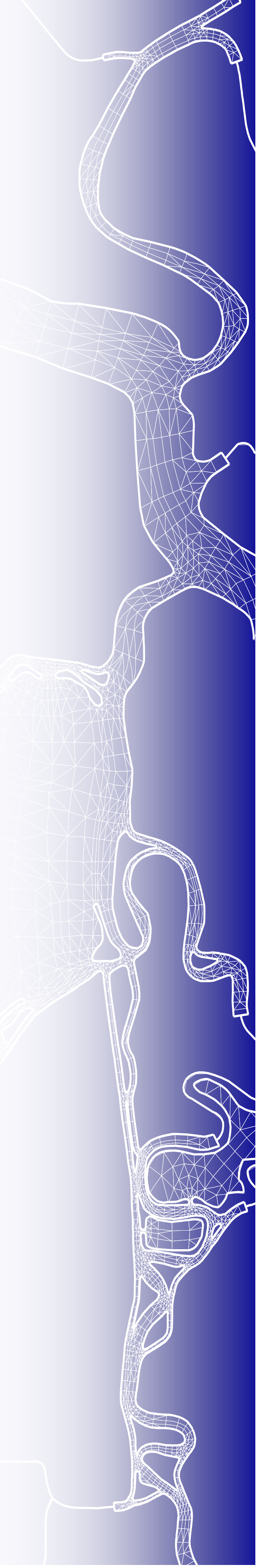

NUMERICAL MODELING FOR
THE DELTA WETLANDS PROJECT

TECHNICAL MEMORANDUM

October 2013

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1 Executive Summary

Resource Management Associates (RMA) was contracted by the Delta Wetlands Project (Project) to provide technical support services, specifically hydrodynamic modeling in the Sacramento-San Joaquin Delta (Delta) as technical input to the Project's Supplemental Environmental Impact Statement (SEIS). The report documents the information developed to evaluate and supplement the conclusions of previous modeling results for the Proposed Project alternative (DEIR/EIS, 1995, RDEIR/EIS, 2000 and FEIS, 2001) in the SEIS.

Numerical modeling of Delta hydrodynamics was conducted using the Delta Simulation Model-2 (DSM2) model HYDRO to determine the potential for the Project diversions to and discharges of water from the Project water storage reservoirs (Bacon Island and Webb Tract) to cause scour due to increases in channel velocity and to impact agricultural diversions due to decreases in south Delta stage. In addition, although changes in maximum net flow conditions in channels affected by Project activities will not in themselves adversely affect Delta conditions, net flow effects were analyzed to evaluate the conclusions of previous Project modeling studies (DEIR/EIS, 1995, RDEIR/EIS, 2000 and FEIS, 2001). DSM2-HYDRO is currently considered the best available numerical modeling tool to assess the hydrodynamic conditions occurring in planning scenarios in the Delta such as the Delta Wetlands Project scenarios.

Project effects were evaluated by comparing modeled hydrodynamic conditions under two planning model scenarios: a Base Case condition scenario and a scenario with the Project implemented under the Proposed Project alternative (Alternative) conditions. The methodology applied to determine the significance level of Project effects uses a "comparative analysis" approach in which the metrics of change from Base (Project – Base) or percent change from Base are adopted. The levels of significance associated with these metrics are similar to significance metrics used in previous modeling analyses with different modeling tools (DEIR/EIS, 1995).

Analysis of the DSM2-HYDRO model results for velocity changes due to Project diversions and discharges indicate that the Project is unlikely to cause scour in the channels near the Project locations or in mid-scale distances from the Project in the central and south Delta. This result was reached by analyzing DSM2 model output at a large number of locations in the model domain and assessing with the metric of 3.0 ft/sec as used in the previous Draft Environmental Impact Report and Statement (DEIR/EIS, 1995). The velocity changes due to the Project did not exceed 2.9% on a daily-averaged basis. The 2.9% increase occurred at one location and on one modeled day only. The potential for scour due to velocity changes from Project operations is thus unlikely when considered on a Monthly Average basis.

Analysis of the potential for the Project to negatively affect stage changes was limited to decreased stage during the discharge period when the potential exists to disrupt agricultural diversions in the south Delta. During the periods when discharges from the flooded islands are occurring, the concurrent increase in exports has the potential to decrease south Delta stage levels. Six locations were analyzed for stage changes– the upstream and downstream sides of the three south Delta agricultural barriers modeled in DSM2 and at three additional locations in the Old+Middle River corridor. These locations geographically extend (*i.e.*, south Delta barriers) and update (*i.e.*, Old+Middle River) stage analyses documented in previous Project modeling studies (DEIR/EIS, 1995). At each of these locations, the percent change from Base on a Monthly Average basis was less than 1.6% and the decrease in stage was 0.1 ft or less.

Analysis of the potential for the Project to increase Base Case maximum net flow was limited to three locations previously identified (DEIR/EIS, 1995) as indicative of the overall potential for increases in maximum net flow due to Project operations: in Old River near Bacon Island (ROLD024); in Threemile Slough near the confluence with the San Joaquin River (SLTRM004); and, in the lower San Joaquin River (RSAN007) near Antioch. In previous modeling work (DEIR/EIS, 1995), Project effects were evaluated by considering the difference in maximum net flow during Project operations using monthly average model results. Project discharge and diversion periods are considered separately in the analysis in this document. In one diversion period in Threemile Slough the monthly average net flow during Project operations exceeded the Base Case flow by 5.6%. In this case, high inflow conditions on the Sacramento, San Joaquin and other tributary rivers prompted both high State and Federal exports from the south Delta and maximum Project diversions, contributing to the high net flows at SLTRM004.

The results of the velocity and stage analysis using DSM2 indicate the effect of Delta Wetlands Project effect on scour due to increases in velocity in the Delta and on disruptions to agricultural activities due to decreases in stage in the south Delta are small in magnitude and infrequent. In the one month and location where monthly average net flow exceeded the Base Case maximum by 5.6%, neither velocity changes nor stage changes indicated adverse consequences related to Project operations during this event.

2 Introduction

The Delta Wetlands Project (Project) contracted with Resource Management Associates (RMA) to provide technical support services, specifically hydrodynamic modeling in the Sacramento-San Joaquin Delta (Delta). The Delta Wetlands Project proposes to store water on two Delta islands, Webb Tract and Bacon Island, during periods of high flow and then return water to the Delta for export at the State Water Project export pumps at the Banks Pumping Plant.

This report provides documentation on Delta Simulation Model-2 (DSM2) model set-up and on hydrodynamic results prepared by RMA. Specifically, hydrodynamic results focused on changes in velocity at numerous locations in the Delta due to Project diversions and discharges and on changes in stage at south Delta barrier locations during periods when the Project was discharging. In addition, changes in monthly average net flow are calculated at three Delta locations. Two scenarios were modeled in DSM2 – a Current Condition No Action Alternative, also called the Base Case in this document, and the Delta Wetlands Proposed Project scenario, also called the Alternative scenario in this document.

The version of DSM2 that was used in the analyses documented in this report, Version 8.0.6, is the most recent and best available modeling tool to evaluate Project hydrodynamic effects. Version 8.0.6 improved Delta bathymetry and improved accuracy in hydrodynamic calculation routines over the previous Version 6.0.

2.1 Objective

The objectives of the modeling work discussed in this document are:

1. To provide information for the SEIS on the hydrodynamic influences in the Delta due to the Delta Wetlands Proposed Project alternative.
2. To compare the velocity, water stage and net flow outcomes at selected locations in the DSM2 model domain between Base Case conditions and conditions occurring in the Proposed Project Alternative.

The Project was implemented in DSM2 using the maximum operational assumptions in order to best capture potential adverse effects.

The hydrodynamic analysis includes three components: 1) velocity at numerous near-field and mid-field locations in the Delta; 2) stage at three south Delta agricultural barrier locations implemented in planning model studies –in Middle River, in Old River and in Grant Line Canal – and at three additional locations in the Old+Middle River corridor; and, 3) monthly average net flow at three locations identified in previous modeling work (DEIR/EIS, 1995) as potentially influenced by Project operations. The analysis in this document supplements previous analyses that used different modeling tools. Although the Project operations were conceptualized similarly in applications using these tools, different hydrodynamic boundary conditions were applied. Previous model assumptions were based on historical values for inflow and export conditions but hypothetical stage boundary conditions. The DSM2 models used scenarios based on planning model conditions defined in CalSim scenarios which are described in subsequent sections of this document.

2.2 Model Set-up

In order to model the hydrodynamics in the Delta, the input and/or output from three computational models is used: CalSim II, DSM2 and the DICU model. Model descriptions are covered briefly in this section.

CalSim II model outputs are used to supply boundary conditions to DSM2. Within DSM2, agricultural influences and the effect of meteorological conditions are modeled by boundary conditions supplied by the Delta Island Consumptive Use, or DICU, model.

A distinction needs to be made between the uses of models for *absolute* versus *comparative* analyses. In an *absolute analysis*, the model is run once to predict an outcome – for example, the outcome could be the concentration of salinity at one of the Delta water intakes. In a *comparative analysis*, the model is run twice, once with conditions representing a baseline and another time with some specific changes. The change in modeled conditions is then computed in order to assess the change in modeled outcome due to the change in model input configuration. The assumption is that, while the model might not produce results reflecting these changes with absolute certainty, it nevertheless produces a reasonably reliable estimate of the relative change in outcome.

In this Project, as is customary in most projects using CalSim II planning models combined with DSM2, we are using the comparative analysis approach[1]. Our baseline scenario represents a condition that approximates an operational and regulatory framework that is assumed to determine the hydrodynamics and water quality in the Delta at a Current Condition time frame. The Alternative scenario is the Delta Wetlands Project added to the Current Condition time frame.

For Project analyses, DSM2 output was used at selected locations to determine changes in velocity patterns in the Delta due to the Project in comparison to the Base Case, stage changes in the south Delta and along the Old+Middle River corridor, and changes in maximum net flow.

2.2.1 CalSim II

CalSim is a model that was developed by the California Department of Water Resources to simulate California State Water Project (SWP) and Central Valley Project (CVP) operations in planning studies. CalSim II is the latest version of CalSim available for general use. CalSim II is a planning model designed to simulate the operations of the CVP and SWP reservoirs and water delivery systems for current and future facilities, flood control operating criteria, water delivery policies, instream flow and Delta outflow requirements, and hydroelectric power generation operations. It represents the Central Valley with a node and link structure to simulate natural and managed flows in rivers and canals. It generates monthly flows showing the effect of land use, potential climate change, and water operations on flows throughout the Central Valley.

CalSim II is a simulation by optimization model. The model simulates operations by solving a mixed-integer linear program to maximize an objective function for each month of the simulation. CalSim II simulates the operation of the CVP and SWP systems for defined physical

[1] **2003, http://sacramentoriverportal.org/modeling/CALSIM-Review.pdf**

conditions and a set of regulatory requirements. The model simulates these conditions using 82 years of historical hydrology from Water Year (WY) 1922 through WY 2003. For this Project, the DSM2 modeled time frame is restricted to a 16-year planning study period, Water Years 1976 – 1991, an evaluation period commonly used for Delta hydrodynamic studies.

The system objectives and constraints are specified as input to the model, and CalSim II then utilizes optimization techniques to route water through a network representing the California water system given user-defined priority weights. A linear programming (LP)/mixed integer linear programming (MILP) solver determines an optimal set of decisions for each time period given this set of weights and system constraints. The CalSim II model has been designed to separate the physical and operational criteria from the actual process of determining the allocations of water to competing interests. Thus, CalSim II provides quantitative hydrologic-based information to those responsible for planning, managing and operating the State Water Project (SWP) and the federal Central Valley Project (CVP). As the official model of those projects, CalSim II is the default system model for any inter-regional or statewide analysis of water in the Central Valley of California.[2]

2.2.2 DSM2

2.2.2.1 *DSM2- General Background Information*

DSM2 is a one-dimensional (1-D) hydrodynamic and water quality simulation model used to represent conditions in the Sacramento-San Joaquin Delta. The model was developed by the Department of Water Resources (DWR) and is frequently used to model impacts associated with projects in the Delta, known as planning studies, such as changes in exports, diversions, or channel geometries associated with dredging in Delta channels. It is frequently used in conjunction with CalSim II in planning studies. CalSim II hydrological output and specification of the operation of in-Delta gates and barriers are used to set the appropriate DSM2 boundary conditions.

DSM2 has been used extensively to model hydrodynamics and salinity in the Delta. DSM2 contains three separate modules, a hydrodynamic module (HYDRO), a water quality module (QUAL), and a particle tracking module (PTM). QUAL and PTM modules were not used in the analysis covered in this document. HYDRO was developed from the USGS FOURPT model (USGS, 1997). DWR adapted the model to the Delta, accounting for such features as operable gates, open water areas, and export pumps.

[2] http://sacramentoriverportal.org/modeling/CALSIM-Review.pdf, Section 6.1

Detailed descriptions of the mathematical formulation implemented in the hydrodynamic module, DSM2-HYDRO, the data required for simulation, calibration of HYDRO, and past applications of the DSM2 Historical model are documented in a series of reports[3].

Documentation on the calibration and validation of the HYDRO module used in the current implementation of DSM2 is available at that website. Changes to the network of the DSM2 model were implemented in 2009 (Chilmakuri, 2009), and the updated grid was used for the HYDRO hydrodynamic simulations in this study. The major changes are the inclusion of the Liberty Island open water area (this is modeled as a "reservoir" in DSM2 terminology) and an extension and refinement in the grid at the northern boundary of the model. Figure 2-1 shows the earlier DSM2 Version 6 grid with channels, nodes and open water areas other than Liberty Island.

2.2.2.2 *Astronomical Tide*

In addition to CalSim II's monthly time series inflows, diversions, operations and water quality data, DSM2 planning studies also require stage data at Martinez, which is the downstream boundary of the model. The Martinez boundary stage used in planning studies is a continuous time series of stage data known as the "adjusted astronomical" tide. This tide is based on historical Martinez stage data with missing data synthesized through the development and application of a statistical model using available stage data, astronomical cycles and hydrologic variations (Ateljevich 2001). The astronomical tides are calibrated to both San Francisco and Martinez observed data.

2.2.2.3 *Gates, barriers and Exports*

Permanent gates and temporary barriers represented in the model include the Delta Cross Channel (DCC), Old River near Tracy barrier, Old River at Head barrier, Middle River barrier, Suisun Marsh Salinity Control Gates (SMSCG), Grant Line Canal barrier, and Lawler buffer ditch culvert. The SMSCG control season is from early October through the end of May.

Delta exports applied in the model include SWP, CVP, North Bay Aqueduct, as well as at Contra Costa Water District (CCWD) diversions or exports at the Rock Slough and Old River intakes. (See also Section 3.1). The CCWD intake at Victoria Canal was not included in the CalSim scenario used in these analyses.

[3] Available at http://baydeltaoffice.water.ca.gov/modeling/deltamodeling/annualreports.cfm .

2.2.3 DICU

2.2.3.1 *DICU Background Information*

The Delta Island Consumptive Use Model, or DICU[4] model, was developed by the Planning Division of DWR to estimate agricultural diversions and return flows to Delta channels. The DICU model is used in DSM2 both to estimate historical agricultural flows and to estimate project planning model agricultural volumes, and to assign these volumes and associated concentration of water quality parameters to DSM2 nodes. In this report, we use "DICU" to refer both to the conceptual model and to the associated computer programs.

The values calculated for consumptive use in the conceptual model include the following parameters:

- Evapotranspiration – includes climatic conditions, soil type and plant type and associated acreage
- Precipitation – spatially distributed using Delta weather station values
- Surface runoff
- Soil moisture
- Irrigation – water diverted from channels, estimated by season
- Seepage – water used by plants flows from channels to Delta islands
- Drainage – return flows from irrigation and leaching to channels from Delta islands
- Leach water – heavy applications of water in winter months used to leach salts from soils.

The DICU model calculations for water diversions and returns are most sensitive to changes in efficiency of irrigation (a factor applied to irrigation withdrawals) and in evapotranspiration. Changes in seepage values can cause changes in irrigation demands or in return flows, but only have a small impact on return flows. Studies have indicated that DICU seepage estimates are probably low. The model as a whole is most sensitive to changes in irrigation efficiency (a constant value) and to leaching water estimates.

The DICU model provides time series of values that are applied as boundary conditions on a monthly average basis[5],[6] (DWR, 1995a; DWR 2002) (Figure 2-2) in DSM2 at 257[7] locations throughout the Delta – these locations are subdivided into 142 regions. There are three components to DICU flows – diversion, drainage and seepage. The total monthly diversions incorporate agricultural use, evaporation and precipitation, drains incorporate agricultural

[4] http://modeling.water.ca.gov/delta/reports/misc/EstDICU.pdf
[5] http://baydeltaoffice.water.ca.gov/modeling/deltamodeling/models/dicu/dicu.cfm
[6] http://www.iep.ca.gov/dsm2pwt/reports/DSM2FinalReport_v07-19-02.pdf, http://baydeltaoffice.water.ca.gov/modeling/deltamodeling/models/dicu/DICU_Dec2000.pdf
[7] Note that Byron-Bethany irrigation district is included as a DICU flow in Clifton Court Forebay, so there are actually 258 DICU nodes

returns, and seeps incorporate channel depletions. These flows are distributed as boundary conditions that vary by region and by Water Year Type. Acreages for land use categories and crop type are varied by two categories of Water Year type, critical and non-critical. The critical years in the DICU model include the D-1485 (same as D-1641) Water Year classification types of Critical and Dry; non-critical years include the remaining Water Year classification types.

There is considerable uncertainty in the estimates of DICU inflow and outflow especially during periods of low inflow, for example during Critical Water years.

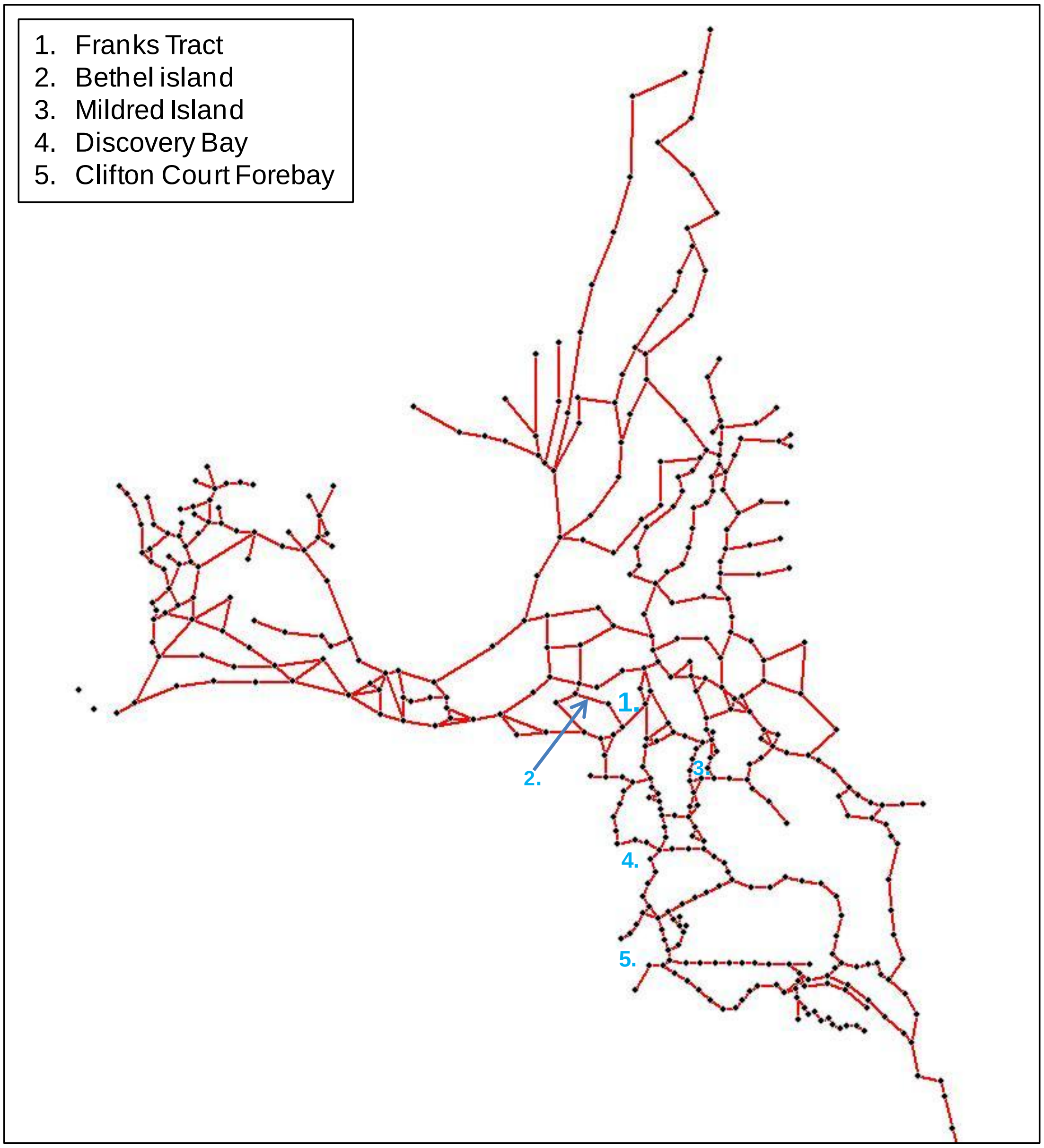


Figure 2-1DSM2 Version 6 model grid showing channels (red), reservoir locations (blue numbers), and model nodes (black).

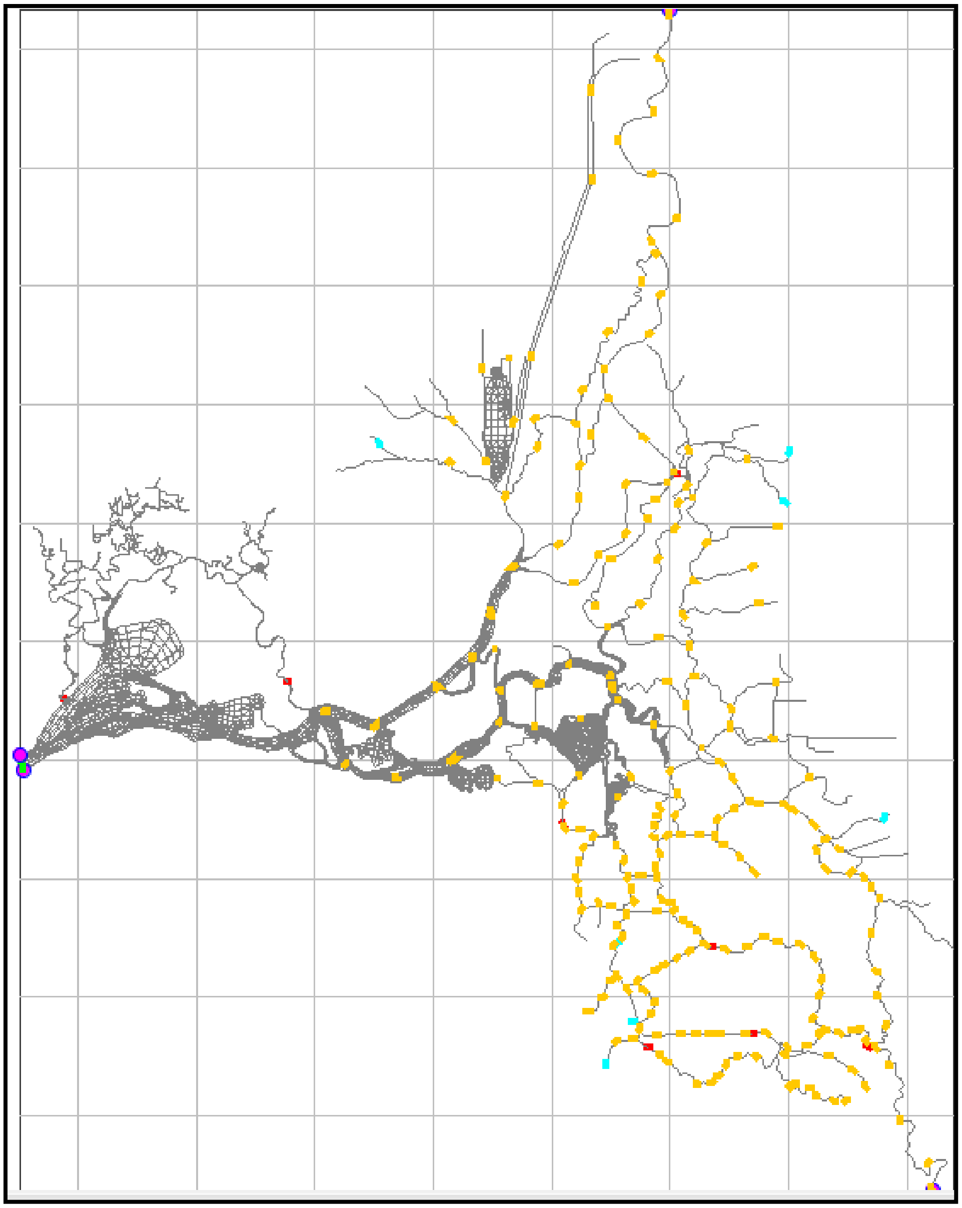


Figure 2-2 This figure illustrates the location of Delta Island Consumptive Use (DICU) locations in the Delta. Note that this is NOT the DSM2 grid; it is the RMA 2-dimesional model Delta grid.

3 Modeling Methodology – Boundary Conditions

The Delta Modeling Section (DMS) in DWR has developed a series of computer applications to automate the generation of DSM2 model inputs and boundary conditions. These applications produce input time series for DSM2 flows from CalSim II output, as well as time series for the timing of operations for certain gates and barriers, for example, the gates at the entry of Clifton Court Forebay (CCFB) and the gates in the Delta Cross Channel (DCC). For some studies, the VAMP (Vernalis Adaptive Management Plan) assumptions are prepared for the San Joaquin inflow at Vernalis and for the SWP and CVP exports. The preprocessors prepare time series that are copied into a single input file that is read directly by DSM2 executable instructions. These applications also produce time series for the DICU flows and constituent concentrations for EC using standardized planning study model inputs. The DICU time series are also copied into the input file that is read into DSM2.

The DICU time series used in this Project for the two scenarios were each generated using standard Current Condition time series for planning projects (dicu2005_2005A01A.dss).

3.1 Inflow and Export Boundary Conditions

Boundaries that define the movement of water into and out of the Delta consist of inflow boundaries, outflow boundaries and a stage boundary set at Martinez. In Figure 3-2, the main inflow boundaries are denoted by blue dots as is the stage boundary at Martinez. The inflow boundaries are found at the each of the major rivers (Sacramento, San Joaquin, Calaveras, Mokelumne and Cosumnes), and at the Yolo Bypass. Martinez is also the outflow boundary for tributary flows. In Figure 3-3, the approximate positions of Delta export locations (water intakes) are shown. Section 7.1 in the Appendix documents the export values at the main export locations in the south Delta considered in this study.

The stage boundary at Martinez was obtained from a standardized time series developed by the DMS under direction of the preprocessor logic.

3.2 Delta Wetlands Project boundary conditions

The locations of Delta Wetlands diversions and returns are shown in Figure 3-1.

The CalSim II planning study used in preparing the DSM2 models discussed in this report was obtained from staff at MBK Engineers. The study package (denoted *CALSIM_042108_9B_5stepTXFR*) was finalized on April 21, 2008 so regulatory criteria or actions occurring after that date are not included[8]. A 5stepTXFR study includes the following CalSim II calculation steps:

[8] Note – this date was before the Wanger decision was finalized, and thus does not include Old+Middle River flow criteria

- D1485, D1461 and B2 steps were run for the purposes of including B2 Accounting
- An additional step was included to determine Delta project operations without wheeling or third party water transfers
- The 5stepTXFR calculation then included wheeling and third party transfers

Monthly time series for Project diversion and return flows for HYDRO were obtained from IDSM model output supplied to RMA by MBK Engineering. IDSM is a spreadsheet model prepared for the Project by MBK Engineering. The IDSM model output is identical to output documented in the Place of Use EIR (2010). In addition, MBK supplied the monthly export levels at the SWP pumps, which were increased during periods of discharge from the flooded Delta islands. This time series was used as input to the DSM2 preprocessing step for the Alternative scenario.

The withdrawal logic for conversion from monthly to daily time series for Project diversions onto Webb and Bacon Islands was supplied to RMA Staff by Dave Forkel (Delta Wetlands Project).

3.3 Model set-up

DSM2 was run with the Mini-calibration set-up and V8.0.6 of HYDRO. The original CalSim run was developed while a previous version of DSM2 was in use (V6.0). Since improvements were made both to the underlying grid representing the bathymetry of the Delta and to the executable program, HYDRO, the modeling by RMA for the Project used the later version (V8.0.6) of DSM2. This required minor changes to the DSM2 preprocessor logic used to generate boundary conditions for HYDRO. Thus, the numerical results may be slightly different from those produced using previous versions of DSM2 due to bathymetry and HYDRO changes; however, the accuracy in V8.0.6 is better than in previous versions.

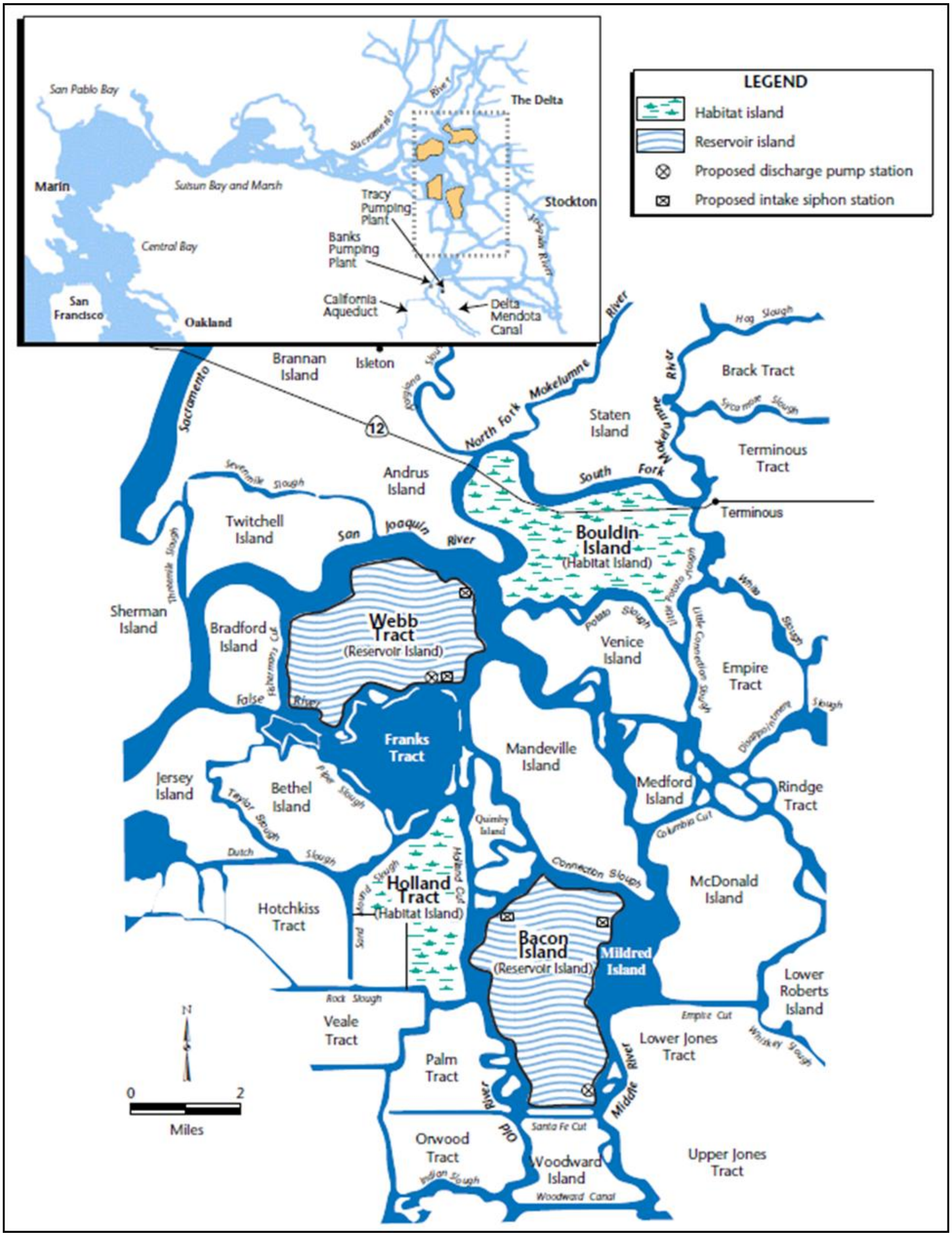


Figure 3-1 Delta Wetlands Project diversion and discharge locations on Webb Tract and Bacon Island– this figure obtained from (DWP, 2001).

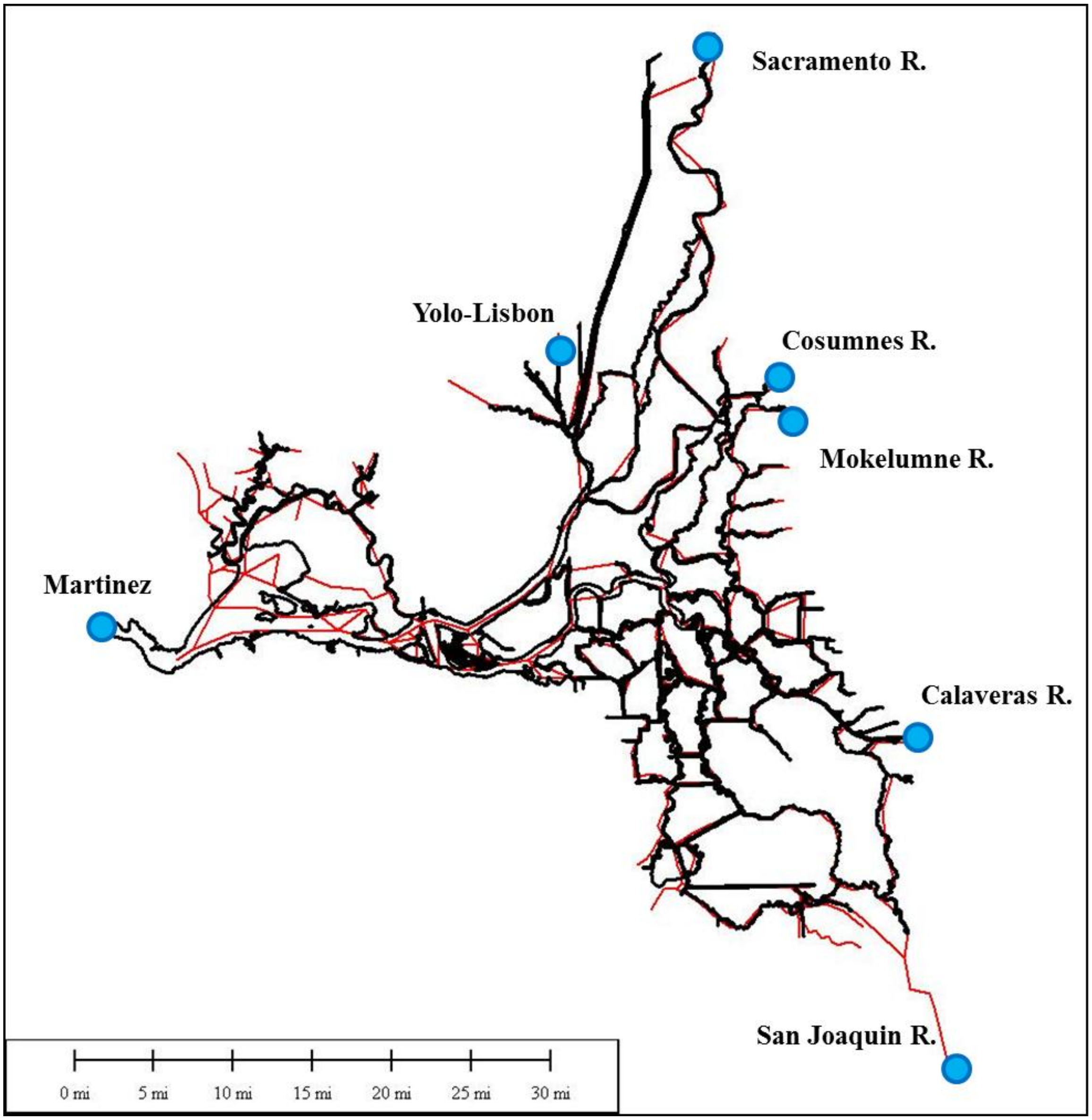


Figure 3-2 Approximate location of the model inflow (or outflow) boundaries (blue circles). The stage boundary at Martinez is also an outflow boundary.

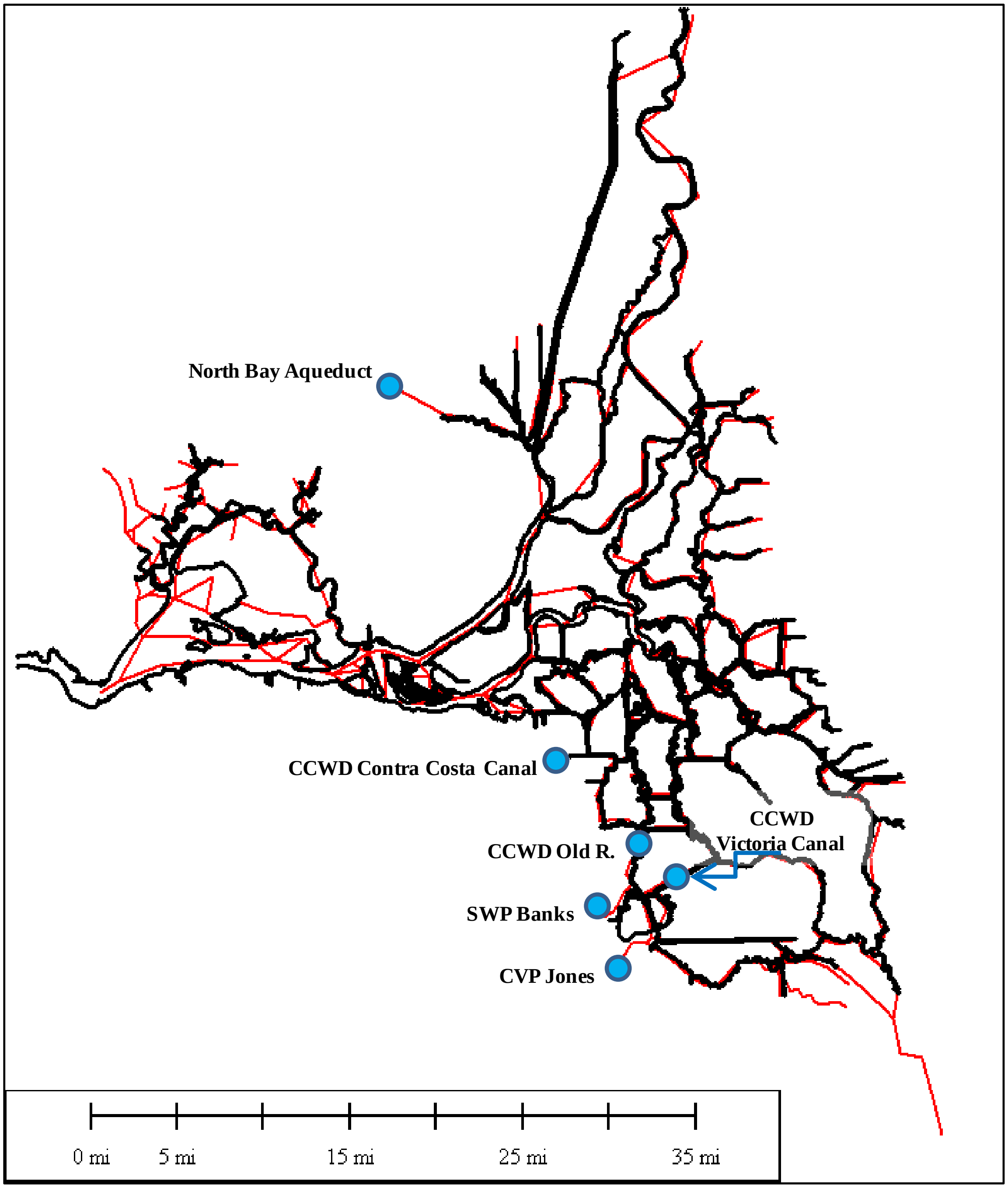


Figure 3-3 Approximate location of Delta water intakes (export locations).

4 Model Results

DSM2 HYDRO scenarios for the Base Case and the Alternative were run for the standard 16-year planning study time frame; Water Years 1976 – 1991, with an initial model spin-up period in Water Year 1975. Model output was specified as 15-minute time series at numerous locations in the model domain. Subsets of the modeled output locations were used for: QA/QC; analyzing velocity results; analyzing monthly average net flow results; and, analyzing stage results. Plots illustrating QA/QC of the model boundary conditions are found in the Appendix, Section 7.1.

4.1 Analysis Approach

4.1.1 Comparison of Current and Previous Modeling and Analysis Approaches

The previous hydrodynamic modeling with the RMA Delta model (see: Appendix B1 (DEIR/EIS, 1995) or Chapter 3B (FEIS, 2001) for further detail) used monthly average historical flow, export and barrier/gate operation conditions and an average tidal boundary condition (i.e., a 25-hour repeating tide) as a Base Case. Calculations are made at a 1.5 minute time step. In contrast, for the DSM2 modeling used in this document, the boundary conditions were set used CalSim-derived inflow boundary and operational conditions and an astronomical stage (non-repeating) that better replicates the spring-neap cycle of tidal filling and draining of the Delta than a repeating tide. Calculations are made at a 15-min time step.

Maximum effects of Project operations were previously determined during maximum Project diversion and discharge conditions applied under representative boundary conditions during periods representing those conditions (DEIR/EIS, 1995). The DSM2 modeling in this document instead used the entire expected range of Proposed Project diversion and discharge operations simulated in conjunction with expected changes to upstream reservoir operations (i.e., changes to Delta inflow) and export operations that conform to D-1641 (SWRCB, 2000) hydrodynamic criteria in the CalSim simulation.

Maximum Project effects for velocity and stage were previously evaluated (DEIR/EIS, 1995) in channels surrounding the four Project islands (i.e., islands used for either storage or habitat restoration).Maximum effects were expected adjacent to proposed pumps and discharges. In the current document, calculations to evaluate velocity were obtained at similar locations near Proposed Project pumps and discharges, and also in channels at mid-scale distances from these locations. Thus, the locations used for velocity calculations were performed using a similar strategy in both previous and current modeling studies of the Proposed Project. Given that there are differences in the set-up of the models, the physical locations used for evaluating velocity changes are not identical.

Stage differences (see Table B1-9 in (DEIR/EIS, 1995)) were previously found to be greatest in the expected locations (near siphon and discharge locations) and also in the south Delta. However, stage changes were not previously evaluated at the agricultural barrier locations, indicated in D-1641 (SWRCB, 2000), that might be affected by changes in south Delta export operations as these barriers were not included in the previous model set-up. Thus, in the current document, stage changes were evaluated at these three south Delta agricultural barrier locations. In addition, stage changes were evaluated in the current study in Old and Middle Rivers where stage changes were previously found (i.e., non-zero), albeit found to be not significant (see Table B1-9, in (DEIR/EIS, 1995)). Model results at these locations would confirm the DSM2 stage results were similar to previous modeling results, although using somewhat different calculation methodologies appropriate to each study. For example, in the current study only decreases in stage are considered as these may produce adverse consequences for south Delta diversions from increased export pumping during Project discharge periods.

Net flow results were evaluated at the same locations in both studies, as the previous modeling work (DEIR/EIS, 1995) found these three locations to be representative of expected changes in the affected area during maximum Project operations. A monthly average maximum net channel flow result was cited in both modeling studies, although using different net flow calculation methodologies appropriate to each study.

4.1.2 Analysis Approach using DSM2 V8.0.6

Modeled velocity was output in channels near the Project diversion and discharge locations as well as in channels that were at mid-scale distances from the Project locations in the central and south Delta. The output nomenclature and the DSM2 channel information are specified in and the nomenclature is explained in Figure 4-1. Diversion and discharge locations are identified in the DSM2 grid in Figure 3-1 for Webb Tract and in Figure 4-3 for Bacon Island. DSM2 grid sections where the velocity output channels are located are shown in Figure 4-4 and in Figure 4-5. As the Delta is a tidally-influenced system, a sign convention for the positive flow and velocity direction is included alongside DSM2 channels in these figures.

Stage levels were examined at the three south Delta locations where agricultural barriers have been installed to protect water levels near agricultural siphons upstream of the barriers – the barrier locations are indicated in Figure 4-6. The location upstream of the agricultural barrier can be determined by the direction of the arrows in this figure – in each channel (black line) the arrows points in the downstream direction. In addition, three locations in the Old and Middle River Corridor, RMID015, ROLD024 and ROLD034 (see Figure 4-5) were examined to evaluate the potential for stage changes in this area of the south Delta.

Only decreases in stage due to the Project were considered during Project discharge periods when the concern is that reduced stage due to increased south Delta exports may limit withdrawal of water for agricultural purposes from the Delta (SWRCB, 2000). Stage increases are not analyzed in this document because the Project will not discharge water at a time when high stage threatens levee stability during periods of high Delta outflow and high tide. In addition, during high flow/stage conditions in the Delta, Project withdrawals will lower water surface elevations, so withdrawals are a benefit due to the potential reduction in levee overtopping.

As discussed Section 2.2, this report is adopting a standard comparative analysis approach. In this case, the relevant quantities used to determine Project effects are the Alternative change from Base and Alternative percent change from Base. Note that some level of difference is allowed due to factors such as model inaccuracy and the inherent inaccuracies in measurement equipment. Average monthly quantities (e.g., the quantity for August is the average over the 16 average monthly values calculated from model output) are used following standard conventions (for example, see RMA, 2010).

4.2 Velocity

Velocity time series from model output for the Base Case and Alternative scenarios were analyzed to calculate daily results from 15-min results in two ways – as the maximum daily velocity and as the minimum daily velocity – in order to compare the velocity changes induced by the Project withdrawals and discharges with those found in the Base Case. These daily time series were then compared by calculating the difference (Alternative – Base Case). As the Delta is a tidally-driven system, velocity directions need to be checked against standard conventions as described above.

Velocity changes indicate the potential for scour if the velocity in the Alternative exceeds both the Base Case and a threshold velocity. A Delta-wide threshold of 3.0 ft/sec was used in the previous Final Environmental Impact Statement (FEIS, 2001) (see page 3B-12 in Chapter 3-B, citing Bob Suits, (DWR, pers. comm.)) and was also included in this analysis.

4.2.1 Selected locations for velocity results

Changes in channel velocity due to Project diversions and discharges were calculated at all of the locations specified in Table 4-1. The results are displayed as two sets of two plots – one set has a plot comparing the Base Case and Alternative maximum velocity and a plot showing the difference (Alternative – Base) in maximum velocities (i.e., positive flow velocities), and another set showing the respective minimum velocities (i.e., negative flow velocities) and velocity difference. Velocity at the discharge and diversion locations was checked – the nomenclature in Table 4-1 indicates these locations. In addition, quantitative results are found inTable 4-2 through Table 4-5.

In this section, five plots are discussed to illustrate the general nature of the results – plots for all of the velocity locations are documented in Section 0 in the Appendix. Figure 4-4 and Figure 4-5 illustrate the approximate locations of all of the locations in the DSM2 grid.

Figure 4-7 and Figure 4-8 illustrate velocity results downstream and upstream, respectively, of the Bacon Island discharge point at DSM2 node 122. The upper plot in each figure shows the maximum daily velocity for the Base Case (red line) and the Alternative (blue line), and the 3.0

ft/sec maximum scour velocity (green line), and the change in maximum velocity (Alternative – Base). The maximum velocity is less than 1.5 ft/sec in magnitude for both scenarios, below the 3.0 ft/sec threshold. The lower plot in each figure shows the minimum daily velocity for the Base (red line) and the Alternative (blue line), and the -3.0 ft/sec minimum scour velocity (green line), and the change in minimum velocity (Alternative – Base). The absolute velocity is less than 3.0 ft/sec in magnitude at those locations.

Figure 4-9 illustrates velocity results at the northern side of Woodward Island in DSM2 channel 143. Both the maximum and the absolute value of the minimum velocities are less than 3.0 ft/sec for the Base Case and the Alternative.

Figure 4-10 illustrates velocity results at the western side of Bouldin Island in DSM2 channel 349. In this case, the maximum channel velocities are between 1.5 and 2.5 ft/sec, below the 3.0 ft/sec threshold.

Figure 4-11 illustrates velocity results in Three Mile Slough in DSM2 Channel 310. In this case, there are instances where the Base Case and/or Alternative minimum velocities are less than -3.0 ft/sec. Table 4-2 and Table 4-3 further document the analysis of minimum daily velocity in Channel 310 – in this case the threshold velocity is -3.0 ft/sec and it is exceeded when the minimum daily velocity is less than that value. Table 4-4 and Table 4-5 document the analysis of maximum daily velocity in Channel 310, when the threshold is 3.0 ft/sec. In both tables, the percent differences are only calculated when the velocity of the Base and/or Alternative exceeds the threshold.

The analysis of minimum daily velocities is most pertinent to Project diversion periods, and the analysis is shown in Table 4-2 when the velocity in Channel 310 exceeds the -3.0 ft/sec threshold minimum velocity. The average daily minimum velocity in the Base Case and Alternative are always within 0.1 ft/sec on average (a maximum of 1.6% difference) in each diversion period. Note that percent differences were calculated only when Base and/or Alternative exceeded the velocity threshold on a given day. The greatest daily percent difference of 2.9% over all of the diversion periods occurred on a single day when the Alternative daily minimum velocity exceeded the threshold but the Base Case did not.

Table 4-3 documents the number of days over the entire modeled period when the Base Case and Alternative minimum daily velocities exceeded the threshold. Over the diversion period, the Alternative exceeded the threshold 89% of the time while the Base Case exceeded the threshold 88% of the time – a difference of 4 days out of 339 days.

Table 4-4 analyzes periods when the velocity in Channel 310 exceeds the +3.0 ft/sec maximum threshold velocity. The average daily maximum velocity in the Base Case and Alternative are always within 0.1 ft/sec and the daily maximum velocity during diversion periods is generally lower in the Alternative than in the Base Case. Note that percent differences were calculated only when Base and/or Alternative exceeded the threshold on a given day, and there are several periods when neither scenario exceeded the maximum threshold velocity. As the daily percent difference was always negative, the maximum daily percent difference is shown as N/A.

Table 4-5 documents the number of days over the entire modeled period when the Base Case and Alternative maximum daily velocities exceed the threshold. It shows that the Alternative maximum velocities are generally less than the Base Case as the Alternative exceeded the threshold on fewer days than the Base Case. Over the diversion period, the Alternative exceeded the threshold 9% of the time while the Base Case exceeded the threshold 12% of the time.

4.3 Stage

Model results for stage were output as 15-min time series that were then analyzed to calculate the daily minimum stage, and then the difference (Alternative – Base Case) in minimum daily stage was calculated at upstream and downstream of the agricultural barrier locations and at the three locations in the Old+Middle River Corridor.

Figure 4-12 illustrates the rationale behind the use of difference between daily minimum results rather than differences between 15-min model results. The upper plot shows the 15-min differences at the three locations for a specific month and year, August 1988, when all three agricultural barrier locations show large differences in stage between Alternative and Base. The central plot shows the difference (Alternative – Base) at upstream barrier location in Old River near Tracy for the daily minimum results. The lower plot shows the 15-min stage output on August 29th at this location. The arrows in this plot show that the minimum stage can occur at different times during the day, so calculating 15-min differences will not yield the difference between the absolute minimum stages that occur during that day. Thus, calculating the difference between the minimum stages on a daily basis gives a lower bound on the magnitude of the lowering of stage levels near the agricultural barriers. Note that stage changes also occur during diversion time periods for the islands, but as mentioned in Section 4.1 withdrawals during high flow periods may be beneficial in preventing levee overtopping events, so the analysis focused on stage changes during discharge time periods.

Figure 4-13 through Figure 4-21 illustrate the results of the daily minimum stage calculations. For example, in Figure 4-13 results at the upstream end of the barrier in Grant Line Canal, shows that the decrease in stage due to the Project is generally less than 0.1 ft., and usually between 0.04 and 0.08 ft. of decrease. Similarly, Figure 4-15, results at the upstream end of the barrier in Middle River, shows that the decrease stage due to the Project are generally 0.1 ft or less except in a few instances. Figure 4-17, results at the upstream end of the barrier in Old River, shows that the decrease stage due to the Project are generally 0.1 ft. or less, and only in the Fall of 1987 and of 1988 did the stage decrease by slightly more than that amount by 0.12 ft.

As a quantitative comparison at each of the six stage analysis locations, the Monthly Average of the daily minimum stage (e.g., one average for all the modeled Augusts) was calculated during months when water from the flooded islands was discharged into the Delta, along with the percent difference for each monthly minimum. The results are compiled in tables – see Table 4-6 through Table 4-9. The first two columns in each table give the Monthly Average of the daily minimum stage in those months when the Project discharged water into the Delta. The third (final) column gives the percent difference for the Monthly Averages appearing in the Table. Negative values in the final column indicate a decrease in stage for the Alternative, and positive values indicate an increase in stage. The percent differences for all locations are less than 1.6% in magnitude.

4.4 Net Flow

Net flow results are shown in Figure 4-22 through Figure 4-27 for the three locations identified as representative for net flow analyses during Project discharge (#1-35) and diversion (#1-29) periods, considered separately. In each figure, the Base Case (blue bar) and Alternative (red bar) results are shown side-by-side for each period – the final two sets of bars show the maximum positive and negative monthly average net flows, respectively (i.e., over the entire simulation).

At the SLTRM004 location in Threemile Slough, the Project diversion period is shown in Figure 4-22 and the discharge period in Figure 4-23. During one of the diversion periods, the maximum monthly average net flow in the Alternative is 5.6% greater than the Base Case maximum. This month (February, 1986) is a period of some of the highest inflow levels on the Sacramento, San Joaquin and other tributary rivers as well as a period of high State and Federal export levels. During this period, the additional routing of flow through Threemile Slough for Project diversions increases flow above the maximum Base Case level.

Figure 4-24 and Figure 4-25 show the results at the location near Antioch in the lower San Joaquin River. In this case, Project operations clearly do not increase monthly average net flow at this location above the Base Case maximum. Figure 4-26 and Figure 4-27 show the results for Old River near Bacon Island. At this location, both positive and negative net flows need to be considered. As can be seen, Project operations do not increase the magnitude of either positive or negative net flows at this location in comparison with the Base Case maxima.

Table 4-1Model output locations analyzed for velocity changes between Base Case and the Alternative. See Figure 4-2 and Figure 4-3 for approximate locations in the DSM2 grid.

Output Name	Channel	Location in Channel
webbsiphon1_us	44	End of Channel
webbsiphon1_ds	45	Start of Channel
webb_both2a_ds	276	Start of Channel
webb_both2b_ds	124	Start of Channel
webb_both2c_us	123	Start of Channel
webb_both2d_us	122	Start of Channel
baconsiphon1_us	250	End of Channel
baconsiphon1a_ds	114	Start of Channel
baconsiphon1b_ds	116	Start of Channel
baconsiphon2_us	152	End of Channel
baconsiphon2_ds	153	Start of Channel
bacondischarge_us	144	End of Channel
bacondischarge1_ds	146	Start of Channel
bacondischarge2_ds	148	Start of Channel
channel_277_mid	277	Middle of Channel
channel_278_len	278	End of Channel
channel_279_len	279	End of Channel
channel_280_zero	280	Start of Channel
channel_309_len	309	End of Channel
channel_310_len	310	End of Channel
channel_147_zero	147	Start of Channel
channel_145_zero	145	Start of Channel
channel_111_len	111	End of Channel
channel_115_len	115	End of Channel
channel_265_zero	265	Start of Channel
channel_117_len	117	End of Channel
channel_349_zero	349	Start of Channel
channel_328_zero	328	Start of Channel
channel_258_zero	258	Start of Channel
channel_259_zero	259	Start of Channel
channel_143_len	143	End of Channel
channel_96_len	96	End of Channel

Table 4-2 Average daily minimum velocity (ft/sec) and percent difference calculations during Project Diversion periods for the Base Case and Alternative daily minimum velocity in Channel 310 in Threemile Slough. Percent differences calculated only when Base and/or Alt exceeded the threshold.

	Avg Daily Velocity Base	Avg Daily Velocity Alt	Avg Daily % Diff When Exceeded	# Days In Diversion Period
Jan. 1978	-3.5	-3.5	0.9	27
Feb. 1979	-3.2	-3.3	1.4	27
Jan. 1980	-3.3	-3.3	1.3	27
Jan. 1981	-3.3	-3.3	1.0	27
Mar. 1981	-3.3	-3.4	0.9	10
Dec. 1981	-3.5	-3.5	1.2	27
Dec. 1982	-3.2	-3.2	1.4	27
Dec. 1983	-3.1	-3.1	1.4	27
Dec. 1984	-3.1	-3.2	1.3	27
Feb. 1986	-3.0	-3.1	1.6	27
Mar. 1987	-3.2	-3.2	1.2	27
Jan. 1988	-3.2	-3.3	1.1	27
Mar. 1989	-3.4	-3.4	1.4	27
Mar. 1991	-3.0	-3.0	0.8	5
Max Daily % Diff			2.9	

Table 4-3 Comparison of number of days the Base Case and Alternative daily minimum velocity is less than -3.0 ft/sec in Channel 310 in Threemile Slough for the model analysis period and restricted to Project diversion periods.

Velocity < -3.0 ft/sec	Base Case	Alternative
# Days Overall	3819	3813
# Days During DW Diversions	298	302

Table 4-4 Average daily maximum velocity (ft/sec) and percent difference calculations during Project Diversion periods for the Base Case and Alternative daily maximum velocity in Channel 310 in Threemile Slough. Percent differences calculated only when Base and/or Alt exceeded the threshold, N/A indicates threshold was never exceeded during that period.

	Avg Daily Velocity Base	Avg Daily Velocity Alt	Avg Daily % Diff When Exceeded	# Days In Diversion Period
Jan. 1978	2.6	2.6	N/A	27
Feb. 1979	2.8	2.8	-0.2	27
Jan. 1980	2.4	2.3	N/A	27
Jan. 1981	2.8	2.8	-1.2	27
Mar. 1981	2.9	2.9	-1.2	10
Dec. 1981	2.3	2.2	N/A	27
Dec. 1982	2.9	2.8	-1.0	27
Dec. 1983	2.1	2.0	N/A	27
Dec. 1984	2.9	2.9	-1.8	27
Feb. 1986	1.0	0.9	N/A	27
Mar. 1987	2.8	2.8	N/A	27
Jan. 1988	2.8	2.8	-0.8	27
Mar. 1989	2.6	2.6	N/A	27
Mar. 1991	2.5	2.5	N/A	5
Max Daily % Diff			N/A	

Table 4-5 Comparison of number of days the Base Case and Alternative daily maximum velocity is greater than 3.0 ft/sec in Channel 310 in Threemile Slough for the model analysis period and restricted to Project diversion periods.

Velocity > 3.0 ft/sec	Base Case	Alternative
# Days Overall	1611	1615
# Days During DW Diversions	40	29

Table 4-6 Monthly Average (feet) for Daily Minimum Stage for the Base and Alternative at the upstream (Channel 206) and downstream locations of the Grant Line Canal agricultural barrier. The final two columns respectively give Monthly Average: % change from Base; and, Difference (Alternative – Base). Negative values indicate a decrease in stage for the Alternative, and positive values indicate an increase in stage.

	Base GLC_206	Alt GLC_206	% Diff GLC_206	Avg.Diff GLC_206
Oct	1.38	1.38	-0.25	0.00
Nov	1.67	1.67	0.12	0.00
Dec	-	-	-	-
Jan	-	-	-	-
Feb	-	-	-	-
Mar	-	-	-	-
Apr	-	-	-	-
May	-	-	-	-
Jun	-	-	-	-
Jul	1.56	1.56	-0.32	0.00
Aug	1.55	1.55	-0.70	-0.01
Sep	1.62	1.62	-0.63	-0.01

	Base GLC_207	Alt GLC_207	% Diff GLC_207	Avg. Diff GLC_207
Oct	-1.05	-1.04	-0.5	0.00
Nov	-0.96	-0.95	-1.2	0.01
Dec	-	-	-	-
Jan	-	-	-	-
Feb	-	-	-	-
Mar	-	-	-	-
Apr	-	-	-	-
May	-	-	-	-
Jun	-	-	-	-
Jul	-0.75	-0.75	0.1	0.00
Aug	-0.88	-0.88	-0.4	0.00
Sep	-0.80	-0.80	-0.9	0.01

Table 4-7 Monthly Average (feet) for Daily Minimum Stage for the Base and Alternative at the upstream (Channel 79) and downstream locations of the Old River agricultural barrier. The final two columns respectively give Monthly Average: % change from Base; and, Difference (Alternative – Base). Negative values indicate a decrease in stage for the Alternative, and positive values indicate an increase in stage.

	Base OLDR_TRACY_79	Alt OLDR_TRACY_79	% Diff OLDR_TRACY_79	Avg.Diff OLDR_TRACY_79
Oct	1.36	1.35	-0.24	0.00
Nov	1.61	1.61	0.08	0.00
Dec	-	-	-	-
Jan	-	-	-	-
Feb	-	-	-	-
Mar	-	-	-	-
Apr	-	-	-	-
May	-	-	-	-
Jun	-	-	-	-
Jul	1.35	1.35	-0.33	0.00
Aug	1.52	1.51	-0.71	-0.01
Sep	1.59	1.59	-0.56	-0.01

	Base OLDR_TRACY_80	Alt OLDR_TRACY_80	% Diff OLDR_TRACY_80	Avg. Diff OLDR_TRACY_80
Oct	-1.15	-1.14	-0.43	0.00
Nov	-1.15	-1.14	-1.23	0.01
Dec	-	-	-	-
Jan	-	-	-	-
Feb	-	-	-	-
Mar	-	-	-	-
Apr	-	-	-	-
May	-	-	-	-
Jun	-	-	-	-
Jul	-1.04	-1.04	0.13	0.00
Aug	-1.02	-1.02	-0.37	0.00
Sep	-0.96	-0.95	-0.86	0.01

Table 4-8 Monthly Average (feet) for Daily Minimum Stage for the Base and Alternative at the upstream (Channel 133) and downstream locations of the Middle River agricultural barrier. The final two columns respectively give Monthly Average: % change from Base; and, Difference (Alternative – Base). Negative values indicate a decrease in stage for the Alternative, and positive values indicate an increase in stage.

	Base MIDR_BAR_133	Alt MIDR_BAR_133	% Diff MIDR_BAR_133	Avg. Diff MIDR_BAR_133
Oct	1.06	1.06	-0.14	0.00
Nov	1.15	1.15	0.09	0.00
Dec	-	-	-	-
Jan	-	-	-	-
Feb	-	-	-	-
Mar	-	-	-	-
Apr	-	-	-	-
May	-	-	-	-
Jun	-	-	-	-
Jul	0.88	0.87	-0.73	-0.01
Aug	1.13	1.12	-0.66	-0.01
Sep	1.18	1.17	-0.36	0.00

	Base MIDR_Ch134	Alt MIDR_Ch134	% Diff MIDR_Ch134	Avg. Diff MIDR_Ch134
Oct	-0.94	-0.93	-0.7	0.0
Nov	-0.97	-0.96	-1.6	0.0
Dec	-	-	-	-
Jan	-	-	-	-
Feb	-	-	-	-
Mar	-	-	-	-
Apr	-	-	-	-
May	-	-	-	-
Jun	-	-	-	-
Jul	-0.86	-0.85	-0.5	0.0
Aug	-0.80	-0.79	-1.1	0.0
Sep	-0.74	-0.73	-1.3	0.0

Table 4-9 Monthly Average (feet) for Daily Minimum Stage for the Base and Alternative at three locations in the Old+Middle River corridor. The final two columns respectively give Monthly Average: % change from Base; and, Difference (Alternative – Base). Negative values indicate a decrease in stage for the Alternative, and positive values indicate an increase in stage.

	Base RMID015	Alt RMID015	% Diff RMID015	Average Diff
Oct	-0.81	-0.80	-0.8	0.0
Nov	-0.88	-0.86	-1.9	0.0
Dec	-	-	-	-
Jan	-	-	-	-
Feb	-	-	-	-
Mar	-	-	-	-
Apr	-	-	-	-
May	-	-	-	-
Jun	-	-	-	-
Jul	-0.76	-0.76	-0.2	0.0
Aug	-0.67	-0.66	-1.0	0.0
Sep	-0.61	-0.60	-1.4	0.0

	Base ROLD024	Alt ROLD024	% Diff ROLD024	Average Diff
Oct	-0.73	-0.73	-0.2	0.0
Nov	-0.81	-0.80	-1.3	0.0
Dec	-	-	-	-
Jan	-	-	-	-
Feb	-	-	-	-
Mar	-	-	-	-
Apr	-	-	-	-
May	-	-	-	-
Jun	-	-	-	-
Jul	-0.69	-0.69	0.2	0.0
Aug	-0.60	-0.60	0.2	0.0
Sep	-0.54	-0.54	-0.4	0.0

	Base ROLD034	Alt ROLD034	% Diff ROLD034	Average Diff
Oct	-0.90	-0.90	-0.8	0.0
Nov	-0.96	-0.95	-1.5	0.0
Dec	-	-	-	-
Jan	-	-	-	-
Feb	-	-	-	-
Mar	-	-	-	-
Apr	-	-	-	-
May	-	-	-	-
Jun	-	-	-	-
Jul	-0.84	-0.84	-0.4	0.0
Aug	-0.77	-0.76	-1.1	0.0
Sep	-0.71	-0.70	-1.4	0.0

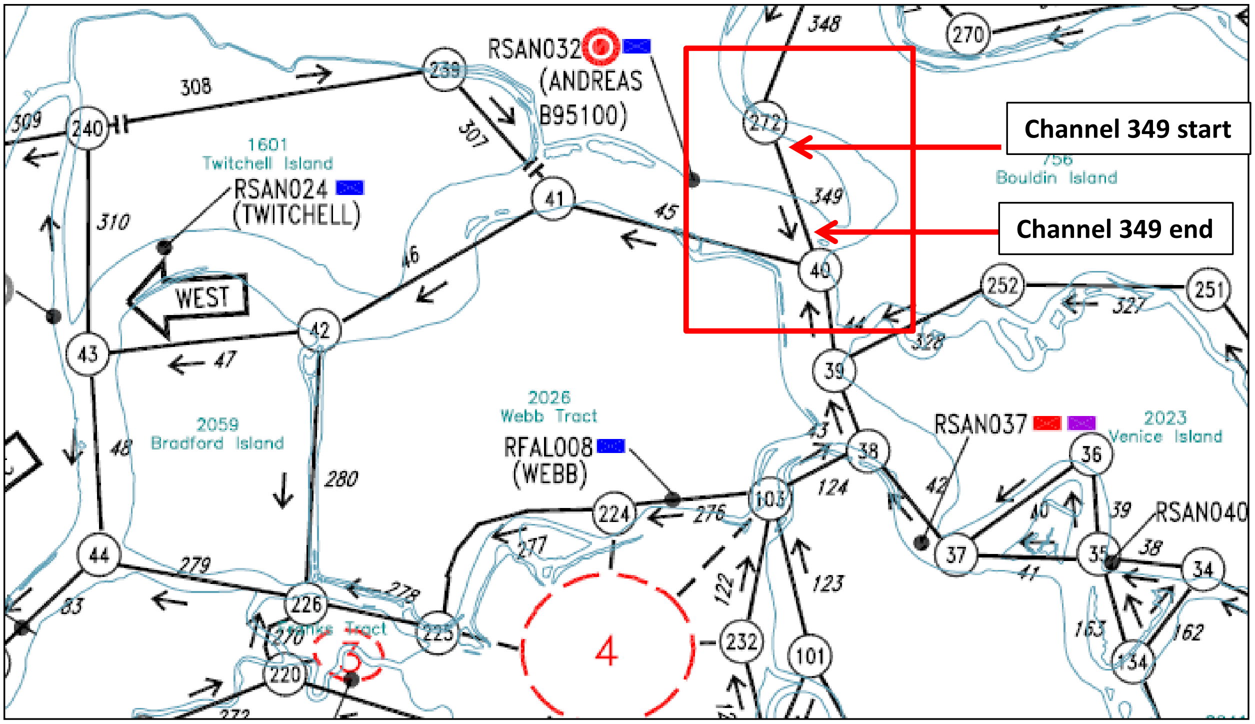


Figure 4-1 Nomenclature for the DSM2 model output locations analyzed for velocity used in this document.

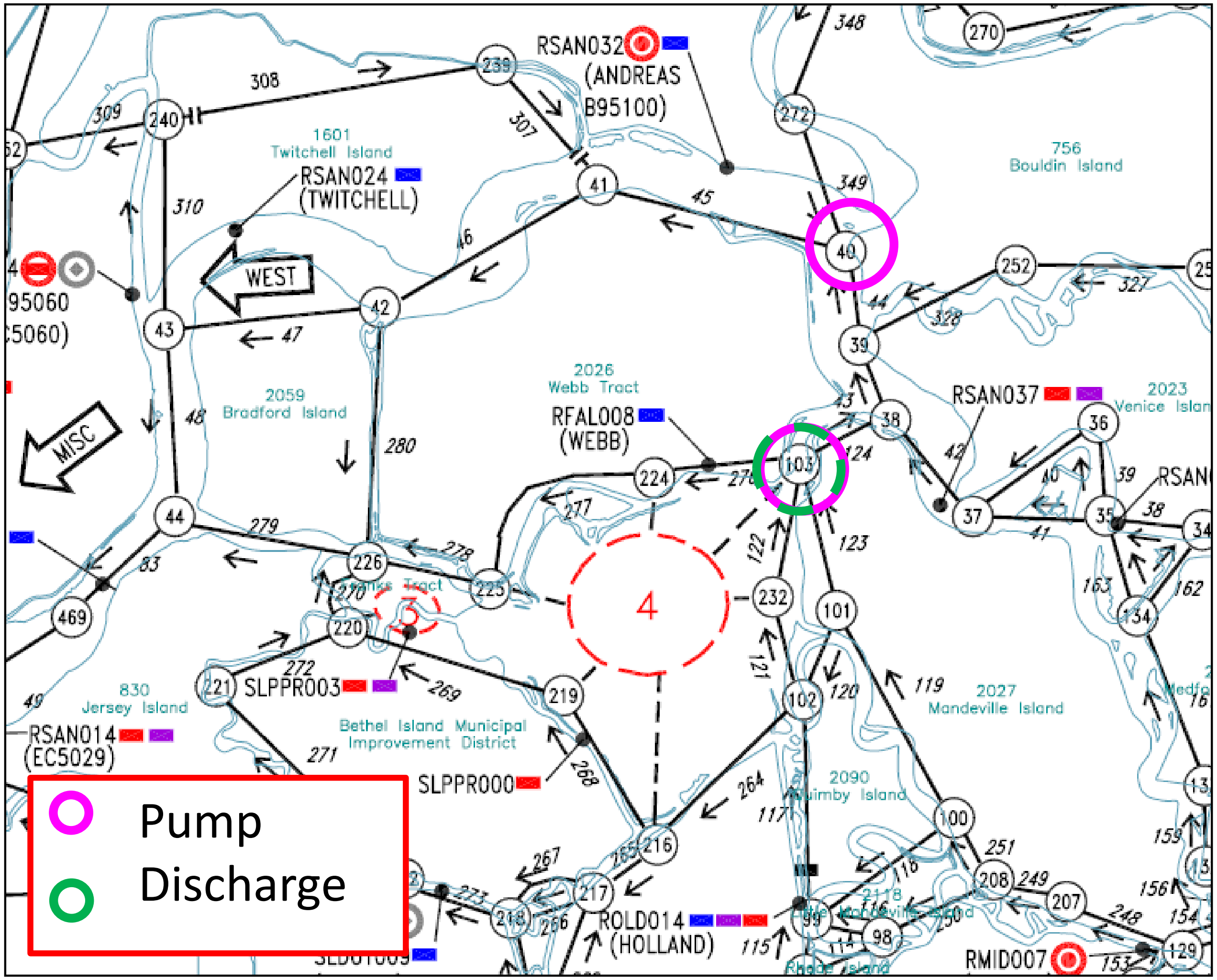


Figure 4-2 Pumping and discharge locations on Webb Tract for the Project. These occur at DSM2 nodes.

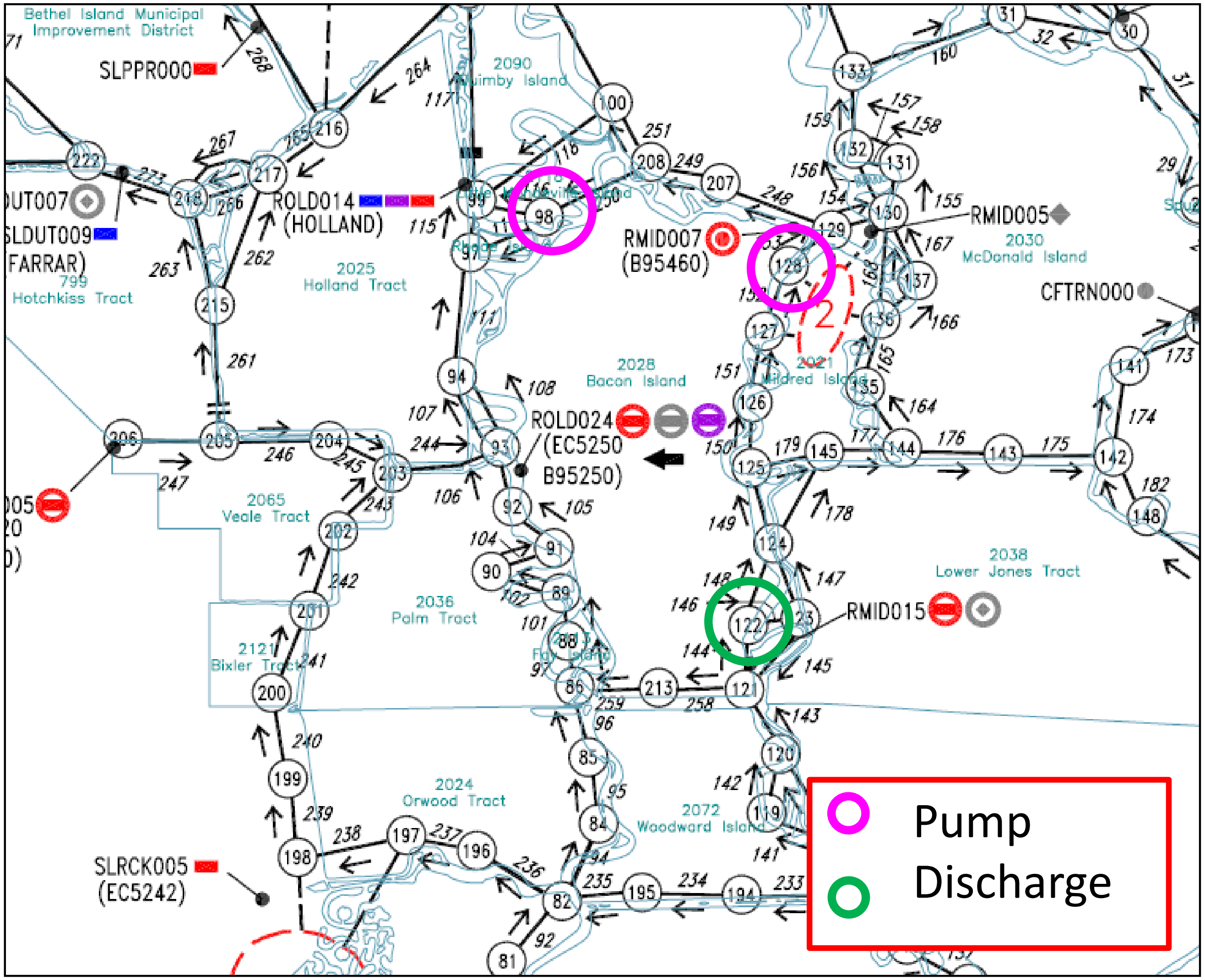


Figure 4-3 Pumping and discharge locations on Bacon Island for the Project. These occur at DSM2 nodes.

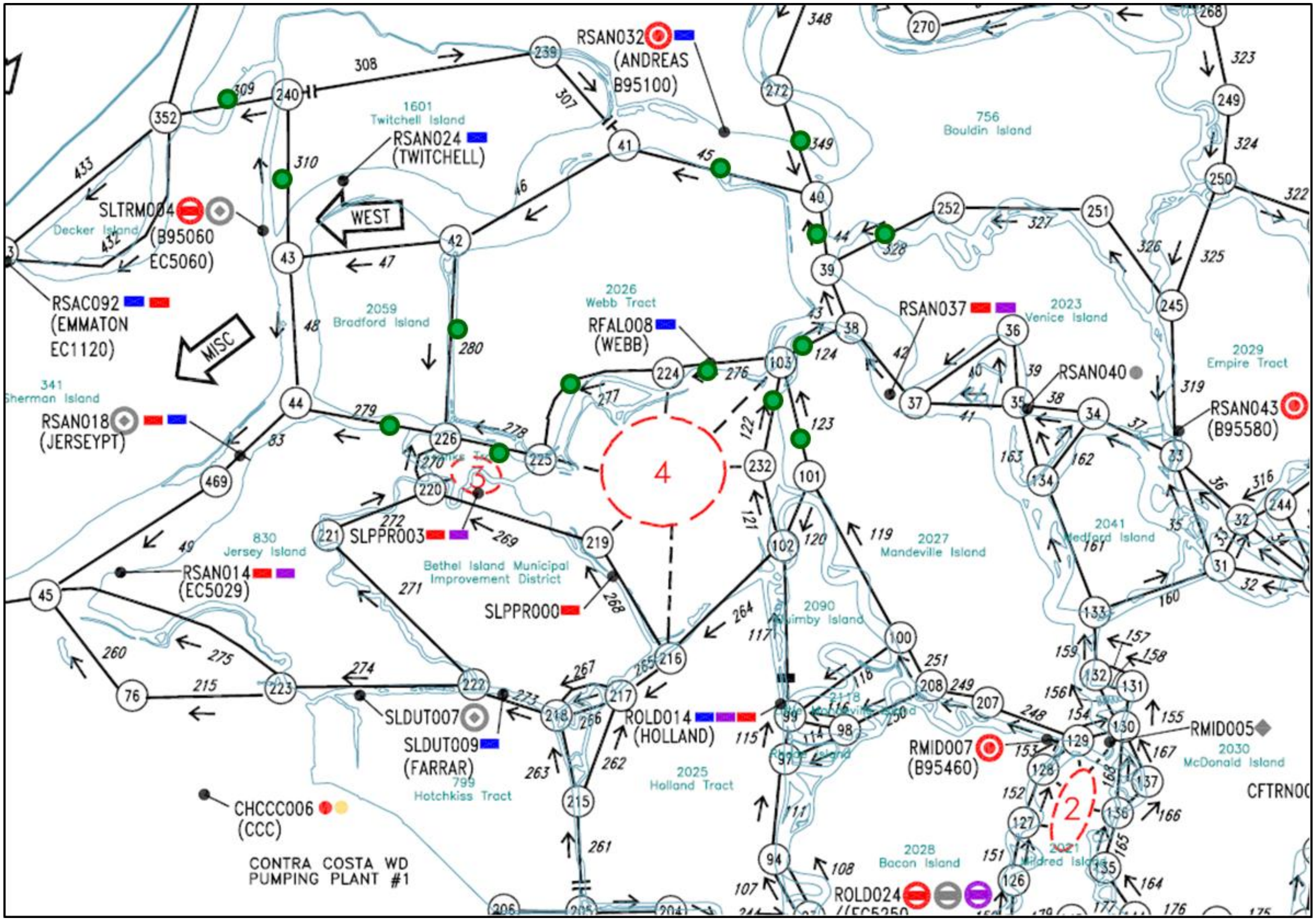


Figure 4-4 This figure is a section of the DSM2 grid where the model output channels near Webb Tract are located. Green dots indicate output locations. See Table 4-1 for nomenclature.

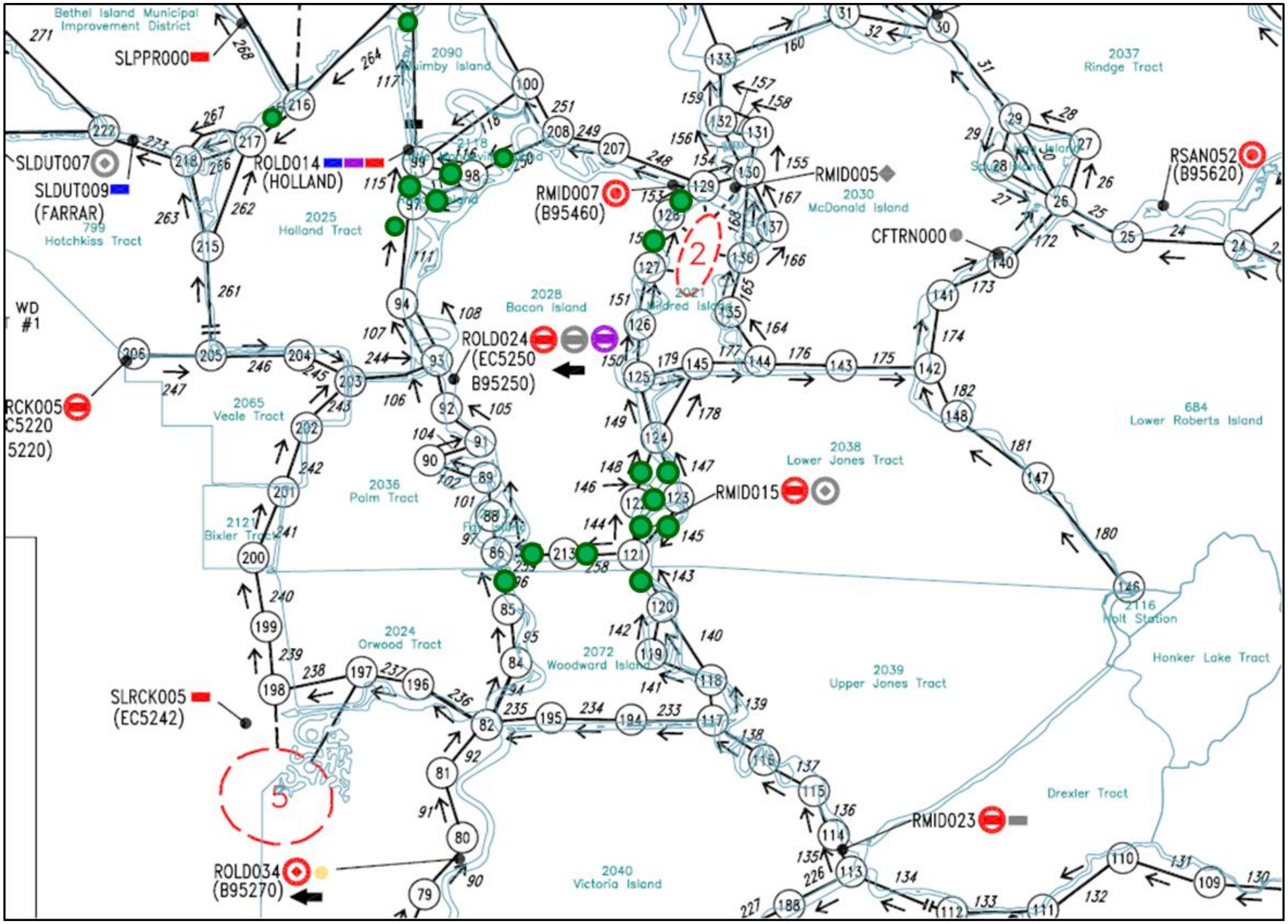


Figure 4-5 This figure is a section of the DSM2 grid where the model output channels near Bacon Island are located. Green dots indicate output locations. See Table 4-1 for nomenclature.

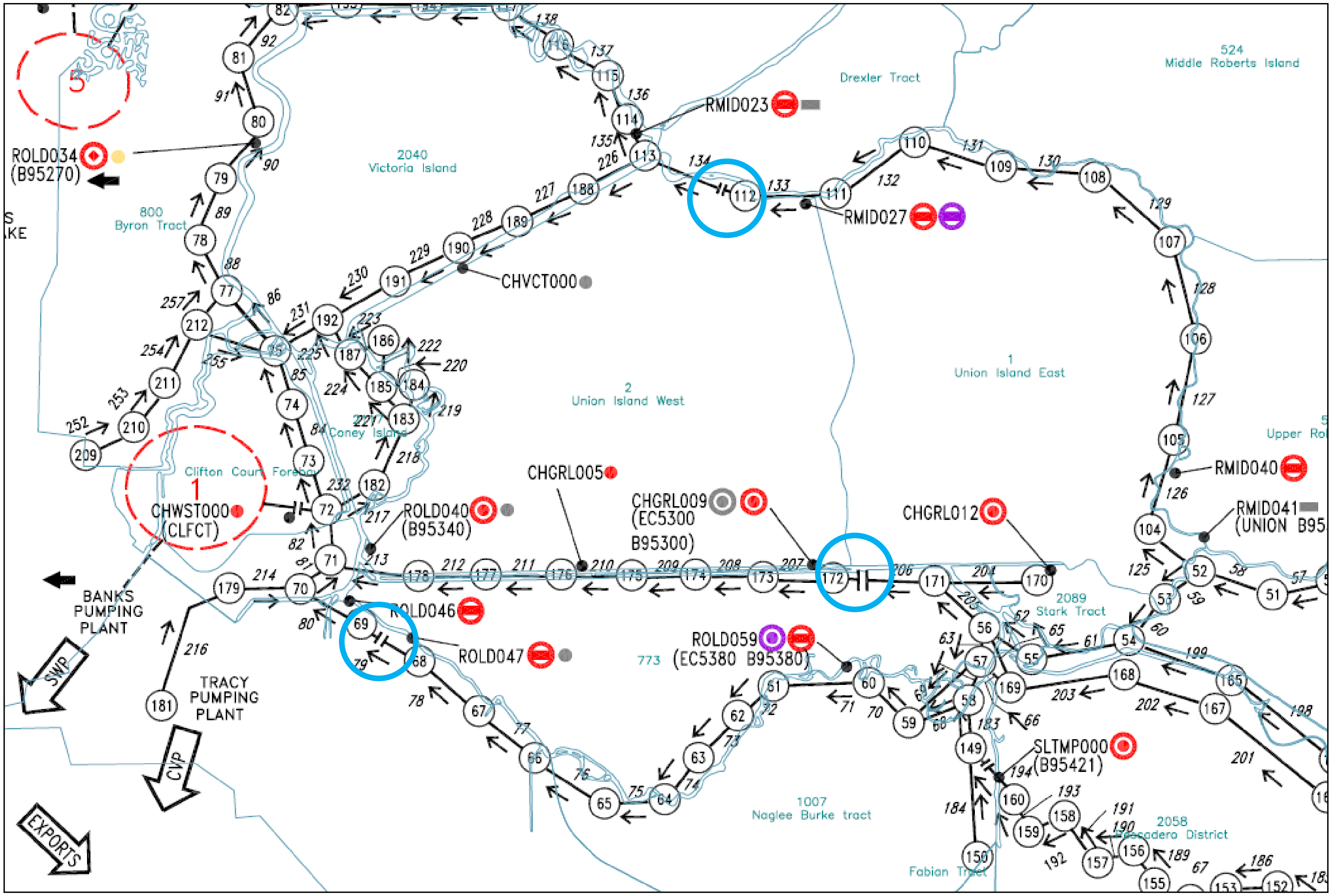
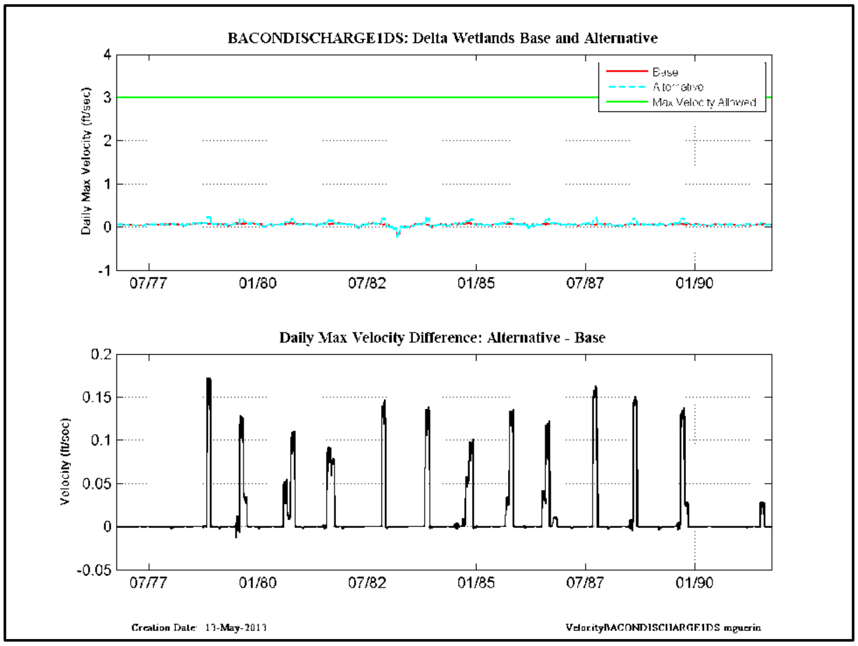


Figure 4-6 Modeled agricultural barrier locations where stage differences between the Base Case and the Alternative were analyzed.



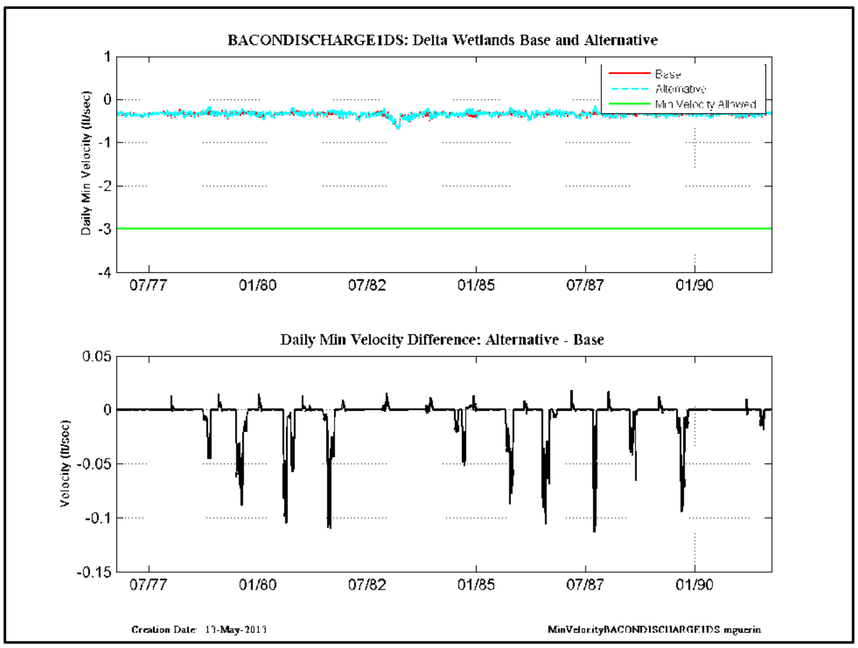
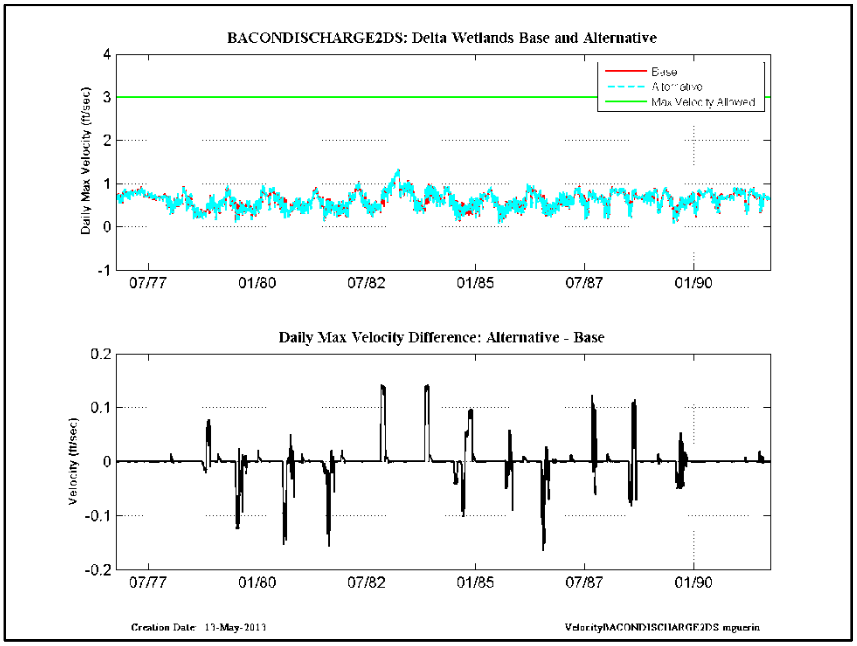


Figure 4-7 Velocities at the downstream end of the channel near the Bacon discharge location in Node 122, channel 148 (see Figure 4-3).



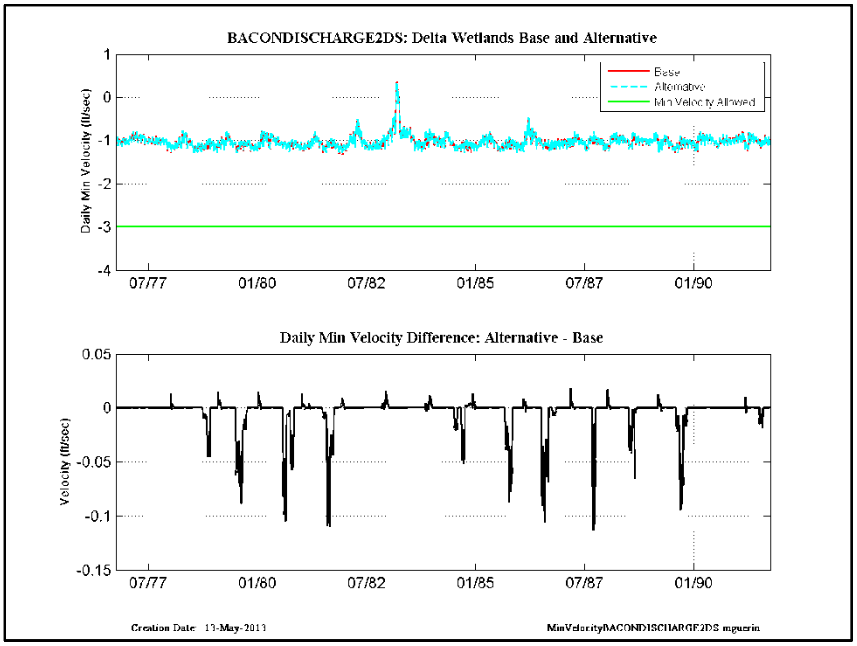
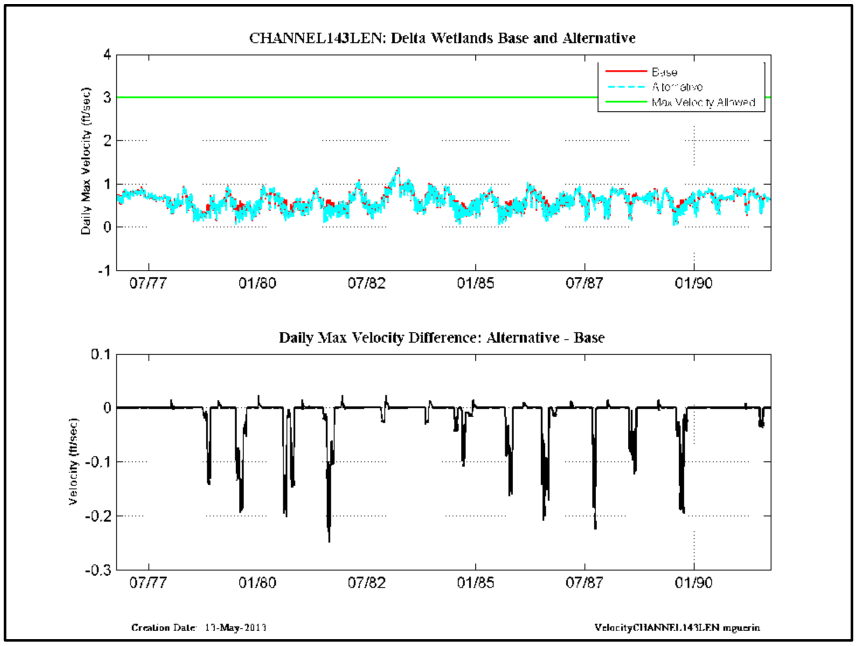


Figure 4-8 Velocities at the upstream end of the channel near the Bacon discharge location in Node 122, channel 144 (see Figure 4-3).



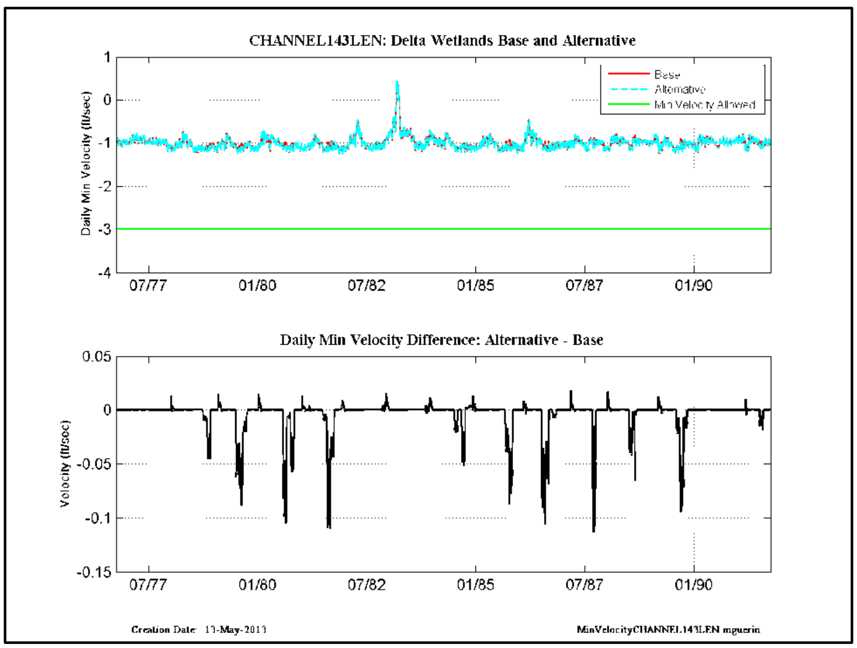
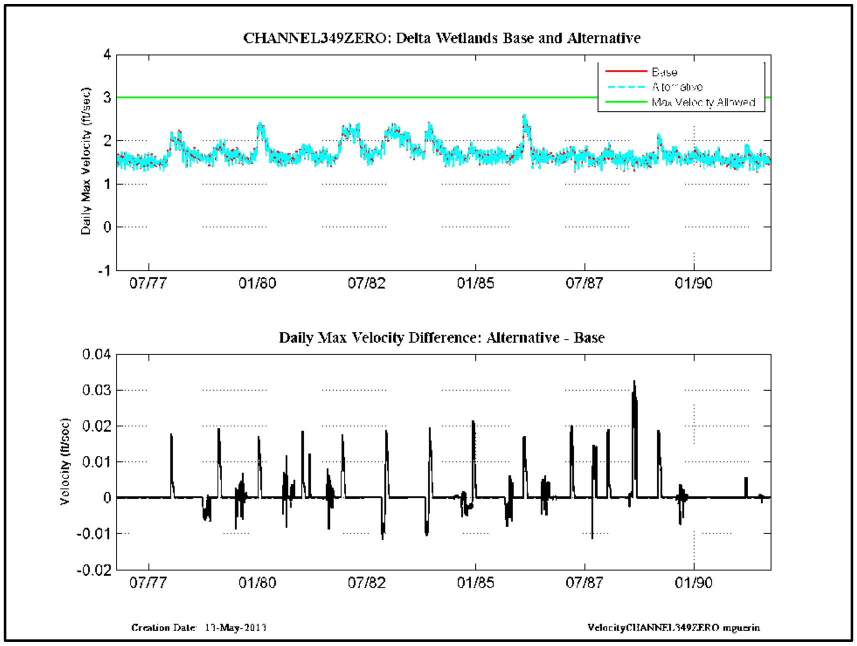


Figure 4-9 Velocities at the downstream end of channel 143 at the northeastern end of Woodward Island (see Figure 4-5).



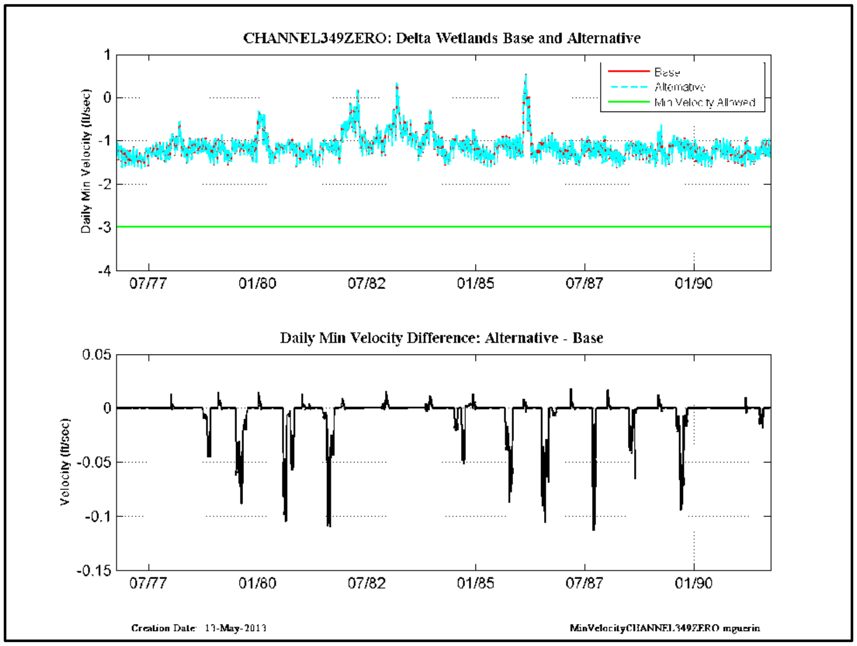


Figure 4-10 Velocities at the upstream end of channel 349 near the mouth of the San Joaquin on the western side of Bouldin Island (see Figure 4-4).

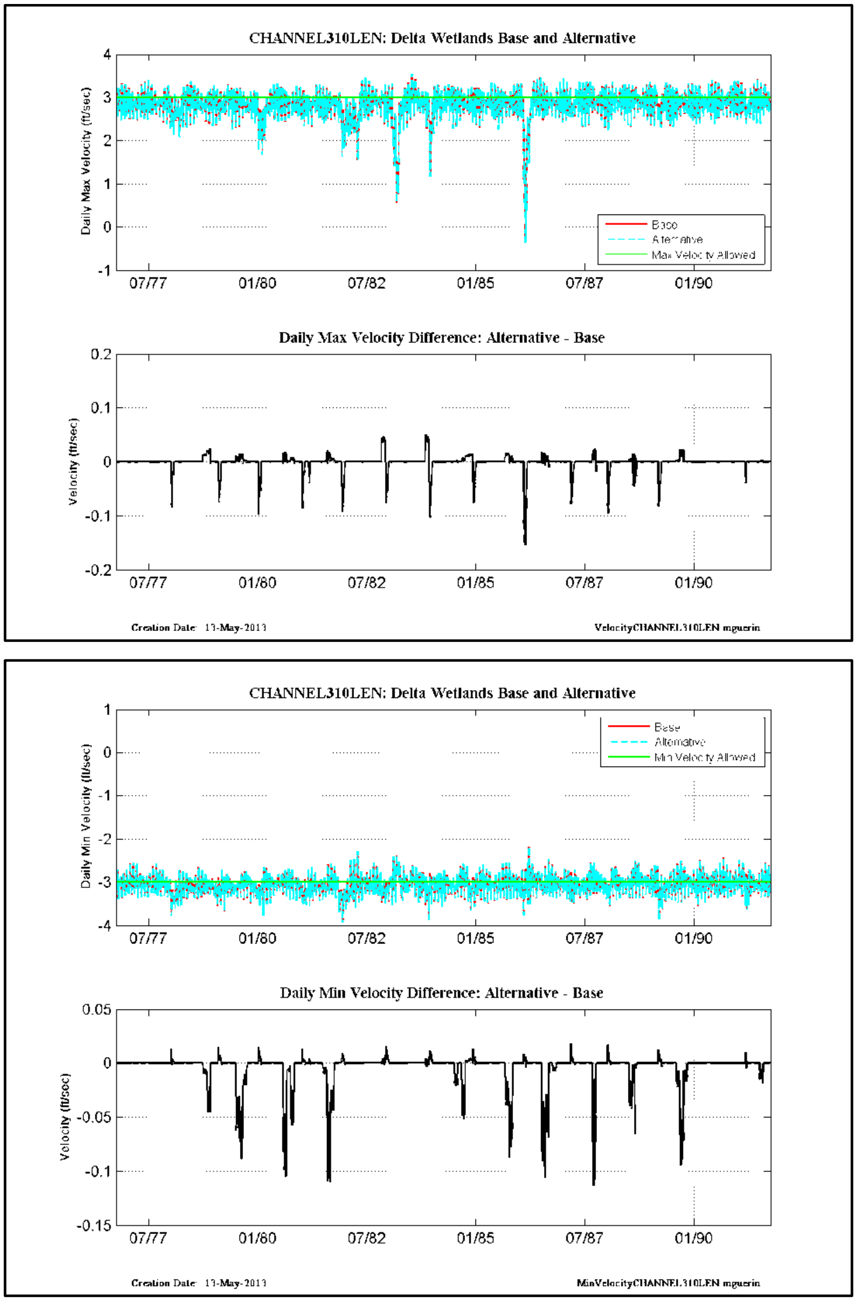


Figure 4-11 Velocities at the downstream end of channel 310 in Three Mile Slough (see Figure 4-4).

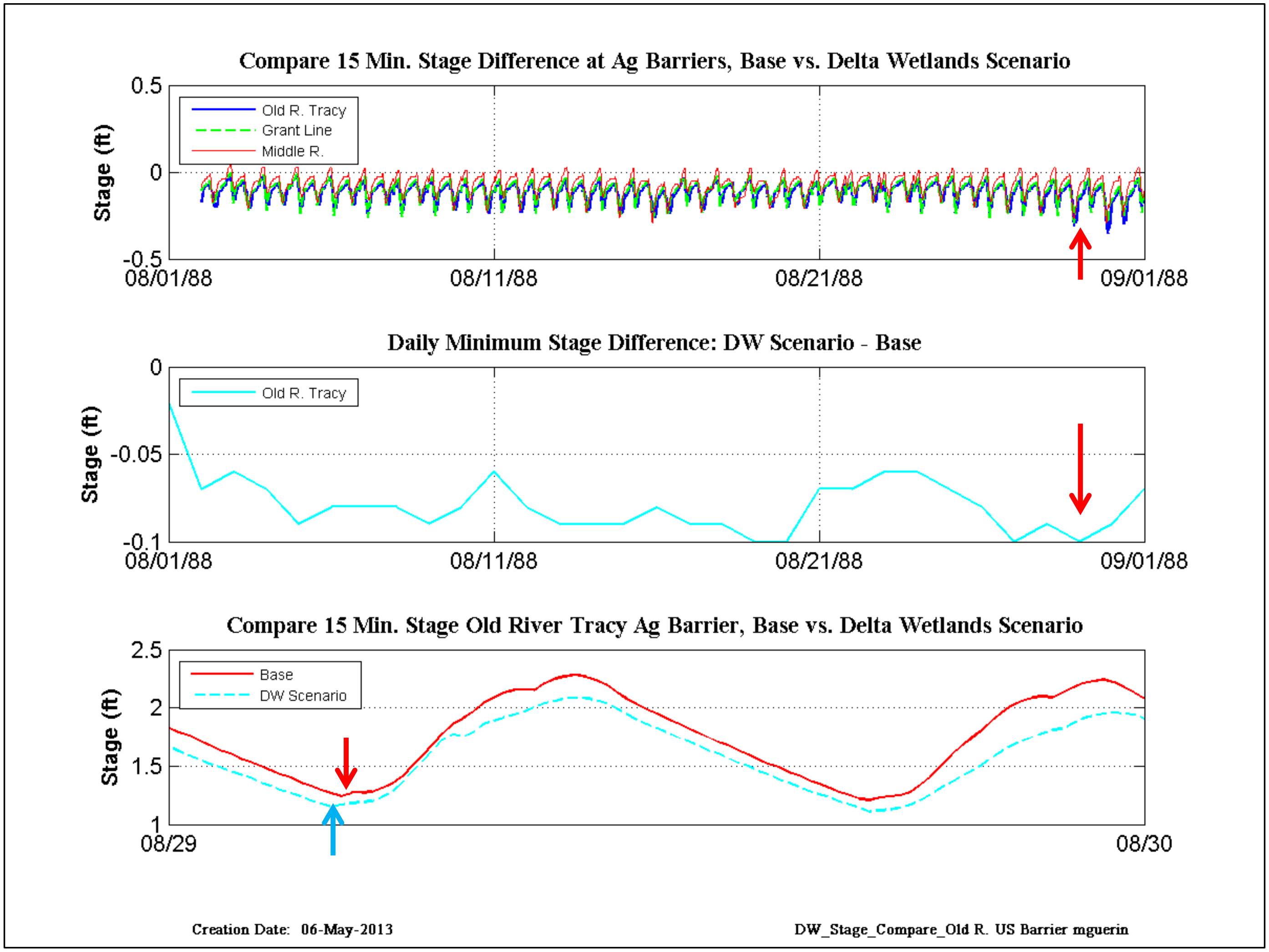


Figure 4-12 Illustration of the rationale for using daily minimum stage differences.

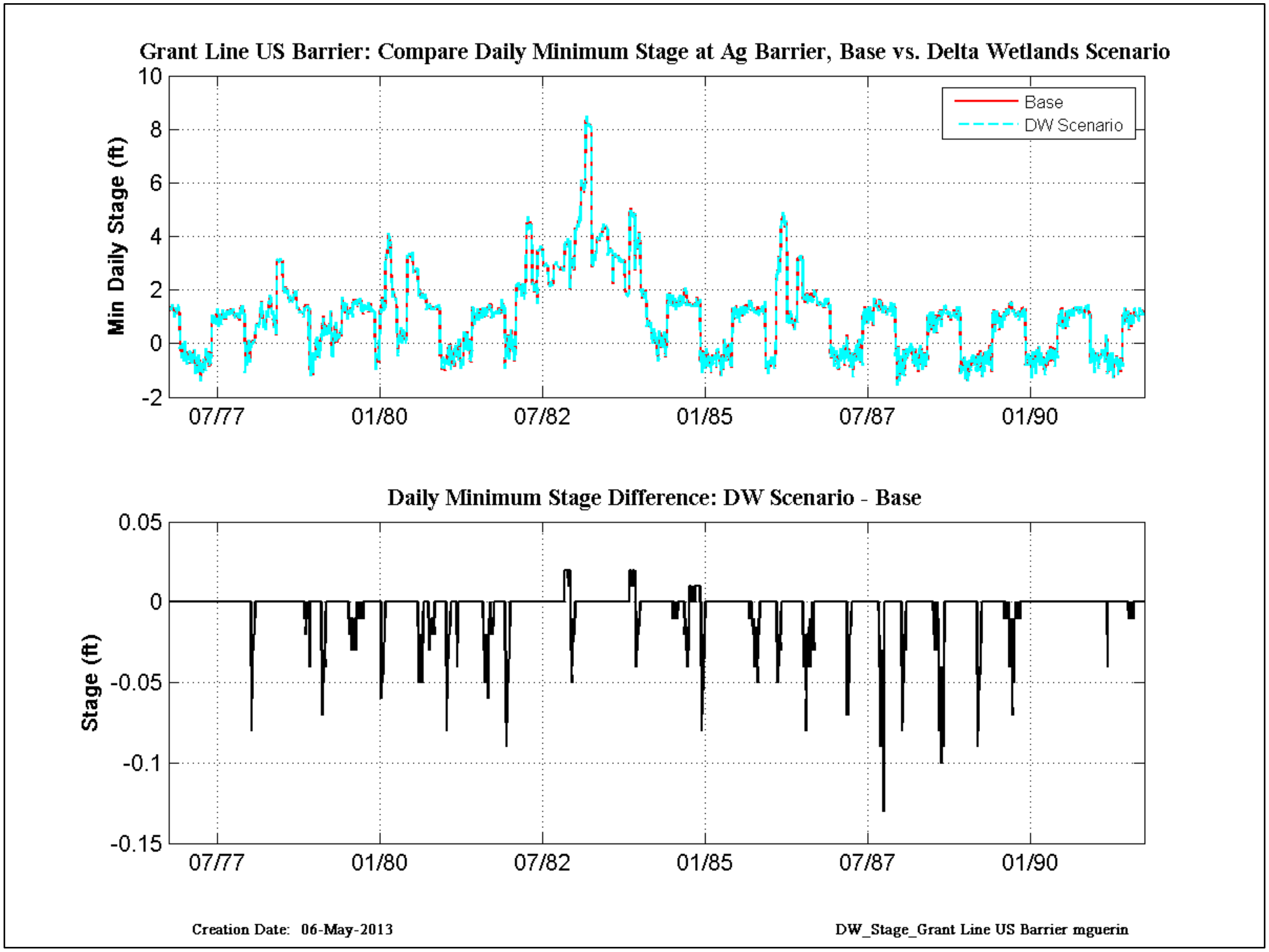


Figure 4-13 Comparison plots of daily minimum stage at the Grant Line barrier upstream location (upper plot) and the difference plot (Alternative scenario – Base Case).

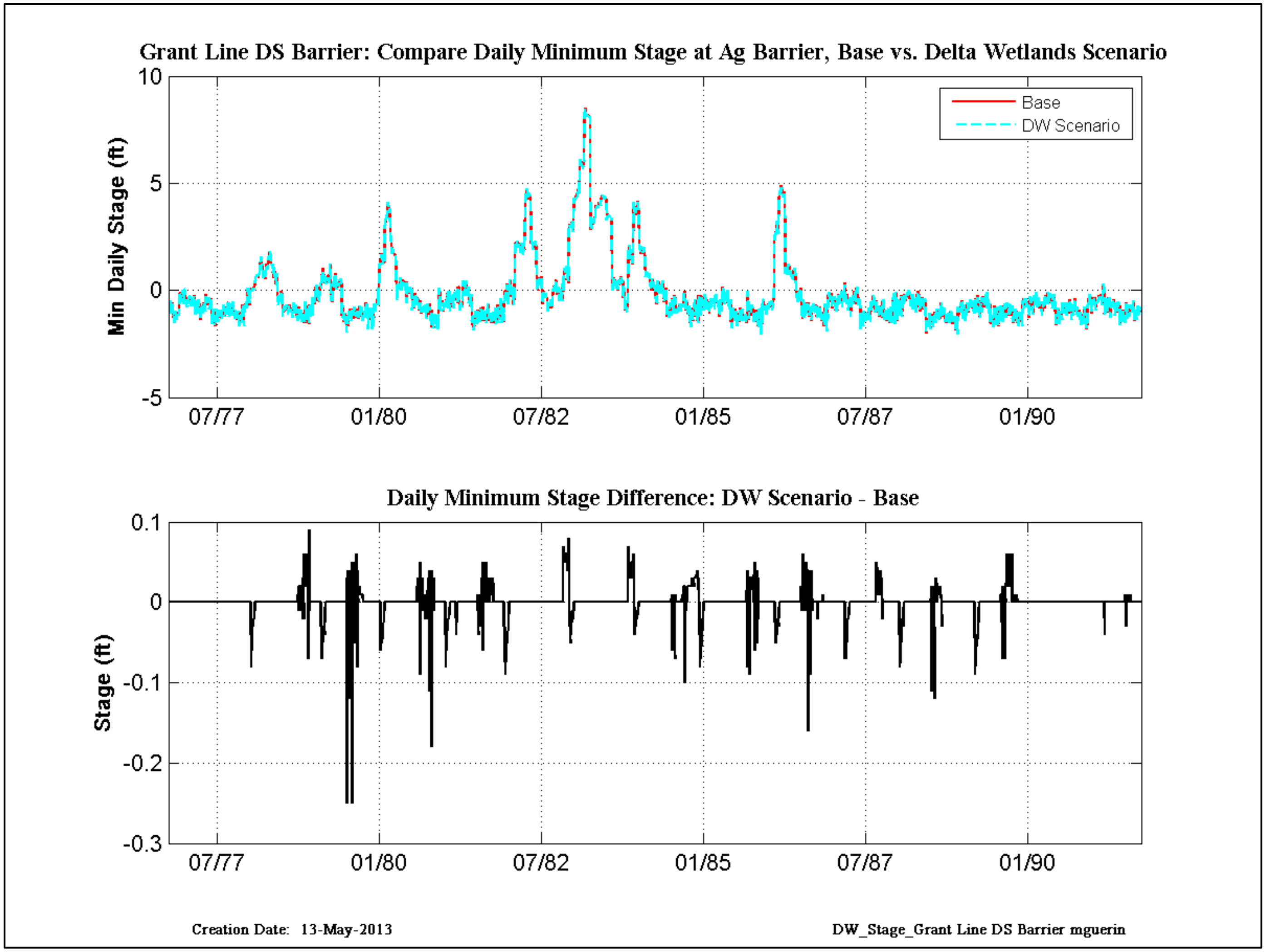


Figure 4-14 Comparison plots of daily minimum stage at the Grant Line barrier downstream location (upper plot) and the difference plot (Alternative scenario – Base Case).

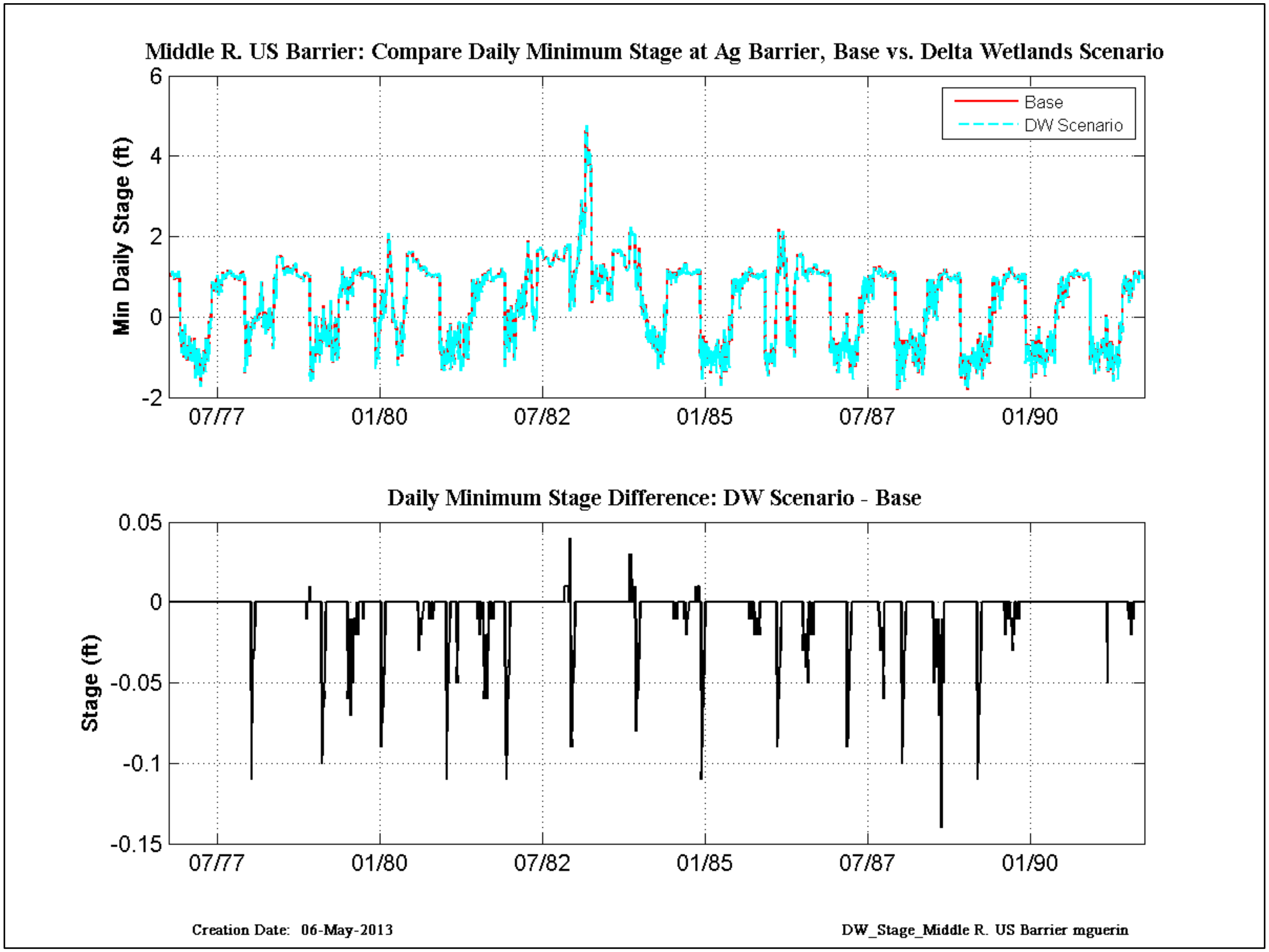


Figure 4-15 Comparison plots of daily minimum stage at the Middle River upstream barrier location (upper plot) and the difference plot (Alternative scenario – Base Case).

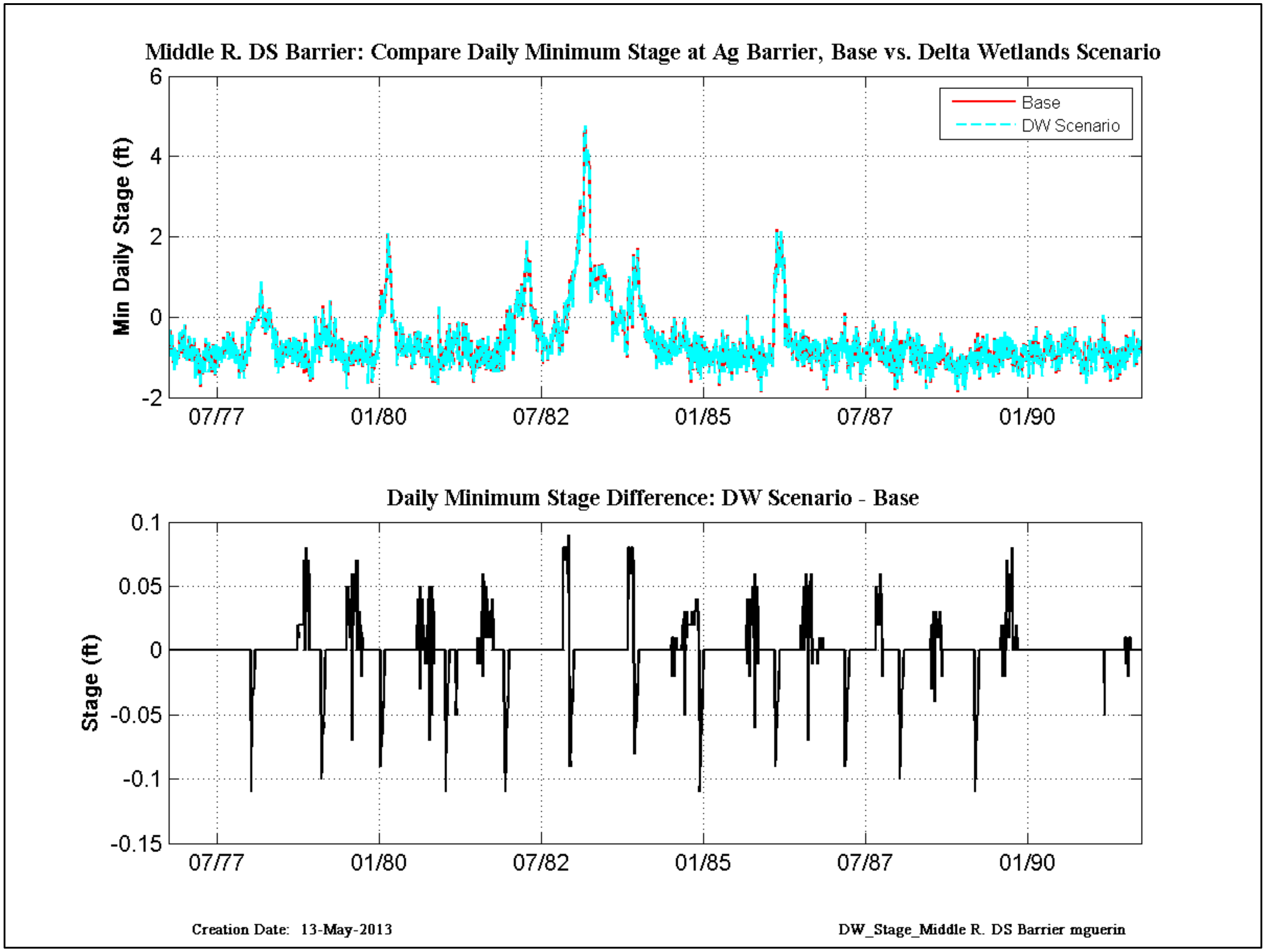


Figure 4-16 Comparison plots of daily minimum stage at the Middle River downstream barrier location (upper plot) and the difference plot (Alternative scenario – Base Case).

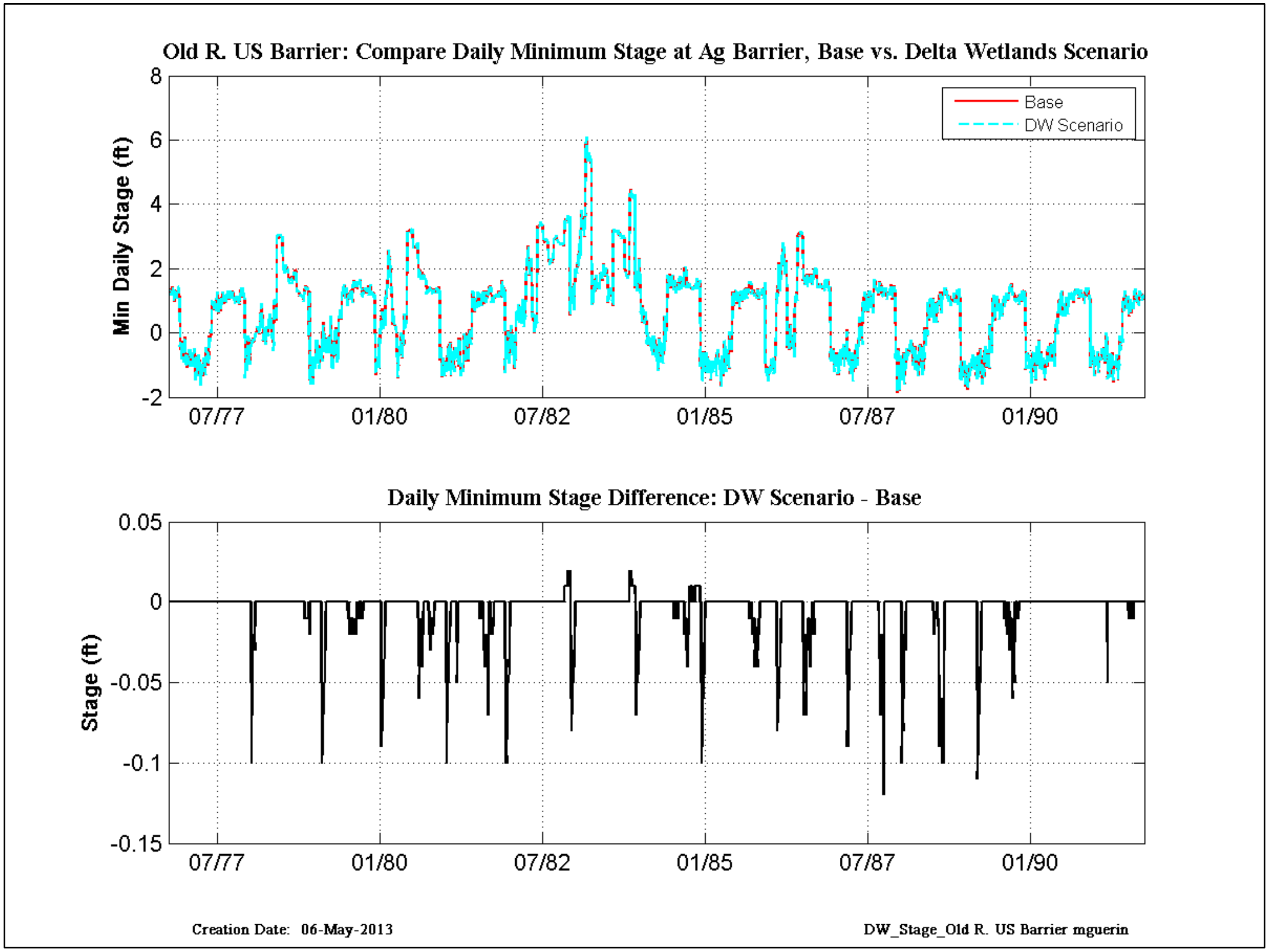


Figure 4-17 Comparison plots of daily minimum stage at the Old River upstream barrier location (upper plot) and the difference plot (Alternative scenario – Base Case).

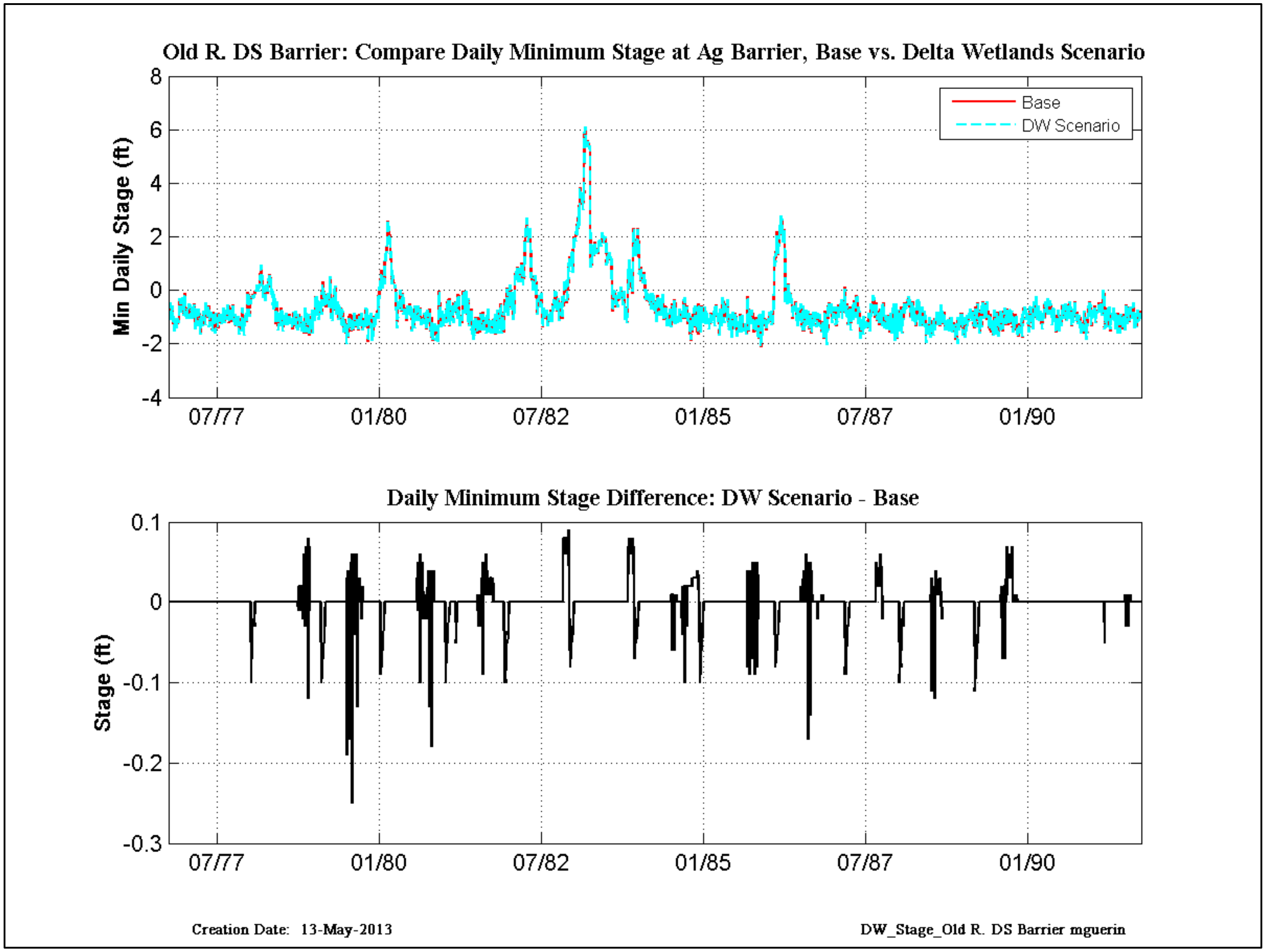


Figure 4-18 Comparison plots of daily minimum stage at the Old River downstream barrier location (upper plot) and the difference plot (Alternative scenario – Base Case.

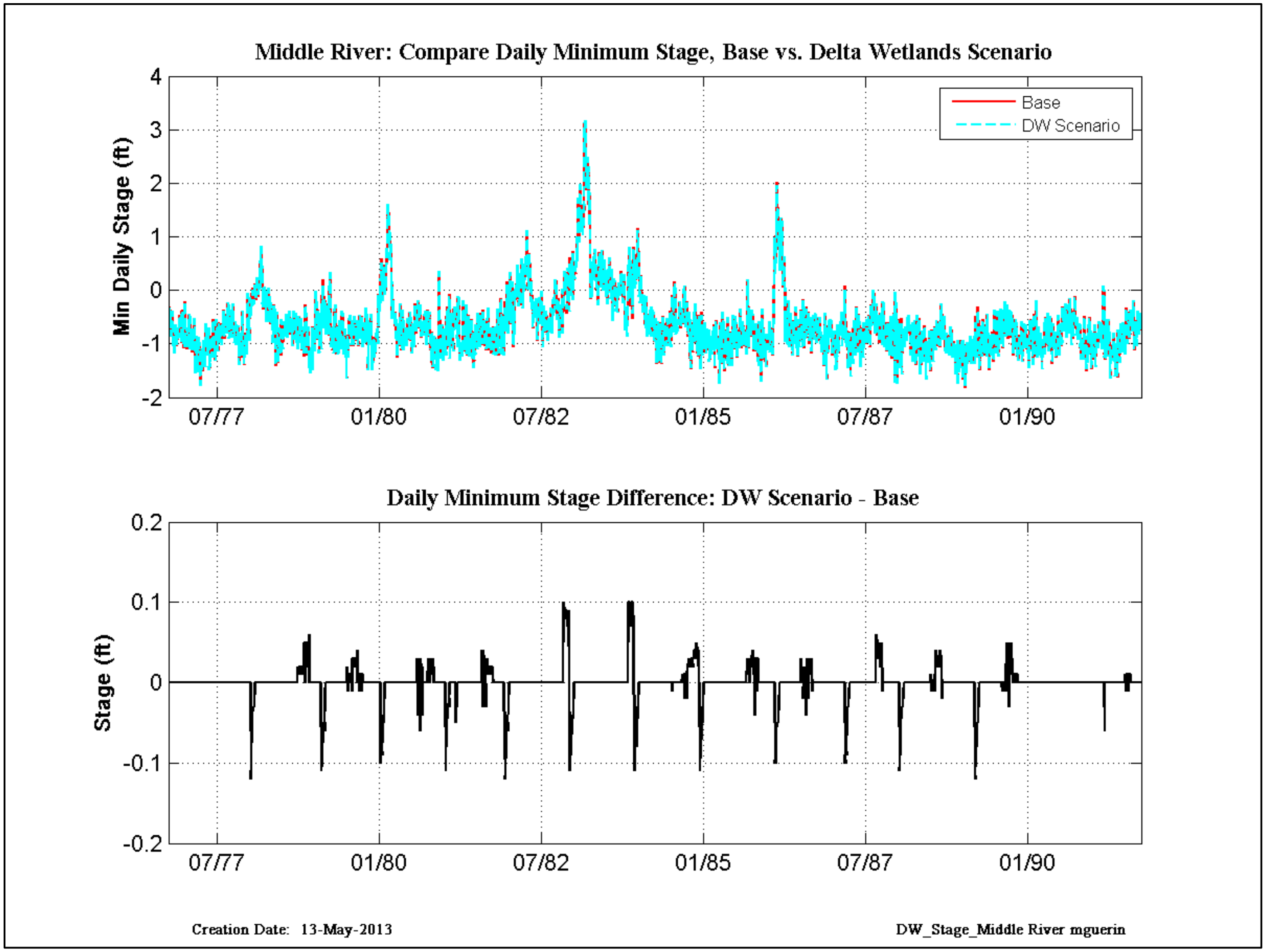


Figure 4-19 Comparison plots of daily minimum stage in Middle River at RMID015 (upper plot) and the difference plot (Alternative scenario – Base Case).

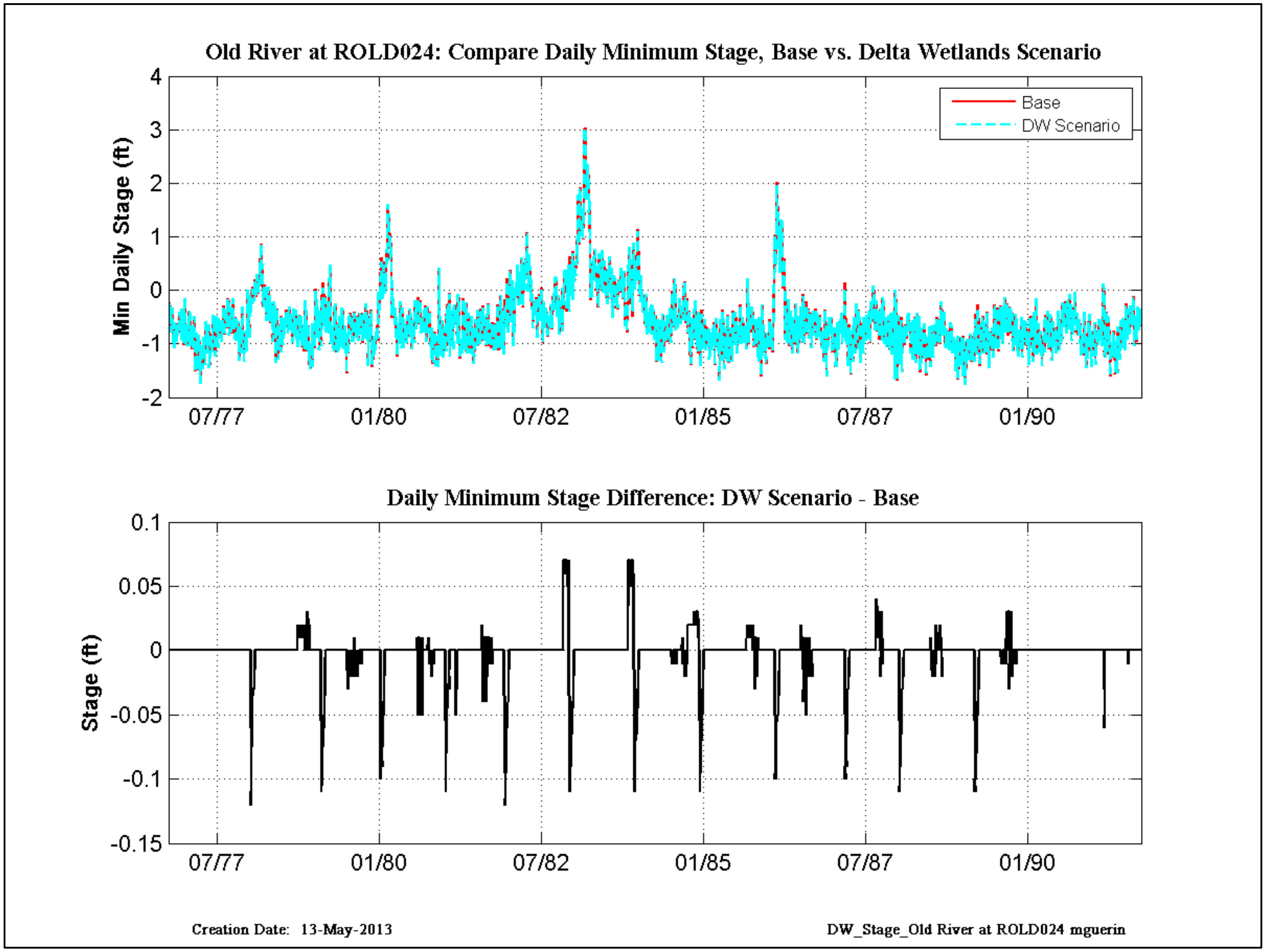


Figure 4-20 Comparison plots of daily minimum stage in Old River at ROLD024 (upper plot) and the difference plot (Alternative scenario – Base Case).

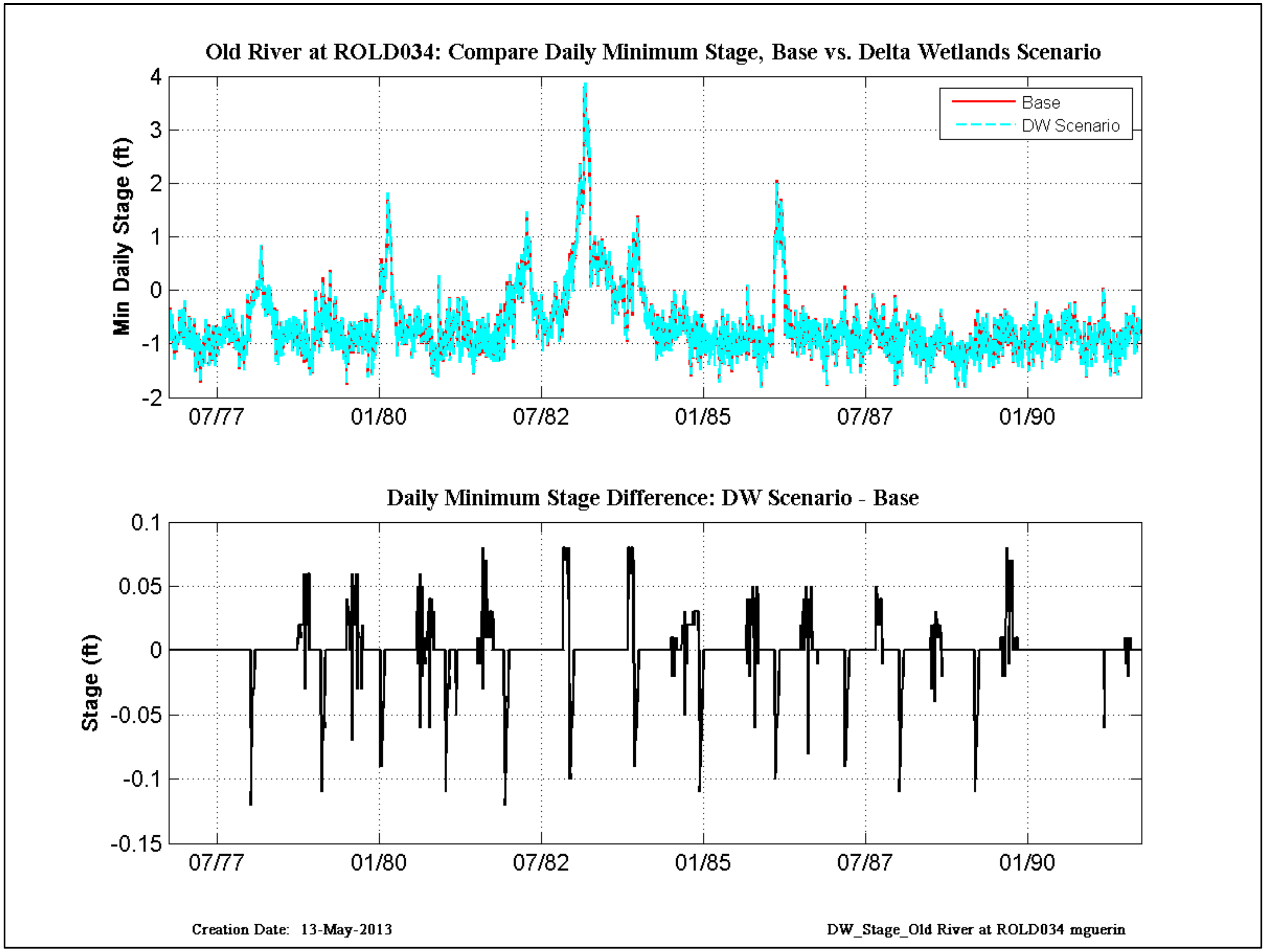


Figure 4-21 Comparison plots of daily minimum stage in Old River at ROLD034 (upper plot) and the difference plot (Alternative scenario – Base Case).

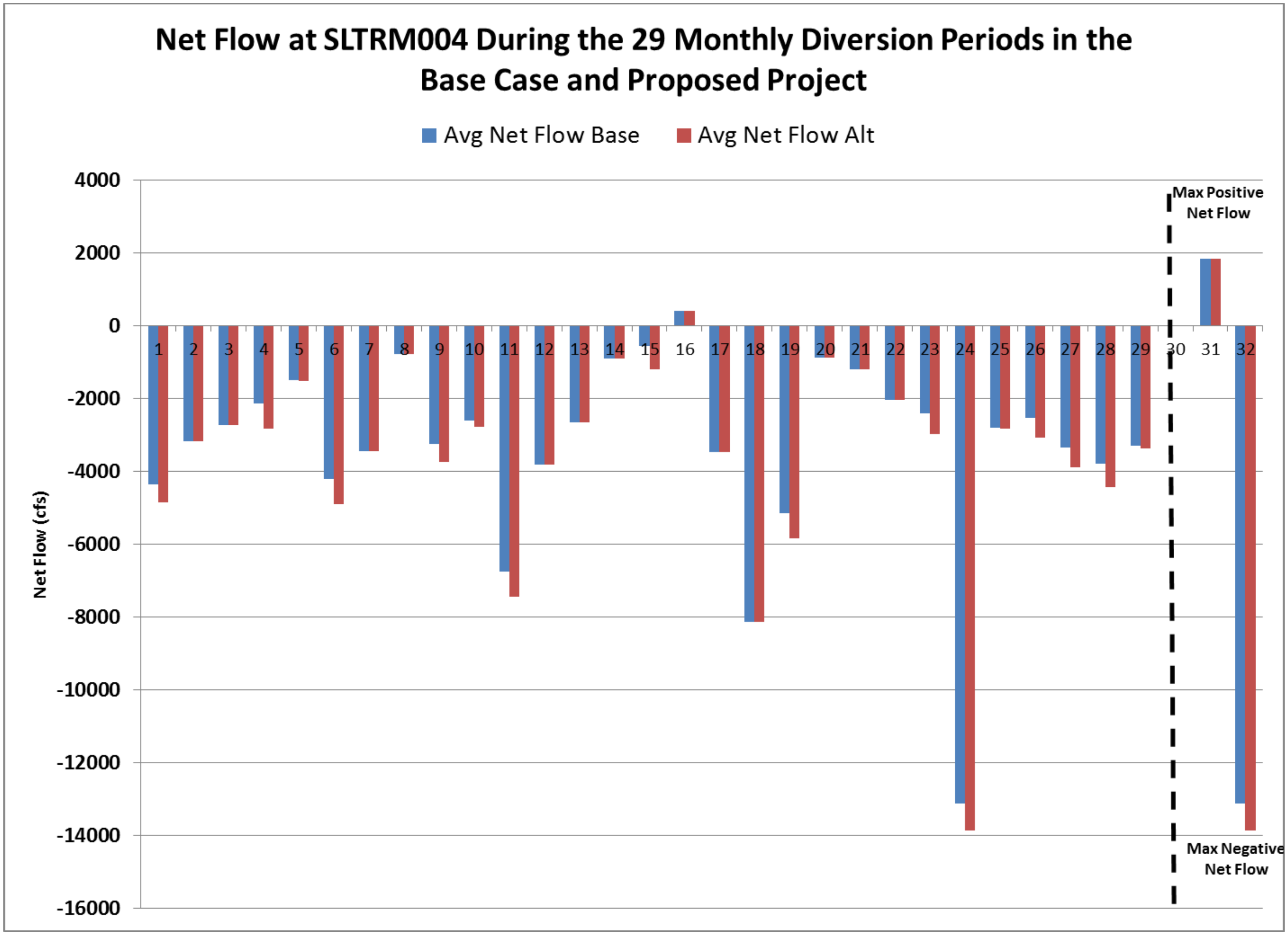


Figure 4-22 Monthly average net flow in Threemile Slough during Project diversion periods.

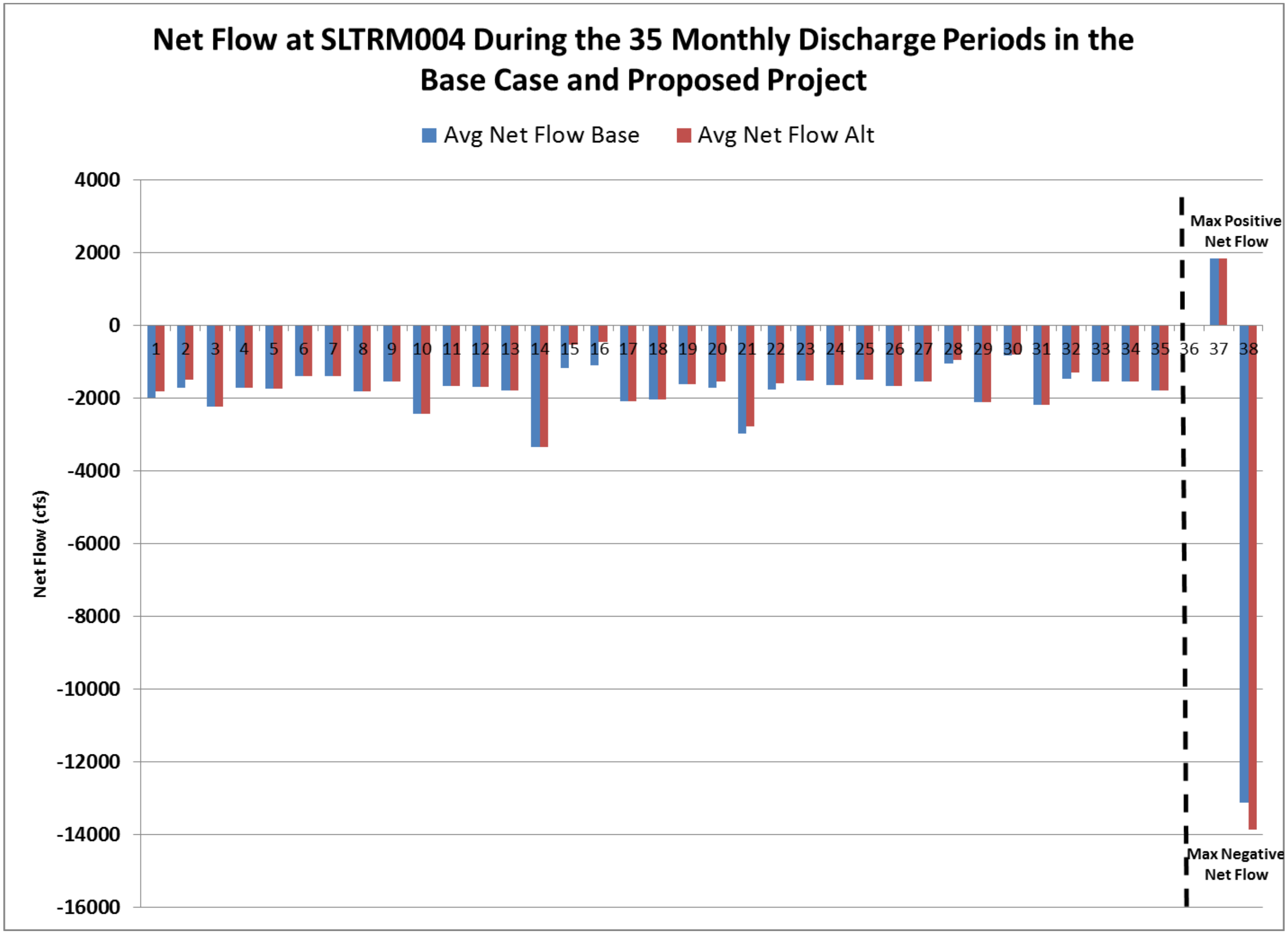


Figure 4-23 Monthly average net flow in Threemile Slough during Project discharge periods.

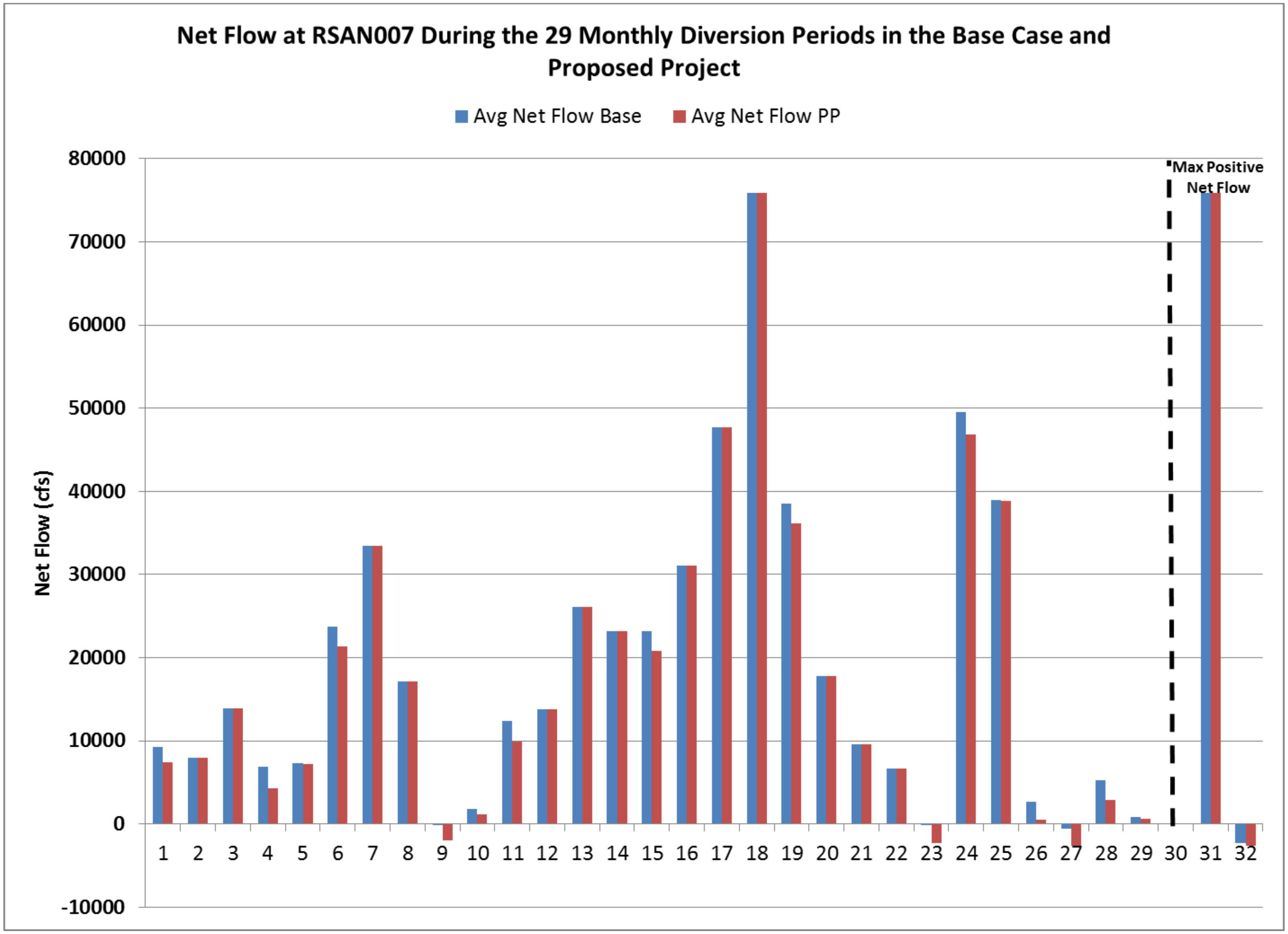


Figure 4-24 Monthly average net flow near Antioch during Project diversion periods.

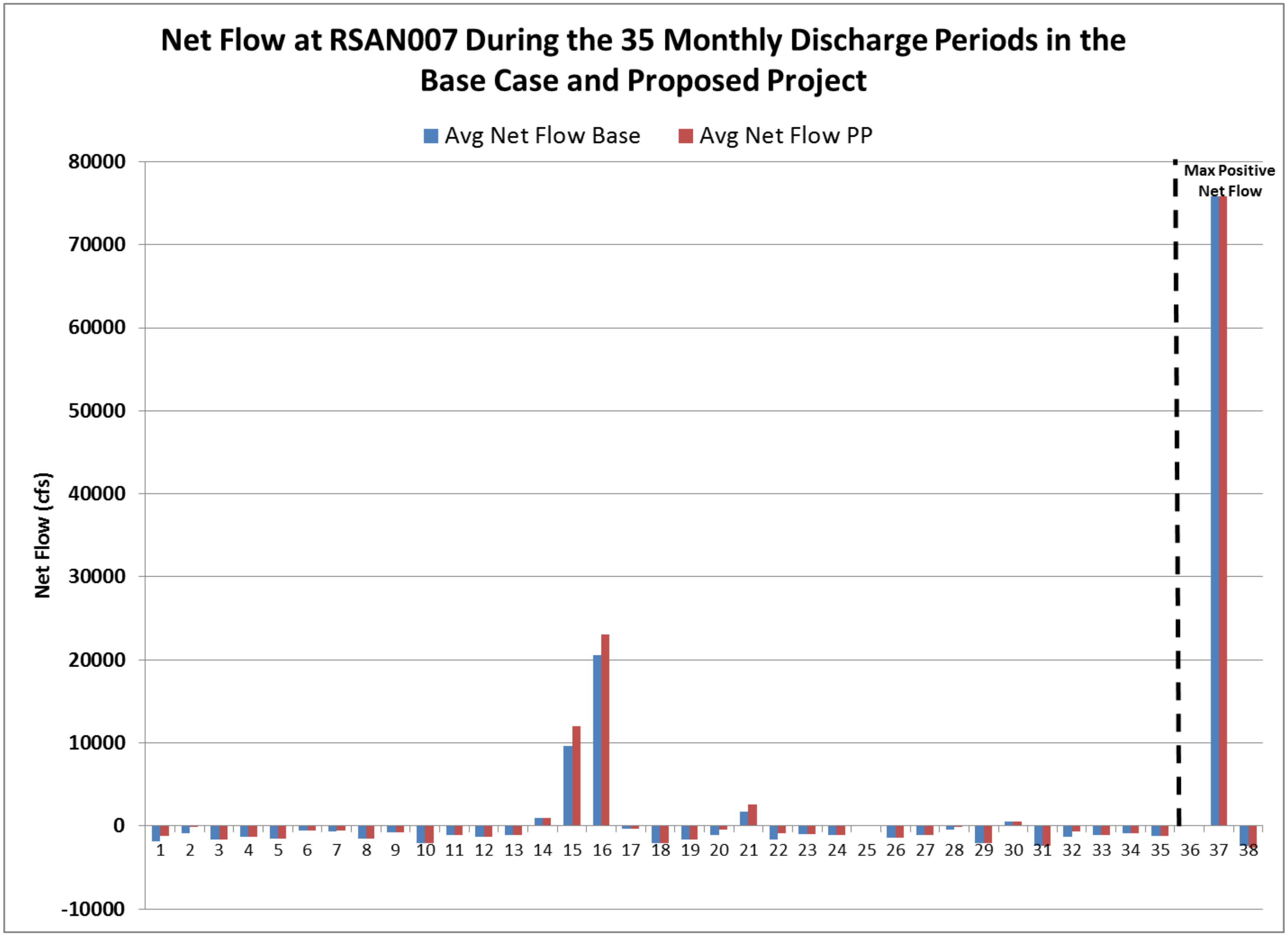


Figure 4-25 Monthly average net flow near Antioch during Project discharge periods.

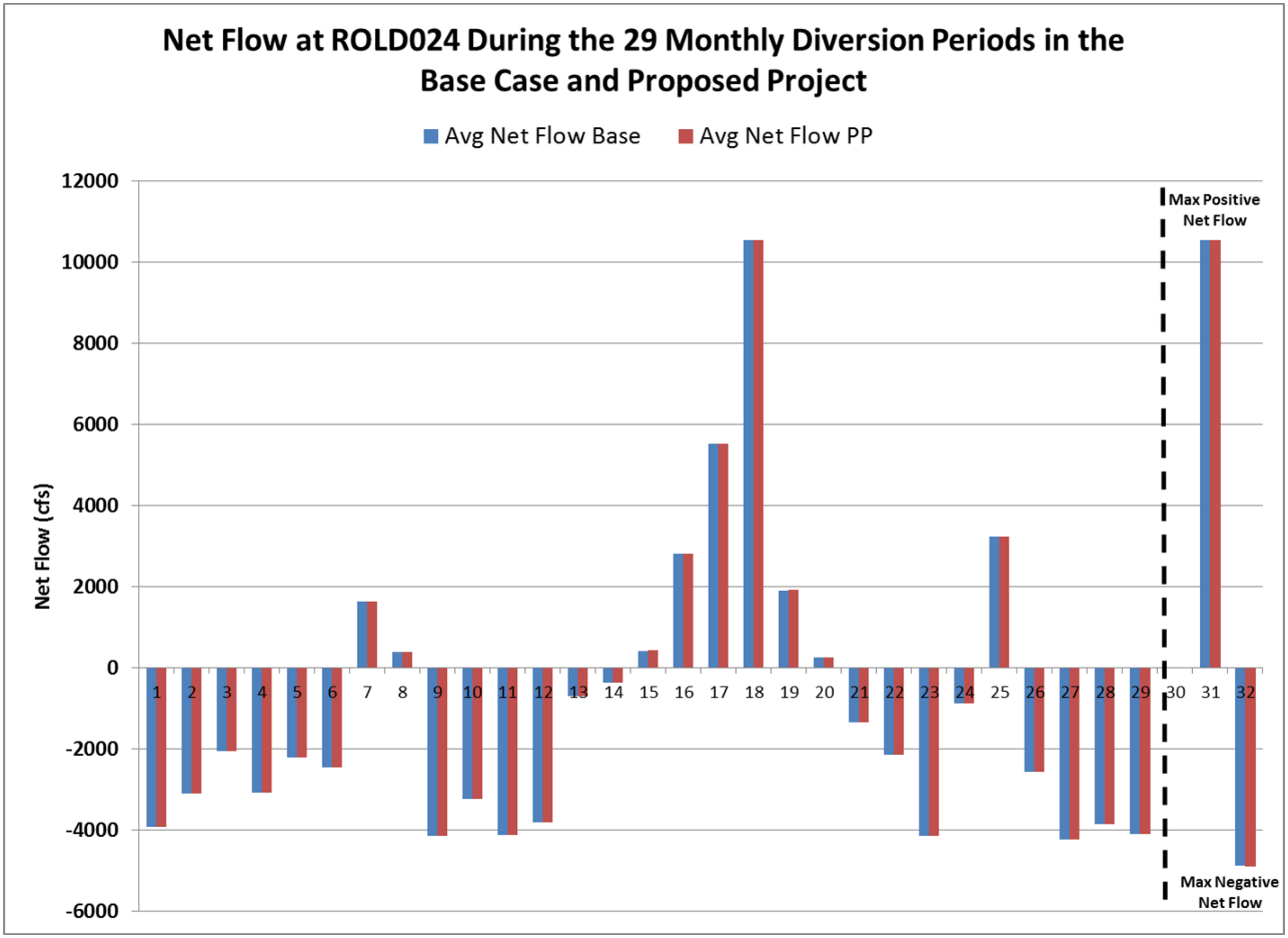


Figure 4-26 Monthly average net flow in Old River near Bacon Island during Project diversion periods.

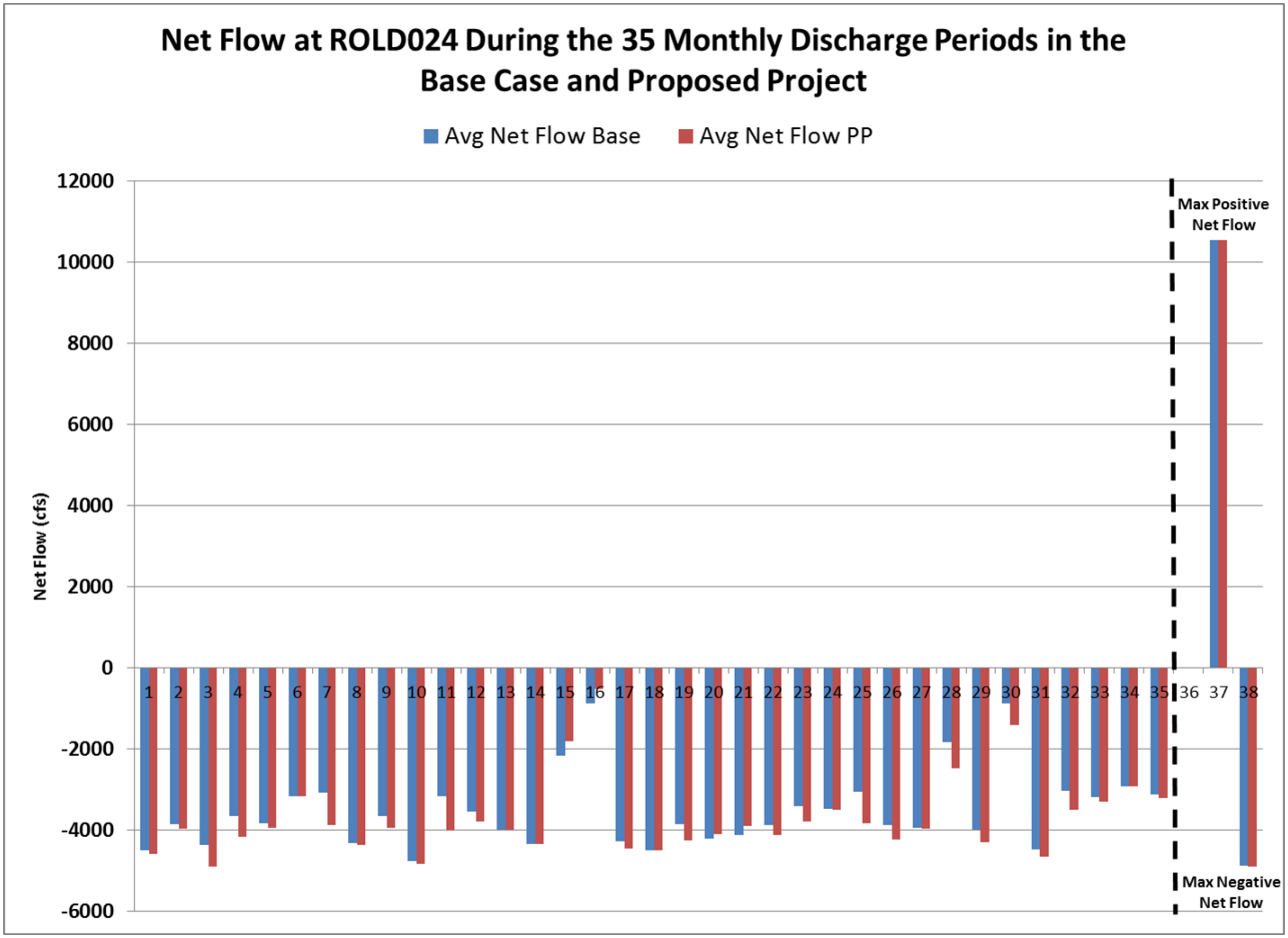


Figure 4-27 Monthly average net flow in Old River near Bacon Island during Project discharge periods.

5 Discussion

Analysis of the model results show that velocity changes due to Project diversions and discharges are unlikely to cause scour in the region affected by Project operations. This result was reached by analyzing DSM2 model output at a large number of locations in the near-field and at mid-scale distances from the Project. The analysis metric was that absolute velocity should be less than 3.0 ft/sec in the Alternative, and the analysis considered this by comparing Base Case and Alternative to this threshold velocity. The analysis methodology was conservative in analyzing potential Project effects as daily minimum and maximum velocities were used in calculating the metric.

The analysis showed velocity magnitude was most important during Project diversion periods. There was only one location, DSM2 Channel 310 in Threemile Slough, where the magnitude of the daily velocity exceeded the threshold, in this case -3.0 ft/sec, during the Diversion period. Both the Base Case and the Alternative regularly exceeded the threshold during these periods, 96% and 97% of the time, respectively. During these periods, the daily average percent change from Base did not exceed 1.6%, and the peak daily velocity increase was 2.9% (one event).

As mentioned in Sections 4.1 and 4.3, the analysis for potential stage effects was limited to decreases in daily minimum stage during Project discharge periods when a decrease in stage due to increased SWP export pumping may limit withdrawal of Delta water for agricultural purposes or for other potential uses in the south Delta. However, note that Project withdrawals that decrease stage during high flow periods may decrease the likelihood of levee overtopping events.

As discussed in Section 4.1, the metric for analyzing the potential for the Project to impact Delta stage levels is the percent change from Base on a Monthly Average basis. This metric has been used in numerous planning studies, for example in the Franks Tract Project (RMA, 2010). The analysis methodology was conservative in determining potential Project effects, in that daily minimum stage was calculated.

Analysis of the potential for the Project to decrease stage at the three south Delta agricultural barriers and at three additional locations on the Old+Middle River corridor yielded that at both the upstream and downstream barrier locations and the Old+Middle River locations, the percent change from Base was less than 1.6% on a monthly average basis and the monthly average difference in stage was -0.1 ft or less.

For monthly average net flow calculations, three locations were identified (DEIR/EIS, 2000) as representative of potential net flow changes in the Delta due to Project operations. In two of these locations, Project operations do not increase the monthly average net flow above the maximum Base Case monthly average net flow. At the third location in Threemile Slough, there was one month in the 16-year study period where the monthly average net flow during a diversion period in the Alternative was 5.6% greater than the maximum monthly average net flow in the Base Case. Neither velocity changes nor stage changes indicated adverse consequences related to Project operations occurred during this event.

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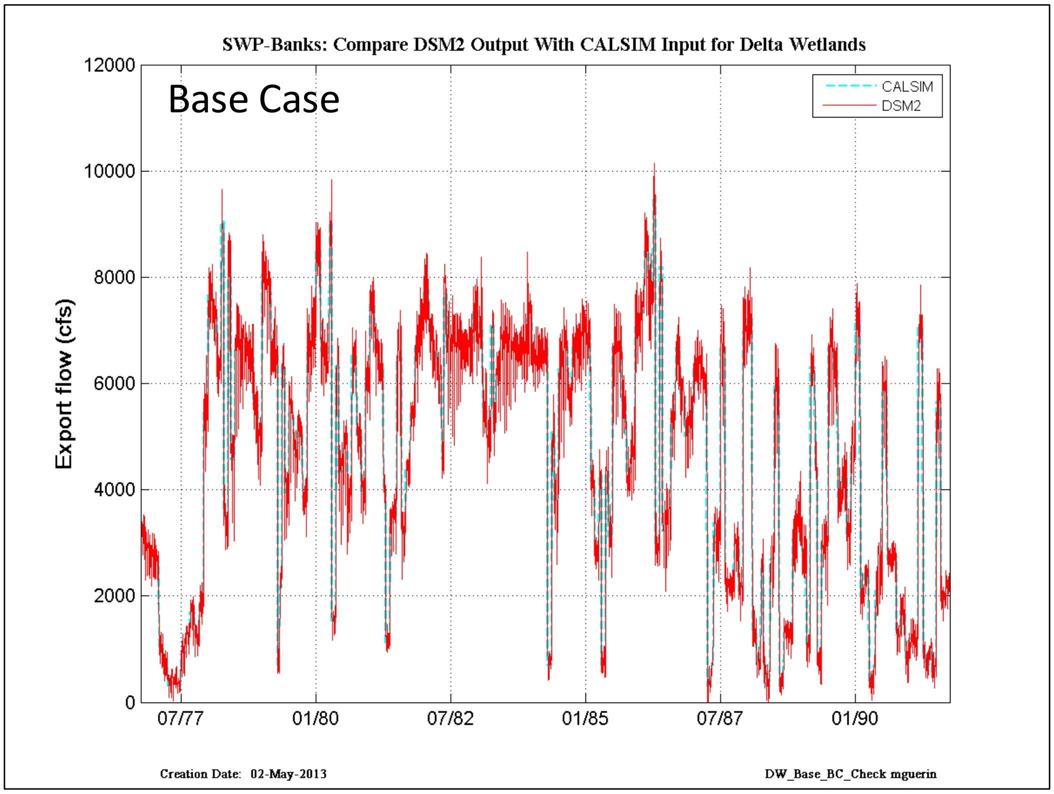
7 Appendix

7.1 Boundary conditions checks

Preprocessors for DSM2 are used to extract CALSIM time series and create DSM2 time series. For the Sacramento River inflow boundary, the CALSIM monthly results are converted to daily time series and smoothed to remove the step change between months. For San Joaquin River inflow boundary and the SWP and CVP export boundaries, the preprocessor implements a VAMP routine that changes the three monthly time series to daily time series and additionally implements the VAMP ramping from April 15 – May 15 that is not implemented in CALSIM.

For each of the major export locations (SWP and CVP) and all of the inflow boundaries, MATLAB routines were prepared to extract and plot monthly time series to compare the CALSIM output with DSM2 output to ensure that the preprocessors were implemented correctly and the input files were specified correctly. For the Vernalis and export time series, the preprocessor output was compared with DSM2 output. At the Yolo Bypass location, the DSM2 model output shows the effects of the strong tidal influences so flows will not match the CALSIM output. However, the CALSIM and DSM2 output show the same general trends.

Figures illustrating the comparisons are found below (Figure 7-1to Figure 7-8).



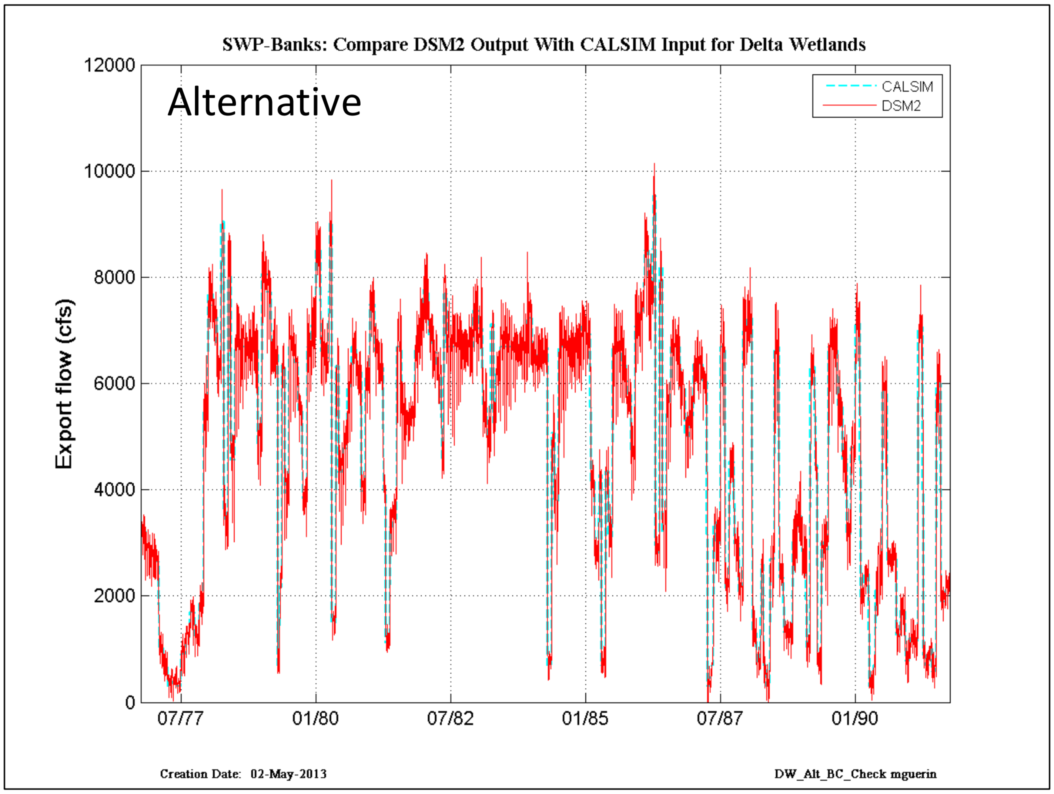
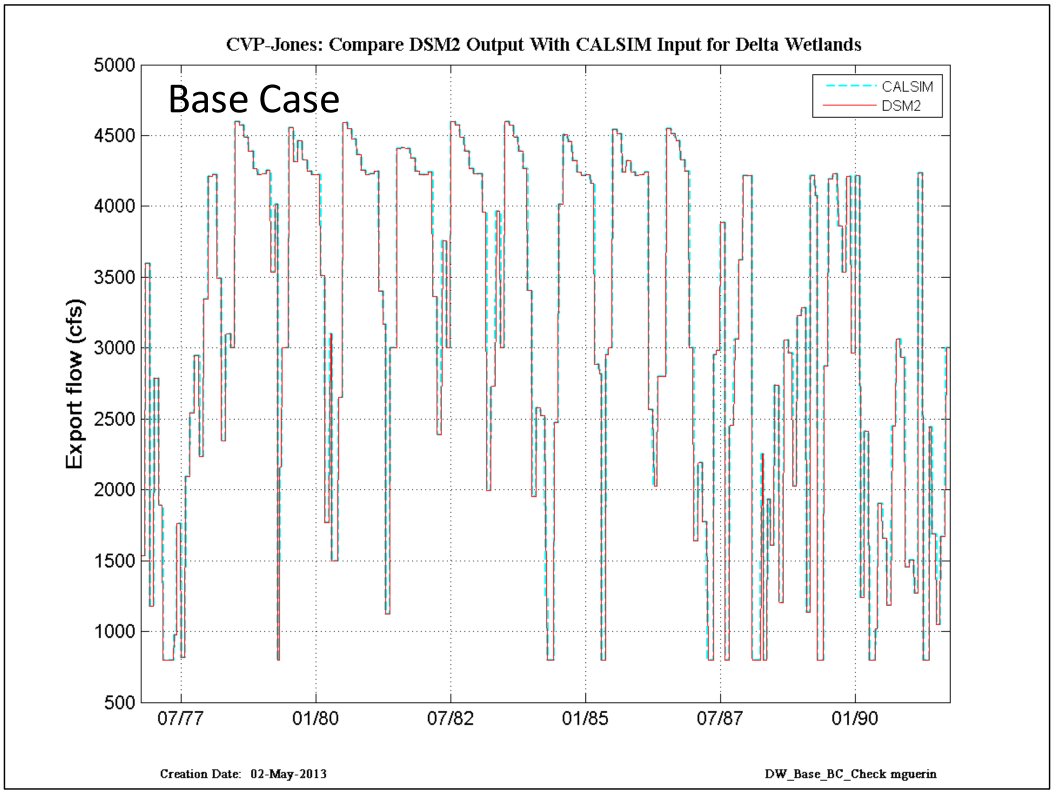


Figure 7-1 SWP-Banks export comparison plots for the Base Case (upper) and the Alternative (lower).



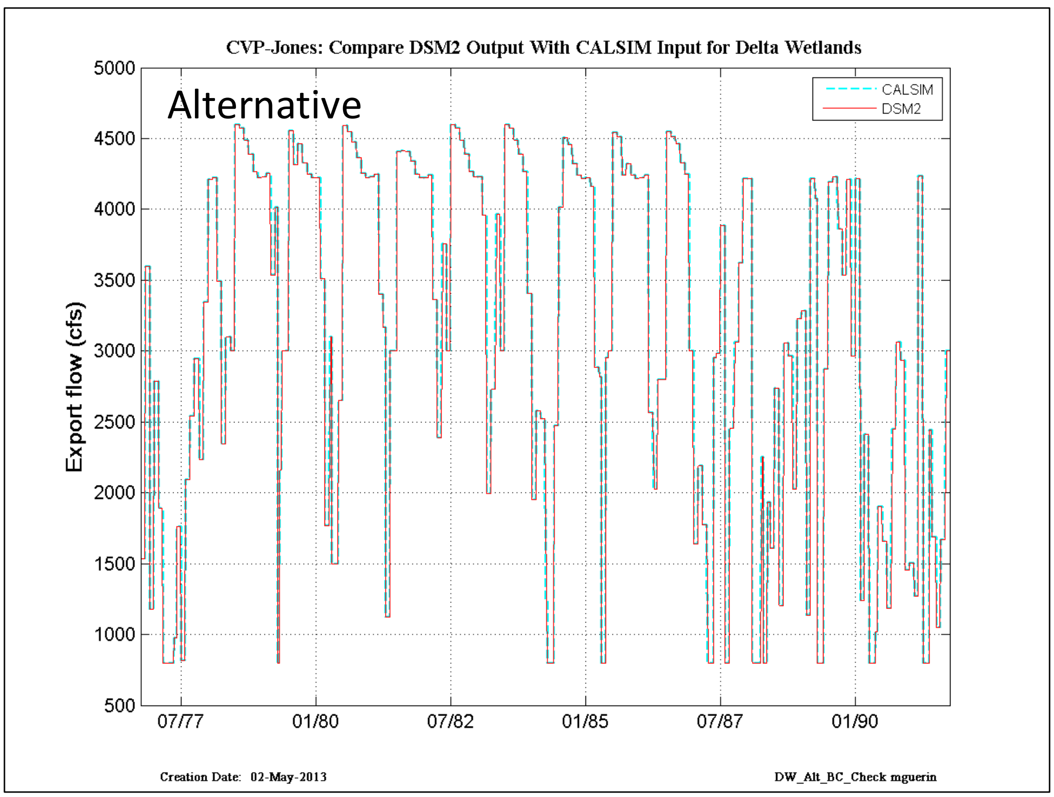
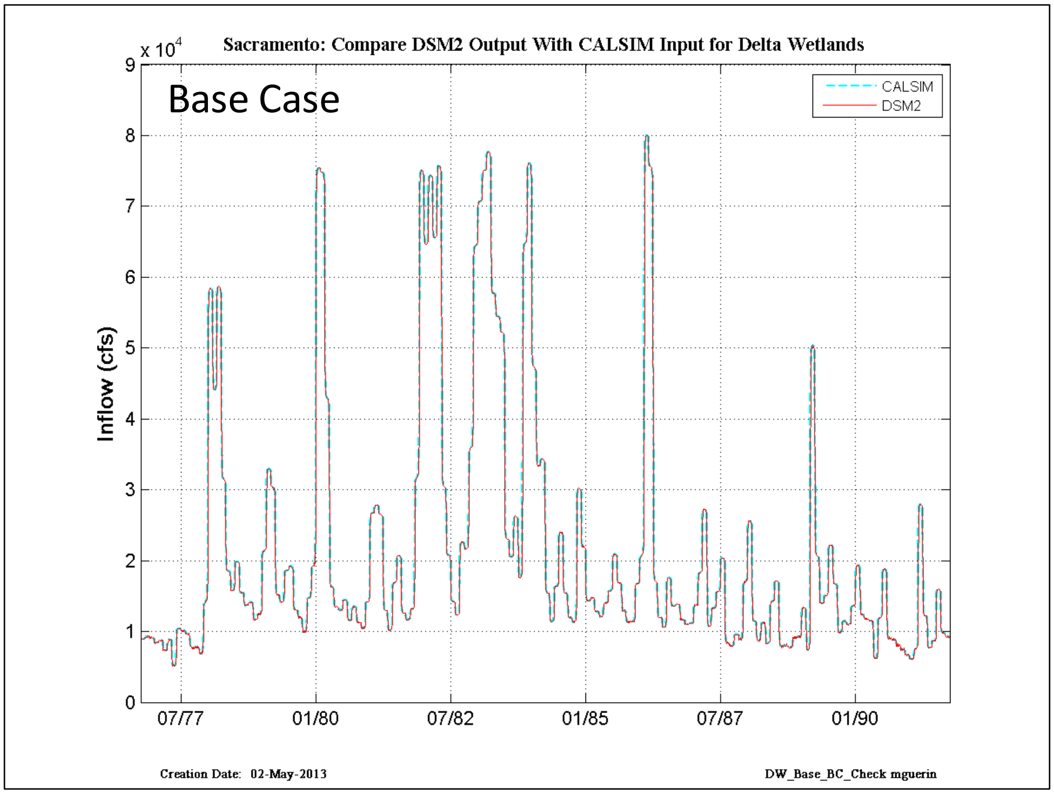


Figure 7-2 CVP-Jones export comparison plots for the Base Case (upper) and the Alternative (lower).



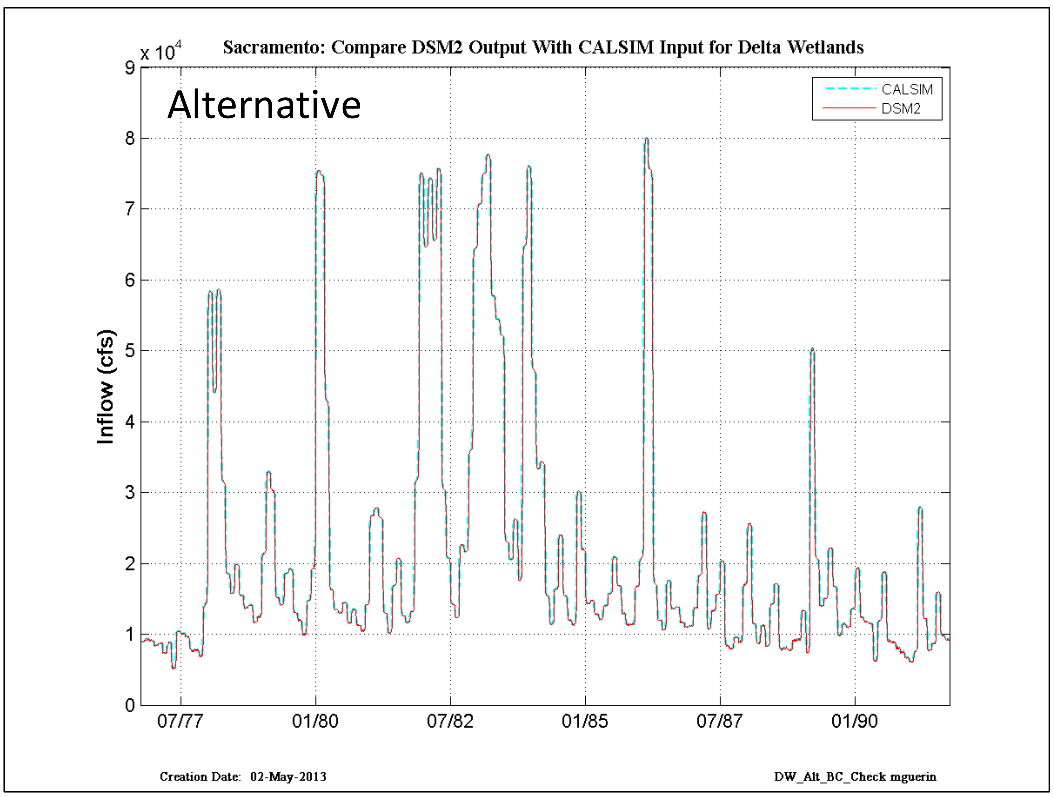
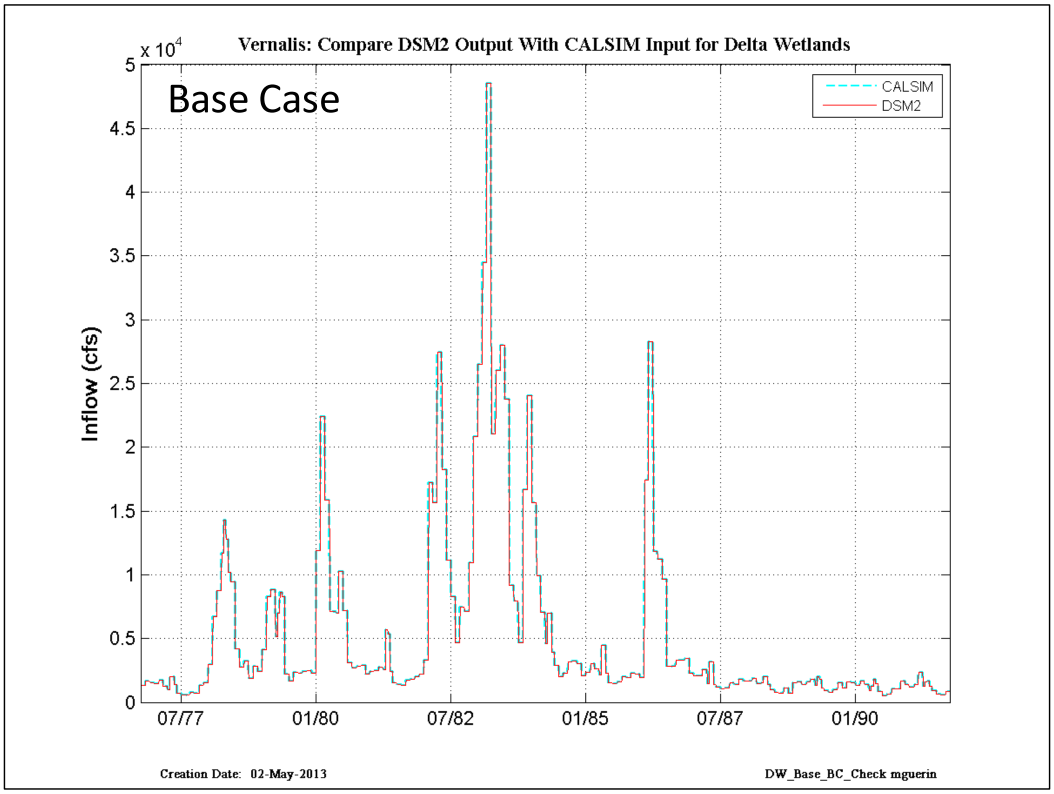


Figure 7-3 Sacramento inflow comparison plots for the Base Case (upper) and the Alternative (lower).



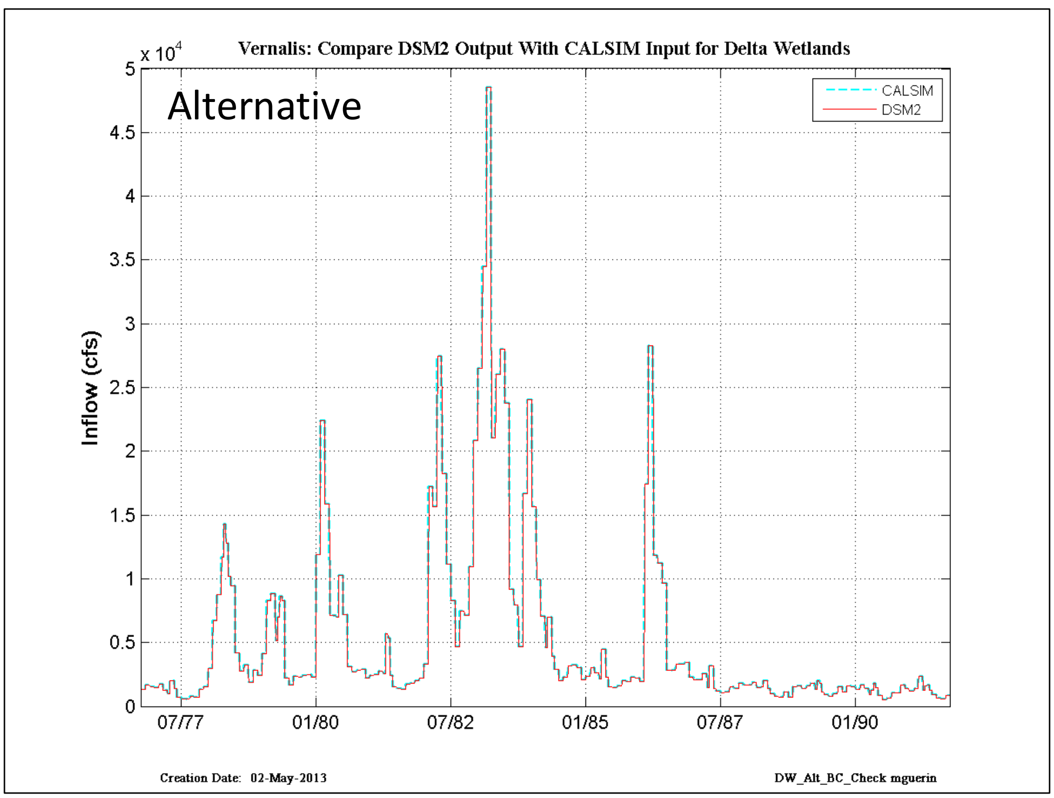
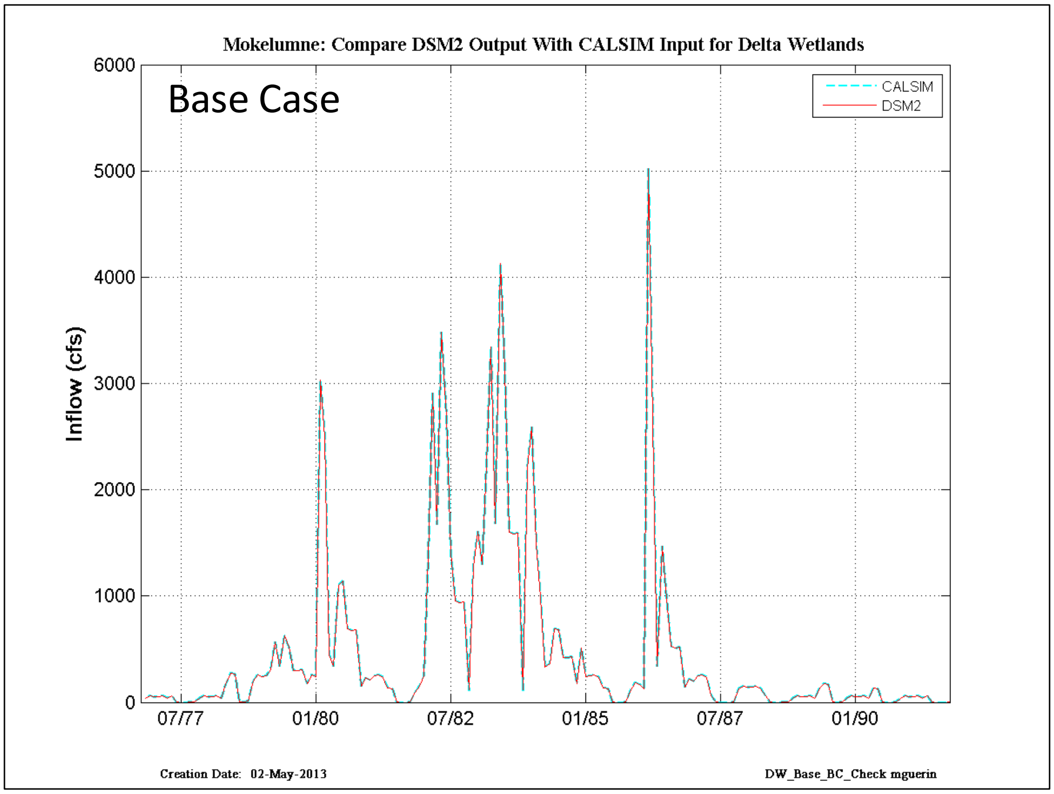


Figure 7-4 San Joaquin comparison plots for the Base Case (upper) and the Alternative (lower).



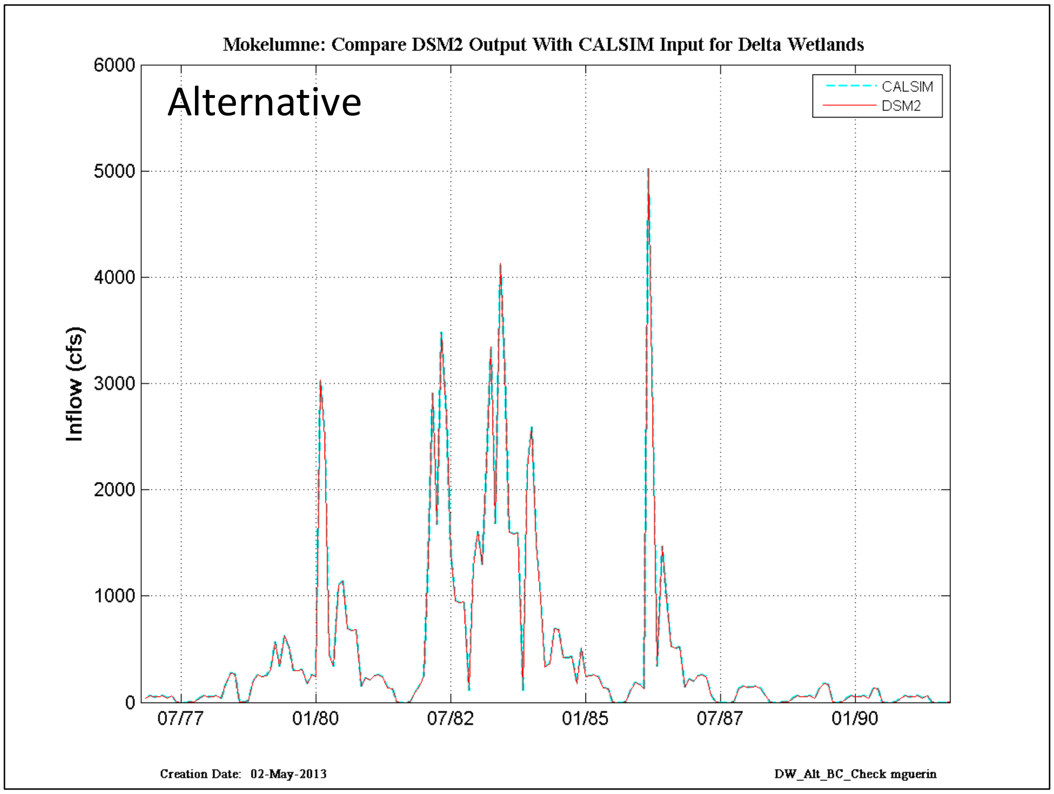
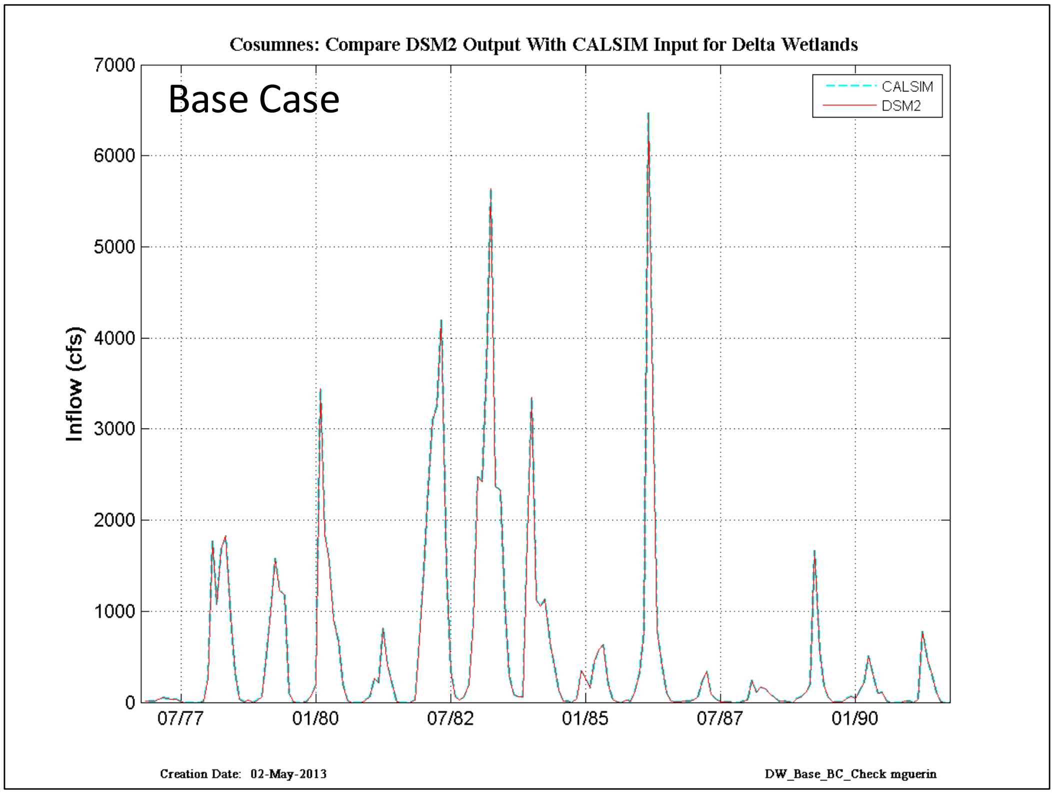


Figure 7-5 Mokelumne comparison plots for the Base Case (upper) and the Alternative (lower).



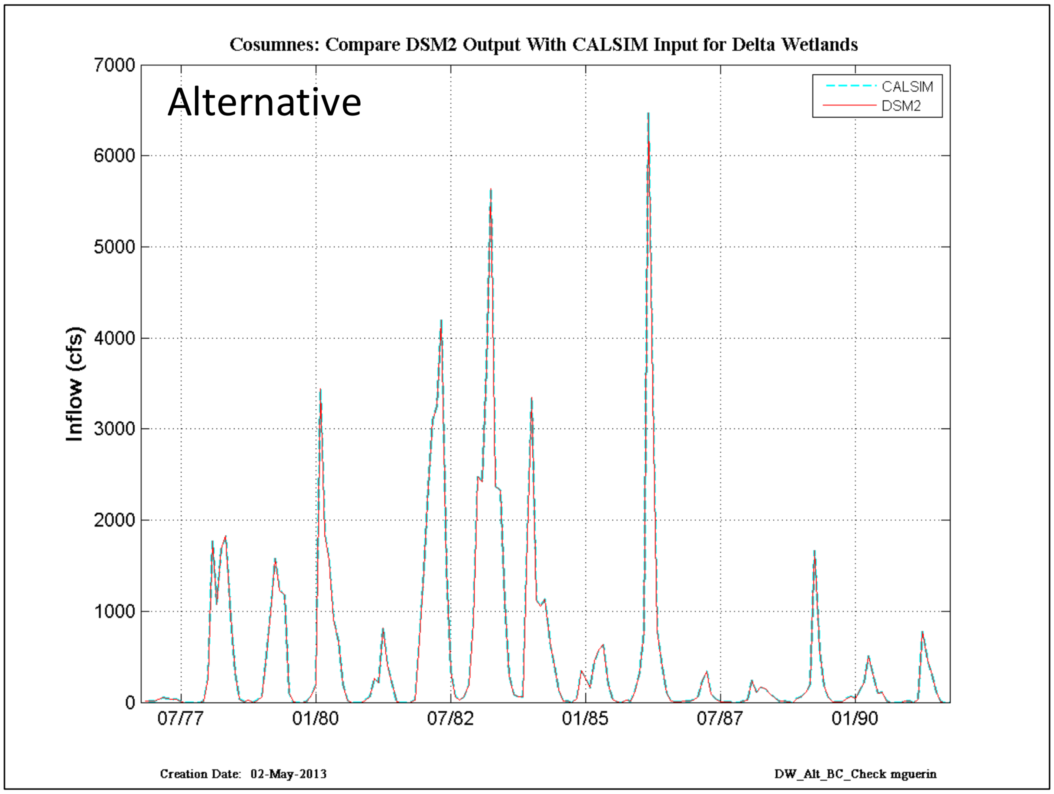
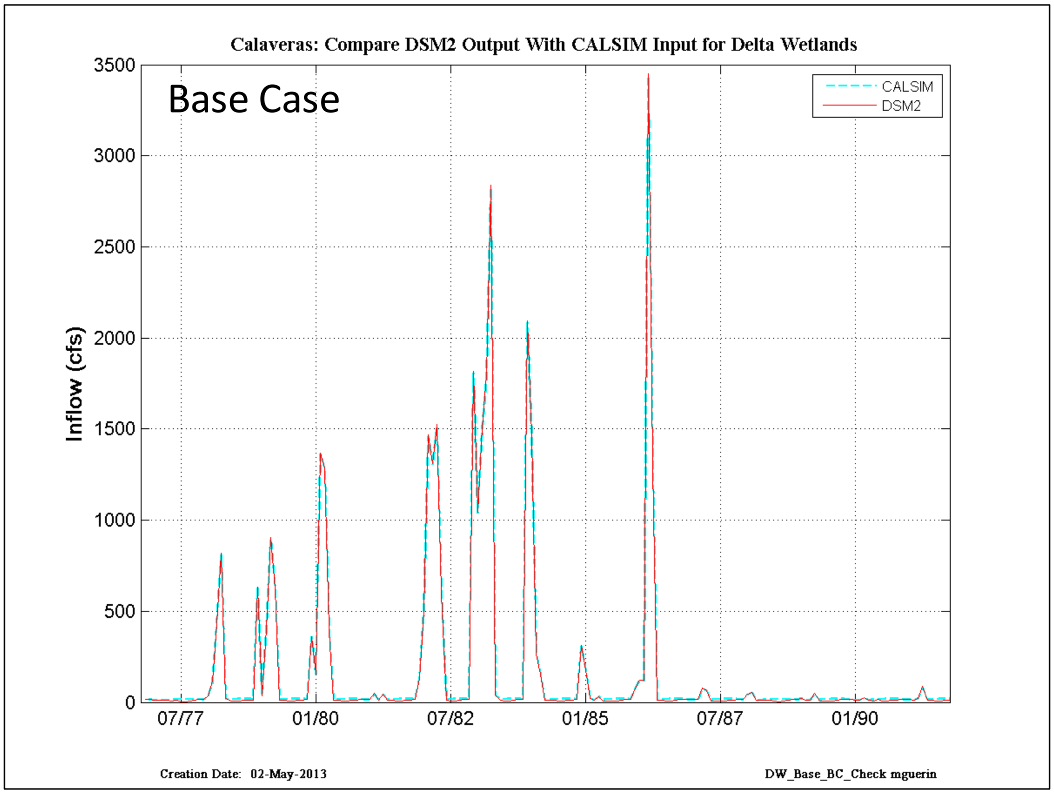


Figure 7-6 Cosumnes comparison plots for the Base Case (upper) and the Alternative (lower).



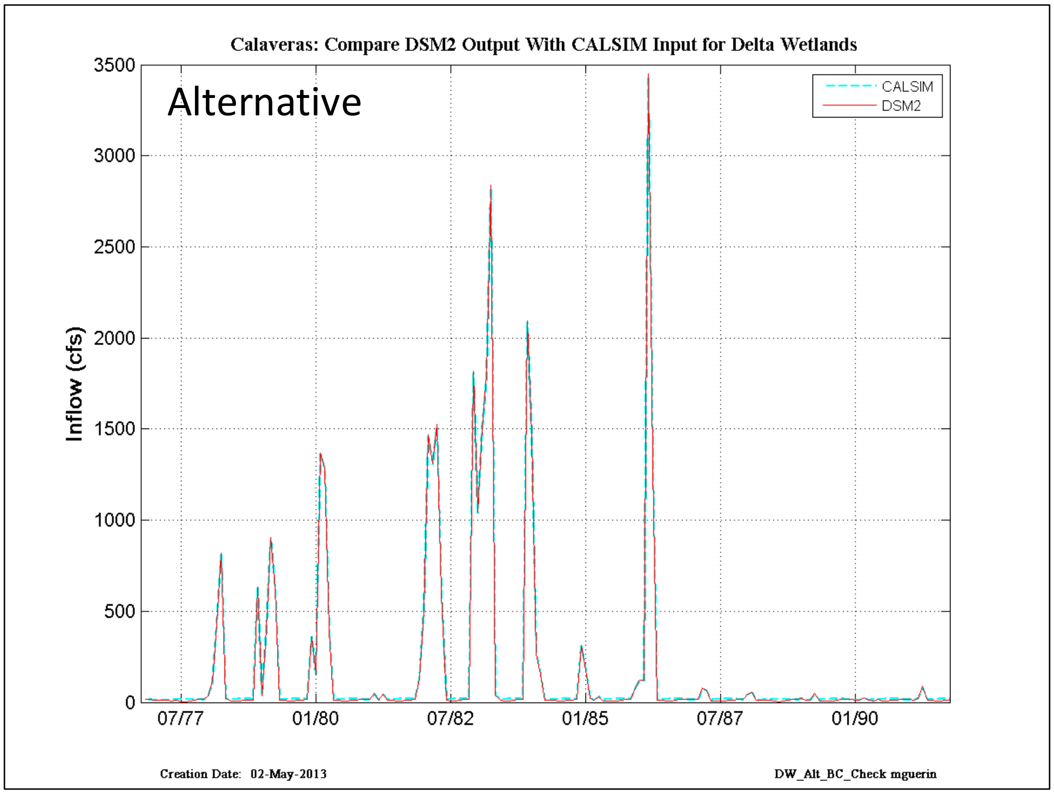
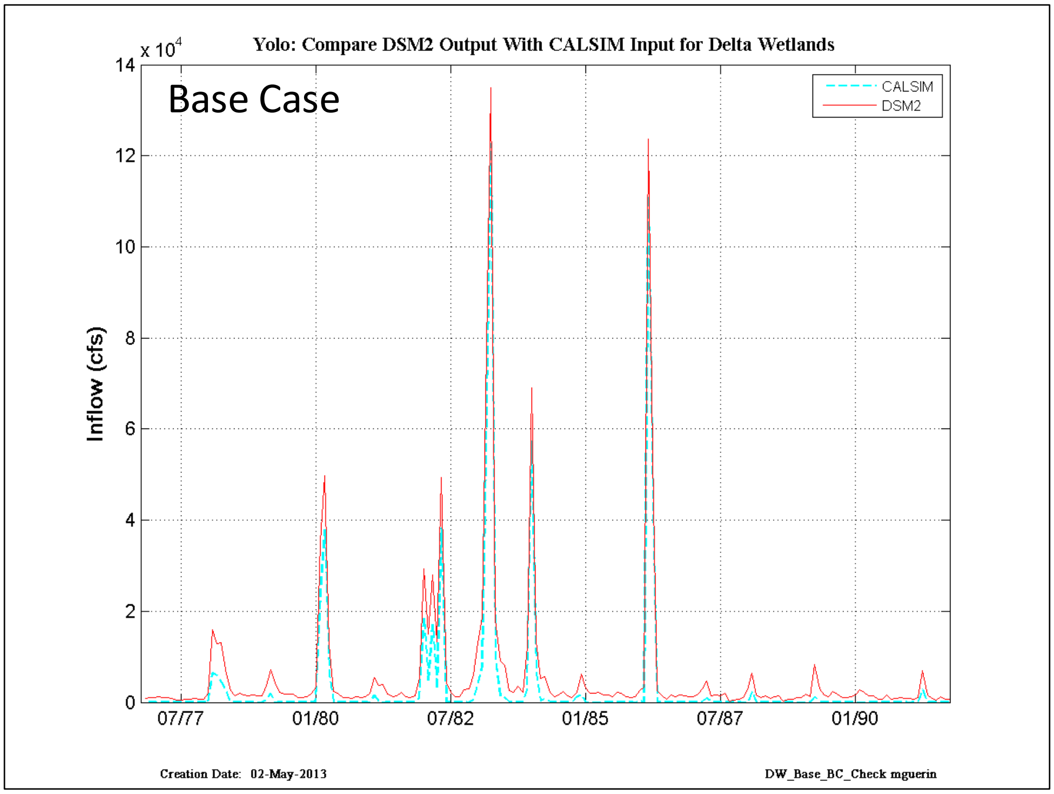


Figure 7-7 Calaveras comparison plots for the Base Case (upper) and the Alternative (lower).



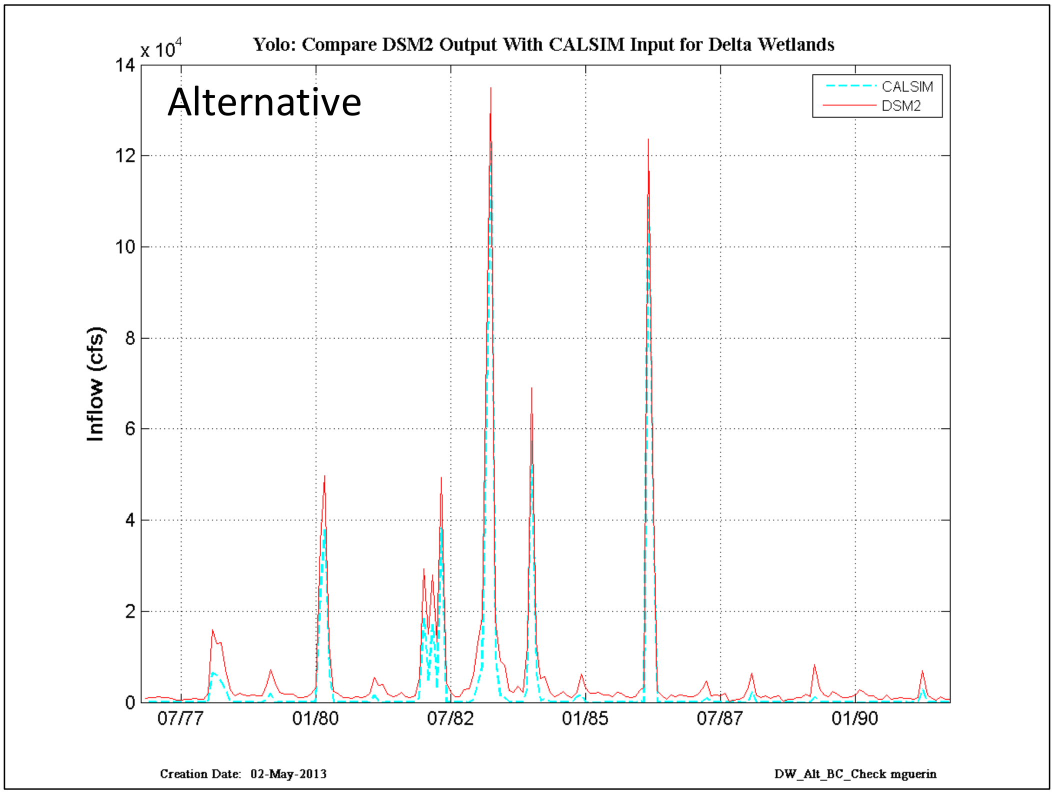


Figure 7-8 Yolo Bypass comparison plots for the Base Case (upper) and the Alternative (lower).

7.1 Velocity plots

Figure 7-9 through Figure 7-39 document the results of the velocity analysis. The nomenclature is explained in Figure 4-1 and Table 4-1.

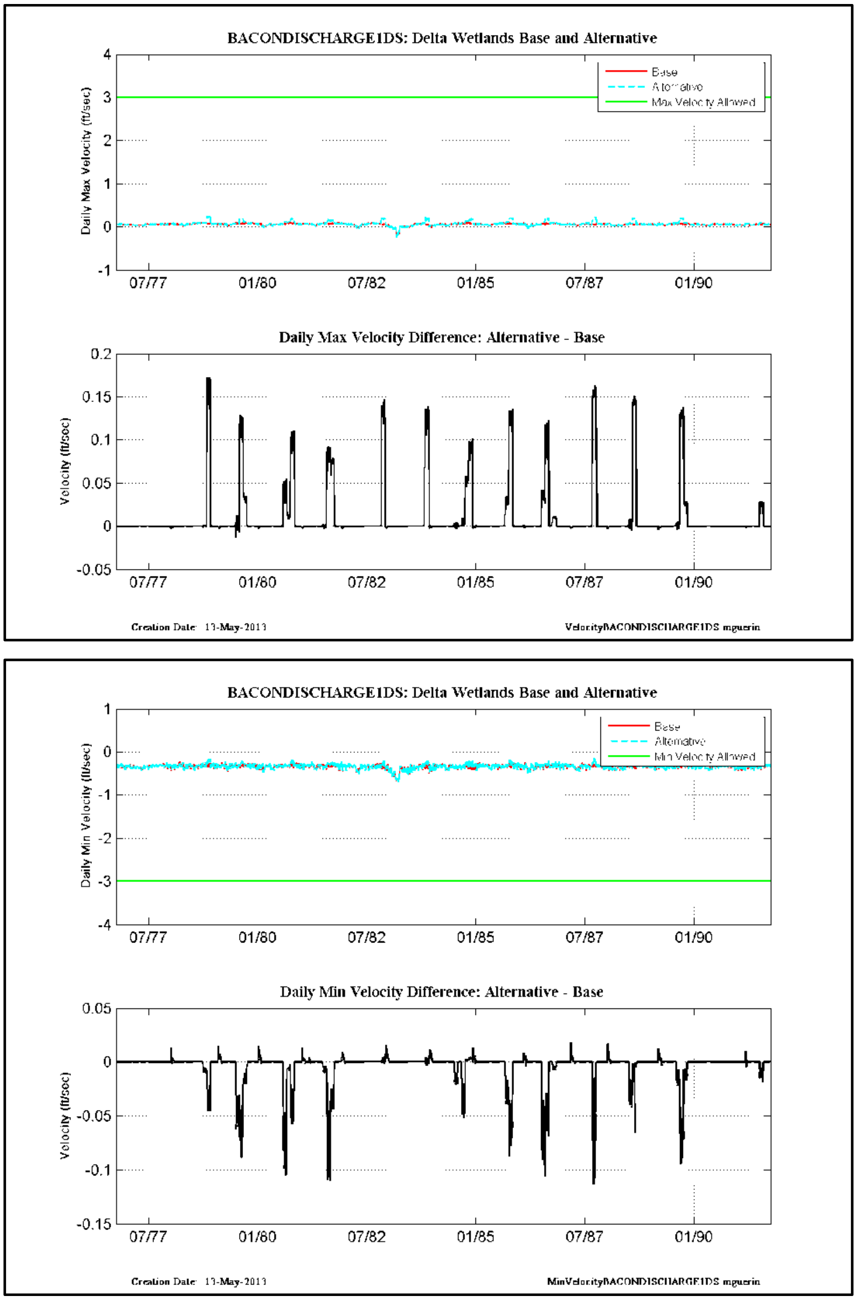
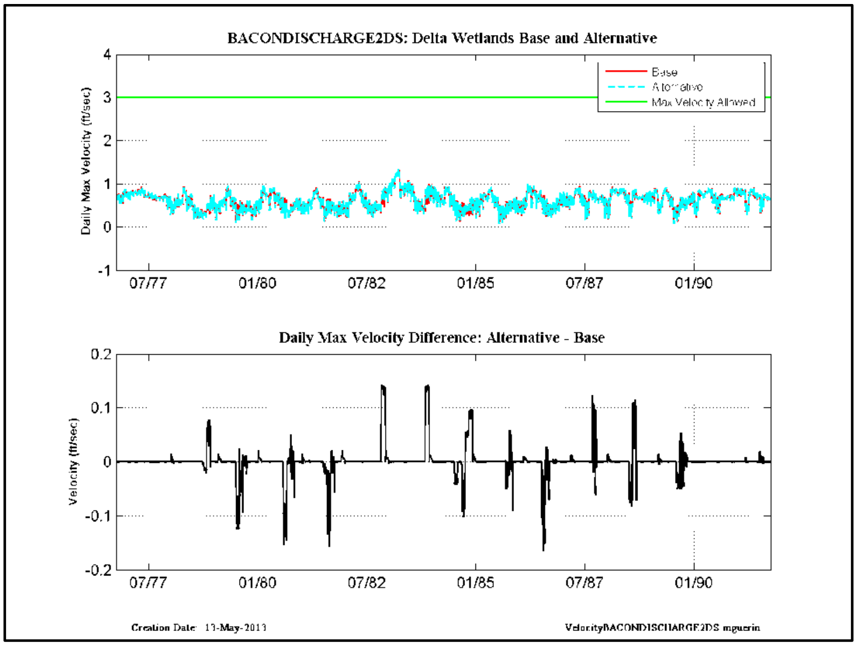


Figure 7-9 Bacondischarge1DS daily velocity maximum and difference (Alternative – Base) and daily velocity minimum and difference.



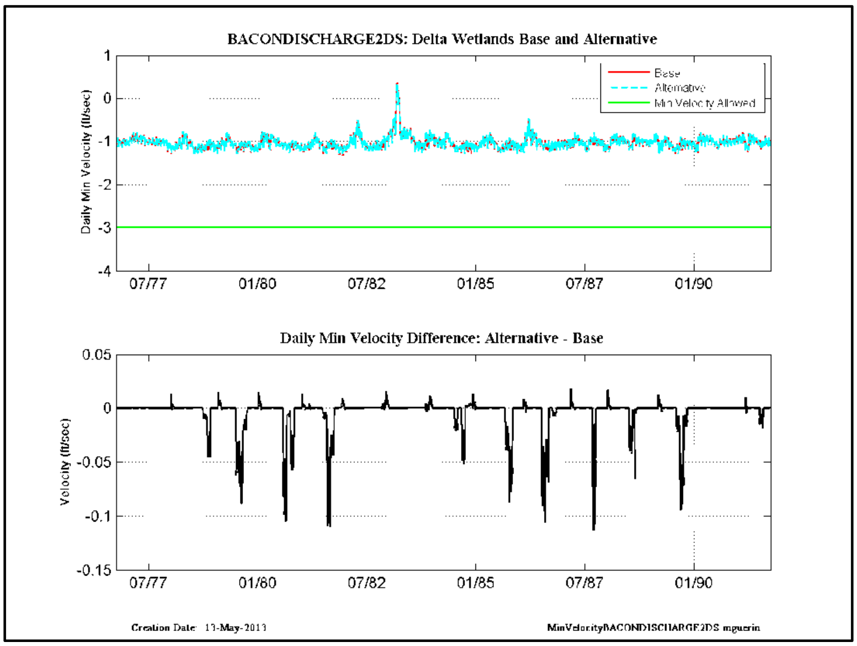


Figure 7-10 Bacondischarge2DS daily velocity maximum and difference (Alternative – Base) and daily velocity minimum and difference.

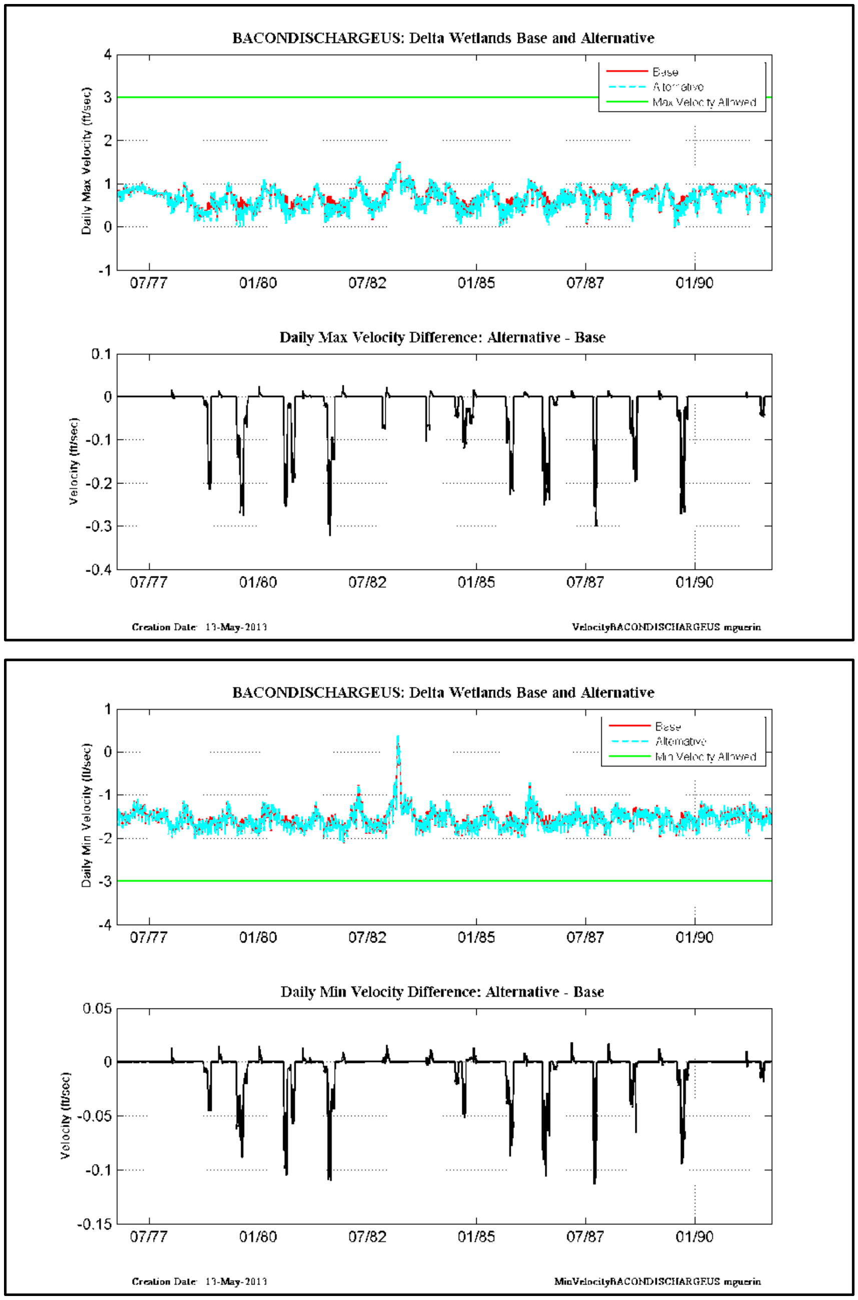


Figure 7-11 BacondischargesUS daily velocity maximum and difference (Alternative – Base) and daily velocity minimum and difference.

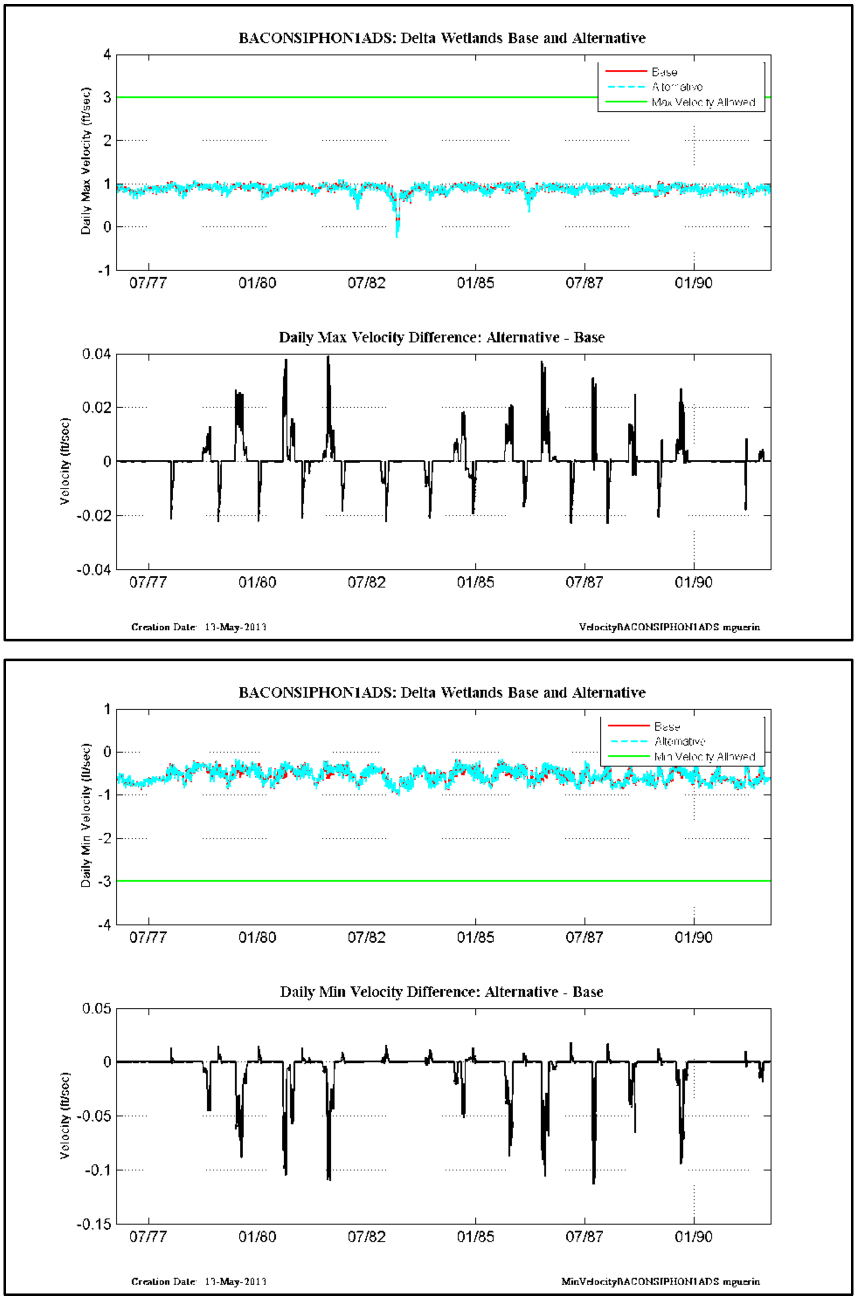
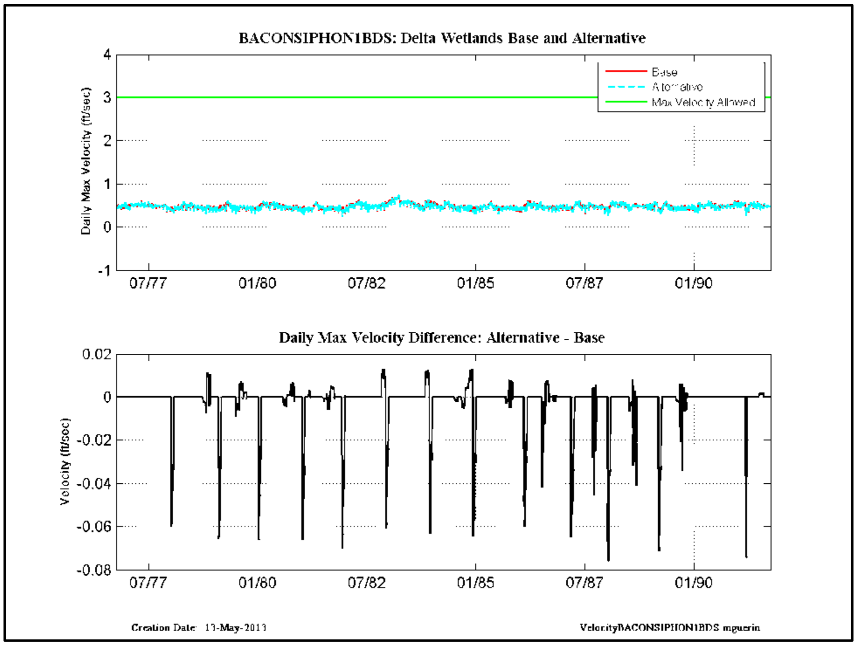


Figure 7-12 Baconsiphon1ADS daily velocity maximum and difference (Alternative – Base) and daily velocity minimum and difference.



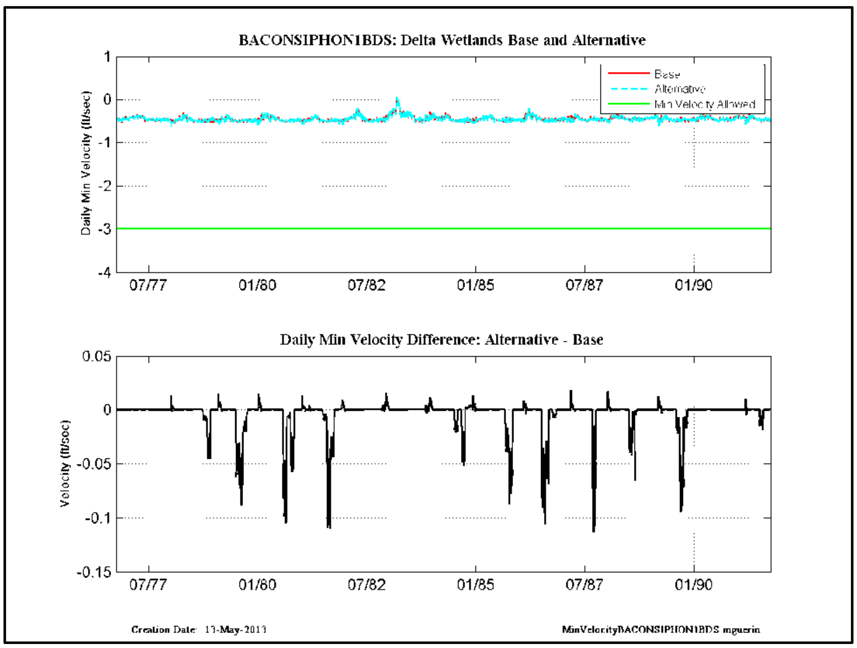
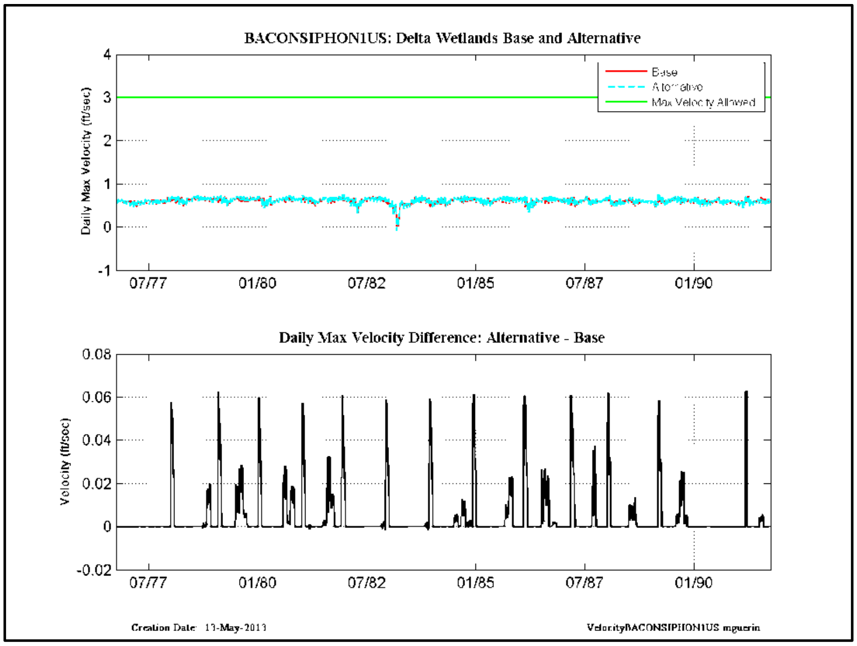


Figure 7-13 Baconsiphon1BDS daily velocity maximum and difference (Alternative – Base) and daily velocity minimum and difference.



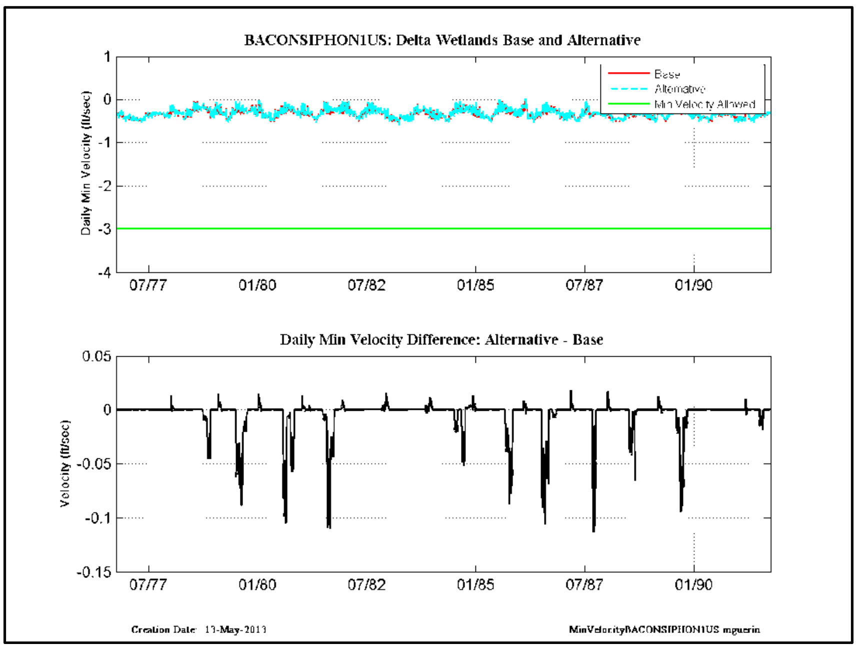


Figure 7-14 Baconsiphon1US daily velocity maximum and difference (Alternative – Base) and daily velocity minimum and difference.

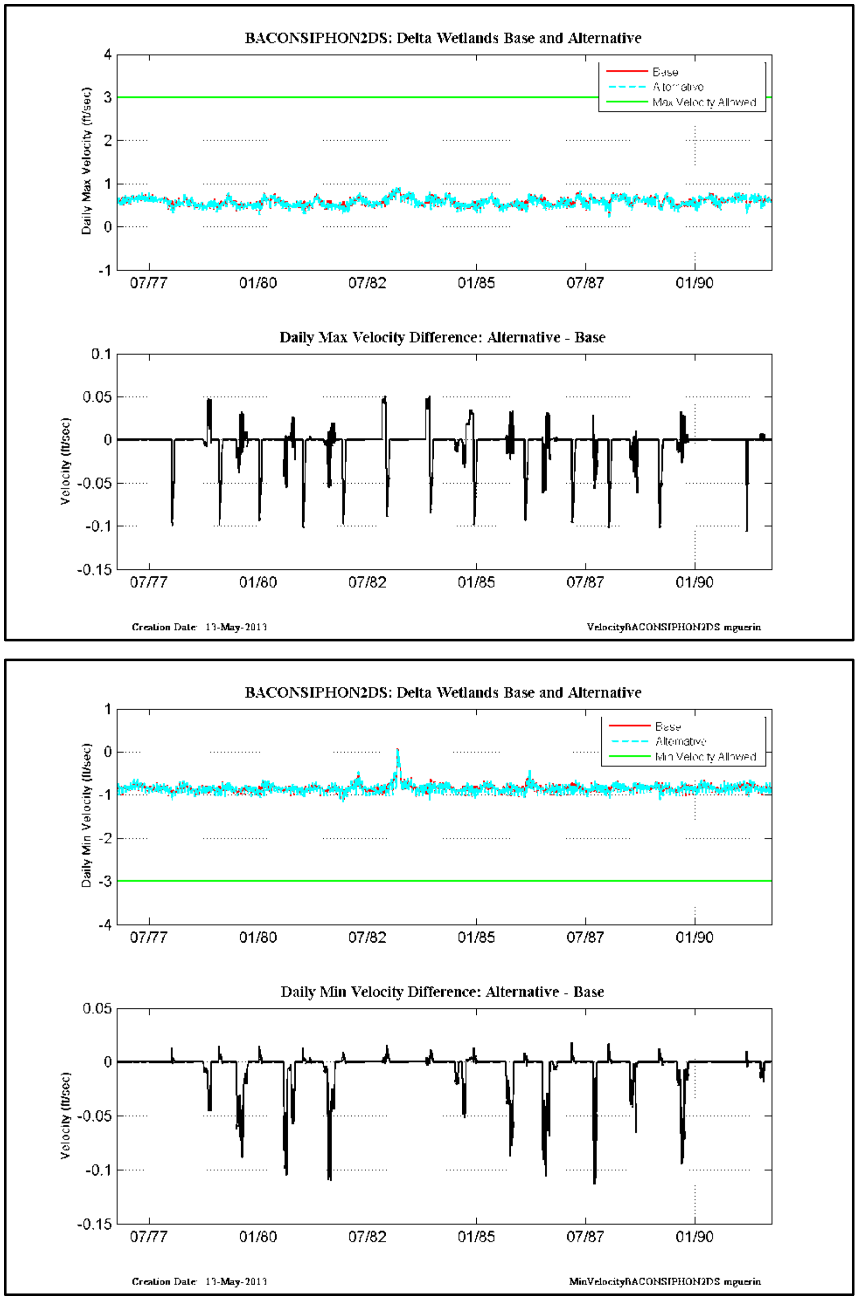
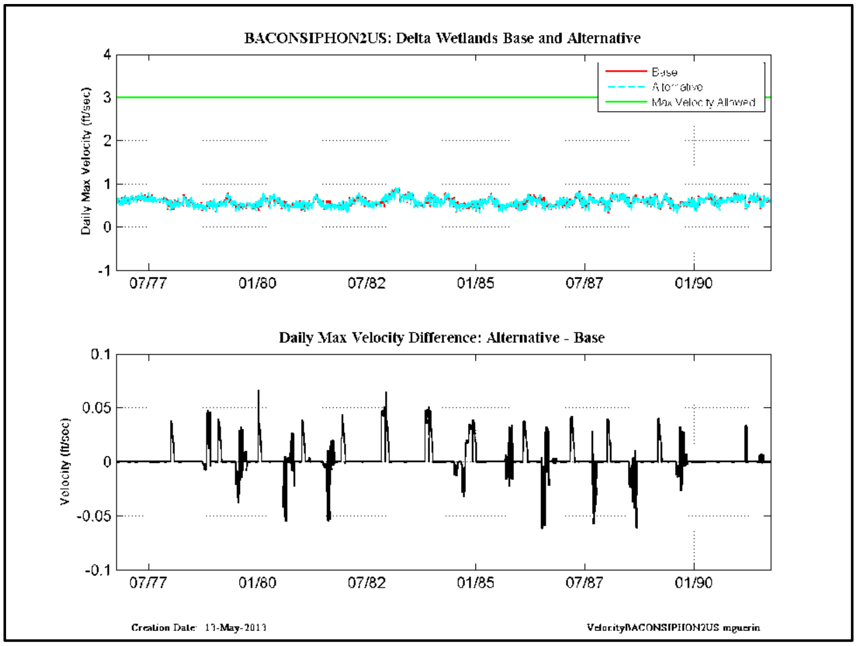


Figure 7-15 Baconsiphon2DS daily velocity maximum and difference (Alternative – Base) and daily velocity minimum and difference.



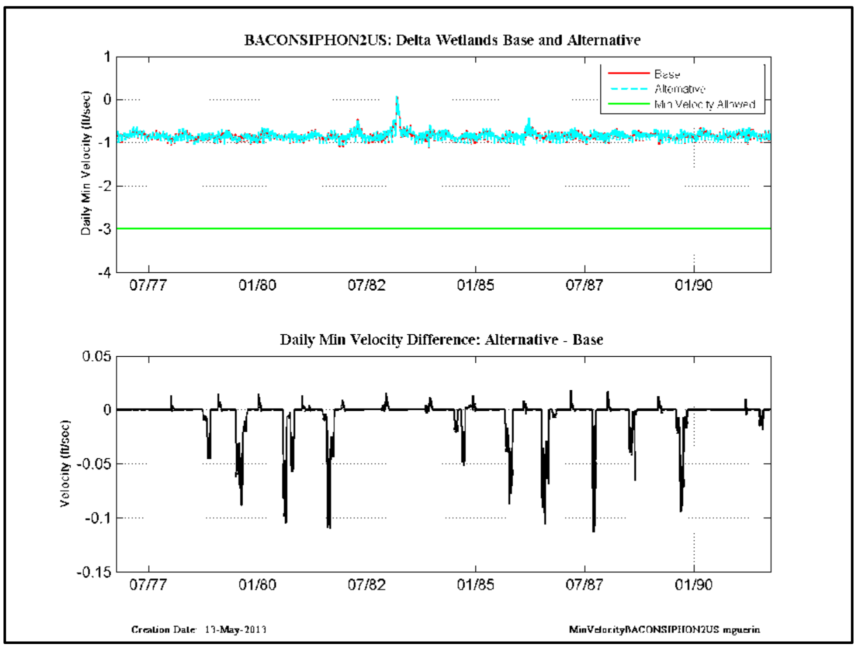
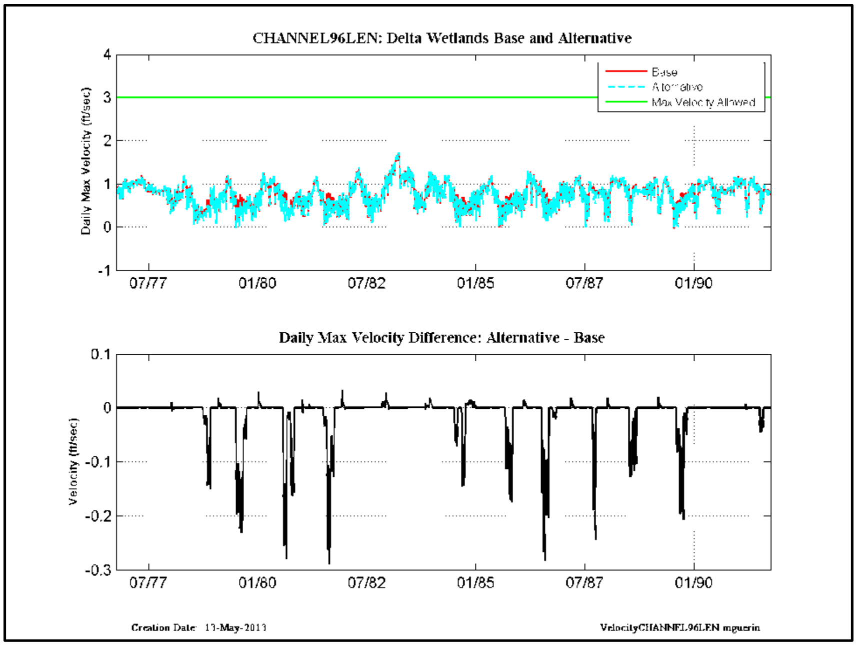


Figure 7-16 Baconsiphon2US daily velocity maximum and difference (Alternative – Base) and daily velocity minimum and difference.



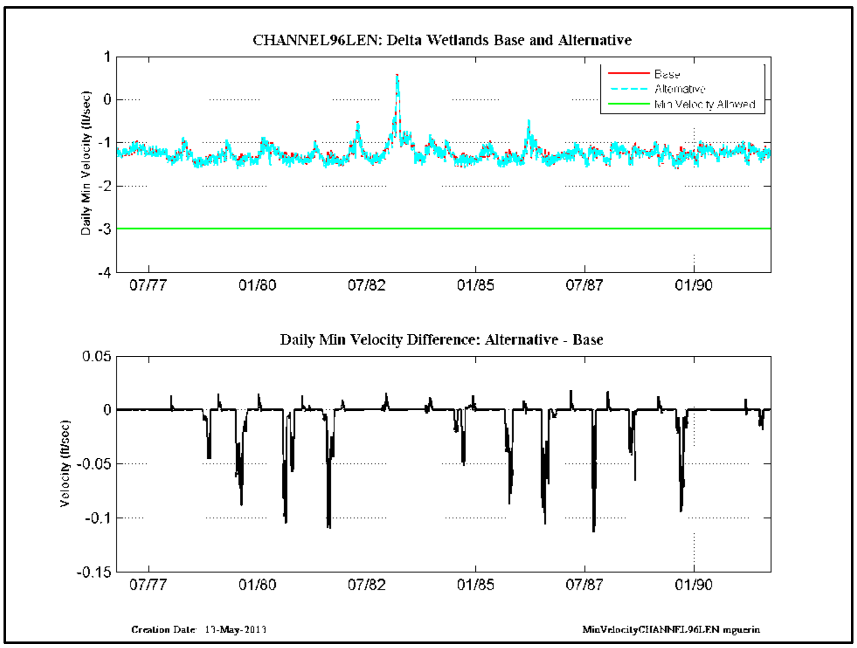
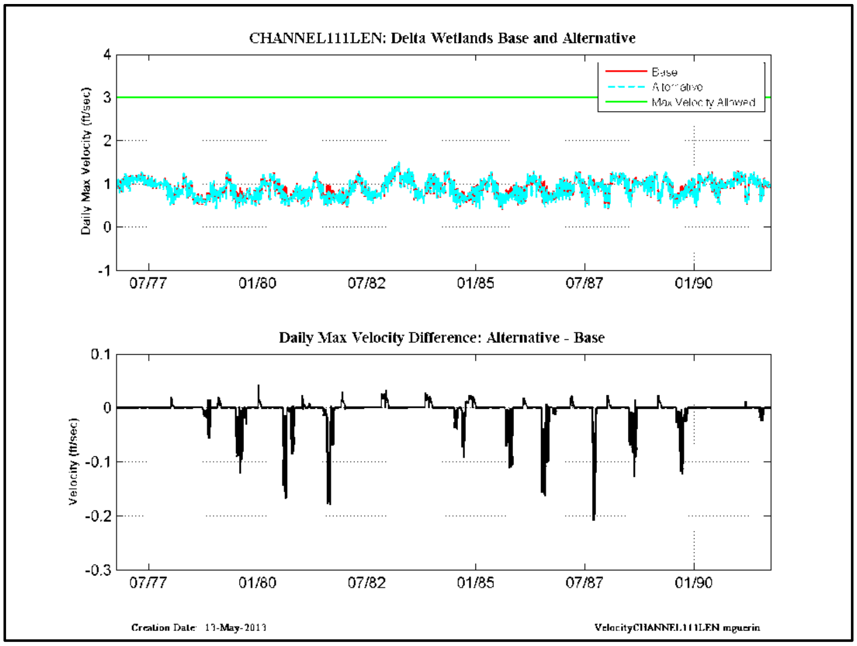


Figure 7-17 Channel96LEN daily velocity maximum and difference (Alternative – Base) and daily velocity minimum and difference.



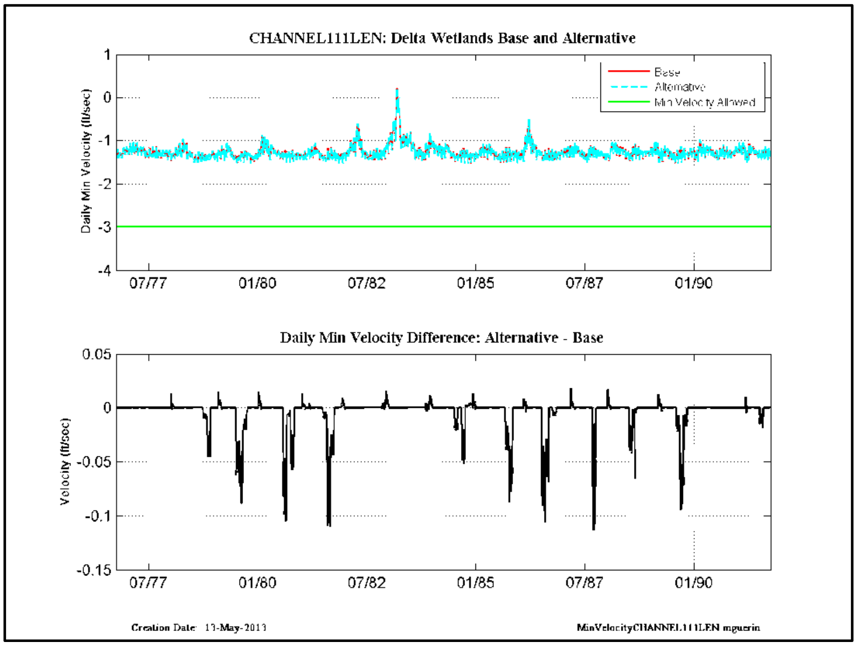
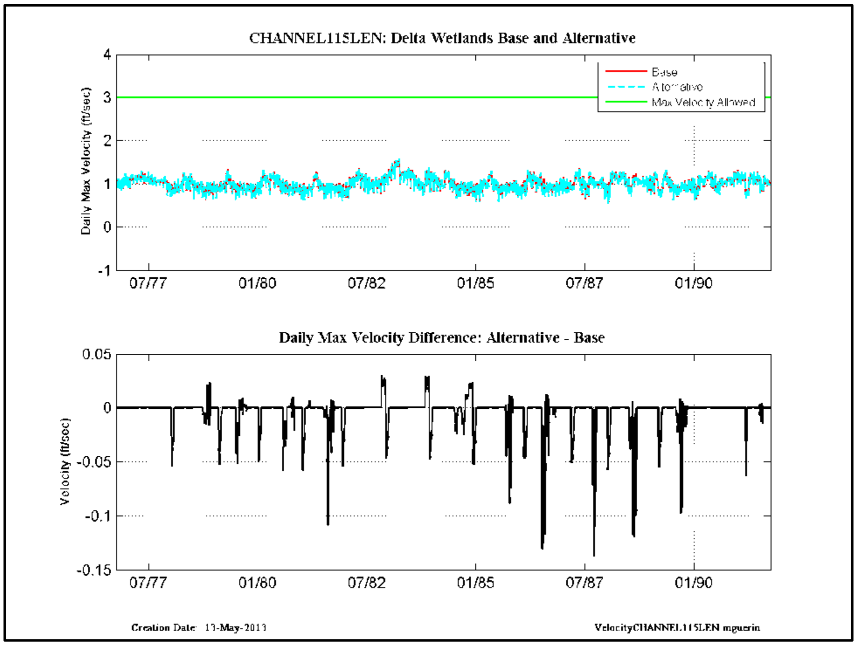


Figure 7-18 Channel111LEN daily velocity maximum and difference (Alternative – Base) and daily velocity minimum and difference.



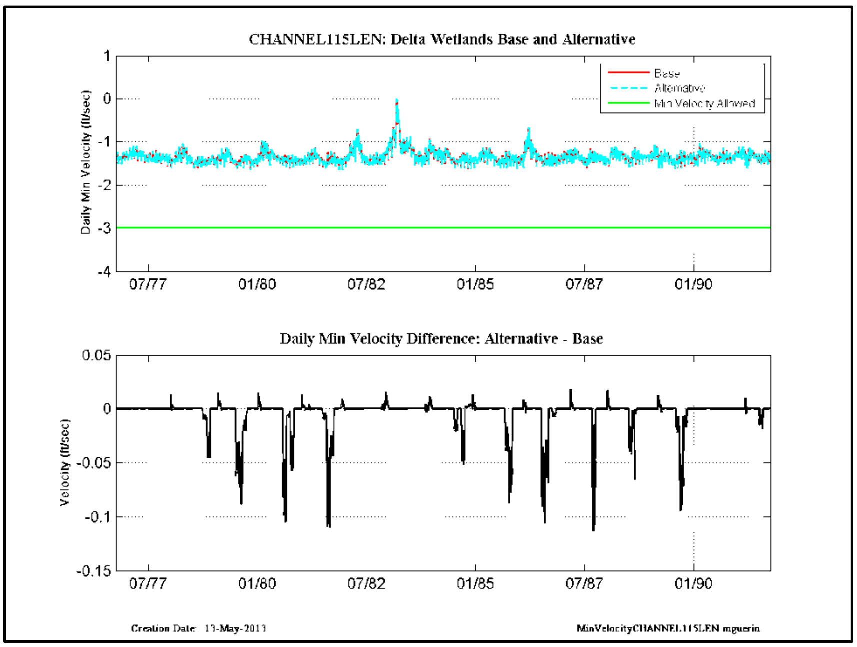


Figure 7-19 Channel115LEN daily velocity maximum and difference (Alternative – Base) and daily velocity minimum and difference.

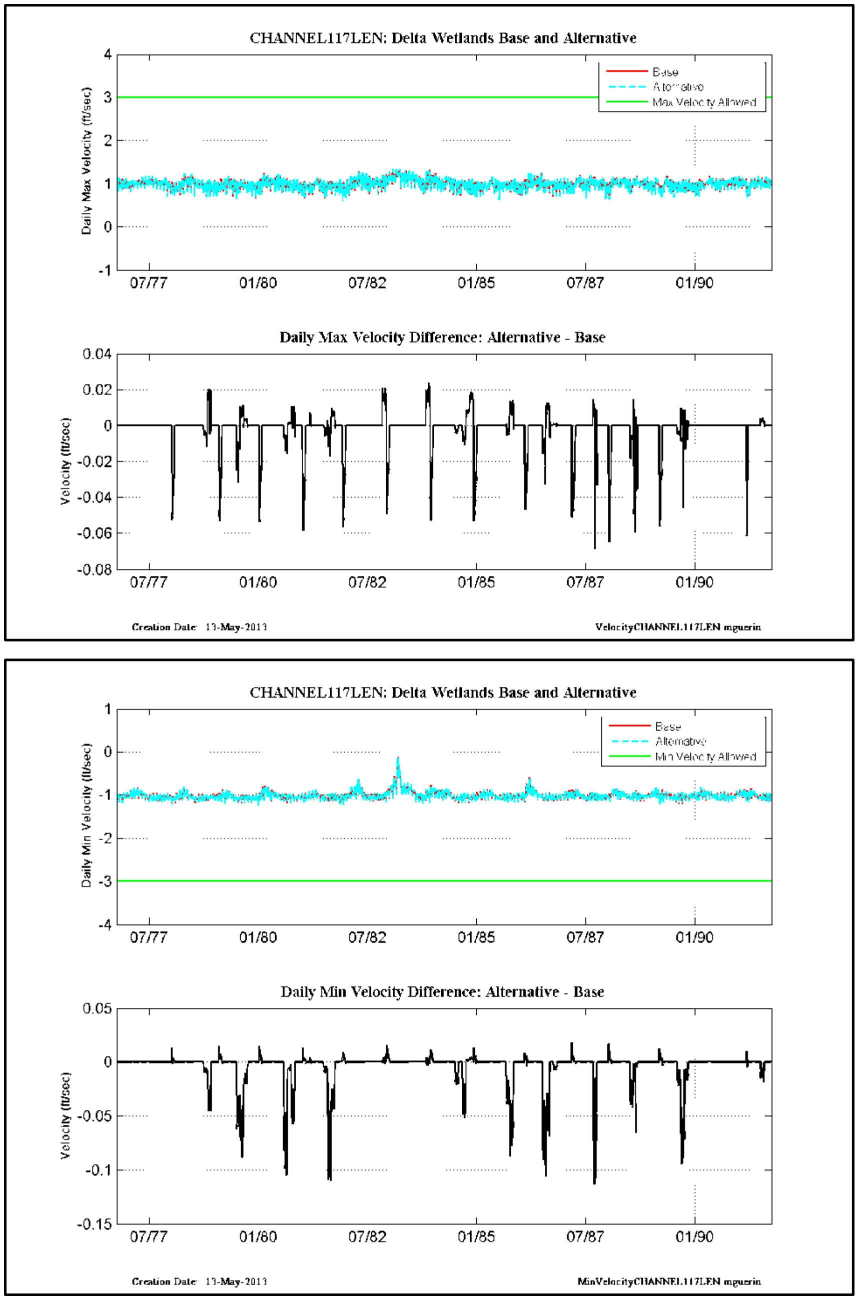
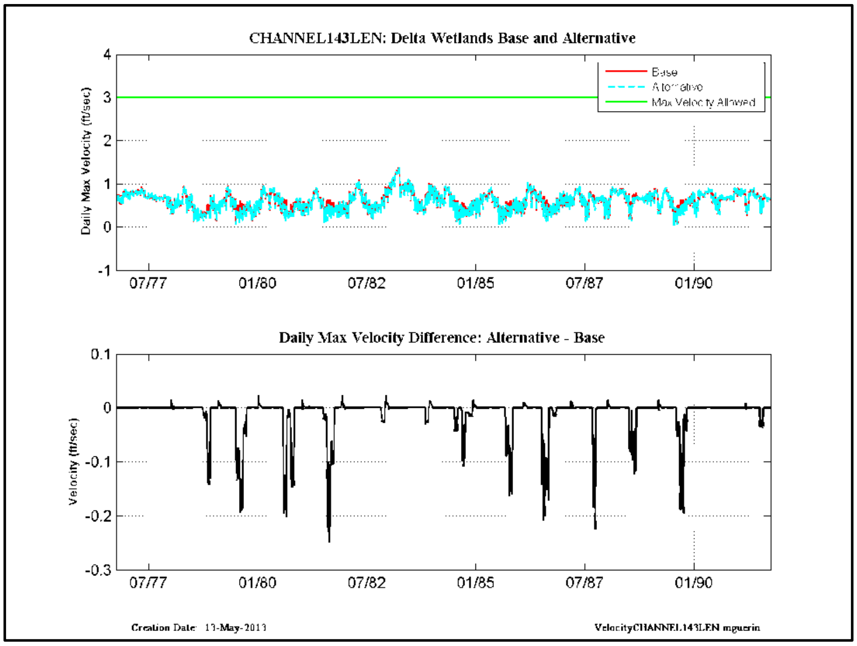


Figure 7-20 Channel117LEN daily velocity maximum and difference (Alternative – Base) and daily velocity minimum and difference.



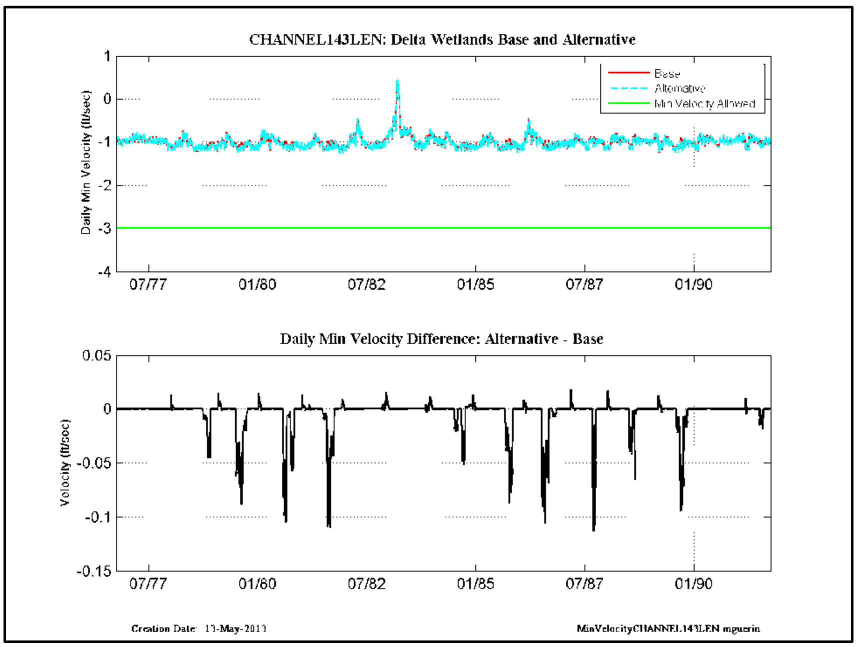
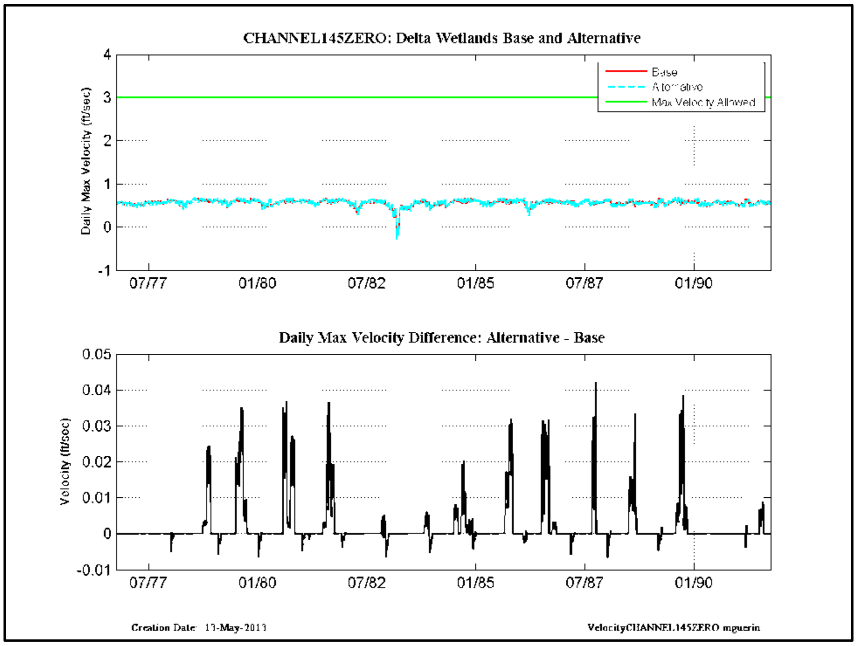


Figure 7-21 Channel43LEN daily velocity maximum and difference (Alternative – Base) and daily velocity minimum and difference.



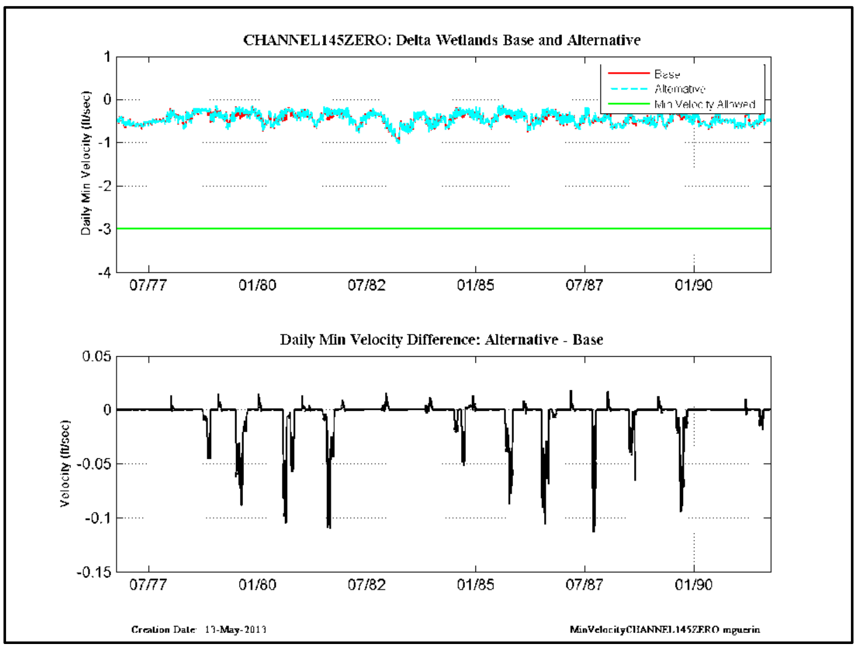
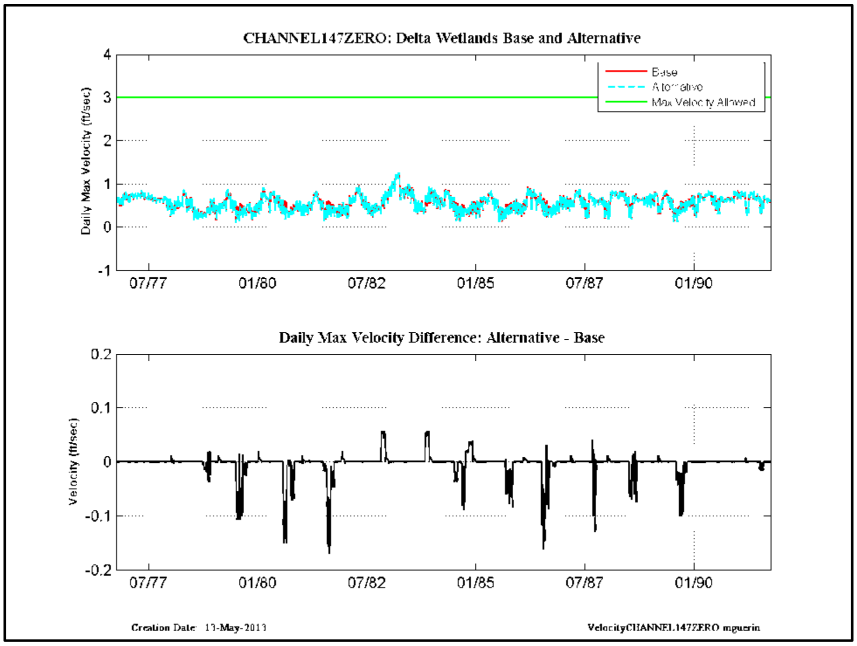


Figure 7-22 Channel45ZERO daily velocity maximum and difference (Alternative – Base) and daily velocity minimum and difference.



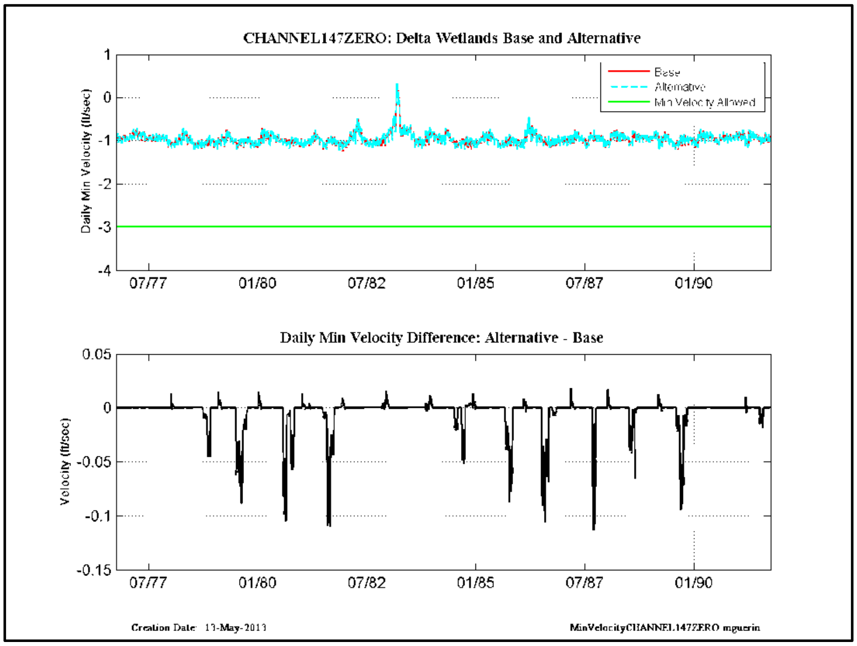
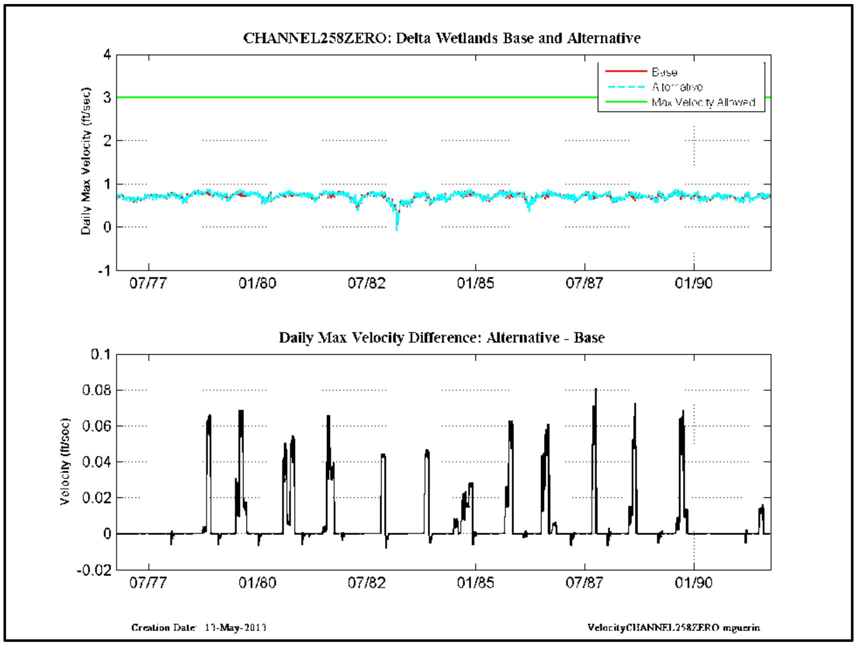


Figure 7-23 Channel47ZERO daily velocity maximum and difference (Alternative – Base) and daily velocity minimum and difference.



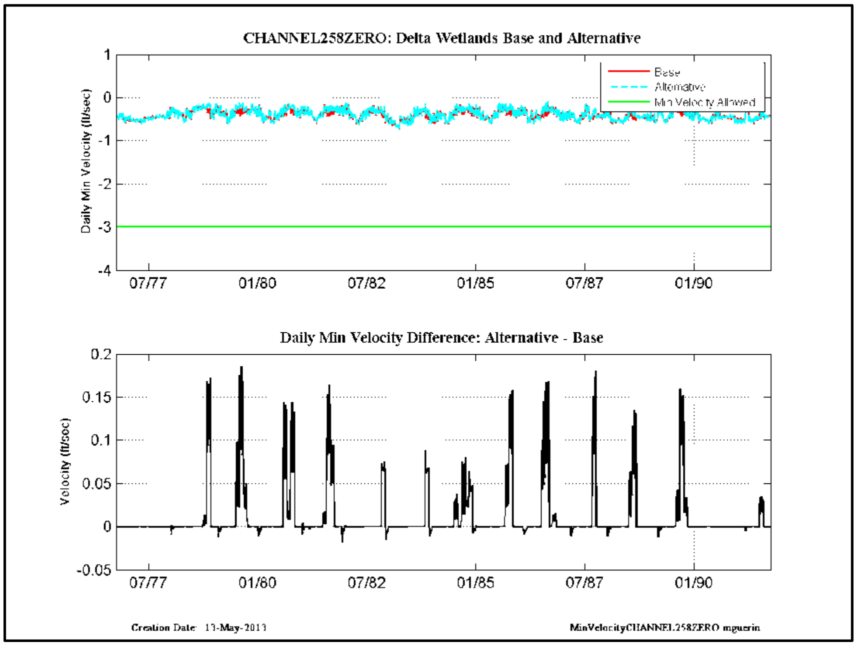
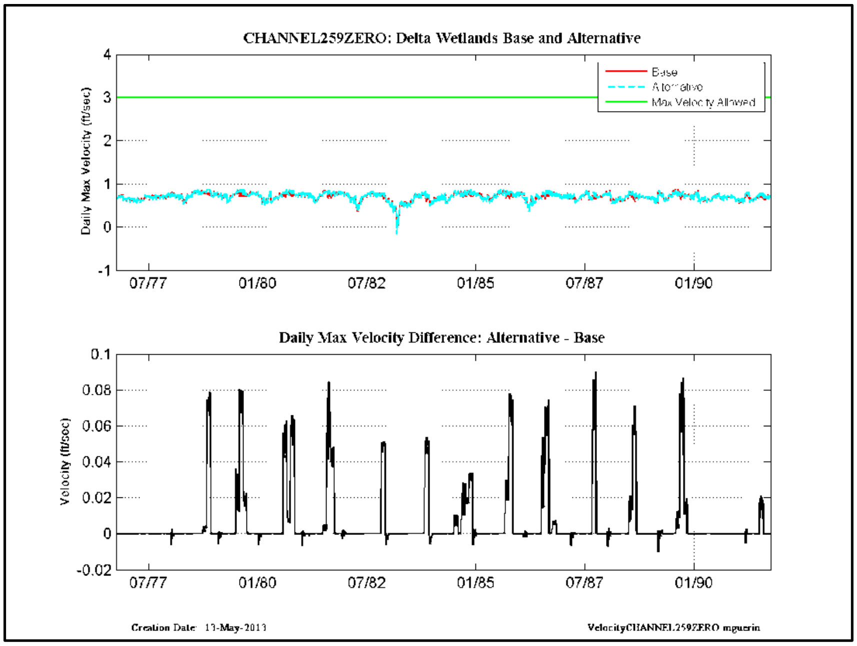


Figure 7-24 Channel258ZERO daily velocity maximum and difference (Alternative – Base) and daily velocity minimum and difference.



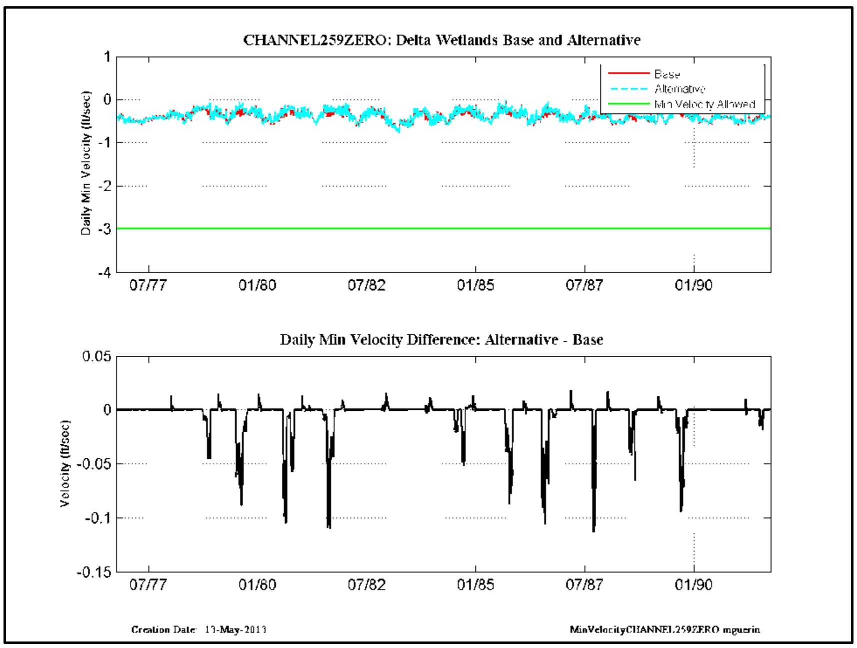


Figure 7-25 Channel259ZERO daily velocity maximum and difference (Alternative – Base) and daily velocity minimum and difference.

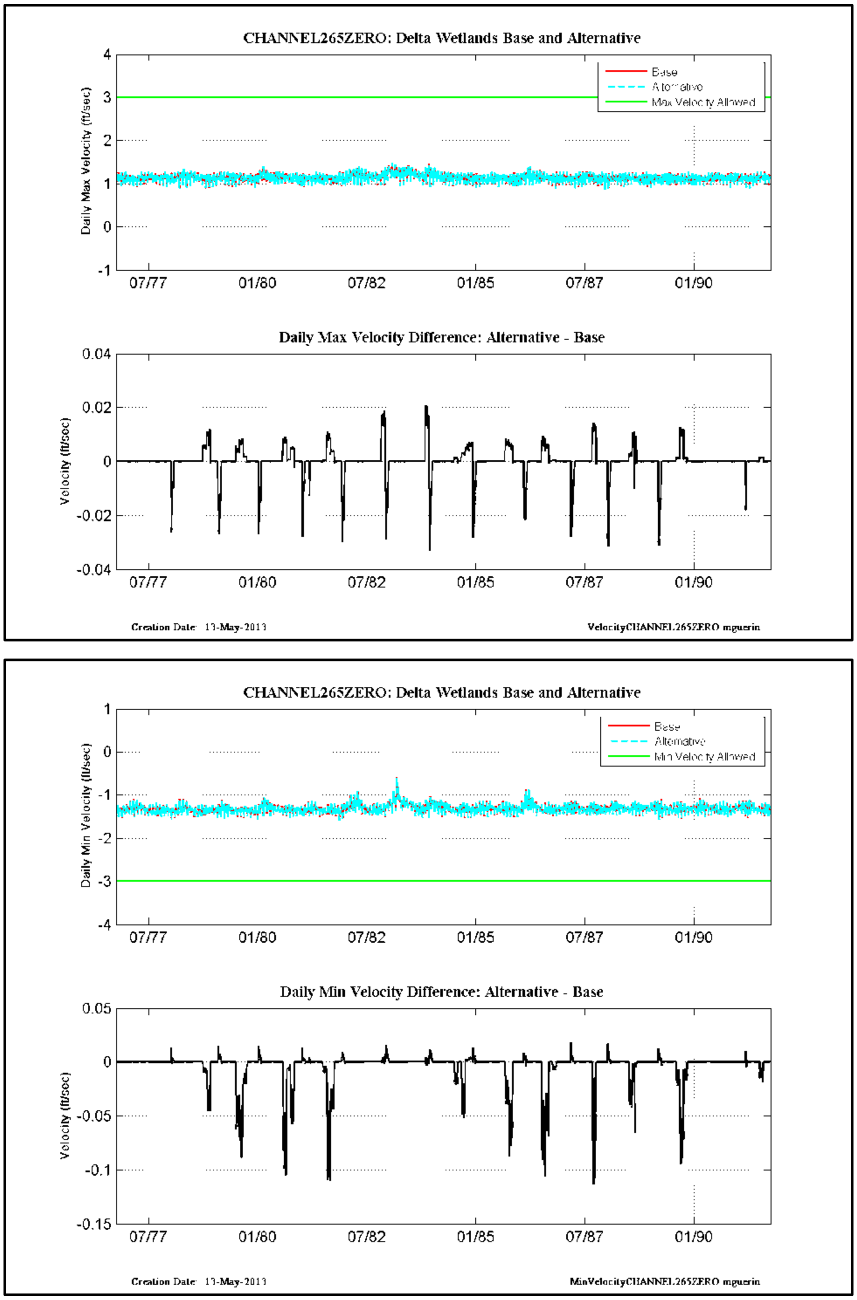
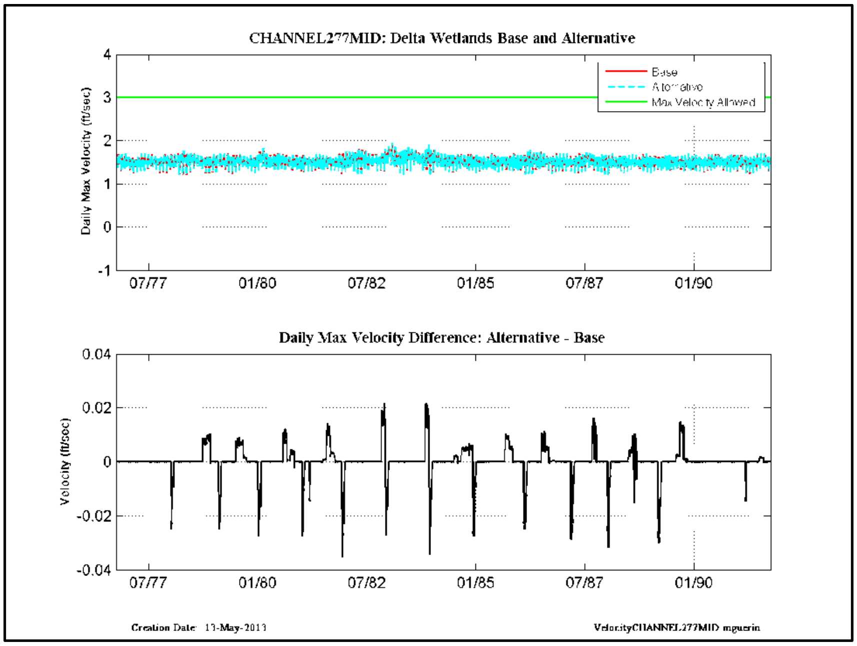


Figure 7-26 Channel265ZERO daily velocity maximum and difference (Alternative – Base) and daily velocity minimum and difference.



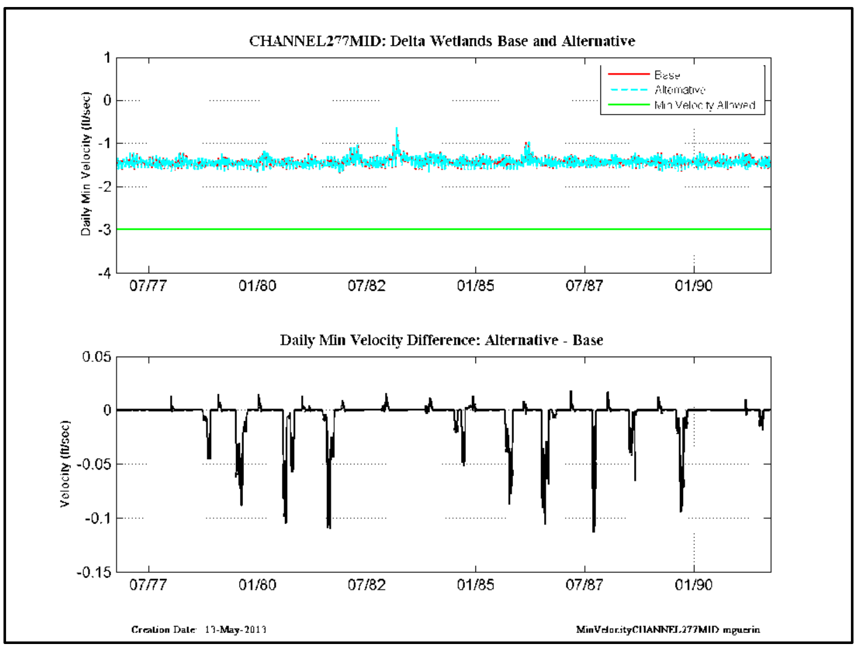
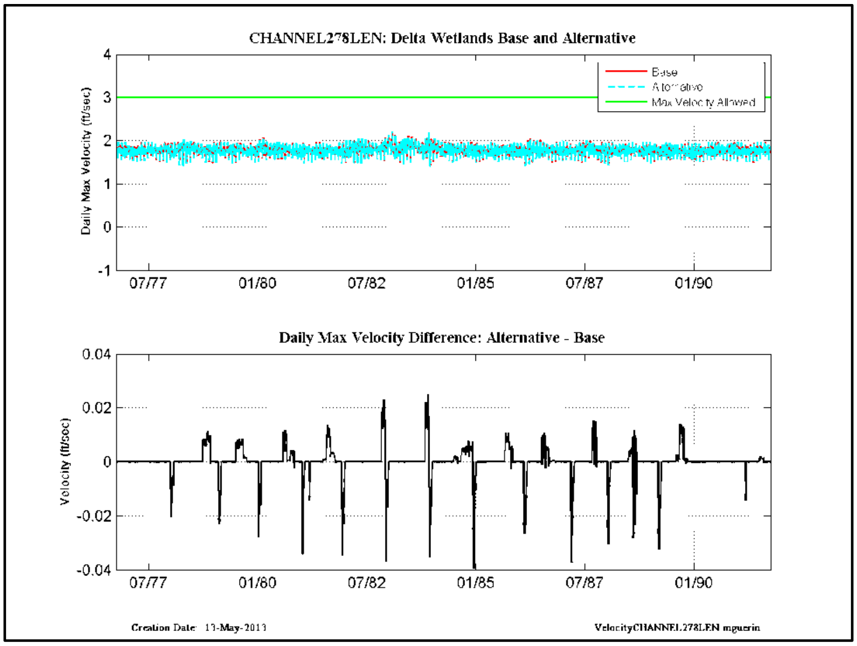


Figure 7-27 Channel277MID daily velocity maximum and difference (Alternative – Base) and daily velocity minimum and difference.



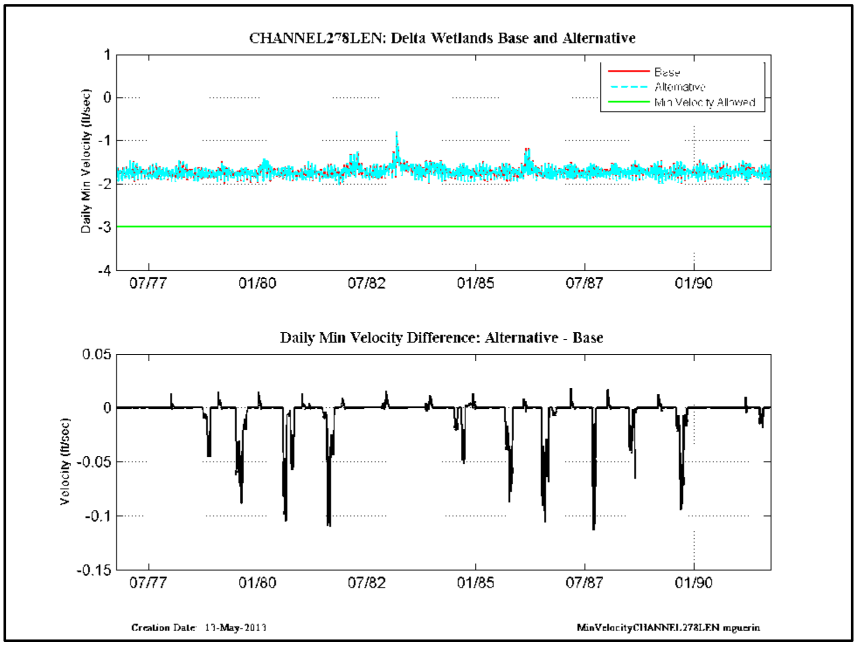
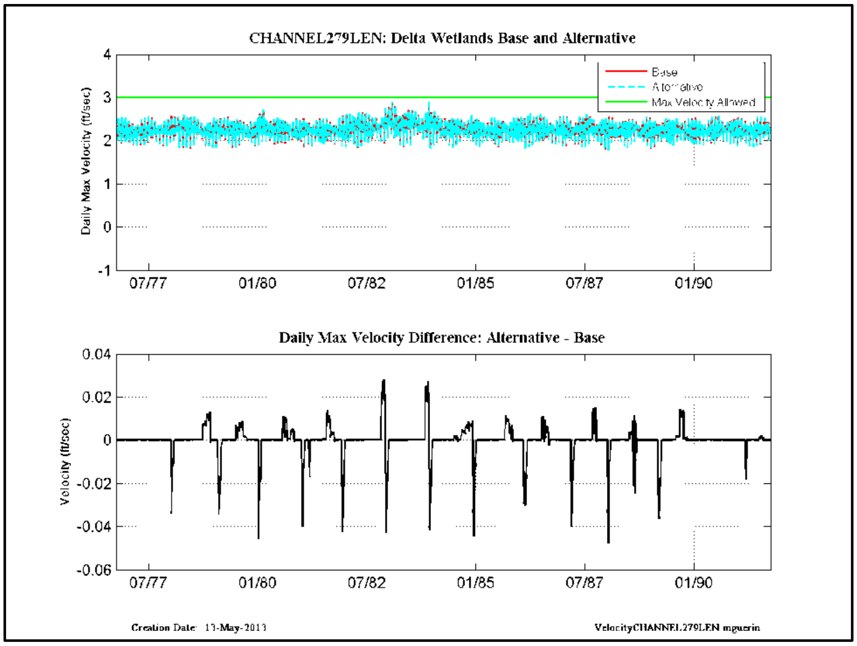


Figure 7-28 Channel278LEN daily velocity maximum and difference (Alternative – Base) and daily velocity minimum and difference.



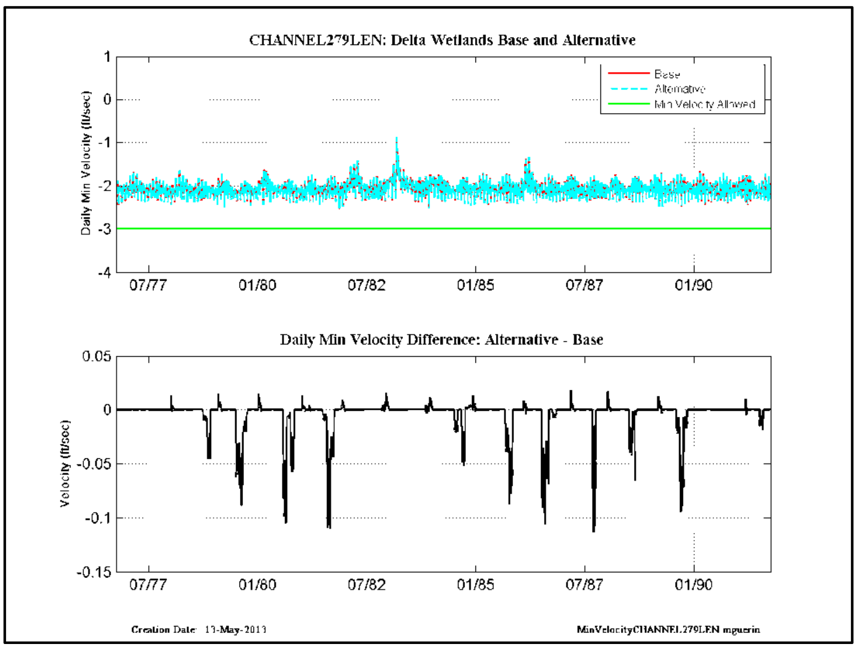
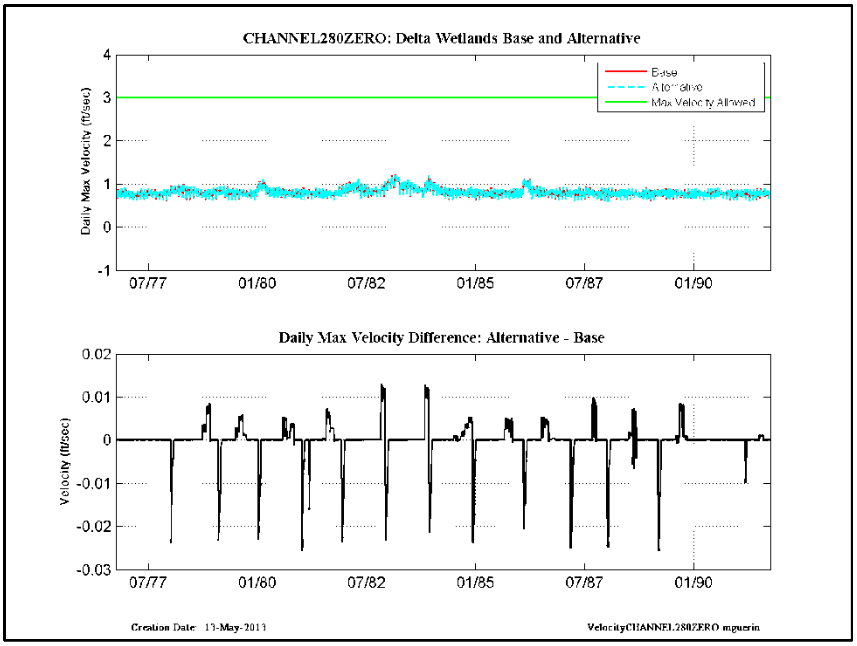


Figure 7-29 Channel279LEN daily velocity maximum and difference (Alternative – Base) and daily velocity minimum and difference.



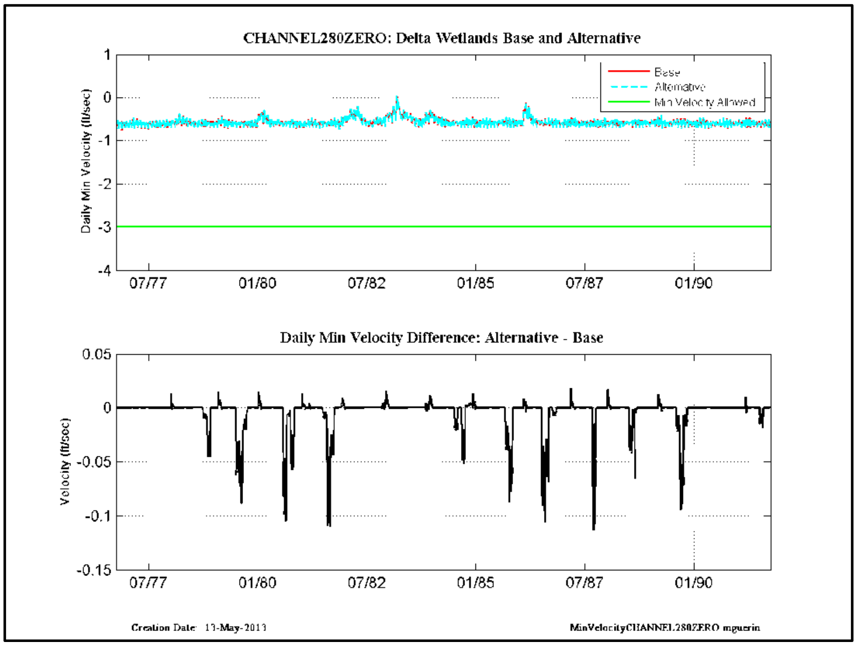


Figure 7-30 Channel280ZERO daily velocity maximum and difference (Alternative – Base) and daily velocity minimum and difference.

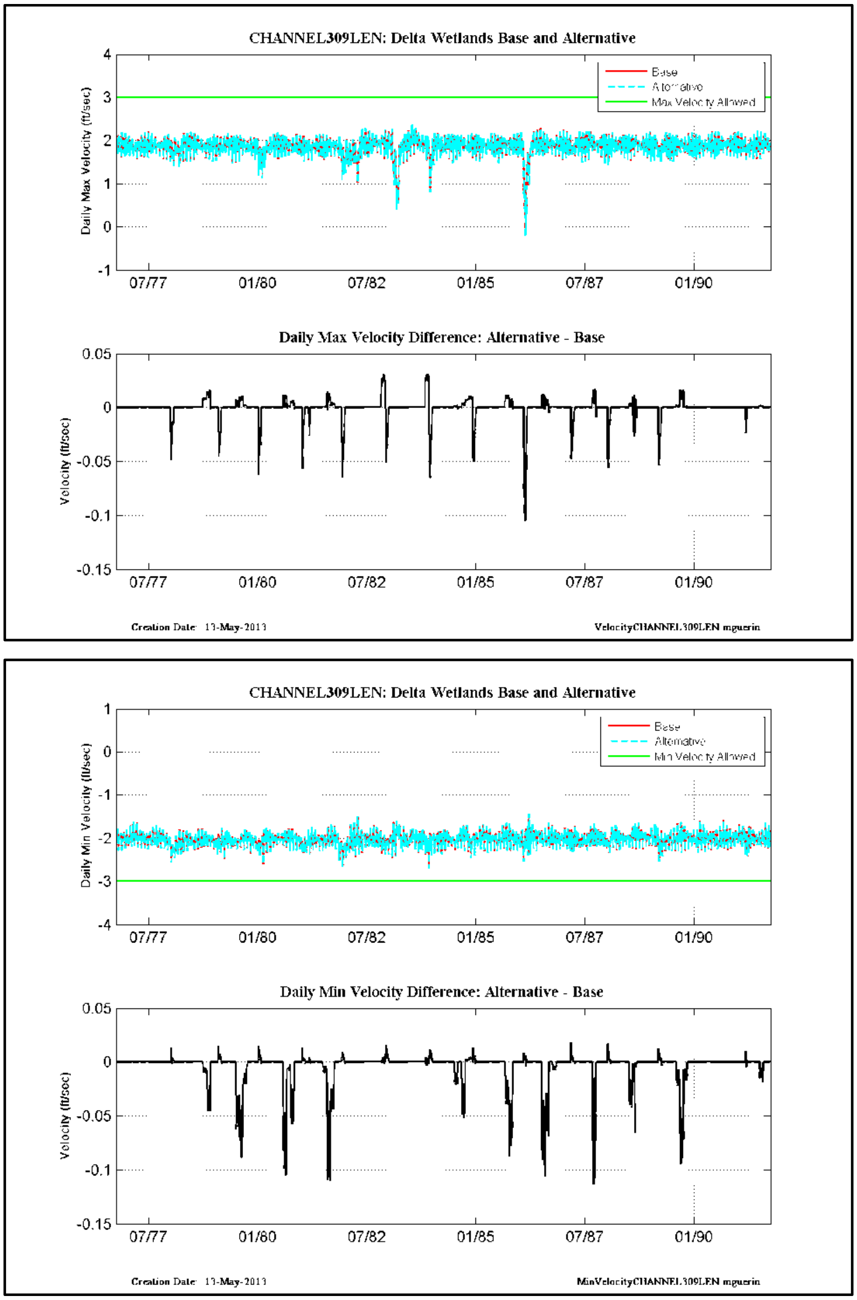
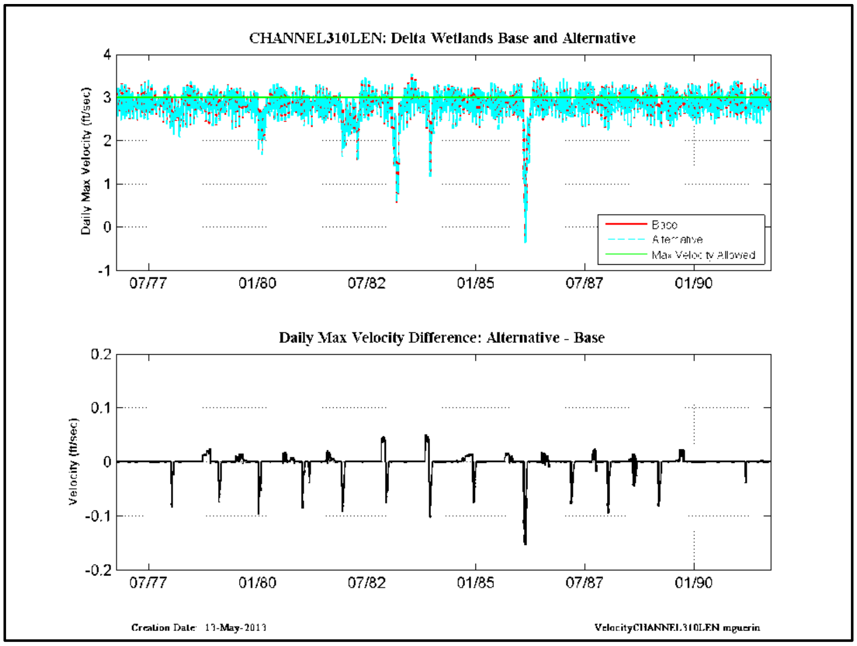


Figure 7-31 Channel309LEN daily velocity maximum and difference (Alternative – Base) and daily velocity minimum and difference.



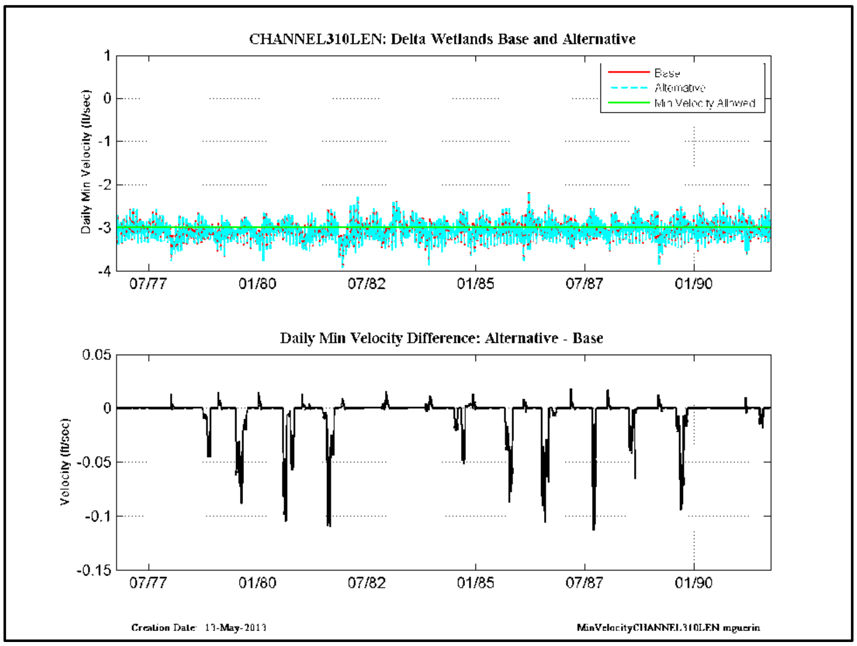
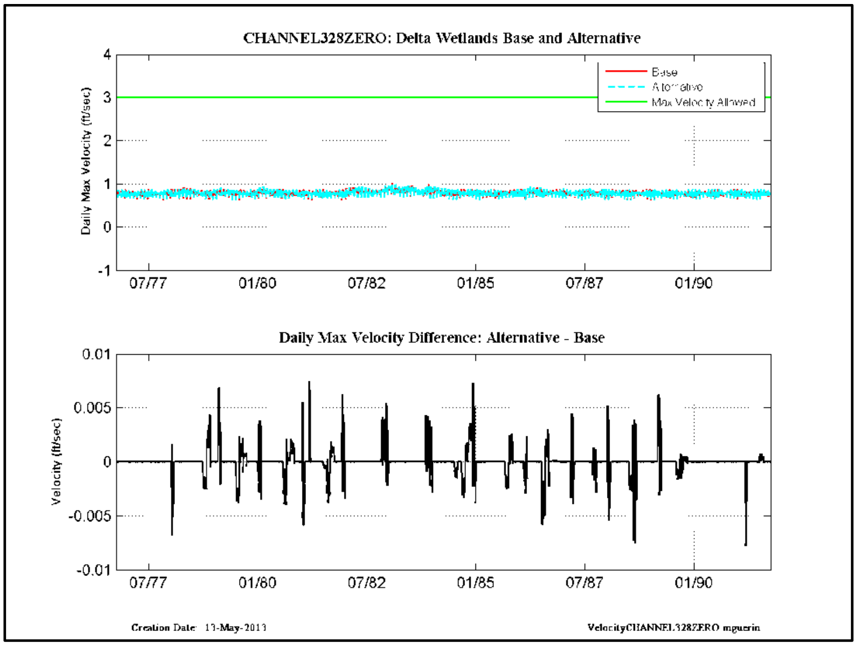


Figure 7-32 Channel310LEN daily velocity maximum and difference (Alternative – Base) and daily velocity minimum and difference.



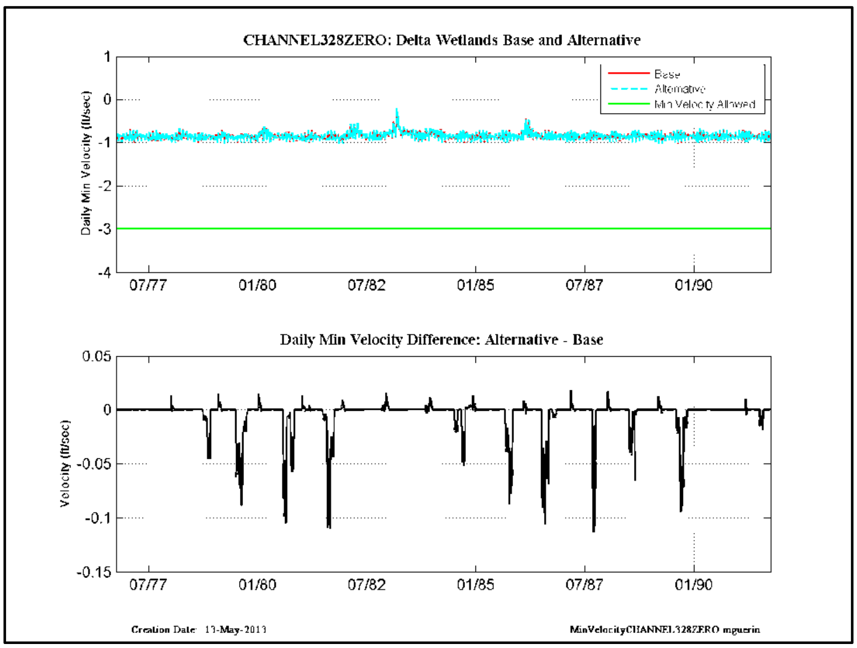
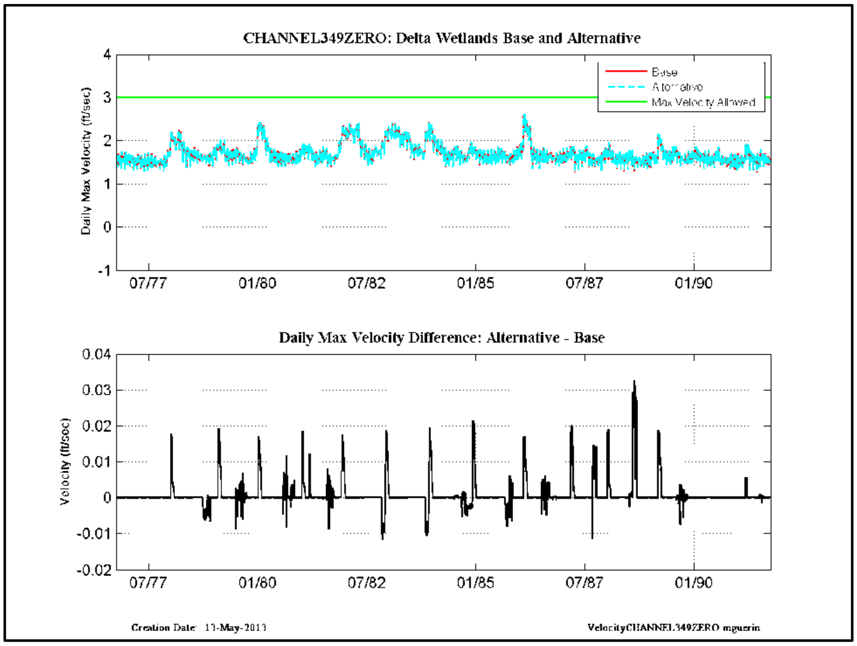


Figure 7-33 Channel328ZERO daily velocity maximum and difference (Alternative – Base) and daily velocity minimum and difference.



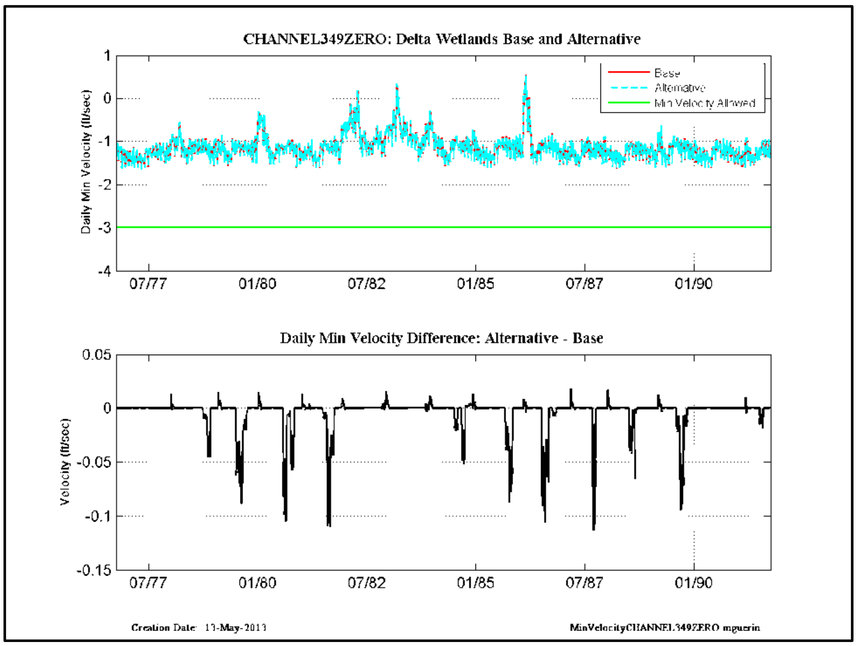
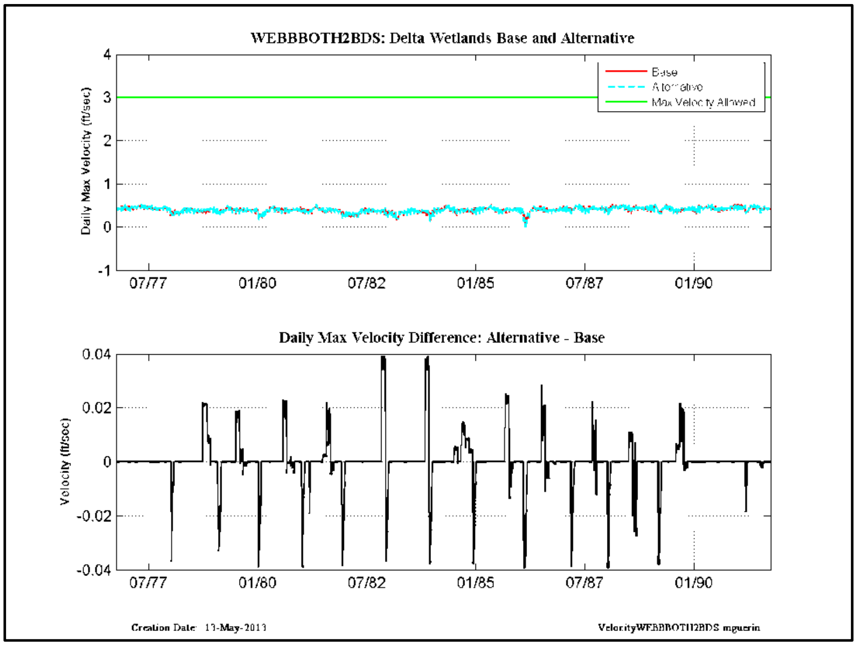


Figure 7-34 Channel349ZERO daily velocity maximum and difference (Alternative – Base) and daily velocity minimum and difference.



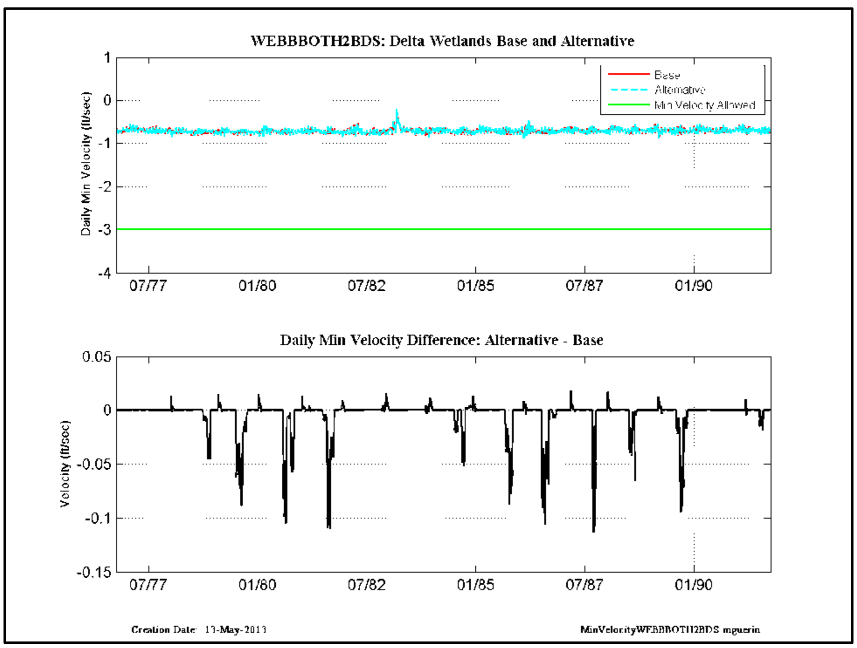
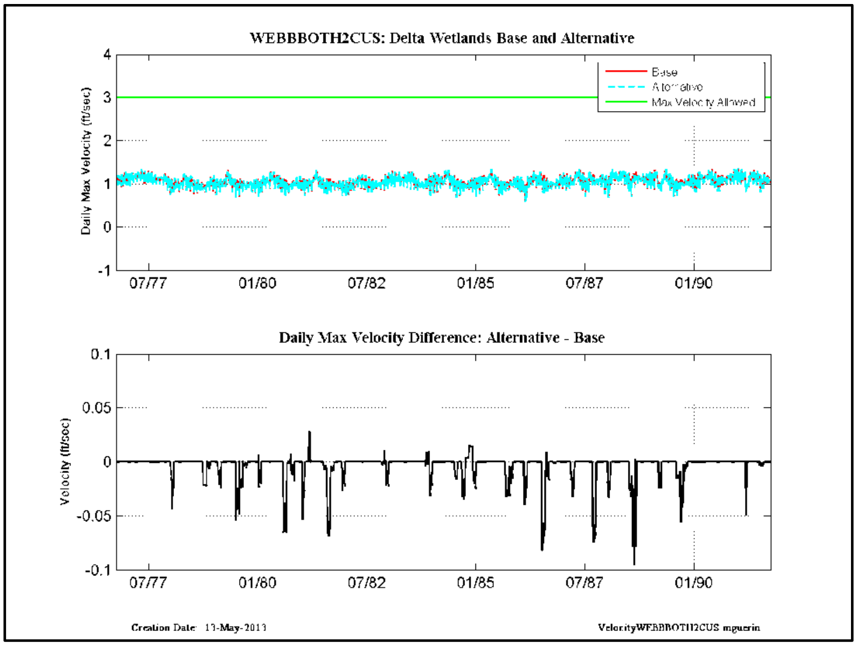


Figure 7-35 WEBBOTH2BDS daily velocity maximum and difference (Alternative – Base) and daily velocity minimum and difference.



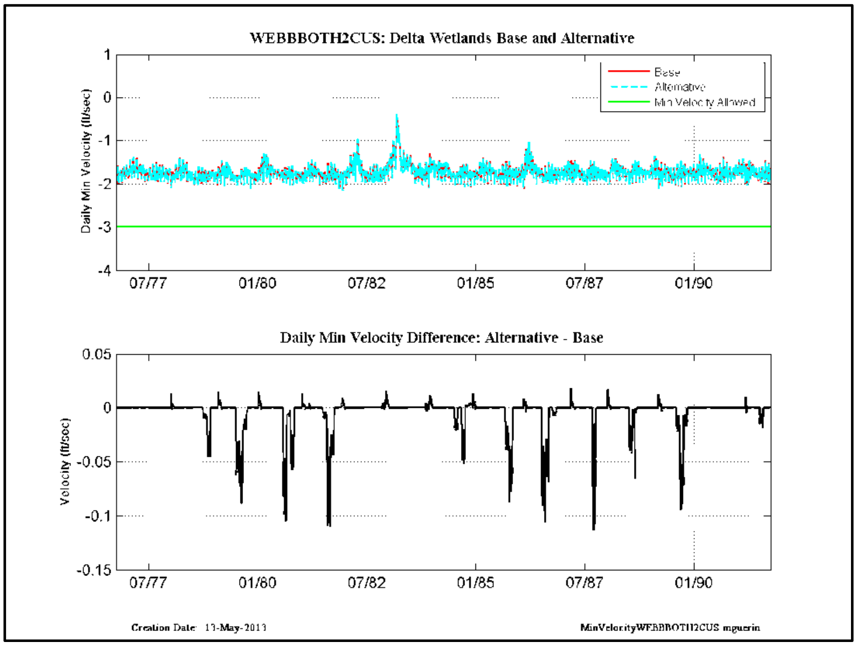
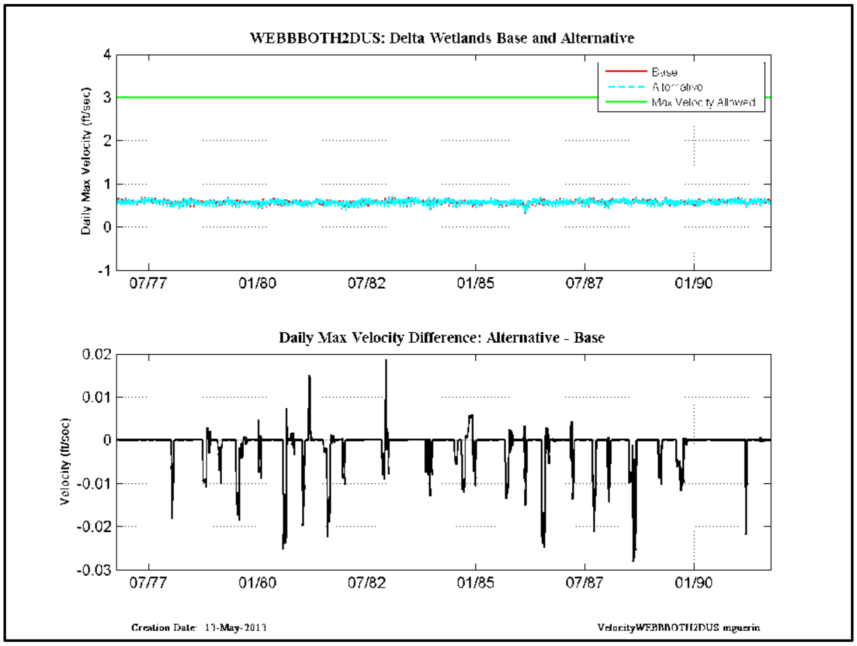


Figure 7-36 WEBSOTH2CUS daily velocity maximum and difference (Alternative – Base) and daily velocity minimum and difference.



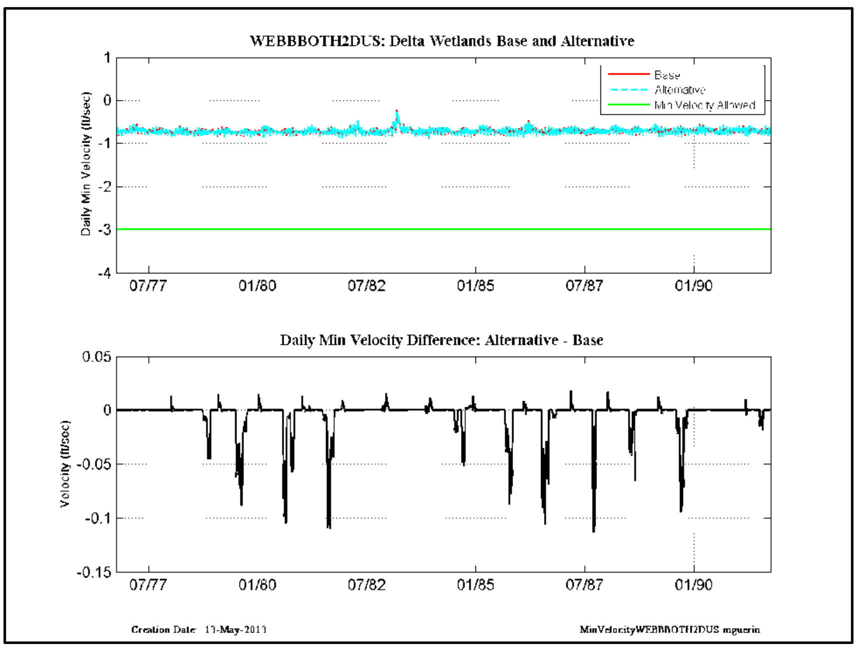


Figure 7-37 WEBSOTH2DUS daily velocity maximum and difference (Alternative – Base) and daily velocity minimum and difference.

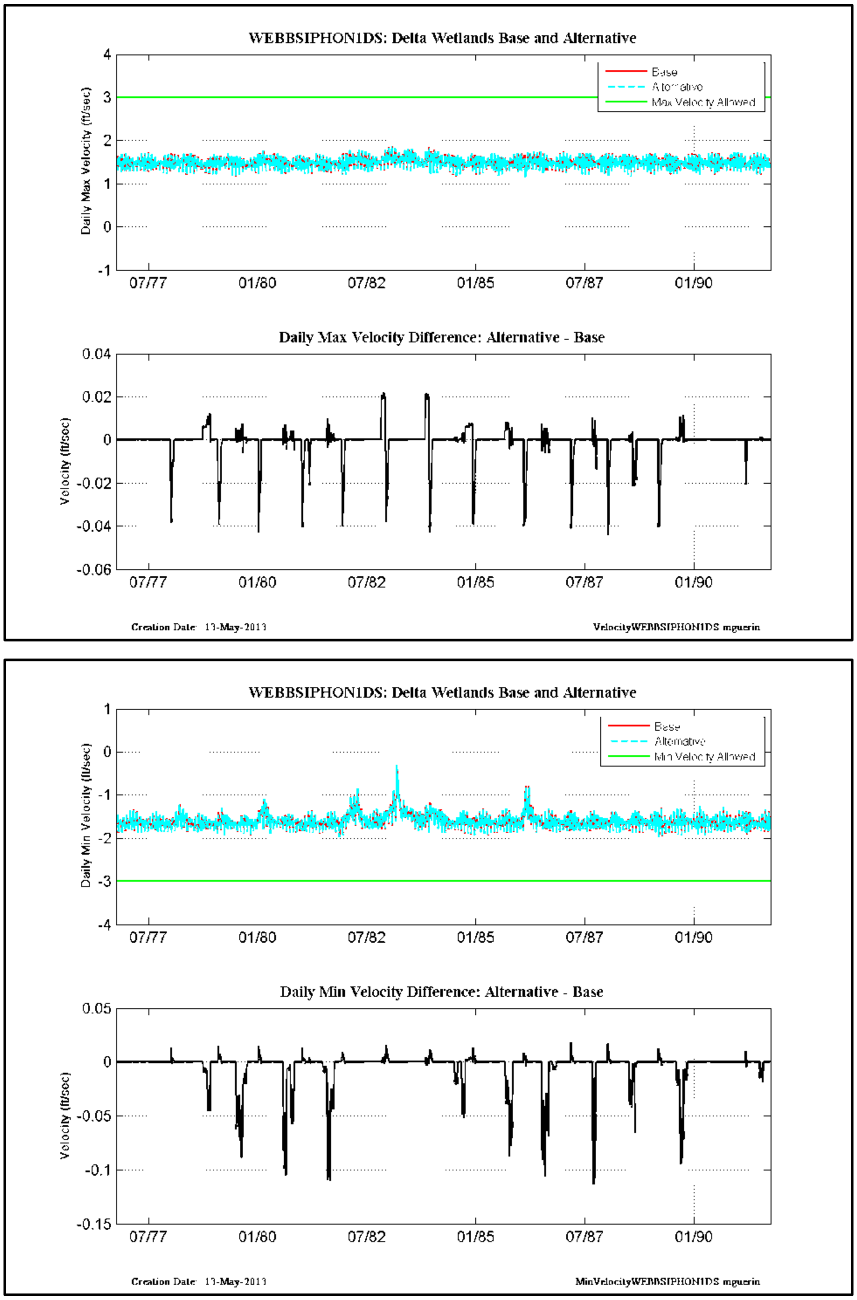
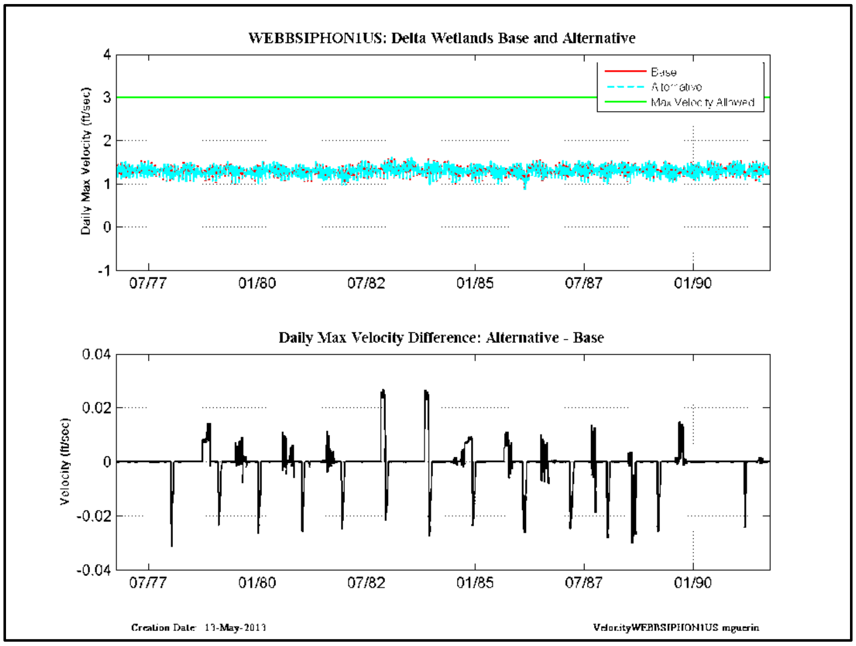


Figure 7-38 WEBBSIPHON1DS daily velocity maximum and difference (Alternative – Base) and daily velocity minimum and difference.



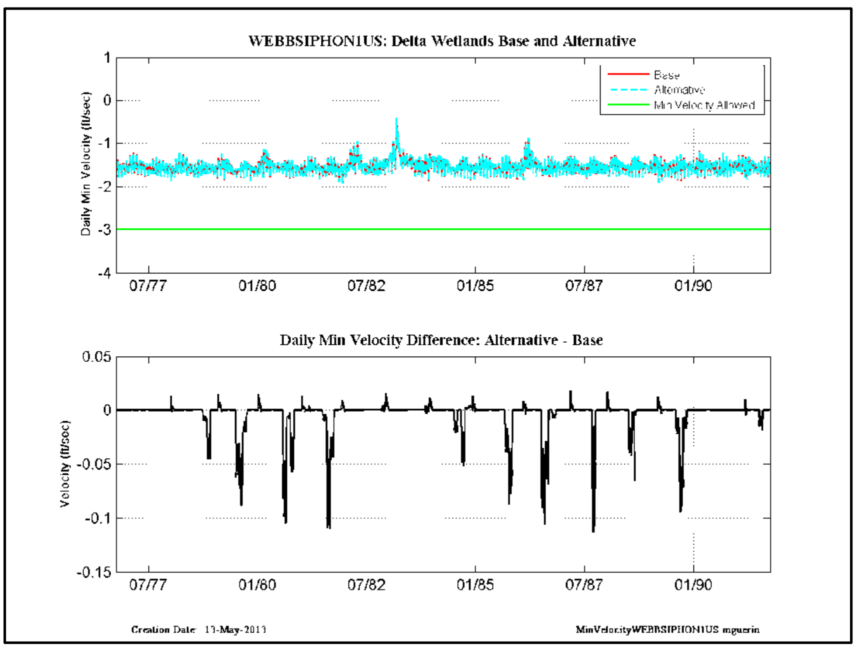


Figure 7-39 WEBBSIPHON1US daily velocity maximum and difference (Alternative – Base) and daily velocity minimum and difference.

7.2 Siphon rates and island capacity

The island capacity for storage of water and the siphon rates used in preparing the daily diversion time series were supplied to RMA by the Project. The details on diversion targets are documented in Table 7-1 through Table 7-4 below. Monthly average diversions were supplied to RMA from MBK as computed in their IDSM model.

The information from the Delta Wetlands staff was used to disaggregate the monthly diversions to daily time series. Diversions started on Day five for each month scheduled for diversion at the combined rate of 6,000 cfs. This translated to 1,500 cfs at each diversion locations initially, until the siphon capacity started to decline at about -10 ft. MSL (mean sea level) in each island reservoir (see Table 7-3 and Table 7-4).Additionally, there were a few months where full diversion was not scheduled – in those cases diversions rates were ramped down earlier than indicated in the tables to achieve the approximate volume scheduled.

Monthly average discharge rates from the two flooded islands were supplied to RMA from MBK, and the values were used as-in for input into DSM2 after conversion from TAF to cfs (see Figure 7-40). The scaled diversion rates are shown in Figure 7-41 for two of the four diversion locations. Figure 7-42 shows a finer time scale of the diversions at one of the Bacon Island locations.

Table 7-1 Bacon Island Area-Capacity Table (ac-ft).

Elevation (ft)	Area (ac)	Storage (ac-ft)
-16.0	0	0
-15.0	2219	1109.5
-10.0	5007	19174.5
-5.0	5430	71359.5
0.0	5439	98532
4.0	5450	115000

Table 7-2 Webb Tract Area-Capacity Table (ac-ft).

Elevation (ft)	Area (ac)	Storage (ac-ft)
-17.0	0	0
-15.0	2861	2861
-10.0	4659	21661
-5.0	4877	45501
0.0	5090	70418.5
4.0	5260	100000

Table 7-3 Storage target for Bacon Island diversions.

Day	Capacity (cfs)	Volume (AF)	Storage (AF)
1	0	0	0
2	0	0	0
3	0	0	0
4	0	0	0
5	3000	5940	5940
6	3000	5940	11880
7	3000	5940	17820
8	3000	5940	23760
9	3000	5940	29700
10	3000	5940	35640
11	3000	5940	41580
12	2875	5692.5	47272.5
13	2750	5445	52717.5
14	2625	5197.5	57915
15	2500	4950	62865
16	2375	4702.5	67567.5
17	2250	4455	72022.5
18	2125	4207.5	76230
19	2000	3960	80190
20	1875	3712.5	83902.5
21	1750	3465	87367.5
22	1625	3217.5	90585
23	1500	2970	93555
24	1500	2970	96525
25	1500	2970	99495
26	1500	2970	102465
27	1500	2970	105435
28	1500	2970	108405
29	1500	2970	111375
30	1200	2376	113751
31	600	1188	114939

Table 7-4 Storage target for Webb Tract diversions.

Day	Capacity (cfs)	Volume (AF)	Storage (AF)
1	0	0	0
2	0	0	0
3	0	0	0
4	0	0	0
5	3000	5940	5940
6	3000	5940	11880
7	3000	5940	17820
8	3000	5940	23760
9	3000	5940	29700
10	2875	5692.5	35392.5
11	2750	5445	40837.5
12	2625	5197.5	46035
13	2500	4950	50985
14	2375	4702.5	55687.5
15	2250	4455	60142.5
16	2125	4207.5	64350
17	2000	3960	68310
18	1875	3712.5	72022.5
19	1750	3465	75487.5
20	1625	3217.5	78705
21	1500	2970	81675
22	1500	2970	84645
23	1500	2970	87615
24	1500	2970	90585
25	1500	2970	93555
26	1500	2970	96525
27	1200	2376	98901
28	600	1188	100089
29	0	0	100089
30	0	0	100089
31	0	0	100089

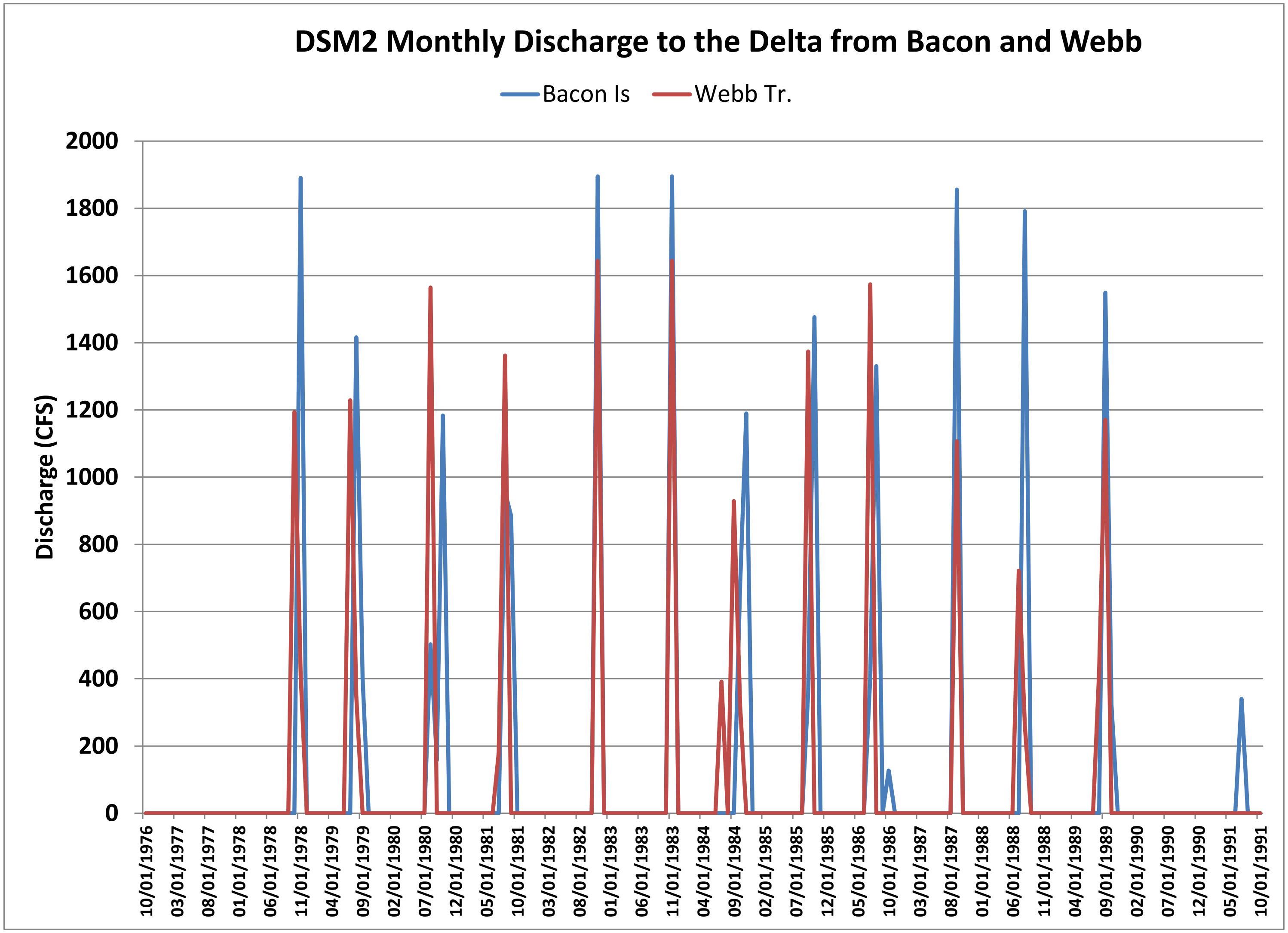
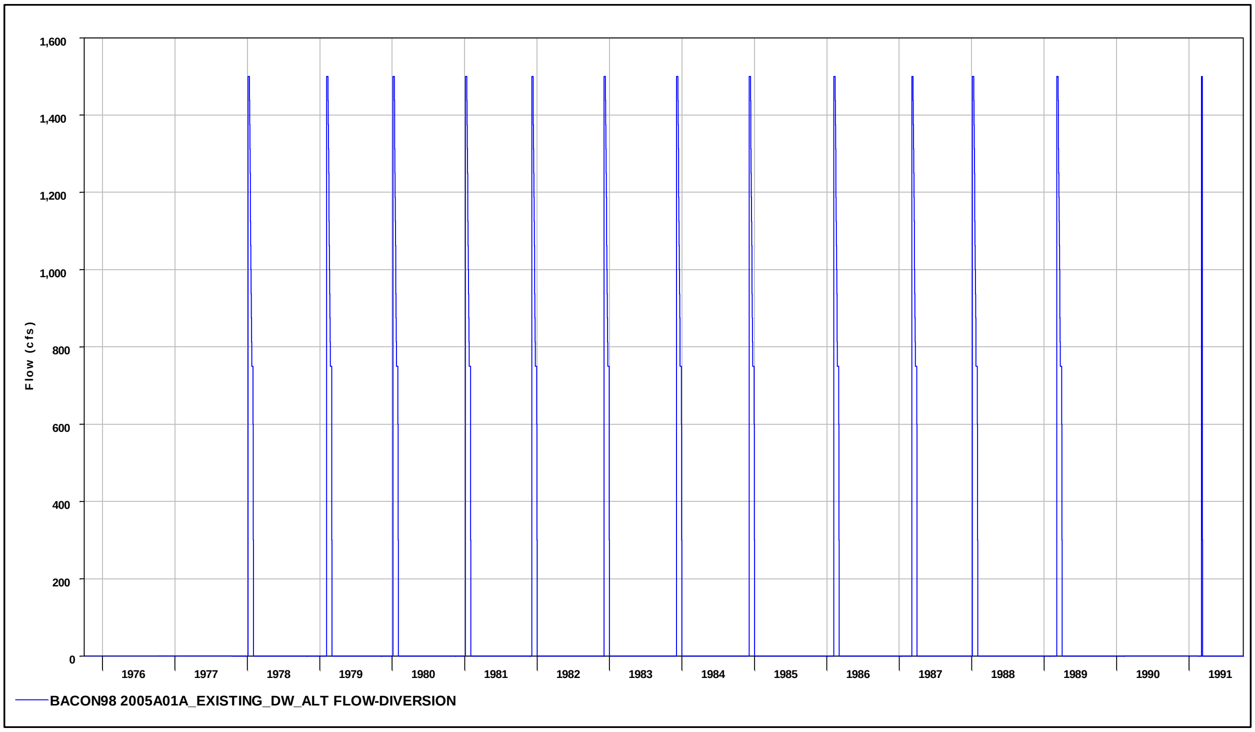


Figure 7-40 DSM2 discharge rates as supplied to RMA from MBK (after conversion from TAF to cfs).



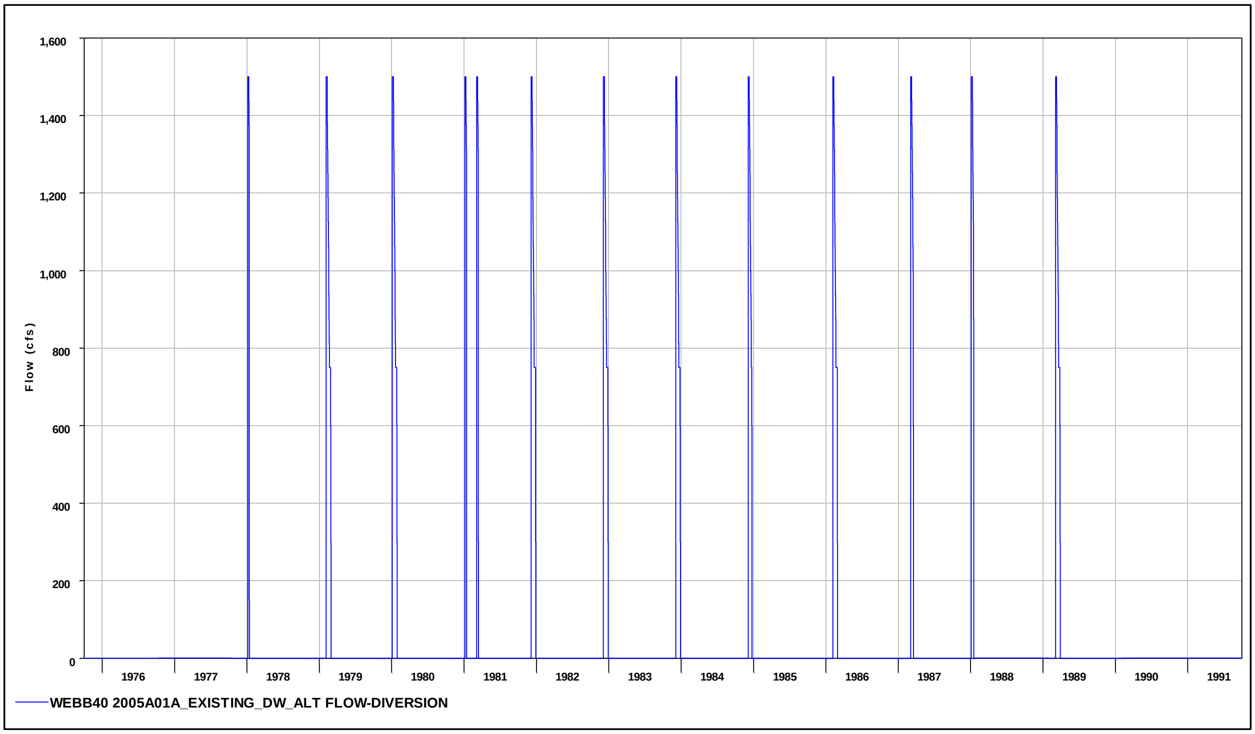


Figure 7-41Diversion timing and rate for the Alternative at one of the Bacon Island locations (upper) and one of the Webb Tract locations (lower).

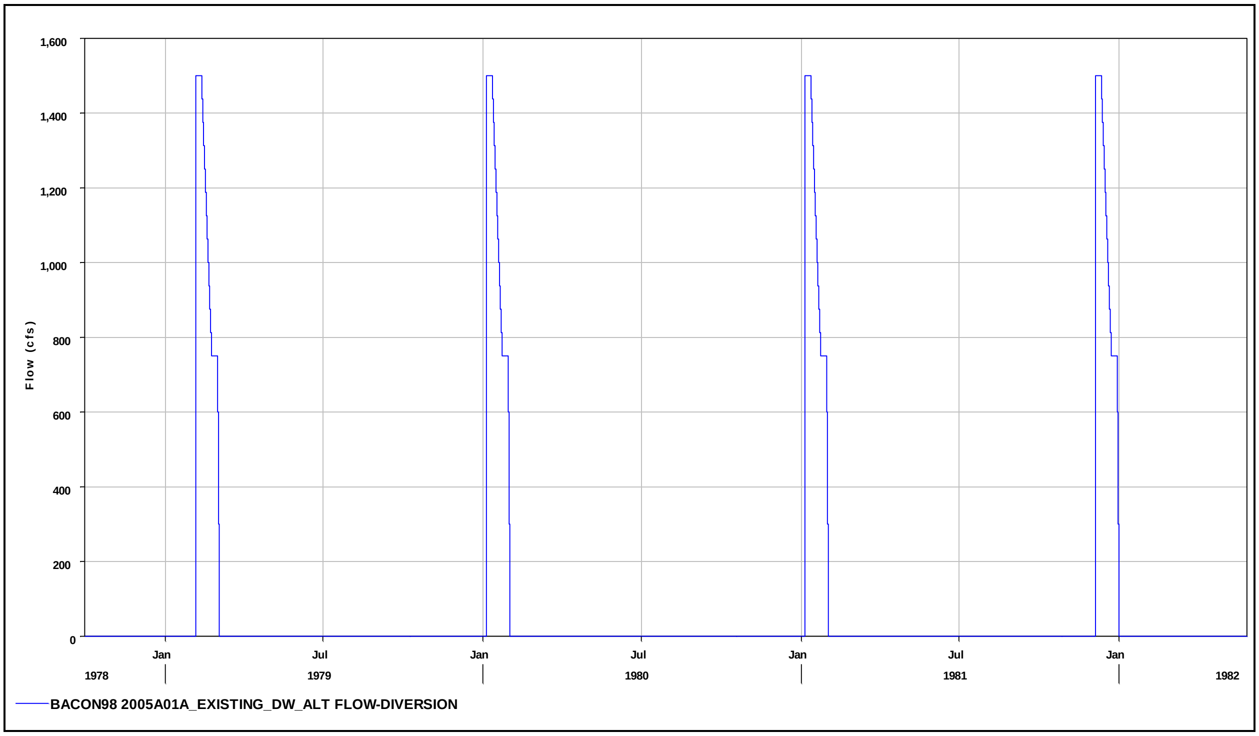


Figure 7-42 Finer time scale view of diversion timing and rate for the Alternative at one of the Bacon Island locations.