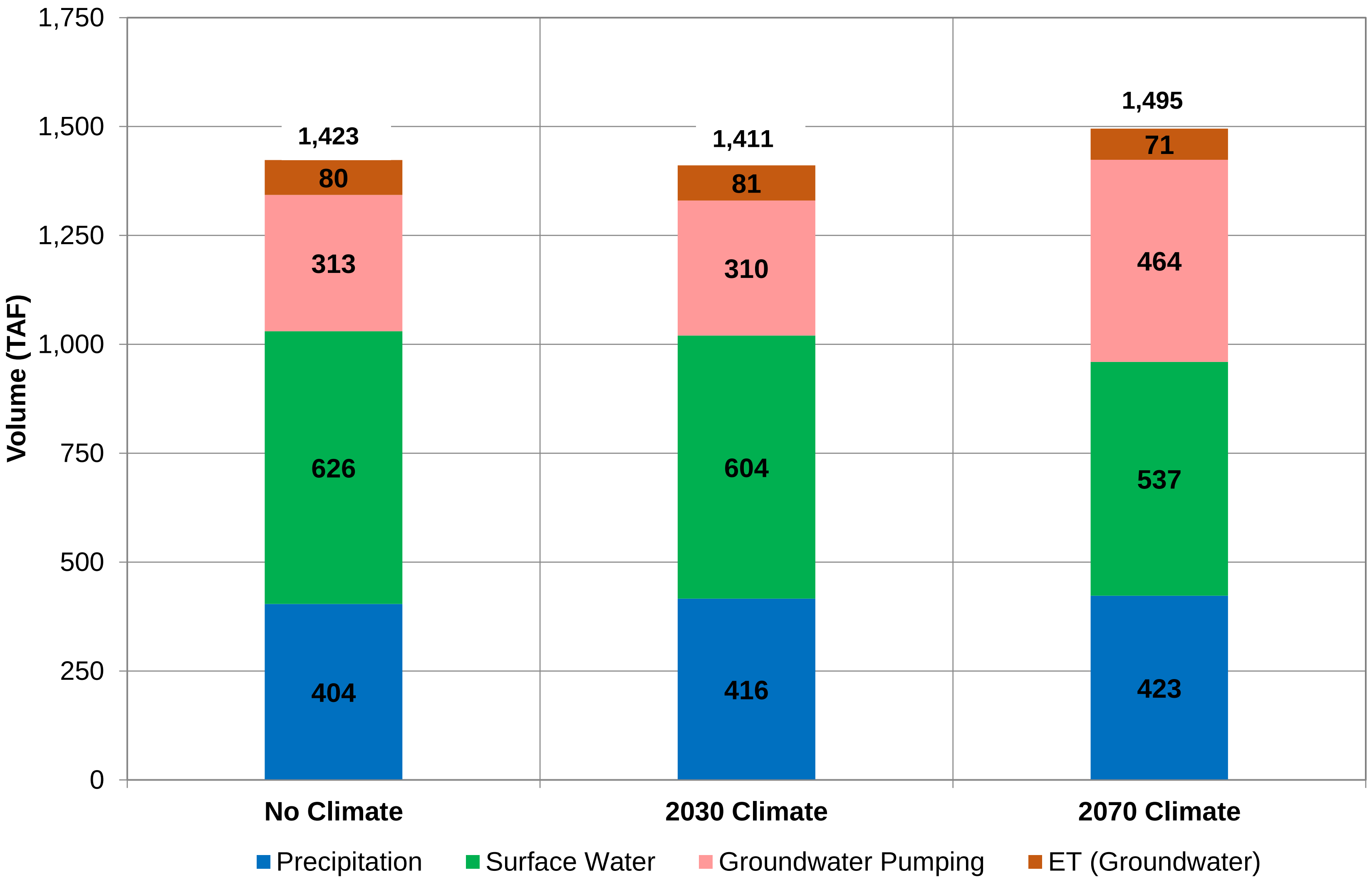

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Figure 7-18
PMA No. 4 Average Subbasin Land Surface System Inflows
2020-2070

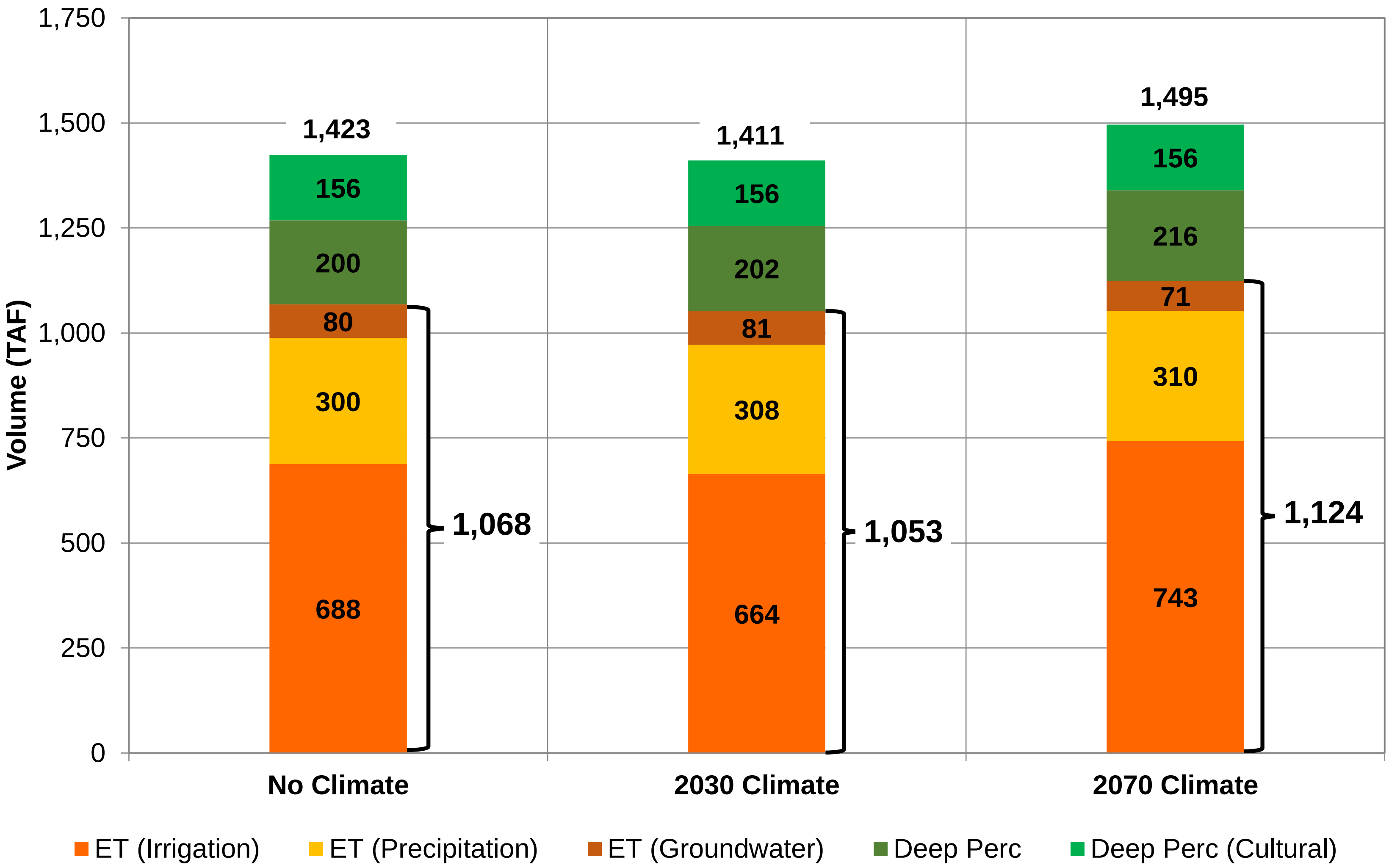

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Figure 7-19
PMA No. 4 Average Subbasin Land Surface System Outflows
2020-2070

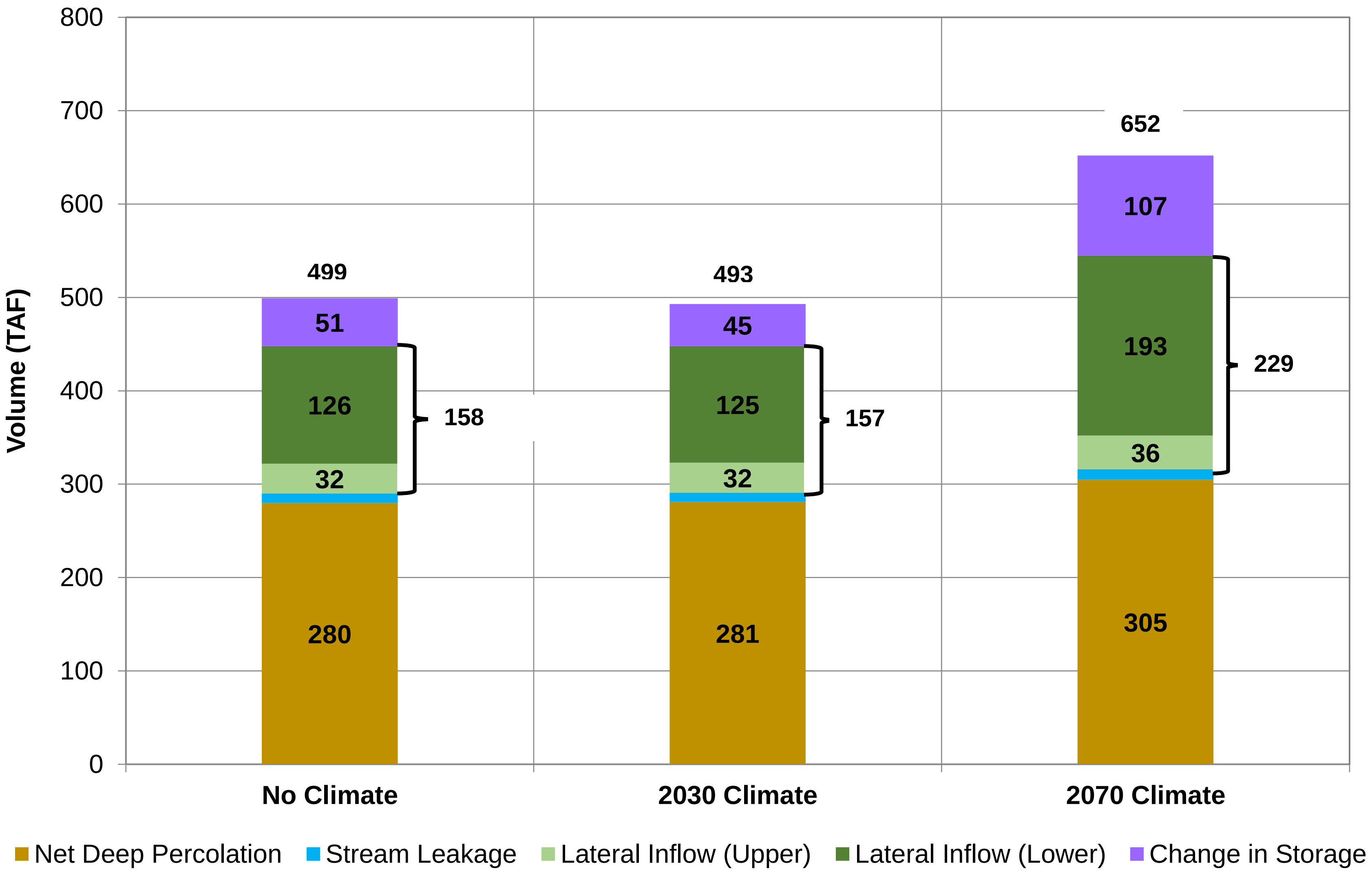

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Figure 7-20
PMA No. 4 Average Subbasin Groundwater Budget Inflows
2020-2070

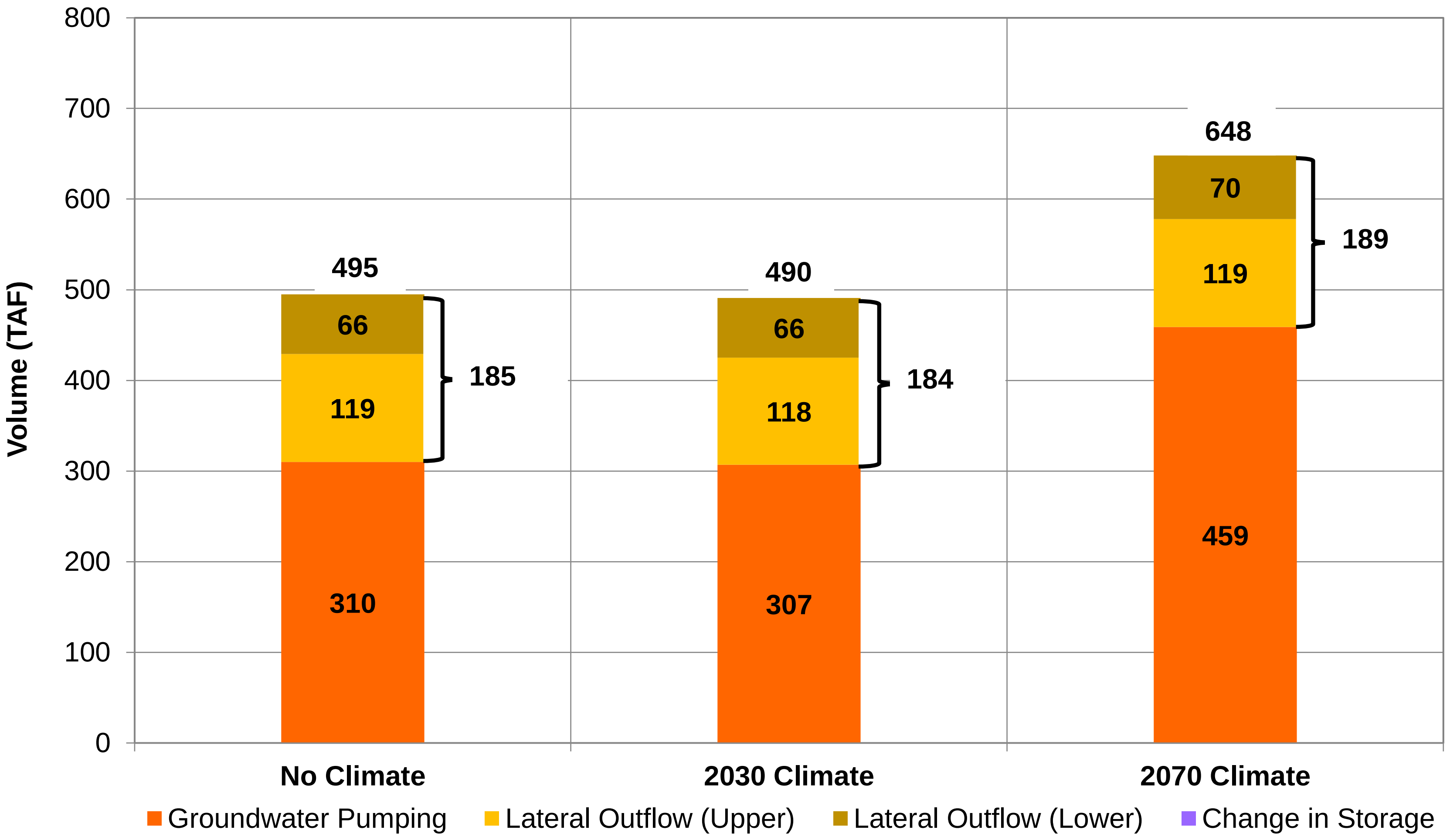

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Figure 7-21
PMA No. 4 Average Subbasin Groundwater Budget Outflows
2020-2070

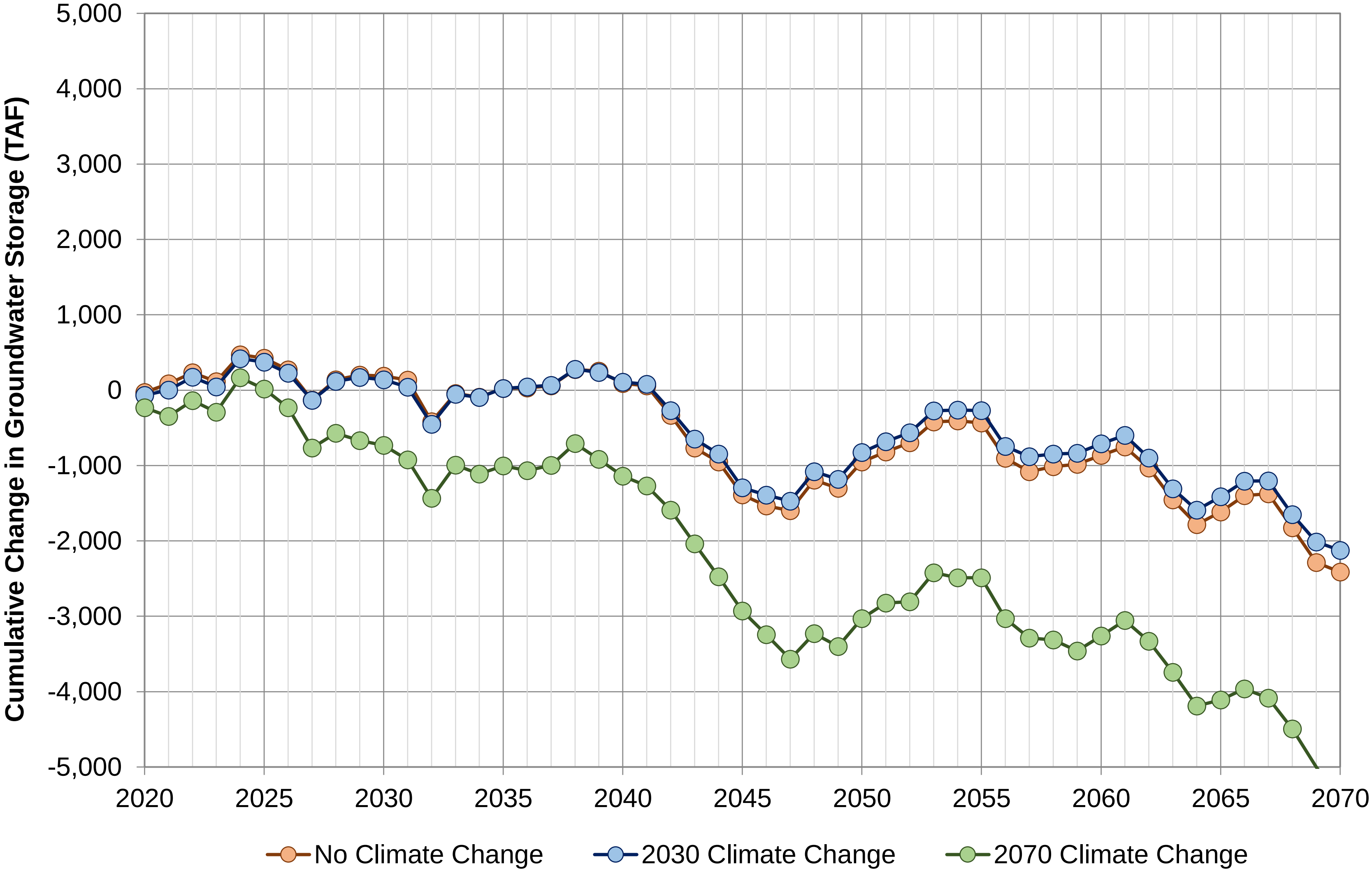

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Figure 7-22
PMA No. 3 Cumulative Change in Groundwater Storage
2020-2070

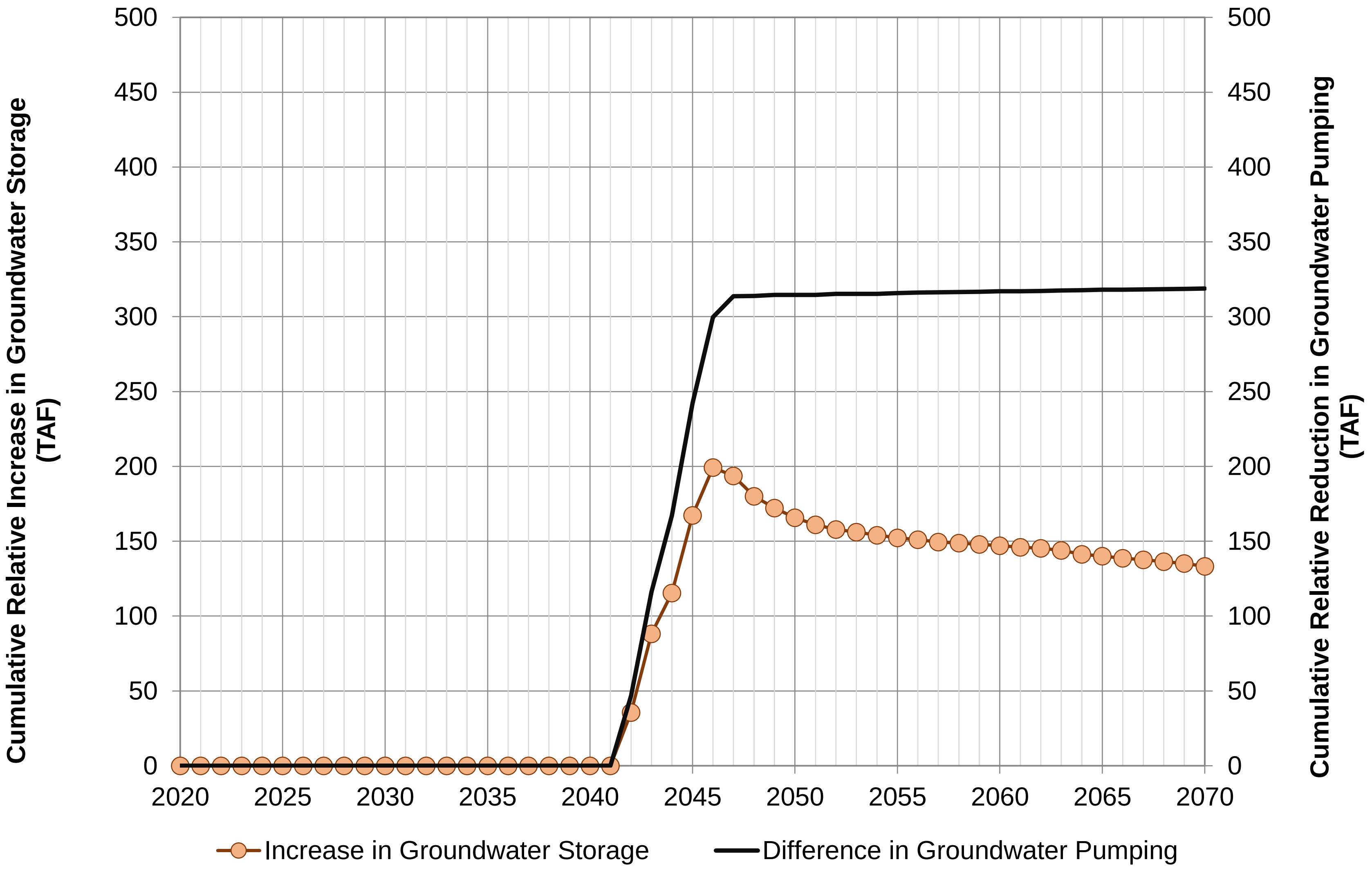

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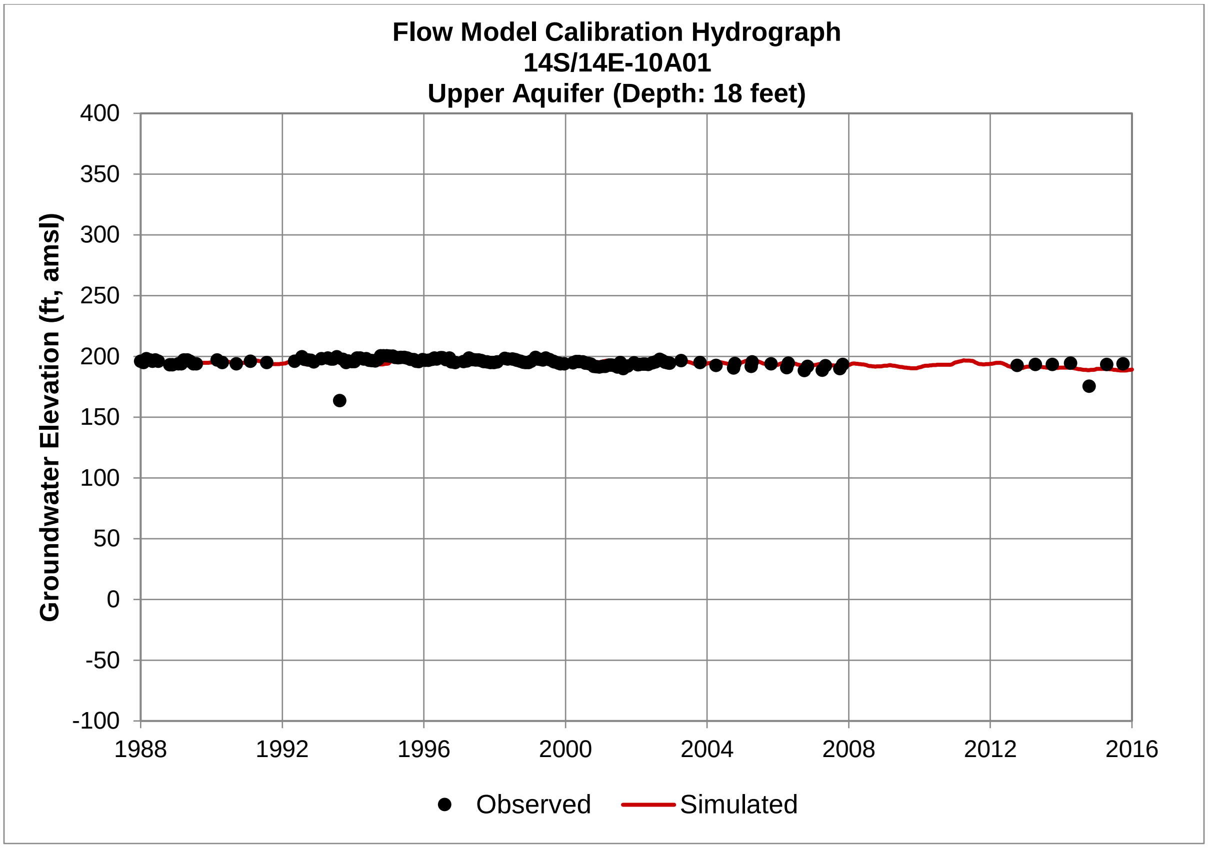
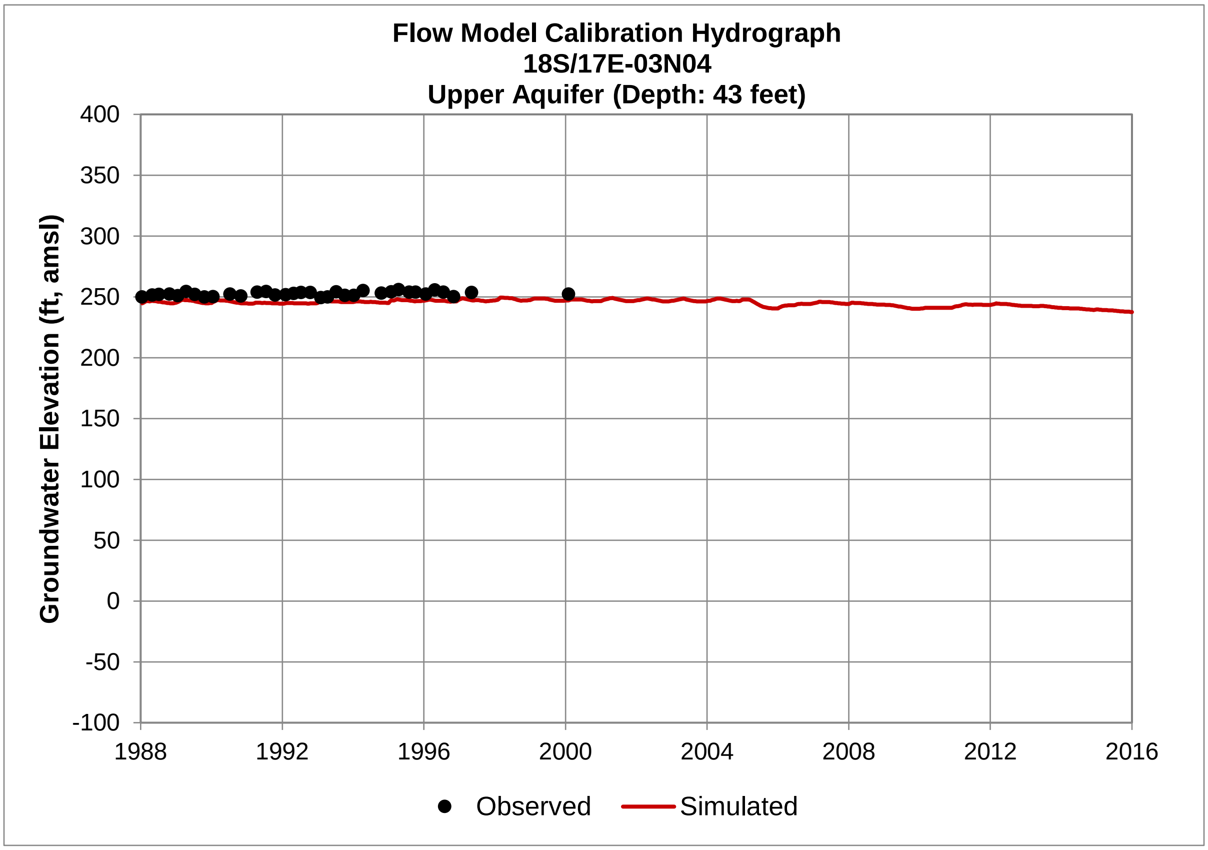
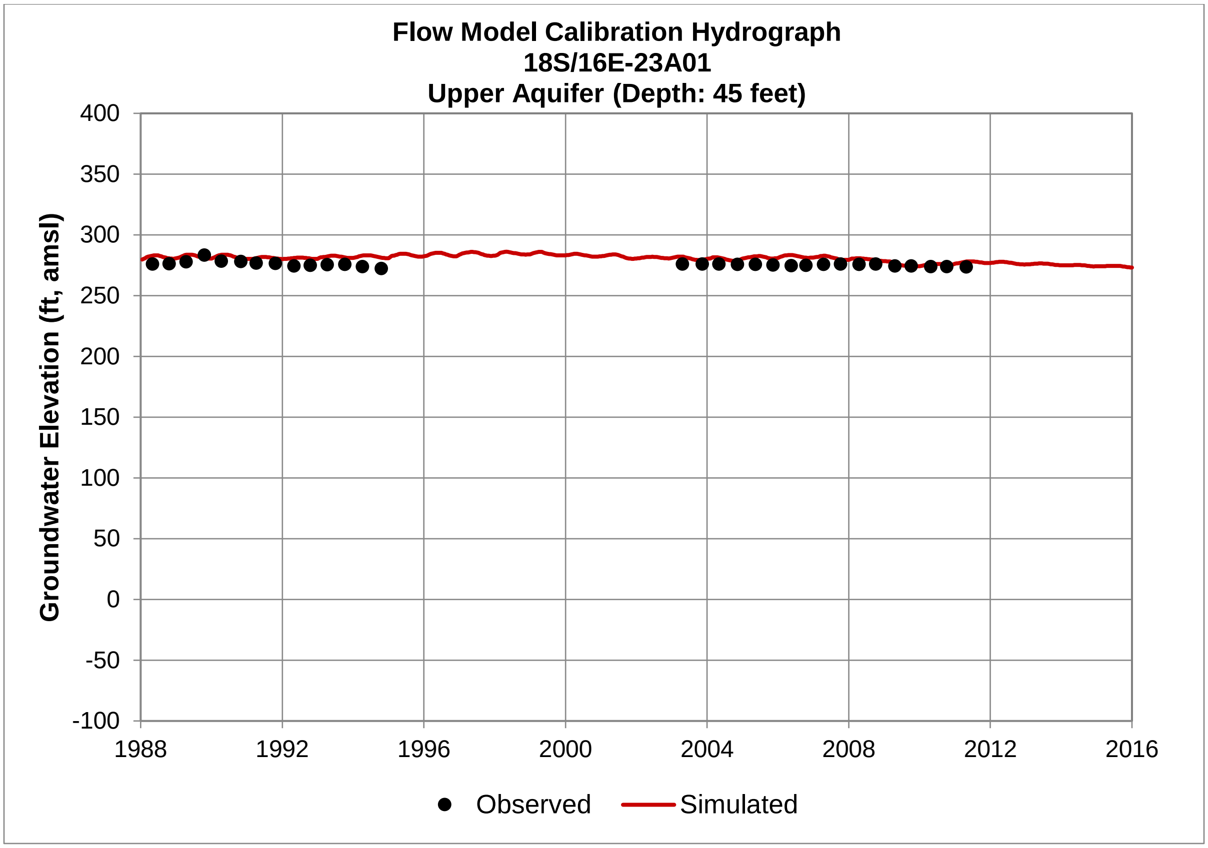
Figure 7-23
Difference in Relative Groundwater Storage in Relation to Pumping Reduction (2020-2070)

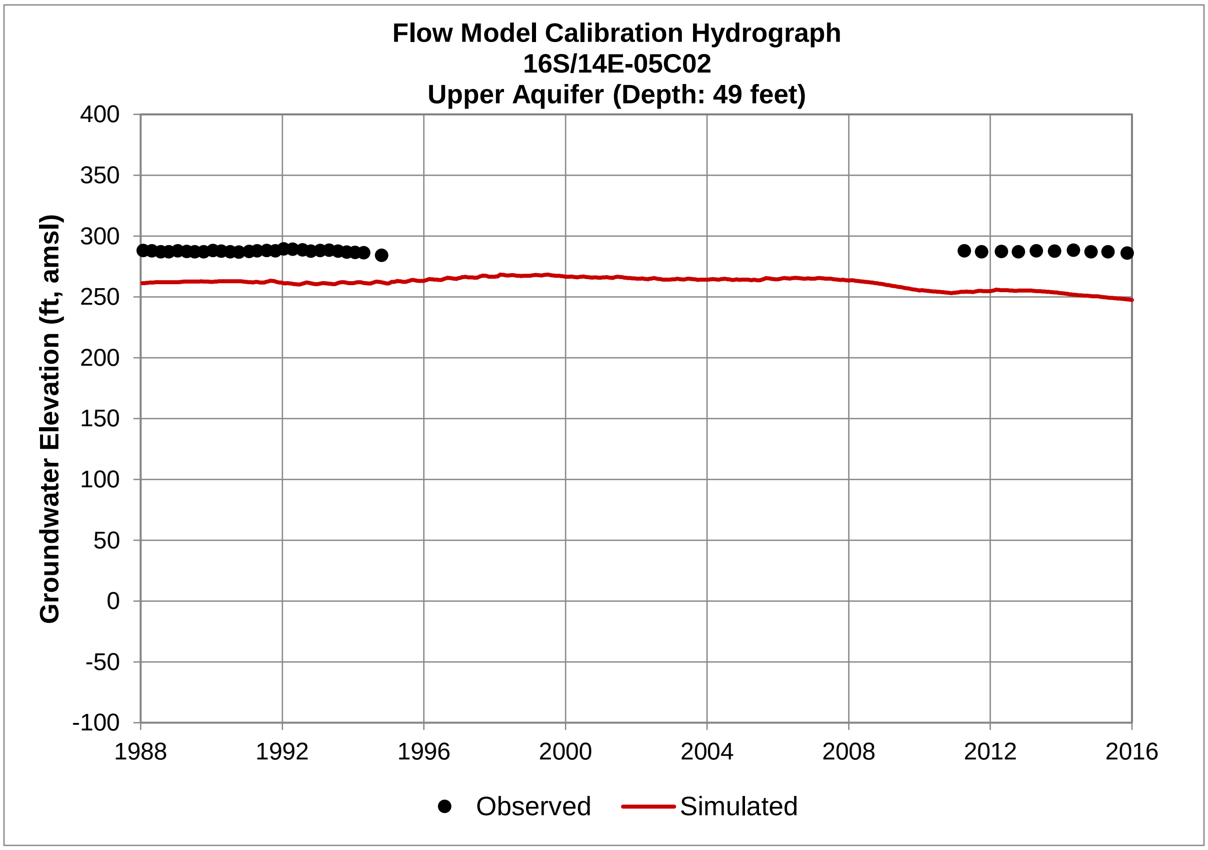
Appendix A:

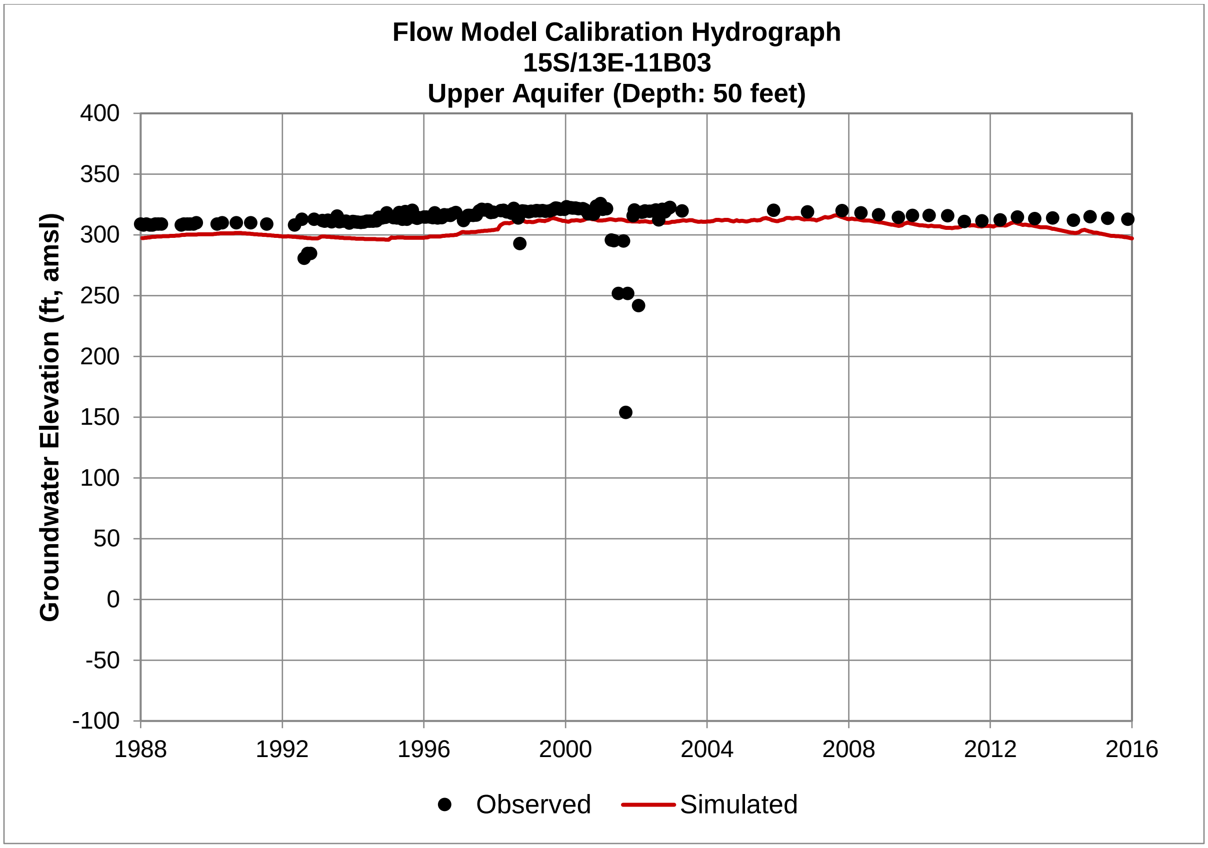
Simulated and Observed Groundwater Levels

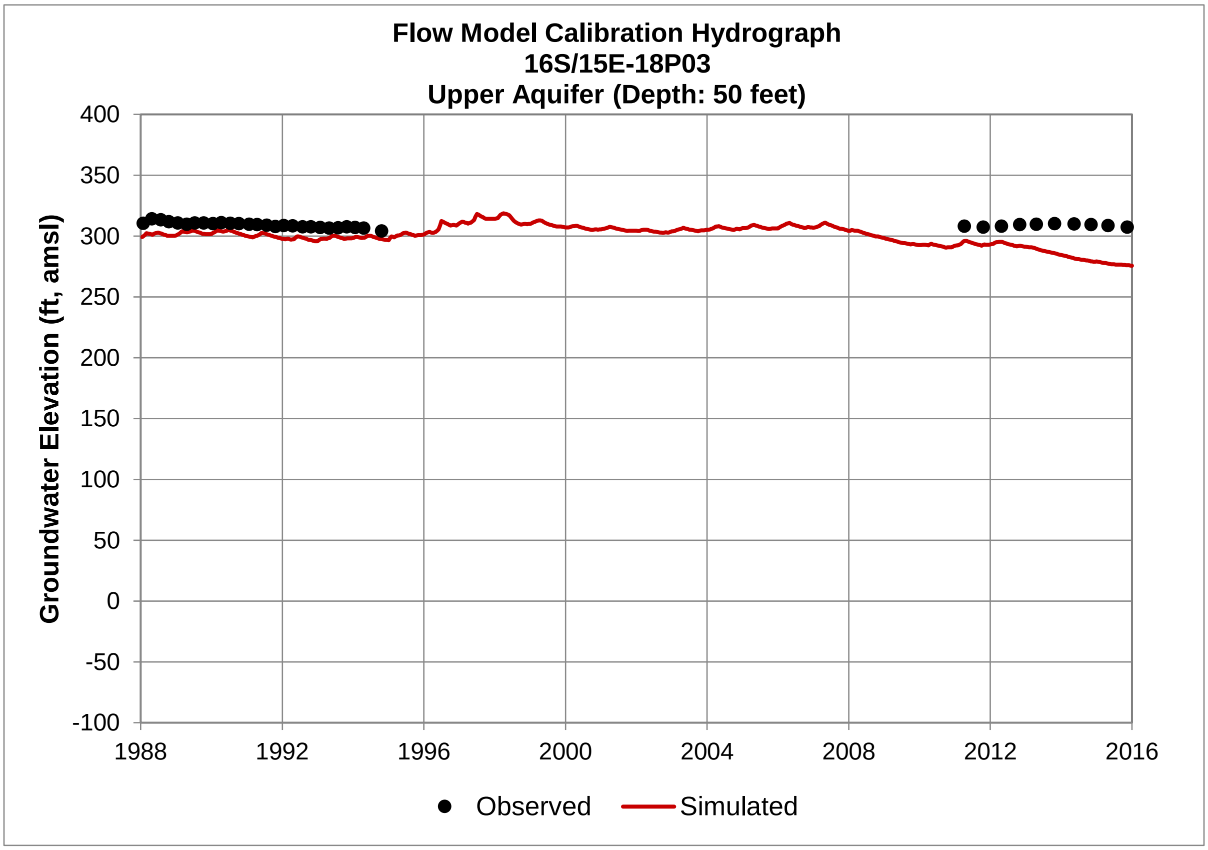

Flow Model Calibration Hydrograph
14S/14E-10A01
Upper Aquifer (Depth: 18 feet)
Groundwater Elevation (ft, amsl)
400
350
300
250
200
150
100
50
0
-50
-100
1988
1992
1996
2000
2004
2008
2012
2016
● Observed
Simulated

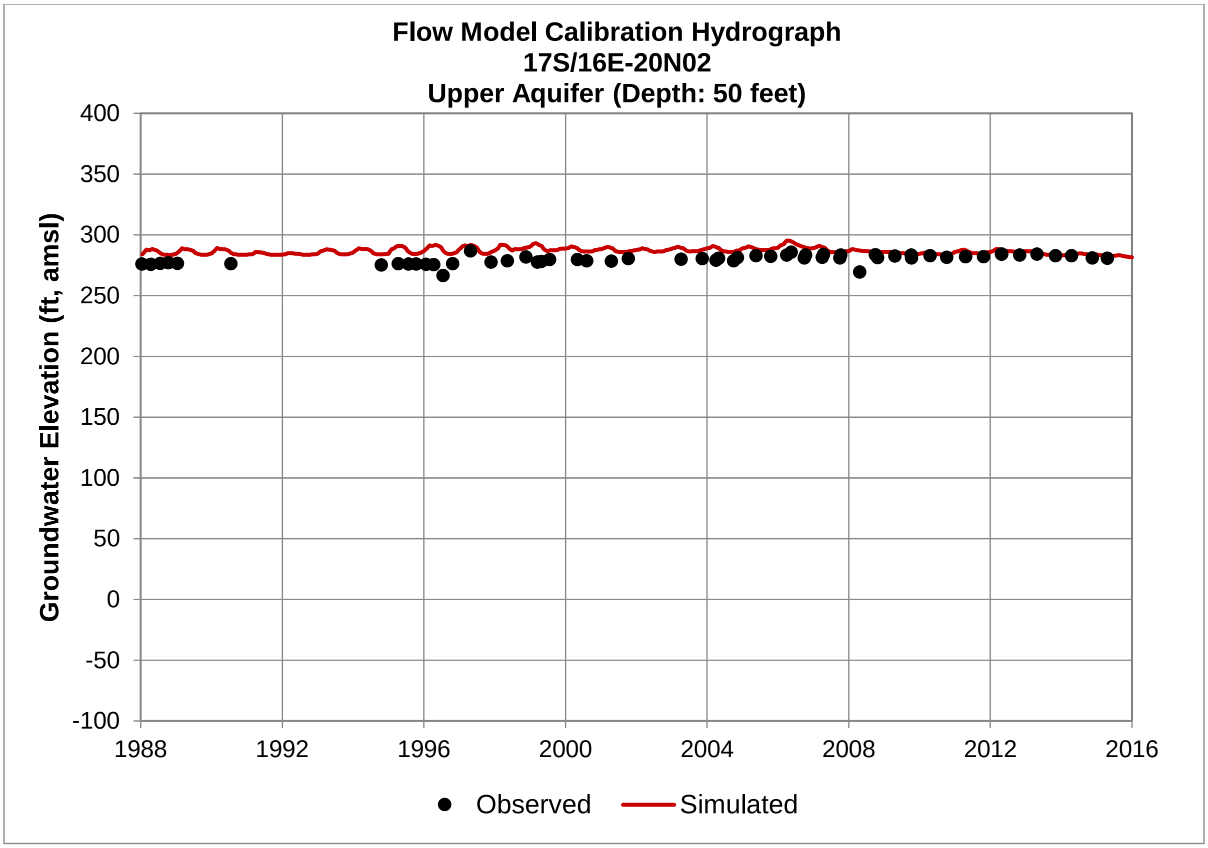

Flow Model Calibration Hydrograph
18S/17E-03N04
Upper Aquifer (Depth: 43 feet)
Groundwater Elevation (ft, amsl)
400
350
300
250
200
150
100
50
0
-50
-100
1988
1992
1996
2000
2004
2008
2012
2016
● Observed
Simulated


Flow Model Calibration Hydrograph
18S/16E-23A01
Upper Aquifer (Depth: 45 feet)
Groundwater Elevation (ft, amsl)
400
350
300
250
200
150
100
50
0
-50
-100
1988
1992
1996
2000
2004
2008
2012
2016
● Observed
Simulated

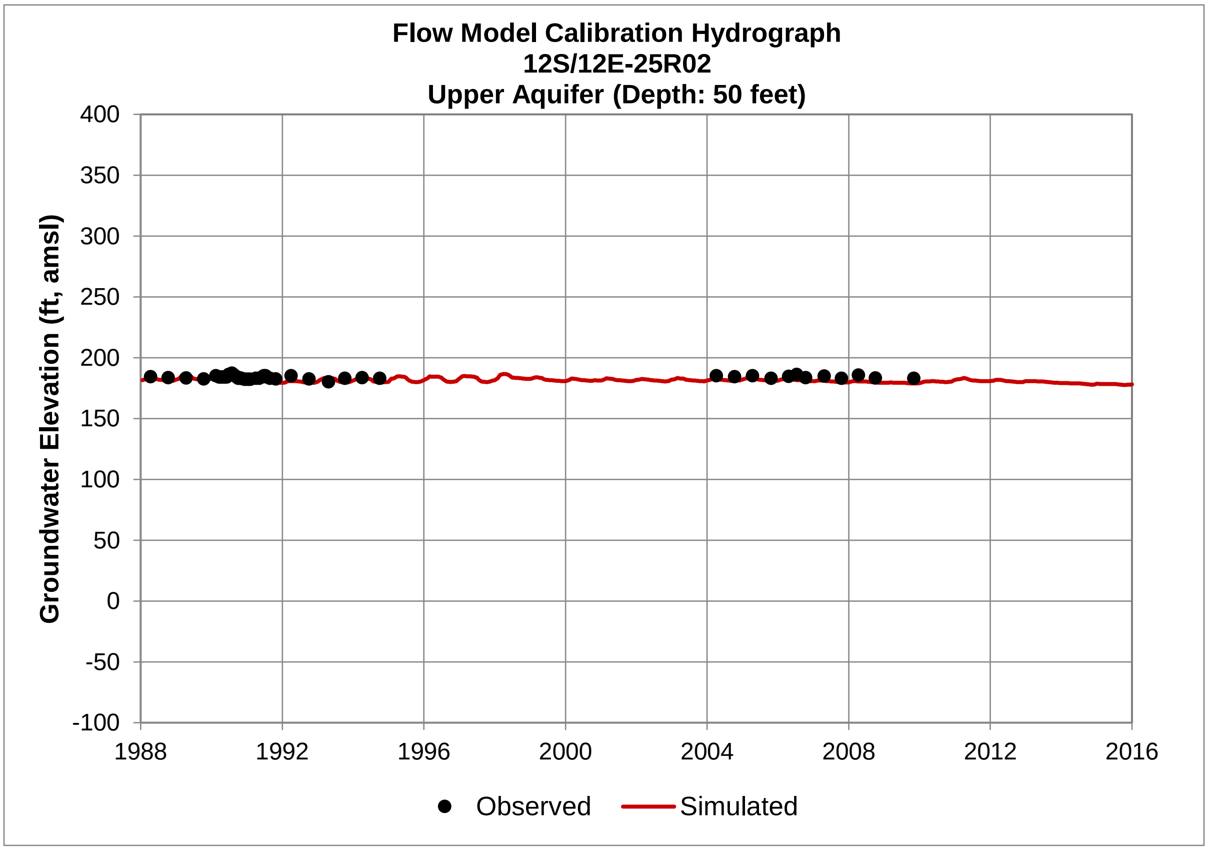

Flow Model Calibration Hydrograph
16S/14E-05C02
Upper Aquifer (Depth: 49 feet)
Groundwater Elevation (ft, amsl)
400
350
300
250
200
150
100
50
0
-50
-100
1988
1992
1996
2000
2004
2008
2012
2016
● Observed
Simulated


Flow Model Calibration Hydrograph
15S/13E-11B03
Upper Aquifer (Depth: 50 feet)
Groundwater Elevation (ft, amsl)
400
350
300
250
200
150
100
50
0
-50
-100
1988
1992
1996
2000
2004
2008
2012
2016
● Observed
Simulated


Flow Model Calibration Hydrograph
16S/15E-18P03
Upper Aquifer (Depth: 50 feet)
Groundwater Elevation (ft, amsl)
400
350
300
250
200
150
100
50
0
-50
-100
1988
1992
1996
2000
2004
2008
2012
2016
● Observed
Simulated

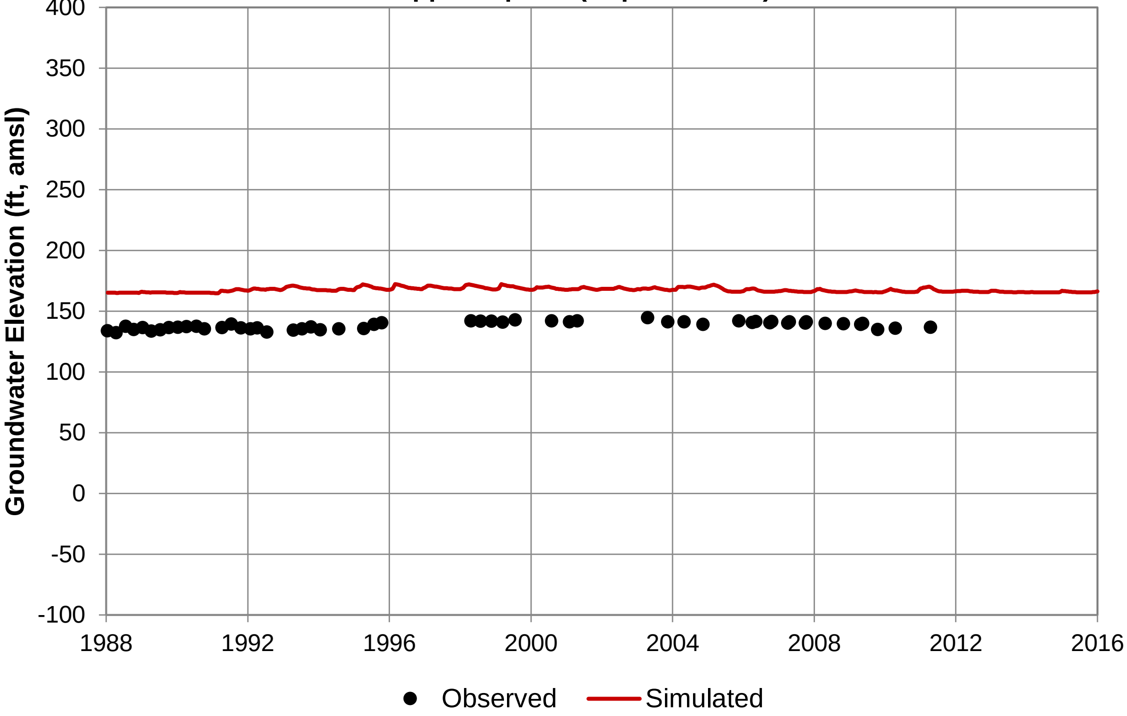


Flow Model Calibration Hydrograph
17S/16E-20N02
Upper Aquifer (Depth: 50 feet)

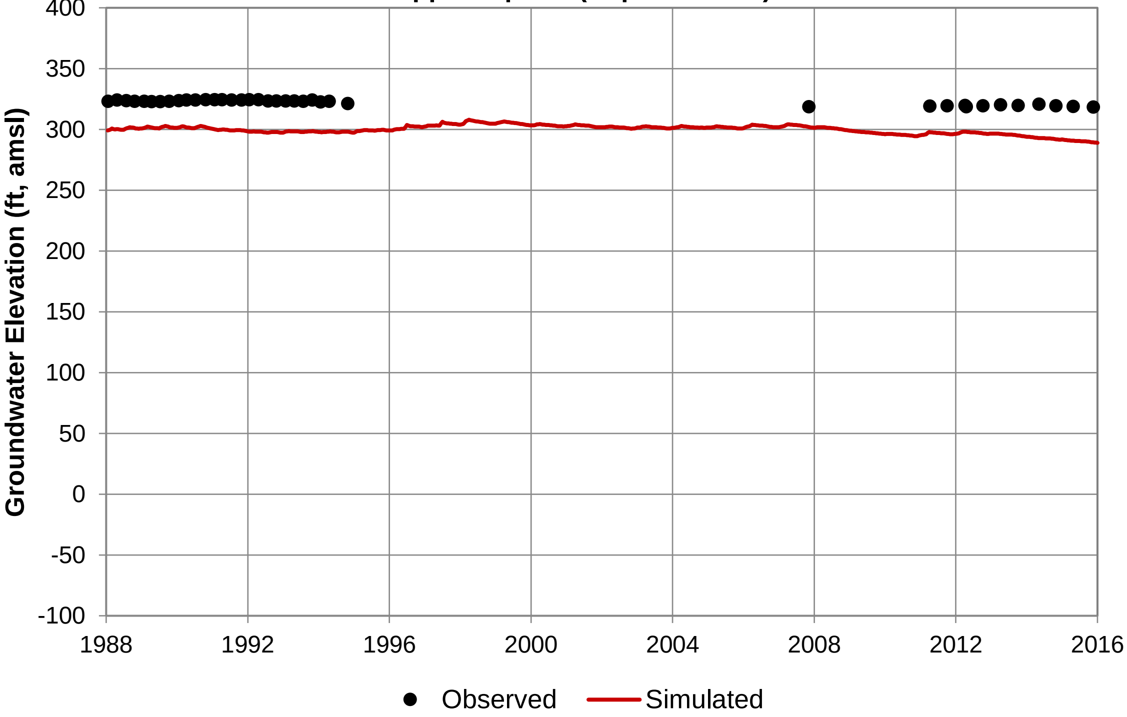


Flow Model Calibration Hydrograph
12S/12E-25R02
Upper Aquifer (Depth: 50 feet)

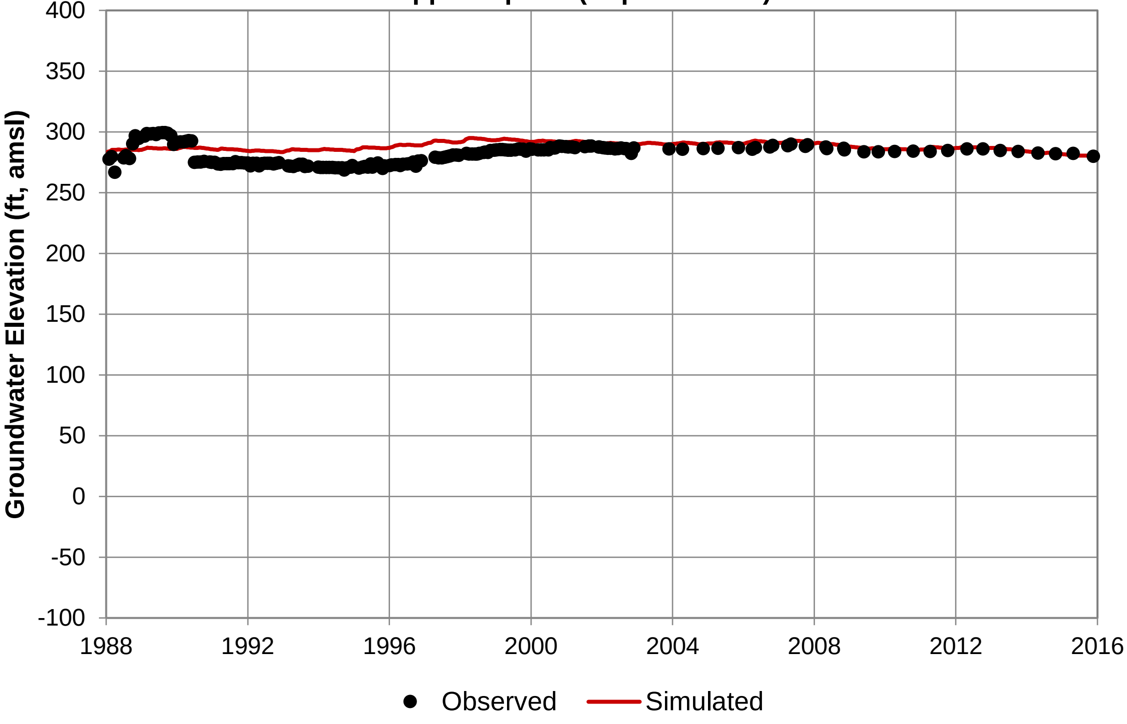
Flow Model Calibration Hydrograph
16S/16E-03E01
Upper Aquifer (Depth: 50 feet)



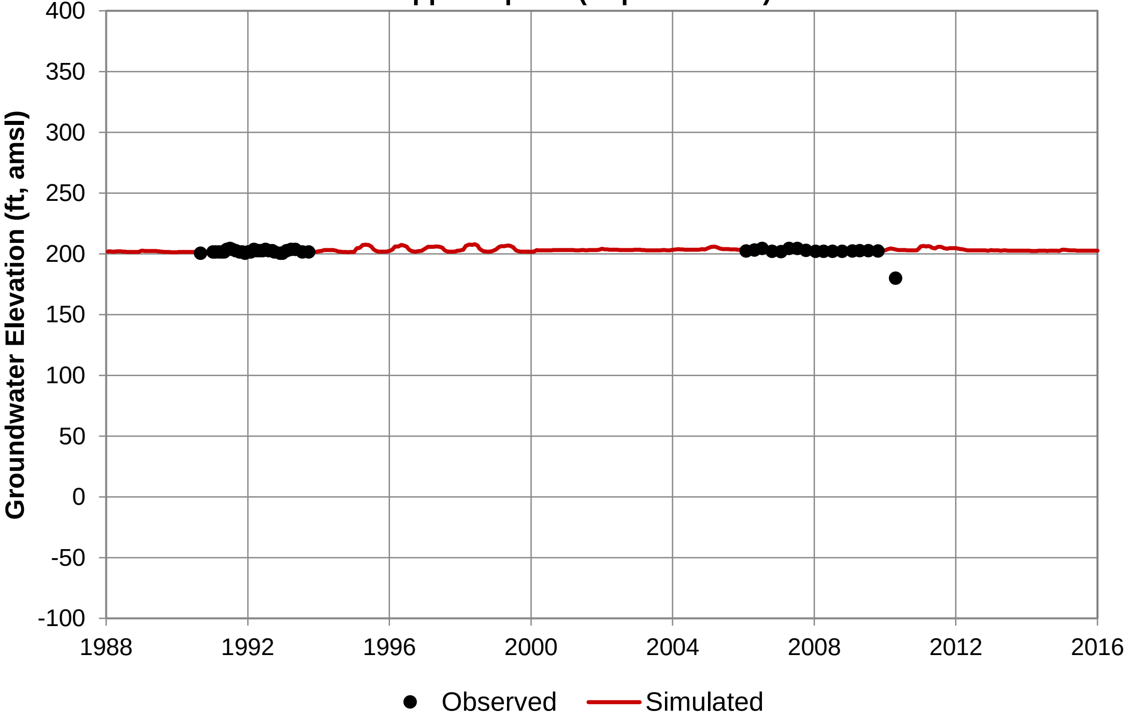
Flow Model Calibration Hydrograph
15S/13E-13J01
Upper Aquifer (Depth: 52 feet)

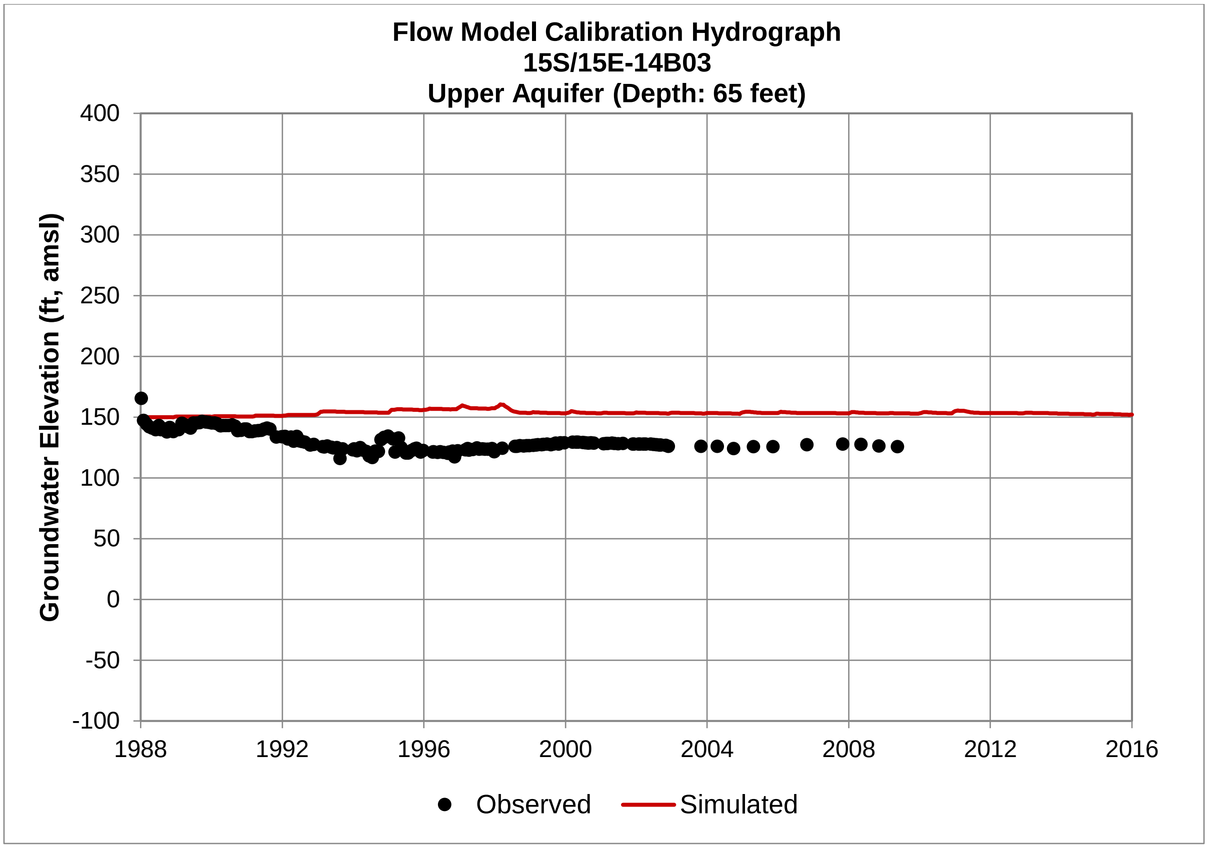


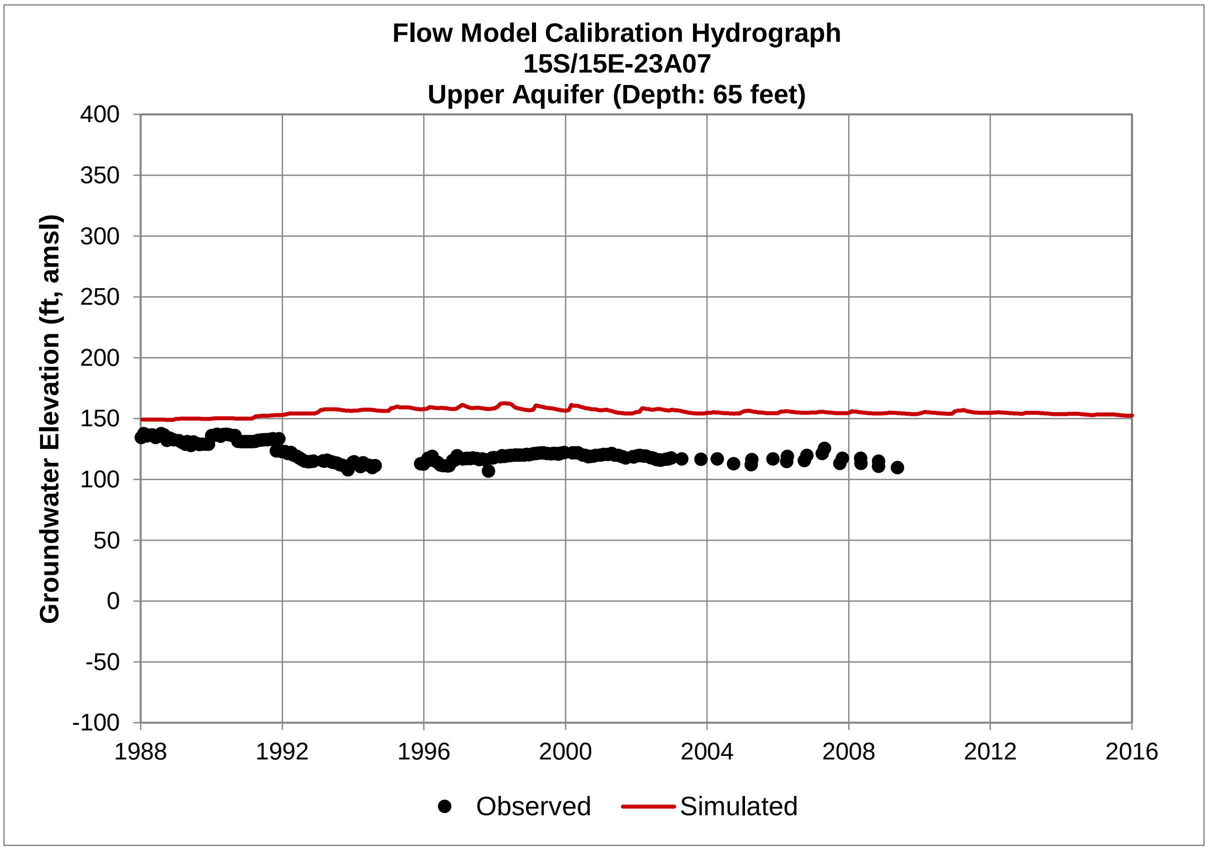
Flow Model Calibration Hydrograph
15S/13E-01D02
Upper Aquifer (Depth: 54 feet)

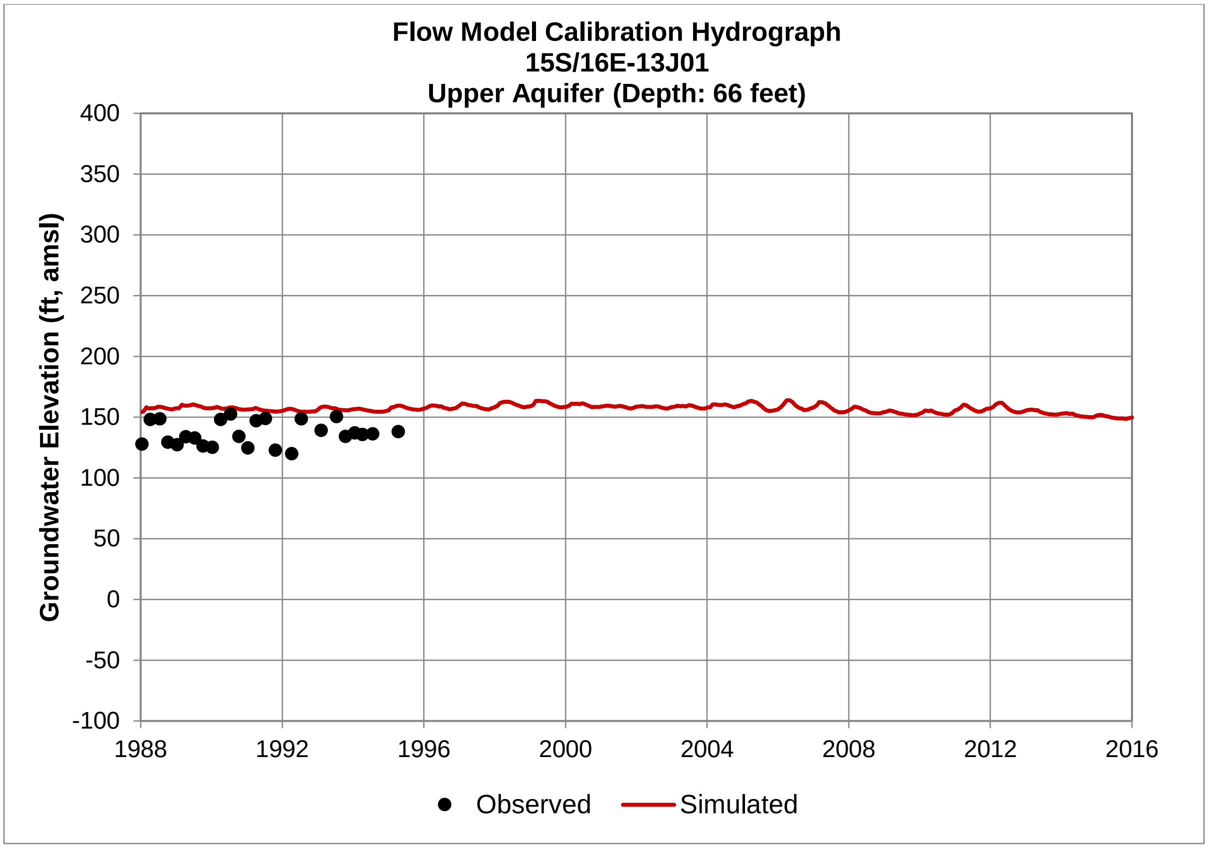


Flow Model Calibration Hydrograph
19S/20E-29E02
Upper Aquifer (Depth: 60 feet)

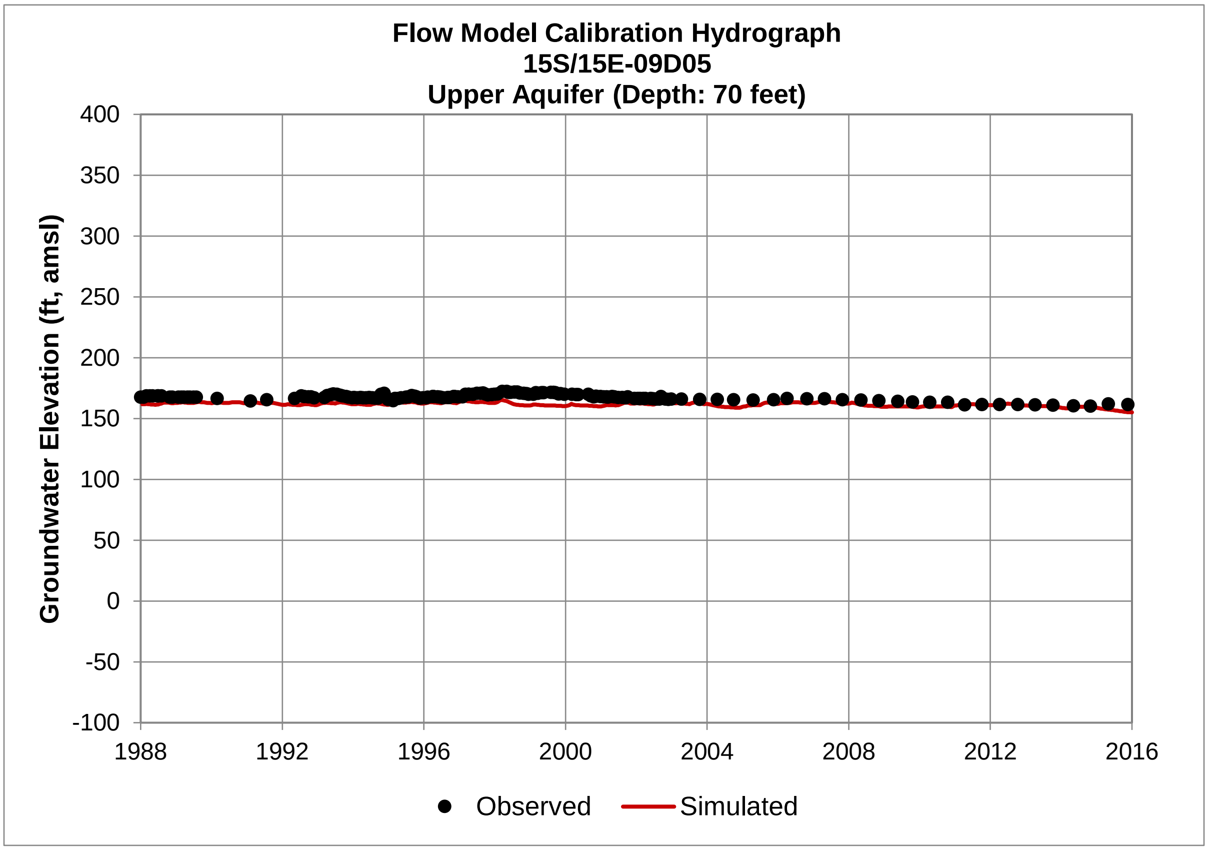



Flow Model Calibration Hydrograph
15S/15E-14B03
Upper Aquifer (Depth: 65 feet)
Groundwater Elevation (ft, amsl)
400
350
300
250
200
150
100
50
0
-50
-100
1988
1992
1996
2000
2004
2008
2012
2016
● Observed
Simulated


Flow Model Calibration Hydrograph
15S/15E-23A07
Upper Aquifer (Depth: 65 feet)
Groundwater Elevation (ft, amsl)
400
350
300
250
200
150
100
50
0
-50
-100
1988
1992
1996
2000
2004
2008
2012
2016
● Observed
Simulated

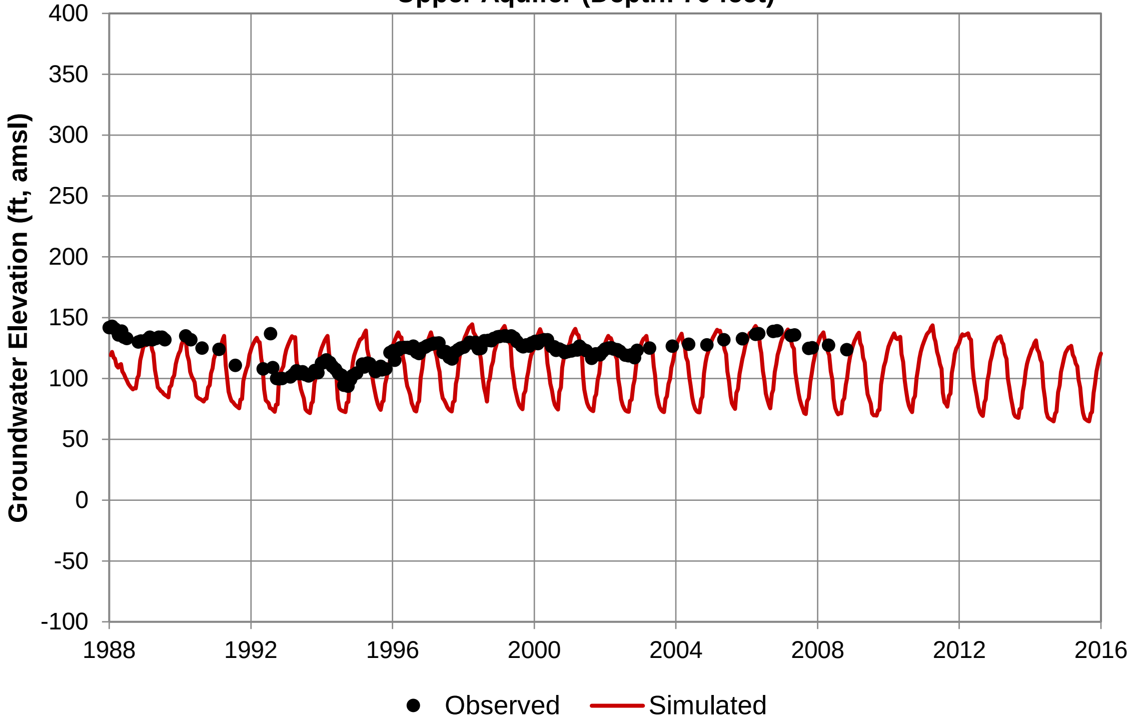


Flow Model Calibration Hydrograph
15S/16E-13J01
Upper Aquifer (Depth: 66 feet)

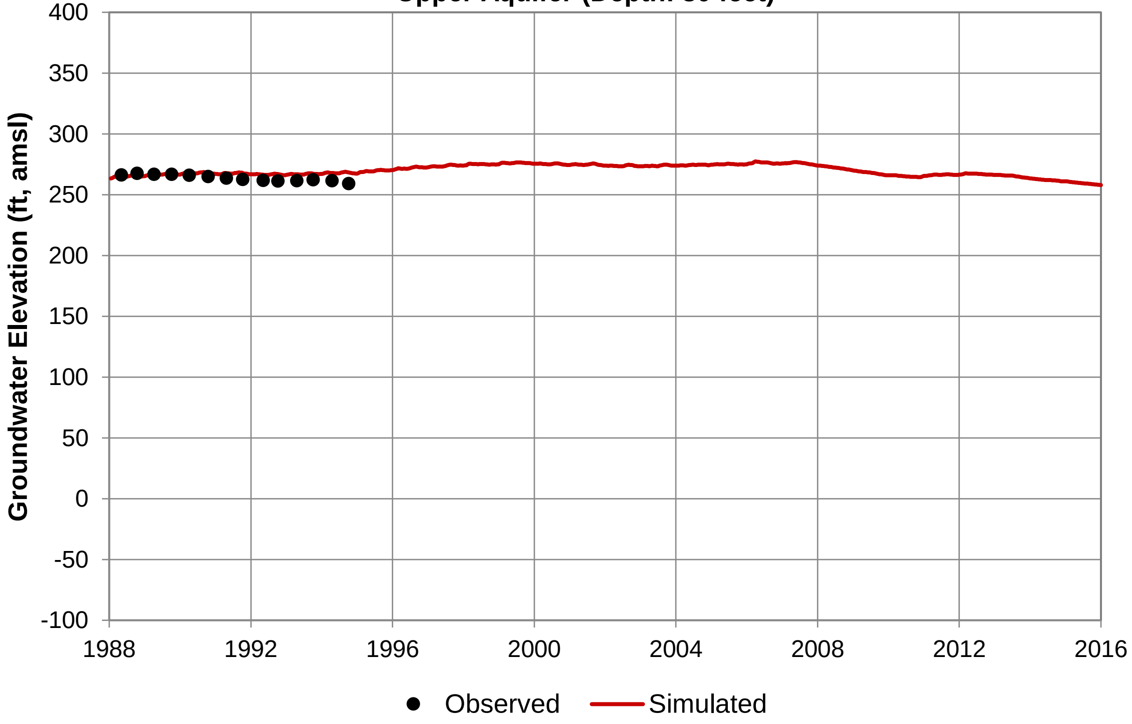


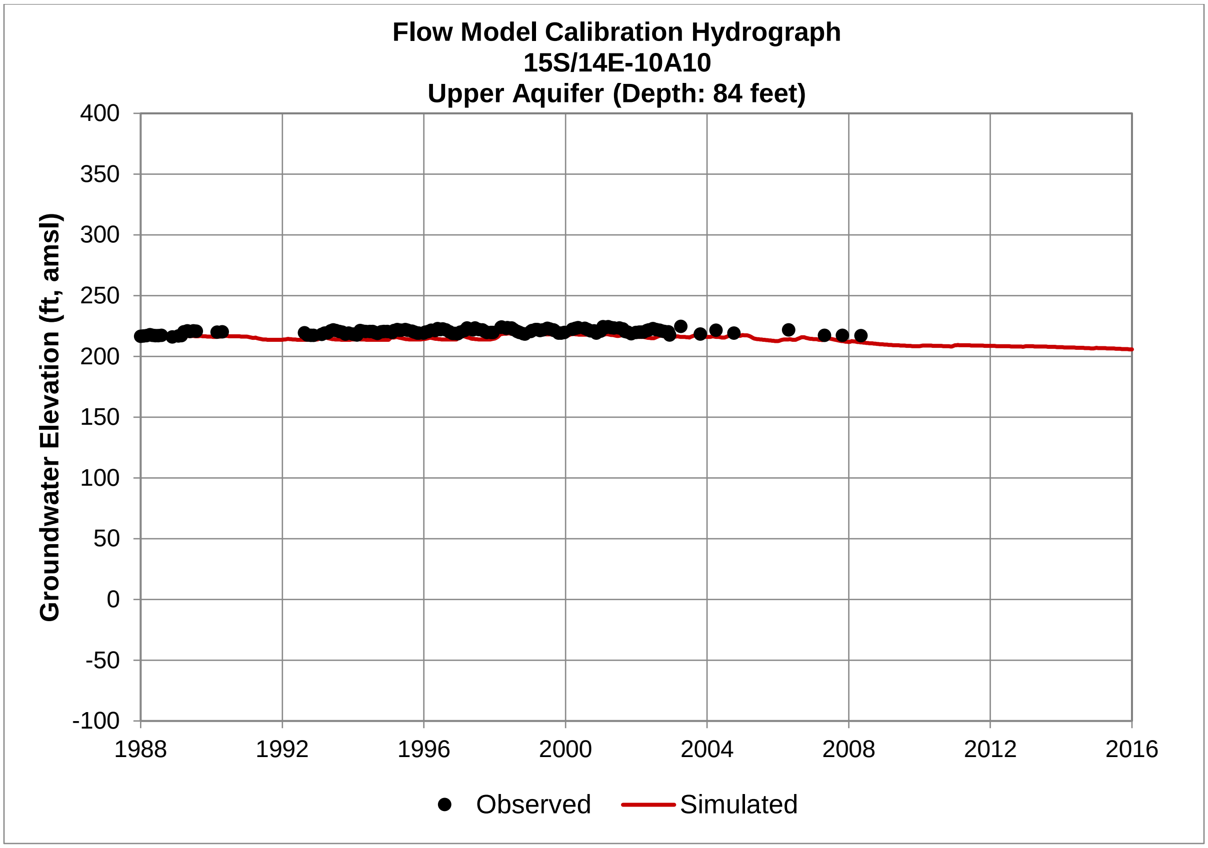
Flow Model Calibration Hydrograph
15S/15E-09D05
Upper Aquifer (Depth: 70 feet)

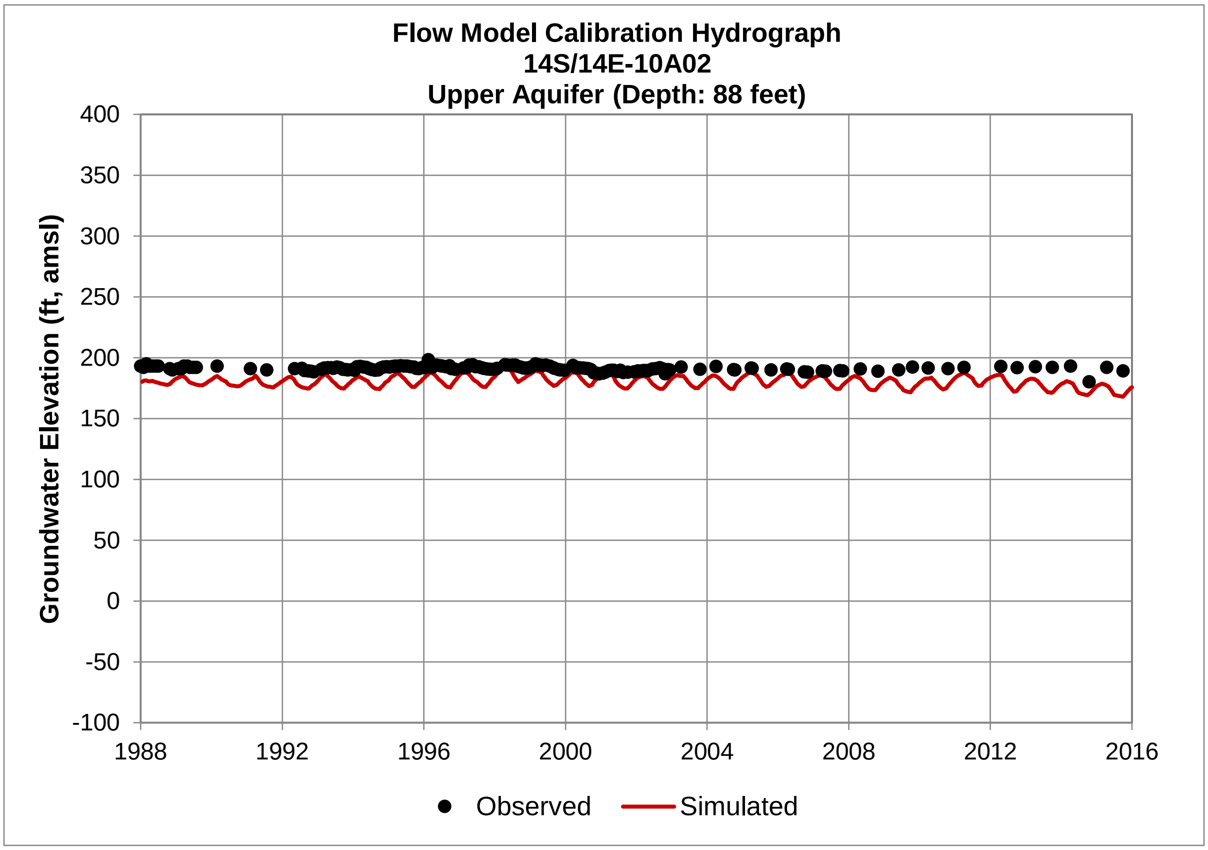
**Flow Model Calibration Hydrograph
13S/15E-31J04
Upper Aquifer (Depth: 70 feet)**

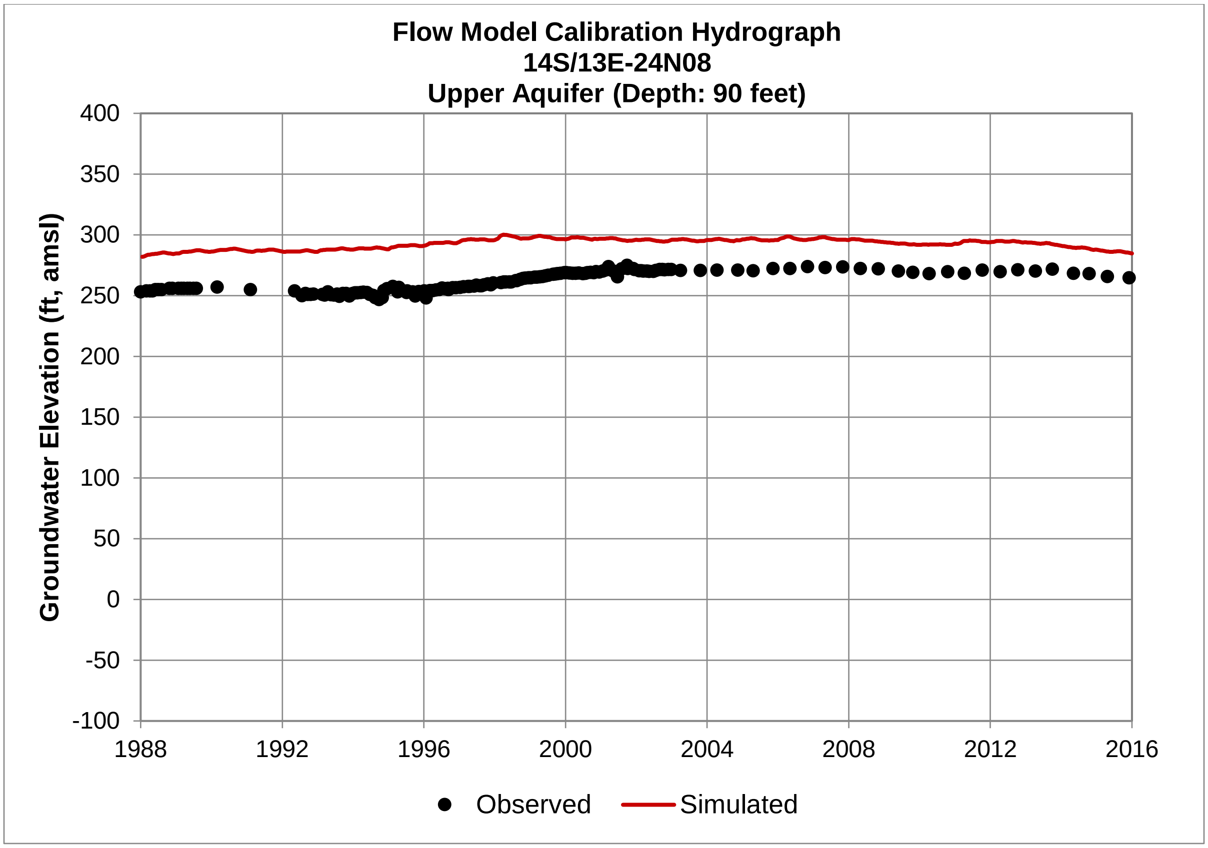


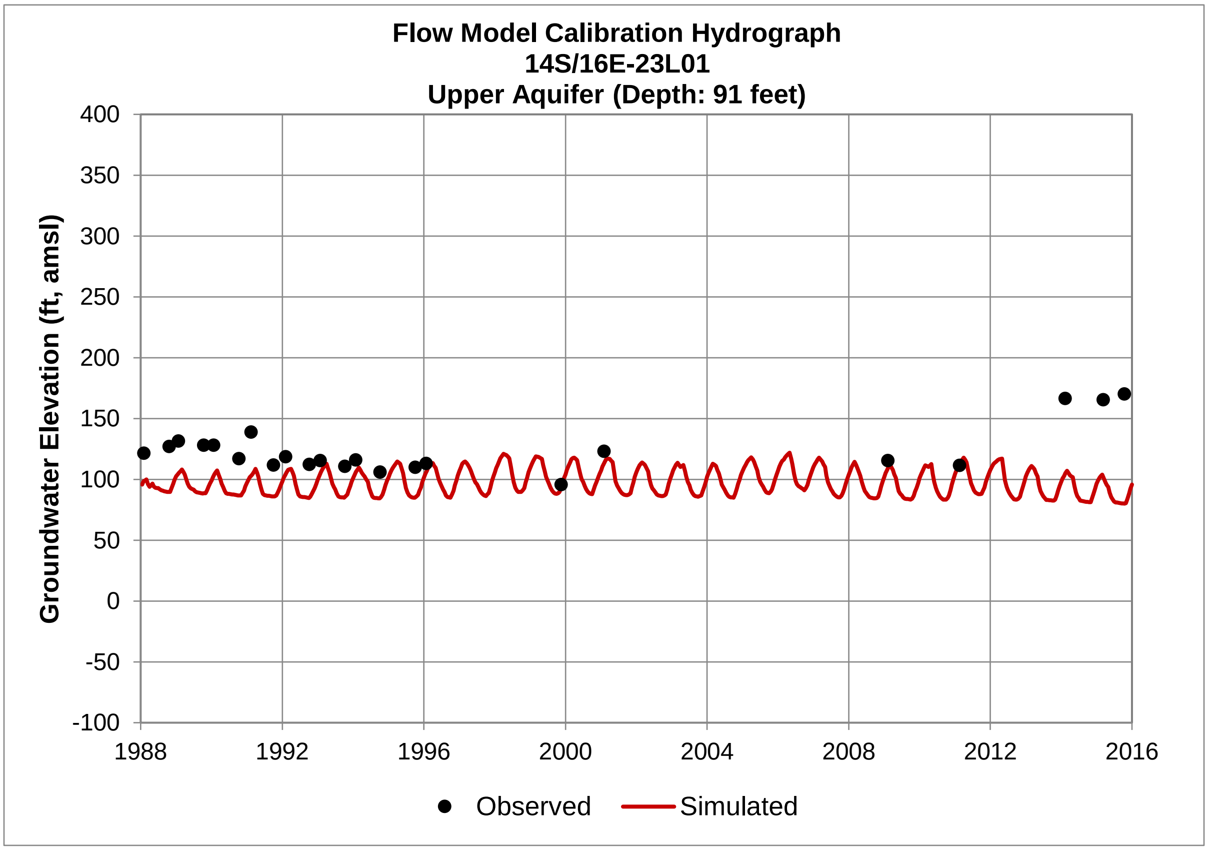
**Flow Model Calibration Hydrograph
20S/18E-34N01
Upper Aquifer (Depth: 80 feet)**

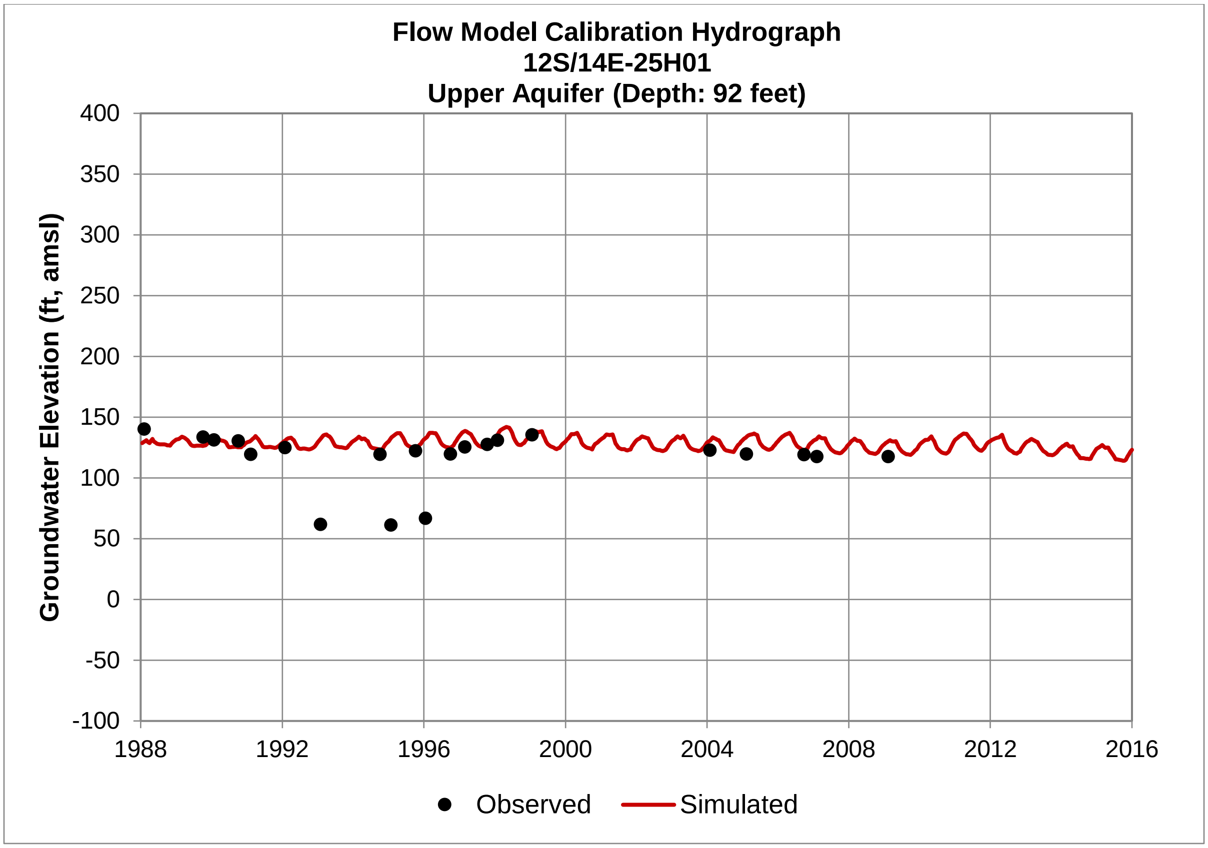


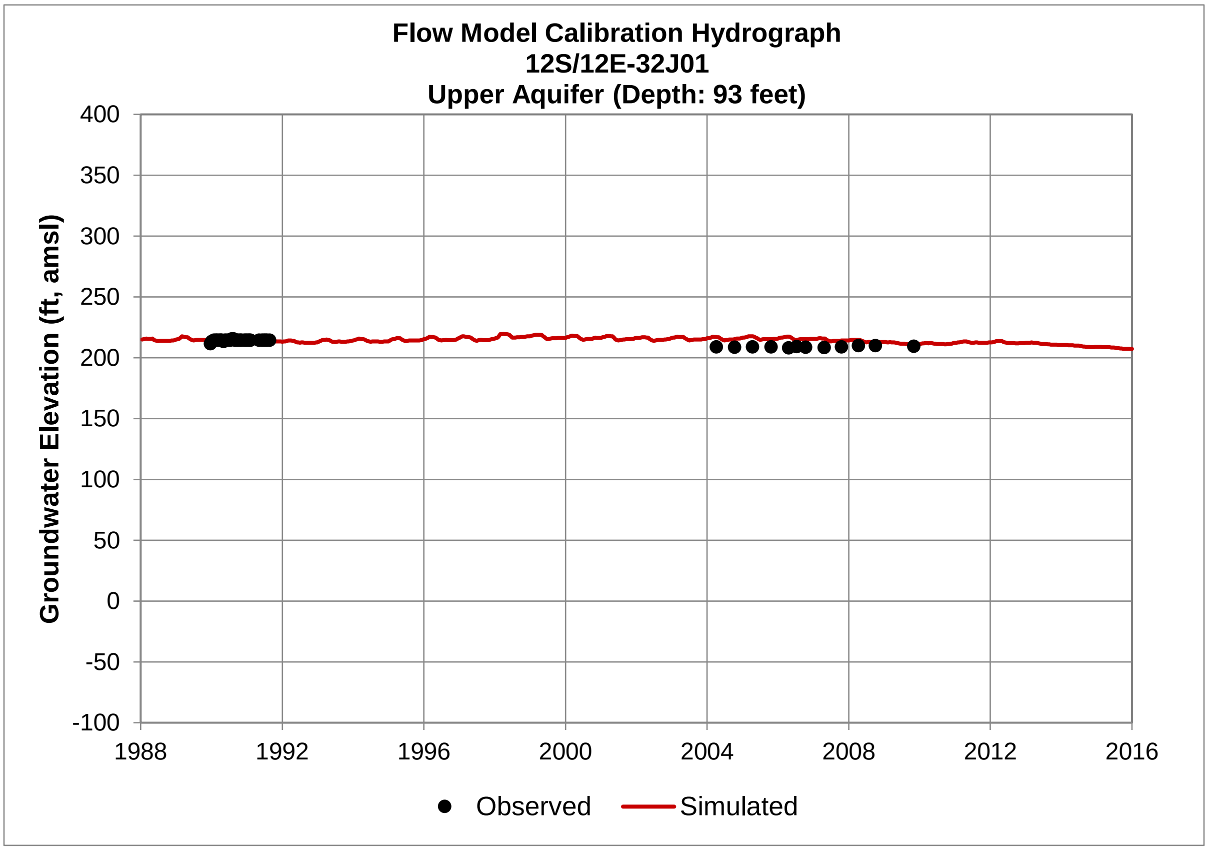

Flow Model Calibration Hydrograph
15S/14E-10A10
Upper Aquifer (Depth: 84 feet)

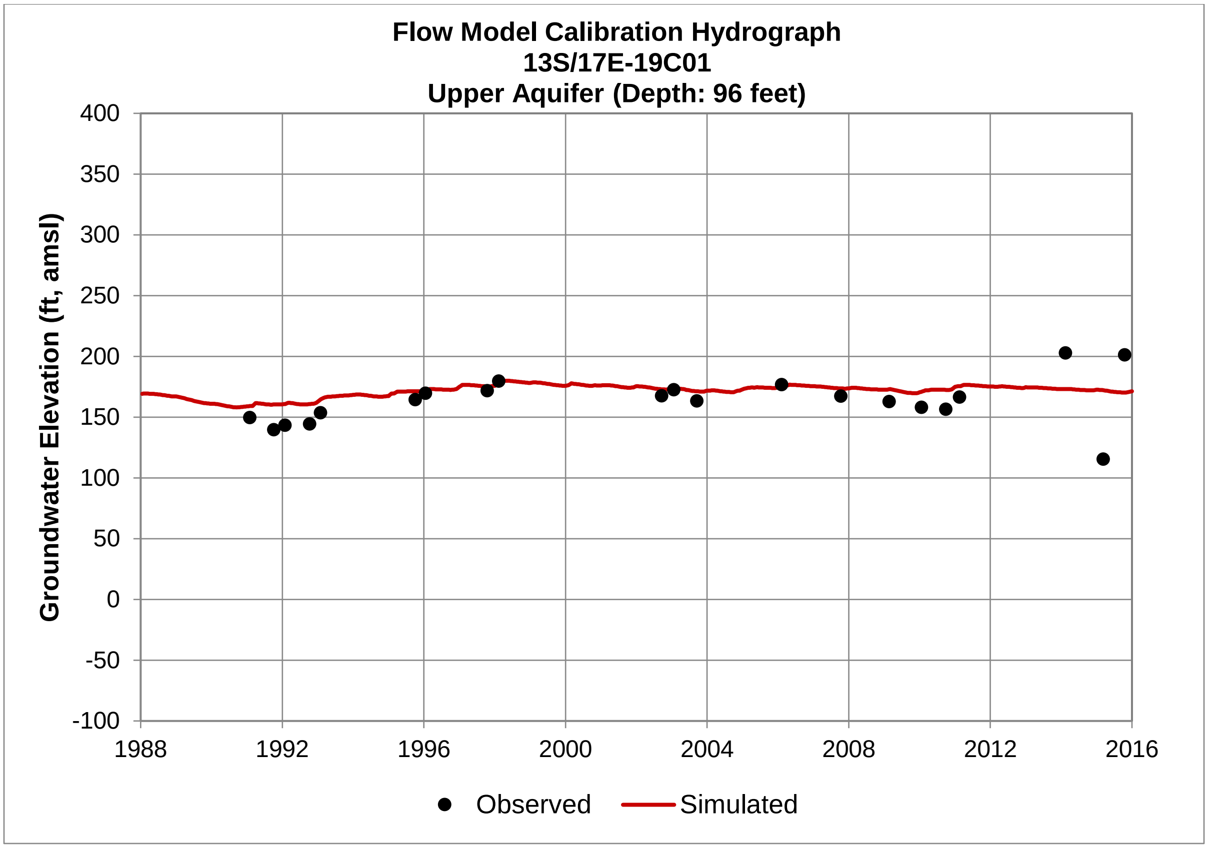

Flow Model Calibration Hydrograph
14S/14E-10A02
Upper Aquifer (Depth: 88 feet)

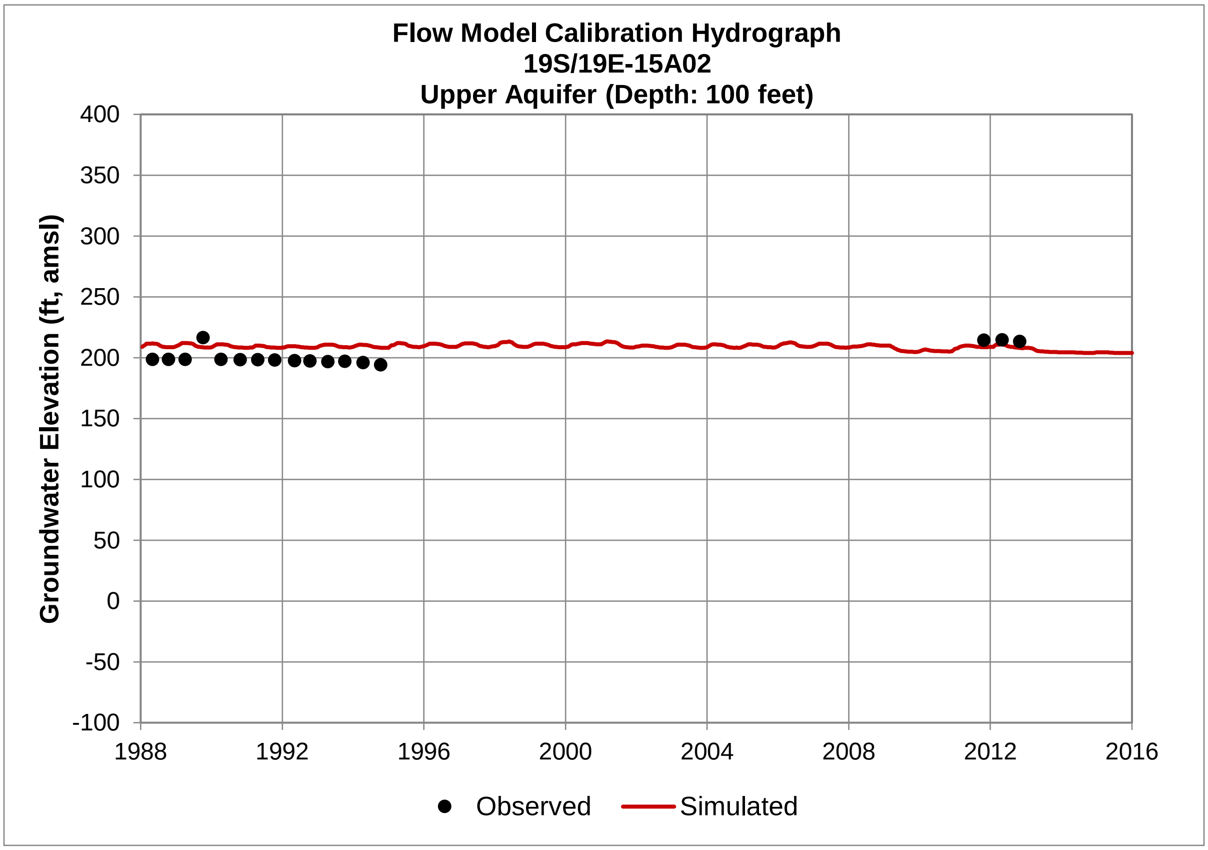

Flow Model Calibration Hydrograph
14S/13E-24N08
Upper Aquifer (Depth: 90 feet)
Groundwater Elevation (ft, amsl)
400
350
300
250
200
150
100
50
0
-50
-100
1988
1992
1996
2000
2004
2008
2012
2016
● Observed
Simulated

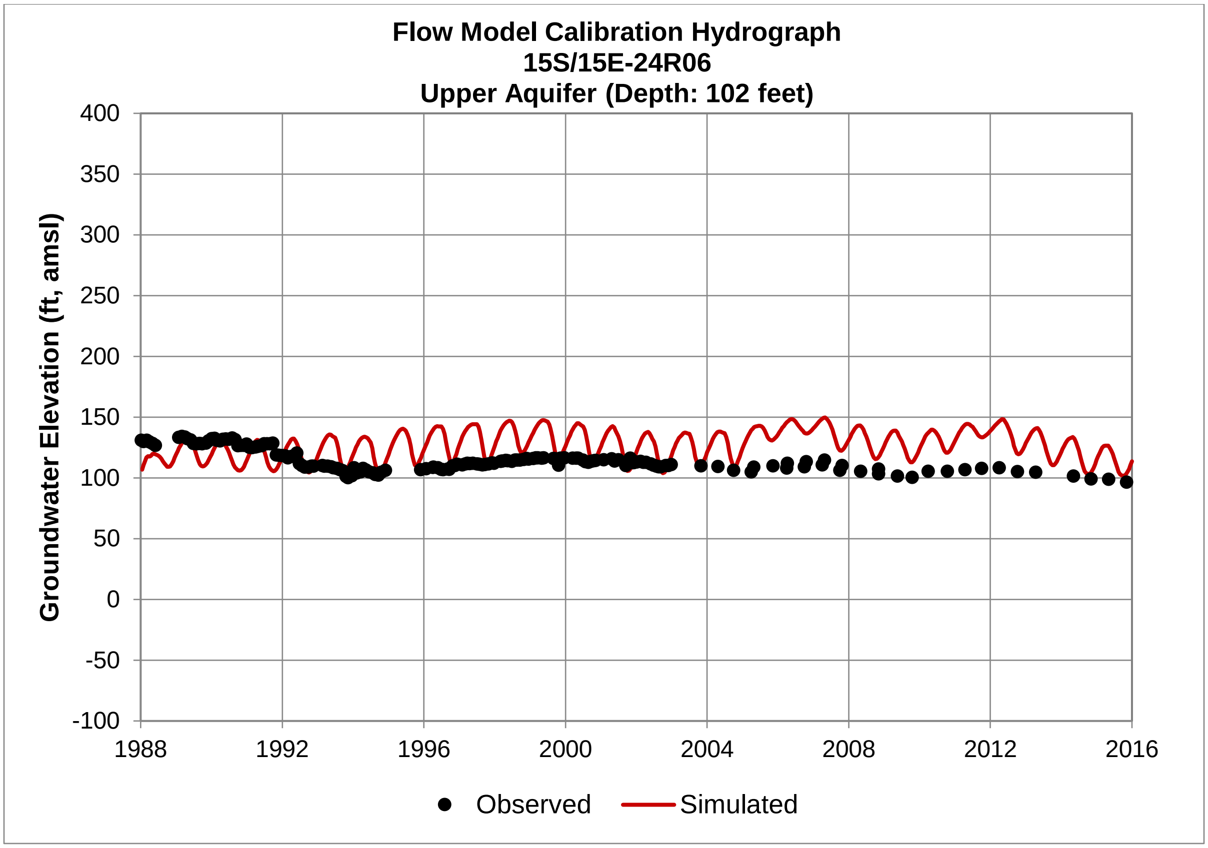

Flow Model Calibration Hydrograph
14S/16E-23L01
Upper Aquifer (Depth: 91 feet)
Groundwater Elevation (ft, amsl)
400
350
300
250
200
150
100
50
0
-50
-100
1988
1992
1996
2000
2004
2008
2012
2016
● Observed
Simulated

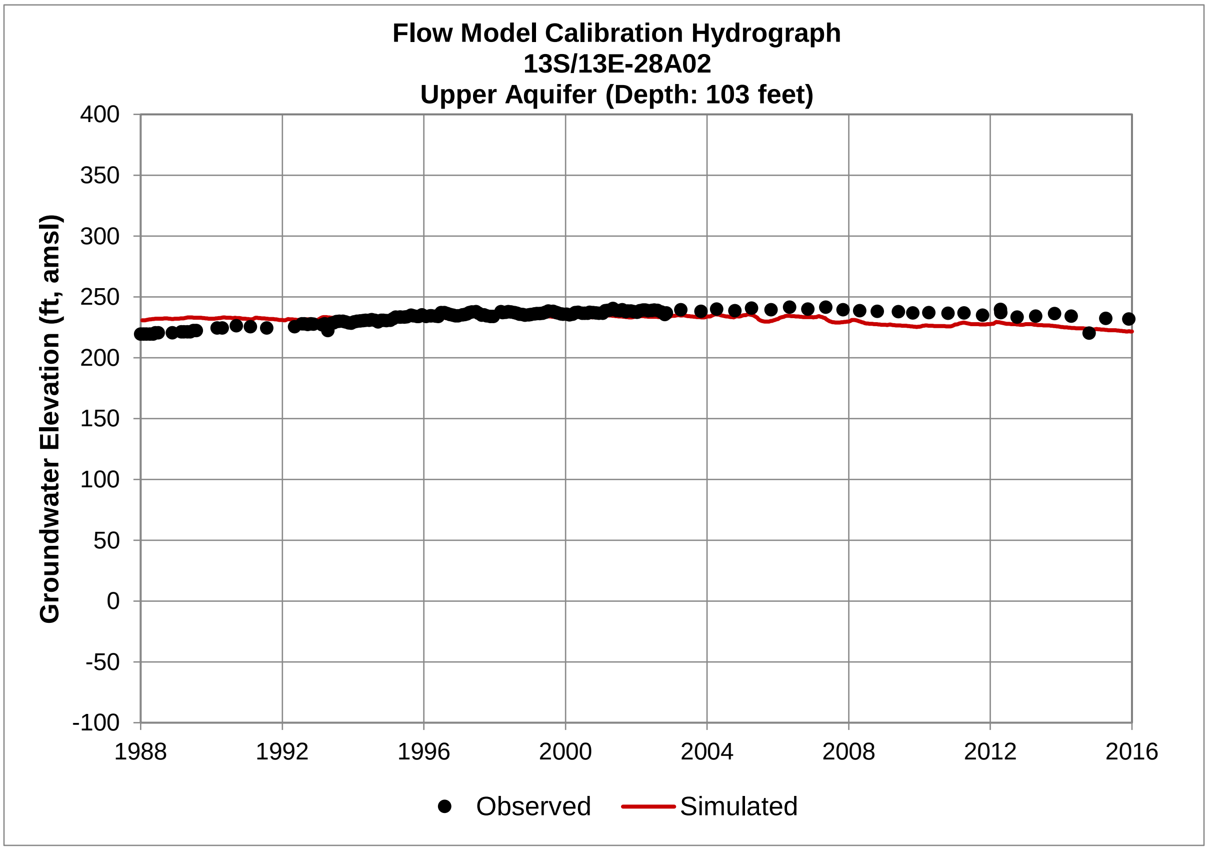

Flow Model Calibration Hydrograph
12S/14E-25H01
Upper Aquifer (Depth: 92 feet)
Groundwater Elevation (ft, amsl)
400
350
300
250
200
150
100
50
0
-50
-100
1988
1992
1996
2000
2004
2008
2012
2016
● Observed
Simulated

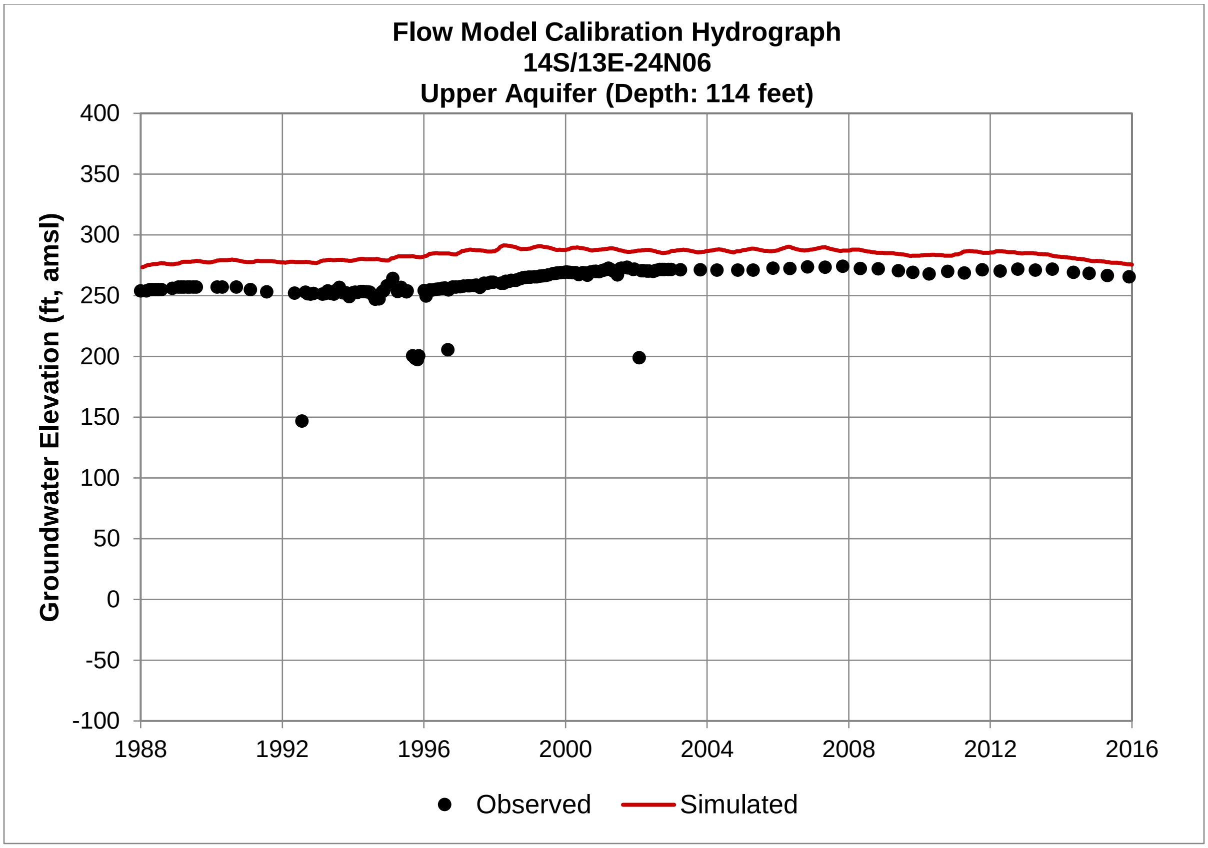

Flow Model Calibration Hydrograph
12S/12E-32J01
Upper Aquifer (Depth: 93 feet)
Groundwater Elevation (ft, amsl)
400
350
300
250
200
150
100
50
0
-50
-100
1988
1992
1996
2000
2004
2008
2012
2016
● Observed
Simulated

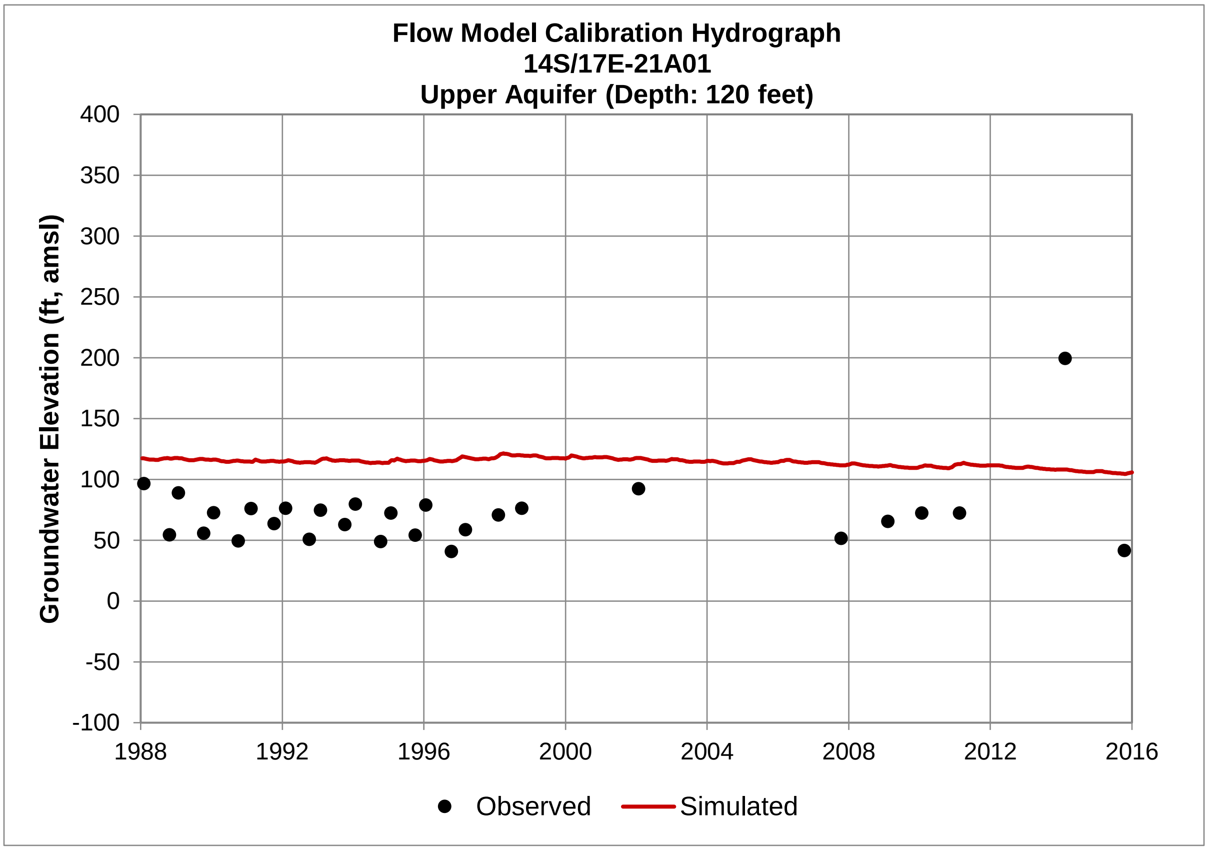

Flow Model Calibration Hydrograph
13S/17E-19C01
Upper Aquifer (Depth: 96 feet)
Groundwater Elevation (ft, amsl)
400
350
300
250
200
150
100
50
0
-50
-100
1988
1992
1996
2000
2004
2008
2012
2016
● Observed
Simulated


Flow Model Calibration Hydrograph
19S/19E-15A02
Upper Aquifer (Depth: 100 feet)
Groundwater Elevation (ft, amsl)
400
350
300
250
200
150
100
50
0
-50
-100
1988
1992
1996
2000
2004
2008
2012
2016
● Observed
Simulated

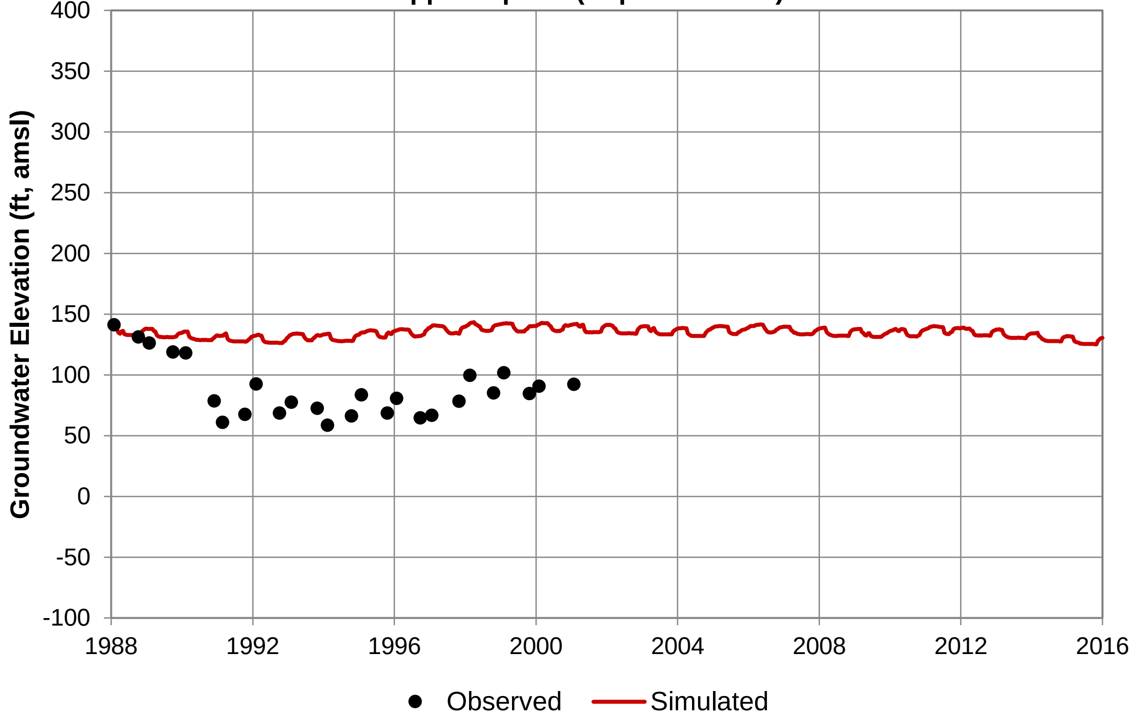

Flow Model Calibration Hydrograph
15S/15E-24R06
Upper Aquifer (Depth: 102 feet)
Groundwater Elevation (ft, amsl)
400
350
300
250
200
150
100
50
0
-50
-100
1988
1992
1996
2000
2004
2008
2012
2016
● Observed
Simulated


Flow Model Calibration Hydrograph
13S/13E-28A02
Upper Aquifer (Depth: 103 feet)
Groundwater Elevation (ft, amsl)
400
350
300
250
200
150
100
50
0
-50
-100
1988
1992
1996
2000
2004
2008
2012
2016
● Observed
Simulated

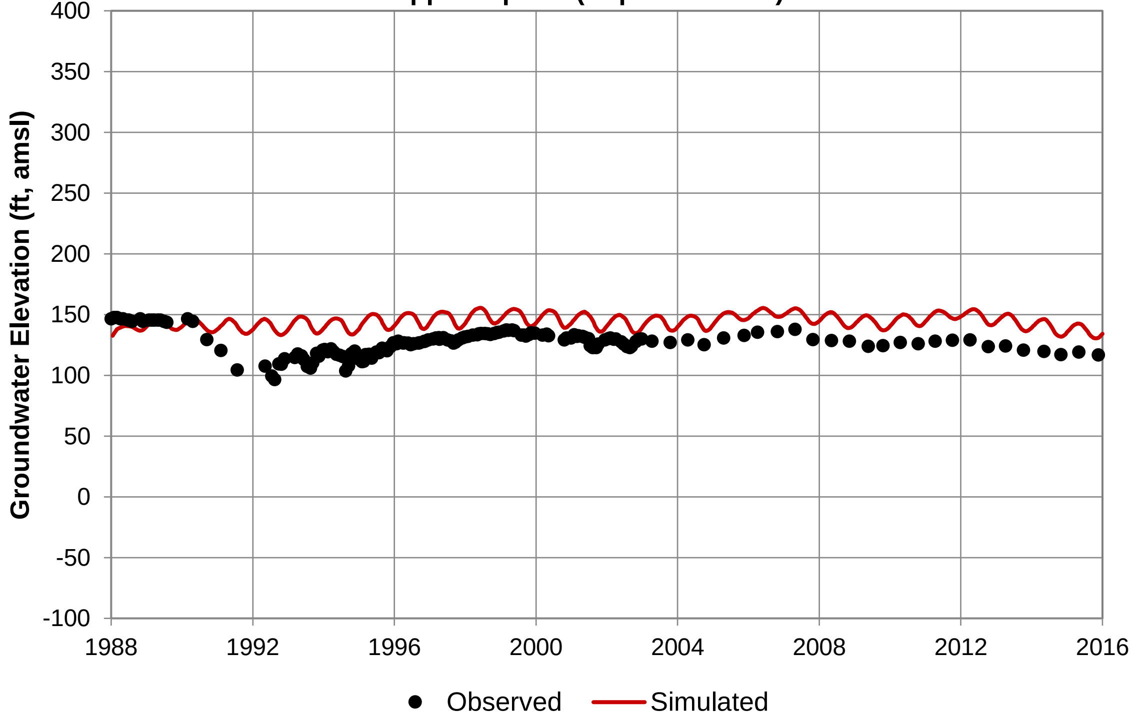

Flow Model Calibration Hydrograph
14S/13E-24N06
Upper Aquifer (Depth: 114 feet)
Groundwater Elevation (ft, amsl)
400
350
300
250
200
150
100
50
0
-50
-100
1988
1992
1996
2000
2004
2008
2012
2016
Observed
Simulated

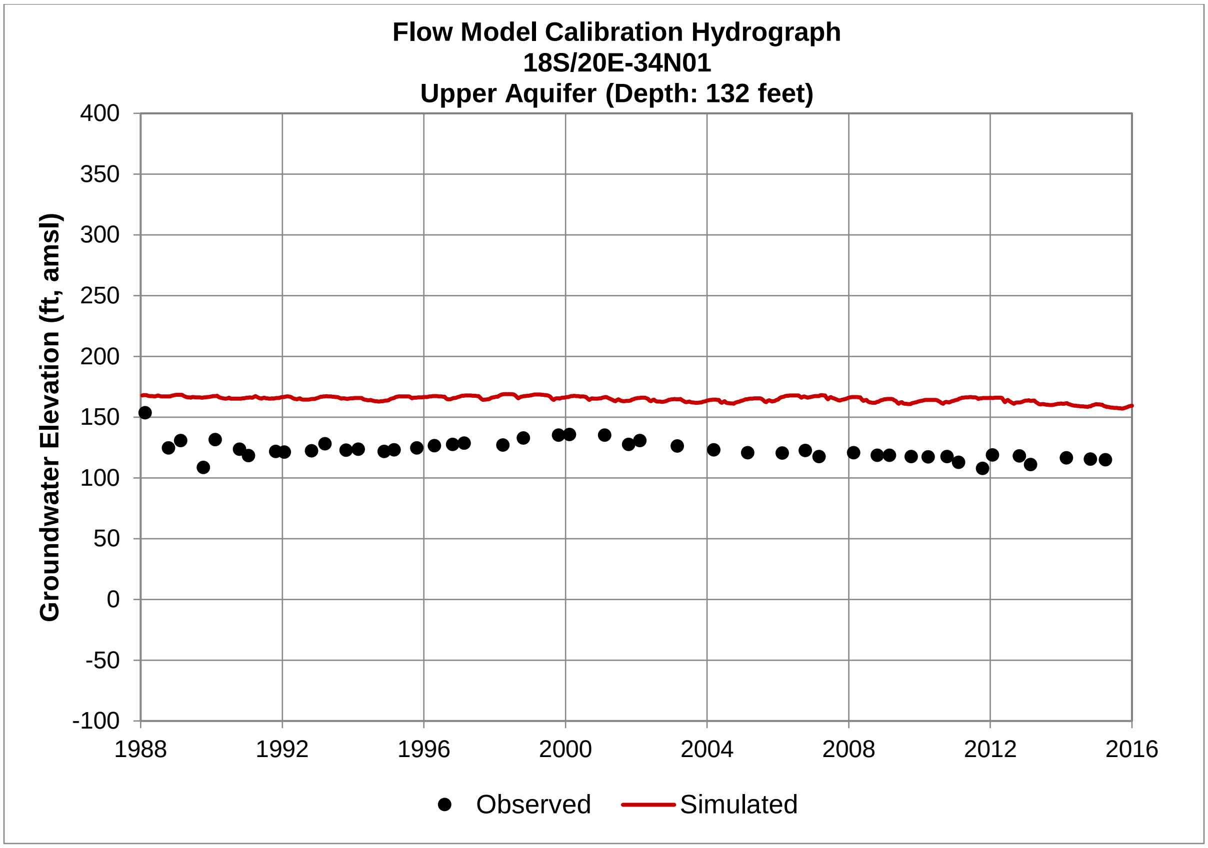

Flow Model Calibration Hydrograph
14S/17E-21A01
Upper Aquifer (Depth: 120 feet)
Groundwater Elevation (ft, amsl)
400
350
300
250
200
150
100
50
0
-50
-100
1988
1992
1996
2000
2004
2008
2012
2016
Observed
Simulated

Flow Model Calibration Hydrograph
10S/15E-27D03
Upper Aquifer (Depth: 130 feet)

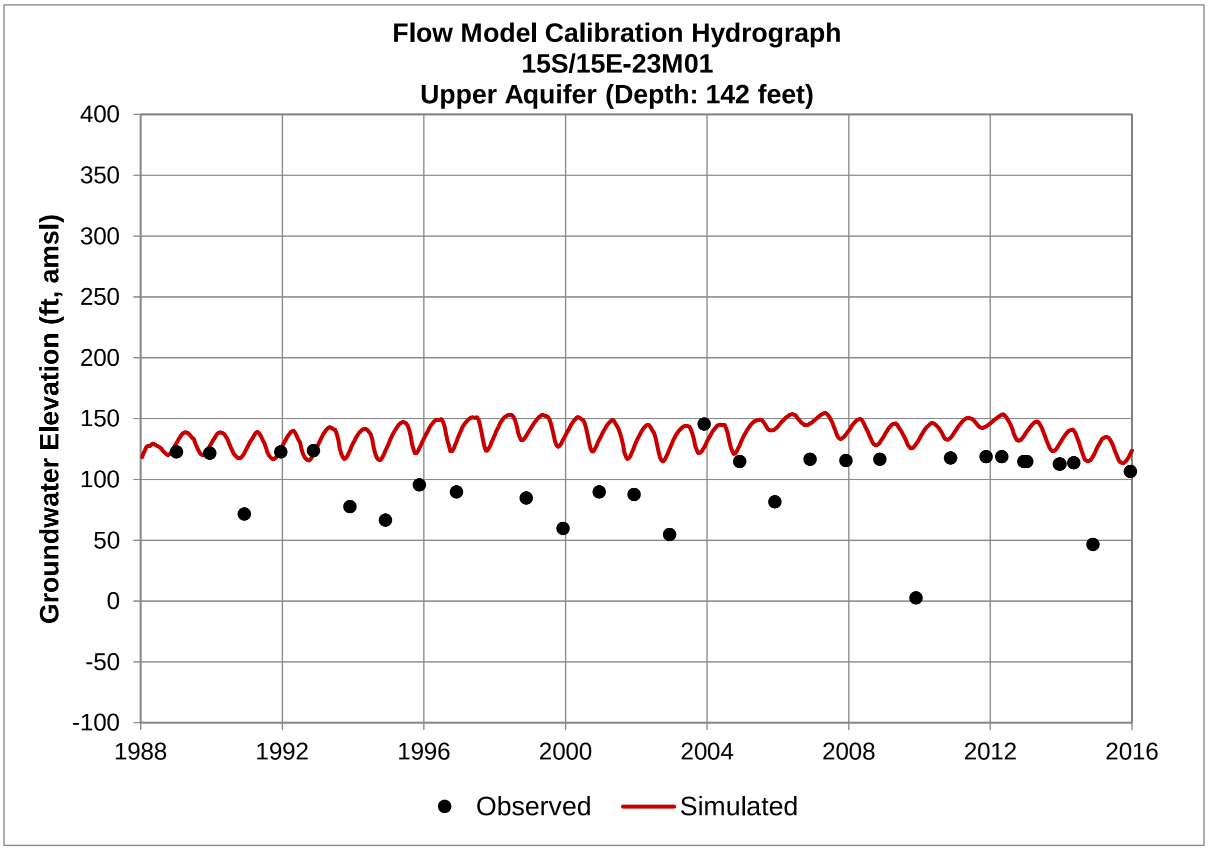


Flow Model Calibration Hydrograph
15S/15E-09D04
Upper Aquifer (Depth: 130 feet)





**Flow Model Calibration Hydrograph
18S/20E-34N01
Upper Aquifer (Depth: 132 feet)**



**Flow Model Calibration Hydrograph
15S/15E-23M01
Upper Aquifer (Depth: 142 feet)**