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

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Chapter 3:
Simulation of Historical DOC and UVA Conditions in the Delta

Author: Ganesh Pandey

3 Simulation of Historical DOC and UVA Conditions in the Delta

3.1 Introduction

The purpose of this study is to validate DSM2 transport of disinfection by-product (DBP) precursor surrogates in the Delta. The study was conducted by an *ad hoc* workgroup that included staff from the Department's Municipal Water Quality Investigations (MWQI) Program as well as from the Delta Modeling Section. This *ad hoc* workgroup was assembled in late 1999 to assist CALFED's Drinking Water Constituents Workgroup in defining baseline Delta water quality conditions.

DSM2 is currently being used by the Section to evaluate transport of dissolved organic carbon (DOC) and ultraviolet absorbance at 254 nm (UVA) – two widely accepted DBP precursor surrogates – in support of the Integrated Storage Investigation (ISI) In-Delta Storage Project Feasibility Study. Model-derived DOC and UVA values are being used to compute carbon loading and DBP formation at the urban intakes under base and plan conditions.

3.2 Study Assumptions

The assumptions used in the DSM2 validation study are shown in Table 3-1 and discussed below.

Table 3-1: Summary of Study Assumptions

Delta inflow and export/diversion rates	Daily average IEP data
Martinez stage	15-minute IEP data
Delta island diversion and return flows	Monthly DICU data
Delta inflow water quality	Monthly grab sample MWQI data
Martinez water quality	Monthly grab sample MWQI data at Mallard Island
Delta island return flow water quality	Monthly aggregated MWQI data

3.2.1 Model Version

This study was conducted with the current version of DSM2, which was recently calibrated in collaboration with the DSM2 IEP Project Work Team (see Chapter 2). Flow, stage, and electrical conductivity (EC) data were used to calibrate DSM2. DOC and UVA data were not used in model calibration.

3.2.2 Simulation Constituents and Period

This study evaluated the transport of two drinking water quality constituents: DOC and UVA. Both constituents were modeled as conservative tracers. The simulation covered the period October 1, 1990 through December 31, 1997. This simulation period includes a five-month "warm up" period that allows for adequate mixing of the initial boundary conditions within

DSM2. The simulation period was selected based on availability of grab sample data to run the model and validate results.

3.2.3 Hydrodynamics, Hydrology, and Operations

DSM2 hydrodynamics, hydrology, and operations were generally specified with a daily time step. The IEP database was the primary source of historical information for Delta inflow, Delta export and diversion rates, stage at the downstream boundary, and gate operations. Stage at the DSM2 downstream boundary (Martinez) was specified with a 15-minute time step. The IEP database contains data collected by various state and federal agencies, and can be downloaded via Internet at http://wwwiep.water.ca.gov/dss/.

3.2.4 Boundary Water Quality

DOC and UVA boundary conditions were developed by MWQI Program staff from grab sample data on a monthly time step (Agee 2000). A simple interpolation scheme was used to complete each time series. Field observations suggest that DOC and UVA values can vary considerably during a month at the model boundary locations, particularly during high precipitation runoff periods in the winter. But due to a lack of continuous monitoring, a smaller time interval was not justified.

DOC and UVA boundary conditions for the Sacramento and San Joaquin rivers are shown in Figures 3-1 and 3-2. Sacramento River DOC and UVA ranged from 1.5-5.6 mg/l and 0.01-0.17 cm^{-1} over the simulation period, respectively. San Joaquin River DOC and UVA ranged from 2.2-11.4 mg/l and 0.05-0.44 cm^{-1} over the simulation period, respectively. The East Side Streams' water quality boundary conditions (not shown in the figures) were based on data collected at the American River Water Treatment Plant intake that serves the City of Sacramento. This site was selected for its low DOC characteristics, as little data have been collected on the Cosumnes or Mokelumne rivers. DOC ranged from 1.1-4.3 mg/l during the simulation period, and UVA ranged from 0.01-0.15 cm^{-1}. The Yolo Bypass, also specified as a DSM2 boundary but not shown in the figures below, was assumed to have the same water quality as the Sacramento River under high-flow conditions (> 50 cfs). Under low-flow conditions, Yolo Bypass water quality was assumed to be characteristic of low-DOC agricultural drainage (see Section 3.2.5). The downstream water quality boundary at Martinez was based on data collected at Mallard Island. Mallard Island DOC and UVA ranged from 1.6-7.0 mg/l and 0.05-0.21 cm^{-1} over the simulation period, respectively. Previous DSM2 simulations have shown that Delta organic concentrations are insensitive to Martinez water quality boundary conditions (Hutton and Chung 1992).

3.2.5 Delta Islands Diversions and Returns

Delta island diversion and return flow volumes were not measured in the field but were estimated with the DWR's Delta Island Consumptive Use (DICU) model (California Department of Water Resources 1995a). The DICU model computes diversion and return volumes on a monthly time step and allows for annual variability in response to changes in Delta land use, precipitation and pan evaporation. Return water quality estimates were based on MWQI measurements. Due to a lack of comprehensive monitoring of over 200 agricultural drains in the Delta, return water quality data were compiled using a simplified aggregation technique (Jung 2000). In his report, Jung segregated the Delta into three DOC subregions:

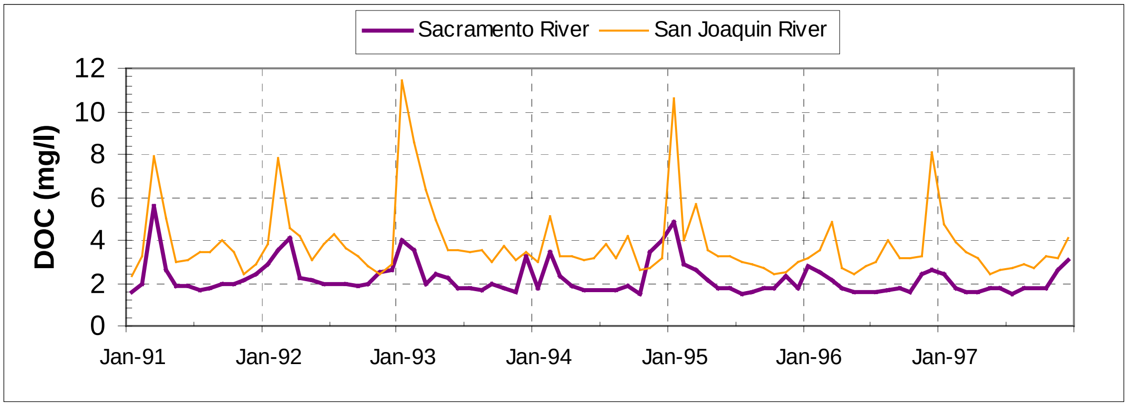


Figure 3-1: Monthly Delta Inflow DOC Boundary Conditions.

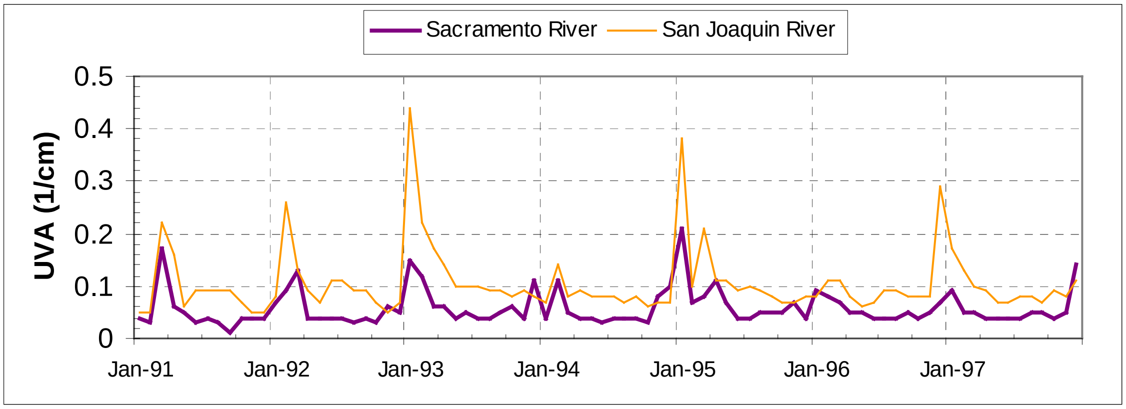


Figure 3-2: Monthly Delta Inflow UVA Boundary Conditions.

high-, mid- and low-DOC. Representative monthly average DOC and UVA values were developed for each subregion. UVA values were assumed as a linear function of DOC concentrations in all Delta island return flows:

$$\text{UVA (1/cm)} = 0.024 + 0.044 \text{ DOC (mg/l)} \qquad \text{[Eqn. 3.1]}$$

DOC and UVA values were assumed to vary by month but not by year. Monthly DOC concentrations from the three sub-regions are displayed in Figure 3-3.

3.3 Validation Results

Selection of model validation locations was based upon the availability of grab sample data during the 82-month validation period (March 1, 1991 through December 31, 1997). Geographic coverage for the DSM2 validation is reasonably broad; refer to Figure 3-4. The relatively dense coverage along Old and Middle rivers coincides with key locations at or near drinking water diversions and storage diversions being considered by the ISI In-Delta Storage Project.

Data availability at the DSM2 output locations are summarized in Table 3-2. Output locations include reservoirs, nodes and channels. Channel locations are designated “U”, “M” and “D” to

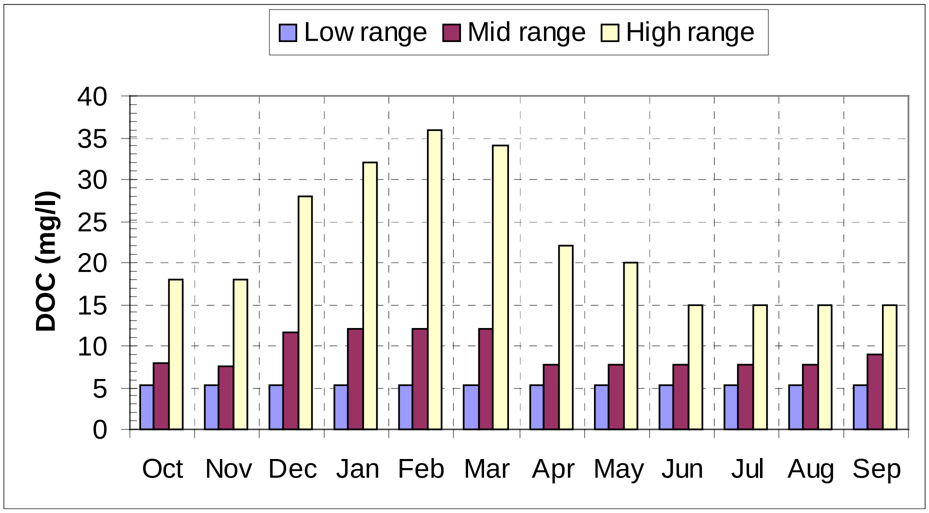


Figure 3-3: Monthly Agricultural Return Flow DOC Concentrations.

represent the upstream, longitudinal midpoint and downstream ends of a channel, respectively. Channel locations are also designated with a numerical value; these values represent the distance (measured in feet) from the upstream node.

Limited grab sample DOC and UVA data allowed for only a crude evaluation of the model's time series output. Figures 3-5 through 3-11 compare field data to predicted monthly average, minimum, and maximum DOC values. Figures 3-12 through 3-18 compare field data to predicted monthly average, minimum, and maximum UVA values.

The predicted minimum and maximum values represent the lowest and highest instantaneous (hourly) values for each month. Together, the minimum and maximum values bound the predicted monthly average values. Large differences in the minimum and maximum values occur in regions with high tidal variation or locations where the input parameters are subject to large fluctuations. Comparison of grab sample data with an envelope of minimum and maximum values is appropriate because grab samples are collected during different times on the tidal cycle.

Three significant results and conclusions from the model validation are as follows:

- ❑ Overall, DSM2 does a satisfactory job simulating the distribution of organics in the Delta region where data are available. The model captures the observed distribution of lower organic concentrations in the western and central Delta and higher organic concentrations in the southern Delta. The model also preserves trends in the observed time series. In particular, the effect of seasonality is well represented. Therefore, DSM2 is an appropriate tool for evaluating In-Delta Storage alternatives.

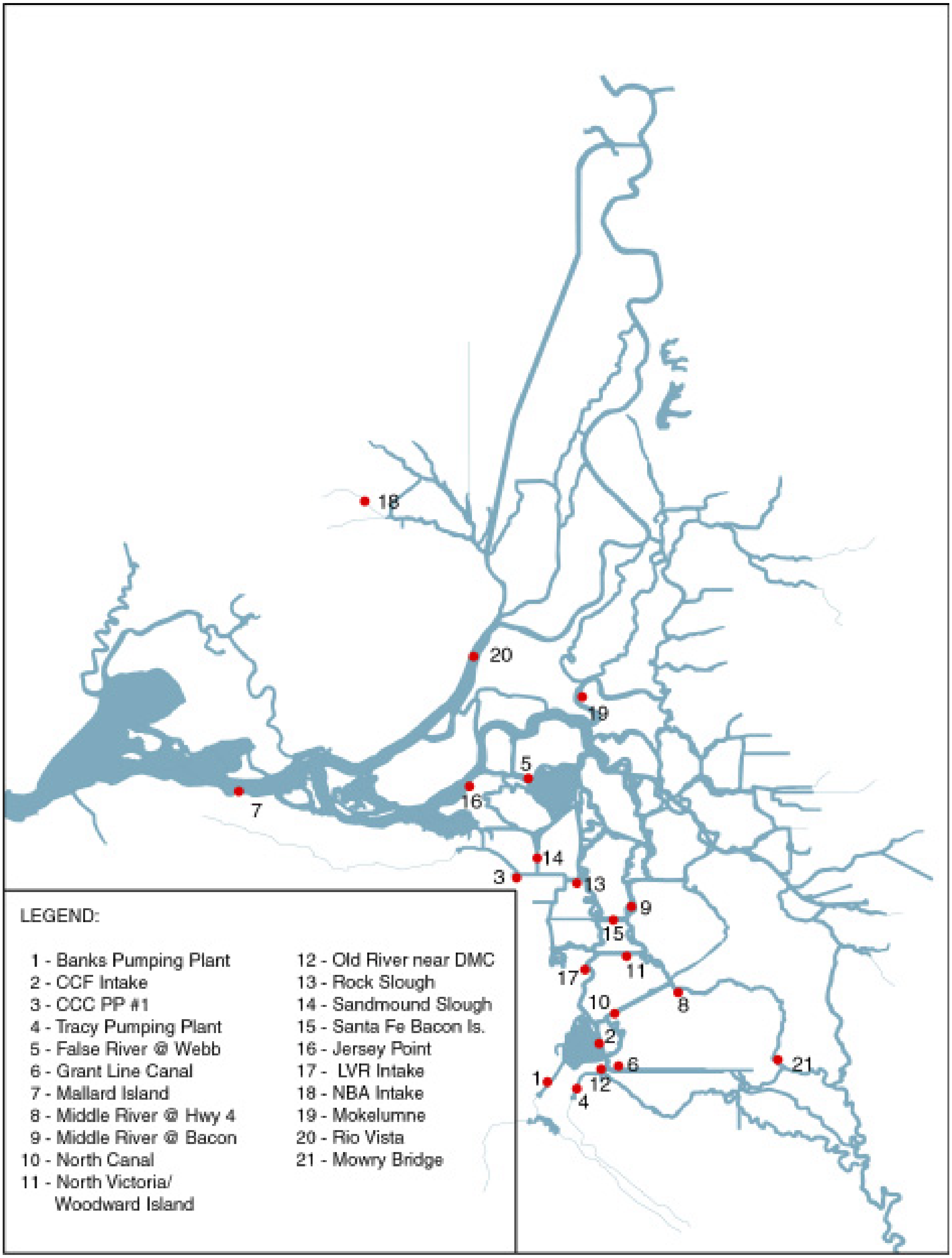


Figure 3-4: DSM2 Output Locations.

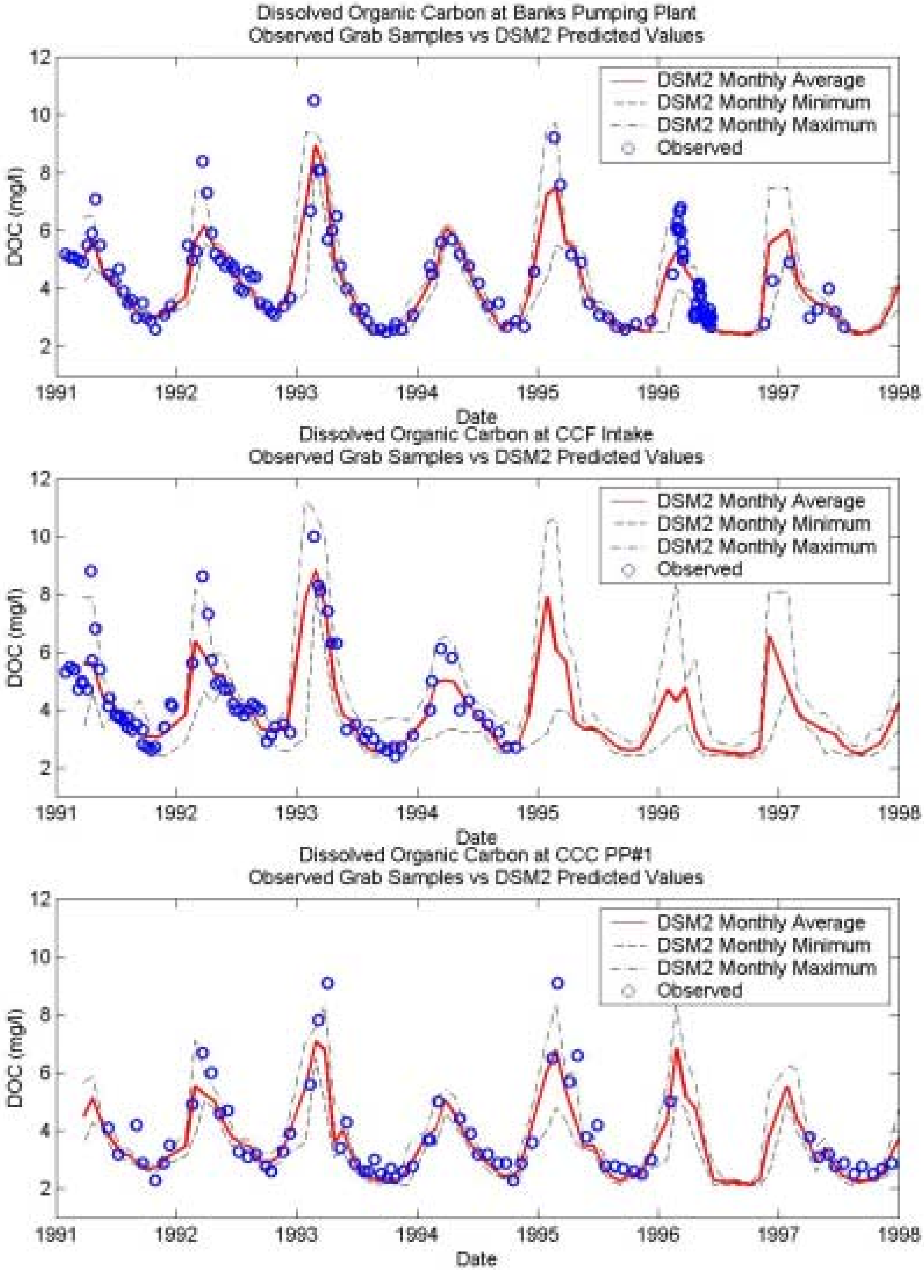
Table 3-2: Data Availability at DSM2 Output Locations.

Field Data Station	Abbreviation	Figures	Data Points	DSM2 Output Location
1- Banks Pumping Plant Headworks	Banks Pumping Plant	3-5; 3-12	181	Clifton Ct. Res.
2- Clifton Court Forebay Intake[1]	CCF Intake	3-5; 3-12	111	Node 72
3- Contra Costa Canal Pumping Plant #1	CCC PP #1	3-5; 3-12	80	Node 206
4- Delta Mendota Canal Intake	Tracy Pumping Plant	3-6; 3-13	134	Node 181
5- False River @ Southern Tip of Webb Tract	False R. @ Webb	3-6; 3-13	56	Ch 278 (U)
6- Grant Line Canal near Old River	Grant Line Canal	3-6; 3-13	56	Ch 213 (D)
7- Mallard Island	Mallard Island	3-7; 3-14	131	Ch 437 (M)
8- Middle River @ Highway 4	Middle River @ Hwy 4	3-7; 3-14	97	Ch 134 (D)
9- Middle River @ Bacon Island Bridge	Middle River @ Bacon	3-7; 3-14	91	Ch 148 (D)
10- North Canal near Old River	North Canal	3-8; 3-15	57	Ch 230 (D)
11- N. Victoria / Woodward Island near Old R.	NVICWOOD	3-8; 3-15	58	Ch 234 (U)
12- Old River near DMC Intake[2]	Old R near DMC	3-8; 3-15	111	Ch 81 (D)
13- Old River @ Rock Slough[3]	Rock Slough	3-9; 3-16	250	Ch 106 (2875)
14- Sandmound Slough	Sandmound Slough	3-9; 3-16	63	Ch 261 (D)
15- Santa Fe Railroad @ Bacon Island	Santa Fe Bacon	3-9; 3-16	58	Ch 258 (M)
16- San Joaquin River @ Jersey Point	Jersey Point	3-10; 3-17	63	Ch 83 (D)
17- Los Vaqueros Reservoir Intake	LVR Intake	3-10; 3-17	103	Node 80
18- NBA Intake @ Barker Slough	NBA Intake	3-10; 3-17	156	Node 273
19- Mokelumne River @ Georgiana Slough	Mokelumne	3-11; 3-18	18	Ch 374 (4627)
20- Sacramento River @ Rio Vista	Rio Vista	3-11; 3-18	72	Ch 430 (8731)
21- Middle River @ Mowry Bridge	Mowry Bridge	3-11; 3-18	17	Ch 126 (4044)

(1) includes data collected at West Canal near Clifton Court Forebay Intake
(2) includes data from a similarly located MWQI stations
(3) includes data from two similarly located MWQI stations (Old River @ Bacon Island and Station 04b)

- DSM2 results are less than satisfactory at the NBA Aqueduct intake at Barker Slough, an important urban intake. This location is strongly influenced by local hydrology (that is not modeled in DSM2) and agricultural return flows (Hutton and Chung 1992); Barker Slough is less influenced by reservoir releases and south Delta pumping operations. The Section does not advocate the use of DSM2 to predict changes in water quality at this location.

- Observed data represent instantaneous values throughout the tidal cycle, while model predictions represent monthly averages. This discrepancy introduces some difficulty in validating the model's ability to capture winter peak DOC and UVA values. Most of the observed values fall within the simulation envelope defined by monthly minimum and maximum values. However, it is doubtful that differences between observed data and monthly average predictions are due entirely to tidal variation, particularly in winter months. Some of the differences likely result from the coarse definition of Delta inflow and agricultural return water quality conditions. Some of the differences may also result from the DICU model's limited ability to estimate agricultural return flows.



Dissolved Organic Carbon at Banks Pumping Plant
Observed Grab Samples vs DSM2 Predicted Values

Dissolved Organic Carbon at CCF Intake
Observed Grab Samples vs DSM2 Predicted Values

Dissolved Organic Carbon at CCC PP#1
Observed Grab Samples vs DSM2 Predicted Values

Figure 3-5: Dissolved Organic Carbon at Banks Pumping Plant, Clifton Court Forebay, and Contra Costa Pumping Plant #1.

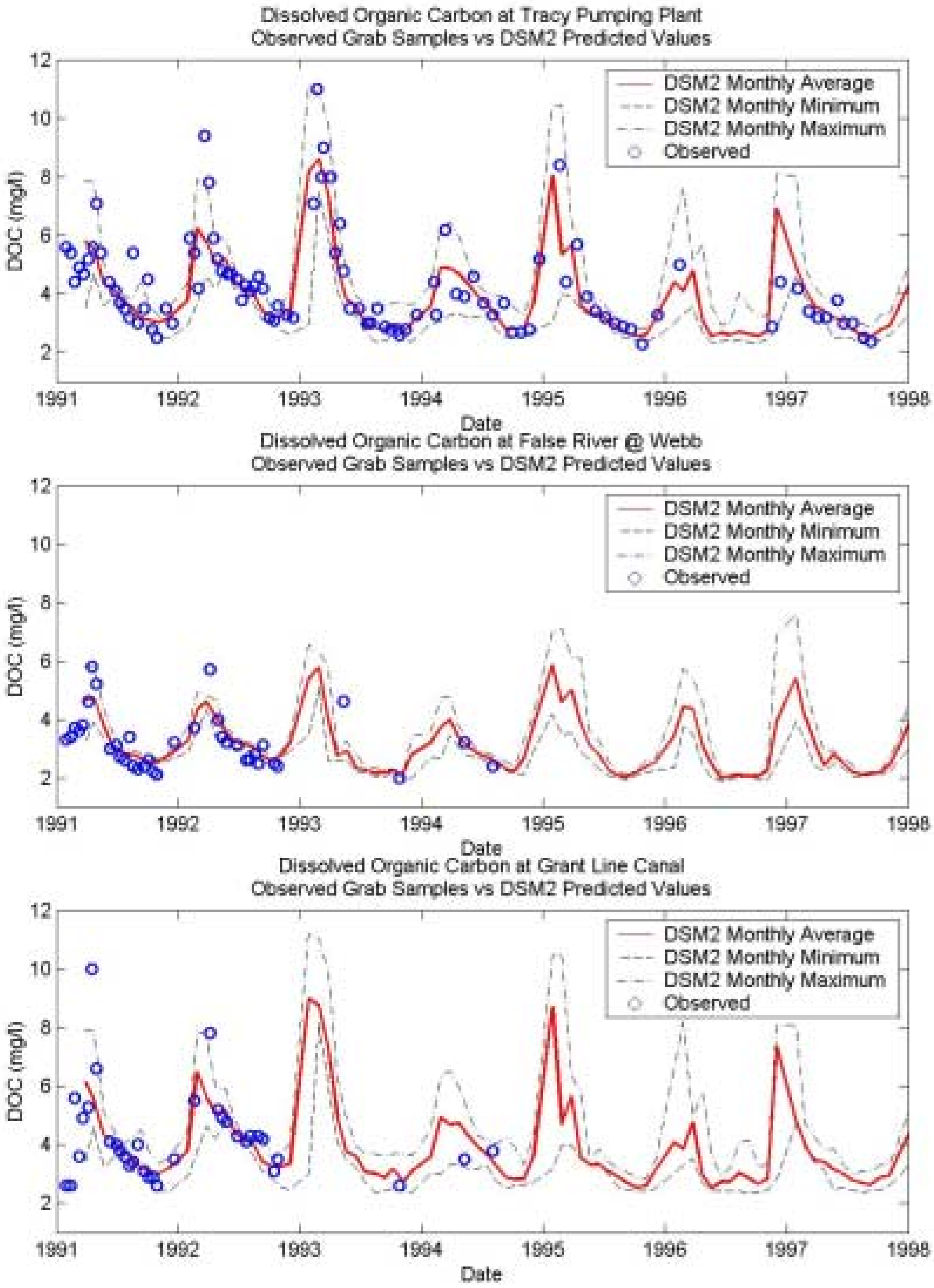


Figure 3-6: Dissolved Organic Carbon at Tracy Pumping Plant, False River at Webb Tract, and Grant Line Canal.

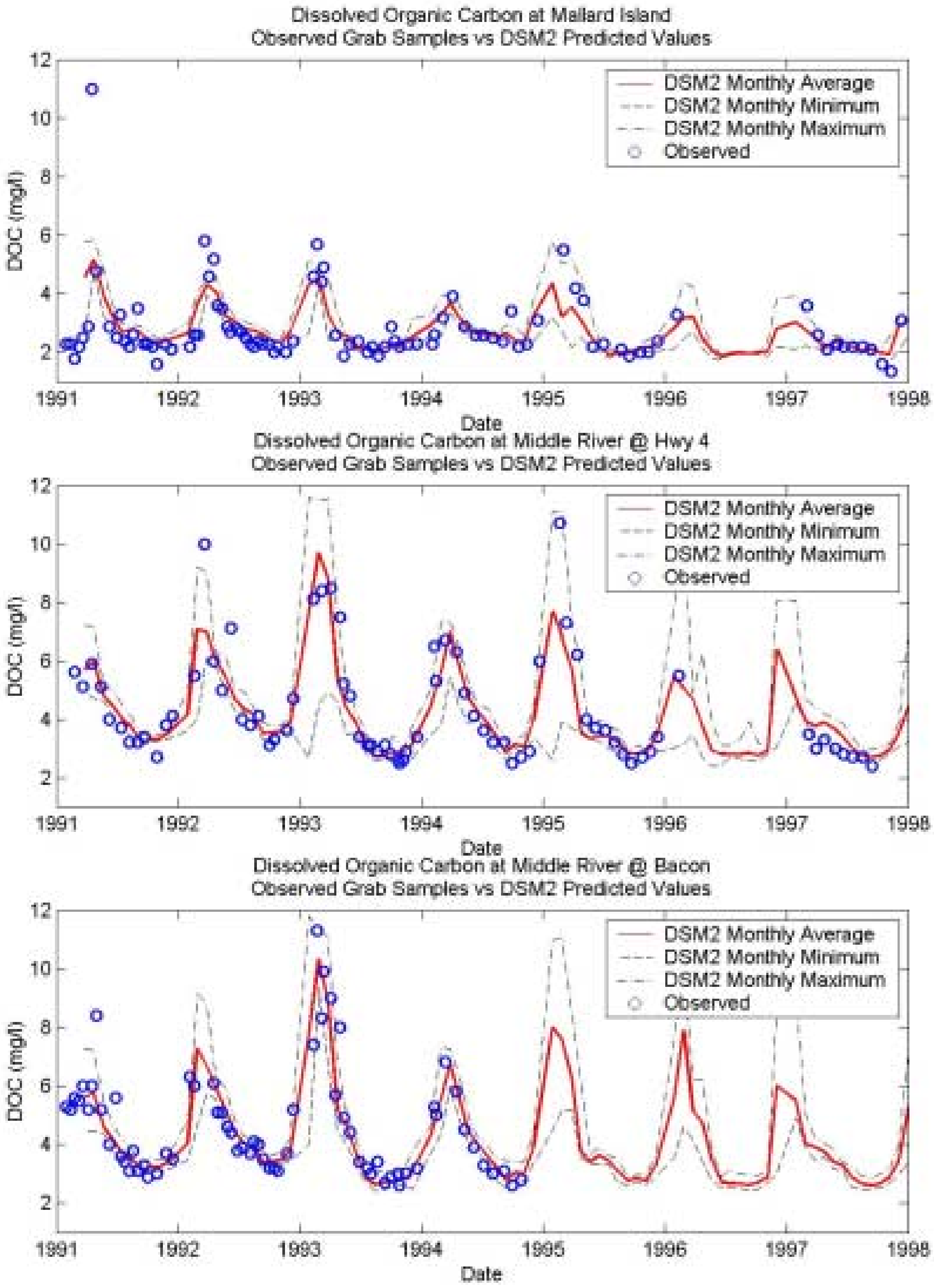


Figure 3-7: Dissolved Organic Carbon at Mallard Island, Middle River at Highway 4, and Middle River at Bacon Island.

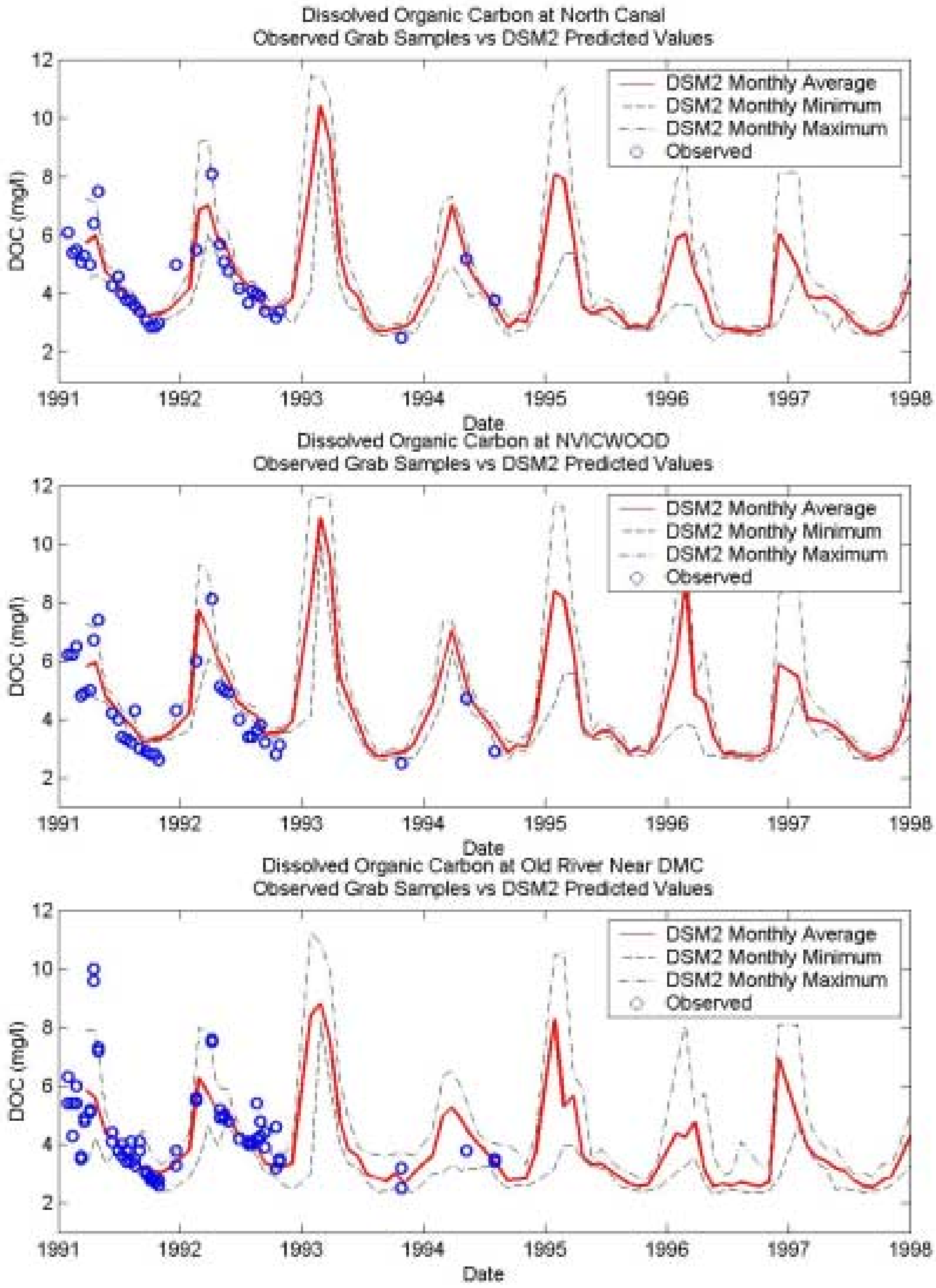


Figure 3-8: Dissolved Organic Carbon at North Canal, North Victoria Canal and Woodward Island, and Old River Near DMC.

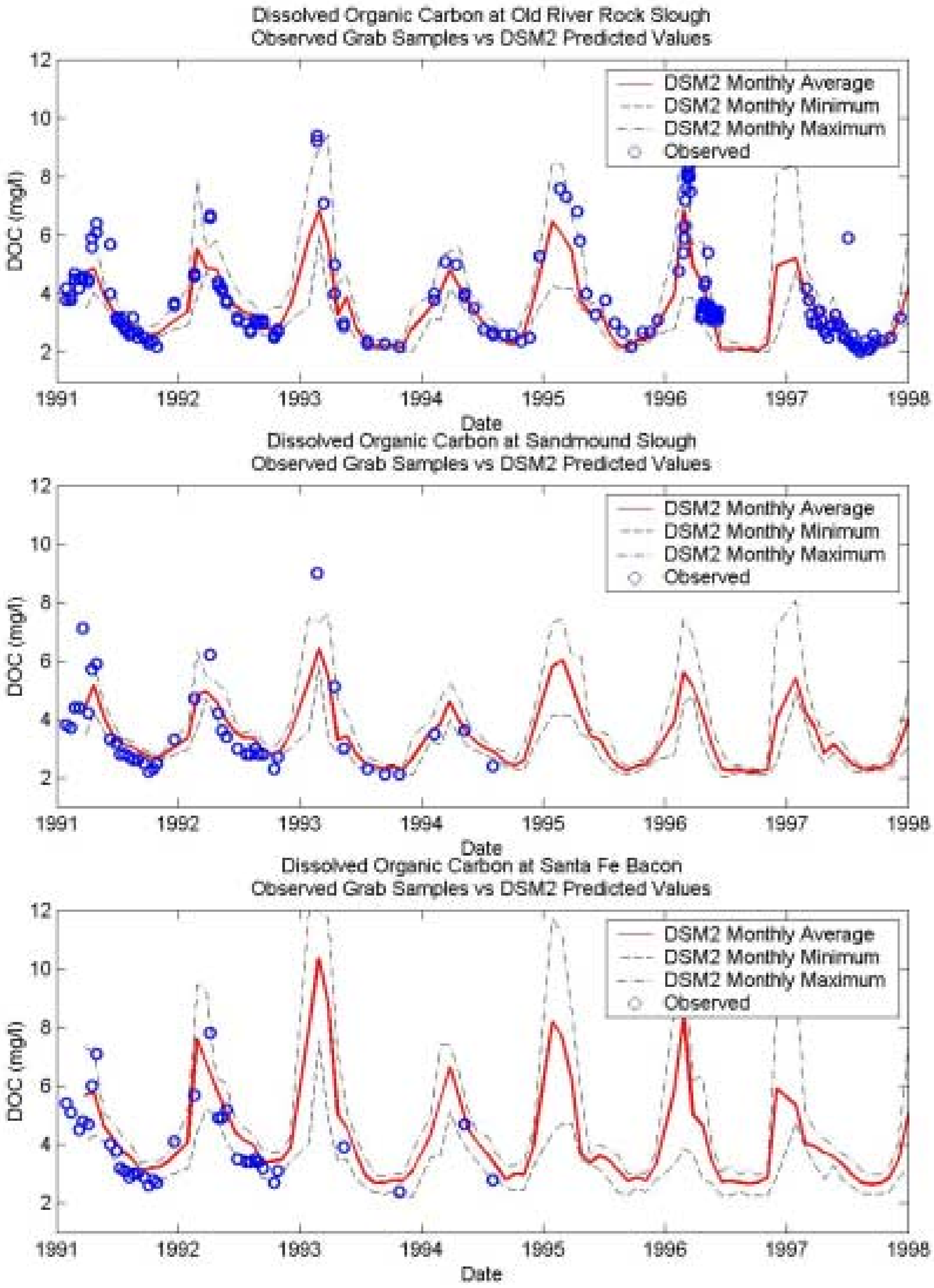


Figure 3-9: Dissolved Organic Carbon at Old River at Rock Slough, Sandmound Slough, and Santa Fe Railroad at Bacon Island.

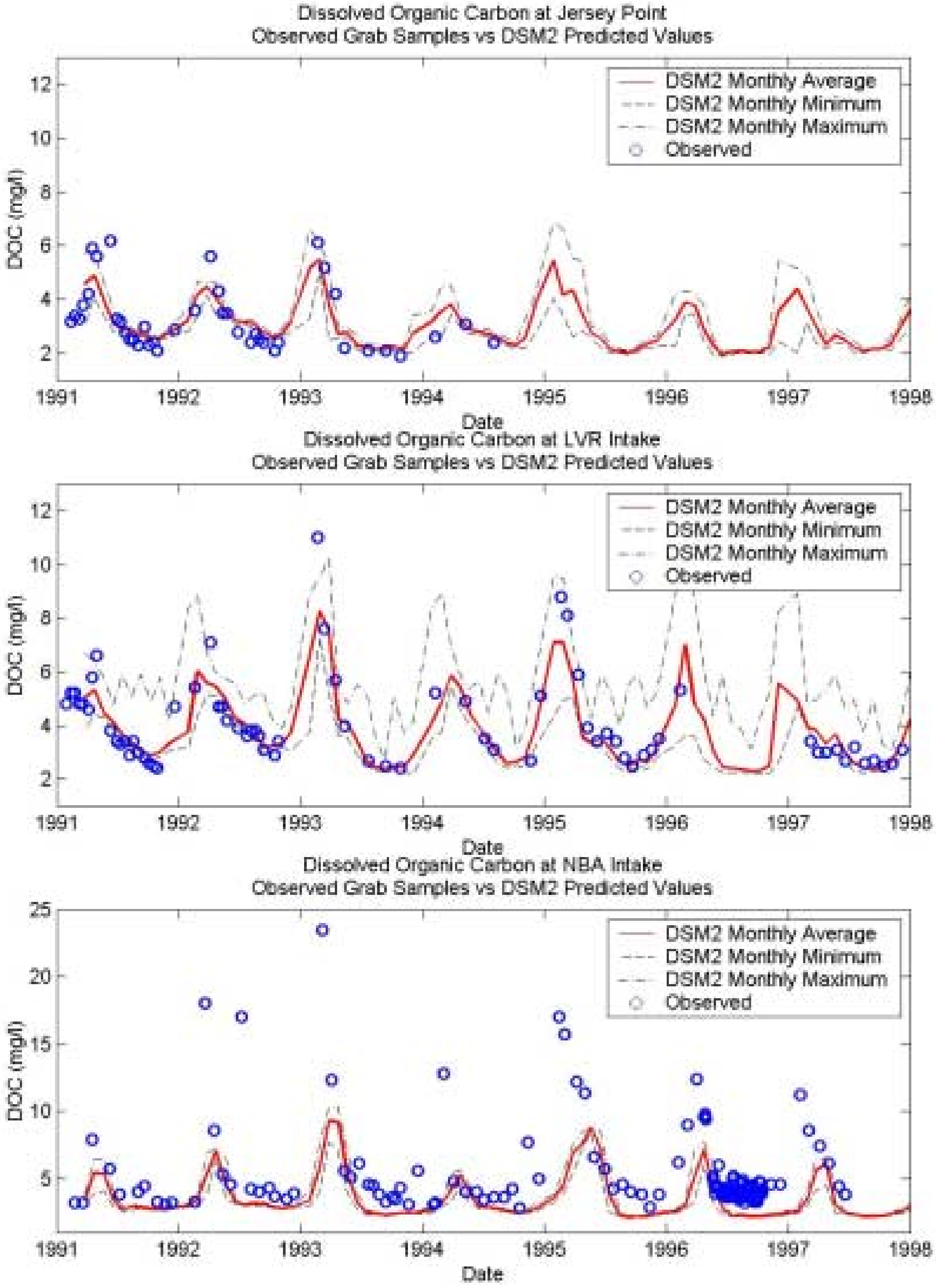


Figure 3-10: Dissolved Organic Carbon at Jersey Point, Los Vaqueros Reservoir Intake on Old River, and North Bay Aqueduct Intake.

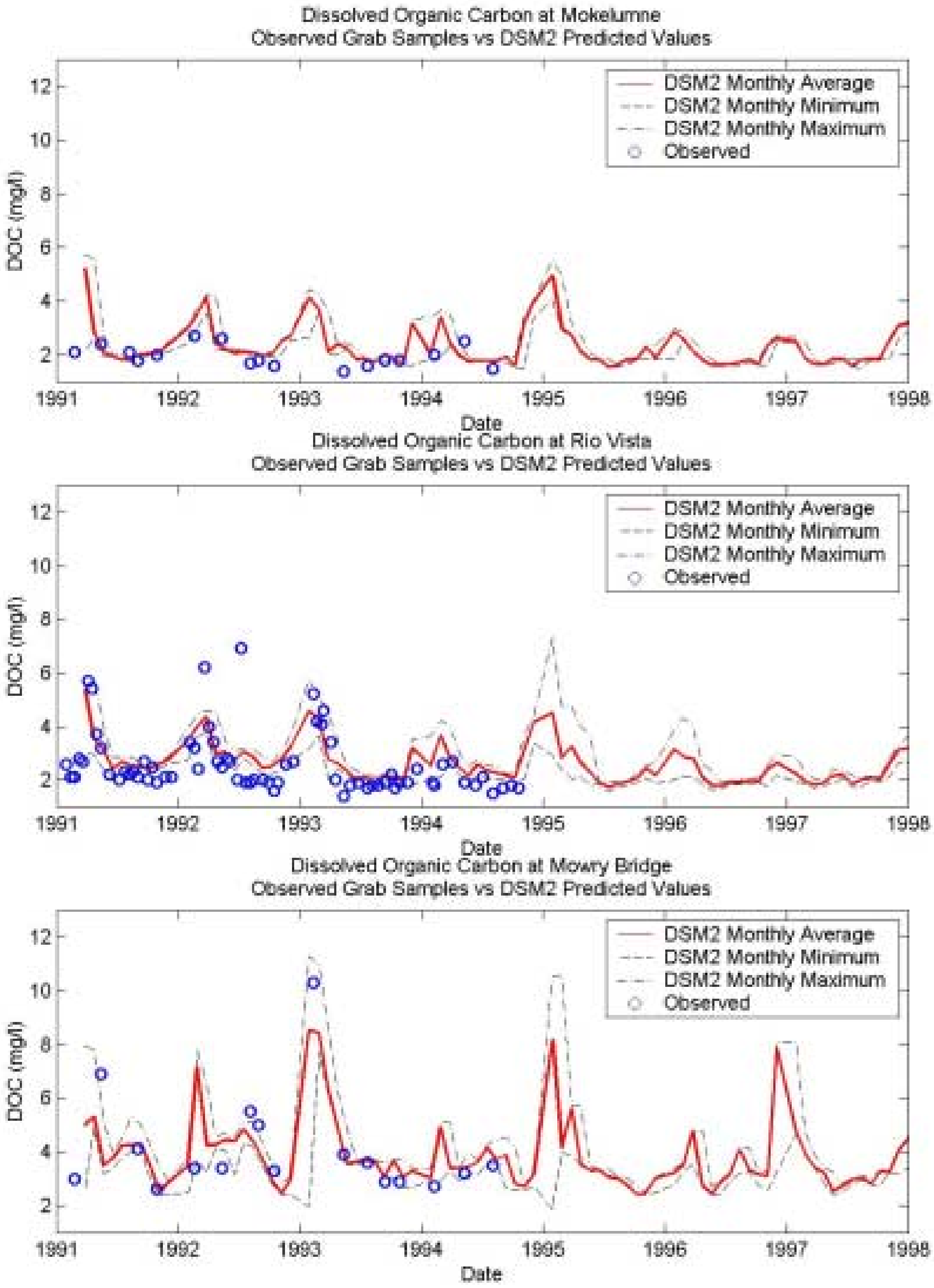


Figure 3-11: Dissolved Organic Carbon at the Mokelumne River, Rio Vista, and the Middle River at Mowry Bridge.

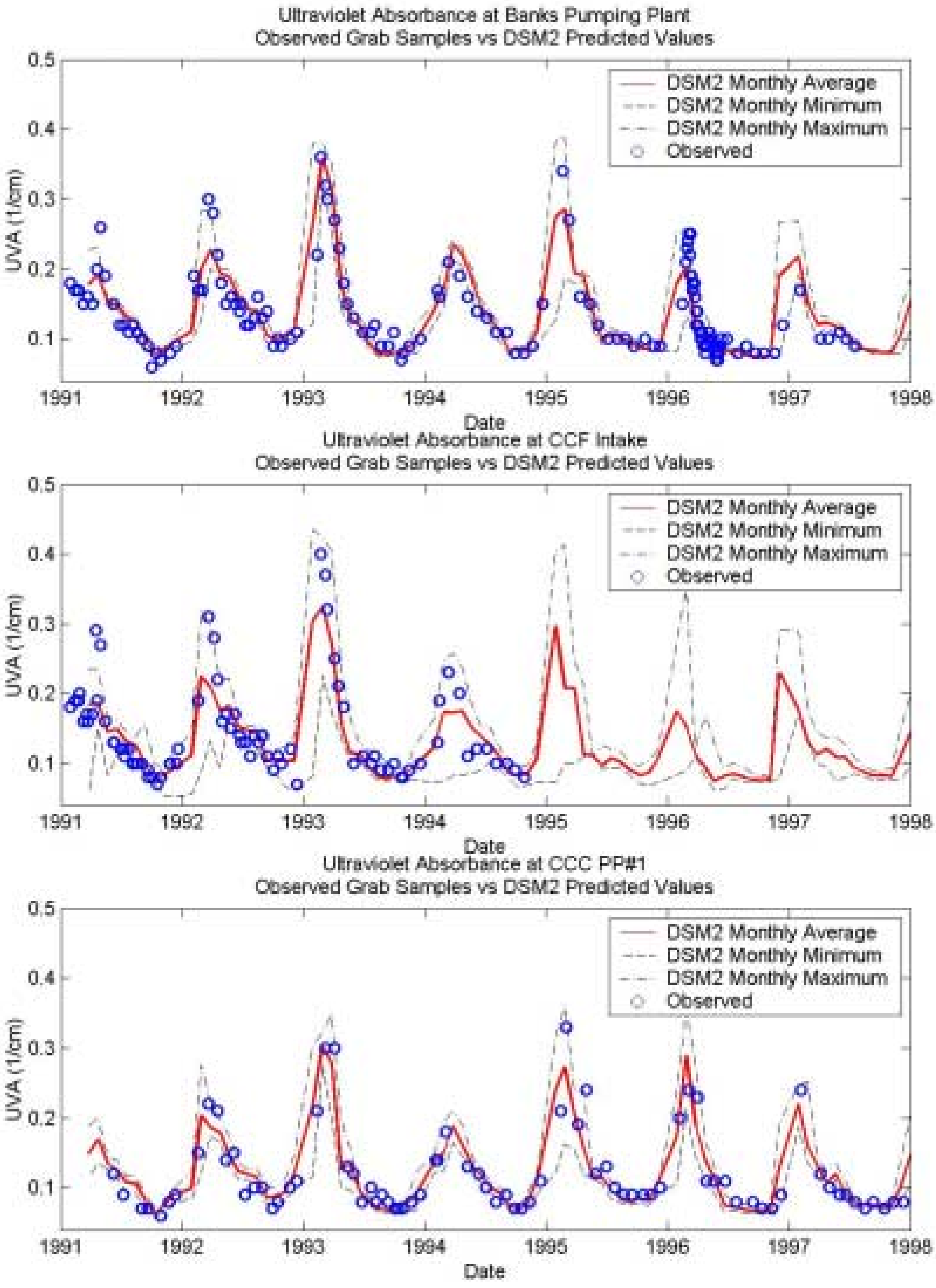


Figure 3-12: Ultraviolet Absorbance at Banks Pumping Plant, Clifton Court Forebay, and Contra Costa Pumping Plant #1.

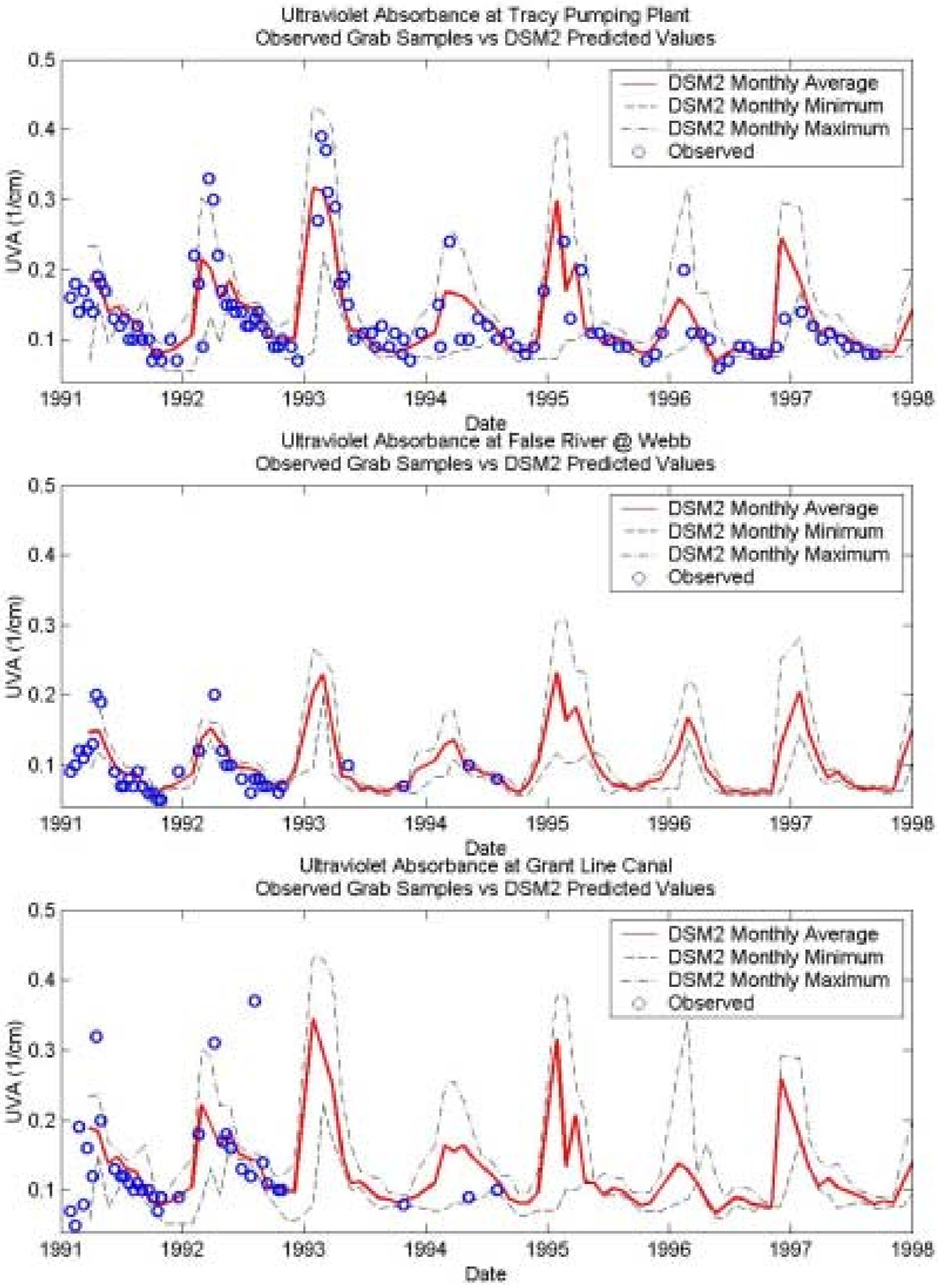


Figure 3-13: Ultraviolet Absorbance at Tracy Pumping Plant, False River at Webb Tract, and Grant Line Canal.

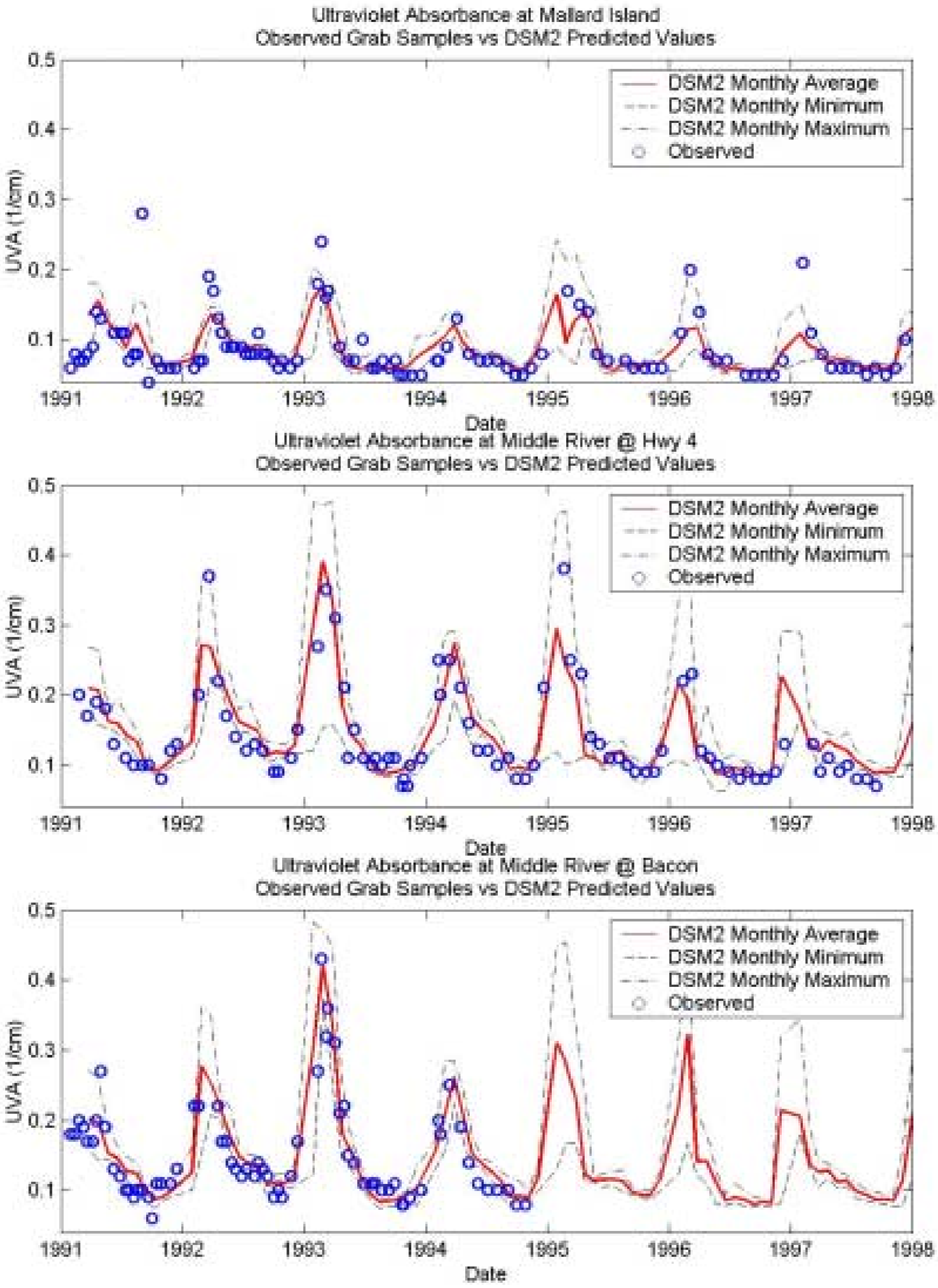


Figure 3-14: Ultraviolet Absorbance at Mallard Island, Middle River at Highway 4, and Middle River at Bacon Island.

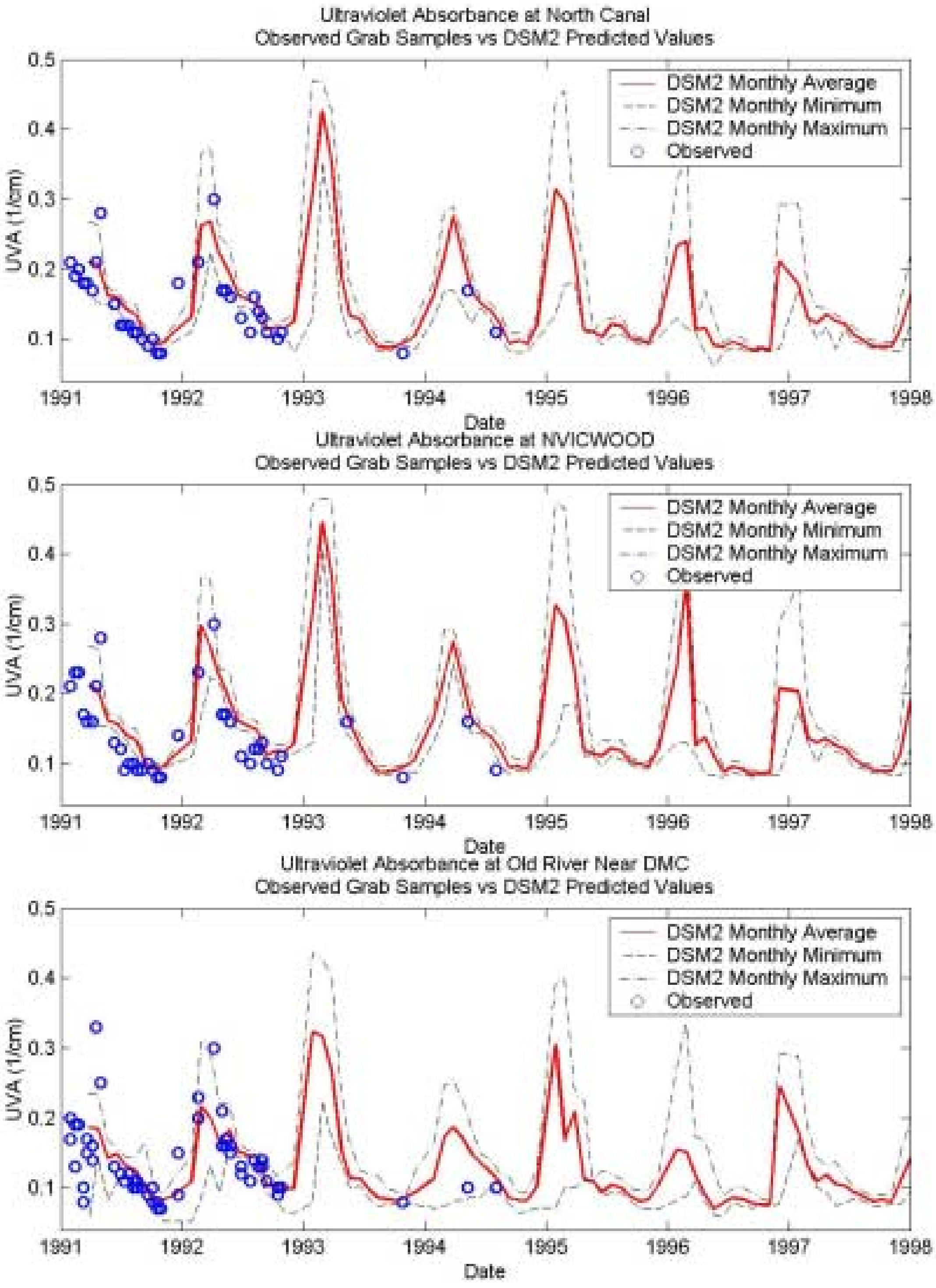


Figure 3-15: Ultraviolet Absorbance at North Canal, North Victoria Canal and Woodward Island, and Old River Near DMC.

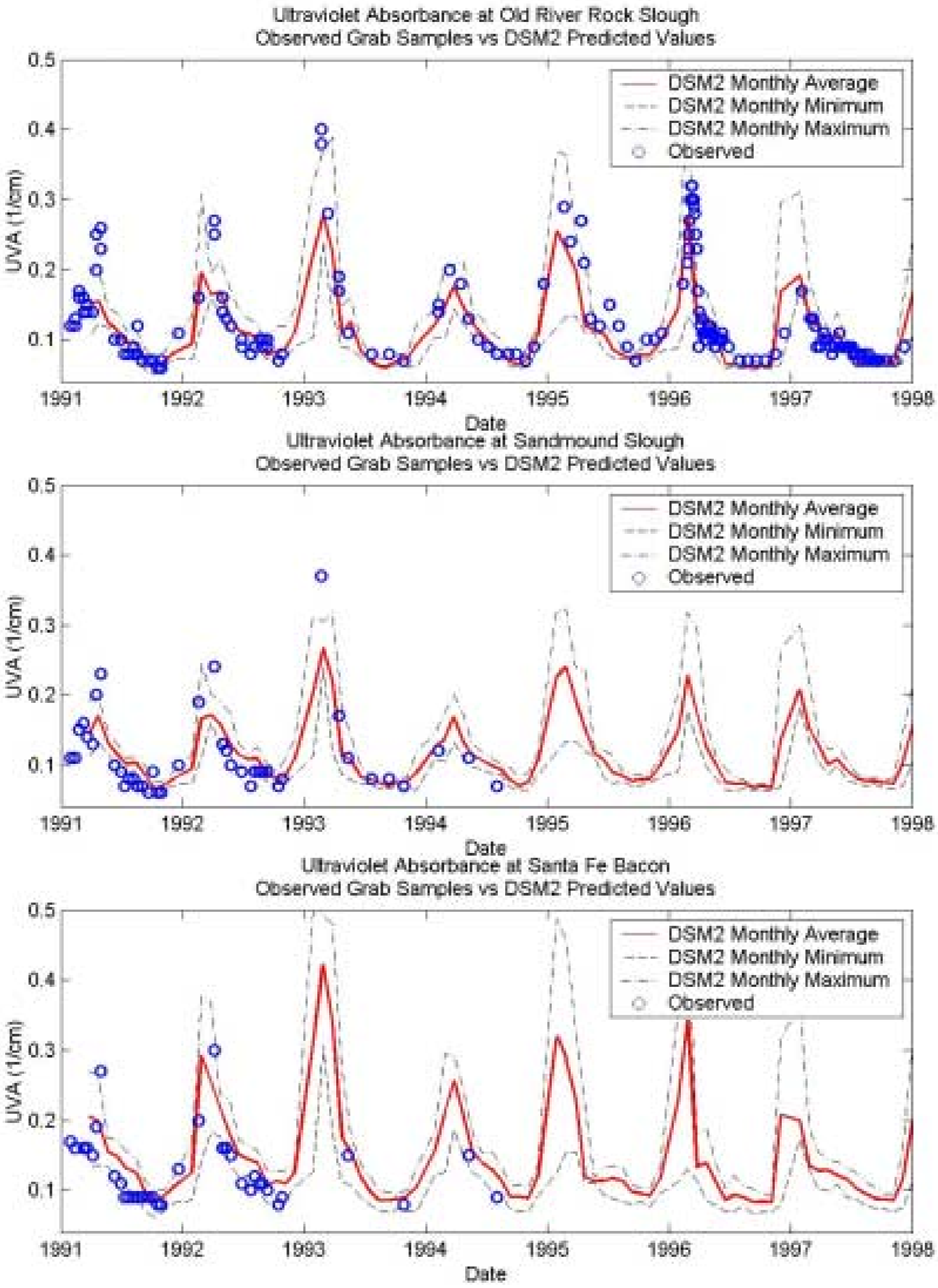


Figure 3-16: Ultraviolet Absorbance at Old River at Rock Slough, Sandmound Slough, and Santa Fe Railroad at Bacon Island.

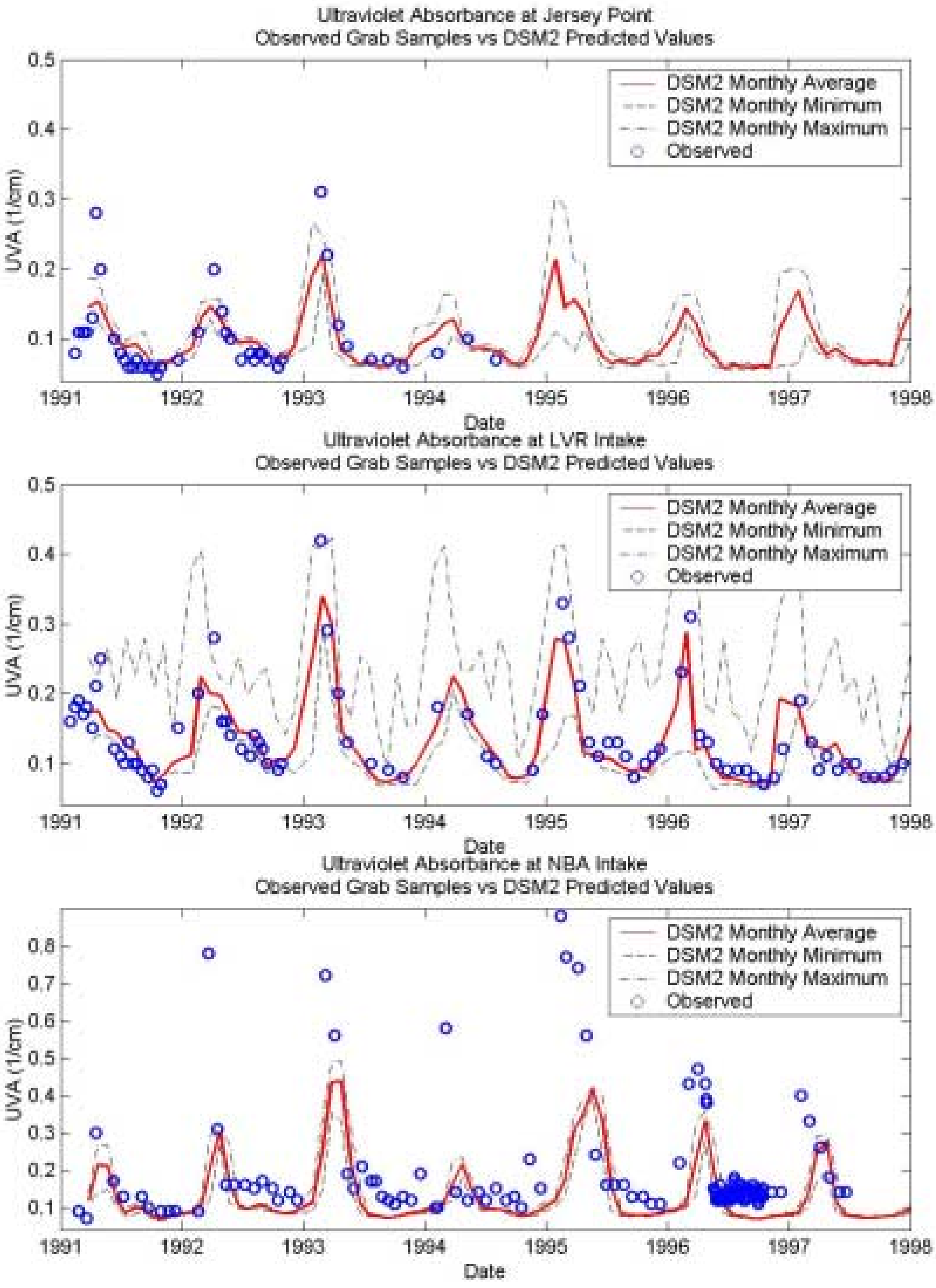


Figure 3-17: Ultraviolet Absorbance at Jersey Point, Los Vaqueros Reservoir Intake on Old River, and North Bay Aqueduct Intake.

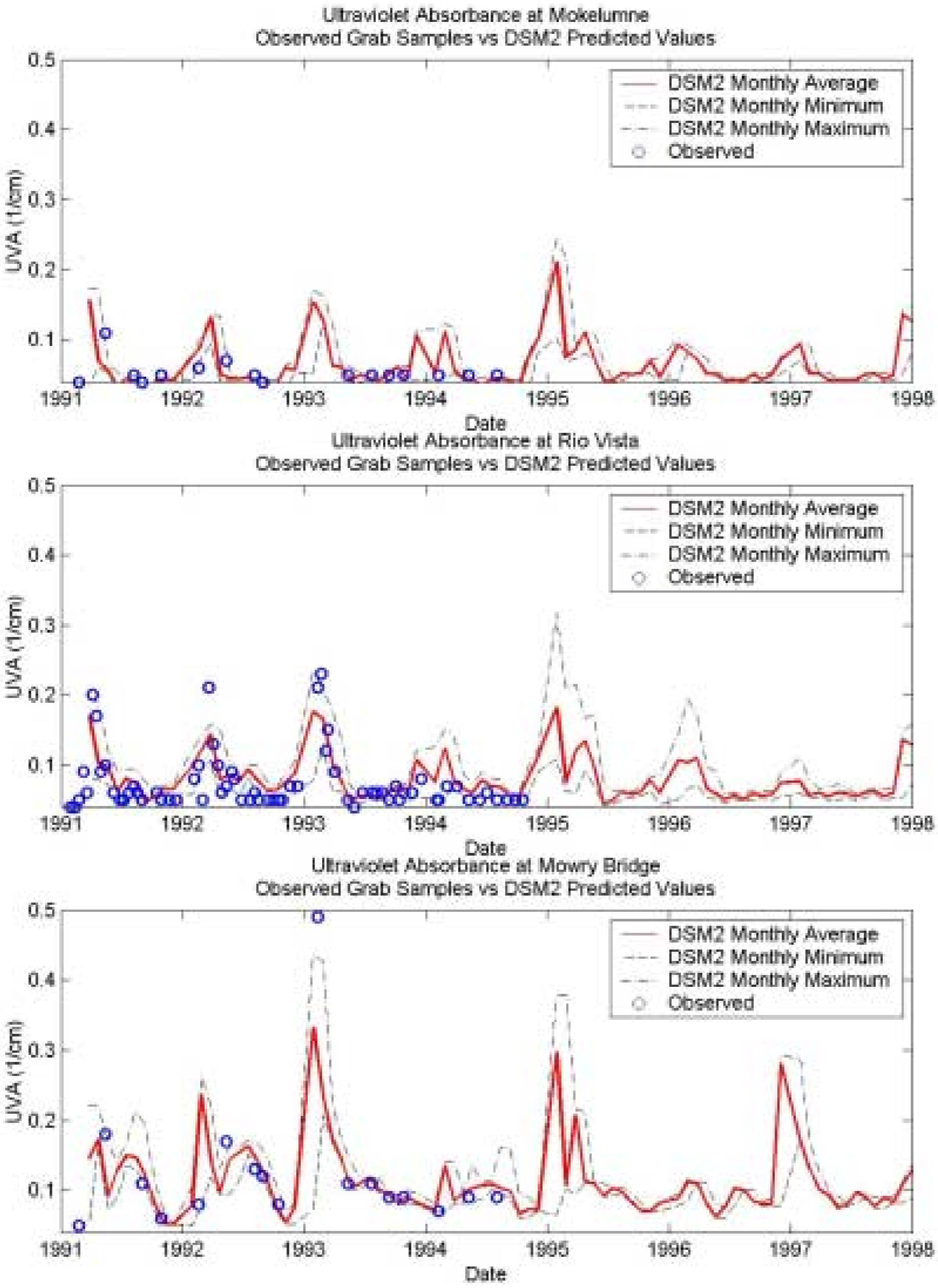


Figure 3-18: Ultraviolet Absorbance at the Mokelumne River, Rio Vista, and Middle River at Mowry Bridge.

3.4 Future Directions

- ☐ Model validation would likely be improved through a more refined specification of boundary conditions. Continuous monitoring of DOC and UVA at the Sacramento and San Joaquin river model boundaries may allow for these boundaries to be specified in daily time steps. Future DSM2 calibrations could also potentially improve results.

- ☐ Model validation would likely be improved through enhanced estimates of Delta island return flow and water quality. Assuming continued reliance on the DICU model to estimate return flows, compilation of historical land use during the simulation period would be a promising enhancement to the DSM2 validation.

- ☐ The sensitivity of model results to assumed boundary conditions should be explored. As a first step, a "fingerprint" analysis could be conducted to determine the relative impact of the Sacramento River, San Joaquin River, and agricultural return flows on urban intake water quality.

- ☐ Model results could be analyzed through statistical methods used by CALFED (Woodard 2000) to characterize Delta baseline water quality conditions, including frequency and seasonal analysis. Such an analysis should determine if the model provides a baseline characterization that is consistent with field observations.

3.5 References

Agee, B. (2000). *Generation of Time Series Boundary Data for the Delta Simulation Model.* unpublished draft report, California Department of Water Resources, Division of Planning and Local Assistance. Sacramento, CA. April.

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Hutton, P.H. and F.I. Chung. (1992). "Simulating THM Formation Potential in the Sacramento Delta. Part II." *Journal of Water Resources Planning and Management.* 118(5). American Society of Civil Engineers. pp. 530-42.

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Woodard, R. (2000). *Sources and Magnitudes of Water Quality Constituents of Concern in Drinking Water Supplies Taken From the Sacramento-San Joaquin Delta.* Prepared for the CALFED Bay-Delta Program, September.