

DRAFT Model Inputs and Boundary Conditions for the Base Case Simulation

1 Offshore, River, and Marsh Boundary Concentrations

Several changes have been made to the boundary conditions in the WASP model as a result of preliminary dissolved oxygen (DO) simulations of the summer 1999 conditions. The major changes include the addition of a time series input option for the river and open boundaries and the implementation of a dynamic marsh boundary condition with an optional decay constant for each water quality parameter.

1.1 Offshore Boundary

The WASP model was modified to allow for a time series input of water chemistry constituent concentrations at the offshore boundary. Previously, constant concentrations were specified at the open boundary, with a percent saturation for the DO.

The hydrodynamic and salinity model calibration process showed that the offshore concentration of salinity was an important variable in determining the salinity distribution in the estuary. The model calibration was improved during periods when a dynamic offshore salinity boundary could be provided from measured data. Using a constant offshore salinity based on the average of the measured data resulted in poorer model-to-measured data salinity comparisons in the estuary. Similarly, it is expected that a dynamic offshore boundary for water chemistry constituents will result in better model-to-measured data comparisons in the estuary.

The offshore boundary concentrations will be provided by the output from a DO data mining analysis to be performed by the USGS and Advanced Data Mining (ADM). At present, adequate measured data in the offshore area are not available to provide a dynamic offshore boundary of measured concentration time series. For the DO data mining effort the USGS and ADM will analyze the measured data and develop an ANN model to predict the offshore concentrations. This analysis will provide the necessary dynamic model boundary time series for the offshore boundary.

1.2 River Boundary

Similar to the offshore boundary, the WASP model was modified to allow for a time series input of water chemistry constituent concentrations at the upriver boundary. The river boundary concentrations are provided by upstream river modeling results. The RIV1 model developed by the GAEPD and USEPA was used to simulate the 1999 period (EPA, 2003). This will be used as a time series input to the upriver boundary in the model. The RIV1 model predicted CBOD_u at Clio is shown in Figure 1-1 and compared to the long term CBOD_u data. The time series of ammonia and nitrate compared to data are shown in Figures 1-2 and 1-3, respectively. The model predicted DO and BOD are presented together in Figure 1-4 for comparison. Similarly the ammonia, nitrate and organic nitrogen are presented together in Figure 1-5. For reference purposes the RIV1 predicted temperature at Clio is shown in Figure 1-6.

As will be seen in the loading analysis, the use of the RIV1 output significantly increases the CBOD loading compared to the constant concentrations based on the geometric mean of the 1999 measured data which was used in earlier tests.

1.3 Marsh Boundary

The marsh boundaries have been modified to allow the specification of a decay rate (positive, negative or zero) for each constituent. The baseline run will use an average decay rate, approximated based on the observed change in flood and ebb constituent concentrations at the marsh stations monitored in 1999.

The marsh storage cell and the average concentration in the cell will flow out during ebb tide conditions. Sensitivity analyses will be used to determine the improvement in the model predictions when using a decay rate.

The dissolved oxygen constituent is an exception, which may be specified as a constant concentration or as a percent saturation. The percent saturation will be determined based on the average percent saturation observed in the water ebbing from the marshes at the marsh monitoring stations.

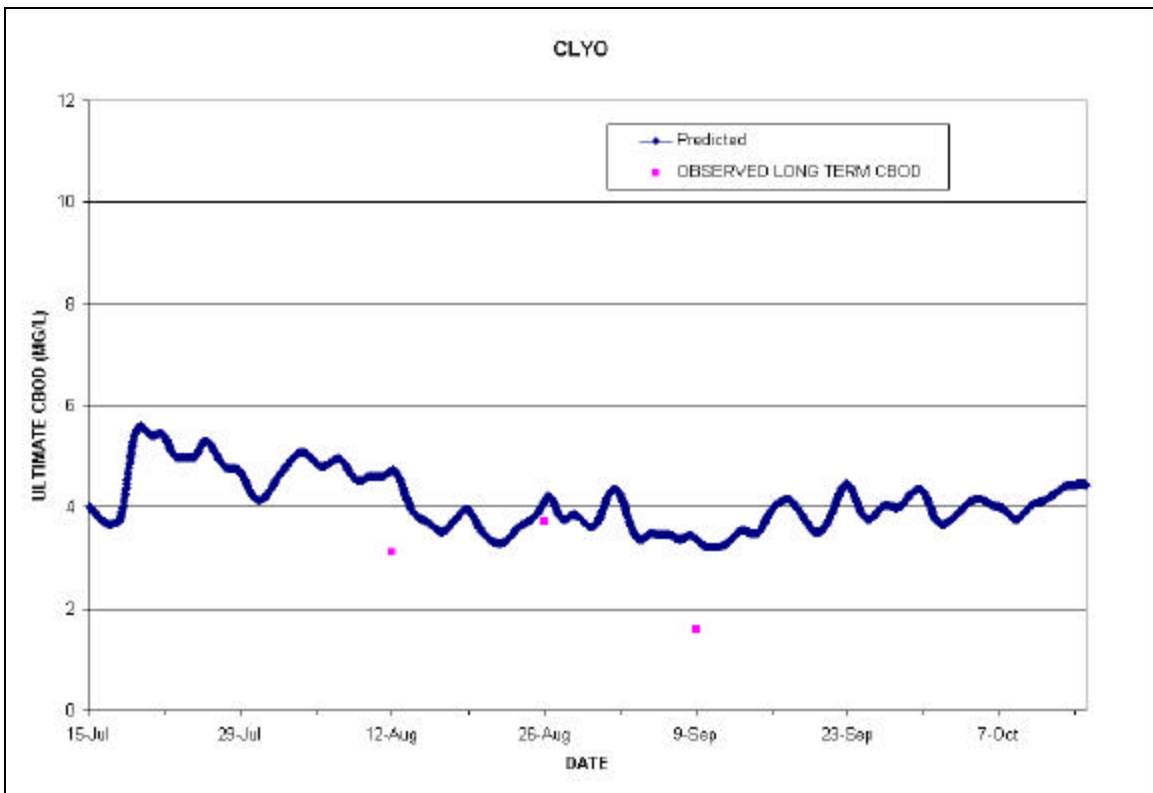


Figure 1-1 CBOD, predicted vs long-term test at Clyo (taken from EPA, 2002).

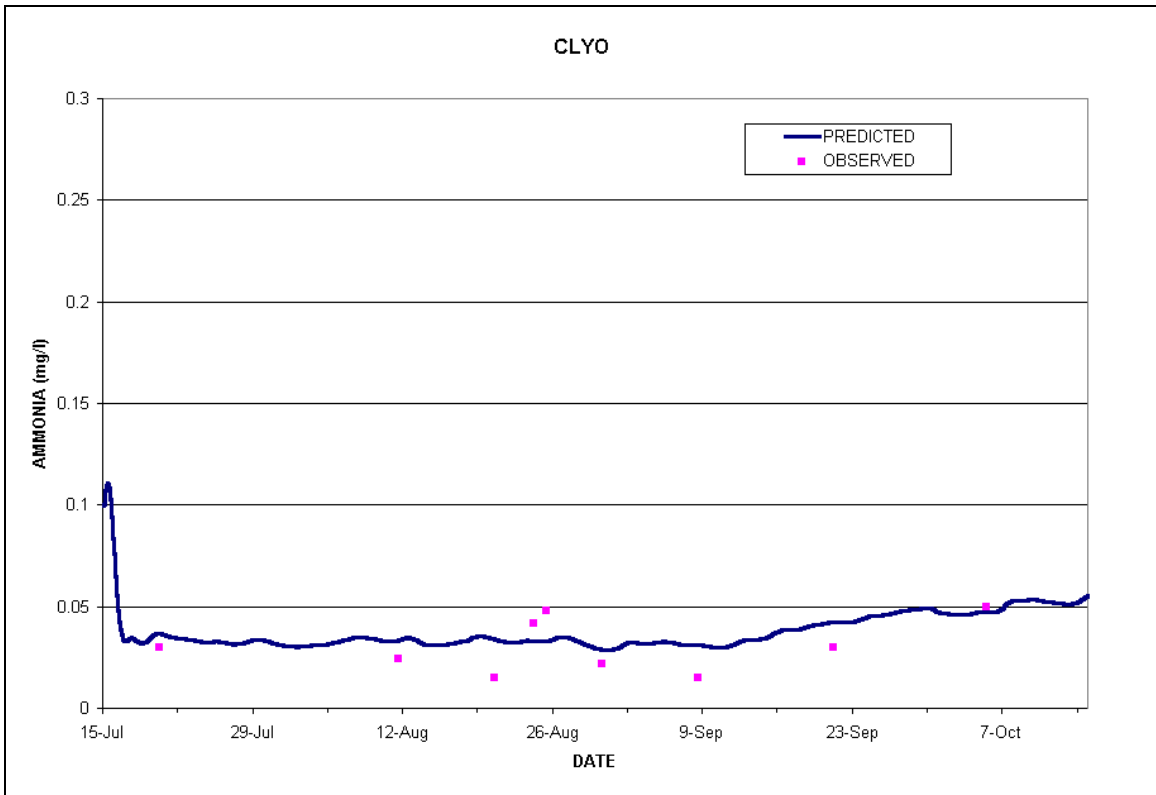


Figure 1-1 Ammonia at Clio (taken from EPA, 2002).

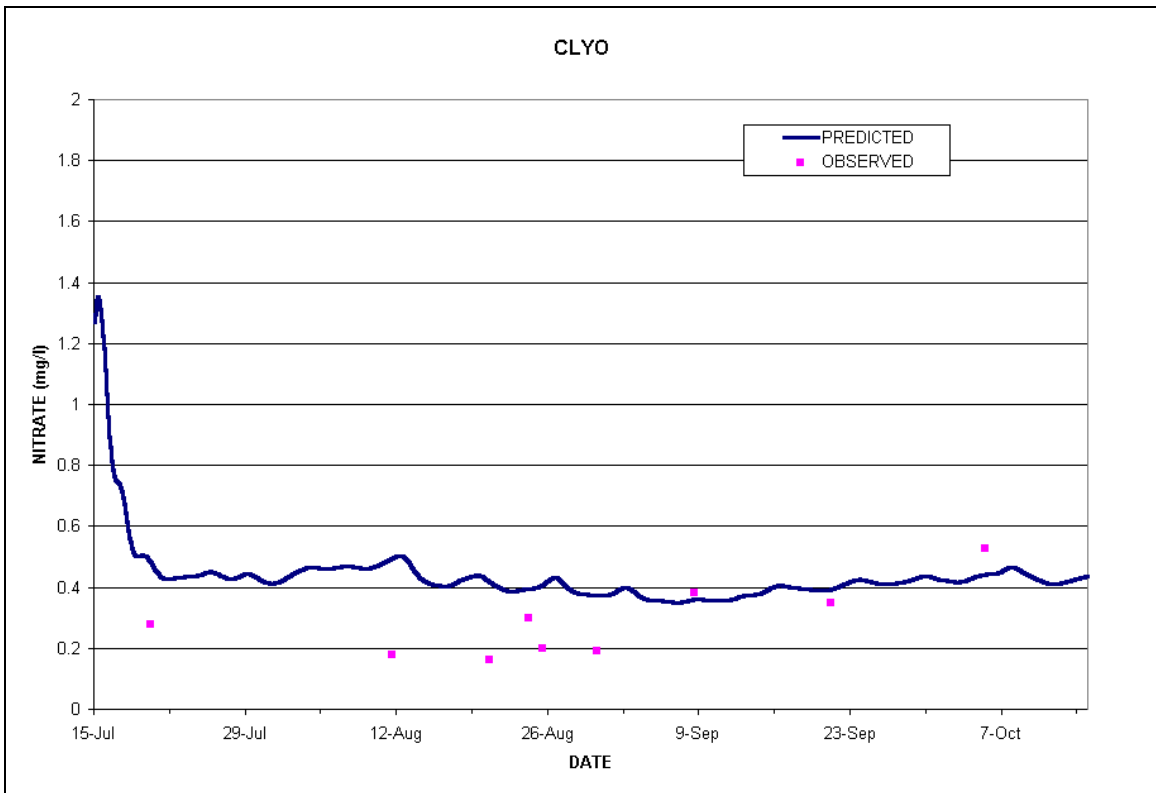


Figure 1-2 Nitrate at Clio (taken from EPA, 2002).

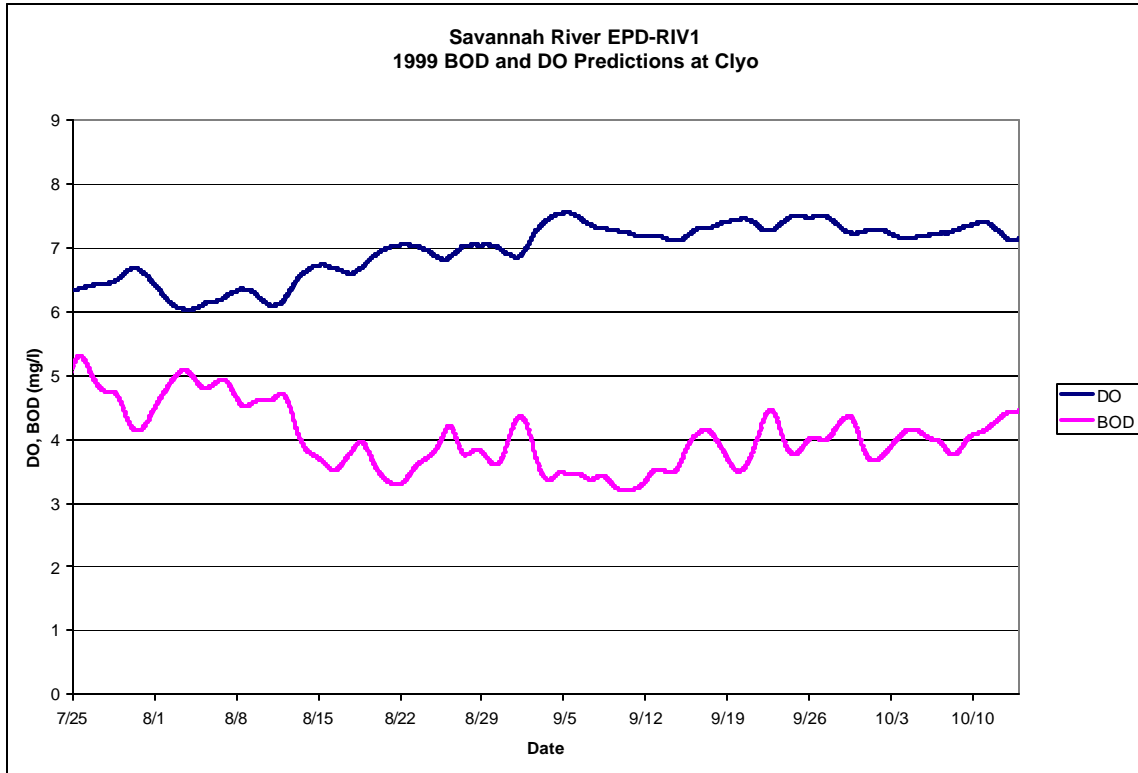


Figure 1-4 Predicted DO and CBODu at Cloyo.

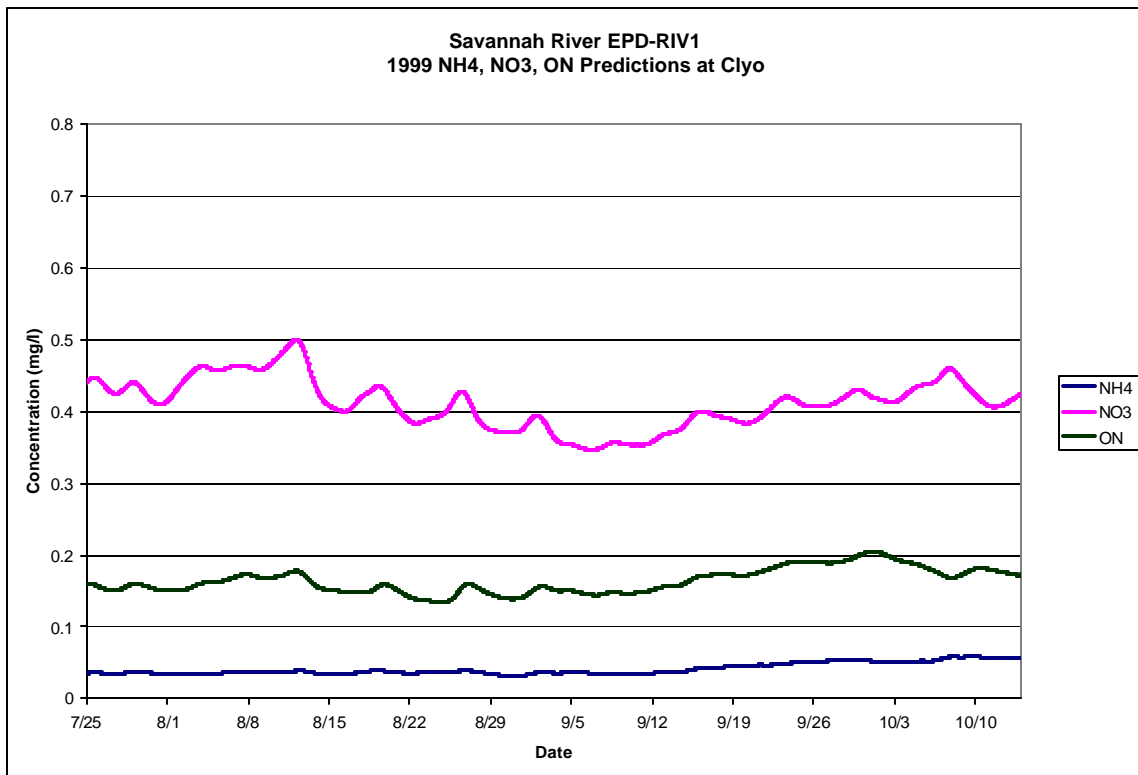


Figure 1-5 Predicted NH4, NO3 and ON at Cloyo.

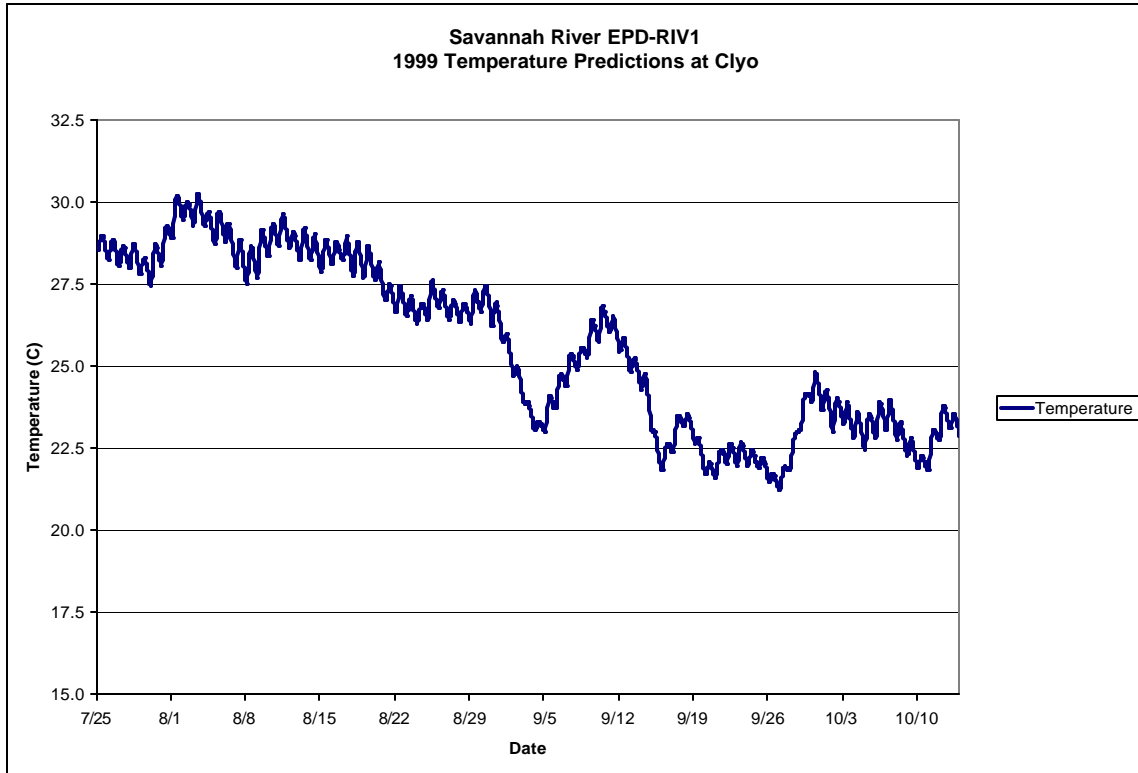


Figure 1-6 Predicted temperature at Clio.

2 Sediment Oxygen Demand and Sediment NH4 Flux

As described in the Data Analysis report, the USEPA monitored SOD rates at four locations in the estuary in 1999. Mean SOD rates varied from 0.86 to 2.58 g-O₂/m²/day. Additionally, there were SOD collected for two previous studies. These data show that there is considerable variation in the SOD rate in Savannah Harbor. The selected distribution of SOD on the model grid is shown in Figure 2-1.

In addition to the offshore dynamic boundary condition described in section 1.1 above the DO data mining effort will seek to evaluate the SOD in the overall DO balance in the estuary. The intent is to develop a better understanding of the SOD distribution in the estuary and to develop a more detailed input data set for the model.

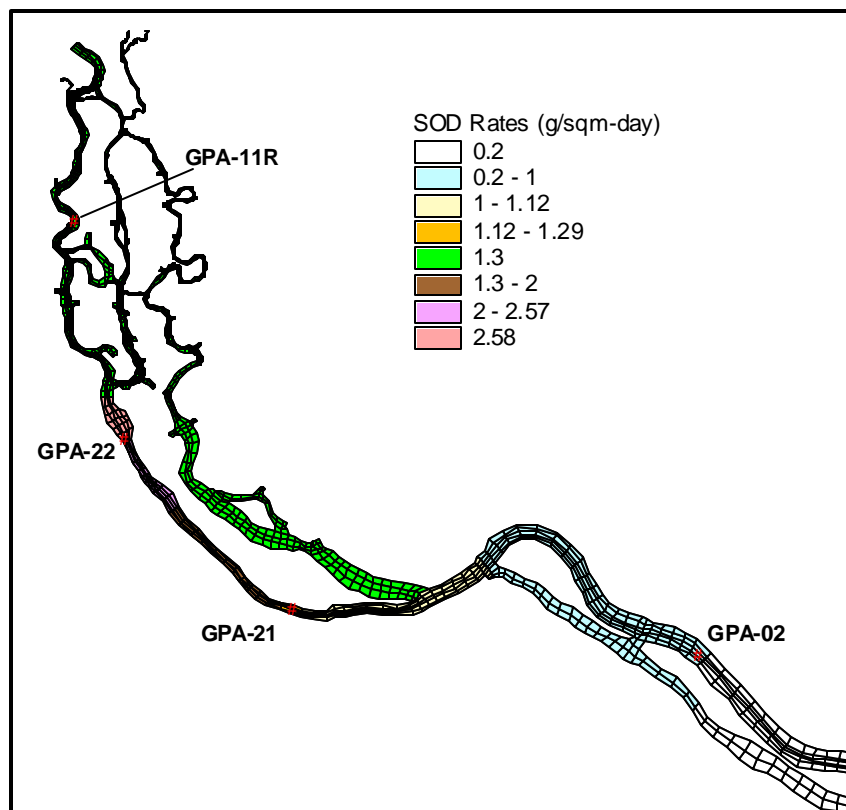


Figure 2-1 SOD Station Locations and Spatial SOD Distribution

In addition to the SOD, an NH₄ load from the sediments will also be used. The loading is calculated using the SOD for each WQMAP grid cell (Figure 2-1) and the sediment excretion relationship of 0.07 grams NH₄-N/gram SOD. This value is in accordance with the Georgia EPD document, Savannah River Classification Study – October 1985, Sediment Oxygen Demand Surveys (Burke, 1987). Base on the SOD range, the range in the NH₄ loading rate is 0.06 – 0.18 grams NH₄-N/m²-day.

3 Point Source Loads for 1999 Simulations

The point source loads were presented in detail in the preliminary DO modeling report (ATM 2002) and will not be presented again, with the exception of one correction, and one addition. An error in the calculation of the Fort James CBOD loading rate was discovered and corrected. The original and revised loading calculations are shown in Figures 3-1 and 3-2 respectively. The calculated CBOD concentrations (dashed line) was multiplied by the flow rate (not shown) to get the loading rate (solid red line) shown on the plots. It can be seen that the recalculated load is significantly greater than the previously presented load. Note the change in the loading scale on the right hand side of Figure 3-2.

The load for the chemical oxygen demand from the Kerr McGee outfall 004 has also been added. The load is calculated from the observed chemical oxygen demand concentration multiplied by the permitted discharge rate. The load will be input to the model as a negative dissolved oxygen load.

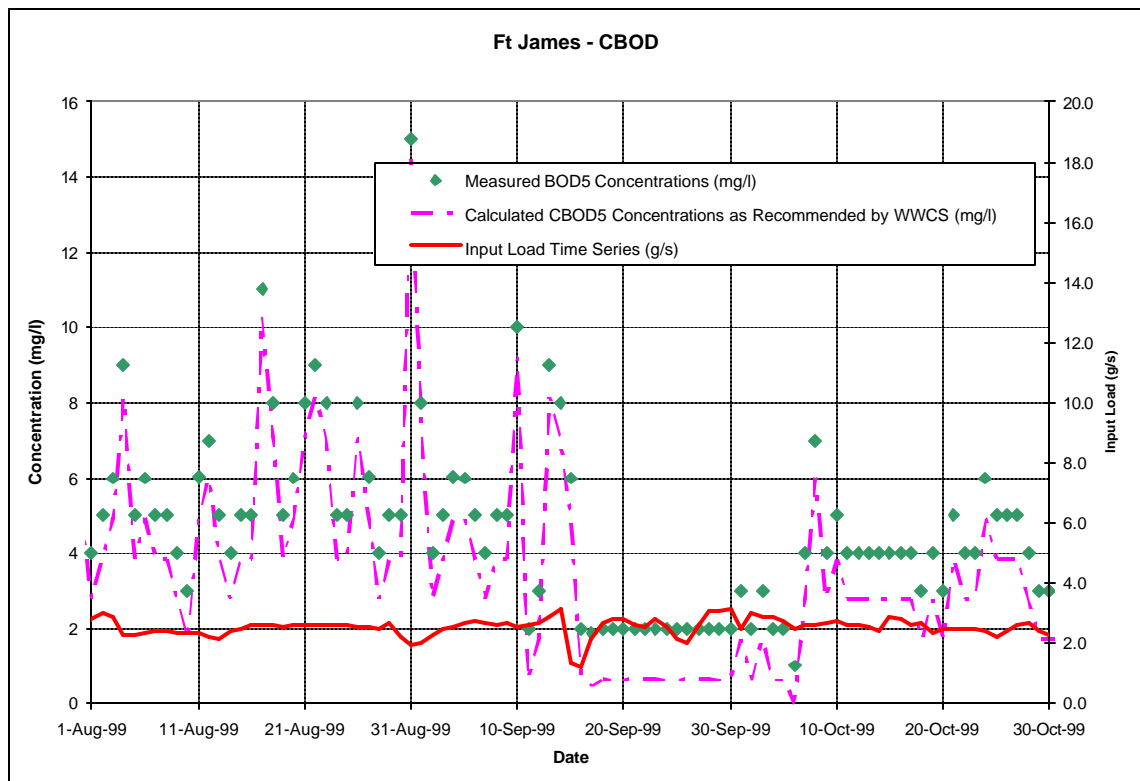


Figure 3-1 – Original Fort James CBOD loading rate Fort James CBOD loading rate.

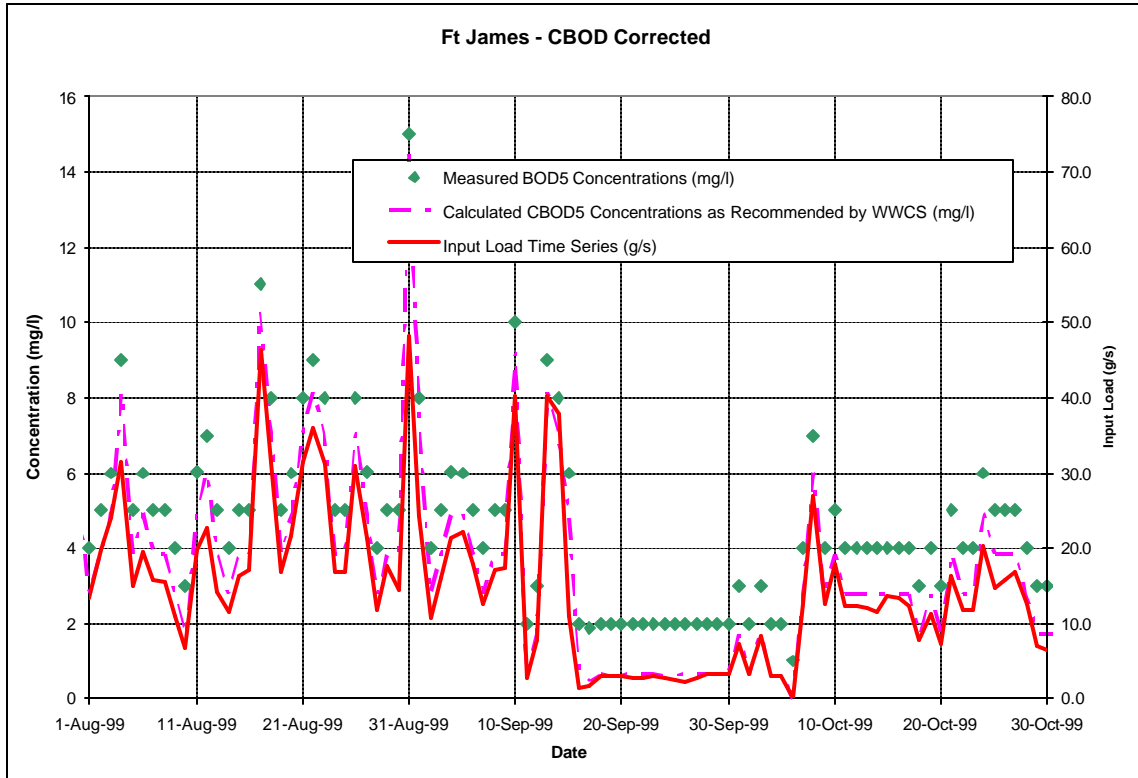


Figure 3-2 – Revised Fort James CBOD loading rate Fort James CBOD loading rate

4 Urban Stormwater

Daily stormwater loading rates for NH₄, TKN, and BOD₅ were provided for 8 Savannah catchments by MACTEC Engineering and Consulting in their January 10, 2003 report to the Savannah Harbor Committee (Report of Results, Savannah Harbor-Stormwater Quality Modeling, Savannah Harbor Expansion).

The total BOD₅ load was converted to a total CBOD_u load using a f-ratio of 3.91 which is the average of the f-ratios calculated for the 10 point sources. Although the total load from the stormwater loads is relatively small as can be seen in the loading analysis, they will be included in the Bases Case scenario.

5 Reaeration

For reaeration, the O'Connor-Dobbins formula will be used. The WASP model has been modified to allow for the specification of the number of vertical layers for use in the depth term when calculating the reaeration coefficient. The depth term is essentially the vertical distance over which the DO exchange with the environment is distributed. Any DO input from reaeration is averaged over that depth.

For the hydrodynamic model calibration simulation configuration, the total depth at each cell was divided up into 11 layers. The same configuration will be used for the DO model setup. The baseline model run will use the top 3 layers for the reaeration depth term calculation on the 11 layer vertical grid.

6 Horizontal Dispersion

The horizontal dispersion for the baseline model run will be set to a value of 1.0 m²/s. This is the same value used for the hydrodynamic and salinity model calibration.

7 Vertical Mixing

The vertical mixing term calculation is based on the log law approach used by the hydrodynamic model (ATM 2001). The identical time series of vertical mixing used in the hydrodynamic model calibration simulation will be used for the DO model Base Case.

8 Model Constants and Coefficients

The necessary WASP model constants and coefficients for the base case are given in Table 7.1 below. The constants and coefficients have been broken down into four major groups for discussion and specification. A noticeable omission from the list of constants is the phytoplankton group. It was determined from the Characterization of the DO environment in the estuary that phytoplankton do not play a significant role and will therefore not be modeled explicitly. Rather, a constant background phytoplankton concentration will be specified, based on the average of the observations, and the constituent will be bypassed in the WASP model simulations.

The majority of the coefficients assigned for the base case are equivalent to those specified in the literature, particularly the WASP Manual (Ambrose et. al, 1993), with a few notable exceptions.

8.1 DO Group Coefficients

The coefficients selected for the DO group essentially conform to the literature values suggested in the WASP manual. Referring to Table 7.1, the formula to be used for reaeration is the O'Connor-Dobbins formula with a standard temperature coefficient. Finally, the range of the observed SOD data (described above) has been scaled to the 20°C temperature range for input to the model.

8.2 CBOD Group Coefficients

With the exception of the CBOD deoxygenation rate the coefficients selected for the CBOD terms are essentially standard. For the present modeling effort the Savannah LTBOB Curve Fitting Discussion Group recommended that a single oxidation rate would be sufficient to accurately represent the Lower Savannah River Estuary System and that an oxidation rate of 0.06 1/day be used. This is at the lower end of the literature range, but was determined through analysis of LTBOB data and will be included in the Base Case definition.

8.3 Nitrogen Group Coefficients

The nitrogen group coefficients are primarily set from literature values for the Base Case setup. The exception is for the nitrification rate which was recommended to be 0.035 1/day by the LTBOB Curve Fitting Discussion Group based on the long term data analysis.

Table 7.1 Base Case, WASP model constants and coefficients

Savannah Harbor DO Model Base Case Constants and Coefficients				
Category	Coefficient	Symbol	Units	Constants
DO	Reaeration Rate @ 20	K2C	1/day	Formula
DO	Temp Coefficient	K2T	--	1.024
DO	Endogenous Respiration Rate @ 20	K1RC	1/day	0.125
DO	Temp Coefficient	K1RT	--	1.045
DO	SOD @ 20	SODC	g / m ² - day	0.9 - 1.5
DO	Temp Coefficient	SODT	--	1.047
CBOD	Carbonaceous Deoxygenation Rate @ 20	KDC	1/day	0.06
CBOD	Temp Coefficient	KDT	--	1.047
CBOD	Half-Saturation Constant for O ₂ Limitation	KBOD	mg O ₂ / L	0.5
CBOD	Organic Matter Settling Velocity	CVSETTLE	m/day	0.1
CBOD	Dissolved Fraction of CBOD	fdlcbod	--	1
CBOD	Organic Carbon Decomposition Rate (benthic)	KDSC	1/day	0.0004
CBOD	Temp Coefficient	KDST	--	1.08
CBOD	Oxygen/Carbon Ratio in Phytoplankton	OCRB	--	2.66
N	Organic Nitrogen Mineralization Rate @ 20	K1013C	1/day	0.04
N	Temp Coefficient	K1013T	--	1.08
N	Nitrification Rate @ 20	K1320C	1/day	0.035
N	Temp Coefficient	K1320T	--	1.08
N	Half-Saturation Constant for O ₂ Limitation	KNIT	mg O ₂ / L	2
N	Denitrification Rate @ 20	K140C	1/day	0.1
N	Temp Coefficient	K140T	--	1.045
N	Michaelis Constant for Denitrification	KNO3	mg O ₂ / L	0.1
N	Nitrogen/Carbon Ratio	NCRB	--	0.175
N	Fraction of Phytoplankton Recycled to ON	FON	--	0.5
N	ON Decomposition Rate in benthic @ 20	KONDC	1/day	0.001
N	Temp Coefficient	KONDT	--	1.08
N	Dissolved Fraction of Organic Nitrogen	fdlnitr	--	0.4
P	Phosphorus/Carbon Ratio	PCRB	--	0.025
P	DOP Mineralization Rate @ 20	K58C	1/day	0.2
P	Temp Coefficient	K58T	--	1.08
P	Fraction of Phytoplankton Recycled to OP	FOP	--	0.5
P	Half-Saturation Constant for P Recycle	KMPHYT	mg C / L	1
P	OP Decomposition Rate in benthic @ 20	KOPDC	1/day	0.001
P	Temp Coefficient	KOPDT	--	1.08
P	Dissolved Fraction of Organic Phosphorus	fdlphos	--	0.05
Spatial	Benthic Layer Thickness	Dj	cm	10
Transport	Vertical Diffusion Coefficient	EDIF	m ² / s	variable

9 References

- Ambrose, R.B. et al. 1993. The Water Quality Analysis Simulation Program, WASP5 Part A: Model Documentation, Part B: The WASP5 Input Data set. U.S. Environmental Protection Agency, Athens, GA.
- ATM, 2002. Water Quality Model Calibration Approval Package, Savannah Harbor Ga. Preliminary Report delivered to Georgia Ports Authority, Savannah Ga., Applied Technology & Management, Inc., Mt. Pleasant SC, September 12, 2002.
- ATM, 2001. Draft SEGDO2 Report: Hydrodynamic and Salinity Model Calibration Report. Submitted to Georgia Ports Authority, Savannah Ga., Applied Technology & Management, Inc., Mt. Pleasant SC, March 22, 2001.
- EPA, 2002. Application of EPD-RIV1 to the Savannah River from Augusta, GA to Hardeeville, SC to provide river boundary data for the Savannah Harbor Model. EPA Region IV, Atlanta, Ga. December 2002.