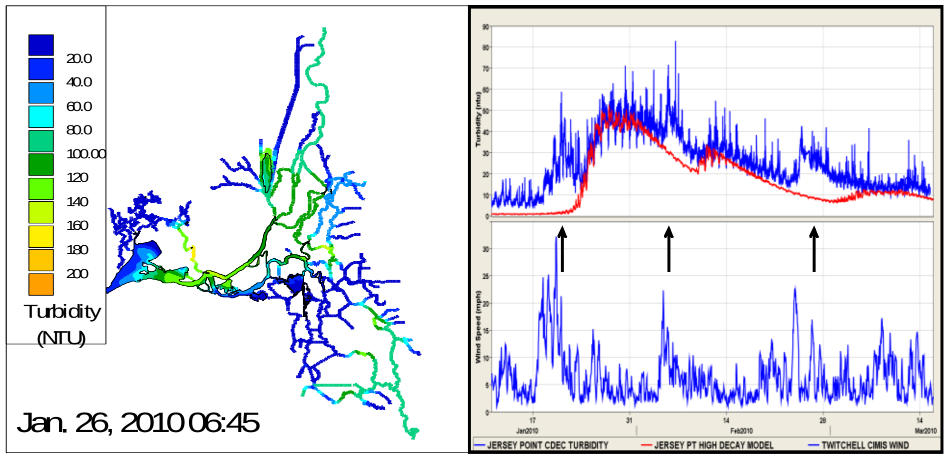
Turbidity and Adult Delta Smelt Modeling with RMA 2-D Models: December 2010 – February 2011



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1. Executive Summary

Metropolitan Water District of Southern California (MWD) has funded the development and application of a transport model simulating the distribution of turbidity in the Delta and a particle tracking model simulating a habitat-seeking behavior for adult delta smelt (RMA 2008, 2009a, 2009b, 2010a, 2010b). The particle tracking model uses EC and turbidity gradients as well as hydrodynamics to drive delta smelt movement, simulating their habitat-seeking behavior and their potential to become "salvage" in the State Water Project (SWP) and Central Valley Project (CVP) export locations.

This document describes the modeling results for Water Year 2011 (WY2011) simulating flow, turbidity, EC and delta smelt behavior using RMA models for forecasting simulations, for historical simulation (Hindcast), and for running the models under hypothetical scenarios. Documentation is included for hydrodynamic and water quality model inputs and outputs in each of these modes, as well as modeled predictions for the movement of delta smelt. Previous documentation (RMA, 2010b) covered the recent calibration efforts for the turbidity model, as well as WY2010 forecast and hindcast results. As mentioned in this previous documentation (RMA, 2010b), turbidity modeling does not incorporate the in-Delta storage and release of sediments, for example due to changes in channel velocity or wind-driven effects, so RMA's turbidity model cannot capture these sinks and sources of turbidity.

In cooperation with the Department of Water Resources (DWR) Operations and Maintenance (O&M) staff and Joel Herr from Systech Engineering (Systech[1]), RMA used O&M-supplied flow and salinity forecast model input and output used for DSM2 weekly forecasts and Systech-supplied flow, salinity and turbidity forecast model output from Systech's WARMF model as a basis for developing a two-dimensional modeling protocol for short-term hydrodynamic, water quality and particle tracking forecasting in RMA models. The methodology described in this document differs from previous methodology (RMA, 2010b) with the incorporation of WARMF model output as boundary conditions in RMA models at some locations, particularly for turbidity. Although the WARMF model offers great promise for forecasting water quality at RMA model boundaries, the use of WARMF model output as an additional source of information had several aspects which complicated the timely production of forecasts.

In forecasting mode, the incorporation of the WARMF model output into the forecasting data stream significantly increased the complexity of and the amount time needed for the development of boundary conditions. As an additional source of information, WARMF model

[1] http://www.systechengineering.com/

results increased the effort needed to create a logically consistent set of boundary conditions for forecasting. Also, because the WARMF model was apparently being developed during the forecast period, the quality of the results could change between forecasts, imposing an additional QA/QC burden on forecast preparation.

Although useful as an additional source of boundary conditions for forecasting at some locations, WARMF water quality results at some boundaries were not reliable enough to use directly, as evidenced by downstream RMA forecasting model results. For example, WARMF modeled turbidity at the Calaveras R. boundary was found to be too high by up to an order of magnitude.

Weekly forecast simulations were conducted roughly from December 2010 through early February 2011. DWR's weekly forecasts were generally delivered mid- to late-afternoon Thursday, and WARMF model results were generally delivered on Thursday afternoon. This schedule made timely compilation of results into model boundary conditions a demanding process. In order to send model results to 34North for web publishing by Friday afternoon, the RMA2 hydrodynamic forecast model run had to be completed Thursday night in order to run the RMA11 salinity and turbidity forecast models Friday morning. The results and analysis of the delta smelt particle tracking model was not finished until the following Monday morning. Documentation of model results was generally sent to MWD staff on Tuesday.

For each forecast, the RMA modeled and forecast time periods depended on the week in question. Although O&M forecast conditions extended three weeks into the future, the forecasts themselves were generally delivered to RMA several days after the start of their forecast period so the RMA forecast period was offset from O&M's. Data was used to fill-in boundary conditions in the period between the beginning of the O&M forecast and the date the RMA forecast was run. The WARMF forecast period extended two weeks into the future. Each RMA flow, salinity and turbidity model run began at the beginning of a month, so the modeled period for a given forecast could cover two months. Each adult delta smelt model run, on the other hand, began on November 1, 2010 and proceeded through the end of the forecast period.

RMA evaluated several sources of flow boundary conditions, including those supplied by O&M, data from the USGS, CDEC and the CNRFC websites, and WARMF model output. Turbidity boundary conditions were developed from CDEC data and from WARMF model output. Salinity boundary conditions were developed from a mixture of O&M forecast materials, CDEC data and WARMF model output.

The turbidity model results for the WY2011 hindcast followed the magnitude and trend of turbidity measurements through most of the Delta, with better results than the WY2010 hindcast at some locations. The improvement is due to the expansion of the database of in-Delta turbidity measurements available through CDEC for this water year - four new stations were used. The new turbidity time series for the South Mokelumne R. station was used to supply turbidity boundary conditions for the Cosumnes and Mokelumne Rivers, with very good model results at downstream locations. The turbidity measurement in Cache Sl. at Ryer Island was used for the Yolo boundary. Using a scaled value for the WARMF Calaveras River turbidity boundary condition produced better timing for the turbidity field downstream locations than the methodology used in WY2010.

A turbidity bridge never formed in the south/central Delta regions during the Hindcast period. The adult delta smelt behavioral model results for the Hindcast showed no particles reached the export locations. This result is in general agreement with salvage data, as only twelve delta smelt were salvaged from November 2010 through February 2011.

One hypothetical scenario was implemented – the Modified Deriso scenario – to examine the effect of increases in SWP export rates on the turbidity field and the movement of particles in the adult delta smelt model. The Modified Deriso scenario resulted in changes on the order of a few NTU in the turbidity field in the south Delta in comparison with the Hindcast. The changes in particle distribution were also small in comparison with the Hindcast model - up to a couple of percent – but the changes extended into the north Delta. Exports volumes increased by 47 TAF (Thousand Acre-Feet) in December 2010, 159 TAF in January, 2011 and 108 TAF in February, 2011, for a 3-month total increase of 314 TAF.

The following are suggestions on ways to improve and simplify the forecast methodology, and to make WARMF model output a more useful supplement to currently available data:

- Develop a methodology for forecasting bottom salinity for the RMA11 EC simulations.
    - Forecast salinity distribution in the Delta is not being modeled in accordance with standard RMA protocol. This introduces error in modeled salinity during low outflow periods.
- Develop tools to automate or partially automate development of forecast model boundary conditions (*i.e.*, to merge time series) to decrease work load and forecast preparation time.
- Develop a protocol and a tool to automate an initial survey of turbidity data to eliminate clearly spurious measurements.
- Acquire additional data if possible in the Yolo/Cache Sl./Liberty Island area and or the Eastside inflow locations to improve the development of EC and turbidity boundary conditions in those areas.
- Develop better relationships between WARMF-simulated sediment load and the turbidity boundary condition supplied to RMA:

- If the current WARMF calibration is used, Systech can use the RMA turbidity hindcast run as a basis to develop better relationships between WARMF sediment calculations and turbidity.
- If the WARMF model calibration is improved, running the RMA hindcast with the improved model results can demonstrate the improvement in downstream results in the Delta.

2. Objectives

The objectives of the work summarized in this document are to: revise and document the methodology for producing hydrodynamic, water quality (EC and turbidity), and adult delta smelt behavioral forecasting in conjunction with real-time data monitoring activities, DWR O&M group forecasting, and WARMF model output; to prepare and document a historical hindcast for the period November 2010 – February 2011; and, to document the results of a scenario testing hypothetical alteration of the SWP and CVP pumping regimes to control the turbidity of water in the central Delta.

Using previous work funded by Metropolitan Water District (MWD) as a starting point, for WY2011 the near-real-time forecasting methodology for flow, EC and turbidity was modified to incorporate WARMF forecast model output for salinity and turbidity. Forecasts were conducted roughly from December 2010 through February 2011 using historical and forecast operations provided by DWR's Operations and Maintenance group for the hydrodynamics and salinity boundary conditions, and using WARMF forecast boundary conditions developed by Systech.

3. Background

The work discussed in this document builds on previous work funded by MWD to develop methodologies to model and forecast turbidity (RMA 2008, 2009a, 2009b, 2010a, 2010b) and to simulate the movement of adult delta smelt during periods of high Delta inflow based on simulated distributions of salinity (represented as electrical conductivity, EC) and turbidity using a particle tracking behavior model (RMA, 2008). Because turbidity is hypothesized as an important driver for the distribution of adult delta smelt, the ability to minimize adult entrainment is assumed to be dependent on monitoring and potentially controlling and reducing the progress of turbidity plumes from the Sacramento and San Joaquin Rivers, and possibly from other boundary inflows, into the central Delta through Old and Middle Rivers downstream of the export facilities.

One of the main applications of the turbidity model summarized in this document is its use in a near-real-time context to forecast water quality parameters that are used in the prediction of delta smelt distributions using the RMA adult delta smelt behavioral model. In addition, the turbidity model is used to develop a hindcast turbidity simulation and in the development of 'what-if' scenarios.

3.1. Previous turbidity models

Hydrodynamics and turbidity were simulated and turbidity was calibrated (a "reconnaissance" level calibration) using the RMA Bay-Delta Model for Water Year 2010. Locations of turbidity data available at that time are shown in Figure 3-1. Other turbidity models developed at RMA are documented in (RMA, 2010b).

3.2. New Turbidity Measurement Locations in the Delta

Four new turbidity monitoring stations were added to the Delta network this water year – they are indicated in Figure 3-2.

3.3. RMA Delta model configuration

3.3.1. RMA numerical models

Documentation on the RMA suite of finite element hydrodynamic and water quality models employed for this study can be found in (RMA, 2010b). Hydrodynamics are simulated using RMA-2, a two-dimensional depth-averaged finite element model. Salinity and turbidity are simulated using RMA-11. RMA-11 has been designed for compatibility with model results obtained from one-, two-, or three-dimensional hydrodynamic simulations (King, 1995). Velocities and water depths obtained from hydrodynamic model results are used to solve the advection-dispersion equation for each water quality constituent simulated.

3.3.2. Grid and bathymetry

The RMA finite element gird of the Delta, shown in Figure 3-3 extends from Martinez to the confluence of the American and Sacramento Rivers and to Vernalis on the San Joaquin River. A two-dimensional depth-averaged approximation is used to represent the Suisun Bay region, the Sacramento-San Joaquin confluence area, Sherman Lake, Liberty Island, the Sacramento River up to Rio Vista, Big Break, the San Joaquin River up to its confluence with Middle River, False River, Franks Tract and surrounding channels, Old River south of Franks Tract, and the Delta Cross Channel area. Delta channels and tributary streams are represented using a one-dimensional cross-sectionally averaged approximation.

The RMA-Delta network used for the RMA forecast modeling is the same as that used in preparing the WY 2010 forecasts (RMA, 2010b).

3.3.3. Stage and flow boundaries

Boundary conditions for hydrodynamics include tidal elevations at the Martinez boundary and tributary inflows to the system and exports (see Figure 3-3). Details on setting the hydrodynamic boundary conditions for the forecast, hindcast and hypothetical scenario model applications are covered under the specific sections as different strategies were used depending on the application.

Delta exports applied in the model include State Water Project (SWP), Central Valley Project (CVP), Contra Costa Water District diversions and exports at Rock Slough and at the Old River and Victoria Canal intakes, respectively. Finally, exports are applied at the North Bay Aqueduct.

3.3.4. Gates and barriers

Permanent gates and temporary barriers represented in the model include the Delta Cross Channel (DCC), Old River near Tracy (DMC) barrier, Old River at Head barrier, Middle River barrier, Montezuma Slough salinity control gates, Grant Line Canal barrier, and Lawler buffer ditch culvert (see Figure 3-4). In addition, there is a tidal gate at Rock Slough. Historical or forecast gate and barrier operations were applied in the models as appropriate.

3.3.5. DICU

Delta Island Consumptive Use (DICU) values were applied on a monthly average basis and were derived from monthly DSM2 input values[2].

3.3.6. Salinity and turbidity

Salinity and turbidity concentration time series are required at all inflow locations and at the stage boundary at Martinez. Electrical conductivity (EC) is used as a surrogate for salinity and modeled as a conservative constituent. Turbidity is conceptualized as a non-conservative constituent with decay. At DICU locations, the turbidity of the inflow is assumed to be the ambient concentration (i.e., the DICU inflow concentration is equal to the concentration in that cell during the computational step). EC concentrations at DICU locations are derived from DSM2 input values.

3.3.7. Turbidity model – regional decay values

A three-region model, shown in Figure 3-5, was used to model the turbidity regime with three decay parameters.

[2] http://baydeltaoffice.water.ca.gov/modeling/deltamodeling/models/dicu/dicu.cfm

3.4. Meteorological data (CIMIS)

CIMIS meteorological data was delivered by email on a weekly basis for several CIMIS locations – Hastings Tract, Lodi West, Tracy and Twitchell – the approximate locations are shown in Figure 3-6. Wind and rainfall data for the RMA forecast periods from these four locations are shown in Figure 12-1 through Figure 12-4 in the Appendix. Increases in turbidity at some Delta locations are associated with wind and/or rain events during WY2011 as they were in WY2010.

3.5. Description of the WARMF model

The Watershed Analysis Risk Management Framework (WARMF) was developed under sponsorship from the Electric Power Research Institute (EPRI) as a decision support system for watershed management. The numerical model is used to simulate watershed hydrology and pollutant transport. The system provides the capability to calculate most conventional pollutants (coliform, TSS, BOD, nutrients). The scientific bases of the model and the consensus process have undergone several peer reviews by independent experts under EPA guidelines. WARMF is organized into five (5) linked modules under one GIS-based graphical user interface (GUI). More detail on the WARMF model can be found on the U.S. Environmental Protection Agency website (http://www.epa.gov/athens/wwqtsc/html/warmf.html).

A WARMF model has been developed for the watersheds draining into the Sacramento-San Joaquin Delta. WARMF has output locations that coincide with RMA inflow locations. For this project, RMA received flow, turbidity and salinity output from WARMF at the locations listed in Table 3-1.

Table 3-1 Correspondence between WARMF model output and RMA model input.

WARMF Location Nomenclature	WARMF ID	RMA Model Location
Sac-At-I-Street	R0751	Sacramento R. at Freeport
Vernalis	R0184	San Joaquin R. at Vernalis
Yolo	R0797	Yolo Bypass at Yolo-Lisbon
Mokelumne	R0061	Mokelumne R.
Cosumnes	R0062	Cosumnes R.
Calaveras	R0127	Calaveras R.

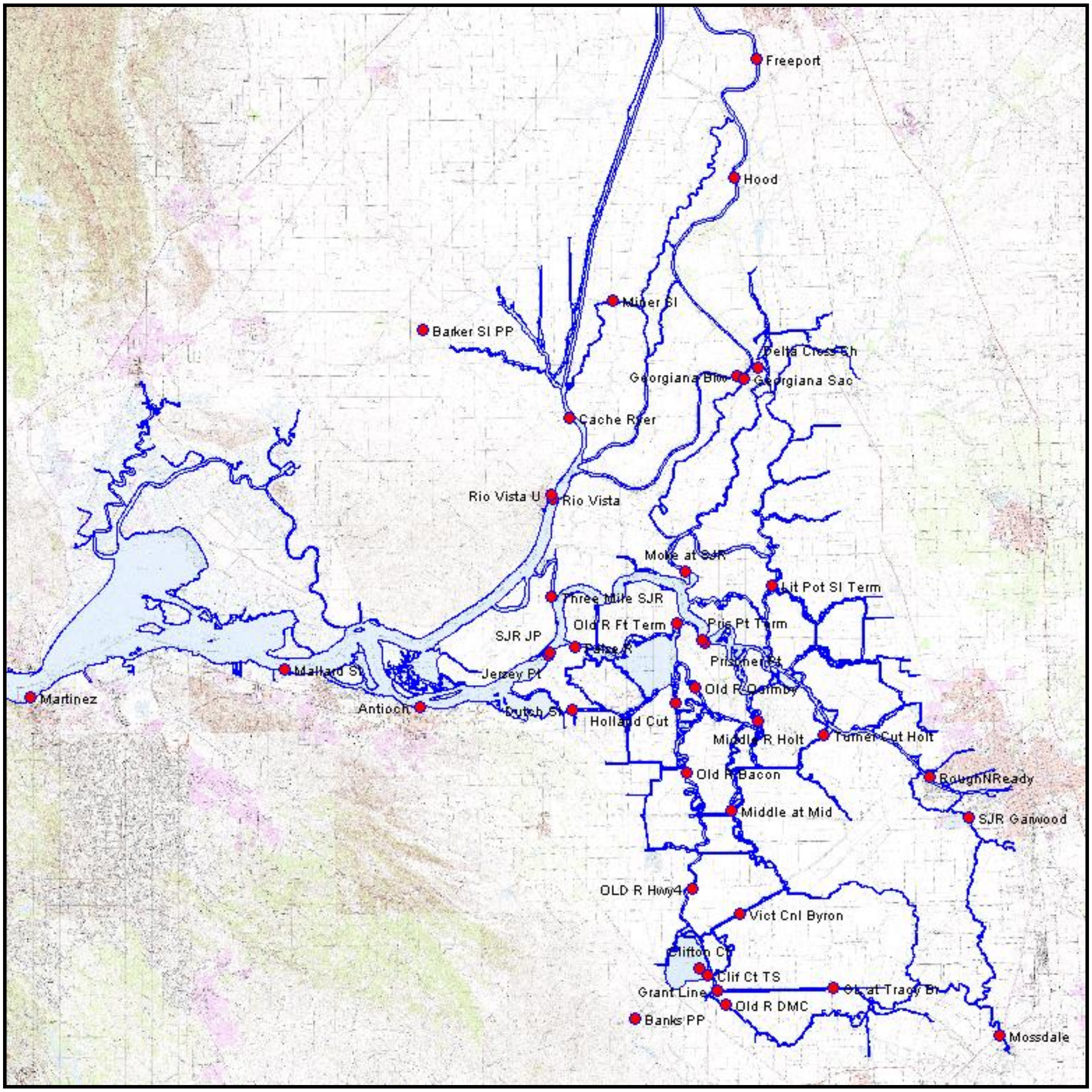


Figure 3-1 Locations of WY2010 turbidity monitoring stations.

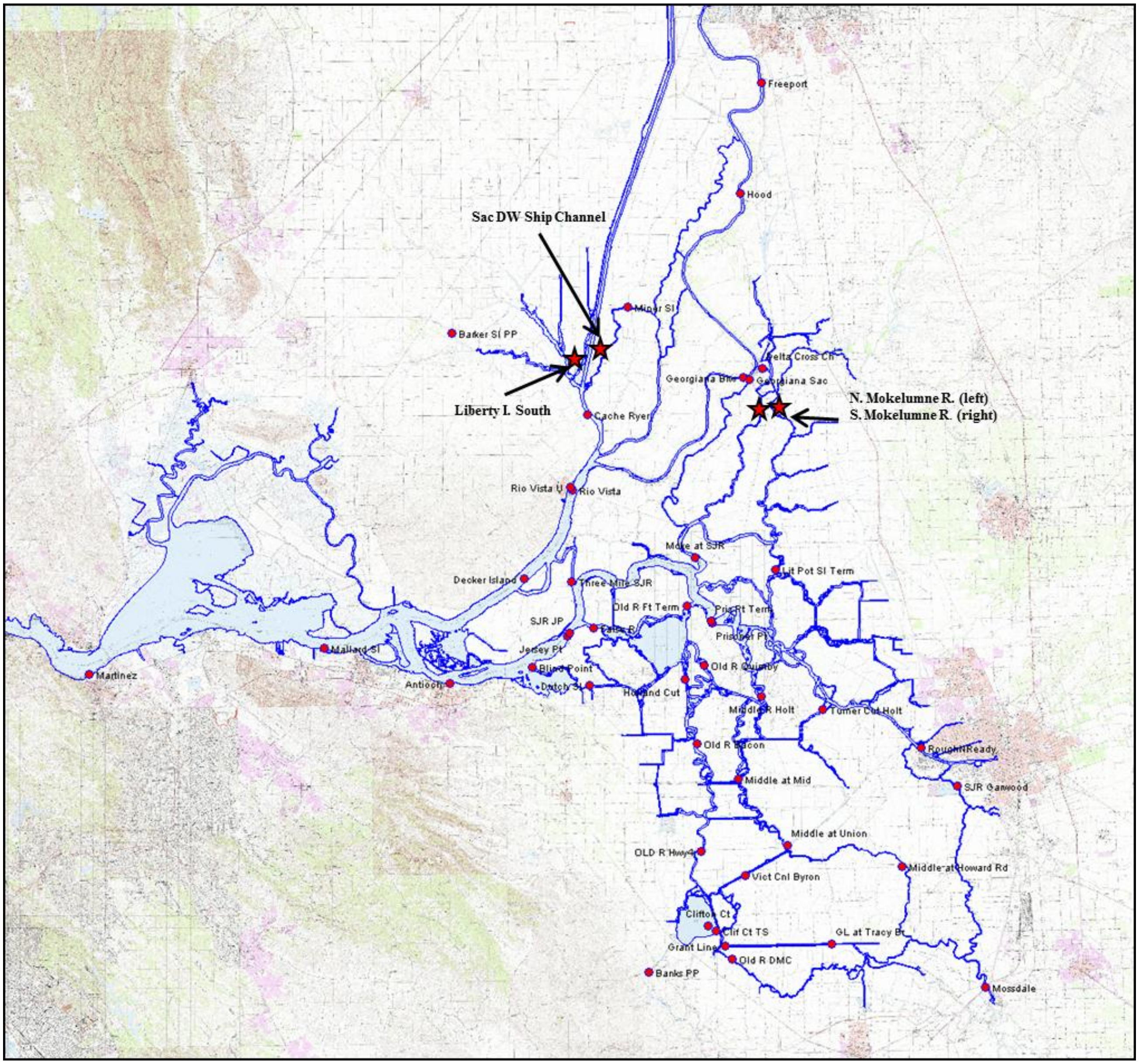


Figure 3-2 Locations of new WY2011 turbidity monitoring stations are indicated by stars, WY2010 monitoring station locations are indicated by circles.

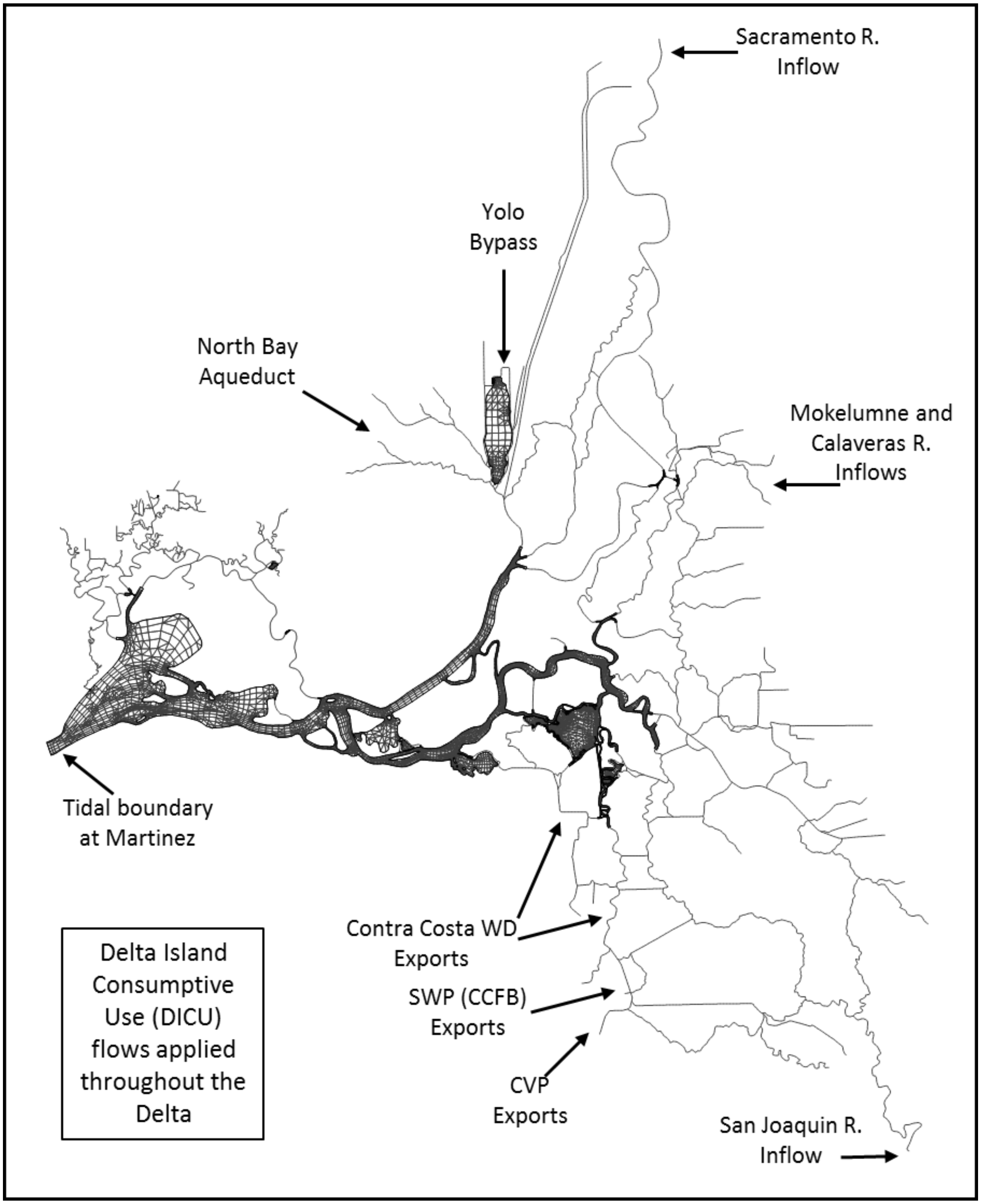


Figure 3-3 Finite element model configuration of the Sacramento – San Joaquin Delta.

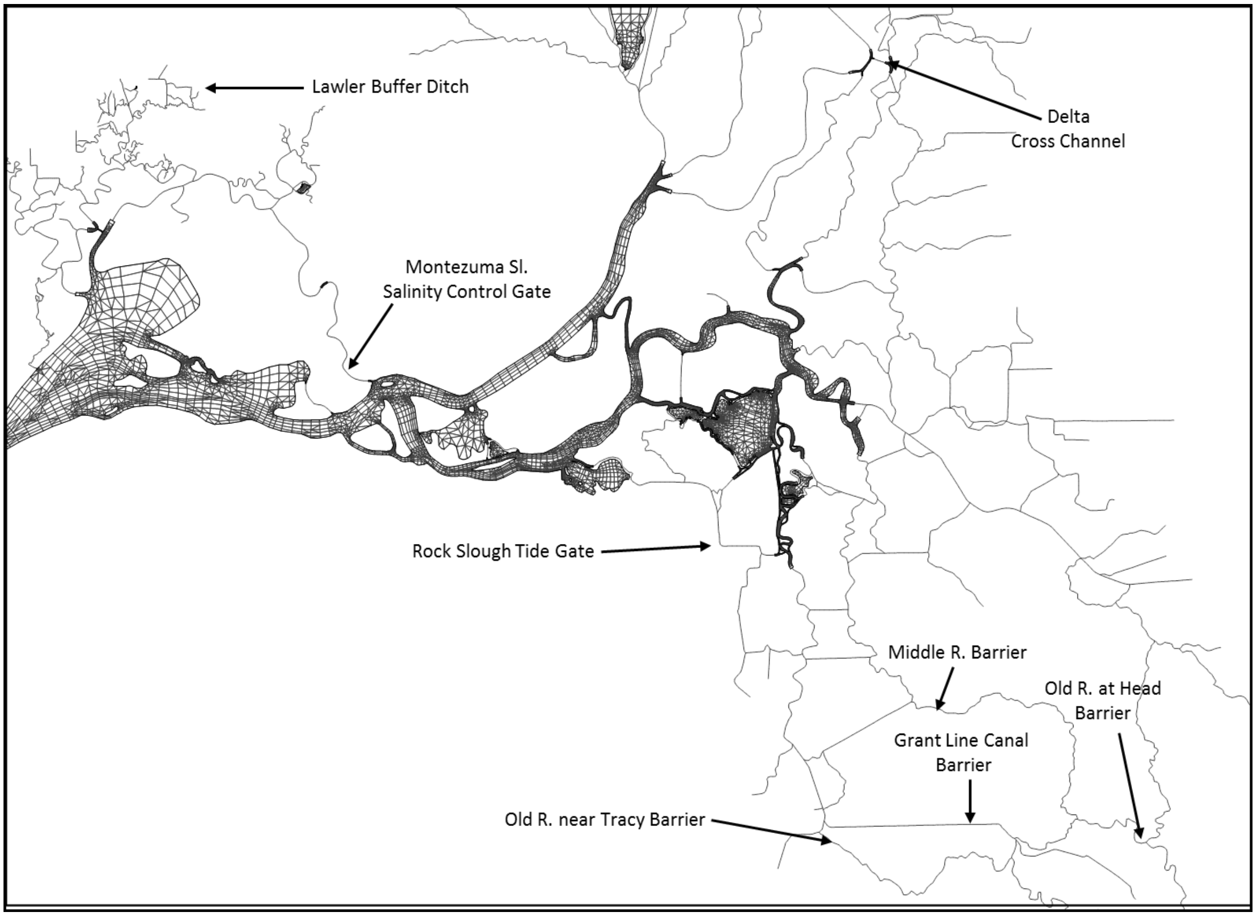


Figure 3-4 Approximate gate and barrier locations in the RMA grid.

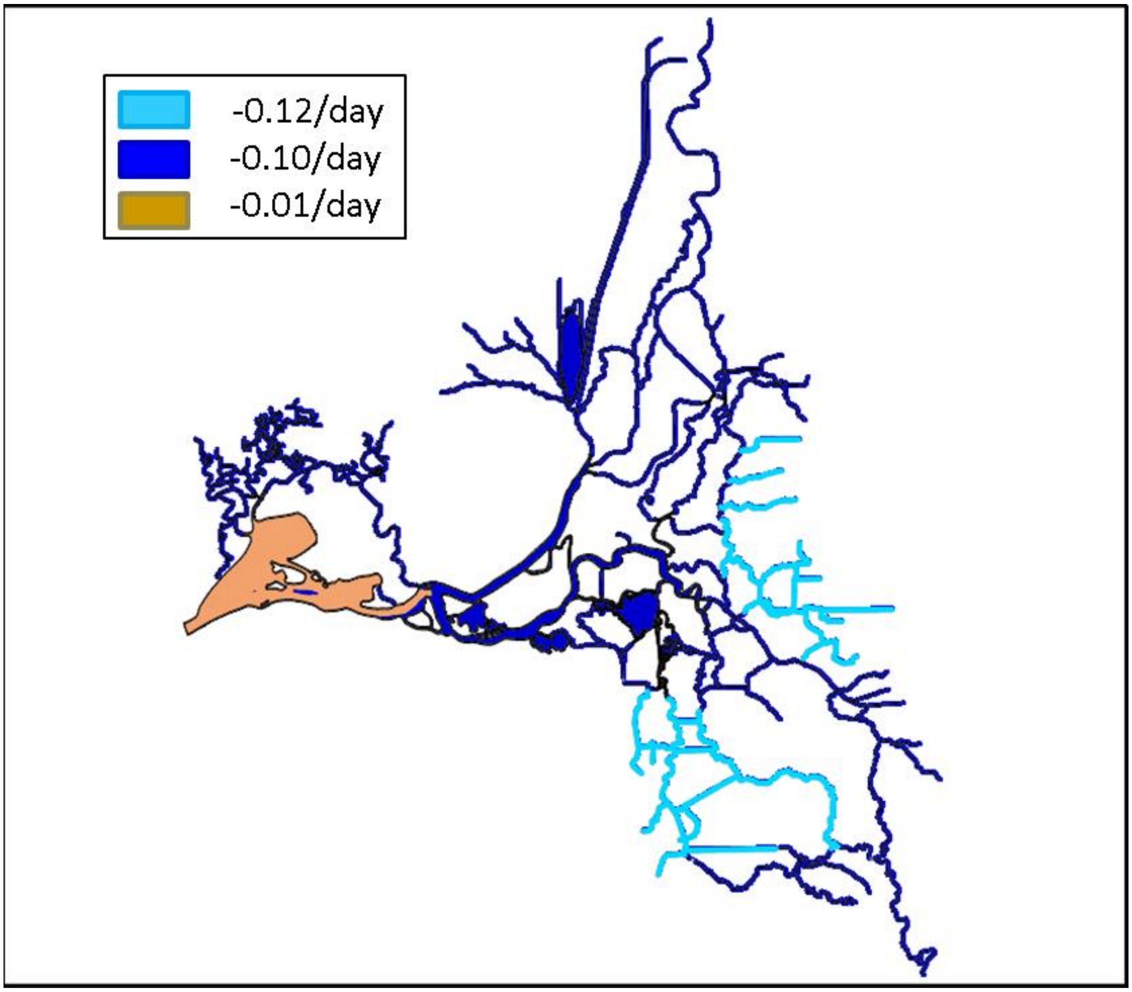


Figure 3-5 Decay values and regions used in the current turbidity model.

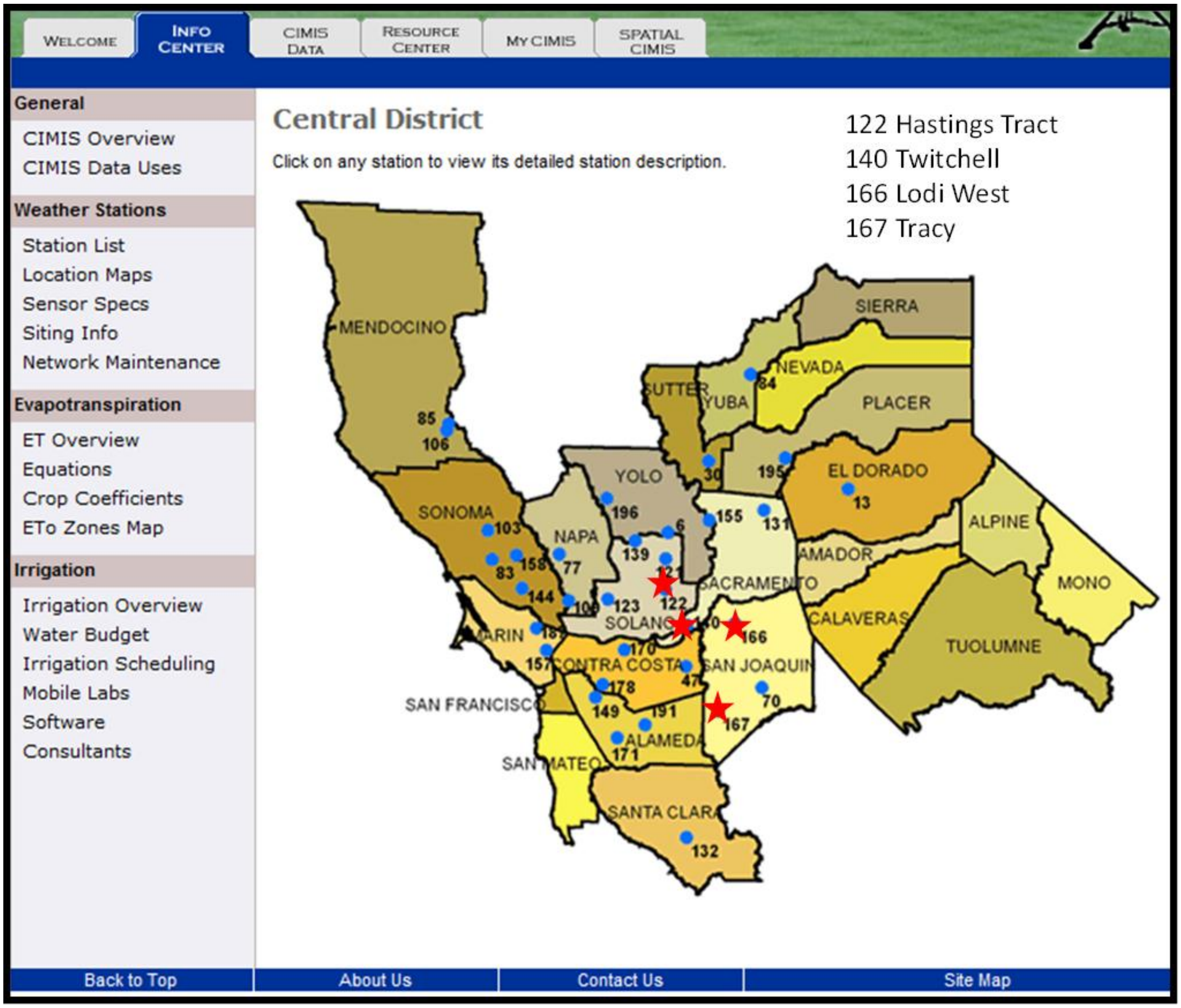


Figure 3-6 The CIMIS website map with the location of the four stations whose meteorological data was downloaded on a weekly basis (red stars).

4. Adult delta smelt particle tracking models

The basic hypotheses behind the adult delta smelt behavior model are covered in previous documents, so will not be repeated here (RMA 2009, RMA 2010b). However, the information needed to interpret current model results is summarized in this section although it also appears in previous documents (RMA, 2010b).

4.1. Adult delta smelt behavior model

During visualization of particle tracking simulations, particle behavior is color-coded by the triggers influencing their behavior during the computation. Figure 4-1 illustrates the color coding scheme.

The behavior algorithm utilizes the local concentration and gradient of electrical conductivity (EC, simulated as a surrogate for salinity) and turbidity computed by the RMA Delta Model to determine behavioral adjustments to the transport velocity for a neutrally buoyant passive particle moving with the streamline velocity.

The behavior algorithm is implemented as follows:

- If the local EC is greater than the required maximum limit
    - Surf toward lower EC.
- Else if the local turbidity is lower than the required minimum limit
    - If the local turbidity gradient is greater than the minimum detectible gradient
        - Surf toward higher turbidity
    - Else if the local turbidity gradient is lower than the minimum detectible gradient
        - Hide
- Else if the local EC is lower than the desired minimum limit
    - Surf toward higher EC.
- If the local EC and local turbidity are within required limits
    - Randomly move (explore desirable habitat).

The surfing behavior is implemented by applying a scalar velocity factor to the transport velocity vector computed for neutrally buoyant particles. The velocity factors for moving with the tidal flow and resisting tidal flow are user-defined constants. Random movement to explore desirable habitat is currently implemented as addition random mixing. When a particle is at a location where the EC is below the required maximum limit and the turbidity is above the required minimum limit, a random velocity component is computed based on user defined dispersion coefficients in the longitudinal (streamline) and transverse directions.

4.2. Adult delta smelt modeled period and particle count.

For the near-real-time simulations and the Hindcast, at the start of the simulation and before turbidity starts to increase due to a flow event, 50,000 particles were randomly distributed in the Suisun Bay Region. This insertion occurred November 01, 2011 for WY2011 as there were moderate increases in flow and turbidity in early December on the Sacramento River.

4.3. Particle observation locations

Particle numbers were recorded periodically during the simulation at individual locations, such as at the state (SWP) and federal (CVP) export locations. For the hindcast simulation, particle numbers were also evaluated at pre-defined regions of the model grid (Figure 4-3 through Figure 4-5).

4.4. Delta smelt salvage data

Delta smelt salvage data was obtained from the Bureau of Reclamations Mid-Pacific Central Valley Office (CVO) region website and from the California Department of Fish and Game website. The CVO web location that hosts the previous monthly reports is:

http://www.usbr.gov/mp/cvo/fishrpt.html

Links to current fish salvage data, as well as other CVO operational data, can be found at:

http://www.usbr.gov/mp/cvo/

Daily historical records of salvage data can be found at:

http://www.dfg.ca.gov/delta/apps/salvage/SalvageExportCalendar.aspx

Figure 4-6 illustrates the salvage numbers for delta smelt recorded at the SWP and CVP export locations from November 2010 through mid-March 2011

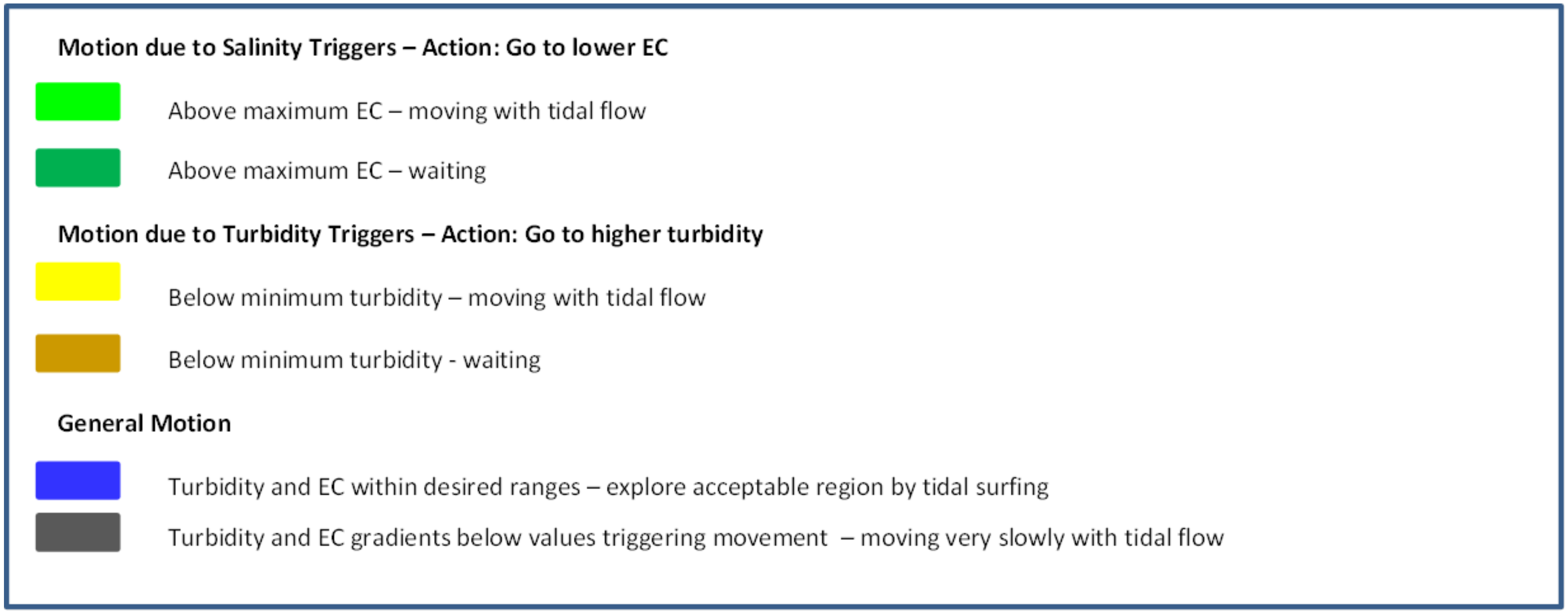


Figure 4-1 Particles in the Adult Delta Smelt particle tracking model are color-coded by the triggers influencing their behavior during the simulation. Use this figure to interpret the simplified color scale in the particle plots.

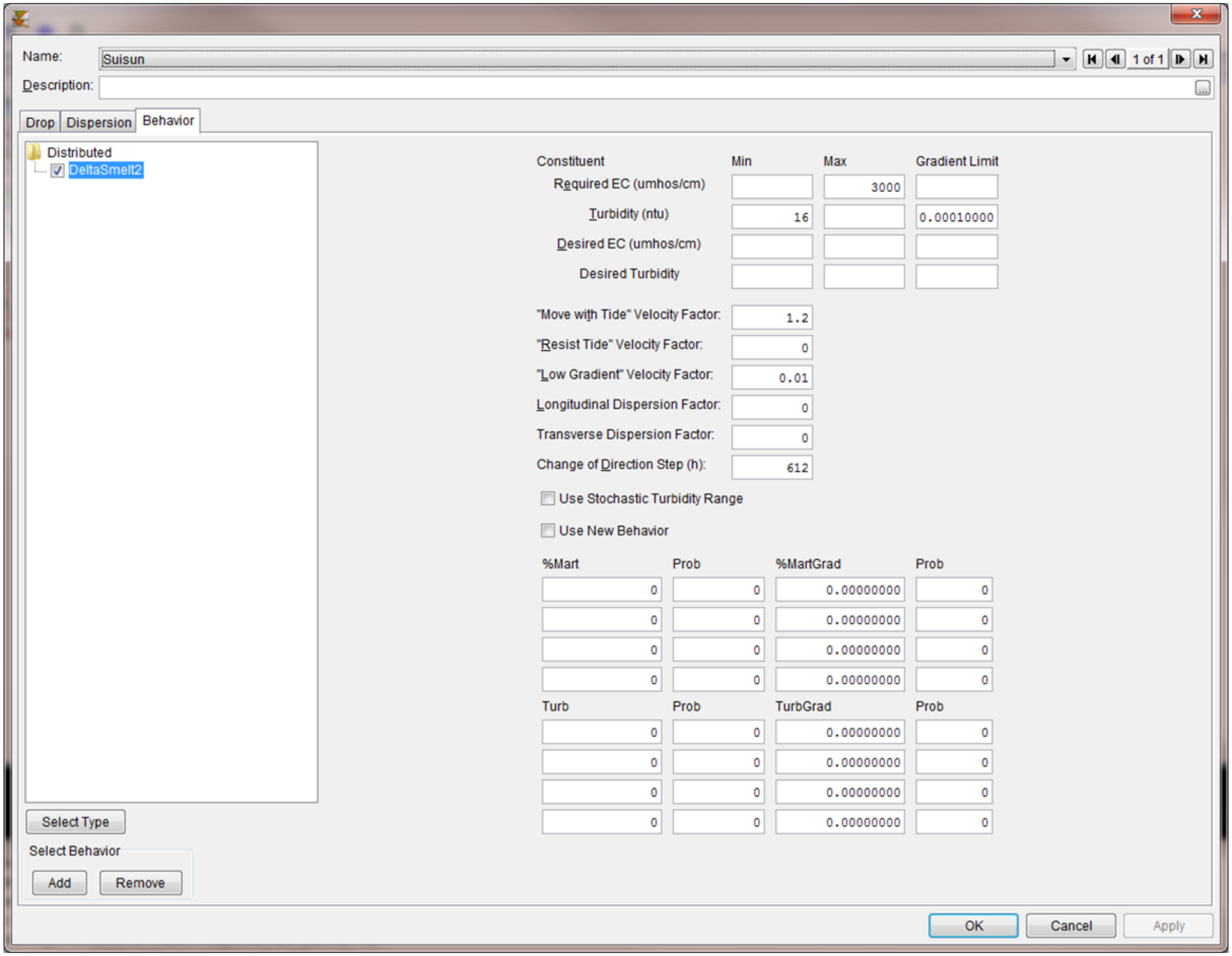


Figure 4-2 Parameter settings in the adult delta smelt particle tracking model.

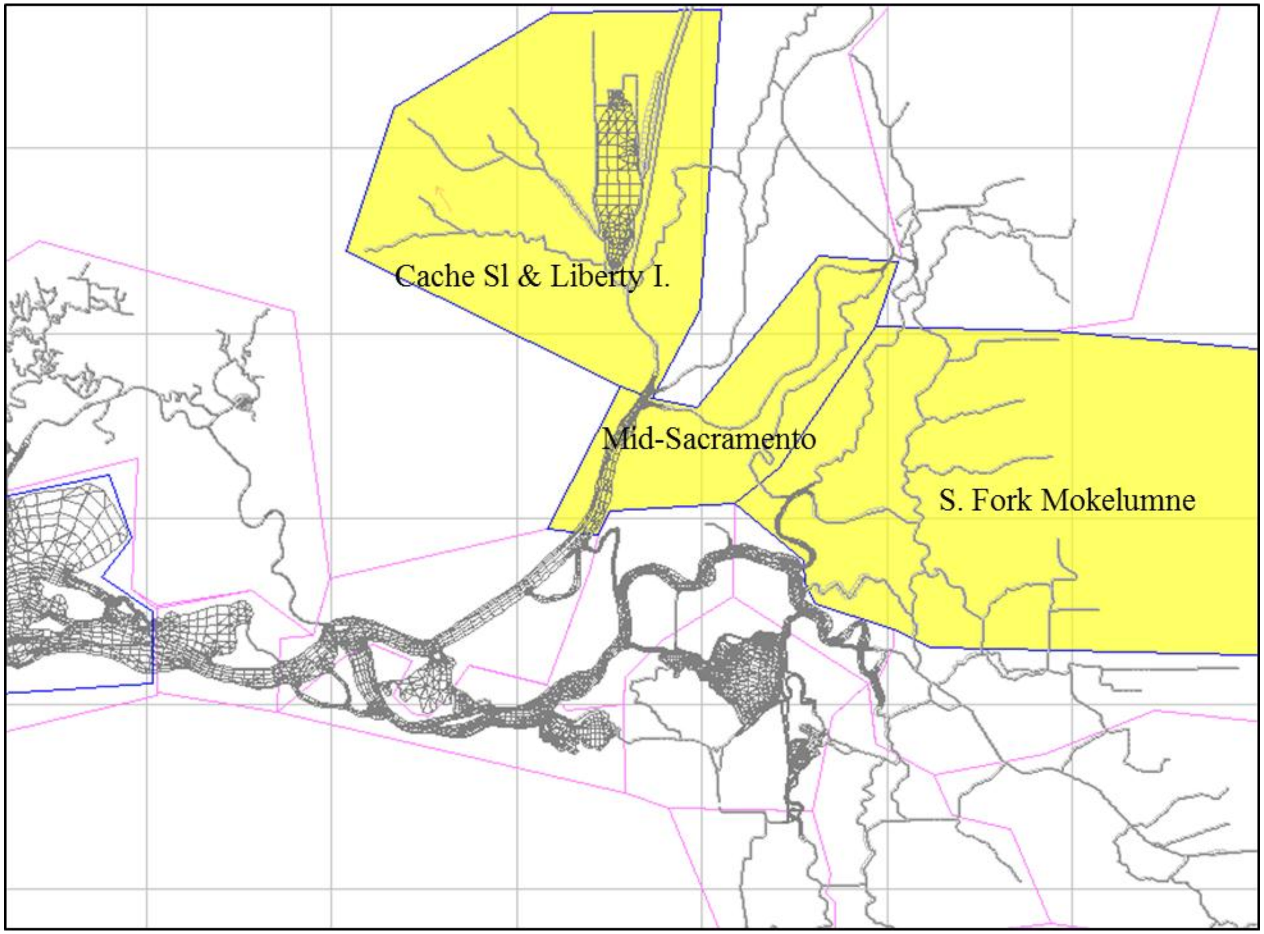


Figure 4-3 The fate of particles in the delta smelt PTM model is recorded in many regions including the three regions shown above in the north Delta.

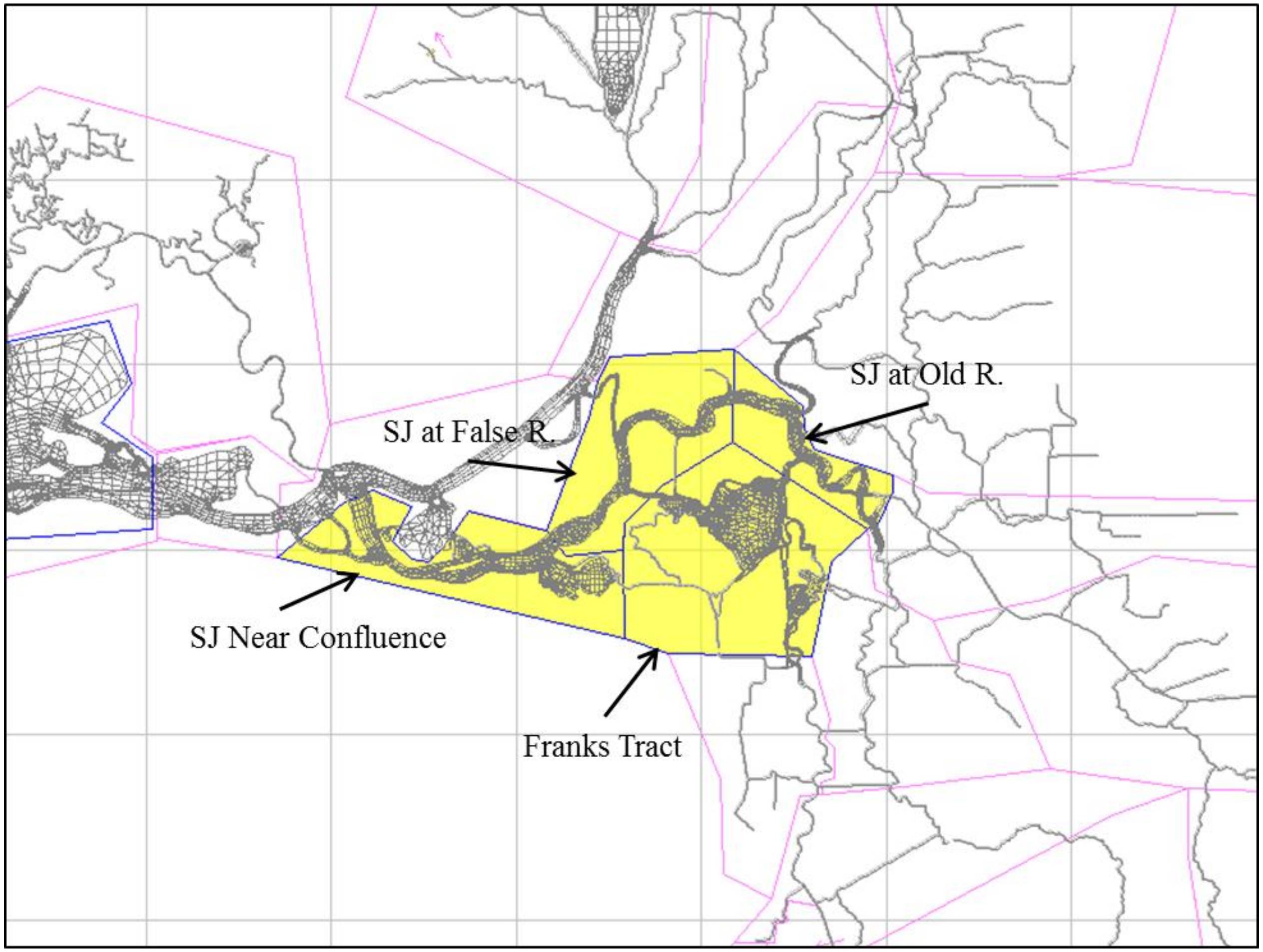


Figure 4-4 The fate of particles in the delta smelt PTM model is recorded in many regions including the four regions shown above in the central Delta.

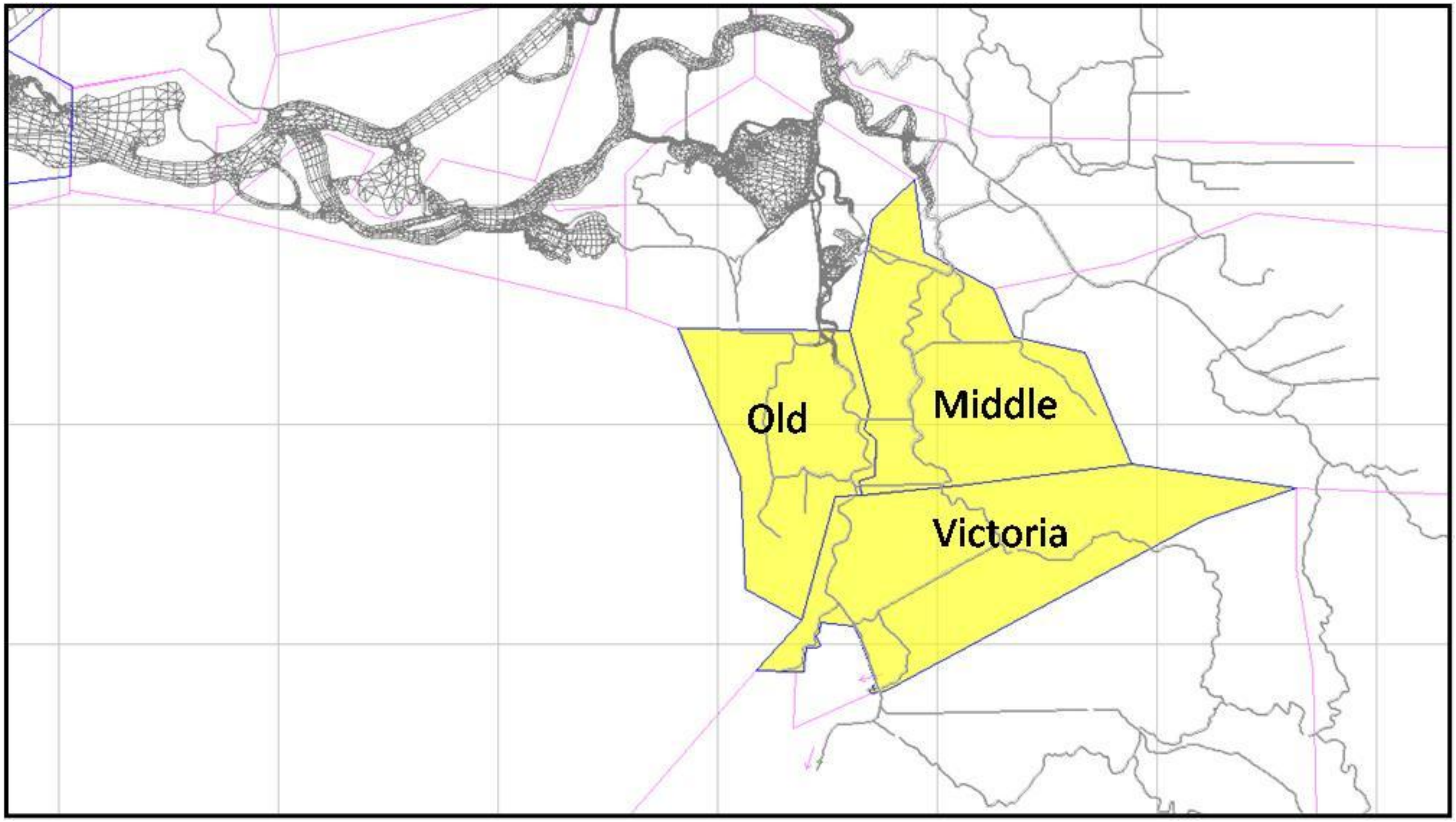


Figure 4-5 The fate of particles in the delta smelt PTM model is recorded in many regions including the three regions shown above in the south Delta. Particle fate is also recorded at the SWP and CVP export facilities – particles are removed from the simulation at these export locations.

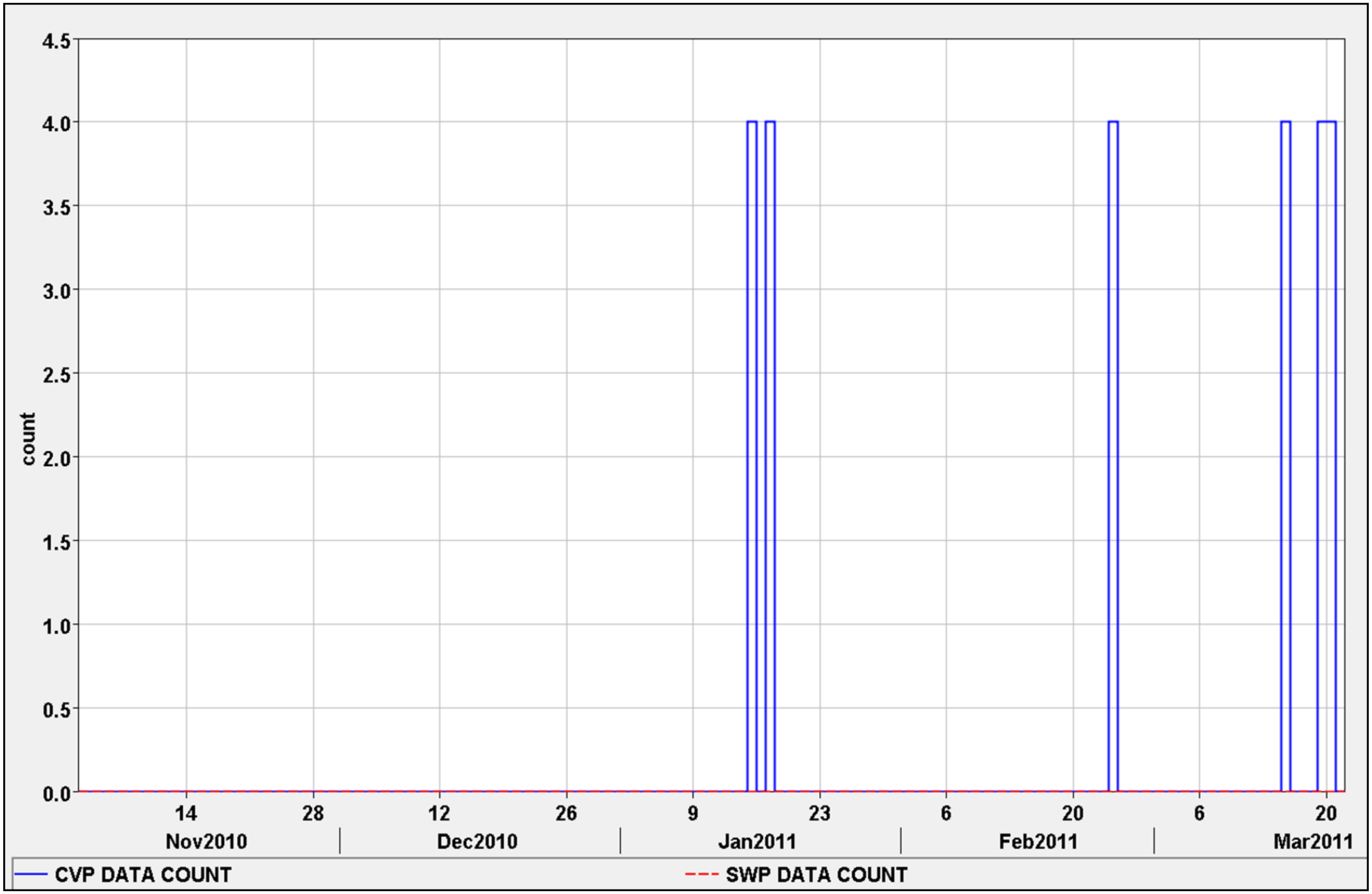


Figure 4-6 Delta smelt salvage observed at the SWP and CVP export locations, November 2010 through mid-March 2011.

5. Forecast modeling for Water Year 2011

5.1. Background

The forecasting protocol for WY2011 changed substantially from the WY2010 protocol (RMA, 2010b) with the introduction of WARMF model output into the data stream for developing forecast boundary conditions. WARMF model output includes flow and water quality parameters at many locations at (or, within) the RMA Delta model boundaries. For this project, RMA used only those WARMF output locations for flow and water quality parameters which coincide with RMA inflow locations. WARMF calculates suspended sediment load - the model calculations are then transformed to turbidity by Systech. The turbidity time series are supplied to RMA along with flow and salinity output from WARMF.

For each forecast period, this additional source of information from WARMF was evaluated along with the sources used in WY2010 for its suitability for application in RMA forecast model boundary conditions.

Details from each of the individual forecasts are not included in this document – this section is a summary of: the process used to create weekly forecast models; selected forecast input and output; and, some of the difficulties encountered producing forecasts for WY2011.

5.2. Sources of boundary condition information

Table 5-1 lists potential sources of boundary condition information used to develop boundary conditions in RMA forecast models for hydrodynamics and water quality.

5.2.1. O&M-supplied flow, stage, export and EC boundary conditions

On a weekly basis, DWR Operations and Maintenance (O&M) section provided RMA with boundary conditions used in the DSM2 HYDRO and QUAL (salinity) models for each forecast period. O&M staff emailed RMA a set of DSS files containing flow and EC forecasts for a three-week period, information on in-Delta gate operations and DSM2-HYDRO model output, including flow into Clifton-Court Node 72 (in DSM2 terminology) that RMA used to specify Clifton Court export operations. Typically, the O&M forecast period began two days before RMA received information.

Table 5-2 lists the information supplied by O&M. Table 5-3 lists the forecast simulation periods for O&M and RMA simulations.

5.2.2. WARMF model output

Systech developed WARMF model forecasts on a weekly basis with forecast conditions beginning up to two days before the RMA forecast began. The WARMF model forecast extended two weeks into the future. Systech would email WARMF output as CSV-format files with daily WARMF simulation results for flow, salinity and turbidity. RMA transferred these time series by hand into EXCEL, adjusted file formatting, and then loaded the time series into HEC-DSSVue software to produce DSS files using an application developed at RMA.

The WARMF modeled period started on December 01, 2010 for each forecast, so the modeled period increased with each successive forecast. During the weeks in which forecasts were produced, the WARMF model calibration was apparently being updated, leading to shifts in historical time period model output results.

5.2.3. Turbidity data

Turbidity data at all in-Delta monitoring stations identified in WY2010, as well as at a few upstream locations outside of the model boundary, was downloaded on a weekly basis from the CDEC website using HEC-DSSVue software and a script developed to automate the process. Several new turbidity monitoring stations, which were not identified until after forecasting had ended for WY2011, were added to the real-time network accessible through CDEC – all of the WY2011 monitoring stations are shown in Figure 3-2. Table 5-1 lists the potential sources of data used to create model boundary conditions during forecasting exercises in WY2011.

5.2.4. EC Data

EC data at all in-Delta monitoring stations was downloaded on a weekly basis from the CDEC website using HEC-DSSVue software and a script developed to automate the process. Table 5-1 lists the potential sources of EC data used to create model boundary conditions.

5.2.5. Flow and stage data

Flow and stage data at all in-Delta monitoring stations was downloaded on a weekly basis from the CDEC website using HEC-DSSVue software and a script developed to automate the process.

The California-Nevada River Forecasting Center (CNRFC) develops forecasts of hourly flows and/or stage on many California Rivers using a five-day forecast window. This data, along with the previous five days of hourly recorded values, are posted and regularly updated on their website. On a twice-weekly basis, data was downloaded automatically from the CNRFC website using a script developed in RMA for the HEC-DSSVue software. Table 12-1 lists the locations and parameters downloaded from CNRFC.

Rating tables were used during data evaluation and/or the preparation of boundary conditions at three locations. We obtained rating tables from CNFRC for computing Sacramento River flows at Sac-I-Street (near the CDEC FPT, or, Freeport location, Table 12-2 and Table 12-3 in the Appendix) and Cosumnes River flows near McConnell (the MCC station on CDEC, Table 12-4 in the Appendix). We obtained a rating table for the Lisbon (LIS) station on the Yolo Bypass from the CDEC webmaster (Table 12-5 in the Appendix).

5.2.1. Gate and barrier operations

Historical gate and barrier operations were developed from raw text data at:

http://www.iep.water.ca.gov/dsm2pwt/Bay-Delta_barriers_activ.txt

5.3. Development of initial conditions for RMA models

Initial conditions for RMA11 water quality models were developed using RMA utility functions and our standard methodology for 'warm starts'. A' warm start' produces an initial condition for water quality parameters based on data values obtained for the start date at multiple Delta locations, and then using a diffusion solution to populate the entire grid with concentrations using the data to seed the calculation. EC and turbidity data were selected from raw data on November 01, 2010 at all available EC and turbidity locations. The initial condition for the RMA2 flow model was developed by running the model for a five day period starting October 27, 2010 to develop an initial condition for November 01, 2010. This initial hydrodynamic run was then used with the initial condition for each water quality parameter from the diffusion solution and appropriate time series data to produce an initial condition for November 01, 2010.

RMA models produce restart files at the end of the calculation for each month. When multiple months are simulated, subsequent months are run with the initial conditions read in from these restart files.

The forecast simulations with start dates in December 2010 each began on November 01, 2010 – these models used the restart files as described above. The forecast simulations with forecast start dates in January each began on December 01, 2010, and used restart files from the November models. The single forecast simulation in February 2011 began on January 01, 2011, and used restart files developed from the December model runs.

5.4. Developing weekly forecasts

5.4.1. Background

Results from O&M and Systech generally arrived the Thursday of each week. O&M results would arrive mid- to late-afternoon, and WARMF results would arrive sometime in the afternoon. Preparation for each weekly forecast generally began the day prior, Wednesday, to assemble the background information from the previous forecast – the historical portion of the previous forecast boundary condition time series was used to develop the boundary conditions for the current forecast. Thursday morning, data from the CDEC and CNRFC databases would be updated (CNRFC data was also downloaded on Monday mornings). Once the O&M and WARMF model results arrived, boundary condition development would begin in earnest.

Nine weekly near-real-time hydrodynamic, water quality, and particle tracking modeling forecasts were developed during the winter and spring period Dec. 2010 - Feb. 2011. Model runs included actual and predicted conditions that were developed at the time. Due to the holiday period, forecasts were not produced the weeks of December 20 and 27, 2010.

Model forecast results include:

- Time series of instantaneous and averaged flow and turbidity at selected physical monitoring locations. Flow was tidally averaged while turbidity was presented as a daily average.
- Spatial contours of selected turbidity results.
- Particle tracking model estimates of potential salvage at the State and Federal export facilities using the adult delta smelt behavior model, and a comparison to measured salvage.

5.4.2. Forecast Methodology

The following were the general steps used in the RMA forecasts for WY2011 – the timing of the implementation of each step could vary depending on the time of receipt of the flow and salinity forecast from DWR O&M section and of output from the WARMF model.

1) Download updated CDEC, USGS and CNRFC data into DSS format files. (Note: CNFRC data was downloaded on Mondays and Thursdays to obtain continuous time series of measurements, as CNRFC data is only available for a five day historical window and a five day forecast window).

2) Use information sent by DWR O&M staff to develop the modeled export and Martinez EC and stage time series for the historical and forecast periods. The process entailed extending the historical time series (from the previous weeks' forecast) by one (or more) week(s) and appending the forecast time series.

    a. QA/QC historical Martinez time series data from O&M for stage and salinity by comparing to CDEC data. Fill data time series if necessary.

    b. Increase the Martinez stage supplied by O&M by 0.3 feet to improve the Martinez salinity boundary for use in RMA models.

    c. Note: Ordinarily, the RMA11 Martinez boundary condition for EC is composed of the average of top and bottom EC – for these model runs, we are accepting that

EC will not be accurately simulated in the interest of reduced model preparation time. This compromise can be somewhat justified because under the high flow conditions of greatest importance to (hypothesized) adult delta smelt movement, Martinez salinity has little influence on salinity in the Delta.

3) Update historical and forecast gate operations in the RMA2 input files.

4) Process WARMF model output– port text data into EXCEL and then into DSS format. Evaluate flow, salinity and turbidity daily time series by comparing with data from all other sources.

5) Develop inflow BC – for QA/QC check data at downstream locations to look for measurement problems:

   a. Evaluate the three data sources at the Yolo/Lisbon Toe Drain location - CNRFC (current and forecast flow and stage), CDEC and USGS - to create a consistent historical time series as well as a forecast time series. Compare with WARMF modeled flow.

   b. 'Clean' the CDEC flow data at Freeport and Vernalis, extend the historical time series from the previous forecast, and append the CNRFC flow forecast at each location. Note that the Sacramento I-street CNRFC data forecast stage must be converted to flow using supplied rating tables (Table 12-2 and Table 12-3 in Appendix). Compare with WARMF modeled flow. Two options are possible for extending the RMA forecast time period to three weeks from the end of the CNRFC time period at Freeport and Vernalis: 1.) Set the inflow to a constant using the final value in the CNRFC time series, or, 2.) Set the inflow to the values supplied by O&M for the remainder of the RMA forecast period (Note: there may be problems with data inconsistency with this latter method).

   c. Use inflow BC from DWR O&M as-is for the Mokelumne and Cosumnes Rivers. Compare with WARMF modeled flow.

   d. For the Calaveras River boundary condition, check the Mormon Slough flow data from CDEC to ensure that enough flow is incorporated in the DSM2-supplied time series for the Calaveras. Modify Calaveras flow with Mormon Sl. flow if indicated, and assess implementation of a time shift if there are high flows in Mormon Sl. Compare with WARMF modeled flow.

6) Develop EC and turbidity boundary conditions – for QA/QC check data at downstream locations to look for measurement problems:

   a. 'Clean' the CDEC EC and turbidity data at Freeport and Vernalis.

b. Evaluate the three data sources – CDEC, O&M and WARMF – and use professional judgment to create a set of consistent, combined historical and forecast time series for each boundary. Implement a time shift (back seven to eleven hours) so the model time series features match data at downstream locations. Check timing by running the RMA11 model with the shifted time series, and rerun with a better time shift if indicated.

5.5. Examples of flow boundary condition development

Figure 5-1 and Figure 5-2 illustrate the data sources and the final flow boundary condition at the Sacramento and San Joaquin River inflow boundaries, respectively, for the Jan. 06, 2011 forecast period. In each figure, raw CDEC data is shown in blue and the final boundary condition used in the RMA2 forecast is shown in red. These two locations are used to demonstrate the development of flow boundary conditions specifically, and the general process for all boundary conditions in general.

For the Sacramento River (Figure 5-1), the data has only one ‘bad’ point that was removed and filled within HEC-DSSVue software (linear fill). The CNRFC data (green line) does not match the CDEC data, but the forecast time series (green dash line) matches the end of the data in magnitude. Only CNFRC forecast data was used for this boundary condition. The final boundary condition time series (red) was extended linearly to the end of the forecast period. The DWR O&M forecast (yellow) is different than CNRFC – in general the CNRFC forecast was used preferentially to other sources. The WARMF model output (black line) shows a significantly lower flow.

For the San Joaquin River (Figure 5-2), the data has several ‘bad’ points, and suspicious data prior to it (the ‘hump’ in the data) that was removed and filled. A portion of CNRFC data (green line) was used, as well as all of the forecast time series (green dash line). The final boundary condition time series was extended linearly down to the end of the WARMF forecast period, and then as a constant to the end of the simulation forecast period. The DWR O&M forecast (yellow) is much higher than CNRFC – in general the CNRFC forecast was used preferentially to other sources. The WARMF model output (black line) is a fairly good representation of historical flow.

A similar process was used at each of the other inflow boundaries for each forecast period, except the initial forecast, which used WY2010 protocol, and the final forecast. For the final forecast, the process was simplified to use all WARMF boundary conditions to reduce forecast preparation time.

5.6. Forecast results summary

The documents submitted to MWD at the end of each forecast period are inserted in the Appendix, Sections 12.3.1through 12.3.7, in their entirety. A summary of the most pertinent results is covered in this section.

Two sets of forecast results were analyzed and results sent to MWD in December, 2010 – Dec. 9th and Dec. 16th. A forecast was also prepared on Dec 2nd, but results were not distributed. The Dec. 9th forecast was prepared using RMA's WY2010 methodology (RMA, 2010b) as WARMF results were not delivered to RMA modeling staff. The Dec. 16th forecast used WARMF turbidity output for forecast boundary conditions. No delta smelt were salvaged during the pre-forecast period. The adult delta smelt model particles did not reach the SWP or CVP export locations.

Four sets of forecast results were prepared in January, 2011 – Jan. 6th, Jan 13th, Jan. 20th and Jan. 27th. For these forecasts, WARMF model output was used at those locations where turbidity or EC boundary conditions were not available (Mokelumne, Cosumnes, Calaveras and Yolo). Generally, flow boundary conditions were set using sources other than WARMF whenever possible. RMA turbidity model results were generally greater than data values at the three compliance locations (Prisoner Point, Holland Cut and Victoria Canal). At no time did data (or, daily averaged data) exceed the 12 NTU compliance limit at all three locations. However, the RMA model results did exceed compliance values at all locations in early January. The Jan. 20th forecast shows that the RMA modeled turbidity at Holland Cut exceeded the compliance value, but that the data did not (Figure 5-3). Salvage data and adult delta smelt particles tracking results were in general agreement during historical periods, as both showed a few delta smelt appearing at the export locations in early or mid-January.

Only one set of forecast results was prepared in February, 2011 - on Feb. 3rd. Adult delta smelt model results differed slightly from previous forecast results as the historical boundary conditions were altered somewhat from the Jan. 27th set. No particles reached the export locations during February. RMA turbidity results for February showed that turbidity remained below the 12 NTU compliance level at all three locations during February.

Modeled turbidity results in the forecasts indicated that the Calaveras River turbidity boundary condition supplied by the WARMF model output was too high. The results are seen downstream at Holland Cut (Figure 5-3). This was addressed in the Hindcast simulation (see Section 6) by decreasing the Calaveras turbidity by an order of magnitude. Also, the Mokelumne and Cosumnes turbidity boundary conditions supplied by the WARMF model were generally too high – this is seen at the downstream location Little-Potato-Sl.-At-Terminous, as shown in Figure 5-4. This problem was also addressed in the Hindcast simulation by using the new turbidity data location on the South branch of the Mokelumne River.

5.7. *Observations on forecasting in WY2011*

Because the RMA2 flow model took several hours to run each week, developing a good set of boundary conditions quickly by Thursday afternoon was crucial to producing a timely turbidity forecast result by Friday. The modeling objective was to develop the best possible inflow values and stage definition as both water quality results and particle tracking results rely on the output of the flow model, and there was no time to rerun a flow model if hydrodynamic results did not look satisfactory. Once the flow model was running, water quality model development could begin. Water quality simulations in RMA11 were initiated either on Thursday night or Friday morning – the two simulations, EC and turbidity, were run concurrently but in different model runs.

Although the use of WARMF model output in the forecasting process holds great promise, the incorporation of the WARMF model output into the forecasting data stream significantly increased the complexity of and the amount time needed for the development of boundary conditions. As an additional source of information, WARMF model results increased the effort needed to create a logically consistent set of boundary conditions in order to develop the most accurate possible forecast. Also, because the WARMF model was apparently being developed on an ongoing basis during the forecast period, the quality of the results could change between forecasts, imposing an additional QA/QC burden on forecast preparation.

Figure 5-5 and Figure 5-6 illustrate the changes in WARMF modeled turbidity in different forecasts at Freeport and Vernalis, respectively, in comparison with CDEC turbidity data (blue). Similarly, Figure 5-7 and Figure 5-8 illustrate the changes in WARMF modeled EC in different forecasts at Freeport and Vernalis, respectively, in comparison with CDEC EC data (blue). Most of the WARMF forecast boundary conditions for turbidity and EC at each of the inflow locations are documented in figures without discussion in the Appendix (Figure 12-168 through Figure 12-173 for turbidity, and Figure 12-174 through Figure 12-179 for EC). WARMF water quality forecasts eventually 'stabilized' (*i.e.*, stopped changing) in the historical period at all locations except at Vernalis – which shifted dramatically between successive forecast periods (Figure 5-6).

WARMF water quality results at some boundaries were sometimes questionable, as evidenced by comparison with data and by comparison of RMA model output with data at downstream locations in RMA forecasting results. An example of this is WARMF modeled turbidity at the Calaveras R. boundary, which appears to be too high by an order of magnitude (illustrated in the Hindcast section of this document, Section 6.1.2, Figure 6-10 – compare to Figure 5-3).

Table 5-1 Data sources for forecast boundary conditions implemented in RMA models.

PARAMETER	LOCATION	DATA SOURCES
INFLOW	RSAC155	CDEC, O&M, CNRFC, WARMF
	RSAN112	CDEC, O&M,CNRFC, WARMF
	RCAL009	CDEC, O&M, CNRFC, WARMF
	RMKL070	CDEC, O&M, WARMF
	BYOLO040	CDEC, USGS, CNRFC, WARMF
EC	RSAN112	CDEC, O&M, WARMF
	RSAC142	CDEC, O&M, WARMF
	RCAL009	O&M, WARMF
	BYOLO040	O&M, WARMF
	RMKL070	O&M, WARMF
	RCSM075	O&M, WARMF
	RSAC054	CDEC/O&M
TURBIDITY	RSAN112	CDEC
	RSAC142	CDEC
	RSAC054	CDEC
	RCAL009	WARMF
	BYOLO040	WARMF
	RMKL070	WARMF
	RCSM075	WARMF

Table 5-2 Boundary conditions from DWR O&M.

PARAMETER	DWR O&M	Used by RMA (Y/N)	O&M Filename
INFLOW	RSAC155	N	
	RSAN112	N	
	RCAL009	N	
	RMKL070	Y	Hydro.dss, Forecast.dss
	RCSM075	Y	Hydro.dss, Forecast.dss
	BYOLO040	N	
STAGE	RSAC054	Y	Hydro.dss
EXPORTS	CHSWP003	N	
	CHDMC004	Y	Hydro.dss, Forecast.dss
	CHCCC006	Y	Hydro.dss, Forecast.dss
	ROLD034	Y	Hydro.dss, Forecast.dss
	SLBAR002	Y	Hydro.dss, Forecast.dss
EC	RSAC054	Y	Quality.dss
	RSAN112	Y/N	Quality.dss, Forecast.dss
	RSAC142	N	
DSM2 MODEL OUTPUT	CLFCT-NODE 72 FLOW	Y (SWP EXPORT)	RMAOutput.dss

Table 5-3 O&M *vs.* RMA forecast simulation periods.

O&M Forecast period	RMA Forecast period
Dec. 01 – Dec. 21, 2010 [a.]	Dec. 03 – Dec. 21, 2010
Dec. 07 – Dec. 28, 2010 [b.]	Dec. 09 – Dec. 28, 2010
Dec. 14, 2010 – Jan. 04, 2011	Dec. 16, 2010 – Jan. 04, 2011
Dec. 21, 2010 – Jan. 11, 2011	Dec. 23, 2010 – Jan. 11, 2011
Jan.04 – Jan. 25, 2011	Jan.06 – Jan. 25, 2011
Jan.11 – Feb. 01, 2011	Jan.13 – Feb. 01, 2011
Jan.18 – Feb. 08, 2011	Jan.20 – Feb. 08, 2011
Jan.25 – Feb. 15, 2011	Jan.27 – Feb. 15, 2011
Feb.01 – Feb. 22, 2011	Feb.03– Feb. 22, 2011

a. This forecast was developed but not distributed.

b. This forecast was developed using the WY2010 methodology as WARMF results were not distributed to RMA modeling staff.

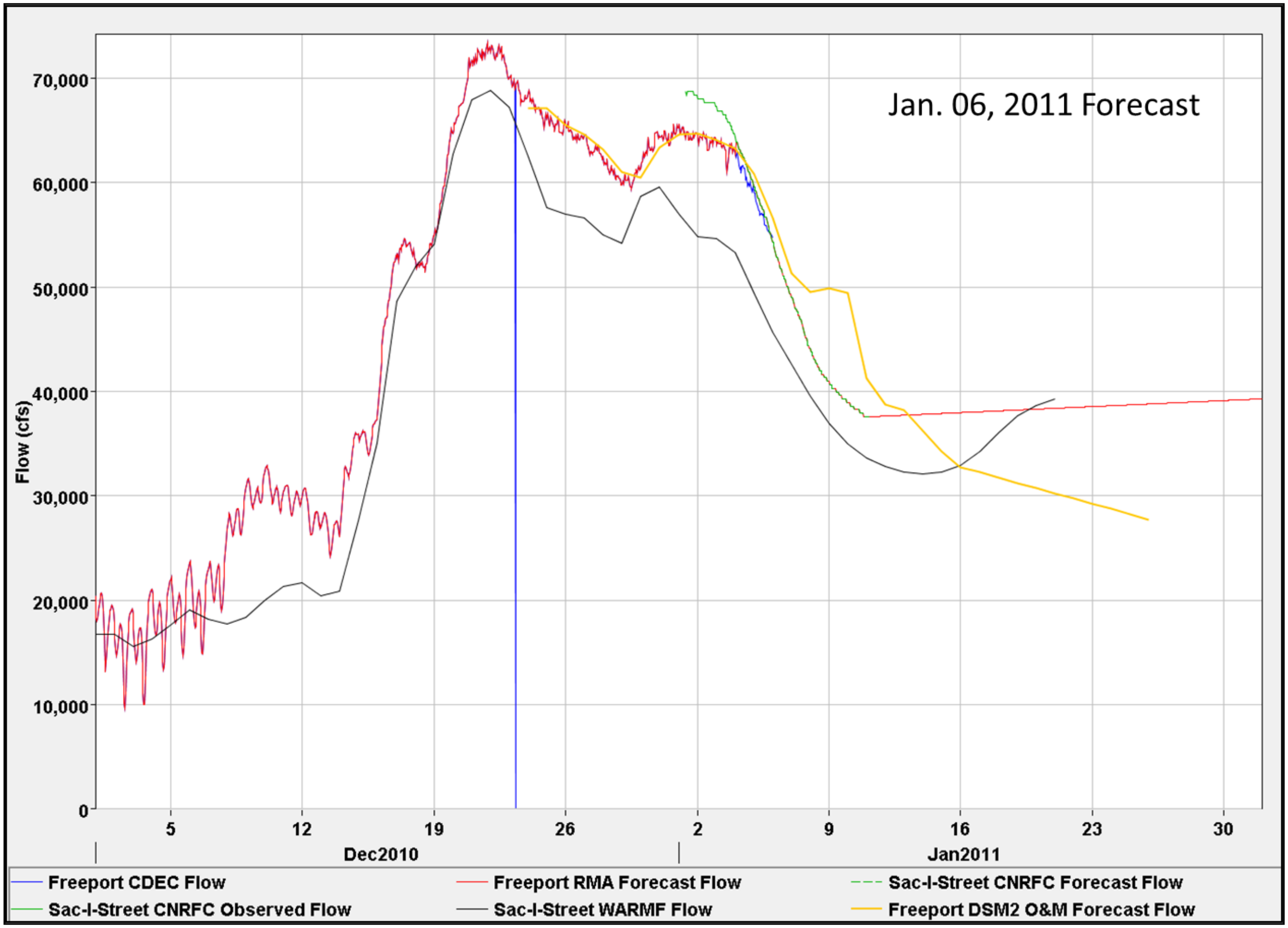


Figure 5-1 Sources of data/information for developing the Freeport boundary inflow for the Jan 6th, 2011 forecast. The red line shows the flow values used in the forecast simulation.

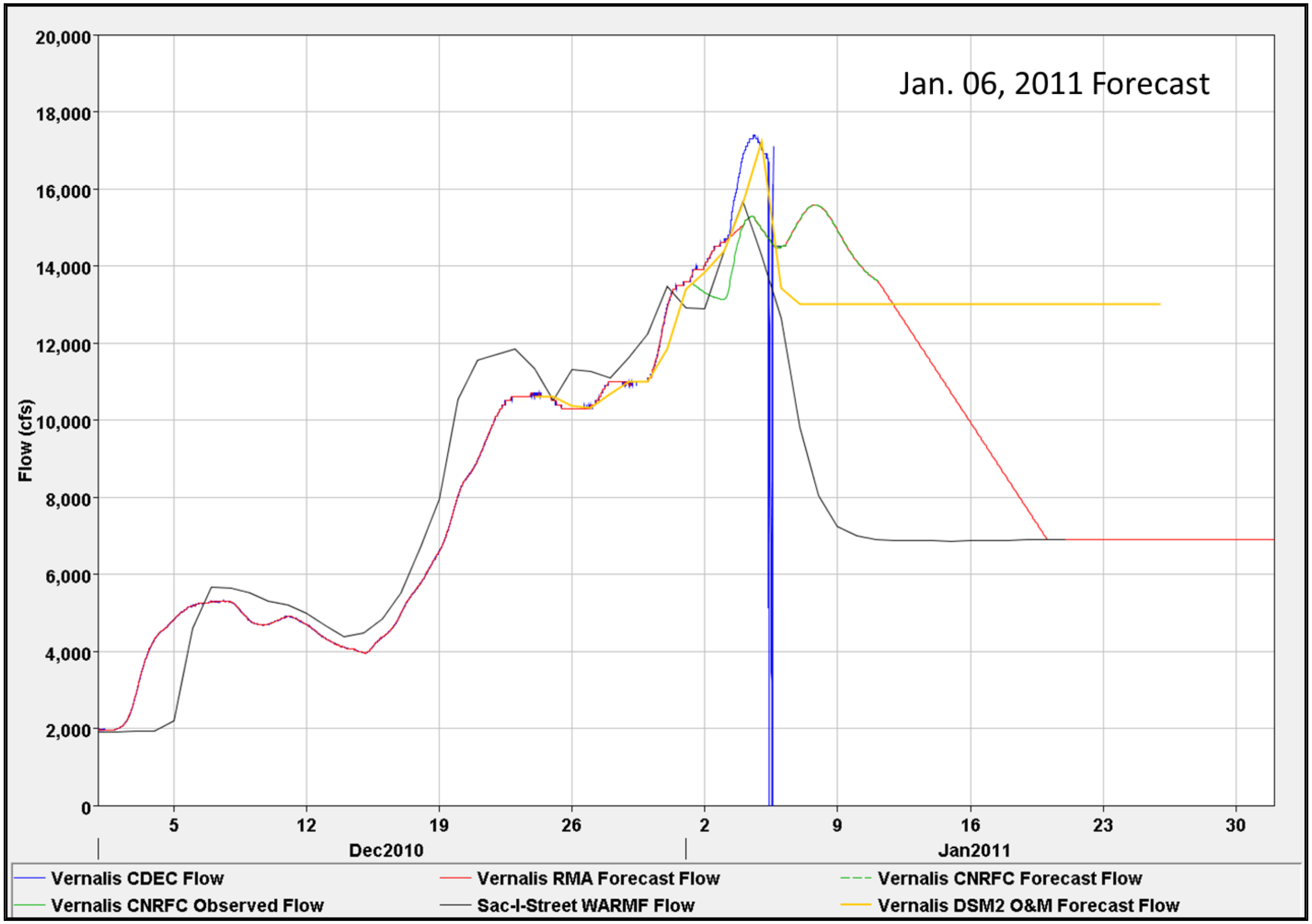


Figure 5-2 Sources of data/information for developing the Vernalis boundary inflow for the Jan 6th, 2011 forecast. The red line shows the flow values used in the forecast simulation.

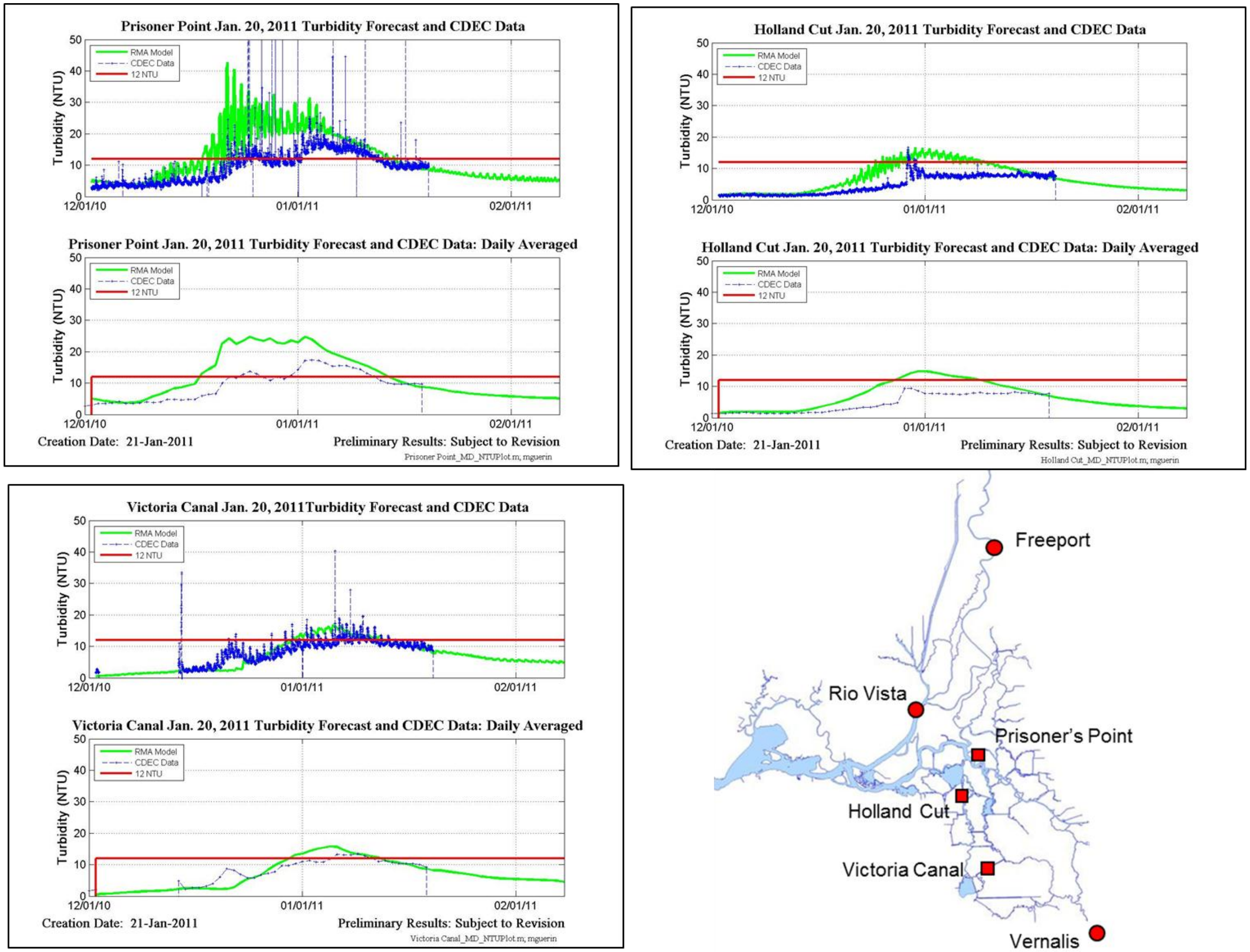


Figure 5-3 Modeled turbidity and data at the three compliance locations for the Jan 20th forecast. Both 15-min model output and data and daily averaged plots are shown. Red line illustrates the 12-NTU compliance value.

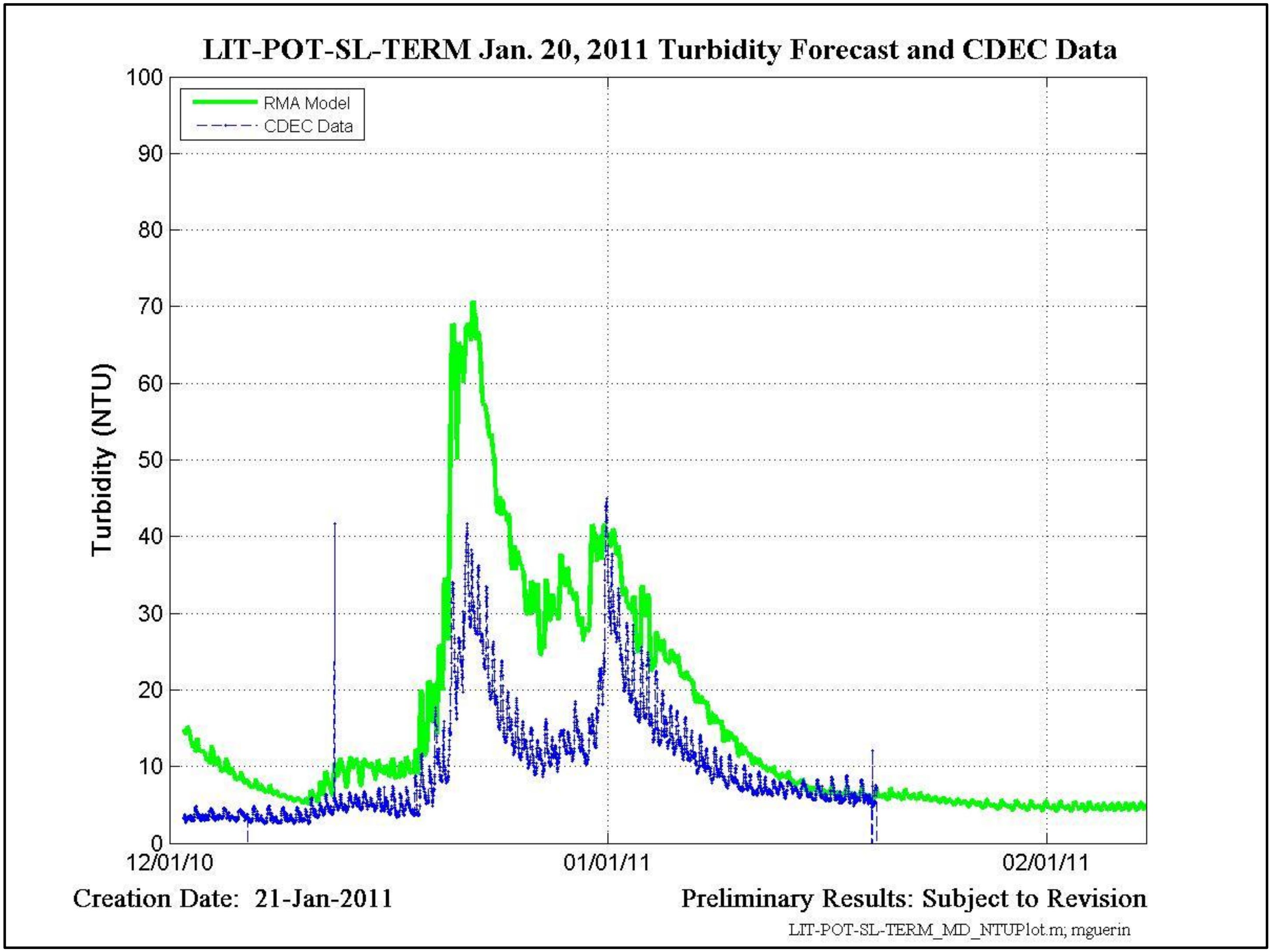


Figure 5-4 Modeled turbidity and data Little-Potato-Sl.-at-Terminous for the Jan 20th forecast. The RMA model significantly overestimates the data.

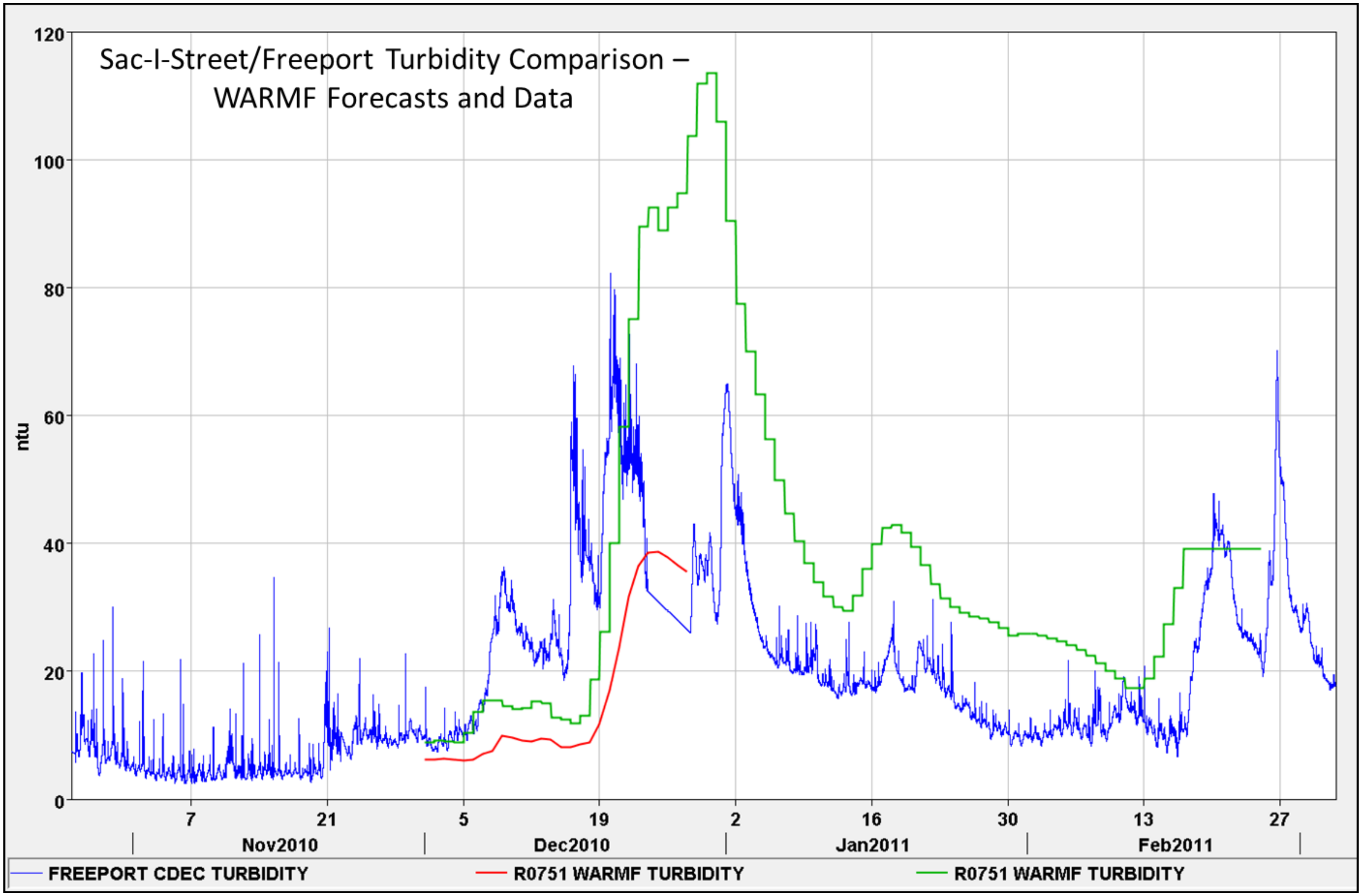


Figure 5-5 Comparison of turbidity data (blue) at Freeport with WARMF turbidity output for two forecast periods, an early period in December, 2010 and the final forecast in February, 2011.

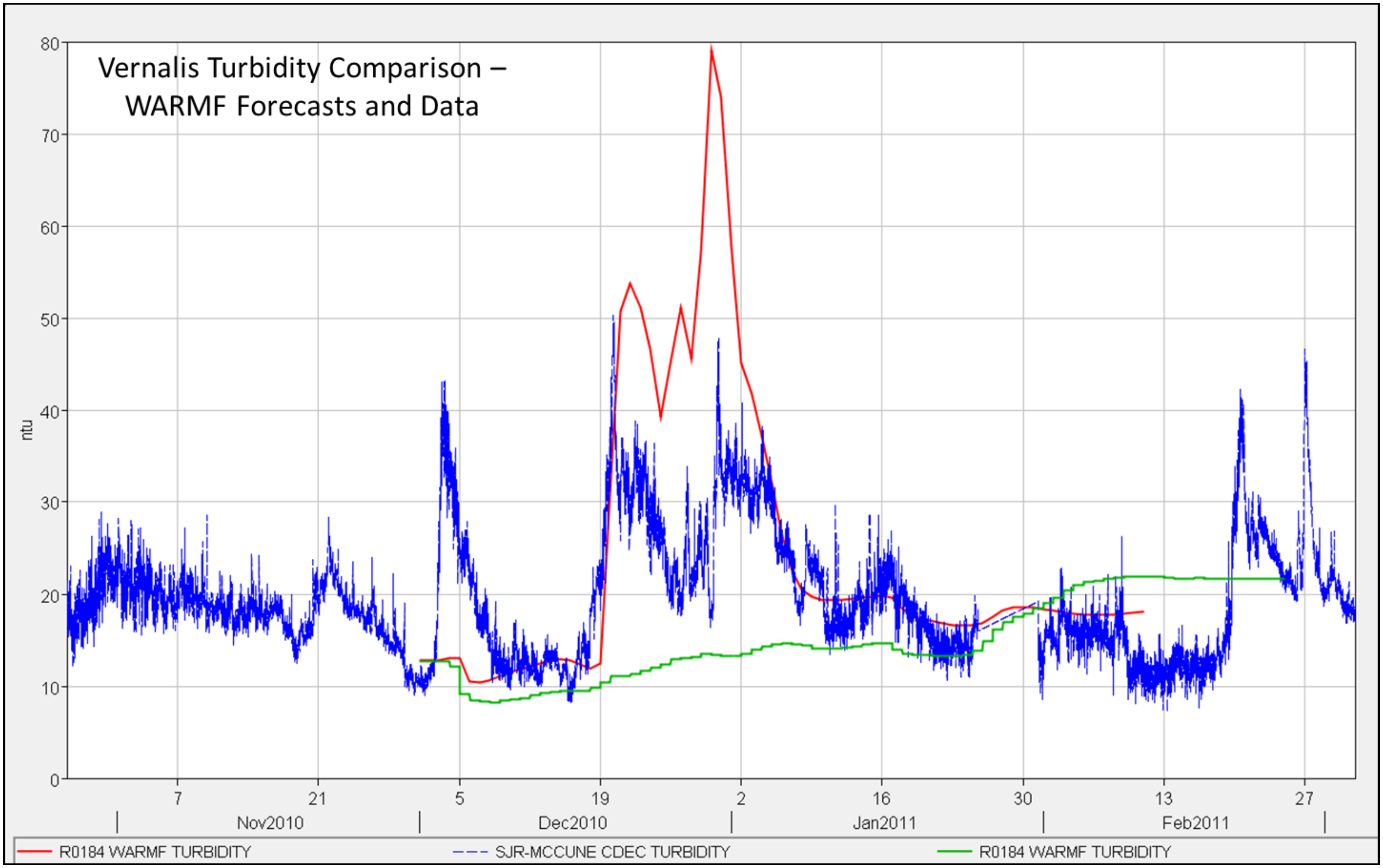


Figure 5-6 Comparison of turbidity data (blue) at Vernalis with WARMF turbidity output for two forecast periods, one near the end of January and the final forecast in February.

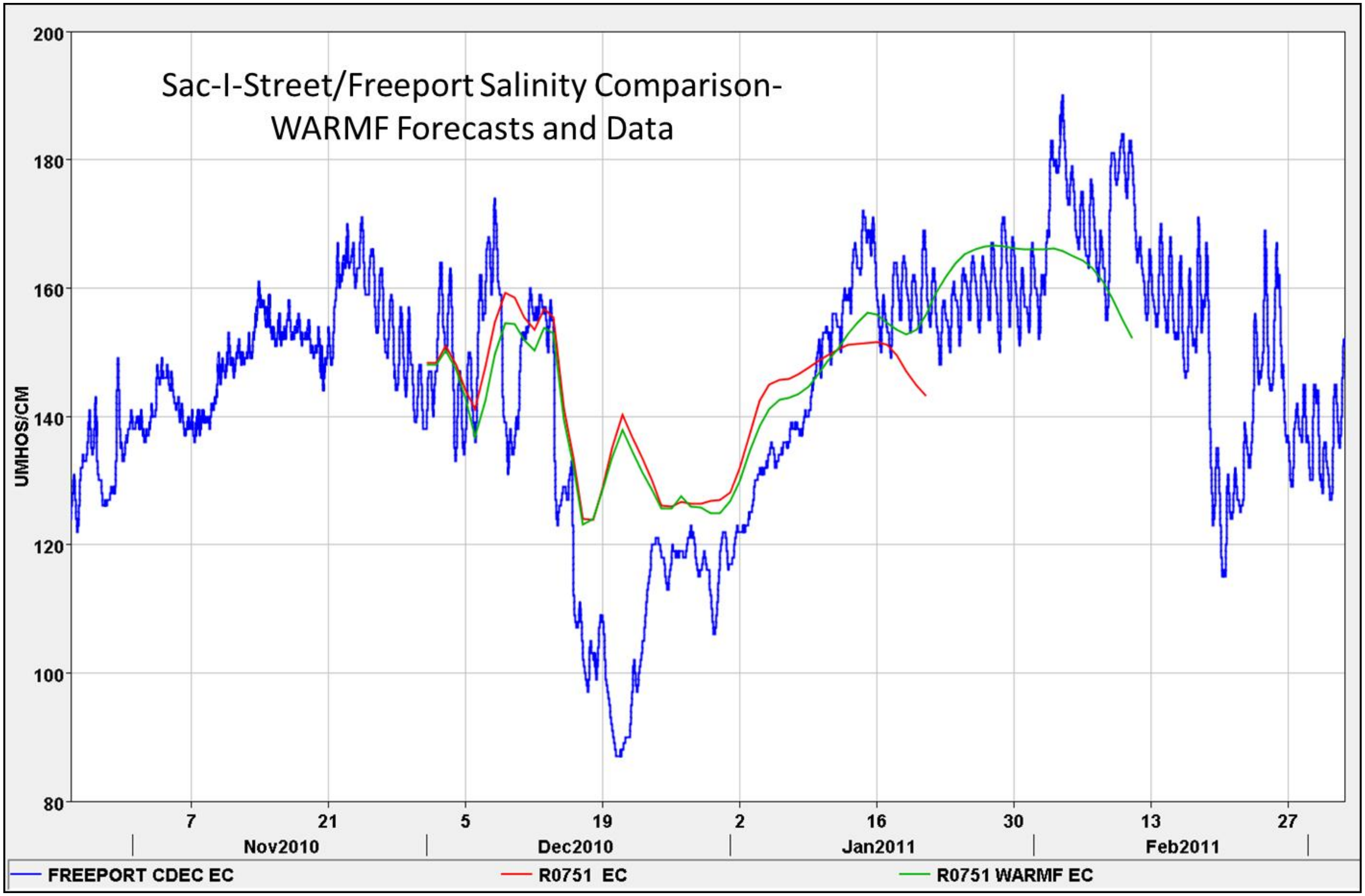


Figure 5-7 Comparison of EC data (blue) at Freeport with WARMF EC output for two forecast periods, one in early January and another in late January.

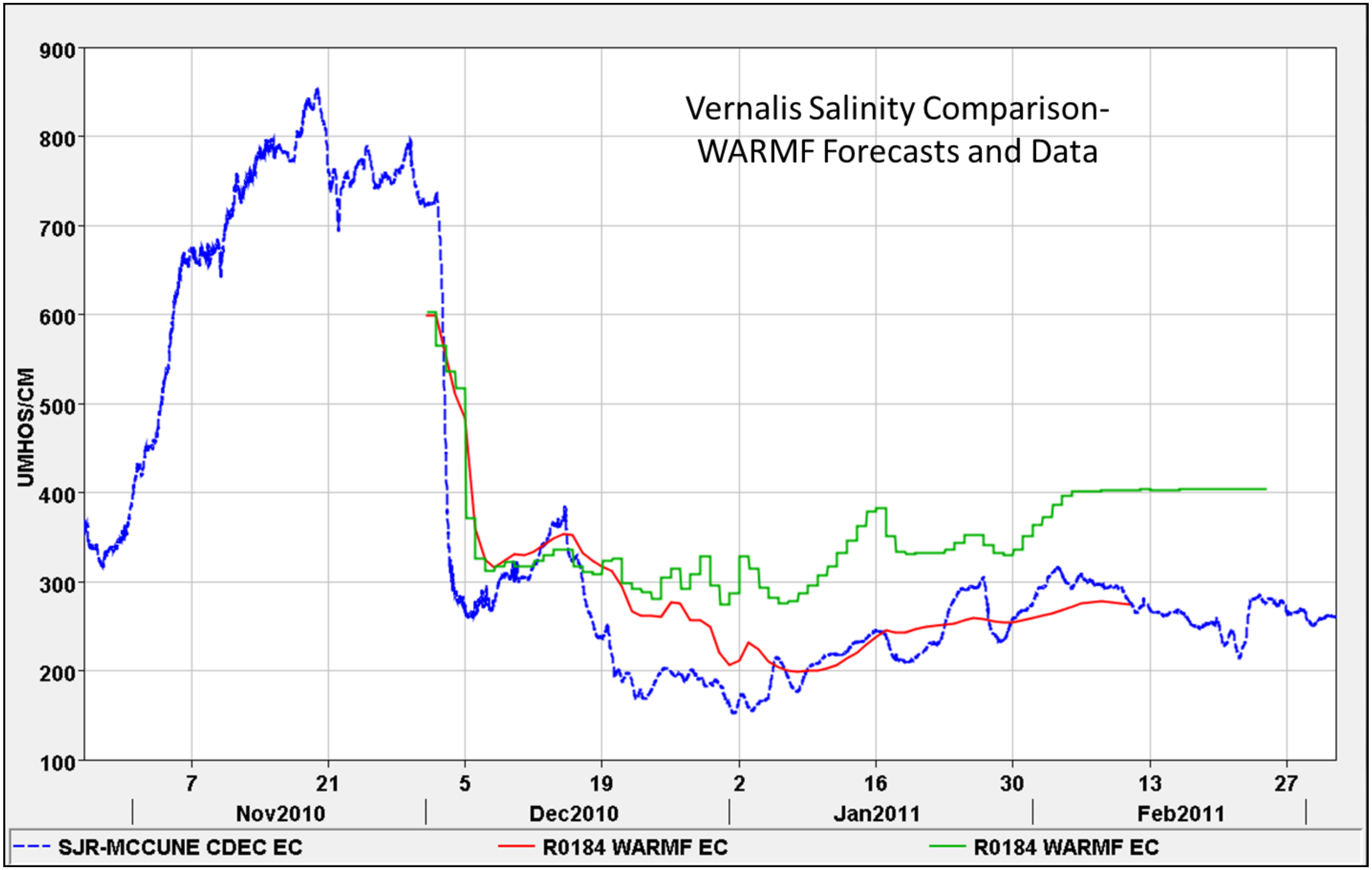


Figure 5-8 Comparison of EC data (blue) at Vernalis with WARMF EC output for two forecast periods, one near the end of January and the final forecast in February.

6. Turbidity Hindcast

The turbidity Hindcast simulation covers the period November 01, 2010 through February 28, 2011. Readers should refer to Figure 3-2 for the names and locations illustrated in the figures in this section.

6.1. Boundary Condition Development

6.1.1. RMA2

The RMA2 boundary conditions for the Hindcast were in part developed using the time series from the final forecast, with additional time series and gate operation information appended to the final forecast input files. Table 6-1 through Table 6-3 specify the details used to create the boundary conditions for inflow, exports and stage for the RMA2 hydrodynamic model. A stage-discharge rating table was obtained from CNFRC staff and used to compute flow from the CDEC stage data on the Cosumnes River (CDEC station MCC).

Figure 6-1 through Figure 6-6 illustrate the flow boundary conditions applied in the Hindcast model in comparison with WARMF model output for the final forecast.

6.1.2. RMA11

The development of the RMA11 boundary conditions for the Hindcast differed from the forecast boundary development, particularly on the Eastside (Calaveras, Cosumnes, and Mokelumne) and at the Yolo boundary. A series of test simulations were run – seven for turbidity and five for salinity – to refine the time series used for the Eastside and Yolo boundaries. In the Appendix, Section 12.1, Table 12-13 and Table 12-14 show the parameters varied in the development of turbidity and salinity boundary conditions, respectively, for the final hindcast. The test simulations were run sequentially changing one boundary condition at a time. The Hindcast used the turbidity boundary conditions from Run 7 (Table 12-13). EC boundary conditions for the Hindcast were taken from Run 2 (Table 12-14), as changes in subsequent model runs did not improve the results noticeably.

On the Calaveras R. boundary, evaluation of forecast model results indicated the WARMF modeled turbidity value was too high - for the Hindcast it was reduced by a factor of 10 to bring the downstream modeled values closer to those measured at Turner Cut. The WARMF EC value at the Calaveras boundary was used as given by the final WARMF model – note that this includes several weeks of forecast. However, since flows were generally low during the latter days of February and large storms did not perturb the Eastside flows, the WARMF values were accepted as given.

On the Mokelumne and Cosumnes Rivers, the turbidity data collected at the CDEC SMR station – South Mokelumne – was used as a boundary condition, but shifted back by five hours. For the

EC boundary at these stations, the individual WARMF values were used. Test runs (see Table 12-14) using the EC data collected at SMR indicated that use of this data did not improve model results, even when shifted back in time.

At the Yolo boundary, the turbidity data at the RYI station – Cache Slough at Ryer – was used in preference to the WARMF model output. Test runs using the EC data collected at RYI indicated that use of this data did not improve modeled results compared with a simulation run with WARMF EC, even when increased in magnitude to better match the downstream data.

Freeport turbidity data was noisy, so a section of data in late December was removed at Freeport (Figure 6-7). At the Vernalis boundary (Figure 6-8), Mossdale data, shifted back in time by eight hours, was used instead of data collected at Vernalis to improve downstream results.

The details of data usage for water quality boundary conditions are documented in Tables.

Table 6-4 details the information used to develop turbidity boundary conditions for the Hindcast, while Table 6-5 details the information used for EC boundary conditions. Table 6-6 is a compilation of the time shift formulas used in the development of the boundary conditions. Figure 6-7 through Figure 6-12 illustrate the turbidity boundary conditions applied in the Hindcast model in comparison with WARMF model output for the final forecast. Figure 6-13 through Figure 6-18 illustrate the final EC boundary conditions applied in the Hindcast model in comparison with WARMF model output for the final forecast.

6.2. Hindcast results

6.2.1. Flow

Figure 6-19 through Figure 6-27 illustrate the hindcast flow simulation results in comparison with data, and tidally-averaged results for model and data at multiple locations in the Delta. With the introduction of new measurement locations on the North and South branches of the Mokelumne River (NMR and SMR, respectively, both plots in Figure 6-21) we can see that that either better boundary conditions or improving the flow through these branches needs to be improved in the RMA2 model – the differences here can also be seen at the downstream location at Little-Potato-Slough-at-Terminous (Figure 6-22). On the upper San Joaquin River, what appears to be insufficient flow at Mossdale and Head of Old River (Figure 6-25), seems to have been resolved at the downstream locations at Garwood and Brandt-Bridge (Figure 6-26).

The flows on the Sacramento and San Joaquin Rivers in WY2011 appear to have been modeled somewhat better than in WY2010, particularly at the higher flows in late December and early January, although there are still a few differences to be resolved (e.g., where the Mokelumne River branches, Figure 6-22).

6.2.2. Turbidity

Figure 6-28 through Figure 6-42 illustrate the turbidity model results in comparison with data, and three-day-moving-average results for model and data at each location in the Delta where turbidity data is available. Data gaps or filled sections in the time series appear as peaks, valleys or spikes in the averaged plots (lower plots).

Turbidity data was noisy at Freeport and at some downstream locations, which made setting the boundary condition at Freeport problematic. A section of data in late December was removed at Freeport (Figure 6-7) – the model results were improved at Georgiana-Sac, Rio Vista and Cache-Ryer (respectively: Figure 6-28, Figure 6-29, Figure 6-31). Mossdale turbidity data (shifted back eight hours) was used in preference to Vernalis data at the Vernalis boundary, as it significantly improved downstream model results at Garwood and Brandt Bridge (Figure 6-36).

Using South-Mokelumne-River turbidity (shifted back in time) at both the Cosumnes and Mokelumne River boundaries (respectively, Figure 6-11 and Figure 6-12) produced excellent model results at those locations (Figure 6-33) as well as further downstream (Figure 6-34). WARMF modeled turbidity was used at the Calaveras boundary (Figure 6-10), where an order-of-magnitude decrease in turbidity improved results at Turner Cut (Figure 6-37).

As in WY2010, the effect of wind events are seen in the data but not in Hindcast results at several Delta locations – for example in the Yolo-Cache Sl.-Liberty Island area (Figure 6-48) and at Dutch Slough (Figure 6-49). Additional locations where wind events increased turbidity are found in the Appendix, Figure 12-180 through Figure 12-182 (Prisoner Point, Jersey Point and Antioch, respectively). The wind events increased turbidity in different magnitudes at the individual locations.

Figure 6-50 through Figure 6-53 illustrate the turbidity model results in comparison with data, and daily-average results for model and data at the three compliance locations in the Delta, and at the SWP export location in comparison with CCFB data. At the three compliance locations, the 12 NTU compliance value is also shown. The RMA model generally overestimated turbidity at each of the three compliance locations, although the timing of peaks and their general shape was preserved. The modeled turbidity at Holland Cut was improved substantially by decreasing the WARMF turbidity model output by an order of magnitude - for the Jan 20th forecast, modeled turbidity was over the 12 NTU limit (Figure 5-3), but for the Hindcast it remained under the limit as did the data.

The wind events increased turbidity above 12 NTU at Prisoner's Point and at Holland Cut, but not in a sustained manner, and not in Victoria Canal. Modeled turbidity at the SWP export location is lower than measured turbidity in Clifton Court Forebay (Figure 6-53).

6.2.3. Adult delta smelt behavior model – particle tracking time series

Figure 6-55 through Figure 6-57 illustrate the particle tracking time series results in the north, central, and south Delta, respectively. No particles reached the SWP or CVP export locations. This result is in general agreement with salvage data, as only twelve delta smelt were salvaged from November 2010 through February 2011 (Figure 6-54).

Turbidity moving down the Sacramento River and out of the Yolo/Liberty area influenced particles to move into Liberty Island (Figure 6-55), at times over 20% of particles were in the area. A small percentage of particles moved into the lower San Joaquin River (Figure 6-56), and a very small percentage then ventured further south into Middle River (Figure 6-57). No particles reached the Old River or Victoria regions.

6.2.4. Two-dimensional results – turbidity contours and particle tracking results for the Hindcast

Figure 6-58 through Figure 6-70 present weekly turbidity contour plots and particle tracking model results for the Hindcast simulation starting Dec. 01, 2010. Although model simulations began on November 01, 2010, turbidity was low in the Delta during November and the results are of no interest.

By Dec. 08, 2010 (Figure 6-59), turbidity has started to increase down the Sacramento River (Figure 6-7, Figure 6-59) attracting particles in the mid-Sacramento region (Figure 4-3) to move toward the increase. Modeled turbidity has also started to move down the Mokelumne River (Figure 6-11, Figure 6-12), and attract particles into the Mokelumne region (Figure 4-3).

Increases in turbidity in Liberty Island (Figure 6-61) have increased particle percentages in the Cache-Liberty region (Figure 4-3) by December 22, 2010, and turbidity from the Sacramento River has now entered the lower San Joaquin and particles have moved into these regions (Figure 4-4). Although turbidity from the San Joaquin River has increased in the south Delta, there is no ‘bridging’ turbidity to attract particles into those regions (Figure 4-5).

By December 29th (Figure 6-62), a small number of particles have been attracted to increased turbidity from the Calaveras and San Joaquin Rivers, and have reached the area downstream of Rough-N-Ready Island. More particles have ventured into the Cache-Liberty region, and are remaining there.

By early January (Figure 6-63), a small number of particles have ventured in the Middle Region (Figure 4-5) following the small amount of turbidity increase there from the San Joaquin River. By January 12th (Figure 6-64), turbidity from the December turbidity event is decreasing everywhere, and particles have begun searching for higher turbidity locations in some regions or just remaining where there are or moving with tidal flow (Figure 4-1 describes the color-coding scheme). Particles in the Liberty area have moved back into the mid-Sacramento region (Figure 6-55), while particles in the Middle region remain in place (Figure 6-57).

By early February (Figure 6-67), turbidity and EC gradients are below triggering values throughout much of the Delta. The effects of a new turbidity event on the boundaries begins to influence particle movement by February 23rd (Figure 6-69), particles move back into the Cache-Liberty region and along the San Joaquin River in the area near to and downstream of Rough-N-Ready Island. A turbidity bridge doesn’t form, so particle percentages in the Middle Region have not increased (Figure 6-57).

Table 6-1 Details specifying the inflow boundary time series for the RMA2 Hindcast model.

Common Name	RKI	Model Name	Data Source(s)	Comment
Freeport	RSAC155	-	CDEC FPT Station [USGS]	Filled in data gaps with linear approximation
Vernalis	RSAN112	-	CDEC VNS Station [USGS and DWR]	Filled in data gaps with linear approximation; Incorrectly high flow Jan 3-5 fixed
Calaveras	RCAL009	-	CDEC MRS Station [USACE]	Filled in data gaps with linear approximation
Cosumnes	RCSM075	-	CDEC MCC Station [DWR]	Stage record at MCC converted to flow using CNRFC stage-discharge rating table
Yolo at Lisbon	-	-	CDEC LIS Station [DWR]	Filled in data gaps with linear approximation
Mokelumne	RMKL070	DSM2	-	

Table 6-2 Details specifying the export boundary time series for the RMA2 Hindcast model.

Common Name	RKI	Model Name	Data Source(s)	Comment
SWP	CLFCT-NODE72	DSM2	-	
CVP	CHDMC004	DSM2	-	
North Bay Aqueduct	SLBAR002	DSM2	-	
CCWD Old River	ROLD034	DSM2	-	
CCWD Rock Slough	CHCCC006	DSM2	-	
CCWD Victoria Canal	CHVCT001	DSM2	-	

Table 6-3 Details specifying stage boundary time series for the RMA2 Hindcast model.

Common Name	RKI	Model Name	Data Source(s)	Comment
Martinez	RSAC054	-	CDEC MRZ Station [DWR]	Filled in data gaps with linear approximation; shifted -2.68 ft. to convert from NGCD29 to NAVD88, then shifted +0.3 ft. for correction with EC model boundary condition.

Table 6-4 Details specifying turbidity boundary time series for the RMA11 Hindcast model.

Common Name	RKI	Model Name	Data Source(s)	Comment
Martinez	RSAC054	-	CDEC MRZ Station [DWR]	Filled in data gaps with linear approximation
Freeport	RSAC155	-	CDEC FPT Station [USGS]	Filled in data gaps with linear approximation; shifted data -7 hours; remove suspect turbidity at ~ Dec. 24th
Vernalis	RSAN112	-	CDEC MSD Station [DWR]	Use Mossdale station, shifted – 8 hours – less noisy. Filled in data gaps with linear approximation
Calaveras	RCAL009	WARMF	-	WARMF predictions too high; Multiplied by 0.1 to bring closer to values measured at Turner Cut
Cosumnes	RCSM075	-	CDEC SMR Station [DWR]	Use CDEC turbidity data, WARMF at start before data available
Yolo at Lisbon	-	-	CDEC RYI Station [USGS]	CDEC used because WARMF predictions too high; Data gaps filled with linear approximation
Mokelumne	RMKL070	-	CDEC SMR Station [DWR]	Same as Cosumnes

Table 6-5 Details specifying EC boundary time series for the RMA11 Hindcast model.

Common Name	RKI	Model Name	Data Source(s)	Comment
Martinez	RSAC054	-	CDEC MRZ Station [DWR]	Filled in data gaps with linear approximation
Freeport	RSAC155	-	CDEC FPT Station [USGS]	Filled in data gaps with linear approximation; shifted data -7 hours
Vernalis	RSAN112	-	CDEC SJR Station [DWR]	Filled in data gaps with linear approximation
Calaveras	RCAL009	WARMF	-	
Cosumnes	RCSM075	WARMF	-	
Yolo at Lisbon	-	-	CDEC RYI Station [USGS]	CDEC used because WARMF predictions too high; Data gaps filled with linear approximation
Mokelumne	RMKL070	WARMF	-	

Table 6-6 Summary of boundary condition formulas for the RMA Hindcast starting November 01, 2010 and ending Feb. 28, 2011.

Location	Parameter	Time Shift	Data source
Freeport			
	Turbidity	Back 7 hours	CDEC FPT
	EC	Back 7 hours	CDEC FPT
	Flow	N/A	CDEC FPT
Yolo			
	Turbidity	N/A	CDEC RYI
	EC	N/A	CDEC RYI
	Flow	N/A	CDEC/USGS/CNRFC
Calaveras			
	Turbidity	N/A	WARMF
	EC	N/A	WARMF
	Flow	N/A	CDEC MRS
Cosumnes			
	Turbidity	Back 5 hours	CDEC SMR
	EC	Back 5 hours	WARMF
	Flow	N/A	CDEC MCC
Mokelumne			
	Turbidity	Back 5 hours	CDEC SMR
	EC	Back 5 hours	WARMF
	Flow	N/A	DSM2
Vernalis/SJR-McCune			
	Turbidity	Back 8 hours	CDEC MSD
	EC	N/A	CDEC SJR
	Flow	N/A	CDEC SJR

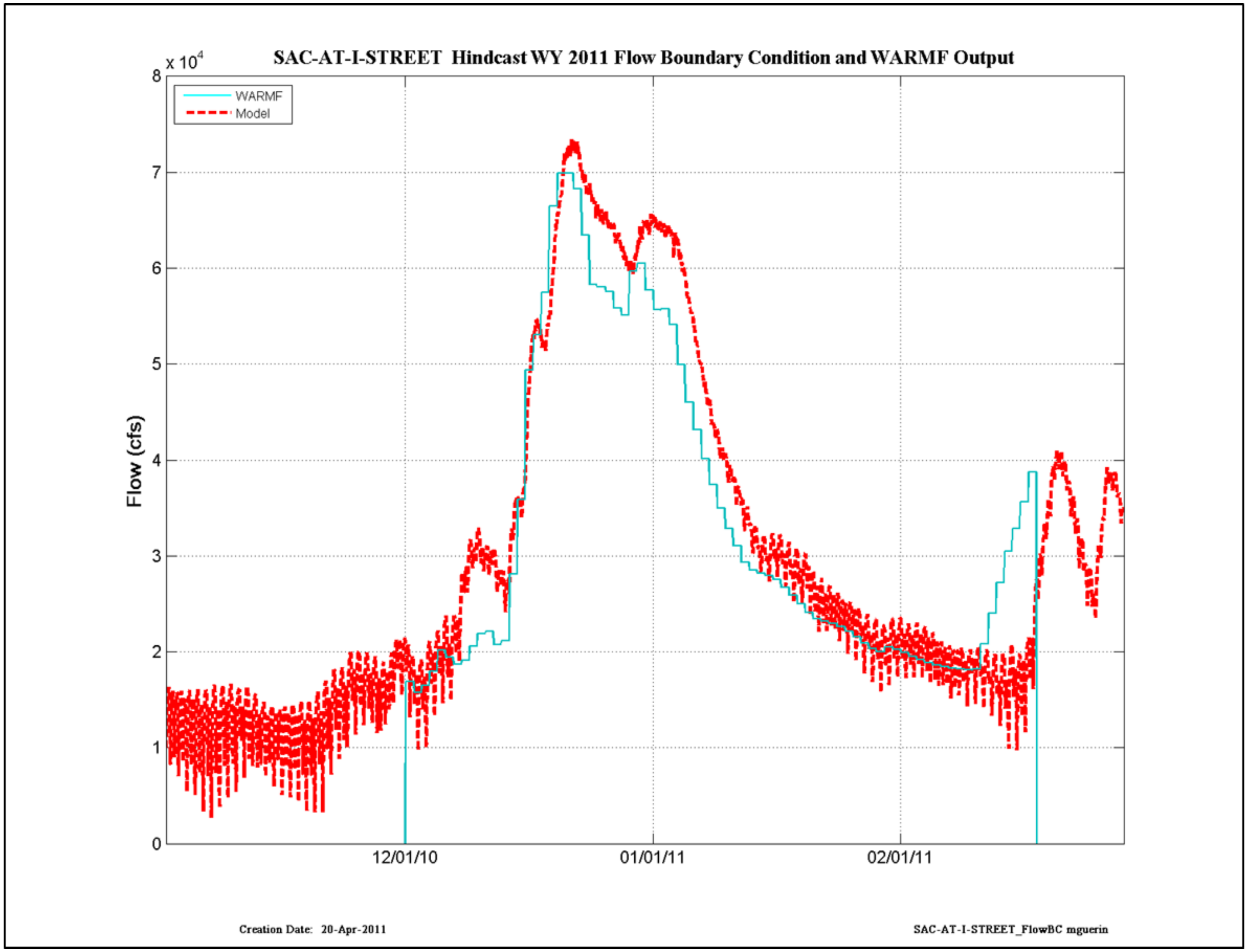


Figure 6-1 Freeport flow boundary condition for the Hindcast and WARMF model output.

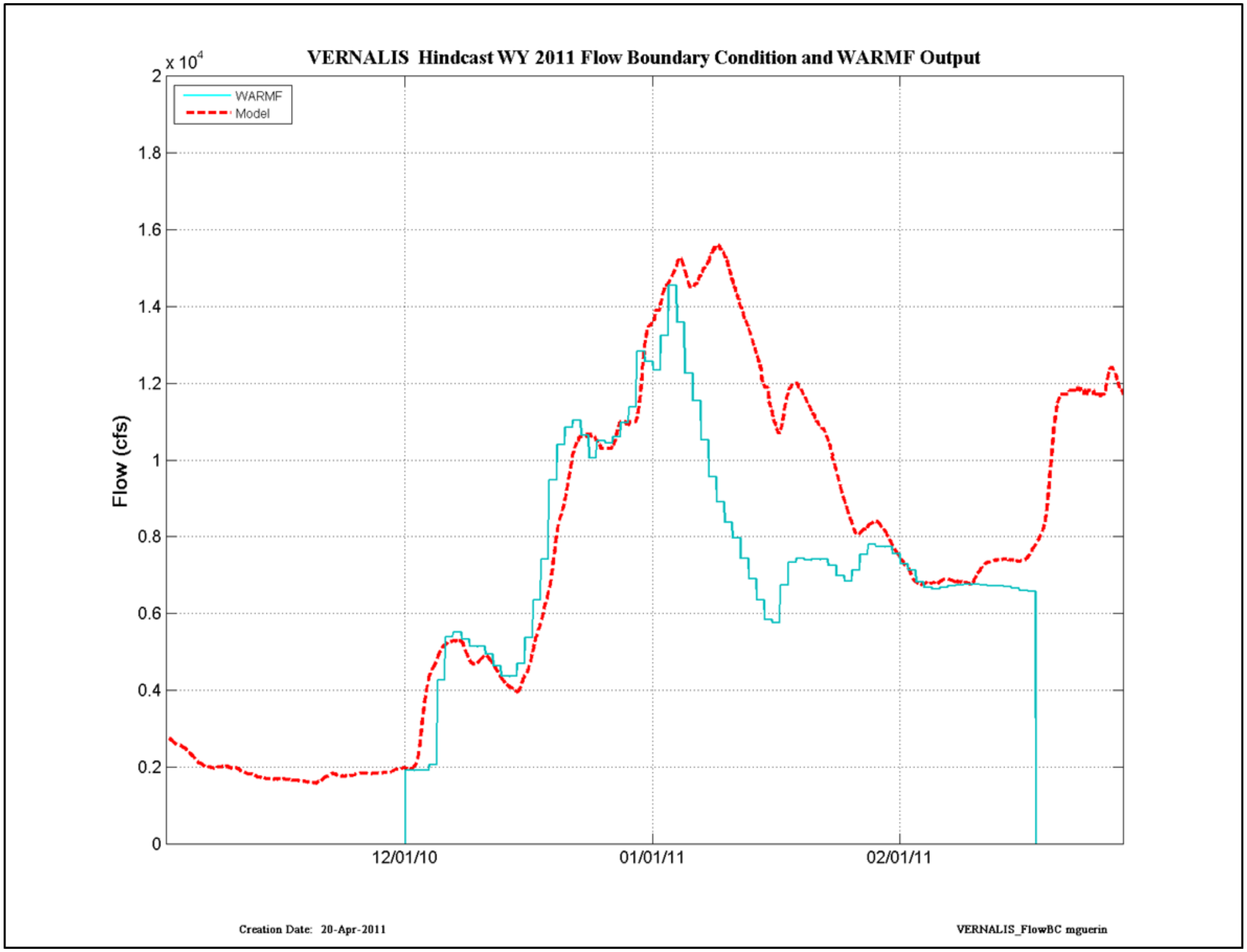


Figure 6-2 Vernalis flow boundary condition for the Hindcast and WARMF model output.

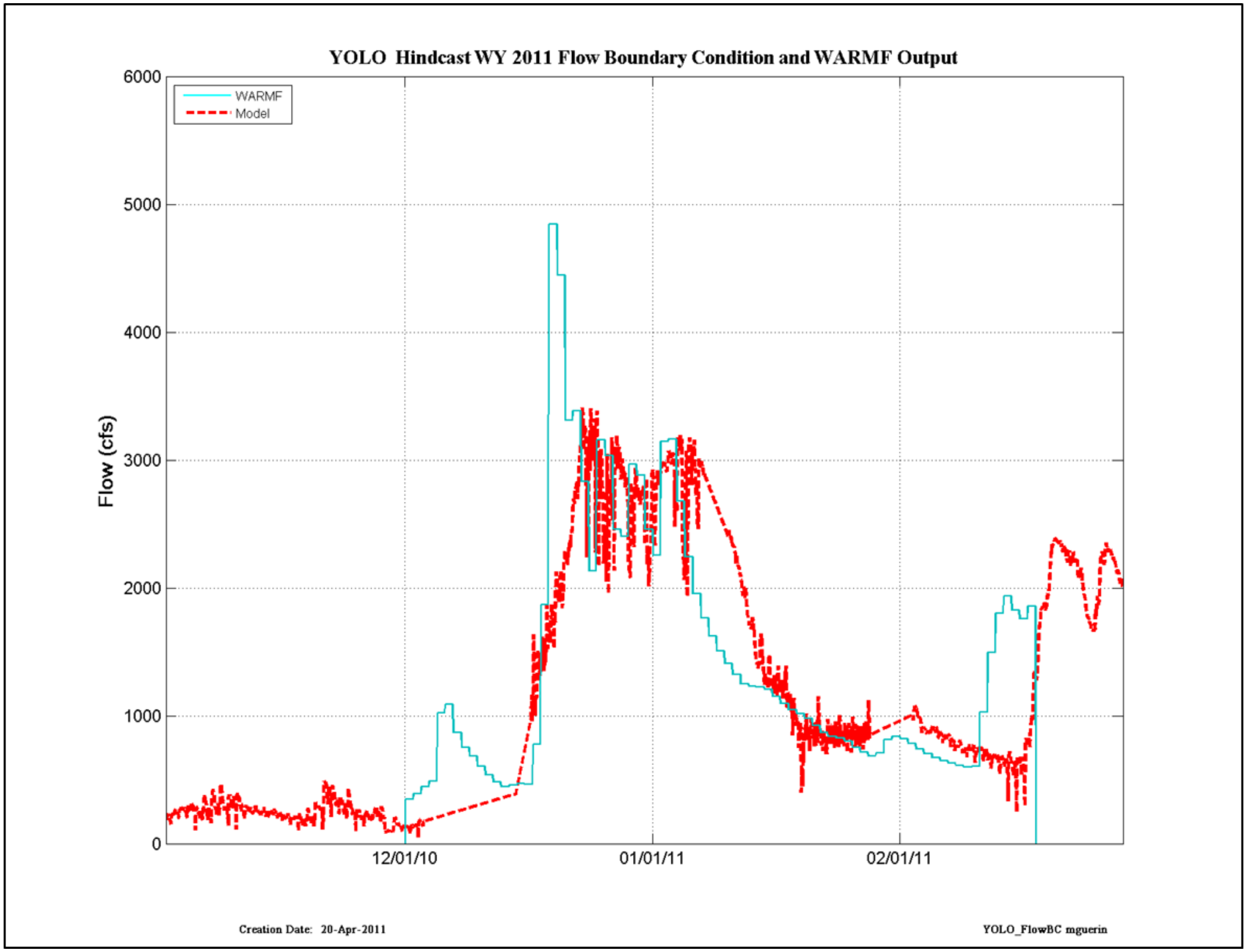


Figure 6-3 Yolo flow boundary condition for the Hindcast and WARMF model output.

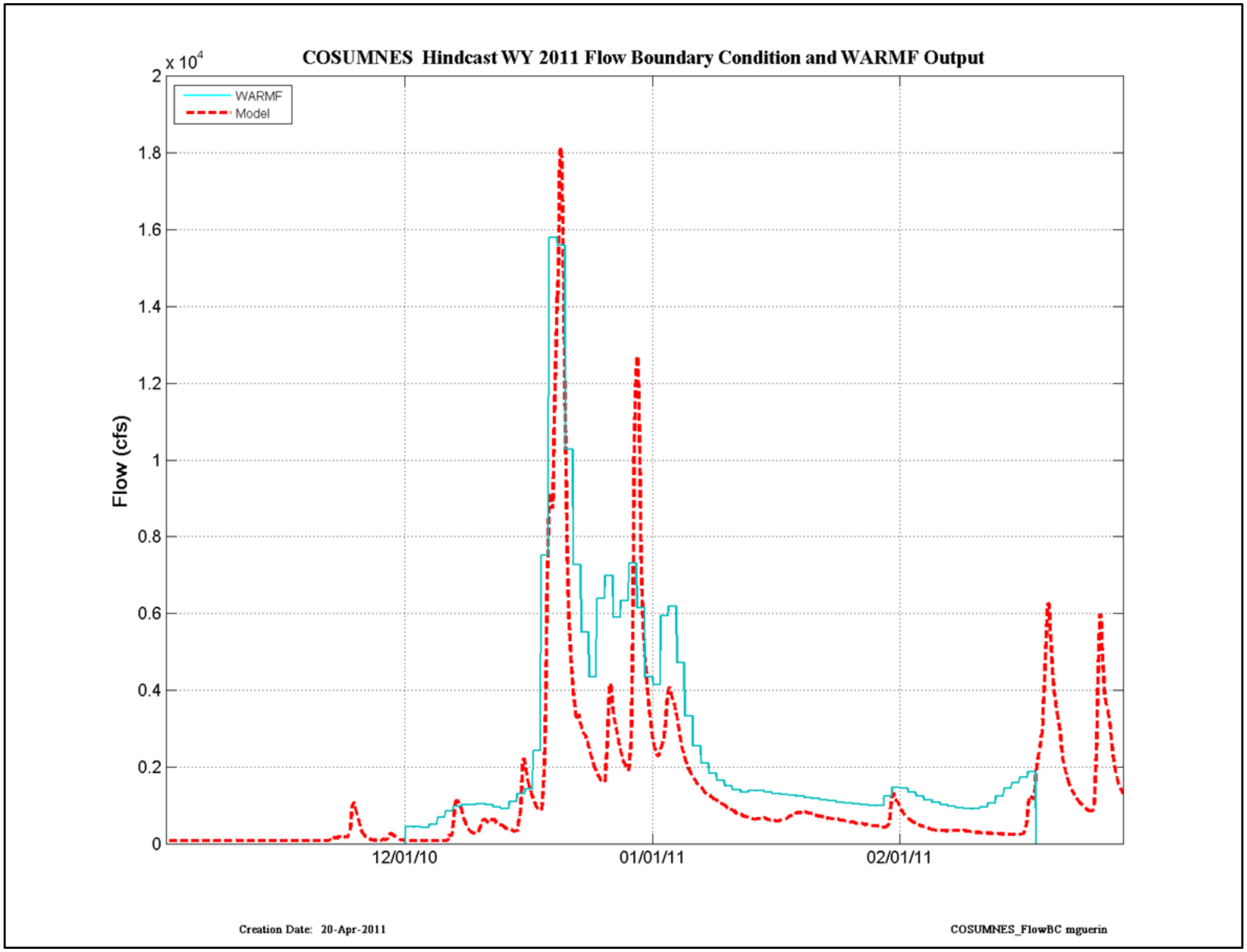


Figure 6-4 Cosumnes R. flow boundary condition for the Hindcast and WARMF model output.

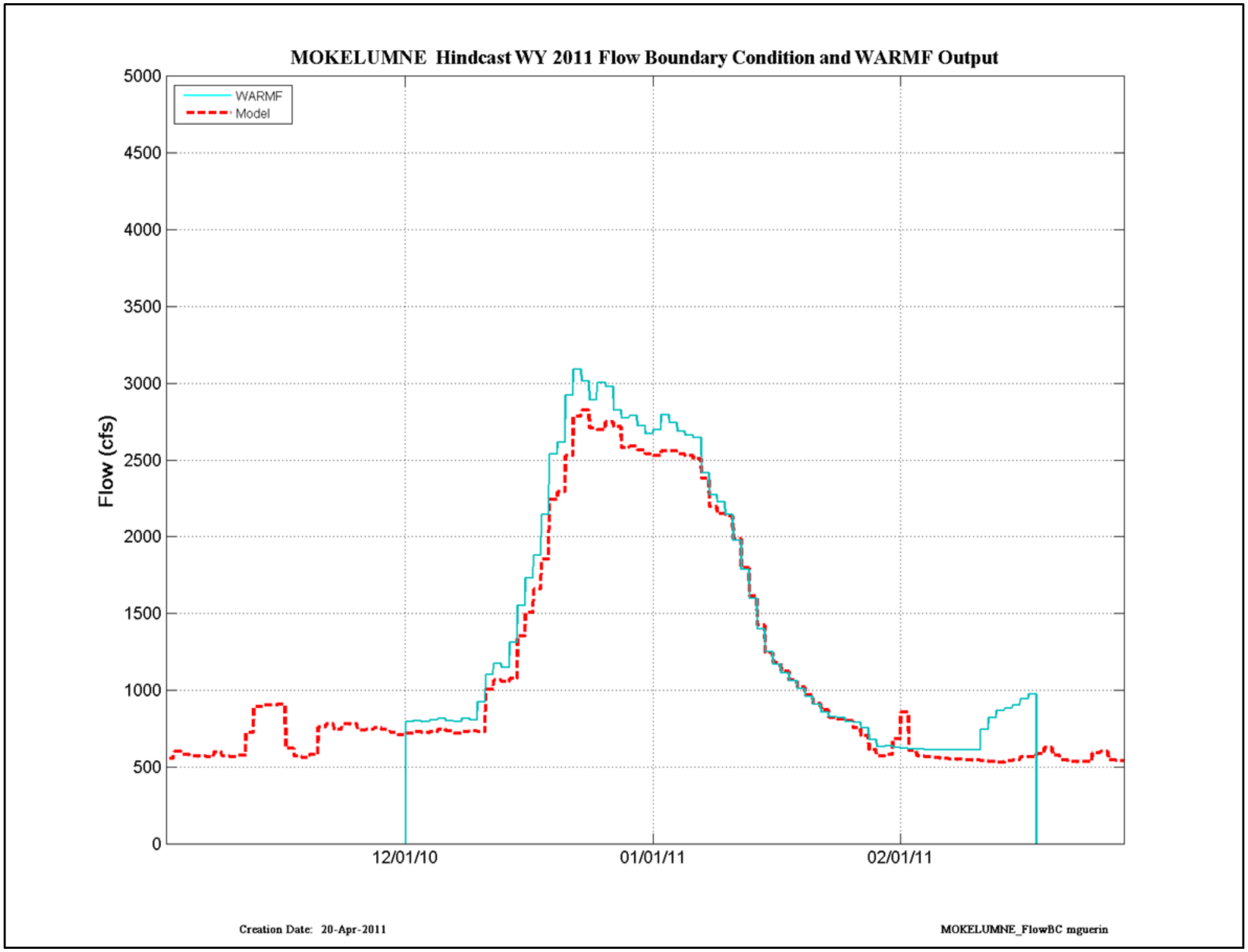


Figure 6-5 Mokelumne R. flow boundary condition for the Hindcast and WARMF model output.

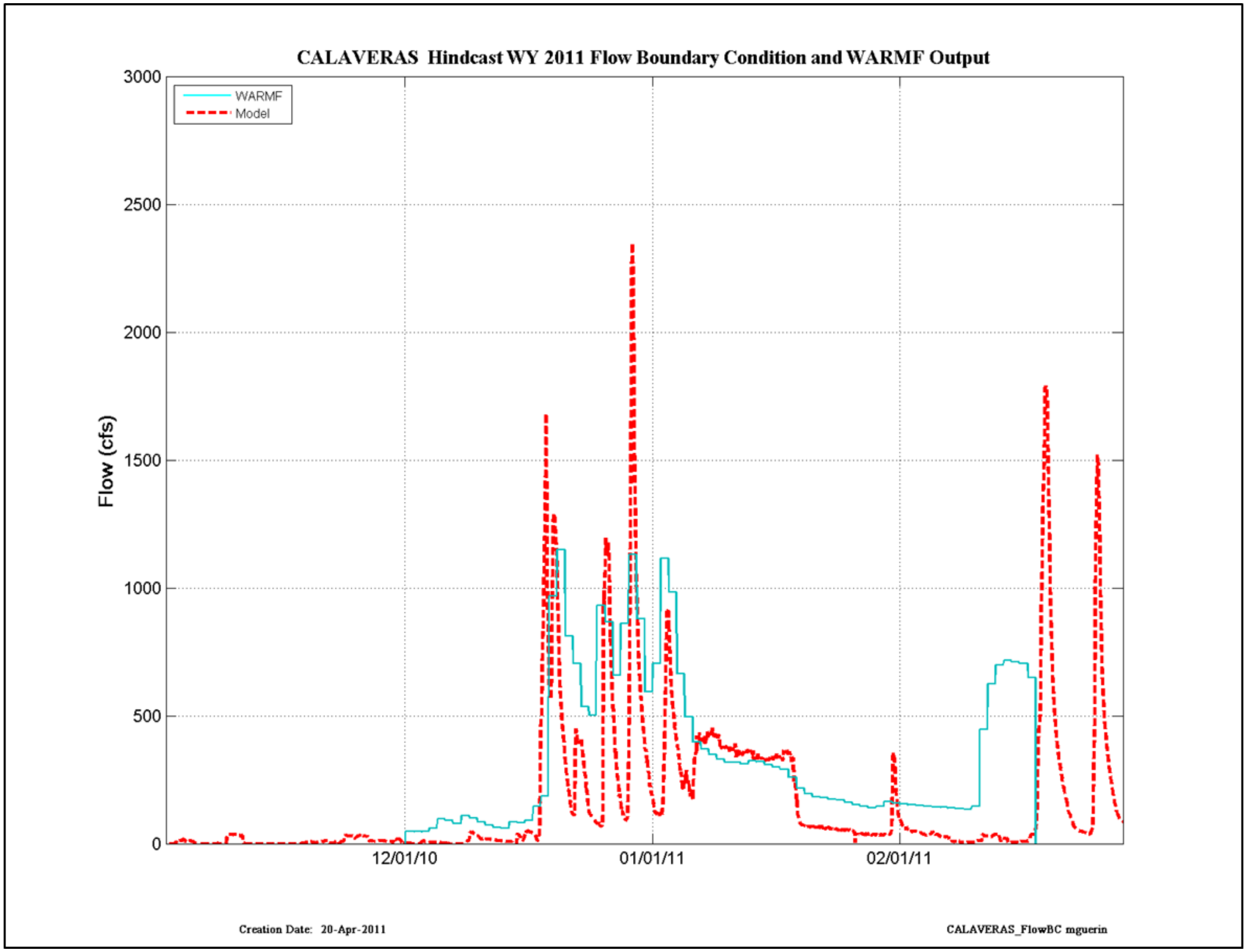


Figure 6-6 Calaveras R. flow boundary condition for the Hindcast and WARMF model output.

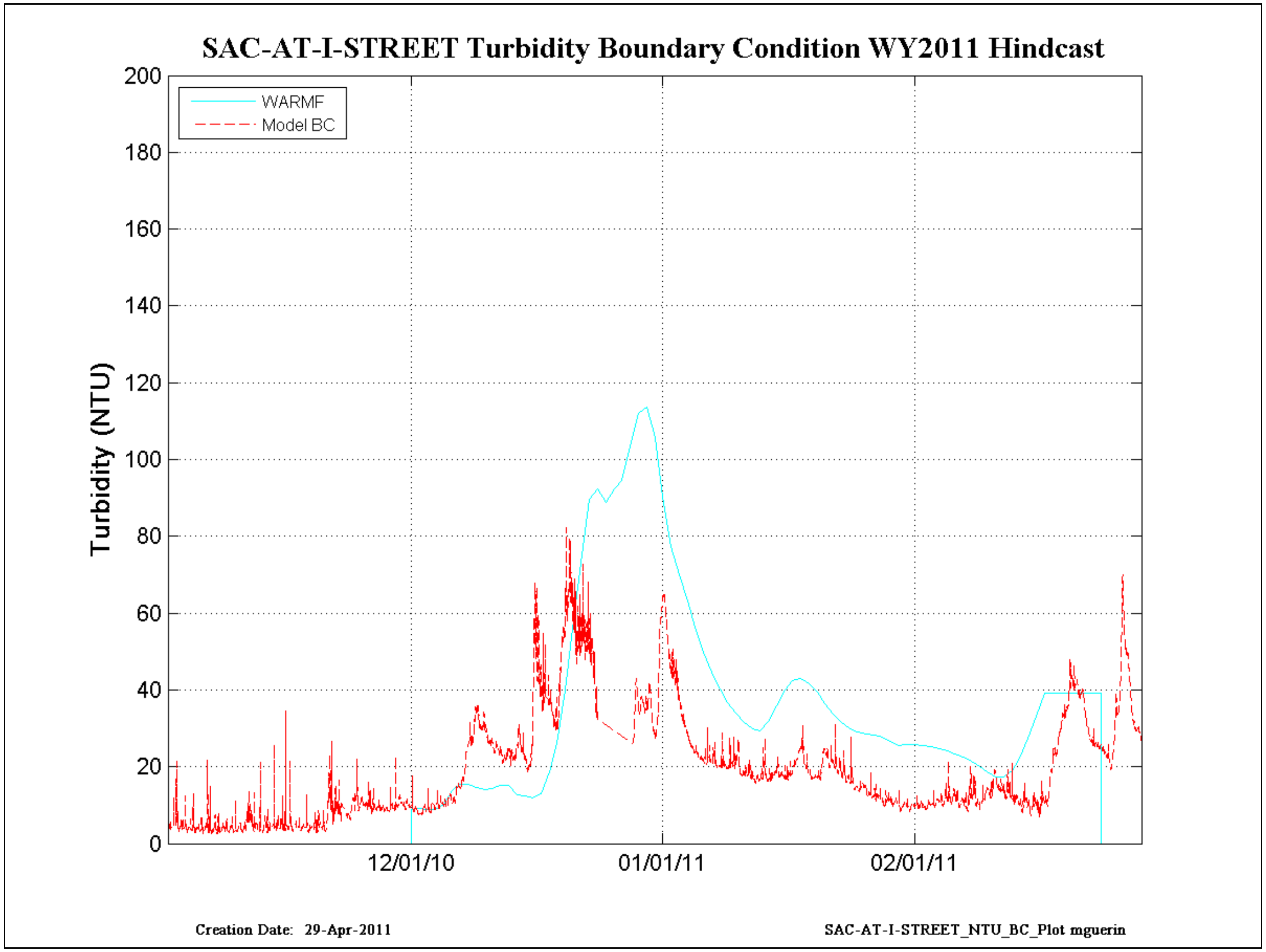


Figure 6-7 Freeport turbidity boundary condition for the Hindcast and WARMF model output.

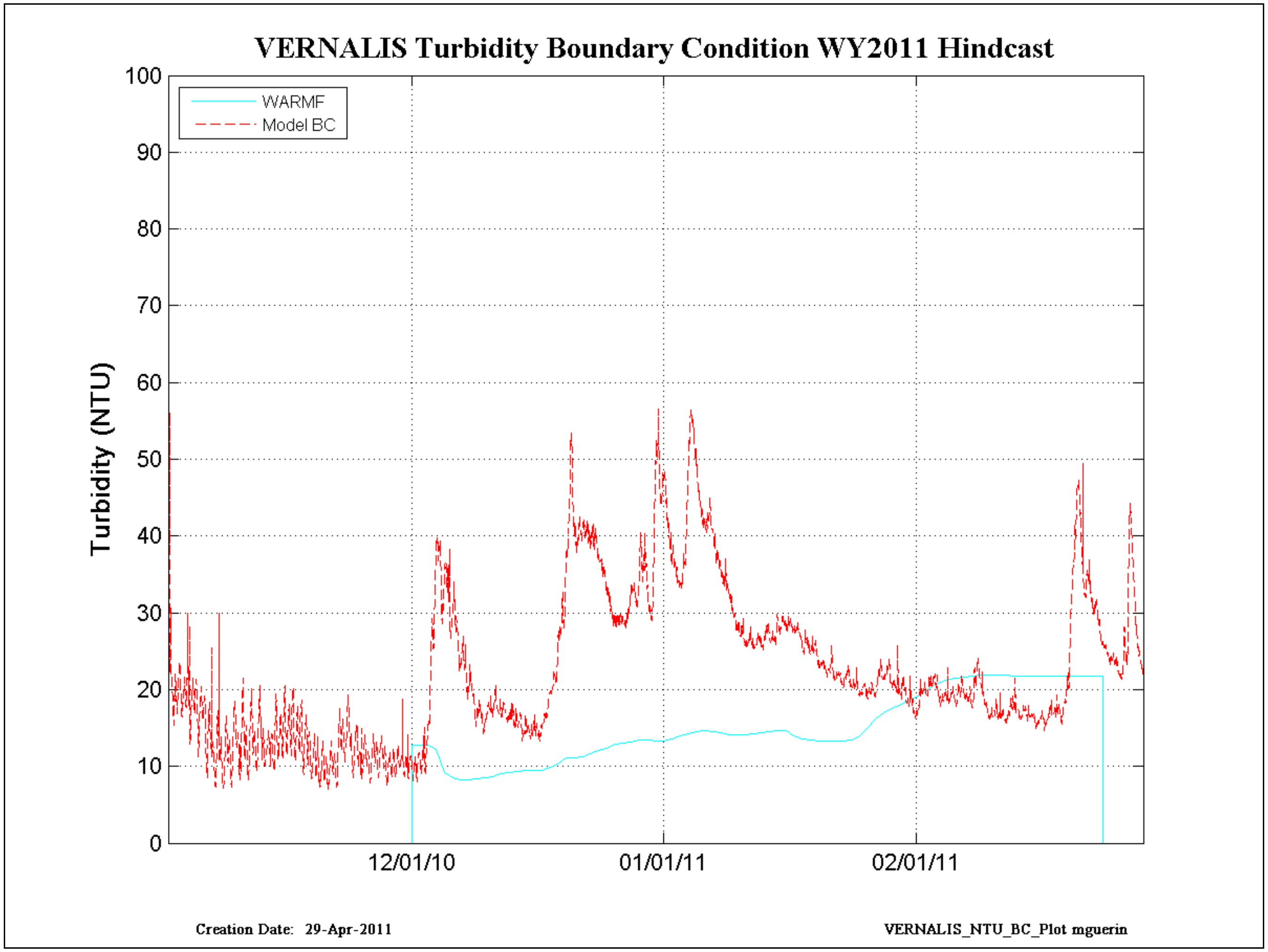


Figure 6-8 Vernalis turbidity boundary condition for the Hindcast and WARMF model output.

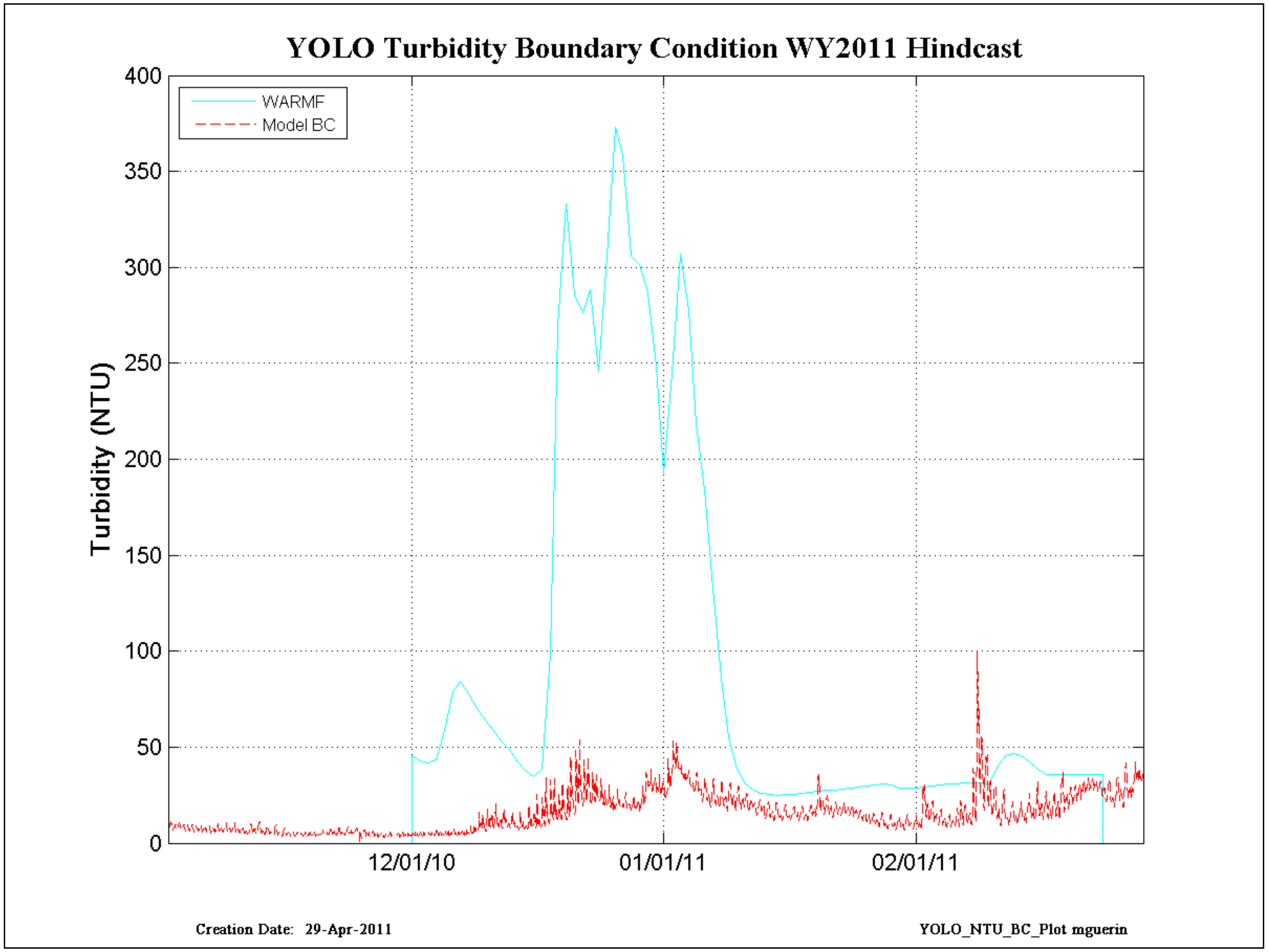


Figure 6-9 Yolo turbidity boundary condition for the Hindcast and WARMF model output.

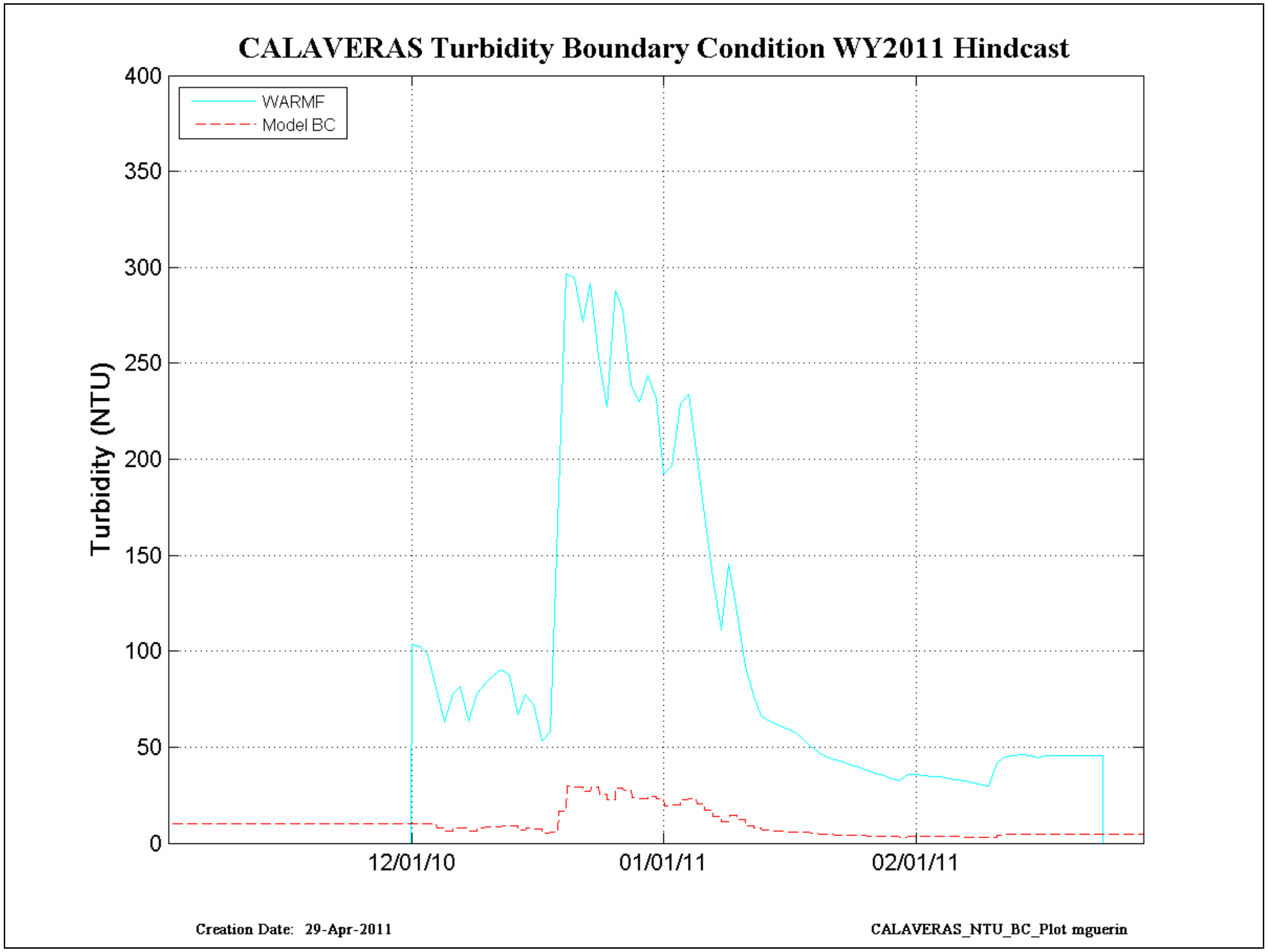


Figure 6-10 Calaveras R. turbidity boundary condition for the Hindcast and WARMF model output.

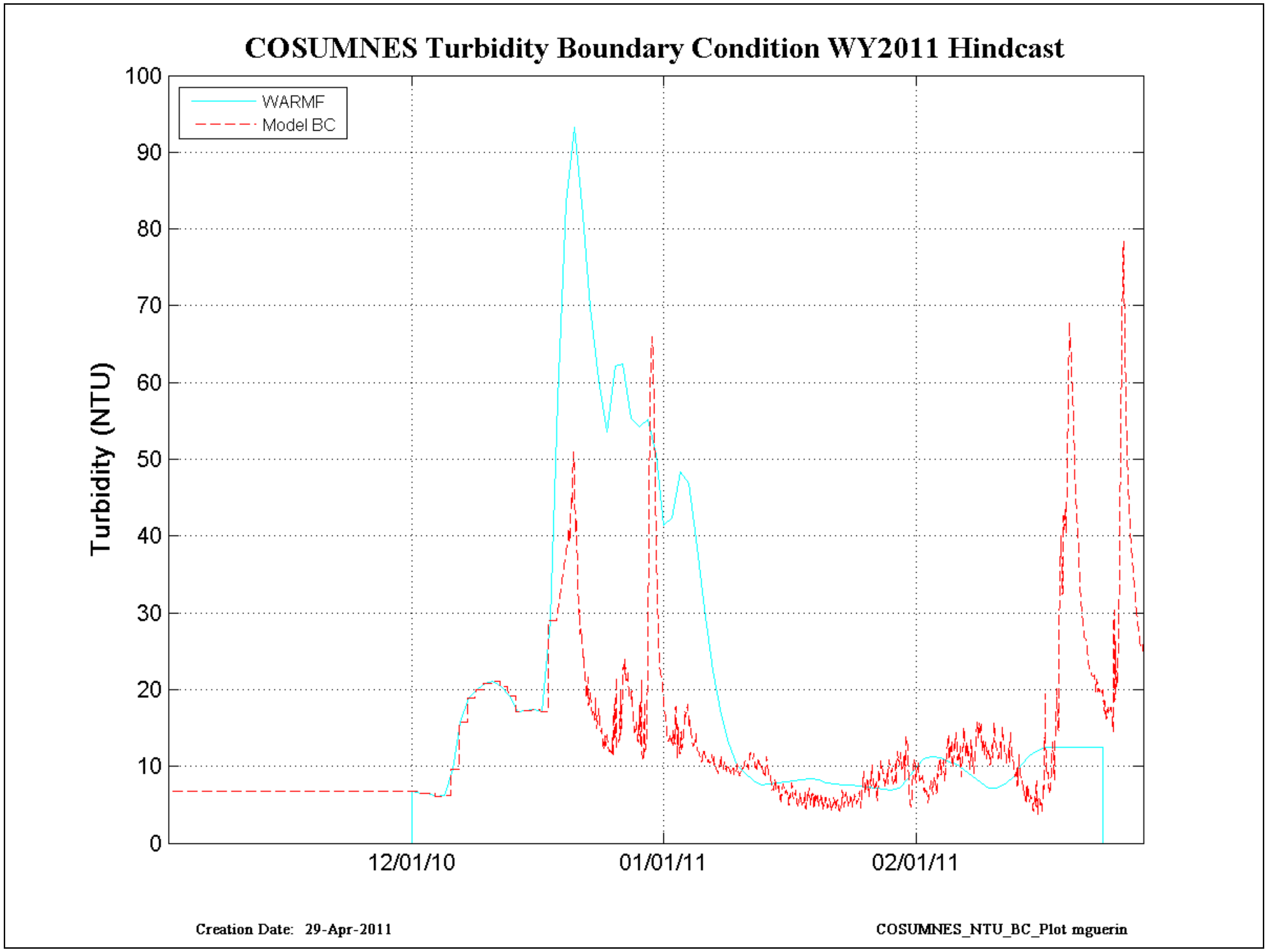


Figure 6-11 Cosumnes R. turbidity boundary condition for the Hindcast and WARMF model output.

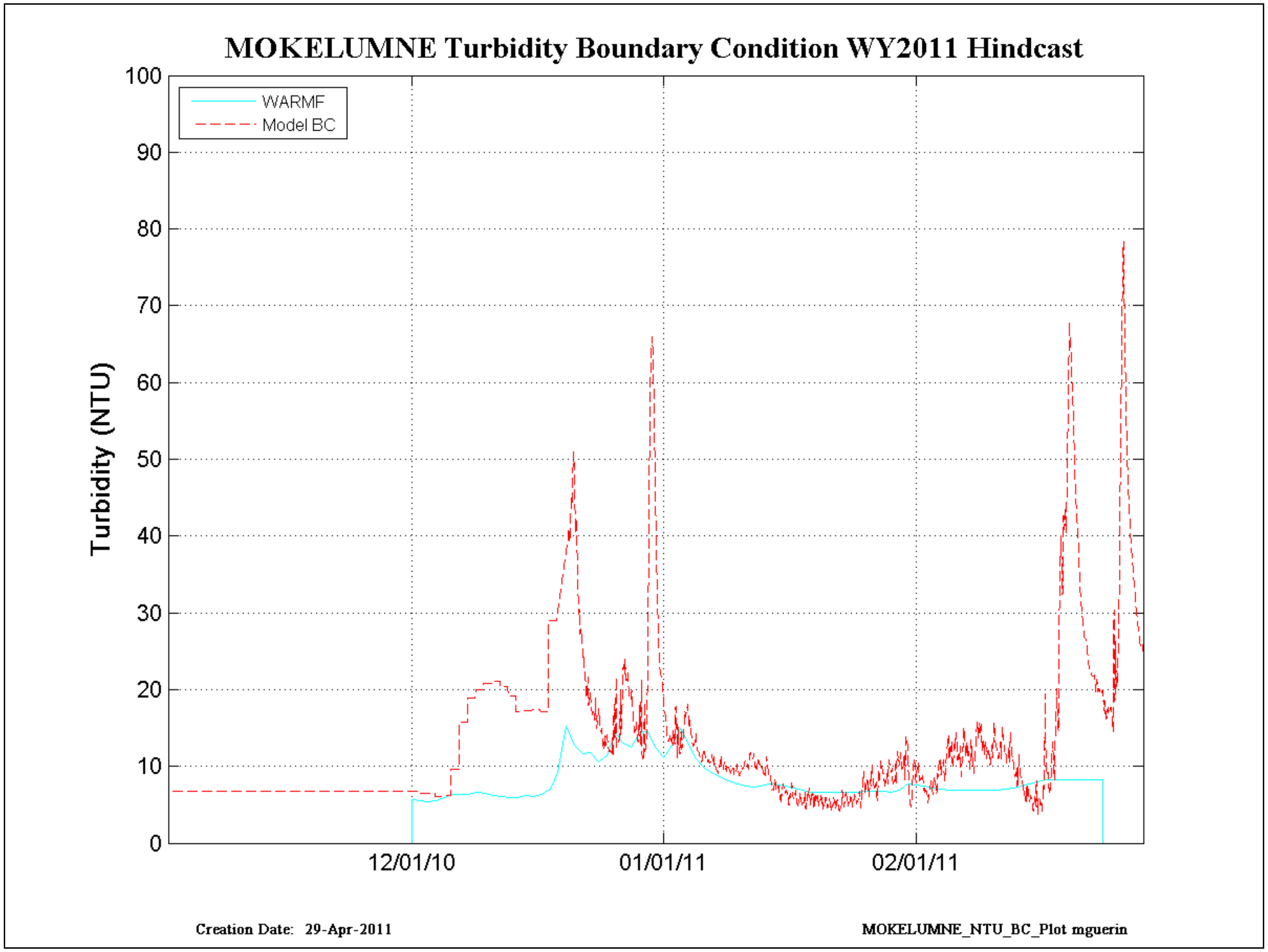


Figure 6-12 Mokelumne R. turbidity boundary condition for the Hindcast and WARMF model output.

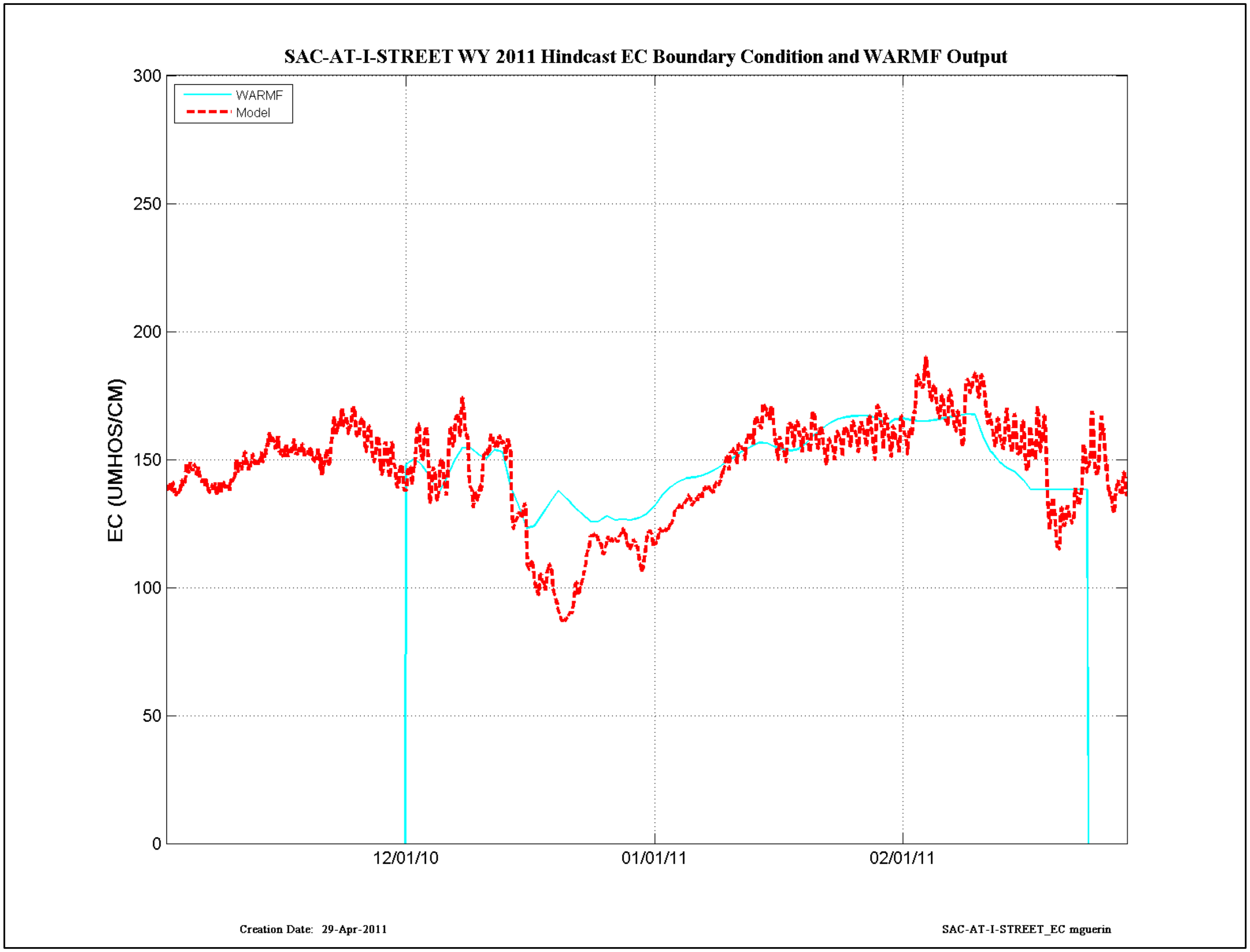


Figure 6-13 Freeport EC boundary condition for the Hindcast and WARMF model output.

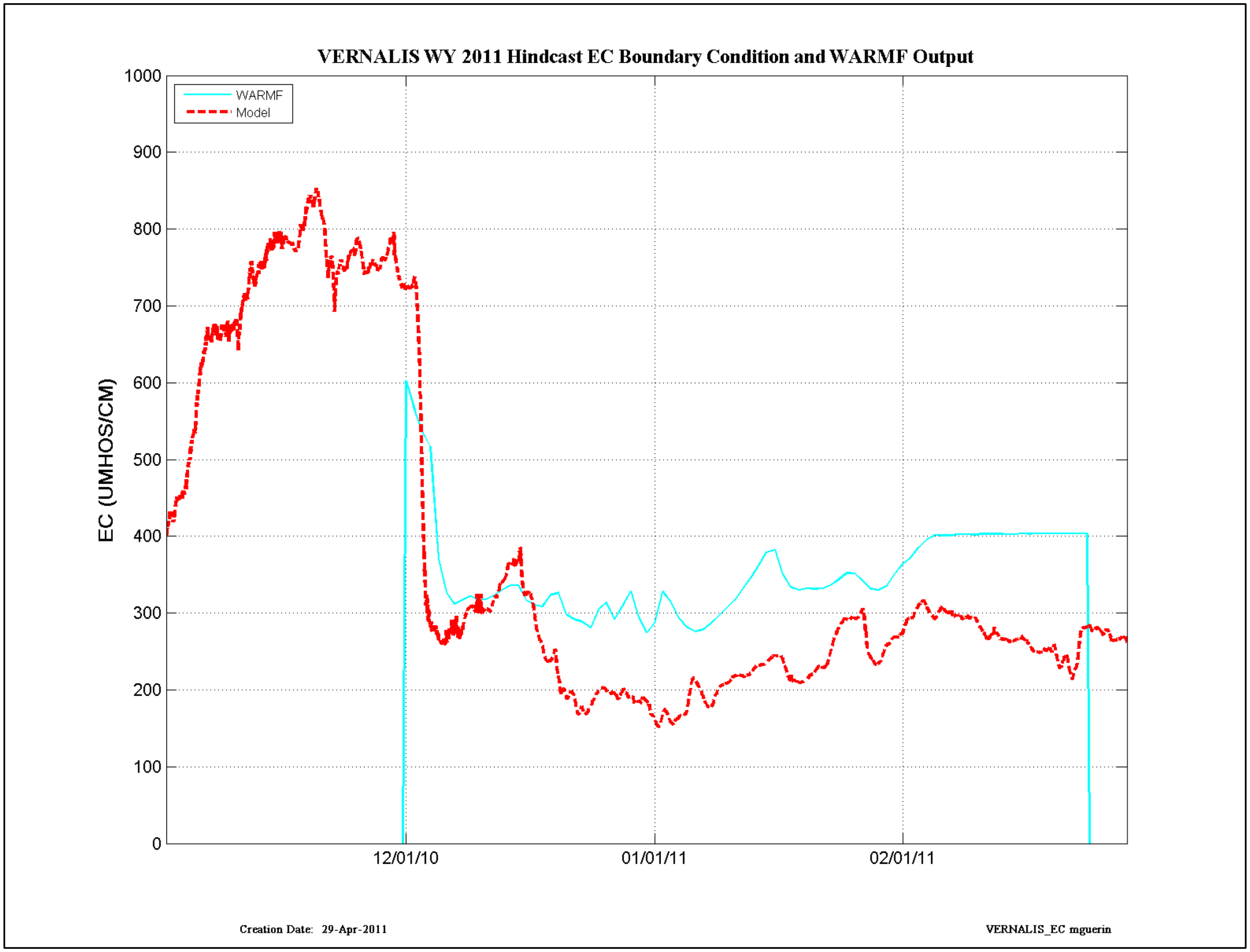


Figure 6-14 Freeport EC boundary condition for the Hindcast and WARMF model output.

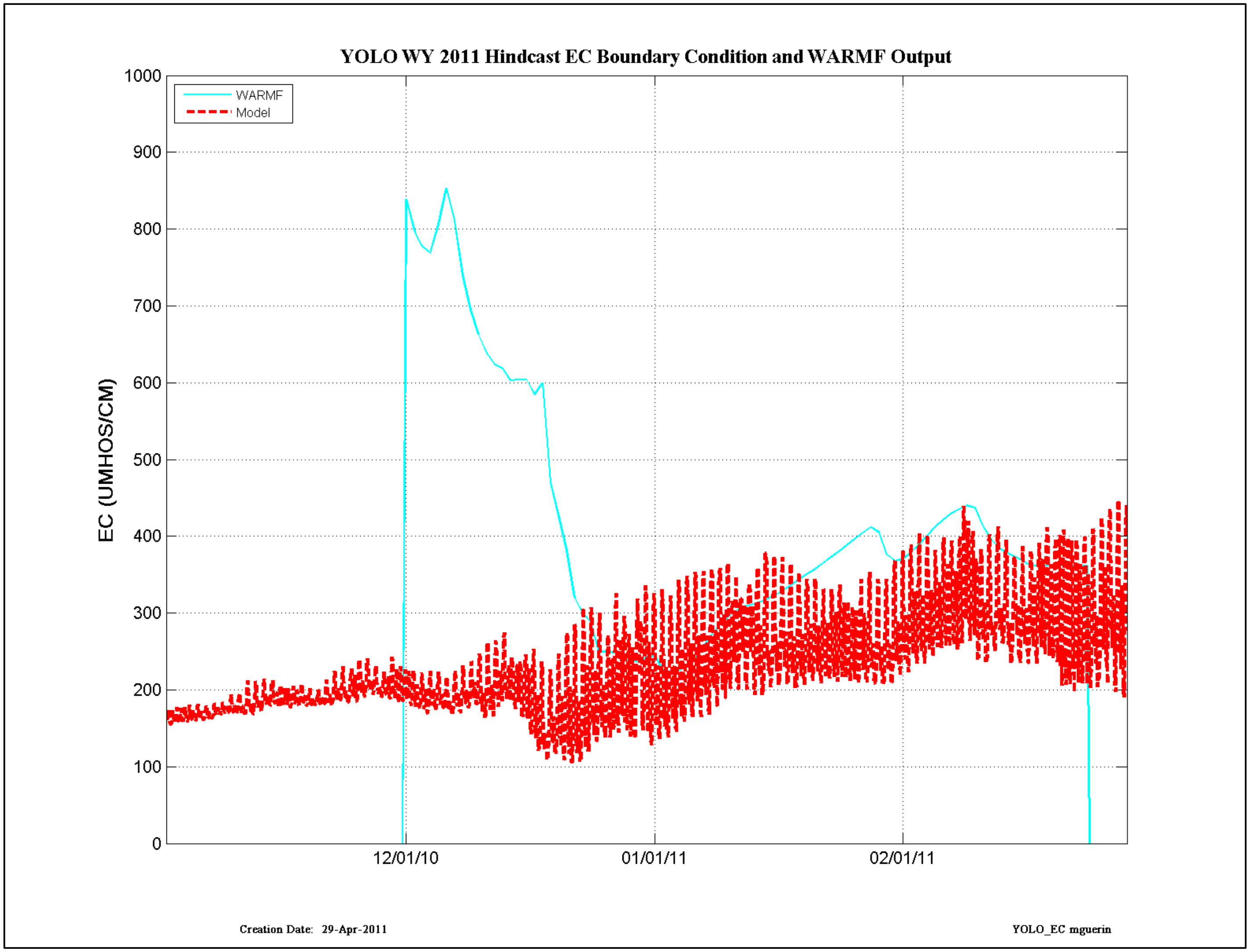


Figure 6-15 Yolo EC boundary condition for the Hindcast and WARMF model output.

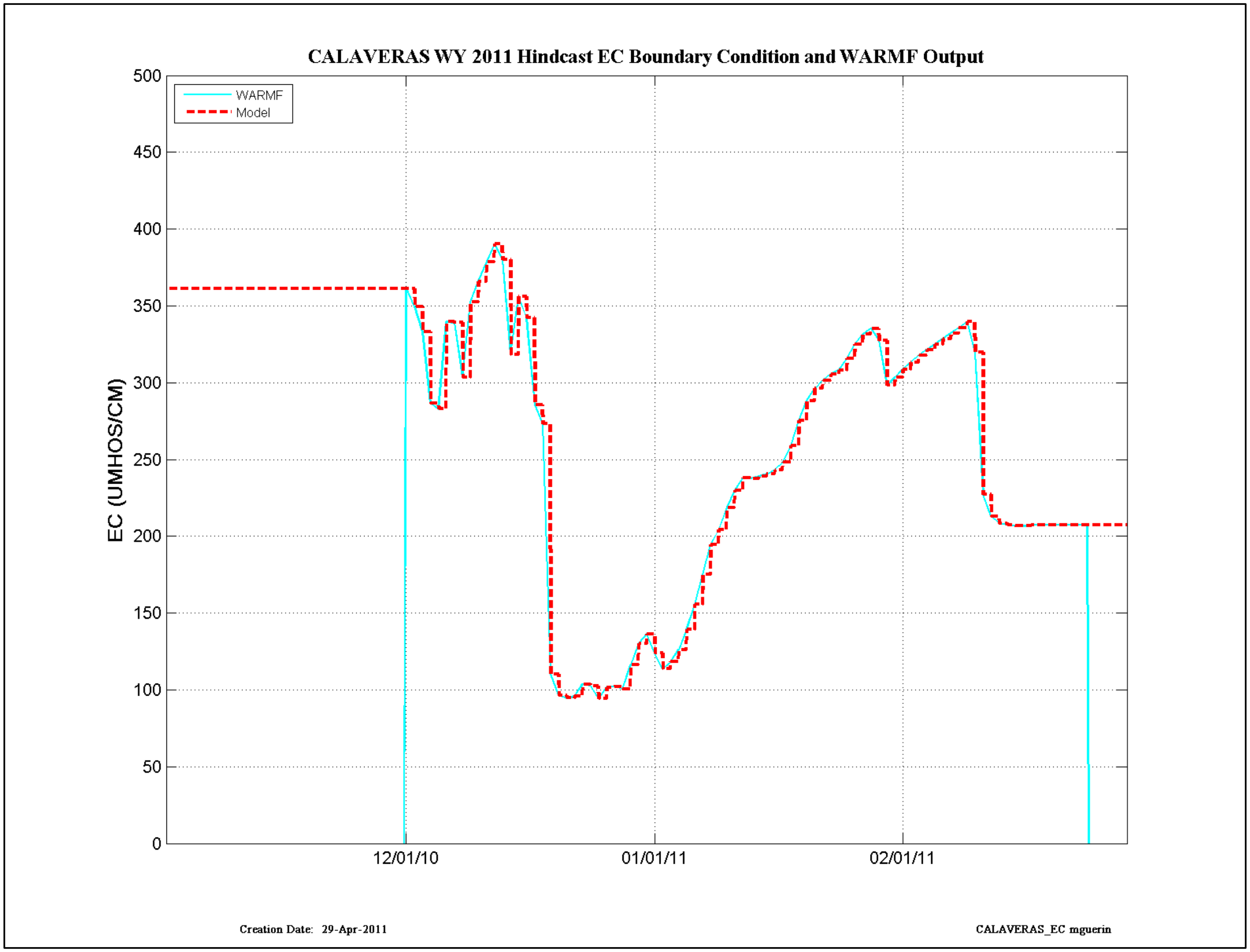


Figure 6-16 Calaveras EC boundary condition for the Hindcast and WARMF model output.

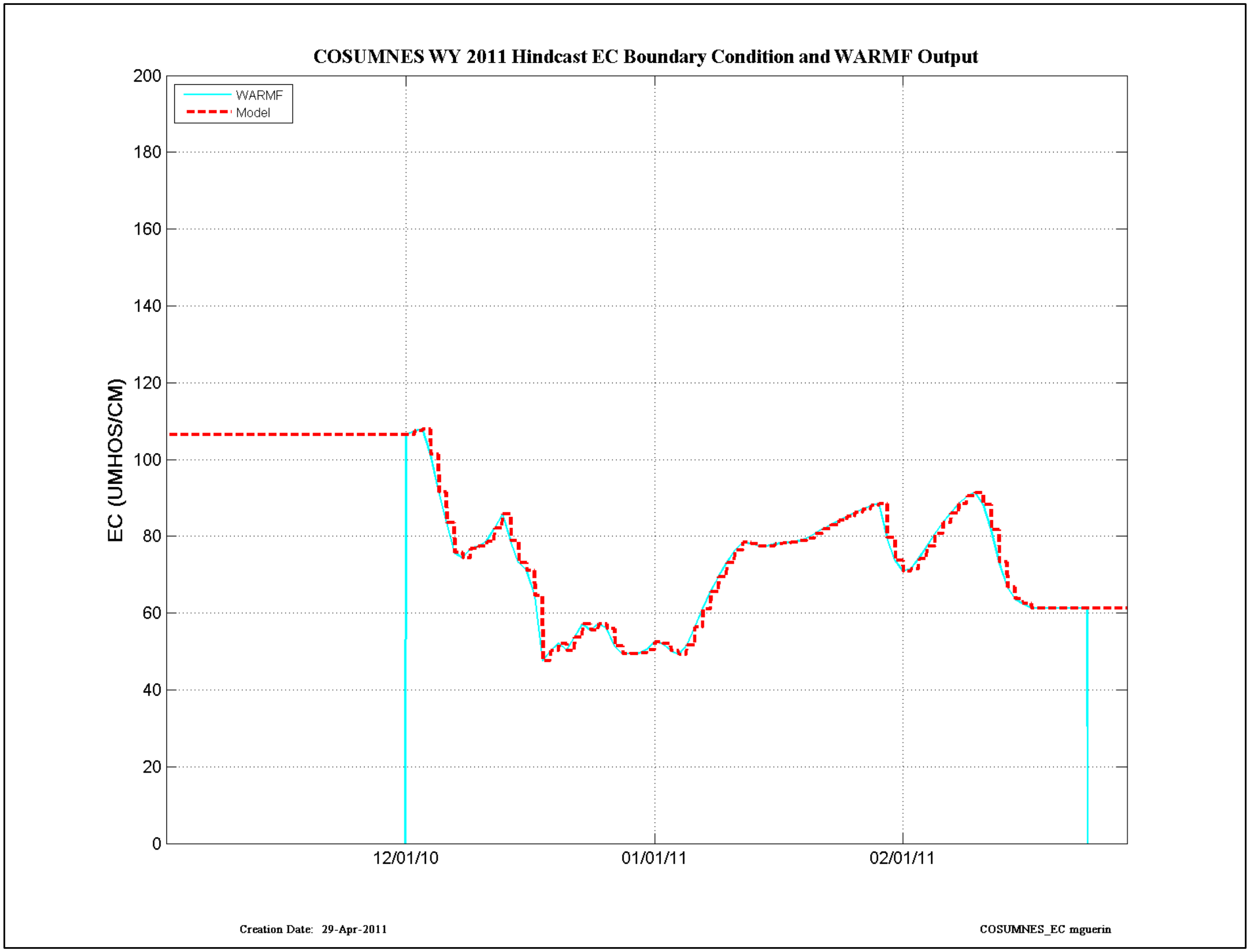


Figure 6-17 Cosumnes EC boundary condition for the Hindcast and WARMF model output.

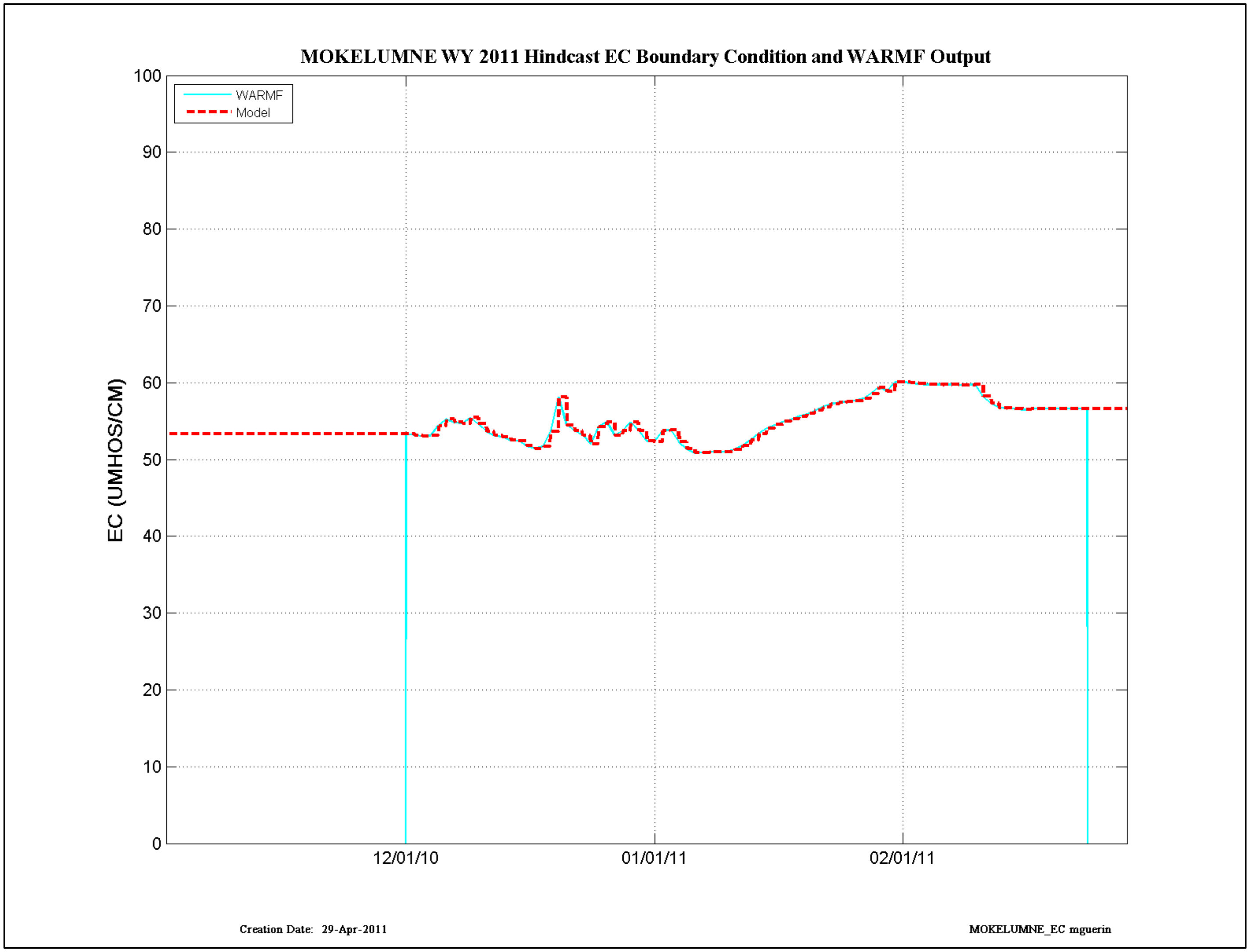


Figure 6-18 Mokelumne EC boundary condition for the Hindcast and WARMF model output.

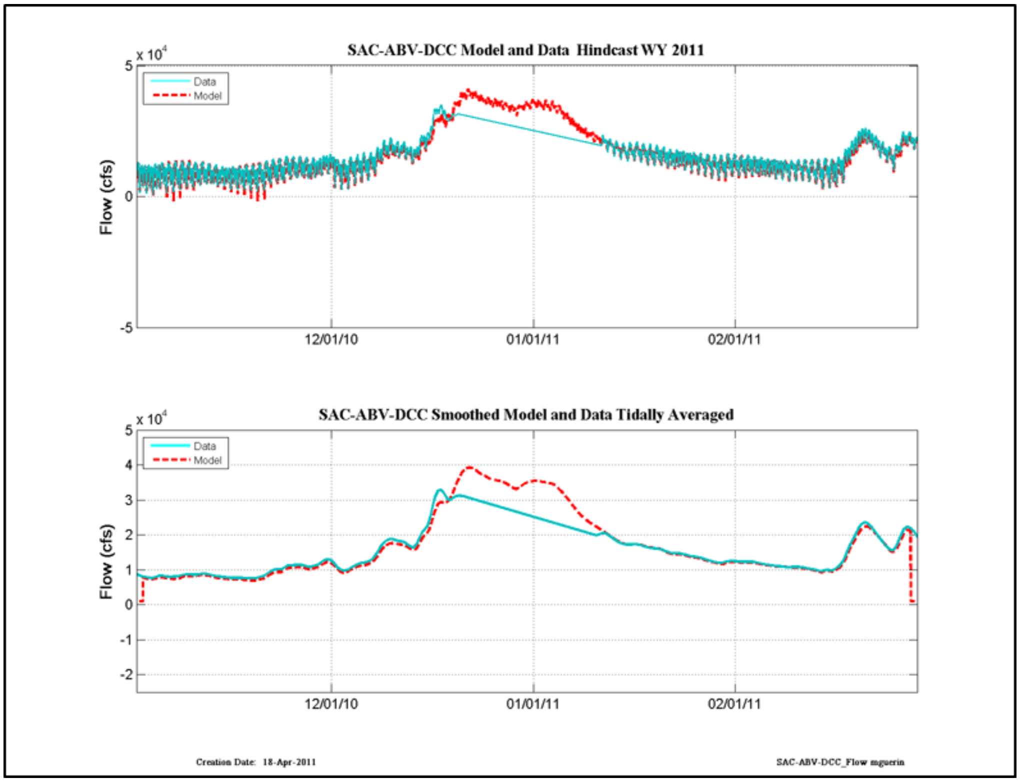
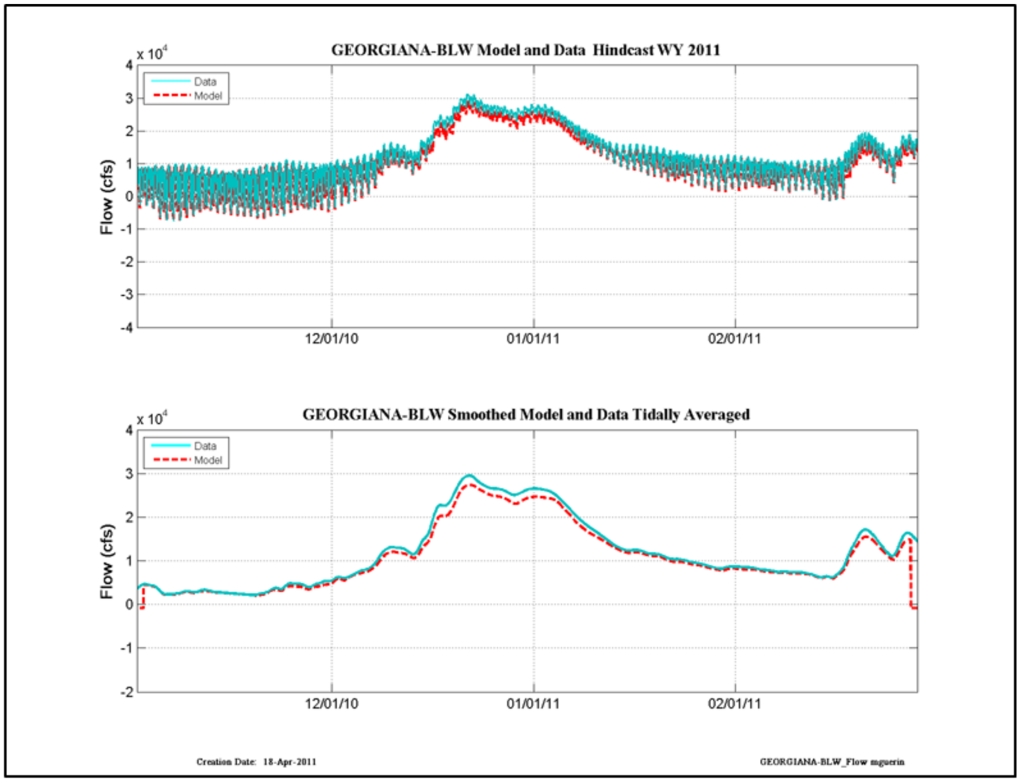


Figure 6-19 Flow Hindcast model results and tidally averaged results at SAC-ABV-DCC.



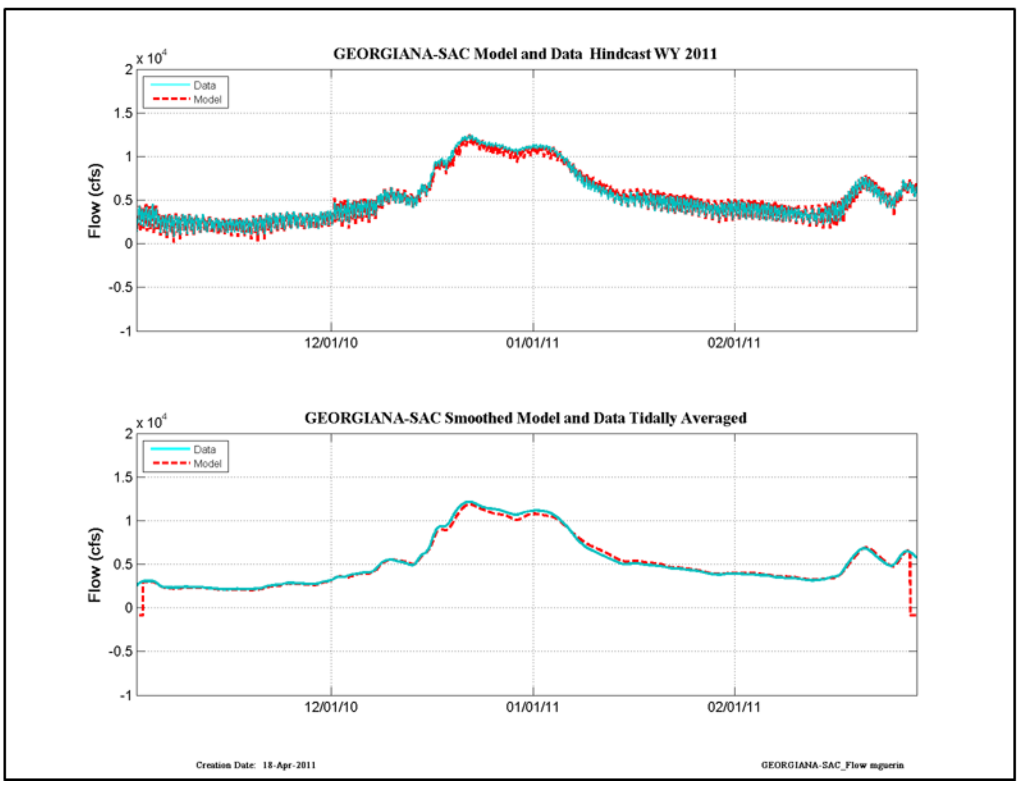
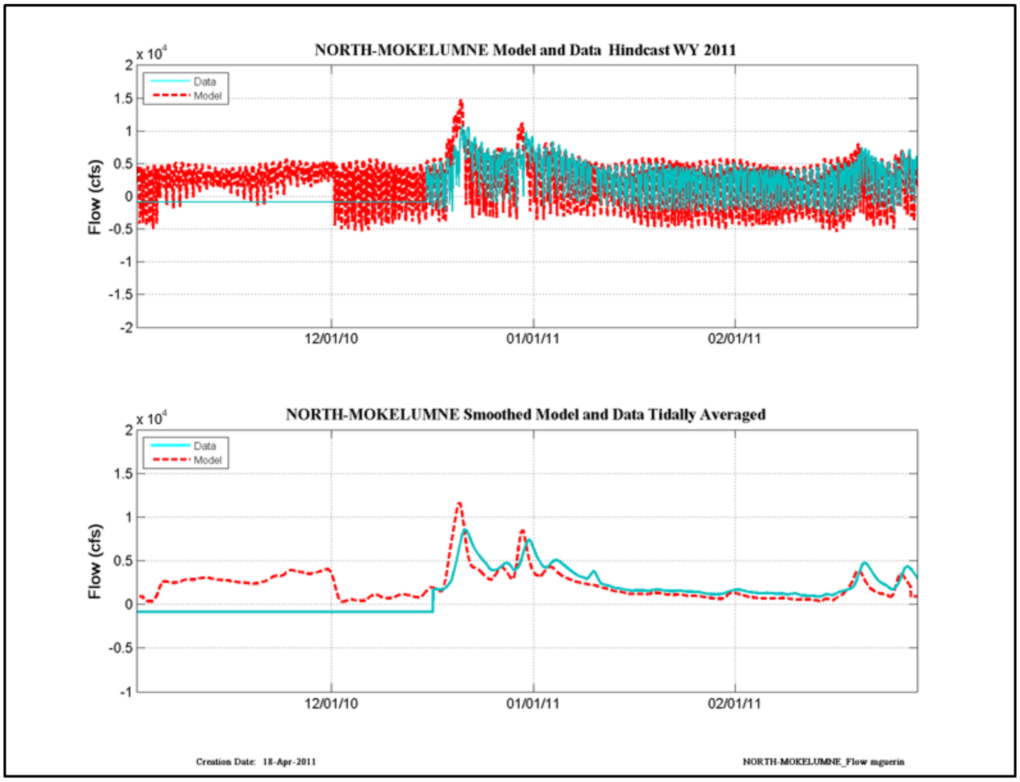


Figure 6-20 Flow Hindcast model results and tidally averaged results at GEORGIANA-BLW (upper) and at GEORGIANA-SAC (lower).



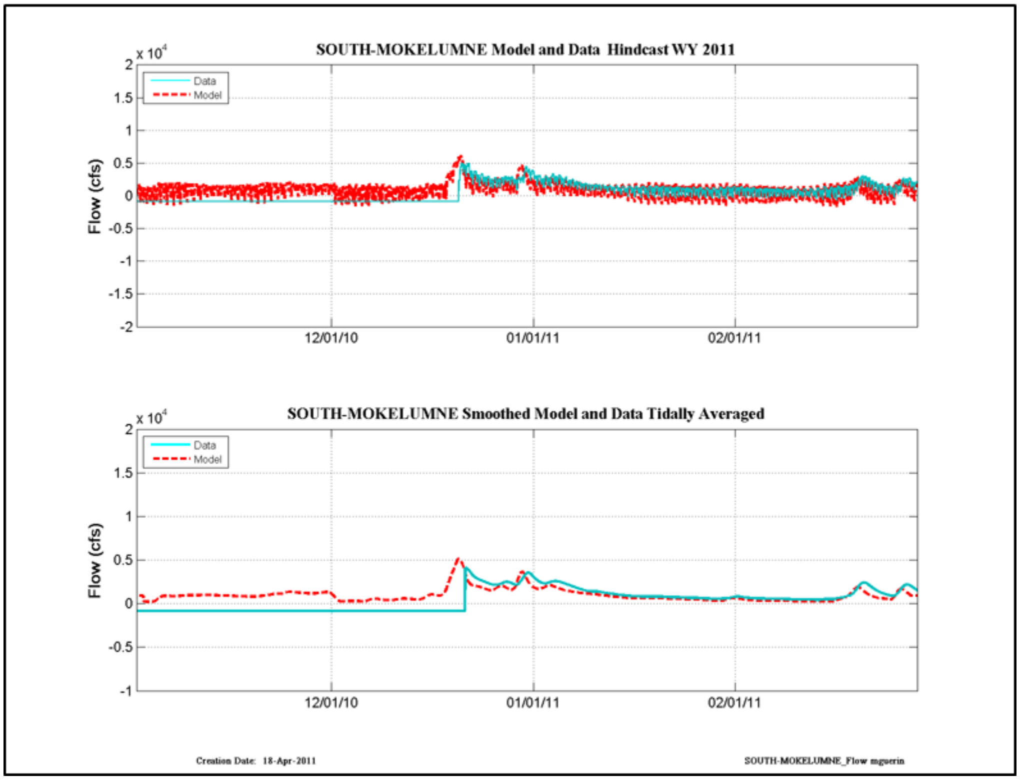


Figure 6-21 Flow Hindcast model results and tidally averaged results at NORTH-MOKELUMNE (upper) and at SOUTH-MOKELUMNE (lower).

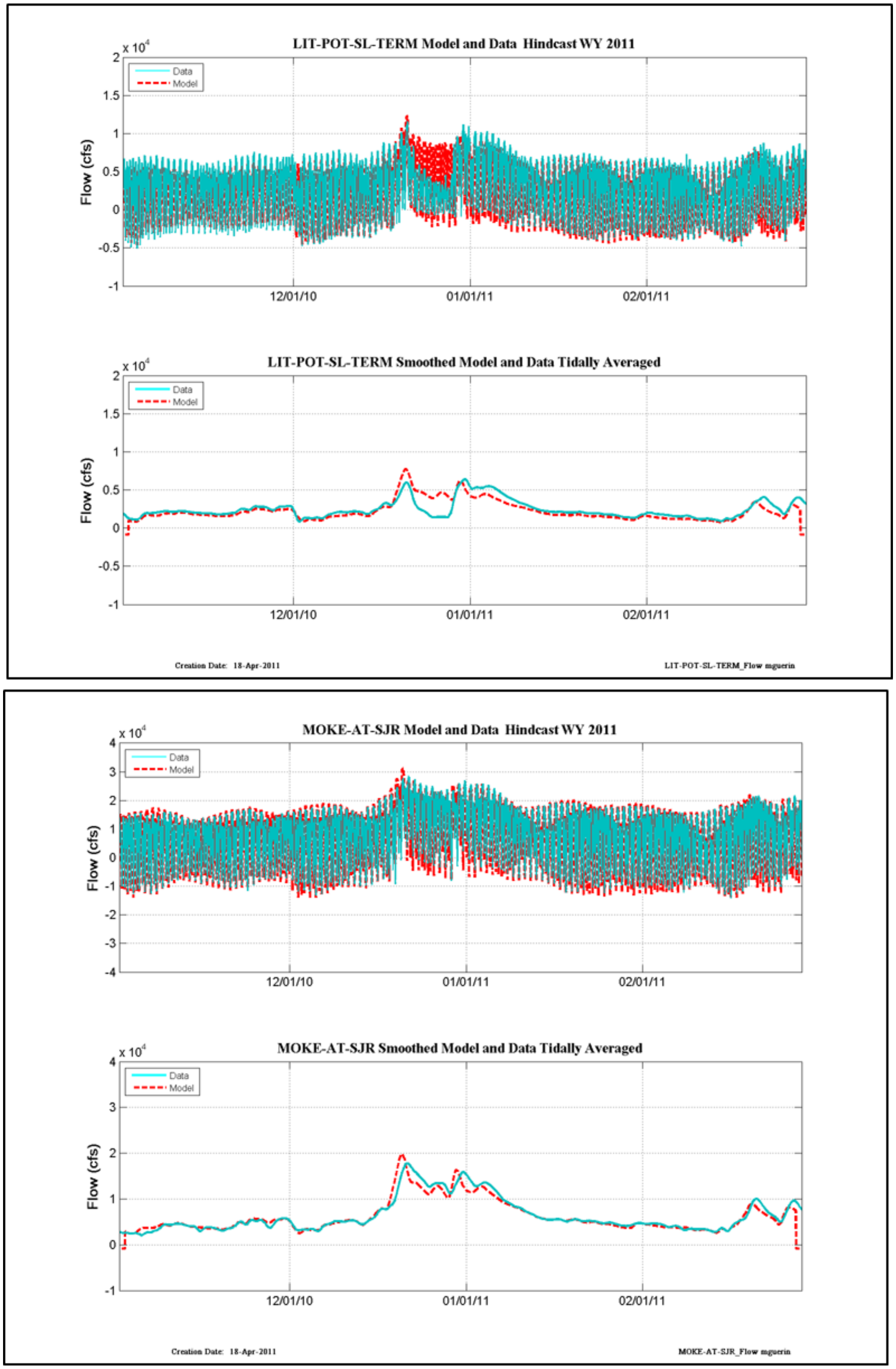


Figure 6-22 Flow Hindcast model results and tidally averaged results at LITTLE-POTATO-SL-TERM (upper) and at MOKE-AT-SJR (lower).

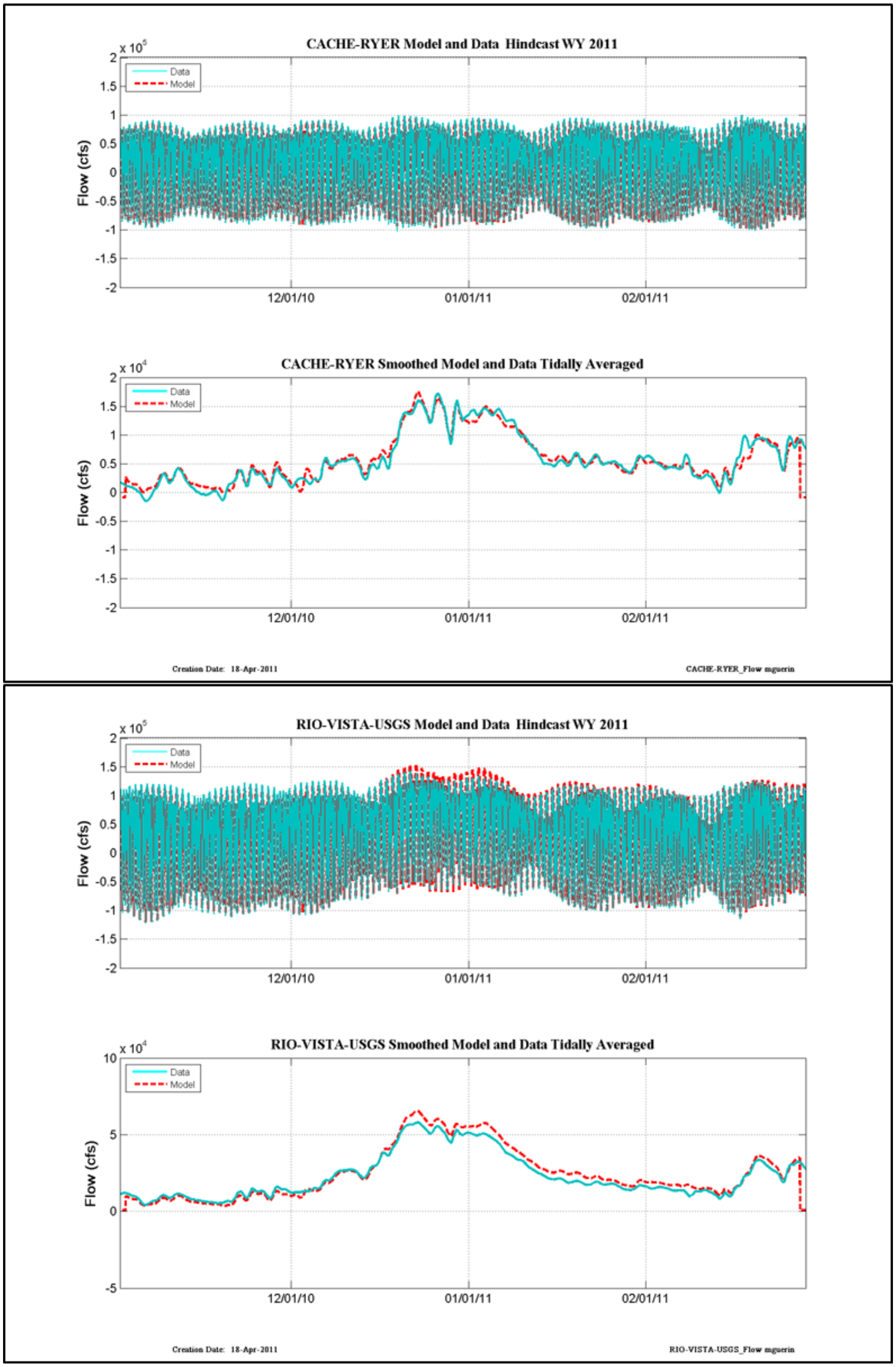


Figure 6-23 Flow Hindcast model results and tidally averaged results at CACHE-RYER (upper) and at RIO VISTA (lower).

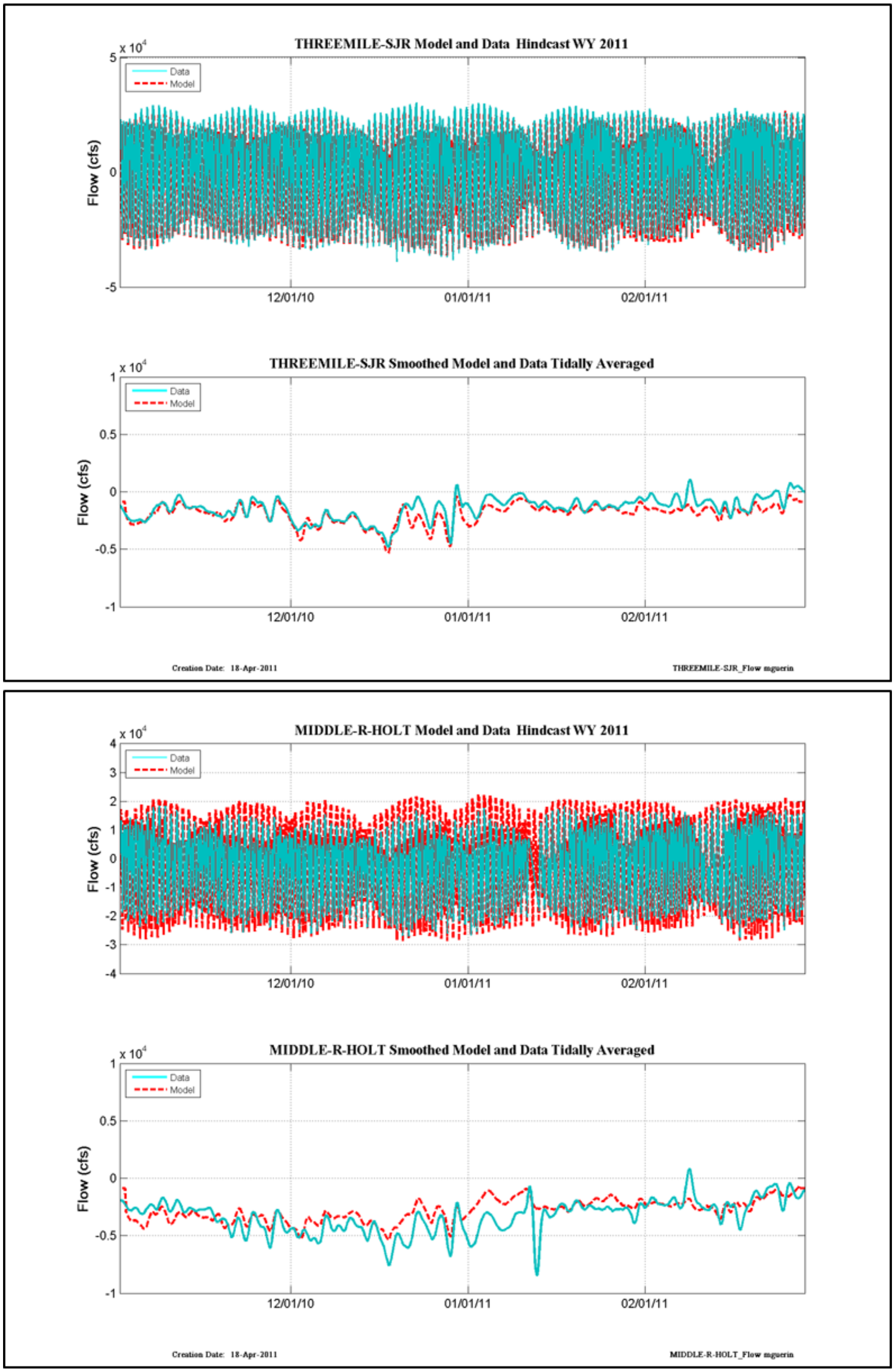


Figure 6-24 Flow Hindcast model results and tidally averaged results at THREEMILE-SJR (upper) and at MIDDLE-R-HOLT (lower).

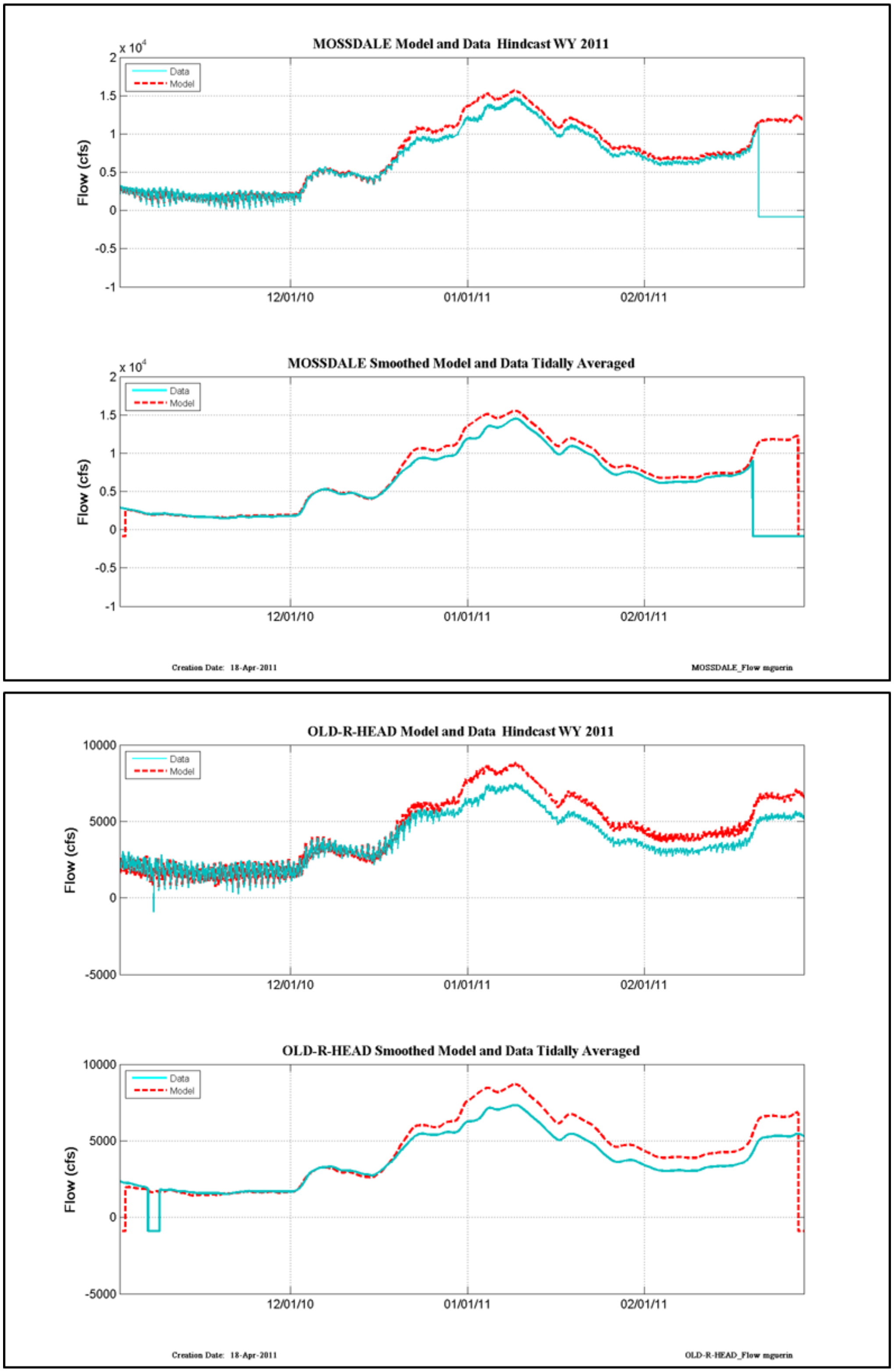


Figure 6-25 Flow Hindcast model results and tidally averaged results at MOSSDALE (upper) and at OLD-R-HEAD (lower).

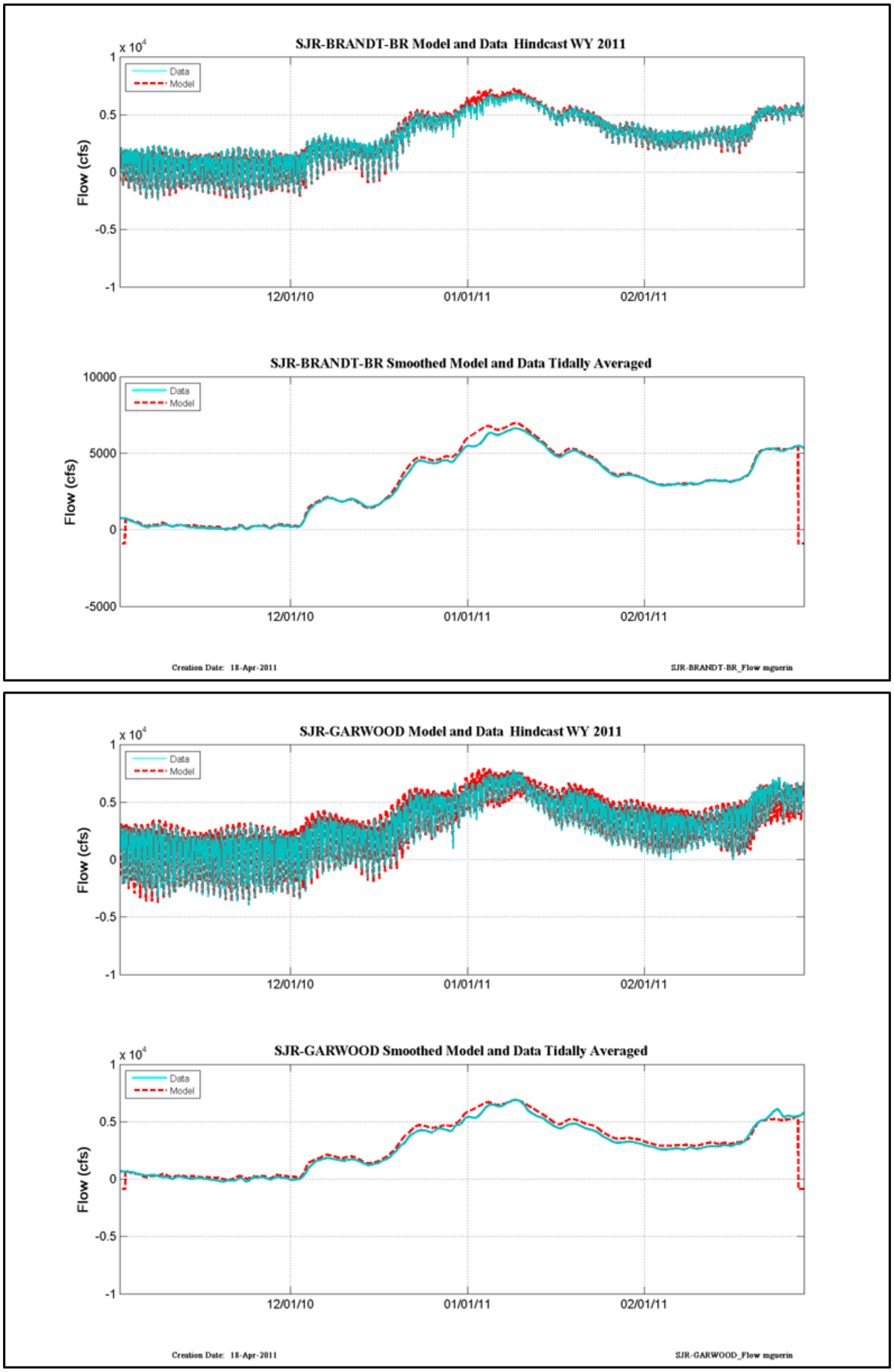


Figure 6-26 Flow Hindcast model results and tidally averaged results at SJR-BRANDT-BR (upper) and at SJR-GARWOOD (lower).

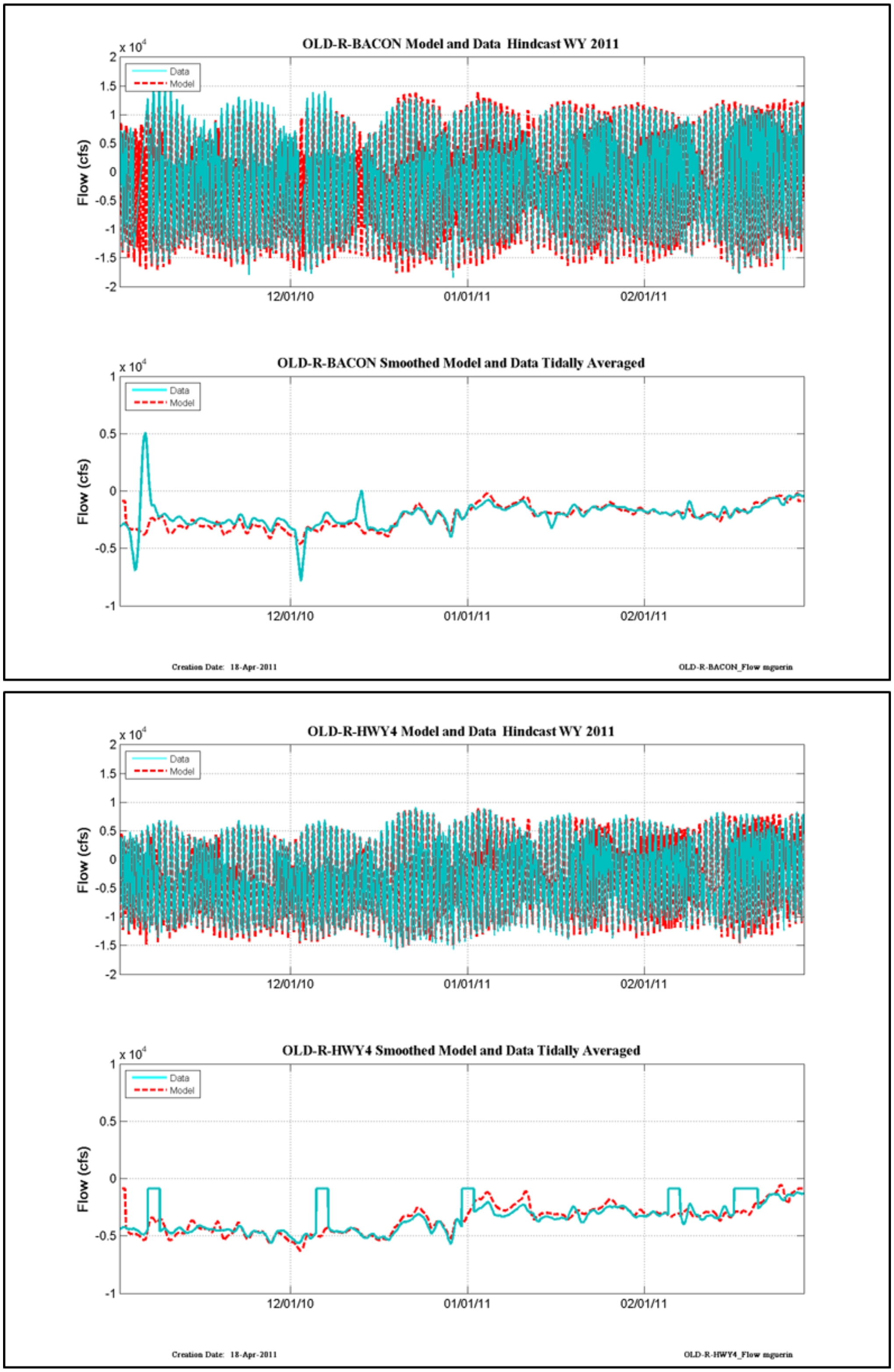
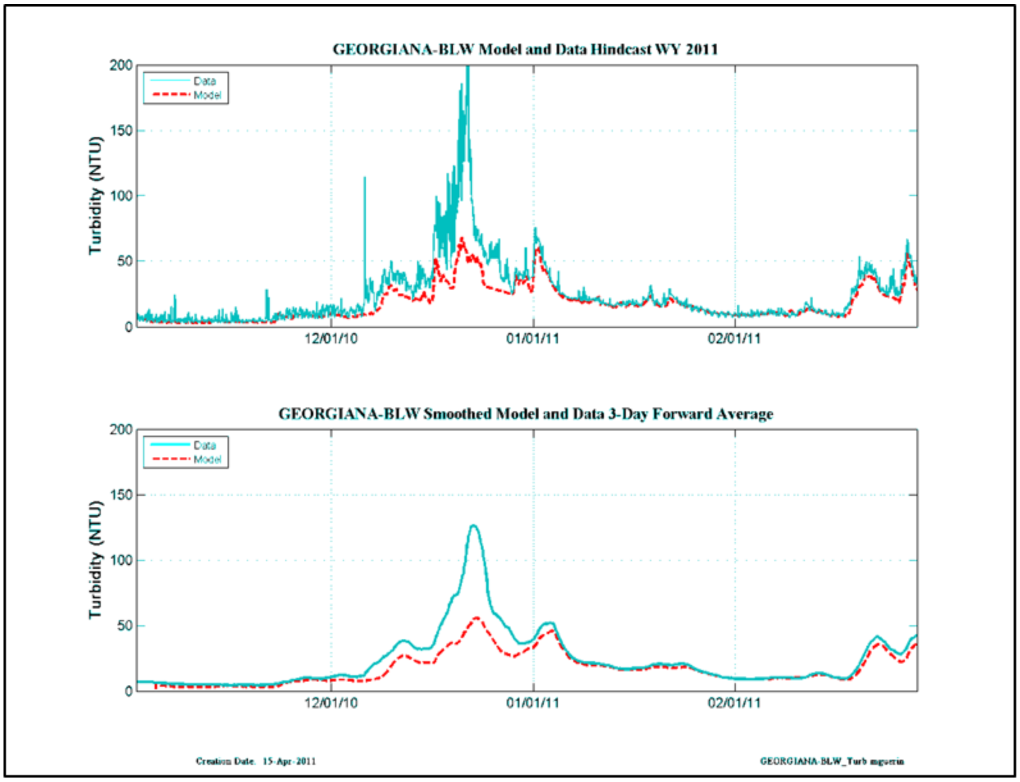


Figure 6-27 Flow Hindcast model results and tidally averaged results at OLD-R-BACON (upper) and at OLD-R-HWY-4 (lower).



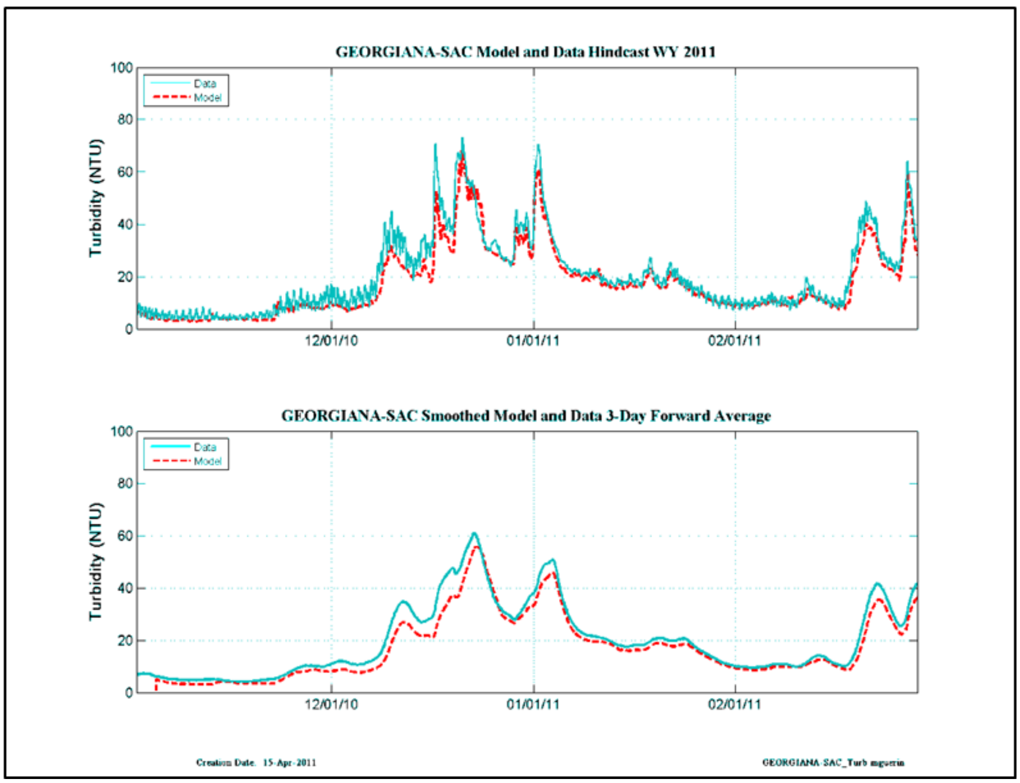


Figure 6-28 Turbidity Hindcast model results and averaged results at GEORGIANA-BLW (upper) and at GEORGIANA-SAC (lower).

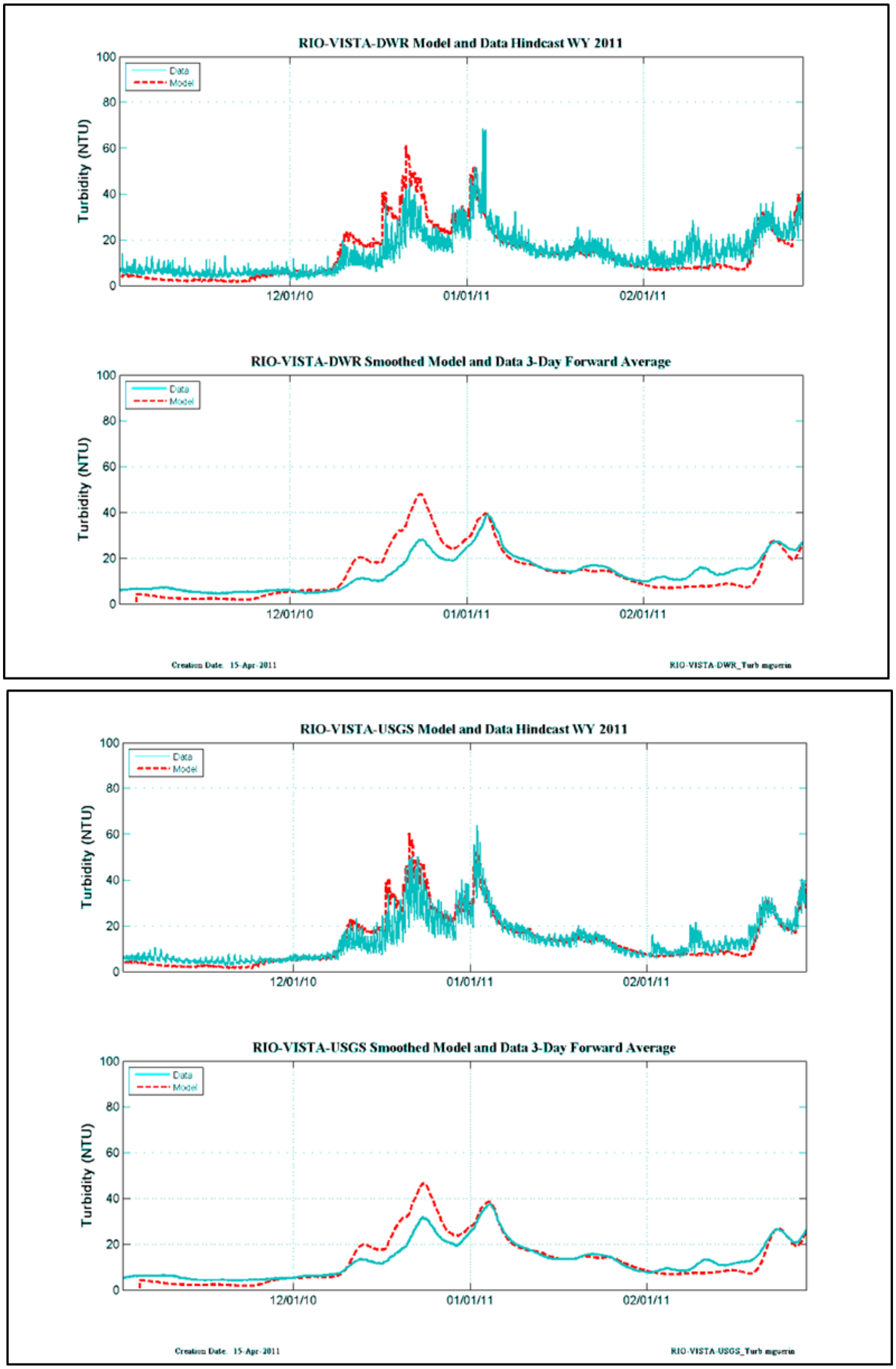


Figure 6-29 Turbidity Hindcast model results and averaged results at RIO-VISTA-DWR (upper) and at RIO-VISTA-USGS (lower).

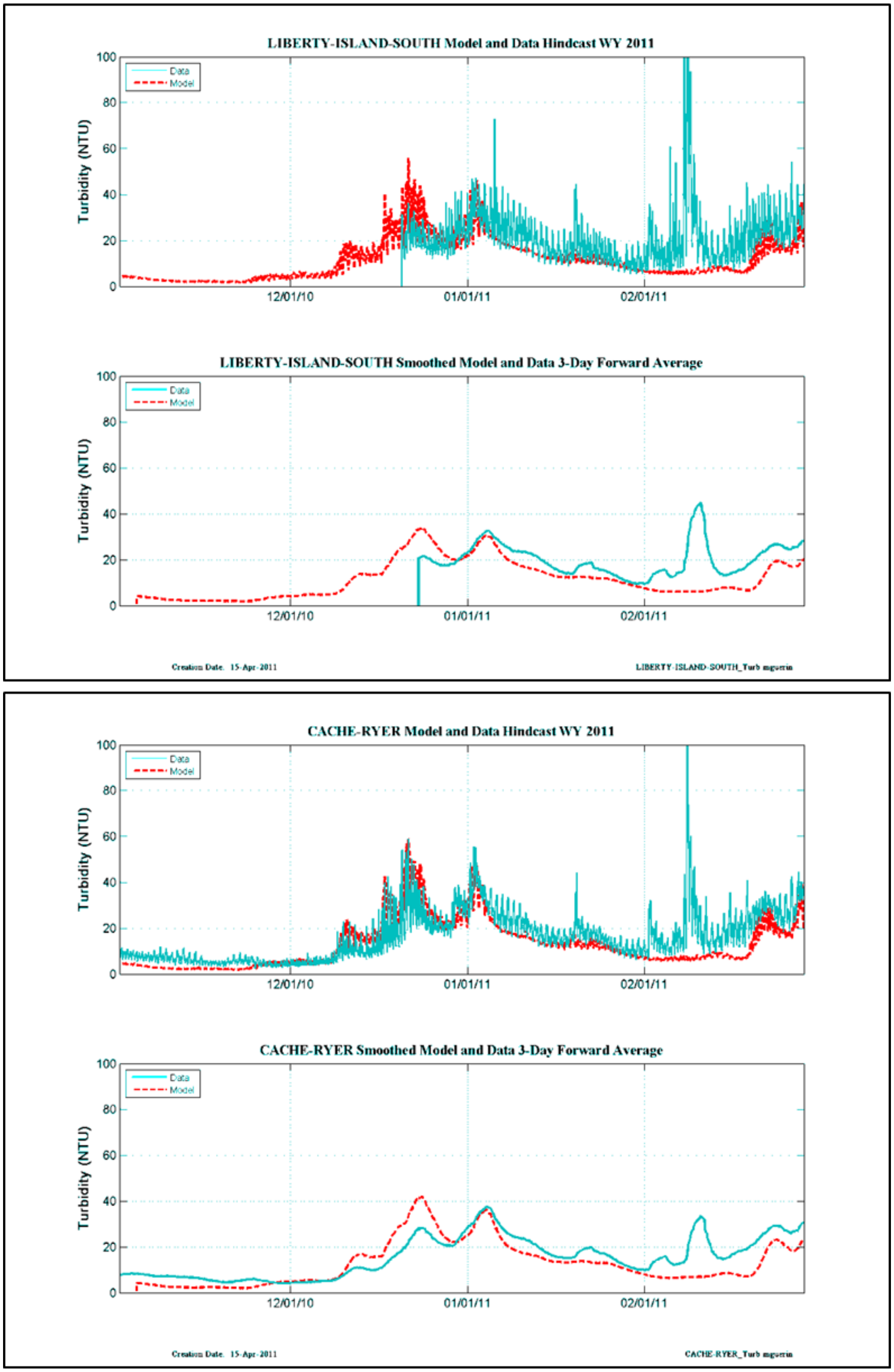


Figure 6-30 Turbidity Hindcast model results and averaged results at LIBERTY-ISLAND-S (upper) and at CACHE-RYER (lower).

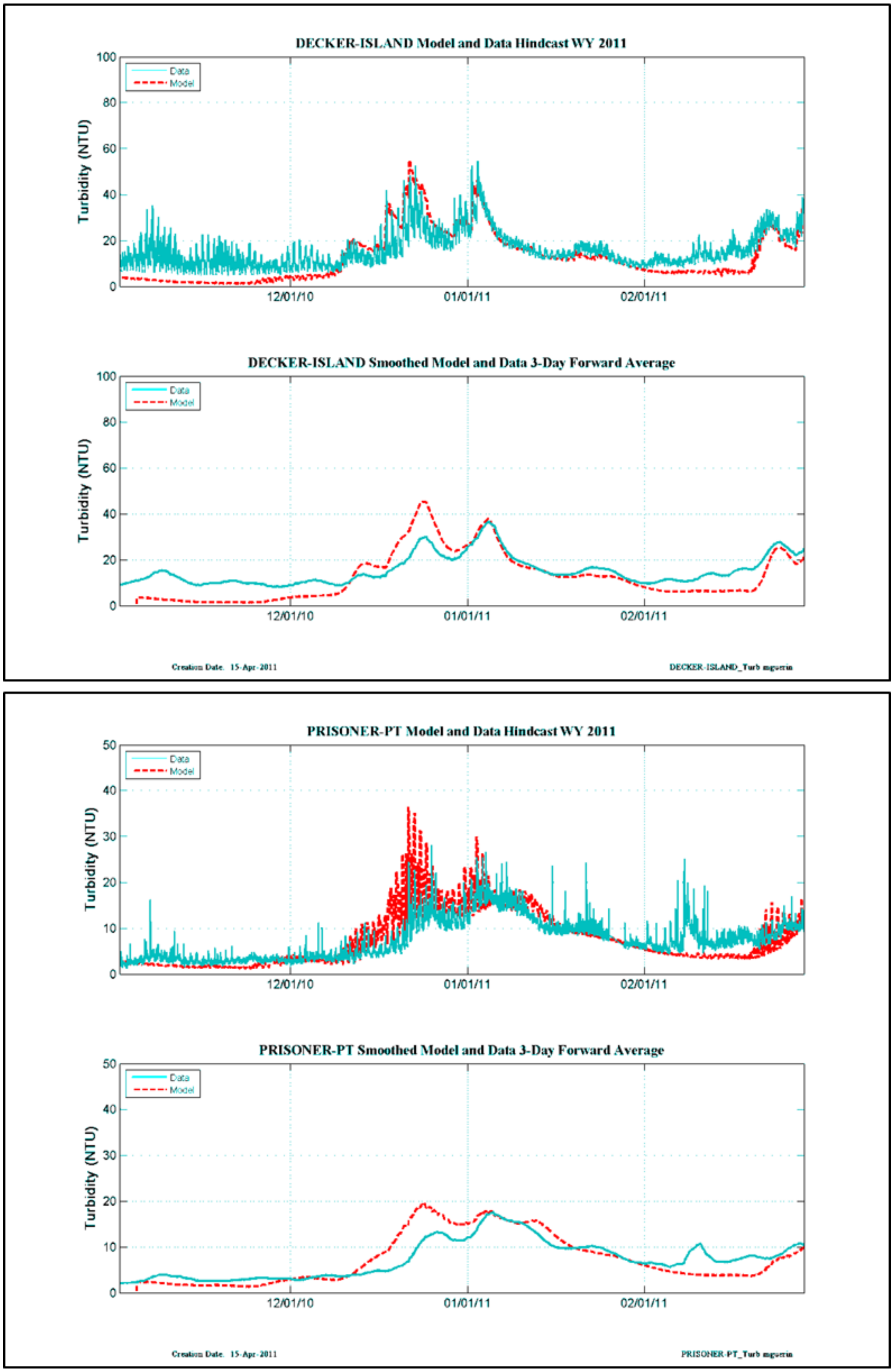


Figure 6-31 Turbidity Hindcast model results and averaged results at DECKER ISLAND (upper) and at PRISONER-PT (lower).

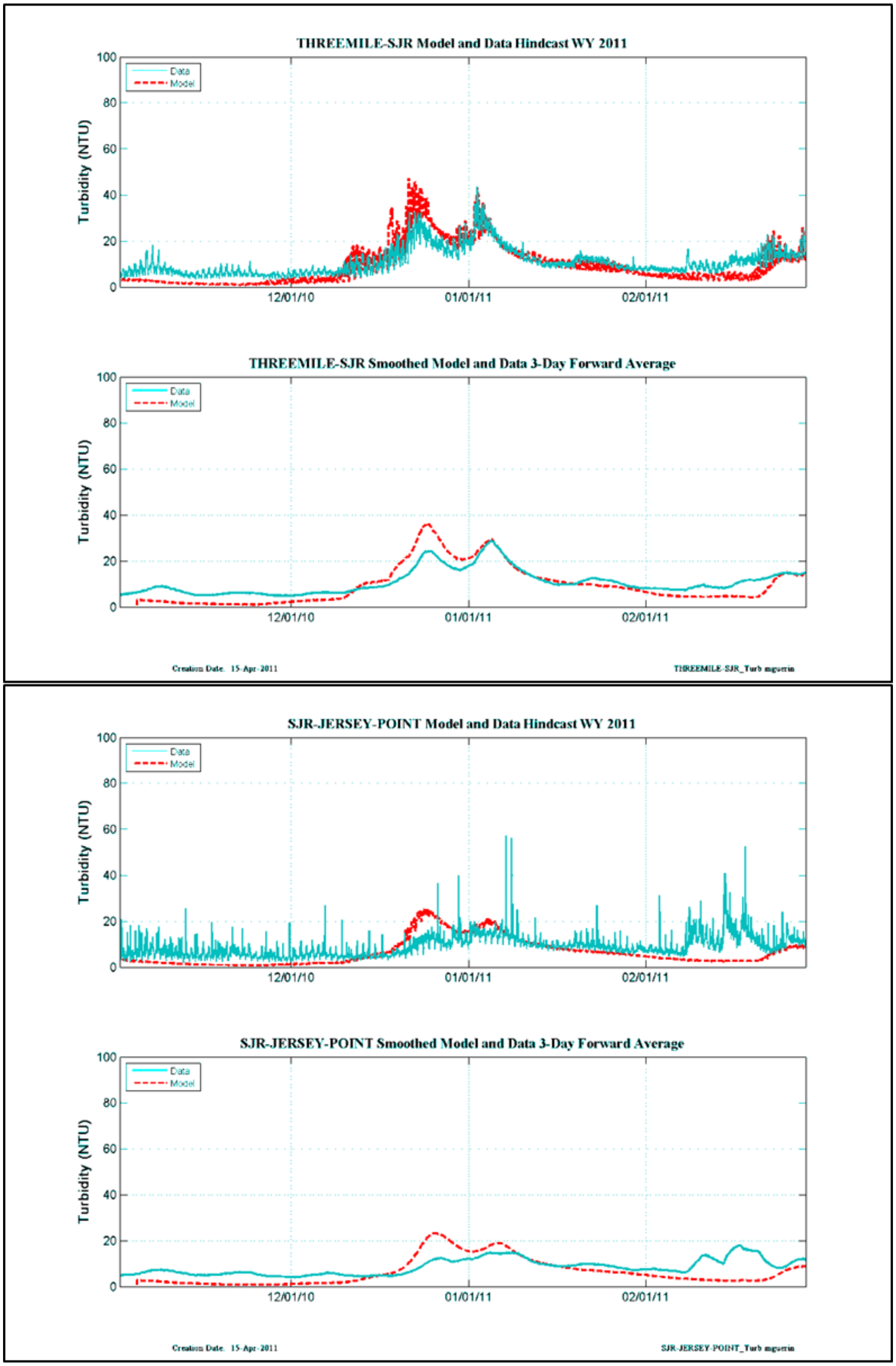


Figure 6-32 Turbidity Hindcast model results and averaged results at THREEMILE-SJR (upper) and at SJR-JERSEY-POINT (lower).

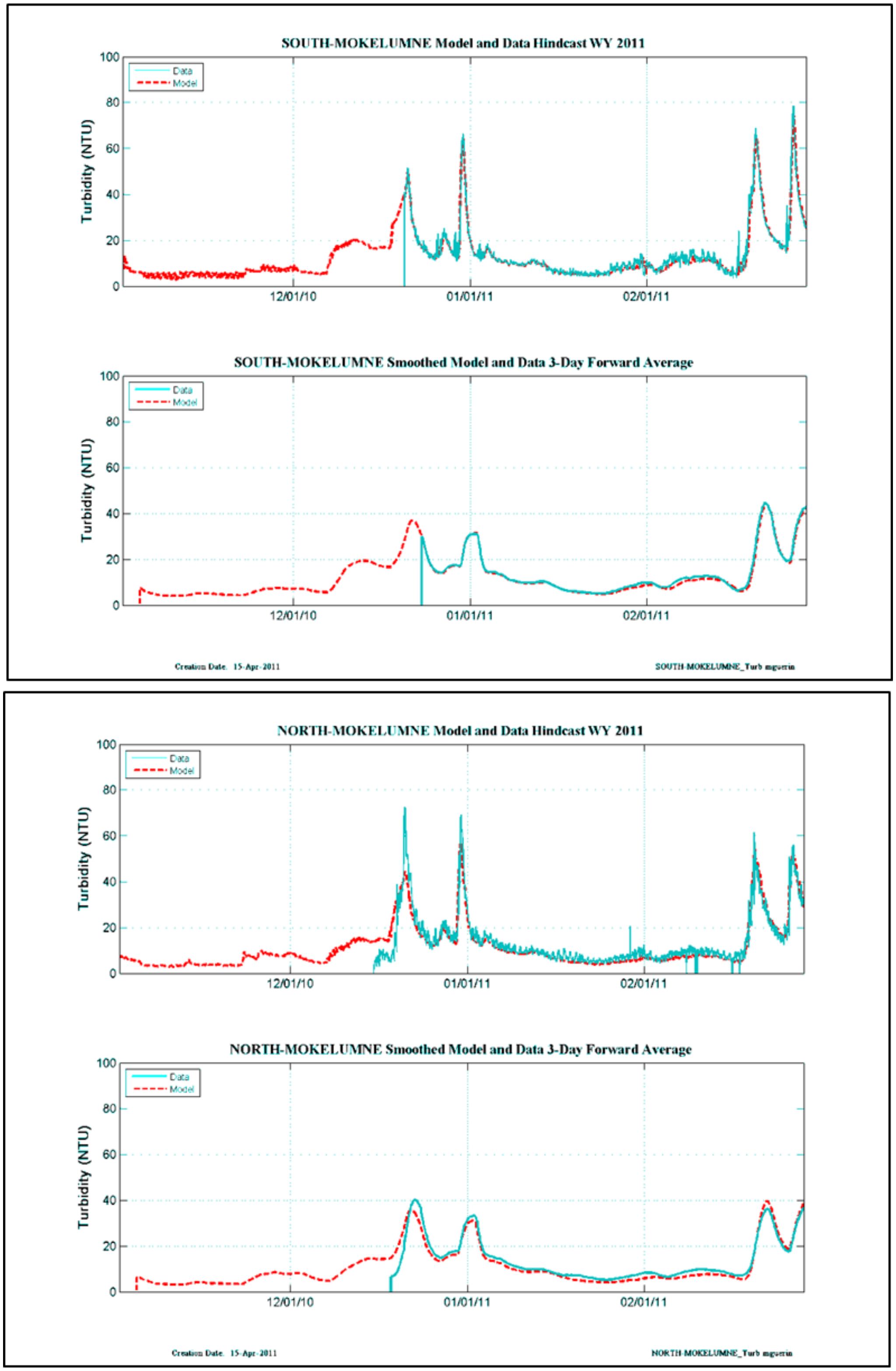
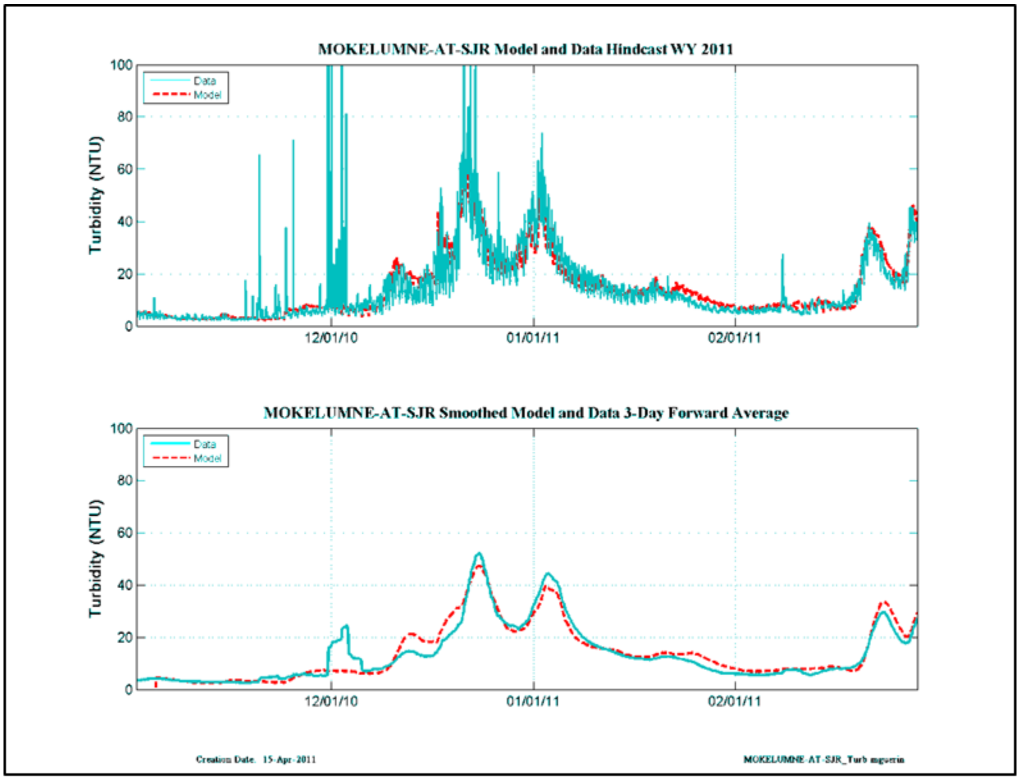


Figure 6-33 Turbidity Hindcast model results and averaged results at SOUTH-MOKELUMNE (upper) and at MORTH-MOKELUMNE (lower).



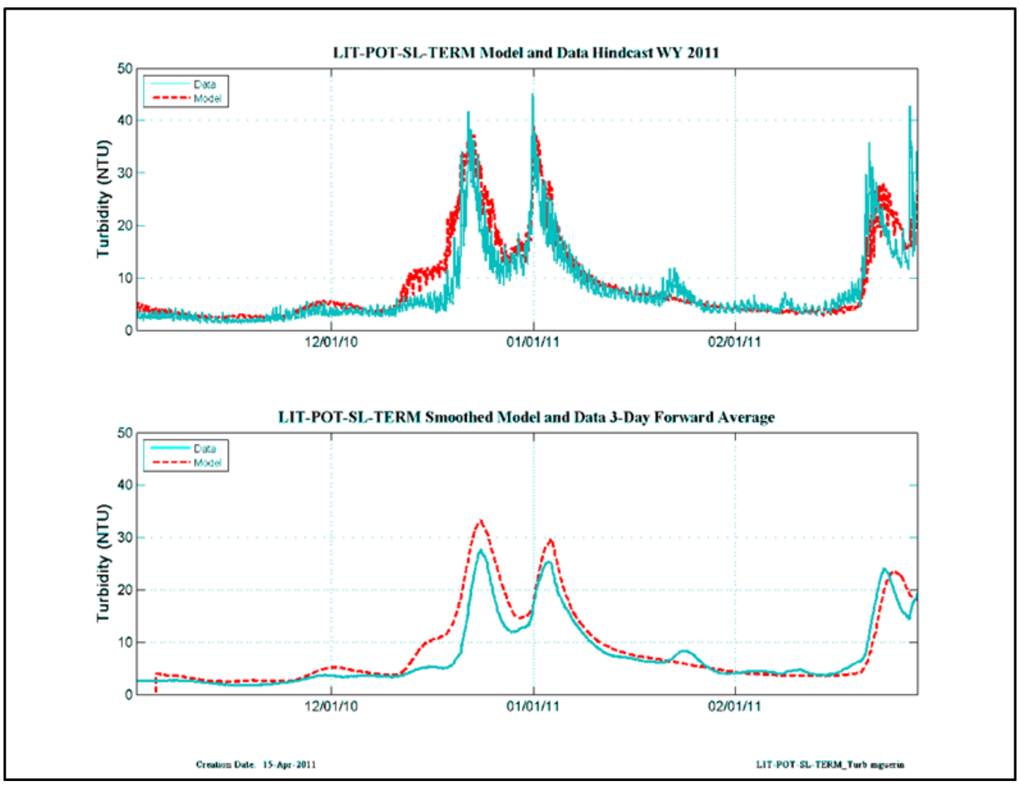


Figure 6-34 Turbidity Hindcast model results and averaged results at MOKEULMNE-AT-SJR (upper) and at LIT-POT-SL-TERM (lower).

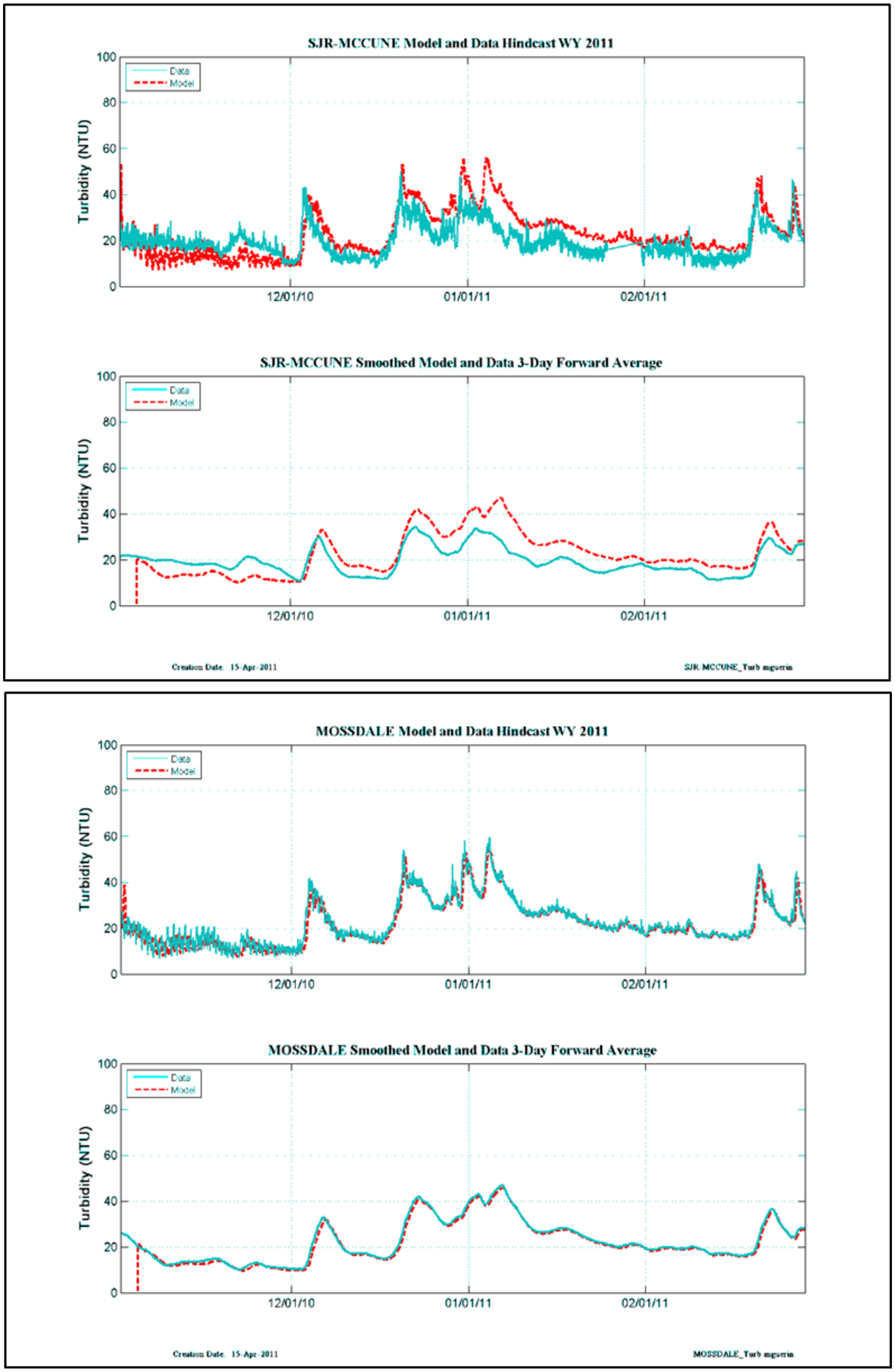


Figure 6-35 Turbidity Hindcast model results and averaged results at SJR-MCCUNE (upper) and at MOSSDALE (lower).

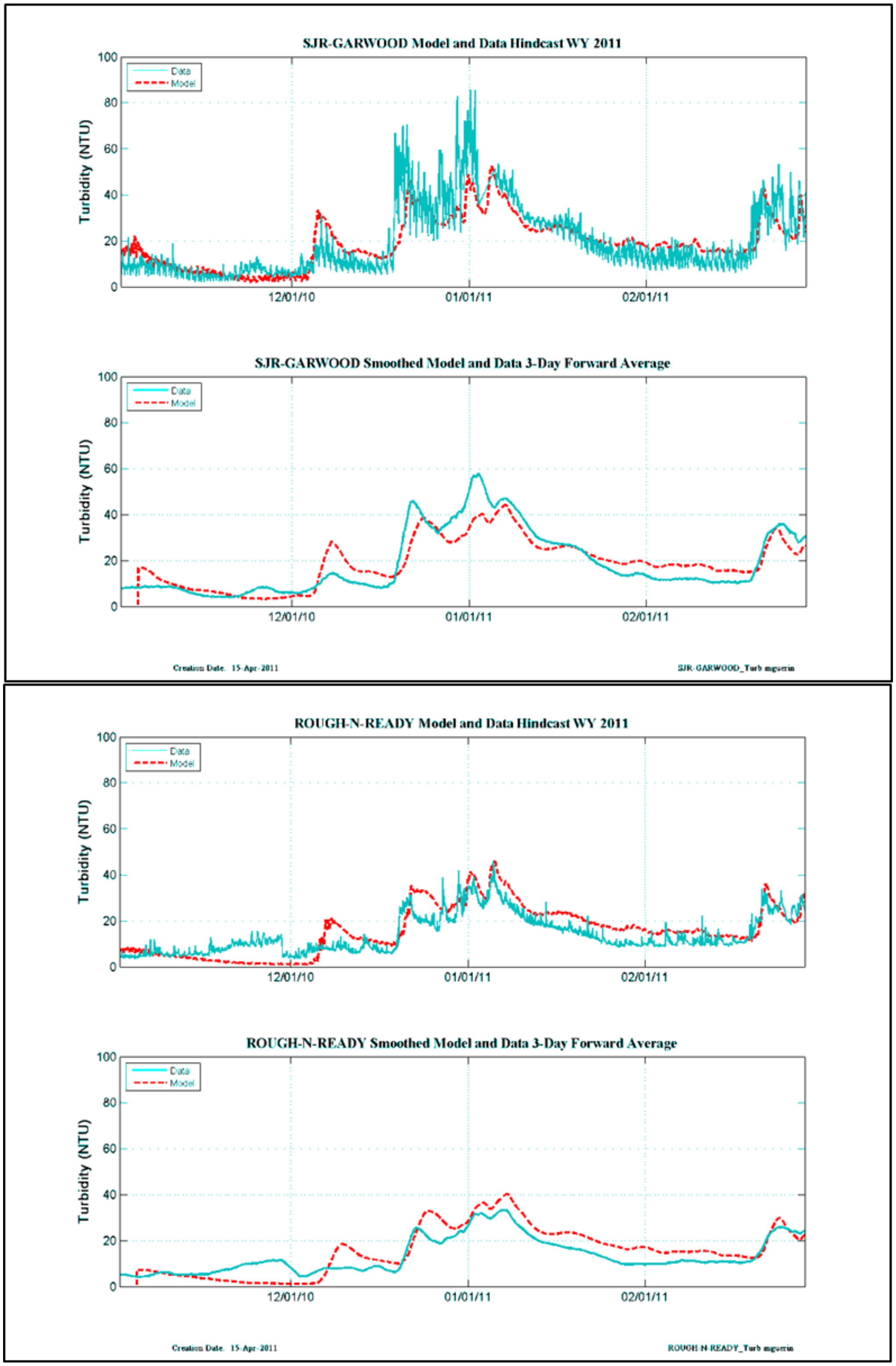


Figure 6-36 Turbidity Hindcast model results and averaged results at SJR-GARWOOD (upper) and at ROUGH-N-READY (lower).

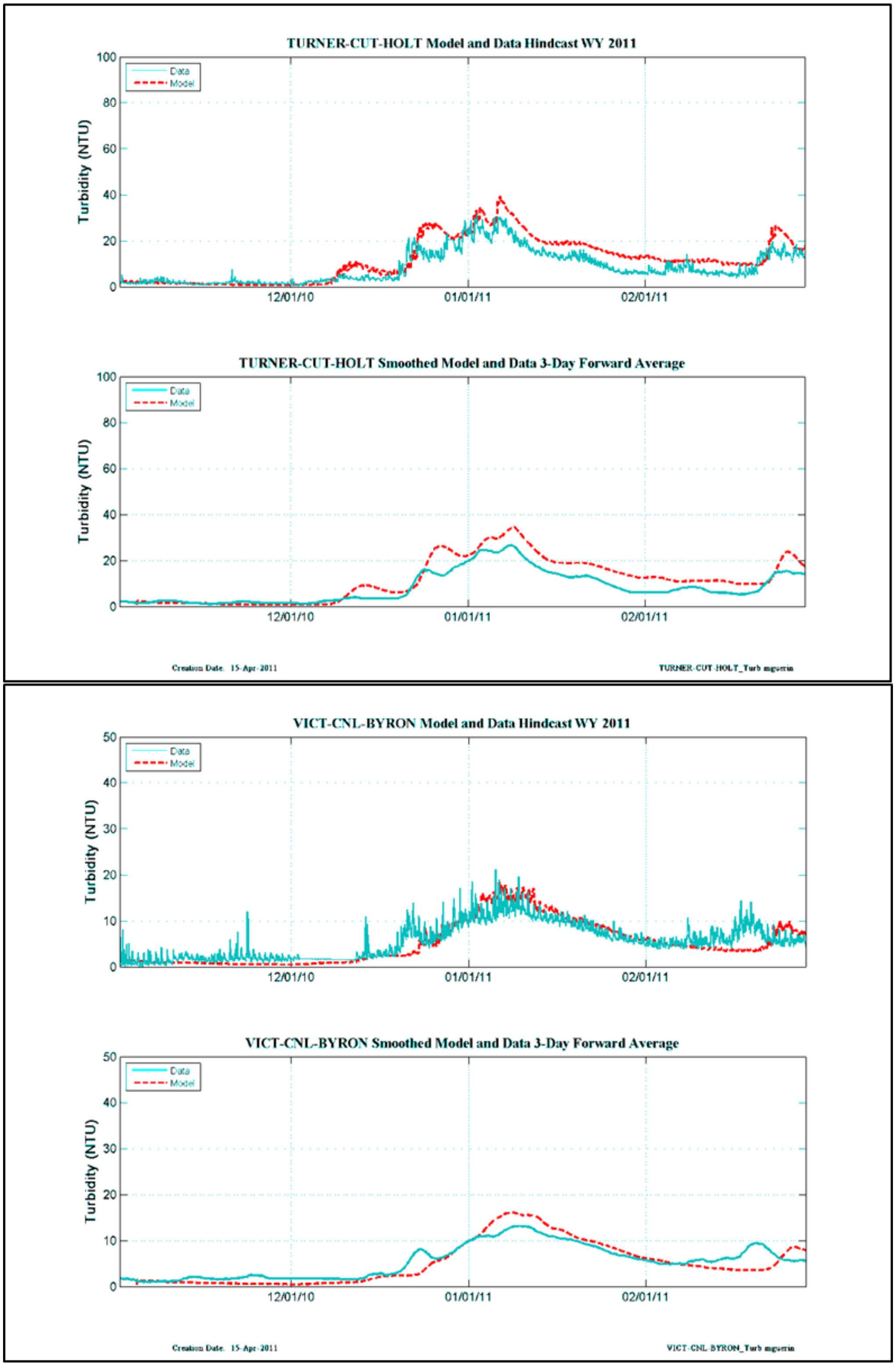


Figure 6-37 Turbidity Hindcast model results and averaged results at TURNER-CUT (upper) and at VICT-CNL-BYRON (lower).

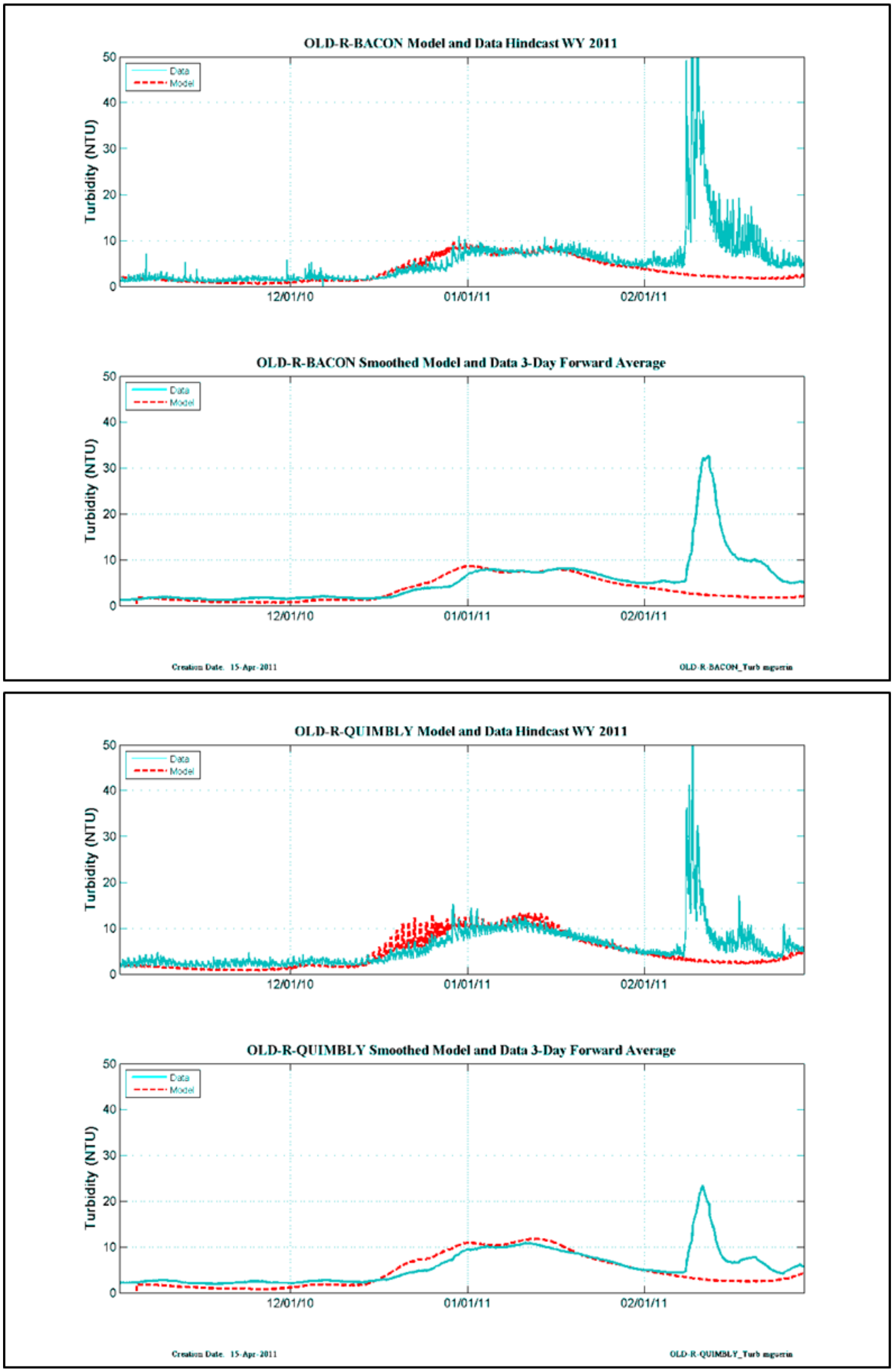
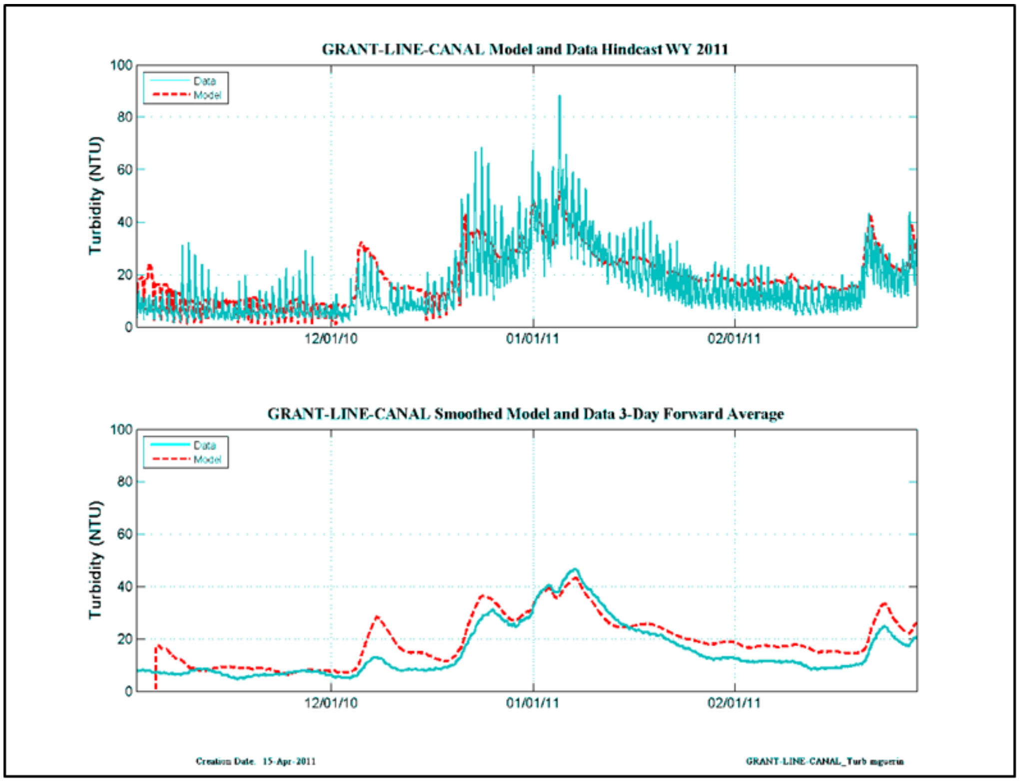


Figure 6-38 Turbidity Hindcast model results and averaged results at OLD-R-BACON (upper) and at OLD-R-QUIMBLY (lower).



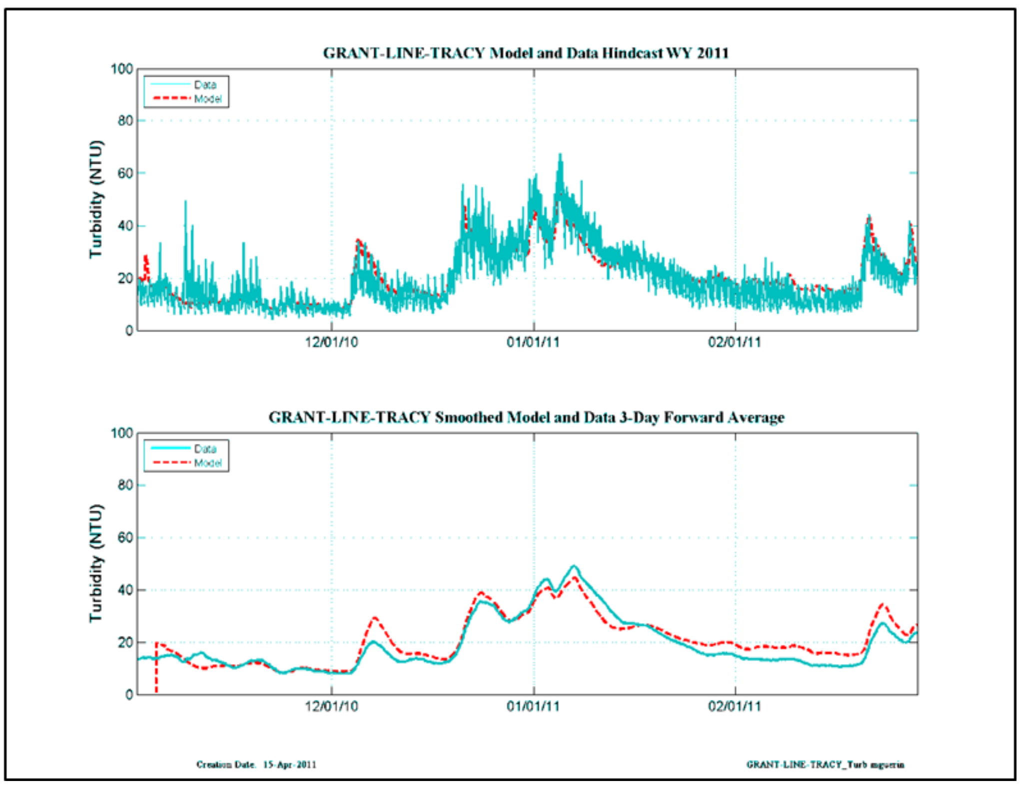


Figure 6-39 Turbidity Hindcast model results and averaged results at GRANT-LINE-CANAL (upper) and at GRANT-LINE-TRACY (lower).

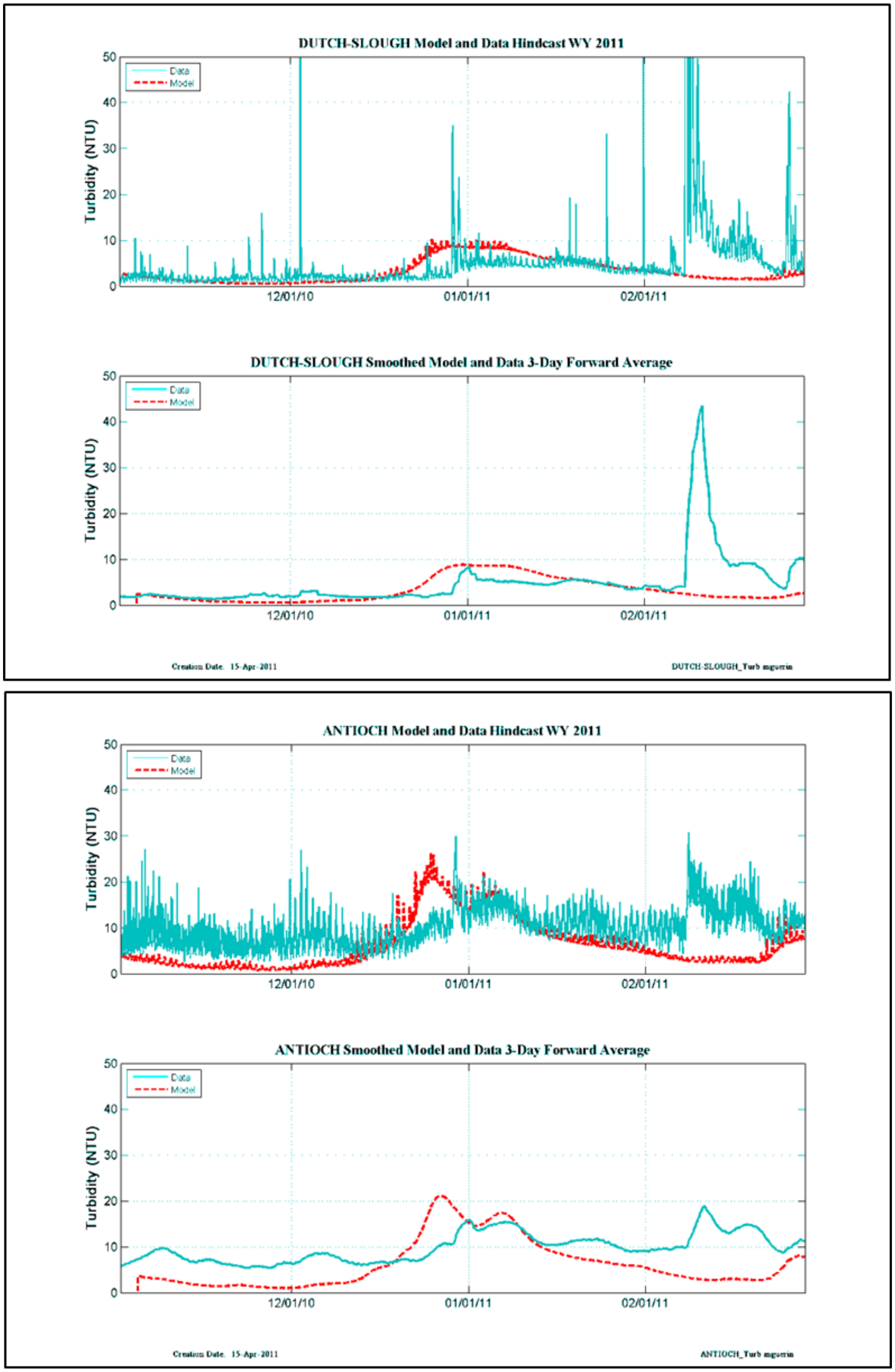


Figure 6-40 Turbidity Hindcast model results and averaged results at DUTCH-SLOUGH (upper) and at ANTIOCH (lower).

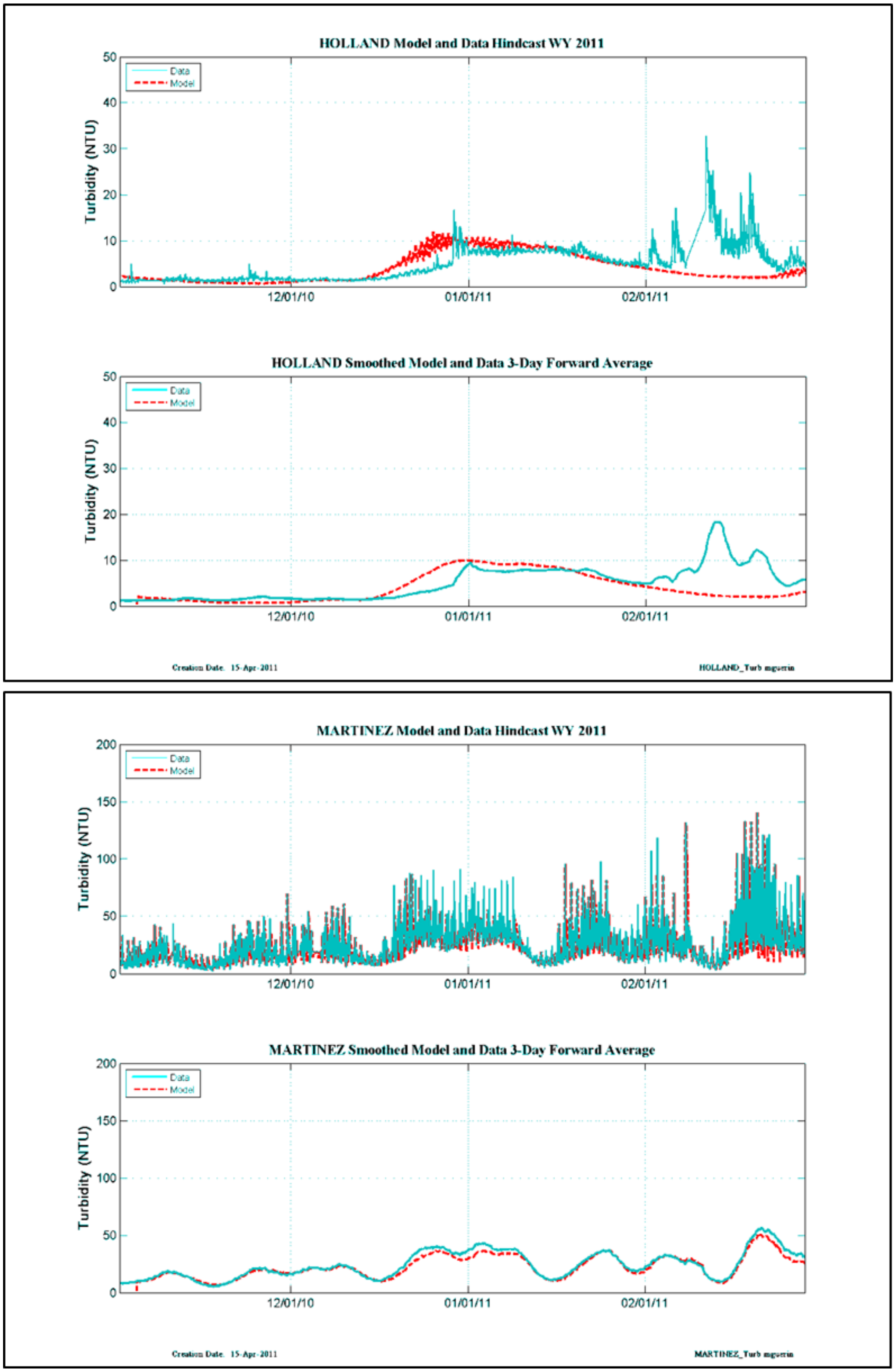


Figure 6-41 Turbidity Hindcast model results and averaged results at HOLLAND-CUT (upper) and at MARTINEZ (lower).

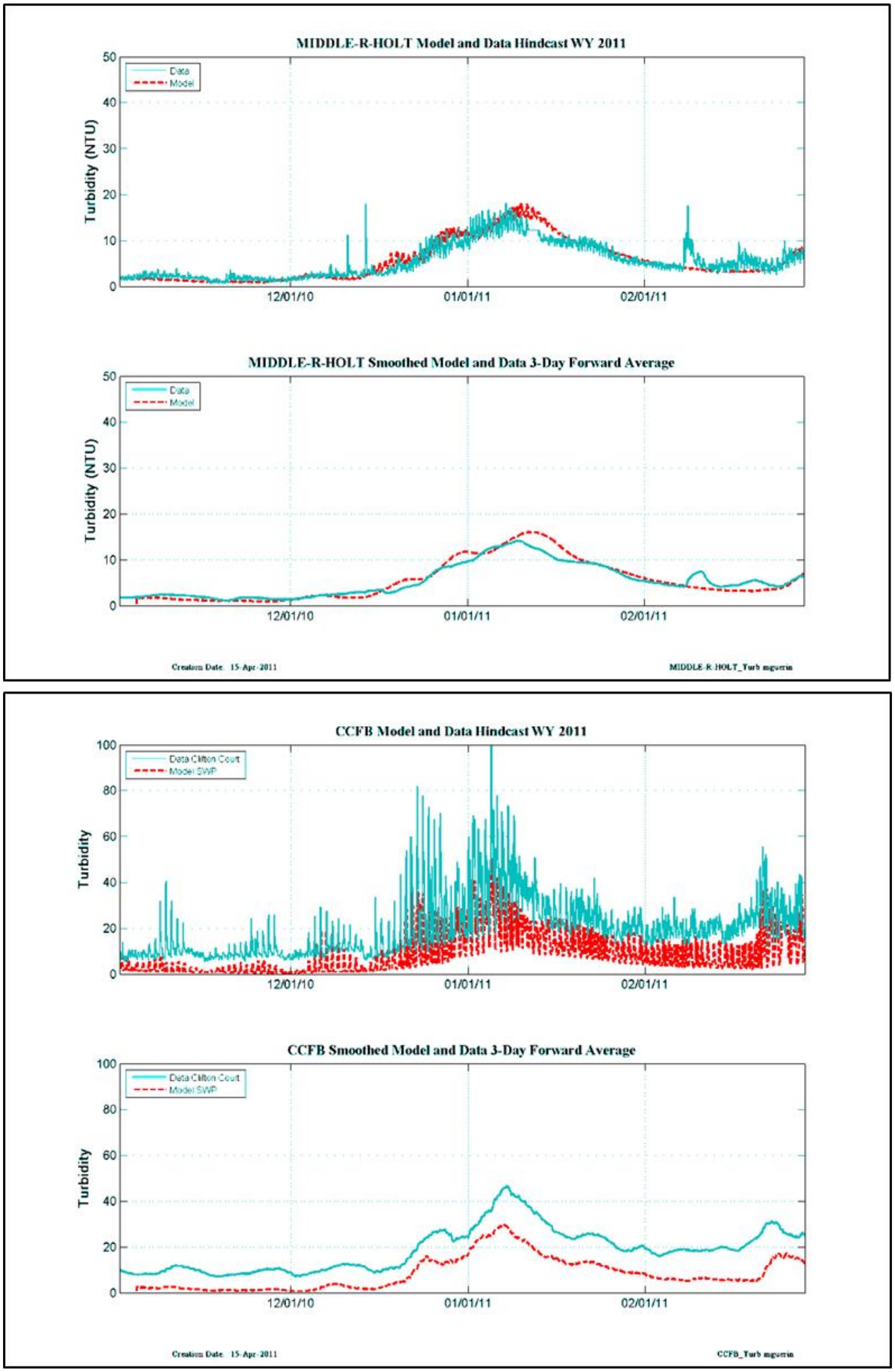
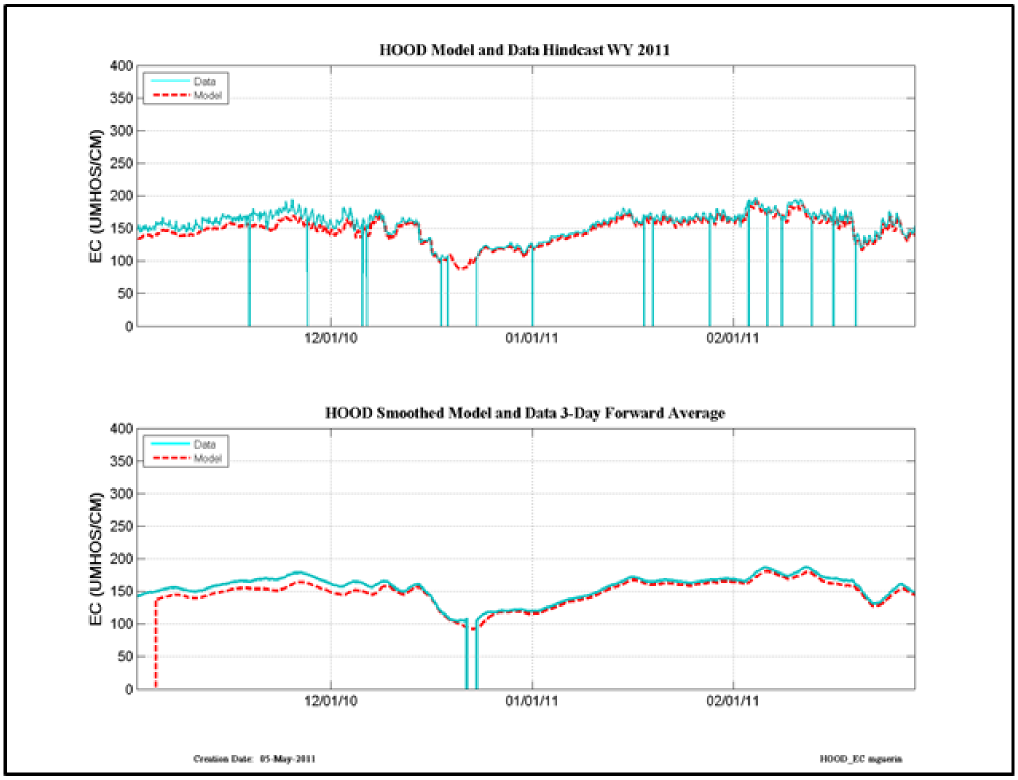


Figure 6-42 Turbidity Hindcast model results and averaged results at MIDDLE-R-HOLT (upper) and in CCFB (lower).



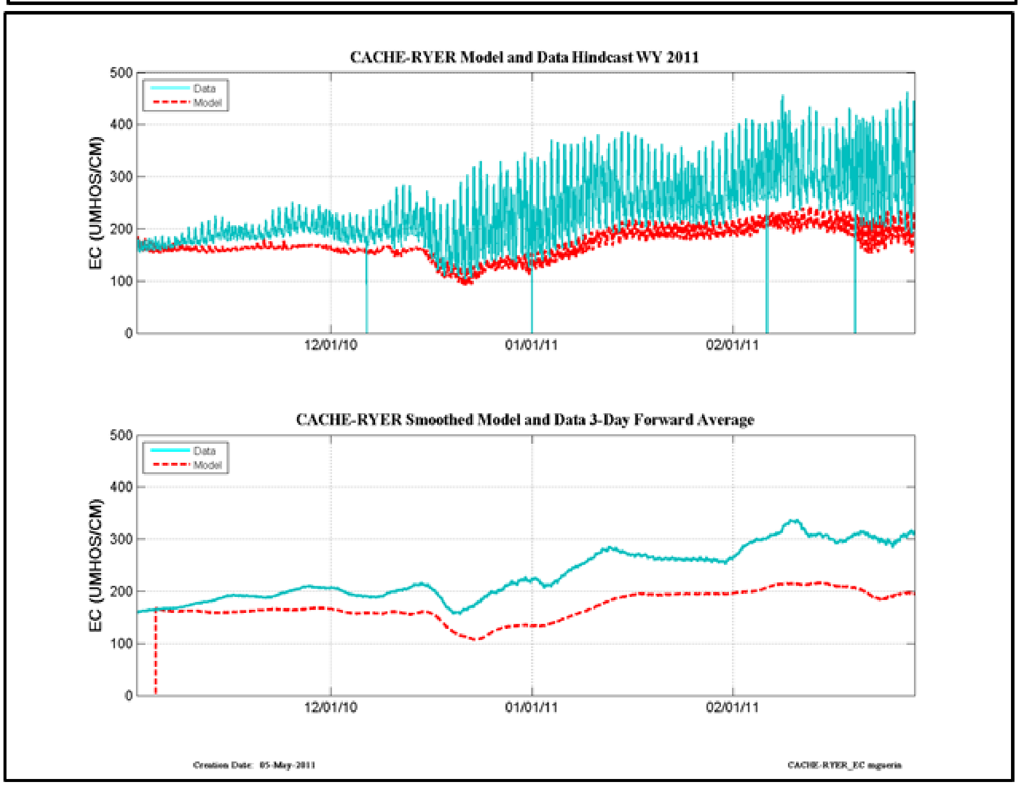


Figure 6-43 EC Turbidity Hindcast model results and averaged results at HOOD (upper) and at CACHE-RYER (lower).

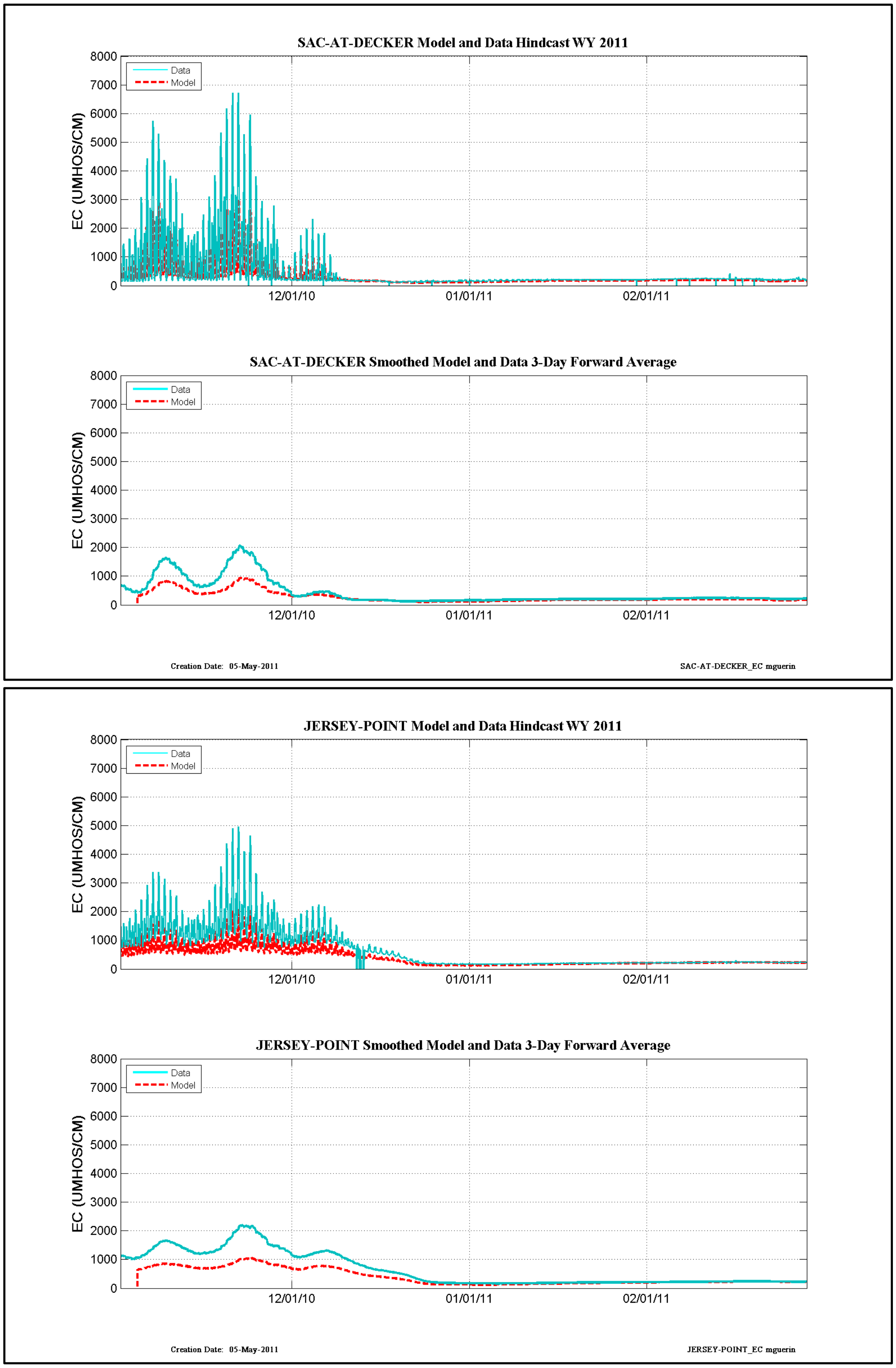


Figure 6-44 EC Turbidity Hindcast model results and averaged results at SAC-AT-DECKER (upper) and at JERSEY-POINT (lower).

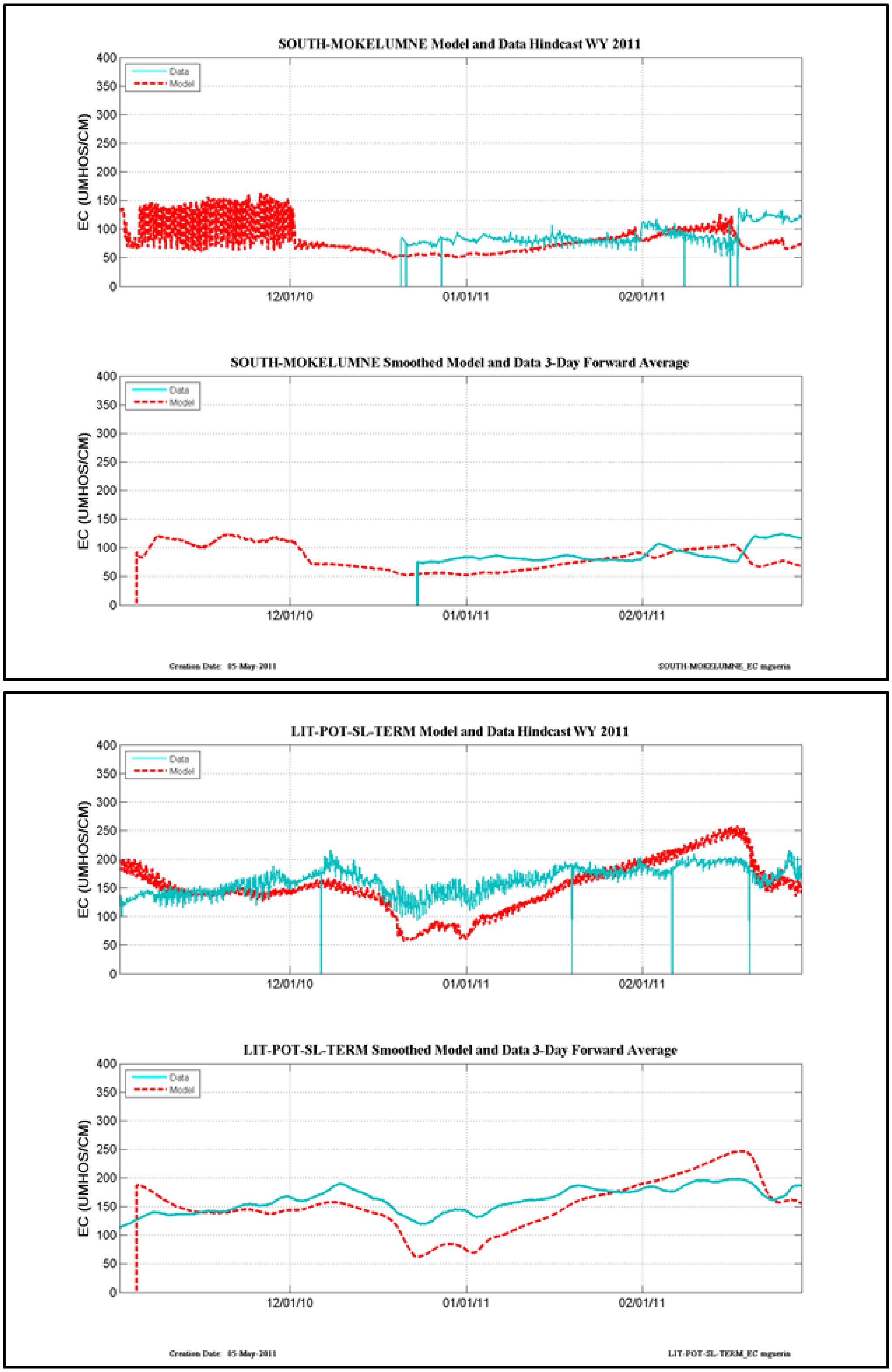


Figure 6-45 EC Turbidity Hindcast model results and averaged results at SOUTH-MOKELUMNE (upper) and at LIT-POT-SL-TERM (lower).

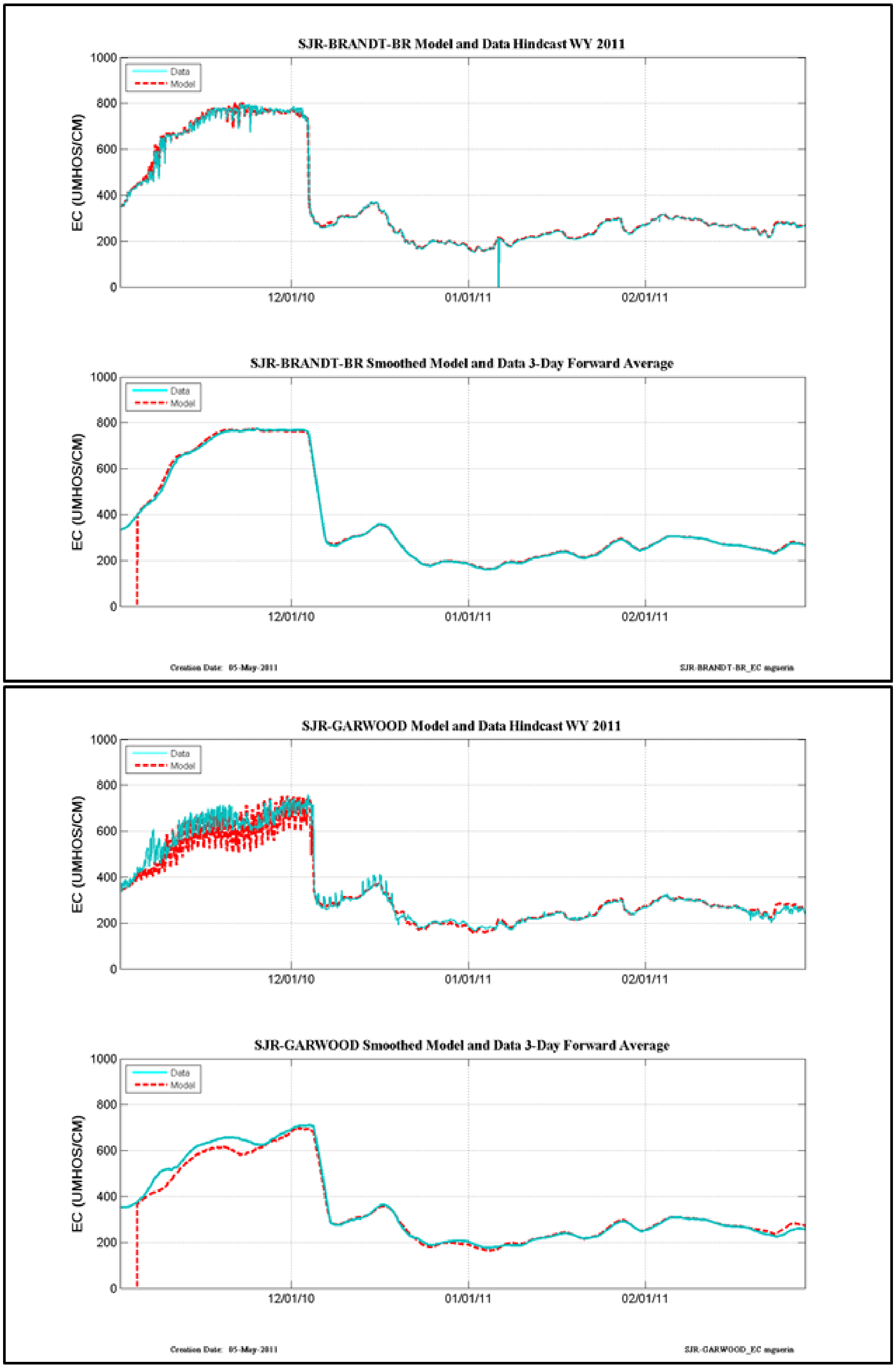


Figure 6-46 EC Turbidity Hindcast model results and averaged results at SJR-BRANDT-BR (upper) and at SJR-GARWOOD (lower).

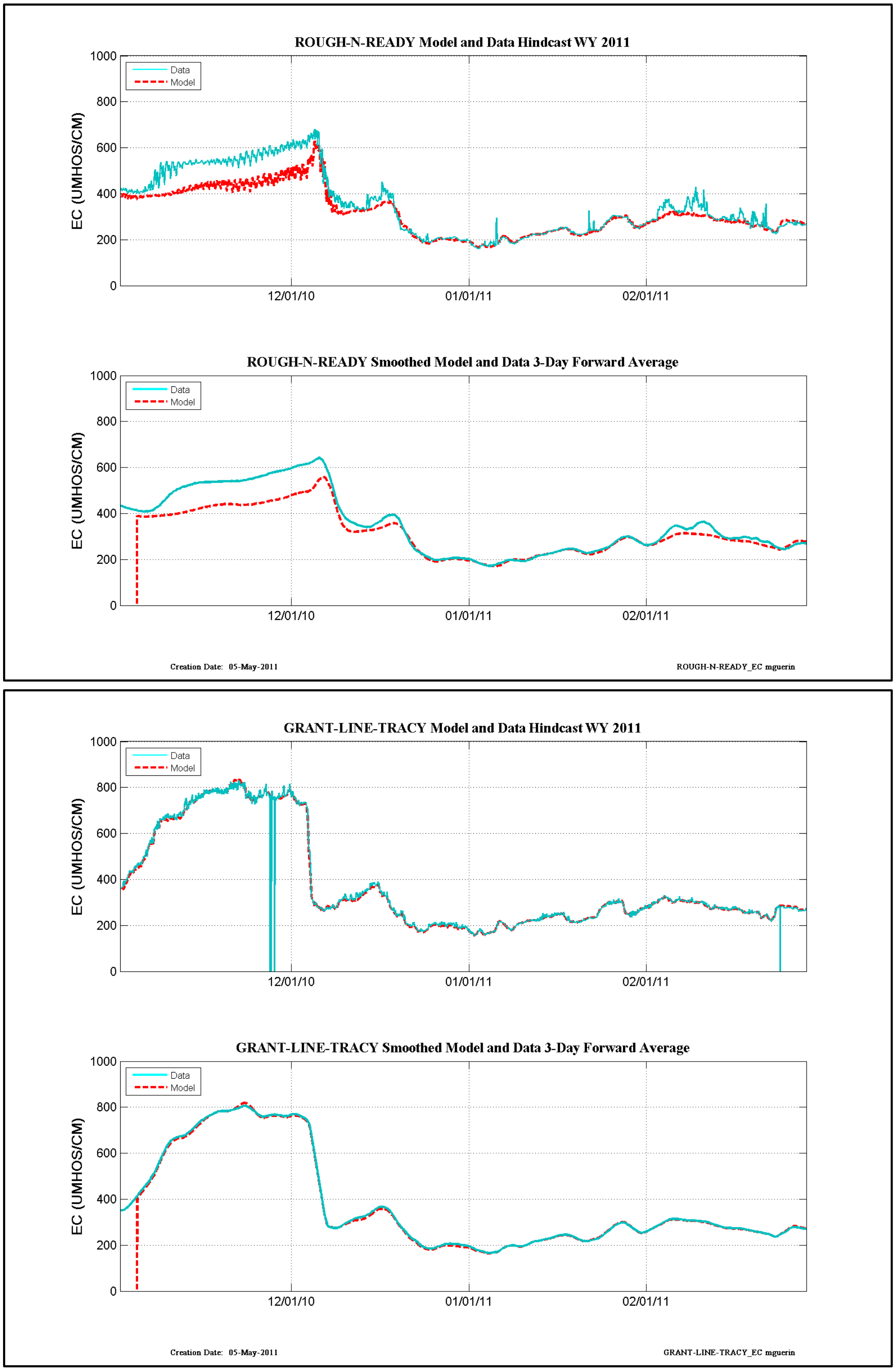


Figure 6-47 EC Turbidity Hindcast model results and averaged results at ROUGH-N-READY (upper) and at GRANT-LINE-TRACY (lower).

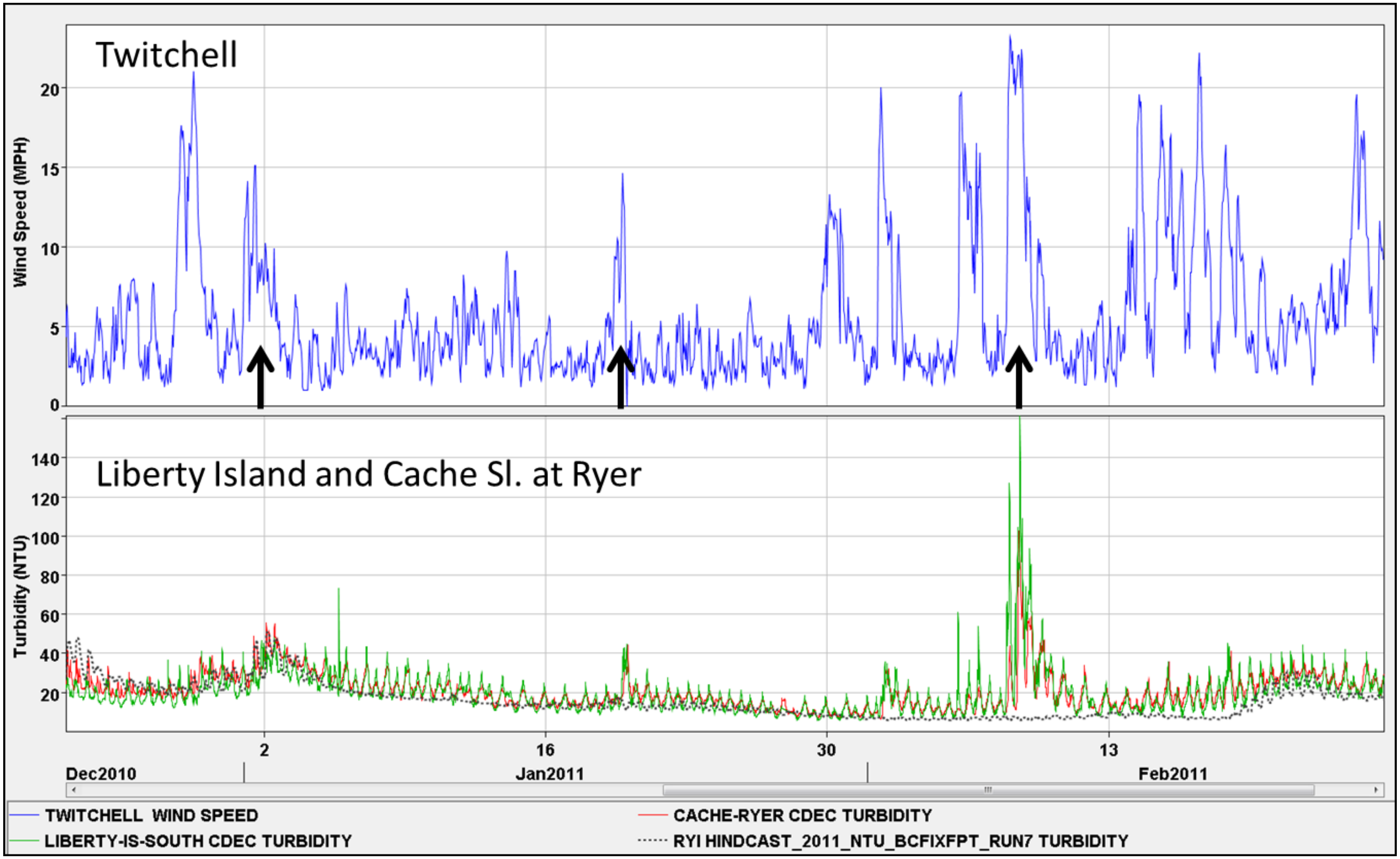


Figure 6-48 Wind events, recorded as increased wind velocity, measured at the CIMIS/Twitchell station in January and February increased turbidity in the Yolo-Cache Slough-Liberty area that wasn't captured in the modeling.

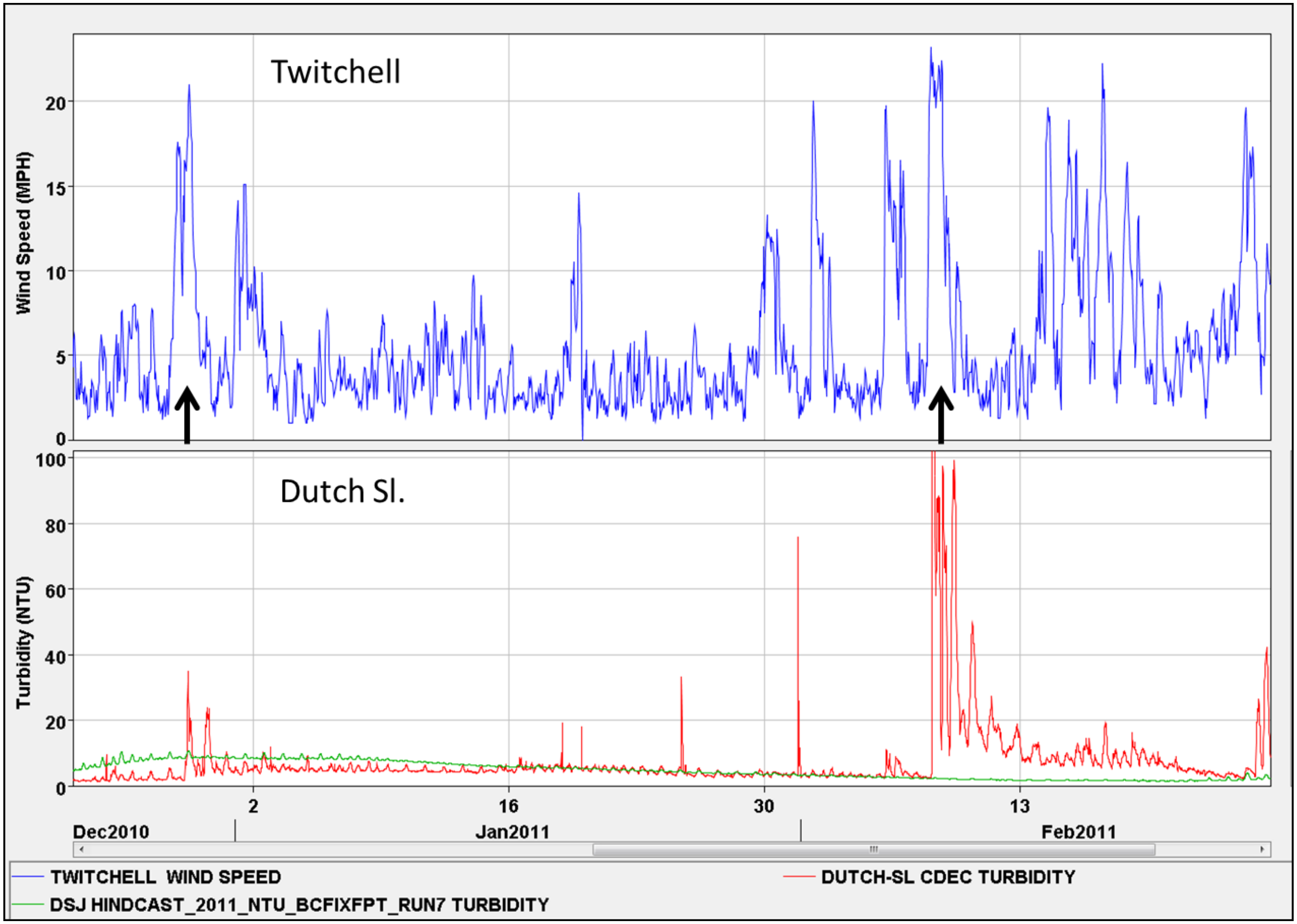


Figure 6-49 Wind events, recorded as increased wind velocity, measured at the CIMIS/Twitchell station in late December and in February increased turbidity in Dutch Slough that wasn't captured in the modeling.

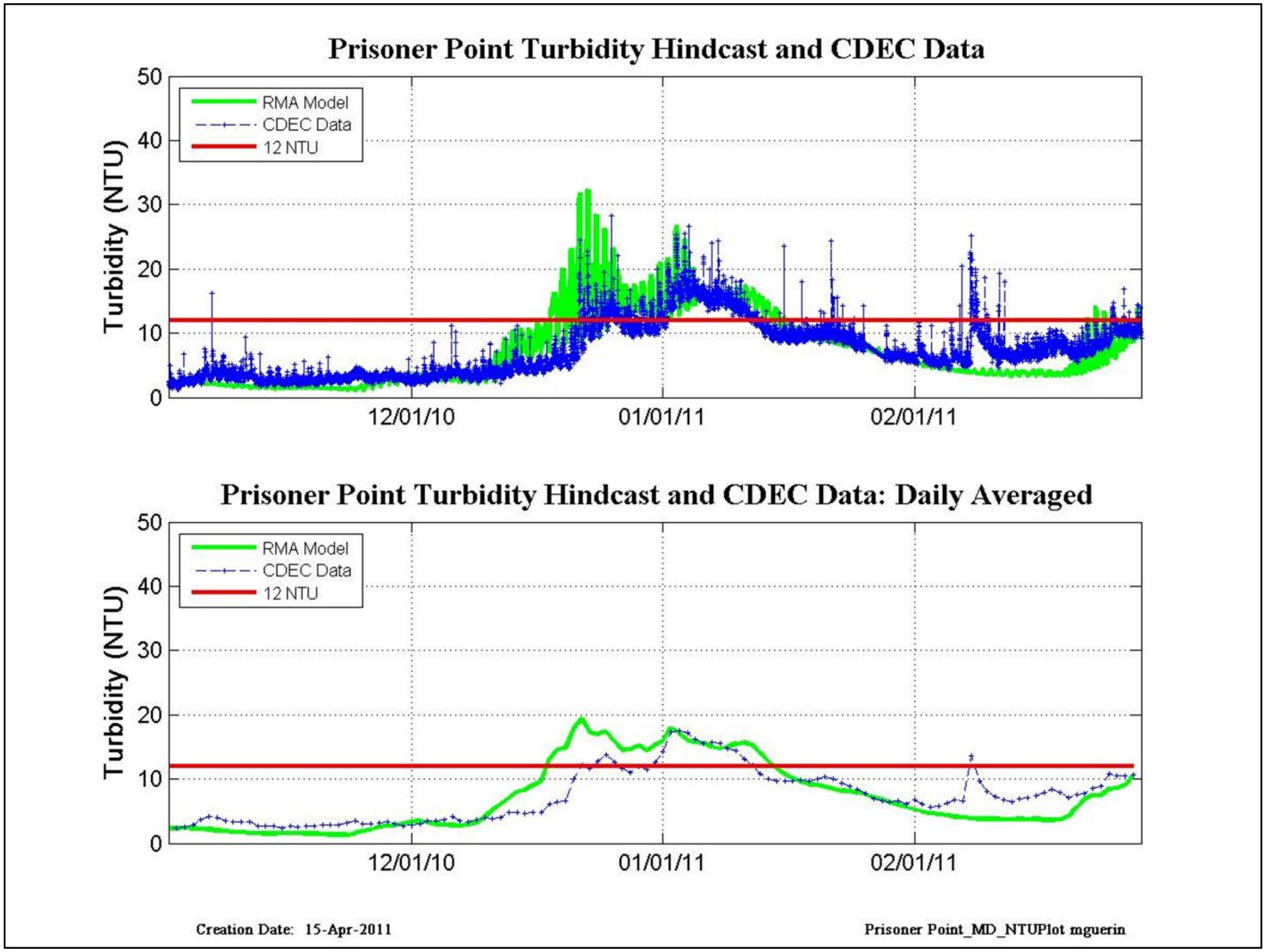


Figure 6-50 Turbidity Hindcast model results and data and daily-averaged results at Prisoner Point with 12 NTU compliance limit.

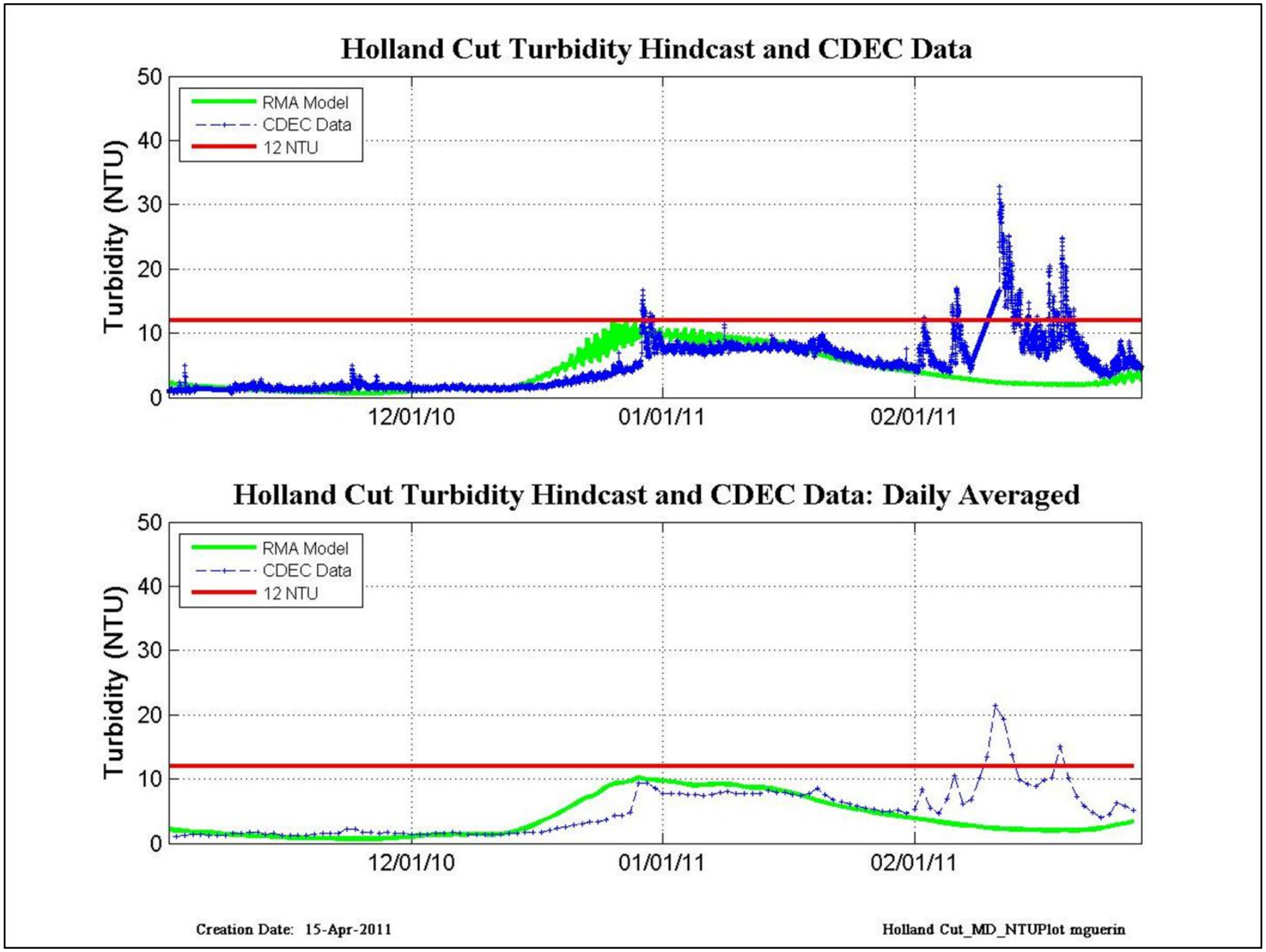


Figure 6-51 Turbidity Hindcast model results and data and daily-averaged results at Holland Cut with 12 NTU compliance limit.

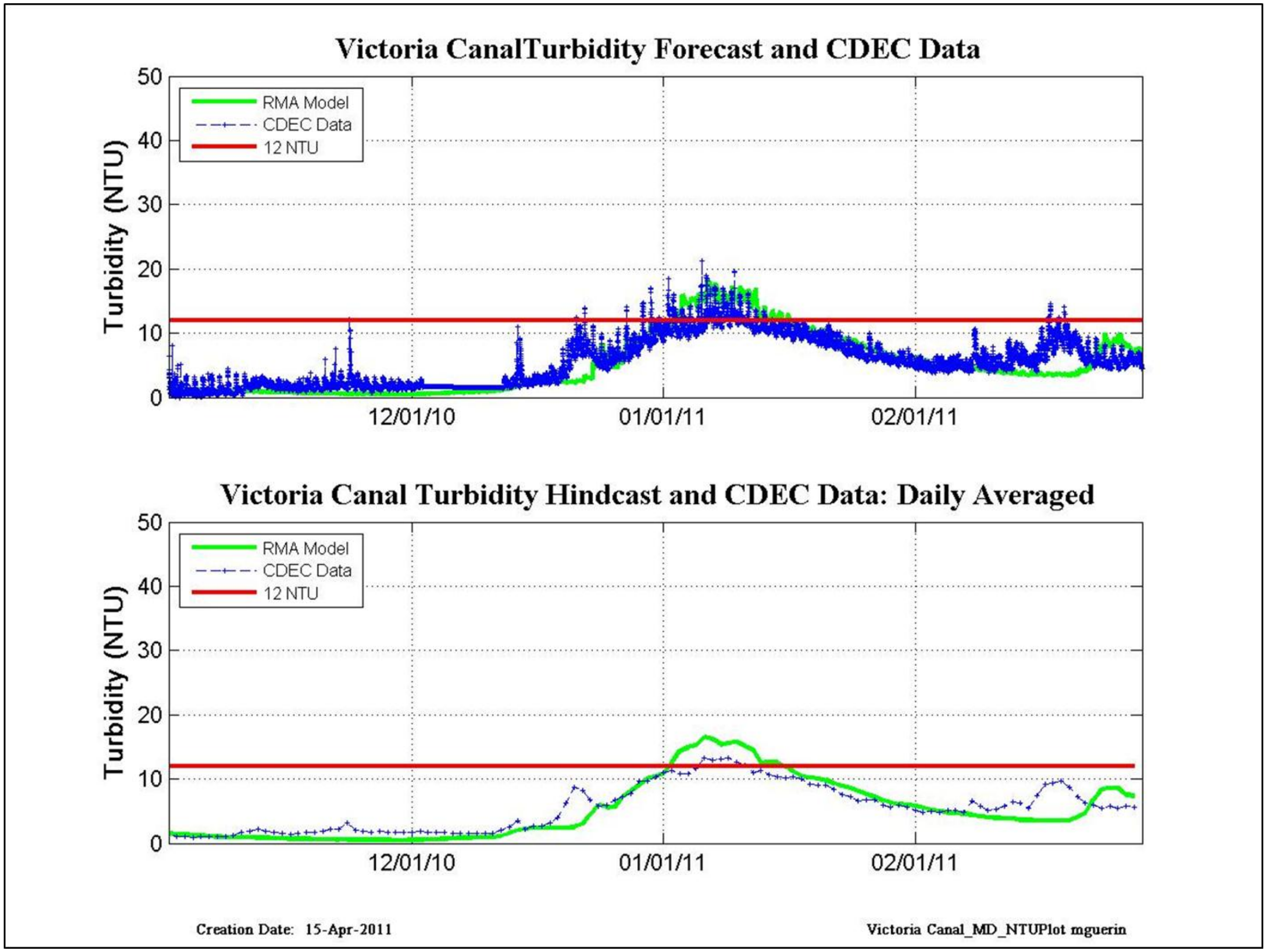


Figure 6-52 Turbidity Hindcast model results and data and daily-averaged results at Victoria Canal with 12 NTU compliance limit.

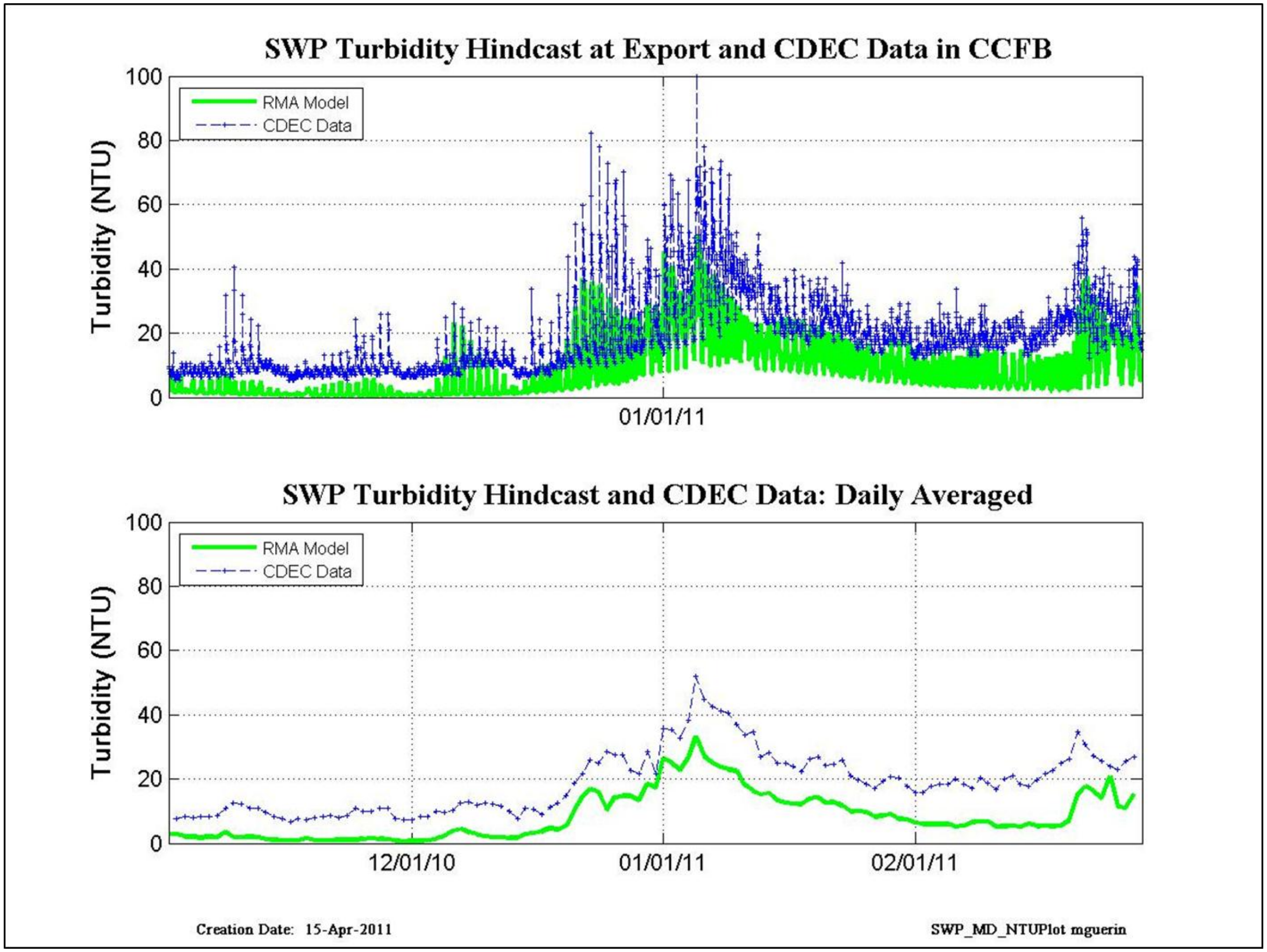


Figure 6-53 Turbidity Hindcast model results at the SWP export location and data in CCFB, and daily-averaged results.

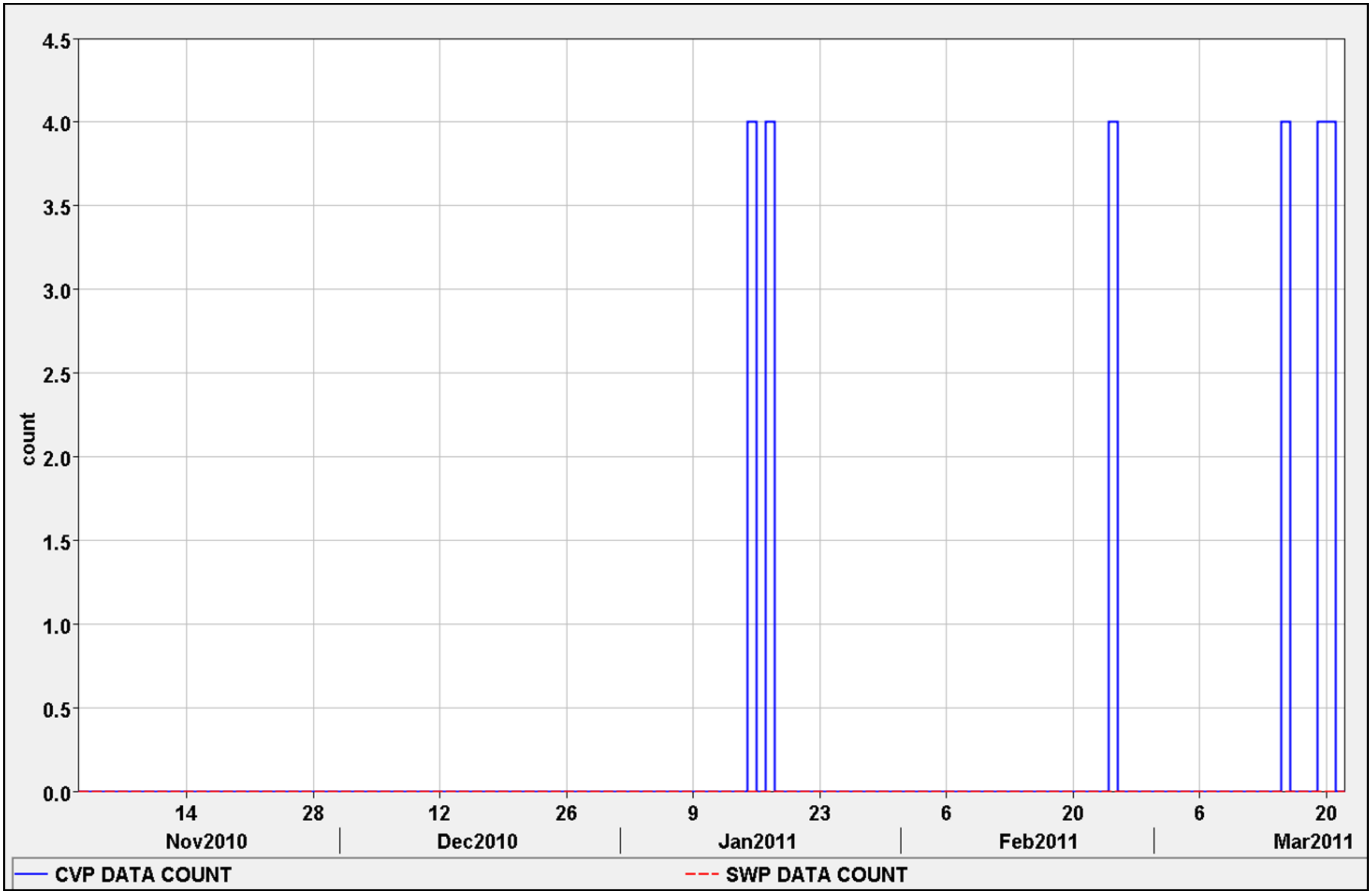


Figure 6-54 Salvage count at the SWP and CVP export locations November 2010 to mid-March 2011.

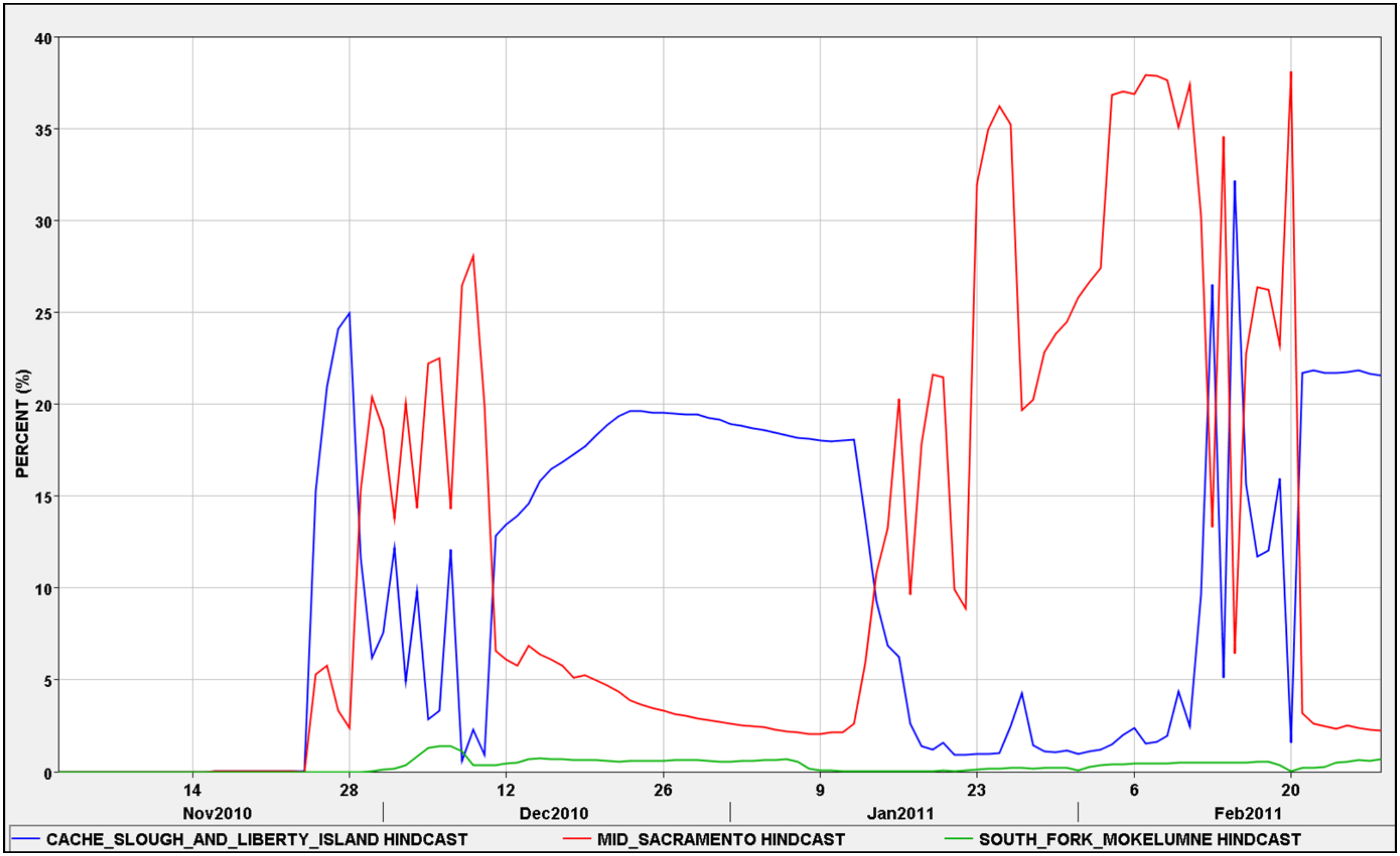


Figure 6-55 Delta smelt particles in the north Delta November 2010 to February 2011.

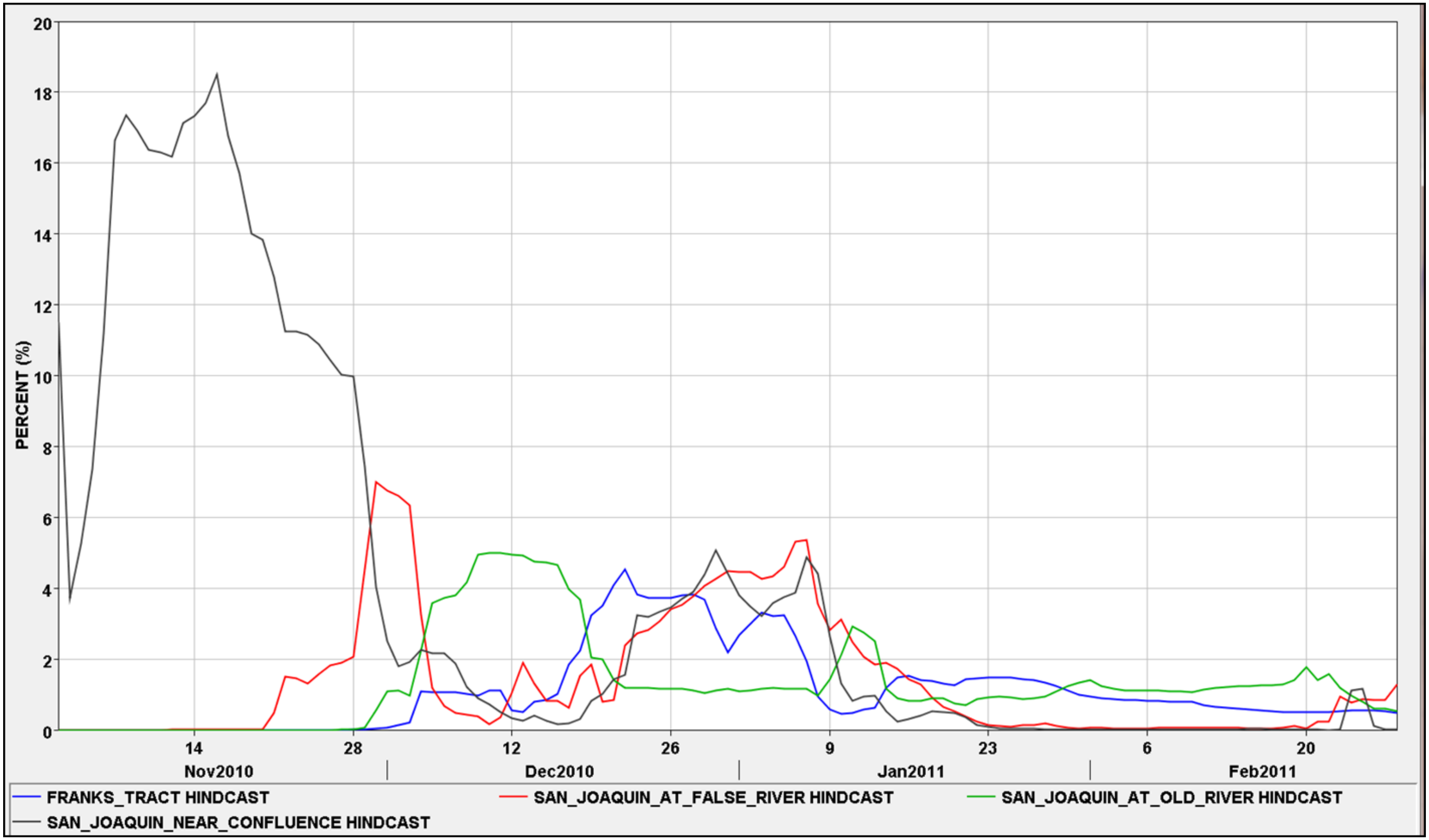


Figure 6-56 Delta smelt particles in the central Delta November 2010 to February 2011.

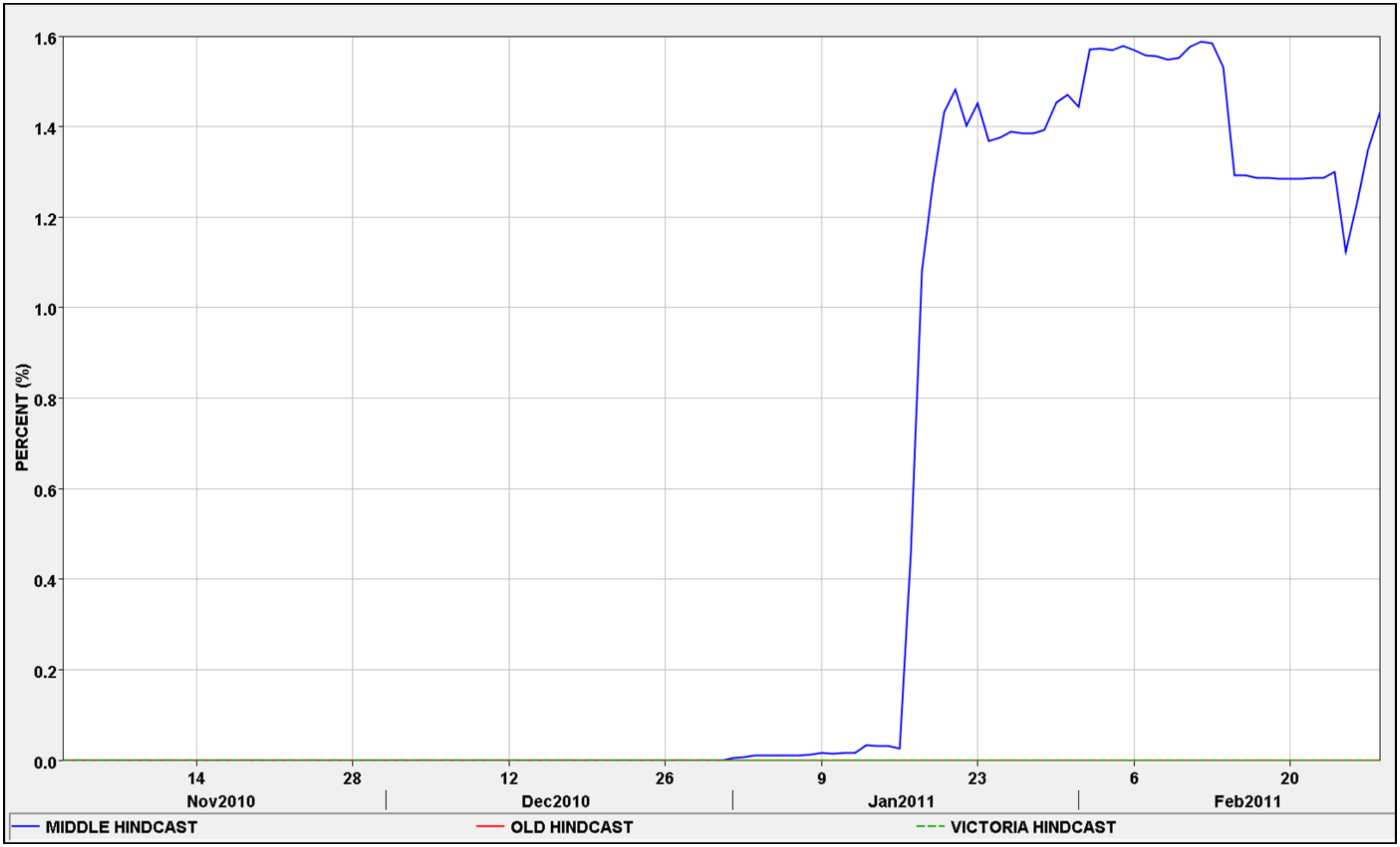


Figure 6-57 Delta smelt particles in the south Delta November 2010 to February 2011. No particles were observed at either the state (SWP) or federal (CVP) export locations.

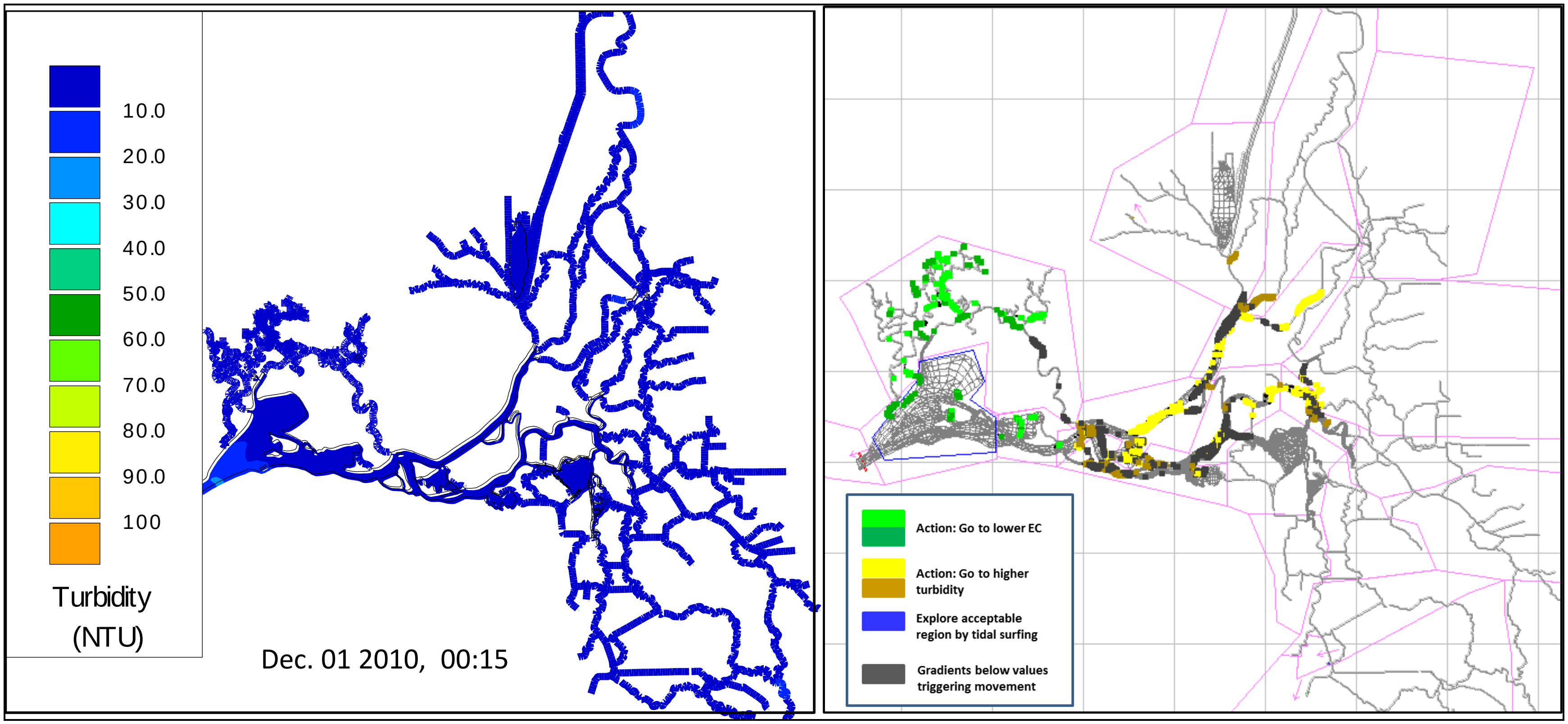


Figure 6-58 Turbidity contour plot (left) and adult delta smelt particle tracking results (right) on Dec. 01, 2010.

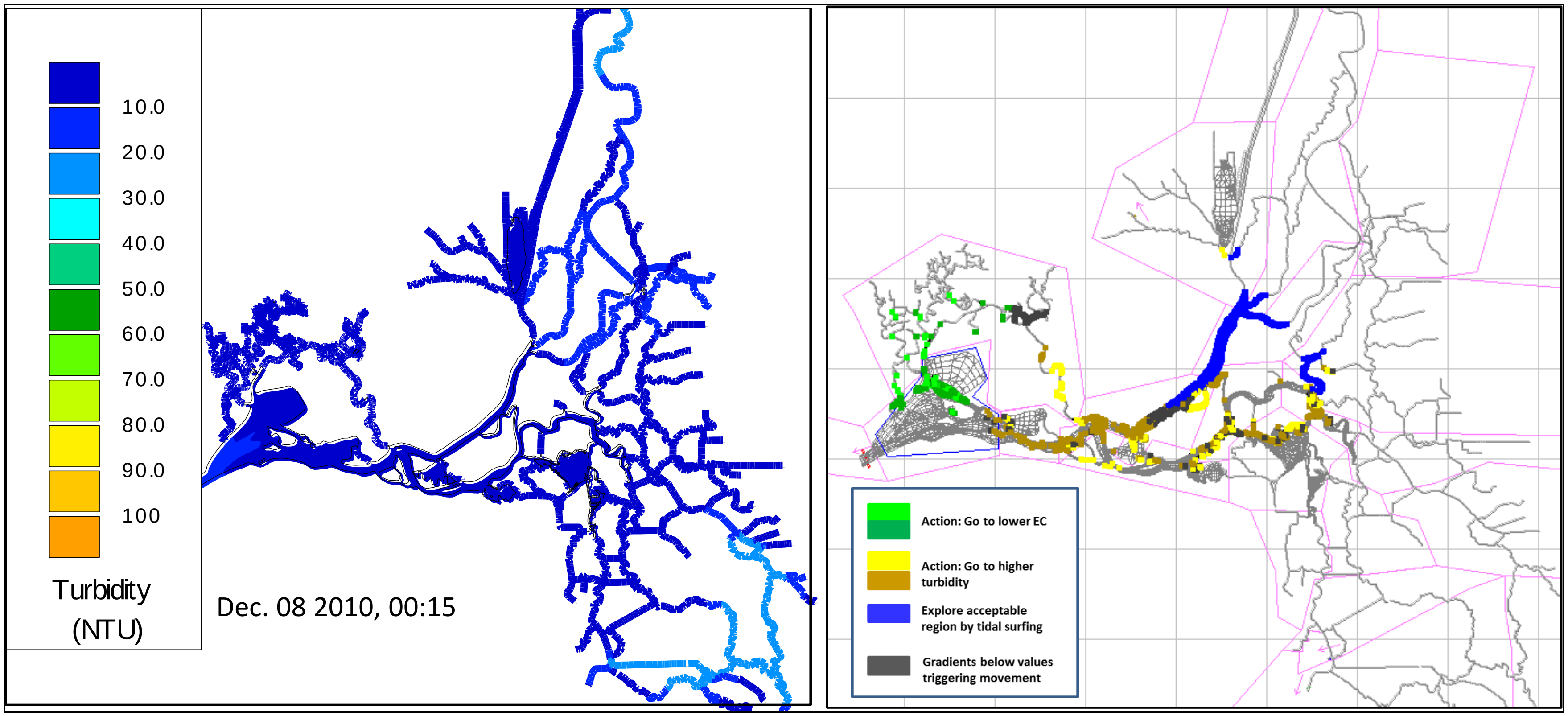


Figure 6-59 Turbidity contour plot (left) and adult delta smelt particle tracking results (right) on Dec. 08, 2010.

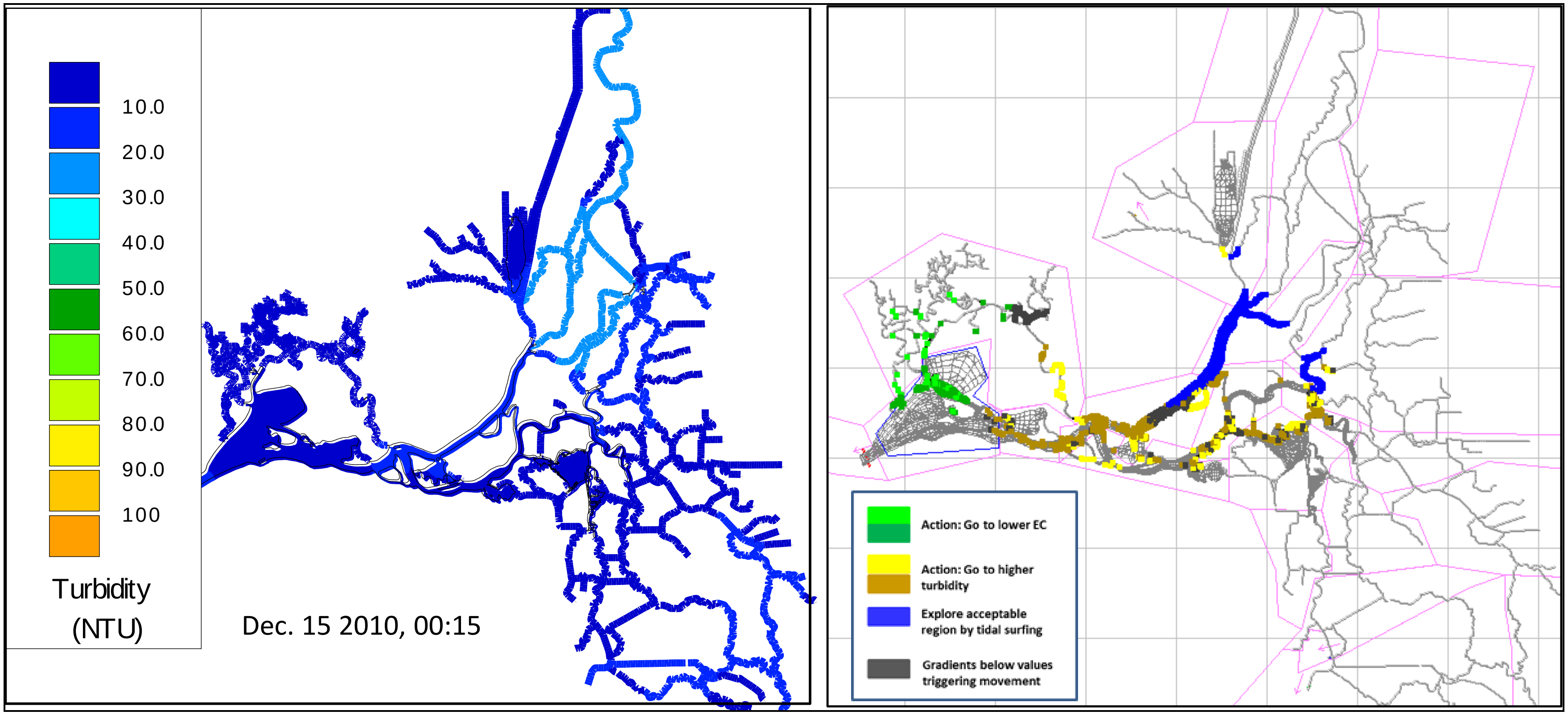


Figure 6-60 Turbidity contour plot (left) and adult delta smelt particle tracking results (right) on Dec. 15, 2010.

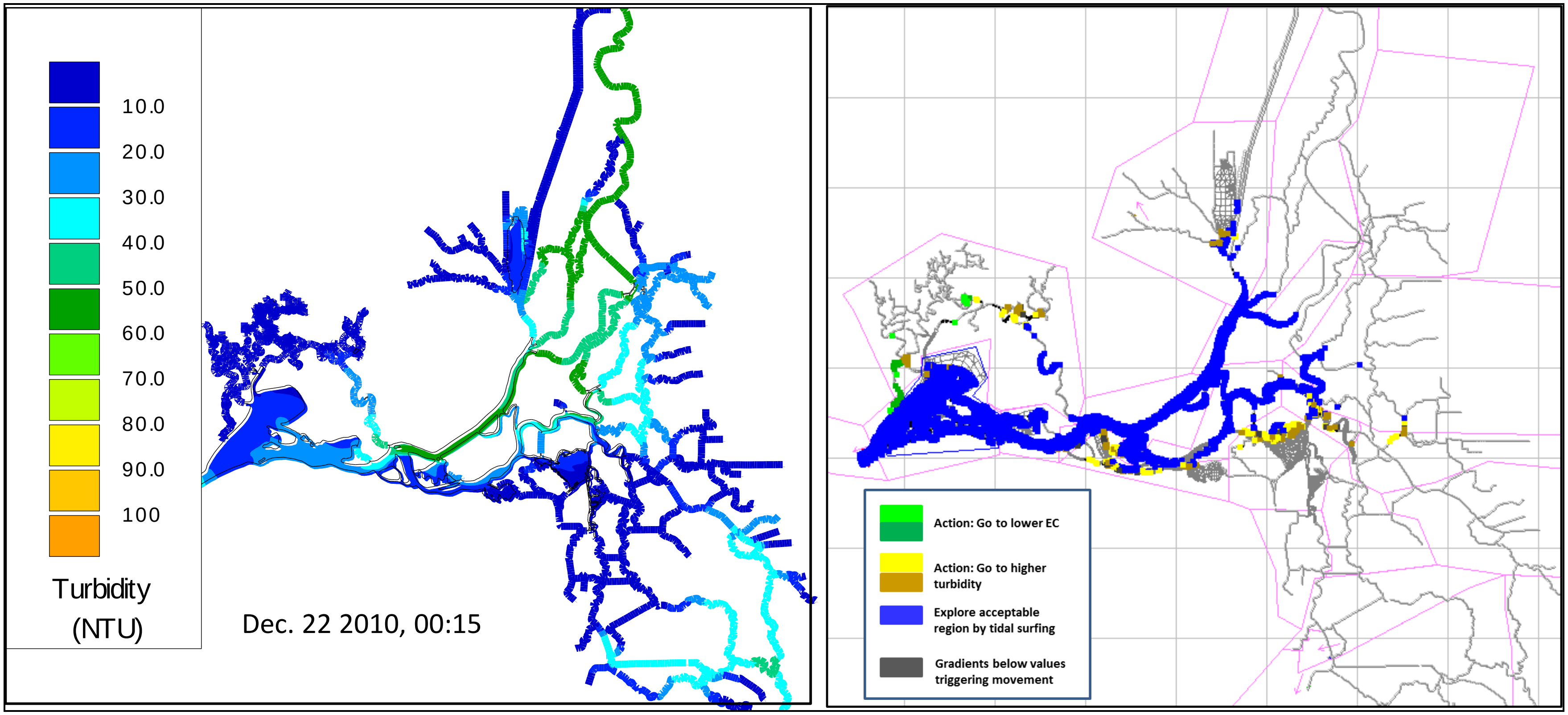


Figure 6-61 Turbidity contour plot (left) and adult delta smelt particle tracking results (right) on Dec. 22, 2010.

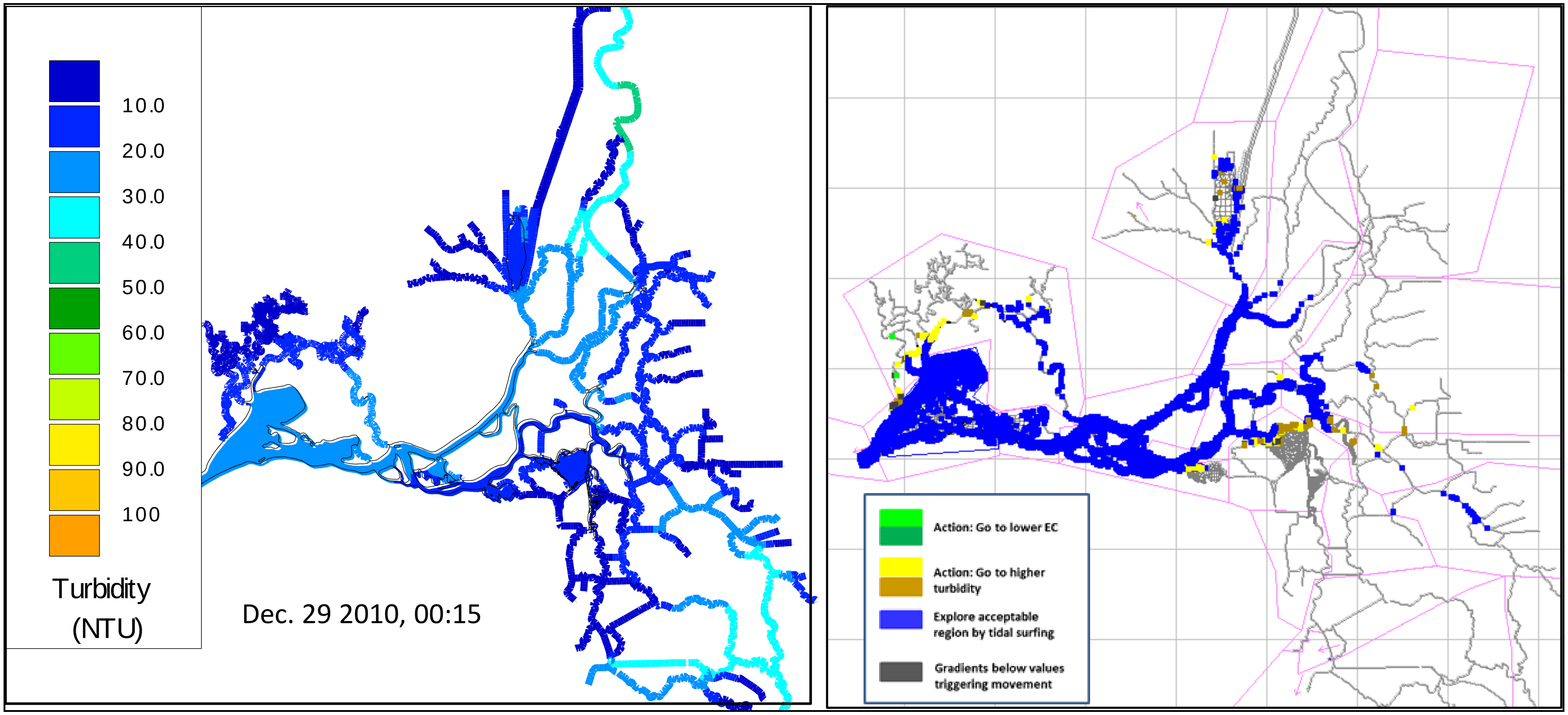


Figure 6-62 Turbidity contour plot (left) and adult delta smelt particle tracking results (right) on Dec. 29, 2010.

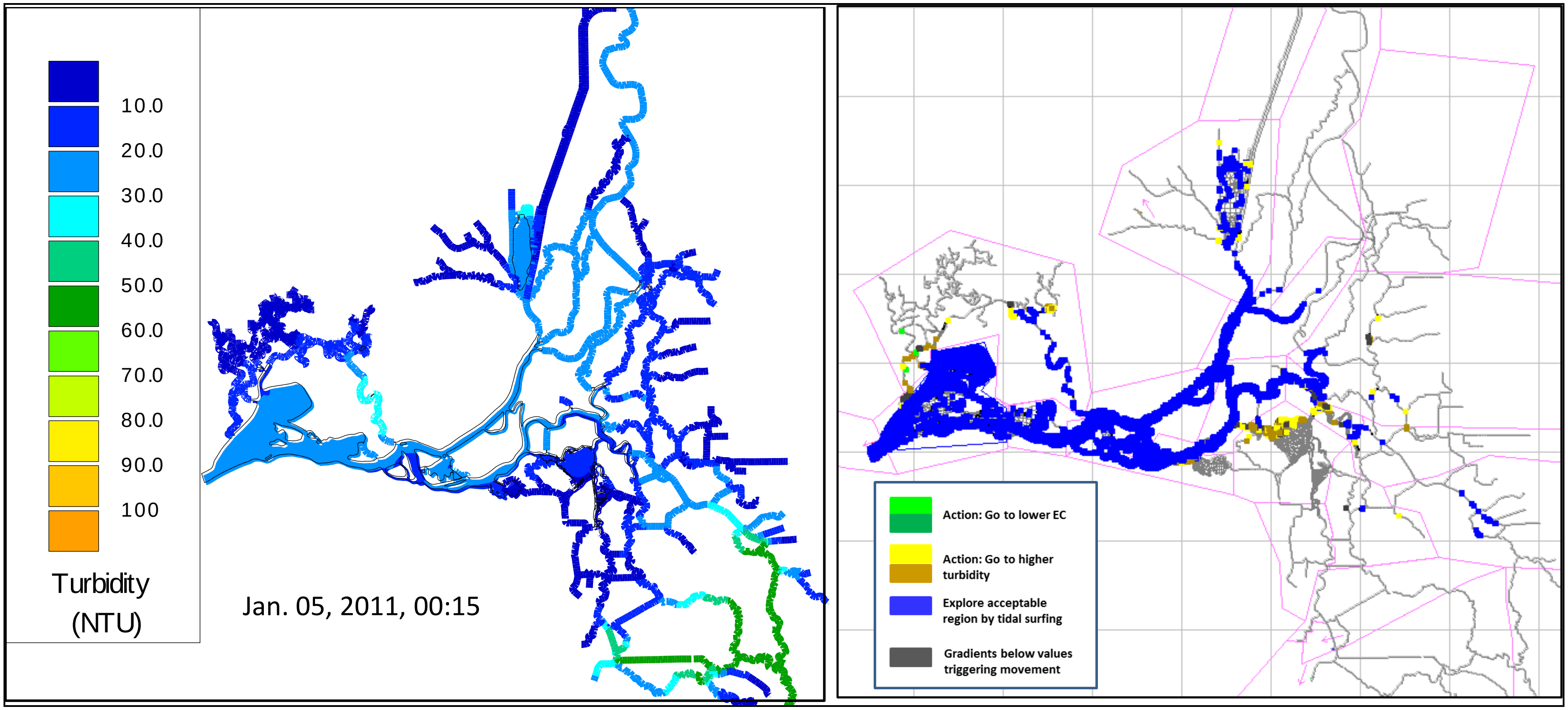


Figure 6-63 Turbidity contour plot (left) and adult delta smelt particle tracking results (right) on Jan. 05, 2011.

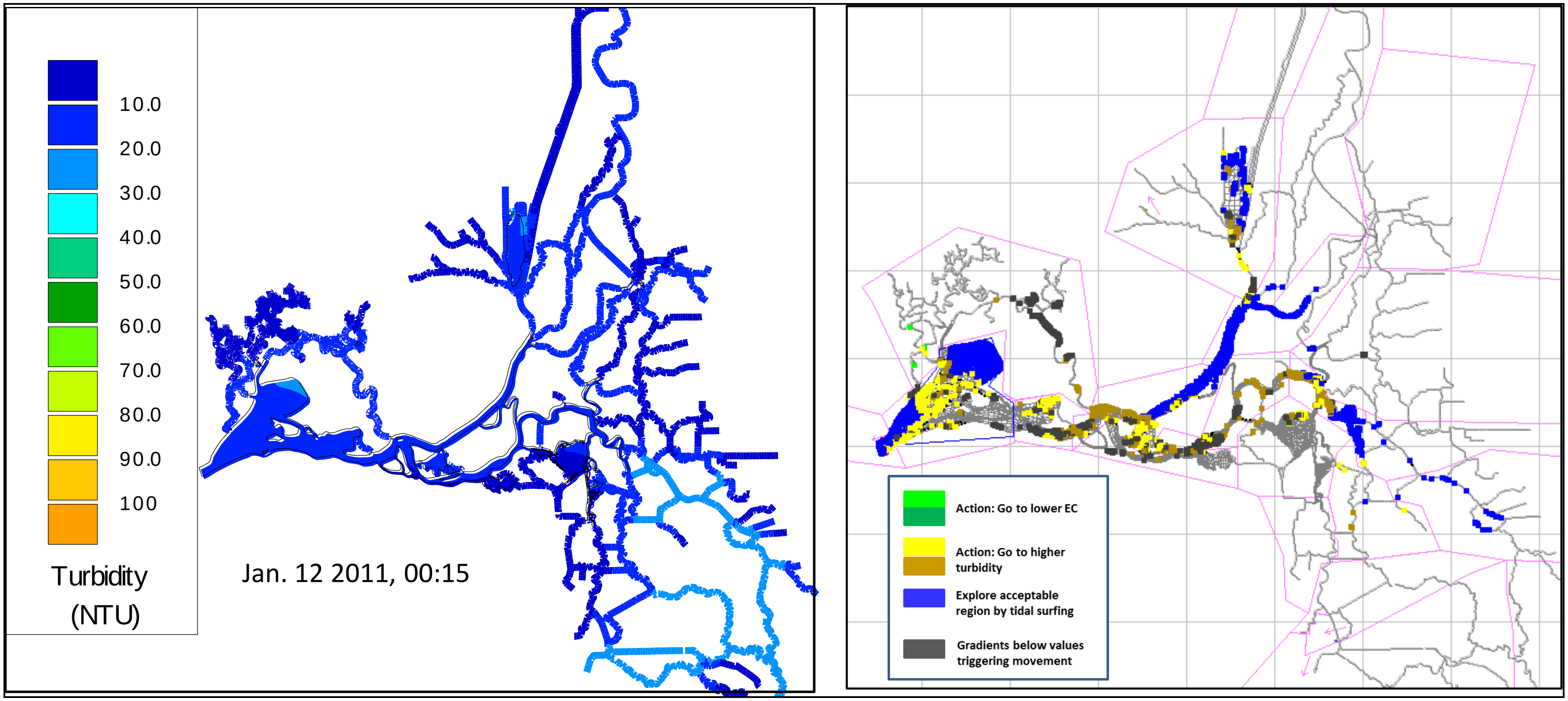


Figure 6-64 Turbidity contour plot (left) and adult delta smelt particle tracking results (right) on Jan. 12, 2011.

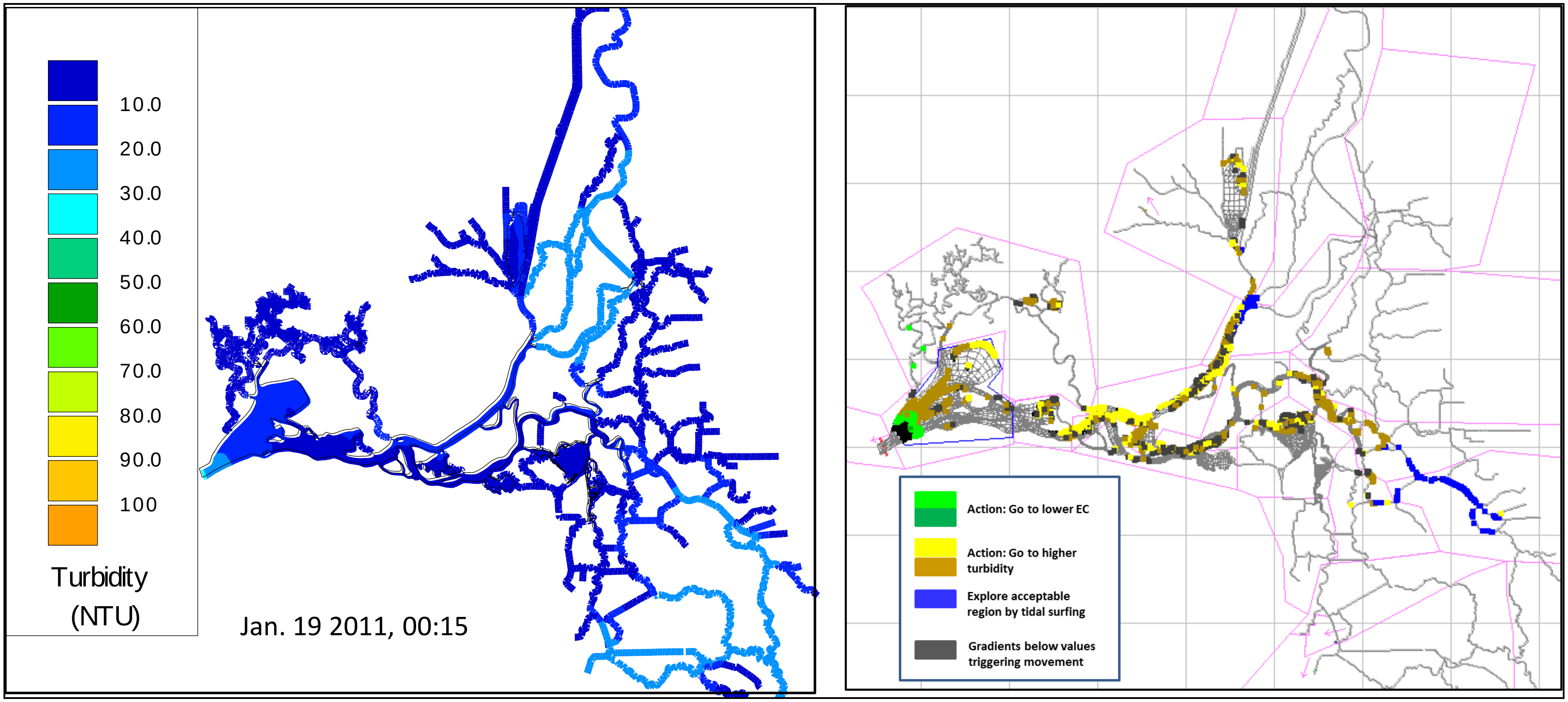


Figure 6-65 Turbidity contour plot (left) and adult delta smelt particle tracking results (right) on Jan. 19, 2011.

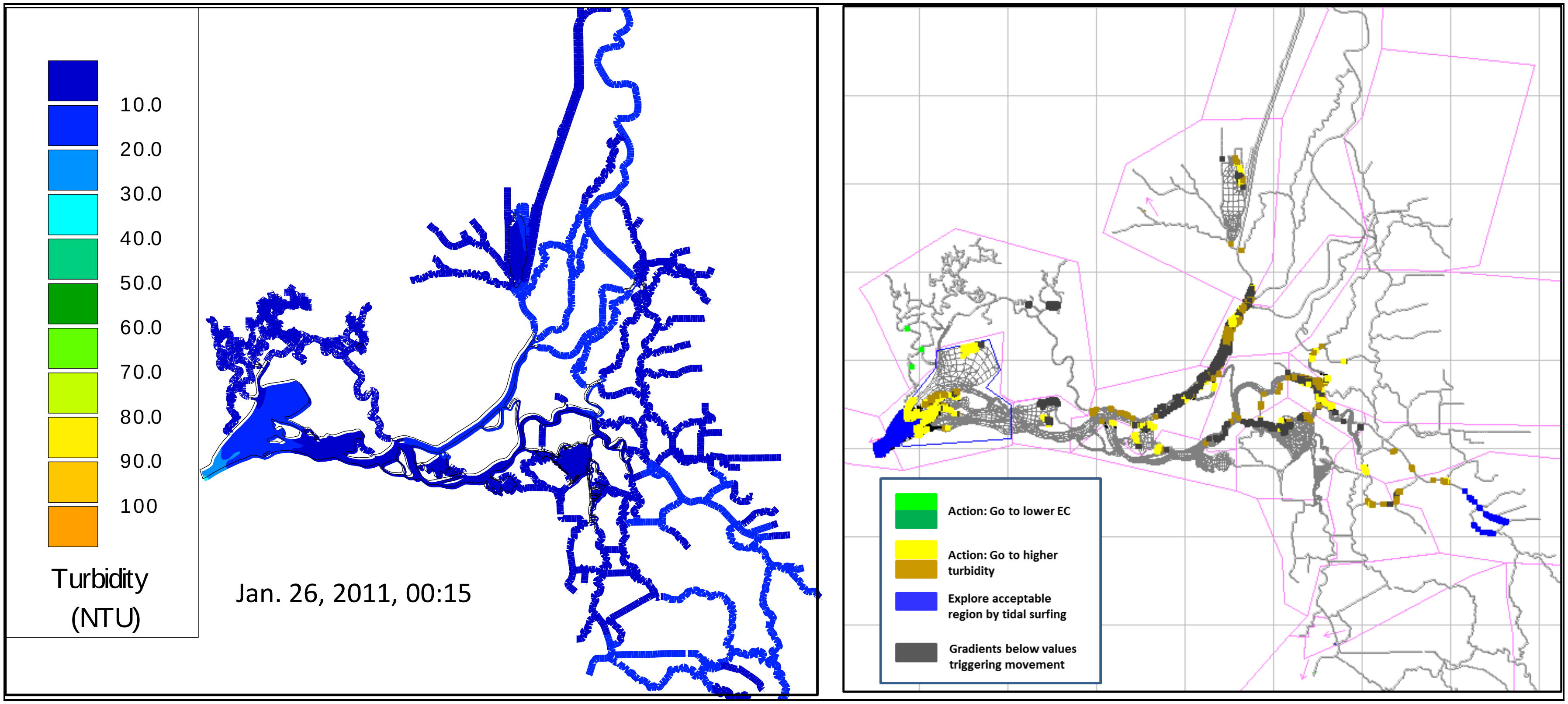


Figure 6-66 Turbidity contour plot (left) and adult delta smelt particle tracking results (right) on Jan. 26, 2011.

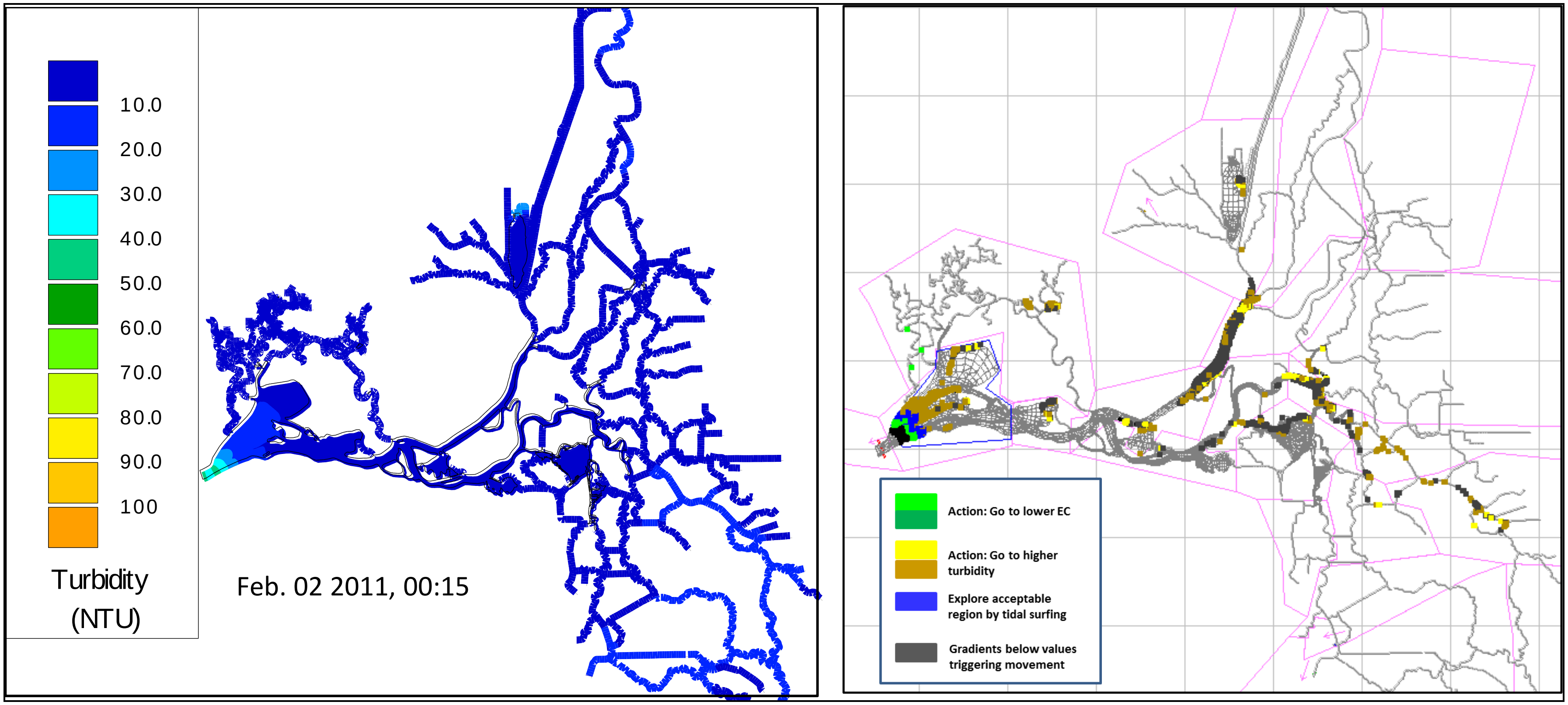


Figure 6-67 Turbidity contour plot (left) and adult delta smelt particle tracking results (right) on Feb. 02, 2011.

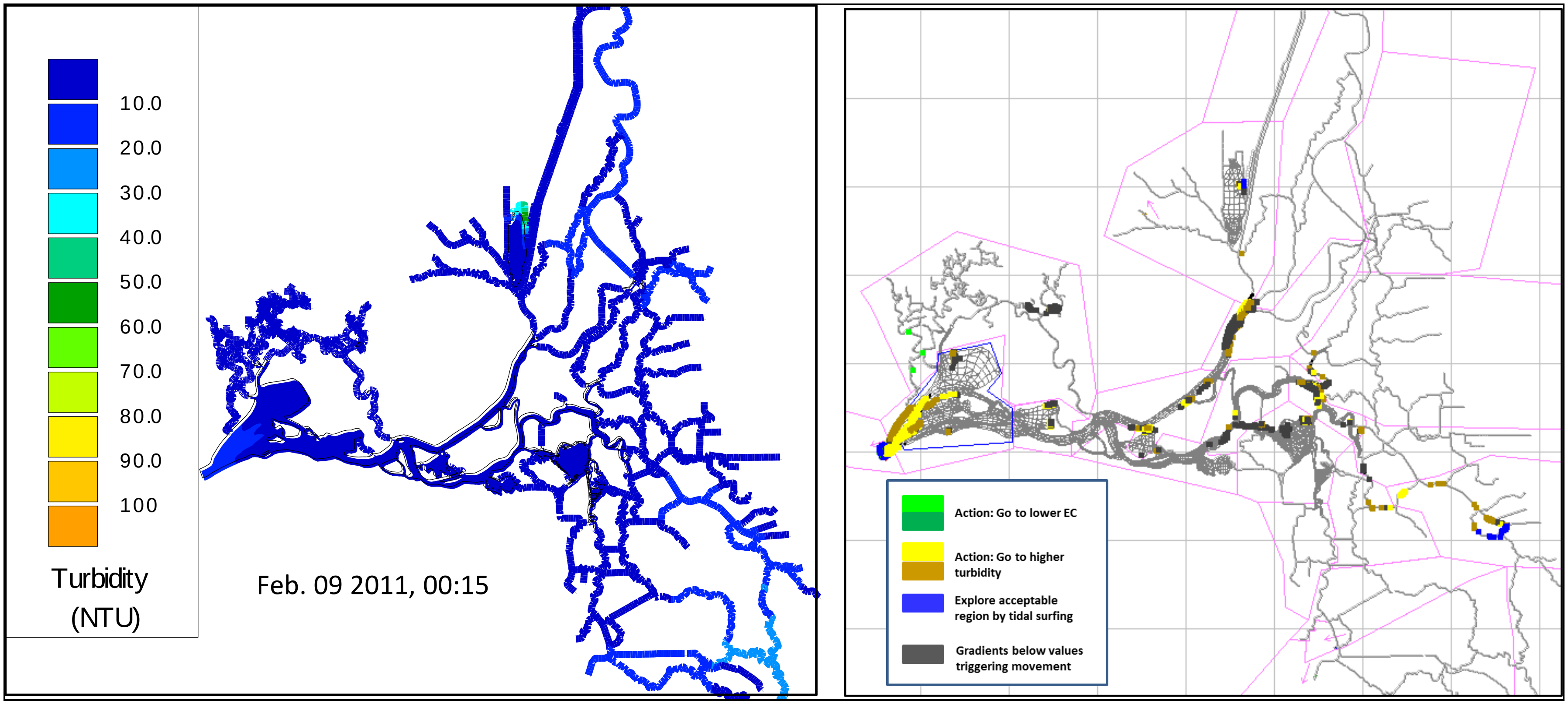


Figure 6-68 Turbidity contour plot (left) and adult delta smelt particle tracking results (right) on Feb. 09, 2011.

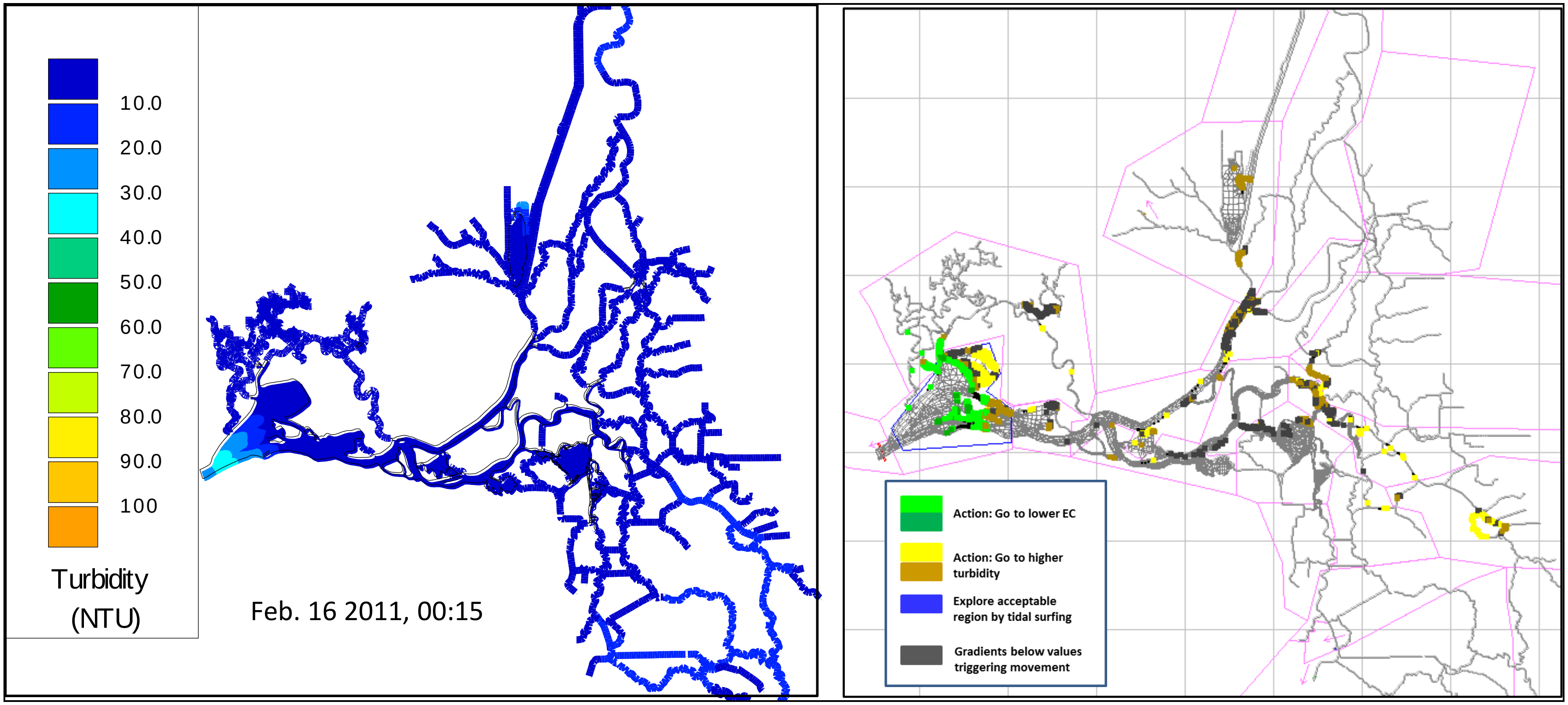


Figure 6-69 Turbidity contour plot (left) and adult delta smelt particle tracking results (right) on Feb. 16, 2011.

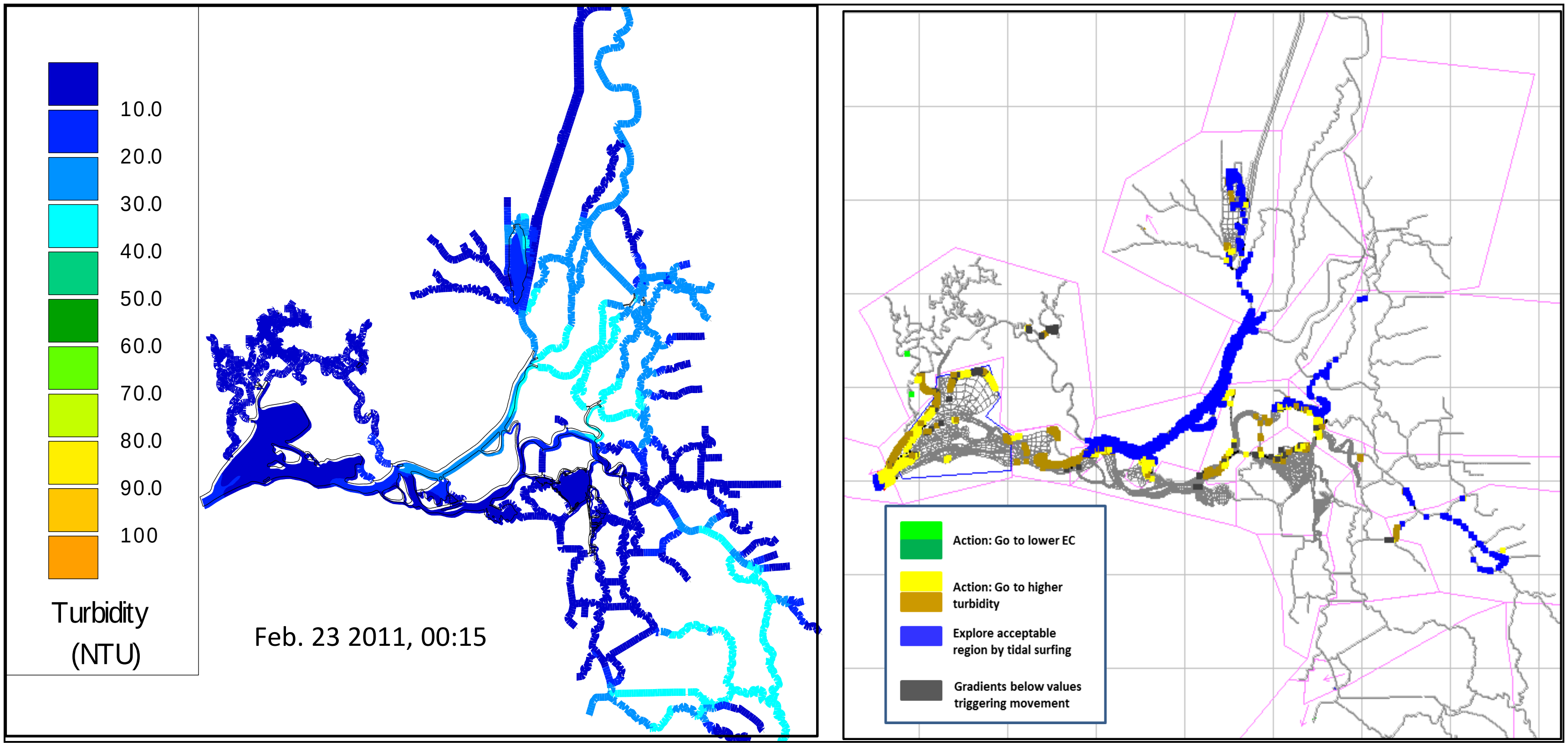


Figure 6-70 Turbidity contour plot (left) and adult delta smelt particle tracking results (right) on Feb. 23, 2011.

7. Modified export scenario

7.1. Background

MWD staff (Hutton, pers. comm.) supplied RMA with an EXCEL file[3] specifying a scenario for modified export operations in the south Delta denoted the "Modified Deriso Model", which is based on a model (the Deriso model) which relates an average SWP salvage rate for delta smelt with turbidity in Clifton Court Forebay (CCF) and the flow through Old and Middle Rivers. The Modified Deriso scenario was implemented in the Hindcast model by changing the export rates at the SWP and CVP export facilities in the RMA2 model. Water quality boundary conditions from the Hindcast model (turbidity and EC) were left unchanged (see Section 6). The adult delta smelt particle tracking model was then run as usual using the RMA2 and RMA11 model results for the Modified Deriso scenario.

7.2. Methodology to calculate Modified Deriso export flows

In support of the weekly turbidity forecast modeling, RMA received 15 minute CCF inflows computed as an output from DSM2 supplied with the O&M weekly flow forecast runs. The DSM2 CCF inflows are used to specify a boundary condition for the SWP exports in RMA2. The "historical" portions of the computed CCF inflows were extracted for the period from November 1, 2010 to March 1, 2011 and used in the Hindcast model run (see Section 6). Developing an RMA2 simulation using the Modified Deriso scenario defining daily SWP exports required adjusting Hindcast SWP export time series to reflect the changed conditions defined in the scenario and converting the daily SWP export values from the scenario to an instantaneous time series. CVP exports were changed to a constant 4200 cfs under the Modified Deriso scenario.

The DSM2 forecast CCF gate opening schedule follows a "Priority 3" operation (Le, 2004; Wilde, 2006), with CCF gate openings and closings operated on a tidal schedule to limit impacts on water levels in the south Delta. Historically, the CCF gate opening/closure operations may vary from the Priority 3 schedule. In order to implement the daily Modified Deriso SWP exports in the RMA2 model, a utility program was developed to compute a new time series of 15-minute CCF inflows. The program follows the DSM2 v.6.2 methodology where inflow is based on the difference between the stage inside and outside of CCF. The elevation inside CCF is tracked in the CCF Utility program by computing the net of the CCF inflow and the daily SWP export flow rate is divided by the area in CCF. The outside stage is taken from the O&M DSM2 model runs.

[3] 042611 Turbidity_Sensitivity_Ops.xlsx

Figure 7-1 compares the CCF inflows computed by the DSM2 model and the CCF Utility program for the Hindcast SWP exports. The results show that the CCF Utility program nearly reproduces the DSM2-computed CCF inflow for the Hindcast case. The CCF inflow computed by the utility generally follows the historical and DSM2 model gate opening/closings.

The Modified Deriso model often generated higher SWP exports relative to the Hindcast exports. The higher exports increased the head difference between the inside and outside CCF water surface elevation and increased the inflow rates. To avoid potential problems (*e.g.*, with channels drying out or low stage elevations in the south Delta), the calculated instantaneous inflow rates were limited by the utility program algorithm to a maximum of 20,000 cfs. The DSM2 historical computed inflows were sometimes zero even though the CCF gates were allowed to be open in the Priority 3 operational scheme. This occurred when the DSM2-computed CCF inside water surface elevation was higher than the outside water surface elevation. The gates were "closed" in the model to prevent reverse flow out of CCF. The new operation included inflow during this period if the CCF inside water surface elevation was lower due to greater SWP exports. If the Modified Deriso SWP exports were significantly higher, the CCF gates were opened some additional time (outside of time allowed by Priority 3) to reduce higher inflow rates and decrease south Delta stage.

Figure 7-2 shows a detailed comparison of the CCF inflows developed using the utility program for a Modified Deriso alternative with the Hindcast CCF inflows from the DSM2 run. For the February 4-6 period shown in the plot, the SWP exports for the Modified Deriso alternative are about 138% of the Baseline exports. The additional SWP export flow was accomplished by higher CCF inflow rates, inflows when the DSM2 inflows were zero but the gates were historically open, and additional time of gate opening (beyond Priority 3 Gate Operation schedules).

7.3. Results

Figure 7-3 illustrates the change in Old+Middle River flow as a fourteen-day running average for the Modified Deriso model scenario in comparison with Hindcast modeled flow and with CDEC data. Note that the Hindcast Old+Middle River flow is generally less negative than indicated by CDEC data. Figure 7-4 illustrates the daily inflow to CCF expected from the Hindcast (historical inflow), from the Deriso model, and from the Modified Deriso Model used in this scenario. Figure 7-5 illustrates the total daily exports as the sum of CCF inflow and CVP exports, which were modeled as a constant export rate of 4200 cfs. The brief period in late December, 2010 when Hindcast exports were higher than exports in the Modified Deriso scenario (Figure 7-5) was due to turbidity at Prisoner Point reaching values greater than 12 NTU, leading to reduced allowable negative Old+Middle River flow in the scenario.

The increased exports in the Modified Deriso scenario resulted in greater reverse flow in Old+Middle R. (Figure 7-3, green line). Table 7-1 details the export volumes obtained on a monthly basis under historical conditions and for the Modified Deriso scenario for the combined SWP+CVP export locations. Exports volumes increased by 47 TAF in December 2010, 159 TAF in January, 2011 and 108 TAF in February, 2011, for a 3-month total increase of 314 TAF.

Although exports increased under the Modified Deriso scenario, changes in modeled turbidity results were minor. Figure 7-6 through Figure 7-8 illustrate the turbidity differences between CDEC data (blue), the Hindcast model (red) and the Modified Deriso scenario (green) at Prisoner’s Point, Victoria Canal and Holland Cut, the turbidity compliance locations. Similarly, Figure 7-9 illustrates the turbidity differences between the CDEC data in CCF (blue), and at the SWP export location in the Hindcast model (red) and in the Modified Deriso scenario (green). The turbidity differences between the Hindcast the Modified Deriso scenario results amount to at most several NTU, with the scenario turbidity slightly higher than the Hindcast.

The adult delta smelt particle tracking results show small percent differences between the Hindcast and the scenario – the time series results are shown in Figure 7-12 through Figure 7-16 for the regions shown in Section 4.3. The increased exports in the Modified Deriso scenario drew more particles into the Franks Tract (Figure 7-13) and Middle (Figure 7-14) regions, by at most a couple of percent. In contrast, particles were drawn out of the South Fork Mokelumne and Cache Slough and Liberty Island regions, again with changes amounting to at most a couple of percent.

Thus, overall the Modified Deriso scenario had only minor influences on the turbidity field, and then only in the south Delta. Similarly, changes to the particle distributions representing adult delta smelt were minor, but here the effects were felt into the north Delta as particles were influenced to move out of the area near Cache Slough and Liberty Island.

Comparisons of 2-dimensional model results of turbidity contours and particle distributions show no detectible differences between the Hindcast and the Modified Deriso scenario. Weekly plots, starting December 01, 2010 through the end of the Hindcast in February 2011, showing these results are found in the Appendix (Figure 12-183 through Figure 12-208).

Table 7-1 Monthly cumulative combined export volume for the Hindcast (Historical values) and for the Modified Deriso scenario.

	December Export Volume (TAF)	**January Export Volume (TAF)**	**February Export Volume (TAF)**
Historical/Hindcast	672	657	495
Modified Deriso	719	816	603

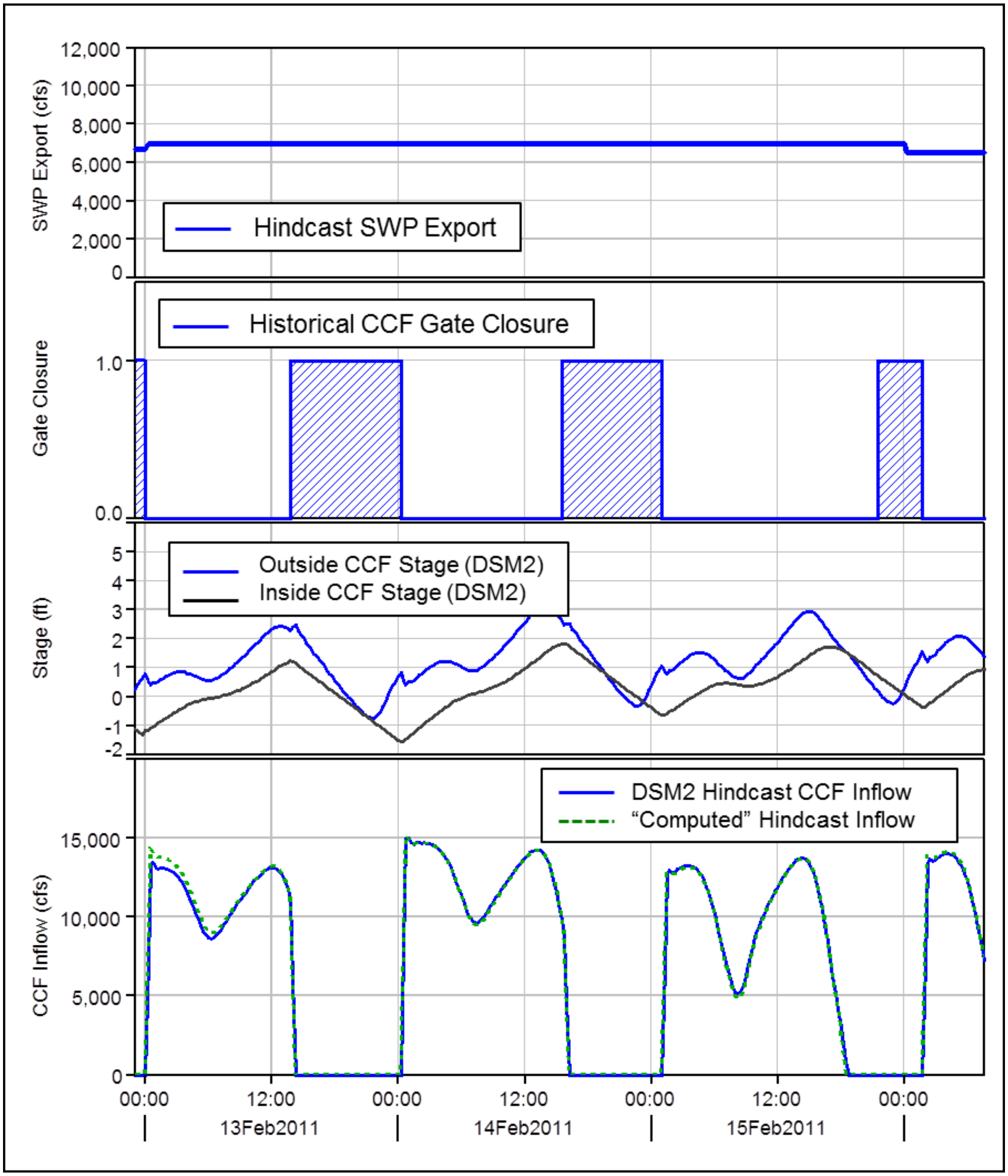


Figure 7-1 Comparison of Baseline CCF inflow computed from DSM2 Hindcast and the CCF Utility program (bottom).

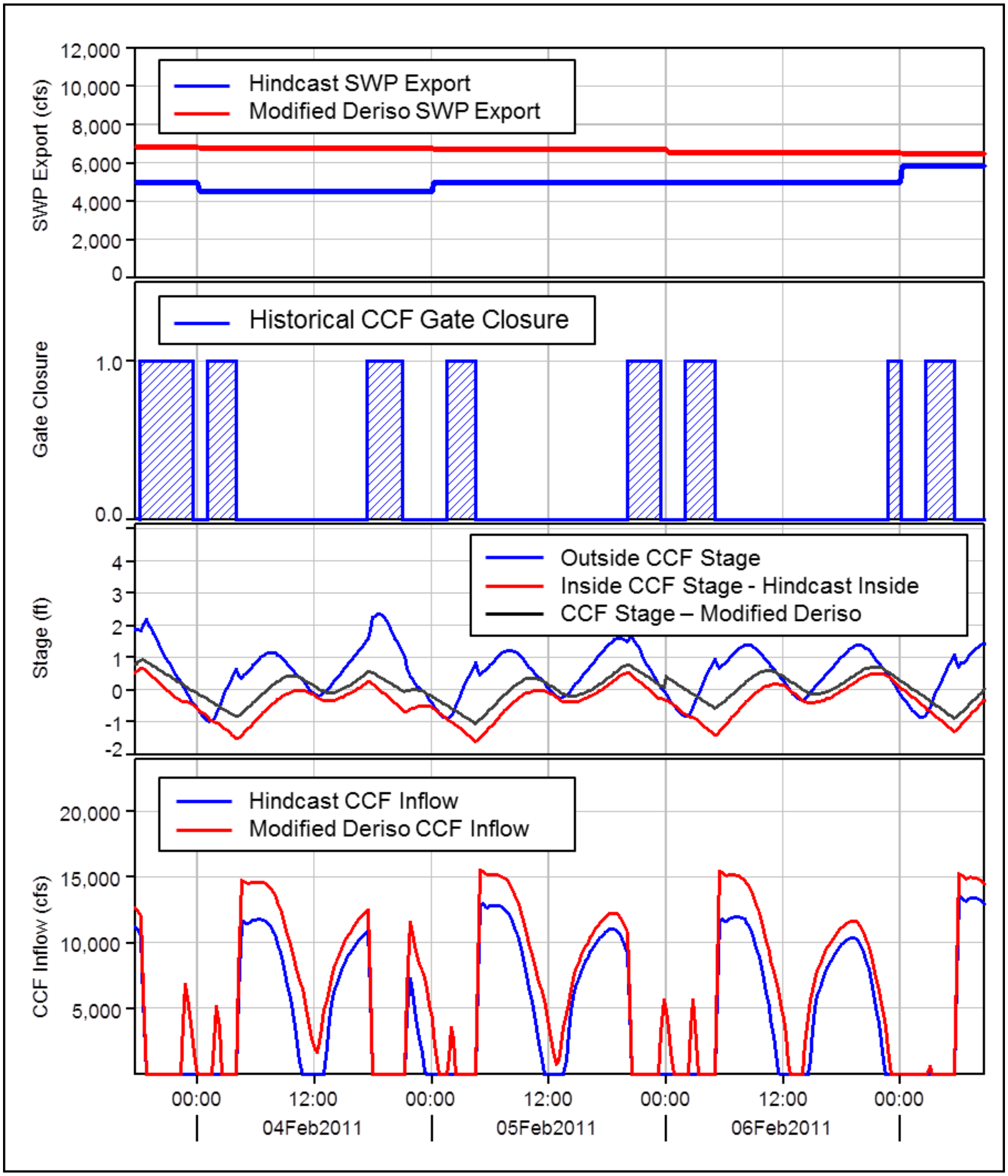


Figure 7-2 Baseline CCF inflow from the DSM2 Hindcast and scenario runs and the Modified Deriso based CCF Inflow computed with the CCF Utility program (bottom).

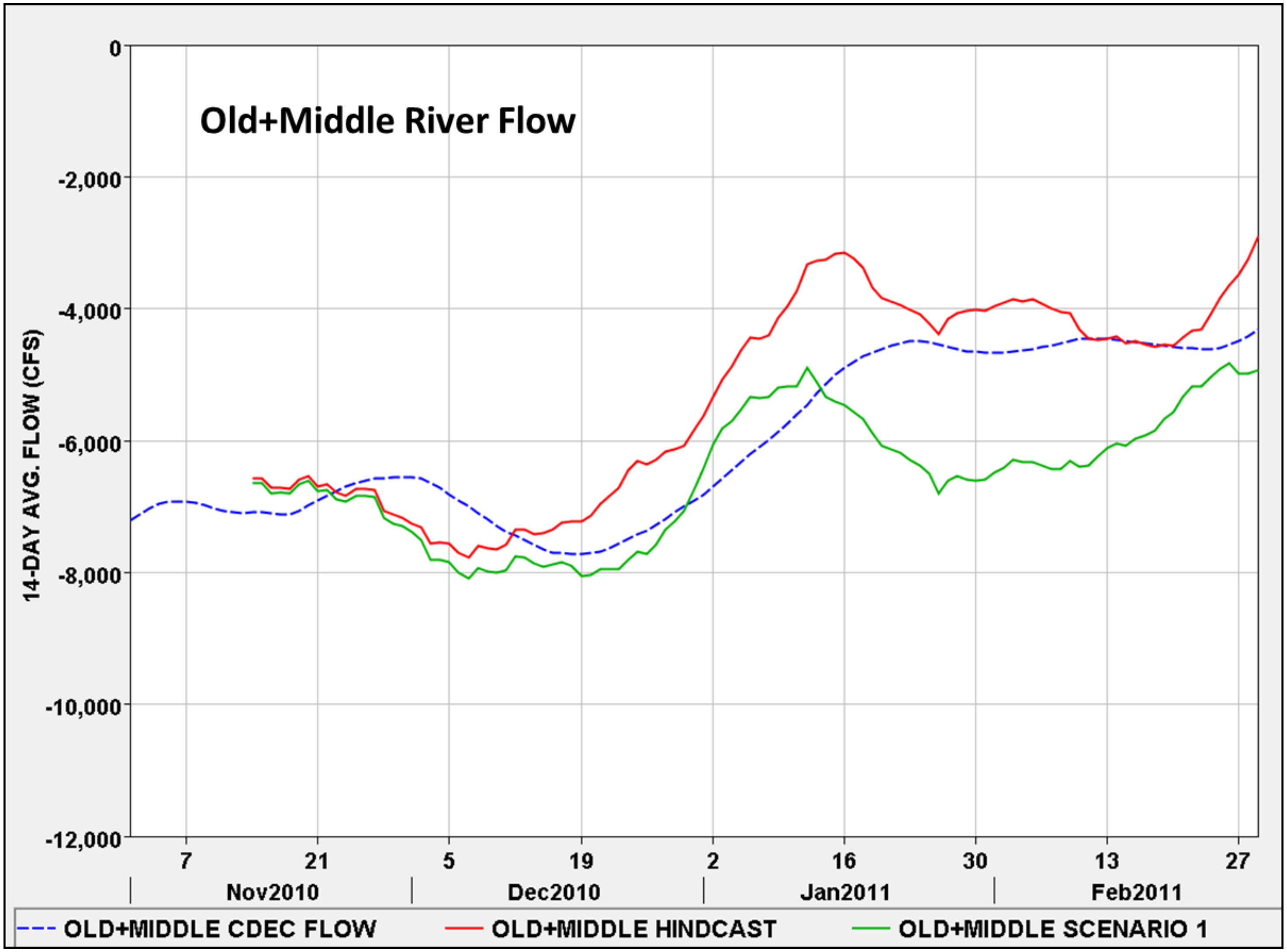


Figure 7-3 Fourteen-day forward-averaged Old+Middle River flow comparing data from CDEC (Blue) with the Hindcast Model (red) and the Modified Deriso model (green, Scenario 1).

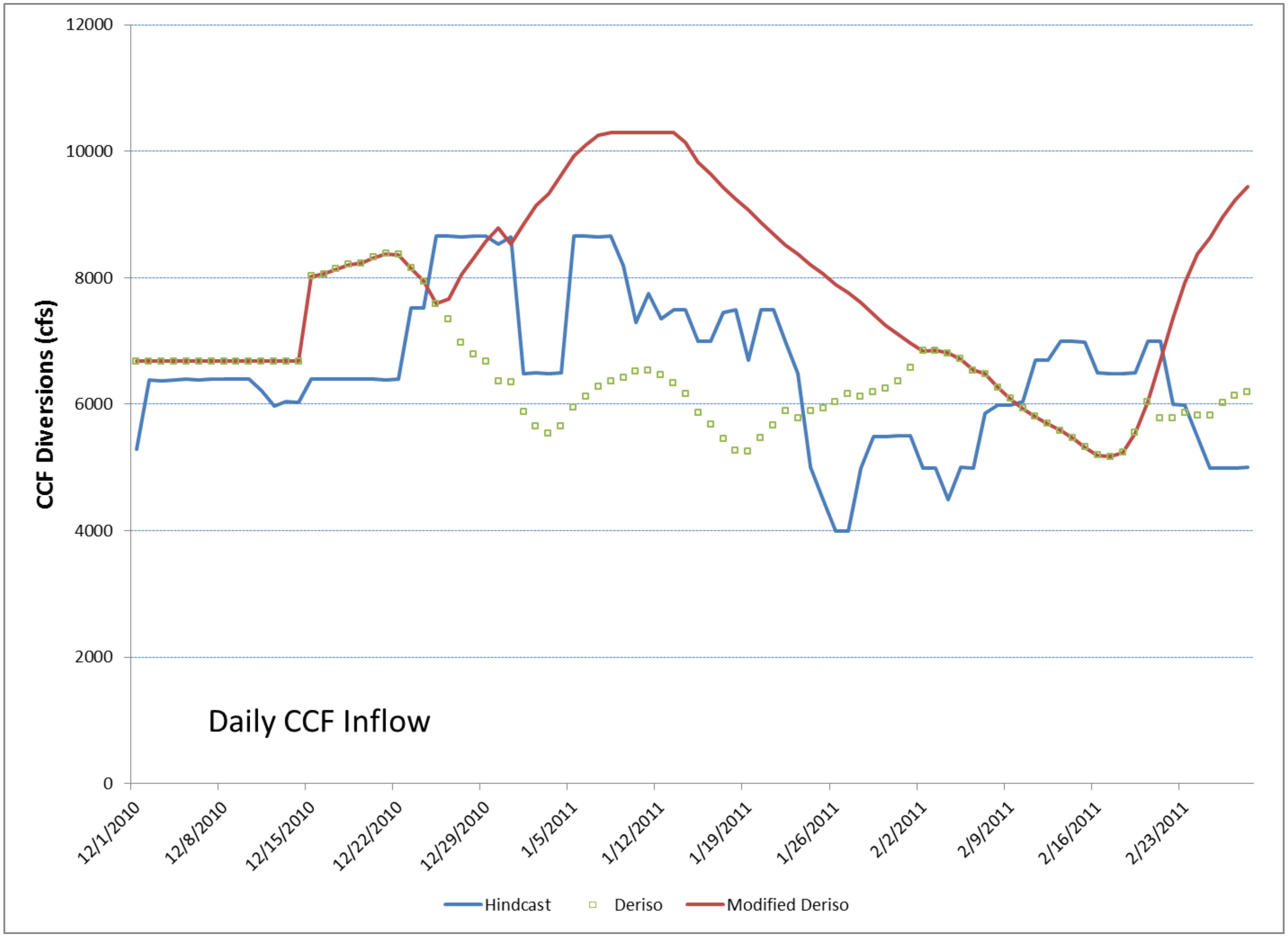


Figure 7-4 CCF inflow comparison for the Hindcast/Historical (blue), calculated by the Deriso model (green) and by the Modified Deriso Model (red) (from MWD/Hutton).

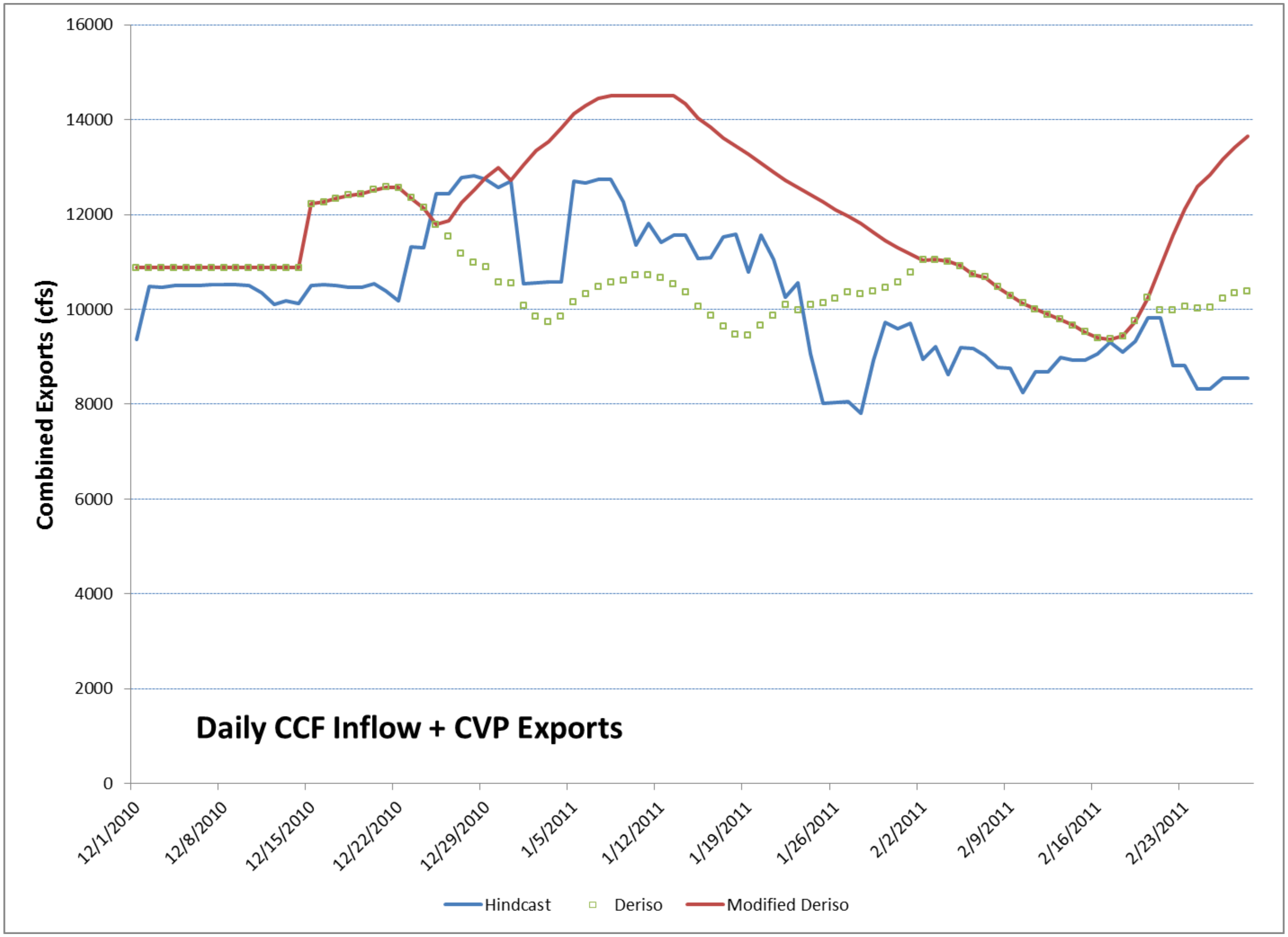


Figure 7-5 Comparison of combined S. Delta exports, *i.e.*, CCF inflow plus CVP exports, for the Hindcast/Historical (blue), calculated by the Deriso model (green) and by the Modified Deriso Model (red) (from MWD/Hutton).

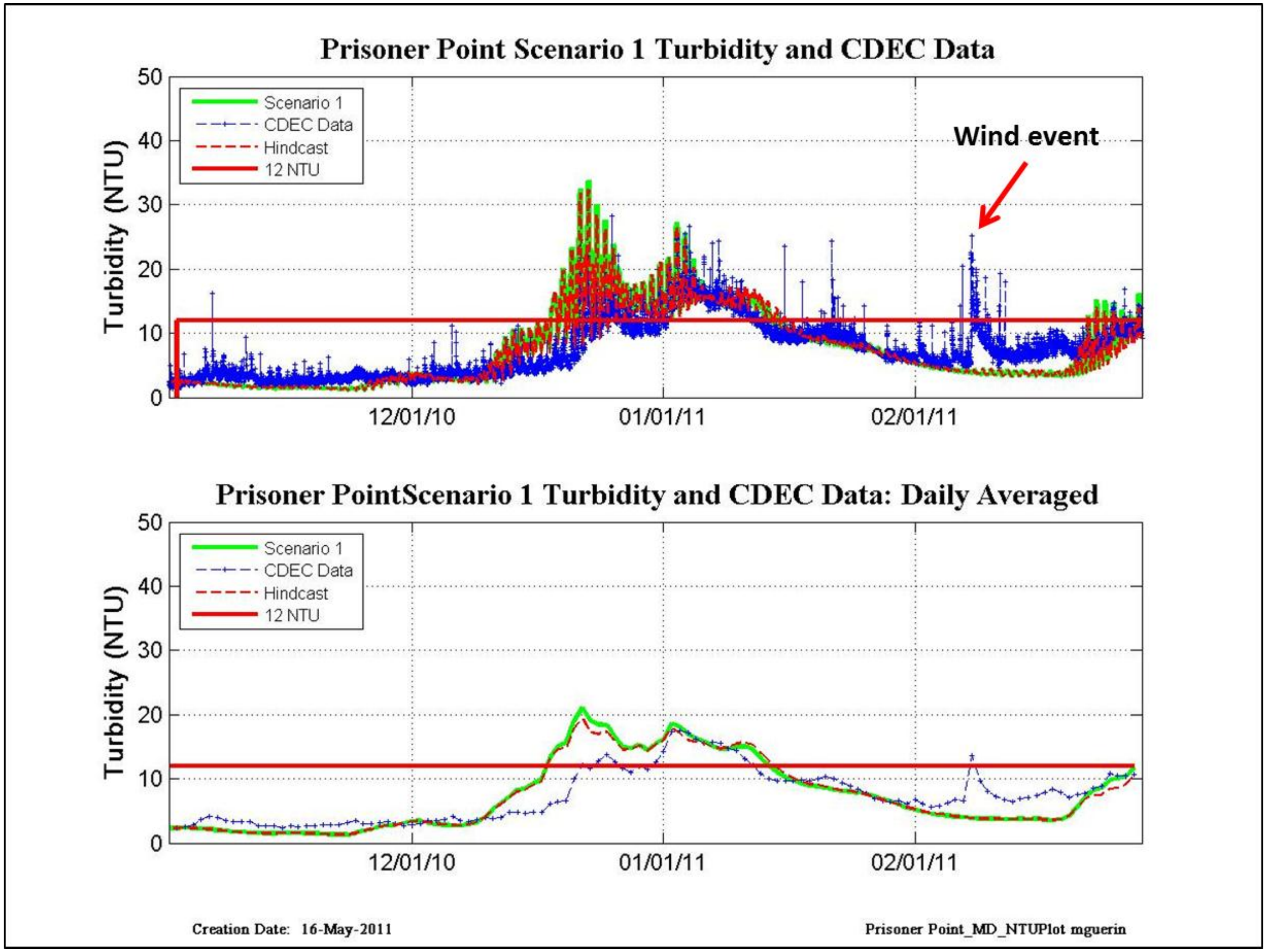


Figure 7-6 Comparison of Prisoner Point turbidity and daily averaged turbidity (lower plot) using CDEC data (blue), the Hindcast model (red) and the Modified Deriso model (green, Scenario 1). The wind event in early February raised turbidity values seen in the data, but is not reflected in model results.

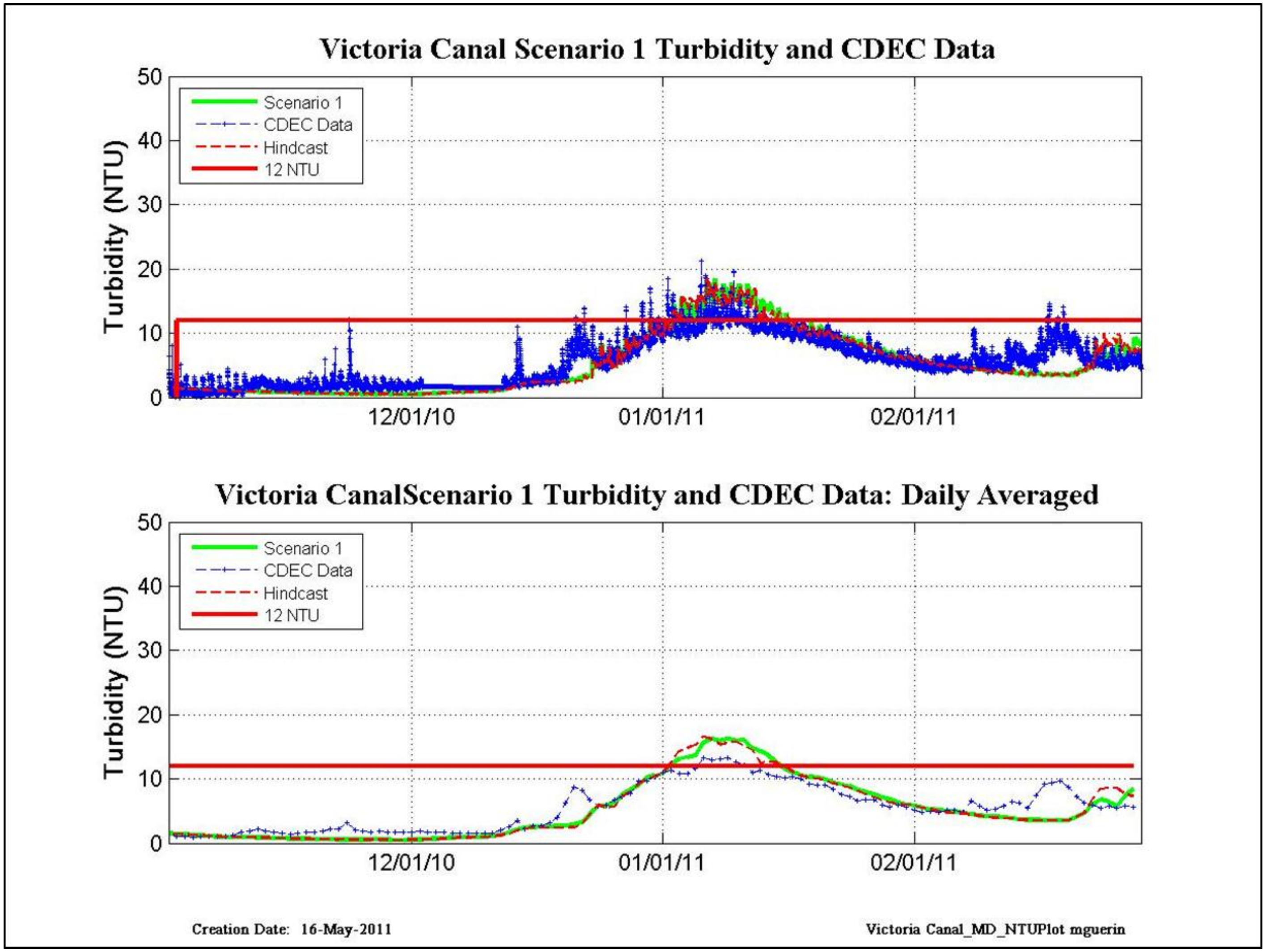


Figure 7-7 Comparison of Victoria Canal turbidity and daily averaged turbidity (lower plot) using CDEC data (blue) the Hindcast model (red) and the Modified Deriso model (green, Scenario 1).

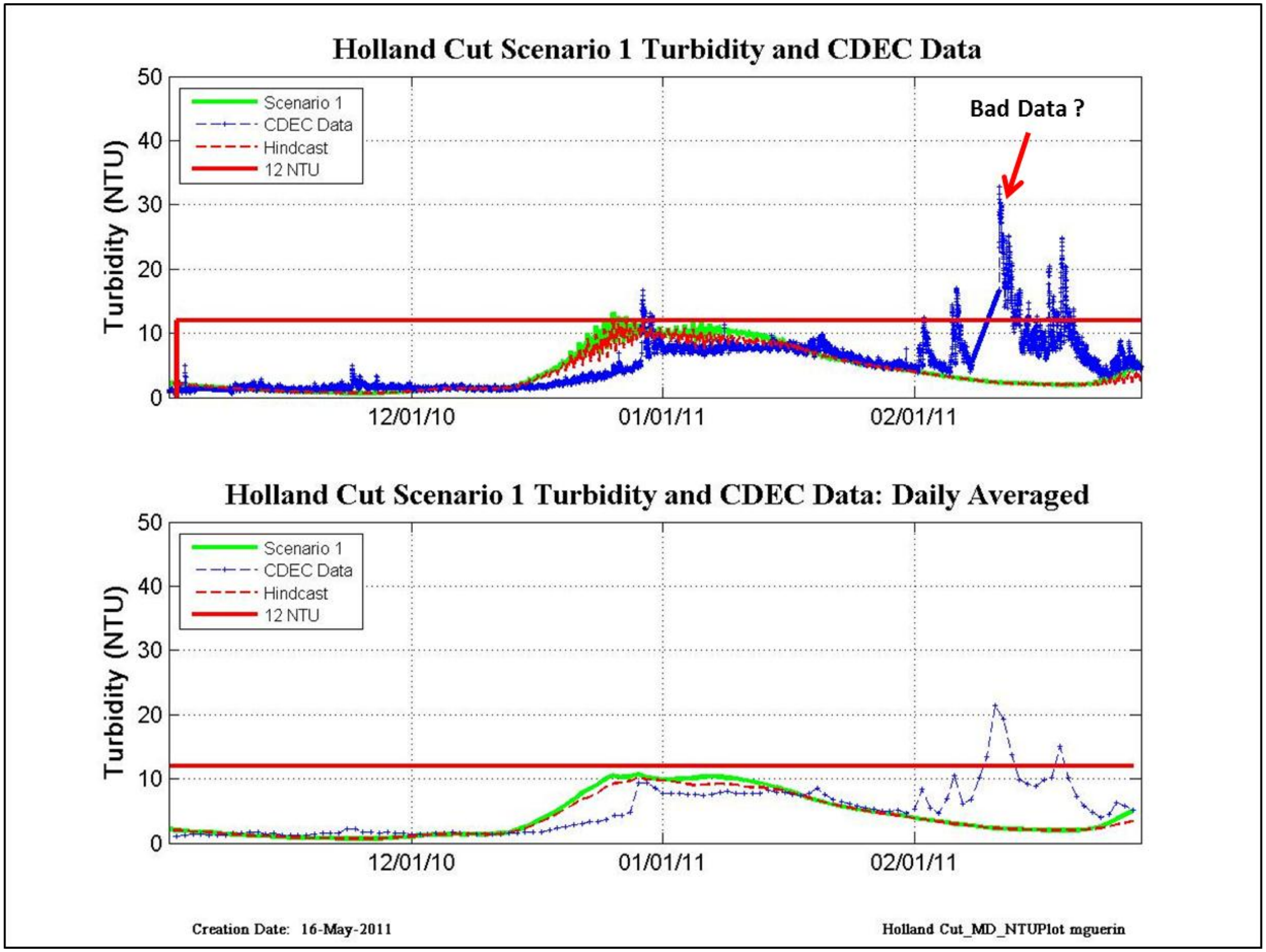


Figure 7-8 Comparison of Holland Cut turbidity and daily averaged turbidity (lower plot) using CDEC data (blue) the Hindcast model (red) and the Modified Deriso model (green, Scenario 1). The wind event in early February raised turbidity values seen in the data, although the magnitude of the increase may reflect problems with the sensor.

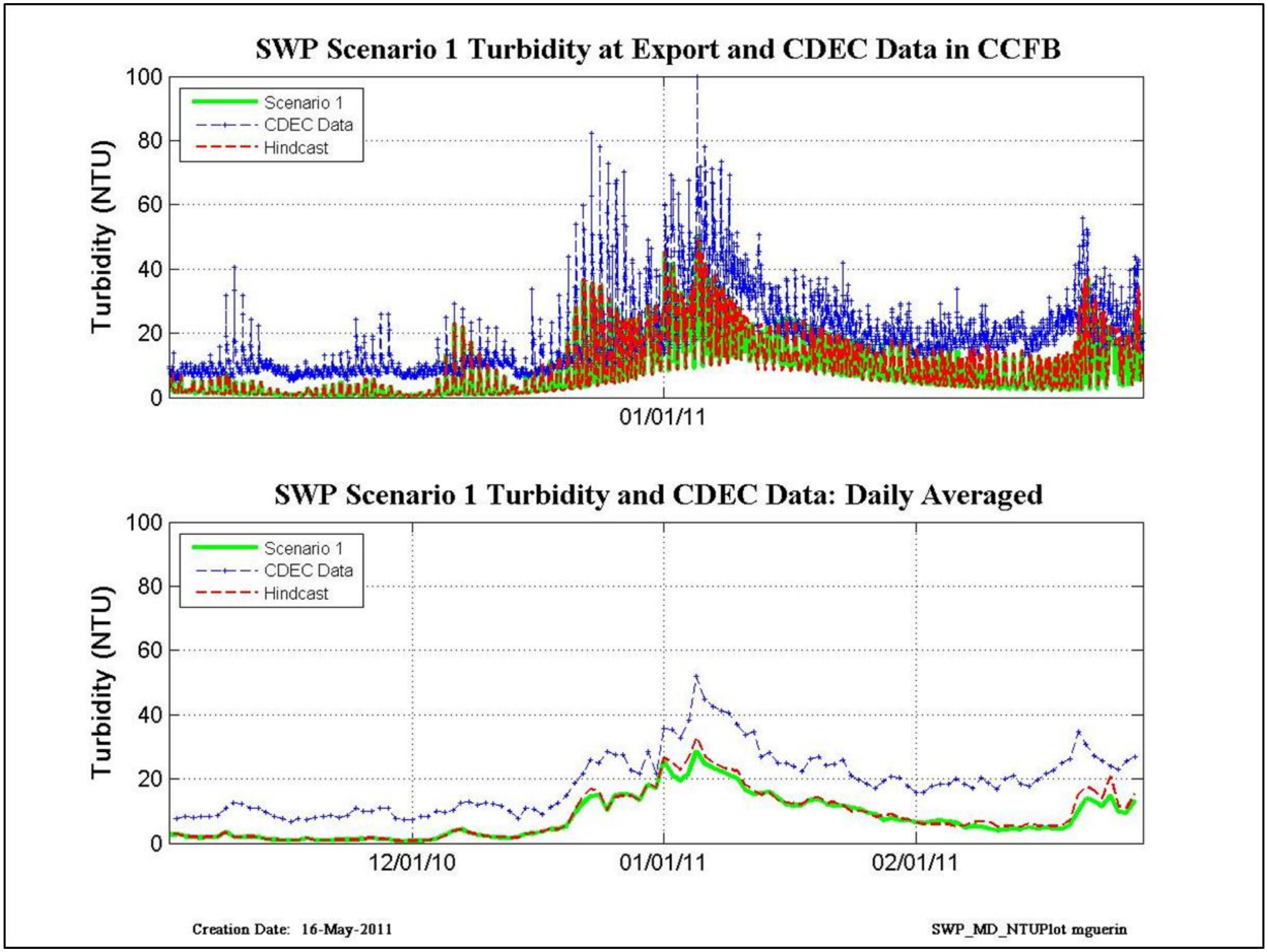


Figure 7-9 Comparison of turbidity at the SWP export location and data in CCFB, plus daily-averaged turbidity (lower plot), using CDEC data (blue) the Hindcast model (red) and the Modified Deriso model (green, Scenario 1).

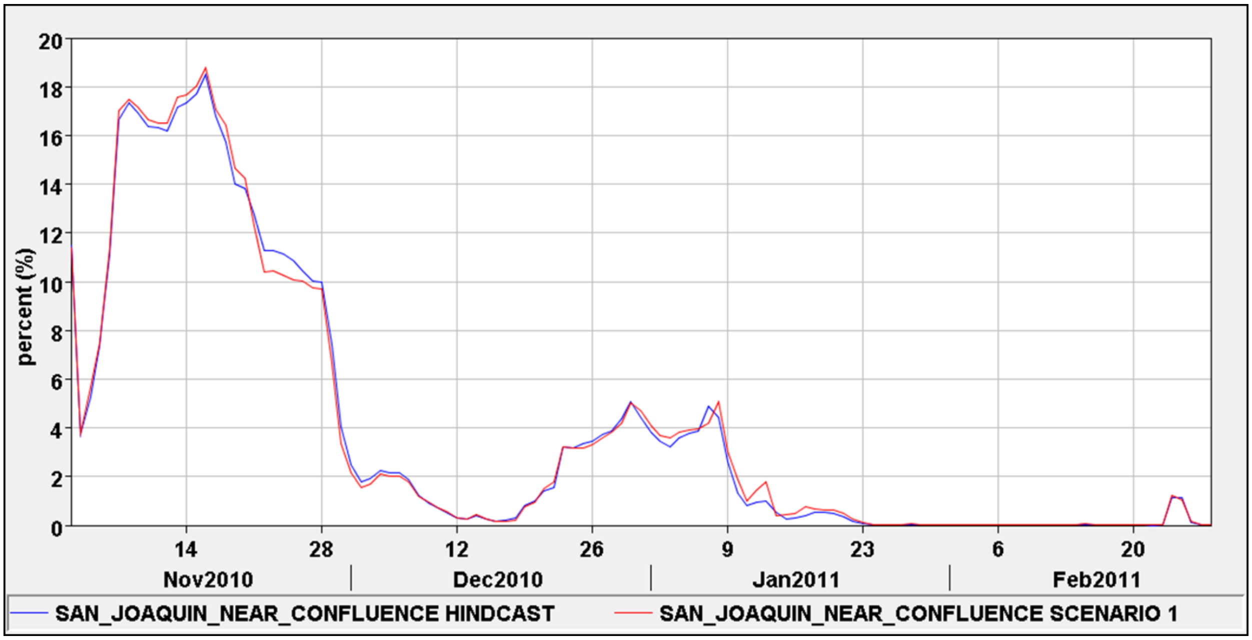


Figure 7-10 Comparison of adult delta smelt particle tacking model time series results for the San Joaquin Near Confluence Region for the Hindcast (blue) and the scenario (red).

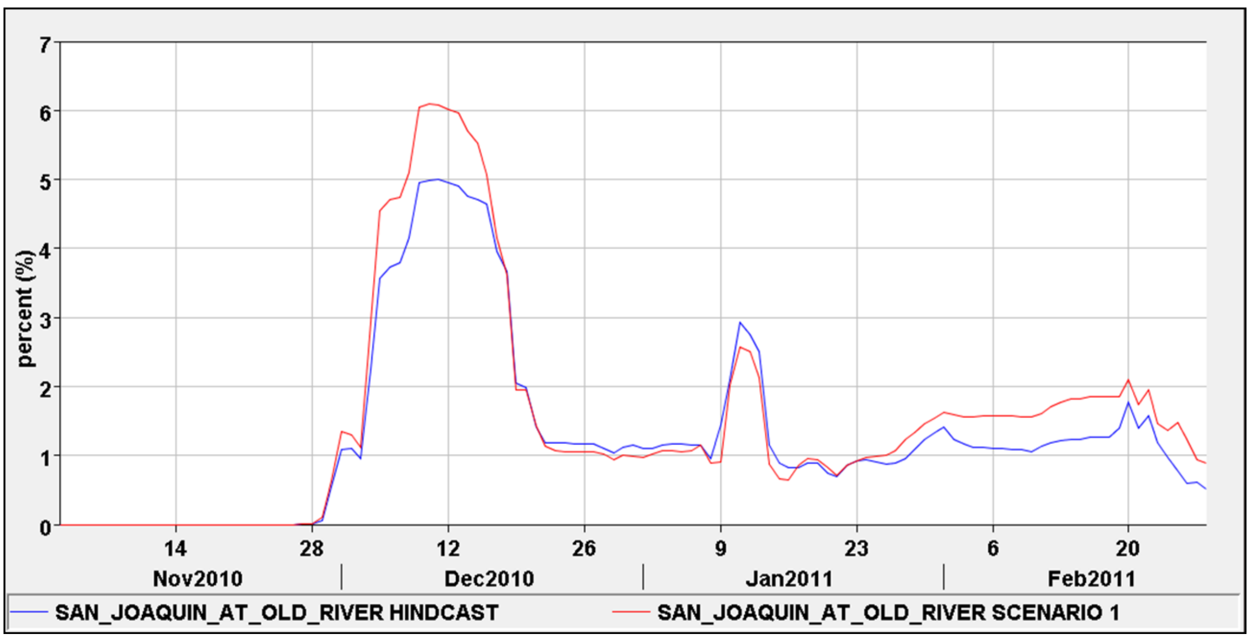


Figure 7-11 Comparison of adult delta smelt particle tacking model time series results for the San Joaquin At Old River Region for the Hindcast (blue) and the scenario (red).

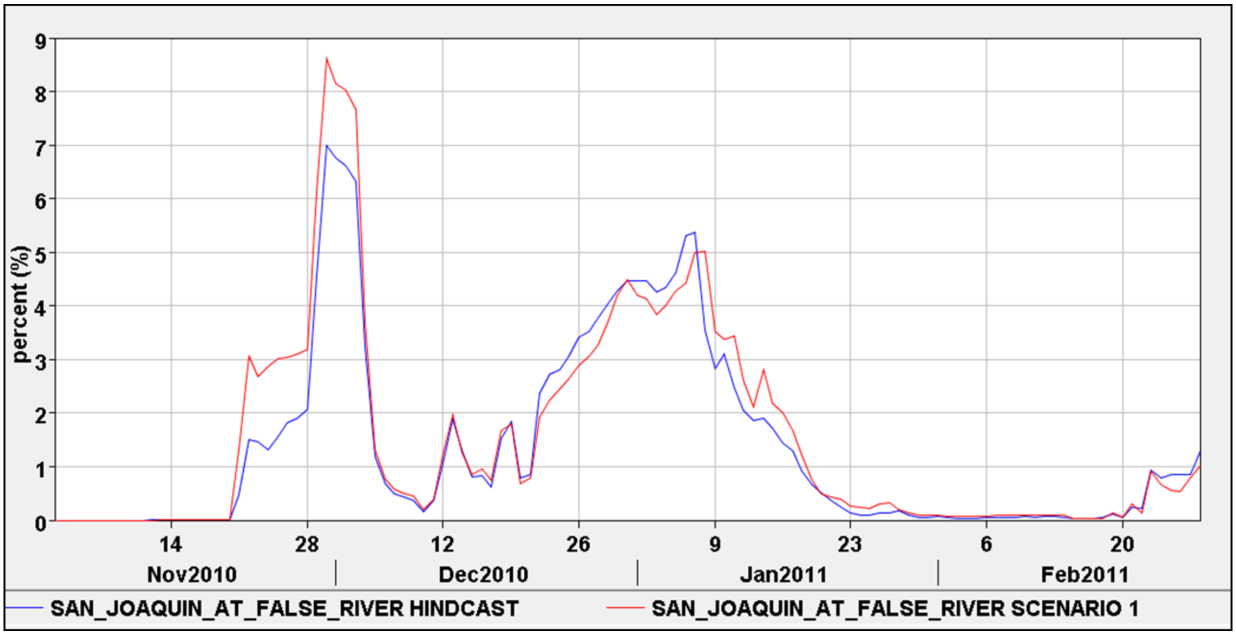


Figure 7-12 Comparison of adult delta smelt particle tacking model time series results for the San Joaquin At False river Region for the Hindcast (blue) and the scenario (red).

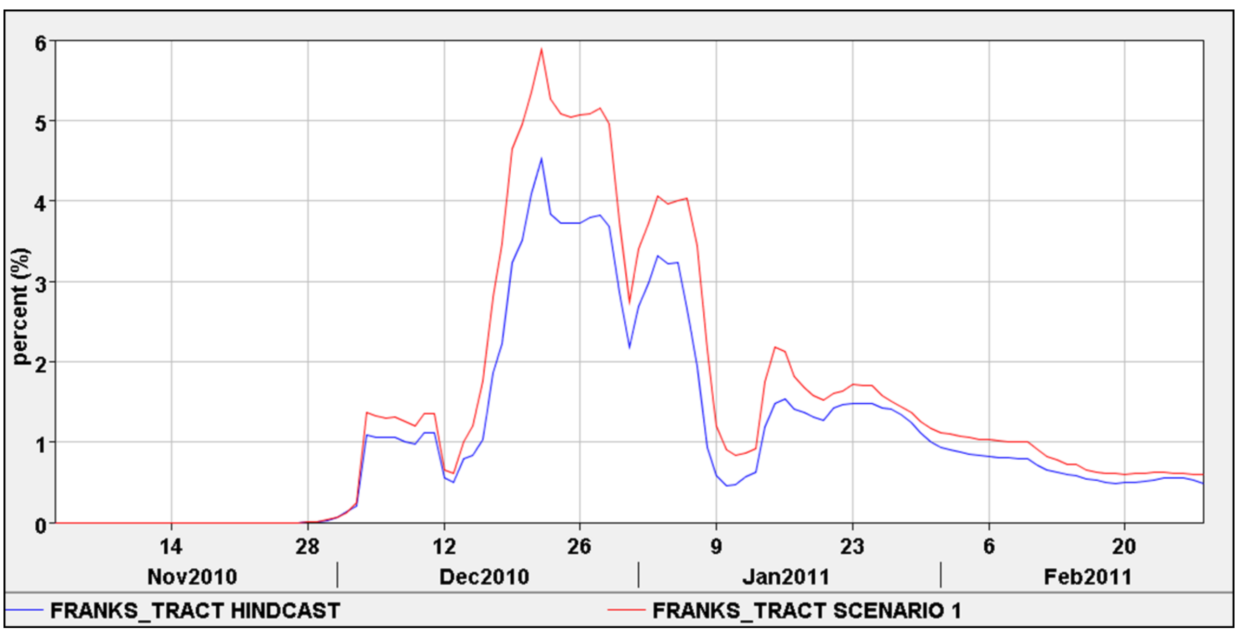


Figure 7-13 Comparison of adult delta smelt particle tacking model time series results for the Franks Tract Region for the Hindcast (blue) and the scenario (red).

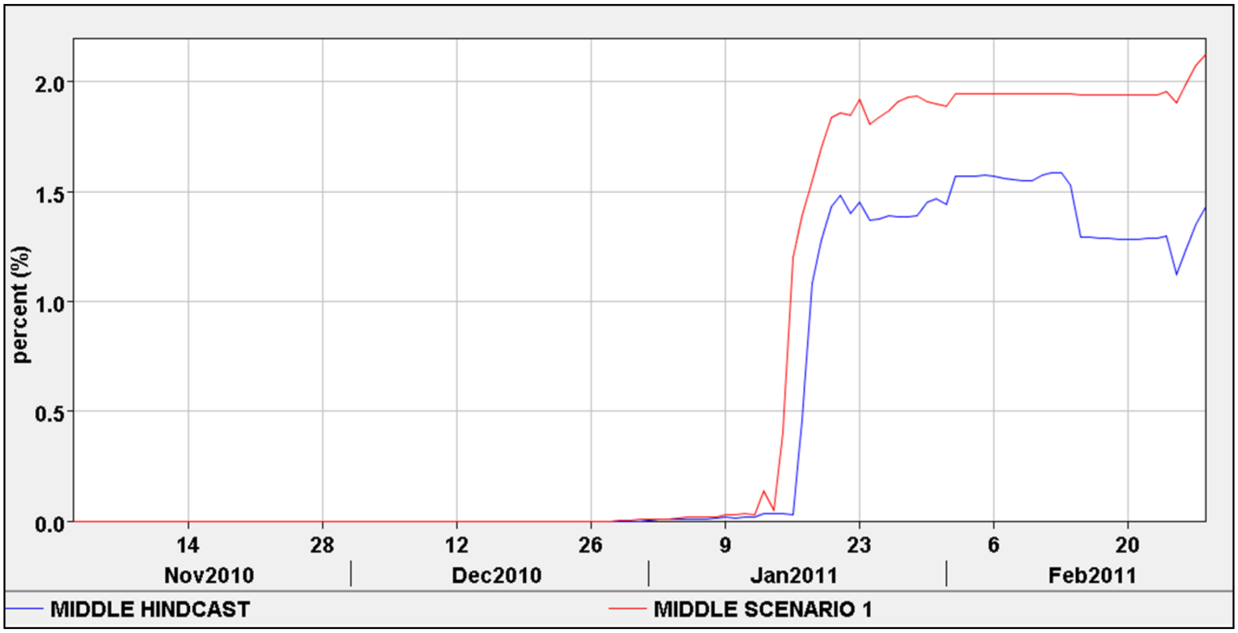


Figure 7-14 Comparison of adult delta smelt particle tacking model time series results for the Middle Region for the Hindcast (blue) and the scenario (red).

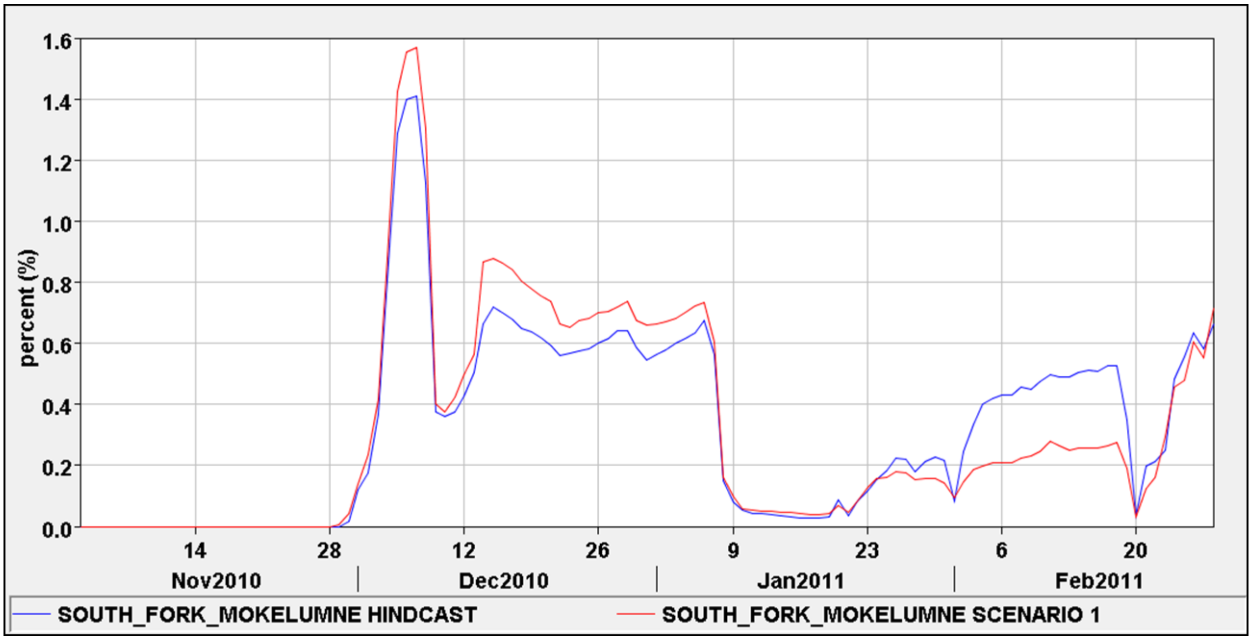


Figure 7-15 Comparison of adult delta smelt particle tacking model time series results for the South Fork Mokelumne Region for the Hindcast (blue) and the scenario (red).

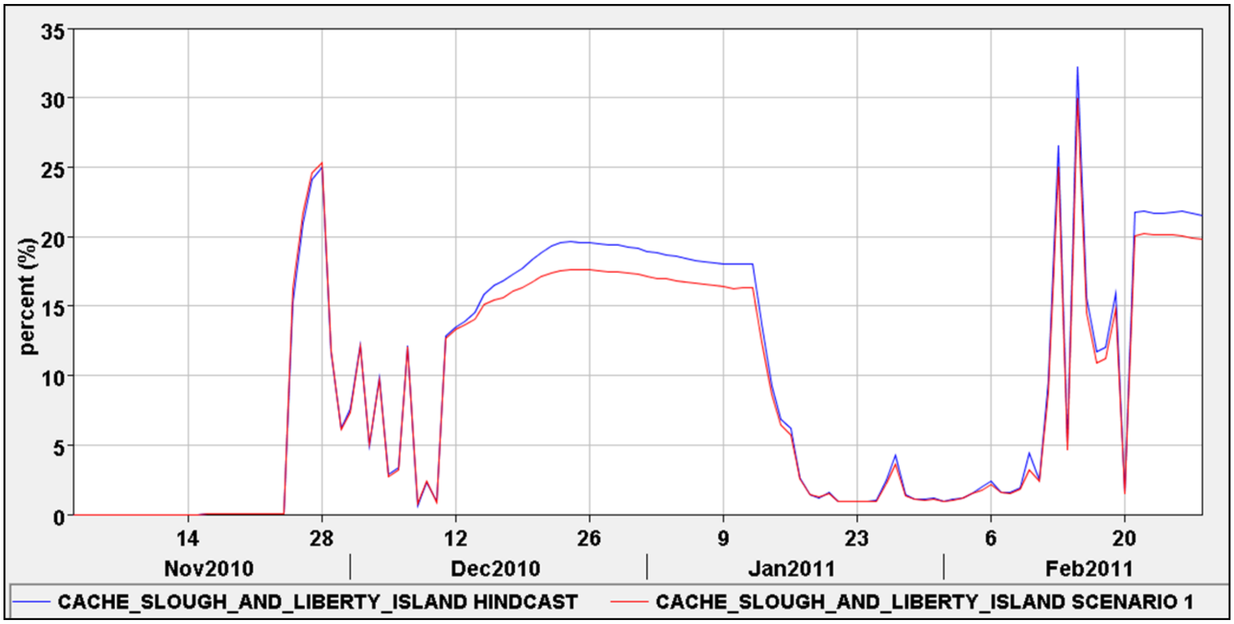


Figure 7-16 Comparison of adult delta smelt particle tacking model time series results for the Cache Slough And Liberty Island Region for the Hindcast (blue) and the scenario (red).

8. Discussion

8.1. *Weekly Forecast Results*

The WARMF model output supplied an additional source of boundary condition information for the development of weekly forecasts, including water quality time series at locations where data was not previously available. This addition, while potentially very useful in the long run, complicated the process for developing the forecast model for several reasons: WARMF model development was apparently occurring during the months forecasts were being run, as WARMF model results sometimes changed from week-to-week; mismatches between WARMF or DSM2 model output and data complicated the appending of new data and forecast data to time series being developed for new forecast runs; and, WARMF model results sometimes appeared to be quite inaccurate, producing boundary conditions that could strongly influence model results downstream.

The increased workload and the timing of information delivered from O&M and Systech (Thursday afternoon) made delivery of model results to 34North by Friday afternoon difficult. Work preparing the forecast began on Wednesday, 12 – 16 hours of work were needed on Thursday to prepare boundary conditions for the RMA models, and an early start was required on Friday to run water quality models, check model results and prepare documentation to accompany forecast results sent to 34North.

Documentation for the weekly forecasts, including particle tracking results from the adult delta smelt model, was prepared and sent to MWD staff by Tuesday the following week. In addition, model set-up, background data, boundary conditions and RMA model input and output files were assembled and made available to MWD staff for practice and review.

Comparison with data showed that turbidity model results followed the general shape and magnitude of the data time series over much of the Delta. During WY2011, a turbidity bridge did not form connecting north Delta and south Delta turbidity sources. Modeled EC results during lower flow periods show the effect of the non-standard Martinez boundary condition (i.e., top salinity instead of the average of top and bottom salinity). Adult delta smelt particle tracking results indicated that, under the model hypotheses, delta smelt were not attracted to the south Delta.

8.2. *Hindcast Results*

The turbidity model results for the WY2011 hindcast followed the magnitude and trend of turbidity measurements through most of the Delta, with better results than the WY2010 hindcast at some locations. The improvements are due to the expansion of the database of in-Delta turbidity measurements for this water year - four new stations were added. Several of these stations were found to be useful in developing turbidity (and to a lesser extent EC) boundary and time series for the Hindcast. The turbidity time series for the South Mokelumne R. station was used to supply turbidity boundary conditions for the Cosumnes and Mokelumne Rivers, with very good model results at downstream locations.

The turbidity measurement location in Cache Sl. at Ryer Island was used for the Yolo boundary – the additional station in Liberty Island for WY2011 had very similar turbidity. Using a scaled value for the WARMF Calaveras River turbidity boundary condition produced better timing for the turbidity field at downstream locations than the methodology used in WY2010.

WARMF time series for EC were used at the Eastside boundaries. EC Hindcast results are not entirely satisfactory for several reasons. First, the Martinez EC boundary condition was not developed according to standard RMA protocol, which uses the average of top and bottom salinity at Martinez for its boundary condition. Also, the EC in the Cache Sl./Liberty/Yolo area is not well-represented. Finally, EC downstream of the Mokelumne and Cosumnes Rivers indicates that these EC boundaries are not being set correctly and that flow through the Mokelumne branches may not be represented at some times.

The effects of wind events are seen in the turbidity data, but not in Hindcast results, at several Delta locations – in the Yolo-Cache Sl.-Liberty Island area, and at Dutch Slough, Prisoner's Point, Jersey Point and Antioch. The wind events raised turbidity by different magnitudes at the individual locations.

Time series results for the adult delta smelt model showed no particles reached the SWP or CVP export locations. This result is in general agreement with salvage data, as only twelve delta smelt were salvaged from November 2010 through February 2011. Particles moved into Liberty Island as higher flows and turbidity on the Sacramento River and through the Yolo Bypass attracted significant percentages of particles (at times over 20%). A small percentage of particles moved into the Middle region, but no particles moved into the Old or Victoria regions.

8.3. Export scenario results

Increases in export rates implemented in the Modified Deriso scenario resulted in only very small changes (on the order of a few NTU) in the turbidity field in the south Delta in comparison with the Hindcast. Although the changes in particle distribution were also small in comparison with the Hindcast model, at most a couple of percent, the changes extended into the north Delta. More particles were drawn into Franks Tract and down Middle River, but they did not reach the Old or Victoria regions or enter the export pumps. Exports volumes increased by 47 TAF in December, 2010, 159 TAF in January, 2011 and 108 TAF in February, 2011, for a 3-month total increase of 314 TAF.

9. Conclusion and Suggestions

With the introduction of new water quality measurement locations (see Figure 3-2), the Hindcast model development and results demonstrate that some of the new turbidity measurement locations can be used to create turbidity and EC boundary conditions at the Mokelumne and Cosumnes Rivers and also at the Yolo inflow location (Section 6.1.2). The Calaveras River water quality boundary conditions still remain somewhat problematic, as the magnitude of WARMF model turbidity output used as a boundary condition at that location was too high during the forecast period. Measurements at locations downstream of the Calaveras are subject to many influences (*e.g.*, tidal mixing and mixing of waters from different sources), so the best choice for boundary condition values is not obvious from examining data-model comparisons.

The RMA11 EC forecast methodology need to be improved by refining the development of the Martinez boundary condition, to make it commensurate with standard RMA methodology. This will require the development of forecast methodology for the bottom salinity at Martinez. The Eastside boundaries for EC also remain somewhat problematic, and additional data would be welcome to help determine the best method for setting these EC boundary conditions.

The following list summarizes suggestions on ways to improve and/or simplify the forecast methodology, and to make WARMF model output a more useful supplement to currently available data:

- Develop a better relationship between WARMF-simulated sediment load and the turbidity boundary condition supplied to RMA.
    - If the current WARMF calibration is used, this could be done by using RMA turbidity model results to develop better relationships with downstream data.
    - If WARMF model calibration is improved, running the RMA hindcast with the improved model can demonstrate the level of improvement with downstream results.
- Develop a methodology for forecasting bottom salinity for the RMA11 EC simulations, and implement the ‘standard’ RMA11 Martinez salinity boundary time series as an average of top and bottom EC at Martinez.
    - The reason for this suggestion is that there is error in modeled salinity during lower outflow periods because the Martinez boundary condition is not being developed in accordance with standard RMA protocol.
- Develop tools to automate or partially automate development of forecast model boundary conditions (*i.e.*, to merge time series) to ease work load and decrease forecast preparation time.

- Develop protocol and a tool to automate an initial survey of turbidity data and to eliminate clearly spurious measurements.

- Acquire additional data if possible in the Yolo/Cache Sl./Liberty Island area and for the Eastside inflow locations to improve the development of EC and turbidity boundary conditions at these boundaries.

10. Acknowledgements

Assistance from staff at CDEC, CNRFC, and DWR is gratefully acknowledged.

11. References

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12. Appendix I

12.1. Setting flow boundaries

12.1.1. CNFRC Parameters

Although not all of them were used as boundary conditions, all of the parameters downloaded from the CNRFC website listed in Table 12-1 were used in the process of data evaluation.

Table 12-1 Parameters downloaded from the CNRFC website.

Location	Parameters
AMERICAN - SACRAMENTO AT H STREET	Stage
CACHE CREEK - YOLO	Stage, Flow
COSUMNES RIVER - MCCONNELL	Stage, Flow
MOKELUMNE RIVER - BENSON FERRY	Stage
SACRAMENTO RIVER - SACRAMENTO AT I STREET	Stage
SACRAMENTO RIVER - VERONA	Stage, Flow
SAN JOAQUIN RIVER - MOSSDALE	Stage, Flow
SAN JOAQUIN RIVER - VERNALIS	Stage, Flow
YOLO BYPASS - LISBON	Stage, Flow

12.1.2. Sacramento River at I Street – CNRFC stage to flow conversion

According to NOAA/CNRFC staff[4], the I-Street rating is difficult since I-Street is "in tides" for most of the year. When the stage is below 7-10 feet, the flows at these levels are not officially

[4] Pete Fickenscher, Senior Hydrologist, NOAA/NWS/CNRFC

rated. The rating available on the CDEC website (http://cdec.water.ca.gov/rtables/IST.html) (DWR rating curve) only goes from 10 to 31 feet, as shown in Table 12-2. NOAA/CNRFC staff have extended the DWR I-Street rating below 10 feet to allow modeling of the river flows throughout the year, and also made some adjustments to the DWR rating at higher flows (above 22 feet) based on their calibration efforts. The higher flow values in the NOAA/CNRFC synthetic rating have a better correlation to the flows that the USGS measured at Freeport; for stages above 22 feet, although there are two different ratings, the variation between them is minor.

The rating table available on the CDEC website is reproduced in the following Table:

Table 12-2 Conversion from stage (ft.) to flow (cfs) for the Sacramento R. at I street for stages from 10 – 32 feet.

From (Ft.)	To(Ft.)	Add (cfs) for each 0.01 Ft	Add (cfs) For Each 0.1 Ft	Add (cfs) For Each 1.0 Ft	To (cfs)
10	12.99	34	340	3400	31800
13	16.99	35	350	3500	42000
17	18.99	36	360	3600	56000
19	20.99	37	370	3700	63200
21	22.99	38	380	3800	70600
23	24.99	39	390	3900	78200
25	31	40	400	4000	86000

NOAA/CNRFC staff recommended that for a proof-of-concept model, such as the current turbidity model, for stages 10-22 feet the rating curves work sufficiently well. For stages below 10 feet, tides have an influence and the CNRFC synthetic rating does not really model true flow in the tidal range (e.g., a high tide would actually have a lower flow as the tide impedes flow downstream). The rating table is shown in Table 12-3. Since in this project we are generally interested in events occurring at peak flows, this should not present any difficulty.

Table 12-3 Rating table to covert from stage (ft.) to flow (cfs) for the Sacramento R. at I street for stages from 1 – 31 feet.

Stage	Flow (cfs)	Stage	Flow (cfs)	Stage	Flow (cfs)
1	4100	11	35200	21	70600
2	6600	12	38600	22	74400
3	9300	13	42000	23	78500
4	12200	14	45500	24	83000
5	15300	15	49000	25	87800
6	18500	16	52500	26	92700
7	21700	17	56000	27	97700
8	25000	18	59600	28	102800
9	28400	19	63200	29	108000
10	31800	20	66900	30	113200
				31	118400

12.1.3. Cosumnes River at McConnell - CNRFC stage to flow conversion

Table 12-4 Rating table to covert from stage (ft.) to flow (cfs) for the Cosumnes River at McConnell for stages from 26 – 50 feet.

Stage	Flow (cfs)	Stage	Flow (cfs)	Stage	Flow (cfs)
26.0	0	36.0	3600	46.0	27000
27.0	20	37.0	4200	47.0	36000
28.0	100	38.0	4800	48.0	48000
29.0	300	39.0	5500	49.0	63000
30.0	700	40.0	6400	50.0	81000
31.0	1150	41.0	7600		
32.0	1600	42.0	9400		
33.0	2050	43.0	12000		
34.0	2500	44.0	15500		
35.0	3050	45.0	20000		

12.1.4. Yolo Bypass at Lisbon – CDEC stage to flow conversion

Table 12-5 Rating table to covert from stage (ft.) to flow (cfs) for the Yolo Bypass at Lisbon for stages from 0 – 27 feet.

Stage	Flow (cfs)	Stage	Flow (cfs)	Stage	Flow (cfs)
0.0	50	11.0	5500	21.0	167000
2.0	150	12.0	8500	22.0	205000
3.0	200	13.0	13500	23.0	250000
4.0	250	14.0	19000	24.0	302000
5.0	320	15.0	32000	25.0	370000
6.0	420	16.0	48000	26.0	445000
7.0	600	17.0	67000	27.0	525000
8.0	900	18.0	88000		
9.0	2000	19.0	111000		
10.0	3500	20.0	137000		

12.2. CIMIS wind and precipitation data

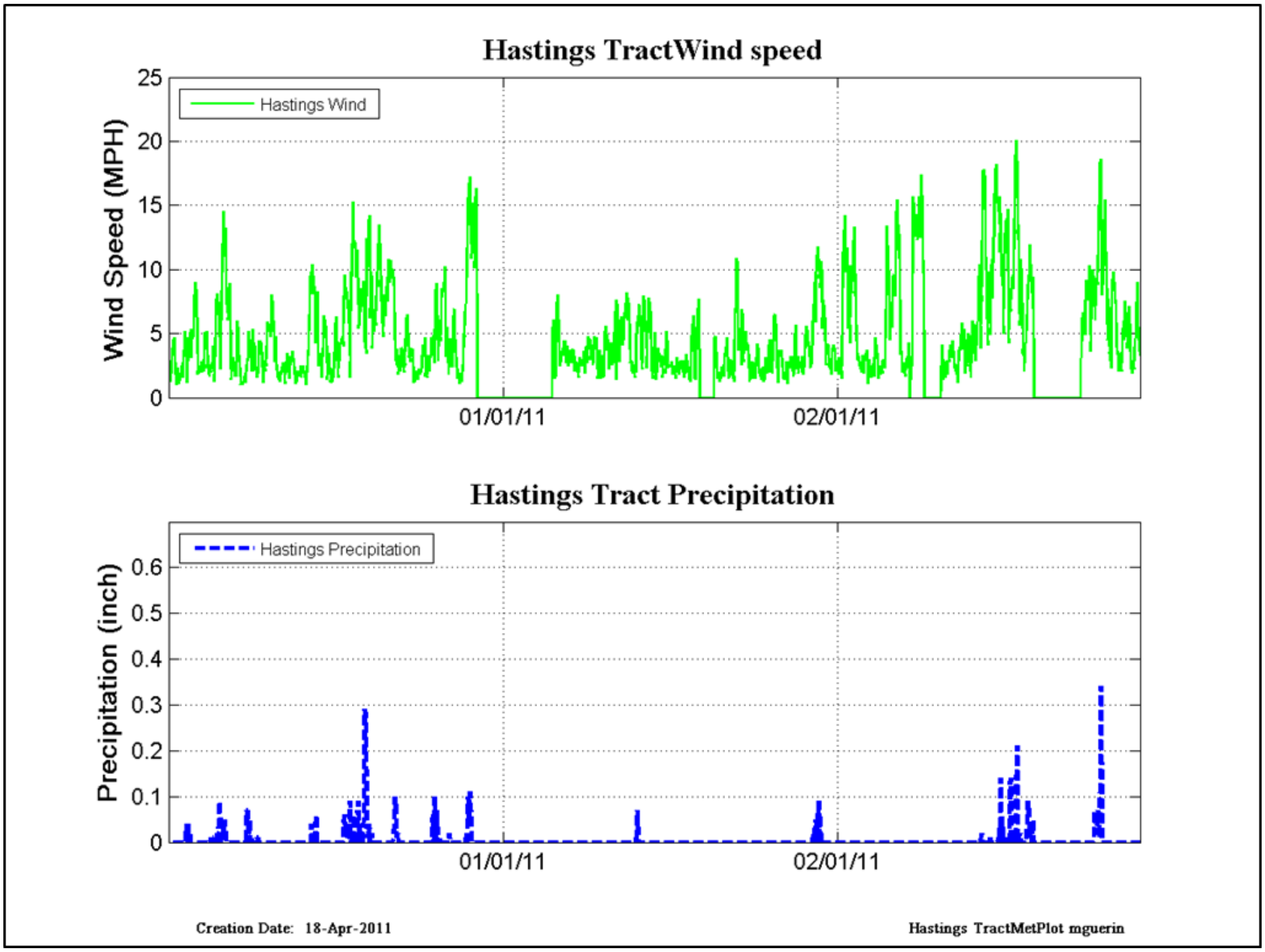


Figure 12-1 CIMIS wind and precipitation data at Hastings Tract December 2010 – February 2011.

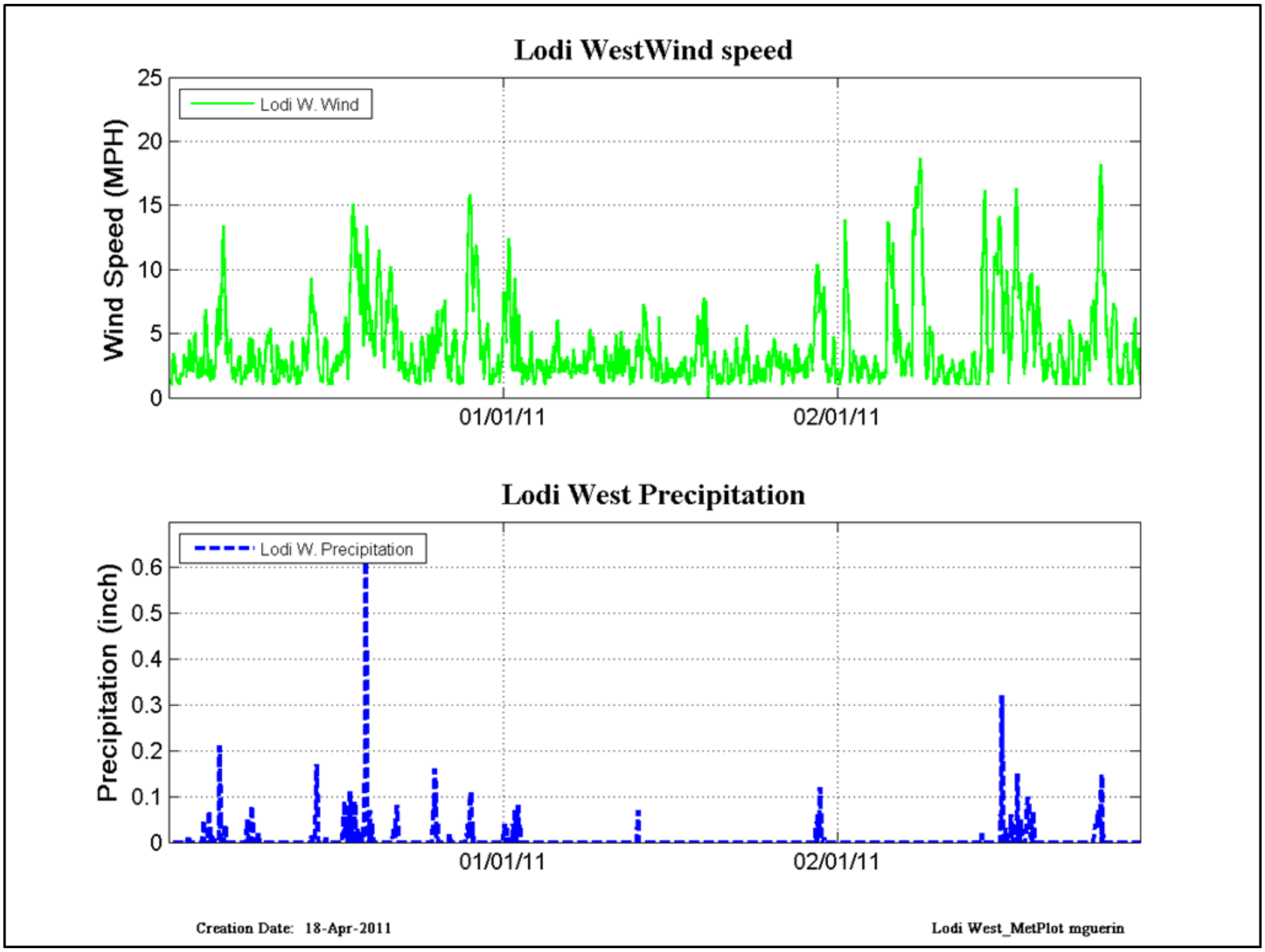


Figure 12-2 CIMIS wind and precipitation data at Lodi West December 2010 – February 2011.

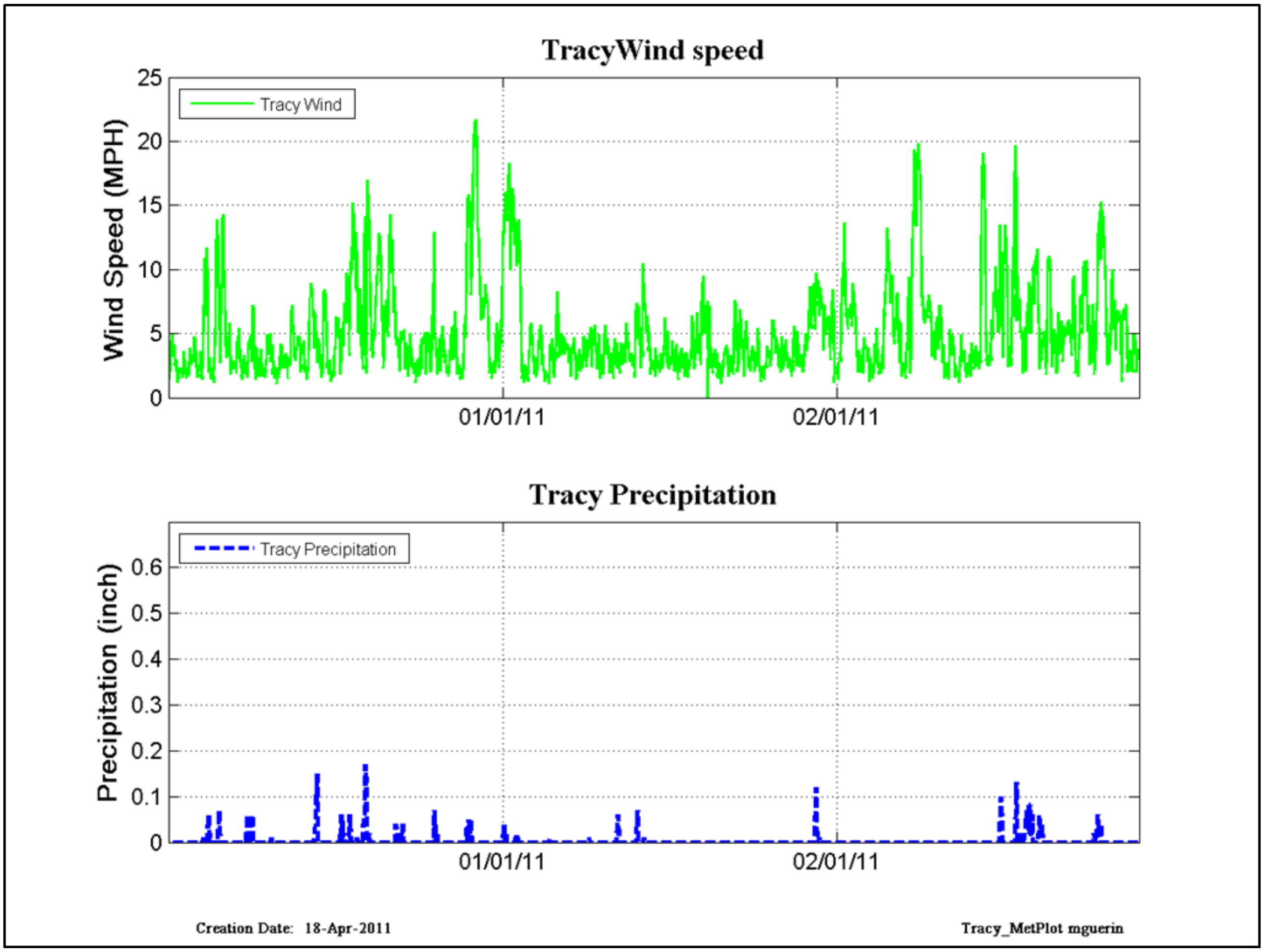


Figure 12-3 CIMIS wind and precipitation data at Tracy December 2010 – February 2011.

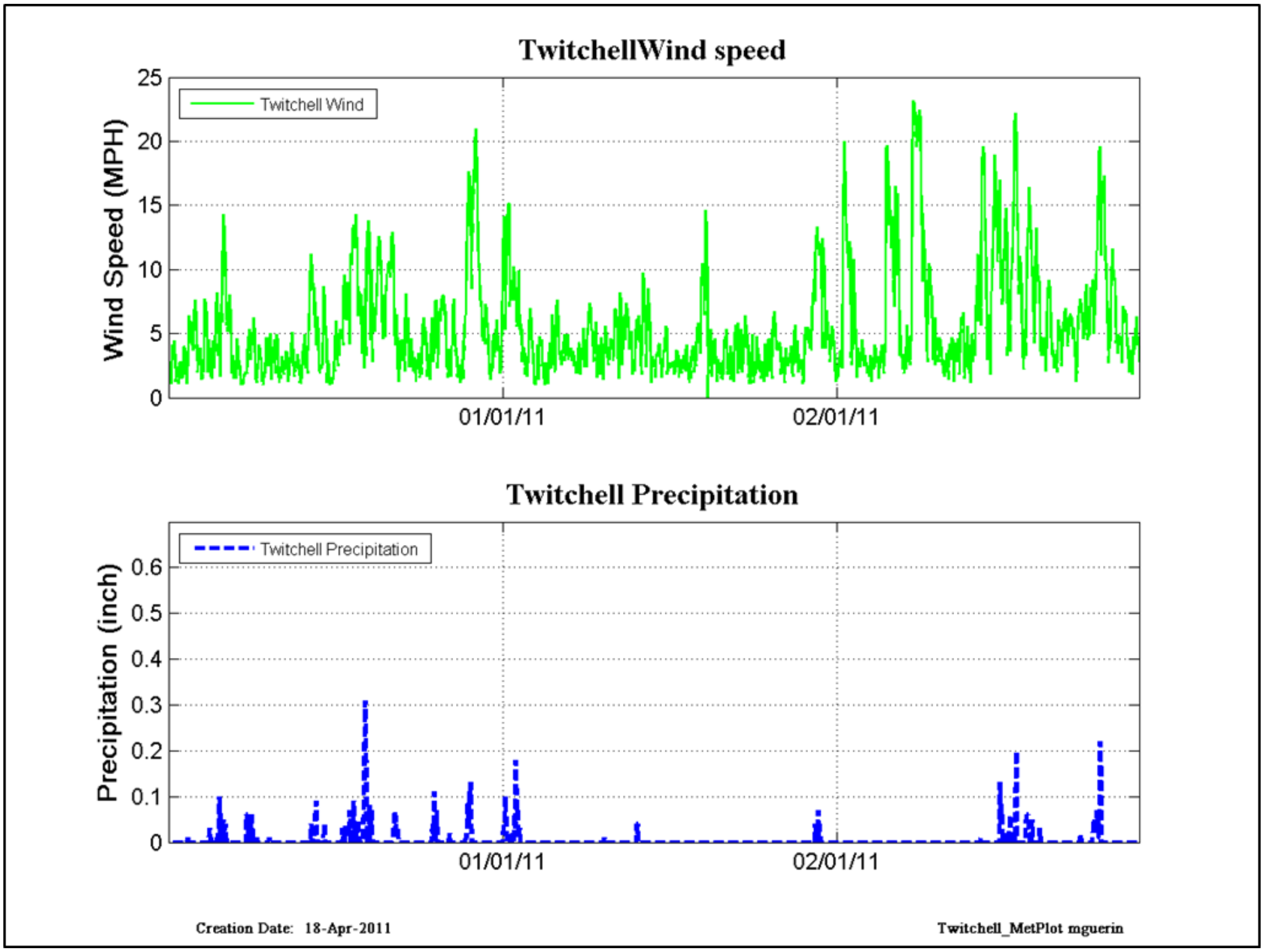


Figure 12-4 CIMIS wind and precipitation data at Twitchell December 2010 – February 2011.

12.3. Forecast Documentation

12.3.1. Forecast for Dec. 09, 2010

This document provides a quick summary of the most recent forecast prepared using the RMA hydrodynamic, salinity, turbidity and Adult Delta Smelt Behavioral models. Graphical results are provided to document the results of the modeling, with a focus on turbidity and the Adult Delta Smelt Behavioral Model (Delta Smelt PTM Model). Forecast results were prepared using DWR-supplied forecast conditions, CNRFC flow predictions, and previously-derived turbidity forecasts developed for the Dec 2009 – April 2010 wet season. WARMF model results were not used as RMA modeling staff members were inadvertently missing from the WARMF model results email distribution list.

The modeled period is November 01, 2010 to December 26, 2010. DWR Operations and Maintenance (O&M) provided RMA with boundary conditions used in the DSM2 HYDRO and QUAL/salinity models for a forecast period Dec. 06, 2010 through Dec. 26/7, 2010. Additional flow and EC data was downloaded for the period Dec. 07 – 08, 2010 from the CDEC, CNRFC and USGS websites. Salinity and turbidity boundary conditions were developed and synthesized for model boundaries as discussed in the DRAFT report for real-time Turbidity modeling. Following this procedure, a significant turbidity event was not forecast.

The Delta Smelt behavioral model was run from Nov. 01, 2010 through Dec 26, 2010. No delta smelt were salvaged at the SWP or CVP locations during the pre-forecast period[5]. No particles reached the SWP or CVP export locations during the modeled period (*i.e.*, historical plus forecast).

Several plots are included below as a pictorial summary of the model results. Model input files and results were provided to Churching Wang for remote access on the RMA intranet.

[5] http://www.usbr.gov/mp/cvo/fishrpt.html

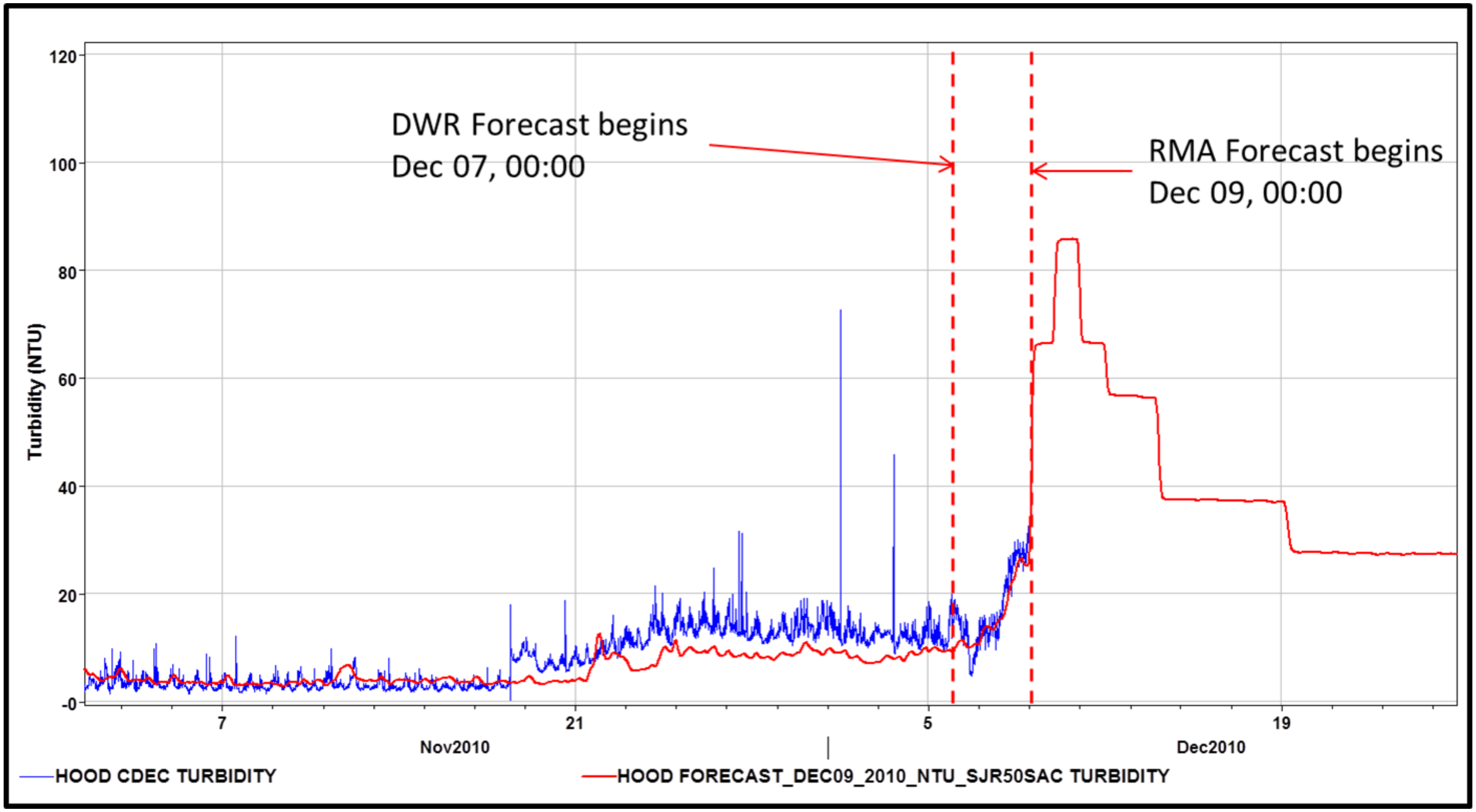
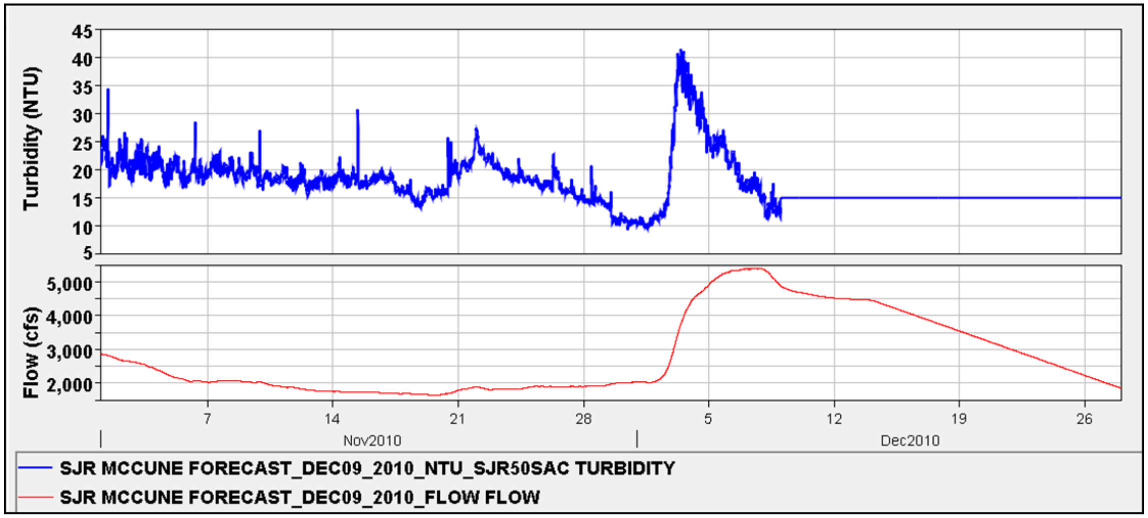


Figure 12-5 Freeport boundary condition illustrating the timing of the forecast periods.



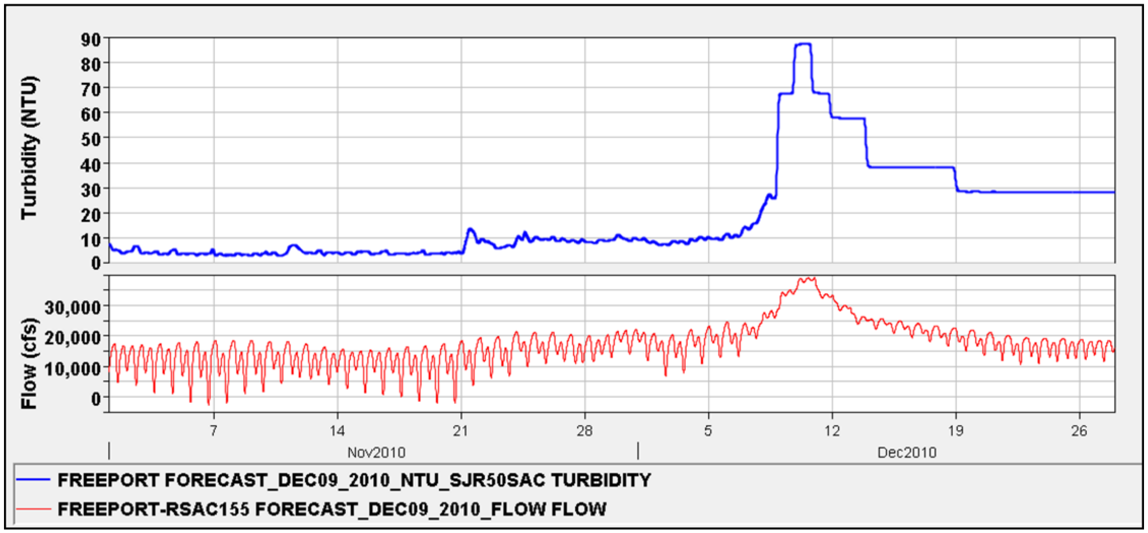


Figure 12-6 Vernalis (upper plots) and Freeport (lower plots) modeled turbidity and flow for the entire modeled period.

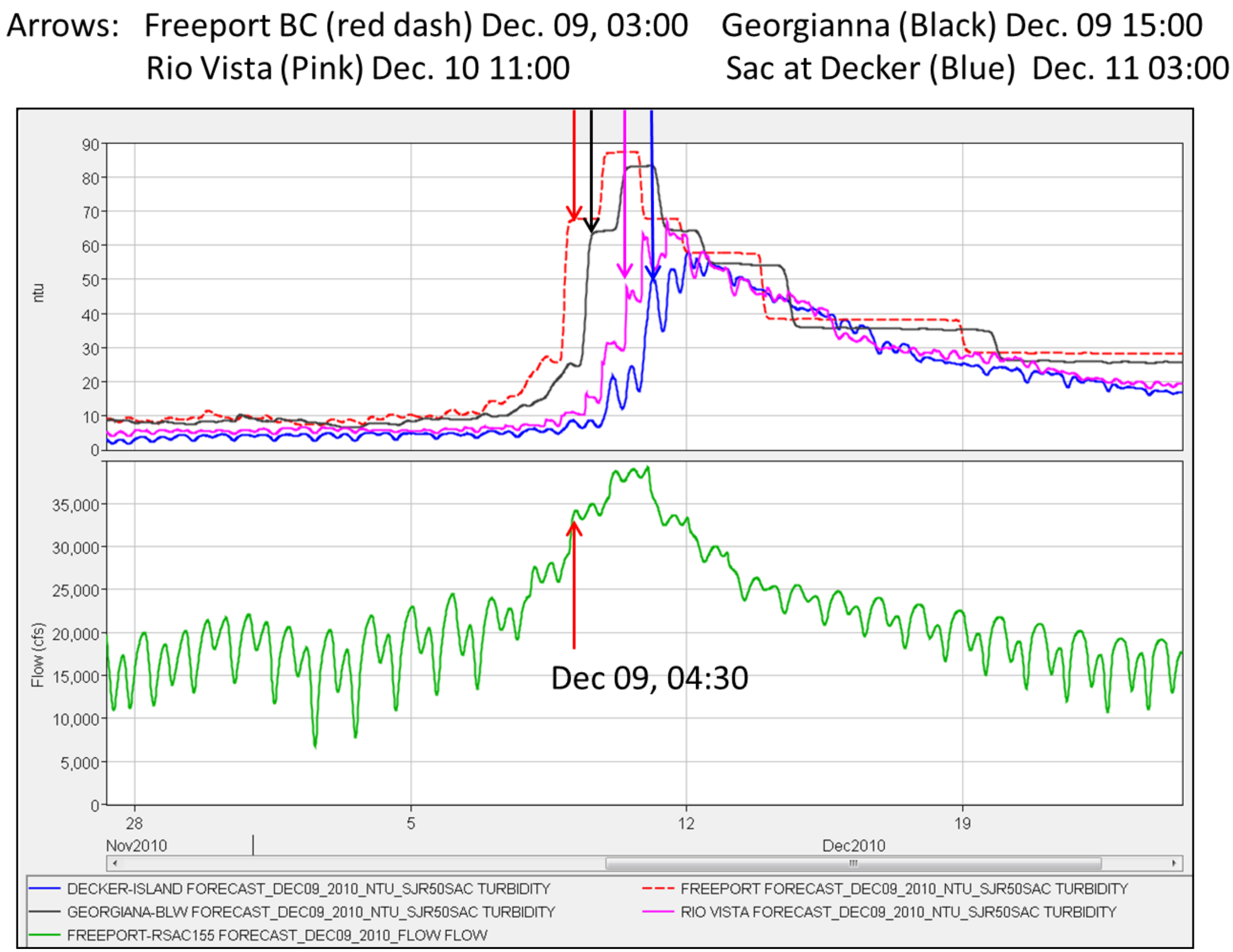


Figure 12-7 Progression of the turbidity boundary condition from Freeport to Decker Island.

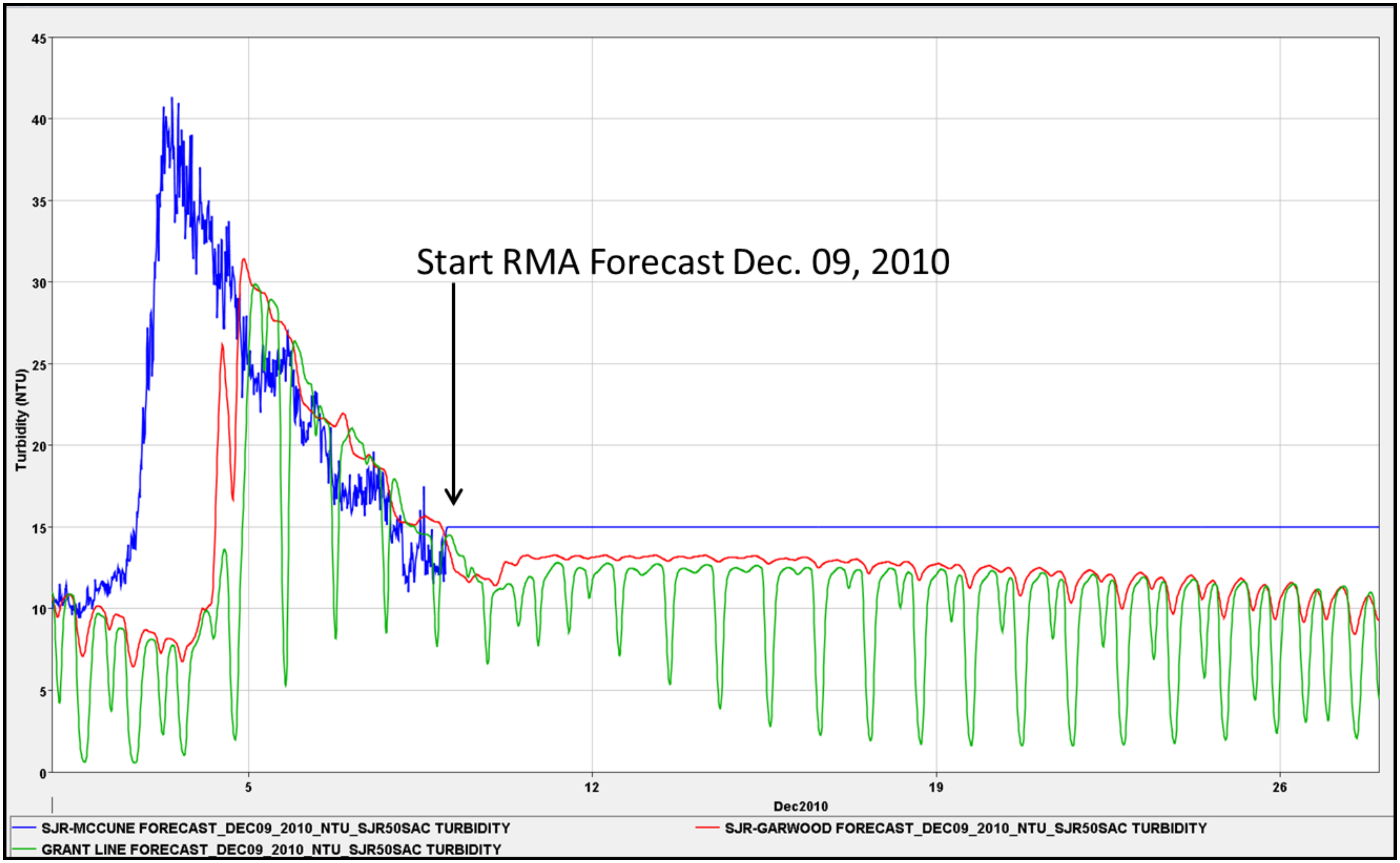


Figure 12-8 Progression of the Vernalis turbidity boundary condition down the San Joaquin River to Garwood and down Old River to Grant Line canal.

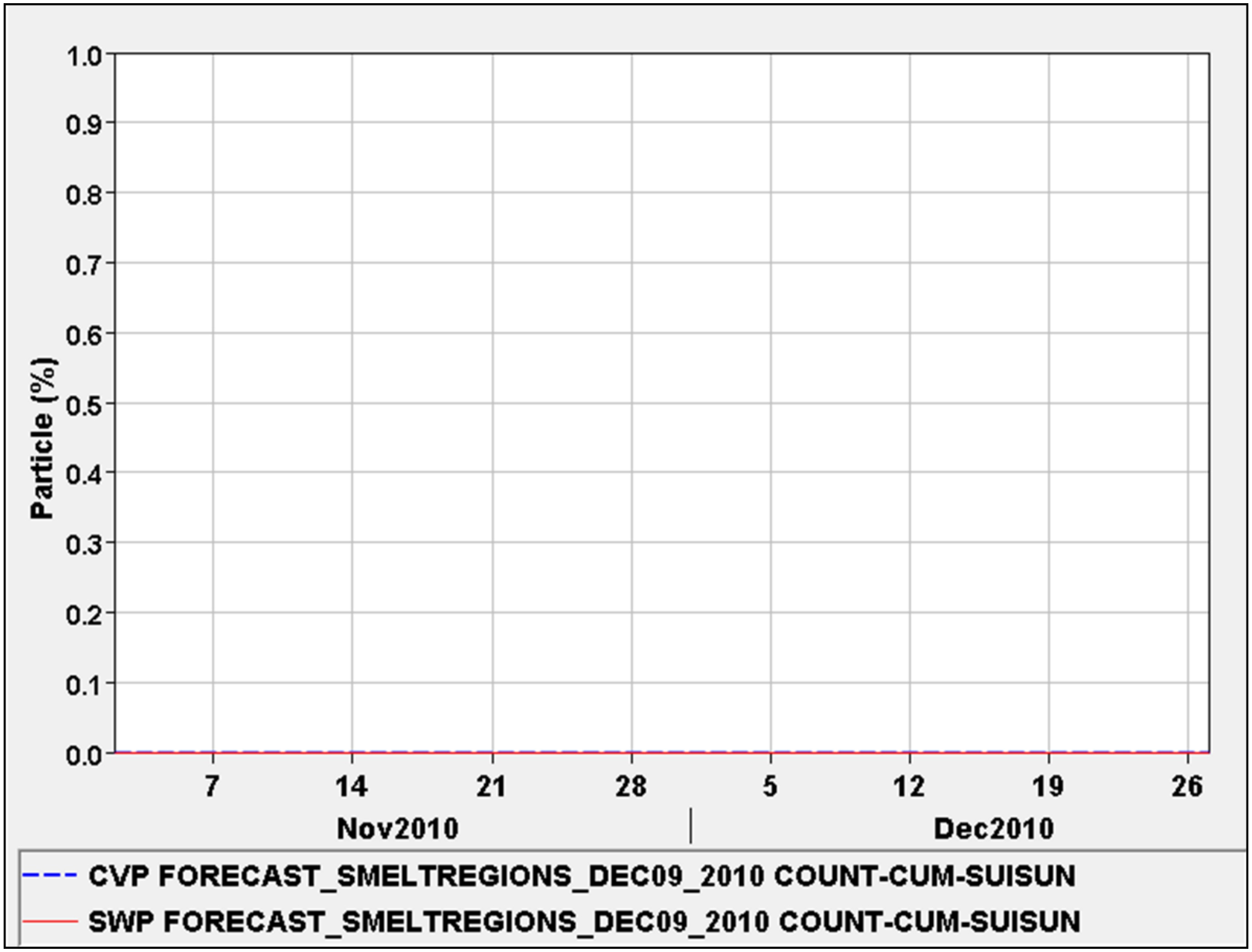


Figure 12-9 No particles reached the SWP of CVP export locations during the simulation.

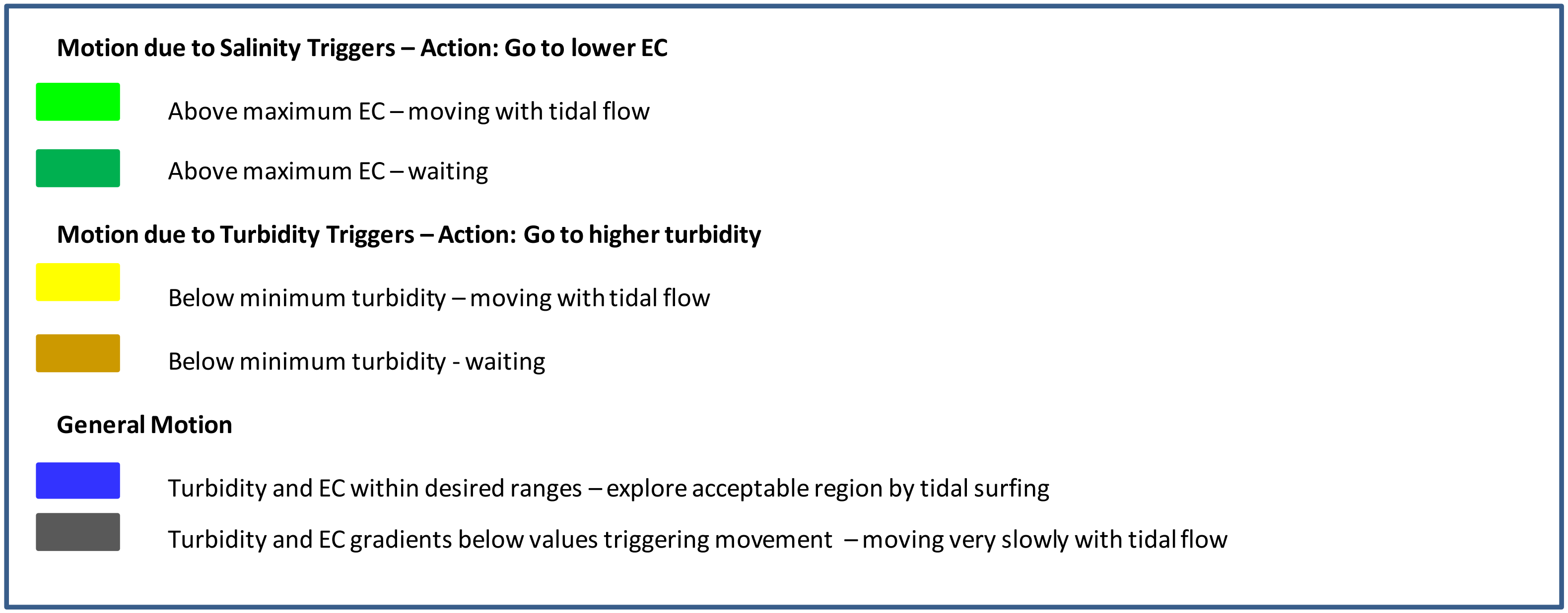


Figure 12-10 Particles in the Adult Delta Smelt particle tracking model are color-coded by the triggers influencing their behavior during the simulation. Use this figure to interpret the simplified color scale in the next three figures.

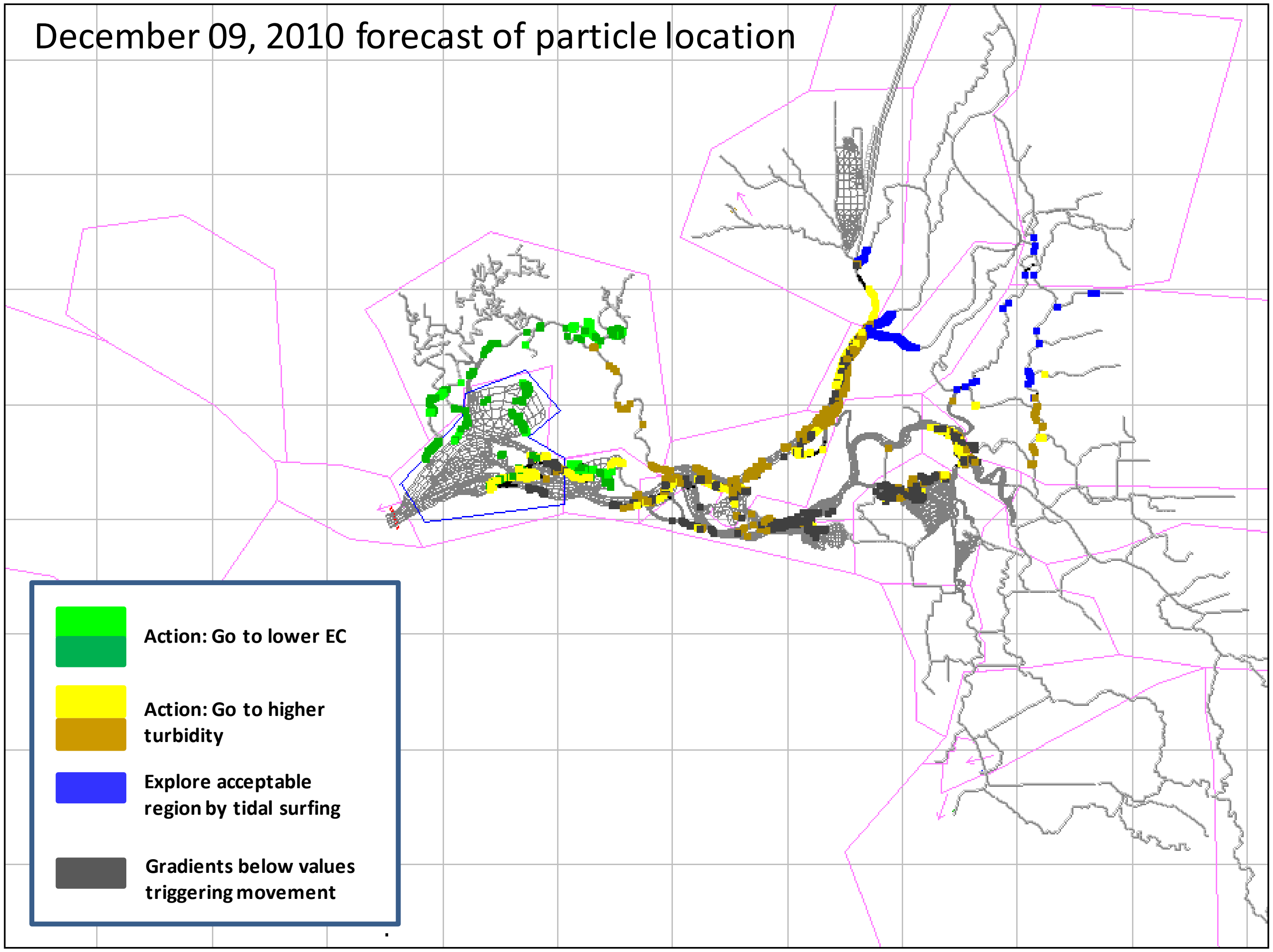


Figure 12-11 Particle location in the RMA model grid at the beginning of the forecast period, on Dec. 09, 2010.

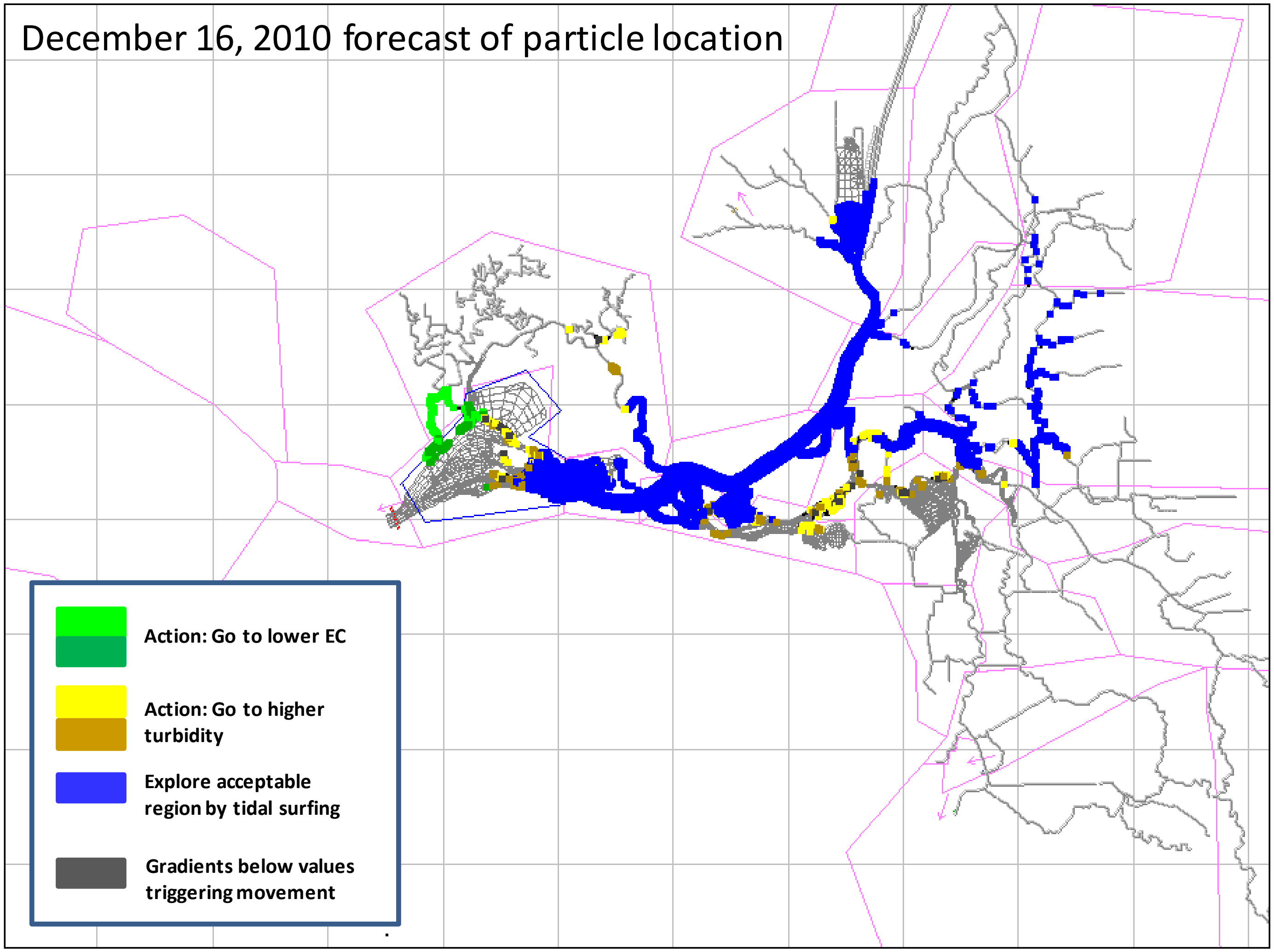


Figure 12-12 Particle location in the RMA model grid one week into the forecast period, on Dec. 16, 2010.

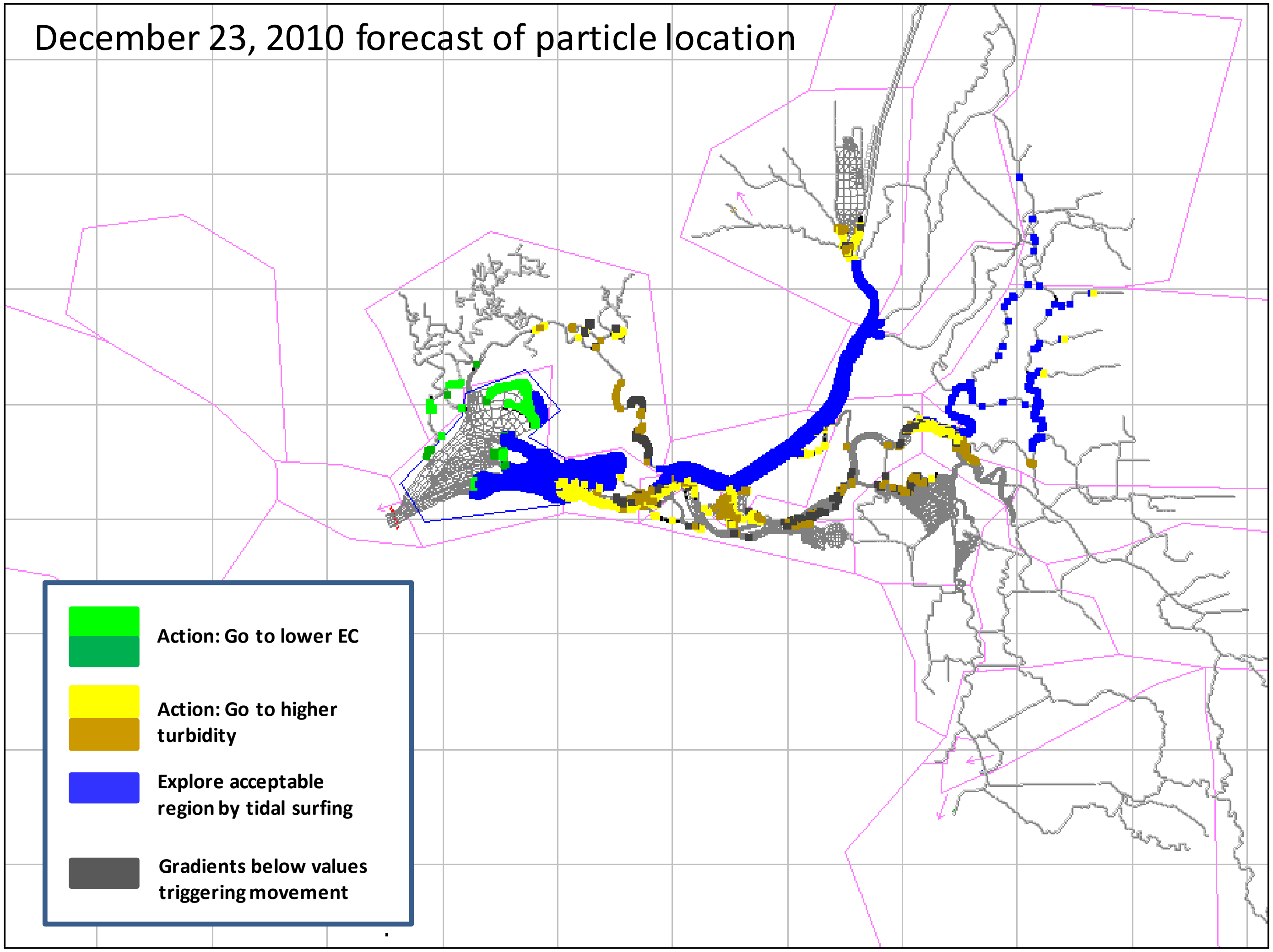


Figure 12-13 Particle location in the RMA model grid two weeks into the forecast period, on Dec. 23, 2010.

12.3.2. Forecast Dec. 16, 2010

This document provides a quick summary of the Dec. 16, 2010 forecast prepared using the RMA hydrodynamic, salinity, turbidity and Adult Delta Smelt Behavioral models. Graphical results are provided to document the results of the modeling, with a focus on turbidity. Forecast results were prepared using WARMF-supplied forecast conditions, CNRFC flow predictions, and DWR-supplied model inputs and results for their flow and salinity forecasts. WARMF model results were used as indicated in Table 12-6. This simulation is called the “ALL WARMF” simulation in plots.

Due to the special modeling exercise requested by Paul Hutton, only a limited set of model output are supplied in this document. Figures were created by Marianne Guerin for general distribution on Friday Dec. 17, 2010, and by Richard Rachiele for the special exercise on Dec. 20, 2010. For the special exercise, model boundary conditions prepared using a mixed set of WARMF and RMA-prepared flow boundary conditions were used as indicated in Table 12-7- the simulation is called “RMA BCs” in plots.

The modeled period is December 01, 2010 to January 04, 2010 for flow, and December 01, 2010 to December 31, 2010 for salinity and turbidity[6]. DWR Operations and Maintenance (O&M) provided RMA with boundary conditions used in the DSM2 HYDRO and QUAL/salinity models for a forecast period Dec. 13, 2010 through January 04, 2011. Additional low, turbidity and EC data was downloaded for the period Dec. 07 – 15/16, 2010 from the CDEC, CNRFC and USGS websites.

The Delta Smelt behavioral model was run from Nov. 01, 2010 through Dec 31, 2010 – for the “ALL WARMF” model only - 50,000 particles were inserted to improve statistics. No delta smelt were salvaged at the SWP or CVP locations during the pre-forecast period[7], Nov. 01 – Dec. 15, 2010. No particles reached the SWP or CVP export locations during the modeled period (*i.e.*, historical plus forecast). A few particles reached Middle River region due to high turbidity from the high Cosumnes and Calaveras boundary conditions. No particles reached the Old River region.

Several plots are included below as a pictorial summary of the model results. Model input files and results were provided to Churching Wang for remote access on the RMA intranet.

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[6] Only one day in January would have been modeled as additional days of input values are needed for daily water quality boundary conditions.

[7] http://www.usbr.gov/mp/cvo/fishrpt.html

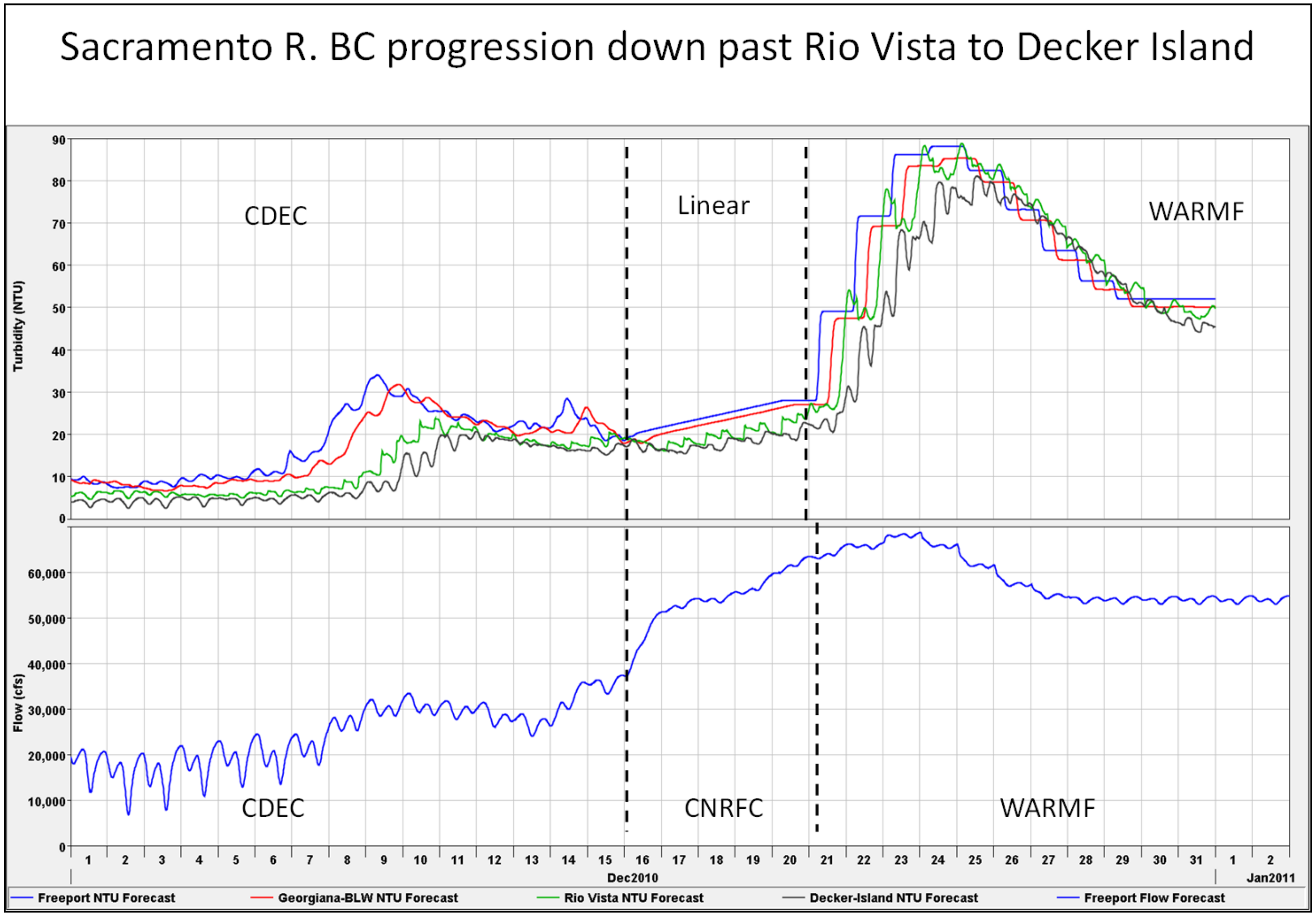

Figure 12-14 Freeport boundary condition progression down the Sacramento R. with an illustration of data used during the historical and forecast periods. Forecast began on December 16th.

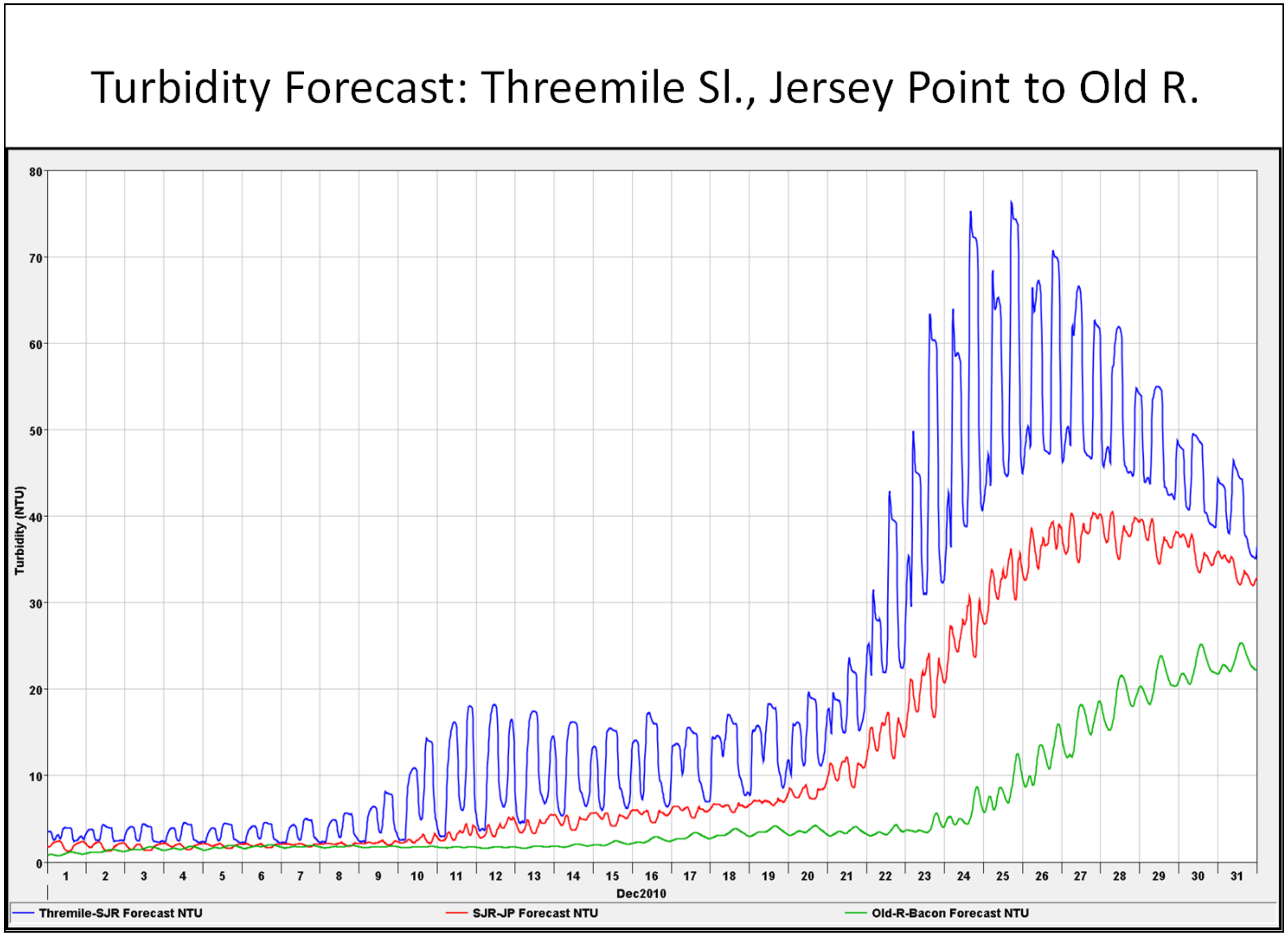

Figure 12-15 Modeled turbidity results at three in-Delta locations.

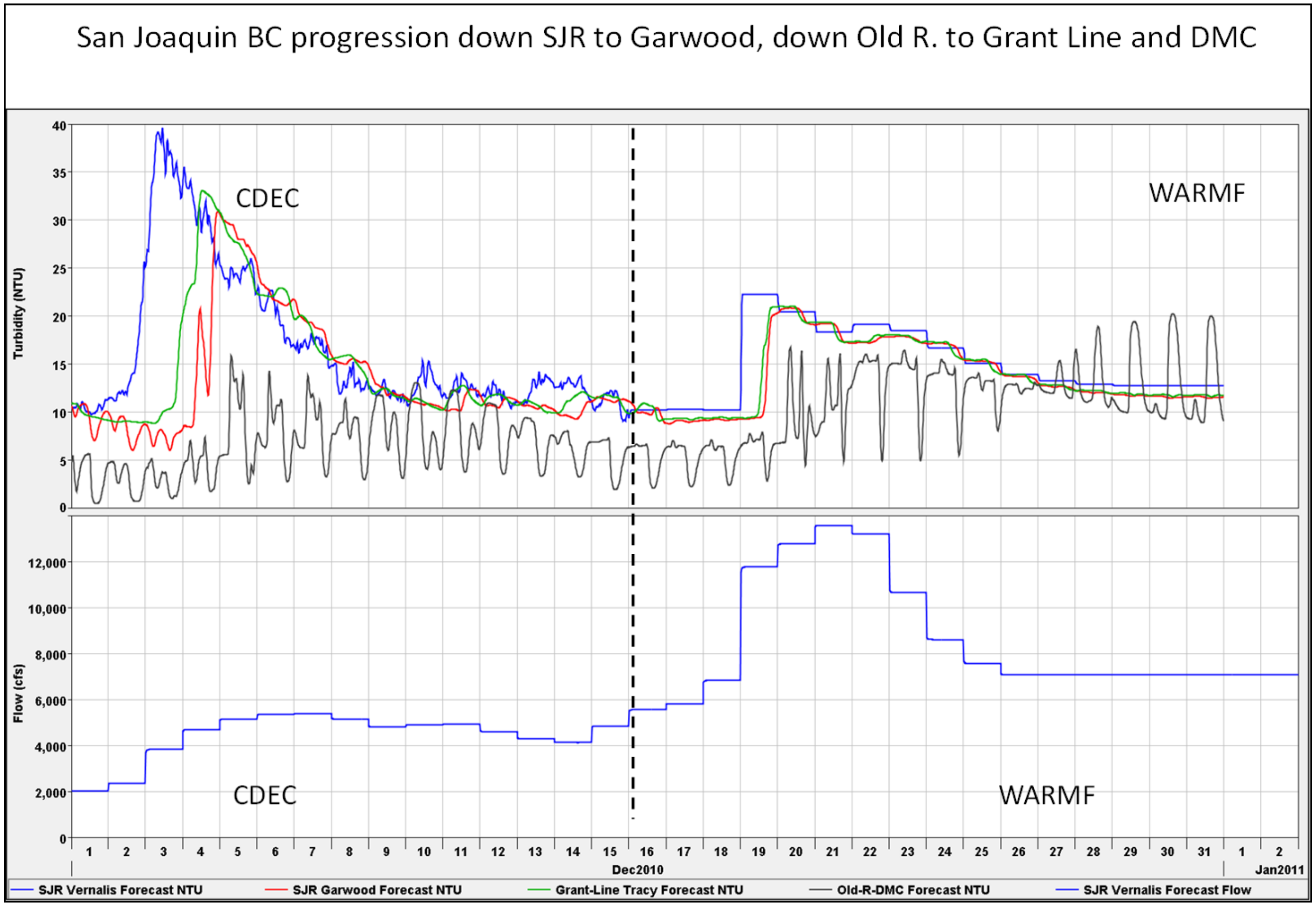

Figure 12-16 Progression of the turbidity boundary condition from Vernalis – historical and forecast periods are separated by the vertical line.

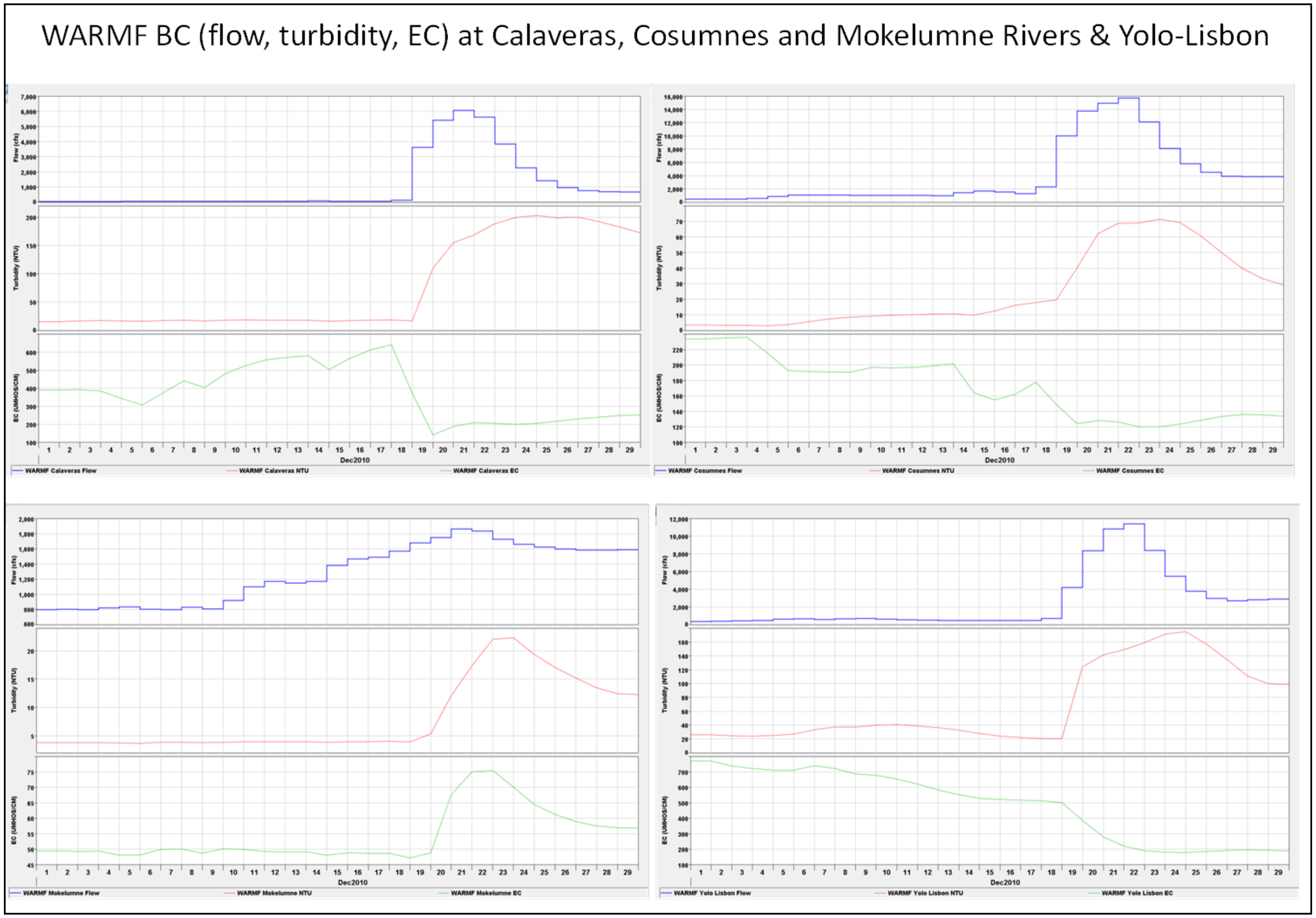

Figure 12-17 Illustration of the WARMF flow, salinity and turbidity boundary conditions at four inflow locations.

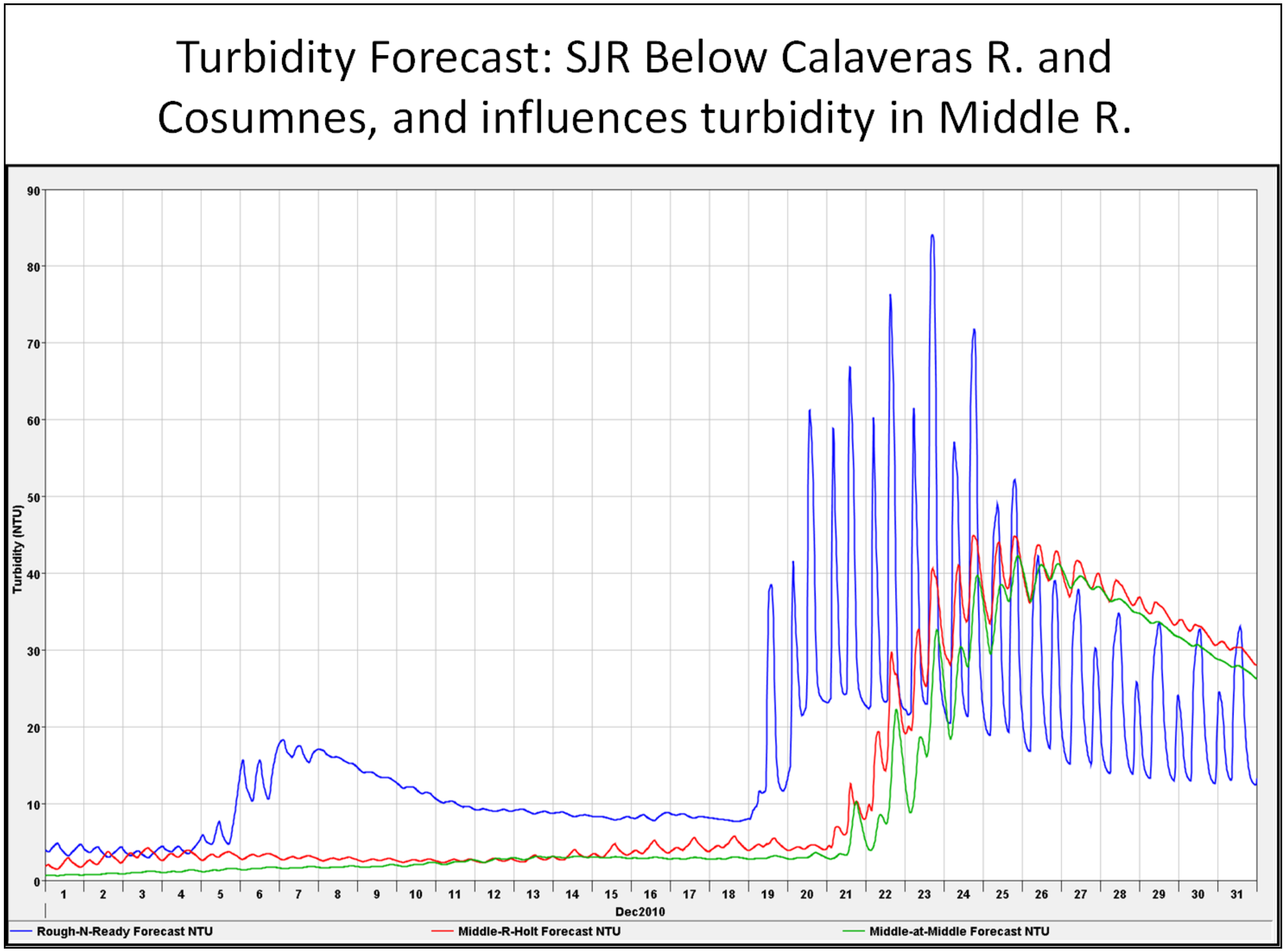

Figure 12-18 Modeled turbidity results at three in-Delta locations.

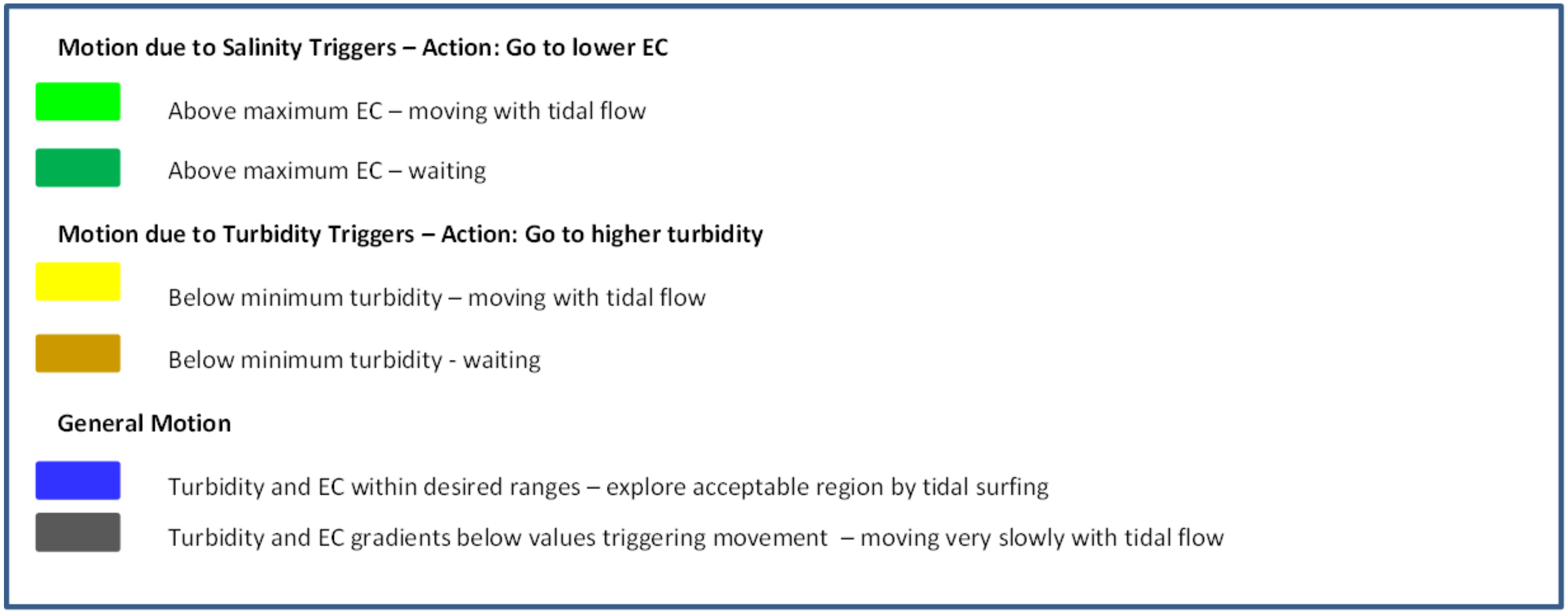

Figure 12-19 Particles in the Adult Delta Smelt particle tracking model are color-coded by the triggers influencing their behavior during the simulation. Use this figure to interpret the simplified color scale in the next three figures.

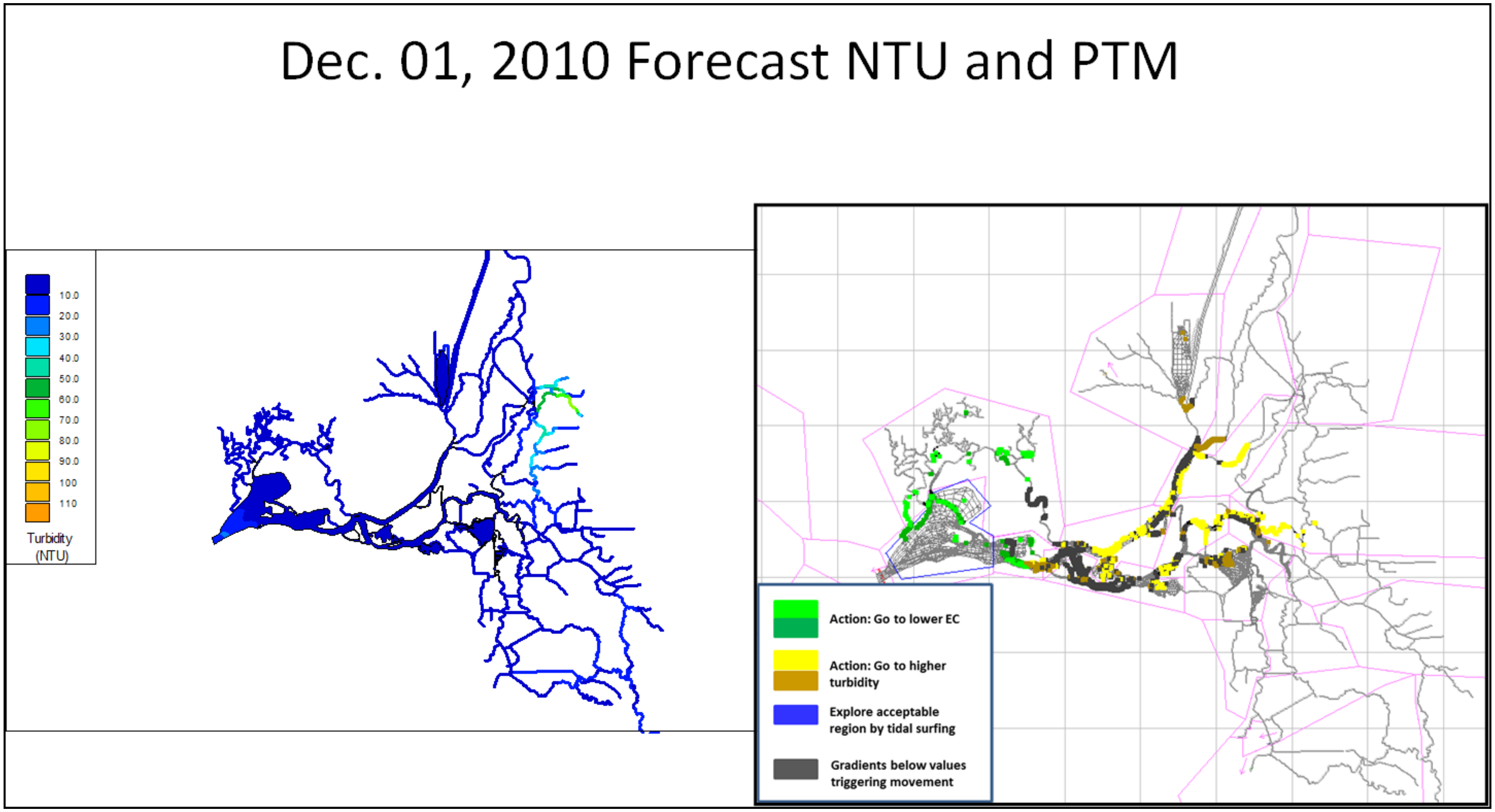

Figure 12-20 Turbidity contours and particle location in the RMA model grid on Dec. 01, 2010.

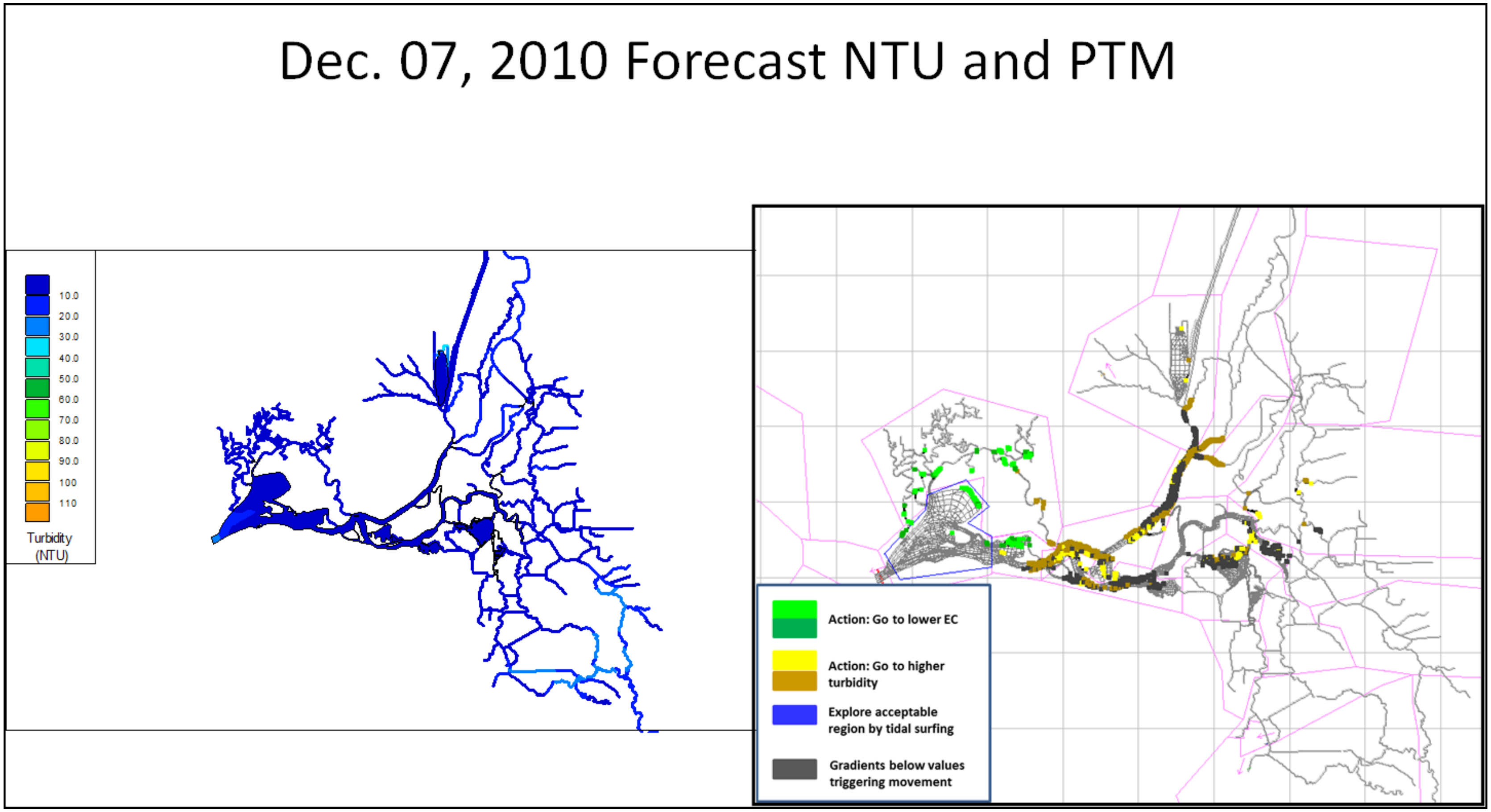

Figure 12-21 Turbidity contours and particle location in the RMA model grid on Dec. 07, 2010.

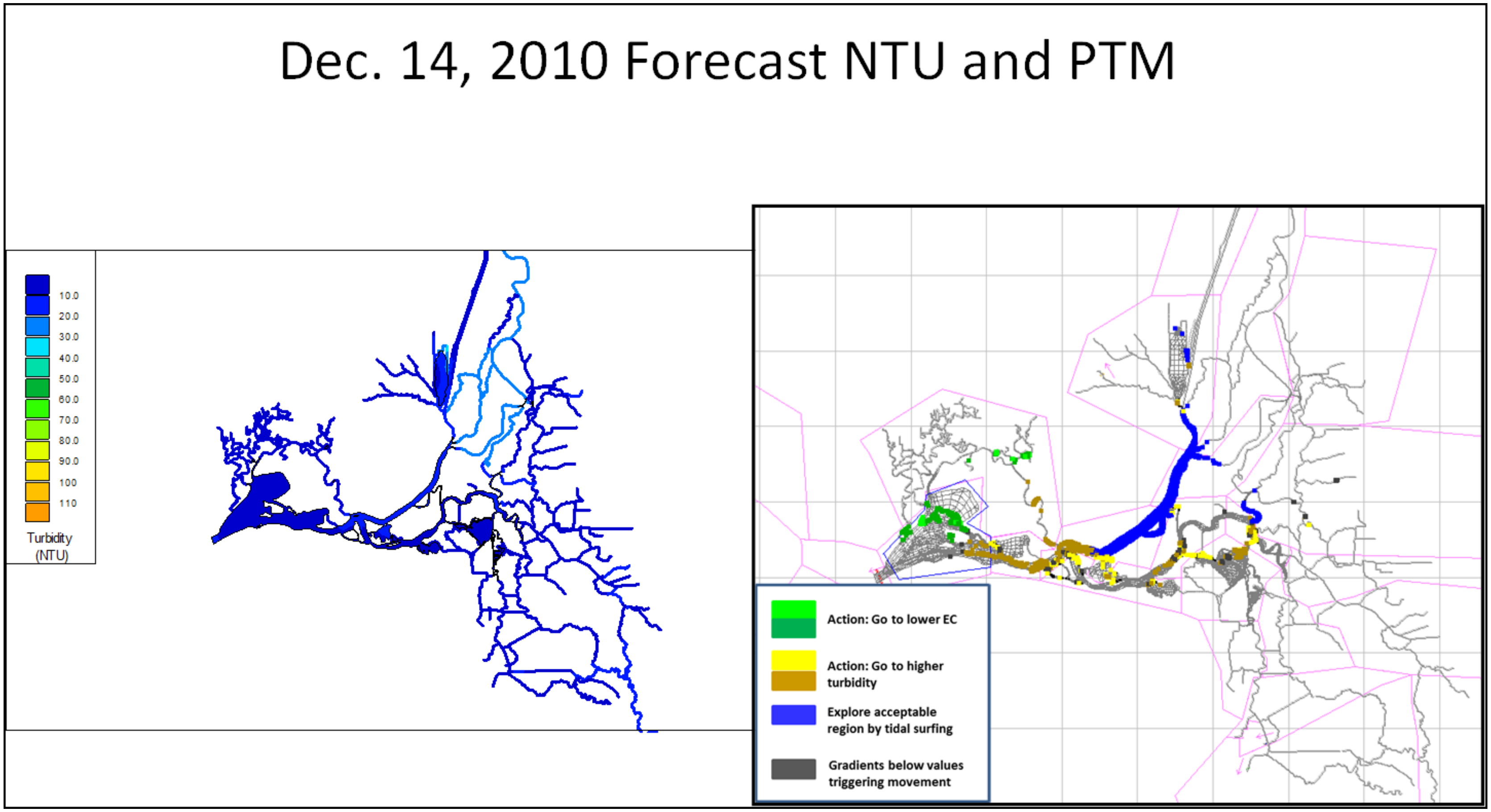

Figure 12-22 Turbidity contours and particle location in the RMA model grid on Dec. 14, 2010.

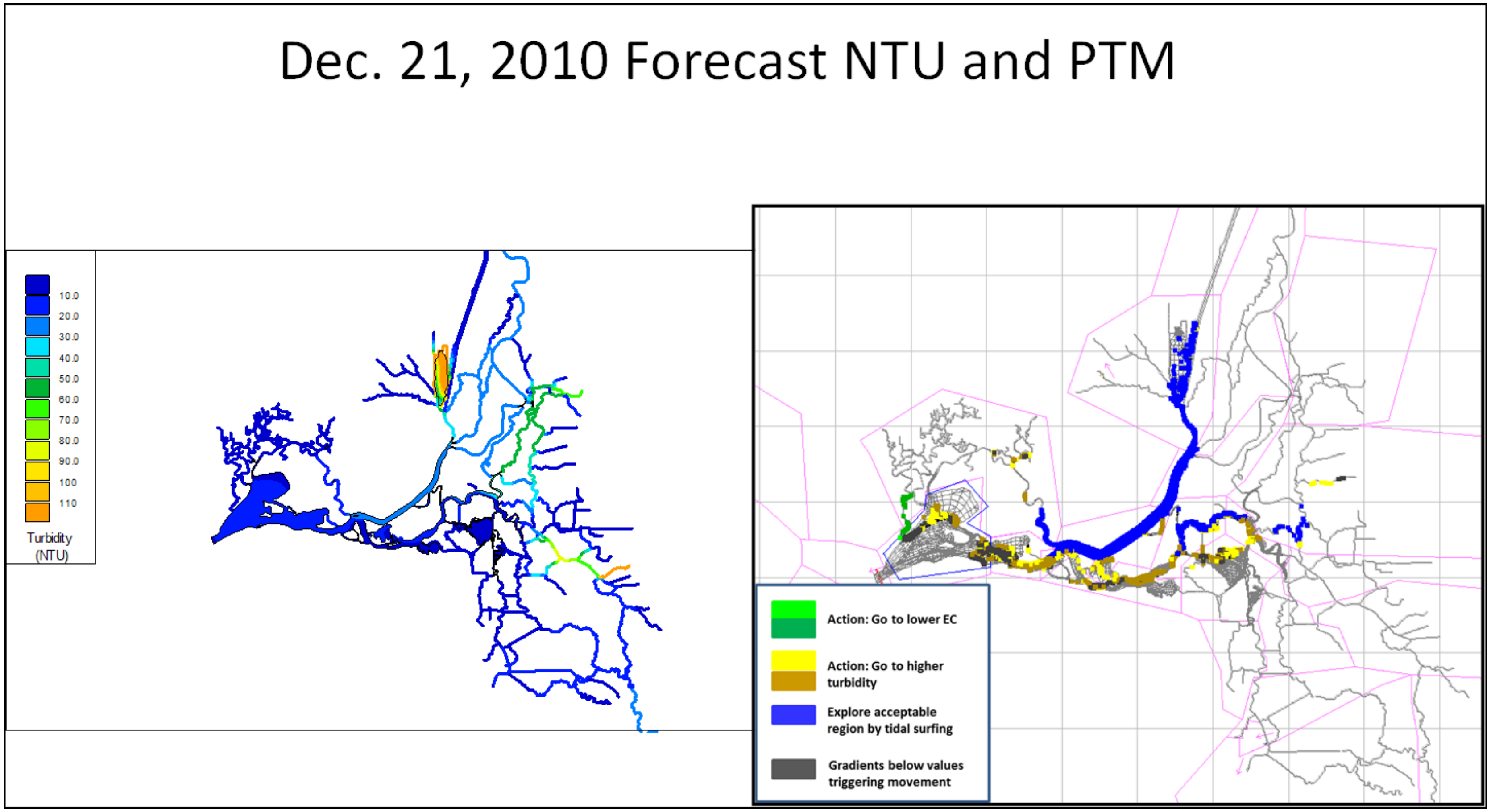

Figure 12-23 Turbidity contours and particle location in the RMA model grid on Dec. 21, 2010.

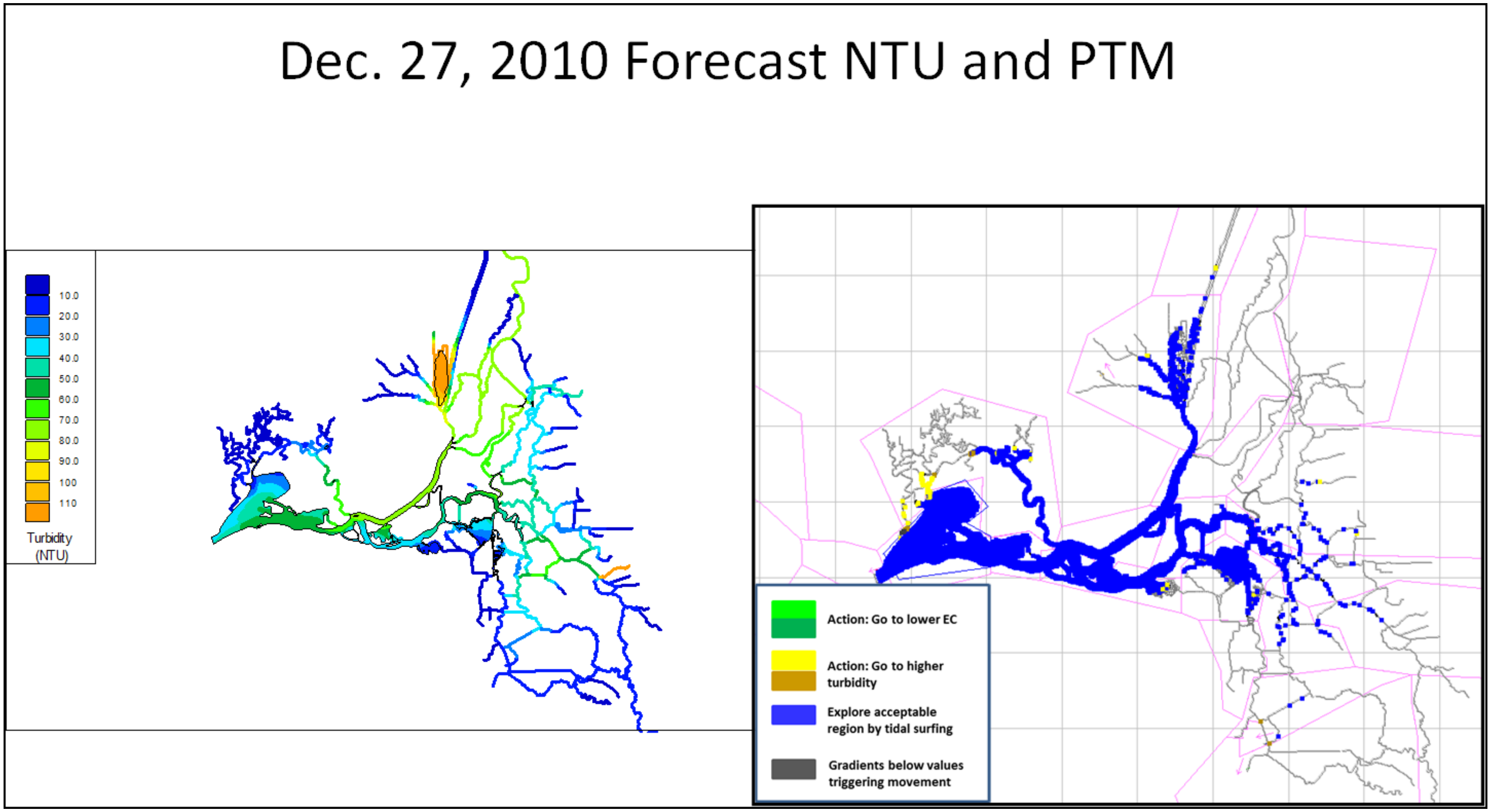

Figure 12-24 Turbidity contours and particle location in the RMA model grid on Dec. 27, 2010.

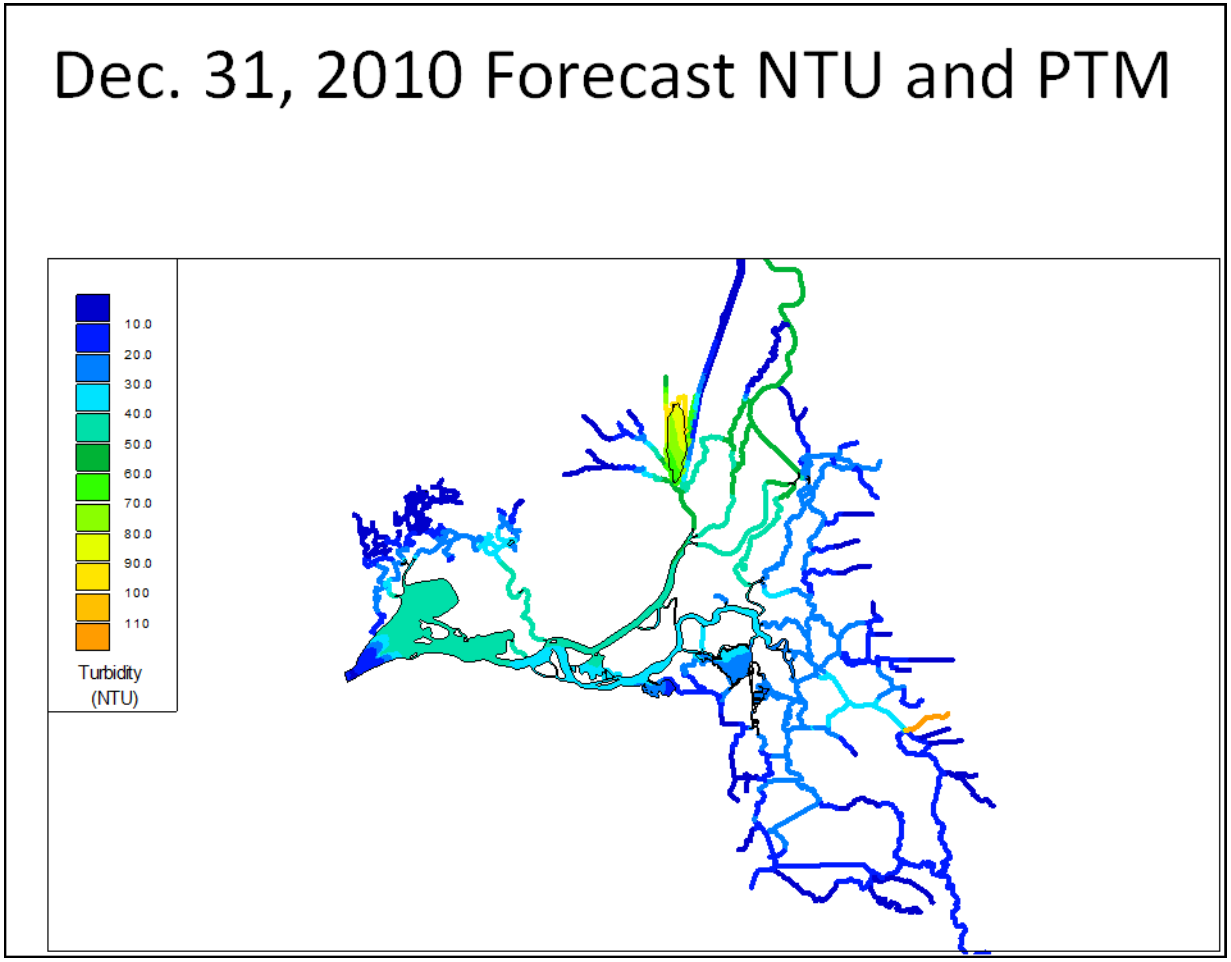

Figure 12-25 Turbidity contours in the RMA model grid on Dec. 31, 2010.

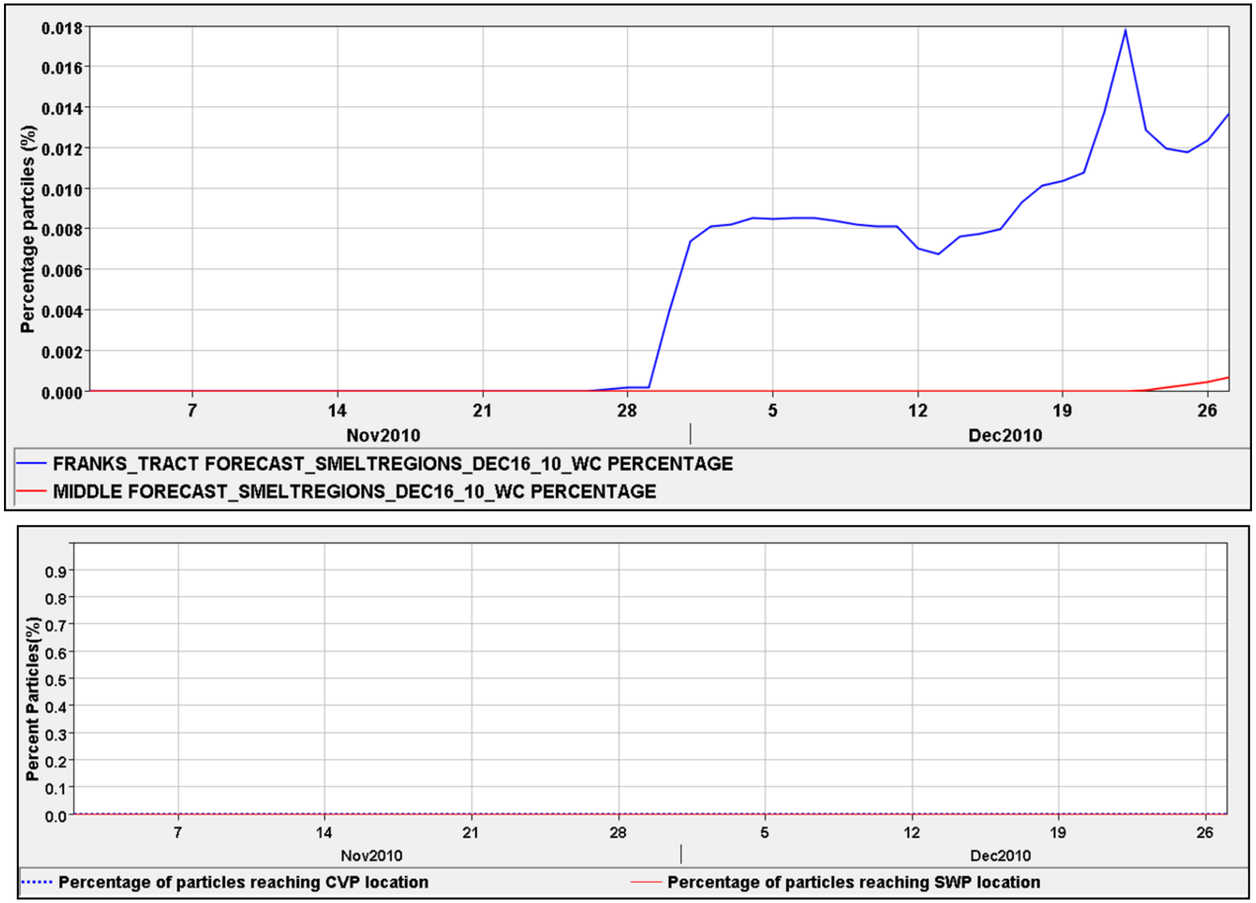

Figure 12-26 No particles reached either export location (lower plot), but some particles reached Franks Tract and Middle River (upper plot). No particles entered the Old river region. These results are for the "ALL WARMF" model.

Table 12-6 Model boundary conditions used in the forecast prepared Dec. 16, 2010. This simulation used WARMF boundary conditions exclusively.

"ALL WARMF" BCS

Location	*WARMF ID*	WARMF BC for Flow (Otherwise, use CDEC for historical)	CDEC+WARMF BC for NTU (Historical period is CDEC)
Yolo Bypass at Lisbon	797	Use WARMF starting 12/01/2010, CNRFC+CDEC before then	Use WARMF starting 12/01/2010
Sacramento River at I Street Bridge	751	Use WARMF starting 12/22/2010	Use WARMF starting 12/20/2010
Cosumnes River	62	Use WARMF starting 12/01/2010	Use WARMF starting 12/01/2010
Mokelumne River	61	Use WARMF starting 12/01/2010	Use WARMF starting 12/01/2010
Calaveras River	127	Use WARMF starting 12/01/2010	Use WARMF starting 12/01/2010
San Joaquin River at Vernalis	184	Use WARMF starting 12/16/2010	Use WARMF starting 12/16/2010

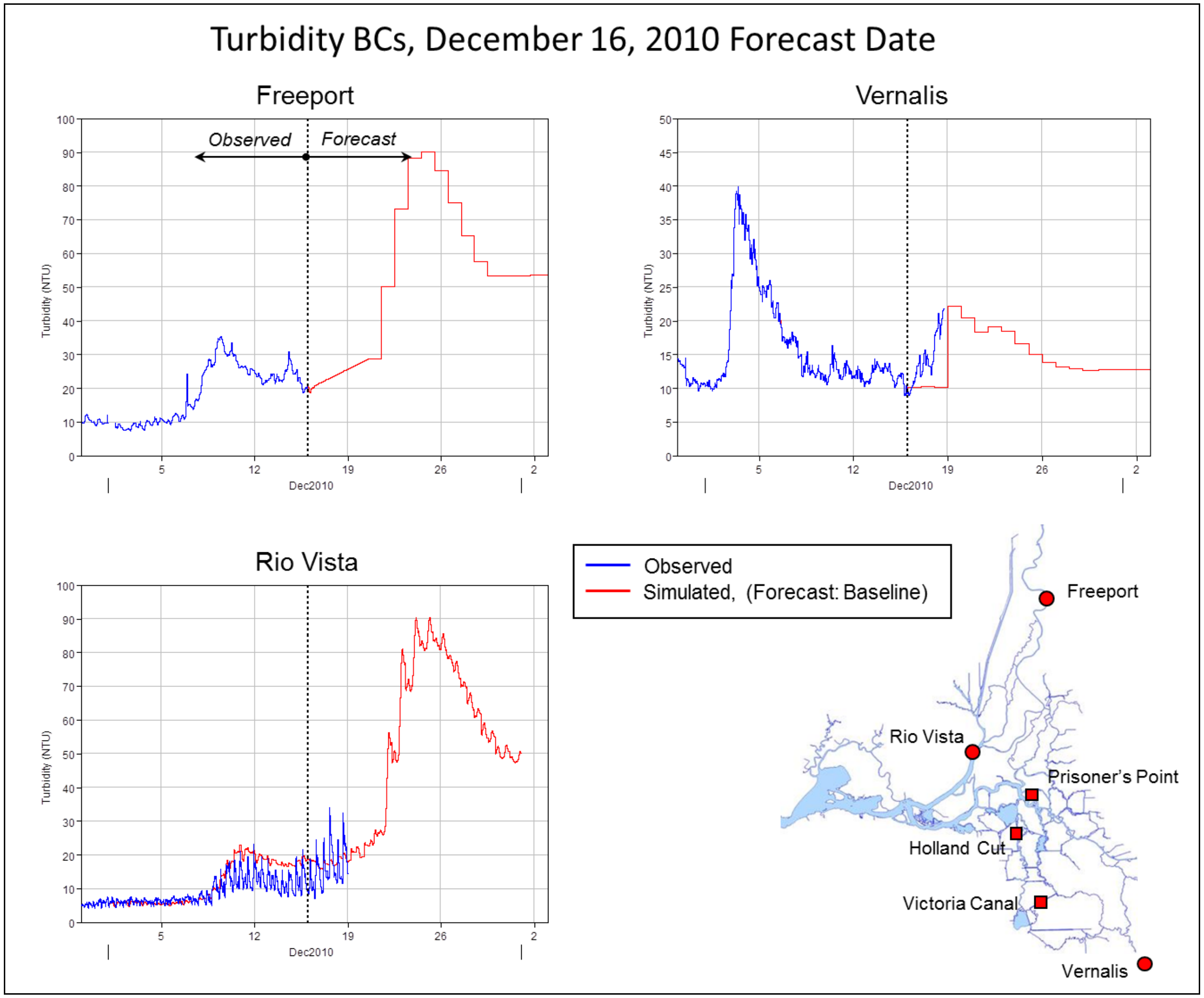

Figure 12-27 Illustration of modeled conditions for the "All WARMF" model simulation.

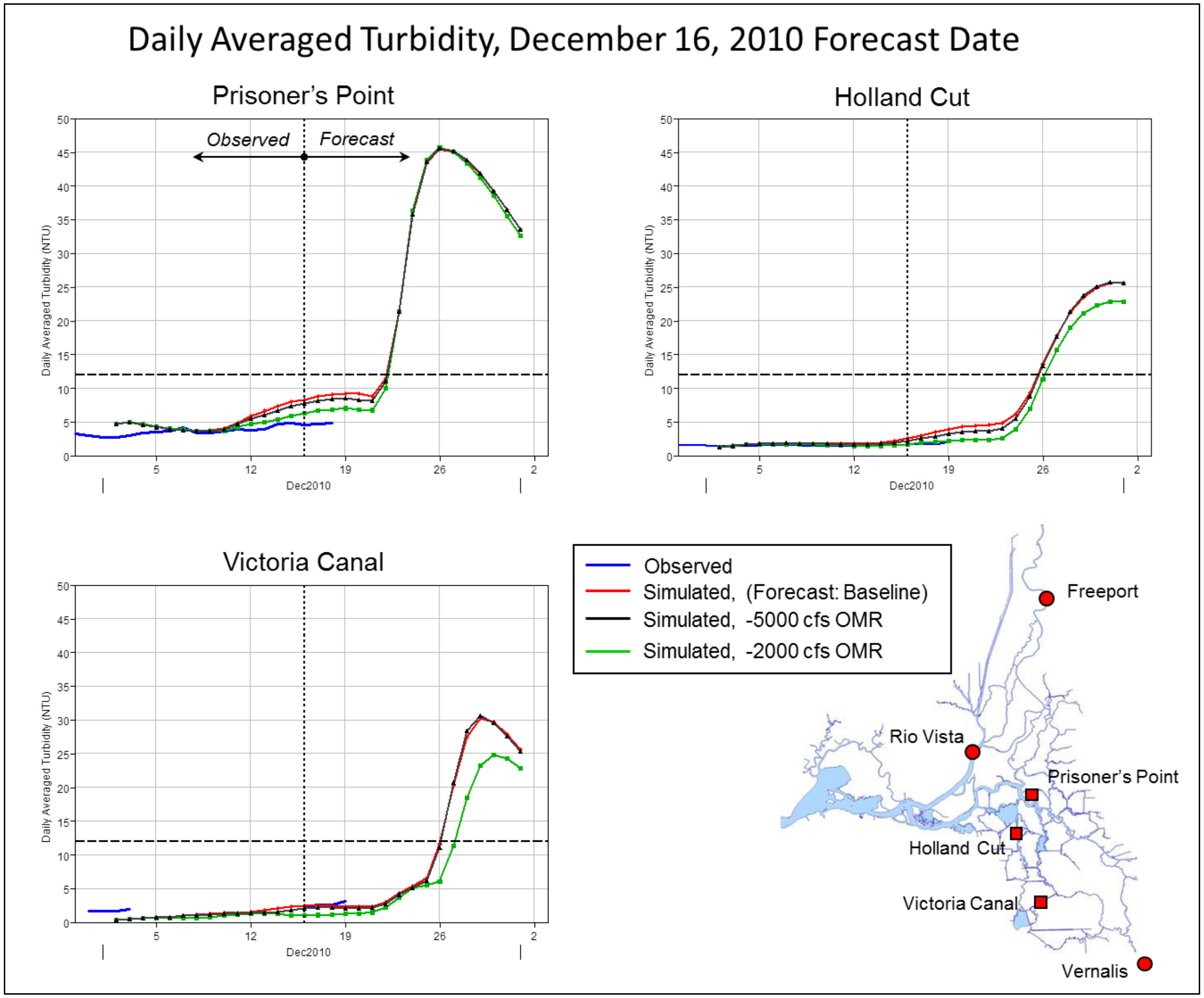

Figure 12-28 Model output at turbidity compliance locations for the "All WARMF" model simulation.

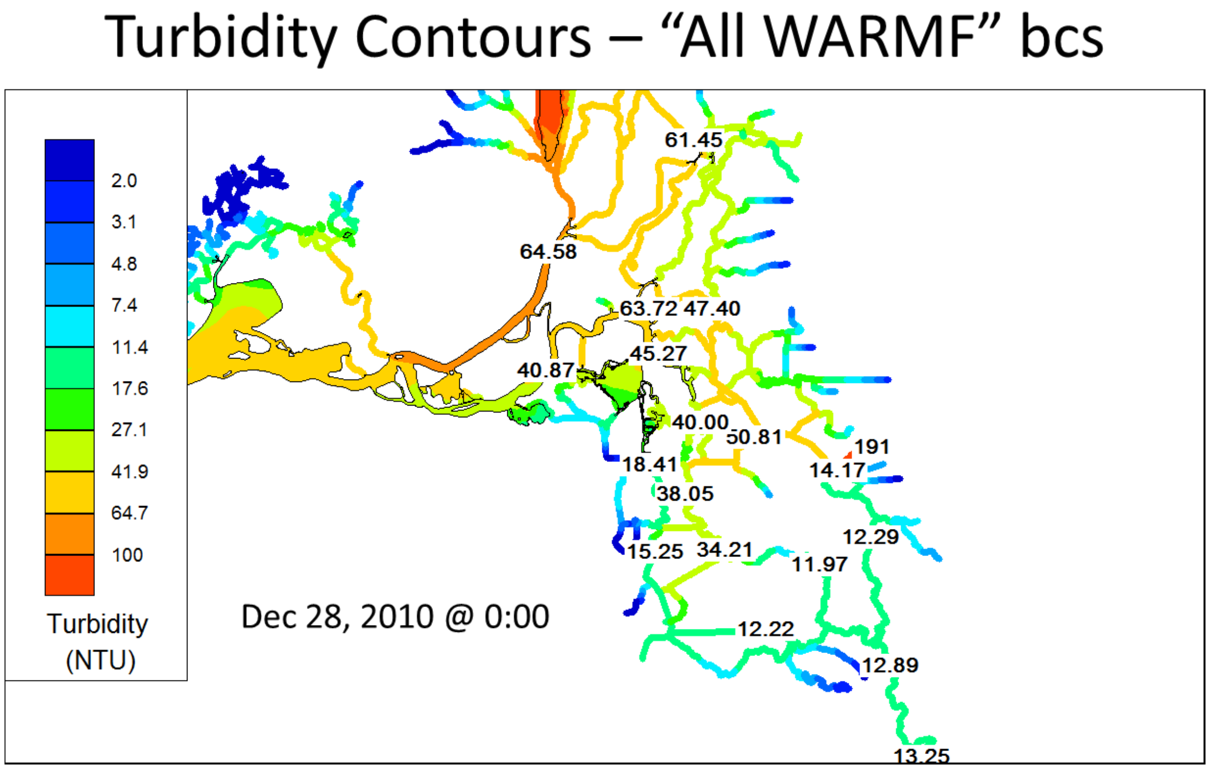

Figure 12-29 Contour plot illustrating the effect of high-inflow, high-turbidity boundary conditions at Eastside locations (mainly Cosumnes and Calaveras) for the "All WARMF" model simulation.

Table 12-7 Model boundary conditions used in the special forecast run prepared by special request for Paul Hutton. This simulation used a combination of WARMF and RMA-prepared flow boundary conditions.

RMA" BCS

Location	***WARMF ID***	**BC for Flow**	**CDEC+WARMF BC for NTU (Historical period is CDEC)**
Yolo Bypass at Lisbon	797	Use CDEC+CNRFC	Use WARMF starting 12/01/2010
Sacramento River at I Street Bridge	751	Use CDEC+CNRFC then WARMF starting 12/22/2010	Use WARMF starting 12/20/2010
Cosumnes River	62	CDEC+DWR+CNRFC	Use WARMF starting 12/01/2010
Mokelumne River	61	Use WARMF starting 12/01/2010	Use WARMF starting 12/01/2010
Calaveras River	127	Use DWR+CDEC	Use WARMF starting 12/01/2010
San Joaquin River at Vernalis	184	Use CDEC then WARMF starting 12/16/2010	Use WARMF starting 12/16/2010

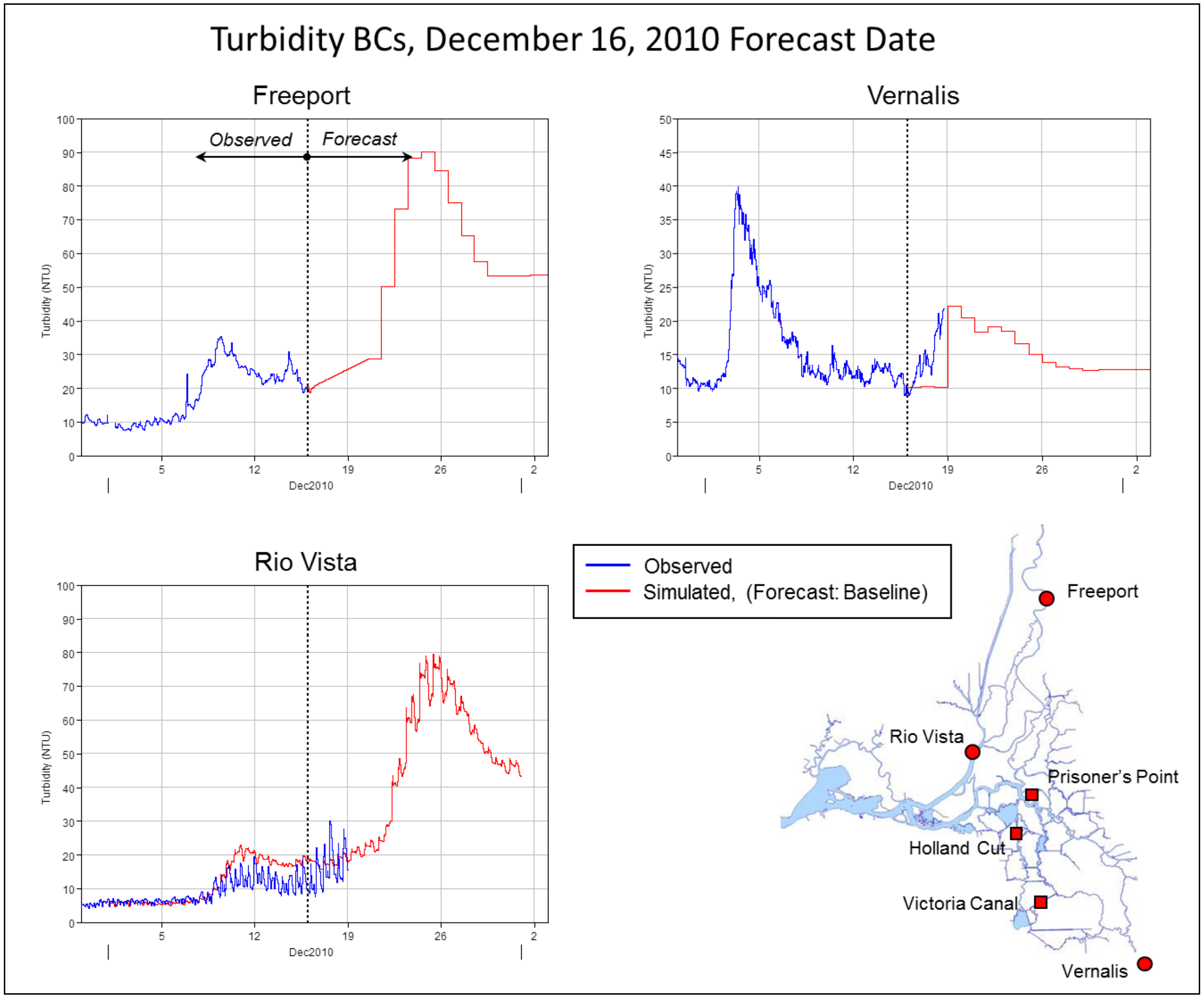

Figure 12-30 Illustration of modeled conditions for the "RMA BC" model simulation.

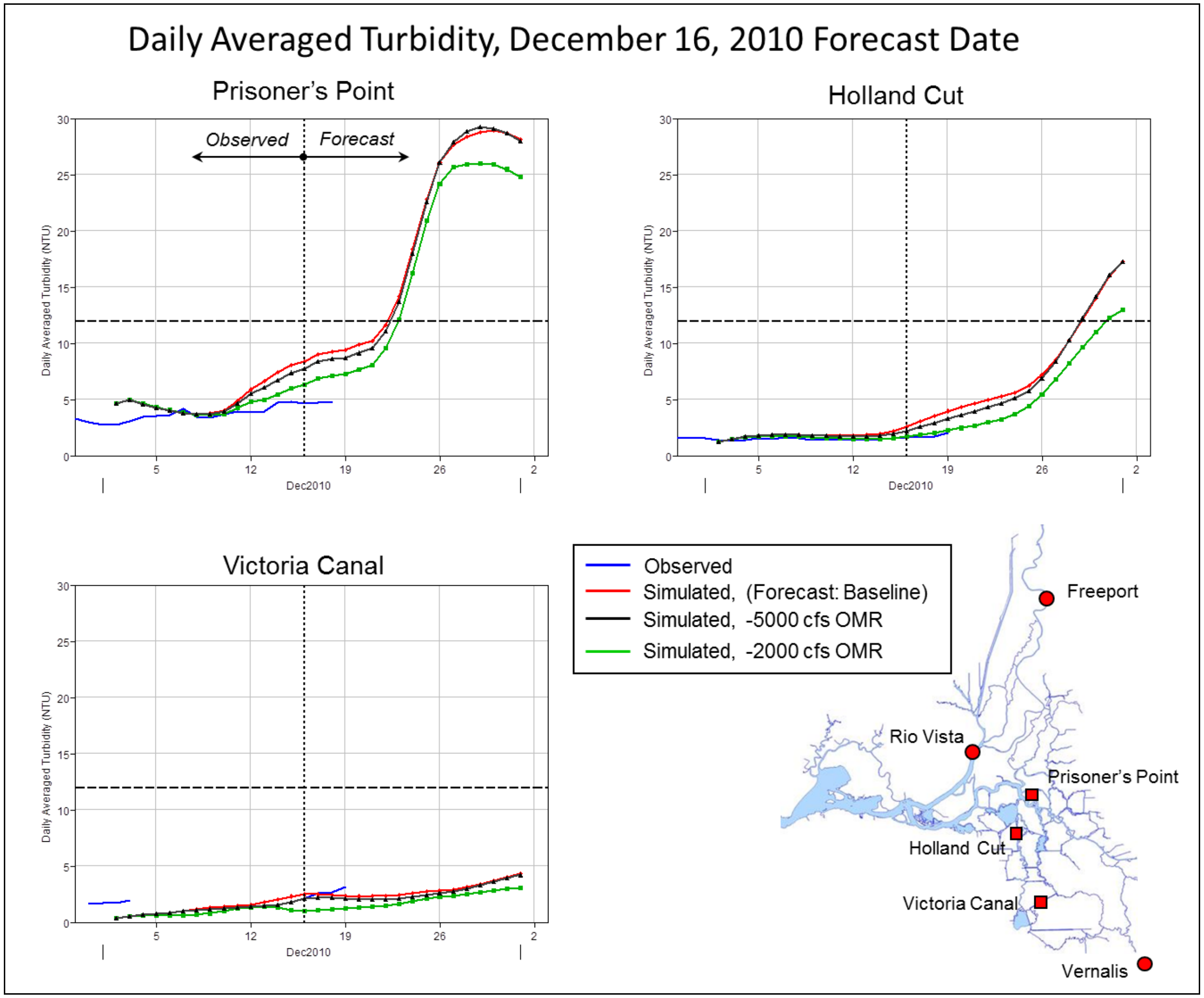

Figure 12-31 Model output at turbidity compliance locations for the "RMA BC" model simulation

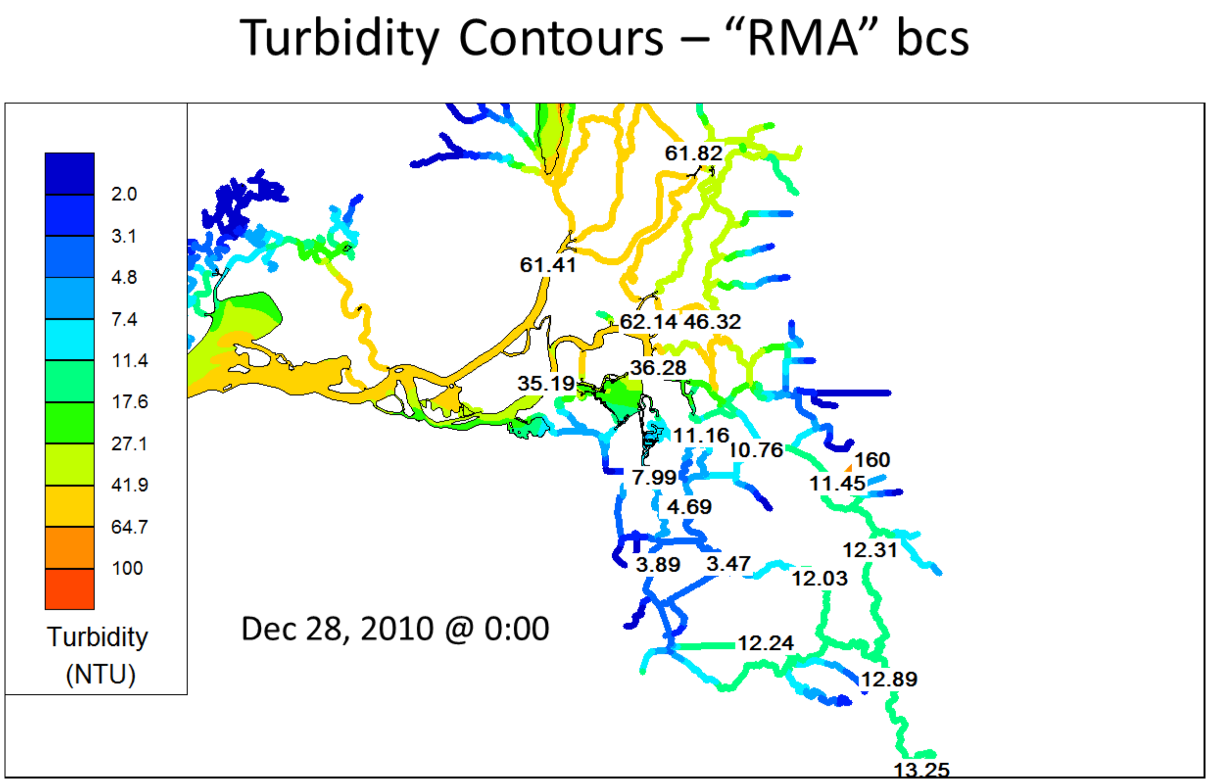

Figure 12-32 Contour plot illustrating the effect of changing the flow boundary conditions at Eastside locations (mainly Cosumnes and Calaveras) for the "RMA BC" model simulation – modeled turbidity on Middle River and in the S. Delta was much lower.

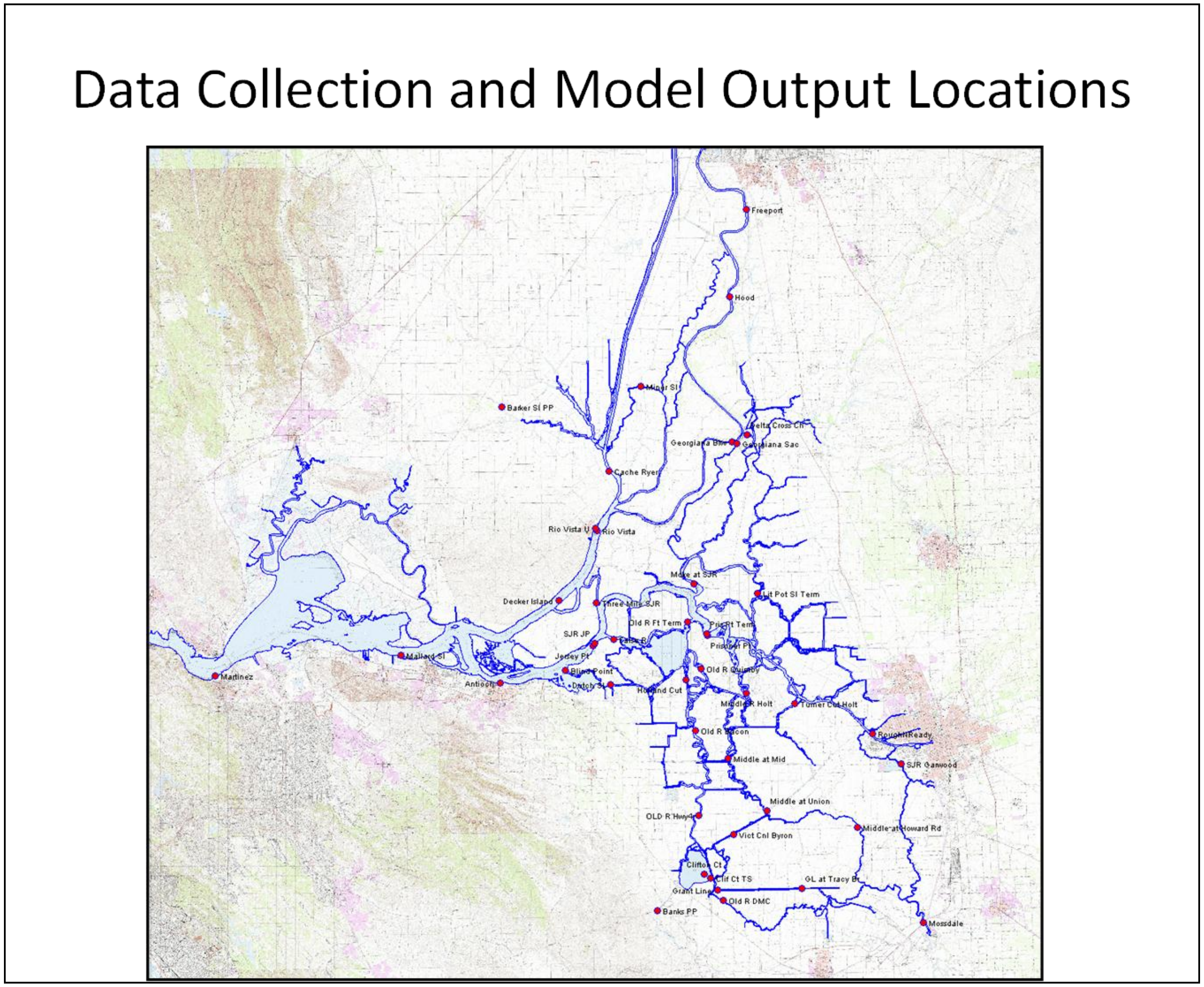

Figure 12-33 Figure illustrating model output and data collection locations.

12.3.3. Forecast Jan. 06, 2011

This document provides a quick summary of the January 06, 2011 forecast prepared using the RMA hydrodynamic, salinity, turbidity and Adult Delta Smelt Behavioral models. Graphical results are provided to document the results of the modeling with a focus on turbidity. Model BC (Boundary Conditions) for the forecast model were prepared using WARMF-supplied forecast conditions, CNRFC flow data and predictions, CDEC and USGS data, and DWR-supplied model inputs and results from their flow and salinity forecasts.

In general, producing BC during this forecast period was challenging, due to the number of data sources, data discrepancies, and the need to piece the data together for BC.

The RMA modeled period was December 01, 2010 to January 25, 2011 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 Dec. 23, 2010 through January 25, 2011. The WARMF model forecast period, consisting of daily model output for flow, salinity and turbidity, was Jan. 01 – Jan. 20, 2011. Additional flow, turbidity and EC data was downloaded for the period Dec. 01 – Jan 05/06, 2010 from the CDEC, CNRFC and USGS websites.

Historical and forecast BC were developed from several sources, as summarized in Table 12-8 below. Setting inflow BC was complicated, as the data sources sometimes did not agree (*e.g.*, at YOLO-Lisbon) and data many times did not agree with WARMF model output. As a consequence, inflow BC were compiled using best professional judgment. Stage and export BC were compiled solely from DWR O&M sources. Boundary conditions were synthesized or obtained from the DWR forecast for the period Jan. 21 – Jan. 25, 2011.

Turbidity data at Freeport was very noisy, so the data was “cleaned” to make it suitable as a BC. This data and “cleaning” procedure will be reviewed again for the next forecast. WARMF boundary condition turbidity estimates at Yolo-Lisbon and at the Calaveras R. were high, so these BC will also need to be reexamined. Similarly, WARMF salinity BC at Yolo-Lisbon and Calaveras seemed high – see Table 12-8 for revised salinity BC sources.

Modeled turbidity was high at Rio Vista, but low upstream (Georgiana-BLW location) indicating the high Yolo-Lisbon turbidity forecast influenced downstream results during and subsequent to the high flow period.

Plots are included below as a pictorial summary of the model results.

Figure 12-41illustrates a comparison of model output and data at the three compliance locations, and Figure 12-42 illustrates a similar comparison in the SWP export area. Note thatFigure 12-42 is a comparison of data inside Clifton Court Forebay with model output at the model boundary at the entrance to the Forebay. For these plots, data were cleaned (noisy values removed) and missing data filled with linear approximation. The cleaned and filled data were then daily averaged.

Only at the Prisoner's Point compliance location did averaged data exceed 12 NTU – modeled turbidity was high at this location and also exceeded the 12 NTU value for several weeks (Figure 12-41). Modeled turbidity at Prisoner's Point was high due to relatively high WARMF turbidity BC (Figure 12-40) in the eastside inflow locations at the Cosumnes and Calaveras Rivers, which also experienced fairly high flows (Figure 12-39). At Victoria Canal, averaged modeled turbidity exceeded the 12 NTU limit for two weeks late December through early January also due to eastside influences. Data was below the 12 NTU compliance value at Holland Cut, but modeled averaged turbidity exceeded 12 NTU for twelve days late December through early January.

The Delta Smelt behavioral model was run from Nov. 01, 2010 through Jan 25, 2011 - 50,000 particles were inserted on Nov.01, 2010 as in previous forecast models. No delta smelt were salvaged at the SWP or CVP locations during the pre-forecast period[8], Nov. 01 – Jan. 05, 2010. A couple of particles reached the SWP and CVP export locations during the modeled period (*i.e.*, historical plus forecast), and a very small percentage of particles entered the Middle R. Region – none entered the Old R. Region. See Figure 12-54 through Figure 12-59 for turbidity contour plots and particle tracking model results.

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

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[8] http://www.usbr.gov/mp/cvo/fishrpt.html - Note delta smelt salvage data was not available for the entire historical period, so this statement may change once final salvage data is posted.

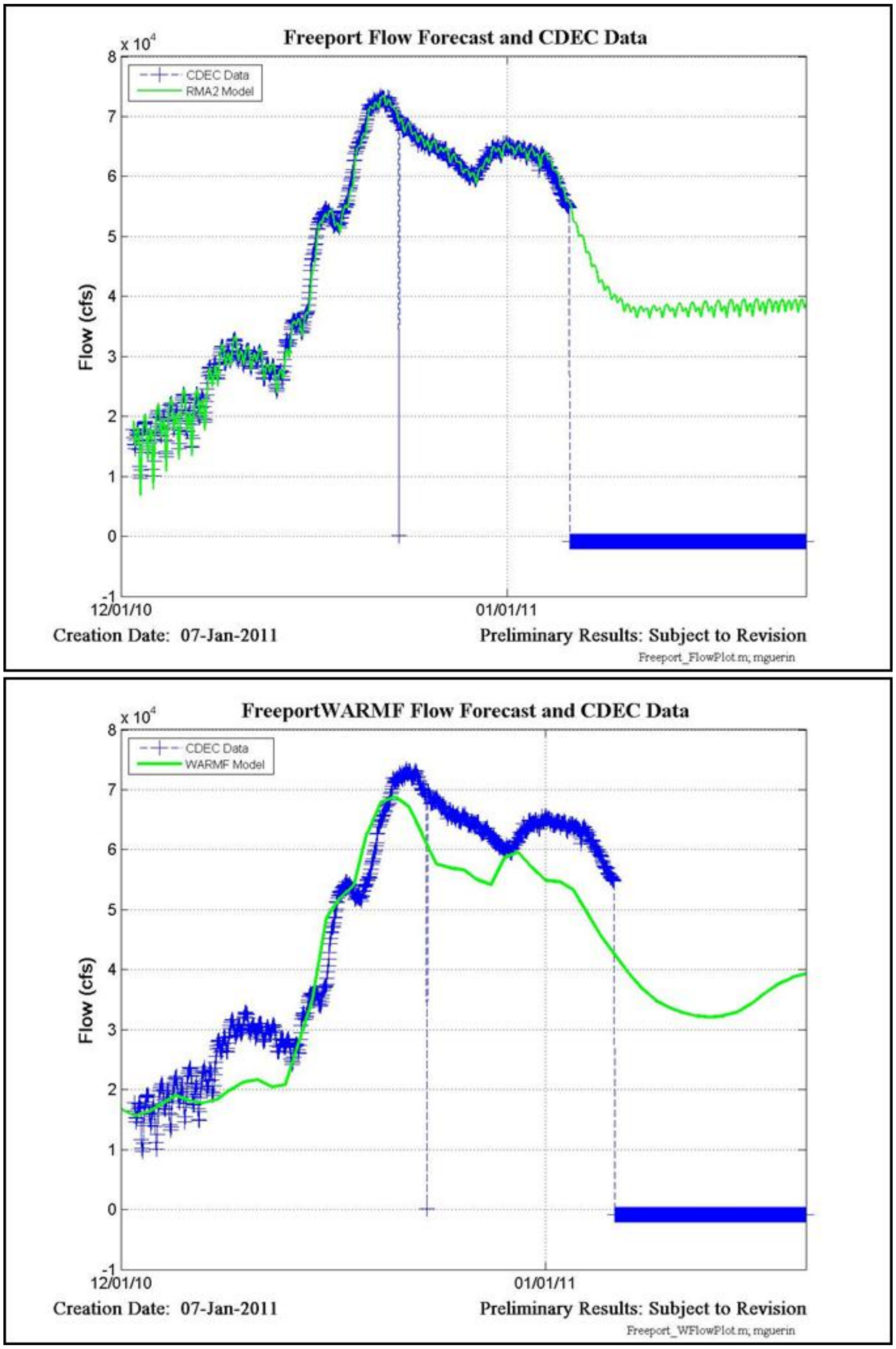

Figure 12-34 Freeport flow BC was compiled from CDEC and CNRFC data, and then extended to a constant flow on Jan. 25th, 2011 as indicted by the WARMF forecast. Note y-axis unit is cfs*10,000. Zero values indicate the end of data (blue).

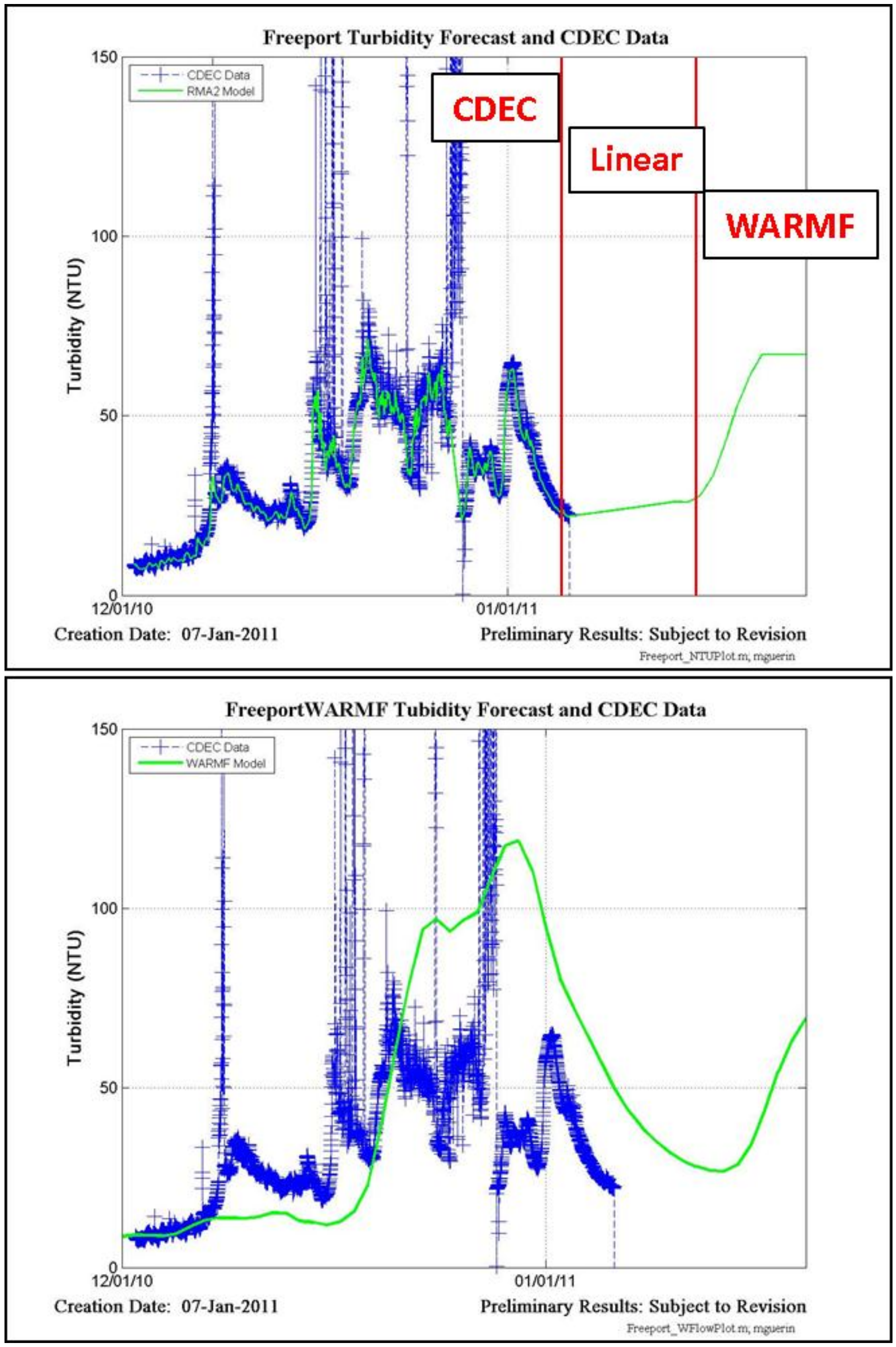

Figure 12-35 Freeport turbidity BC was compiled from CDEC data, a linear interpolation followed by WARMF model output, then extended as a constant after Jan. 20th, 2011.

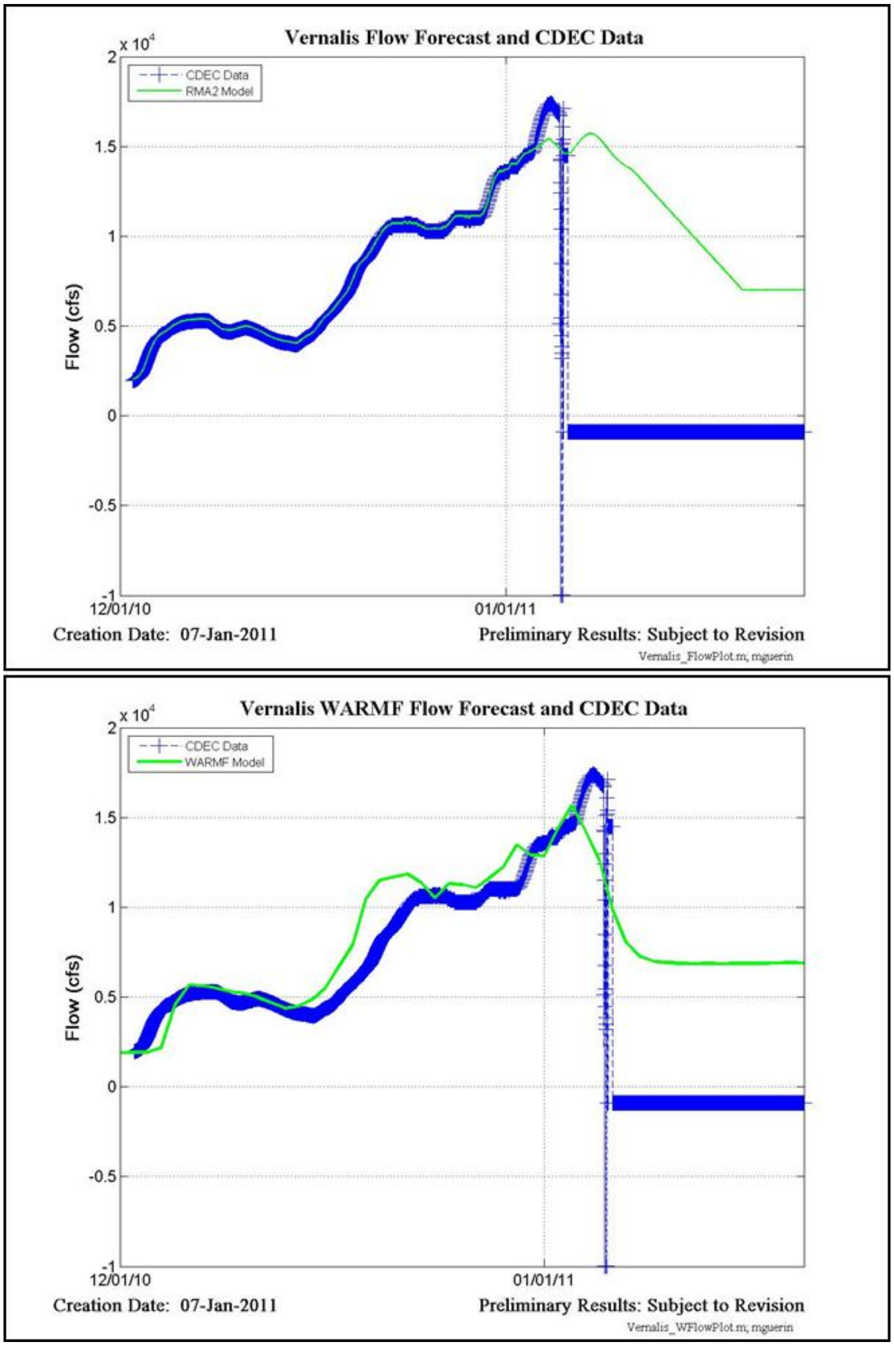

Figure 12-36 Vernalis flow BC was compiled from CDEC and CNRFC data, and then extended to a constant flow ~ Jan. 25th, 2011 indicted by the DWR forecast. Note y-axis unit is cfs*10,000. Zero values indicate the end of data (blue).

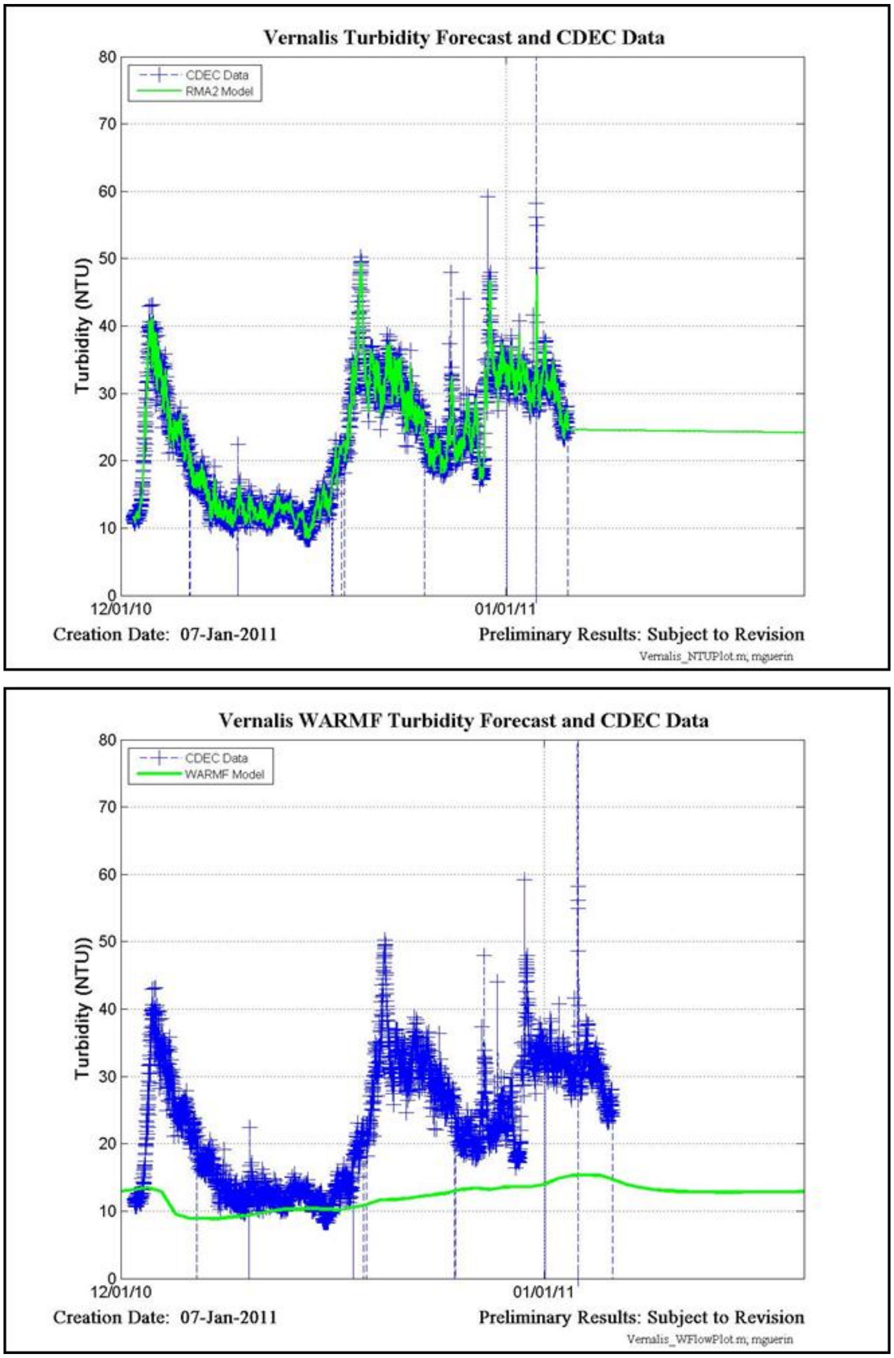

Figure 12-37 Vernalis turbidity BC was compiled from CDEC data, and then extended to a constant value from Jan. 06 – Jan. 25, 2011. WARMF forecast turbidity was deemed too low to use.

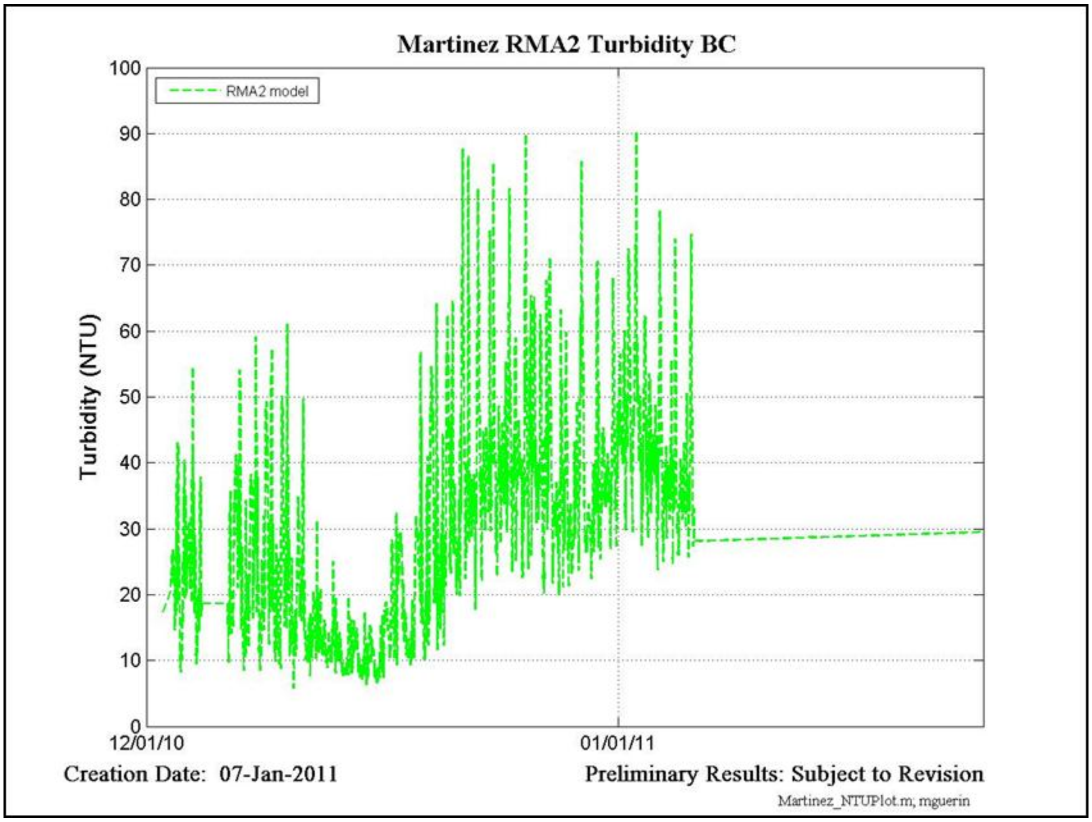

Figure 12-38 Martinez turbidity BC was compiled from CDEC data then extended linearly to a value of 30 NTU.

Table 12-8 Boundary condition development for Jan.06, 2011 forecast for flow, turbidity and salinity (EC).

	WARMF Ouput Usage	Sources for FlowBC	Sources for Turbidity BC	Definition EC
Location				
Yolo Bypass at Lisbon	After 01/11/2011	USGS+CDEC+CNRFC+WARMF	WARMF	Freeport BC
Sacramento River at I Street Bridge	No	CDEC+CNRFC	CDEC Freeport/WARMF starting 01/16/11	CDEC, WARMF then constant
Cosumnes River	After 01/11/2011	CNRFC+WARMF	WARMF	WARMF
Mokelumne River	Yes	WARMF	WARMF	WARMF
Calaveras River	After 01/11/2011	CDEC+WARMF	WARMF	Vernalis BC
San Joaquin River at Vernalis	No	CDEC+CNRFC+DWR	CDEC then constant	CDEC then constant

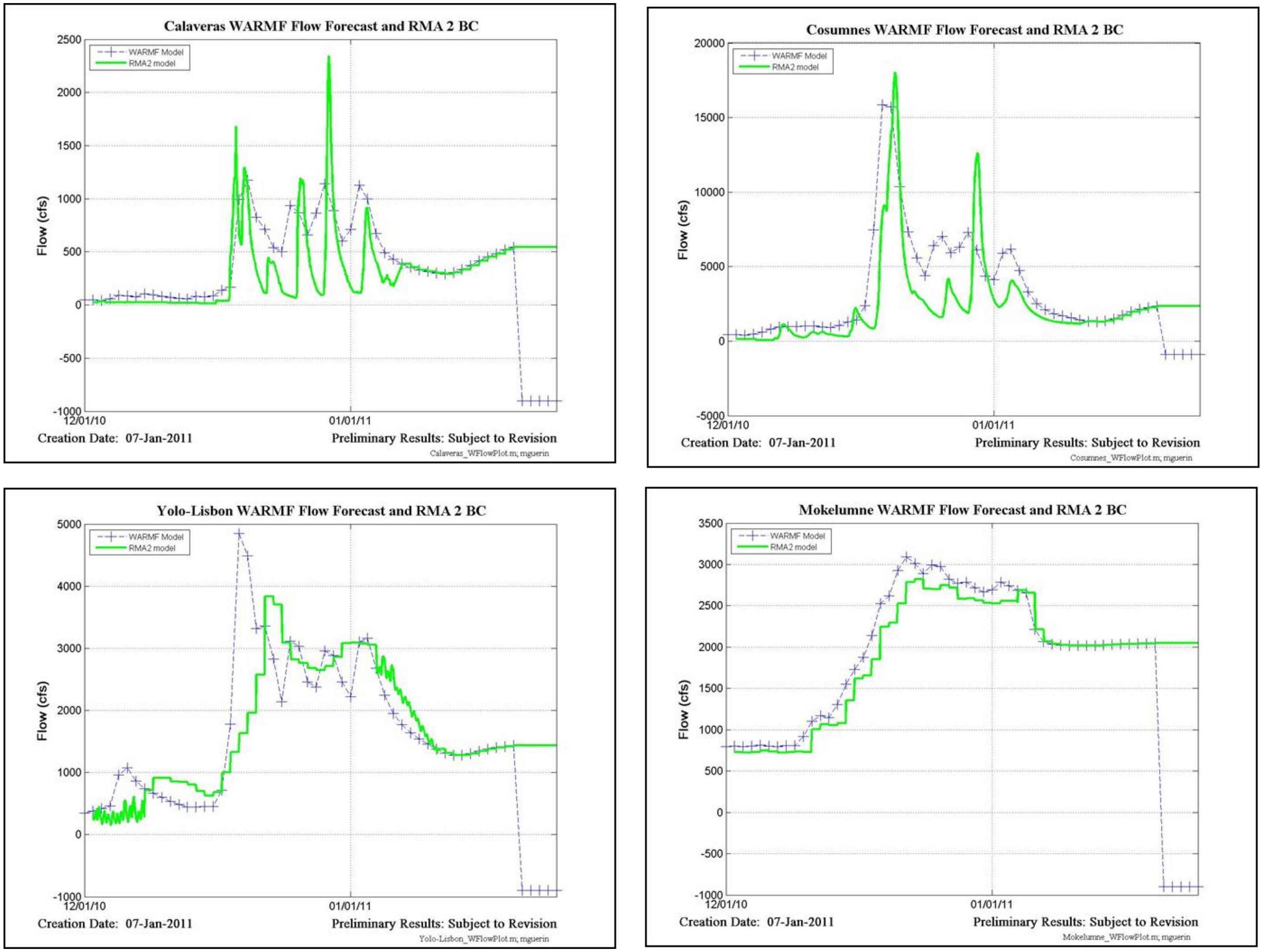

Figure 12-39 Flow boundary conditions used in the model along with the WARMF model output.

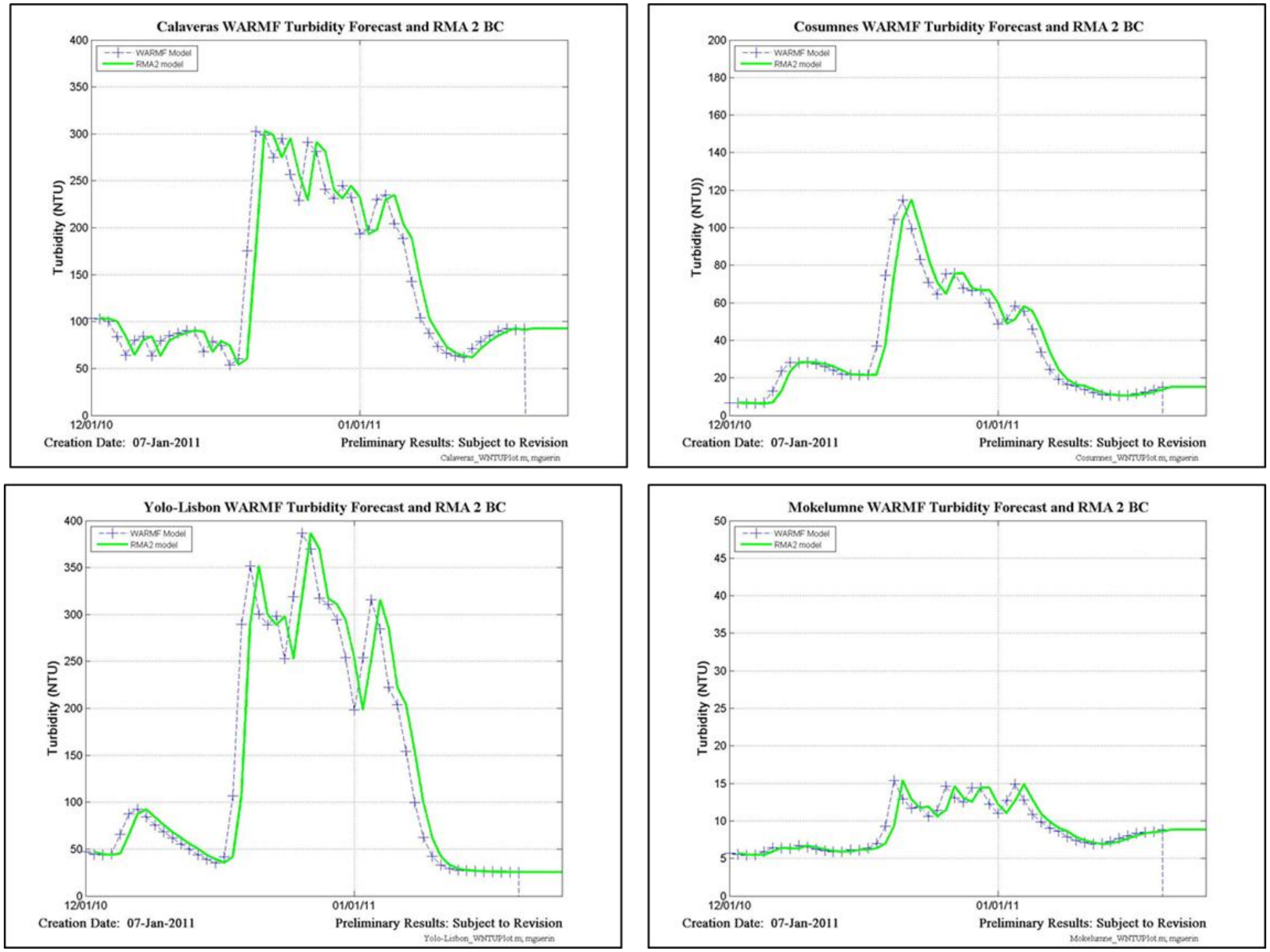

Figure 12-40 Turbidity boundary conditions used in the model along with the WARMF model output – note the shift in model boundary values in comparison with WARMF is most likely a plotting artifact which will be addressed in the next forecast. Note difference in vertical scales.

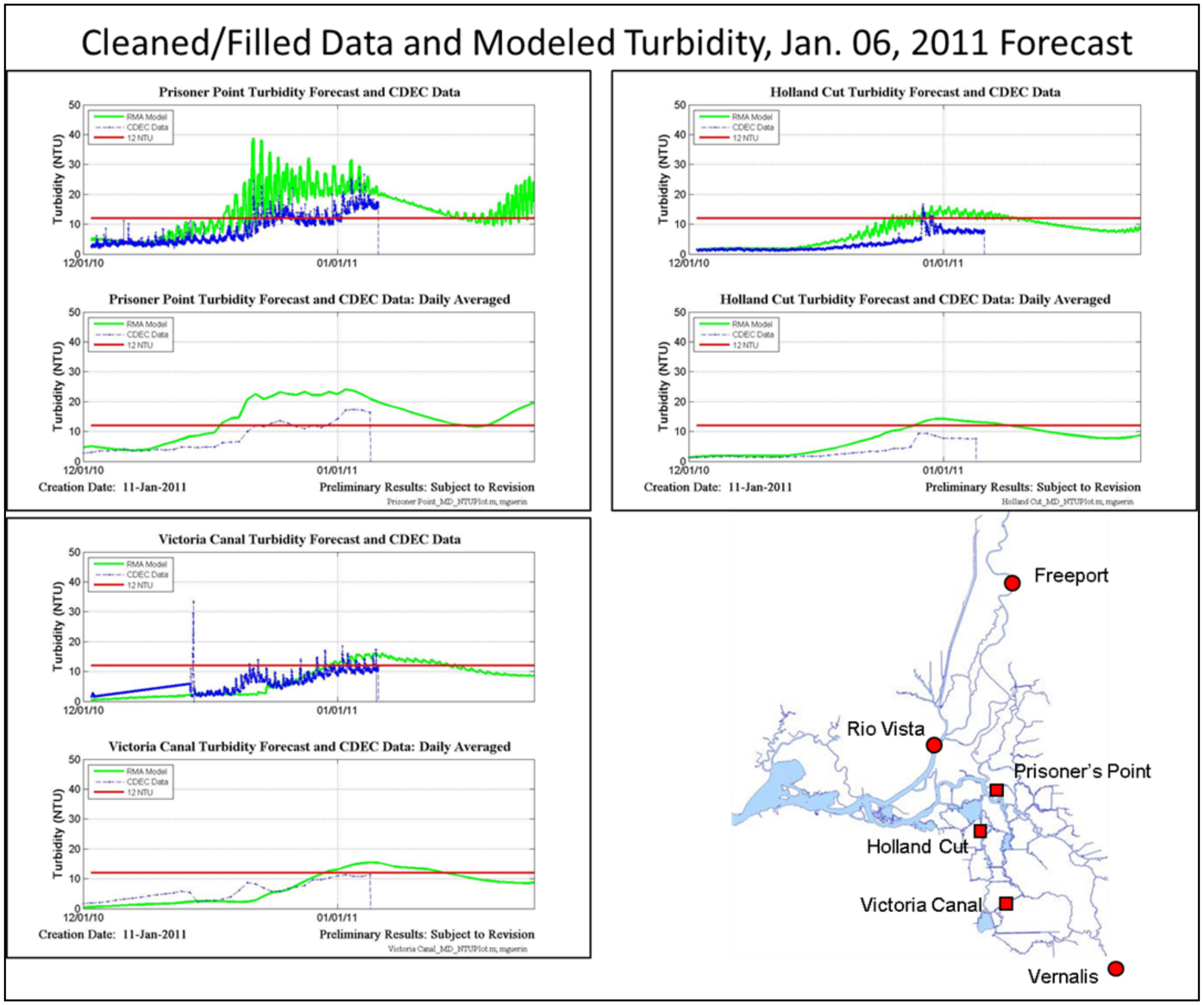

Figure 12-41 Modeled turbidity and data (cleaned and filled) at the three compliance locations. Both 15-min model output and data and daily averaged plots are shown. Red line illustrates the 12-NTU compliance value.

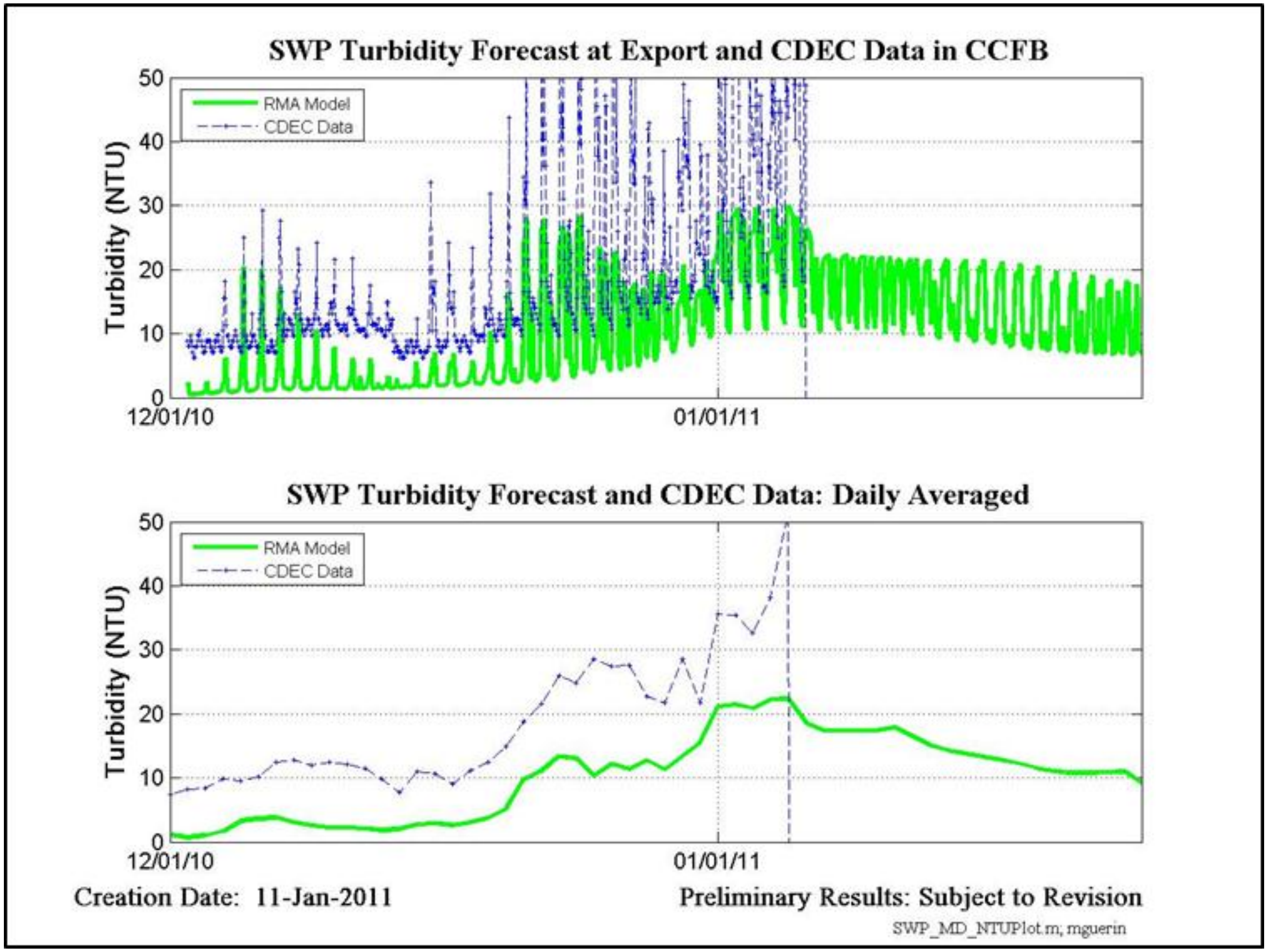

Figure 12-42 Plots compare model output at the SWP export location with data gathered inside Clifton Court Forebay. Both 15-min model output and daily averaged plots are shown.

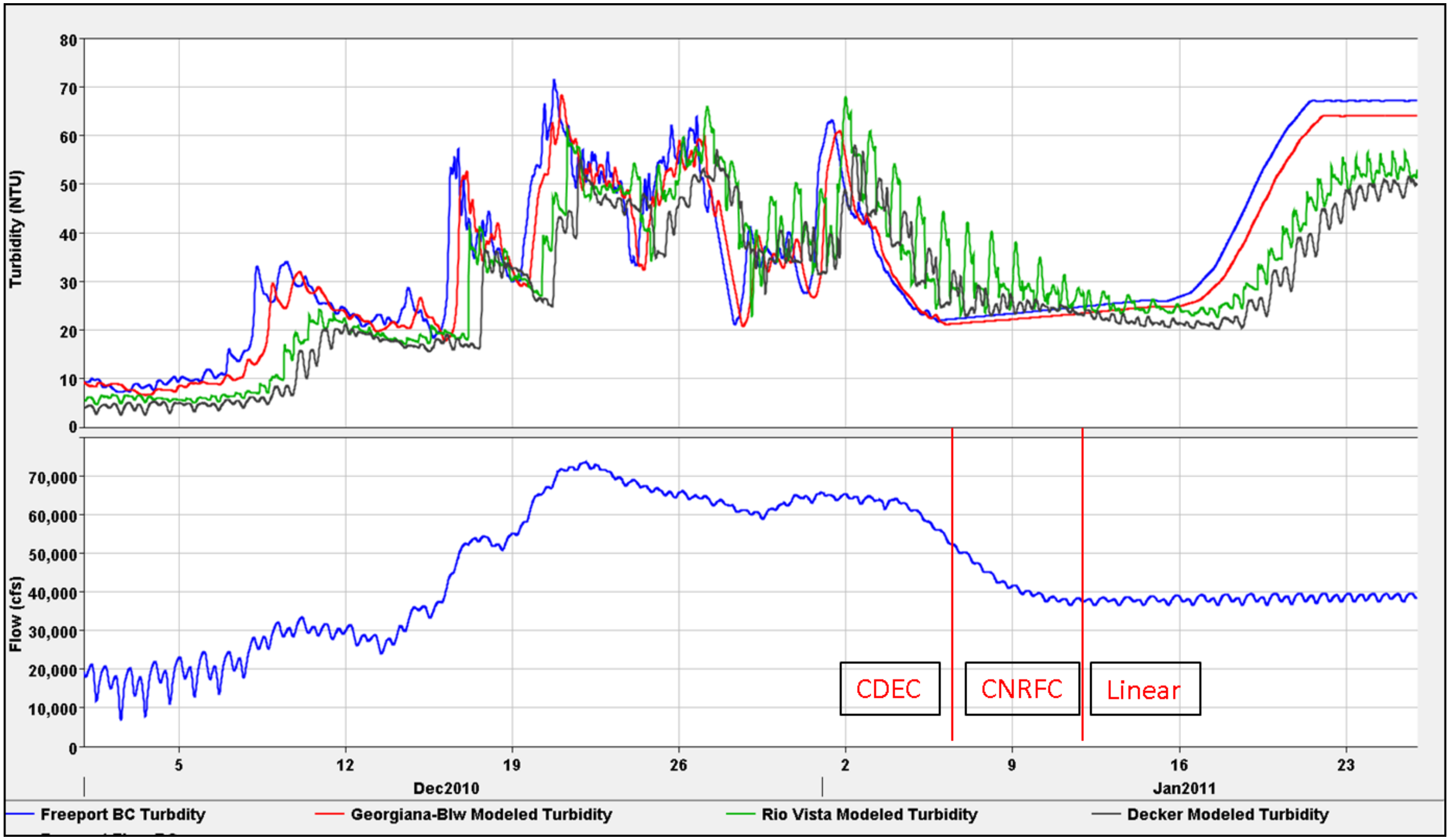

Figure 12-43 Freeport turbidity boundary condition progression down the Sacramento R. (upper plot) along with the flow boundary (lower plot) used during the historical and forecast periods. Forecast began on January 6th.

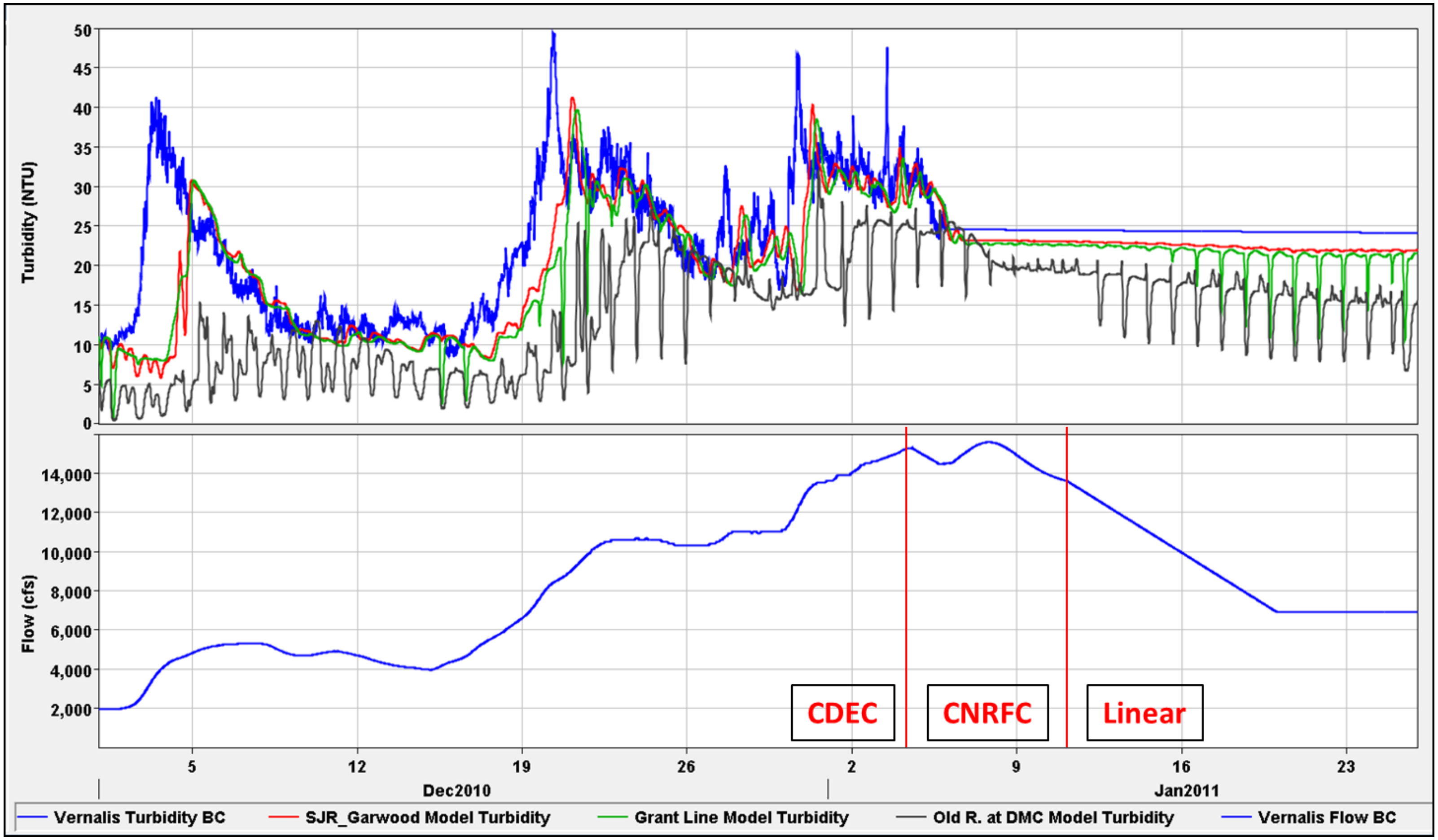

Figure 12-44 Progression of the turbidity boundary condition from Vernalis down the San Joaquin R to Garwood, and down Old R. Vernalis flow forecast periods indicated by red lines (upper plot). Flow boundary conditions at Vernalis are shown in the lower plot.

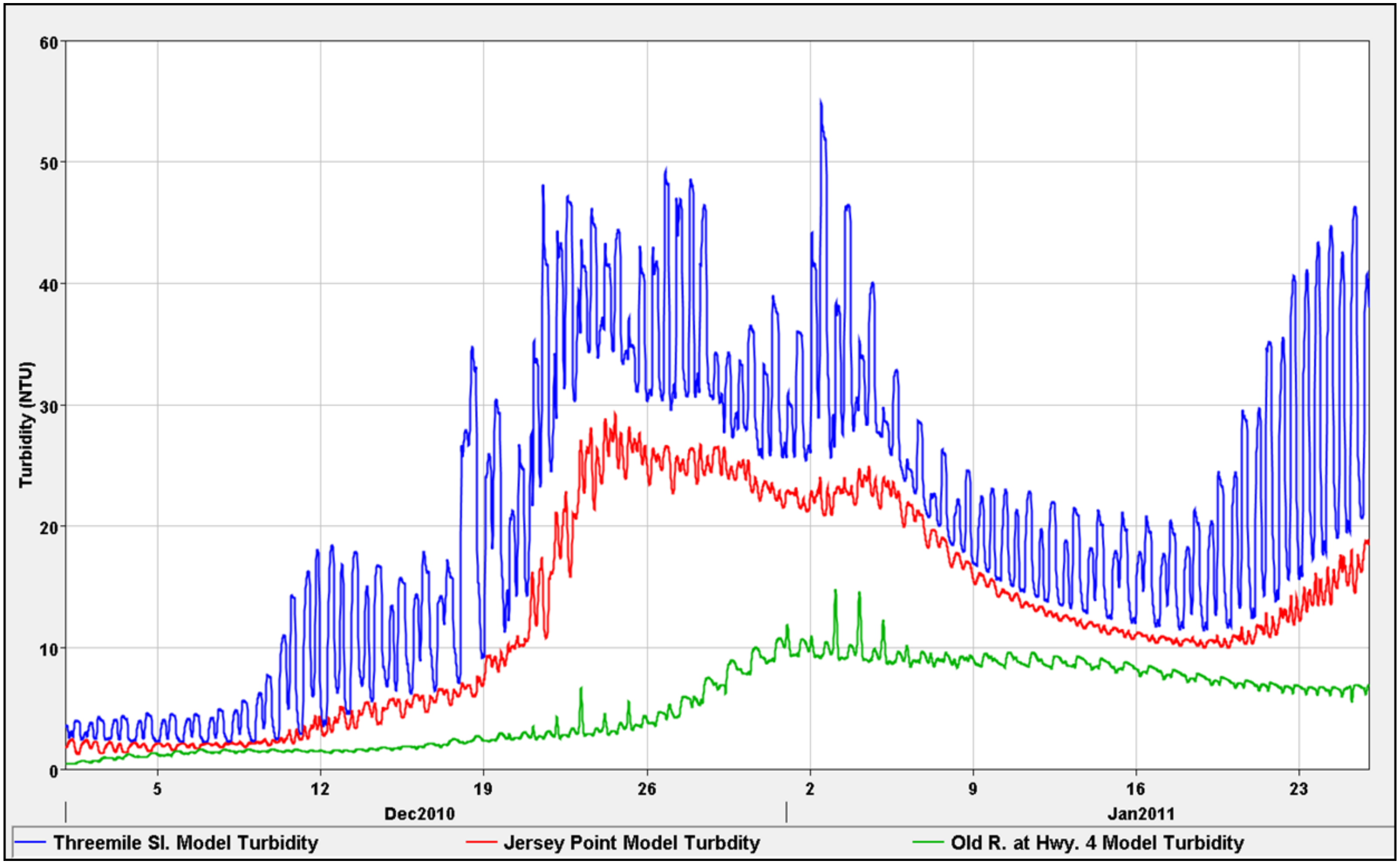

Figure 12-45 Modeled turbidity results at three in-Delta locations – Threemile Sl., Jersey Point and Old River at Highway 4.

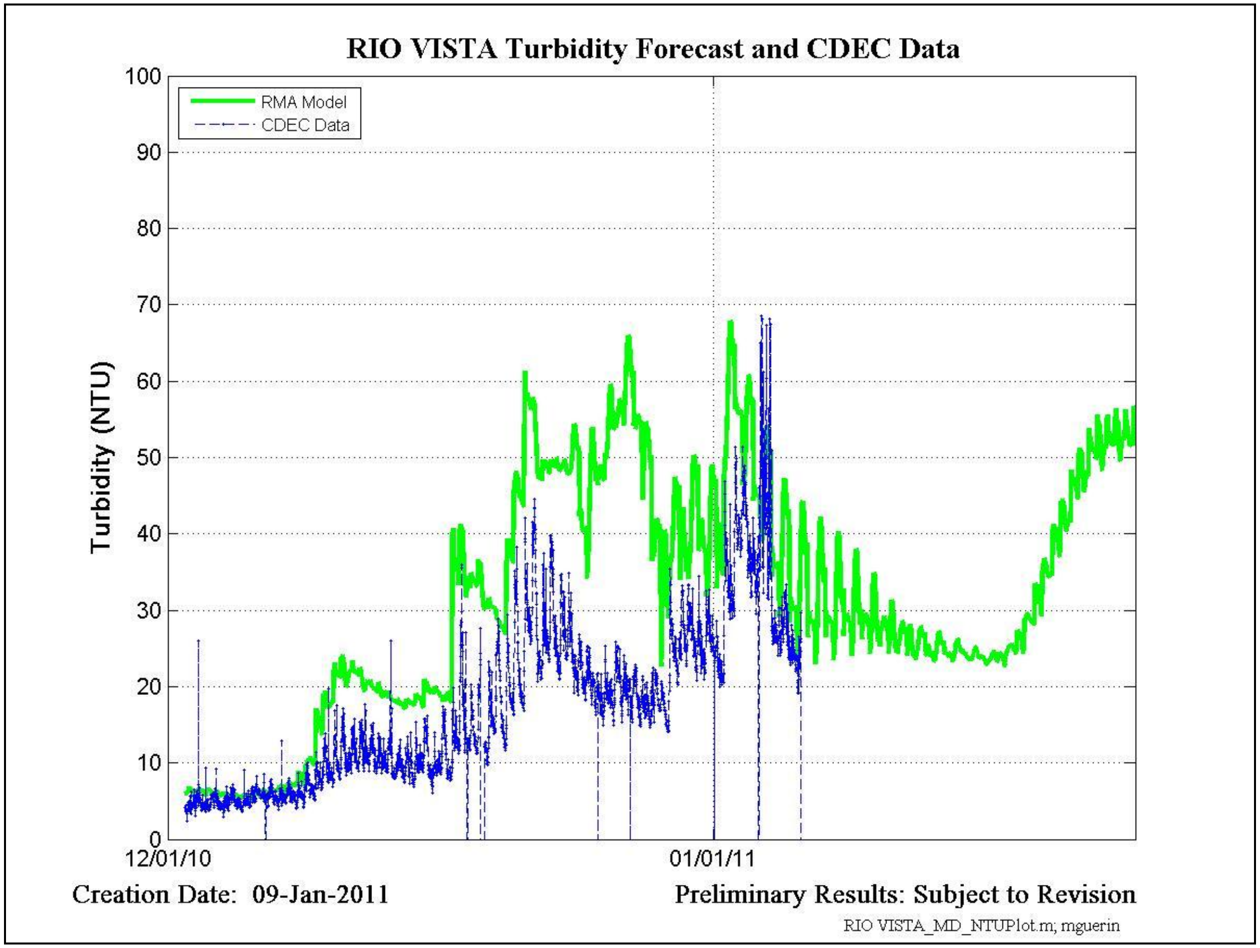

Figure 12-46 Model forecast and CDEC data at Rio Vista.

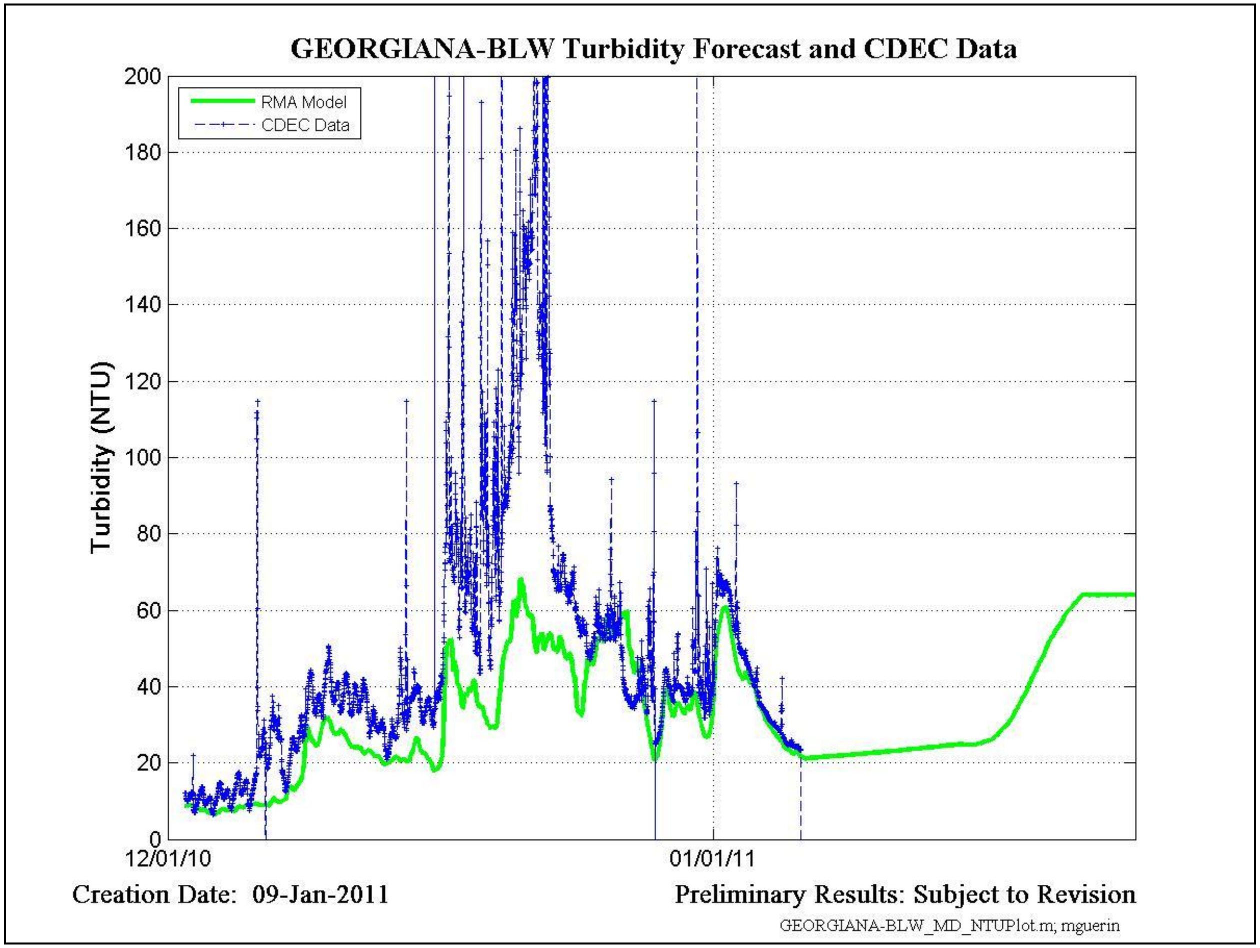

Figure 12-47 Model forecast and CDEC data at Georgian-BLW.

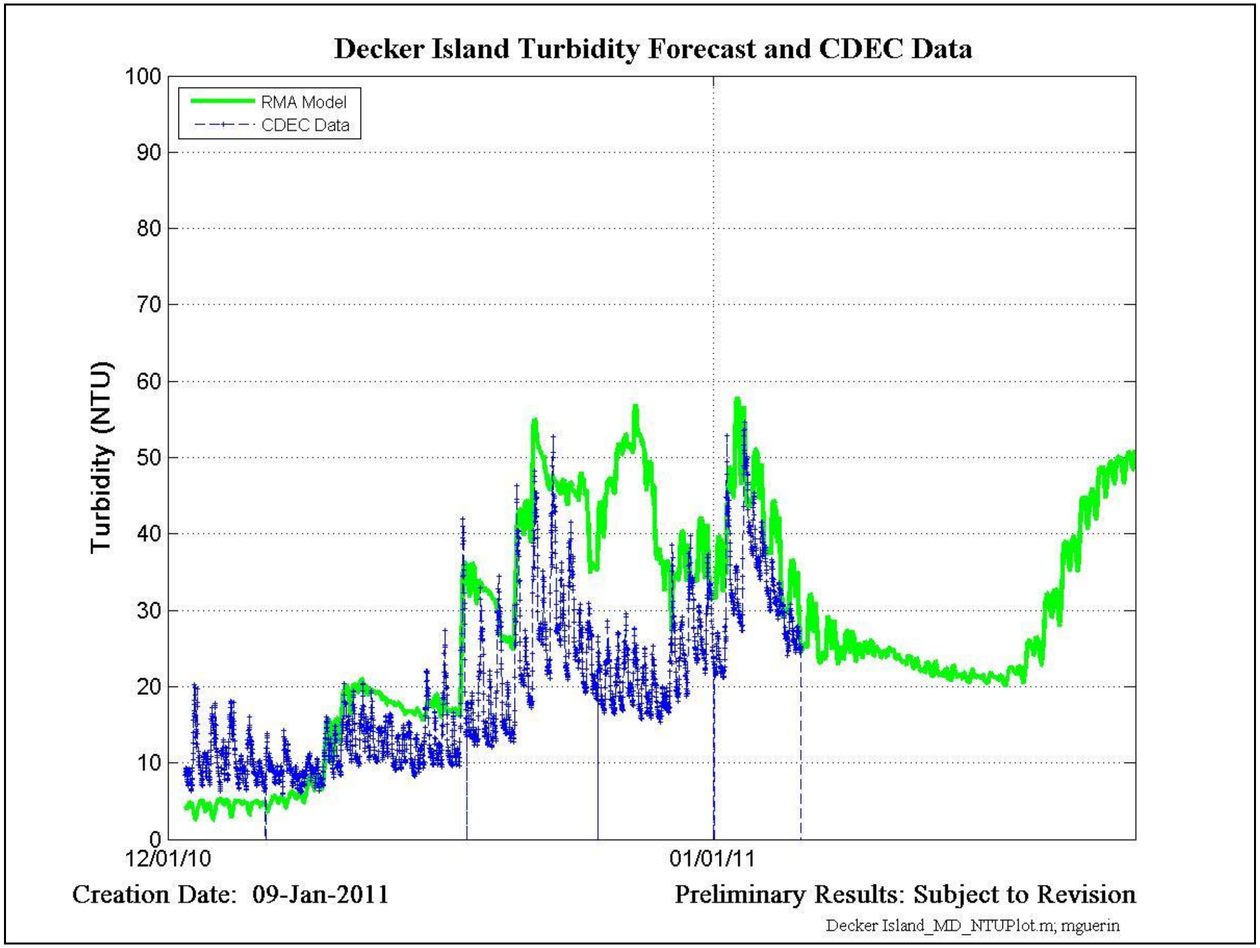

Figure 12-48 Model forecast and CDEC data at Decker Island.

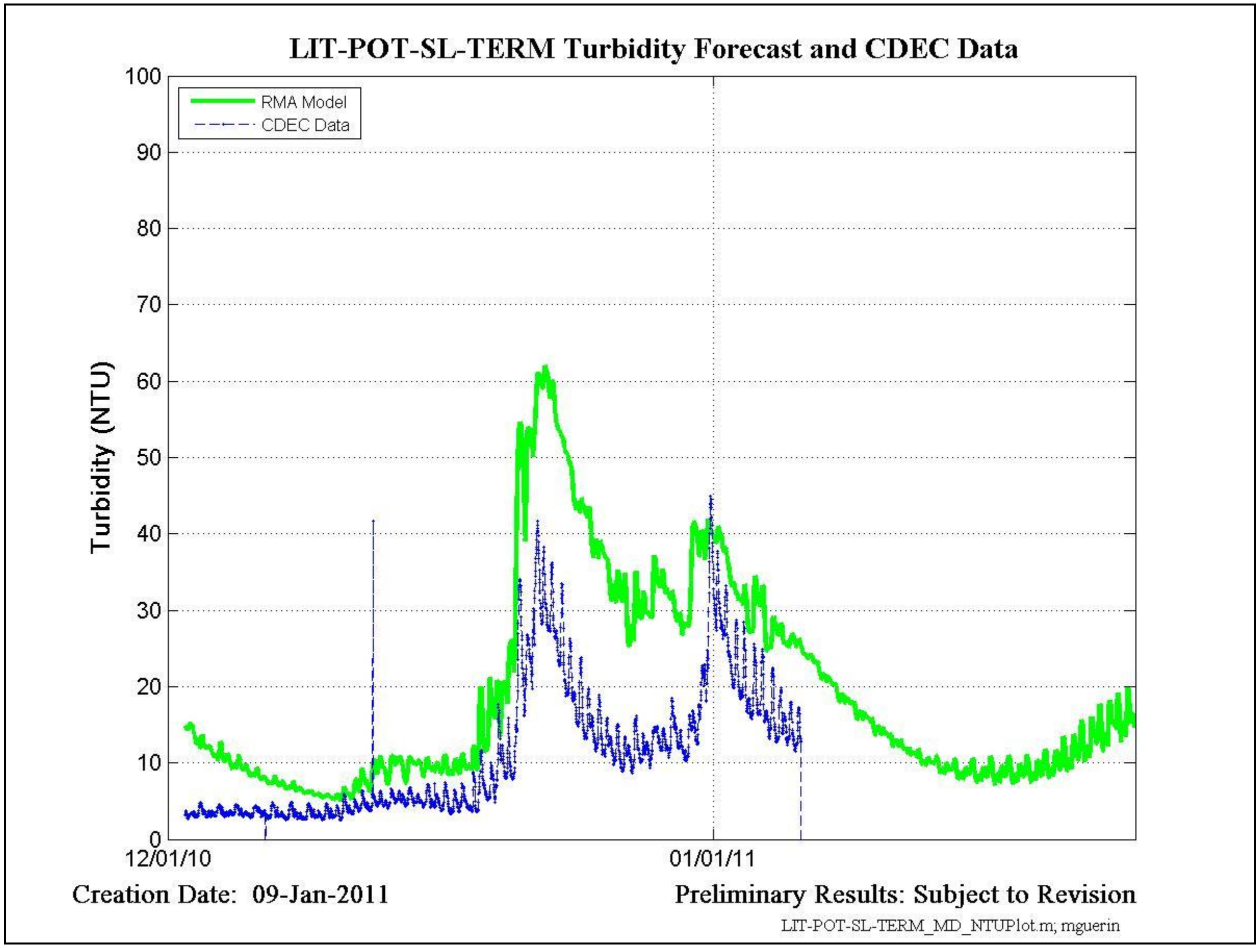

Figure 12-49 Model forecast and CDEC data at Little Potato Slough at Terminous.

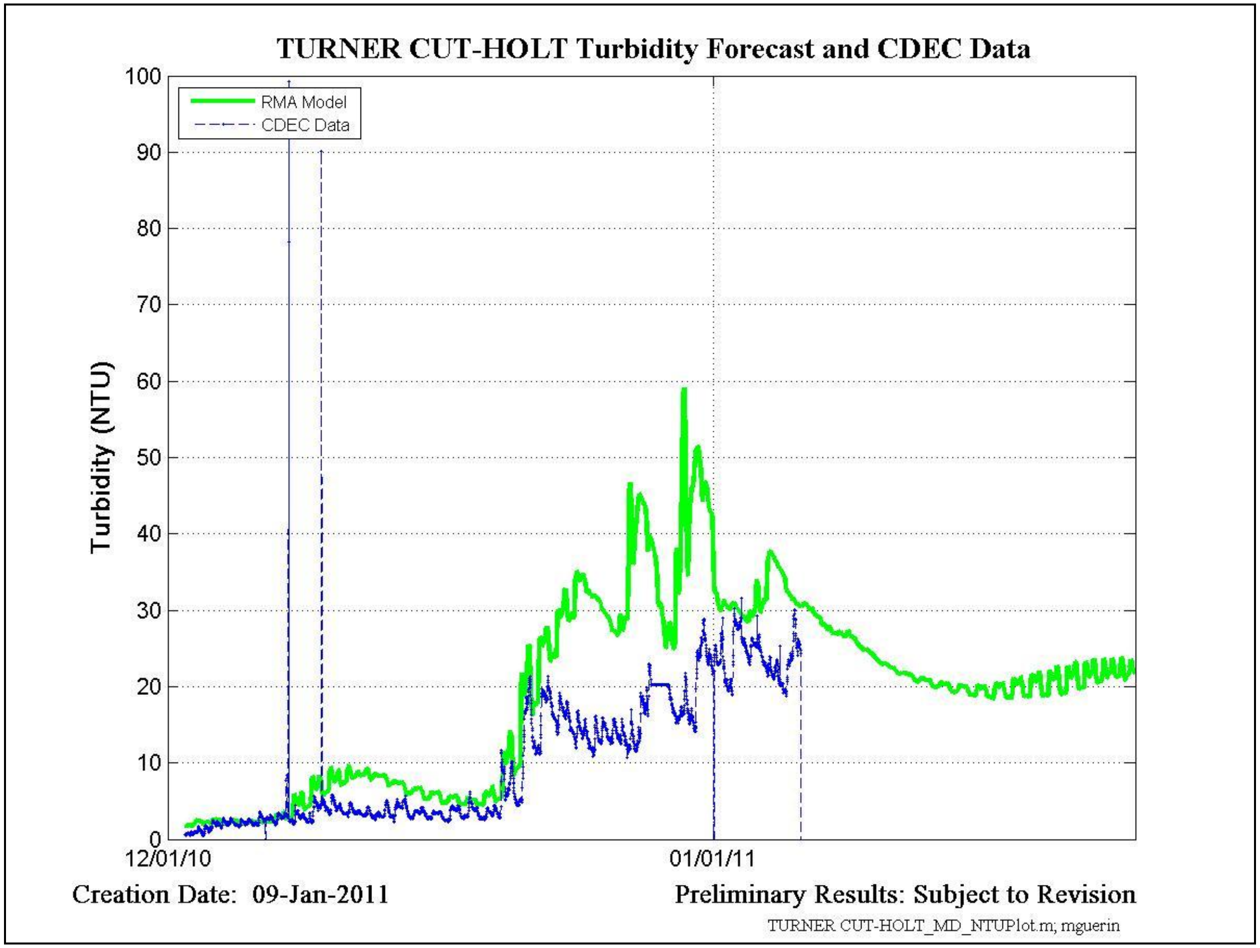

Figure 12-50 Model forecast and CDEC data at Turner Cut near Holt.

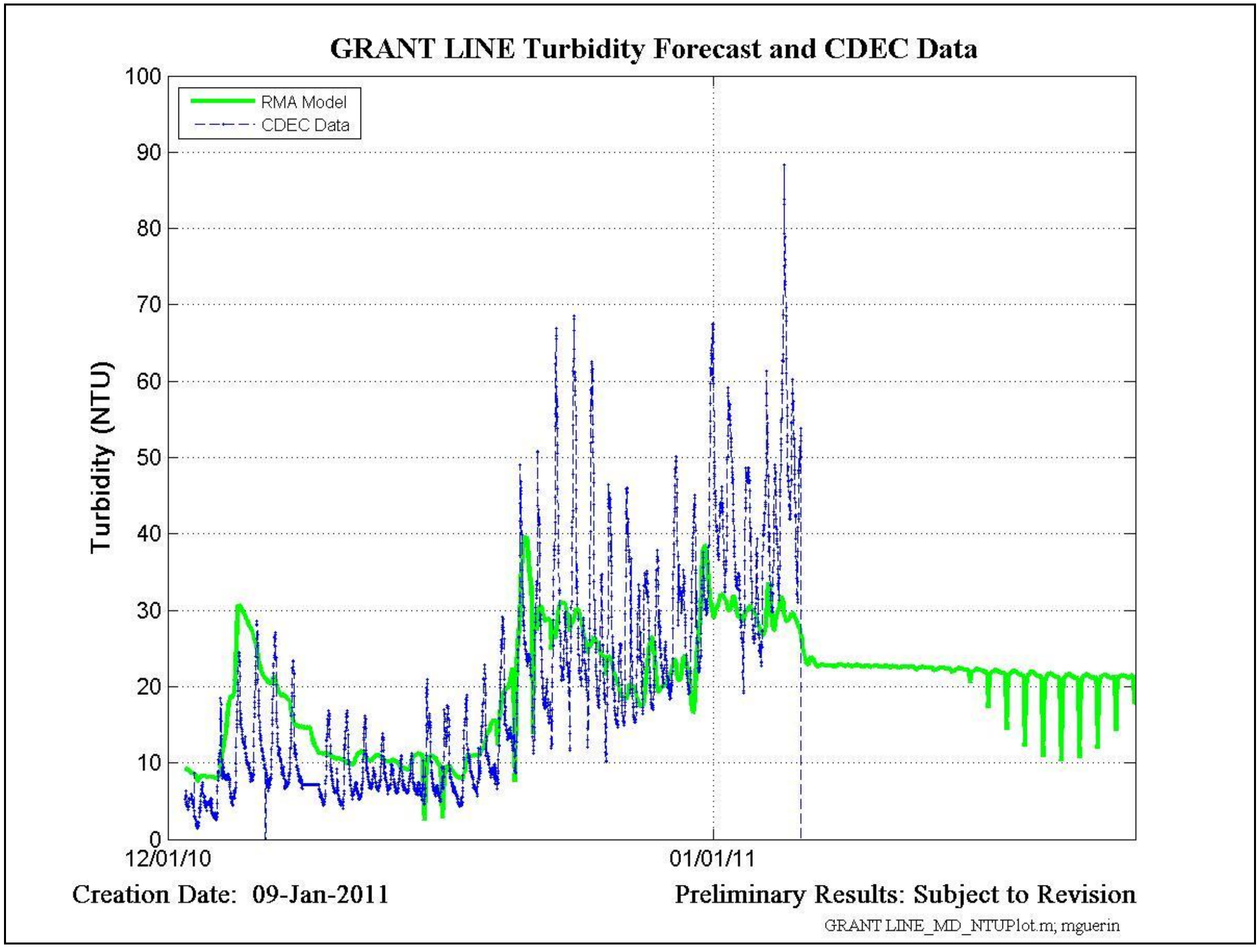

Figure 12-51 Model forecast and CDEC data at Grant Line.

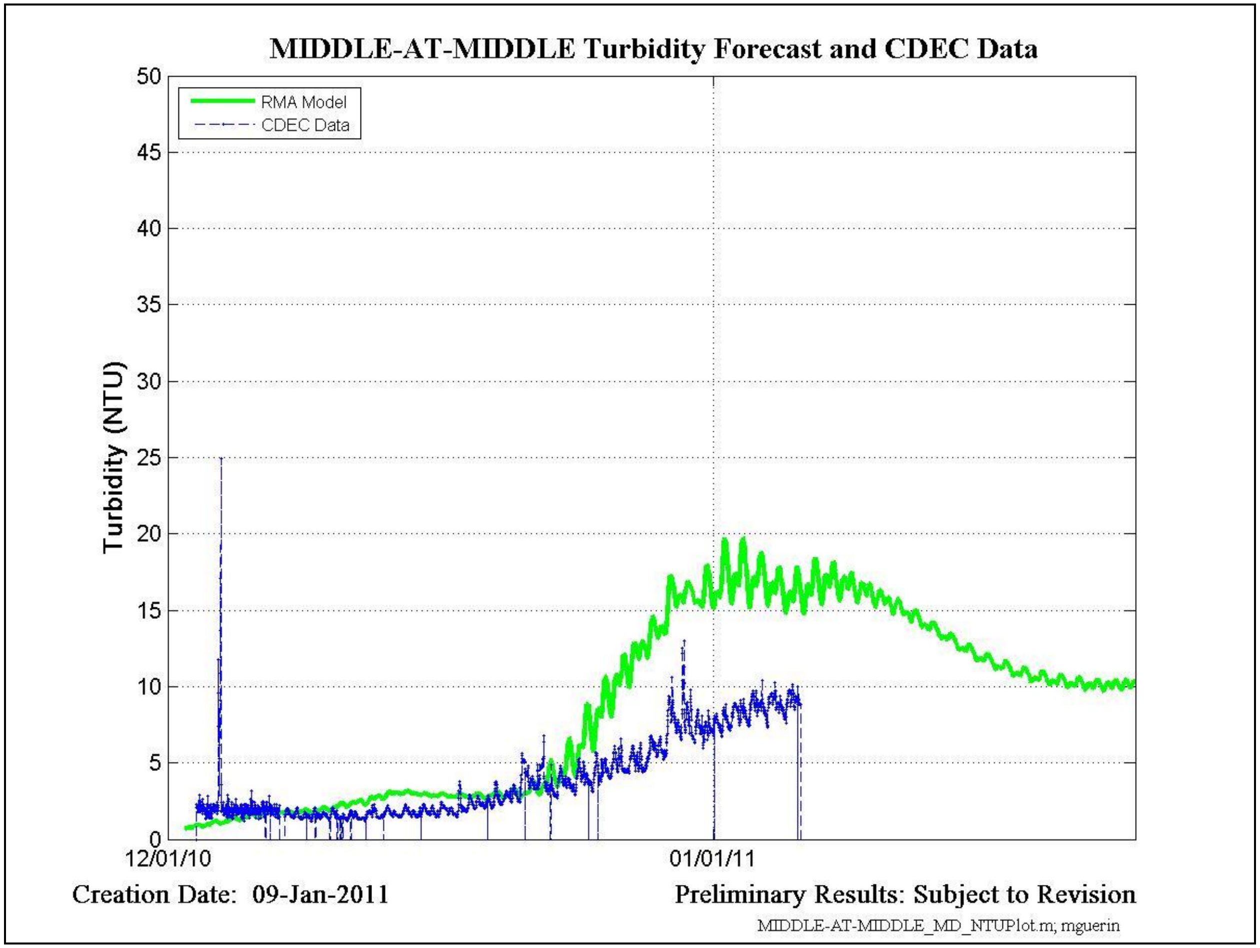

Figure 12-52 Model forecast and CDEC data at Middle R. at Middle R.

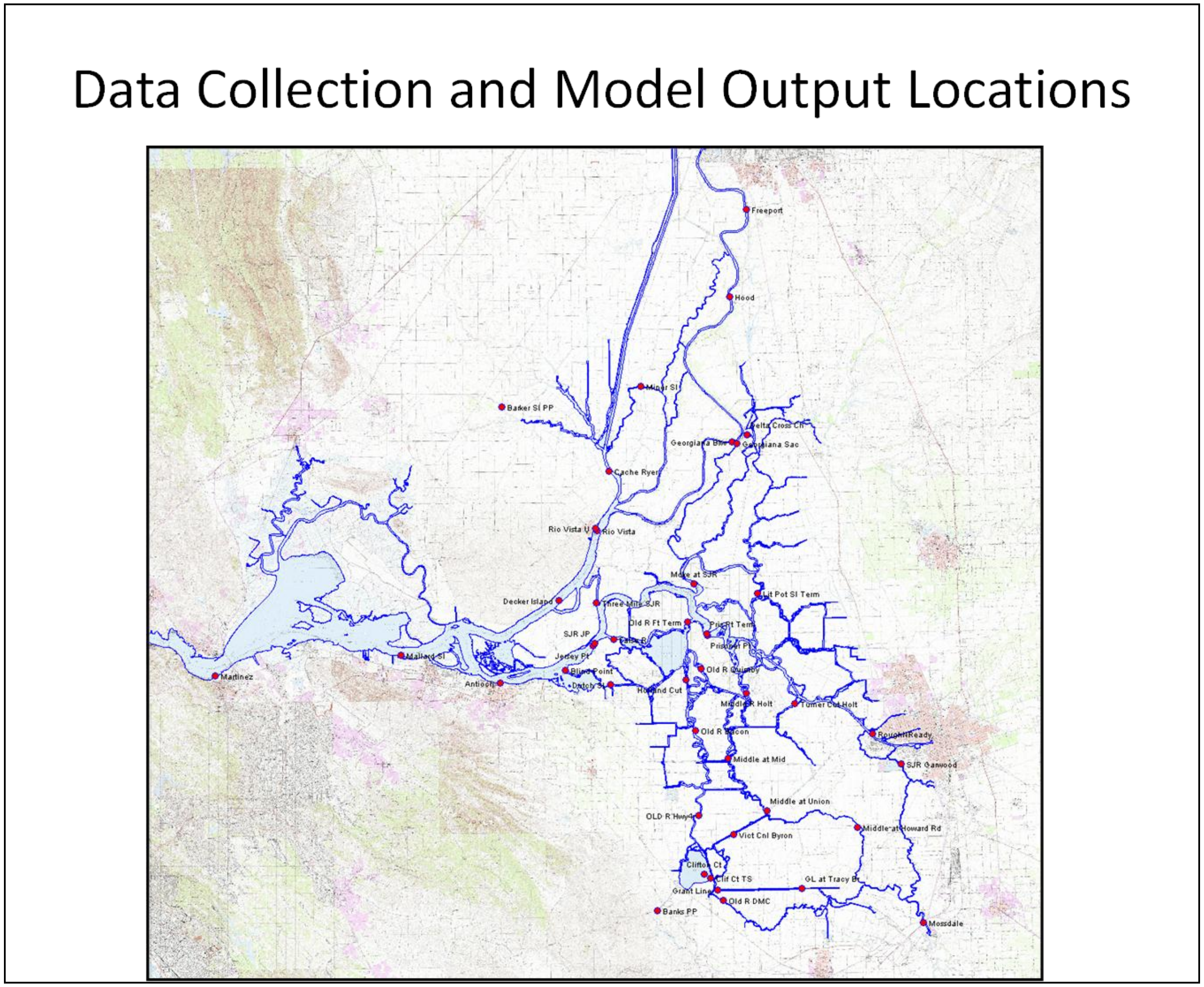

Figure 12-53 Figure illustrating model output and data collection locations.

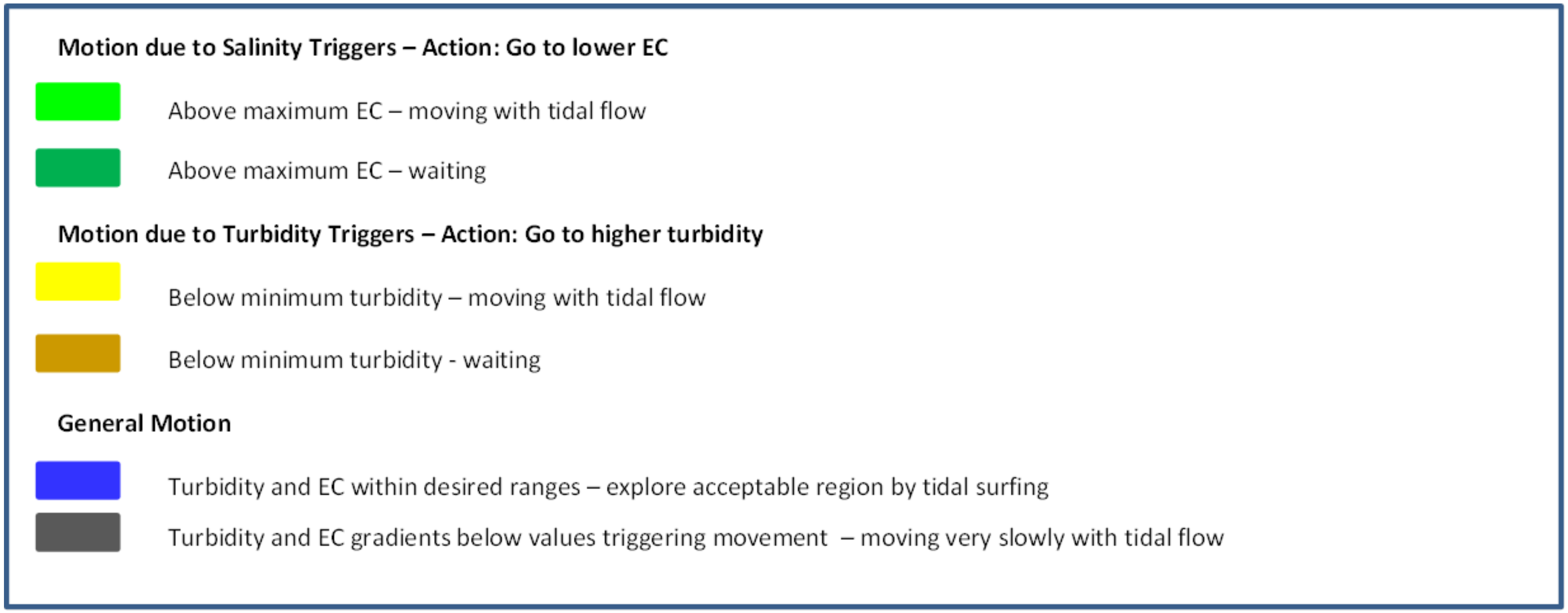

Figure 12-54 Particles in the Adult Delta Smelt particle tracking model are color-coded by the triggers influencing their behavior during the simulation. Use this figure to interpret the simplified color scale in the next three figures.

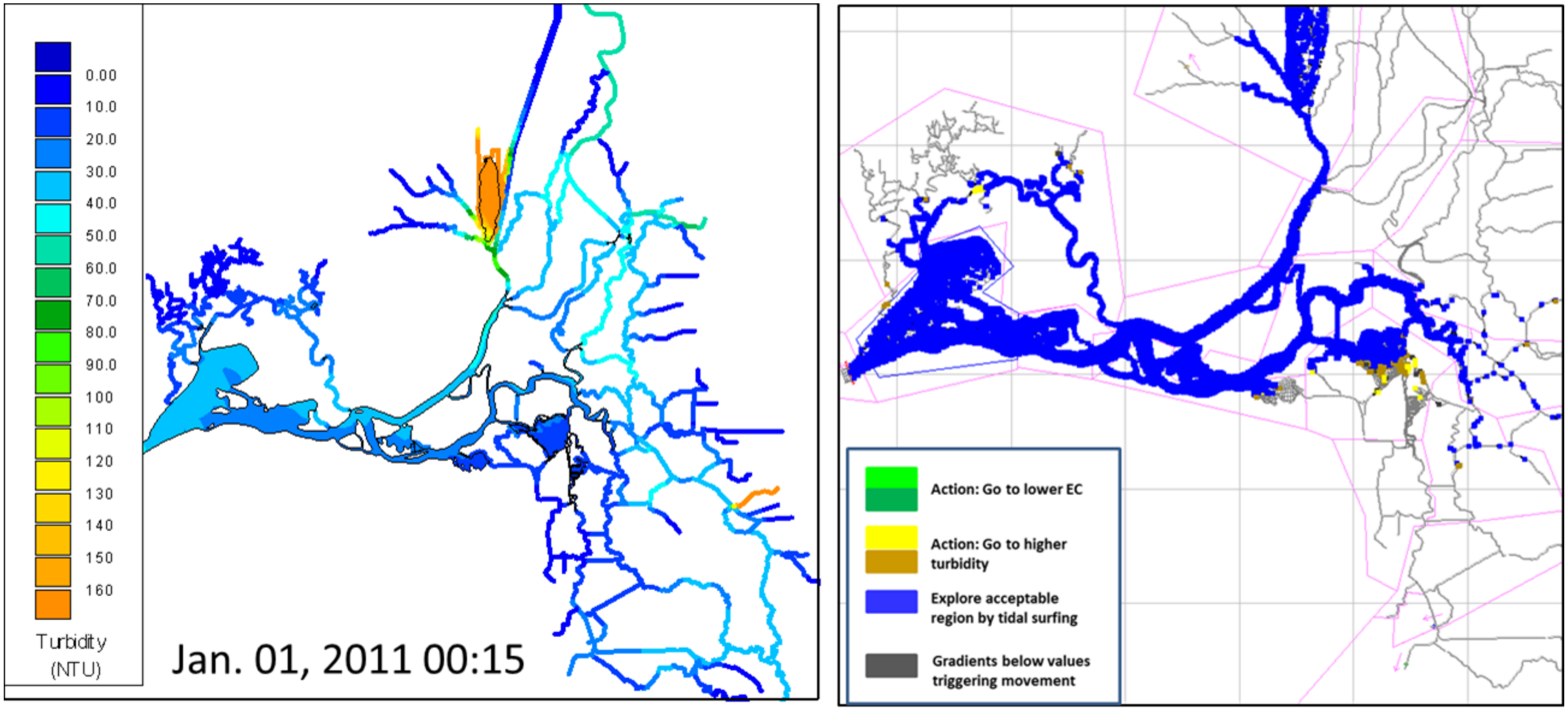

Figure 12-55 Turbidity contours and particle location in the RMA model grid on Jan. 01, 2011.

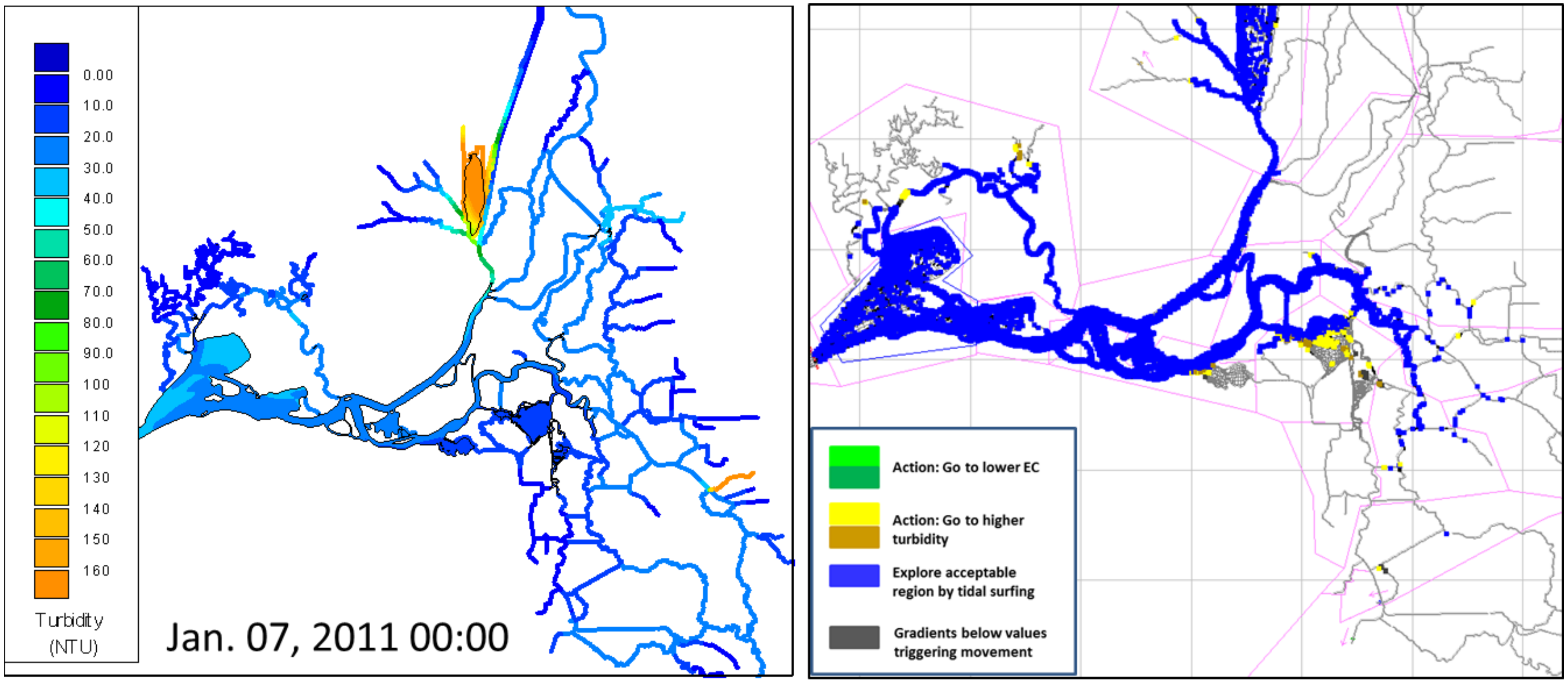

Figure 12-56 Turbidity contours and particle location in the RMA model grid on Jan. 07, 2011.

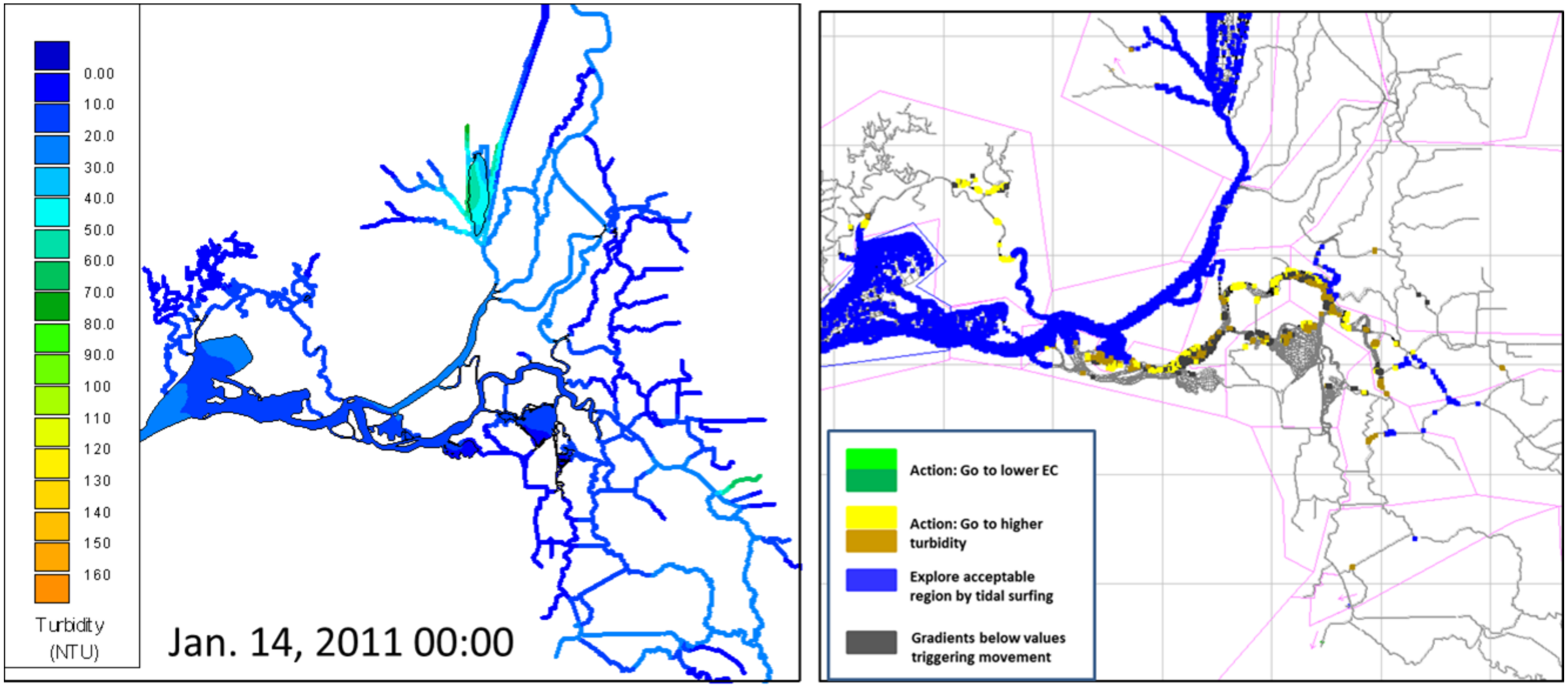

Figure 12-57 Turbidity contours and particle location in the RMA model grid on Jan. 14, 2010.

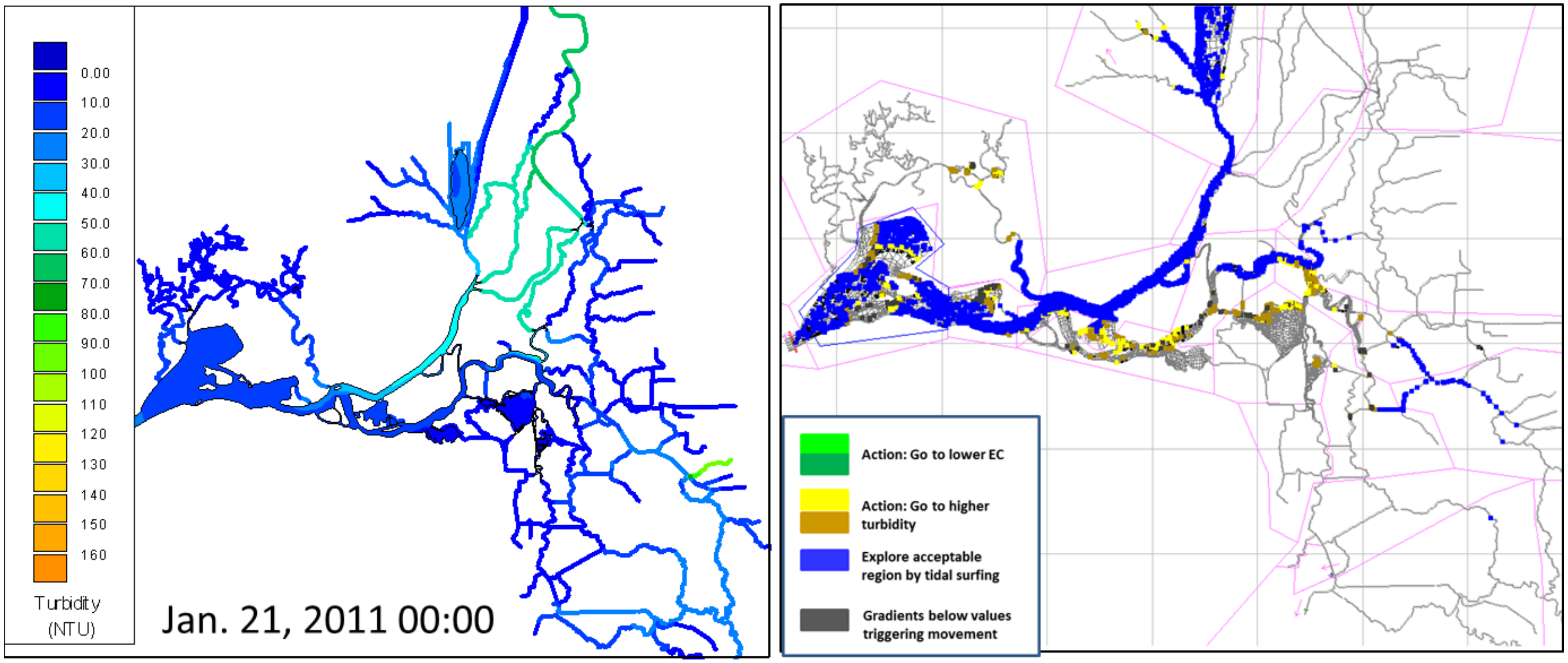

Figure 12-58 Turbidity contours and particle location in the RMA model grid on Jan. 21, 2010.

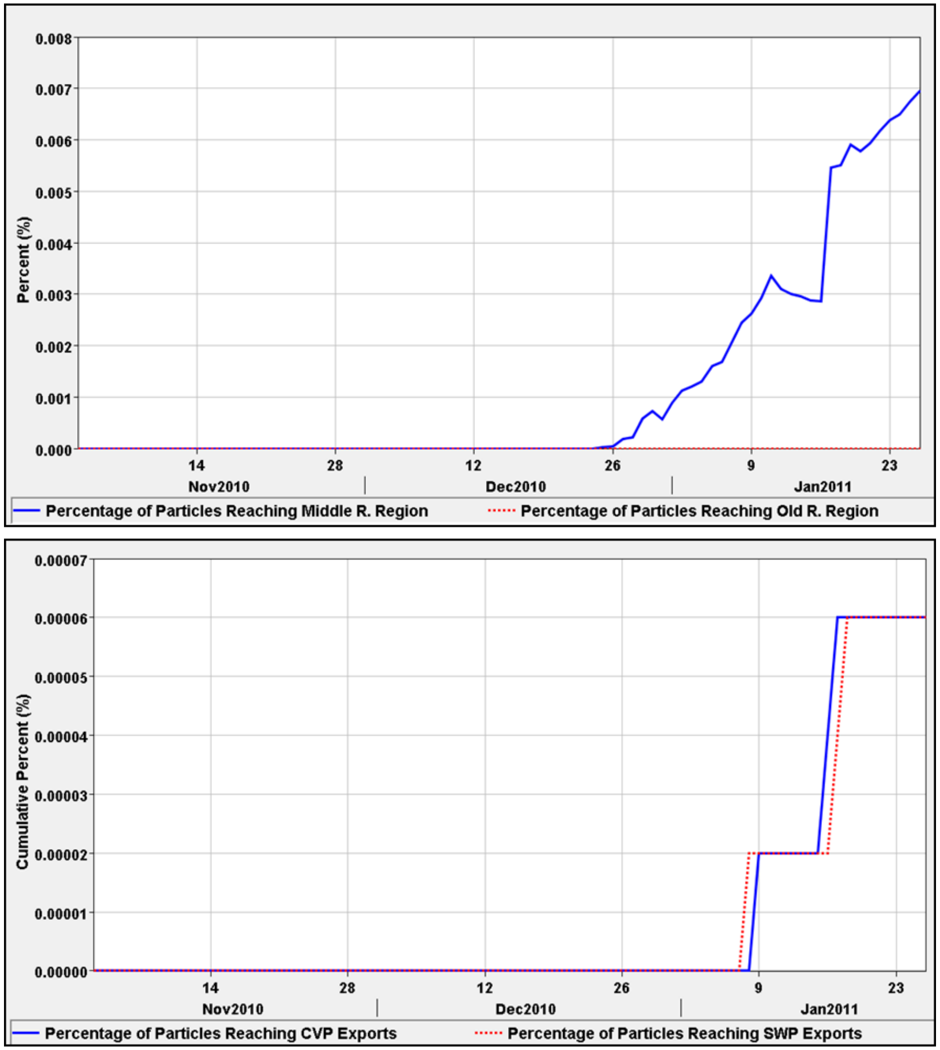

Figure 12-59 Only a couple of particles reached the export locations (lower plot, cumulative percentage). Some particles reached the Middle River Region (upper plot). No particles entered the Old River region.

12.3.4. Forecast Jan. 13, 2011

This document provides a quick summary of the January 13, 2011 forecast prepared using the RMA hydrodynamic, salinity, turbidity and Adult Delta Smelt Behavioral models. Graphical results are provided to document the results of the modeling with a focus on turbidity. Model BC (Boundary Conditions) for the forecast model were prepared using WARMF-supplied forecast conditions, CNRFC flow data and predictions, CDEC and USGS data, and DWR-supplied model inputs and results from their flow and salinity forecasts.

This simulation is similar to the one prepared on Jan. 06, 2011, except that more WARMF boundary conditions were incorporated (for EC) to allow eventual comparison of how the model output varied with these changes between the two forecast dates.

The RMA modeled period was December 01, 2010 to January 31, 2011 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 Jan. 01, 2011 through January 31, 2011. The WARMF model forecast period, consisting of daily model output for flow, salinity and turbidity, was Jan. 01 – Jan. 27, 2011. Additional flow, turbidity and EC data was downloaded for the period Jan 06 – Jan 12/13, 2010 from the CDEC, CNRFC and USGS websites to augment previous data.

In general, producing BC during this forecast period was challenging as it was for the Jan. 6^{th} forecast, due to the number of data sources, data discrepancies, and Table 12-9 the need to piece the data together for BC. Historical and forecast BC were developed from several sources, as summarized in Table 12-9 below. As a consequence, where there were discrepancies BC were compiled using best professional judgment. Stage and export BC were compiled solely from DWR O&M sources. Boundary conditions were synthesized or obtained from the DWR forecast for the period Jan. 01 – Jan. 31, 2011.

WARMF boundary condition estimates for turbidity and EC were used at all locations except Vernalis and Freeport. See Table 1 for BC sources and timing. BC time series were extended as constants to fill the forecast time frame.

Plots are included below as a pictorial summary of the model results.

Figure 12-67 illustrates a comparison of model output and data at the three compliance locations, and Figure 12-68 illustrates a similar comparison in the SWP export area. Note that Figure 12-68 is a comparison of data inside Clifton Court Forebay with model output at the model boundary at the entrance to the Forebay. For these plots, model and data were used at 15-min or hourly time intervals, as collected or modeled, and also daily averaged.

Only at the Holland Cut compliance location did averaged data remain below 12 NTU – modeled turbidity exceeded the 12 NTU value at each compliance location (**Figure 12-67**). Modeled turbidity was high in comparison with data in most of the model domain (**Figure 12-71** through **Figure 12-78**) due to relatively high WARMF turbidity BC (

Figure 12-66) at the Yolo and the eastside inflow locations at the Cosumnes and Calaveras Rivers, which also experienced fairly high flows. Note that WARMF-predicted flows were higher on average than the flows used in the Historical model for December and the first week in January**.**

The Delta Smelt behavioral model was run from Nov. 01, 2010 through Jan 31, 2011 - 50,000 particles were inserted on Nov.01, 2010 as in previous forecast models. Because the historical and forecast boundary conditions are somewhat different than the Jan 6th model during overlapping times, the PTM results are slightly different.

No delta smelt were salvaged at the SWP or CVP locations during the pre-forecast period[9], Nov. 01 – Jan. 13, 2010. A couple of particles reached the SWP export location during the modeled period (*i.e.*, historical plus forecast), and a small percentage of particles entered the Middle R., Victoria and Franks Tract Regions – no particles entered the Old R. Region. See Figure 12-81 through Figure 12-86 for turbidity contour plots and particle tracking model results.

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

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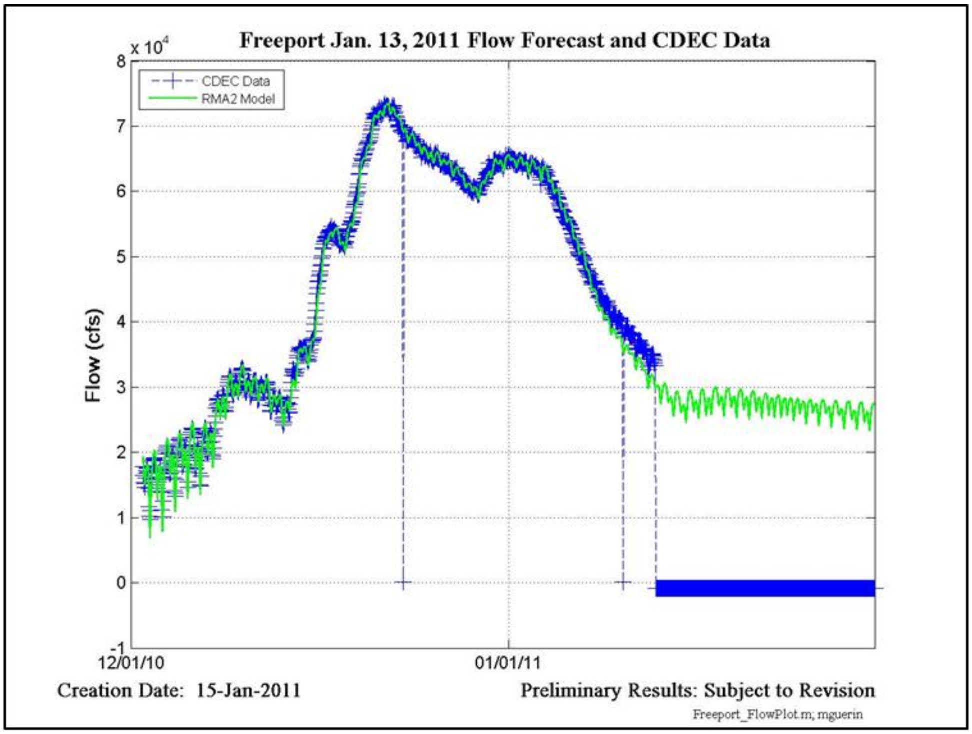
[9] http://www.usbr.gov/mp/cvo/fishrpt.html - Note delta smelt salvage data was not available for the entire historical period, so this statement may change once final salvage data is posted.



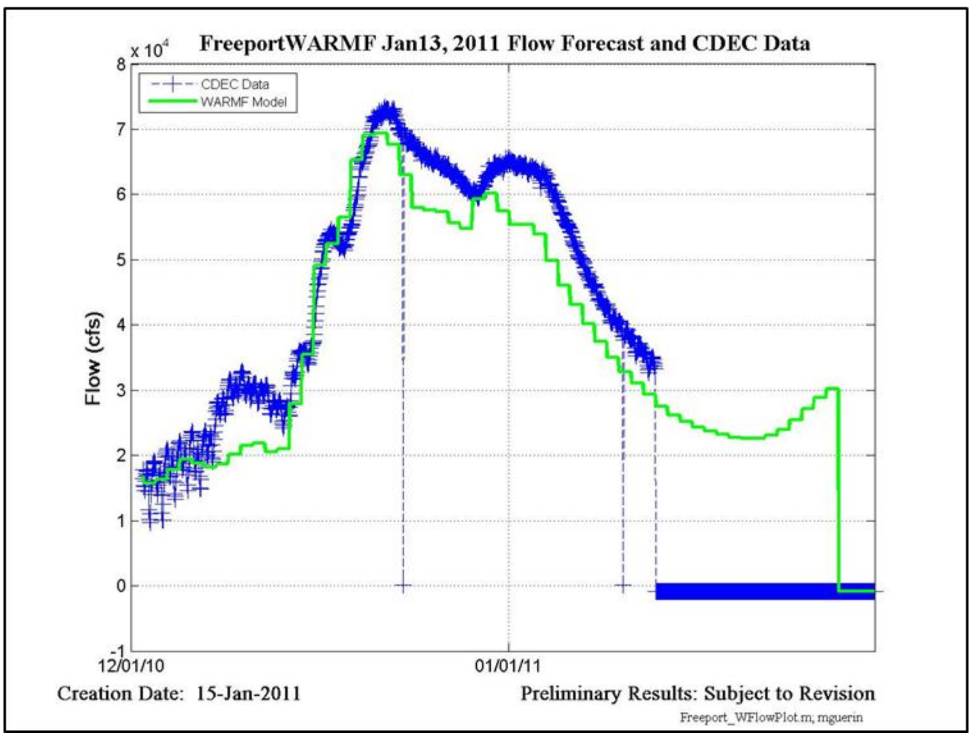
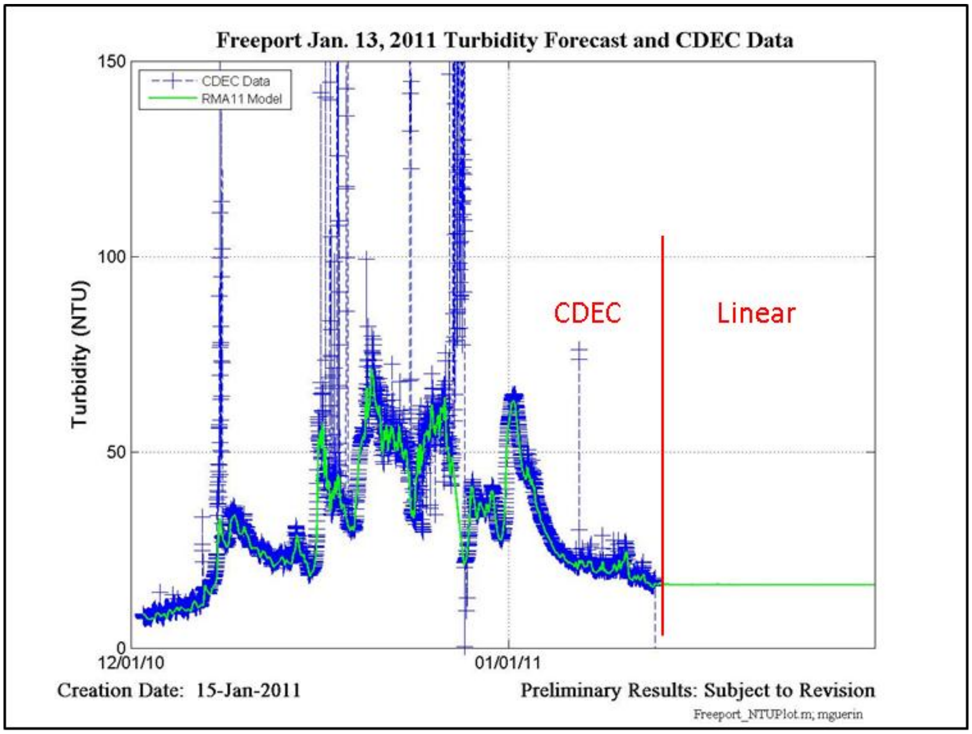


Figure 12-60 Freeport flow BC was compiled from CDEC and CNRFC data, and then extended to a constant flow. Note y-axis unit is cfs*10,000. Zero values indicate the end of data (blue).



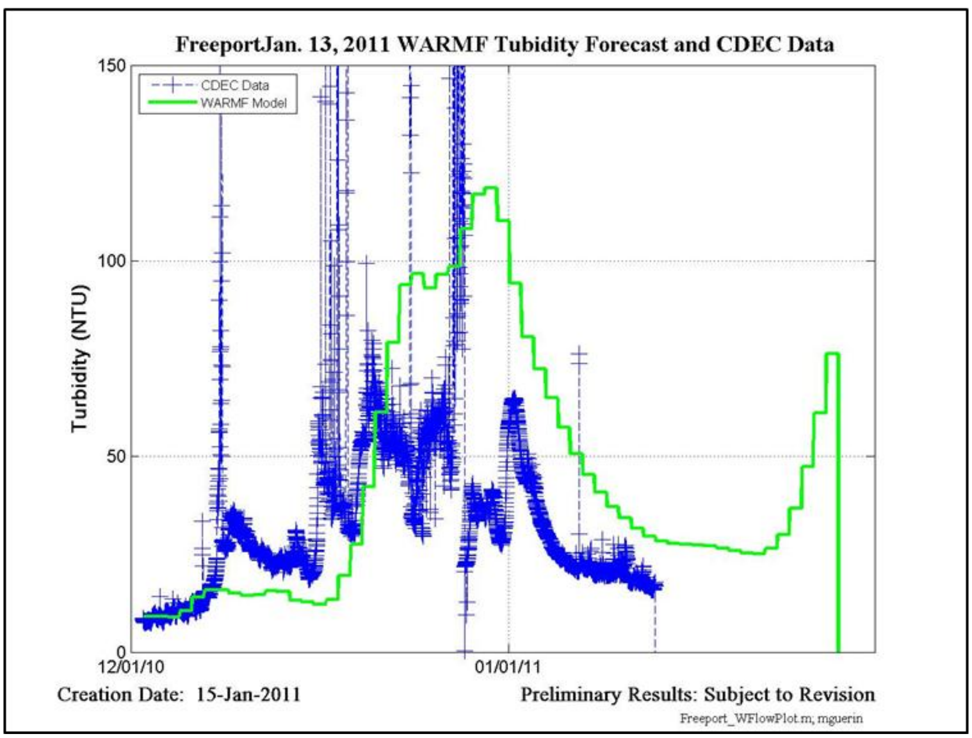


Figure 12-61 Freeport turbidity BC was compiled from CDEC data, then extended as a constant after Jan. 5th, 2011.

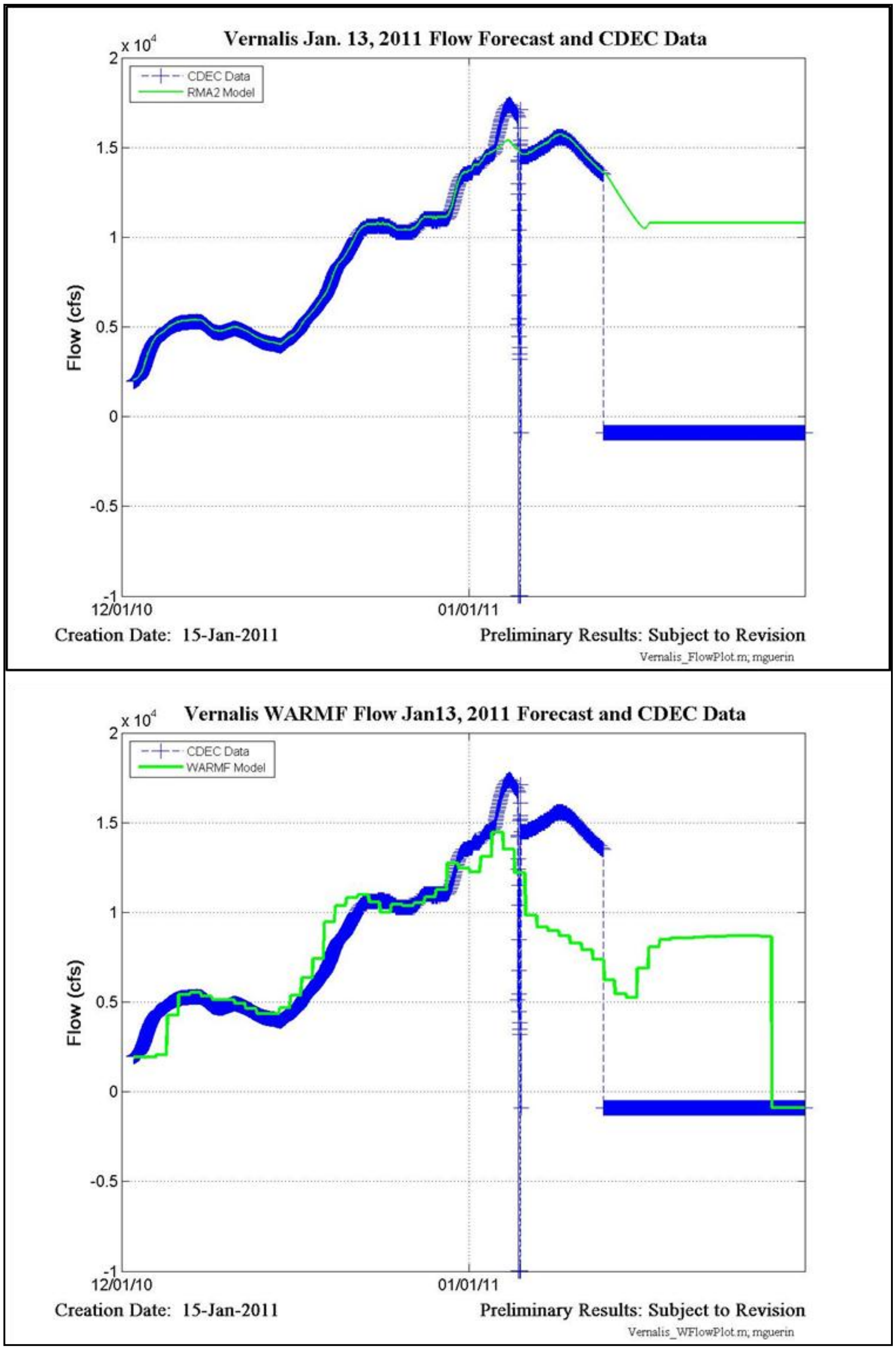


Figure 12-62 Vernalis flow BC was compiled from CDEC and CNRFC data, and then extended to a constant flow indicted by the DWR forecast. Note y-axis unit is cfs*10,000. Zero values indicate the end of data (blue).

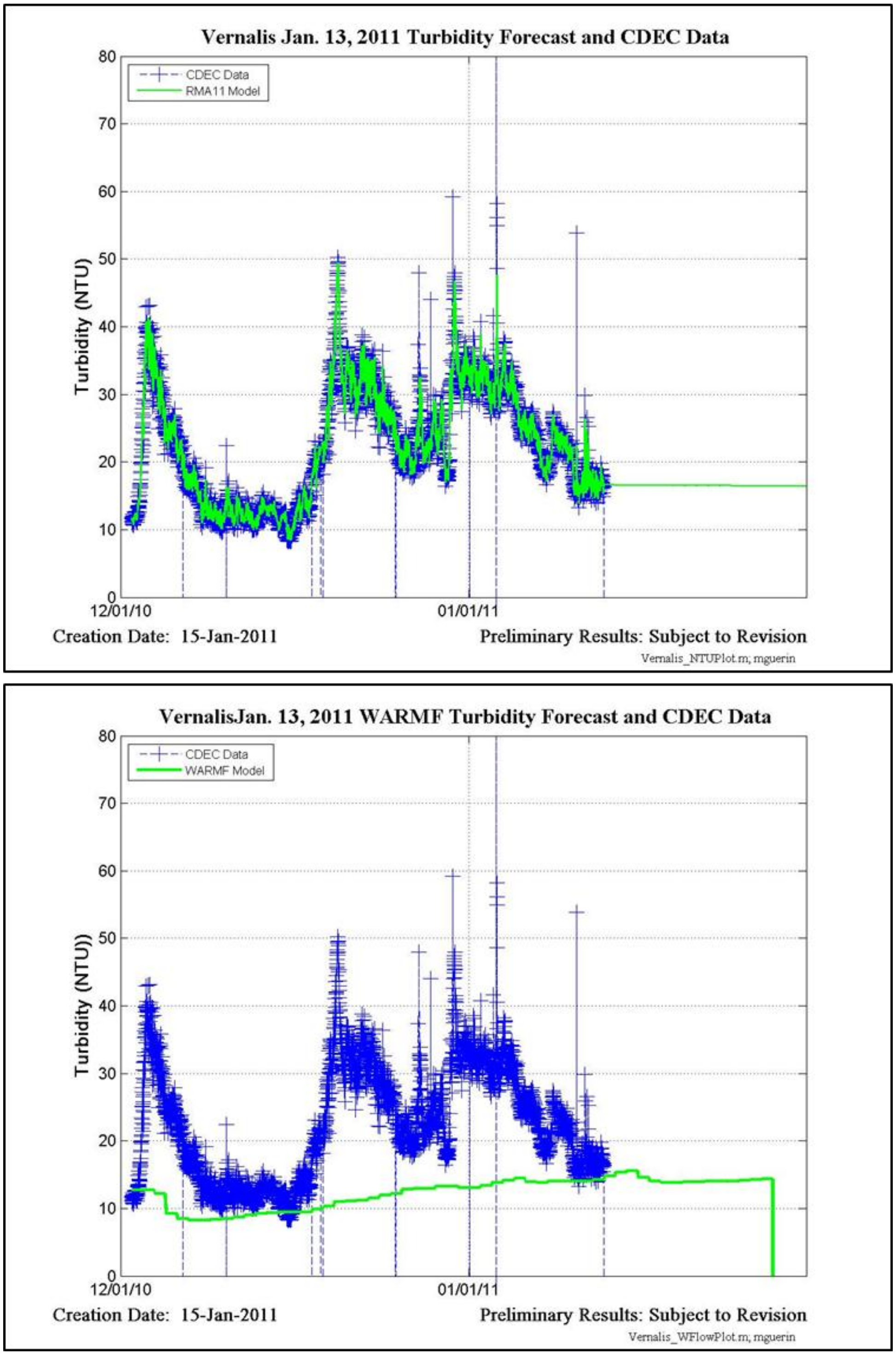


Figure 12-63 Vernalis turbidity BC was compiled from CDEC data, and then extended to a constant. WARMF forecast turbidity was deemed too low to use.

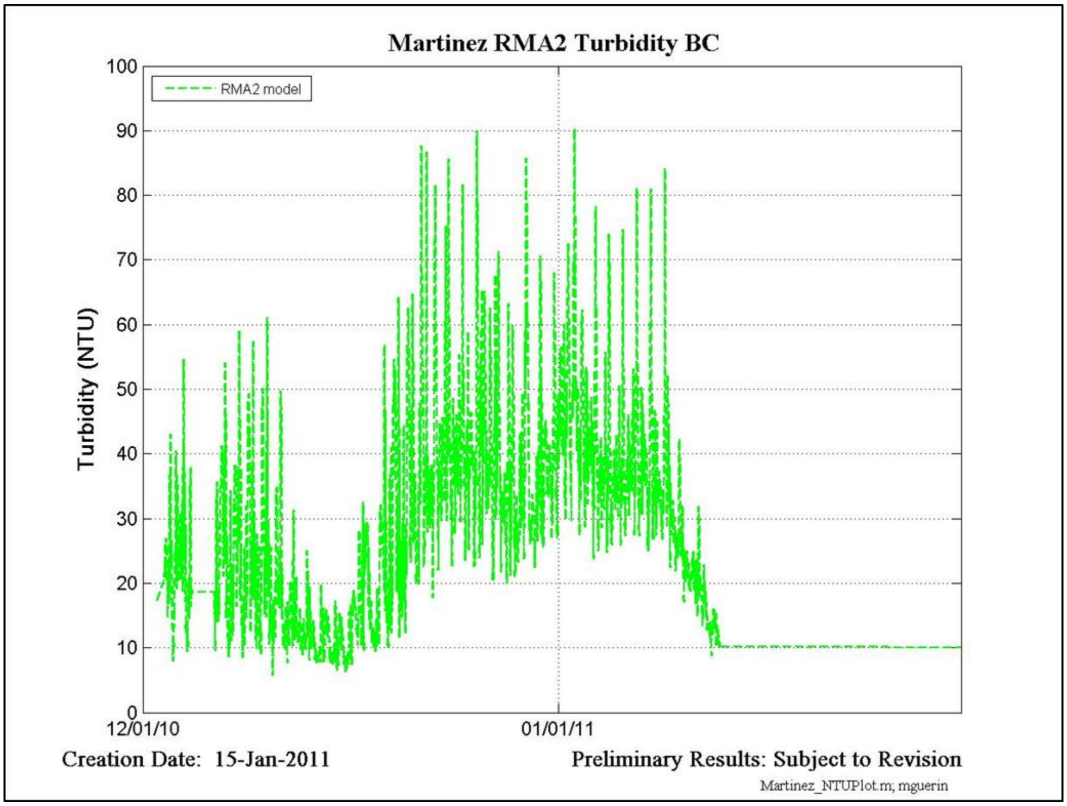


Figure 12-64 Martinez turbidity BC was compiled from CDEC data then extended linearly to a value of 10 NTU.

Table 12-9 Boundary condition development for Jan. 13, 2011 forecast for flow, turbidity and salinity (EC).

Location	**Sources for Flow BC**	**Sources for Turbidity BC**	**Sources for EC BC**
Yolo Bypass at Lisbon	CDEC+USGS, then linear to WARMF 12/17/11 then constant	WARMF	WARMF
Sacramento River at I Street Bridge	CDEC+CNRFC, DWR, then Constant	CDEC, then constant	CDEC+DWR
Cosumnes River	CNRFC, then constant	Use WARMF starting 12/01/2010	WARMF
Mokelumne River	DWR, WARMF start 1/07/2011, then constant	Use WARMF starting 12/01/2010	WARMF
Calaveras River	DWR+CDEC (Mormon Sl.), then constant	Use WARMF starting 12/01/2010	WARMF
San Joaquin River at Vernalis	CDEC+CNRFC, DWR, then Constant	CDEC, then constant	CDEC+DWR

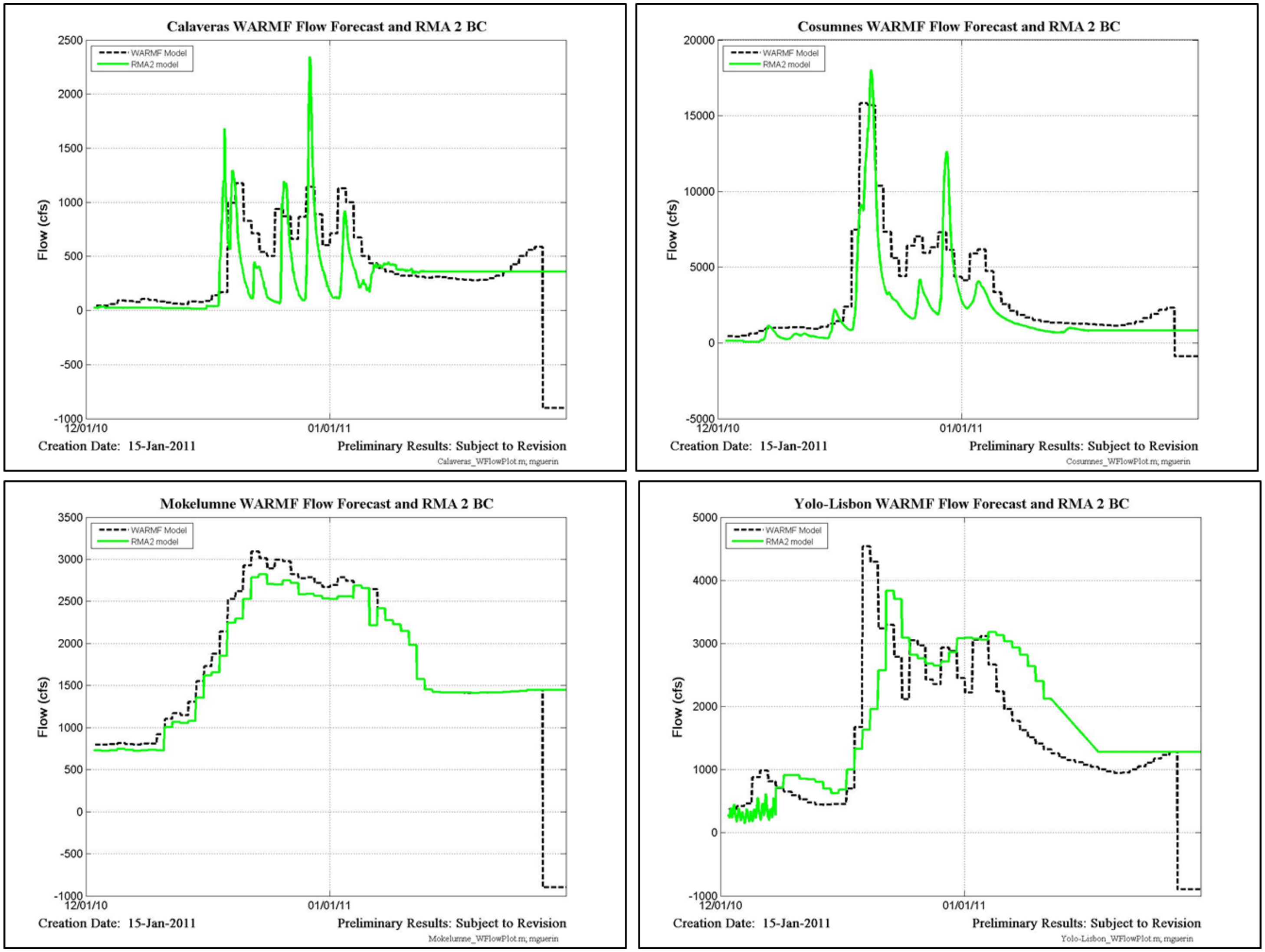


Figure 12-65 Flow boundary conditions used in the model along with the WARMF model output.

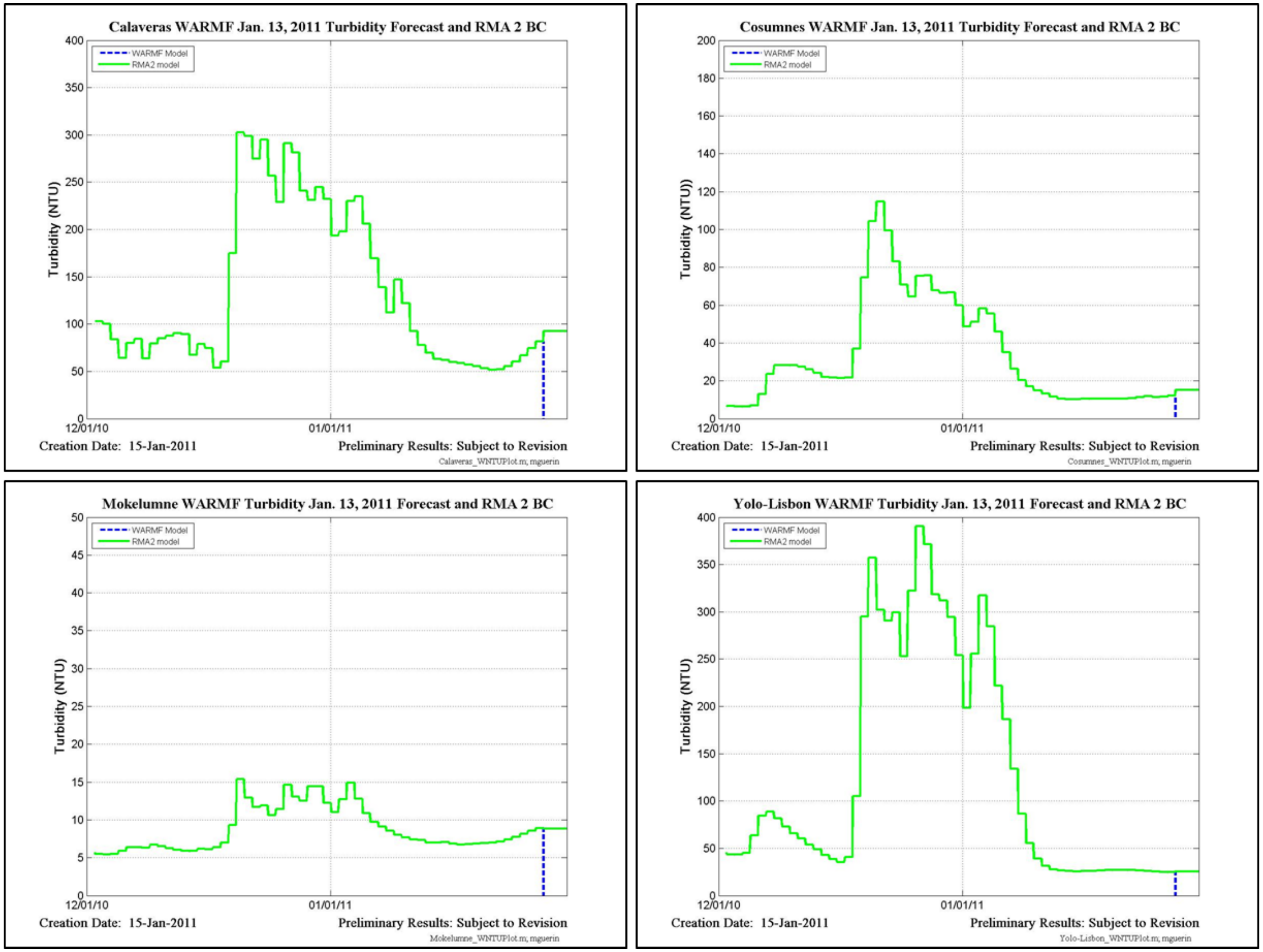


Figure 12-66 Turbidity boundary conditions used in the model along with the WARMF model output – note the shift in model boundary values in comparison with WARMF is most likely a plotting artifact which will be addressed in the next forecast. Note difference in vertical scales.

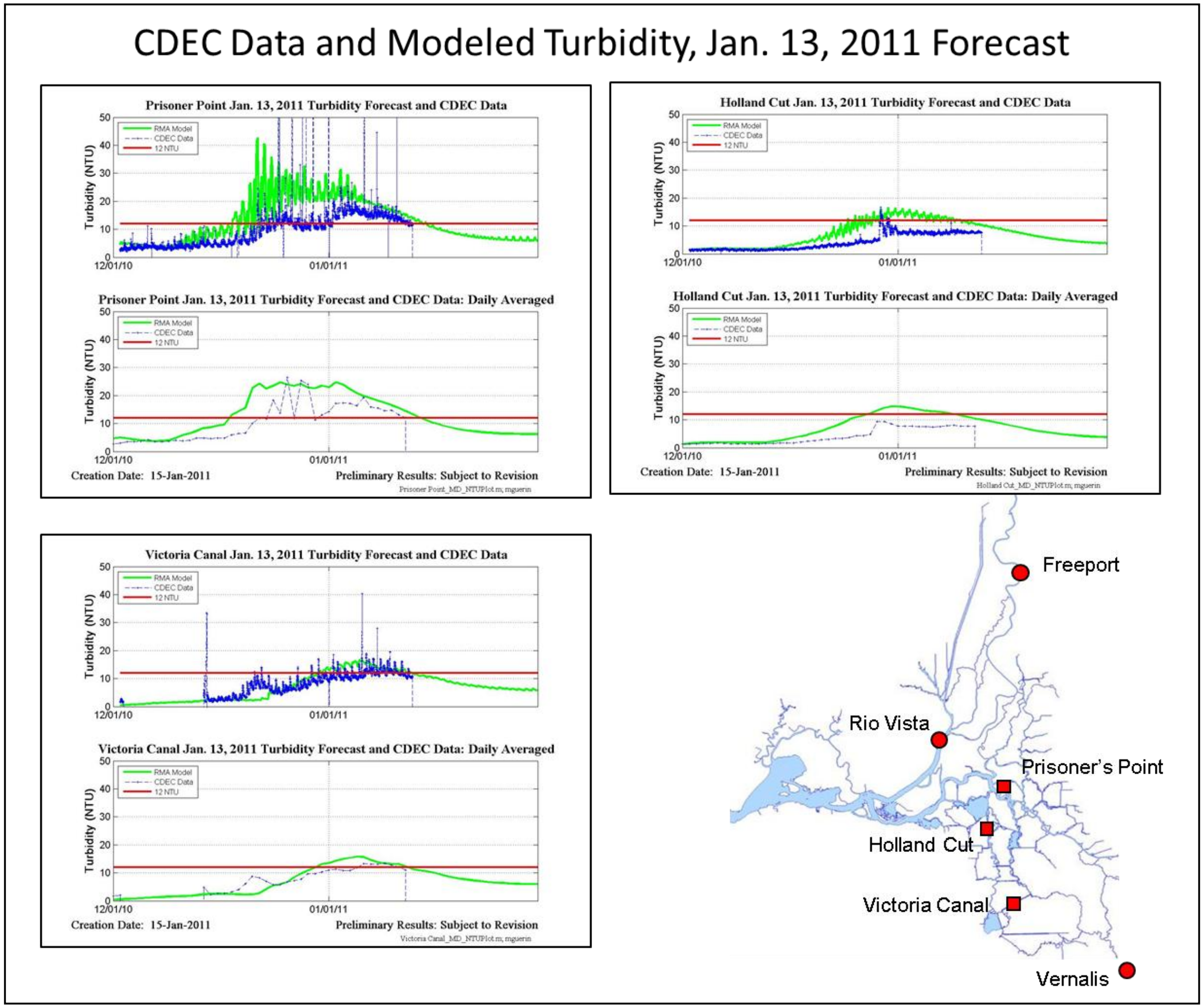


Figure 12-67 Modeled turbidity and data at the three compliance locations. Both 15-min model output and data and daily averaged plots are shown. Red line illustrates the 12-NTU compliance value.

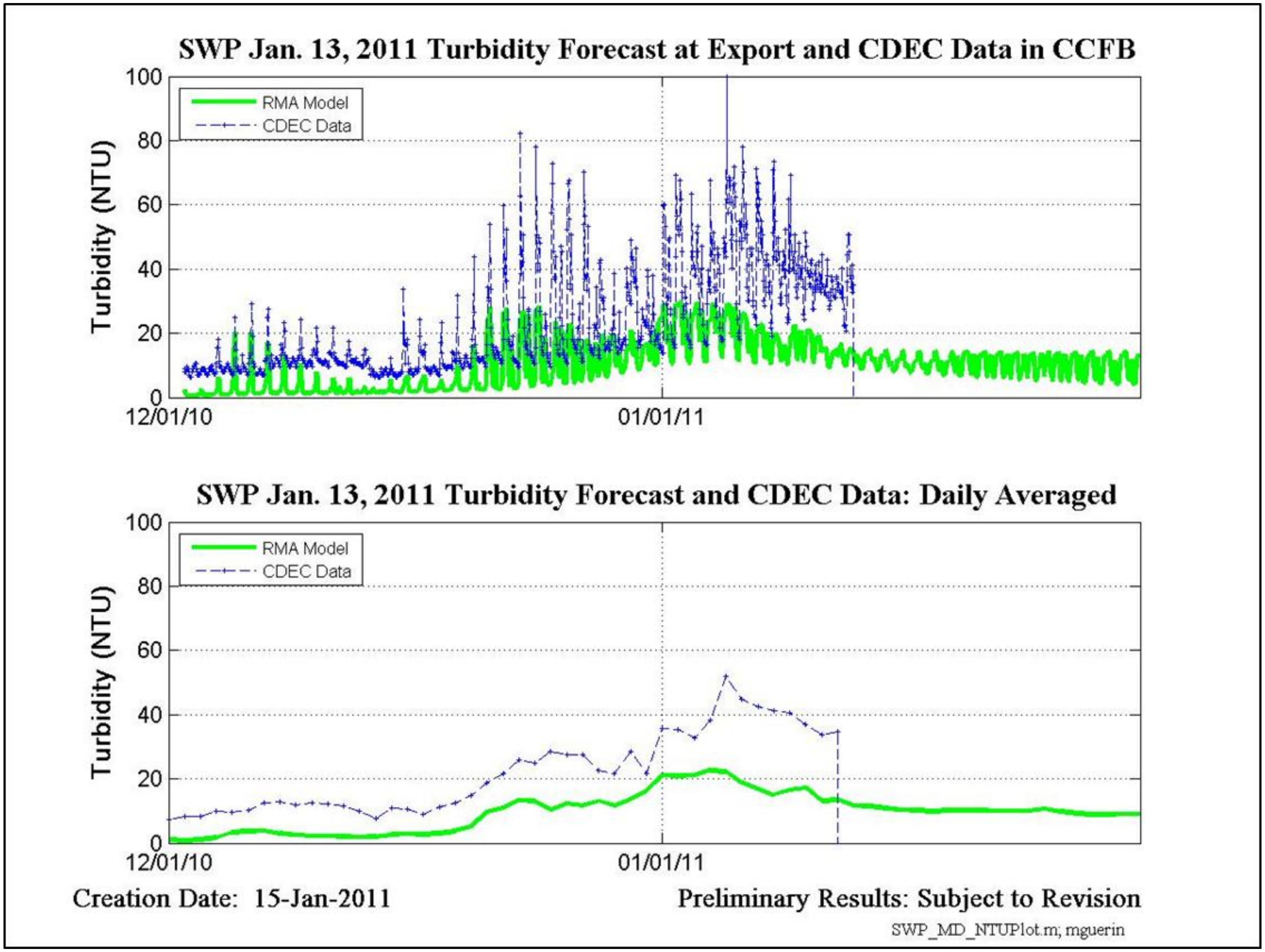


Figure 12-68 Plots compare model output at the SWP export location with data gathered inside Clifton Court Forebay. Both 15-min model output and daily averaged plots are shown.

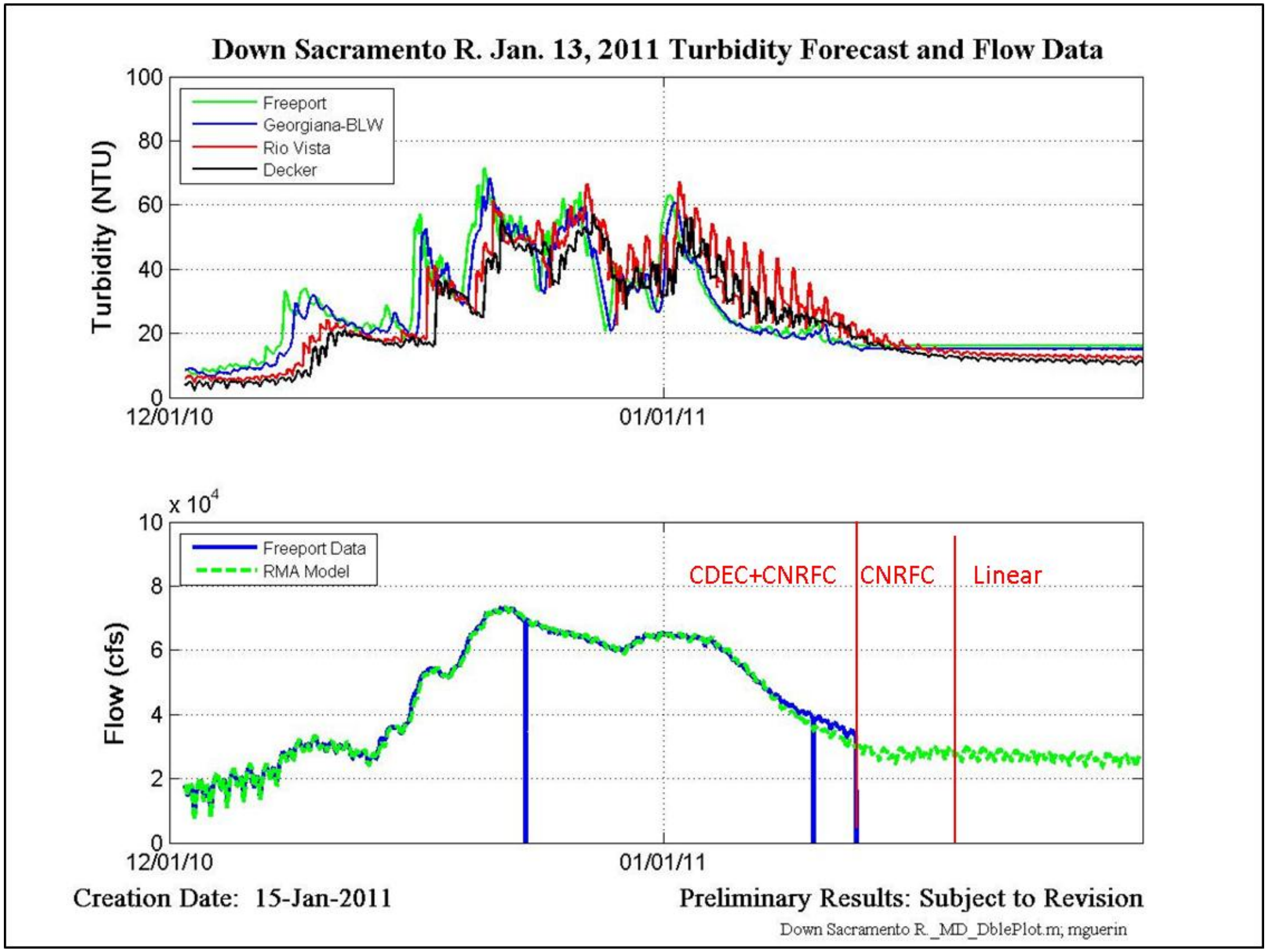


Figure 12-69 Freeport turbidity boundary condition progression down the Sacramento R. (upper plot) along with the flow boundary (lower plot) used during the historical and forecast periods. Forecast began on January 13th. Vertical bar placement is approximate.

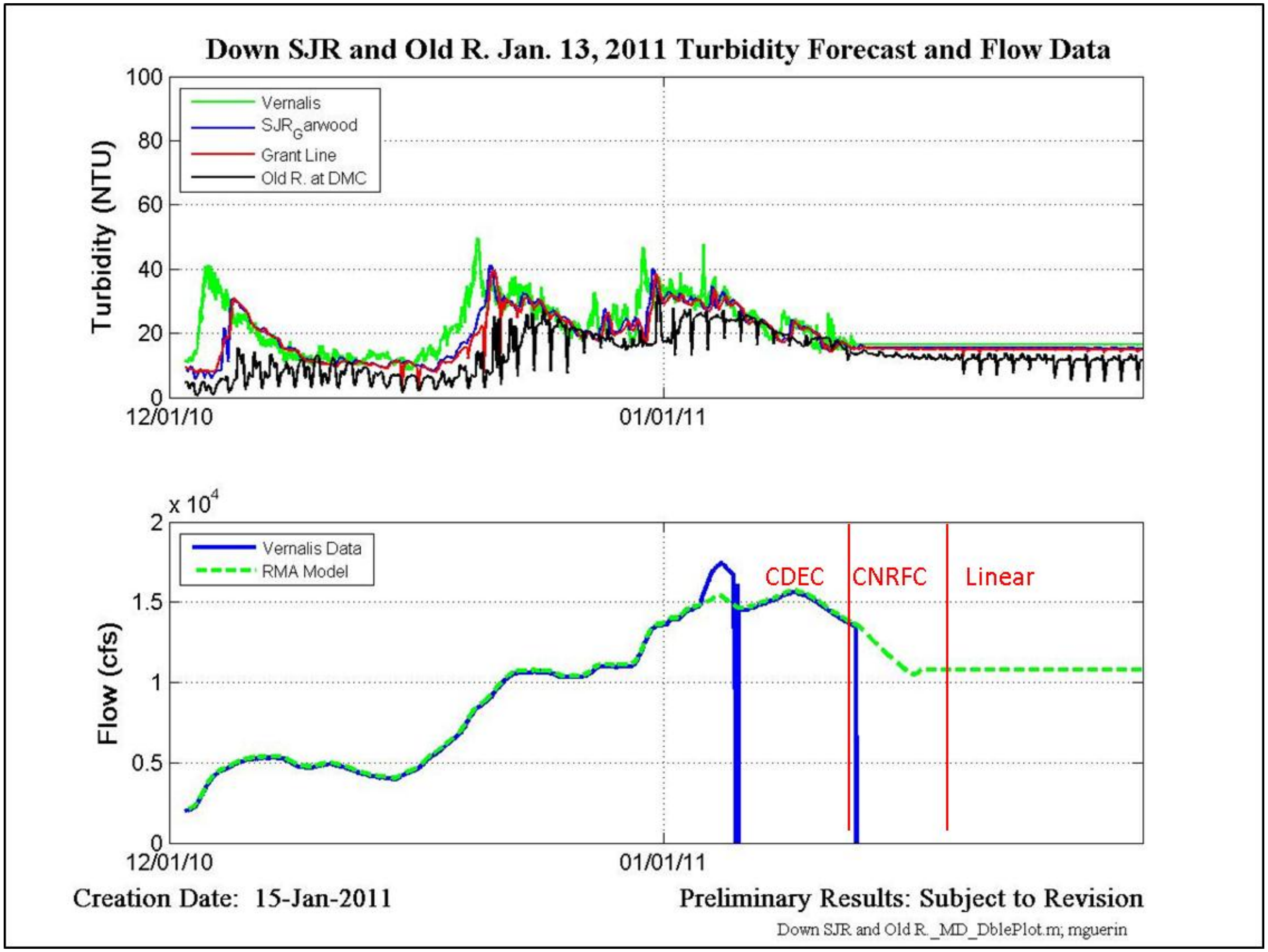


Figure 12-70 Progression of the turbidity boundary condition from Vernalis down the San Joaquin R to Garwood, and down Old R. Vernalis flow forecast periods indicated by red lines (upper plot). Flow boundary conditions at Vernalis are shown in the lower plot. Vertical bar placement is approximate.

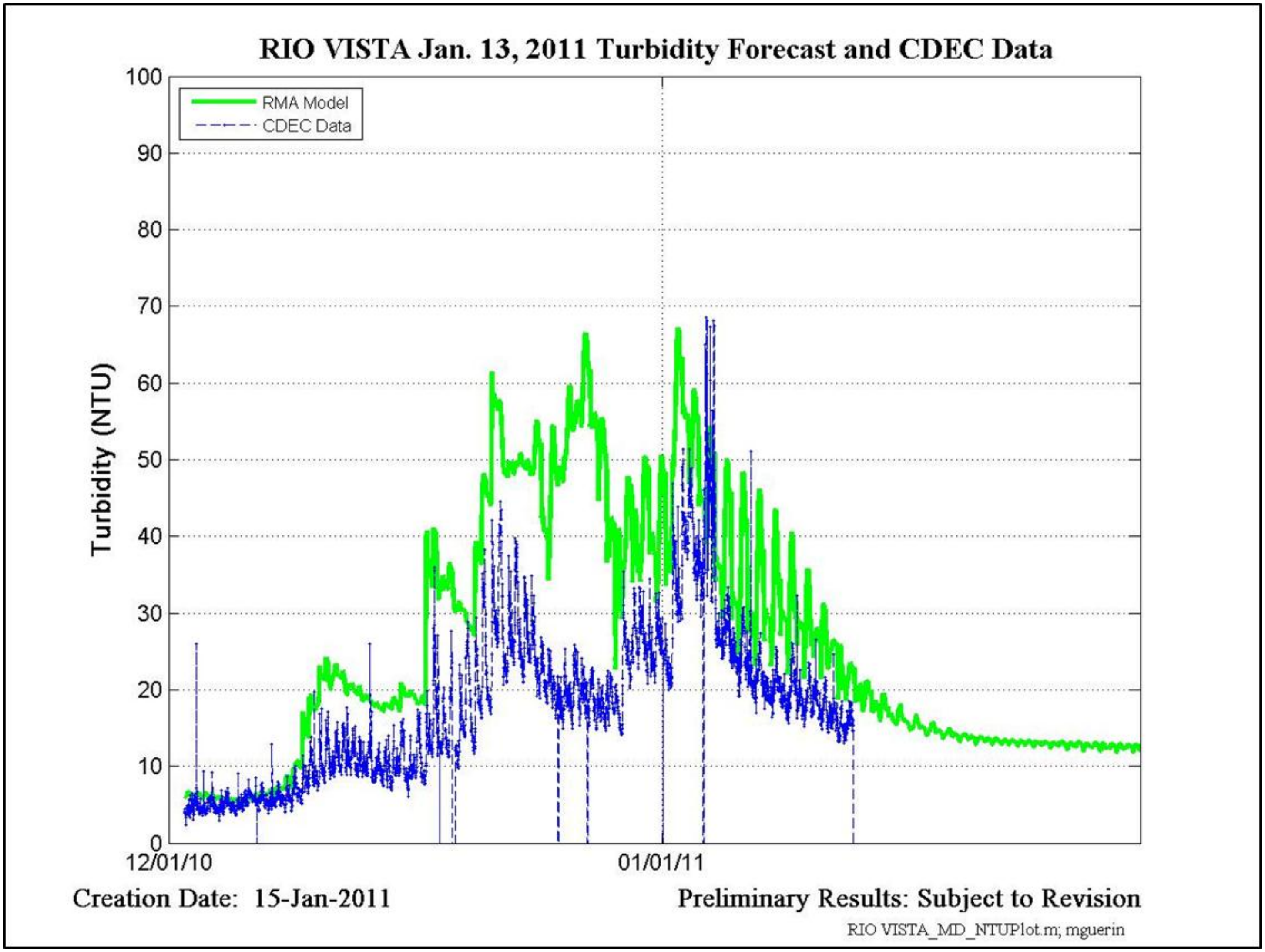


Figure 12-71 Model forecast and CDEC data at Rio Vista.

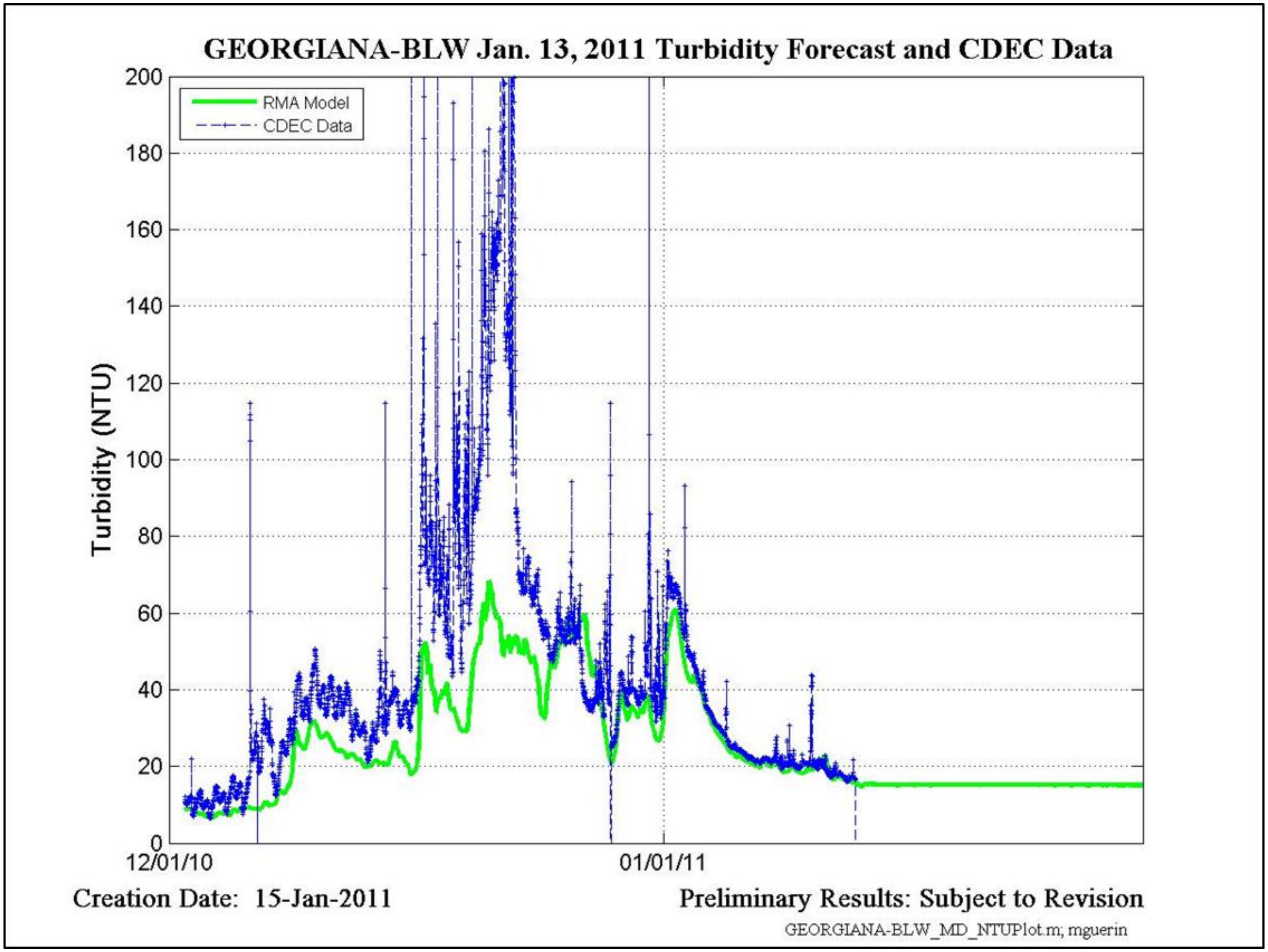


Figure 12-72 Model forecast and CDEC data at Georgian-BLW.

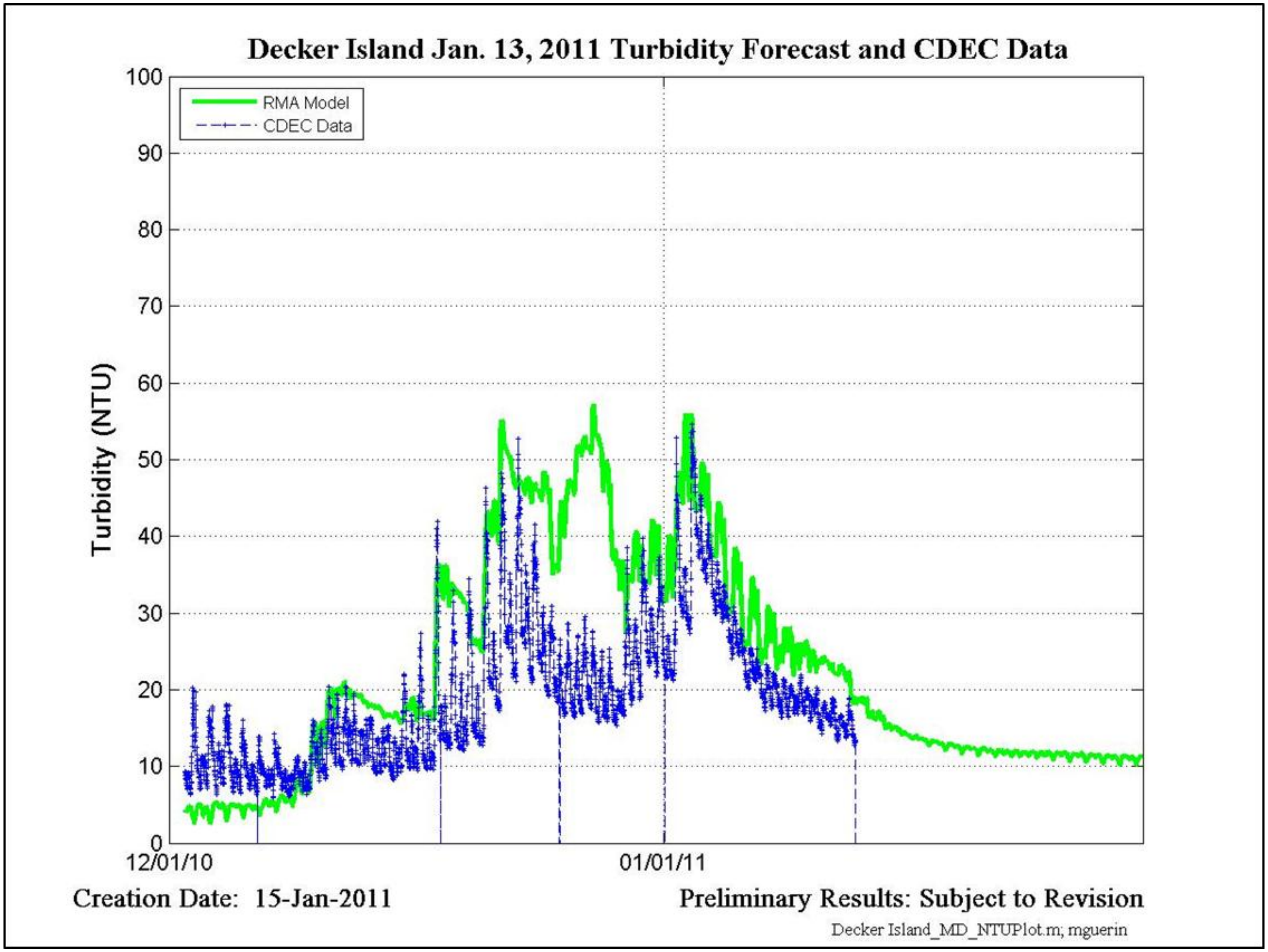


Figure 12-73 Model forecast and CDEC data at Decker Island.

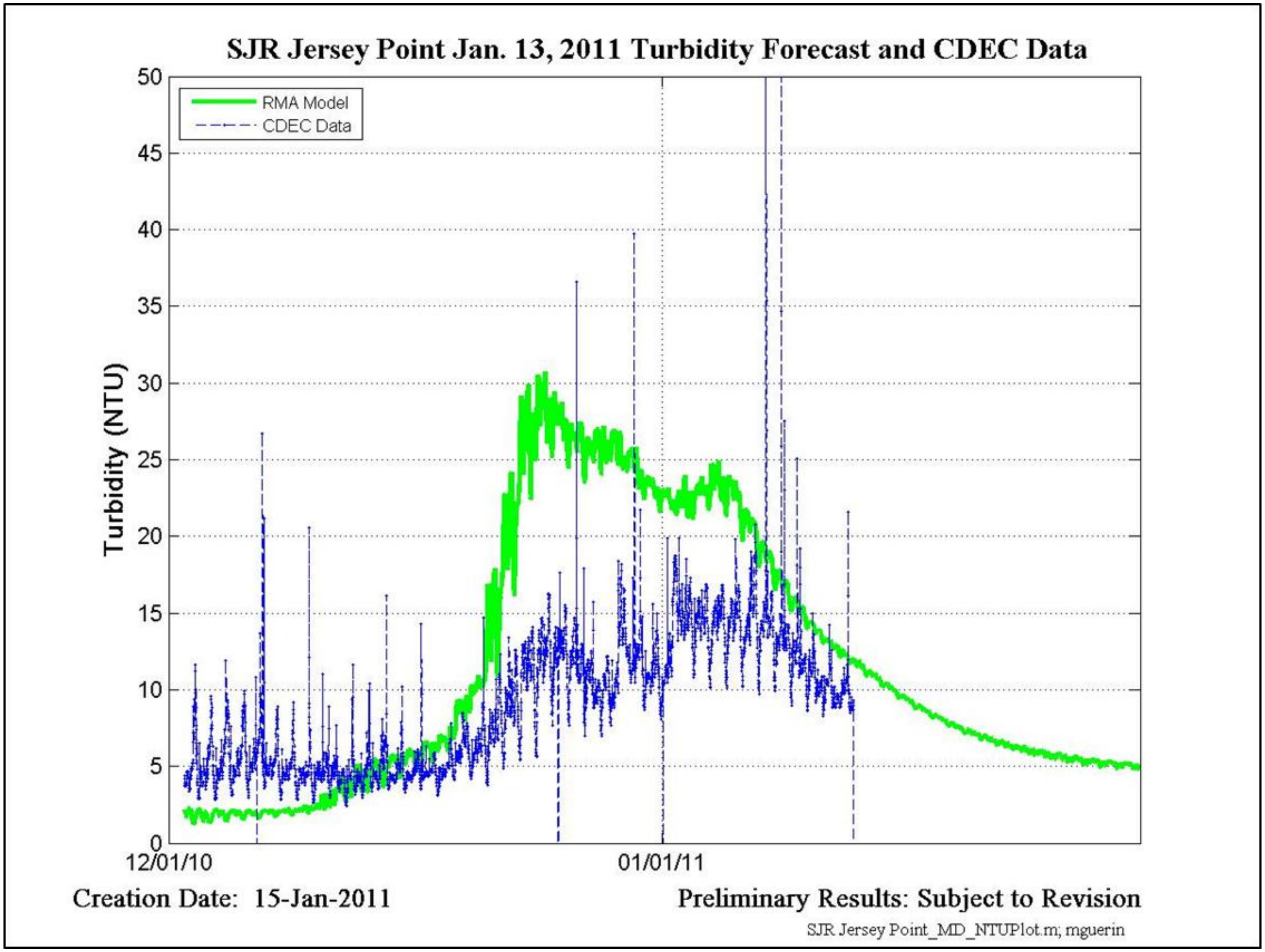


Figure 12-74 Model forecast and CDEC data at Jersey Point.

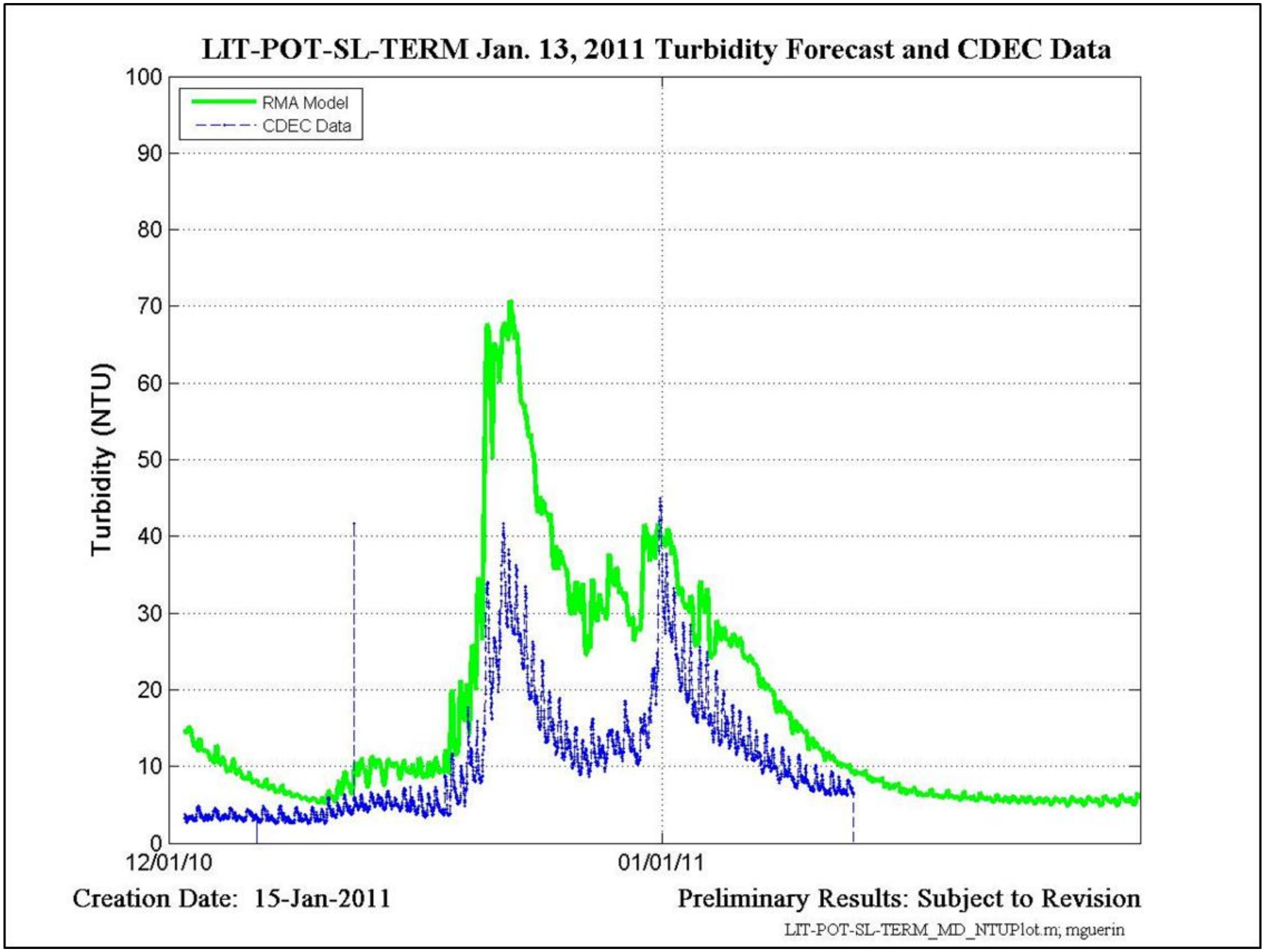


Figure 12-75 Model forecast and CDEC data at Little Potato Slough at Terminous.

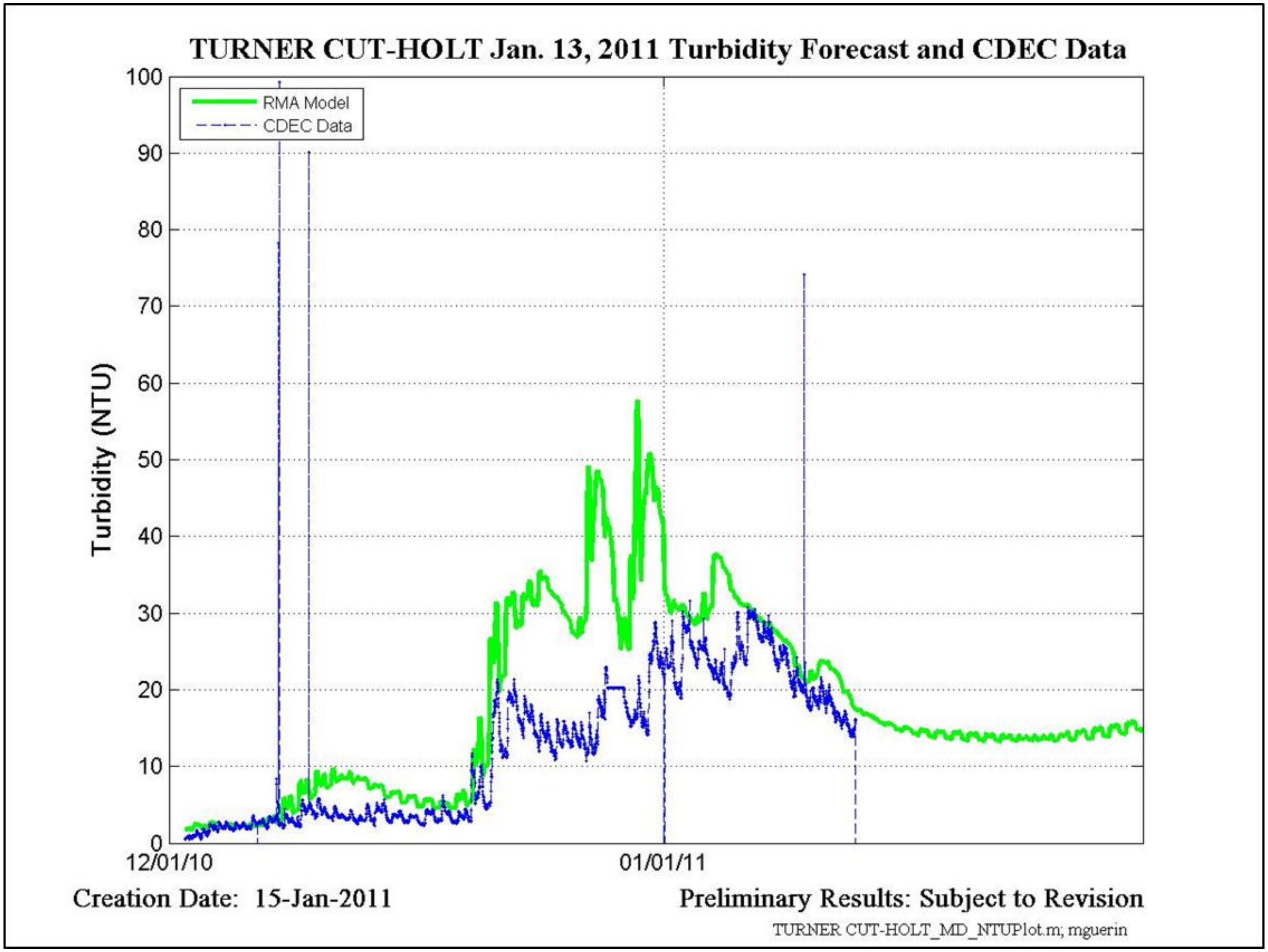


Figure 12-76 Model forecast and CDEC data at Turner Cut near Holt.

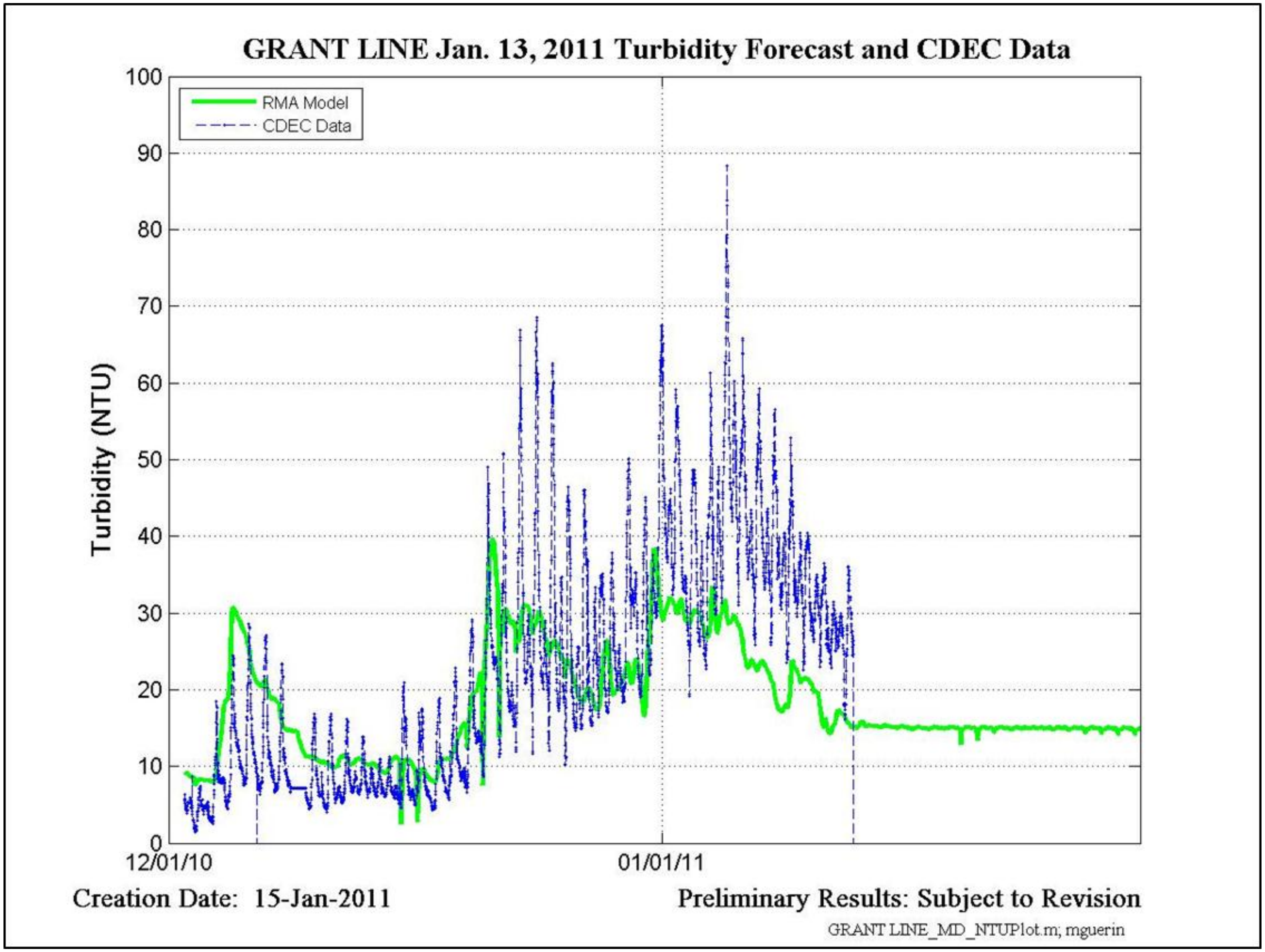


Figure 12-77 Model forecast and CDEC data at Grant Line.

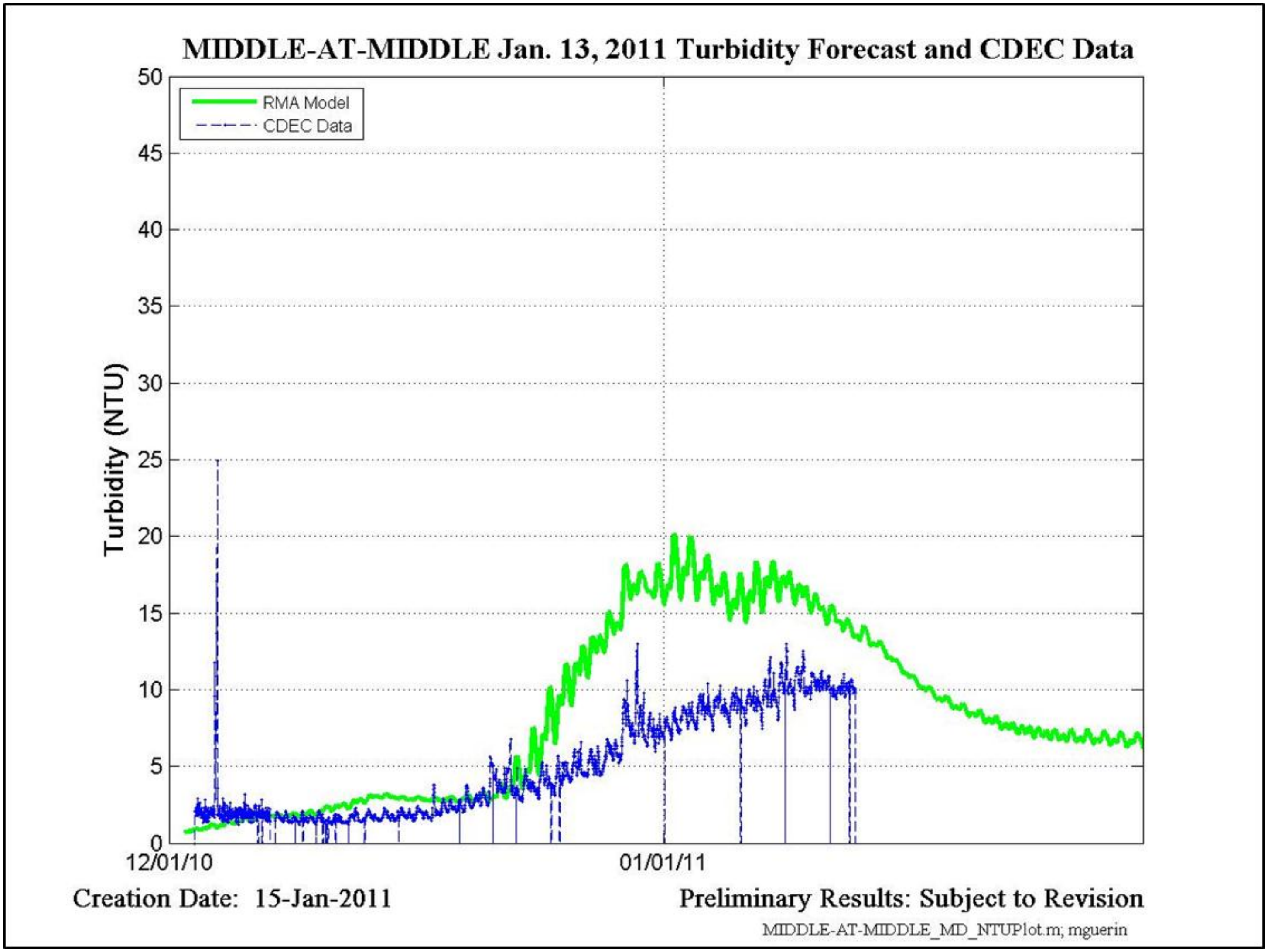


Figure 12-78 Model forecast and CDEC data at Middle R. at Middle R.

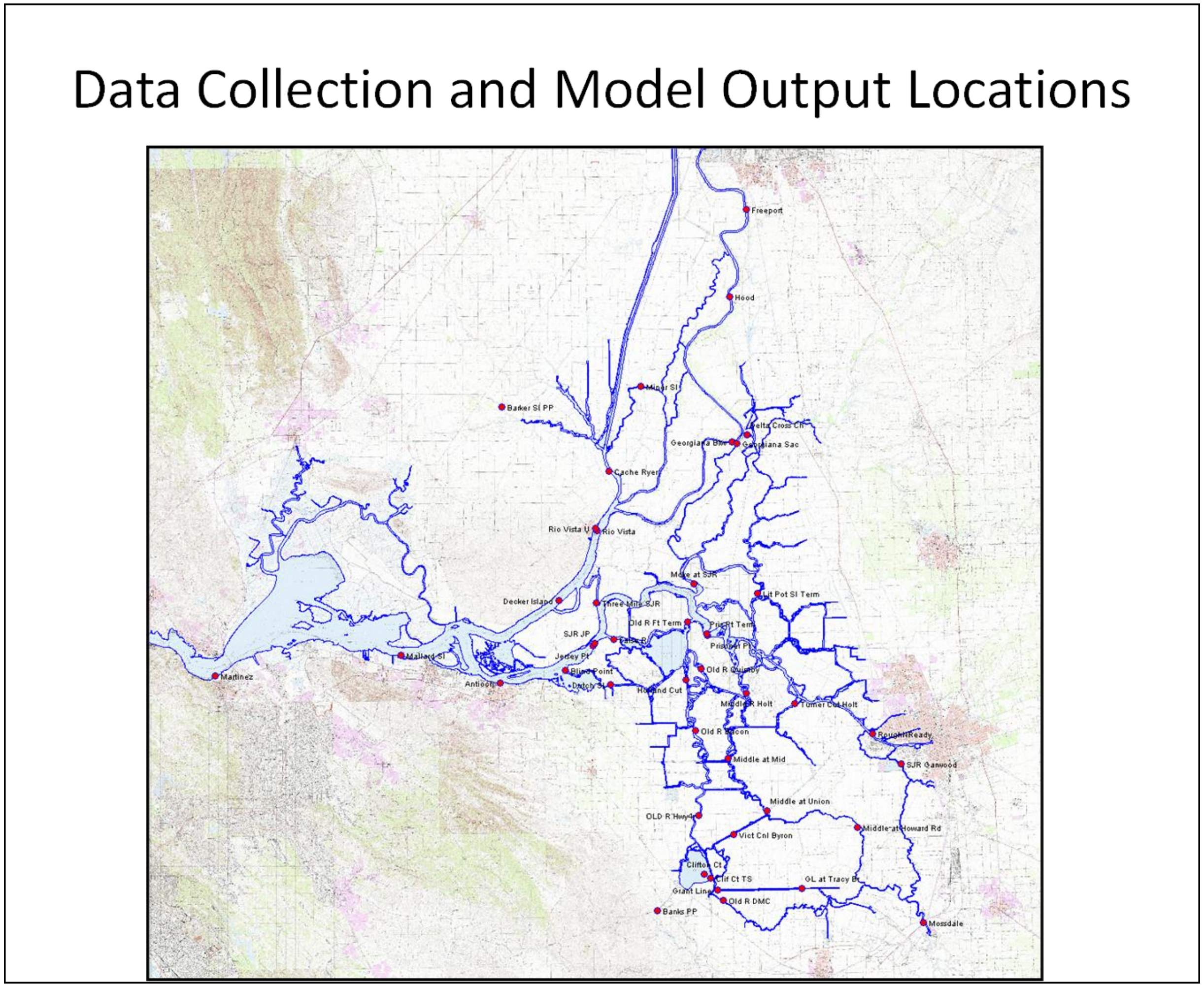


Figure 12-79 Figure illustrating model output and data collection locations.

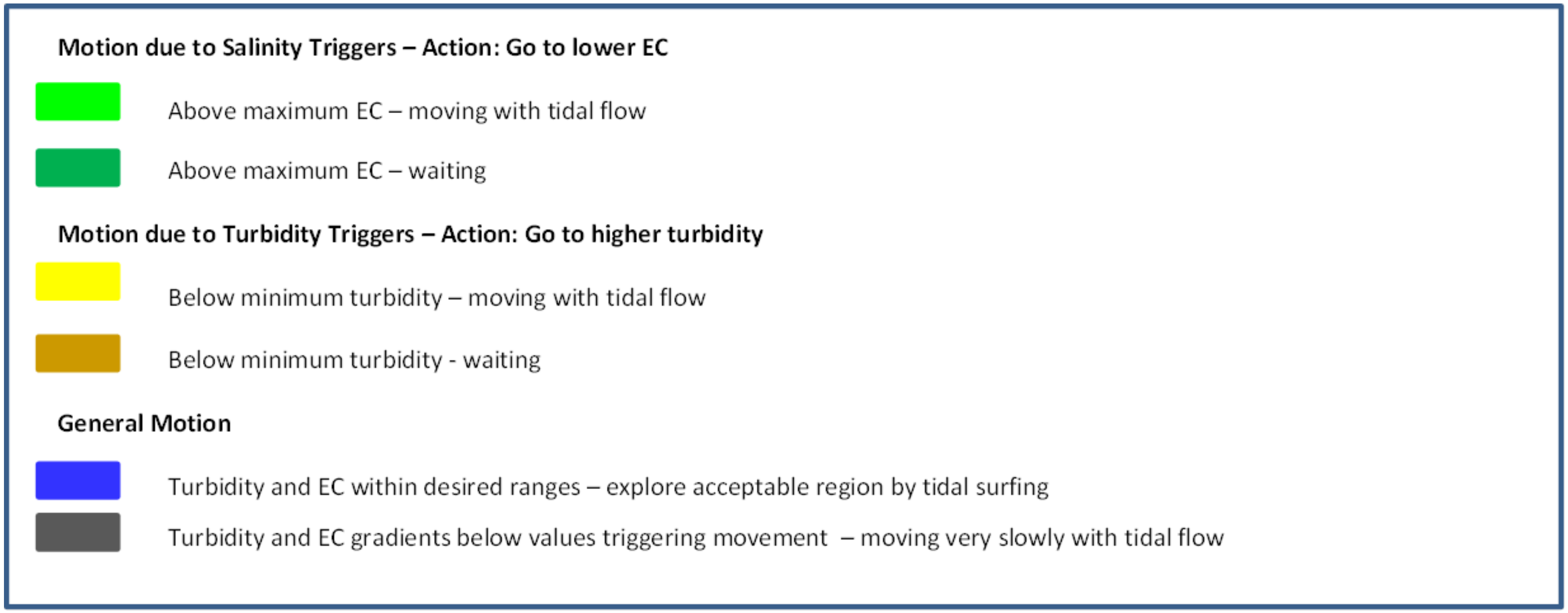


Figure 12-80 Particles in the Adult Delta Smelt particle tracking model are color-coded by the triggers influencing their behavior during the simulation. Use this figure to interpret the simplified color scale in the next three figures.

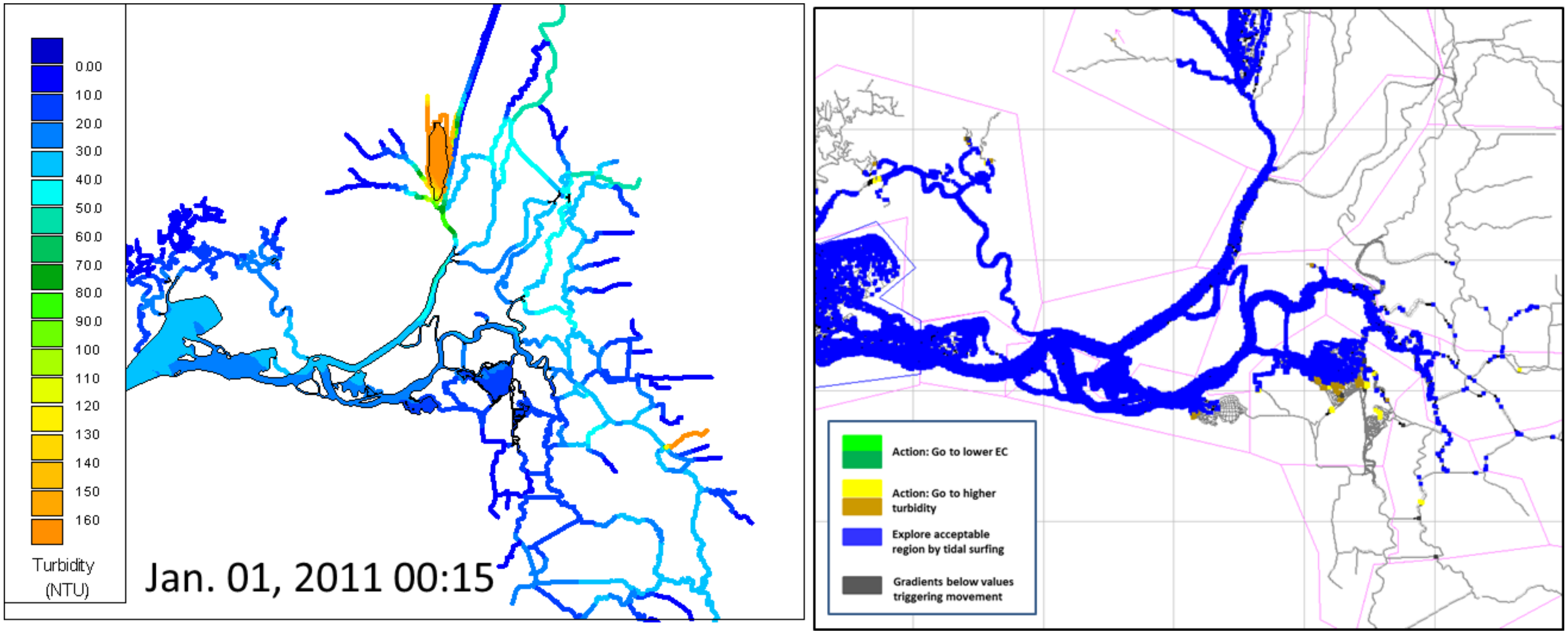


Figure 12-81 Turbidity contours and particle location in the RMA model grid on Jan. 01, 2011.

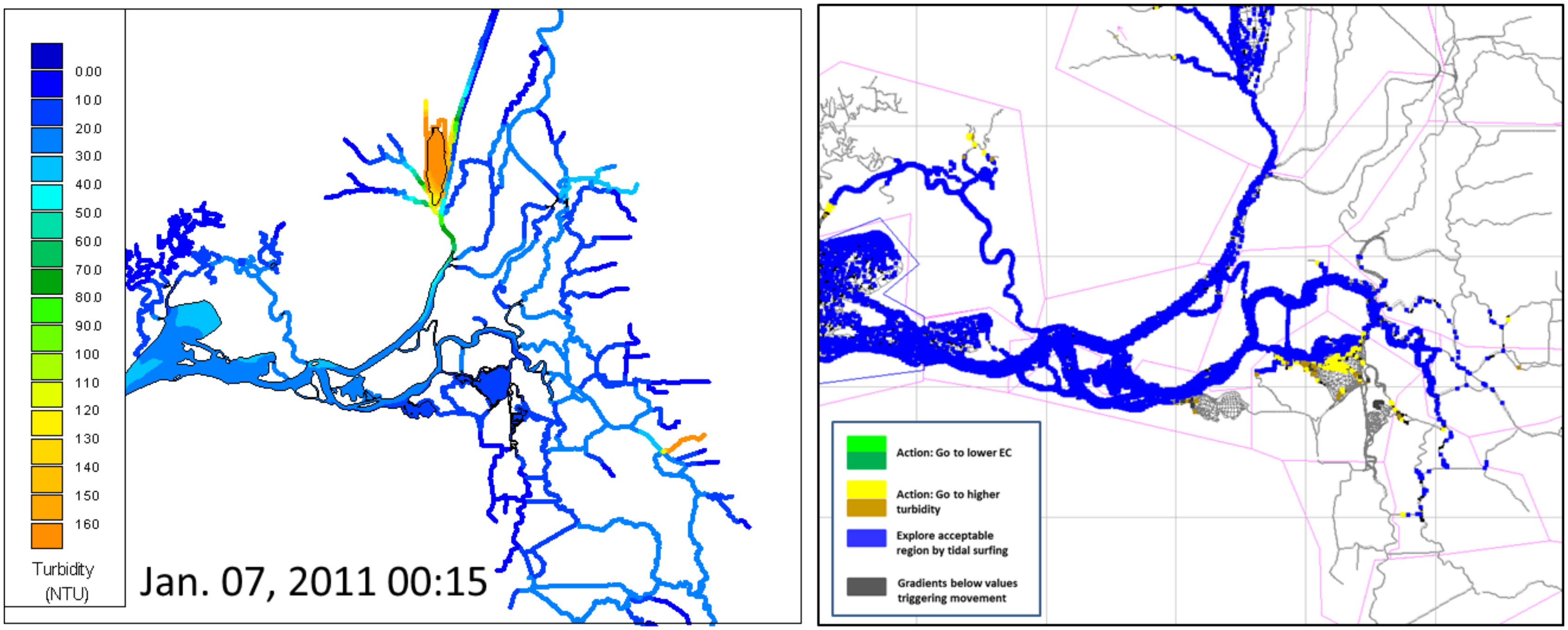


Figure 12-82 Turbidity contours and particle location in the RMA model grid on Jan. 07, 2011.

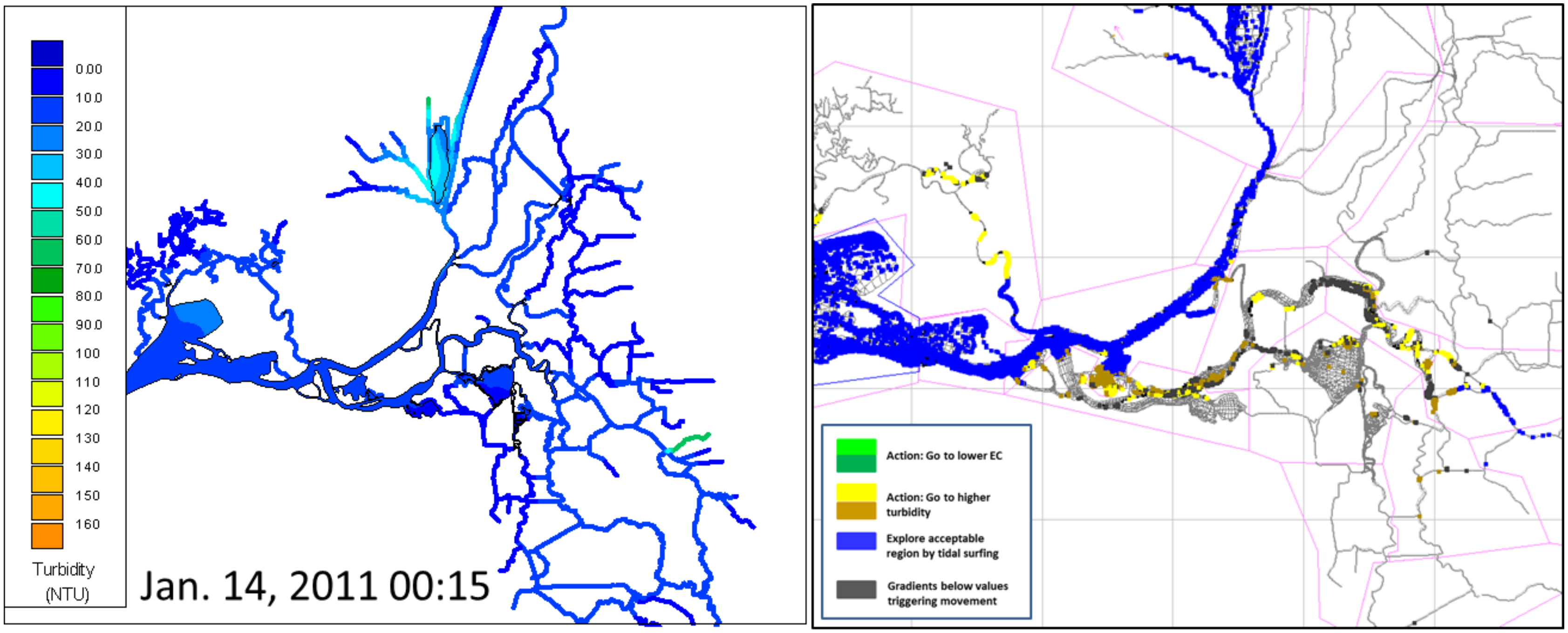


Figure 12-83 Turbidity contours and particle location in the RMA model grid on Jan. 14, 2010.

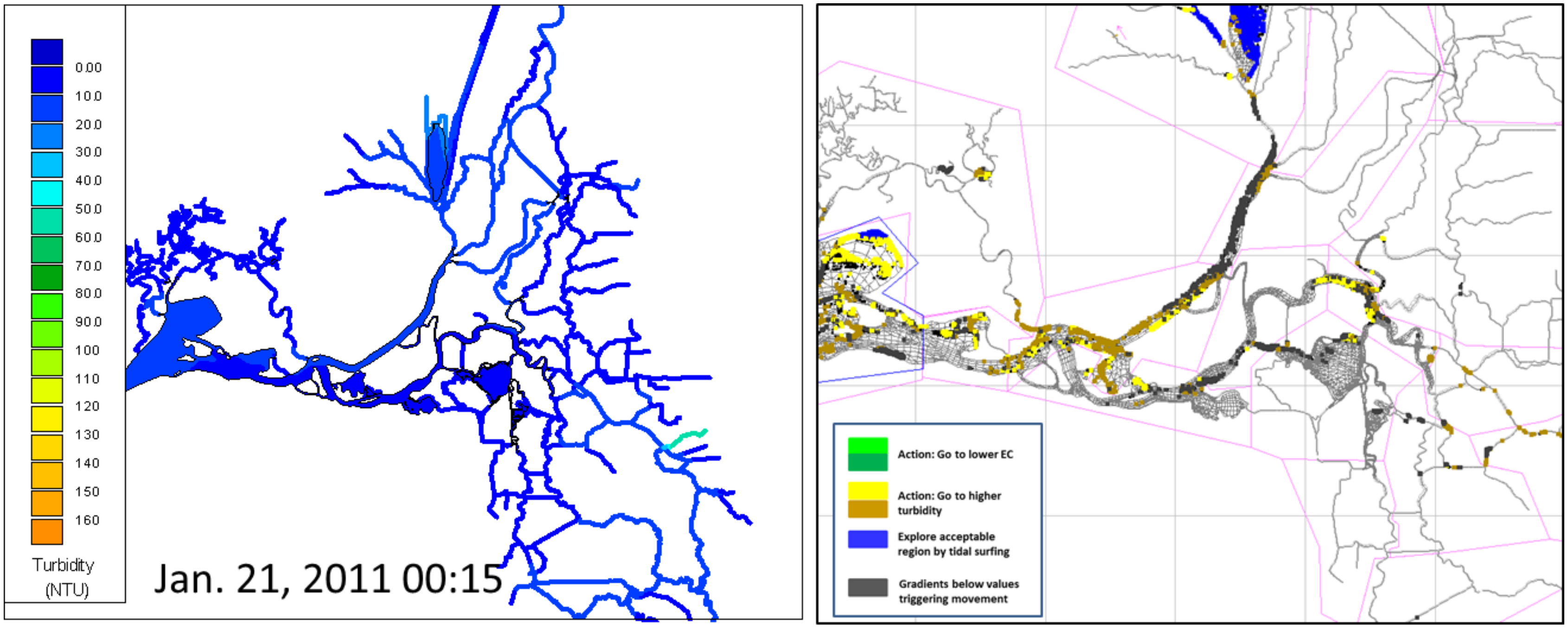


Figure 12-84 Turbidity contours and particle location in the RMA model grid on Jan. 21, 2010

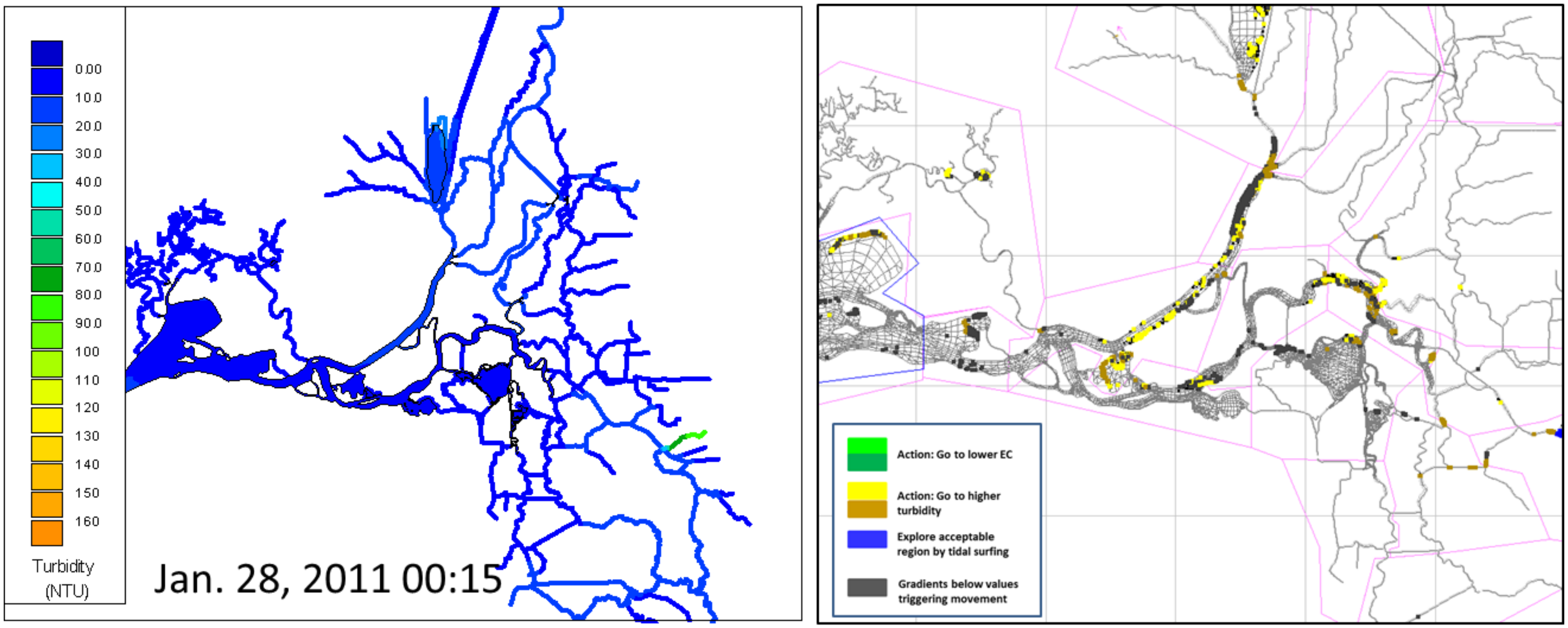


Figure 12-85 Turbidity contours and particle location in the RMA model grid on Jan. 28, 2010.

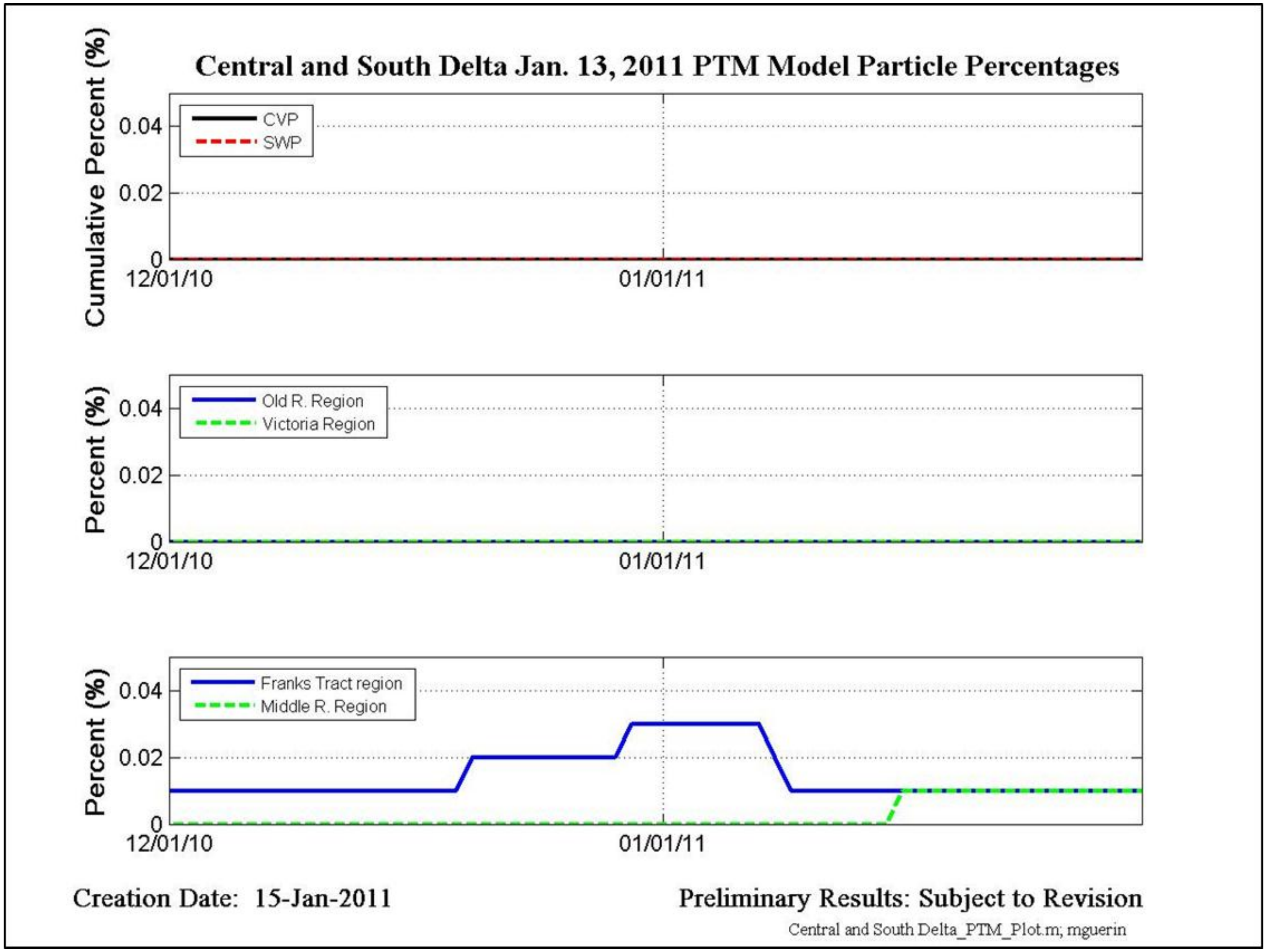


Figure 12-86 Only a couple of particles reached the SWP export location, none reached CVP (upper plot, cumulative percentage). No particles entered the Old River Region, a few reached the Victoria Region. A very small percentage reached the Franks Tract and Middle River Regions (lower plot).

12.3.5. Forecast Jan. 20, 2011

This document provides a quick summary of the January 20, 2011 forecast prepared using the RMA hydrodynamic, salinity, turbidity and Adult Delta Smelt Behavioral models. Graphical results are provided to document the results of the modeling with a focus on turbidity. Model BC (Boundary Conditions) for the forecast model were prepared using WARMF-supplied forecast conditions, CNRFC flow data and predictions, CDEC and USGS data, and DWR-supplied model inputs and results from their flow and salinity forecasts.

The RMA modeled period was January 01, 2010 to February 08, 2011 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 Jan. 07, 2011 through Feb. 08, 2011. The WARMF model forecast period, consisting of daily model output for flow, salinity and turbidity, was Dec. 01, 2010 – Feb. 03, 2011. Additional flow, turbidity and EC data was downloaded for the period Jan. 13 – Jan. 19/20, 2011 from the CDEC, CNRFC and USGS websites to augment previous data.

In general, producing BC during this forecast period was challenging as it was for the previous two forecasts. The WARMF forecast arrived late on Thursday afternoon due to some computational problems. Also, the RMA forecast model BC development is complicated by the number of data sources, model sources, model/data discrepancies and the need to piece the data together for RMA BC (see Table 12-10).

Historical and forecast BC were developed from several sources, as summarized in Table 12-10. As a consequence, where there were discrepancies between data and model or between DWR and WARMF models, BC were compiled using best professional judgment. Stage and export BC were compiled solely from DWR O&M sources. The Martinez salinity boundary condition was also obtained from the DWR forecast, and the turbidity BC from CDEC data.

WARMF boundary condition estimates for turbidity and EC were used at all locations except Vernalis and Freeport. See Table 12-10 for BC sources and timing. BC time series were extended as constants to fill the forecast time frame.

Plots showing model/data comparisons and model output are included below as a pictorial summary of the results. Figure 12-87 through Figure 12-93Figure 12-40 illustrate BC time series used in the RMA forecast model as well as the WARMF-supplied model output for flow and turbidity.

Figure 12-94 illustrates a comparison of model output and data at the three compliance locations, and Figure 12-95 illustrates a similar comparison in the SWP export area. Note that Figure 12-95 is a comparison of data inside Clifton Court Forebay with model output at the model boundary at the entrance to the Forebay. For these figures, model and data were used at 15-min or hourly time intervals as collected or modeled, and also daily averaged. The data at Prisoner's Point was noisy, so turbidity values that appeared unreasonably high were deleted before averaging. Note that the time series used to create Figure 12-94 and Figure 12-95 are included in the email communication accompanying this document as a separate EXCEL file.

Only at the Holland Cut compliance location did averaged data remain below 12 NTU – modeled turbidity exceeded the 12 NTU value at each compliance location (Figure 12-94). Modeled turbidity was high in comparison with data in most of the model domain (Figure 12-71 through Figure 12-78) due to relatively high WARMF turbidity BC (Figure 12-93) at the Yolo and the eastside inflow locations at the Cosumnes and Calaveras Rivers, which also experienced fairly high flows. Note that WARMF-predictions for high flow and turbidity BC result in modeled turbidity that is too high throughout much of the model domain – i.e., in areas influenced by these boundary conditions.

The Delta Smelt behavioral model was run from Nov. 01, 2010 through Feb. 08, 2011 - 50,000 particles were inserted on Nov.01, 2010 as in previous forecast models. Because the historical and forecast boundary conditions are somewhat different than the Jan. 13th model during overlapping times, the PTM results are slightly different. Timing of particle insertion needs to be reconsidered for the future forecast periods - a trial PTM run with particles placed on Dec. 01, 2011 produced slightly different results.

Eight delta smelt were salvaged at the CVP location during the pre-forecast period[10], Jan. 01 – Jan. 18, 2011 – no delta smelt were salvaged at either location in December 2010. December delta smelt values are not available on the CVO website, but are available on the California Department of Fish and Game website[11]. A couple of particles reached the SWP export location during the modeled period (i.e., historical plus forecast), and a small percentage of particles entered the Middle R. and Franks Tract Regions – no particles entered the Old R. Region. See Figure 12-108 through Figure 12-112 for turbidity contour plots and particle tracking model results.

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

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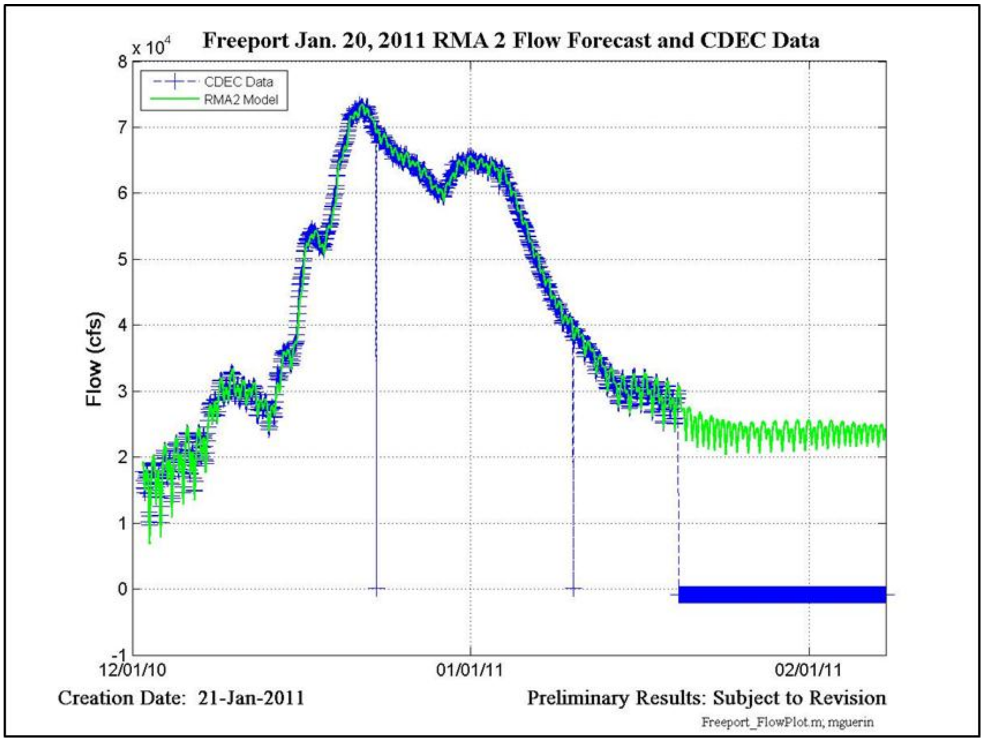
[10] http://www.usbr.gov/mp/cvo/fishrpt.html

[11] http://www.dfg.ca.gov/delta/apps/salvage/SalvageExportCalendar.aspx



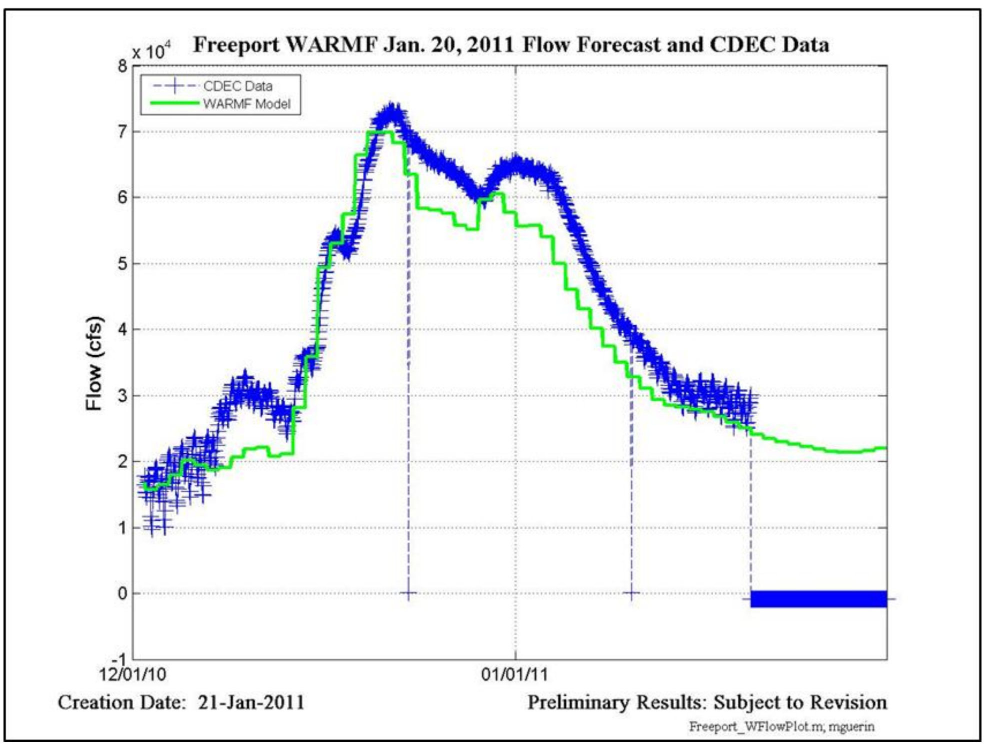


Figure 12-87 Freeport flow BC was compiled from CDEC and CNRFC data (top), and then extended to a constant flow. WARMF model output, which was not used, is shown in the lower plot. Note y-axis unit is cfs*10,000. Zero values indicate the end of data (blue).

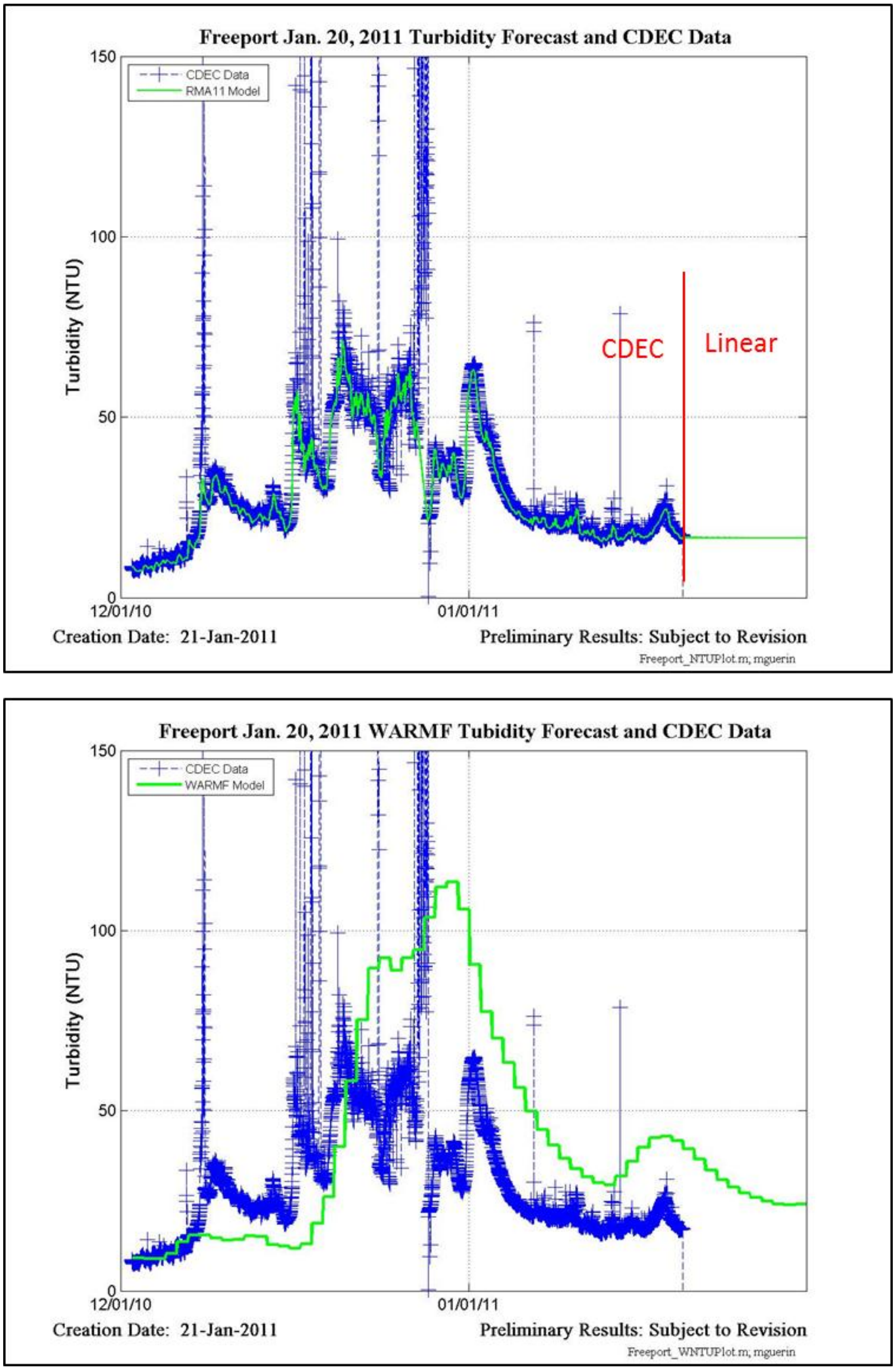
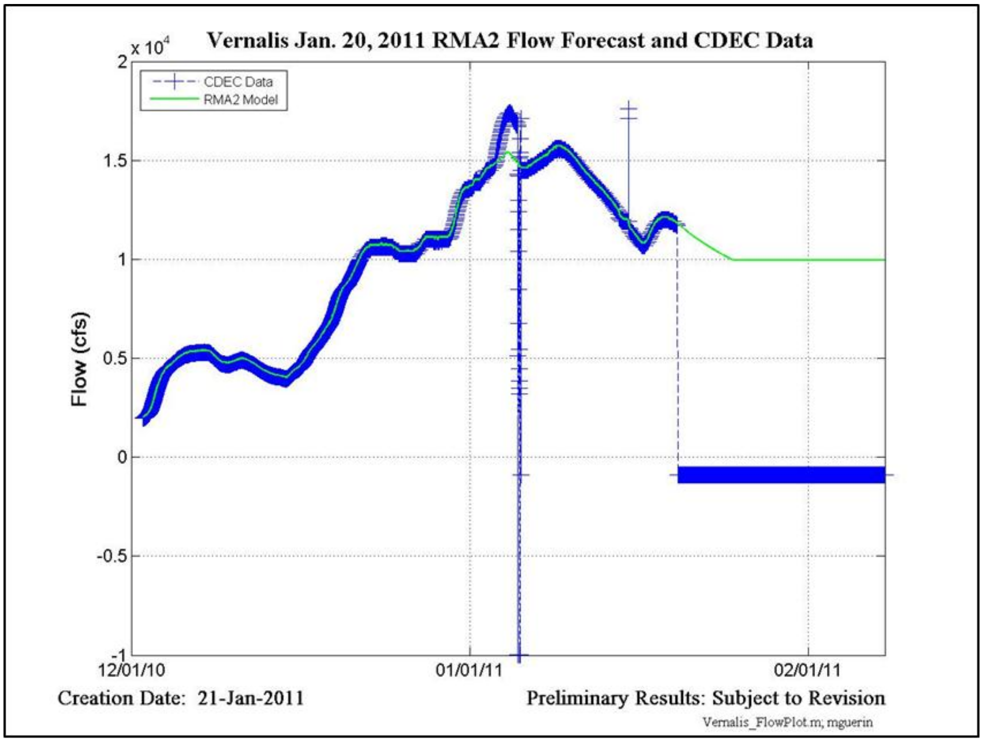


Figure 12-88 Freeport turbidity BC was compiled from CDEC data, then extended as a constant after Jan. 19th, 2011. WARMF model output, which was not used, is shown in the lower plot.



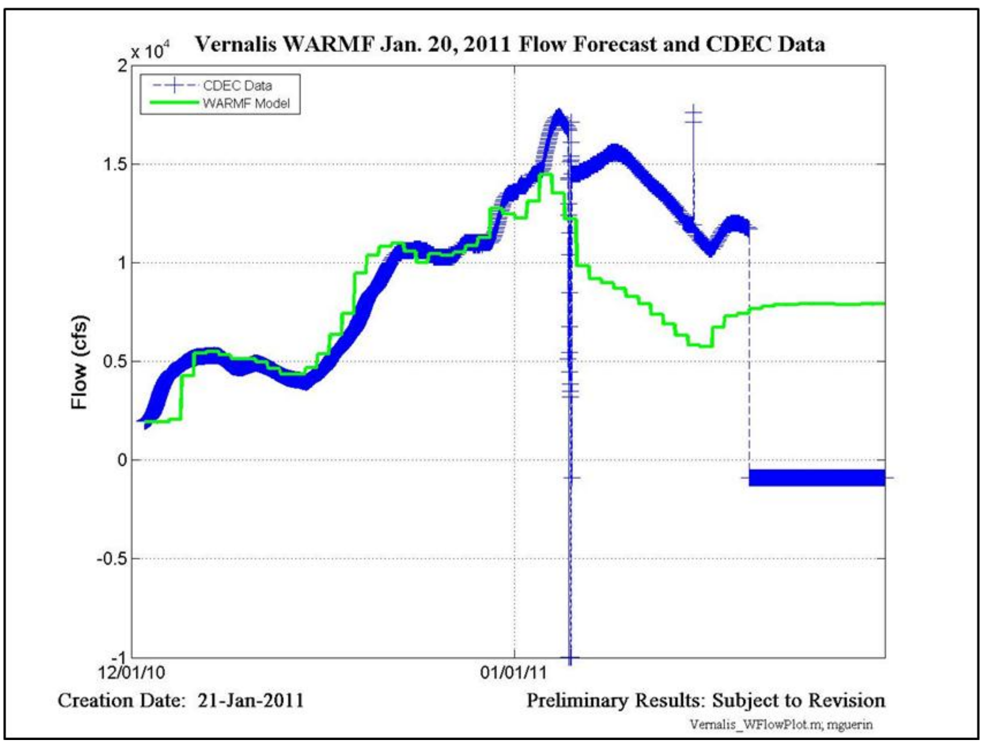
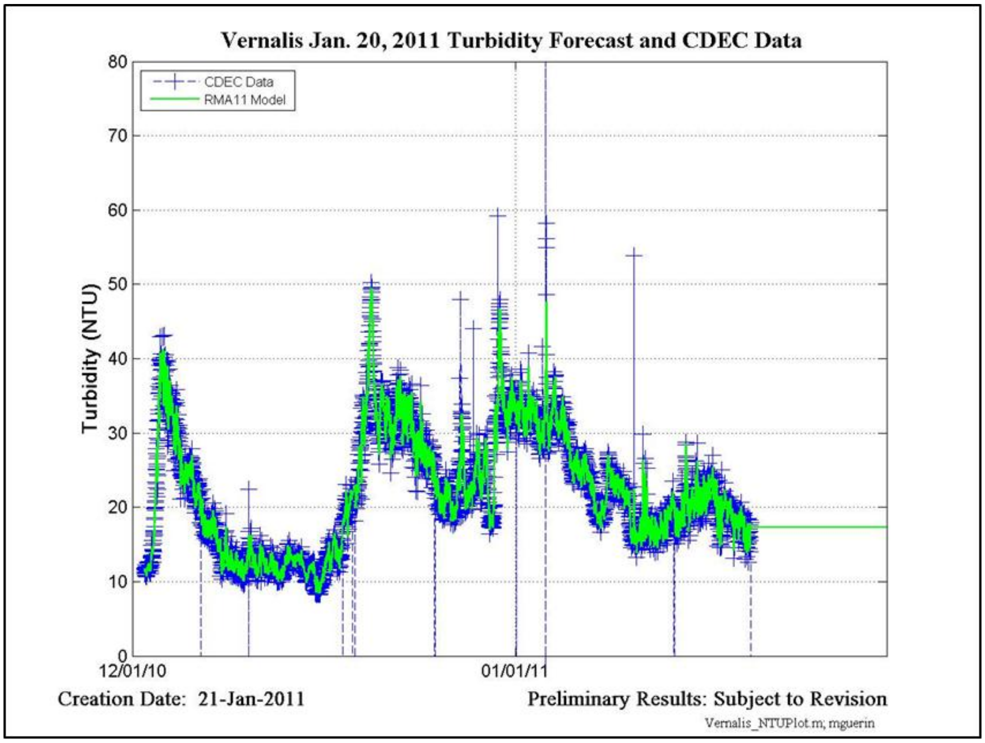


Figure 12-89 Vernalis flow BC was compiled from CDEC and CNRFC data, and then extended to a constant flow indicted by the DWR forecast. WARMF model output, which was not used, is shown in the lower plot. Note y-axis unit is cfs*10,000. Zero values indicate the end of data (blue).



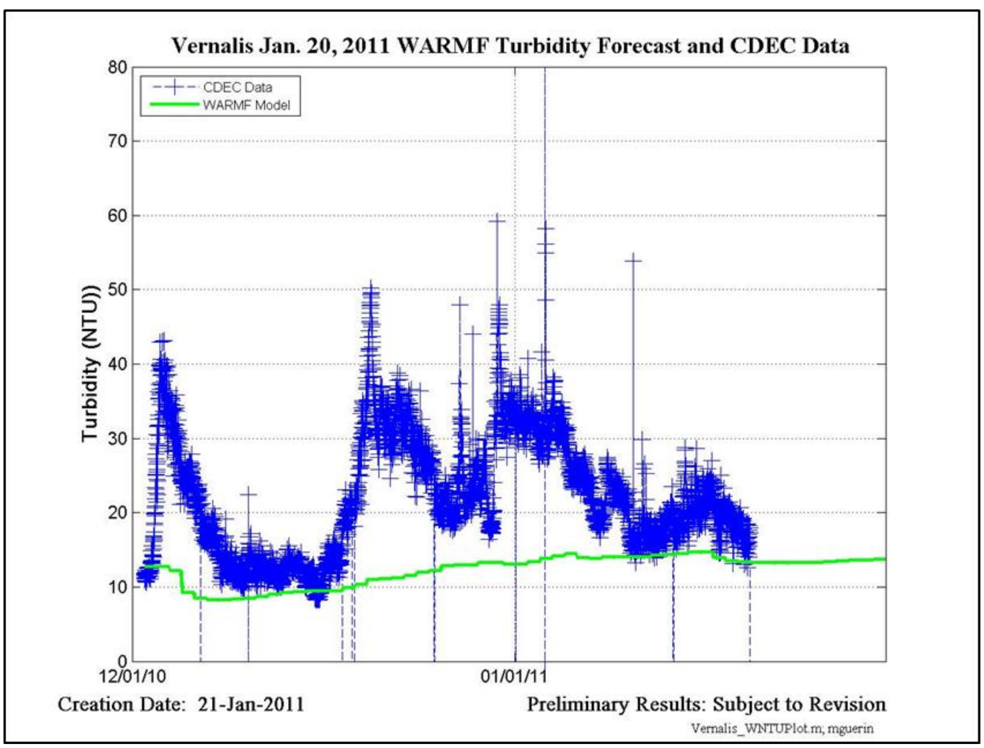


Figure 12-90 Vernalis turbidity BC was compiled from CDEC data, and then extended to a constant. WARMF model output, which was not used, is shown in the lower plot.

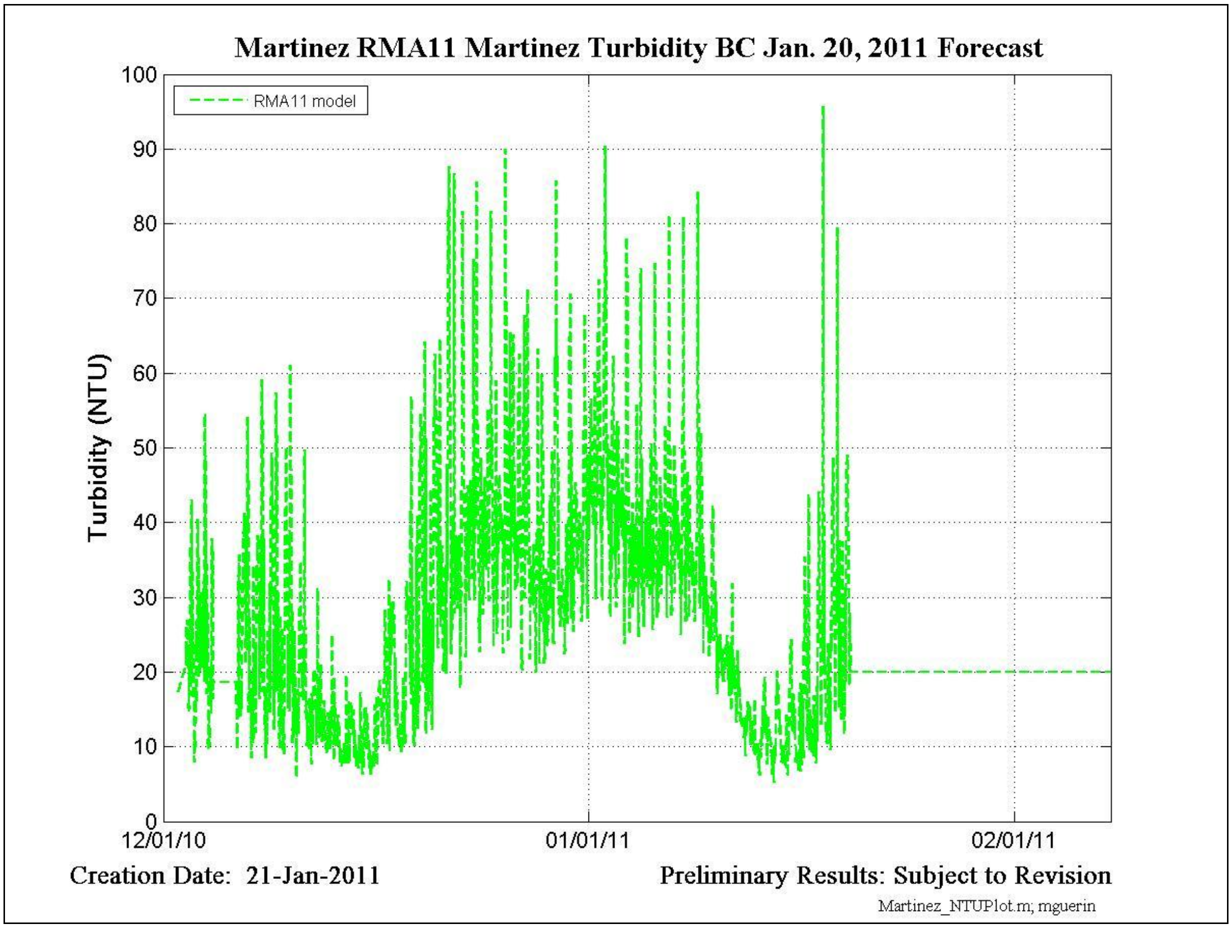


Figure 12-91 Martinez turbidity BC was compiled from CDEC data then extended linearly to a value of 20 NTU.

Table 12-10 Boundary condition development for Jan. 20, 2011 forecast for flow, turbidity and salinity (EC).

Location	**Sources for Flow BC**	**Sources for Turbidity BC**	**Sources for EC BC**
Yolo Bypass at Lisbon	USGS+CDEC	WARMF	WARMF
Sacramento River at I Street Bridge	CDEC+CNRFC	CDEC, then constant	CDEC
Cosumnes River	CNRFC	WARMF	WARMF
Mokelumne River	DWR+WARMF	WARMF	WARMF
Calaveras River	CDEC (Mormon Sl.)+DWR	WARMF	WARMF
San Joaquin River at Vernalis	CDEC+CNRFC	CDEC, then constant	CDEC+DWR

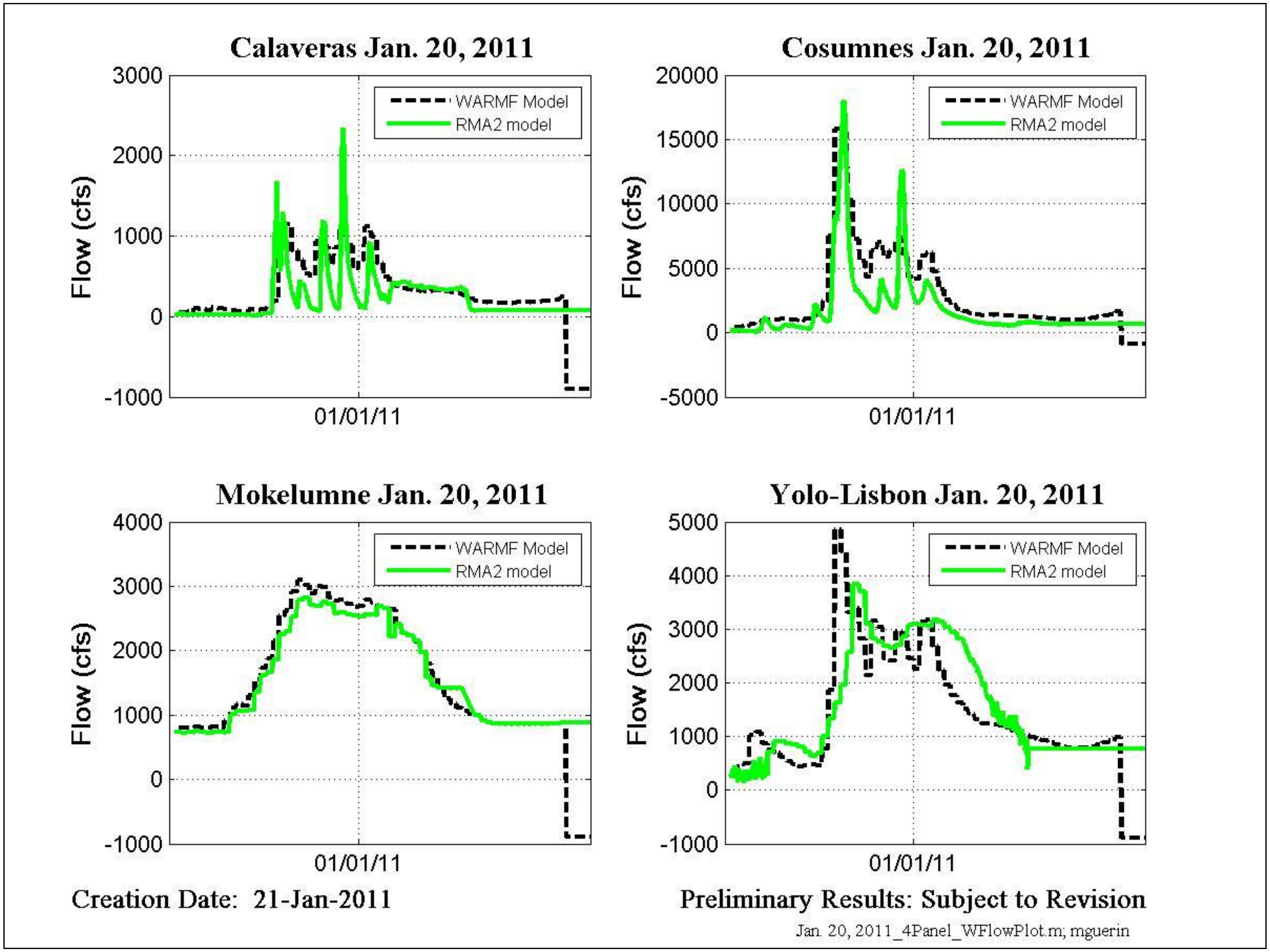


Figure 12-92 Four flow boundary conditions used in the model along with the WARMF model output.

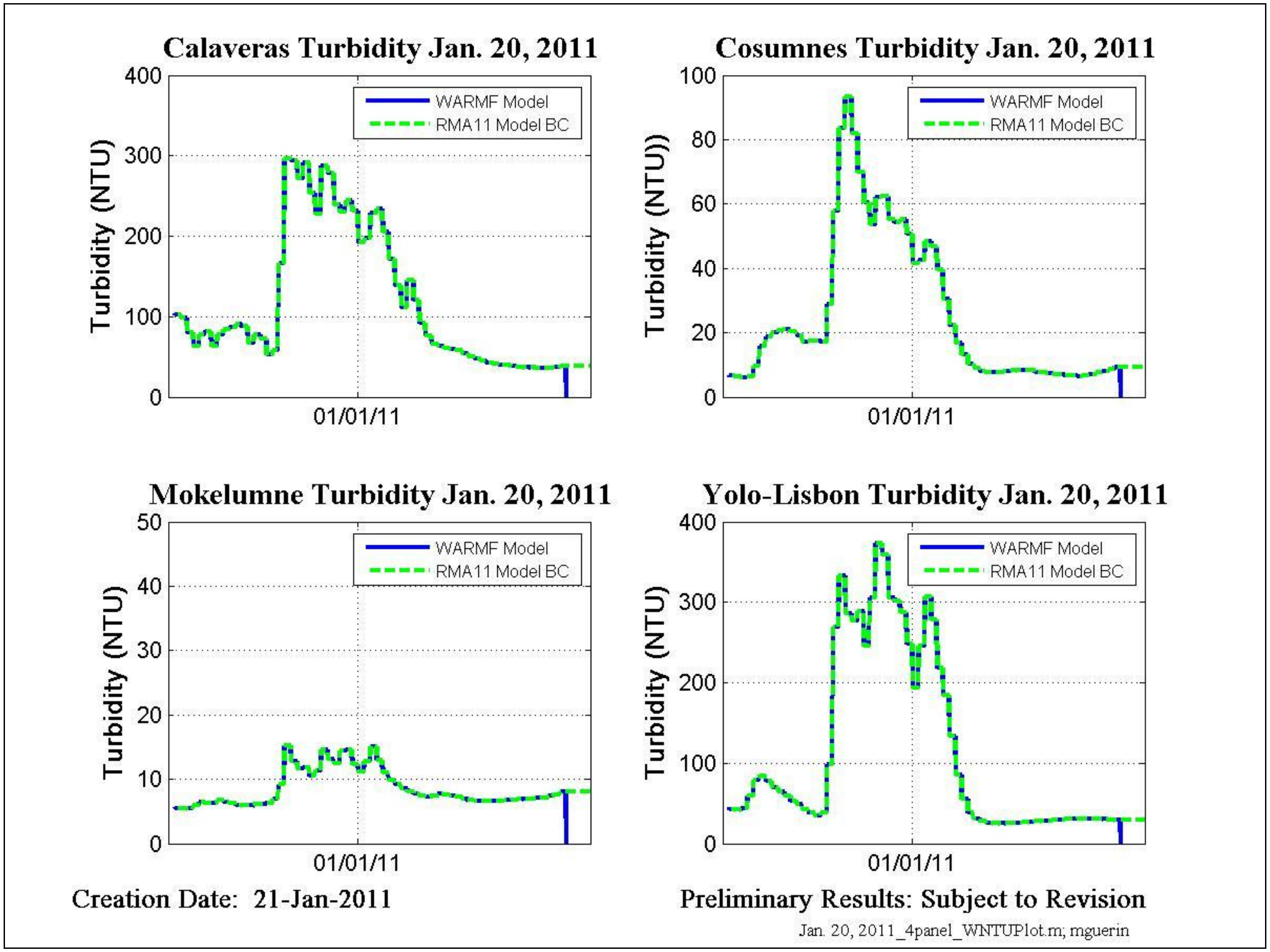


Figure 12-93 Turbidity boundary conditions used in the model along with the WARMF model output. Note difference in vertical scales.

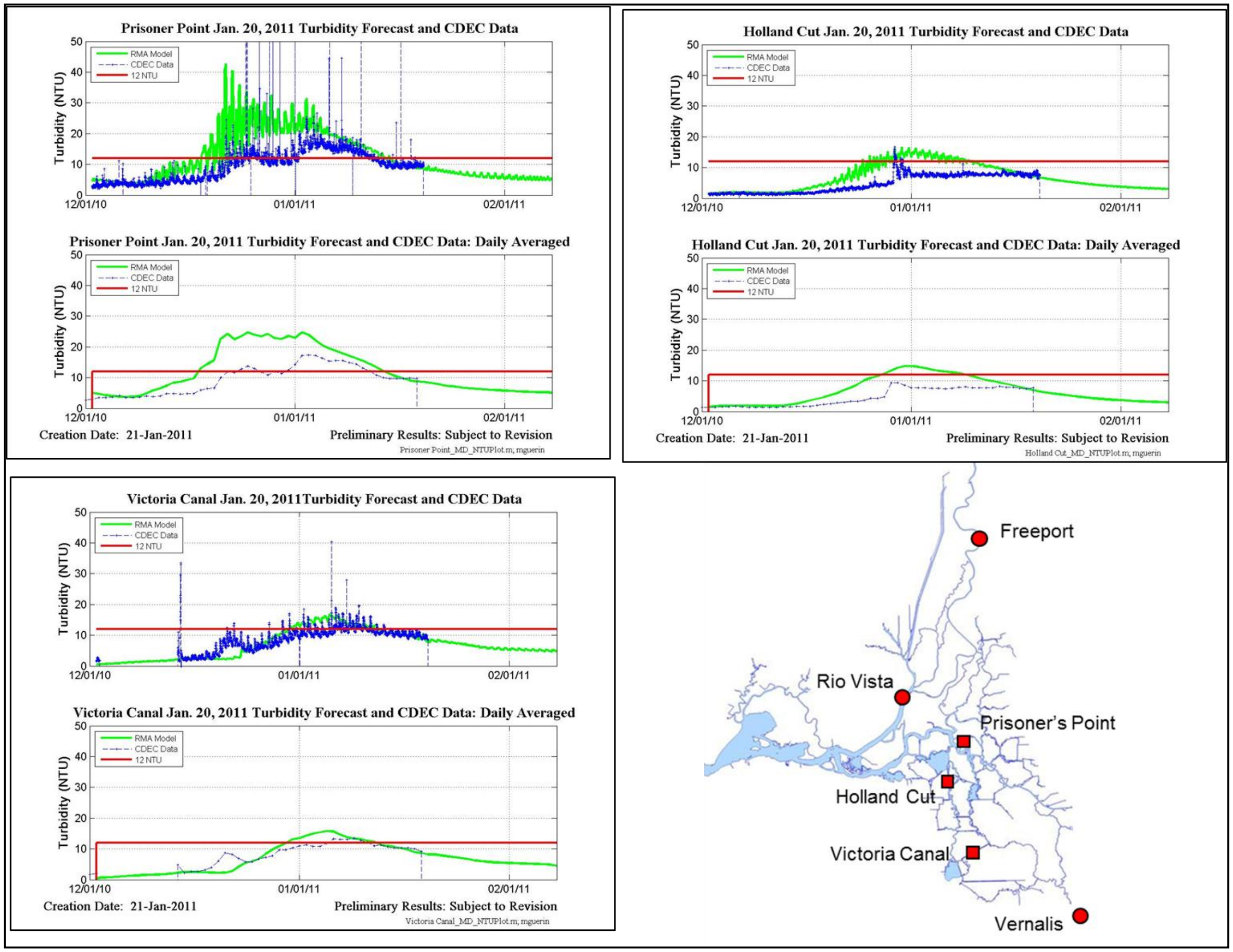


Figure 12-94 Modeled turbidity and data at the three compliance locations. Both 15-min model output and data and daily averaged plots are shown. Red line illustrates the 12-NTU compliance value. Very high values in Prisoner's Point data were removed before averaging.

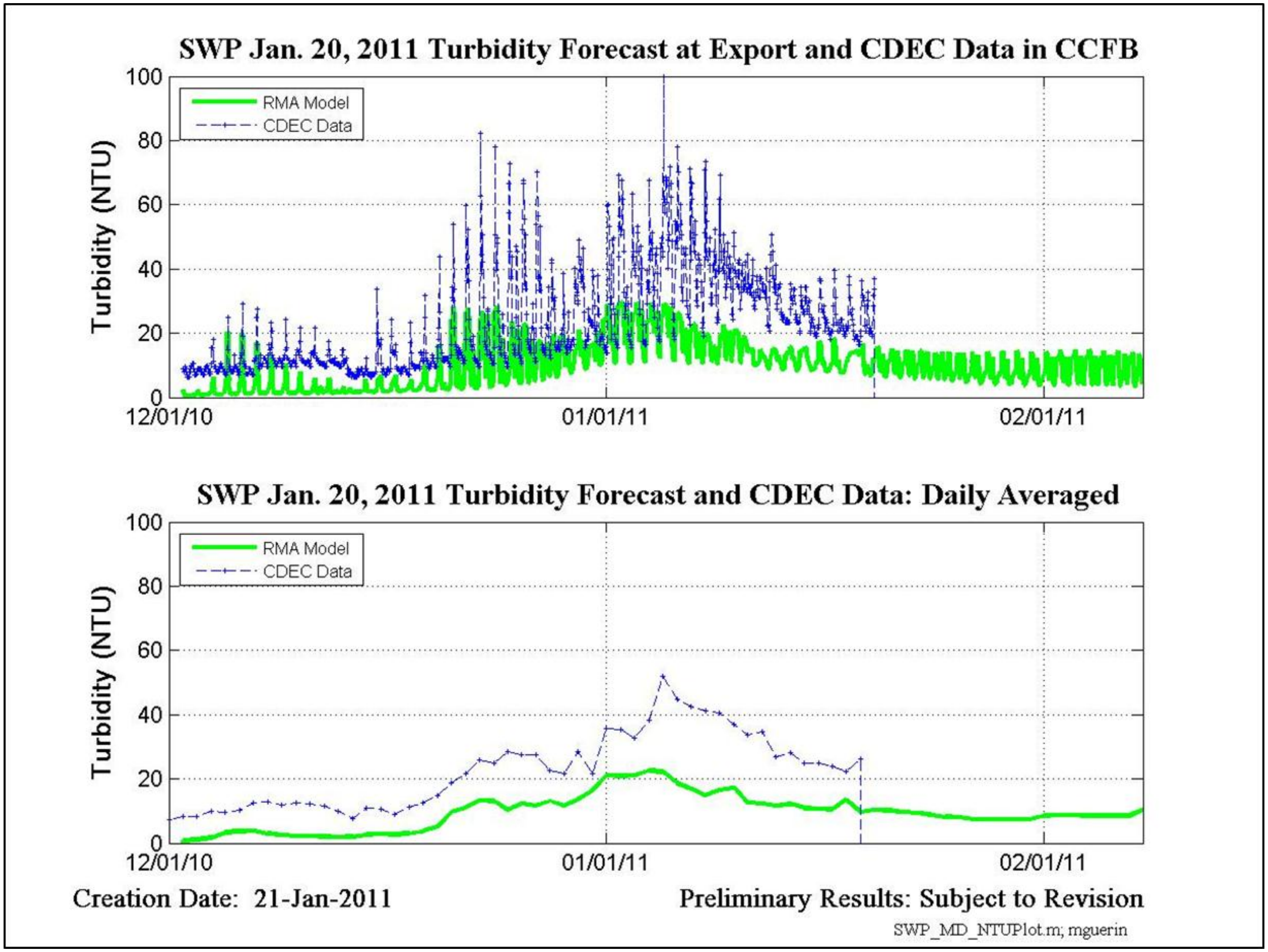


Figure 12-95 Plots compare model output at the SWP export location with data gathered inside Clifton Court Forebay. Both 15-min model output and daily averaged plots are shown.

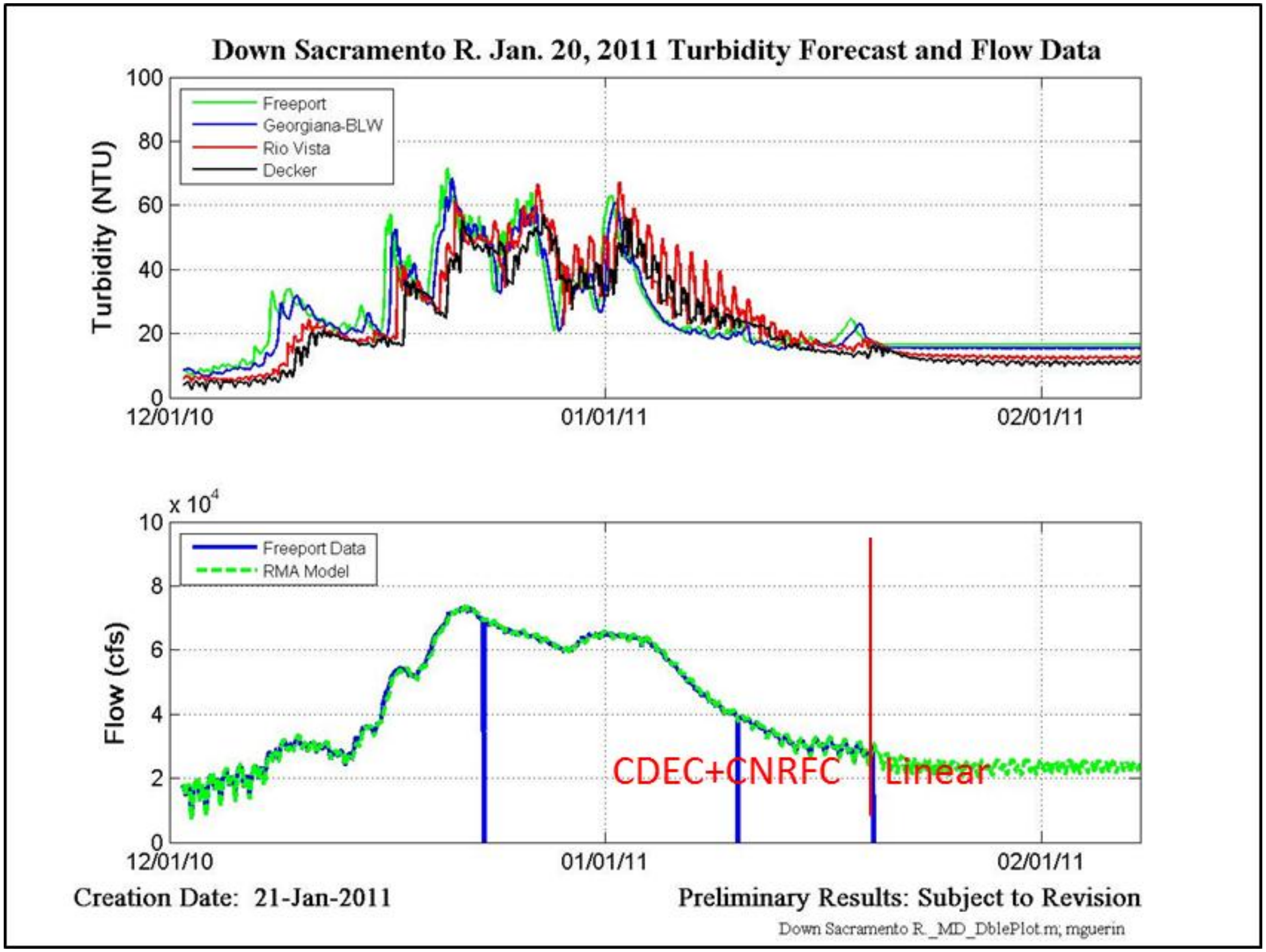


Figure 12-96 Freeport turbidity boundary condition progression down the Sacramento R. (upper plot) along with the flow data and RMA model boundary conditions (lower plot) used during the historical and forecast periods. Forecast began on January 20th. Vertical bar placement is approximate.

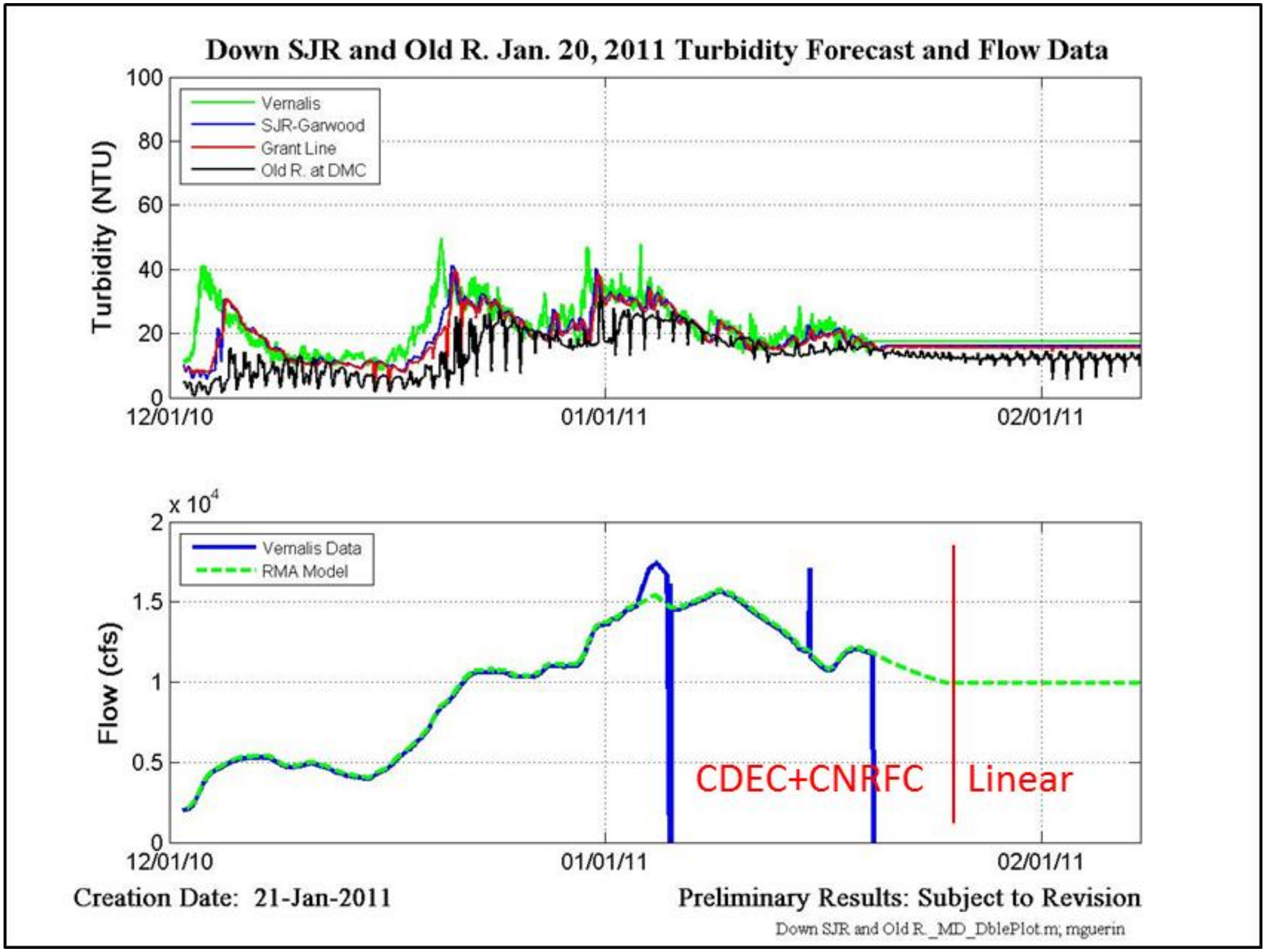


Figure 12-97 Progression of the turbidity boundary condition from Vernalis down the San Joaquin R. to Garwood, and down Old River. Vernalis flow forecast periods indicated by red lines (upper plot). Flow data and RMA model boundary conditions at Vernalis are shown in the lower plot. Forecast began on Jan 20th. Vertical bar placement is approximate.

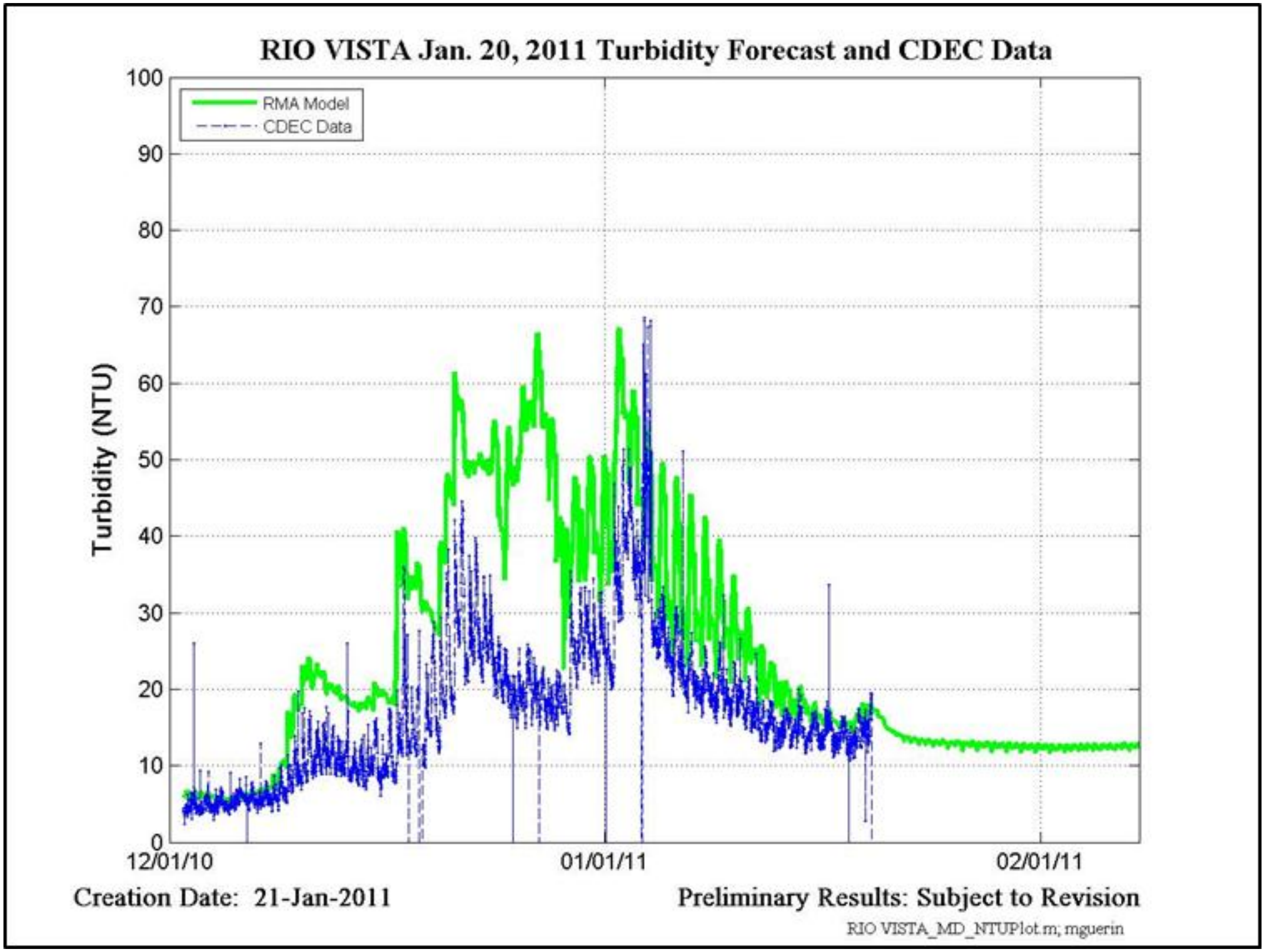


Figure 12-98 Model forecast and CDEC data at Rio Vista.

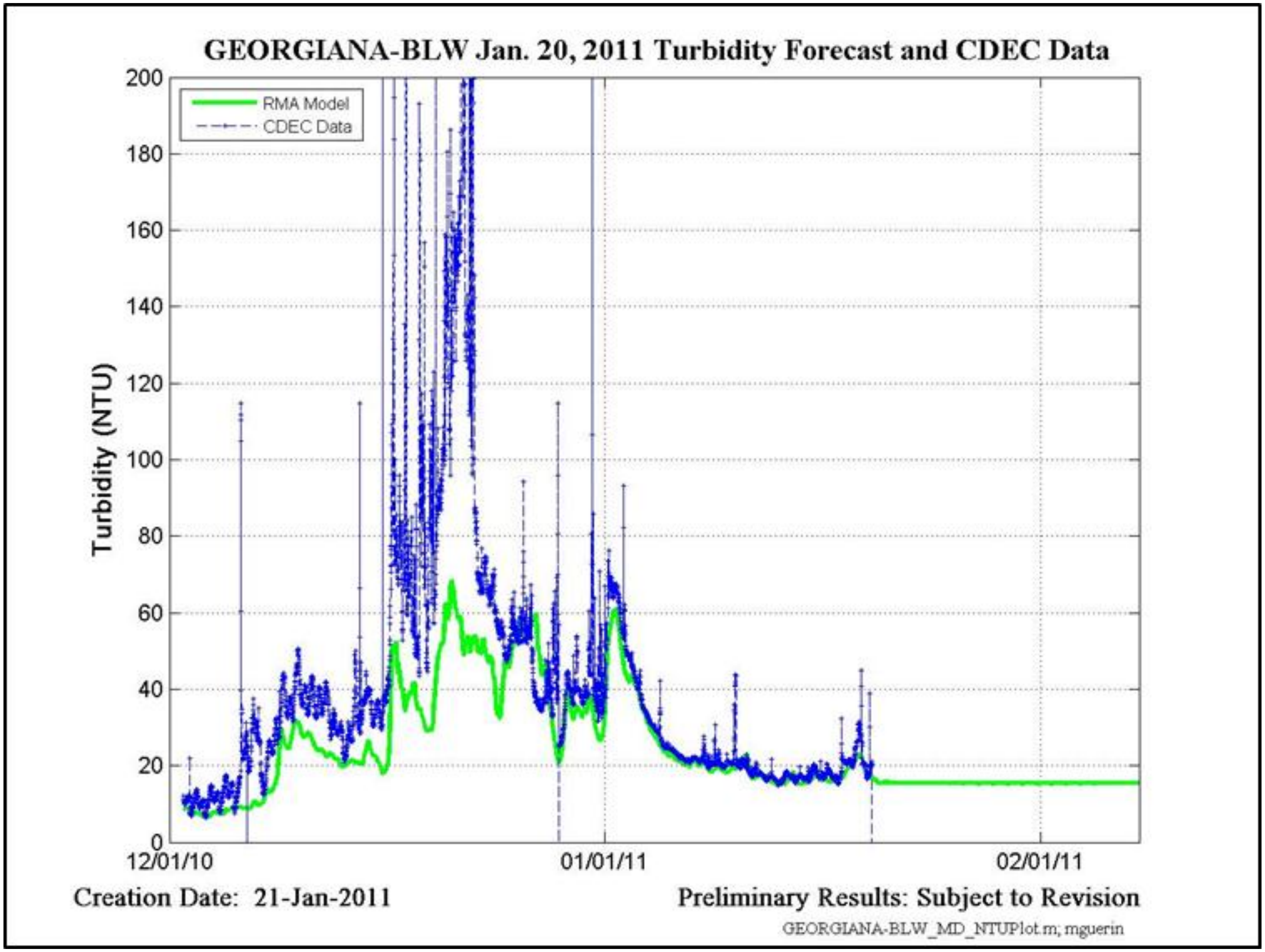


Figure 12-99 Model forecast and CDEC data at Georgian-BLW.

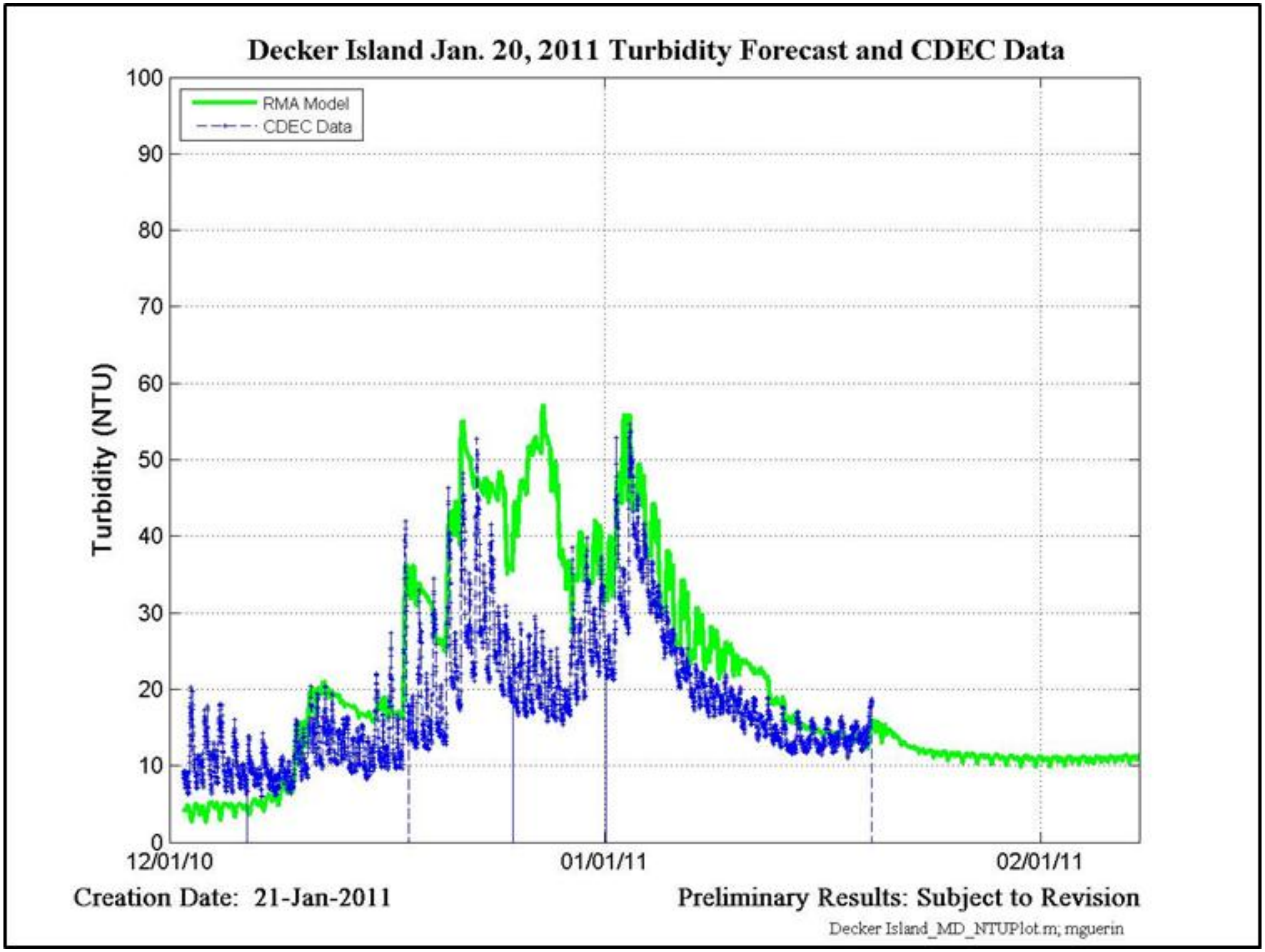


Figure 12-100 Model forecast and CDEC data at Decker Island.

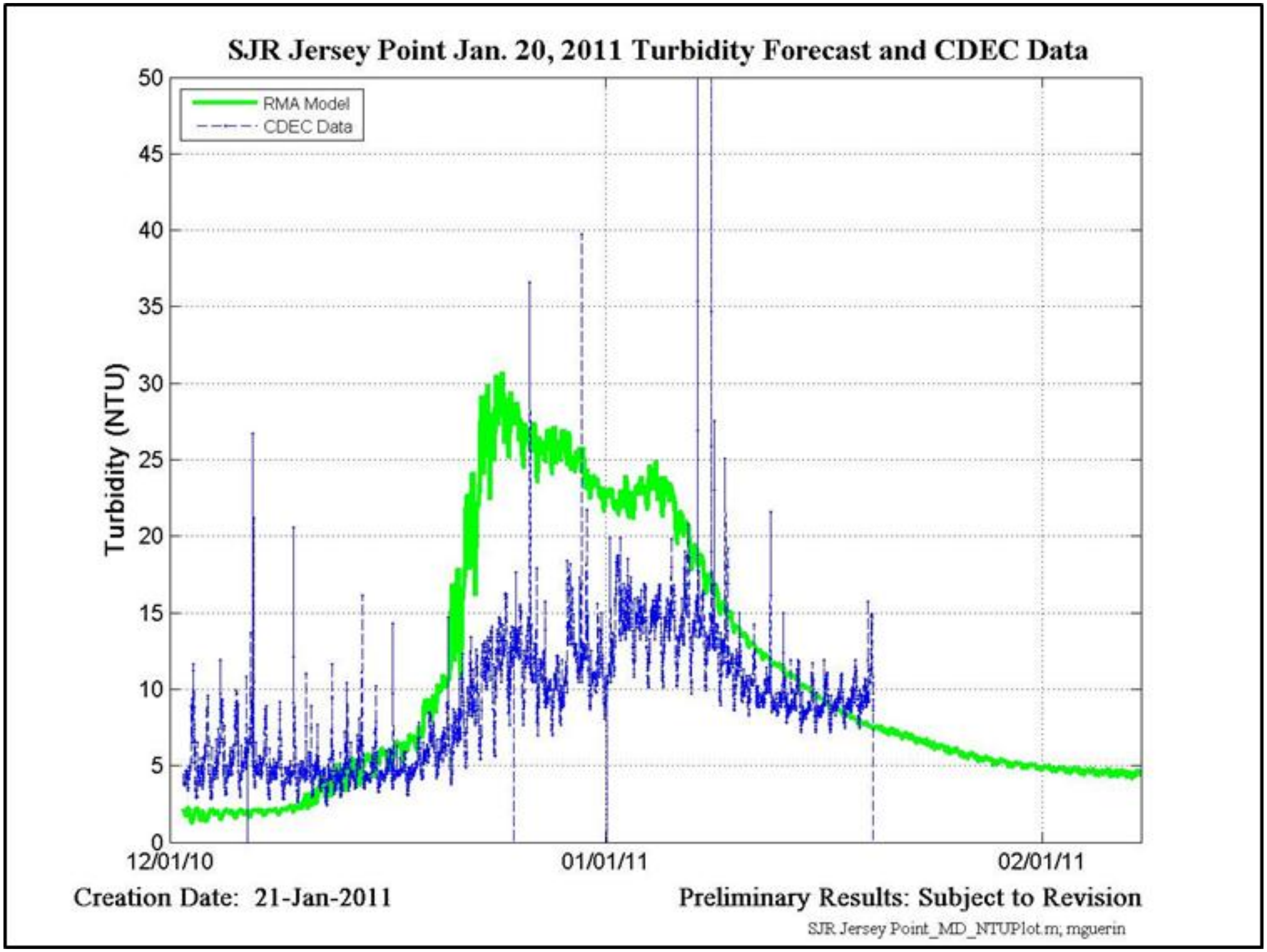


Figure 12-101 Model forecast and CDEC data at Jersey Point.

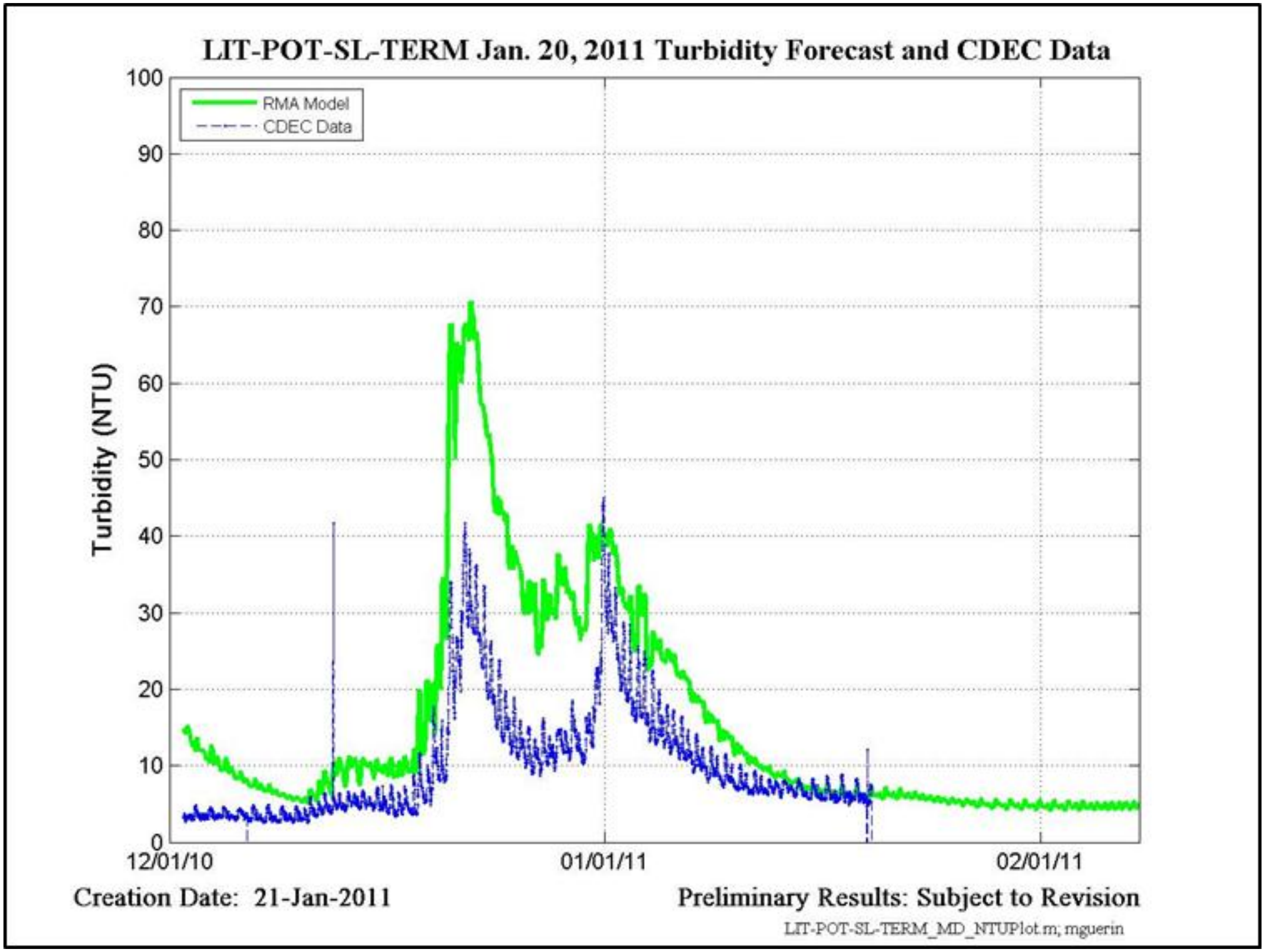


Figure 12-102 Model forecast and CDEC data at Little Potato Slough at Terminous.

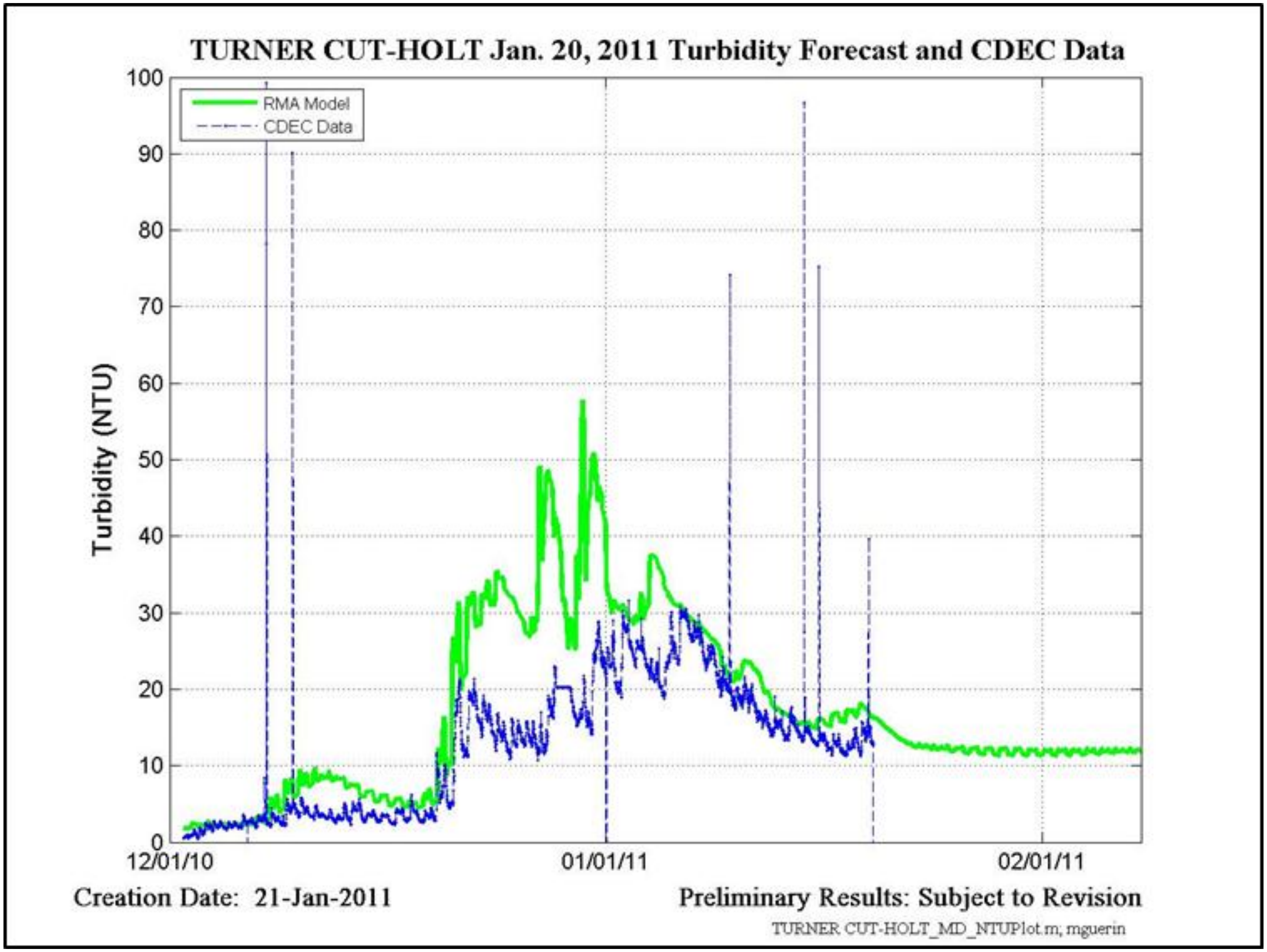


Figure 12-103 Model forecast and CDEC data at Turner Cut near Holt.

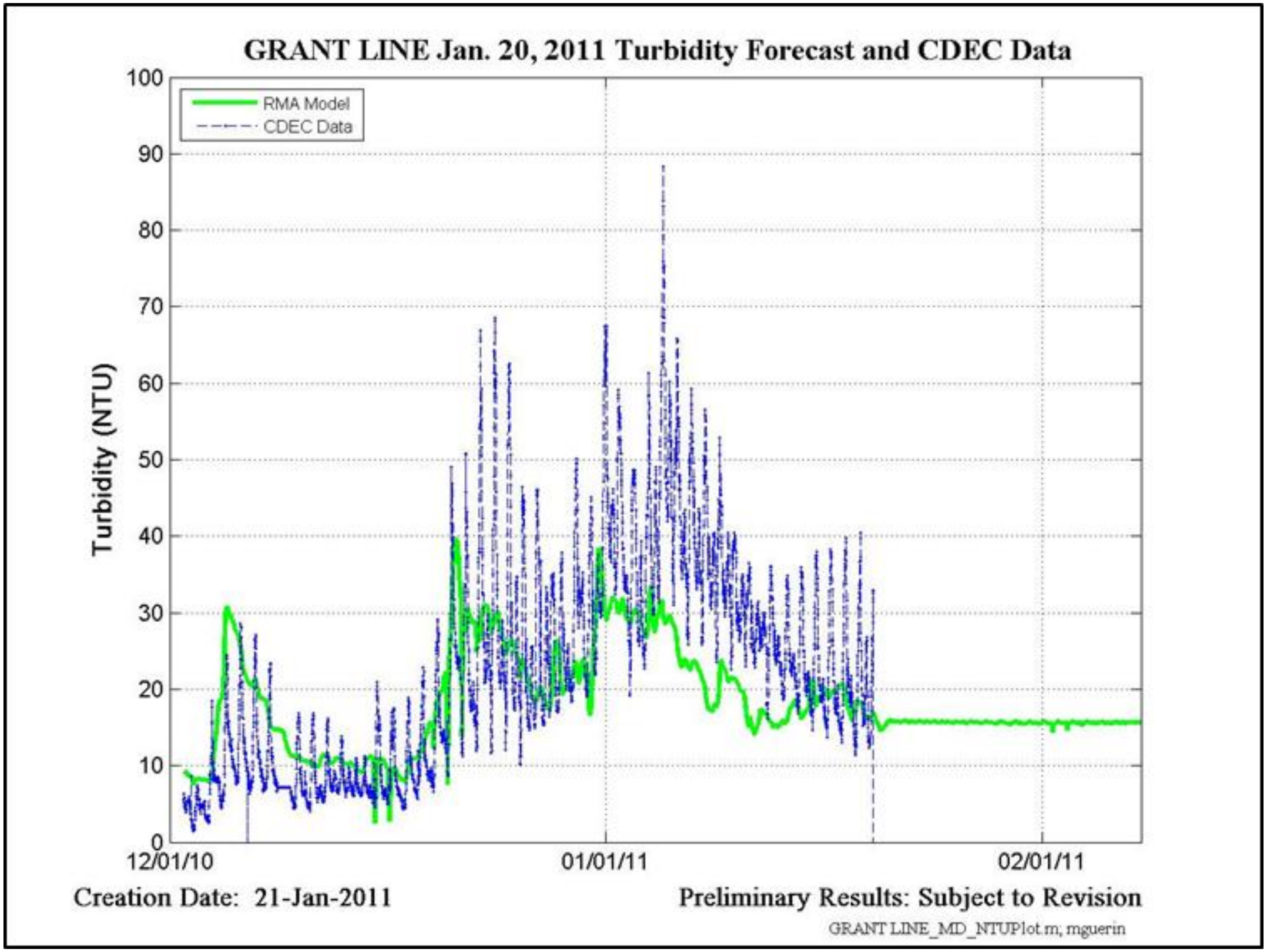


Figure 12-104 Model forecast and CDEC data at Grant Line.

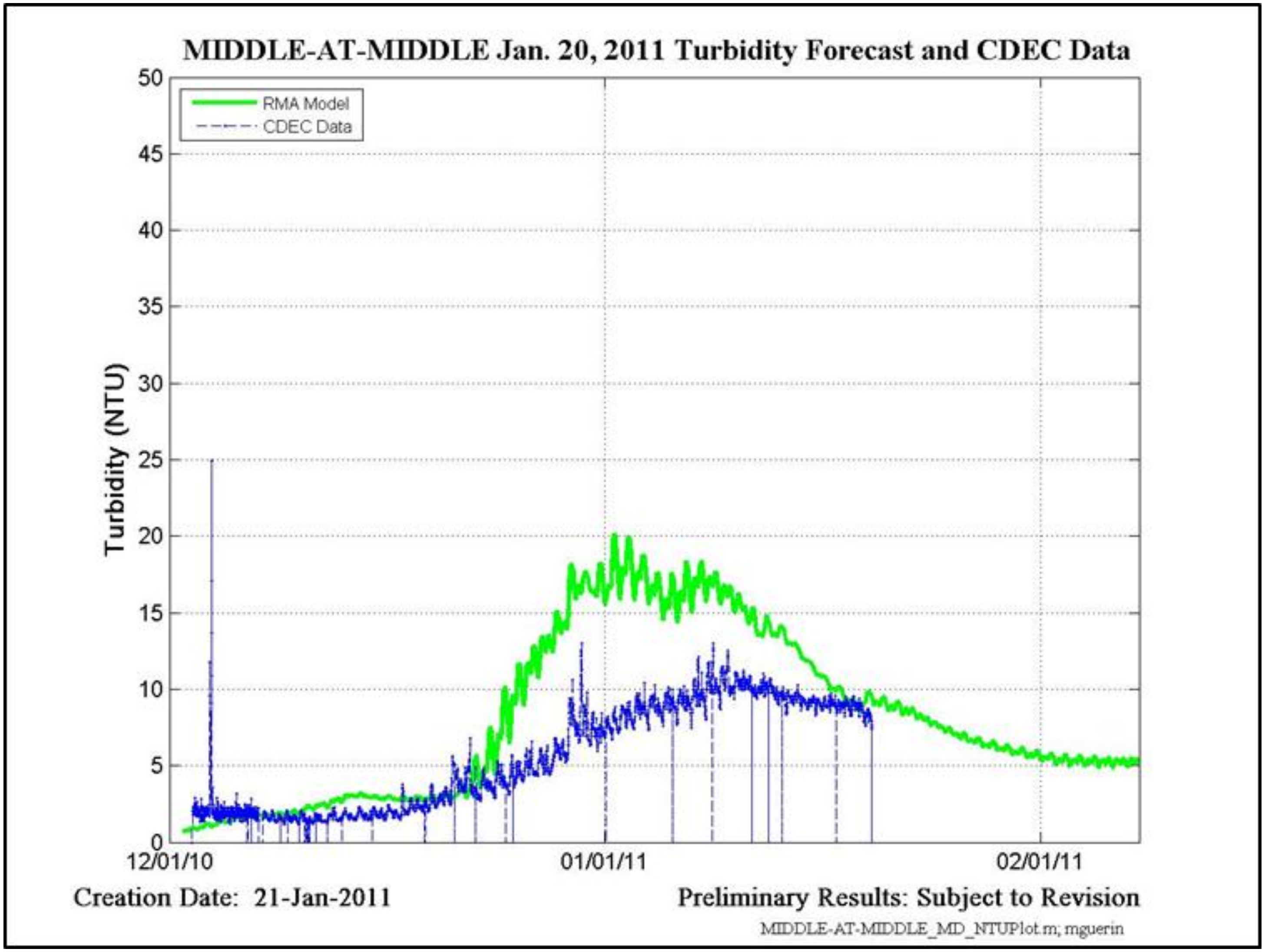


Figure 12-105 Model forecast and CDEC data at Middle R. at Middle R.

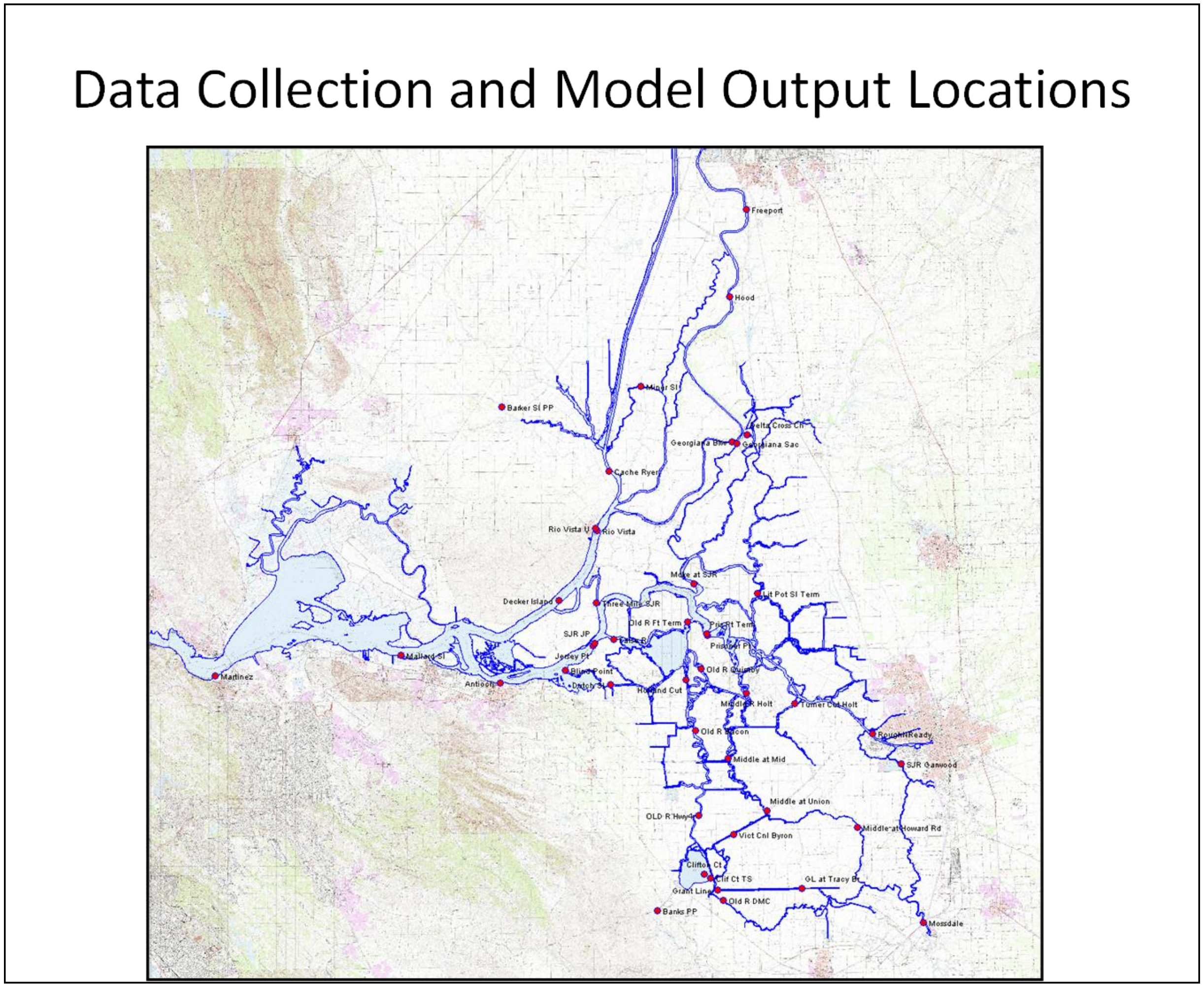


Figure 12-106 Figure illustrating model output and data collection locations.

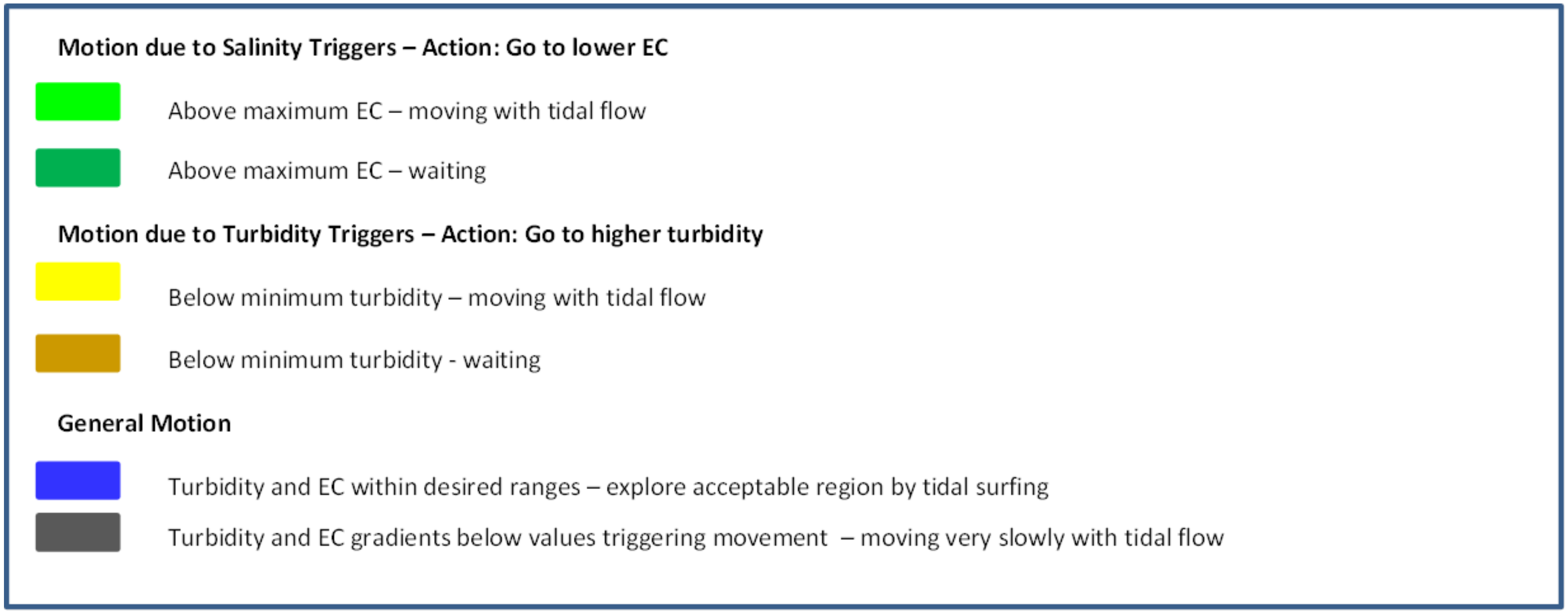


Figure 12-107 Particles in the Adult Delta Smelt particle tracking model are color-coded by the triggers influencing their behavior during the simulation. Use this figure to interpret the simplified color scale in the next several figures.

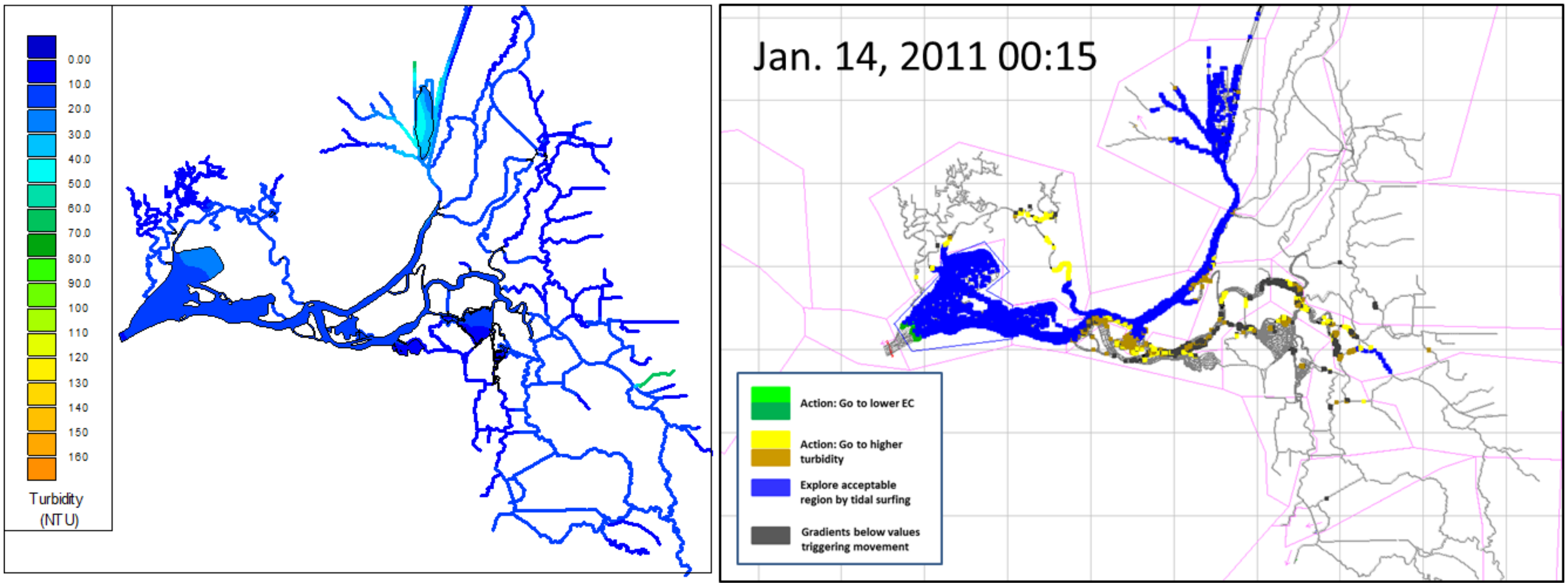


Figure 12-108 Turbidity contours and particle location in the RMA model grid on Jan. 14, 2011.

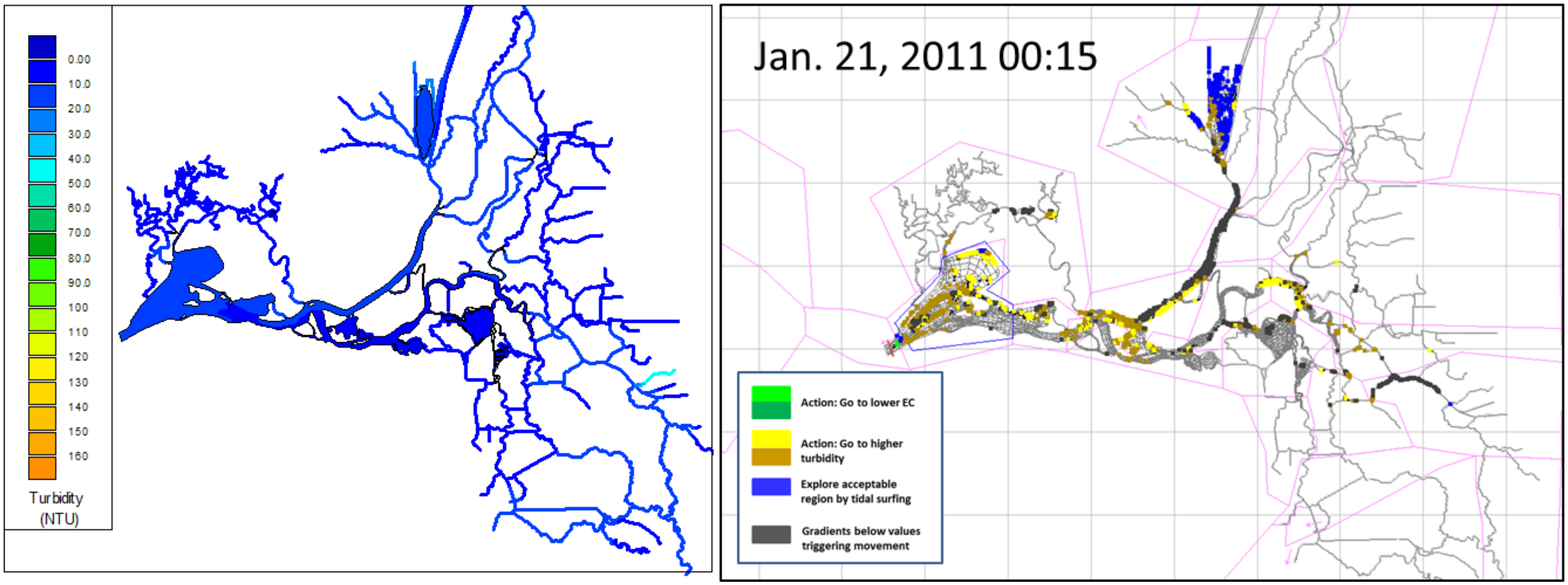


Figure 12-109 Turbidity contours and particle location in the RMA model grid on Jan. 21, 2011.

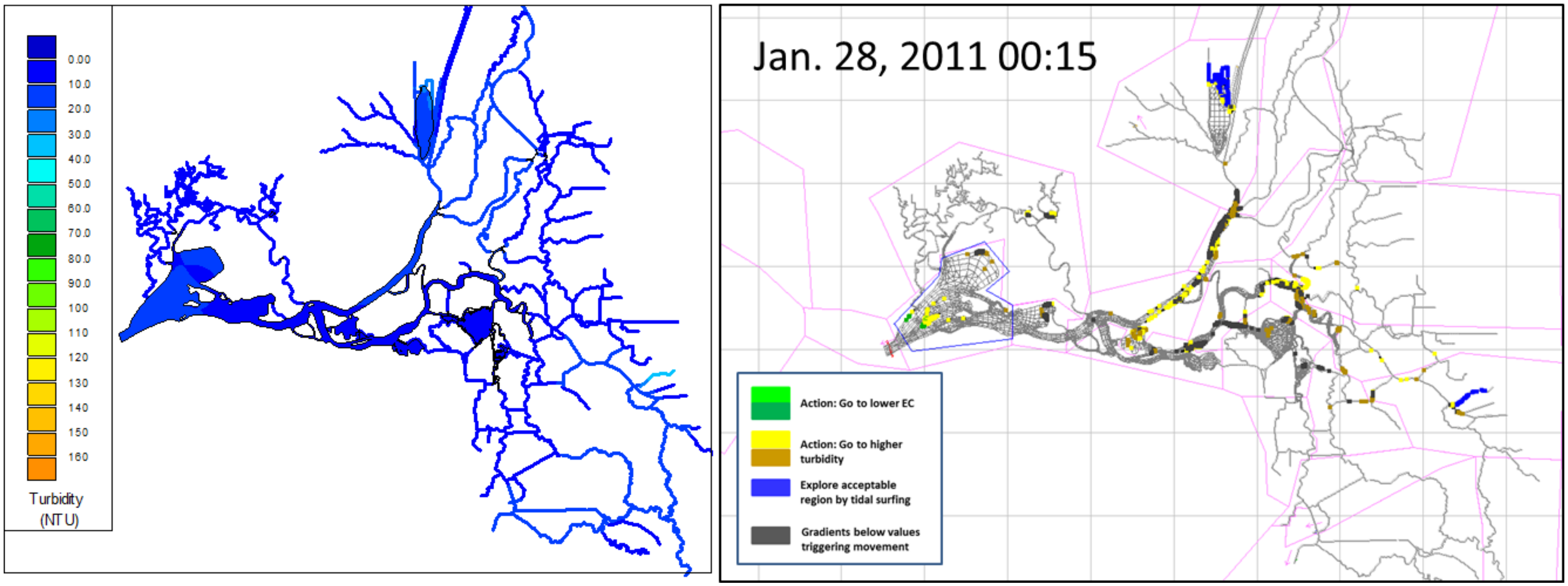


Figure 12-110 Turbidity contours and particle location in the RMA model grid on Jan. 28, 2011.

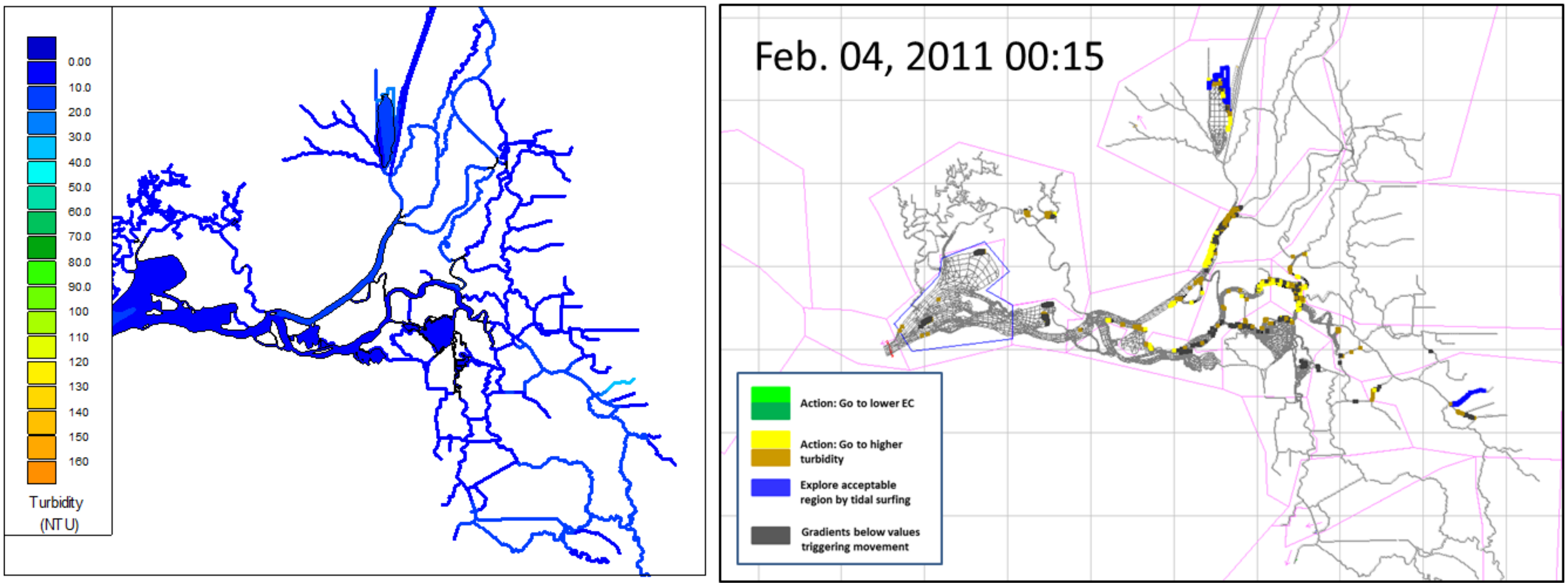


Figure 12-111 Turbidity contours and particle location in the RMA model grid on Feb. 04, 2011.

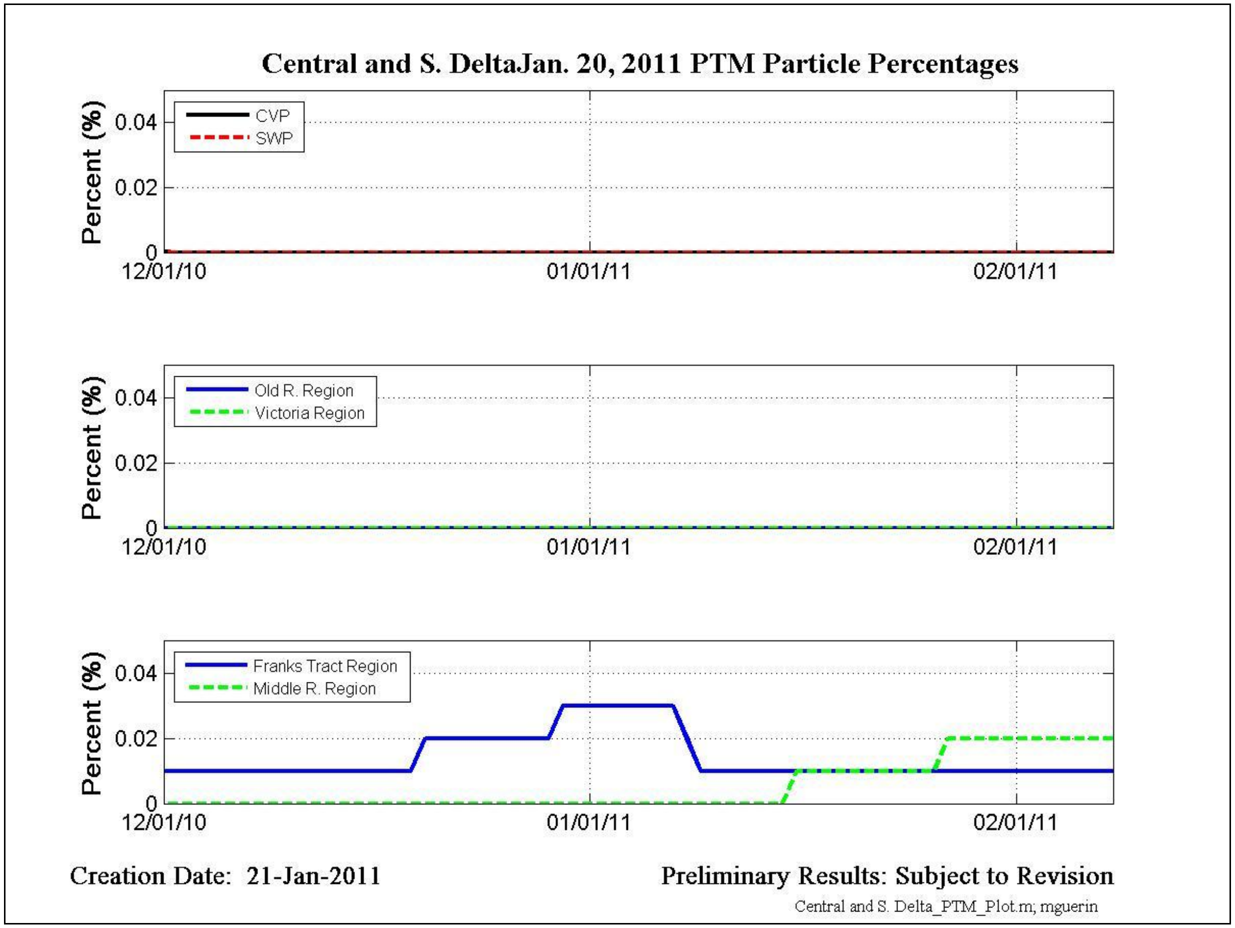


Figure 12-112 Only a couple of particles reached the SWP export location, none reached CVP (upper plot). No particles entered the Old River or Victoria Regions (center plot). A very small percentage reached the Franks Tract and Middle River Regions (lower plot).

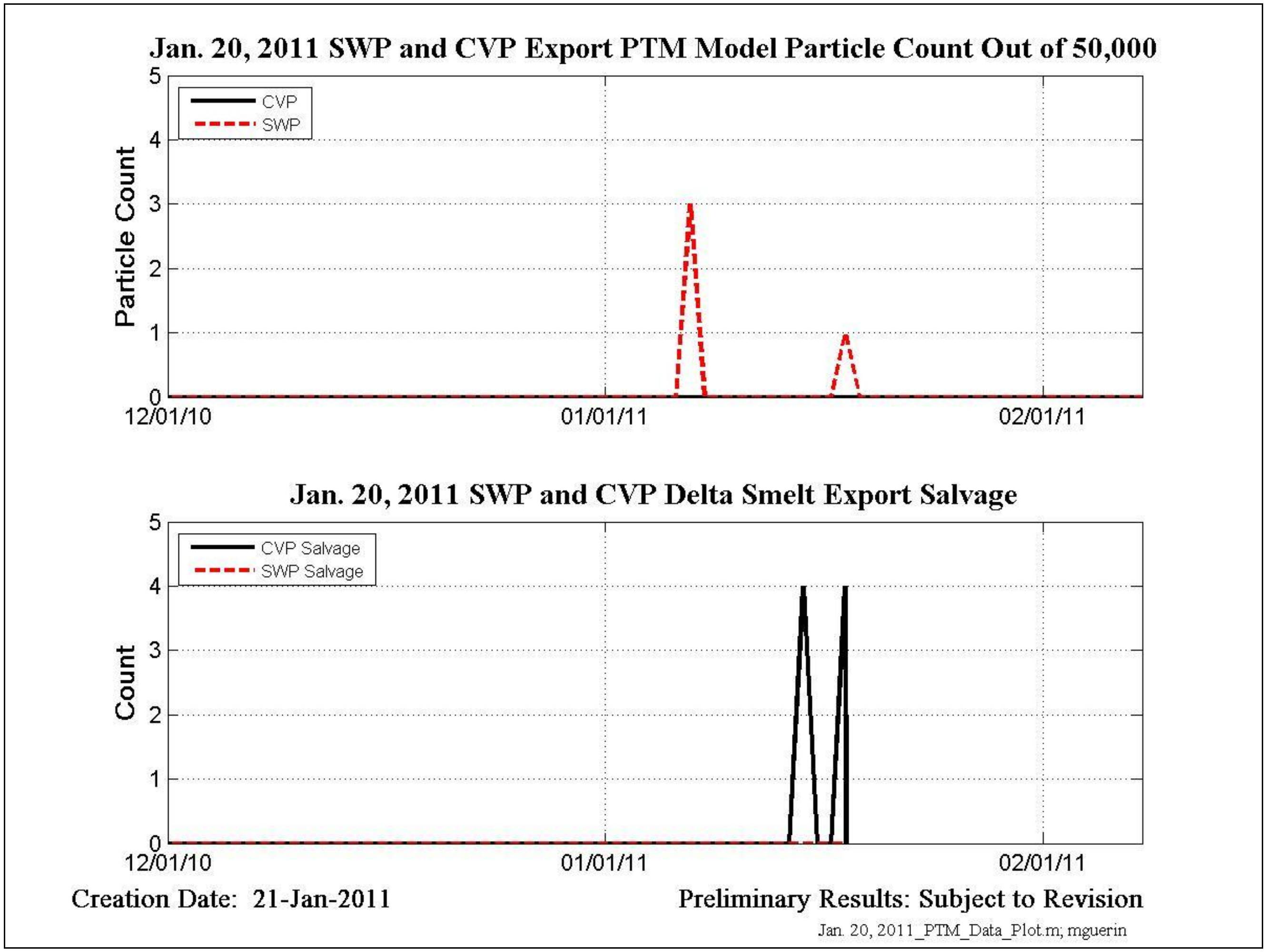


Figure 12-113 Four delta smelt were salvaged on Jan 15th and again on Jan 18th at the CVP location (lower plot). The upper plot shows that a few particles reached the SWP export location, but the percentage was so small as to be insignificant (see Figure 12-59).

12.3.6. Forecast Jan. 25, 2011

This document provides a quick summary of the January 27, 2011 forecast prepared using the RMA hydrodynamic, salinity, turbidity and Adult Delta Smelt Behavioral models. Graphical results are provided to document the results of the modeling with a focus on turbidity. Model BC (Boundary Conditions) were prepared using WARMF-supplied historical and forecast conditions, CDEC data, and DWR-supplied model inputs and results from their flow and salinity forecasts. The development of BCs was simplified extensively as per agreement with P. Hutton. The reason for the simplification was that errors in the WARMF, and to some extent, the DWR BCs overwhelmed the increase in accuracy the more accurate RMA BC modifications had been developing to date.

The RMA modeled period was January 01, 2010 to February 15, 2011 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 and with model output for a combined historical and forecast period Jan. 14, 2011 through Feb. 15, 2011. The DWR forecast period began Jan. 25, 2011. The WARMF modeled period, consisting of daily model output for flow, salinity and turbidity, was Dec. 01, 2010 – Feb. 10, 2011. Additional flow, turbidity and EC data was downloaded for the period Jan. 20 – Jan. 26, 2011 from the CDEC websites to augment the DWR and WARMF model output and for the turbidity boundary condition development.

Due to the simplifications, producing BC during this forecast period was much less challenging than it was for previous forecasts. The WARMF and DWR forecasts arrived early on Thursday afternoon. Historical and Forecast BC were developed from several sources, as summarized in Table 12-11. Where there were discrepancies between data and model or between DWR and WARMF models, BC were compiled using best professional judgment. For the first time, the WARMF turbidity for Vernalis was used for the forecast period as WARMF reproduced historical turbidity fairly well at Vernalis (Figure 12-117). Stage and export BC were compiled solely from DWR O&M sources. The Martinez salinity boundary condition was obtained from the DWR forecast, and the turbidity BC from CDEC data.

Plots showing model/data comparisons and model output for the modeled period Jan. 01 – Feb. 15, 2011 are included below as a pictorial summary of the results. Figure 12-114 through Figure 12-120 illustrate BC time series used in the RMA forecast model as well as the WARMF-supplied model output for flow and turbidity.

Figure 12-121 illustrates a comparison of model output and data at the three compliance locations, and Figure 12-122 illustrates a similar comparison in the SWP export area. Note that Figure 12-122 is a comparison of data inside Clifton Court Forebay with model output at the model boundary at the entrance to the Forebay. For these figures, model and data were used at

15-min or hourly time intervals as collected or modeled, and also daily averaged. The data at Prisoner's Point was noisy, so turbidity values that appeared unreasonably high were deleted before averaging. Note that the time series used to create Figure 12-121 are included in the email communication accompanying this document as a separate EXCEL file.

Only at the Holland Cut compliance location did averaged data remain below 12 NTU – modeled turbidity exceeded the 12 NTU value at each compliance location (Figure 12-121. Modeled turbidity was high in comparison with data in most of the model domain through mid-January (Figure 12-125 through Figure 12-132) due to relatively high WARMF turbidity BC (Figure 12-120) at the Yolo and the eastside inflow locations at the Cosumnes and Calaveras Rivers, which also experienced fairly high flows.

The Delta Smelt behavioral model was run from Nov. 01, 2010 through Feb. 15, 2011 - 50,000 particles were inserted on Nov.01, 2010 as in previous forecast models. Because the historical and forecast boundary conditions are somewhat different than the previous model during overlapping times, the PTM results are slightly different. Note that the particle percentages shown in previous forecasts were incorrectly labeled – the Y-axis in previous forecasts should have been labeled 'Particle Fraction'. The graphs in the current document are labeled correctly as Particle Percentages.

Eight delta smelt were salvaged at the CVP location during the modeled period – four each on Jan. 15 and Jan. 18, 2011 – no delta smelt were salvaged at either location in December 2010. January delta smelt salvage numbers are available on the CVO website[12], and December delta smelt salvage numbers are available on the California Department of Fish and Game website[13]. A couple of particles reached the SWP export location during the modeled period (i.e., historical plus forecast), and a small percentage of particles entered the Middle R. and Franks Tract Regions – no particles entered the Old R. or Victoria Regions. See Figure 12-54 through Figure 12-59 for turbidity contour plots and particle tracking model results.

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

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[12] http://www.usbr.gov/mp/cvo/fishrpt.html

[13] http://www.dfg.ca.gov/delta/apps/salvage/SalvageExportCalendar.aspx

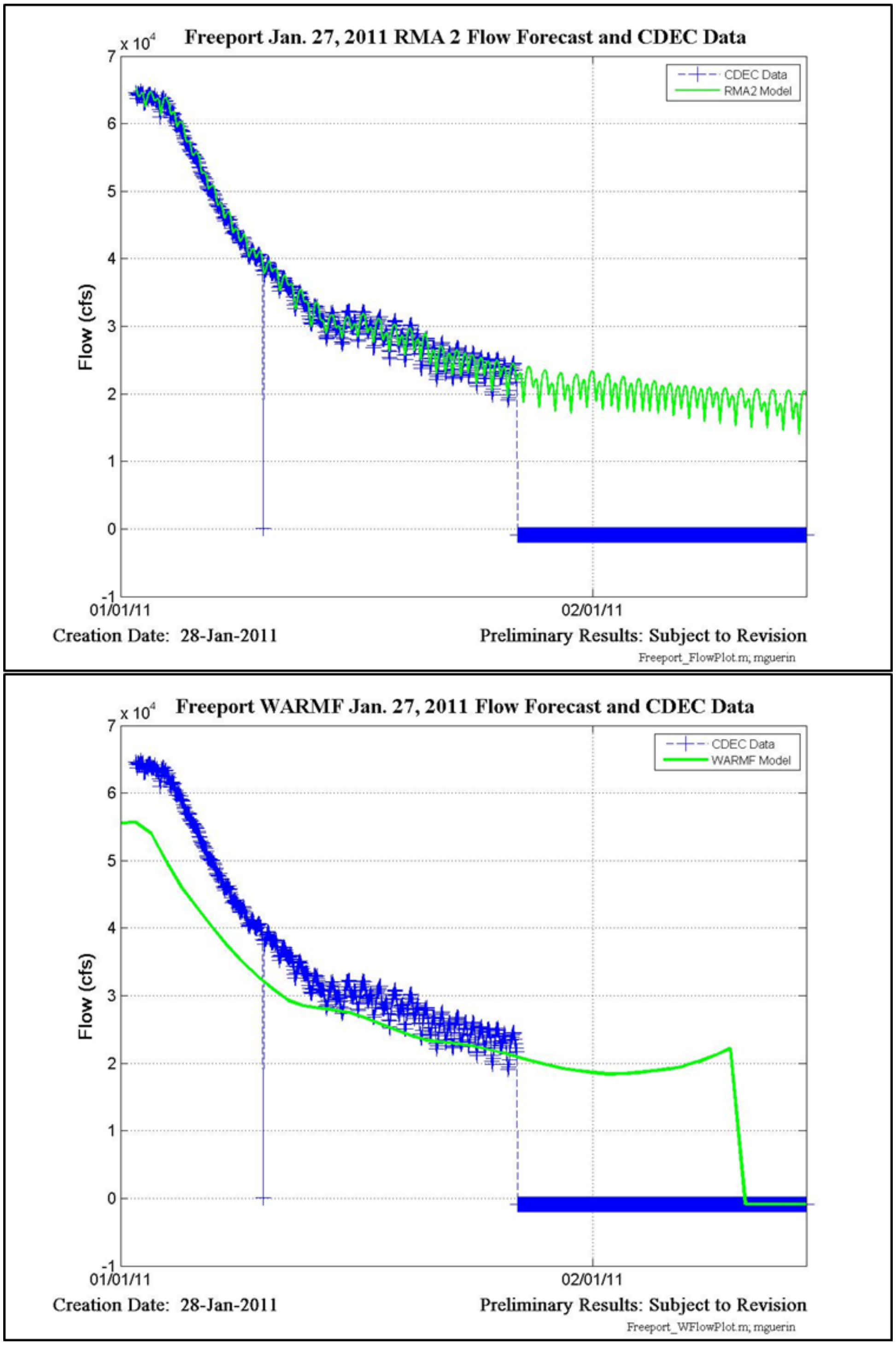
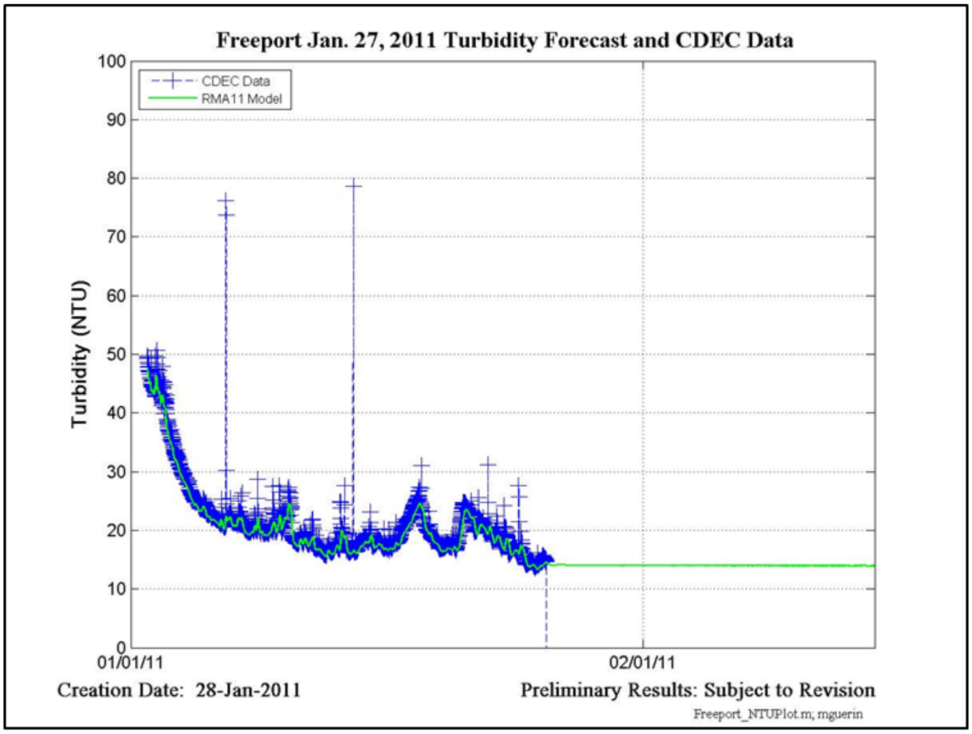


Figure 12-114 Freeport flow BC was compiled from CDEC data and the DWR forecast (top). WARMF model output, which was not used, is shown in the lower plot. Note y-axis unit is cfs*10,000. Zero values indicate the end of data (blue), and beginning of the forecast.



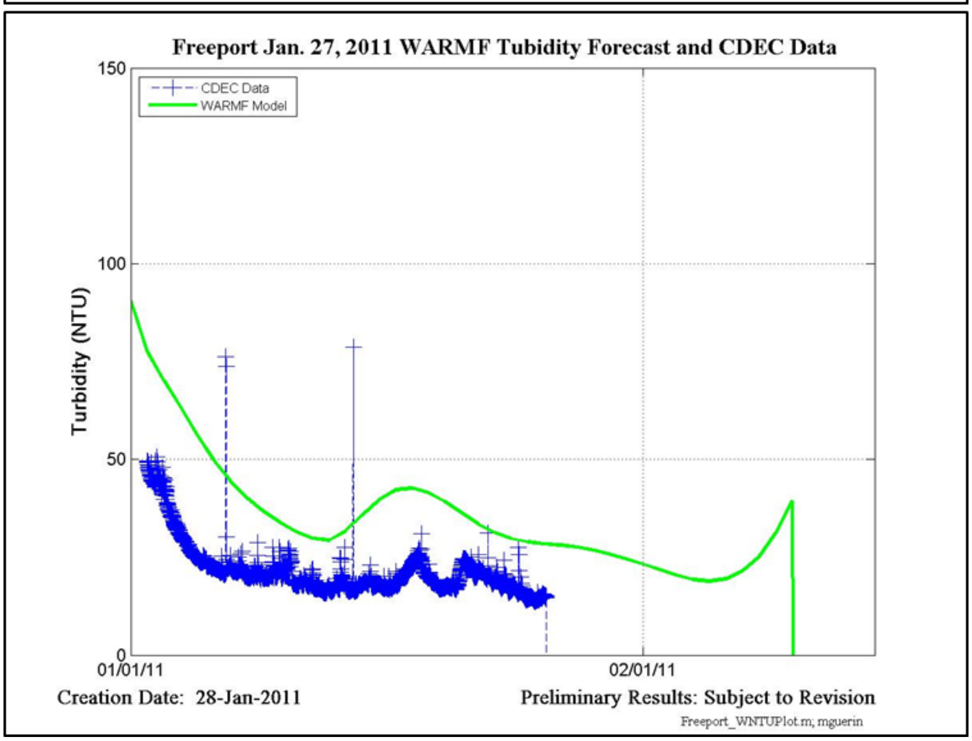


Figure 12-115 Freeport turbidity BC was compiled from CDEC data and then extended as a constant after Jan.25th, 2011. WARMF model output, which was not used, is shown in the lower plot. The beginning of the turbidity forecast occurs at the end of the CDEC data.

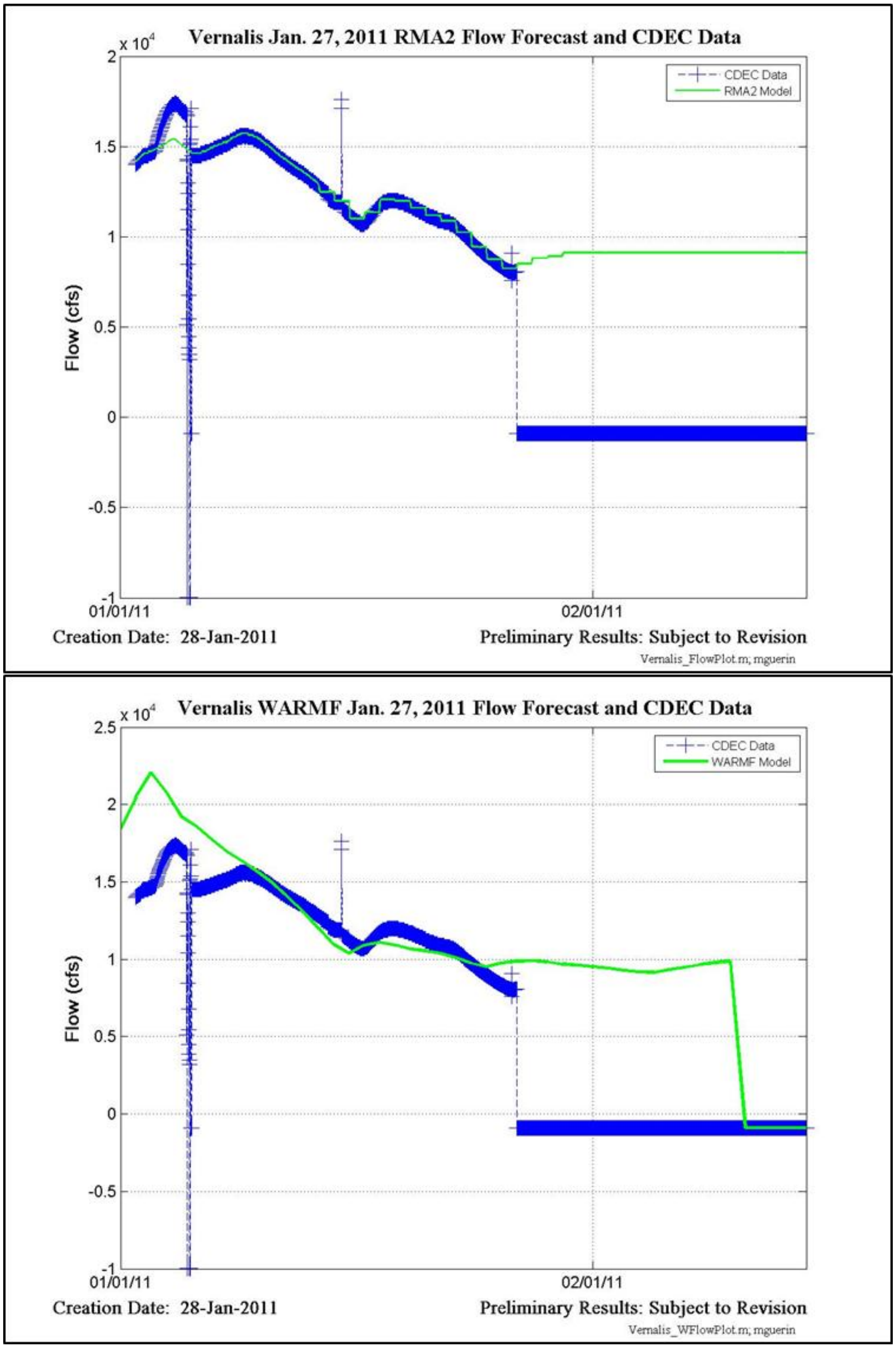
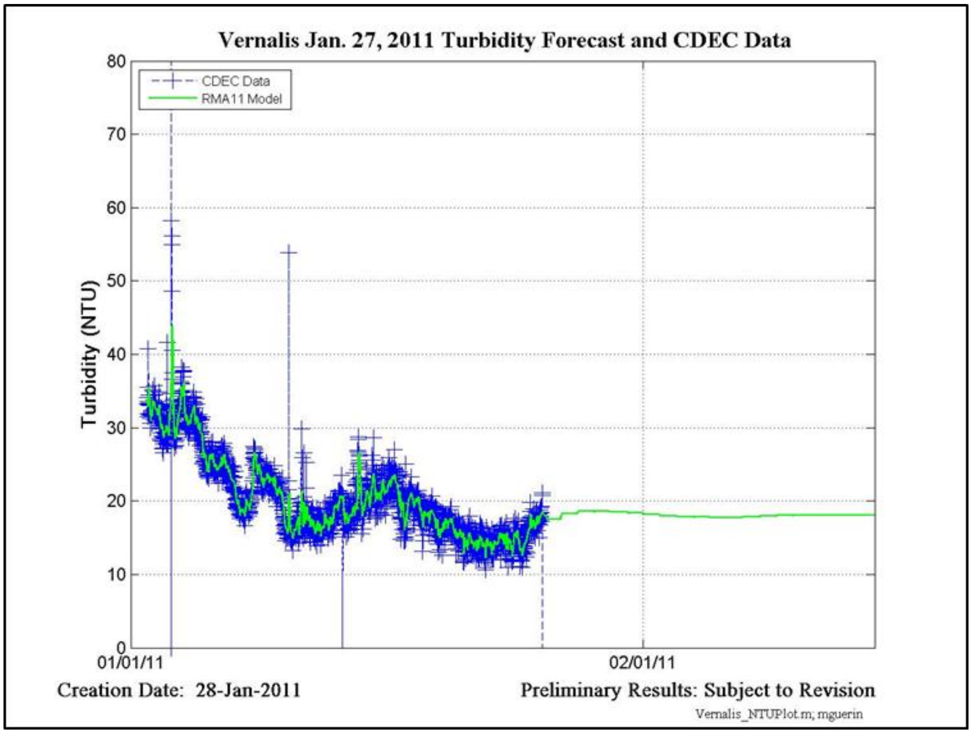


Figure 12-116 Vernalis flow BC was compiled from CDEC data and the DWR forecast. WARMF model output, which was not used, is shown in the lower plot. Note y-axis unit is cfs*10,000. Zero values indicate the end of data (blue) and the beginning of the forecast.



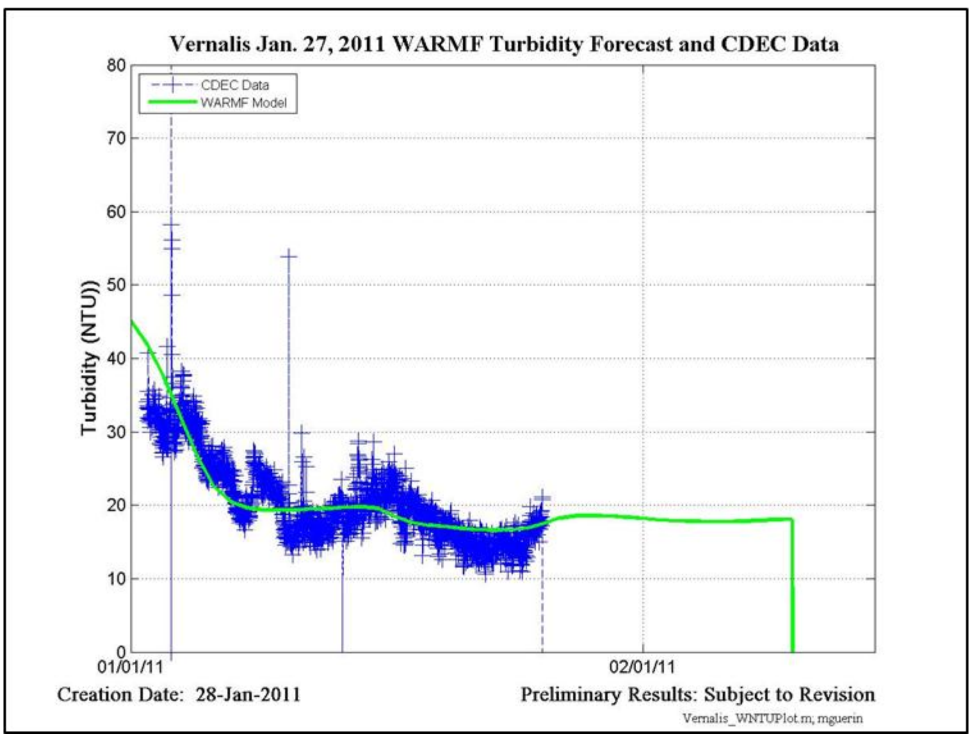


Figure 12-117 Vernalis turbidity BC was compiled from CDEC data, and then extended with WARMF model output, which is shown in the lower plot. The beginning of the forecast occurs at the end of the CDEC data.

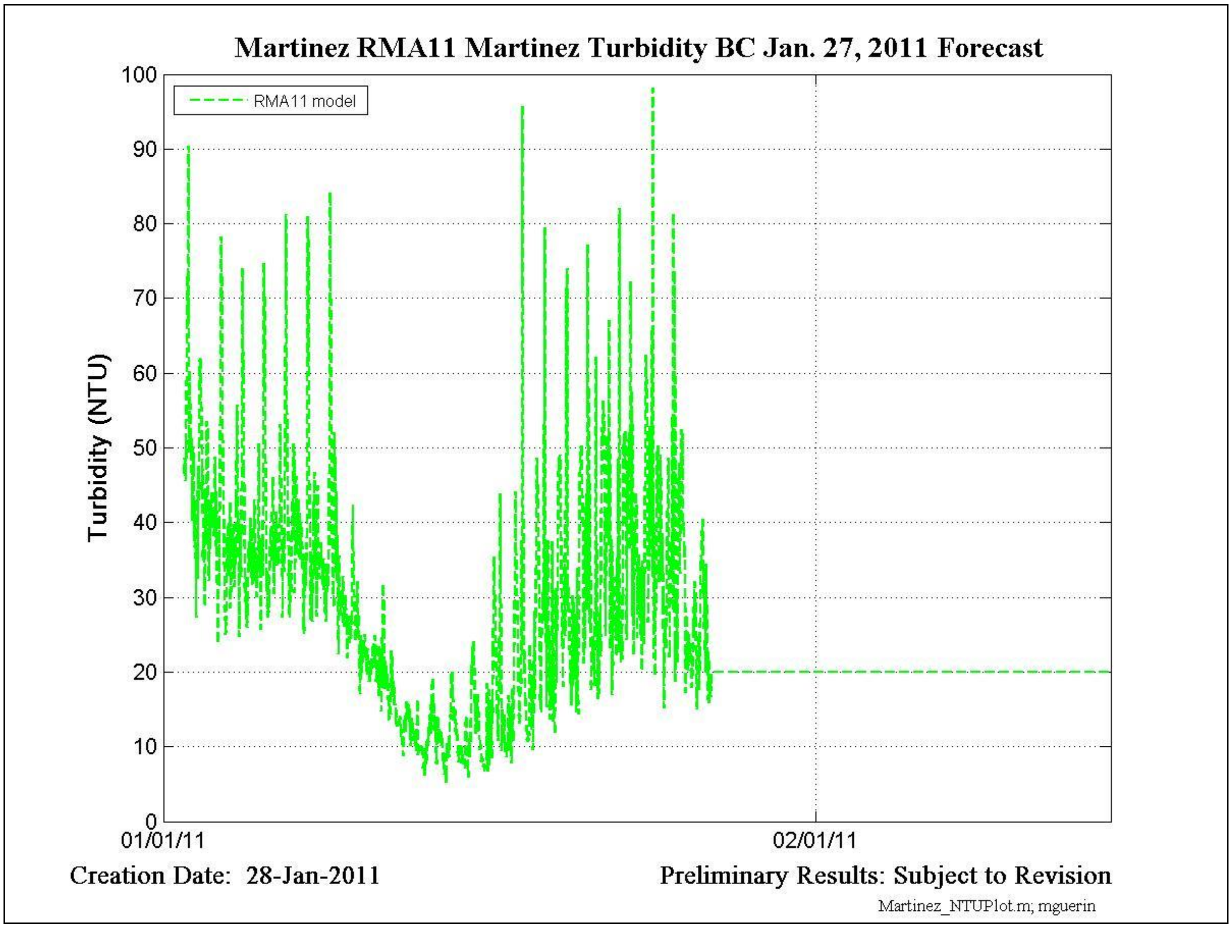


Figure 12-118 Martinez turbidity BC was compiled from CDEC data then extended linearly to a value of 20 NTU.

Table 12-11 Boundary condition development for Jan. 27, 2011 forecast for flow, turbidity and salinity (EC). Upper section lists the source for Historical BC, and lower section lists the Source for Forecast BC.

		Historical	
Location	**Sources for Flow BC**	**Sources for Turbidity BC**	**Sources for EC BC**
Yolo Bypass at Lisbon	Previous model	WARMF	WARMF
Freeport/Sacramento R. at I St. Bridge	DWR	CDEC	CDEC
Cosumnes River	DWR	WARMF	WARMF
Mokelumne River	DWR	WARMF	WARMF
Calaveras River	DWR	WARMF	WARMF
San Joaquin River at Vernalis	DWR	CDEC	DWR
Martinez	DWR - stage	CDEC	DWR

		Forecast	
Location	**Sources for Flow BC**	**Sources for Turbidity BC**	**Sources for EC BC**
Yolo Bypass at Lisbon	WARMF	WARMF	WARMF
Freeport/Sacramento R. at I St. Bridge	DWR	Constant	DWR (RSAC142)
Cosumnes River	DWR	WARMF	WARMF
Mokelumne River	DWR	WARMF	WARMF
Calaveras River	DWR	WARMF	WARMF
San Joaquin River at Vernalis	DWR	WARMF	DWR
Martinez	Constant stage	Constant	Constant

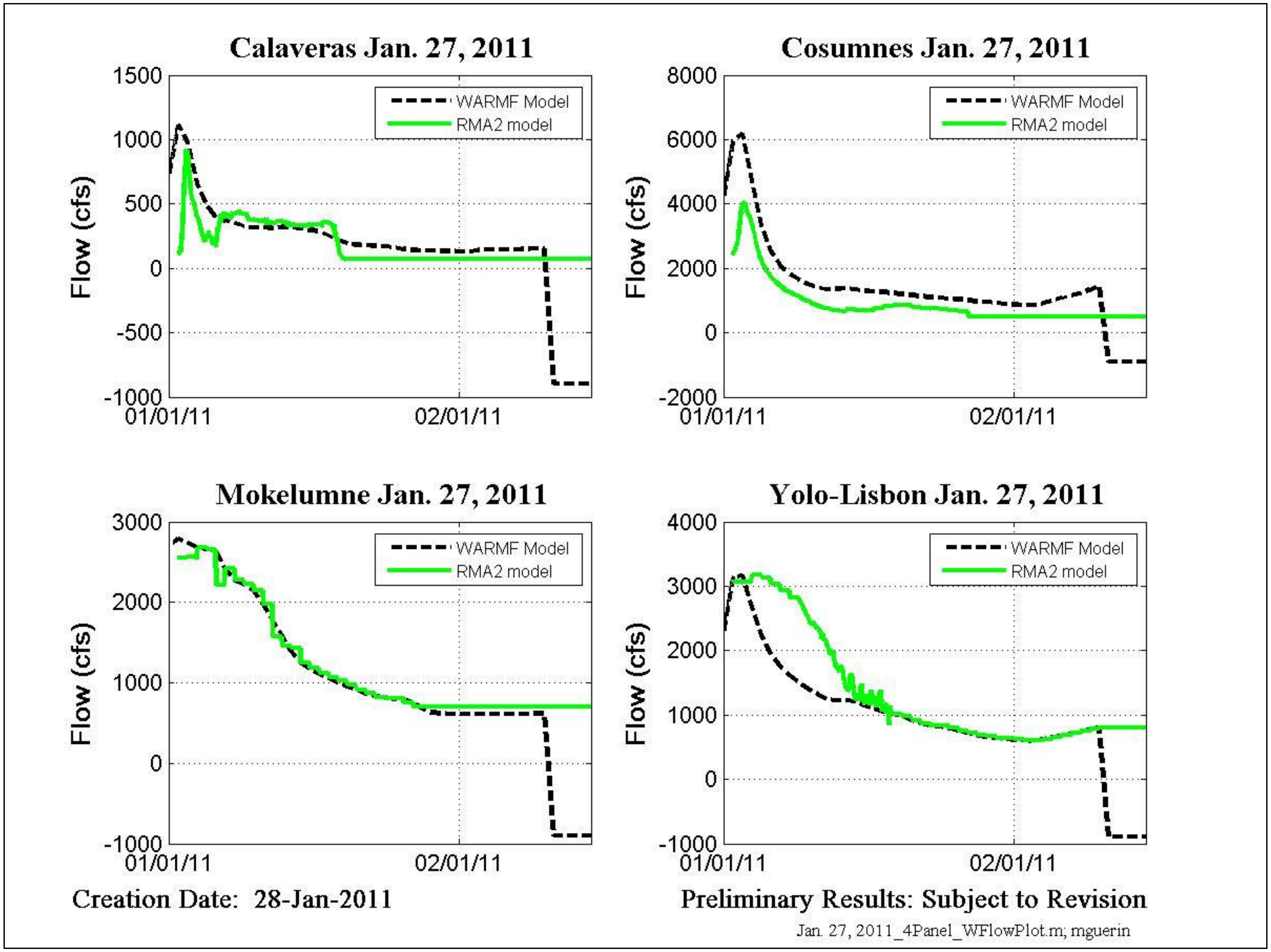


Figure 12-119 Four flow boundary conditions used in the model along with the WARMF model output.

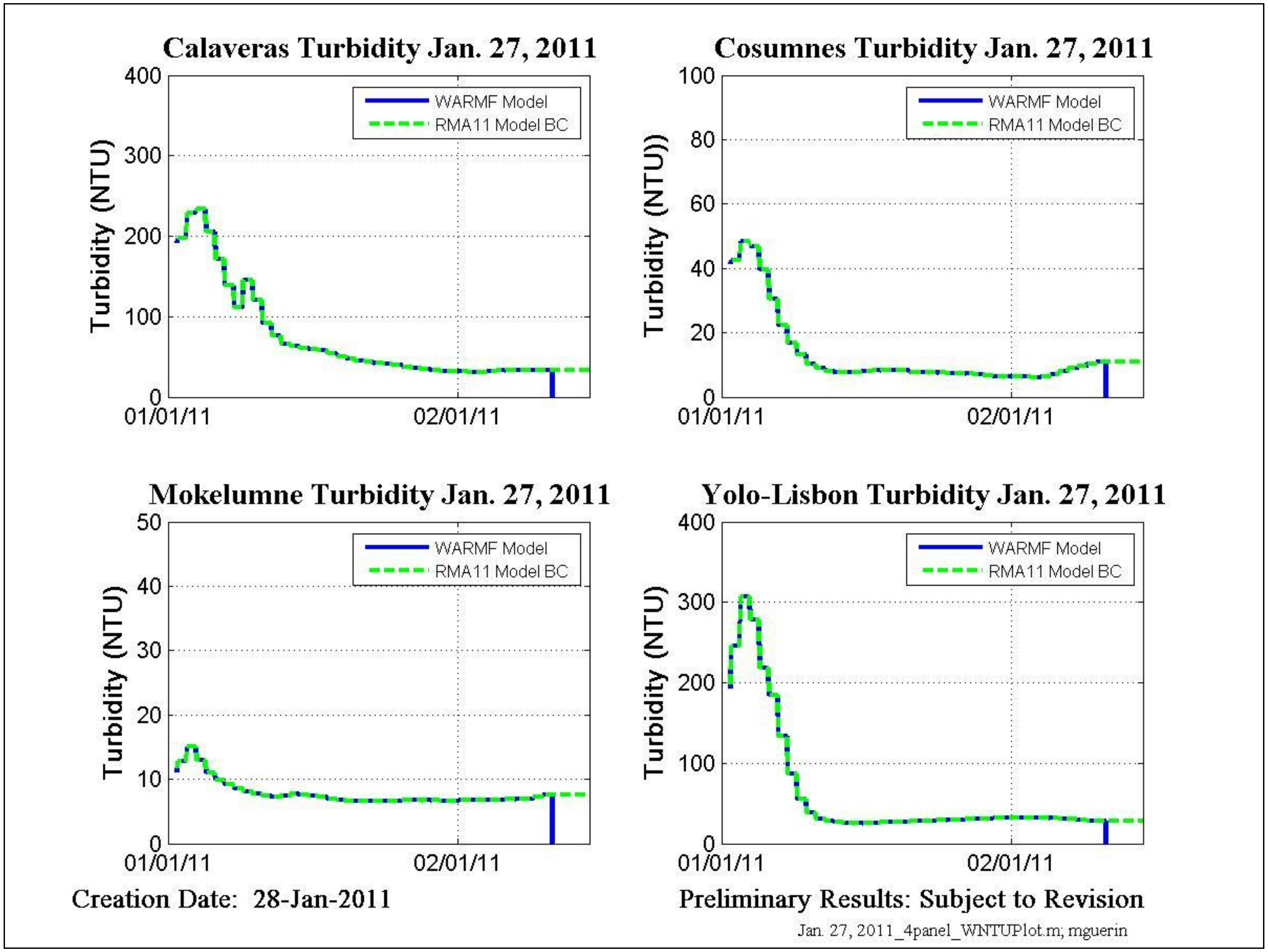


Figure 12-120 Turbidity boundary conditions used in the model along with the WARMF model output. Note difference in vertical scales.

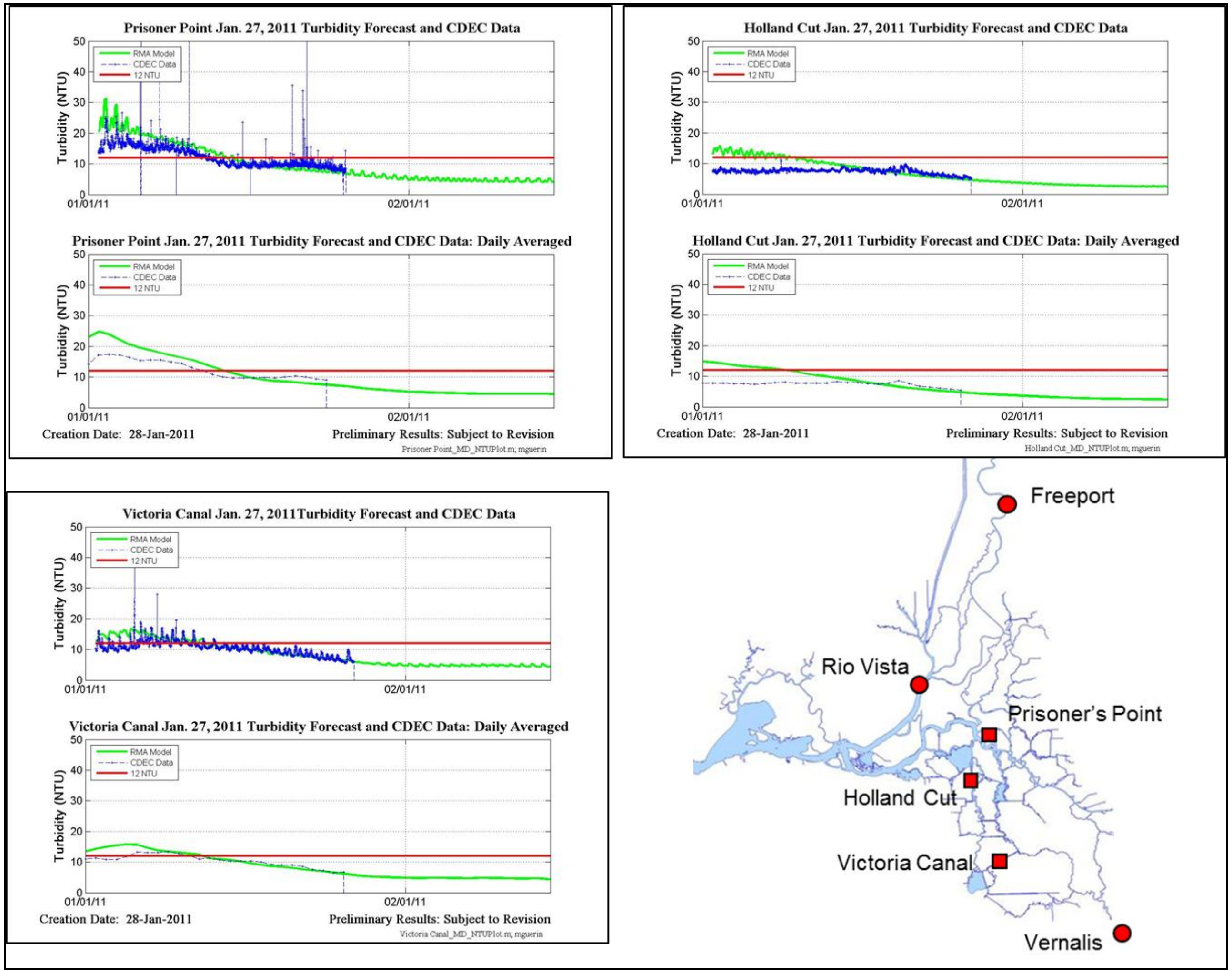


Figure 12-121 Modeled turbidity and data at the three compliance locations. Both 15-min model output and data and daily averaged plots are shown. Red line illustrates the 12-NTU compliance value. High turbidity values in Prisoner's Point data were removed before averaging.

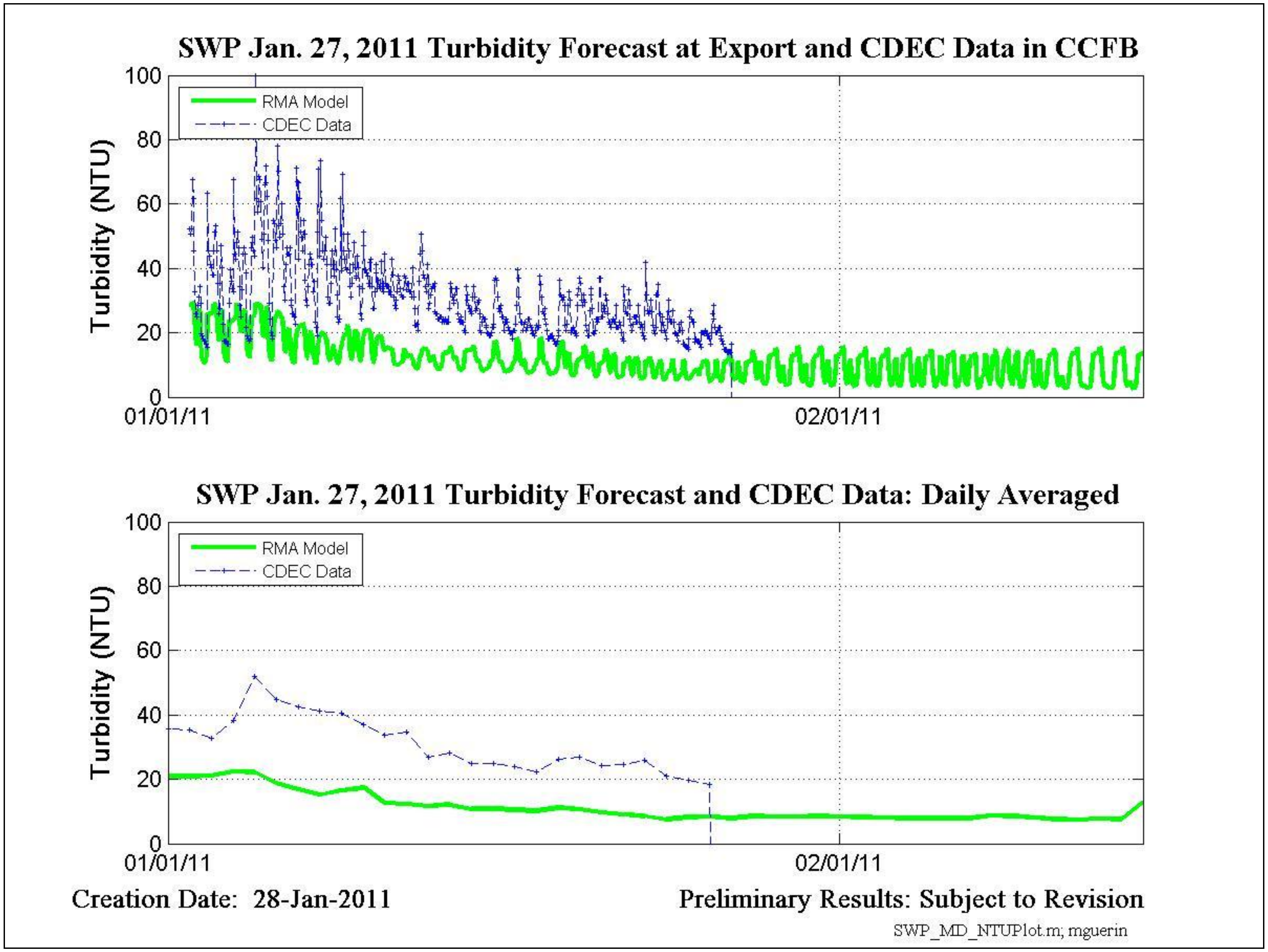


Figure 12-122 Plots compare model output at the SWP export location with data gathered inside Clifton Court Forebay. Both 15-min model output (upper) and daily averaged plots (lower) are shown.

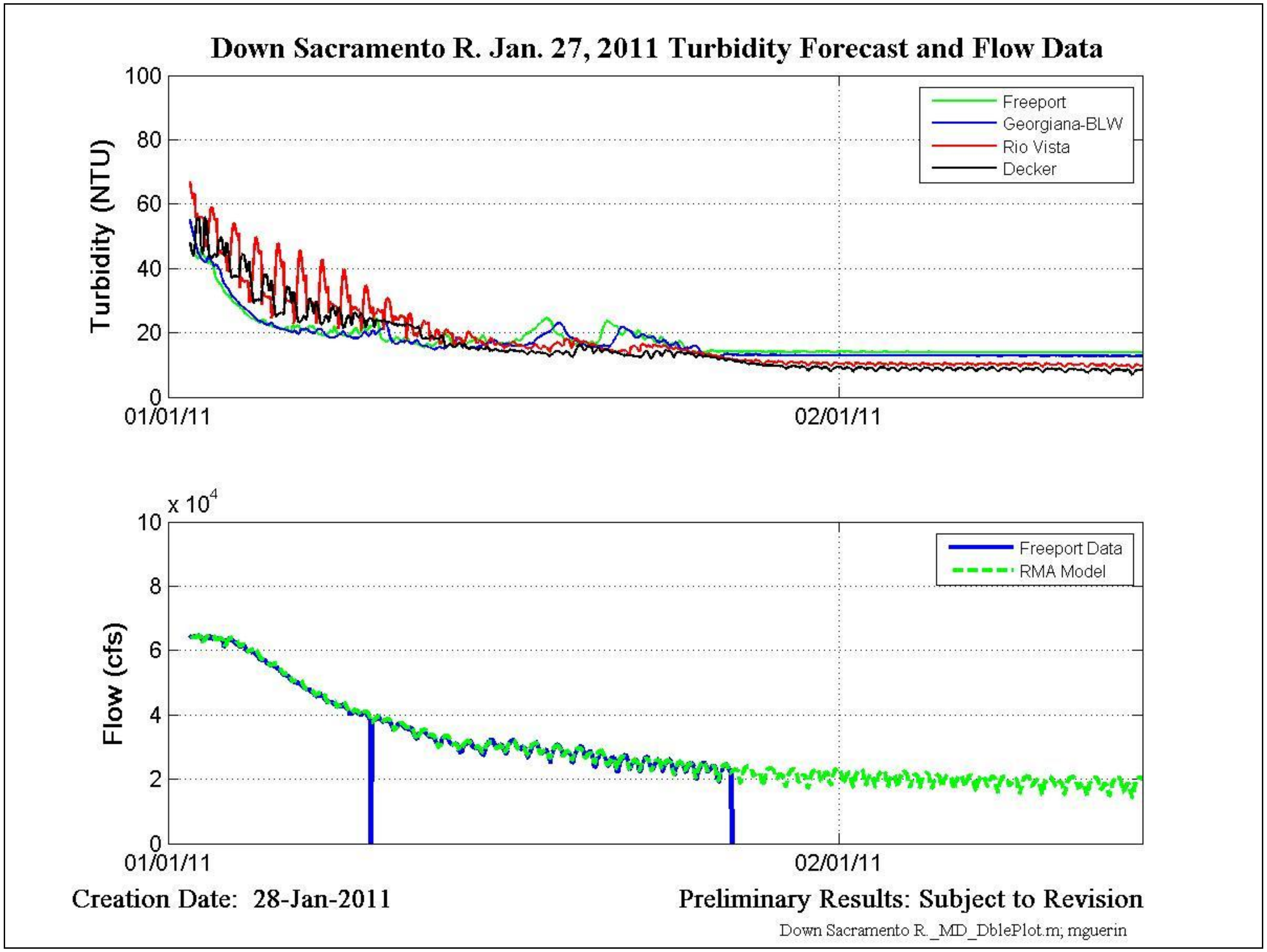


Figure 12-123 Freeport turbidity boundary condition progression down the Sacramento R. (upper) along with the flow data and RMA model boundary conditions (lower) used during the modeled period. Forecast began on January 25th. End of flow data signals the beginning of the forecast.

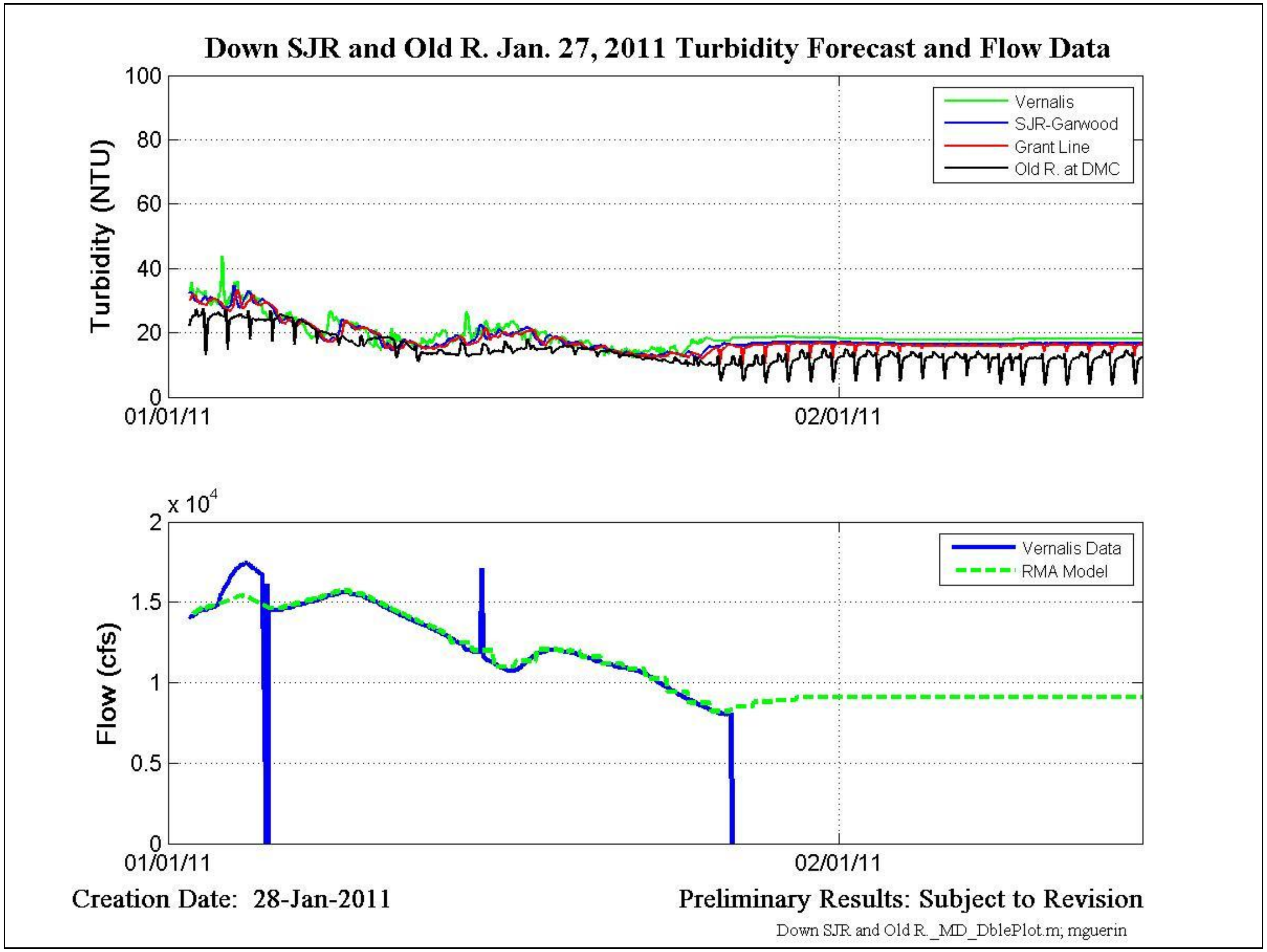


Figure 12-124 Progression of the turbidity boundary condition from Vernalis down the San Joaquin R. to Garwood, and down Old River (upper plot). Flow data and RMA model boundary condition at Vernalis are shown in the lower plot. Forecast began on Jan 25th. End of flow data signals the beginning of the forecast.

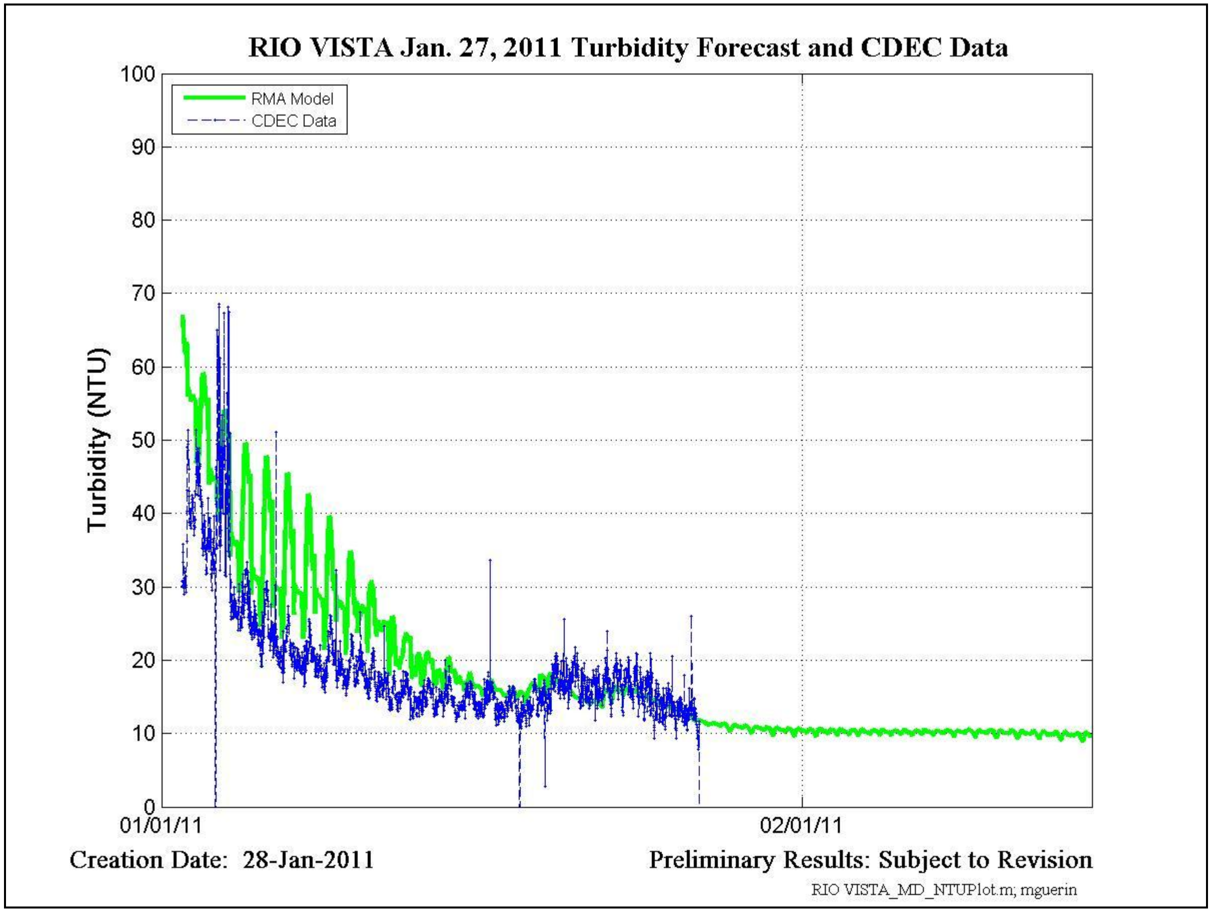


Figure 12-125 Model forecast and CDEC data at Rio Vista.

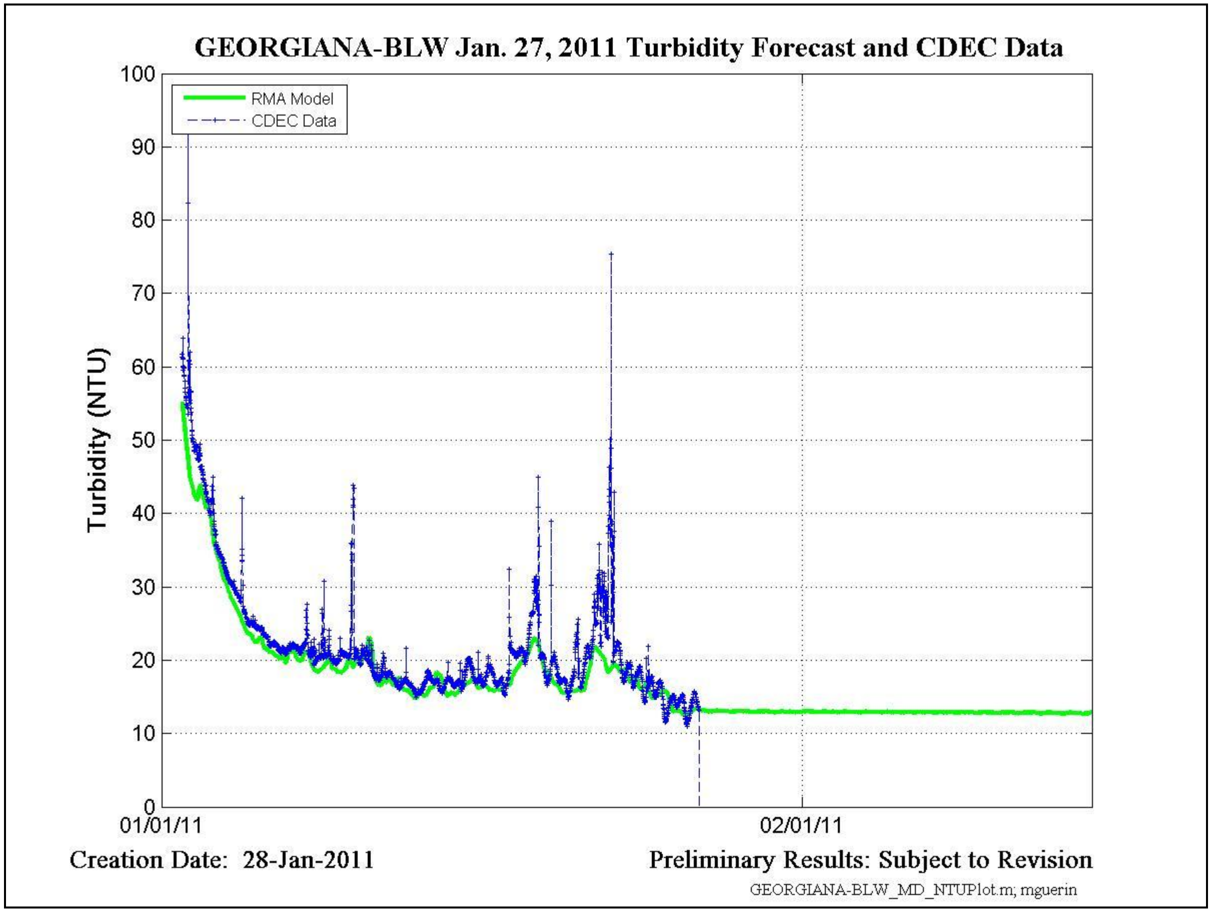


Figure 12-126 Model forecast and CDEC data at Georgian-BLW.

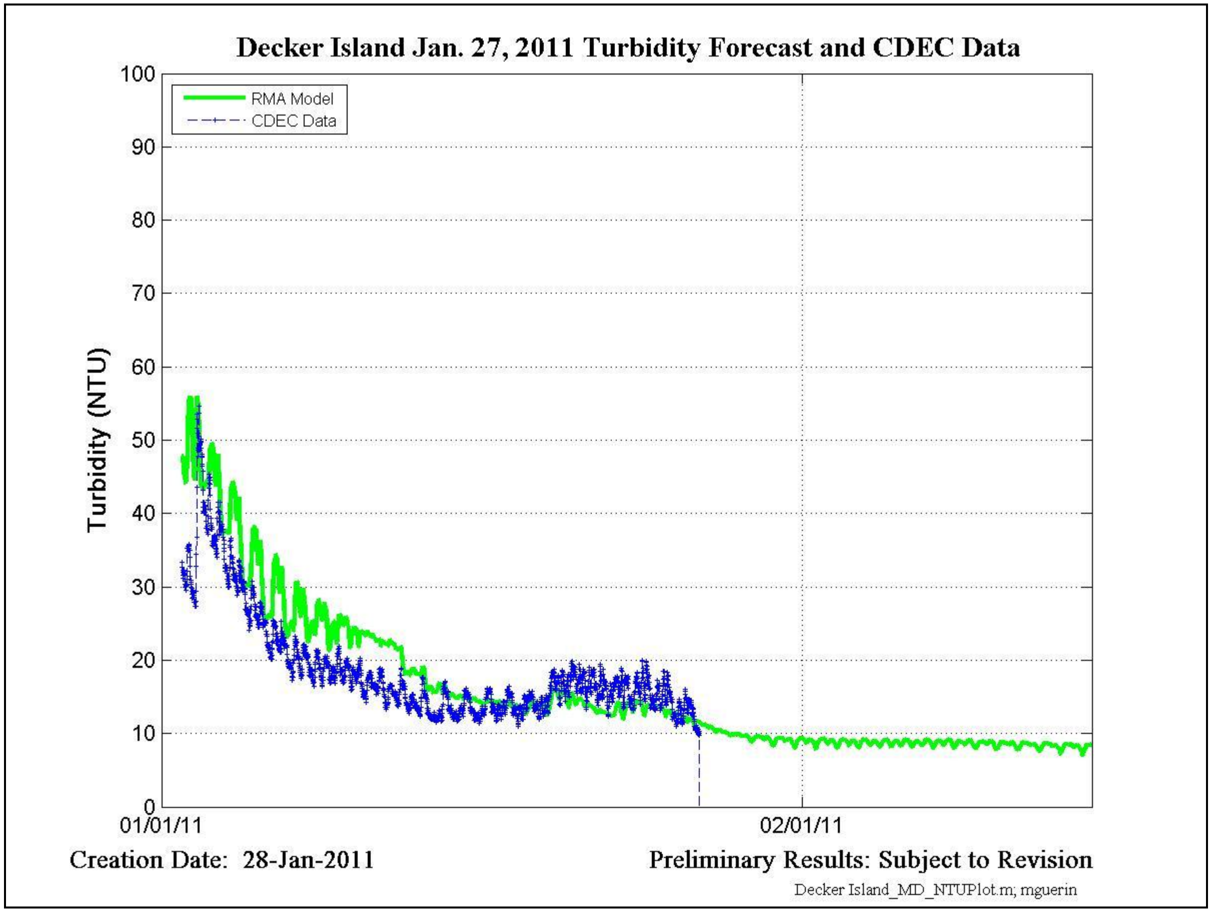


Figure 12-127 Model forecast and CDEC data at Decker Island.

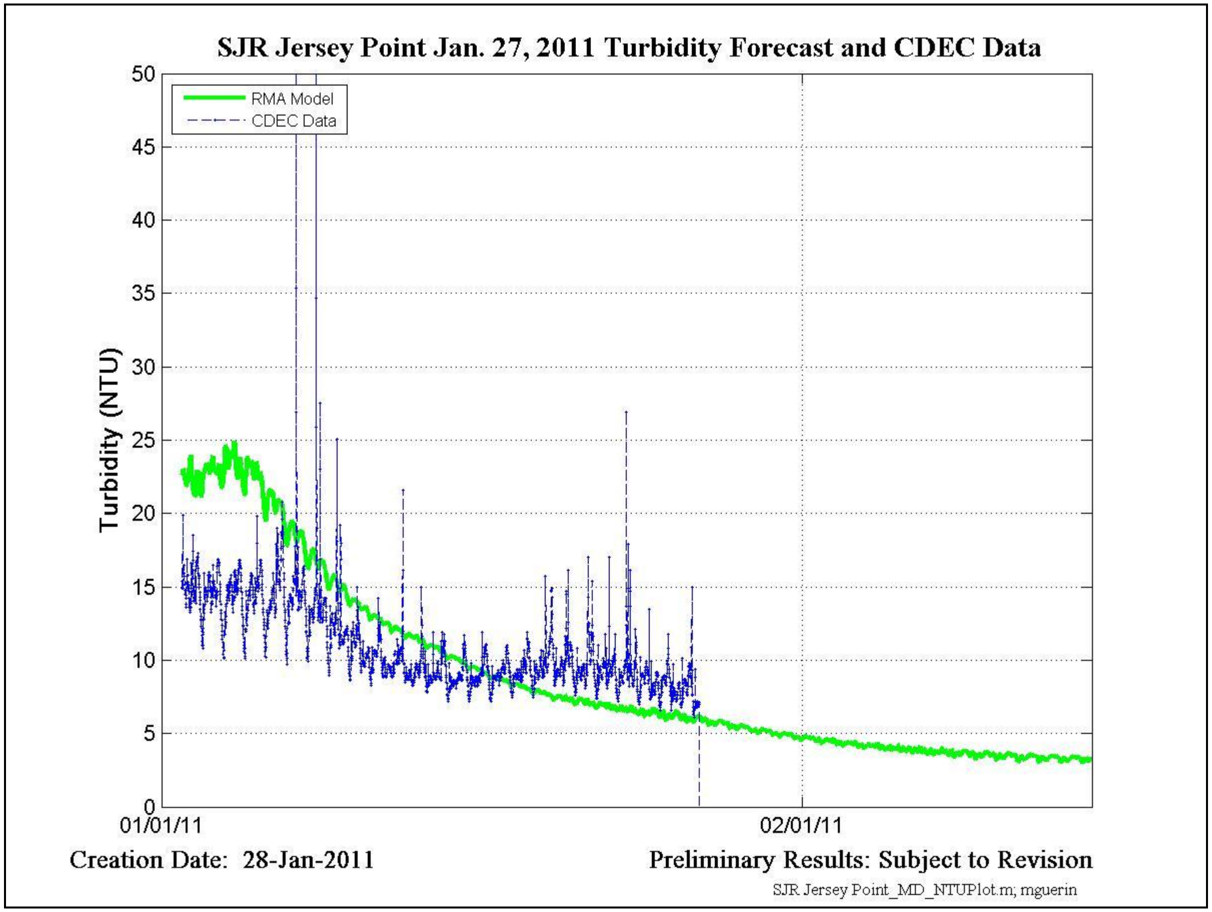


Figure 12-128 Model forecast and CDEC data at Jersey Point.

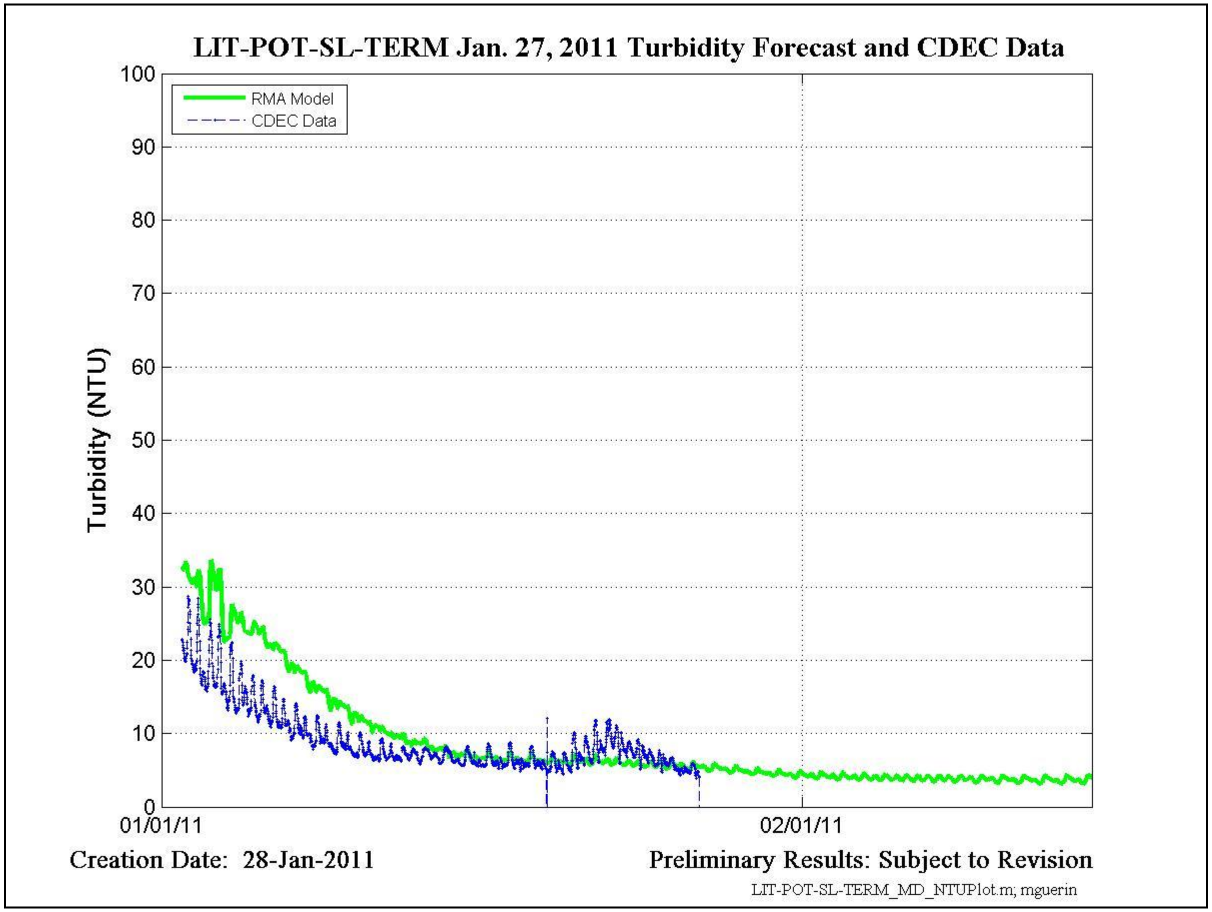


Figure 12-129 Model forecast and CDEC data at Little Potato Slough at Terminous.

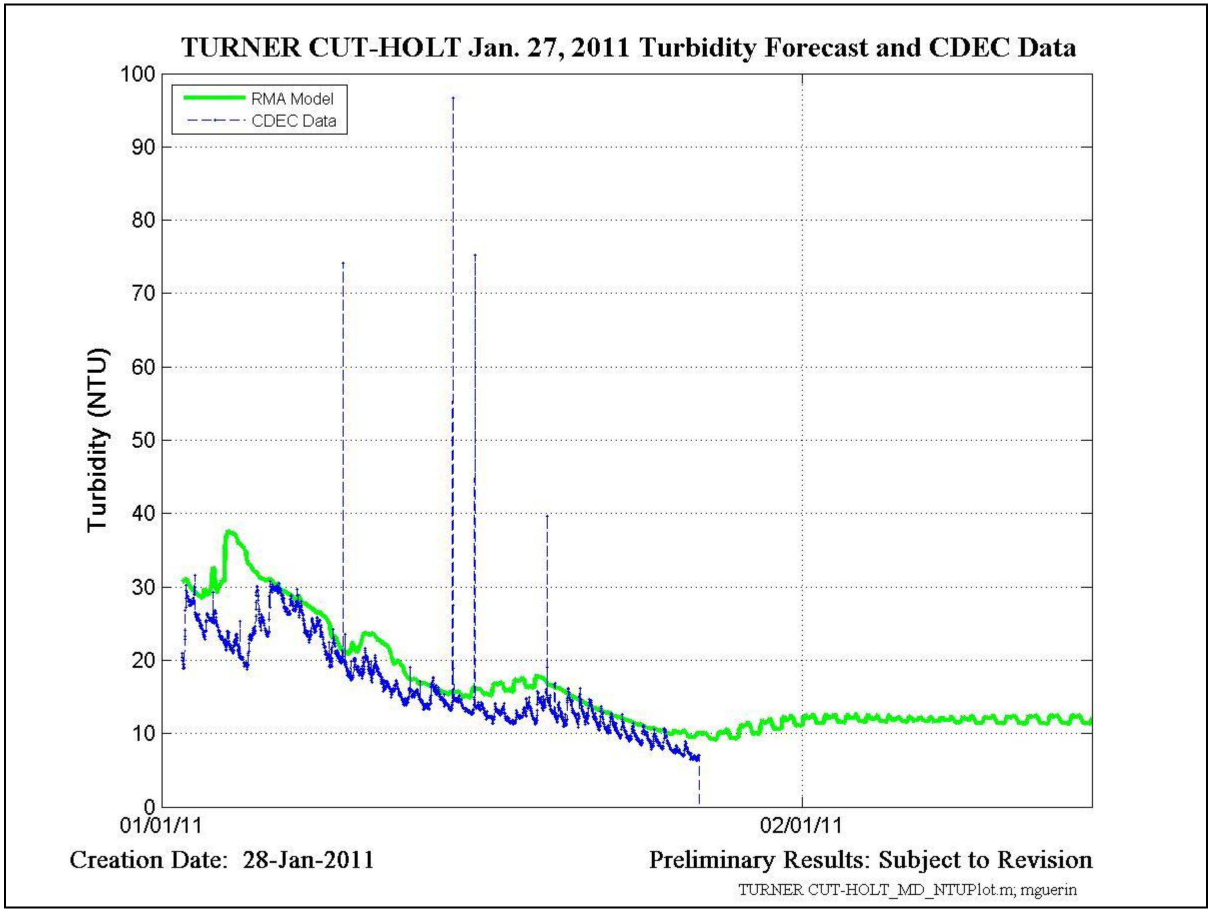


Figure 12-130 Model forecast and CDEC data at Turner Cut near Holt.

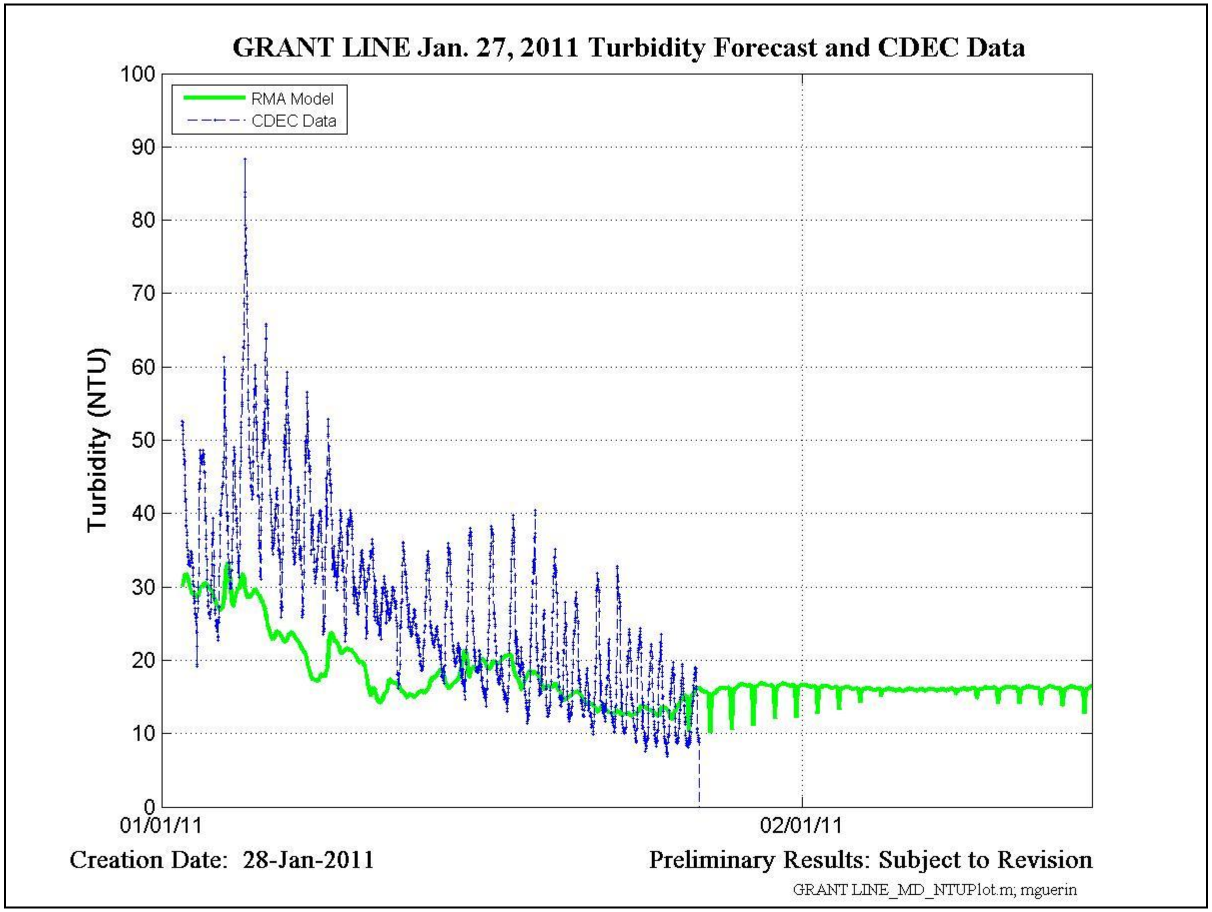


Figure 12-131 Model forecast and CDEC data at Grant Line.

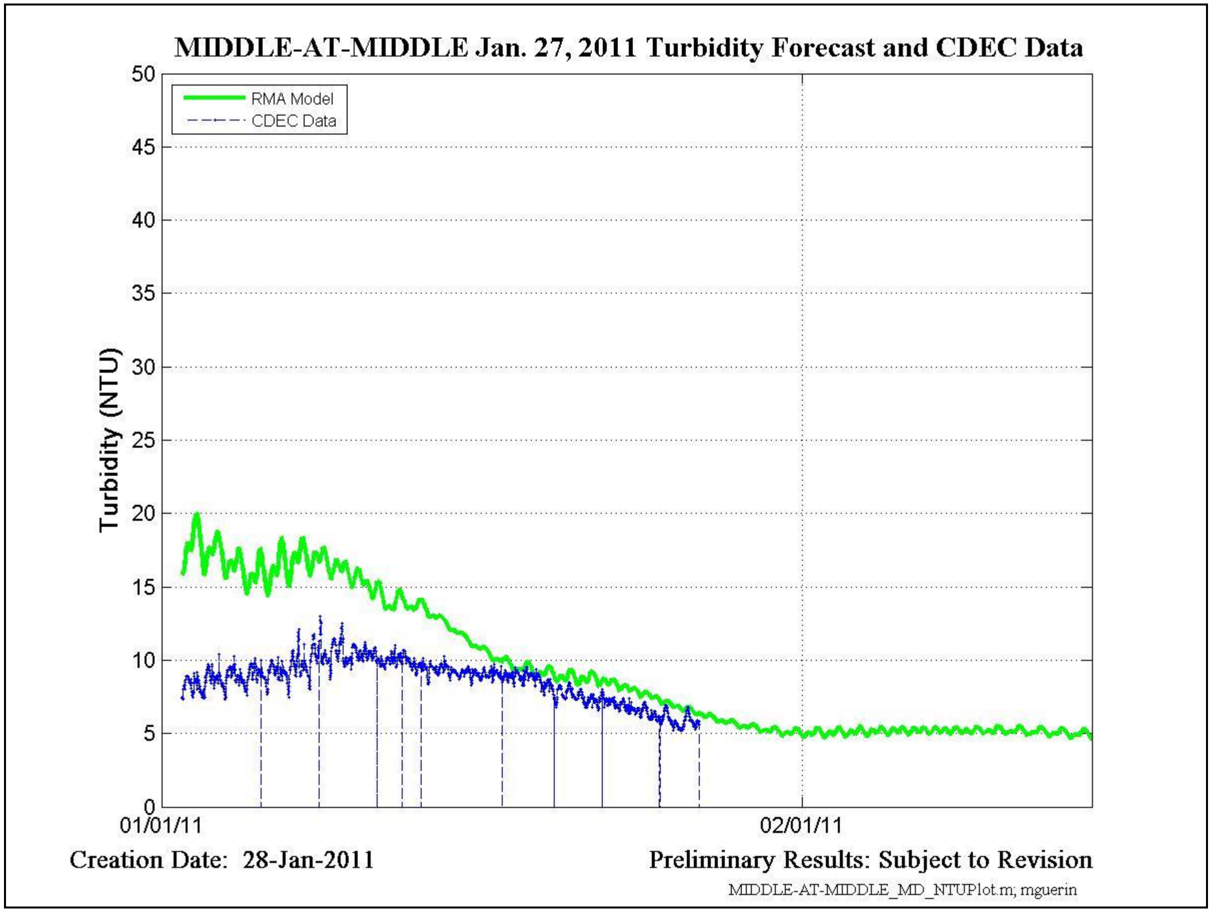


Figure 12-132 Model forecast and CDEC data at Middle R. at Middle R.

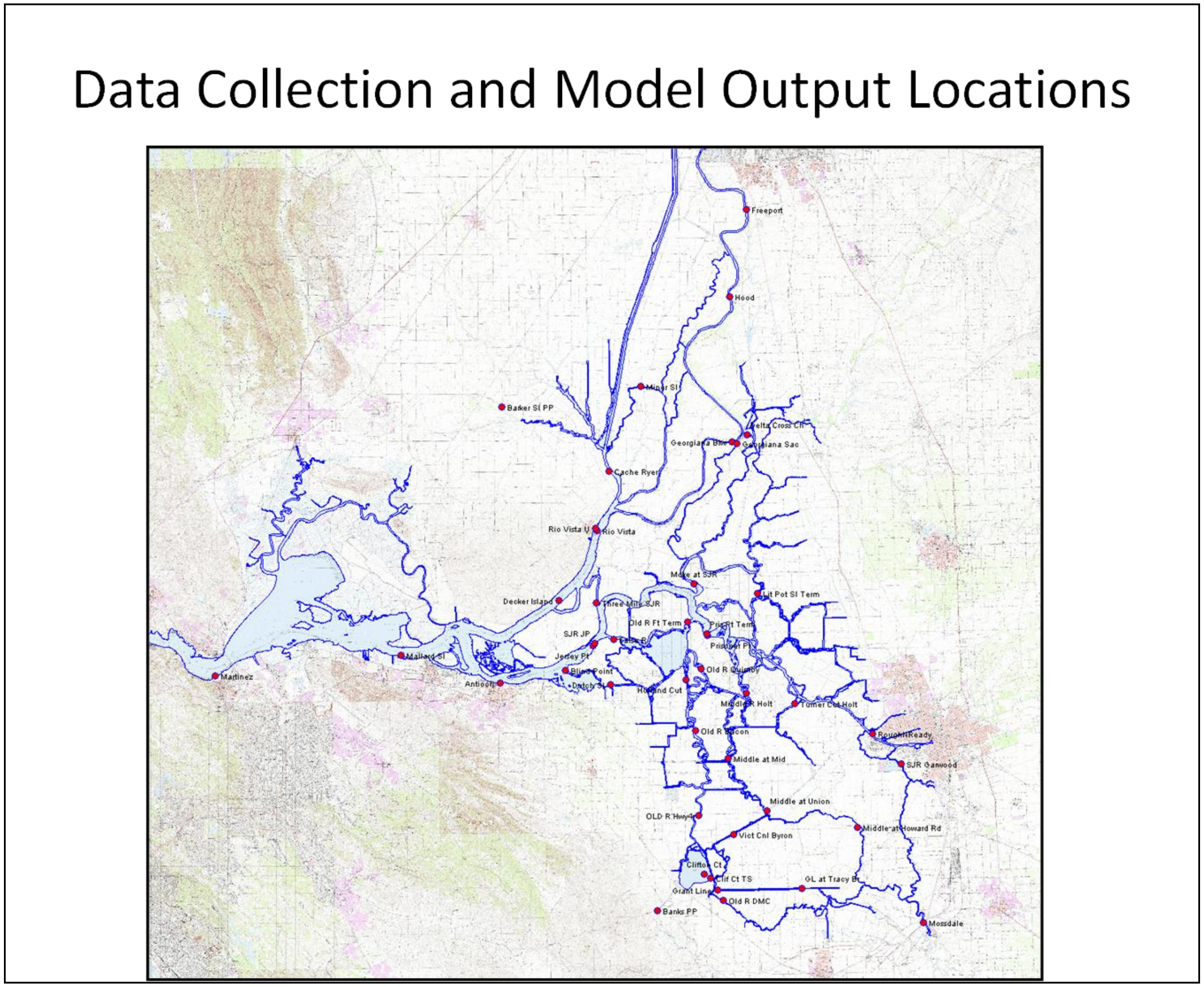


Figure 12-133 Figure illustrating model output and data collection locations.

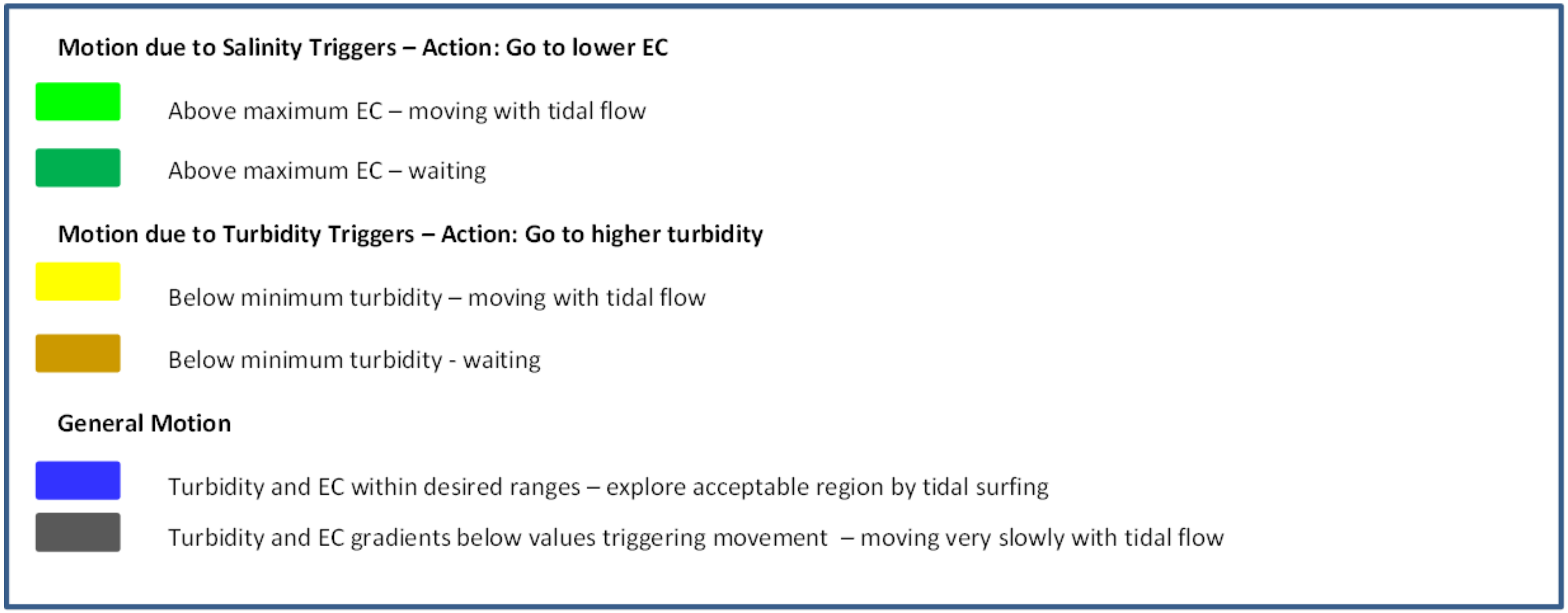


Figure 12-134 Particles in the Adult Delta Smelt particle tracking model are color-coded by the triggers influencing their behavior during the simulation. Use this figure to interpret the simplified color scale in the next several figures.

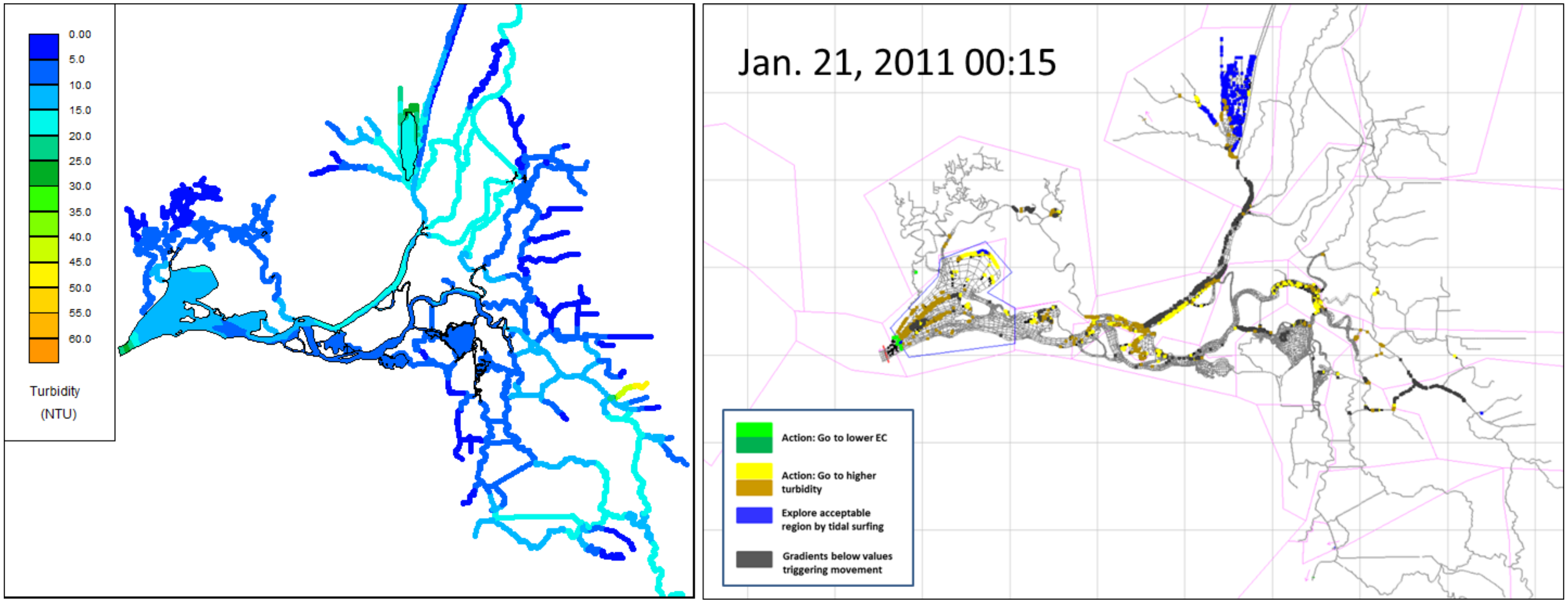


Figure 12-135 Turbidity contours and particle location in the RMA model grid on Jan. 21, 2011.

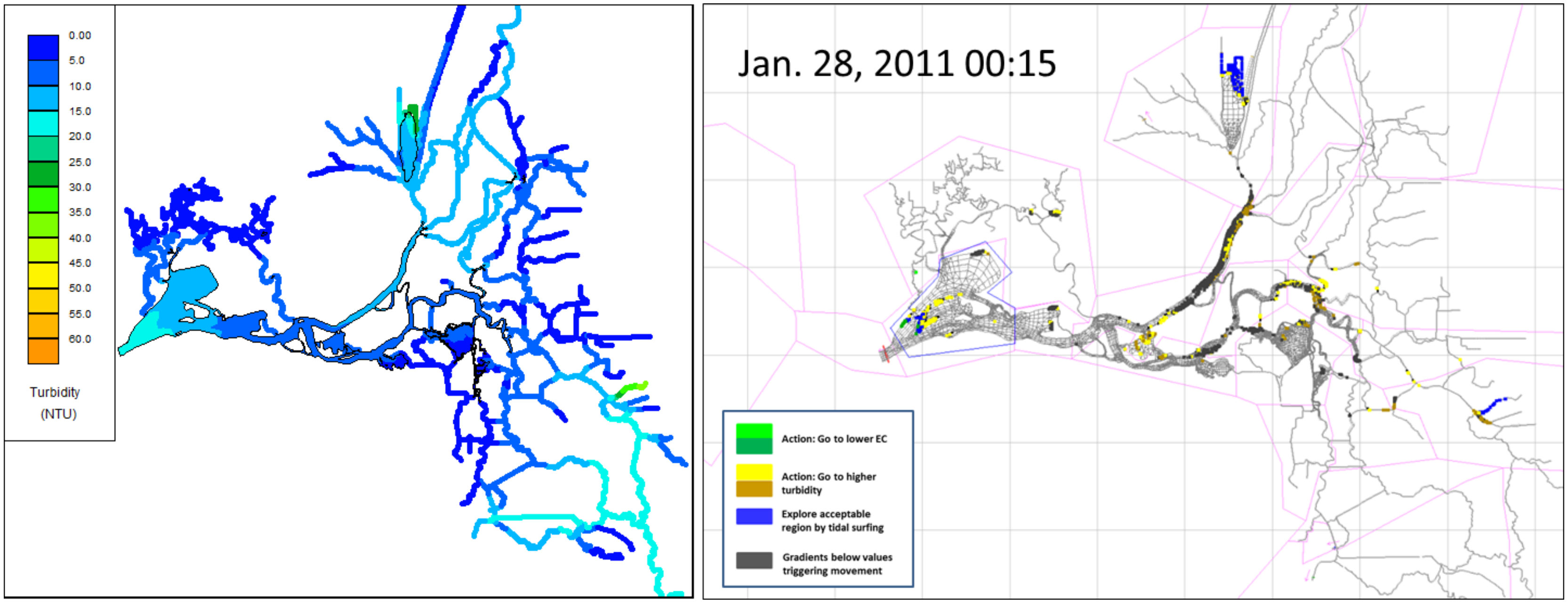


Figure 12-136 Turbidity contours and particle location in the RMA model grid on Jan. 28, 2011.

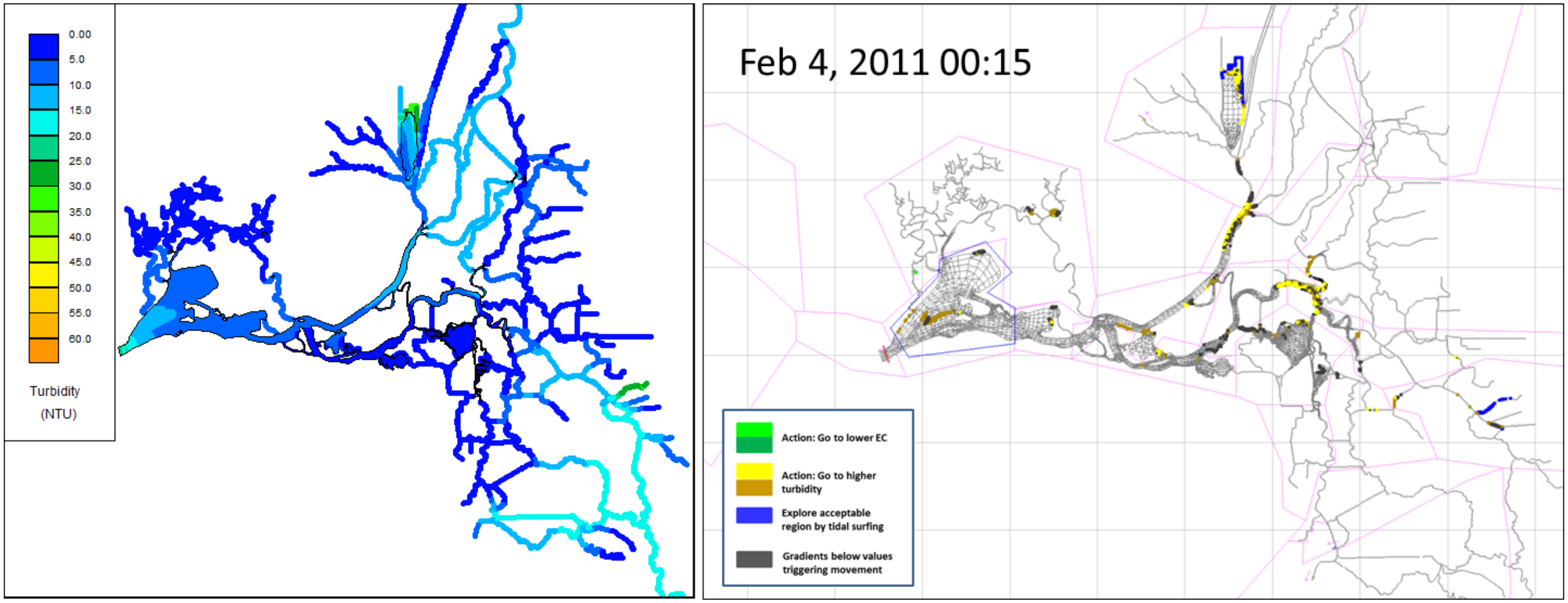


Figure 12-137 Turbidity contours and particle location in the RMA model grid on Feb 04, 2011.

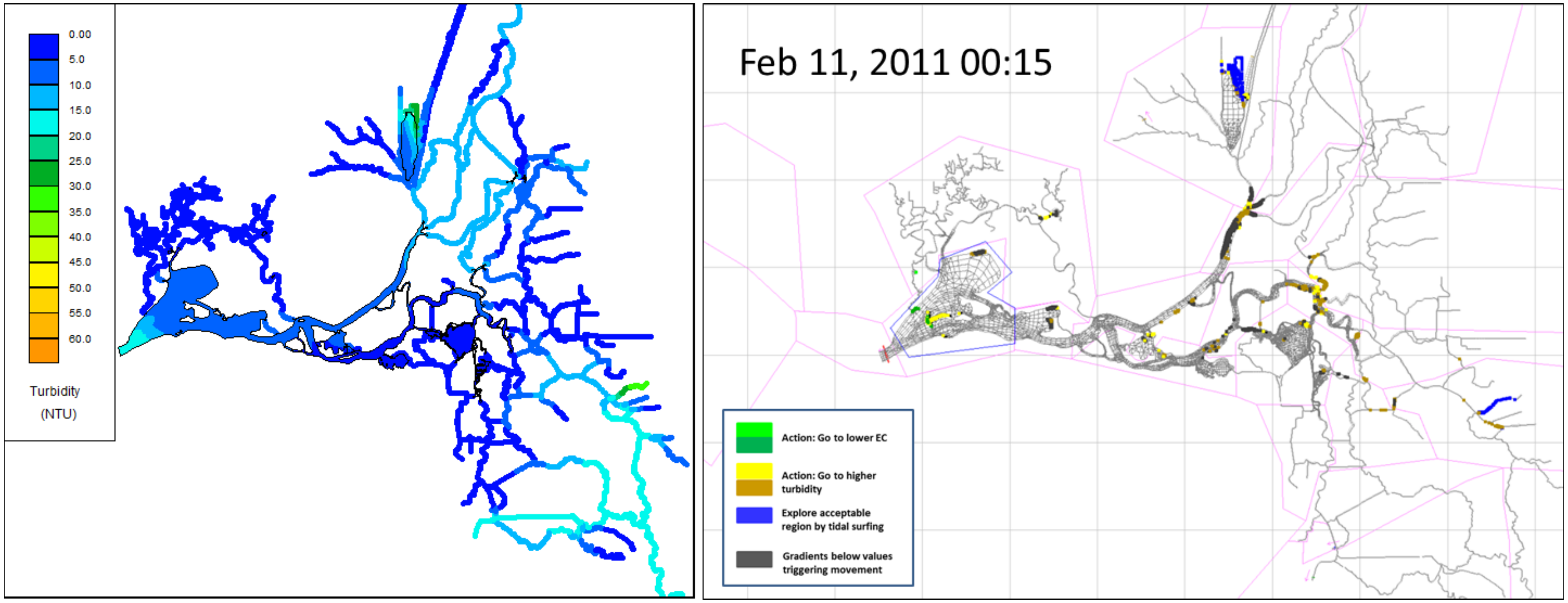


Figure 12-138 Turbidity contours and particle location in the RMA model grid on Feb. 11, 2011.

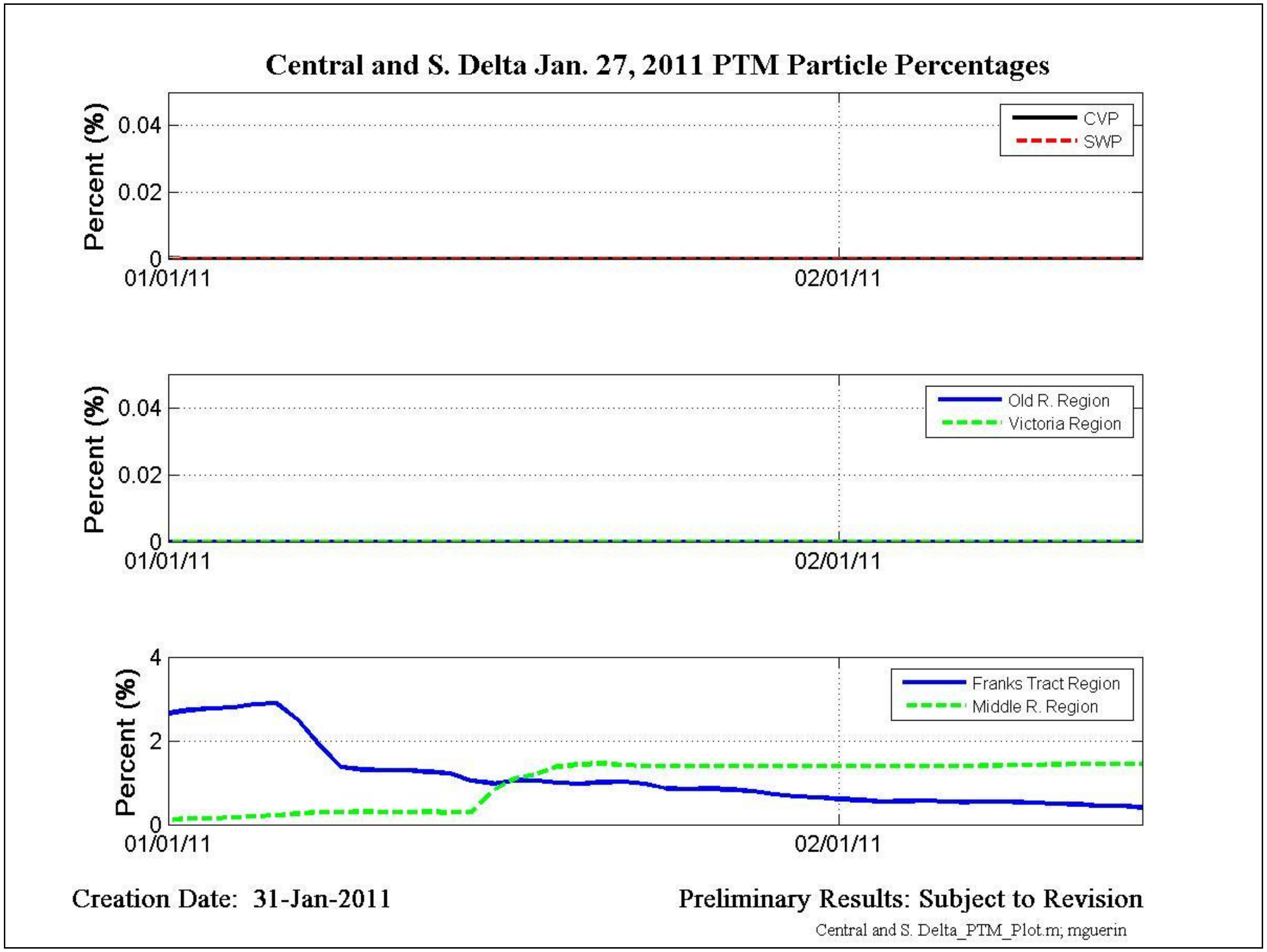


Figure 12-139 Only a couple of particles reached the SWP export location, none reached CVP (upper plot). No particles entered the Old River or Victoria Regions (center plot). A small percentage reached the Franks Tract and Middle River Regions (lower plot).

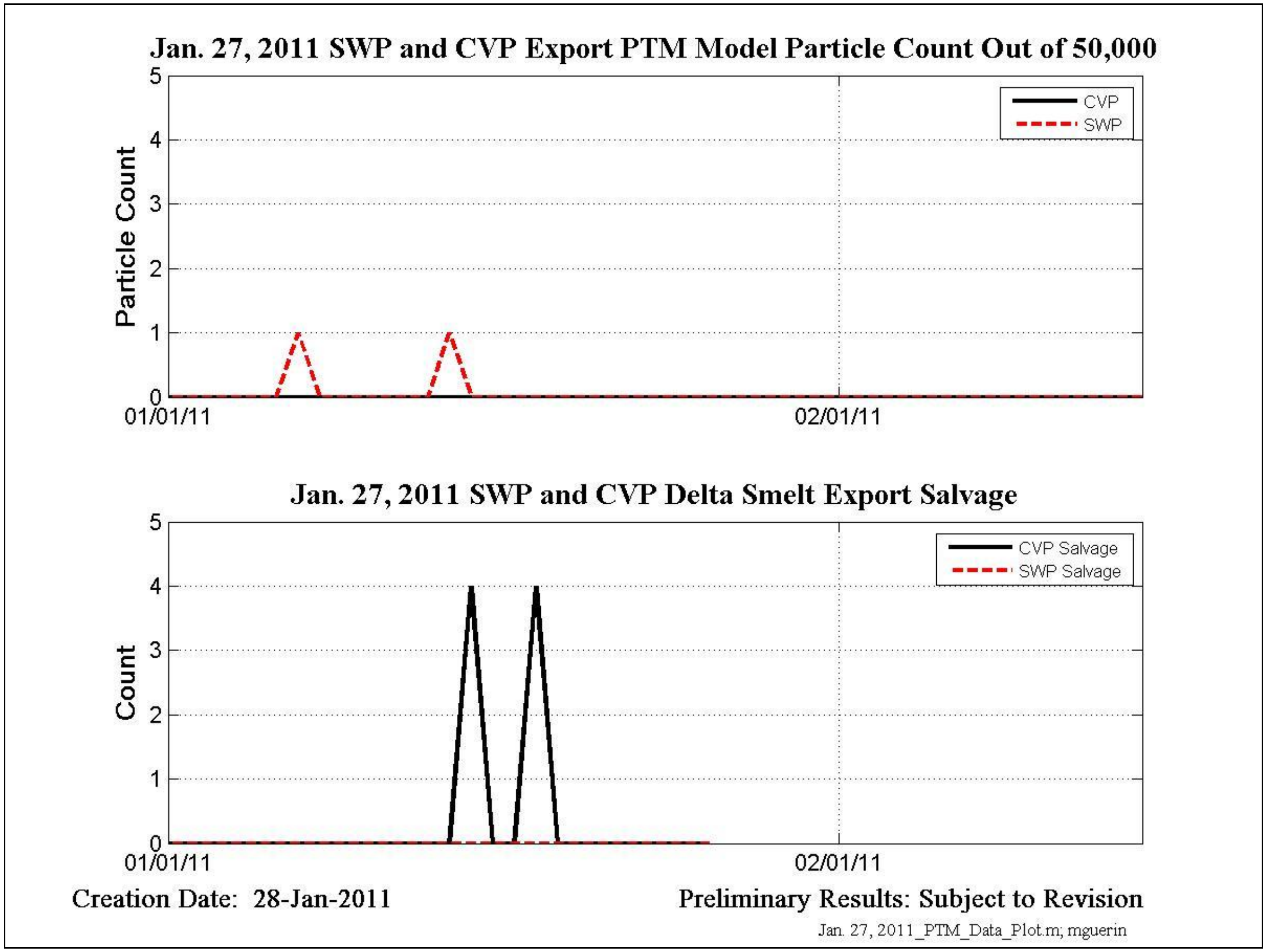


Figure 12-140 Four delta smelt were salvaged on Jan 15th and again on Jan 18th at the CVP location (lower plot). The upper plot shows that a few particles reached the SWP export location, but the percentage was so small as to be insignificant (see Figure 12-59).

12.3.7. Forecast Feb. 03, 2011

This document provides a quick summary of the February 3, 2011 forecast prepared using the RMA hydrodynamic, salinity, turbidity and Adult Delta Smelt Behavioral models. Graphical results are provided to document the results of the modeling with a focus on turbidity. Model BC (Boundary Conditions) were prepared using WARMF-supplied historical and forecast conditions, CDEC data, and DWR-supplied model inputs and results from their flow and salinity forecasts.

The RMA modeled period was January 01, 2010 to February 22, 2011 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 and with model output for a combined historical and forecast period Jan. 21, 2011 through Feb. 22, 2011. The DWR forecast period began February 1, 2011. The WARMF modeled period, consisting of daily model output for flow, salinity and turbidity, was Dec. 01, 2010 – Feb. 17, 2011. Additional flow, turbidity and EC data was downloaded for the period Jan. 27 – Feb. 2, 2011 from the CDEC websites to augment the DWR and WARMF model output and for the turbidity boundary condition development.

The WARMF and DWR forecasts arrived on Thursday afternoon. Historical and Forecast BC were developed from several sources, as summarized in Table 12-12. Where there were discrepancies between data and model or between DWR and WARMF models, BC were compiled using best professional judgment. WARMF turbidity was used for the forecast period, except at Freeport and Martinez. Stage and export BC were compiled solely from DWR O&M sources. The Martinez salinity boundary condition was obtained from the DWR forecast, and the turbidity BC from CDEC data.

Plots showing model/data comparisons and model output for the modeled period Jan. 01 – Feb. 22, 2011 are included below as a pictorial summary of the results. Figure 12-141 through Figure 12-147 illustrate BC time series used in the RMA forecast model as well as the WARMF-supplied model output for flow and turbidity.

Figure 12-148 illustrates a comparison of model output and data at the three compliance locations, and Figure 12-149 illustrates a similar comparison in the SWP export area. Only at the Holland Cut compliance location did averaged data remain below 12 NTU – modeled turbidity exceeded the 12 NTU value at each compliance location (Figure 12-148) in January. Note that Figure 12-149 is a comparison of data inside Clifton Court Forebay with model output at the model boundary at the entrance to the Forebay. For these figures, model and data were used at 15-min or hourly time intervals as collected or modeled, and also daily averaged. Note that the time series used to create Figure 12-148 are included in the email communication accompanying this document as a separate EXCEL file.

The Delta Smelt behavioral model was run from Nov. 01, 2010 through Feb. 22, 2011 - 50,000 particles were inserted on Nov.01, 2010 as in previous forecast models. Because the historical and forecast boundary conditions are somewhat different than the previous model during overlapping times, the PTM results are slightly different.

Eight delta smelt were salvaged at the CVP location during the modeled period – four each on Jan. 15 and Jan. 17, 2011 – no delta smelt were salvaged at either location in December 2010. January delta smelt salvage numbers are available on the CVO website[14], and December delta smelt salvage numbers are available on the California Department of Fish and Game website[15]. A couple of particles reached the SWP export location during the modeled period (i.e., historical plus forecast), and a small percentage of particles entered the Middle R. and Franks Tract Regions – no particles entered the Old R. Region. See Figure 12-162 through Figure 12-167 for turbidity contour plots and particle tracking model results.

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

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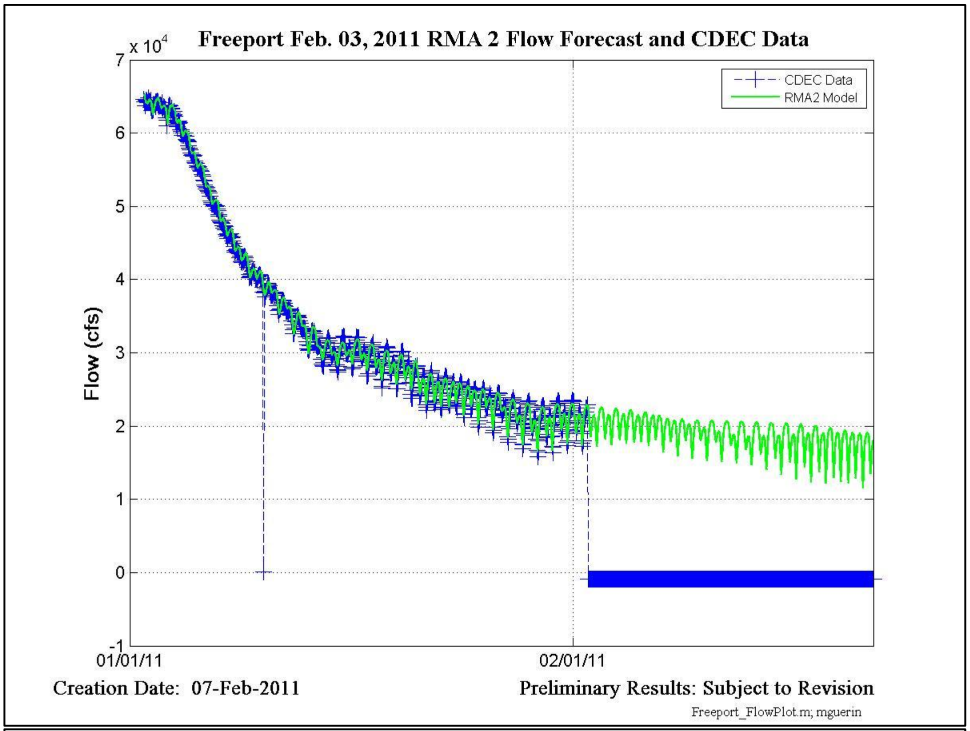
[14] http://www.usbr.gov/mp/cvo/fishrpt.html

[15] http://www.dfg.ca.gov/delta/apps/salvage/SalvageExportCalendar.aspx



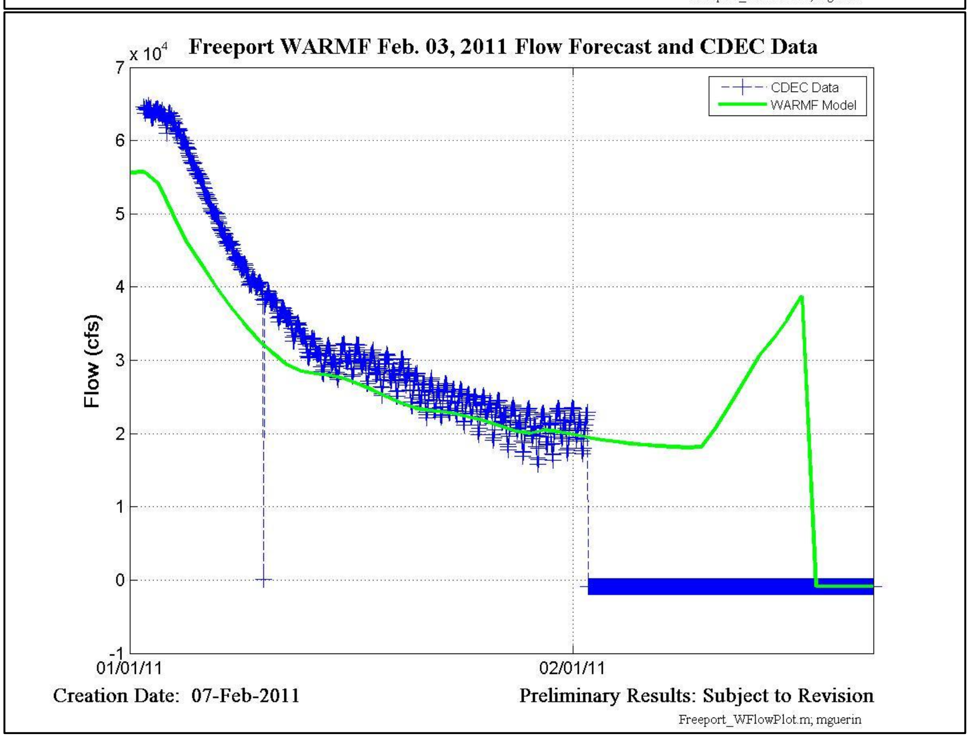


Figure 12-141 Freeport flow BC was compiled from CDEC data and the DWR forecast (top). WARMF model output, which was not used, is shown in the lower plot. Note y-axis unit is cfs*10,000. Zero values indicate the end of data (blue), and beginning of the forecast.

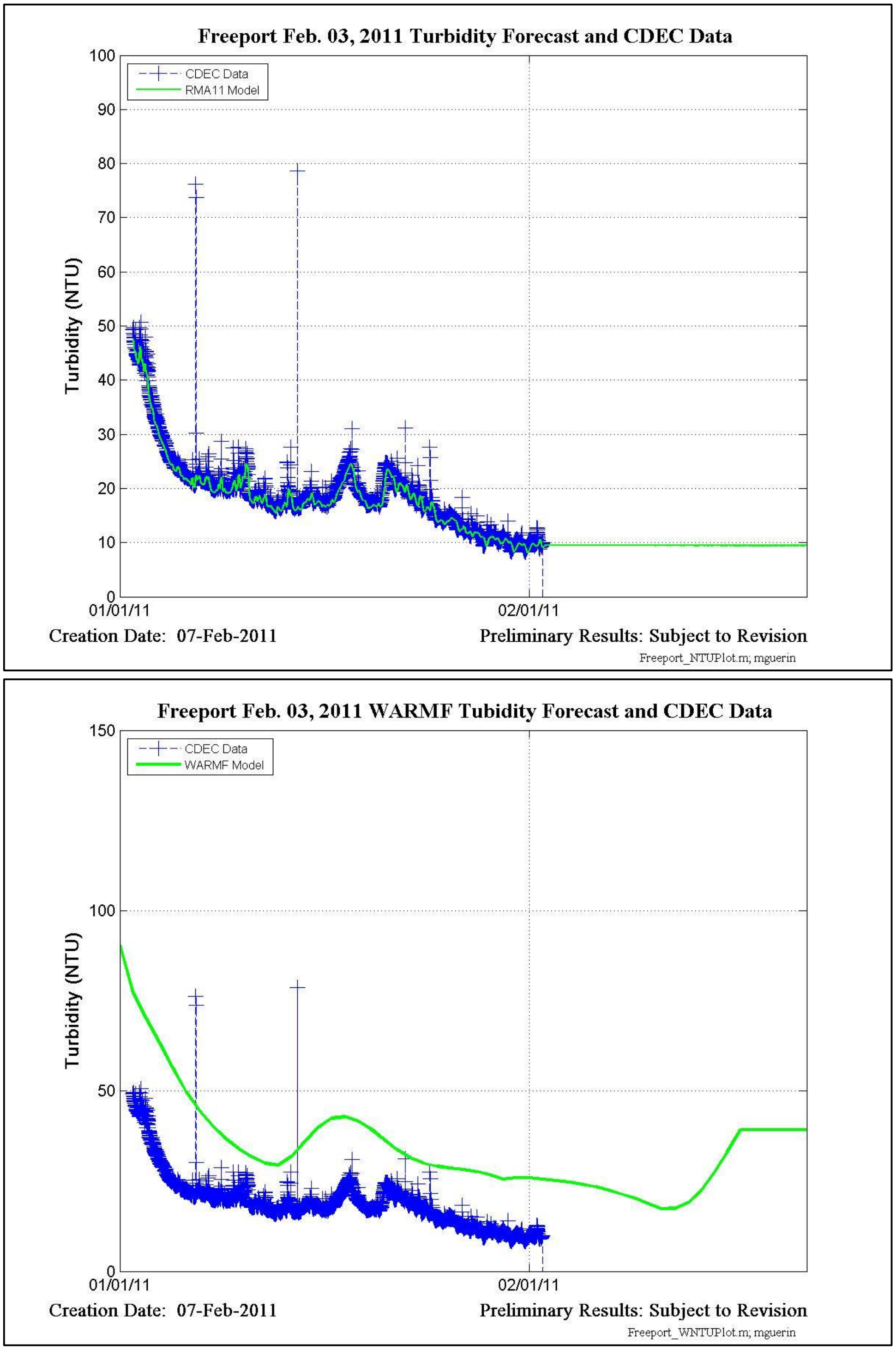


Figure 12-142 Freeport turbidity BC was compiled from CDEC data and then extended as a constant after Feb 1st, 2011. WARMF model output, which was not used, is shown in the lower plot. The beginning of the turbidity forecast occurs at the end of the CDEC data.

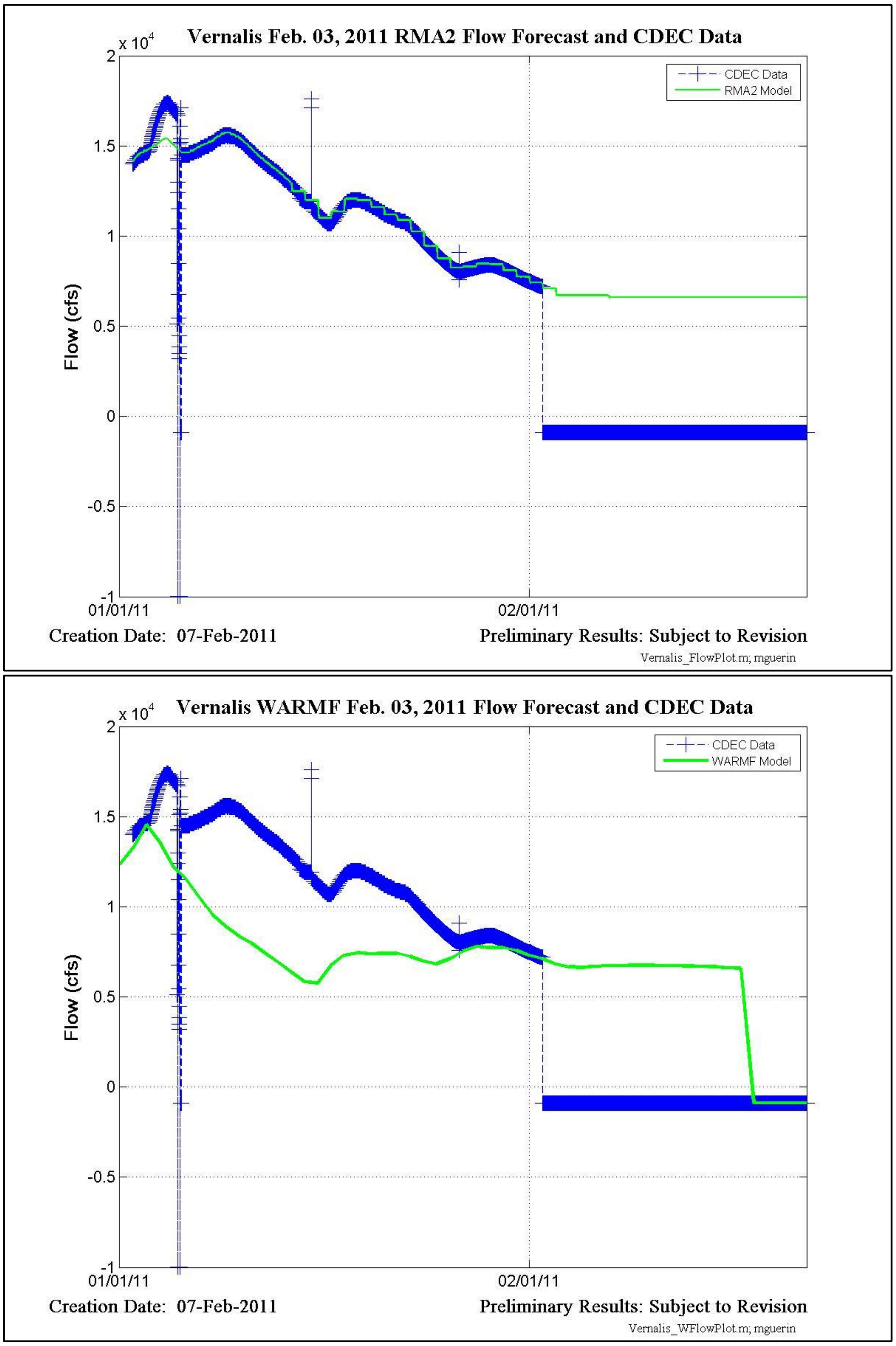
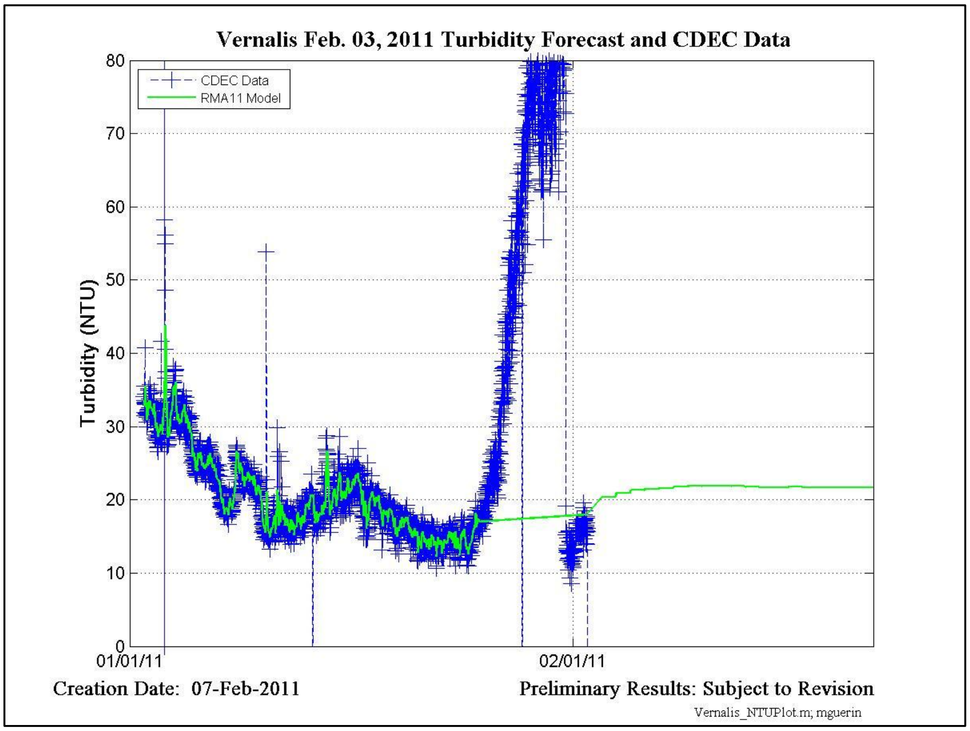


Figure 12-143 Vernalis flow BC was compiled from CDEC data and the DWR forecast. WARMF model output, which was not used, is shown in the lower plot. Note y-axis unit is cfs*10,000. Zero values indicate the end of data (blue) and the beginning of the forecast.



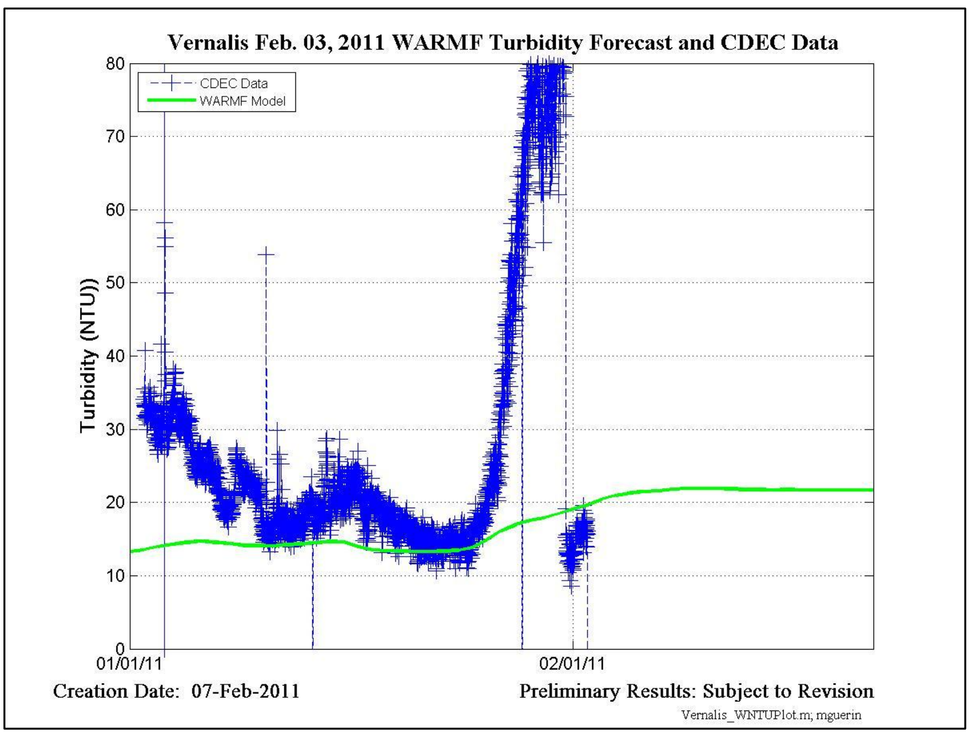


Figure 12-144 Vernalis turbidity BC was compiled from CDEC data, and then extended with WARMF model output, which is shown in the lower plot. The beginning of the forecast occurs at the end of the CDEC data. The noisy turbidity data at the end of January was replaced with a linear interpolation.

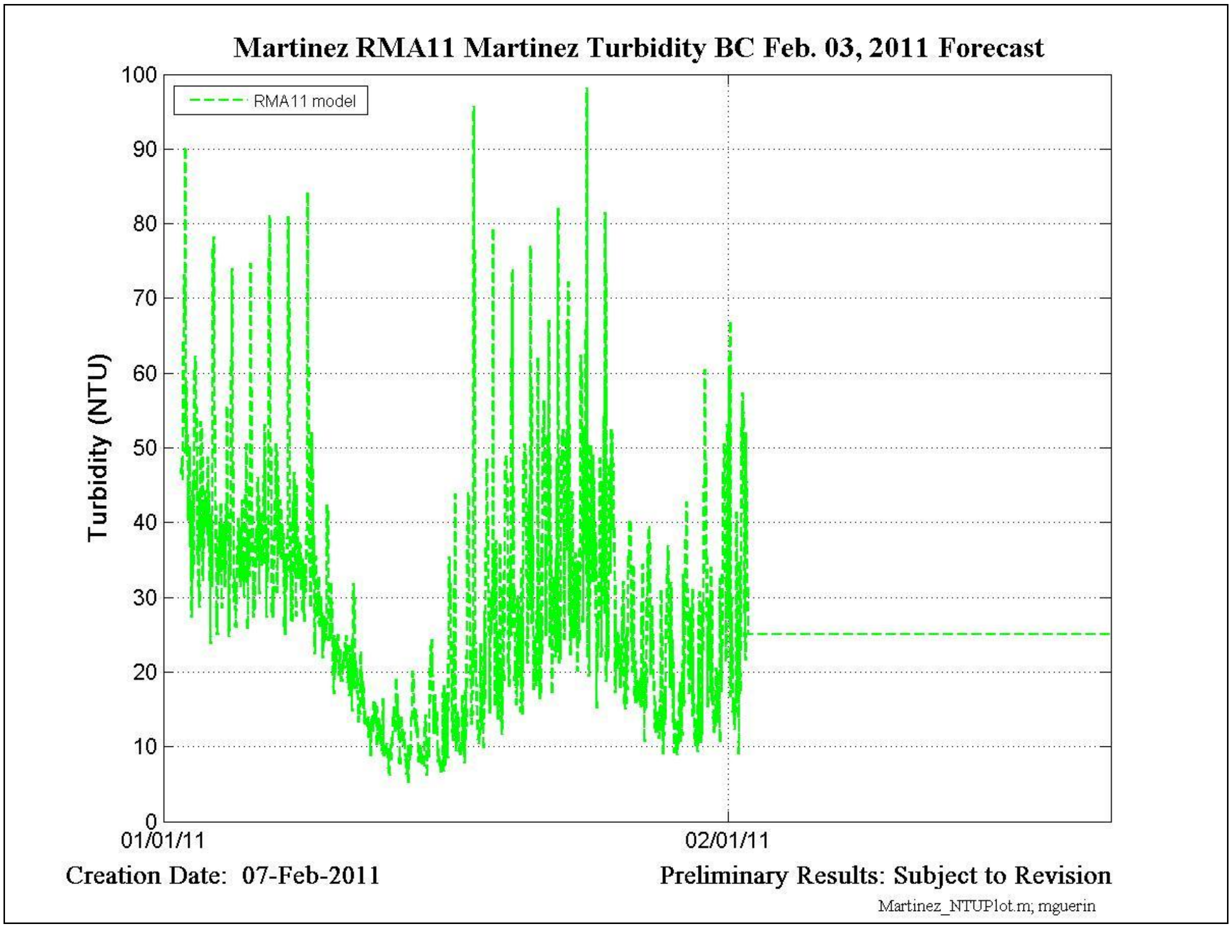


Figure 12-145 Martinez turbidity BC was compiled from CDEC data then extended linearly to a value of 20 NTU.

Table 12-12 Boundary condition development for Feb. 03, 2011 forecast for flow, turbidity and salinity (EC). Upper section lists the source for Historical BC, and lower section lists the Source for Forecast BC.

		Historical	
Location	**Sources for Flow BC**	**Sources for Turbidity BC**	**Sources for EC BC**
Yolo Bypass at Lisbon	Previous model	WARMF	WARMF
Freeport/Sacramento R. at I St. Bridge	DWR	CDEC	CDEC
Cosumnes River	DWR	WARMF	WARMF
Mokelumne River	DWR	WARMF	WARMF
Calaveras River	DWR	WARMF	WARMF
San Joaquin River at Vernalis	DWR	CDEC	DWR
Martinez	DWR - stage	CDEC	DWR
		Forecast	
Location	**Sources for Flow BC**	**Sources for Turbidity BC**	**Sources for EC BC**
Yolo Bypass at Lisbon	WARMF	WARMF	WARMF
Freeport/Sacramento R. at I St. Bridge	DWR	Constant	DWR (RSAC142)
Cosumnes River	DWR	WARMF	WARMF
Mokelumne River	DWR	WARMF	WARMF
Calaveras River	DWR	WARMF	WARMF
San Joaquin River at Vernalis	DWR	WARMF	DWR
Martinez	DWR - stage	Constant	DWR

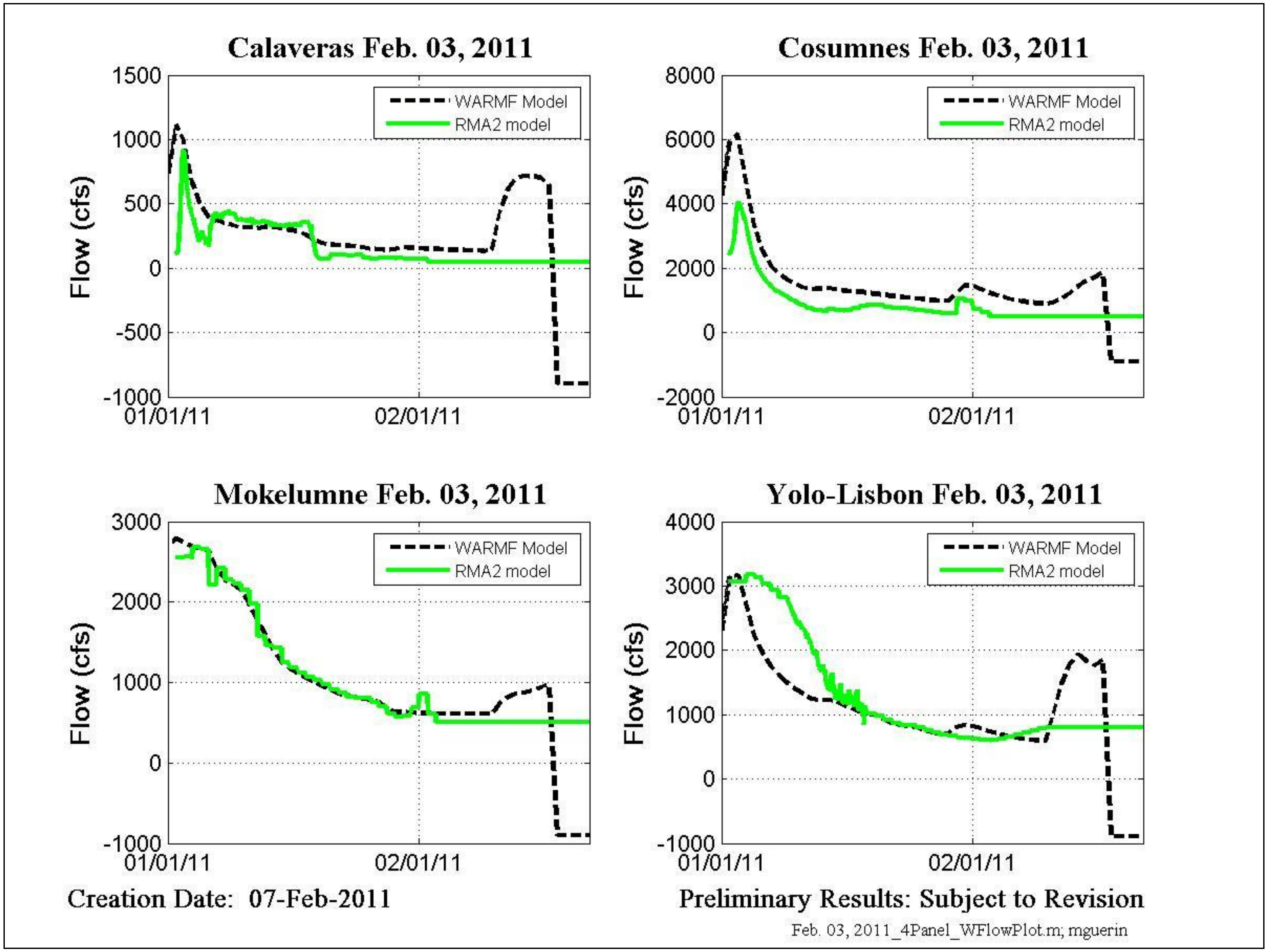


Figure 12-146 Four flow boundary conditions used in the model along with the WARMF model output.

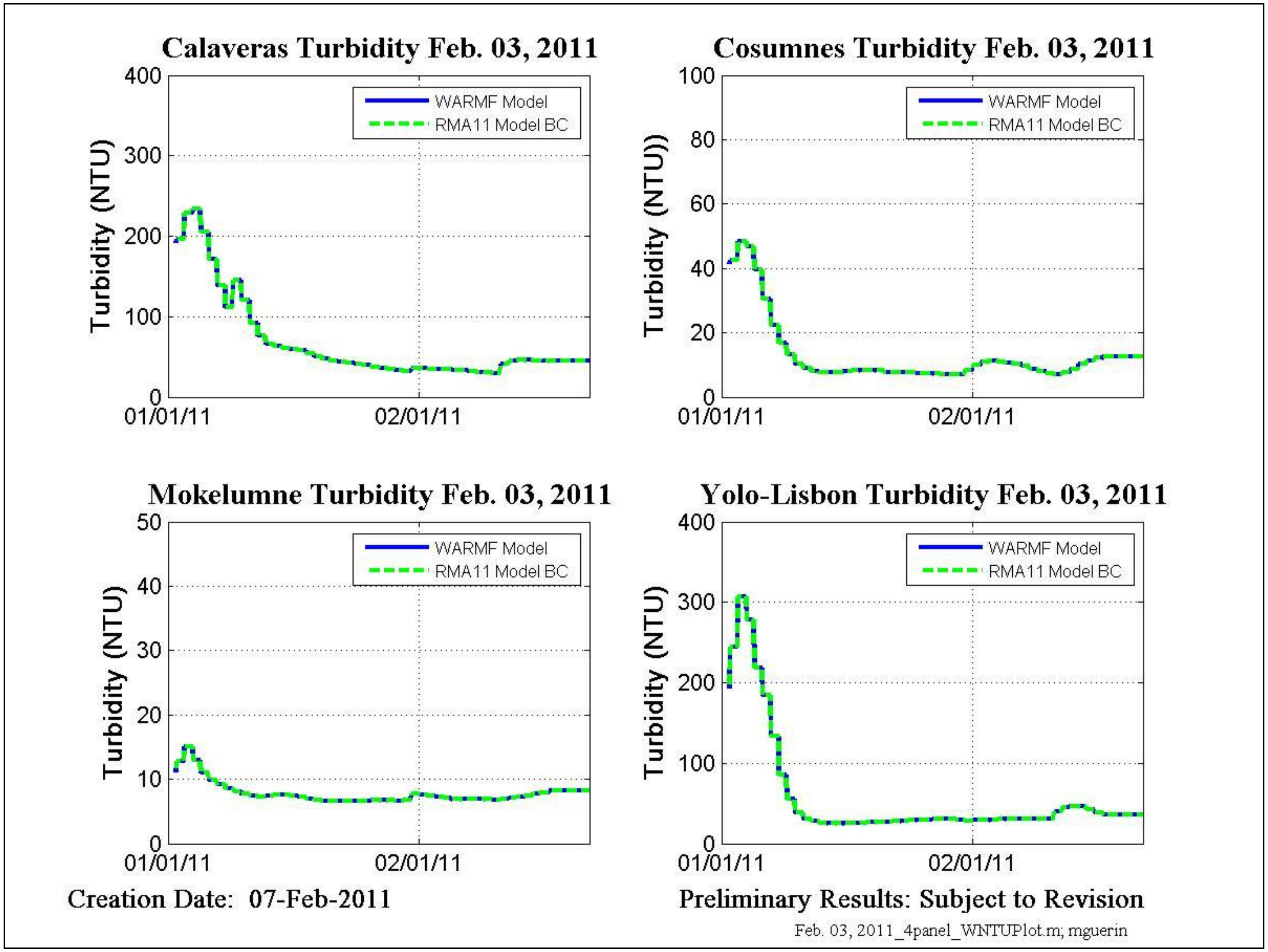


Figure 12-147 Turbidity boundary conditions used in the model along with the WARMF model output. Note difference in vertical scales.

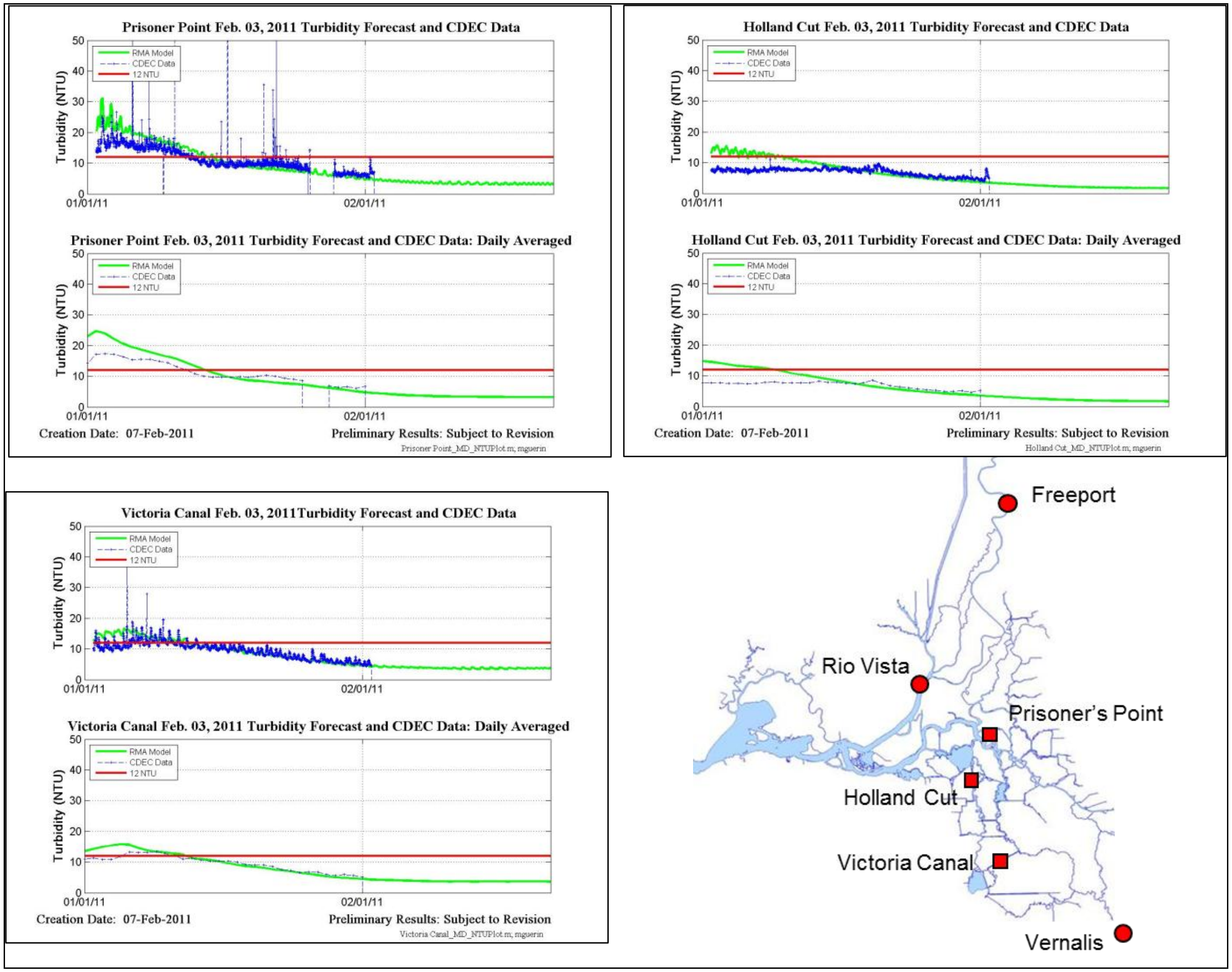


Figure 12-148 Modeled turbidity and data at the three compliance locations. Both 15-min model output and data and daily averaged plots are shown. Red line illustrates the 12-NTU compliance value.

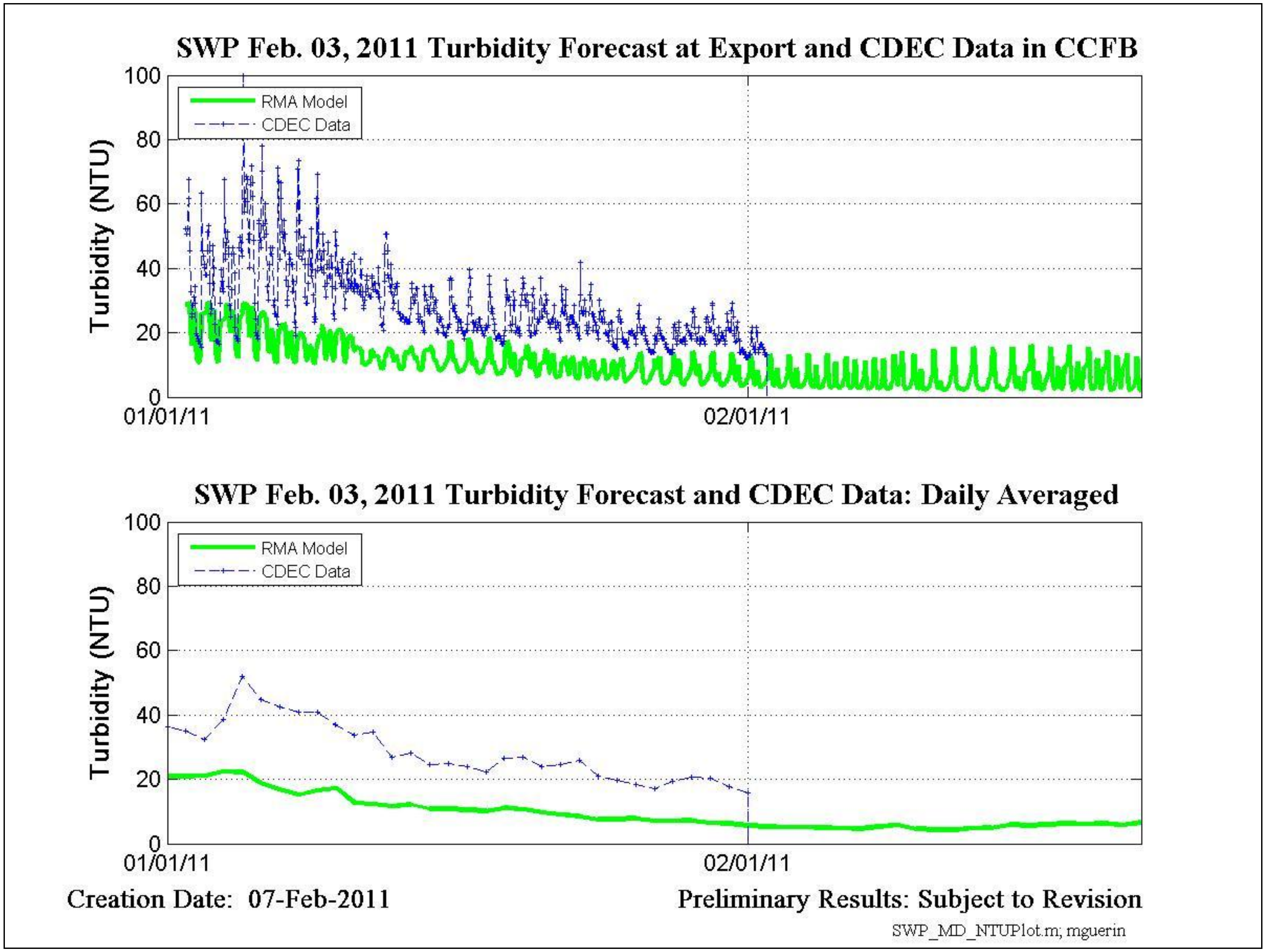


Figure 12-149 Plots compare model output at the SWP export location with data gathered inside Clifton Court Forebay. Both 15-min model output (upper) and daily averaged plots (lower) are shown.

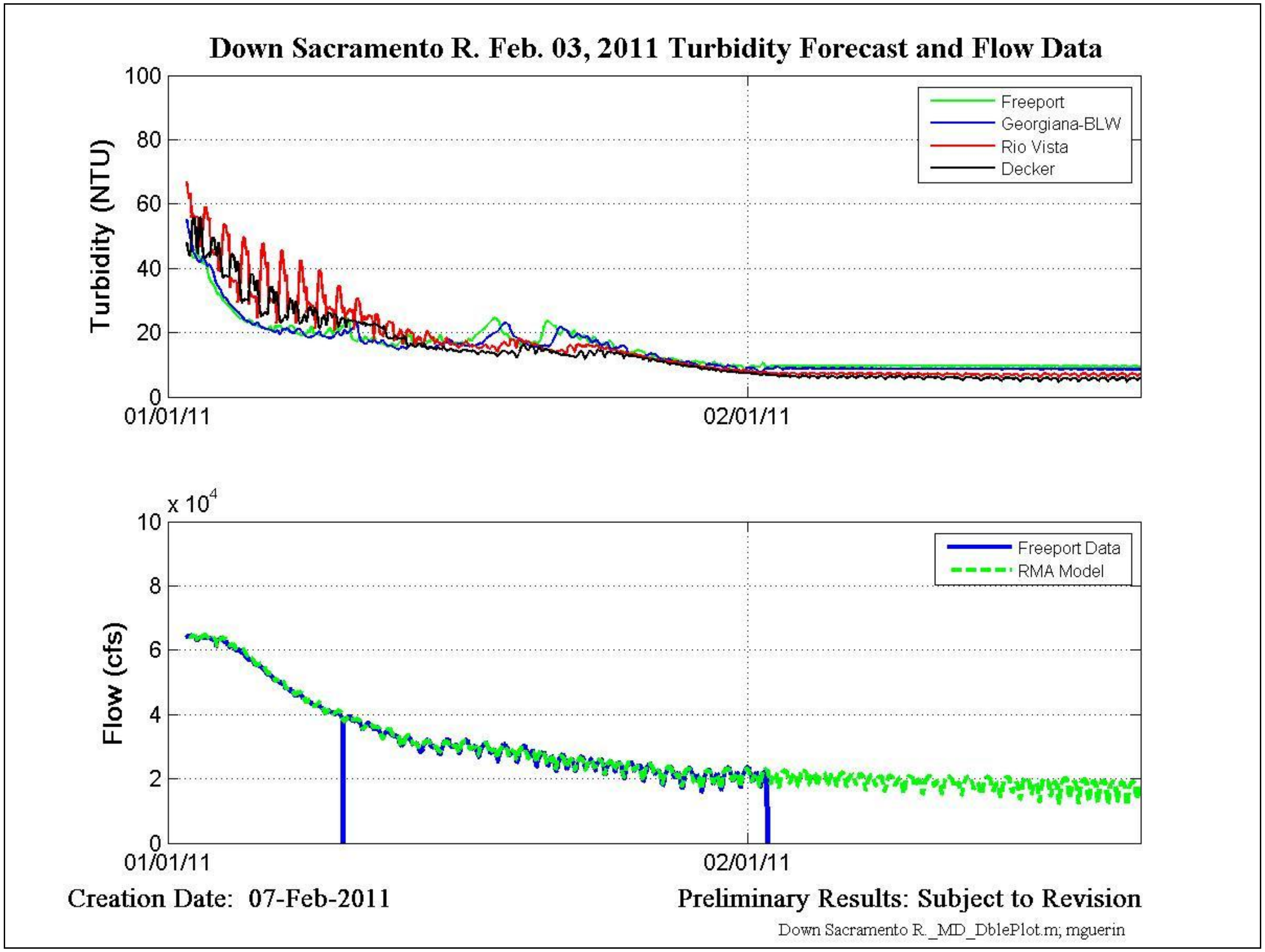


Figure 12-150 Freeport turbidity boundary condition progression down the Sacramento R. (upper) along with the flow data and RMA model boundary conditions (lower) used during the modeled period. Forecast began on February 1st. End of flow data signals the beginning of the forecast.

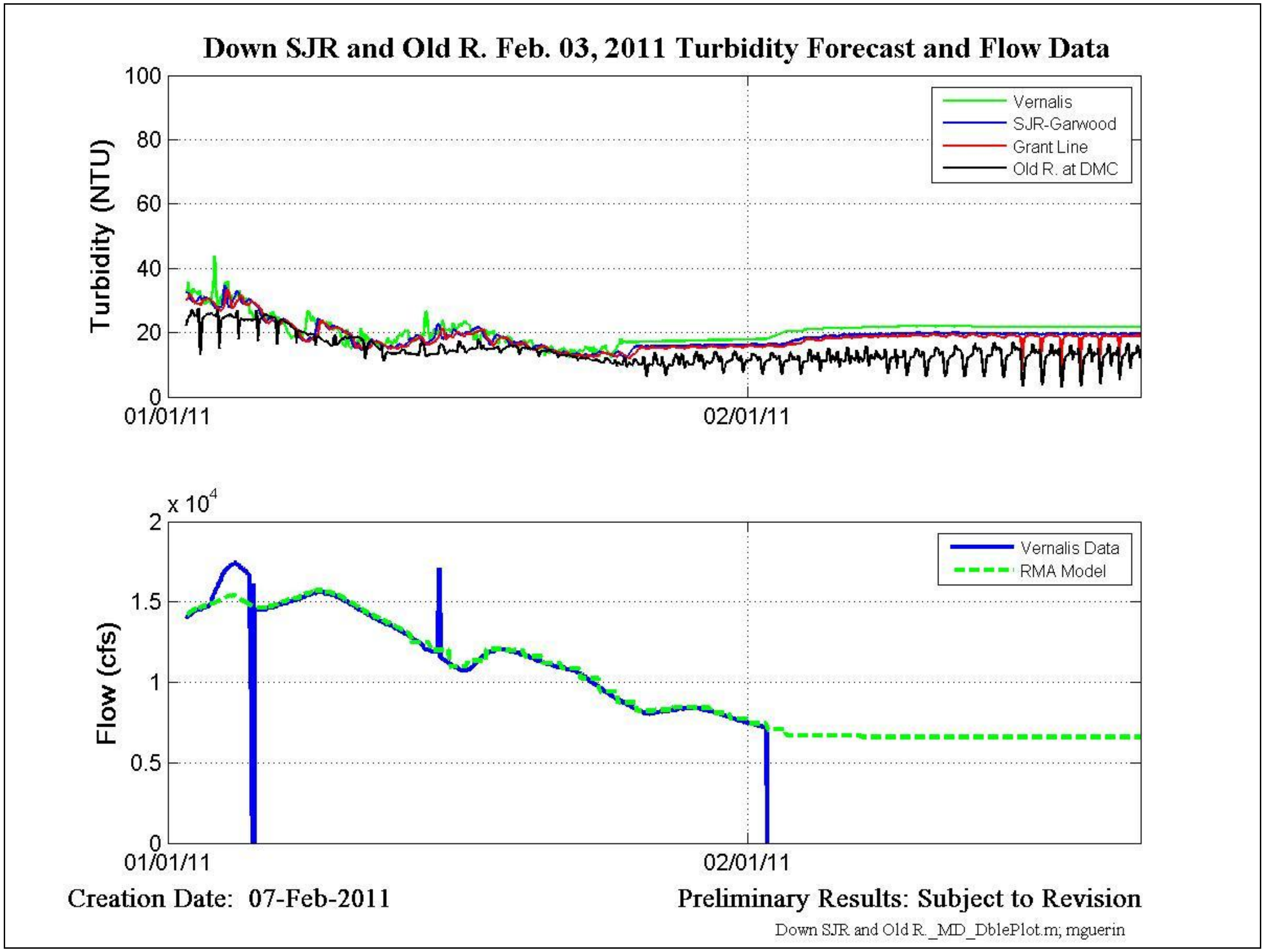


Figure 12-151 Progression of the turbidity boundary condition from Vernalis down the San Joaquin R. to Garwood, and down Old River (upper plot). Flow data and RMA model boundary condition at Vernalis are shown in the lower plot. Forecast began on Jan 25th. End of flow data signals the beginning of the forecast.

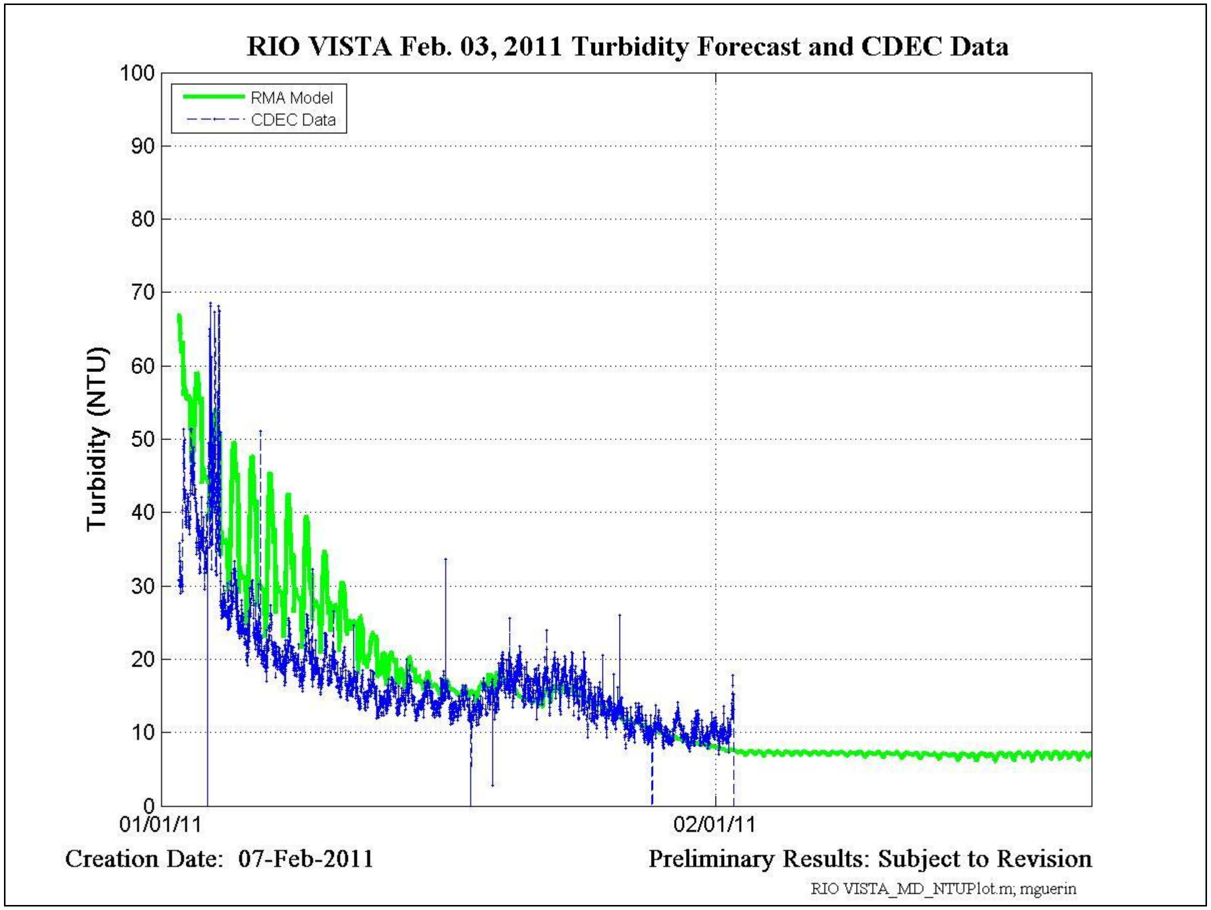


Figure 12-152 Model forecast and CDEC data at Rio Vista.

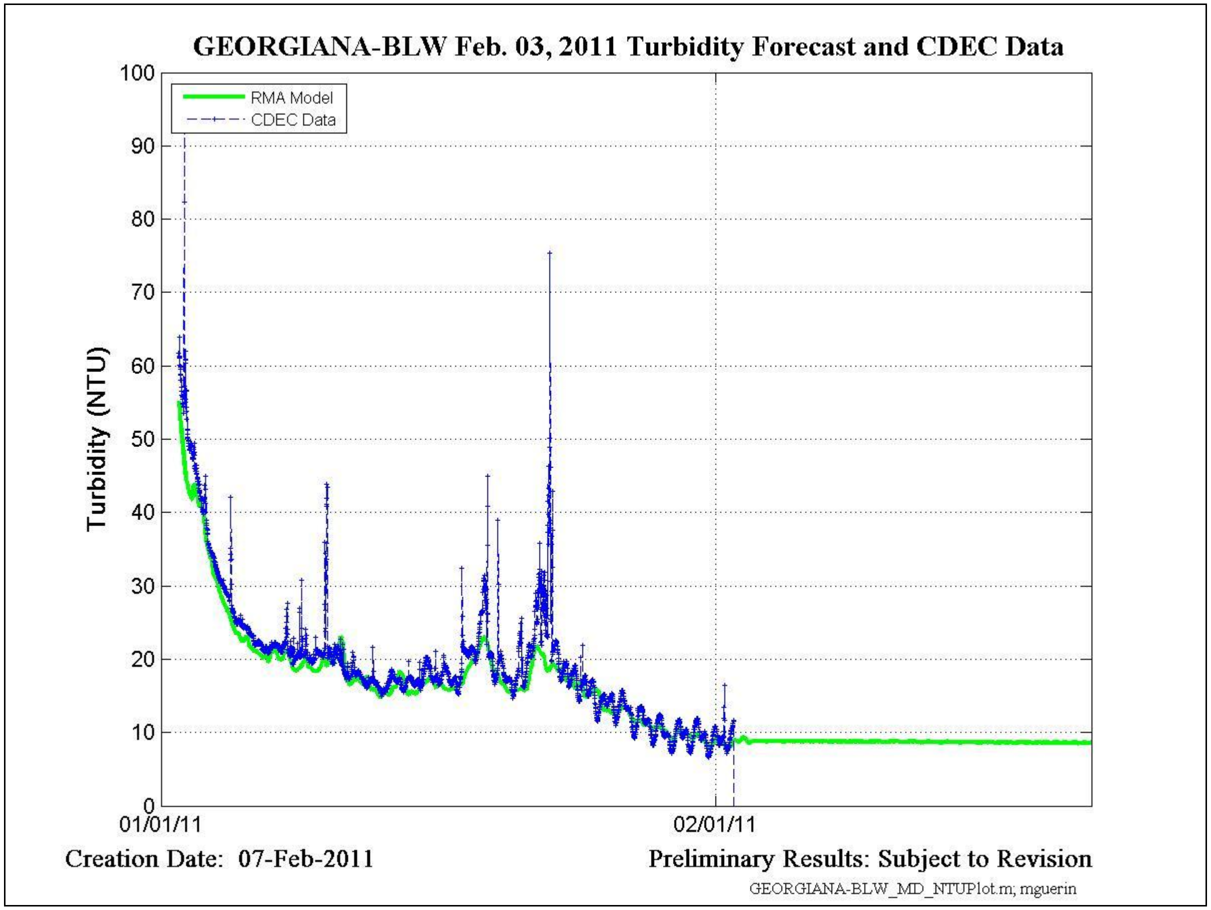


Figure 12-153 Model forecast and CDEC data at Georgian-BLW.

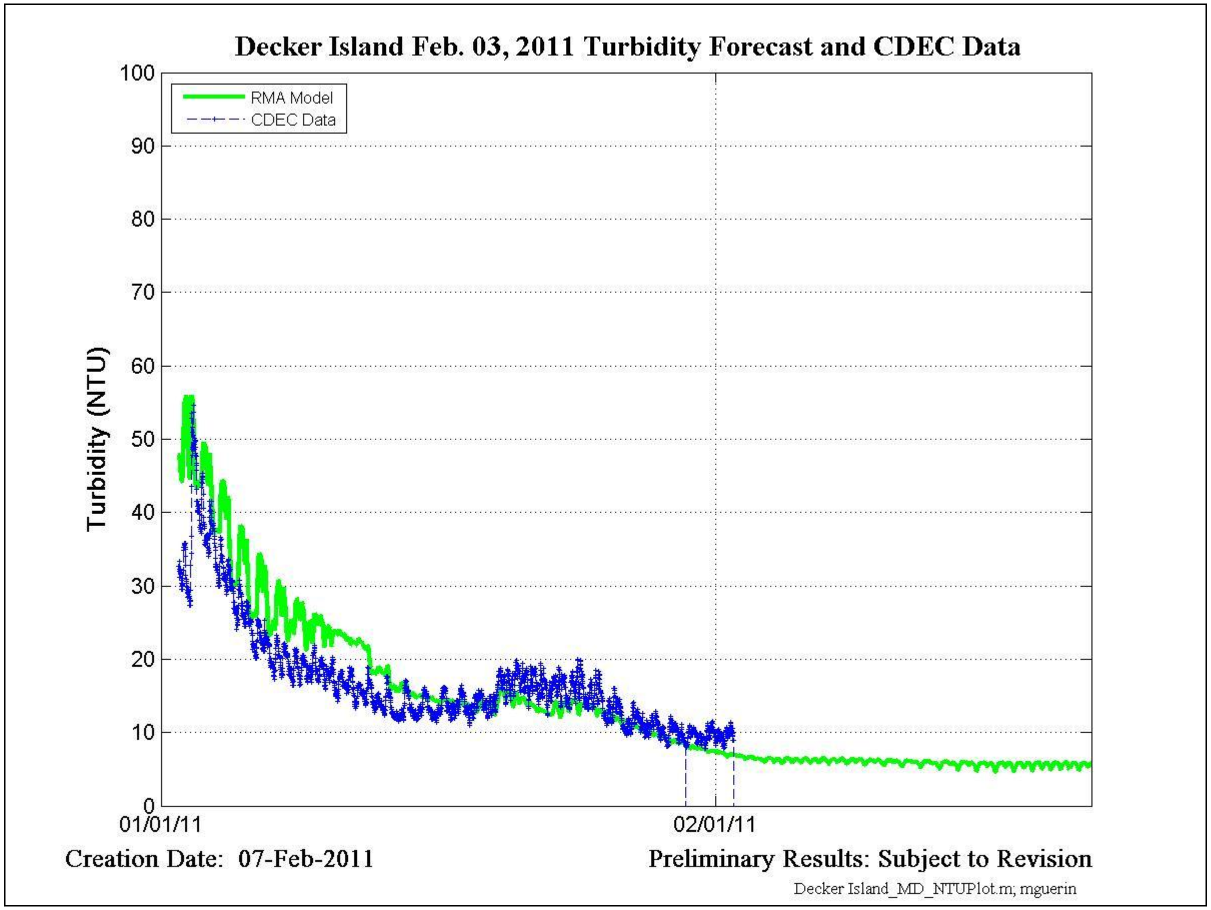


Figure 12-154 Model forecast and CDEC data at Decker Island.

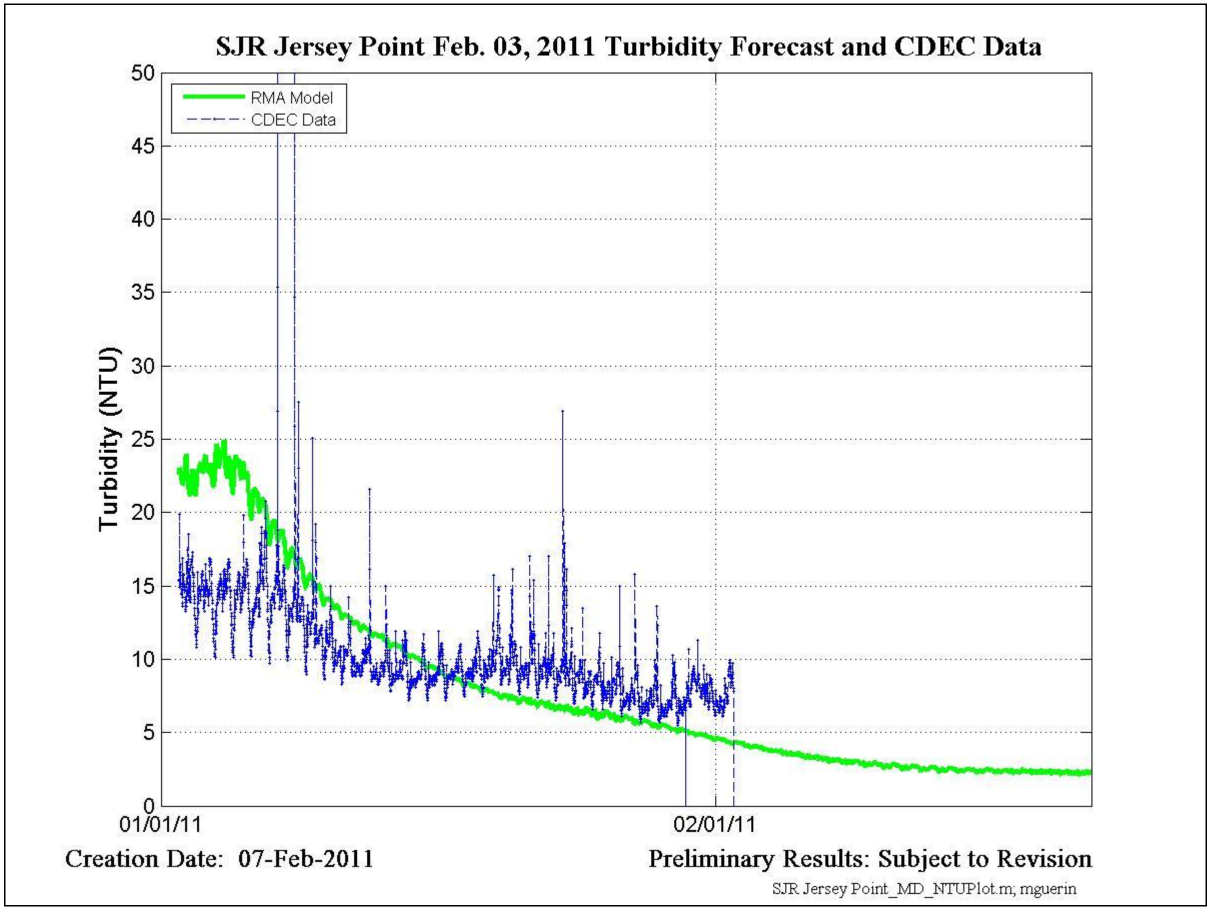


Figure 12-155 Model forecast and CDEC data at Jersey Point.

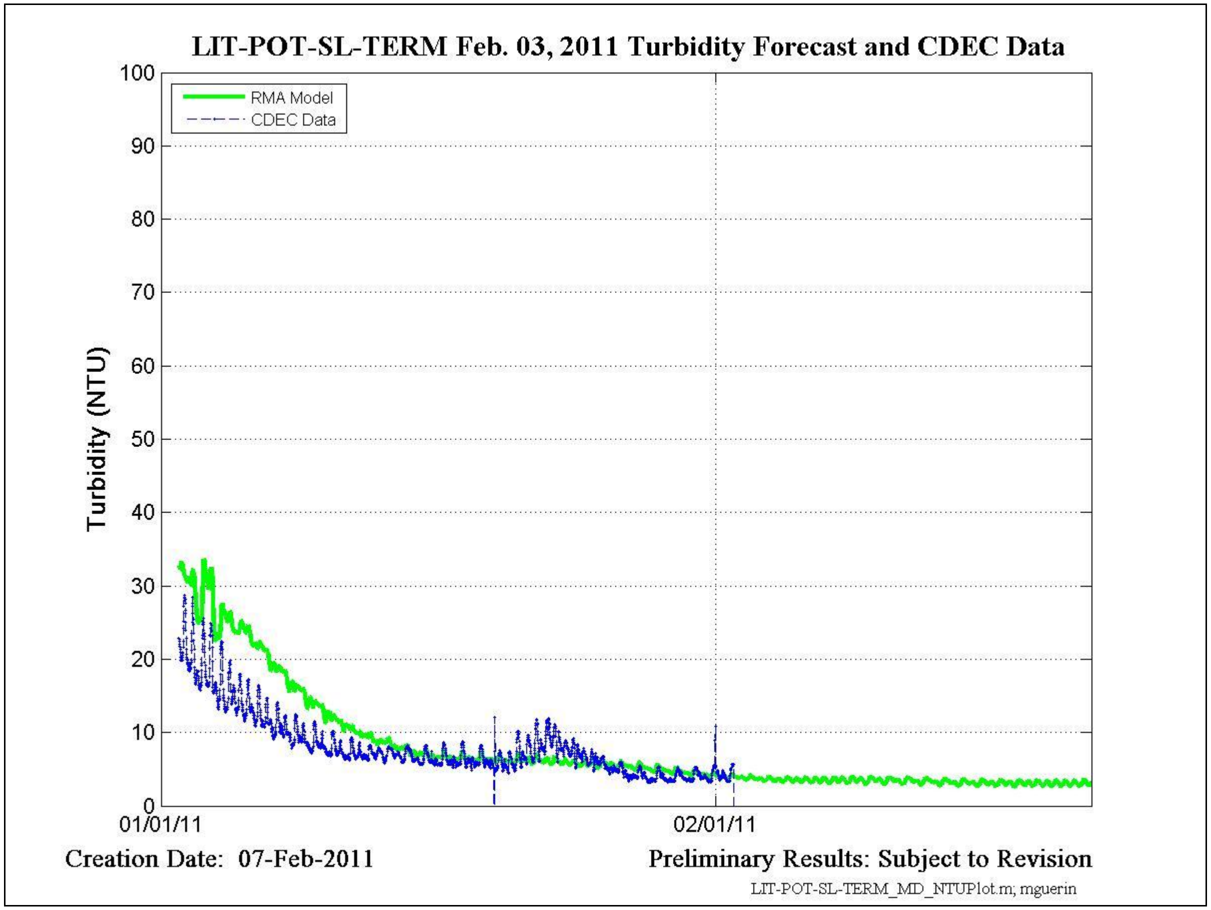


Figure 12-156 Model forecast and CDEC data at Little Potato Slough at Terminous.

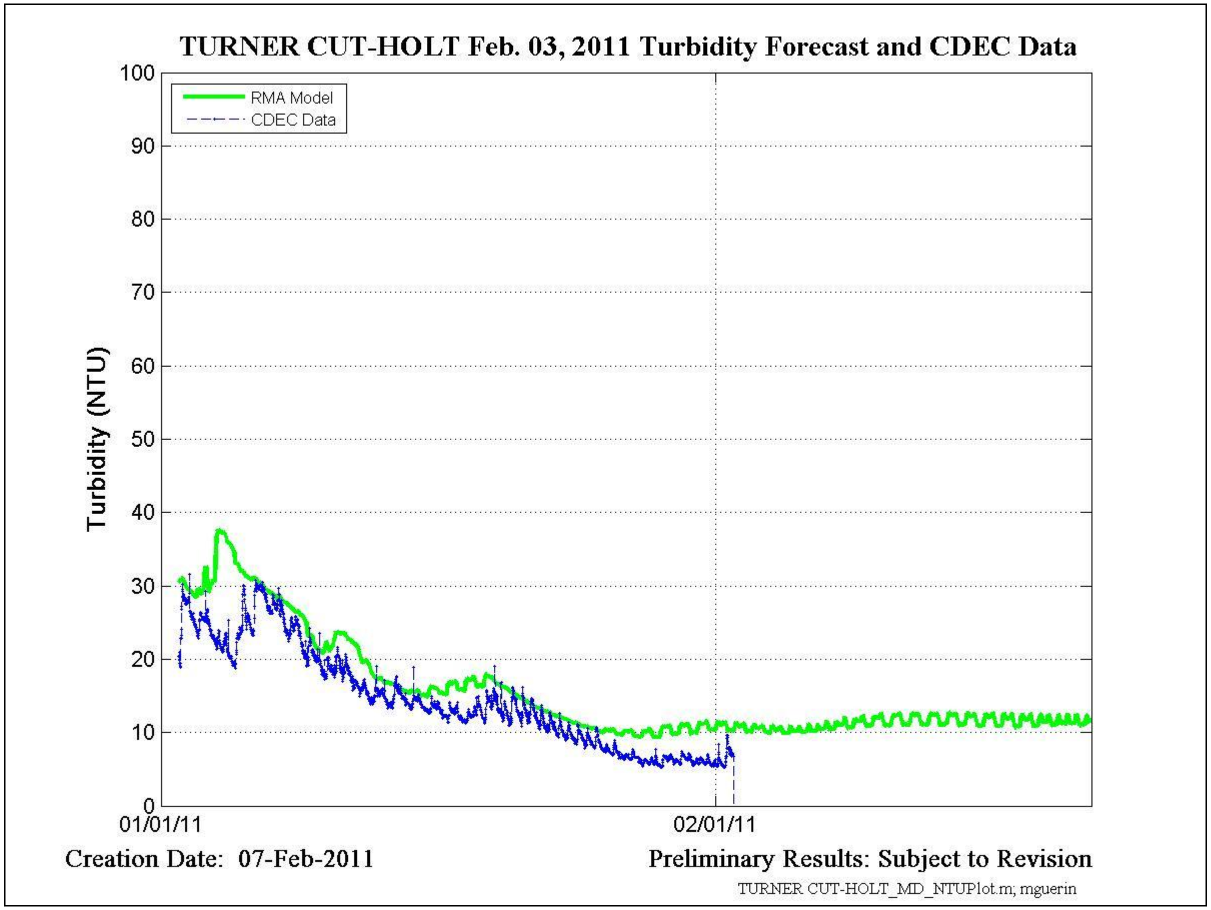


Figure 12-157 Model forecast and CDEC data at Turner Cut near Holt.

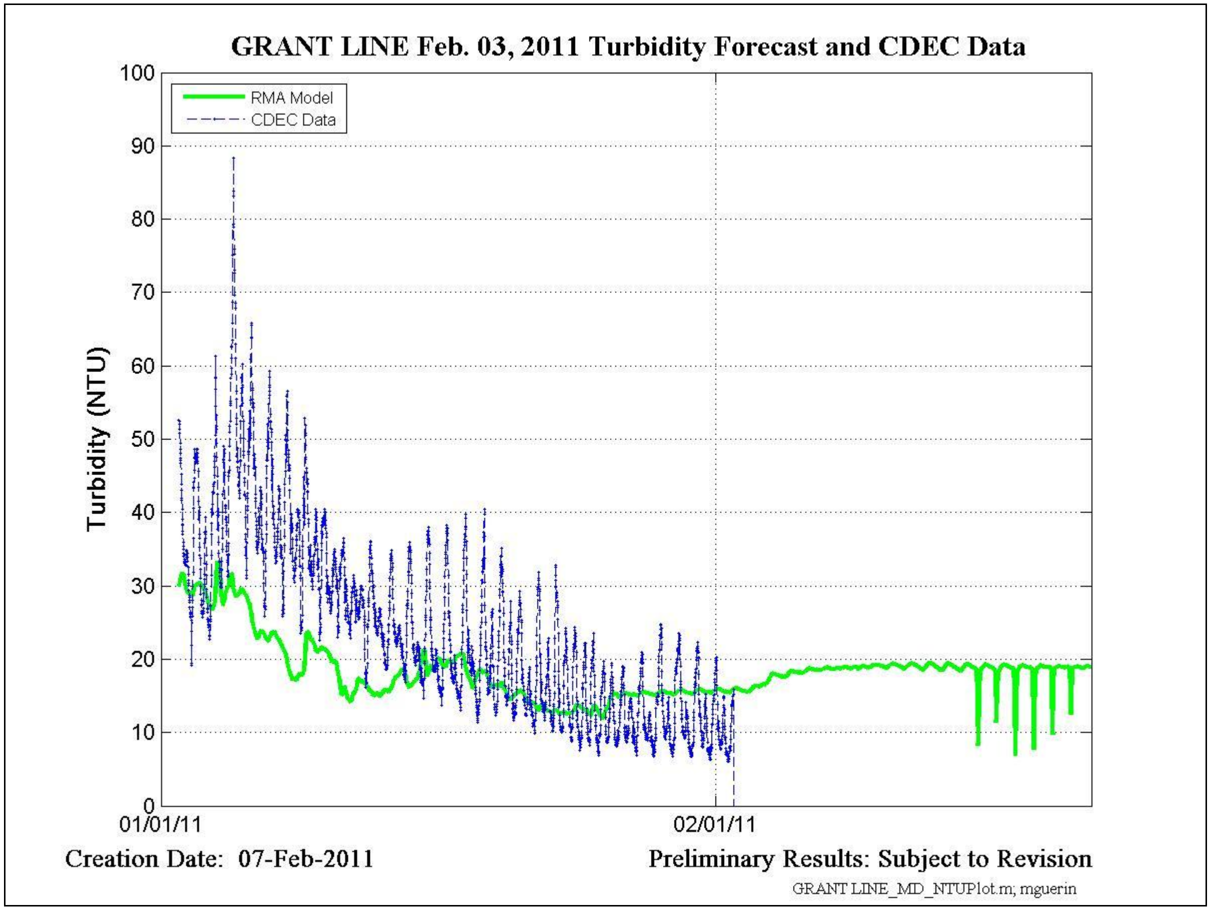


Figure 12-158 Model forecast and CDEC data at Grant Line.

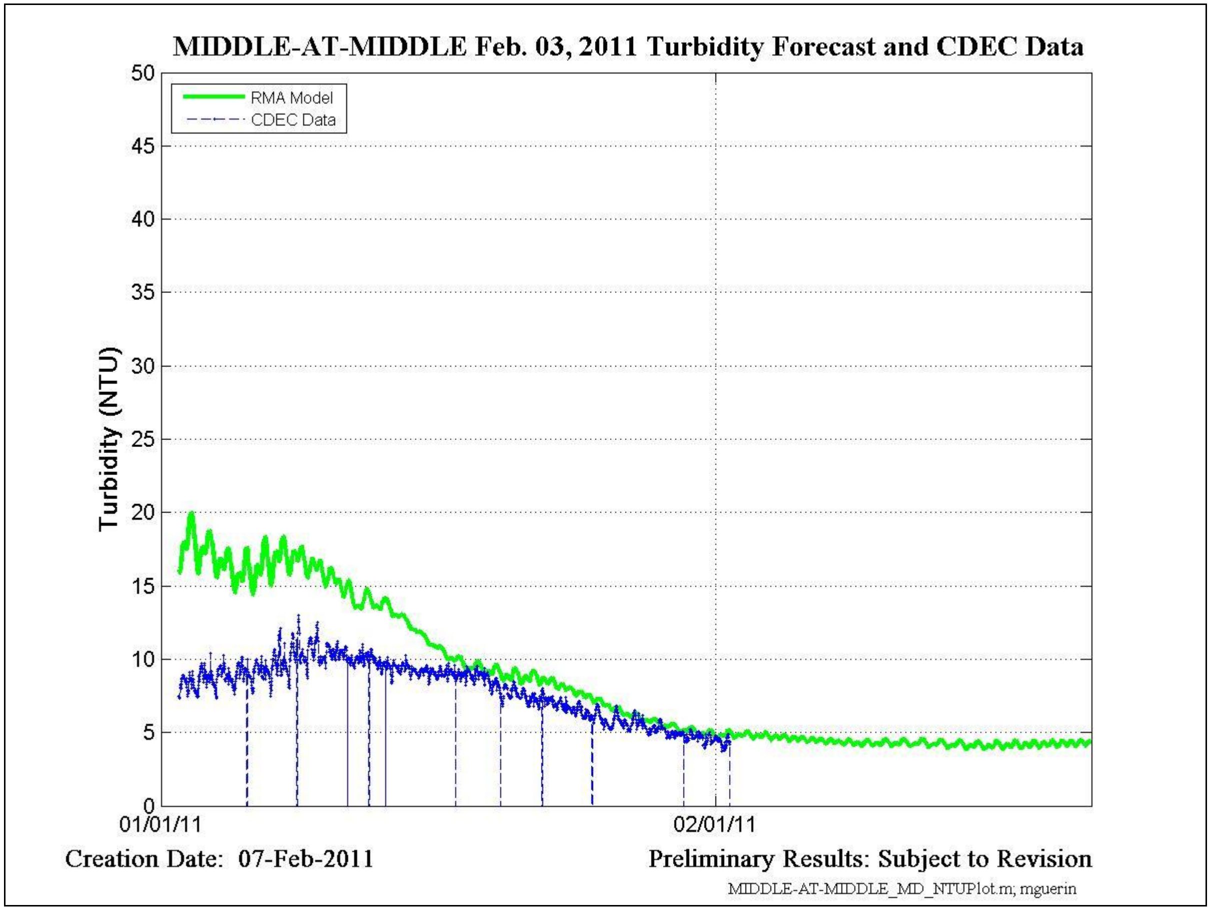


Figure 12-159 Model forecast and CDEC data at Middle R. at Middle R.

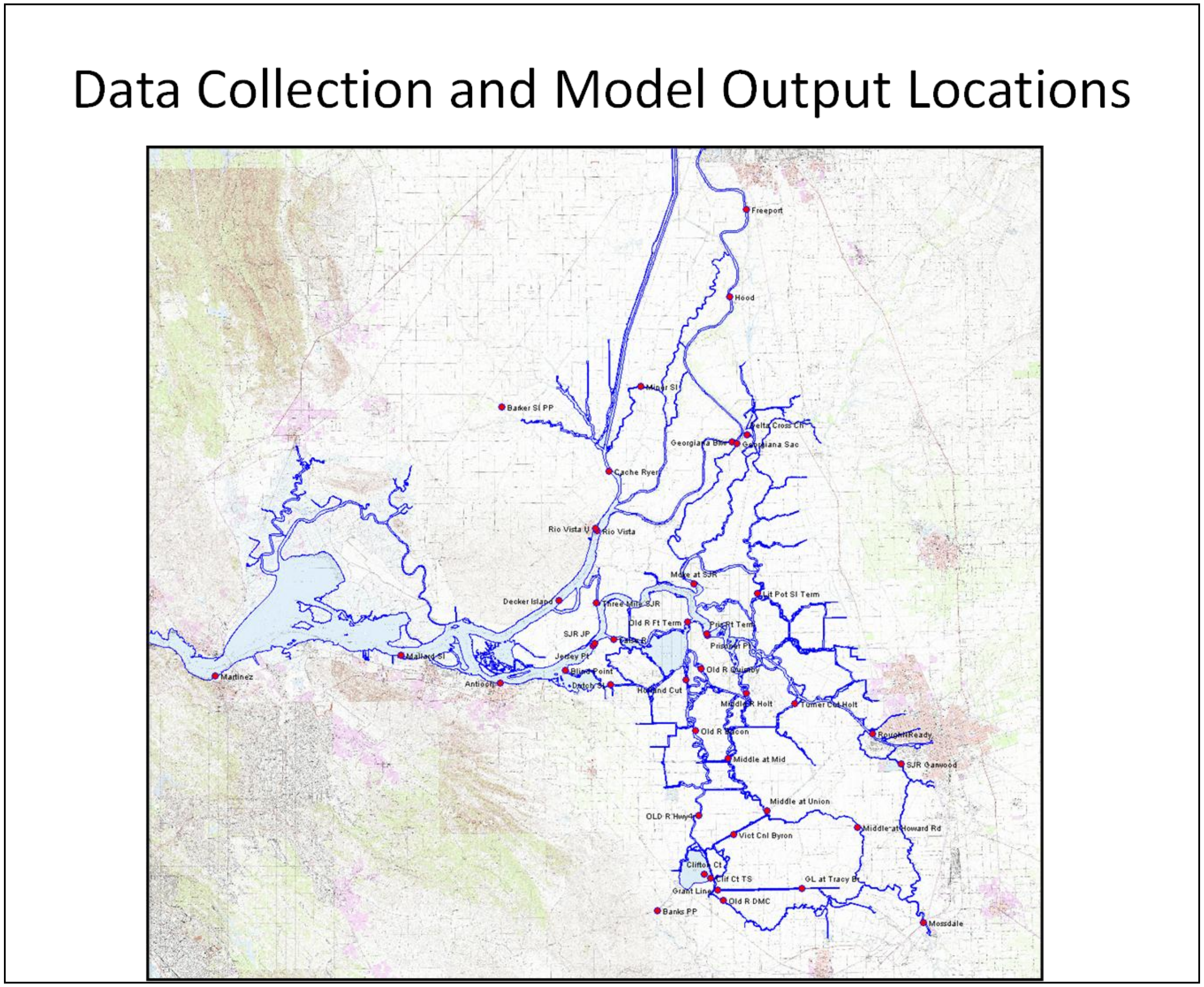


Figure 12-160 Figure illustrating model output and data collection locations.

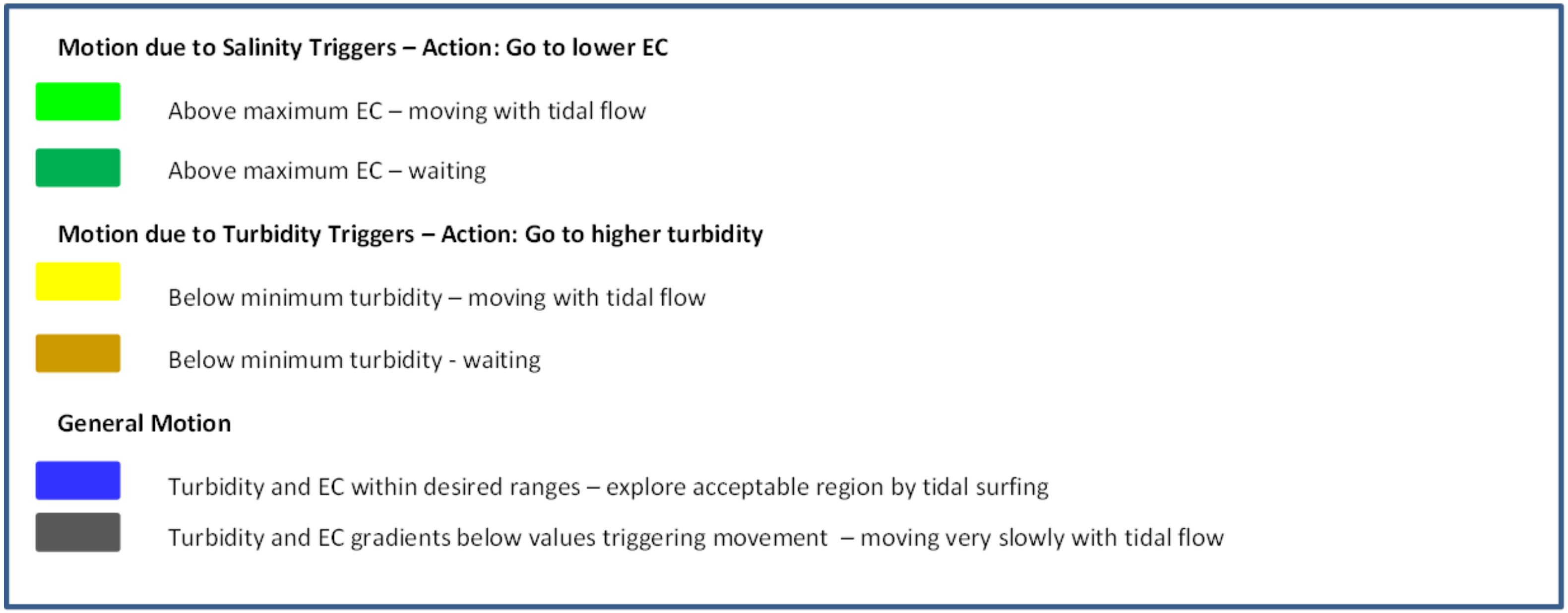


Figure 12-161 Particles in the Adult Delta Smelt particle tracking model are color-coded by the triggers influencing their behavior during the simulation. Use this figure to interpret the simplified color scale in the next several figures.

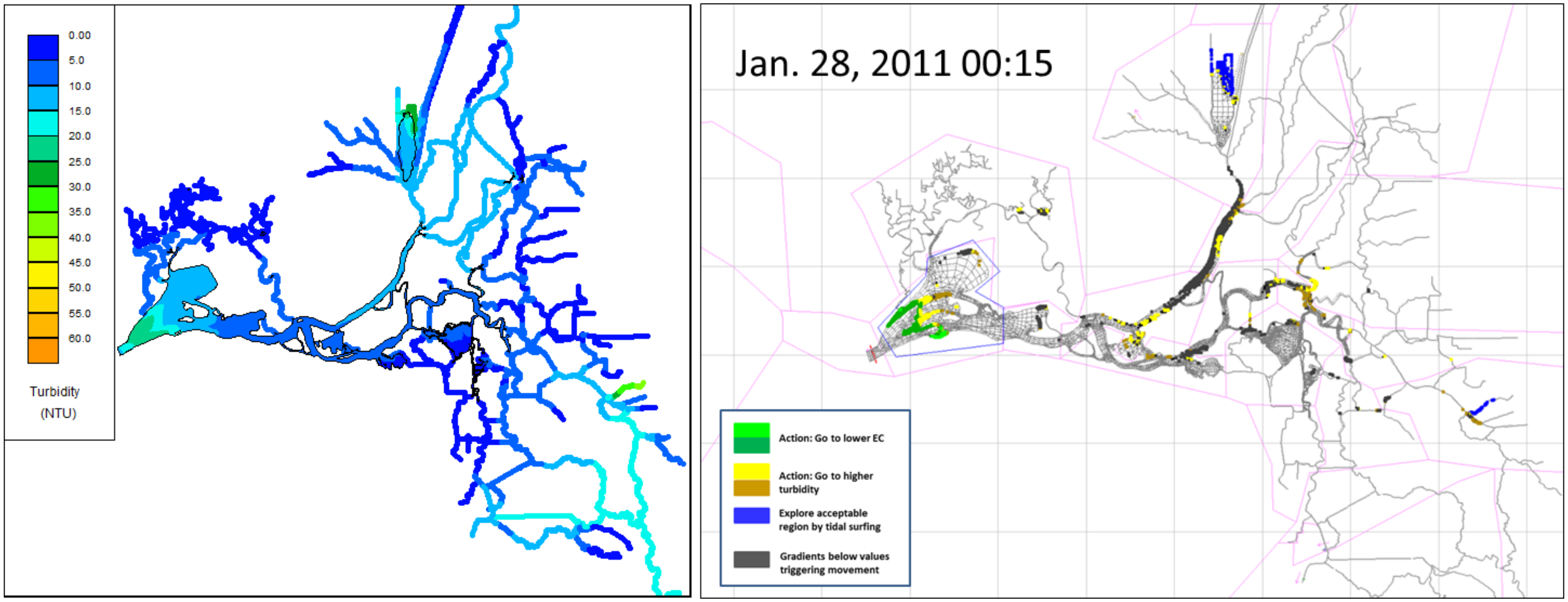


Figure 12-162 Turbidity contours and particle location in the RMA model grid on Jan. 28, 2011.

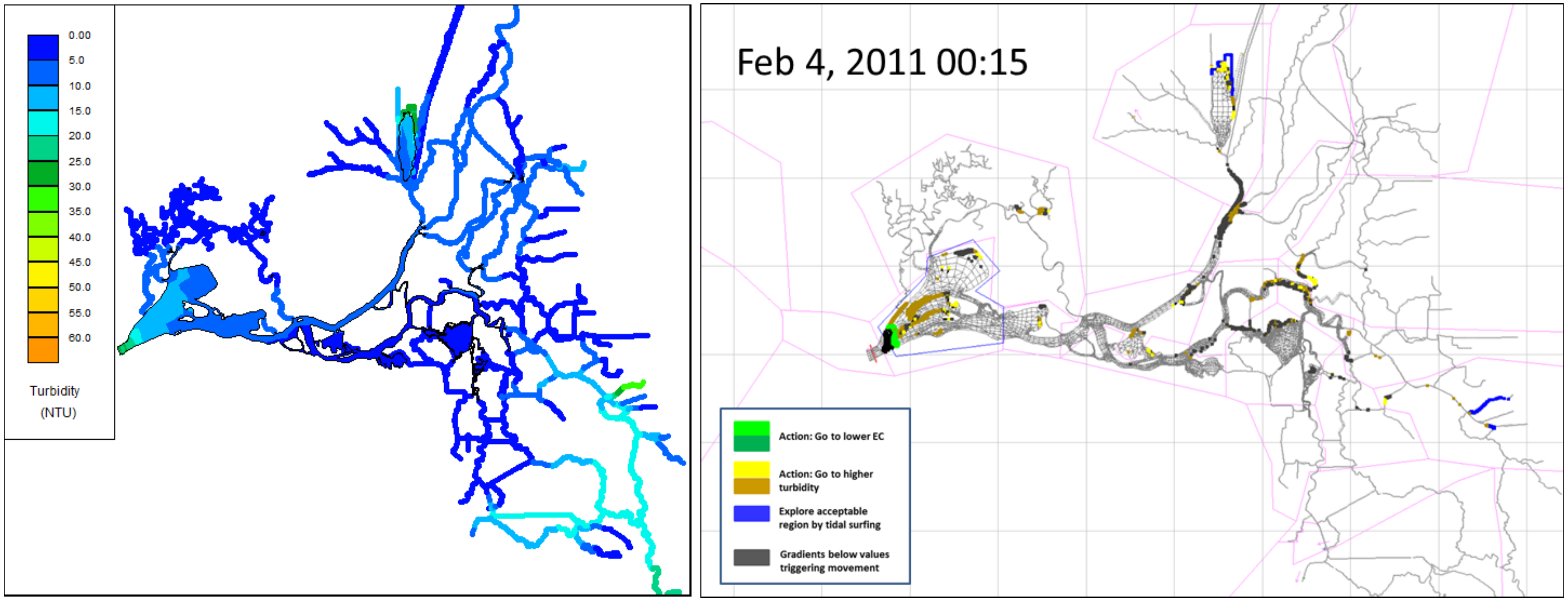


Figure 12-163 Turbidity contours and particle location in the RMA model grid on Feb. 04, 2011.

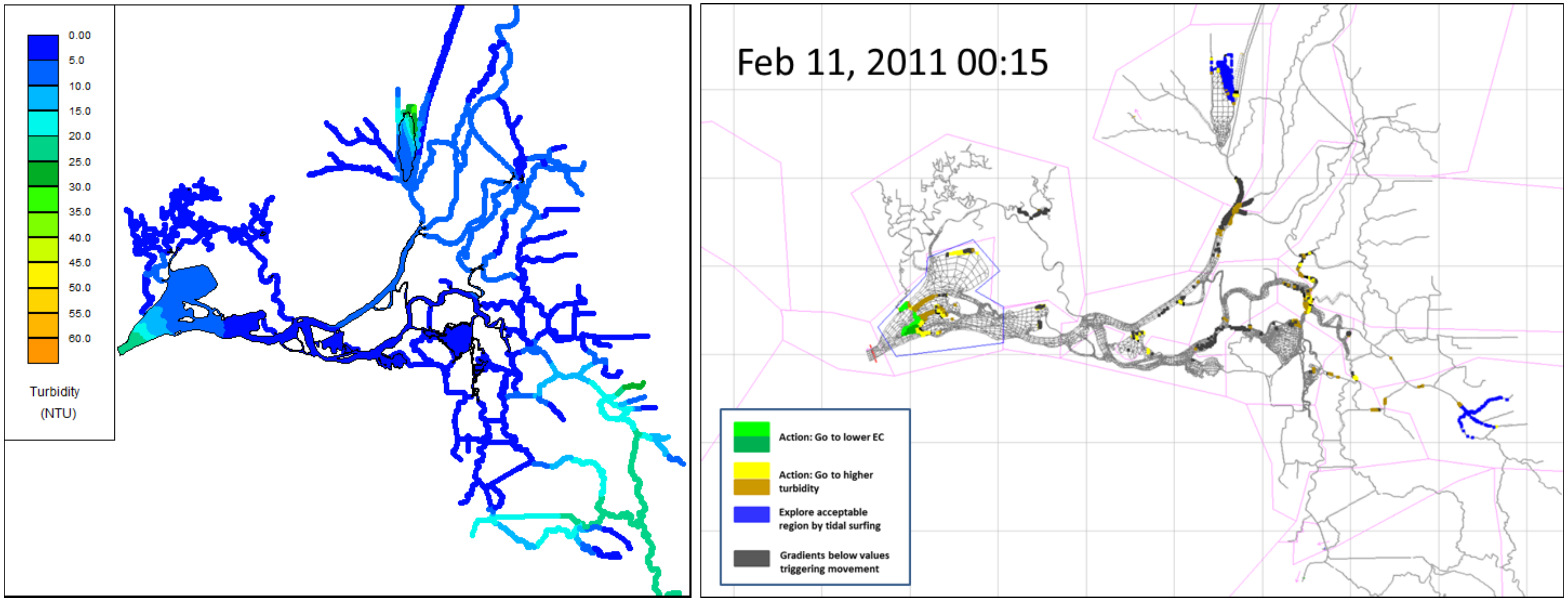


Figure 12-164 Turbidity contours and particle location in the RMA model grid on Feb 11, 2011.

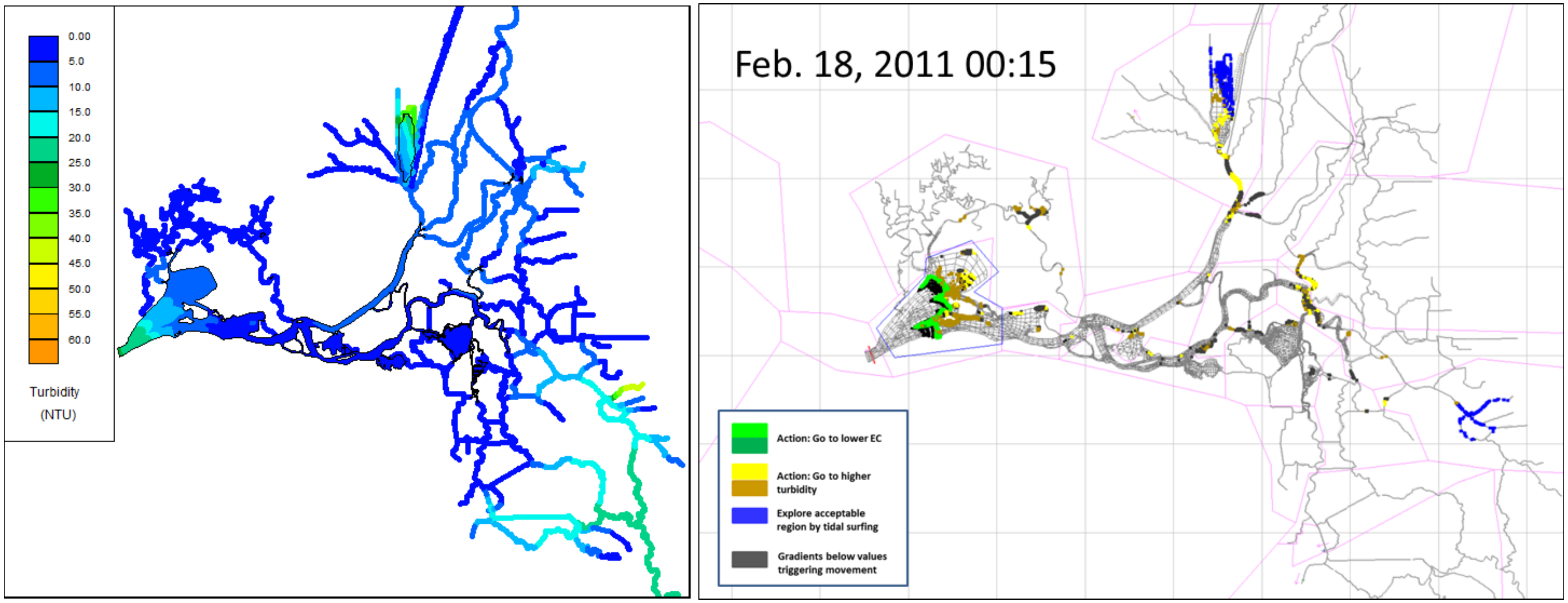


Figure 12-165 Turbidity contours and particle location in the RMA model grid on Feb. 18, 2011.

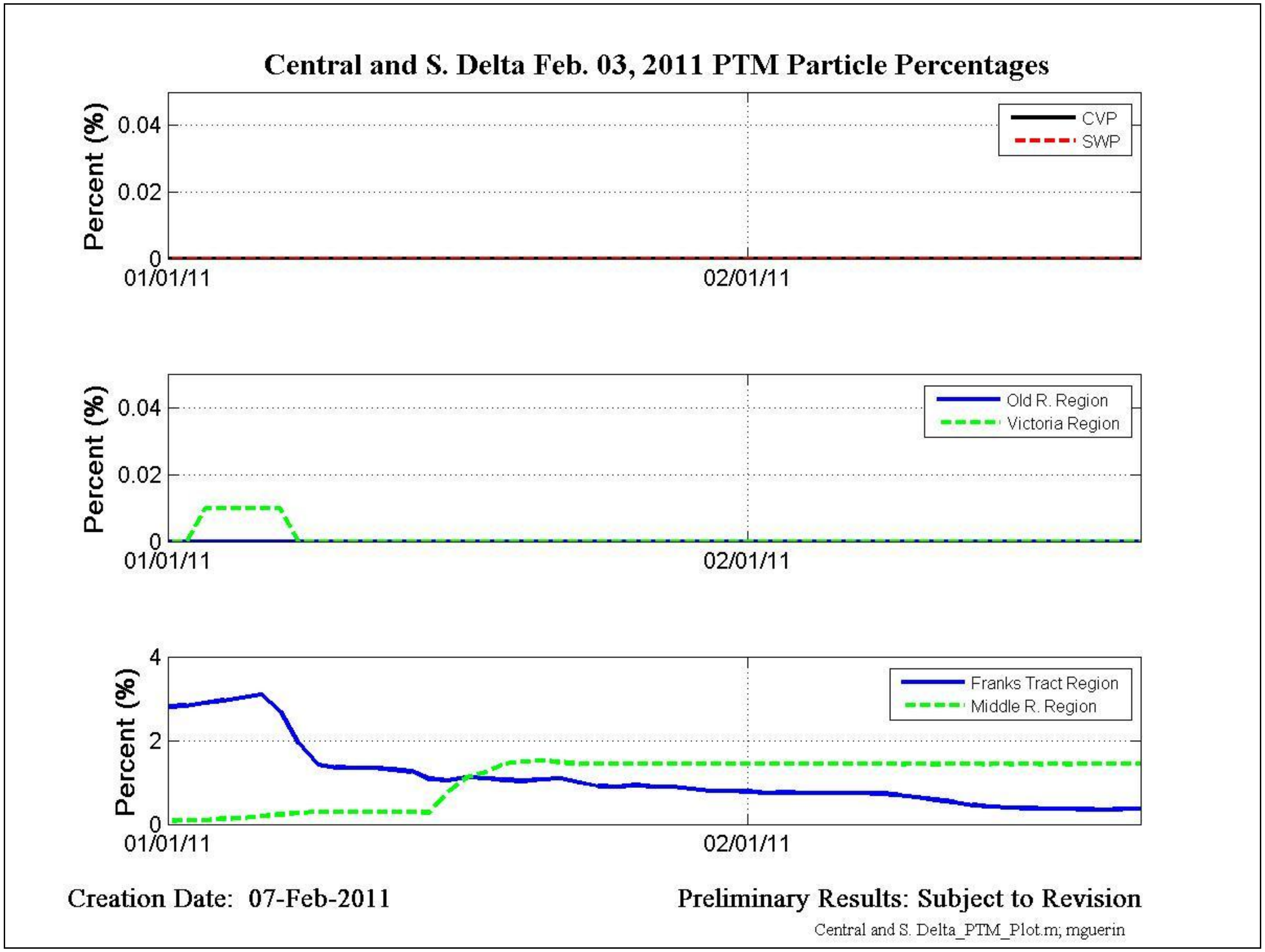


Figure 12-166 Only a couple of particles reached the SWP export location, none reached CVP (upper plot). No particles entered the Old River Region (center plot). A small percentage reached the Franks Tract and Middle River Regions (lower plot).

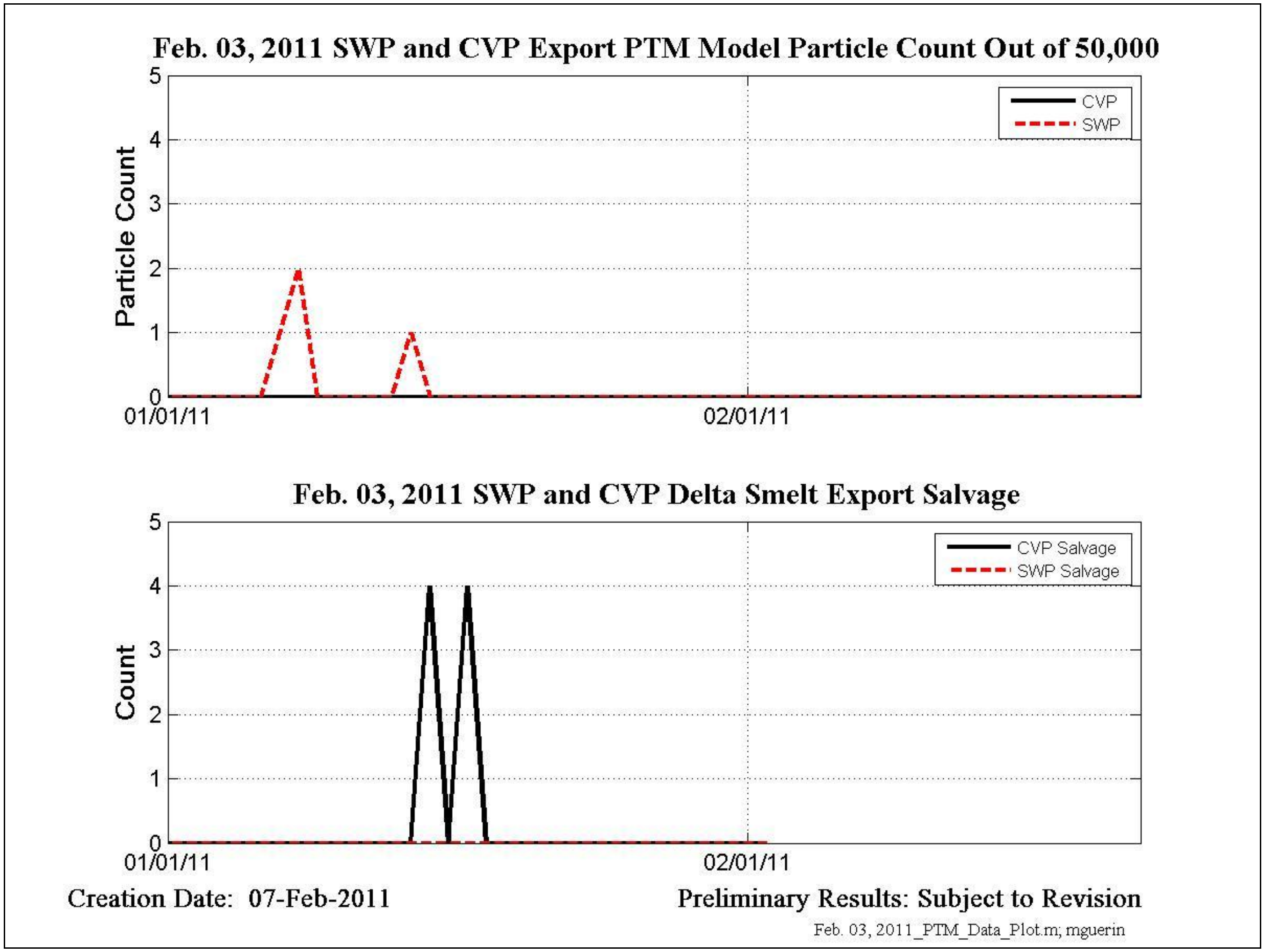


Figure 12-167 Four delta smelt were salvaged on Jan 15th and again on Jan 17th at the CVP location (lower plot). The upper plot shows that a few particles reached the SWP export location, but the percentage was so small as to be insignificant (see Figure 12-59).

12.4. WARMF model output for selected forecast periods

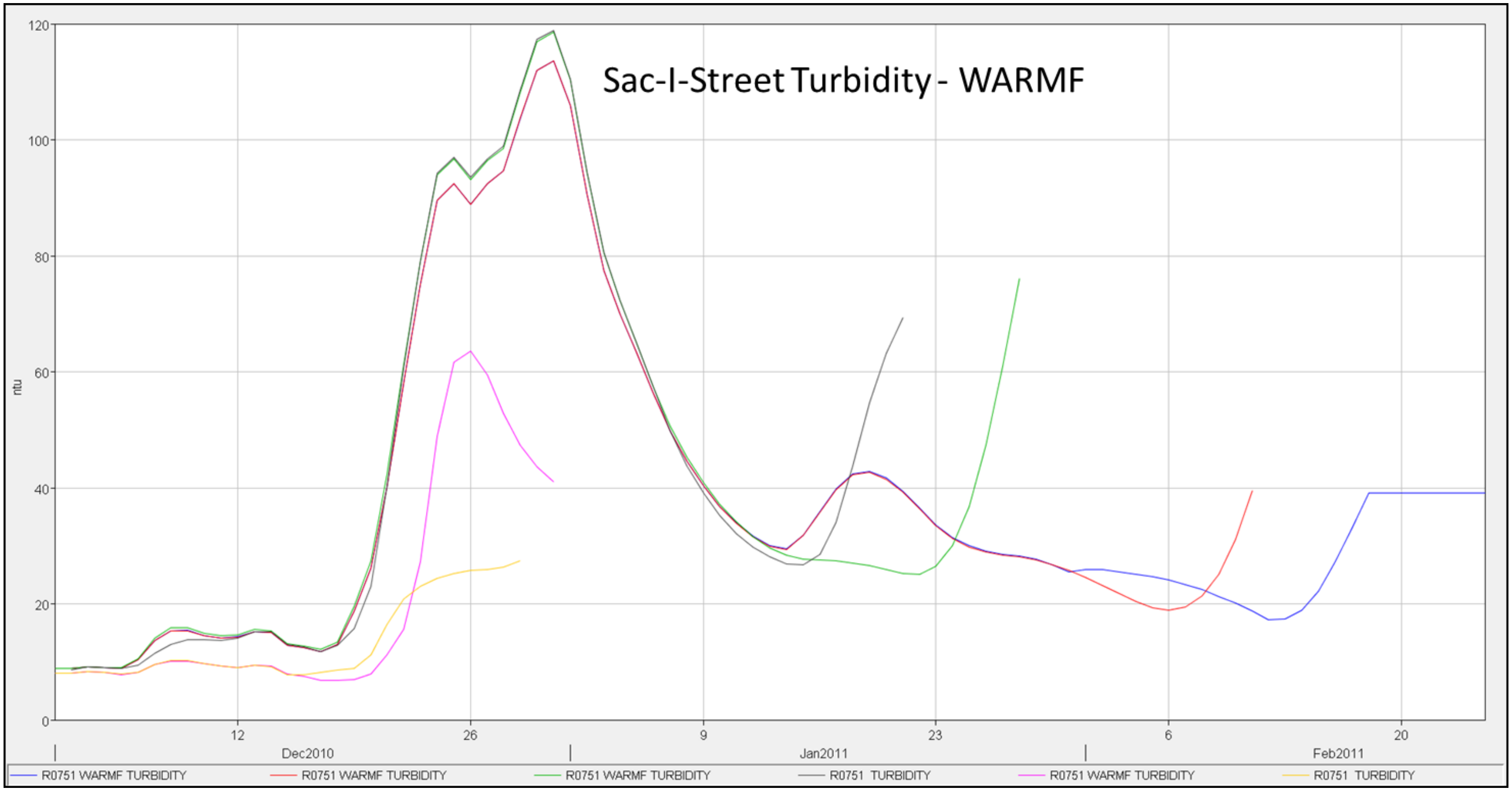


Figure 12-168 WARMF forecast turbidity at Sac-I-Street for six of the forecast periods.

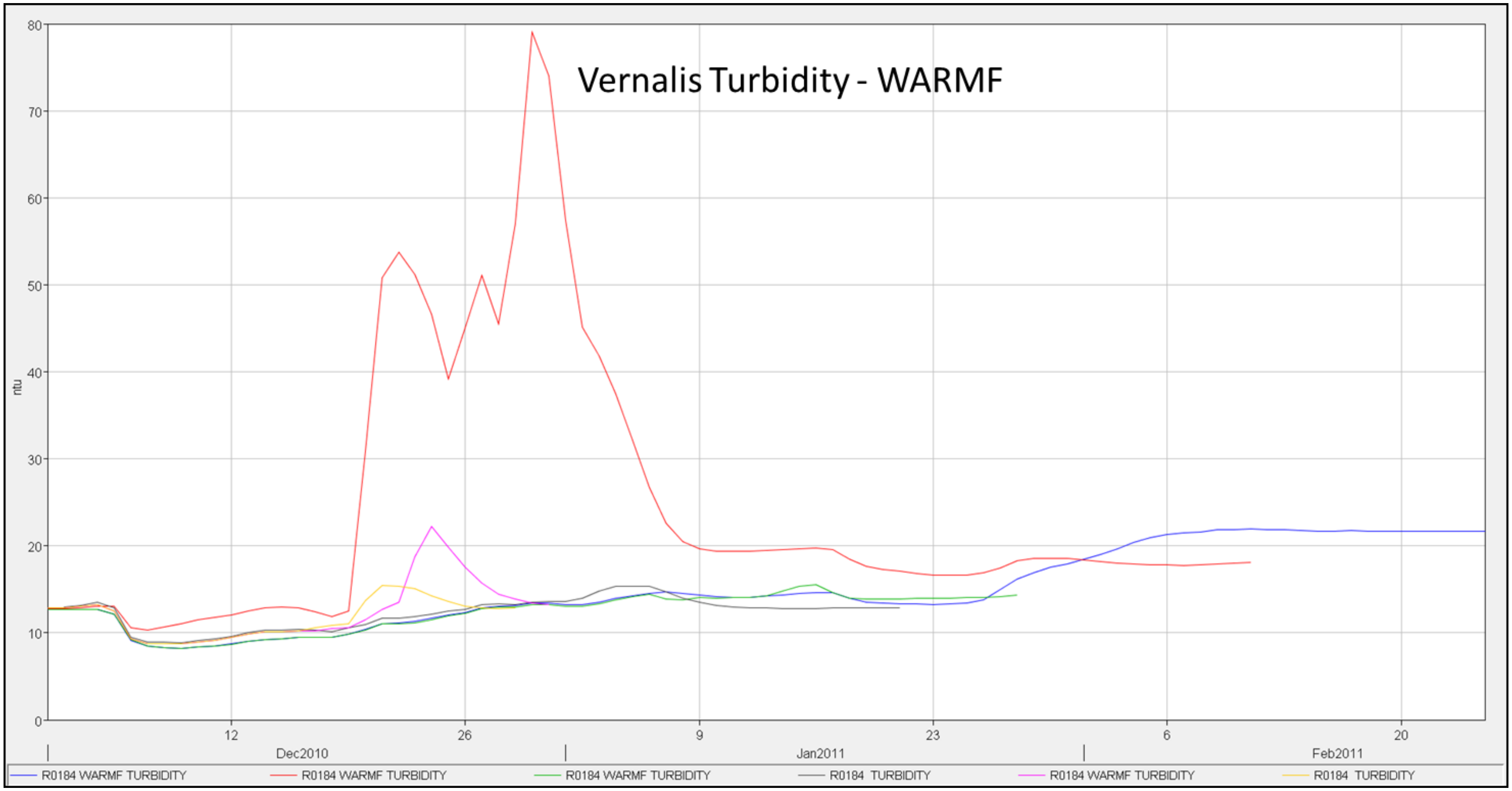


Figure 12-169 WARMF forecast turbidity at Vernalis for six of the forecast periods.

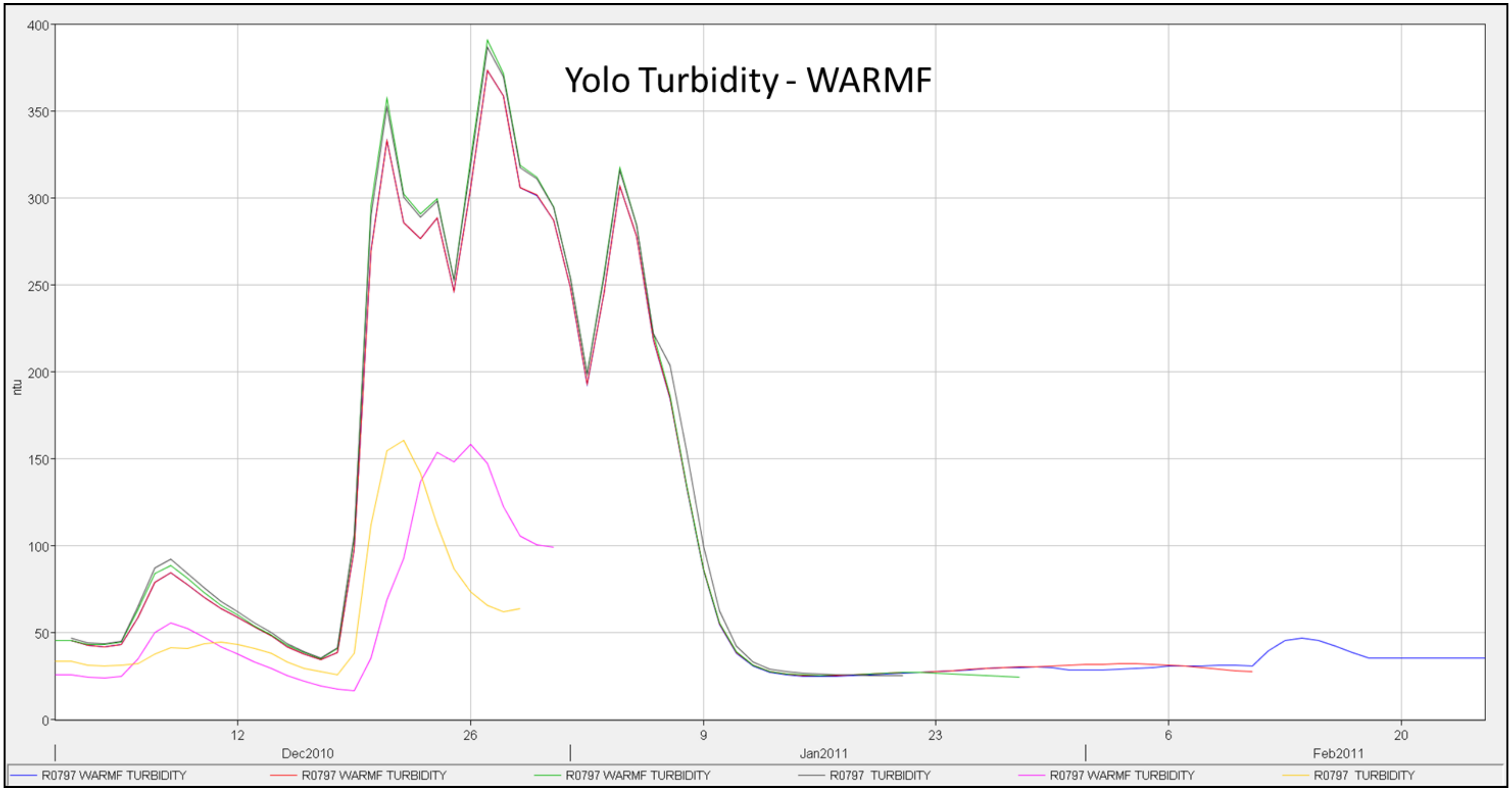


Figure 12-170 WARMF forecast turbidity at Yolo for six of the forecast periods.

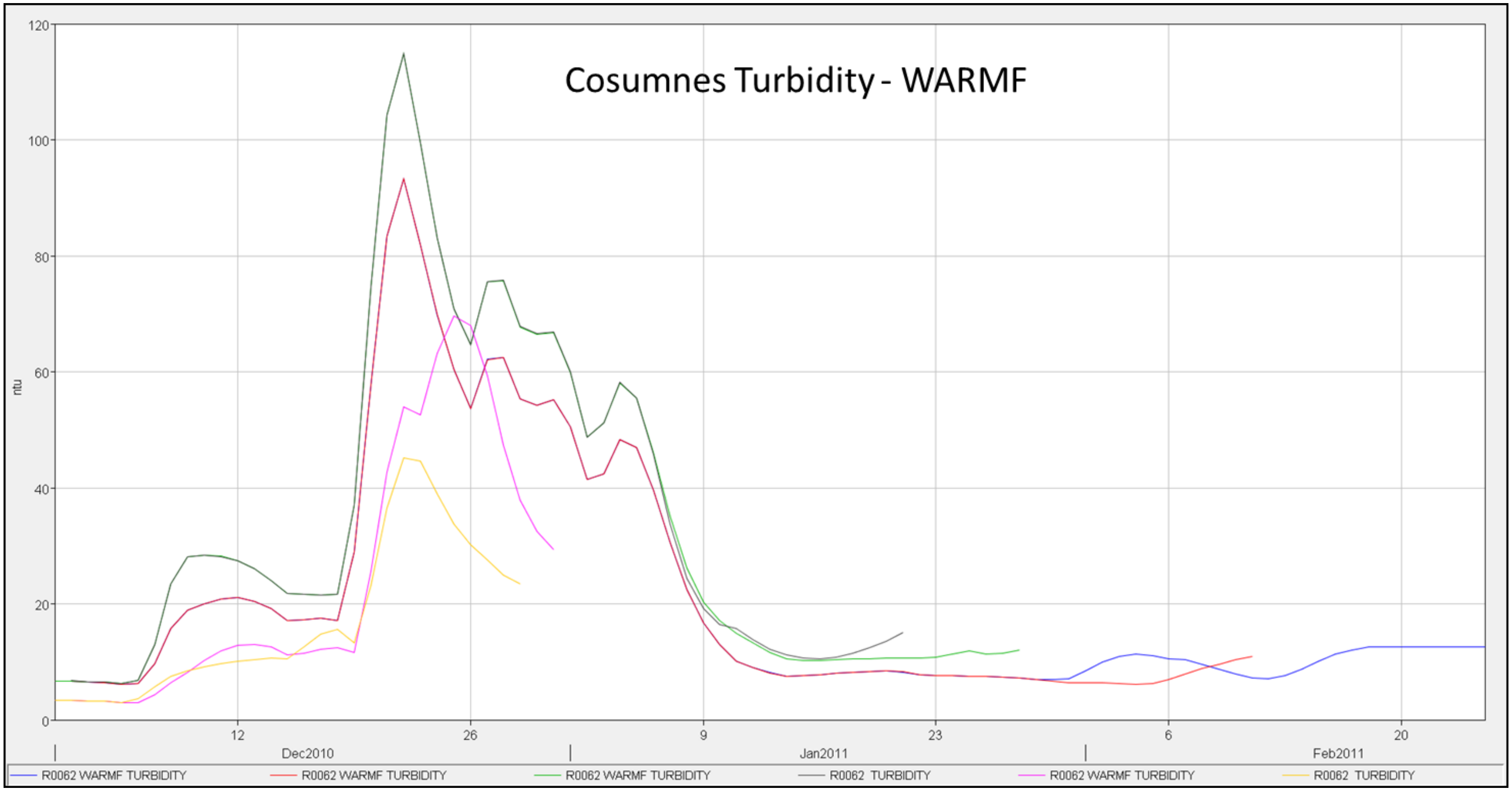


Figure 12-171 WARMF forecast turbidity at Cosumnes for six of the forecast periods.

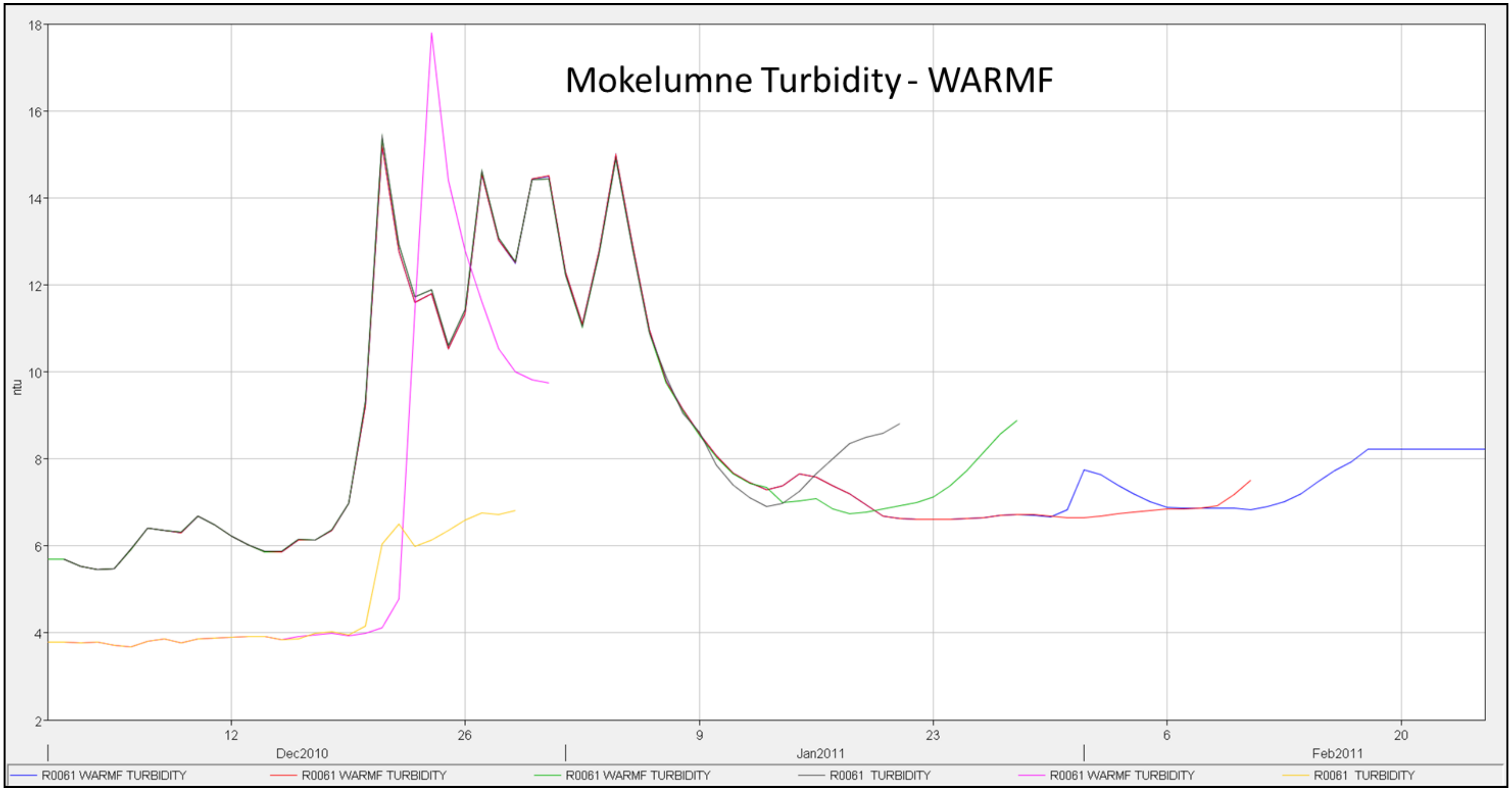


Figure 12-172 WARMF forecast turbidity at Mokelumne for six of the forecast periods.

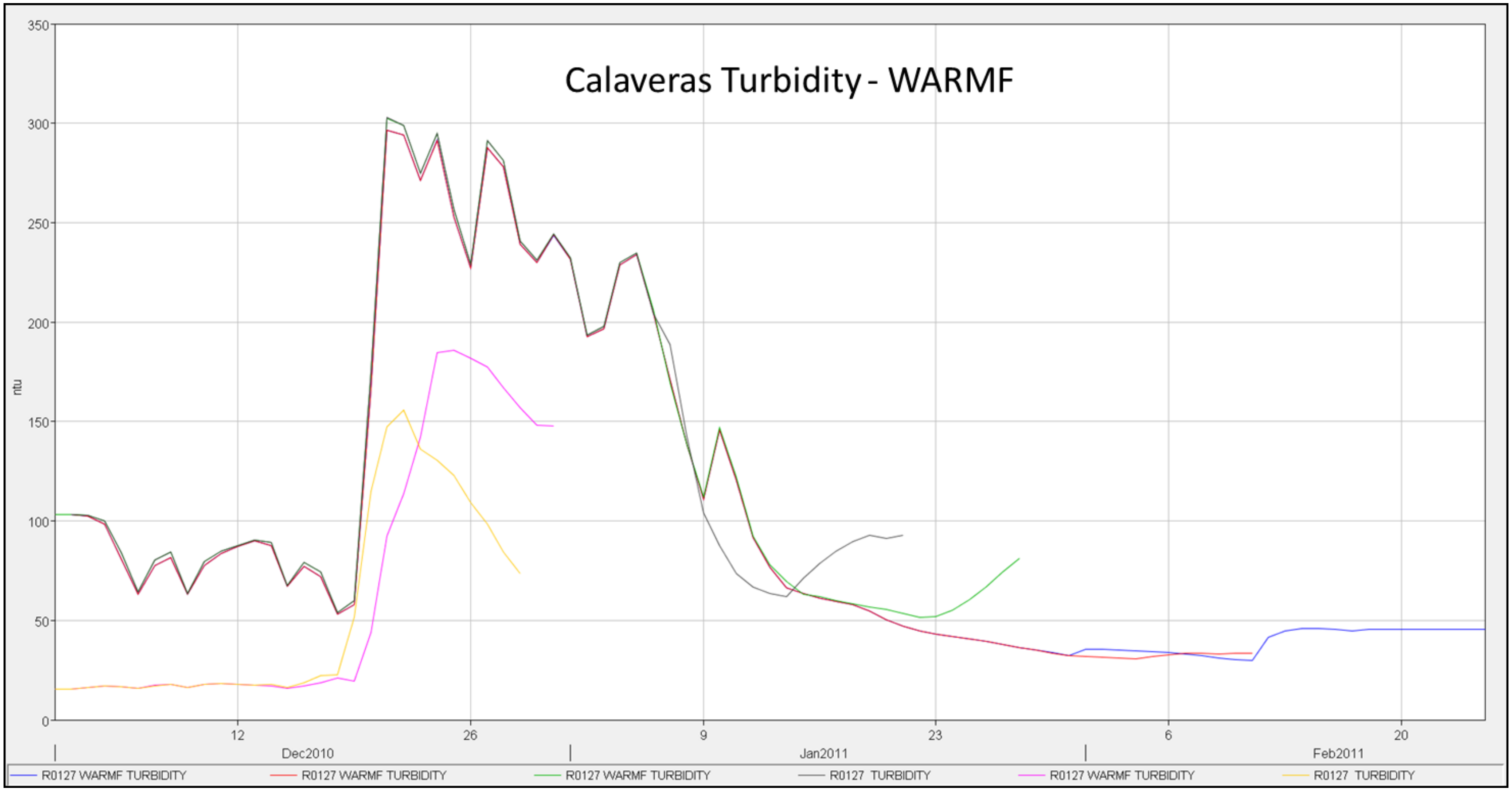


Figure 12-173 WARMF forecast turbidity at Calaveras for six of the forecast periods.

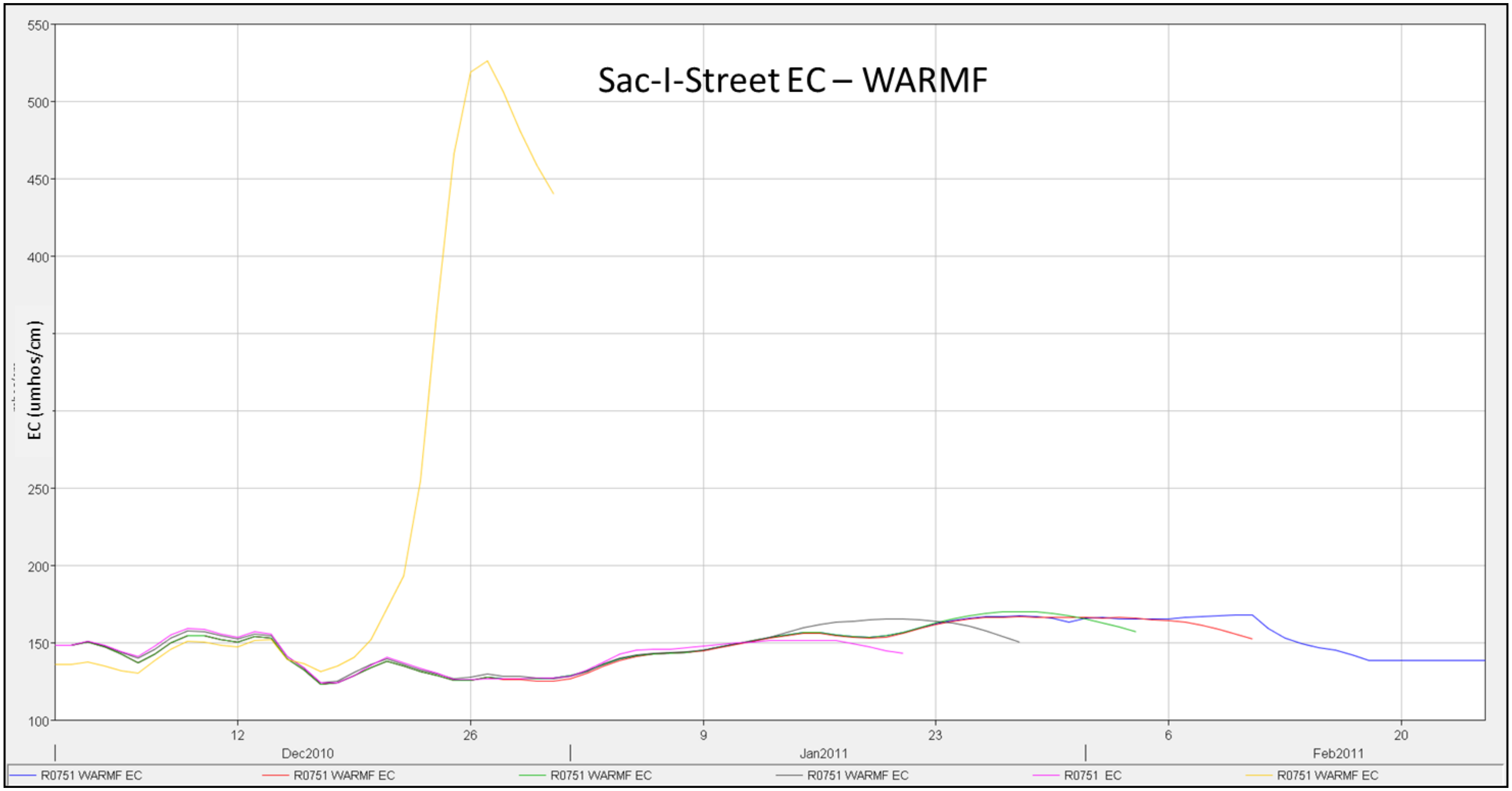


Figure 12-174 WARMF forecast EC at Sac-I-Street for six of the forecast periods.

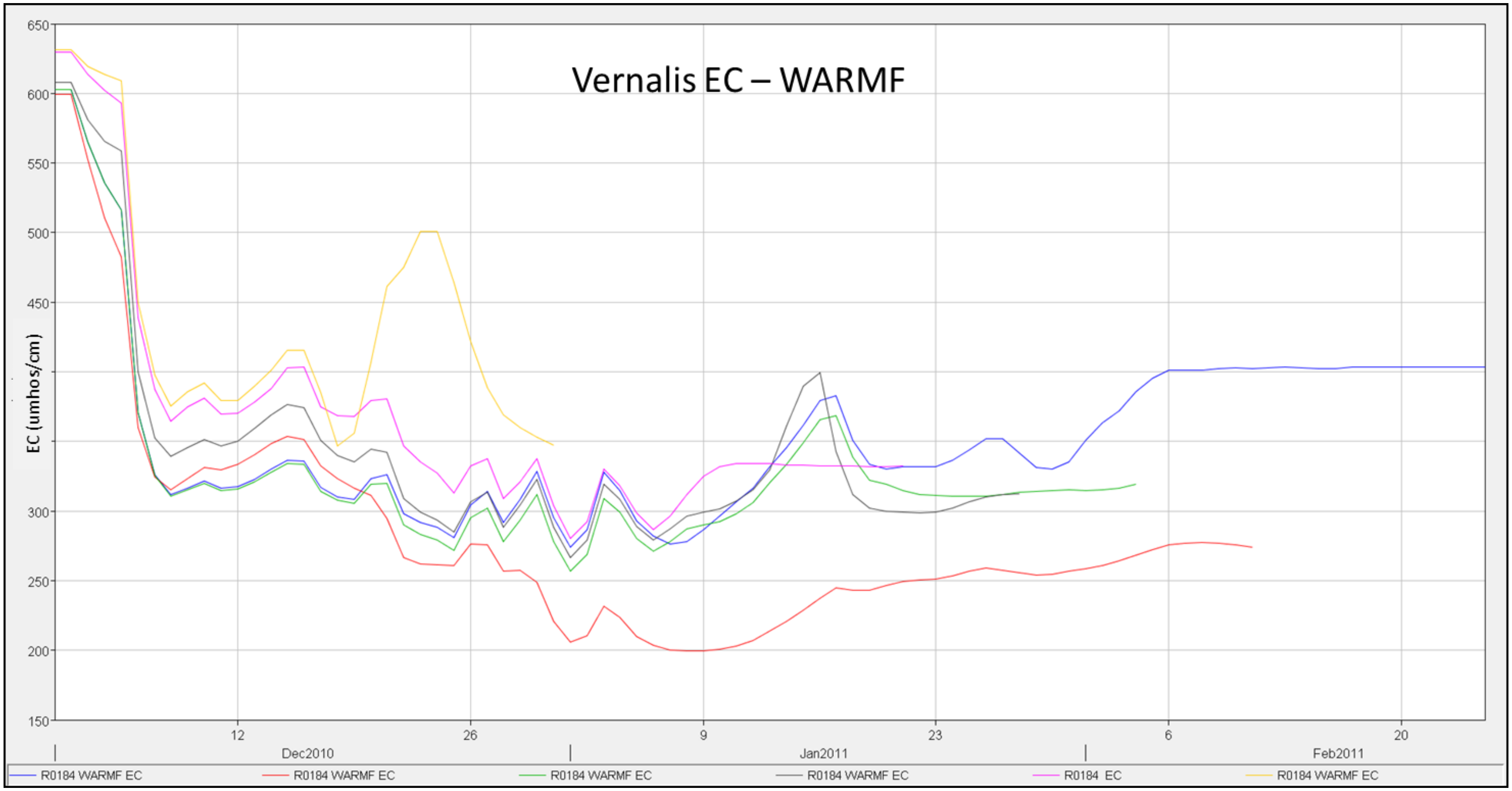


Figure 12-175 WARMF forecast EC at Vernalis for six of the forecast periods.

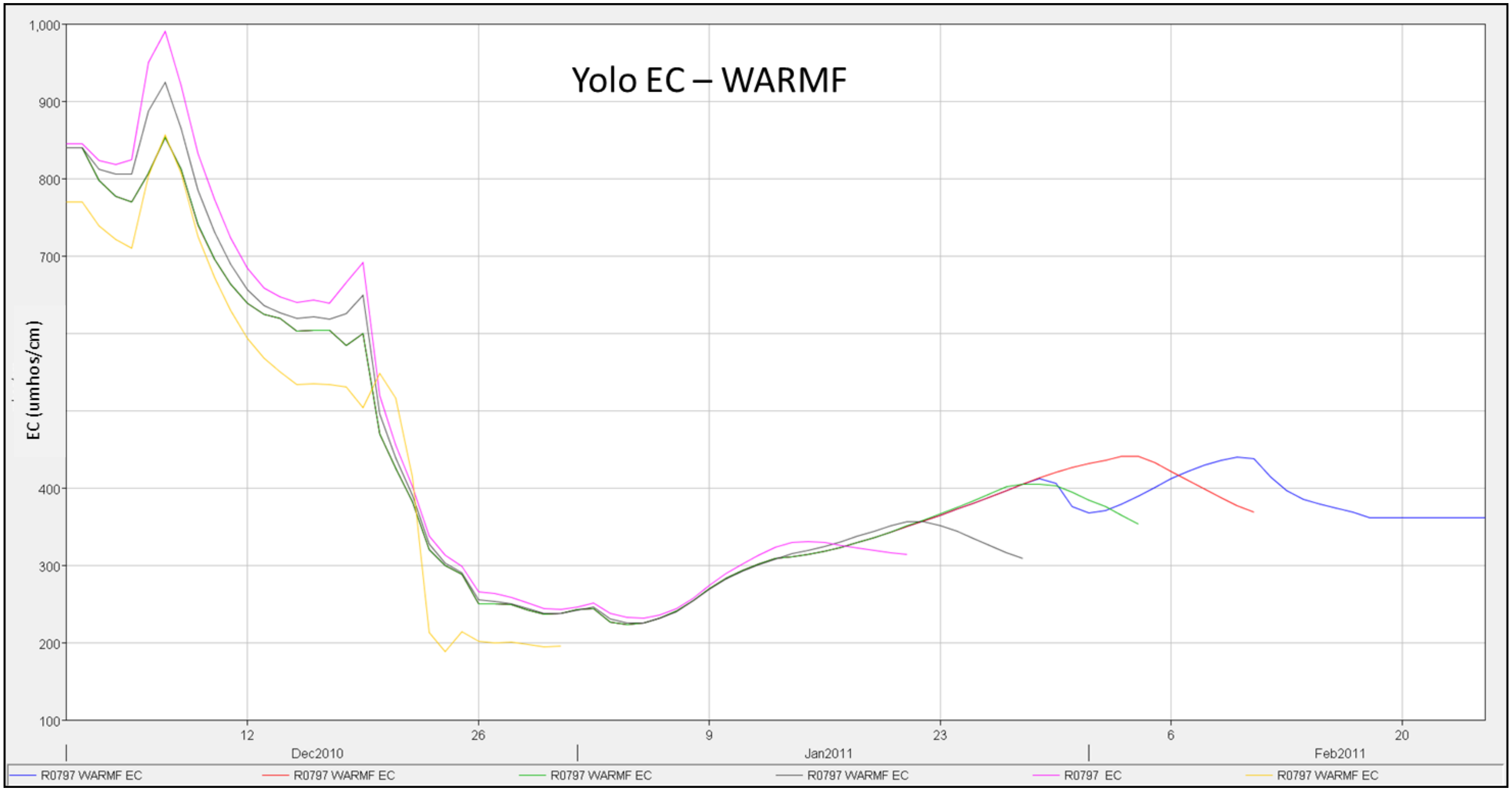


Figure 12-176 WARMF forecast EC at Yolo for six of the forecast periods.

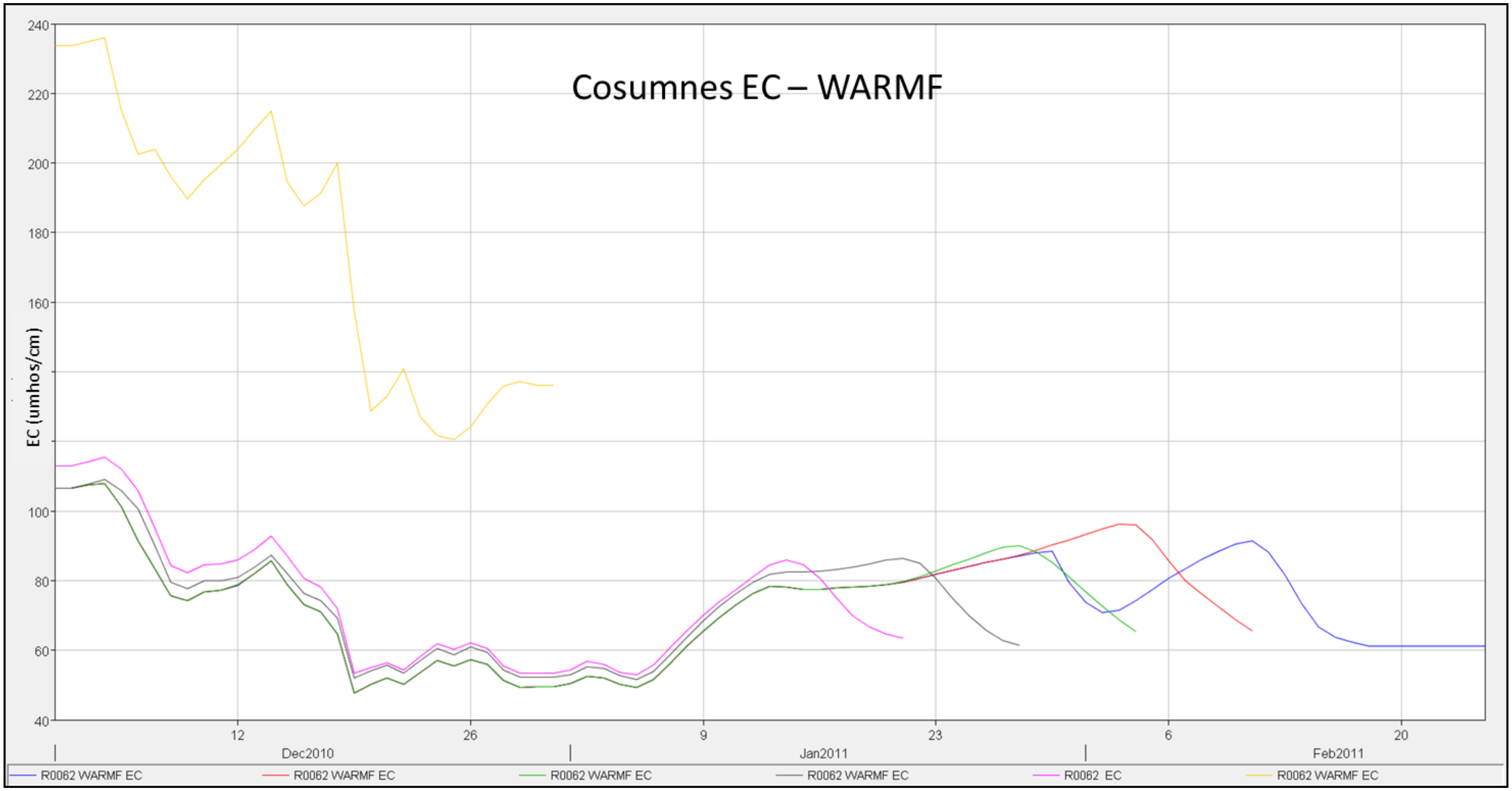


Figure 12-177 WARMF forecast EC at Cosumnes for six of the forecast periods.

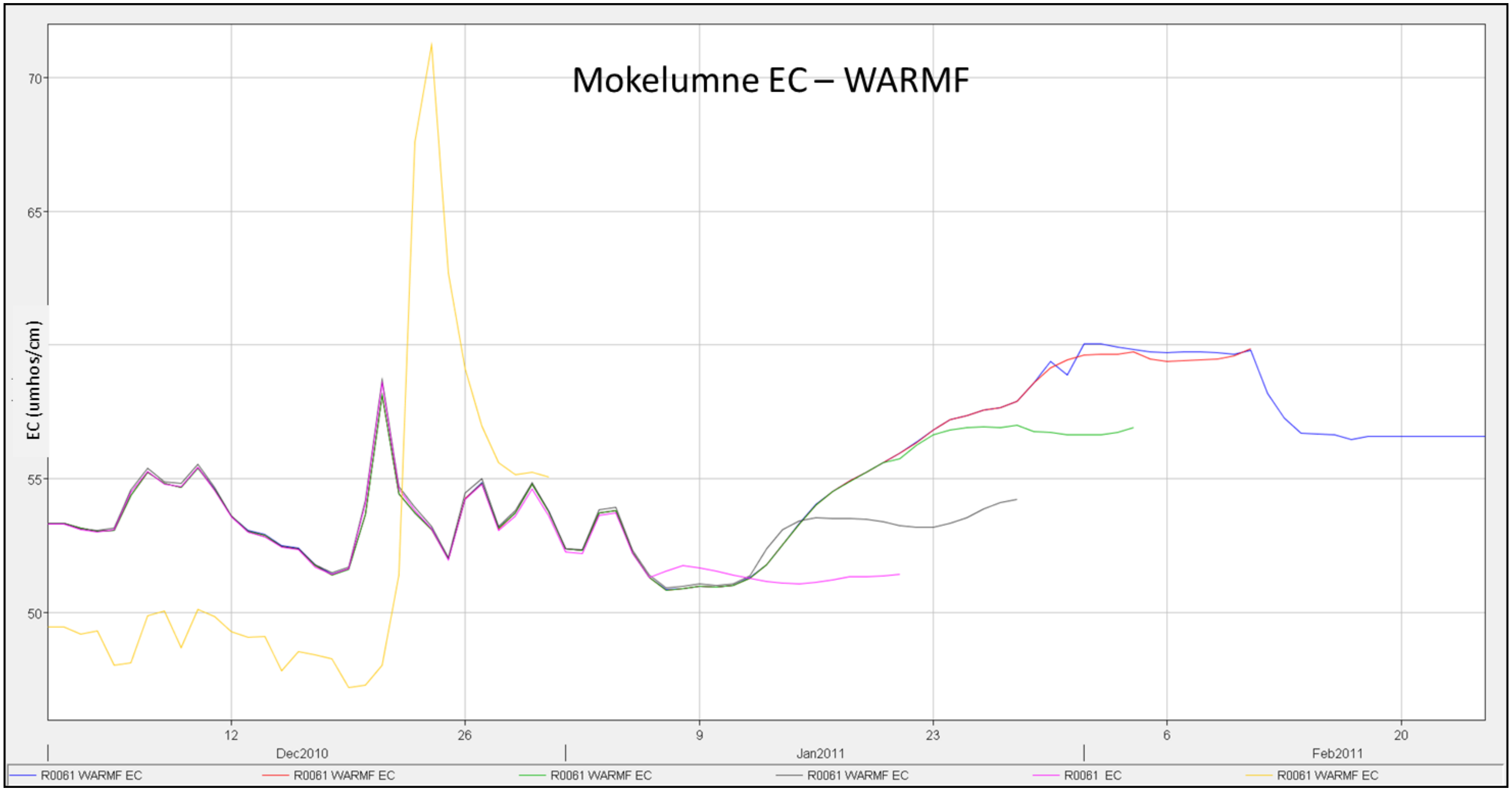


Figure 12-178 WARMF forecast EC at Mokelumne for six of the forecast periods.

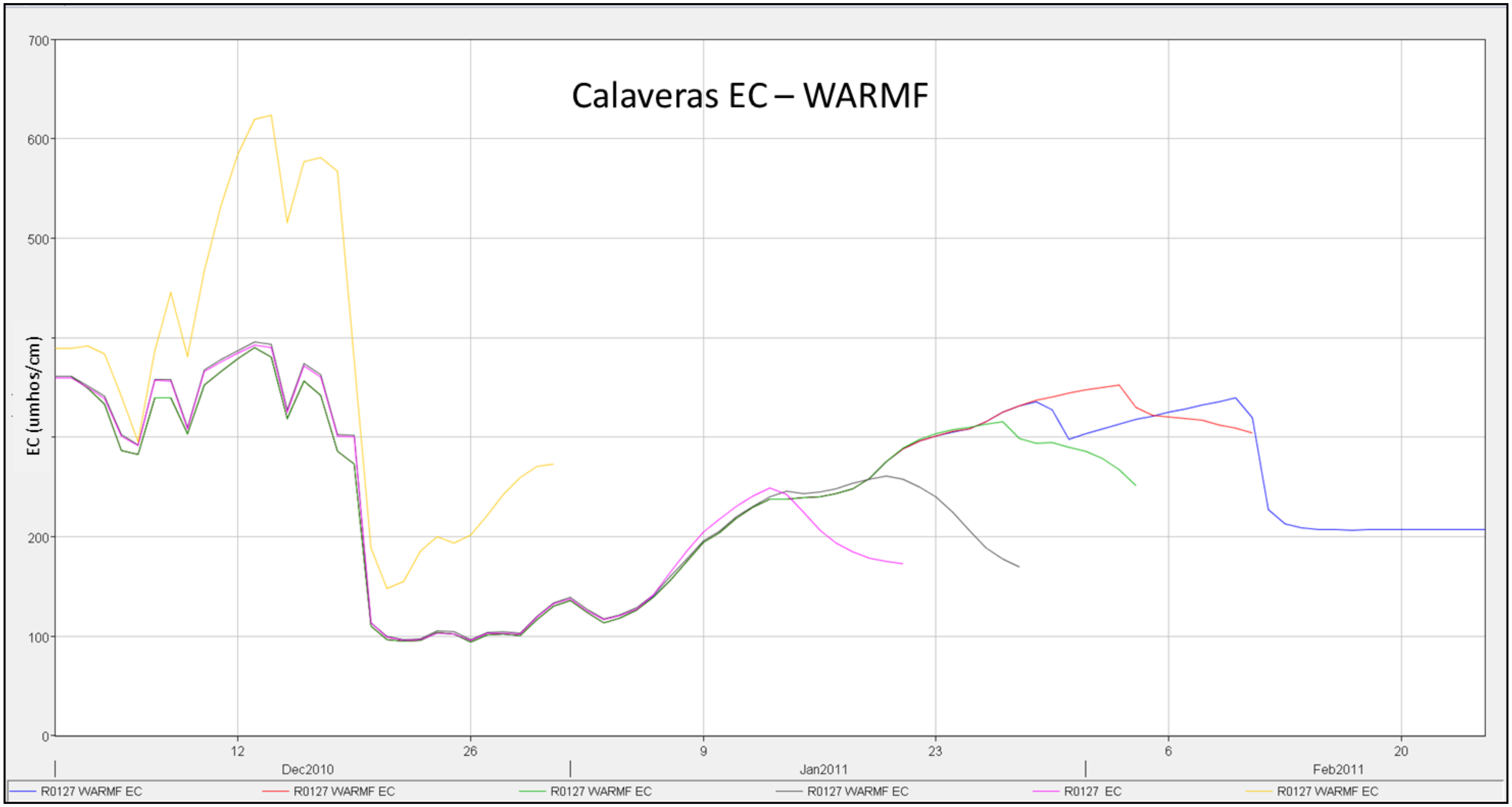


Figure 12-179 WARMF forecast EC at Calaveras for six of the forecast periods

12.1. Hindcast Test Simulations

Table 12-13 Test simulations to set turbidity in the Hindcast model. The final Hindcast used Run 7 turbidity boundary conditions.

	Sacramento	San Jaoquin	Yolo	Cosumnes	Mokelumne	Calaveras	MTZ
Run1	CDEC FPT as is, shift -7	CDEC SJR, cleaned	WARMF	WARMF	WARMF	WARMF	CDEC
Run2	CDEC FPT as is, shift -7	CDEC SJR, cleaned	CDEC RYI	WARMF	WARMF	WARMF*0.1	CDEC
Run3	CDEC FPT cleaned, shift -7	CDEC SJR, cleaned	CDEC RYI	WARMF	WARMF	WARMF*0.1	CDEC
Run4	CDEC FPT cleaned, shift -7	CDEC SJR, cleaned	CDEC RYI	CDEC SMR/WARMF early	WARMF	WARMF*0.1	CDEC
Run5	CDEC FPT cleaned, shift -7	CDEC SJR, cleaned	CDEC RYI	CDEC SMR/WARMF early	CDEC SMR/WARMF early	WARMF*0.1	CDEC
Run6	CDEC FPT cleaned, shift -7	CDEC SJR, cleaned	CDEC RYI	Shift SMR -5hr Cosumnes, Moke	Shift SMR -5hr Cosumnes, Moke	WARMF*0.1	CDEC
Run7	CDEC FPT cleaned, shift -7	Mossdale, -8 hrs	CDEC RYI	Shift SMR -5hr Cosumnes, Moke	Shift SMR -5hr Cosumnes, Moke	WARMF*0.1	CDEC

Table 12-14 Test simulations to set EC in the Hindcast model. The final Hindcast used Run 2 EC boundary conditions.

	Sacramento	San Jaoquin	Yolo	Cosumnes	Mokelumne	Calaveras	MTZ
Run1	CDEC , shift -7	CDEC, cleaned	WARMF	WARMF	WARMF	WARMF	CDEC
Run2	CDEC , shift -7	CDEC, cleaned	CDEC RYI	WARMF	WARMF	WARMF	CDEC
Run3	CDEC cleaned, shift -7	CDEC, cleaned	CDEC RYI + 50 EC	WARMF	WARMF	WARMF	CDEC
Run4	CDEC cleaned, shift -7	CDEC, cleaned	CDEC RYI + 50 EC	CDEC SMR	CDEC SMR	WARMF	CDEC
Run5	CDEC cleaned, shift -7	CDEC, cleaned	CDEC RYI + 50 EC	CDEC SMR, -5 hr	CDEC SMR, -5 hr	WARMF	CDEC

12.2. *Additional Hindcast Results – wind and turbidity*

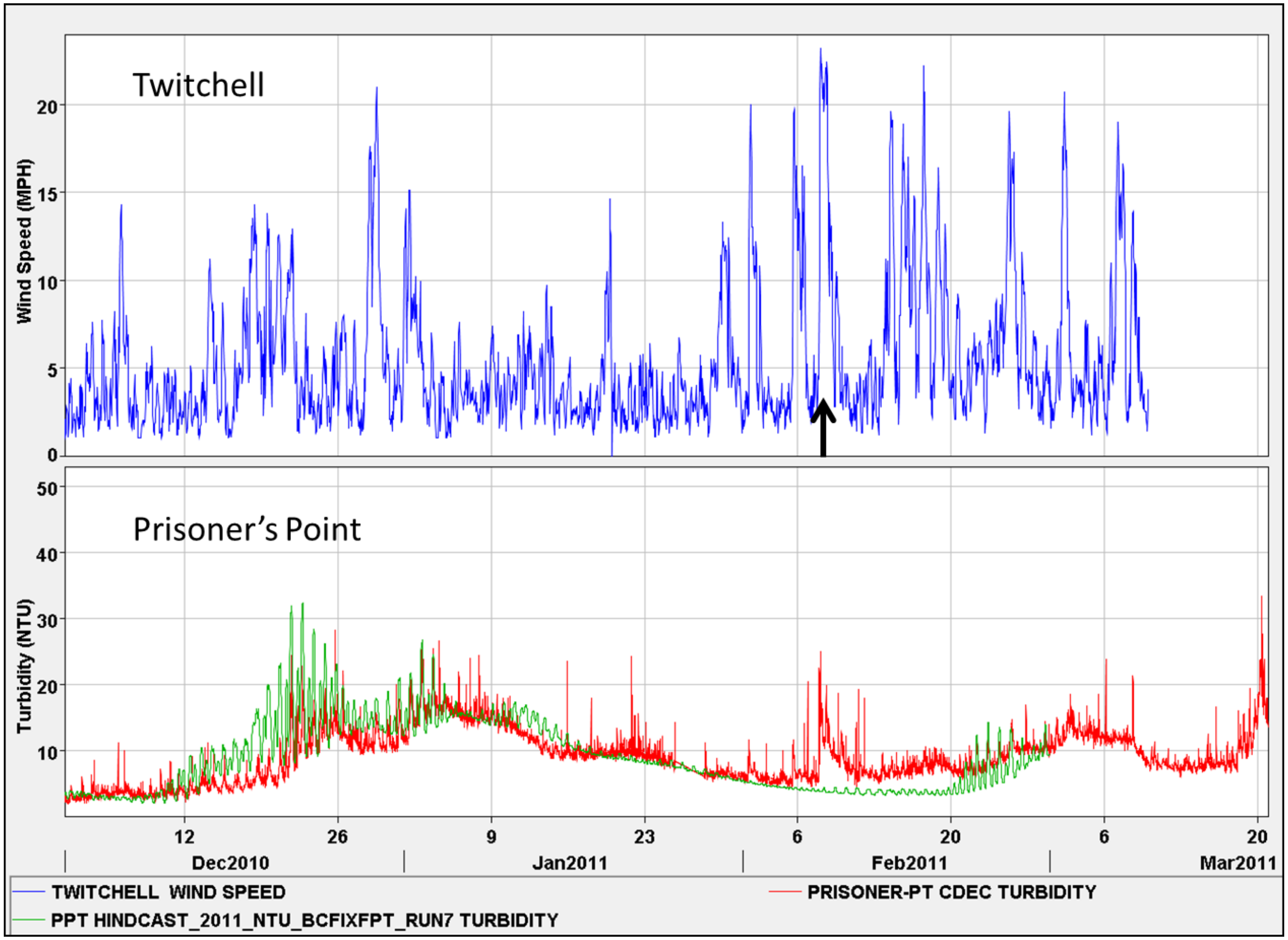


Figure 12-180 Wind events, seen by wind velocity measured at the CIMIS/Twitchell station, in February increased turbidity at Prisoner's Point that wasn't captured in the modeling.

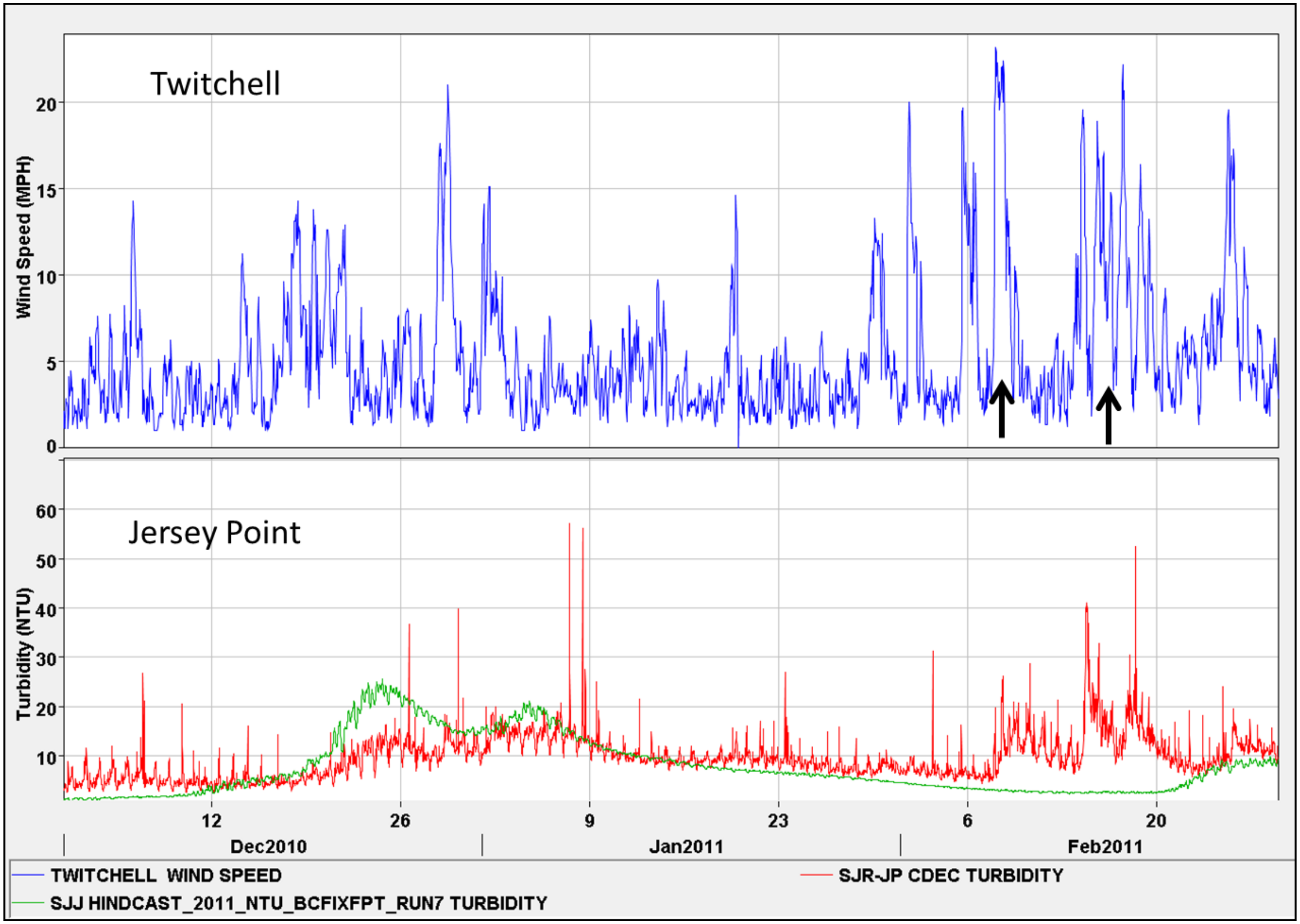


Figure 12-181 Wind events, seen by wind velocity measured at the CIMIS/Twitchell station, in February increased turbidity at Jersey Point that wasn't captured in the modeling.

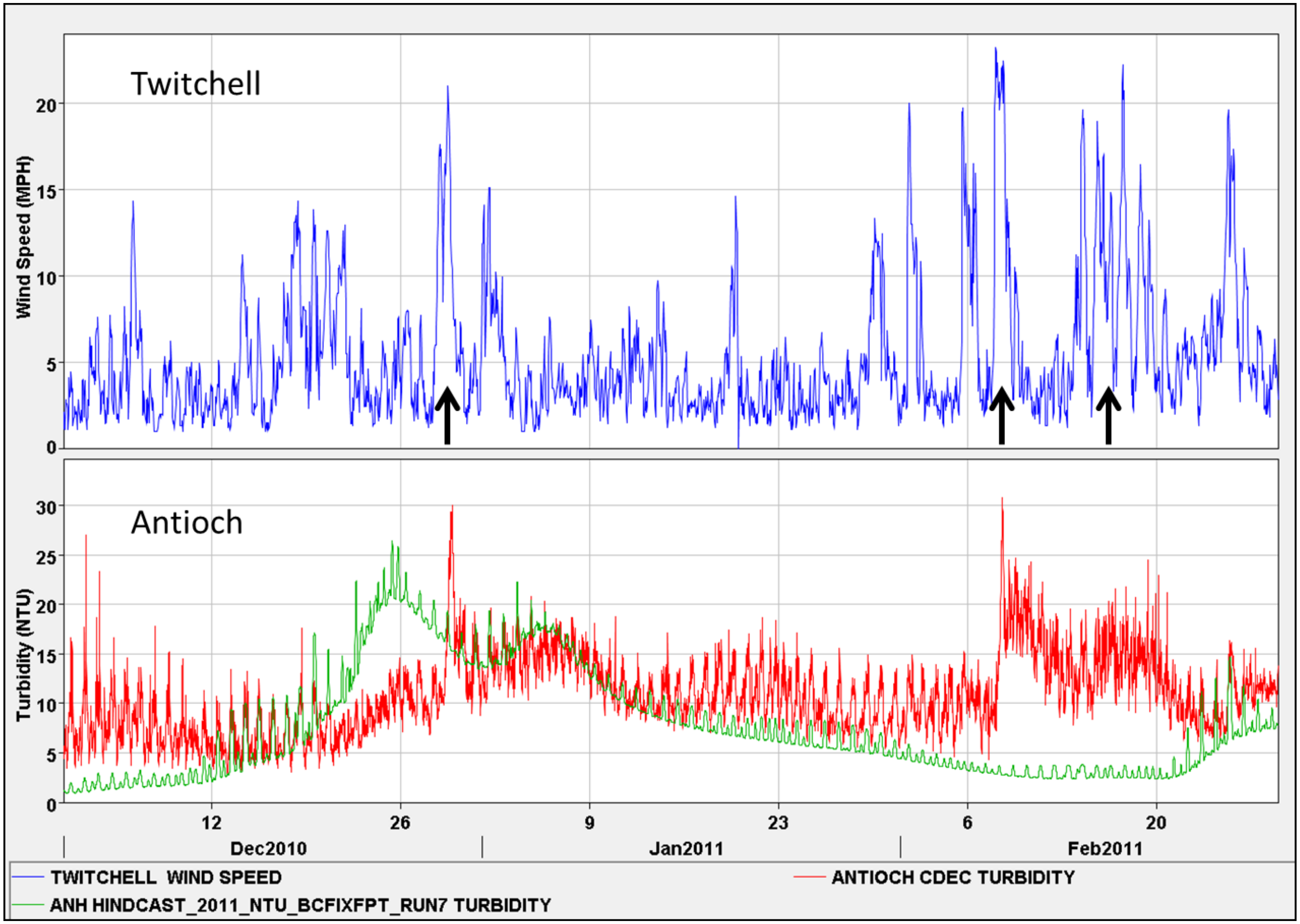


Figure 12-182 Wind events, recorded as increased wind velocity, measured at the CIMIS/Twitchell station in February increased turbidity at Antioch that wasn't captured in the modeling.

12.3. *Export Scenario 2-D results - turbdity contours and particle tracking plots*

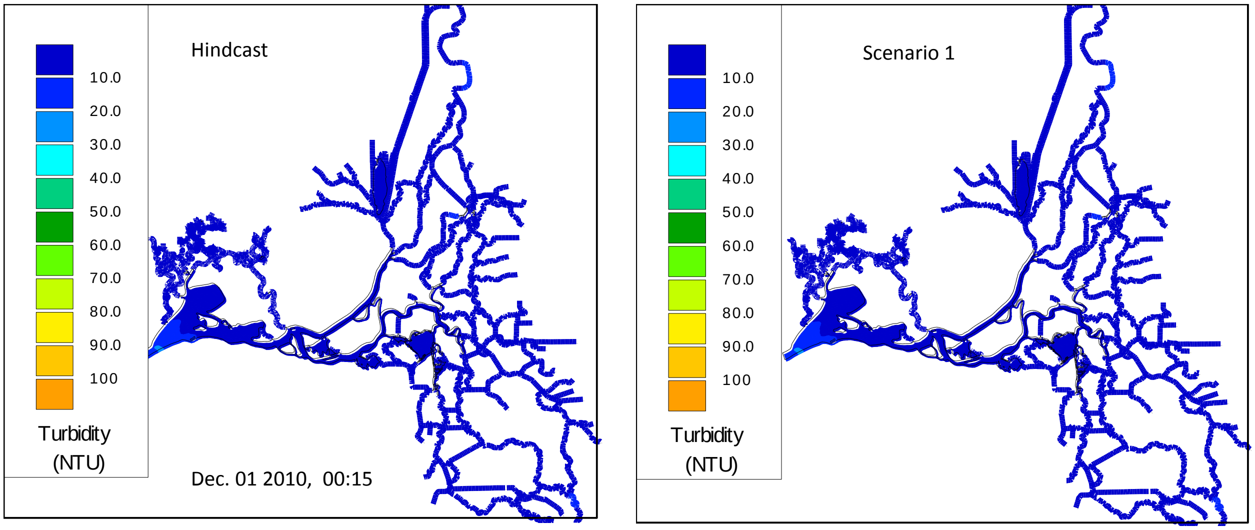


Figure 12-183 Comparison of turbidity contour results for the Hindcast (left) and the Modified Deriso scenario (right) on Dec. 01, 2010.

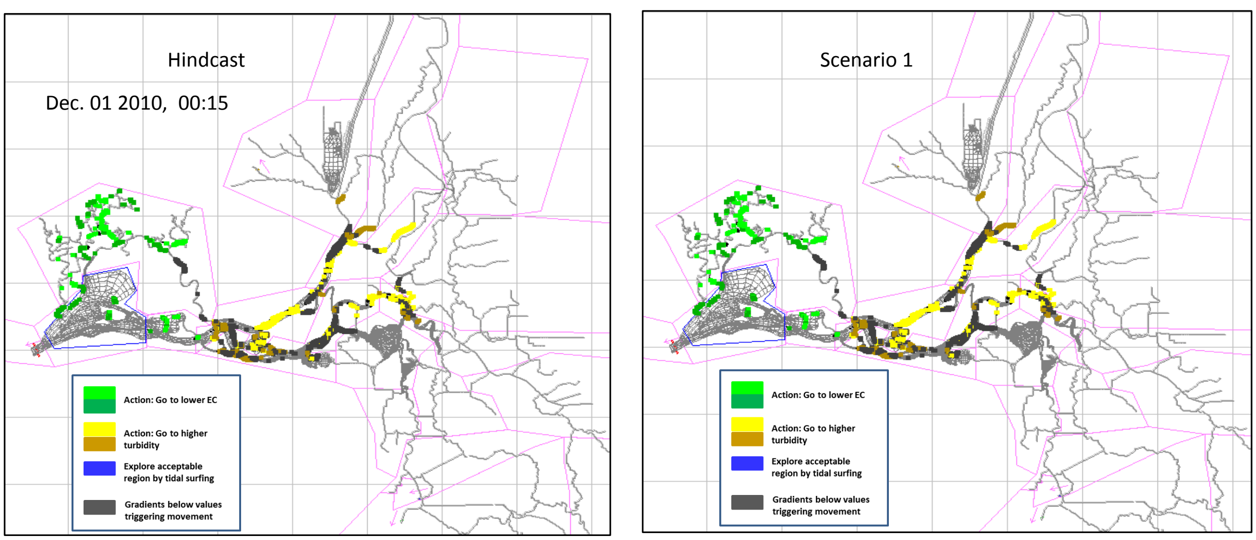


Figure 12-184 Comparison of adult delta smelt particle tracking results for the Hindcast (left) and the Modified Deriso scenario (right) on Dec. 01, 2010.

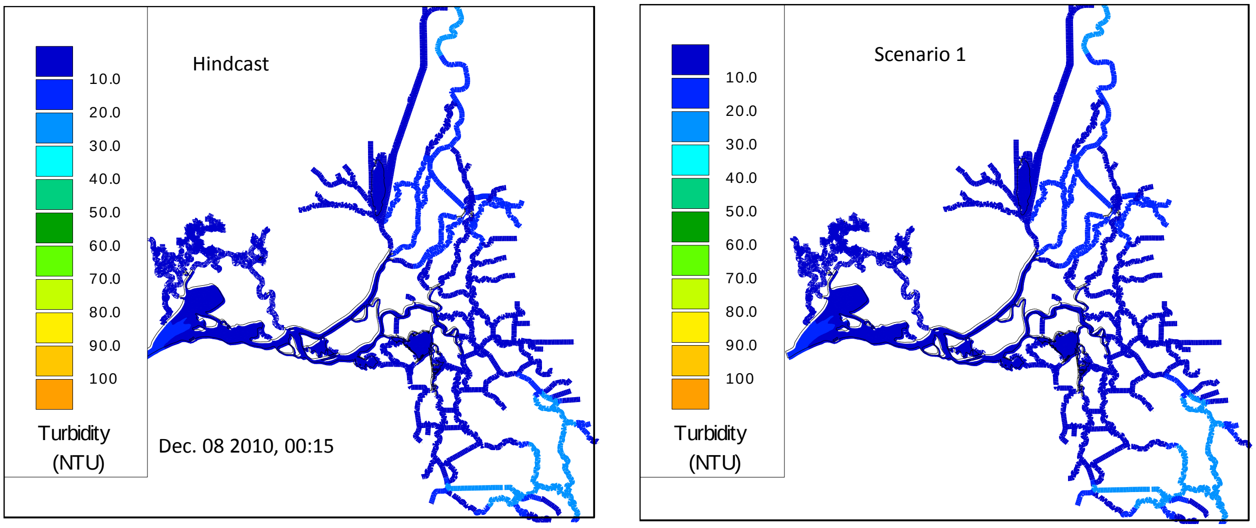


Figure 12-185 Comparison of turbidity contour results for the Hindcast (left) and the Modified Deriso scenario (right) on Dec. 08, 2010.

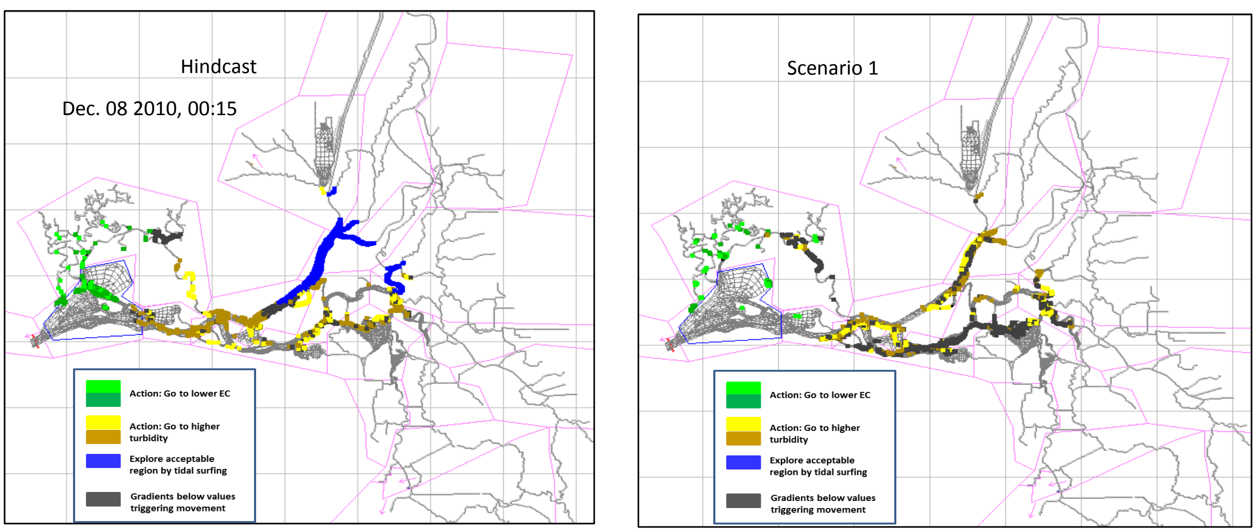


Figure 12-186 Comparison of adult delta smelt particle tracking results for the Hindcast (left) and the Modified Deriso scenario (right) on Dec. 08, 2010.

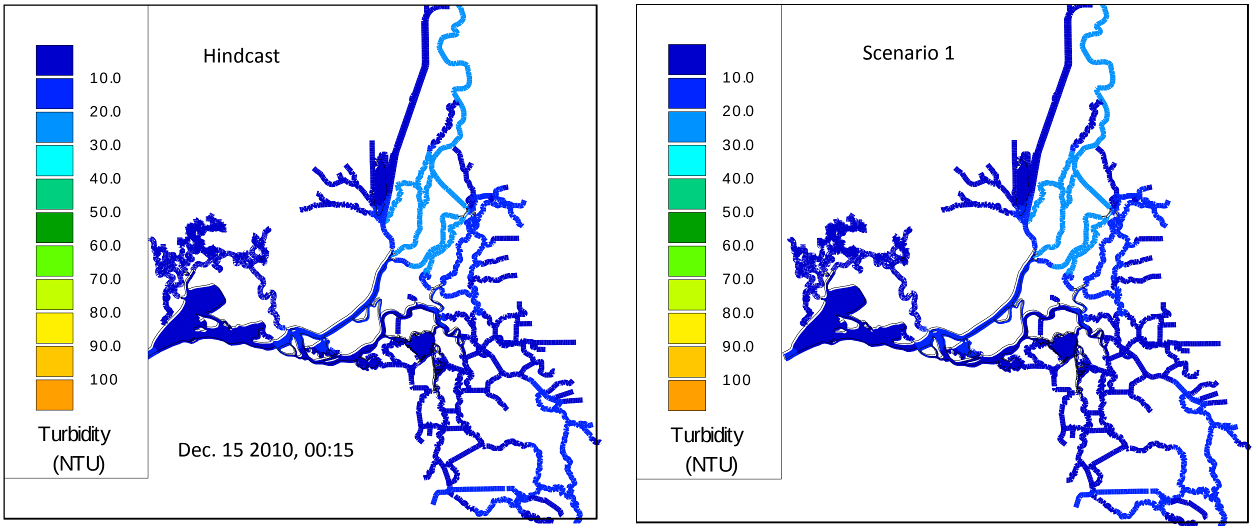


Figure 12-187 Comparison of turbidity contour results for the Hindcast (left) and the Modified Deriso scenario (right) on Dec. 15, 2010.

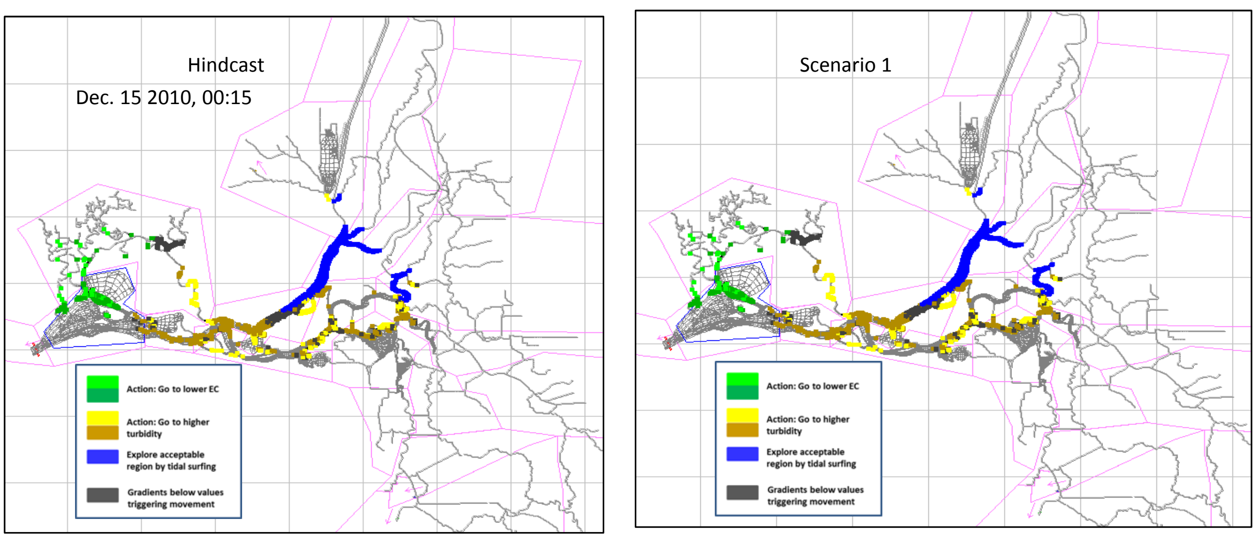


Figure 12-188 Comparison of adult delta smelt particle tracking results for the Hindcast (left) and the Modified Deriso scenario (right) on Dec. 15, 2010.

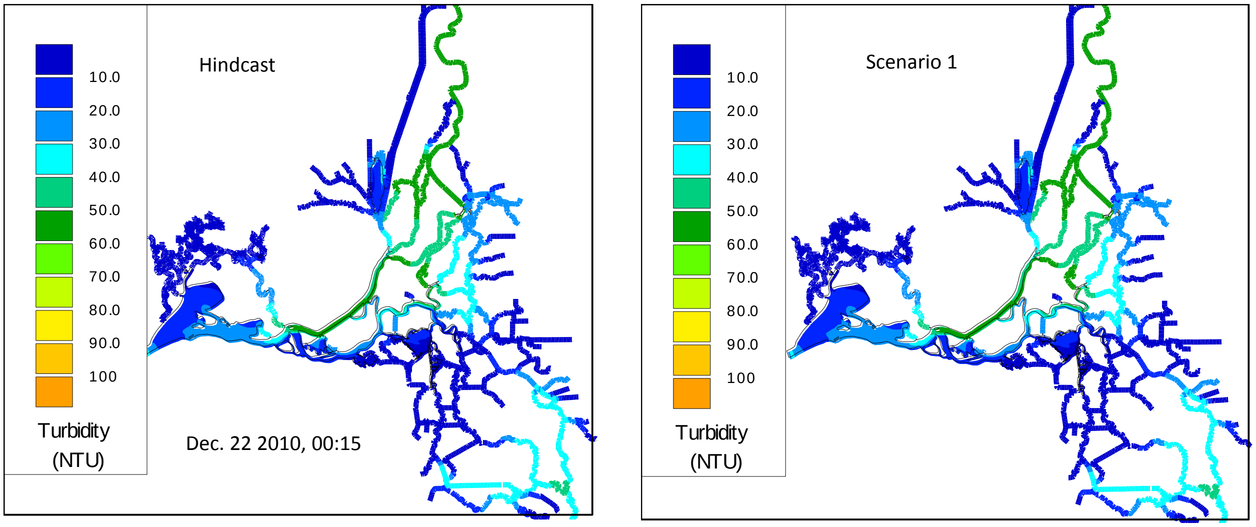


Figure 12-189 Comparison of turbidity contour results for the Hindcast (left) and the Modified Deriso scenario (right) on Dec. 22, 2010.

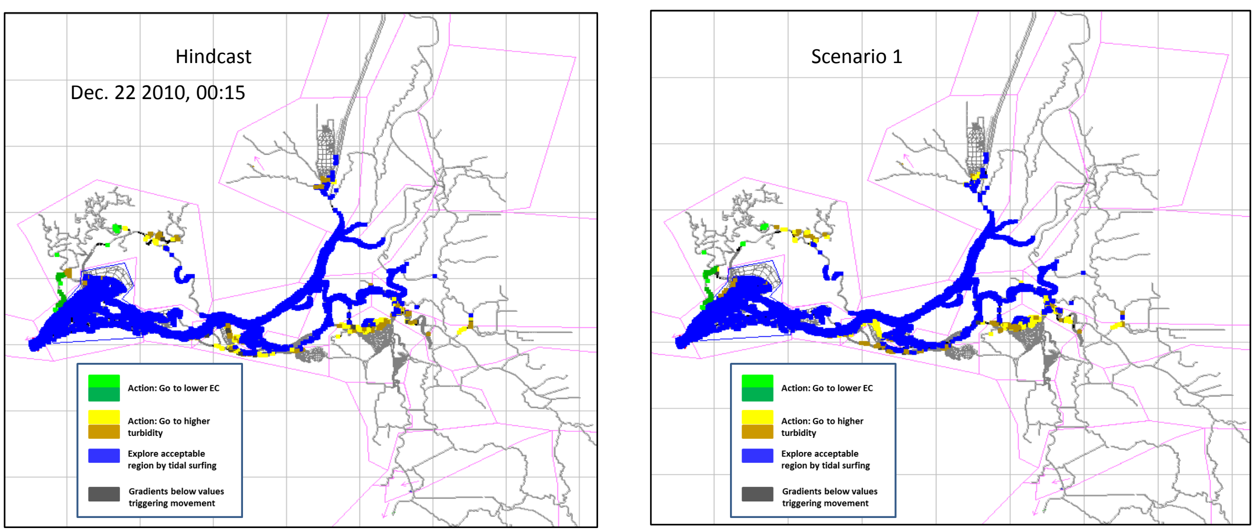


Figure 12-190 Comparison of adult delta smelt particle tracking results for the Hindcast (left) and the Modified Deriso scenario (right) on Dec. 22, 2010.

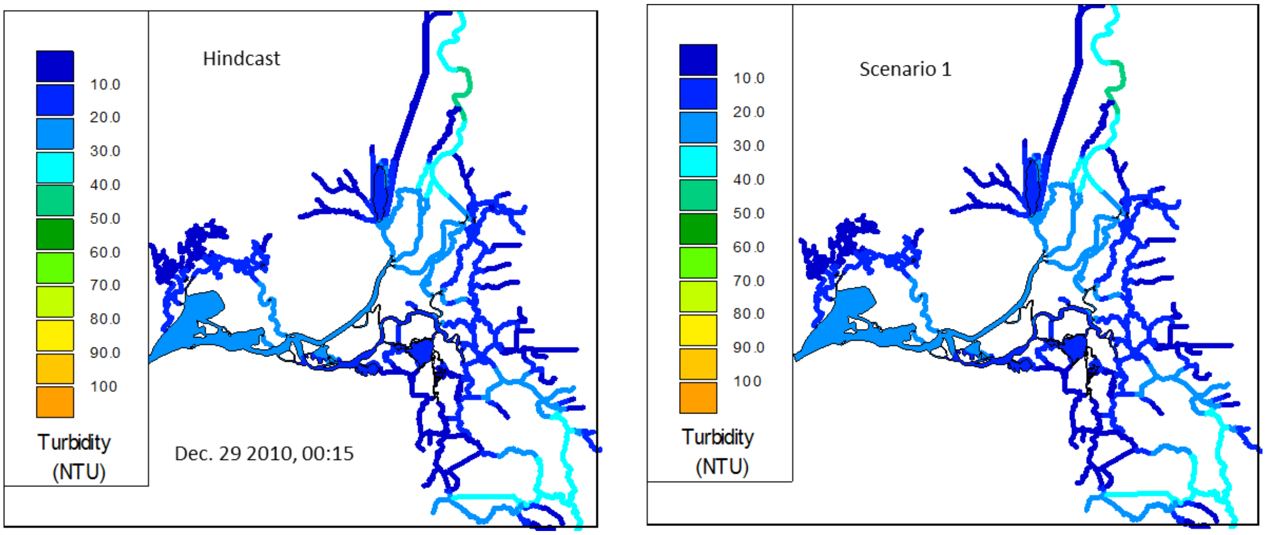


Figure 12-191 Comparison of turbidity contour results for the Hindcast (left) and the Modified Deriso scenario (right) on Dec. 29, 2010.

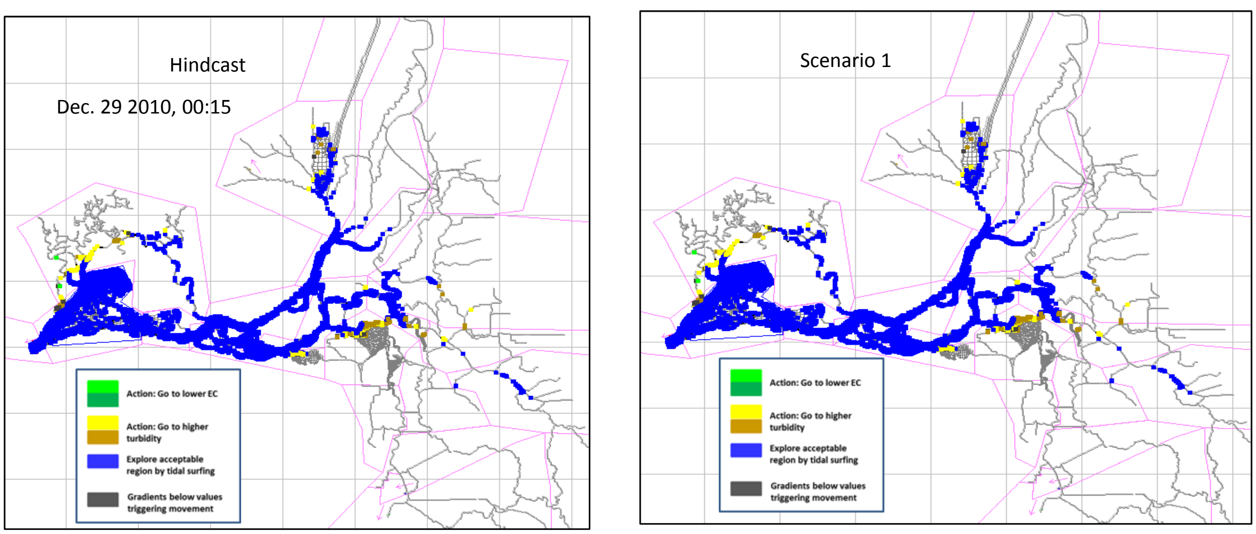


Figure 12-192 Comparison of adult delta smelt particle tracking results for the Hindcast (left) and the Modified Deriso scenario (right) on Dec. 29, 2010.

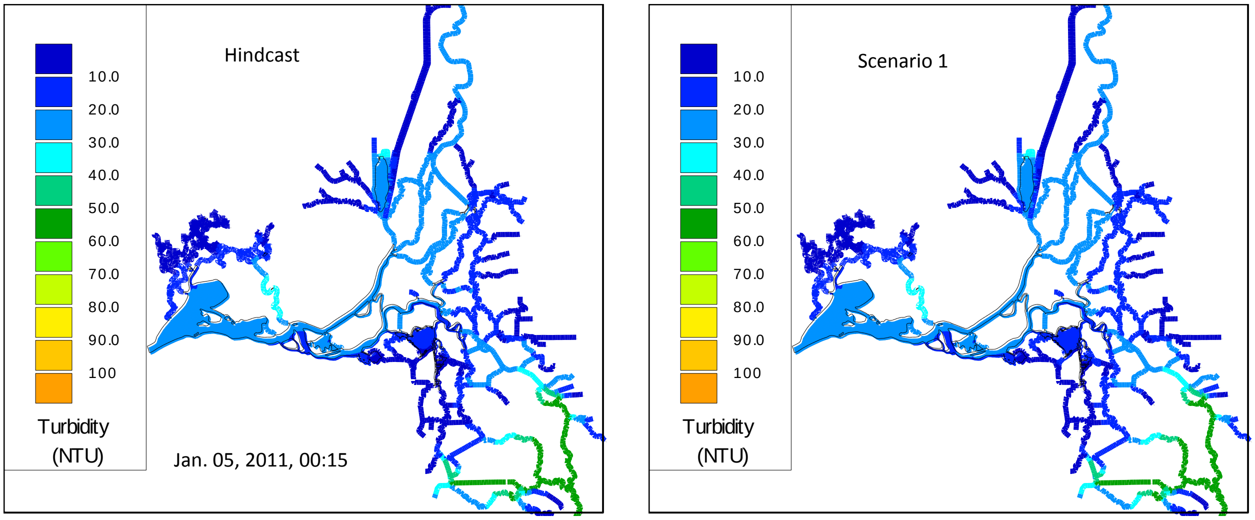


Figure 12-193 Comparison of turbidity contour results for the Hindcast (left) and the Modified Deriso scenario (right) on Jan. 05, 2011.

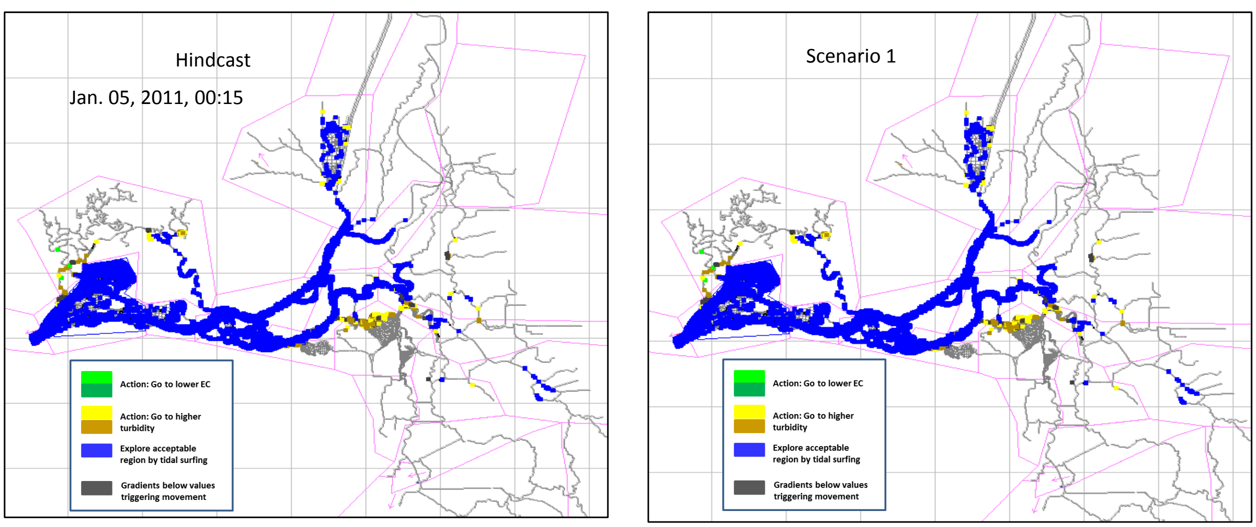


Figure 12-194 Comparison of adult delta smelt particle tracking results for the Hindcast (left) and the Modified Deriso scenario (right) on Jan. 05, 2011.

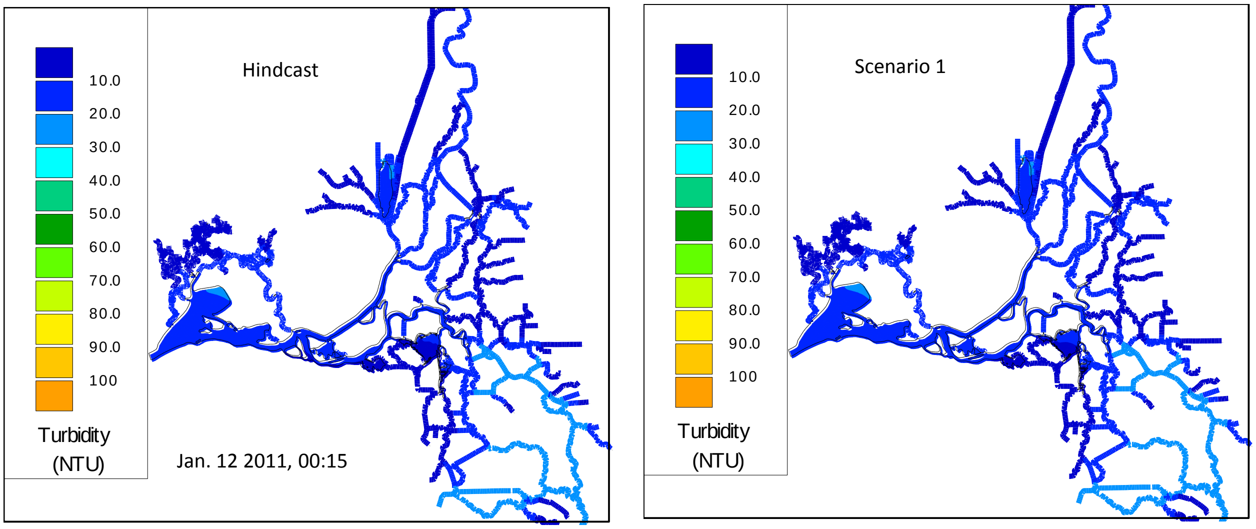


Figure 12-195 Comparison of turbidity contour results for the Hindcast (left) and the Modified Deriso scenario (right) on Jan. 12, 2011.

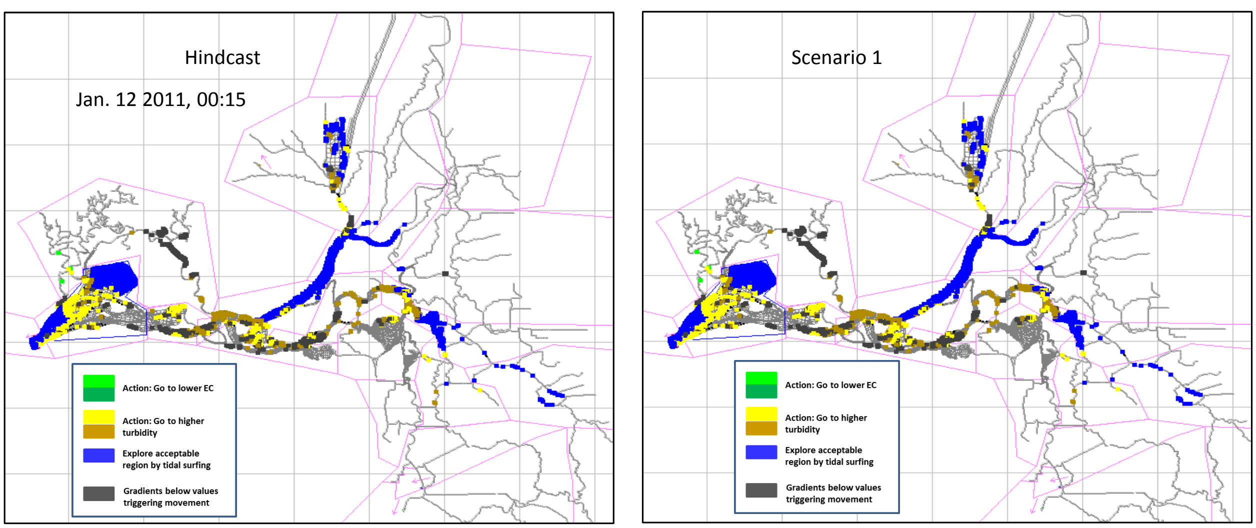


Figure 12-196 Comparison of adult delta smelt particle tracking results for the Hindcast (left) and the Modified Deriso scenario (right) on Jan. 12, 2011.

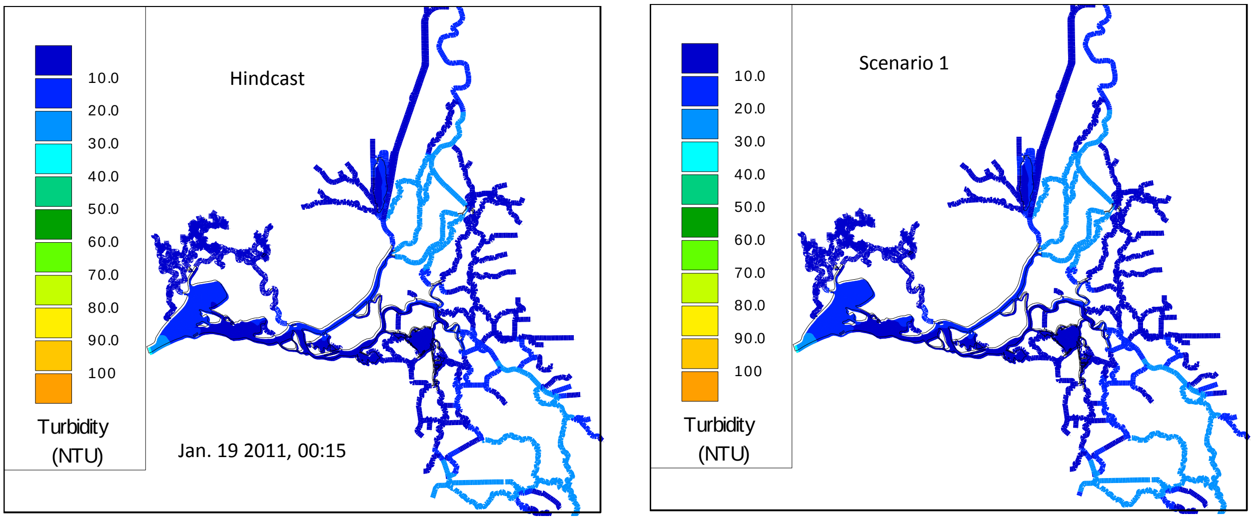


Figure 12-197 Comparison of turbidity contour results for the Hindcast (left) and the Modified Deriso scenario (right) on Jan. 19, 2011.

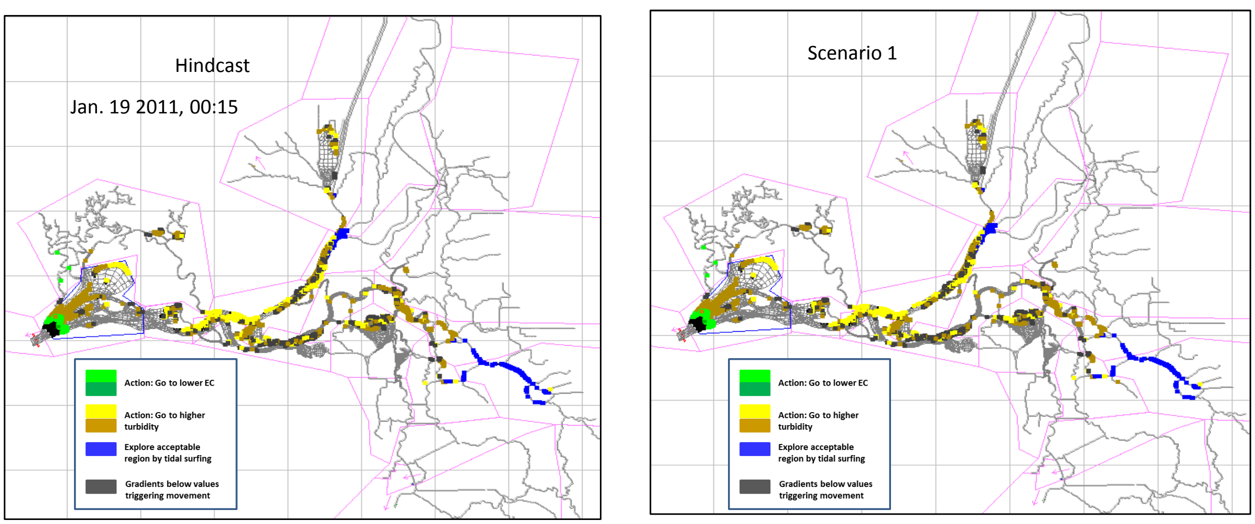


Figure 12-198 Comparison of adult delta smelt particle tracking results for the Hindcast (left) and the Modified Deriso scenario (right) on Jan. 19, 2011.

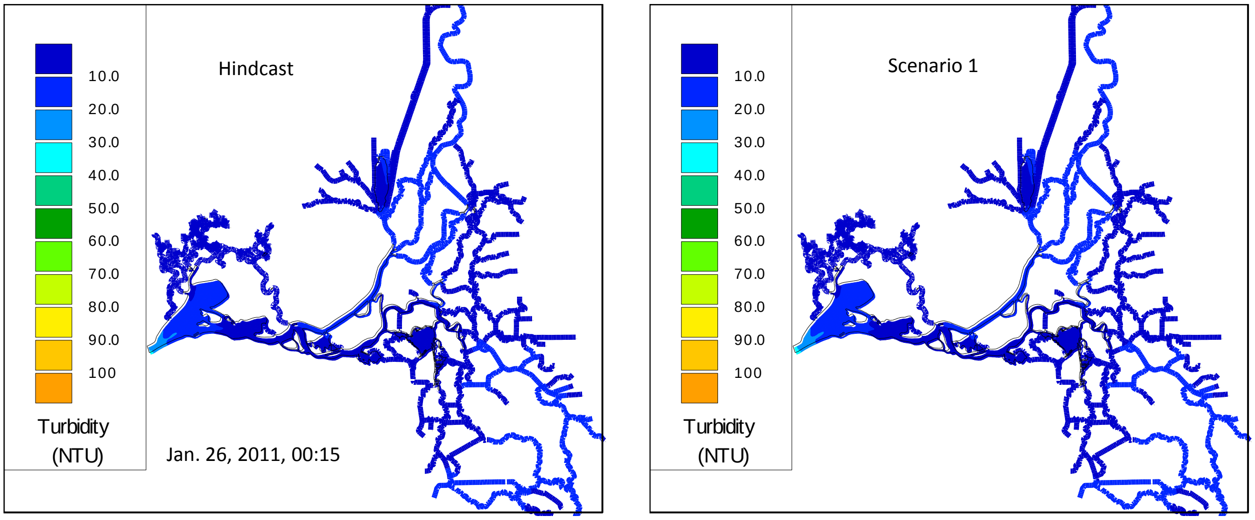


Figure 12-199 Comparison of turbidity contour results for the Hindcast (left) and the Modified Deriso scenario (right) on Jan. 26, 2011.

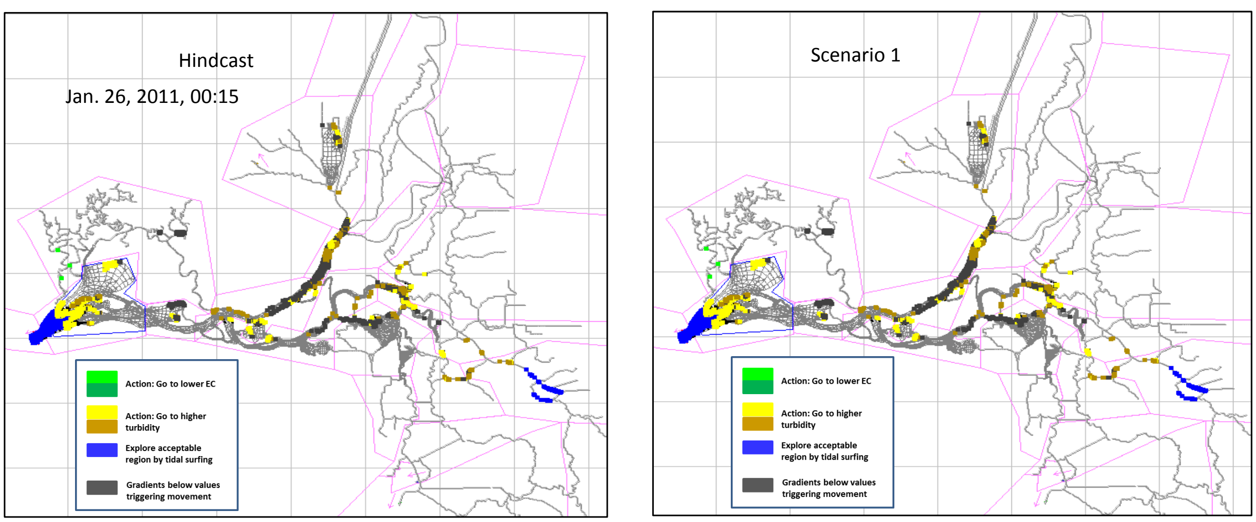


Figure 12-200 Comparison of adult delta smelt particle tracking results for the Hindcast (left) and the Modified Deriso scenario (right) on Jan. 26, 2011.

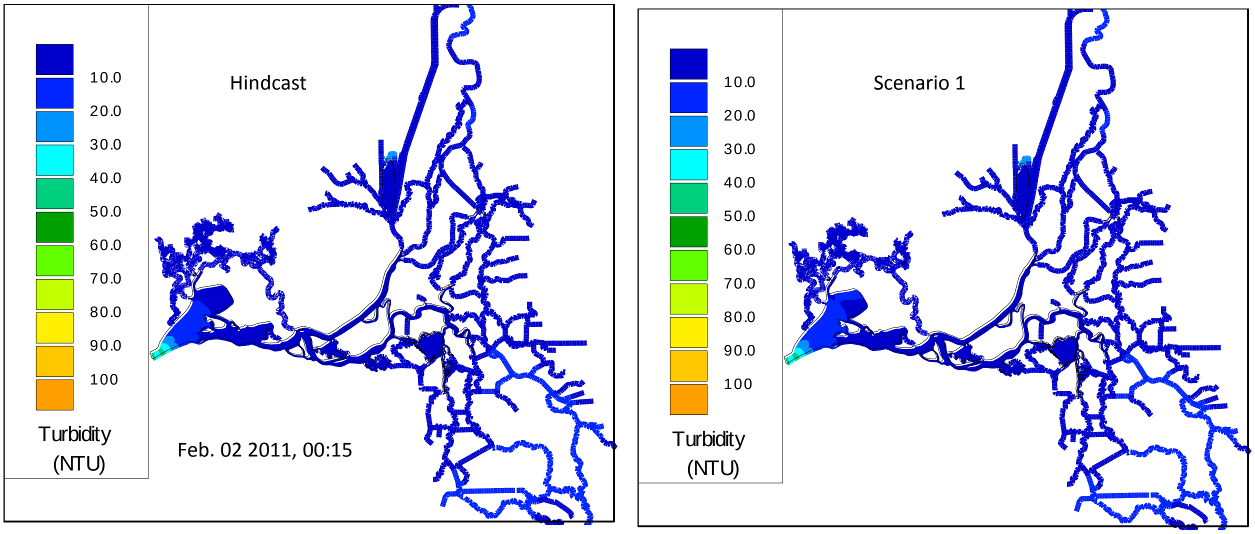


Figure 12-201 Comparison of turbidity contour results for the Hindcast (left) and the Modified Deriso scenario (right) on Feb. 02, 2011.

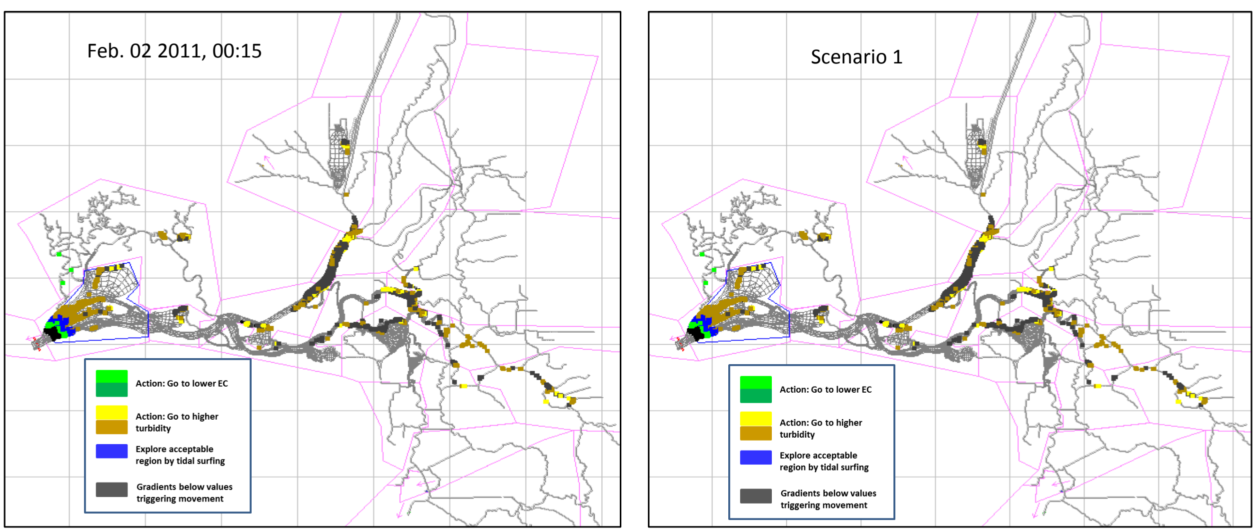


Figure 12-202 Comparison of adult delta smelt particle tracking results for the Hindcast (left) and the Modified Deriso scenario (right) on Feb. 02, 2011.

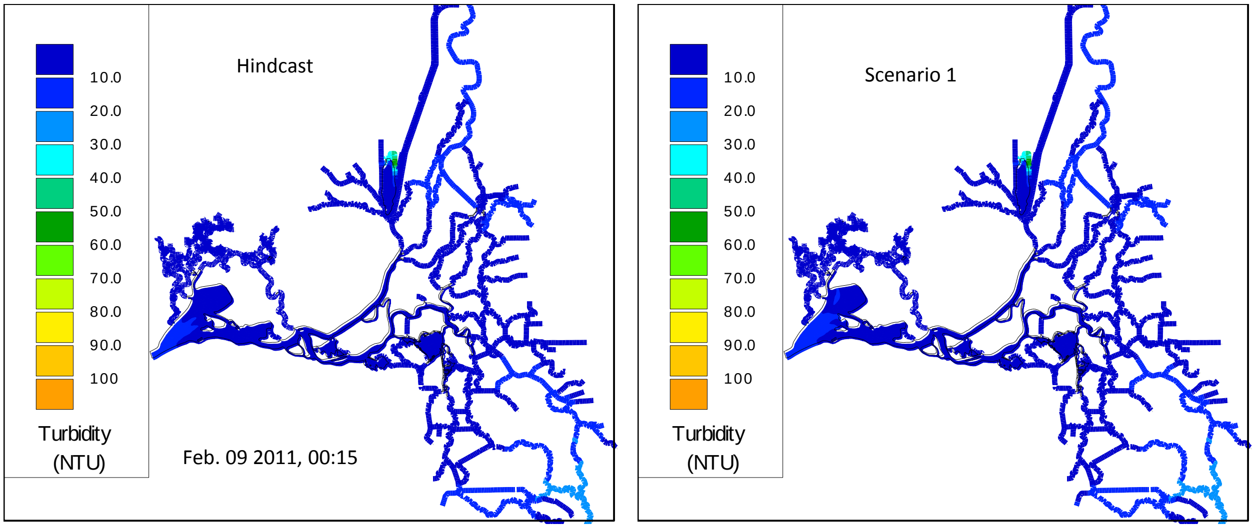


Figure 12-203 Comparison of turbidity contour results for the Hindcast (left) and the Modified Deriso scenario (right) on Feb. 09, 2011.

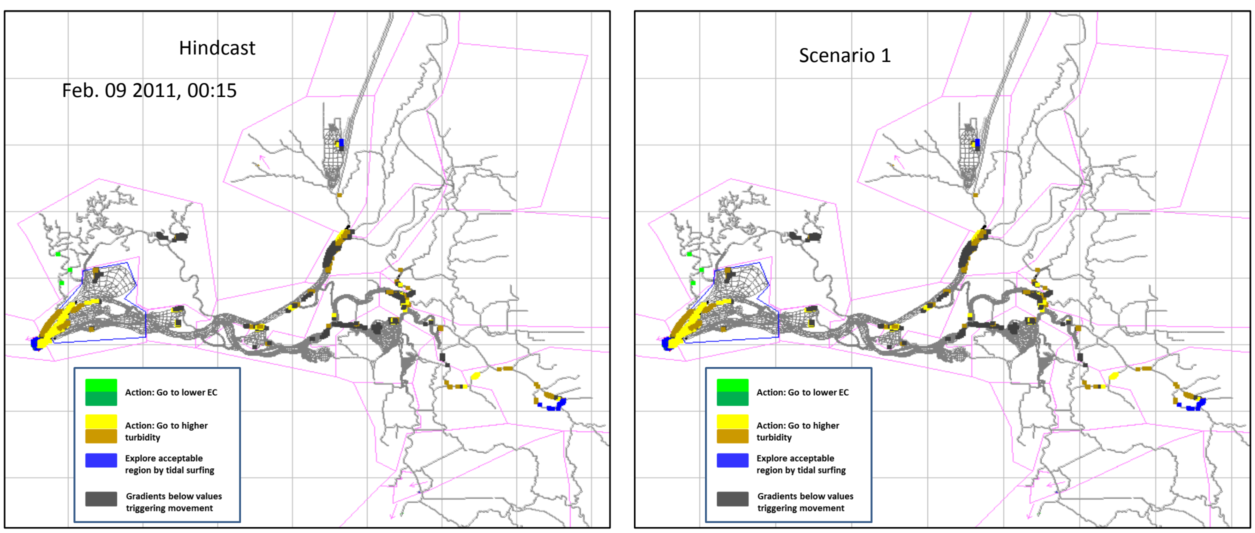


Figure 12-204 Comparison of adult delta smelt particle tracking results for the Hindcast (left) and the Modified Deriso scenario (right) on Feb. 09, 2011.

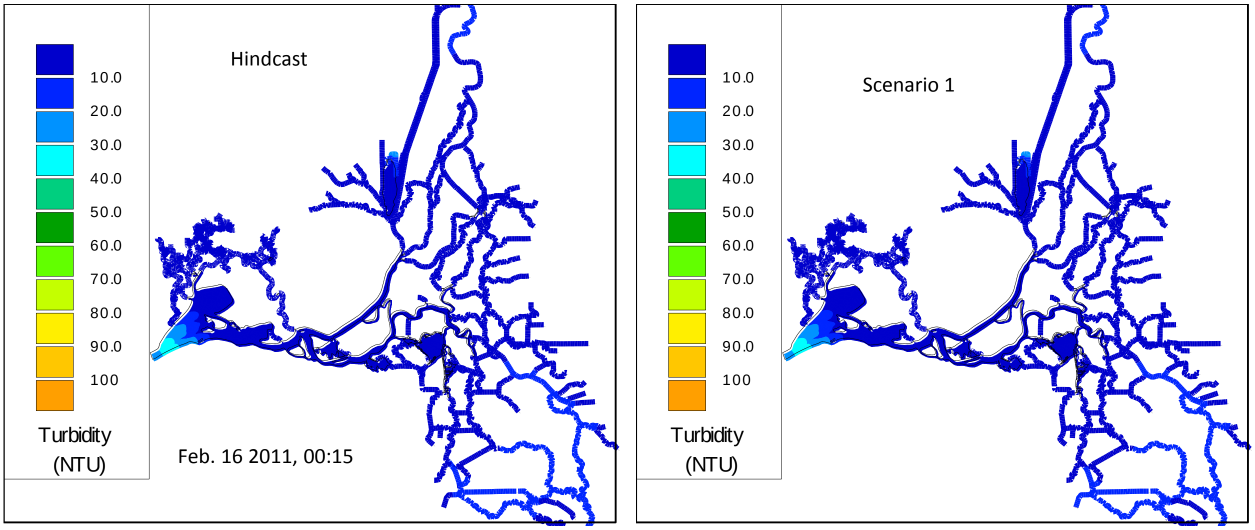


Figure 12-205 Comparison of turbidity contour results for the Hindcast (left) and the Modified Deriso scenario (right) on Feb. 16, 2011.

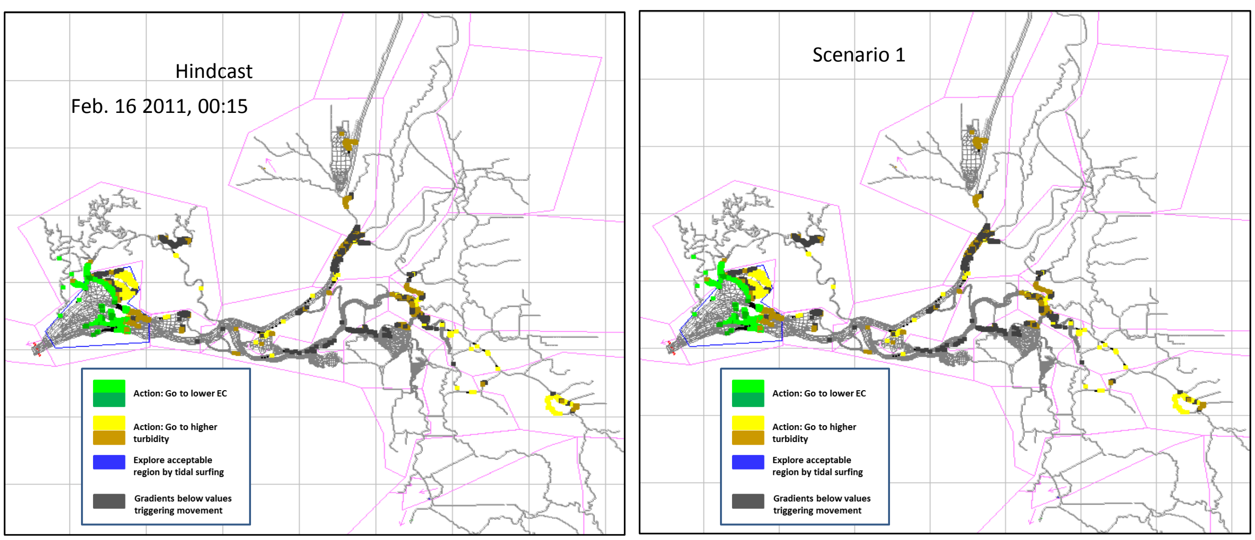


Figure 12-206 Comparison of adult delta smelt particle tracking results for the Hindcast (left) and the Modified Deriso scenario (right) on Feb. 16, 2011.

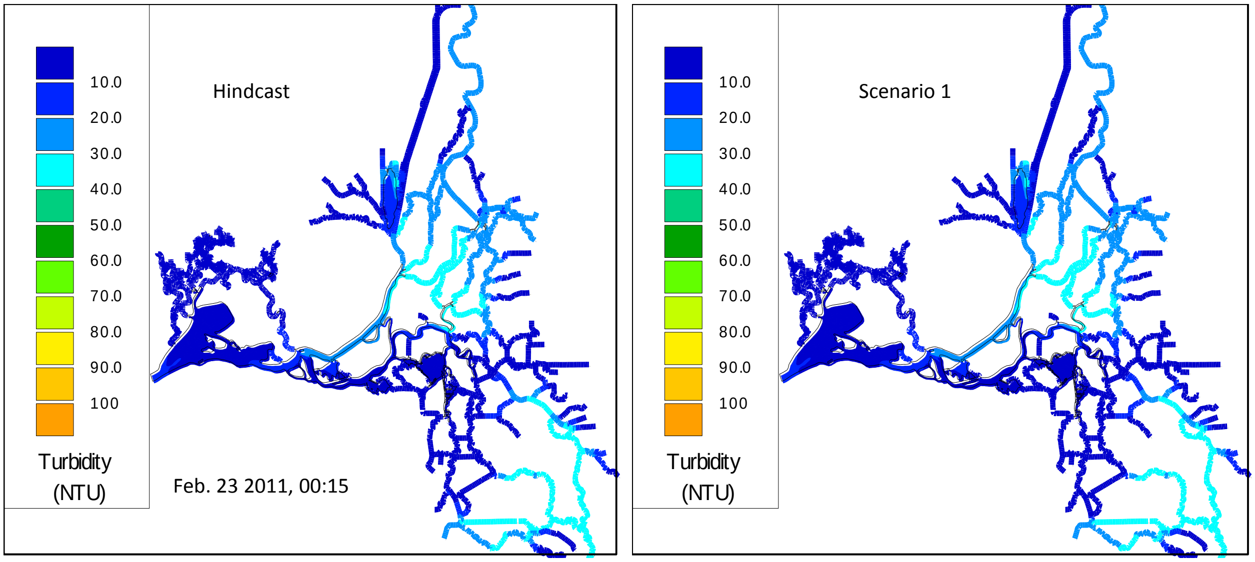


Figure 12-207 Comparison of turbidity contour results for the Hindcast (left) and the Modified Deriso scenario (right) on Feb. 23, 2011.

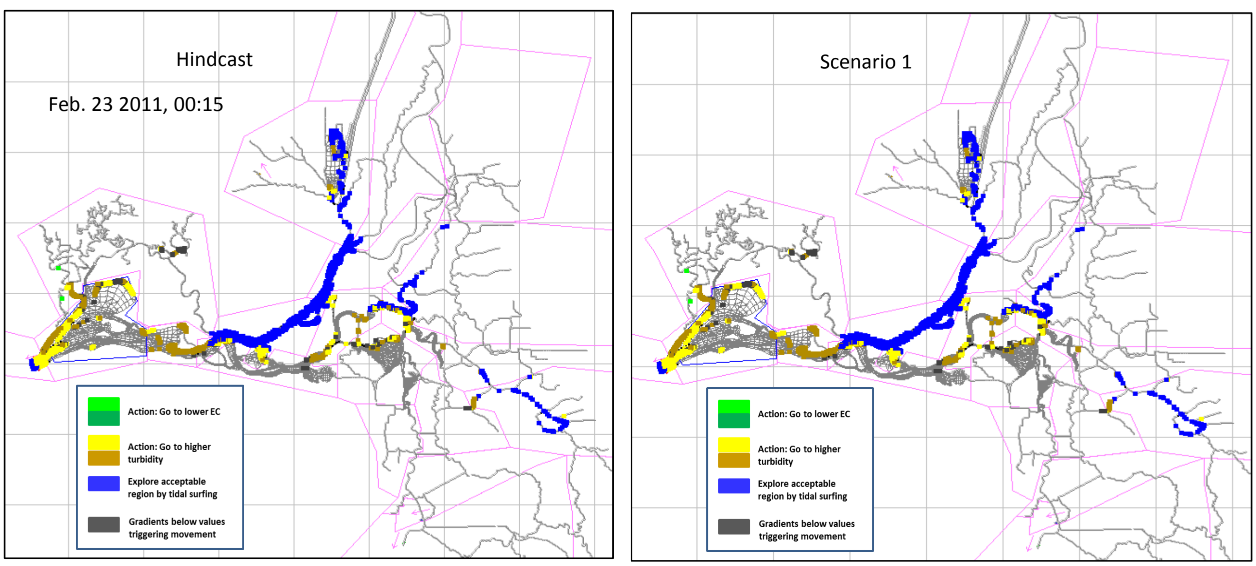


Figure 12-208 Comparison of adult delta smelt particle tracking results for the Hindcast (left) and the Modified Deriso scenario (right) on Feb. 23, 2011.