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## **RMA Turbidity and Adult Delta Smelt Behavioral Model Covering the Forecast Period February 16, 2012 to March 1, 2012**

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Date: February 17, 2012  
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Subject: Results of Recent Forecasting Work

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### **Summary Assessment**

**PERIOD:** The Delta turbidity and adult delta smelt forecast was produced this week, and this documentation covers the forecast period February 16, 2012 to March 1, 2012 plus a period of historical conditions.

**PRE-FORECAST SUMMARY:** Apart from the rain event the week of January 30, 2012, the earlier pattern of a general lack of significant precipitation has resumed in this forecast period. As a consequence, turbidity in the Delta decreased below 20 NTU at most locations in the model results during the forecast period.

**TURBIDITY 3-STATIONS PERFORMANCE & SUMMARY EVALUATION:** Forecast turbidity remained below compliance values at the three compliance locations during the two week forecast period. During the recent historical period, including the rain and turbidity event, modeled daily average turbidity at Prisoner Point, the northernmost compliance location, exceeded compliance values (12 NTU) briefly. Observed CDEC data exceeded compliance values at Holland Cut four times in January and February, due to resuspended sediment from wind events.

**SMELT MOVEMENT SUMMARY:** Under the influence of turbidity from the Sacramento River turbidity pulse associated with the rain event last month, many of the delta smelt particles that had moved up the Sacramento River and into the Northern and Central Delta remained in those regions during the forecast period.

### **Background**

This document provides a summary of the ninth forecast for WY2012 prepared by RMA on February 17, 2012. The forecast was developed using the RMA models for hydrodynamics, salinity, and turbidity and particle tracking using the Adult Delta Smelt Behavioral model. Figures are provided to document the results of the modeling with a focus on turbidity.

Additional documentation can be found on the Bay-Delta Live website: <http://www.baydeltalive.com/>.

## Boundary Condition Development and Simulation Timing

Boundary conditions (BCs) for the forecast models were developed using several sources for historical and forecast conditions including: CNRFC flow data and predictions, CDEC and USGS data, DWR-supplied model inputs and results from their flow and salinity forecasts, and WARMF modeled salinity, and turbidity forecasts, provided by Systec Water Resources, Inc. BCs were prepared using these data sources and using professional judgment where necessary to resolve data discrepancies and to piece the data together for reasonable BCs.

The RMA modeled period was January 1, 2012 to March 6, 2012 for flow, salinity and turbidity. This document presents results for the period January 1, 2011 through March 1, 2012, which include two weeks of forecasted conditions. DWR Operations and Maintenance (O&M) group provided RMA with BCs they used in the DSM2 HYDRO and QUAL/salinity models for a combined historical and forecast period February 4 through March 6, 2012; the three week DWR forecast period was February 14 through March 6, 2012. WARMF model results were provided for the period November 1, 2011 to March 7, 2012.

Additional flow, turbidity, and EC data was downloaded for the period February 14–15, 2012 from the CDEC website to fill-in observed historical conditions in the RMA forecast models.

Historical and forecast BC for flow, turbidity and salinity were developed from sources as summarized in Table 1 through Table 3 below. Stage and export BC were compiled solely from DWR O&M sources. Flow BCs were developed using DWR flow predictions for this forecast, which were qualitatively similar to WARMF predictions. WARMF turbidity forecasts were used at the Sacramento at Freeport and Cosumnes and Mokelumne River BCs. Water quality forecasts at the other model boundaries were extended as constants, due to poor agreement of WARMF predictions with historical observed data.

As with the previous forecasts, internal turbidity boundary conditions were applied in the turbidity model (Figure 1) at both the Sacramento River at Mallard Island and Cache Slough at Ryer Island (from previous forecasts) and in the central Delta (Old River at Quimby, Mokelumne River at the San Joaquin River confluence, and the San Joaquin River at Jersey Point; as described in the Jan. 19, 2012 forecast) to improve model fit during the modeled historical time period. With the exception of Mallard Island (where forecast data was extended as a constant), these internal boundary conditions were not applied during the forecast period.

Two changes to model boundary conditions coefficients were made for this forecast. The first change concerns the data provided by DWR for forecasted Delta Island Consumptive Use (DICU). DICU forecasts are used to predict small scale water exports and return flows at over two hundred locations in the interior of the Delta. The values used in previous RMA forecasts were generated by DWR O&M at the start of WY2012 and were created using average water year precipitation conditions. Since WY2012 precipitation in the Delta region has been significantly less than a typical year, the predicted DICU flows for the historical period have been much larger than the actual DICU values. This discrepancy has had a large effect on modeled salinity in the Delta, as DICU return flows are usually higher in salinity than ambient Delta conditions. In response to this problem, the RMA flow model was run for this forecast using December DICU flows (dry conditions) for January and February.

The second model change concerned the dispersion coefficients used to quantify the amount of horizontal mixing occurring at different locations throughout the Delta. A calibration on the salinity model results yielded an improved model fit with new dispersion coefficients. The coefficients were altered from previous values primarily in the area of the western Delta. A detailed description of the salinity model results pre- and post-calibration will be included as an appendix in the project final report.

## WARMF Model Information

WARMF simulations in forecast mode require the best available real-time and forecast time series data to drive the simulation. There are five types of time series data used as inputs to the WARMF model: meteorology, air & rain chemistry, point sources, reservoir releases, and diversions. Data up to real-time is collected for those model inputs for which it is available—reservoir releases and many meteorology stations. All remaining time series inputs except meteorology are filled in by extrapolation using average values for each day of the year based on the historical record.

There are seven meteorology parameters used by WARMF: precipitation, minimum temperature, maximum temperature, cloud cover, dewpoint temperature, air pressure, and wind speed. The 6-day forecast meteorology is collected from the National Weather Service and entered into the WARMF database. Missing past and future meteorology data is filled in by comparing stations with missing data to nearby stations which have more complete data. Meteorology beyond the 6-day forecast window is filled in by extrapolation. All but precipitation are extrapolated by calculating the average value for each day of the year from historical data and then applying that average in the extrapolation. Extrapolated precipitation is defaulted to zero.

Forecast reservoir releases are acquired from the California Data Exchange Center and entered into the WARMF time series database. Reservoir releases beyond the scheduled period are extrapolated by continuing the last scheduled release flow through the forecast period. WARMF is first run for at least one year prior to the forecast time period to establish good initial conditions for the forecast. Then the forecast is run using the updated time series inputs.

## Flow and Turbidity Model Results

Boundary inflow was low during early–mid January and most of the forecast period of the simulation due to the lack of rain events. One rain event briefly increased inflow to the Delta for the period roughly from January 22 to January 30, 2012. This weather system resulted in a significant increase in flows and turbidity on the Sacramento River at Freeport (see Figures 2 and 3), the Yolo Bypass, and the Cosumnes River. These turbidity pulses caused local increases in turbidity as they made their way through the Delta, but, because of low-to-moderate export levels, stayed north of the south Delta region.

Except during this rain event, turbidity measurements indicate suspended sediment loading from the watersheds was also very low. Turbidity remained below 40-50 NTU throughout most of the Delta, except on the Sacramento River in the northern portion of the model domain. Turbidity data was noisy at many locations, which was particularly evident when turbidity values were low.

The conditions of low boundary inflow and low watershed sediment loading, with in-Delta turbidity due to sediment resuspension, are outside the current turbidity model design as turbidity is being modeled not suspended sediment. Additionally, the turbidity model calibration was optimized for high flow conditions with substantial loading from the watersheds, conditions that are hypothesized to lead to movement of delta smelt into the interior of the Delta as they follow flow and turbidity cues.

Flow and turbidity BC are illustrated in Figure 2 through Figure 9, while Figure 10 through Figure 13 illustrate export levels and Old+Middle River flows. Using information supplied by O&M for historical and forecast State (SWP) and Federal (CVP) exports, Figure 10 illustrates that daily-averaged exports decreased from a maximum of ~6,000 cfs in January to around 3,000 cfs by early February. Figure 11 and Figure 12 are plots of Old River and Middle River flows and daily-averaged flows, respectively, while Figure 13 illustrates the combined Old+Middle River flow criterion (3-day center-weighted average) compared with CDEC data.

Figure 14 is a comparison of model output and data at the three compliance locations, and Figure 15 is a similar plot in the SWP export area. Note that Figure 15 is a comparison of data inside Clifton Court Forebay with model output at the entrance to the Forebay. For these two figures, data were cleaned (noisy values removed) and missing data filled with linear approximation. The cleaned and filled data were also daily averaged for comparison with daily-averaged model output.

Turbidity was below compliance values (12 NTU) at the three compliance locations for the majority of the historical and forecast periods. At Holland Cut the turbidity exceeded the compliance value for several days in January and February in response sediment resuspended during wind events. The most recent of these occurred just prior to the forecast period. At Prisoner's Point, the northernmost compliance location, modeled daily-average turbidity exceeded compliance values briefly in early February in response to the pulse of turbid Sacramento River water traveling into the Central Delta. The Victoria Canal compliance station, located closest to the export locations was uniformly below compliance turbidities.

Figure 16 and Figure 17 illustrate the progression of the main turbidity boundary conditions at Freeport and Vernalis down the Sacramento and San Joaquin Rivers, respectively. Figure 18 through Figure 24

are plots of model output compared with raw CDEC turbidity data at several in-Delta locations—these locations can be found on a map of the Delta in Figure 25. The turbidity model captured the transport of the turbidity pulse through the north and central Delta, and the generally low turbidity in the south.

## **Adult Delta Smelt Particle Tracking Model Results**

Figure 26 through Figure 29 present the turbidity contour plots and particle tracking model results for the runs using the data-derived turbidity and EC boundary conditions listed in Table 2 and Table 3. RMA-modeled turbidity is in the left plot and particle tracking model results are in the right plot. The Delta Smelt behavioral model was run November 1, 2011 to March 1, 2012; 50,000 particles were inserted on November 01. These plots illustrate that just prior to the forecast period, turbidity increased in the north and central Delta, but then quickly decreased due to lower turbidity inflows from the Sacramento by the end of the 2-week forecast period (Figure 29). None of the modeled particles reached the export locations during the simulation; however small numbers of delta smelt were reported by DFG as being salvaged at the CVP pump locations in late January and early February, 2012 (Figure 30).

## **MWD Training**

Model input files and results were provided to Chuching Wang for remote access on the RMA intranet.

### **List of Acronyms:**

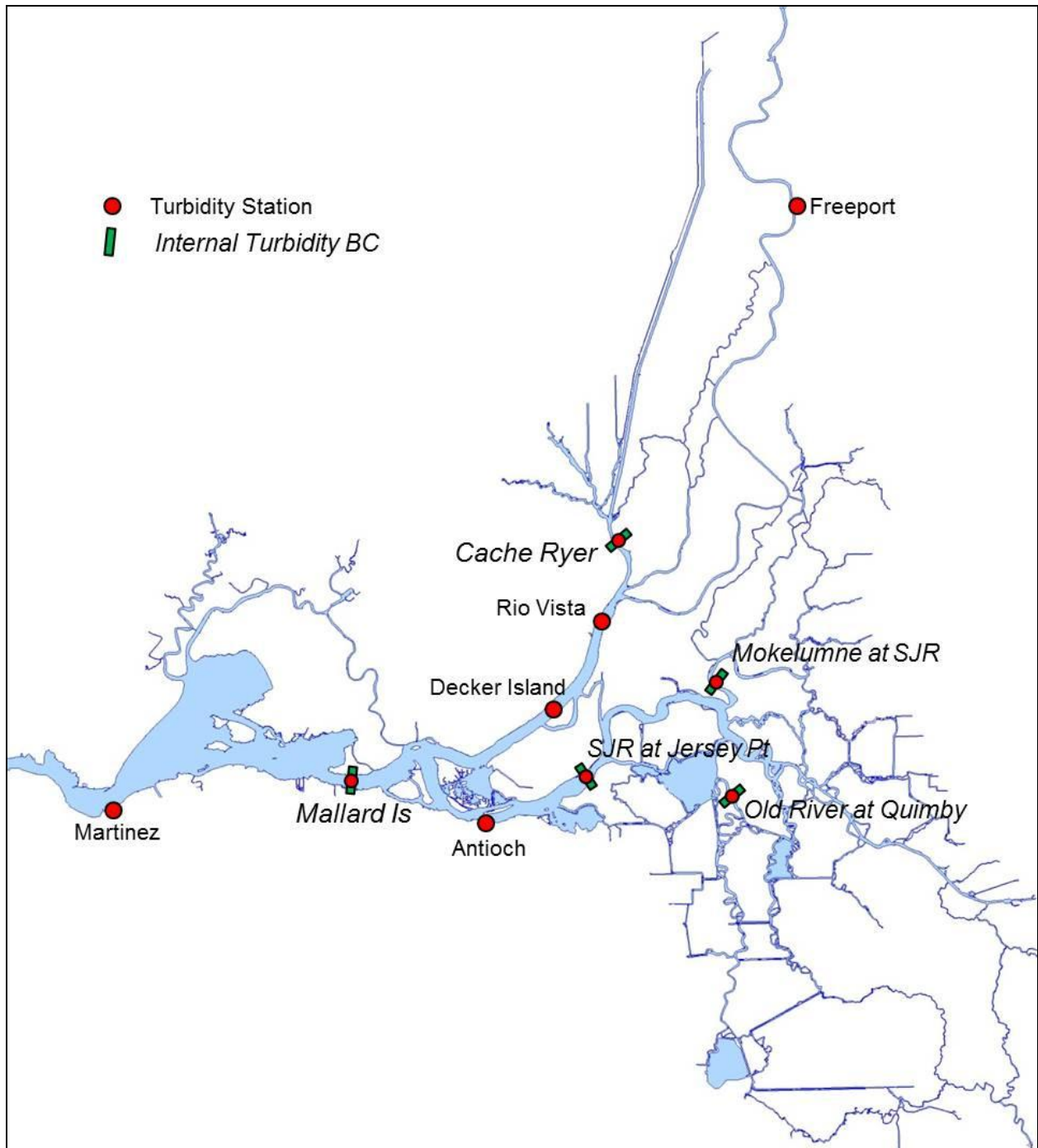
WY ~ Water Year  
SWP ~ State Water Project  
CVP ~ Central Valley Project  
CCFB ~ Clifton Court Forebay  
CNRFC ~ California-Nevada River Forecasting Center  
CDEC ~ California Data Exchange Center  
CIMIS ~ California Irrigation Management System  
DWR ~ California Department of Water Resources  
USGS ~ United States Geological Survey  
RMA ~ Resource Management Associates  
WARMF ~ Watershed Analysis Risk Management Framework  
DFG ~ California Department of Fish and Game  
DICU ~ Delta Island Consumptive Use

### **CDEC Stations:**

FPT ~ Freeport  
MAL~ Sacramento River at Mallard Island  
RYI ~ Cache Sl. at Ryer Island  
SMR ~ South Fork Mokelumne River  
MRZ ~ Martinez  
VNS ~ Vernalis

### **DSM2 Boundary Locations:**

RMKL070 ~ Mokelumne River  
RCSM075 ~ Cosumnes River  
RCAL009 ~ Calaveras River  
RSAN112 ~ San Joaquin River  
BYOLO040 ~ Yolo Bypass  
RSAC054 ~ Martinez



**Figure 1** Locations of the internal turbidity boundary conditions used in the current turbidity forecast model run. Boundary conditions at the Mokelumne River at SJR, the SJR at Jersey Point, and Old River at Quimby Island were implemented in the January 19, 2012 forecast.

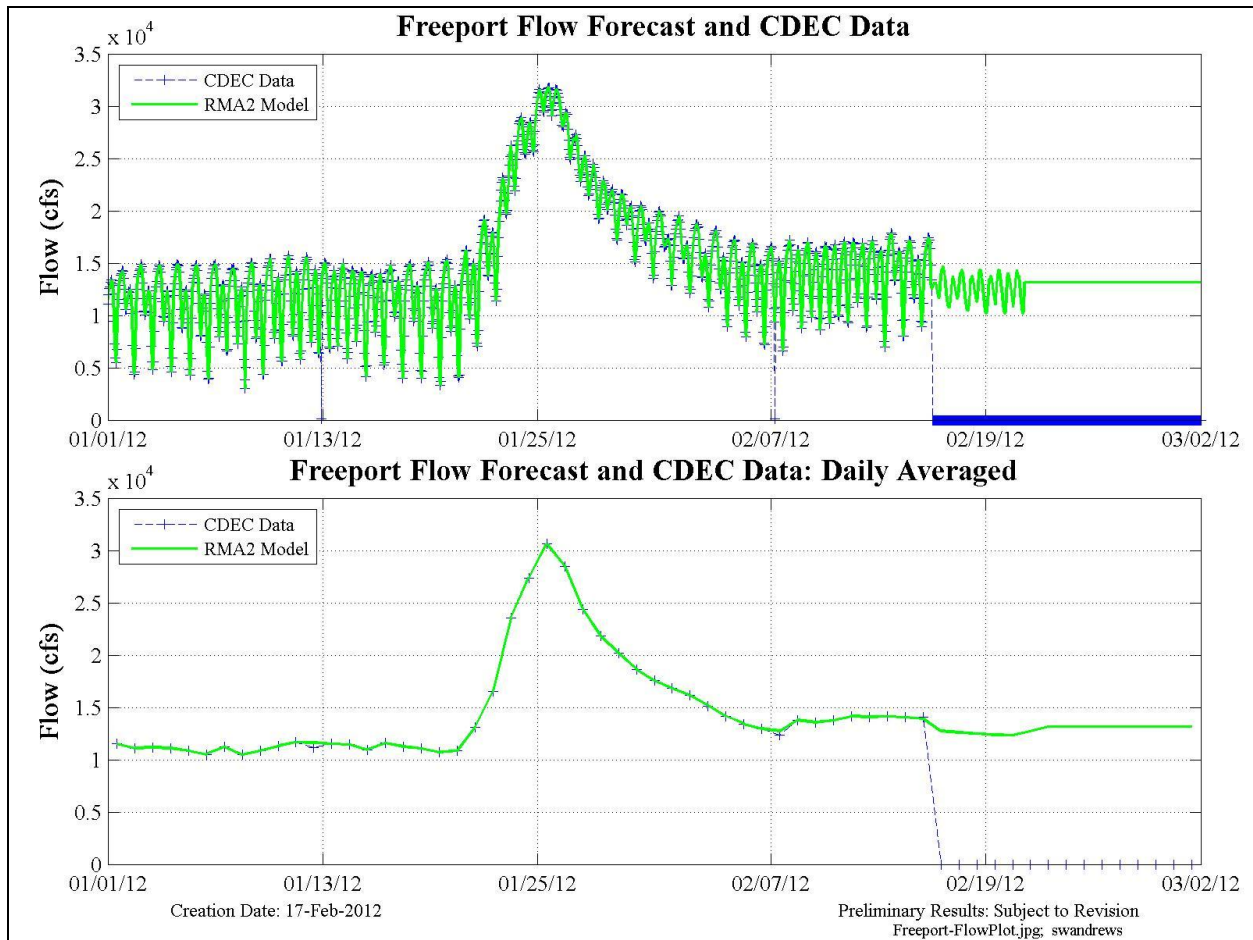
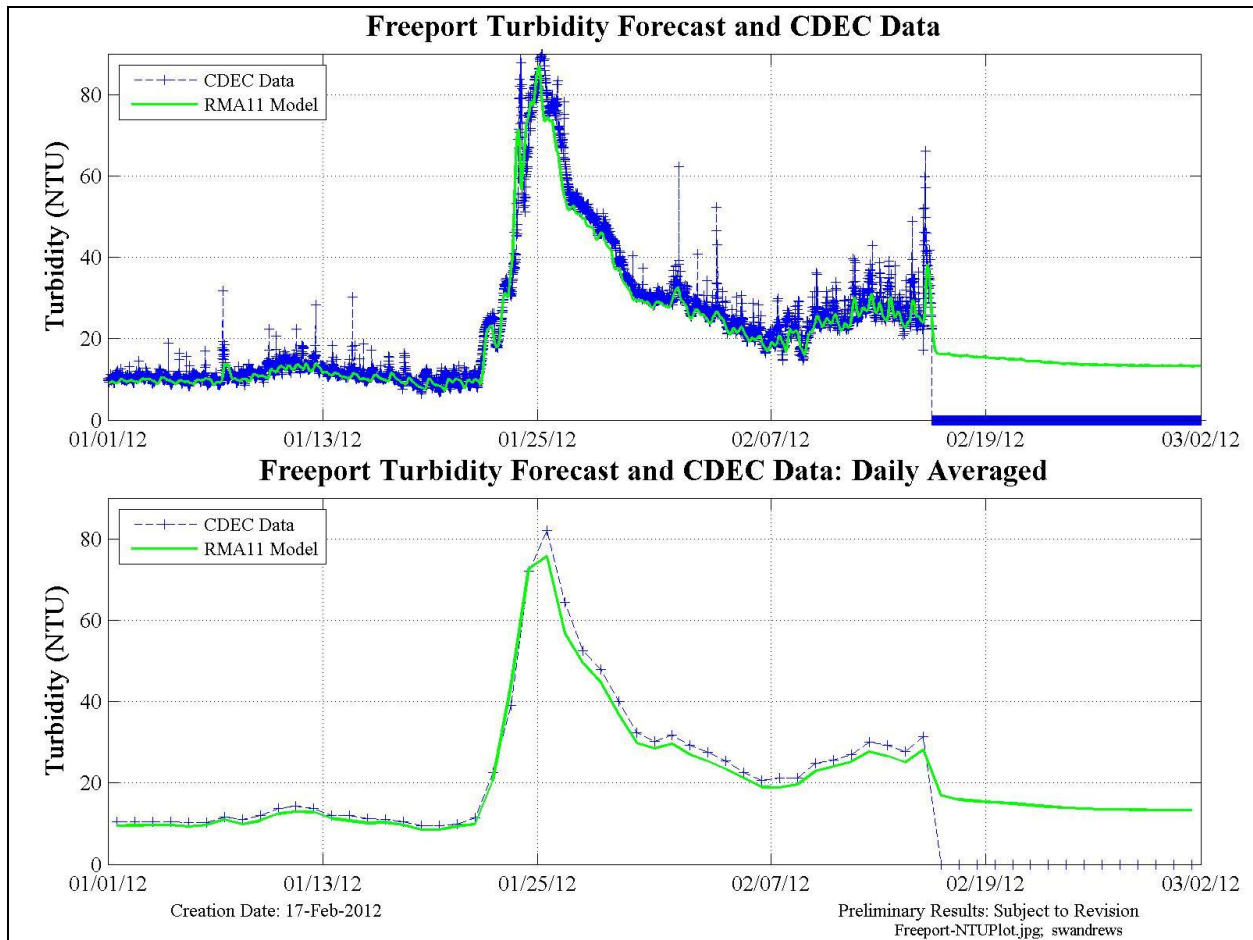
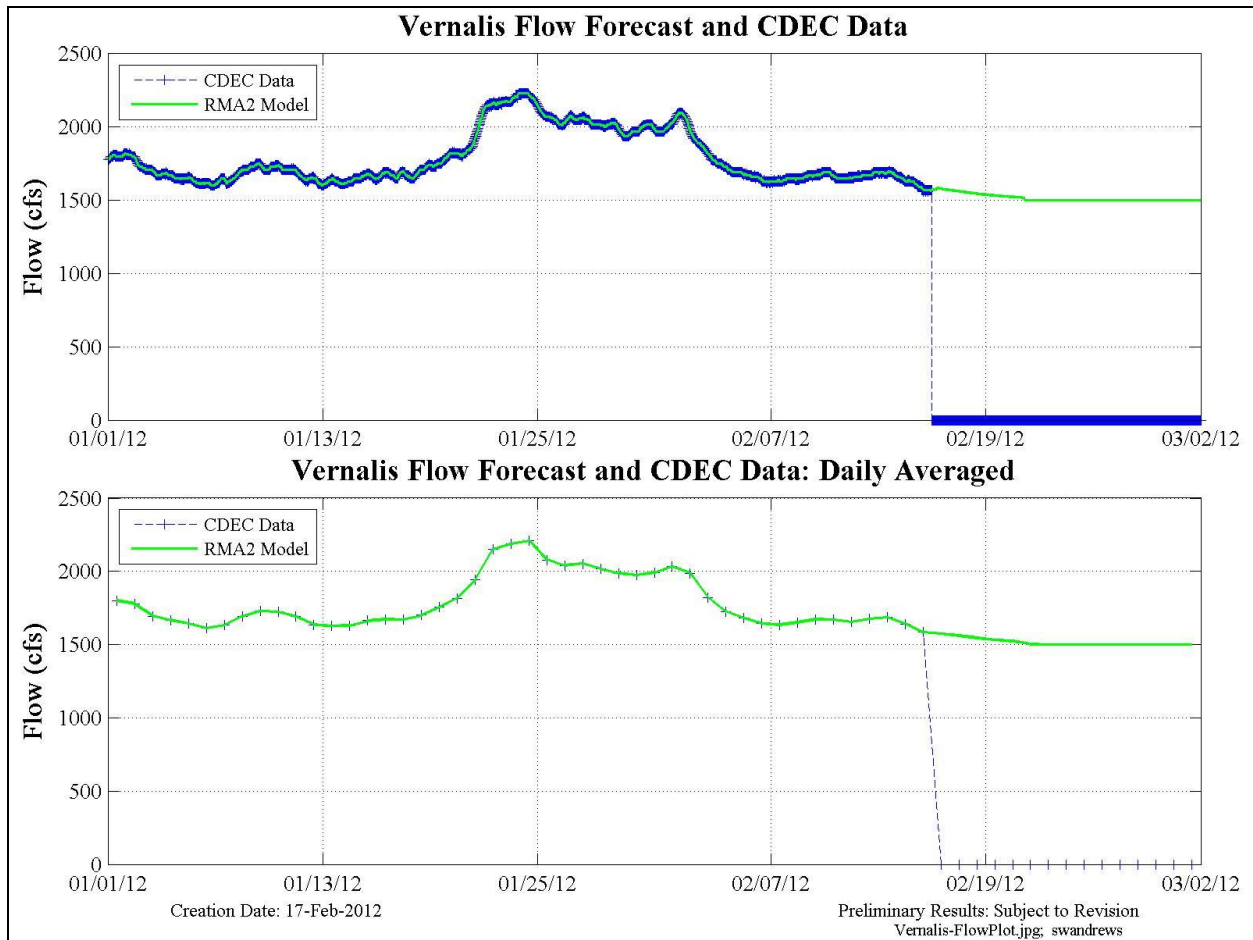


Figure 2 Freeport flow BC was compiled using CDEC data, CNRFC forecast, and then DWR DSM2 forecast. Note the y-axis unit is cfs\*10,000. Zero values indicate the end of data (blue).

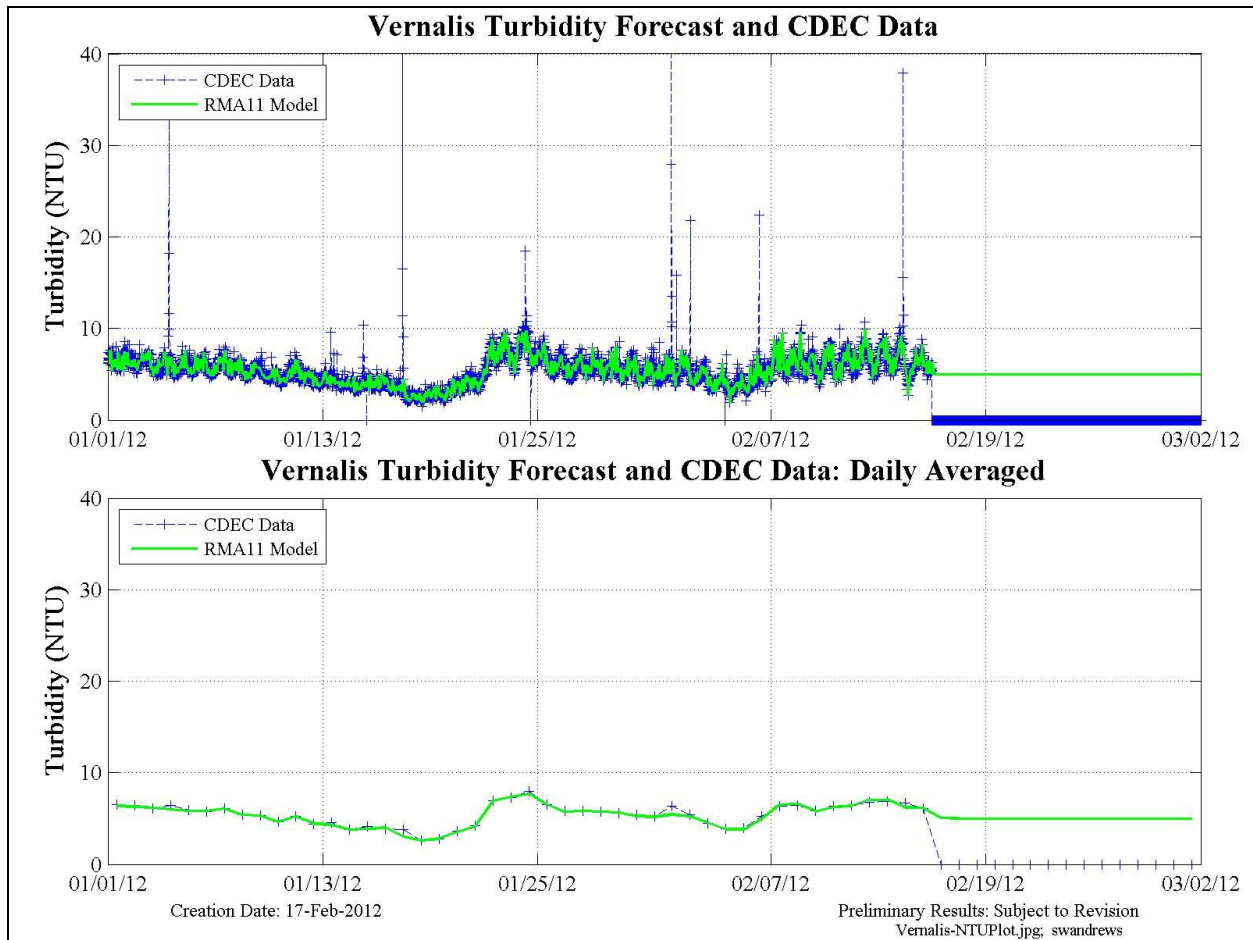


**Figure 3** Freeport turbidity BC was compiled using CDEC data followed by the WARMF forecast. Zero values indicate the end of data (blue).

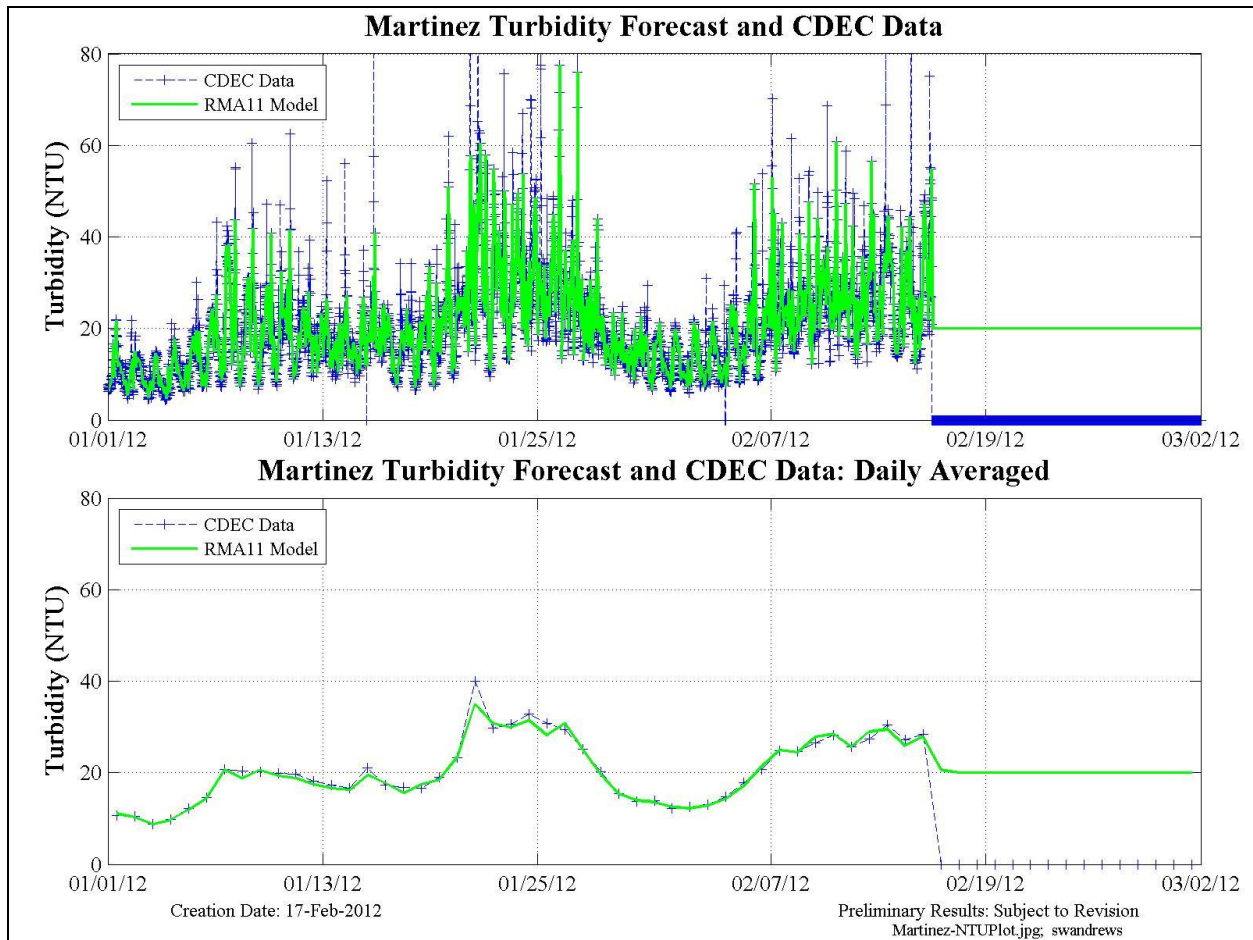


**Figure 4 Vernalis flow BC was compiled using CDEC and USGS data and DWR DSM2 forecast flow. Zero values indicate the end of data (blue).**

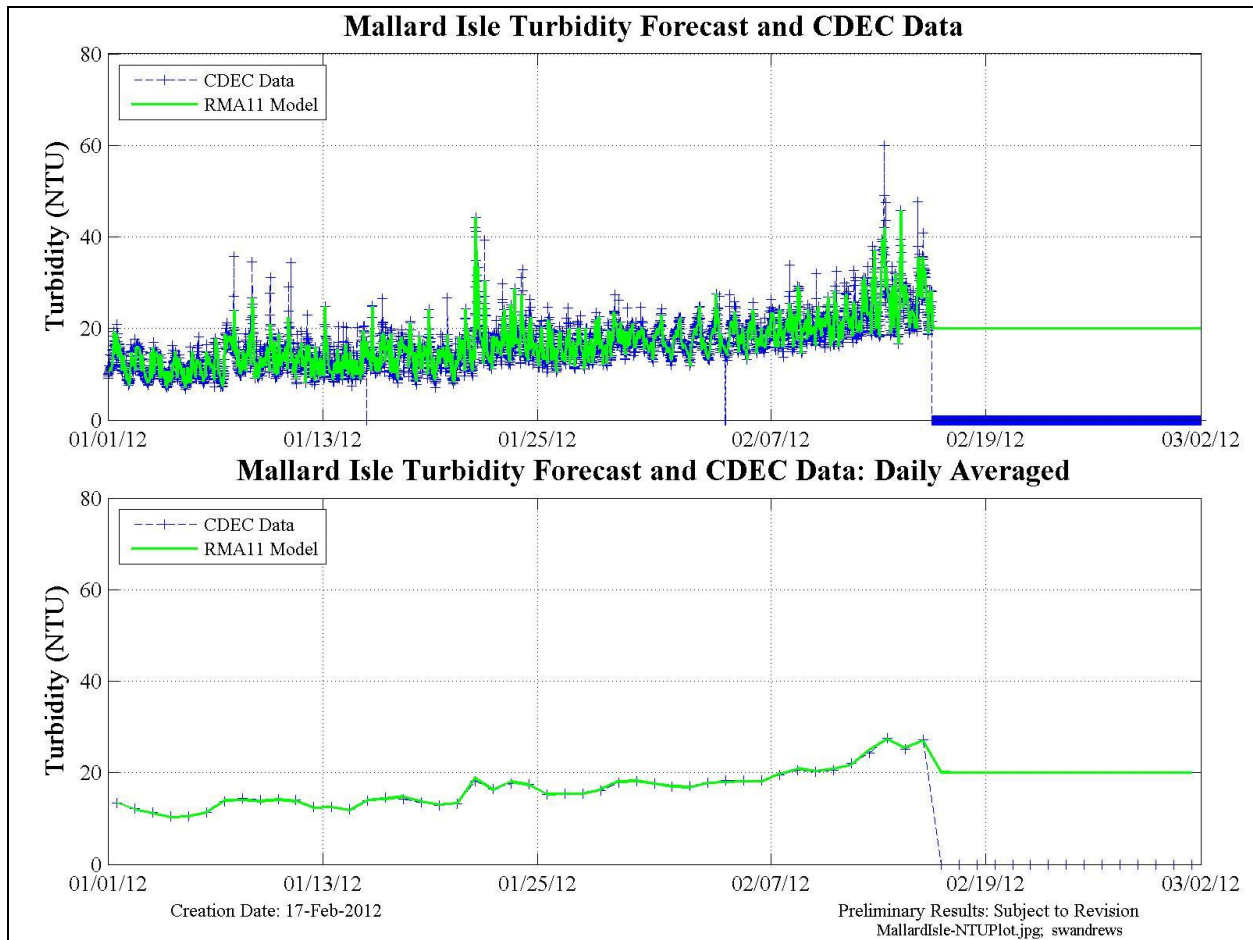




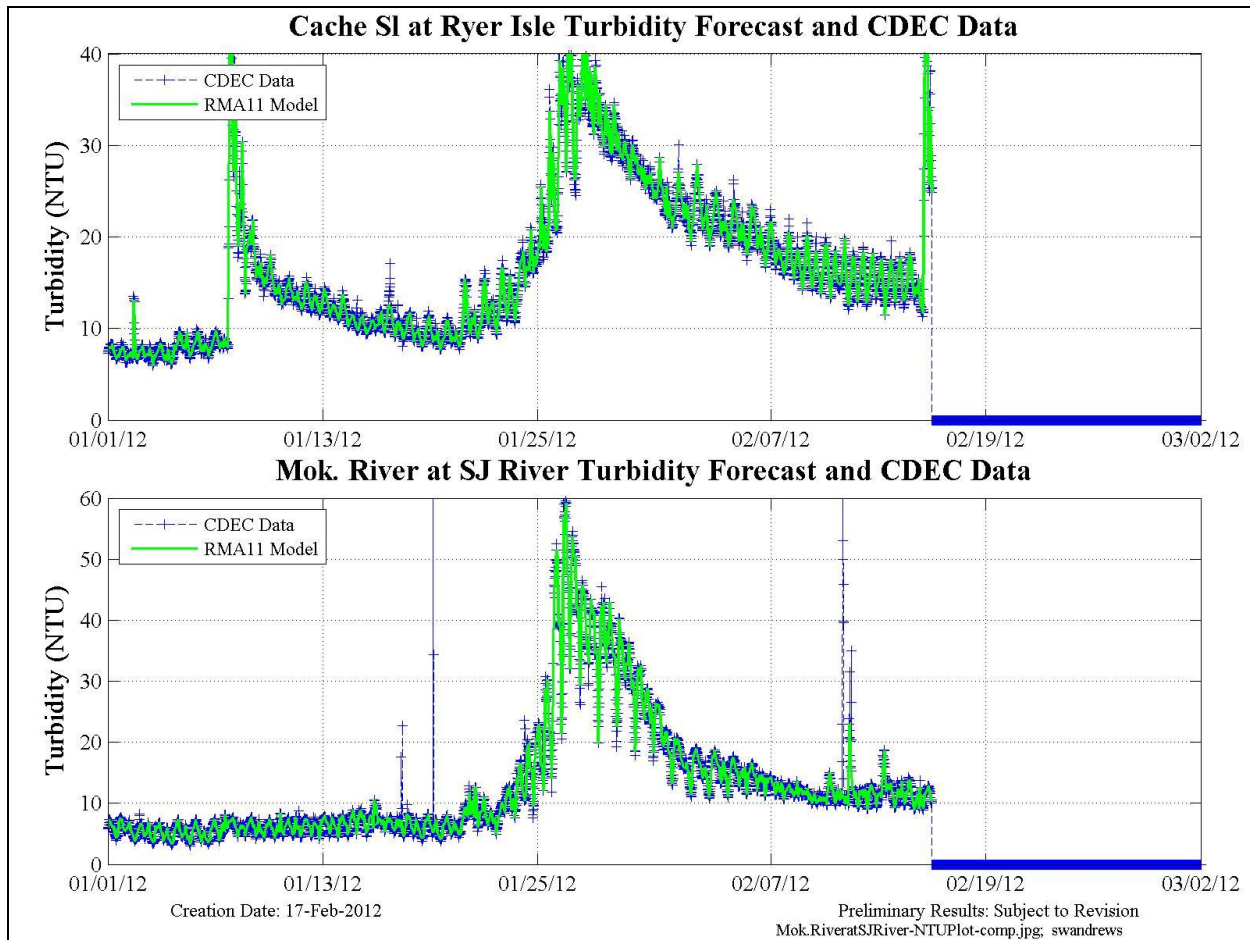
**Figure 5 Vernalis turbidity BC was compiled using CDEC data, then extended as a constant. Zero values indicate the end of data (blue).**



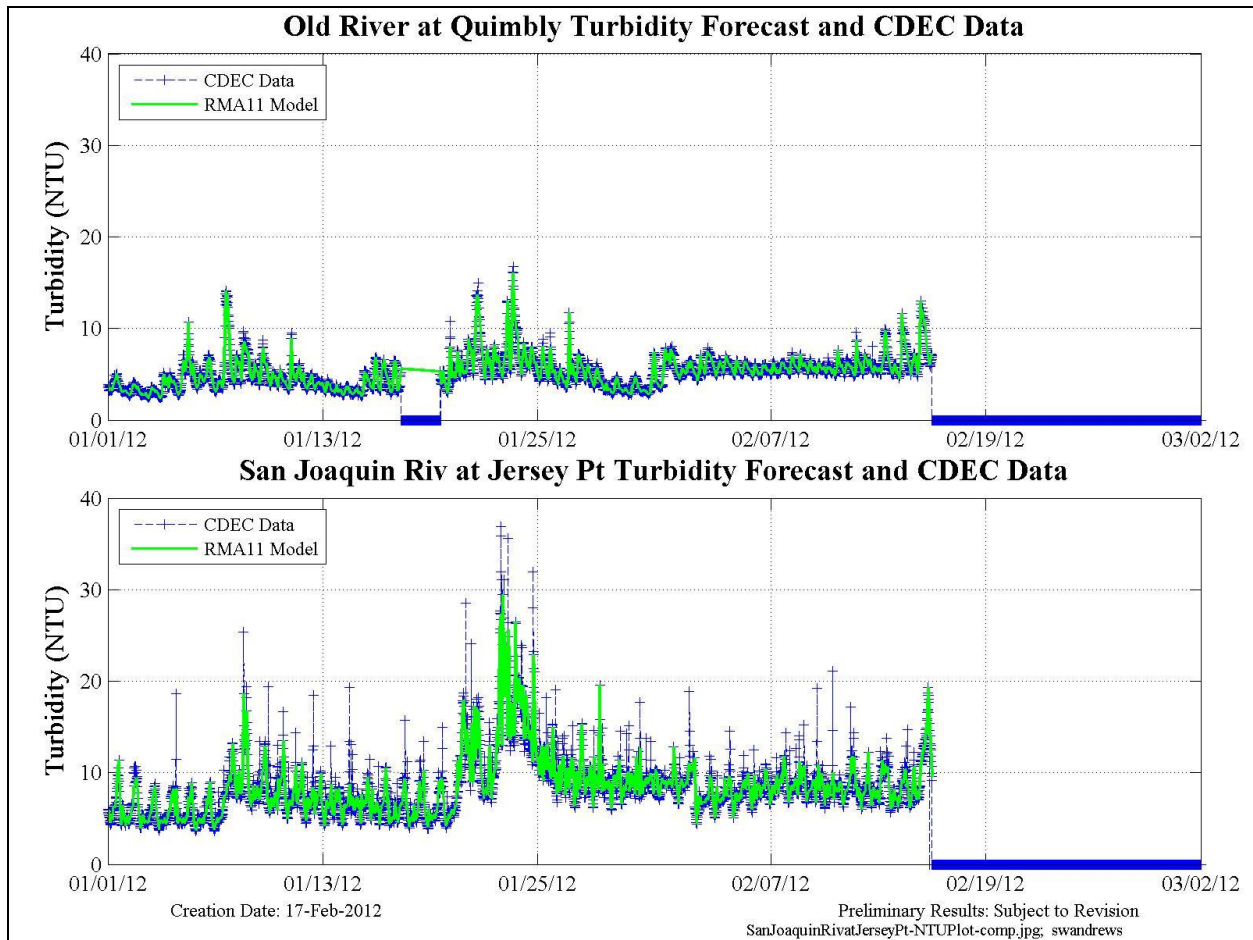
**Figure 6** Martinez turbidity BC was compiled from CDEC data then extended linearly to a value of 20 NTU. Zero values indicate the end of data (blue).



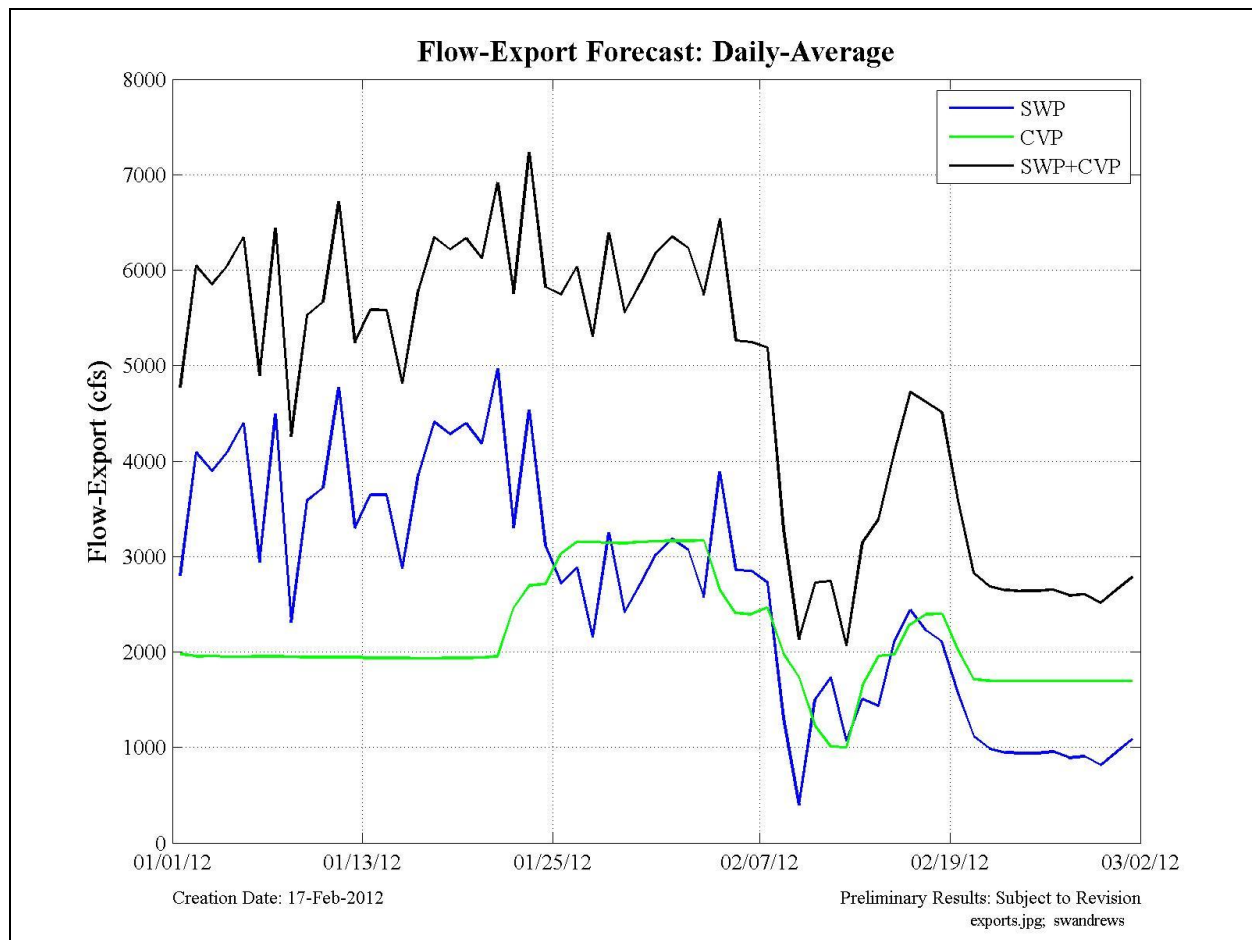
**Figure 7 The Sacramento River at Mallard Island internal turbidity BC was compiled from CDEC data then extended linearly to a value of 20 NTU. Zero values indicate the end of data (blue).**



**Figure 8 The Cache Slough at Ryer Island (top) and Mokelumne River at SJR (bottom) turbidity internal boundary conditions. Both were compiled using CDEC data and were not applied beyond the end time of the observed data. Zero values indicate the end of data application period (blue).**

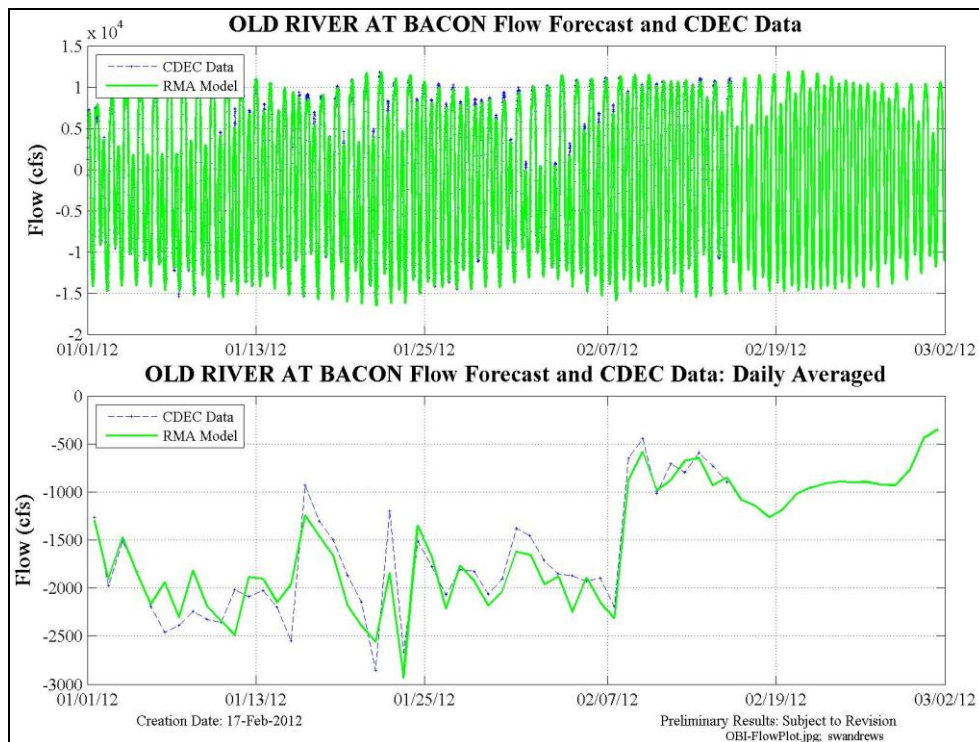


**Figure 9 The Old River at Quimby Island (top) and San Joaquin River at Jersey Point (bottom) turbidity internal boundary conditions. Both were compiled using CDEC data and were not applied beyond the end time of the observed data. Zero values indicate the end of data application period (blue).**

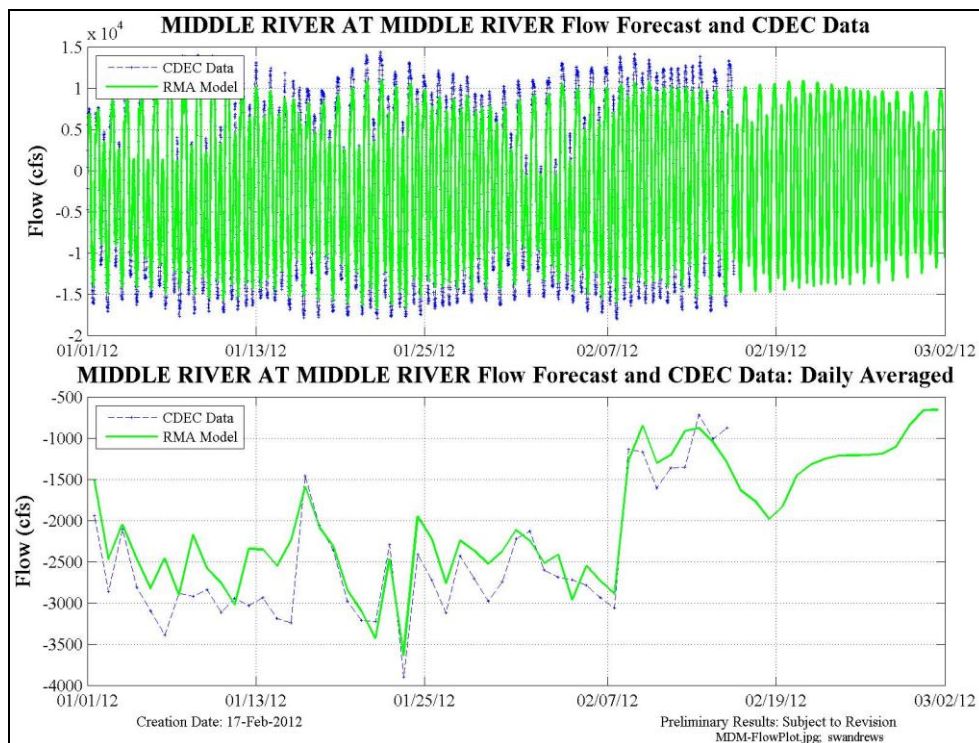


**Figure 10 Historical and modeled daily-averaged exports at the SWP and CVP export locations, and the combined SWP+CVP exports.**

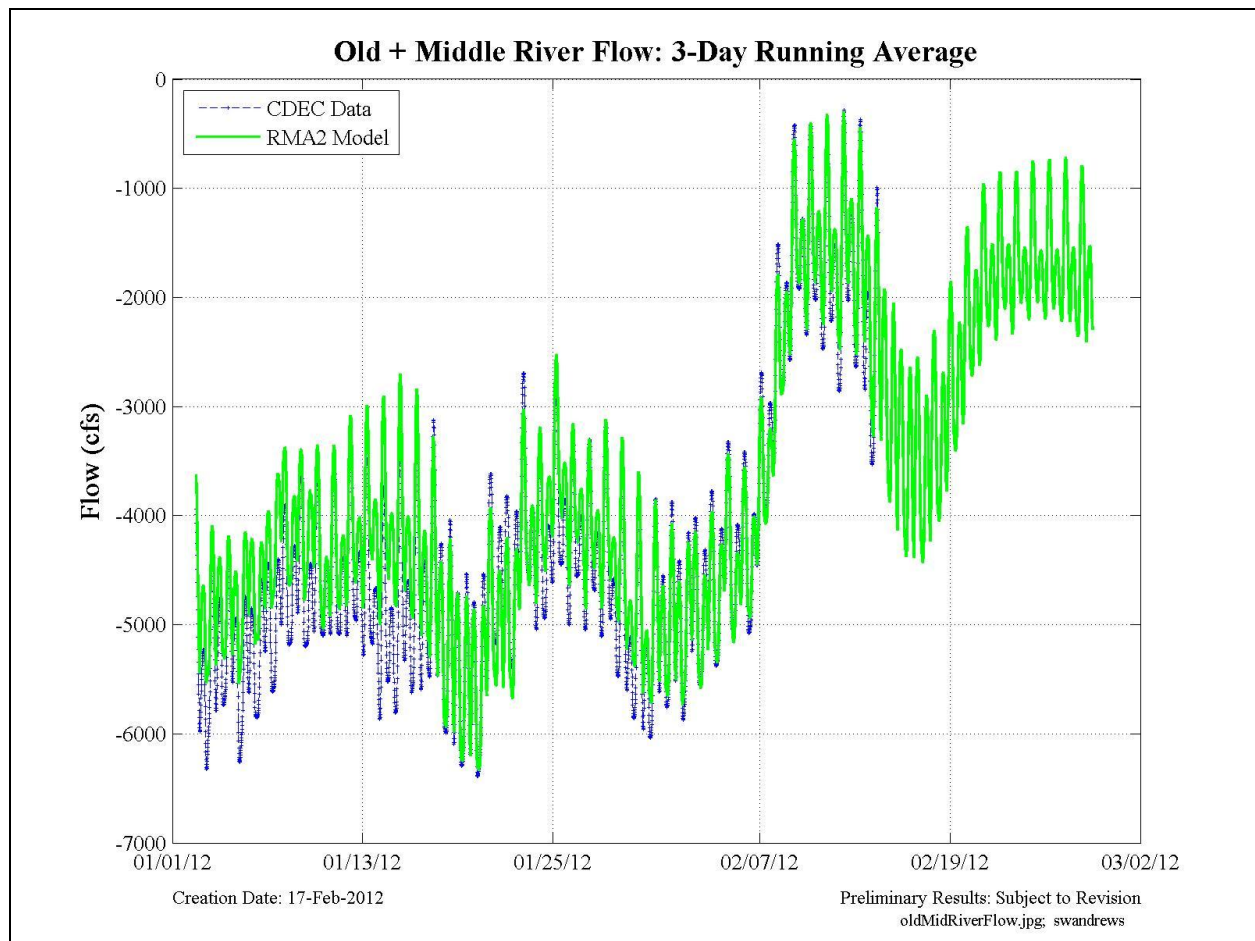




**Figure 11 Model flow forecast output and raw CDEC data at Old River at Bacon (ROLD024) location. Both 15-min (upper) and daily averaged (lower) plots are shown.**



**Figure 12 Model flow forecast output and raw CDEC data the Middle River-at-Middle (RMID015) location. Both 15-min (upper) and daily averaged (lower) plots are shown.**



**Figure 13 Model flow forecast output (green) and raw CDEC data (blue) for the Old+Middle River flow criterion for three-day running-average flow.**



**Table 1 Boundary condition development for flow for this forecast period.**

February 16, 2012	Historical DWR BC	Definition Historical Flow	Definition Forecast Flow	Comment
<b>BC Location</b>				
Yolo Bypass	Not used	Hourly CDEC LIS, cleaned+filled	Hourly CNRFC forecast (Yolo at Lisbon) for 5 days, constant 400cfs flow after	DWR flow prediction too low
Sacramento River at Freeport	Not used	Hourly CDEC FPT, cleaned+filled	Hourly CNRFC forecast (Sac R at I St.) for 5 days, Daily DSM2 RSAC155 results after, converted to hourly	
Mokelumne River	Daily DSM2 RMKL070, converted to hourly	Not used	Daily DSM2 RMKL070 results, converted to hourly	
Cosumnes River	Not used	Hourly CNRFC Cosumnes-McConnell, cleaned+filled	Hourly CNRFC forecast (Cosumnes R at McConnell) for 5 days, Daily DSM2 RCSM075 results after, converted to hourly	
Calaveras River	Not used	Hourly CDEC MRS, cleaned+filled	Daily DSM2 RCAL009 results, converted to hourly	
San Joaquin River at Vernalis	Not used	Hourly CDEC VNS, cleaned+filled	Hourly CNRFC forecast (SJ R at Vernalis) for 5 days, Daily DSM2 RSAN112 results after, converted to hourly	
Stage - Martinez	Not used	15min CDEC Martinez stage, cleaned+filled, and shifted -2.38 ft.	15min astronomically based DSM2 RSAC054	

**Table 2 Boundary condition development for turbidity for this forecast period.**

February 16, 2012	Definition Historical NTU	Definition Forecast NTU	Comment
<b>BC Location</b>			
Yolo Bypass	15min CDEC RYI, cleaned+filled, hourly averaged	linearly interpolated from last observed NTU to 15 NTU, then extended as constant	
Cache Slough at Ryer internal BC	15min CDEC RYI, cleaned+filled, hourly averaged	not applied	
Sacramento River at Freeport	15min CDEC FPT, cleaned+filled, hourly averaged then shifted - 15hrs to account for travel time from upstream boundary	WARMF	
Mokelumne River	15min CDEC SMR, cleaned+filled, daily averaged then converted to hourly	WARMF	
Cosumnes River	15min CDEC SMR, cleaned+filled, daily averaged then converted to hourly	WARMF	
Calaveras River	15min CDEC RRI, cleaned+filled, hourly averaged	extended as constant	
San Joaquin River at Vernalis	15min CDEC SJR, cleaned+filled, hourly averaged	extended as constant	
Mokelumne River at San Joaquin confluence internal BC	15min CDEC MOK, cleaned+filled, hourly averaged	not applied	
Old River at Quimbly Island internal BC	15min CDEC ORQ, cleaned+filled, hourly averaged	not applied	
San Joaquin at Jersey Pt internal BC	15min CDEC SJJ, cleaned+filled, hourly averaged	not applied	
Sacramento River at Mallard Island internal BC	15min CDEC MAL, cleaned+filled, hourly averaged	extended as constant	
Martinez	15min CDEC MRZ, cleaned+filled, hourly averaged	extended as constant	

**Table 3 Boundary condition development for EC for this forecast period.**

February 16, 2012	Historical DWR BC	Definition Historical EC	Definition Forecast EC	Comment
<b>BC Location</b>				
Yolo Bypass	Not used	15min CDEC RYI, cleaned+filled, hourly averaged	extend as constant	
Sacramento River at Freeport	Not used	15min CDEC FPT, cleaned+filled, hourly averaged	extend as constant	Shift back 15 hrs
Mokelumne River	Not used	15min CDEC SMR, cleaned+filled, daily averaged then converted to hourly	extend as constant	Daily-avg to remove tidal variation
Cosumnes River	Not used	15min CDEC SMR, cleaned+filled, daily averaged then converted to hourly	extend as constant	Daily-avg to remove tidal variation
Calaveras River	Not used	15min CDEC RRI, cleaned+filled, hourly averaged	extend as constant	Tidal variation not removed
San Joaquin River at Vernalis	Not used	15min CDEC SJR, cleaned+filled, hourly averaged	extend as constant	
Martinez	Not used	15min CDEC MRZ, cleaned+filled, hourly averaged	DWR forecast (quality.dss)	

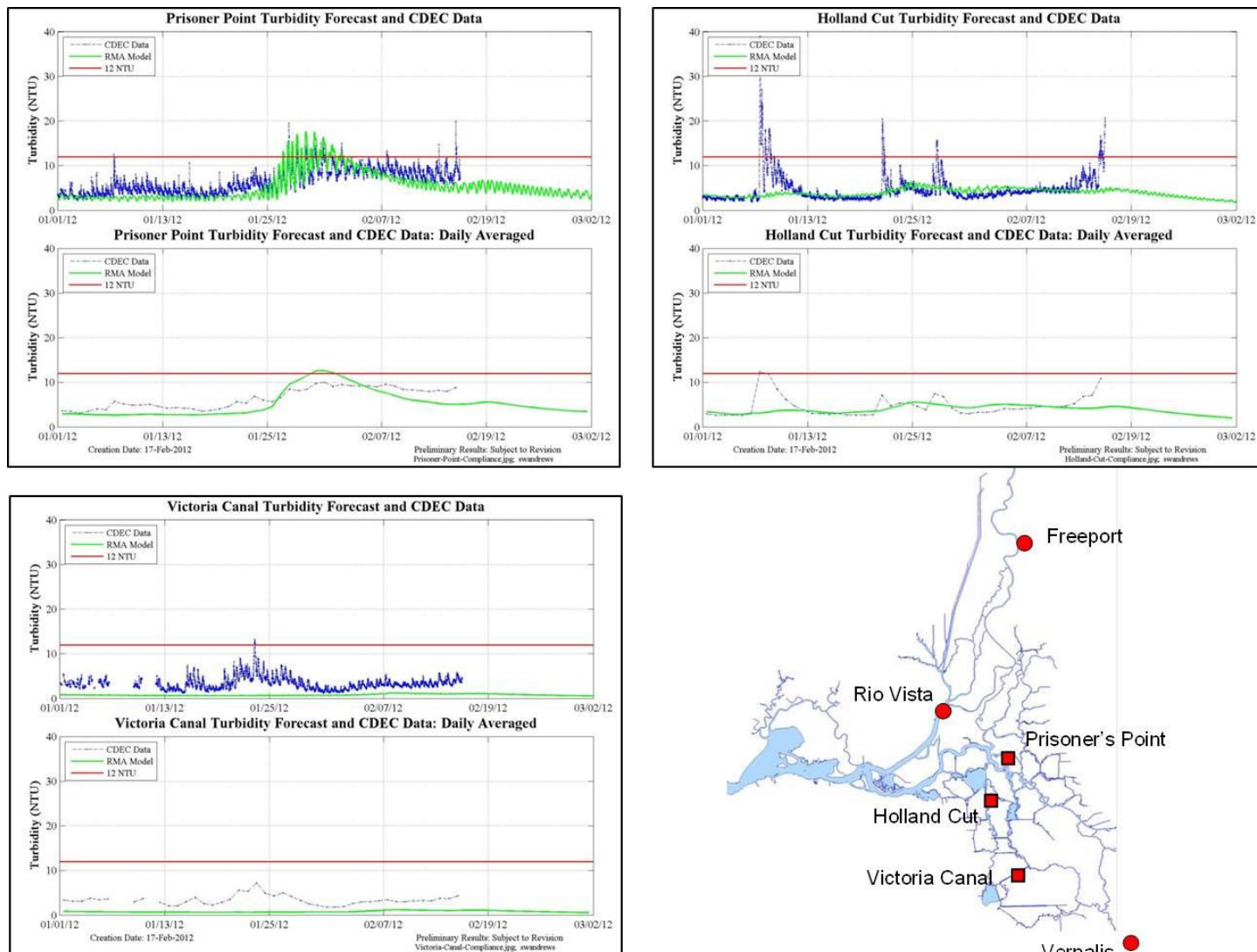
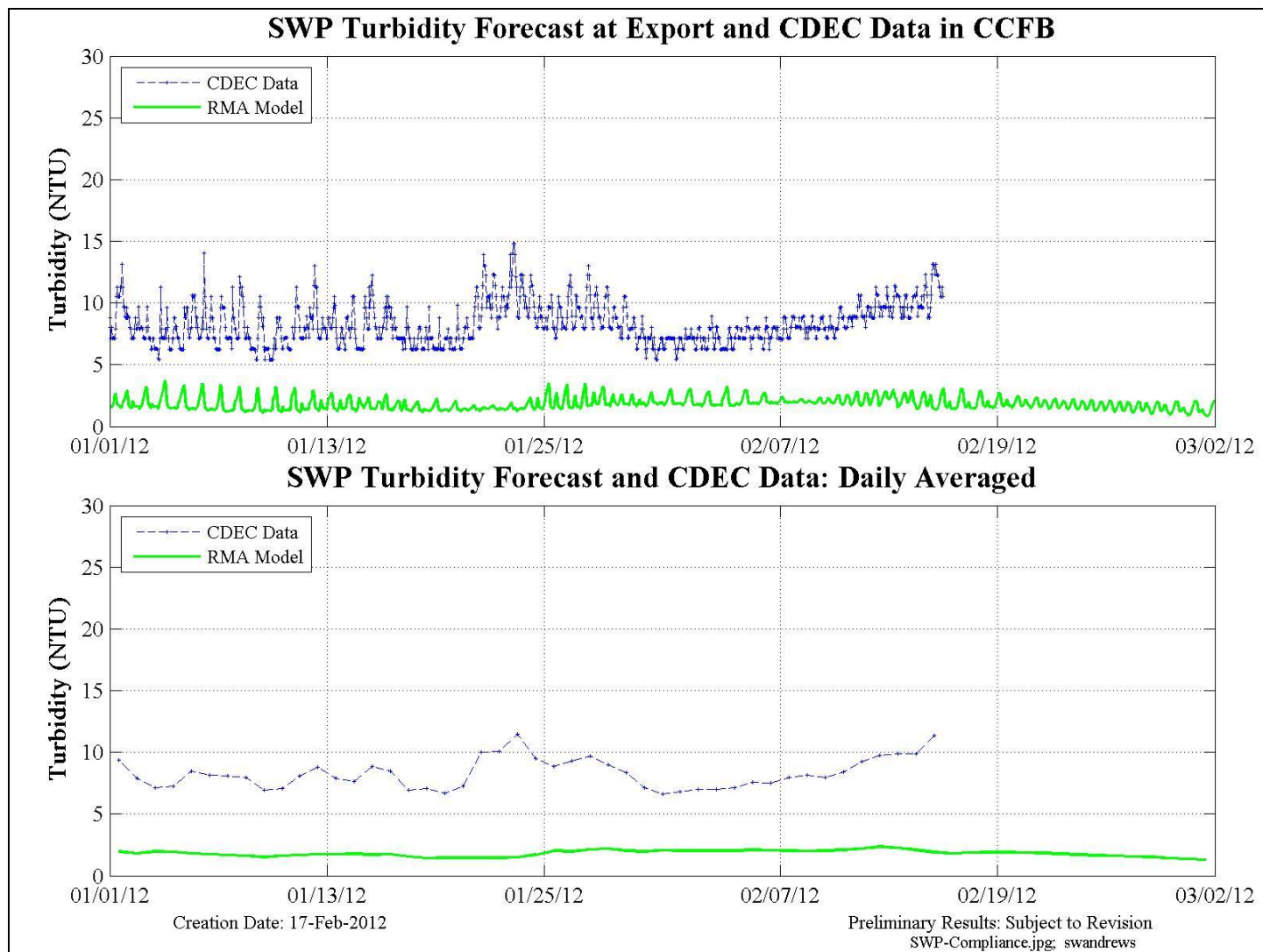
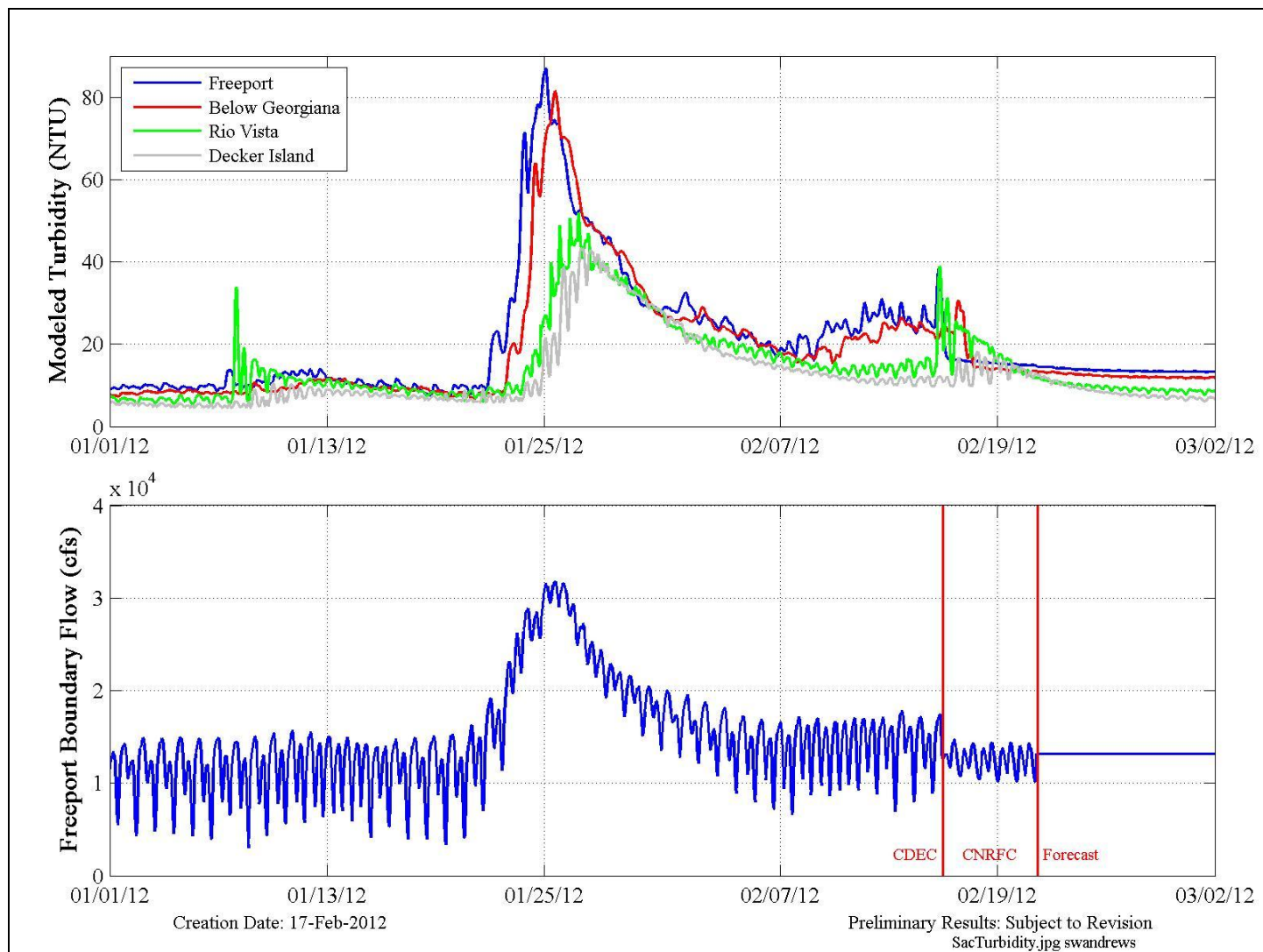


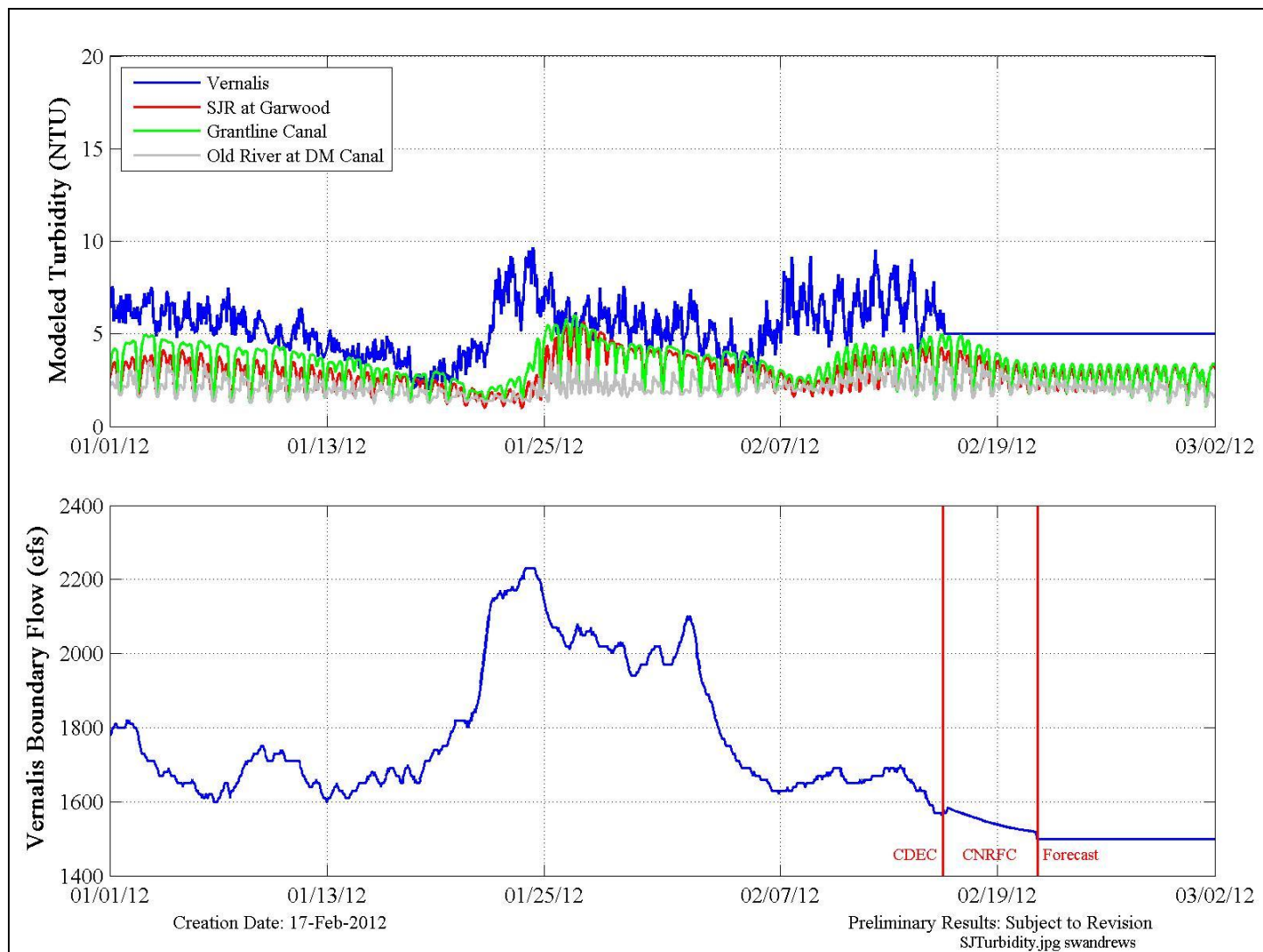
Figure 14 Modeled turbidity and data (cleaned and filled) at the three compliance locations. Both 15-min model output and data and daily averaged plots are shown. Red line illustrates the 12-NTU compliance value.



**Figure 15** Plots compare model output near the SWP export location (outside of Clifton Court Forebay) with CDEC data gathered inside Clifton Court Forebay. Note that large differences in flow conditions inside and outside of the forebay may hinder direct comparisons of the data. Both 15-min model output and daily averaged plots are shown.

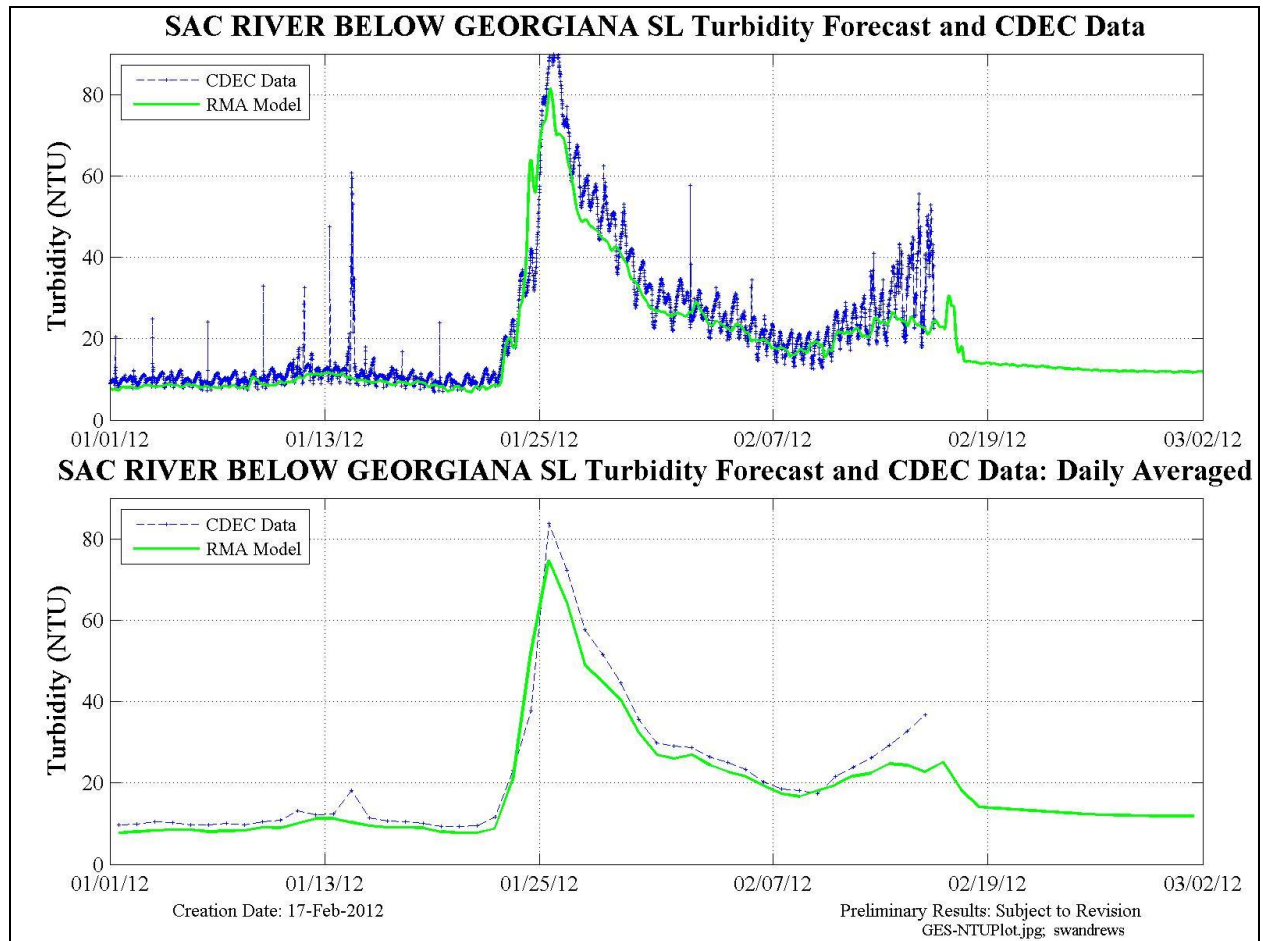


**Figure 16 Freeport turbidity boundary condition progression down the Sacramento R. (upper plot) along with the flow boundary (lower plot) used during the historical and forecast periods. Forecast began on February 16, 2012.**



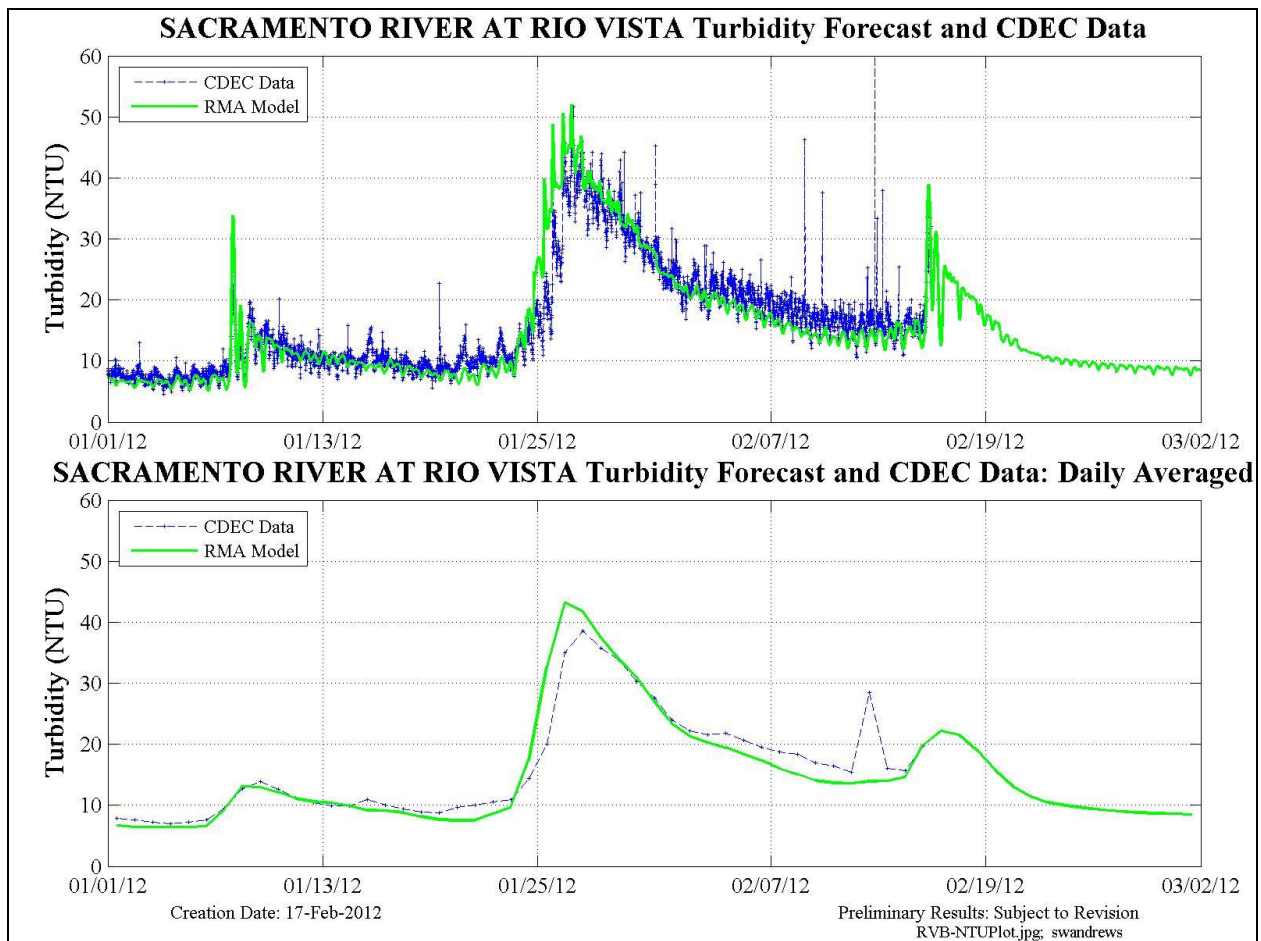
**Figure 17 Vernalis turbidity boundary condition progression down the San Joaquin R. and Old River to Grantline Canal (upper plot) along with the flow boundary (lower plot) used during the historical and forecast periods. Forecast began on February 16, 2012.**



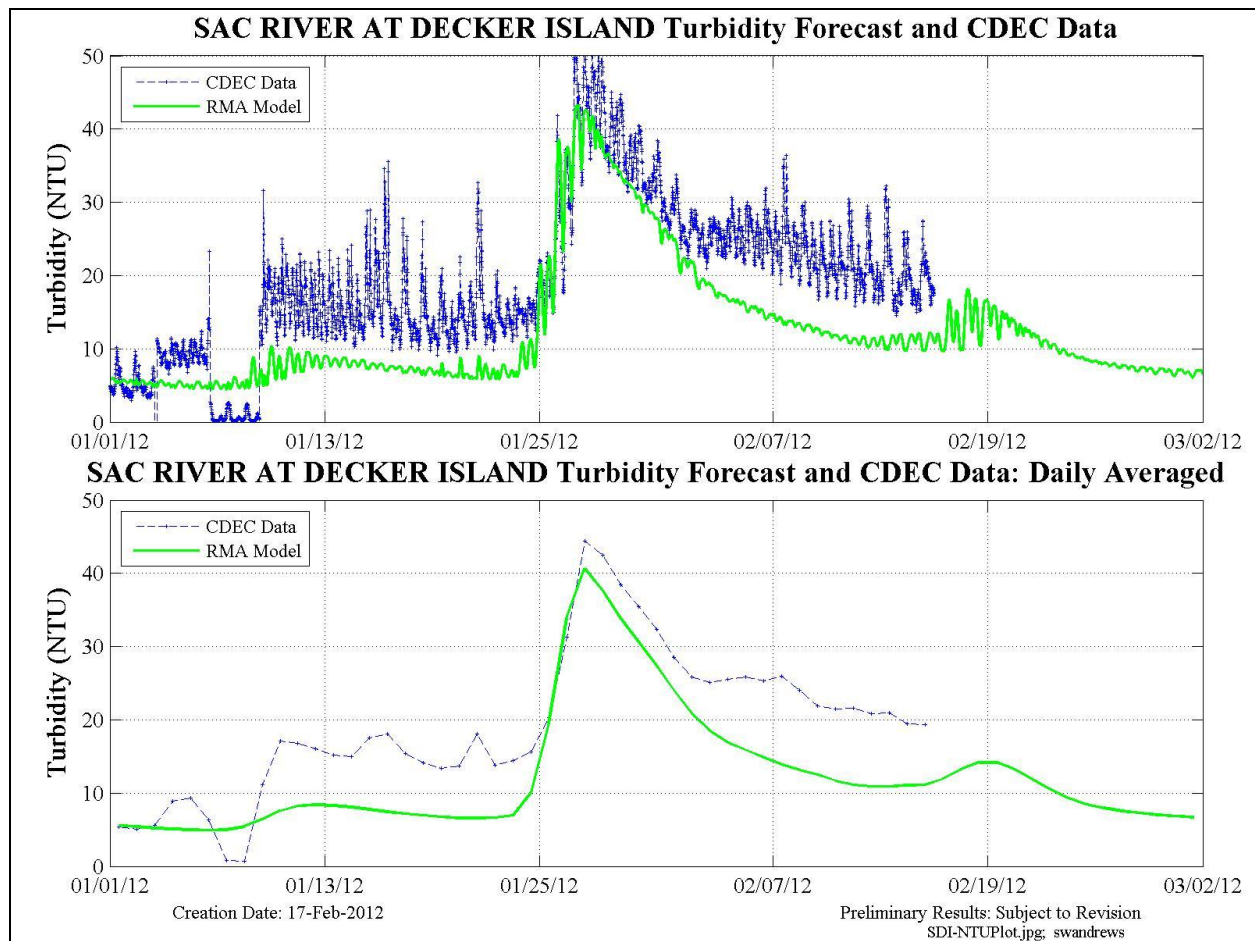


**Figure 18 Model forecast and raw CDEC data at Sac. River Below Georgiana Sl. Both 15-min (upper) and daily averaged (lower) plots are shown.**

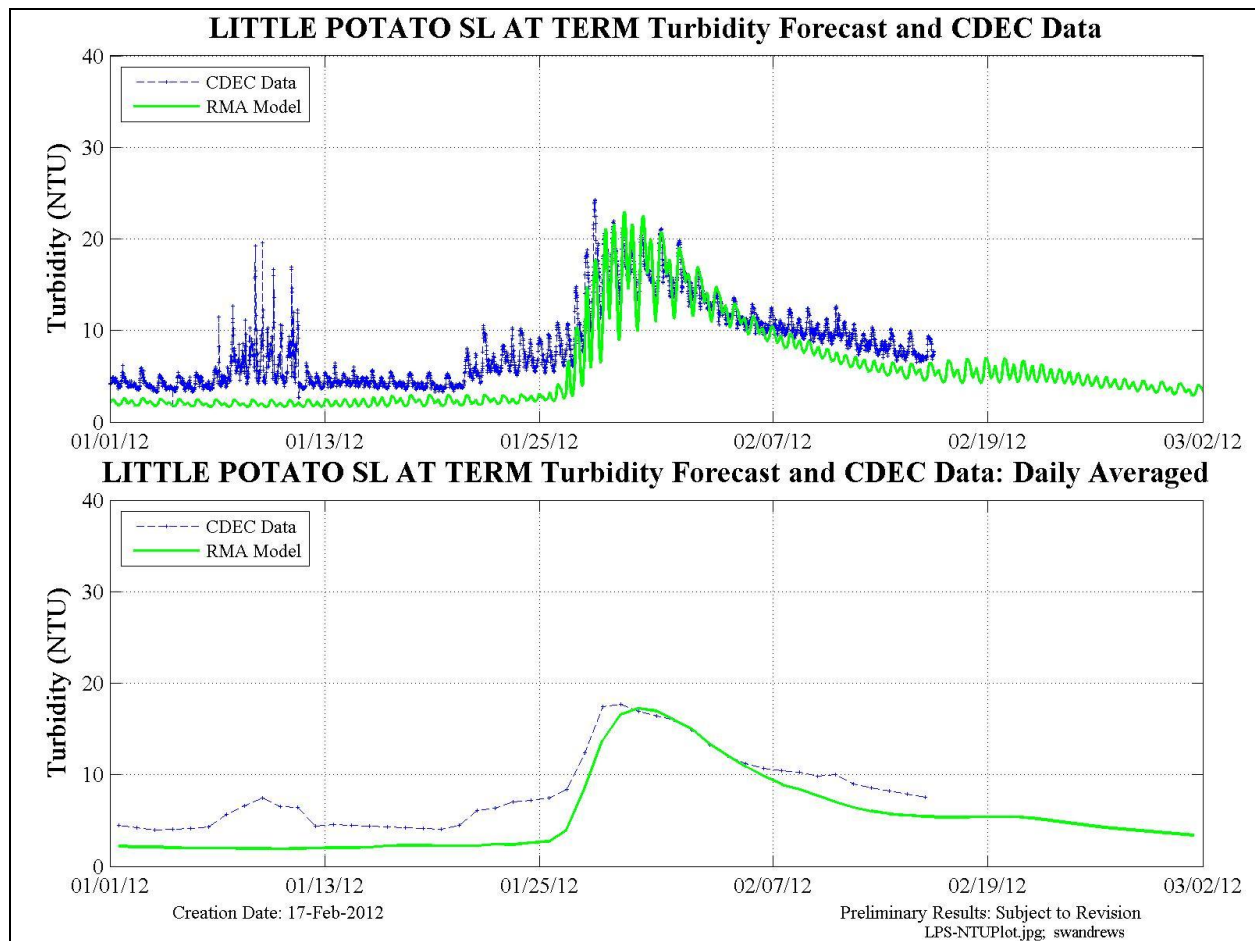




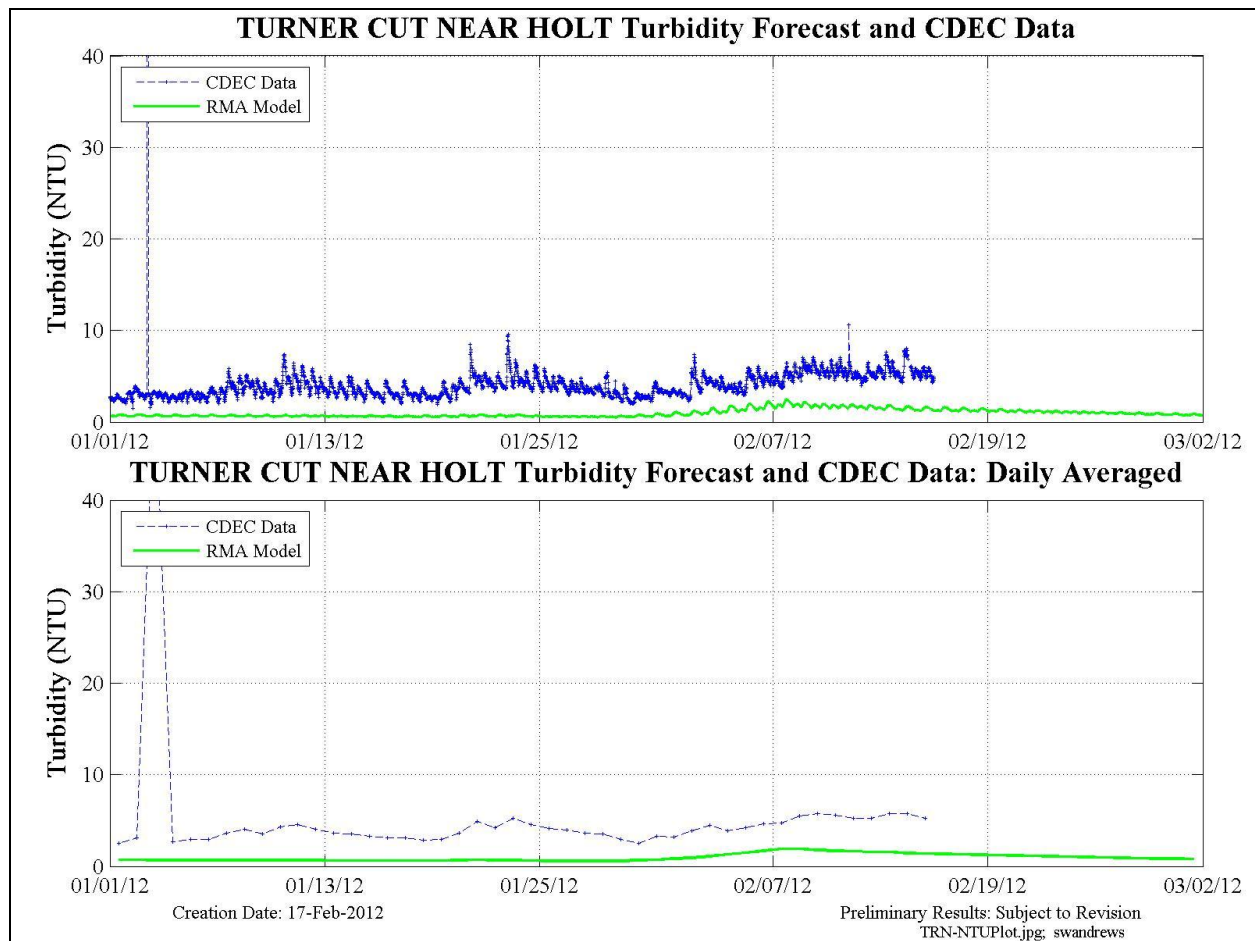
**Figure 19 Model forecast and raw CDEC data at Rio Vista. Both 15-min (upper) and daily averaged (lower) plots are shown.**



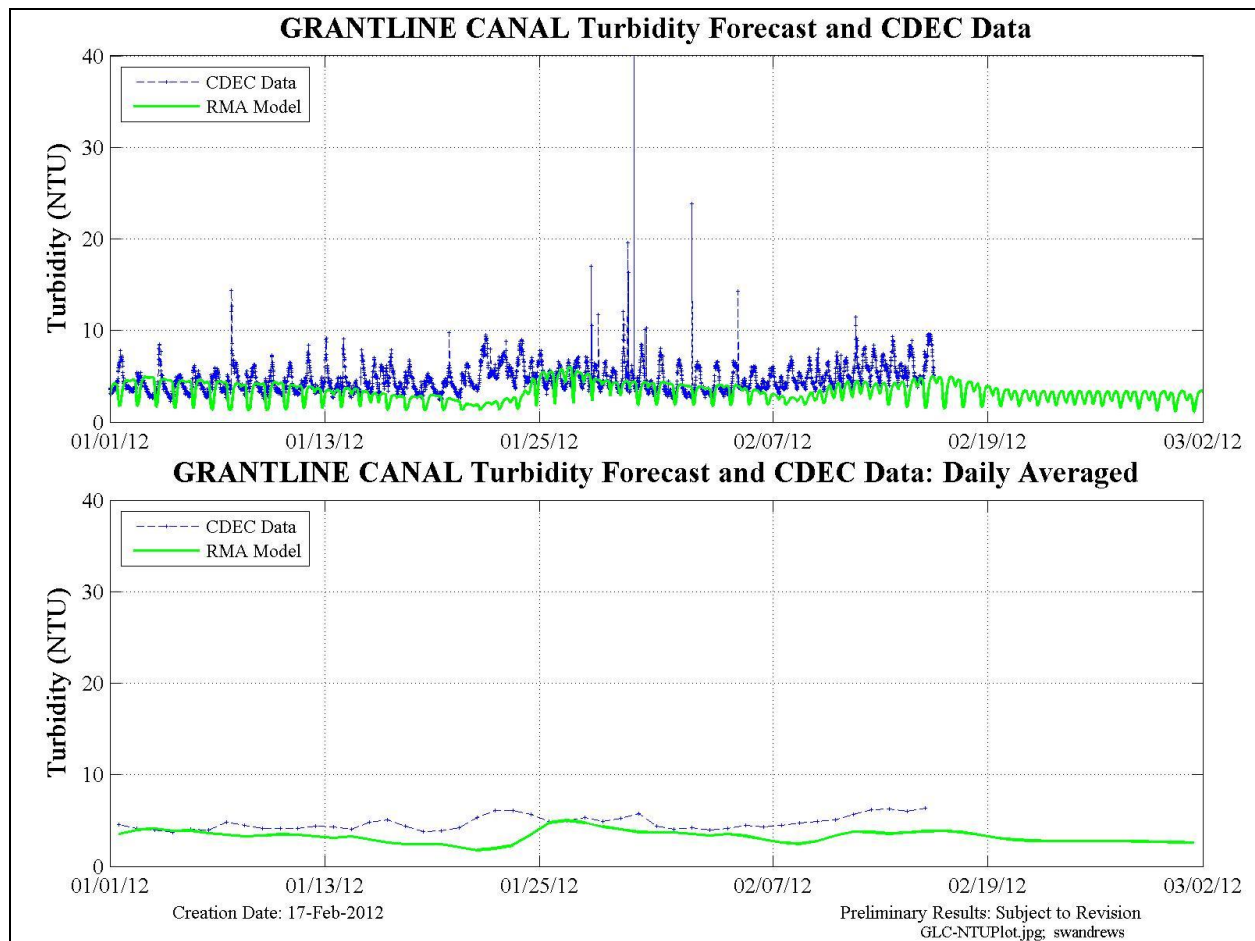
**Figure 20 Model forecast and raw CDEC data at Decker Island. Both 15-min (upper) and daily averaged (lower) plots are shown.**



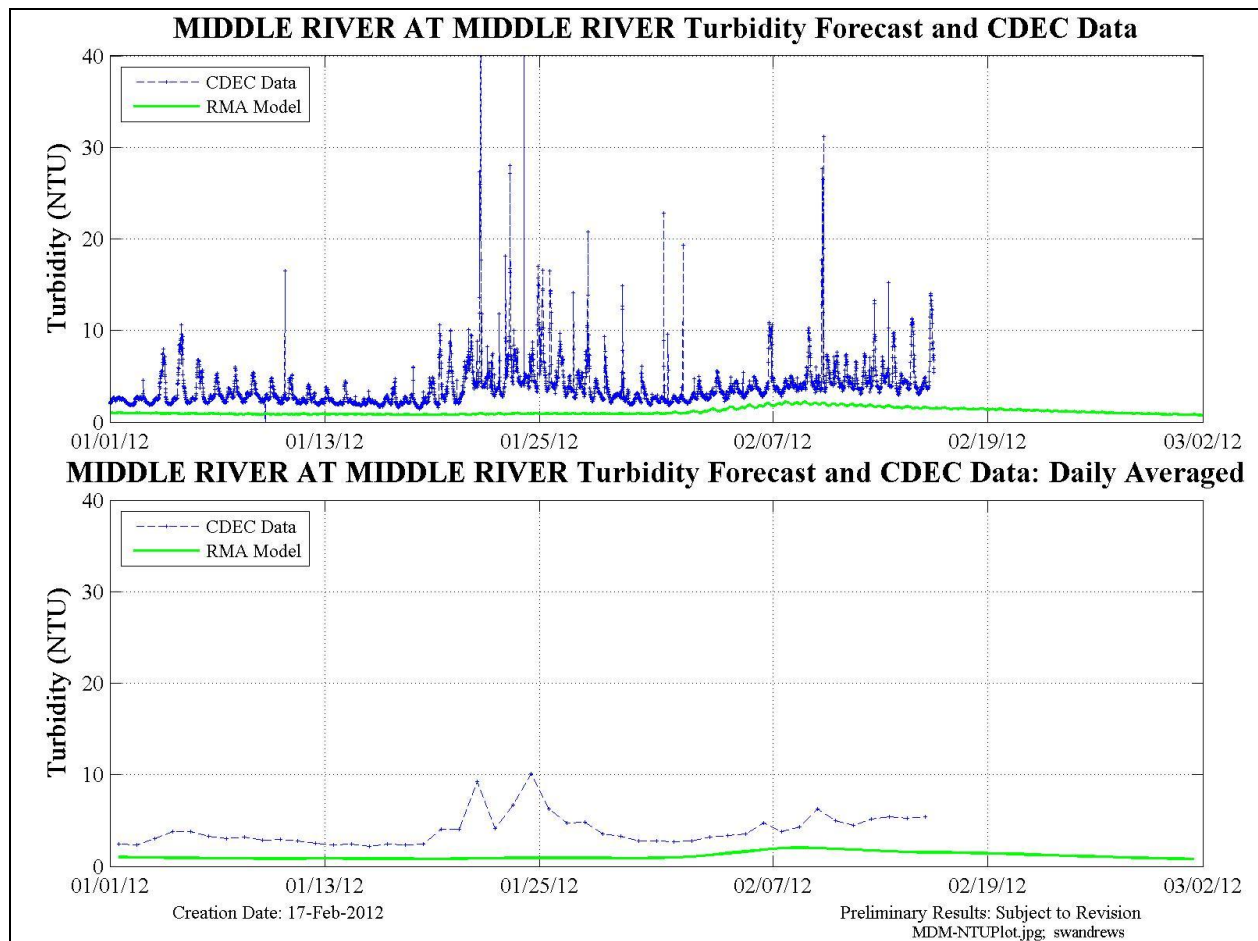
**Figure 21 Model forecast and raw CDEC data at Little Potato Slough at Terminous. Both 15-min (upper) and daily averaged (lower) plots are shown.**



**Figure 22 Model forecast and raw CDEC data at Turner Cut near Holt. Both 15-min (upper) and daily averaged (lower) plots are shown.**

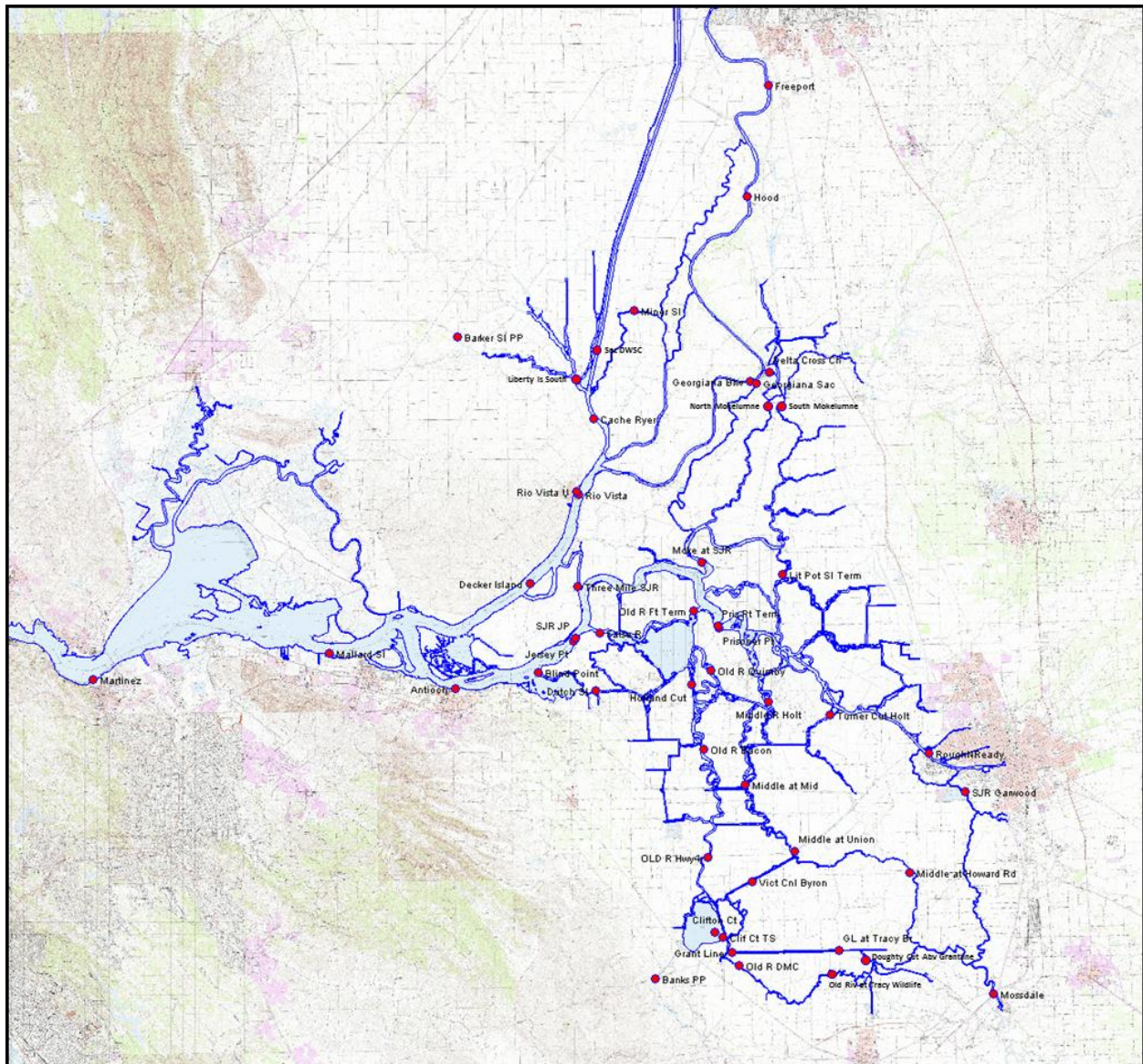


**Figure 23 Model forecast and raw CDEC data at Grant Line. Both 15-min (upper) and daily averaged (lower) plots are shown.**

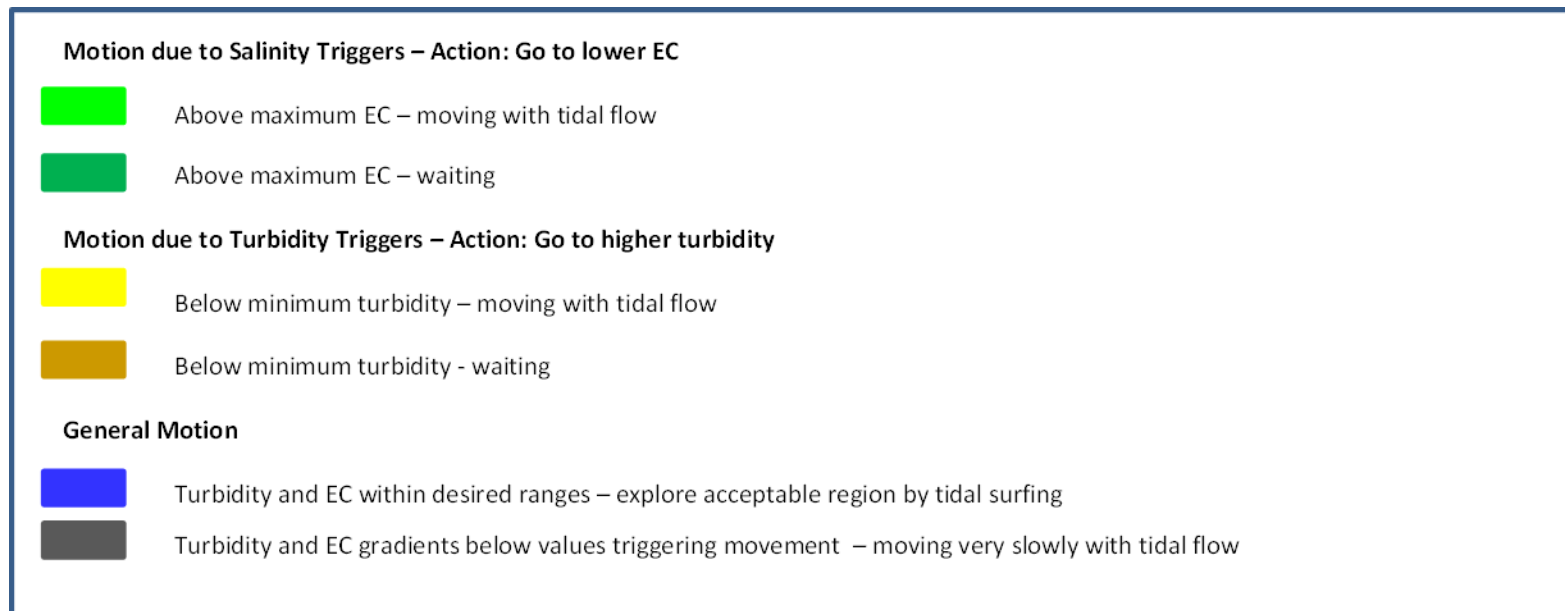


**Figure 24 Model forecast and raw CDEC data at Middle R. at Middle R. Both 15-min (upper) and daily averaged (lower) plots are shown.**





**Figure 25 Figure illustrating model output and data collection locations.**



**Figure 26** Particles in the Adult Delta Smelt particle tracking model are color-coded by the triggers influencing their behavior during the simulation. Use this figure to interpret the simplified color scale in the next three figures.



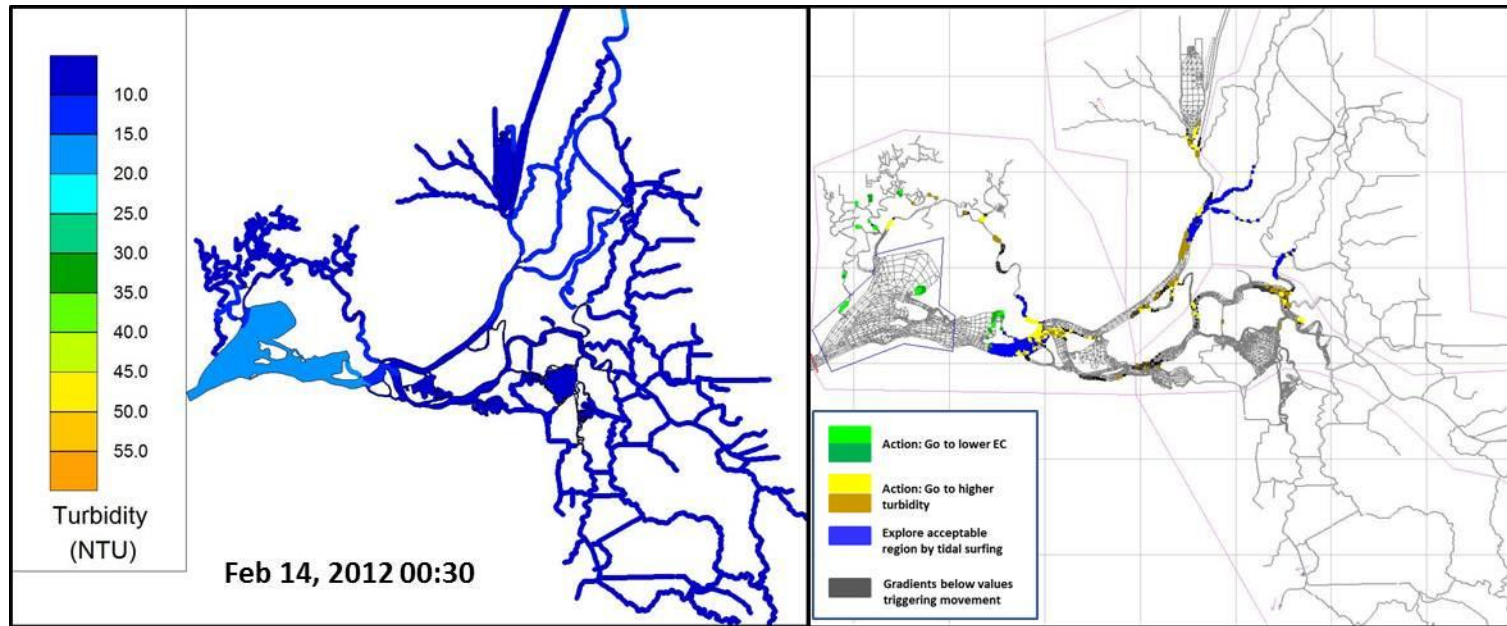


Figure 27 Turbidity contours and particle location in the RMA model grid on Feb. 14, 2012.

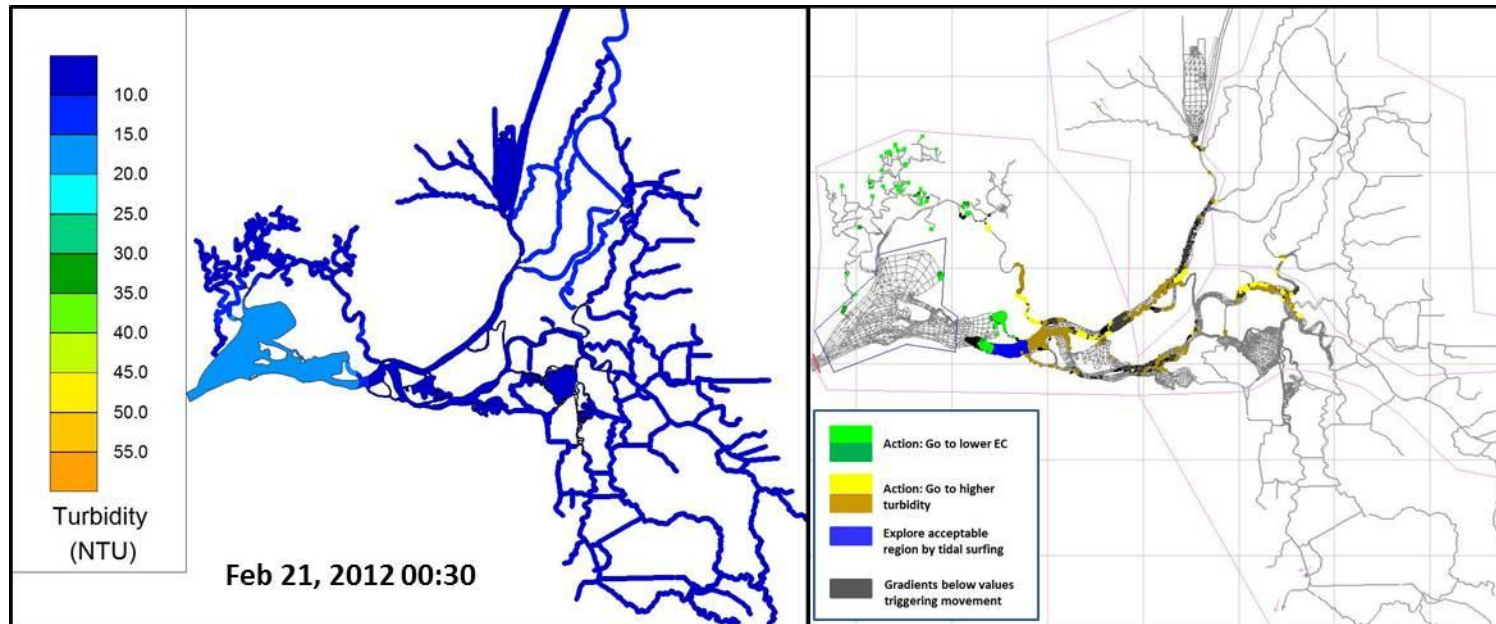


Figure 28 Turbidity contours and particle location in the RMA model grid on Feb. 21, 2012.

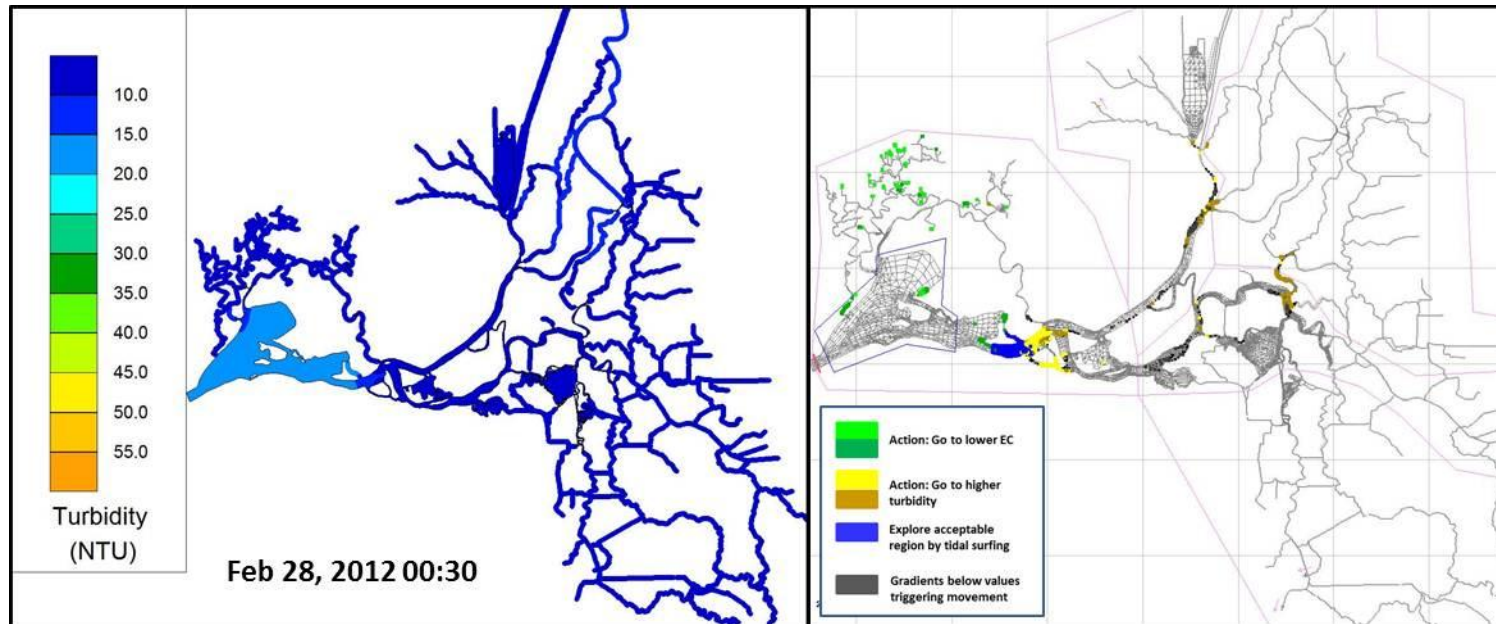


Figure 29 Turbidity contours and particle location in the RMA model grid on Feb. 28, 2012.

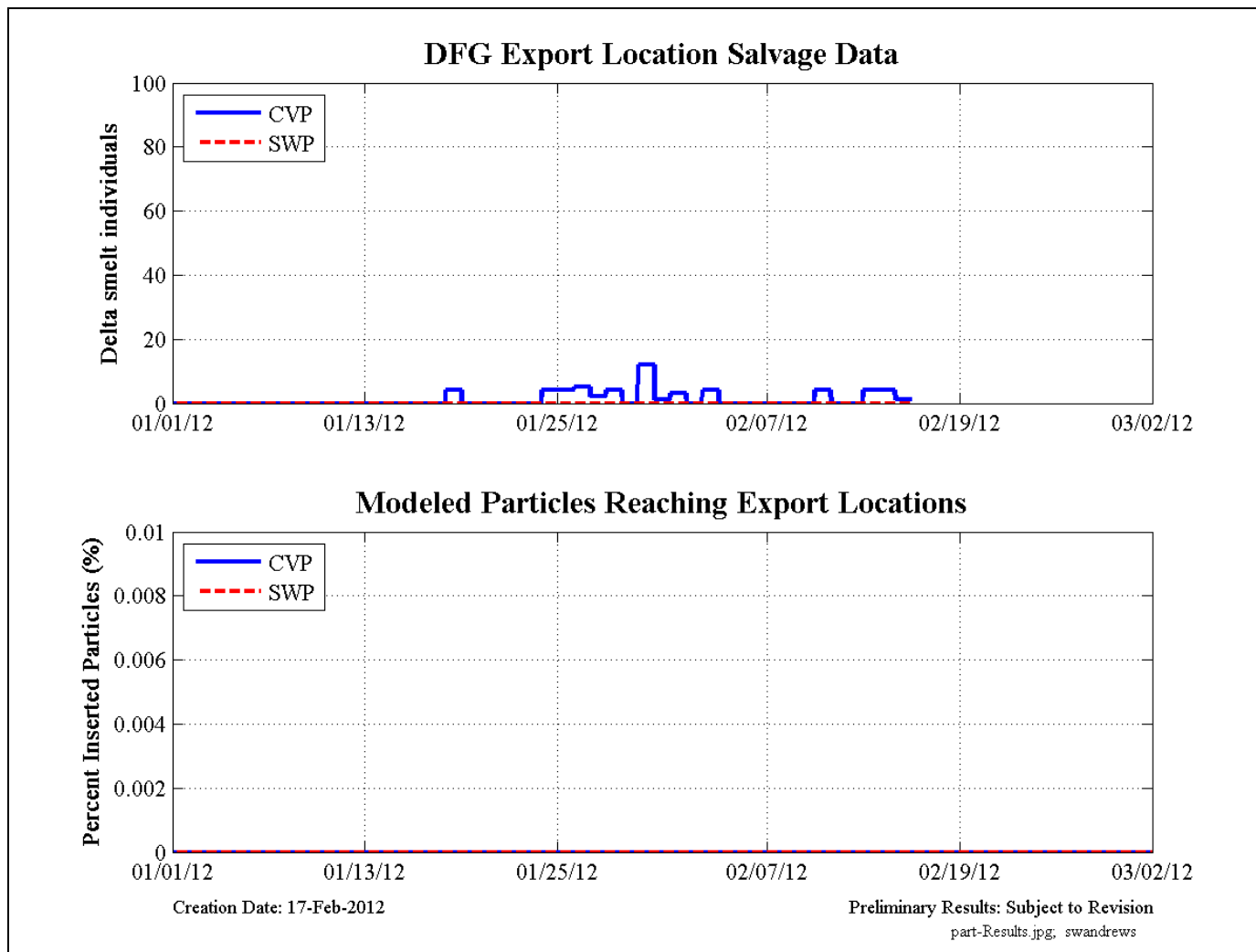


Figure 30 Comparison of DFG export location delta smelt salvage data (top) and RMA adult delta smelt particle tracking behavioral model results (bottom).