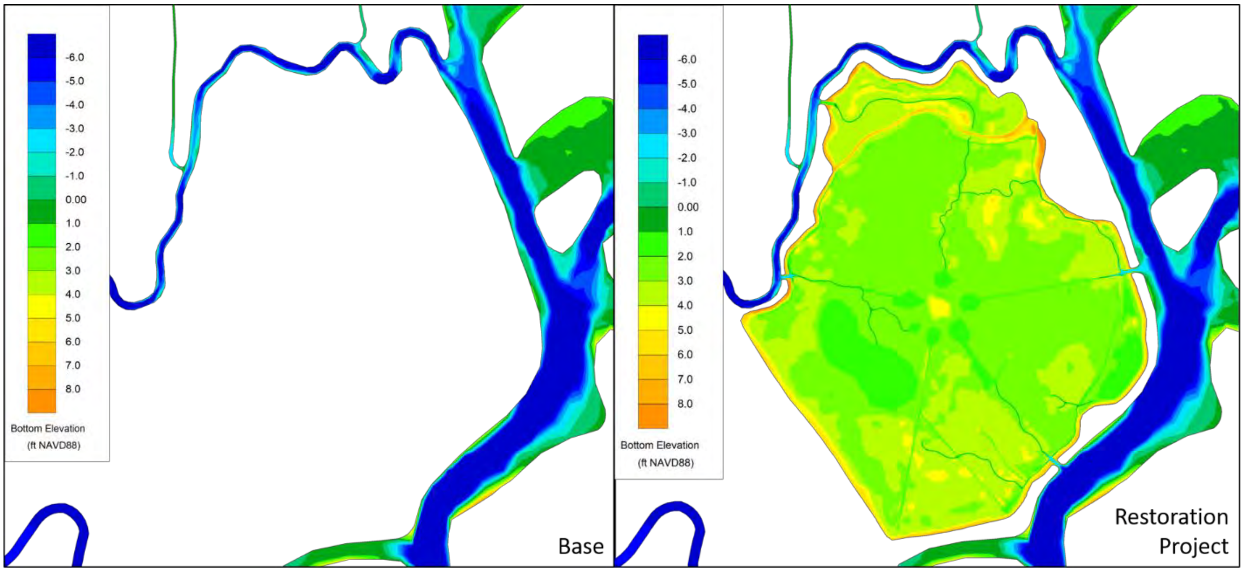
Modeling of Local and Regional Effects of the Wings Landing Tidal Marsh Restoration, Suisun Marsh, California



TECHNICAL MEMORANDUM

February 2018

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EXECUTIVE SUMMARY

The RMA Bay-Delta numerical model for flow and water quality was applied to evaluate local and regional effects of the proposed 270-acre Wings Landing tidal marsh restoration project.

The proposed restoration includes four exterior breaches to connect the restoration site to the surrounding channels of Suisun Slough and Peytonia Slough. A single interior breach is proposed through the Brood Pond levee. Enhanced and newly created channels extend from the breaches into the site. Existing channels adjacent to the south and southwestern exterior levees are filled to reduce risk of levee erosion.

The model was run for the dry/critically dry period of January through December of 2013 because modeling critically dry conditions would tend to accentuate the effects of the restoration project.

Modeled hydrodynamic effects included increased velocities and tidal prism, and slightly reduced tidal range in local channels. Within the restoration site, modeled velocities at breaches and in connecting channels can exceed 5 ft/s.

A comparison between Base and Wings Landing Restoration channel velocities shows that modeled velocities increase by 2 ft/s or more in Suisun Slough near the breaches. Modeled velocities in Peytonia Slough increase by around 0.5 ft/s.

Modeling indicates that Restoration results in a small reduction in tidal range in the channels in the vicinity of Wings Landing, reducing the average higher high tide by 0.03 ft and increasing the lower low tide by 0.01 ft in Suisun Slough and reducing the average higher high tide by 0.03 ft and increasing the lower low tide by 0.04 ft in Peytonia Slough.

Higher high tide within the Restoration site matches the height of higher high tide in adjacent Suisun Slough, while lower low tide is approximately 2 ft higher inside Wings Landing compared with Suisun Slough, due to higher Wings Landing marsh plain elevation and incomplete draining of the Restoration site.

Modeling results indicate that the Wings Landing Restoration results in increases in tidal prism in the local channels. On average, tidal prism is increased by 24% in Suisun Slough and by 94% in Peytonia Slough for the modeled period.

Particle track modeling results indicate that the average particle exposure time to Wings Landing was 7.6 days, with 21% of the particles exiting the restoration site within one day. The average time for particles to travel from Wings Landing out of Suisun Marsh was 10.8 days.

Residence time simulations indicate lower residence times occurring near the breaches to Suisun Slough, with highest residence times near the center of the site. Average residence time in Wings Landing during July 2013 was approximately 3 days.

Modeled salinity effects include small EC reductions (less than 1%) in the central and south Delta, and EC increases of 2-4% in northwestern Suisun Marsh.

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INTRODUCTION

This report provides a detailed description of numerical modeling for the proposed Wings Landing tidal restoration project. Potential local hydrodynamic changes and local and regional salinity effects resulting from the restoration are evaluated. Electrical conductivity (µmhos/cm), or EC, was modeled as a surrogate for salinity. Residence times within the Restoration site are assessed and particle track modeling was performed to analyze particle exposure time in the Restoration site and particle travel time out of Suisun Marsh. Details are provided describing model boundary condition data sources and the application of boundary conditions in the model.

Background

Tidal habitat restoration is being proposed for Wings Landing, which is an approximately 270-acre site in Suisun Marsh that currently operates as a managed wetland (duck club).

Objectives

The objective of this study was to use model simulations to evaluate expected stage and tidal range at the restoration site, effects on local velocities and tidal range, local and regional salinity effects resulting from the restoration, and residence time and exposure time within the restoration site.

RMA BAY-DELTA MODEL

The RMA Bay-Delta model has been used for this analysis. The RMA Bay-Delta model is a well-established tool for analysis of hydrodynamic and water quality impacts of proposed projects in the San Francisco Bay, Suisun Marsh and the Sacramento-San Joaquin Delta.

The RMA Bay-Delta Model was chosen for this study due to its ability to provide sufficiently accurate simulation of Bay-Delta-wide hydrodynamics and water quality transport and its ability to perform predictive simulations to evaluate the impacts of proposed tidal marsh restoration. The RMA Bay-Delta Model utilizes the RMA2 hydrodynamics and RMA11 water quality transport finite element computational engines. The finite element model formulation allows use of an unstructured computation mesh where resolution can be increased locally to represent the topographic details of a restoration site. RMA2 and RMA11 engines support combining two-dimensional depth-averaged (2-D) computational elements and one-dimensional cross-sectionally averaged (1-D) elements in a single mesh. In the RMA Bay-Delta Model all large channels, embayments, and tidal marsh restoration areas are represented in 2-D. The model has been shown to provide accurate simulation of tidal exchange through constrictions, such as levee breaches into a restoration site, based on the breach geometry, site topography, and friction parameter (Manning's n value) estimated within typical accepted range.

The RMA Bay-Delta Model does not directly simulate the effects of stratified flow, which would require application of a three-dimensional (3D) model. The effects of stratification are approximately incorporated into the model through calibration exercises where mixing coefficients are adjusted to best represent the observed salinity field for a historic period, or to best represent the simulated salinity field from a 3D model simulation for a proposed condition.

Model coefficients have been added to RMA11 that increase dispersion with higher horizontal salinity gradients to account for strengthened gravitational circulation. Dispersion associated with gravitation circulation is based on a horizontal Richardson number. The dispersion computations rely on the horizontal density gradient, depth of water and tidally averaged shear velocity, following the method in Gross et al. (2009). The Richardson number is scaled by calibrated linear and power coefficients to provide an extra dispersion term in RMA11.

Geometric Extents

RMA's San Francisco Bay - Sacramento–San Joaquin Delta network was developed using an in-house GIS-based graphical user interface program (RMA, 2003). The program allows for development of the finite element mesh over layers of bathymetry points and bathymetry grids, GIS shapefiles and aerial images.

The RMA Bay-Delta model, shown in Figure 1, extends from the Golden Gate at the west end to the Sacramento River at the confluence with the American River, and to the San Joaquin River near Vernalis. A two-dimensional depth-averaged approximation is used to represent the San Francisco Bay, Suisun Bay region and the other open water, major channels of the Delta, and upper Suisun Slough and Nurse Slough in Suisun Marsh. The other Delta and Suisun Marsh channels and tributary streams are represented using a one-dimensional cross-sectionally averaged approximation.

For the purpose of this project, grid enhancements were made in Suisun Marsh in the vicinity of the Wings Landing restoration project site. The 2-D grid was refined in Suisun Slough near the Restoration site. 2-D grid was extended into Peytonia Slough past the Restoration site. Wings Landing is represented fully in 2-D.

A detail view of the Wings Landing restoration area, is shown in Figure 2. The development of the restoration project grid is discussed further in the Wings Landing Restoration Project Configuration section.

Bay-Delta Bathymetry

Bay-Delta model bathymetry is shown in Figure 1 for the Base case. A comparison of Base and Restoration case model bathymetry in the project region is shown in Figure 2. For all areas of the RMA2 model grid, the most current, best quality bathymetric data were used to set grid elevations.

Elevation data used to set model grid elevations within the Wings Landing site were collected by USGS and ESA in 2016 and provided to RMA by Natural Resources Group.

Bay-Delta geometry has been updated with recent data collected and posted on the Department of Water Resources (DWR) DEM website:
http://baydeltaoffice.water.ca.gov/modeling/deltamodeling/modelingdata/DEM.cfm

And DWR's Delta Bathymetry Catalog:
https://gis.water.ca.gov/app/bathymetry/

Bathymetry in the Cache Slough area were set using bathymetric data collected in 2012 by DWR (DWR, 2012) and Environmental Data Solutions (EDS, 2013), in 2009 by cbec (cbec, 2011) and in 1997 and 2005 by USACE data (USACE, 2005 and 2002). Coarsely space single beam transects from the Central Valley Floodplain Evaluation and Delineation (CVFED) (cbec, 2011) were used to set model elevations in various locations in the northern Delta and Sacramento River.

For all other areas, bottom elevations and the extent of mudflats were based on bathymetry data collected by NOAA, DWR, USACE and USGS. These datasets have been compiled by DWR and can be downloaded from DWR's Cross Section Development Program (CSDP) website at http://baydeltaoffice.water.ca.gov/modeling/deltamodeling/models/csdp/csdp.cfm. Topography data from DWR's Delta LiDAR survey (2007) was used where elevation data for channel banks, tidal marsh and flood plains was not available from the other sources.

A detailed description of model refinements in the vicinity of the Restoration project is discussed in the Wings Landing Restoration Project Configuration section.

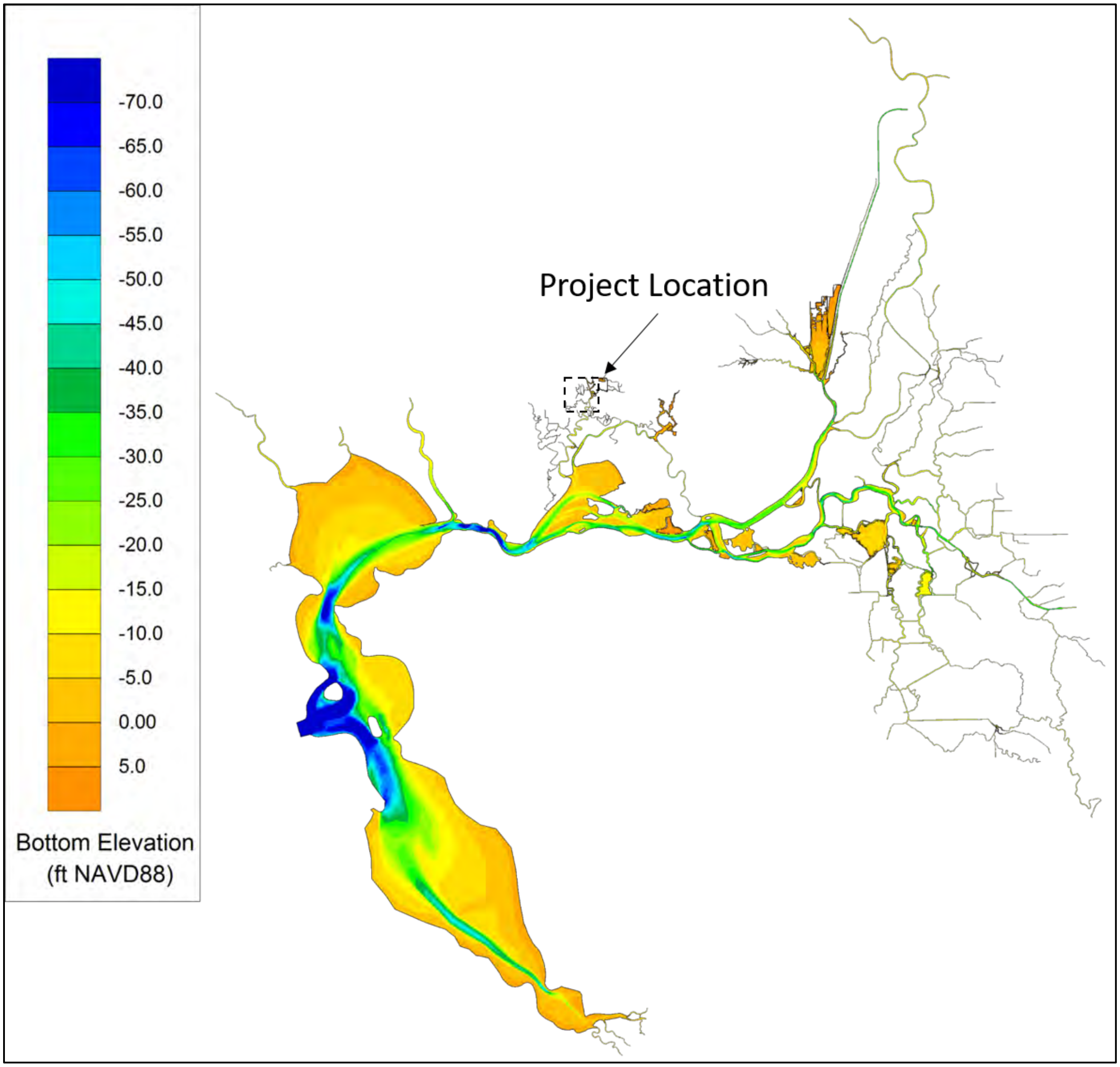

Figure 1 Base case model bathymetry.

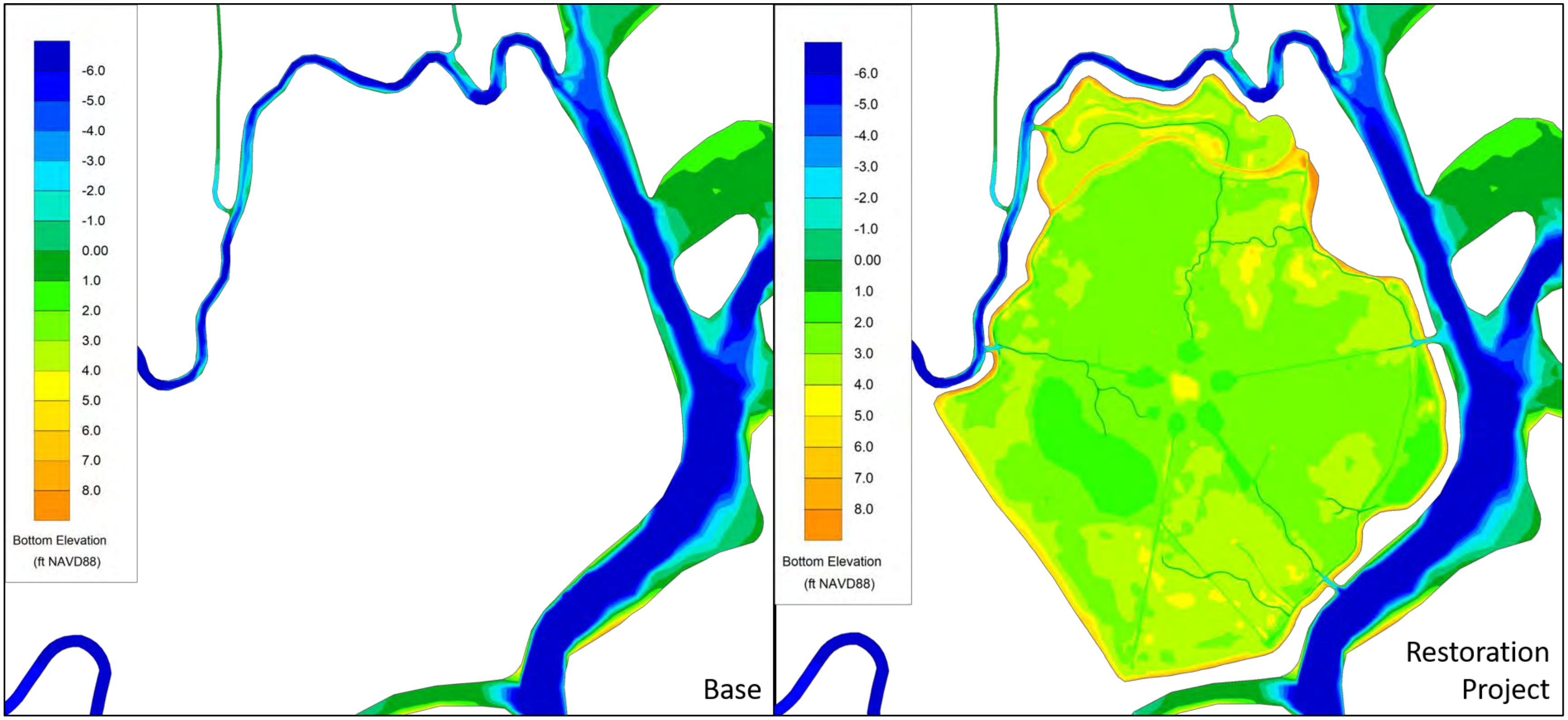

Figure 2 Model bathymetry in the project vicinity for the Base and Restoration Project configurations.

BOUNDARY CONDITIONS

The RMA Bay-Delta hydrodynamic model operation requires specification of the tidal stage at the Golden Gate and inflow and withdrawal rates at other external boundaries as shown in Figure 3.

Hydrodynamic and water quality models were run for the January – December 2013 periods. The 2013 period includes dry and critically dry conditions (see http://cdec.water.ca.gov/cgi-progs/iodir/wsihist). Delta outflow is plotted in Figure 4.

Boundary conditions are detailed in the Appendix.

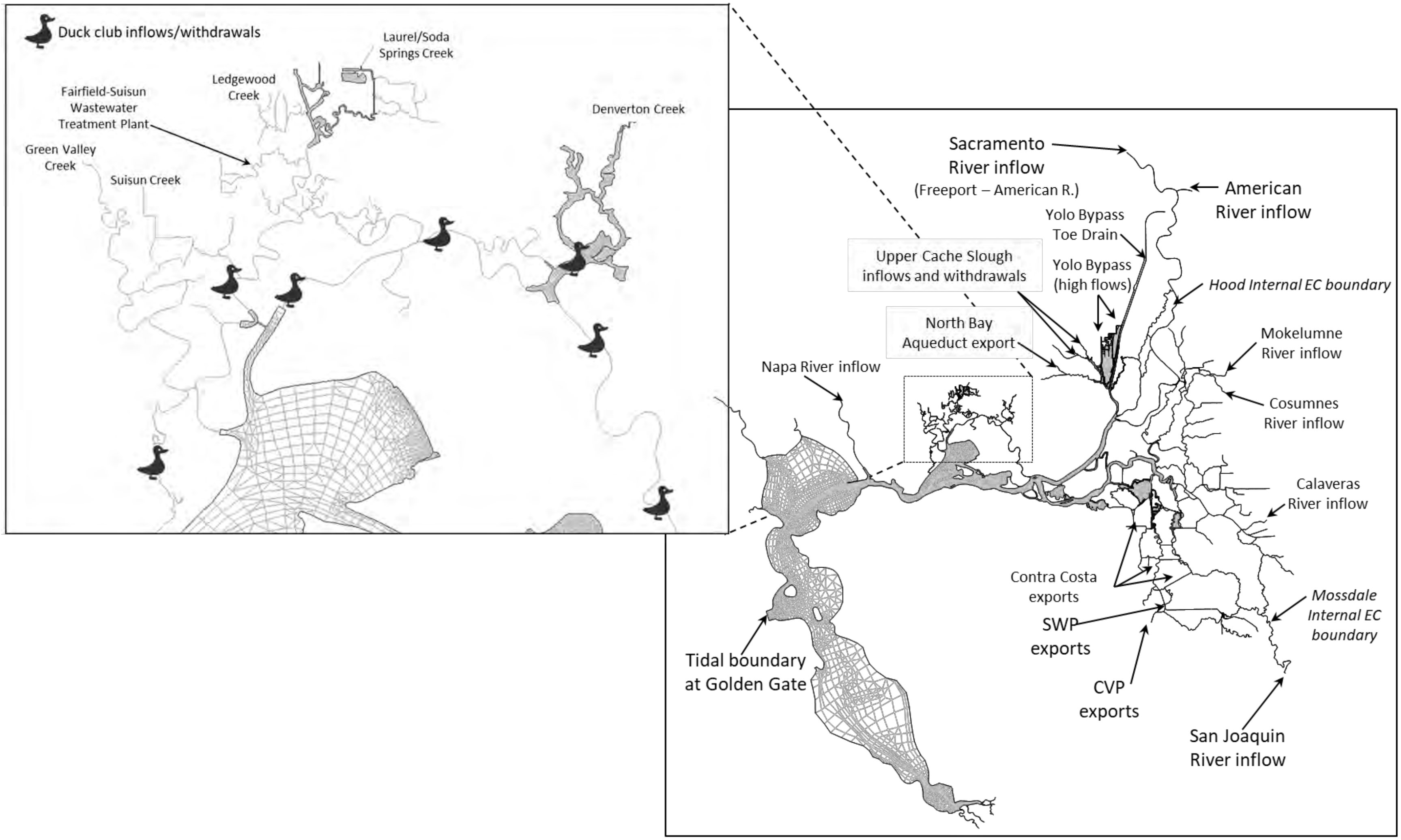

Figure 3 Model boundary condition locations.

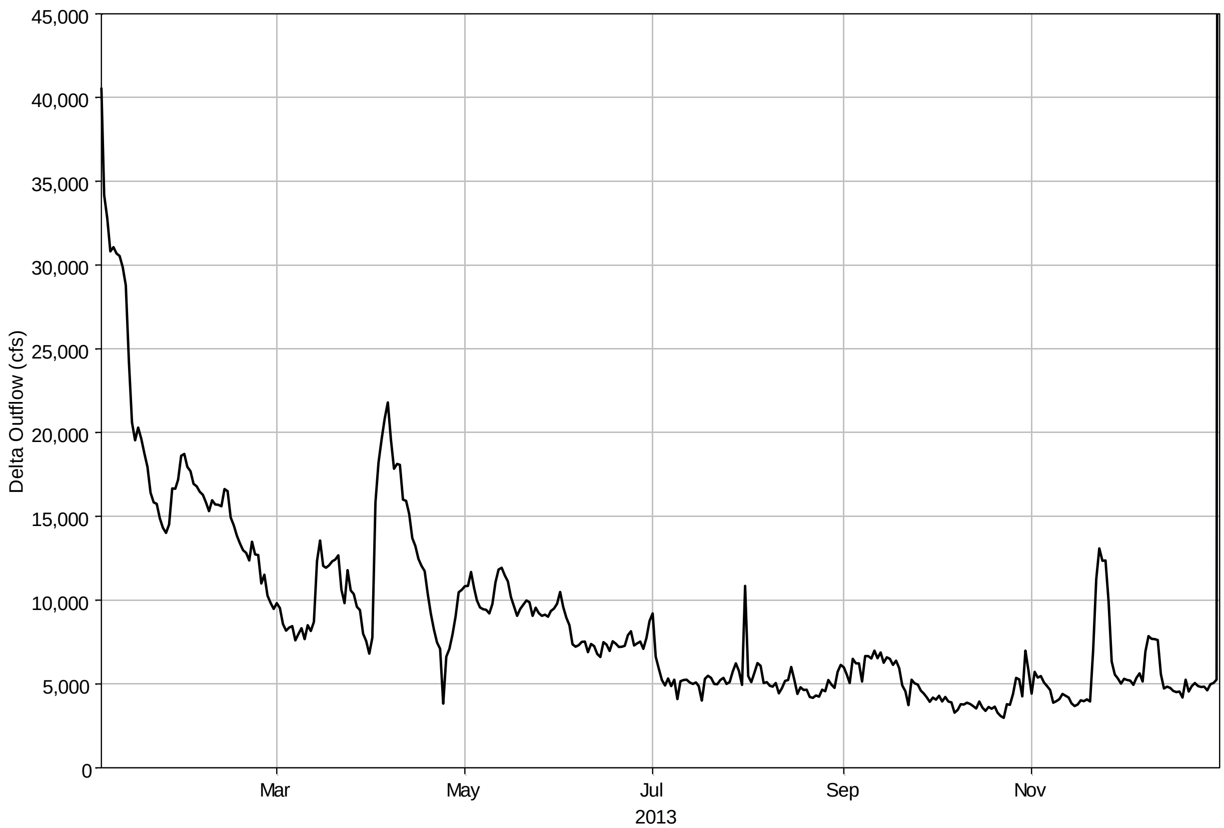

Figure 4 Delta outflow for the 2013 analysis period.

CALIBRATION CHECK

To assure that the Base model is in good agreement with observed data following the grid enhancements in the project vicinity, a quick calibration check was done. The 2013 computed Base stage was compared with observed data at Volanti (see Figure 5 for location map) in Figure 6. The modeled stage is in excellent agreement with observed values during the summer period and computed stage is slightly high during the fall and winter months. The tidally averaged stage is as much as 0.4 ft higher than observed in the winter. The mean computed stage for the entire simulation period is 0.18 ft above observed. The varying difference over the year in computed and observed average stage produces the scatter in the linear regression plot. The tidal amplitude is in good agreement with observed with a ratio of 1 averaged over the simulation.

The 2013 computed Base EC was compared with observed data at Volanti, Hunter Cut, Godfather and Beldons Landing (see Figure 5 for location map). Overall, the model does a reasonably good job of reproducing observed EC values in Suisun Marsh. The model produces the best results during the summer months and early fall months, and tends to be slightly low during the winter and spring. Because of uncertainties in the boundary conditions, particularly the duck club flows, some deviations from observed data can be expected.

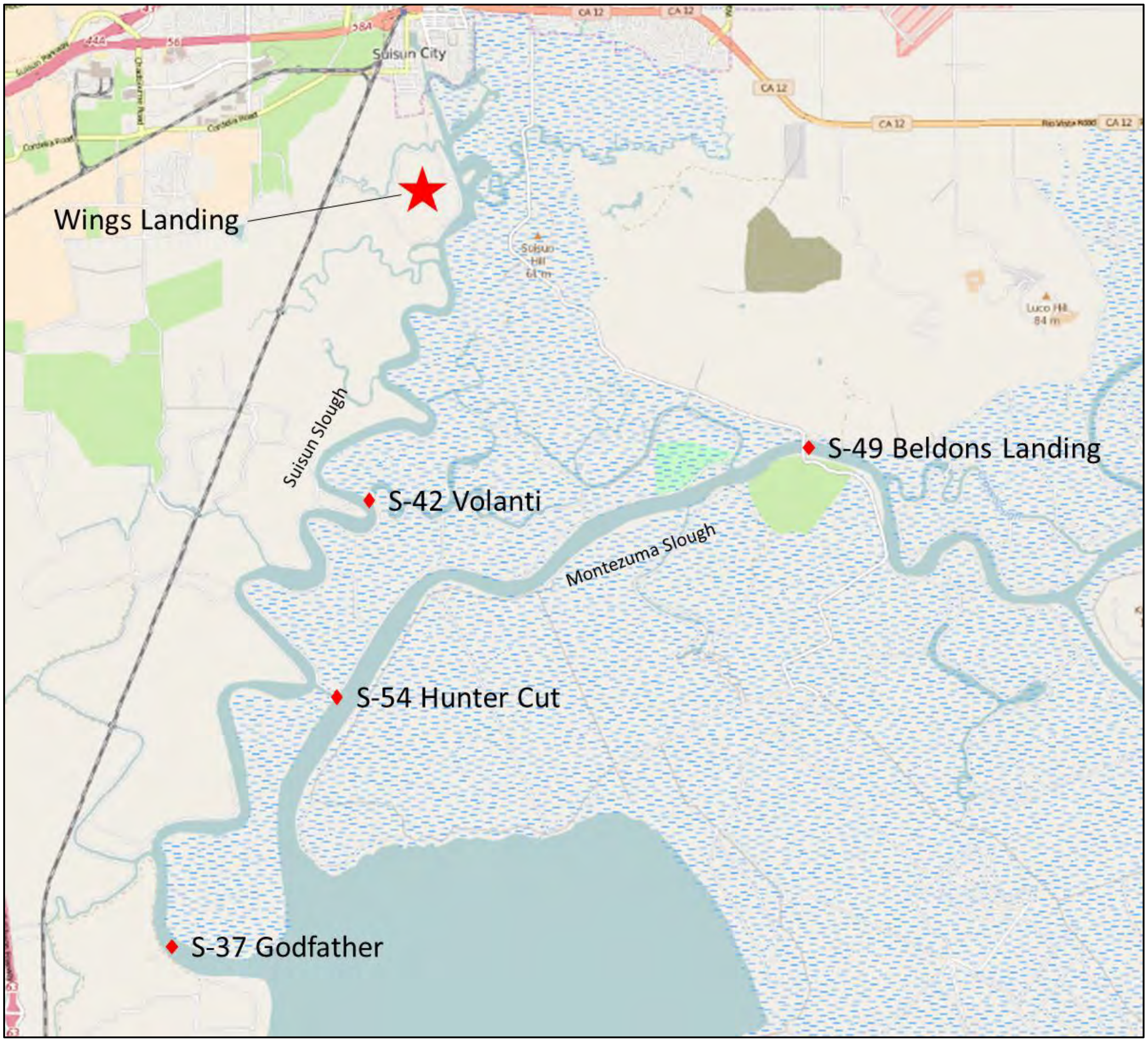

Figure 5 Suisun Marsh stage and EC calibration check locations.

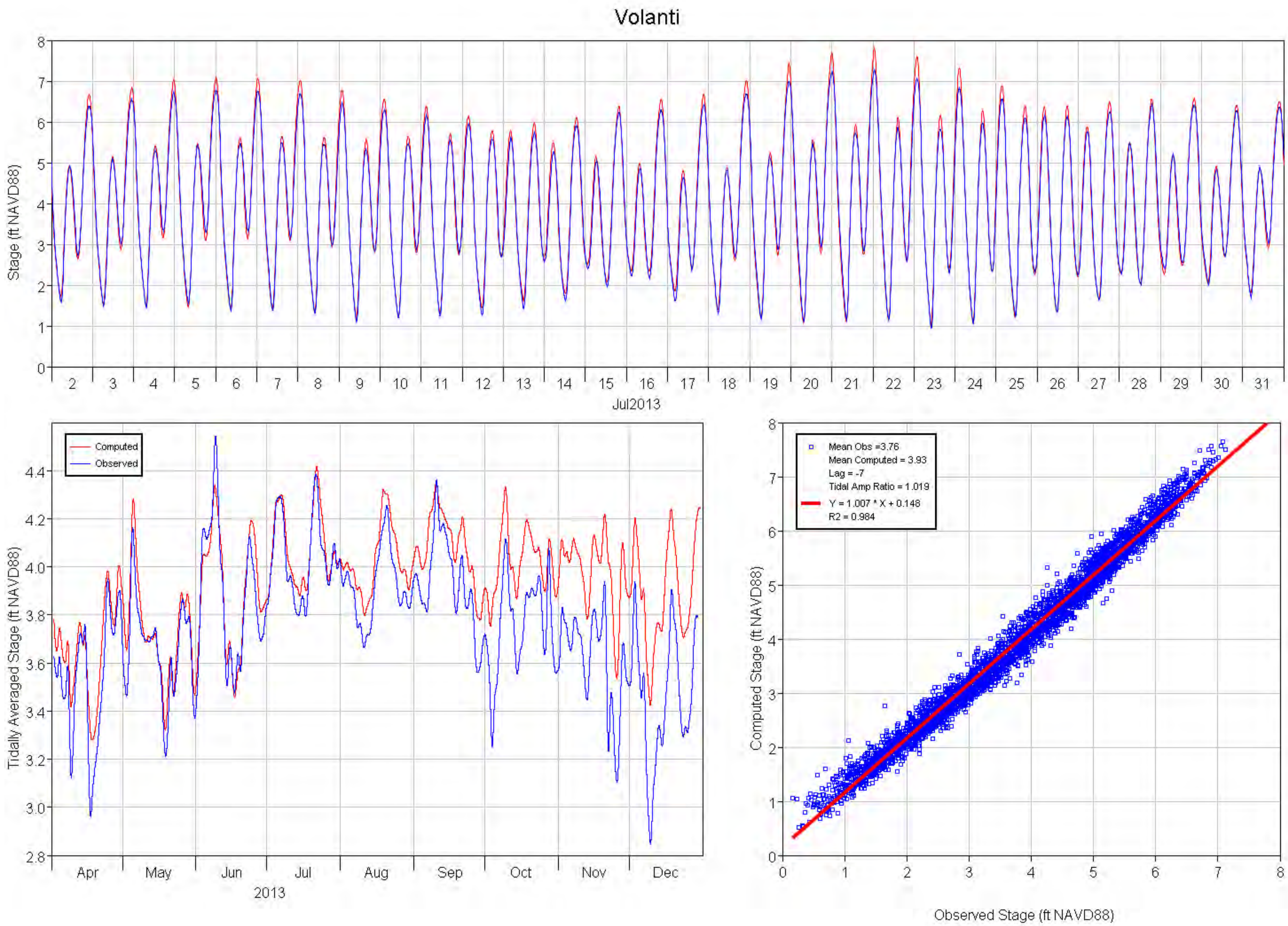

Figure 6 Base case computed and observed stage at Volanti for April 1 – December 31, 2013.

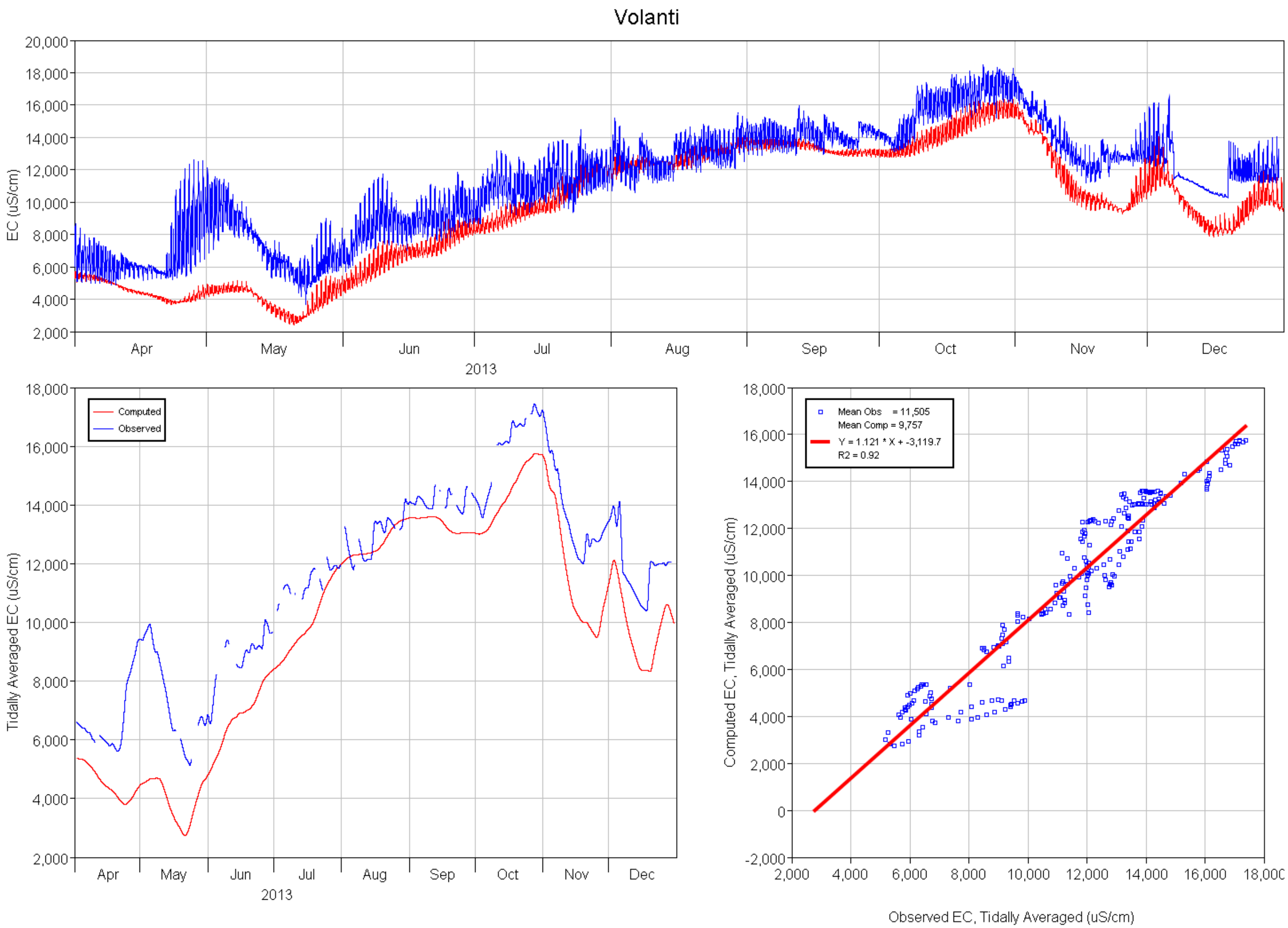

Figure 7 Base case computed and observed EC at Volanti for the April 1 – December 2013 simulation period.

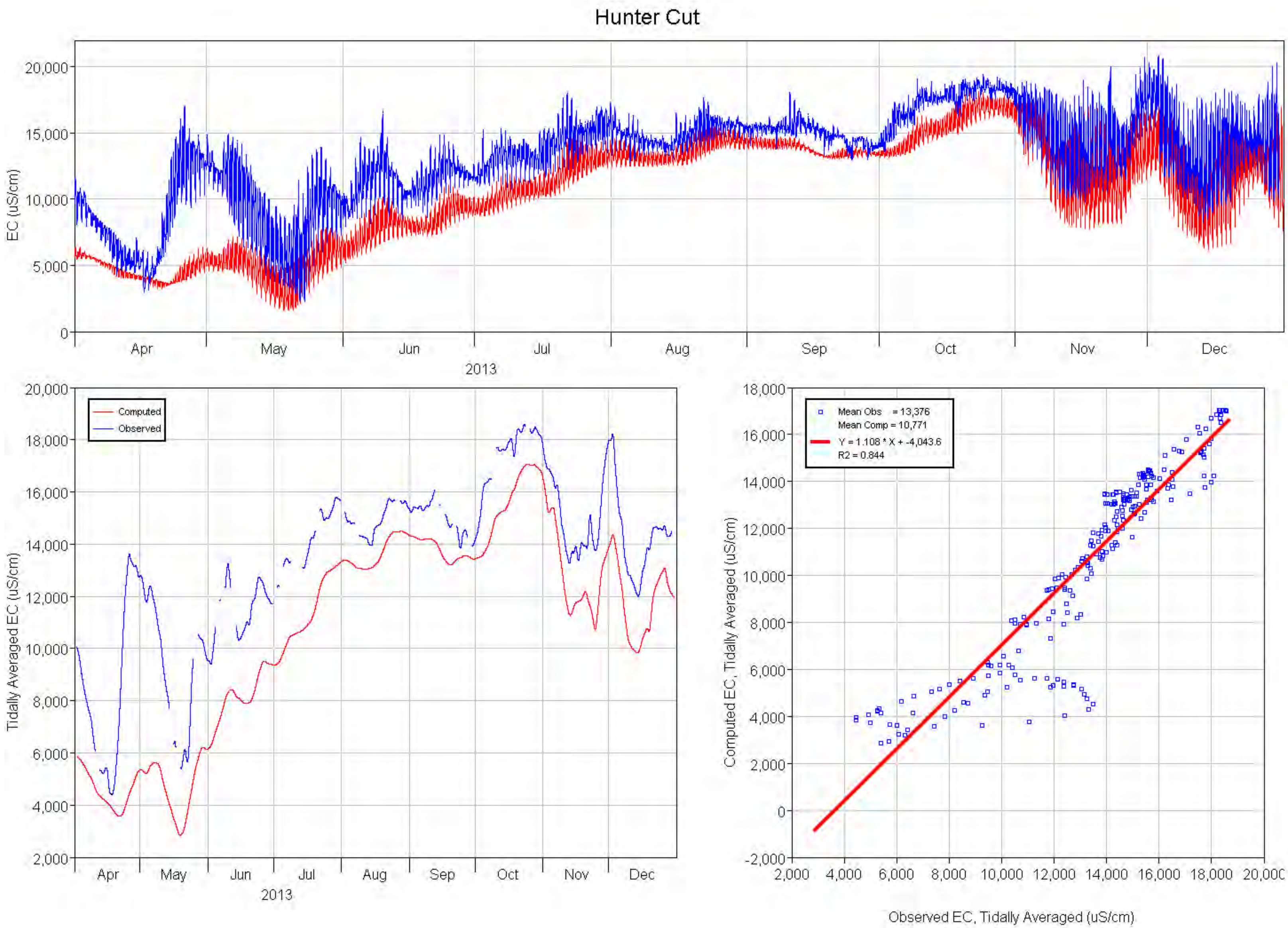

Figure 8 Base case computed and observed EC at Hunter Cut for the April 1 – December 2013 simulation period.

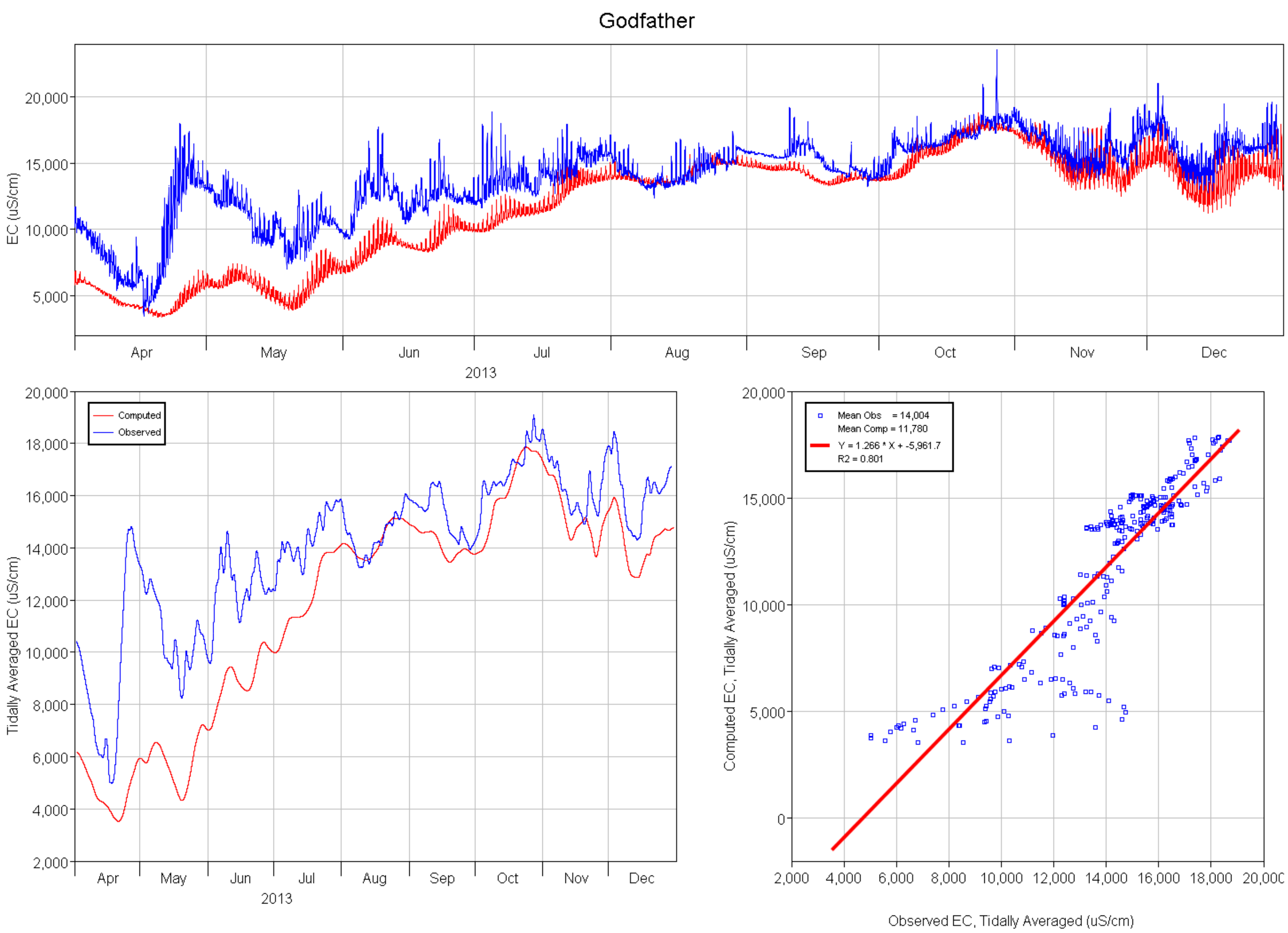

Figure 9 Base case computed and observed EC at Godfather for the April 1 – December 2013 simulation period.

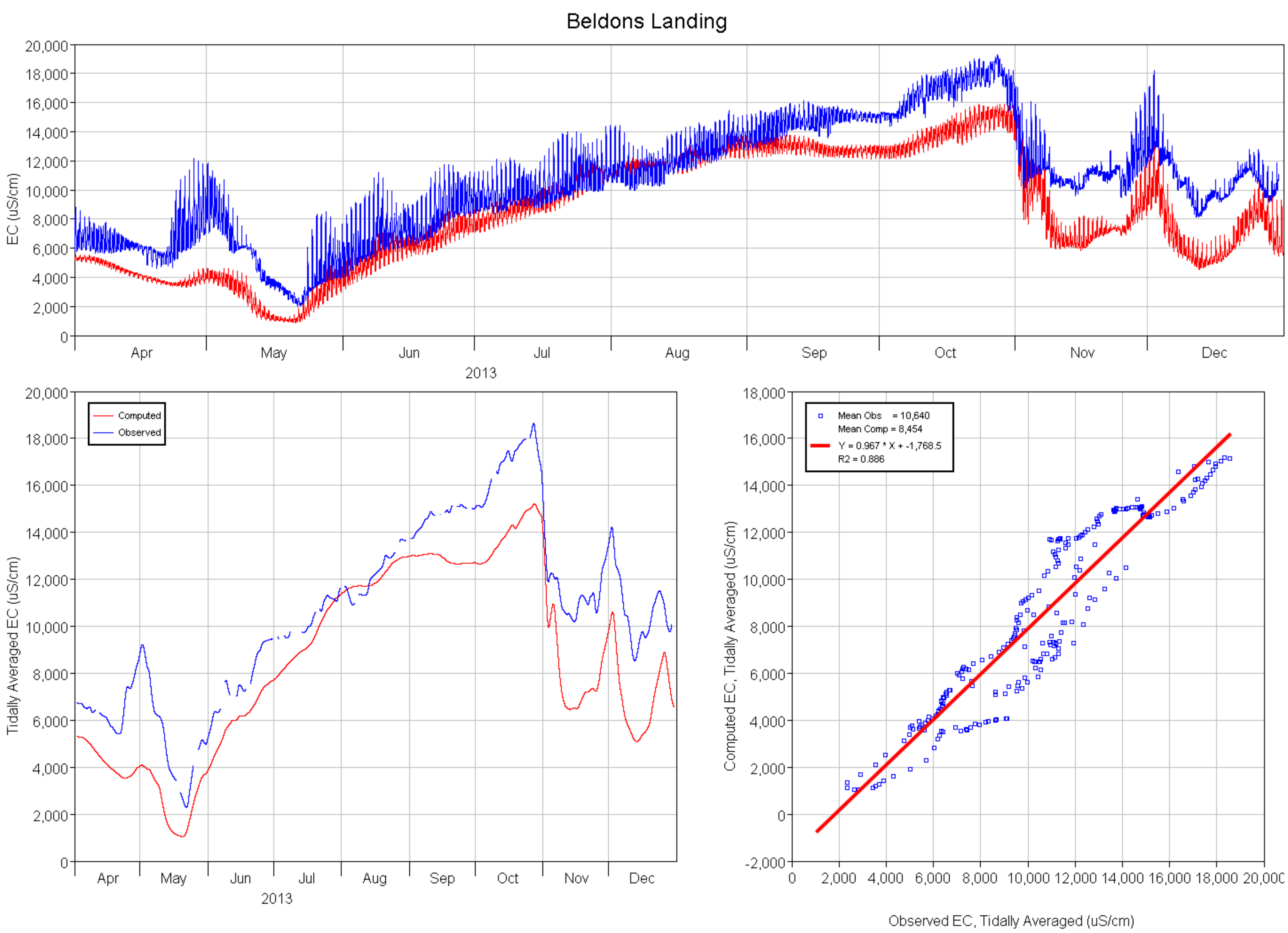

Figure 10 Base case computed and observed EC at Beldons Landing for the April 1 – December 2013 simulation period.

WINGS LANDING RESTORATION PROJECT CONFIGURATION

The Wings Landing proposed restoration design is shown in Figure 11. The restoration model grid was developed using KMZ files (geo-referenced markup files) for breach and channel construction/modification locations, provided by Natural Resources Group. Four exterior breaches (Breaches 1, 2, 3 and 5) are excavated to connect the restoration site to the surrounding channels of Suisun Slough and Peytonia Slough. A single interior breach (Breach 4) is proposed through the Brood Pond levee. Breach dimensions are listed in Table 1. Enhanced and newly created channels extend from the breaches into the site. All channels that extend from the breaches into the restoration site were designed with a 6 ft bottom width, 2H:1V side slopes and bottom elevation of 1 ft NAVD88. Existing channels adjacent to the south and southwestern exterior levees are filled to reduce risk of levee erosion.

Point topographic survey data were collected on the site by ESA and USGS in 2016. These were the primary datasets used to set model grid elevations in Wings Landing. Areas not covered by these data were set using 2010 adjusted LiDAR data provided by Natural Resources Group. A visual representation of the elevation data sets is provided in Figure 12 to illustrate data coverage.

Figure 13 shows the model grid developed for the Wings Landing restoration site and vicinity, and the inclusion of the Wings Landing grid into the greater RMA Bay-Delta model grid. A 3-D perspective view of the model grid for the Wings Landing restoration site is presented in Figure 14.

Table 1 Breach Geometry

Breach	Location	Bottom Width	Bottom Elevation (NAVD88)	Side slopes
Breach 1	External Levee	25′	-2′	1:1
Breach 2	External Levee	25′	-2′	1:1
Breach 3	External Levee	25′	1.24′	1:1
Breach 4	Internal Levee	6′	3.5′	1:1
Breach 5	External Levee	25′	-2′	1:1

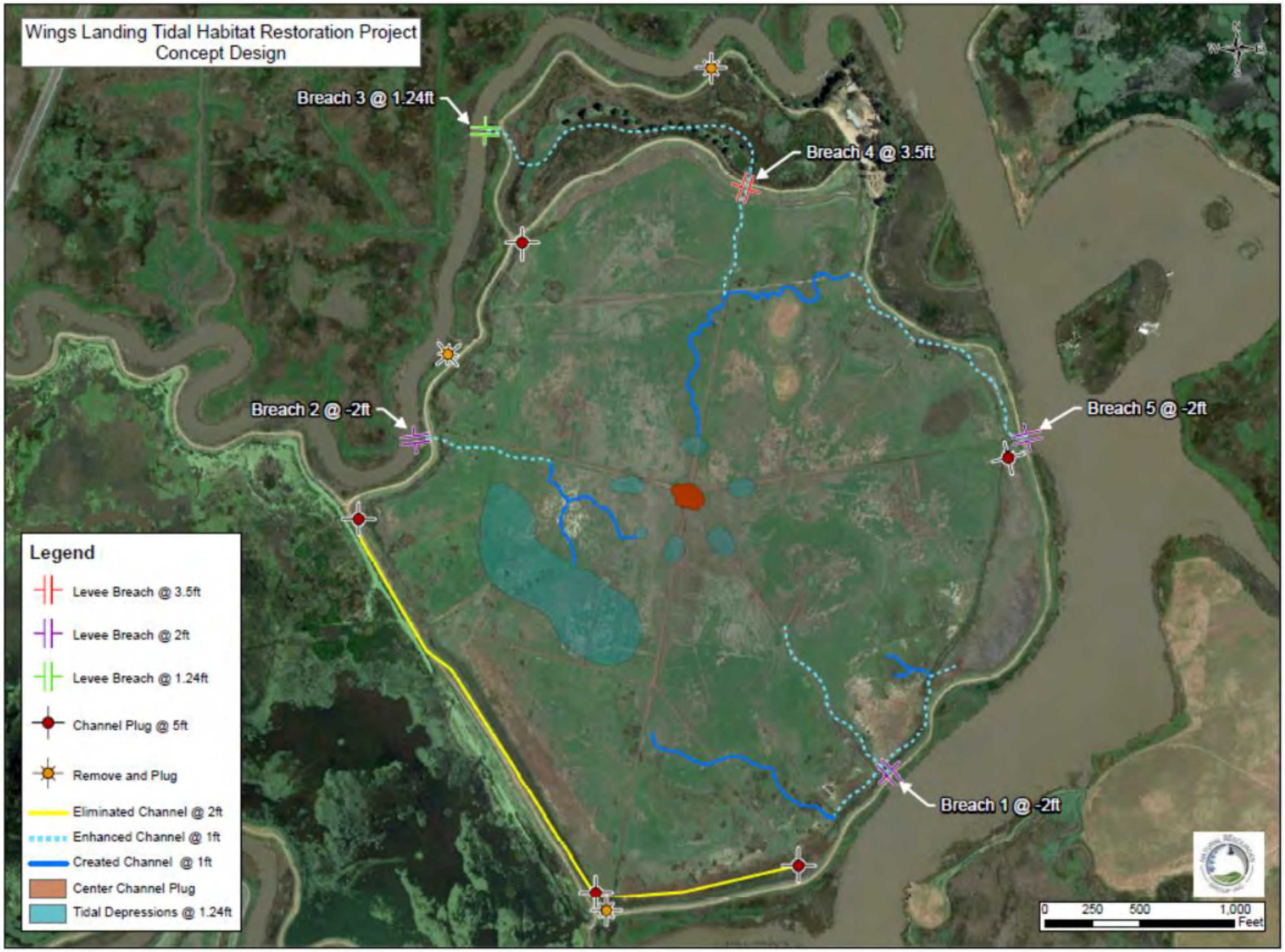

Figure 11 Wings Landing restoration design.

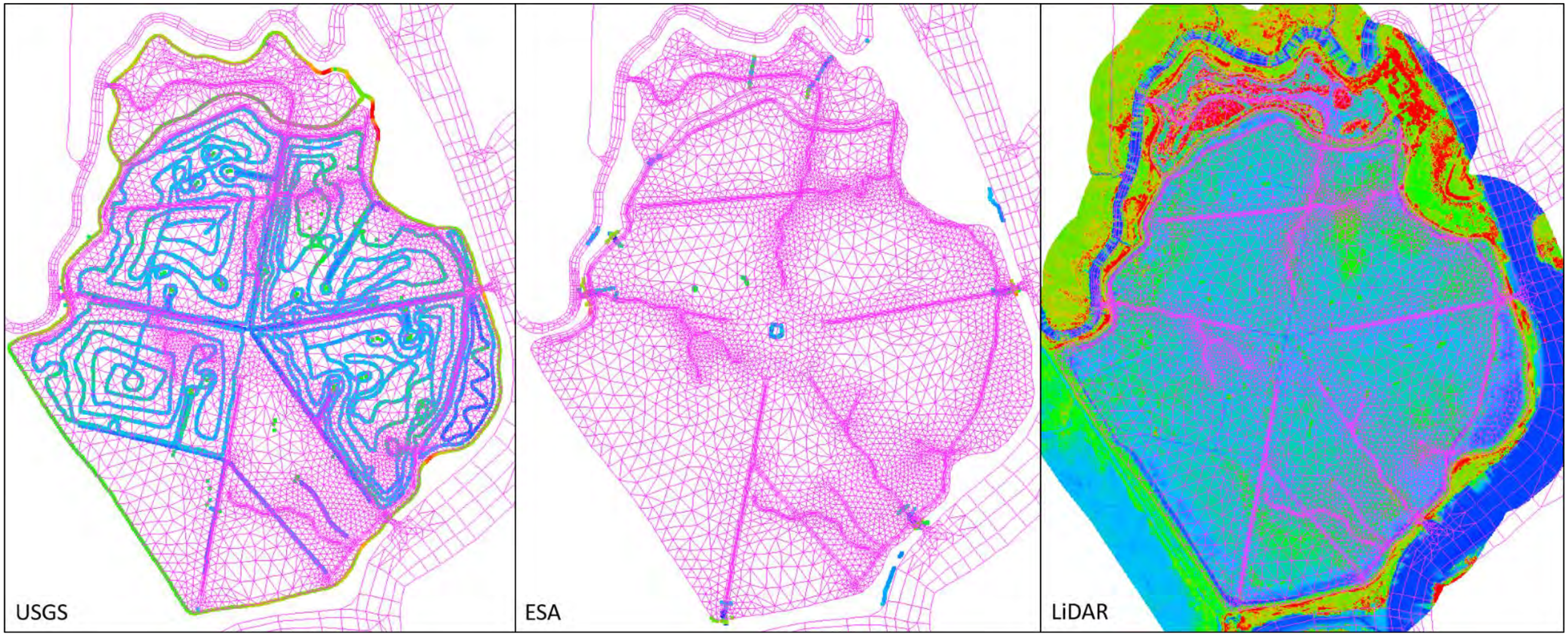

Figure 12 Point topographic survey data collected by USGS and ESA in 2016, and 2010 adjusted LiDAR data.

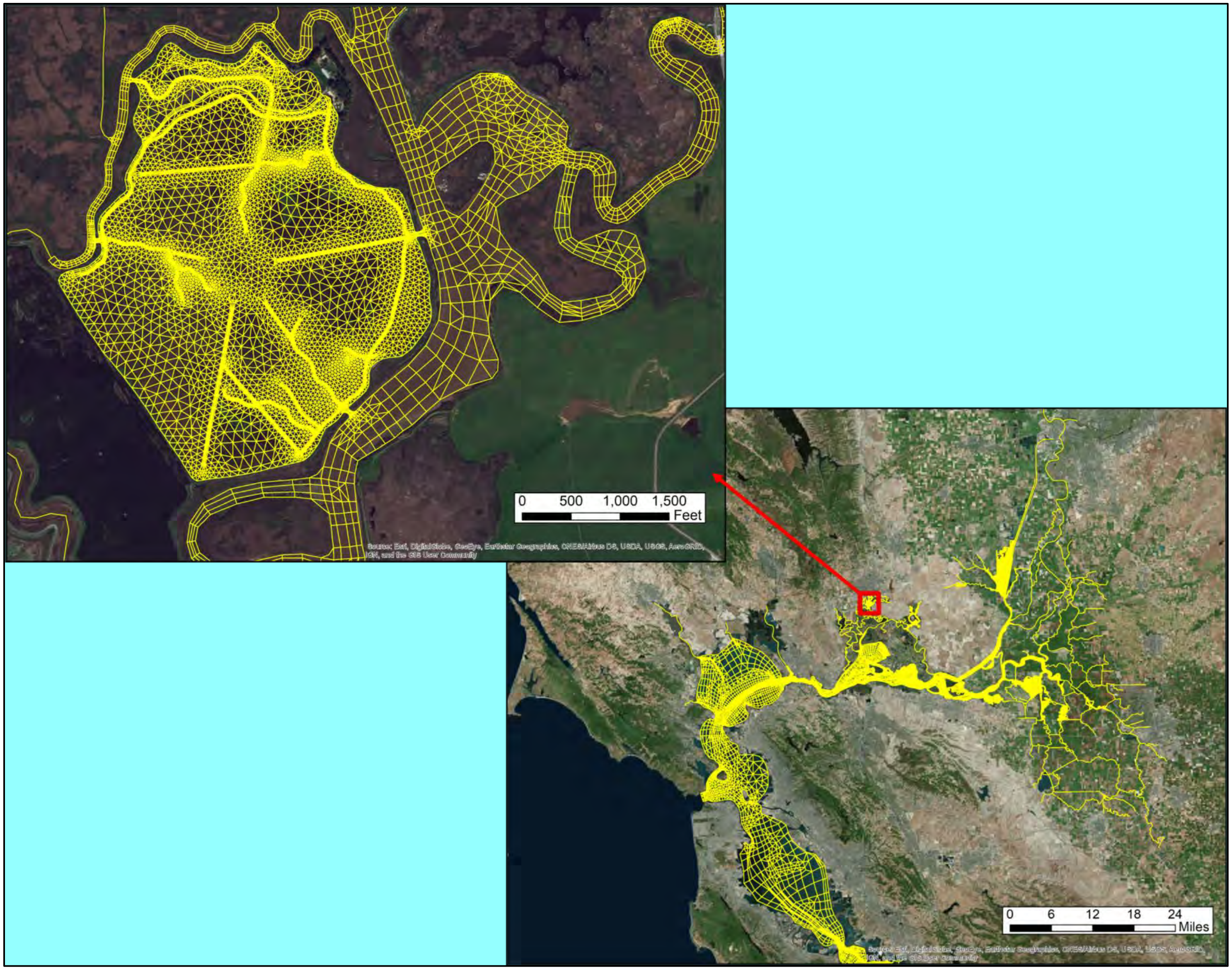

Figure 13 Numerical model network for the Bay-Delta grid and the detailed model network for the Wings Landing restoration site.

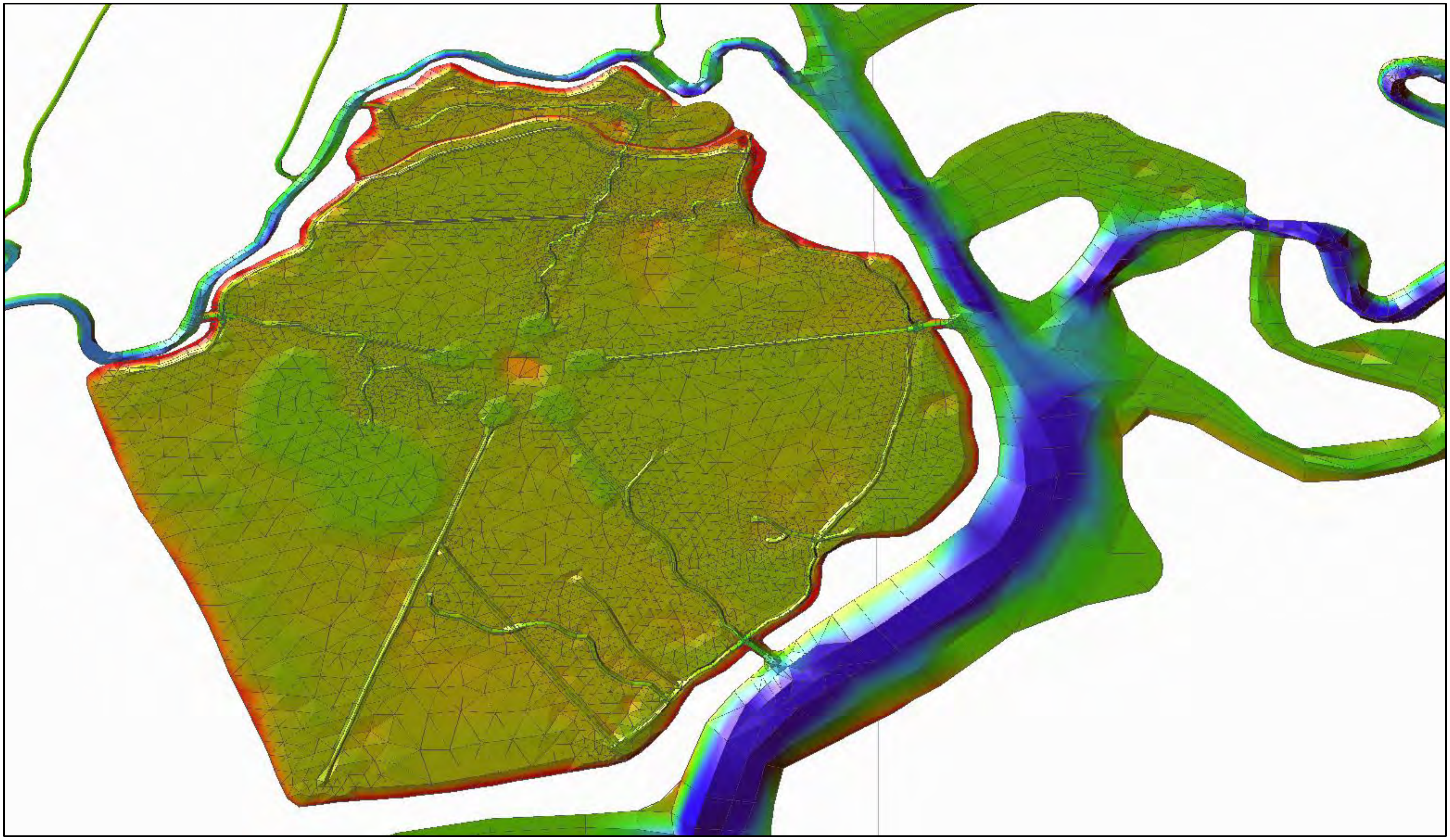

Figure 14 3-D perspective view of the Wings Landing restoration grid.

WINGS LANDING RESTORATION PROJECT EFFECTS ANALYSIS

Hydrodynamic Effects

Base and Wings Landing restoration project hydrodynamic simulation results for July 2013 were analyzed and compared to evaluate expected Restoration effects on tidal range and velocities in adjacent channels. Modeled stage, tidal range and breach velocities within the restoration project site were also examined.

Peak Velocities

July 2013 modeled velocity results were post-processed to extract the peak velocities occurring at each node in the model grid. Figure 15 shows the post-processed peak velocity magnitude contours within Wings Landing. Modeled peak velocities at each breach are shown in Figure 16 through Figure 20 with model bathymetry for reference. Modeled peak velocities in channels and breaches occur during ebb tide. Maximum velocities at breaches are approximately 5 ft/s, with the highest velocities occurring at Breach 1 and Breach 5. Higher velocities, up to approximately 6 ft/s, occur within the restoration site in some channels near breaches, particularly near Breach 1 and Breach 2.

Wings Landing restoration case, change from modeled Base peak velocities during July 2013 are plotted in Figure 21 near the Restoration site. Compared with the Base case, velocities increase by 2 ft/s or more in small areas of Suisun Slough near Breach 1 and Breach 5. Velocities in Peytonia Slough increase by around 0.5 ft/s. An expanded view of velocity increases in the Suisun Slough region in Figure 22, shows that regional velocity increases in and near Suisun Slough range from 0.1 to 0.5 ft/s.

Brief time series of modeled Base and Restoration case velocities in Suisun Slough and Peytonia Slough, adjacent to Wings Landing (locations shown in Figure 23), are provided in Figure 24 and Figure 25. These plots show velocity increases due to restoration occurring during both peak ebb tide and peak flood tide.

Breach Flows

Brief time series of modeled external breach flows are plotted in Figure 26. The largest breach flows are through Breach 1 and Breach 5, with up to 1,300 cfs inflow on flood tide. The smallest exchange is through Breach 3, with up to 350 cfs inflow on flood tide.

Stage and Tidal Range

July 2013 modeled Base and Restoration case stage time series are plotted for comparison to illustrate the potential effects of Wings Landing restoration on local stage and tidal range. Stage time series in Suisun Slough seaward of Breach 1 and Peytonia Slough landward of Breach 2 (locations shown in Figure 27) are plotted in Figure 28 through Figure 31. For each location there are plots of the full month of July and, to show more detail, only four days during the strongest spring tide.

At each of these locations, the modeled Base and Restoration stage time series were post-processed to extract mean higher high water (MHHW) and mean lower low water (MLLW) for July 2013 and determine the difference between Base and Restoration. These results showed that, on average for July 2013, Restoration reduces MHHW by 0.03 ft and increases MLLW by 0.01 ft, for a total tidal range reduction of 0.04 ft in Suisun Slough seaward of Breach 1. In Peytonia Slough landward of Breach 2, Restoration reduces MHHW by 0.03 ft and increases MLLW by 0.04 ft, for a total tidal range reduction of 0.07 ft.

To assess tidal range within the Restoration site, Figure 32 and Figure 33 show modeled Restoration case stage within Wings Landing (location shown in Figure 27) plotted along with stage at the Suisun Slough location. Within the restoration site, modeled high tide is approximately equal to modeled high tide in Suisun Slough seaward of Breach 1. Lower low tide is approximately 2 ft higher inside Wings Landing compared with the adjacent Suisun Slough location. Much of the site goes dry at lower low tide, but channels do not fully drain. A color contour plot of water depth in Wings Landing is shown in Figure 34 on July 23, 2013 at lower low water. Beige areas indicate exposed marsh plain across much of the site, while as much as 2 ft of water remains in some channels. The modeled water surface elevation within the Restoration site at the time of this plot is approximately 3 ft NAVD88. Scour may improve the tidal range on the low tide and improve draining of the channels.

Tidal Prism

The Restoration increases tidal prism in the channels adjacent to Wings Landing. To illustrate modeled changes in tidal prism, short time series of ebb and flood volume in Suisun Slough and Peytonia Slough for the Base and Restoration case simulations are shown in Figure 35 and Figure 37 (locations shown in Figure 23). The associated tidal flows are plotted in Figure 36 and Figure 38. On average, tidal prism is increased by 24% in Suisun Slough and by 94% in Peytonia Slough for the modeled period.

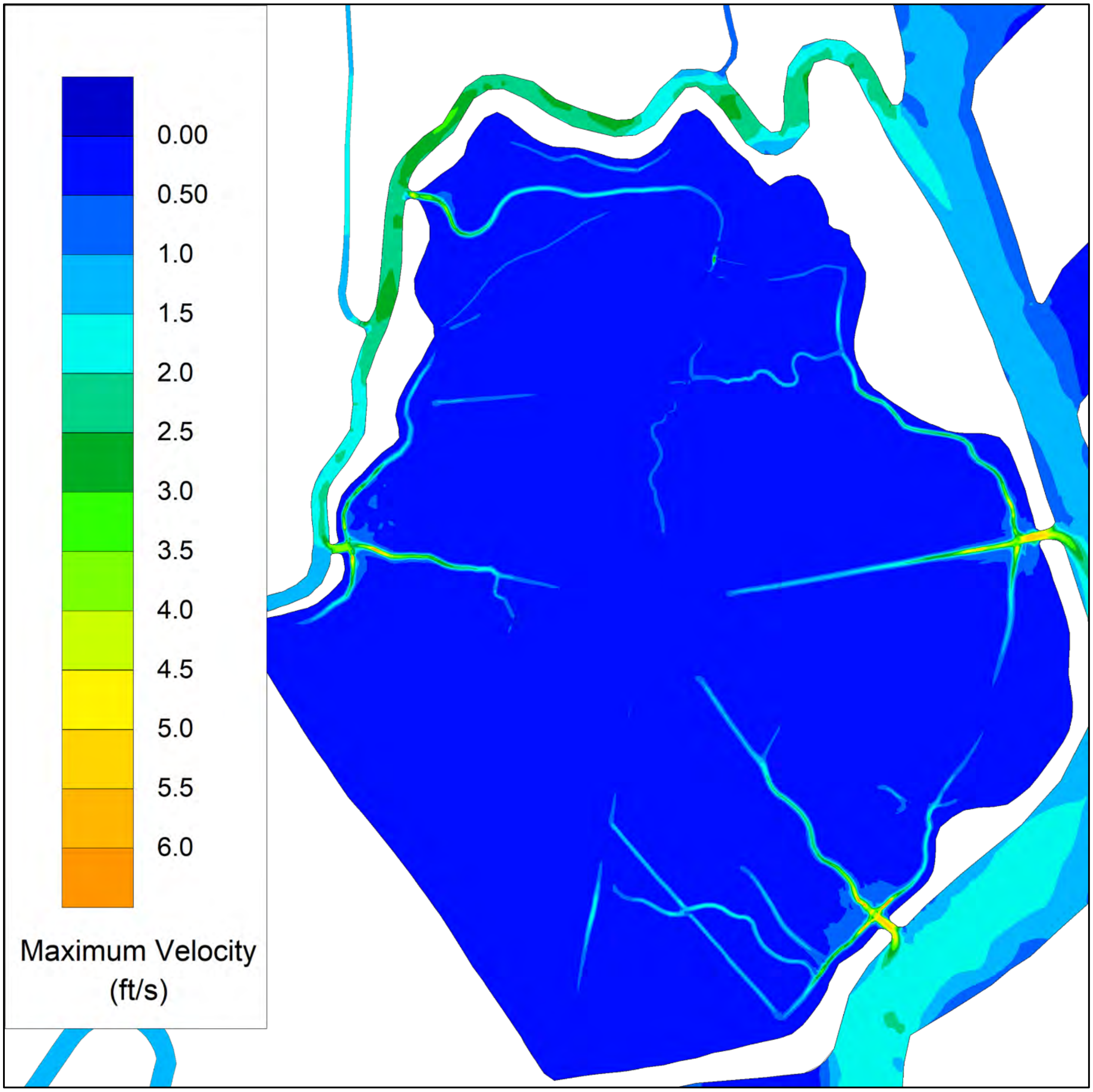

Figure 15 Modeled peak velocities in Wings Landing during July 2013.

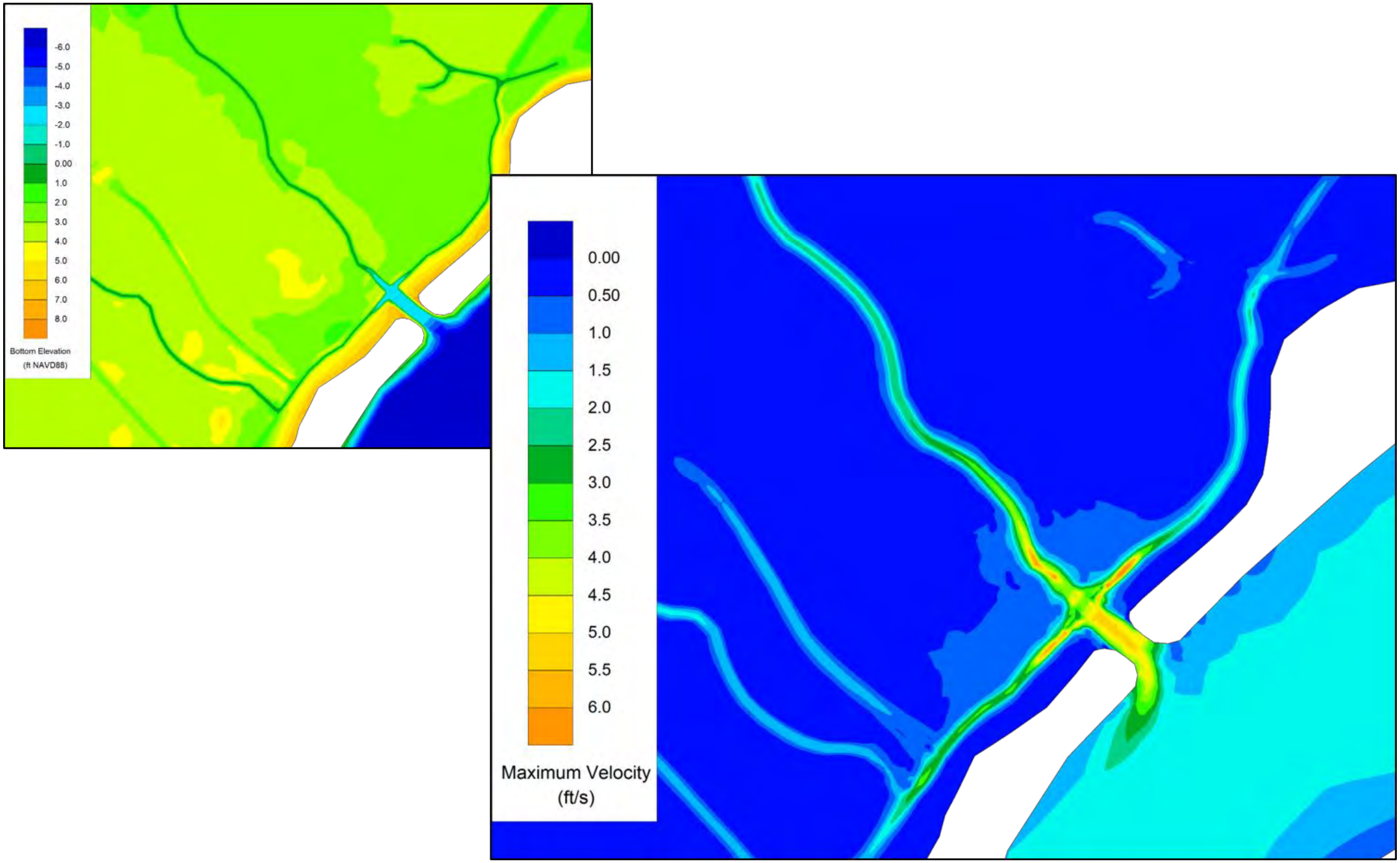

Figure 16 Modeled peak velocities at Breach 1, with model bathymetry for reference.

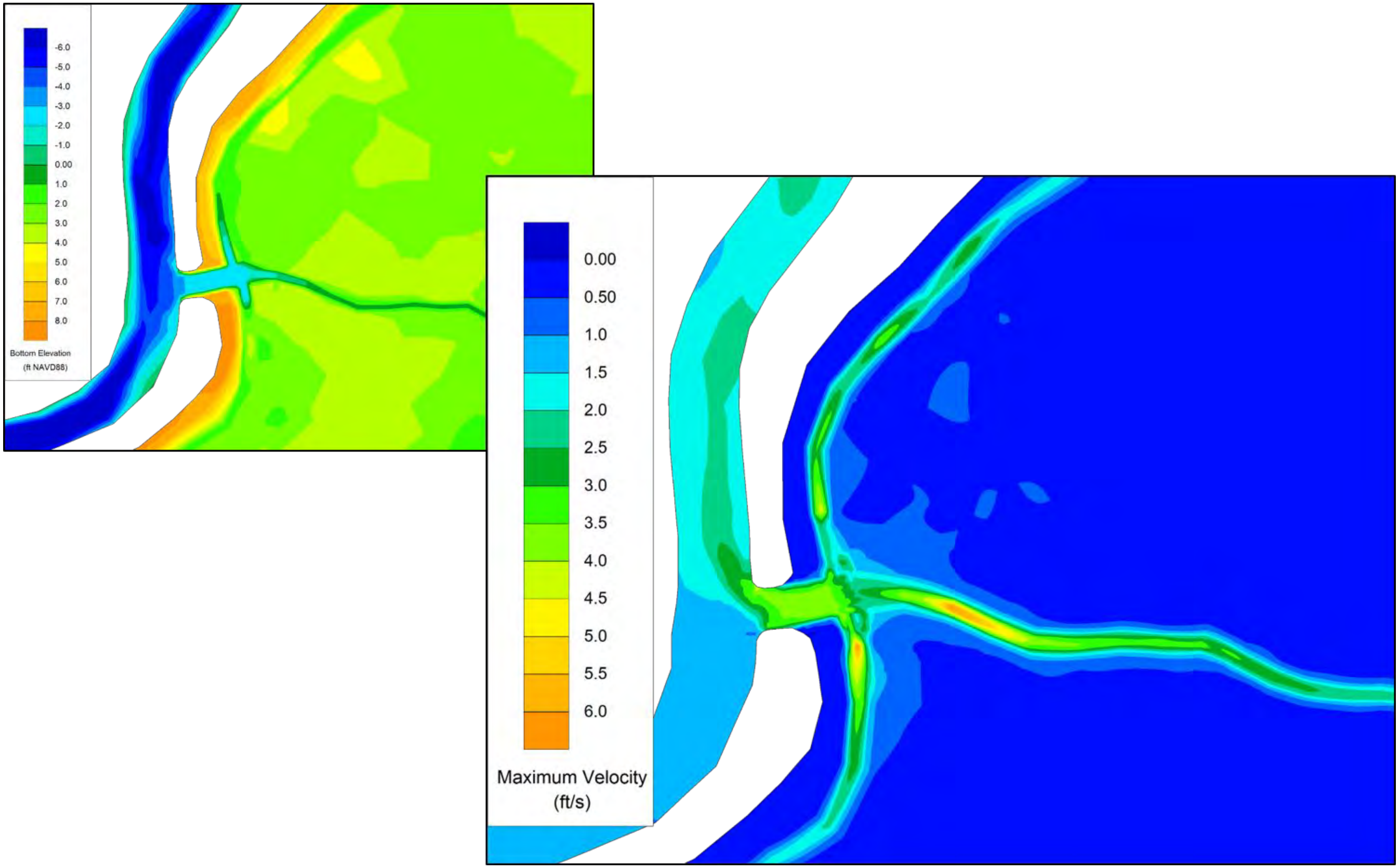

Figure 17 Modeled peak velocities at Breach 2, with model bathymetry for reference.

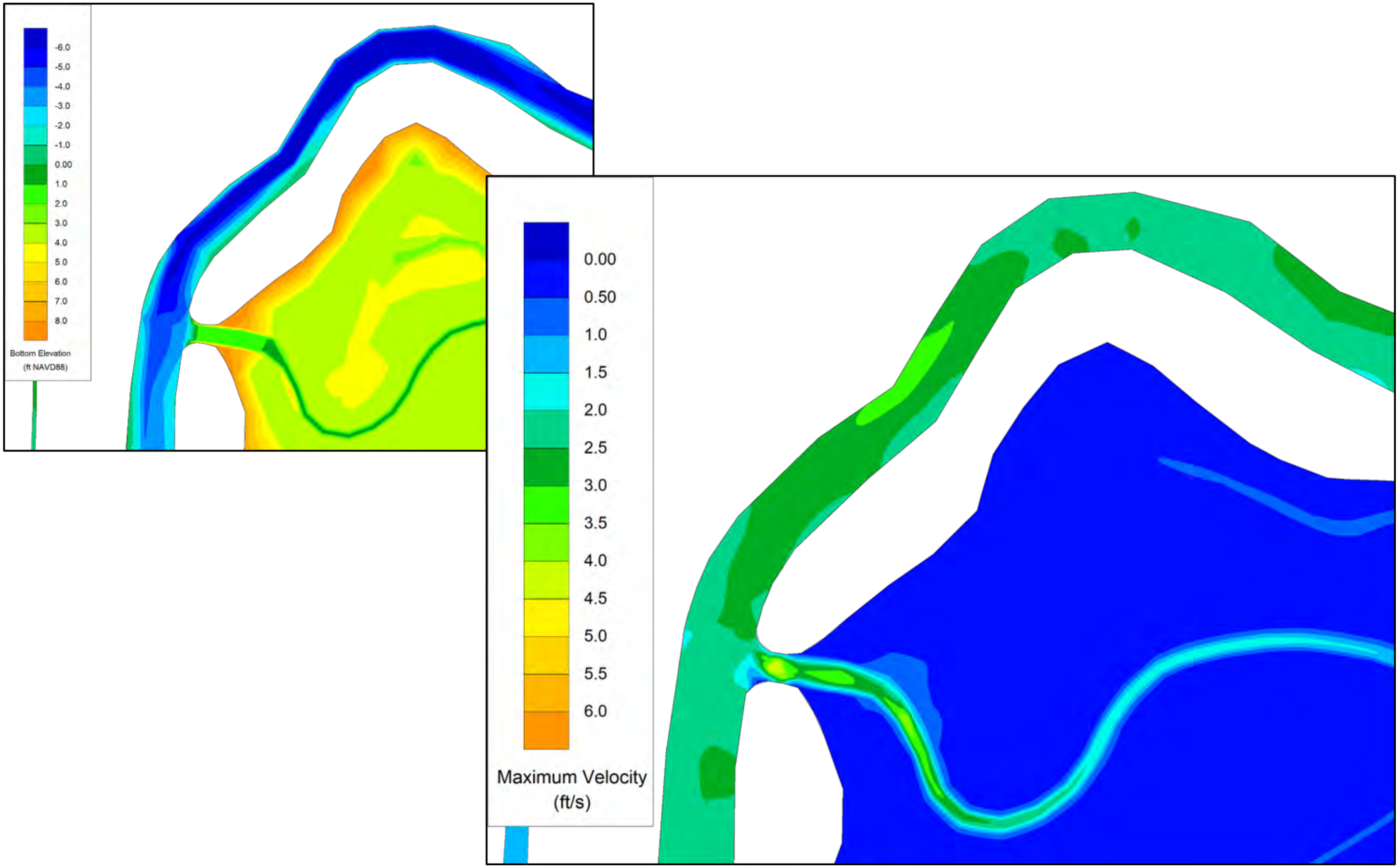

Figure 18 Modeled peak velocities at Breach 3, with model bathymetry for reference.

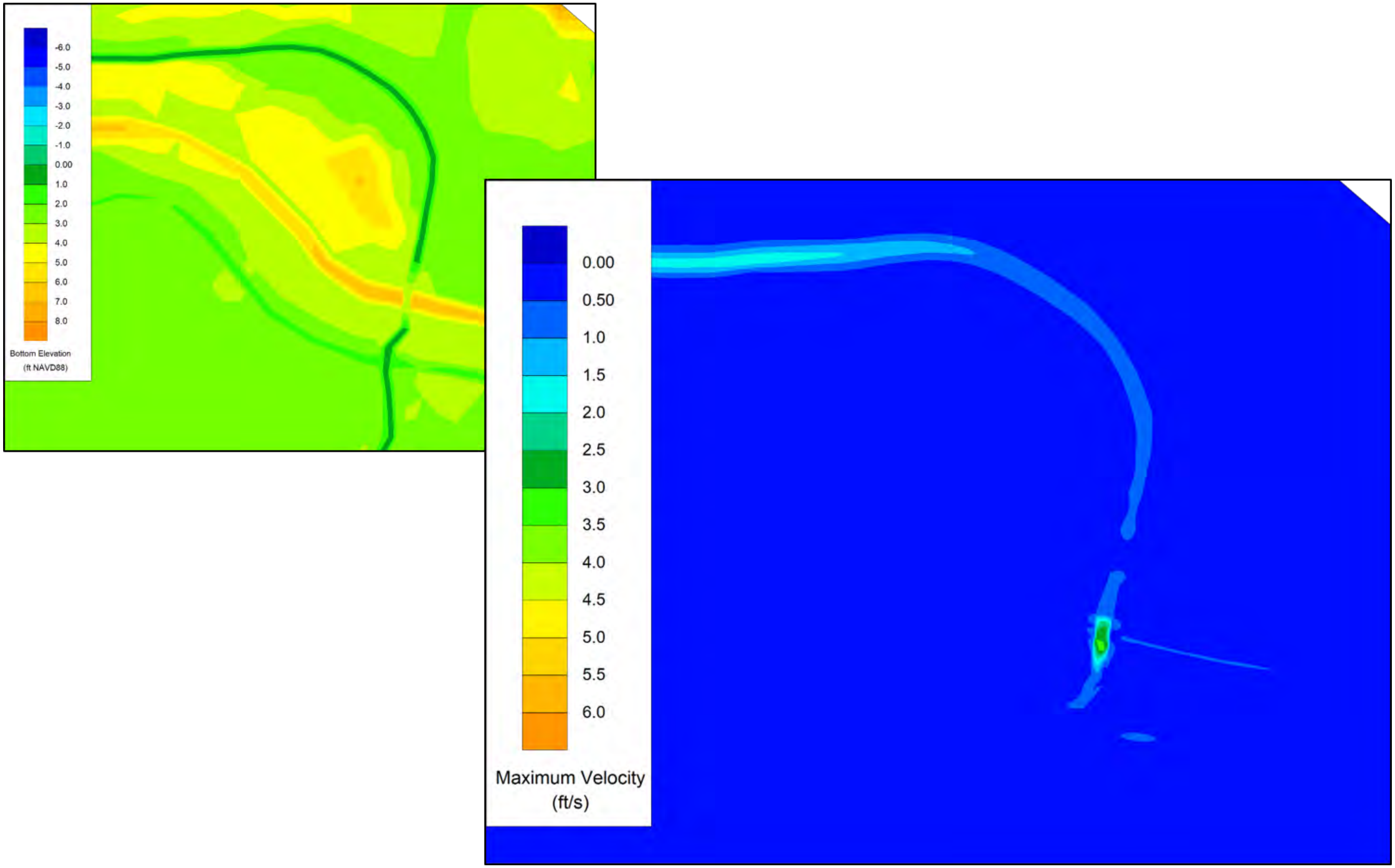

Figure 19 Modeled peak velocities at Breach 4, with model bathymetry for reference.

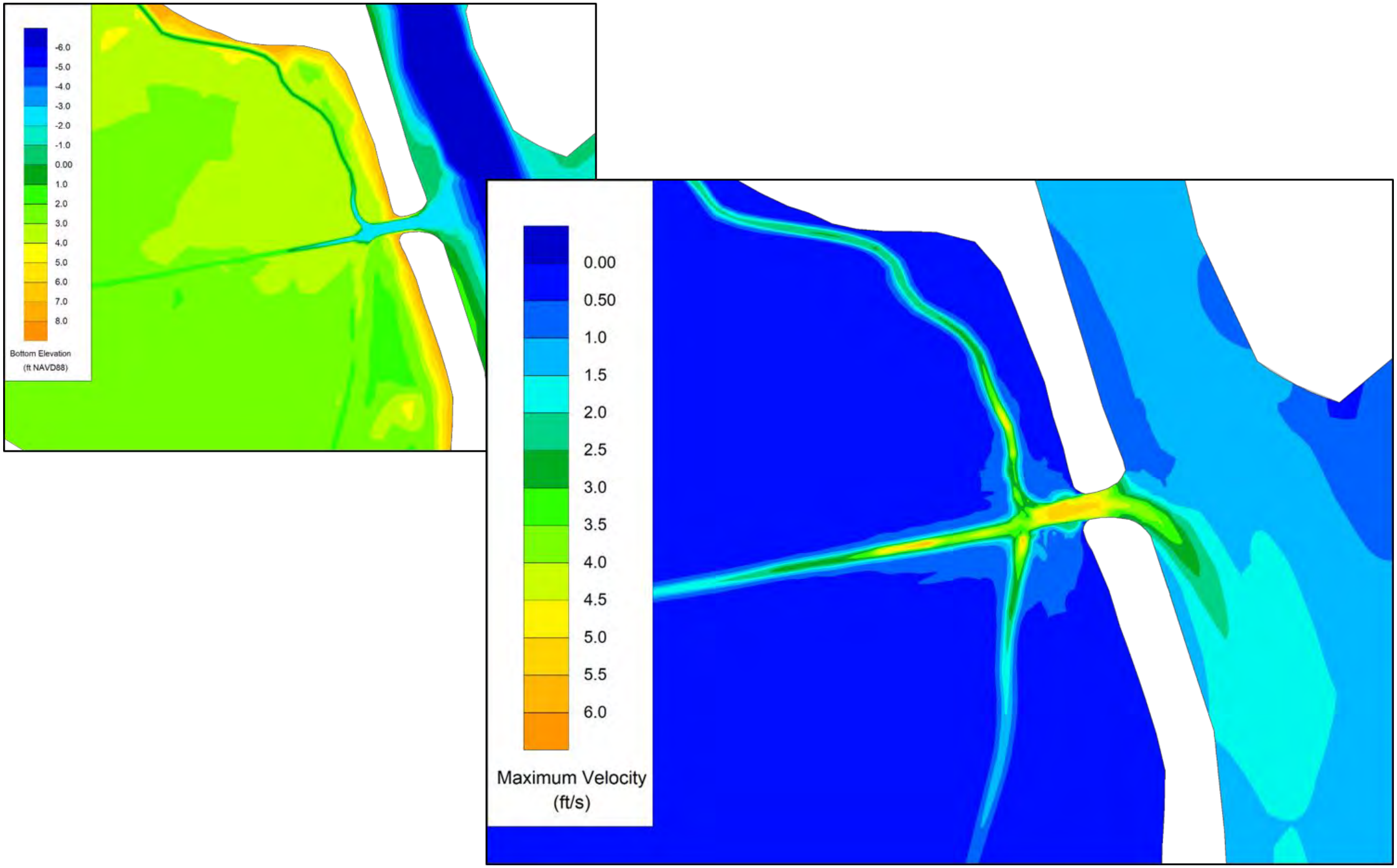

Figure 20 Modeled peak velocities at Breach 5, with model bathymetry for reference.

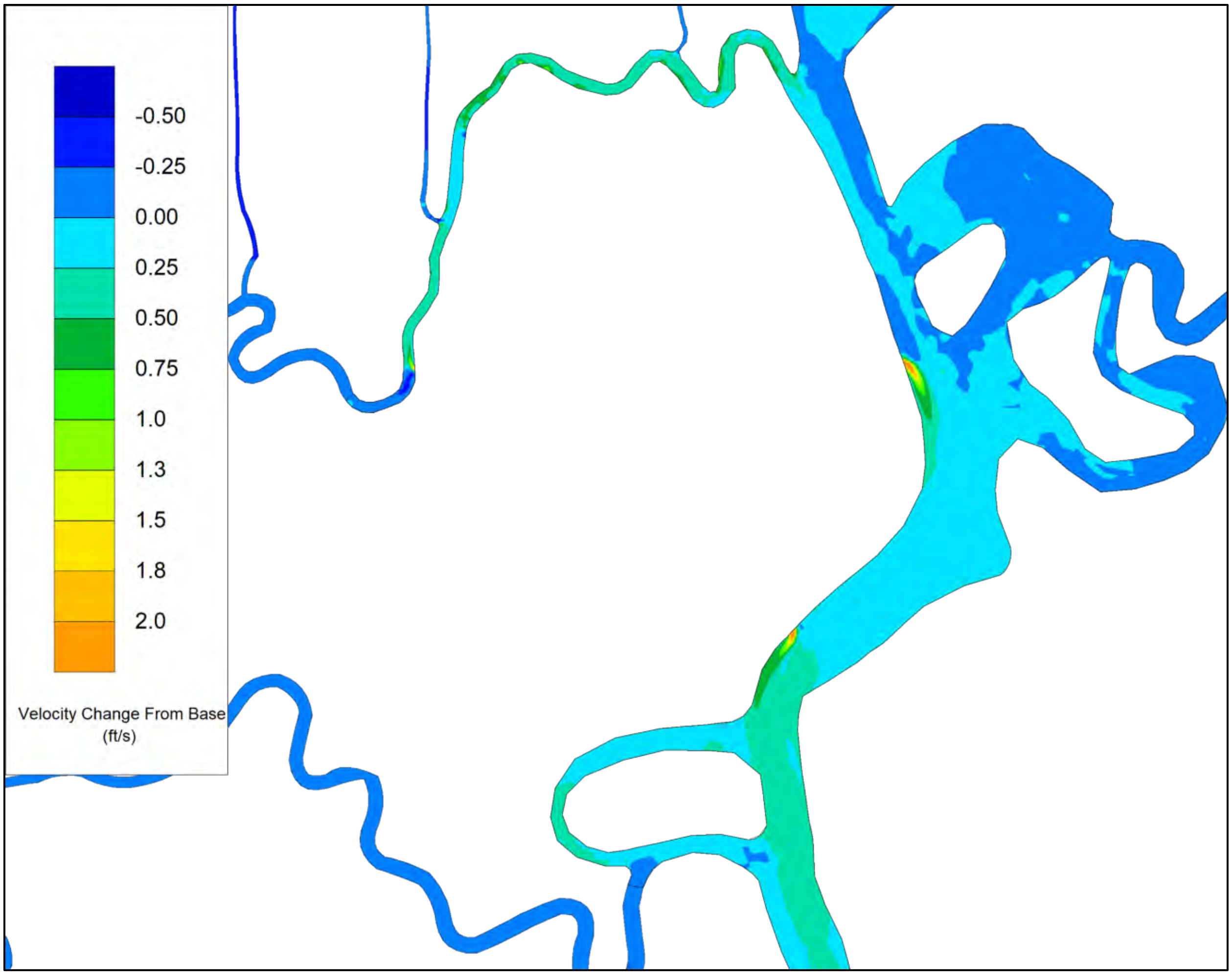

Figure 21 Wings Landing restoration case, change from Base peak modeled velocities near Restoration site during July 2013.

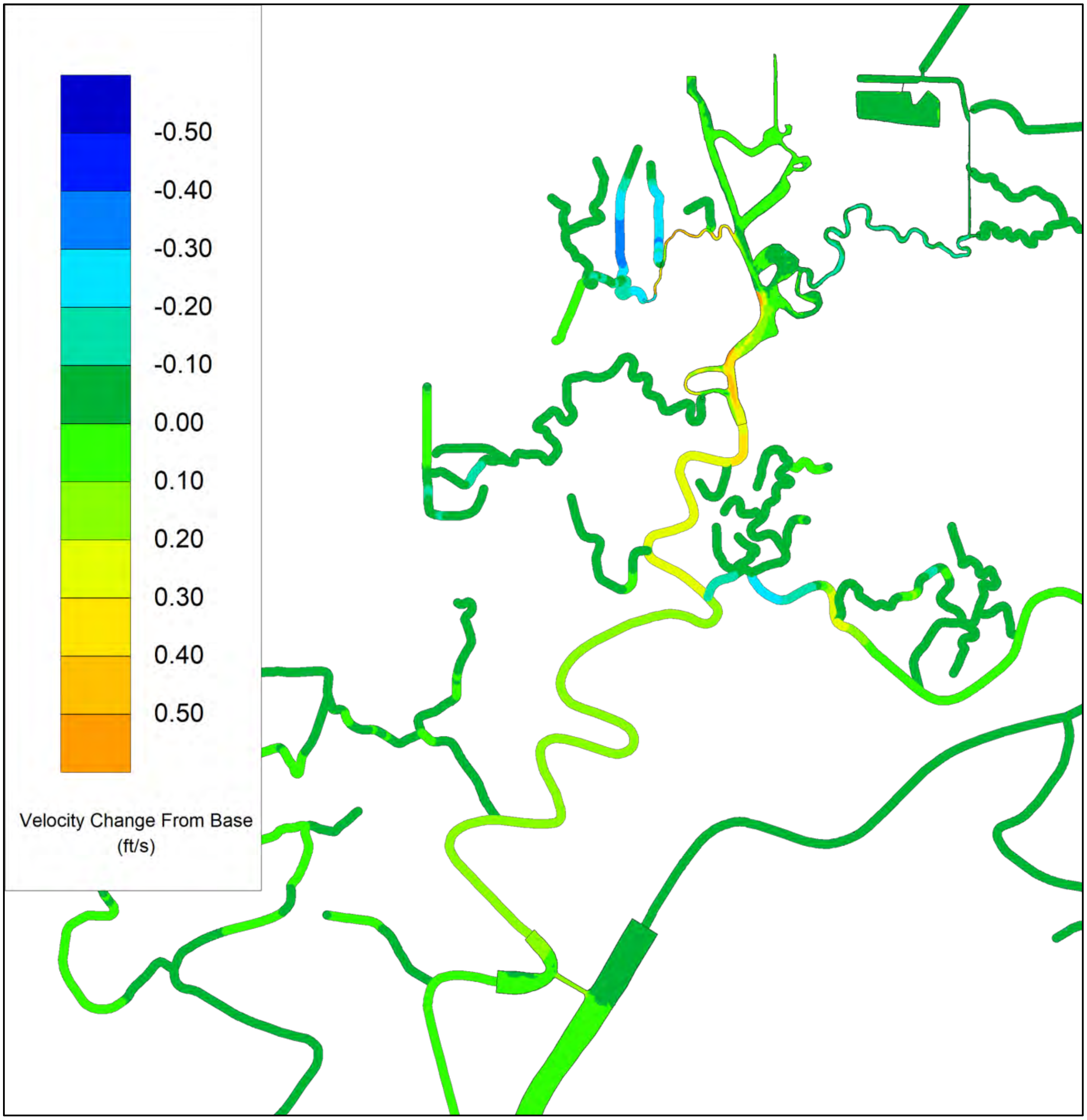

Figure 22 Wings Landing restoration case, change from Base peak modeled velocities in Suisun Slough region during July 2013 (note different contour scale).

Figure 23 Velocity time series plot locations.

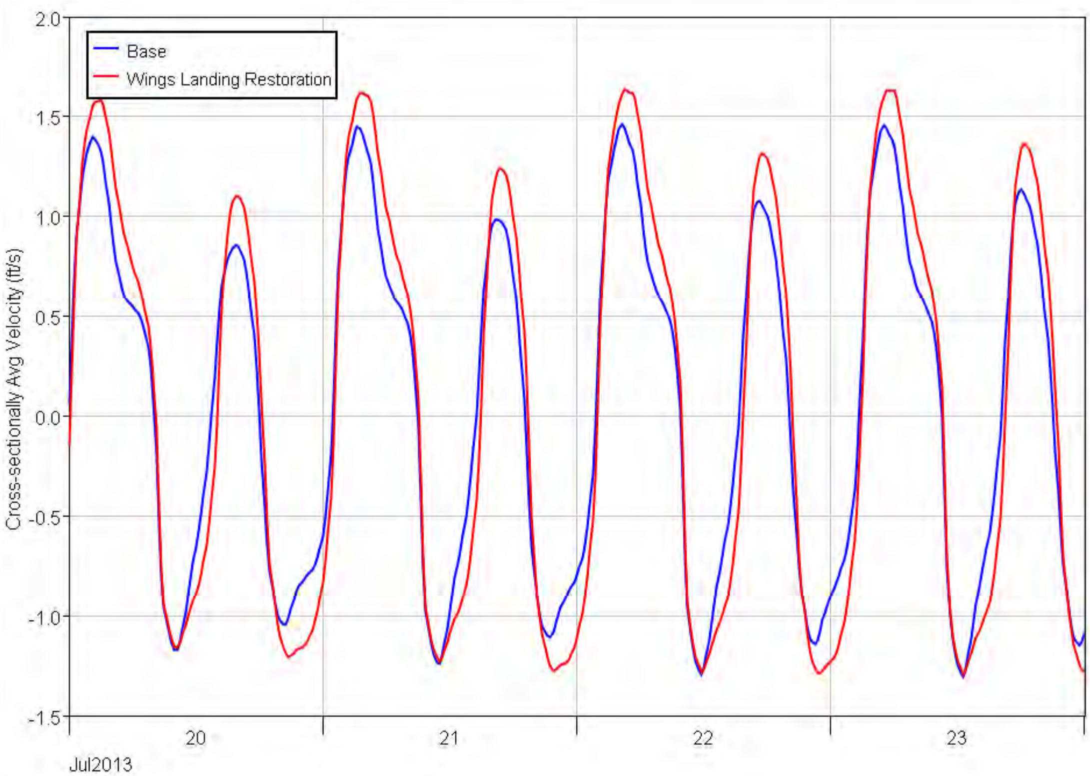

Figure 24 Time Series of Base and Restoration case modeled velocities in Suisun Slough, landward of Breach 1 during July 2013 (ebb is positive).

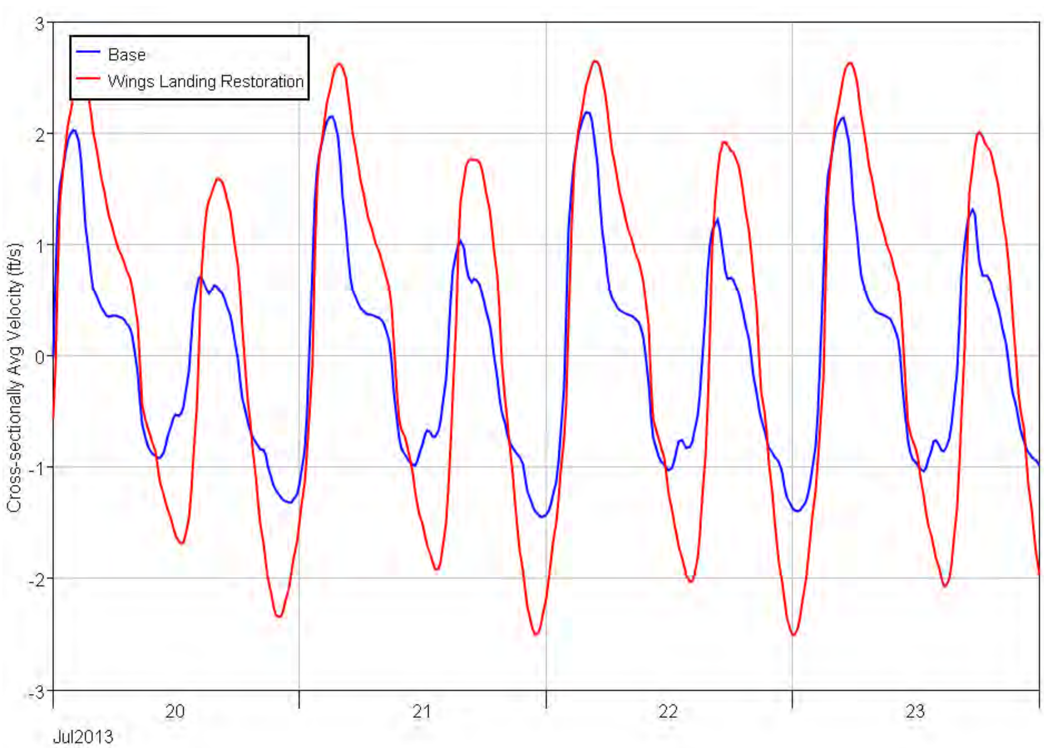

Figure 25 Time series of Base and Restoration case modeled velocities in Peytonia Slough, seaward of Breach 3 during July 2013 (ebb is positive).

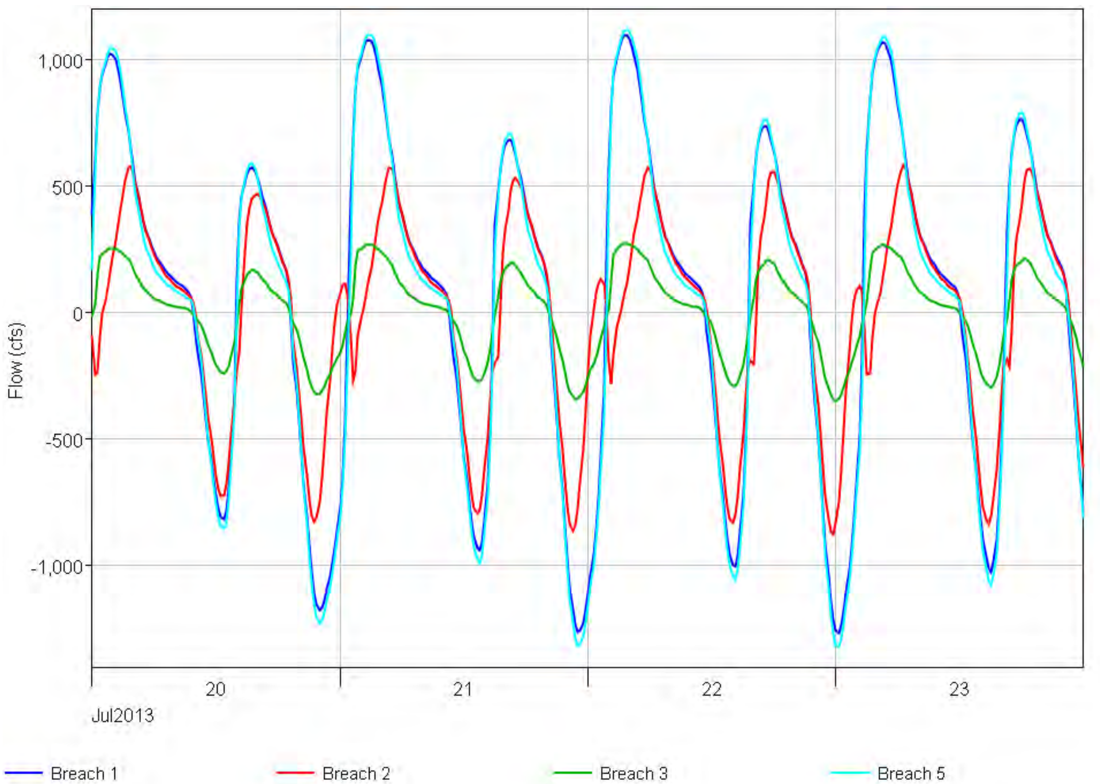

Figure 26 Time series of modeled external Breach flows during July 2013 (ebb is positive).

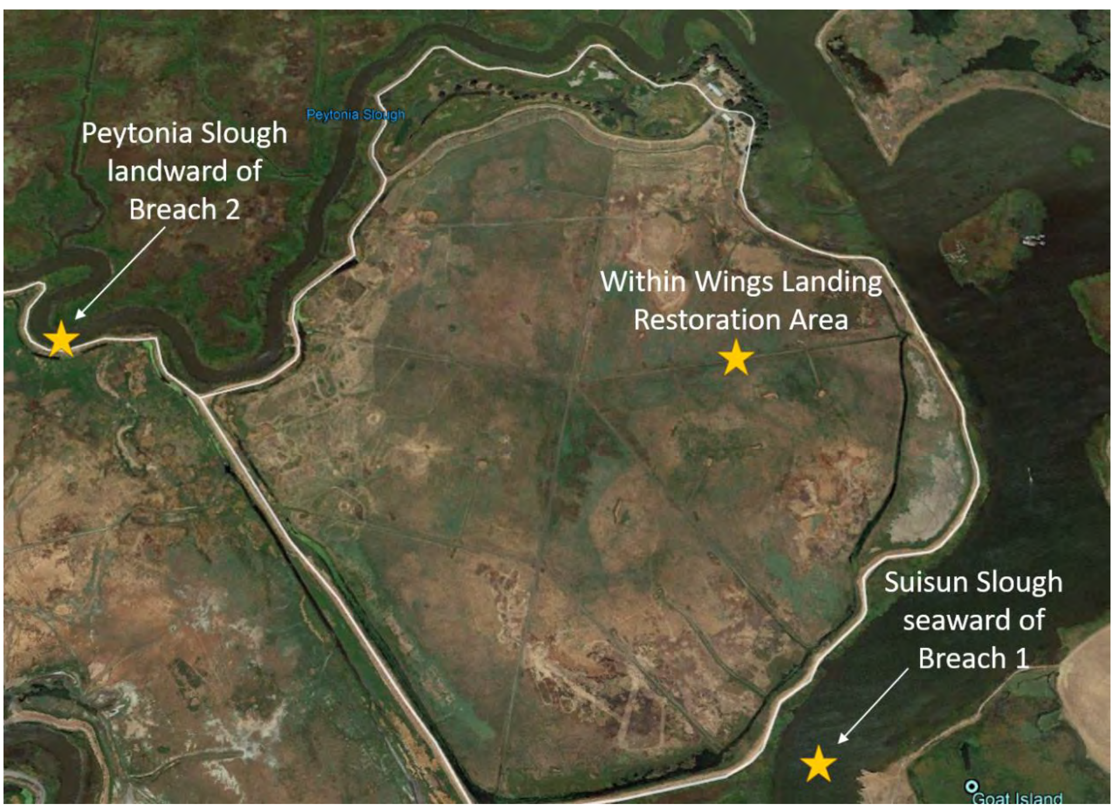

Figure 27 Stage time series plot locations.

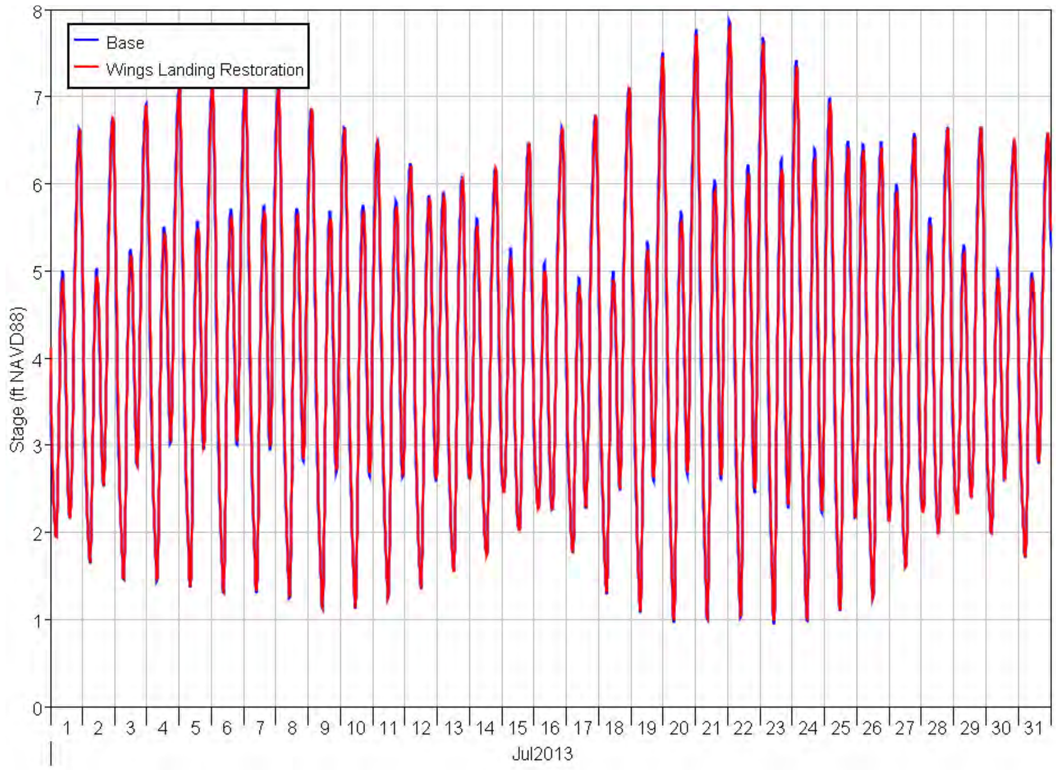

Figure 28 July 2013 time series of Base and Restoration case modeled stage in Suisun Slough, seaward of Breach 1.

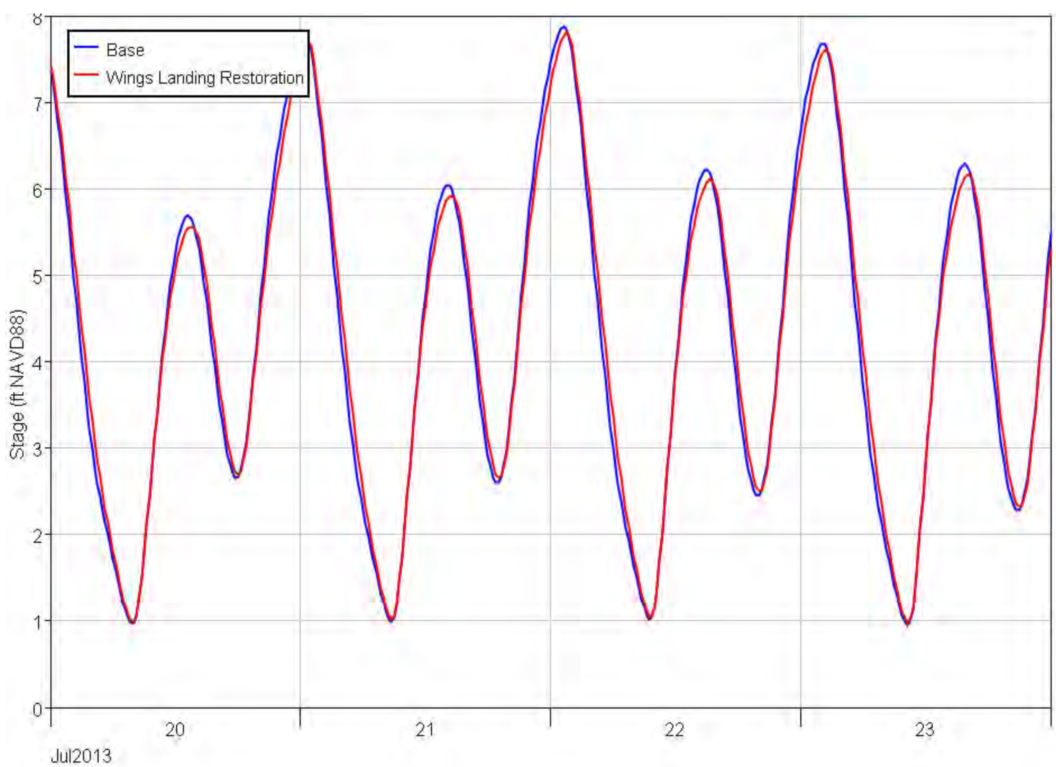

Figure 29 Time series of Base and Restoration case modeled stage in Suisun Slough, seaward of Breach 1, during July 2013 spring tide.

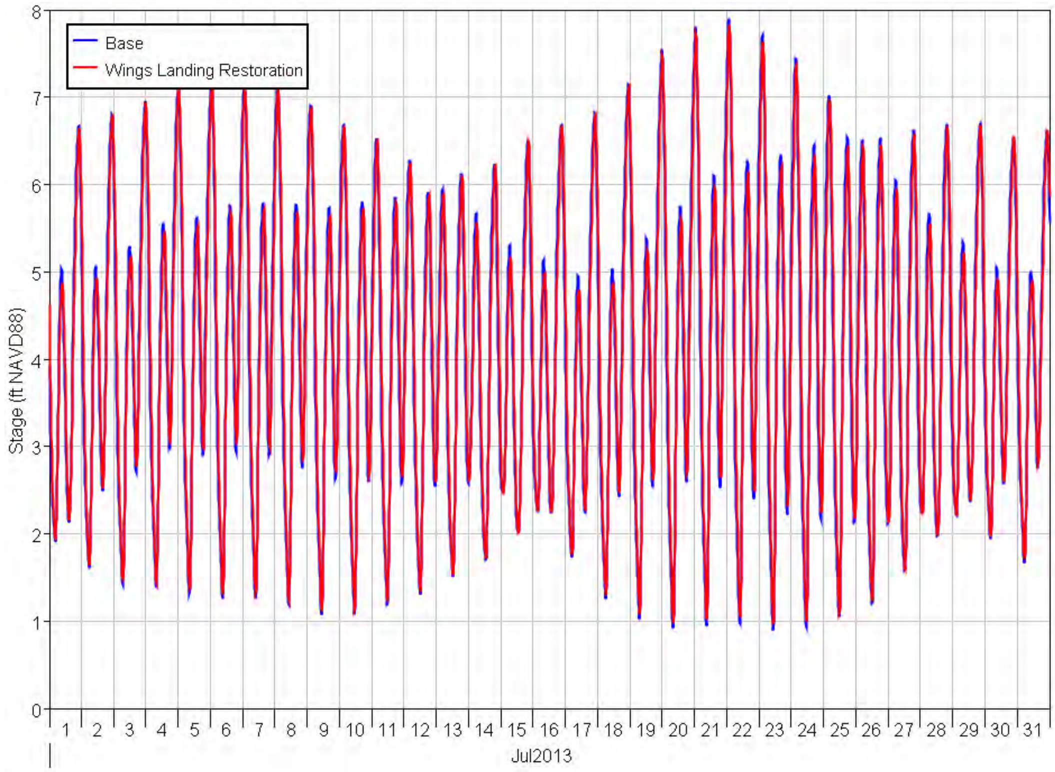

Figure 30 July 2013 time series of Base and Restoration case modeled stage in Peytonia Slough, landward of Breach 2.

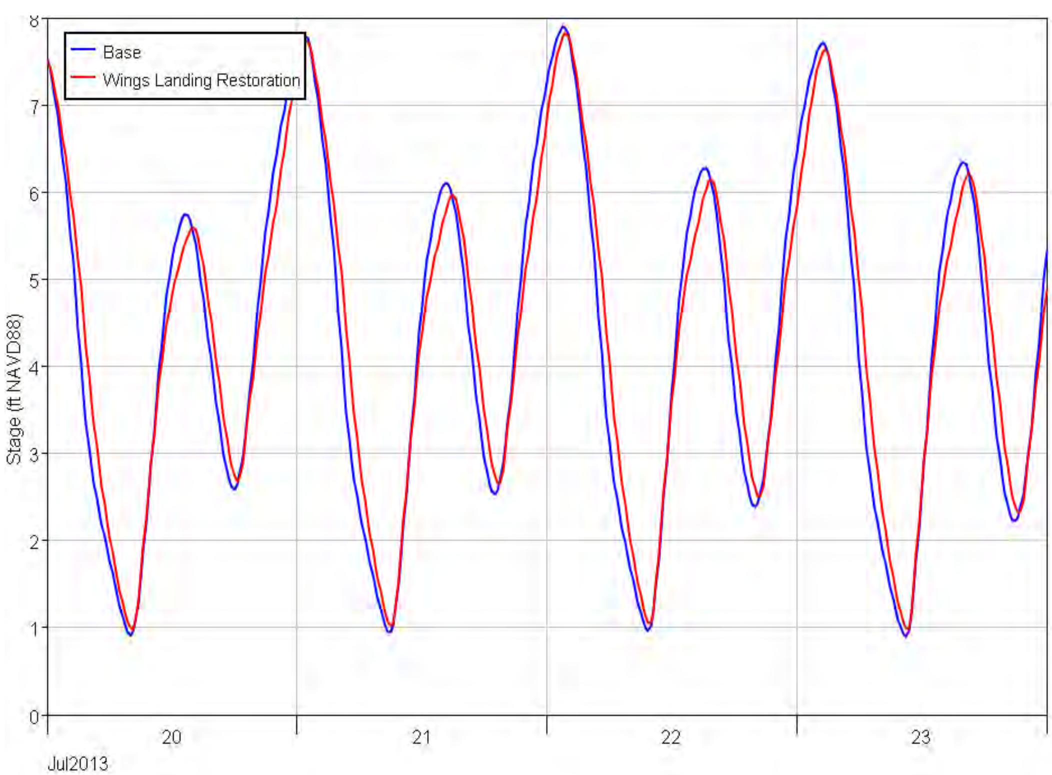

Figure 31 Time series of Base and Restoration case modeled stage in Peytonia Slough, landward of Breach 2, during July 2013 spring tide.

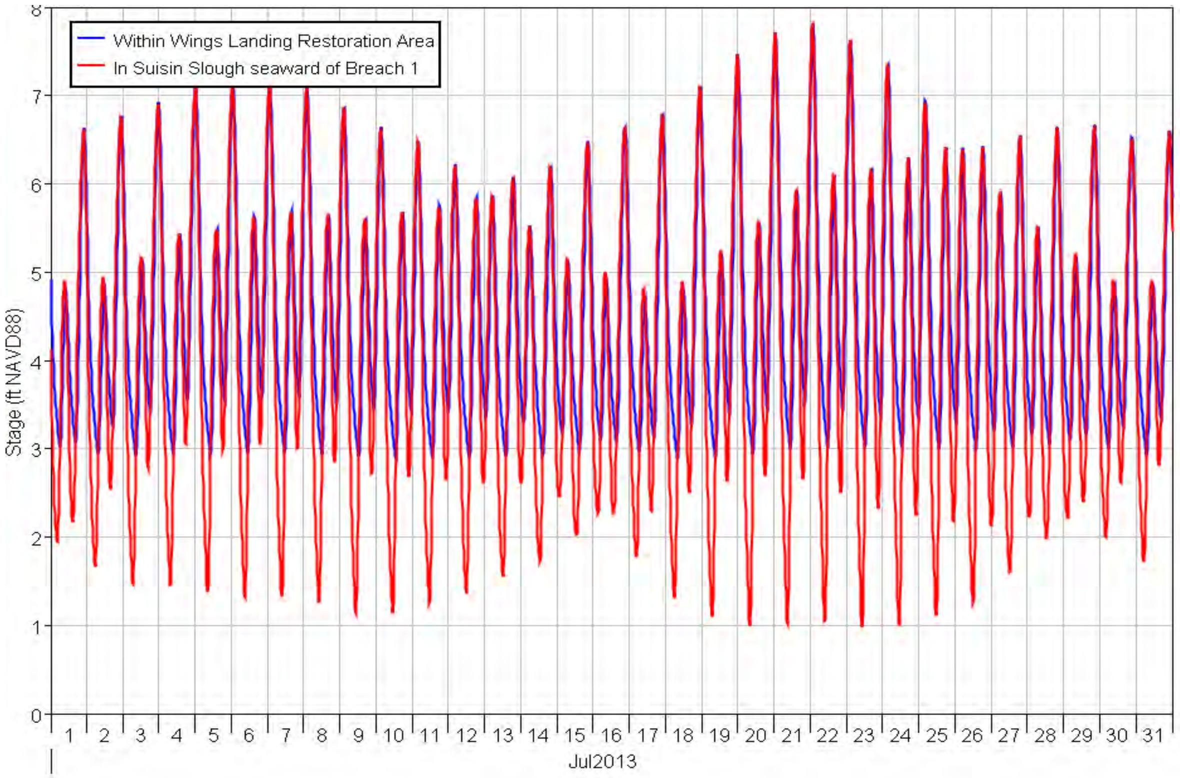

Figure 32 July 2013 time series of Restoration modeled stage in Wings Landing and in Suisun Slough.

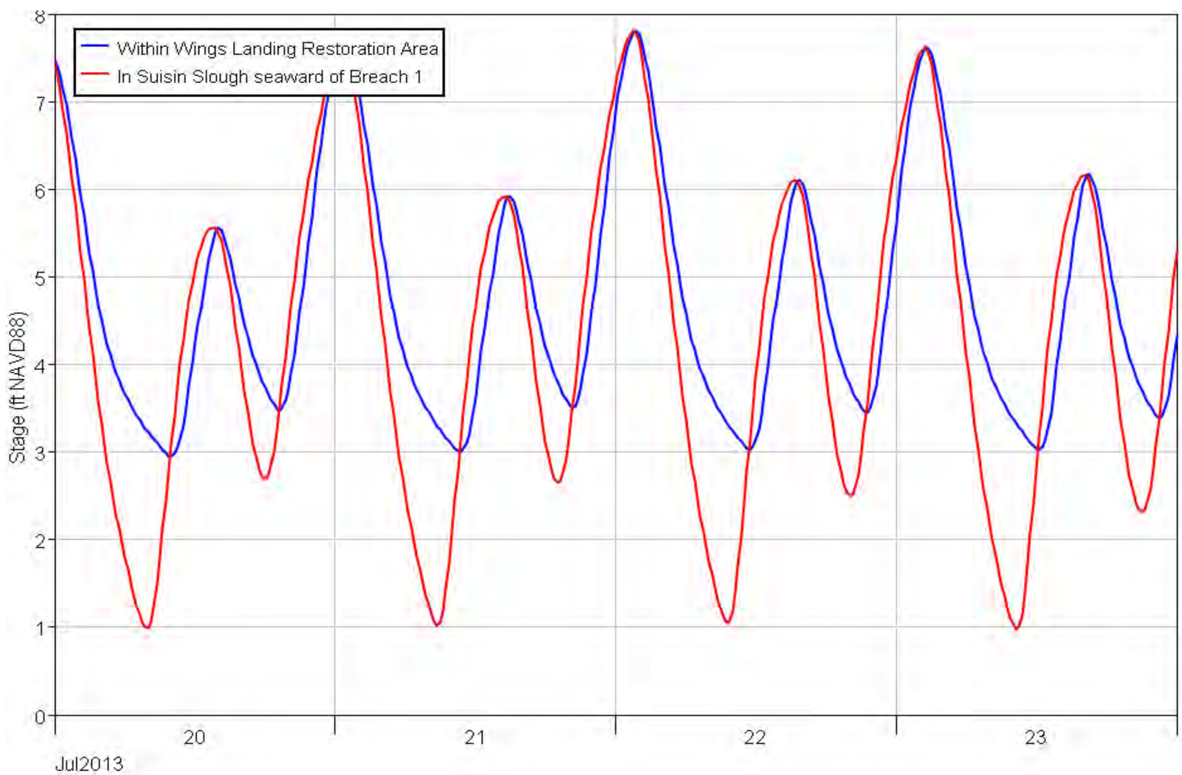

Figure 33 Time series of Restoration case modeled stage in Wings Landing and in Suisun Slough, during July 2013 spring tide.

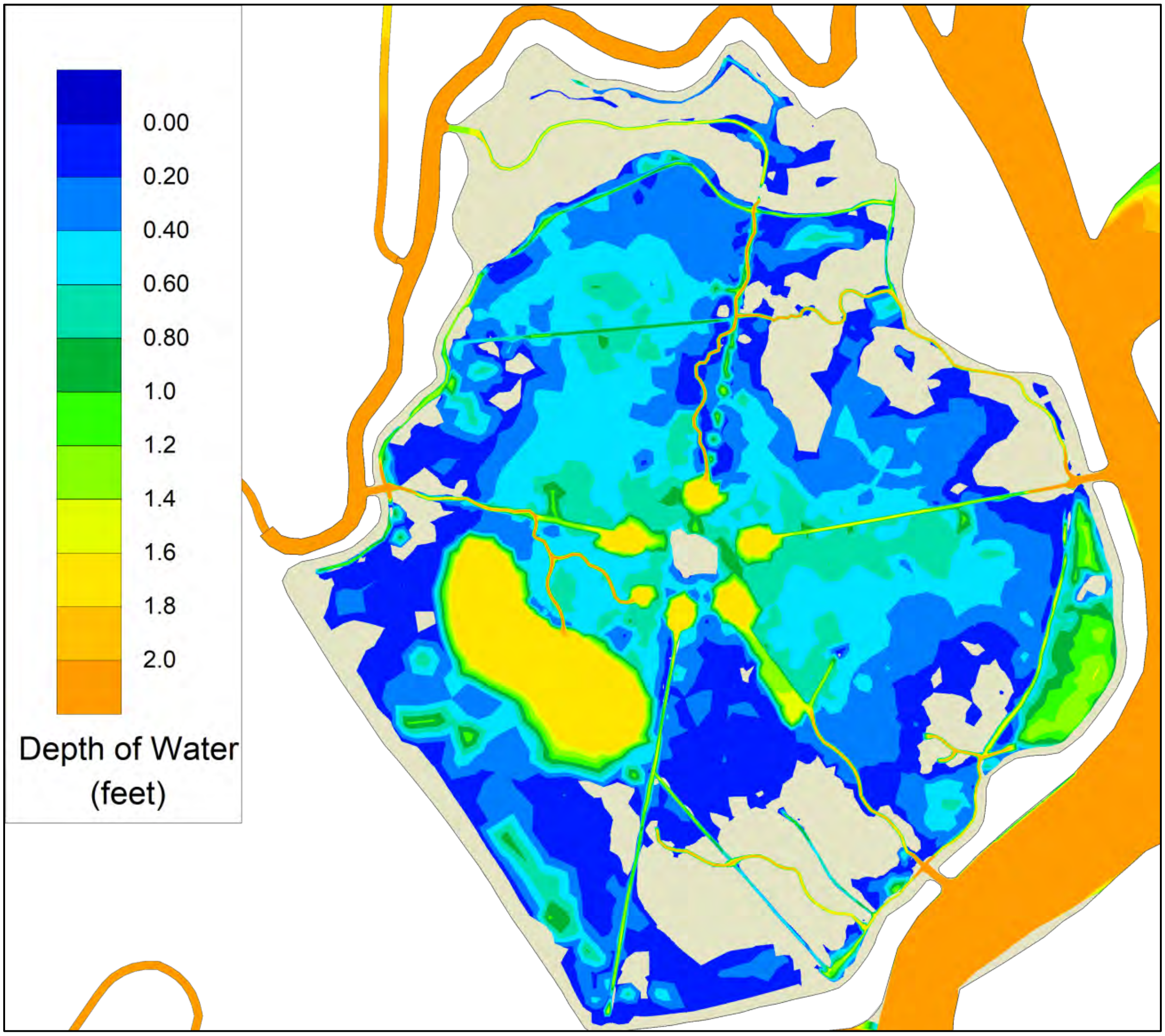

Figure 34 Modeled depth of water in Wings Landing on July 23, 2013 at lower low water. Exposed marsh plain shown in beige. The water surface elevation inside Wings Landing at this time is approximately 3 ft NAVD88.

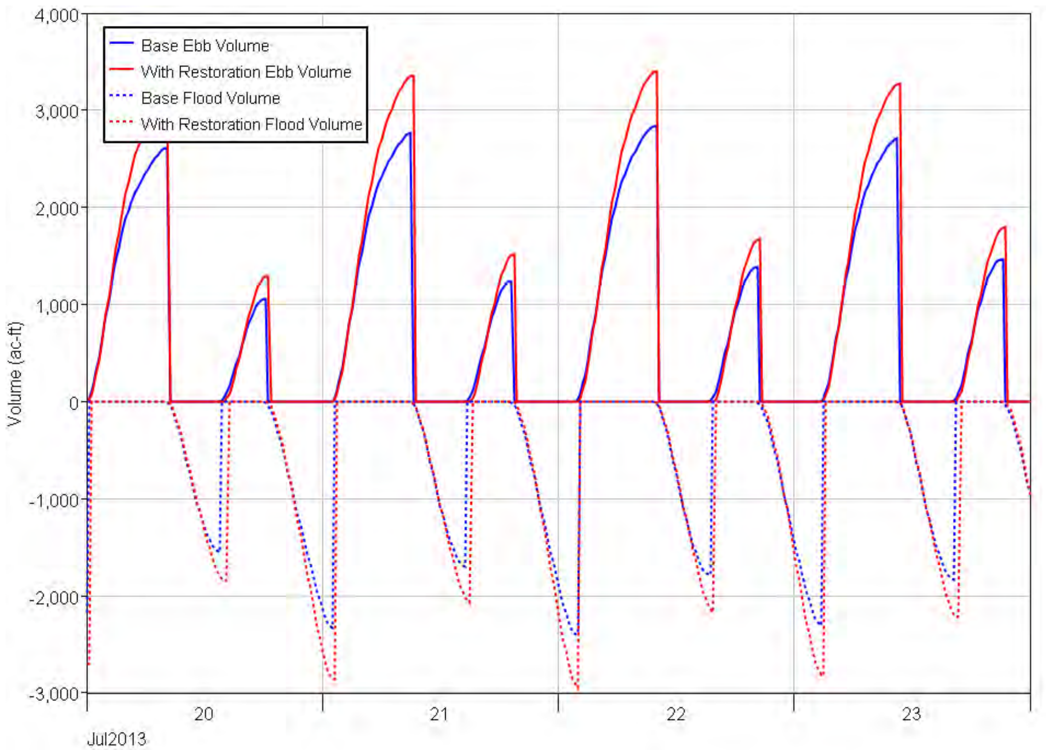

Figure 35 Modeled ebb and flood volume for Base and Restoration case simulations in Suisun Slough landward of Breach 1, during July 2013.

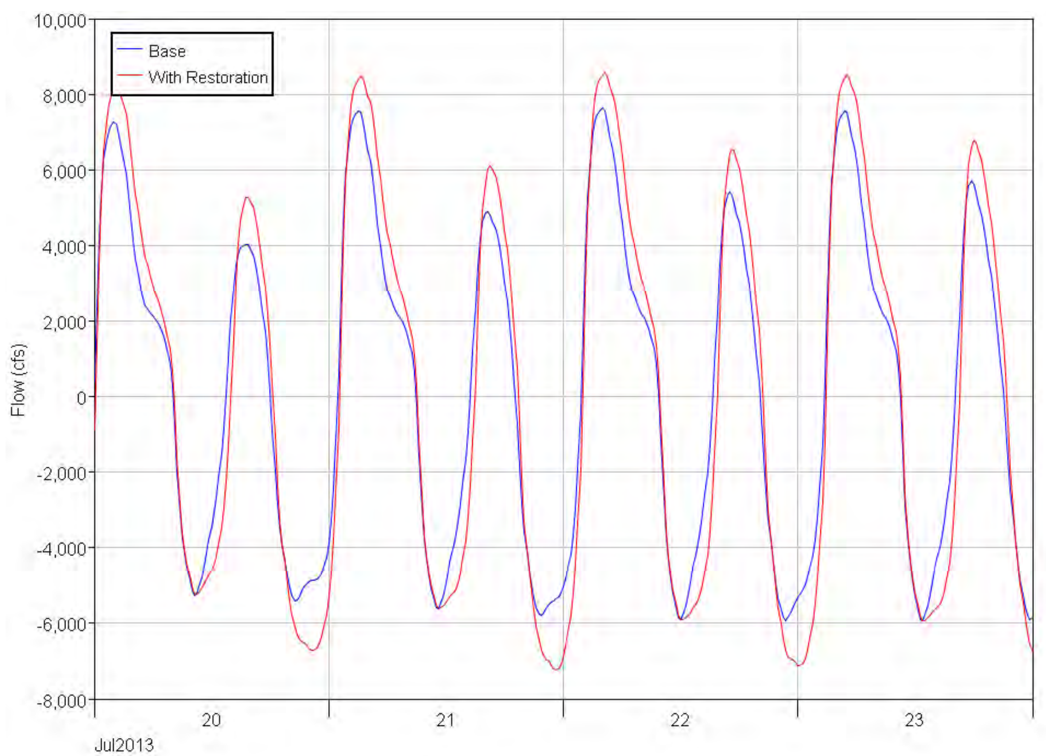

Figure 36 Modeled Base and Restoration case flows in Suisun Slough landward of Breach 1, during July 2013.

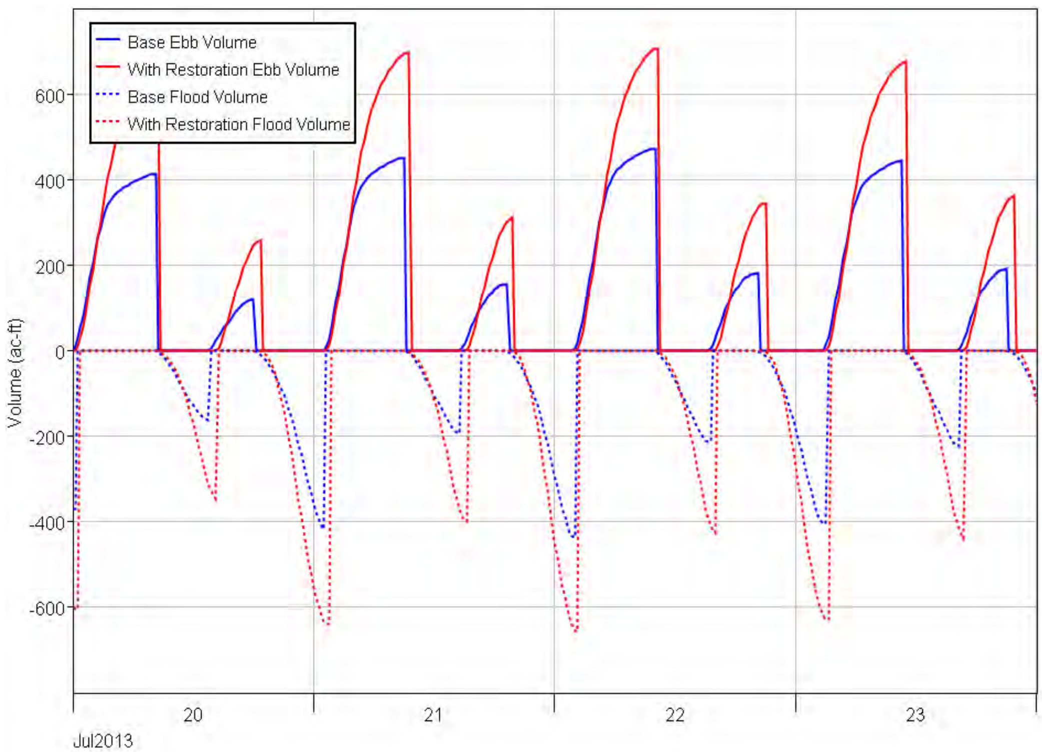

Figure 37 Modeled ebb and flood volume for Base and Restoration case simulations in Peytonia Slough seaward of Breach 3, during July 2013.

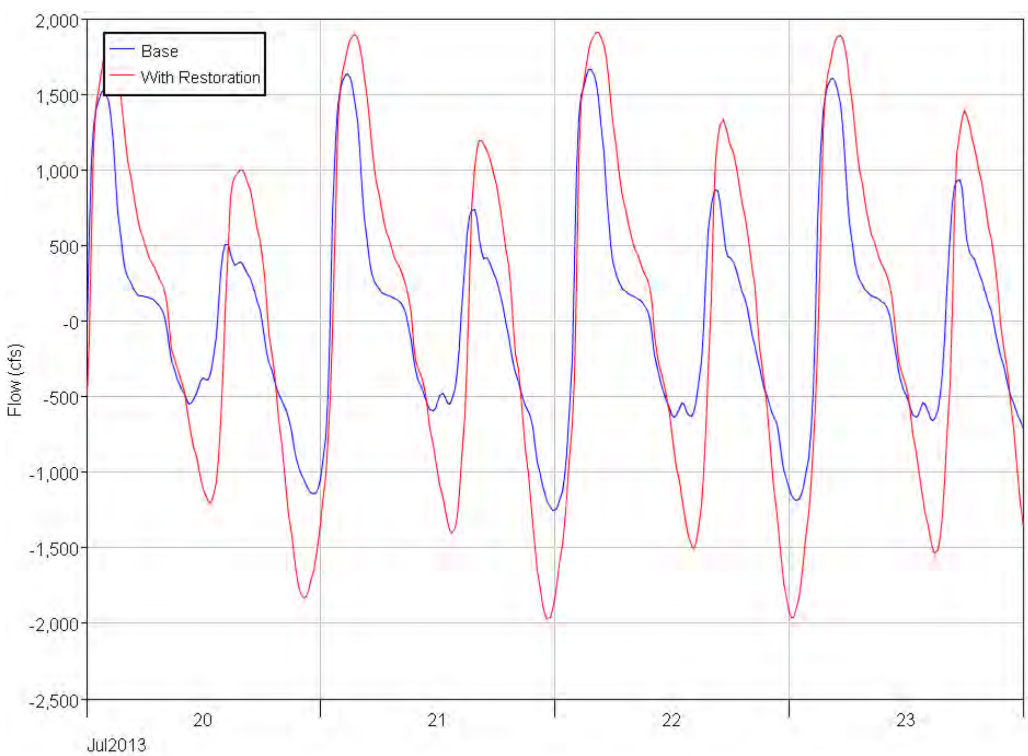

Figure 38 Base and Restoration case modeled flows in Peytonia Slough seaward of Breach 3, during July 2013.

Particle Track Modeling

Particle tracking simulations were performed for July 1 – July 29, 2013 to assess exposure time in Wings Landing and travel time out of Suisun Marsh. One thousand particles were dropped every 2 hours within the restoration area for the first 14 days of the simulation. Particle drop locations are shown in Figure 39. Any particles dropped in dry areas were removed from the simulation.

Particle exposure time in the restoration area was tracked. Exposure time is the total time a particle spends in the restoration site. If a particle moves out and back into the site, the times spent within the site are summed. Particles reaching Suisun marsh were inventoried and removed from the simulation.

Particle Track Modeling Results

A distribution of Wings Landing particle exposure time at the end of the 28-day simulation is plotted in Figure 40. The average particle exposure time to Wings Landing was 7.6 days. Twenty-one percent of the particles exited the restoration site within one day.

Particle distribution after 14 days of simulation is shown in Figure 41, with particles colored by age. Particle "kill lines" are shown, where particles are inventoried and removed from the simulation upon existing Suisun Marsh. The average particle travel time to exit Suisun Marsh was 10.8 days, with 64% of all particles exiting by the end of the 28-day simulation.

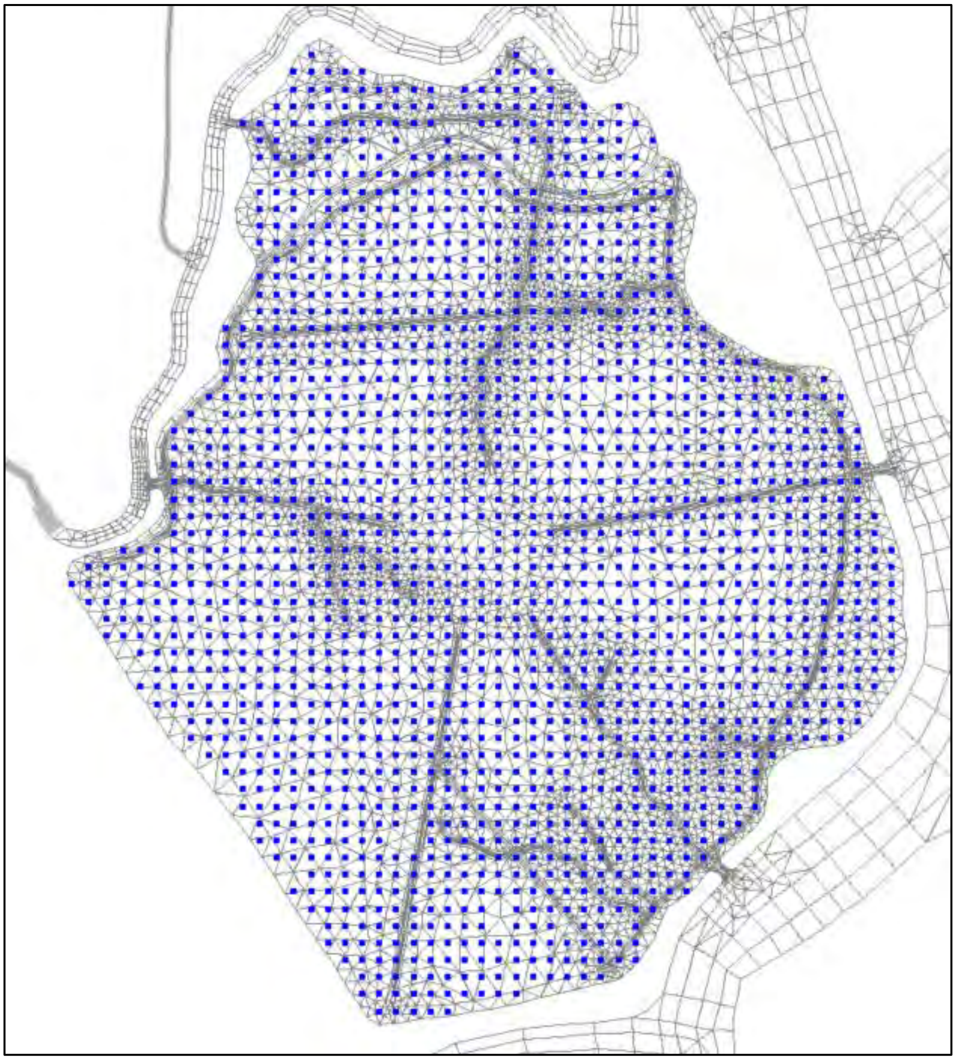

Figure 39 Wings Landing particle drop locations.

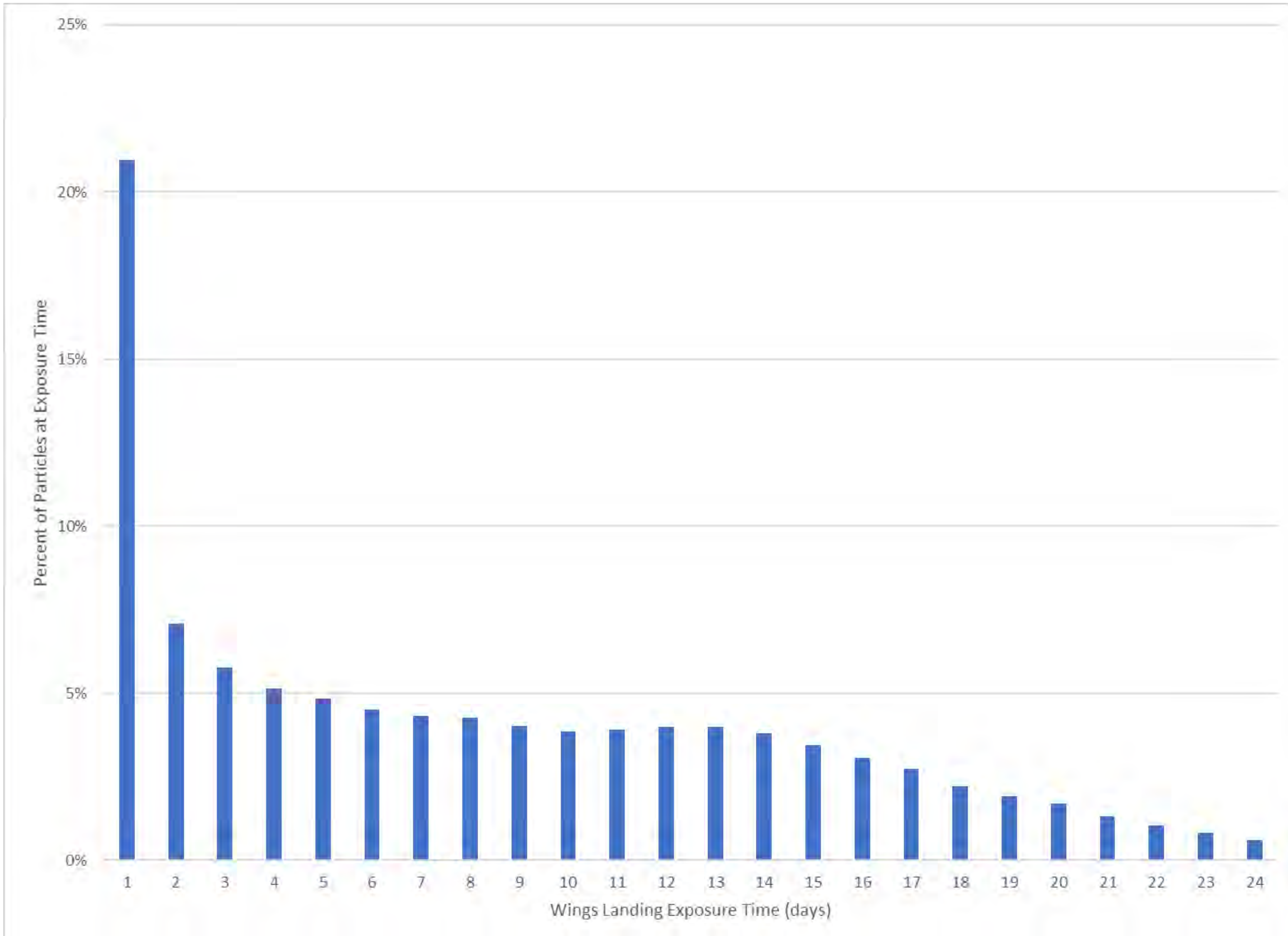

Figure 40 Distribution of Wings Landing particle exposure time.

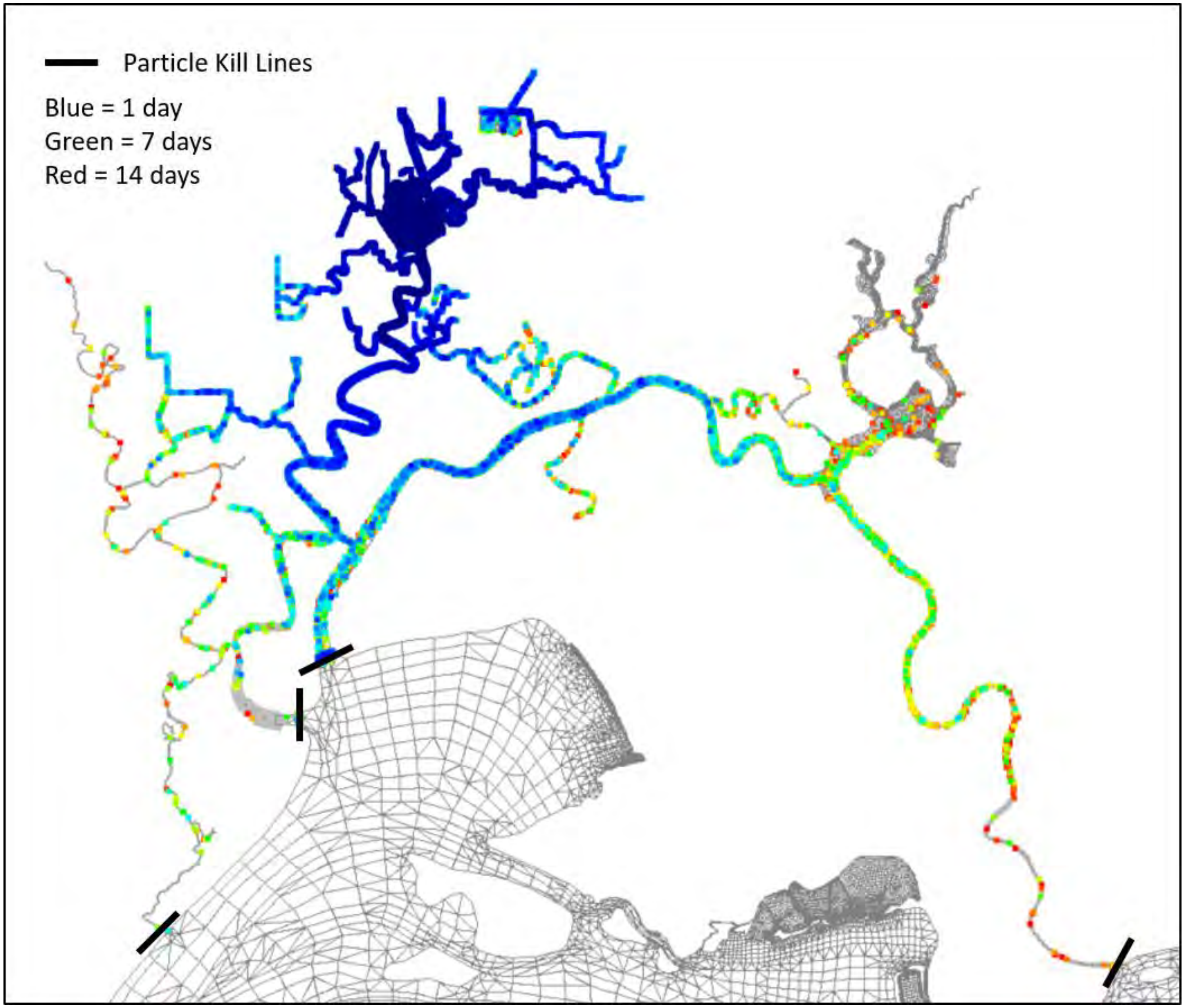

Figure 41 Particle distribution after 14 days.

Residence Time Modeling

Residence time simulations were performed for July 2013 to assess the average amount of time water has spent within the Wings Landing restoration site. The model was spun up for January – June 2013 to assure equilibrium conditions for the July analysis. These simulations utilized a water quality simulation with a volumetric tracer applied within Wings Landing, with results interpreted as average days of residence time.

Residence Time Modeling Results

Residence time results illustrate water volume exchange within the site. Figure 42 shows a color contour plot of daily average residence time on July 17, 2013, the time of peak residence time in Wings Landing during July. The plot indicates the lowest residence times (greatest water volume exchange) occur near Breaches 1 and 5 and highest residence times occur near the center of the site, furthest from all exterior breaches. Residence time in Wings Landing is approximately 3 days.

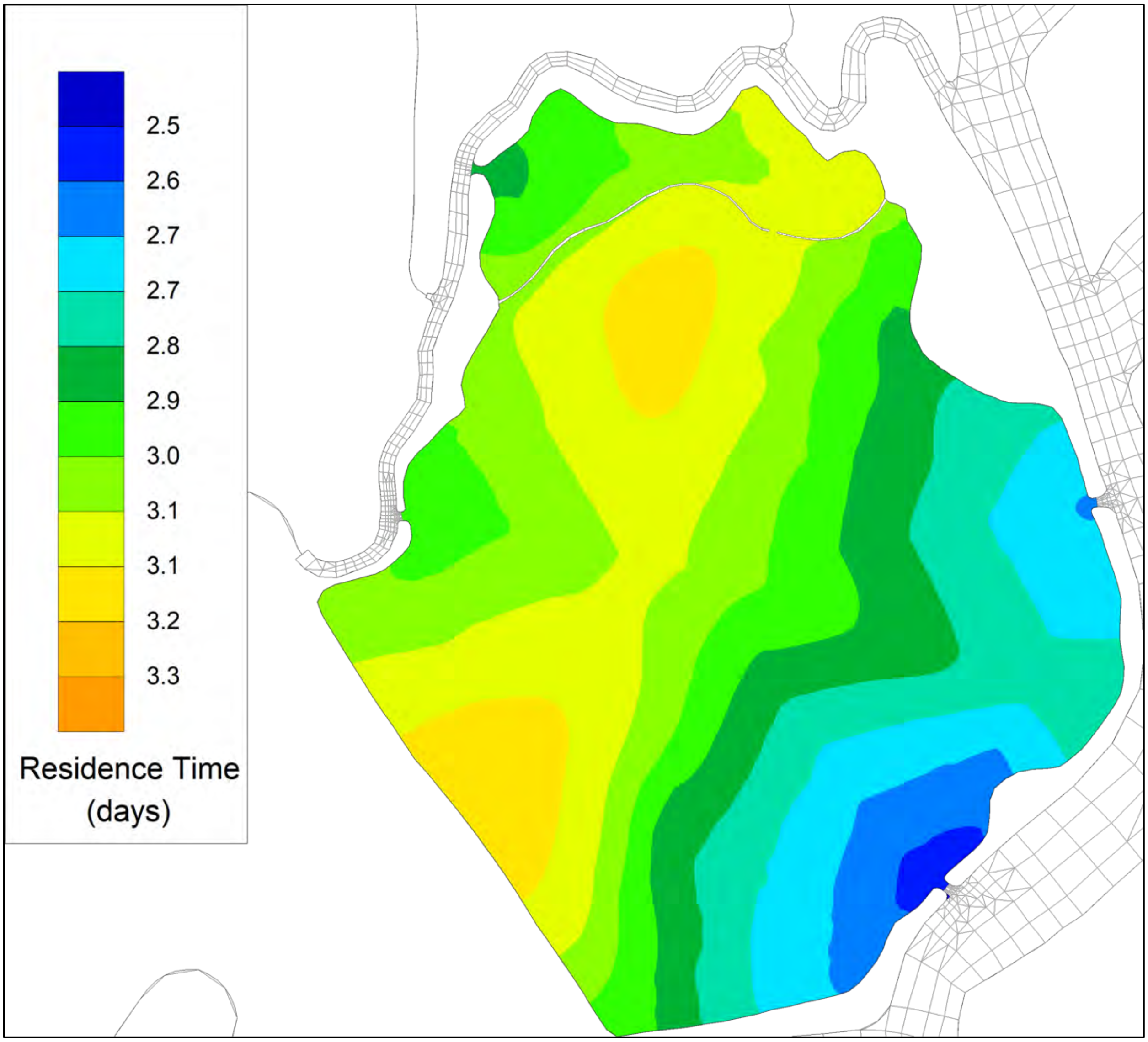

Figure 42 Daily average residence time in Wings Landing on July 17, 2013.

Modeled EC Effects

EC simulations were performed for the 2013 period to assess the potential effects of the Wings Landing restoration project on local and regional EC. April through December results are considered for analysis, leaving January through March for model spin-up.

Using September EC model results for illustration, monthly average Restoration EC percent change from modeled Base EC was computed throughout the model network. In Figure 43, color contours are displayed so that EC increases are shades of red and decreases are shades of blue. The September monthly averaged model results show salinity decreases in the Delta (around 0.4 – 0.5% near the exports) and salinity increases in Suisun Marsh. The largest increases (around 2%) occur in the northwestern marsh in the vicinity of Wings Landing. An expanded plot of Suisun Marsh is shown in Figure 44.

Tidally averaged Base and Restoration modeled EC time series for April through December 2013 are plotted for Hill Slough, Boynton Slough and Volanti (see Figure 48 for locations). These plots show small salinity increases in the northwestern marsh with the Restoration in place.

Table 2 summarizes monthly average modeled Base EC, and Restoration change and percent change from Base EC at key locations (see Figure 48 for locations). In the Delta, modeled peak EC values tend to occur during November and December and the largest EC reductions and percent EC reductions occur in December (around -0.3% to -0.7% at the south Delta water export locations). At the Suisun Marsh stations, modeled EC peaks in October. The largest EC increase occurs at Hill Slough. Increases of 200 - 300 umhos/cm occur at this location during June through December, with percent increase of approximately 2 – 4%. During these months, salt is mixing into the marsh more quickly with the Wings Landing Restoration in place. The greatest reductions in modeled EC (around 50 umhos/cm) are seen at Mallard Island during October through December. The largest percent EC reductions occur at Emmaton, where the Restoration results in approximately 1% reduction between June and December.

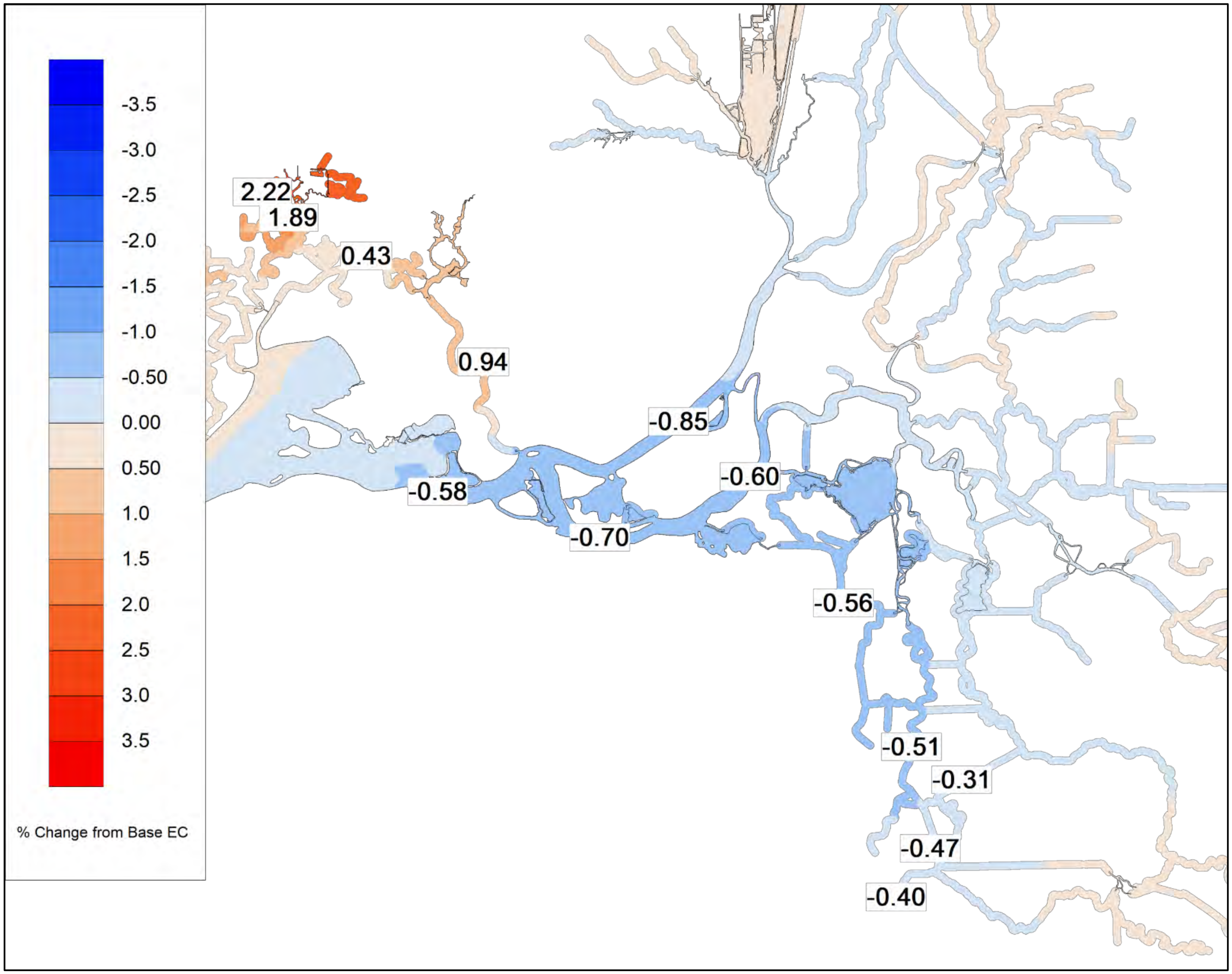

Figure 43 Average Restoration percent increase from modeled Base EC for September 2013.

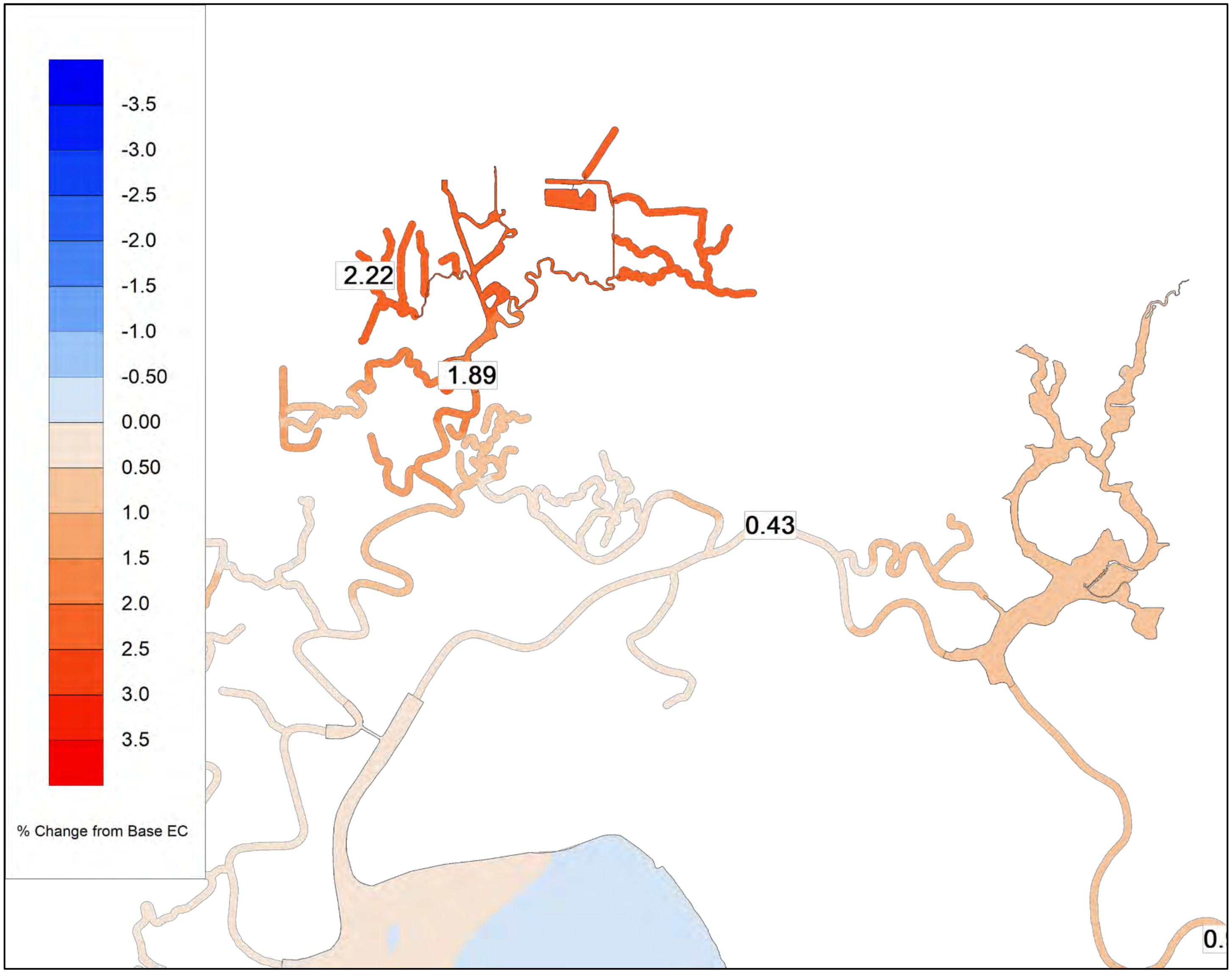

Figure 44 Average Restoration percent increase in Suisun Marsh from modeled Base EC for September 2013.

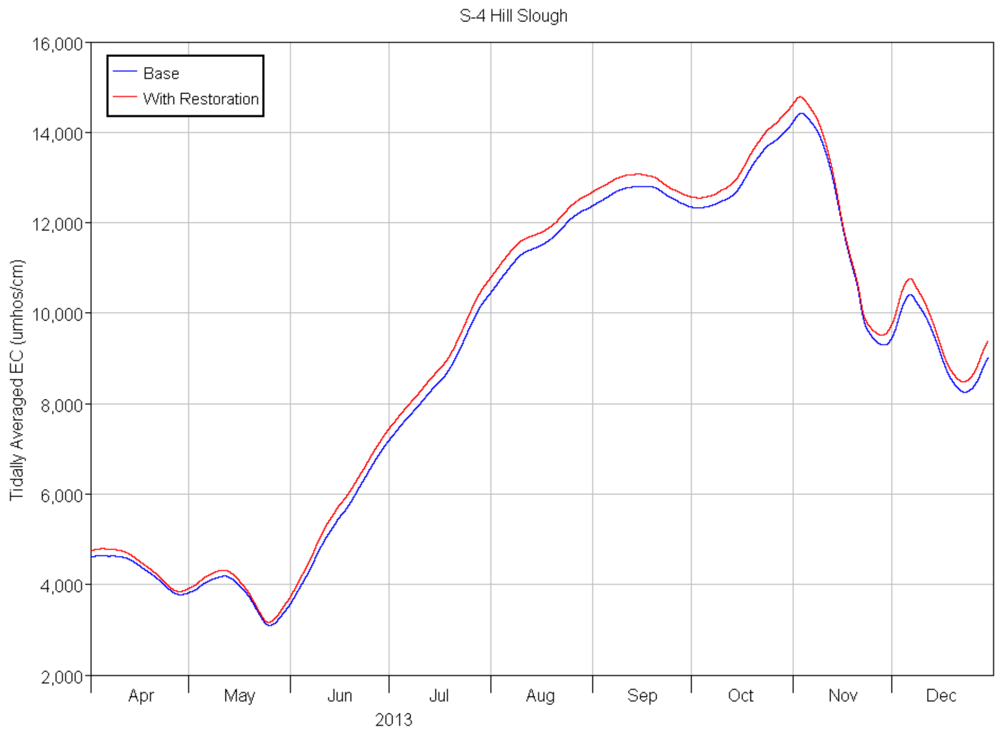

Figure 45 Modeled tidally averaged Base and Restoration EC at Hill Slough Station S-4 for April – December 2013.

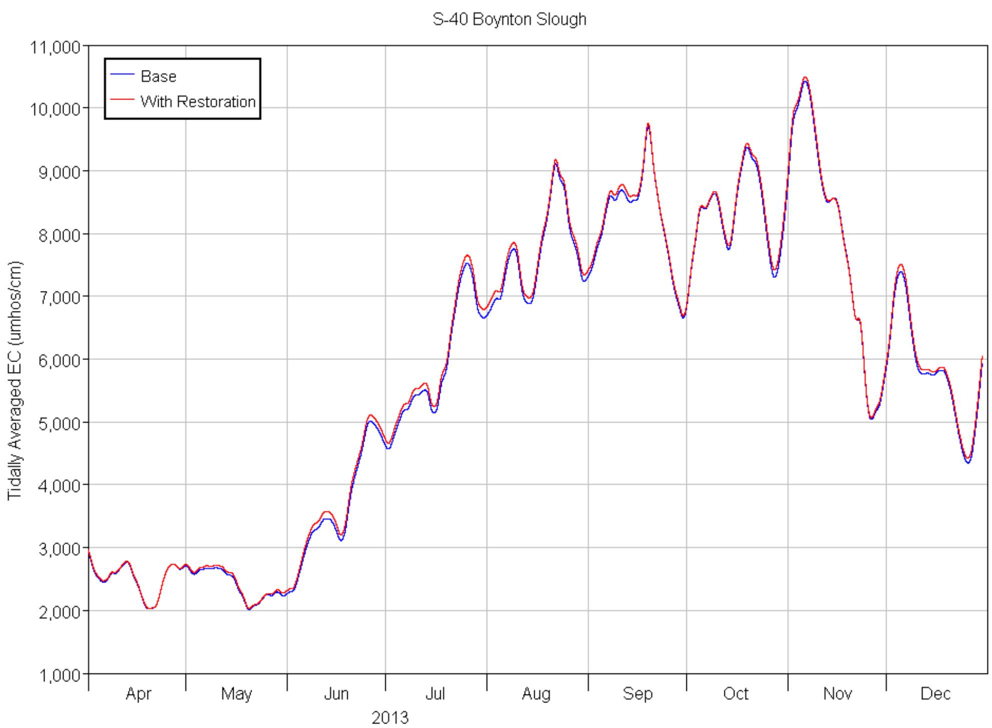

Figure 46 Modeled tidally averaged Base and Restoration EC at Boynton Slough Station S-40 for April – December 2013.

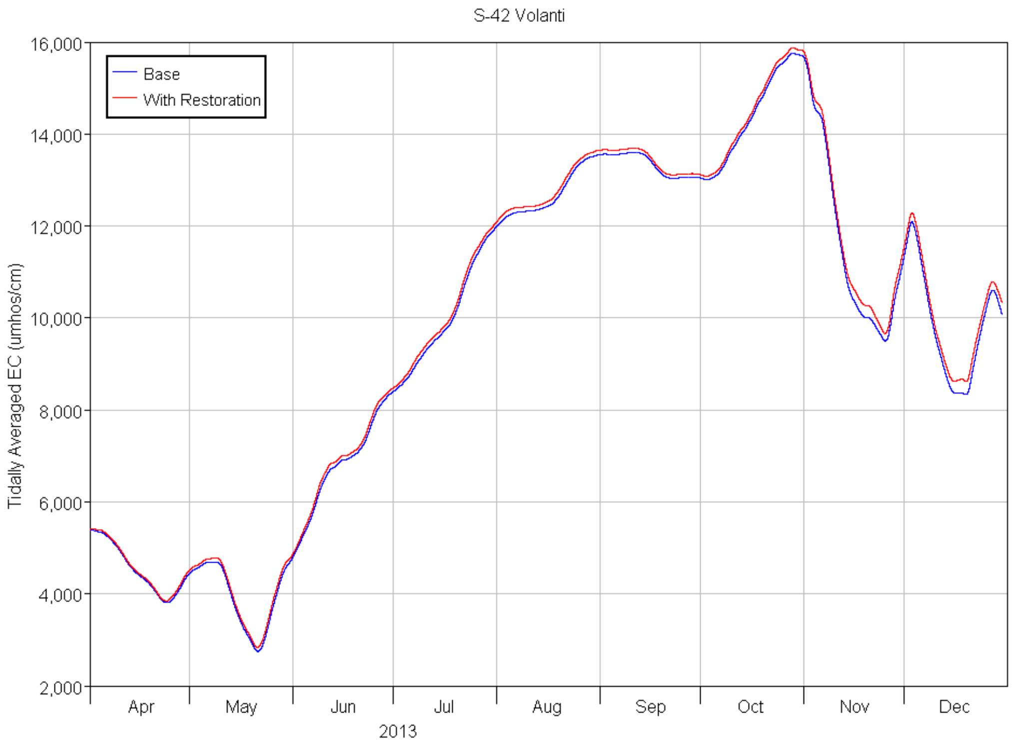

Figure 47 Modeled tidally averaged Base and Restoration EC at Volanti Station S-42 for April – December 2013.

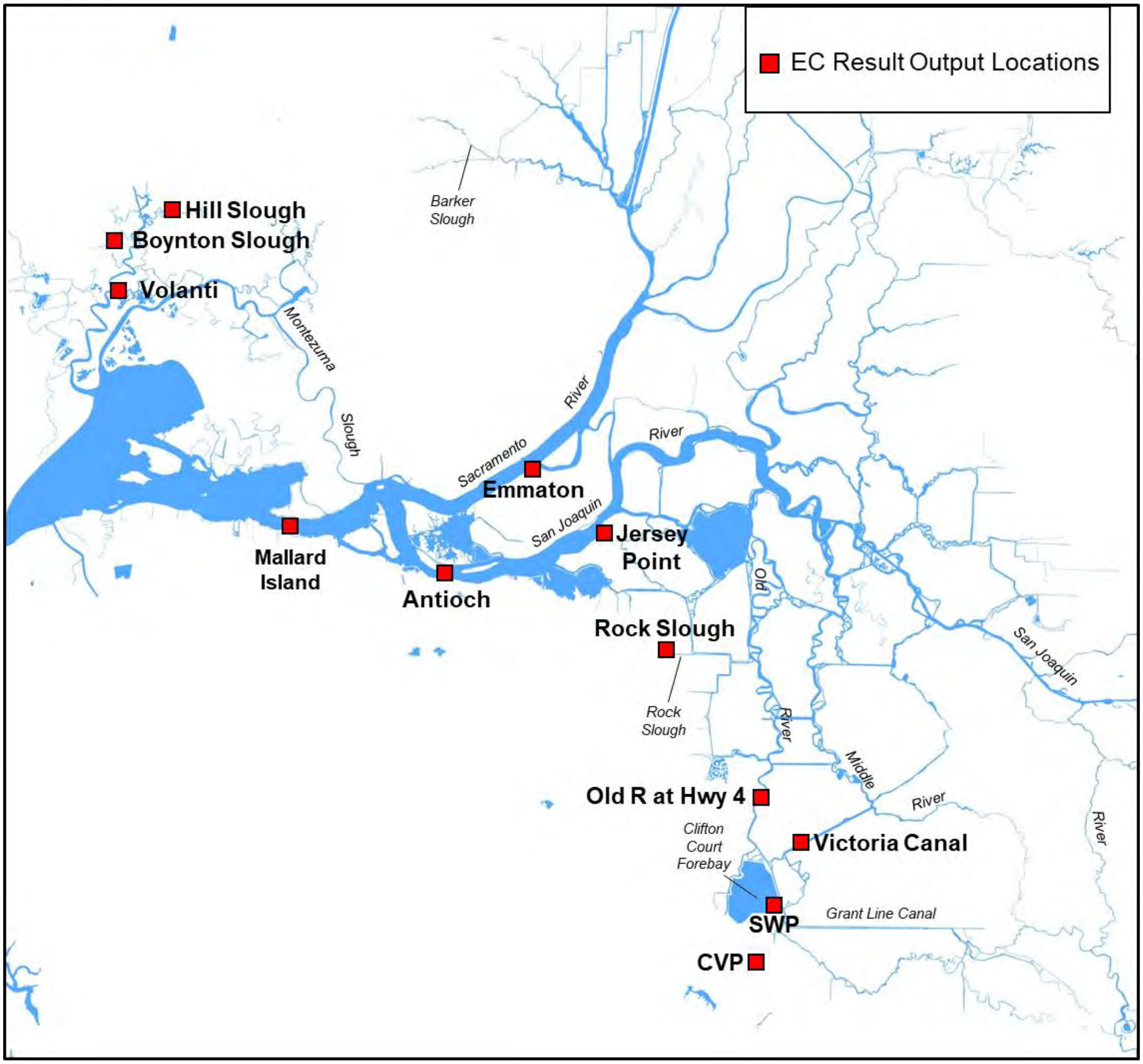

Figure 48 EC result output locations.

Table 2 Summary of 2013 monthly average modeled Base EC and modeled Restoration change and percent change from Base EC at key locations.

	S-4 Hill Slough			S-40 Boynton Slough			S-42 Volanti			Mallard Island		
	Base EC µS/cm	EC Change µS/cm	EC % Change	Base EC µS/cm	EC Change µS/cm	EC % Change	Base EC µS/cm	EC Change µS/cm	EC % Change	Base EC µS/cm	EC Change µS/cm	EC % Change
Apr 2013	4308	107	2.5%	2508	12	0.5%	4548	40	0.9%	1842	-14	-0.8%
May 2013	3739	105	2.8%	2408	31	1.3%	3974	88	2.2%	3222	-24	-0.7%
Jun 2013	5453	240	4.4%	3639	89	2.5%	6799	101	1.5%	4838	-31	-0.6%
Jul 2013	8666	286	3.3%	5901	105	1.8%	10010	113	1.1%	7100	-39	-0.5%
Aug 2013	11535	300	2.6%	7648	95	1.2%	12689	105	0.8%	8160	-43	-0.5%
Sep 2013	12631	255	2.0%	8197	59	0.7%	13335	82	0.6%	7660	-43	-0.6%
Oct 2013	13043	297	2.3%	8282	66	0.8%	14396	103	0.7%	10161	-48	-0.5%
Nov 2013	11914	195	1.6%	7925	39	0.5%	11606	199	1.7%	11553	-55	-0.5%
Dec 2013	9235	279	3.0%	5815	81	1.4%	9870	228	2.3%	10672	-56	-0.5%

	Emmaton			Antioch			Jersey Pt			Rock Slough		
	Base EC µS/cm	EC Change µS/cm	EC % Change	Base EC µS/cm	EC Change µS/cm	EC % Change	Base EC µS/cm	EC Change µS/cm	EC % Change	Base EC µS/cm	EC Change µS/cm	EC % Change
Apr 2013	218	-1	-0.2%	394	-2	-0.6%	248	0	-0.1%	352	0	0.0%
May 2013	269	-1	-0.5%	622	-5	-0.8%	276	-1	-0.3%	357	0	0.0%
Jun 2013	399	-3	-0.8%	1086	-9	-0.9%	362	-2	-0.5%	313	0	-0.1%
Jul 2013	516	-5	-1.0%	2079	-16	-0.8%	756	-5	-0.7%	355	-2	-0.4%
Aug 2013	574	-6	-1.1%	2671	-19	-0.7%	1127	-7	-0.7%	557	-3	-0.6%
Sep 2013	631	-6	-1.0%	2335	-17	-0.7%	997	-6	-0.6%	658	-4	-0.6%
Oct 2013	1271	-13	-1.0%	3130	-22	-0.7%	963	-7	-0.8%	502	-3	-0.5%
Nov 2013	1407	-14	-1.0%	3756	-27	-0.7%	1196	-10	-0.8%	569	-4	-0.7%
Dec 2013	1277	-13	-1.0%	3451	-26	-0.8%	1163	-9	-0.8%	643	-4	-0.7%

	Old River at Hwy 4			Victoria Canal			SWP			CVP		
	Base EC µS/cm	EC Change µS/cm	EC % Change	Base EC µS/cm	EC Change µS/cm	EC % Change	Base EC µS/cm	EC Change µS/cm	EC % Change	Base EC µS/cm	EC Change µS/cm	EC % Change
Apr 2013	359	0	0.0%	356	0	0.0%	493	0	0.0%	548	0	0.0%
May 2013	349	0	0.0%	362	0	0.0%	328	0	0.0%	332	0	0.0%
Jun 2013	307	0	-0.1%	305	0	0.0%	333	0	-0.1%	387	0	0.0%
Jul 2013	323	-1	-0.4%	240	0	-0.2%	298	-1	-0.4%	293	-1	-0.3%
Aug 2013	489	-3	-0.6%	292	-1	-0.3%	432	-2	-0.5%	400	-2	-0.4%
Sep 2013	552	-3	-0.5%	348	-1	-0.3%	498	-2	-0.5%	483	-2	-0.4%
Oct 2013	439	-2	-0.5%	342	-1	-0.3%	418	-2	-0.4%	434	-1	-0.3%
Nov 2013	524	-3	-0.6%	408	-2	-0.4%	506	-2	-0.5%	536	-2	-0.3%
Dec 2013	579	-4	-0.6%	464	-2	-0.5%	590	-3	-0.5%	665	-2	-0.3%

SUMMARY

The 270-acre Wings Landing Restoration project site in Suisun Marsh is being considered for tidal marsh restoration. Hydrodynamic, particle tracking, residence time and EC simulations have been performed for the dry/critically dry 2013 period to assess the potential effects of proposed Wings Landing tidal marsh restoration.

Within the Restoration site, modeled peak velocities in channels and breaches occur during ebb tide. Maximum velocities at breaches are approximately 5 ft/s, with the highest velocities occurring at Breach 1 and Breach 5. Higher velocities, up to approximately 6 ft/s, occur within the restoration site in some channels near breaches, particularly near Breach 1 and Breach 2.

A comparison between Base and Wings Landing Restoration modeled channel velocities shows that velocities increase by 2 ft/s or more in Suisun Slough near Breach 1 and Breach 5. Modeled velocities in Peytonia Slough increase by around 0.5 ft/s.

Modeling indicates that Restoration results in a small reduction in tidal range in the channels in the vicinity of Wings Landing, reducing the average higher high tide by 0.03 ft and increasing the lower low tide by 0.01 ft in Suisun Slough and reducing the average higher high tide by 0.03 ft and increasing the lower low tide by 0.04 ft in Peytonia Slough.

Higher high tide within the Restoration site matches the height of higher high tide in adjacent Suisun Slough, while lower low tide is approximately 2 ft higher inside Wings Landing compared with Suisun Slough, due to higher Wings Landing marsh plain elevation and incomplete draining of the Restoration site.

Modeling results indicate that the Wings Landing Restoration results in increases in tidal prism in the local channels. On average, tidal prism is increased by 24% in Suisun Slough and by 94% in Peytonia Slough for the modeled period.

Particle track modeling results indicate that the average particle exposure time to Wings Landing was 7.6 days, with 21% of the particles exiting the restoration site within one day. The average time for particles to travel from Wings Landing out of Suisun Marsh was 10.8 days.

Residence time simulations indicate lower residence times occurring near the breaches to Suisun Slough, with highest residence times near the center of the site. Average residence time in Wings Landing during July 2013 was approximately 3 days.

Modeled salinity effects include small EC reductions (less than 1%) in the central and south Delta, and EC increases of 2-4% in northwestern Suisun Marsh.

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APPENDIX

Model Boundary Conditions

The RMA Bay-Delta hydrodynamic model operation requires specification of the tidal stage at the Golden Gate and inflow and withdrawal rates at other external boundaries as shown in Figure 3. Water quality model operation requires specification of quality boundary conditions at the stage and inflow boundaries.

The tidal boundary was set at Golden Gate using observed 6-minute NOAA stage data and a constant EC of 50,000 umhos/cm.

Inflows include:

Sacramento River above American River
American River near Sacramento
San Joaquin River near Vernalis
Yolo Bypass and Yolo Bypass Toe Drain
Mokelumne River near Thornton
Cosumnes River
Calaveras River near Stockton
Lindsey Slough, Upper Cache and Hass Slough inflows
Napa River

Suisun Marsh flows include:

Denverton Creek
Green Valley Creek
Laurel/Soda Springs Creek
Ledgewood Creek
Suisun Creek
Fairfield wastewater treatment plant
Duck Club inflows and withdrawals
Roaring River withdrawals

Exports/Diversions include:

State Water Project (SWP), Clifton Court Forebay gates.
Central Valley Project (CVP) Tracy Pumping Plant
Contra Costa Water District (CCWD) intakes at Rock Slough, Old River and Victoria Canal
North Bay Aqueduct (NBA), Barker Slough Pumping Plant
Delta Island Consumptive Use (DICU), throughout Delta
Lindsey Slough, Upper Cache and Hass Slough diversions

The following boundary condition data sources were used:

- CDEC: http://cdec.water.ca.gov
- DWR-DAYFLOW: http://www.water.ca.gov/dayflow/
- DWR-DES (Division of Environmental Services): http://www.water.ca.gov/environmentalservices/
- DWR-DMS (Delta Modeling Section): http://baydeltaoffice.water.ca.gov/modeling/deltamodeling/
- DWR-NCRO (North Central Region Office): http://www.cd.water.ca.gov/

- DWR-WDL (Water Data Library): http://www.water.ca.gov/waterdatalibrary/
- SCWA (Solano County Water Agency): http://www.scwa2.com/
- USGS-NWIS (National Water Information System): http://waterdata.usgs.gov/nwis
- NOAA (National Oceanic and Atmospheric Administration): http://tidesandcurrents.noaa.gov/map/

DICU flows are applied on a monthly average basis for all simulation periods. These flows incorporate channel depletions, infiltration, evaporation, and precipitation, as well as Delta island agricultural use. DICU flow and EC values and were derived from monthly DSM2 input values (DWR, 1995).

Gate and barrier operations are also included in the model. Permanent gates and temporary barriers represented in the model include the Delta Cross Channel, Old River near Tracy (DMC) barrier, Old River at Head barrier, Middle River barrier, Montezuma Slough salinity control gates and Grant Line Canal barrier. The historical operation schedules for these structures are available over the Web.

Delta Cross Channel gates:
http://www.usbr.gov/mp/cvo/vungvari/Ccgates.pdf

Suisun Marsh Salinity Control Gates:
http://www.water.ca.gov/suisun/docs/histsmscgopnew.pdf

South Delta Temporary Barriers

- Old River near Tracy (DMC) temporary barrier
- Old River at Head temporary barrier
- Middle River temporary barrier
- Grant Line Canal temporary barrier

http://baydeltaoffice.water.ca.gov/sdb/tbp/web_pg/tempbar/weekly.cfm

2013 Boundary Conditions

Hydrodynamic and water quality models were run for the January – November 2013 period. January – April were used for model spin-up and May through November was used for EC effects analysis. This period includes dry and critically dry conditions (see http://cdec.water.ca.gov/cgi-progs/iodir/wsihist).

Tide

The Golden Gate tidal boundary stage shown in Figure 49 was set using 6-minute NOAA tide data at San Francisco. The vertical datum is NAVD88. The data were smoothed using a Butterworth filter and shifted upward by 0.46 ft to account for density effects.

Inflows

Time series of daily average inflow boundary conditions are plotted in Figure 50 to Figure 52 for the 2013 simulation period. These flows are applied for the Sacramento River, American River, Yolo Bypass/Cache Slough area inflows, San Joaquin River, Cosumnes River, Mokelumne River, Calaveras River and Napa River.

Suisun Marsh Flows

Additional boundary conditions within Suisun Marsh include several creek inflows, the Fairfield-Suisun Waste Water Treatment Plant discharge into Boynton Slough (Figure 56), Roaring River withdrawals and duck club inflows and withdrawals (Figure 57). The Roaring River withdrawals were calculated using the RRDS Intake calculator formulas develop by Brad Tom of the DWR. Duck club inflows and withdrawals were estimated based on duck club acreages and seasonal water operations. The total duck club flows plotted in Figure 57 are divided into regional flows based on acreage and applied at the six duck club locations shown in Figure 3.

Daily precipitation minus evaporation from the CIMS station at Concord was applied throughout Suisun Marsh.

Local creek inflow data collection was stopped in 2006, therefore inflows for local creeks (e.g. Green Valley Creek, Suisun Creek, Ledgewood Creek and Laurel Creek) were estimated based on Napa River flow data and drainage area.

Exports

Delta exports applied in the model include Clifton Court (SWP), CVP, Contra Costa exports at Rock Slough and Old River intakes, and North Bay Aqueduct intake at Barker Slough. Exports are plotted for the 2013 period in Figure 53 and Figure 54. Although 10-minute export flows are applied at the SWP, daily averages are plotted for ease of viewing.

EC

Time series of EC are applied at major River inflows as shown in Figure 56 and Figure 58. Cache Slough inflow EC is set constant at 350 µmhos/cm. Napa River, Fairfield wastewater treatment plant inflow and all Suisun creek flows are set constant at 120 µmhos/cm. EC for Suisun Marsh duck club inflows is estimated based on available observed data during flood-up period.

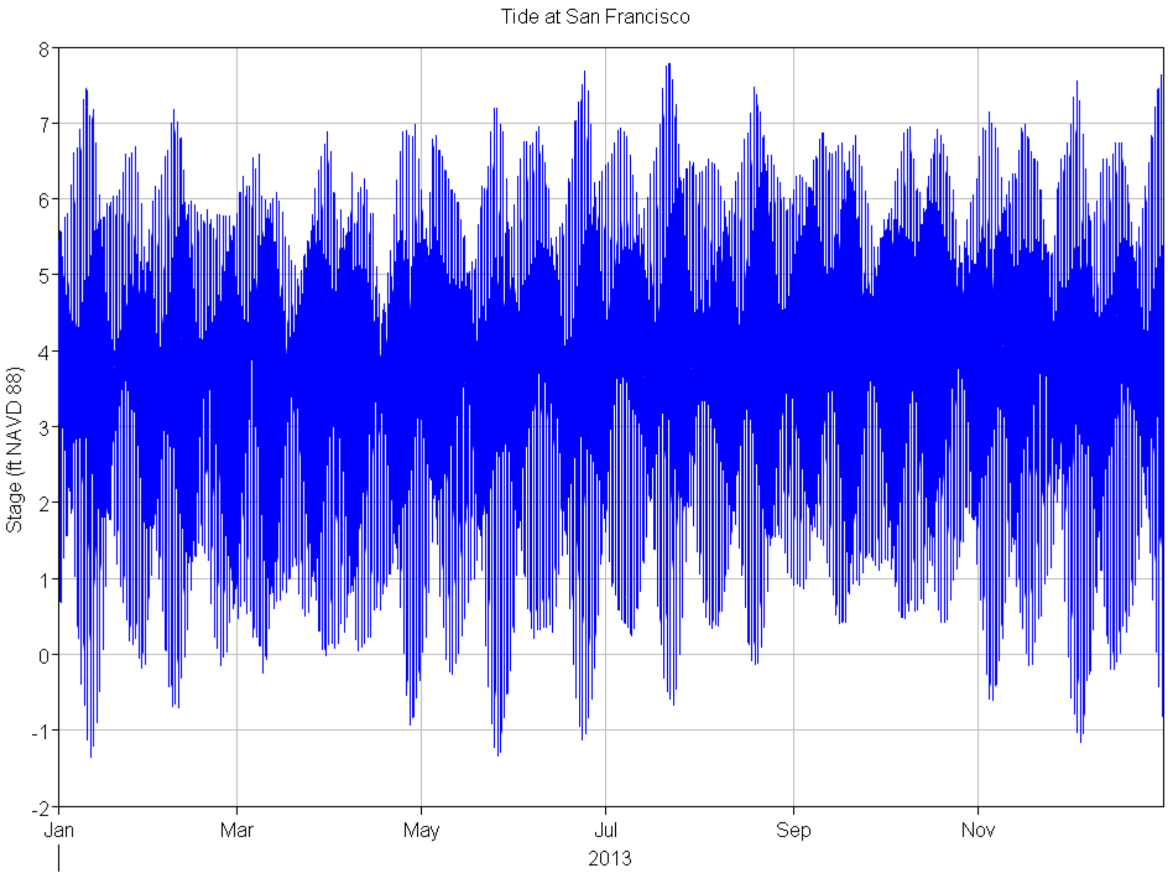

Figure 49 San Francisco stage applied at tidal boundary for the 2013 simulation period.

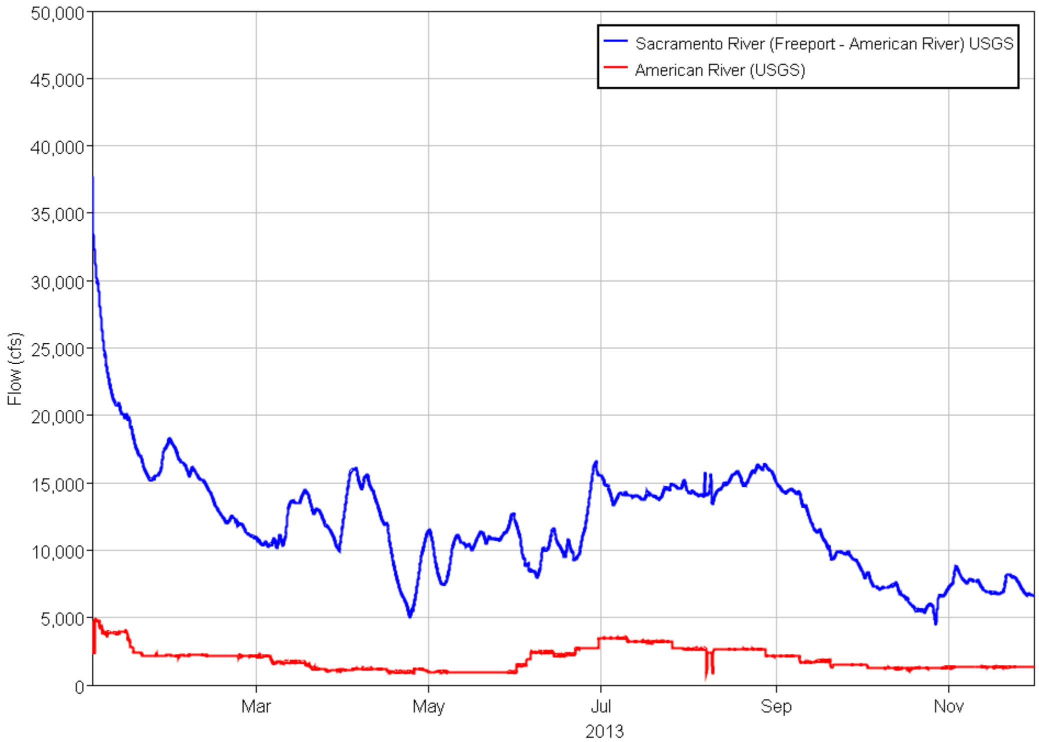

Figure 50 Sacramento River and American River inflow boundary conditions for the 2013 simulation period.

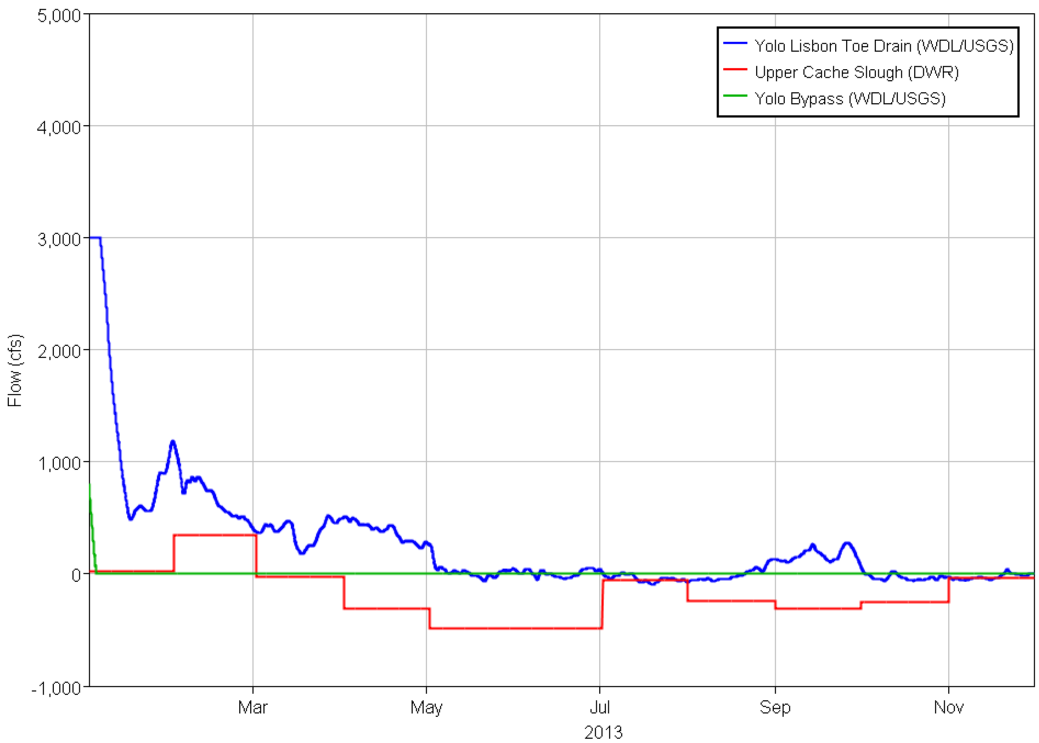

Figure 51 Yolo Bypass/Cache Slough area inflow boundary conditions for the 2013 simulation period.

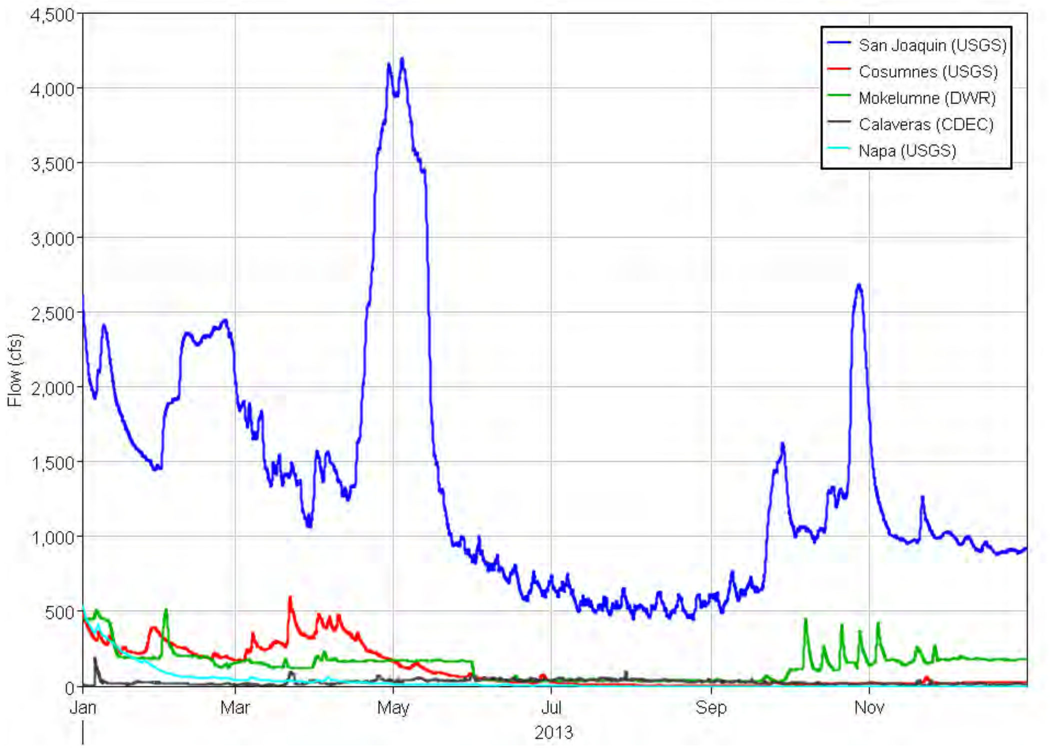

Figure 52 San Joaquin River, Cosumnes River, Mokelumne River, Calaveras River and Napa River inflow boundary conditions for the 2013 simulation period.

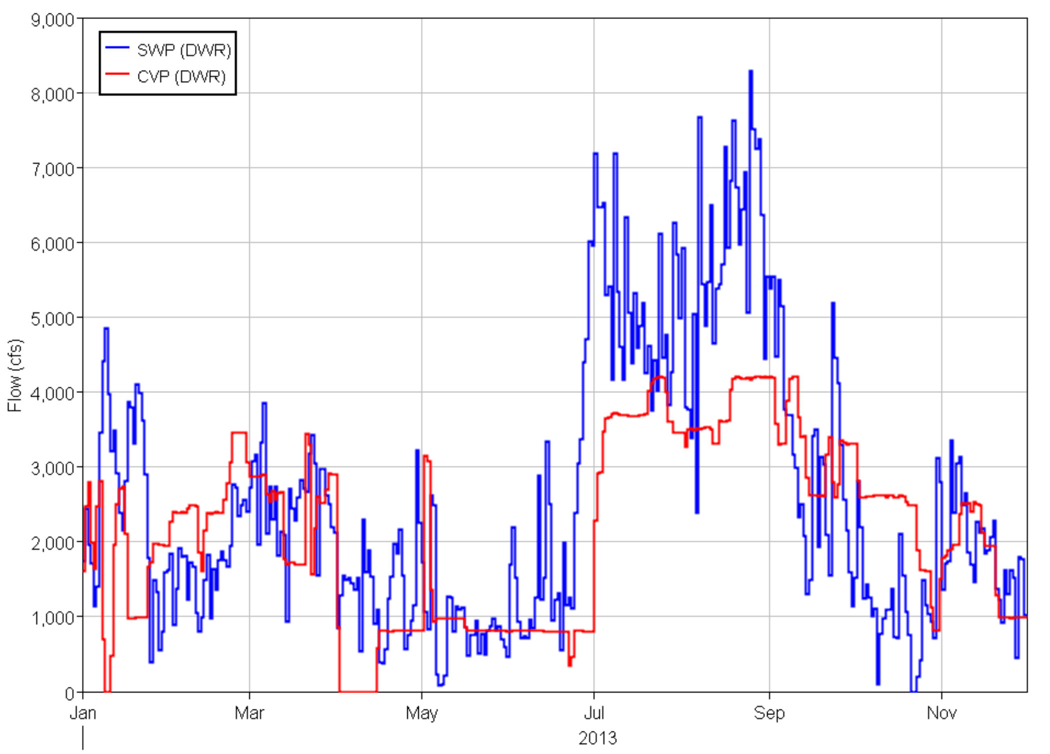

Figure 53 Clifton Court and CVP export boundary conditions for the 2013 simulation period.

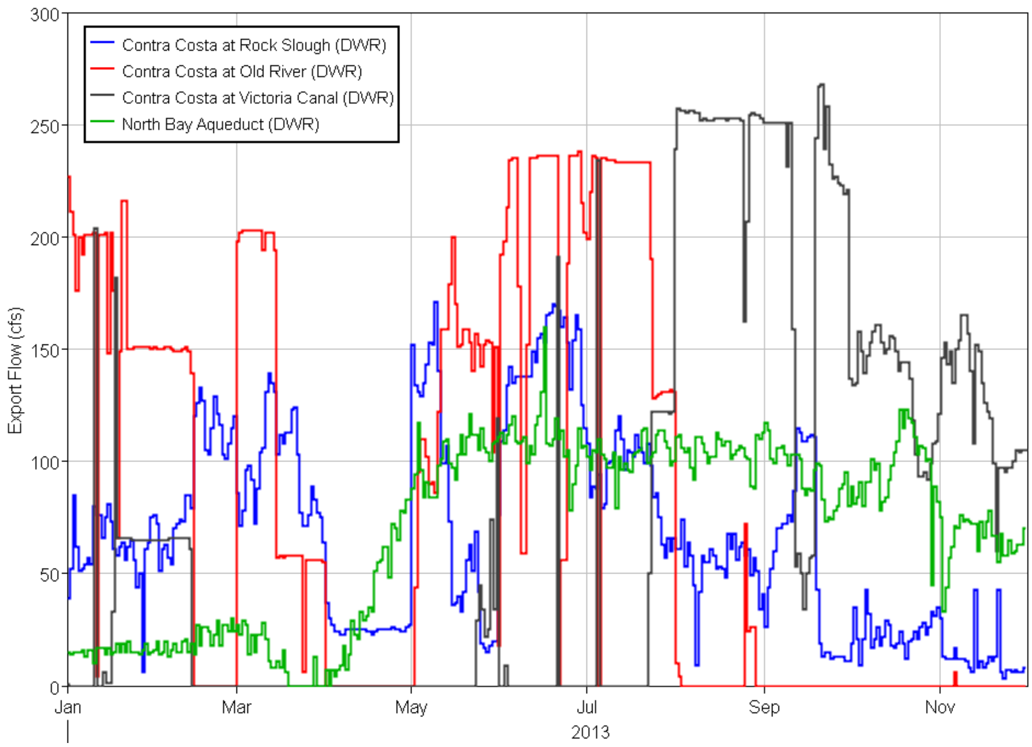

Figure 54 Contra Costa and North Bay Aqueduct export boundary conditions for the 2013 simulation period.

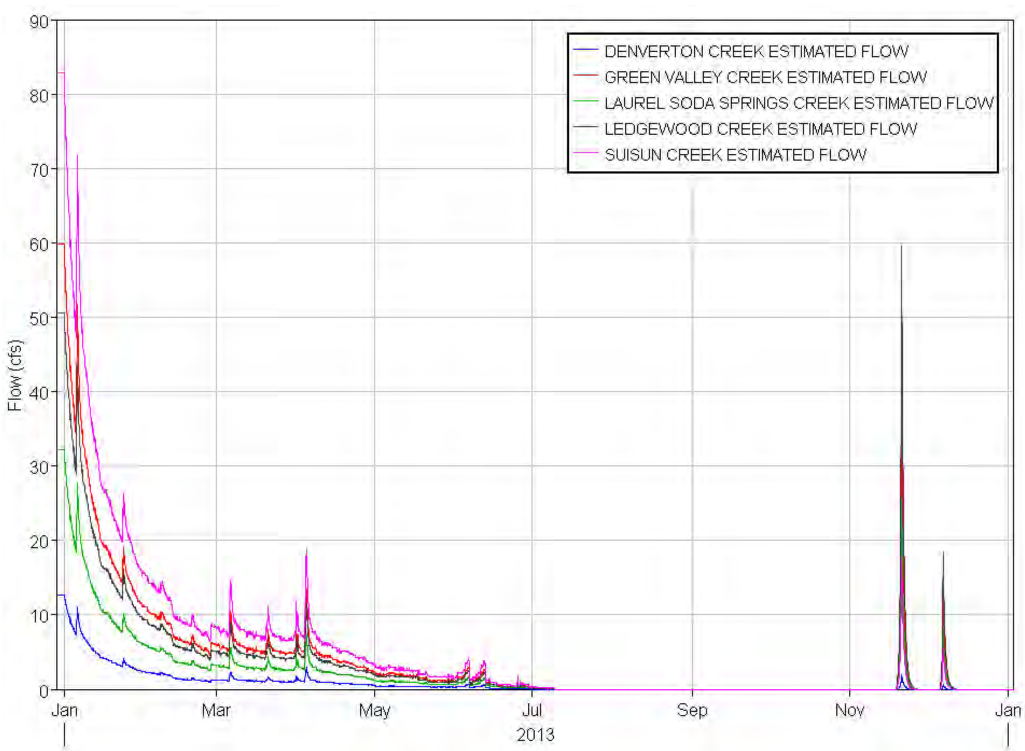

Figure 55 Suisun Marsh estimated creek flows for the 2013 simulation period.

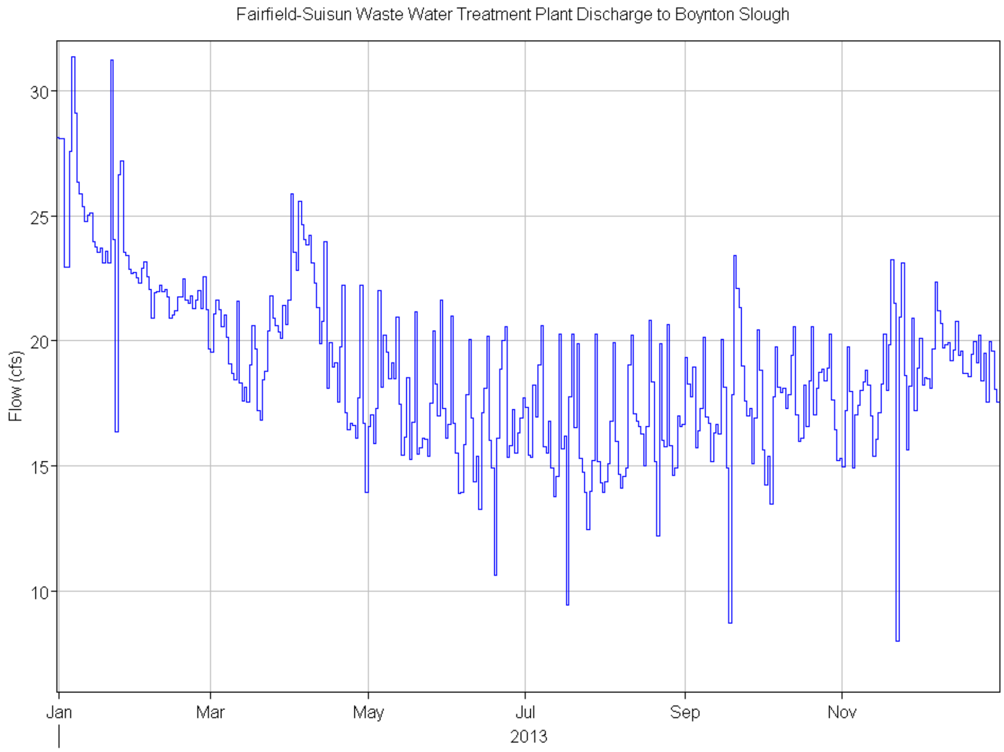

Figure 56 Fairfield-Suisun Waste Water Treatment Plant Discharge to Boynton Slough for 2013 simulation period.

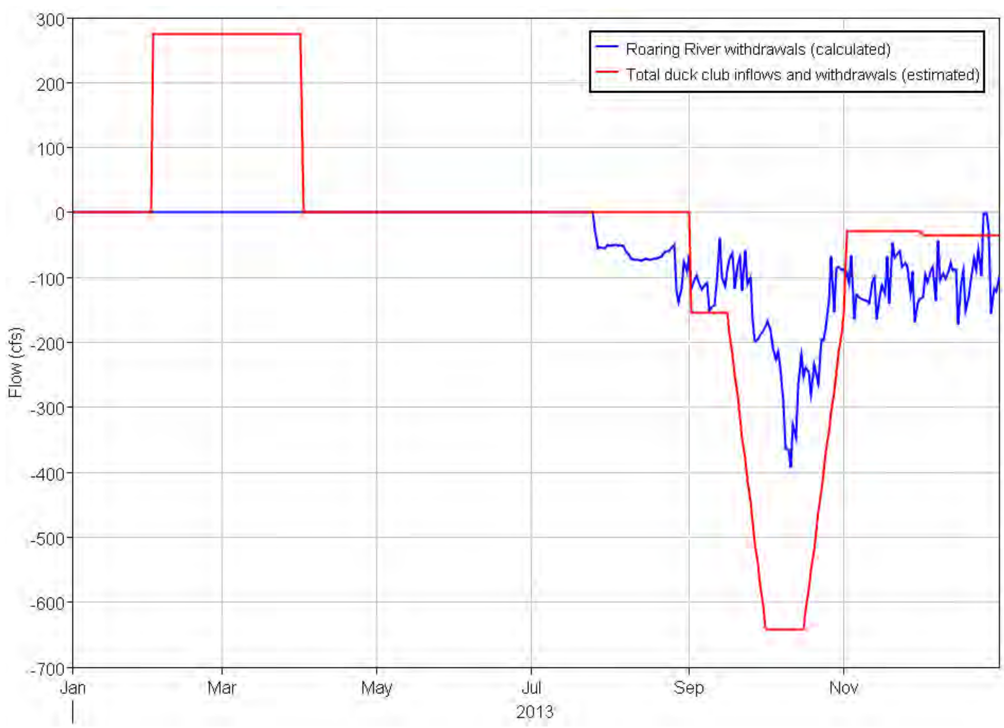

Figure 57 Calculated Roaring River withdrawals and estimated Suisun Marsh duck club inflows and withdrawals for the 2013 simulation period.

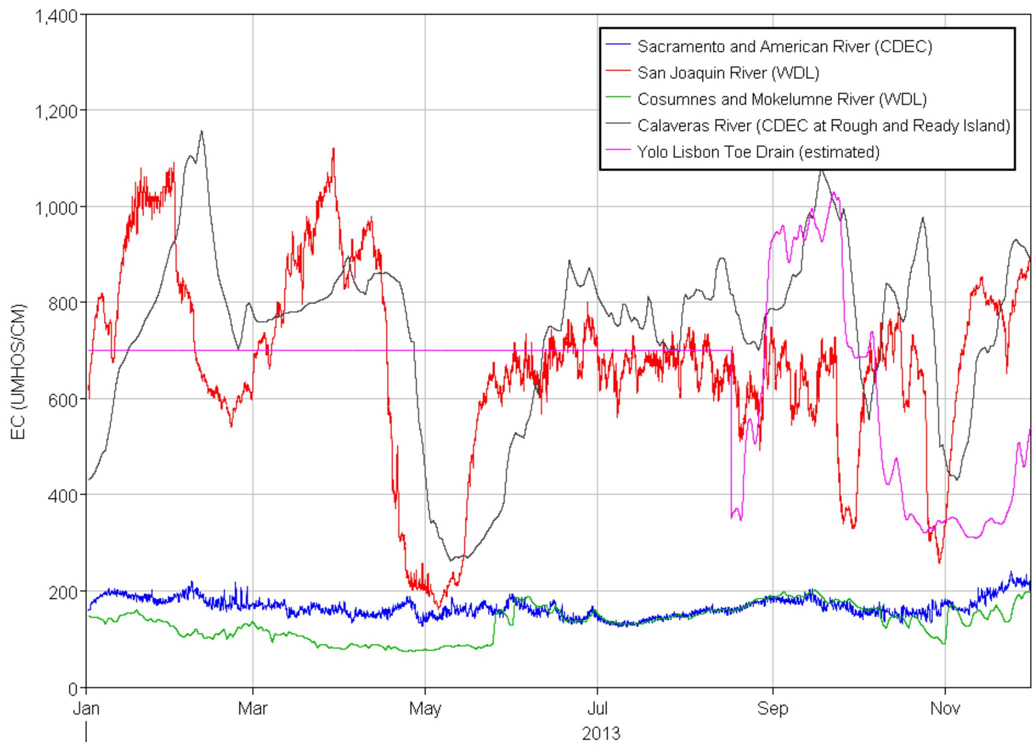

Figure 58 Time-varying EC boundary conditions for the 2013 simulation period.