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RMA Turbidity and Adult Delta Smelt Behavioral Model Covering the Forecast Period Dec. 29, 2011 to January 17, 2012

Date:	January 2, 2012
To:	Chuching Wang, Senior Engineer, Metropolitan Water District Paul Hutton, Senior Engineer, Metropolitan Water District
From:	Richard Rachiele, Principal Steve Andrews, Water Resources Engineer
Subject:	Results of Recent Forecasting Work

Summary Assessment

PERIOD: The Delta turbidity and adult delta smelt forecast was produced this week, covering the period December 29, 2011 to January 17, 2012.

PRE_FORECAST SUMMARY: Leading up to the forecast, Delta inflows and turbidity have been low due to dry conditions.

TURBIDITY 3-STATIONS PERFORMANCE & SUMMARY EVALUATION: Turbidity was low throughout the Delta, ranging from about 5 - 25 NTU in the raw data. Turbidity was below compliance values (12 NTU) at two of these three locations. At Holland Cut, the turbidity went above the compliance value for several days in early December and December 22-23, almost certainly due to wind events. The forecast does not anticipate any storms or significant turbidity events.

SMELT MOVEMENT SUMMARY: As a result, the forecast does not anticipate smelt movement into the south Delta.

Background

This document provides a summary of the third forecast for WY2012 prepared by RMA on December 29, 2011. 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.

Because the funding for this project was delayed for several weeks past the initially agreed-upon start date, there was insufficient time to develop all of the preparatory materials needed for the model forecast simulations. For this reason, the salinity forecast is not presented.

Boundary Condition Development and Simulation Timing

Model BCs (Boundary Conditions) for the forecast model were prepared using several sources for historical and forecast conditions including: CNRFC flow data and predictions, CDEC and USGS data, and DWR-supplied model inputs and results from their flow and salinity forecasts.

BC for this forecast period were prepared using these data sources, and using professional judgment where necessary to resolve data discrepancies and to piece the data together for reasonable BC.

The RMA modeled period was November 01, 2011 to January 17, 2012 for flow, salinity and turbidity. DWR Operations and Maintenance (O&M) group provided RMA with BC they used in the DSM2 HYDRO and QUAL/salinity models for a combined historical and forecast period December 16, 2011 through January 17, 2012 – the three week DWR forecast period was December 27 through January 17, 2012. Additional flow, turbidity and EC data was downloaded for the period December 28 – 29, 2011 from the CDEC, CNRFC and USGS websites to fill-in 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. Due to low turbidity at the model boundaries, forecast turbidity was modeled as a constant.

Examination of the CDEC and USGS flow time series for the San Joaquin River at Vernalis showed a shift in the flow rating on December 13, 2011 of about +240 cfs. The new flow time series was used for the Vernalis flow bc for the November 01, 2011 to December 29, 2011 "historical" period. The downloaded CNRFC "observed" and "forecast" flows incorporate the shift in the flow rating.

As with the previous forecast, two "internal" turbidity boundary conditions were applied in the turbidity modeling. The two internal turbidity boundaries were located on the Sacramento River at Mallard Island and Cache Slough at Ryer Island (Figure 1).

WARMF Model

The WARMF model forecast output was delivered to RMA December 29. The WARMF output boundary conditions included flow, turbidity and EC for the period November 1, 2011 through January 18, 2012. A separate set of turbidity, EC and particle tracking simulations were performed using the WARMF turbidity and EC boundary conditions. These simulations maintained the previous set of flow boundary conditions listed in Table 1. The WARMF turbidity run included the "internal" boundary condition for the Sacramento River at Mallard Island. The internal boundary condition for the Cache-Ryer location was not applied for the WARMF turbidity run as this would override the WARMF derived Yolo boundary condition.

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. 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. Forecast reservoir releases are acquired from the California Data Exchange Center and entered into the WARMF time series database. 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 this period as there have been no recent rain events, and turbidity measurements indicate suspended sediment loading from the watersheds is very low. Depending on time and location within the Delta, measured turbidity was instead partly due to resuspension of sediments due to tidal action and/or wind events. Turbidity was low throughout the Delta, ranging from about 5 - 25 NTU in the raw data. Turbidity data was noisy at many locations, which was particularly evident as turbidity values were so low.

These types of conditions - 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 8, while Figure 9 through Figure 12 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 9 illustrates that daily-averaged exports decreased from a maximum of ~13,000 cfs in early November to ~ 2,000 cfs by the end of November, then increased to ~10,500 cfs starting in early December to December 22. Total exports varied 6,000 to 8,000 cfs December 23 to 30, 2011, then remained about 6,000 thereafter. On December 31, CVP pumping was reduced to 2,500 cfs, then to 1,900 cfs January 1, 2012 for the remaining forecast period. Banks pumping was set to 4,000 cfs beginning December 30, 2012 to the end of the forecast period. Figure 10 and Figure 11 are plots of Old River and Middle River flows and daily-averaged flows, respectively, while Figure 12 illustrates the combined Old+Middle River flow criterion (3-day center-weighted average) compared with CDEC data.

Figure 13 is a comparison of model output and data at the three compliance locations, and Figure 14 is a similar plot in the SWP export area. Note that Figure 14 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 two of these three locations. At Holland Cut, the turbidity went above the compliance value for several days in early December and December 22-23, almost certainly due to wind events (see first WY2012 forecast report).

Figure 15 and Figure 16 illustrate the progression of the main turbidity boundary conditions at Freeport and Vernalis down the Sacramento and San Joaquin Rivers, respectively. Figure 17 through Figure 23 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 24. The turbidity model captured the very low measured turbidity in the south and central Delta (see, for example Figure 22 and Figure 23).

A separate turbidity model run was performed using the WARMF turbidity boundary conditions. The WARMF turbidity boundary conditions are shown plotted with the CDEC data derived boundary conditions in used in the above results in Figure 25 to Figure 30. Model turbidity results for the compliance locations and the SWP export area are shown in Figure 31 and Figure 32 respectively. Figure 33 through Figure 39 present model turbidity at the six Delta locations for the WARMF turbidity boundary condition run. WARMF Turbidities values were somewhat high relative to observed for the San Joaquin at Vernalis, Calaveras and Yolo Bypass boundary locations. As a likely consequence of the high Vernalis turbidity, the computed turbidity at the Grantline Canal location is high (Figure 38).

Adult Delta Smelt Particle Tracking Model Results

Figure 40 through Figure 44 present the turbidity contour plots and particle tracking model results for the runs using the data derived turbidity and EC boundary conditions listed Table 2 and Table 3 . The Delta Smelt behavioral model was run November 01, 2011 to January 17, 2012 - 50,000 particles were inserted on November 01. Figure 41 through Figure 44 show contour plots of RMA-modeled turbidity (left plot) with particle tracking model results (right plot). These plots illustrate that just prior to and during the forecast period, modeled turbidity in the Delta was very low. The delta smelt behavioral model results illustrate that the distribution of the particles is centered along the Sacramento River and the region at the confluence with the San Joaquin River. A few particles stray into the central Delta after Jan 01. However, no particles reached the export locations by the end of the simulation.

A similar set of turbidity contour plots and particle tracking are shown in Figure 45 through Figure 48 for the model runs using the WARMF turbidity and EC boundary conditions.

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
CCFB ~ Clifton Court Forebay
CNRFC ~ California-Nevada River Forecasting Center
CDEC ~ California Data Exchange Center
CIMIS ~ California Irrigation Management System

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

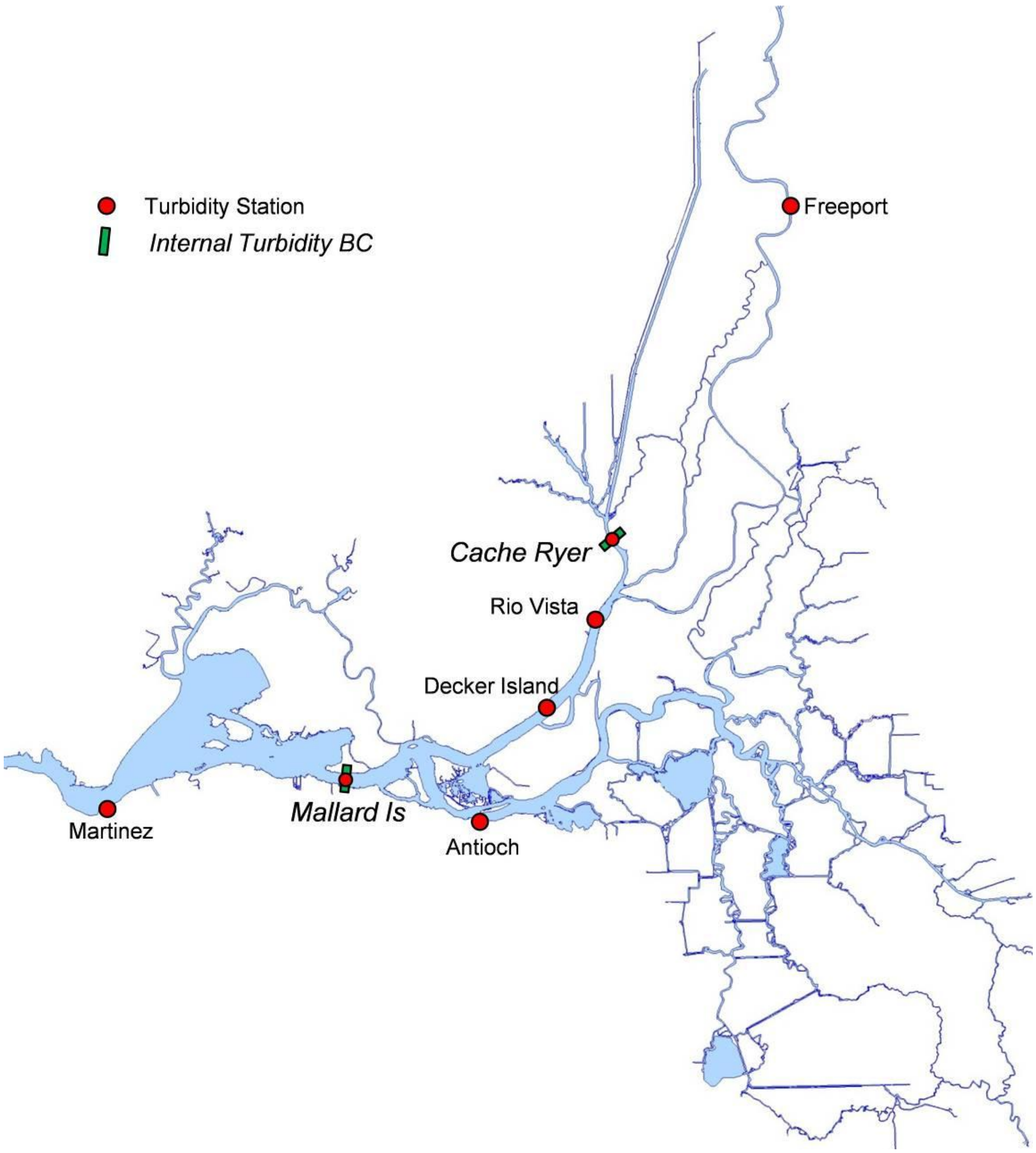

Figure 1 Locations of the internal turbidity boundary conditions added in the current turbidity forecast model run. The internal boundary conditions are located at the Sacramento River at Mallard Island and Cache Slough at Ryer Island.

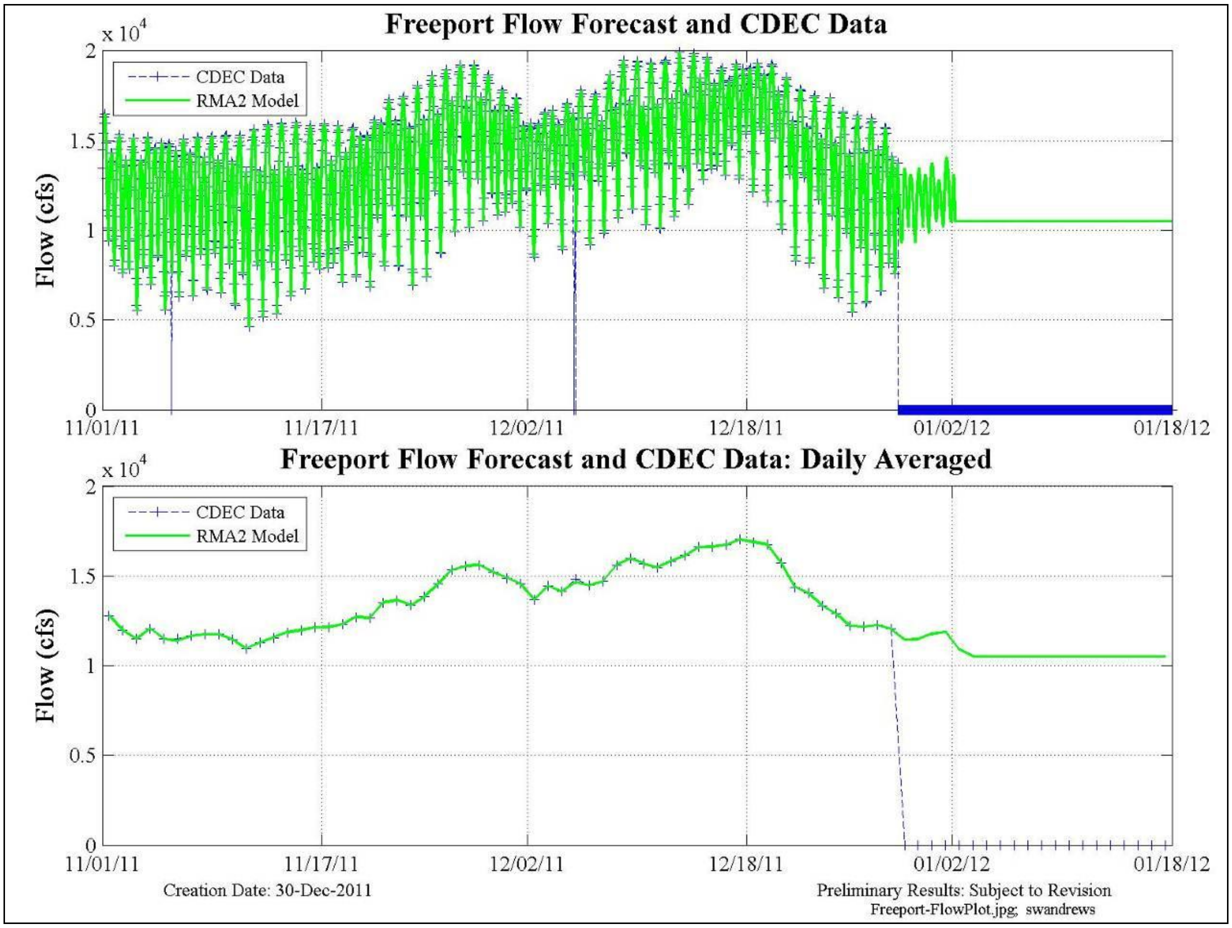

Figure 2 Freeport flow BC was compiled using CDEC data, CNRFC forecast and then extended as a constant. Note y-axis unit is cfs*10,000. Zero values indicate the end of data (blue).

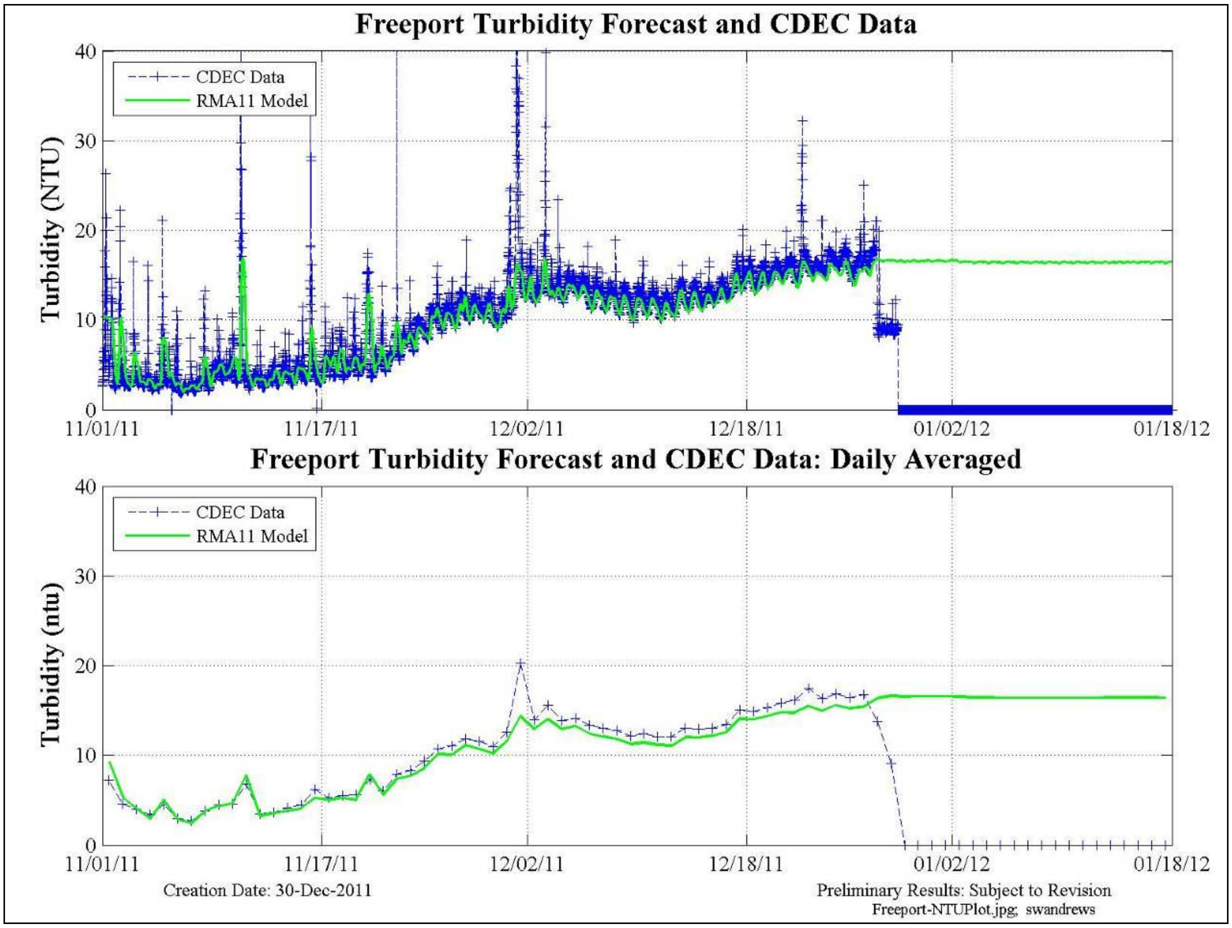

Figure 3 Freeport turbidity BC was compiled using CDEC data, and then extended as a constant. Zero values indicate the end of data (blue).

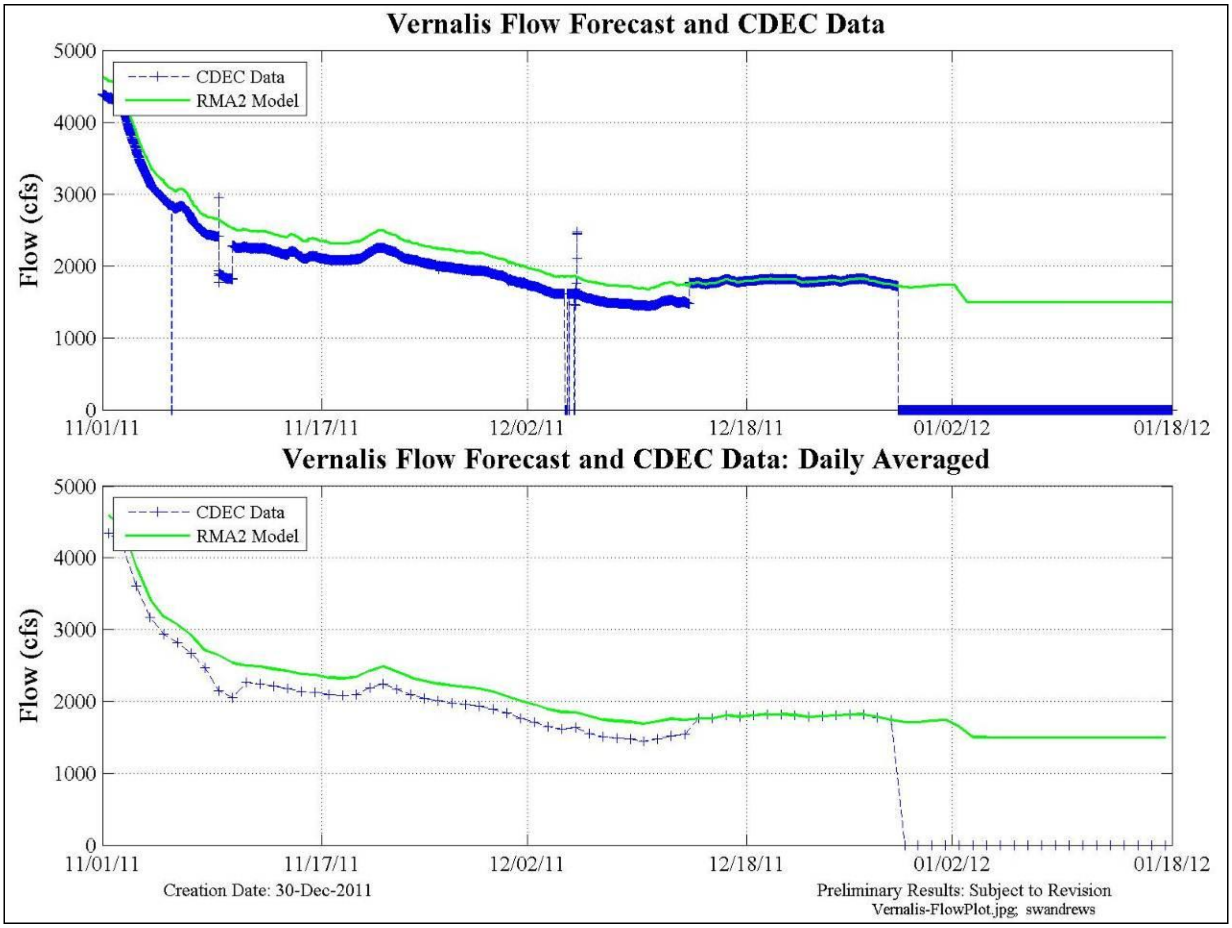

Figure 4 Vernalis flow BC was compiled using CDEC and USGS data and DWR forecast flow. Zero values indicate the end of data (blue). The USGS rating for Vernalis changed Dec. 13, 2011 and is reflected in the RMA2 model flow. The flow was not shifted in the CDEC database prior to Dec. 13, 2011.

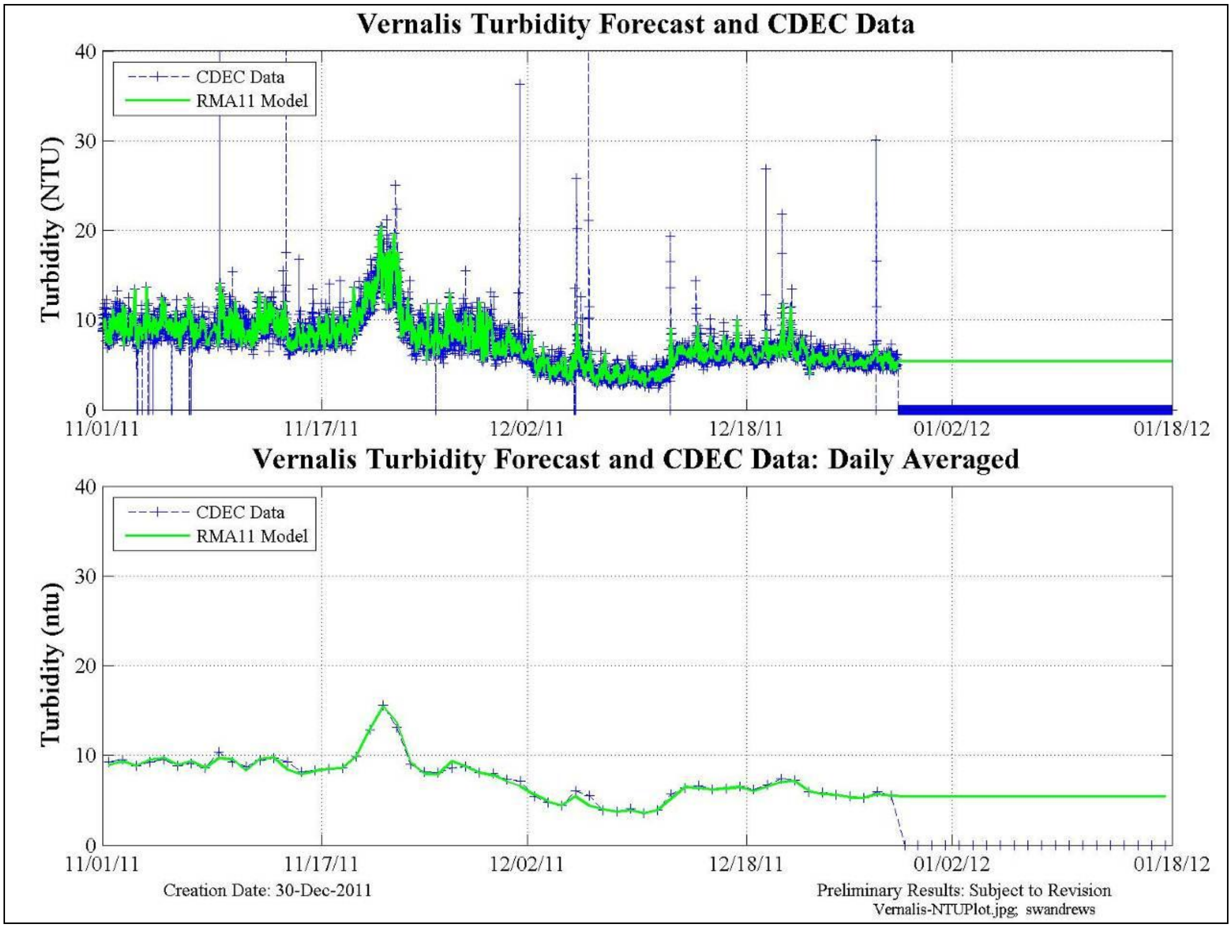

Figure 5 Vernalis turbidity BC was compiled using CDEC data, then extended as a constant. Zero values indicate the end of data (blue).

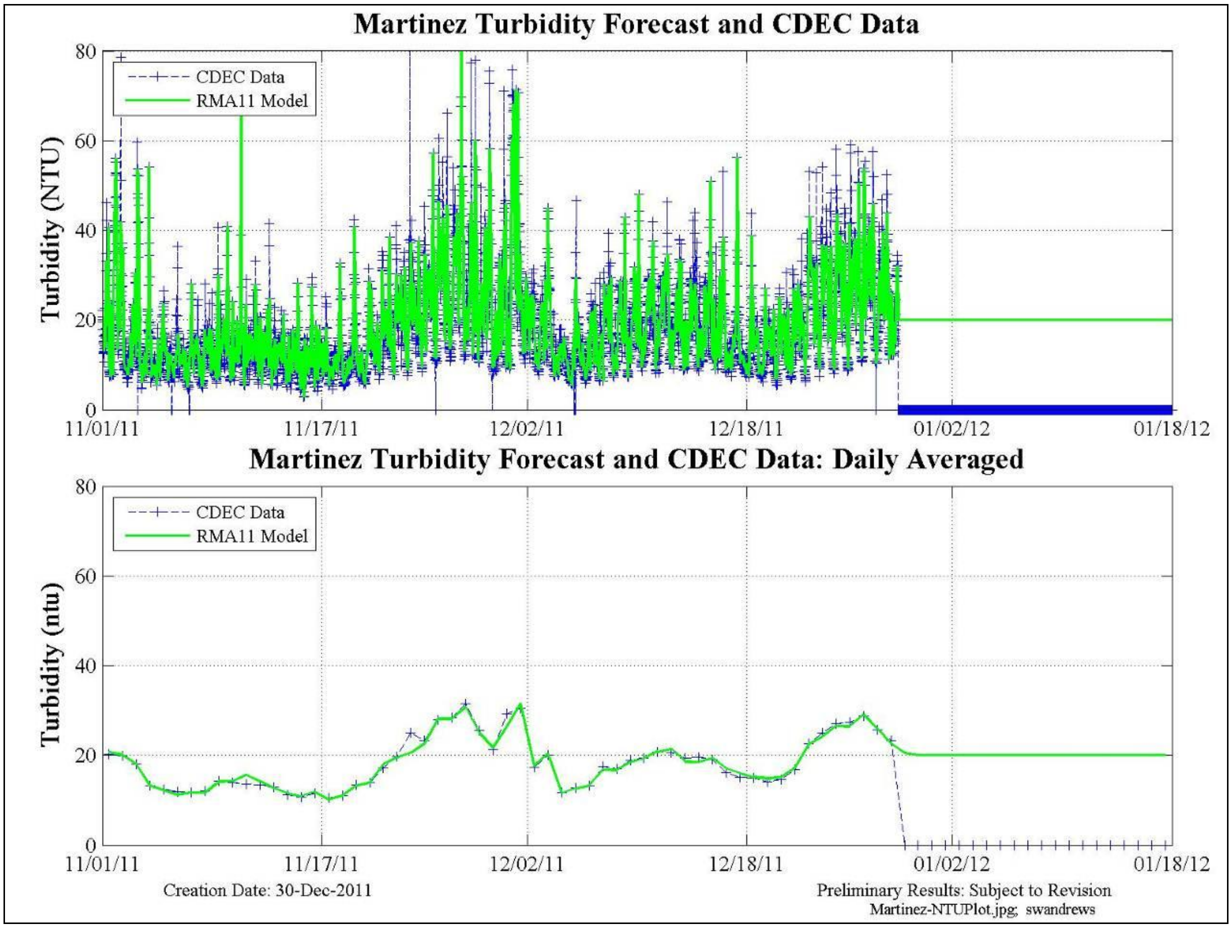

Figure 6 Martinez turbidity BC was compiled from CDEC data then extended linearly to a value of 20 NTU. Zero values indicate the end of data (blue).

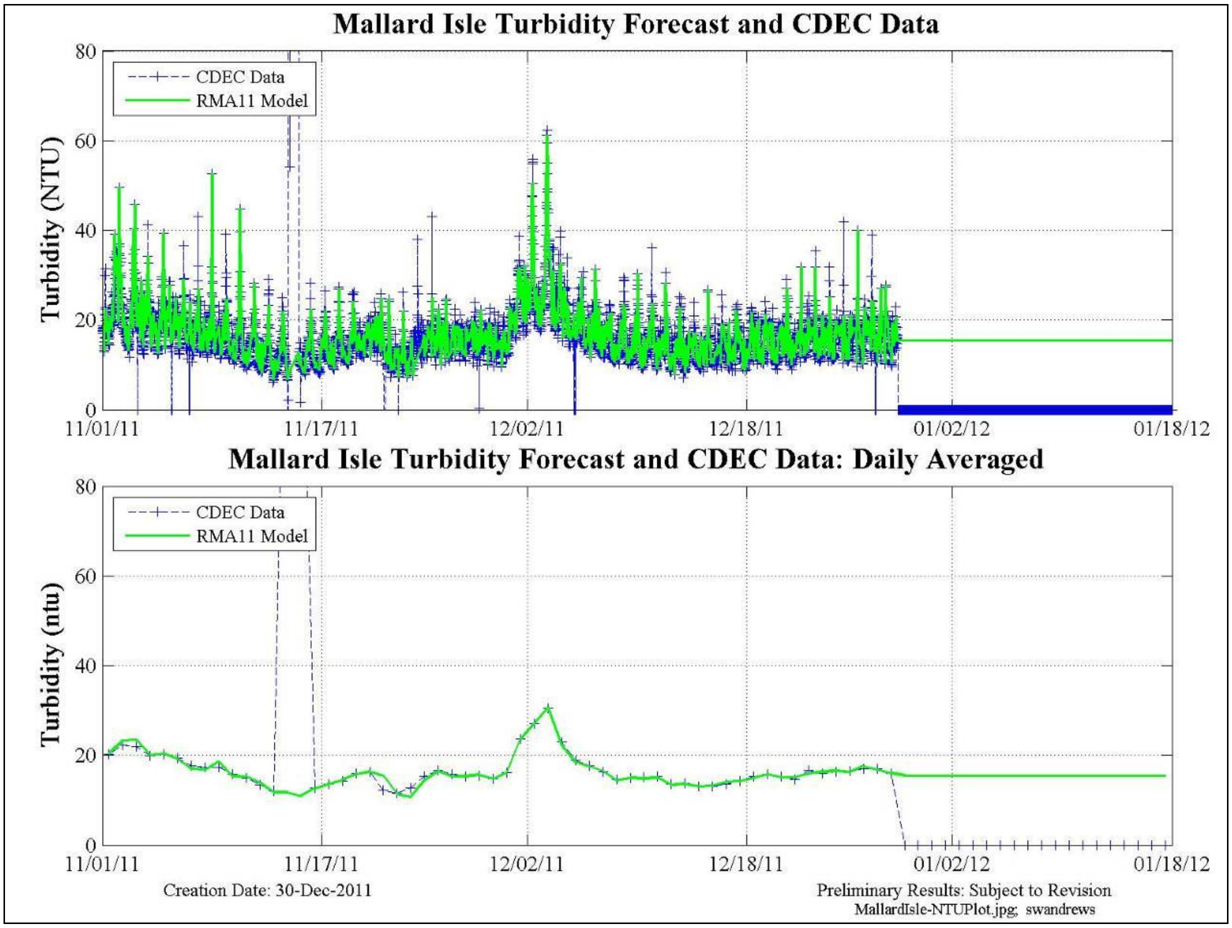

Figure 7 The Sacramento River at Mallard Island internal turbidity BC compiled from CDEC data then extended linearly to a value of 15.5 NTU. Zero values indicate the end of data (blue).

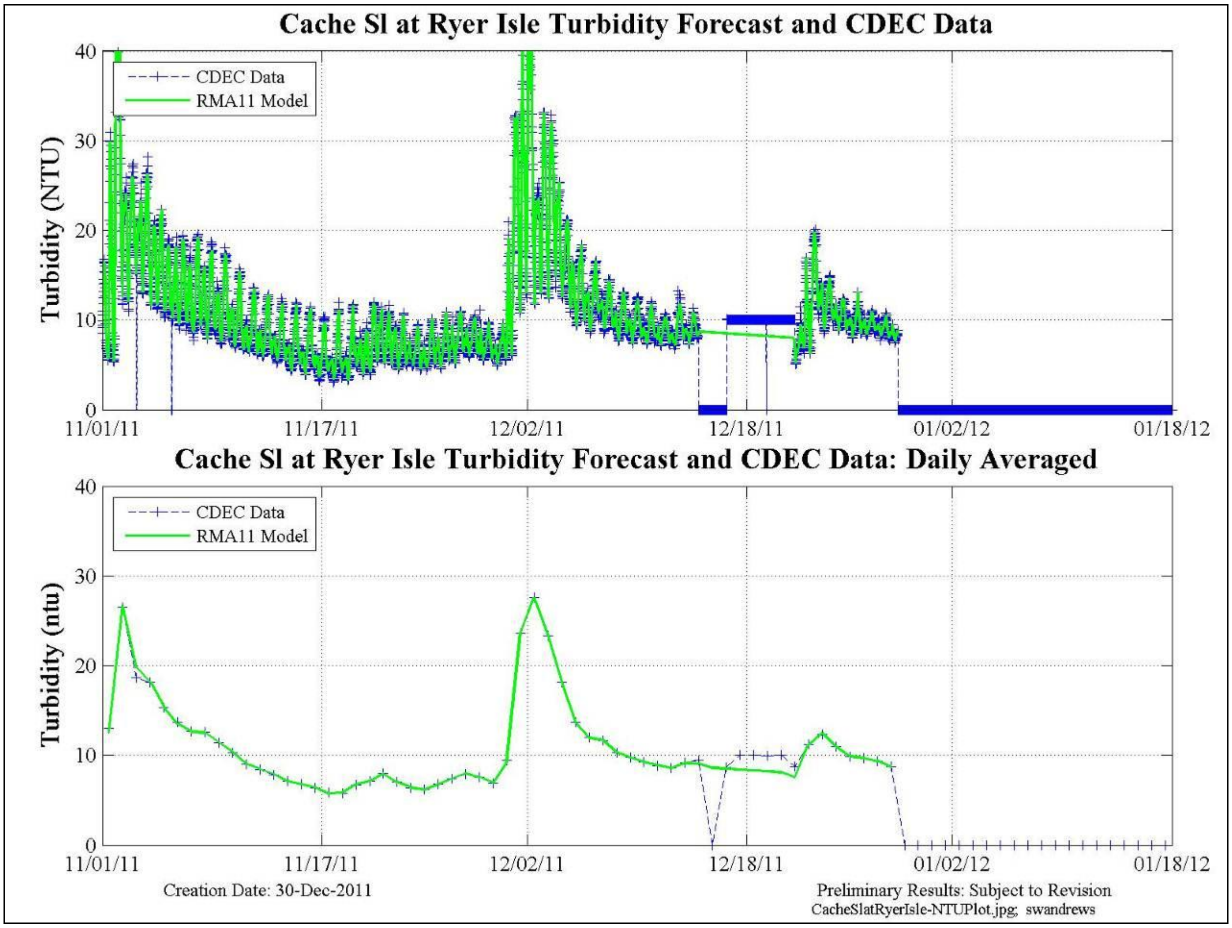

Figure 8 The Cache Slough at Ryer Island internal turbidity BC compiled from CDEC data. The boundary condition was not applied beyond the end time of the observed data. Zero values indicate the end of data (blue).

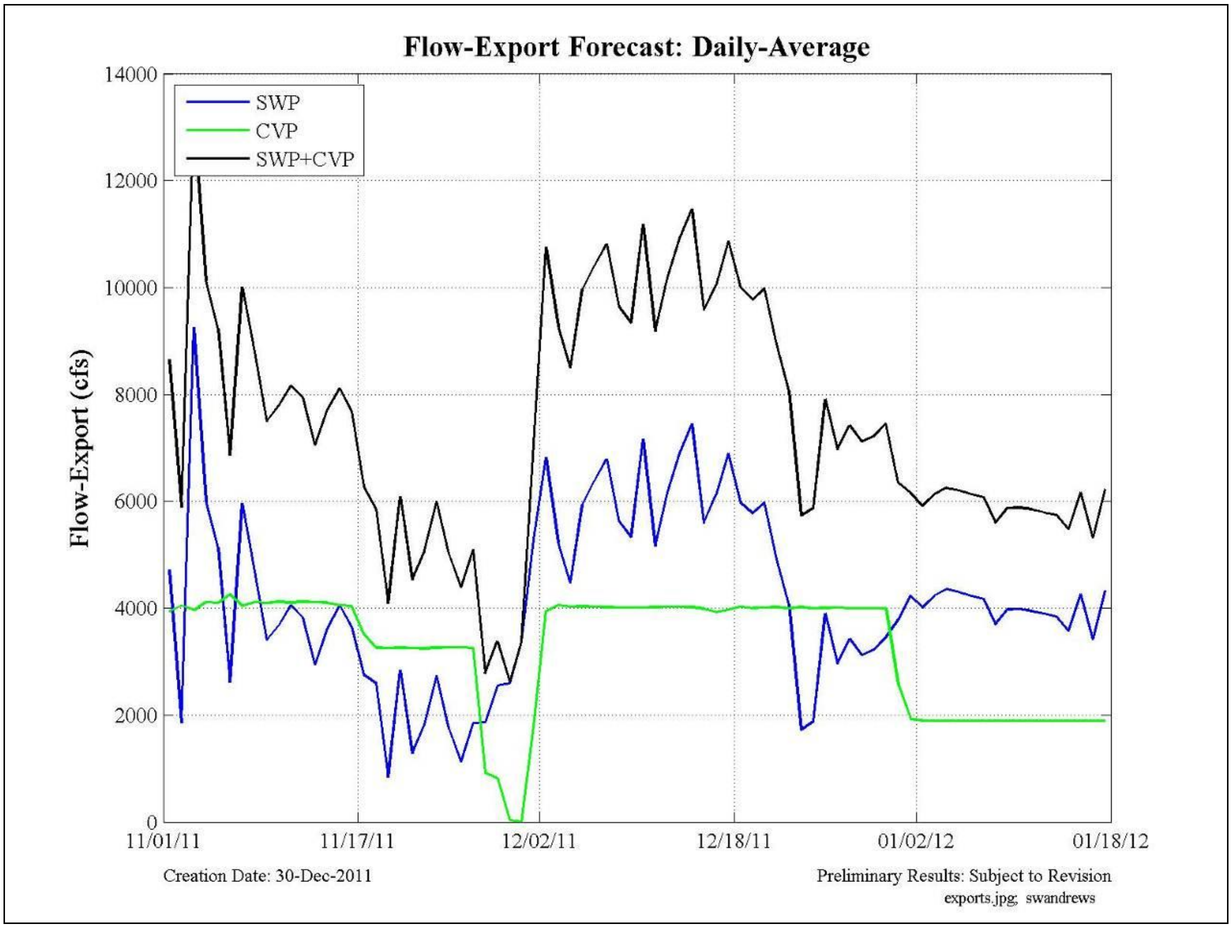

Figure 9 The plot illustrate modeled daily-averaged exports at the SWP and CVP) export locations, and the combined SWP+CVP exports.

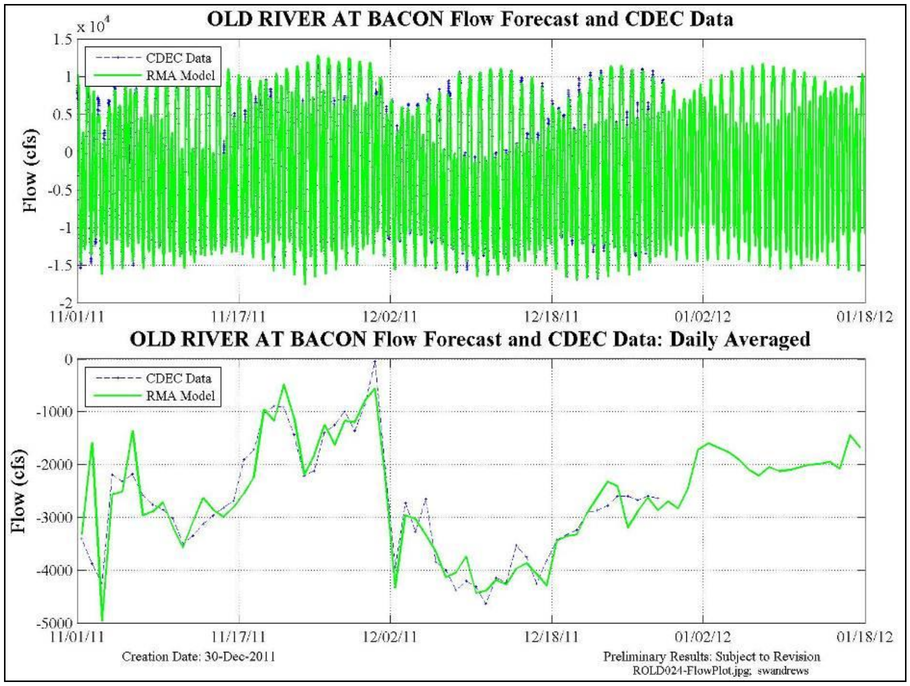

Figure 10 Model flow forecast output and raw CDEC data at Old River at Bacon (ROLD024) location. Both 15-min (upper) and daily averaged (lower) plots are shown.

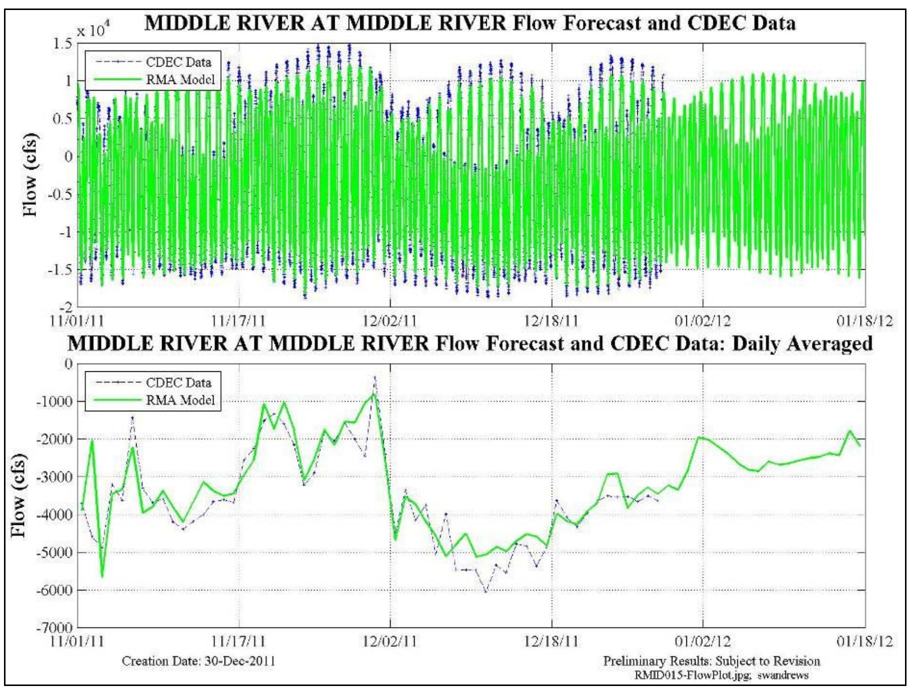

Figure 11 Model flow forecast output and raw CDEC data the Middle River-at-Middle (RMID015) location. Both 15-min (upper) and daily averaged (lower) plots are shown.

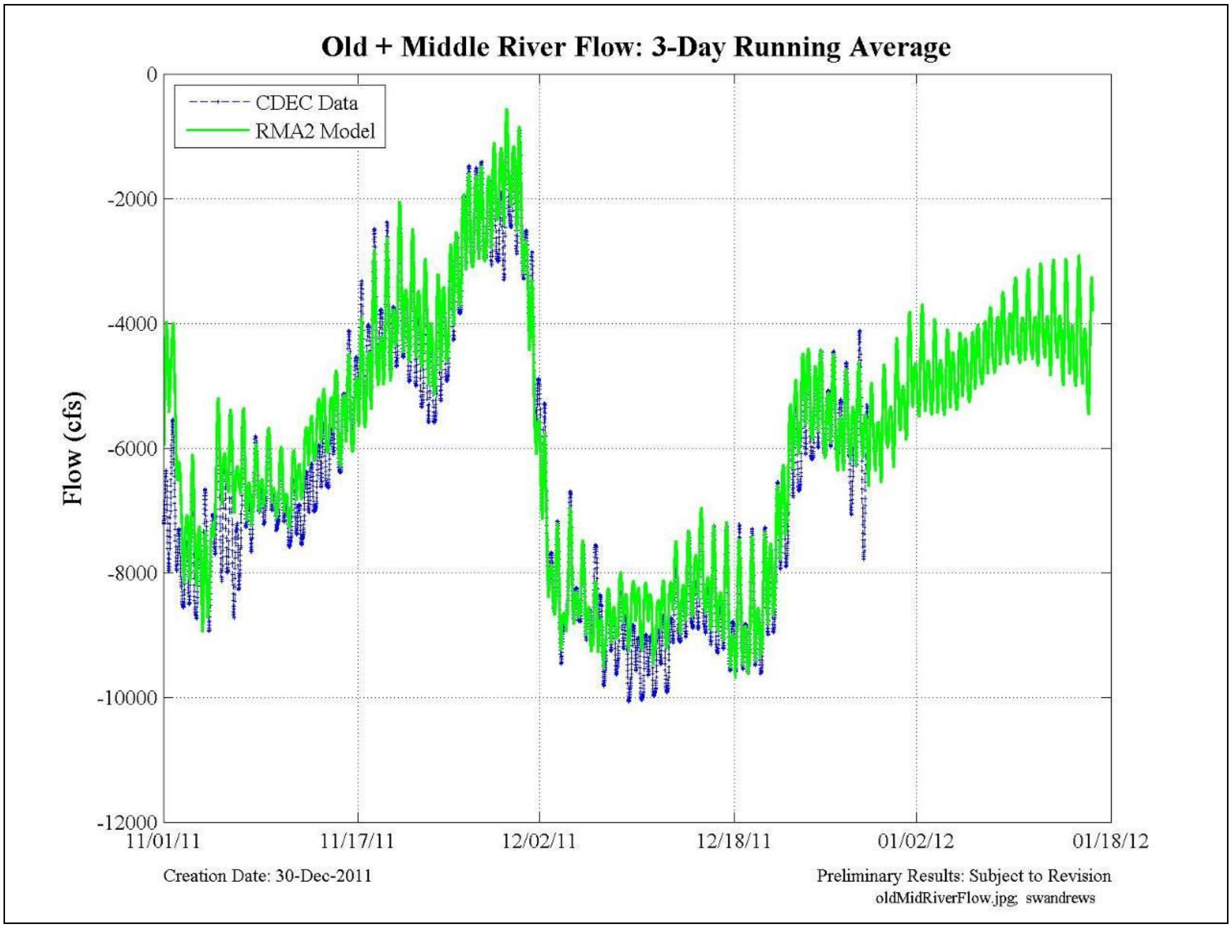

Figure 12 Model flow forecast output and raw CDEC data for the Old+Middle River flow criterion for three-day running-average flow.

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

December 29, 2011	Historical DWR BC	Definition Historical Flow	Definition Forecast Flow	Comment
BC Location				
Yolo Bypass	Not used	Hourly CDEC LIS stage, cleaned+filled, converted flow	Hourly CNRFC forecast (Yolo at Lisbon) for 5 days, 350 cfs after	ignored DWR predicted flow, was too low, kept with constant flow from previous week
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 after	
Mokelumne River	Daily DSM2 RMKL070, converted to hourly	Not used	Daily DSM2 RMKL070, converted to hourly	
Cosumnes River	Not used	Hourly CNRFC Cosumnes-McConnell, cleaned+filled	Hourly CNRFC forecast (Cosumnes R at McCon) for 5 days, Daily DSM2 RCSM075 after	
Calaveras River	Not used	Hourly CDEC MRS, cleaned+filled	Daily DSM2 RCAL009, converted to hourly	
San Joaquin River at Vernalis	Not used	Hourly USGS and CDEC VNS, cleaned+filled	Hourly CNRFC forecast (SJ R at Vernalis) for 5 days, Daily DSM2 RSAN112 after	Rating shift by USGS Dec. 13, 2011. Use USGS flow prior to Dec. 13.
Stage - Martinez	Not used	15min CDEC MRZ, cleaned+filled	15min DSM2 RSAC054 (hydro.dss)	

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

December 29, 2011	Definition Historical NTU	Definition Forecast NTU	Comment
BC Location			
Yolo Bypass	15min CDEC RYI, cleaned+filled, hourly averaged	extend 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	extend as constant	Shifted 15hrs back in time (optimal shift for low Sac flow)
Mokelumne River	15min CDEC SMR, cleaned+filled, daily averaged then converted to hourly	extend as constant	Daily-avg to remove tidal variation
Cosumnes River	15min CDEC SMR, cleaned+filled, daily averaged then converted to hourly	extend as constant	Daily-avg to remove tidal variation
Calaveras River	15min CDEC RRI, cleaned+filled, hourly averaged	extend as constant	
San Joaquin River at Vernalis	15min CDEC SJR, cleaned+filled, hourly averaged	extend as constant	
Sacramento River at Mallard Island internal bc	15min CDEC MAL, cleaned+filled, hourly averaged	extend as constant	
Martinez	15min CDEC MRZ, cleaned+filled, hourly averaged	extend as constant	

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

December 29, 2011	Historical DWR BC	Definition Historical EC	Definition Forecast EC	Comment
BC Location				
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)	

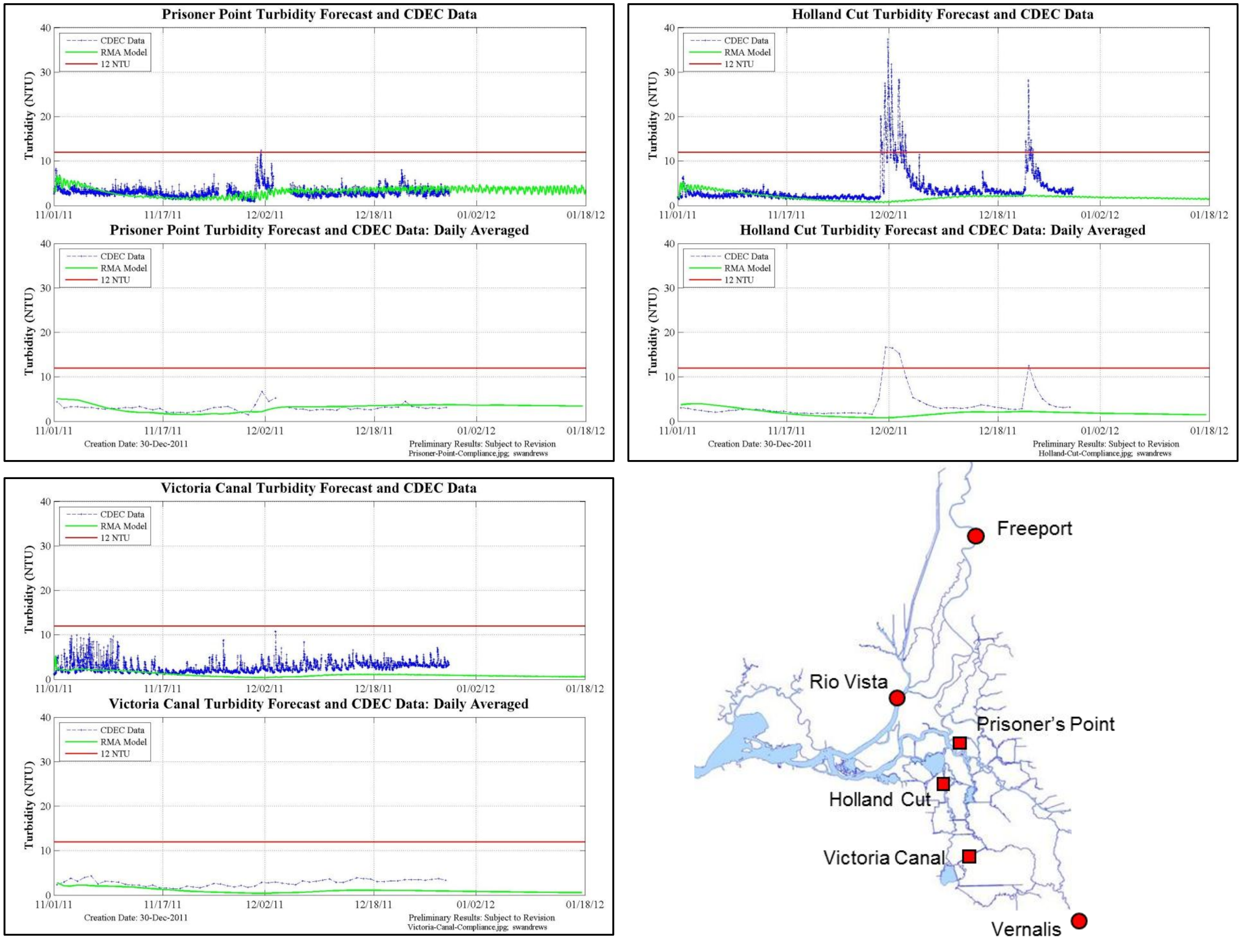

Figure 13 Modeled turbidity and data (cleaned and filled) at the three compliance locations. Both 15-min model output and data and daily averaged plots are shown. Red line illustrates the 12-NTU compliance value.

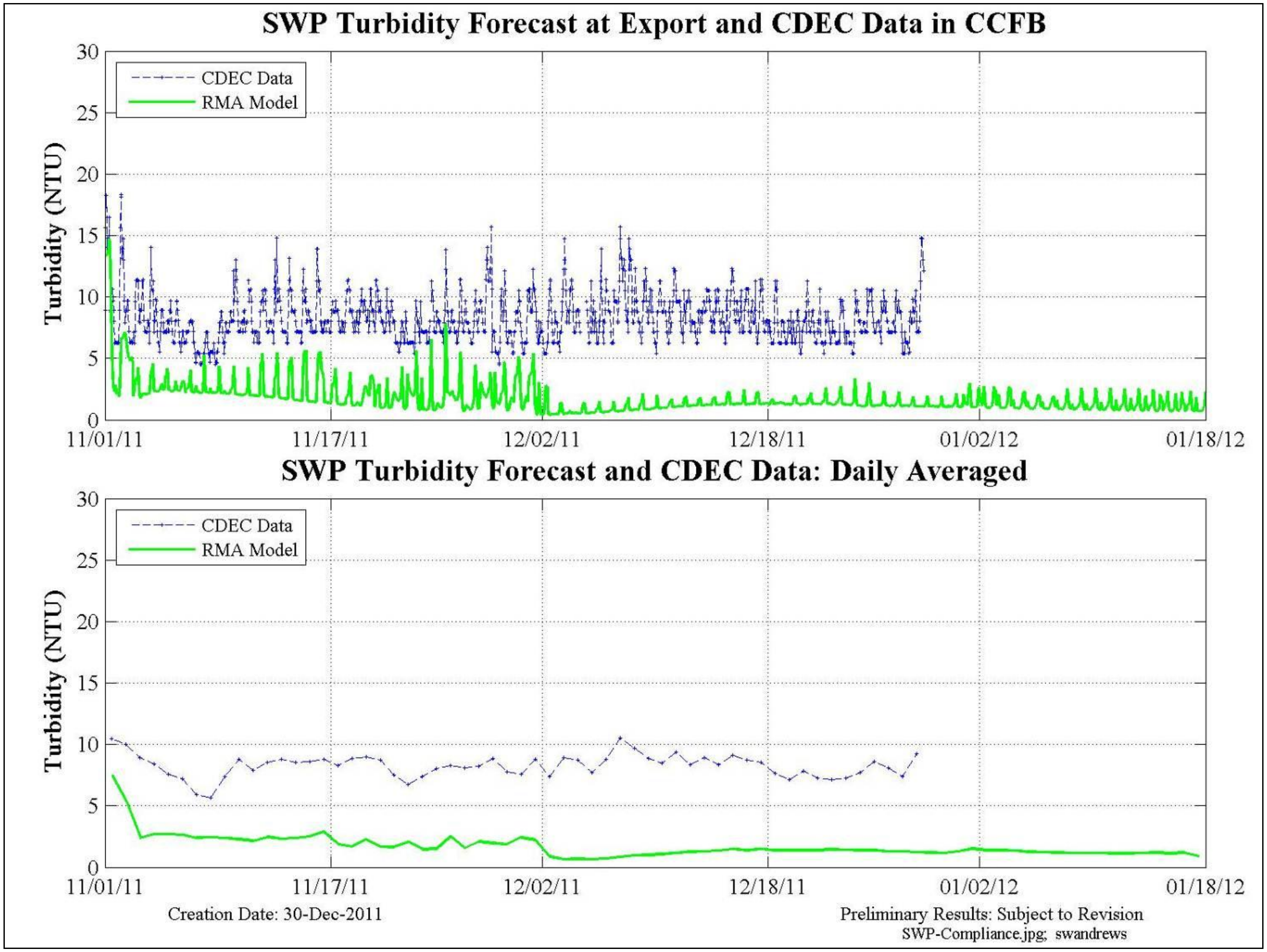

Figure 14 Plots compare model output at the SWP export location with data gathered inside Clifton Court Forebay. Both 15-min model output and daily averaged plots are shown.

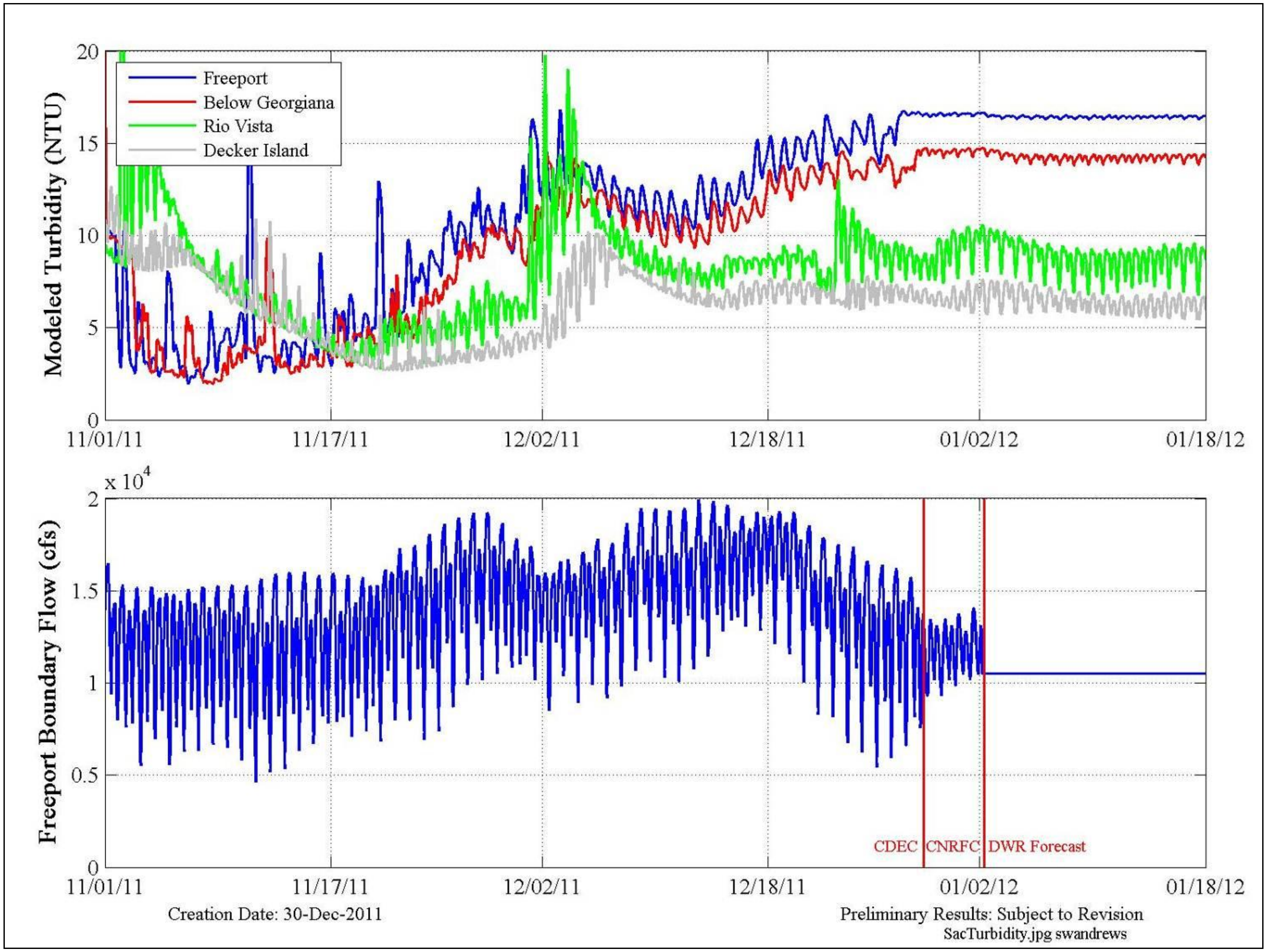

Figure 15 Freeport turbidity boundary condition progression down the Sacramento R. (upper plot) along with the flow boundary (lower plot) used during the historical and forecast periods. Forecast began on Dec. 08, 2011.

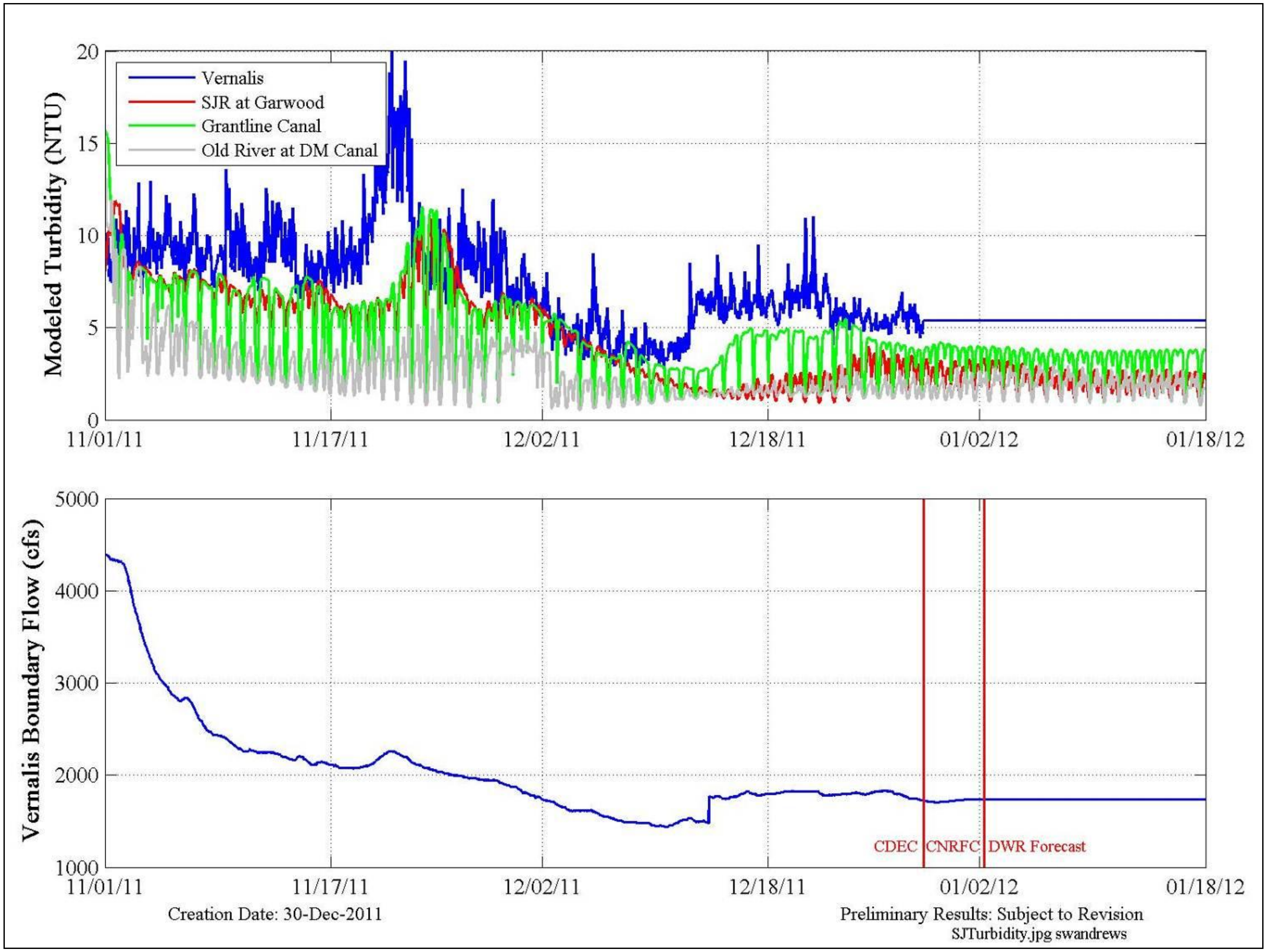

Figure 16 Progression of the turbidity boundary condition from Vernalis down the San Joaquin R to Garwood, and down Old River. Vernalis flow forecast periods indicated by red lines (upper plot). Flow boundary conditions at Vernalis are shown in the lower plot.

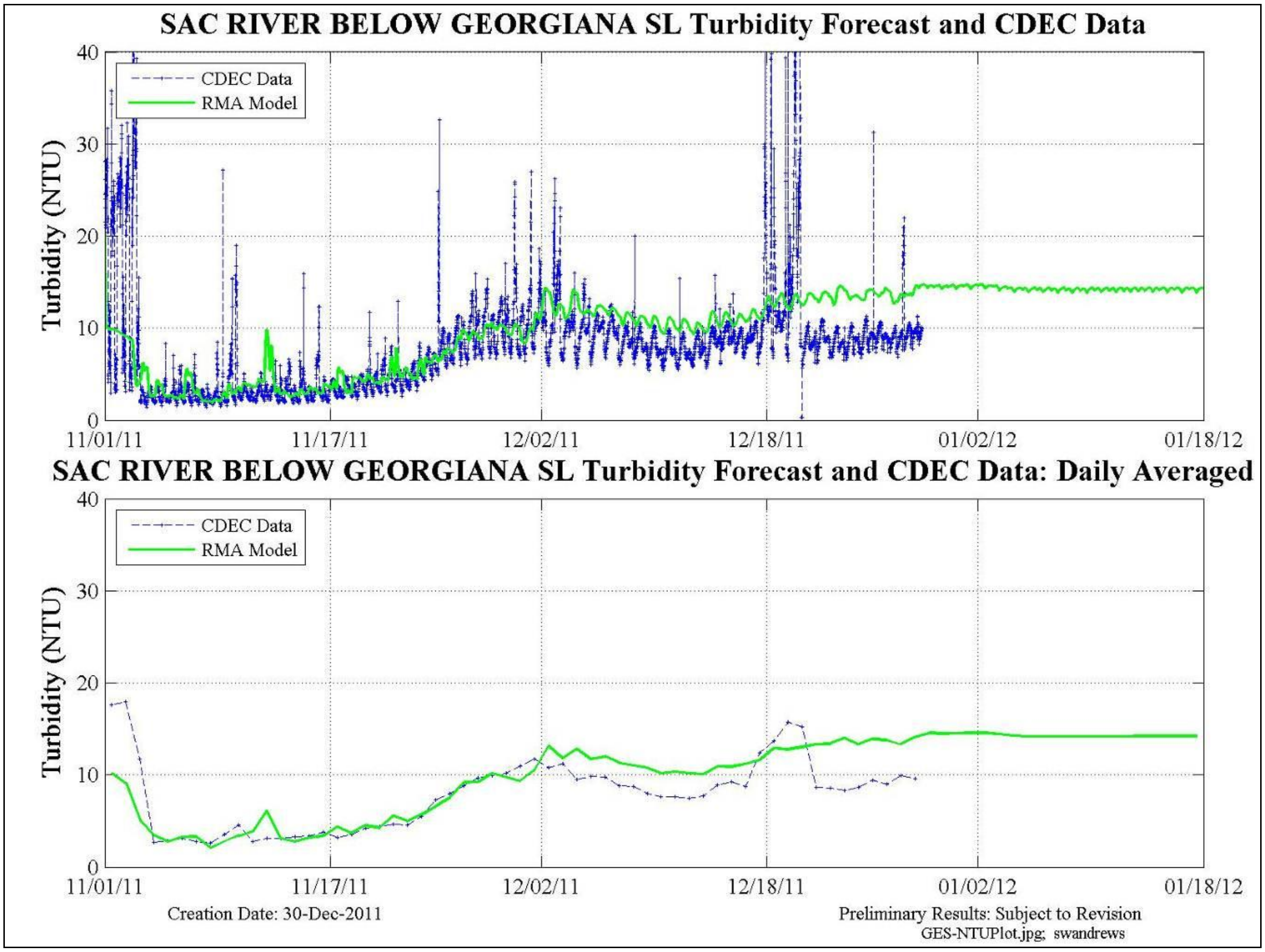

Figure 17 Model forecast and raw CDEC data at Sac. River Below Georgiana Sl. Both 15-min (upper) and daily averaged (lower) plots are shown.

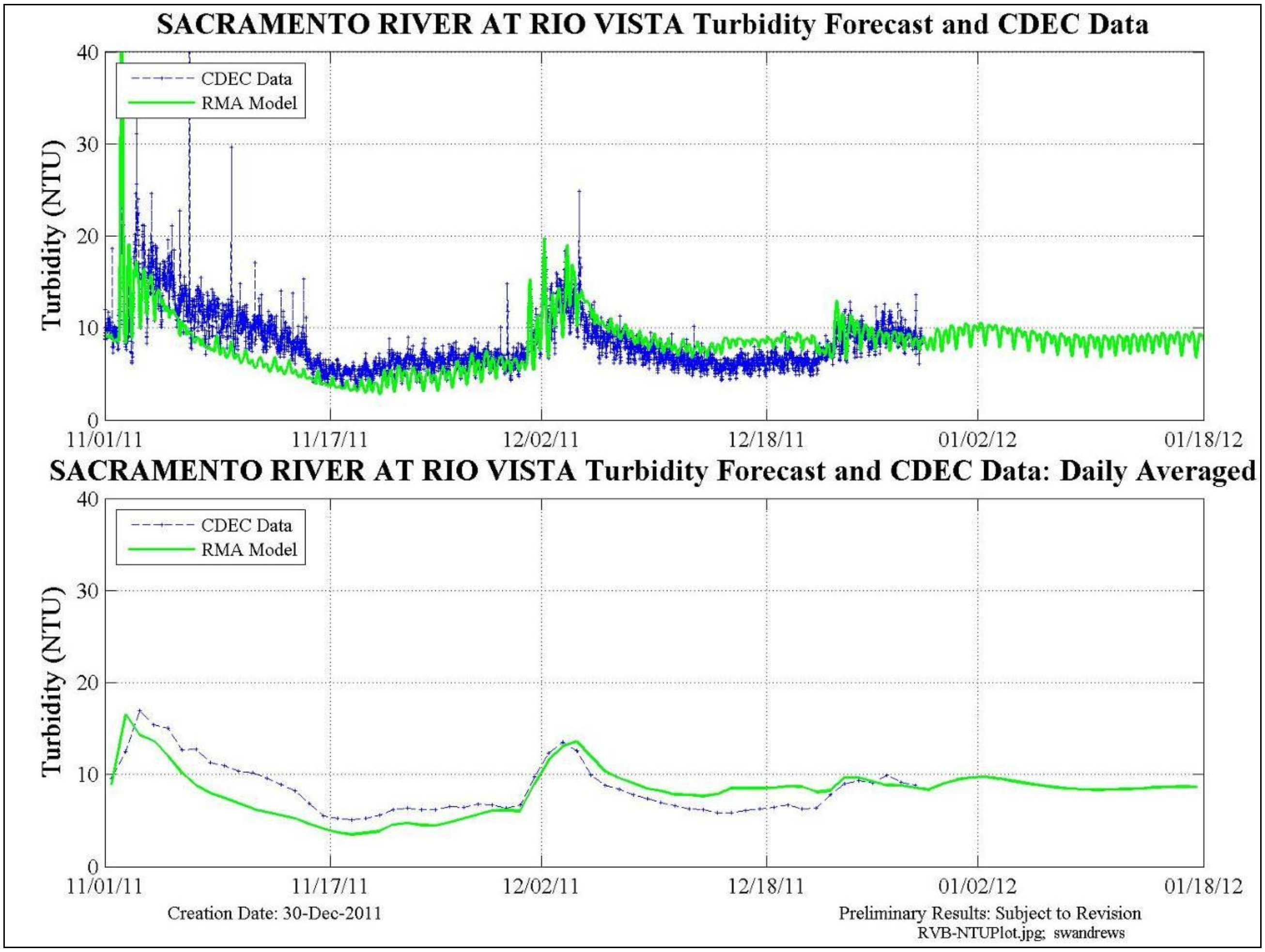

Figure 18 Model forecast and raw CDEC data at Rio Vista. Both 15-min (upper) and daily averaged (lower) plots are shown.

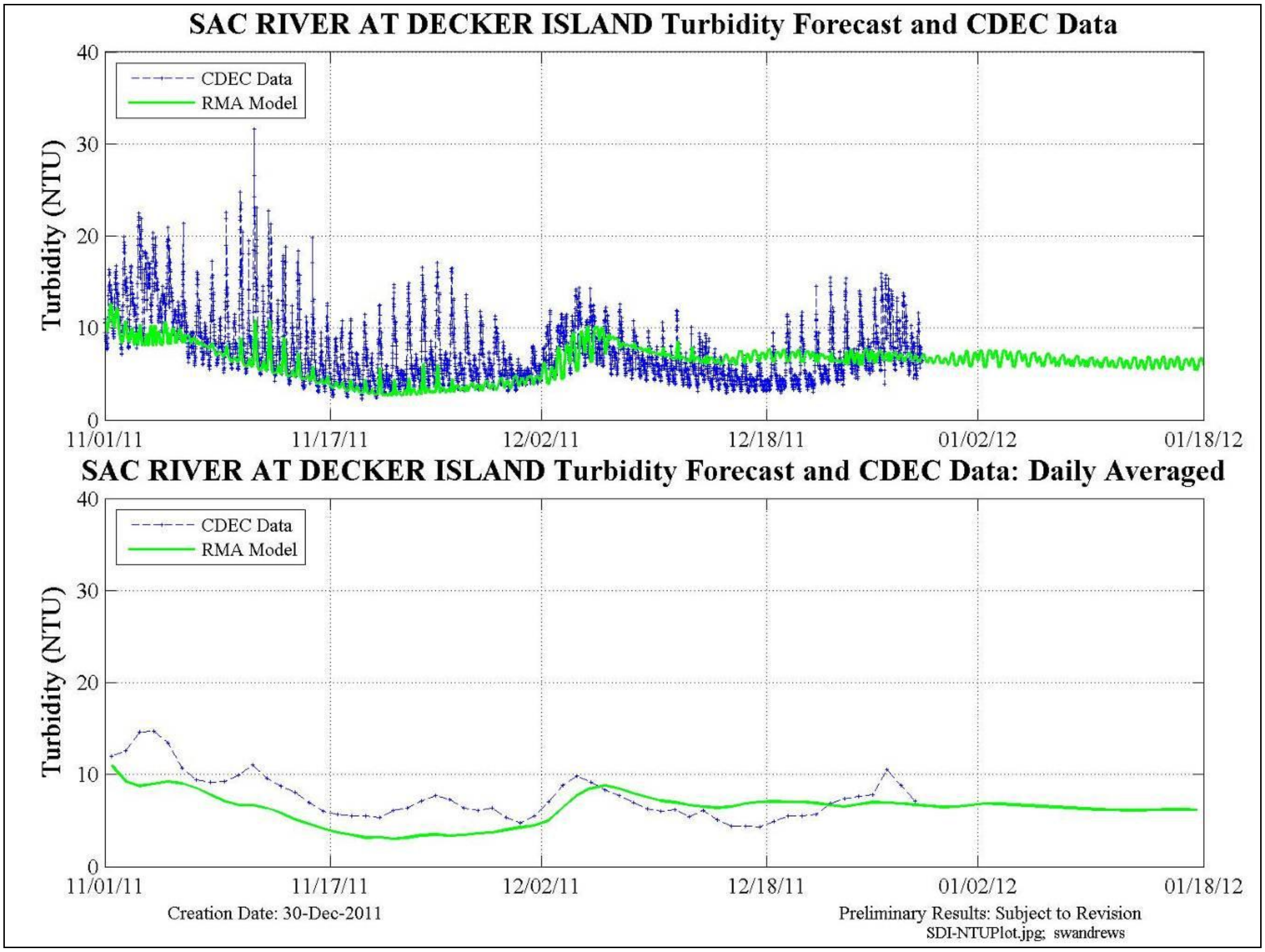

Figure 19 Model forecast and raw CDEC data at Decker Island. Both 15-min (upper) and daily averaged (lower) plots are shown.

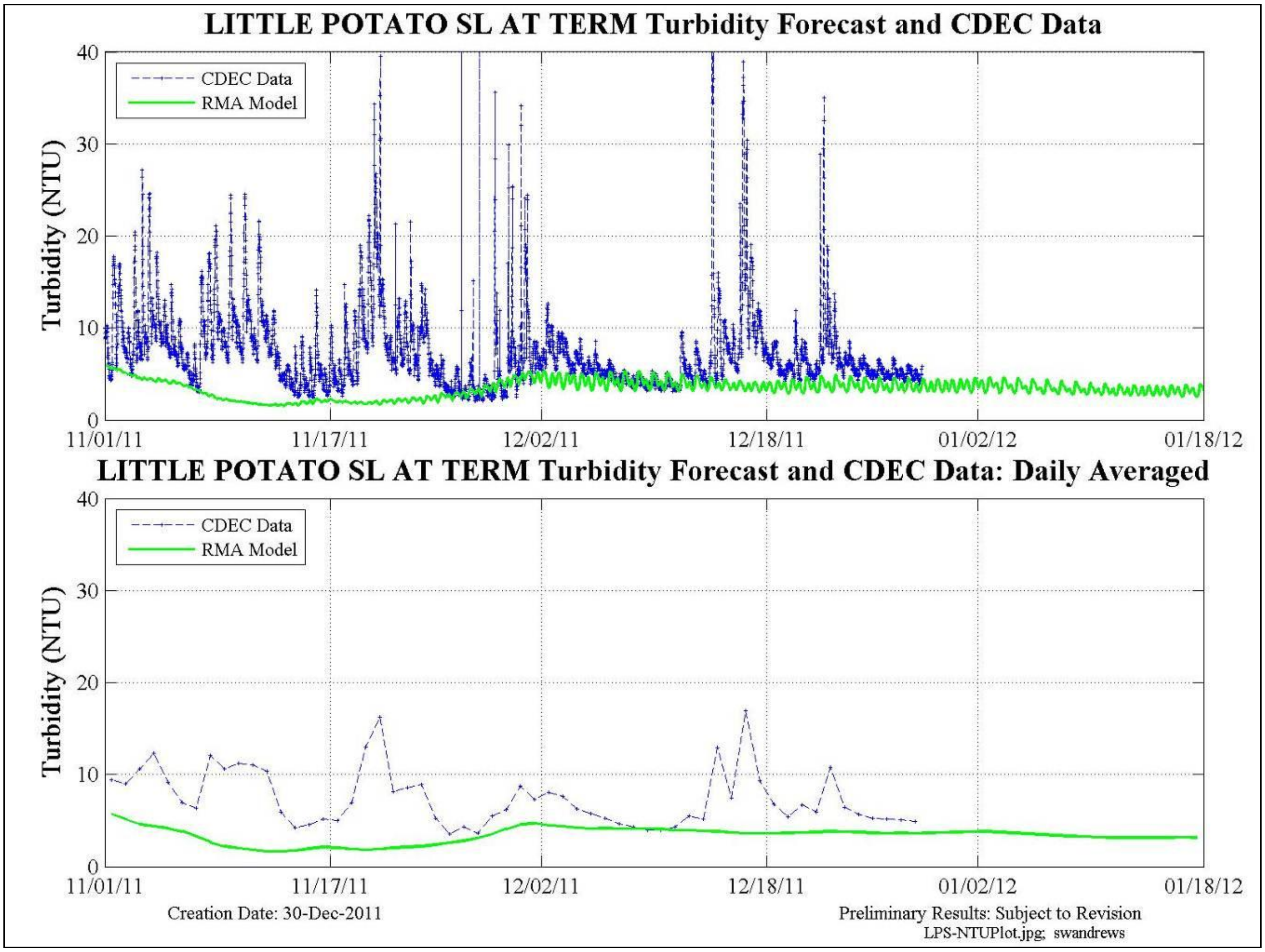

Figure 20 Model forecast and raw CDEC data at Little Potato Slough at Terminous. Both 15-min (upper) and daily averaged (lower) plots are shown.

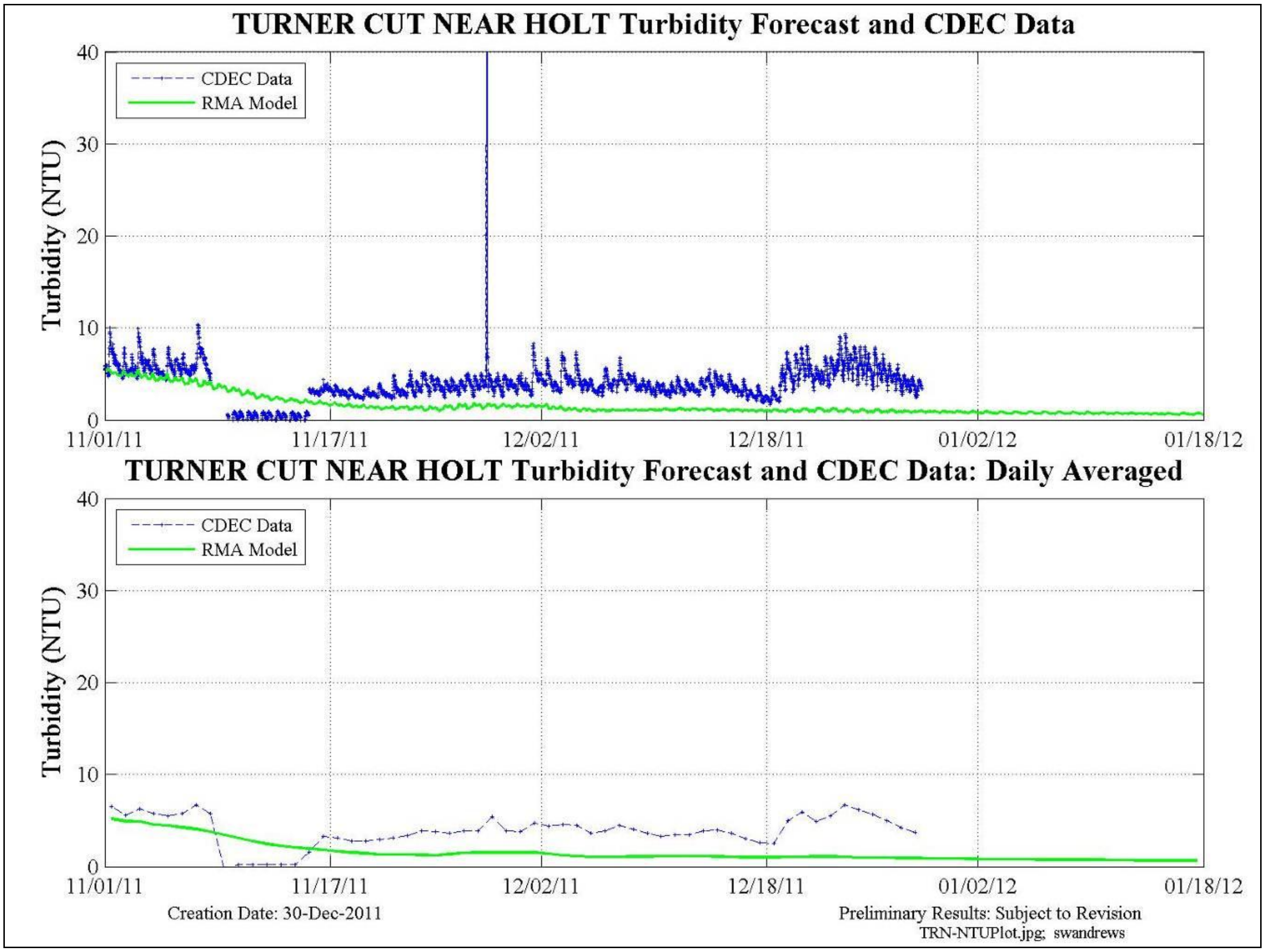

Figure 21 Model forecast and raw CDEC data at Turner Cut near Holt. Both 15-min (upper) and daily averaged (lower) plots are shown.

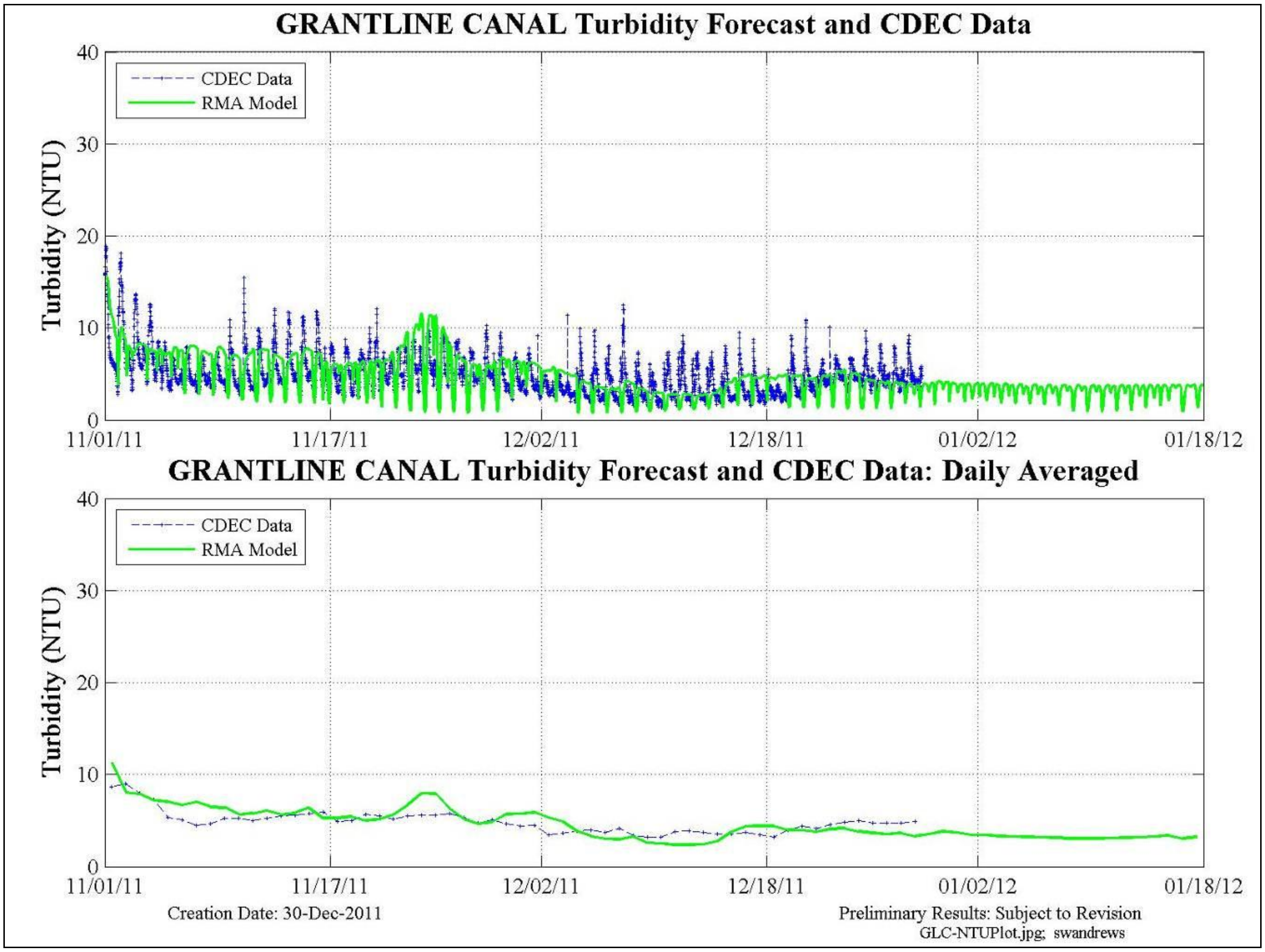

Figure 22 Model forecast and raw CDEC data at Grant Line. Both 15-min (upper) and daily averaged (lower) plots are shown.

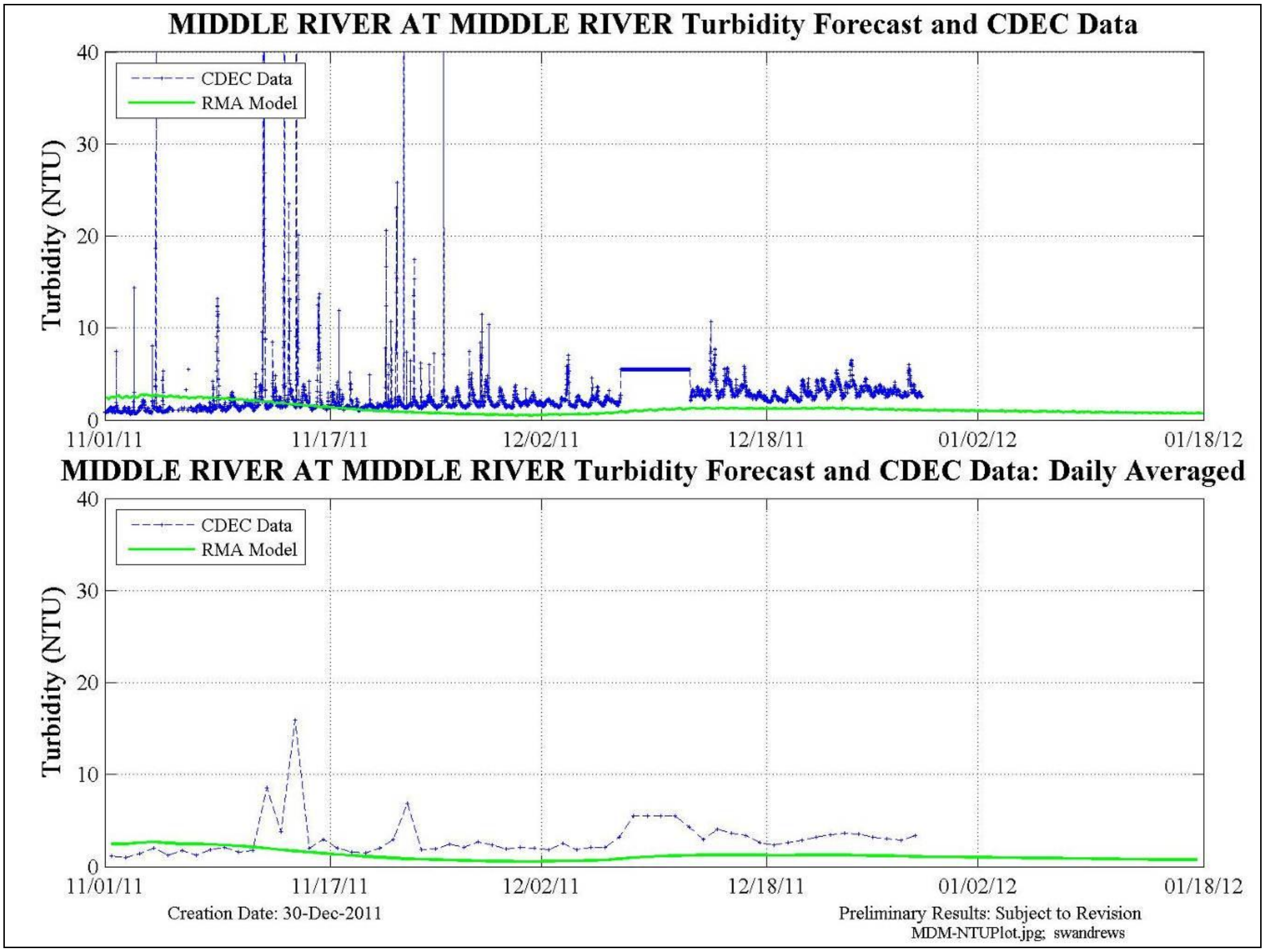

Figure 23 Model forecast and raw CDEC data at Middle R. at Middle R. Both 15-min (upper) and daily averaged (lower) plots are shown.

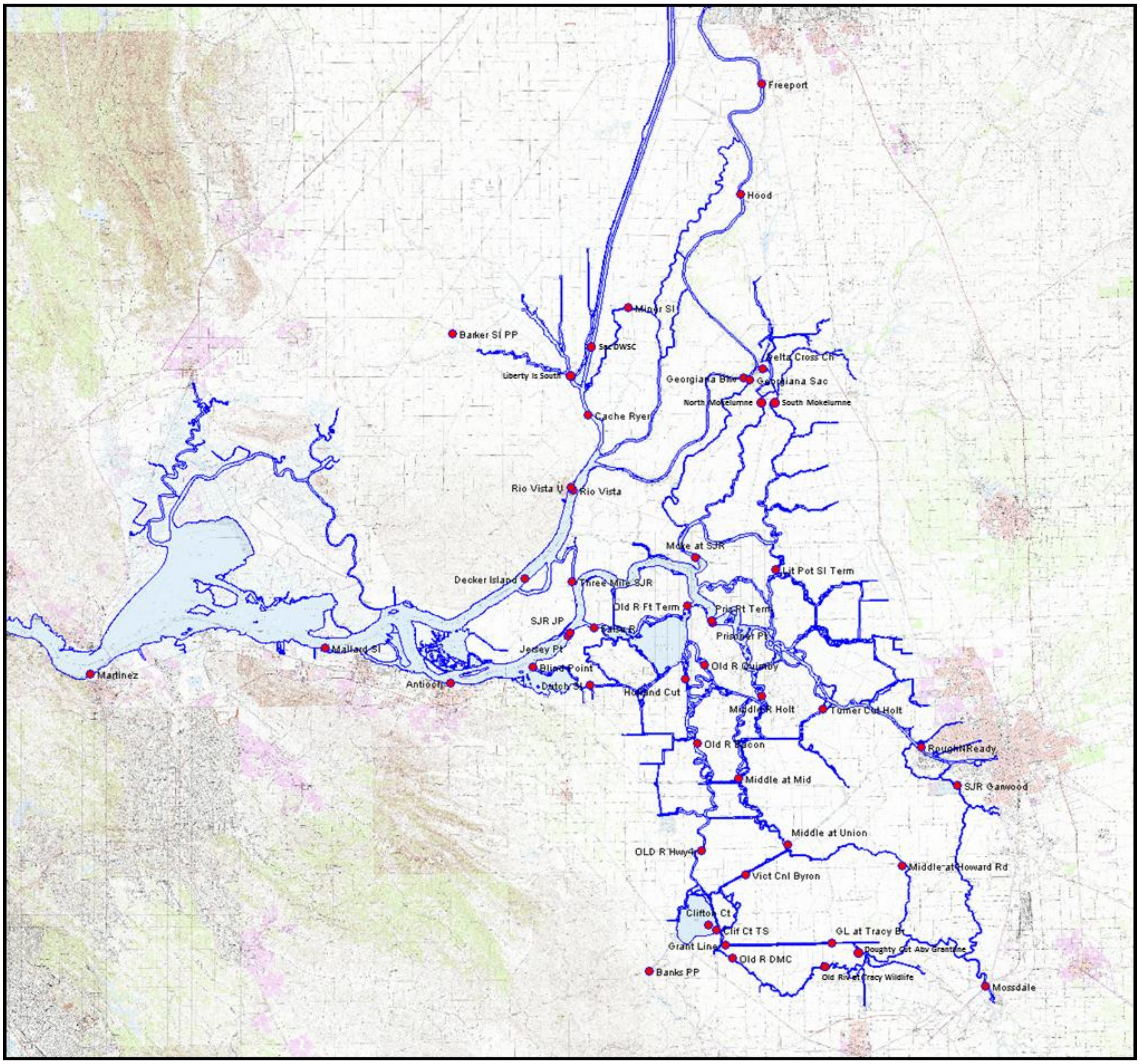

Figure 24 Figure illustrating model output and data collection locations.

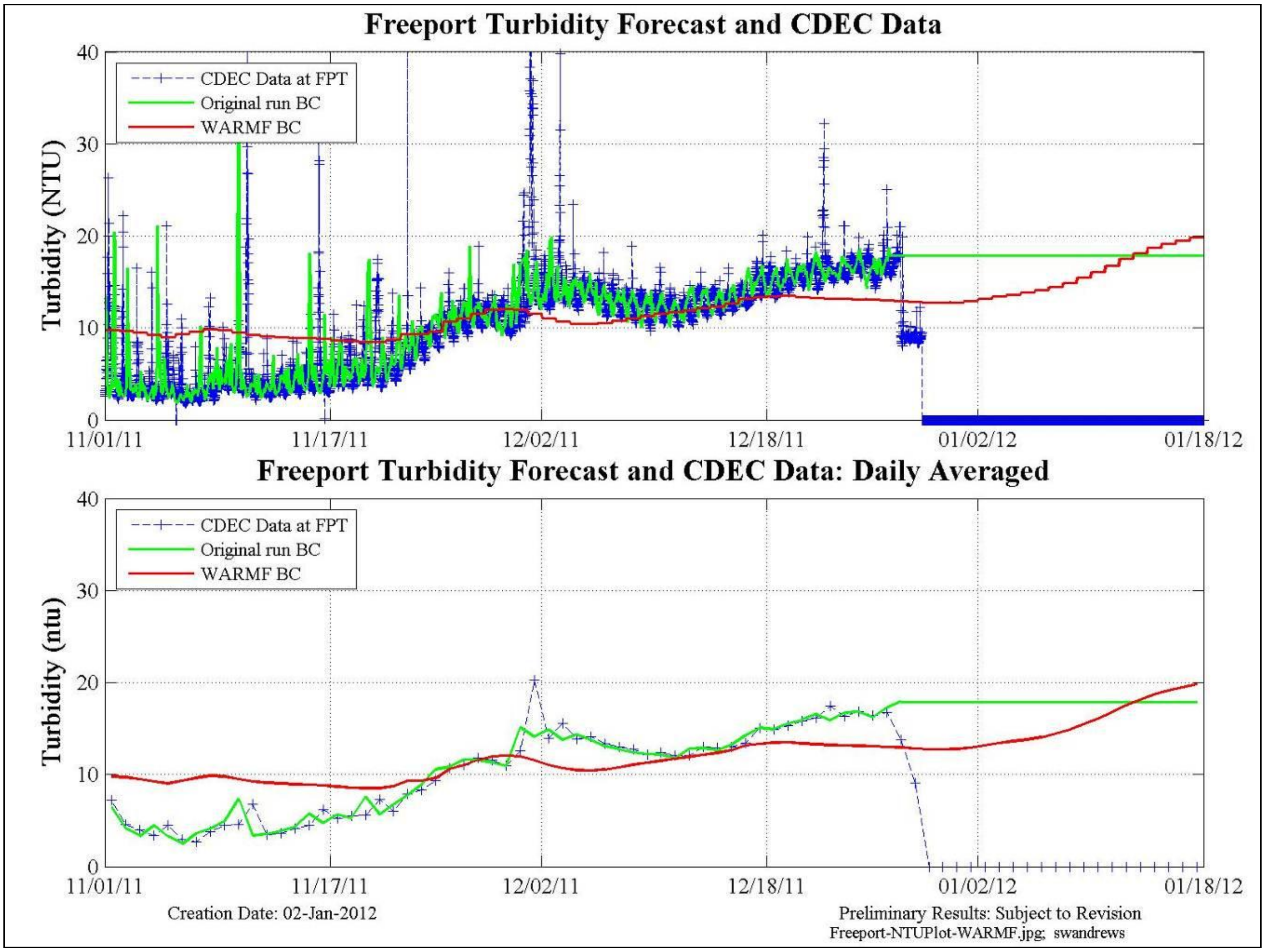

Figure 25 WARMF turbidity BC for the Sacramento River at I Street shown with the CDEC data derived RMA BC used for the Sacramento River. Zero values indicate the end of data (blue).

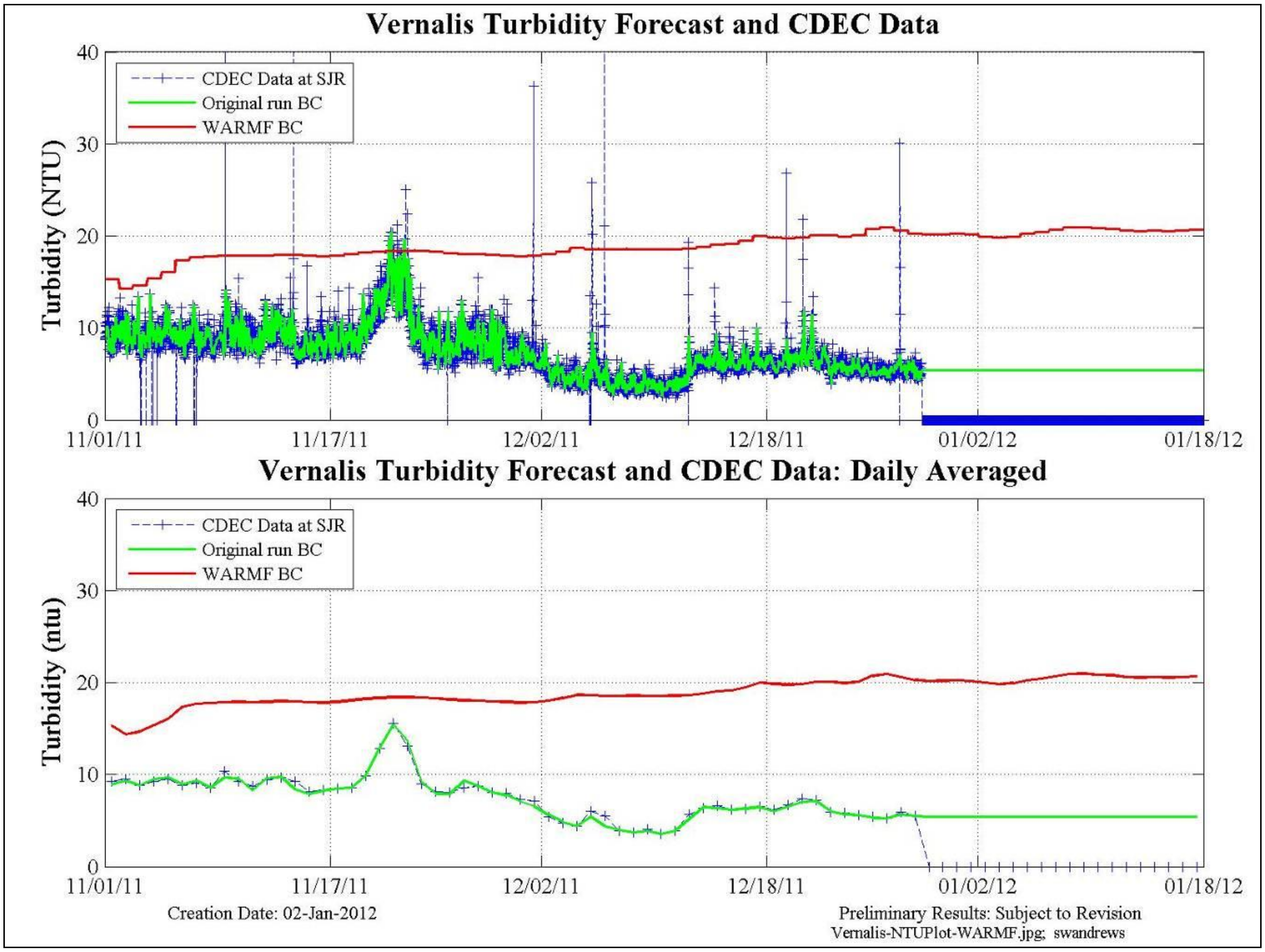

Figure 26 WARMF turbidity BC for the San Joaquin River at Vernalis shown with the CDEC data derived RMA BC. Zero values indicate the end of data (blue).

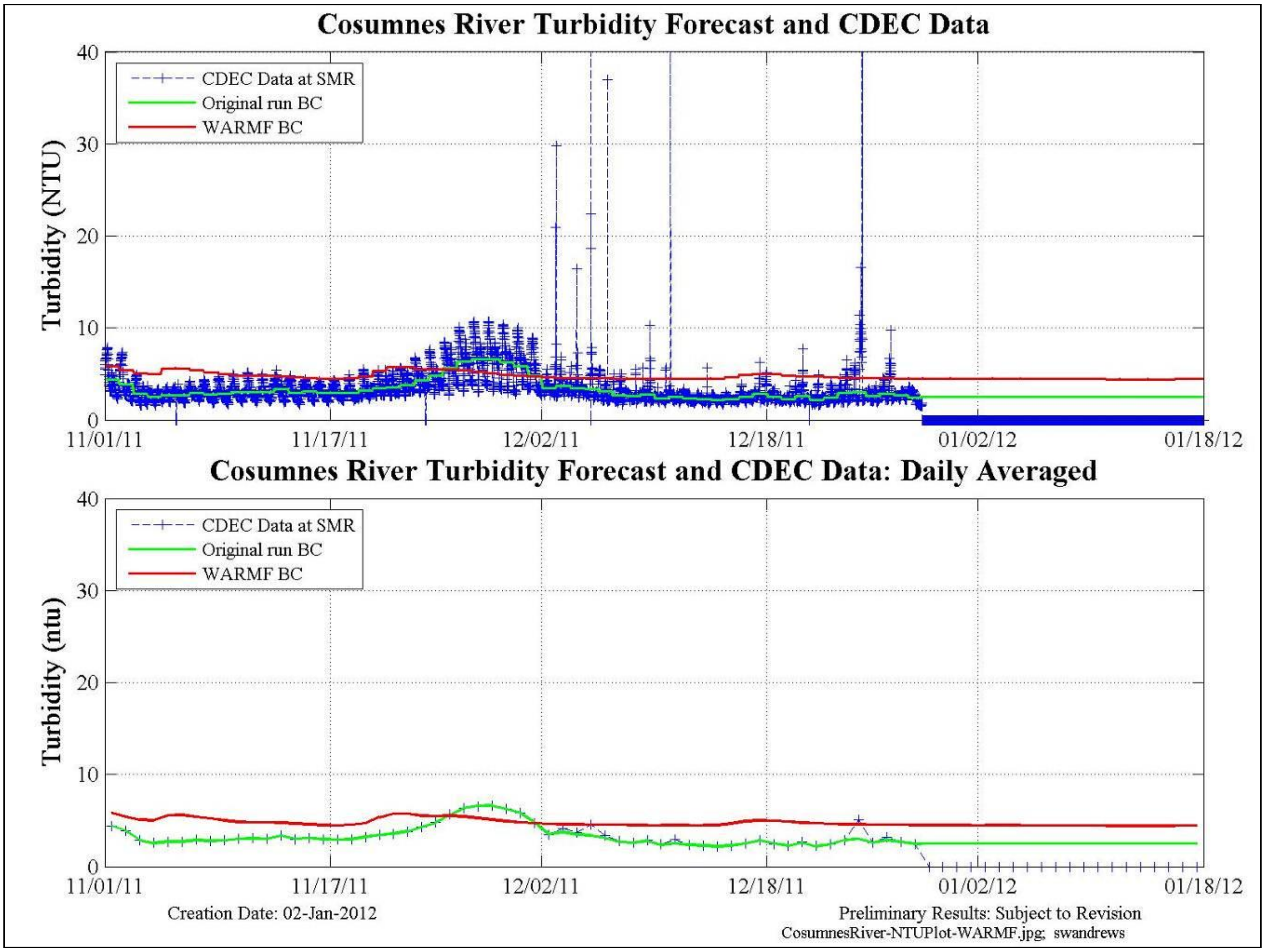

Figure 27 WARMF turbidity BC for the Cosumnes River shown with the CDEC data (South Fork Mokelumne River) derived RMA BC. Zero values indicate the end of data (blue).

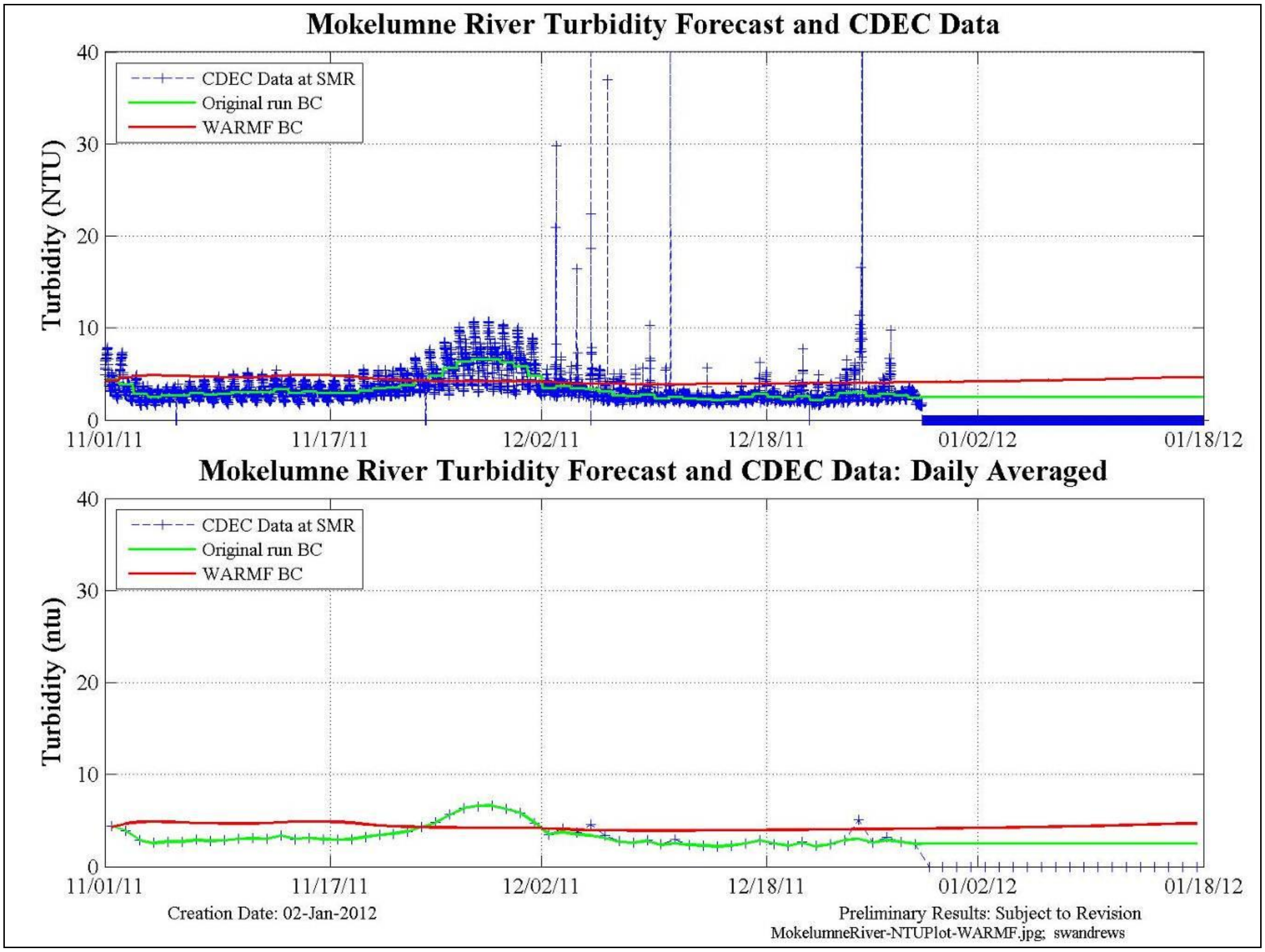

Figure 28 WARMF turbidity BC for the Mokelumne River shown with the CDEC data (South Fork Mokelumne River) derived RMA BC. Zero values indicate the end of data (blue).

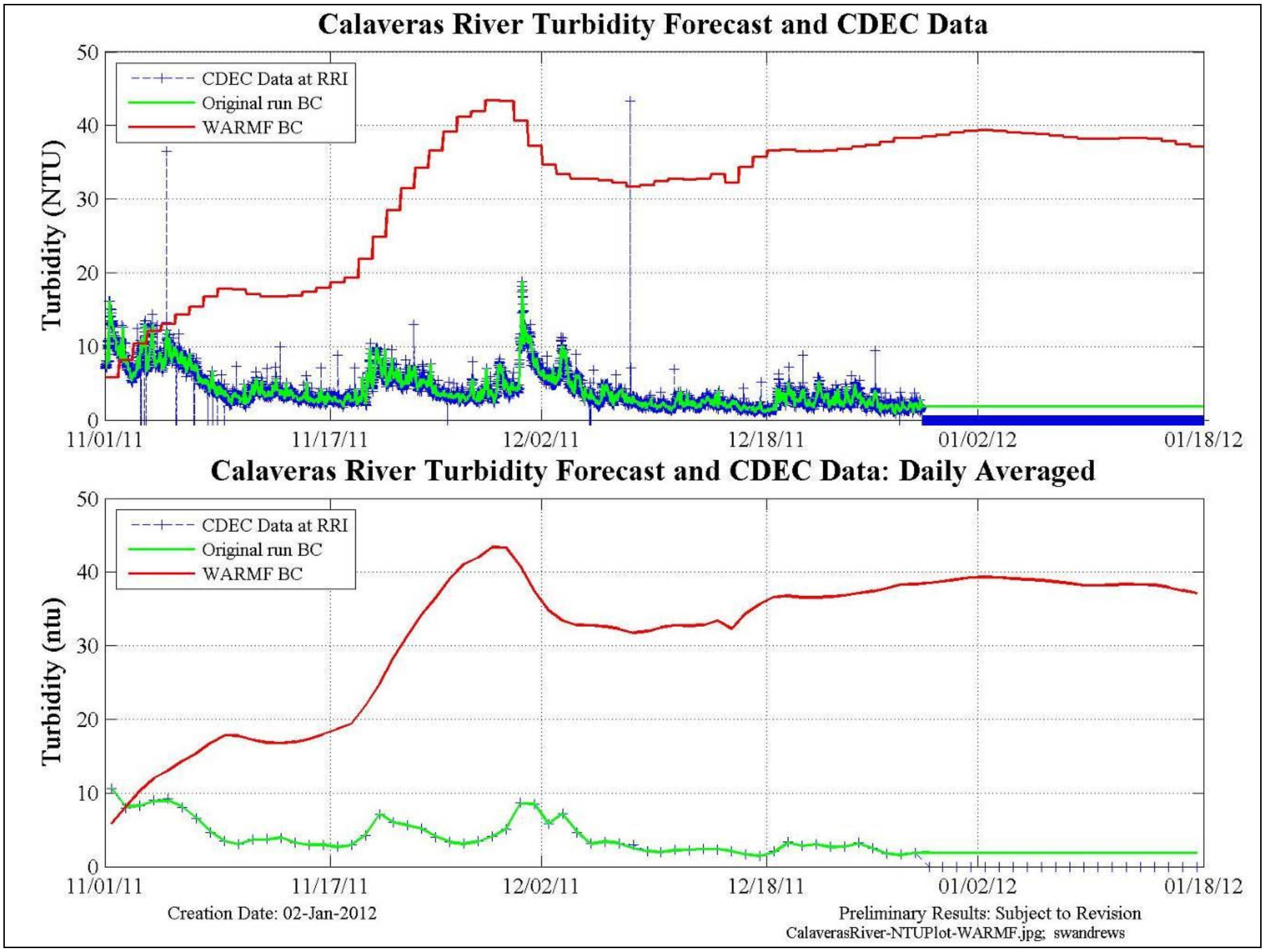

Figure 29 WARMF turbidity BC for the Calaveras River – Mormon Slough shown with the CDEC data (Rough and Ready Island) derived RMA BC. Zero values indicate the end of data (blue).

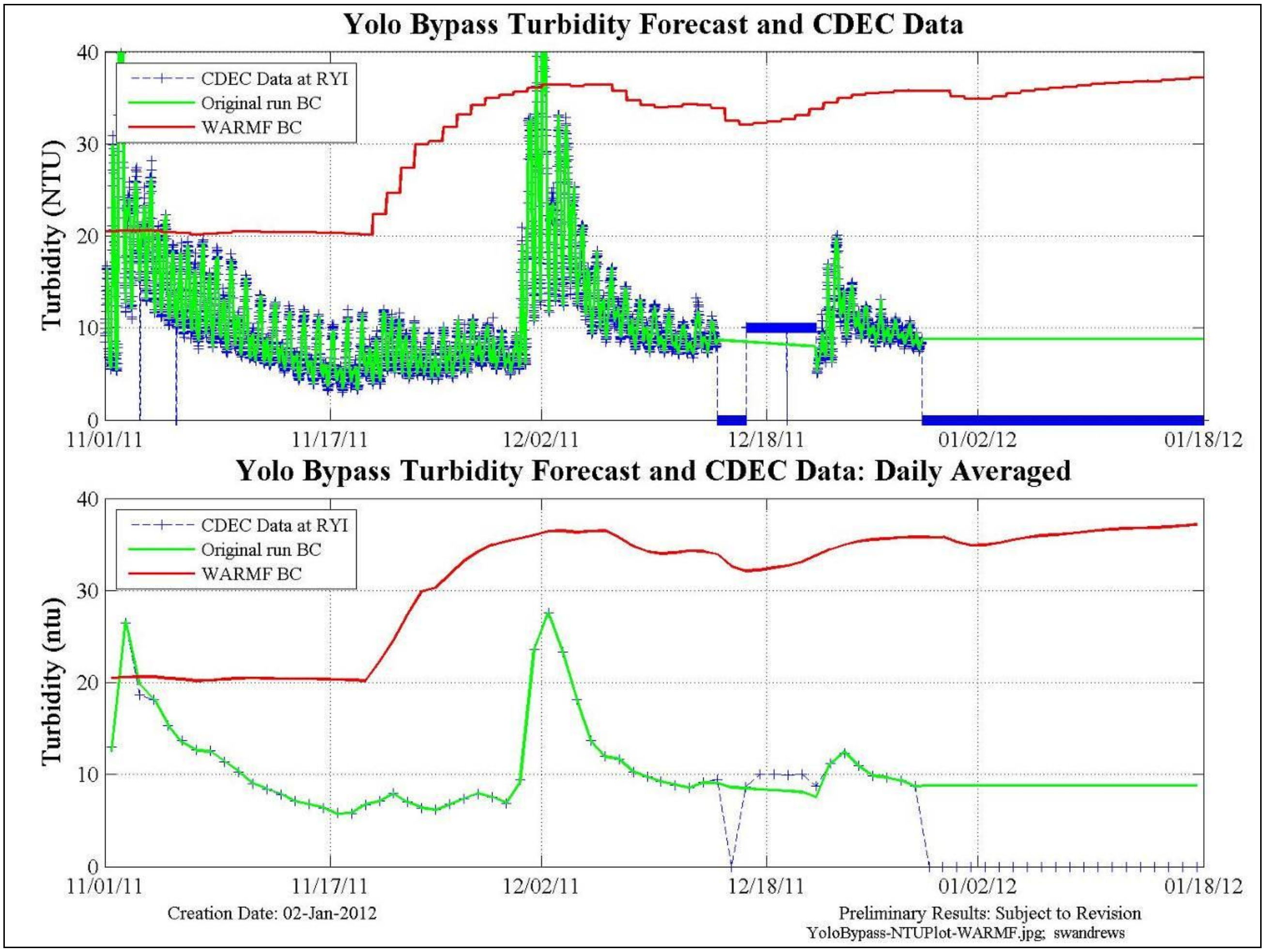

Figure 30 WARMF turbidity BC for the Yolo Bypass shown with the CDEC data (Cache Slough at Ryer Island) derived RMA BC. Zero values indicate the end of data (blue).

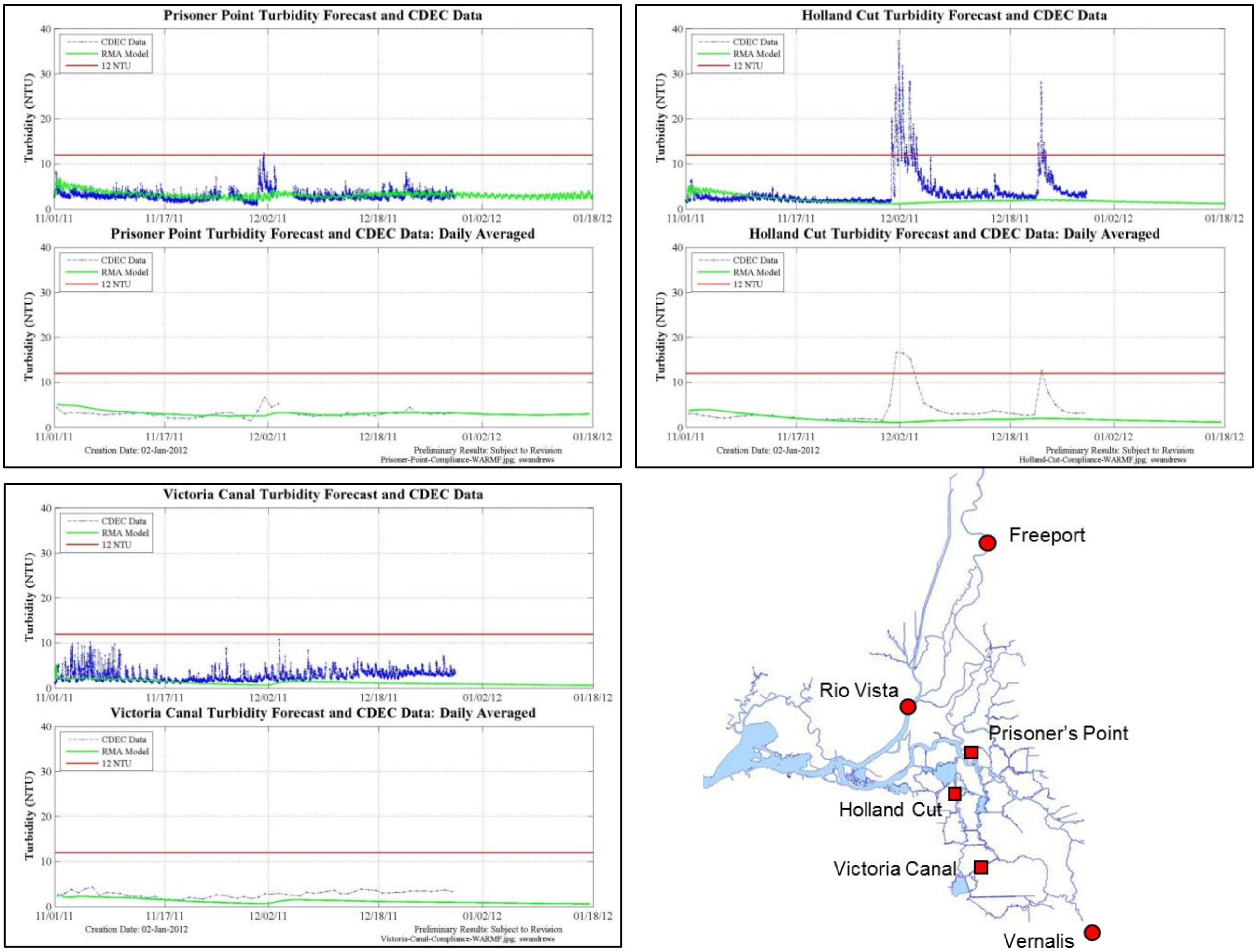

Figure 31 Modeled turbidity using the WARMF turbidity boundary conditions and data (cleaned and filled) at the three compliance locations. Both 15-min model output and data and daily averaged plots are shown. Red line illustrates the 12-NTU compliance value.

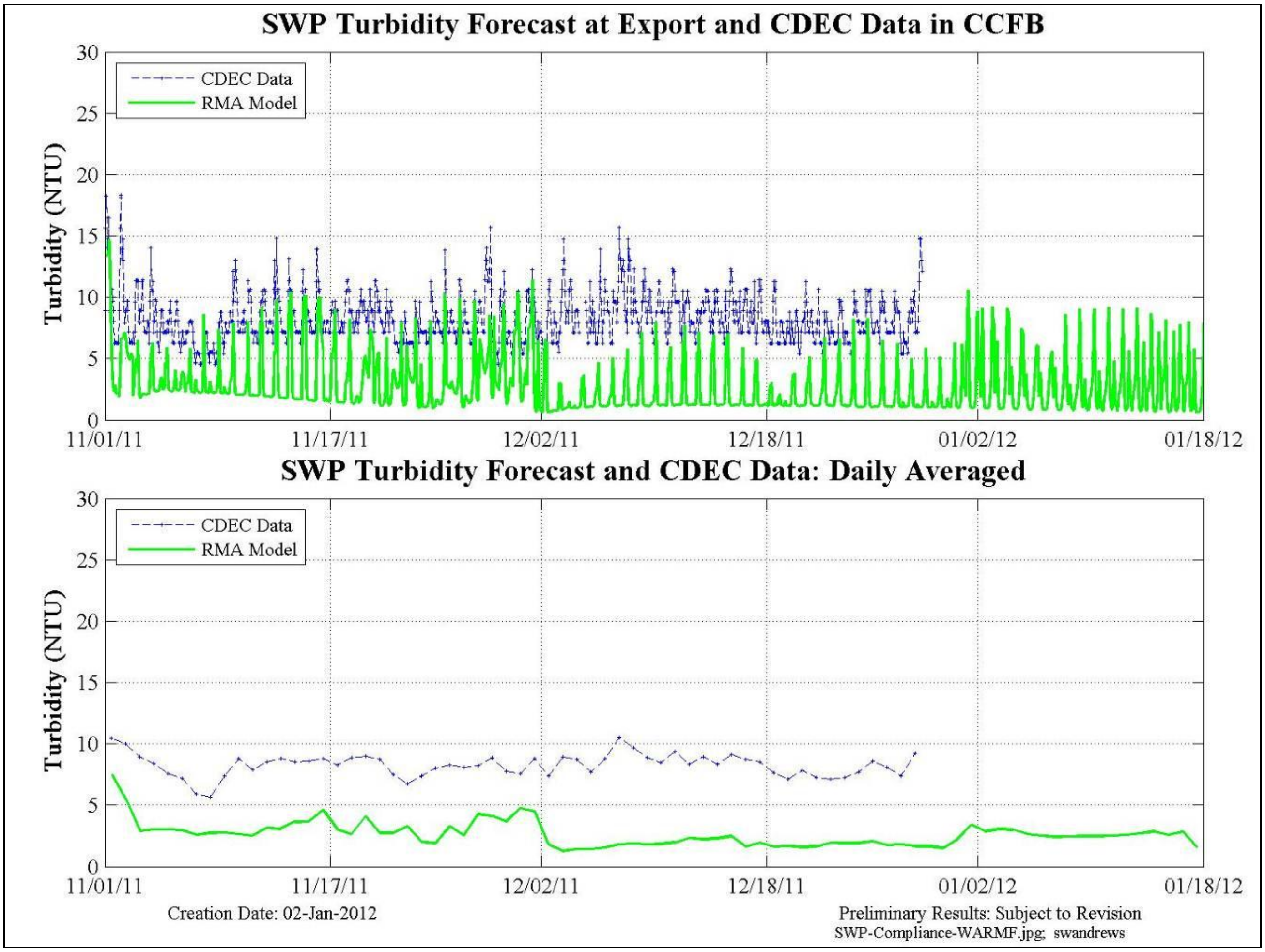

Figure 32 Modeled turbidity using the WARMF turbidity boundary conditions. Plots compare modeled turbidity at the SWP export location with data gathered inside Clifton Court Forebay. Both 15-min model output and daily averaged plots are shown.

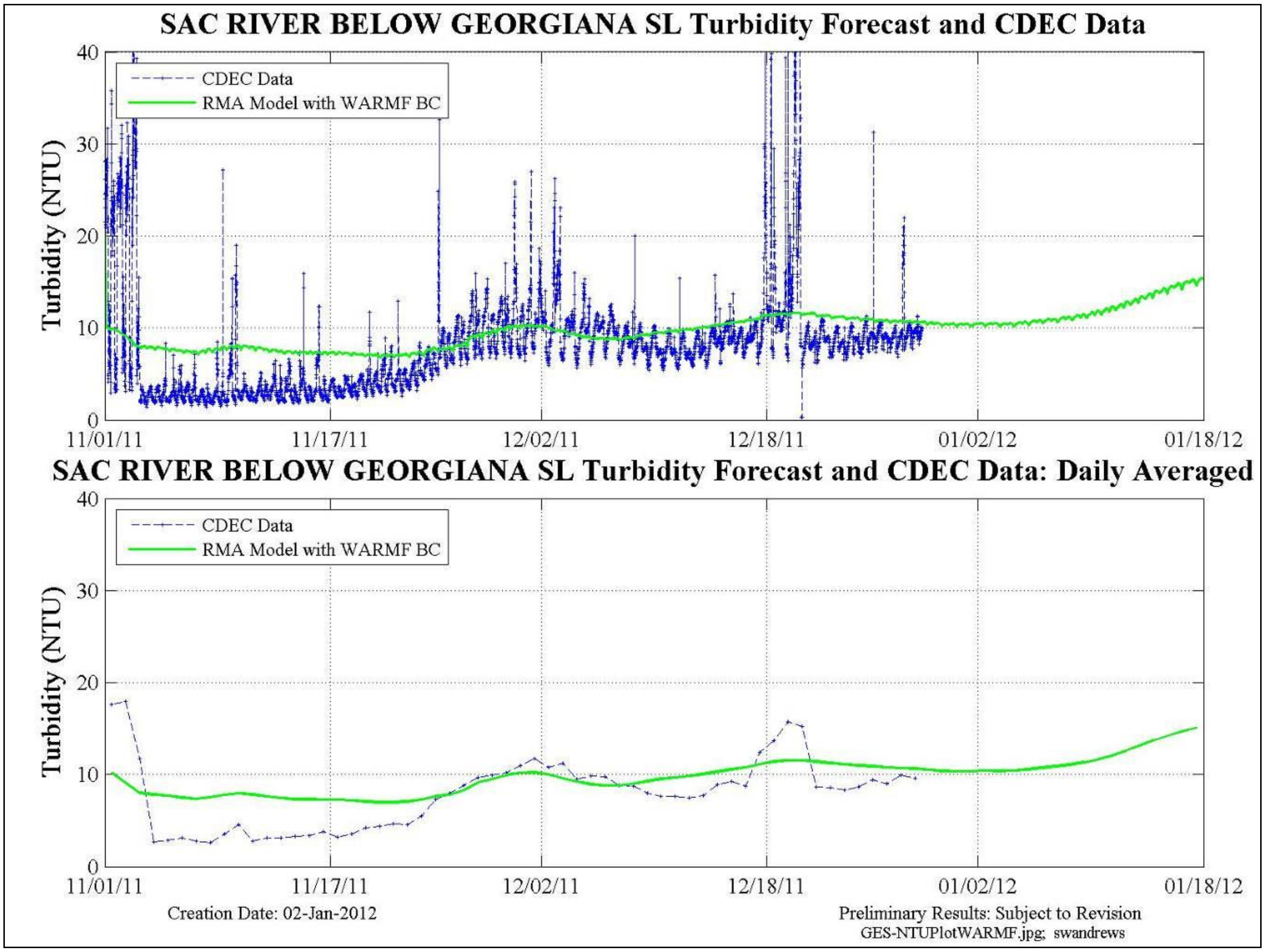

Figure 33 Model turbidity using the WARMF turbidity boundary conditions, and raw CDEC data at Sac. River Below Georgiana Sl. Both 15-min (upper) and daily averaged (lower) plots are shown.

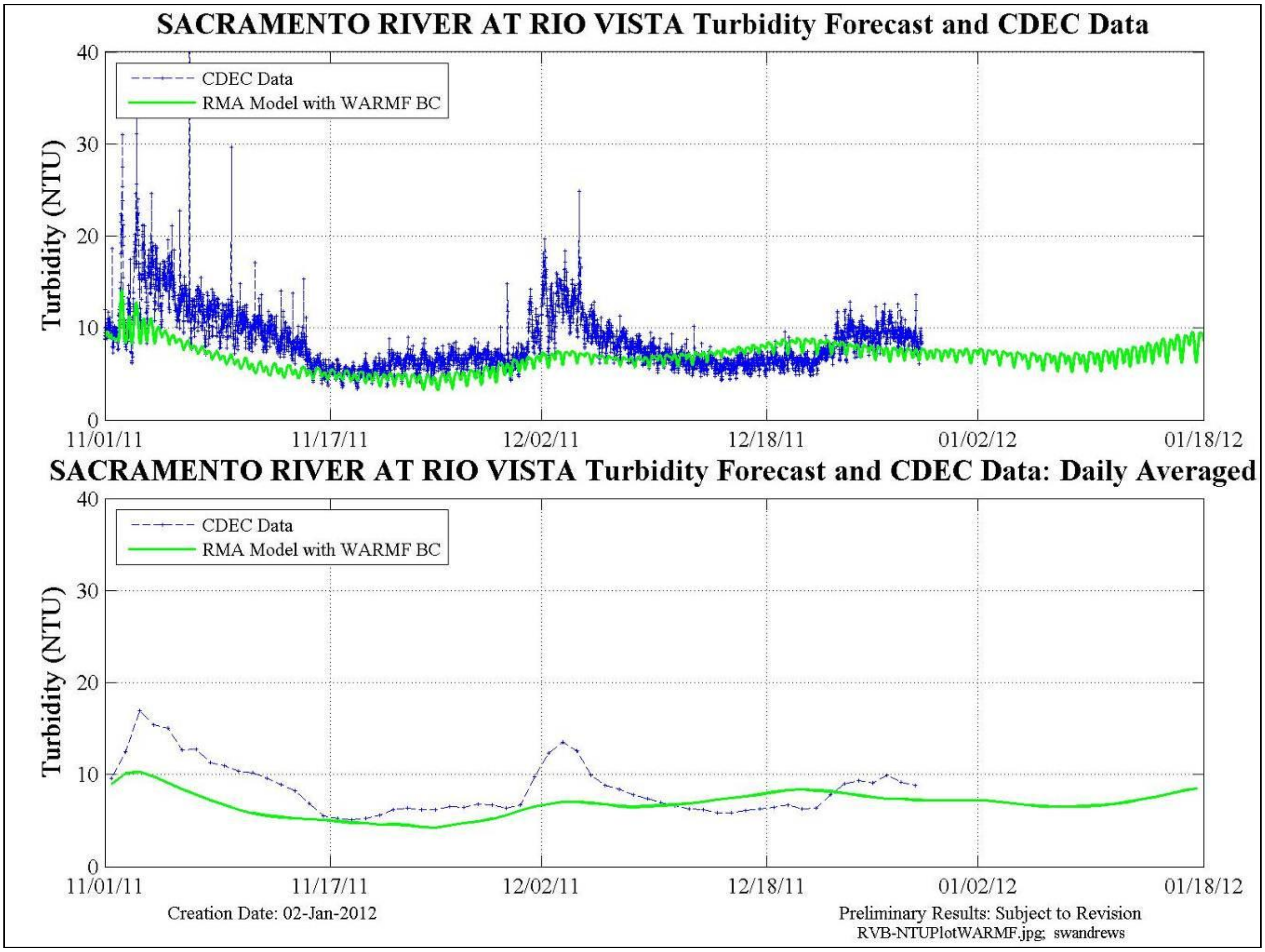

Figure 34 Model turbidity using the WARMF turbidity boundary conditions, and raw CDEC data at Rio Vista. Both 15-min (upper) and daily averaged (lower) plots are shown.

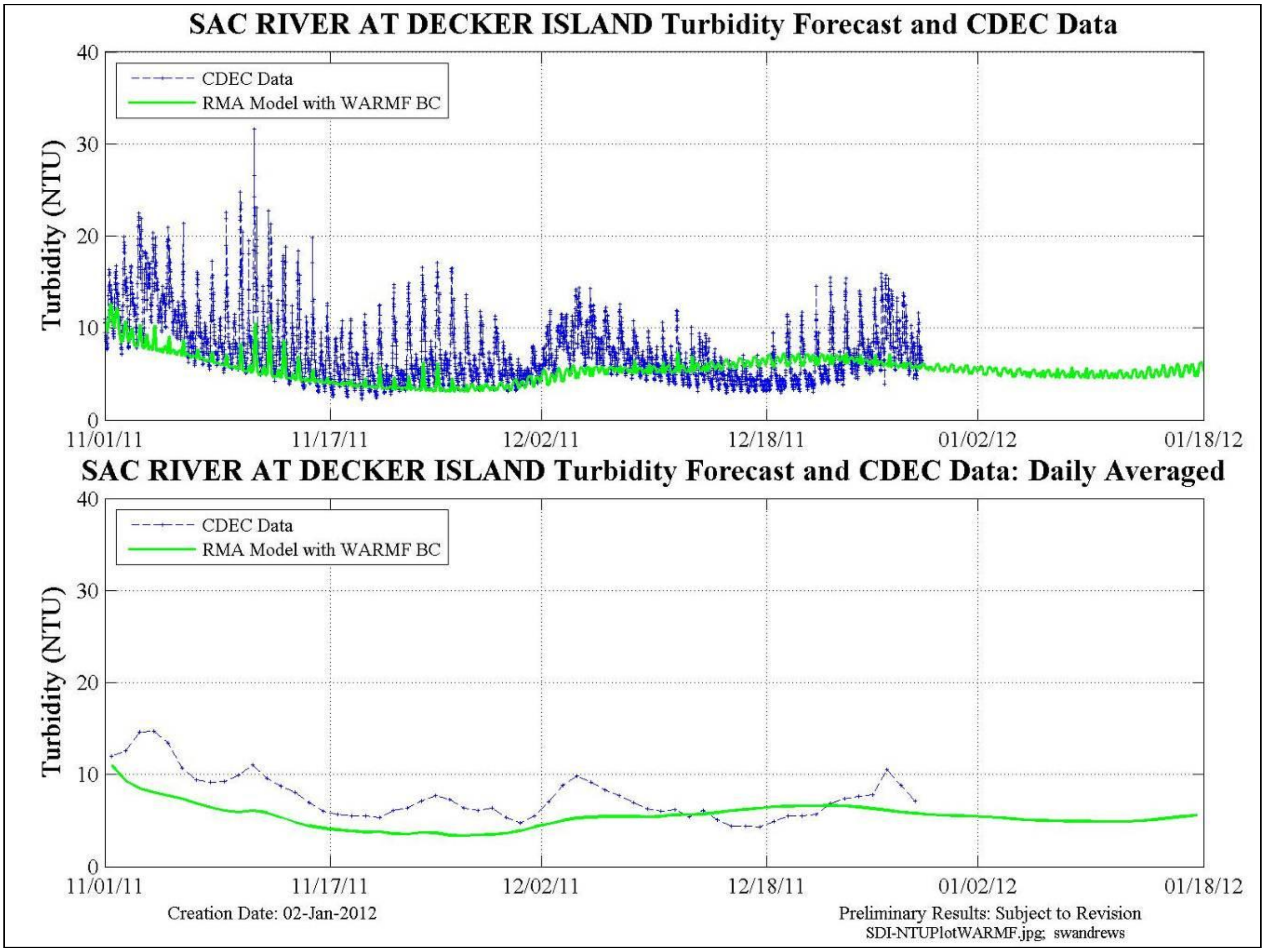

Figure 35 Model turbidity using the WARMF turbidity boundary conditions, and raw CDEC data at Decker Island. Both 15-min (upper) and daily averaged (lower) plots are shown.

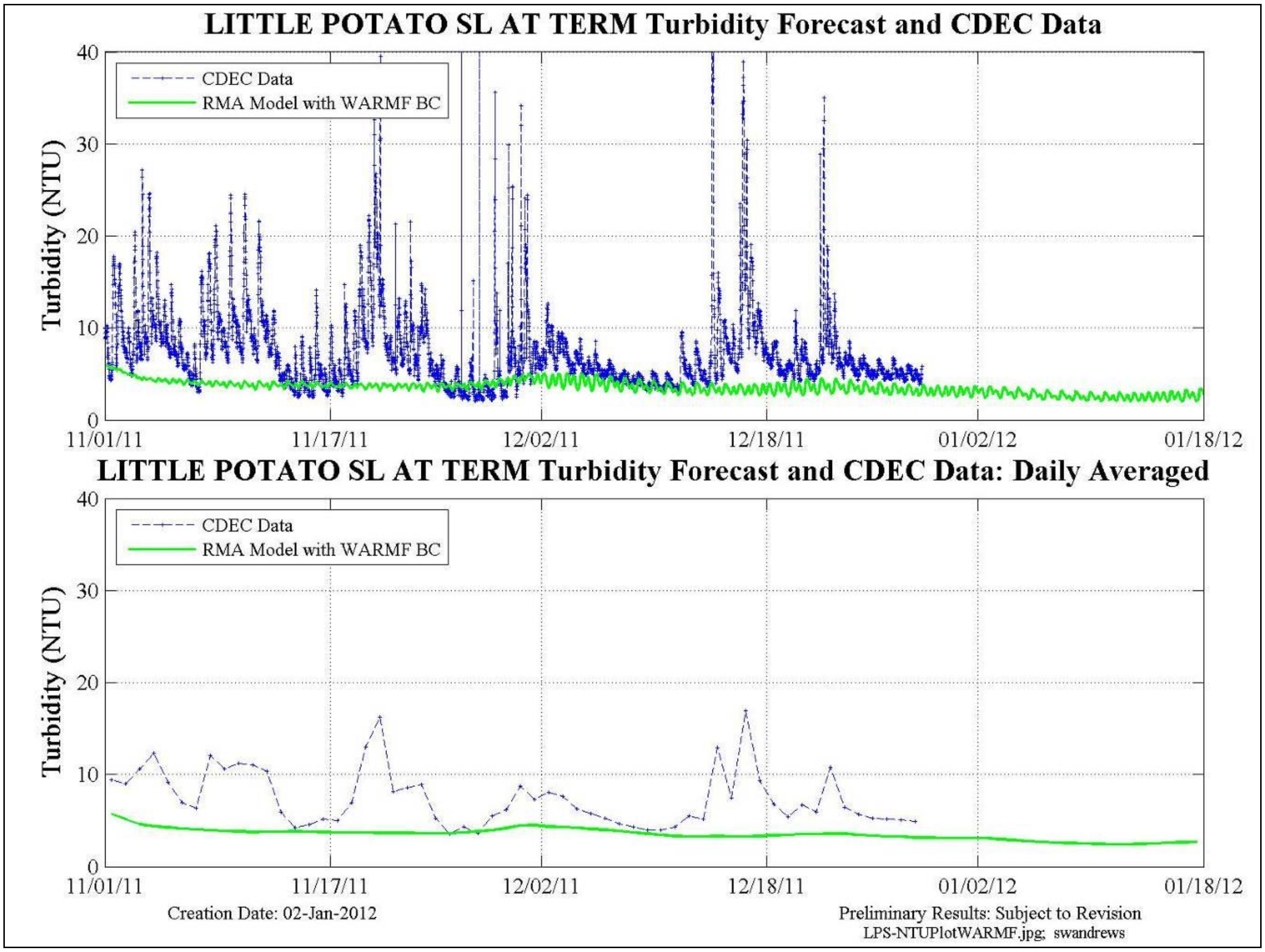

Figure 36 Model turbidity using the WARMF turbidity boundary conditions, and raw CDEC data at Little Potato Slough at Terminous. Both 15-min (upper) and daily averaged (lower) plots are shown.

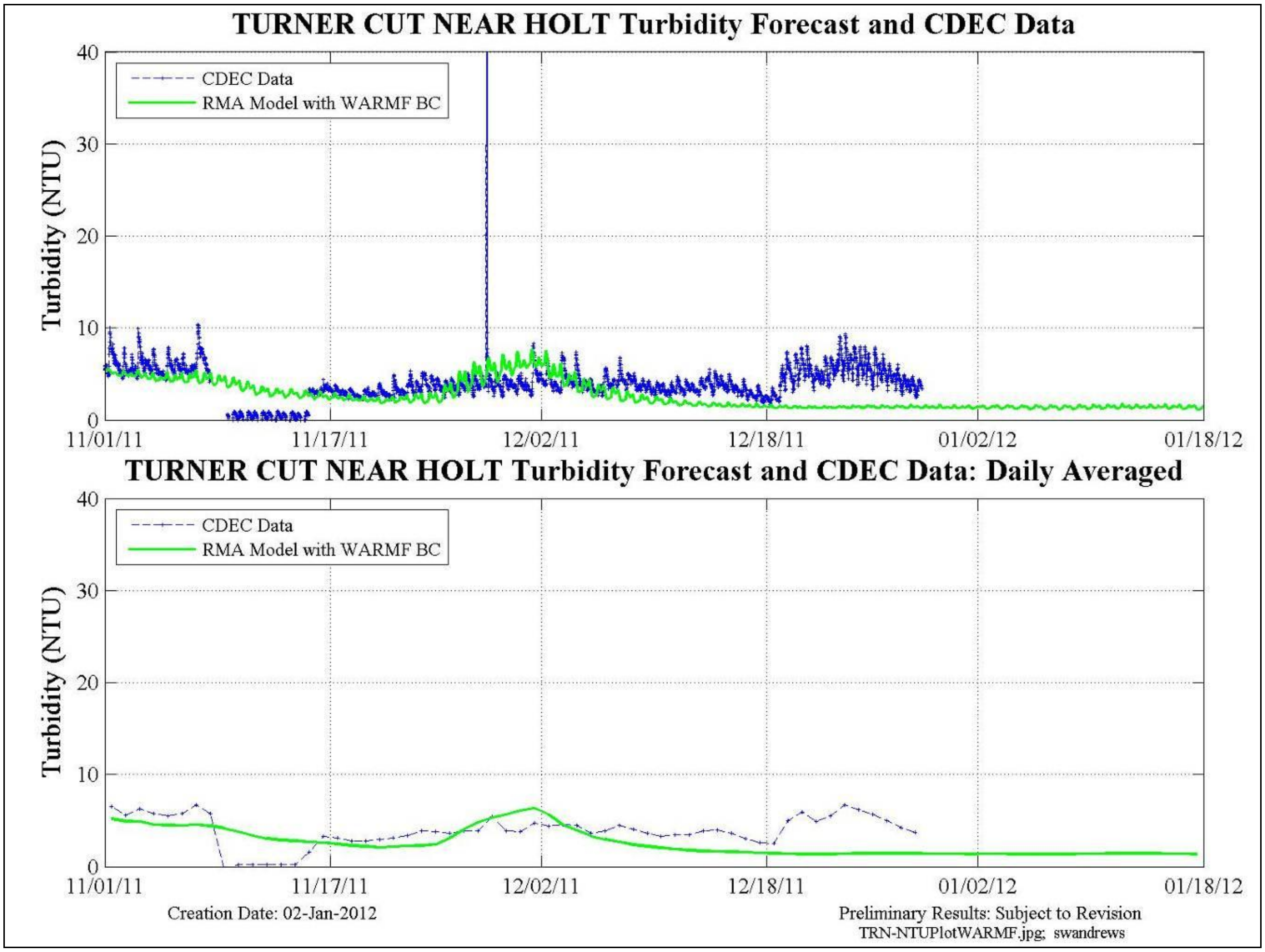

Figure 37 Model turbidity using the WARMF turbidity boundary conditions, and raw CDEC data at Turner Cut near Holt. Both 15-min (upper) and daily averaged (lower) plots are shown.

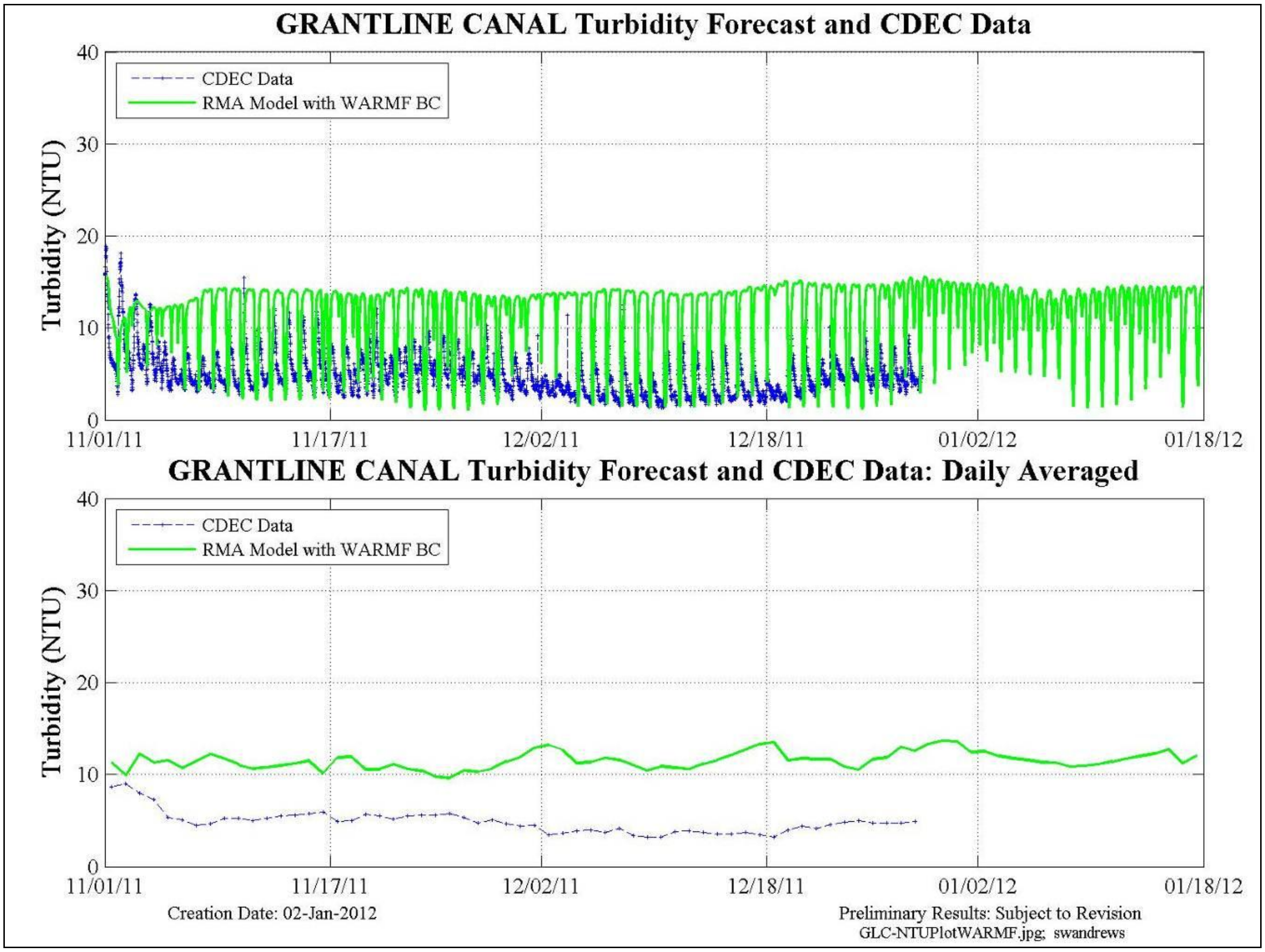

Figure 38 Model turbidity using the WARMF turbidity boundary conditions, and raw CDEC data at Grant Line. Both 15-min (upper) and daily averaged (lower) plots are shown.

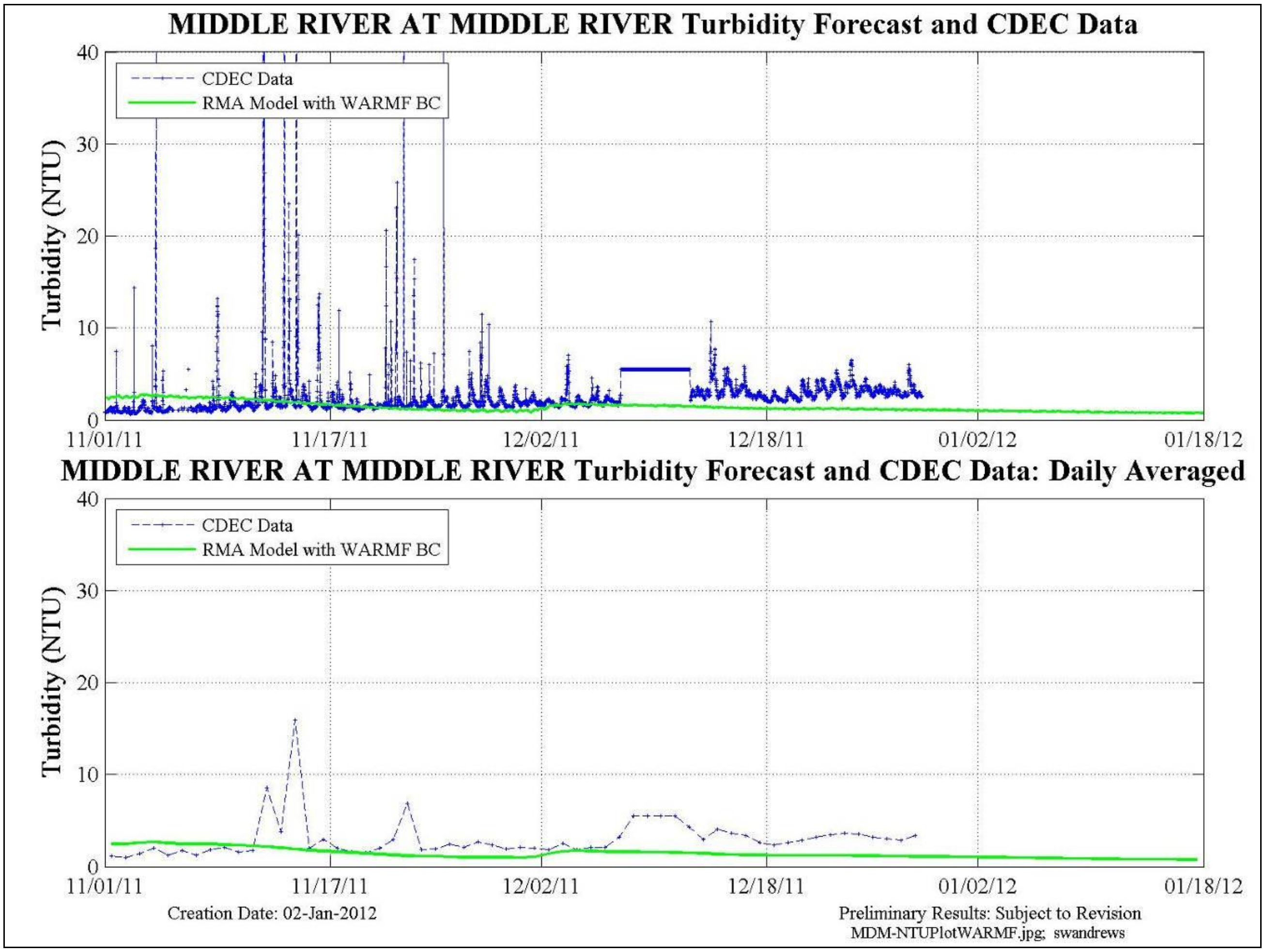

Figure 39 Model turbidity using the WARMF turbidity boundary conditions, and raw CDEC data at Middle R. at Middle R. Both 15-min (upper) and daily averaged (lower) plots are shown.

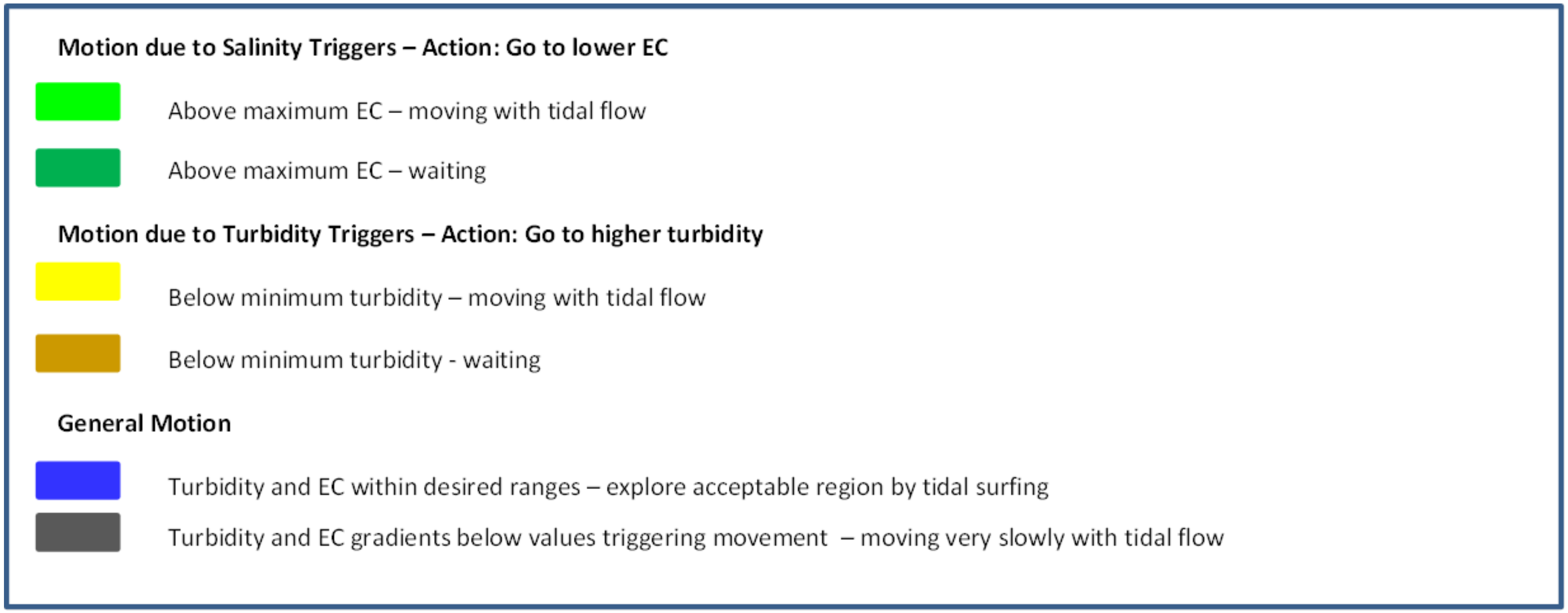

Figure 40 Particles in the Adult Delta Smelt particle tracking model are color-coded by the triggers influencing their behavior during the simulation. Use this figure to interpret the simplified color scale in the next three figures.

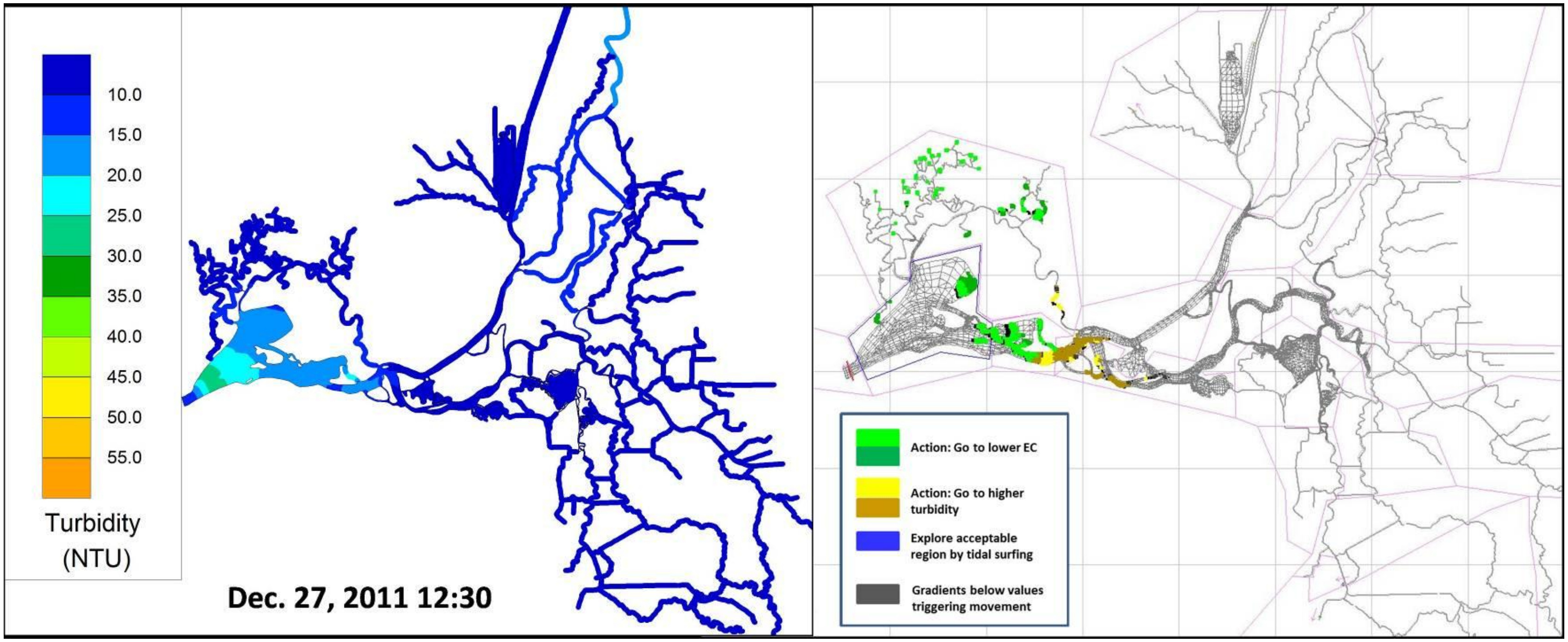

Figure 41 Turbidity contours and particle location in the RMA model grid on Dec. 27, 2011.

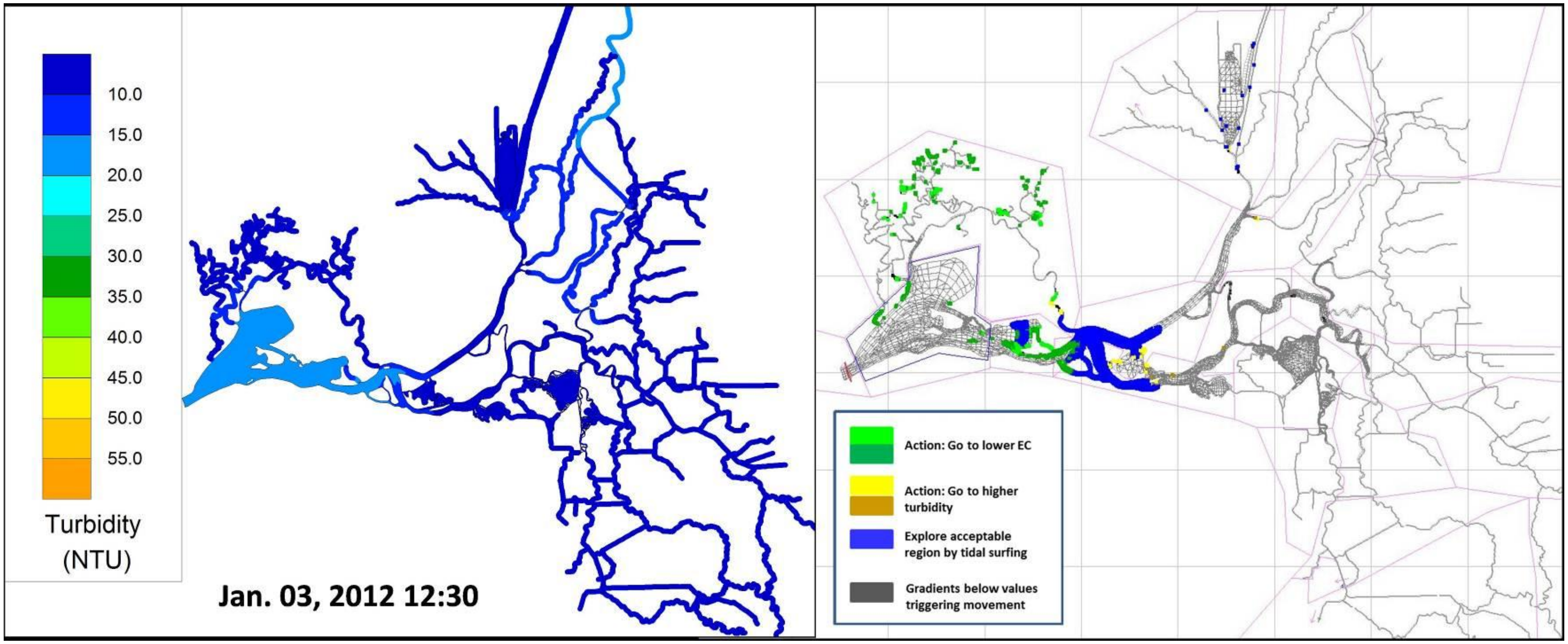

Figure 42 Turbidity contours and particle location in the RMA model grid on Jan 03, 2012.

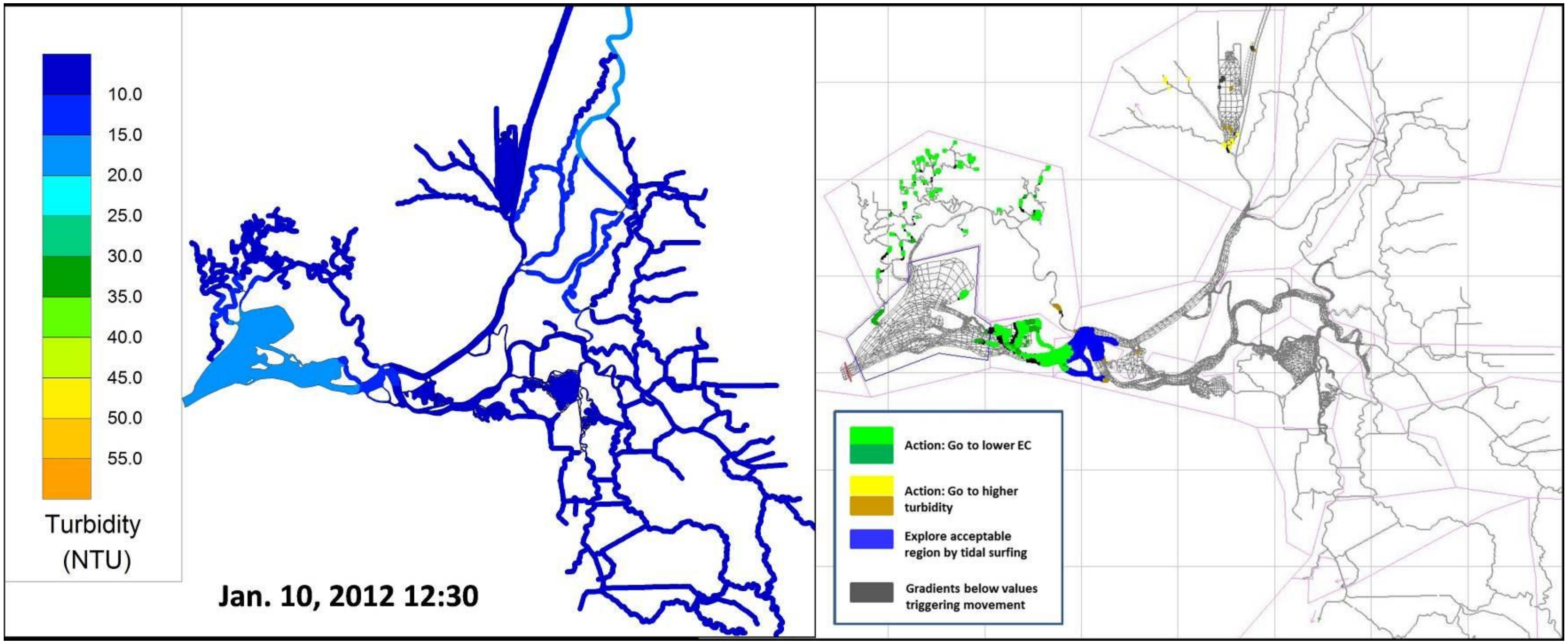

Figure 43 Turbidity contours and particle location in the RMA model grid on Jan. 10, 2012.

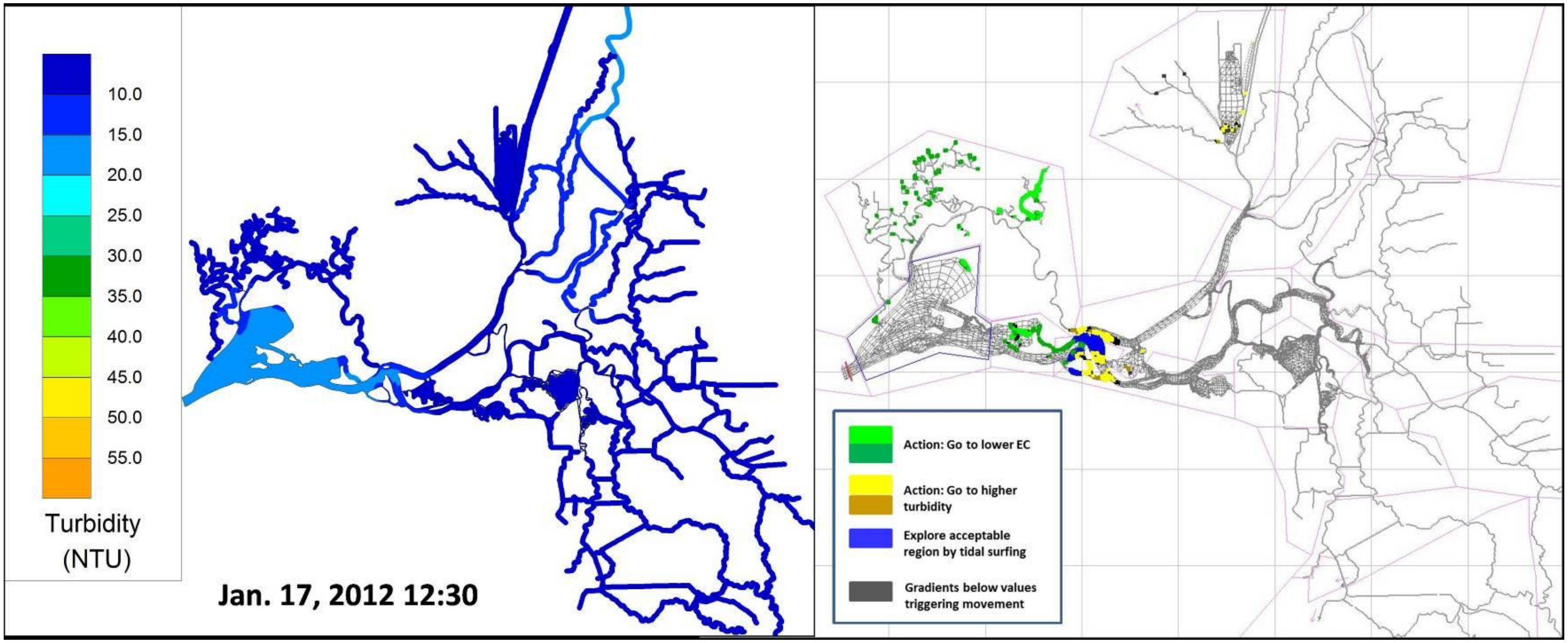

Figure 44 Turbidity contours and particle location in the RMA model grid on Jan 17, 2012.

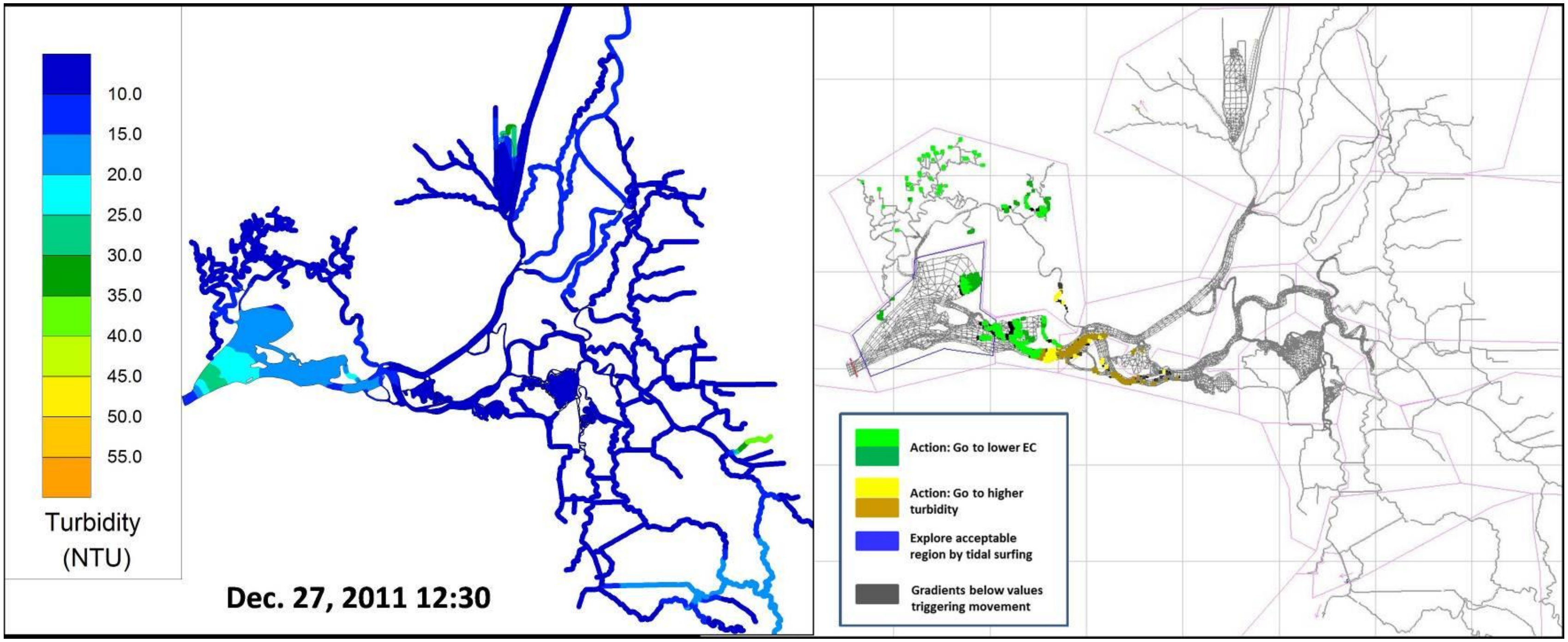

Figure 45 WARMF boundary conditions model results. Turbidity contours and particle location in the RMA model grid on Dec 27, 2011.

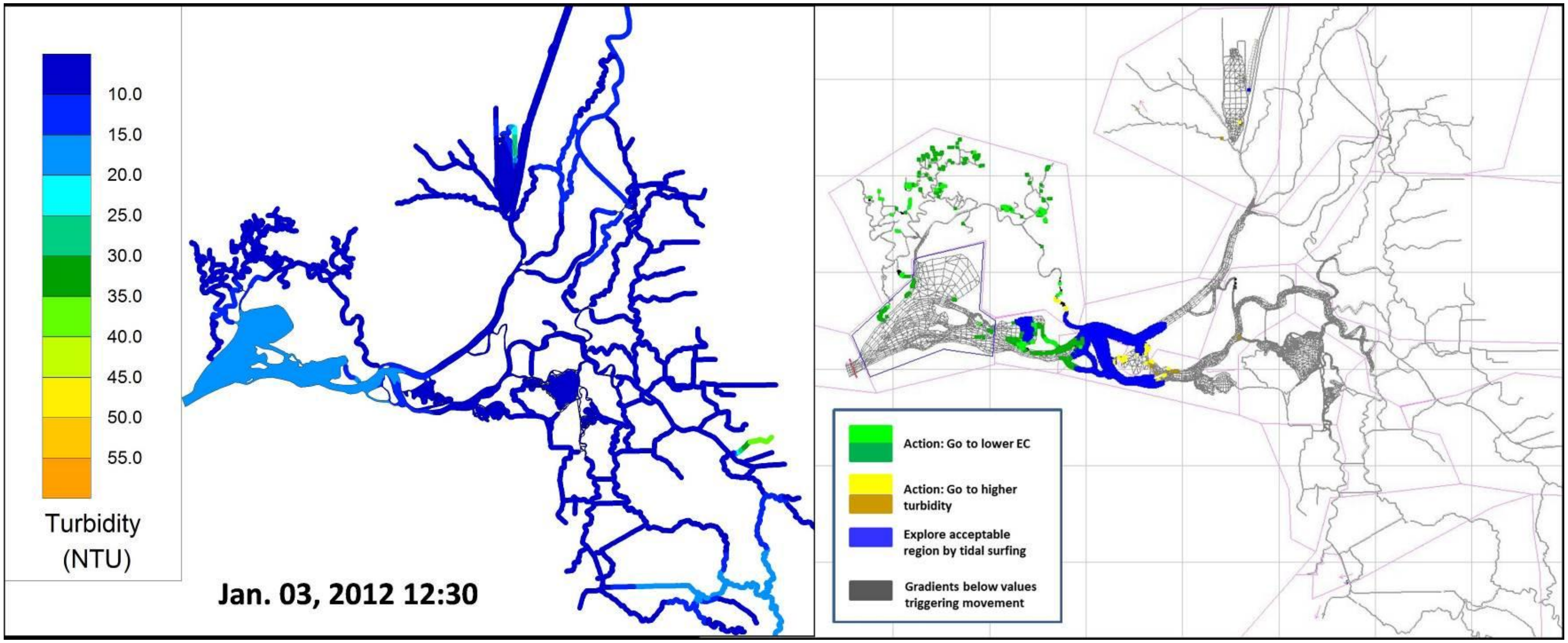

Figure 46 WARMF boundary conditions model results. Turbidity contours and particle location in the RMA model grid on Jan 03, 2012.

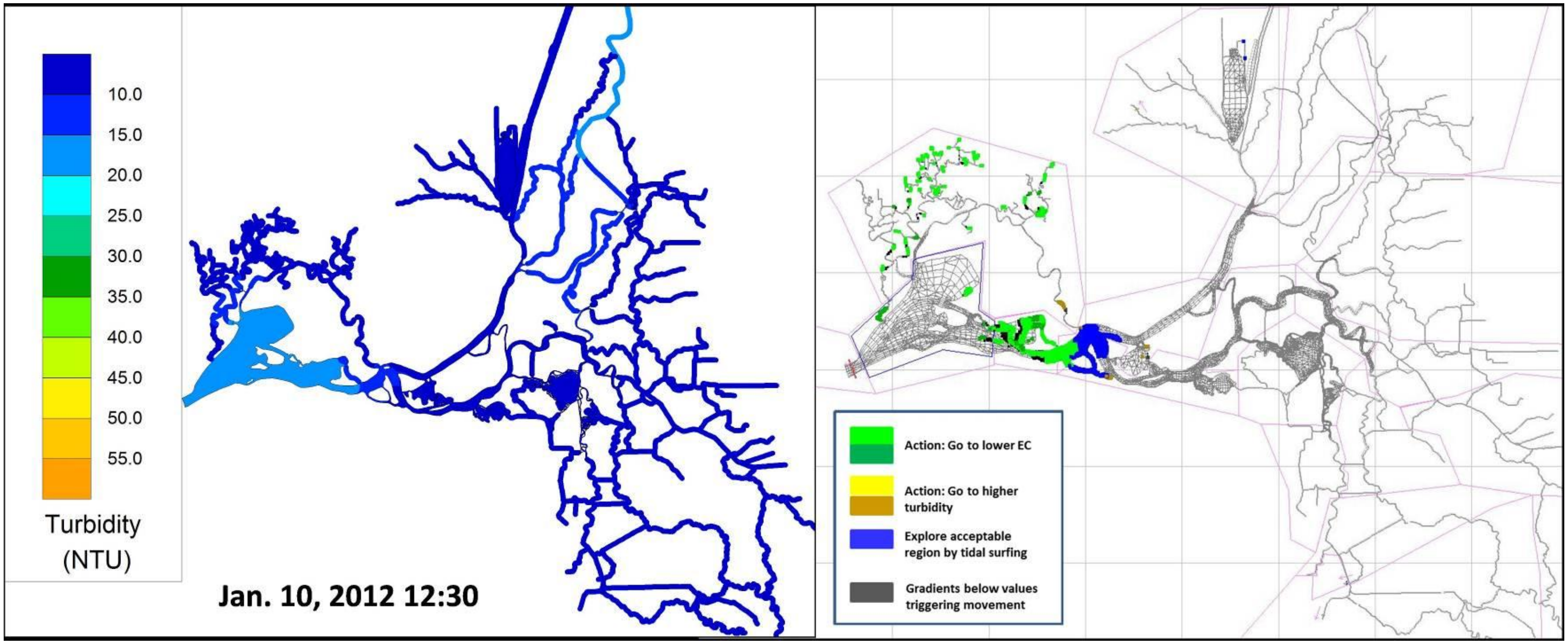

Figure 47 WARMF boundary conditions model results. Turbidity contours and particle location in the RMA model grid on Jan 10, 2012.

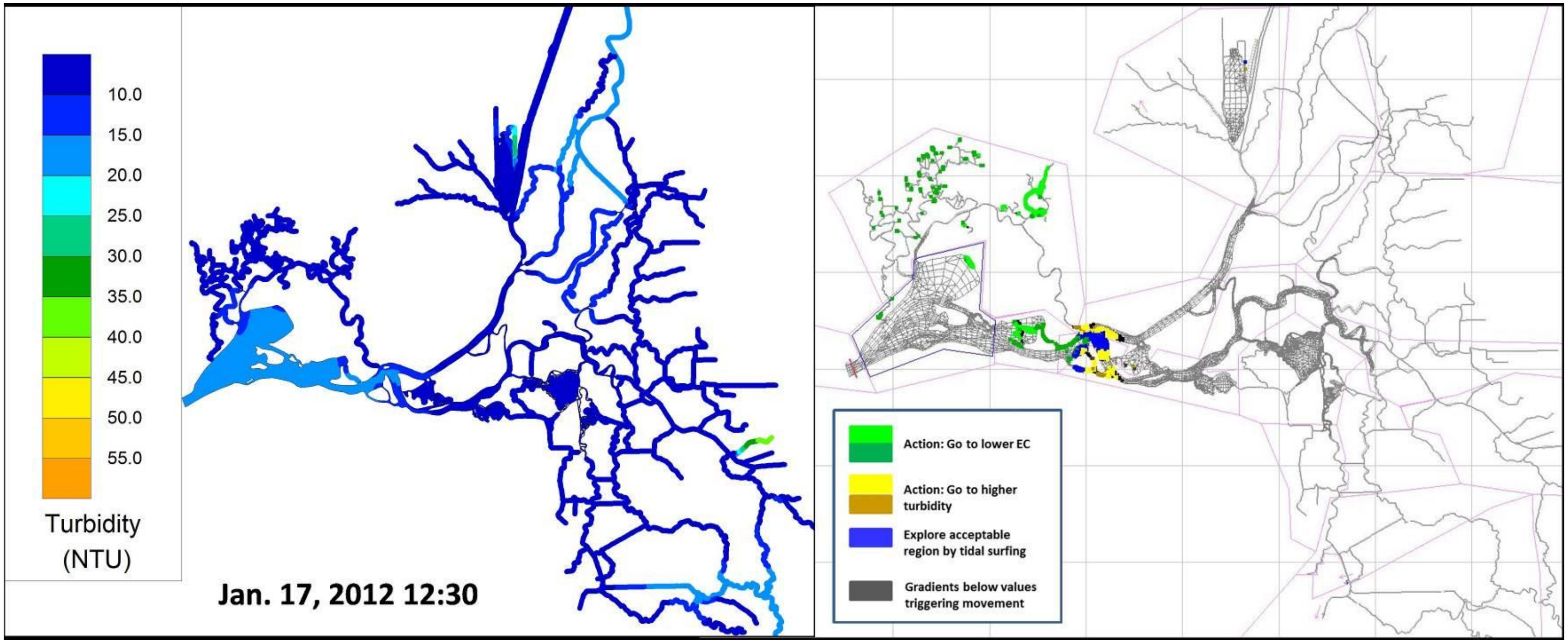

Figure 48 WARMF boundary conditions model results. Turbidity contours and particle location in the RMA model grid on Jan 17, 2012.