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TECHNICAL MEMORANDUM 4

DATE: April 27, 2026 **PROJECT #:** 9100.8905

TO: Salinas Valley Basin Groundwater Sustainability Agency

CC: Monterey County Water Resources Agency; Marina Coast Water District; Seaside Watermaster

FROM: Hanni Blair

REVIEWER: Derrik Williams, P.G., C.Hg.

PROJECT: Salinas Valley Seawater Intrusion Model

SUBJECT: 2026 Seawater Intrusion Model Updates (Addendum 4 to the Salinas Valley Seawater Intrusion Model Report)

INTRODUCTION

Montgomery & Associates (M&A) developed the Salinas Valley Seawater Intrusion Model (SWIM) for the Salinas Valley Basin Groundwater Sustainability Agency (SVBGSA). The model was developed as a tool for agencies and stakeholders to use in assessing seawater intrusion in coastal portions of the Salinas Valley, including potential benefits and risks of seawater intrusion mitigation options. The SWIM was initially developed in 2023 with updates in 2024 and 2025 (M&A, 2023, 2024a, 2025). This technical memorandum documents the most recent SWIM update, which is referred to as SWIM v4. M&A worked with Marina Coast Water District Groundwater Sustainability Agency's (MCWDGSA) consultant, EKI Environment & Water, Inc. (EKI), and the Seaside Watermaster's modeler to update the SWIM. The objective of the SWIM update was to improve the model calibration in the Seaside and Monterey Subbasins so that the model is reasonably well calibrated across all coastal subbasins and can be used for modeling regional groundwater projects and management actions in support of Sustainable Groundwater Management Action (SGMA) planning and implementation objectives. Revisions were funded through a Round 2 Sustainable Groundwater Management (SGM) Implementation Grant to MCWDGSA and SVBGSA.

AGENCY COLLABORATION

M&A coordinated regularly with the MCWD and Seaside Watermaster modeling teams during the model updates. Throughout Fall and Winter 2025, the MCWD and Seaside Watermaster modeling teams led the model update efforts that focused on improving groundwater level calibration within the coastal portions of the Seaside and Monterey Subbasins, particularly in the Deep Aquifers (EKI, 2026). During Spring 2026, M&A conducted additional recalibration of the groundwater levels in Corral de Tierra and Laguna Seca areas. M&A also performed a limited recalibration of the simulated extent of the 500 milligram per liter (mg/L) chloride contour to maintain a seawater intrusion calibration in the 180/400 Subbasin that is similar to the SWIM v3 calibration.

MODEL UPDATES

Model revisions generally focused on the Seaside and Monterey Subbasins. Key model updates included the following:

- Updating the model's hydrogeologic parameter zonation in the Seaside Subbasin and Corral de Tierra area based on the existing Seaside Watermaster's model
- Adjusting recharge assumptions in the Seaside Subbasin to conform with the Seaside Watermaster's model, and in the Corral de Tierra area
- Updating well locations, screen intervals, and pumping data based on additional data and feedback provided by MCWD and Seaside Watermaster
- Modifying the general head boundary condition representing the aquifer/ocean interface
- Modifying streambed leakance properties in the Seaside Subbasin and Corral de Tierra area
- Recalibrating hydraulic conductivity and storage parameters

These update areas are discussed in more detail below.

Updated Model Hydrogeologic Parameter Zonation

The hydrogeologic parameter zones (i.e. hydrogeologic units or HGUs) were modified in the Seaside Subbasin and Corral de Tierra area to roughly reflect the Lower Paso Robles and Santa Margarita Formations as represented in the Seaside Watermaster groundwater model (SSWM) (HydroMetrics, 2018). In most of the SWIM, the Lower Paso Robles Formation (model layer 9) and Santa Margarita Formation (model layer 10) have similar zonation. Based on the SSWM, the 2 layers were assigned separate zonation patterns in an area bounded by the Ord Terrace Fault and the axis of the Laguna Seca Anticline. The SSWM simulates a sharp contrast in hydraulic conductivity across the Ord Terrace and Seaside Faults. The contrast in hydraulic conductivity across the fault represents the offset of the geologic units, which are downthrown on the northeast side (HydroMetrics, 2009). This sharp contrast in hydraulic conductivity was achieved in the SWIM through the subdivision of the parameter zones representing the Lower Paso Robles and Santa Margarita. Additionally, the upper elevations of Corral de Tierra and San Benancio Gulch were divided into separate zones to better reflect the contrast in aquifer structure and properties in this area. Further details about the structure and shallow bedrock mapped in this area are described in the Hydrogeologic Conceptual Model (HCM) of the Monterey Subbasin technical memorandum (M&A, 2024b).

Zones representing thin spots or gaps in the 180/400 Aquitard and the Deep Aquitard in the 180/400 Subbasin were updated based on well screen information added since the last model update. These zones were added around wells with reported screen intervals entirely within the elevations of the aquitard layers – model layer 6 for the 180/400 Aquitard and model layer 8 for the Deep Aquitard. Variation in thickness and clay content is expected within the aquitard layers, which are a simplification of a highly complex, heterogeneous system.

Figure 1 through Figure 11 show the updated model hydrogeologic zonation for various layers. Model layer elevations were not modified during this model update.

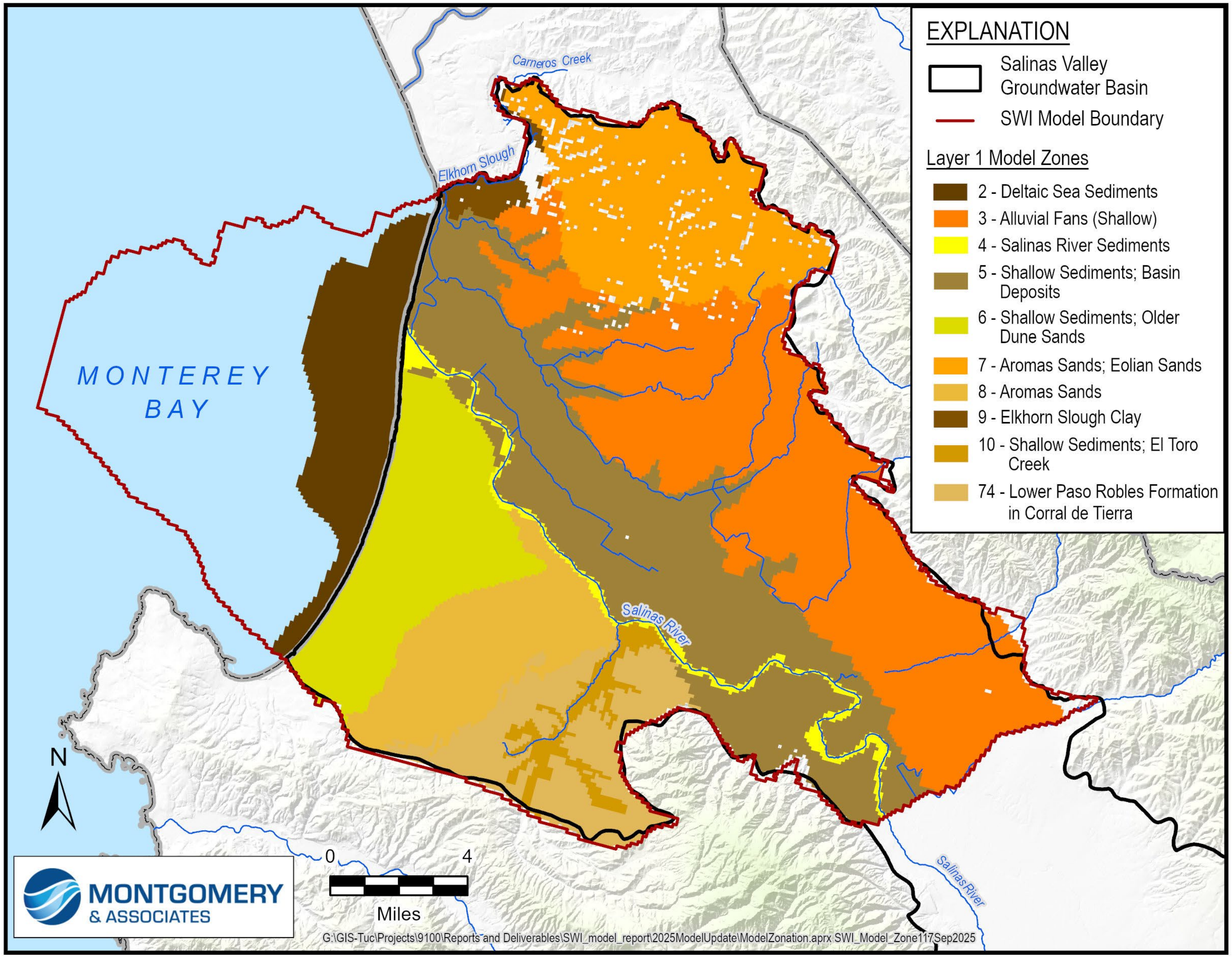

Figure 1. Model Hydrogeologic Zonation in Layer 1

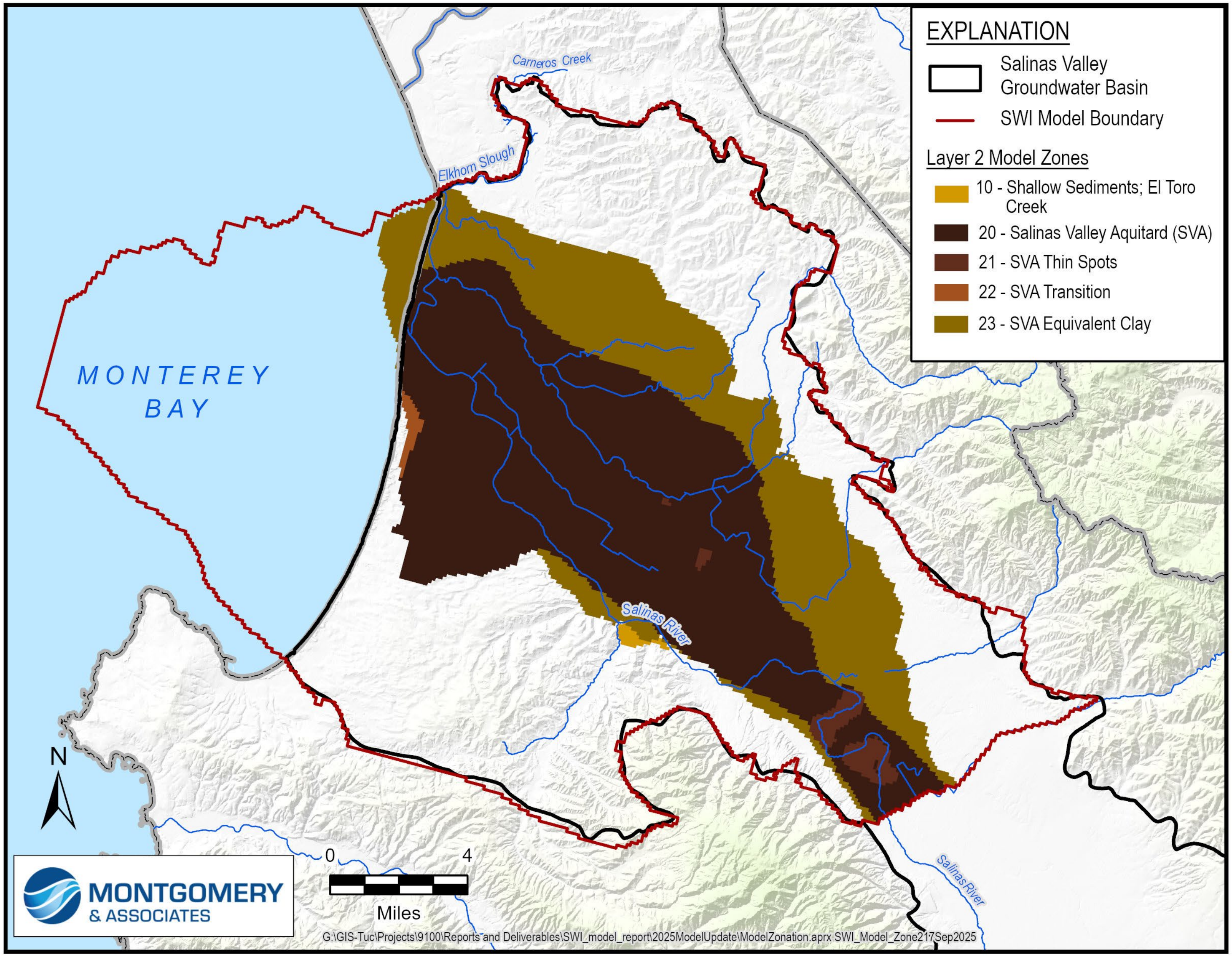

Figure 2. Model Hydrogeologic Zonation in Layer 2

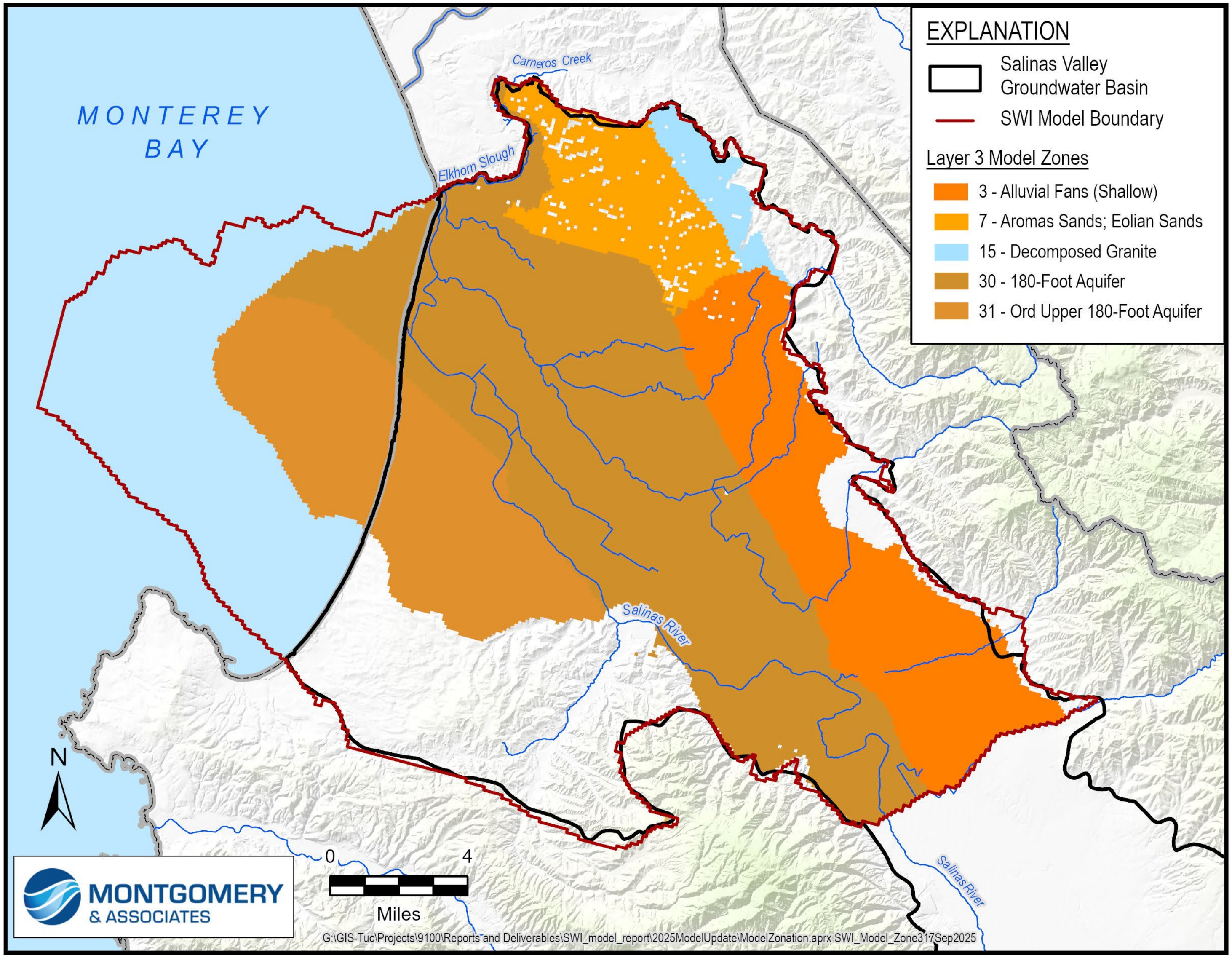

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Figure 3. Model Hydrogeologic Zonation in Layer 3

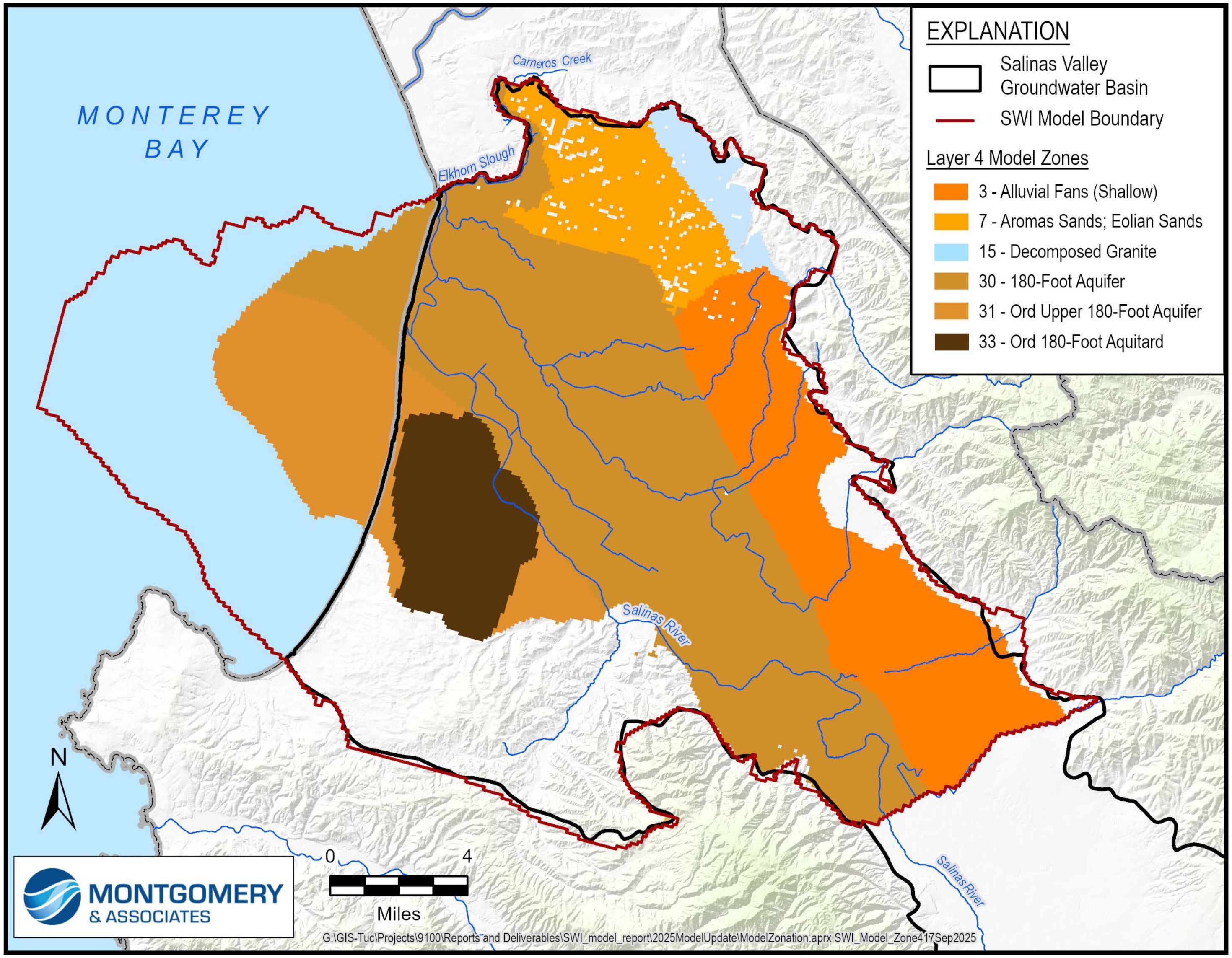

Figure 4. Model Hydrogeologic Zonation in Layer 4

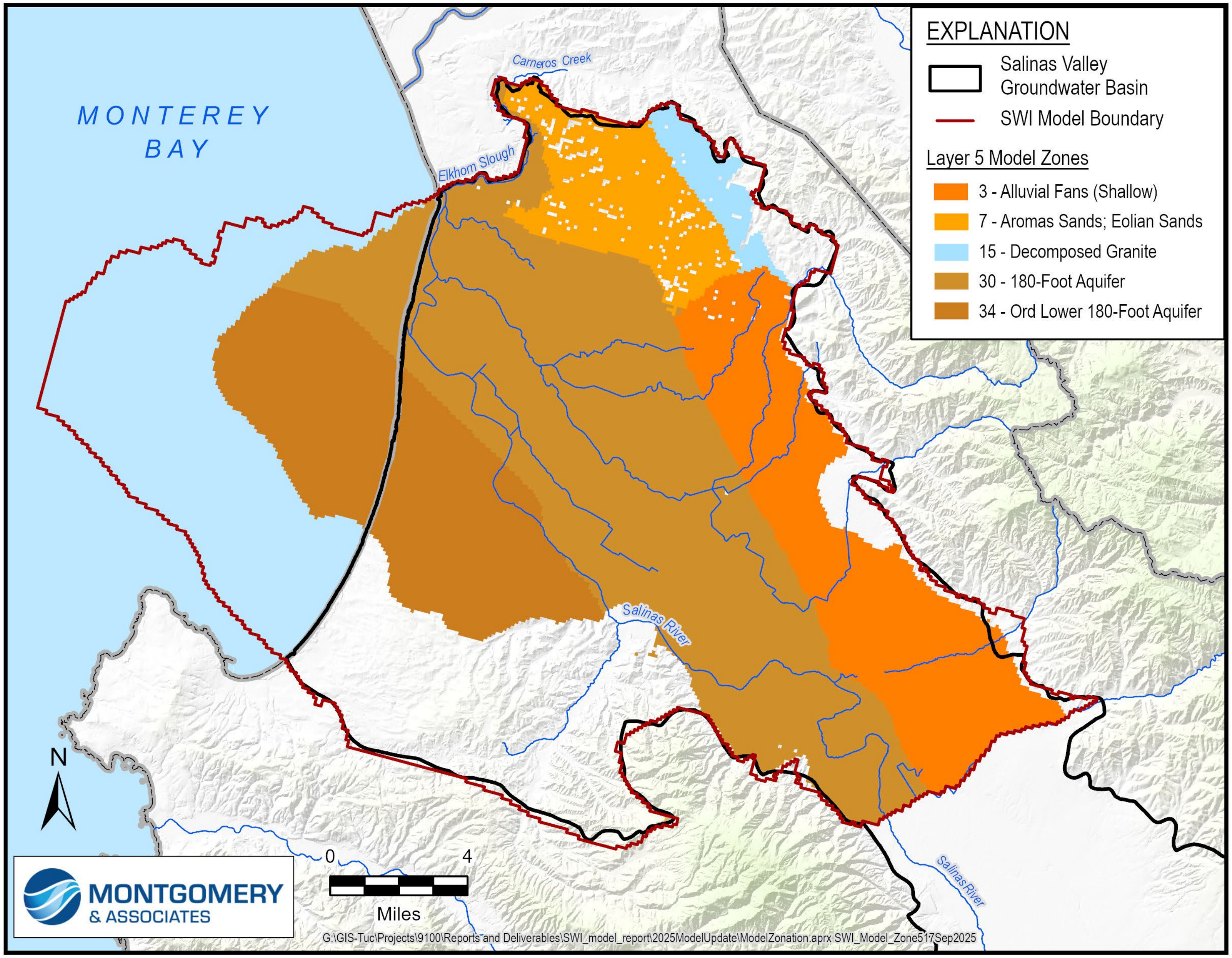

Figure 5. Model Hydrogeologic Zonation in Layer 5

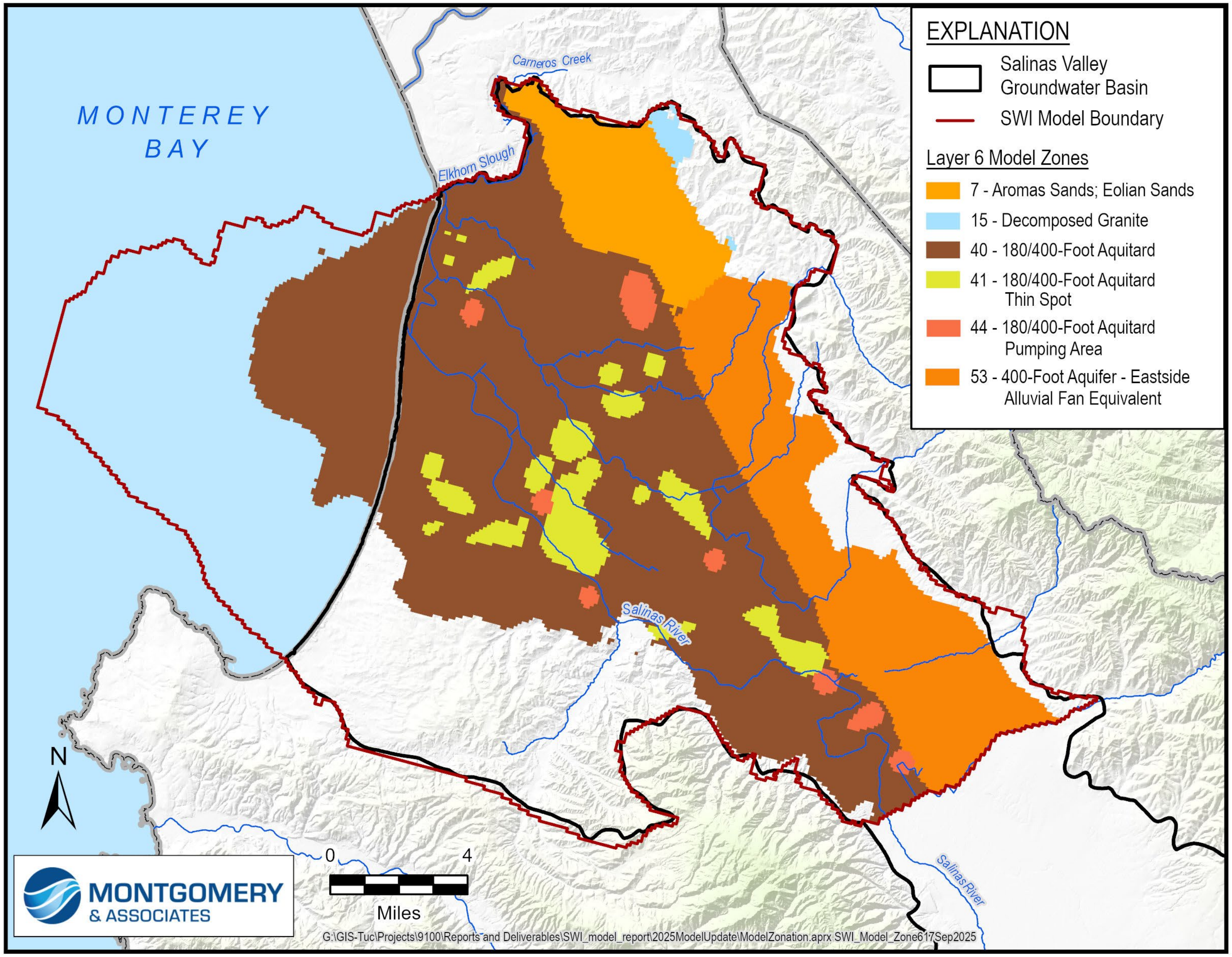

Figure 6. Model Hydrogeologic Zonation in Layer 6

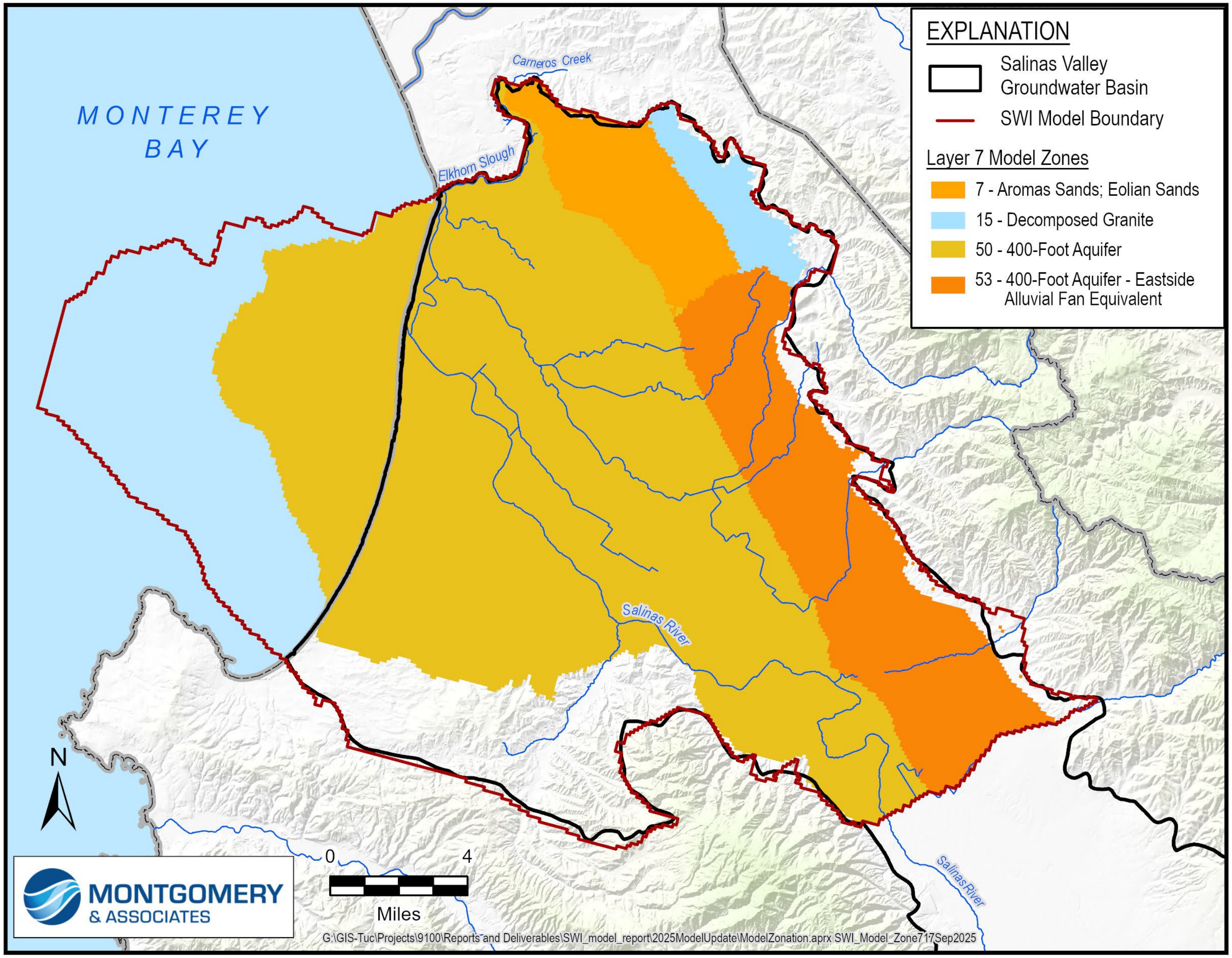

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Figure 7. Model Hydrogeologic Zonation in Layer 7

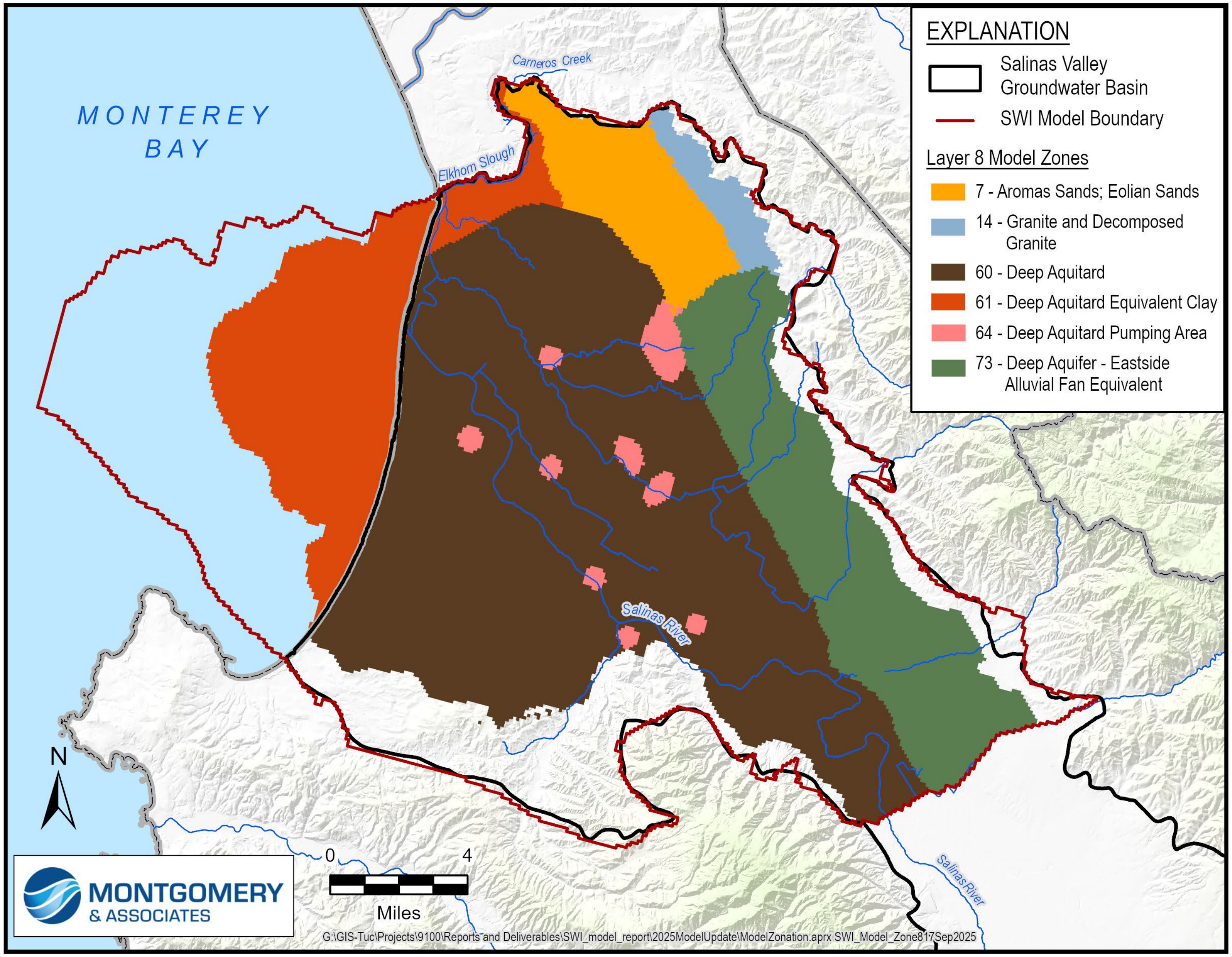

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Figure 8. Model Hydrogeologic Zonation in Layer 8

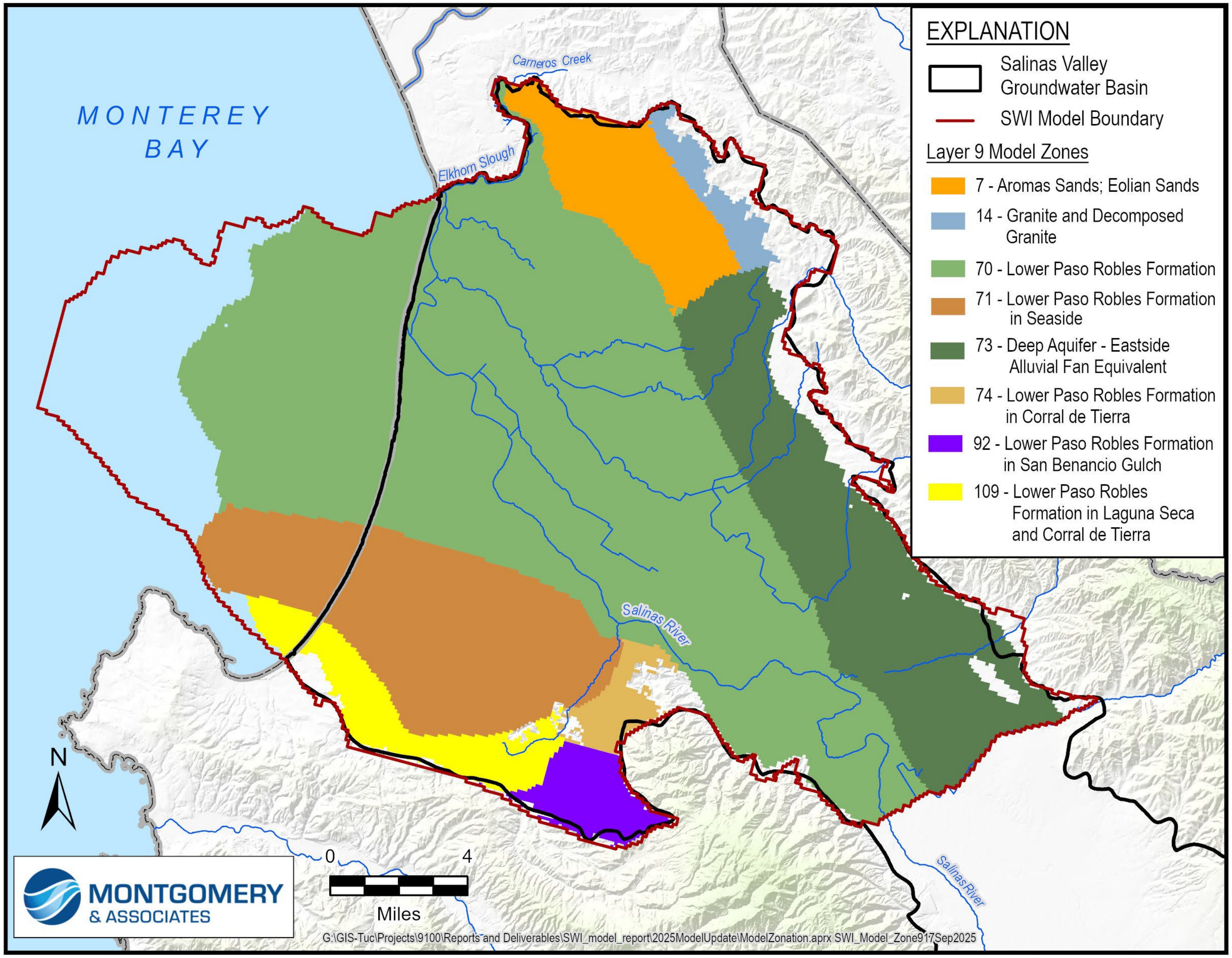

Figure 9. Model Hydrogeologic Zonation in Layer 9

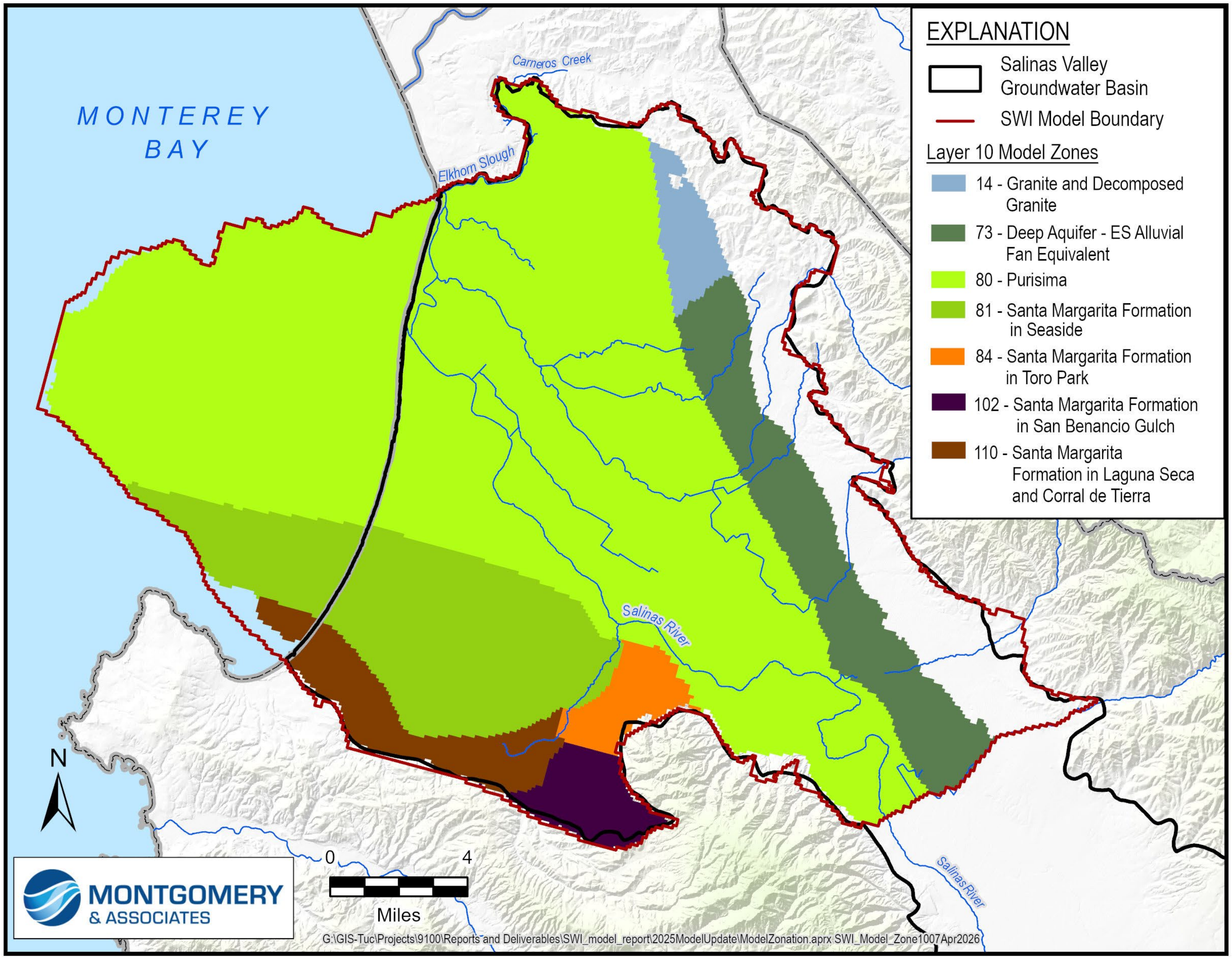

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Figure 10. Model Hydrogeologic Zonation in Layer 10

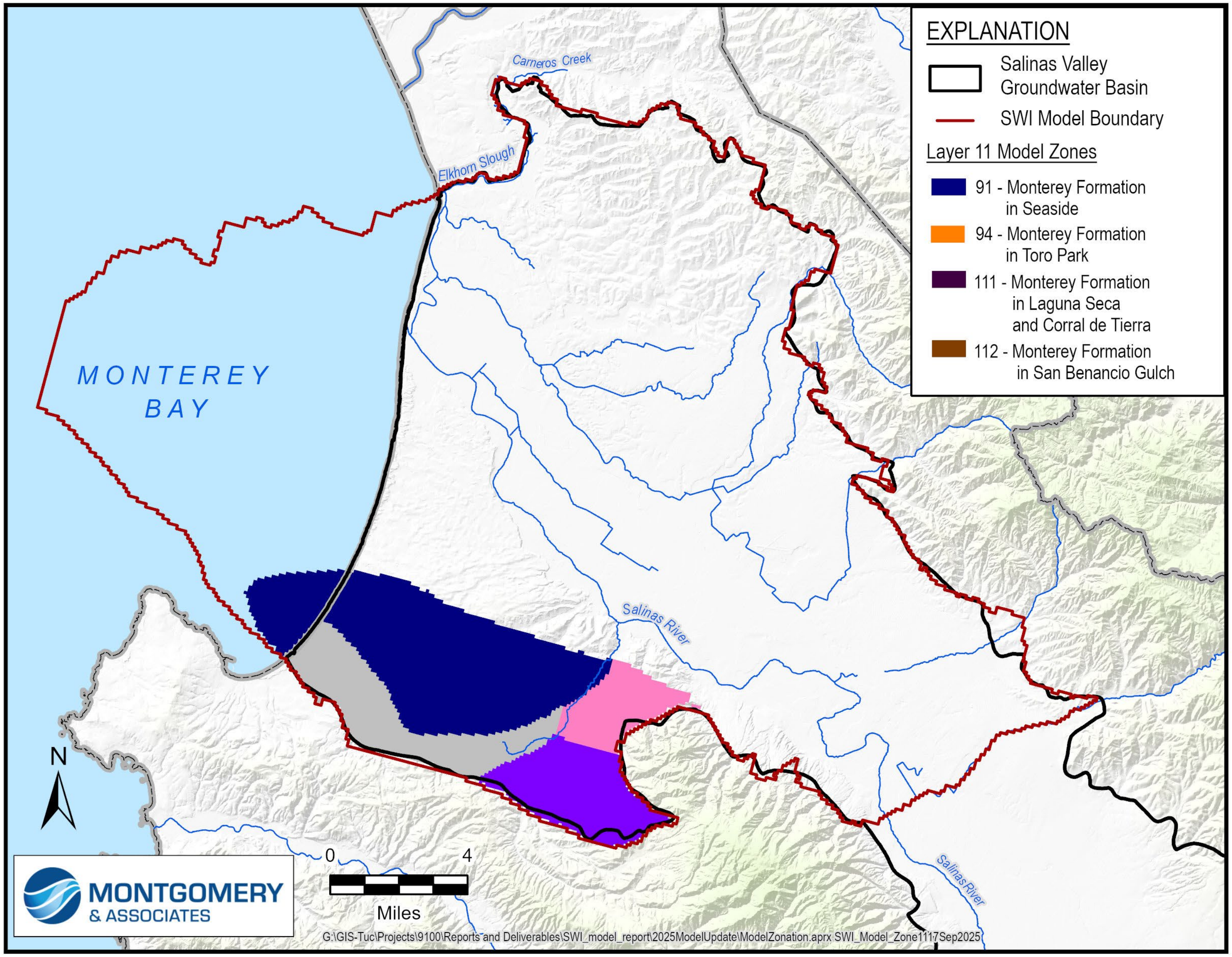

Figure 11. Model Hydrogeologic Zonation in Layer 11

Updated Boundary Conditions

The sections below describe the methods used to update transient boundary conditions.

Ocean Boundary Conditions

The ocean is modeled with General Head Boundary (GHB) cells that represent the aquifer/ocean interface. In SWIM v3 GHB cells are present in the highest active portion of layers 1 through 3, and in the cells adjoining Monterey Canyon in layers 4 through 10. Monterey Canyon is located along the northern offshore model boundary. In SWIM v3, the southern offshore boundary is a no-flow boundary. In SWIM v4, GHB cells were added to the highest active cell in layers 7 through 9, and along the southern offshore model boundary in layer 10 to promote offshore groundwater flow and to prevent groundwater from getting trapped against a no-flow boundary offshore. Figure 12 shows the updated extent of the offshore GHB cells in model layers 7 through 10. The conductance parameters of the ocean GHB in layers 7, 9, and 10 were updated during recalibration.

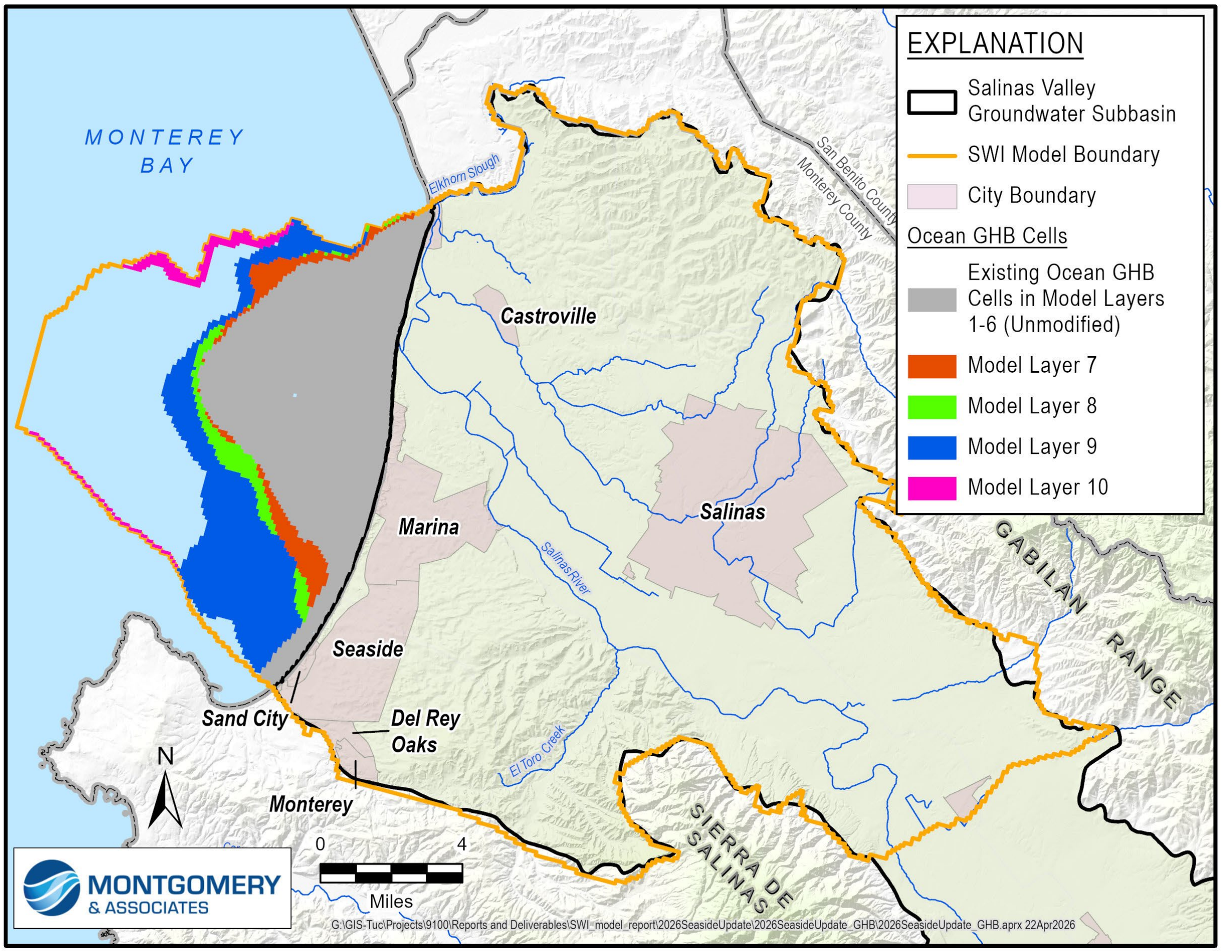

Figure 12. Updated Locations of GHB Cells Representing the Ocean Boundary

Pajaro Valley Boundary Condition

The northern boundary of the model shared with Pajaro Valley near Elkhorn Slough is modeled with a GHB. This boundary condition was not modified as part of the model update.

Southeastern Boundary Condition

The southeastern boundary of the model, near the confluence of Chualar Creek and the Salinas River, is modeled with a time dependent constant head (CHD) boundary. This boundary condition was not modified as part of the model update.

Groundwater Recharge

Groundwater recharge in the SWIM is based on simulated rates in the SVIHM averaged by Water Balance Subregion (WBS). Groundwater recharge in the Seaside Subbasin was compared to the SSWM by WBS, which includes separate urban, coastal, and upland areas. The total annual average recharge rates in Seaside Subbasin in the SVIHM were higher than the rates in the SSWM. While total annual recharge during wet years was similar to the SSWM, the SVIHM simulated greater recharge during drier years. Because the SWIM v3 generally simulates groundwater levels higher than observed in the Seaside Subbasin, the recharge rates were scaled down to align more closely with the SSWM. A scale factor was developed for each of the Seaside Subbasin's urban, coastal, and upland areas, which resulted in an average annual groundwater recharge rate similar to the SSWM for WY 1995 through 2017. Additionally, a scale factor was applied to recharge in San Benancio Gulch and modified during recalibration. The scale factors applied to the SVIHM simulated recharge are shown in Table 1. The updated SWIM v4 Seaside annual recharge is compared to the SSWM and previous SWIM v3 annual recharge on Figure 12.

Table 1. Groundwater Recharge Scale Factor

Area	Recharge Scale Factor
Seaside Subbasin Coastal Dune Sands (WBS 41)	0.81
Seaside Subbasin Urban (WBS 40)	0.56
Seaside Subbasin Uplands (WBS 30)	0.83
San Benancio Gulch (WBS 25)	0.50

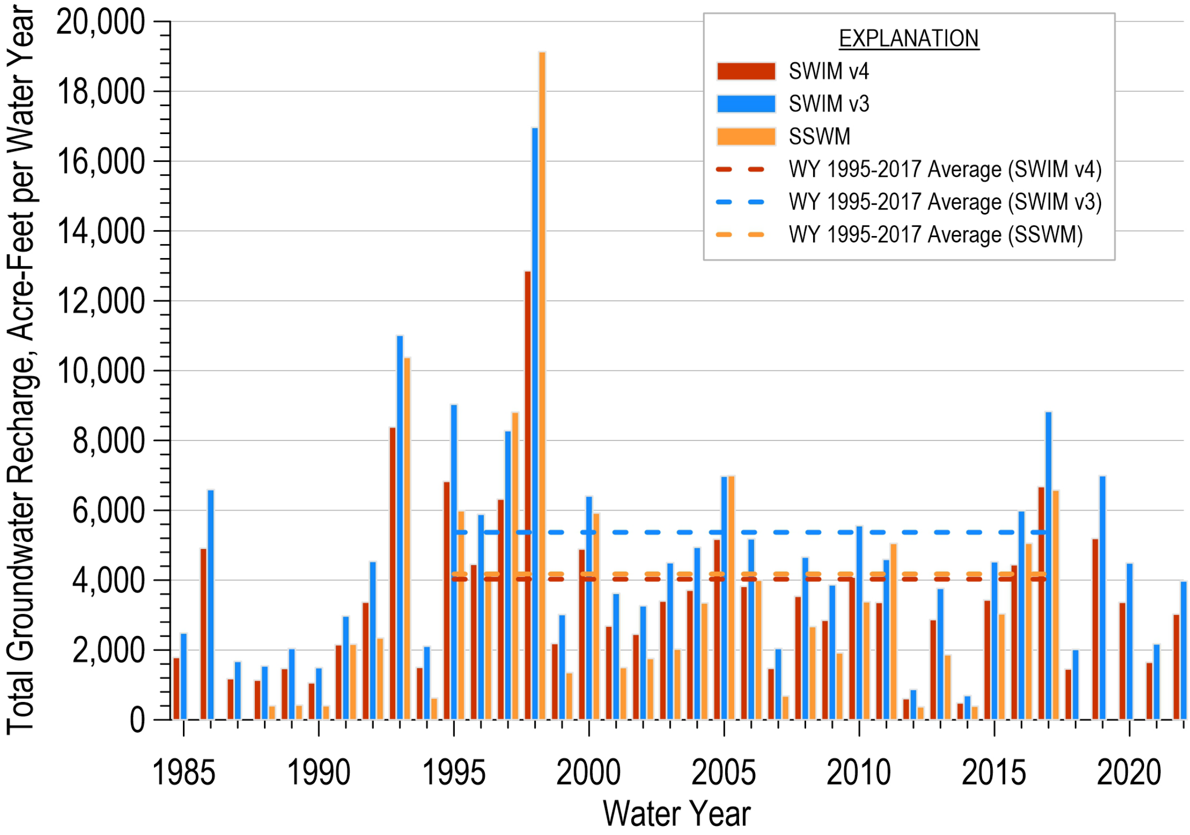

Figure 13. Updated Annual Recharge in Seaside Subbasin

Riparian Groundwater Evapotranspiration

Evapotranspiration (ET) in riparian areas is simulated using the MODFLOW evapotranspiration package (EVT). This boundary condition was not modified as part of the model update.

Surface Water Flows

Streams are simulated using the connected linear node (CLN) package. The streambed leakance was reduced for selected segments of a small intermittent stream in Laguna Seca and El Torro Creek in Corral de Tierra. The leakance was modified to improve numerical solver convergence and reduce excessive spikes in groundwater levels during the wet winter of 1998.

Updated Well and Pumping Data

The SWIM well locations and screen intervals were updated for selected wells in the Monterey and Seaside Subbasins based on new data and recommendations provided by the MCWD and Seaside Watermaster modeling teams.

In the Monterey Subbasin, early time (pre-1985) simulated pumping in a Fort Ord well was found to be duplicated by a second set of wells, which were removed from SWIM v4. Additionally, the simulated well screens for the Fort Ord wells were shifted from the Upper 180-Foot Aquifer to the Lower 180-Foot Aquifer to improve calibration of early time (pre-1985) seawater intrusion conditions within the coastal Monterey Subbasin. The location of Marina municipal well MCWD-35 was corrected in SWIM v4.

In the Seaside Subbasin, simulated well screen intervals and model layer assignments were compared to well log data and prior interpretations of the formations wells are screened across. The Seaside ASR and the Pure Water Monterey Deep Injection Wells (DIW's) are entirely screened within the Santa Margarita Formation. In the SWIM v3, some of these wells were screened in both model layer 10 (Santa Margarita Formation), model layer 9 (Lower Paso Robles Formation), and/or layer 11 (Monterey Formation). The simulated well screens for these 5 wells were shifted so that the wells are exclusively screened in the Santa Margarita Formation. Similar adjustments were made to a small number of other Seaside production wells to align the simulated well screens with the previous interpretations of screened formations. Additionally, simulated pumping at Seaside golf course irrigation wells GC-Coe and GC-Res were found to be duplicated by a second set of wells, which were removed from SWIM v4.

As in the prior model update, there are several wells without screen interval information where the well screen was conservatively assumed to bridge both the 180-Foot and 400-Foot Aquifers. When this resulted in migration of seawater from the 180-Foot Aquifer to the 400-Foot Aquifer through the CLN well in an area where this has not previously been observed, the well screens were reassigned to either the 180-Foot or 400-Foot Aquifer. These changes impacted 8 additional wells in the SWIM v4 update.

Faults

Faults are simulated with the Horizontal Flow Barrier package (HFB). The location and properties of the HFB faults were not modified during the model update except for 1 HFB model cell representing the Ord Terrace Fault, which was moved from the northern to the southern side of the same cell. This HFB location was moved to place the Luzern2 well on the north side of the fault, resulting in better groundwater level calibration. However, the groundwater levels observed at wells on either side of the fault do not show clearly observable difference in hydraulic response across the Ord Terrace Fault.

Updated Groundwater Level Calibration Target Data

Each observation well is assigned to a single representative model layer. The model layer is selected based on the layer in which most of the well is screened. Well locations and target layers were reviewed and updated for selected wells in the Monterey and Seaside Subbasins following recommendations by the MCWD and Seaside Watermaster modeling teams. Within the Monterey Subbasin, MCWD provided groundwater levels for 11 new wells in the Marina area and adjusted model layer assignments for several dozen existing observation wells to better match their previously identified aquifer designations. Within the Seaside Subbasin, as with the production wells, the Seaside Watermaster's consultant recommended that observation wells be assigned to the model layer corresponding to the well logs. The groundwater level target layer was updated for 18 target wells in the Seaside Subbasin.

Many groundwater level observations corresponded to stress period 2: the stress period that simulates steady state pumping between 1924 and 1985. This stress period approximates early groundwater conditions, but the pumping data for this stress period are only approximations and the results of this stress period should not be included in the calibration statistics. These early observations were therefore removed from the calibration statistics.

Initial Conditions

Due to the modification of the ocean boundary condition, recharge, and hydraulic conductivity, the initial heads and concentrations were updated using a similar method to the prior model updates. The heads and concentrations were initiated using a 10,000-year stress period 1 to develop a quasi-steady-state solution for pre-anthropogenic heads and the seawater intrusion wedge. Heads at the beginning of stress period 1 were set to the top elevation of layer 1. Chloride concentrations were initially the background chloride concentration (55 mg/L), with the exception of the Monterey Bay and the model cells beneath it in layer 1, which had initial concentrations equal to seawater (18,537 mg/L).

MODEL RECALIBRATION

Recalibration of SWIM v4 focused on improving the model calibration in the Seaside and Monterey Subbasins. The objective for the recalibration is for the aggregate groundwater level statistics to reasonably match observed data without negatively impacting the groundwater level or chloride calibration elsewhere in the model.

The SWIM was recalibrated by manually varying simulated hydraulic conductivities, storage parameters, and effective porosities. The hydraulic conductivities and storage properties were manually adjusted by modifying individual pilot point and/or HGU Zone values (Doherty *et al.*, 2010). Initial revisions were performed by the MCWD modeling team in coordination with the Seaside Watermaster and M&A modelers. M&A conducted subsequent recalibration working together with partners.

The results of the model recalibration are detailed below.

Hydrogeologic Parameters

Table 2 lists the final hydrogeologic parameter values in SWIM v4 following recalibration. The HGU Zone numbers referenced in Table 2 are shown on Figure 1 through Figure 13. The hydrogeologic parameter zones highlighted in light blue in Table 2 are new zones that have been added to the model or redefined in this update.

Table 2. Updated Summary of Calibrated Hydraulic Conductivity (K) and Storage Properties of the HGUs Within the Model

HGU Zone No.	HGU Description	K_h, K_v Number of Pilot Points	K_h Pilot Point (feet/day)			K_v Pilot Point (feet/day)			Specific Yield (Sy) Effective Porosity	Specific Storage (Ss) (ft^{-1})
			Minimum	Maximum	Geometric Mean	Minimum	Maximum	Geometric Mean		
2	Deltaic Sea Sediments	3,3	2.06	55.7	30.7	1.03	48.1	20.4	0.082	2.36E-02
3	Alluvial Fans (Shallow)	16,16	0.521	179	14.1	0.0646	17.0	1.07	0.195	2.63E-05
4	Salinas River Sediments	1,1	201	201	201	10.5	10.5	10.5	0.232	1.00E-03
5	Shallow Sediments; Basin Deposits	6,6	0.831	167	17.0	0.0197	18.8	1.04	0.185	1.27E-03
6	Shallow Sediments; Older Dune Sands	14,14	10.5	209	51.7	0.371	8.36	3.10	0.263	5.00E-04
7	Aromas Sands; Eolian Sands	4,4	0.203	1.97	0.634	0.00792	0.0617	0.0164	0.220	3.12E-04
8	Aromas Sands	3,3	9.28	42.7	18.2	3.19	15.5	8.79	0.165	1.94E-04
9	Elkhorn Slough Clay	1,1	0.00646	0.00646	0.00646	0.000162	0.000162	0.000162	0.102	2.94E-05
10	Shallow Sediments; El Toro Creek	1,1	40.2	40.2	40.2	7.06	7.06	7.06	0.168	1.37E-04
14	Granite and Decomposed Granite	1,1	0.000703	0.000703	0.000703	0.0000921	0.0000921	0.0000921	0.208	9.28E-05
15	Decomposed Granite	1,1	0.131	0.131	0.131	0.0305	0.0305	0.0305	0.208	1.31E-03
20	Salinas Valley Aquitard (SVA)	11,11	0.00665	0.0973	0.0141	0.0000758	0.0487	0.00262	0.120	5.85E-05
21	SVA Thin Spot	1,1	33.6	33.6	33.6	2.74	2.74	2.74	0.120	2.00E-06
22	SVA Transition	1,1	0.00542	0.00542	0.00542	0.000223	0.000223	0.000223	0.120	3.41E-05
23	SVA Equivalent Clay	3,3	0.00115	0.0615	0.0212	0.0000379	0.0251	0.00323	0.120	3.24E-05
30	180-Foot Aquifer	19,19	49.9	349	204	1.32	25.0	11.0	0.100	2.95E-05
31	Ord Upper 180-Foot Aquifer	13,13	29.7	229	94.6	0.0142	5.43	0.446	0.120	9.30E-06
33	Ord 180-Foot Aquitard	6,6	0.560	0.560	0.560	0.00500	0.00500	0.00500	0.128	7.57E-06
34	Ord Lower 180-Foot Aquifer	12,12	60.9	249	140	0.477	3.87	1.51	0.120	6.65E-05
40	180/400-Foot Aquitard	13,13	0.000770	0.0609	0.00841	0.0000166	0.00976	0.000259	0.117	1.21E-05
41	180/400-Foot Aquitard Thin Spot	3,3	0.691	0.691	0.691	0.00837	0.00837	0.00837	0.100	1.04E-05
44	180/400-Foot Aquitard Pumping Area	1,1	7.85	7.85	7.85	0.00783	0.00783	0.00783	0.100	3.61E-05
50	400-Foot Aquifer	31,31	3.41	195	52.4	0.0106	8.42	0.757	0.100	7.68E-06

HGU Zone No.	HGU Description	K_h, K_v Number of Pilot Points	K_h Pilot Point (feet/day)			K_v Pilot Point (feet/day)			Specific Yield (Sy) Effective Porosity	Specific Storage (Ss) (ft^{-1})
			Minimum	Maximum	Geometric Mean	Minimum	Maximum	Geometric Mean		
53	400-Foot Aquifer - Eastside Alluvial Fan Equivalent	16,16	0.307	85.5	5.45	0.00372	0.839	0.0551	0.195	4.38E-06
60	Deep Aquitard	8,8	0.000763	0.968	0.0723	0.00000895	0.476	0.00662	0.120	5.36E-05
61	Deep Aquitard Equivalent Clay	1,1	0.0000100	0.0000100	0.0000100	0.0000100	0.0000100	0.0000100	0.120	8.58E-06
64	Deep Aquitard Pumping Areas	1,1	1.14	1.14	1.14	1.00	1.00	1.00	0.168	5.35E-04
70	Lower Paso Robles Formation	10,10	0.590	18.4	5.82	0.0591	2.76	0.307	0.168	8.20E-07
71	Lower Paso Robles Formation in Seaside	5,5	3.02	19.8	6.47	0.0304	0.198	0.0760	0.168	5.00E-05
73	Deep Aquifer - Eastside Alluvial Fan Equivalent	13,13	0.988	38.1	7.10	0.0141	3.12	0.162	0.195	3.27E-06
74	Lower Paso Robles in Corral de Tierra	1,1	20.0	20.0	20.0	1.00	1.00	1.00	0.0800	1.00E-06
80	Purisima	6,6	1.00	15.8	2.54	0.0101	0.980	0.0725	0.150	7.39E-07
81	Santa Margarita Formation in Seaside	8,8	0.793	98	3.08	0.0102	0.112	0.0619	0.0800	1.00E-06
84	Santa Margarita Formation in Toro Park	1,1	5.00	5.00	5.00	0.100	0.100	0.100	0.0800	1.00E-06
91	Monterey Formation in Seaside	1,1	0.00100	0.00100	0.00100	0.000100	0.000100	0.000100	0.120	9.13E-05
92	Lower Paso Robles Formation in San Benancio Gulch	1,1	1.00	1.00	1.00	0.350	0.350	0.350	0.120	4.27E-03
94	Monterey Formation in Toro Park	1,1	0.0169	0.0169	0.0169	0.00297	0.00297	0.00297	0.120	9.13E-05
102	Santa Margarita Formation in San Benancio Gulch	1,1	1.00	1.00	1.00	0.100	0.100	0.100	0.0800	1.00E-06
109	Lower Paso Robles Formation in Laguna Seca and Corral de Tierra	5,5	0.511	10.6	1.82	0.0509	0.134	0.101	0.0800	1.00E-06
110	Santa Margarita Formation in Laguna Seca and Corral de Tierra	5,5	0.480	10.6	1.71	0.0105	0.109	0.0438	0.0800	1.00E-06
111	Monterey Formation in Laguna Seca and Corral de Tierra	1,1	0.700	0.700	0.700	0.00297	0.00297	0.00297	0.120	9.13E-05
112	Monterey Formation in San Benancio Gulch	1,1	0.00100	0.00100	0.00100	0.000100	0.000100	0.000100	0.120	9.13E-05

Note: Light blue shading indicates new zones that have been added to the model or redefined in SWIM v4.

Groundwater Level Calibration

Groundwater levels were recalibrated by adjusting hydrogeologic parameters, after implementing the structural and boundary condition refinements noted above. The groundwater level calibration of SWIM v4 has improved compared to SWIM v3, particularly in the Deep Aquifers, Corral de Tierra area, and Seaside Subbasin. The groundwater level calibration of SWIM v4 is approximately the same or slightly better in the rest of the model domain. Figure 13 shows the cross plot of all observed and simulated groundwater levels for SWIM v4. Figure 14 shows the cross plot of observed and simulated groundwater levels for just the Deep Aquifers, Corral de Tierra area, and Seaside Subbasin, which was the focus of this model update. Table 3 summarizes the groundwater level calibration statistics across the model for each aquifer and for the entire model for both SWIM v4 and SWIM v3.

The groundwater level calibration statistics in the surficial sediments, 180-Foot Aquifer, 400-Foot Aquifer, and Eastside equivalent aquifers are generally similar to the previous model version. Table 3 shows the mean residual for these groups is a slightly smaller magnitude, and the Root Mean Squared statistic is either about the same or smaller. The model continues to slightly underpredict groundwater levels in the 180-Foot, 400-Foot, and Eastside equivalent aquifers. As in SWIM v3, the model tends to overestimate groundwater levels in the granite uplands portion of the Langley Subbasin.

The groundwater level calibration statistics in the Deep Aquifers in the 180/400 and Monterey Subbasins improved in SWIM v4. The simulated groundwater levels were previously overestimated by approximately 5 feet in the Deep Aquifers; the SWIM v4 mean residual indicates the average groundwater levels are now overestimated by approximately 1 foot. Additionally, the scaled Root Mean Square Error (RMSE) statistic decreased from 9.16% to 7.97%.

The groundwater level calibration statistics in Seaside Subbasin and Corral de Tierra improved in SWIM v4. The mean residual decreased from -20 feet to approximately -8 feet, where a negative value indicates the simulated water levels are overestimated on average. The RMSE decreased from 38 feet to 33 feet. Additionally, the scaled residual mean and scaled RMSE both decreased and are both less than 5%.

Figure 14 shows the data from the Seaside Subbasin and Corral de Tierra area as gray points. Points at elevations less than approximately 100 feet NAVD88 generally correspond to the coastal portion of Seaside Subbasin. The coastal Seaside points are generally clustered around the 1-to-1 line, though the points corresponding to the lowest observed groundwater levels are overestimated by the model. These correspond to pumping-influenced observations collected at or near large production wells along the coast in Seaside. Recent groundwater level declines in coastal Seaside and Monterey observation wells are underestimated by the model. The group of points between the elevations of approximately 150 to 300 feet NAVD88 correspond to data from the Laguna Seca and Corral de Tierra areas, while the points at elevations above 400 feet correspond to data from San Benancio Gulch. The corresponding figure from SWIM v3 indicated that simulated groundwater levels in Corral de Tierra and Laguna Seca areas were not declining as quickly as observed. This trend is greatly improved in SWIM v4, though groundwater levels in Laguna Seca are sometimes overestimated. During recalibration, the unconfined storage parameters for the upper elevations near Corral de Tierra were reduced in SWIM v4 (see Table 2), in addition to a reduction in input groundwater recharge (Table 1), which results in the SWIM v4 simulated groundwater levels declining at a rate more similar to the observed.

Table 3. Updated Groundwater Level Calibration Statistics

SWIM v4 (Updated Groundwater Level Calibration Dataset)						
	Surficial Sediments	180-Foot Aquifer	400-Foot Aquifer	Deep Aquifers	Corral de Tierra and Seaside[1]	All Data
Mean Residual (feet)	-0.83	4.17	4.60	-1.09	-7.95	0.41
RMS Error (feet)	15.53	15.33	17.46	23.92	33.05	21.16
Number of Observations	19,102	19,017	16,141	6,459	11,831	76,654
Range in Observations (feet)	290	357	325	300	840	840
Scaled RMS Error	5.35%	4.29%	5.38%	7.97%	3.94%	2.52%
Scaled Residual Mean	-0.29%	1.17%	1.42%	-0.36%	-0.95%	0.05%
SWIM v3 (Updated Groundwater Level Calibration Dataset)						
	Surficial Sediments	180-Foot Aquifer	400-Foot Aquifer	Deep Aquifers	Corral de Tierra and Seaside	All Data
Mean Residual (feet)	-2.85	6.17	7.76	-6.68	-19.81	-1.05
RMS Error (feet)	15.27	16.81	19.10	27.48	38.12	23.25
Number of Observations	19,102	19,017	16,141	6,459	11,831	76,654
Range in Observations (feet)	290	357	325	300	840	840
Scaled RMS Error	5.26%	4.71%	5.88%	9.16%	4.54%	2.77%
Scaled Residual Mean	-0.98%	1.73%	2.39%	-2.23%	-2.36%	-0.12%

[1] Corral de Tierra and Seaside Lower Paso Robles, Santa Margarita, and Monterey Formation.

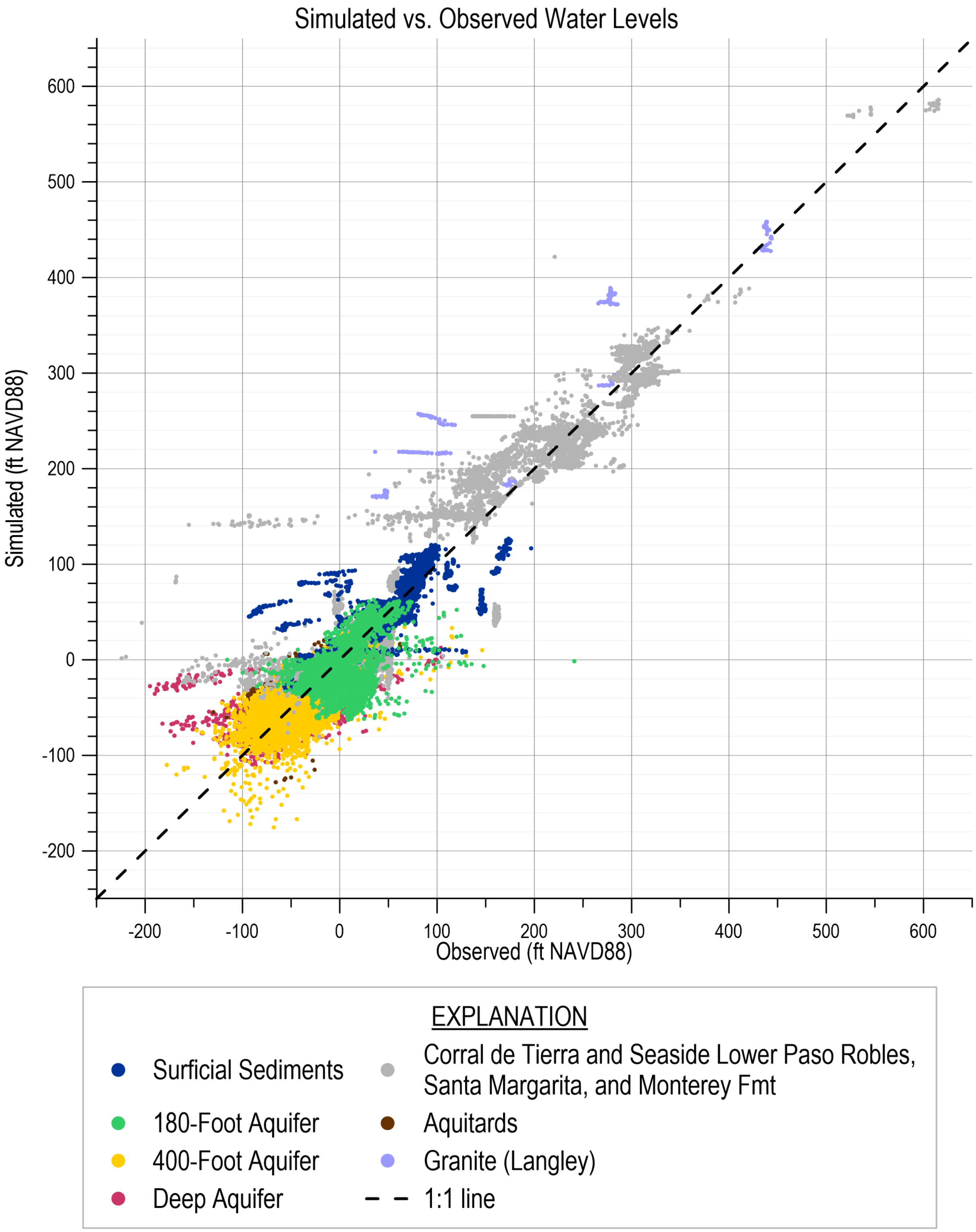

Figure 14. Simulated and Observed Groundwater Level Cross Plot

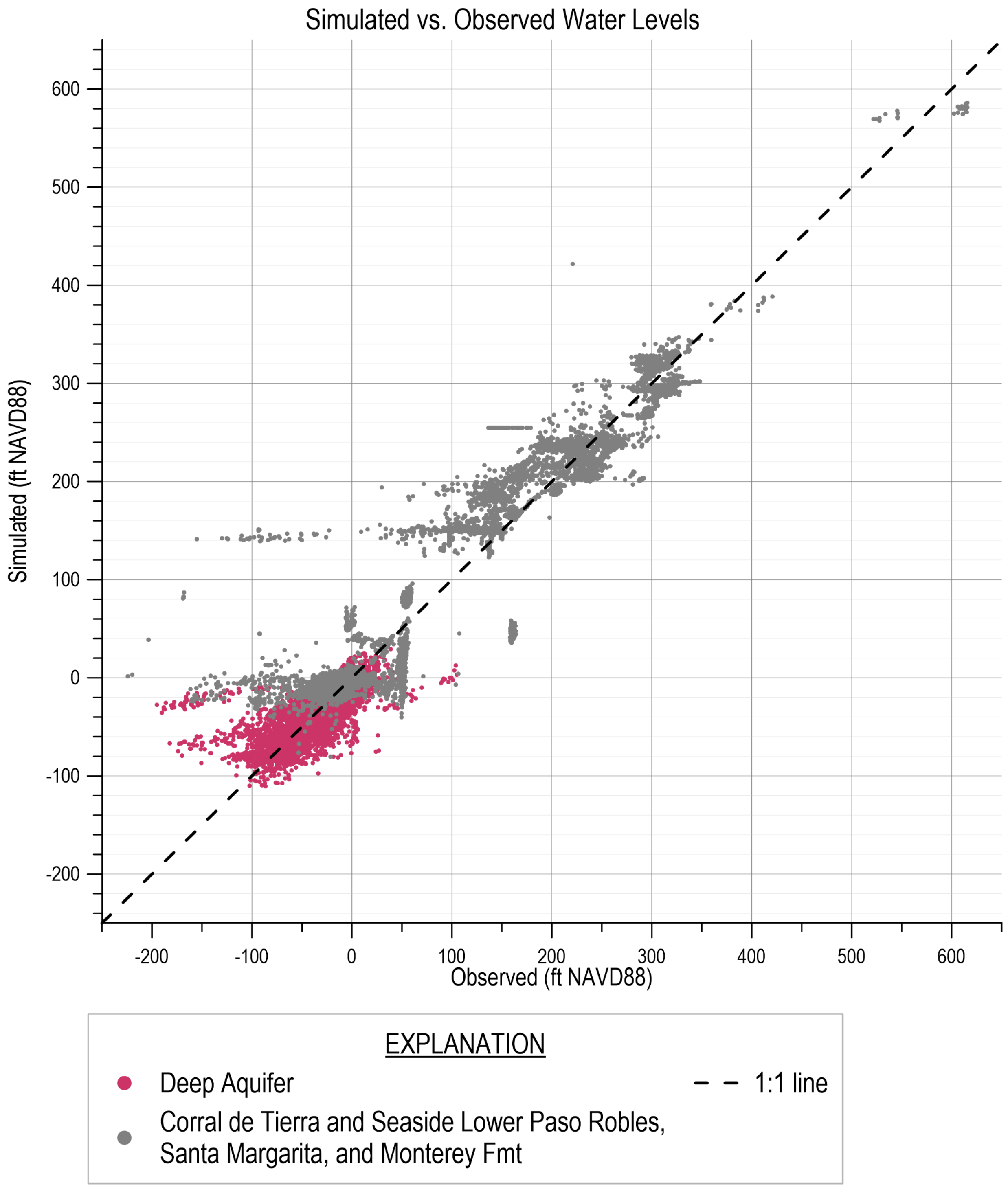

Figure 15. Simulated and Observed Groundwater Level Cross Plot – Deep Aquifers, Corral de Tierra, and Seaside

Figure 15 through Figure 18 show the spatial distribution of mean residuals in the Surficial Sediments, 180-Foot Aquifer, 400-Foot Aquifer, and the Deep Aquifers, respectively. Green bubbles indicate that simulated groundwater levels underestimate measured groundwater levels. Orange bubbles indicate that simulated groundwater levels overestimate measured groundwater levels. The mean residual maps for the Surficial Sediments, 180-Foot Aquifer, and 400-Foot Aquifer are approximately the same as the maps from SWIM v3.

Figure 18 shows the groundwater level mean residual in the Deep Aquifers and equivalent aquifers in the Eastside Subbasin, Corral de Tierra area, and Seaside Subbasin. The mean residuals are the smallest along the coast of the 180/400 Subbasin. As in SWIM v3, the groundwater levels in the Deep Aquifers west of the City of Salinas are generally overestimated, though in SWIM v4 the overestimation is less. Hydrographs in this area indicate that the model underestimates the summer drawdown of groundwater levels, while accurately estimating the winter groundwater levels (see 14S03E19C01 on Figure 20). Also, as in SWIM v3, the groundwater levels in the Eastside subbasin to the east of the City of Salinas tend to be underpredicted. The model tends to underestimate the recovery from the drought in the mid-1990s, and overestimate gradual groundwater level decline that occurs in hydrographs between the early 2000s and 2022.

Figure 18 shows that the SWIM v4 mean groundwater level residuals in Seaside Subbasin and Corral de Tierra area are a mixture of overestimated and underestimated groundwater levels, whereas in SWIM v3 the mean residuals were all overestimated. The mean residuals in Laguna Seca remain overestimated, at a similar magnitude to SWIM v3, though hydrographs indicate that groundwater levels decline at a rate more similar to observed in SWIM v4. (also see Figure 21 and Figure 22).

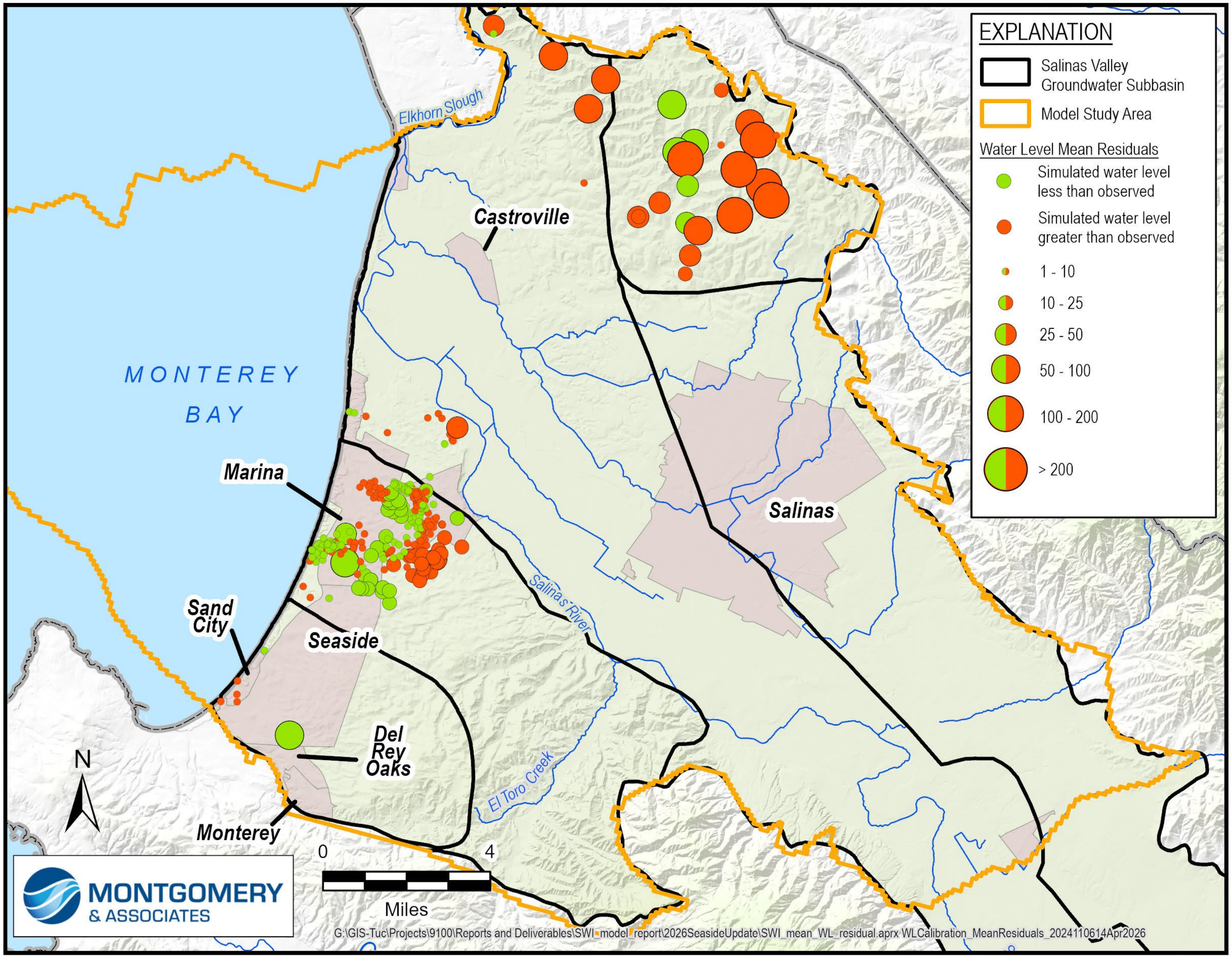

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Figure 16. Mean Residual Groundwater Level Bubble Plot for the Surficial Sediments and Langley Granite

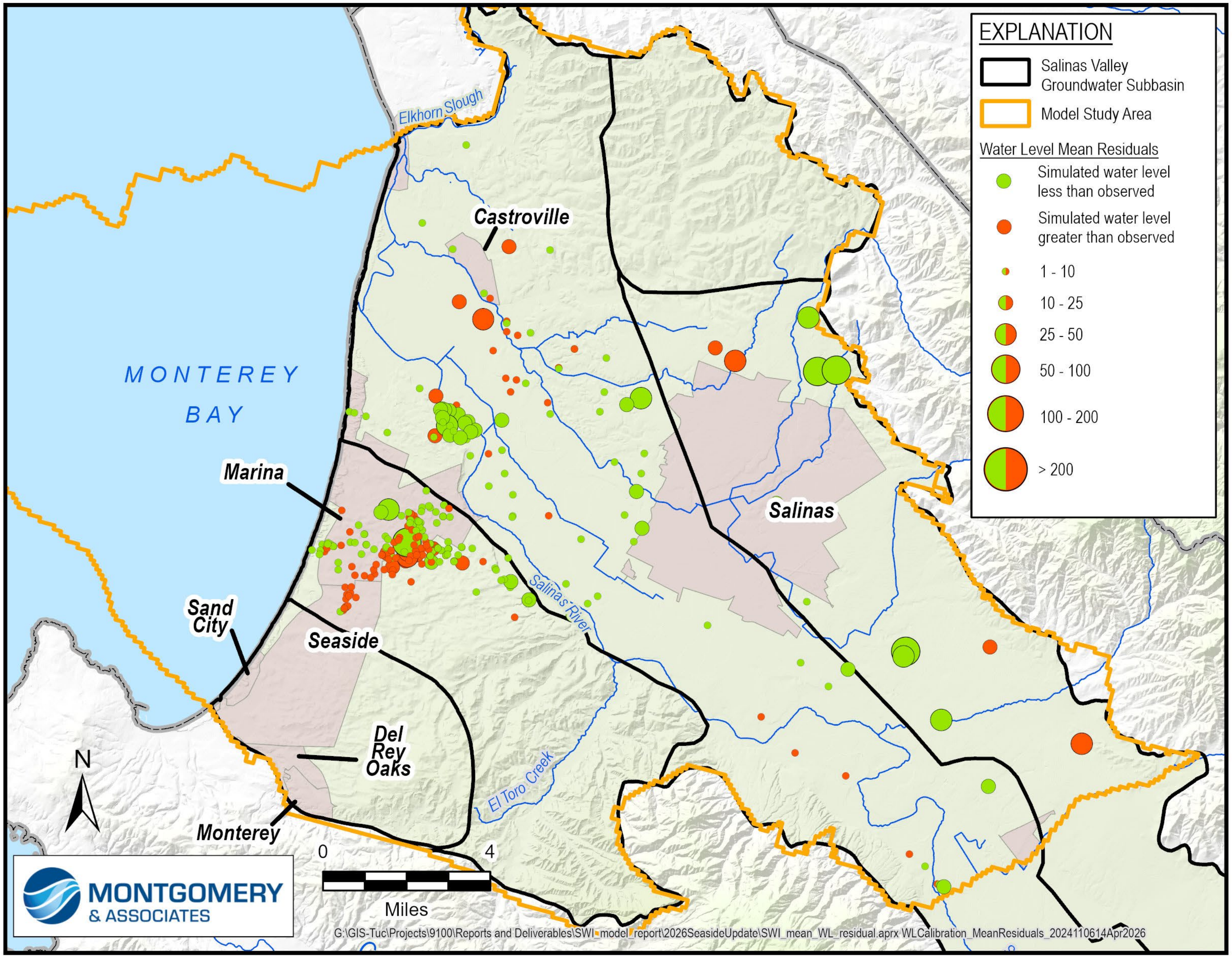


Figure 17. Mean Residual Groundwater Level Bubble Plot for the 180-Foot Aquifer and Equivalent Areas

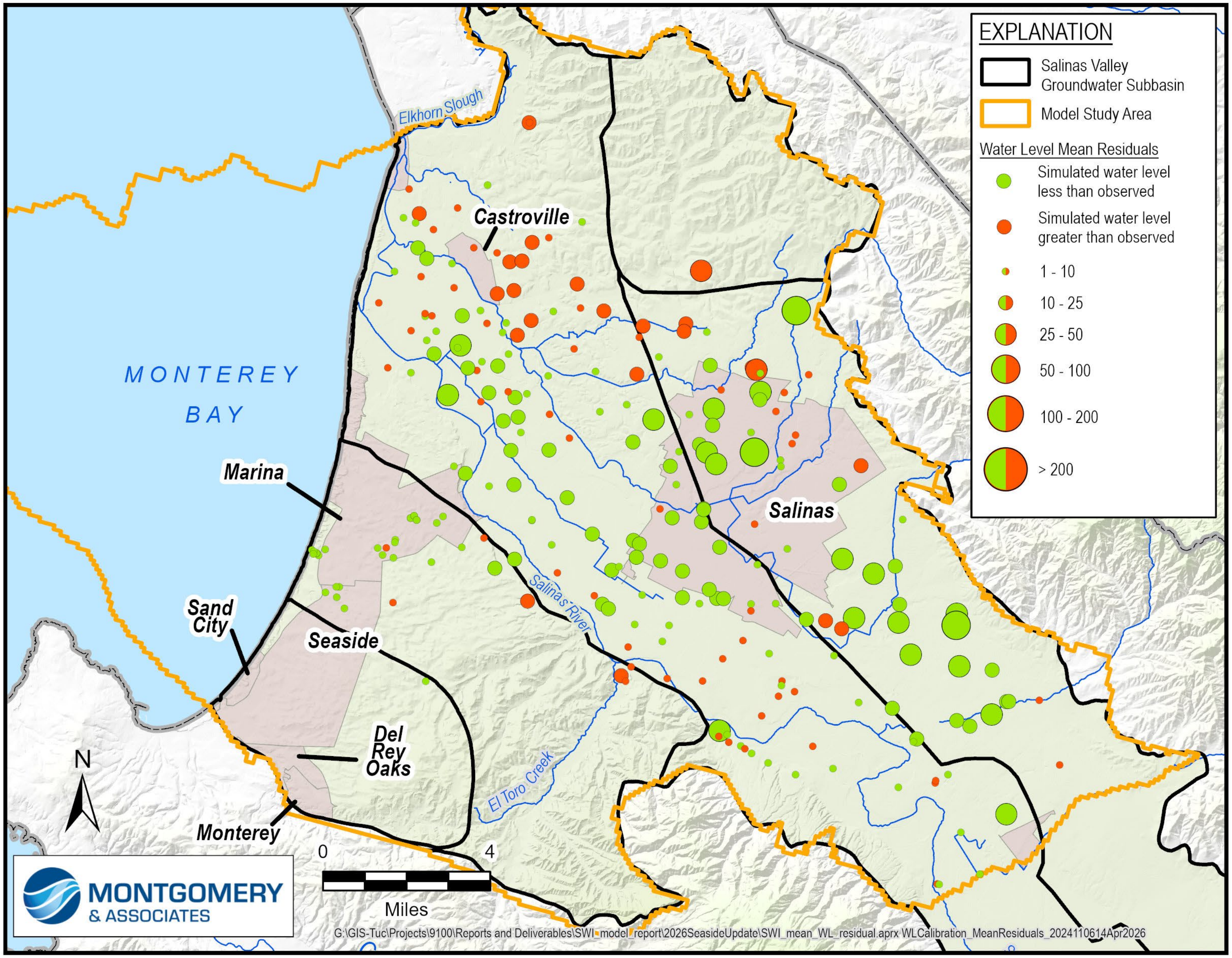


Figure 18. Mean Residual Groundwater Level Bubble Plot for the 400-Foot Aquifer and Equivalent Areas

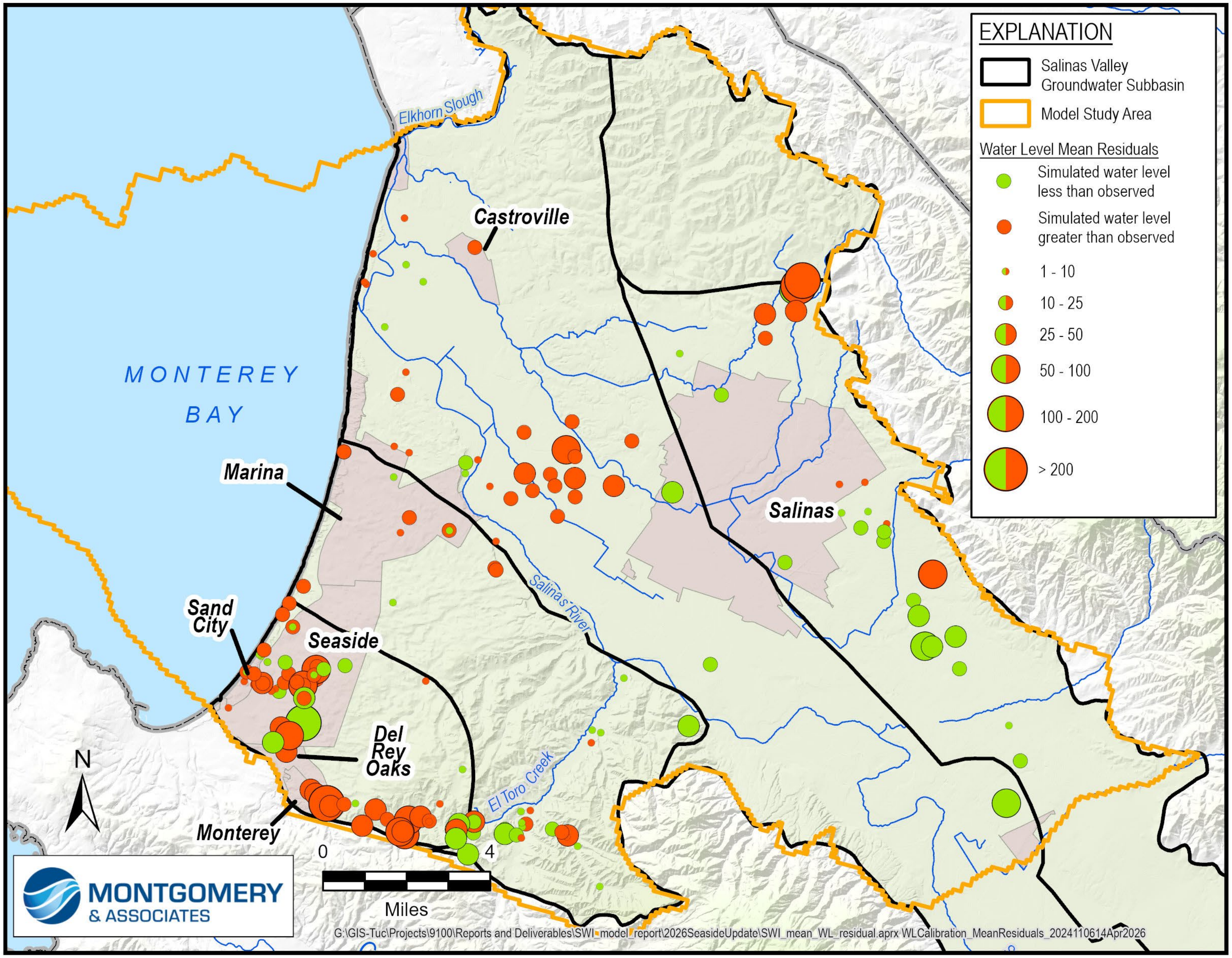


Figure 19. Mean Residual Groundwater Level Bubble Plot for the Deep Aquifer and Equivalent Areas

Figure 20 shows the location of monitoring wells selected for representative hydrographs of the Deep Aquifers, Seaside Subbasin, and Corral de Tierra area. The representative hydrographs are shown on Figure 21 through Figure 23.

Figure 21 shows that simulated groundwater levels in the Deep Aquifers are lower in SWIM v4, which is an improvement over SWIM v3. As in SWIM v3, the groundwater levels along the coast do not decline as rapidly as observed from the mid-2000s onward. This is also true for some coastal Seaside wells in the Santa Margarita Formation, such as MPMWDFO09D. In SWIM v4, seasonal variation in simulated groundwater levels in coastal Seaside Subbasin wells matches the observed trends much better than in SWIM v3.

Figure 22 and Figure 23 show that simulated groundwater levels in the Laguna Seca and Corral de Tierra areas are both lower and decline more rapidly in SWIM v4, which is an improvement over SWIM v3. Simulated groundwater levels are still overestimated in some wells, particularly in the Laguna Seca area.

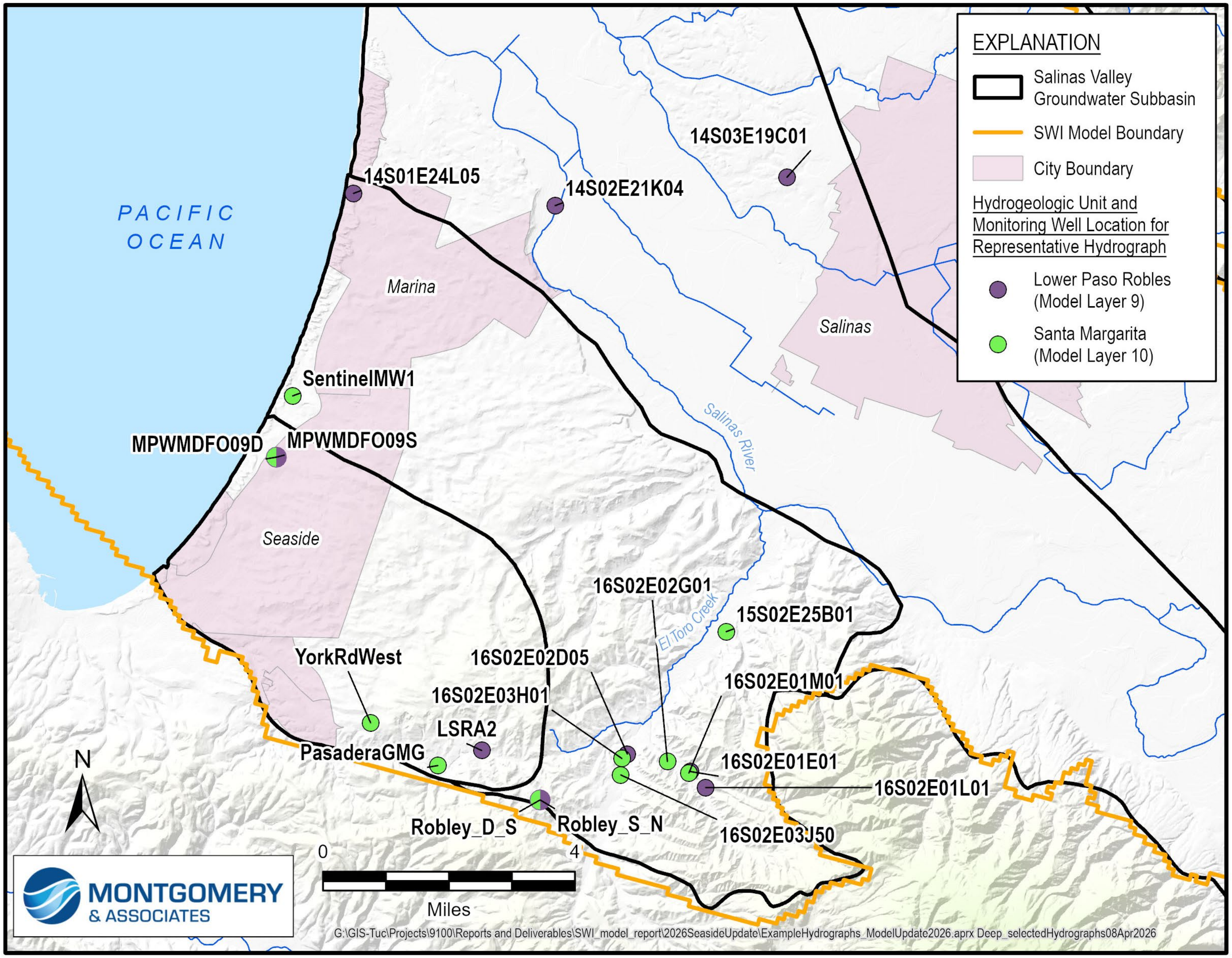
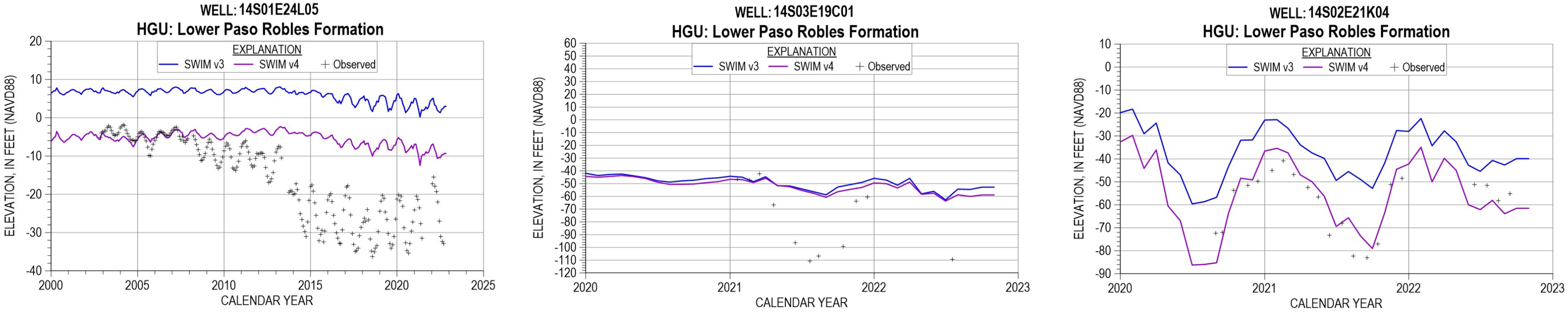


Figure 20. Monitoring Well Locations for Representative Hydrographs in the Deep Aquifers and Equivalent Areas

Deep Aquifers



Coastal Seaside

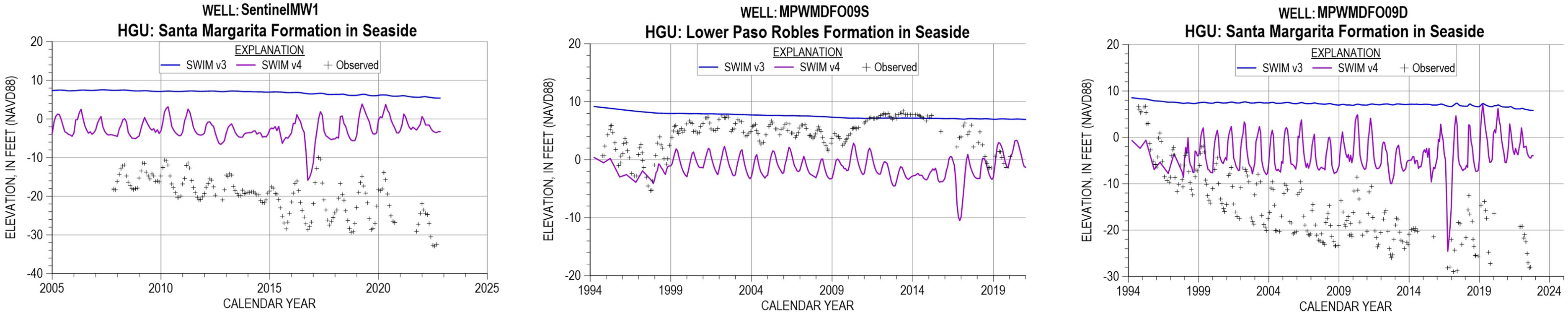
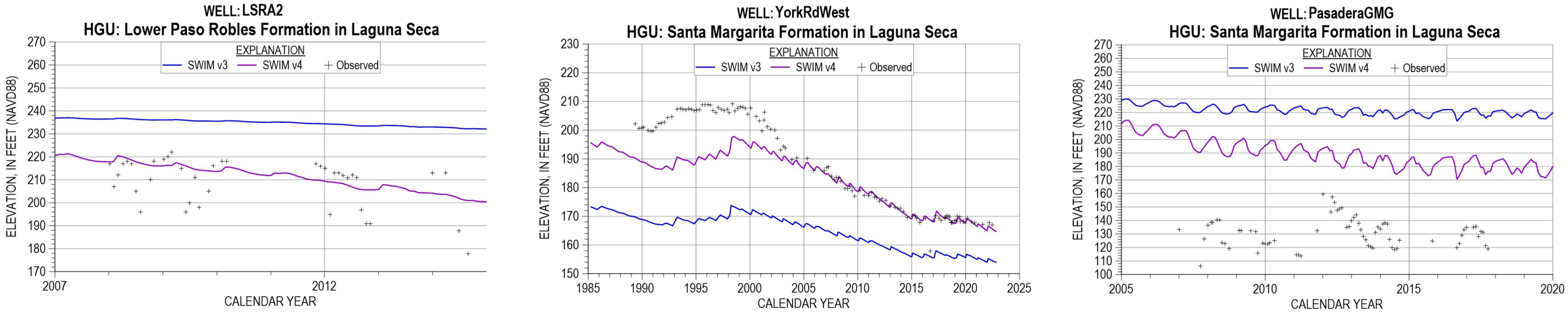


Figure 21. Representative Hydrographs in the Deep Aquifers and Coastal Seaside

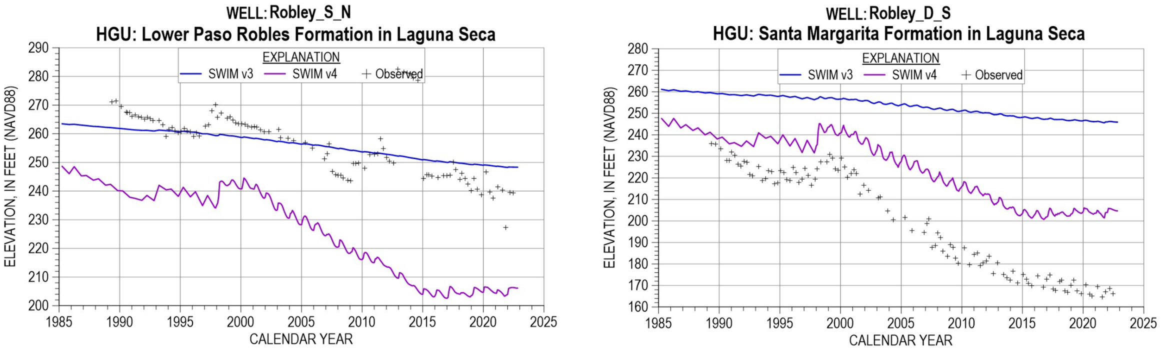
Laguna Seca


WELL: LSRA2
HGU: Lower Paso Robles Formation in Laguna Seca

WELL: YorkRdWest
HGU: Santa Margarita Formation in Laguna Seca

WELL: PasaderaGMG
HGU: Santa Margarita Formation in Laguna Seca

Corral de Tierra


WELL: Robley_S_N
HGU: Lower Paso Robles Formation in Laguna Seca

WELL: Robley_D_S
HGU: Santa Margarita Formation in Laguna Seca

Figure 22. Representative Hydrographs in Laguna Seca and Corral de Tierra Areas

Corral de Tierra

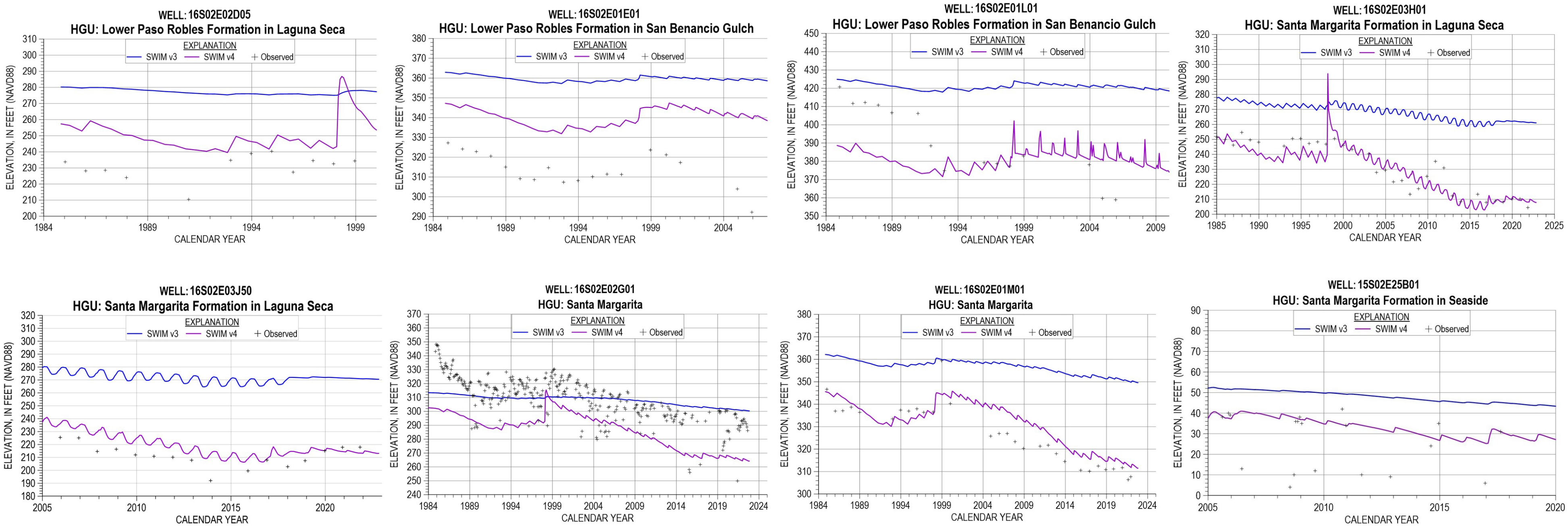


Figure 23. Representative Hydrographs in Corral de Tierra Area

Chloride Concentration Calibration

The primary metric of the chloride calibration is the simulated extent of the 500 mg/L chloride contour line in the 180-Foot and 400-Foot Aquifers. The extent of the simulated 500 mg/L chloride contour was compared to the 500 mg/L chloride contours produced by MCWRA. The inland progression of the simulated 500 mg/L contours are compared to the MCWRA contours on Figure 23 and Figure 24. The crosshatched areas on these 2 figures represent the area of intrusion estimated by MCWRA. The contour lines on these 2 figures represent the simulated 500 mg/L chloride concentration fronts. The simulated chloride concentration fronts are color-coded to match the equivalent MCWRA crosshatched area. The simulated distribution of chloride concentrations in the 180-Foot Aquifer, 400-Foot Aquifer, and Deep Aquifers at the end of the simulation in 2022 is shown on Figure 25, Figure 26, and Figure 27, respectively. 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 9 are selected to represent the Deep Aquifers because most coastal Deep Aquifer wells in the 180/400 Subbasin are screened in this model layer.

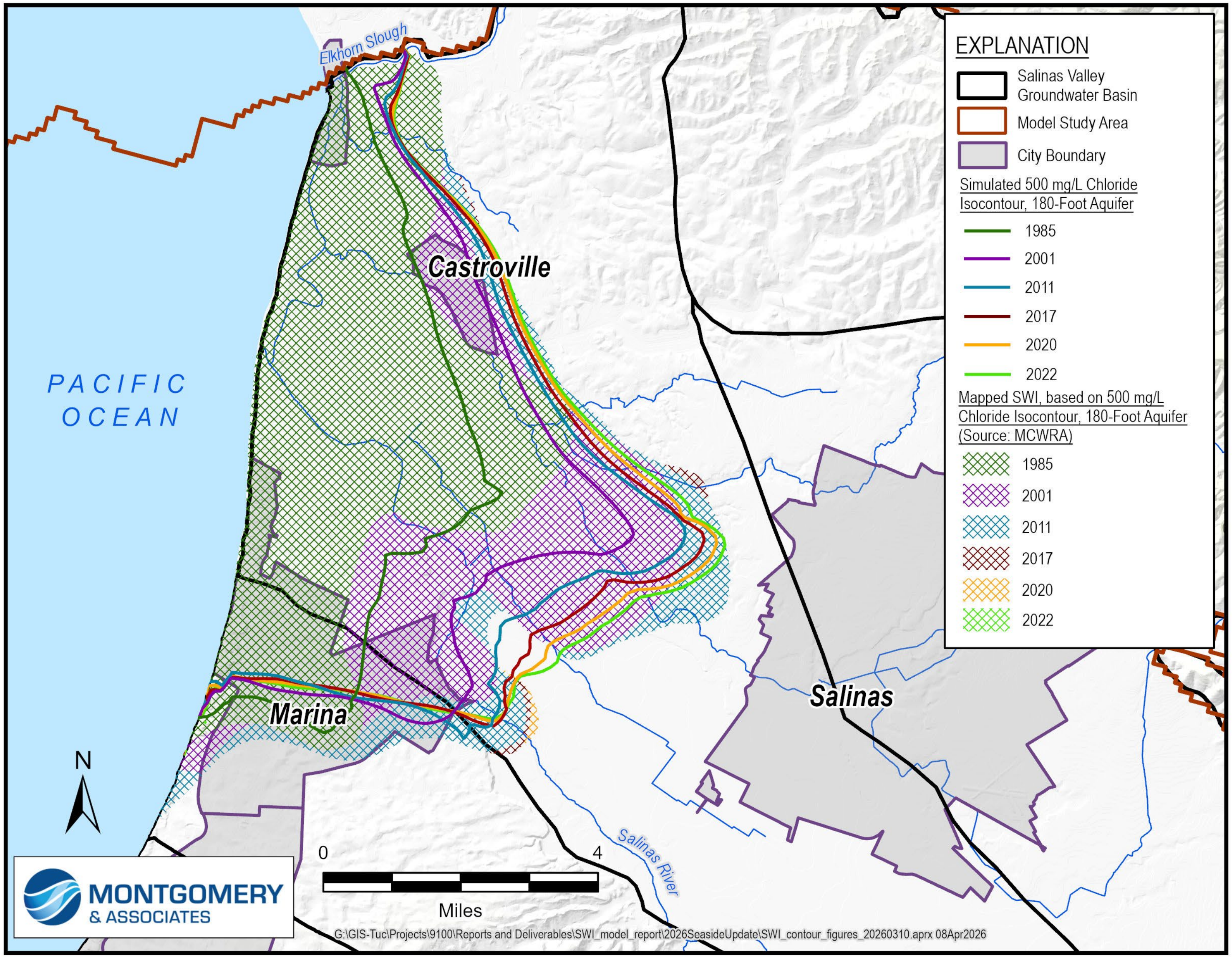


Figure 24. 180-Foot Aquifer Simulated and Observed 500 mg/L Chloride Concentration Contours in 1985, 2001, 2011, 2017, 2020, and 2022

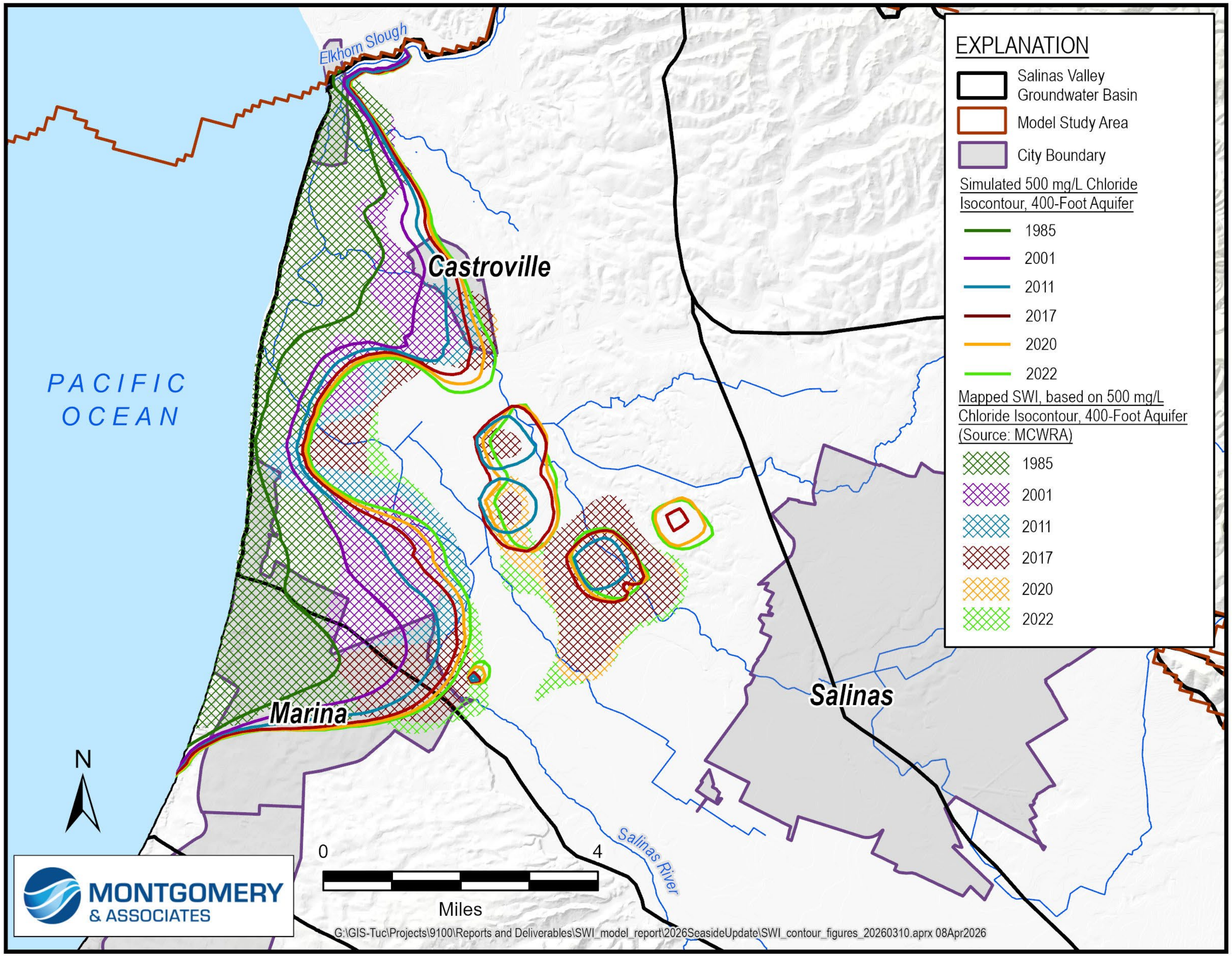


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Figure 25. 400-Foot Aquifer Simulated and Observed 500 mg/L Chloride Concentration Contours in 1985, 2001, 2011, 2017, 2020, and 2022

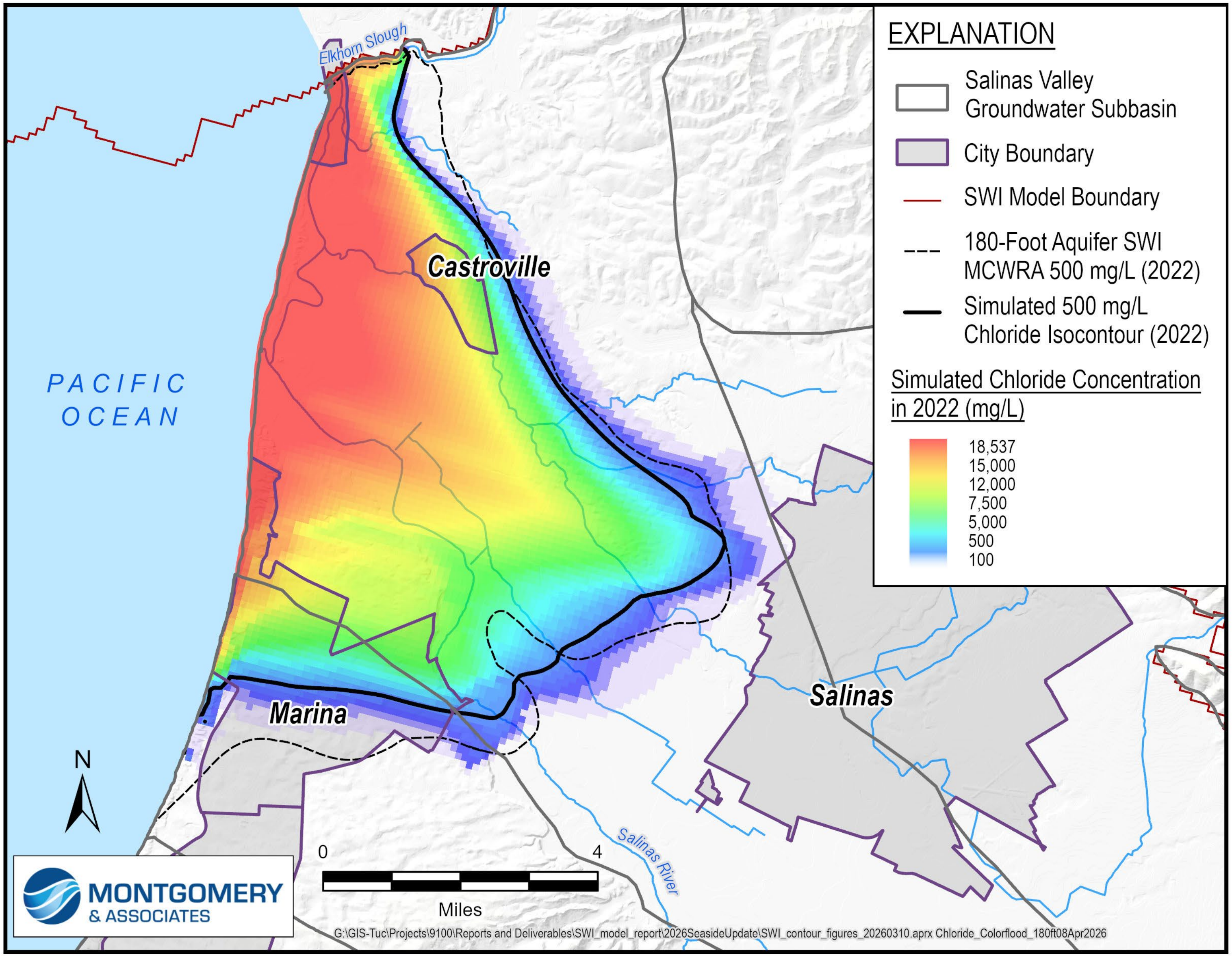


Figure 26. 180-Foot Aquifer Simulated Chloride Concentration in 2022

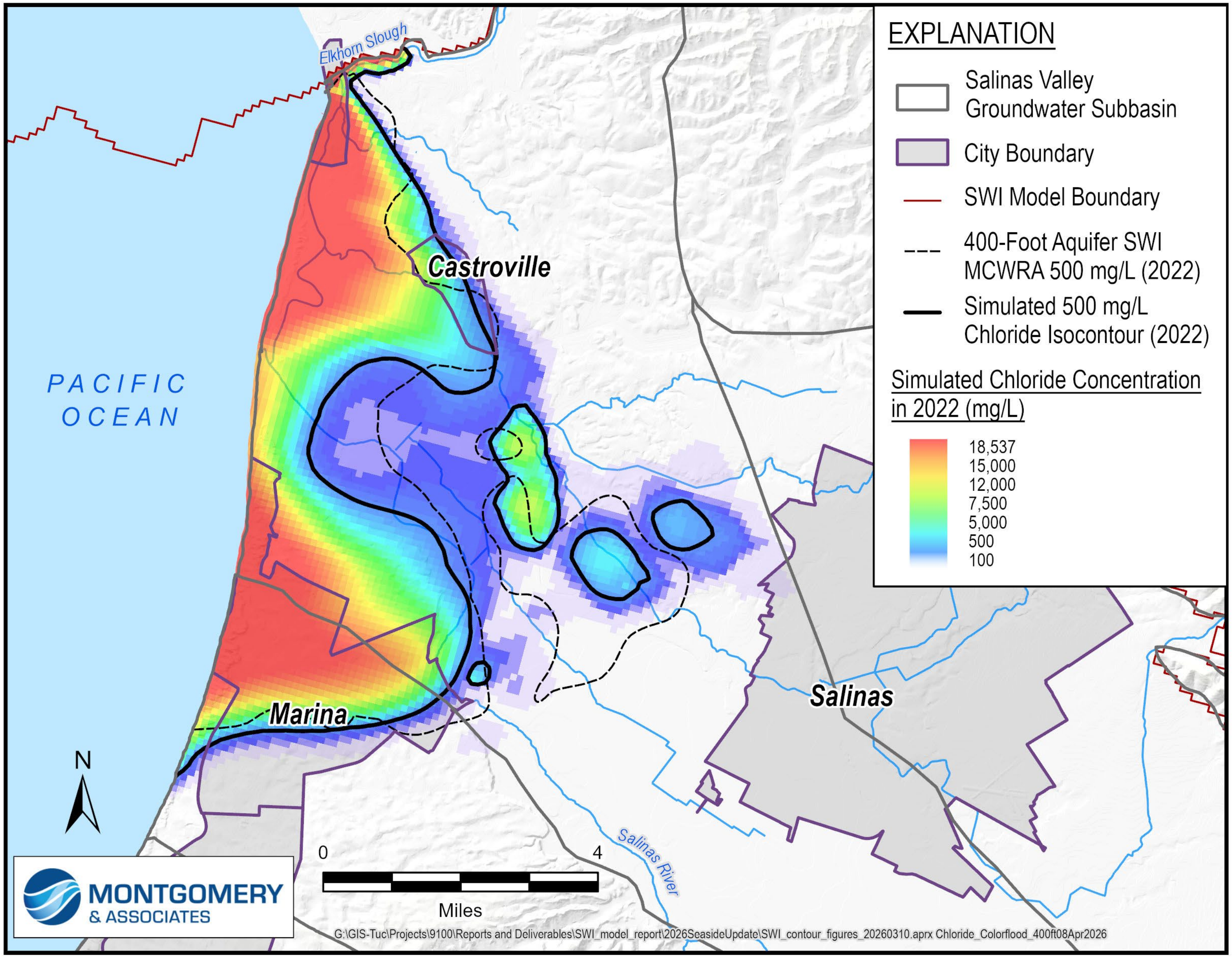


Figure 27. 400-Foot Aquifer Simulated Chloride Concentration in 2022

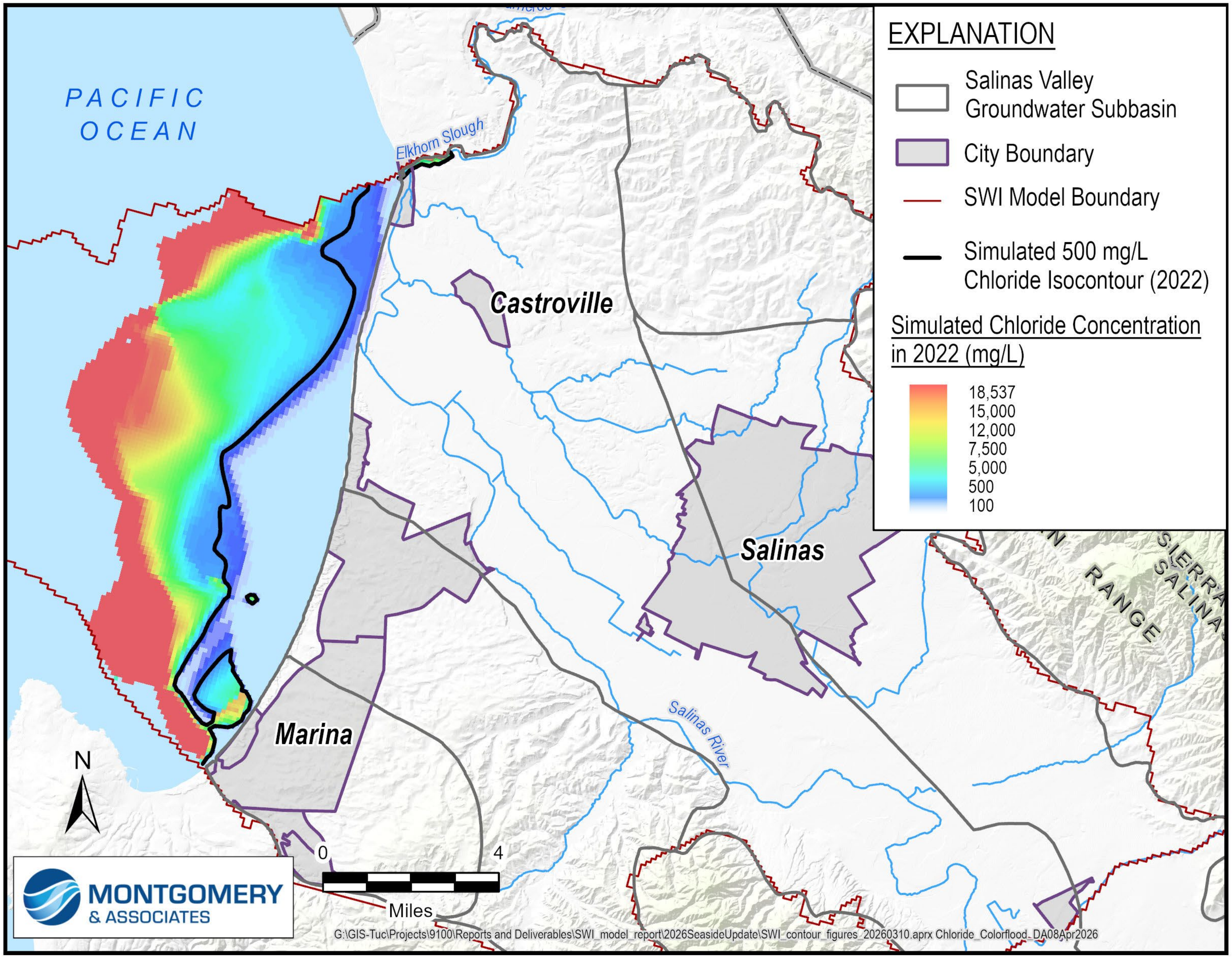


Figure 28. Deep Aquifers Simulated Chloride Concentration in 2022

The calibration of the seawater intrusion front's progression in SWIM v4 is similar to SWIM v3 in extent and rate in both the 180-Foot Aquifer and the 400-Foot Aquifer. Figure 23 shows that in the 180-Foot Aquifer, the simulated extent of seawater intrusion matches the MCWRA contours better near Castroville in SWIM v4. Additionally, the southern lobe of seawater intrusion observed in 1985 is better simulated in SWIM v4 because the Fort Ord estimated pumping was assigned to the lower 180-Foot Aquifer. In 2001, the northern lobe of the simulated seawater plume is narrower than the observed in SWIM v4, though it is approximately the same as SWIM v3 by 2011. The southern lobe of the seawater intrusion plume in the 180-Foot Aquifer is less clearly defined and remains slightly underestimated in SWIM v4, though the overall extent is approximately the same in the rest of the seawater intruded area.

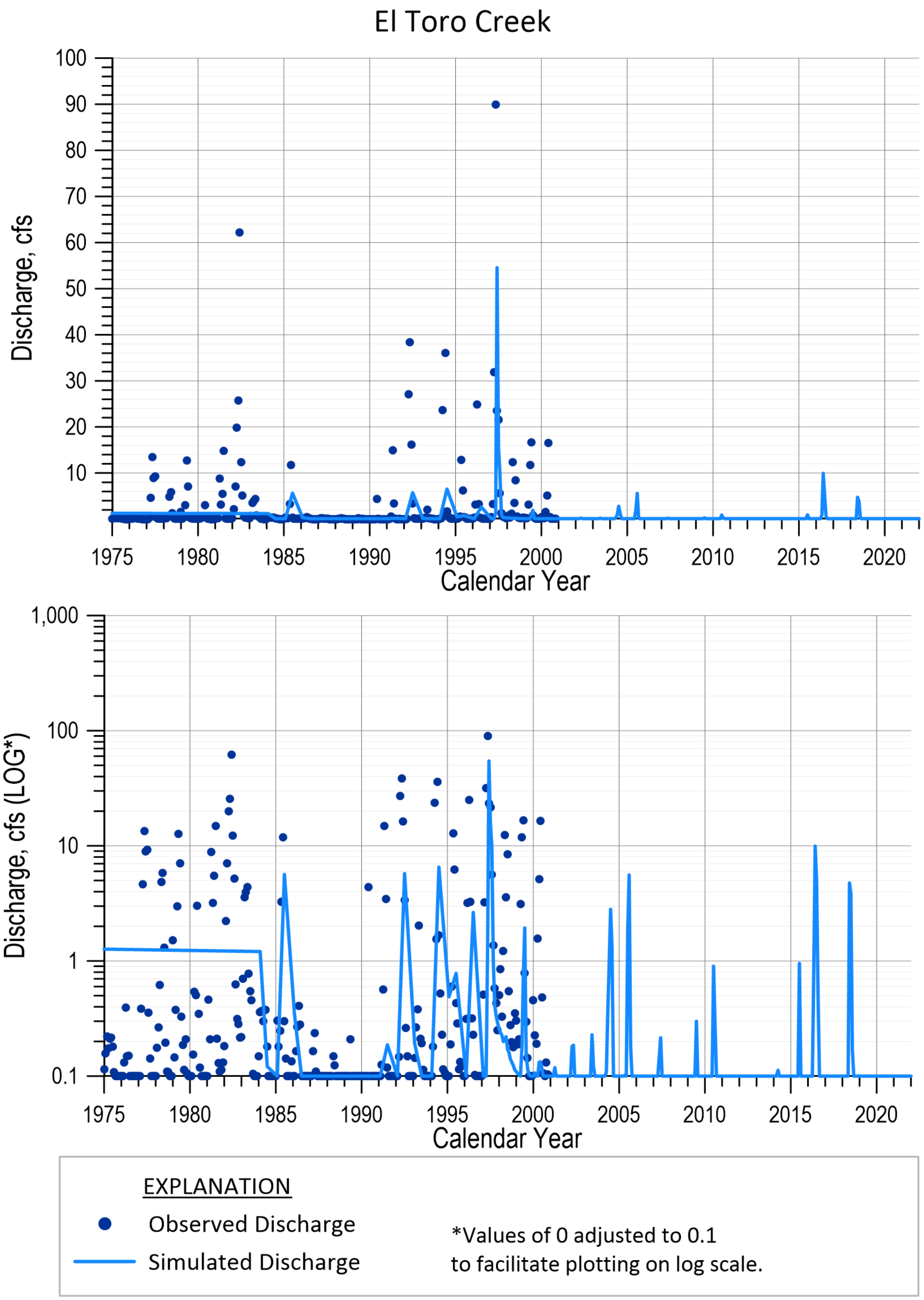
Figure 24 shows that in the 400-Foot Aquifer, the simulated extent of the seawater intrusion also matches the MCWRA contours better near Castroville in SWIM v4. There is slightly more seawater intrusion by 1985 in SWIM v4, which also better matches the MCWRA contours. The extent of seawater intrusion in Marina in the 400-Foot Aquifer is slightly farther south, but still generally corresponds to the MCWRA contours. In SWIM v4, the seawater islands in the 400-Foot Aquifer are separated from the main plume in the 400-Foot Aquifer, which corresponds to mapping by MCWRA. However, the simulated extent of the largest seawater island is still smaller than mapped by MCWRA.

The distribution of chloride mass in the 180-Foot Aquifer and 400-Foot Aquifer shown on Figure 25 and Figure 26 is similar in SWIM v4 to SWIM v3. The most notable difference is that the simulated chloride concentrations are higher in Marina and near Castroville in the 400-Foot Aquifer.

Figure 27 shows the offshore seawater/freshwater interface simulated below the ocean in the units connected to the Deep Aquifers. Seawater intrusion has not been observed in Deep Aquifers wells and is also not simulated in SWIM v4.

Surface Water Flow Calibration

Figure 28 shows the updated simulated and observed streamflow measurements at the gage in El Toro Creek, plotted on both linear and logarithmic scales. The hydrograph for El Toro Creek shows that simulated streamflow drops below 0.1 cubic feet per second, which matches the observed trends. This is an improvement over SWIM v3, which showed extended periods of baseflow due to elevated simulated groundwater levels near the creek. The simulated streamflow measurements at other gage locations in the model area are similar in SWIM v4.



*Values of 0 adjusted to 0.1
to facilitate plotting on log scale.

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Figure 29. Simulated and Measured Stream Flow in El Toro Creek

Water Budget

The average annual water budget for SWIM v3 between WY 1985-2022 is summarized in Table 4.

Table 4. Updated Water Budget Summary

Inflows		SWIM v3 WY 1985-2022 Average AF/yr[a]	SWIM v4 WY 1985-2022 Average AF/yr
Recharge		85,600	83,700
Net Stream Leakage to Groundwater		35,900	40,200
Subsurface Inflow	Valley Upgradient Inflow near Chualar	22,900	21,800
	Seawater Intrusion	14,700	13,700
Injection	ASR - Seaside	500	500
Outflows			
Pumping		168,300	170,700
Groundwater Evapotranspiration	Riparian	16,300	11,800
Subsurface Outflow	Valley Outflow to Ocean + Pajaro	100	900
Net Change in Groundwater Storage		-24,200	-22,800

[a]AF/yr = acre-feet per year

The updated recharge is slightly less in SWIM v4 than in SWIM v3 due to reduction in recharge rates in Seaside Subbasin and the San Benancio Gulch portion of the Monterey Subbasin. The recharge in the other subbasins was unchanged. The net stream leakage to groundwater is slightly higher in SWIM v4 than in SWIM v3 as a result of recalibration of the hydraulic conductivities in the 180/400 Subbasin. Net stream leakage was slightly lower in the Corral de Tierra area due to modification of streambed leakance parameters. Subsurface inflows from the upgradient portions of the Salinas Valley near Chualar and the ocean are slightly lower in SWIM v4 than in SWIM v3 because the groundwater levels are generally higher in the 180-Foot and 400-Foot Aquifers and the southern portion of the Eastside Subbasin. However, with SWIM v4, the net direction of flow with the ocean in the Seaside Subbasin switched from net discharge to net intrusion (at less than 1,000 acre-feet per year). This is due to lower simulated groundwater levels along the coast in the Deep Aquifer and equivalent units in the Seaside Subbasin in SWIM v4. ASR injection in the Seaside Subbasin is unchanged from the previous model and is specified from historical records.

Total pumping is slightly higher in SWIM v4 due to less automatic flow reductions. Automatic flow reductions occur when the simulated groundwater level in a well falls below the bottom of the screen and cannot support the extraction rate. Lower automatic flow reductions in SWIM v4 are a result of higher groundwater levels in the areas noted above, and modified aquifer hydraulic properties.

Total riparian ET is slightly lower in SWIM v4 than in SWIM v3. This results from modifications to the aquifer hydraulic properties adjacent to and underlying the Salinas River which results in lower groundwater levels in model cells near the river, and thus less simulated ET in these shallow groundwater areas.

CONCLUSION

M&A updated the SWIM in coordination with the MCWD and Seaside Watermaster modeling teams. Revisions generally focused on improving the model calibration in Seaside and Monterey Subbasins. Key model updates included the following:

- Updating the model's hydrogeologic parameter zonation in the Seaside Subbasin and Corral de Tierra area based on the existing Seaside Watermaster's model
- Adjusting recharge assumptions in the Seaside Subbasin to conform with the Seaside Watermaster's model, and in the Corral de Tierra area
- Updating well locations, screen intervals, and pumping data based on feedback from MCWD and Seaside Watermaster
- Modifying the general head boundary condition representing the offshore aquifer/ocean interface
- Modifying streambed leakance properties in the Seaside Subbasin and Corral de Tierra area
- Recalibrating hydraulic conductivity and storage parameters

The model updates result in an improved groundwater level calibration model-wide, with the most significant improvements in the Seaside and Monterey Subbasins. Groundwater levels were calibrated using a groundwater level data set that was reviewed by the MCWD and Seaside Watermaster modelers. The chloride calibration was verified by comparing the simulated 500 mg/L chloride contours to the MCWRA maps between 1985 and 2022. The revised model reasonably simulates seawater intrusion in the 180/400 and Monterey Subbasins. The calibration of seawater intrusion in the 180-Foot and 400-Foot Aquifers is about the same in SWIM v4 as SWIM v3, and improved in the Deep Aquifers.

NEXT STEPS

No model, regardless of its complexity, can fully replicate the intricacies of real-world systems. The SWIM is a mathematical approximation of real-world processes relying on input data, assumptions, and simplifications. These factors are necessary to make the problem tractable; however, they introduce a degree of uncertainty and limit the model's predictive accuracy. The model captures regional groundwater system behavior; as expected for a regional model, calibration is stronger at broader spatial scales than at individual wells.

Model refinements benefited from close collaboration with Seaside Watermaster and MCWD modelers and incorporation of local hydrogeologic expertise. Despite these combined efforts, some simulated groundwater levels do not adequately match measured data, in particular, the underrepresentation of recent declines in several coastal wells within the Seaside and Monterey Subbasins, reflecting the inherent complexity of the geologic setting. Some groundwater level calibration inaccuracies in the Seaside Subbasin may reflect the complex faulting and folding of the Lower Paso Robles and Santa Margarita Formations, and uncertainty in offshore geologic controls. Furthermore, there may be a discrepancy between the model layering and the local understanding of the depths of the Santa Margarita Formation at places. Additional refinement of the Santa Margarita–Lower Paso Robles stratigraphic separation and layer discretization (e.g., further subdivision of deeper model layers) may help better resolve observed local water-level trends in future model updates. Simulated groundwater levels in several coastal Seaside and Monterey Subbasin Deep Aquifer wells are below sea level, but at a lesser magnitude than recent observations. Future studies could assess the representation of local groundwater gradients controlling seawater intrusion in the Deep Aquifers and equivalent units.

This model update prioritized refinements in Seaside and Monterey Subbasins, while calibration in the Langley Subbasin remains a challenge and represents an appropriate focus for future model development. In addition, the SVIHM will require a subsequent update to ensure consistency with the revised parameterization and recharge assumptions incorporated in SWIM v4.

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