# 2. RMA Suisun Marsh Modeling

## 2.1. Introduction

The goal of the Suisun Marsh project numerical modeling effort is to evaluate the effects of each of the four marsh restoration scenarios (Figure 1-1) on tidal range, scour, and tidal prism in Suisun Marsh, and on salinity in Suisun Marsh and the Delta. To accomplish these objectives, Resource Management Associates, Inc. (RMA) was tasked with developing a numerical model of the Suisun Marsh area to accurately simulate the current hydrodynamics and salinity regimes in the marsh, as well as the changes to these regimes in the marsh and to the salinity regime in the Delta under the four scenarios. EC is used as a surrogate for salinity in the Bay-Delta model for this project – this is discussed in more detail in Section 2.3.

During the Suisun Marsh Levee Breach modeling project (RMA, 2000), considerable detail was added to the representation of Suisun Bay and the western Delta, and to a lesser extent to representations of the Central Bay and Carquinez Strait. Wetting and drying of the tidal mudflats was represented in sufficient detail to provide a good definition of change in the tidal prism with change in tidal stage. The current model development and calibration efforts focused on further refinement of the finite element mesh and model capabilities in and around Suisun Marsh.

When the RMA Bay-Delta model was first developed, there was very limited observed data available to verify its performance in Suisun Marsh Region. Comparison of RMA model results to recent DWR monitoring data collected in 2004 and 2005 identified some deficiencies in the previous model representation of the Suisun Marsh Region. The discrepancies in flow results were primarily due to inaccurate representation of tidal prism at high tide. Before the model was used for alternative analysis simulations, the model was updated to better represent observed flows. The update primarily included assessment of inundated area and review/refinement of model geometry.

## 2.2. Background

RMA has developed and refined a numerical model of the San Francisco Bay and Sacramento-San Joaquin Delta system (Bay-Delta model) utilizing the RMA finite element models for surface waters. RMA2 (King, 1990) is a generalized free surface hydrodynamic model that is used to compute two-dimensional depth-averaged velocity and water surface elevation. RMA11 (King, 1998) is a generalized two-dimensional depth-averaged water quality model that computes a temporal and spatial description of conservative and non-conservative water quality parameters. RMA11 uses the results from RMA2 for its description of the flow field. As shown in Figure 2-1, the full model extends from the Golden Gate to the confluence of the American and Sacramento Rivers and to Vernalis on the San Joaquin River.

The current version of RMA's Bay-Delta model has been developed and continually refined during numerous studies over the past 11 years. One of the most important additions has been the capability to accurately represent wetting and drying in shallow estuaries. The most comprehensive calibration efforts in recent years were performed during studies for the City of Novato (RMA, 1997), the City of Palo Alto Regional Water Quality Control Plant (RMA, 1998), Central Contra Costa Sanitary District (RMA, 2000), CALFED (RMA, 2000), and Flooded Islands Feasibility Study (RMA, 2005).

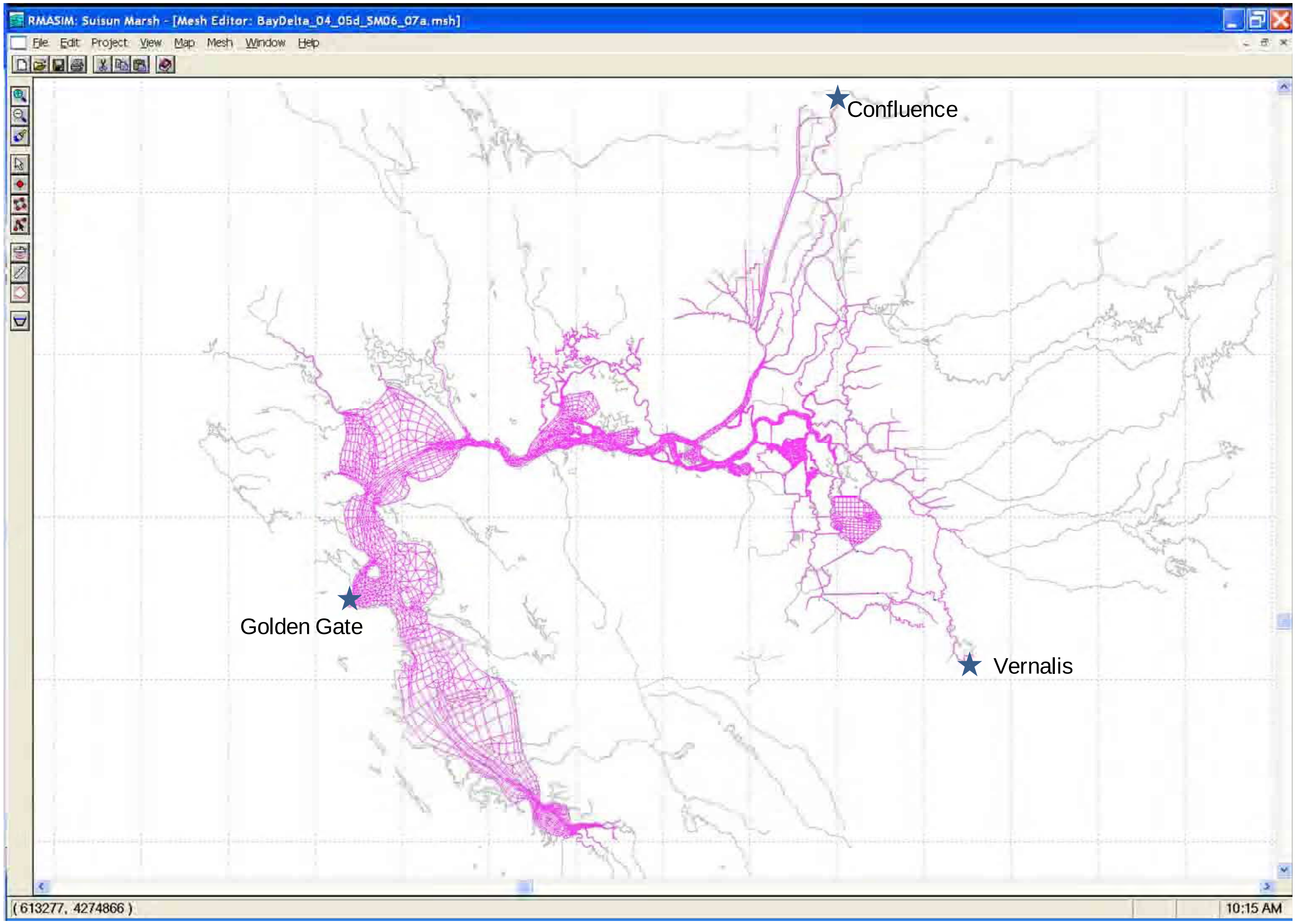



**Figure 2-1 RMA Bay-Delta model finite element mesh.**

### *2.3. General Description of Model Capabilities*

Hydrodynamic and water quality model output from RMA's Bay-Delta models, RMA2 and RMA11, provided temporal and spatial descriptions of velocities and water depths, and EC (µmhos $cm^{-1}$), respectively, throughout the model domain. The results of the flow simulation are saved and used by the water quality model to compute EC[4]. The computational time step used for modeling the depth-averaged flow and EC transport in the Delta is 7.5 minutes, and output from each model is saved every 15 minutes.

The version of the Bay-Delta model used in this study sets the tidal boundary condition at the Golden Gate. Although the RMA11 formulation assumes transport of a conservative constituent, EC is used as a practical surrogate for modeled salinity in the Bay-Delta model for several reasons, despite concerns about its non-conservative behavior. The number and reliability of measurement locations in the Bay-Delta region is much greater for EC than for other measures of salinity. In addition, transformation relationships between EC and constituents generally considered conservative, such as chloride and Total Dissolved Solids (TDS), can introduce additional error. EC underestimates true salinity at high concentrations (DWR, 2002). Because the Bay-Delta transport model is calibrated using EC, dispersion coefficients may be too high to utilize the model for truly conservative constituents.

Significant vertical salinity gradients are often present in the western Delta and Suisun Bay which can lead to three dimensional circulation patterns not fully represented by a two-dimensional depth-averaged model, but are instead approximated by two-dimensional mixing parameters.

Due to the variable grid capability of the finite element method, fine detail can be added to emphasize specific areas in the vicinity of the current project without increasing detail elsewhere in the model grid.

# 3. Model Set-up

The standard Bay-Delta Model hydrodynamic model operation (RMA2) requires specification of the tidal stage at the Golden Gate and inflow and withdrawal rates at other boundaries. Inflows include Sacramento River, Yolo Bypass, San Joaquin River and other rim flows, channel depletions and exports (SWP, CVP, Contra Costa Canal, and North Bay Aqueduct). The water quality model (RMA11) requires specification of EC boundary conditions at all inflow boundaries. The refined model developed for the current project added new boundary conditions for flow and EC within Suisun Marsh that are covered in Section 3.3.

[4] RMA11 can also compute the transport of other water quality constituents with more complex interactions

## 3.1. Model Geometry

Figure 2-1 shows the entire mesh of the Bay-Delta model used in the calibration effort (the calibration effort is covered in Section 4 of this report). In the previous version of the model, a two-dimensional, depth-averaged representation was used for the San Francisco Bay and Suisun Bay regions, the Sacramento-San Joaquin confluence area, Sherman Lake, the Sacramento River up to Rio Vista, Big Break, the San Joaquin River up to its confluence with Middle River, False River, Frank's Tract and the surrounding channels, and the Delta Cross Channel. Suisun Marsh and Delta channels, and tributary streams were represented using a one-dimensional cross-sectionally averaged approximation.

The Bay-Delta finite element network was developed using an in-house GIS based graphical user interface program. This program allows for specification of the finite element mesh over layers of bathymetry points and contours, USGS digital line graph (DLG) and digital orthoquad (DOQ) images, and aerial photo surveys processed by USGS and Stanford University. Bottom elevations and the extent of mudflats were based on bathymetry data collected by NOAA, DWR, USACE and USGS. These data sets 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/index.html.

Additional data were collected around Franks Tract by DWR and the USGS in 2004. USGS 10 m resolution Delta Bathymetry grids were obtained from the Access USGS website at http://sfbay.wr.usgs.gov/access/Bathy/Delta/.

## 3.2. Network Refinement

The existing finite element mesh was refined in the Suisun Marsh area. The length of the 1-D elements was reduced and additional channels were added. Overbank/fringe marsh was added as off-channel storage based on flow data, LIDAR elevation data and aerial photos. An example illustrating the level of detail in the old and new meshes is shown in Figure 3-1. The entire updated Suisun Marsh network is shown in Figure 3-2.

Five new models grids, each with a project-specific finite element mesh, were developed for the four marsh restoration scenarios as well as for a Base case. The Base case added three new tidal areas to the calibration grid, at Hill Slough, Meins Landing and Blacklock. Hill Slough and Meins Landing represent projects that are under development. The model details for each scenario and the Base case are discussed in Section 5 of this report.

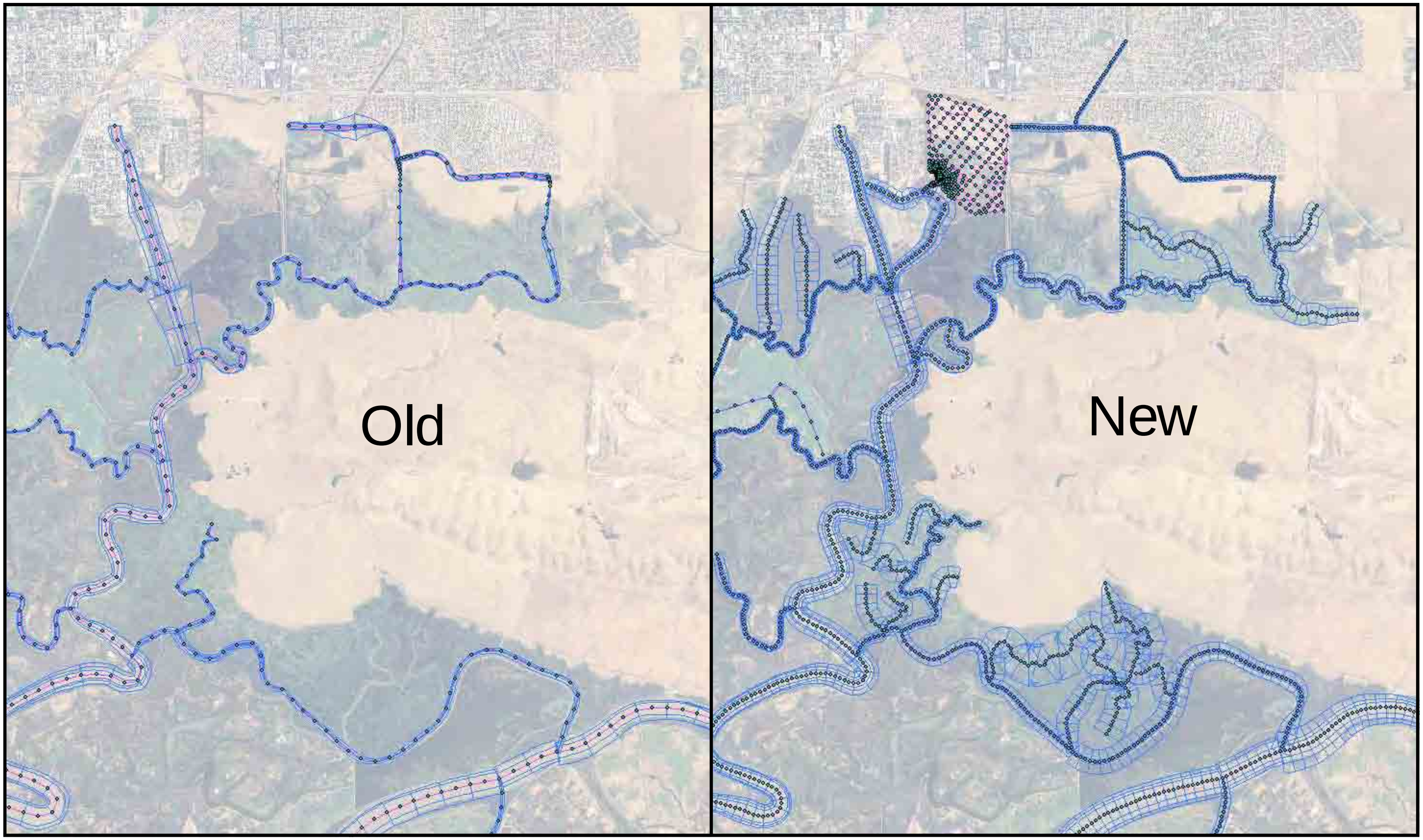



**Figure 3-1 Comparison between old and new grid details in the Suisun Marsh Area.**

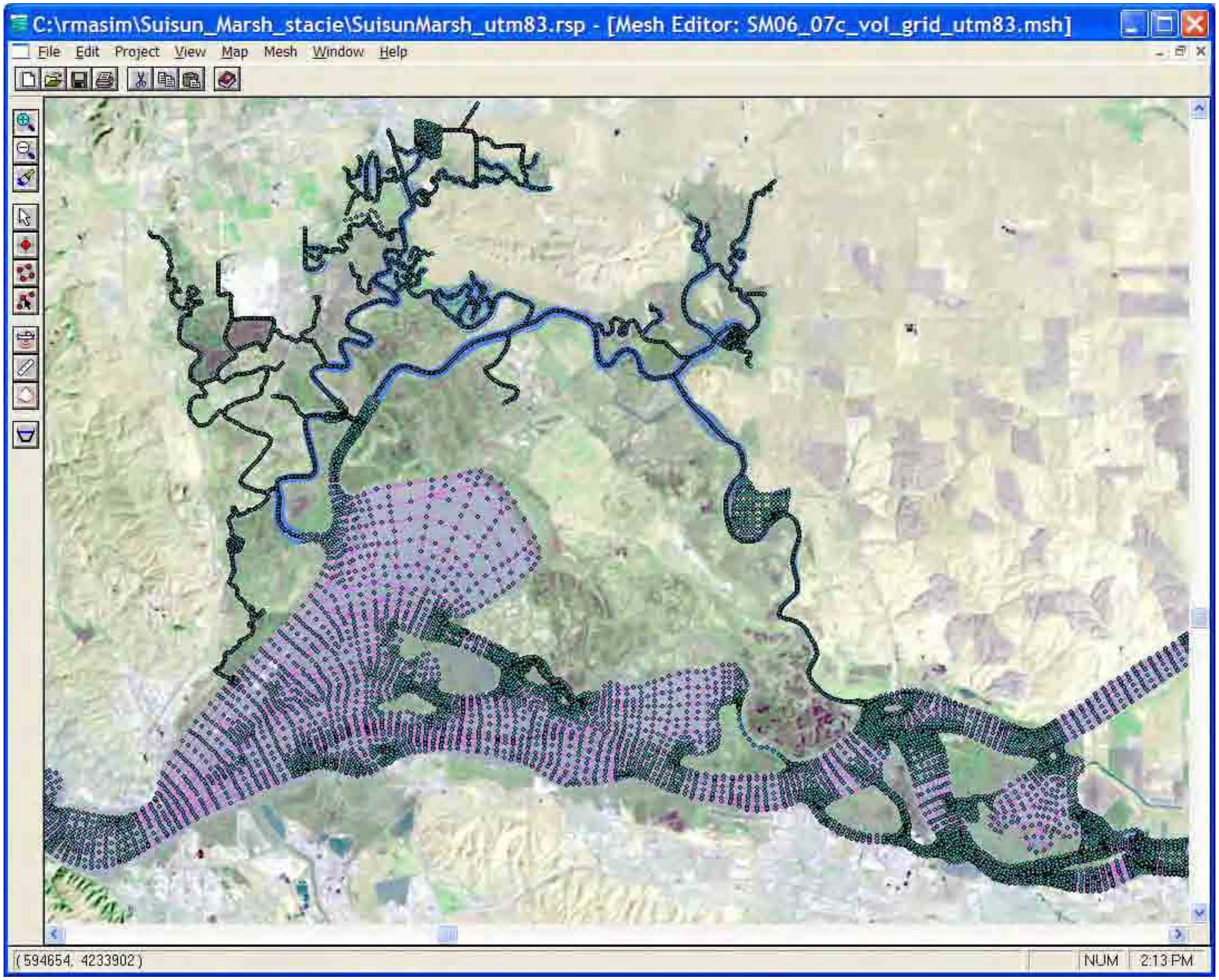



**Figure 3-2 Base case Suisun Marsh finite element network.**

## *3.3. Boundary Conditions*

Boundary conditions are specified for all inflow and outflow locations and for flow control structures. The locations of the model boundaries for the calibration grid are shown in Figure 3-4.

### 3.3.1. **Simulation periods**

The hydrodynamic calibration was April – July, 2004, a period where a DWR data collection effort (DWR 2007) provided a crucial dataset. The EC calibration period was April 2002 through December 2003, the same as for the Base case and marsh restoration scenarios simulations. Delta outflow during this period, shown in Figure 3-5, ranged from below average to slightly above average. With a few exceptions noted in Section 5.1, the scenario and Base case boundary conditions are the same as those used in the EC calibration.

### 3.3.2. **Tidal boundary**

The tidal boundary is set at the Golden Gate, the western boundary of the model, using observed data for the NOAA station at San Francisco. These data were smoothed using a 5 point moving average of the 6-minutes data, and shifted to NGVD + 0.1 m. The 0.1 m shift accounts for density effects between the tidal boundary and Suisun Marsh. The result at Martinez varies with Delta outflow, tidal and atmospheric conditions. An example plot of computed and observed stage at Martinez is shown in Figure 3-3.

### 3.3.3. **Flows, exports, precipitation, evaporation, DICU**

Inflow locations in the model are shown in Figure 3-4, with the exception of Delta Island Consumptive Use (DICU), which is discussed below. DICU flows incorporate channel depletions, infiltration, evaporation, and precipitation, as well as Delta island agricultural use. (DWR 1995)

Time series of daily average inflow boundary conditions are plotted in Figure 3-5 to Figure 3-7 for the 2002-2003 EC calibration/scenario simulation period and in Figure 3-9 and Figure 3-10 for the 2004 hydrodynamic calibration period. These flows are applied for the Sacramento River, Yolo Bypass, Napa River, San Joaquin River, Cosumnes River, Mokelumne River, and miscellaneous eastside flows which include Calaveras River and other minor flows. The model interpolates between the daily average flows at noon each day. Data from Dayflow (http://www.iep.ca.gov/dayflow/index.html) and the IEP database (http://iep.water.ca.gov/dss/) are used to set these boundary conditions.

Estimated Fairfield Wastewater Treatment Plant (WWTP) flows were are plotted in Figure 3-6 (lower) for the 2002-2003 period. The reported average dry weather flow (ADWF) for the Fairfield WWTP is 13.2 – 14.8 mgd, with a peak wet weather capacity of 34.8 mgd. During dry periods, the WWTP flow in the model was set to 14 mgd. Daily precipitation data from the CIMIS station at Suisun Valley were used to estimate wet weather flows. Total wet weather flows were 14 mgd plus an additional flow of 3.8 mgd for each inch of the previous day's precipitation. These flows were not included in the hydrodynamic calibration because, although they have a large effect on EC, their effect on hydrodynamics is insignificant.

Flow data for Suisun Creek at Putah South Canal and Green Valley Creek at Green Valley Country Club are plotted in Figure 3-7 for the 2002-2003 period. Data were provided by Solano County Water Agency. Gaps in the Suisun Creek data were filled using flows estimated from Napa River flows scaled based on drainage area. This Suisun Creek data set was in turn scaled by drainage area for application to Ledgewood and Laurel Creeks. These flows were not included in the hydrodynamic calibration, as their effect on hydrodynamics is only significant during storm flow periods.

DICU values are applied on a monthly average basis and were derived from monthly DSM2 input values (DWR, 1995). Table 3-1 summarizes the total monthly diversions (incorporates agricultural use, evaporation and precipitation), drains (agricultural returns), seeps (channel depletions) and total flows used for DICU flows. Negative flows indicate net withdrawal from the system. These flows are distributed to multiple elements throughout the Delta using an in-house utility program.

Delta exports applied in the model include 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 2002-2003 period in Figure 3-8 and the 2004 period in Figure 3-10. Dayflow and IEP database data are used to set daily average export flows for the CVP, North Bay Aqueduct and Contra Costa's exports.

Hourly SWP export flows for 2003 and 2004 are computed using the Clifton Court gate ratings and inside and outside water levels. The flows are adjusted on a monthly basis so the total computed flow matches the monthly SWP export. For 2002, when water levels inside and outside the gates were not available, SWP exports were defined using DSM2 node 72 flow, modified to remove erroneously large flows. Further details on Clifton Court Forebay gate operations can be found in (RMA, 2000), RMA's Flooded Islands Feasibility Study (RMA, 2005), and in (DWR 2004).

Duck club ponds are filled and drained seasonally to provide appropriate habitat and opportunity to attract migrating ducks. Flows had to be estimated to approximate diversion (filling) and return (draining) flows in the vicinity of the marsh. For modeling purposes, it was assumed that they filled at a constant rate (no tidal variation) from a depth of -1.0 ft to +1.0 ft over a 14 day period beginning October 1. The ponds were subsequently drained at a constant rate between March 1 and June 1. Flow rates were computed as the area to be filled multiplied by the depth of water (2.0 ft) divided by the time to fill or drain. No exchange between the modeled marsh flows and the duck club ponds occurred during the summer, from June 1 through October 1.

Evaporation and precipitation data were used to compute flows required to maintain ponds at a constant level from October 15 (following filling) through February. Flow volumes were based on areas for the following locations: Montezuma Slough (East, Middle and West), Suisun Slough, Nurse Slough, Morrow Island (fill only) and Roaring

River. Locations of inflow/withdrawal in the Marsh are shown for the Base case mesh in Figure 3-13 – these locations are the same for the four scenarios.

Daily Suisun Valley CIMIS station precipitation data was used to compute additional inflows from tidal marsh areas during rainfall events. Areas of tidal marsh were estimated and multiplied by the daily precipitation data. Inflows from tidal marsh were input at Beldon's Landing, Boynton Slough, Cutoff Slough, First Mallard Slough, Hill Slough and Peytonia Slough. Locations are shown in Figure 3-12.

### 3.3.4. **Electrical Conductivity (EC)**

The western EC boundary of the model, at the Golden Gate is set at 50,000 µmhos $cm^{-1}$, the EC of seawater. EC boundary conditions are set at all inflow boundaries. Table 3-2 gives the source of the EC boundary conditions. Figure 3-13 shows the EC time series boundary conditions at the major boundaries.

### 3.3.5. **Suisun Marsh Slough Salinity Control Gate operation**

The model representation of the Suisun Marsh Salinity Control Gates (SMSCG) consists of a series of three tide gates to represent the radial gates, and a standard gate to represent the flashboard (Figure 3-14). All four gates can be operated individually. Figure 3-15 and Figure 3-16 illustrate the timing of the radial gate operation and the flashboard structure placement during the 2002-2003 simulation period, and the 2004 hydrodynamic calibration period, respectively. The SMSCG control season is from early October through the end of May.

### 3.3.6. **Precipitation and evaporation by element type**

The ability to apply daily time series of precipitation and evaporation was added to the model for the Suisun Marsh simulations. In previous versions of the model, the monthly DICU inflows/outflows were the only evaporation and precipitation inputs, and these were applied to individual model elements only in the Delta. In Suisun Marsh, the impacts of evaporation and short time scale variations in precipitation were incorporated in selected areas of the grid by element type ID, and applied on a per-unit-area basis using daily time series of precipitation and evaporation data from the Suisun Valley CIMIS Station.

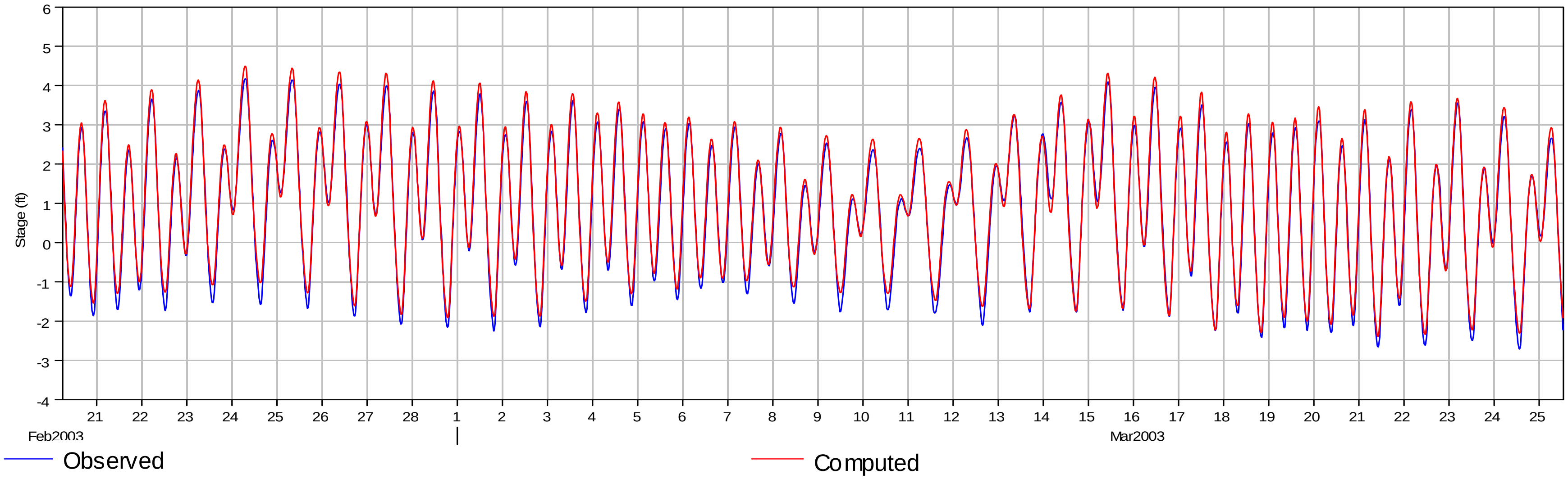



**Figure 3-3 Example of computed and observed stage at Martinez.**

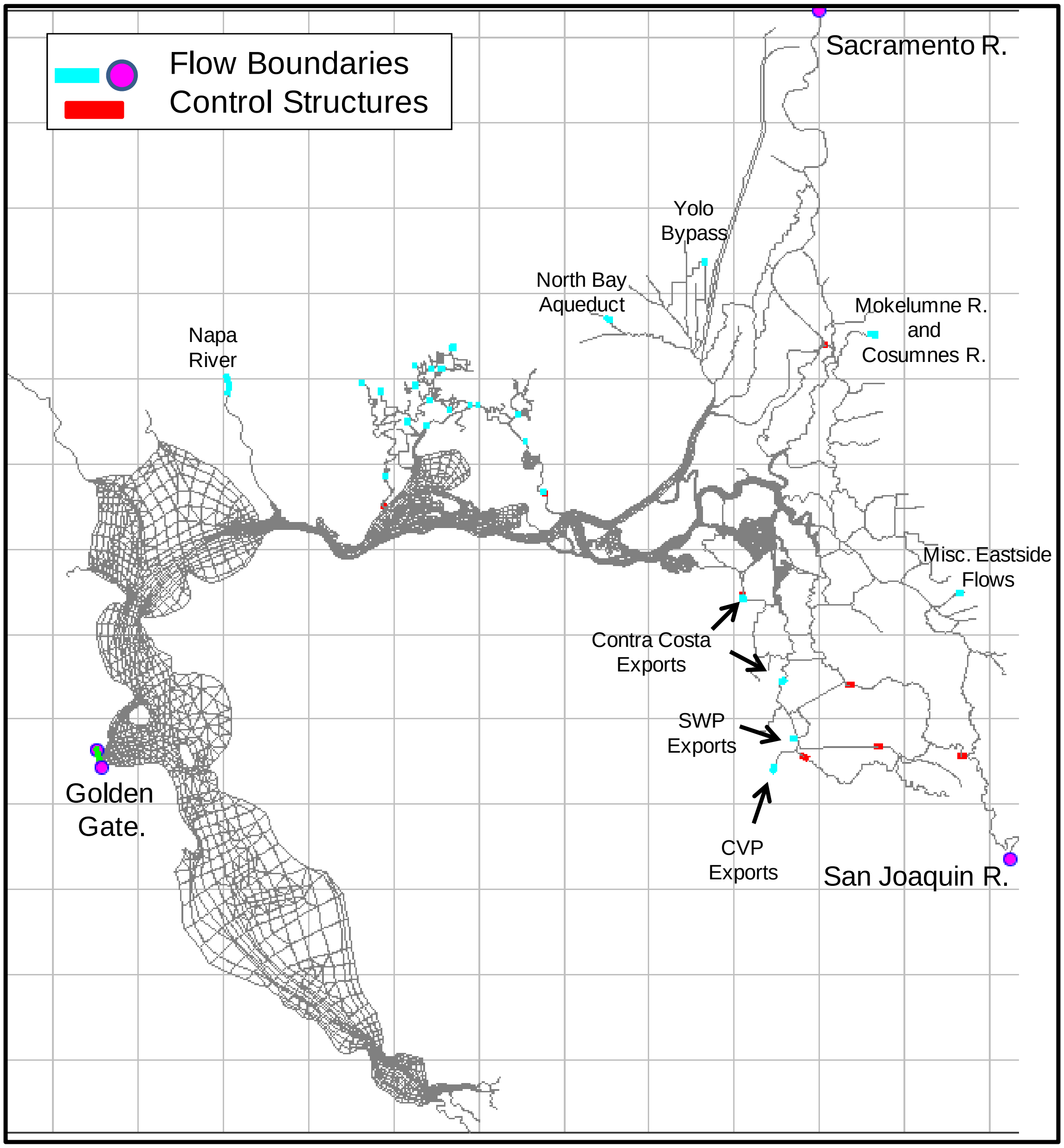



**Figure 3-4 Model grid showing inflow and export locations, and flow control structures.**

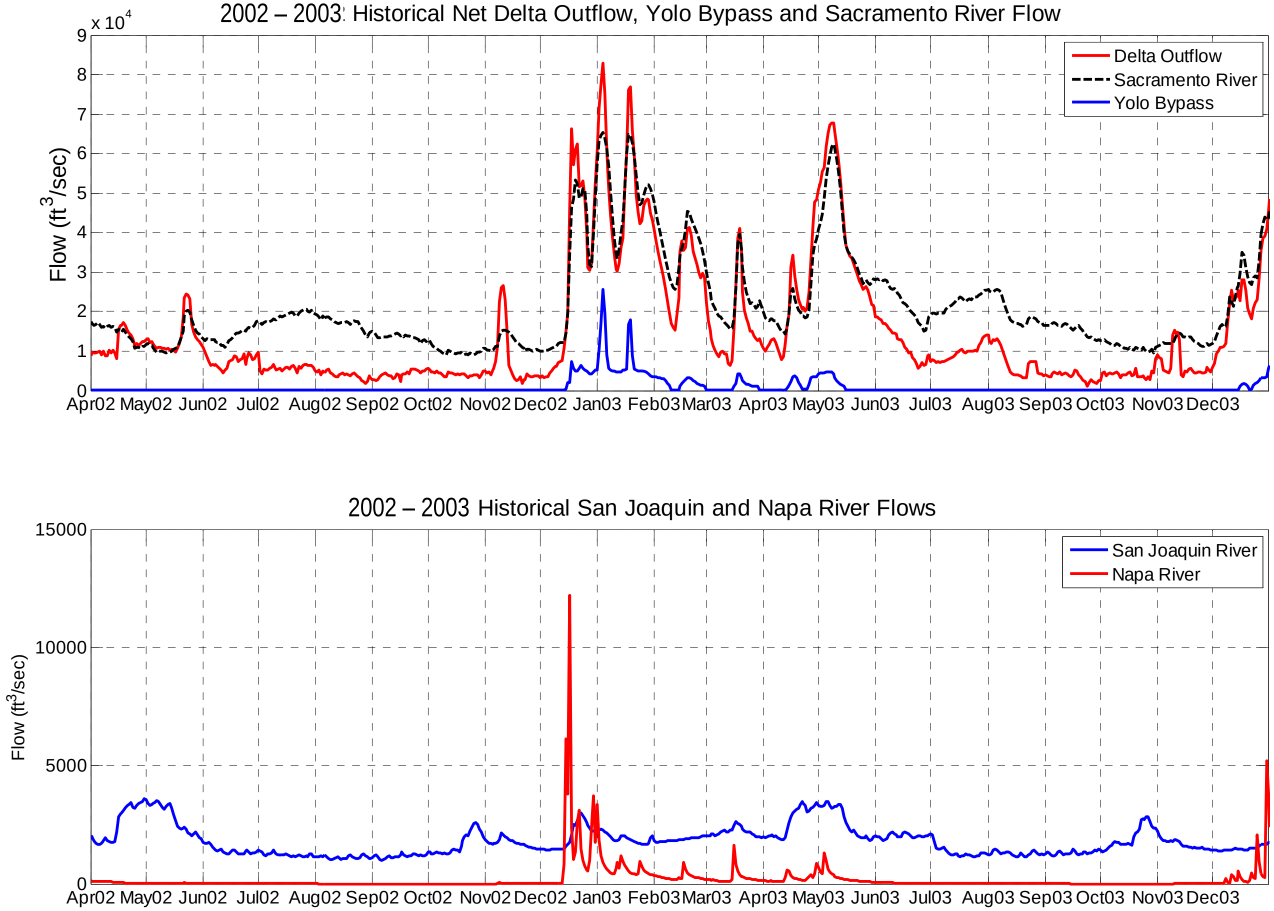



**Figure 3-5 Net Delta outflow and major boundary flows for the 2002-2003 EC calibration/scenario simulation period.**

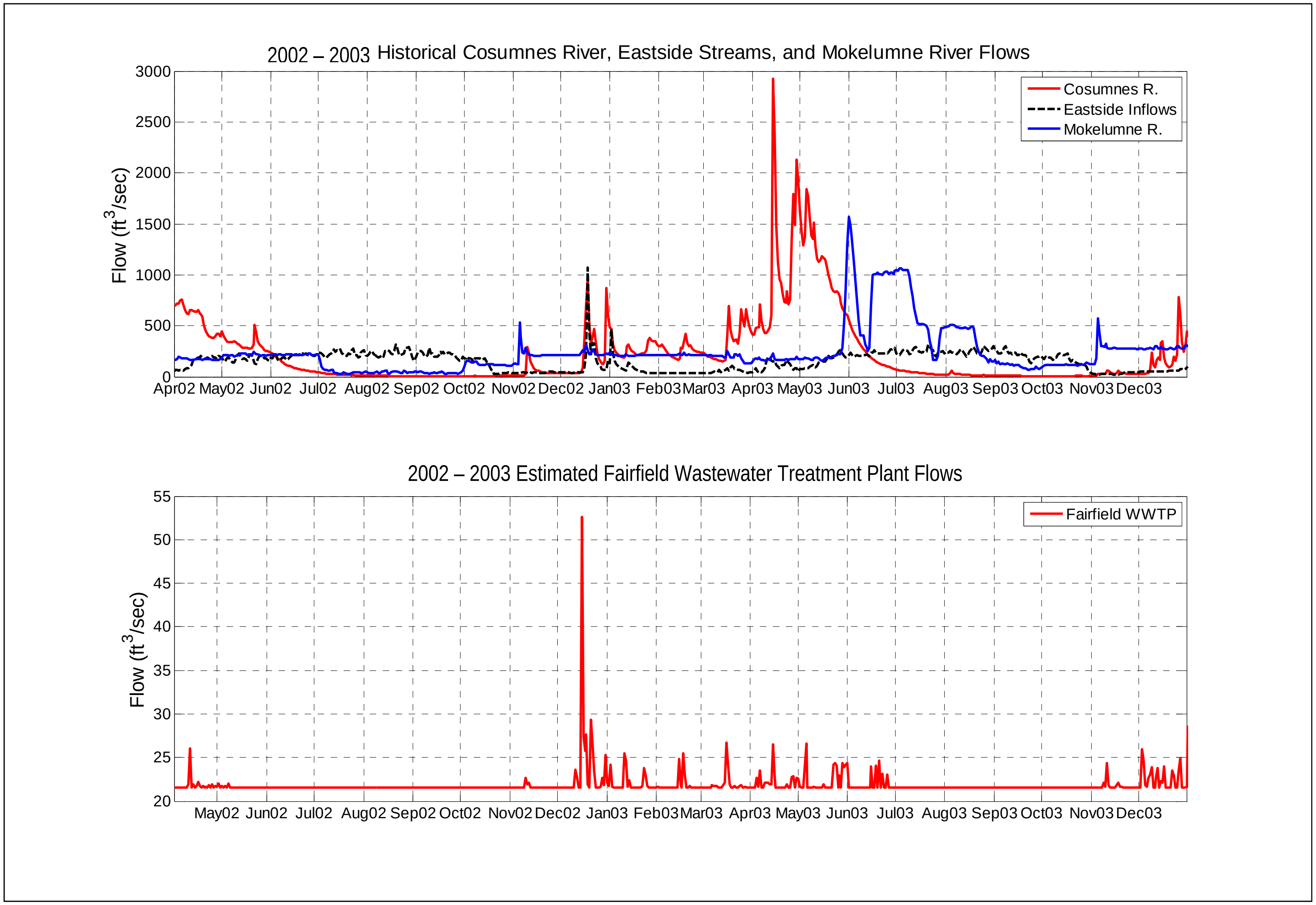



**Figure 3-6 Minor boundary flows for the 2002-2003 EC calibration/scenario simulation period.**

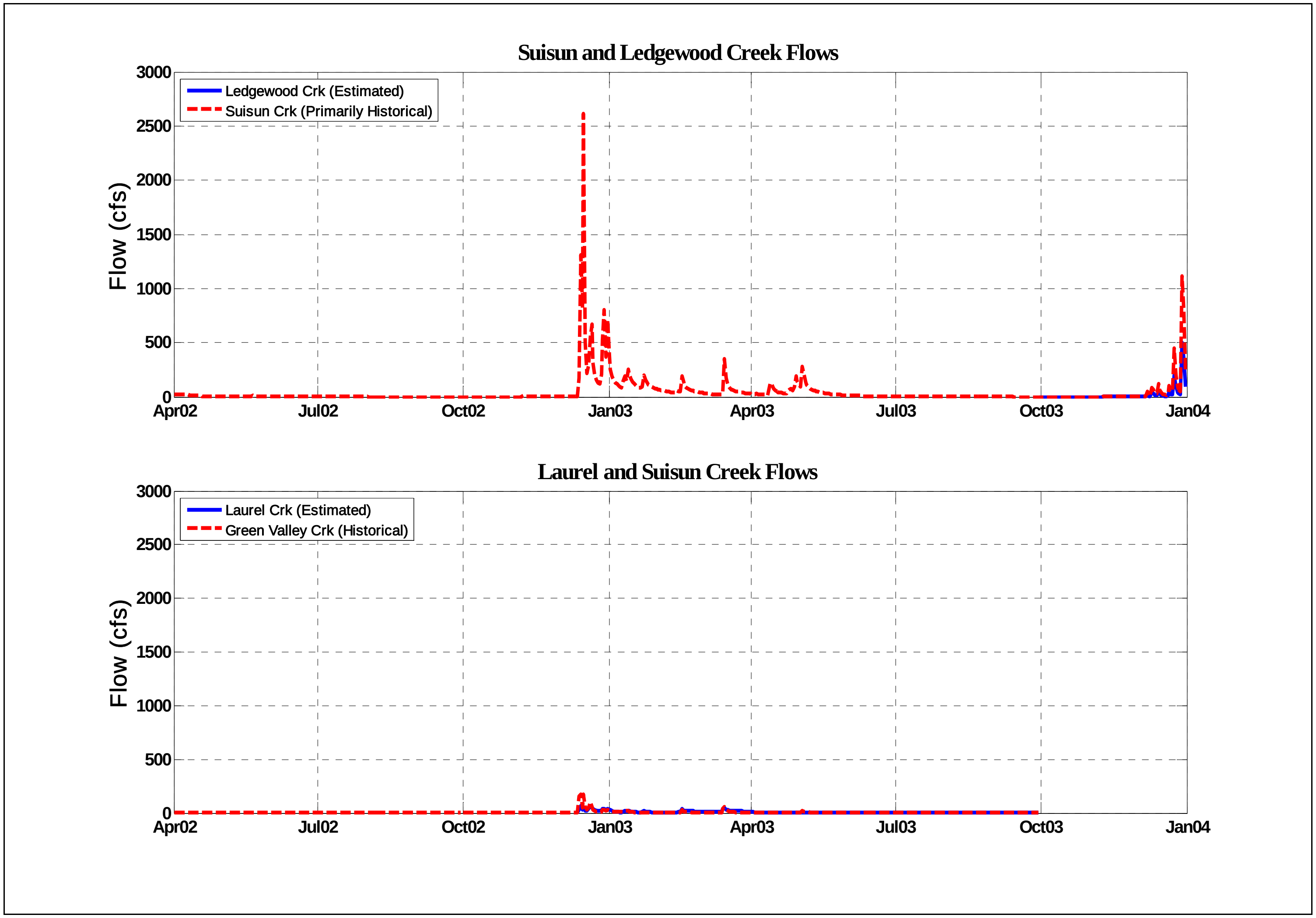



**Figure 3-7 Suisun Marsh local creek flows for the 2002-2003 EC calibration/scenario simulation period.**

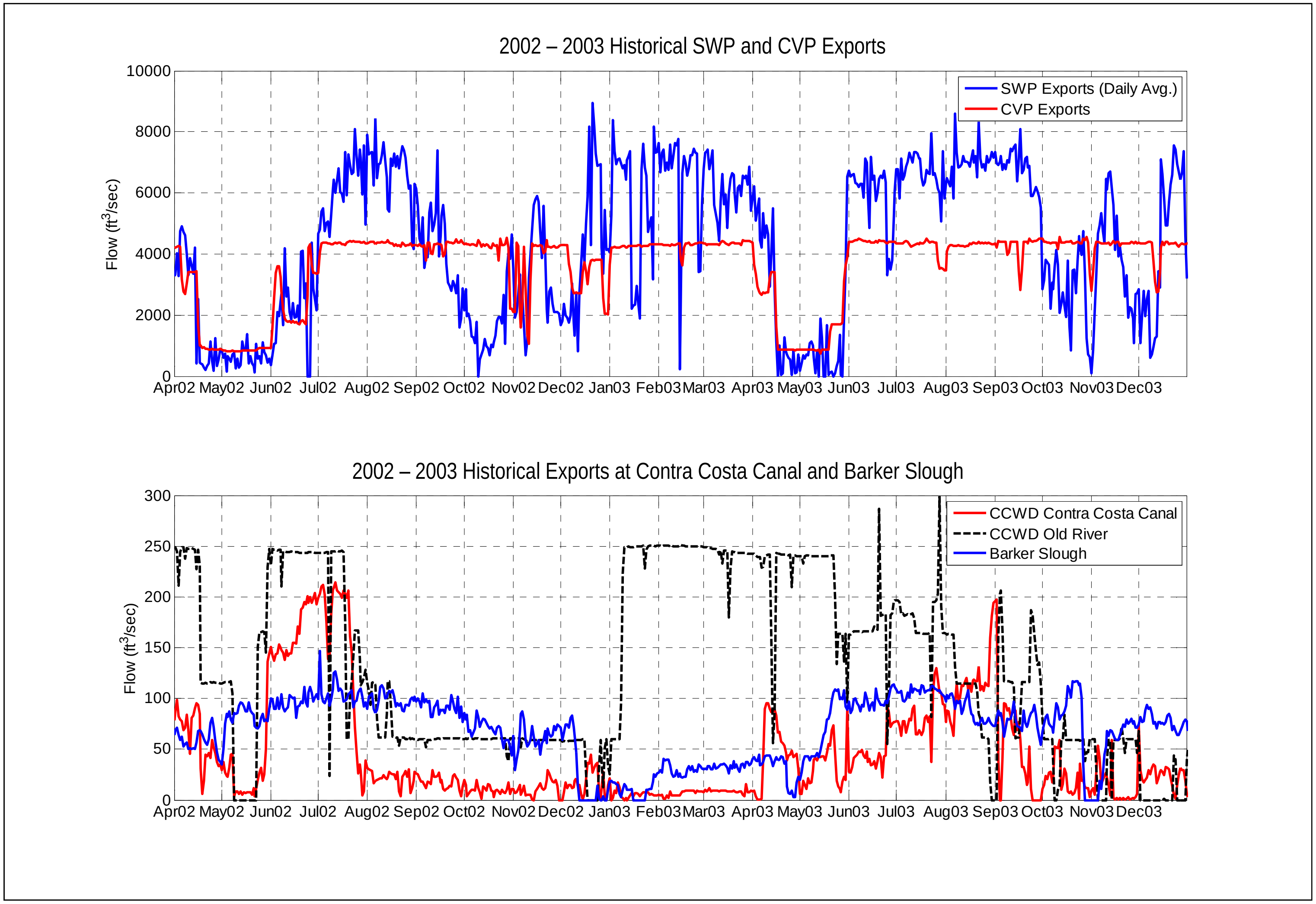



**Figure 3-8 Historical exports and diversions used in the model for the 2002-2003 EC calibration/scenario simulation period. Note that daily averaged SWP exports are plotted, however the model uses 15-minute inputs.**

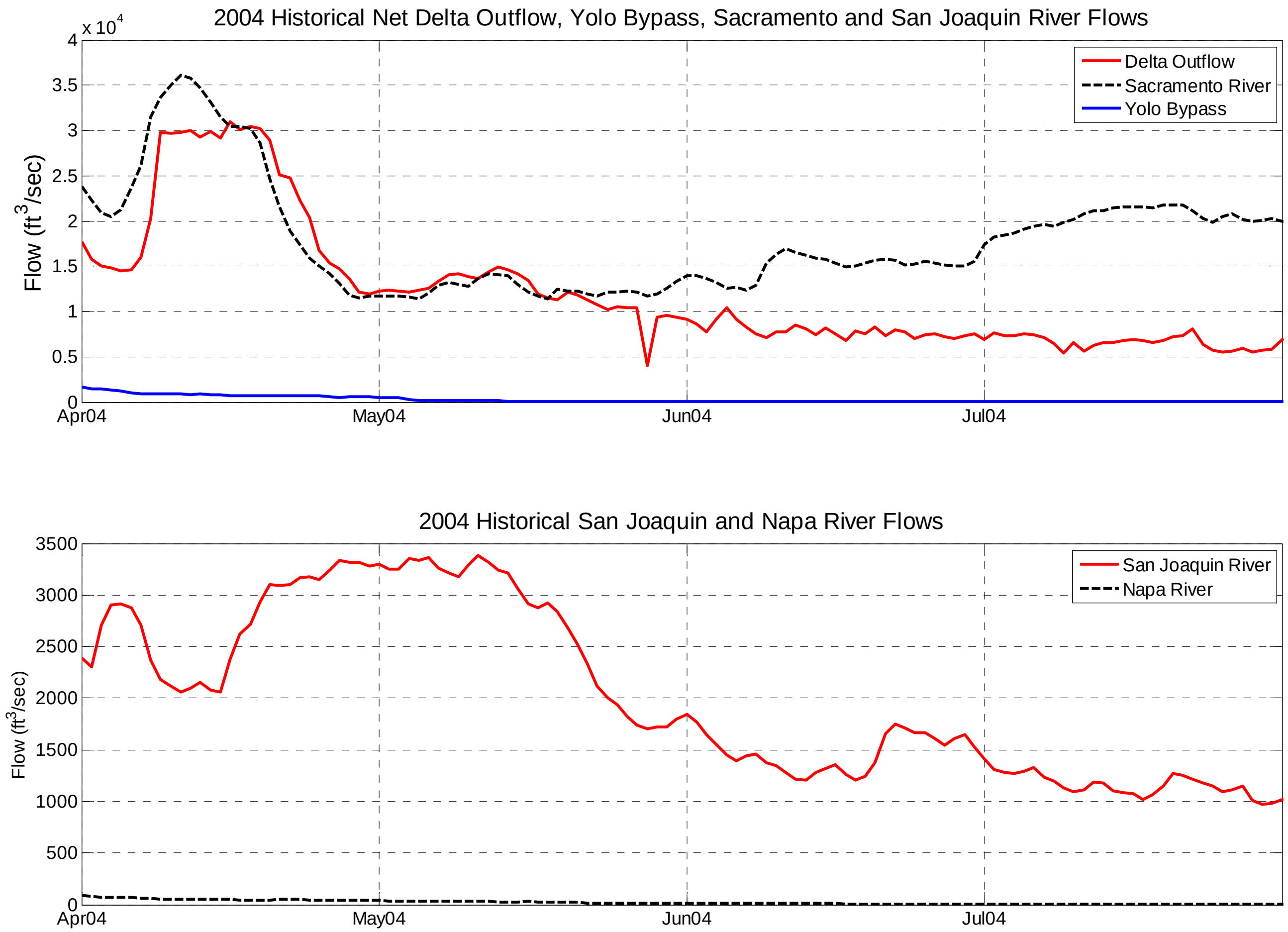



**Figure 3-9 Major boundary flows for the 2004 hydrodynamic calibration period.**

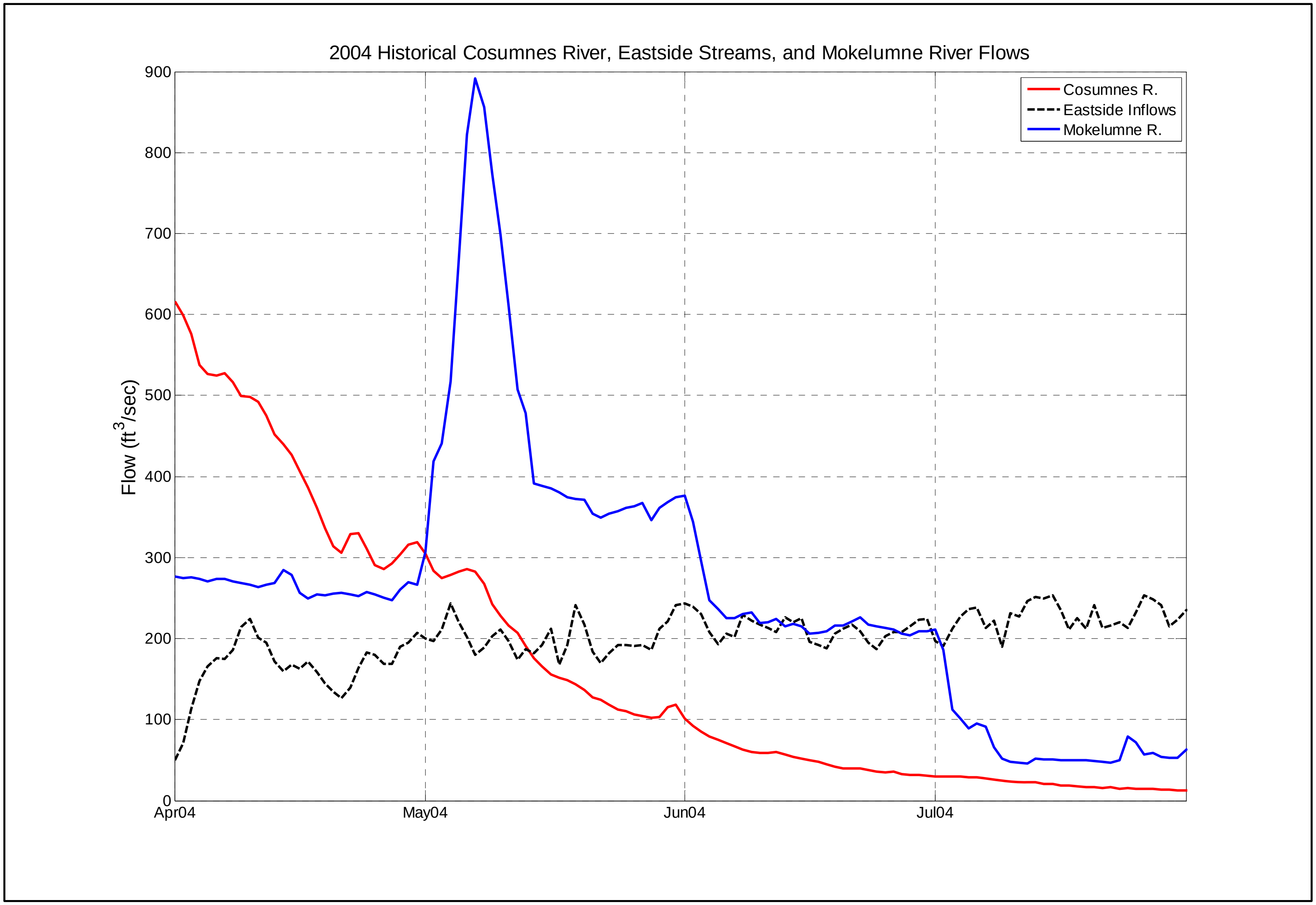



**Figure 3-10 Minor boundary flows for the 2004 hydrodynamic calibration period.**

**Table 3-1 Summary of monthly DICU flows ($ft^3\ sec^{-1}$) for the calibration and scenario simulation periods. Negative values indicate Delta withdrawal.**

| Month | Diversions (-) | Drains (+) | Seeps (-) | Total |
|---|---|---|---|---|
| **EC calibration period** | | | | |
| April 2002 | 2109.9 | 1121.8 | 1006.4 | -1994.5 |
| May 2002 | 3978.0 | 1710.4 | 973.4 | -3241.0 |
| June 2002 | 4850.2 | 1995.6 | 1006.4 | -3860.9 |
| July 2002 | 4943.0 | 2011.0 | 973.4 | -3905.4 |
| August 2002 | 2659.8 | 1265.9 | 973.4 | -2367.3 |
| September 2002 | 1231.2 | 848.4 | 1006.2 | -1389.1 |
| October 2002 | 875.2 | 681.1 | 973.2 | -1167.4 |
| November 2002 | 268.9 | 576.2 | 1018.0 | -710.8 |
| December 2002 | 429.2 | 2318.5 | 633.9 | 1255.4 |
| January 2003 | 2.0 | 133.4 | 575.7 | 755.7 |
| February 2003 | 62.6 | 873.8 | 714.1 | 97.1 |
| March 2003 | 314.5 | 741.1 | 725.6 | -299.0 |
| April 2003 | 405.9 | 825.8 | 701.1 | -281.2 |
| May 2003 | 1438.8 | 894.3 | 980.5 | -1525.0 |
| June 2003 | 2929.1 | 1346.7 | 1006.2 | -2588.6 |
| July 2003 | 5254.4 | 2108.3 | 973.1 | -4119.2 |
| August 2003 | 2569.5 | 1237.3 | 985.8 | -2318.0 |
| September 2003 | 1351.0 | 884.2 | 1006.2 | -1472.9 |
| October 2003 | 981.1 | 709.1 | 973.1 | -1245.2 |
| November 2003 | 272.5 | 528.7 | 1027.2 | -771.0 |
| December 2003 | 429.2 | 1011.2 | 791.9 | -209.9 |
| **Hydrodynamic calibration period** | | | | |
| April 2004 | 1559.5 | 951.8 | 1003.9 | -1611.6 |
| May 2004 | 3014.1 | 1364.0 | 975.0 | -2625.1 |
| June 2004 | 4018.5 | 1705.6 | 1006.3 | -3319.2 |
| July 2004 | 5006.5 | 2030.6 | 973.4 | -3949.4 |

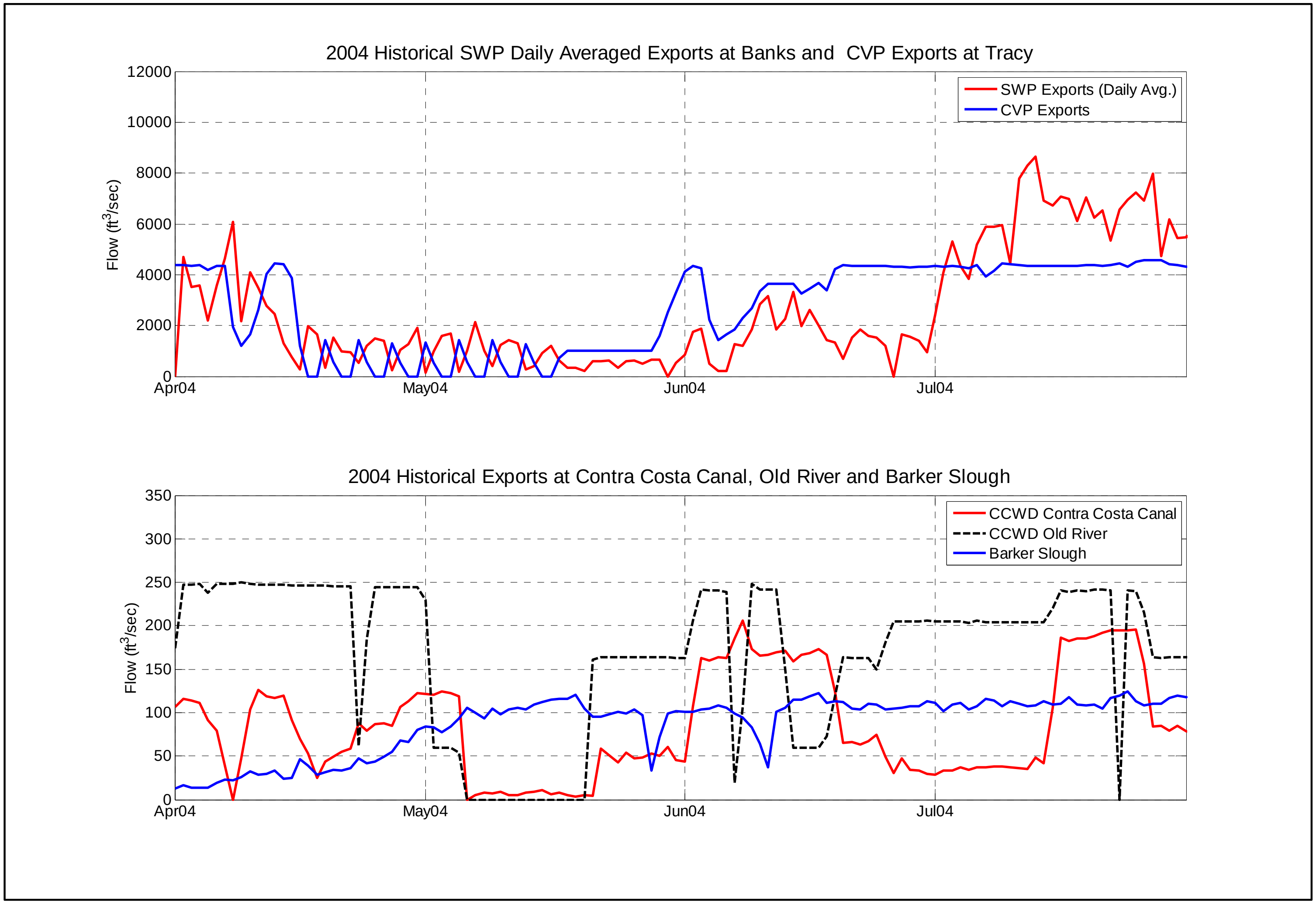



**Figure 3-11 Historical exports and diversions used in the model for the 2004 hydrodynamic calibration period. Note that daily averaged SWP exports are plotted, however the model uses 15-minute inputs.**

| | |
|---|---|
| 1 | Morrow Island managed wetland |
| 2 | Green Valley Creek |
| 3 | Suisun Creek |
| 4 | Suisun Slough |
| 5 | Montezuma Slough west managed wetland |
| 6 | Boynton Slough tidal marsh |
| 7 | Fairfield WWTP |
| 8 | Ledgewood Creek |
| 9 | Peytonia Slough tidal marsh |
| 10 | Hill Slough tidal marsh |
| 11 | Laurel Creek |
| 12 | First Mallard Slough tidal marsh |
| 13 | Cutoff Slough tidal marsh |
| 14 | Beldons Landing tidal marsh |
| 15 | Montezuma Slough middle managed wetland |
| 16 | Nurse Slough managed wetland |
| 17 | Montezuma Slough east managed wetland |
| 18 | Roaring River managed wetland |

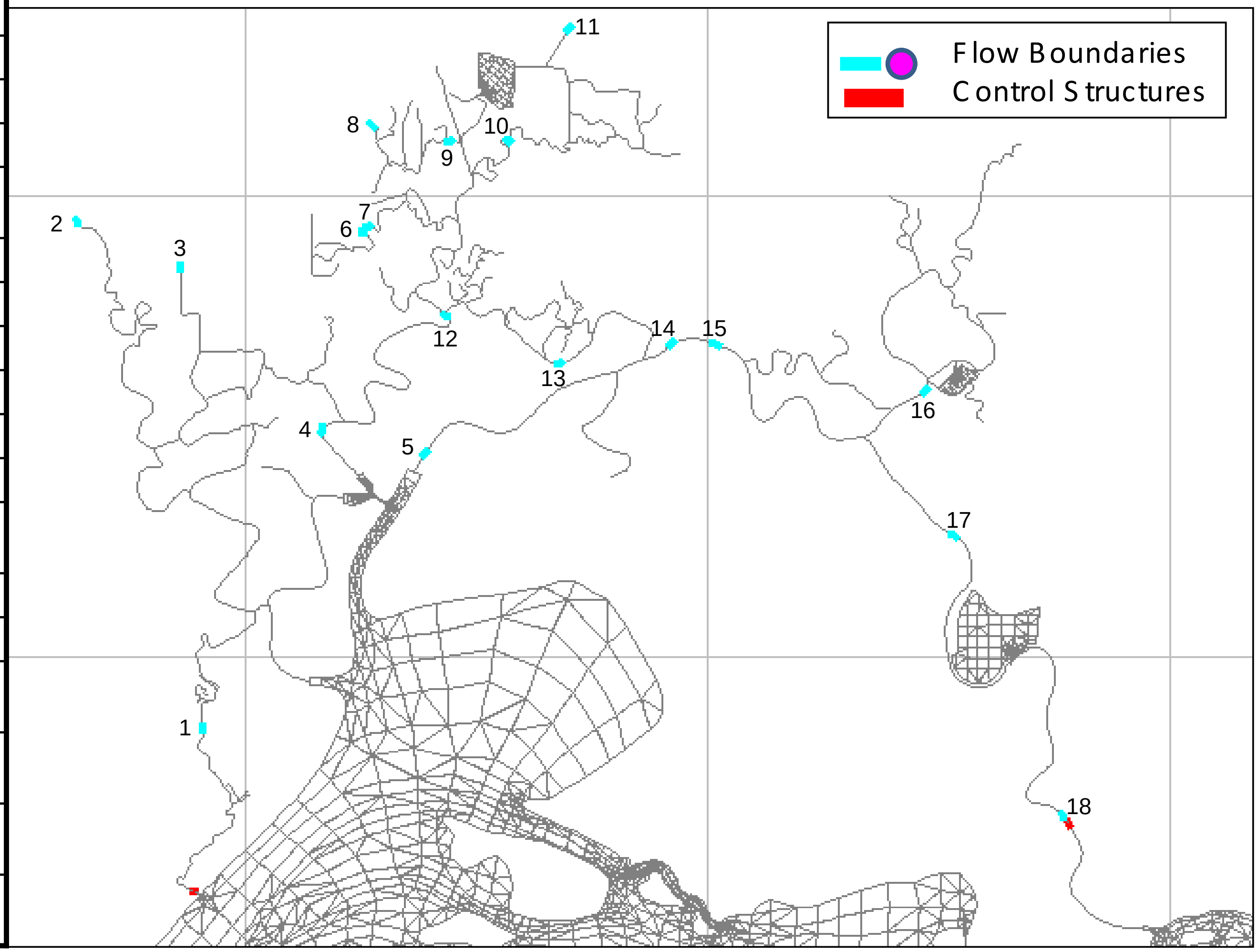



**Figure 3-12 Inflow/export locations in Suisun Marsh.**

**Table 3-2 EC boundary conditions for the EC calibration, Base case and scenarios simulations.**

| Boundary Location | Value (µmhos cm$^{-1}$) | Data Source |
|---|---|---|
| Golden Gate | 50,000 | Seawater EC |
| Sacramento River | Time Series | DWR DSM2 |
| Yolo Bypass | Sac. River Time Series | DWR DSM2 |
| San Joaquin River | Time Series | DWR DSM2 |
| DICU | Monthly Time Series | DWR's DICU model |
| Cosumnes River | 150 | Estimated |
| Mokelumne River | 150 | Estimated |
| Misc. Eastside Rivers | 750 | Estimated |
| Fairfield WWTP | 120 | Estimated |
| Napa River, Green Valley Creek, Suisun Creek, Ledgewood Creek, Laurel Creek | 120 | Estimated; Napa R. based on measured data |
| Duck Club Drains:<br>Nurse Slough drain<br>Suisun Slough drain<br>Roaring River drain<br>Montezuma Slough West<br>Montezuma Slough Middle<br>Montezuma Slough East | Estimated Using Source Time Series Data: | <br>Beldon's Landing Observed EC<br>Boynton Sl. Observed EC, shifted in time<br>Roaring River Observed EC<br>Hunter Cut Observed EC<br>Beldon's Landing Observed EC<br>National Steel Observed EC |
| Tidal Marsh –<br>Boynton Slough<br>Peytonia Slough<br>Hill Slough<br>First Mallard Slough<br>Cutoff Slough | Estimated Using Source Time Series Data: | <br>Boynton Sl. Observed EC, shifted in time<br>Hill Slough Observed EC<br>Hill Slough Observed EC<br>Beldon's Landing Observed EC<br>Beldon's Landing Observed EC |

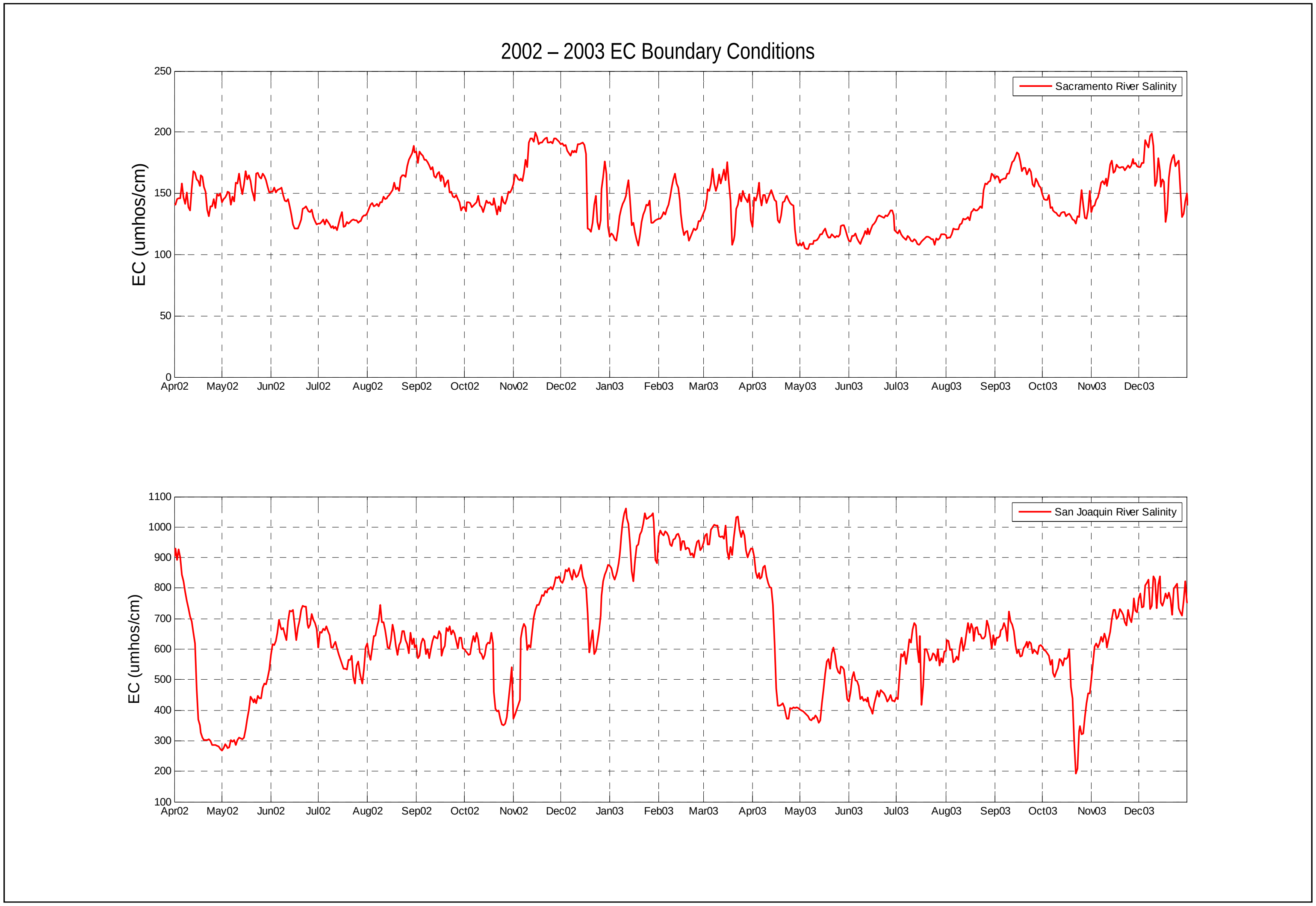



**Figure 3-13 Daily EC time series used as boundary conditions for the Sacramento River and Yolo Bypass (upper) and for the San Joaquin River (lower) for the 2002-2003 EC calibration/scenario simulation period.**

**Figure 3-14 Aerial view of the Suisun Marsh Salinity Control Gates.**

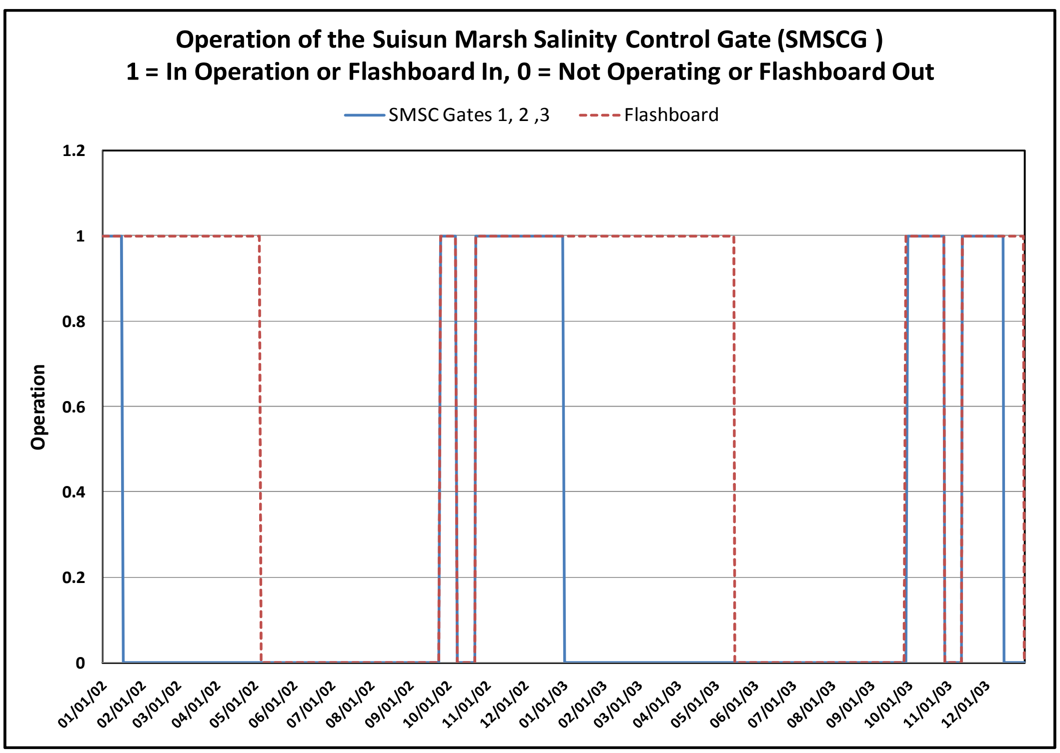



**Figure 3-15 Operational schedule for the SMSCG during the 2002-2003 EC calibration/scenario simulation period.**

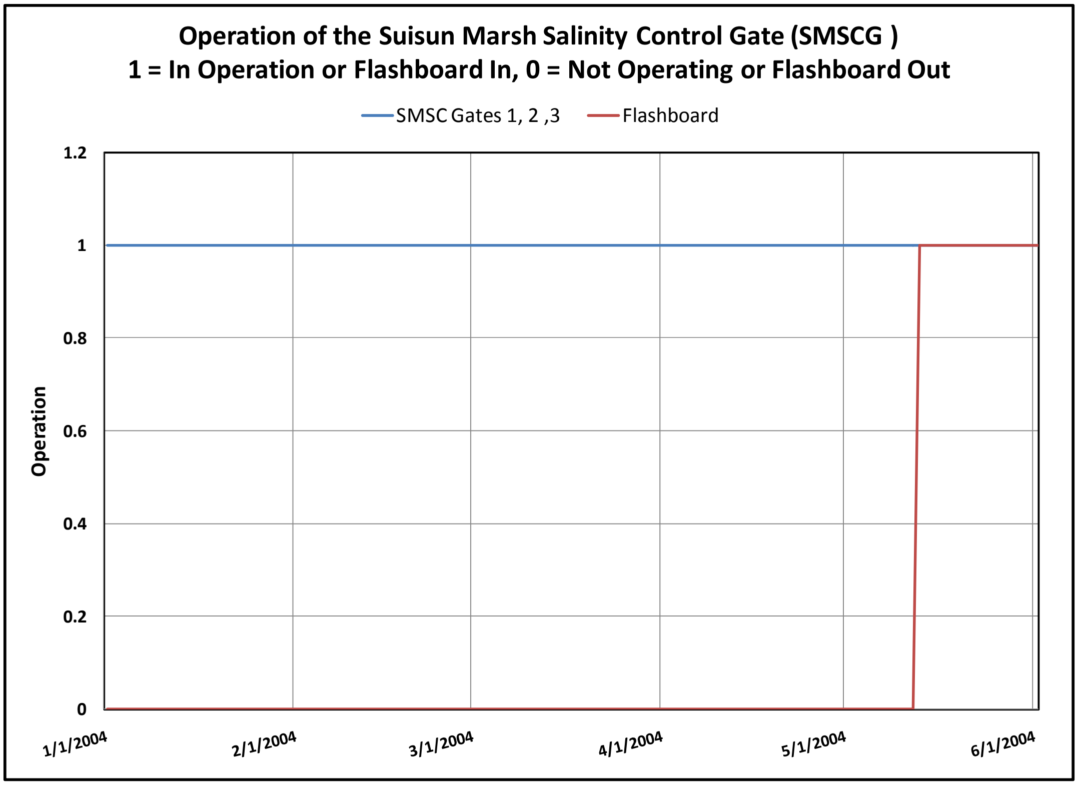



**Figure 3-16 Operational schedule for the SMSCG during the 2004 hydrodynamic calibration period.**

# 4. Model Calibration

The objective of the calibration effort was to prepare the model for detailed evaluation of flow and EC effects associated with the four marsh restoration scenarios proposed in the Suisun Marsh study. Understanding and accurately representing the changes in short time scale flow and mixing processes in the model is important in predicting the effects of these scenarios.

A recent calibration of RMA's Bay-Delta model for the Flooded Islands Feasibility Study (RMA, 2005) was used as the starting point for the current effort to improve the representation in Suisun Marsh. There was no recalibration of flow or EC in the Delta.

## *4.1. Hydrodynamics Calibration*

The RMA2 hydrodynamic model calibration covered the period April – July, 2004. The Jones Tract levee break occurred during this period, which is included in the model representation (RMA, 2005). Both the breach event and the subsequent levee repair were explicitly modeled.

In 2004, the DWR field program collected continuous flow data in major channels and dead-end sloughs in Suisun Marsh from April through early August – these data were used for calibrating the hydrodynamic model (DWR 2004a). Figure 4-1 gives the locations of stations in Suisun Marsh providing data for the hydrodynamic calibration. A new LiDAR dataset provided detailed elevation data, shown in Figure 4-2, which was instrumental in improving the model representation and the subsequent calibration in Suisun Marsh along with aerial photographs.

The flow and stage calibration greatly improved the representation of hydrodynamics in the Suisun Marsh region. DWR's continuous monitoring data from Suisun Marsh (Figure 4-1, white boxed labels) for flow and stage was used to guide the calibration, and LiDAR data (DWR, 2007) and aerial photographs were used to help define the extent and elevation of tidal marsh areas. The revised mesh geometry incorporated new marsh channels and off-channel storage to represent marsh overbank. RMA2 was updated to include the ability to represent daily time series of precipitation and evaporation.

### 4.1.1. Refining Suisun Marsh sloughs

The 2004 DWR field survey included the monitoring of flow and stage at the mouths of a number of dead-end sloughs. These sloughs were Nurse Slough (NS1), Hill Slough (HS1), First Mallard Slough (FM1), Cutoff Slough (C01 and C02), Boynton Slough (B01) and Shelldrake Slough (SH1). The first step of the calibration procedure was to model an individual dead-end slough and refine the network representation until the model flow closely matched the observed flow as recorded at the mouth of the slough. The model slough tidal boundary was driven by the observed stage at the mouth of the slough or from a nearby Suisun Marsh monitoring/compliance station (Figure 4-1). The refined and calibrated dead-end sloughs were then inserted back into the RMA Bay-Delta model for the subsequent calibration of the major Suisun Marsh sloughs and channels, specifically Montezuma (M01, M02, M03 and M04) and Suisun Sloughs (SS1) and Hunter Cut (HC1).

Details of the observed flow and stage records were used to iteratively refine the model representation. LiDAR images and aerial photographs were used to understand the geography, and to estimate the location, extent and elevation of tidal marsh. For example, aerial photographs sometimes helped define areas covered with specific vegetation such as tules, which gives an indication of inundation around Mean Higher High Water (MHHW).

Figure 4-3 illustrates how differences between the observed and computed values for flow as the tidal marsh filled and drained were used to refine the initial estimates of marsh area associated with Boynton Slough. As the water level rises above 3.0 feet (June 16 @ 22:00), the initial slough model (red line) shows an early fall off in flood flow relative the observed flow. Similarly, the initial slough model is low on the following peak ebb flow as the stage begins to fall. The slough model was modified to increase the amount of overbank marsh and the simulation rerun. The green line in Figure 4-3 shows the better fit to observed flow with the revised slough representation.

### 4.1.2. **Incorporating managed wetlands**

Figure 4-4 presents the tidally averaged observed and computed flow for Boynton (B01) and Hill (HS1) Sloughs and the observed stage at Hill Slough (S-4). The observed tidally averaged flows show a distinct net flow landward during most spring tide periods. This was typical of all observed flow records for the dead-end sloughs for the April – July, 2004 monitoring period. The tidally averaged computed flows show only small fluctuations in the net flows as the average water level rises with the spring tide and falls with the neap tide. The observed flow records show a significantly greater net landward flow during the spring tide periods. The Boynton Slough observed flow also exhibits notable net outward flow around July 5 and July 31.

The differences between the observed and initial computed net flows are most likely related to exchange with the managed wetlands and the wetting and evaporation of the tidal marsh on the spring tide. A trial model simulation was performed for Boynton Slough in which an adjacent managed wetland was added and connected to the slough by open culverts. Evaporation was simulated with a withdrawal from the managed wetlands of 7 cfs in the May 1-27 period and 21 cfs in the May 27 – June 30 period.

The addition of the managed wetland with evaporation significantly improves the fit of the model to the observed net flows. Figure 4-5 compares the new simulation result to the observed record and to a simulation with no evaporation or managed wetland. Figure 4-6 shows the improved fit to the intertidal flow with the managed wetland addition, in particular where the computed flood flow was initially too low. Evaporation from adjacent tidal marsh and the channel water surface is another source of water loss from Boynton Slough and other marsh channels. The 21 cfs rate of water loss modeled for late May and June is equivalent to 1260 ac-ft/month. The open tidal marsh and water surface upstream of the Boynton Slough flow meter is about 230 acres. Thus evaporation from the tidal marsh alone is not sufficient to account for the 1260 ac-ft/month flow loss.

The trial model demonstrated that the addition of managed wetland with evaporation significantly improved intertidal flow. However, simulation of tidal flow through the managed wetlands was not incorporated into the final model simulations.

The observed flow records may also indicate the diversion of flow from Montezuma Slough. Figure 4-7 shows the tidally averaged observed flow for the Montezuma Slough stations M03, south of Nurse Slough, and M04, south of the Suisun Marsh Salinity Control Gates. The curves show more flow into Montezuma Slough at M04 than exiting at M03 for portions of April and May 2004. The net flows at the two stations are roughly equal in June and July. Peak difference is about 500 cfs around May 5, 2004. The stage records inside the managed wetlands at the Roaring River intake location and for Montezuma Slough suggests large diversions occurring at the intake in early May (Figure 4-7).

Except for the trial simulations for the model of only Boynton Slough, diversions to the managed wetlands were not generally part of the 2004 hydrodynamic calibration. There was not sufficient detailed knowledge to attempt to reproduce all the characteristics of the managed wetlands culvert structures and operation within the tidal cycle. The observed flow data suggests the diversions and returns by the managed wetland, and evaporative losses for the tidal marsh. The differences in observed and computed net flows were used to help guide estimates of the wetlands diversions and returns. Further estimation of wetlands diversions/returns and evaporative losses for the channels and marsh were refined in the EC calibration phase.

### 4.1.3. Results of the hydrodynamic calibration

As described above, the dead-end sloughs were first calibrated in the isolated fashion, and then the revised slough networks were reinserted into the full RMA Bay-Delta model. The model flows and stages presented in this section are for the full Bay-Delta model. The diversions to the managed wetlands were not included in this hydrodynamic calibration and would likely influence both the net and intertidal flows. The estimation of the managed wetlands diversions/returns on a gross basis was performed as part of the EC calibration. The detailed hydraulic properties of the many culvert structures throughout the Suisun Marsh and the operation of these structures on a tidal and daily time scale create a large set of unknown variables. As such, the managed wetlands diversions/returns were not generally included during the hydrodynamic calibration except on an experimental basis.

Flow in dead-end sloughs and stage representations were generally good through-out the marsh. Figure 4-8 through Figure 4-11 give representative results for stage calibration (NGVD29) at three monitoring locations. Timing was slightly retarded in comparison with observed stage. Modeled stage tended to be somewhat low in Montezuma Slough, particularly during neap tides.

Tidal flow results were more variable. Figure 4-12 illustrates the tidal flow calibration at station NS-1 in Nurse Slough , showing that calculated flood tide flow was generally too low at this location. The tidally averaged observed flows for Nurse Slough showed large negative values on average of -400 cfs. There was no attempt to simulate culvert flows to managed wetlands for Nurse Slough, which may have improved the computed vs. observed fit. The computed flow vs. observed for Hill Slough (HS1) is very good, with the computed tidal flow amplitude slightly overestimated (Figure 4-9).

Tidal flow in Cutoff Slough (Figure 4-13) and First Mallard Slough (Figure 4-14) is slightly too large during ebb tide, but otherwise good in phase and magnitude. Tidal flow in Montezuma Slough was generally too low (Figure 4-15 through Figure 4-17), and the differences were significant here although phasing was quite good. Trial simulations were performed which examined incorporating culvert flows into the Roaring River distribution system (just north of the Suisun Marsh Salinity Control Gates). These results suggested that computed tidal flow and net flow for M04 may be somewhat improved by explicit modeling of the culverts to the Roaring River distribution system and to other managed wetlands diversions.

The differences between observed and calculated tidal flow in Suisun Slough and Hunter’s Cut are likely related, as Suisun Slough above Hunter Cut is filled by both channels. Figure 4-18 and Figure 4-19 show modeled and observed tidal flows at the mouth of Suisun Slough and in Hunter Cut, respectively. The low values for tidal flow in Hunter Cut may be compensated by larger-than-observed tidal flow through the mouth of Suisun Slough.

Generally, these calibration results showed good agreement between the simulated and measured tidal elevations (stage) and between the simulated and measured tidal flows at many different locations in the marsh during 2004. The model results can be used with confidence to estimate the effect of additional tidal restoration.


**Figure 4-1 Locations of stations in Suisun Marsh used for flow and EC calibration. The white boxed labels indicate special continuous monitoring stations implemented during spring 2004.**


**Figure 4-2 Suisun Marsh LiDAR data used in the model calibration – elevations shown in the color scale are in feet (NGVD29).**

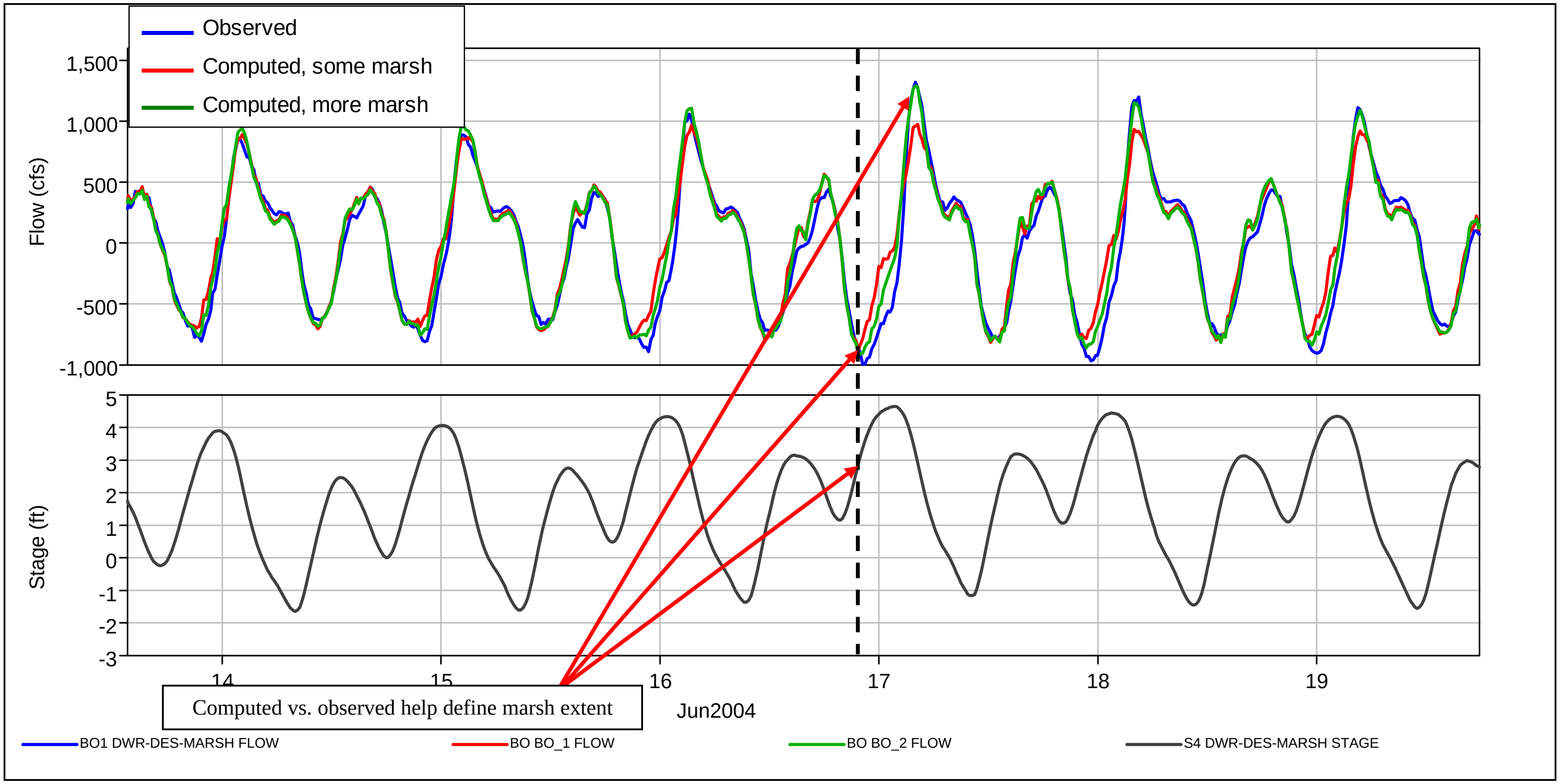



**Figure 4-3 Observed and computed flow and stage data in Boynton Slough with two iterations of flow results showing how addition of tidal marsh affects computed flows.**

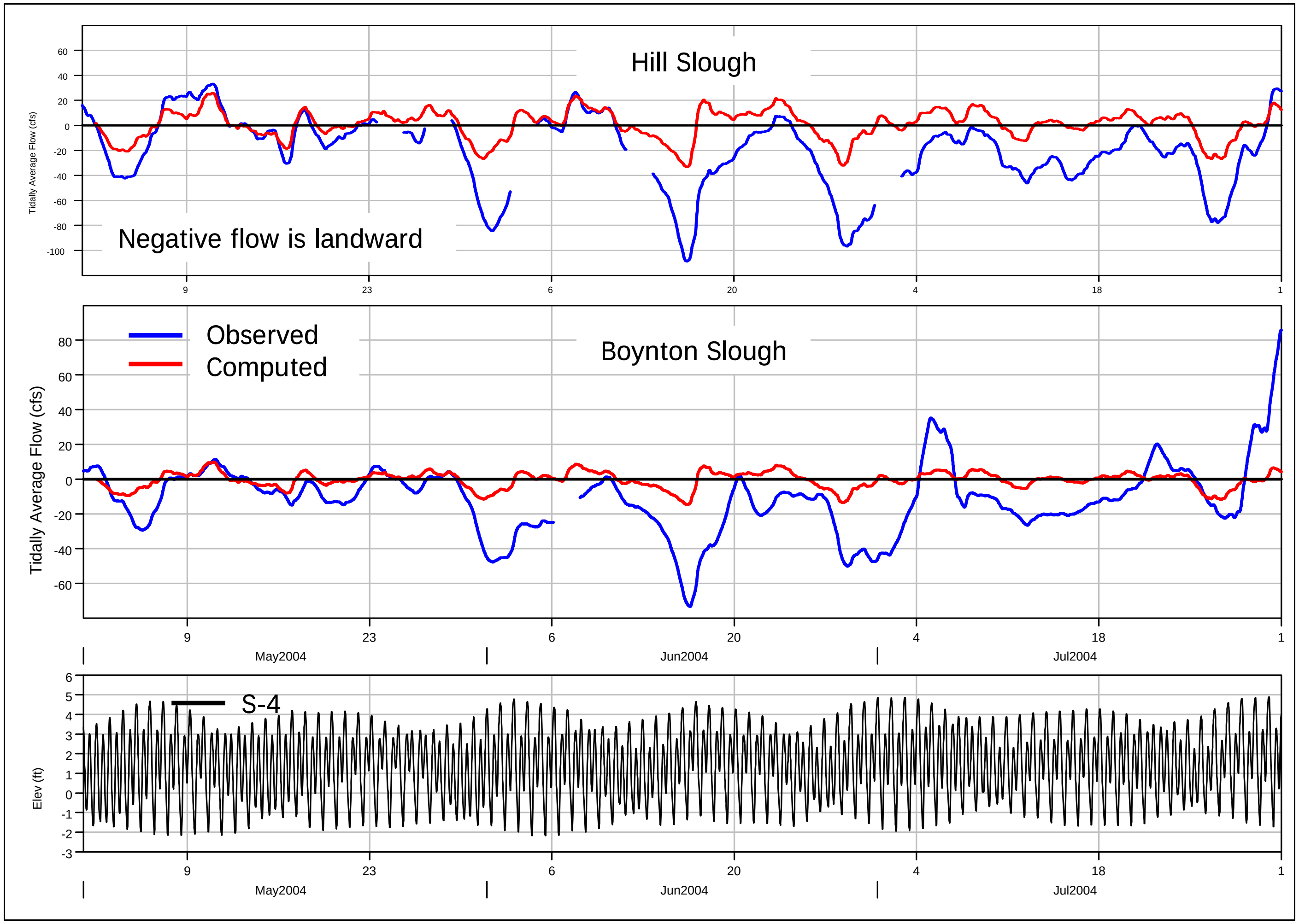



**Figure 4-4 Observed and computed tidally averaged flow in Boynton Slough (B01) and Hill Slough (HS1), and observed stage at Hill Slough (S-4).**

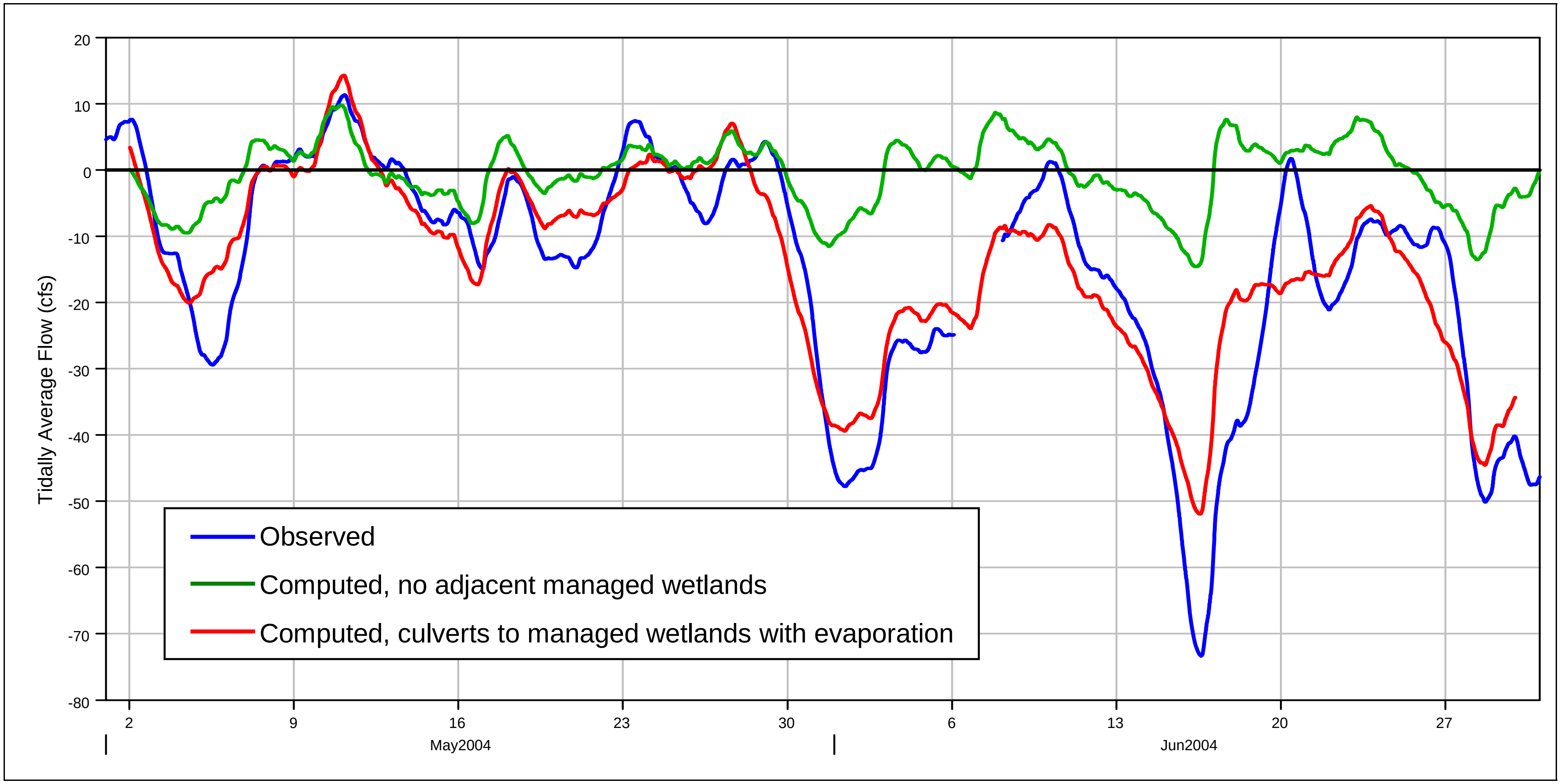



**Figure 4-5 Observed and computed tidally averaged flow for Boynton Slough. The red line is the flow for a modeled system with an adjacent managed wetland connected by open culverts to Boynton Slough.**

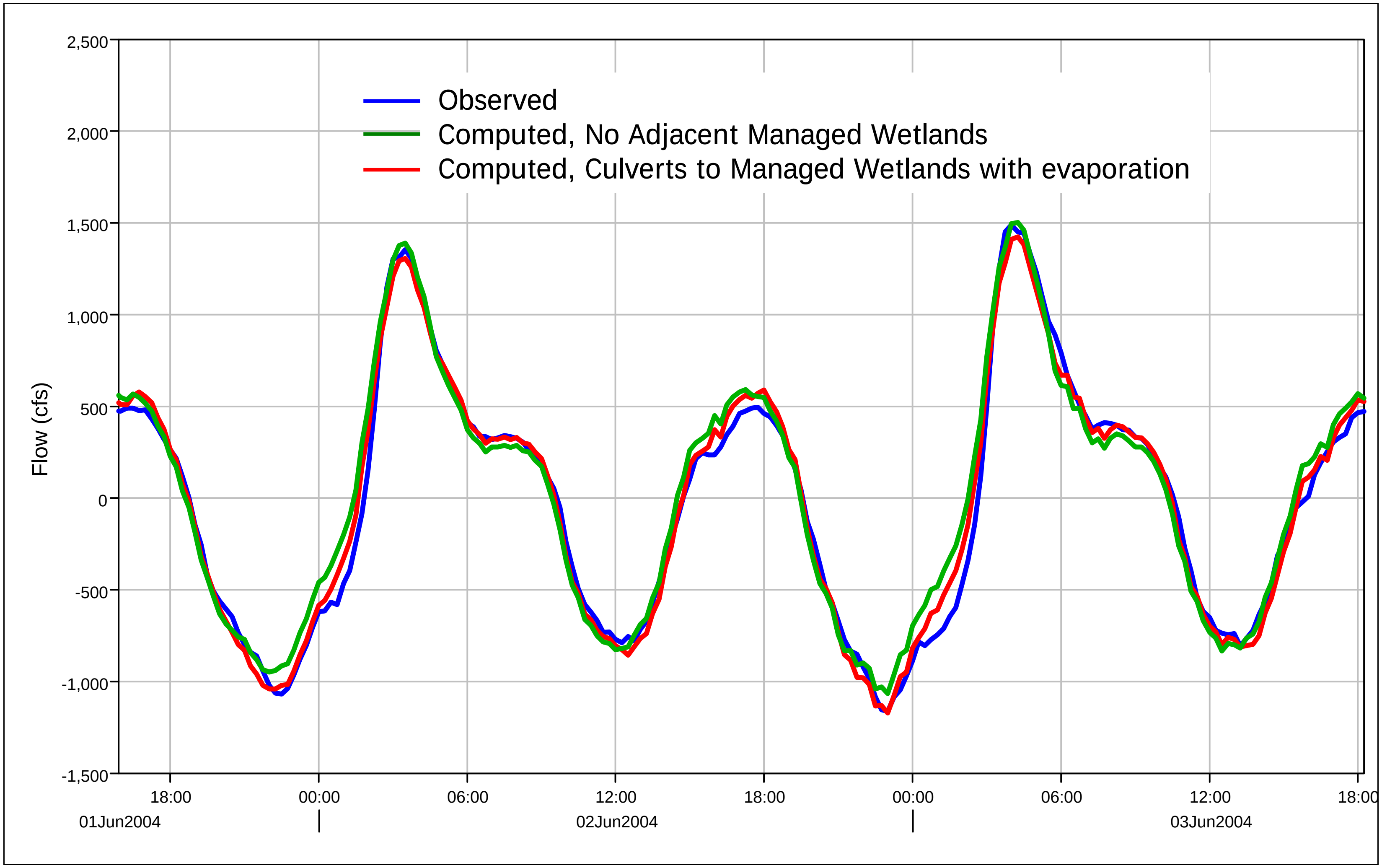



**Figure 4-6 Observed and computed flow for Boynton Slough. The red line is the flow for a modeled system with an adjacent managed wetland connected by open culverts to Boynton Slough.**

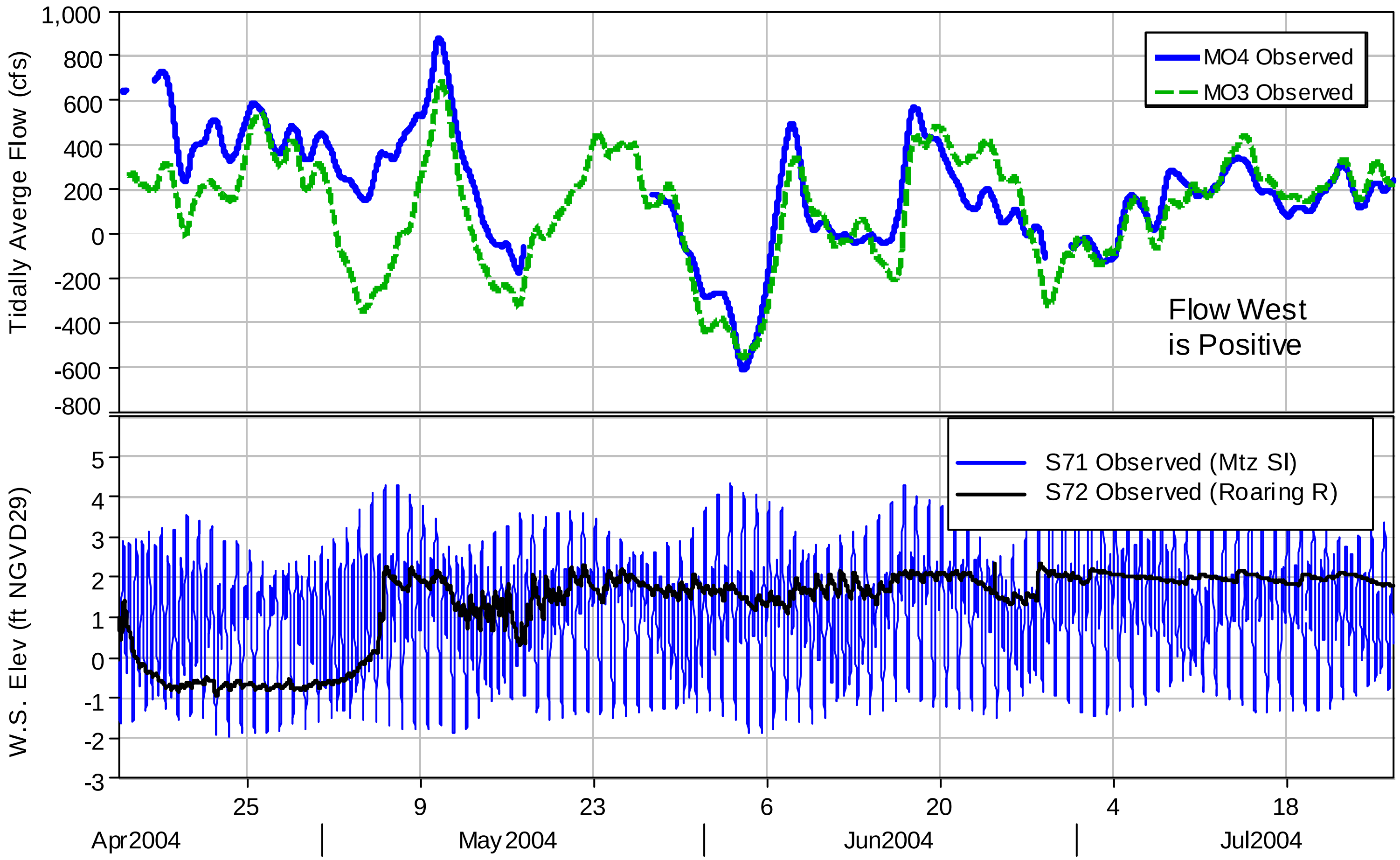



**Figure 4-7 Observed tidally averaged flow for the east side Montezuma Slough stations M04 and M03, and the Observed Stage at S71 and S72.**

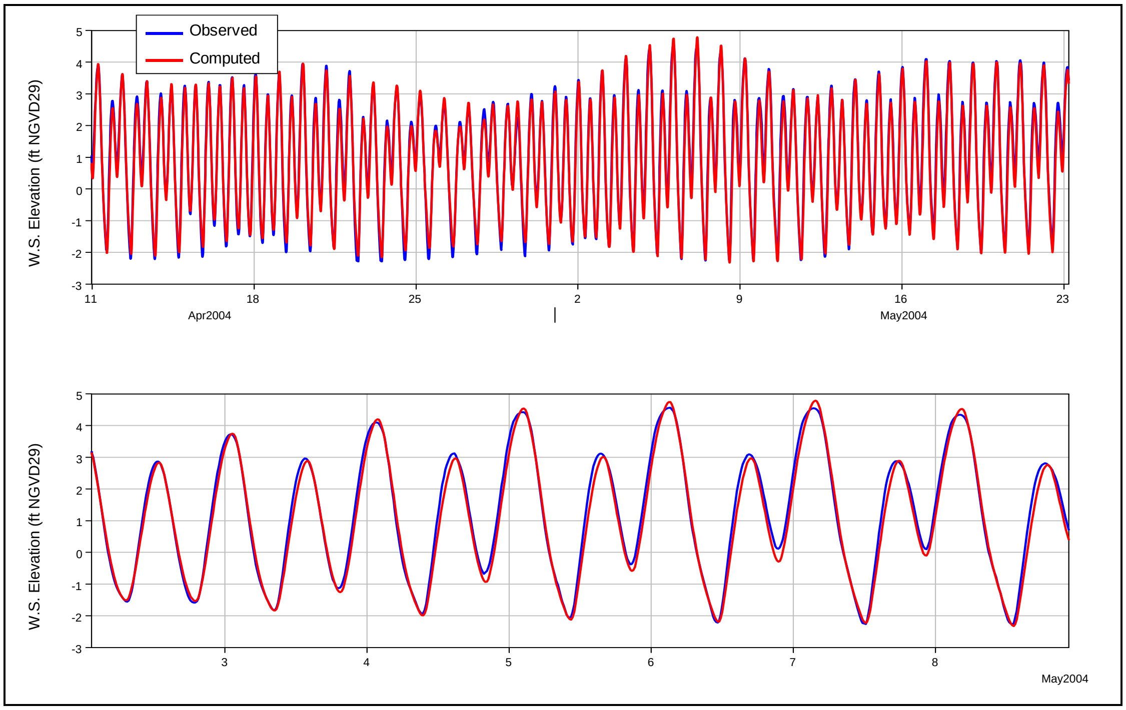



**Figure 4-8 Observed and computed stage at monitoring station S-4 in Hill Slough during April – May 2004 (shorter time period shown in lower plot).**

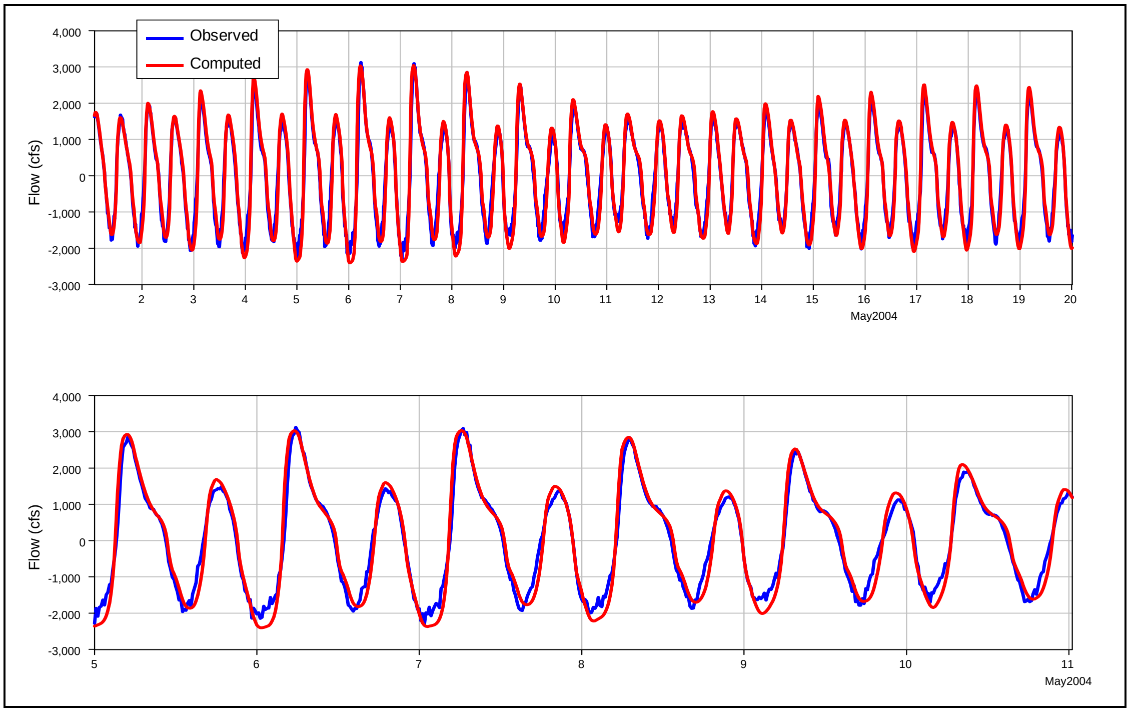



**Figure 4-9 Observed and computed flow at Hill Slough, station HS1 during May 2004 (shorter time period shown in lower plot).**

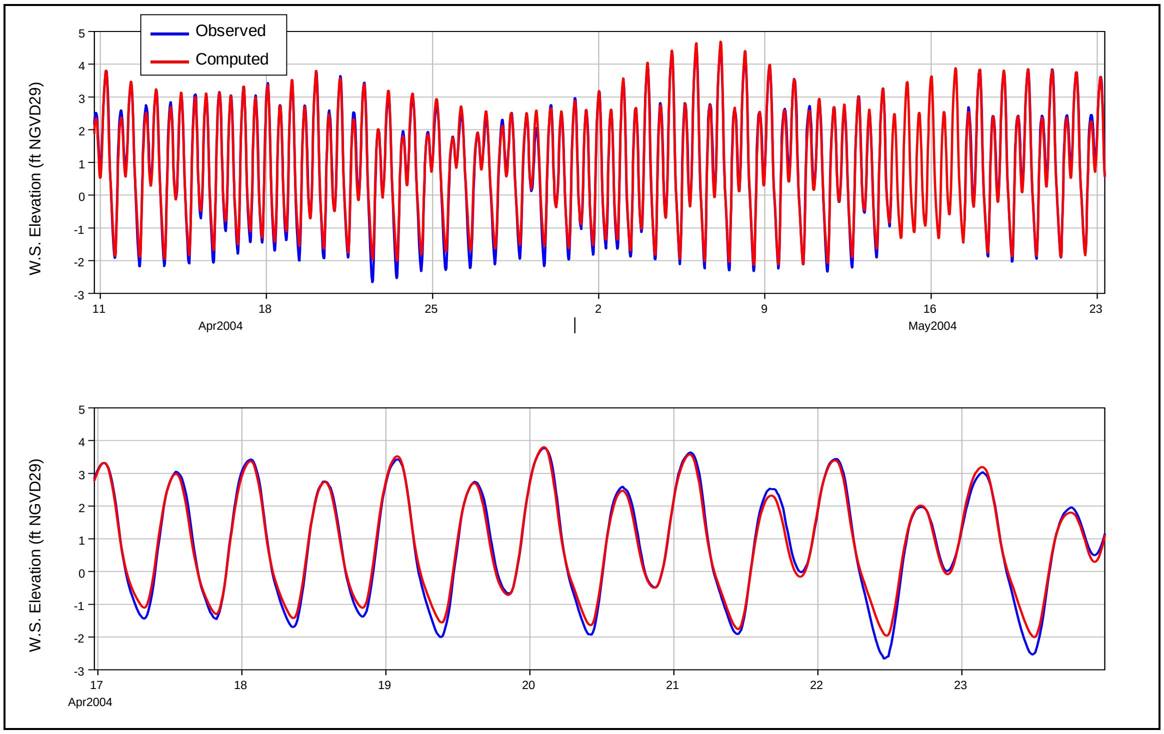



**Figure 4-10 Observed and computed stage at monitoring station S-49 at Beldon's Landing on Montezuma Slough during April – May 2004 (shorter time period shown in lower plot).**

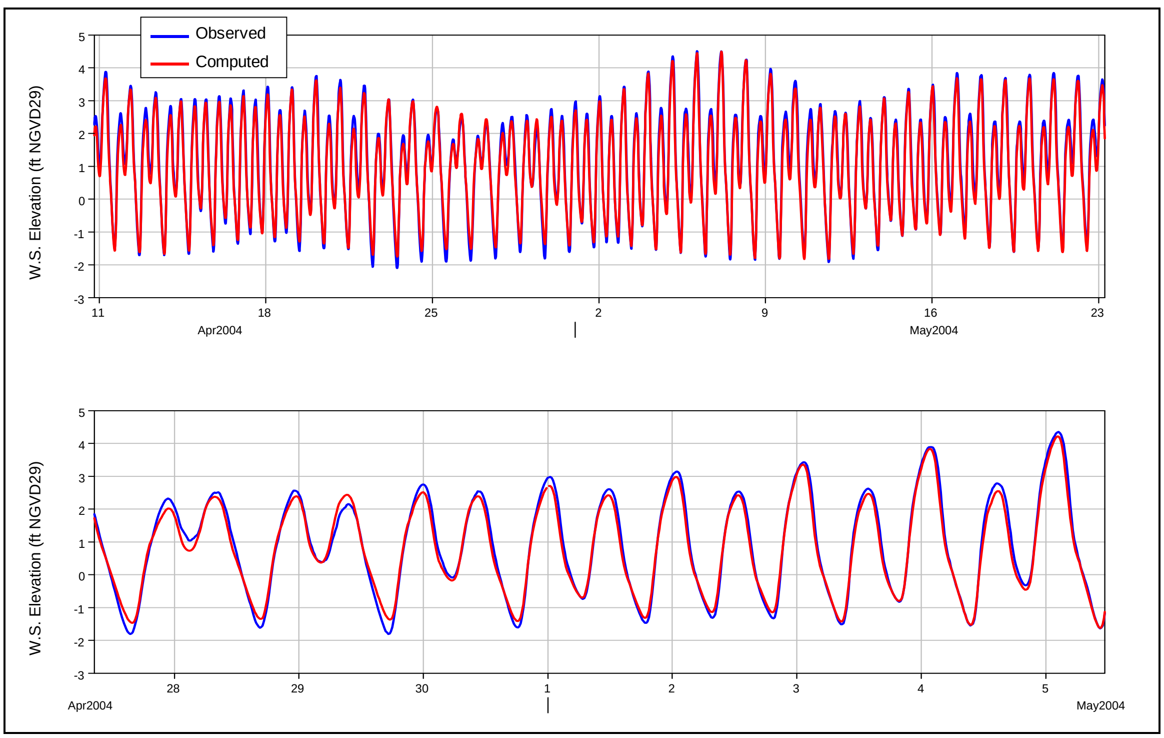



**Figure 4-11 Observed and computed stage at monitoring station S-64 at National Steel on Montezuma Slough April – May 2004 (shorter time period shown in lower plot).**

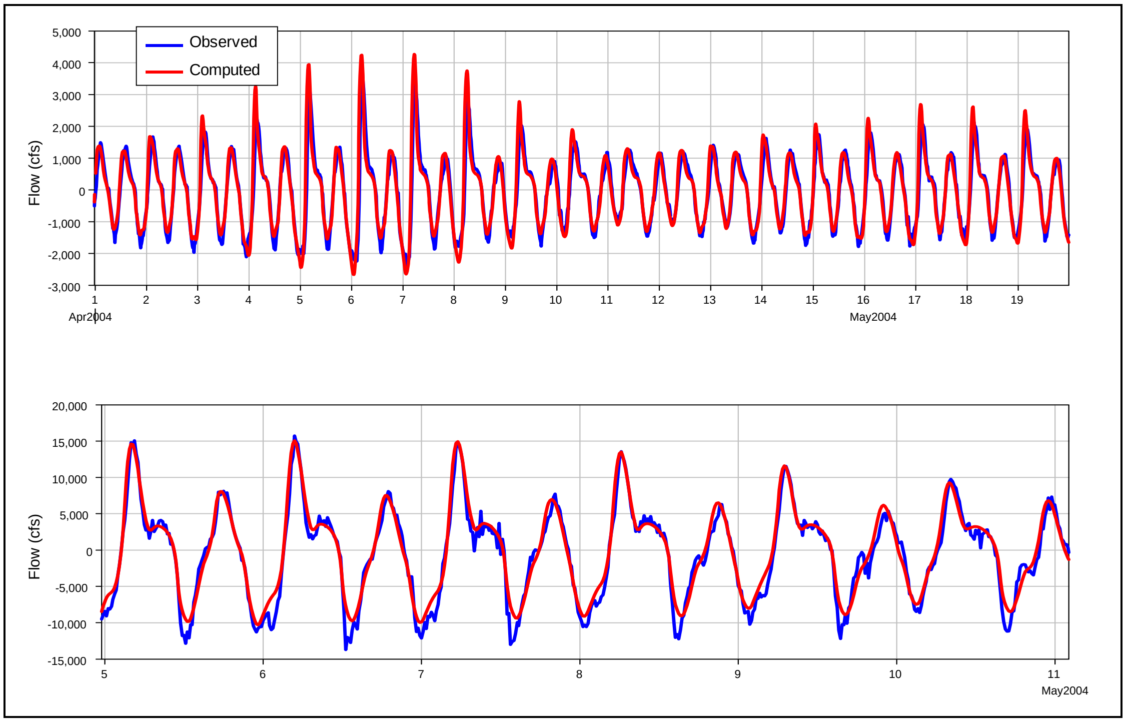



**Figure 4-12 Observed and computed flow at the Nurse Slough monitoring station, NS1 May 2004 (shorter time period shown in lower plot).**

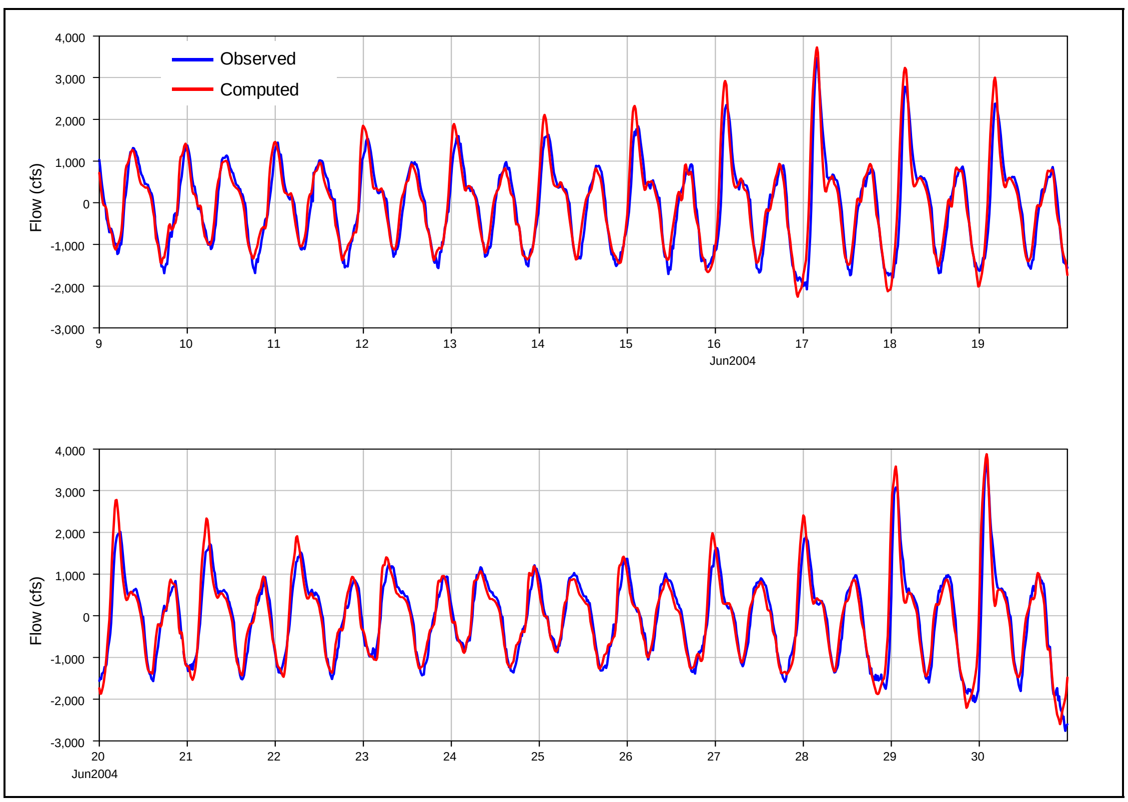



**Figure 4-13 Observed and computed flow at the Cutoff Slough monitoring station, CO2 during June 2004.**

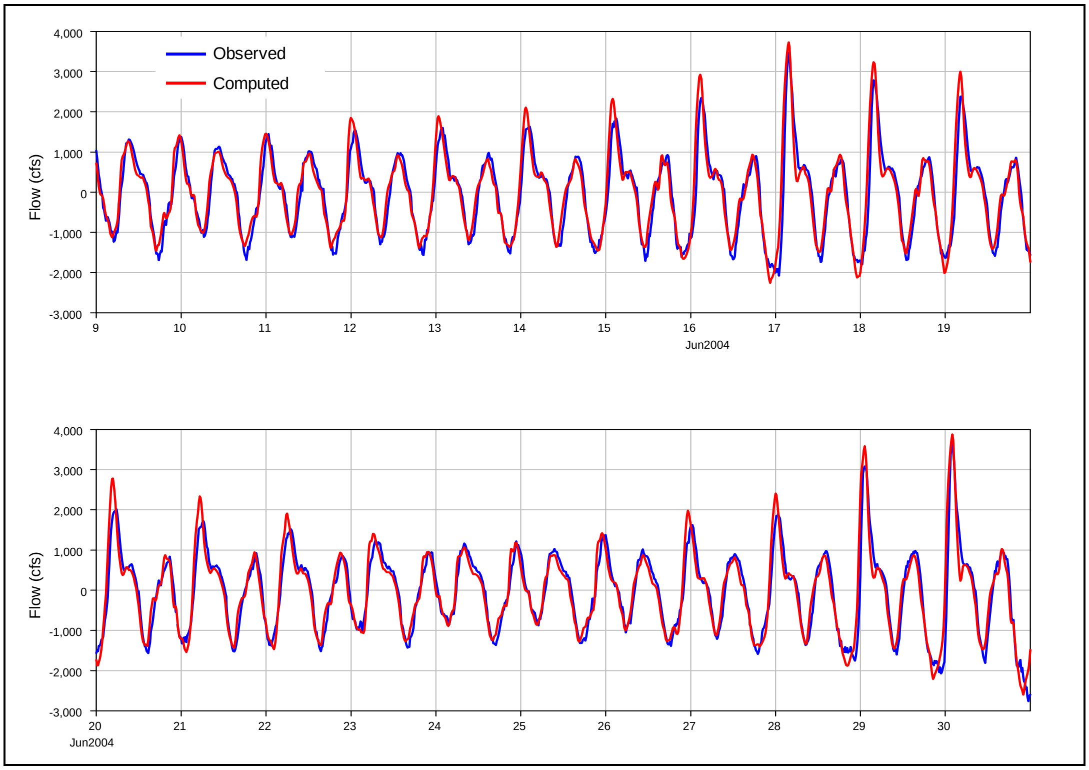



**Figure 4-14 Observed and computed flow in First Mallard Slough at station FM1 during June 2004.**

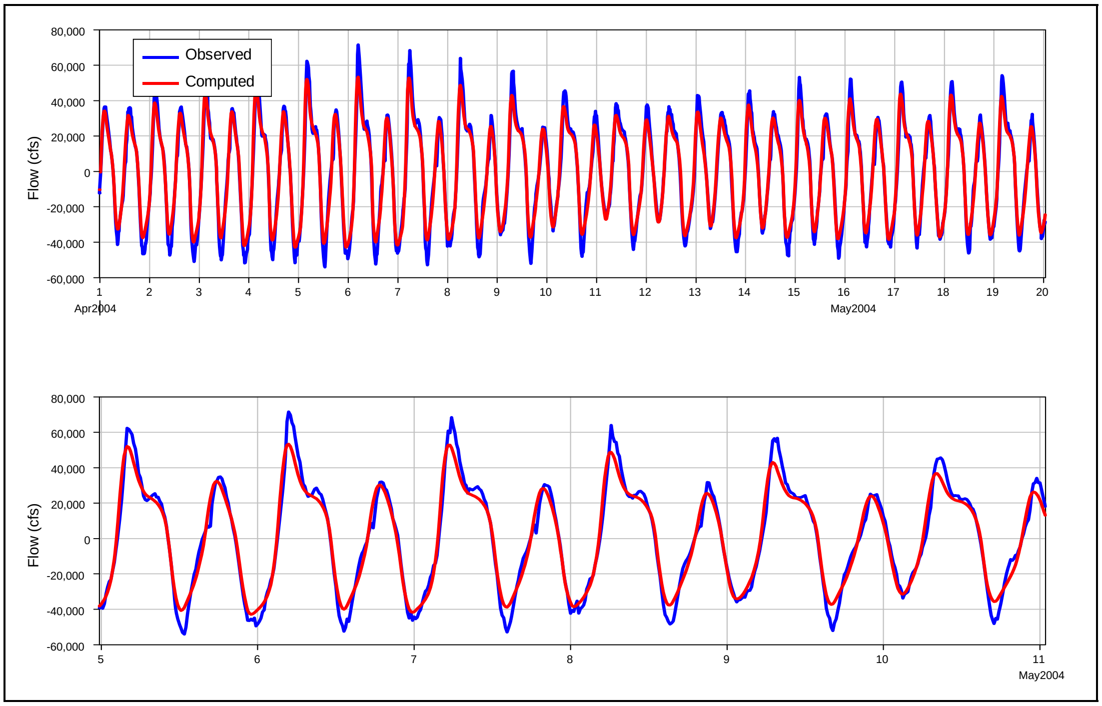



**Figure 4-15 Observed and computed flow in Montezuma Slough at station MO1 during May 2004 (shorter time period in lower plot) – positive values indicate flow is eastward.**

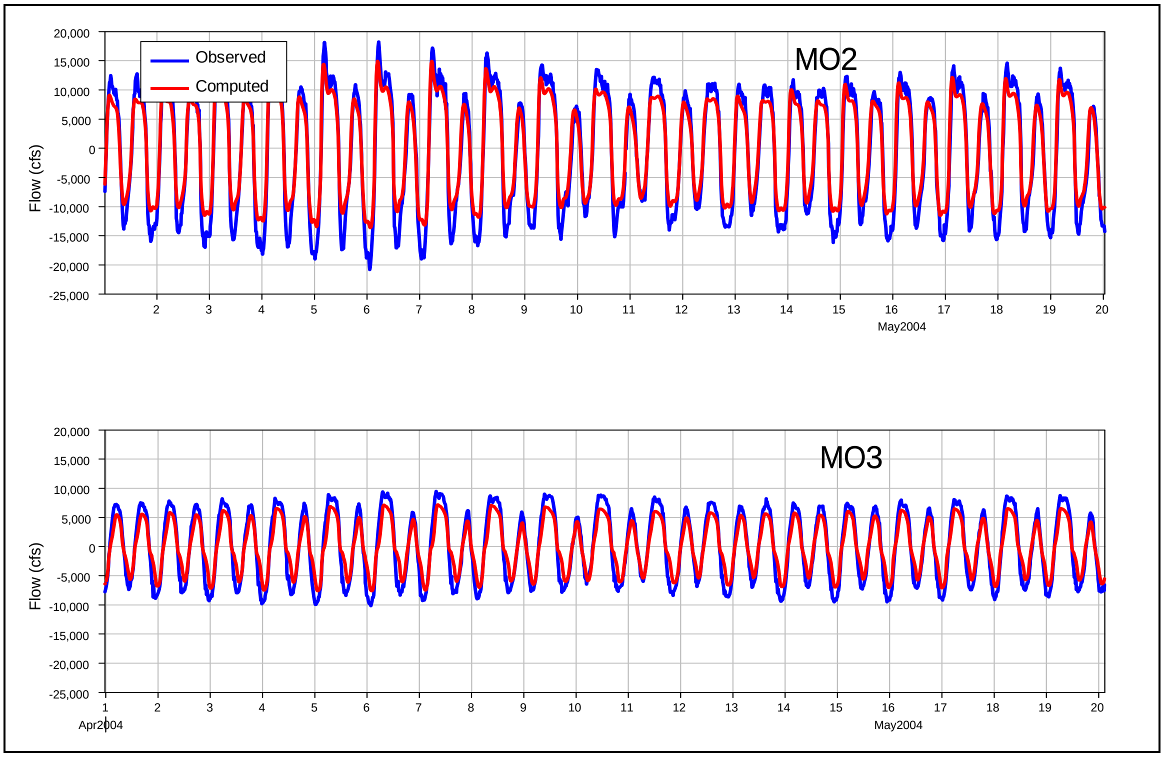



**Figure 4-16 Observed and computed flow in Montezuma Slough at monitoring locations MO2 and MO3 – positive values indicate flow is eastward.**

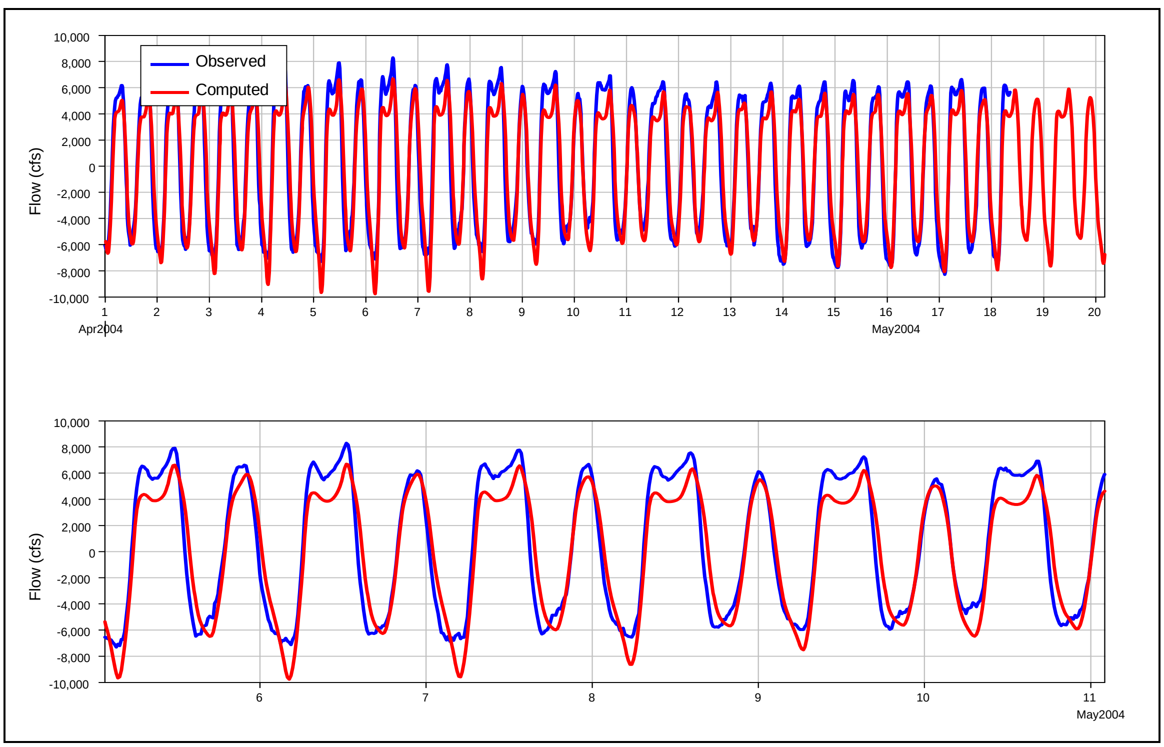



**Figure 4-17 Observed and computed flow in Montezuma Slough at monitoring location MO4 (shorter time period shown in lower plot) – positive values indicate flow is eastward.**

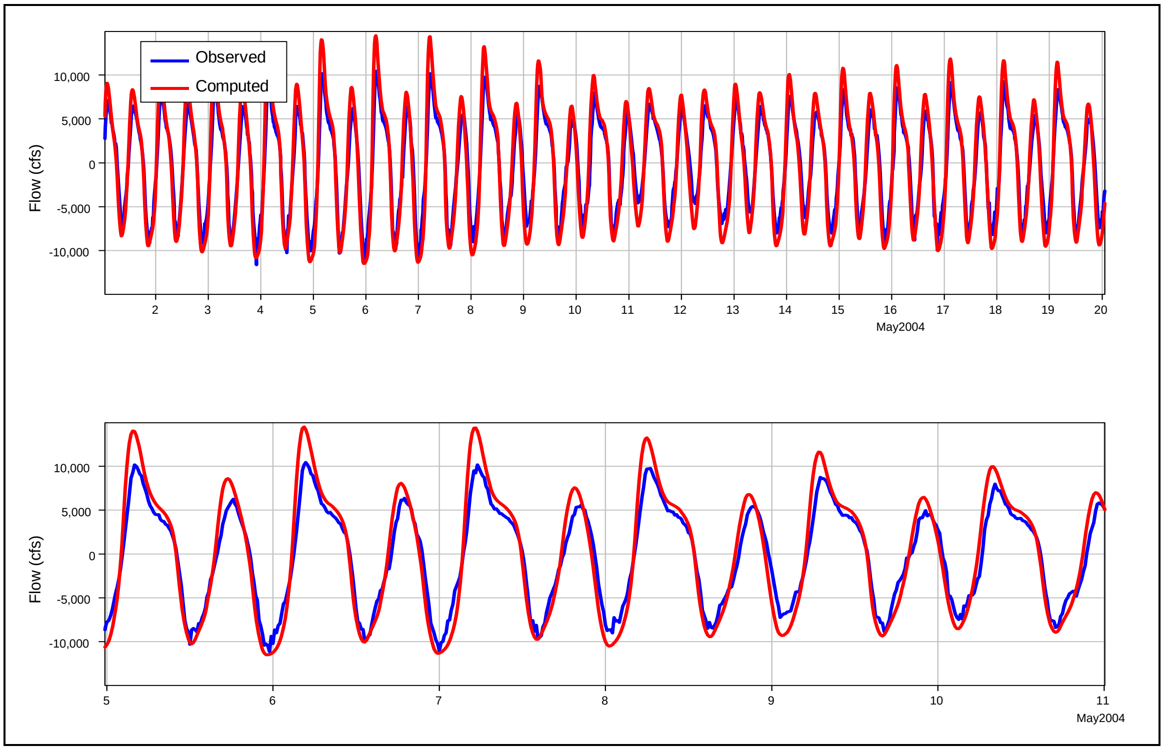



**Figure 4-18 Observed and computed flow at the mouth of Suisun Slough, station SS1 (shorter time period shown in lower plot).**

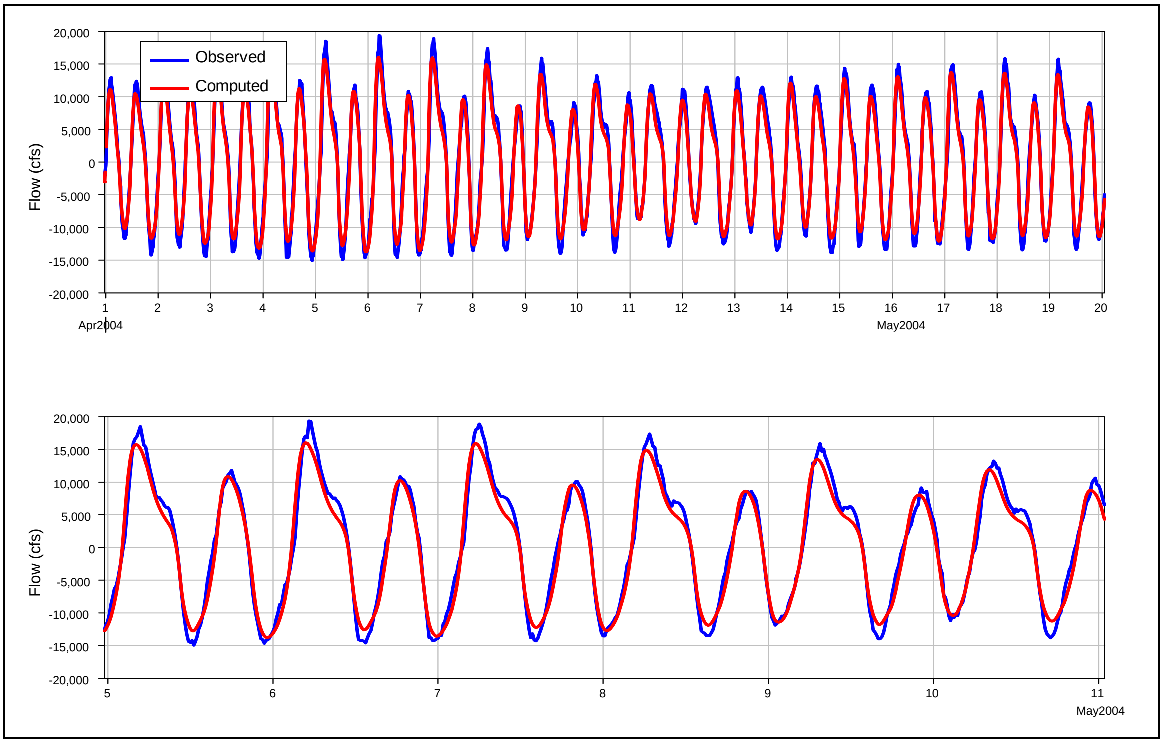



**Figure 4-19 Observed and computed flow through Hunter Cut at monitoring station HC1 (shorter time period shown in lower plot).**

## 4.2. Electrical Conductivity (EC) Calibration

### 4.2.1. Background

The RMA11 EC calibration was performed for the period of April 2002 – December 2003. To calibrate the EC model, computed EC was compared with observed data at the sampling locations shown in Figure 4-2.

Calibration results were hampered by the lack of sufficient model input data, for example the lack of managed wetlands withdrawals and returns and local creek flows, and by approximations to some mechanisms that are intrinsic to the model. Specifically, density stratification cannot be explicitly represented in the depth-averaged model formulation.

Density stratification is particularly important following high flow periods during neap tide, although periods of stratification also occur intermittently during neap tide periods when net Delta outflow is sufficiently low. Periods of higher (> 30,000 cfs) and lower ( ~ 4,000 cfs) outflow, are illustrated in Figure 4-21 and Figure 4-22, respectively, which show observed top and bottom EC, stage at Martinez, and Delta outflow. In Figure 4-22, during a neap tide in a lower outflow period around August 19, 2003, top and bottom EC data indicate that significant stratification developed at Martinez, which lasted for about five days.

The result of neglecting density stratification in the 2-D model is slow recovery of model EC following high flow periods. In the calibration results, attempts to compensate for the stratification using diffusion coefficients have pushed computed EC too high during the late fall. These problems become evident in the model at the Martinez station and are propagated through Suisun Marsh. Modeled, tidally-averaged EC at Martinez (Figure 4-23) illustrates the effect of the 2-D model approximation in comparison with data. The winter period of low EC accentuates the inability of the model to capture stratification, and the high fall EC shows the effect of the compensating diffusion coefficients.

### 4.2.2. Results

EC calibration results were geographically and seasonally variable along Montezuma Slough. The inclusion of managed wetlands and evaporation resulted in significant improvements in modeled EC at Beldon’s Landing, S-49 (Figure 4-24), during some periods. The tidally averaged computed EC (Figure 4-25) is a fairly good match with tidally averaged observed data throughout most of the calibration period, except during winter 2003 and late fall 2002 and 2003. This location seems to be near the balancing point between the overestimated EC at Martinez in the fall, and the incorrect net flow balance in Montezuma Slough during the periods when SMSCG is not operating (although flow data are not available specifically for this time and location to confirm this). Intertidal results at this location show slightly less tidal variation in computed EC compared with observed data.

In eastern Montezuma Slough, modeled EC is lower than observed EC year-round. This can be seen at stations S-64 at National Steel, in Figure 4-26, and S-71 at Roaring River, in Figure 4-27. This is due to insufficient propagation of higher EC up Montezuma

Slough from the west, possibly because of incorrect net flows and/or due to insufficient representation of local effects, for example, exchange with Roaring River. Also, the hydrodynamic calibration did not include wetland diversions, while EC calibration did.

Calibration results at Collinsville (Figure 4-29) are relatively good on a tidally averaged basis. Throughout much of the year the tidal signal in the computed EC is dampened compared with the observed data, and at other times, the agreement between computed and observed 15-minute data is quite good. Although it is not always true, the results tend to be best when the SMSCG is operating (Figure 4-30).

The addition of Green Valley Creek, Suisun Creek, Ledgewood Creek and Laurel Creek and WWTP flows in the model representation greatly improved the storm period results in the eastern and northeastern marsh. Figure 4-32 to Figure 4-36 illustrate these effects at S-4 in Hill Slough, S-42 at Volanti in Suisun Slough, and at S-97 in Cordelia Slough at Ibis, respectively. EC results at S-4 and S-42, although very much improved with the addition of creek flows, seem to indicate either missing inflows, or possibly that the shape of the hydrograph is not quite right. Ledgewood and Laurel Creek flows, which contributed to this area of the marsh, were estimated because no data were available, so an excellent match with observed data is not expected.

Results in western Montezuma Slough at S-54, Hunter Cut (Figure 4-28), follow the pattern of EC under- and over-estimation observed at Martinez in Figure 4-23. The results are similar in the south-western areas of the marsh (Figure 4-37 to Figure 4-40), although EC increases are somewhat muted at S-37 in Suisun Slough (Figure 4-38).

### 4.2.3. **Summary**

Although the model development and calibration effort improved modeled EC in Suisun Marsh, the improvements were geographically and seasonally variable. The inclusion of managed wetlands and evaporation alone resulted in significant improvements in modeled EC in some areas, such as Beldon’s Landing (Figure 4-24). The addition of creek flows greatly improved the representation of EC in the northern and north-eastern portions of the marsh.

Modeled EC tended to be too low January – June, 2003 in most of Suisun Marsh. Computed EC was generally good in the western and middle portions of Montezuma Slough and in the south-western regions of the marsh. EC was low in the eastern portion of Montezuma Slough, and high in the northern portions of Suisun Slough.


**Figure 4-20 Locations of monitoring stations used in EC model calibration.**

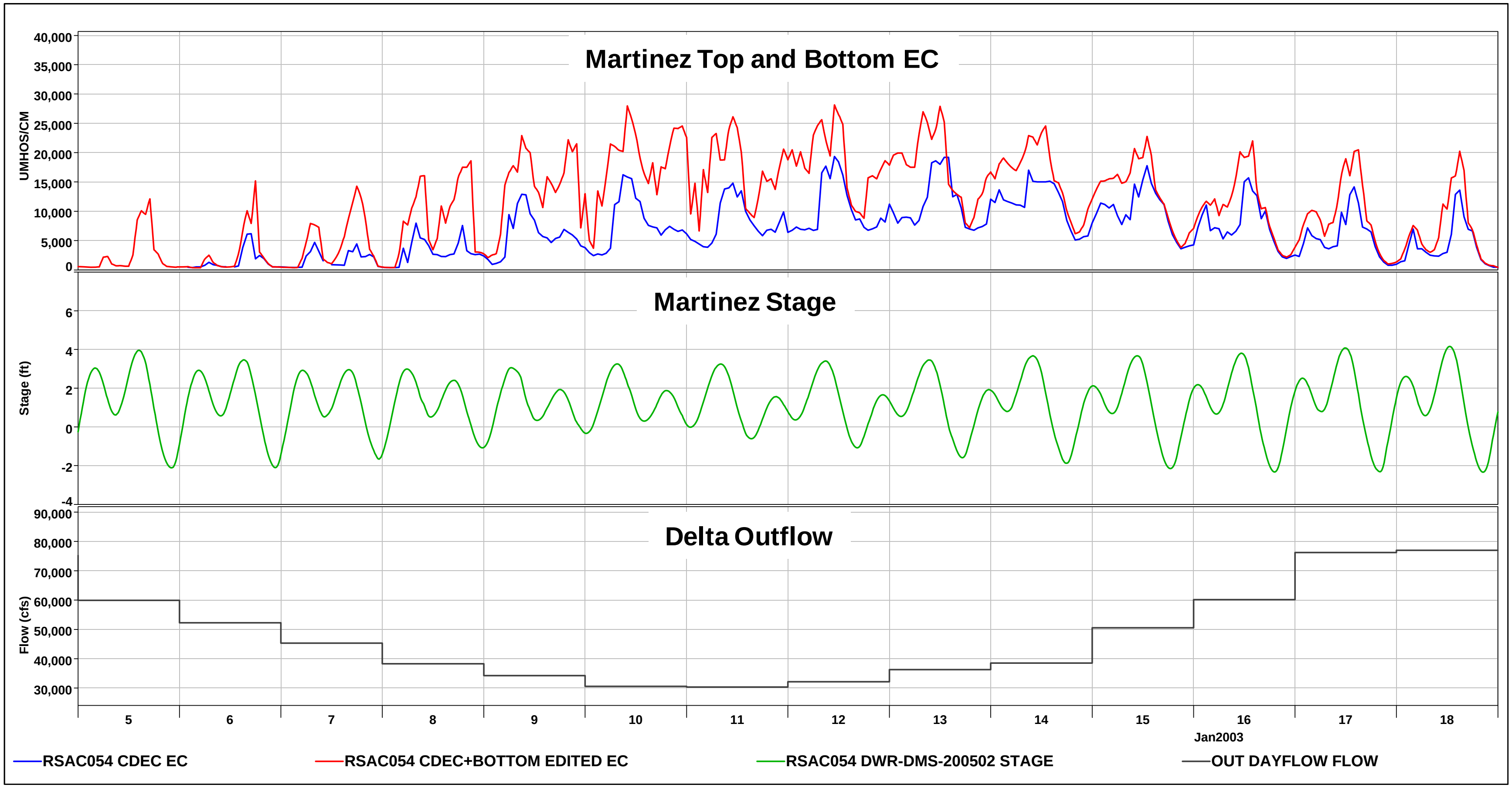



**Figure 4-21 Top/bottom EC and stage at Martinez (RSAC054), and Sacramento River flow during a high outflow, neap tide period.**

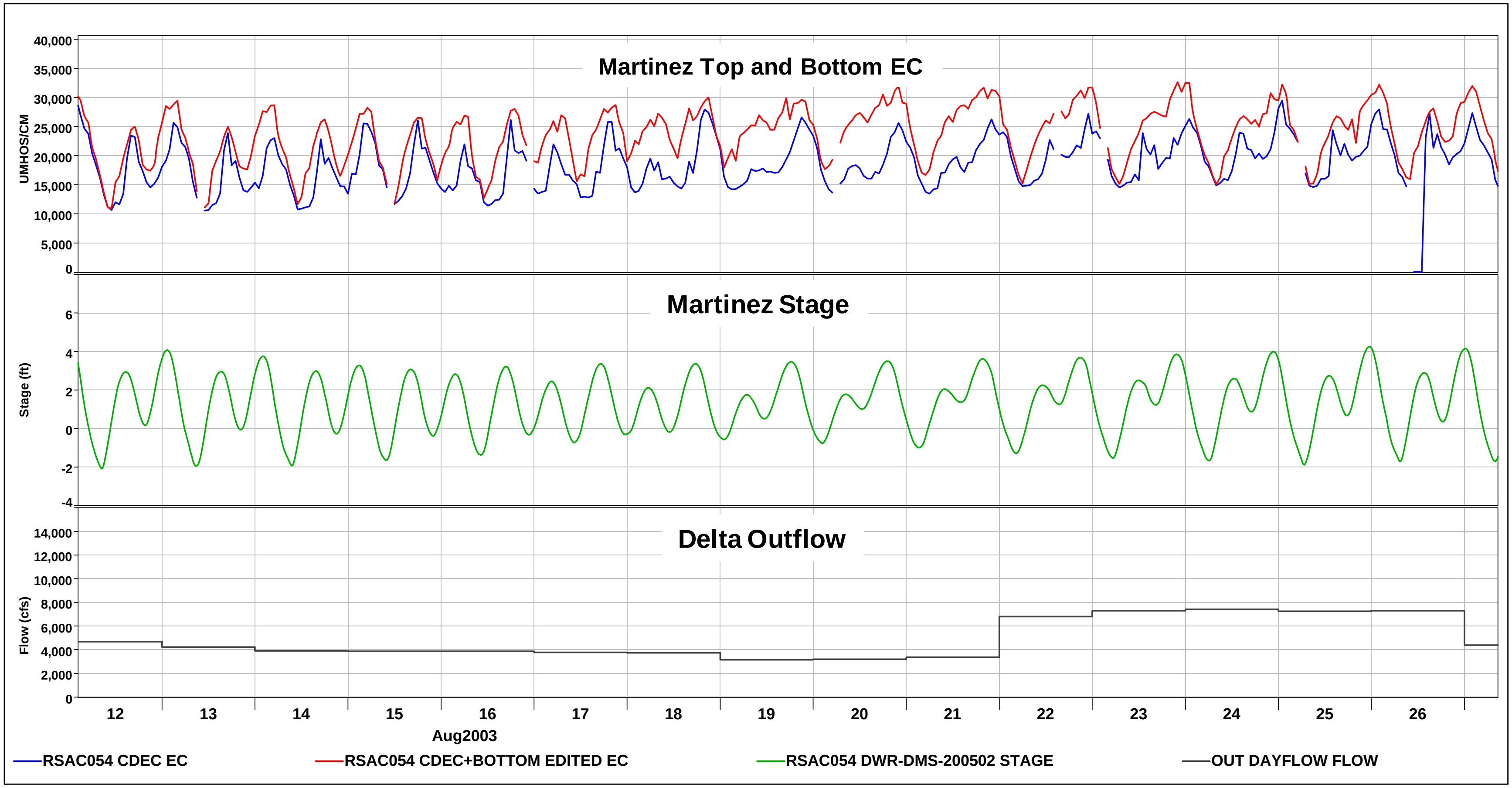



**Figure 4-22 Top/bottom EC and stage at Martinez (RSAC054), and Sacramento River flow during a lower outflow period, neap tide period.**

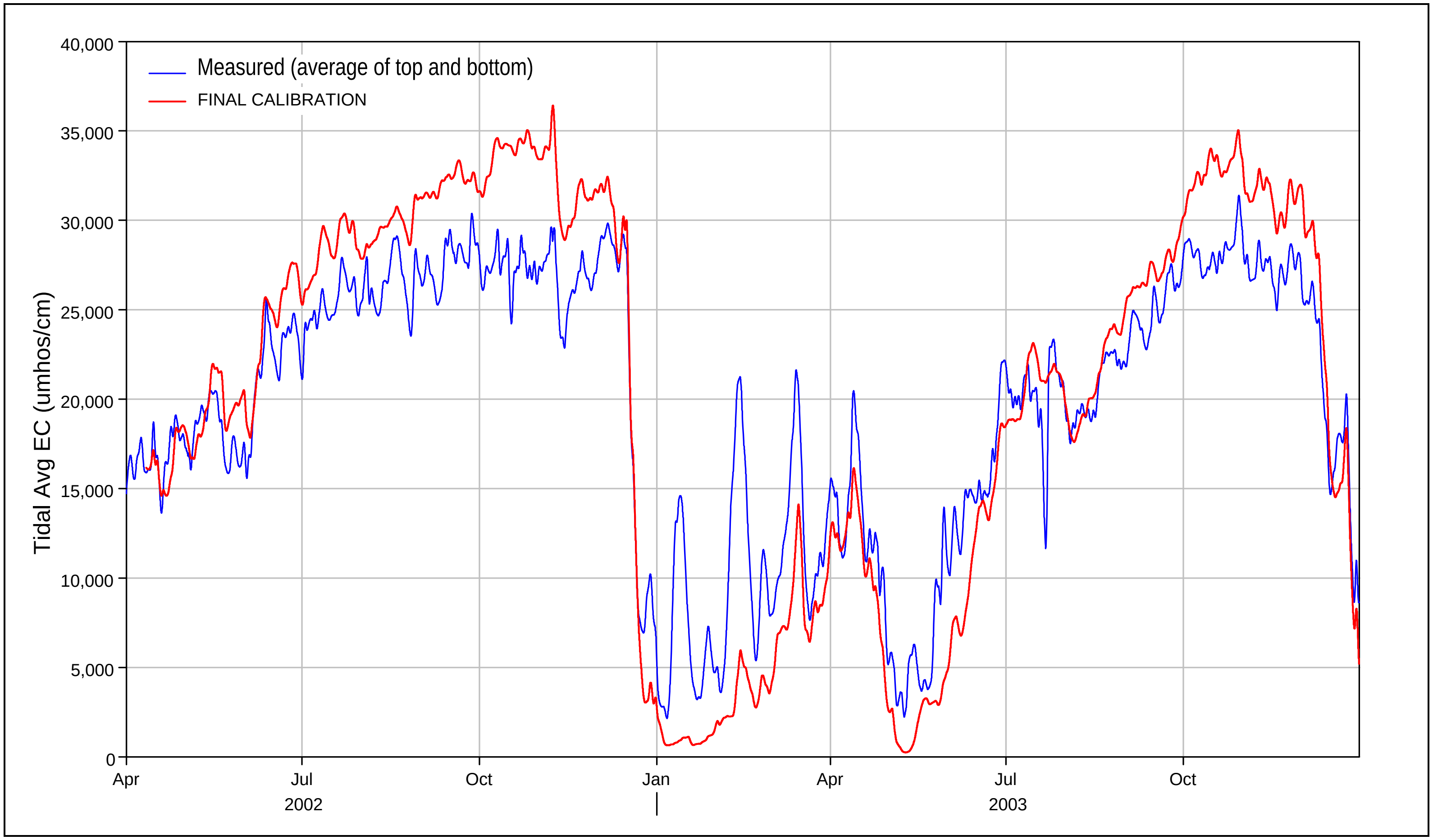



**Figure 4-23 Tidally averaged measured (average of top and bottom) and computed EC at Martinez station (RSAC054).**

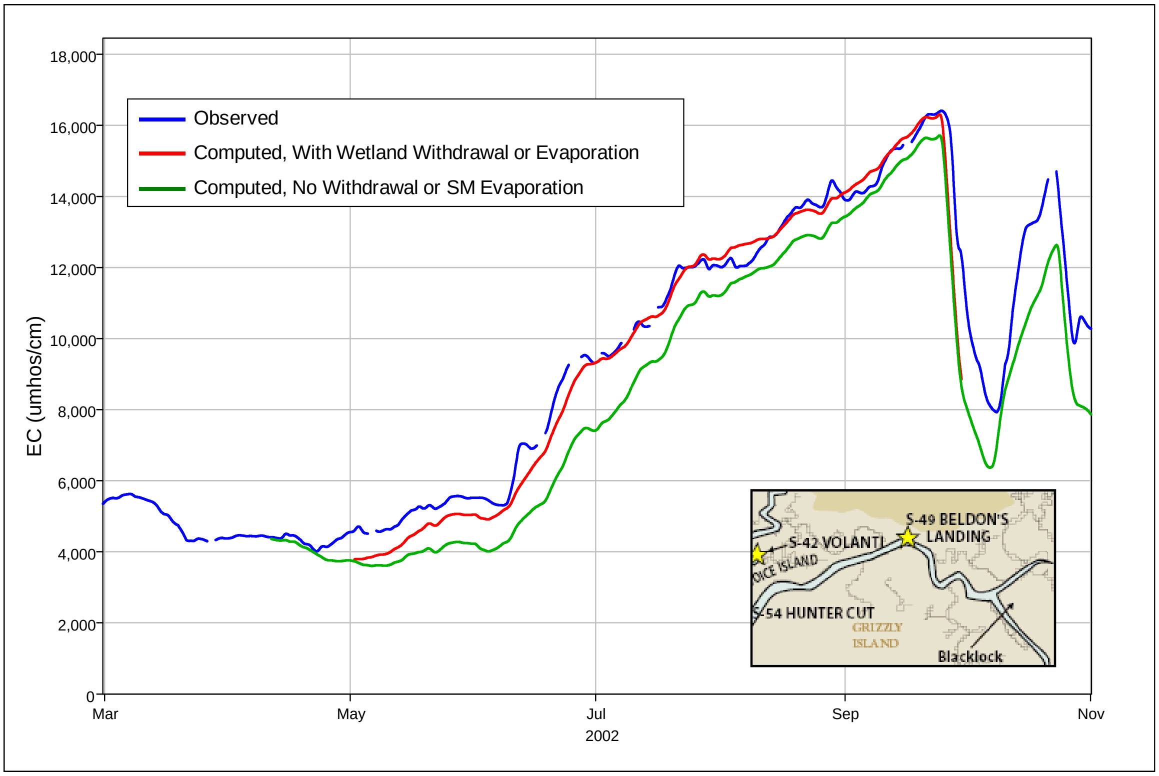



**Figure 4-24 Tidally averaged observed and computed EC at S-49, Montezuma Slough at Beldon's Landing. Computed shown with and without duck club withdrawals and evaporation.**

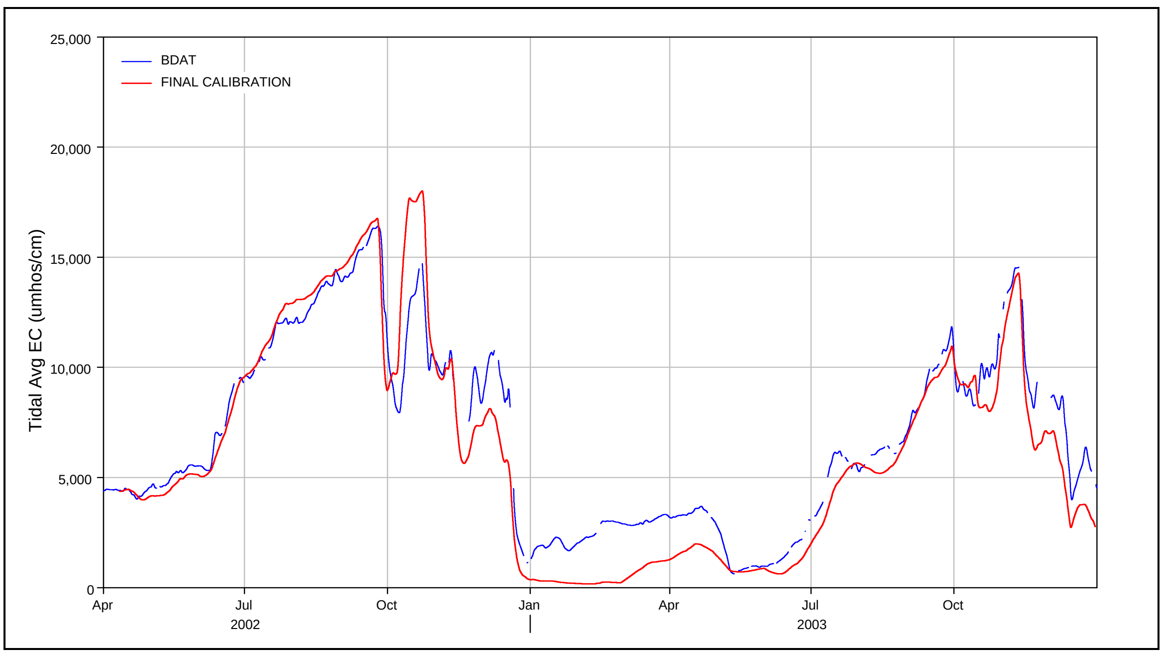



**Figure 4-25 Tidally averaged observed and computed EC at station S-49, Beldon's Landing.**

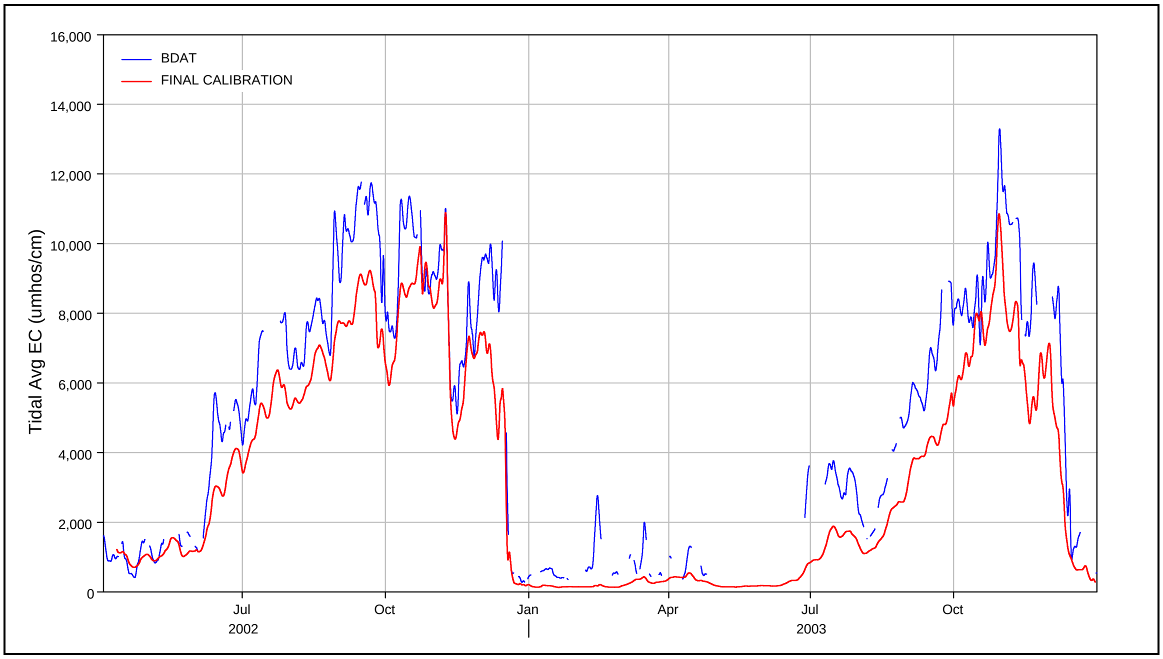



**Figure 4-26 Tidally averaged observed and computed EC at station S-64, National Steel in eastern Montezuma Slough.**

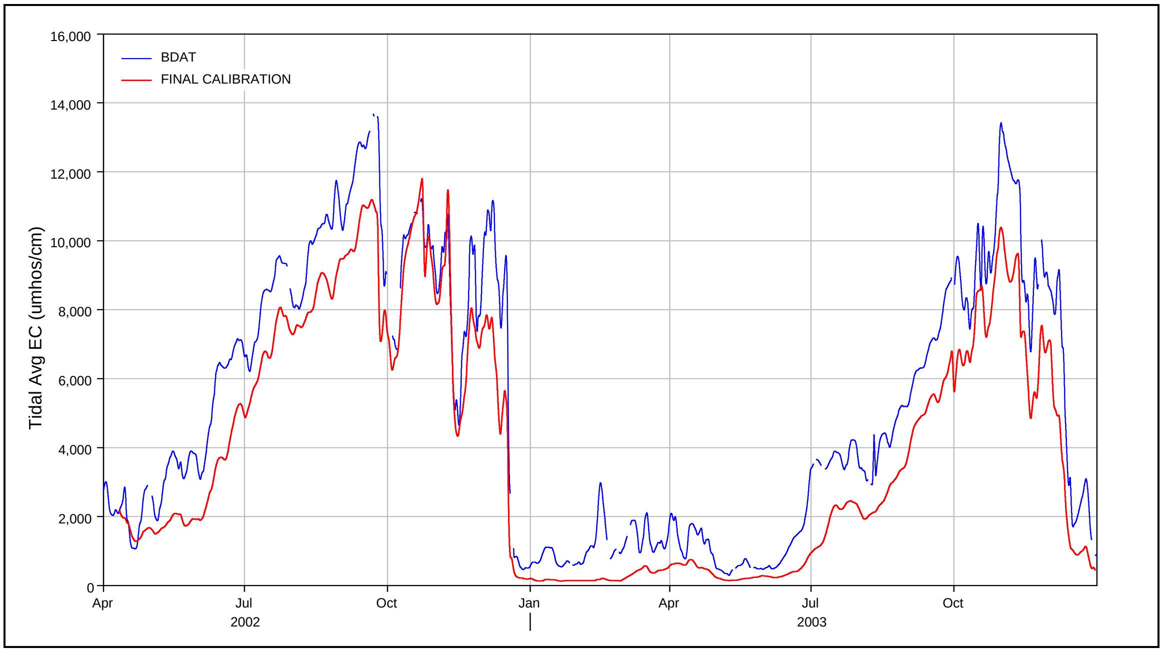



**Figure 4-27 Tidally averaged observed and computed EC at station S-71 Roaring River in eastern Montezuma Slough.**

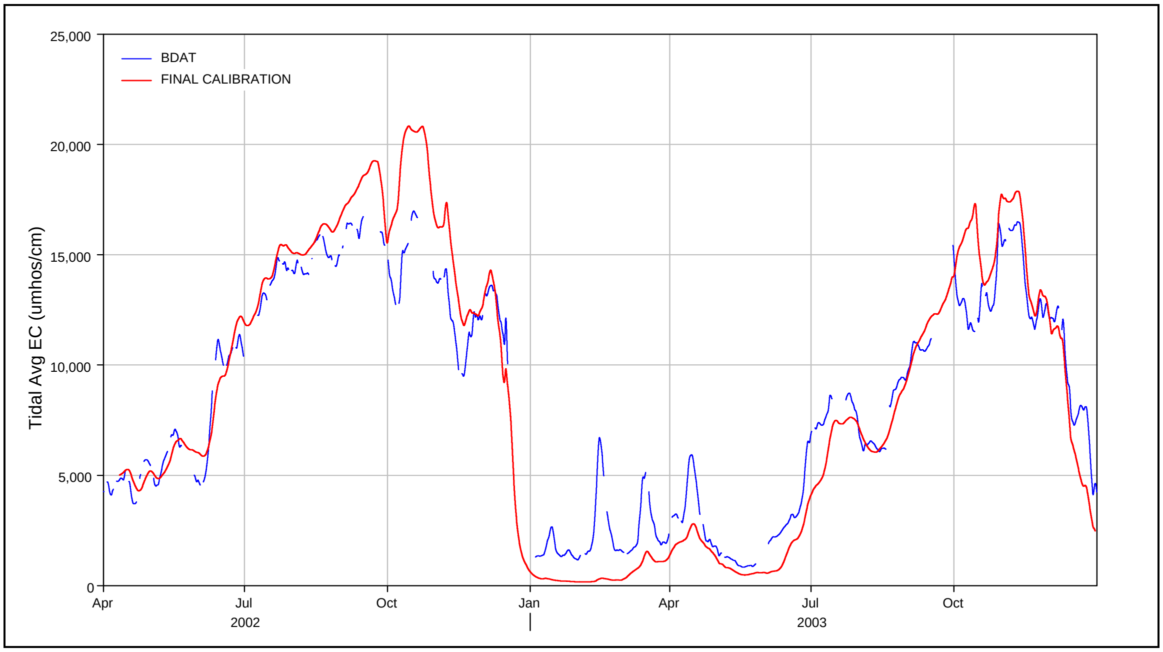



**Figure 4-28 Tidally averaged observed and computed EC at station S-54, Hunter Cut.**

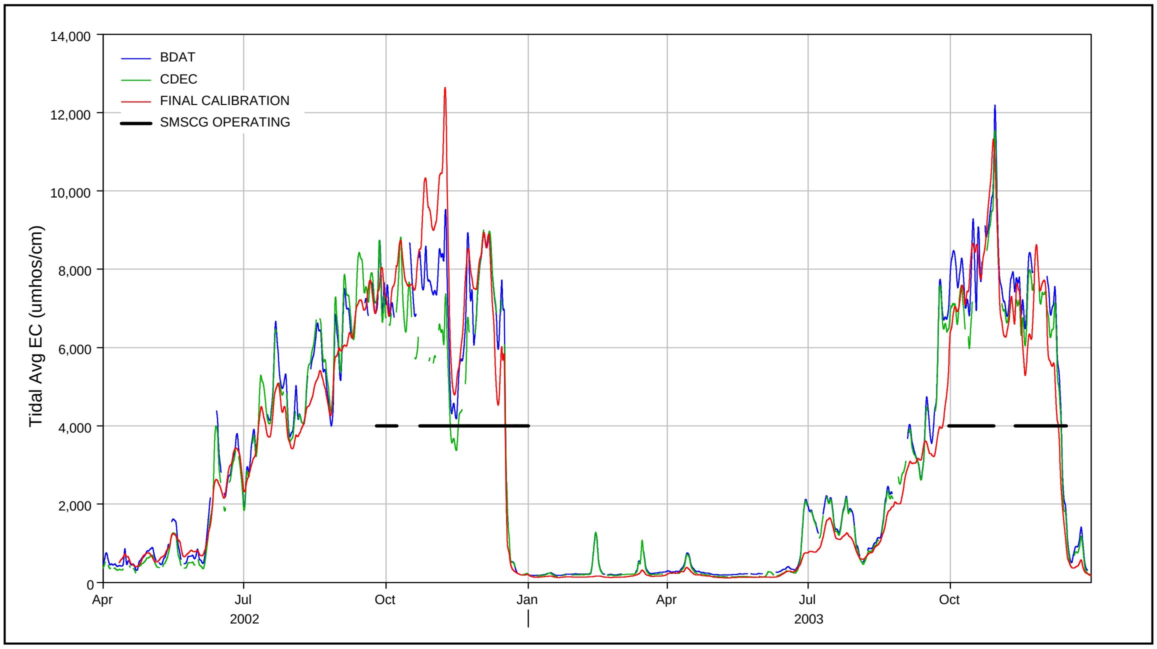



**Figure 4-29 Tidally averaged observed and computed EC at Collinsville (RSAC081).**

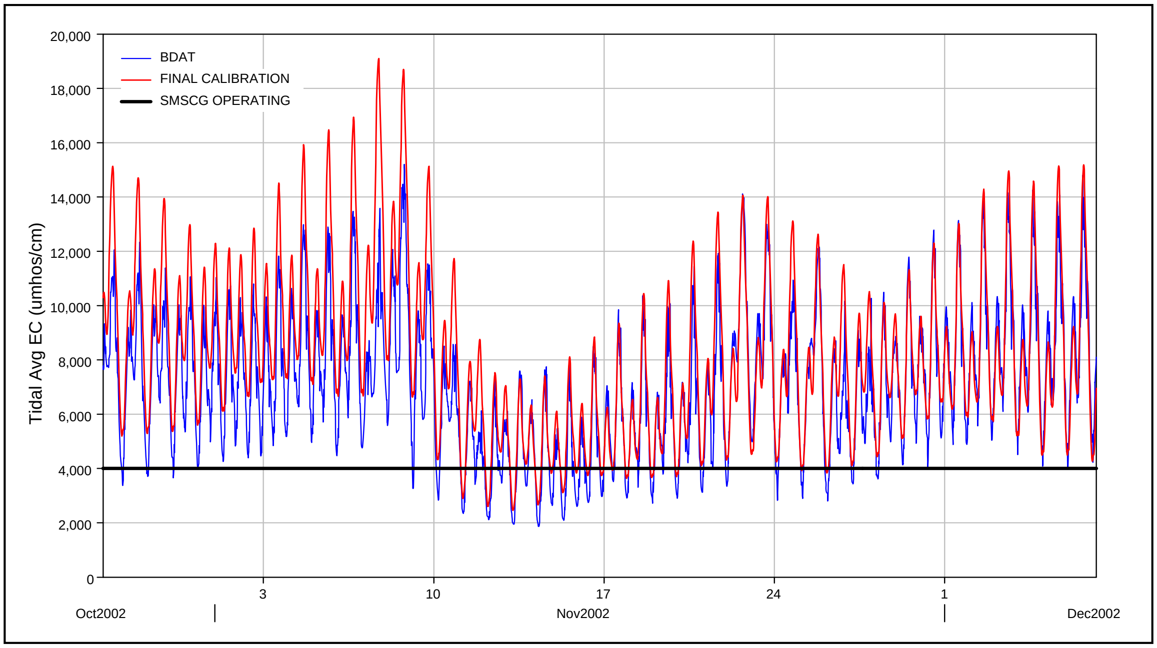



**Figure 4-30 Observed and computed EC at Collinsville (RSAC081) during a period of SMSCG operation.**

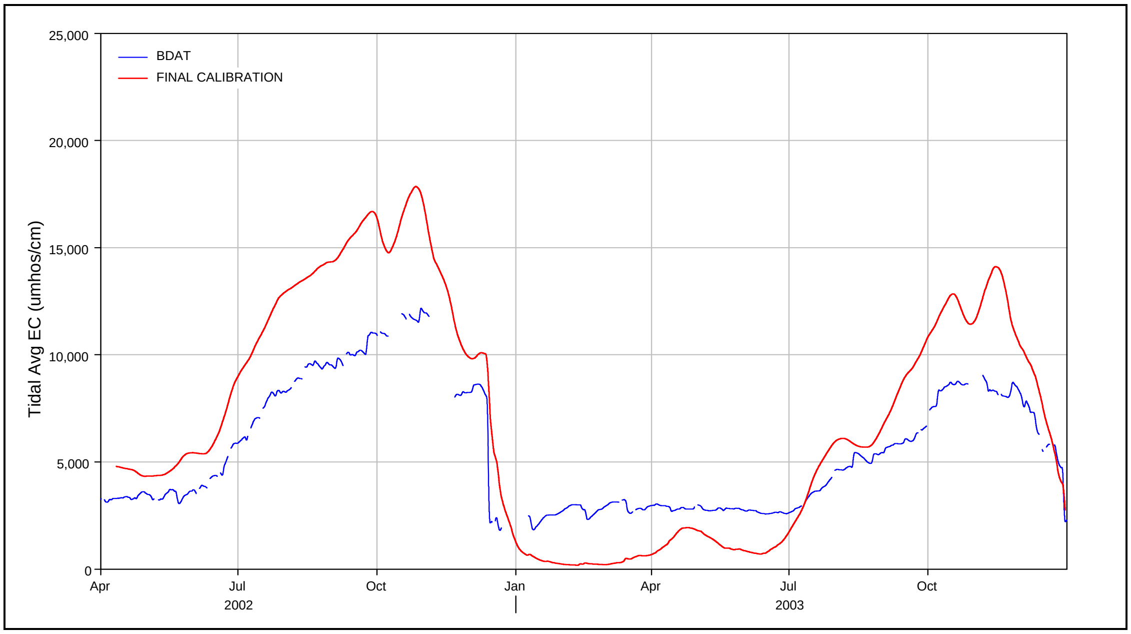



**Figure 4-31 Tidally averaged observed and computed EC at station S-4, Hill Slough.**

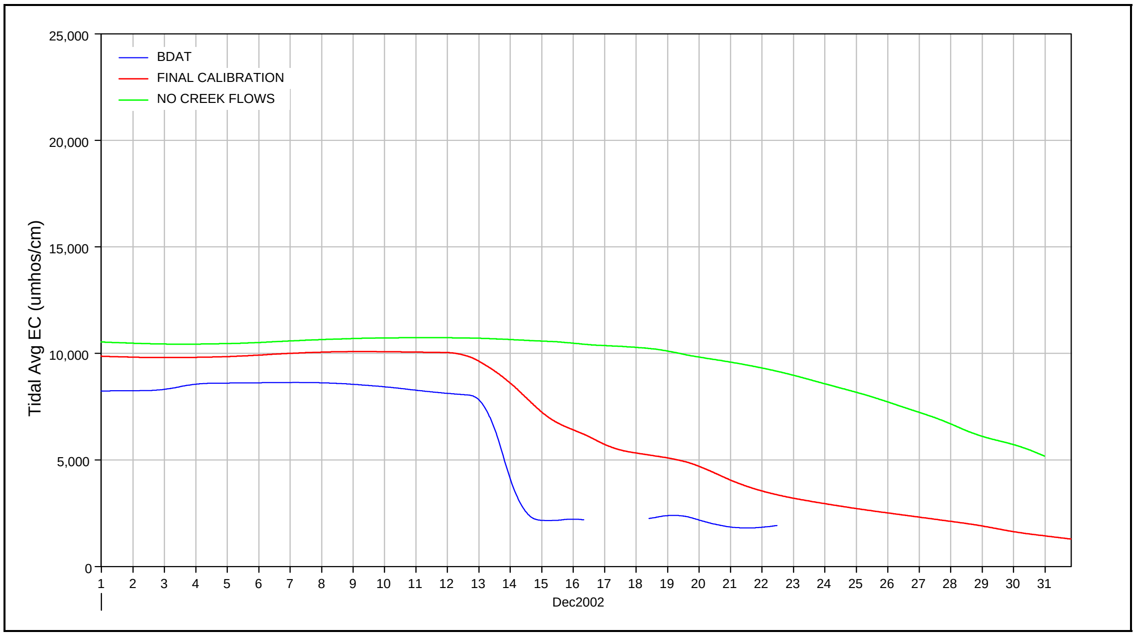



**Figure 4-32 Tidally averaged observed and computed EC at station S-4, Hill Slough in December, 2002. Computed results shown with and without local creek flow addition.**

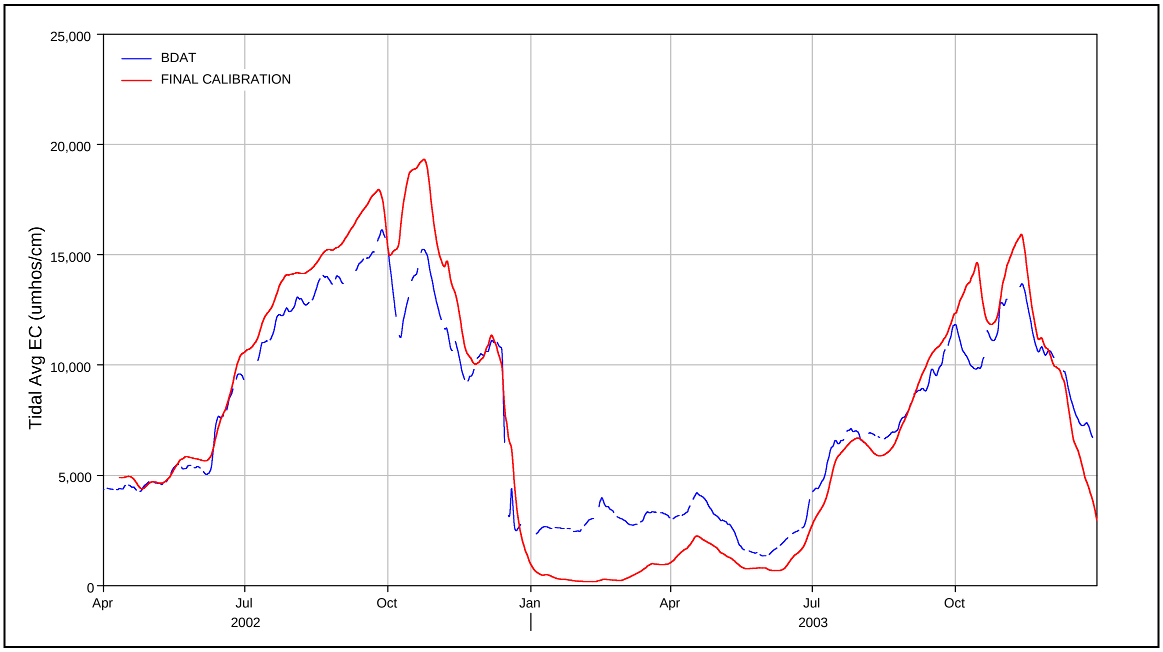



**Figure 4-33 Tidally averaged observed and computed EC at station S-42, Volanti.**

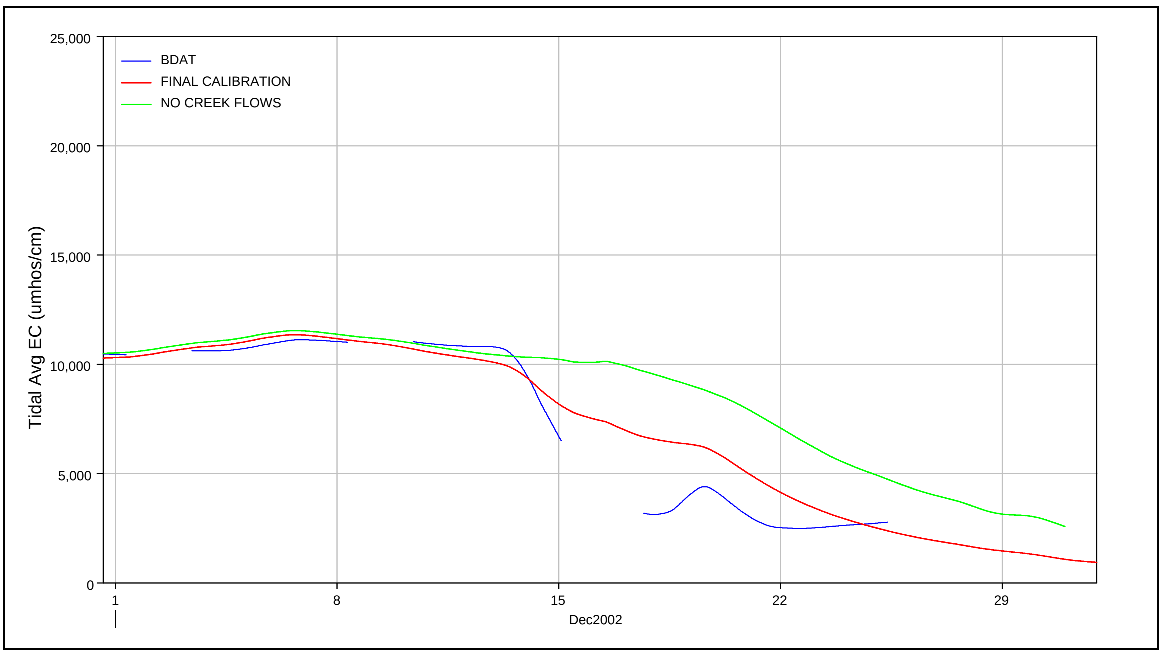



**Figure 4-34 Tidally averaged observed and computed EC at station S-42, Volanti in December, 2002. Computed results shown with and without local creek flow addition.**

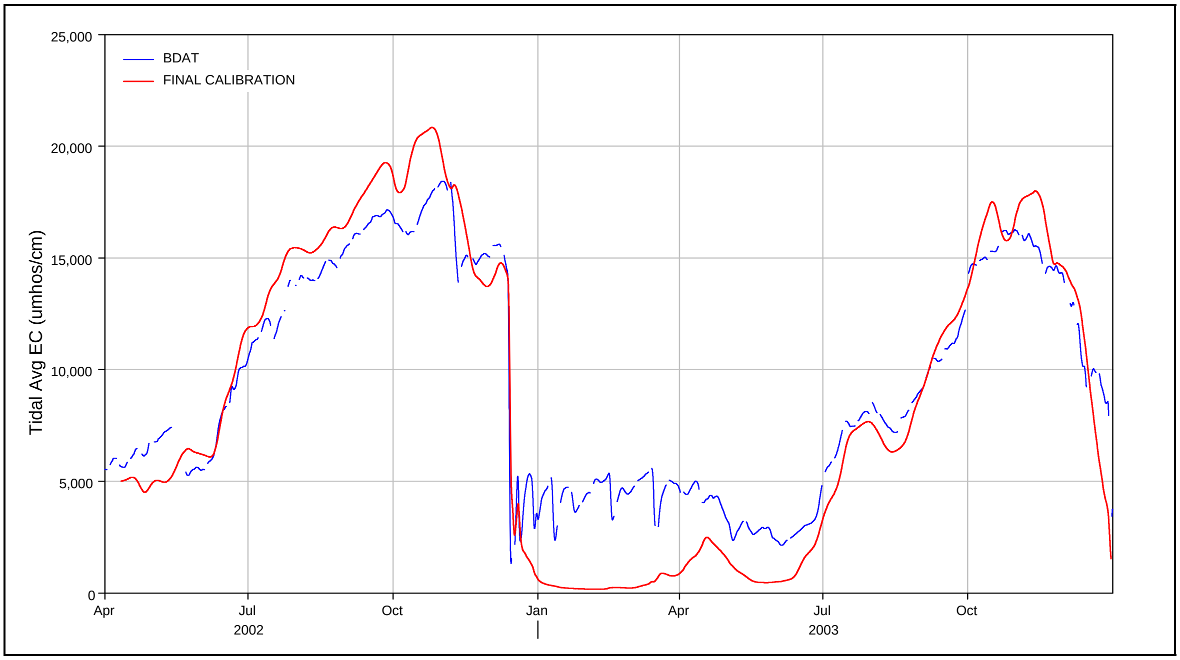



**Figure 4-35 Tidally averaged observed and computed EC at station S-97, in Cordelia Slough at Ibis.**

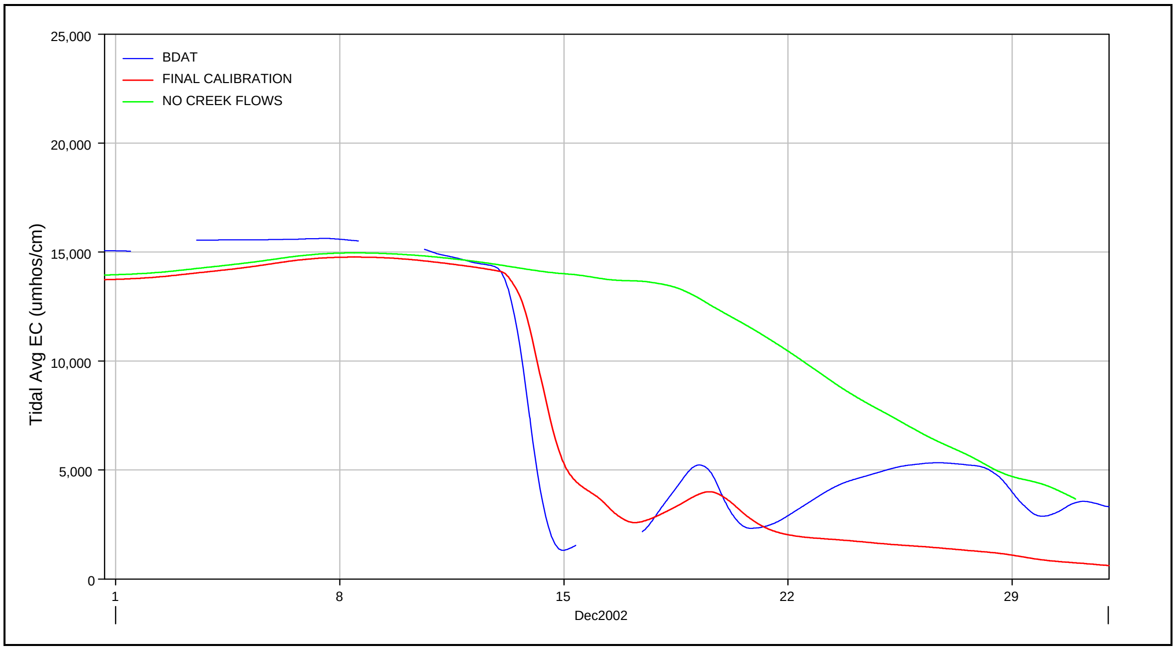



**Figure 4-36 Tidally averaged observed and computed EC at station S-97, in Cordelia Slough at Ibis December, 2002. Computed results shown with and without local creek flow addition.**

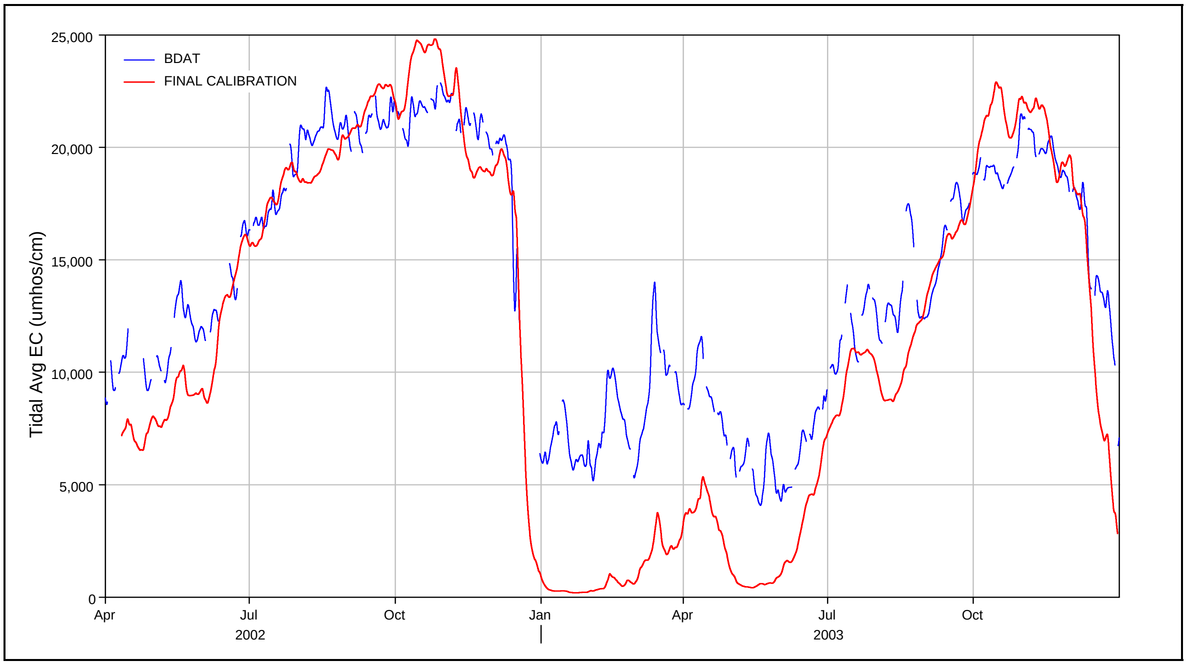



**Figure 4-37 Tidally averaged observed and computed EC at station A-96 on Goodyear Slough at Fleet.**

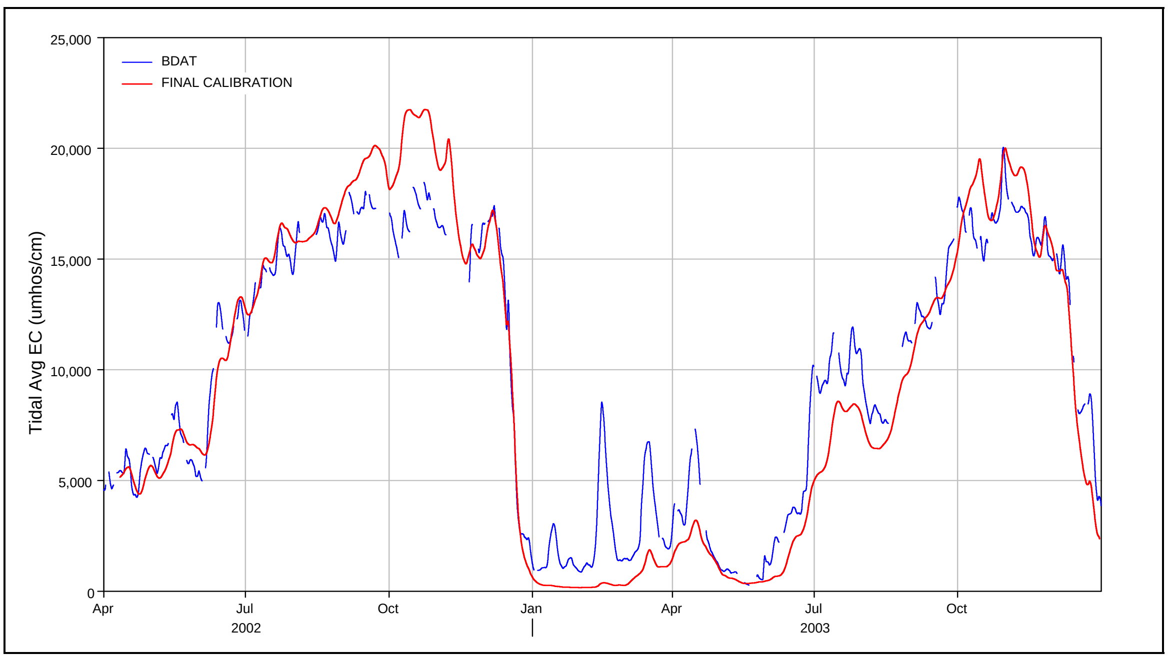



**Figure 4-38 Tidally averaged observed and computed EC at station S-37 in Suisun Slough at Godfather.**

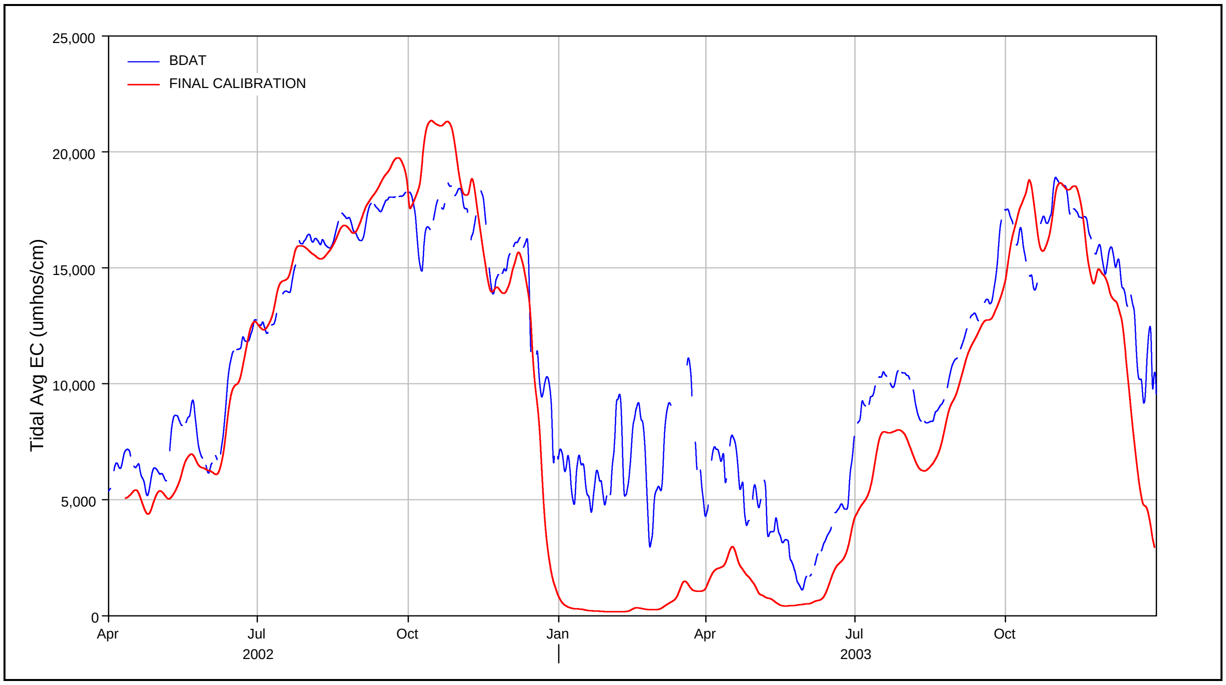



**Figure 4-39 Tidally averaged observed and computed EC at station S-35 at Morrow Island.**

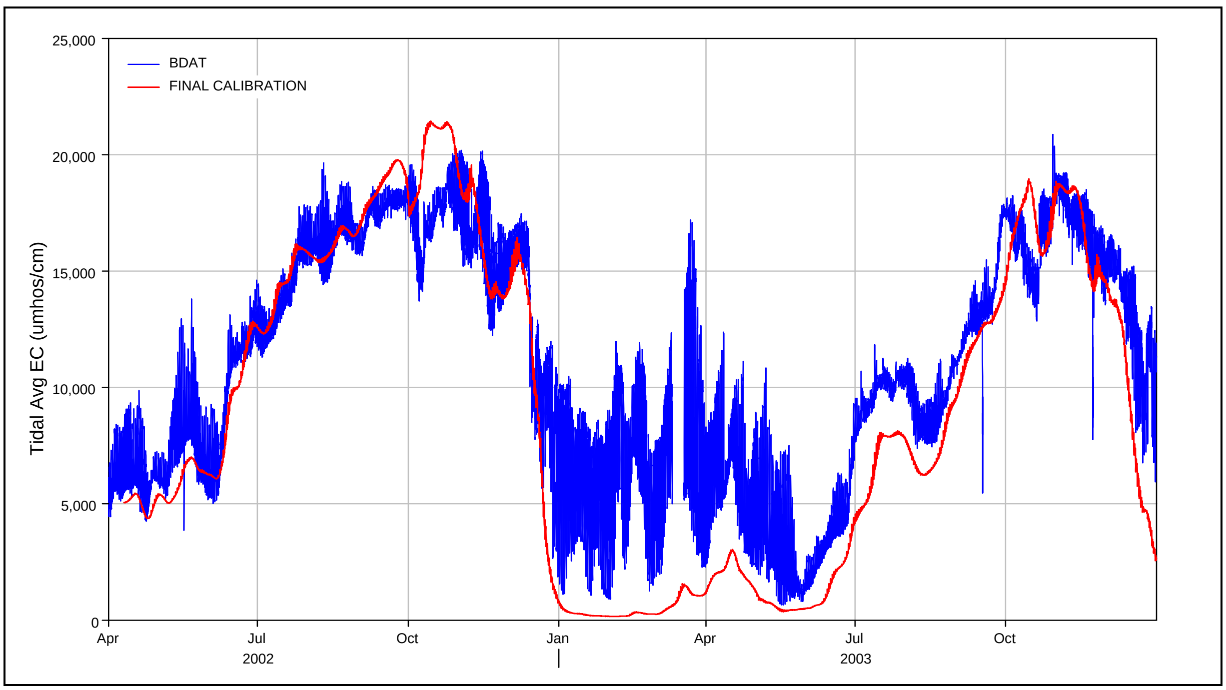



**Figure 4-40 Intertidal observed and computed EC at station S-35 at Morrow Island.**

### *4.3. Summary of Unresolved Calibration Issues*

Although the model additions and improvements, and the hydrodynamic and EC calibration efforts greatly improved the representation of flows and EC in Suisun Marsh, there are several issues that may influence the representation of scenario results. One modification to the model that could potentially improve calibration results would be to include a formulation for gravitational circulation to improve the representation of salinity stratification effects.

There was insufficient data in some critical areas of the model, such as insufficient data to represent local inflows and withdrawals in Suisun Marsh. Although modeled stage representation was generally good, some of the flows in major sloughs had substantial error, such as in Montezuma and Suisun Sloughs, which may bias EC model results in the scenarios. In the periphery areas of Suisun Marsh, much of the difference between modeled and measured EC and flow may be due to estimation of local creek flows and managed wetland diversions and returns.

## 5. Tidal Restoration Scenario Simulations

Each of the Suisun Marsh restoration scenarios (Figure 1-1) was modeled to evaluate its effect on tidal range, scour, tidal prism and EC in Suisun Marsh and EC in the Delta. A Base case scenario was also modeled. In cases where 1-D sections of the Base case mesh were extended to 2-D for the scenarios, the comparison between the cross-sectionally averaged 1-D Base case mesh results and depth-averaged 2-D scenario mesh results is not necessarily direct. However, comparison plots are still used to get a general idea of the potential magnitude of the differences.

Zone 1 has one breached levee near the mouth of Suisun Slough and another on Goodyear Slough. This restored area is incorporated in Set 2, which also has two restored areas with breaches on or near Honker Bay, an area off of Montezuma Slough, and two areas on smaller sloughs in the interior of the northeastern area of Suisun Marsh. Zone 4 has two breach locations on Montezuma Slough. Set 1 includes the Zone 4 area, as well as areas in the interior of the marsh, with breaches on smaller sloughs in the northeastern and northwestern corners of the marsh.

### *5.1. Boundary Conditions*

Boundary conditions for the four scenarios were in large part the same as those for the Base case, with the primary difference in filling and draining of the duck club ponds to accommodate changes in geometry. The fill and drain flow rates of the duck ponds were reduced by eliminating the flooded area from the volume calculation.

## 5.2. Simulation Period

The simulation period for the Base case and four scenarios extends from April 10, 2002 through December 31, 2003.

## 5.3. Mesh

LiDAR data (DWR, 2007) and aerial photographs were used to guide the elevation and extent of the breached and flooded areas incorporated in each of the scenarios.

### 5.3.1. Base

The Base case model differs slightly from the calibration model. It was assumed that the Meins Landing and Hill Slough marsh restoration projects, although not currently complete, would be in place by the time any of the scenarios would be implemented. Therefore, these areas were included in the Base case and in each of the scenarios. Figure 5-1 and Figure 5-2 illustrate the grid and bottom elevation, respectively, in the Suisun Marsh region for the Base case.

### 5.3.2. Set 2 and Zone 1

The total restoration area for Set 2 is approximately 7529 acres (not including Meins Landing, Hill Slough or Blacklock). Figure 5-3 and Figure 5-4 illustrate the grid and bottom elevation, respectively, in the Suisun Marsh region for Set 2.

Set 2 scenario geometry incorporates the Zone 1 (see Figure 1-1) marsh restoration which occurs at Morrow Island with breaches off of Suisun Slough and Goodyear Slough. The flooded area is approximately 2003 acres. The remainder of the restoration area for Set 2 consists of breaches flooding approximately 2107 acres north of Suisun Slough at Cutoff Slough, north and south of Cross Slough, and between Nurse Slough and Luco Slough. Two additional breaches off of Suisun Bay flood approximately 3419 acres of Simmons, Dutton and Wheeler Islands.

### 5.3.3. Set 1 and Zone 4

Total restoration area for Set 1 is approximately 7821 acres (not including Meins Landing, Hill Slough or Blacklock). Figure 5-5 and Figure 5-6 illustrate the grid and bottom elevation, respectively, in the Suisun Marsh region for Set 1.

Set 1 scenario geometry incorporates Zone 4 (see Figure 1-1), as well as the breached area between Nurse Slough and Luco Slough (approximately 582 acres), and several breached areas in western Suisun Marsh totaling approximately 3895 acres. Zone 4 scenario geometry includes proposed tidal marsh restoration area south of Suisun Slough at Frost Slough, with two breaches off of Suisun Slough. The flooded area is approximately 3344 acres.

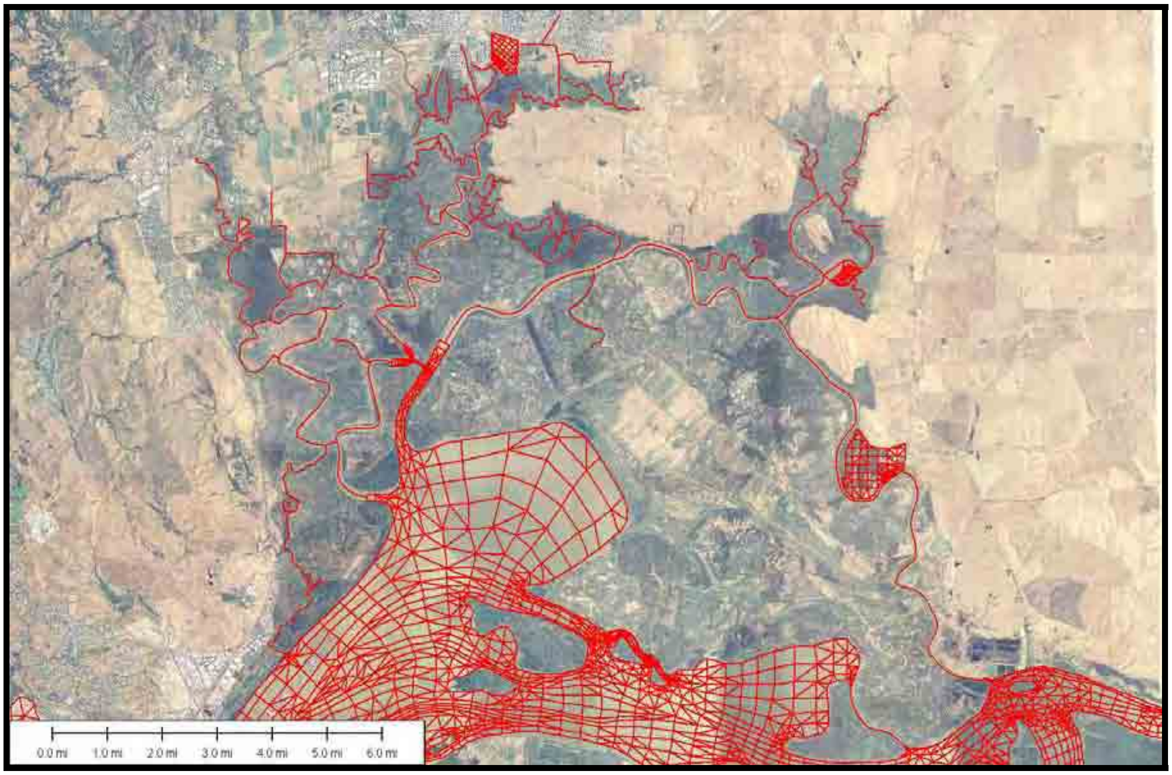



**Figure 5-1 Base case grid in Suisun Marsh.**

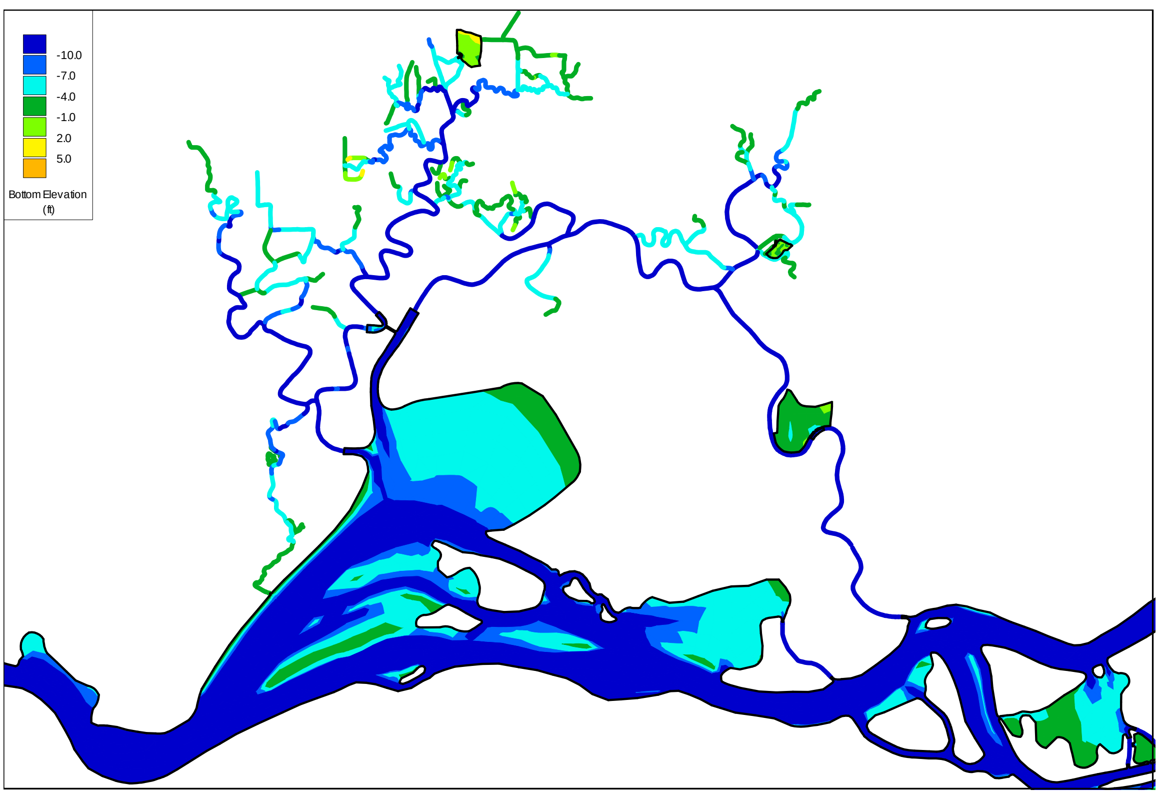



**Figure 5-2 Bottom elevation for the Base case grid.**

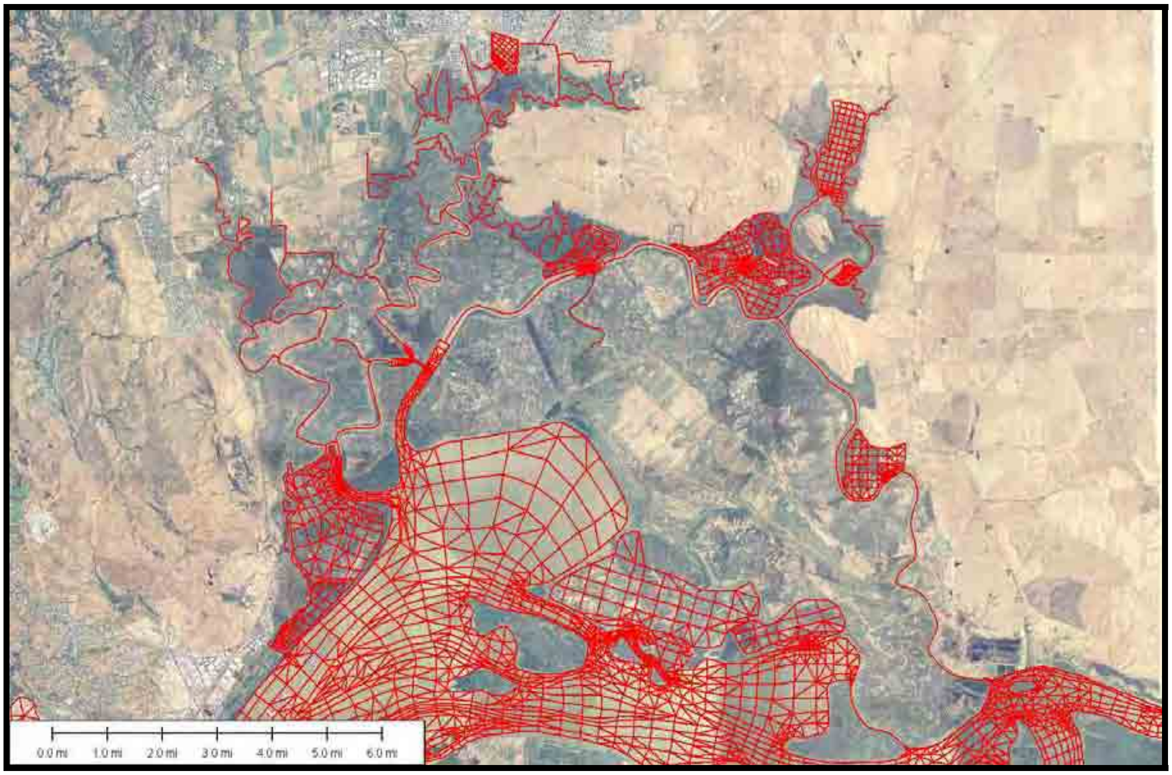



**Figure 5-3 Set 2 grid in Suisun Marsh.**

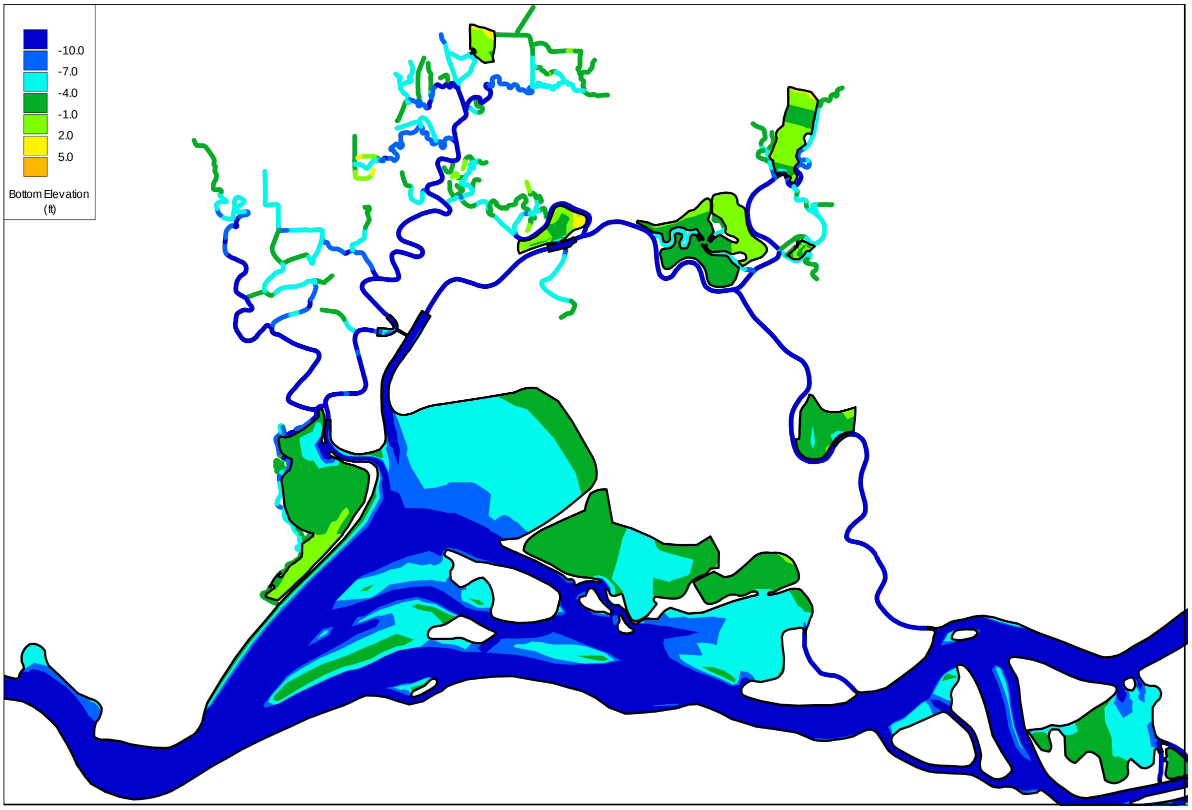



**Figure 5-4 Bottom elevation for the Set 2 grid.**

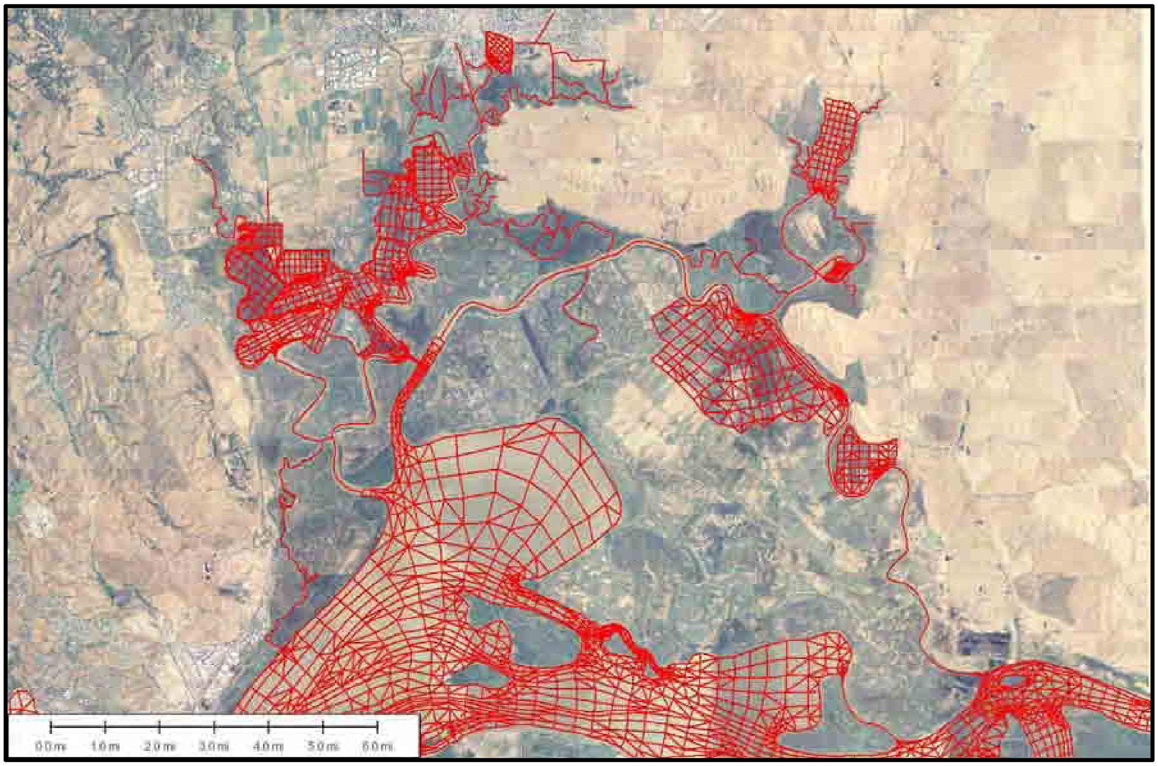



**Figure 5-5 Set 1 grid in Suisun Marsh**

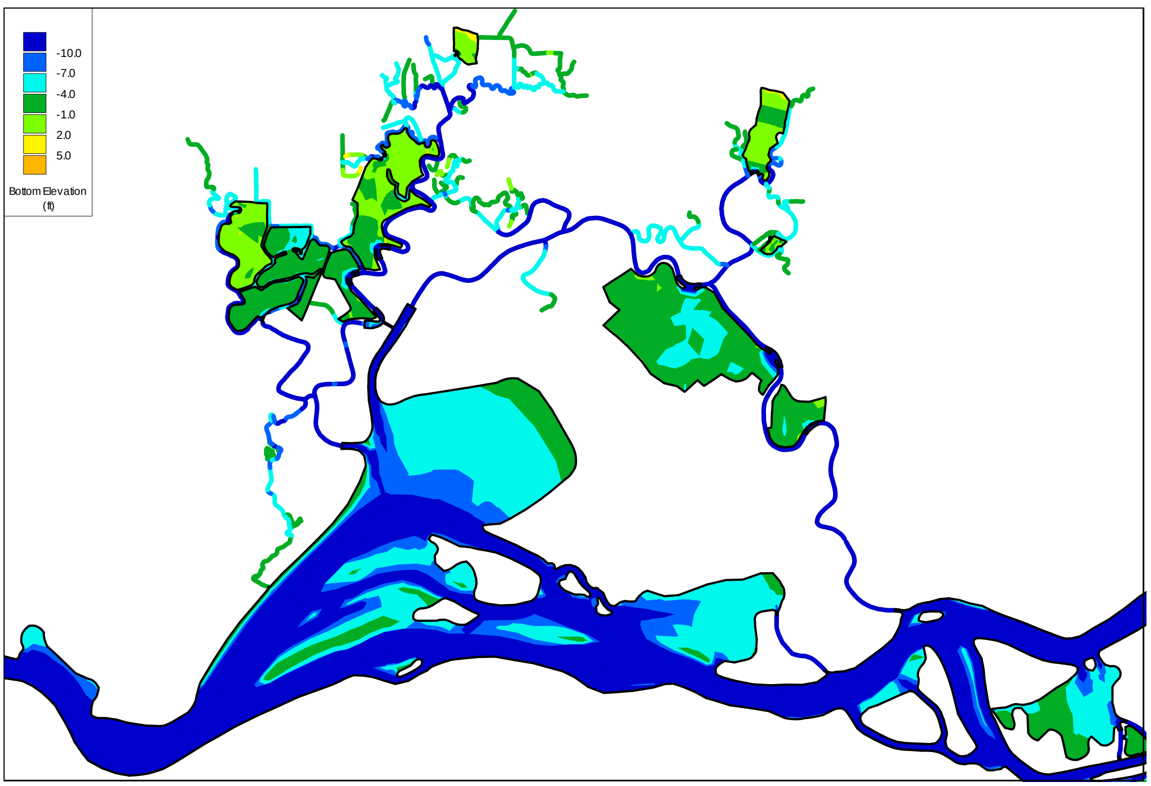



**Figure 5-6 Bottom elevation for the Set 1 grid.**

## 5.4. Stage Results

### 5.4.1. Background

Tidal damping can occur if channels are not large enough to convey the full tidal prism of the restored areas. This effect will persist until channel scour (or levee breaches) increase the capacity of the channels feeding the upstream marshes. Velocity results indicate that some channels (Montezuma Slough, Hunter Cut) will be subject to scouring and tidal damping until sufficient conveyance is established.

### 5.4.2. Results

Each scenario resulted in reduced tidal amplitude throughout Suisun Marsh, and a shift in timing. These changes were generally the most pronounced in Set 1 and Set 2 scenarios, and varied depending on location in the marsh (Figure 5-7). Time series plot of stage at Beldon's Landing, S-49, during October 2003 (Figure 5-8, duck clubs filling) shows that the Set 1 and Zone 4 scenarios have the most prominent effect at this location, while the Zone 1 scenario has very little effect.

The significant dampening effect for the Set 1 scenario can be seen in plots of MHHW and MLLW for April and October 2003, shown in Figure 5-9 and Figure 5-10, respectively. During these months, MHHW was reduced by as much as 0.8 ft and MLLW increased by as much as 1.2 ft. Greater differences are seen in the immediate vicinity of the breaches in the western marsh.

Although the restriction of Set 1 restoration area to Zone 4 (not shown) had less effect in the western marsh, with no breaches there, in the eastern portion, MHHW was reduced by as much as 0.6 ft and MLLW increased by as much as 1.1 ft.

Set 2 restoration areas resulted in MHHW reduced by up to 0.3 ft and an increase in MLLW of up to 0.2 ft (Figure 5-11). Restriction of Set 2 restoration area to Zone 1 (not shown) demonstrated this area had minimal effect on stage throughout Suisun Marsh. The tidal dampening effect was generally less than 0.1 ft overall.

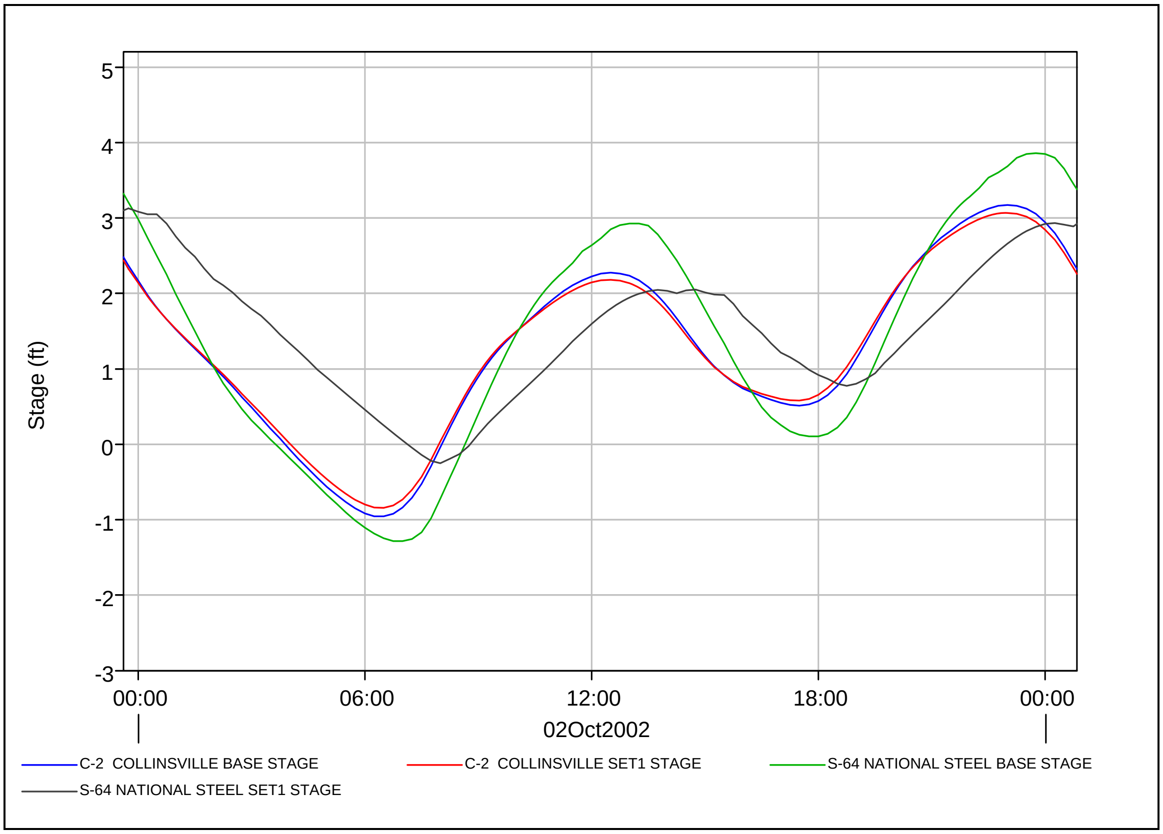



**Figure 5-7 Stage time series showing stage shifts at Collinsville monitoring station C-2 and National Steel monitoring location S-64 for Base and Set 1 Scenarios.**

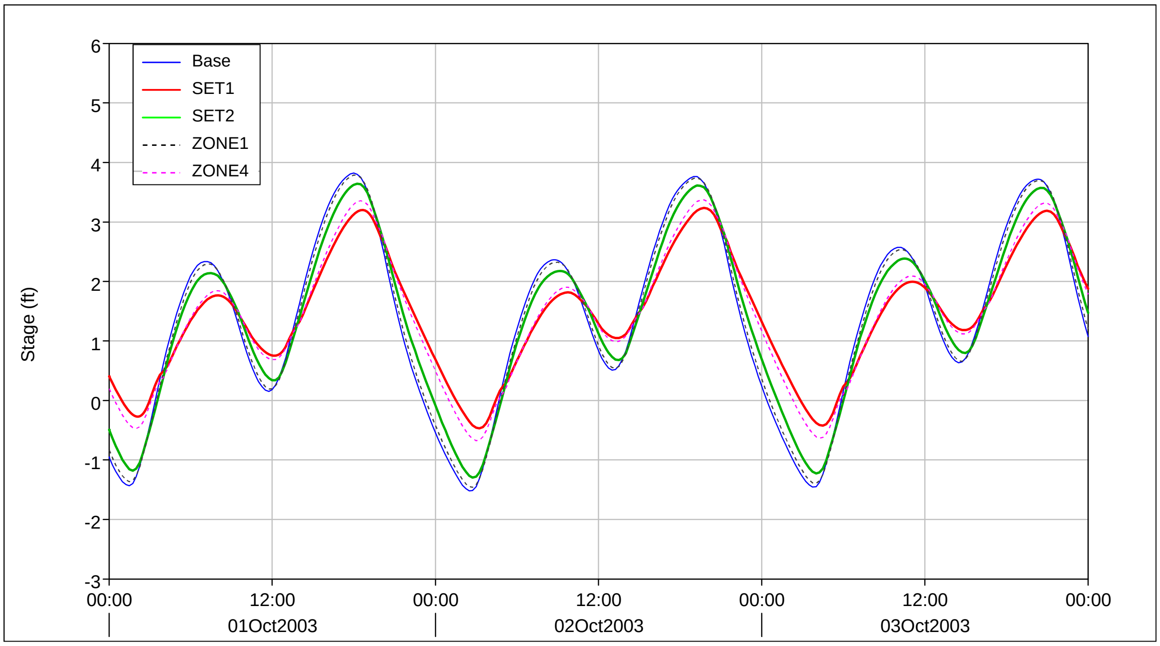



**Figure 5-8 Stage time series at monitoring station S-49 at Beldon's Landing when Duck Clubs in the Suisun Marsh region are filling in the fall.**

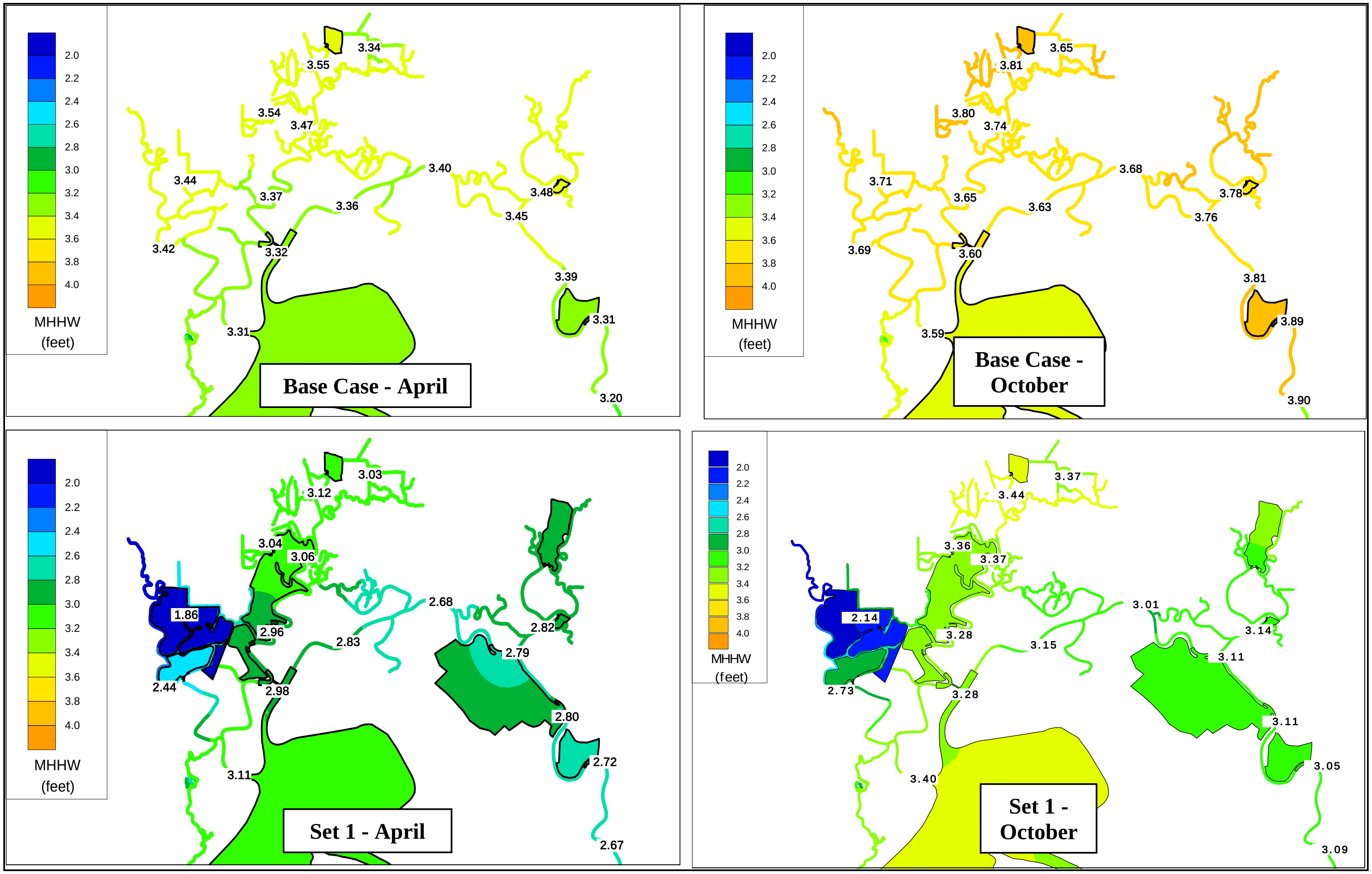



**Figure 5-9 Color contour plots of Base case (upper) and Set 1 (lower) MHHW elevations for April (left) and October (right) 2003.**

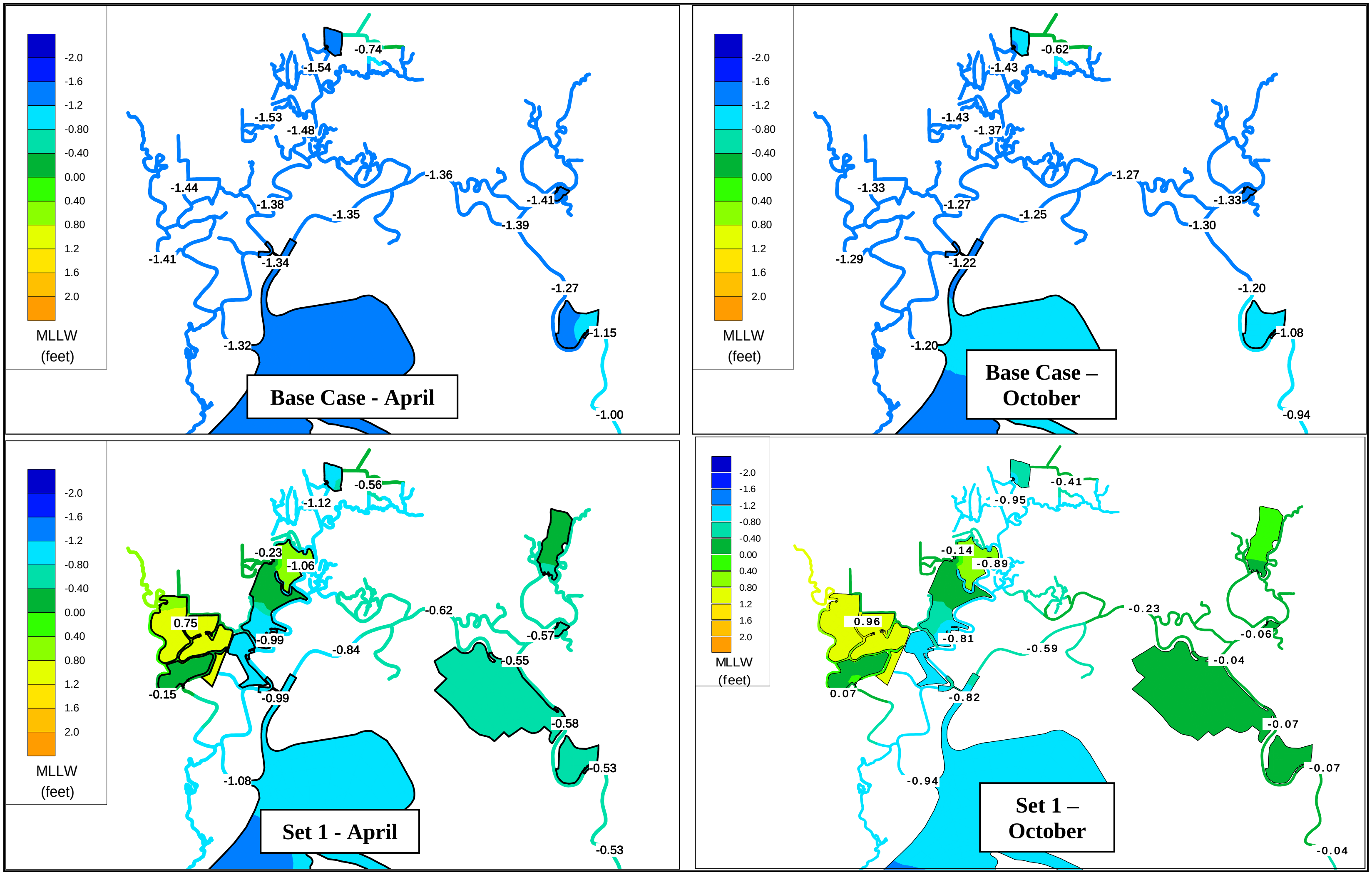



**Figure 5-10 Color contour plots of Base case (upper) and Set 1 (lower) MLLW elevations for April (left) and October (right) 2003.**

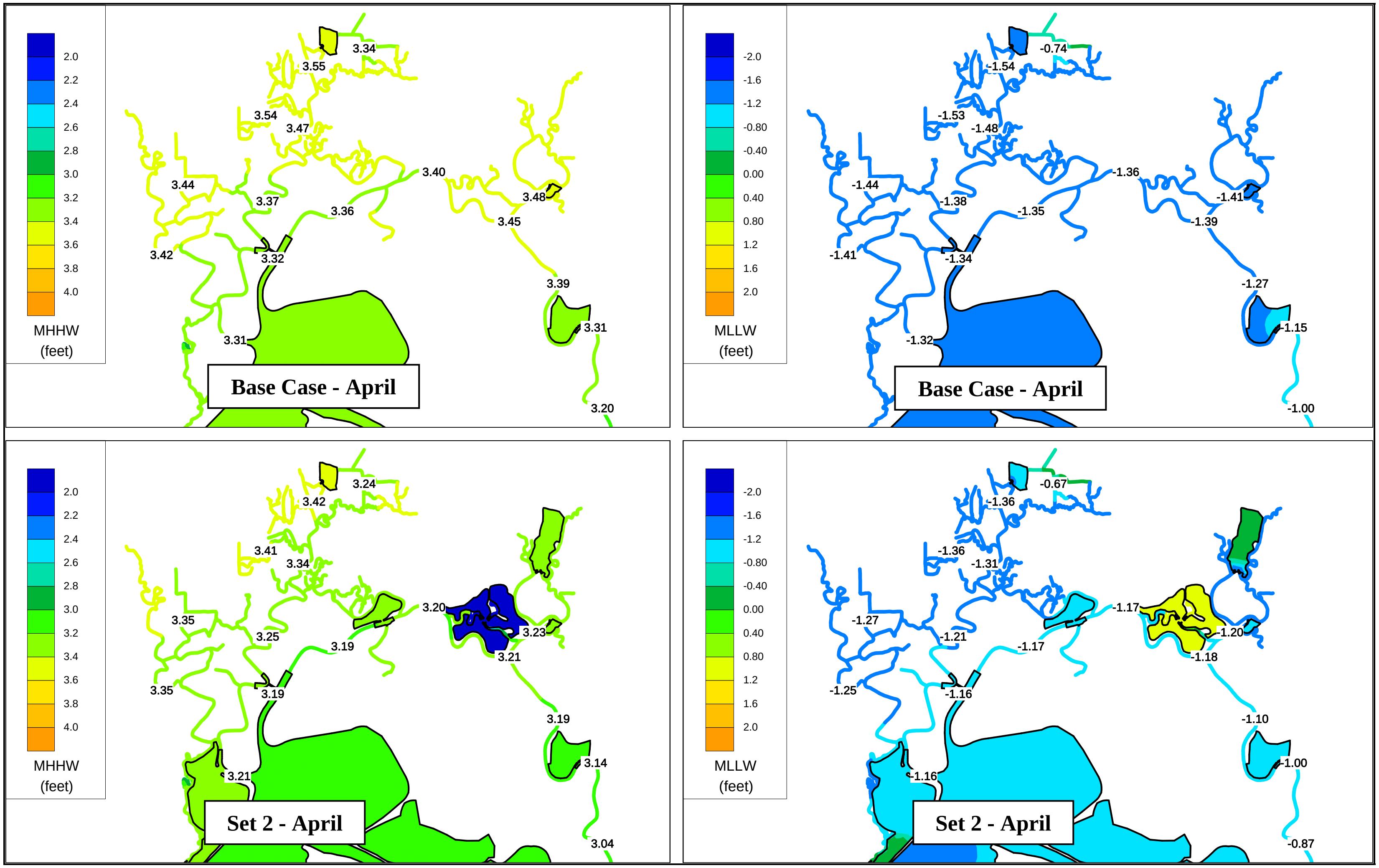



**Figure 5-11 Color contour plots of Base case (upper) and Set 2 (lower) MHHW (left) and MLLW (right) elevations for April 2003 (note scale differences for MHHW and MLLW).**

## *5.5. Tidal Prism Results*

### 5.5.1. **General observations**

As expected, each of the scenarios increased the tidal prism, i.e., the volume of water exchanged in the Suisun Marsh area, in comparison with the Base case. Figure 5-12 shows locations where net tidal flow results are presented for July 2003. Values for tidal flow were calculated by accumulating ebb and flood (tidal) flow in ac-ft/day and averaging over the month. The results are grouped by general location in Suisun Marsh and by range of tidal flow.

The Set 1 scenario increased tidal flow everywhere except the boundary sloughs of the Marsh (e.g. Hill Slough) as flow increased through both ends of Montezuma Slough, and through Suisun Slough and Hunter Cut. Tidal flows in boundary sloughs decrease when tidal marsh restoration occurs at downstream locations because not as much of the tidal prism makes it past these new areas. For the Set 2 scenario, the increased flow in Suisun Slough and western Montezuma Slough increased tidal flow in the larger sloughs and adjacent sloughs, but decreased flow to the boundary areas of the Marsh and through the eastern end of Montezuma Slough. Zone 4 resulted in increased flow through Montezuma Slough and through the northern-central portion in the Marsh interior through Suisun Slough, but decreased tidal flow in the north eastern and western regions of the Marsh. Zone 1 decreased tidal flow everywhere, except in areas in the immediate vicinity (e.g., Hunter Cut) of the breached area.

### 5.5.2. **Central Marsh**

The increase in tidal flow through the largest sloughs in the central portion of the Marsh depended on the location of the breached area. Set 1 and Zone 4 increased average tidal flow through both ends of Montezuma Slough to fill the Zone 4 breached area. At the western end of Montezuma Slough, tidal flow increased ~ 24% for the Zone 4 scenario and ~ 48% for the Set 1 scenario in comparison with the base, and at the eastern end ~ 60% for both Zone 4 and Set 1. Zone 4 filled through the breaches at both ends, with the timing of the filling and draining of the eastern breach delayed for a short while in comparison with the western end.

Set 2 and Zone 1 also increased tidal flow through the western end of Montezuma Slough, but decreased tidal flow through the eastern end.

Changes in the Set 2 and Zone 1 scenarios were very similar, as tidal flow through the mouth of Suisun Slough to fill the Zone 1 breached area increased substantially, while the tidal flow increases were more moderate through Hunter Cut. Zone 1 flows were higher than Set 2 flows by ~ 7% in Hunter Cut, and by ~ 2 % at the mouth of Suisun Slough. Set 1 also increased flows in these two locations, except that the flow increase through Hunter Cut was larger than in Suisun Slough to fill the breached areas northeast of the Cut.

### 5.5.3. North Interior Marsh

The tidal flow in the northern region of the Marsh decreased as distance from Montezuma Slough increased, and all scenarios were less than the Base case at the four northernmost interior locations (Figure 5-14 and Figure 5-15) because of the downstream restoration areas.

### 5.5.4. Western Interior Marsh

Filling and draining of the Zone 1 breached area decreased the tidal flow in interior locations of the western Marsh, west and north of the breached area. Zone 1 and Set 2 tidal flows increased through Hunter Cut and the mouth of Suisun Slough (Figure 5-13), and decreased at the interior Suisun Slough locations(Figure 5-15). Flow through Goodyear Slough only increased at the southern end (Figure 5-16), and then only for the Zone 1 and Set 2 scenarios.

The Set 1 scenario increased flow through Hunter Cut and through portions of Suisun Slough south of the Cut to fill the breached areas in the western Marsh, partly through Cordelia Slough. For Zone 4, there were minor increases in tidal flows through Suisun Slough downstream of Hunter Cut, but decreases in Hunter Cut and in Suisun Slough upstream of Hunter Cut.

### 5.5.5. Comparison of flood flow for the scenarios

Figure 5-17 and Figure 5-18 illustrate the magnitude of flows ($ft^3 sec^{-1}$) near peak flood tide for the Set 1 and Set 2 scenarios on July 11, 2003 22:00. These results are also shown in Table 5-1 Flow magnitude (cfs) at four locations near peak flood tide (July 11, 2003 22:00)., below. The plots give the magnitude vectors at key locations in Suisun Marsh for the Base case and the two restoration configurations. The flow arrows are scaled by flow magnitude, which is indicated on each plot for the downstream openings at Suisun Slough, Montezuma Slough and Hunter Cut. The color scale gives water surface elevation (ft).

The plots show that when the area on Morrow Island is restored (Set 2, Figure 5-17), Hunter Cut provides almost all of the flow for Suisun Slough above the junction with Cordelia Slough. When filling the Zone 4 breached area in Set 1, most of the flow comes through the mouth of Montezuma Slough (Set 1, Figure 5-18). The red arrows in these figures give the direction and magnitude of the indicated flows.

**Table 5-1 Flow magnitude (cfs) at four locations near peak flood tide (July 11, 2003 22:00).**

| | Base | Set1 | Set2 |
|---|---|---|---|
| **Suisun Sl. @ Mouth** | 10,900 cfs | 17,400 cfs | 20,050 cfs |
| **Montezuma Sl. - west** | 39,200 cfs | 62.300 cfs | 44,800 cfs |
| **Hunter Cut** | 10,600 cfs | 19,600 cfs | 15,600 cfs |
| **Montezuma Sl. - east** | 3,440 cfs | 1,500 cfs | 5,820 cfs |

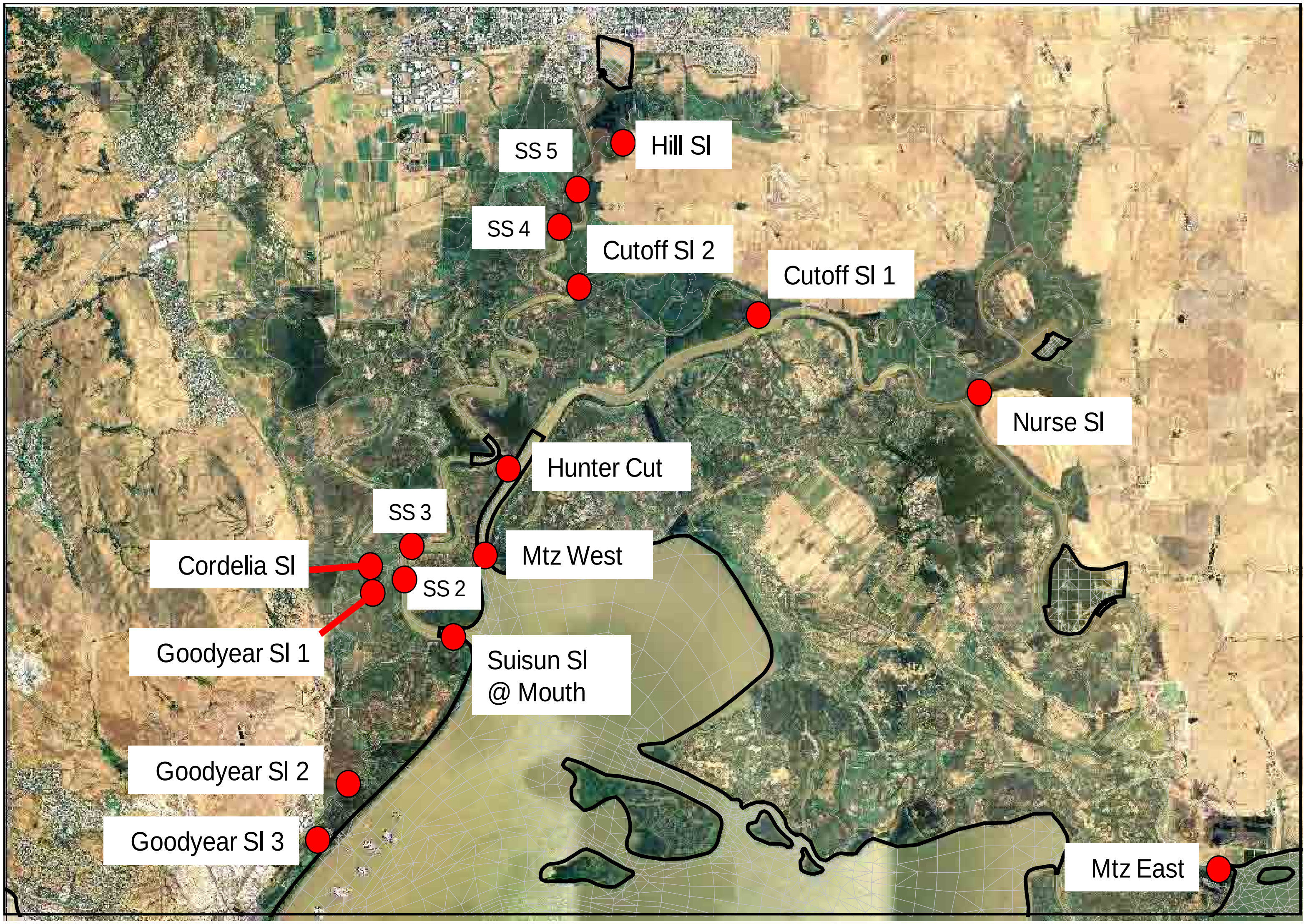



**Figure 5-12 Locations where tidal flow was calculated (Base case grid).**

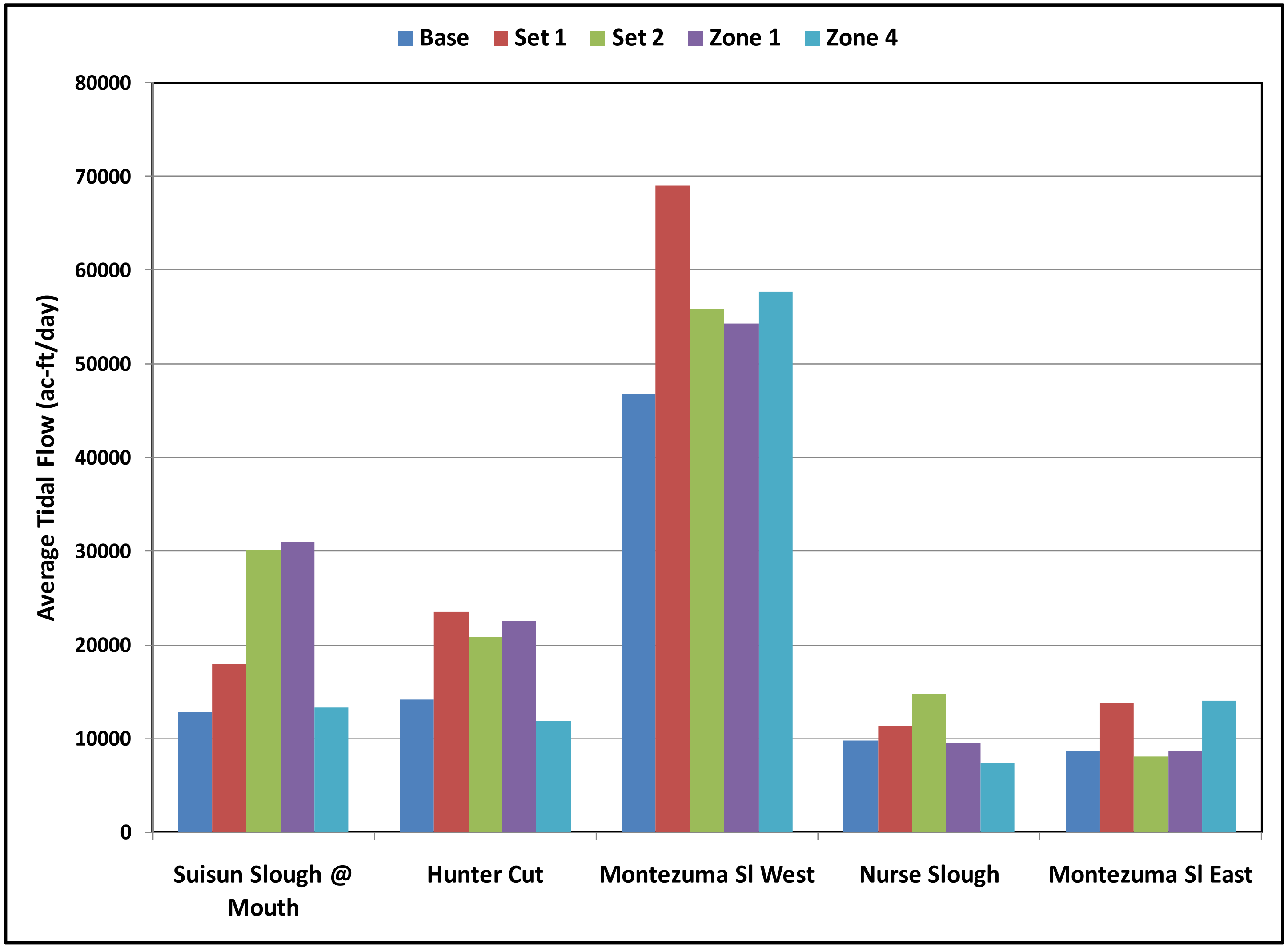



**Figure 5-13 Average modeled tidal flow in the larger sloughs in central Suisun Marsh.**

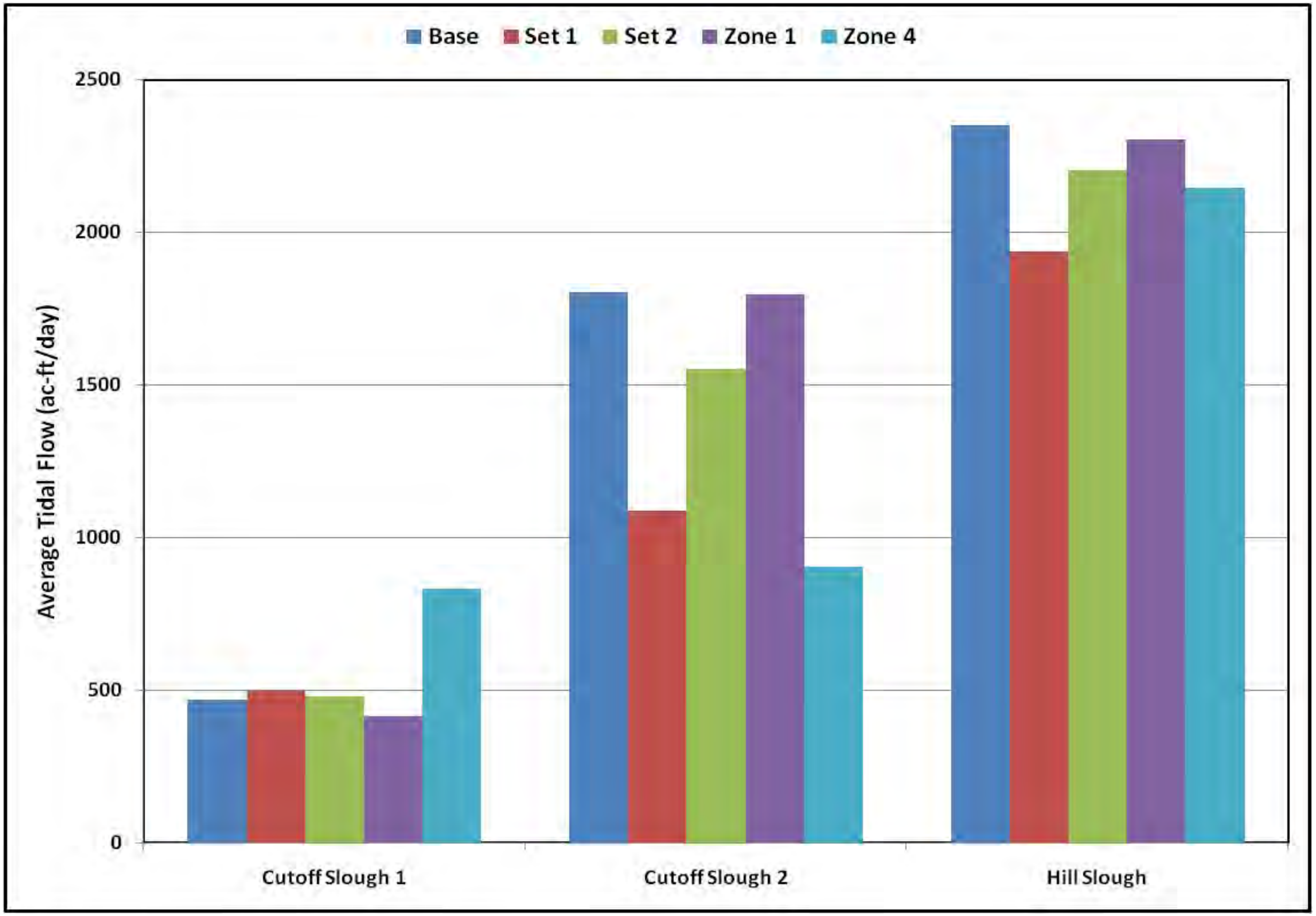



**Figure 5-14 Average modeled tidal flow in the smaller sloughs in the northern interior region of Suisun Marsh.**

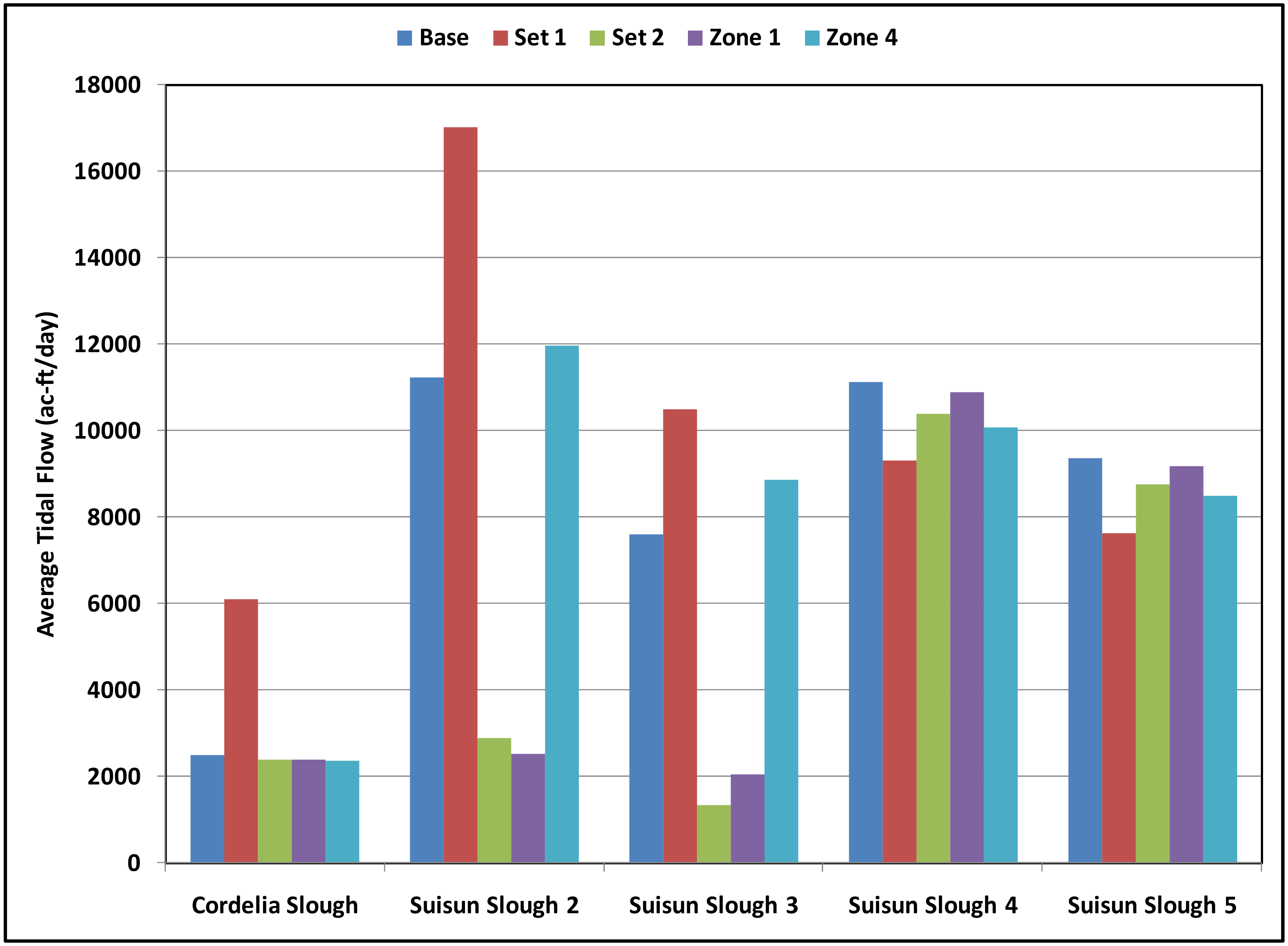



**Figure 5-15 Average modeled tidal flow in the sloughs west and north of the Zone 1 area.**

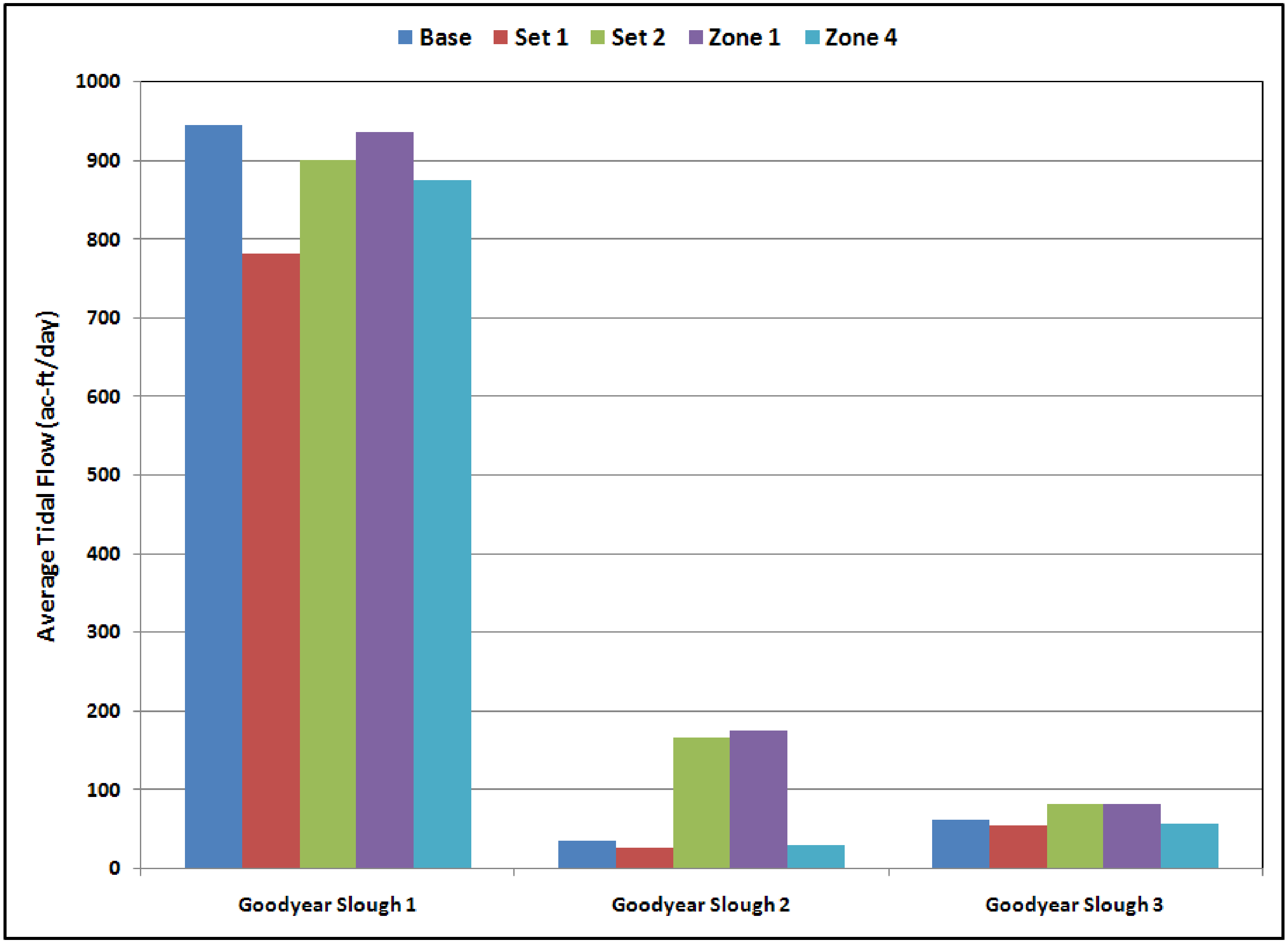
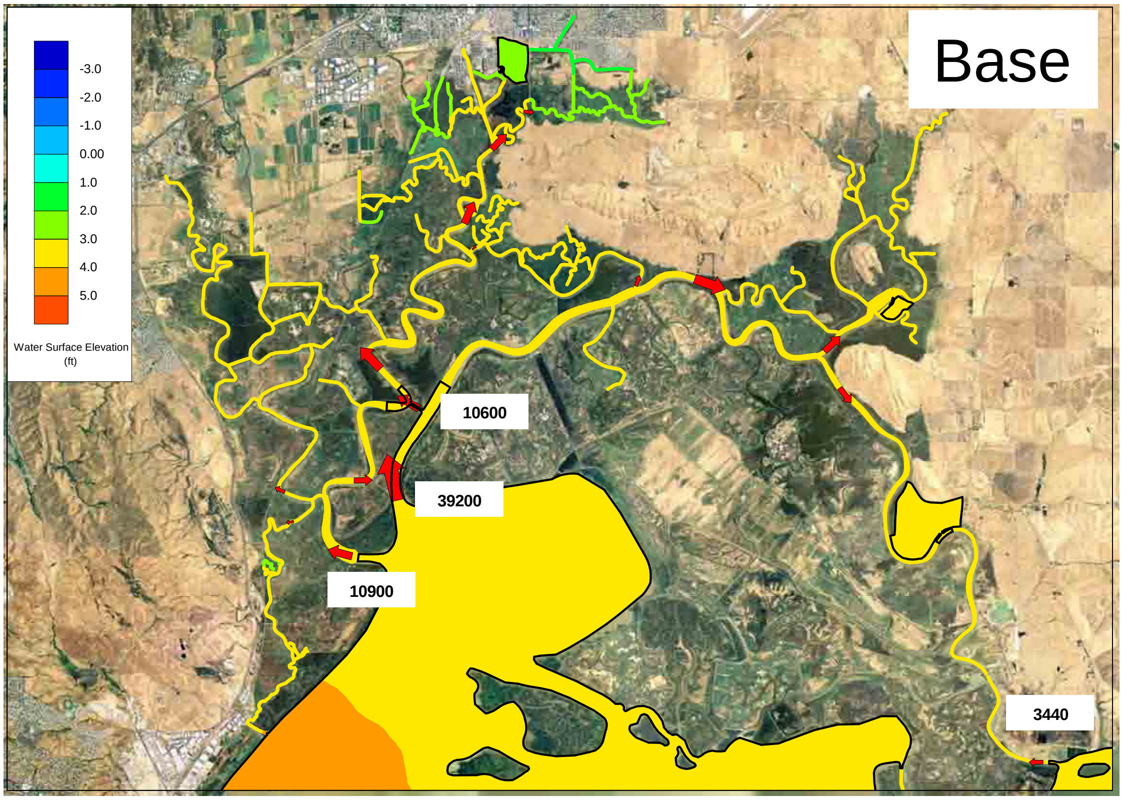



**Figure 5-16 Average modeled tidal flow in Goodyear Slough.**



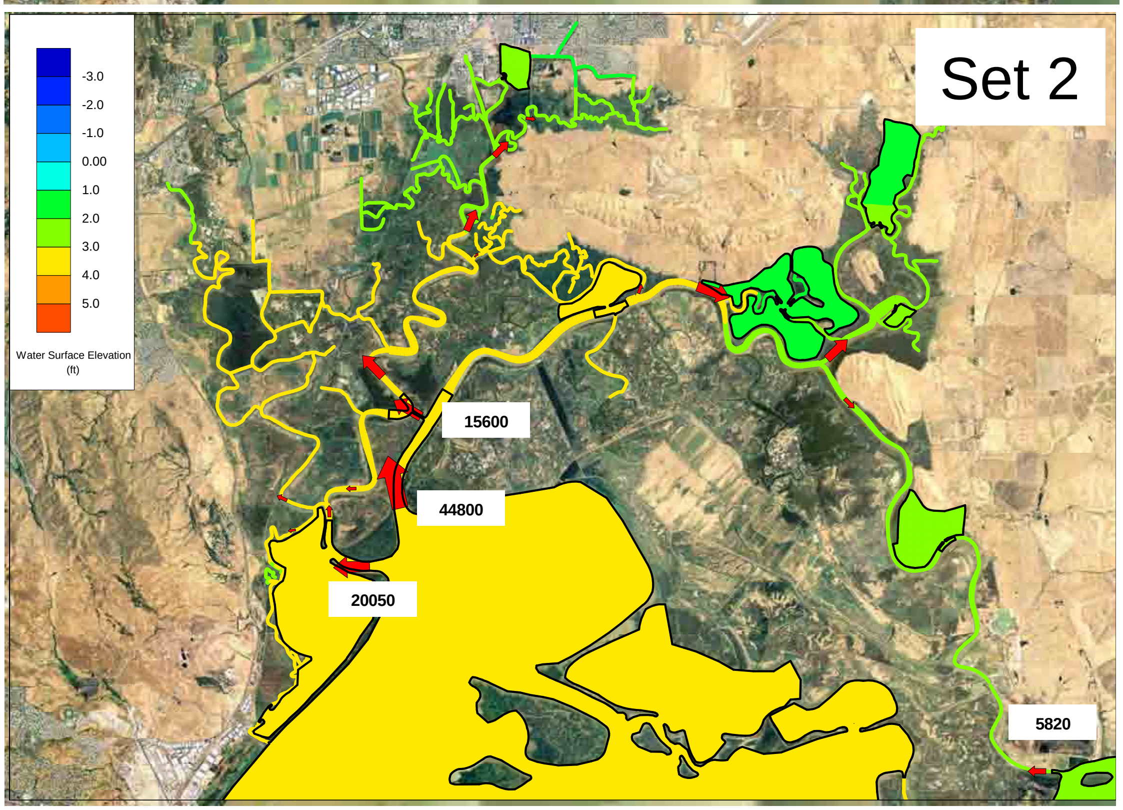




**Figure 5-17 Red arrows illustrate flow magnitude (cfs) near peak flood tide (July 11, 2003 22:00) for Base case in comparison with Set 2. Color Scale is water surface elevation.**

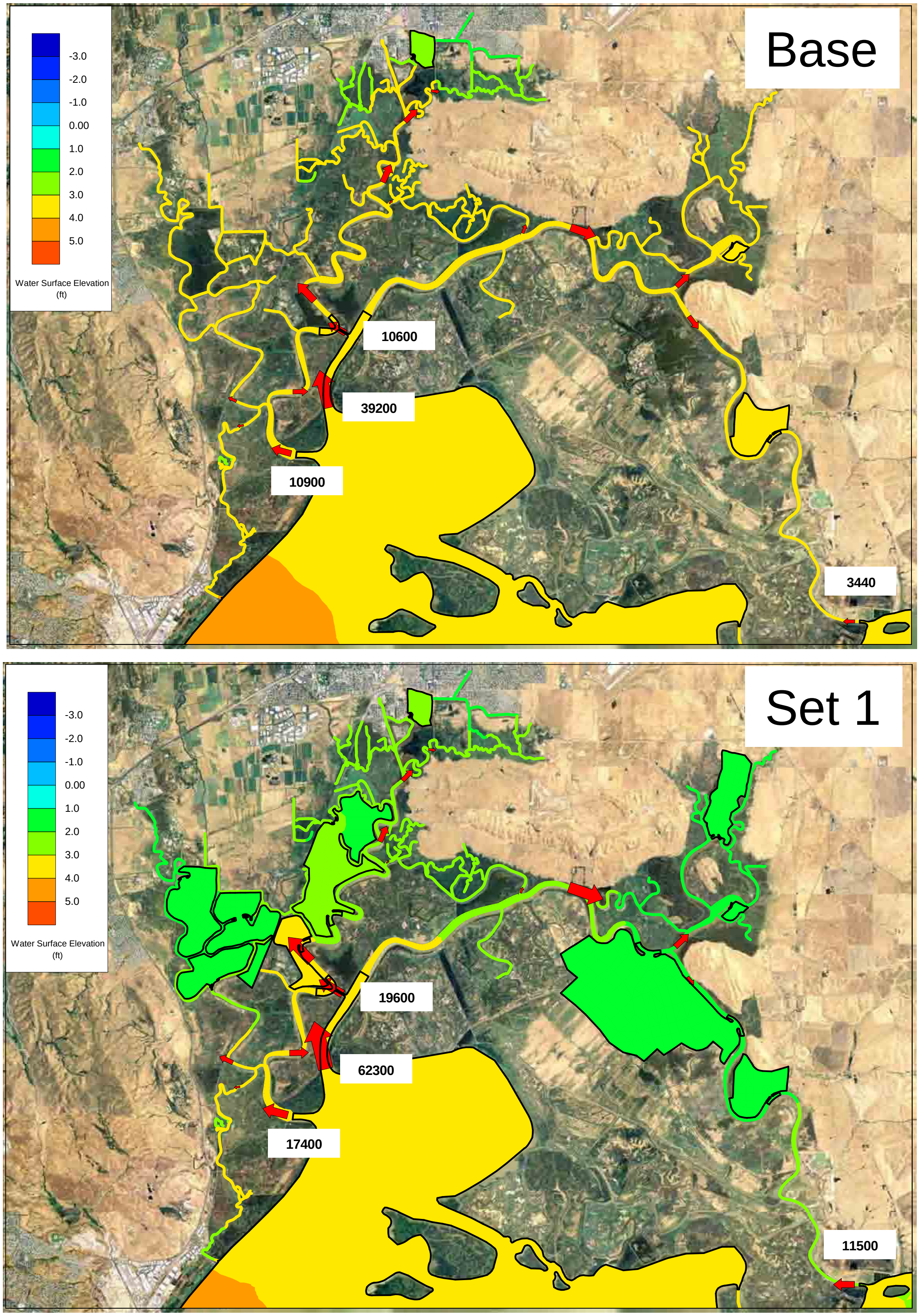



**Figure 5-18 Red arrows illustrate flow magnitude (cfs) near peak flood tide (July 11, 2003 22:00) for Base case in comparison with Set 1. Color Scale is water surface elevation.**