Methodology for Flow and Salinity Estimates in the Sacramento-San Joaquin Delta and Suisun Marsh

26th Annual Progress Report
October 2005

Chapter 3: Jones Tract 2004 Levee Break DSM2 Simulation

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3 Jones Tract 2004 Levee Break DSM2 Simulation

3.1 Introduction

On June 3, 2004, the Upper Jones Tract levee near Woodward Island failed, resulting in the flooding of both Upper and Lower Jones Tracts. Because flooded peat soils like those found on Upper and Lower Jones Tracts can be significant sources of organic carbon, Delta Simulation Model II (DSM2) was used to make short- and long-term water quality forecasts. Two- to four-week long, short-term forecasts made by the California Department of Water Resources' Division of Operations and Maintenance (O&M) focused on the hydrodynamic and electrical conductivity impacts related to the Jones Tract levee break and pump-off operations. Long-term forecasts, conducted by DWR's Delta Modeling Section, focused more on projecting the organic carbon concentrations at the urban intakes caused by the pump-off operations through the rest of 2004 (Mierzwa, 2004, Mierzwa et al., 2004). For these long-term forecasts, the representation of Upper and Lower Jones Tracts was refined by calibrating the timing of the break, the coefficient of flow through the breach, the scheduled pump-off of the two islands, and the organic carbon growth rate. Four of these DSM2 calibration scenarios are presented in this chapter. The final results of this calibration were incorporated into the DSM2 2004 simulation of south Delta hydrodynamics (Suits et al., 2005).

3.2 Conditions in the Delta Prior to the Levee Break

October 2003 through September 2004 was classified as a "Below Normal" water year type. However, calendar year 2004 Net Delta Outflow was characterized by extremely high flows in March and then low flows through the rest of the year. NDO can be used as a measure of water availability in the Delta. As shown in Figure 3.1, NDO was higher in March 2004 (around calendar day 60) than in March 1993 and 2003 despite the fact that 1993 and 2003 were both classified as "Above Normal" years. The high NDO of March 2004 caused low salinity concentrations in the Delta through early April. In mid-April San Joaquin River flows were increased, and the combined State Water Project (SWP) and Central Valley Project (CVP) exports were decreased as part of the Vernalis Adaptive Management Plan (VAMP). This helped maintain low salinity concentrations in much of the Delta. Two of the south Delta temporary barriers and the head of Old River fish protection barrier were installed in mid-April. Although San Joaquin River flows were decreased in mid-May, San Joaquin River electrical conductivity (EC) at Vernalis doubled in the course of a few weeks. During this same time, the head of Old River barrier was removed, thus allowing San Joaquin River water to travel through Grant Line Canal to the SWP and CVP export facilities. By the time the Upper Jones Tract levee failed (calendar day 155), salinity in the Delta was beginning to increase.

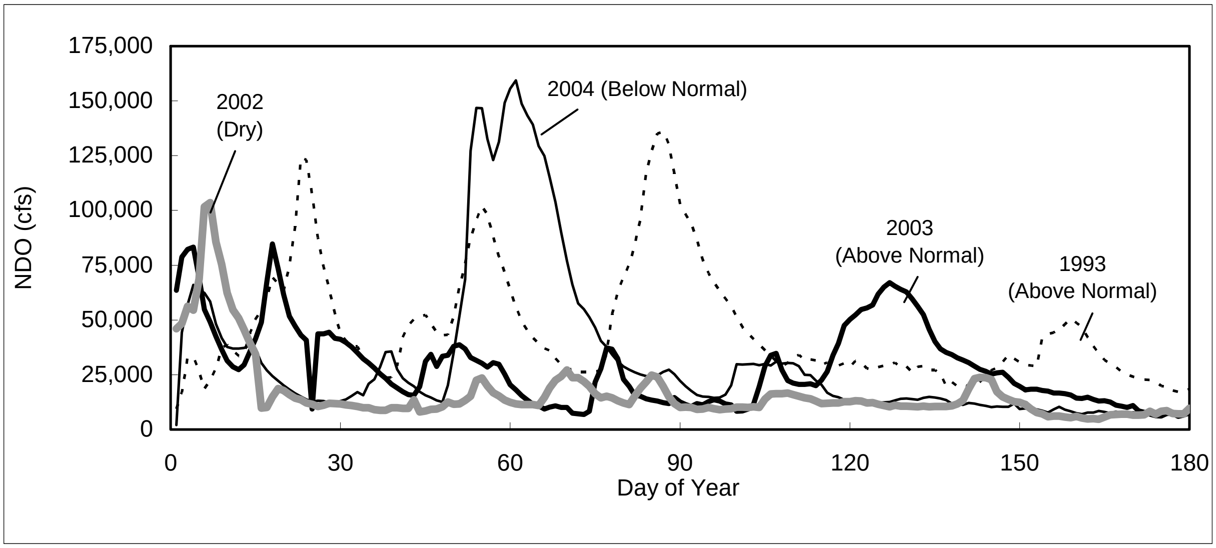

Figure 3.1: Selected Net Delta Outflows by Year and Water Year Type.

3.3 Timeline of Jones Tract 2004 Events

The hydrodynamic response of the Delta to the flooding of Jones Tract was influenced by four key events (see Table 3.1). When the Upper Jones Tract levee broke, between 150 and 200 thousand acre-feet (taf) of water flooded both Upper and Lower Jones Tracts in less than a week. The break occurred during a spring tide (a tide with maximum range in stage) as central Delta water levels were dropping from the higher-high to the lower-low tide. As Upper Jones Tract filled, water moved to Lower Jones Tract via an access road under the Santa Fe Railroad. Once both islands were filled, water moved in and out of Upper Jones Tract based on changes in Delta water levels due to the tide. Lower Jones Tract was more isolated than Upper Jones Tract. This period of tidal exchange between Upper Jones Tract and the Middle River continued until late June, when enough material had been deposited in the levee breach to effectively restrict the majority of the flow in and out of Upper Jones Tract. When the levee breach was first closed, the organic carbon-rich water on both Jones Tract islands was isolated from the Delta. However, when the pump-off operations began on July 12, the high organic carbon concentration water on the island was again mixed with the lower concentration Middle River water near Santa Fe Cut. The pump-off operations continued until December 18.

Table 3.1: Estimated DSM2 Timeline of Jones Tract 2004 Events.

Levee Break	June 3 6:51 PST
Closure of Levee Breach	June 30 12:00 PST
Start of Major Pump-off Operations	July 12 00:00 PST
End of Major Pump-off Operations	December 18 00:00 PST

In DSM2 the levee break and repair were assumed to be instantaneous in order to simplify the calibration process. The Department was not able to install accurate flow meters in the pipes used to remove water from the islands, thus it was necessary to estimate the pump-off flow rates, which for the purpose of modeling were assumed to be daily average flows. Because DSM2 does not account for daylight-saving time, the reported time of the breach, 7:50 a.m. Pacific Daylight Time (DWR, 2004), was converted to Pacific Standard Time. The start times of the other three events were estimated.

3.4 Representation of Jones Tract in DSM2

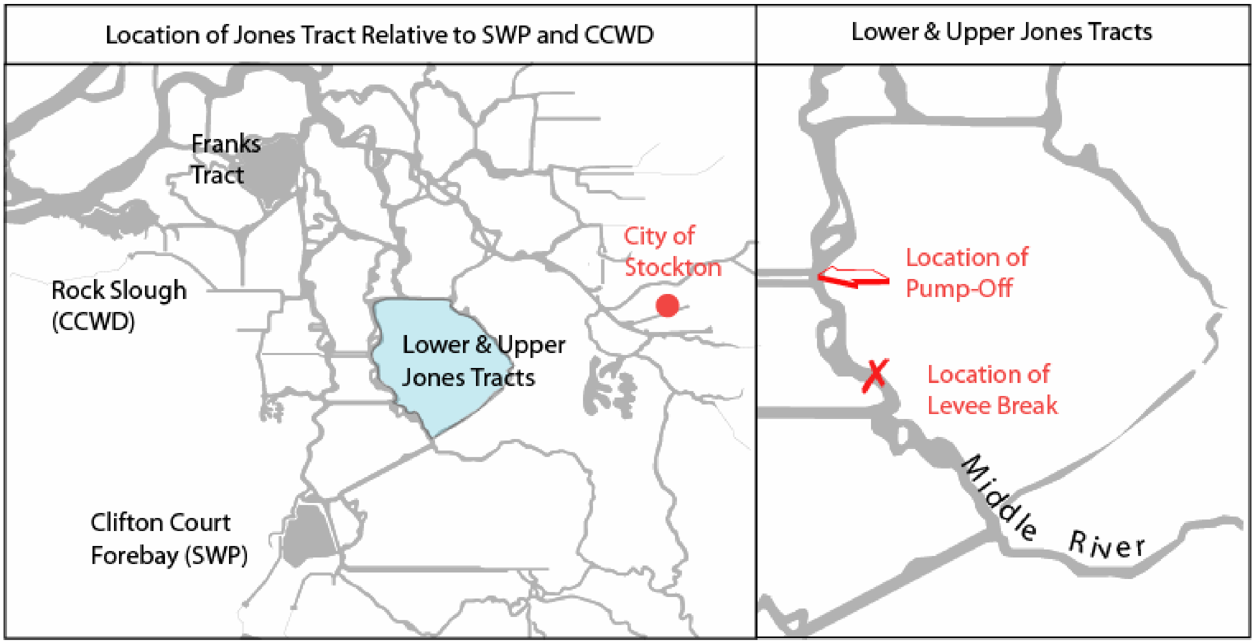

Figure 3.2: Location of Lower and Upper Jones Tracts.

Immediately following the Upper Jones Tract levee break, DWR's Division of Operations and Maintenance (O&M) needed to incorporate the flooded Upper and Lower Jones Tracts into its regular short-term forecasts. Because these forecasts were after the break, O&M hydrodynamic and EC forecasts assumed that the two islands were already flooded and allowed water to move in and out of a combined Jones Tract reservoir (see Figure 3.2) based on differences in the stage inside the island reservoir and the Middle River.[1] When the levee breach was assumed closed, the island was no longer directly simulated in DSM2. Instead releases from the island were simulated as a new boundary input into the Delta. The flows associated with these operations were estimated based on information provided by field crews.

Because the long-term forecasts and historical update also focused on organic carbon impacts due to both the flooding and pump-off associated with Jones Tract, a more detailed representation of the two islands was developed for DSM2. The representation of Jones Tract

[1] Immediately after the break, O&M ran DSM2 historical simulations that included estimates for the flows onto the islands in order to develop initial conditions for the short-term forecasts, but as the forecast period moved further away from the levee failure event, the need to estimate this dynamic response was unnecessary in the short-term forecasts.

used in the long-term forecasts and historical simulation is described below in three sections: the treatment of Jones Tract as a flooded island, the levee break and repair, and the pump-off operations.

3.4.1 Jones Tract as a Flooded Island

Although Upper and Lower Jones Tracts are divided by the Santa Fe Railroad, an access road that runs under the railroad tracks connects the two islands and allowed water to travel from Upper Jones Tract to Lower Jones Tract and flood both islands. Because flooded islands are treated as well-mixed reservoirs in DSM2, there was not enough information available to justify simulating Lower Jones Tract as a separate island reservoir. Instead, a single reservoir was used to represent both Upper and Lower Jones Tracts. The reservoir was opened at the time of the break as described below in *Section 3.4.2*.

```
# Boundary flow input file
# DSM2 Real-Time Simulations
# Updated: 2005.02.27 mmierzwa

# JONES TRACT GEOMETRY
#
# Reservoir Grid Map Info:
# 6. Jones Tract (JONES) <-- Levee Break 2004.06.03

# NOTE: Place this file *before* the original reservoirs.inp in the dsm2.inp file
# Due to a programming style you have to name jones tract as "baconisland"

RESERVOIRS
NAME         AREA   STAGE  BOTELV NODE   COEFF2RES    COEFF2CHAN
baconisland  522.72  -13.9 -14.0  118    2000.        2000.
END

# Source: Correspondence with Rob DuVall and field trips from Oct - Dec, 2004
# Jones Tract Assumptions:
# - Ave. Depth = -5 m NGVD --> ~ -15 ft NGVD (MWQI)
# - Surface Area = 12,000 acre = 523 E06 sq. ft
# - Calculated Storage Capacity @ 0 ft NVGD = 180 TAF
# - Single Breach near Woodward Isl.
# - Coeff in / out based on calibration of model / USGS 15-min data in mid and old r
```

Figure 3.3: Example Jones Tract Configuration in a DSM2 Input File.

An example of the DSM2 input code that was used to represent the combined Jones Tracts is shown in Figure 3.3. The organic carbon growth algorithm was originally developed as part of the In-Delta Storage program. Because of the way the DSM2-QUAL organic carbon growth algorithm was programmed and the need to quickly forecast the water quality impacts of the Jones Tract event, the Jones Tract island reservoir was named “baconisland.” The surface area and starting elevation of the reservoir were based on field information provided by a number of DWR and US Geological Survey sources. Because these sources estimated slightly different values for the surface area and island land surface elevations, these numbers were refined during the DSM2 calibration. Furthermore, the “COEFF2RES” and “COEFF2CHAN” variables were determined after running a series of simulations using different coefficients to regulate the amount of flow into and out of the reservoir and comparing DSM2 stage and flow results in the south and central Delta with field results.

Based on a bookend approach that was originally developed in support of In-Delta Storage planning studies (Mierzwa and Pandey, 2003), two different organic carbon growth rates were used to simulate increases in organic carbon concentrations due to flooding an island rich in peat soils. The organic carbon growth rates varied each month, as shown in Table 3.2. The results of both the high and low bookends were compared with organic carbon Jones Tract grab samples from Municipal Water Quality Investigations (MWQI) and the measured organic carbon at SWP's Clifton Court Forebay (see *Section 3.7.2*).

Table 3.2: DSM2 Jones Tract Organic Carbon Growth Rates ($gC/m^2/day$).

Growth Rate	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep
High	0.50	0.00	0.00	0.00	0.00	0.50	0.50	0.50	0.50	0.50	0.50	0.50
Low	0.05	0.00	0.00	0.00	0.00	0.05	0.05	0.05	0.05	0.05	0.05	0.05

3.4.2 Jones Tract Levee Break and Repair

The Jones Tract levee break and repair were simulated in DSM2 by treating the levee break as a gated structure. When the reservoir gate was opened on June 3 in DSM2, it took three to five days for the island to completely flood. The gate was closed until the time of the levee break, and then closed again when the levee was effectively repaired on June 30. The gate / levee breach was simulated on Middle River near the actual breach location. An example of the DSM2 input code used to control the levee breach is shown in Figure 3.4. The jones.dss file shown in Figure 3.4 contains the opening and closing times of the reservoir gate.

```
GATES
NAME           OPER    NODE
baconisland    time    118
END

# gate timing from other dss files
INPUTPATHS
NAME        A_PART     B_PART         C_PART  E_PART    F_PART   FILLIN  PRIORITY  FILENAME
Baconisland hist+gate  ${JONESBREACH} POS     IR-DECADE  DWR-DMS last    0 ./timeseries/jones.dss
END
```

Figure 3.4: Example Jones Tract Levee Breach in a DSM2 Input File.

In order to prevent a numerical instability that would cause the model to abort when the levee was opened, DSM2-HYDRO's computational time step was shortened from the normal 15 minutes to 5 minutes. This time step was used in all of the scenarios. These scenarios were designed to test the sensitivity of DSM2 flows and stage to different levee break times, effective levee repair dates, pump-off flow rates, and organic carbon growth rates.

Even when using a 5-minute computational time step, changing the time of the levee break would result in small differences in the flow into and stage inside of Jones Tract for the week following the break. The timing of the closure of the levee breach was significant in determining the maximum water level inside the DSM2 island reservoir. For example, if the levee breach was closed near a low tide, the water level (and hence volume of water stored on the islands) would be lower than if the levee breach was effectively closed near a high tide. In reality, as the levee breach repair neared completion, changes in Middle River water levels would have a less significant impact on the amount of water exchanged between the flooded islands and the Delta. However, given the lack of detailed information regarding the amount of water that was stored on Upper and Lower Jones Tracts when the breach was closed, it was not possible to time the DSM2 closure of the levee breach to match a target storage volume.

3.4.3 Jones Tract Pump-Off

Because the flow rate of water pumped off the two islands was not directly measured, it was necessary to estimate this flow in order to correctly simulate the historical hydrodynamic and water quality impacts the draining of Jones Tract had on the Delta. Water was removed from both islands via a series of pumps and pipes, which had a combined maximum capacity of 800 cubic feet per second (cfs). It was assumed that the actual pump-off flow rate was near this value from mid-July through mid-September. In mid-September the pumps on Upper Jones Tract were shut down, leaving only the Lower Jones Tract pumps operational. Located on either side of the Santa Fe Railroad, both sets of pipes discharged Jones Tract water to the Middle River near Santa Fe Cut and the southern end of Bacon Island.

By using the dates when (1) pumping began, (2) the Upper Jones Tract pumps were shut down, and (3) the Lower Jones Tract pumps were shut down and by estimating the total volume of water stored on Jones Tract (approximately 180 taf), it was possible to reconstruct the daily average flow rate for the pump-off operations. Figure 3.5 shows the flow rate used in DSM2 to simulate the combined pump-off of both Upper and Lower Jones Tracts. Water was pumped from Jones Tract using an object-to-object approach (Figure 3.6). This approach allowed the organic carbon-rich water from Jones Tract to mix into the Middle River.

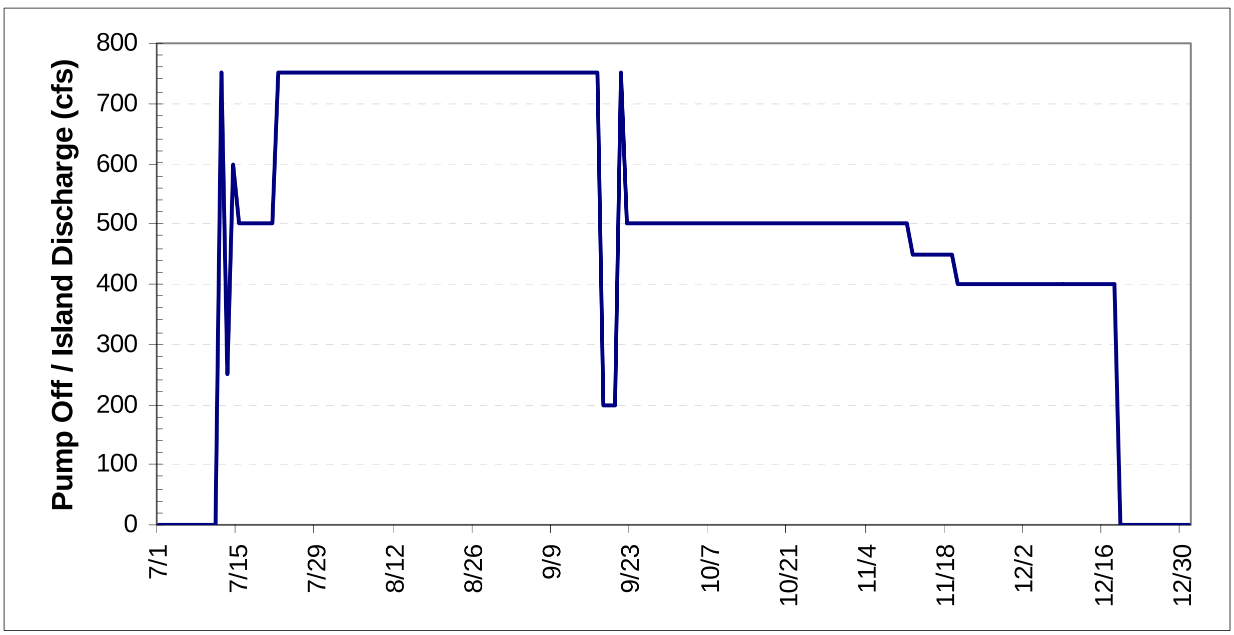

Figure 3.5: Estimated Jones Tract Pump-Off Flow Rate Used in DSM2 Simulation of Historical 2004 Conditions.

```
# JONES TRACT OPERATIONS
# To move water to / from the ISI-IDS project islands
OBJ2OBJ
FROM_TYPE      FROM_NAME      TO_TYPE        TO_NAME        INPUT_LABEL
reservoir      baconisland    node           121            jonespump
END

# Jones Tract Levee Breach Scheduled Releases
# jonespump for object-2-object
INPUTPATHS
name           a_part         b_part  c_part  e_part  f_part         fillin  filename
jonespump      hist+chan      jones   flow    1DAY    ${PUMPOUT}     last    ./timeseries/jones.dss
END

TYPE
STRING         PART   MATCH   ACCOUNT
/JONES/FLOW    P      sub     RIM
END
```

Figure 3.6: Example of Jones Tract Pump-Off in a DSM2 Input File.

3.5 DSM2 Scenarios

More than 38 different scenarios were run in order to test the sensitivity of the DSM2 parameters and assumptions described above. In this report, the historical simulation is presented in the hydrodynamics section, and results of two organic carbon growth rate scenarios and two alternative scenarios are presented in the water quality section. A summary of the scenarios presented in this report is shown in Table 3.3.

Table 3.3: Summary of DSM2 Jones Tract Scenarios.

Scenario	Date of Levee Break	Date of Pump-off	Organic Carbon Growth Rate
Historical (High Growth)	Jun 3	Jul 12	0.50 $gC/m^2/day$
Historical (Low Growth)	Jun 3	Jul 12	0.05 $gC/m^2/day$
No Pump-off	Jun 3	-	0.50 $gC/m^2/day$
No Break	-	-	0.50 $gC/m^2/day$

The two different organic carbon growth rate scenarios were chosen in order to provide bookends for likely organic carbon concentrations in Jones Tract. The monthly varying organic carbon growth rates used in these two scenarios are shown in Table 3.2 (see *Section 3.4.1*). The historical hydrodynamic simulation was used for both of these two organic carbon simulations, thus the only difference in water quality between these two scenarios was due to the organic carbon growth rates.

The two alternative scenarios were conducted to determine the impact of the Jones Tract levee breach and the pump-off operations. The impact can be accessed by comparing the two organic carbon growth rate, historical flow-based simulations with observed water quality data with the model results from the two scenarios.

3.6 Hydrodynamic Modeling

The calibrated Jones Tract DSM2 simulation was incorporated into the annual DSM2 2004 South Delta Historical Hydrodynamic simulation. Suits et al. (2005) provides a more detailed description of the boundary conditions and model results of the 2004 historical simulation. This report compared the DSM2-simulated stages and flows at several locations in the south Delta. Below is an overview of hydrodynamic information presented in this report.

3.6.1 Geometry

The changes incorporated into DSM2 to represent Upper and Lower Jones Tracts are described in *Section 3.4*. All three south Delta temporary agricultural barriers and the spring and fall fish protection barriers at the head of Old River were installed in 2004. Timing of the installation and removal of all four structures was estimated based on 15-minute observed water level data. The Delta Cross Channel and Clifton Court Forebay gates were operated according to their historical schedules. The Delta Cross Channel was opened on June 3, 2005, shortly after the levee break.

3.6.2 Hydrology

The flow and stage values used as boundary conditions in DSM2 were downloaded from the Interagency Ecological Program (IEP) and California Data Exchange Center (CDEC) web sites. The daily average flows for the major DSM2 flow inputs—Sacramento River, Yolo Bypass, and San Joaquin River—are shown in Figures 3.7, 3.8, and 3.9. Although 2004 was classified as a Below Normal water year, flows were high on each of the three main Delta tributaries in late February through March 2004. However, in the month preceding the Jones Tract levee break, Sacramento River and Yolo Bypass flows were fairly low. The increases in San Joaquin River flows in mid-April through mid-May were part of VAMP and correspond with a 31-day decrease in SWP and CVP exports.

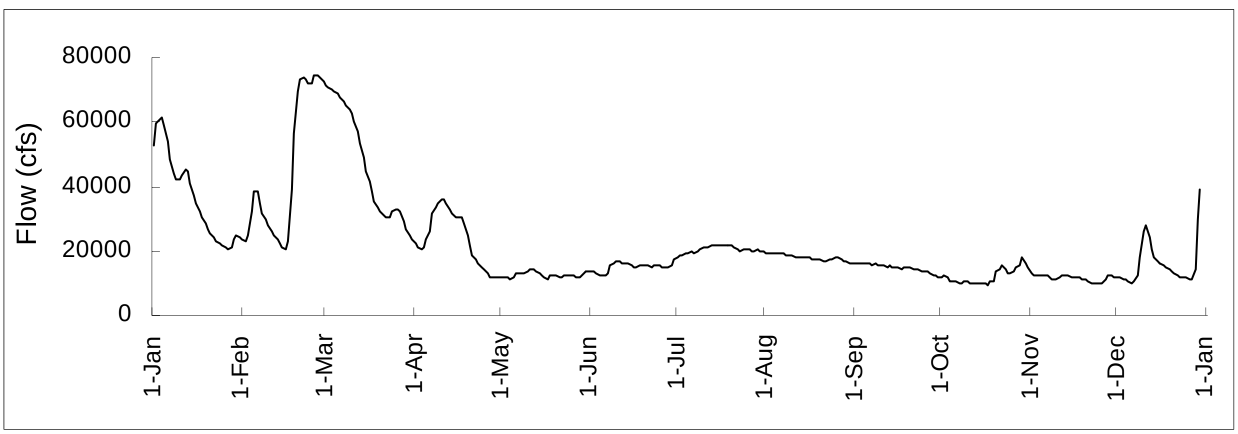

Figure 3.7: Sacramento River 2004 Daily Average Historical Flows.
(Source: Suits et al., 2005)

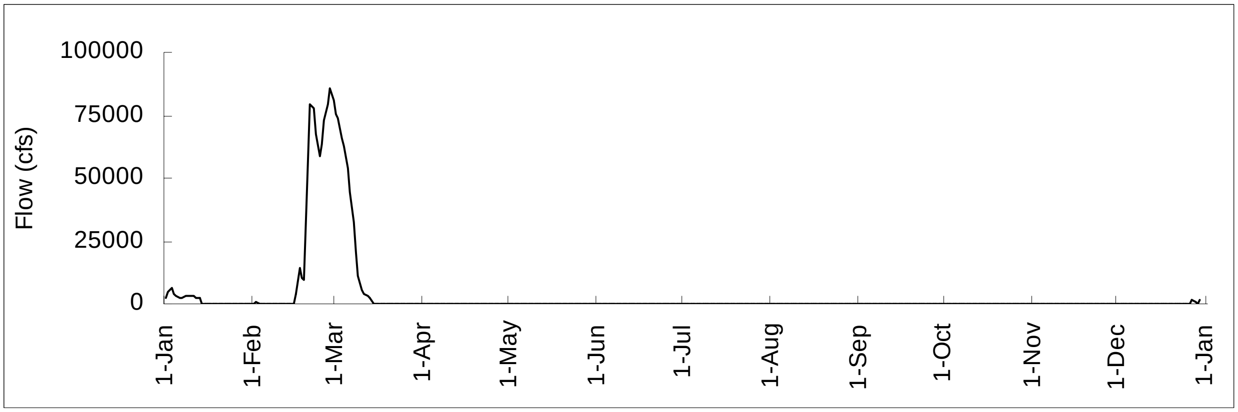

Figure 3.8: Yolo Bypass 2004 Daily Average Historical Flows.
(Source: Suits et al., 2005)

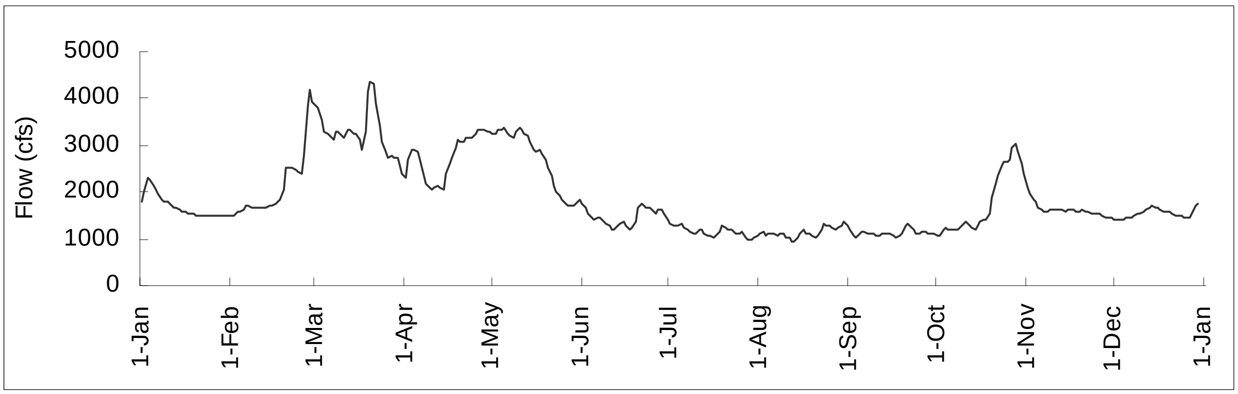

Figure 3.9: San Joaquin River 2004 Daily Average Historical Flows.
(Source: Suits et al., 2005)

Historical consumptive use in the Delta was estimated by the Delta Island Consumptive Use (DICU) model, which uses precipitation, pan evaporation, and water year type to determine the agricultural water needs in the Delta and distribute these flows throughout the DSM2 model domain. The agricultural demands for Upper and Lower Jones Tract were not altered, even though the flooding of the islands eliminated agricultural use. However, during the pump-off operations, the existing agricultural drains and return siphons were used to assist removing water from the flooded island.

3.6.3 Hydrodynamic Results

The hydrodynamic results are presented according to stages in the south Delta, flows in the south Delta, and flows and water levels inside Jones Tract. The stages and flows presented in this report for the south Delta were taken from Suits et al. (2005). A more detailed description of the 2004 simulated hydrodynamics for the south Delta can be found in that memo. A few locations that are near the Jones Tract levee break and pump-off locations are also presented here.

Stages in the South Delta

Suits et al. (2005) showed that the DSM2-simulated stages generally followed the observed daily maximum and minimum stage at several locations in the south Delta. Stage results for 2004 for two locations near the Jones Tract levee break, Old River at Rock Slough (ROLD024) and Middle River near Tracy Blvd. (RMID027), are shown in Figure 3.10. DSM2 consistently modeled the minimum stages in the Old River at Bacon Island about one foot below field observations. Suits et al. (2005) showed several other locations with similar trends, but it is important to note that this trend was not limited to the period when Jones Tract was flooded.

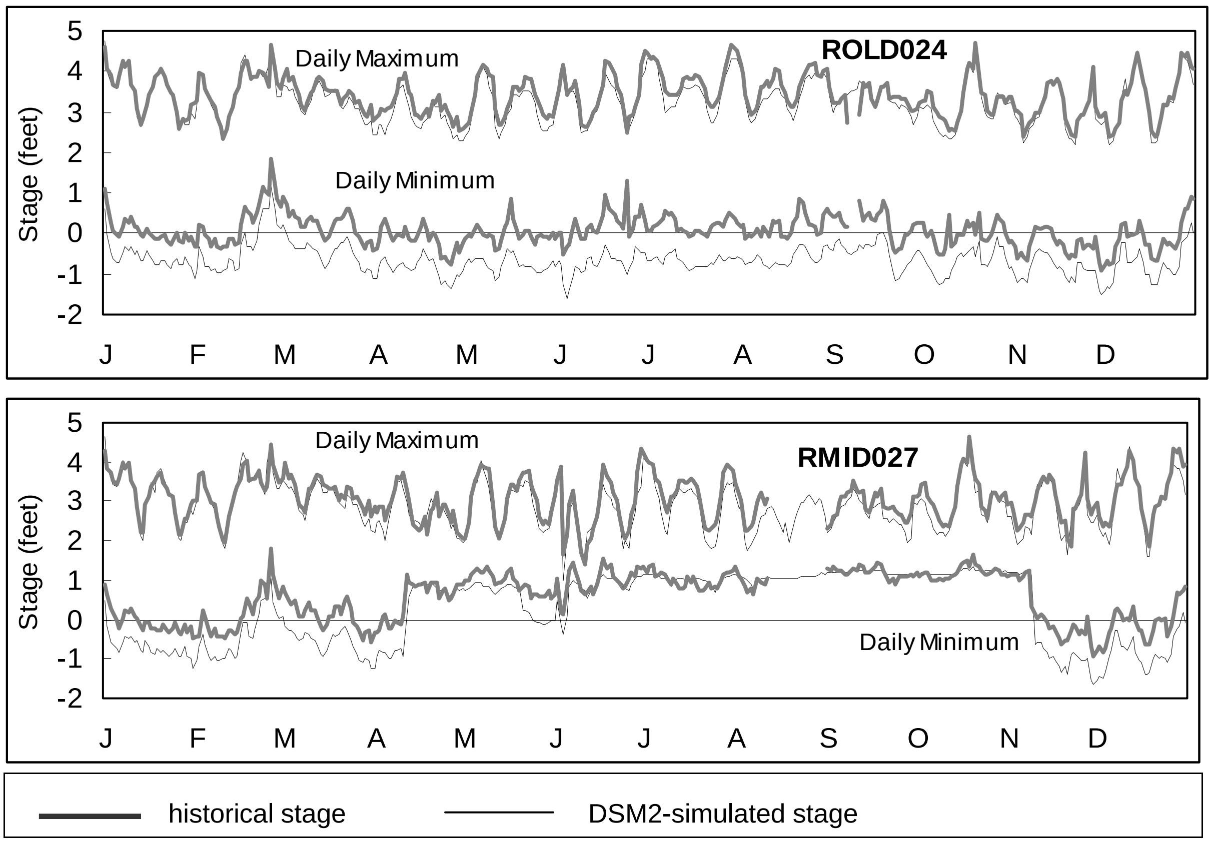

Figure 3.10: DSM2 and Observed Old River at Rock Slough and Middle River near Tracy Blvd. Daily Maximum and Minimum Stage.
(Source: Suits et al., 2005)

Flows in the South Delta

Suits et al. (2005) showed the historical and DSM2-simulated daily average flows at several locations in the Delta, including near the Delta Cross Channel and through Three Mile Slough. Daily average flows for Old River near the Contra Costa Water District Los Vaqueros intake (ROLD034) and Middle River at Santa Fe Cut (RMID015) are shown in Figure 3.11. Negative flows represent flows toward the SWP and CVP exports (south). The DSM2-simulated Middle River flows match the historical field data well, including during the period when the Jones Tract was flooded on June 3. DSM2 overestimated Old River flows heading downstream during the levee breach, but shortly after the breach the DSM2-simulated flows matched the historical field data.

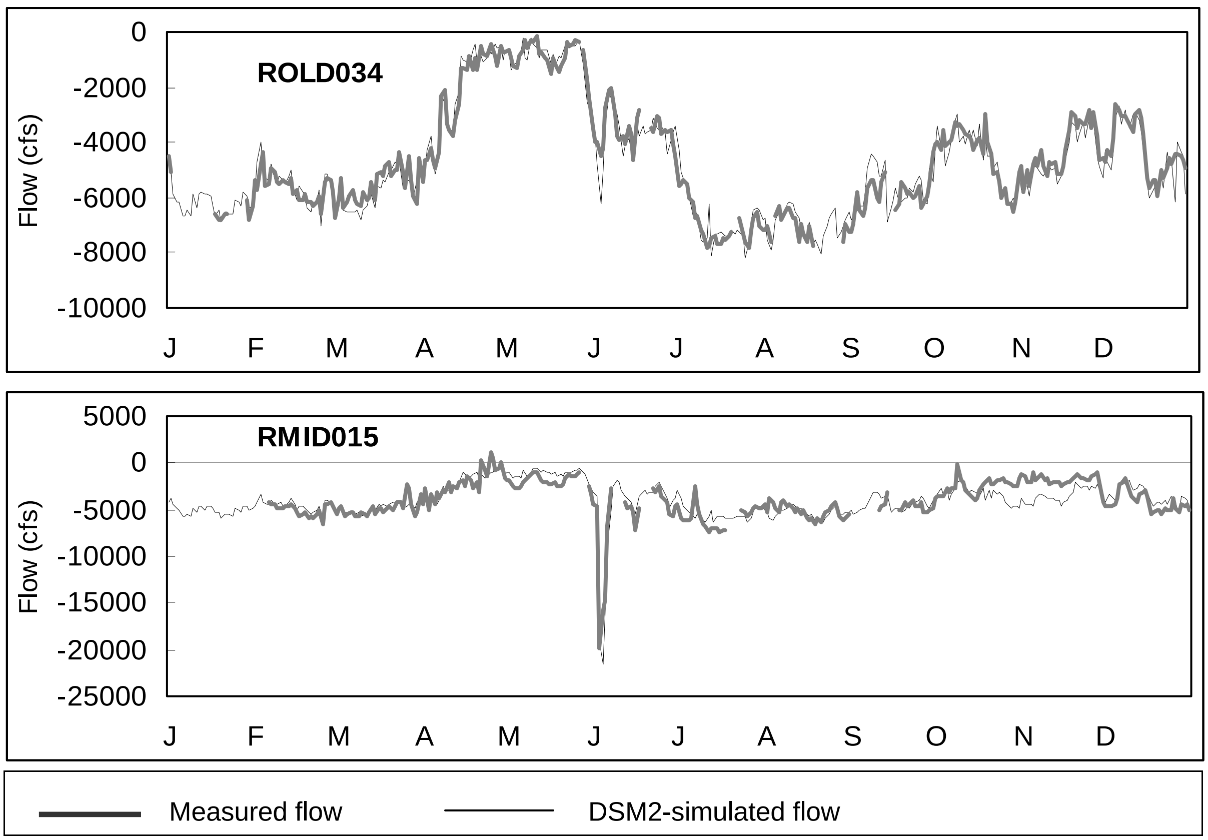

Figure 3.11: DSM2 and Observed Old River at the Los Vaqueros Reservoir Intake and Middle River at Santa Fe Cut Daily Average Flows.

(Source: Suits et al., 2005)

Flow and Stage in Jones Tract

As discussed above, following the failure of the Upper Jones Tract levee, the DSM2 simulation took several days to fill Jones Tract. The island was considered to be filled when the daily average flow in and out of Jones Tract approached zero. As the water levels in the Delta increased and decreased with the Spring / Neap tide cycle, the water levels in Jones Tract also changed. The DSM2-simulated stage in Jones Tract varied between 1 and 2 feet (NGVD) during June. The stage outside of Jones Tract on the Middle River near Santa Fe Cut varied between minus-1 foot and 4 feet during this same period, suggesting that the levee breach was dampening a significant amount of the tidal variation in the model. Unfortunately, no accurate measurements of stage inside or flow in and out of either Jones Tract island could be used to validate these DSM2 results.

Figures 3.12 and 3.13 show the simulated water levels inside and flows into Jones Tract during the first several days after the levee failed. The shaded period in Figure 3.12 represents a transition period when the islands began to show some tidal effect on water level, but over the course of a tidal cycle more water was still entering the islands than leaving. The DSM2-simulated flow in and out of Jones Tract for the rest of June is shown in Figure 3.14. The DSM2-simulated stage inside Jones Tract and on Middle River near Santa Fe Cut for the rest of June is shown in Figure 3.15. The gradual change in minimum and maximum stage for both locations was related to the Spring / Neap tide cycle.

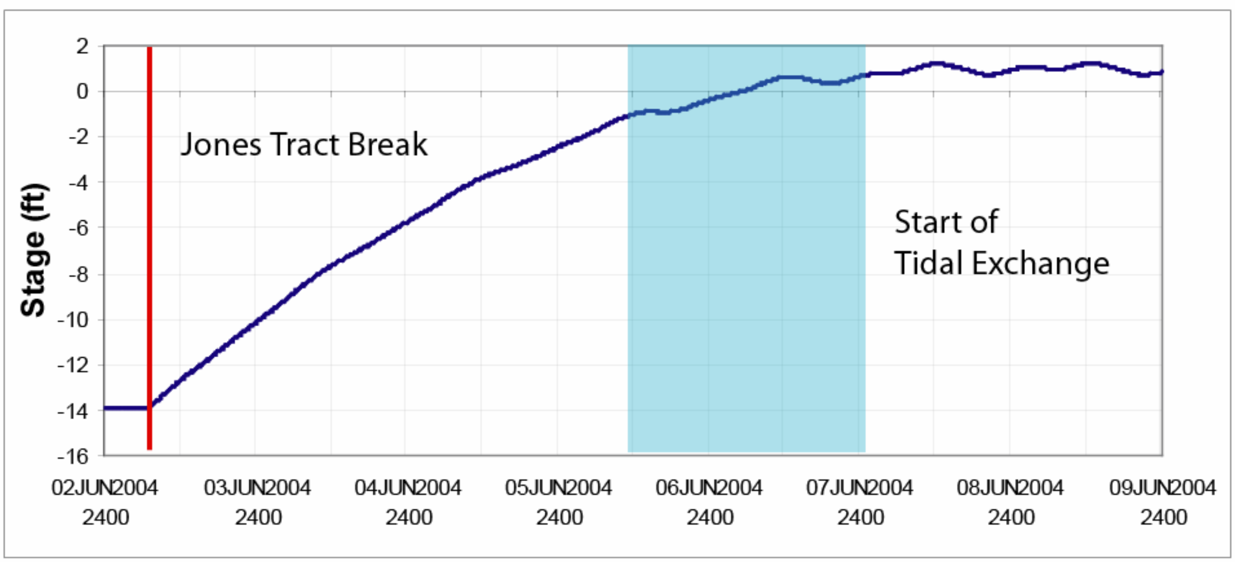

Figure 3.12: DSM2 Stage inside Jones Tract While Jones Tract Filled.

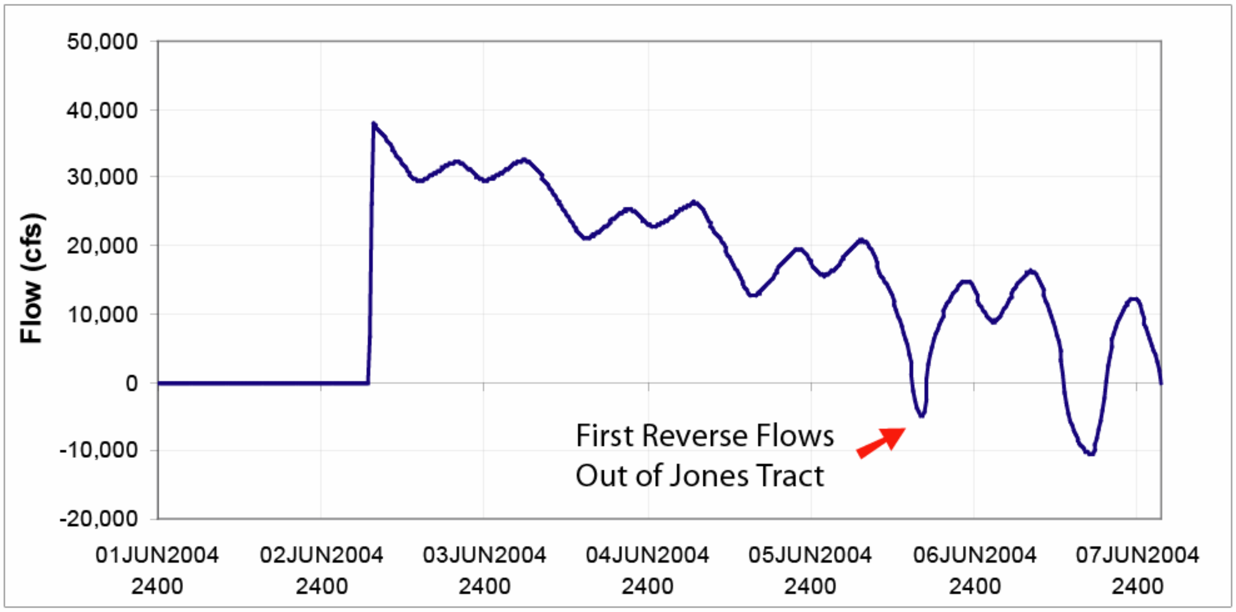

Figure 3.13: DSM2 Flows In (Positive) and Out (Negative) of Jones Tract While Jones Tract Filled.

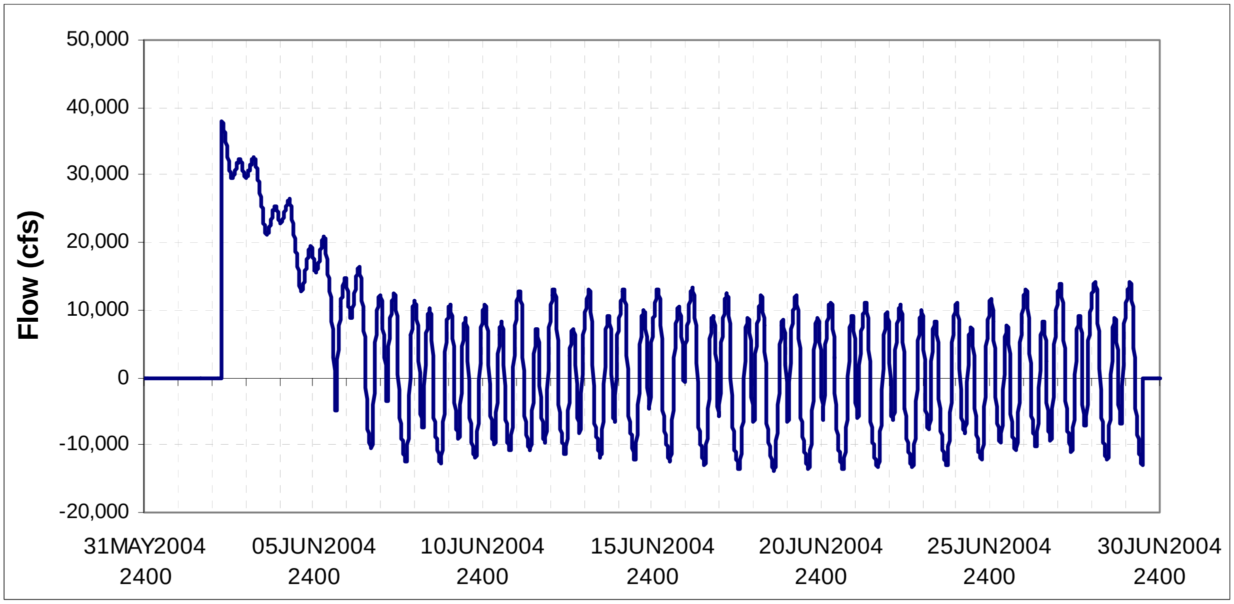

Figure 3.14: DSM2 Flows In and Out of Jones Tract in June 2004.

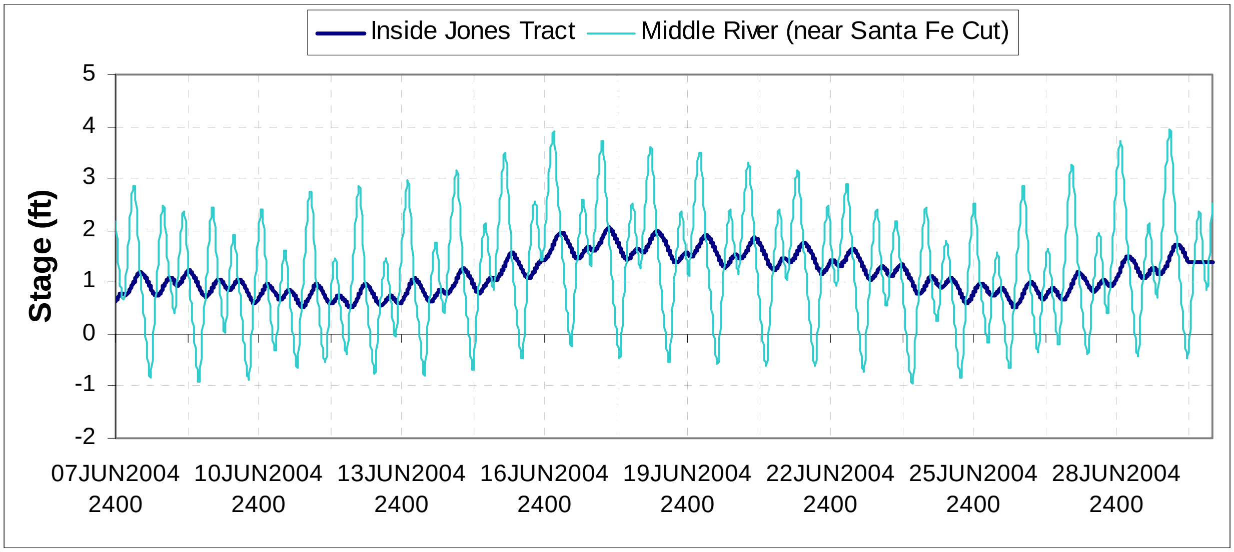

Figure 3.15: DSM2 15-minute Stage inside Jones Tract and on the Middle River near Santa Fe Cut in June 2004.

3.7 Water Quality Modeling

Simulated EC is a function of both the concentration of EC at the DSM2 boundary conditions and the mixing of the various water sources in the Delta, thus there was need for only one historical water quality simulation for EC. The results of this EC simulation were compared to observed EC at three Delta in-channel locations (Jersey Point, Old River at the entrance to Rock Slough, and Victoria Canal), on Jones Tract, and at SWP's Clifton Court Forebay. Two DSM2 historical flow-based dissolved organic carbon (DOC) scenarios, using high and low DOC growth rates, were run and compared to MWQI grab sample data from Jones Tract and Clifton Court Forebay. Two alternative scenarios were also run for both EC and DOC. These two alternative scenarios were designed to explore the water quality impact of the flooding of Upper and Lower Jones Tracts for the duration of 2004.

3.7.1 Boundary Conditions and Organic Carbon Growth Rates

Daily average DOC time-series at the Delta boundaries were developed using MWQI continuous monitoring data from Freeport and grab sample data from Vernalis and the American River. The daily Freeport DOC was based on a combustion sampling technique and was used as the Sacramento River boundary condition in DSM2. The combustion-based grab sample data from Vernalis were used as the DSM2 San Joaquin River boundary loading condition, but converted to a daily time step by filling in missing daily values using the most recent previous grab sample value. This same procedure was used to develop a daily time step for the loading condition at Mokelumne and Cosumnes rivers (Eastside streams) by using MWQI American River oxidation-based DOC grab samples. Although only data from January 2004 through February 2005 are shown in Figure 3.16, DOC time-series were developed starting in October 2003 in order to remove the impact of assumed initial DOC conditions on the DSM2 simulation of 2004 conditions.

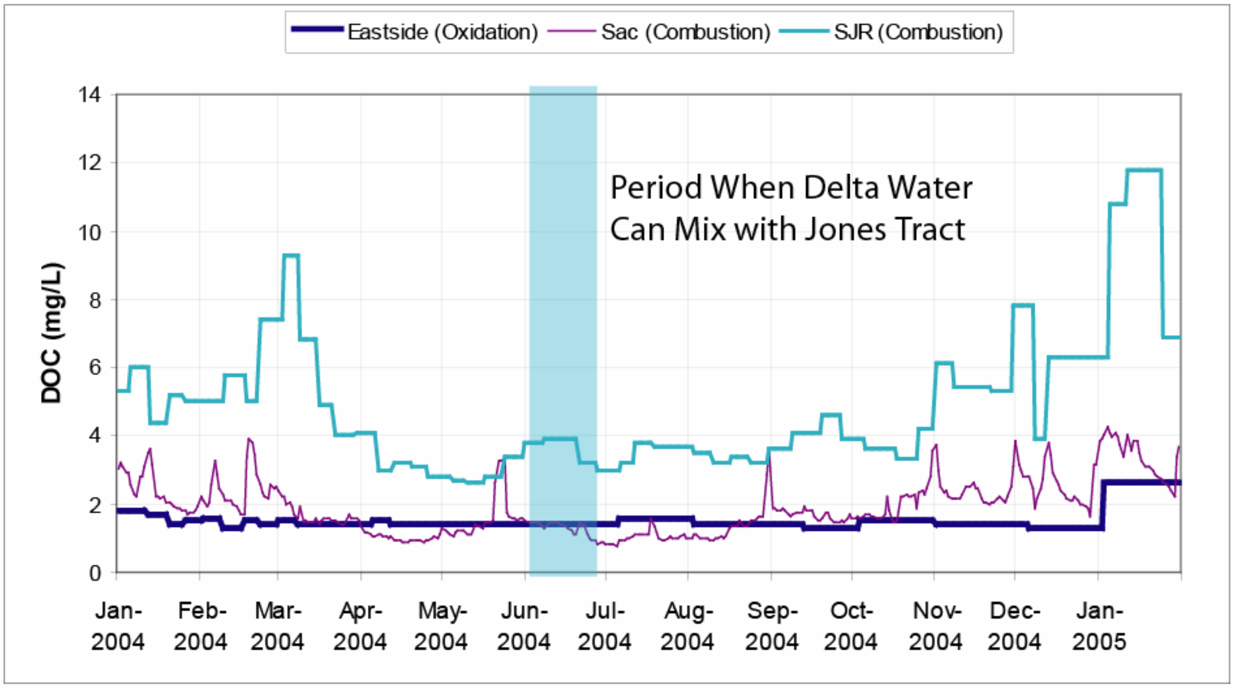

Figure 3.16: DSM2 Dissolved Organic Carbon Boundary Conditions.

The organic carbon growth rates used in the two historical simulations are described in *Section 3.4.1* and Table 3.2. The purpose of the two organic carbon bookend rates was to compare the DSM2 results using both with organic carbon field data and, based on the differences between DSM2 and the field data, determine an appropriate organic carbon growth rate for Jones Tract.

3.7.2 Water Quality Results

The water quality results for all of the scenarios are described in three different sections: various Delta in-channel locations, inside Jones Tract, and inside Clifton Court Forebay. Daily organic carbon samples were only taken at a few locations in the Delta, including Jones Tract and Clifton Court Forebay, which limited DSM2's water quality analysis at various Delta in-channel locations to comparing EC.

EC at Various Delta In-Channel Locations

Because the Delta's in-channel organic carbon field data are limited, only the simulated and observed EC at Jersey Point, Old River at Rock Slough, and along Victoria Canal are presented (Figure 3.17). These three locations can be used to indicate a gradient of salinity from the ocean to the urban exports. In early 2004, both the DSM2-simulated and observed EC at Victoria Canal was slightly higher than the EC at Old River at Rock Slough and Jersey Point. However, in early June (around the time Jones Tract flooded), EC significantly increased at Jersey Point and Old River at Rock Slough. Unfortunately, the observed Old River at Rock Slough EC was not available in most of June 2004. The increase in Jersey Point and Old River EC relative to Victoria Canal EC is typical in the summer and late fall when Sacramento River flows often begin to decrease. However, the timing of this EC increase in Delta can change from year to year.

Prior to the break, the DSM2-simulated daily average EC matched the daily average field data at all three locations. Following the break, the simulated EC still matched the Victoria Canal field observations, but overestimated the Jersey Point EC from June through mid-September and underestimated the Old River at Rock Slough EC from late-September through October.

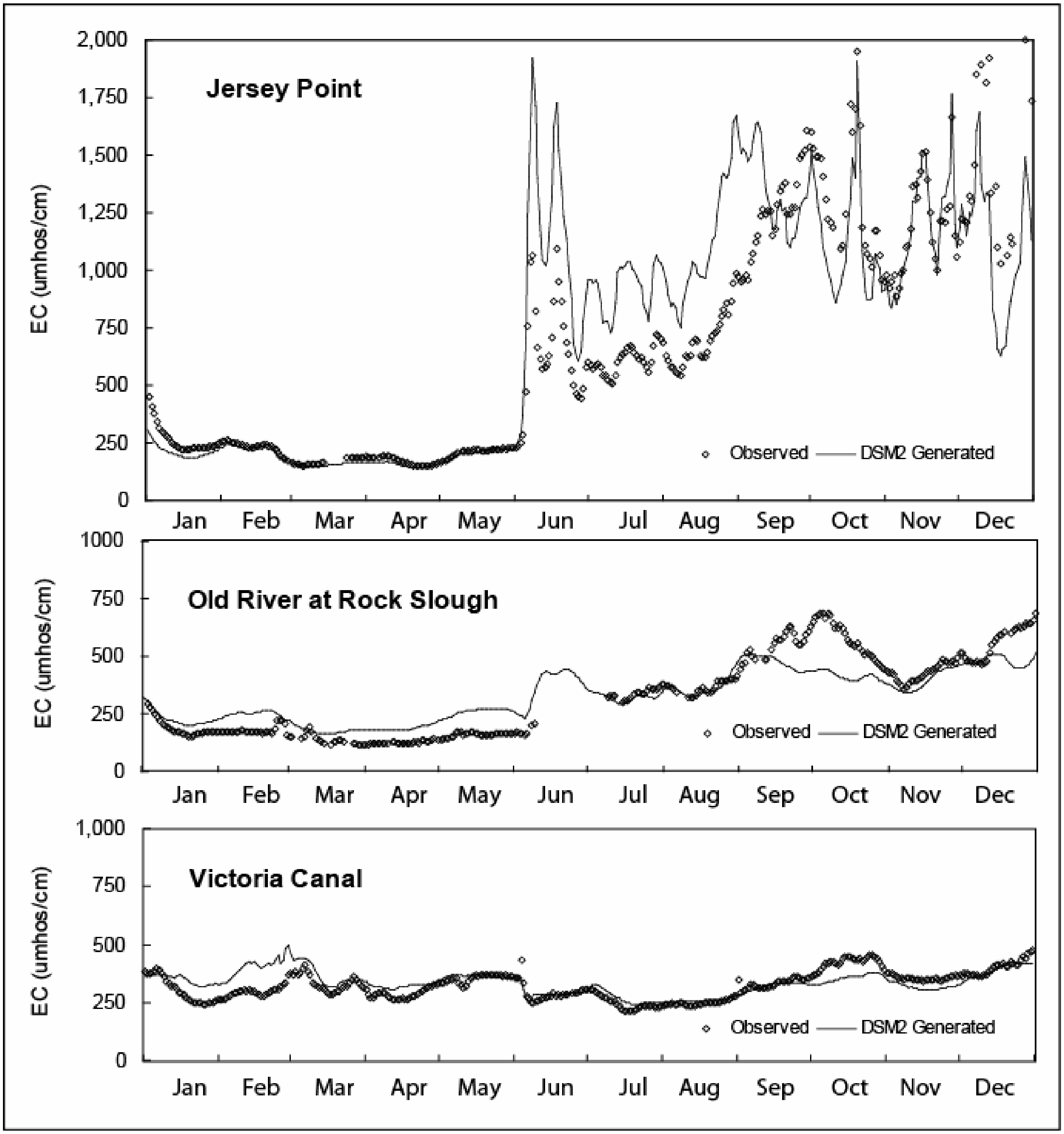

Figure 3.17: DSM2 and Observed Delta In-channel EC in 2004.

A closer view of the Delta's EC response to the flooding and repair of Jones Tract is shown in Figure 3.18, which is divided into four periods: the filling or "transition" period, the tidal exchange period when the islands exchange water with the Middle River based on the tidal cycle, the isolation period starting when the levee was repaired, and the pump-off period when water from the islands was introduced back into the Middle River. During the flooding period, Jersey Point and Old River EC increased, and Victoria Canal EC slightly decreased. Once Jones Tract was filled, both DSM2 and the observed data showed no significant changes in the EC at the three locations.

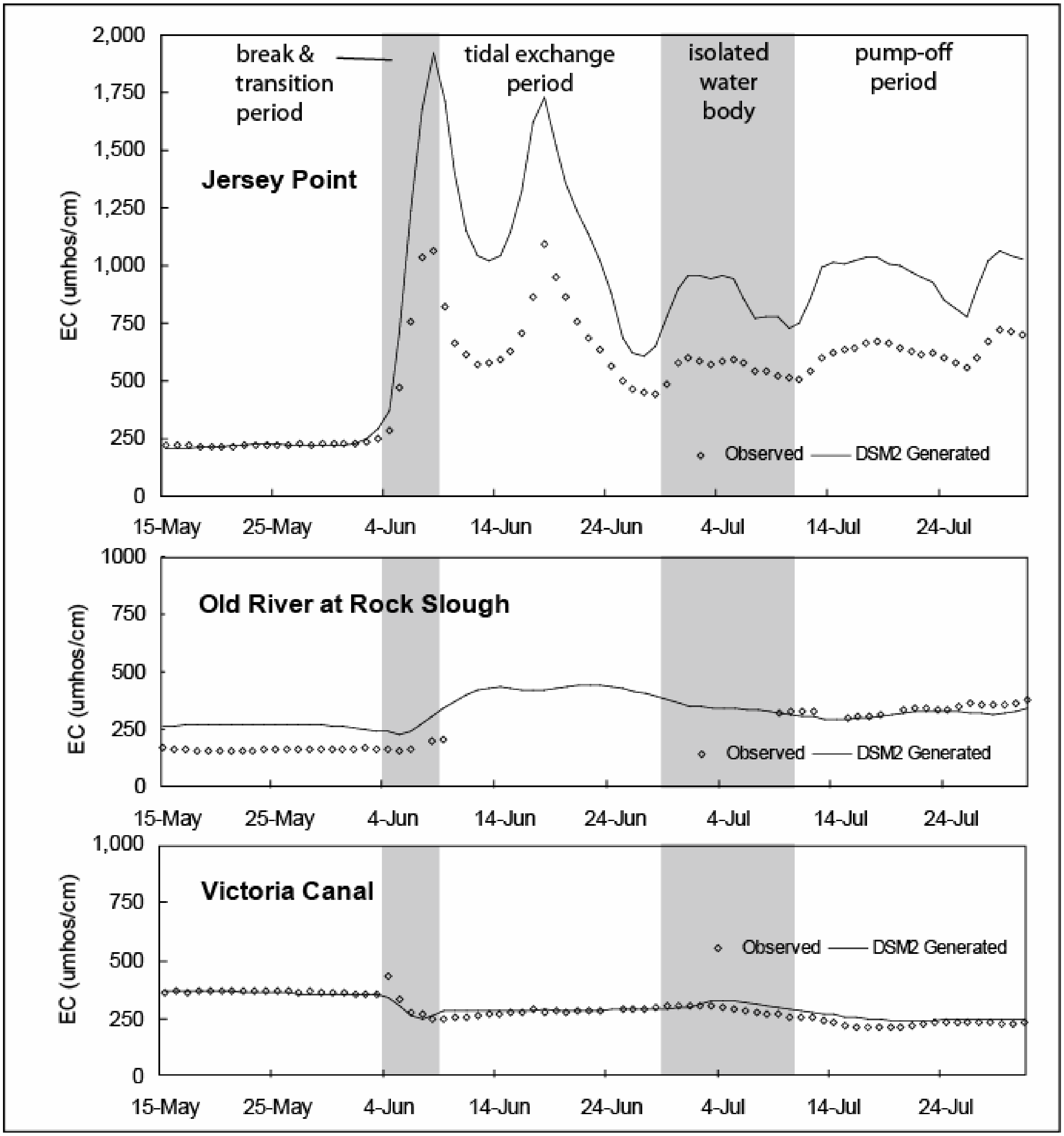

Figure 3.18: DSM2 and Observed Delta In-channel EC during the Jones Tract Flooding and Levee Repair Periods.

EC and DOC in Jones Tract

MWQI collected EC and DOC grab samples at several locations in flooded Upper and Lower Jones Tracts (DuVall et al., 2005). The organic carbon grab samples were measured by both wet oxidation and combustion analytical methods on approximately a weekly basis from early June through late November 2005. These grab samples represent the only organic carbon data collected from a flooded peat soil-rich Delta island, and were used in the analysis of the DSM2-simulated water quality results (Figures 3.19 and 3.20).

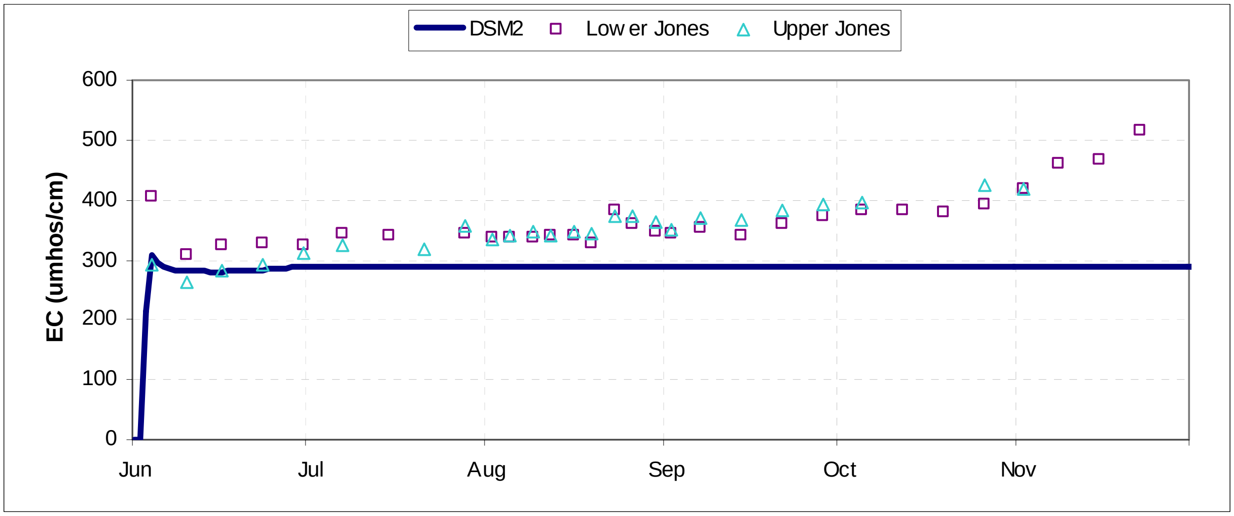

Figure 3.19: DSM2 and Observed Electrical Conductivity in Flooded Jones Tract in 2004.

Once the Jones Tract levee was repaired, the DSM2 EC concentration on the island did not change. However, the MWQI grab samples on both Upper and Lower Jones Tracts indicate that the concentration of EC slowly increased through the beginning of December (the last grab samples were collected in late November). By late November the difference between the simulated and observed Jones Tract EC was around 200 umhos/cm. The volume and depth of water stored on Jones Tract began decreasing on July 12 when the pump-off operations began.

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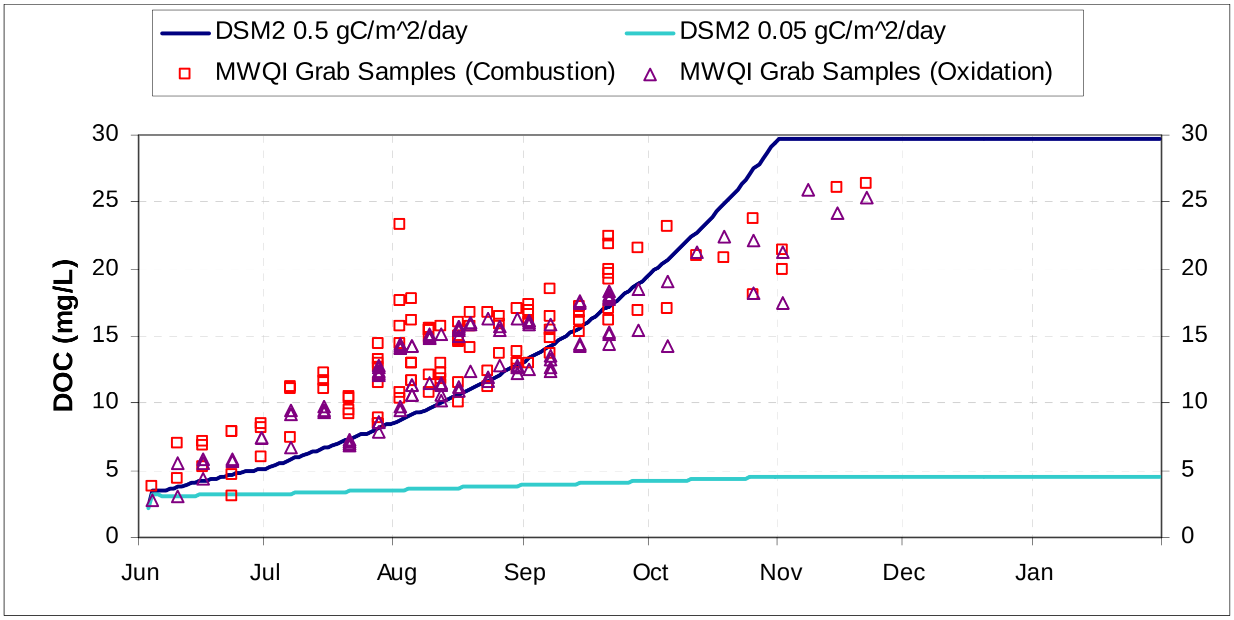

Figure 3.20: DSM2 and Observed Dissolved Organic Carbon in Flooded Jones Tract in 2004.

The DSM2-simulated DOC based on the 0.5 gC/m^2/day (high-bookend) organic carbon growth rate only slightly underestimated the observed DOC in June through September, and slightly overestimated the observed DOC in October and November. Overall the DSM2-simulated DOC based on the high-bookend simulation generally followed the measured DOC values. The 0.05 gC/m^2/day (low-bookend) organic carbon growth rate resulted in no significant increase in the DSM2-simulated flooded Jones Tract DOC concentration.

EC and DOC in Clifton Court Forebay

In addition to the historical simulation, daily average EC and DOC results for the no pump-off and no levee break alternative scenarios for Clifton Court were compared to daily average observed EC and DOC (Figures 3.22 – 3.24). Figures 3.21 and 3.23 illustrate the EC and DOC for all of 2004, while Figures 3.22 and 3.24 focus primarily on the water quality during the Jones Tract flooding and pump-off periods. The no levee break alternative results are only shown for EC (Figures 3.22 and 3.23). With the exception of June 2004, there were no significant differences between the EC and DOC of the no pump-off and non levee break alternatives in Clifton Court.

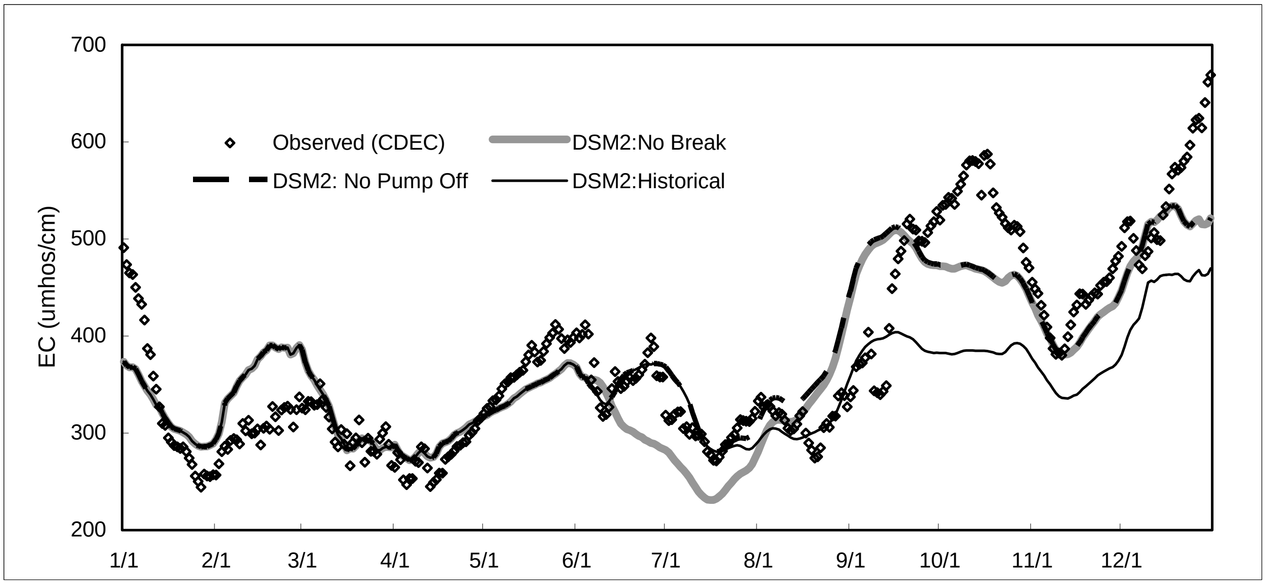

Figure 3.21: DSM2 and Observed Electrical Conductivity at Clifton Court in 2004.

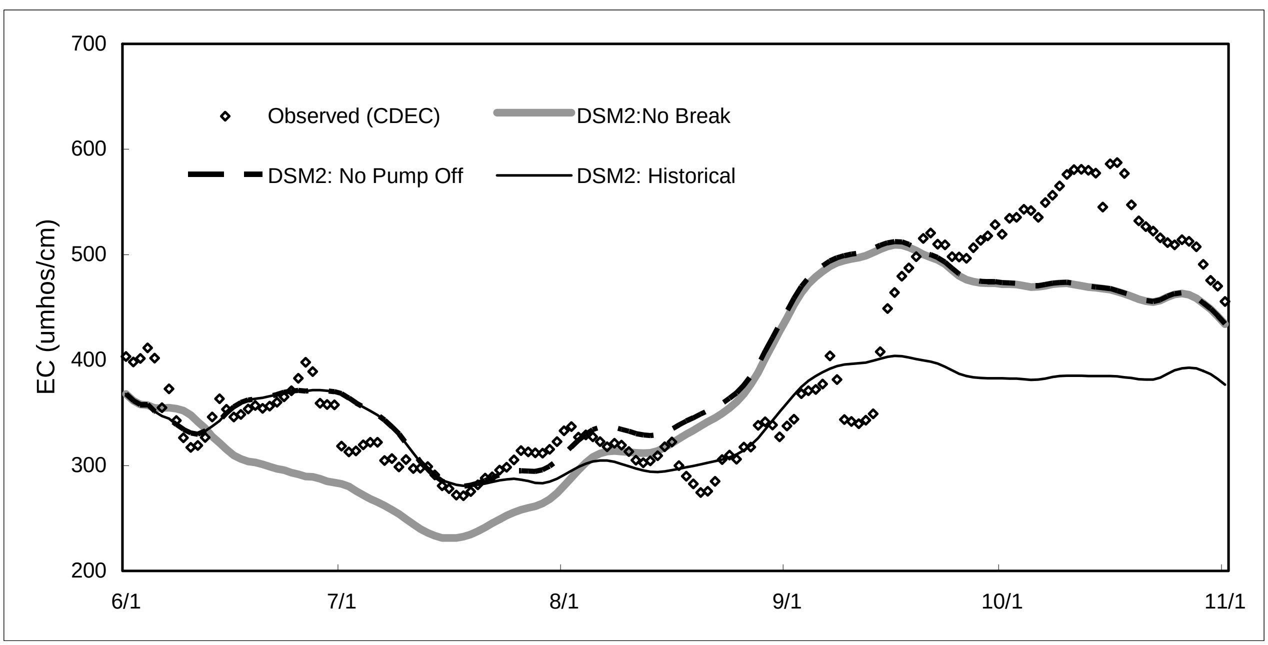

Figure 3.22: DSM2 and Observed Electrical Conductivity at Clifton Court after Jones Tract Flooded in 2004.

The historical DSM2 Clifton Court EC generally followed the observed EC through mid-September 2005, but mid-September through November the simulated EC underestimated the observed EC by a maximum of 200 umhos/cm. Although DSM2 also underestimated the EC on Jones Tract, thus accounting for some of the difference between the simulated and observed EC in Clifton Court, DSM2 also underestimated the EC on the Old River at Rock Slough (see Figure 3.18) for the same period. The difference between simulated and observed Old River and Clifton

Court EC may also be related to differences between the assumed and actual agricultural return flow quality (for example, the DSM2 DICU agricultural return flow EC concentrations may be in error).

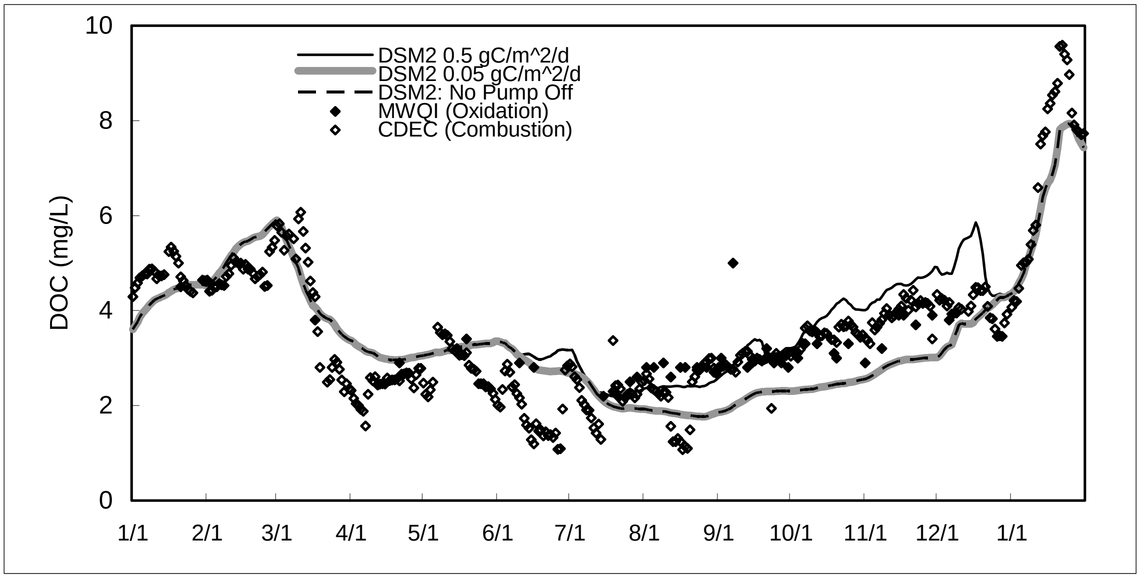

Figure 3.23: DSM2 and Observed Dissolved Organic Carbon at Clifton Court in 2004.

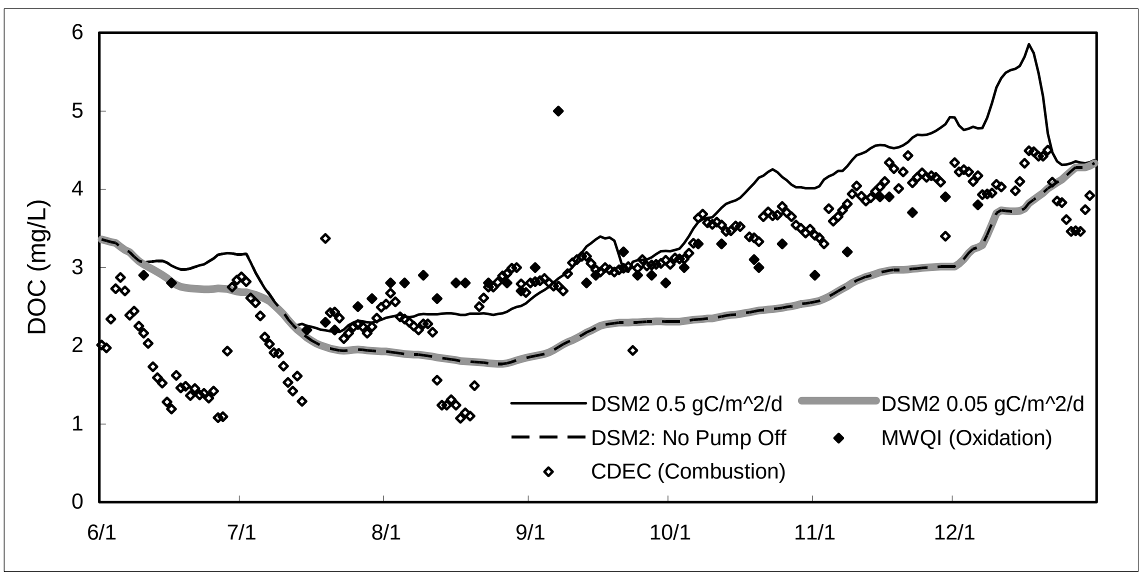

Figure 3.24: DSM2 and Observed Dissolved Organic Carbon at Clifton Court after Jones Tract Flooded in 2004.

The modeled DOC at Clifton Court was compared to both automated daily average combustion-based samples and oxidation-based grab samples (Figures 3.23 and 3.24). The difference was small between the automated combustion and oxidation grab samples in the forebay. With the exception of mid-December, the simulated DOC based on the high DOC growth rate bookend generally followed the observed DOC. In mid-December, DSM2 overestimated Clifton Court DOC by 1 to 2 mg/L for a few weeks. However, by January 2005, DSM2 did a better job at simulating DOC concentrations. By late January 2005, DSM2 was underestimating Clifton Court DOC.

The differences in simulated and observed DOC may be partially explained by limited DOC data from the San Joaquin River, an important source of water to the forebay. The DOC concentrations for the San Joaquin River were based on grab sample data, which were collected less frequently in November 2004 through January 2005. However, as shown in Figure 3.16, the DOC concentrations for the Sacramento River, varied a great deal in January through March 2004 and again in November 2004 through January 2005. If the same daily variability exists on the San Joaquin River, then the over- and underestimation of Clifton Court DOC could be related to under- and overestimations of the organic carbon loading on the San Joaquin River.

From mid-July through mid-December, the simulation using low-growth bookend DOC in flooded Jones Tract consistently underestimated Clifton Court DOC (Figure 3.24). This suggests that the organic carbon concentration of the water stored on Jones Tract increased and that the low bookend growth rate did not account for the amount of additional carbon added to the water on Jones Tract. Not only did both the no break and no pump-off scenarios underestimate Clifton Court DOC, but by mid-July the simulated DOC in both scenarios matched the DSM2 low-growth DOC concentrations. The flooding and pump-off of Jones Tract did result in DOC concentrations in Clifton Court increasing by more than 1.5 mg/L by mid-October.

3.8 Fingerprinting for Jones Tract

In addition to standard EC and DOC simulations, a historical DSM2 volumetric fingerprinting simulation was used to assist in investigating the source of organic carbon and taste and odor drinking water quality problems in Clifton Court. As described by Anderson (2002), volumetric fingerprints can be used to aid in determining the relative contributions of various sources at any given Delta location. In July and August 2004, South Bay Aqueduct users were complaining about taste and odor problems related to SWP water from Clifton Court. In response to these complaints a short July 2004 historical simulation, which included a volumetric fingerprint, was conducted. When the entire 2004 historical simulation was completed in 2005, a new volumetric fingerprinting simulation was conducted (Figure 3.25).

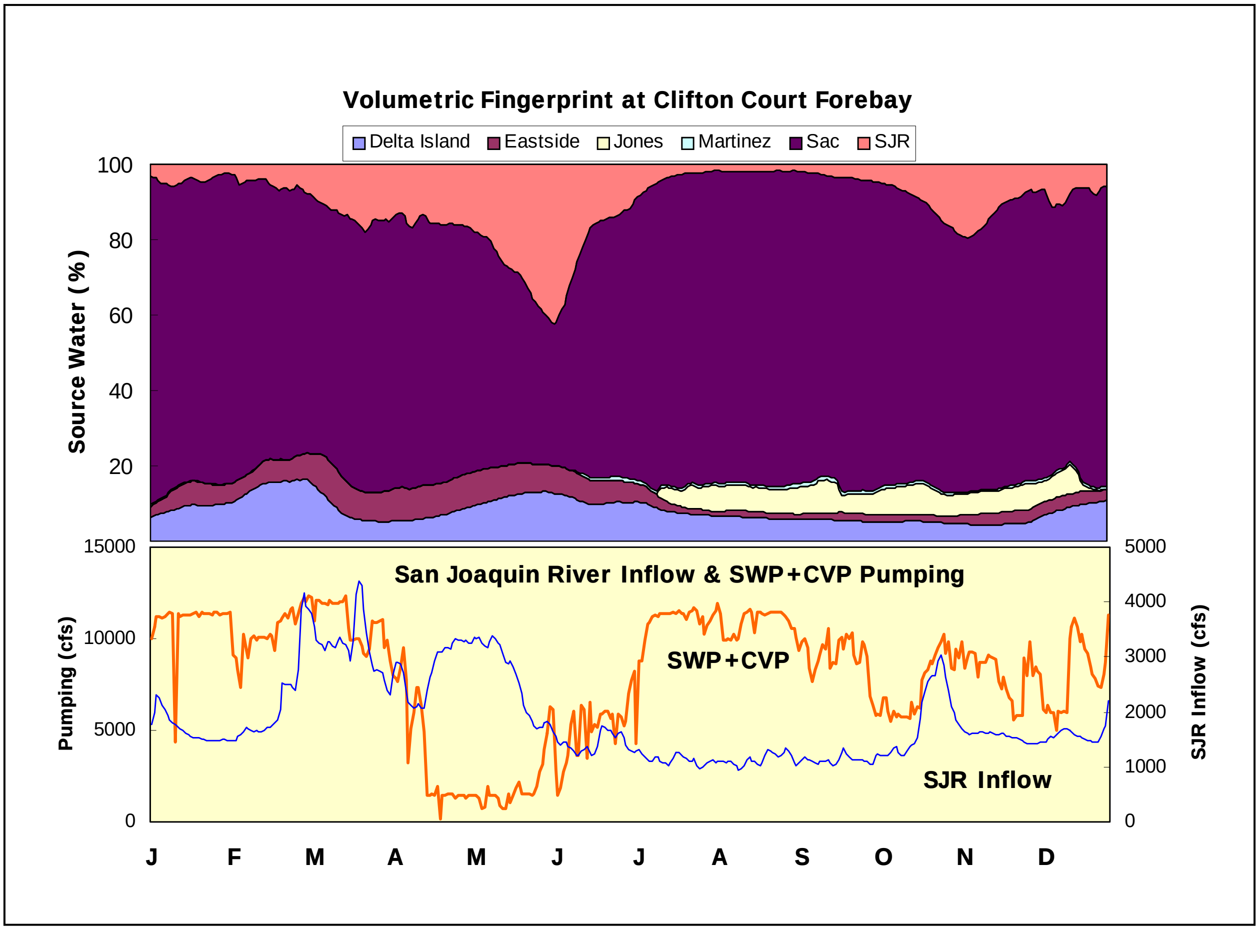

Figure 3.25: Clifton Court 2004 Volumetric Fingerprint.

The results of the historical 2004 volumetric fingerprinting simulation suggest that 5% to 7% of the water reaching Clifton Court from July through mid-December came from Jones Tract. Furthermore, the fingerprinting results also suggest that a significant volume of the water in the forebay prior to the June 3 levee failure came from the San Joaquin River. The graph under the volumetric fingerprint results in Figure 3.25 displays the combined SWP and CVP exports and San Joaquin River flows. The increase in San Joaquin River water in the forebay in May is in part related to the VAMP increase in San Joaquin River flows in April and May, the operation of the south Delta temporary barriers in April and May, and the mid-May increase in SWP and CVP exports.

Using this technique it would be possible to generate a similar volumetric fingerprint for Jones Tract to gain insight into where the water that filled the islands following the levee break originally came from. Better understanding the source of water in Jones Tract or Clifton Court may aid in finding ways to improve the drinking water quality in Delta exports and address issues like those related to the July and August 2004 taste and odor complaints. Fingerprinting not only is useful in analyzing what has already happened, but also can be very important when included in a water quality forecast. The Jones Tract volumetric fingerprints served as a working example of how DSM2 fingerprinting results could be incorporated into water quality management.

3.9 Discussion

The collection of water quality data on Upper and Lower Jones Tract following the break of the Upper Jones Tract levee on June 3 and subsequent flooding of both islands provided a rare opportunity to validate DSM2's ability to simulate hydrodynamics during a levee break and water quality impacts associated with the flooding of an organic carbon-rich Delta island. Although not originally designed to simulate transient events such as a levee failure, DSM2 must be able to simulate hydrodynamics during a flood event in order to allow the model to run for long continuous periods, such as a multi-year event. Extended historical simulations are instrumental in the calibration and validation of both DSM2's hydrodynamic and water quality modules. Furthermore, since DSM2 has been used to simulate the long-term water quality impacts of the proposed In-Delta Storage project islands, which like Jones Tract are composed of organic carbon-rich peat soils, the Jones Tract pump-off operations provided the first opportunity for the DSM2 organic carbon flooded island routine to be validated with actual organic carbon data collected directly from a flooded Delta island.

Upper and Lower Jones Tracts were simulated as a single reservoir in DSM2 because of limited information on the islands' surface elevations and the volume of water that flooded the islands. The levee breach was simulated by adding a gate to the DSM2 reservoir near the location of the break. The gate was opened at the reported time of the levee breach, 6:51 a.m. (Pacific Standard Time) on June 3, 2004 (DWR, 2004). The amount of water that entered Jones Tract caused instabilities in DSM2 when a 15-minute computational time-step was used, thus it was necessary to use a shorter time-step (5 minutes) to simulate the first few days when Jones Tract was filling. With a few exceptions, the DSM2-simulated daily average, maximum, and minimum flow and stage generally followed the observed (CDEC) flow and stage at several locations in the Delta.

Three different EC and four different DOC scenarios were run in order to evaluate DSM2's flooded island organic carbon growth rate algorithm and also to access the water quality impacts of both the Jones Tract flooding and subsequent pump-off. For most of 2004, the simulated daily average EC at Jersey Point, Old River at Rock Slough, and Victoria Canal followed the same trends as the observed EC. These three Delta in-channel locations were chosen based on the availability of observed data and because they can be used to represent a gradient of water quality from the ocean to the urban exports.

DSM2 underestimated the EC on Jones Tract. Once the levee was repaired, DSM2 had no means to accumulate or add additional EC to the water stored on the island. The source of additional salt could be due to evaporation, seepage (for example, water leaving the island, but trapping the salts behind), or a gradual leaching of the salts on the soils. However, there are not enough field data to suggest what mechanism caused this increase in salt on the island. Until the reason for this increase is better understood, DSM2 will maintain a conservative estimate of flooded island EC.

The underestimation of EC on Jones Tract may explain some of the mid-September through late-October DSM2 underestimation of Clifton Court EC; however, the difference in Jones Tract EC continued through the end of November, while the difference in DSM2 and observed Clifton Court EC decreased in late-October. Although the volume of water pumped off Jones Tract was less in October, November, and December, suggesting that the difference in Jones Tract simulated EC from the observed might have been less important, a volumetric fingerprint of Clifton Court source waters showed that the relative amount of Jones Tract water that reached the forebay remained fairly consistent from July through mid-December. However, a plot of the combined SWP and CVP exports and San Joaquin River inflows illustrated that in October 2004 the combined exports decreased. When the exports increased again in mid-October, San Joaquin River inflow exceeded 3,000 cfs. The volumetric fingerprint showed that the relative contribution of Clifton Court water from the San Joaquin River increased over October and November. Bearing this in mind, it is possible that some of the Delta island agricultural return flow volumes and /or EC concentrations (which change on a monthly basis) may have been off in September 2004, but that it took several weeks for the October DICU flows and concentrations or the increased San Joaquin River flows to reduce these high levels.

The DSM2 historical DOC results from the 0.5 gC/m^2/day (high-bookend) organic carbon growth rate scenario followed the MWQI DOC grab samples, suggesting that 0.5 gC/m^2/day is an appropriate organic carbon growth rate for a flooded Jones Tract. Although the flux of organic carbon into Jones Tract was constant over the first five months that water was stored on Jones Tract, DSM2 DOC concentrations showed a non-linear increase in DOC over these months perhaps because the volume of water was constantly decreasing due to the pump-off operations. This non-linear behavior was most apparent between October and November. However, the MWQI DOC grab samples continued to increase as a linear function through November. DuVall et al. (2005) discussed the possible differences in these growth rates, pointing out that the actual DOC flux rate from the soil to the water on Jones Tract may have been a function of water and soil temperatures. Jones Tract water temperatures collected along with the DOC grab samples significantly decreased from September through November (DuVall et al., 2005). DuVall et al. suggested that a more appropriate implementation of the organic carbon modeling would have been to decrease the organic carbon growth rates in September, October, and November.

Two alternative DOC simulations were used to estimate the amount of additional organic carbon present in the forebay due to the flooding and pump-off of Jones Tract. The simulated DOC from these two simulations consistently underestimated the observed Clifton Court DOC, while the high bookend growth rate results produced a good fit to the observed data from July through mid-October. Although some of the DSM2 overestimation of DOC can be attributed to the late-October and November overestimation of DOC in Jones Tract, the accuracy of the San Joaquin River DOC boundary condition may also have been a cause for the difference between modeled and observed DOC. The San Joaquin River DOC grab samples were collected less frequently in the 2004-2005 winter months, but historically this is the time when DOC on a river can change the most. Given the proximity of the San Joaquin River to Clifton Court, an over- or underestimation of the San Joaquin River DOC can lead to significant errors in DSM2 simulation of DOC in the South Delta. However, despite the difference between modeled historical and observed DOC, the high-bookend growth rate results still did a better job at following the observed Clifton Court DOC. Furthermore, when the pumping stopped in mid-December, the historical and alternative scenarios all quickly merged into a single trend, suggesting that the flooded Jones Tract peat soils were in fact a significant source of organic carbon in the Clifton Court Forebay in 2004.

3.10 Future Directions

The results of the DSM2 Jones Tract studies have been integrated into the standard DSM2 historical simulation. Future DSM2 runs that wish to include 2004, need to find some way to account for the flows into and later out of Upper and Lower Jones Tracts. Based on the relatively good fit of stage, flow, and EC data at several Delta in-channel locations and Clifton Court, it is recommended that the procedure used in this simulation be adopted as part of a standard DSM2 2004 simulation. The work related to investigating the Jones Tract levee failure in DSM2 was already incorporated into the 2004 South Delta Temporary Barriers annual report (Suits et al., 2005) and will be distributed to other DSM2 users via the DSM2 Users Group.

Some of the important modeling issues that came up in the process of this work included:

- Some events, such as floods and levee breaks, may require that small time-steps be used in order to avoid numerical instabilities in DSM2. This is an issue that other models may or may not have, but does serve as an important reminder to the appropriateness of scale (both temporal and physical) in numerical modeling.

- Fortunately for 2004 short- and long-term forecasting modeling efforts, the Jones Tract levee break did not result in a significant change in the Martinez boundary condition. The first step in the historical simulation was to examine the stage and salinity boundary condition at Martinez. There was no apparent impact in either of these parameters at Martinez, meaning that the standard tools used to forecast Martinez stage and salinity could be used in this particular situation. However, had the break occurred at a location closer to Martinez, it is possible that use of these standard forecasting assumptions may not be valid.

- The system-wide response to short-term events might not be completely driven by the events themselves, but also may depend upon the antecedent conditions and the short- and long-term management responses to those events. In the case of Jones Tract, the ratio of San Joaquin River compared to Sacramento River water in the Central Delta at the time of the levee break was high because of the 2004 VAMP flows and export curtailments. Had the levee break occurred at a different time, the system response may have been different. Analytical tools like DSM2 are useful in evaluating these sorts of responses, and could even be used to access what would have happened if Jones Tract had flooded in May or July.

- Unfortunately, the amount of hydrodynamic data collected at the Jones Tract levee break and throughout the Delta were limited. For example, the new Coney Island CDEC stage station only went online in late June 2004. This station would have provided important data on the Delta water level impacts near Clifton Court. The Old River at Rock Slough water quality data were available during the break, but the flow information for this location was not available for half of 2004. While it is possible to infer some information from the changes in the EC at this location, the ability to relate hydrodynamic and water quality information at the same location is critical in gaining a more complete understanding of the system-wide impacts.

- The water quality data collected throughout Jones Tract and in Clifton Court were instrumental to this analysis. This event represents the first time that detailed organic carbon and EC data were collected from the large scale flooding of a Delta island rich in organic carbons. By combining a hydrodynamic, water quality, and fingerprinting analysis with large data sets, it was possible to validate and improve the general understanding of the Delta.

- The comparison of modeled and observed DOC through the end of January 2005 (that is, after the end of the Jones Tract pump-off) highlighted the importance of refining the water quality boundary conditions. In this case, the San Joaquin River DOC boundary condition was created based on grab samples. Fewer grab samples were taken in the winter months, meaning it is possible that changes in the San Joaquin River DOC were not reflected in the DSM2 boundary conditions.

3.11 References

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