Appendix C – Addressing DO Criteria in the Anacostia Watershed

The TAM/WASP model was calibrated to the daily average DO concentrations (mg/l) in the Anacostia River. MD's and DC's water quality standards specify seasonal DO criteria for (1) instantaneous DO concentrations, (2) seven-day average DO concentrations, and (3) 30-day average concentrations, as shown in Table 21 of the main report. Table C.1 succinctly summarizes the relevant DO standards.

Table C.1. Summary of DO Water Quality Standards (mg/l) in the Anacostia River

Criteria	**February – May**	**June – January**
Instantaneous	>= 5.0	>= 3.2
7-Day Average	>= 6.0	>= 4.0
30-DayAverage	>= 5.5	>= 5.5

To compare simulated DO concentrations with the DO criteria, three time series for each model segment were calculated from the TAM/WASP time series of daily average DO concentrations: (1) daily minimum DO concentration, (2) seven-day DO average concentration, and (3) 30-day average DO concentration. The latter two time series are simply the seven-day and 30-day moving averages of the daily time series.

<u>Options for Estimating Daily Minimum Dissolved Oxygen</u>

The daily average TAM/WASP model DO predictions are not directly amenable to comparison with the instantaneous daily minimum criteria, such that model predictions needed to be adjusted to represent daily minima. Two alternative approaches were considered for performing this correction: 1) Use of the daily minimum estimated within the TAM/WASP model, and 2) Use of observed diurnal dissolved oxygen data from continuous monitors historically operating in the Anacostia.

The TAM/WASP model currently being used on the Anacostia contains computer code to allow the daily minimum dissolved oxygen to be estimated from predictions of daily average dissolved oxygen and algal productivity. This feature is not described in the model documentation. The TAM/WASP computer code was reviewed and the calculation of daily DO minima was found to be based on a simplification of the delta method (Chapra and DiToro 1991) for relating diurnal oxygen variation to plant productivity and reaeration. Application of the equation that encompasses the delta method to the Anacostia violates some of the fundamental assumptions upon which the theory is based, i.e.:

- Plant productivity is constant over long distances
- The dissolved oxygen deficit does not vary spatially
- The reaeration rate remains constant over the course of the day at a value less than 1/day

The second approach is empirical. It consists of using observed continuous dissolved oxygen data to define the difference between daily average and daily minimum dissolved oxygen. This difference can then be subtracted from the TAM/WASP-predicted daily average dissolved oxygen to obtain an estimate of the daily minimum dissolved oxygen. There are two advantages to using the empirical approach to estimate minimum dissolved oxygen. First, it is potentially more accurate than the WASP-based approach. The empirical approach uses site-specific data to define diurnal variability in dissolved oxygen, and is not subject to the theoretical assumptions required by the WASP-based approach. Second, there is strong precedent for its use other TMDLs. Fourteen other EPA-approved TMDLs were identified that have successfully used this approach. The empirical approach does have the potential limitation in that the historical continuous monitoring data only reflects the diurnal that occurred in response to historical productivity. Future plant productivity is expected to change in the Anacostia in response to the TMDL, meaning that the historically observed diurnals are not directly applicable to future conditions. However, future diurnal changes can be reasonably approximated from historical data by scaling the observed diurnal relative to the predicted change in chlorophyll *a*.

Evaluation of Options for Estimating Daily Minimum Dissolved Oxygen

The approach taken for determining which option to use for estimating minimum dissolved oxygen consisted of comparing results from the TAM/WASP approach to historically observed diurnals to determine if the TAM/WASP predictions of the difference between daily average and minimum DO were reasonably accurate. Should the WASP approach be found to poorly describe historically observed diurnals, the observed diurnal data should be used to define daily minima.

The time series of simulated daily minimum DO concentrations were calculated from the simulated daily average concentrations using data from the continuous monitoring program described in Section 2.3.1 of the main report. Observations from the continuous monitors deployed by DDOE and MWCOG were used to calculate the median value of the difference between the daily average and daily minimum DO concentrations. A total of 4134 days of hourly data were available. These data came from DDOE monitoring stations ANA01, ANA13, and ANA21 for the period 1998-2002, and MCOG monitoring stations P04, P07, and P09 for the period 1996-2002. The data were pooled and then statistically analyzed by season.

The observed median difference from all Anacostia stations February through May was 0.81 mg/l, while the observed median June through January was 1.28 mg/l under current conditions (Hinz 2007). In contrast, the TAM/WASP-predicted minimum dissolved oxygen was generally only 0.1 mg/l less than the predicted daily average, and was not an accurate representation of the diurnals that were occurring. For this reason, the empirical approach was selected for converting daily average model prediction into daily minima.

The use of a median diurnal was deemed appropriately protective because:

- The continuous DO data used to calculate the observed diurnal were measured near the surface, and may overstate the true depth-averaged diurnal.

- The continuous data contained some erratic measurements, such that occasional large differences existed between observed daily maxima and minima that did not represent true diurnal variability. The use of a median provides a means to filter out these erratic data.

- All of the existing approved TMDLs using the empirical approach with multiple days of data to estimate daily minimum DO from a daily average model used a central tendency of the observed data when adjusting model output (IEPA 2007; MDE 2001; MDEP 2000).

Correction of Diurnals to Reflect Reduced Future Productivity

The primary cause of diurnal DO fluctuations is due to algal photosynthesis. The difference between daily average DO and daily minimum DO is expected to decrease in proportion to the decrease in algal productivity, so it was assumed in the TMDL scenario that the diurnal DO fluctuation would be reduced in proportion to the 50% decrease in average chlorophyll *a* concentrations (or phytoplankton biomass) between the Baseline and TMDL scenarios. On this basis, the simulated daily DO minimum was calculated to be 0.46 mg/l below the daily average, February through May, and 0.64 mg/l below the average, June through January.

Results

The simulated daily minimum DO concentration time series, the seven-day average time series, and the 30-day average time series were compared to the relevant standard each day in each segment; the TMDL Scenario represents a simulation in which all three standards are met each day in each segment without exceptions. Figures C.1 through C.3 compare the simulated DO minimum, seven-day average, and 30-day average time series with their corresponding criteria for Segment 1, where major monitoring station ANA0082 is located. Figures C.4 –C.6, C.7-C. 9, C.10-C.12, and C.13-C.15 show the same time series, respectively, for ANA30, ANA01, ANA14, and ANA21. These results demonstrate that the TMDL will maintain compliance with all facets of the dissolved oxygen water quality standard at all times and locations throughout the Anacostia.

References

Chapra, S. C. and D. M. Di Toro. 2001. Delta Method for Estimating Primary Production, Respiration, and Reaeration in Streams. Journal of Environmental Engineering, Vol. 117, No. 5, pp. 640-655

Hinz, S. 2007. Personal communication with Scott Hinz, LimnoTech, Inc.

Illinois Environmental Protection Agency. 2007. Sangamon River/Lake Decatur Watershed Final TMDL. Illinois Environmental Protection Agency.

MDE. 2001. Total Maximum Daily Loads of Carbonaceous Biochemical Oxygen Demand (CBOD) and Nitrogenous Biochemical Oxygen Demand (NBOD) for the Little Youghiogheny River. Maryland Department of the Environment. http://www.mde.state.md.us/assets/document/tmdl/yough/yough_main_fin.pdf

MDEP. 2000. Penobscot River Modeling Report. Maine Department of Environmental Protection.
http://www.maine.gov/dep/blwq/docmonitoring/penob2000.pdf
http://www.maine.gov/dep/blwq/docmonitoring/penobfig2.pdf

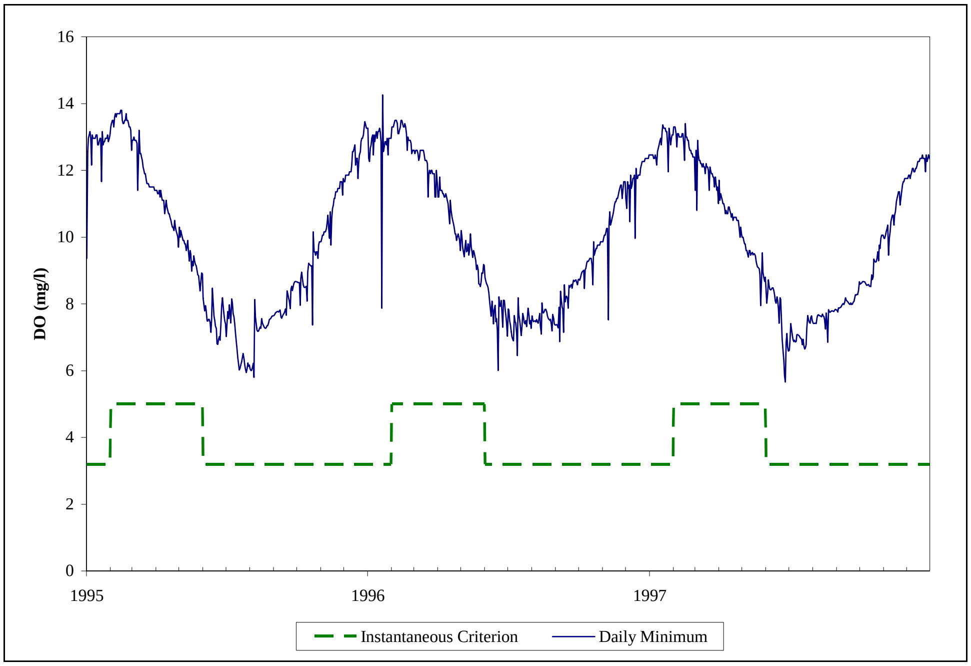

Figure C.1 Simulated Daily Minimum DO (mg/l) and Corresponding DO Criteria, TMDL Scenario, ANA0082

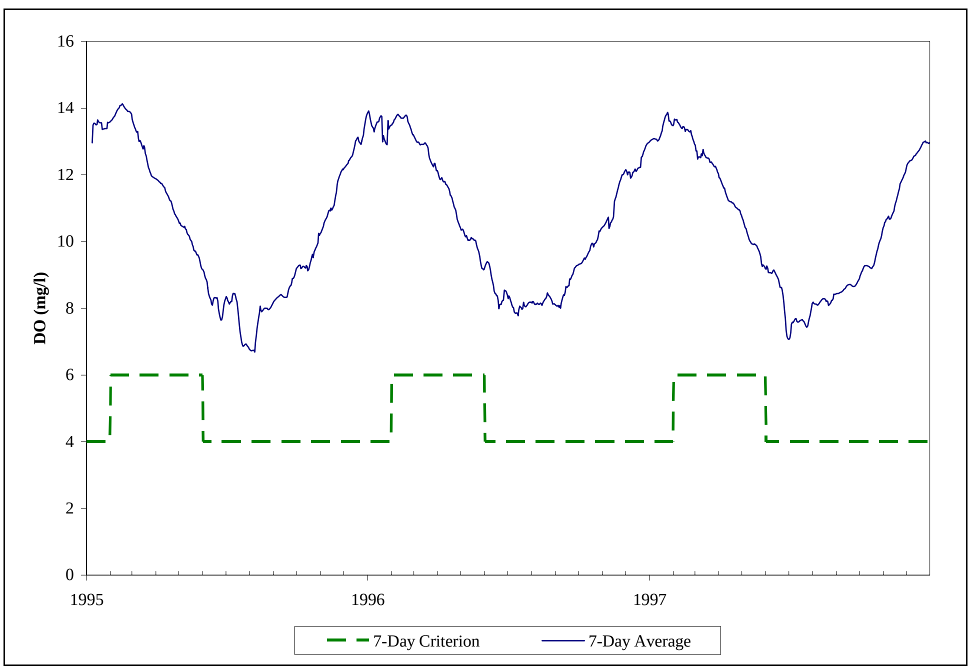

Figure C.2 Simulated Seven-Day Average DO (mg/l) and Corresponding DO Criteria, TMDL Scenario, ANA0082

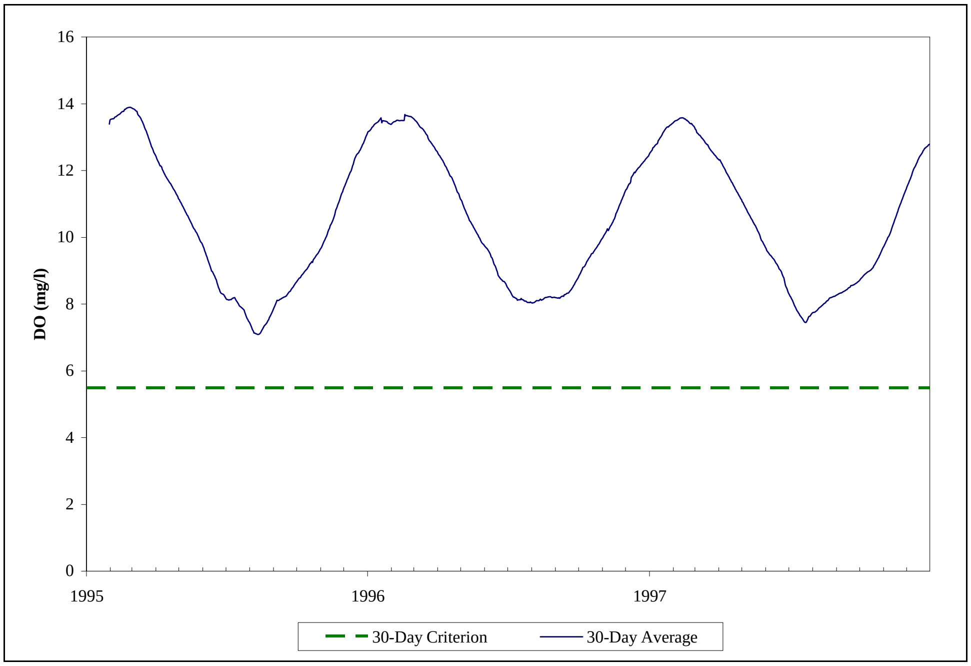

Figure C.3 Simulated 30-Day Average DO (mg/l) and Corresponding DO Criteria, TMDL Scenario, ANA0082

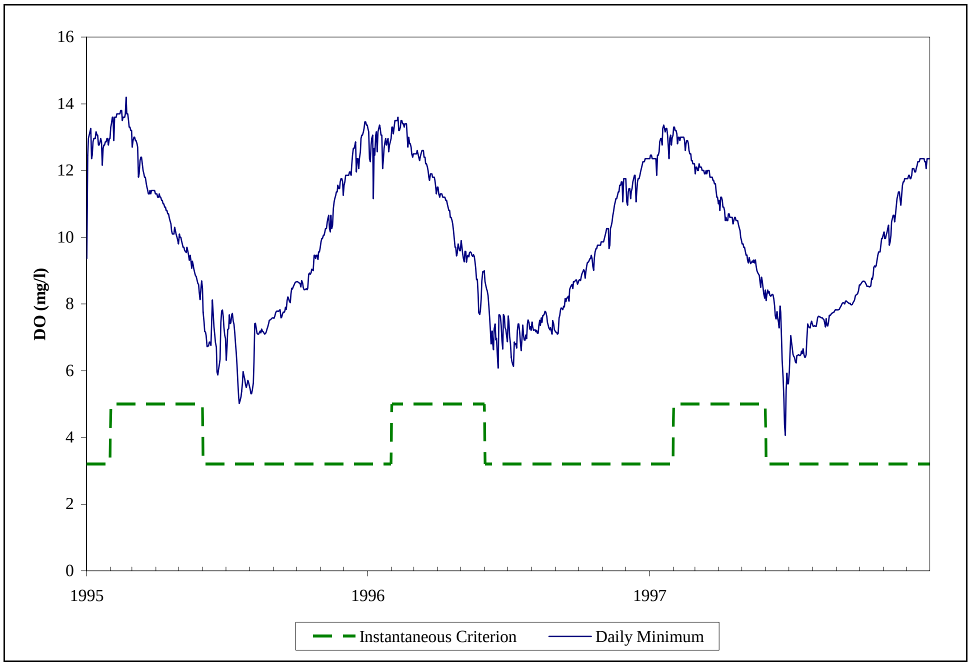

Figure C.4 Simulated Daily Minimum DO (mg/l) and Corresponding DO Criteria, TMDL Scenario, ANA30

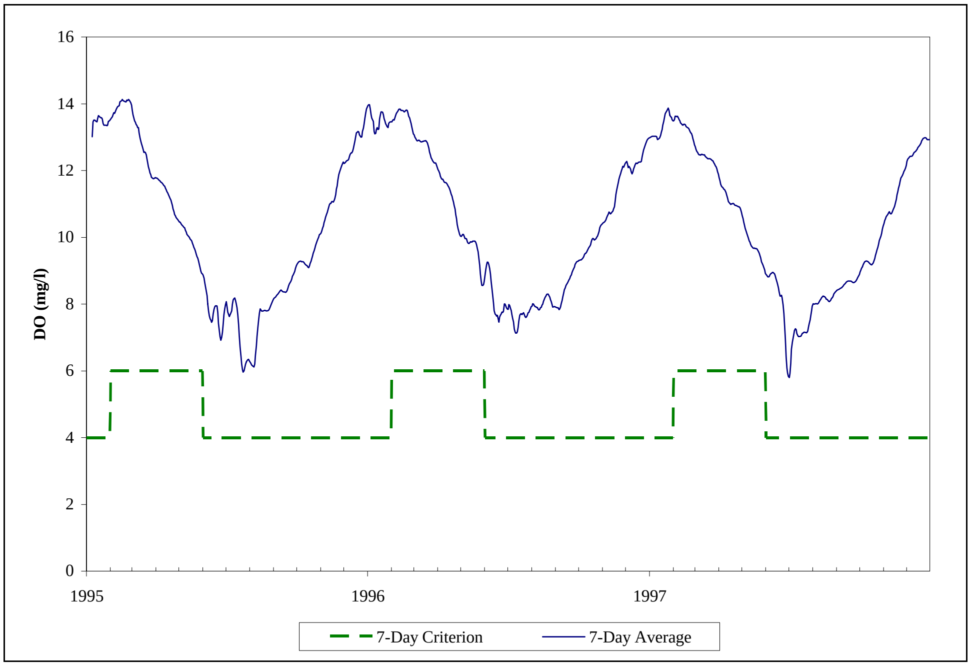

Figure C.5 Simulated Seven-Day Average DO (mg/l) and Corresponding DO Criteria, TMDL Scenario, ANA30

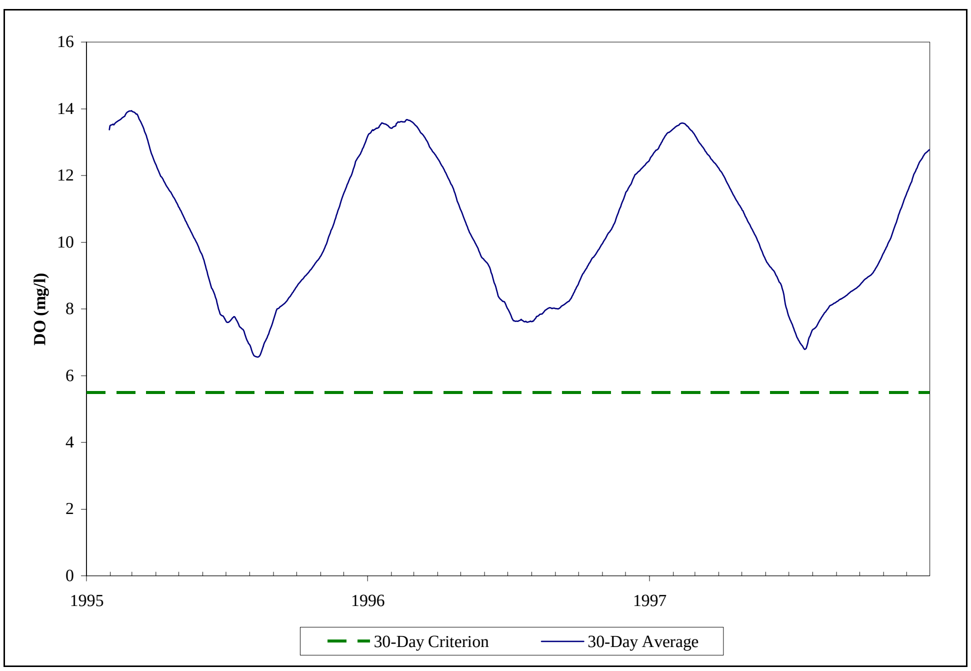

Figure C.6 Simulated 30-Day Average DO (mg/l) and Corresponding DO Criteria, TMDL Scenario, ANA30

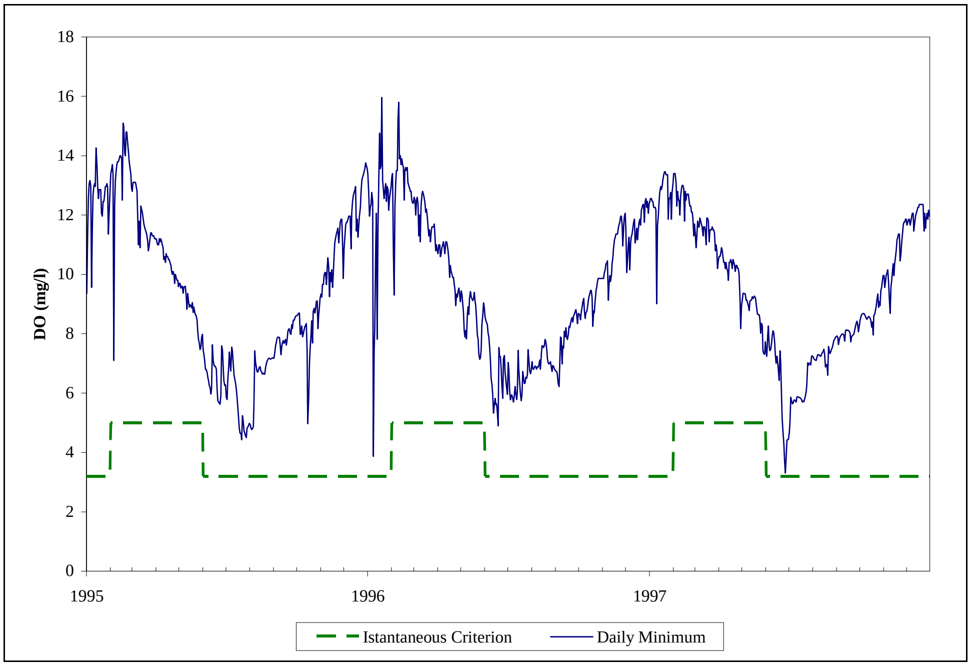

Figure C.7 Simulated Daily Minimum DO (mg/l) and Corresponding DO Criteria, TMDL Scenario, ANA01

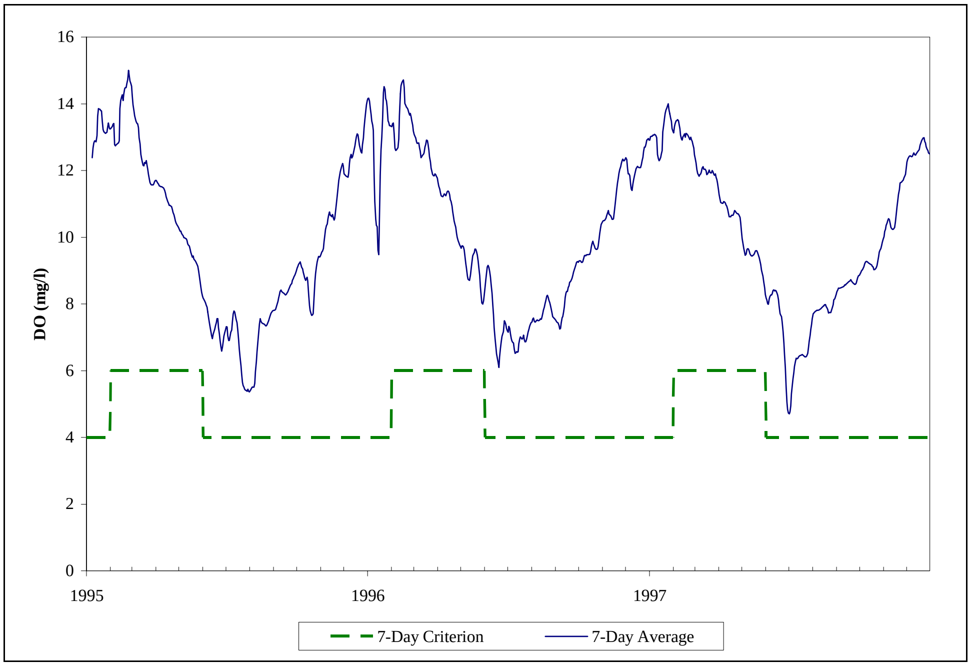

Figure C.8 Simulated Seven-Day Average DO (mg/l) and Corresponding DO Criteria, TMDL Scenario, ANA01

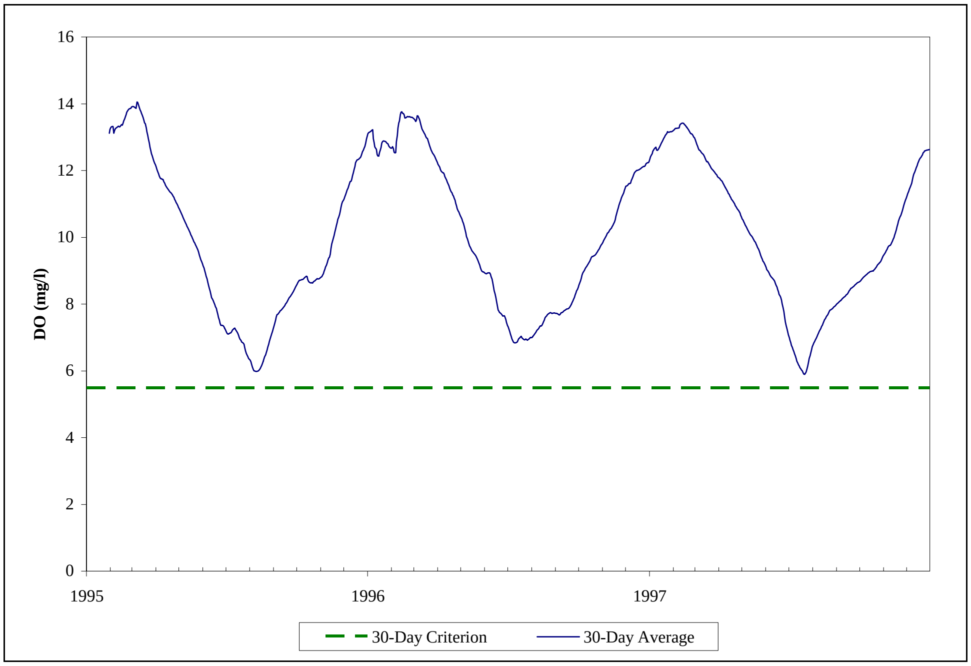

Figure C.9 Simulated 30-Day Average DO (mg/l) and Corresponding DO Criteria, TMDL Scenario, ANA01

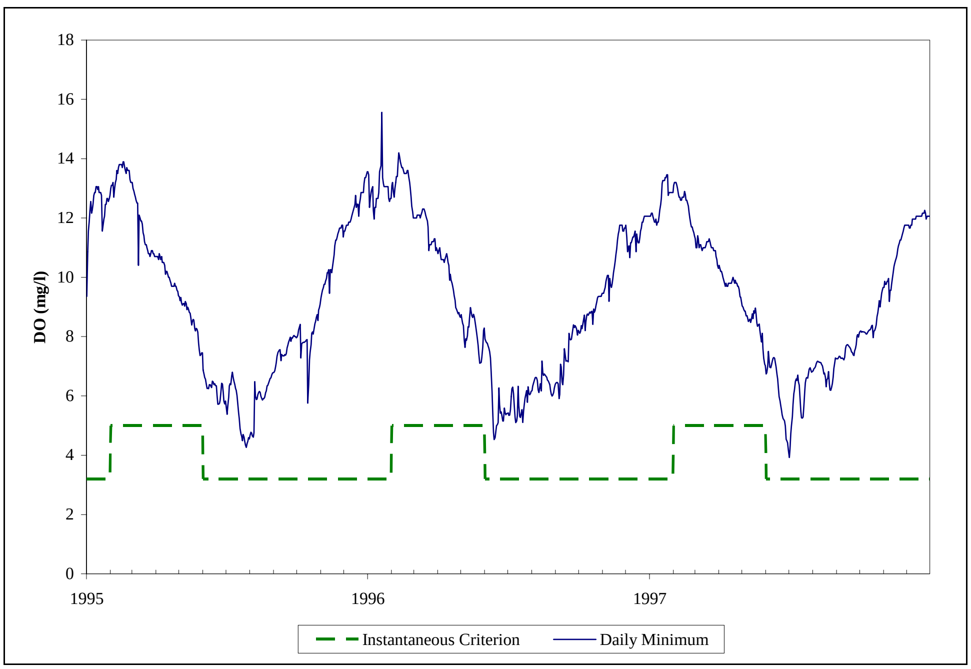

Figure C.10 Simulated Daily Minimum DO (mg/l) and Corresponding DO Criteria, TMDL Scenario, ANA14

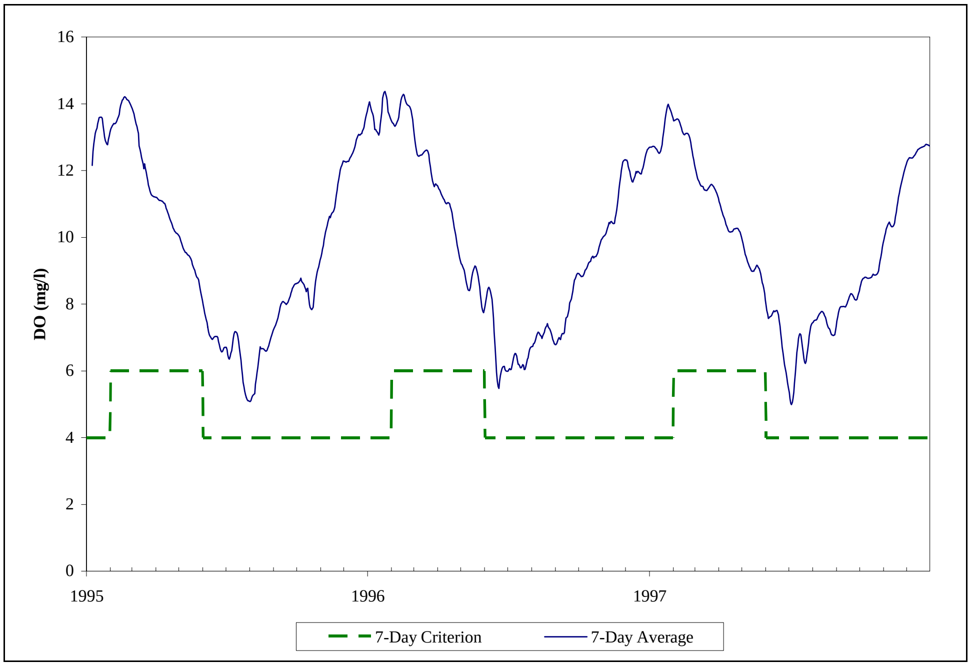

Figure C.11 Simulated Seven-Day Average DO (mg/l) and Corresponding DO Criteria, TMDL Scenario, ANA14

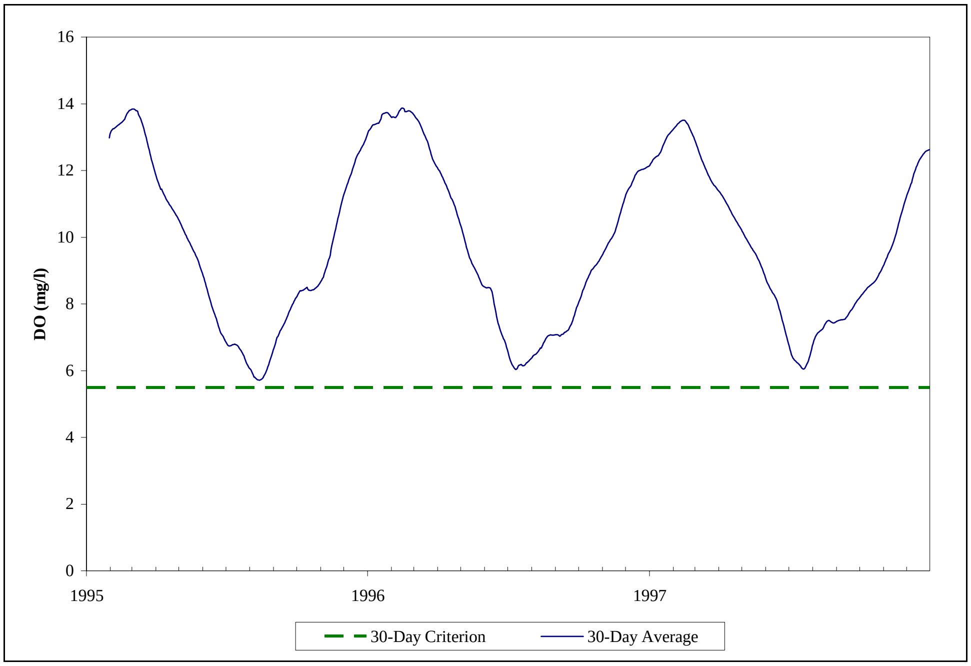

Figure C.12 Simulated 30-Day Average DO (mg/l) and Corresponding DO Criteria, TMDL Scenario, ANA14

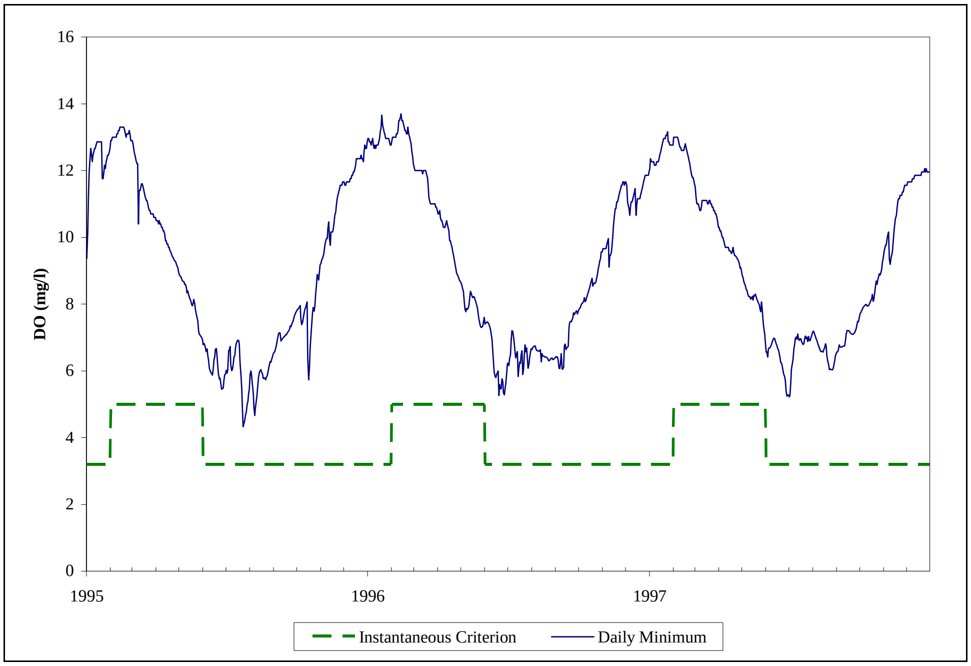

Figure C.13 Simulated Daily Minimum DO (mg/l) and Corresponding DO Criteria, TMDL Scenario, ANA21

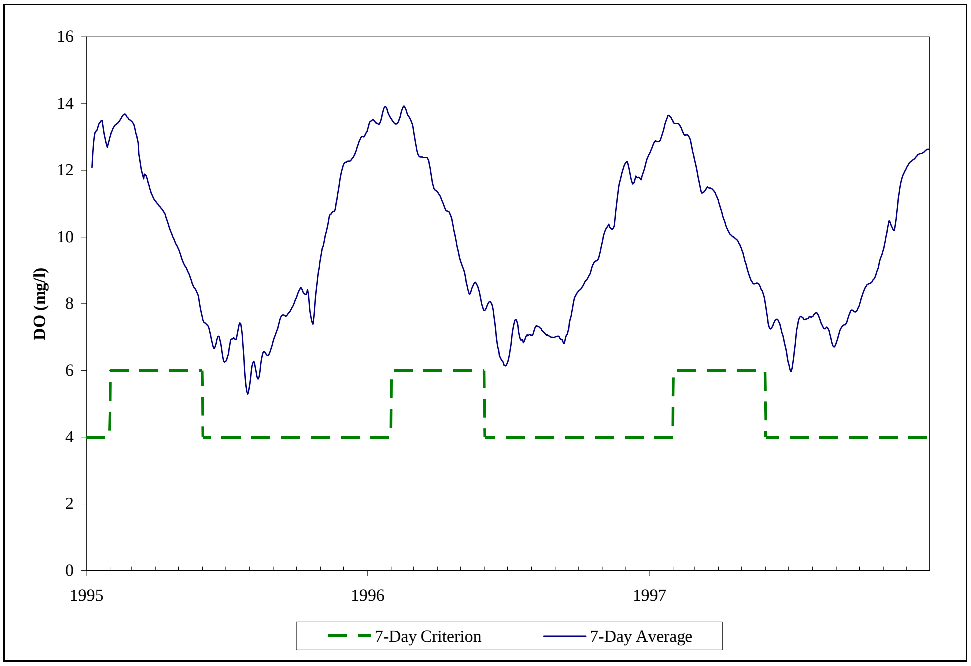

Figure C.14 Simulated Seven-Day Average DO (mg/l) and Corresponding DO Criteria, TMDL Scenario, ANA21

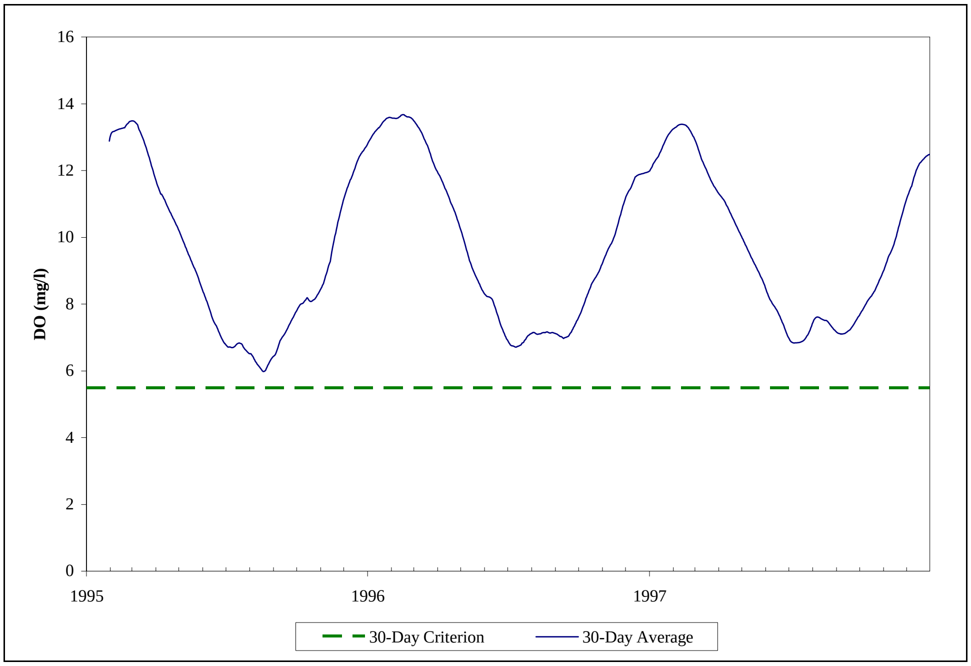

Figure C.15 Simulated 30-Day Average DO (mg/l) and Corresponding DO Criteria, TMDL Scenario, ANA21