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

**26th Annual Progress Report**
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# Chapter 4:
# Sensitivity of DSM2 Temperature Simulations to Time Step Size

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# 4 Sensitivity of DSM2 Temperature Simulations to Time Step Size

## 4.1 Introduction

Computational time steps are important considerations when conducting historical or planning simulations.  Increasing the time step reduces the amount of time needed to run the simulation, but it also reduces the ability to accurately represent phenomena with diurnal variation.  The goal of the current analysis was to determine the range of time steps in Delta Simulation Model II-QUAL (DSM2-QUAL) that could be used for different types of temperature studies without compromising computational stability and hence the accuracy of the results.

In developing an appropriate numerical scheme for DSM2-QUAL, numerical characteristics of the transport scheme were considered.  Lagrangian box models such as DSM2-QUAL are most accurate when computational time steps are small enough to adequately define the important time variations of flow and concentration.  Advantage was taken of such small time steps by employing a Modified Euler method to update temperature and reactive constituent concentrations.  This method achieves sufficient accuracy when time steps are relatively small (Rajbhandari, 1995).  In the approximation in DSM2-QUAL, the Taylor series is truncated after the second order term, so the time steps should not be large.

## 4.2 Methodology

The time steps tested were 5, 15, 30, and 60 minutes with all the other input variables set to the standard values normally used with DSM2 simulations.  The run length was set to 4 years and 5 months.  As is typically done in all DSM2 simulations conducted by the Department of Water Resources, the hourly averaged flows generated by HYDRO were used as hydrodynamic input to QUAL.

A 15-minute time step was used for all simulations of DSM2-HYDRO.  The study of the sensitivity of simulated temperature to computational time step was based on varying only the QUAL execution time step.  For most studies, QUAL is run on a 15-minute time step, which is the condition under which DSM2 was calibrated for temperature (Rajbhandari, 2001).

Test simulations were conducted using the 4.4-year calibration/validation period of July 1996 through November 2000 (Rajbhandari, 2003), but simulation results are shown for only the 1998–2000 period in this report.  Simulated temperature was generated at hourly averaged values because DSM2 is typically used to produce output in 15-minute, 1-hour, or daily average values.  An hourly output can accommodate output from both the 30-minute and 60-minute time steps.  Also, the field data, even those that are monitored continuously, are usually reported as hourly averaged values.  However, smaller time steps are usually required to minimize the error due to numerical schemes as described earlier.

## 4.3 Simulation Results

In the following analysis, temperature simulated using a 15-minute time step was used as the standard. Figure 4.1 presents simulated temperature for the period of July 1996 through January 2000 near the Rough and Ready Island station in the San Joaquin River. A comparison of simulated temperature using a 15-minute time step to field data was discussed in a previous report describing extension of the DSM2 calibration period (Rajbhandari, 2003) and is presented in Figures 4.2 and 4.3 for reference.

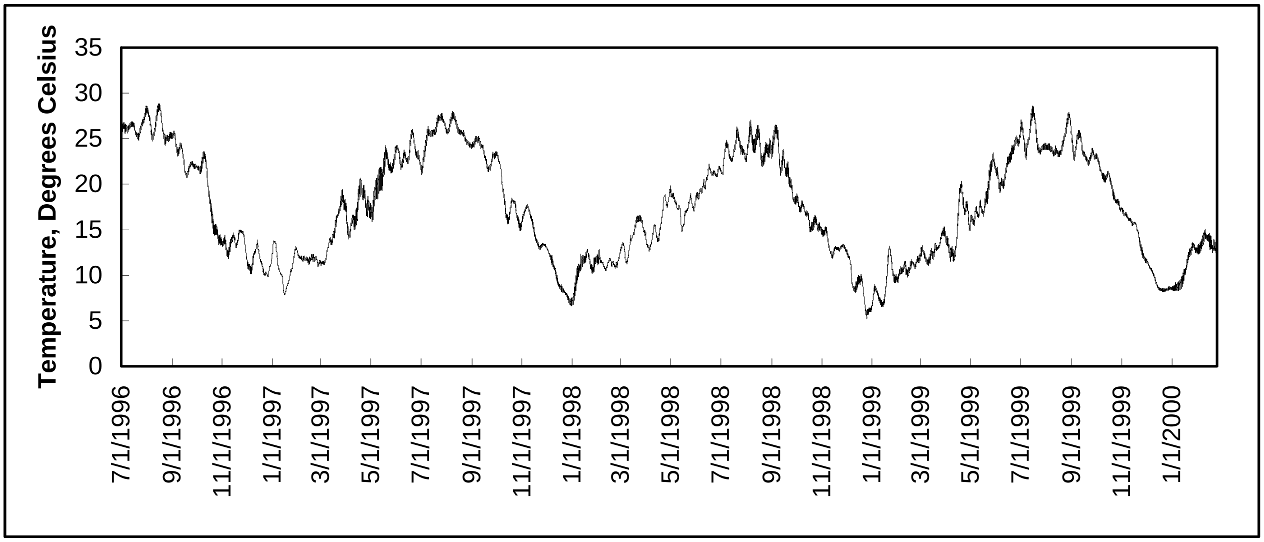


**Figure 4.1: Hourly Averaged DSM2-Simulated Temperature in San Joaquin River at Rough and Ready Island Using a 15-Minute Time Step.**

Hourly averaged temperature based on time-steps of 5, 15, 30, and 60 minutes were compared (Figures 4.1, 4.2, 4.3, 4.6, and 4.7). Because the temperatures were very close, the differences in simulated temperature were also plotted in the figures shown below (Figures 4.4, 4.5, and 4.8).

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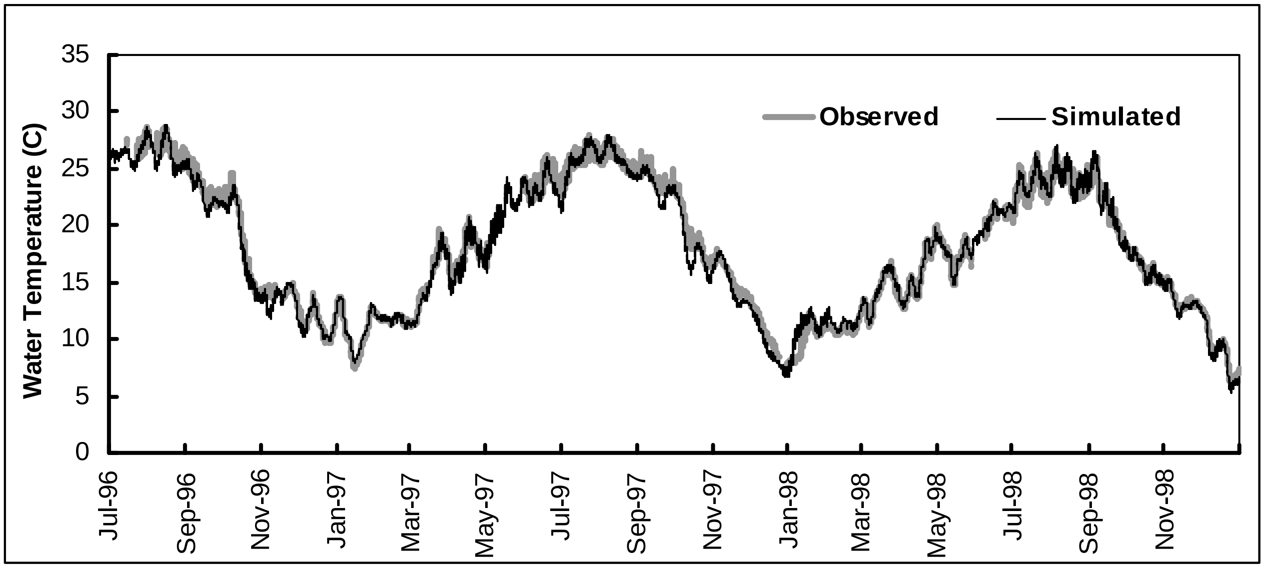


**Figure 4.2: Water Temperature in San Joaquin River at Rough and Ready Island, 1996–1998.**

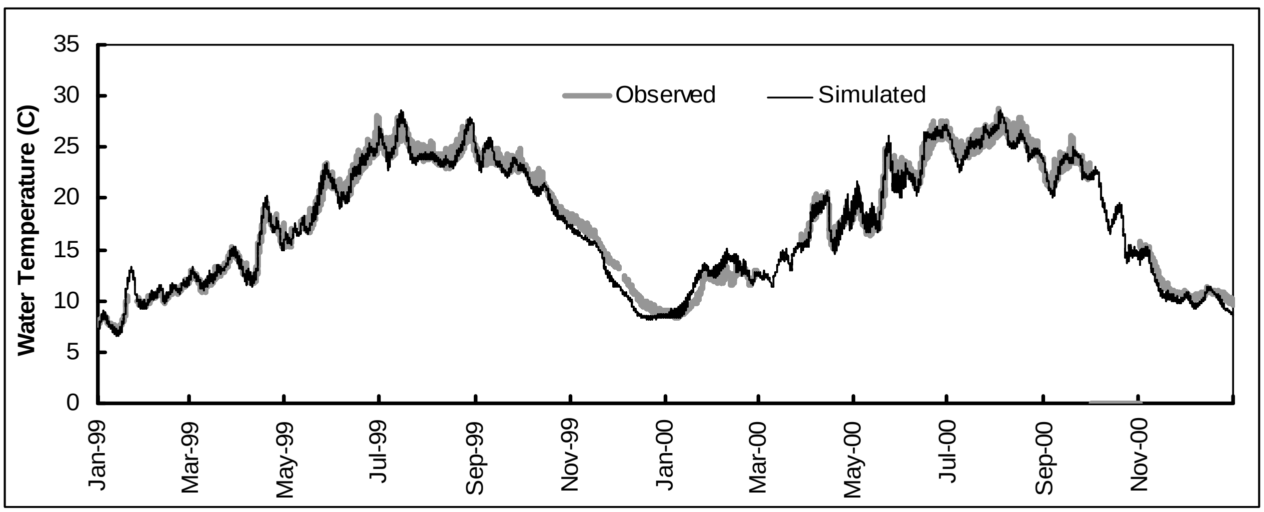


**Figure 4.3: Water Temperature in San Joaquin River at Rough and Ready Island, 1999–2000.**

In general, hourly temperatures are much closer to each other when generated using 15-minute and 5-minute steps than when using 15-minute and larger time steps. The differences between temperatures for the two smaller time steps during the simulation period are relatively small (Figure 4.4), being less than 0.2 degrees Celsius for almost the entire simulation period.  On only 12 occasions in 1998 and 6 instances during 1999 through 2000 were temperature differences greater than 0.5 degrees. Differences were below 1 degree Celsius for the entire simulation period.

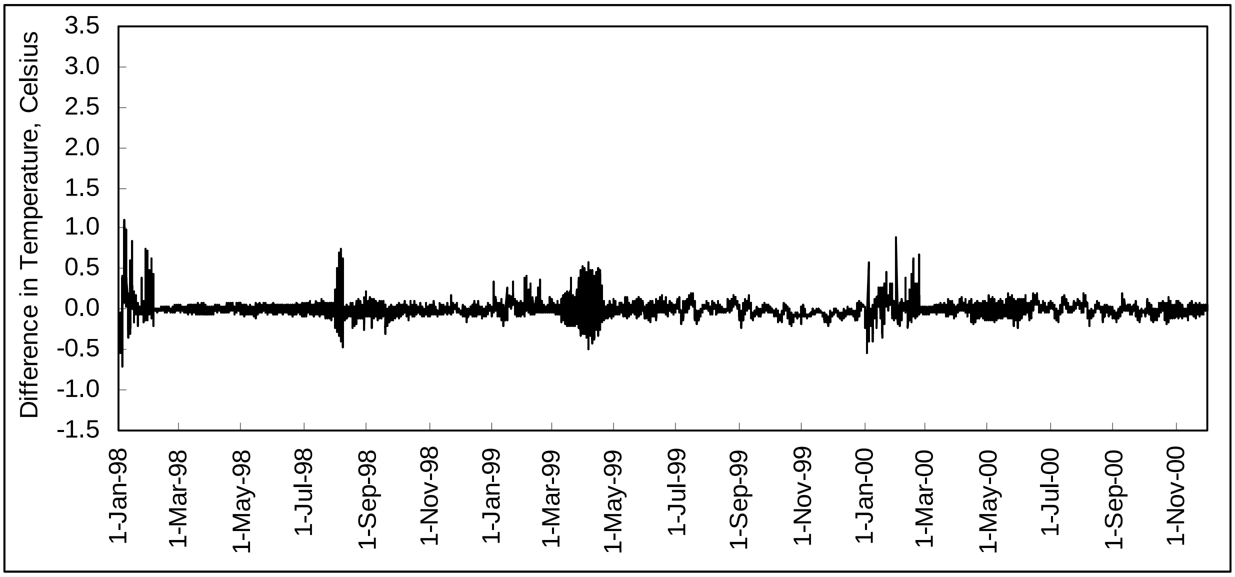


**Figure 4.4: Difference in Simulated Hourly Averaged Temperature in San Joaquin River at Rough and Ready Island Using 5- and 15-Minute Time Steps.**

The differences in simulated hourly temperature based on 15-minute and 30-minute time steps are at times large (Figure 4.5). For most of the simulated period, the differences are within 0.3 degrees Celsius. For 8 instances each in 1998 and 2000 and 3 instances in 1999, the differences were greater than 0.5 degrees Celsius. Larger differences of about 3 degrees are further examined in the detailed hourly plots shown in Figures 4.6 and 4.7.

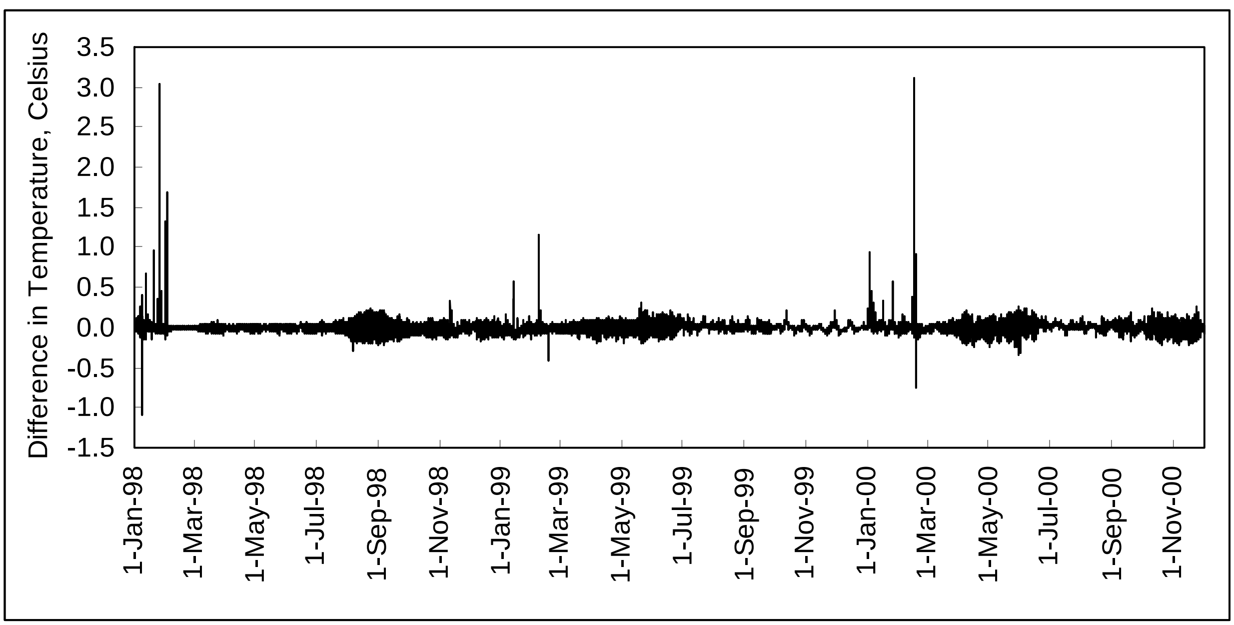


**Figure 4.5: Difference in Simulated Hourly Averaged Temperature in San Joaquin River at Rough and Ready Island using 15- and 30-Minute Time Steps.**

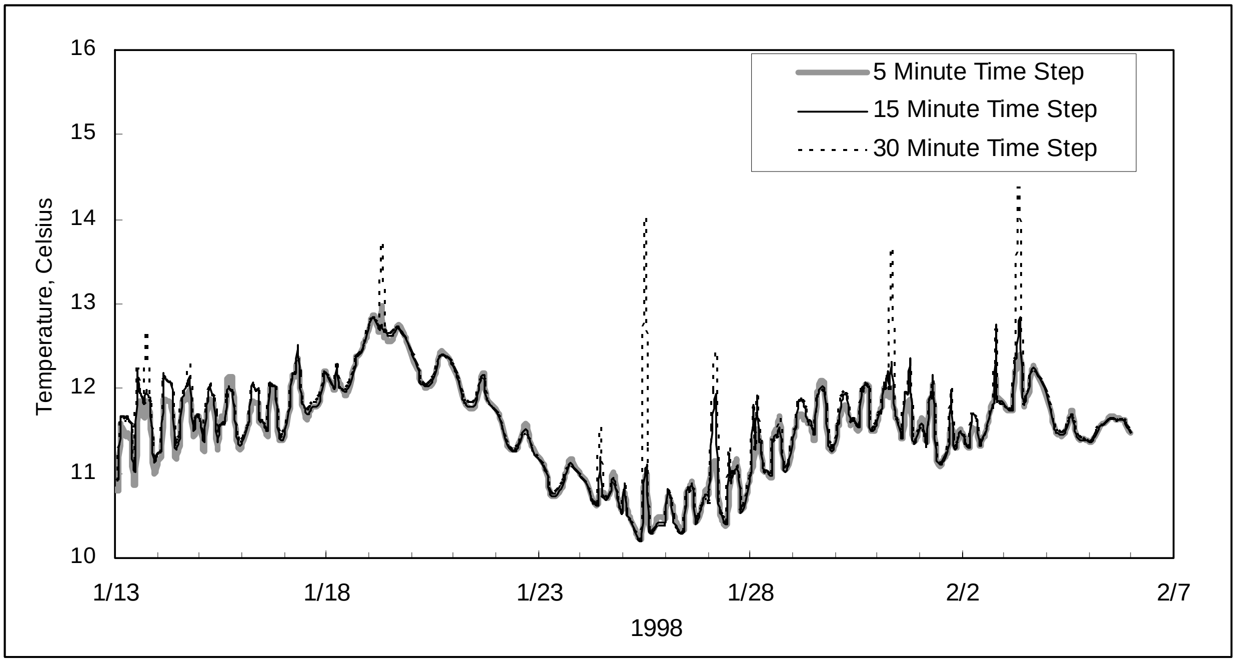


**Figure 4.6: Sensitivity of Simulated Hourly Averaged Temperature in San Joaquin River at Rough and Ready Island Using 5-, 15-, and 30-Minute Time Steps, Jan and Feb 1988.**

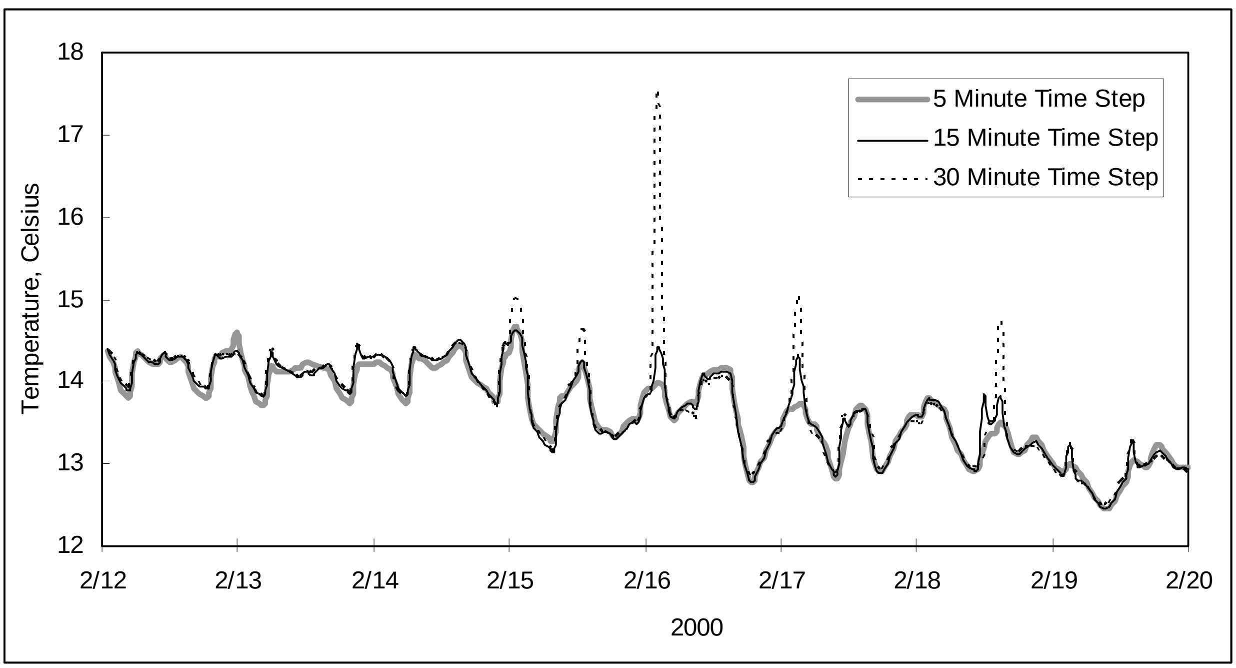


**Figure 4.7: Sensitivity of Simulated Hourly Averaged Temperature in San Joaquin River at Rough and Ready Island Using 5-, 15-, and 30-Minute Time Steps, Feb 2000.**

These plots focus on a few days of the simulation period to highlight the larger differences in temperatures between the 15-minute and 30-minute time steps ranging from 0.7 to 1.7 degrees Celsius on 5 occasions during the period 1998 through 2000. The largest differences of 3 degrees Celsius are noted on 2 occasions: January 25, 1998 and February 16, 2000. When comparing simulated to observed data, it is apparent that the larger temperatures resulting from the 30-minute time steps are not realistic and are likely a result of numerical errors.

Figure 4.8 displays the differences in temperature using the time steps of 15 and 60 minutes. These differences are similar to those described earlier for the comparison of the results of using a 30-minute time step to those when using a 15-minute time step. Because a similar argument holds for this case, the detailed hourly plots as shown in Figures 4.6 and 4.7 are not included for the 60-minute simulation.

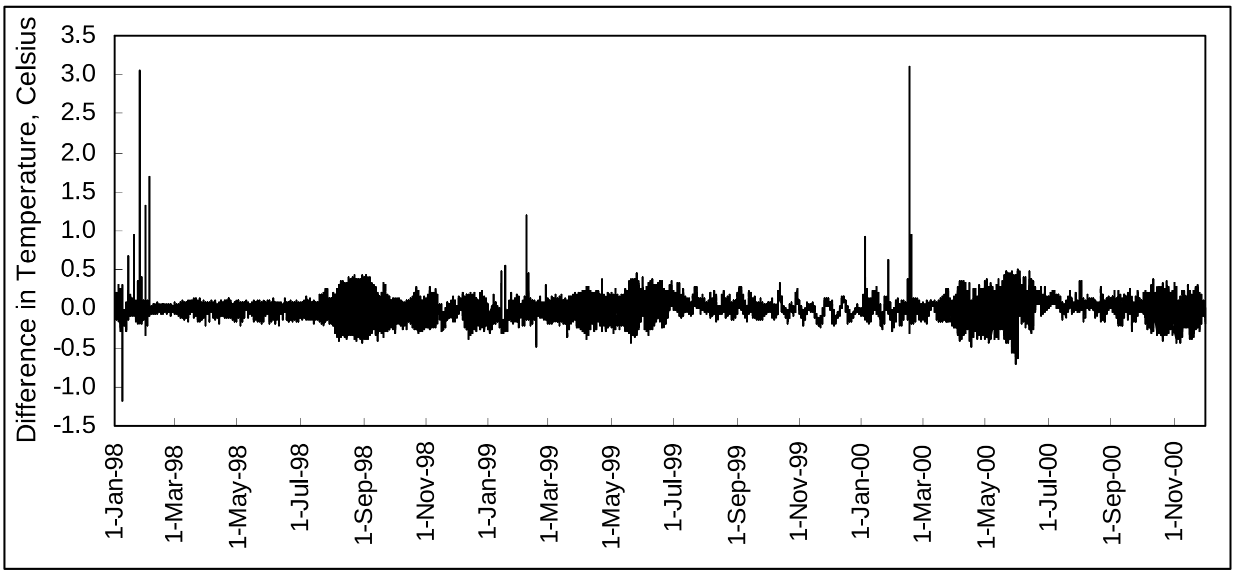


**Figure 4.8: Difference in Simulated Hourly Averaged Temperature in San Joaquin River at Rough and Ready Island Using 15- and 60-Minute Time Steps.**

## 4.4 Daily Averaged Data

DSM2 planning study water quality results are often reported as a daily average because the dispersion factors in DSM2-QUAL have been calibrated to daily average salinity. Thus, it is pertinent to examine the temperature sensitivity to computational time step in terms of daily-averaged temperatures. Figures 4.9 and 4.10 present the daily averaged temperatures from DSM2 using 5-, 15- and 30-minute time steps. As expected, the simulated daily-averaged temperatures using 5- and 30-minute time steps are close to those based on a 15-minute time step. The magnitudes of the differences were less than 0.1 degree Celsius for most of the simulation.

Although the simulated temperatures will typically be more accurate using smaller time-steps than larger time steps, the differences are generally smaller between temperatures using the 30-minute and the 15-minute time steps (Figure 4.9) than between temperatures using the 15-minute and the 5-minute time-steps (Figure 4.10). This apparent counterintuitive result is most likely an artifact of averaging values over an hour.

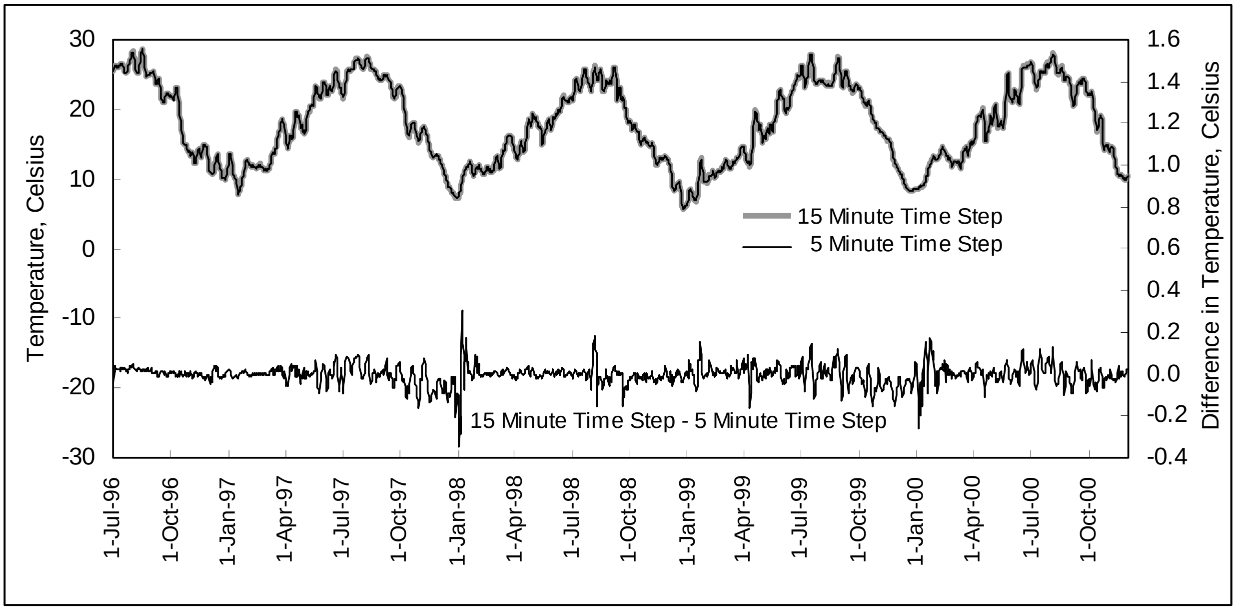


**Figure 4.9: Daily Averaged DSM2 Temperature in San Joaquin River at Rough and Ready Island Using 5- and 15-Minute Time Steps.**

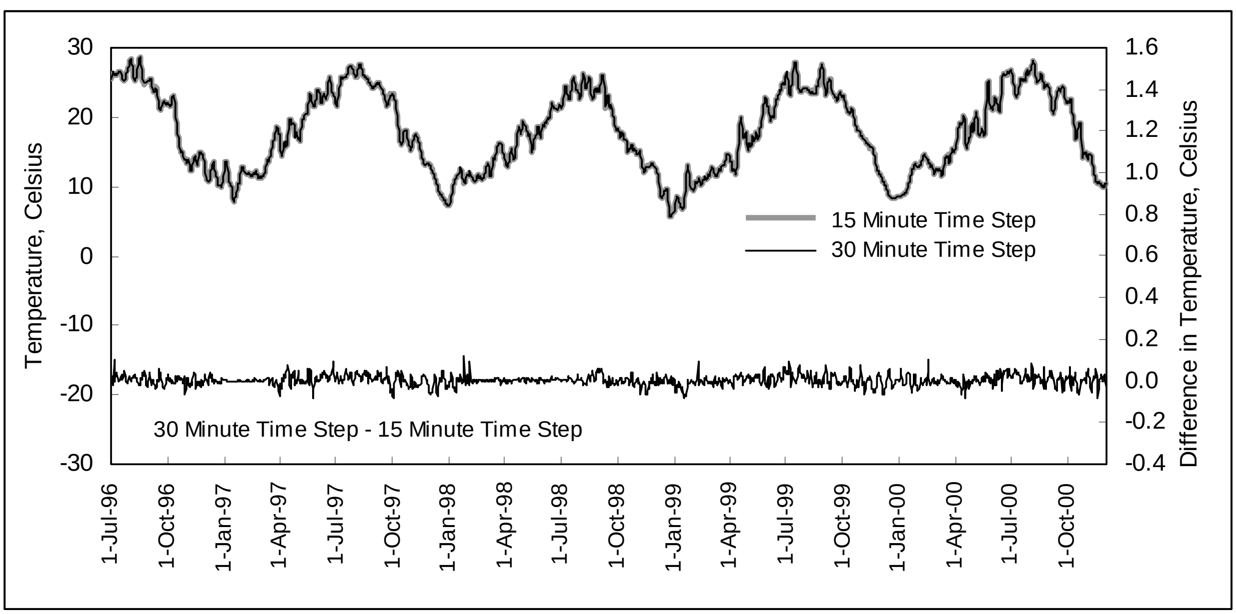


**Figure 4.10: Daily Averaged DSM2 Temperature in San Joaquin River at Rough and Ready Island Using 15- and 30-Minute Time Steps.**

## 4.5 Computer Time

Temperature is normally simulated by DSM2-QUAL in the context of simultaneously simulating 10 other constituents in the process of modeling dissolved oxygen. The computer Central Processing Unit (CPU) time needed to simulate 4.4 years of temperature and the 10 other constituents was studied and is provided in Table 4.1.

**Table 4.1: DSM2-QUAL Run Time vs. Time Step Size for 4.4 years of Simulation of Temperature Plus 10 Other Constituents.**

| Time Step in Minutes | CPU Time on Xeon 3.06 GHz |
|---|---|
| 5 | 7 hours, 6 minutes |
| 15 | 2 hours, 16 minutes |
| 30 | 58 minutes |
| 60 | 24 minutes |

## 4.6 Conclusions

The time steps chosen for the sensitivity analysis of DSM2 temperature simulations were based on the numerical aspects of the model and on practical considerations of computer execution time. While it is tempting to use larger time steps to reduce run time, important considerations of underlying numerical schemes are crucial to consider. The current analysis indicates that the time step size of 15 minutes is most suitable; however, time-step sizes of 30 minutes or 60 minutes may be acceptable for certain studies because unrealistic solutions occurred in only a very few instances. A DSM2 user should check the results for anomalies if these larger time steps are used. It is important to note that this analysis has been conducted for temperature but not for other constituents, and these constituents should also be evaluated. A previous study by Lee and Nader (1997) did focus on time step sensitivity in QUAL to modeled salinity.

The time steps of 30 minutes or 60 minutes may be especially useful for screening runs or simulating a long simulation period, such as a CALSIM-based 73-year period. For example, a shorter run time could certainly be helpful for studies that examine the effect of climate change on the Delta.

## 4.7 References


Lee, S. and P. Nader. (1997). "Chapter 2: DSM2 Model Development." *Methodology for Flow and Salinity Estimates in the Sacramento-San Joaquin Delta and Suisun Marsh. 18th Annual Progress Report to the State Water Resources Control Board.* Sacramento, CA: California Department of Water Resources.

Rajbhandari, H.L. (1995). *Dynamic Simulation of Water Quality in Surface Water Systems Utilizing a Lagrangian Reference Frame.* Ph.D. Dissertation. University of California, Davis.

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Rajbhandari, H.L. (2003). "Chapter 3: Extending DSM2-QUAL Calibration of Dissolved Oxygen." *Methodology for Flow and Salinity Estimates in the Sacramento-San Joaquin Delta and Suisun Marsh. 24th Annual Progress Report to the State Water Resources Control Board.* Sacramento, CA: California Department of Water Resources.