MONTGOMERY & ASSOCIATES
Water Resource Consultants

Groundwater experts since 1984

TECHNICAL MEMORANDUM

DATE:	December 13, 2023	PROJECT #: 9100
TO:	Salinas Valley Basin Groundwater Sustainability Agency	
CC:	Monterey County Water Resources Agency	
FROM:	Hanni Haynes, Gregory Nelson, Staffan Schorr	
PROJECT:	Salinas Valley Seawater Intrusion Model	
SUBJECT:	2023 Model Updates to Address Groundwater Technical Advisory Comments	

INTRODUCTION

Upon completion of the Salinas Valley Seawater Intrusion Model (SWI Model), the Salinas Valley Basin Groundwater Sustainability Agency (SVBGSA) Groundwater Technical Advisory Committee (GTAC) reviewed and commented on model development and calibration. The GTAC raised 3 main concerns that could affect stakeholder trust in model results. M&A subsequently revised and recalibrated the SWI Model to address the main GTAC concerns. This technical memorandum documents the model updates and is provided as an addendum to the Seawater Intrusion Model Report, noting the sections and figures of the Report that are affected by this update.

SUMMARY OF COMMENTS AND REVISIONS

SWI Model revisions focused on the following 3 main areas of future improvement identified by the GTAC:

1. Recommendation to improve model calibration of inland groundwater levels

While the seawater intrusion calibration provided a good match between simulated and observed intrusion, the GTAC suggested the groundwater level calibration be improved. Improvement to the groundwater level calibration without compromising the seawater intrusion calibration would strengthen the Model as a tool for project modeling.

2. Address simulated chloride concentrations in the Seaside area of the model where not observed

The GTAC noted seawater intruding into the southwestern portion of the Model; however, intrusion hasn't been observed there before so it's unclear what conditions would allow for future seawater intrusion in that area. The GTAC recommended adjusting the calibration to reduce or eliminate simulated seawater intrusion in that area.

3. Adjust Monterey Formation uplift in the Monterey Subbasin based on more recent data

Previous geologic cross sections showed the Monterey Formation, which is considered the bottom of the groundwater basin, uplifting near the boundary between the Monterey Subbasin and the Seaside Subbasin. However, more recent geologic investigations show the Monterey Formation is located at greater depth and the GTAC recommended adjustments be made to reduce the uplift.

MODEL UPDATES

M&A made the following adjustments to the SWI Model to address the GTAC comments and recalibrated the Model.

1. Improvement of inland groundwater levels

Modification of Surface Water Feature Parameters

Surface water channels and diversions are simulated using the CLN package of MODFLOW-USG. Stream parameters including elevations, channel width, and surface water inflows were extracted from the provisional Salinas Valley Integrated Hydrologic Model (SVIHM) and applied to the same streams at the model active extent boundary. Stream parameters such as the conduit hydraulic conductivity and the leakance term have a strong control on the connectivity between the surface water and groundwater. The conduit conductivity also influences the modeled stage within the stream. The leakance term represents the ease with which water may flow through the stream bed, which also relies on the head difference between the stream stage and the connected groundwater aquifer.

The previously simulated average flow from surface water to groundwater along the portion of the Salinas River in the model was less than 1 AF/yr. The magnitude of this component of the water budget is uncertain, but analysis of the stream flow between the Chualar and Spreckels gages suggest that surface water leakage from just this section of the Salinas River is approximately 15,000 to 20,000 AF/yr; the Monterey County Water Resources Agency (MCWRA) estimates a leakage rate between 30,000 and 80,000 AF/yr (2023 MCWRA River Series). The conduit conductivity and leakance parameters were adjusted to significantly increase the simulated stream leakage from the Salinas River. These same stream parameters for other streams in the model were also adjusted to slightly increase their simulated leakage.

Table 1. Surface Water Parameter Updates

Change to Model	Previous Model Value	Updated Model Value
Conduit Conductivity	3.2e7	Salinas R. = 1,000 Other Streams = 50,000
Leakance	100	Salinas R. = 1,000 to 200,000 Other Streams = 500
Total 1995-2020* Simulated Average Net Stream Leakage	700 AF/yr	40,800 AF/yr
1995-2020* Simulated Average Net Stream Leakage Salinas River b/w Chualar and Spreckels	<1 AF/yr	22,700 AF/yr

*For consistency with MCWRA calculations, 1995-2020 does not include drought years 2012-2016.

Modification of Southeastern Boundary Groundwater Inflow

The southeastern boundary of the model is at the upgradient portion of the valley at Chualar Creek. Groundwater inflow across the boundary is simulated using a time-variant constant head boundary (CHD) active in layers 2 through 11. The specified heads used in the model were simulated heads from the provisional SVIHM. A review of observed groundwater elevations in wells located near the southeastern boundary revealed that the simulated heads from the provisional SVIHM were on average 20 feet lower than observed groundwater elevations. The heads in the CHD boundary were updated to reflect the observed groundwater elevations in this region as described below.

Ten wells with a sufficient record of annual data extending back to around 1980 were identified near the southeastern boundary. Eight of the wells are within the Pressure subarea and 2 are within the Eastside subarea. In the Pressure subarea, heads were similar between wells screened in the 180-Foot and 400-Foot Aquifers. The heads in the shallow portion of the Eastside Aquifer were lower than deeper screened wells, though data are limited. The timeseries of average observed heads across the 8 Pressure wells was used for layer 2 through 11 where the CHD boundary is within the Pressure subarea. Where the CHD boundary is in the Eastside subarea, the timeseries of heads from well 15S04E24N03 is used for shallow layers (2 through 6) and heads from well 15S04E14N01 are used for the deeper layers (7 through 11).

Adjustment of Hydraulic Conductivity in 180-Foot and 400-Foot Aquifers

The horizontal hydraulic conductivity in the 180-Foot and 400-Foot Aquifers (parameter zones 30 and 50, respectively) was initially updated based on aquifer testing data. The portion of the

180-Foot Aquifer in Monterey was not adjusted. Hydraulic conductivity distribution was estimated using the pilot point methodology (Doherty et al., 2010). The hydraulic conductivity was manually adjusted by adjusting individual pilot point values to achieve an improved fit between simulated and observed groundwater levels, as well as between the simulated and observed 500 milligrams per liter (mg/L) chloride concentration contour. The changes to hydraulic conductivity are summarized in Table 2.

Table 2. Hydraulic Conductivity Updates to 180-Foot and 400-Foot Aquifers

Horizontal Hydraulic Conductivity (ft/d)	Previous Model Value	Updated Model Value
180-Foot Aquifer (Zone 30)		
Geometric mean	57	143
Minimum	12	50
Maximum	184	257
400-Foot Aquifer (Zone 50)		
Geometric mean	10	53
Minimum	2.5	13
Maximum	51	133

ft/d = feet per day

Refinements based on Review of Seawater Intrusion Calibration

The inland progression of the 500 mg/L chloride concentration contour was reviewed following other adjustments summarized above. The effective porosity was adjusted in the 180-Foot and 400-Foot Aquifers to improve the calibration between the simulated 500 mg/L chloride concentration contour and MCWRA's observed contours. Previously the simulated effective porosity in the modeled 180-Foot Aquifer ranged from 11.7% to 16% and was reduced to 10%. In the 400-Foot Aquifer, the effective porosity was increased from 15% to 21%. Modification of the effective porosity resulted in a balance between the calibration of groundwater levels and seawater intrusion.

2. Seaside Seawater Intrusion Calibration

M&A reduced the horizontal hydraulic conductivity in the coastal sediments where they underlie the ocean and near the coastline in Seaside in all layers. The inland hydraulic conductivity was increased slightly during the model update. This was accomplished through the addition of several pilot points along the coast. The resulting hydraulic conductivity ranged from 16 feet per day (ft/d) near the coast to 75 ft/d inland near Seaside, compared to the prior 38 to 66 ft/d. This slowed the simulated seawater intrusion without substantially impacting the simulated groundwater levels in this area. Additionally, groundwater pumping in Seaside during the second ramp-up stress period (1924-1984) was removed as pumping in this area was minimal during this time-period.

3. M&A Reduced Uplift of the Monterey Formation in the Monterey Subbasin

M&A adjusted the hydrostratigraphic units represented through the model layering and hydraulic parameter zonation in this area to reflect more recent understanding of the basin geology. The uplift of the Monterey Formation between the Monterey Subbasin and Seaside Subbasin was reduced by modifying the parameter zonation of the Monterey Formation in this area (zone 90) in the subject layers 7 through 10 to reflect the surrounding zones (400-Foot Aquifer, Deep Aquitard, Paso Robles Formation, and Purisima Formation). Then the elevations of layers 7 through 10 were adjusted to extend the surrounding formations through the area where the uplift had previously been delineated in the model.

Initial Conditions and Ramp-Up Periods Update

Due to the modification of the model layering, the initial heads and initial concentrations were updated according to the method described in Section 3.3 of the SWI Report.

With the adjustments to hydraulic conductivity noted above, it was not necessary to modify the initial ramp-up stress periods to achieve a better match between measured and simulated water levels at the beginning of 1985. The only adjustments to the ramp-up stress periods were to eliminate the pumping in Seaside during the second ramp-up stress period.

UPDATED MODEL CALIBRATION

Inland Groundwater Levels

Simulated water levels were compared to the same water level dataset developed for the SWI Model. Table 3 summarizes the model groundwater level calibration statistics across the model and for equivalent aquifer model layers. The water level statistics indicate a better calibration to observed groundwater levels than previously simulated, particularly in the 180-Foot and 400-Foot Aquifers, which were the focus of the model improvement updates. The mean residuals in the individual aquifer model layers indicate that the model tends to underpredict water levels by an average of 20 feet. The mean residuals are now approximately 10 feet or less across the model and generally less than 5 feet in the 180-Foot and 400-Foot Aquifers. The model continues to underpredict water levels but with a smaller magnitude than before the model update.

Table 3. Updated Water Level Calibration Statistics

Model Update					
	Surficial Sediments	180-Foot Aquifer	400-Foot Aquifer	Deep Aquifers	All Data
Mean Residual (ft)	10.56	4.11	2.27	9.48	6.98
RMS Error (ft)	51.31	25.32	19.76	46.66	41.26
Number of Observations	14,709	12,781	9,751	7,251	45,599
Range in Observations (ft)	833	464	252	498	833
Scaled RMS Error	6.16%	5.46%	7.83%	9.38%	4.96%
Scaled Residual Mean	1.27%	0.89%	0.90%	1.91%	0.84%
Previous Model					
	Surficial Sediments	180-Foot Aquifer	400-Foot Aquifer	Deep Aquifers	All Data
Mean Residual (ft)	27.44	28.69	52.09	23.01	32.91
RMS Error (ft)	65.42	45.10	73.52	51.79	62.09
Number of Observations	14,709	12,781	9,751	7,251	45,599
Range in Observations (ft)	833	464	252	498	833
Scaled RMS Error	7.86%	9.72%	29.14%	10.41%	7.46%
Scaled Residual Mean	3.30%	6.18%	20.64%	4.62%	3.95%

Figure 1 and Figure 2 show the mean residual for each water level target in the model layers of the 180-Foot and 400-Foot Aquifers, respectively. Green bubbles indicate the mean residual for that location is positive and simulated water levels underestimate measured water levels. Orange bubbles indicate the mean residual for that location is negative and simulated water levels overestimate measured water levels. These figures show improvements to the model fit compared to Figures 4-5 and 4-6 in the earlier report.

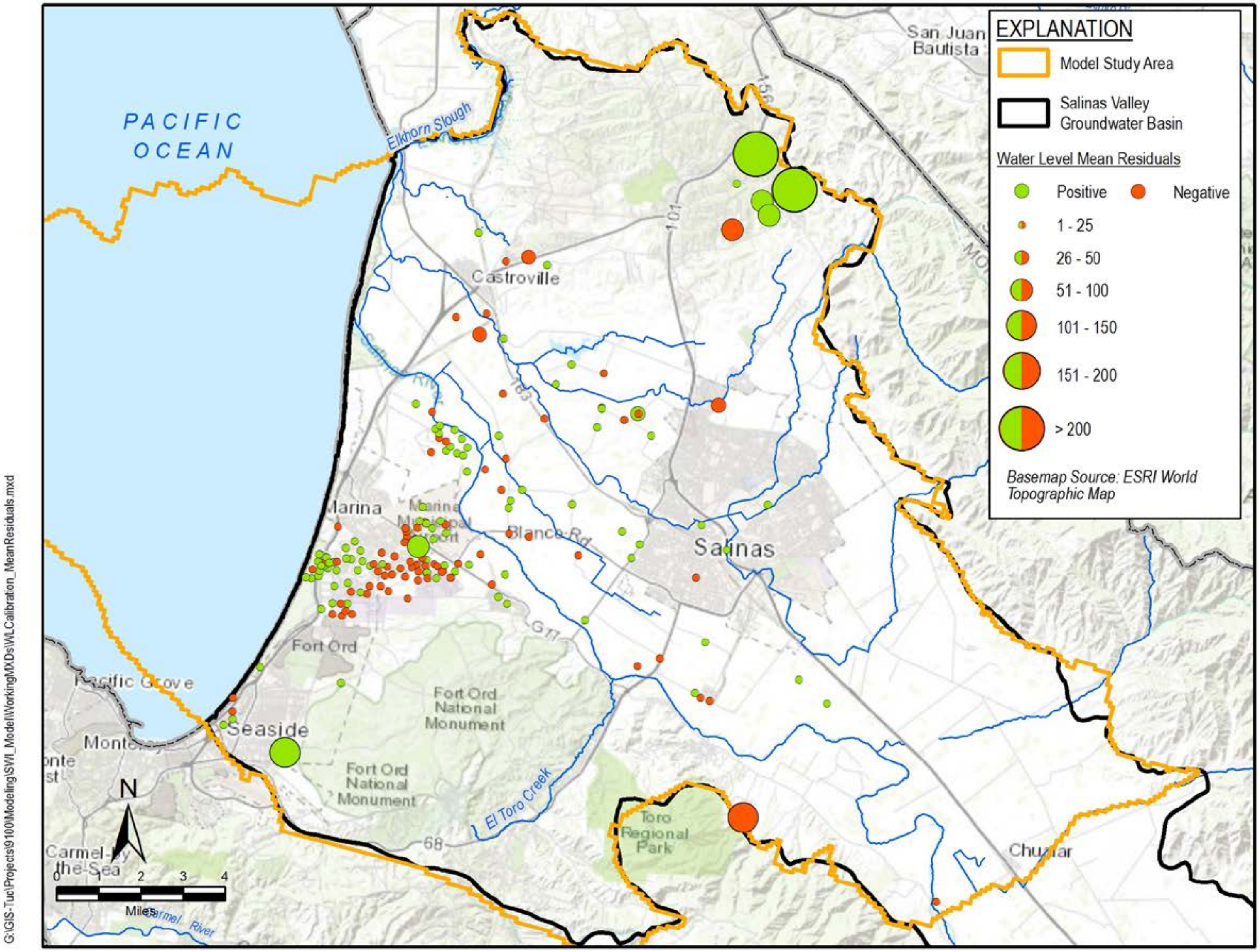


Figure 1. Mean Residual Water Level Bubble Plot within the 180-Foot Aquifer and Equivalent Areas

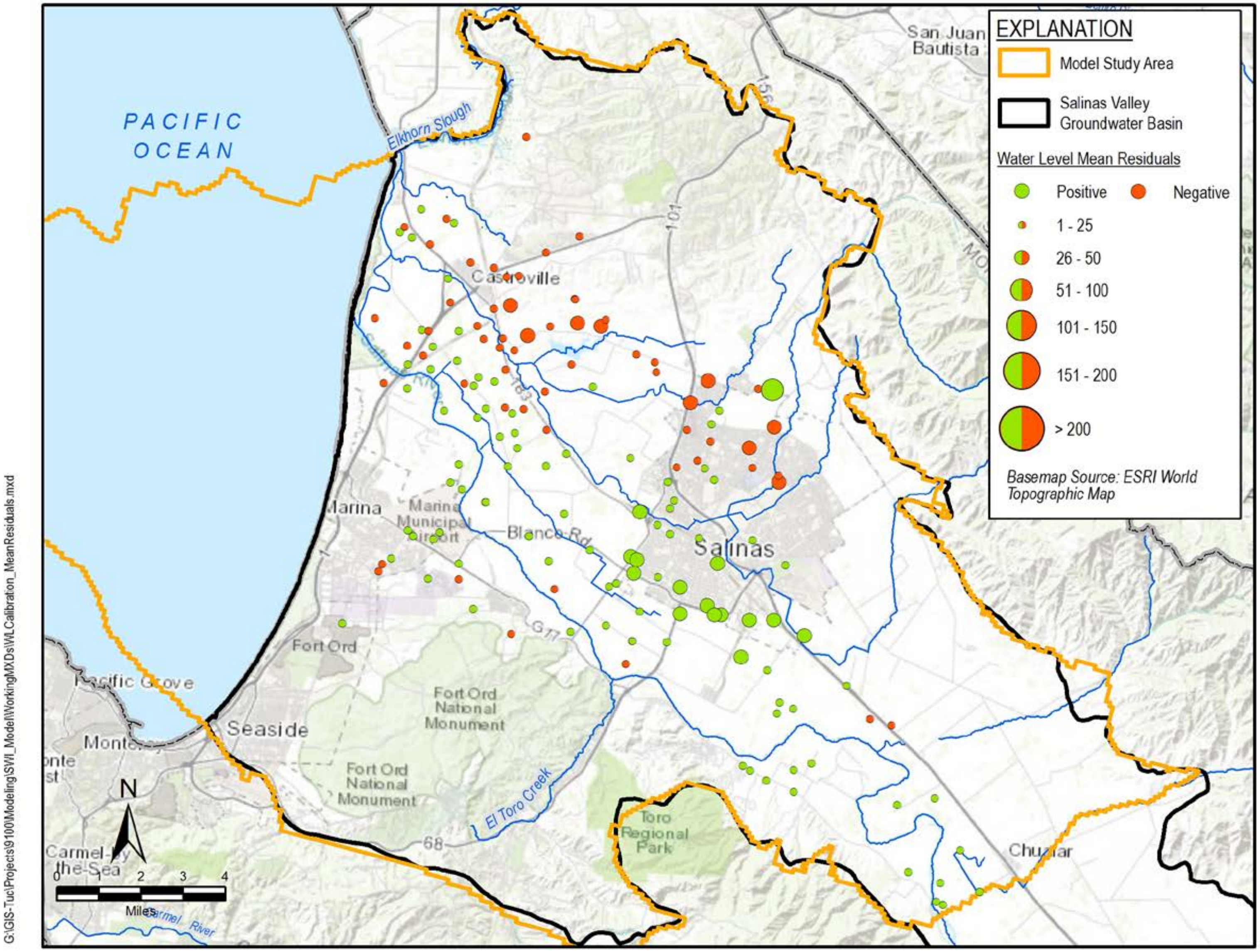


Figure 2. Mean Residual Water Level Bubble Plot within the 400-Foot Aquifer and Equivalent Areas

The previously reported mean residual plots (Figures 4-5 and 4-6) indicated a simulated water level depression south and southwest of the City of Salinas that was greater than the observed water level depression in that area. The updated mean residual plots indicate that the simulated water levels closely correspond to the observed water levels near the City of Salinas and near the coast. There is not a strong spatial trend in the mean residuals in the 180-Foot Aquifer. In the 400-Foot Aquifer, there is a trend that the water levels are slightly too low to the south of the City of Salinas, and a little too high to the north and northwest of Salinas toward Castroville. The water level calibration in the 400-Foot Aquifer is better near the coast and in the seawater intruded area.

The improved water level calibration in the 180-Foot and 400-Foot Aquifers is demonstrated by the simulated and observed water level cross plot (Figure 3). The points plot in a cloud evenly distributed above and below the 1-to-1 line. The points in the 180-Foot and 400-Foot Aquifers are generally closer to the 1-to-1 line than before, indicating an improved water level calibration. The calibration of water levels in the other aquifer groups (Surficial Sediments, Deep Aquifer, and Aquitards & Monterey Formation) is similar to before the model update. Water levels in these groups were not the focus of the model update.

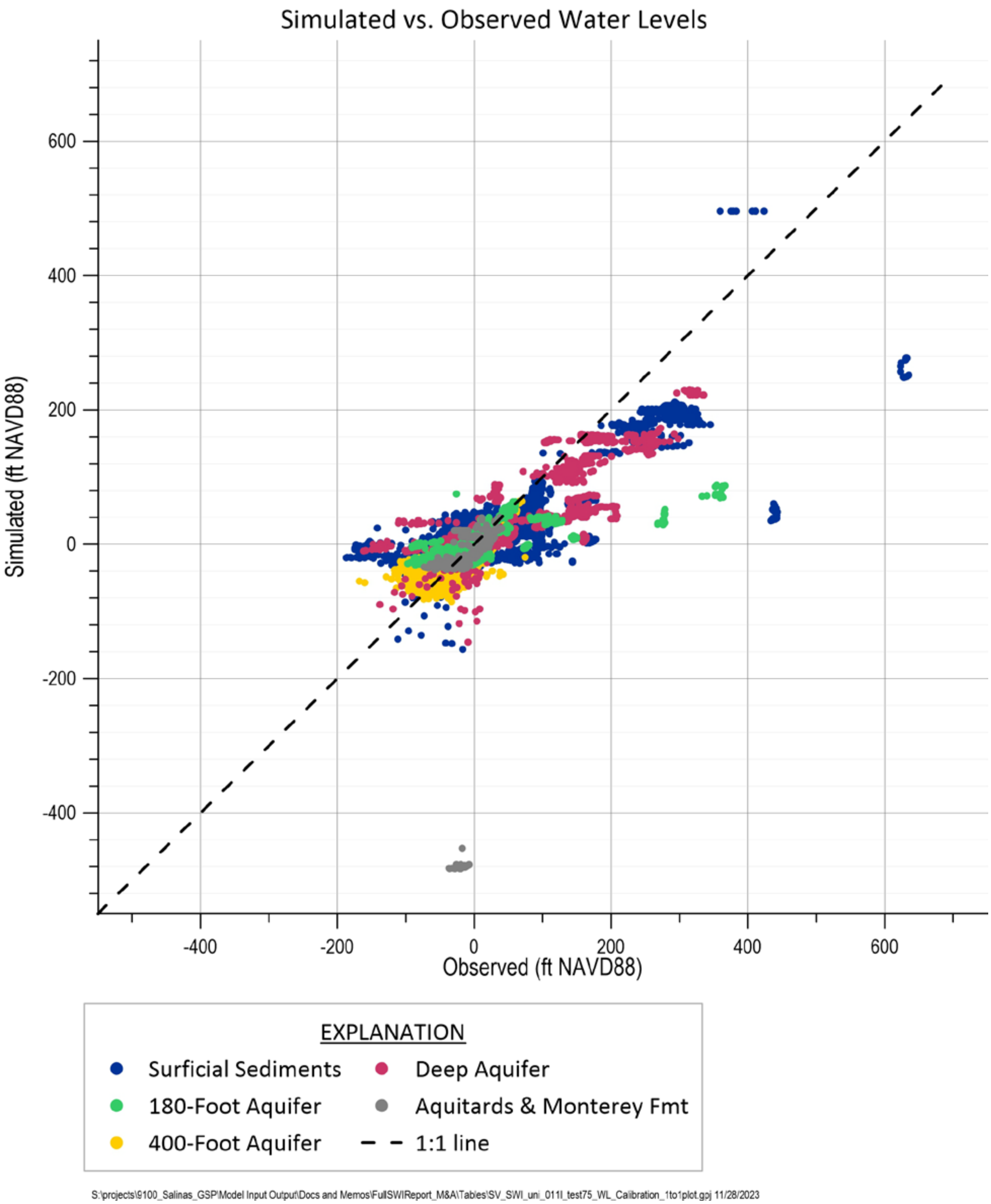


Figure 3. Simulated and Observed Water Level Cross plot

Updated Water Budget

The average annual water budget for the updated model between water years 1985-2020 is summarized in Table 4.

Table 4. Updated Water Budget Summary

Inflows		Previous Model WY 1985-2020 Average AF/yr	Updated Model WY 1985-2020 Average AF/yr
Recharge		64,600	64,600
Subsurface Inflow	Valley Upgradient Inflow near Chualar	1,300	7,700
	Seawater Intrusion	21,000	18,700
Injection	ASR - Seaside	100	2,800
Outflows			
Pumping		146,100	149,000
Groundwater Evapotranspiration	Riparian	3,600	16,300
Subsurface Outflow	Valley Outflow to Ocean + Pajaro	30	1,100
Net Stream Exchange		<1	31,700

The updated CHD boundary and hydraulic conductivity directly impacts the valley upgradient inflow near Chualar. The valley upgradient inflow near Chualar was previously estimated from observed groundwater gradients to be approximately 23,000 AF/yr. Following the model updates, this flux increased to approximately 8,000 AF/yr. The resulting general increase in groundwater elevations in the valley resulted in less seawater intrusion. Meanwhile, the updates to the stream parameters increased the amount of stream exchange with groundwater.

The net stream exchange was compared to estimated surface water leakage along the Salinas River reported in the 2023 MCWRA River Series Report. The surface water leakage in the report has been converted from cubic feet per second (cfs) loss per river mile to AF/yr and is compared to the simulated result in the updated model in Table 5. The simulated stream leakage resulting from the updated stream parameters has increased from the previous model and is near the estimated order of magnitude. However, the simulated stream leakage is consistently lower than the amount estimated in the 2023 MCWRA River Series Report.

Table 5. Surface Water Leakage to Groundwater

1995-2021* (AF/yr)	2023 MCWRA River Series Report Chualar to Spreckels	Updated Model Chualar to Spreckels	Updated Model Spreckels to Ocean
Average	51,400	22,700	16,200
Minimum	30,000	5,600	4,300
Maximum	78,200	40,500	29,100

*Does not include drought years 2012-2016; the SWI Model simulation ends October 2020.

Though the model inputs for groundwater evapotranspiration and well pumping were not updated, the output water budget is indirectly affected due to the other modifications stated previously. These water budget components are impacted generally due to the increased groundwater elevations in the model.

Chloride Concentrations

The primary driver of the chloride calibration is the simulated extent of the 500 mg/L chloride contour line within the 180-Foot and 400-Foot Aquifers. The extent of the simulated 500 mg/L chloride contour was compared to the MCWRA contours available. The inland progression of the simulated 500 mg/L contours are compared to the contours as reported by MCWRA on Figure 4 and Figure 5 below.

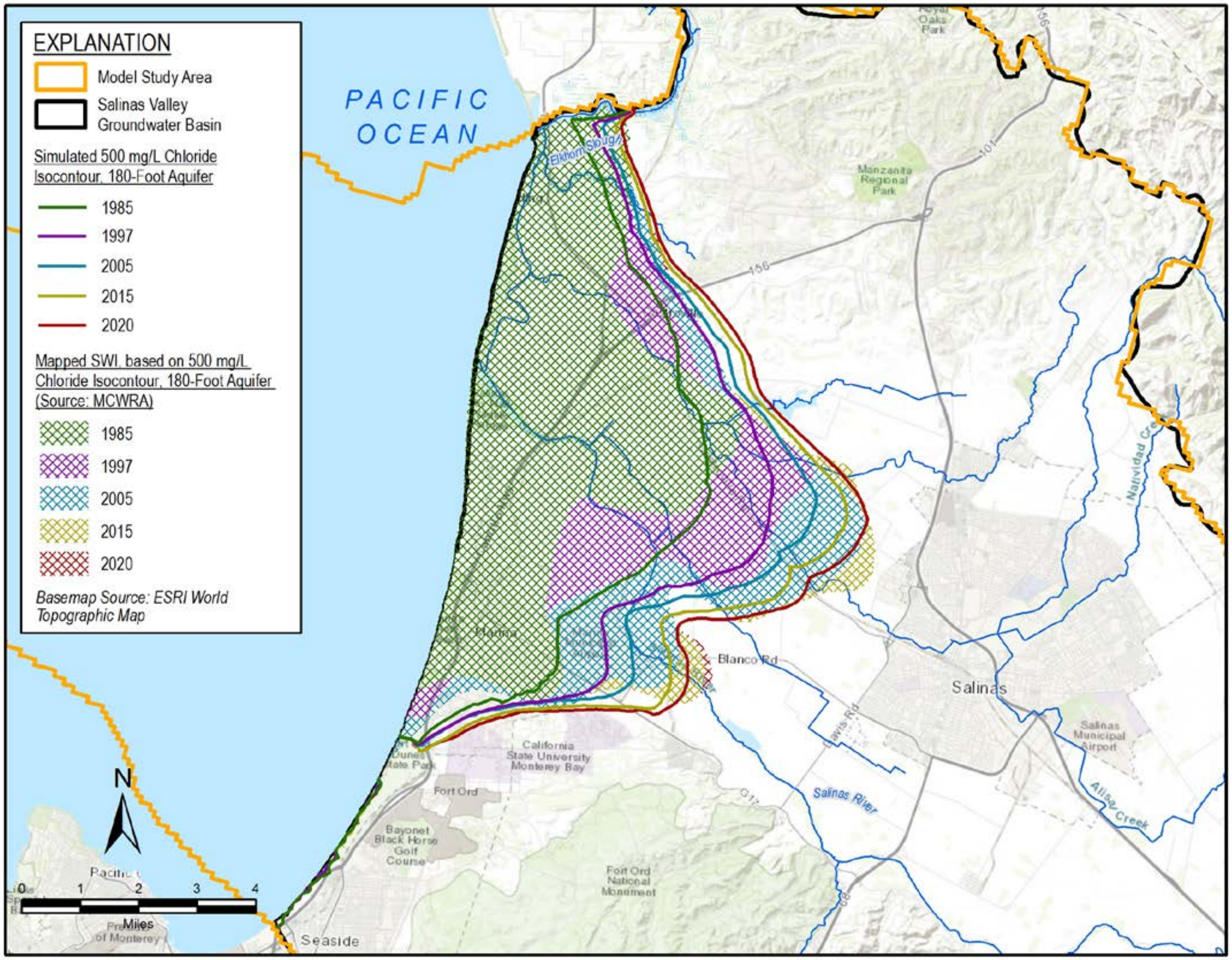


Figure 4. Simulated and Observed 500 mg/L Chloride Concentration Contours within the 180-Foot Aquifer in 1985, 1997, 2005, 2015, and 2020

G:\GIS-Tuc\Projects\9100\Reports and Deliverables\SWI_model_report\SWIContours180_Simulated&Observed_ModelUpdate.mxd 28Apr2022

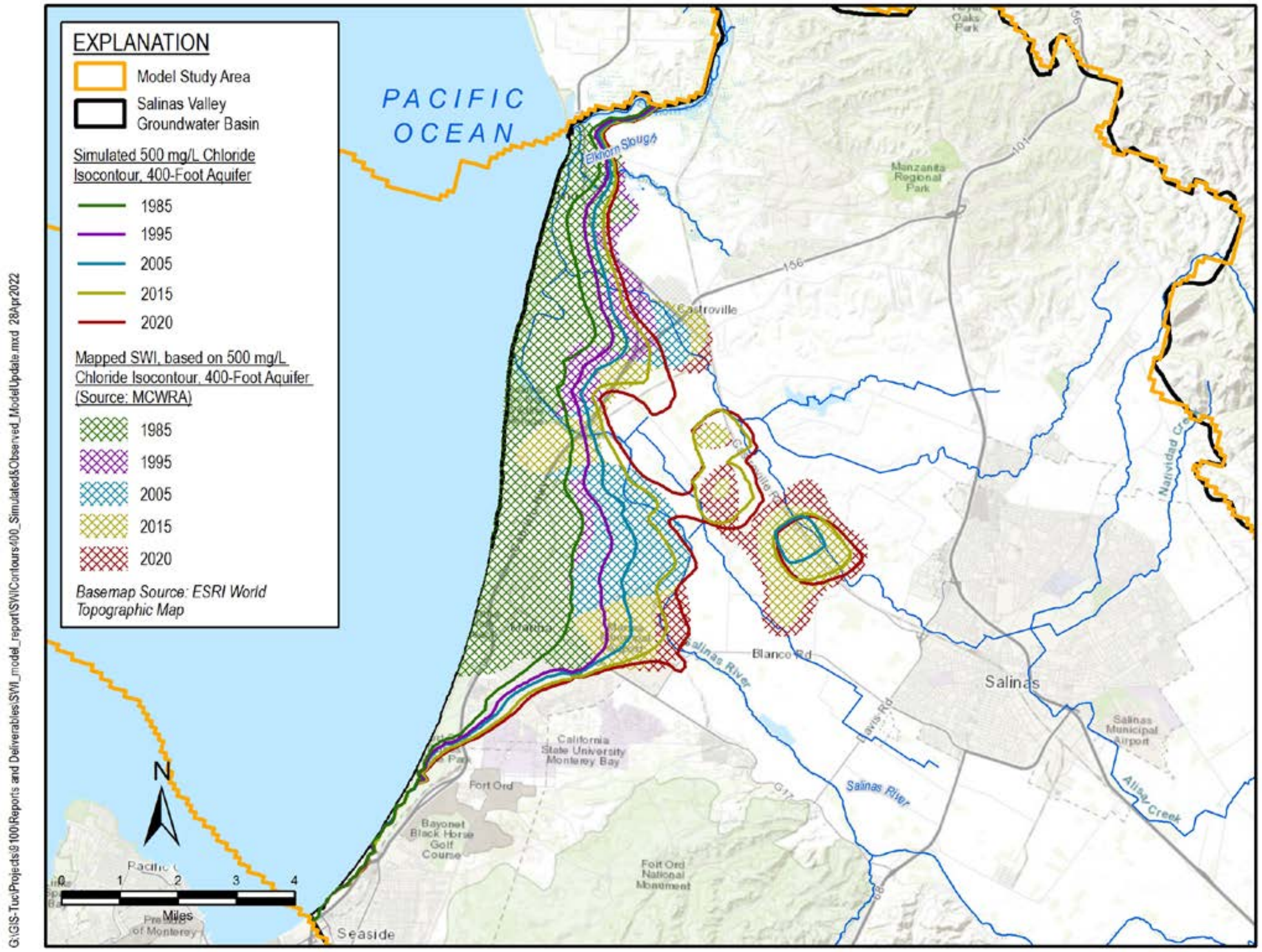


Figure 5. Simulated and Observed 500 mg/L Chloride Concentration Contours within the 400-Foot Aquifer in 1985, 1995, 2005, 2015, and 2020

The updated model simulates the inland progression of seawater intrusion in the 180-Foot and 400-Foot Aquifers at similar but slightly slower rates than the previous model version. The simulated seawater intrusion in the updated model is closer to the observed in several areas. The extent of simulated seawater intrusion in the southern portion of the intruded area in the 180-Foot Aquifer matches the MCWRA observed contours, and also simulates the formation of the second, smaller seawater intrusion lobe near the Salinas River and Blanco Road. In the 400-Foot Aquifer, the updated model more accurately simulates the observed separation between the seawater intruding in from the coast and the saline "islands" that occur inland near Salinas. Though, between 2015 and 2020 the model simulates the connection of the saline island to the main plume. Additionally, seawater intrusion is not simulated in the Seaside area in the 180-Foot or 400-Foot Aquifers.

The model simulates a continuous inland progression of seawater intrusion since 1985. In the 180-Foot Aquifer, MCWRA observed no change in seawater intrusion in the southern lobe between 1985 and 1997, and no change in the main lobe between 2015 and 2020. The model simulated advancing seawater intrusion in these areas where it was not supported by the observed data. Additionally, MCWRA observed a significant increase in the intruded extent between the mid-1990s and 2005. The simulated seawater intrusion advanced at a slower rate than observed during that period; however, the final simulated extent of seawater intrusion in 2020 was similar to the MCWRA observed in both the 180-Foot and 400-Foot Aquifers.

AEM geophysical surveys were conducted in 2017 and 2019 over the seawater intrusion intruded areas in the model study area (Kang *et al.* 2023). The 5 ohm-meter resistivity line roughly corresponds to a chloride concentration of 9,000 mg/L. The 5 ohm-meter contour mapped during the 2019 AEM survey was compared to the 9,000 mg/L chloride contour in 2019 (Figure 6). The 2019 survey was used because the 2017 survey results were generally similar. The 400-Foot Aquifer is below the maximum depth of the AEM geophysical survey; therefore, the AEM data is compared to simulated concentrations in the 180-Foot Aquifer. The simulated 9,000 mg/L chloride contour is shown in the upper and lower portions of the 180-Foot Aquifer (layers 3 and 5, respectively). The upper portion of the 180-Foot Aquifer matches the AEM survey better than the lower portion. The AEM method has a higher resolution at shallow depths and is believed to represent the upper portion of the 180-Foot Aquifer more accurately. Seawater intrusion occurs in the same part of the valley in both the AEM survey and the model, and the farthest inland extent of the seawater intrusion is also roughly the same. AEM data indicates that the seawater intrusion is focused in a narrow area on the north side of the Salinas River, but in the model the plume is wider. Simulated concentrations west of Castroville are also higher than indicated by AEM data.

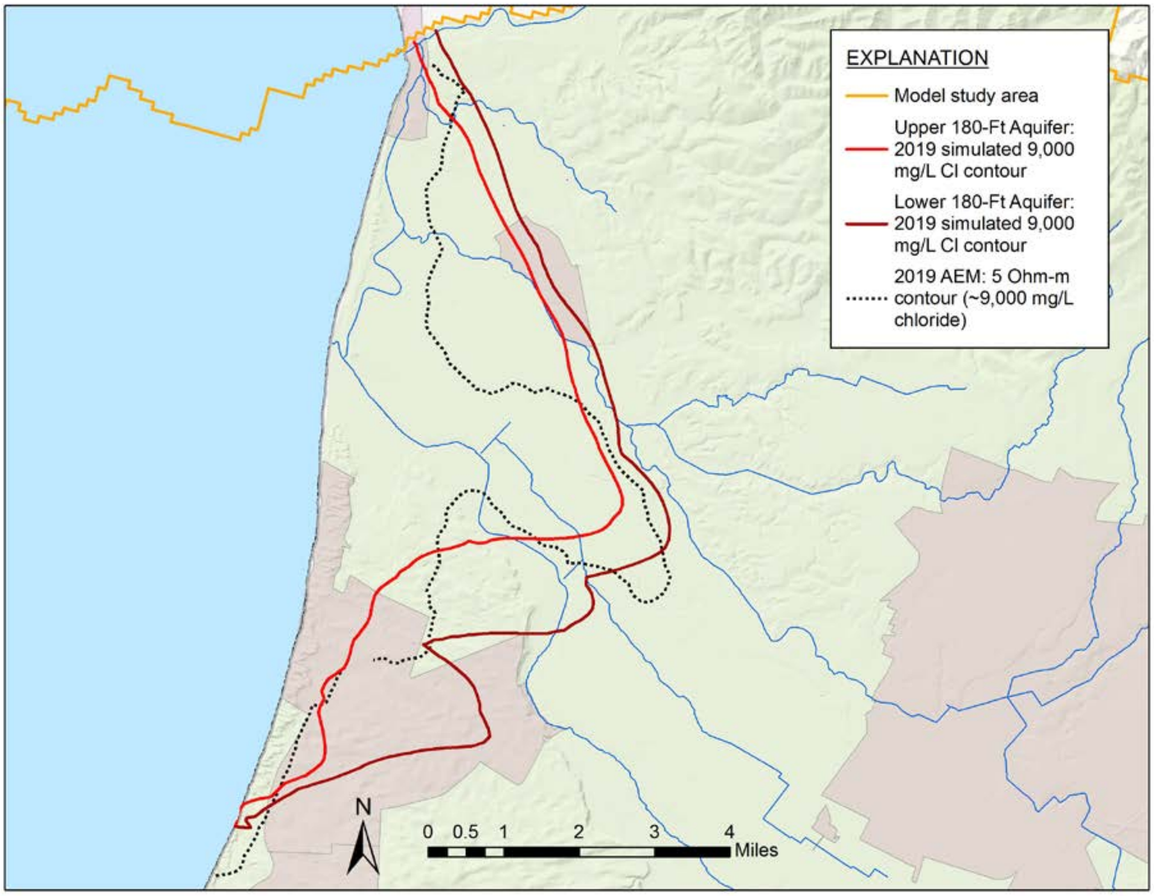


Figure 6. AEM Geophysical Survey Results with Comparable Simulated Chloride Concentration Contour

CONCLUSION

M&A updated the SWI Model to address the GTAC concerns including the improvement of groundwater level calibration, the chloride concentration calibration in the Seaside area, and uplift of the Monterey Formation.

1. Improvement of inland groundwater levels

Groundwater levels were addressed by increasing the overall hydraulic conductivity in the 180-Foot and 400-Foot Aquifers, updating the parameters of the streams to increase surface water exchange with groundwater, and updating the upgradient valley constant head boundary conditions. The groundwater level calibration was significantly improved so that the mean water level residual in the 180-Foot and 400-Foot Aquifers is now less than 5 feet.

2. Improved chloride concentration calibration in the Seaside area

Simulated seawater intrusion in Seaside was addressed by adjusting the hydraulic conductivity of the coastal sediments and by removing pumping in 1 of the ramp-up stress periods, which slowed seawater intrusion in this area. There will continue to be uncertainty regarding the conditions under which seawater intrusion will occur in this area in the future until it is observed.

3. M&A reduced uplift of the Monterey Formation in the Monterey Subbasin

Uplift of the Monterey Formation was reduced by adjusting hydrostratigraphic units represented through the model layering and hydraulic parameter zonation in this area to reflect more recent understanding of the basin geology.

These model updates were completed without significant adverse effects to the seawater intrusion calibration. The progression of the 500 mg/L chloride concentration contour was verified by comparing the simulated contours to the MCWRA observations between 1985 and 2020. In some areas, the model updates improved the calibration of the seawater intrusion to the MCWRA observations. The simulated seawater intrusion better matches MCWRA contours in the southern part of the intruded area in the 180-Foot Aquifer. The model also better simulates the separation of the saline “islands” caused by improperly abandoned wells from the main body of intruding seawater in the 400-Foot Aquifer.

REFERENCES

Doherty, J.E., Fienen, M.N., and Hunt, R.J., 2010, Approaches to highly parameterized inversion: Pilot-point theory, guidelines, and research directions: U.S. Geological Survey Scientific Investigations Report 2010–5168, 36 p.

Harding ESE, 2001. Hydrogeologic investigation of the Salinas Valley Basin in the Vicinity of Fort Ord and Marina Salinas Valley, CA. Harding ESE Project No. 51750 007. Harding ESE, Novato CA.

HLA, 1994. Basewide hydrogeologic characterization Fort Ord, California, Draft Final. HLA Project No. 10775 531. HLA, Novato CA.

Kang, S., R. Knight, G. Nelson, 2023. Integration of Airborne Electromagnetic Data into the Modeling of Saltwater Intrusion. Stanford University, Department of Geophysics. San Francisco.

MCWRA (Monterey County Water Resources Agency). 2023. 2023 Salinas River Discharge Measurement Series Results. Salinas River Discharge Measurement Series. https://www.co.monterey.ca.us/home/showpublisheddocument/126953/638344342317370000.

Yates, E. B., M. B. Feeney, L. I. Rosenberg, 2005. Seaside groundwater basin: update on water resource conditions. Prepared for Monterey Peninsula Water Management District. 2005.

ATTACHMENT 1

Table 6. Seawater Intrusion Model Report Model Development Tables and Figures Affected by Updates

Table Number	Table Caption
4-1	Water Level Calibration Statistics
4-2	Summary of Calibrated Hydraulic Conductivity (K) and Storage Properties of the HGUs within the Model
Figure Number	**Figure Caption**
3-15	Model Hydrogeologic Zonation in Layer 7
3-16	Model Hydrogeologic Zonation in Layer 8
3-17	Model Hydrogeologic Zonation in Layer 9
3-18	Model Hydrogeologic Zonation in Layer 10
3-19	Model Hydrogeologic Zonation in Cross Section A-A'
3-22	Model Hydrogeologic Zonation in Cross Section D-D'
4-3	Simulated and Observed 500 mg/L Chloride Concentration Contours within the 180-Foot Aquifer in 1985, 1997, 2005, 2015, and 2020
4-4	Simulated and Observed 500 mg/L Chloride Concentration Contours within the 400-Foot Aquifer in 1985, 1995, 2005, 2015, and 2020
4-5	Mean Residual Water Level Bubble Plot within the 180-Foot Aquifer and Equivalent Areas
4-6	Mean Residual Water Level Bubble Plot within the 400-Foot Aquifer and Equivalent Areas
4-7	Simulated and Observed Water Level Crossplot
4-8	Observed and Simulated Representative Hydrographs within the 180-Foot Aquifer
4-9	Observed and Simulated Representative Hydrographs within the 400-Foot Aquifer
4-10	Observed and Simulated Representative Hydrographs within the Deep Aquifers
4-11	Simulated and Measured Stream Flow in the Salinas River at the Gage near Chualar
4-12	Simulated and Measured Stream Flow in the Salinas River at the Gage near Spreckels
4-13	Simulated and Measured Stream Flow in Gabilan Creek
4-14	Simulated and Measured Stream Flow in El Toro Creek
4-15	Hydraulic Conductivity Pilot Points Used during Model Calibration

Table 7. Updated Summary of Calibrated Hydraulic Conductivity (K) and Storage Propertiesof the HGUs within the Model

HGU Zone Number	HGU Description	K_h and K_{va} Number of Pilot Points	K_h Pilot Point (ft/day)		K_{va} (K_v / K_h)		Specific Yield (Sy) Effective Porosity	Specific Storage (S_s) (ft^{-1})
			Minimum	Maximum	Minimum	Maximum		
2	Deltaic Sea Sediments	2	5.00	398	0.477	38.0	0.0821	0.00427
3	Alluvial Fans (Shallow)	12	6.48	33.1	0.242	1.24	0.195	0.000743
4	Salinas River	1	176	176	20.7	20.7	0.232	0.00150
5	Shallow Sediments, Basin Deposits	6	11.0	32.8	0.778	1.48	0.185	0.00100
6	Older Dune Sands	14	12.3	75.9	0.413	7.80	0.263	0.00100
7	Aromas Sands Eolian sands	4	49.5	49.5	5.67	5.67	0.220	0.000618
8	Aromas Sands	3	49.5	50.2	4.53	14.5	0.165	0.0000618
9	Elkhorn Slough clay	1	0.0100	0.0100	0.00100	0.00100	0.102	0.0000900
10	Shallow Sediments, El Toro Creek	1	79.3	79.3	10.2	10.2	0.168	0.00144
11	Paso Robles Formation, Santa Margarita	5	1.85	1.85	0.184	0.184	0.168	0.000144
13	Granite	1	0.688	0.688	0.646	0.646	0.208	0.00000505
20	Salinas Valley Aquitard	8	0.0125	0.0125	0.000787	0.00177	0.120	0.0000100
21	Seaside Clay	1	0.00840	0.00840	0.00116	0.00116	0.120	0.0000100
30	180-Foot Aquifer	19	50.0	258	1.00	14.2	0.100	0.0000363
31	Ord 180-Foot Aquifer	11	30.0	191	1.43	7.94	0.120	0.0000363
32	Upper Paso Robles Formation	5	0.455	98.5	0.00541	0.484	0.168	0.000144
33	Ord 180-Foot Aquitard	4	0.00560	0.00560	0.00165	0.00165	0.128	0.0000363
34	Ord Lower 180-Foot Aquifer	9	87.5	169	2.45	4.74	0.120	0.00000363
40	180-400 Foot Aquitard	7	0.00810	0.00810	0.000251	0.00117	0.117	0.0000100
50	400-Foot Aquifer	22	12.9	129	0.193	120	0.210	0.0000100
52	Lower Paso Robles Formation	5	0.506	103	0.127	8.19	0.168	0.000144
53	Alluvial Fans (Deep)	6	12.7	47.4	0.143	0.178	0.195	0.000743
60	Deep Aquitard	6	0.00810	0.00810	0.000683	0.00123	0.120	0.0000100
70	Paso Robles Formation	11	1.10	19.0	0.116	0.998	0.168	0.000144
71	Paso Robles Formation	4	0.846	2.32	0.0105	6.85	0.168	0.000144
80	Purisima	5	1.49	1.49	0.493	0.493	0.150	0.0000749
81	Santa Margarita	9	0.300	50.0	0.0366	1.37	0.150	0.0000749
90	Monterey Formation	1	0.00680	0.00680	0.000634	0.000634	0.150	0.000100

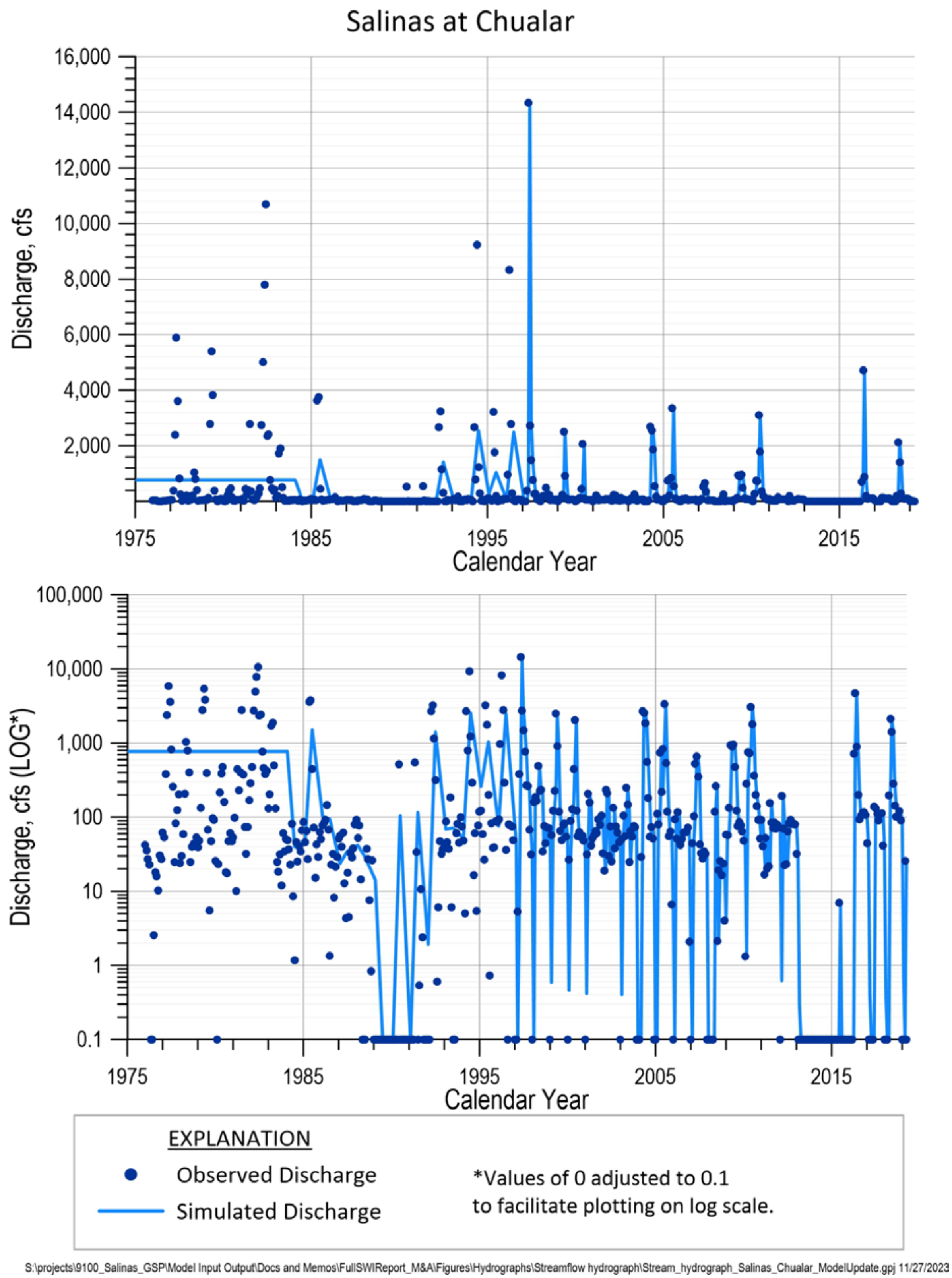
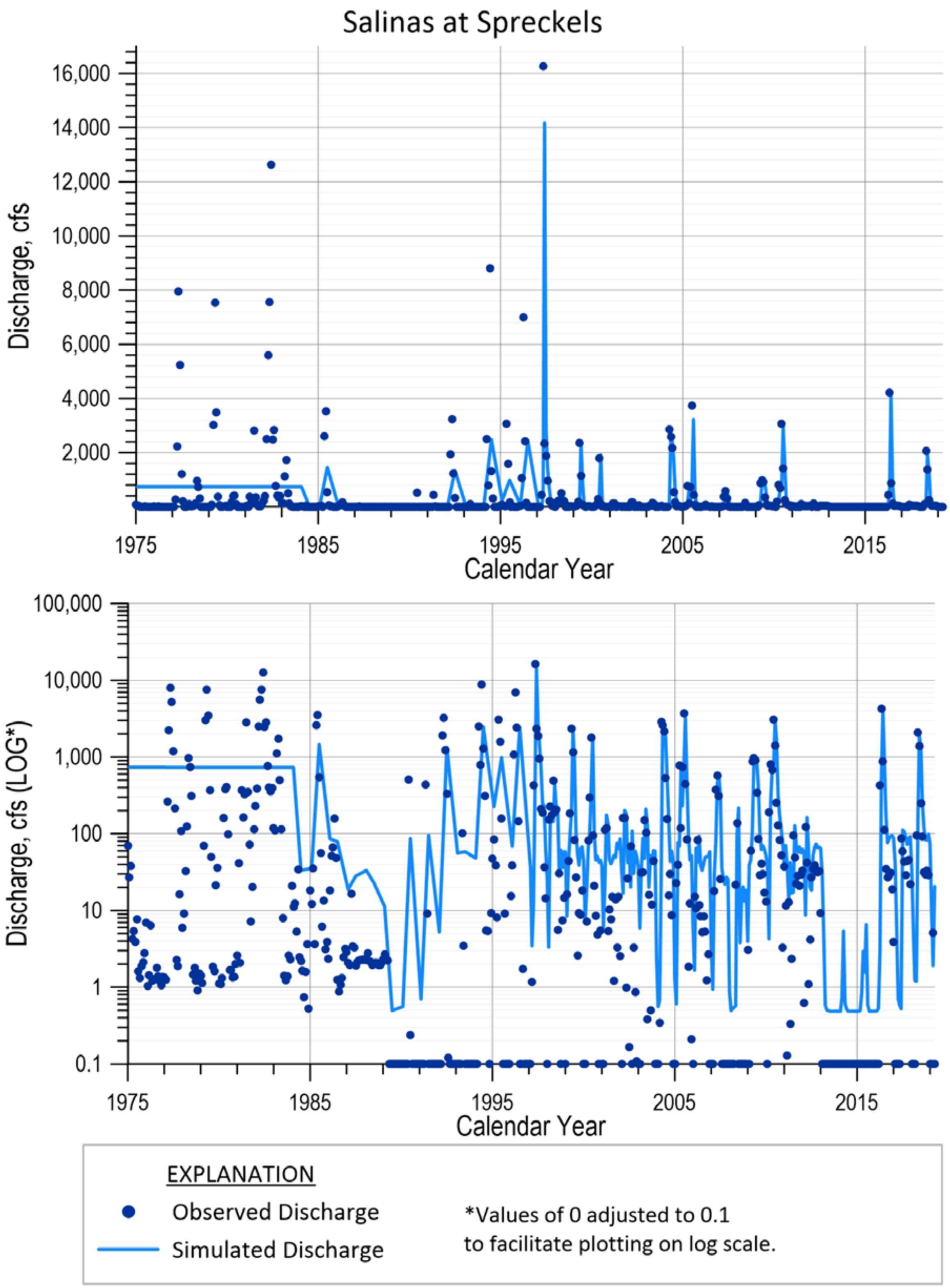


Figure 7. Simulated and Measured Stream Flow in the Salinas River at the Gage near Chualar



S:\projects\9100_Salinas_GSP\Model Input Output\Docs and Memos\FullSWIReport_M&A\Figures\Hydrographs\Streamflow hydrograph\Stream_hydrograph_Salinas_Spreckels_ModelUpdate.gpj 11/27/2023

Figure 8. Simulated and Measured Stream Flow in the Salinas River at the Gage near Spreckels

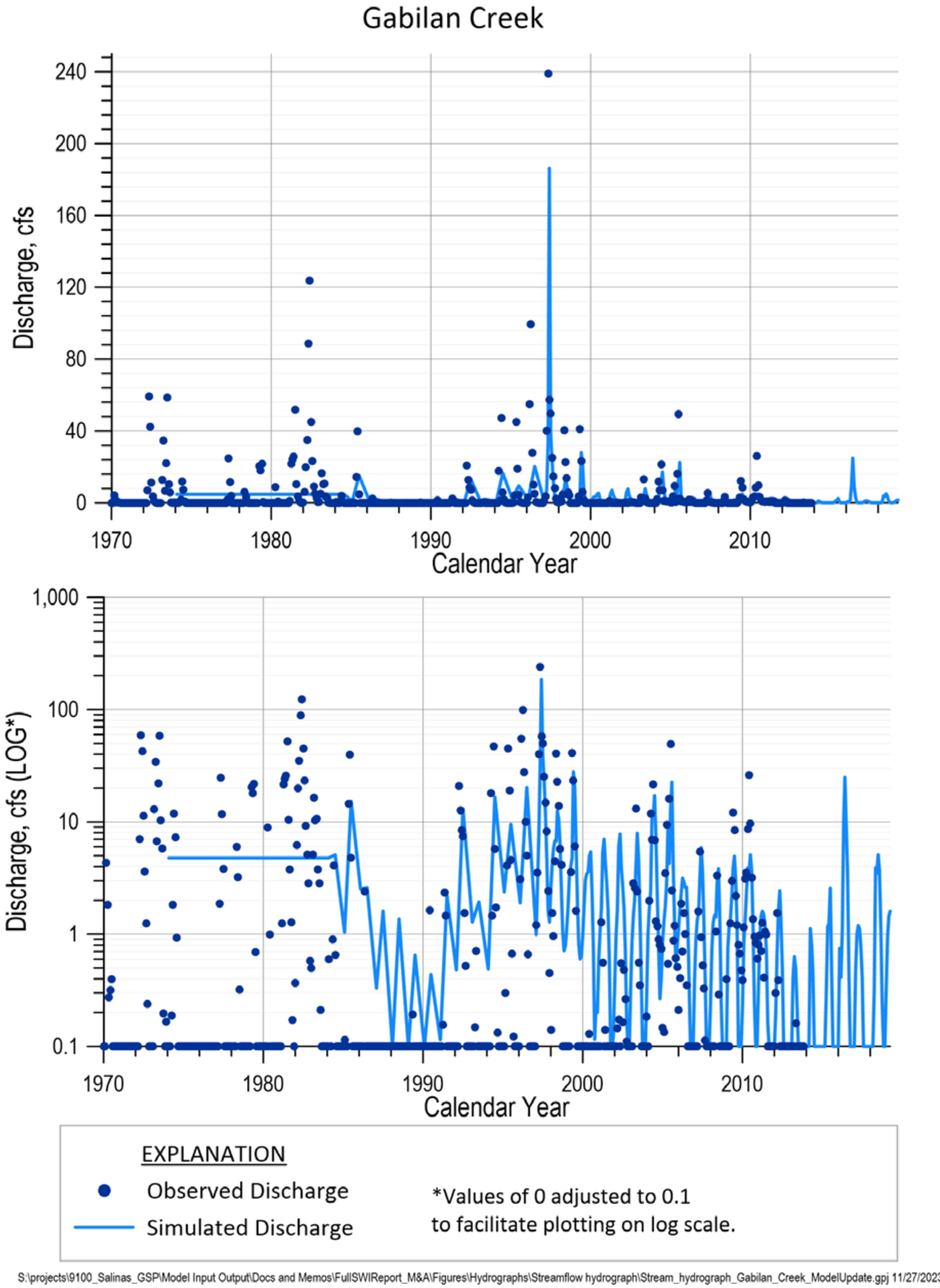
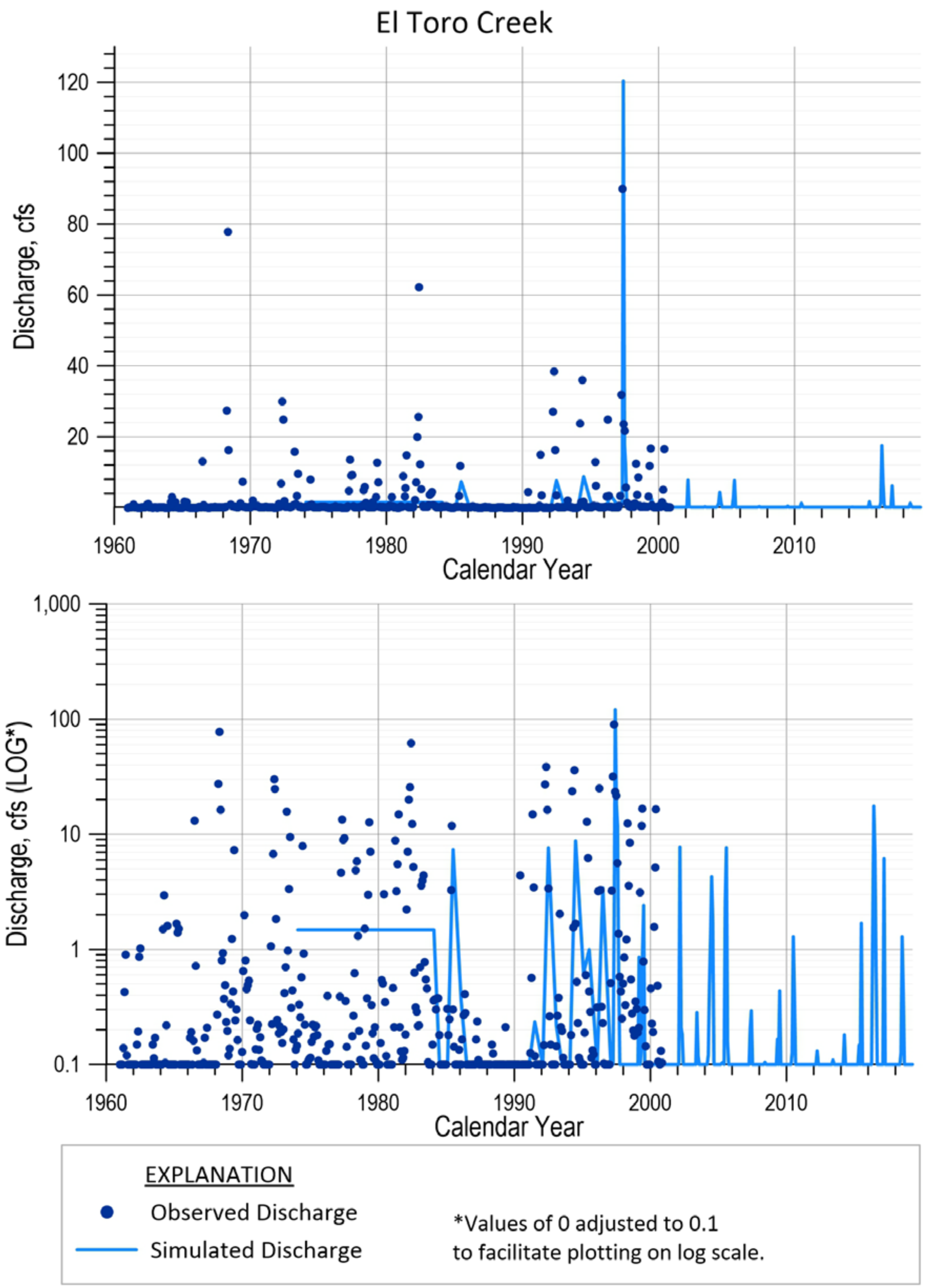


Figure 9. Simulated and Measured Stream Flow in Gabilan Creek



S:\projects\9100_Salinas_GSP\Model Input Output\Docs and Memos\FullSWIReport_M&A\Figures\Hydrographs\Streamflow hydrograph\Stream_hydrograph_El_Toro_Creek_ModelUpdate.gpj 11/27/2023

Figure 10. Simulated and Measured Stream Flow in Gabilan Creek

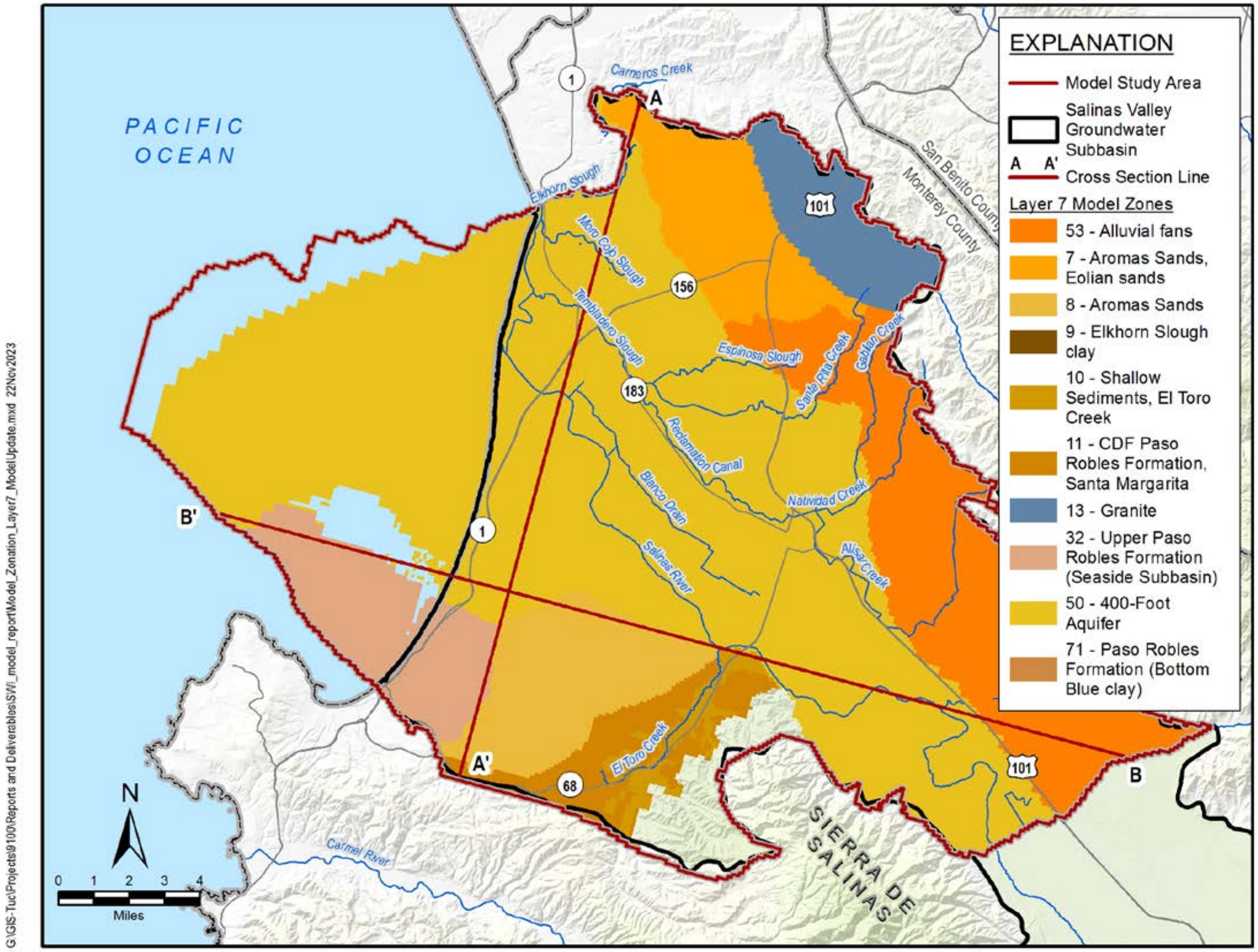


Figure 11. Model Hydrogeologic Zonation in Layer 7

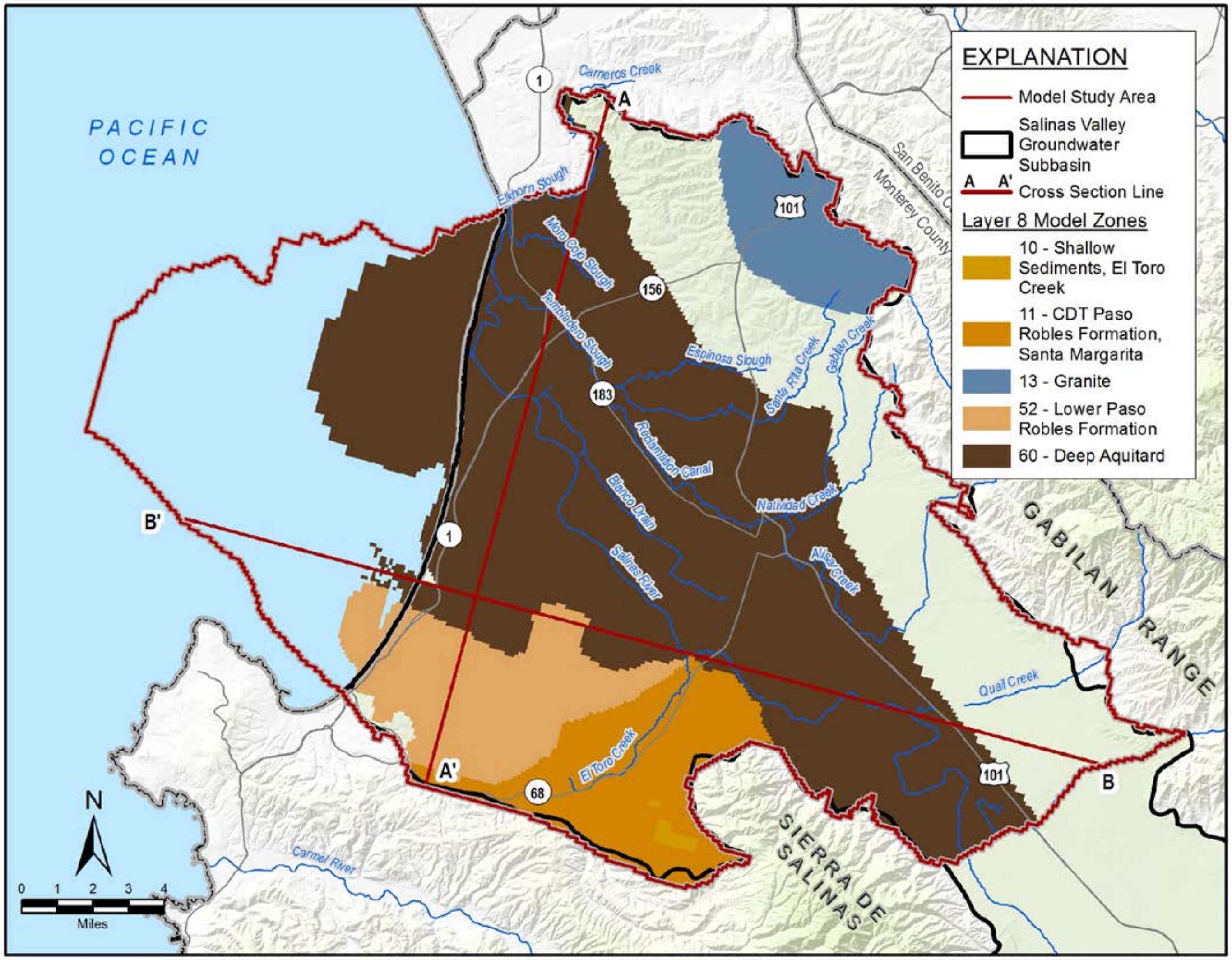


Figure 12. Model Hydrogeologic Zonation in Layer 8

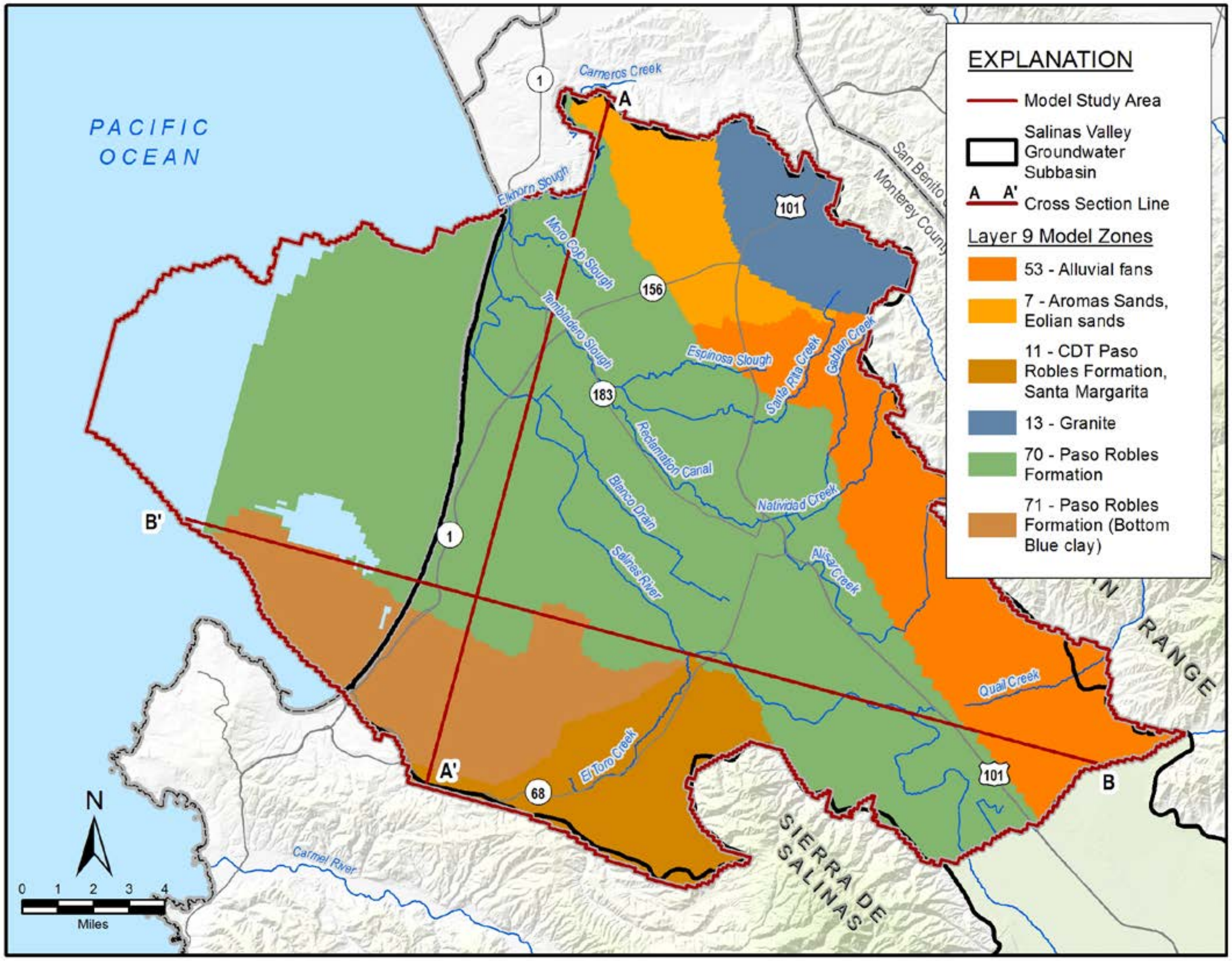


Figure 13. Model Hydrogeologic Zonation in Layer 9

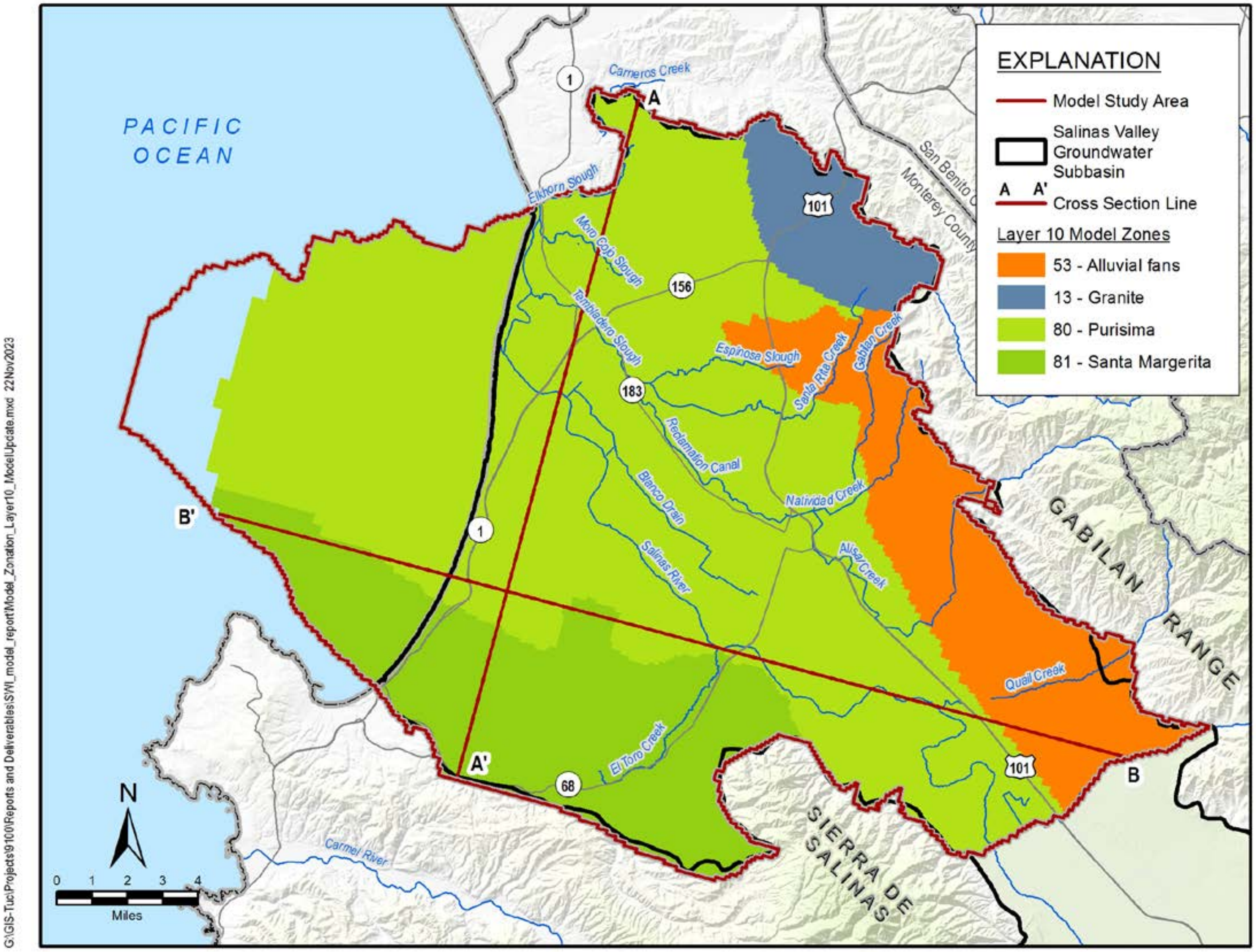


Figure 14. Model Hydrogeologic Zonation in Layer 10

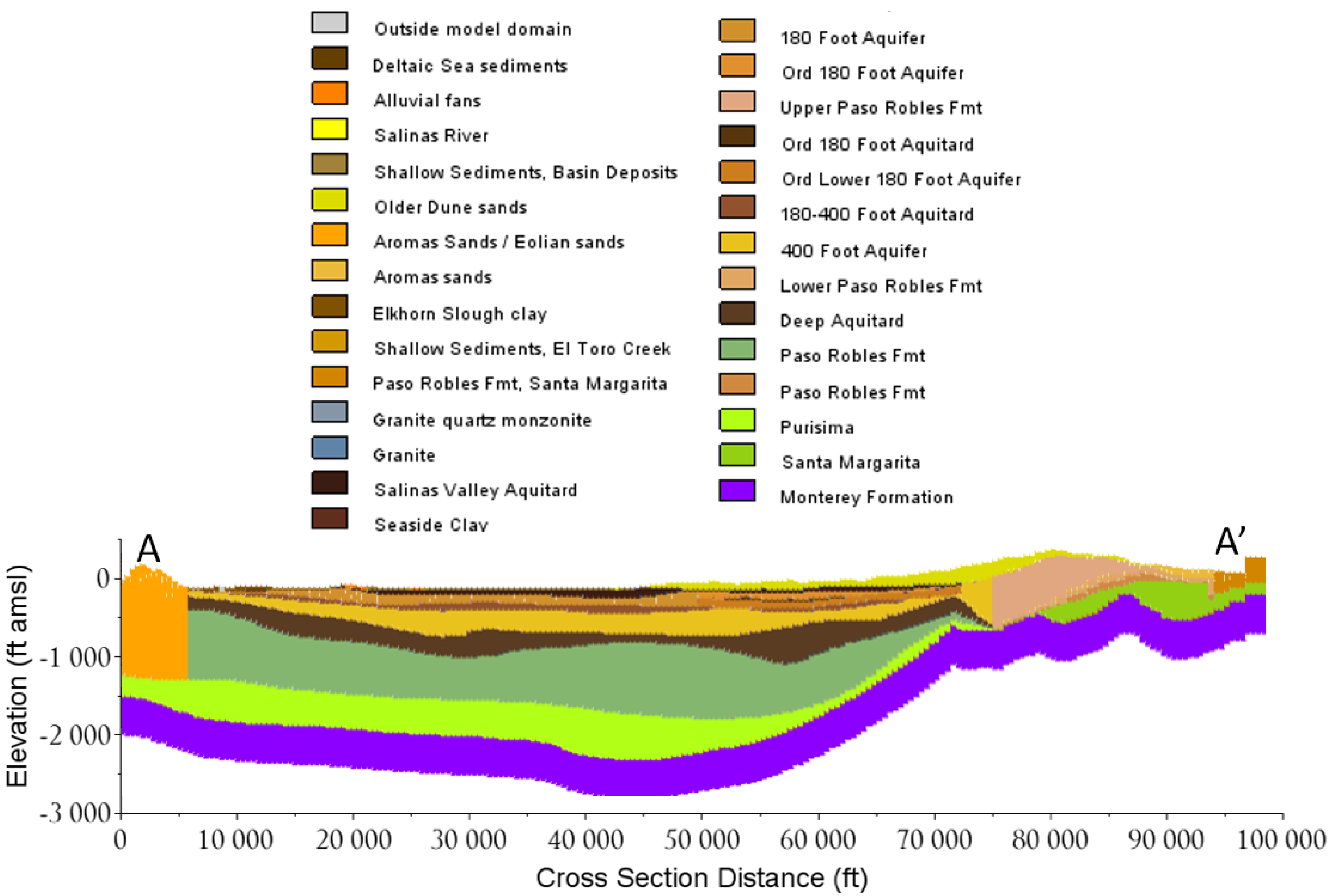


Figure 15. Model Hydrogeologic Zonation in Cross Section A-A'

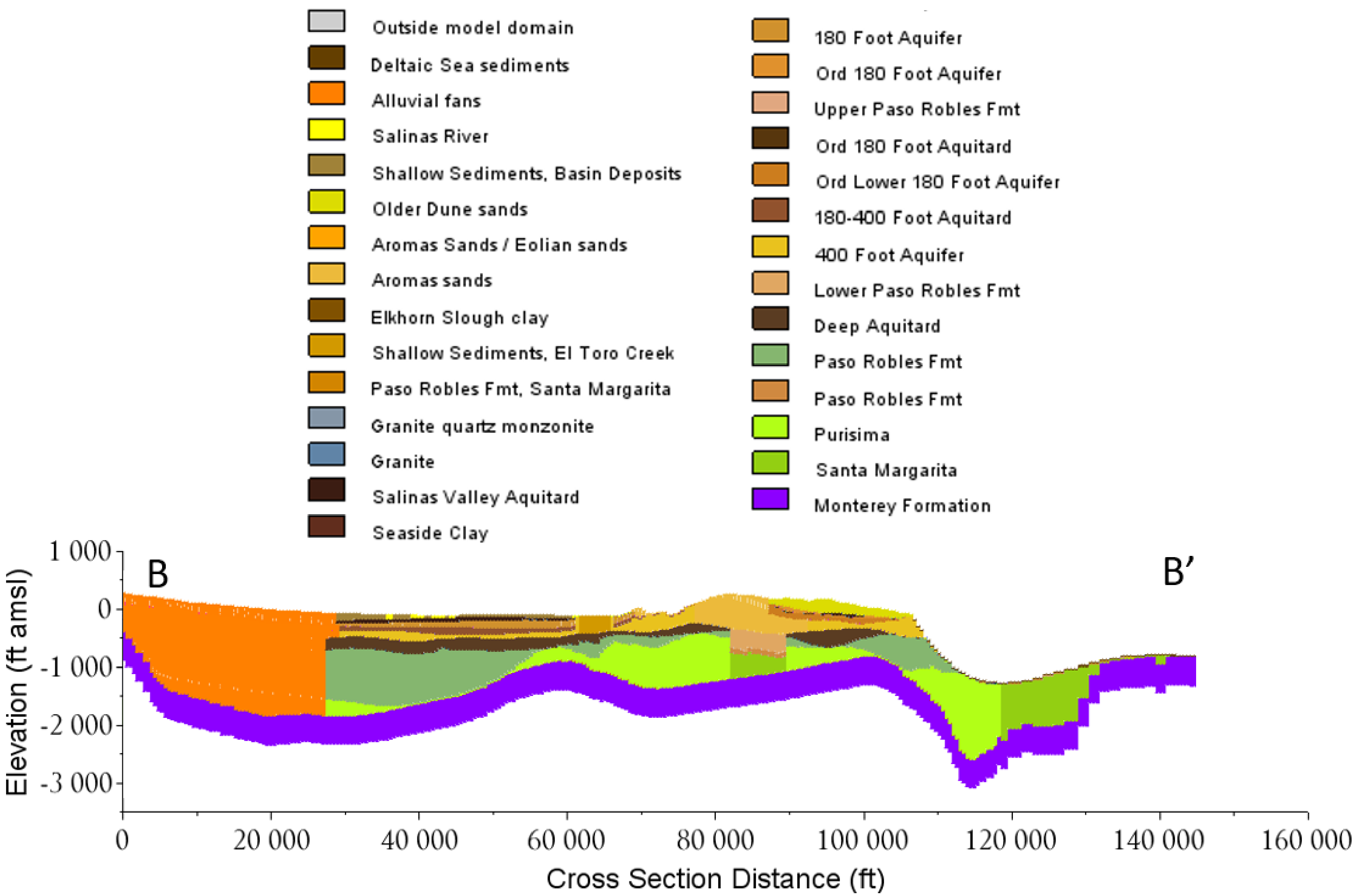


Figure 16. Model Hydrogeologic Zonation in Cross Section B-B'

MONTGOMERY & ASSOCIATES

G:\GIS-Tuc\Projects\9100\Reports and Deliverables\SWI_model_report\ExampleHydrographs_180_FullStudyArea_Sim_modelupdate.mxd

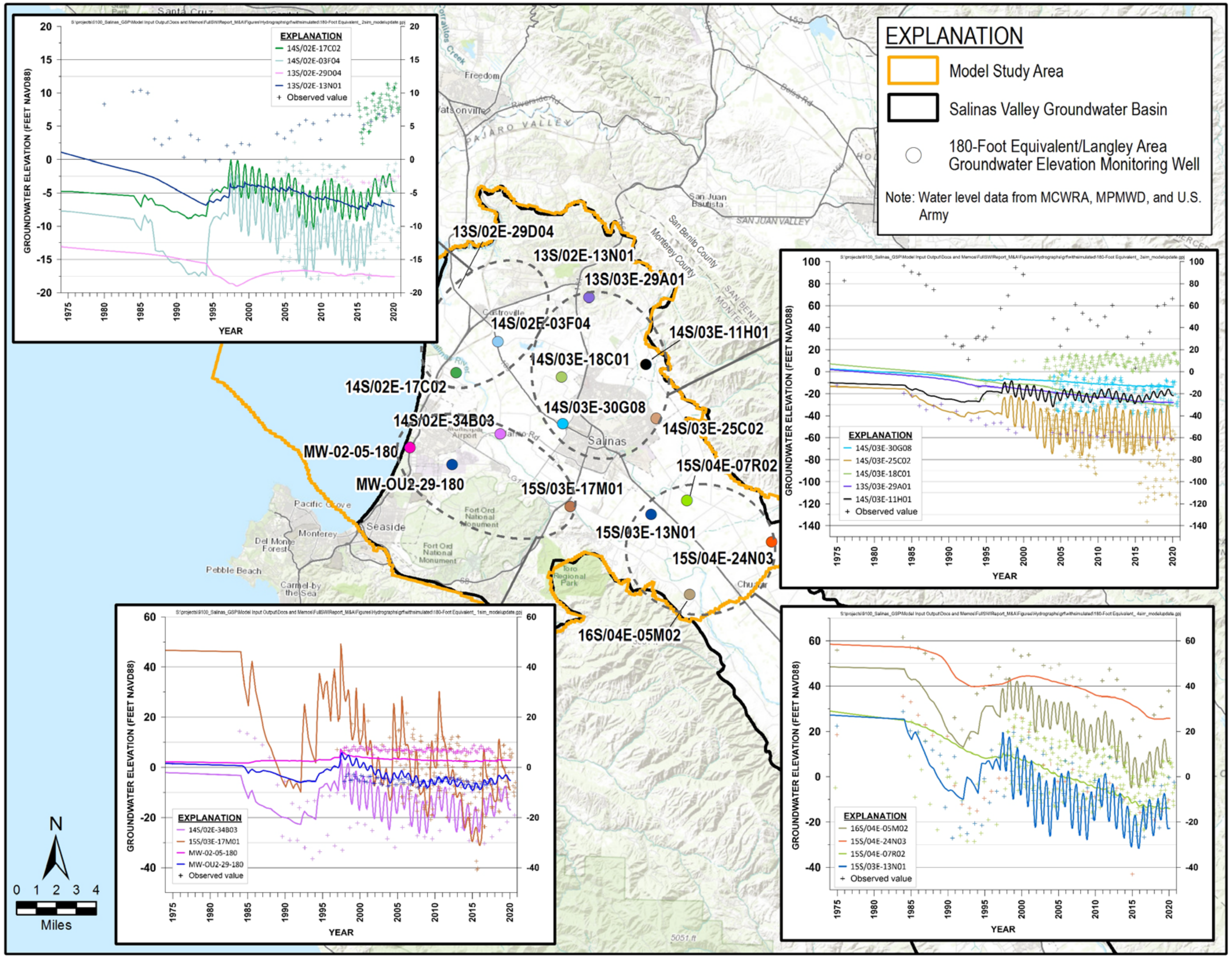


Figure 17. Observed and Simulated Representative Hydrographs within the 180-Foot Aquifer

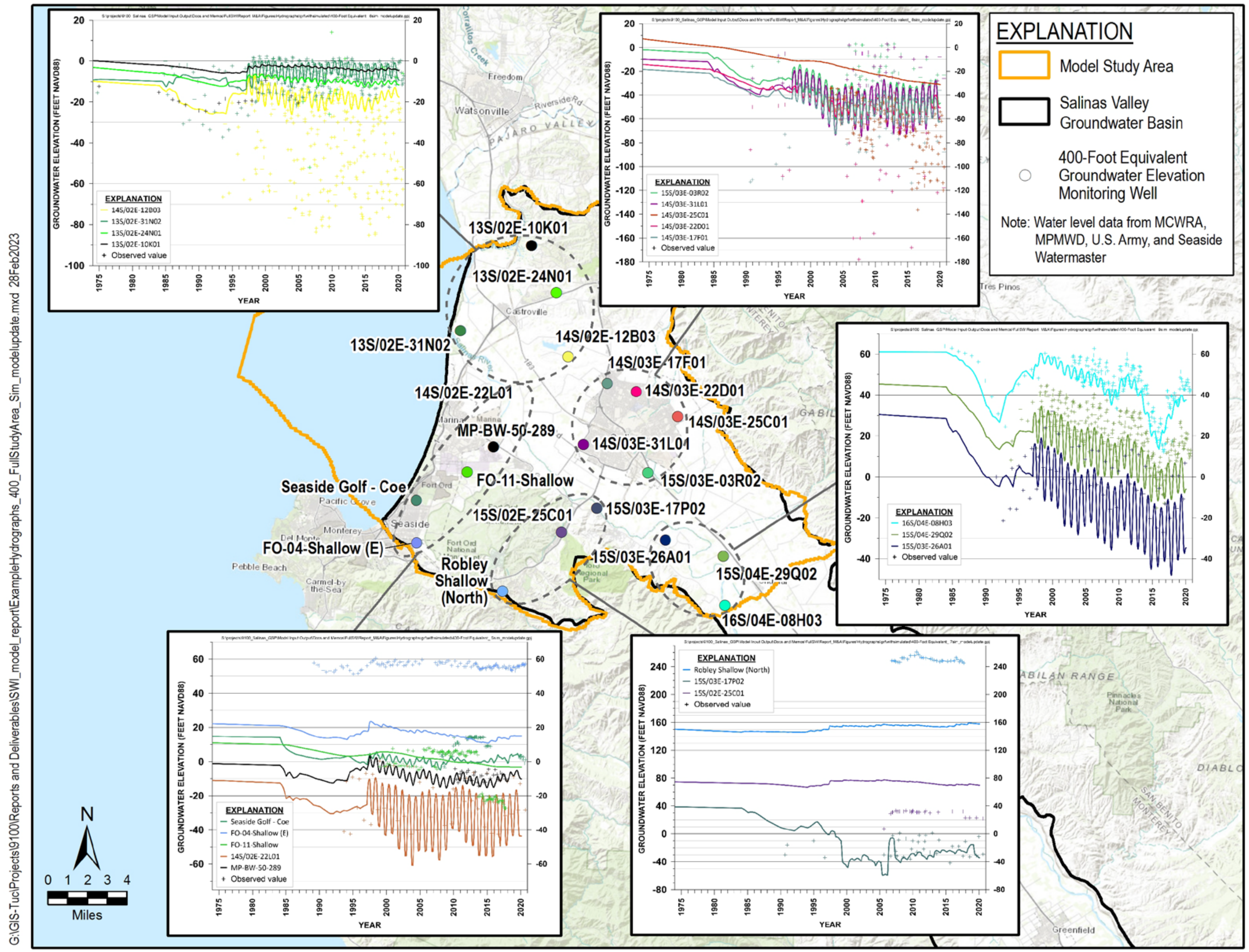


Figure 18. Observed and Simulated Representative Hydrographs within the 400-Foot Aquifer

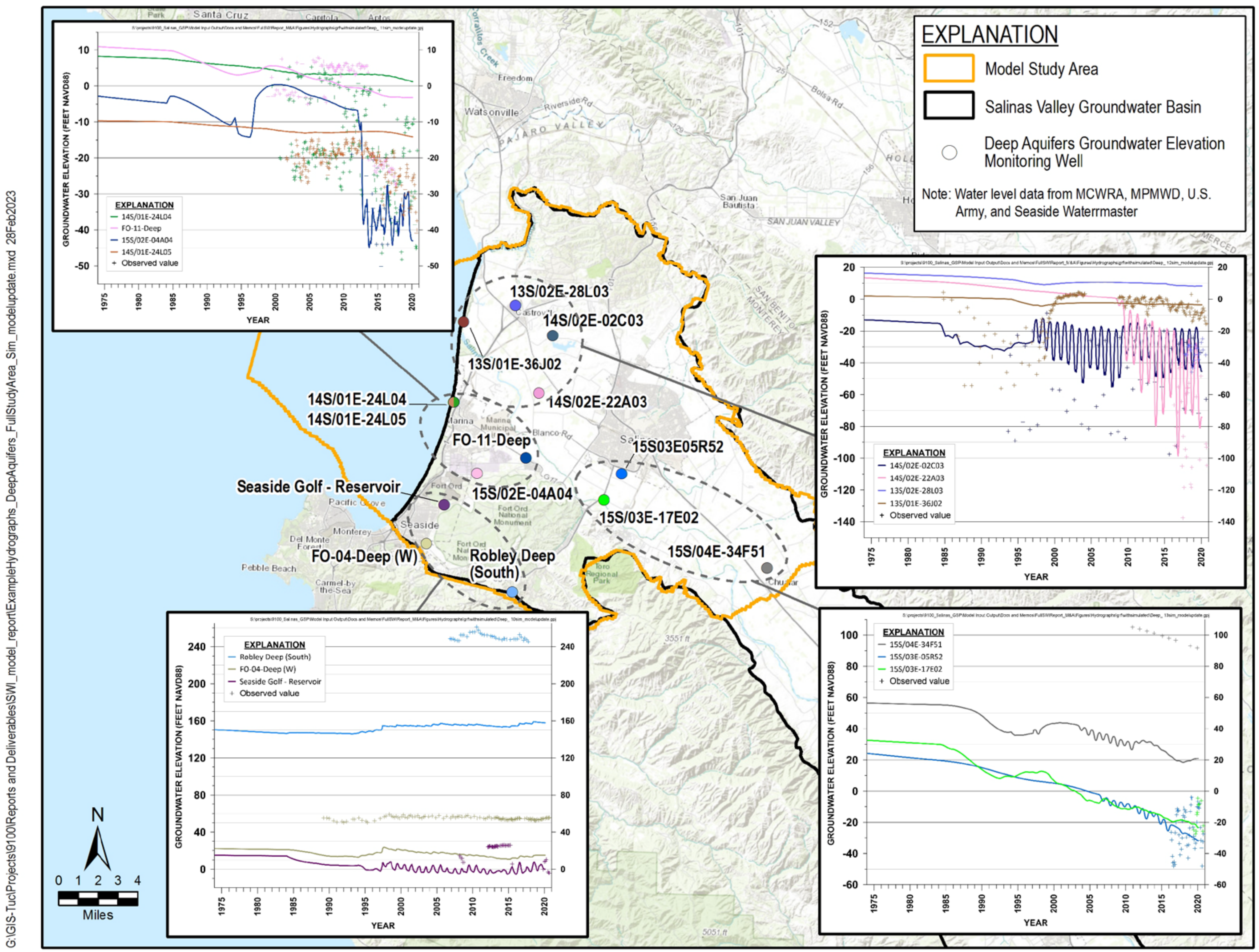


Figure 19. Observed and Simulated Representative Hydrographs within the Deep Aquifer

MONTGOMERY
& ASSOCIATES

Attachment 2

2070 Baseline Predictive Model

MONTGOMERY & ASSOCIATES

CONTENTS

Figures

INTRODUCTION

To assist in evaluating and designing projects and management actions that address seawater intrusion, Mongomery & Associates (M&A) has developed a predictive version of the updated Salinas Valley Seawater Intrusion Model (SWI Model) that estimates future groundwater conditions if no projects and management actions are implemented. This simulation is referred to here as the baseline predictive model. It simulates potential seawater intrusion starting from the end of the historical model, water year (WY) 2021, through 2070. Projected impacts will be reviewed by comparing predictive simulation results of various projects and management actions to baseline model results. This document describes the assumptions used to develop the baseline simulation of the predictive model and summarizes the baseline simulation results. This baseline predictive model will be updated alongside future model improvements.

BASELINE PREDICTIVE MODEL DEVELOPMENT

The baseline predictive model simulates seawater intrusion that may occur in the Salinas Valley through 2070 under a "business as usual" approach to groundwater management. Land use is assumed to remain the same as at the end of the historical SWI Model in 2020. Though the boundary conditions are extended through 2070, they are modified according to projected impacts of climate change. The Salinas Valley Operational Model (SVOM)[1] is used to project the impacts of 2070 climate change on the predictive model boundary conditions. The baseline predictive model includes monthly stress periods from WY 2021 through 2070. Groundwater elevations, chloride concentrations, and groundwater pumping at the end of the historical SWI Model are the initial conditions of the baseline predictive model. The modification of the boundary conditions for the baseline predictive model are summarized in the following section.

SVOM Groundwater Model

The U.S. Geological Survey developed the SVOM as a predictive version of the Salinas Valley Integrated Hydrologic Model (SVIHM). The preliminary version of the SVOM made available in February 2021 was used. Groundwater conditions are simulated using the MODFLOW-OWHM Version 2 code (Boyce *et al.*, 2020). This version of MODFLOW simulates a dynamic interaction between water demand and supply. Agricultural water demands are estimated by the

[1] These data (model and/or model results) are preliminary or provisional and are subject to revision. This model and model results are being provided to meet the need for timely best science. The model has not received final approval by the U.S. Geological Survey (USGS). No warranty, expressed or implied, is made by the USGS or the U.S. Government as to the functionality of the model and related material nor shall the fact of release constitute any such warranty. The model is provided on the condition that neither the USGS nor the U.S. Government shall be held liable for any damages resulting from the authorized or unauthorized use of the model.

SVOM based on crop type and climate. Agricultural water demands are met by precipitation, surface water deliveries and diversions if available, and groundwater pumping. The Surface Water Operations package in the SVOM regulates releases from San Antonio and Nacimiento reservoirs based on MCWRA's existing operating policies.

Projected impacts of 2070 climate change were input into the SVOM based on climate factors developed by the Department of Water Resources (DWR), including sea level rise, impacts to evapotranspiration (ET) and precipitation, and stream inflows from the provisional Salinas Valley Watershed Model. SVOM climate change model runs were completed repeating land use and urban pumping from the last year in the SVIHM, 2017, and run both with and without 2070 climate change. These 2 models were compared to estimate the impact of 2070 climate change on agricultural groundwater pumping, recharge, and surface water and groundwater inflows on the SWI Model boundary conditions. The SVOM scenarios were compared during model years 1996 to 2014. This set of years was selected because it represents climate diversity and does not end with the more extreme impacts of the 2012 to 2016 drought.

Groundwater Pumping

Groundwater pumping is directly input into the SWI Model for urban and agricultural water demands. The SWI Model uses well locations and pumping derived from Monterey County Groundwater Extraction Management System (GEMS). GEMS is the source of the SWI Model's pumping data since 1995 where collected. A year of monthly average SWI Model pumping rates from 2016 to 2020 was used in the baseline predictive model and repeated for 50 years from 2020 through 2070. This recent period was identified as representative of recent basin conditions and includes both wet and dry years.

Agricultural pumping in the 2070 baseline predictive model is scaled from the 2016-2020 monthly average based on the ratio between pumping in the SVOM model runs with and without 2070 climate change. For each water balance subregion, sometimes referred to as "Farms," a land use scaling factor is calculated by comparing the pumping rates modeled in SVOM scenarios with 2017 land use and pumping and either with or without 2070 climate change. The resulting scaling factors represent an increase in agricultural pumping ranging from 2% to 15%. The overall impact on the input agricultural pumping was an increase of 8%.

Urban groundwater use for public supply and industrial water use was not modified from the 2016-2020 monthly average. The baseline predictive model does not consider the impact of expanding urban development, anticipated population growth, or changes in water use efficiency, though these effects may offset one another.

Groundwater Recharge

Groundwater recharge was adjusted similarly to pumping inputs described above. The recharge scaling factor was also calculated for each water balance subregion in the SWI Model. The resulting scaling factors ranged from an increase of 5% to 27%. The overall increase in recharge in the model study area was 12%.

Riparian Groundwater ET

Potential ET (PET) of groundwater in riparian areas is input in the SWI Model. Though PET is likely to increase under 2070 climate change conditions, the simulated ET in the SWI Model was much less than the PET (<20%). In this situation, scaling PET is unlikely to impact model results. Input PET into the baseline predictive model was a year of monthly average PET from the SWI Model in 2016 to 2020.

Surface Water

Stream inflows for the Salinas River at Chualar, mountain streams, and diversions from the Salinas River Diversion Facility (SRDF) from 1996 to 2014 are extracted from the SVOM climate change model run. The subset data are cycled in the baseline predictive model from 2020 to 2070. The SRDF came online in 2010 and diverts water from the Salinas River to the CSIP area; however, SRDF diversions are made throughout the duration of the SVOM whenever reservoir storage and streamflow conditions allow from April through October. During this period in the SVOM, streamflow conditions allowed continuous operation of the SRDF (at 18 cubic feet per second) from April through October for each year of the simulation.

Southeastern Boundary Groundwater Inflow

Specified heads along the cross-valley southeastern boundary at Chualar Creek are based on historical observed groundwater elevations in the SWI Model. In the baseline predictive model, the heads are scaled based on the head difference between the SVIHM historical head or SVOM climate change model runs. Specified heads along the southeastern model boundary are based on 1 year of monthly average heads used in the historical SWI Model. The monthly timeseries is approximately the average heads from WY 1998 to 2014, plus the average head difference between the SVOM model runs with and without 2070 climate change. Heads are extracted from the equivalent model cells in the SVOM models from 1996 to 2014. The head difference between the SVOM models along the boundary was calculated for each stress period between 1996 and 2014. The SVOM model with 2070 climate change projects an average increase in head along the boundary ranging from 0.4 feet to 2.0 feet. The overall average increase in head was 1.5 feet, which was added to the monthly average heads from the SWI Model.

Sea Level Rise

Sea level rise is addressed in the model by increasing the specified head in the cells in layer 1 that represent the ocean and at the seawater interface in Elkhorn Slough. Per DWR guidance, 17.7 inches of sea level rise is added to the 2014 sea level surface used in the SWI Model to simulate 2070 projected sea level rise (DWR, 2018).

MODEL RESULTS

Projected groundwater conditions in 2070 are compared to the initial conditions at the start of the baseline predictive model in WY 2021. Projected chloride results are evaluated in 2030, 2040, 2050, and 2070. Seawater intrusion is evaluated by the inland progression of the simulated 500 milligrams per liter (mg/L) chloride contour.

Groundwater Levels

Simulated change in groundwater head is calculated by subtracting the 2070 groundwater heads from the initial heads in the 180-Foot (Figure 2-1) and 400-Foot (Figure 2-2) Aquifers. The 180-Foot Aquifer is represented by the model layer 3 through 5 average head difference. The 400-Foot Aquifer is represented by the head difference in model layer 7.

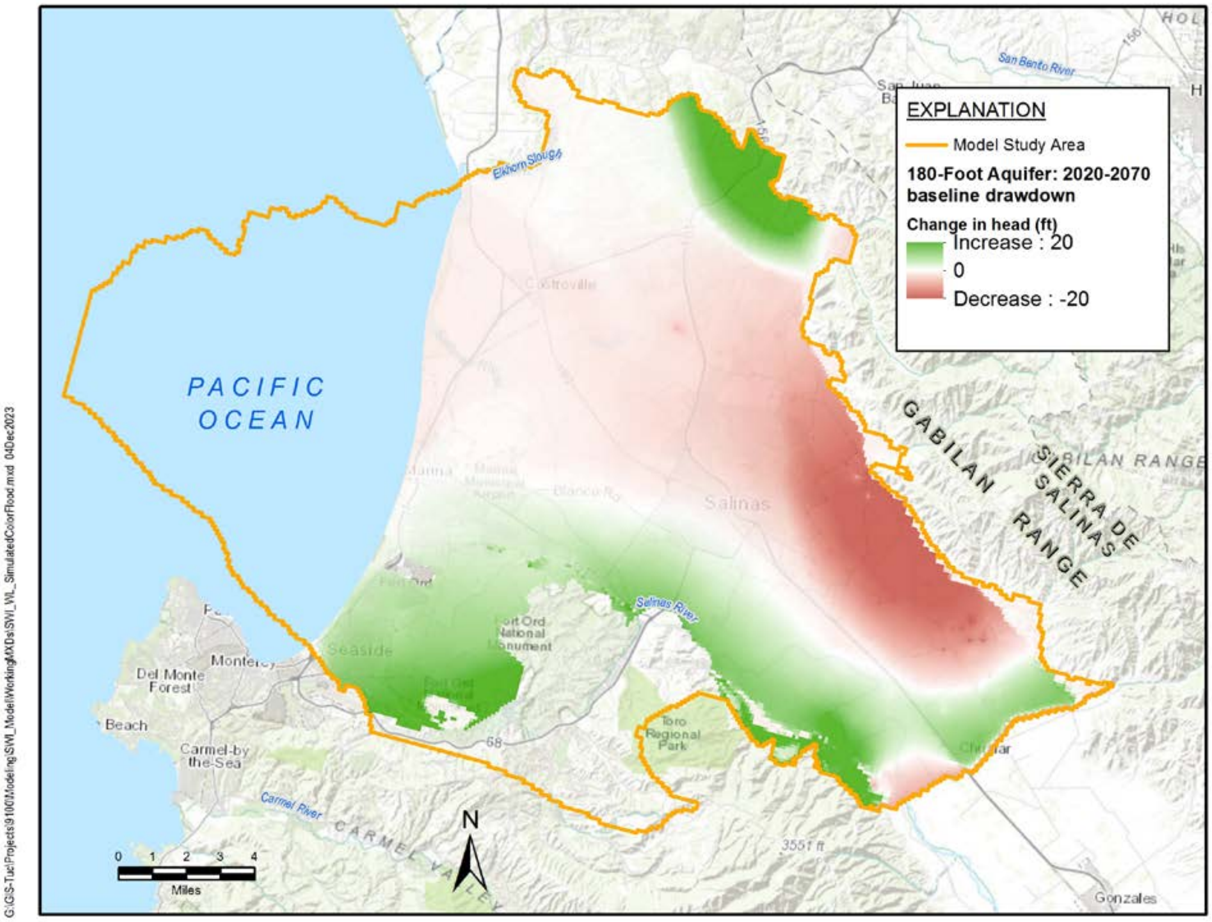


Figure 2-1. Baseline Predictive Model Simulated 2020 to 2070 Drawdown in the 180-Foot Aquifer

The model projects that groundwater heads will decrease in the center of the Salinas Valley and increase near the mountainous valley margins. Increasing heads near the valley margins is a result of projected 2070 climate and increased streamflow input into the model. Decreasing heads in the valley center are caused by groundwater extraction rates exceeding replenishment, despite an increase in recharge input. Heads in the valley generally decline by less than 5 feet in the 180-Foot Aquifer and 5 to 10 feet in the 400-Foot Aquifer. However, heads in the Eastside Subbasin southeast of Salinas decline more than other parts of the valley—by 10 to 30 feet more in both the 180-Foot and 400-Foot Aquifers.

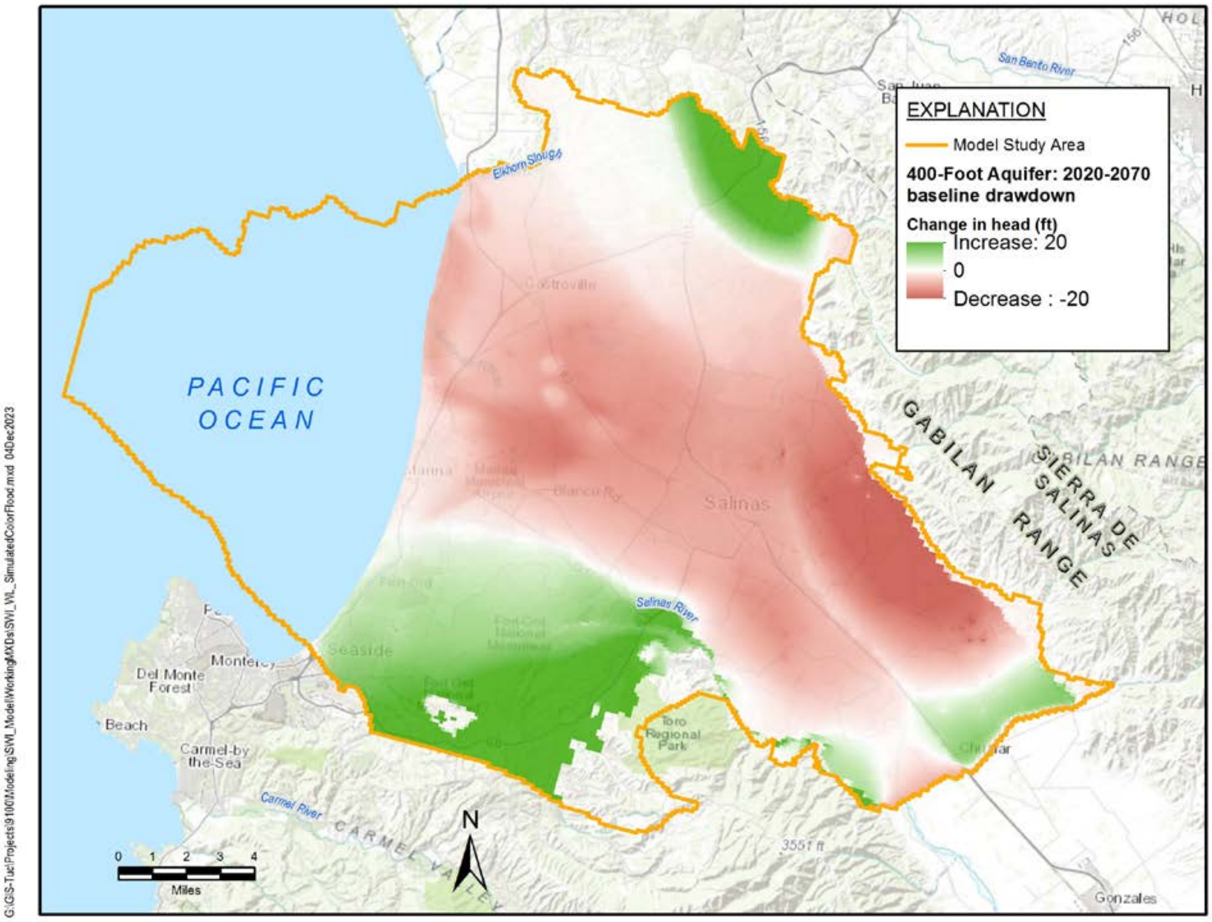


Figure 2-2. Baseline Predictive Model Simulated 2020 to 2070 Drawdown in the 400-Foot Aquifer

Chloride Concentrations

The extent of the simulated 500 mg/L chloride contour was evaluated to project the trend of future seawater intrusion in the Salinas Valley. The progression of 500 mg/L contours in the 180-Foot and 400-Foot Aquifers is presented on Figure 2-3. Chloride concentrations in model layer 5 are selected to represent the 180-Foot Aquifer because the lower portion of the aquifer generally exhibits more advanced seawater intrusion. Chloride concentrations in model layer 7 are shown to represent seawater intrusion in the 400-Foot Aquifer.

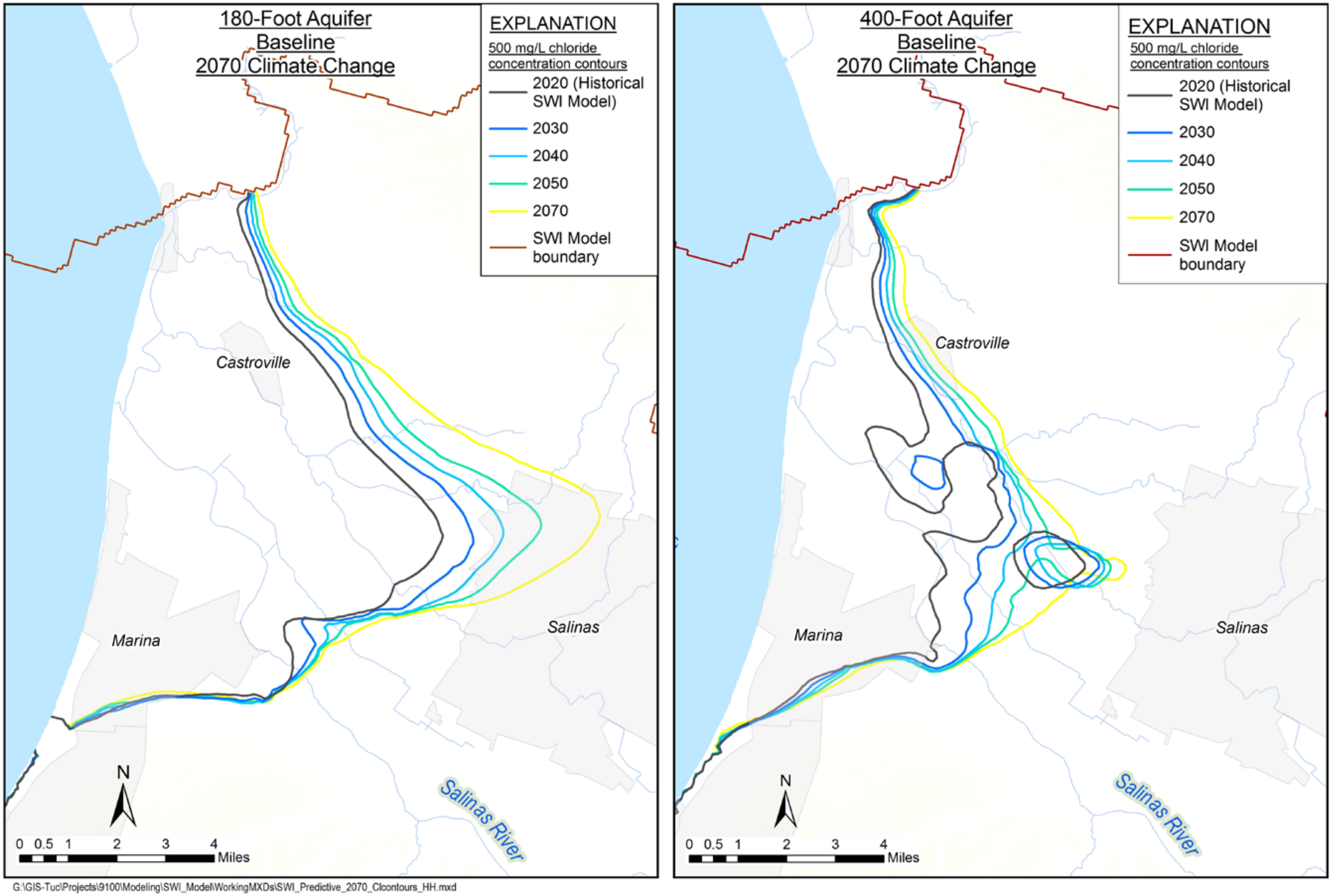


Figure 2-3. Baseline Simulated 500 mg/L Chloride Concentration Contours in 2020, 2030, 2040, 2050, and 2070

The model projects that seawater intrusion in the 180-Foot and 400-Foot Aquifers will steadily continue advancing inland from 2020 through 2070. Though the location of the simulated 500 mg/L chloride contour and rate of movement are approximation of future groundwater conditions, additional seawater intrusion into the Salinas Valley would be expected under the conditions simulated in the baseline predictive model.

Seawater intrusion progresses inland toward the City of Salinas in both the 180-Foot and 400-Foot Aquifers. In the 180-Foot Aquifer, the main lobe of seawater reaches the outskirts of Salinas around 2040 and continues advancing in the direction of the observed groundwater depression to the north of Salinas. In the 400-Foot Aquifer, seawater intrusion is not projected to reach the City of Salinas. The main lobe of seawater advances as far as where the isolated "island" of seawater was in 2020. The island of seawater slowly disperses and shrinks in size, while continuing to move inland. On the northern side of the seawater intrusion front, in the vicinity of Castroville, seawater intrusion is projected to continue but at a slower rate than near Salinas. On the southern side of the seawater intrusion front, little additional seawater intrusion is projected near the City of Marina between 2020 and 2070.

CONCLUSION

M&A developed a predictive version of the SWI Model that simulates groundwater conditions in the Salinas Valley from WY 2021 to 2070. Baseline future groundwater conditions through 2070 and under projected 2070 climate change were simulated with the predictive model to serve as a reference of comparison for other simulations of project and management actions.

The baseline predictive model makes use of the USGS SVOM to project the impacts of 2070 climate change. Climate change in 2070 in this portion of the Salinas Valley is projected to involve increased precipitation and evapotranspiration, resulting in an increase in groundwater extraction for agriculture, increased groundwater recharge, and increased streamflows, which are inputs to the model.

The baseline predictive model projects that groundwater levels will decrease by up to 5 feet in the 180-Foot Aquifer, by 5 to 10 feet in the 400-Foot Aquifer, and by 10 to 30 feet in the portion of the Eastside Subbasin southeast of Salinas. Seawater intrusion in the 180-Foot and 400-Foot Aquifers is projected to continue under the future groundwater conditions simulated in the model. The baseline predictive model will be updated alongside future model improvements. These results demonstrate a baseline against which potential projects and management actions may be compared. The baseline predictive model is a tool that may be used for assessing, comparing, and designing projects and management actions that reach groundwater sustainability goals.

REFERENCES

Boyce, S.E., R.T. Hanson, I. Ferguson, I. W. Schmid, W. Henson, T. Reimann, S.M. Mehl, and M.M. Earll, 2020. One-Water Hydrologic Flow Model: A MODFLOW based conjunctive-use simulation software: U.S. Geological Survey Techniques and Methods 6–A60, 435 p.

DWR, 2018. Guidance for Climate Change Data Use During Groundwater Sustainability Plan Development. July. https://water.ca.gov/-/media/DWR-Website/WebPages/Programs/Groundwater-Management/Sustainable-Groundwater-Management/Best-Management-Practices-and-Guidance-Documents/Files/Climate-Change-Guidance_Final_ay_19.pdf.