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

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Chapter 6:
Dissolved Oxygen and Temperature Modeling Using DSM2

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6 Dissolved Oxygen and Temperature Modeling Using DSM2

6.1 Introduction

Low dissolved oxygen (DO) levels are of concern in the San Joaquin River (SJR) in the vicinity of Stockton because they frequently fall below the U.S. Environmental Protection Agency (EPA) standard of 5 mg/l for aquatic health and the Regional Water Quality Control Board standard of 6 mg/l for upstream migration of fall-run Chinook salmon. The Total Maximum Daily Load (TMDL) Stakeholder process was created for this portion of the SJR to meet the water quality standards established by the Federal Clean Water Act. This chapter focuses on the Section's work to characterize the spatial and temporal distributions of DO and related water quality variables in the river by enhancing DSM2-QUAL (QUAL). This enhanced version of QUAL can be used to identify the principal factors that may contribute to low DO levels in this reach of the SJR.

Using a dynamic flow field obtained from the hydrodynamic model DSM2-HYDRO (HYDRO), QUAL performs advective and dispersive steps of mass transport including net transfer of energy at the air-water interface. Changes are accounted for in mass of constituents due to decay, growth, and biochemical transformation. Calibration and validation of the model were performed using field observation of DO, temperature, and nutrients over two three-month periods representing different hydrologic conditions.

The extension of the DSM2 grid to the region upstream of Vernalis (see Chapter 5) is expected to enhance model prediction of DO levels. However, the DSM2 with SJR extension was not available at the time of this study. Through evaluations of different hypotheses, QUAL can aid in developing potential management strategies to address water quality degradation in the San Joaquin River near Stockton.

6.2 Model Input

Simulation of DO requires information on water temperature, BOD, chlorophyll, organic nitrogen, ammonia nitrogen, nitrite nitrogen, nitrate nitrogen, organic phosphorus, dissolved phosphorus (ortho-phosphate), and EC in the Delta. In order to simulate DO, a group of related variables has to be simulated at the same time. Interaction among water quality variables in DSM2 is shown in Figure 6-1. The rates of mass transfer (shown by the arrows) are functions of temperature. It is important that temperature simulation be included in DO simulation. The sources and sinks of DO are indicated in the figure. Further information on DSM2 kinetics is given in reference (Rajbhandari 1998), also available at the Delta Modeling web site http://modeling.water.ca.gov/delta/repts.

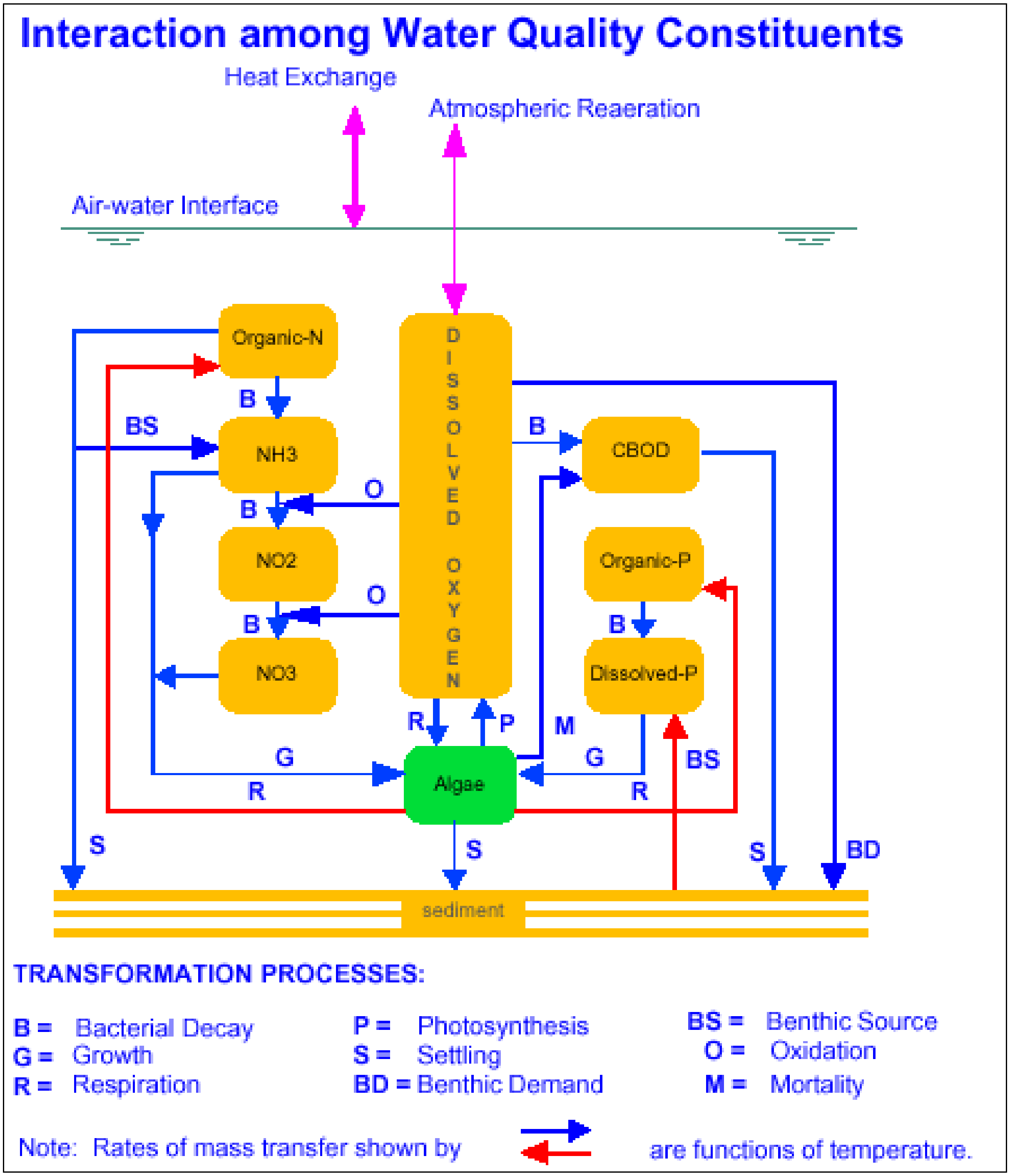

Figure 6-1: Interaction among Water Quality Constituents.

Available data collected at hourly intervals for DO, temperature, and EC provide boundary information needed by DSM2. At most stations in the Delta, only grab samples are available. Usually, these data are collected at biweekly or monthly intervals, which were used as approximations for initial condition input. Since continuous data were not available at Vernalis (RSAN112), hourly values of DO, EC, and temperature available from the nearby station at Mossdale (RSAN087) were used to approximate these quantities for the boundary inflow at

Vernalis. Since the flows at Vernalis are primarily unidirectional, and the hydraulic residence time is relatively short, this assumption is less critical. Data on effluent flows from the City of Stockton's Regional Wastewater Control Facility (RWCF) were obtained from the Stockton Municipal Utilities District. Nutrient data at Vernalis were approximated from the San Joaquin River TMDL measurements sampled at weekly intervals in 1999. The nutrient data at Freeport on the Sacramento River were approximated from the latest publication of the U.S. Geological Survey report (USGS 1997) and chlorophyll data were approximated from DWR (1999). An estimate of flows and water quality of agricultural drainage returns at internal Delta locations was based on DWR studies. Climate data representing air temperature, wetbulb temperature, wind speed, cloud cover, and atmospheric pressure (source: National Climatic Data Center) provided DSM2 input for simulation of water temperature.

6.3 Calibration

The process of calibration for DO is data intensive, and a narrowing of data gaps through additional field measurements is recommended. DSM2 calibration for EC is discussed in chapter 2. Based primarily on availability of data, the period of August through October of 1998 was chosen for calibration (Rajbhandari 2000). During this period, the flows in the SJR at Vernalis ranged from about 5,000 to 7,000 cubic feet per second (cfs). Combined export ranged from about 4,000 to 13,000 cfs. The historical record of tide at Martinez was used for the hydrodynamic simulation of the Delta using DSM2.

Reaction kinetics represented in DSM2 were expanded to include algae mortality and corresponding increases in BOD. This enhancement of phytoplankton-DO dynamics helped the process of calibration by including a mechanism that accounts for the oxygen consumption by volatile suspended solids (VSS) observed in the San Joaquin River. The process of calibration began with the calibration of water temperature. Evaporation coefficients were adjusted until there was reasonable agreement between simulated and measured temperature as discussed below. During DO calibration, the following parameters were adjusted: algae (growth, respiration, settling, and mortality rates), nitrogen (organic nitrogen decay and oxidation rates of ammonia and nitrite), and sediment oxygen demand. Calibrated coefficients are within the range suggested in the literature (Bowie et al 1985, Brown and Barnwell 1987, Thomann and Mueller 1987, Jones and Stokes 1998).

Figure 6-2 is presented to show the comparison of simulated water temperature with field data at the continuous monitoring station at SJR near Rough and Ready Island (RRI). DSM2 seems to overestimate the observed data by less than 1 degree C. The plots seemed to agree better in the cooler period since DSM2 results were within 0.5 degree °C of measured DO during October and the latter part of September.

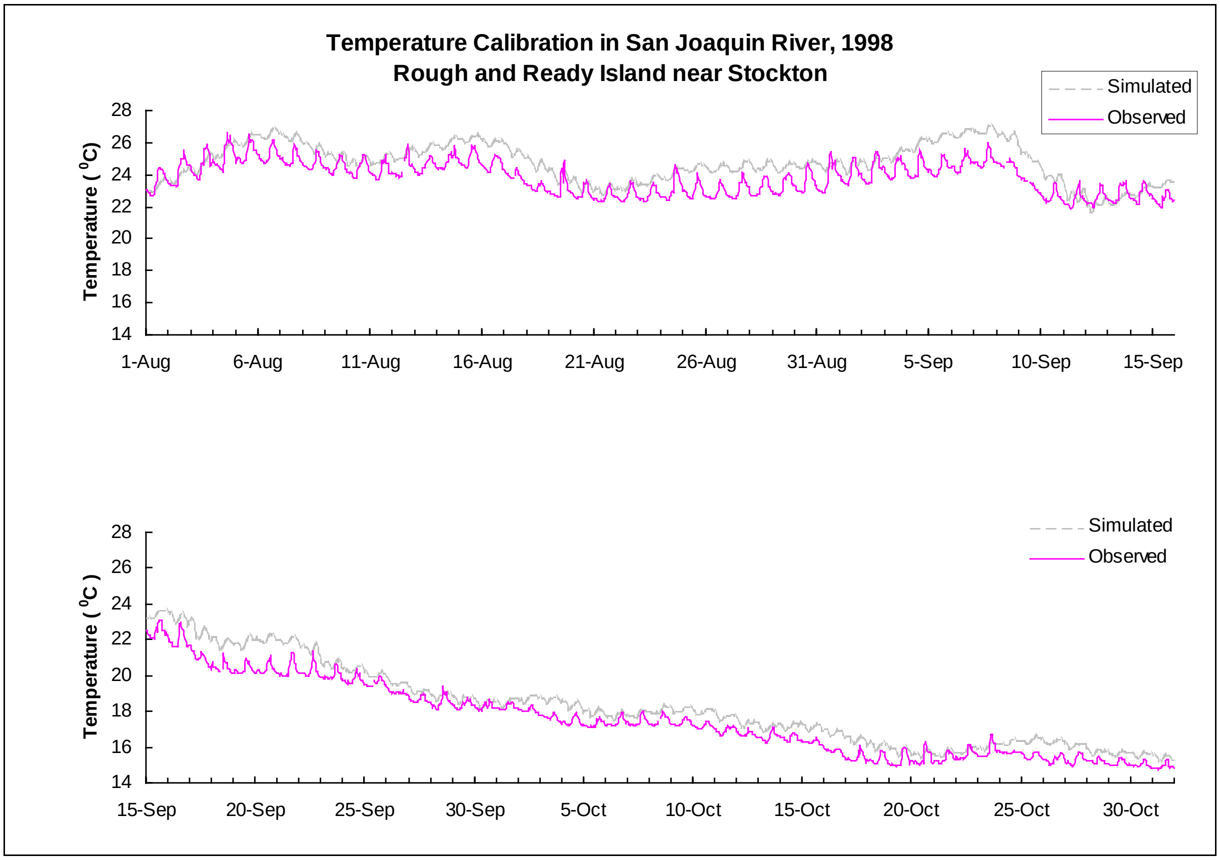

Figure 6-2: Temperature Calibration in the San Joaquin River, at Rough and Ready Island near Stockton, 1998.

Figure 6-3 presents the comparison of model results and field observations in the San Joaquin River near RRI. In general, the differences between model and field DO were within 1 mg/l, and the highs and lows appear to be in phase. During the middle of August and September, the differences between model and field observations are somewhat higher, at times as high as 1.5 mg/l.. Also, the model could not capture the large diurnal range that occurred during the period between the middle of August and the middle of September. There is a possibility that this may have been partially due to DO stratification that tends to occasionally occur in the water column, which cannot be directly accounted for by the 1-dimensional model.

Based on the above, the model was considered calibrated for this reach of the SJR. Figure 6-4 illustrates how QUAL results compare with field measurements when averaged over a day. In evaluating planning alternatives, flow and salinity comparisons were traditionally based on either daily or monthly averaged model output. This mode of analysis made it easier to quantify the impact of different alternatives.

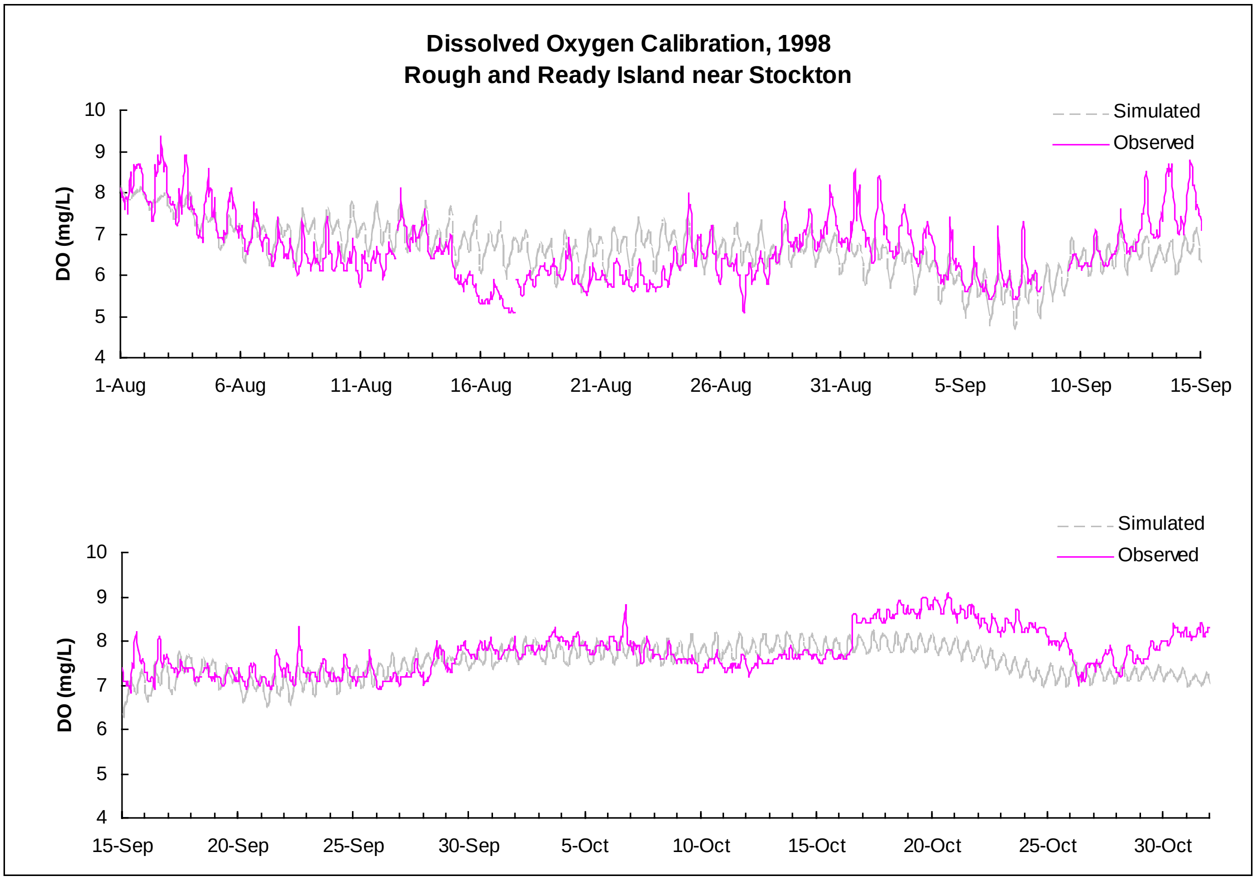

Figure 6-3: Dissolved Oxygen Calibration, Rough and Ready Island near Stockton, 1998.

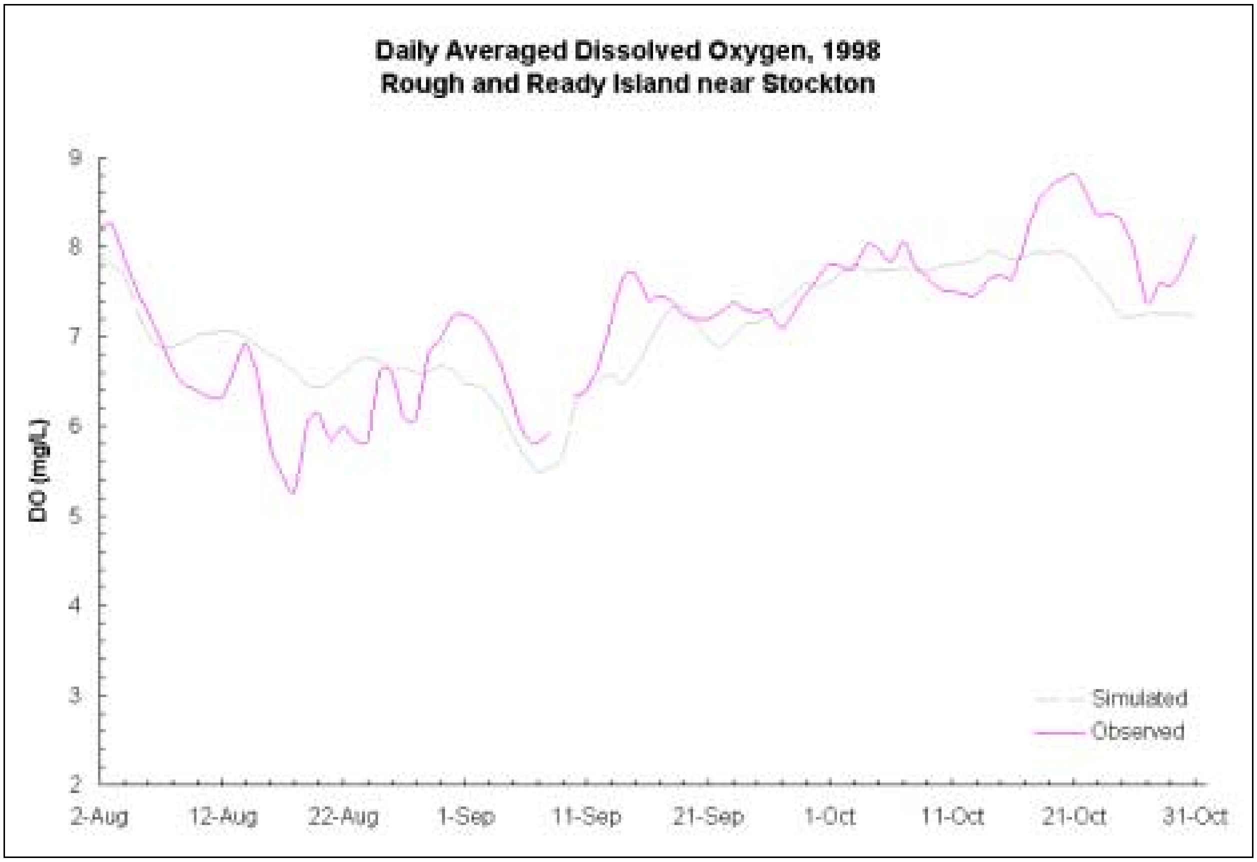

Figure 6-4: Daily Averaged Dissolved Oxygen, at Rough and Ready Island near Stockton, 1998.

6.4 Validation

Model validation was done for the period from July through September 1999, when the flows in the San Joaquin River at Vernalis were around 2,000 cfs, which is considerably lower than the San Joaquin River flows from the calibration period. The rate coefficients adopted during calibration were kept the same during this simulation. Within the region of interest, the first 15 days are considered the "warm up" period and the simulated results for both water temperature and DO should be ignored during this period.

Figure 6-5 is presented to show how DSM2 results compare with the measured water temperature at San Joaquin River near RRI. The comparison seems favorable with the differences being mostly within 1degrees C. Figure 6-6 shows the comparison of simulated and observed DO during this period. There seems to be an agreement in the general trend of the simulated results with field data. Most of the time, the differences are within 1 mg/l. However, during the middle week of July and the first weeks of August and September, the differences are about 1-1.5 mg/l. Beginning on Sept. 23, measured data were missing for the following 25 hours after which DO levels continued to fall, reaching to a low 1.7 mg/l on September 30. This indicates a strong possibility of instrument errors during the last week of September. As for the calibration period, Figure 6-7 is presented to illustrate how DSM2 results compare with field measurements when averaged over a day.

Additionally, model results were compared with field data at San Joaquin River near Fourteen Mile Slough (Figure 6-8), and near Columbia Cut (Figure 6-9) located downstream of Rough and Ready Island. Since field data were available only as grab samples on a weekly basis, model results are shown as the daily maximum and minimum DO enveloping the field data.

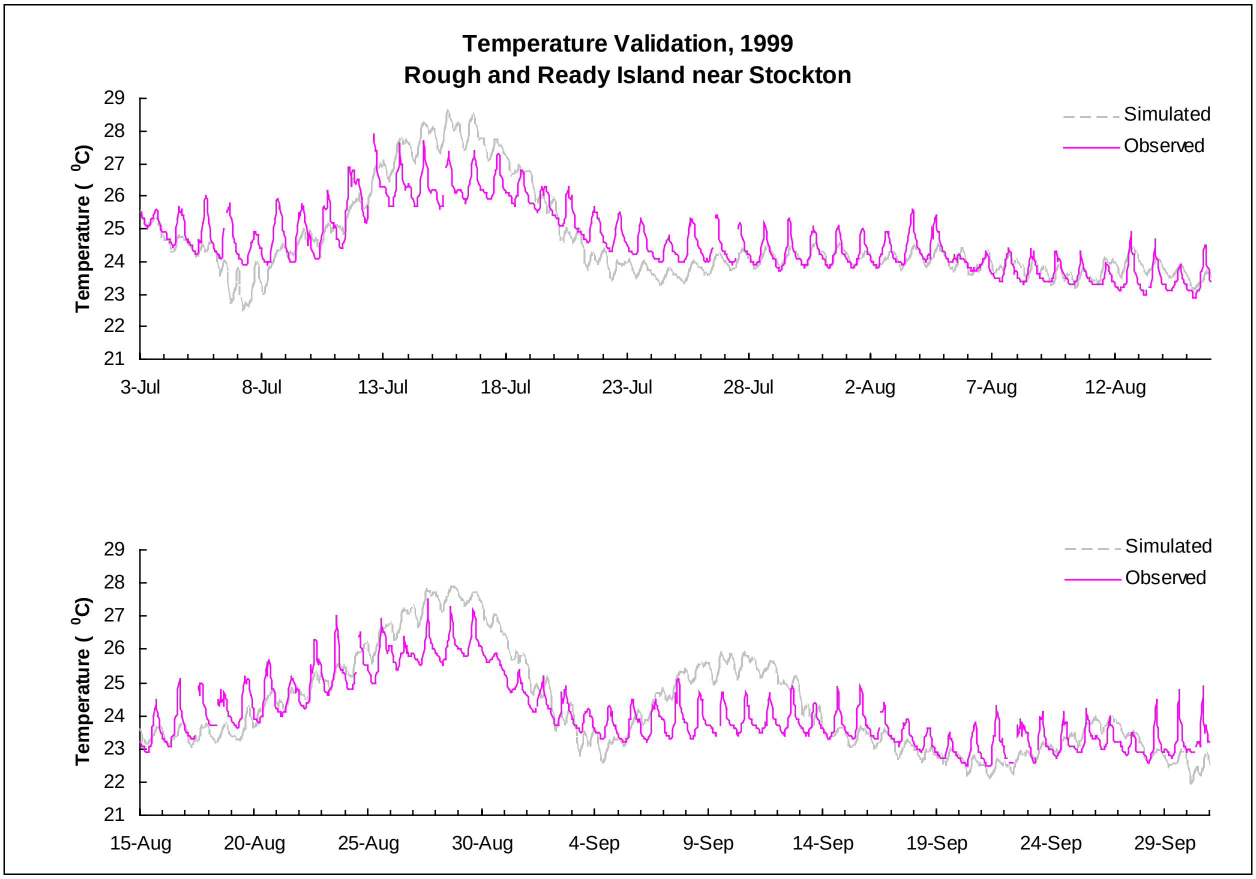

Figure 6-5: Temperature Validation, at Rough and Ready Island near Stockton, 1999.

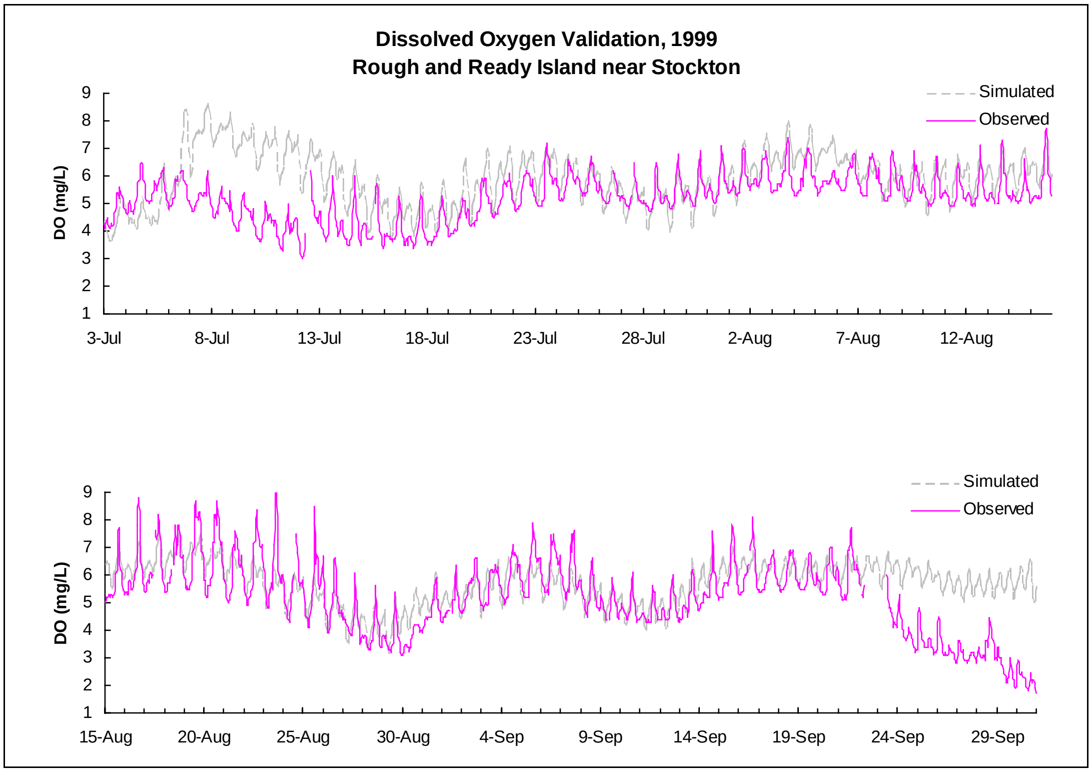

Figure 6-6: Dissolved Oxygen Validation, at Rough and Ready Island near Stockton, 1999.

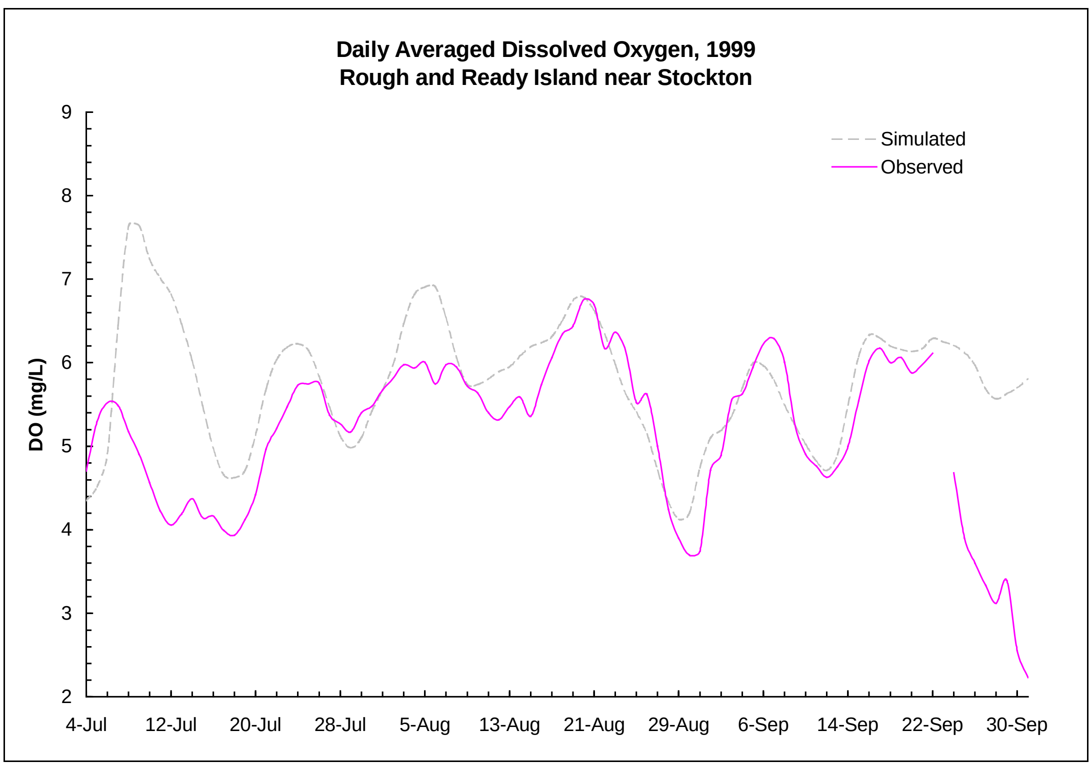

Figure 6-7: Daily Averaged Dissolved Oxygen, at Rough and Ready Island near Stockton, 1999.

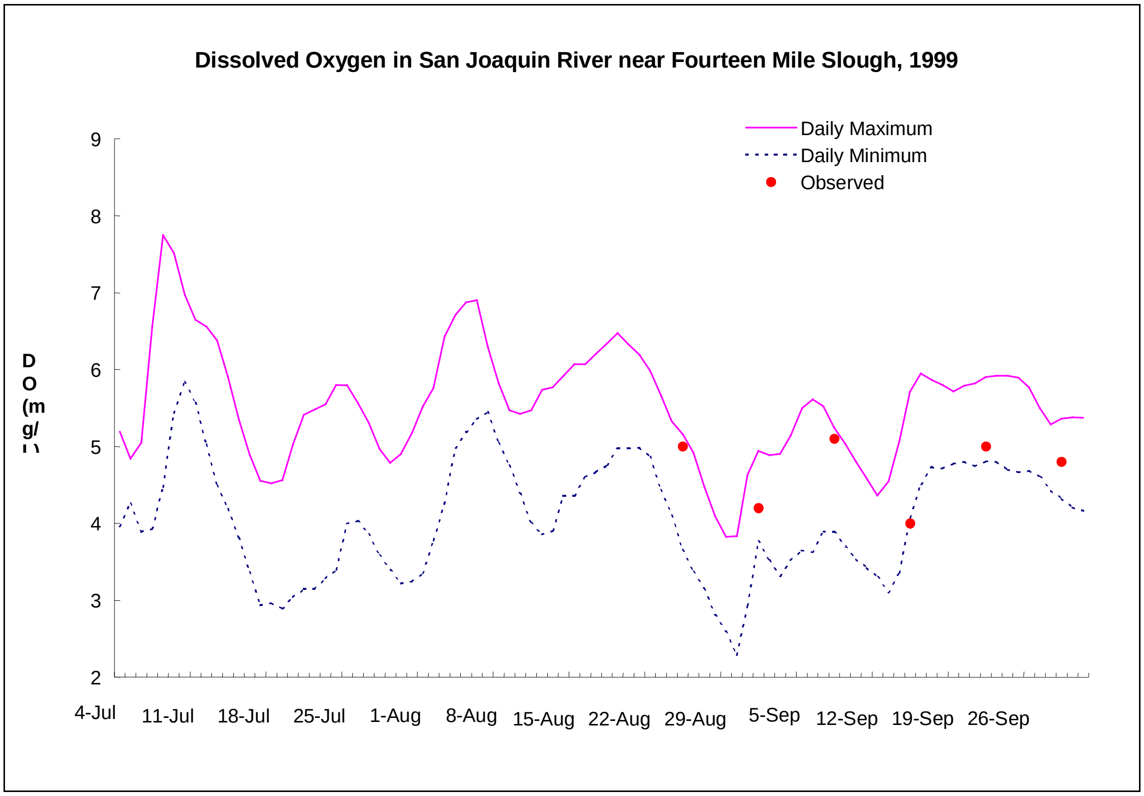

Figure 6-8: Dissolved Oxygen in the San Joaquin River near Fourteen Mile Slough, 1999.

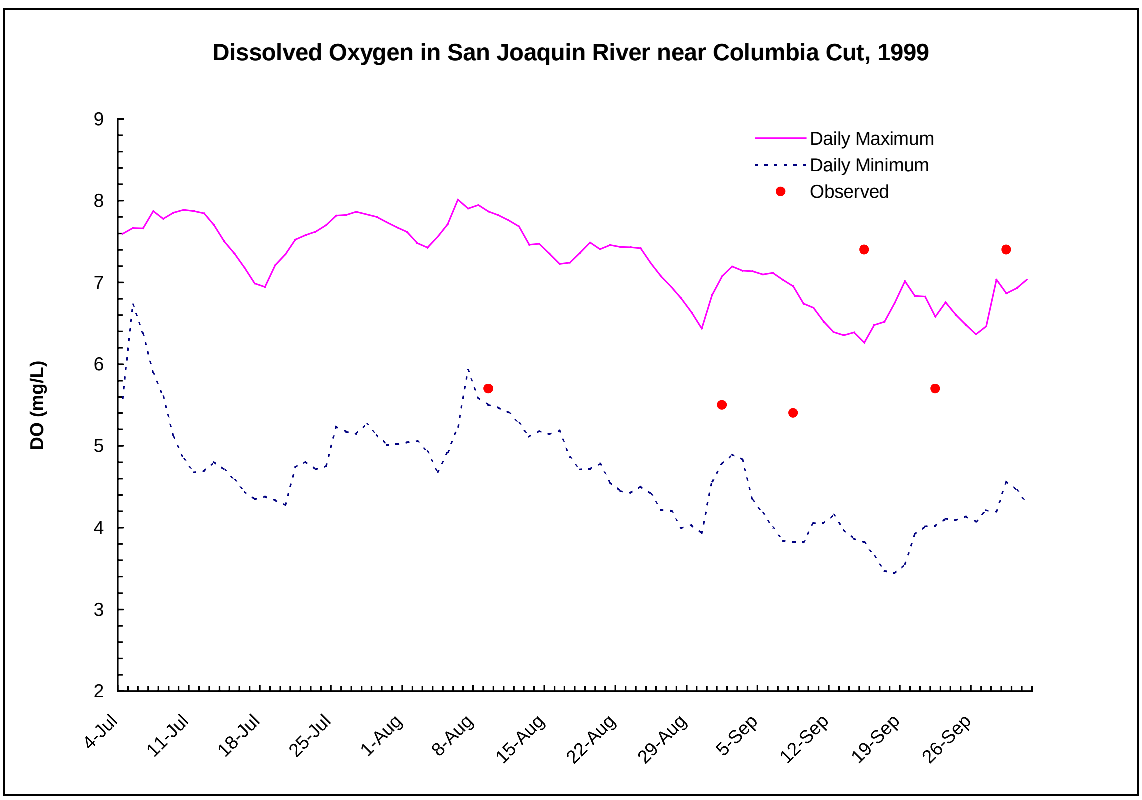

Figure 6-9: Dissolved Oxygen in the San Joaquin River near Columbia Cut, 1999.

6.5 Conclusions

A combination of several important factors contributes to low DO levels in the San Joaquin River near Stockton. Calibration of DO requires an extensive database of field measurements. However, for lack of such a database, a number of approximations and assumptions had to be made. Ideally, a calibration period of 1 to 3 years would be more appropriate. However, blocks of data were missing over different periods of time. Thus, the three-month period of August through October 1998, with mostly continuous data, was chosen. Also, because hourly time series data were available only at the Rough and Ready Island in the region of interest, calibration was primarily based on comparisons in that location. DO and water temperatures were within the range of grab sample values at nearby stations with data during the period. Considering these data limitations, the current calibration and validation results are encouraging.

6.6 References

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