DEVELOPMENT AND USE OF A THREE-DIMENSIONAL WATER QUALITY MODEL TO PREDICT DISSOLVED OXYGEN CONCENTRATIONS IN THE LOWER CAPE FEAR RIVER ESTUARY, NORTH CAROLINA

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EXECUTIVE SUMMARY

An application of the three-dimensional water quality model EFDC (Environmental Fluid Dynamics Code) was developed for the Lower Cape Fear River Estuary, North Carolina. The model was used to investigate the effects of various organic matter and ammonia load reduction scenarios on the dissolved oxygen concentrations within the estuary. The model region included the tidally affected portions of the Cape Fear, Black, and Northeast Cape Fear Rivers near Wilmington, North Carolina, and extended southward to the mouth of the Cape Fear River near Southport, North Carolina.

The model's three-dimensional numerical grid had 1050 horizontal cells and eight vertical layers. The average horizontal grid size was approximately 600 m; individual cell sizes ranged from 100 to 1300 m. Cell water depths varied for river and estuary channel cells from 2.5 to 12.5 m. EFDC uses a "sigma" vertical grid so that the water depth within a horizontal cell was subdivided into eight layers of uniform thicknesses. The model grid included 241 "marsh" cells that were used to model the off-channel storage of wetlands adjoining the estuary. Flow boundary conditions were utilized at the upstream riverine boundaries; a radiation-separation boundary condition was used at the downstream open boundary. Model input data sets and observed data sets used for calibration and confirmation, and model scenario testing were developed using observed data gathered from various agencies. The period December 1, 2003 to December 31, 2004 was found to have sufficient data to create the necessary model data set for calibration. An additional model data set using data from January 1 to December 31, 2005 was used for model confirmation.

The model calibration period (January 1 – December 31, 2004) had streamflows that were generally below average for the first half of the year, and generally above average for the latter half of the year. After a storm in early May 2004, streamflows remained below average until August. The remainder of 2004 and 2005 until the middle of April had streamflows that were near historical average values. Flows through the summer of 2005 were generally below average. Dissolved oxygen (DO) concentrations at two stations that were in the impaired region and had continuous monitors installed in 2004 (Navassa and the Northeast Cape Fear at Wilmington) showed summertime (April 1 – October 31) dissolved oxygen concentrations that varied between 3 and 7.5 mg/L. At both of these sites the median DO concentration was below 4.5 mg/L and the 25th percentile DO concentration was below 4.1 mg/L. DO concentrations were generally lower at the Northeast Cape Fear site, and at this site were generally lower near the bottom of the water column.

Model calibration was performed separately on the hydrodynamic and water quality submodels. Hydrodynamic model calibration relied heavily on a set of continuous in-situ water level and water quality monitors that were deployed through the estuary. Hydrodynamic model calibration consisted primarily of varying the location, width, and bottom roughnesses of shallow model cells located adjacent to the river and estuary channels. The distribution of these "marsh" cells utilized information on the location and lateral extent of saltwater marshes and wetland forests adjoining the estuary. The calibrated hydrodynamic model matched well the attenuation of the tidal amplitude signal from the estuary mouth to the upstream model boundaries. The model was also able to simulate to a reasonable extent the time histories of salinities throughout the estuary.

The twenty-one state variable water quality model available in EFDC included multiple dissolved and particulate organic carbon constituents, as well as organic and inorganic nutrients, dissolved oxygen, and three phytoplankton constituents. To adequately characterize the various organic matter decomposition rates of the riverine and wastewater inputs, both labile and refractory dissolved organic matter constituents were used. The water quality model considered inputs from the three riverine sources at the model boundaries, twenty wastewater point source inputs within the estuary, and fourteen additional point sources that simulated other freshwater inputs to the estuary from tidal creeks and wetlands. Over the three-year time period (2002-2005) for which the freshwater and point source loadings were developed, approximately 10% of the organic matter loading and 50% of the ammonia loading to the estuary came from the twenty wastewater point sources that discharged directly to the estuary.

The dissolved oxygen model utilized a user specified sediment oxygen demand (SOD) that could vary spatially and temporally. Both temporal and spatial variation in SOD was utilized for the model. The temporally variable SOD that was used in this study was based upon an analysis of the available monitoring data. Temporal variation was modeled according the observed variation in measured SOD with changes in water temperature during the SOD measurement. SOD values were then adjusted seasonally according to observed changes in water temperature in the water body. During calibration it was determined that higher SOD values should be used for the Northeast Cape Fear. The ratio between these higher SOD values and the SOD values for remaining portion of the model region was determined during calibration. Discharge and estuary monitoring data were used to quantify the loadings of organic matter, nutrients, and dissolved oxygen to the estuary. As part of calibration SOD values were varied to values above and below the average values from the monitoring program. The calibrated value was found to be nearly identical to the corresponding value from the monitoring program.

The calibrated model matched well time histories of observed dissolved oxygen concentration. Model predictions were compared to over 5200 measured dissolved oxygen concentrations collected at eighteen sites throughout the estuary. The mean model error was less than 0.01 mg/L, and the root mean square error was 0.92 mg/L, which corresponded to 13.8% of the mean value. The correlation r^2 was 84.4%. This is an excellent degree of model fit for an estuarine dissolved oxygen model. Time history comparisons were also made for other important water quality constituents, such as nitrate+nitrite, orthophosphate, total nitrogen, and chlorophyll. In each case the model acceptably simulated the spatial and temporal patterns in the observed data set. A water quality model confirmation test run using input and calibration data from 2005 showed a similar degree of fit between observed and predicted dissolved oxygen concentrations. Based upon this work, the calibrated model is considered to be suitable for conducting scenario tests on the effect of changes in organic matter and ammonia loadings on the dissolved oxygen concentrations in the estuary.

A number of scenario tests were conducted to investigate the system's sensitivity to loading changes and other possible changes in the water body. For each scenario, a model run was used to determine the predicted dissolved oxygen concentrations during the summer period of 2004 (April 1 – October 31) within the state designated impaired region of the estuary. Twice daily dissolved oxygen snapshots were recorded from all eight vertical layers at eighteen sites within the impaired region. More than twenty separate model runs were made and compared to the base case to determine how the dissolved oxygen concentrations might vary for a particular scenario. These eight scenarios were examined:

1. Eliminating wastewater point source loadings
2. Reducing river, creek, and wetland loadings
3. Changing wastewater loadings for various values of sediment oxygen demand
4. Reducing river, creek, and wetland loadings and sediment oxygen demand
5. Eliminating ammonia inputs from wastewater point sources
6. Increasing wastewater inputs to maximum permitted values
7. Deepening of the navigation channel
8. Changing Brunswick County wastewater loadings

Four model runs were made to investigate the effect of completely turning off the discharges from the wastewater treatment plants. These scenarios were run, not because the pollutant removals used were considered achievable or advisable, but instead these scenarios were run to investigate the system's sensitivity to WWTP loads. River, creek, and wetland inputs were maintained at the base condition levels. It was assumed that organic matter and ammonia concentrations in the wastewater inputs would be decreased to 0.0 mg/L. When all WWTP loads were eliminated, the 10th percentile DO concentration increased by approximately 0.3 mg/L, from 4.3 to 4.5 mg/L. The median value DO concentration increased by about 0.10 mg/L, from 5.6 to 5.7 mg/L. Selectively turning off individual WWTP loads, as expected, had a smaller effect. Turning off the International Paper WWTP had an effect that was roughly 2/3 of that when all the plants were turned off. Turning off both Wilmington domestic wastewater treatment plants had an effect that was roughly 1/3 of that when all discharges were turned off. A fourth scenario considered eliminating the ammonia loading for all wastewater treatment plants. This scenario increased the dissolved oxygen concentration by about 0.1 mg/L at the 10th percentile level.

The impact of changing the loadings that entered the model region from rivers, creeks, and wetlands were also investigated. Loading reductions of 30%, 50%, or 70% were assumed for the three river inputs (Cape Fear, Black, and Northeast Cape Fear), and from the fourteen creeks and wetland inputs in the estuary. To reduce the loadings, flows were maintained at the observed levels, but concentrations were reduced by 30%, 50%, or 70%. Loadings for the twenty wastewater point sources were maintained at the levels in the base case scenario. These load reductions were found to have a significant impact on dissolved oxygen concentrations. At the 10th percentile level, DO concentrations for the 30%, 50%, and 70% load reduction increased by 0.20, 0.3, and 0.40 mg/L respectively, from 4.3 mg/l to either 4.5, 4.6 or 4.7 mg/L. Unlike the other scenarios investigated, this level of increase in DO concentration was maintained at the higher percentiles. In fact, the median DO concentration was increased to even a greater extent, increasing from 5.6 to 5.85 mg/L for the 30% load reduction, and from 5.6 to 6.2 mg/L for the 70% load reduction scenario.

Additional water quality model runs were conducted to investigate the sensitivity of the results to the choice of model kinetic parameters. Because of its relative importance in determining dissolved oxygen concentrations, the sensitivity analysis focused on the impact of various choices for the sediment oxygen demand. During calibration it was found that this parameter had a significant impact on dissolved oxygen concentrations in the estuary. In addition to the calibrated SOD value (0.4 g/m^2/d at 20° C), runs were made at a lower value (0.3 g/m^2/d at 20° C) and a higher value (0.5 g/m^2/d at 20° C). Model fit to the observed data set was compared for these three cases. All three cases had similar correlation r^2 values (83.4%, 83.4%, and 84.5%), but on average the low SOD case overpredicted DO concentrations by 0.11 mg/L, while the high SOD case underpredicted DO concentrations by a similar amount (0.09 mg/L). The impact of turning off the organic matter and ammonia loadings from all wastewater treatment plants was investigated for each of these three SOD cases. Each scenario produced a very similar change in DO concentration when all point sources were turned off. Even though DO concentrations were changed with the different SOD cases, in each scenario, turning off the sources increased DO concentrations by approximately 0.25 mg/L at the 10th percentile level. It is expected that changes in other model parameters would have a similar result. Although absolute concentrations are affected by changes in parameter values, relative changes in concentration are less affected by changing parameter values.

An additional set of model runs were conducted to investigate the effect of reducing both river loading of organic matter and sediment oxygen demand. Three pairs of model runs were made that reduced river loading or river loading and SOD by 30%, 50%, and 70%, using the methods described earlier. As expected, a larger effect was seen when both river loading and SOD were reduced. A 30% reduction raised the 10th percentile DO concentration from 4.3 to 4.8 mg/L; a 50% reduction raised the 10th percentile DO concentration to 5.2 mg/L; a 70% reduction raised the 10th percentile DO concentration to 5.4 mg/L. In this final case where both river load and SOD were reduced by 70% from the base case, only about 1% of the model predicted DO concentrations in the impaired region were less than the water quality standard value of 5.0 mg/L.

The impact of increasing all wastewater treatment plant loadings to the maximum allowed by permit was also investigated. For cases where both the maximum concentration and flow were specified, both these values were used in the scenario. In permits with only a load or concentration limit, the existing flows were maintained, but concentrations were adjusted to produce the permitted limit. Using these maximum permitted loadings decreased predicted dissolved concentrations in the impaired region by approximately 0.1 mg/L. This level of decrease was fairly uniform across the range of predicted concentrations.

The impact of deepening the navigation channel on predicted dissolved oxygen concentrations in the estuary was also investigated. Model grid files were adjusted to match the channel deepening plan developed by the Wilmington district of the US Army Corps of Engineers that will deepen portions of the Cape Fear and Northeast Cape Fear Rivers. It was found that this deepening would decrease dissolved oxygen concentrations by approximately 0.1 to 0.2 mg/L. The percentage of dissolved oxygen concentrations in the summertime in the impaired region that would be below 5.0 mg/L would increase slightly with the channel deepening from 32% to 34%.

Three model scenarios considered the impact of changing the wastewater flow of a single discharger (Brunswick County wastewater treatment plant). Based on the discharge monitoring reports for the model period, the base condition had a time-averaged flow of 0.38 MGD. The three scenarios tested had time-averaged flow of 1.65, 4.65 and 15 MGD. These scenarios therefore represented the effect of changing the wastewater treatment flow by factors of 4.3, 12.1, and 39.1. Despite the relatively large changes in the assumed wastewater flow, there were only very small differences in the predicted dissolved oxygen concentrations, for summertime conditions in the impaired region. Across the entire range of dissolved oxygen concentrations, the differences between the base case and each of the three scenarios were always less than 0.05 mg/L.

An analysis was performed to attribute the observed oxygen depletion within the estuary to riverine loadings of degradable waste, wastewater discharges, and sediment oxygen demand. It was found that for three sites in the impaired region during the summer, less than 10% of the dissolved oxygen deficit was attributable to wastewater discharges. Riverine loadings and sediment oxygen demand each contributed similar amounts to the remaining 90% of the deficit.

The report concludes with some recommendations as to additional development of the model that seems justified. Both this model study and a previous effort demonstrated the importance of benthic fluxes of oxygen. As this model used a prescribed sediment oxygen demand, albeit one that varies temporally and spatially, further refinement of the sediment model seems warranted. In addition, some additional work seems justified to separately consider the effects of wetland and riverine loadings to dissolved oxygen conditions in the estuary.

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1. INTRODUCTION

1.1 Background

The Cape Fear River watershed is the largest in North Carolina with a drainage area of 9,149 square miles. The watershed is nearly 200 miles long and is completely contained within the state (NC DENR 2004). The watershed is divided into upper, middle, and lower regions. The upper region contains the Triad metropolitan area of Greensboro, High Point, and Winston-Salem. The Lower Cape Fear River Estuary occupies the southernmost 60 kilometers of the watershed, from upstream of Wilmington to the Atlantic Ocean (Figure 1). The estuary includes not only the tidally affected portion of the Cape Fear River, but also the lowermost portions of the Black and Northeast Cape Fear Rivers. The Wilmington metropolitan area is located within the estuarine portion of the Lower Cape Fear watershed.

The river and its watershed are vital resources to the state providing not only as a water supply for drinking and industrial use, but also by providing habitat for countless aquatic plants and animals. As such, reaches within the Cape Fear River watershed have been deemed by the North Carolina government to have designated uses such as water supply, primary and secondary recreation, aquatic life propagation, and agriculture depending on the desired use of the water and its quality (see classifications listing at http://h2o.enr.state.nc.us/csu/). State (NC Department of Environment and Natural Resources) and Federal (Environmental Protection Agency) agencies are charged with maintaining, protecting, and restoring the quality of surface waters. Section 303(d) of the Federal Clean Water Act (CWA) requires all states to develop a list of waters not meeting water quality standards or which are not meeting their designated use. Listed waters must be prioritized, and a management strategy or total maximum daily load (TMDL) analysis must subsequently be developed for all listed waters.

A portion of the Lower Cape Fear River Estuary occupying 5,616.7 acres is currently on the state's 303(d) list (NC Division of Water Quality 2008). This listing, having the following description:

> From upstream mouth of Toomers Cr. to a line across the river between Lilliput Creek and Snow's cut

is given in part because of violations of the state's water quality standard for dissolved oxygen (5.0 mg/L for surface waters, and 4.0 mg/L for swamp waters) (NCDEHNR 1994). Because of the history of dissolved oxygen water quality violations, and the 303(d) listing of this portion of the estuary, the NC is currently conducting a dissolved oxygen TMDL analysis of the estuary. As part of this TMDL analysis, a three-dimensional water quality model of the estuarine portion of the Cape Fear River watershed has been developed, tested, and utilized to run management scenarios. This report summarizes the development, testing, and use of this model.

1.2 Study Objectives

The overall objective of the study was to develop a water quality model of the Lower Cape Fear River estuary that would be suitable for use during the dissolved oxygen TMDL analysis performed by the NC Division of Water Quality (DWQ). During the early investigative phase of the project, it was determined that a three-dimensional numerical model would be necessary. Once the model was selected, developed and tested, the project objective was to estimate the nature and magnitude of changes in the water quality of the estuary that would result from changes in inputs of oxygen demanding wastes to the estuary. This objective was achieved by formulating, running, and analyzing several sets of model scenarios that simulated water quality conditions in the estuary for various loading levels of oxygen demanding wastes. A secondary model objective was to assess the reliability of model predictions. This objective was achieved through model confirmation and model sensitivity testing.

1.3 Organization of the Study Report

In order to achieve the model study objectives, the project was divided into the following phases:

- model selection,
- collection of model forcing and calibration data,
- creation of the model computational grid,
- creation of model input files,
- model calibration,
- model confirmation (verification and sensitivity analysis), and
- scenario testing.

The remaining chapters describe each of the phases listed above. Chapter 2 introduces the three-dimensional model and describes the process by which the computational grid was created. This section also reviews the data sources used to create model input and calibration data files. Chapter 3 provides additional details on the specifications of model inputs that were used to create the various model input files. This is followed in Chapter 4 by a description of hydrodynamic and water quality model calibration. Model evaluation, which included a model confirmation test and sensitivity testing, is described in Chapter 5. The sensitivity of the system to changes in inputs of organic matter or other changes in the system is described in chapter 6. In this chapter are described five separate scenario tests that were performed to investigate how water quality in the estuary might change with changes in organic matter loadings. Discussion of the results and some conclusions that come from the study are provided in Chapter 7. References are provided in the final chapter.

Figure 1. The Cape Fear River Basin, North Carolina

2. MODEL AND SYSTEM DESCRIPTION

2.1 Model Description

After a review of the previous monitoring and modeling work done in the Lower Cape Fear River Estuary (e.g. Cahoon et al., 1999; Lin et al. 2006, Mallin et al., 2003, Tetra Tech 2001), it was decided that a three-dimensional water quality model was needed. Because of its flexibility in water quality simulation, its frequent use for hydrodynamic simulation, and its support by EPA, the Environmental Fluid Dynamics Code (EFDC) was selected as the model to be used for this application. EFDC is a hydrodynamic and water quality model that can be used to model one, two or three-dimensional aquatic systems. EFDC uses stretched or sigma vertical coordinates and Cartesian or curvilinear-orthogonal horizontal coordinates to represent the physical characteristics of a water body. It solves the three-dimensional, vertically hydrostatic, free surface, turbulent averaged equations of motion for a variable-density fluid. Dynamically coupled transport equations for turbulent kinetic energy, turbulent length scale, salinity and temperature are also solved. The EFDC model allows for drying and wetting in shallow areas by a mass conservation scheme (Hamrick, 1992).

A water quality model with 21 state variables (Table 1) has been developed and implemented within EFDC to form a three-dimensional coupled hydrodynamic and water quality model (water quality formulation can be found in Park et al., 1995). The model simulates temporal and spatial distributions of several water quality parameters such as dissolved oxygen, suspended algae, several components of carbon, nitrogen, phosphorous, silica as well as fecal coliform bacteria. The model predicts time and space variable concentrations by coupling the fate of these constituents (Figure 2) and performing a mass balance for each constituent at each water quality model time step (Tetra Tech, Inc., 2002a, 2002b).

The complete EFDC model contains three submodels (1: Hydrodynamics and Temperature, 2: Water Quality, 3: Sediment Diagenesis). The complete model, which was originally developed by John Hamrick (Hamrick, 1992) is currently maintained by Tetra Tech, Inc.. The hydrodynamics and temperature submodel is currently supported by the Environmental Protection Agency (EPA). In this application, the hydrodynamics, temperature, and water quality submodels were utilized. The sediment diagenesis model was not used, instead fluxes between the water column and sediments were prescribed.

Table 1. EFDC Water Quality State Variables. Abbreviations refer to constituents as shown in Figure 2.

Water Quality State Variable	**Abbreviation**	**Unit**
Cyanobacteria (blue-green algae)	Bc	g/m^3
Diatoms (algae)	Bd	g/m^3
Green algae (others)	Bg	g/m^3
Refractory particulate organic carbon	RPOC	g/m^3
Labile particulate organic carbon	LPOC	g/m^3
Dissolved organic carbon	DOC	g/m^3
Refractory particulate organic phosphorus	RPOP	g/m^3
Labile particulate organic Phosphorous	LPOP	g/m^3
Dissolved organic Phosphorous	DOP	g/m^3
Total phosphate	TPO_4	g/m^3
Refractory particulate organic Nitrogen	RPON	g/m^3
Labile particulate organic Nitrogen	LPON	g/m^3
Dissolved organic Nitrogen	DON	g/m^3
Ammonium	NH_4	g/m^3
Nitrate Nitrogen	NO_3^-	g/m^3
Particulate biogenic silica	SU	g/m^3
Available silica	SA	g/m^3
Chemical Oxygen Demand	COD	g/m^3
Dissolved Oxygen	DO	g/m^3
Total active metal	TAM	g/m^3
Fecal Coliform Bacteria	FCB	Mpn/ m^3

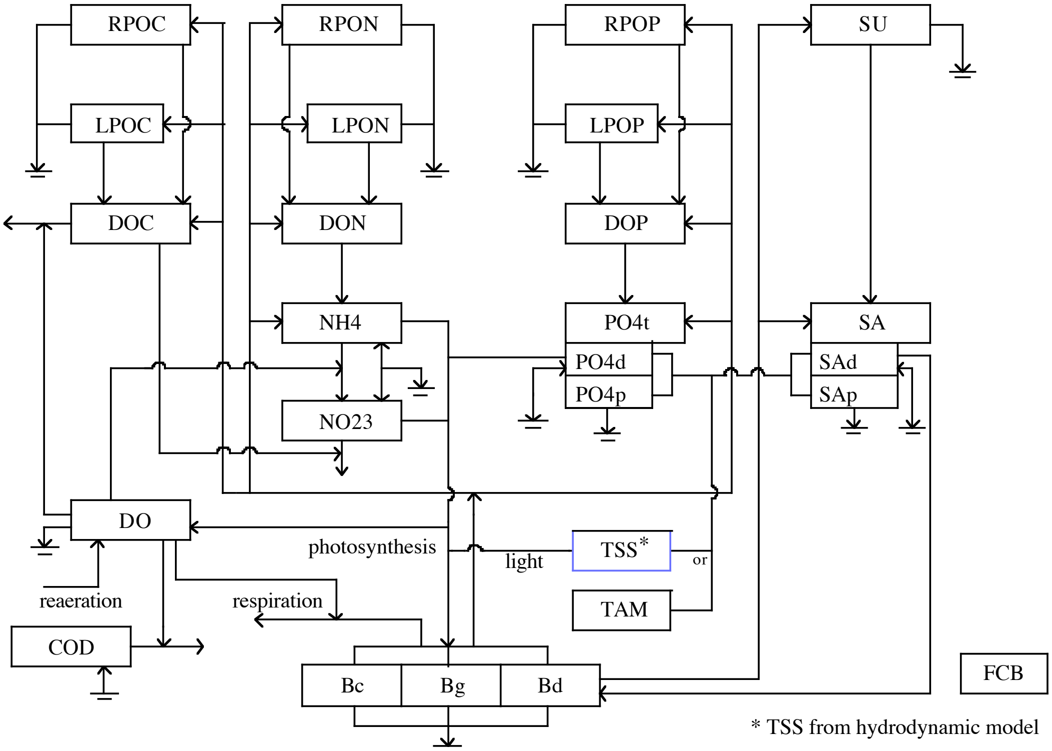


Figure 2. Schematic Description of the State Variables within the EFDC Water Quality Model.

2.2 Description of the Lower Cape Fear River Basin

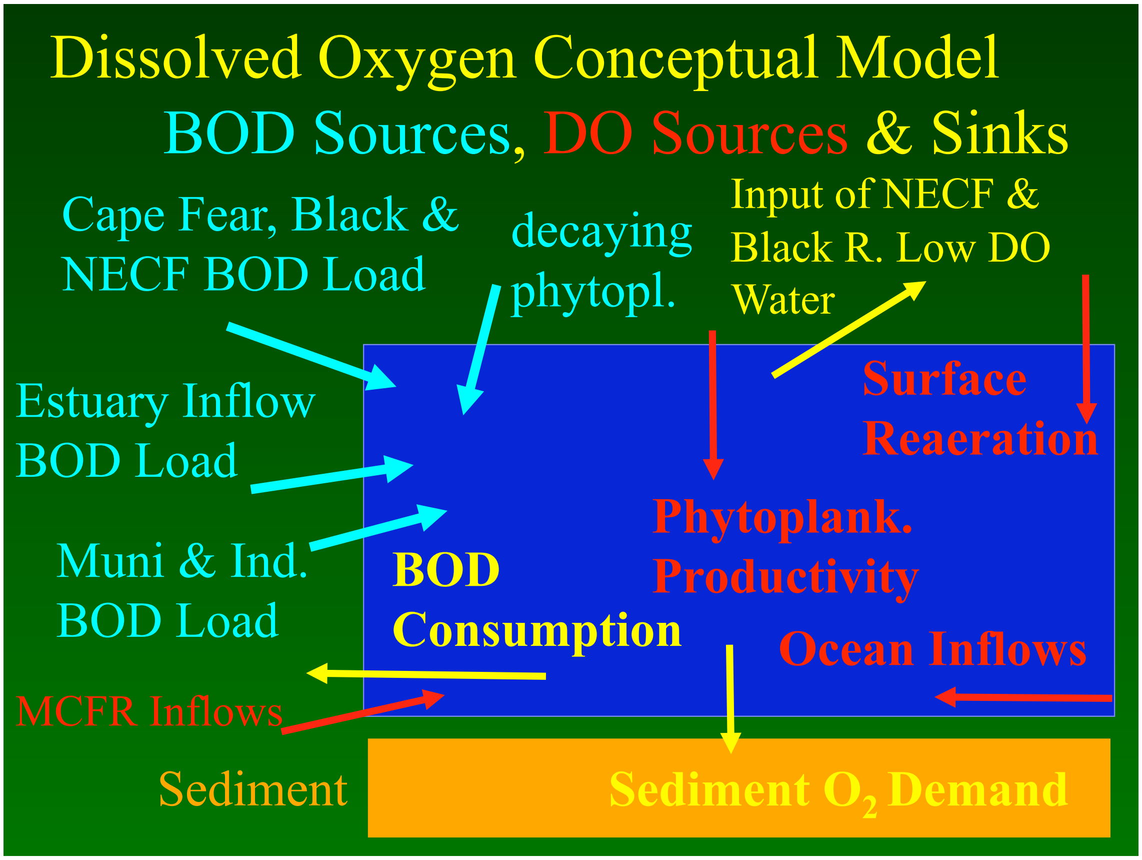
The Cape Fear River flows for 200 miles through the North Carolina piedmont, crosses the coastal plain, and empties into the Atlantic Ocean near Southport, North Carolina. The river begins near Greensboro and Winston-Salem as two rivers, the Deep River and the Haw River. These two rivers converge near Moncure to form the Cape Fear River. The Black River joins the Cape Fear 15 miles above Wilmington, and the Northeast Cape Fear River enters the system at Wilmington (Figure 1).

The Lower Cape Fear River Estuary occupies the southernmost 60 kilometers of the watershed, between Wilmington and the Atlantic Ocean. The estuary includes not only the tidally affected portion of the Cape Fear River, but also the lowermost portions of the Black and Northeast Cape Fear Rivers. This area of the river basin is extremely important for saltwater animals because of its function as a nursery for juvenile fish, crabs, and shrimp. The Cape Fear River system is North Carolina’s largest river system whose basin covers 9,000 square miles and encompasses streams in 29 of the state’s 100 counties. It is the most industrialized of all of North Carolina's rivers (Cahoon et al., 1999; Mallin et al., 2003). The river is also an important natural resource that supports many uses including industry, transportation, recreation, drinking water and aesthetic enjoyment.

The hydrology of the Cape Fear Estuary is similar to that of most of the middle to large estuaries located along the US Atlantic Coast. During the summer and the beginning of the fall, the estuary has relatively low flows, whereas it has high flows from the end of the fall to the beginning of the spring. From a hydrodynamic perspective, the Cape Fear has approximately a two-meter tide range and strong tidal currents (> 0.5 m/s) in the navigational channel of the open estuary and in the narrow tidal river channels of the three tributaries (Ensign et al. 2004).

A region of the estuary near the junction of the Cape Fear, Black, and Northeast Cape Fear Rivers is prone to low dissolved oxygen concentrations during the warm summer and early fall seasons (Mallin et al. 2003) as a result of natural and anthropogenic (both point and nonpoint source) organic matter loadings. Dissolved oxygen concentrations are frequently below saturation concentrations, and typically exhibit an unusual vertical distribution in which surface concentrations are consistently lower than bottom concentrations (Lin et al. 2006). Previous modeling studies of the estuary have replicated this behavior, and have shown reaeration to be an important component of the dissolved oxygen budget for this region (Tetra Tech 2001).

A conceptual model of dissolved oxygen in the Lower Cape Fear River Estuary considers that the mass balance of dissolved oxygen in the water-column is simultaneously affected by several sources (Figure 3). Biologically or chemically degradable organic matter, quantified according to a biochemical oxygen demand load (BOD in kg/day), is introduced into the estuary from a variety of sources including the three major rivers (Cape Fear River, Northeast Cape Fear River, Black River), wastewater treatment plant discharges, and local inputs of non-point source loadings from the fringing wetlands and tidal creeks within the estuary. These same sources may also contribute or deplete the estuaries water column of dissolved oxygen as they either add or remove dissolved oxygen from the water. Likewise the bottom sediments of the estuary, which accepts the organic matter that settles from the water column, will also produce a water column dissolved oxygen sink as the organic matter in the bottom sediments is aerobically decomposed by benthic microbes and animals. Sources of dissolved oxygen to the estuary water column includes phytoplankton that produces oxygen as they photosynthesize new plant material, and the overlying atmosphere, which will replenish the water column with dissolved oxygen whenever surface water dissolved oxygen concentration are less than 100% saturated. Together these dissolved oxygen sources and sinks and BOD sources produces a dissolved oxygen concentration that varies both in time and space within the estuary. In general the cumulative effects result in dissolved oxygen concentrations that are lowest in the warm summer months when organic matter decomposition occurs at a maximum rate while dissolved oxygen saturation concentrations, which decrease with increasing temperature and salinity, are at their seasonal minimum values.



Dissolved Oxygen Conceptual Model

BOD Sources, DO Sources & Sinks

Cape Fear, Black & NECF BOD Load

decaying phytopl.

Input of NECF & Black R. Low DO Water

Estuary Inflow BOD Load

Surface Reaeration

Muni & Ind. BOD Load

Phytoplank. Productivity

BOD Consumption

Ocean Inflows

MCFR Inflows

Sediment

Sediment O_2 Demand

Figure 3. A Conceptual Model of the Dissolved Oxygen Mass Balance in the Lower Cape Fear River Estuary

2.3 Previous Modeling of the Lower Cape Fear River Estuary

A three-dimensional water quality model of the Lower Cape Fear River Estuary has previously been developed for the City of Wilmington and New Hanover County (Tetra Tech 2001). This work had these stated objectives:

- Simulation of the mixing and transport of the City/County existing and proposed future Northside and Southside facility effluents.
- Simulation of the impact of existing and proposed future Northside and Southside facility pollutant loads for oxygen-demanding substances.

- Evaluation of multiple sources and cumulative loads of oxygen-demanding substances to the lower Cape Fear River estuary.

- Analysis of the various processes affecting dissolved oxygen and their relative contribution to ambient dissolved oxygen deficit levels.

Included in the model analysis was a prediction of the near-field and far-field dilution of the two Wilmington wastewater treatment plants and a water quality analysis for various scenarios that considered changes to wastewater treatment plant loadings, changes to sediment oxygen demand values within the estuary, changes to river loadings of organic matter and ammonia, and changes arising from elimination of the fringing wetland areas of the estuary. The hydrodynamic model was calibrated using continuous monitoring of water surface elevation and salinity during the summer of 1993 and long-term measurements of water surface elevation at the NOAA tide gauge at Wilmington. A radiation separation boundary condition was used for the open boundary at the mouth of the Cape Fear River Estuary. The water quality model calibration utilized in-stream data from the Lower Cape Fear Program and wastewater treatment plant loading data from the NC Division of Water Quality. The water quality calibration was based upon model predicted and observed data comparisons for the entire 1998 calendar year. The scenario analysis also considered the 1998 calendar year.

The scenario analyses focused on changes to dissolved oxygen concentration that would be seen at five monitoring stations within the Cape Fear and Northeast Cape Fear Rivers (Navassa, NCF6, M61, M54, M42). The scenario analysis considered time-averaged changes in dissolved oxygen concentrations at these five stations. It was concluded based upon the results of the scenario analyses that sediment oxygen demand had the largest effect on dissolved oxygen concentrations, followed by either the point source loads or the wetland effect, depending on the station examined. Overall the tributary loadings of organic matter had the smallest effect on dissolved oxygen concentrations at the five stations examined, although there were significant differences in the relative magnitudes of the effects at the five stations. The study concluded with recommendations for additional studies and water quality modeling of the estuary aimed at better quantifying the relative magnitude of the factors causing dissolved oxygen depletion.

2.4 Model Grid and Bathymetry

The model's three-dimensional numerical grid had 1050 horizontal cells and eight vertical layers. The average horizontal grid size was approximately 600 m; individual cell side dimensions ranged from 100 to 1300 m (Figure 3). Cell water depths varied for river and estuary channel cells from 2.5 to 12.5 m. EFDC uses a "sigma" vertical grid so that the total water depth within a horizontal cell was subdivided into eight layers of uniform thicknesses.

Of the 1050 horizontal cells in the Lower Cape Fear River, the model grid included 241 "marsh" cells that were used to model the off-channel storage of wetlands adjoining the estuary. The model also has 809 channel cells that provide the majority of transport into and out of the estuary. Horizontal sizes and location of the channel cells were set to match as much as possible the estuary bathymetric information obtained from NOAA (available at http://NOSDataExplorer.noaa.gov). The size, location, water depth, and bottom roughness of the marsh cells was determined during calibration of the hydrodynamic model. The method for specifying marsh cell characteristics will be described in more detail in the calibration section of this report (see Chapter 4).

The overall distribution of marsh cells within the estuary was initially set according to wetland delineations conducted by the North Carolina Division of Coastal Management NC Division of Coastal Management, 1999). Marsh cells were assumed to be located in regions of the estuary that had two of the wetland types identified in the NC DCM delineation: riverine swamps and saltwater marshes. Of the wetland types identified by the NC DCM, these two represented the majority of wetlands adjoining the Cape Fear River in the estuary. According to the Division of Coastal Management, within the Lower Cape Fear River estuary, saltwater marshes can be found south of Wilmington (Figure 4), while the riverine marshes are generally located farther upstream (Figure 4). The marsh cells in the calibrated EFDC model are also located both upstream and downstream of Wilmington (Figure 5).

Figure 4. Channel Cells Within the Model Region

Figure 5. Riverine Swamps and Saltwater Marshes in the Lower Cape Fear River Estuary

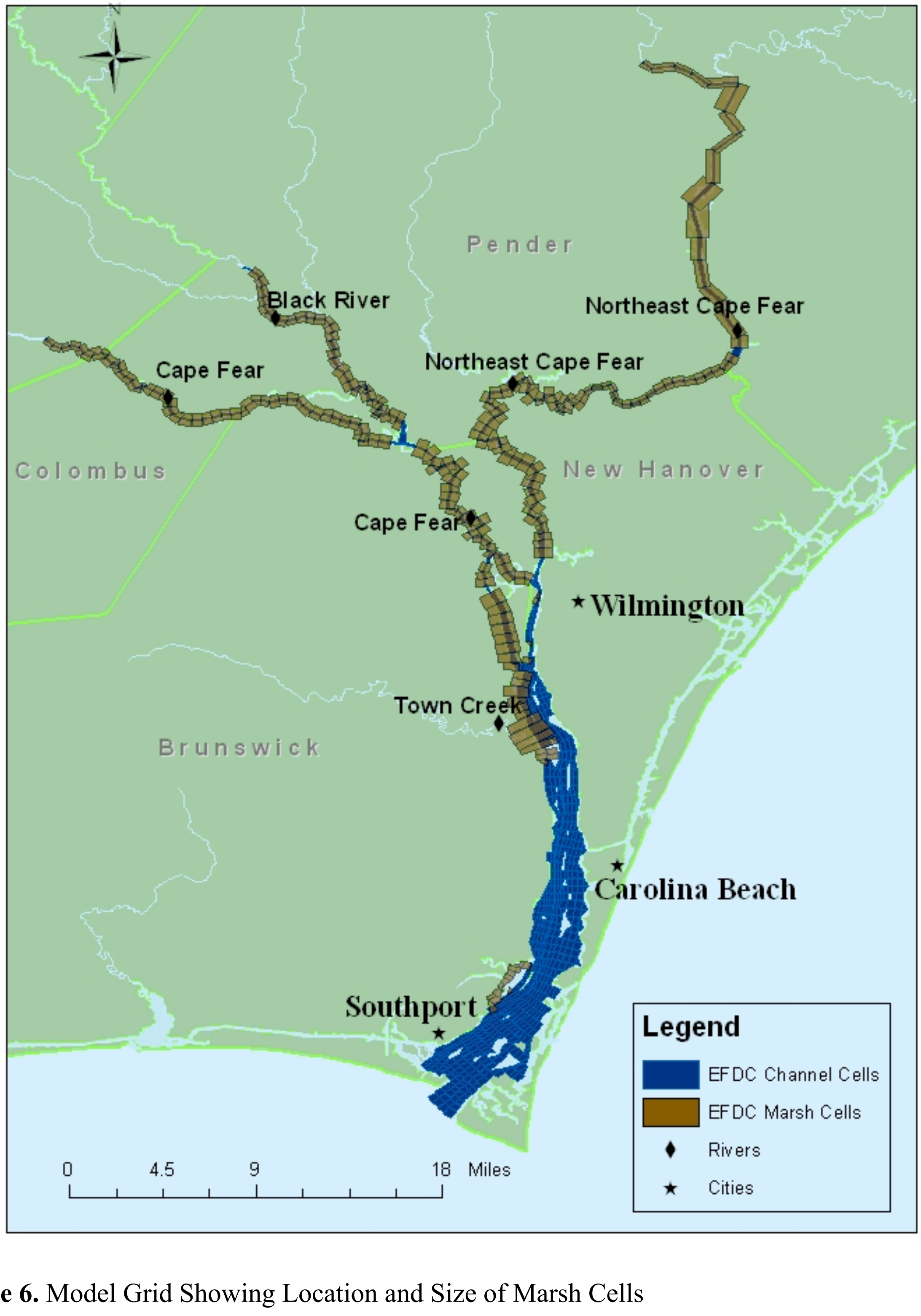


Figure 6. Model Grid Showing Location and Size of Marsh Cells

2.4 Monitoring Data Used for Model Setup and Calibration

Monitoring data is needed to define the model system characteristics and system inputs of mass, momentum, and energy. Table 2 summarizes the data types and sources used for setting up and running the Lower Cape Fear River estuary water quality model.

Table 2. EFDC Input Files and Data Sources

EFDC Input Filename	Description of Data Contained in File	Data Sources
QSER.INP	Flow time series data at flow specified model boundaries and point source locations	US Geological Survey, NC Division of Water Quality
ASER.INP	Meteorological time series data	National Weather Service
PSER.INP	Water surface elevation time series data at elevation specified model boundaries	National Oceanographic and Atmospheric Administration (NOAA)
TSER.INP	Temperature time series data at all model boundaries and point source inputs	Lower Cape Fear River Program, US Geological Survey, NC Division of Water Quality
WSER.INP	Wind time series data	National Weather Service
DXDY.INP	Horizontal cell lengths, widths, depths, bottom roughness	National Oceanographic and Atmospheric Administration (NOAA)
LXLY.INP	Horizontal cell size location, orientation relative to E-W, N-S direction	National Oceanographic and Atmospheric Administration (NOAA)
WQ3DWC.INP	Sediment oxygen demand specification	NC Division of Water Quality
SALT.INP	Initial condition for salinity for every model cell and layer	US Geological Survey, NC Division of Water Quality
TEMP.INP	Initial condition for temperature for every model cell and layer	Lower Cape Fear River Program, NC Division of Water Quality
WQPSL.INP	Time series mass load for each water quality constituent at each flow boundary or point source input	Lower Cape Fear River Program, NC Division of Water Quality
CWQSRXX.INP (XX indicates constituent number)	Time series concentration boundary condition at elevation specified boundaries	US Division of Water Quality, Lower Cape Fear River Program

Much of the water quality information for specifying initial and boundary conditions and calibration data came from the Lower Cape Fear River Program (e.g. Mallin et al. 2003). This water quality monitoring program, which is administered by the Center for Marine Science at UNC Wilmington, collects monthly data at a large number of sites throughout the estuary (Figure 6). The following monitoring data from this program were used for model specification and calibration:

Physical Parameters: temperature, salinity
Water Quality Parameters: nitrate-nitrite, ammonium, total nitrogen, orthophosphate, total phosphorus, total kjedahl nitrogen, dissolved oxygen
Biological Parameters: chlorophyll-a, biological oxygen demand

Additional water quality and physical data were collected using continuous *in-situ* monitors. This monitoring program was administered by the US Geological Survey, with financial support from the NC Division of Water Quality. The following data, which were collected every 15 minutes at each site, were used for model specification:

Physical parameters: temperature, salinity, water depth or water elevation, streamflow
Water Quality Parameters: dissolved oxygen

The continuous monitors were operated for roughly a one-year period beginning in November 2003 at six sites (Figure 7) throughout the estuary. Two of the sites (NE Cape Fear at Wilmington, Marker 12) had a near-surface and near-bottom monitor. The other stations had the monitors installed in the upper portion of the water column. The actual start and stop date of the monitoring differed somewhat for each of the sites. Two additional sites operated by the USGS that were upstream of the model region on the Black and NE Cape Fear Rivers were also used for establishing boundary conditions for flow (Figure 7).

Several other special studies administered by the NC Division of Water Quality collected important additional physical, water quality, and biological data. A short-term special study collected data from 12 sites within the estuary (Figure 7) during July and August 2004 (NC Division of Water Quality 2004). The study data were used along with the Lower Cape Fear River Program data to specify boundary conditions and calibration data for the model. The following data were collected and used in this study:

Field parameters: dissolved oxygen, temperature, salinity

Chemical parameters: 5-day biochemical oxygen demand, 30-day biochemical oxygen , total organic carbon, dissolved organic carbon, chlorophyll, ammonia nitrogen, total kjeldahl nitrogen (tkn), nitrite + nitrate nitrogen, total phosphorus, ortho-phosphorus

Figure 7. Lower Cape Fear River Monitoring Program Monitoring Stations

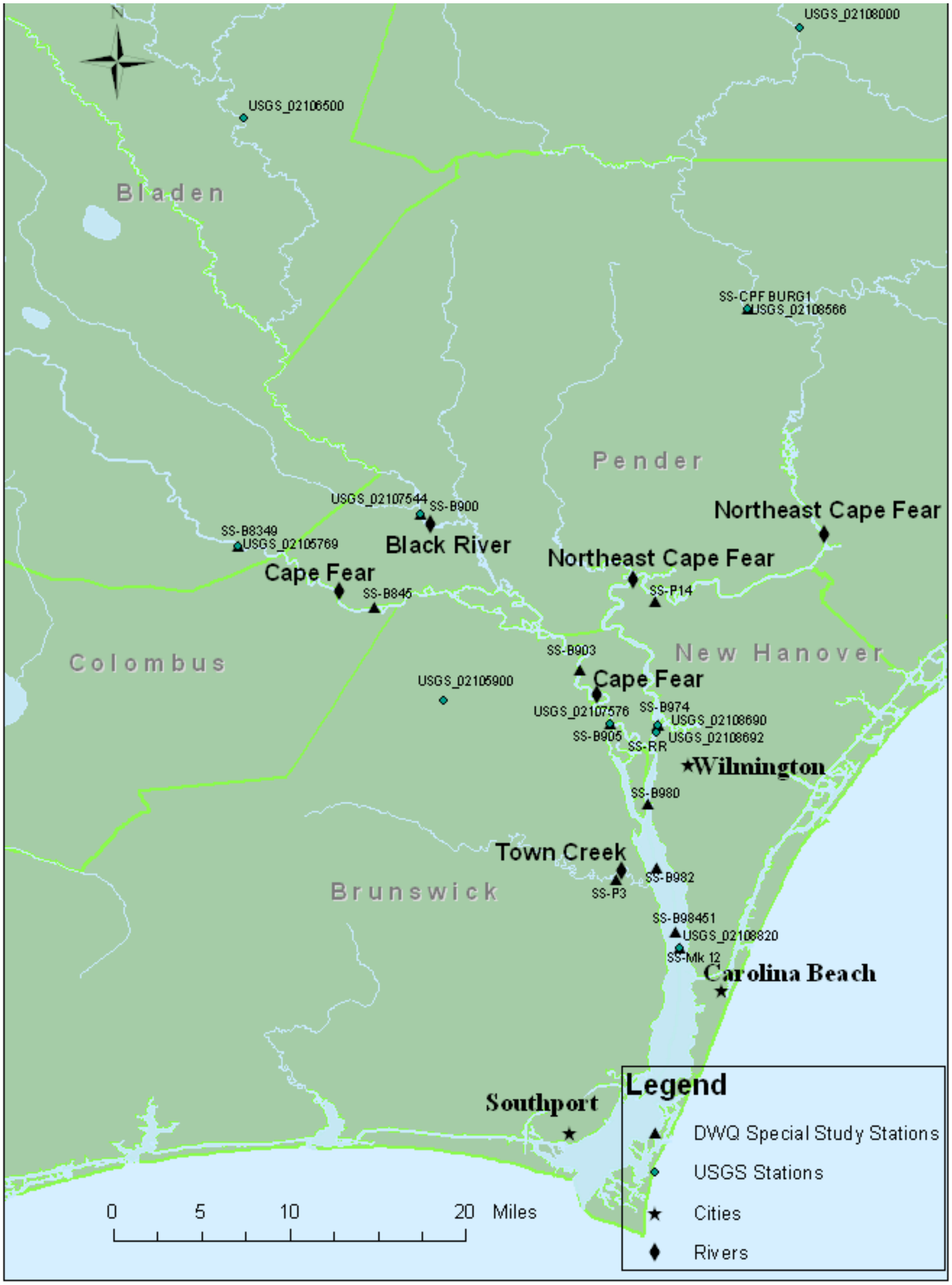


Figure 8. USGS Continuous Monitoring Stations and the Division of Water Quality Special Study Monitoring Stations

A second special study conducted by the NC Division of Water Quality surveyed river cross-sections at 21 stations throughout the estuary (Figure 8). These data were used to specify the width and depth of each channel cell. A third sampling program performed by the NC Division of Water Quality used chambers to measure *in-situ* sediment oxygen demand (SOD). Measurements were taken at five separate locations (Figure 10) on five separate days during the Summer and Fall of 2003.

Several other agencies also provided data necessary to specify model forcings or calibration data. Meteorological data (wind speed and direction, cloud cover, air and dewpoint temperature, short-wave solar radiation) were provided by the National Weather Service (NWS). The data were collected by the NWS at the Wilmington Airport. Water surface elevations at several locations (Southport, Sunset Beach, Wilmington) was provided by the National Oceanographic and Atmospheric Administration (NOAA).

Figure 9. Cross-Sections Surveyed by the Division of Water Quality

Figure 10. Division of Water Quality SOD Monitoring Stations

3. SPECIFICATION OF MODEL INPUT FILES

Using the complete set of monitoring data described in the previous section, a set of model input data files was created for a time period beginning in November 2003 and ending January 1, 2006. Flow, temperature, and water quality inputs were specified for all of the freshwater that was expected to enter the estuary. These sources included upstream inputs from the rivers (3 sources: Cape Fear, Black, and Northeast Cape Fear Rivers), wastewater loadings entering directly to the estuary (20 sources), and watershed loadings that enter directly into the estuary (14 sources). The overall approach to the specification of input loadings was to consider all loading categories (rivers, tidal creeks, wetlands, wastewater treatment plants), and to quantify these loadings according to the best information available on the particular loading to the estuary. For instance, loadings from tidal creeks downstream of Wilmington and outside of the impaired region were nonetheless estimated based upon available streamflow and/or drainage area data. In addition to this "upstream" source information, water surface elevation and water quality conditions were specified at the model's open boundary near Southport, NC. Specification of all of these model input data sets is described in Sections 3.1, 3.2, and 3.3. In addition to water inputs from point sources, flow boundaries, and elevation boundaries, the estuary's surface waters also exchange mass, momentum, and energy with the sediments below and the atmosphere above. Quantification of this transport requires another set of model input files. Specification of these model inputs is described in Sections 3.4 and 3.5.

3.1 Riverine and Wetland Inputs

3.1.1 Flow Specification

Upstream flow boundary conditions for the Cape Fear, Black, and Northeast Cape Fear Rivers were based upon continuous gauging stations operated by the United States Geological Survey at the Cape Fear River Lock & Dam #1 (USGS Station 02105769), the Black River near Tomahawk (USGS Station 02106500) and the Northeast Cape Fear River near Chinquapin (USGS Station 02108000). The Cape Fear station was located at the model boundary while the other two stations were located approximately 40 km upstream of the model boundary. To better quantify the river flows entering the modeled region from the Black River and the NE Cape Fear River the NC Department of Environment and Natural Resources (NC DENR) funded the creation of two additional shorter-term flow monitoring sites. The US Geological Survey installed the sites (Black River near Currie, USGS Station 02107544, and NE Cape Fear at Burgaw, USGS Station 02108566) collected the data, and distributed the data via their web site. These data, and additional measurements of drainage area also performed by the USGS were used to establish the needed flow time histories, both at the model boundaries, and for the creeks and wetlands that drain directly to the estuary.

With the extra data collected by the USGS, data from the two sites on the Black River and the two sites on the NE Cape Fear River were pooled to create a continuous time history at the appropriate model boundary. To model the full three-year time period modeled (November

2003 – January 2006) it was necessary to use data from both the upstream and downstream sites for each river to construct the complete flow time history at the model boundary. By examining time periods when flow data were available at both sites (e.g. Black at Tomahawk and Currie), a time lag was established for the more upstream of the two stations. This lag represented the typical travel time of flood waves from the upper to the lower station. The flows from the upstream station after lagging were then scaled according to the drainage area ratios of the two sites. This lagged and scaled upstream site data site was then combined with the downstream site to create the full time history at each of the three upstream model boundaries.

The three flow time histories data were also used to quantify the flow draining directly to the estuary from creeks and riparian wetlands. These flow estimates utilized drainage area measurements of each of the USGS monitoring sites (Table 3). Using these data, the total watershed area of the Cape Fear River was apportioned into seven groupings; three upstream rivers and four areas draining directly to the estuary (Table 4). For each of these groupings one of the flow time histories was used with a scaling constant based upon the corresponding drainage areas. For the four areas draining directly to the estuary, the closest of the three model boundary time histories was used to quantify the flow. The area draining directly to the estuary was further subdivided into a total of fourteen point sources (Figure 11), with the contribution of each source determined according to the particular drainage area of that subwatershed (Table 5).

Table 3. USGS Monitoring Station Data

Location	**USGS Station Number**	**Drainage Area (mi^2)**	**Latitude (deg, min, sec)**	**Longitude (deg, min, sec)**
Cape Fear R at Lock #1 near Kelly	02105769	5255	34, 24, 15	78, 17, 38
Black River Near Tomahawk	02106500	676	34, 45, 17	78, 17, 21
NE Cape Fear near Chinquapin	02108000	599	34, 49, 40	77, 50, 0
Hood Creek near Leland	02105900	21.6	34, 16, 43	78, 7, 34
Black River near Currie	02107544	1405	34, 24, 54	78, 08, 37
Cape Fear at Navassa	02107576	7060	34, 15, 36	77, 59, 15
NE Cape Fear near Burgaw	02108566	920	34, 35, 54	77, 52, 31
NE Cape Fear near Wilmington	02108690	1669	34, 15, 32	77, 56, 54
Cape Fear at Marker 12	02108820	9,000	34, 04, 35	77, 55, 53

Table 4. Subdivision of the Cape Fear River Watershed

Area No.	Watershed	Drainage Area (mi^2)	Flow Time History Used
1	Cape Fear River at Model Boundary	5,255	CF @ L&D 1
2	Black River at Model Boundary	1,405	Black at Currie
3	NE Cape Fear at Model Boundary	920	NE CF @ Burgaw
4	Estuary draining to Cape Fear above NE Cape Fear (upper estuary)	270	NE CF @ Burgaw
5	Estuary draining to Cape Fear below NE Cape Fear (lower estuary)	250	NE CF @ Burgaw
6	Estuary draining to Black River	120	Black @ Currie
7	Estuary draining to NE Cape Fear River	749	NE CF @ Burgaw
	Total	8,979	

Table 5. Subwatersheds Draining Directly to the Estuary

Point Source Number	Estuary Watershed Name	Drainage Area (mi^2)
21	NE Cape Fear, estuary 1	31
22	NE Cape Fear, estuary 2	6
23	NE Cape Fear, estuary 3	319
24	NE Cape Fear, estuary 4	101
25	NE Cape Fear, estuary 5	194
26	NE Cape Fear, estuary 6	109
	Total	**760**
27	Black River, estuary 1	91
28	Black River, estuary 2	30
	Total	**121**
29	Cape Fear, upper estuary 1	156
30	Cape Fear, upper estuary 2	31
31	Cape Fear, upper estuary 3	78
	Total	**265**
32	Cape Fear, lower estuary 1	61
33	Cape Fear, lower estuary 2	164
34	Cape Fear, lower estuary 3	22
	Total	**247**

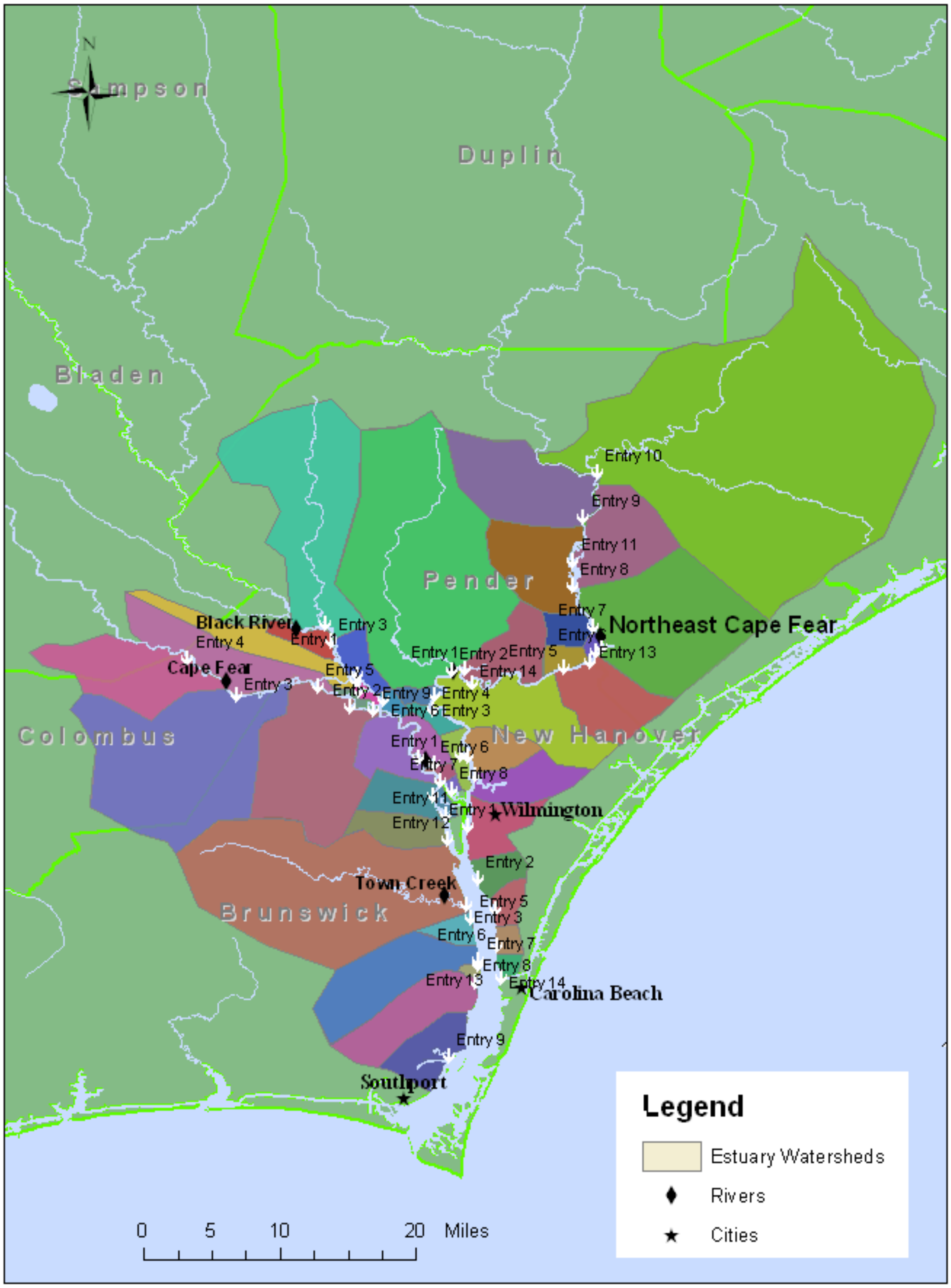


Figure 11. Watersheds Draining Directly into the Cape Fear River Estuary

3.1.2 Temperature and Concentration Specification

Specification of temperature and water quality inputs for the riverine sources utilized the monitoring programs described in the previous section. Temperature time histories were available at the Lower Cape Fear Monitoring Program sites on a monthly basis, and from the USGS continuous monitoring sites on a 15-minute basis. A total of five different monitoring locations were used to specify the temperature time histories. When available, roughly from November 2003 to November 2004, the USGS continuous monitoring data were used. After examining the temporal variability present in the 15-minute data, it was decided that daily time averaging would be sufficient for purposes of defining the temporal variation in the data. Since the model period (November 2003 – January 2006) extended beyond the period when the continuous monitoring data were available, each temperature time history also utilized data from the Lower Cape Fear River Program. All freshwater sources thus utilized two separate sources to specify temperatures and water quality concentrations (Table 6).

Table 6. Temperature Time History Specification

Time Series No.	Location	Time Period Using USGS Data and Station Number	Lower Cape Fear River Program Station Used	Point Source Numbers Using This Location
1	Black River, Upstream Model Boundary	9/8/03 – 12/3/04, 02107544	B210	19, 27-28
2	Cape Fear River, Upstream Model Boundary,	9/8/03 – 12/3/04, 02105769	NC11	6, 18
3	Navassa	9/10/03-11/24/04, 02107576	Nav	1-5, 9, 10, 13-17, 35-37
4	NE Cape Fear River, Upstream Model Boundary	9/10/03-12/2/04, 02108566	NCF117	20, 21-26, 29-34
5	Carolina Beach	11/7/03-12/2/04, 02108820	M18	7, 8, 11, 12

Water quality input specification consisted of quantifying both the flow and the time varying mass load for each source and for each water quality model constituent (Table 1). In EFDC, the mass loads from all point sources are quantified in the WQPSL.INP file. This one file gives the time varying mass loads for the riverine sources described in this section, and the point sources described in the next section for every model constituent. The term riverine sources is used rather generally here, and includes not only the three major river inputs to the estuary (Cape Fear, Northeast Cape Fear, Black Rivers), but also the loadings of water quality constituents from the tidal creeks and fringing wetland areas that discharge directly to the estuary. It should be noted here that this approach, which explicitly defines the loading from the entire watershed area draining to any portion of the estuary, is a departure from the method used in the previous modeling study of the Lower Cape Fear River estuary (Tetra Tech 2001), where the wetlands and tidal creeks did not contribute water or water quality constituents to the estuary.

For each scenario, multiple model runs were used to quantify the water quality impact of a particular change in the system (e.g. deepening the navigation channel, reducing wastewater treatment plant discharges, reducing nonpoint source loadings). Many of these scenario runs required changing the WQPSL.INP file, thus it was necessary to create many different versions (approximately 20) of this file. To simply specification of this file, an automated file generation system was created. This system used a set of Excel spreadsheets, one for each source or flow boundary, to quantify the source data time histories and the conversion of these data to mass loads for each constituent. The mass load time histories taken from each spreadsheet were then combined and reformatted to that required by EFDC using a Matlab script (make_wqpsl_capefear.m). The overall procedure for creating the WQPSL.INP is shown in Figure 12.

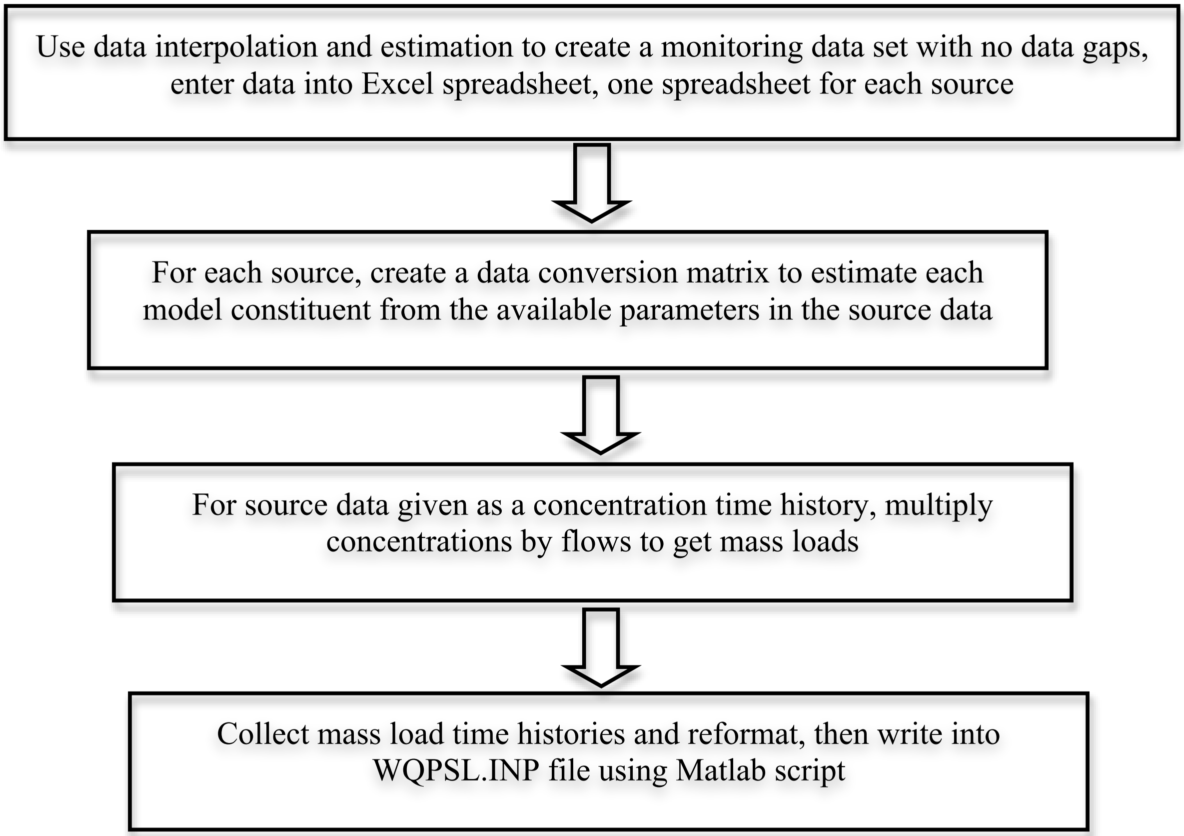


Figure 12. Procedure for creating water quality mass load file, WQPSL.INP

For the riverine and watershed sources, the mass load time history for each of the 21 model constituents was estimated from a data set that combined information from the Lower Cape Fear River Monitoring Program, the DWQ ambient monitoring program, and the USGS continuous monitoring data. The stations used were the same ones as those used for specification of the temperature time histories (Table 6). These data were used with data interpolation to create a daily concentration time history of the following eight water quality parameters:

1. dissolved oxygen (mg/L),
2. chlorophyll-a (µg/L),
3. ammonia nitrogen (mg/L as N),
4. total nitrogen (mg/L as N),
5. nitrate+nitrite nitrogen (mg/L as N),
6. total phosphorus (mg/L as P),
7. 5-day BOD (mg/L),
8. 20-day BOD (mg/L)

Daily flows at the model boundaries were also available from the USGS data set, as described in section 3.1. Together the flow and water quality information was used to create a daily load (g/s) for seven parameters (5-day and 20-day BOD were used together to estimate ultimate BOD loading). These data served as the basis for estimating the twenty-one model constituents in the EFDC water quality model.

An important consideration in specifying the time history of water quality constituent loading was to accurately quantify the quantity and degradation rate of the various sources of organic matter to the estuary. For instance, the degradation rate of detrital algal matter could be significantly different than that of wastewater discharges, which in itself could be significantly different than the degradation rate of the riverine and wetland sources of organic matter. To provide additional flexibility in specifying organic matter inputs from different categories of sources, two different dissolved organic carbon state variables were used. To avoid changing the EFDC code to accomplish this, the refractory particulate organic matter state variables (RPOC, RPON, RPOP) were used to model refractory dissolved organic matter (RDOC, RDON, RDOP) by specifying a settling velocity of 0.0 m/d. A second set of organic matter state variables (DOC, DON, DOP) was used to model the labile dissolved organic matter fraction. Different organic matter sources were modeled by using different fractions of the two dissolved organic matter state variables.

With these considerations, the following assumptions were used to estimate the loading time histories for all 21 state variables present in the EFDC model:

- the following 8 constituents were assumed to have zero loading (labile particulate carbon, nitrogen and phosphorus, particulate biogenic silica, available silica, chemical oxygen demand, total active metal, fecal coliform bacteria),
- the carbon to chlorophyll ratio in phytoplankton was assumed to be 60:1 (mg C/mg chl),
- the phytoplankton biomass was assumed to be equally divided among the three algal constituents (diatoms, greens, blue-greens),
- the total organic nitrogen (TON) was calculated as: TON = total nitrogen – ammonia nitrogen – nitrate+nitrite nitrogen,
- total organic carbon in the EFDC model was estimated from ultimate BOD using the stoichiometric ratio for carbon oxidation (12 g carbon oxidized requires 32 g of oxygen).

From this total was subtracted the carbon associated with phytoplankton biomass, using measured chlorophyll-a concentrations and the assumed carbon:chlorophyll-a ratio.

- the Redfield ratio, 106:16:1 C:N:P molar ratios (Redfield 1934) was used to convert between dissolved organic phosphorus, nitrogen, and carbon,
- ammonia, nitrate, and dissolved oxygen loadings were estimated directly from the monitoring data,
- two separate dissolved organic matter pools (labile and refractory) were used to model various sources of organic matter (labile organic matter is shown as DOC, DON, and DOP in Figure 2), and
- the refractory **dissolved** carbon, nitrogen, and phosphorus constituents were included in the model by using corresponding refractory **particulate** (RPOC, RPON, and RPOP in Figure 2) constituents with an assumed zero settling velocity.

Using these assumptions it was possible to create a 7 x 21 parameter matrix that was used to create twenty-one loading time histories, one for each constituent, from the seven available water quality time histories. Matrix multiplication using the parameter matrix also converted each load to the proper units (kilograms per day). Matrix multiplication within Excel was used to do the conversions in an automated fashion once the monitoring time histories were created.

Different parameter matrices were used for the Cape Fear, Black, and Northeast Cape Fear, as the split between labile (first order decay rate = 0.15 day^{-1}) and refractory (first order decay rate = 0.03 day^{-1}) organic matter was different for these three water bodies. The split between labile and refractory organic carbon was determined from the average BOD20/BOD5 ratio, after correcting for the impact of nitrogenous BOD. A corrected and time-averaged BOD20/BOD5 ratio for each river was used to calculate a corresponding organic matter decay rate and the labile refractory split (Table 7). For instance, the Cape Fear River refractory/labile split was 64.5%/34.5% based on the BOD5 and BOD20 measurements. For the Cape Fear River, this gave the parameter matrix shown in Table 8.

Table 7. Organic Matter Degradation Parameters for Each Riverine Source

River	BOD20/BOD5 ratio	First Order Decay Rate (day^{-1})	Refractory/Labile Split for Organic Matter
Cape Fear	2.58	0.68	0.645/0.355
Black	2.70	0.60	0.690/0.310
Northeast Cape Fear	3.15	0.34	0.786/0.214

3.2 Point Source Inputs

A similar procedure as that described in the previous section was used to define the loading time histories from the point sources that discharge directly to estuary. After reviewing discharge records provided by the NC Division of Water Quality, it was decided that a total of twenty point sources discharged sufficient organic matter and/or nutrients to justify including them in the model of the Lower Cape Fear River Estuary. These point sources were distributed throughout the estuary both upstream and downstream of Wilmington (Figure 13). As the owner of several of these facilities has changed over the years, the twenty sources were uniquely identified using their DWQ permit number (Table 9). The following sections describe the method for estimating the flow, temperature, and water quality load time histories for these point sources.

3.2.1 Flow Specification

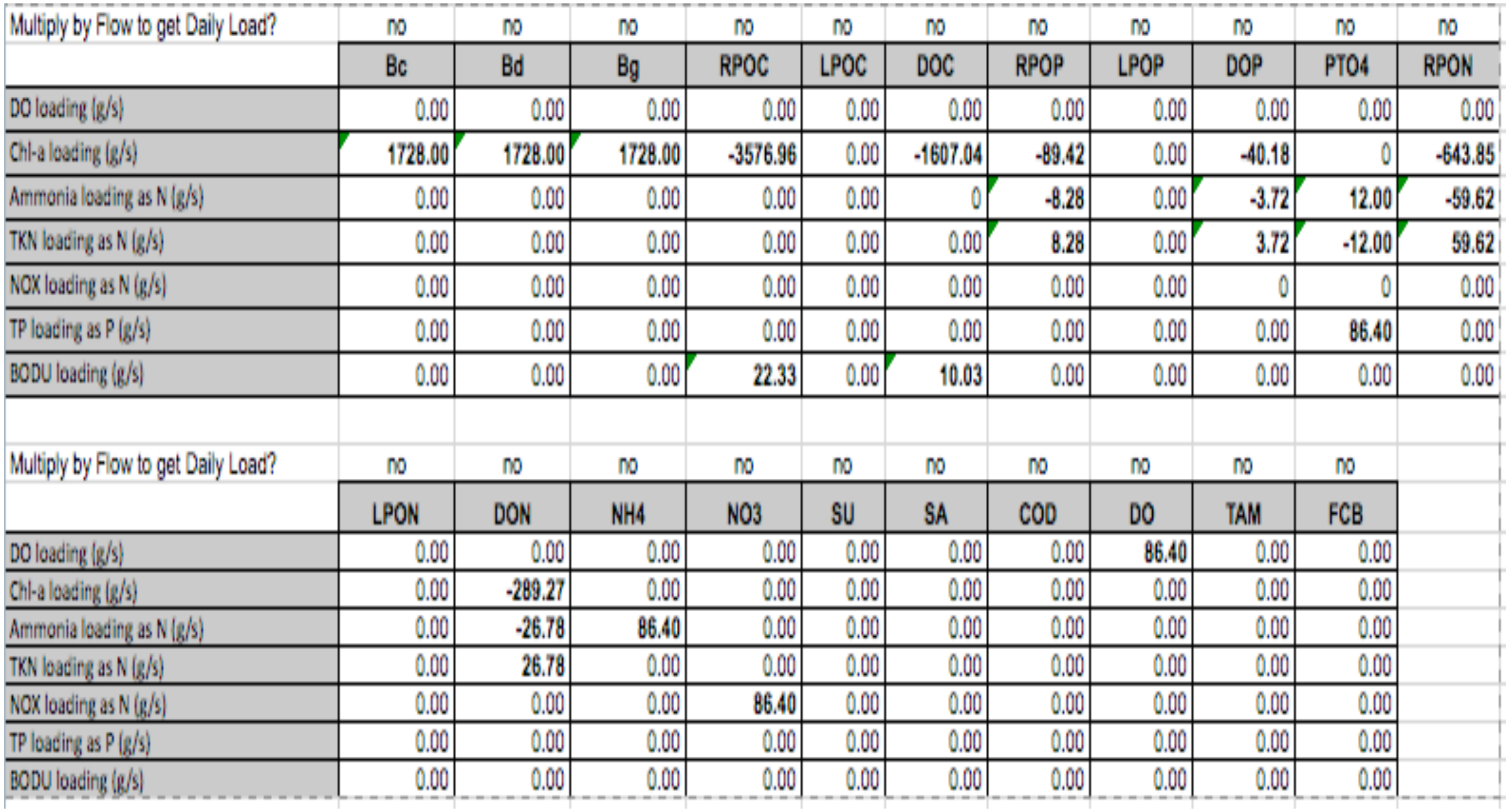
Specification of the flows for the twenty wastewater point sources was taken from the discharge monitoring reports, which were provided by NC Division of Water Quality. Flows were generally provided on a monthly basis in million gallons per day. The only changes made to these flows were to convert them from this unit to that used by the model (m^3/s). Unlike the riverine sources, the wastewater data were not interpolated to a daily time step, but instead were left as monthly data.

3.2.2 Temperature and Concentration Specification

Temperature time histories were not available in the discharge monitoring reports but were required by the model. These time histories were estimated in the same way as the riverine sources. The five data sources available for the riverine inputs (Table 6) were used for the twenty wastewater sources. For each of these, the closest monitoring location was used to represent the temperature of the water for that source.

The EFDC model also requires a water quality load time history for each of the wastewater sources. This information is provided to the model along with the riverine sources in the WQPSL.INP file. The data format needed by the EFDC model for these two types of sources is identical. Because the data needs and input data were so similar, it was decided to create this information using basically the same procedure as that for the riverine sources (Figure 11).

Table 8. Parameter Matrix for Creating Cape Fear Point Source Loading Time History



Multiply by Flow to get Daily Load?	no	no	no	no	no	no	no	no	no	no	no
	Bc	Bd	Bg	RPOC	LPOC	DOC	RPOP	LPOP	DOP	PTO4	RPON
DO loading (g/s)	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Chl-a loading (g/s)	1728.00	1728.00	1728.00	-3576.96	0.00	-1607.04	-89.42	0.00	-40.18	0	-643.85
Ammonia loading as N (g/s)	0.00	0.00	0.00	0.00	0.00	0	-8.28	0.00	-3.72	12.00	-59.62
TKN loading as N (g/s)	0.00	0.00	0.00	0.00	0.00	0.00	8.28	0.00	3.72	-12.00	59.62
NOX loading as N (g/s)	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0	0	0.00
TP loading as P (g/s)	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	86.40	0.00
BODU loading (g/s)	0.00	0.00	0.00	22.33	0.00	10.03	0.00	0.00	0.00	0.00	0.00

Multiply by Flow to get Daily Load?	no	no	no	no	no	no	no	no	no	no
	LPON	DON	NH4	NO3	SU	SA	COD	DO	TAM	FCB
DO loading (g/s)	0.00	0.00	0.00	0.00	0.00	0.00	0.00	86.40	0.00	0.00
Chl-a loading (g/s)	0.00	-289.27	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Ammonia loading as N (g/s)	0.00	-26.78	86.40	0.00	0.00	0.00	0.00	0.00	0.00	0.00
TKN loading as N (g/s)	0.00	26.78	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
NOX loading as N (g/s)	0.00	0.00	0.00	86.40	0.00	0.00	0.00	0.00	0.00	0.00
TP loading as P (g/s)	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
BODU loading (g/s)	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00

Figure 13. Wastewater Treatment Plant Source Locations

Table 9. Description of Point Sources

Source No.	NPDES Permit No.	Name of Source	Category
1	NC0000663	Dupont-Wilmington/Brunswick	WWTP
2	NC0000663	Dupont-Wilmington/Brunswick	WWTP
3	NC0000663	Dupont-Wilmington/Brunswick	WWTP
4	NC0001112	Arteva Specialties-Wilmington	WWTP
5	NC0001112	Arteva Specialties-Wilmington	WWTP
6	NC0003298	International Paper	WWTP
7	NC0021334	Southport, Town-WWTP/Southport	WWTP
8	NC0023256	Carolina Beach, Town-WWTP	WWTP
9	NC0023965	Wilmington-Northside WWTP	WWTP
10	NC0023973	Wilmington-Southside WWTP	WWTP
11	NC0025763	Kure Beach WWTP, Town Of	WWTP
12	NC0027065	Archer Daniels Midland Co.	WWTP
13	NC0059234	Takeda Chemical Products USA	WWTP
14	NC0059234	Takeda Chemical Products USA #2	WWTP
15	NC0065676	Leland Industrial Park WWTP	WWTP
16	NC0075540	Belville, Town – WWTP	WWTP
17	NC0082295	Fortron Industries	WWTP
18	NA	Cape Fear River	Upstream River
19	NA	Black River	Upstream River
20	NA	NE Cape Fear River	Upstream River
21	NA	NE Cape Fear, estuary 1	Estuarine
22	NA	NE Cape Fear, estuary 2	Estuarine
23	NA	NE Cape Fear, estuary 3	Estuarine
24	NA	NE Cape Fear, estuary 4	Estuarine
25	NA	NE Cape Fear, estuary 5	Estuarine
26	NA	NE Cape Fear, estuary 6	Estuarine
27	NA	Black River, estuary 1	Estuarine
28	NA	Black River, estuary 2	Estuarine
29	NA	Cape Fear, upper estuary 1	Estuarine
30	NA	Cape Fear, upper estuary 2	Estuarine
31	NA	Cape Fear, upper estuary 3	Estuarine
32	NA	Cape Fear, lower estuary 1	Estuarine
33	NA	Cape Fear, lower estuary 2	Estuarine
34	NA	Cape Fear, lower estuary 3	Estuarine
35	NC0086819	Brunswick Co. WWTP	WWTP
36	NC0001228	GE – Wilmington	WWTP
37	NC0003875	Occidental Chemical	WWTP

The only differences in the procedure used to create the loading time histories for the wastewater sources resulted from there being a slightly different set of water quality parameters in the discharge monitoring reports. Twenty-day BOD measurements were not available, but for three of the major sources (International Paper, Wilmington Southside WWTP, Wilmington Northside WWTP) there was a long-term BOD study undertaken. In addition, unlike the riverine water quality data set, some of the reported wastewater data were given as flow-weighted concentrations, whereas others were given as a load. For this reason, the conversion parameter matrix used to create the water quality load time histories varied from location to location, and the load calculations were done only when water quality concentrations were given. A complete set of the conversion parameter matrices is available in Appendix A along with the information showing which parameters for which sources required load calculation using the flow record.

Three of the twenty wastewater sources undertook additional monitoring to quantify the degradation rate of their organic matter. Two long-term BOD studies were done on the International Paper wastewater discharge. In addition, long-term BOD measurements were undertaken for the Wilmington Northside and Wilmington Southside municipal wastewater discharges. In all of these studies BOD was measured over approximately 100 days, while additional monitoring was done to measure changes in nitrogen compounds that might result if the waste contained an appreciable nitrogenous biochemical oxygen demand (NBOD).

These long-term BOD data were analyzed by separating the total BOD into carbonaceous and nitrogenous biochemical oxygen demands (CBOD and NBOD). The NBOD exerted was estimated by assuming that each mg/L reduction in total Kjeldahl nitrogen in the waste would result in an oxygen demand of 4.57 mg/L. The carbonaceous BOD was estimated as the total BOD exerted minus the NBOD exerted. The NBOD and CBOD were plotted as a function of time, and the following equation was used to fit a line to the CBOD vs. time data:

$$CBOD(t) = rBOD_u(1 - e^{-k_{dr}t}) + rBOD_u \frac{k_{dr}}{k_{dr} - k_{dl}}(e^{-k_{dl}t} - e^{-k_{dr}t}) + lBOD_u(1 - e^{-k_{dl}t}) \qquad (1)$$

where CBOD(t) is the carbonaceous BOD exerted at time t, $rBOD_u$ and lBODu are the ultimate BODs of the refractory and labile fractions of organic carbon, and k_{dl} and k_{dr} are the first-order decay rates of the refractory and labile organic carbon fractions. This equation assumes that the carbonaceous BOD exertion occurs as a two-step process where refractory CBOD is first degraded to labile CBOD, which then degrades while exerting an oxygen demand. This model is consistent with the organic carbon fate processes modeled in EFDC (see DOC and RPOC constituents, Figure 2).

For the International Paper waste, the two long-term BOD showed similar results. For the test done with wastewater collected on July 20, 2003 (Figure 14), the NBOD component was approximately 20%, and the CBODu was approximately 90 mg/L. In the wastewater collected on July 27, 2003 (Figure 15), the NBOD was similar to the earlier measurement, but the $CBOD_u$ was lower, at about 60 mg/L.

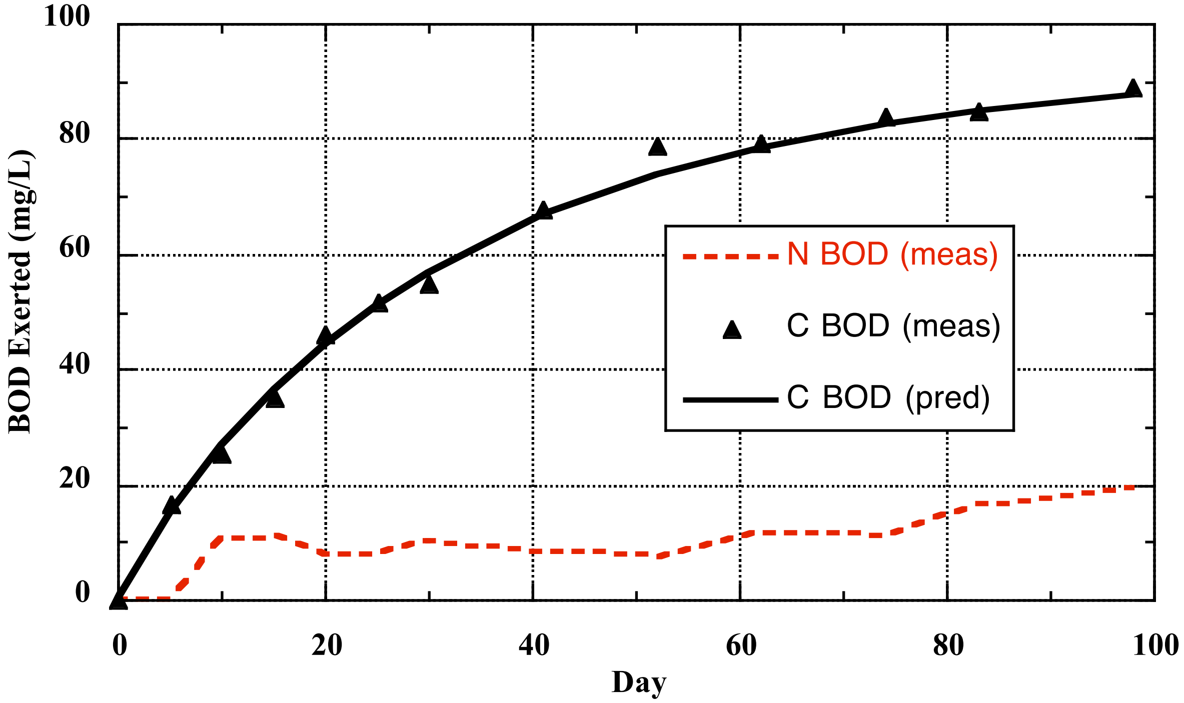


Figure 14. Long-term BOD Measurement, International Paper, July 20, 2003.

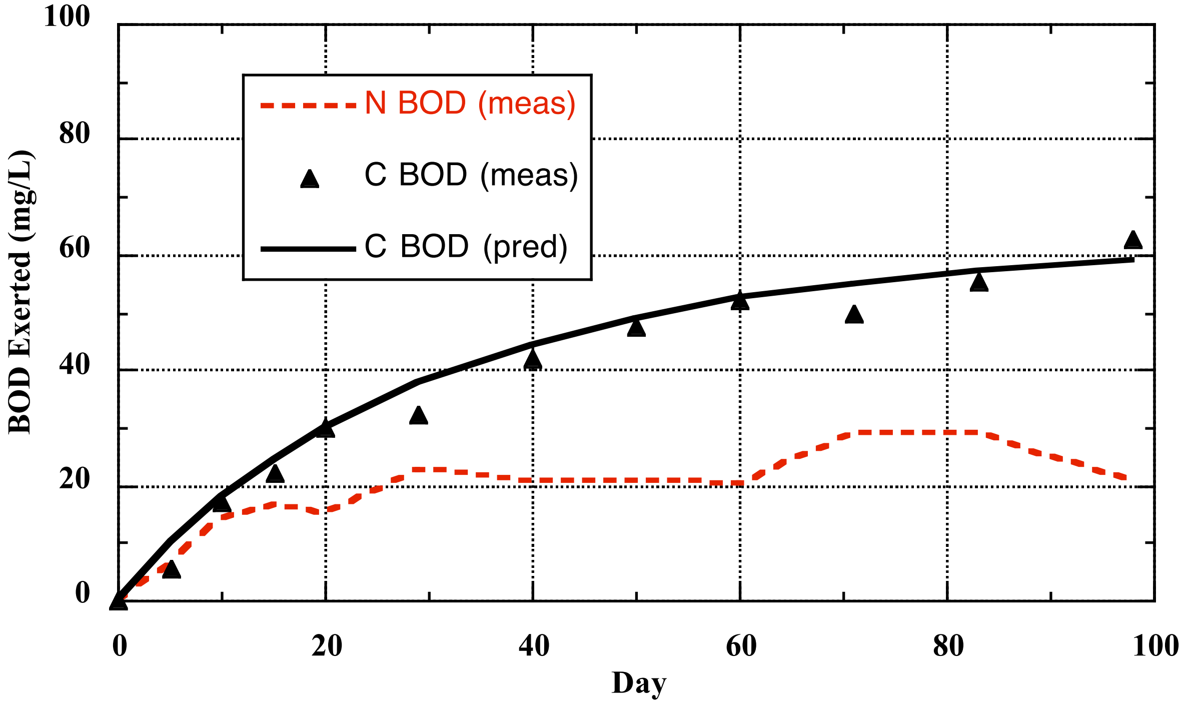


Figure 15. Long-term BOD Measurement, International Paper, July 27, 2003.

In both tests of the International Paper long-term BOD, the predicted CBOD time history matched the observed data quite well (Figure 13 and 14). From these tests, the fraction of organic carbon to be refractory was found to be approximately 75%, when using decay rates of labile and refractory organic carbon of 0.15 day^{-1} and 0.03 day^{-1} respectively (Table 10).

Table 10. Degradation Rates and Fractionation of International Paper and Wilmington Municipal Wastewaters

Location and Test	Labile First Order Decay Rate (day^{-1})	Refractory First Order Decay Rate (day^{-1})	Labile Ultimate BOD (mg/L)	Refractory Ultimate BOD (mg/L)	Fraction of Total Organic Carbon that is Refractory
IP, July 20, 2003	0.15	0.03	23	69	75%
IP, July 27, 2003	0.15	0.03	15.5	46.5	75%
Wilmington Northside	0.15	0.03	16.1	6.9	30%
Wilmington Southside	0.15	0.03	0.7	0.3	30%

The results of the long-term BOD measurements of the two Wilmington wastewater discharges looked significantly different from one another, and also different from the long-term BOD measurement of the International Paper wastewater. The test using the sample from Wilmington Northside WWTP discharge (Figure 16) had significantly more NBOD than CBOD. The NBOD exerted was approximately 30 mg/L after 100 days, but the CBOD at this time was less than 5 mg/L (Figure 16).

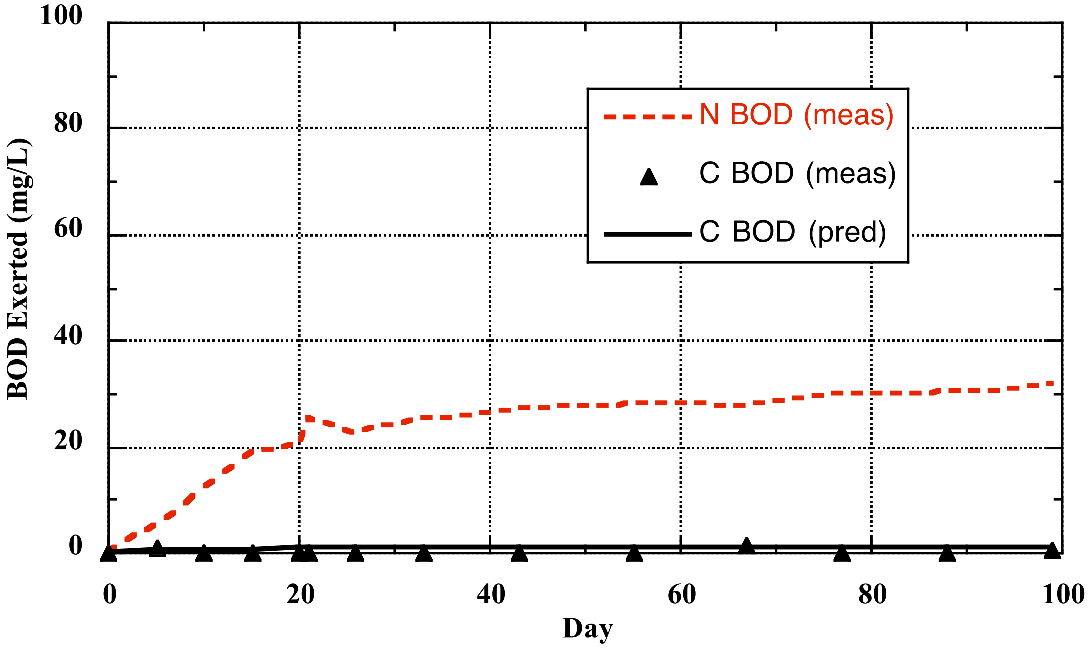


Figure 16. Long-term BOD Measurement, Wilmington Northside WWTP.

The test using a sample from the Wilmington Southside WWTP also had a significantly higher NBOD than CBOD (Figure 17), but both of these values were significantly higher than that seen for the Northside wastewater. The long-term test of the Southside WWTP sample showed an NBOD of nearly 100 mg/L, which was exerted within approximately ten days (Figure 17). The CBOD was lower, and took longer to be fully exerted. For both of these measurements, however, it was possible to model the CBOD exerted curve using the model equation (Eq. 1). Using these long-term BOD measurements, the organic matter in each of these wastewaters was fractionated into labile and refractory components (Table 10), with 30% of the Wilmington Northside and Southside wastewater assumed to be in the refractory component.

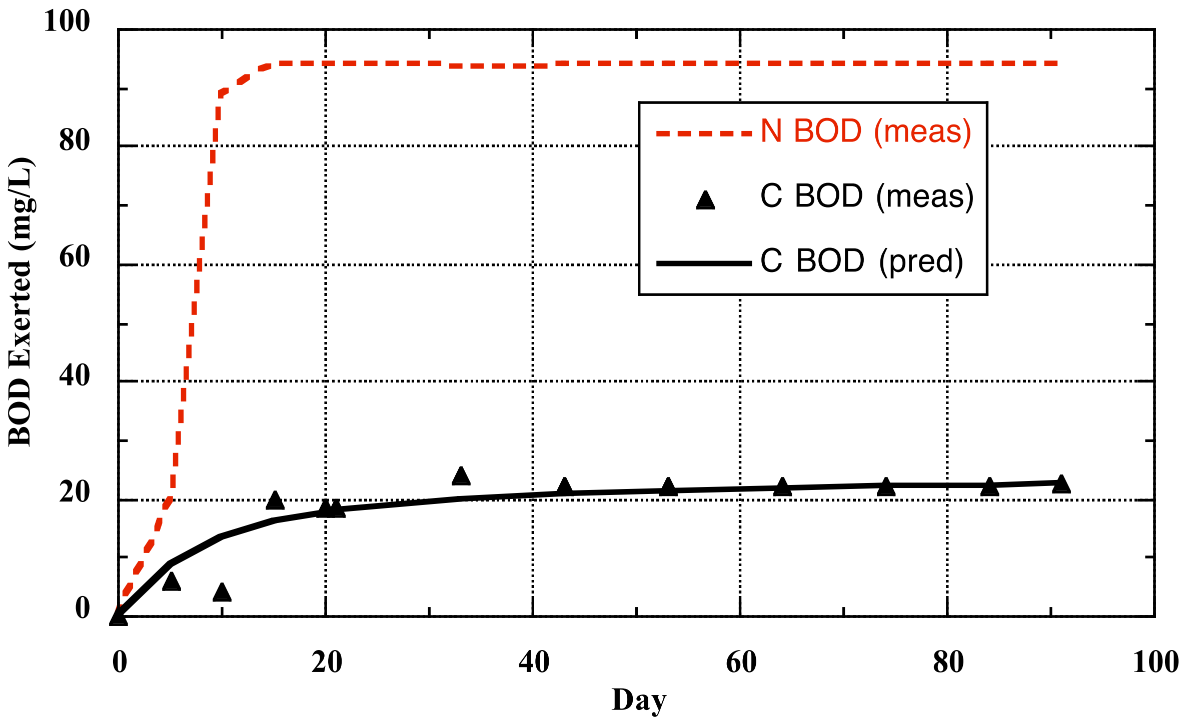


Figure 17. Long-term BOD Measurement, Wilmington Southside WWTP

3.3 Downstream Boundary Inputs

The southern boundary of the model grid, at the mouth of the Lower Cape Fear River near Southport, was specified as an elevation boundary (Figure 3). At this boundary there exist four cells (I=30:33, J=5). For these cells, information specifying the water surface elevations, salinity and temperatures, and water quality concentrations were specified for the complete time period that was modeled (November 2003 – January 2006). The following sections describe how each of these boundary conditions was specified in the model.

3.3.1 Water Surface Elevation Specification

The downstream elevation boundary condition was specified as the sum of elevation variations due to tidal motions, which were specified with tidal harmonic data, and an elevation time history that was used to represent elevation variations due to weather events. For the tidal harmonic data, a radiation separation boundary condition was used that allows for the outgoing radiation of waves generated within the model region (Bennett, 1976; Blumberg & Kantha, 1985). The tidal harmonics were determined from 6-min water surface elevation data from the NOAA station at Southport, North Carolina (Station No. 8659084) that were collected from August 1 – December 31, 2006. The data were downloaded from the NOAA's tides and current web site (tidesandcurrents.noaa.gov). The 6-min water surface elevation data were decomposed into tidal harmonic constituents using the FORTRAN program lsqhs.f that was provided with EFDC. The program produced a harmonic description of the elevation data that was dominated by the semi-diurnal (M_2, S_2, N_2) and diurnal (O_1) components (Table 11).

Table 11. Tidal Harmonic Constituent Data Used to Specify Open Boundary Elevation

Tidal Component	Period (sec)	Amplitude (m)	Phase (sec)
M2	44714	0.6431	-11019
S2	43200	0.0994	-14422
N2	45570	0.1328	-18722
O1	92950	0.0776	-43968
M4	22357	0.0023	6837.7
M6	14905	0.0045	6704.8
K2	43082	0.0296	5368.2

It was expected that a significant amount of flushing of the system might occur during periods when the water surface elevations in the estuary would either rise or fall due to episodic events such as hurricanes and other major weather events. While the effects of flooding rains would be captured with the flow data, it was believed that the effects of storm surges on the open boundary elevation would not be represented either by the flow time history or by the tidal harmonic forcing. For this reason the open boundary elevation specification also included low-pass filtered elevation data. For this specification it was necessary to have a data set near the model's open boundary at Southport during the time period to be modeled (2003-2005). While a NOAA operated tide gauge was available at Wilmington (Station No. 8658120), it was decided that these data were better used as calibration data since the station is located well within the estuary. In addition, it was felt that using Wilmington for specification of tidal amplitudes might bias the specification of wetland areas within the estuary, which was done iteratively in such a way so as to match the observed attenuation of the tidal elevation signal. Instead, elevation data at Sunset Beach (Station No. 86599897), which is on the Atlantic coast near Southport, were used to for this purpose. Hourly data from January 2003 to December 2006 were taken from the NOAA web site. The hourly data were low-pass filtered using a Butterworth filter (Roberts and Roberts 1978) having a 50-hour cutoff time period. The cutoff time period was selected to retain the majority of the elevation variations occurring over a time scale consistent with the passage of storm events. It was found that a 50-hour cutoff time period filtered out the tidal elevations sufficiently well while allowing longer period elevation variations to remain in the filtered data.

3.3.2 Temperature and Concentration Specification

The temperature boundary condition at the southern open boundary was specified in a fashion nearly identical to that of the river boundaries described earlier. A complete time history for the model time period was developed using a combination of sources including the Lower Cape Fear River Program and the continuous monitoring data collection performed by the USGS. The southern open boundary condition for temperature used the fifth time history created for the EFDC temperature time series input file TSER.INP. This time series was also used for some of the wetland sources (Table 6). It was created by combining data from the USGS continuous monitoring station at Marker 12 (Station No. 02108820) while this station was operating (11/7/03-12/2/04), and using the Lower Cape Fear River Program data from station M18 for the other times. The USGS data were used as daily time-averaged data. The LCFRP data were collected at monthly intervals, and were interpolated linearly by EFDC to obtain the necessary temperature time history.

To run the EFDC hydrodynamic model, a salinity time series was also needed for the surface and bottom layer at the open boundary. Since the USGS data station closest to the model boundary (Station No. 02108820, Marker 12) was well removed from the actual boundary at Southport, an estimation procedure was used to create the salinity time history. Near top and near bottom salinities were available for this site, and were used to represent the upper and lower layer salinity. Creation of the boundary condition involved a combination of time-averaging of the 15-minute salinity data, and selection of a number of maximum values per day to represent the time history for that day. Time averaging and selection of the maximum value were used to as a means of estimating the salinity time history that might be expected at the mouth of the Cape Fear. Hourly time averages were calculated from the 15-minute data. From this time history were taken 1, 2, 4, or 8 maximum salinity values per day, with each value representing the maximum salinity for the appropriate fraction of the day. During model calibration each of these time histories was used and the calibration performance was assessed for each. It was found that the time history using two maximum values per day gave the best fit to the observed data and was therefore used to represent the boundary condition. Linear interpolation was used to calculate the salinities for the intermediate layers. During the time period when the USGS data were not available Lower Cape Fear River Program data from station SPD (Figure 6) was used to represent salinity for EFDC layer 5. Each layer was assumed to have a salinity that differed by 0.5 ppth from its neighbor. This layer-to-layer salinity difference was calculated by taking the difference between the mean salinity surface and bottom salinity values at the USGS Marker 12 station.

Several other water quality time histories were created for representing conditions at the model's southern boundary. Time histories were created for the following constituents:

- cyanophytes (blue-green algae)
- diatoms

- chlorophytes (green algae)
- orthophosphate phosphorus
- ammonia nitrogen
- nitrate+nitrite nitrogen
- dissolved oxygen

All of these time histories used data from the Lower Cape Fear River Program station M18. These data were available on a weekly to monthly time period, depending upon the season. All layers were assigned the same concentration. For the other constituents, a time-averaged value was set in the water quality control file WQ3DWC.INP using time-averaged or estimated values at station M18. The dissolved oxygen time history was estimated by assuming that the incoming water to the model region would be saturated with dissolved oxygen. The saturation concentration depended on water temperature and salinity (Chapra 1997). Water temperatures were taken from the temperature time series file. For this calculation only, the salinity was assumed to be 35 ppth.

3.4 Benthic Inputs

The EFDC water quality model includes a predictive sediment diagenesis model. For this study, however, a simpler prescriptive model was used in which benthic fluxes of dissolved oxygen and nutrients were specified as a time history. To better quantify the fluxes of dissolved oxygen between the water column and the benthos, the NC Division of Water Quality measured sediment oxygen demands (SODs) at five sites during the Summer and Fall of 2003 (Table 12).

Five sampling rounds were undertaken as part of the study, in which SOD was measured at one site within the estuary. The sites measured included sites in the upper and lower estuary, and in both the Northeast and Cape Fear Rivers (Figure 9). In general the modeling approach for using these data was to specify the SOD in the simplest manner possible that was sufficient for quantifying the impact of the benthos on the dissolved oxygen budget of the estuary. For this reason, these data were initially used by specifying a constant SOD rate in the water quality control file WQ3DWC.INP. During model calibration it was found that model prediction capability could be improved by varying the SOD as a function of water temperature. It was also found that model prediction of dissolved oxygen were improved by specifying a higher SOD for the Northeast Cape Fear as compared with the remainder of the estuary.

Temporal variation of SOD was considered in the following way. An SOD time history was created by developing a SOD vs. temperature curve that utilized the monitoring data to determine the reference SOD at 20º C and the rate at which SOD changes with changing temperature. Spatially averaged but temporally varying water temperatures were then estimated using the monitoring data. Together this information was used to specify the time variation in SOD, which was provided to the numerical model in the benthic flux input file . A non-zero nitrate flux to the sediments was also included, and was considered to vary according to temperature in the same way as SOD. The ratio of nitrate flux to SOD was determined during calibration by comparing model predicted and observed nitrate concentrations within the model region.

Table 12. Sediment Oxygen Demand (SOD) Measurements

Date	**Measurement Location**	**Latitude & Longitude**	**Water Temp. (°C)**	**SOD at ambient temp (g/m2/d)**	**SOD corrected to 20 deg C (g/m2/d)**
8/6/2003	Prince George Creek, tributary to the Northeast Cape Fear River, station located 0.5 miles upstream from its confluence with the Northeast Cape Fear River	N34° 21' 29.11" W77° 57' 7.55"	26.3	0.5189	0.3490
11/20/2003	Northeast Cape Fear River, upstream from Wilmington near channel marker 4	N34° 16' 7.67" W77° 56' 58.20"	15.9	0.1900	0.2460
10/29/2003	Cape Fear River downstream from Wilmington near channel marker 61	N34° 11' 39.30" W77° 57' 28.24"	19.3	0.4440	0.4640
7/17/2003	Cape Fear River downstream from Wilmington near channel marker 55	N34° 08' 7.8" W77° 56' 46.3"	27.6	0.4679	0.2899
10/2/2003	Town Creek, tributary to the Cape Fear River, station located 0.5 miles upstream from its confluence with the Cape Fear River.	N34° 07' 53'' W77° 57' 43''	20.7	0.6951	0.6651

3.5 Meteorological Inputs

All three EFDC sub-models (hydrodynamics, temperature, water quality) require information on meteorological conditions in the modeled region. Several options exist as to which set of data is given to the model. In the Lower Cape Fear River application, these time histories were specified in the ASER.INP and WSER.INP files:

- atmospheric pressure in millibars,
- air temperature in degrees Celsius,
- relative humidity,
- rainfall (a conversion factor is available to handle various rainfall units)
- evaporation rate (a conversion factor is available to handle various evaporation units)
- short-wave solar radiation (given as Watts/m^2, various units can be used)

- cloud cover (given as sky fraction, various units can be used)
- wind speed in m/s
- wind direction (given as the "to" direction, 0 degrees = to the north)

Data collected from the National Weather Service were used for all values except solar short-wave radiation. Data from the Wilmington International Airport were used and was assumed to represent weather conditions over the entire model region. Evaporation and precipitation were assumed to be in balance, and were therefore assumed both to be zero. Solar short-wave radiation was obtained from the National Renewable Energy Lab's National Solar Radiation Database. Hourly values of solar radiation at the Wilmington Airport (Station No. 723013) for years 2003, 2004, and 2005 were downloaded from the database's web site (www.nrel.gov/rredc/solar_data.html).

4. MODEL CALIBRATION

4.1 Description of the Calibration Time Period

A fourteen-month time period was used for model calibration (November 1, 2003 – January 1, 2005). This period of time was chosen because it offered the best set of monitoring data for establishing model forcings and for assessing model performance. A second time period (January 1, 2005 – January 1, 2006) was used for model confirmation. The model confirmation runs are described in section 5. For model calibration, the first two months of the time period (November 1, 2003 – January 1, 2004) were used for "spinning up" the model to establish initial conditions. Comparison of model predictions to data from the various monitoring programs was done for the period from January 1, 2004 to January 1, 2005.

Calibration was accomplished first using only the hydrodynamic model. Hydrodynamic calibration consisted of comparing model predicted water surface elevations, water velocities, salinities, and temperatures to corresponding values from the monitoring program. The EFDC input files describing the model grid (CELL.INP, DXDY.INP, LXLY.INP) were created as part of the hydrodynamic model calibration. These files are included in this report as Appendix B. The model time step (20 seconds), the number and location of all boundary conditions, the locations for model output, and many other parameters needed for running the model were set in the EFDC control file (EFDC.INP). This file is included in this report as Appendix C. Once the hydrodynamic model was calibrated, water quality calibration was conducted.

The model calibration period had streamflows that were generally below average for the first half of the year, and generally above average for the latter half of the year (Figure 18). After a storm in early May 2004, streamflows remained below average until August. The remainder of 2004 and 2005 until the middle of April had streamflows that were near historical average values. Flows through the summer of 2005 were generally below average (Figure 18).

Dissolved oxygen (DO) concentrations at two stations that were in the impaired region and had continuous monitors installed in 2004 (Navassa and the Northeast Cape Fear at Wilmington) showed summertime (April 1 – October 31) dissolved oxygen concentrations that varied between 3 and 7.5 mg/L (Figure 19). At both of these sites the median DO concentration was below 4.5 mg/L and the 25th percentile DO concentration was below 4.1 mg/L. DO concentrations were generally lower at the Northeast Cape Fear site, and at this site were generally lower near the bottom of the water column (Figure 19).

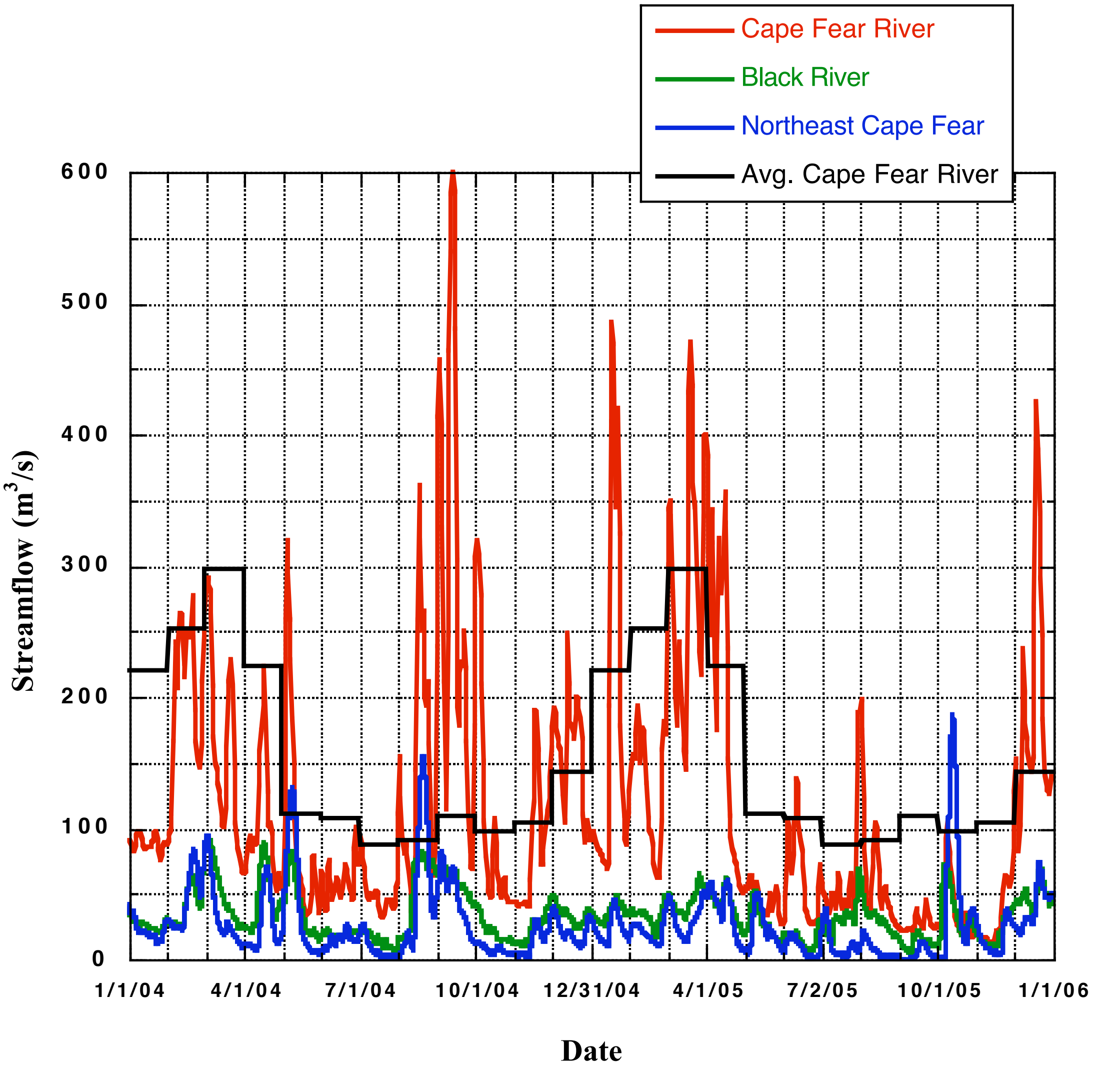
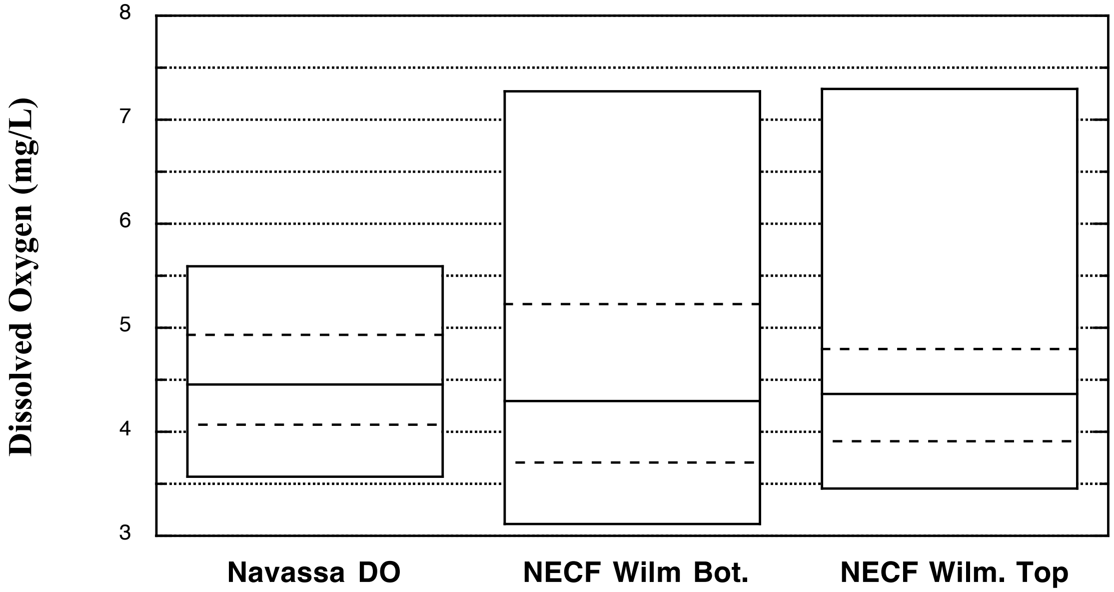


Figure 18. Streamflows at the Cape Fear River at the Lock and Dam 1 Station During the Model Time Period

4.2 Hydrodynamic Model Calibration

Hydrodynamic model calibration was performed by comparing model predictions to observations at twenty-three different locations where data had been collected by the USGS continuous monitoring program, the Lower Cape Fear River Program, or by NOAA (Table 13). These twenty-one sites span the entire model region and all three rivers that make up the Lower Cape Fear River Estuary (Figure 20). Initially hydrodynamic calibration concerned specification of the model grid. The objective of this part of the calibration task was to locate and size all the channel and wetland cells, and to establish a bottom roughness for each of these cells. Once the model grid was specified hydrodynamic calibration continued by comparing model predictions to salinity and temperature observed data. Hydrodynamic calibration is described in more detail in the following sections.



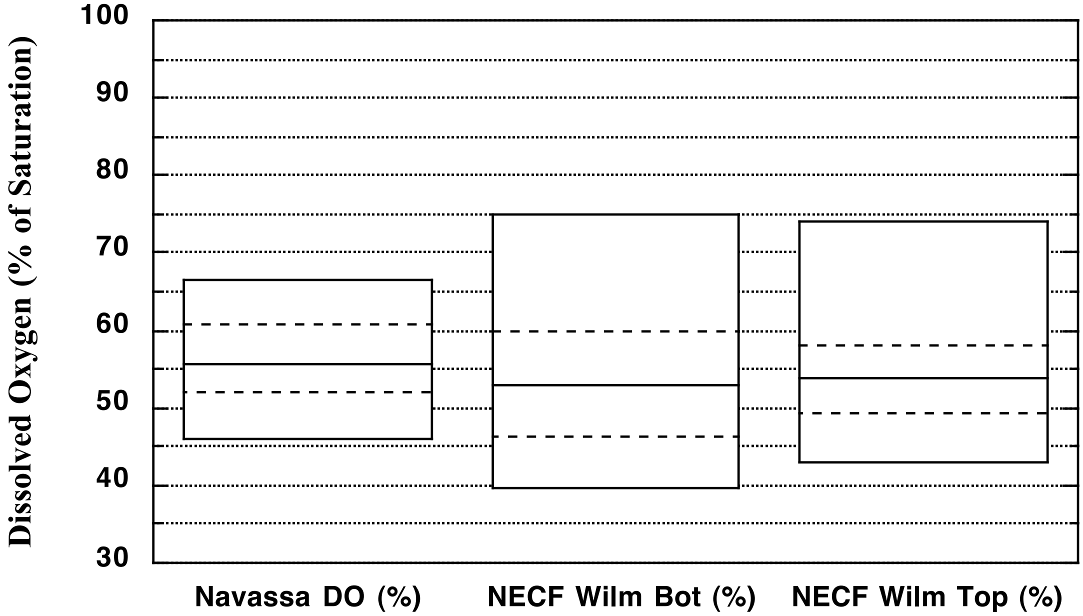


Figure 19. Dissolved Oxygen Concentrations at the Navassa and Northeast Cape Fear at Wilmington Monitoring Stations

Table 13. Locations Used for Model Calibration

EFDC Grid Cell Used (I, J)	Station Name	River	Monitoring Data Collected by
4, 84	Lock and Dam 1, 02105769	Cape Fear	USGS
4, 80	NC11	Cape Fear	LCFRP
7, 67	Black River at Currie, 02107544	Black	LCFRP
7, 66	B210	Black	LCFRP
4, 60	AC	Cape Fear	LCFRP
4, 25	IC	Cape Fear	LCFRP
43, 97	NECF at Burgaw, 02108566	Northeast Cape Fear	USGS
43, 66	NCF117	Northeast Cape Fear	LCFRP
44, 27	NCF6	Northeast Cape Fear	LCFRP
4, 11	Cape Fear at Navassa, 02107576	Cape Fear	USGS
4, 10	Nav	Cape Fear	LCFRP
22, 81	HB	Cape Fear	LCFRP
43, 15	NECF at Wilmington, 02108690	Northeast Cape Fear	USGS
18, 72	Brunswick River	Cape Fear	LCFRP
24, 68	M61	Cape Fear	LCFRP
24, 58	M54	Cape Fear	LCFRP
25, 49	M42	Cape Fear	LCFRP
25, 47	M12, 02108820	Cape Fear	USGS
26, 40	M35	Cape Fear	LCFRP
23, 21	M23	Cape Fear	LCFRP
24, 11	M18	Cape Fear	LCFRP
23,76	Wilmington Tide Gage, Station 8659084	Cape Fear	NOAA
33,5	Cape Fear at Southport, Station 8658120	Cape Fear	NOAA

4.2.1 Modeled and Observed Water Surface Elevations

Hydrodynamic model calibration began by comparing model predictions to observed water surface elevations and depths. This work took advantage of the continuous monitoring data program operated by the USGS and tide gage data available from NOAA. Model predictions of tide varying elevations were compared to observed data at these seven locations:

1. Cape Fear River at Lock and Dam 1 (USGS 02105769)
2. Black River at Currie (USGS 02107544)
3. Northeast Cape Fear River at Burgaw (USGS 02108566)
4. Cape Fear River at Navassa (USGS 02107576)

5. Northeast Cape Fear River at Wilmington (USGS 02108690)
6. Cape Fear River at Marker 12 (USGS 02108690)
7. Cape Fear River at NOAA's Wilmington Tide Gage (NOAA 8658120)

The initial model grid used the Lower Cape Fear River Estuary grid created by Tetra Tech (2001). It was recognized in Tetra Tech's earlier study that additional work needed to be done on the model grid. Specifically, two of the recommendations from the earlier modeling effort were that additional information be gathered on the bathymetry within the estuary, and that additional work be done to quantify the effect of the riparian wetlands within the estuary. Both recommended areas of additional work were undertaken during the hydrodynamic model calibration. Twenty-one river cross-sections (Figure 9) were surveyed by the Division of Water Quality as part of the data collection phase of this modeling project (go to the LCFR model website at www.coe.uncc.edu/~jdbowen/LCFR to view cross-sections). All of this new bathymetric information was incorporated into the updated specification of the model grid.

Additional work was also done to specify the location and size of "wetland" cells that adjoin the main river channel. The overall strategy in determining wetland surface area was to use the information on the attenuation of the tidal amplitude to determine the distribution and overall area of the fringing marshes. Thus the wetland area was determined to some extent as a calibrated value. The wetting/drying routines within EFDC were not used, thus water depths had to be specified to keep the cells wet during spring tides.

This work relied upon wetland delineations performed by the NC Division of Coastal Management (NC Division of Coastal Management, 1999). In the model grid these cells were assumed to be shallower (depth = approximately 1 m) and have a higher bottom roughness (z_0 = 0.04 m) than the channel cells. An initial estimate of the location and size of these cells was meant to approximate the surface area of off-channel storage available in two of the wetland types (riverine swamps and saltwater marshes) identified by the Division of Coastal Management (Figure 5). With this distribution of wetland cells as a starting point a sensitivity analysis was performed to investigate how changing the total surface area of these cells would affect the attenuation of incoming tidal waves. Multipliers of 1, 2, 5, 10 were applied to the width of each marsh cell, and the effect on the M2 component of the tide was calculated for the seven locations listed earlier that span the model region. As expected, it was found that increasing the width of the marsh cells increased the attenuation of the tidal signal (Figure 21). Width ratios of 5 and 10 seemed to over attenuate the tidal signal in the oligohaline portion of the estuary. The width ratio of 2.0 seemed to give the best overall results, but this run showed inadequate damping in the Navassa and Wilmington areas. Three additional cases were tried that used various width ratios, and distributions of wetland cells (Figure 22). In the end, the case with a uniform width ratio of 2.0, and the "v1" version of the wetland cell distribution (shown in green in Figure 22) was chosen as optimal. The final size and distribution of wetland cells has these wetland cells along each river above Wilmington, and also in the area between Wilmington and Town Creek (Figure 6).

Figure 20. Monitoring Stations Used for Comparing Monitoring Data to Hydrodynamic Model Predictions.

With the specification of the model grid set model predictions of elevation were examined during the entire 2004 calibration period and at shorter time periods within the calibration period. The EFDC input files that define the model grid (CELL.INP, DXDY.INP, and LXLY.INP) are available in Appendix B. For the model/data comparison of the full 2004 calibration period, model predictions were printed twice per day and compared with observations at six stations: three near the upstream extent of the model region (Cape Fear at Lock and Dam 1, Black at Currie, NE Cape Fear at Burgaw), two in the impaired region near Wilmington (Cape Fear at Navassa, NE Cape Fear at Wilmington), and one in the lower estuary region south of Wilmington (Marker 12). Of interest was how the model responded to the longer-term changes in water surface elevation that would likely lead to episodes of flushing from the estuary. These flushing events could be seen in the flow record (Figure 18) during late August, September, and October 2004. They would also be expected in the variation of water surface elevation that would occur during the transitions between neap and spring tides. The water elevations at the three most upstream locations show increased elevations during the high flow time period in both the observations and the model predictions (Figures 23 and 24). In general, the model was found to underpredict elevation increases at the Cape Fear and Northeast Cape Fear sites during periods of high river flow. The two sites around Wilmington and the lower estuary site (Navassa, NE Cape Fear at Wilmington, Marker 12) showed elevation differences from spring to neap tide that are well represented by the model (Figures 24 and 25).

To examine elevation fluctuations within a few tide cycles it was necessary to examine shorter periods within the overall calibration time period. Hourly model predictions of elevation were compared to observations at the six sites listed earlier plus one additional site, the NOAA tide gage at Wilmington. The observations at the six sites other than the NOAA tide gage relied upon water measured and logged by the continuous water quality monitors. These pressure transducers were non-vented, thus their water depth measurement were affected by changes in atmospheric measurement. In addition, it seems likely that when the instruments were serviced, they were not always placed back in the water at exactly the depth they occupied previously, which could be seen in the data record as sudden increases or decreases in depth every few weeks. These two factors limited how the observed depth data could be used for comparison to model predictions. Because of the nature of the observed data set, we did not attempt any statistical calibration evaluations of the model's water surface elevation predictions. Rather, we examined the model predictions for evidence that the model was correctly attenuating the tidal wave at various locations within the estuary, and correctly varying tidal ranges through the neap to spring cycle. Two time periods were found to have a sufficiently a long period without disruption of any of the depth data at the six sites under study. These two time periods were January 11-21, 2004 and June 16 – 23, 2004. Tidal constituents predicted by the model at several sites within the estuary were also compared to corresponding observed data (Table 14) to assess how well the model could match the attenuation and phase lag characteristics seen in the observed data set.

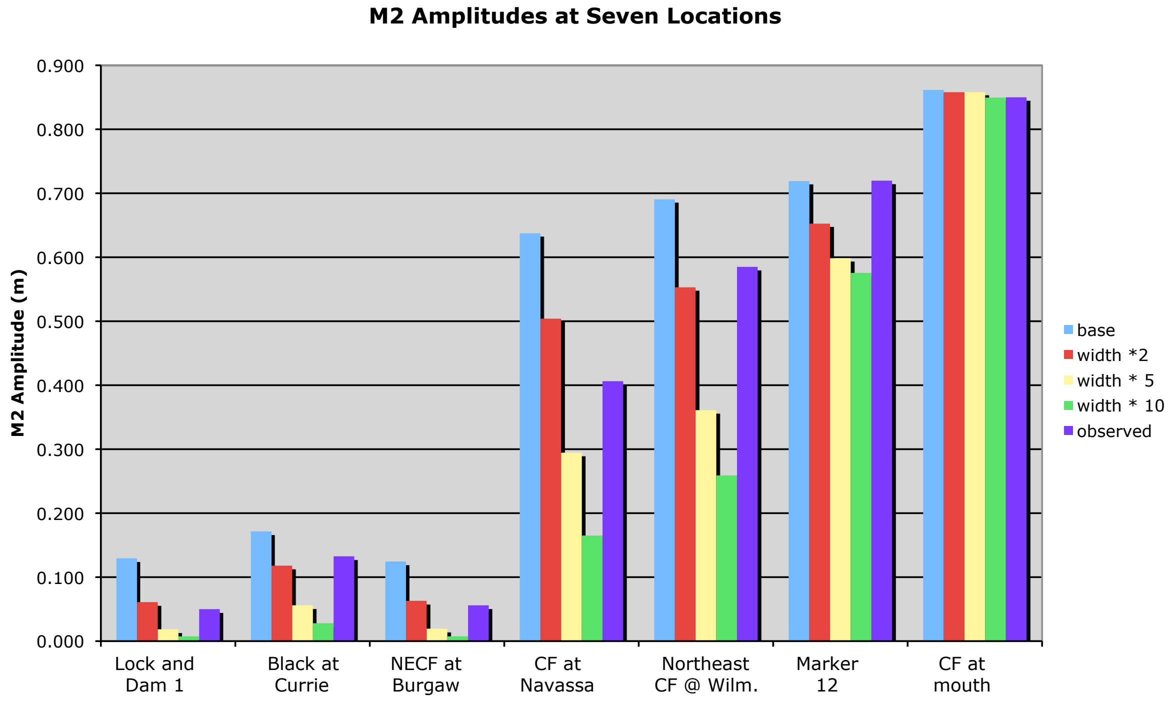


Figure 21. M2 Tidal Amplitude at Seven Stations for Various Wetland Cell Width Scenarios

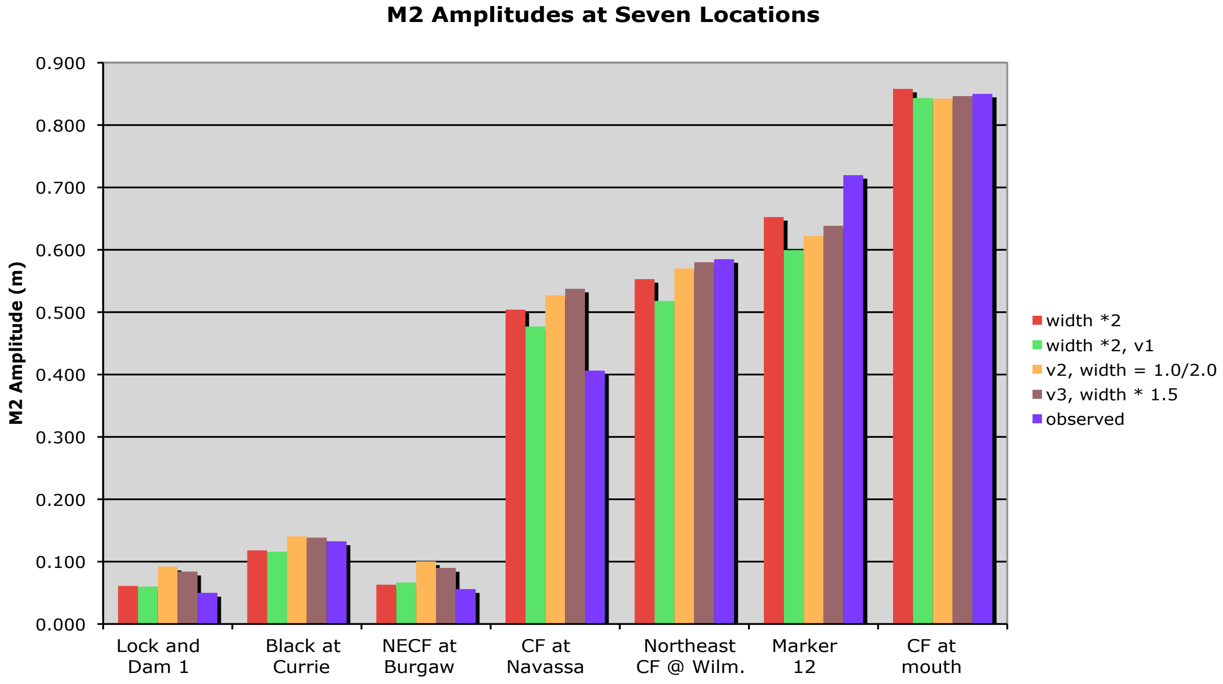
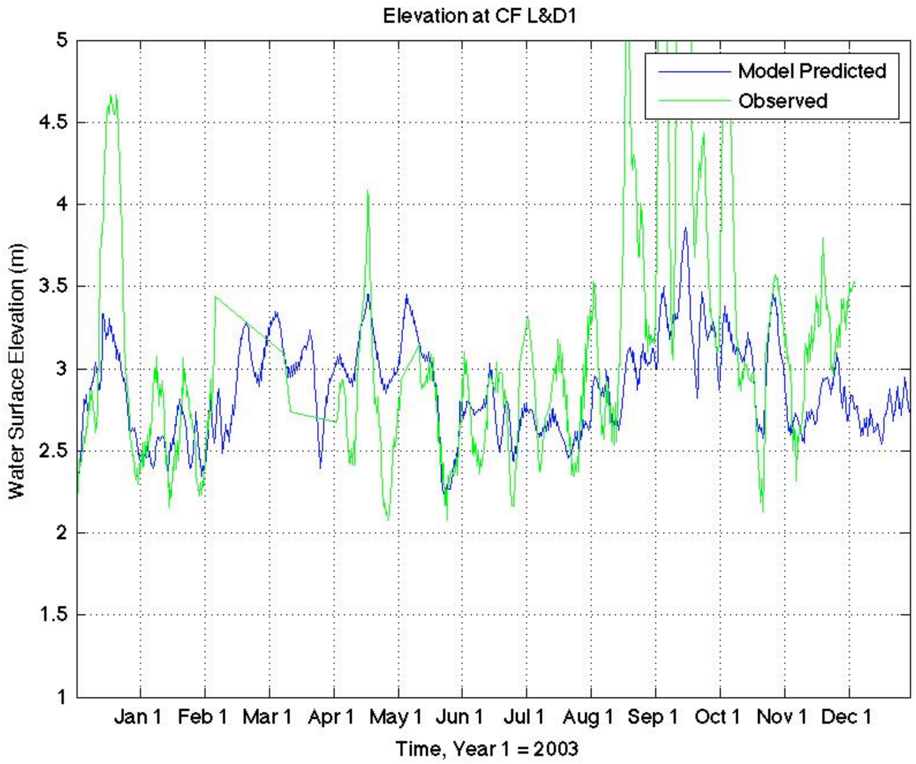


Figure 22. M2 Tidal Amplitude at Seven Stations for Various Wetland Cell Size Scenarios



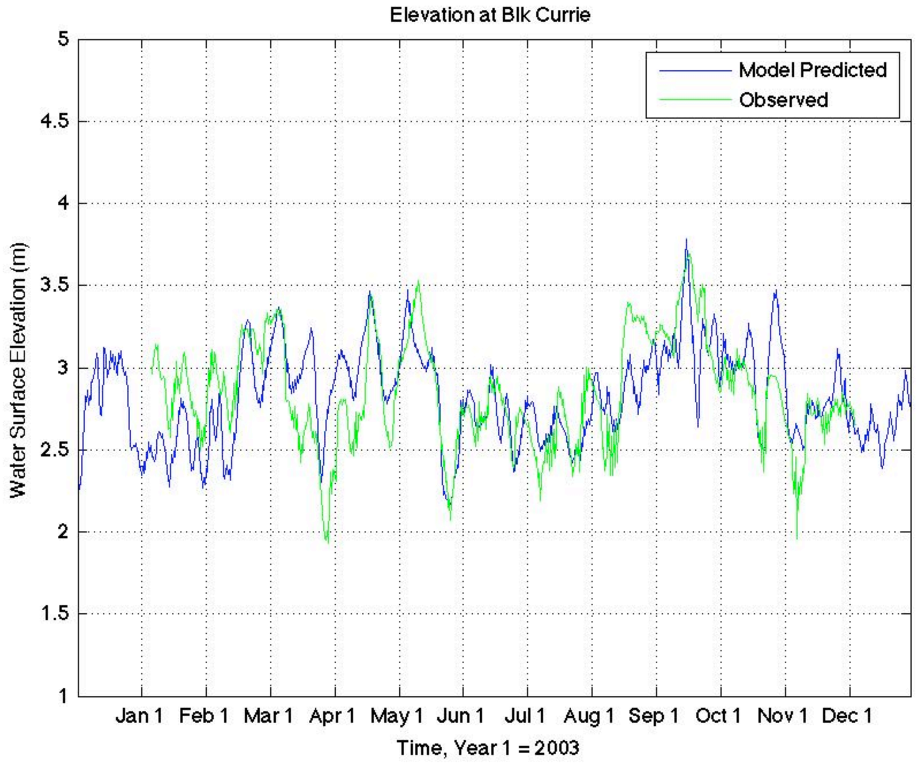


Figure 23. Model Predictions and Observed Water Surface Elevations During 2004 at Cape Fear R. Station Lock and Dam 1 and the Black R. at Currie

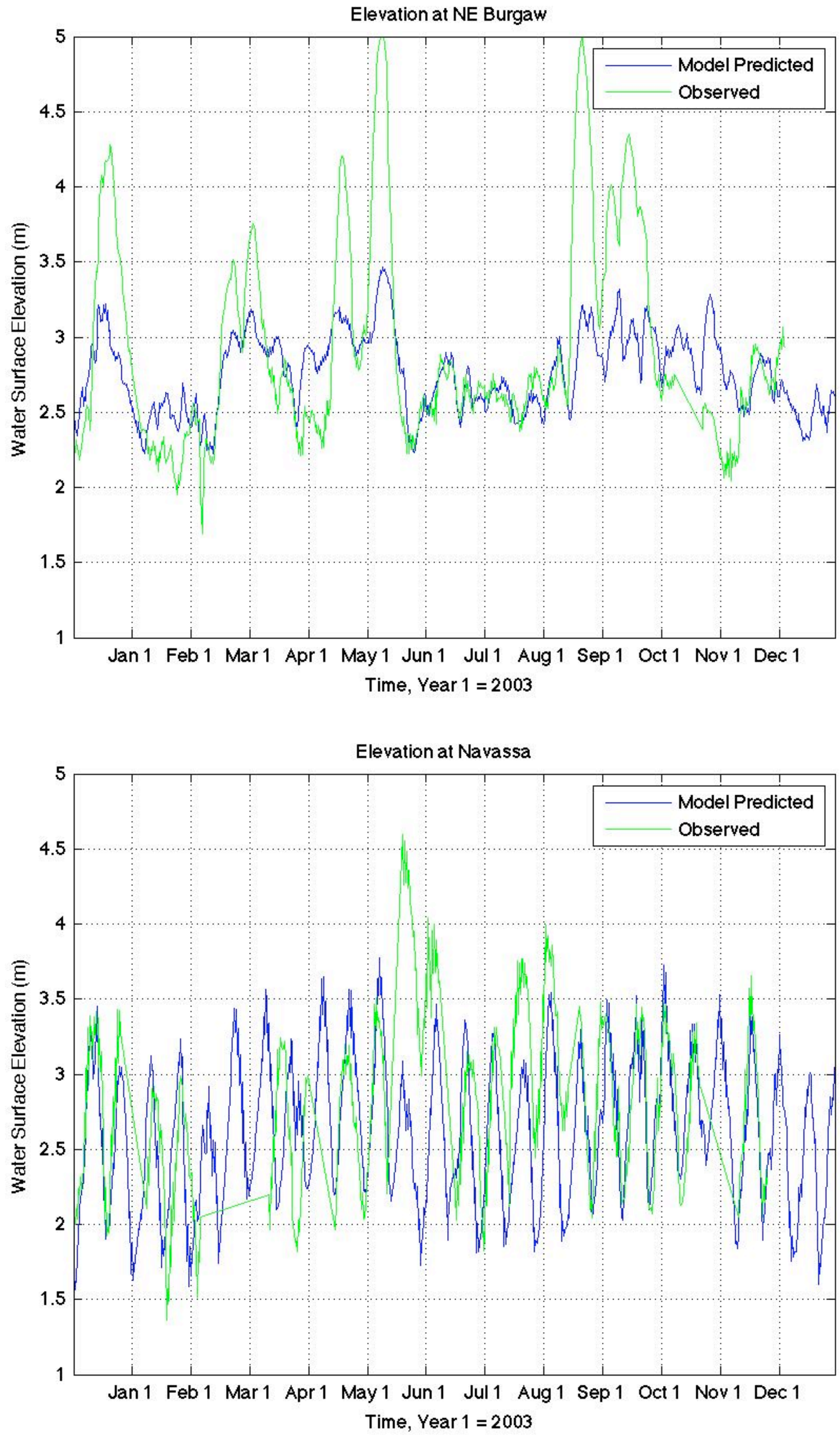
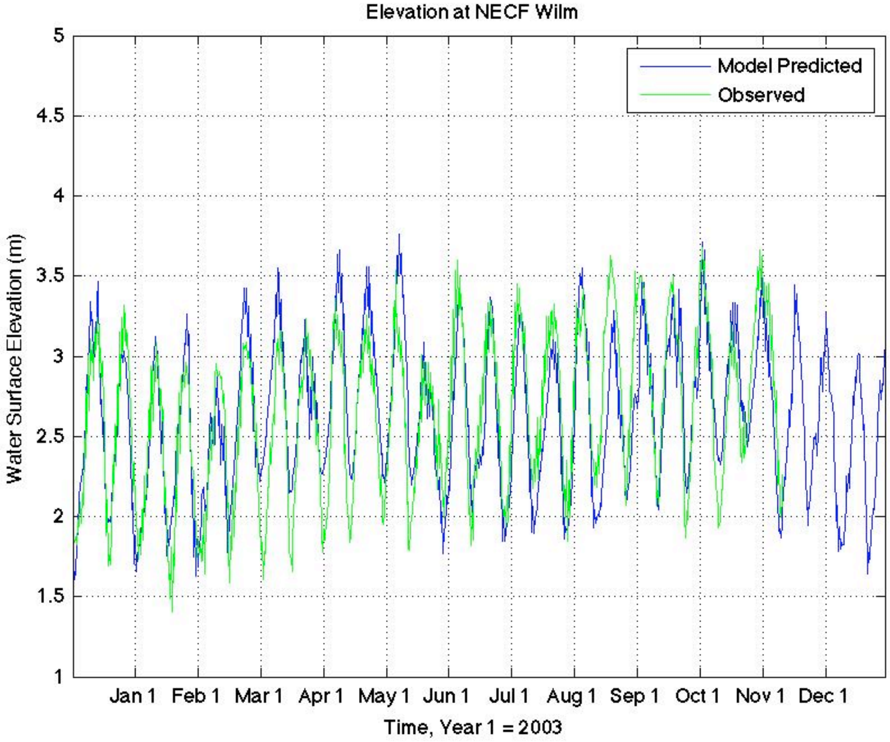


Figure 24. Model Predictions and Observed Water Surface Elevations During 2004 at NE Cape Fear at Burgaw and Cape Fear at Navassa



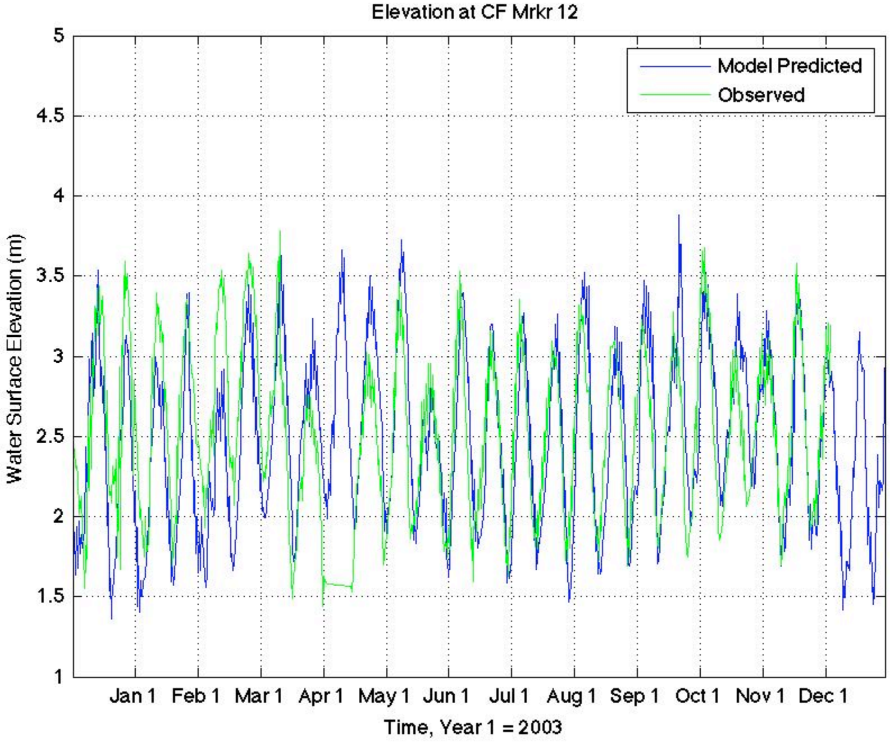


Figure 25. Model Predictions and Observed Water Surface Elevations During 2004 at NE Cape Fear at Wilmington and Cape Fear at Marker 12

Examination of the model predictions and observations during January 2004 showed that the model did a good job of simulating the attenuation of the tidal signal from lower to the upper portions of the estuary. For this comparison hourly snapshot model predictions were compared to hourly time-averaged observed data. The time-averaging of the observed data was necessary to reduce the size of the observed data files. Examination of the observed data revealed no systematic bias resulting from the averaging procedure.

The four stations in either the lower estuary (Marker 12) or the Wilmington area (Wilmington tide gage, NE Cape Fear at Wilmington, Navassa) had a close agreement between the observed and predicted tidal amplitudes (Figures 26 and 27). There does seem to be some drift in observed data at the Marker 12 station, and some disagreement in the tidal amplitude at these three stations, but overall the fit is good between model predictions and the observed data. All the stations predict well the timing of peak, although there is a consistent disagreement of about one hour between the timing of the peaks at Navassa (Figure 27). During the model calibration it was found that model predictions of the tidal phase at Navassa and farther upstream at Lock and Dam 1were relatively insensitive to changes in model parameters. Model predictions of tidal phase at this station were not as good as at the remaining three stations analyzed.

The three stations in the upper portions of the estuary (NE Cape Fear at Burgaw, Cape Fear at Lock and Dam1, Black at Currie) also show good agreement between the observed and predicted tidal amplitudes (Figures 28 and 29) during January 2004. As at the Cape Fear at Navassa, the model prediction of tidal phase at the Cape Fear at Lock and Dam1 misses the observed data by about one hour (Figure 29). Phase predictions are better at the Northeast at Burgaw (Figure 28) and the Black at Currie (Figure 29). At each location the model does a good job in simulating the attenuation of the tidal signal as it moves up into the estuary. Tidal ranges at the three upstream sites are less than 0.5 m (Figure 28 and 29), while the tidal range at Marker 12 is generally more than 1.5 m (Figure 26). In general the model slightly overpredicts attenuation in the Cape Fear and Northeast Cape Fear, and correctly simulates it in the Black River (Figures 28 and 29).

A shorter time period in June 2004 (June 16 – 23) also had an observed elevation data set that was suitable for comparison to model predictions. The same set of seven stations were analyzed by comparing hourly time histories of observed and model predicted water surface elevations. As during the other time period analyzed, the model predicted well the tidal phase at the Wilmington tide gage, at Marker 12, and at the Northeast Cape Fear at Wilmington stations, but underpredicted the tide lag at the Navassa station (Figures 30 and 31). The consistent underprediction of the time lag in the upper portion of the Cape Fear River may have something to do with the effect of the split in the river channel in the Brunswick River area. It is not expected that the relatively slight underprediction of time lag has a negative impact on the model's ability to simulate water quality conditions. As in January 2004, the model underpredicts somewhat the tidal range at Marker 12, but better represents the tidal variation at the three stations around Wilmington: the Wilmington tide gage, the Northeast Cape Fear at Wilmington, and Navassa (Figures 30 and 31).

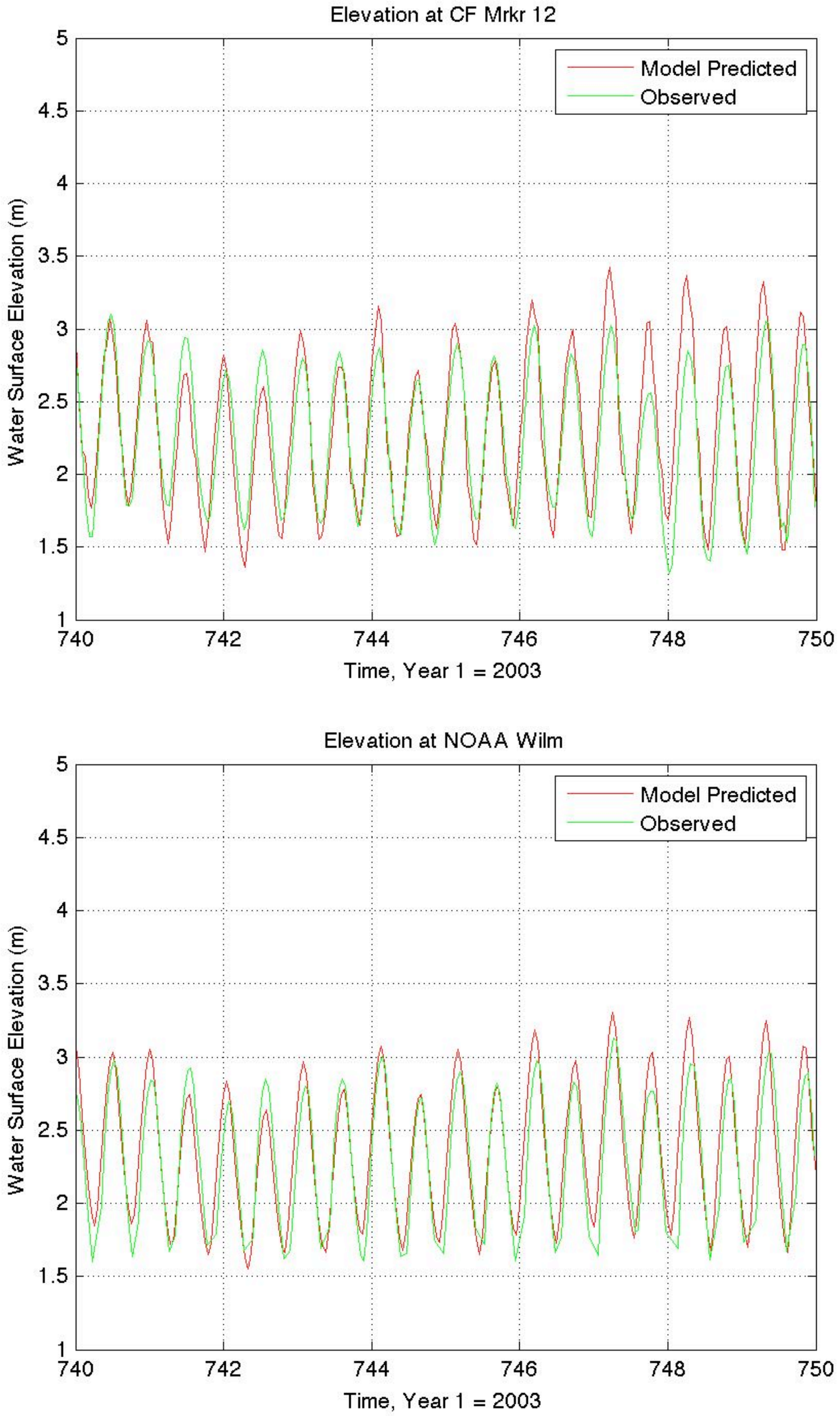


Figure 26. Model Predictions and Observed Water Surface Elevations During January 2004 (Day 740 = 1/11/2004) at Cape Fear R. Marker 12 and the Wilmington Tide Gage

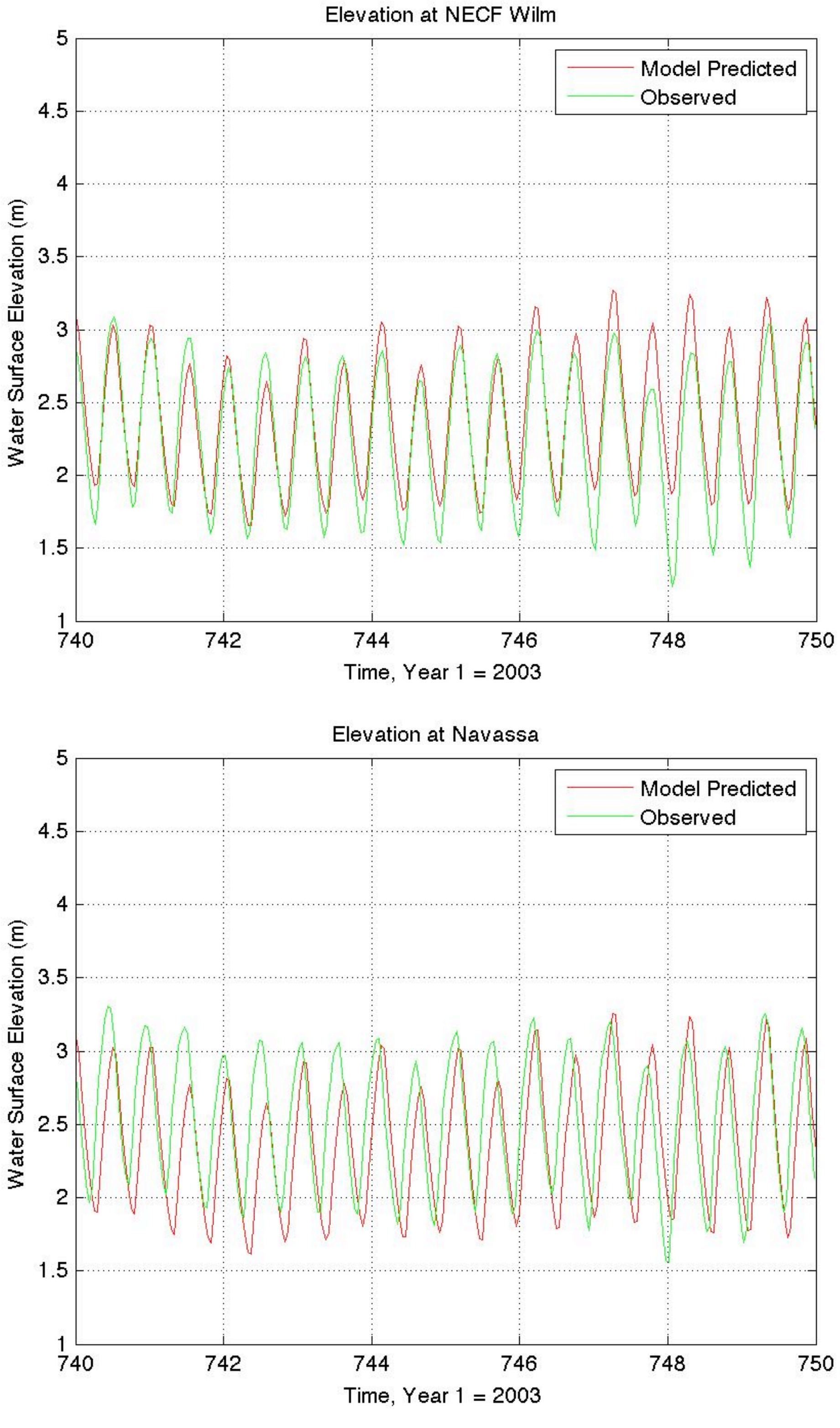


Figure 27. Model Predictions and Observed Water Surface Elevations During January 2004 (Day 740 = 1/11/2004) at NE Cape Fear at Wilmington, and the Cape Fear at Navassa.

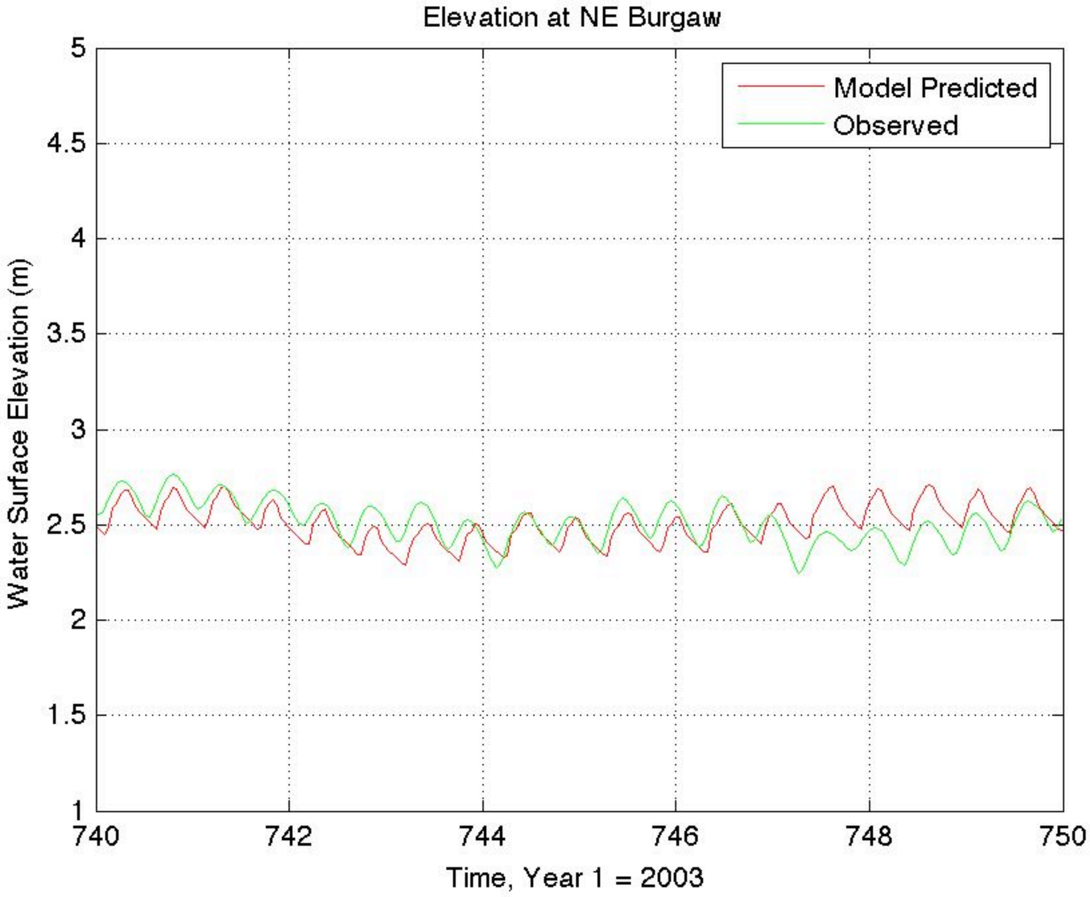


Figure 28. Model Predictions and Observed Water Surface Elevations During January 2004 (Day 740 = 1/11/2004) at NE Cape Fear at Burgaw.

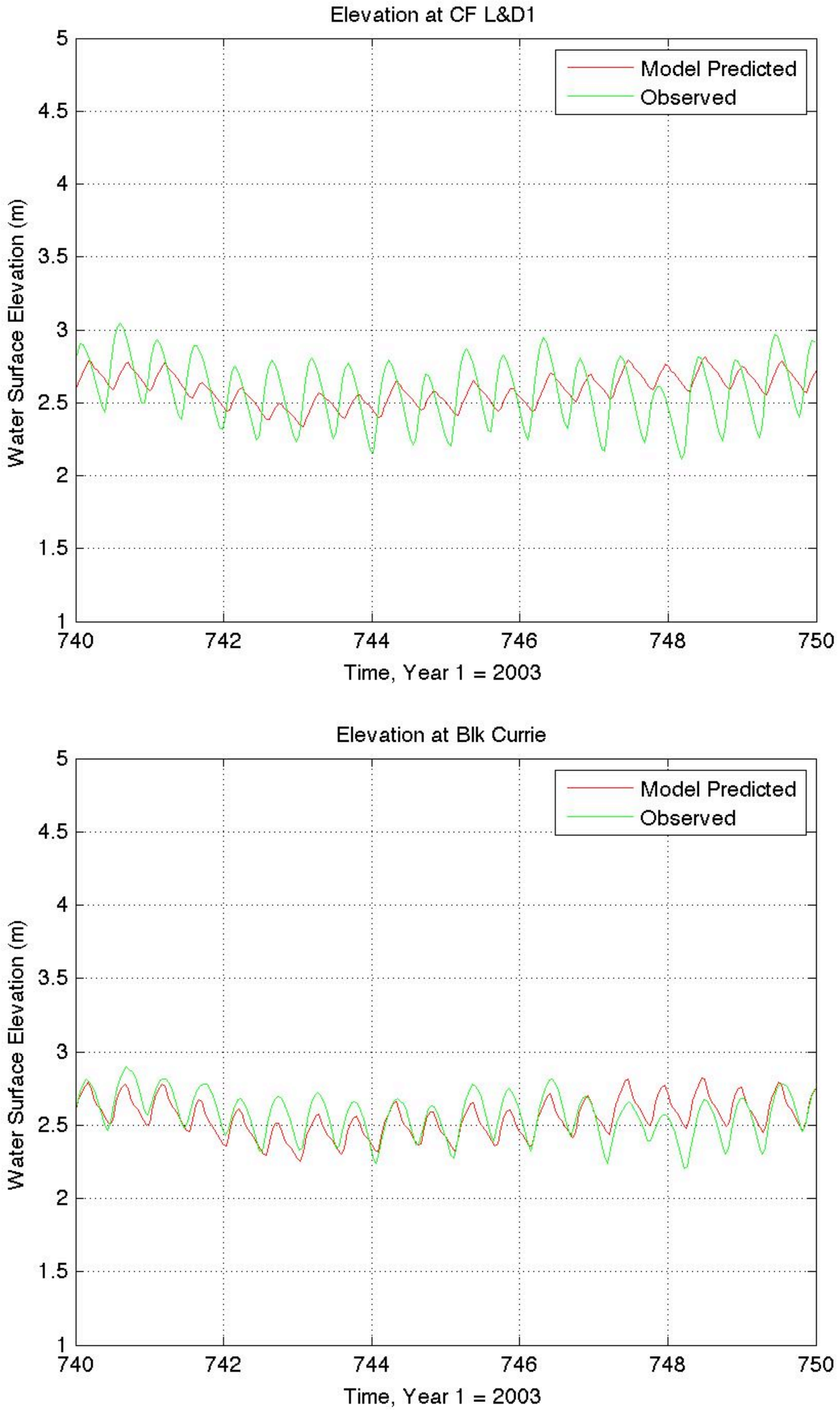


Figure 29. Model Predictions and Observed Water Surface Elevations During January 2004 (Day 740 = 1/11/2004) at the Cape Fear at Lock and Dam 1 and at the Black River at Currie.

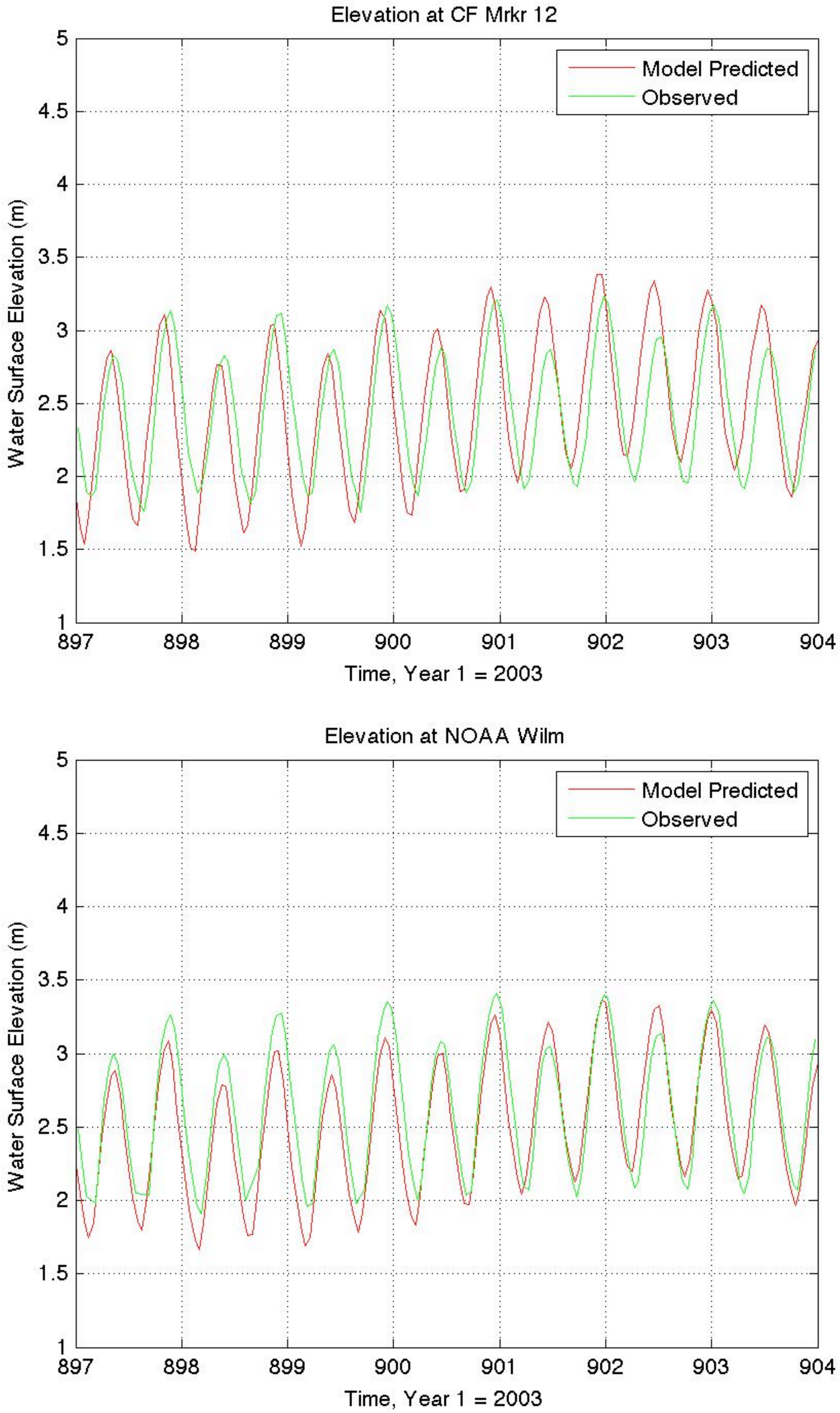


Figure 30. Model Predictions and Observed Water Surface Elevations During June 2004 (Day 900 = 6/19/2004) at the Cape Fear at Marker 12 and the Wilmington Tide Gage.

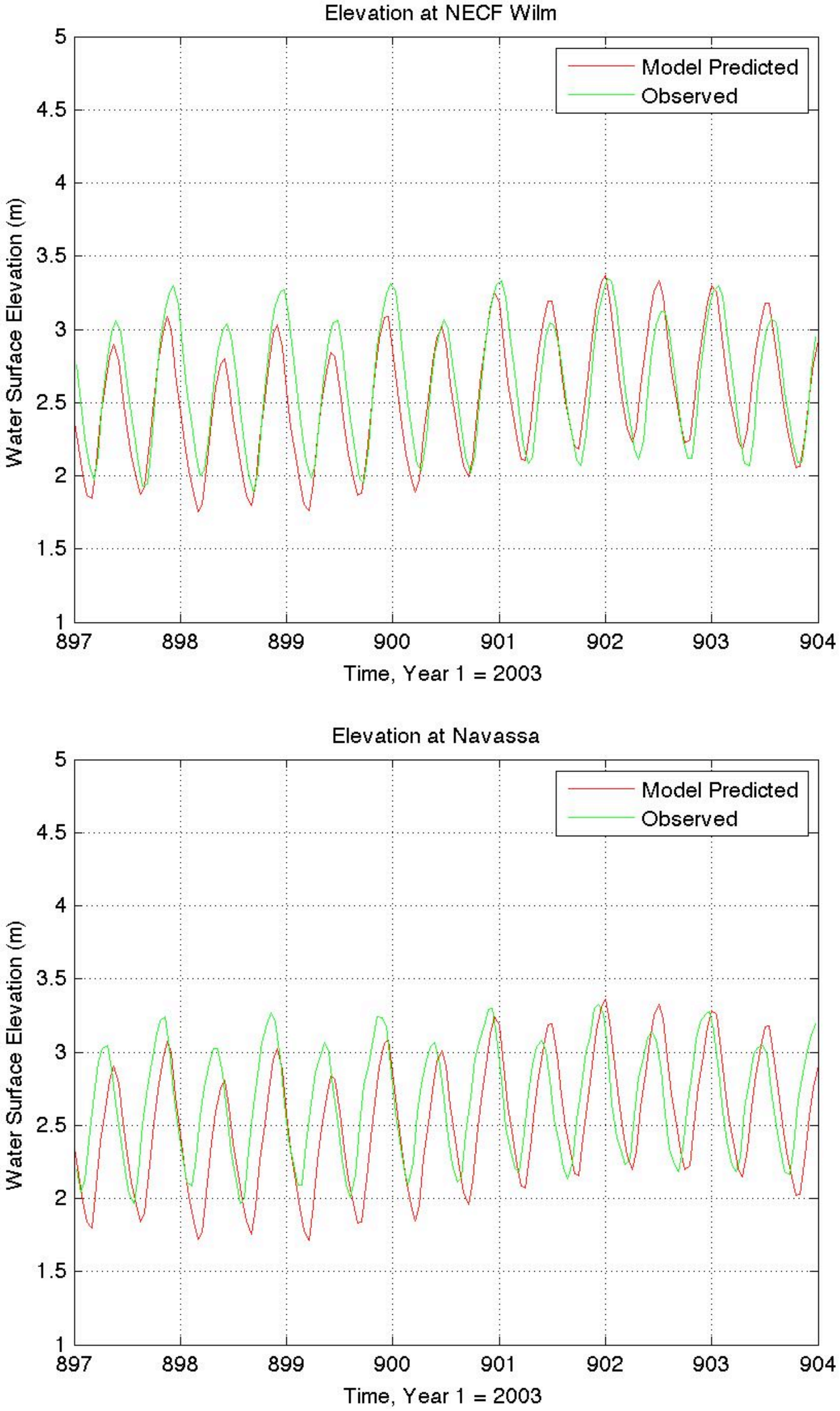


Figure 31. Model Predictions and Observed Water Surface Elevations During June 2004 (Day 900 = 6/19/2004) at the NE Cape Fear at Wilmington and the Cape Fear at Navassa.

Comparison of model predictions and observed water surface elevations at the three upstream locations (Northeast Cape Fear at Burgaw, Black at Currie, Cape Fear at Lock and Dam 1) show the model's ability to simulate the attenuation of the tidal signal as it moves through the estuary. All three locations show tidal amplitudes that are much reduced from the other more downstream stations (Figures 32 and 33). As for the January 2004 time period, the model overpredicts somewhat the attenuation at the Cape Fear station, but in this case also underpredicts slightly the tidal amplitude at the Black River site (Figure 33). Tidal phases are predicted well, although there exists again some error in the predicted phase at the Cape Fear site. Both the tidal phase and amplitude are predicted well at the Northeast Cape Fear site (Figure 32).

An additional examination of hydrodynamic model performance was performed by decomposing both observed data and model predictions into tidal frequency components. Tidal amplitudes and phases were calculated for both the model predictions and the observed data at seven stations scattered throughout the model region (Table 14). The numerical model does a good job in predicting the attenuation of the M2 tidal amplitude from the downstream location (e.g. Marker 12) to the upstream locations within the Northeast Cape Fear, Black, and Cape Fear Rivers. Errors in the predicted M2 tidal amplitude are 1 – 4 cm in the downstream locations and 1 – 8 cm in the upstream locations. Similar model performance is seen for the other tidal constituents (Table 14).

Table 14. Model Predicted and Observed Tidal Constituents at Seven Stations

Cape Fear River at Lock and Dam1							
	Tidal Amplitude (m)			**Tidal Phase (sec)**			
Comp-onent	**Model Predicted**	**Observed**	**Difference**	**Model Predicted**	**Observed**	**Difference**	**Diff. (% per.)**
M2	0.065	0.011	0.054	15790	-2907	18697	41.8%
S2	0.006	0.004	0.002	10830	31689	-20859	-48.3%
N2	0.003	0.041	-0.038	10750	21200	-10450	-22.9%
O1	0.021	0.069	-0.048	85620	88520	-2900	-3.1%
M4	0.015	0.022	-0.007	9578	11804	-2226	-10.0%
M6	0.005	0.013	-0.008	10200	14209	-4009	-26.9%
K1	0.016	0.032	-0.016	48760	87623	-38863	-45.1%

Black River at Currie

Component	Tidal Amplitude (m)			Tidal Phase (sec)			
	Model Predicted	Observed	Difference	Model Predicted	Observed	Difference	Diff. (% per.)
M2	0.124	0.133	-0.009	11070	11315	-245	-0.5%
S2	0.012	0.009	0.003	8905	15073	-6168	-14.3%
N2	0.013	0.023	-0.010	3869	10255	-6386	-14.0%
O1	0.022	0.041	-0.019	80220	80123	97	0.1%
M4	0.033	0.019	0.014	6393	777	5616	25.1%
M6	0.005	0.007	-0.002	13300	11755	1545	10.4%
K1	0.015	0.046	-0.031	42110	57624	-15514	-18.0%

Northeast Cape Fear at Burgaw

Component	Tidal Amplitude (m)			Tidal Phase (sec)			
	Model Predicted	Observed	Difference	Model Predicted	Observed	Difference	Diff. (% per.)
M2	0.090	0.168	-0.078	25520	20265	5255	11.8%
S2	0.013	0.036	-0.023	28190	13525	14665	33.9%
N2	0.018	0.091	-0.073	21750	4167	17583	38.6%
O1	0.008	0.114	-0.106	72480	94049	-21569	-23.2%
M4	0.031	0.020	0.011	18460	8662	9798	43.8%
M6	0.024	0.012	0.012	11550	13397	-1847	-12.4%
K1	0.026	0.117	-0.091	69710	72991	-3281	-3.8%

Cape Fear at Navassa

Component	Tidal Amplitude (m)			Tidal Phase (sec)			
	Model Predicted	Observed	Difference	Model Predicted	Observed	Difference	Diff. (% per.)
M2	0.557	0.562	-0.005	41100	34391	6709	15.0%
S2	0.066	0.060	0.006	37580	32623	4957	11.5%
N2	0.081	0.123	-0.042	33640	28586	5054	11.1%
O1	0.072	0.095	-0.023	56840	55404	1436	1.5%
M4	0.026	0.031	-0.005	13340	2786	10554	47.2%
M6	0.033	0.044	-0.011	14210	8497	5713	38.3%
K1	0.073	0.076	-0.003	19560	41820	-22260	-25.8%

Northeast Cape Fear at Wilmington

Comp- onent	Tidal Amplitude (m)			Tidal Phase (sec)			
	Model Predicted	Observed	Difference	Model Predicted	Observed	Difference	Diff. (% per.)
M2	0.548	0.589	-0.041	41030	40571	459	1.0%
S2	0.064	0.081	-0.017	37360	39184	-1824	-4.2%
N2	0.080	0.135	-0.055	33300	37145	-3845	-8.4%
O1	0.072	0.141	-0.069	56930	48996	7934	8.5%
M4	0.030	0.020	0.010	13650	6138	7512	33.6%
M6	0.026	0.014	0.012	14440	14044	396	2.7%
K1	0.076	0.121	-0.045	19880	42858	-22978	-26.7%

Cape Fear at Marker 12

Comp- onent	Tidal Amplitude (m)			Tidal Phase (sec)			
	Model Predicted	Observed	Difference	Model Predicted	Observed	Difference	Diff. (% per.)
M2	0.646	0.669	-0.023	36410	36955	-545	-1.2%
S2	0.083	0.086	-0.003	31750	31720	30	0.1%
N2	0.105	0.028	0.077	28200	27412	788	1.7%
O1	0.097	0.115	-0.018	50370	83053	-32683	-35.2%
M4	0.024	0.036	-0.012	5872	23125	5872	26.3%
M6	0.024	0.017	0.007	6672	10884	-4212	-28.3%
K1	0.085	0.163	-0.078	32120	35812	-3692	-4.3%

Cape Fear at NOAA Tide Gage Wilmington

Comp- onent	Tidal Amplitude (m)			Tidal Phase (sec)			
	Model Predicted	Observed	Difference	Model Predicted	Observed	Difference	Diff. (% per.)
M2	0.589	0.637	-0.048	40000	40207	-207	-0.5%
S2	0.068	0.084	-0.016	36270	36576	-306	-0.7%
N2	0.089	0.124	-0.035	32350	34988	-2638	-5.8%
O1	0.078	0.072	0.006	55550	55541	9	0.0%
M4	0.022	0.053	-0.031	12060	10217	1843	8.2%
M6	0.020	0.002	0.018	13240	10066	3174	21.3%
K1	0.079	0.090	-0.011	18820	34973	-16153	-18.7%

4.2.2 Modeled and Observed Salinities

To assess the model’s ability to simulate the transport of a conservative substance, twice daily predictions of salinity were compared to observed data at twenty-one sites that spanned the entire model region, and included all three rivers within the estuary (Figure 20). The observed data set included information collected by both the US Geological Survey and Lower Cape Fear River Program. The USGS data came from the in-situ water quality monitors that collected salinity data every fifteen minutes. For this model/data comparison, the USGS observed data were hourly averaged, and two data points per day were taken for the calibration data set. The Lower Cape Fear River Program data was collected at more stations but less frequently. The frequency of sampling varied from season to season. The summer sampling frequency was as often as weekly at some stations. Most of the Lower Cape Fear River Program stations were sampled at a monthly interval during the winter months.

While statistical measures of model fit used all the available data, as described above, here we show time history comparison of model predictions and observations only at the USGS in the lower parts of the estuary. The three USGS sites omitted here (Cape Fear at Lock and Dam 1, Black at Currie, Northeast Cape Fear at Burgaw) all had salinities, both observed and predicted that were always near zero. Two of the sites shown here are in the impaired region (Cape Fear at Navassa, Northeast Cape Fear at Wilmington), and both sites show an excellent agreement between the model predicted and observed salinity (Figure 34). At both sites the salinities are quite dynamic, being near zero during the high flow periods late February and March and also September, and increasing to 10 to 15 ppth in the intervening time periods. Swings in salinity of approximately 5 ppth happen in about a week’s time in both June and July 2004. The model predictions track the changes seen in the observed data quite nicely. While rather difficult to see with this particular data presentation, it appears that the model underpredicts somewhat the stratification seen in the observed data. At the Northeast Cape Fear station, the observed data often shows surface salinities that are approximately two ppth lower than the bottom values, but model predictions show essentially no difference between the surface and bottom values (Figure 34).

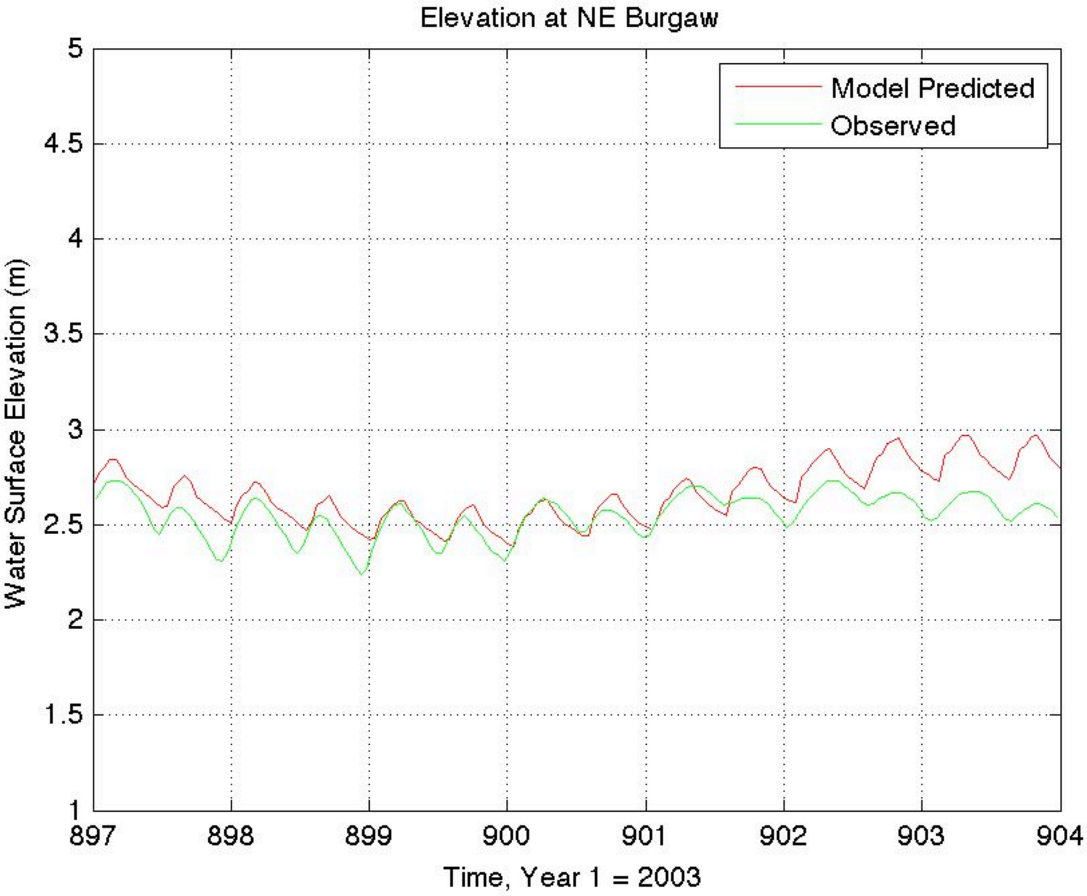


Figure 32. Model Predictions and Observed Water Surface Elevations During June 2004 (Day 900 = 6/19/2004) at the NE Cape Fear at Burgaw.

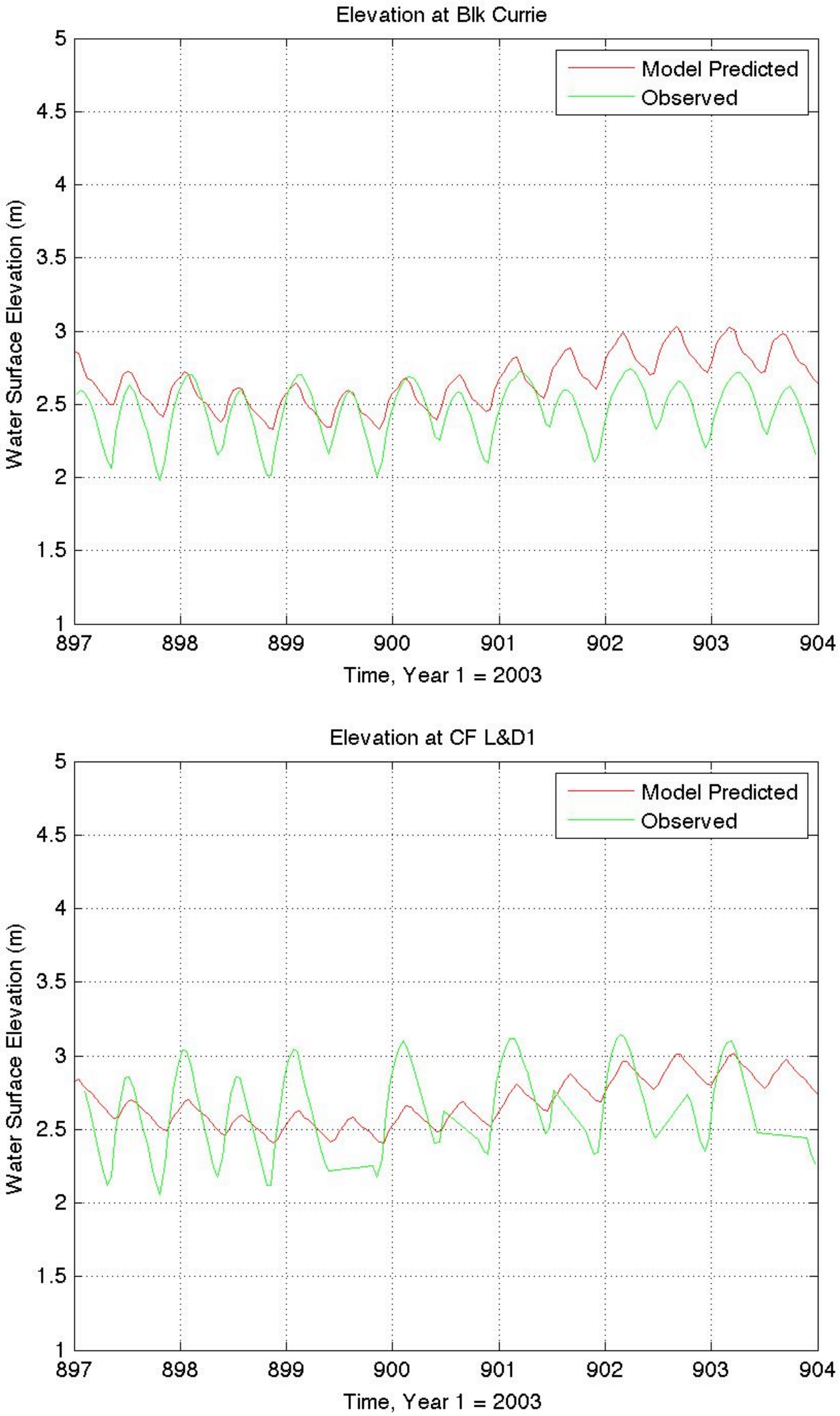
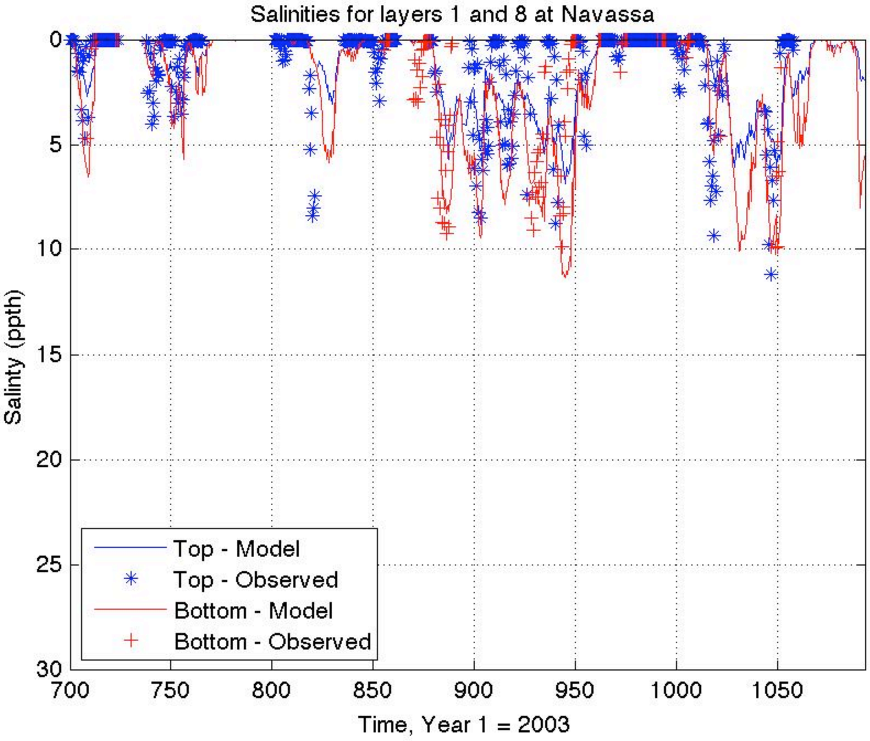


Figure 33. Model Predictions and Observed Water Surface Elevations During June 2004 (Day 897 = 6/16/2004) at the Black River at Currie and the Cape Fear R. at Lock and Dam 1.



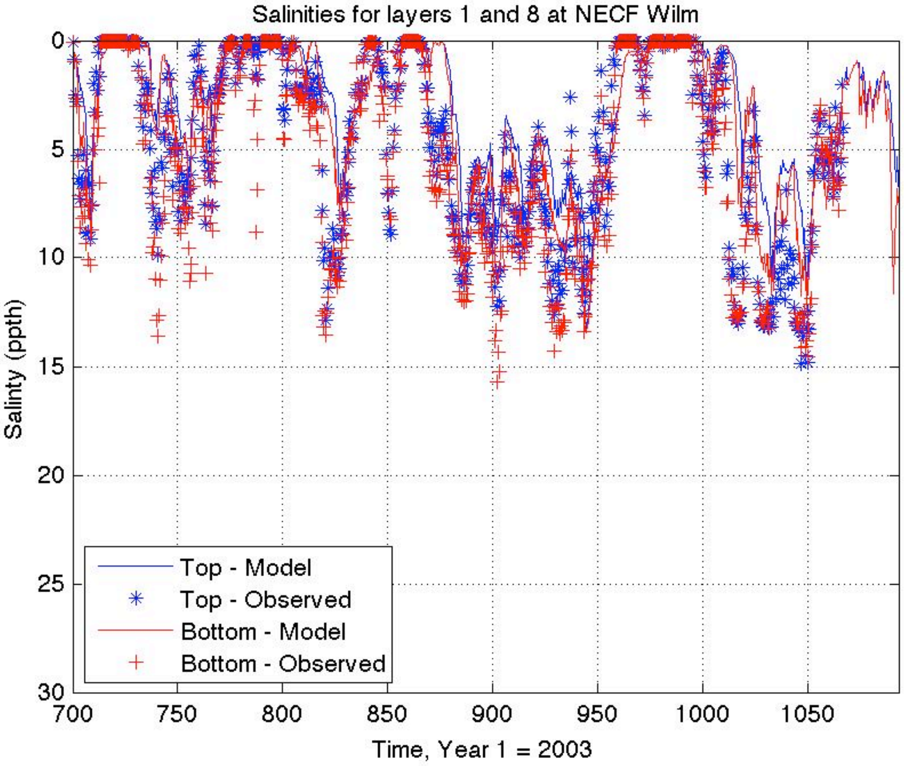


Figure 34. Model Predictions (lines) and Observed (symbols) Salinities During 2004 at the Cape River at Navassa and the NE Cape Fear River at Wilmington.

Salinities at the one station downstream of Wilmington (Cape Fear at Marker 12) are even more dynamic than the two upstream stations. As for the two other stations, salinities approach zero during the high flow periods in Spring and Fall (Figure 35). In mid-May the salinities also approach zero, which does correspond with a high flow event that is seen upstream at the Cape Fear River model boundary earlier in the month (Figure 18). During the summer, a regular variation in salinity can be seen on approximately a two-week period, which likely corresponds to the variations due the neap/spring tide cycle. As at the other two sites the model agrees with the observed data to an excellent extent, showing all of the dynamic features seen in the observed data. Once again, however, it does appear that the model underpredicts somewhat the magnitude of salinity stratification in this lower part of the estuary (Figure 35).

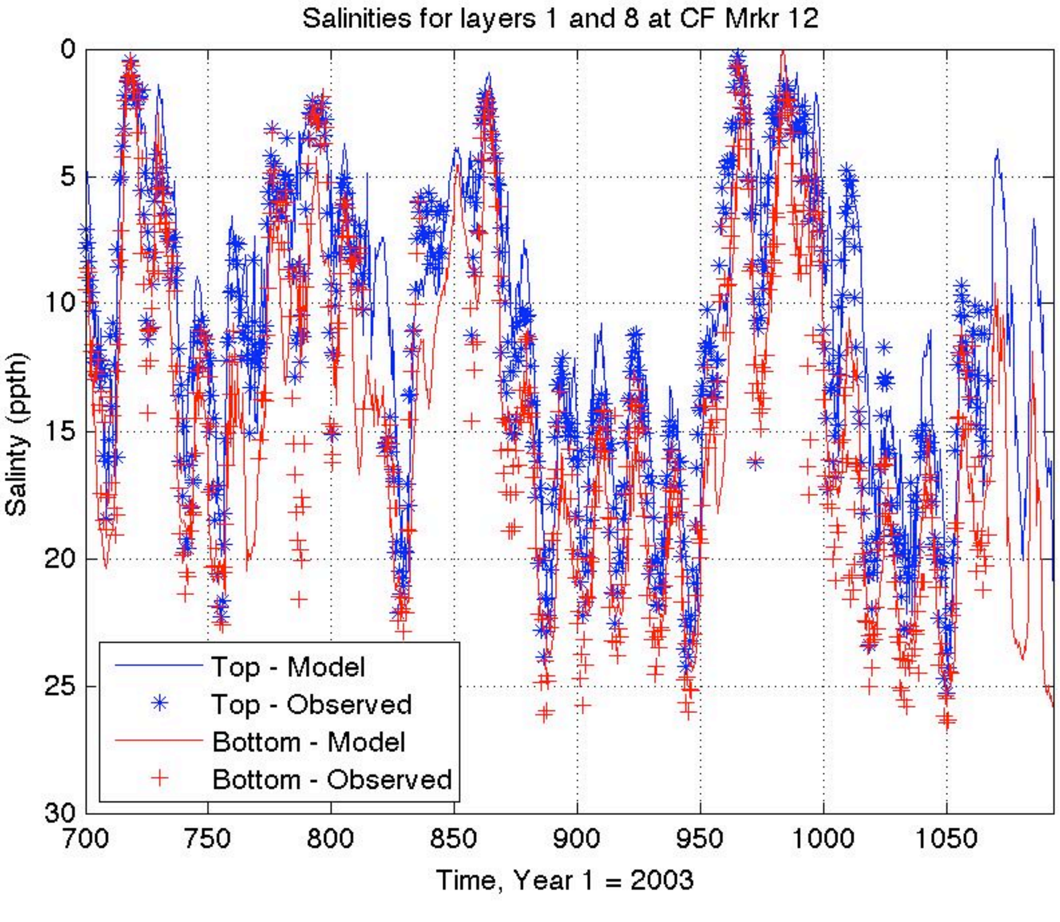


Figure 35. Model Predictions (lines) and Observed (symbols) Salinities During 2004 at the Cape River at Marker 12.

As mentioned earlier, statistical measures of the model's ability to simulate salinity distributions used all of the available salinity observations. A total of 5308 model/data comparisons were made during the 2004 calibration period, with the following statistical measures used to quantify model fit to the data (see Thomann 1982 or Tetra Tech 2001 for explanation of the measures):

- Mean error (absolute and normalized by mean of observations)
- Mean absolute error (absolute and normalized by mean of observations)
- Root mean square error (absolute and normalized by mean of observations)
- Correlation r^2
- Bias corrected r^2, also known as model efficiency

These comparisons indicated that the model slightly overpredicted salinity in the estuary by 0.112 ppth, which corresponds to a normalized mean error of 2.2% (Table 15). Two measures were used to quantify the typical magnitude of the prediction error. The root mean square error was 2.48 ppth and the mean absolute error (mean of the absolute value of each error) was 1.45 ppth (Table 15). The corresponding normalized errors for these two statistical measures of model fit were 50.1% and 29.1%. The correlation R^2 was used as an aggregate measure of model fit. For salinity the correlation R^2 was 87.6%, and the R^2 corrected for model bias was 85.7%. This level of calibration performance compares favorable with other hydrodynamic models of North Carolina estuaries (e.g. Bowen 2000).

Table 15. Calibration Statistics, Salinity

Parameter	Value	Units
Mean Error (predicted – observed)	**0.112**	**ppth**
Normalized Mean Error	**2.2**	**%**
Root Mean Square Error	**2.48**	**ppth**
Normalized Root Mean Square Error	**50.1**	**%**
Mean Absolute Error	**1.45**	**ppth**
Normalized Mean Absolute Error	**29.1**	**%**
Correlation R^2	**87.6**	**%**
Number of Model/Data Comparisons	**5308**	**-**
R^2 Corrected for Bias	**85.7**	**%**

Statistical measures of model fit were also calculated at each site where observed data were available. Each of the measures given in Table 15 were calculated at fourteen stations where salinity data were collected either by the USGS or as part of the Lower Cape Fear Program (Table 16). Mean errors were quite variable, with relatively large values in the Wilmington area, at stations such as the Northeast Cape Fear at Wilmington and Marker 54. Mean errors at sites upstream of Wilmington generally decreased. Both root-mean-square errors and mean absolute errors were generally more uniform, and were less than 2.0 ppth at most sites (Table 16).

Table 16. Model Calibration Statistics for Salinity at Monitoring Sites Within the Model Region

Station	Mean Error (ppth)	%	RMSE (ppth)	%	Mean Absolute Error (ppth)	%	R^2	No. data points
CF L&D1	-0.05	-100.0%	0.05	100.0%	0.05	101.8%	0.4%	572
Blk Currie	-0.03	-100.0%	0.03	100.0%	0.03	102.1%	9.6%	653
NE Burgaw	-0.05	-100.0%	0.05	100.0%	0.05	102.2%	20.5%	689
NCF6, NECF	0.13	5.9%	2.51	116.6%	3.55	165.0%	0.0%	12
USGS, Navassa	0.72	44.7%	1.42	88.4%	2.35	146.4%	47.4%	510
CF @ Nav	1.77	128.3%	2.15	155.7%	2.81	202.9%	27.9%	12
USGS, NECF Wilm	-1.46	-29.4%	1.94	39.1%	2.80	56.3%	68.9%	1439
Brnswk Riv	0.25	7.5%	1.74	52.2%	2.54	76.2%	30.3%	12
CF,Mrkr 61	-0.04	-0.6%	1.92	28.2%	2.52	37.0%	71.4%	13
M54, CFM54	2.34	27.6%	2.61	30.7%	3.60	42.4%	79.7%	13
M42, CFM42	2.43	22.8%	2.76	25.8%	3.35	31.4%	81.5%	13
USGS, CF Mrkr 12	1.76	13.6%	2.84	21.9%	3.61	27.9%	76.8%	1344
M35, CFM35	0.55	3.8%	2.12	14.3%	2.73	18.5%	75.9%	13
M23, CFM23	-3.92	-18.1%	4.80	22.1%	5.60	25.8%	43.9%	13

Scatter plots of observed vs. predicted salinity also give an indication of the relatively good fit of the model to the observed data. Little bias is seen in the predictions overall, with the points shown to be evenly distributed around the 45-degree line indicating observation = prediction (Figure 36). Model error seems not to vary with the magnitude of model prediction, as the magnitude of the error is similar for relatively low and high salinities. At the low salinity values, there are many points where zero salinity is predicted but not observed or vice-versa, but there doesn't exist more of one type of error as opposed to the other. The magnitude of the residuals is significant, however, which may be due to the model's relatively poor ability at matching the temporal variations in the extent of salinity intrusion at certain times (see for example Figure 35).

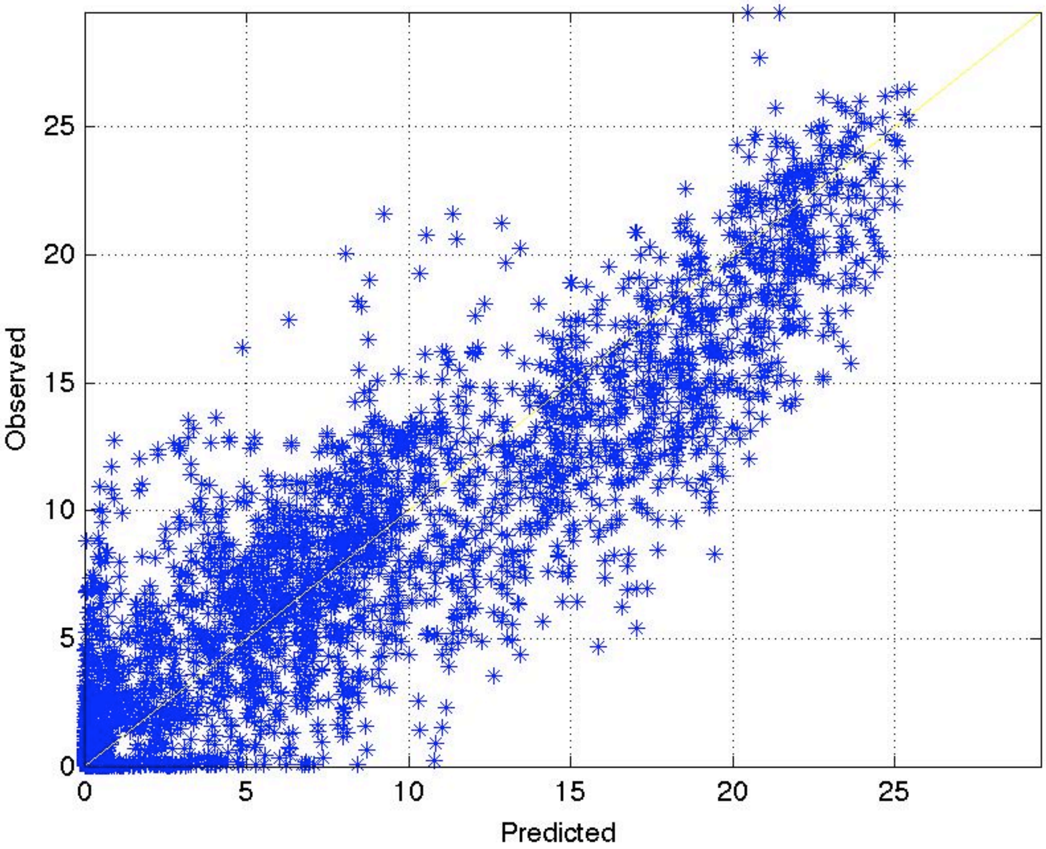


Figure 36. Scatter Plot of Predicted Salinity (ppth, x-axis) vs. Corresponding Observed Salinity (ppth, y-axis).

Percentile plots of observed data and model predictions were also created for the salinity values in the estuary. These percentile plots are useful in assessing how the model predictions values and the corresponding observations are distributed relative to one another. Both model predictions and observed data have approximately 50% of the salinities at zero (Figure 37). At the higher salinity values the model both slightly under and over predicts salinity and the frequency of a particular salinity value. For instance, at the 90th percentile value the observed salinity is 15 ppth. This same salinity value is seen in about only 85% of the model predictions. The lower percentile values, where the salinities are lower also show some error, but in this case the model predictions for a particular salinity value are slightly more frequent than seen in the observations. Over the entire range of salinities, however, there is not a very large difference between the observed and predicted salinities (Figure 37).

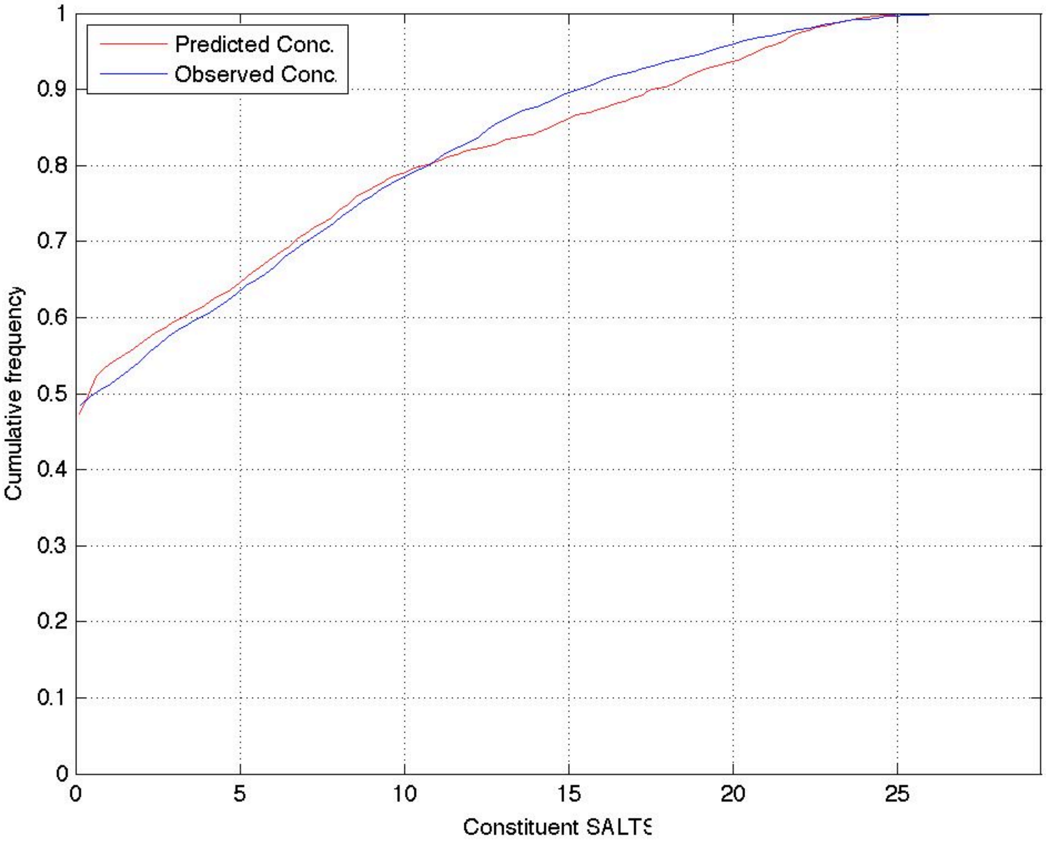


Figure 37. Percentile Plot of Observed and Model Predicted Salinities During the Calibration Period. The y-axis indicates the fraction of values below the corresponding salinity (ppth) indicated on the x-axis.

4.3 Temperature Model Calibration

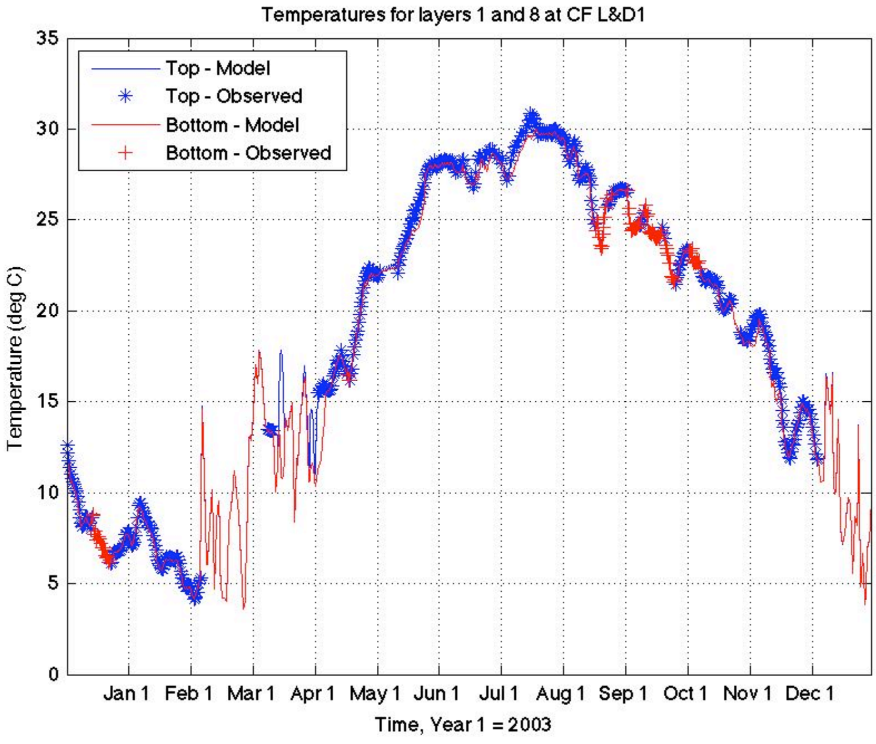
The procedure for assessing the temperature model's calibration performance was very similar to the procedure for salinity. Observations from the twenty-one Lower Cape Fear River Program and USGS stations in the model region (Table 13) were compared. The USGS data were synthesized to produced two hourly-averaged temperatures per day. The Lower Cape Fear River program data were used without any data synthesis. While time histories comparisons were produced at all twenty-one stations, only six representative sites are shown here. Five of the six are the USGS sites where twice daily data are available. Three of the sites are near the upstream model boundary (Cape Fear at Lock and Dam 1, Black River at Currie, Northeast Cape

Fear at Burgaw), and two are in the mesohaline region of the estuary (Navassa, NE Cape Fear at Wilmington, Marker 12). One Lower Cape Fear River Program station from the Northeast Cape Fear River (NCF 117) is shown as well.

The model vs. data time history comparison at the Cape Fear station at Lock and Dam1 is typical of all of the temperature time histories. Model predictions follow the observed data to an excellent extent, with very little difference between model predictions and observed data (Figure 38). In the summertime, the model slightly overpredicts temperatures in the surface layer, but not so in the lower layers at this site. The seasonal variation in temperature from summer to winter is represented very well.

The two stations along the Northeast Cape Fear (Figure 39) and in the mesohaline portion of the estuary (Figure 40) also show an excellent fit between model predictions and observed data. Seasonal variations in temperature are nearly identical between model predictions and observations, and at only one site (Northeast Cape Fear at Wilmington) is there any observable difference between these temperatures. At this one site the model overpredicts summertime temperature by a few degrees.

This excellent degree of model fit is also seen in the other measures of model calibration. The normalized mean error in the model is less than 1%, and the normalized root mean square error is only 5.8% (Table 17). The correlation R^2 is 97.9%, indicating an excellent fit of the model to the observed data. Statistical measures of model fit were also calculated at individual stations (Table 18). All stations had calibration R^2 values above 97% and root mean square errors of less than 9% (Table 18). The scatter plot of observed data vs. corresponding model predictions (Figure 41) and the percentile plot (Figure 42) also indicate the excellent ability of the temperature model to match the observed temperatures.



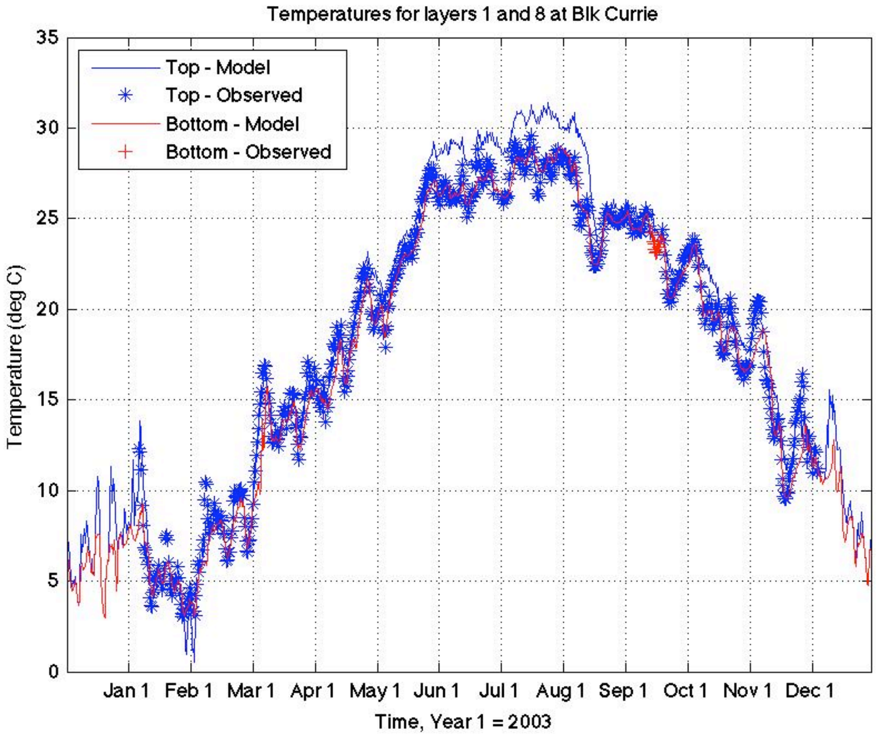


Figure 38. Model Predicted and Observed Temperatures During 2004 at the Cape Fear River at Lock and Dam 1 and the Black River at Currie.

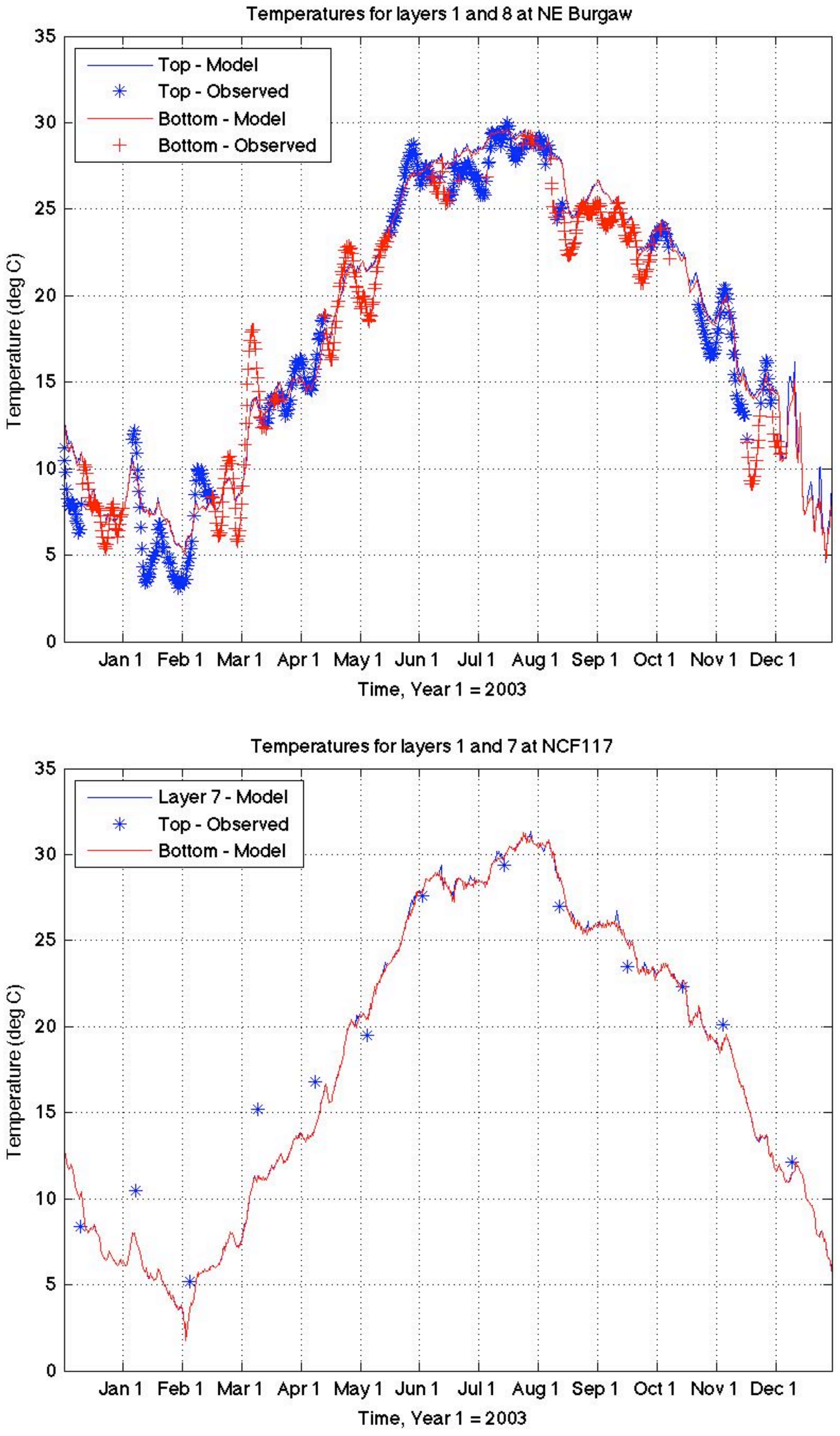


Figure 39. Model Predicted and Observed Temperatures During 2004 at the NE Cape Fear River at Burgaw and at Station NCF 117.

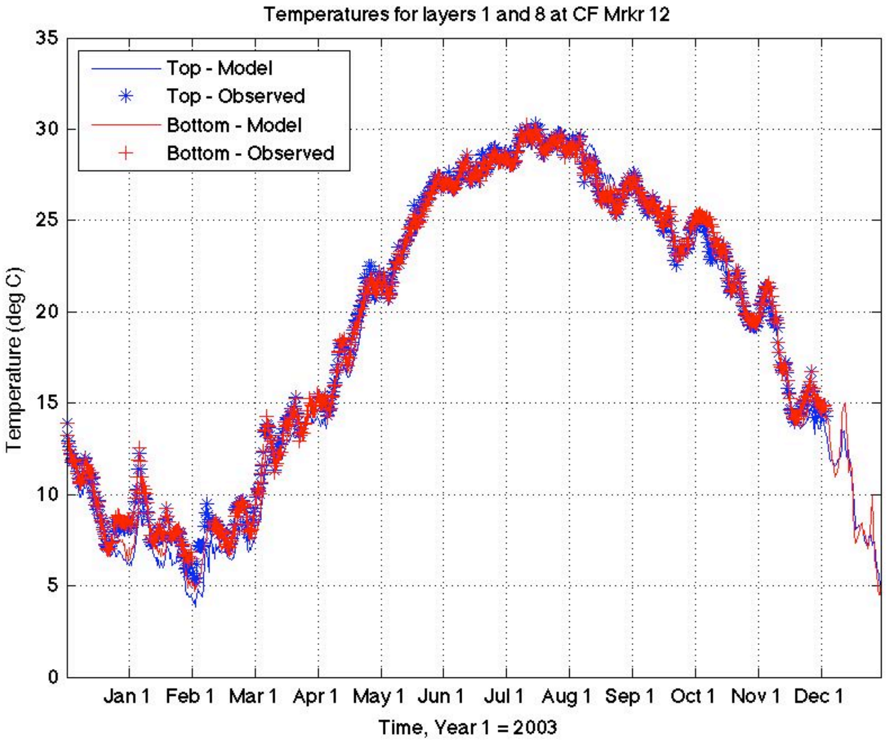


Figure 40. Model Predicted and Observed Temperatures During 2004 at the NE Cape Fear River at Wilmington and the Cape Fear River at Marker 12.

Table 17. Calibration Statistics, Temperature

Parameter	Value	Units
Mean Error (predicted – observed)	**-0.12**	**Deg C**
Normalized Mean Error	**-0.61**	**%**
Root Mean Square Error	**1.12**	**Deg C**
Normalized Root Mean Square Error	**5.8**	**%**
Mean Absolute Error	**0.81**	**Deg C**
Normalized Mean Absolute Error	**4.2**	**%**
Correlation R^2	**98.4**	**%**
Number of Model/Data Comparisons	**6040**	**-**
R^2 Corrected for Bias	**97.9**	**%**

Table 18. Model Calibration Statistics for Temperature at Monitoring Sites Within the Model Region.

Station	Mean Error (ppth)	%	RMS (ppth)	%	MAE (ppth)	%	R^2	No. data points
CF L&D1	-0.21	-1.1%	0.30	1.5%	0.58	3.0%	99.6%	573
NC11, CF	-0.17	-0.7%	0.59	2.7%	0.99	4.4%	98.3%	75
Blk Currie	-0.31	-1.7%	0.63	3.4%	1.01	5.4%	98.4%	653
B210, Blk	-0.66	-3.8%	0.93	5.3%	1.26	7.2%	97.9%	13
AC-CF@Acme	-0.44	-2.0%	0.65	2.9%	0.88	3.9%	98.9%	75
IC, Cape Fear	0.26	1.1%	0.87	3.9%	1.07	4.7%	99.1%	75
NE Burgaw	0.73	4.1%	1.23	6.8%	1.59	8.8%	96.9%	690
NCF117	-0.50	-2.7%	1.49	8.2%	1.84	10.1%	96.3%	13
NCF6, NECF	0.09	0.4%	1.78	8.8%	2.07	10.3%	98.6%	47
Navassa	0.13	0.6%	0.76	3.8%	0.92	4.5%	99.4%	510
CF @ Nav	0.26	1.2%	0.87	3.8%	1.04	4.6%	99.4%	75
HB, CF@HSB	0.14	0.6%	1.06	4.7%	1.36	6.0%	98.6%	74
NECF Wilm	-0.30	-1.6%	1.16	6.1%	1.39	7.3%	99.2%	1462
Brnswk Riv	-0.56	-3.0%	0.92	4.9%	1.29	6.9%	98.9%	39
CF,Mrkr 61	-0.73	-3.6%	1.24	6.1%	1.46	7.2%	99.0%	48
M54, CFM54	-0.63	-3.1%	0.87	4.3%	1.10	5.4%	99.4%	48
M42, CFM42	-0.58	-2.8%	0.85	4.1%	1.15	5.7%	99.0%	48
CF Mrkr 12	-0.25	-1.3%	0.50	2.6%	0.66	3.4%	99.5%	1429
M35, CFM35	-0.58	-2.8%	0.82	4.0%	1.15	5.6%	98.7%	48
M23, CFM23	-0.40	-2.0%	0.96	4.8%	1.22	6.1%	97.7%	45

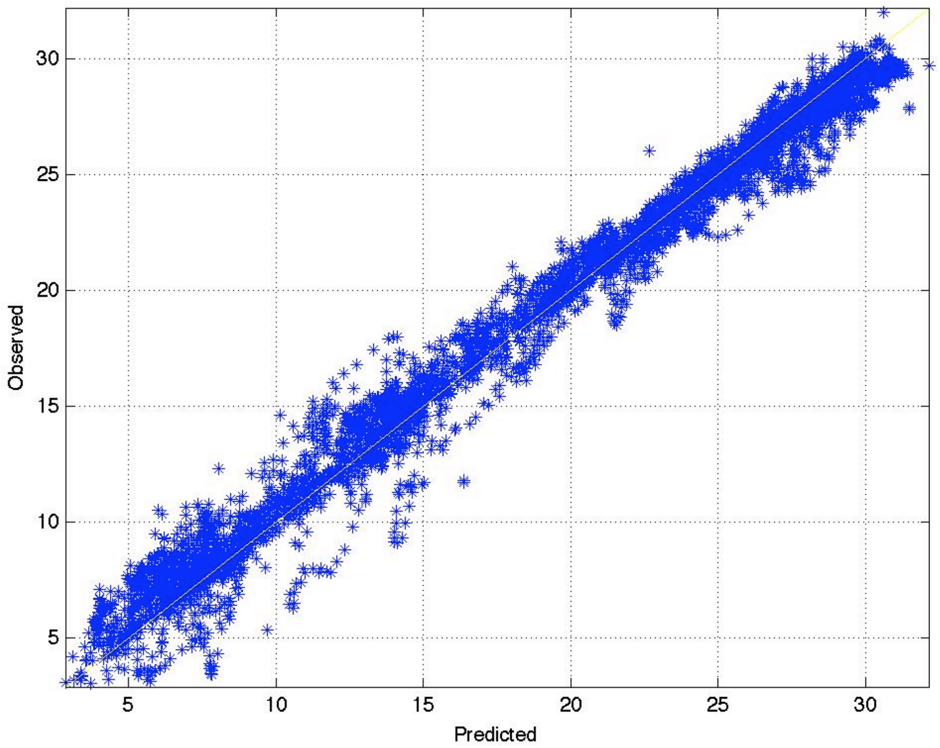


Figure 41. Scatter Plot of Predicted Temperature (ºC, x-axis) vs. Corresponding Observed Temperature (ºC, y-axis) During the 2004 Calibration Run.

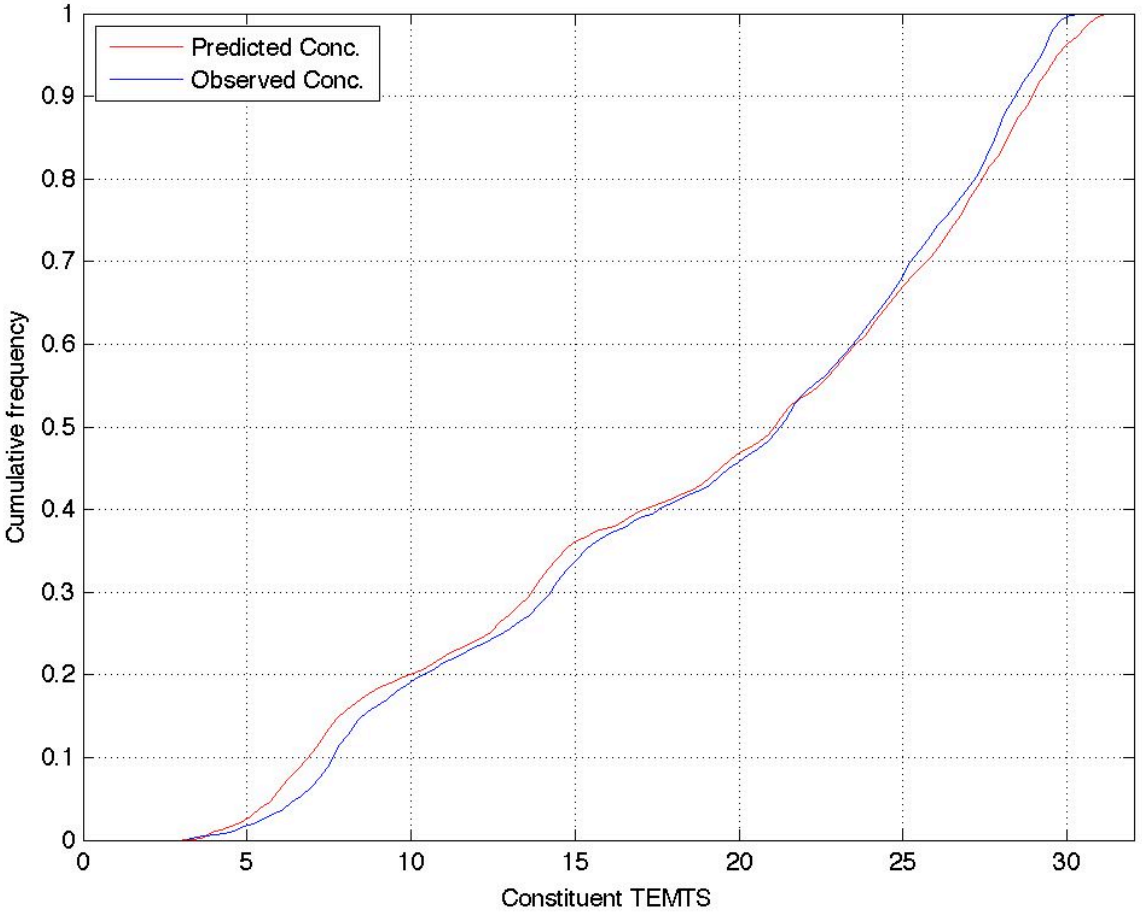


Figure 42. Percentile Plot of Observed and Model Predicted Temperatures During the 2004 Calibration Period. The y-axis indicates the fraction of values below the corresponding temperature (ºC) indicated on the x-axis.

Overall the hydrodynamic model's level of calibration performance is as good, or even better than other hydrodynamic models of North Carolina estuaries (e.g. Bowen 2000). Each component of the hydrodynamic model (hydrodynamics, temperature, conservative transport) fits well the seasonal and event-related dynamics within the system. Examination of time histories in the impaired region indicate the hydrodynamic model is capable of simulating conditions in this part of the estuary. Based upon this evaluation, the hydrodynamic model seems suitable for use as part of the water quality evaluation.

4.4 Water Quality Model Calibration

Following the procedures described in section 2, the input files necessary to run the water quality model were quantified. Specifically, the loadings of all constituents from all water sources where flows were specified in the QSER.INP file were quantified in the WQPSL.INP file. A total of 37 sources of water were quantified this way (Table 9), which required quantifying loads for all 21 constituents (Table 1). These loads were calculated with a procedure that utilized conversion matrix tables that quantified how constituent loading was calculated from the available monitoring data. Twenty-three such conversion tables (Appendix A) were needed to quantify these sources. At the model southern open boundary, concentrations were specified either as a time history or in the water quality control file WQ3DWC.INP (see Appendix D).

During calibration, predicted dissolved oxygen concentrations were compared to observed data at the same twenty-one stations used for hydrodynamic model calibration (Table 14, Figure 19). The USGS continuous monitoring data were synthesized to give two hourly averaged dissolved oxygen values per day. The Lower Cape Fear River Program data were generally collected monthly during the non-summer months, and bi-weekly during the summer. These twice-daily data were combined with the LCFRP data to create an extensive calibration data set that had frequent measurements of DO at stations throughout the estuary and somewhat less frequent measures of other water quality constituents. During calibration, kinetic values in the water quality model were adjusted to improve the fit between model predicted water quality concentrations and observed data. Model/data comparisons were made of the following water quality measures:

- Dissolved oxygen (mg/L)
- Total chlorophyll-a (μg/L)
- Total phosphorus (mg/L as P)
- Ammonia (mg/L as N)
- Nitrite/nitrate (mg/L as N)

Multiple measures were used to quantify the model's fit to the observed data, just as was done during hydrodynamic calibration. As described earlier the following measures were analyzed for each model run during calibration, (see Thomann 1982 or Tetra Tech 2001 for explanation of the measures):

- Mean error (absolute and normalized by mean of observations)
- Mean absolute error (absolute and normalized by mean of observations)
- Root mean square error (absolute and normalized by mean of observations)
- Correlation r^2
- Bias corrected r^2, also known as model efficiency

The calibration had the following multiple objectives

- Use water quality kinetics parameter values that fall within the expected range of values for temperature estuaries (Bowie et al. 1985),

- Produce predicted water quality concentrations that qualitatively agree with the expected seasonal and spatial variations for temperature estuaries,
- Produce predicted water quality concentrations that simultaneously minimized mean error, mean absolute error, and root mean square error
- Produce predicted water quality concentrations that maximum correlation r^2 and bias corrected r^2,
- Produce predicted water quality concentrations with a cumulative frequency distribution that was a close approximation of the observed distribution over the full range of percentiles.

A phased approach to water quality calibration was undertaken. The calibration phasing was done in such a way that recognized the expected relative importance of processes in the estuary's dissolved oxygen budget, and the inherent dependencies between water quality constituents. Thus, special importance was given to maximizing the model's fit to observed dissolved oxygen concentrations. Calibration phasing was done as follows:

- Calibrate first the sediment oxygen demand to give a reasonably low mean error for dissolved oxygen concentrations,
- Calibrate the nitrification rate to give an acceptable value for the mean error for ammonia concentrations within the estuary,
- Calibrate the phytoplankton group specific maximum growth rates, temperature optima, and half-saturation constants for nutrient concentrations to give a reasonable seasonal pattern of total chlorophyll-a concentrations,
- Calibrate the phytoplankton stoichiometric ratios (C/Chl, C/N, C/P) to give acceptable mean errors for total P and total N concentrations
- Calibrate the benthic flux rates for nitrate/nitrite to give an acceptable value for the mean error of nitrite/nitrate concentrations in the water column,
- Calibrate again the sediment oxygen demand to give acceptable error statistics and cumulative frequency distributions for dissolved oxygen,
- Check the statistical measures of model fit for the remaining water quality constituents, and repeat the calibration procedure if warranted.

At the conclusion of this calibration procedure, a complete set of calibrated water quality kinetic parameters was produced for the base case calibration run. These water quality kinetic parameters were then used for all subsequent model confirmation and scenario testing model runs. All of these parameters except SOD are specified in EFDC's water quality control file (see file WQ3DWC.INP, Appendix D). Benthic fluxes are specified in a separate file (benflux_tser.inp, Appendix E).

Of particular interest in the water quality modeling was the point source loadings of oxygen demanding wastes. In the EFDC water quality model as applied here, three EFDC constituents present in the point source loadings accounted for the water-column oxygen demand, refractory dissolved organic carbon (RDOC – in table 1 RDOC is shown as RPOC), dissolved organic carbon (DOC), and ammonia. The RDOC load was found to come primarily from the Cape Fear River inflow, and to a lesser extent the estuary inflows (Figure 43). The

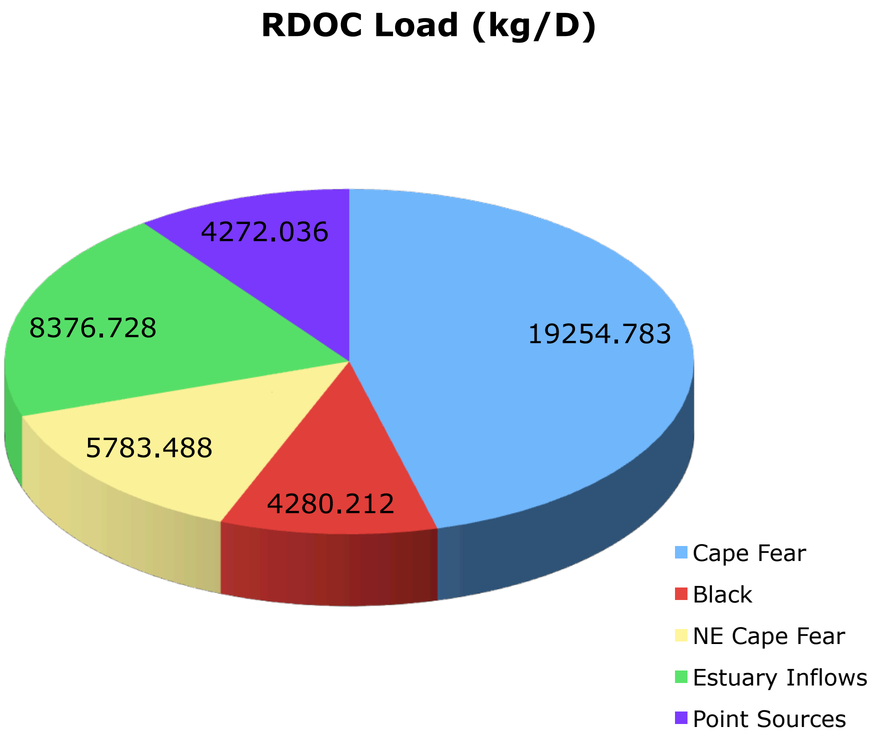


Figure 43. Average Daily Load of Refractory Dissolved Organic Carbon to the Model Region from Various Sources

source contribution to the RDOC loading was relatively small (Figure 43). Likewise, more than half of the DOC load came from the Cape Fear River inflow, while the other four categories of sources (Black River, NE Cape Fear River, estuary inflows, and point sources) were of roughly equal magnitude (Figure 44). The ammonia loading distribution was quite different, with point sources contributing more than half of the total loading, and only small contributions from the Black and Northeast Cape Fear rivers and the estuary inflows (Figure 45).

An additional sink of dissolved oxygen results from the transport of water-column oxygen to satisfy the sediment oxygen demand (SOD). As described in previous sections, an SOD measurement program conducted by the NC Division of Water Quality collected SOD measurements at five locations (Figure 9) during the Summer and Fall of 2003 (Table 13). Initially these data were used to quantify a time-averaged SOD rate that was applied over the entire model grid. During calibration it was found that this strategy resulted in overpredictions of dissolved oxygen concentration in the summer and underprediction during the winter. For this reason, it was decided to introduce a temperature dependence to the SOD specification. The SOD data were fit with the following temperature dependent model:

$$SOD(t) = SOD(20) \times \Theta^{T-20} \qquad (2)$$

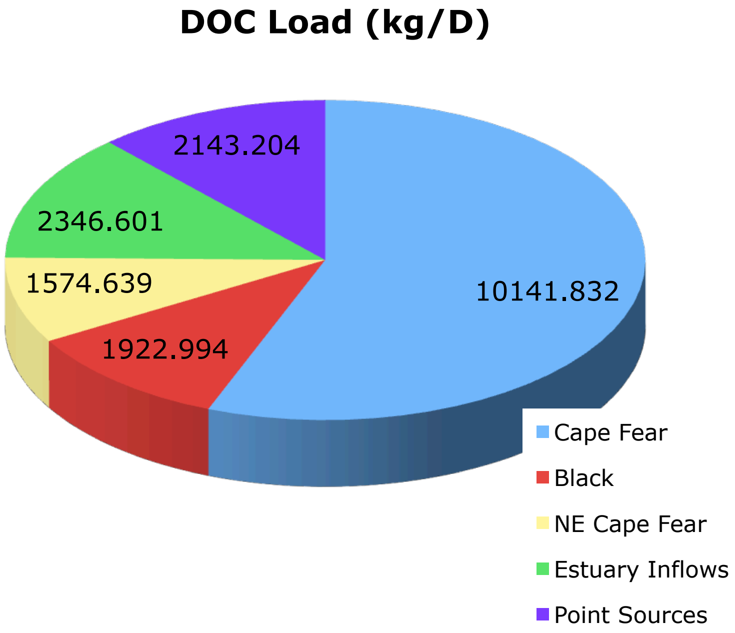


Figure 44. Average Daily Load of Dissolved Organic Carbon to the Model Region from Various Sources

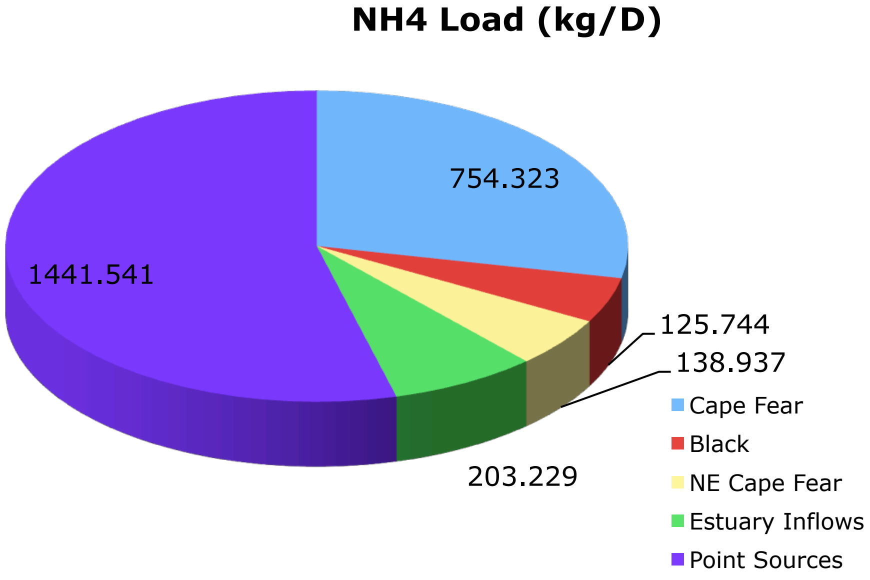


Figure 45. Average Daily Load of Ammonia to the Model Region from Various Sources.

where SOD(t) and SOD(20) is the sediment oxygen demands at the desired temperature and at 20º C, and Θ is an empirical temperature multiplier. When fit to this model (Figure 46), the SOD data produced a SOD(20) of 0.4 g/m^2/d and a temperature multiplier of 1.058. Using this SOD model and spatially averaged observed temperatures, an SOD time history file was created for input to the model. Using this approach it was found during calibration that the model consistently overpredicted dissolved oxygen concentrations in all three of the Northeast Cape Fear stations. This overprediction was confined to these stations, which indicated that SOD values for these stations should be increased for the cells within the Northeast Cape Fear river basin. During calibration an additional factor was introduced that gave the ratio of SOD in the NE Cape Fear and the rest of the model region. This factor was determined during calibration to give the best fit with a value of 1.5. In this way SODs were given temperature and spatial variation during the model

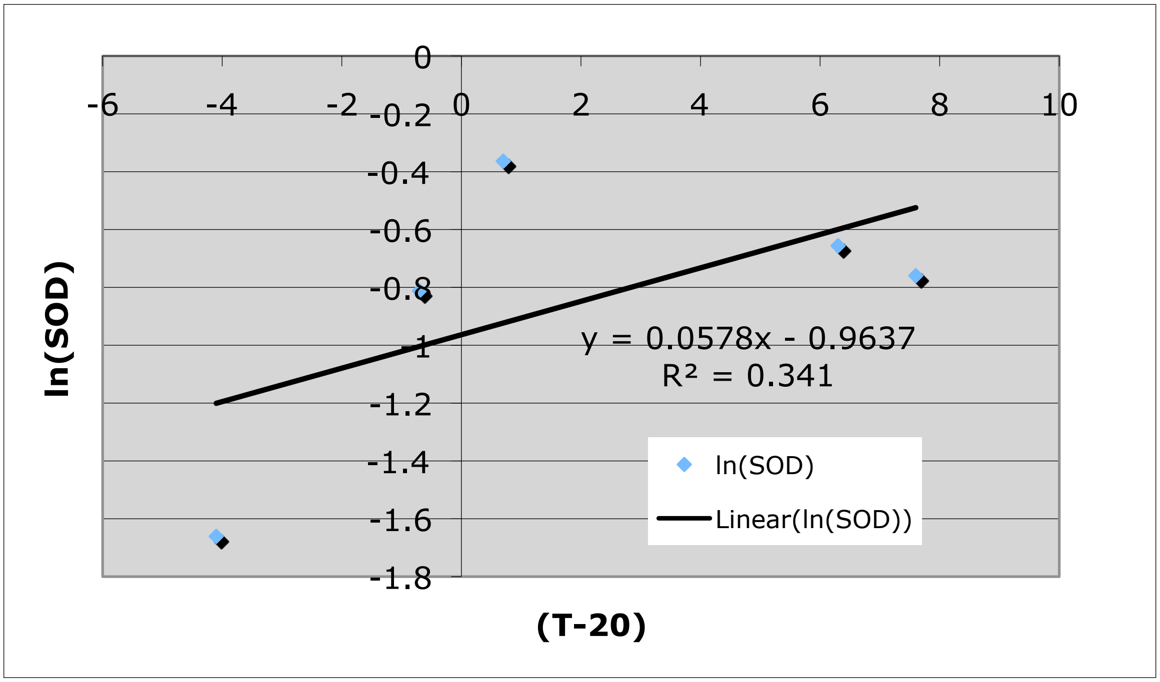
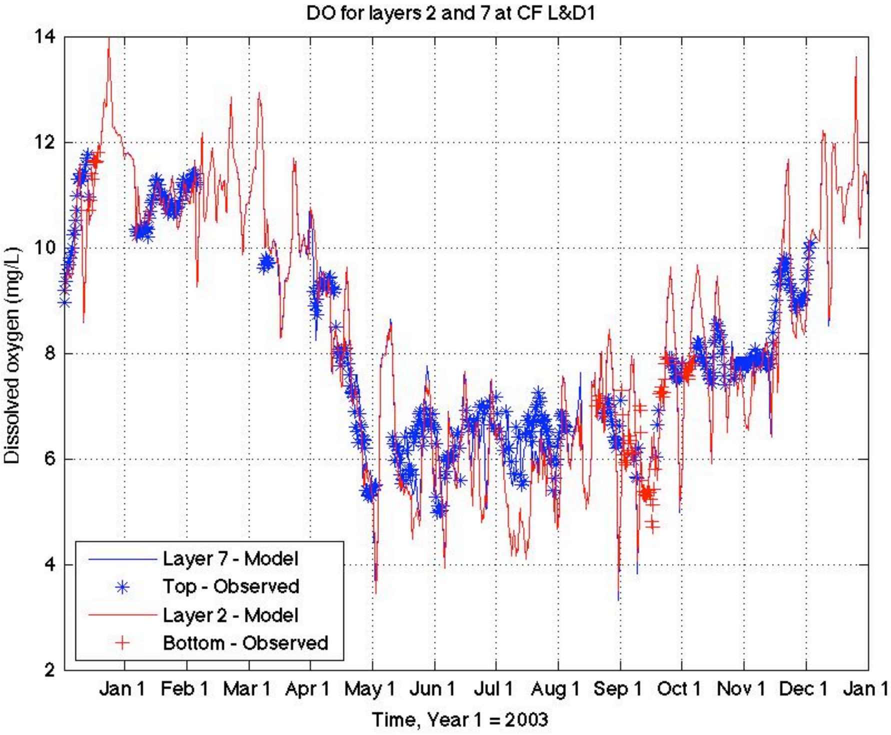


Figure 46. Natural Logarithm of Measured Sediment Oxygen Demand (y-axis) vs. Deviation from 20 Degree ºC Measured Temperature (x-axis).

Time history comparisons of observed vs. predicted dissolved oxygen concentrations were used to assess water quality model calibration performance. Here we show these time histories at seven stations, the six USGS stations used previously, and one LCFRP station in the Northeast Cape Fear River (NCF117) that was presented earlier when showing temperature time histories. In general the time history comparisons show an excellent calibration performance for dissolved oxygen. At the two of the USGS sites in the oligohaline sites (Cape Fear at Lock and Dam 1, Black at Currie), the model closely tracks the seasonal variation in dissolved oxygen, whereby the summertime DO concentrations are low and the wintertime DO concentrations are relatively high (Figure 47). As seen in the temperature time history, some density stratification seems to be present at the Black River site, which seems to produce a relatively low DO concentration in the bottom waters (Figure 47). The surface DO concentration value, however, follows the observed data closely throughout the 2004 calibration period (Figure 47).

The two oligohaline stations along the Northeast Cape Fear produced interesting model results. The upper site (NE Cape Fear at Burgaw) had model predictions and observations that agreed well with one another, but at the more downstream site (NCF 117), the model generally overpredicted the DO concentration (Figure 48). During the summer months at this station the observed DO concentrations were approximately four mg/L while the model predictions were approximately six mg/L. A similar discrepancy was seen further downstream along the NE Cape Fear at the Wilmington site (Figure 49). Once again the observed data, this time from a USGS continuous water quality monitor showed DO concentration through the summer of approximately 4.0 mg/L. The model predictions are higher, but are closer to the observed data than at station NCF 117. The overprediction of DO concentration here is approximately 1 mg/L (Figure 49).

At the other station in the impaired area (Cape Fear at Navassa), the model fits the observed DO concentration very well (Figure 49). Both summertime and wintertime conditions are predicted well, as are more short-term changes during the summer months. The observed concentrations at the station south of Wilmington (Marker 12), showed significantly more variation in dissolved oxygen (Figure 50) than the other two sites in the mesohaline portion of the estuary. Nonetheless, the model did a good job of simulating the dynamic changes in the DO concentrations that occurred throughout the 2004 calibration period (Figure 50). In general the model predictions are somewhat less variable than the observed data, but the model does do a particularly good job of simulating the temporal changes in the minimum dissolved oxygen concentrations that occur through the summer months (Figure 50).



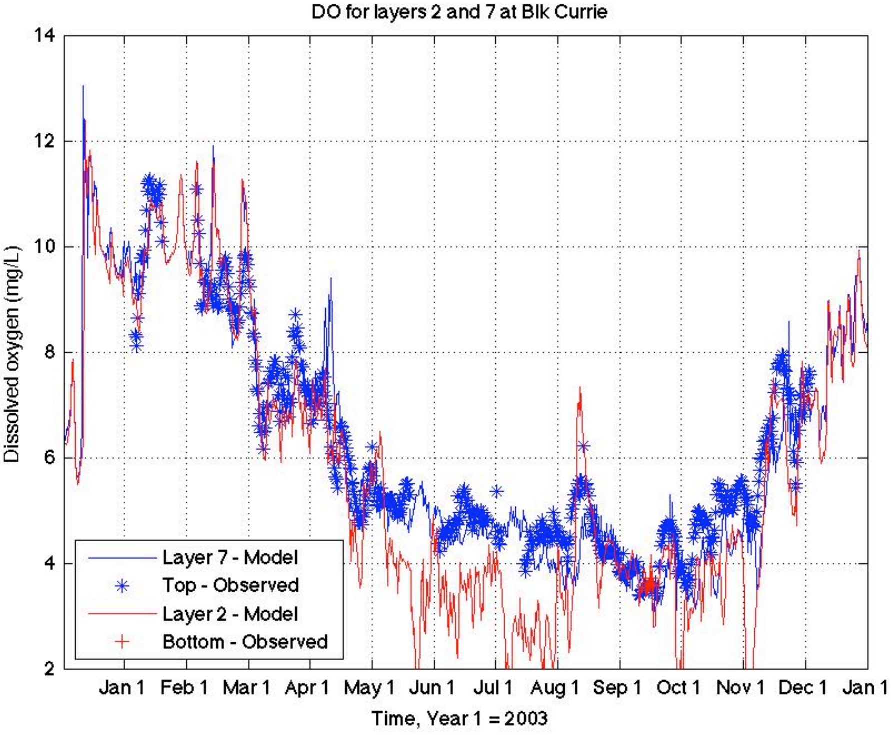
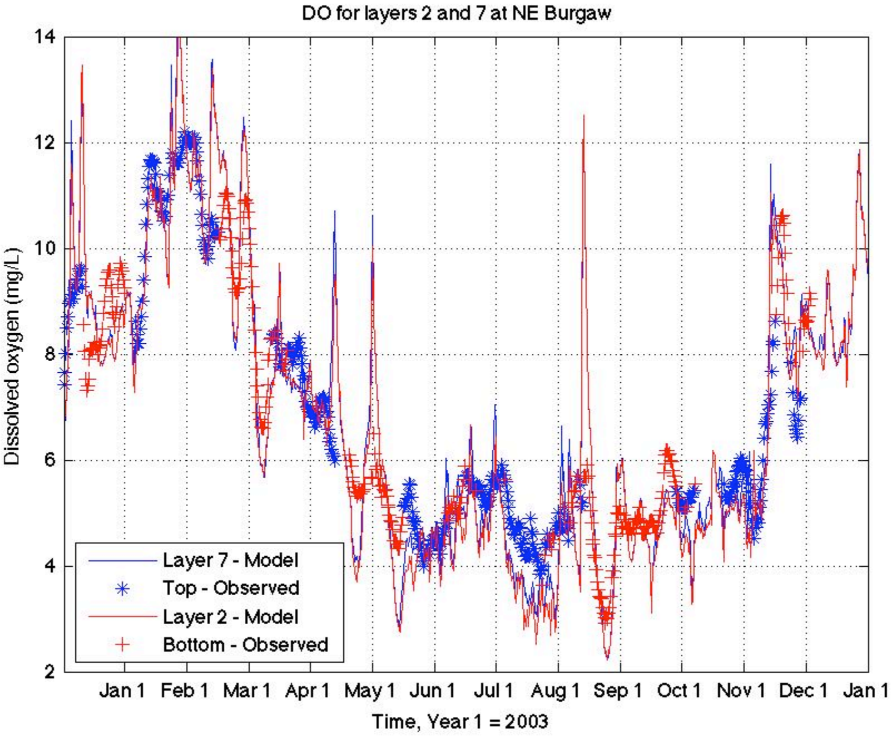


Figure 47. Model Predicted (lines) and Observed (symbols) Dissolved Oxygen Concentrations During 2004 at the Cape Fear River at Lock and Dam1 and the Black River at Currie.



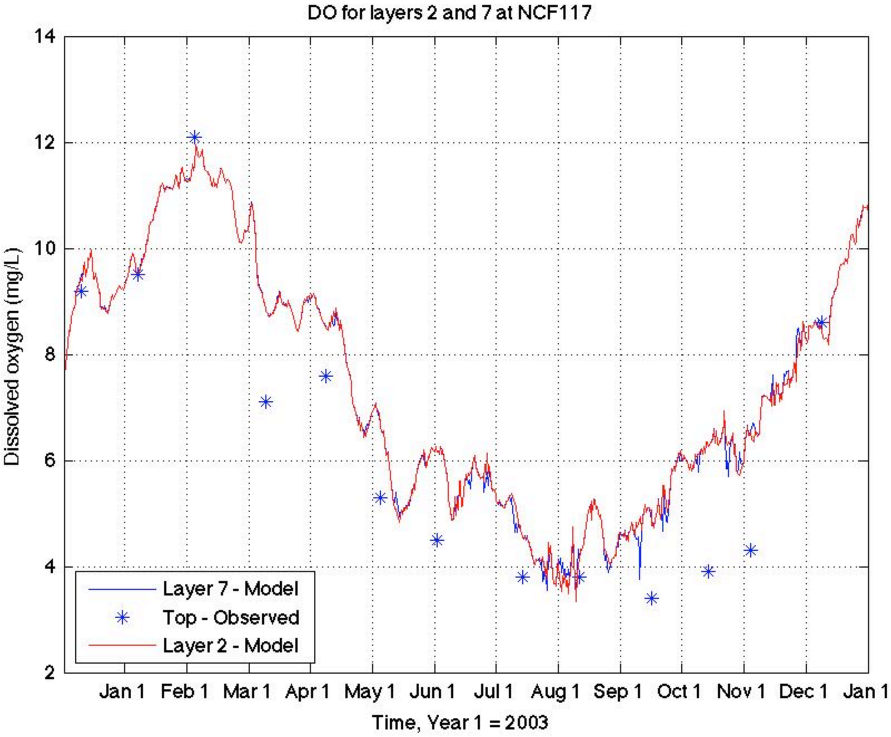
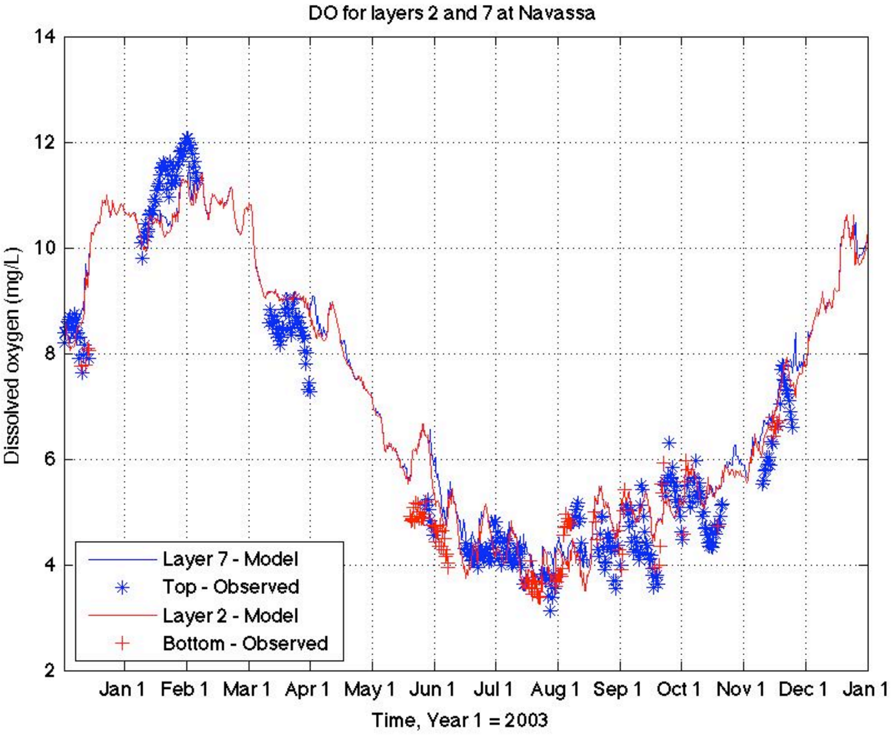


Figure 48. Model Predicted (lines) and Observed (symbols) Dissolved Oxygen Concentrations During 2004 at the NE Cape Fear River at Burgaw and Station NCF 117.



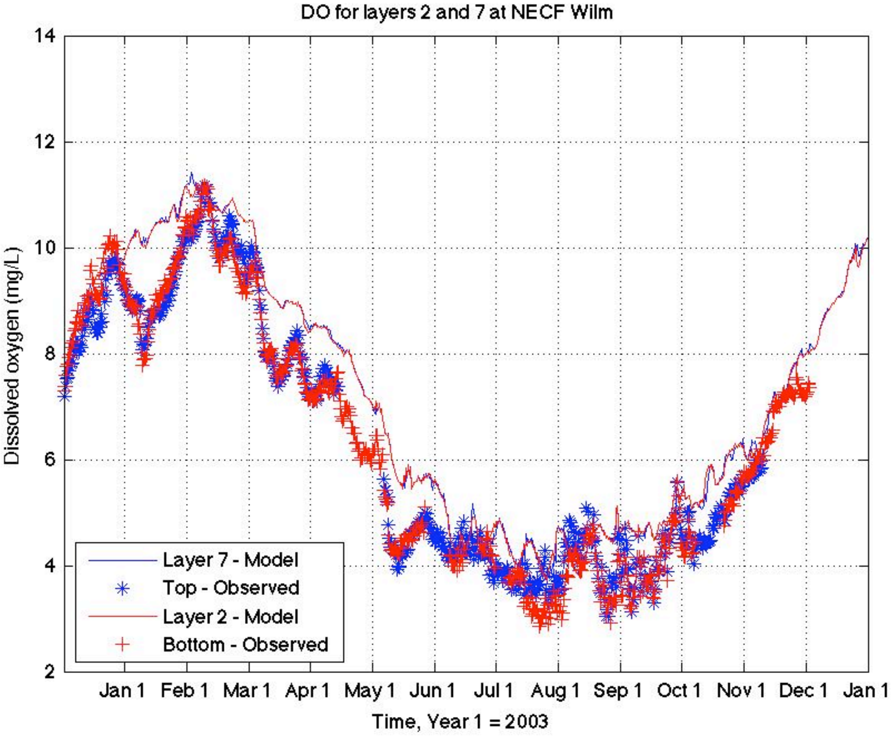


Figure 49. Model Predicted (lines) and Observed (symbols) Dissolved Oxygen Concentrations During 2004 at the Cape Fear River at Navassa and the NE Cape Fear River at Wilmington.

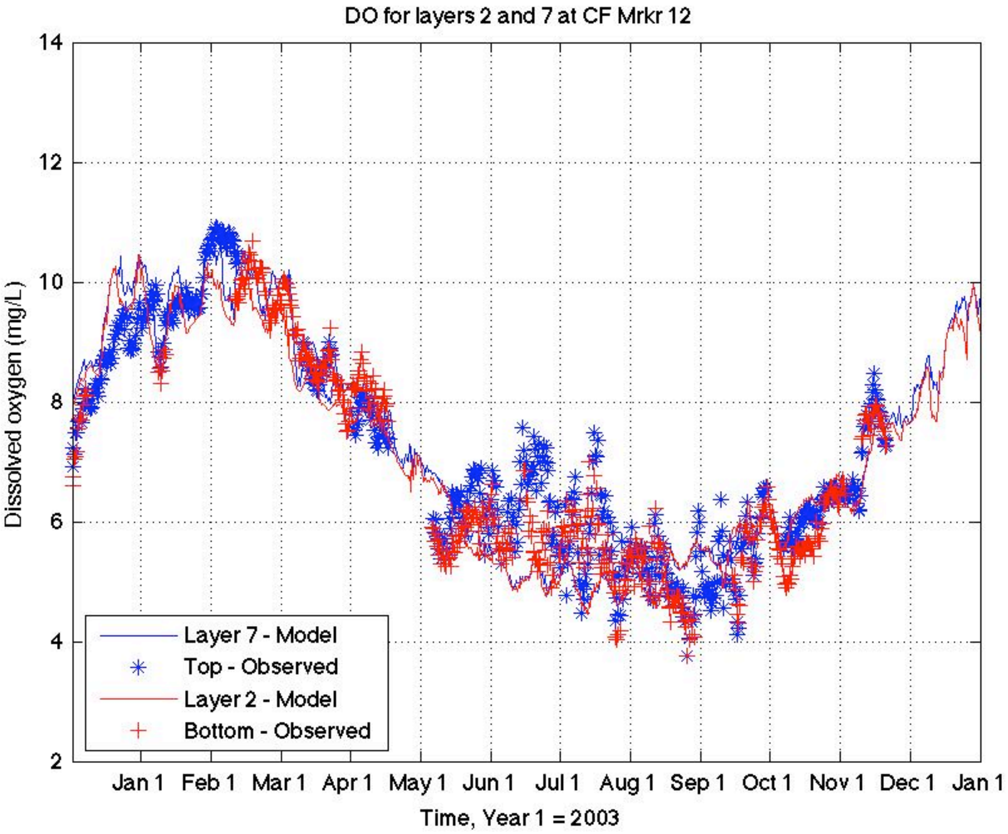


Figure 50. Model Predicted (lines) and Observed (symbols) Dissolved Oxygen Concentrations During 2004 at the Cape Fear River at Marker 12.

Statistical measures of model fit demonstrate the model's ability to simulate the temporal and spatial differences in DO concentration. As for the hydrodynamic model calibration, the calibration statistics are based on model/data comparisons at all twenty-one sites. The USGS sites use hourly average values that have been sampled at two times per day, at twelve hour intervals. The Lower Cape Fear River Program data comes from boat-based sampling that occurred at a variable frequency – as often as weekly during the summer months and stretching to monthly during the winter months. A total of 5,274 model/data comparisons were used to assess model calibration performance for dissolved oxygen. The mean error for dissolved oxygen concentration (predicted – observed) was -0.06 mg/L, which represented a mean error of 0.86% (Table 19). Root mean square errors and mean absolute errors were 0.90 mg/L and 0.69 mg/L respectively, which gives normalized errors of 13.4% and 10.3% respectively. The correlation R^2 for dissolved oxygen model predictions relative to the observed data was 85.4%, or 83.5% when the correlation coefficient is corrected for model bias (Table 19). In general this is excellent calibration performance for an estuary dissolved oxygen model.

Table 19. Calibration Statistics, Dissolved Oxygen

Parameter	Value	Units
Mean Error (predicted – observed)	**0.005**	**g/m^3**
Normalized Mean Error	**0.06**	**%**
Root Mean Square Error	**0.92**	**g/m^3**
Normalized Root Mean Square Error	**13.8**	**%**
Mean Absolute Error	**0.73**	**g/m^3**
Normalized Mean Absolute Error	**13.8**	**%**
Correlation R^2	**84.4**	**%**
Number of Model/Data Comparisons	**5274**	**-**
R^2 Corrected for Bias	**82.7**	**%**

Statistical measures of model fit were also calculated at individual stations (Table 20). The mean error statistics show that the majority of the stations in the Black and Cape Fear Rivers had predicted dissolved oxygen concentrations that were generally under predicted with respect to observed values, while the predictions in the Northeast Cape Fear were slightly above the observed values. Most stations had a mean error of less than 0.5 mg/L. Root mean square errors were similar to that seen for the cumulative data (13.4%, Table 19). Correlation r^2 values ranged from a low of 67.3% at station B210 to a high of 96.3% at Marker 61 in the Cape Fear. Correlation r2 in the impaired region of the estuary near Wilmington were generally near or above 90% (Table 20).

The scatter plots of observed vs. predicted dissolved oxygen concentration also indicate the excellent agreement between model prediction and observation. There is little or no bias in the model predictions, and the residuals appear to be of uniform magnitude across the range of predicted dissolved oxygen concentrations (Figure 51). There are a few values in which the model badly overpredicts DO concentration, but compared to the more than 5,000 model/data comparisons, the number of badly predicted DO concentrations is very small (Figure 51).

Equally impressive is the close agreement between model predictions and observations as seen in the percentile plot. The distribution of DO concentrations in the model predictions matches almost exactly that seen in the observations (Figure 52). Of special interest is the fact the number of relatively low DO concentrations, say for example the percentage of values below 4.0 mg/L is near identical (10%) for both the model predictions and the observed data. Only at the very lowest DO concentrations is there any discrepancy between the two distributions. At these lowest DO concentrations, it appears the observed data have slightly higher percentiles, although the magnitude of the differences (e.g. 0% vs. 3% at 3.0 mg/L) is relatively small (Figure 52).

Table 20. Model Calibration Statistics for Dissolved Oxygen at Monitoring Sites Within the Model Region.

Station	Mean Error (ppth)	%	RMS (ppth)	%	MAE (ppth)	%	R^2	No. data points
CF @ L&D1	-0.18	-2.3%	0.66	8.3%	0.89	11.2%	81.8%	509
NC11, CF	-0.87	-11.1%	1.11	14.1%	1.31	16.6%	79.8%	75
Blk. @ Currie	-0.62	-10.4%	0.88	14.7%	1.13	18.8%	85.8%	571
B210, Blk	-1.43	-19.9%	1.59	22.2%	2.02	28.2%	66.9%	13
CF @ Acme	-0.76	-10.2%	0.96	12.8%	1.22	16.4%	81.7%	75
IC, CF	-0.05	-0.7%	0.61	9.8%	0.76	12.1%	90.4%	75
NE Burgaw	-0.18	-2.7%	0.82	12.1%	1.09	16.1%	85.3%	671
NCF117	1.01	15.7%	1.05	16.4%	1.32	20.6%	92.7%	13
NCF6, NECF	-0.71	-11.1%	1.03	16.0%	1.30	20.3%	82.5%	47
Navassa	0.23	3.7%	0.57	9.3%	0.68	11.1%	93.7%	433
CF @ Nav	-0.43	-6.8%	0.68	10.9%	0.82	13.0%	92.3%	75
CF @ HSB	-0.15	-2.6%	0.61	10.1%	0.76	12.5%	91.5%	74
NECF Wilm	0.74	11.7%	0.78	12.2%	0.90	14.1%	95.6%	1297
Brnswk Riv	-0.45	-6.0%	0.73	9.7%	0.99	13.1%	89.3%	39
CF @ M61	0.11	1.6%	0.46	6.8%	0.58	8.6%	95.7%	48
CF @ M54	-0.24	-3.4%	0.62	8.9%	0.74	10.6%	90.0%	48
CF @ M42	-0.53	-7.3%	0.80	11.0%	0.92	12.7%	86.0%	48
CF Mrkr 12	-0.16	-2.3%	0.59	8.5%	0.74	10.8%	82.4%	1070
CF @ M35	-0.54	-7.3%	0.79	10.7%	0.93	12.6%	83.4%	48
CF @ M23	-0.40	-5.3%	0.62	8.2%	0.75	10.0%	84.5%	45

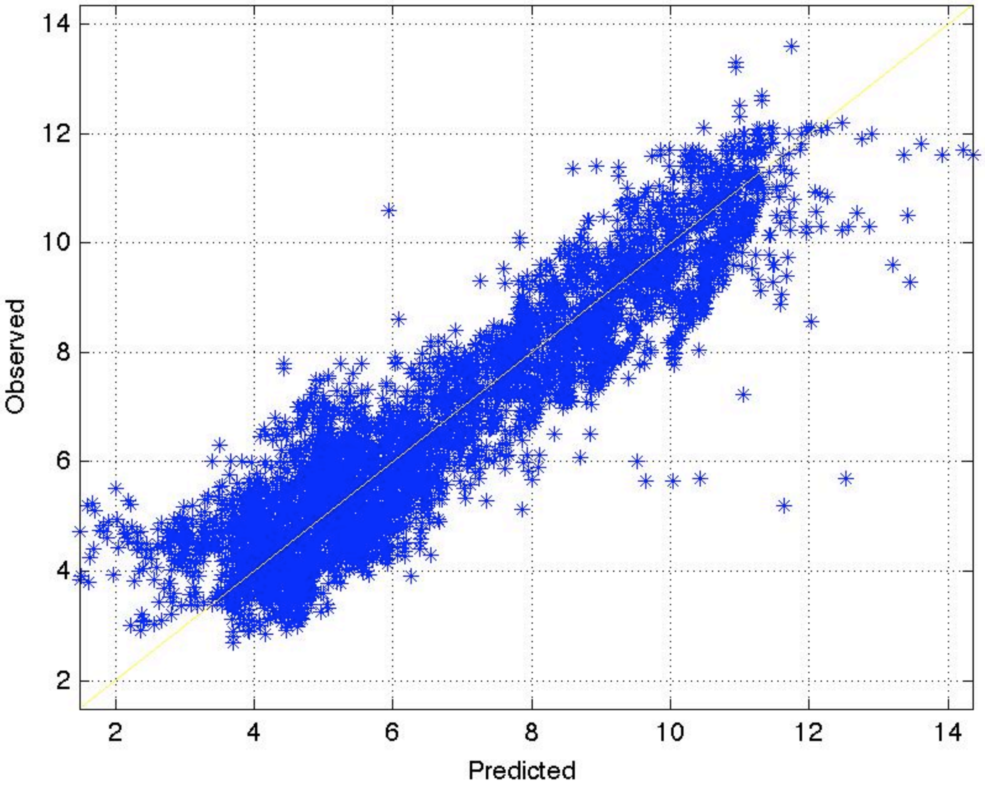


Figure 51. Scatter Plot of Predicted Dissolved Oxygen Concentrations (mg/L, x-axis) vs. Corresponding Observed Dissolved Oxygen Concentrations (mg/L, y-axis) for the 2004 Calibration Period.

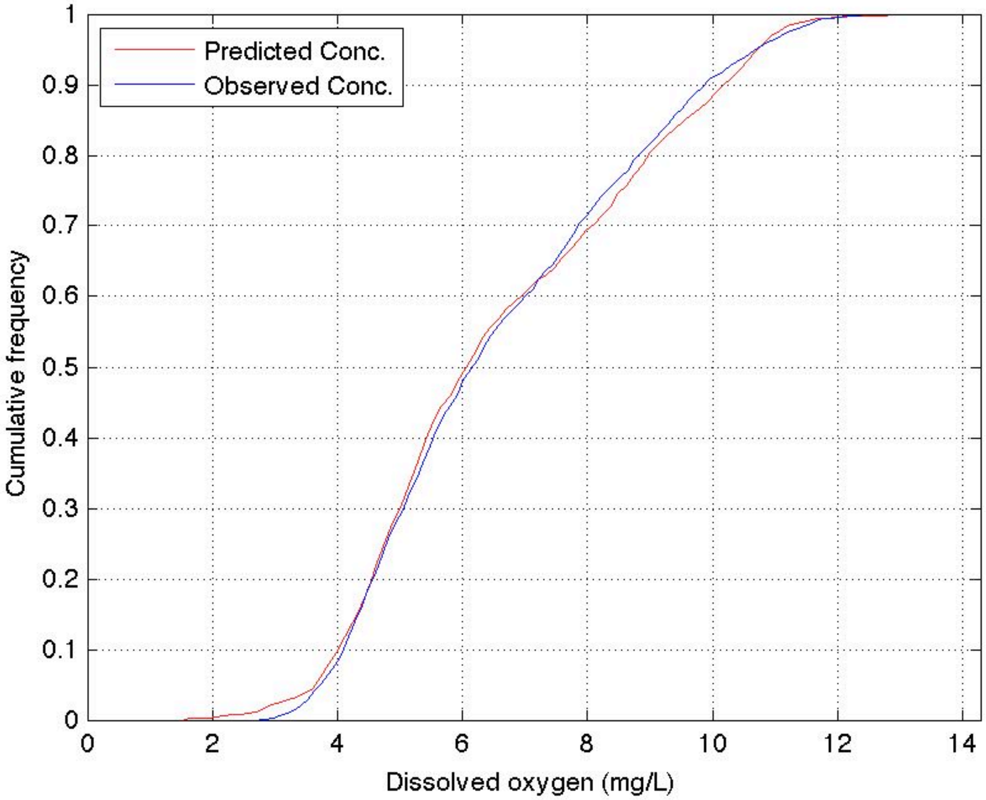


Figure 52. Percentile Plot of Observed and Model Predicted Dissolved Oxygen Concentrations During the Calibration Period. The y-axis indicates the fraction of values below the corresponding DO concentration (mg/L) indicated on the x-axis.

On the following pages time histories comparisons are shown for several other key constituents in EFDC's water quality model:

- Ammonia nitrogen
- Nitrate+nitrite nitrogen
- Total phosphorus
- Total chlorophyll-a

These constituents were chosen for presentation because they represent key information on how organic matter is cycling between organic and inorganic pools within the estuary. Time histories are shown for each of these constituents at the following six sites:

1. Cape Fear River at NC 11
2. Black River at B210
3. Northeast Cape Fear at NCF6
4. Cape Fear River at IC
5. Cape Fear River at Navassa
6. Cape Fear River at Marker 23

These six sites, all monitored by the Lower Cape Fear River Program span the entire model region. Each set of model predicted vs. observed data time histories shows the water quality model's capability to simulate water quality dynamics within the system.

Ammonia concentrations at the six sites (Figures 53-55) are generally less than 0.5 mg/L but are occasionally higher in the summertime. The monitoring data at certain sites (e.g. Black River site B210, and Northeast Cape Fear site NCF6) shows a relatively large amount of sample-to-sample variability. In general the monitoring data are more variable in time than the model predictions. There are no significant spatial or temporal trends in either the monitoring data or model predictions. For instance, the lowest concentrations were seen upstream in the Black River and downstream at Marker 23 (Figures 53 and 55).

Nitrate+nitrate (NOx) concentrations (Figures 56-58) are generally higher in the oligohaline portion of the estuary and are always higher than total phosphorus concentrations (Figure 59-61). The lowest NOx concentrations are at station M23 (Figure 58). The model does a good job of representing these spatial trends. There are no detectable temporal trends in the monitoring data for nitrate+nitrite. Total phosphorus (TP) concentrations show a similar spatial trend, with the highest total phosphorus concentrations in the oligohaline portion of the estuary and the lowest concentrations near the estuary mouth. As for ammonia, the monitoring data shows a large amount of sample variability in total phosphorus concentration. There is no detectable temporal trend either in the monitoring data or the model predictions, although there do seem to be episodic increases in TP concentrations. As for ammonia, the model predictions are less variable in time than the observed data (Figures 59-61).

Total chl-a concentrations are always than 10 µg/L, but do show some significant increases during summertime events (Figures 62-64). Model predictions also show temporal variability, with two distinct peaks occurring at each station, although interestingly, the timing of the peak differs from station to station. For instance at station M23 the peaks occur in the March and July (Figure 64), whereas in the Northeast Cape Fear the peaks occur in May and October. These differences in the timing of the chlorophyll peaks are probably related to differences in timing of nutrient supply between these two areas of the estuary. The overall level of variability in the observations and in the model predictions are similar to one another (Figures 62-64).

Overall the water quality model's calibration performance was considered acceptable for its use as part of a dissolved oxygen TMDL. Calibration performance for the DO model was excellent, with statistical measures of calibration performance indicating that the model does an excellent job of capturing the observed spatial and temporal variability in dissolved oxygen concentrations. Correlation r^2 values at individual sites and overall are comparable, if not better, than those expected for estuarine water quality models. The model's predictions of other water quality constituents are also good. While for these constituents, the model's capability to match observed spatial and temporal patterns is not as good as for dissolved oxygen, the model is able to match the overall concentration level seen across the estuary during the calibration period. Together this information provides confidence that the model is suitable for its intended use, to estimate the system's dissolved oxygen response to changes in the discharge of oxygen demanding waste.

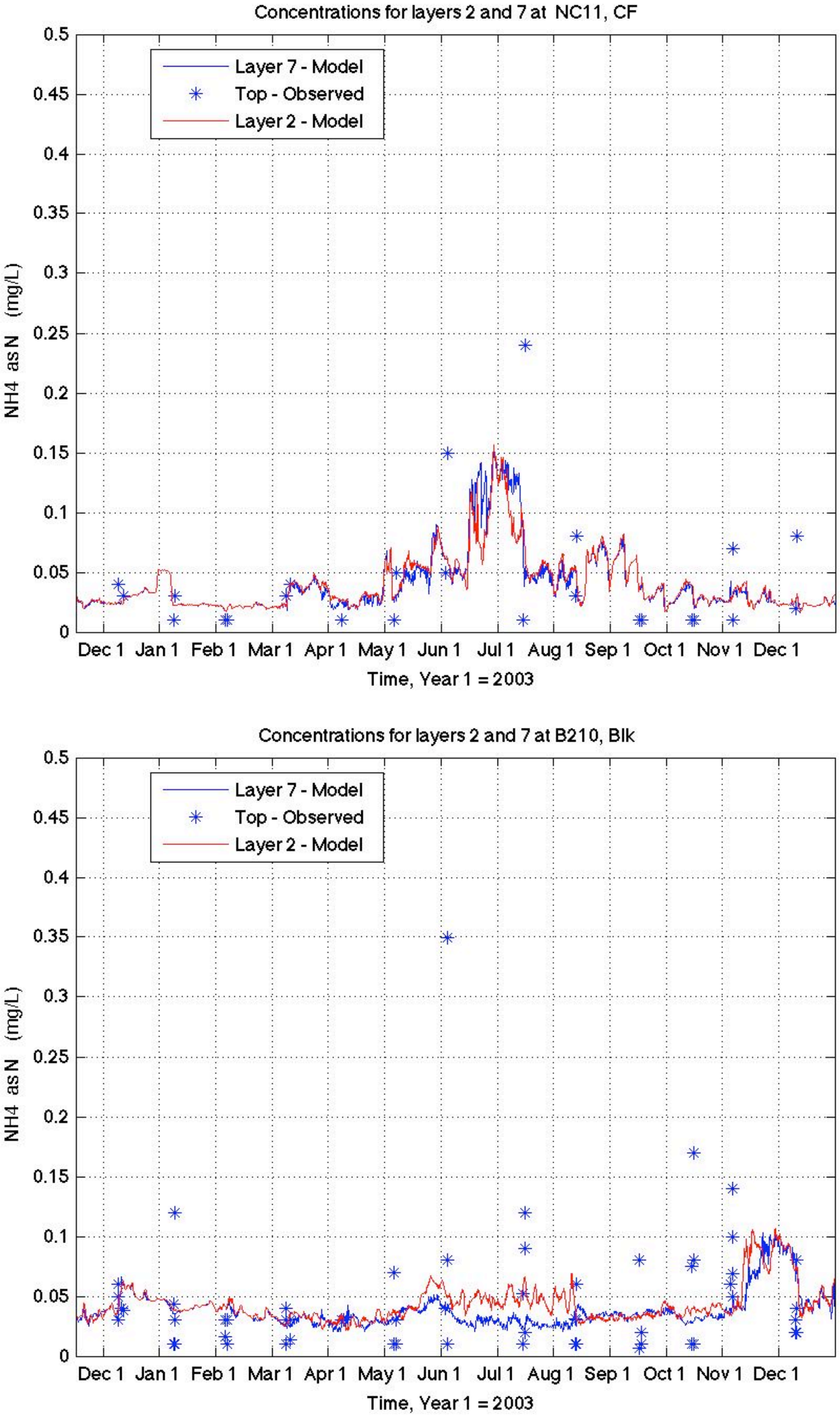
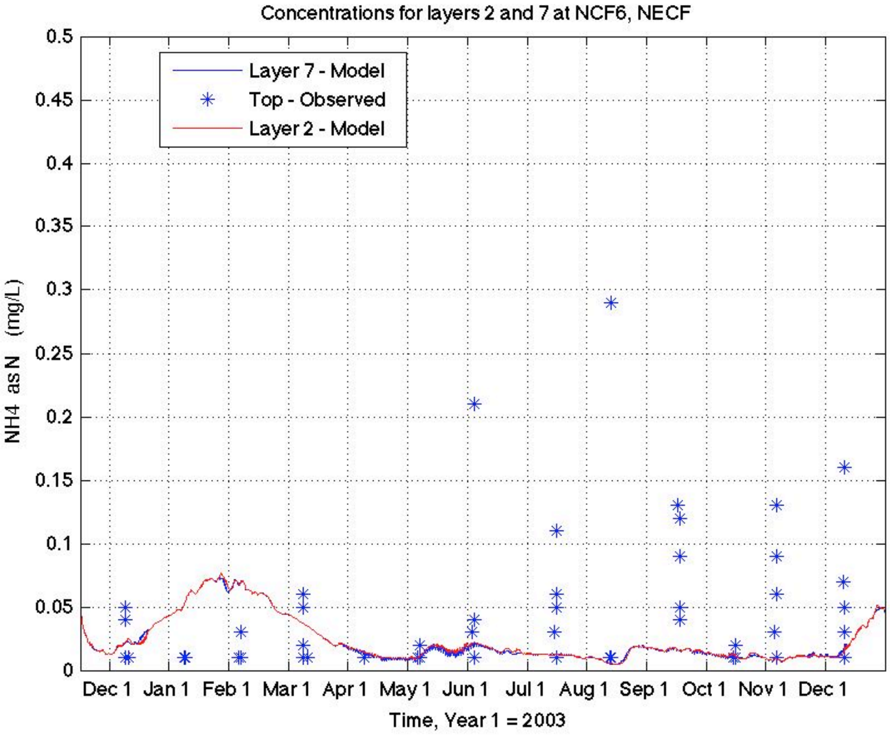


Figure 53. Model Predicted (lines) and Observed (symbols) Ammonia Concentrations During 2004 at the Cape Fear River at Station NC 11 and the Black River at Station B210.



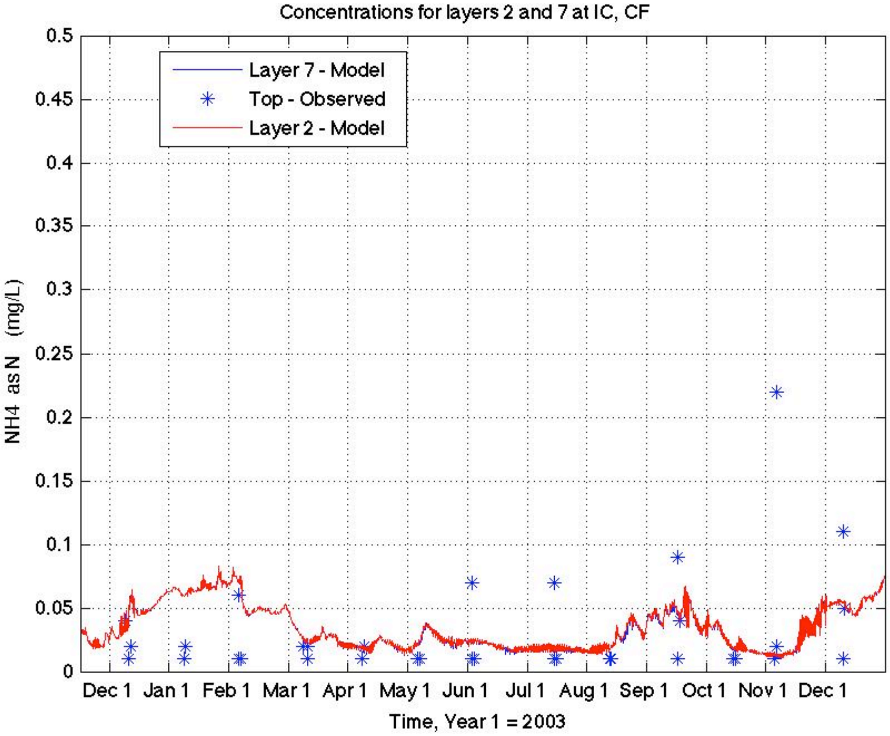


Figure 54. Model Predicted (lines) and Observed (symbols) Ammonia Concentrations During 2004 at the NE Cape Fear River at Station NCF6 and the Cape Fear River at Station IC.

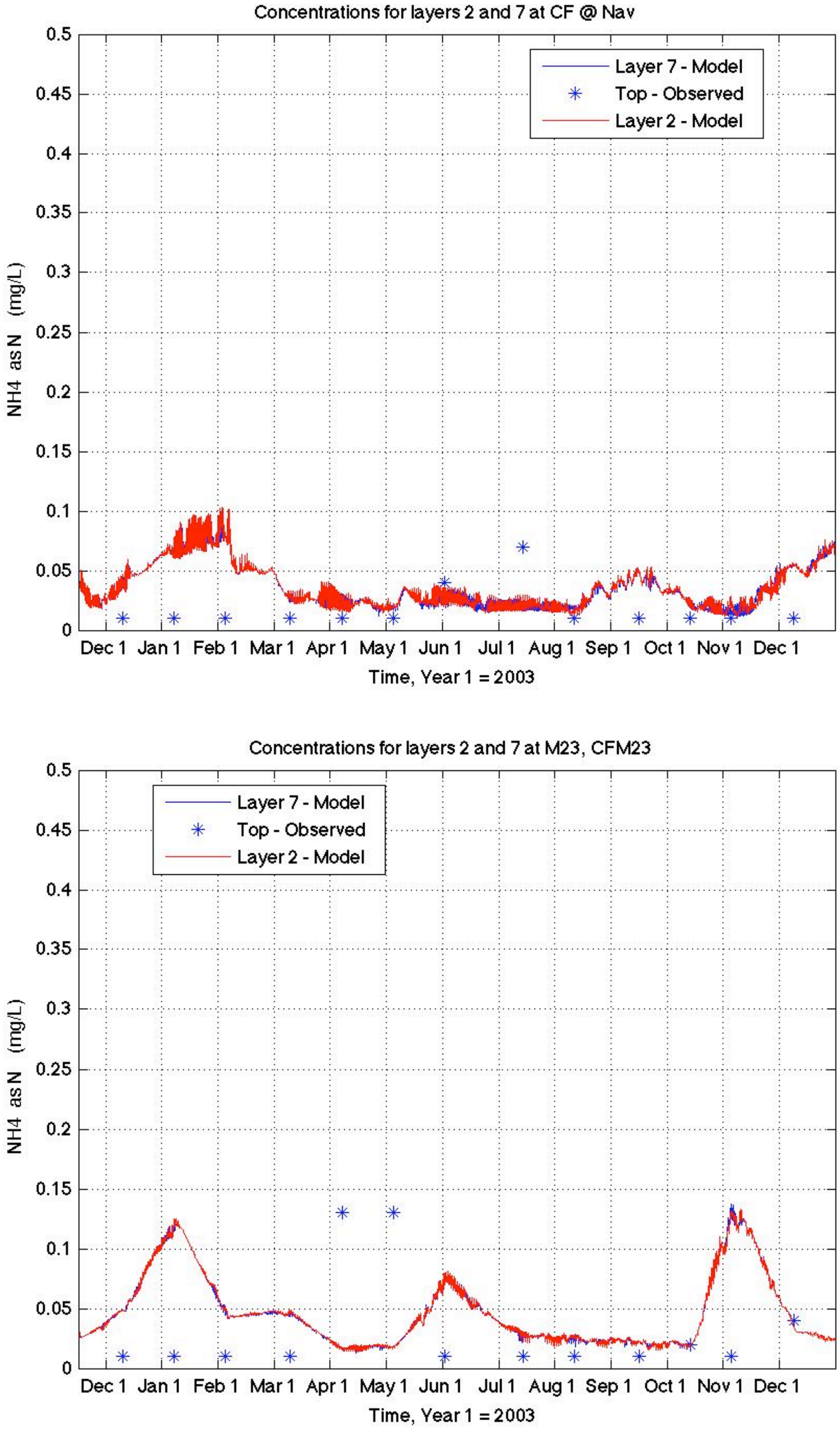
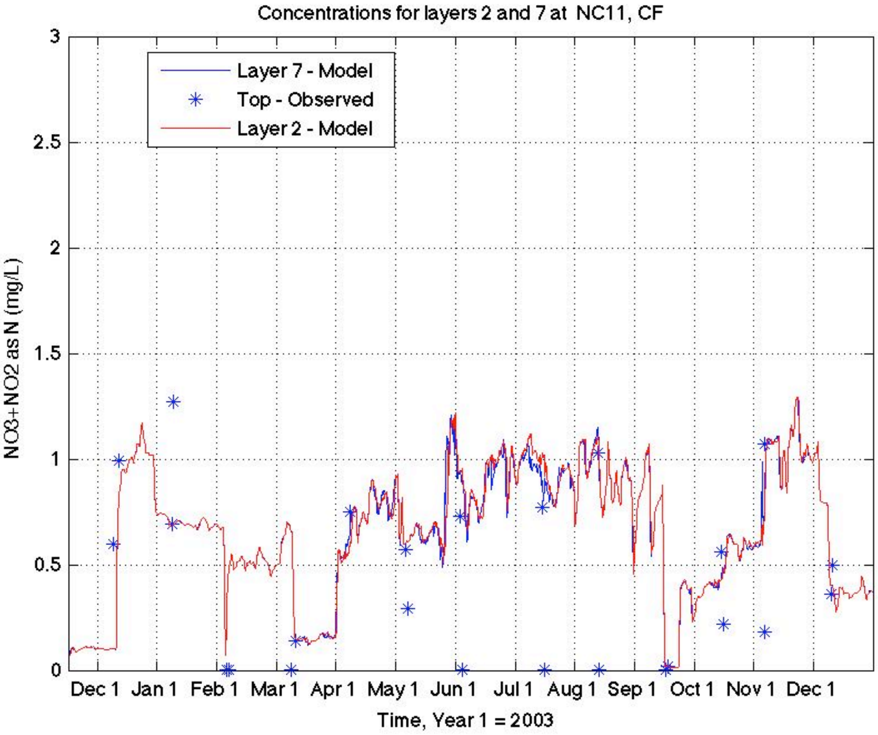


Figure 55. Model Predicted (lines) and Observed (symbols) Ammonia Concentrations During 2004 at the Cape Fear River at Navassa and at Station M23.



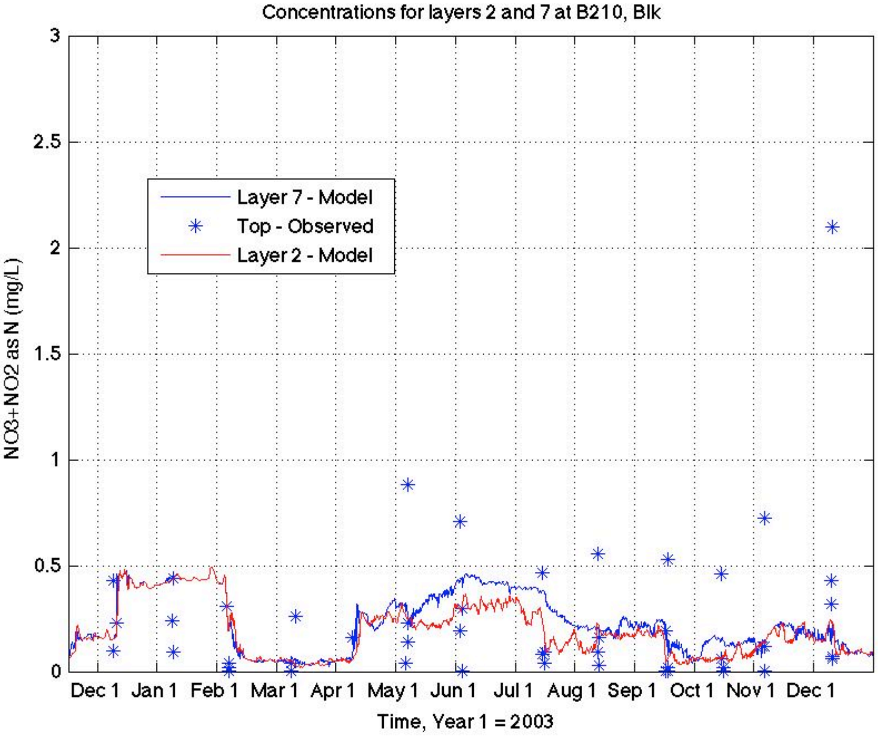
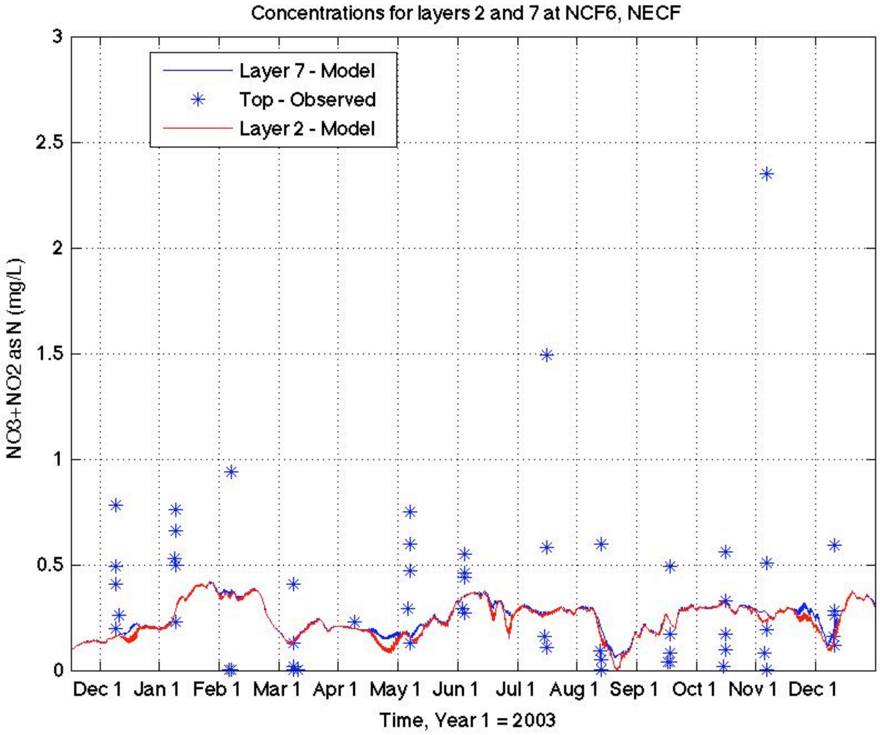


Figure 56. Model Predicted (lines) and Observed (symbols) Nitrate + Nitrite Concentrations During 2004 at the Cape Fear River at Station NC 11 and the Black River at Station B210.



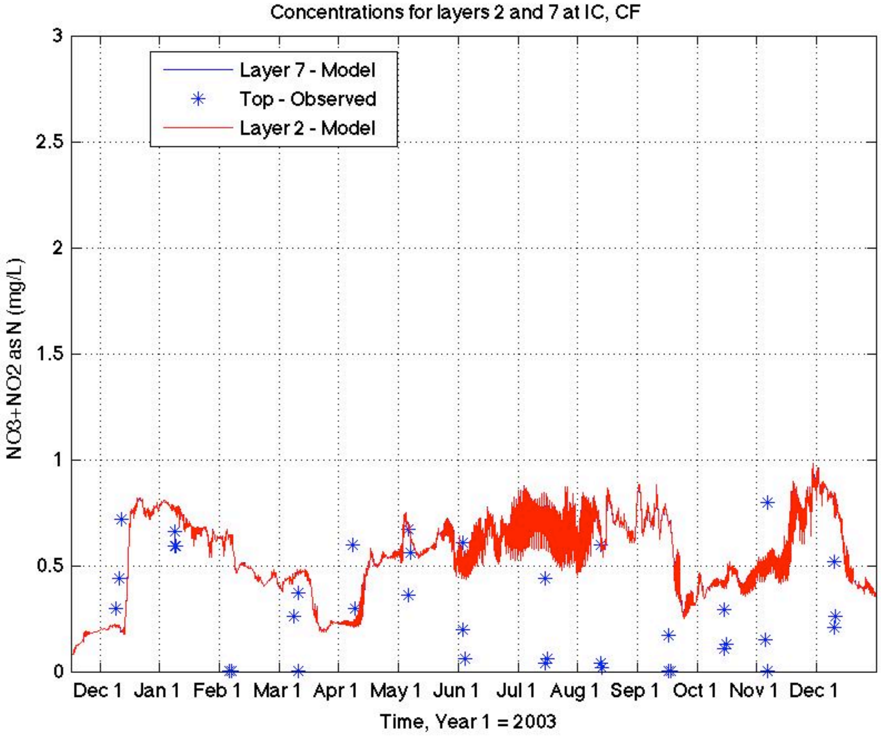
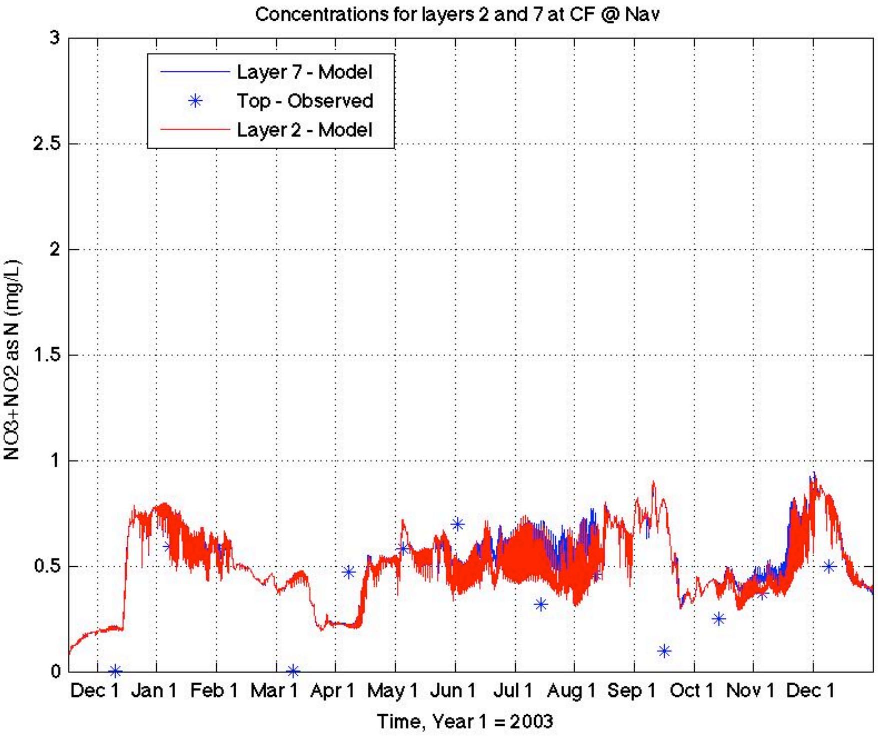


Figure 57. Model Predicted (lines) and Observed (symbols) Nitrate + Nitrite Concentrations During 2004 at the NE Cape Fear River at Station NCF6 and the Cape Fear River at Station IC.



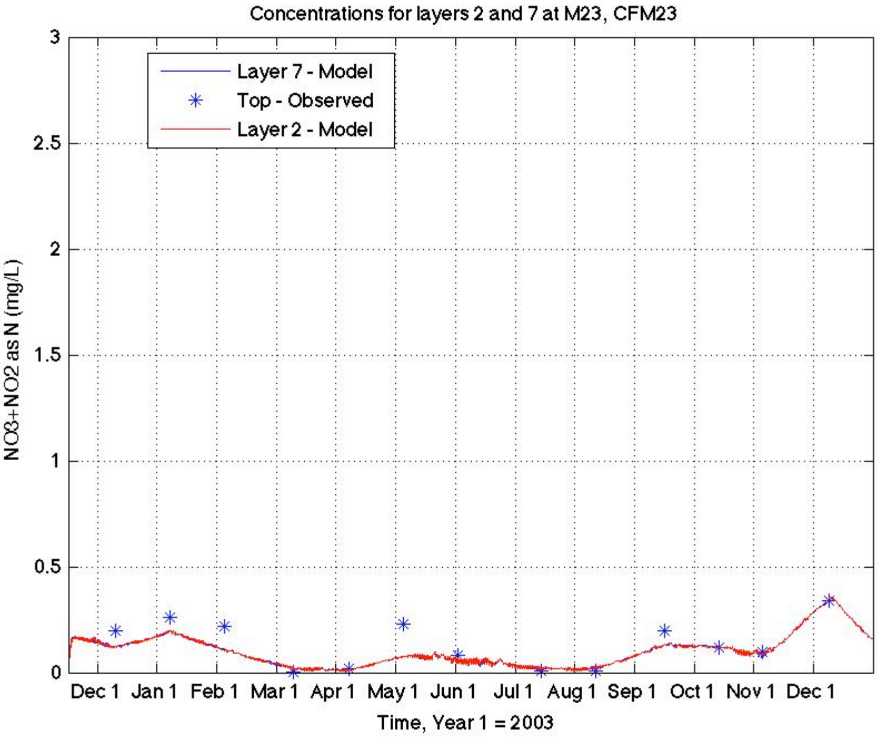


Figure 58. Model Predicted (lines) and Observed (symbols) Nitrate + Nitrite Concentrations During 2004 at the Cape Fear River at Navassa and at Station M23.

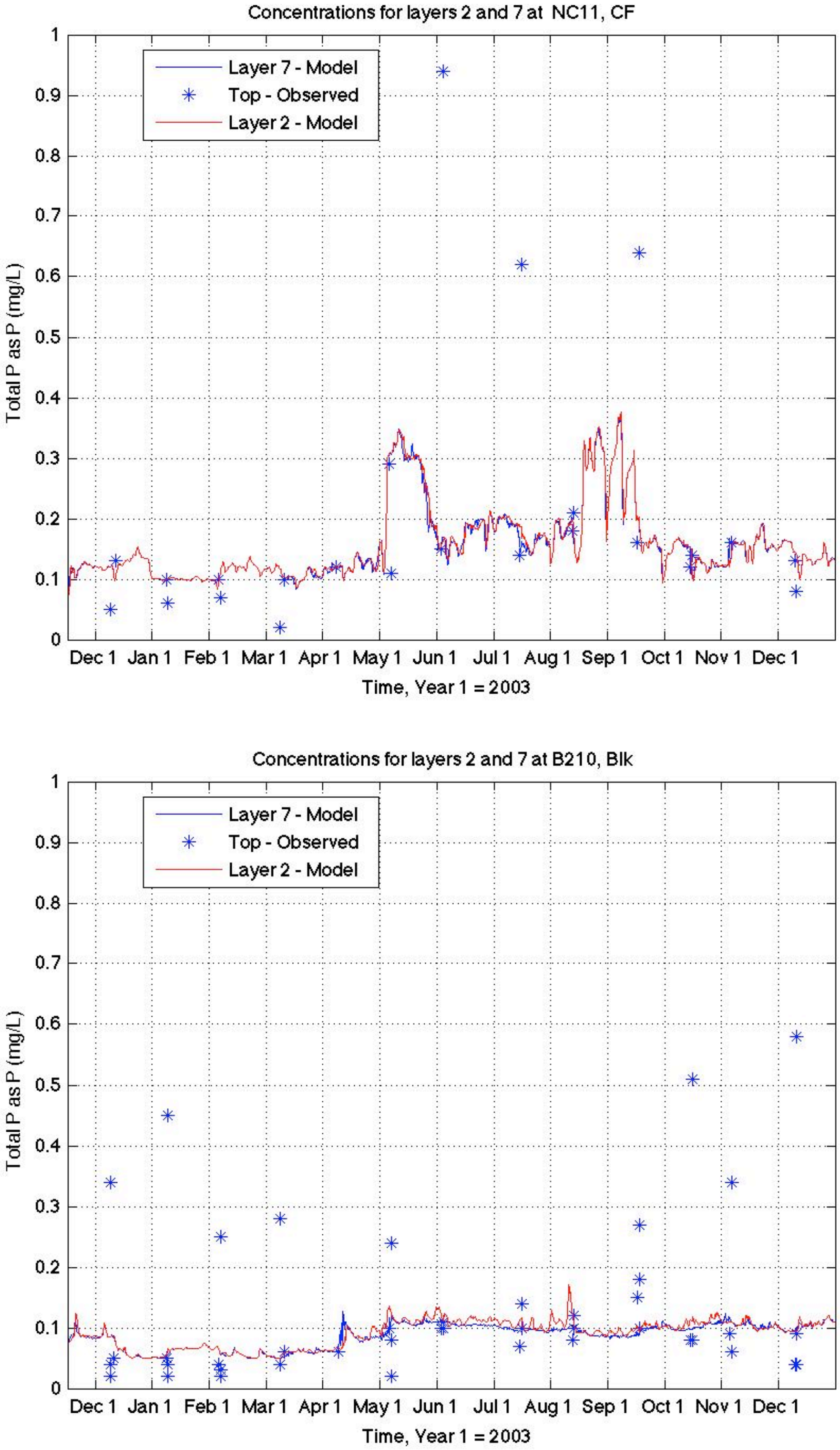


Figure 59. Model Predicted (lines) and Observed (symbols) Total Phosphorus Concentrations During 2004 at the Cape Fear River at Station NC 11 and the Black River at Station B210.

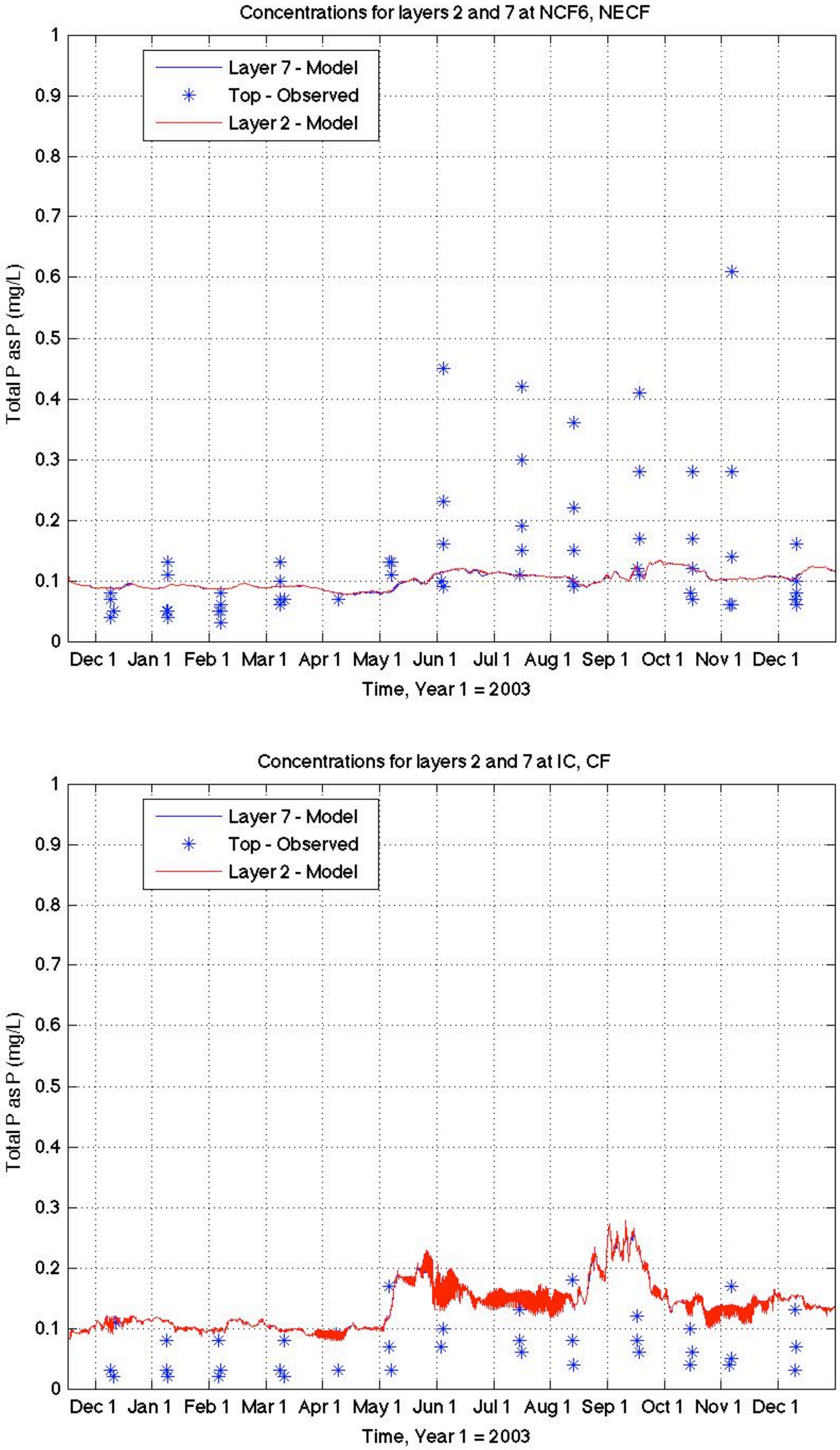
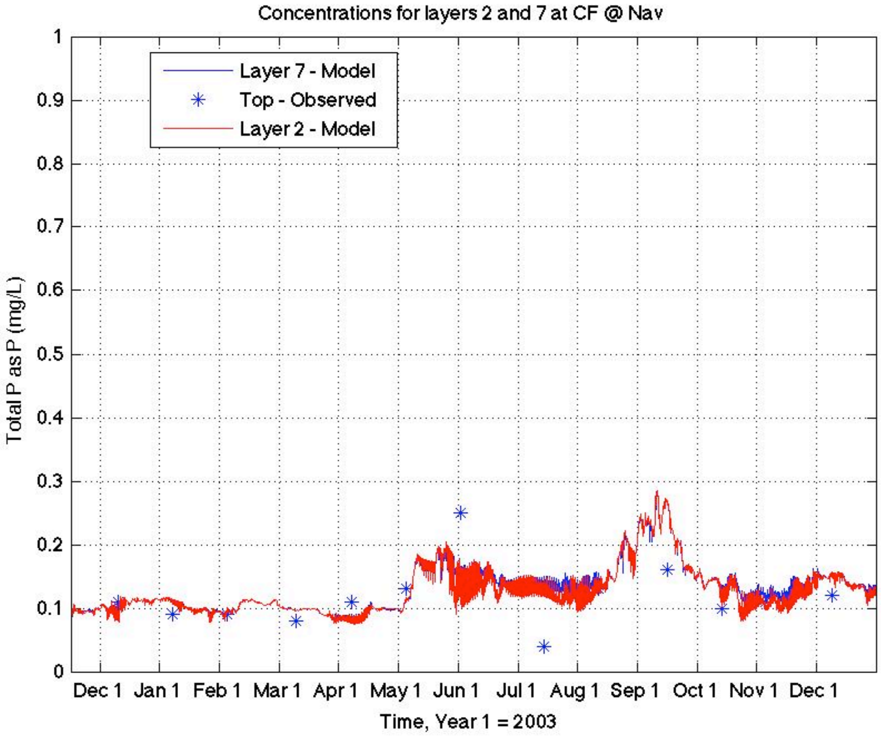


Figure 60. Model Predicted (lines) and Observed (symbols) Total Phosphorus Concentrations During 2004 at the NE Cape Fear River at Station NCF6 and the Cape Fear River at Station IC.



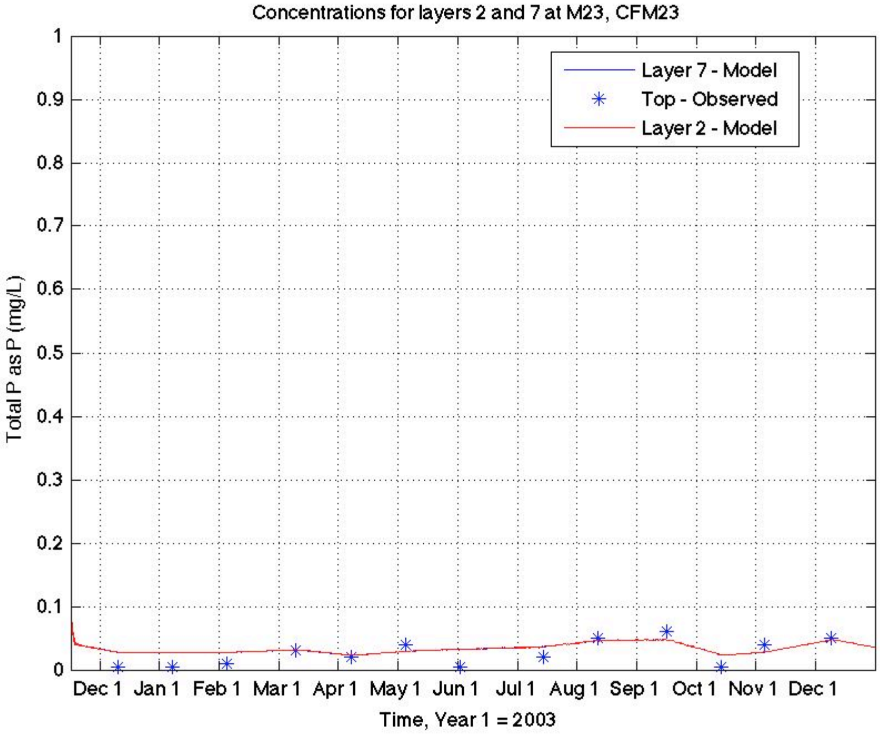


Figure 61. Model Predicted (lines) and Observed (symbols) Total Phosphorus Concentrations During 2004 at the Cape Fear River at Navassa and at Station M23.

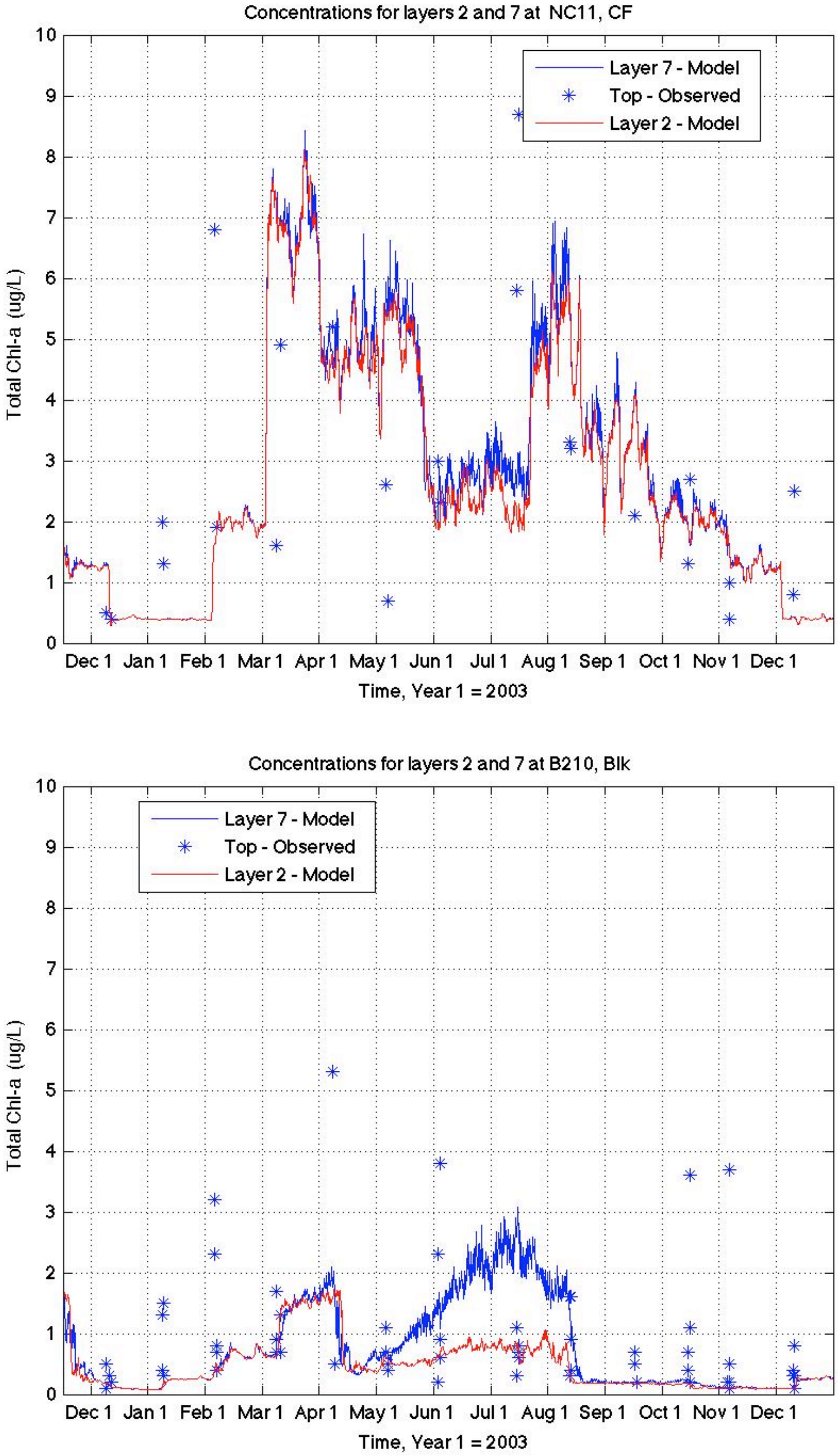
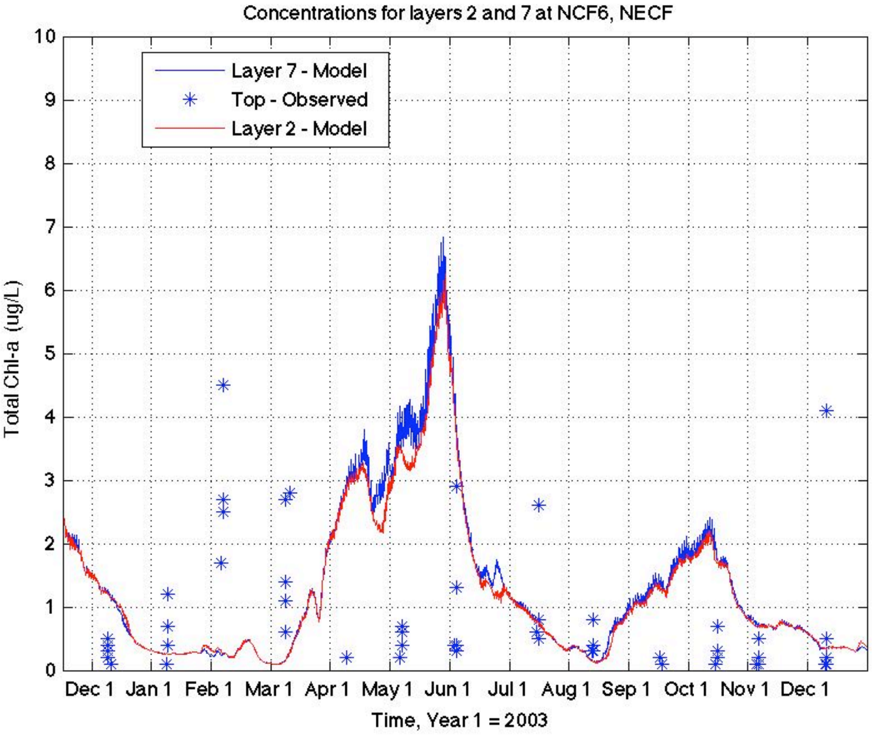


Figure 62. Model Predicted (lines) and Observed (symbols) Chl-a Concentrations During 2004 at the Cape Fear River at Station NC 11 and the Black River at Station B210.



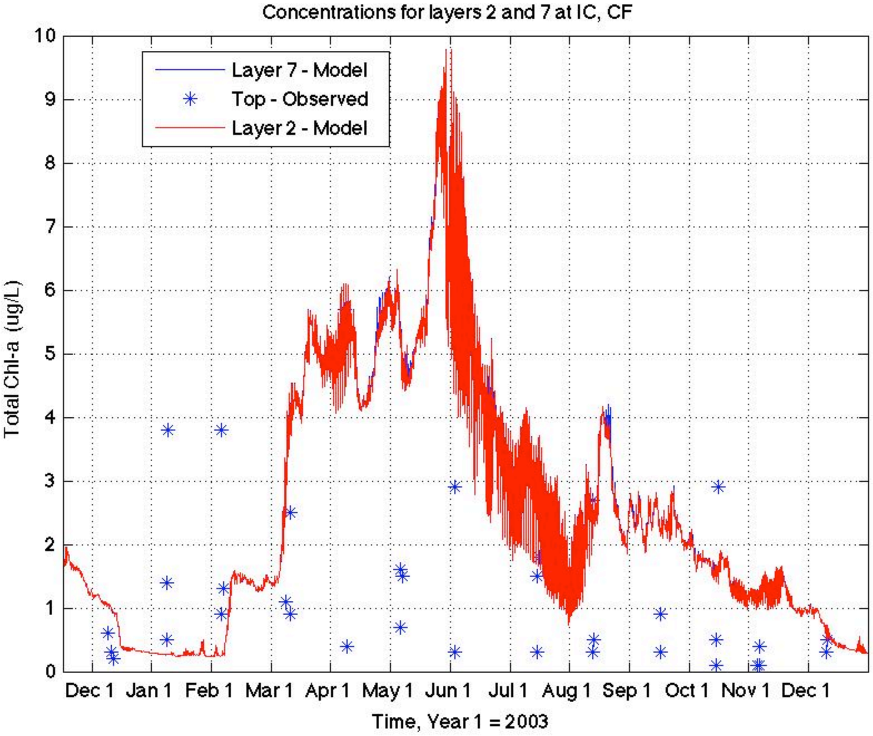
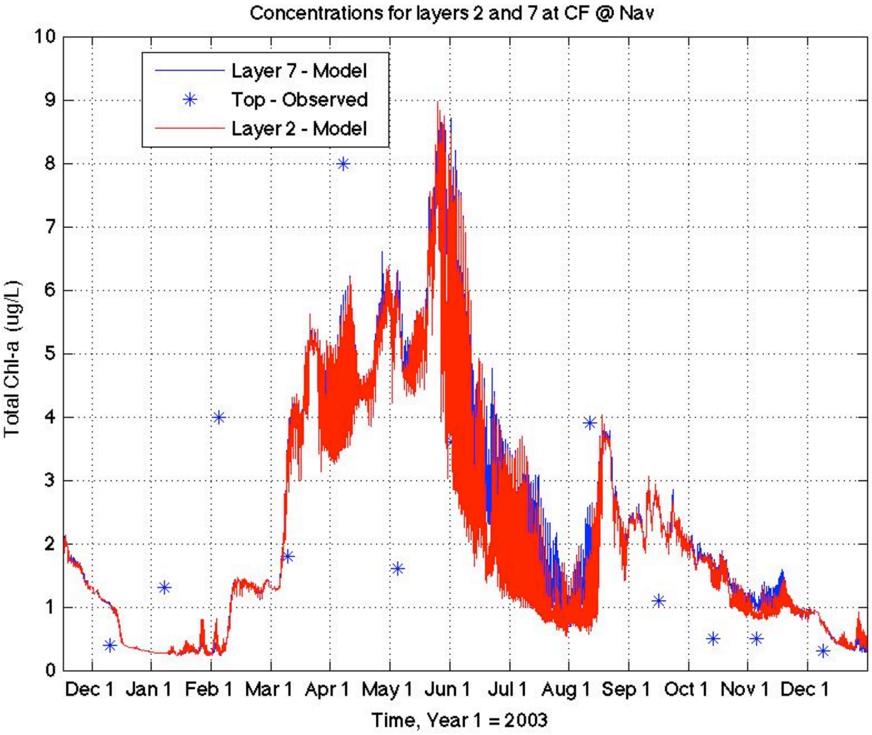


Figure 63. Model Predicted (lines) and Observed (symbols) Chl-a Concentrations During 2004 at the NE Cape Fear River at Station NCF6 and the Cape Fear River at Station IC.



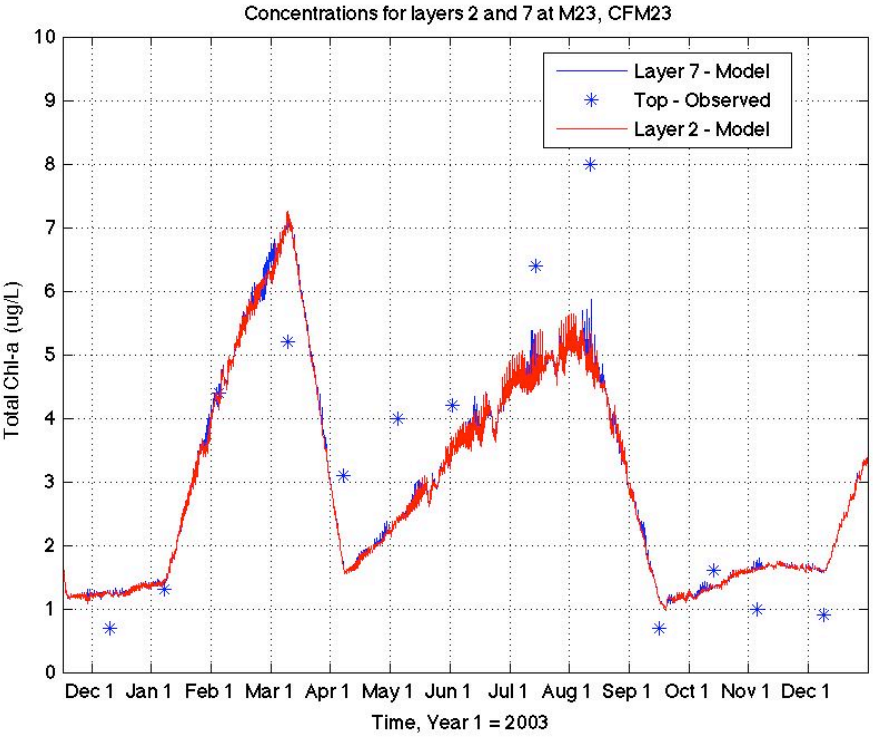


Figure 64. Model Predicted (lines) and Observed (symbols) Chl-a Concentrations During 2004 at the Cape Fear River at Navassa and at Station M23.

5. MODEL EVALUATION

5.1 Model Confirmation

A model confirmation run was conducted to test the calibrated model's ability to simulate water quality conditions during a time period that was not used for model calibration. The 2005 calendar year was used for a model confirmation run. The 2005 calendar year had several high flow events in January and April, but had a dry summer (Figure 18). A short period in early August had streamflows above long-term average values, but otherwise had flows that were consistently below average from mid-April until the end of the year. The Northeast Cape Fear did have one high flow event in October 2004 that was not seen in the larger watershed (Figure 18). This high flow event was the result of heavy rains from tropical storm Jeanne that hit the coastal area but not farther upstream in the watershed.

A significant challenge of the confirmation run was collecting the necessary data to run the model. For the hydrodynamic model, the water surface elevation data was not a problem as both the Sunset Beach and Southport elevation data were sufficient for creating the necessary model forcings. The flow time histories at the upstream boundary on the Cape Fear River used the same location (Lock and Dam 1) as for the calibration run. For the Black and Northeast Cape Fear Rivers, however, data from the two USGS gaging stations nearest the upstream boundary (Black at Currie, Northeast Cape Fear at Burgaw) were no longer available. Instead data from the stations farther upstream (Black at Tomahawk, Northeast Cape Fear at Chinqapin, see Table 3 and Figure 7 for location information) were used instead. The USGS continuous station at Marker 12 was also not available for establishing the downstream boundary condition during 2005. Instead, the monthly salinities at one of the Lower Cape Fear River Stations (M18) was used instead. There was also much less data that could be used for calibration. For instance, over 5000 model/data comparisons were made when calibrating salinity, but for the 2005 confirmation run, only 96 monitored salinities were available. Because of the small amount of monitoring data available only two stations (Navassa, Marker 23) are shown here as time history plots.

Time histories of model predicted salinities and observed salinities during 2005 demonstrate that the model can simulate estuarine dynamics in the system during periods other than the calibration period. Model predicted salinities at two stations in the impaired region (Navassa and Marker 61) and at two other stations in the Northeast Cape Fear and the lower estuary (NCF6 and M35) generally follow the patterns seen in the observed data (Figures 65 and 66). In general the model predicts a somewhat higher salinity than what is observed, but the magnitude of the overprediction is not severe. In addition the model does seem capable of modeling the overall seasonal trends in salinity, and does seem to correctly freshen the estuary during high flow events. For instance early and late 2005 had relatively high flows, and the model correctly simulates the freshening of the estuary that occurs during these times (Figure 65 and Figure 66).

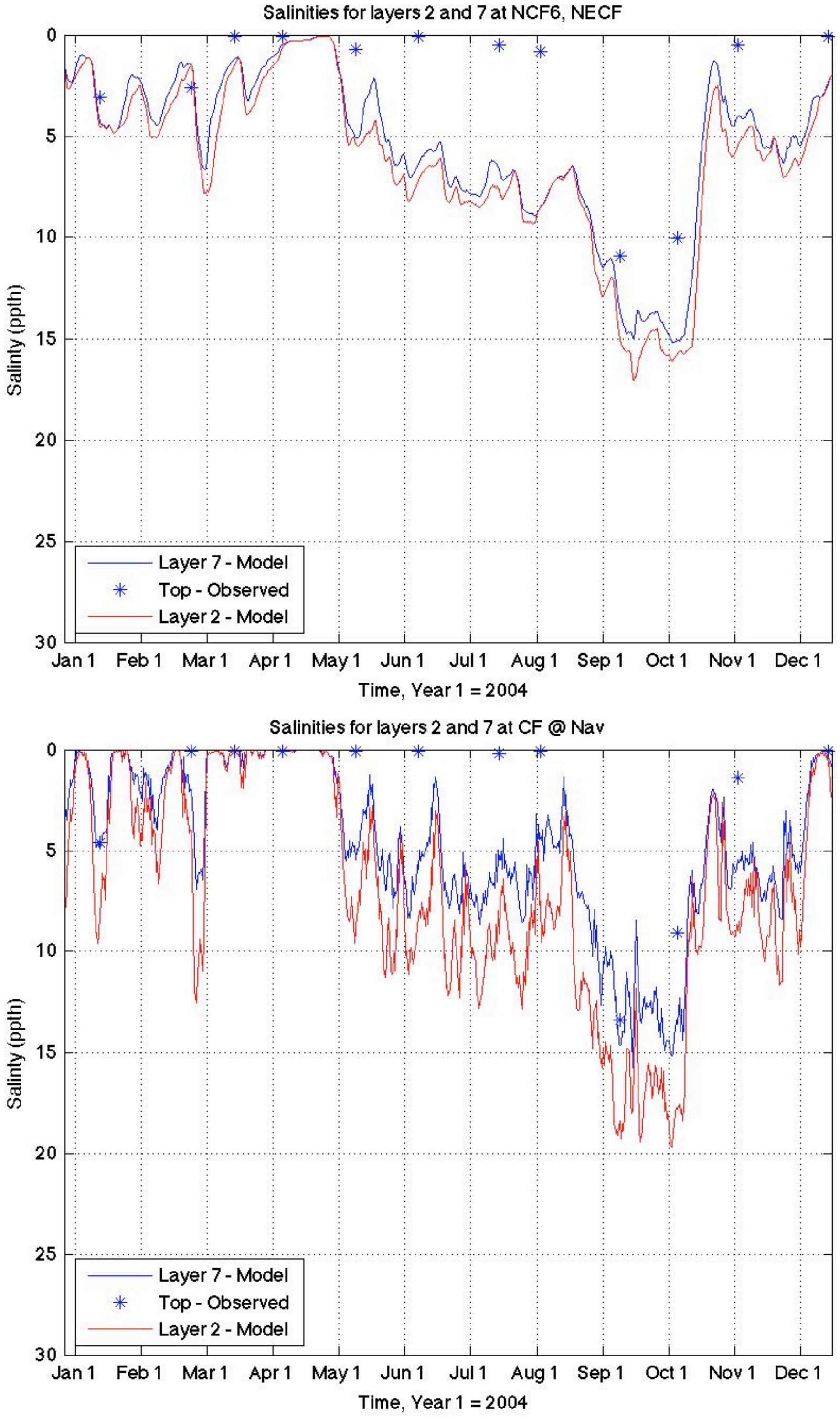


Figure 65. Model Predicted (lines) and Observed (symbols) Salinities During the 2005 Confirmation Run in the NE Cape Fear River at Station NCF6 and in the Cape Fear River at Navassa.

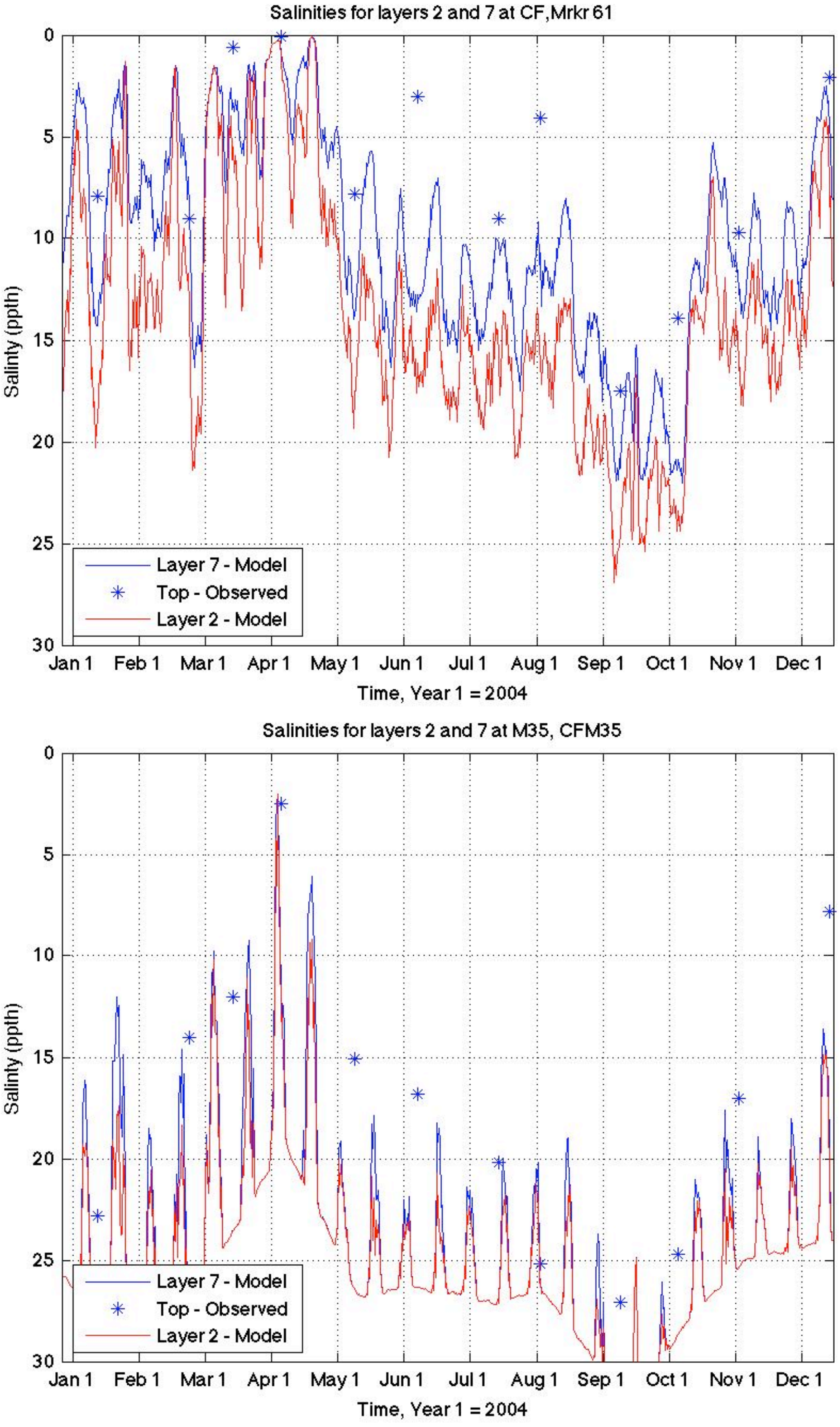


Figure 66. Model Predicted (lines) and Observed (symbols) Salinities During the 2005 Confirmation Run at the Cape Fear River at Marker 61 and at Station M35.

Compared to salinity observations, significantly more observed data were available for assessing the performance of the temperature submodel during the confirmation run. The input data files needed to run the temperature submodel (e.g. meteorological data) were also available for the full 2005 confirmation run. Here we show time history comparisons of model predicted vs. observed temperatures at four sites within the estuary; two sites near Wilmington (Navassa, NCF117), and two sites downstream of Wilmington (Marker 61) and near the mouth of the estuary (Marker 35). Overall, all sixteen of the Lower Cape Fear River Monitoring Program sites used during calibration (Table 12, Figure 20) also had temperature data that could be used for performing a model confirmation run.

At all of the sites examined, the model did a good job predicting temperature time histories. At the two sites near Wilmington, the temperature reaches its maximum value near 30º C during August and drops to approximately 10º C by December 1 (Figure 67). A similar seasonal pattern is seen at the other sites (Figure 68), although it seems that the peak temperature arrives just a little later (mid-August) at these two sites. The model follows the observed seasonal trend very well. At the most downstream site shown here (M35, Figure 68), the peak temperature arrives even a little later than at the other sites. Just as at the other three sites, the peak temperature is approximately 30º C, and occurs sometime during August. At this site temperatures fall slightly less rapidly than at the other three sites. By the end of the year, model predicted temperatures were just above 10º C (Figure 68).

The same procedure used to assess model fit to an observed data set is used for the confirmation run. A total of 780 model/data comparisons were made for the 2005 confirmation run. Predicted temperatures had a mean value that was 0.52º C below that observed. The normalized mean error was only -2.3%, which attests to the model's overall ability to predict temperatures (Table 20). Likewise other measures of calibration performance (e.g. root mean square error, correlation R^2, Table 20) are all similar to corresponding values for the calibration run (Table 16). Likewise the scatter plot (Figure 69) and the percentile plot (Figure 70) for the confirmation run look very similar to that for the calibration run (Figures 41 and 42).

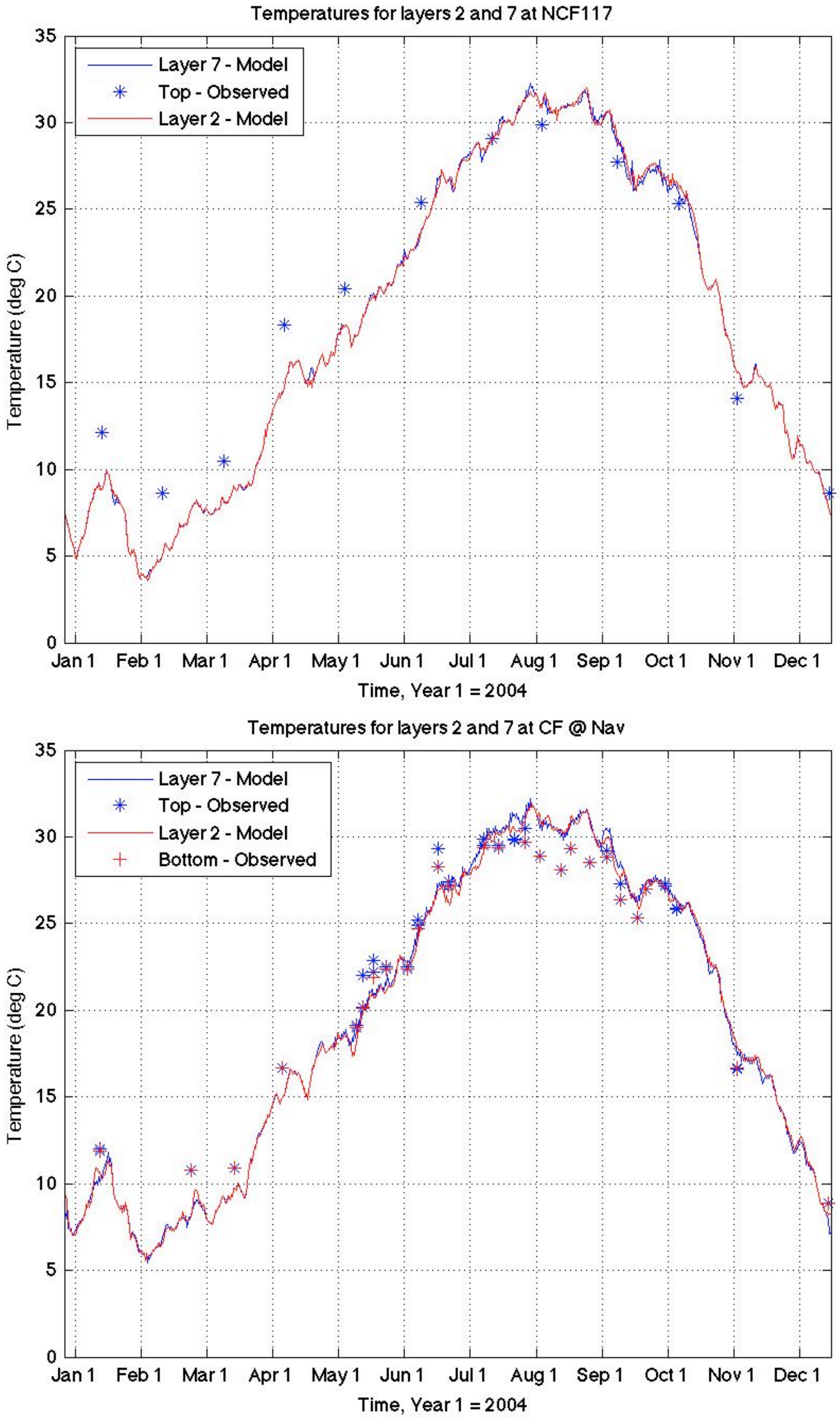
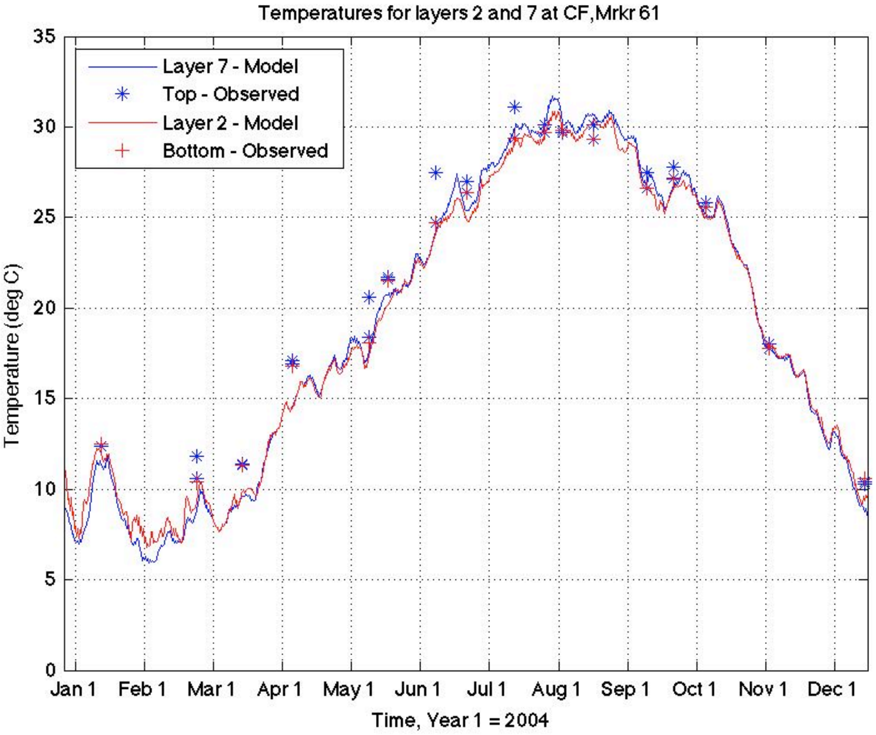


Figure 67. Model Predicted (lines) and Observed (symbols) Temperatures During the 2005 Confirmation Run for the NE Cape Fear River at Station NCF117 and the Cape Fear River at Navasssa.



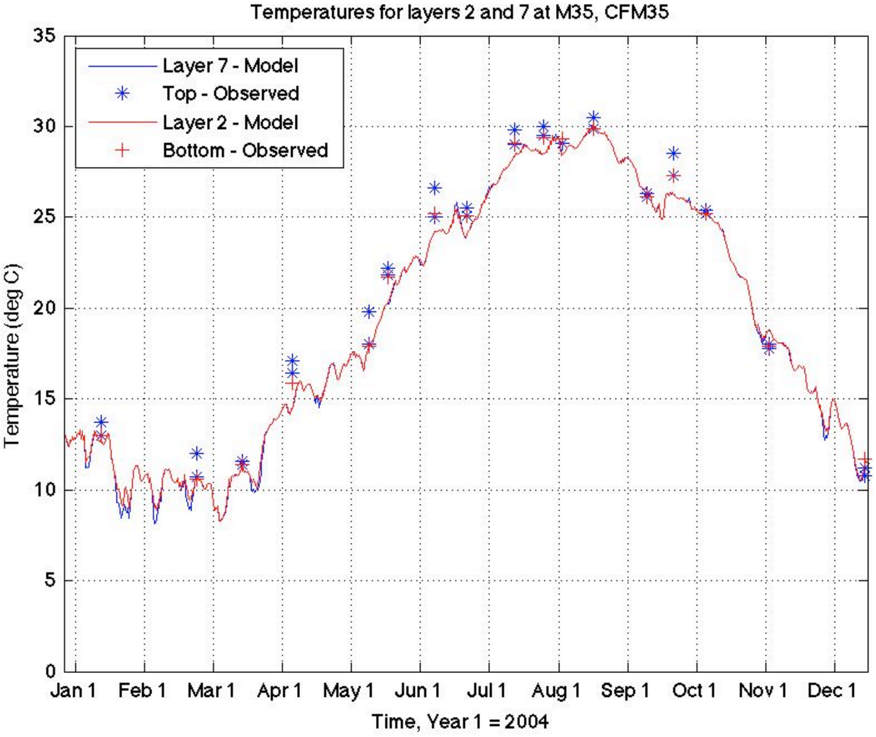


Figure 68. Model Predicted (lines) and Observed (symbols) Temperatures During the 2005 Confirmation Run for the Cape Fear River at Marker 61 and at Station M35.

Table 20. Model Fit Statistics, Temperature, 2005 Confirmation Run

Parameter	Value	Units
Mean Error (predicted – observed)	**-0.52**	**ºC**
Normalized Mean Error	**-2.3**	**%**
Root Mean Square Error	**1.51**	**ºC**
Normalized Root Mean Square Error	**6.7**	**%**
Mean Absolute Error	**1.08**	**ºC**
Normalized Mean Absolute Error	**4.8**	**%**
Correlation R^2	**96.4**	**%**
Number of Model/Data Comparisons	**780**	**-**
R^2 Corrected for Bias	**96.0**	**%**

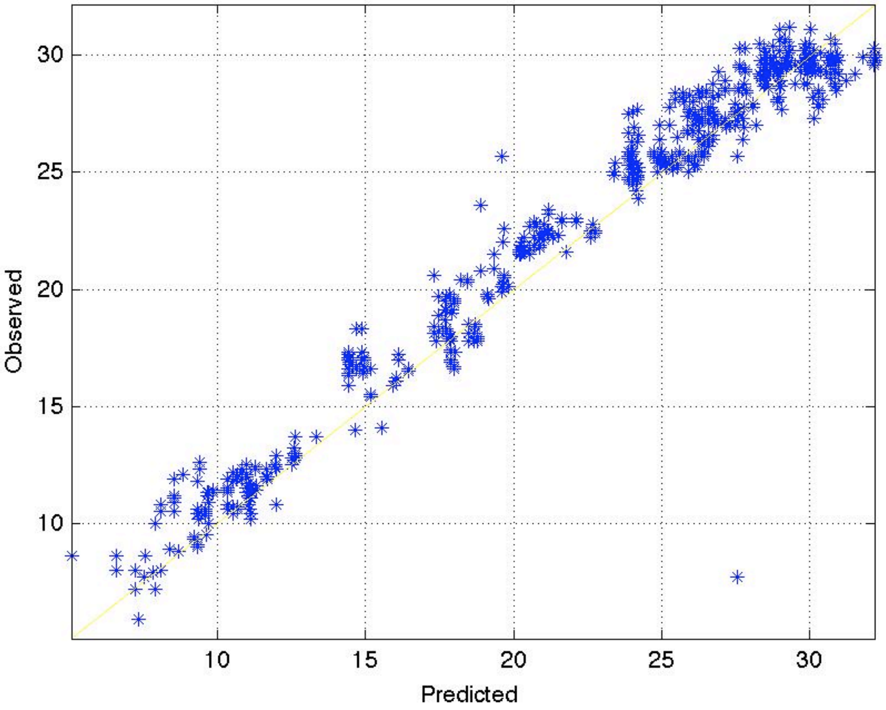


Figure 69. Scatter Plot of Predicted Temperature (ºC, x-axis) vs. Corresponding Observed Temperature (ºC, y-axis) during the 2005 Confirmation Run.

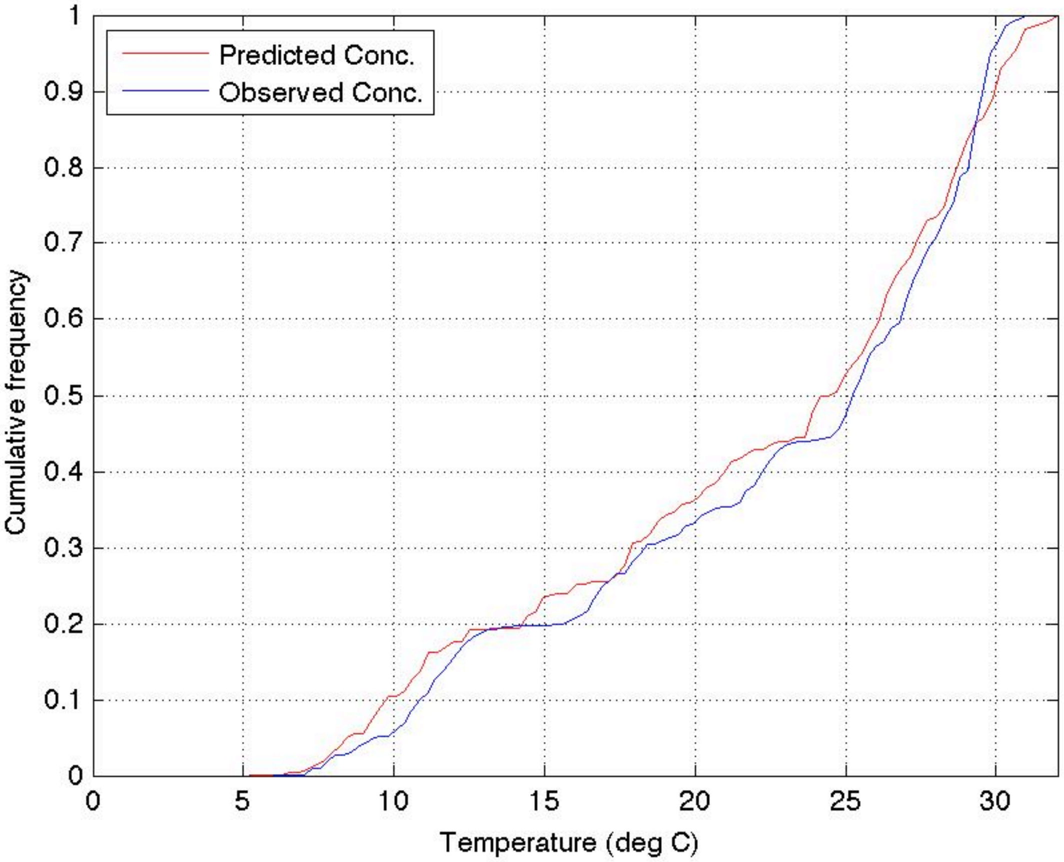


Figure 70. Percentile Plot of Observed and Model Predicted Temperatures During the 2005 Confirmation Period. The y-axis indicates the fraction of values below the corresponding temperature (ºC) indicated on the x-axis.

The model also did an excellent job of simulating DO concentrations during the confirmation run. The two upstream stations examined using time history plots (NC11, B210) had minimum dissolved oxygen concentrations that occurred near early September. The model simulates well the timing and magnitude of the minimum DO concentration (Figure 71). Likewise the recovery that occurs in the subsequent months as the water cools is simulated well by the model. At both upstream sites the model predicts a rise to a DO concentration of about 10 mg/L by December 2005. Observed DO concentrations at the upstream sites in late 2005 closely match the model predictions (Figure 71).

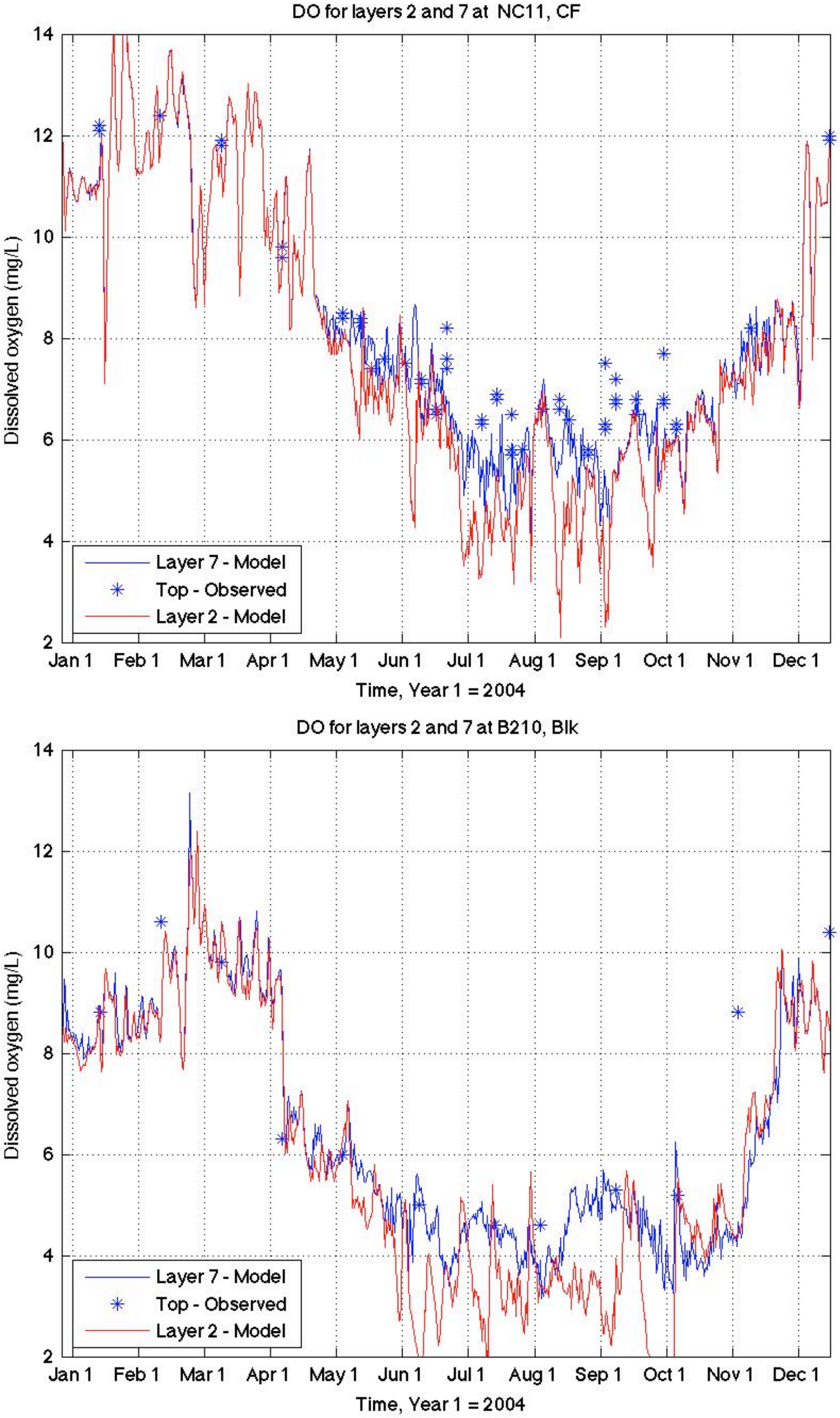


Figure 71. Model Predicted (lines) and Observed (symbols) Dissolved Oxygen Concentrations During the 2005 Confirmation Run for the Cape Fear River at Station NC11 and the Black River at Station B210.

Like the calibration run, the model overpredicts somewhat the DO concentrations in the Northeast Cape Fear during the early summer months. The model does a good job, however, at predicting the minimum dissolved oxygen concentration of approximately 3 mg/L (Figure 72). The duration of low dissolved oxygen (< 4 mg/L) at this site is somewhat underpredicted by the model. The model does a better job predicting DO concentration at this site during late Fall, when the water is cooler and DO concentrations are higher. The model does a better job predicting DO concentrations at Navassa, as both the observed and model predicted minimum DO concentrations are below 4 mg/L (Figure 72). The model does an equally good job matching the observed data at the Brunswick River station and at station M35 (Figure 73). At station M35, the model nicely predicts the timing of the DO minimum concentration, but overpredicts slightly the DO concentration at this time. Both the descent to the minimum DO concentration and the recovery later in the Fall are nicely represented by the model (Figure 73).

Model performance statistics for dissolved oxygen are very similar to those for the calibration run. Again, a total of 780 monitored DO concentrations were compared to the corresponding model prediction at that time and place (Table 21). The normalized mean error was slightly higher as compared with the calibration run (-2.0% vs. 0.06%, see Table 18), but the normalized root mean square error and normalized mean absolute error are both in the range of 10-15%, which is quite good for an estuary DO model.

The excellent fit to observed DO data during the 2005 model confirmation run can also been seen in the scatter and percentile plots. The scatter plot has a fairly tight distribution (Figure 74) and little bias is evident. Likewise the percentile plot for the confirmation run (Figure 75) looks very similar to the corresponding plot for the calibration run (Figure 52).

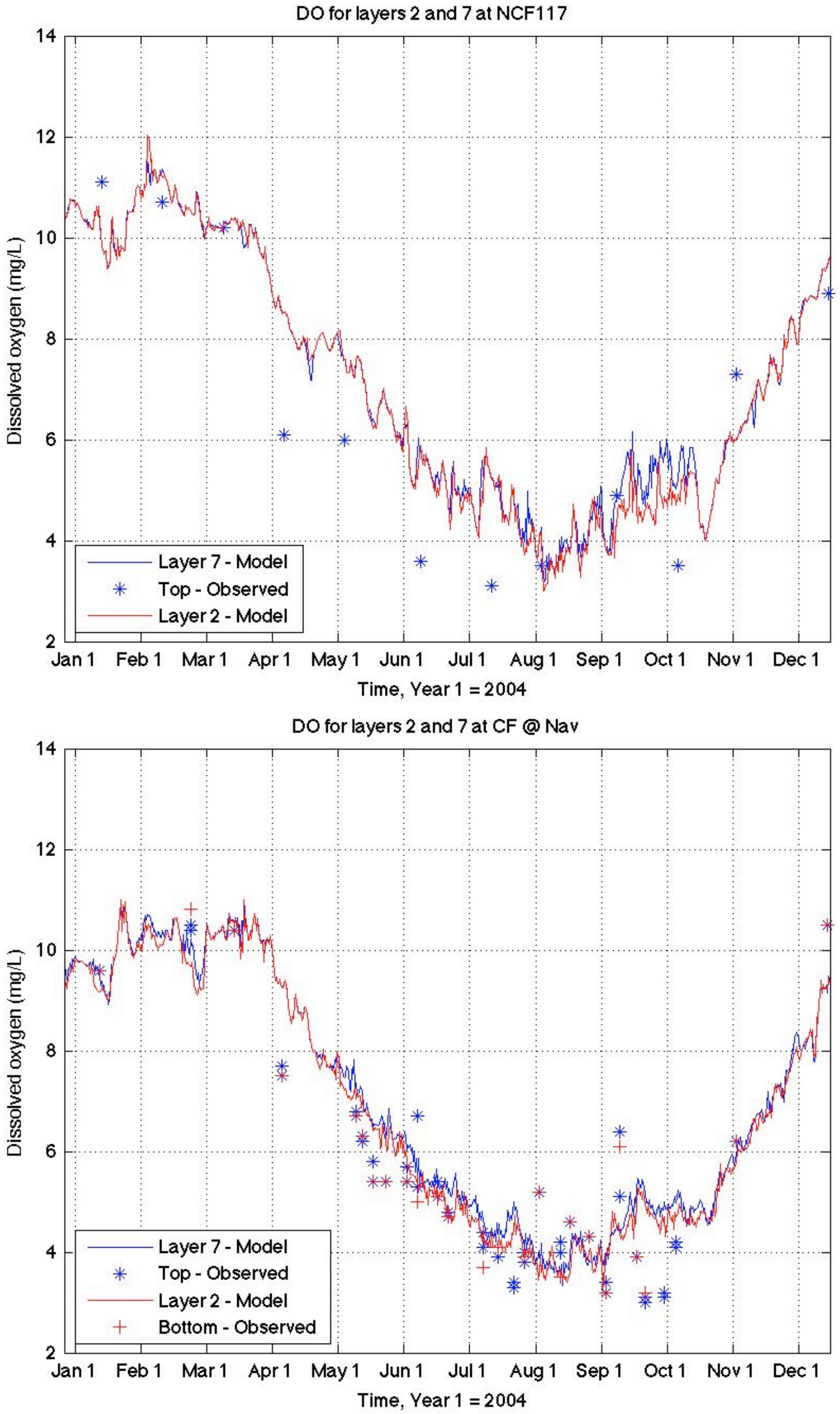


Figure 72. Model Predicted (lines) and Observed (symbols) Dissolved Oxygen Concentrations During the 2005 Confirmation Run for the NE Cape Fear River at Station NCF117 and the Cape Fear River at Navasssa.

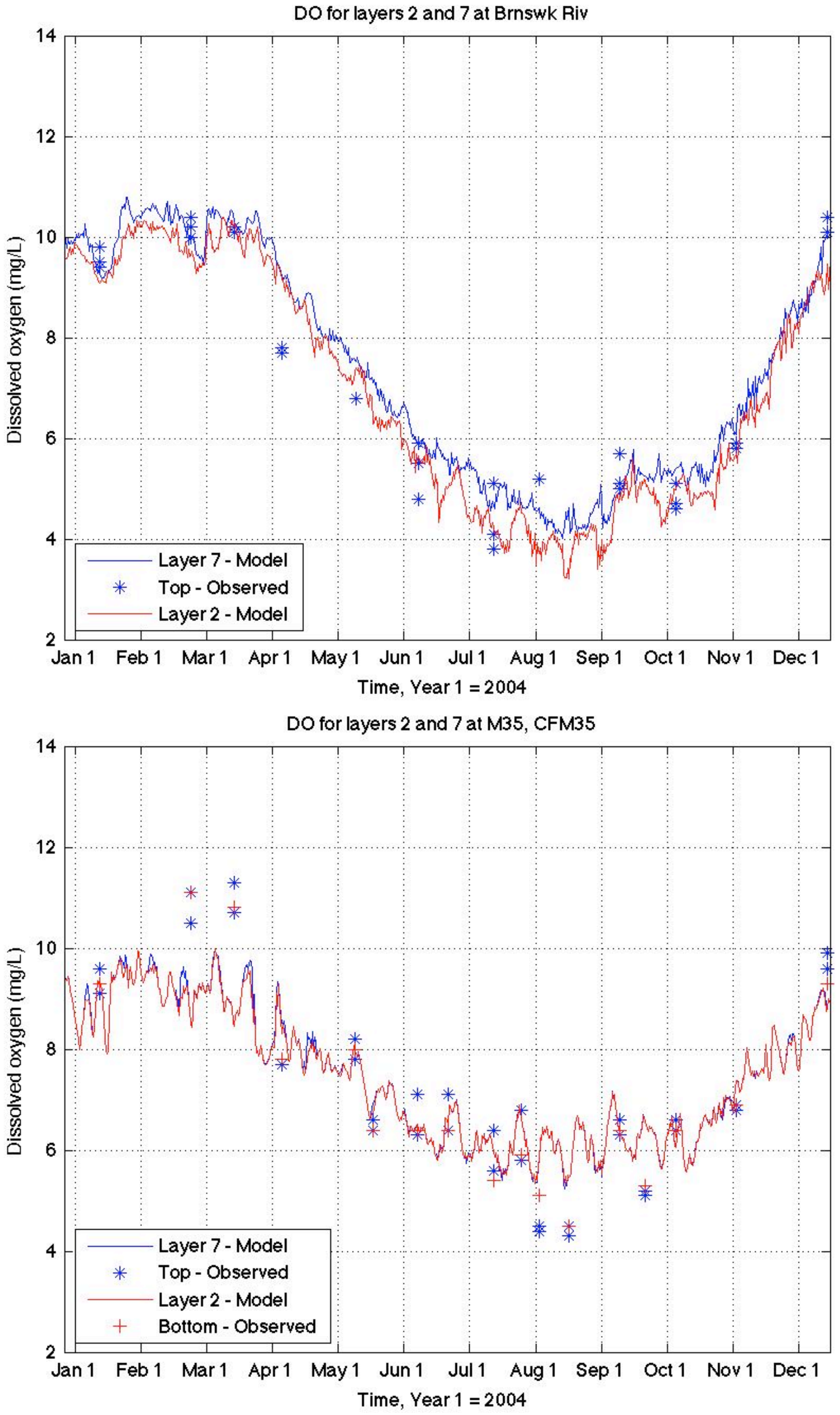


Figure 73. Model Predicted (lines) and Observed (symbols) Dissolved Oxygen Concentrations During the 2005 Confirmation Run for the Cape Fear River at the Brunswick River Station and at Station M35.

Table 21. Model Fit Statistics, Dissolved Oxygen, 2005 Confirmation Run

Parameter	Value	Units
Mean Error (predicted – observed)	**-0.13**	**mg/L**
Normalized Mean Error	**-2.0**	**%**
Root Mean Square Error	**1.20**	**mg/L**
Normalized Root Mean Square Error	**18.2**	**%**
Mean Absolute Error	**0.92**	**mg/L**
Normalized Mean Absolute Error	**14.1**	**%**
Correlation R^2	**73.8**	**%**
Number of Model/Data Comparisons	**780**	**-**
R^2 Corrected for Bias	**73.0**	**%**

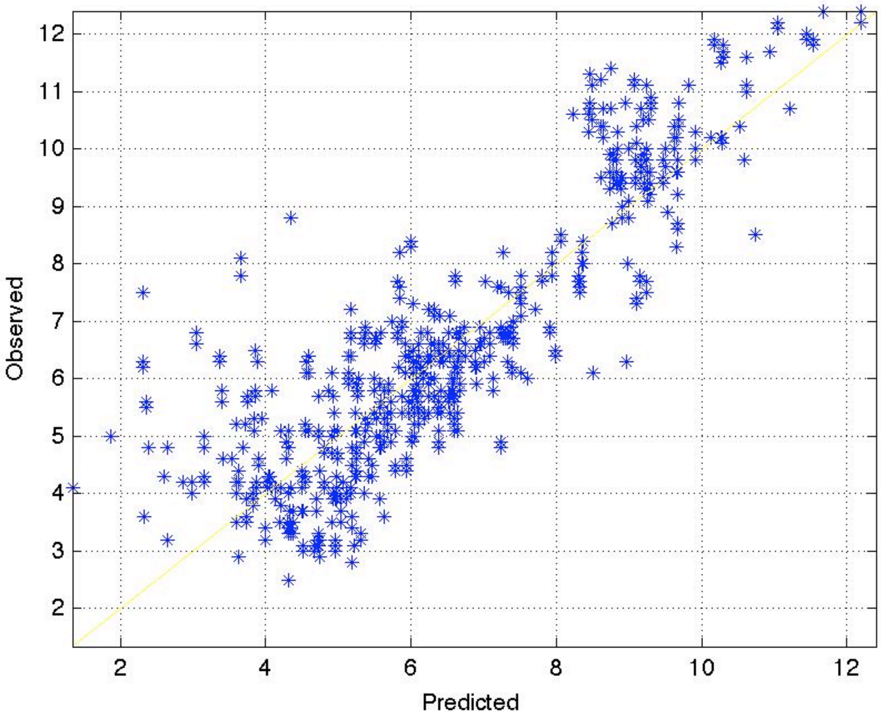


Figure 74. Scatter Plot of Predicted Dissolved Oxygen Concentrations (mg/L, x-axis) vs. Corresponding Observed Dissolved Oxygen Concentrations (mg/L, y-axis) for the 2005 Confirmation Period.

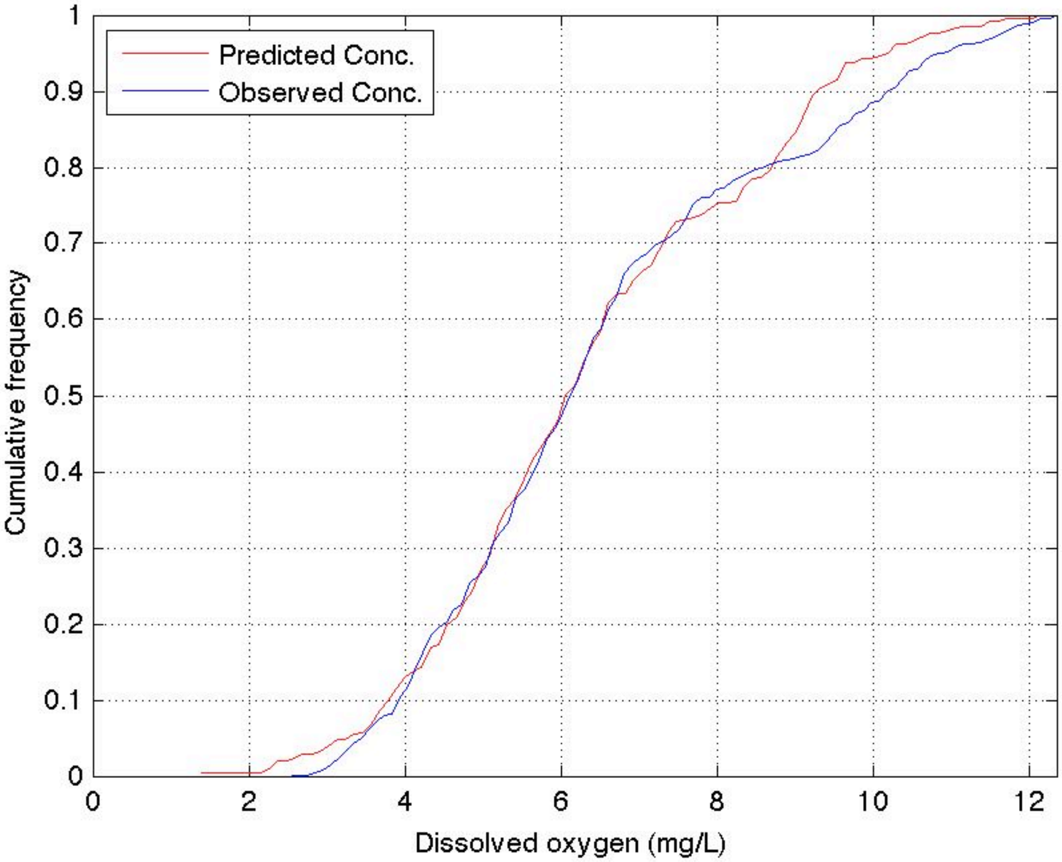


Figure 75. Percentile Plot of Observed and Model Predicted Dissolved Oxygen Concentrations During the 2005 Confirmation Period. The y-axis indicates the fraction of values below the corresponding DO concentration (mg/L) indicated on the x-axis.

5.2 Sensitivity Testing

Model evaluation also included sensitivity testing. During calibration it was realized that the DO results were quite sensitive to the choice of the sediment oxygen demand. The SOD rate was determined during calibration to give a percentile plot that matched the observed data while giving good values for the numerical measures of calibration performance. Here we show how changing the SOD rate at 20º C from the calibrated value of 0.4 $g/m^2/d$ to a value 25% higher (0.5 $g/m^2/d$) and a value 25% lower (0.3 $g/m^2/d$). While we examined the model results several different ways (e.g. time history plots, statistical measures of model fit), here we show only the percentile plot and the scatter plot for the high SOD and low SOD cases. These figures can be compared to the corresponding scatter (Figure 51) and percentile plots (Figure 52) for DO using the calibrated SOD value of 0.4 $g/m^2/d$.

The most noticeable difference between the three runs is in the percentage of low DO concentrations. The scatter plots show more subtle differences. The three scatter plots for low, medium, and high SOD rate (Figures 51, 76, 77) are very similar in overall shape. The higher SOD seems to simply raise predicted DO concentrations without affecting the overall distribution, such that the predicted DO's are moved to the left on the figure (lower predicted DO) without changing the shape or tightness of the distribution. The percentile plots are also very similar, but there is a marked increase in the number of low DO value as the SOD rate is increased (Figures 52, 76, 77). For instance, with the SOD of 0.3 $g/m^2/d$ the percentage of values below 4 mg/L is approximately 7%, while at an SOD rate of 0.5 $g/m^2/d$ the percentage of DO concentrations below is approximately 12%. For this higher SOD rate, there is noticeable difference between the observed and model predicted distribution of data. This offset, where the model predicted frequency exceeds the observed data by approximately 5% exists in the lower range of the distribution, up to a percentile of approximately 65%.

The sensitivity testing did show that the model results are sensitive to the calibrated SOD value. Additional runs were made to determine how changing the SOD rate might change the estuary's sensitivity to changes in organic matter loading. This set of runs, which examined if scenario results were sensitive to the SOD rate used is presented in the following section with the other scenario tests.

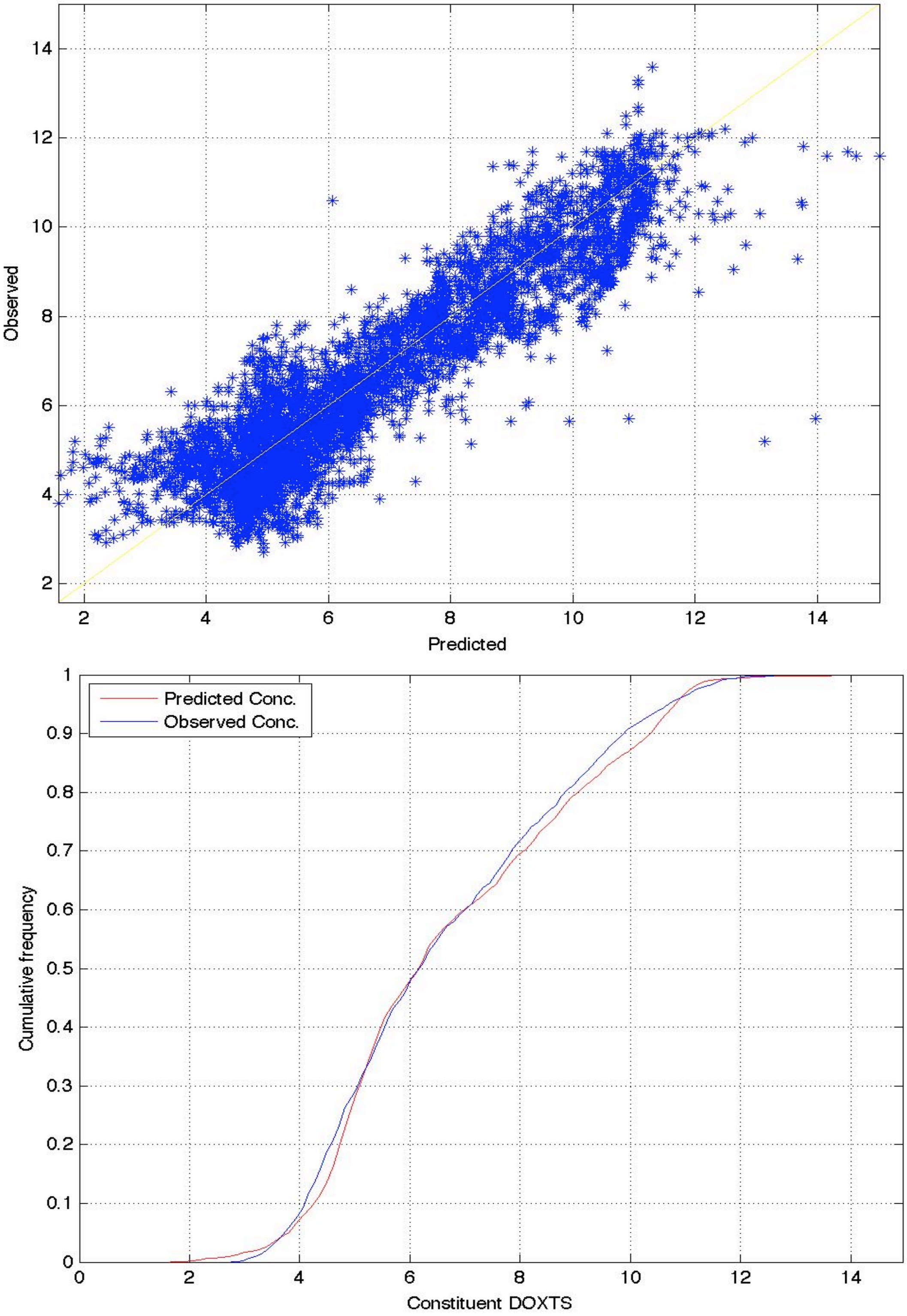


Figure 76. Scatter Plot and Percentile Plot, DO, SOD = 0.3

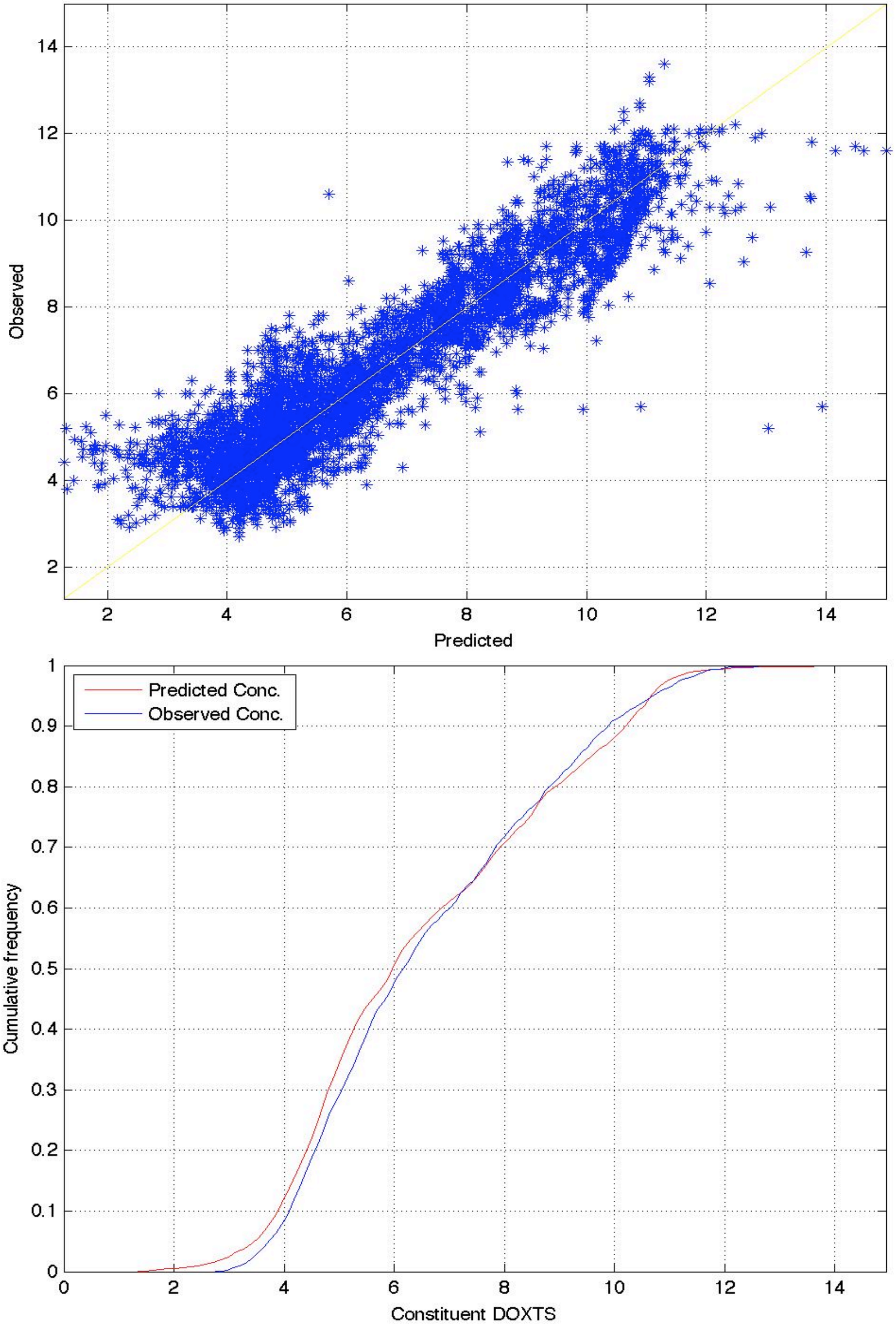


Figure 77. Scatter Plot and Percentile Plot, DO, SOD = 0.5

6. SCENARIO TESTING

6.1 Description of Base and Scenario Cases

A number of scenario tests were conducted to investigate the system's sensitivity to loading changes or to other possible changes in the system. For each scenario, model runs were conducted to estimate the time varying dissolved oxygen concentrations during the summer period of 2004 (April 1 – October 31) within the state designated impaired region of the estuary. For the base case run and each of the various scenario cases, twice-daily dissolved oxygen snapshots were recorded from all eight vertical layers at eighteen sites within the impaired region (Figure 78). This data collection method gave a total of 61,920 DO concentration values for a particular model run (215 days x 18 stations x 8 layers per station x 2 snapshots per day). The distribution of these DO concentration values was then compared between the base case and the various scenario cases by making percentile plots. In the following sections, the following eight different scenarios are examined:

1. Eliminating wastewater point source loadings
2. Reducing river, creek, and wetland loadings
3. Changing wastewater loadings for various values of sediment oxygen demand
4. Reducing river, creek, and wetland loadings and sediment oxygen demand
5. Eliminating ammonia inputs from wastewater point sources
6. Increasing wastewater inputs to maximum permitted values
7. Deepening of the navigation channel
8. Changing Brunswick County wastewater loadings

The final section provides an analysis of the relative magnitudes of the processes that produce a dissolved oxygen deficit in the impaired region of the Lower Cape Fear River Estuary during the summer months.

6.2 Effect of Eliminating Wastewater Point Source Loadings

Three model runs were made to investigate the effect of completely turning off the discharges from the twenty wastewater treatment plants that discharge directly to the Lower Cape Fear River Estuary (see Table 9 for a list of wastewater point sources). These scenarios were run, not because completely eliminating pollutant discharges was considered achievable or advisable, but instead to investigate the system's sensitivity to WWTP loads. For this analysis, the river loads arriving at the model boundary, plus the creek and wetland inputs within the estuary were maintained at the base condition levels. To model the elimination of wastewater loads it was assumed that organic matter (refractory particulate carbon, nitrogen, and phosphorus; dissolved carbon, nitrogen, and phosphorus) and ammonia concentrations in the wastewater inputs would be decreased to 0.0 mg/L.

Figure 78. Eighteen Locations Used to Determine Model Predicted Dissolved Oxygen Concentrations for the Scenario Tests

When all WWTP loads were eliminated, the 10th percentile DO concentration increased by approximately 0.3 mg/L, from 4.3 to 4.6 mg/L (Figure 79). In general the effect of eliminating the wastewater input had a larger impact on the lower dissolved oxygen concentrations than it did on the higher DO concentrations. Whereas the 10th percentile DO concentration increased by 0.3 mg/L, the median value DO concentration increased by about 0.10 mg/L, from 5.6 to 5.7 mg/L when all point source discharges were removed. The distribution of dissolved oxygen concentrations above 6.0 mg/L was only slightly changed (< 0.1 mg/L) by eliminating wastewater inputs of organic matter and ammonia (Figure 79). Selectively turning off individual WWTP loads, as expected, had a smaller effect. Turning off the International Paper WWTP had an effect that was roughly 2/3 of that when all the plants were turned off. Turning off both Wilmington domestic wastewater treatment plants had an effect that was roughly 1/3 of that when all discharges were turned off (Figure 79). It was also found that eliminating the wastewater point sources results in only a small decrease in the percentage of DO concentrations below 5.0 mg/L. For the base case, with discharges from all twenty wastewater treatment plants, approximately 32% of the estimated DO concentrations in the impaired region during the summer months are below 5.0 mg/L. When the oxygen demanding wastes from these point sources are completely eliminated, approximately 27% of summertime DO concentrations are below 5.0 mg/L (Figure 79).

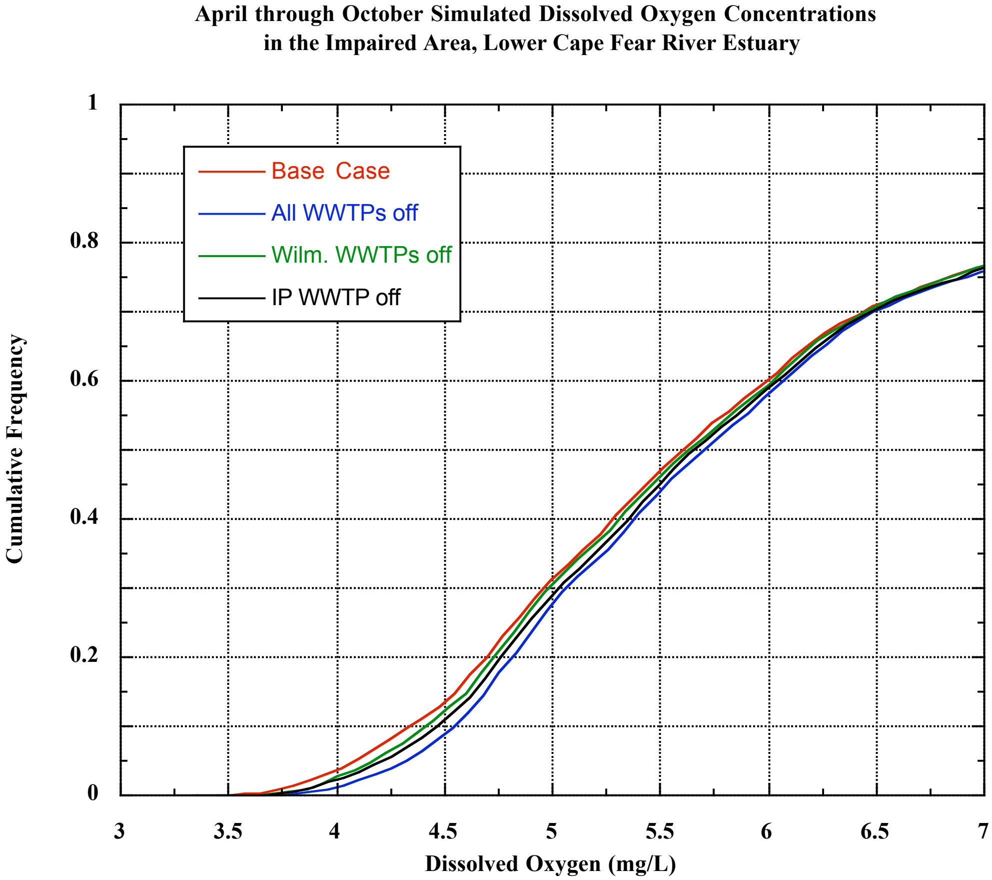


Figure 79. Percentile Plot of Model Predicted Dissolved Oxygen Concentrations During the Summer 2004 for the Base Case and Three Wastewater Treatment Plant Load Reduction Scenarios. The y-axis indicates the fraction of values below the corresponding DO concentration (mg/L) indicated on the x-axis.

6.3 Effect of Reducing River, Creek, and Wetland Loadings

The impact of changing the loadings that entered the model region from rivers, creeks, and wetlands was also investigated. Loading reductions of either 30%, 50%, or 70% were assumed for the three river inputs (Cape Fear, Black, and Northeast Cape Fear), and from the fourteen creek and wetland inputs into the estuary. To reduce the loadings, flows were maintained at the base case levels, but concentrations were reduced by 30%, 50%, or 70% from the base case values. Identical reduction percentages were assumed for the organic matter (refractory particulate carbon, nitrogen, and phosphorus; dissolved carbon, nitrogen, and phosphorus) and ammonia constituents. Loadings for the twenty wastewater point sources were maintained at the levels in the base case scenario. As with all scenarios, twice-daily DO concentration snapshots were analyzed for all eight model layers, at eighteen sites within the impaired region for 215 days during 2004 (April 1, 2004 – October 31, 2004).

The load reductions of riverine, creek, and wetland inputs were found to have a significant impact on the estimated dissolved oxygen concentrations during the summer months in the impaired region of the Lower Cape Fear River Estuary. At the 10th percentile level, DO concentrations for the three load reduction scenarios increased by 0.2, 0.3, and 0.4 mg/L respectively, from 4.3 mg/l to either 4.5, 4.6, or 4.7 mg/L (Figure 80). Unlike the scenarios described in the previous section in which wastewater loading decreases were investigated, the level of increase in DO concentration was maintained at the higher percentiles when reductions in the river, creek, and wetland loadings were made. In fact, for this “clean river” scenario, the median DO concentration increased to even a greater extent than the 10th percentile value, increasing from 5.6 to 5.85 mg/L for the 30% reduction (an increase of 0.25 mg/L), and from 5.6 to 6.2 mg/L (an increase of 0.6 mg/L) for the 70% reduction scenario (Figure 80). Nonetheless, even at this largest assumed loading reduction amount of 70%, a significant fraction (approximately 19%) of DO concentrations are below 5.0 mg/L. For the base case, approximately 32% of DO concentrations during the summer months are below 5.0 mg/L (Figure 80).

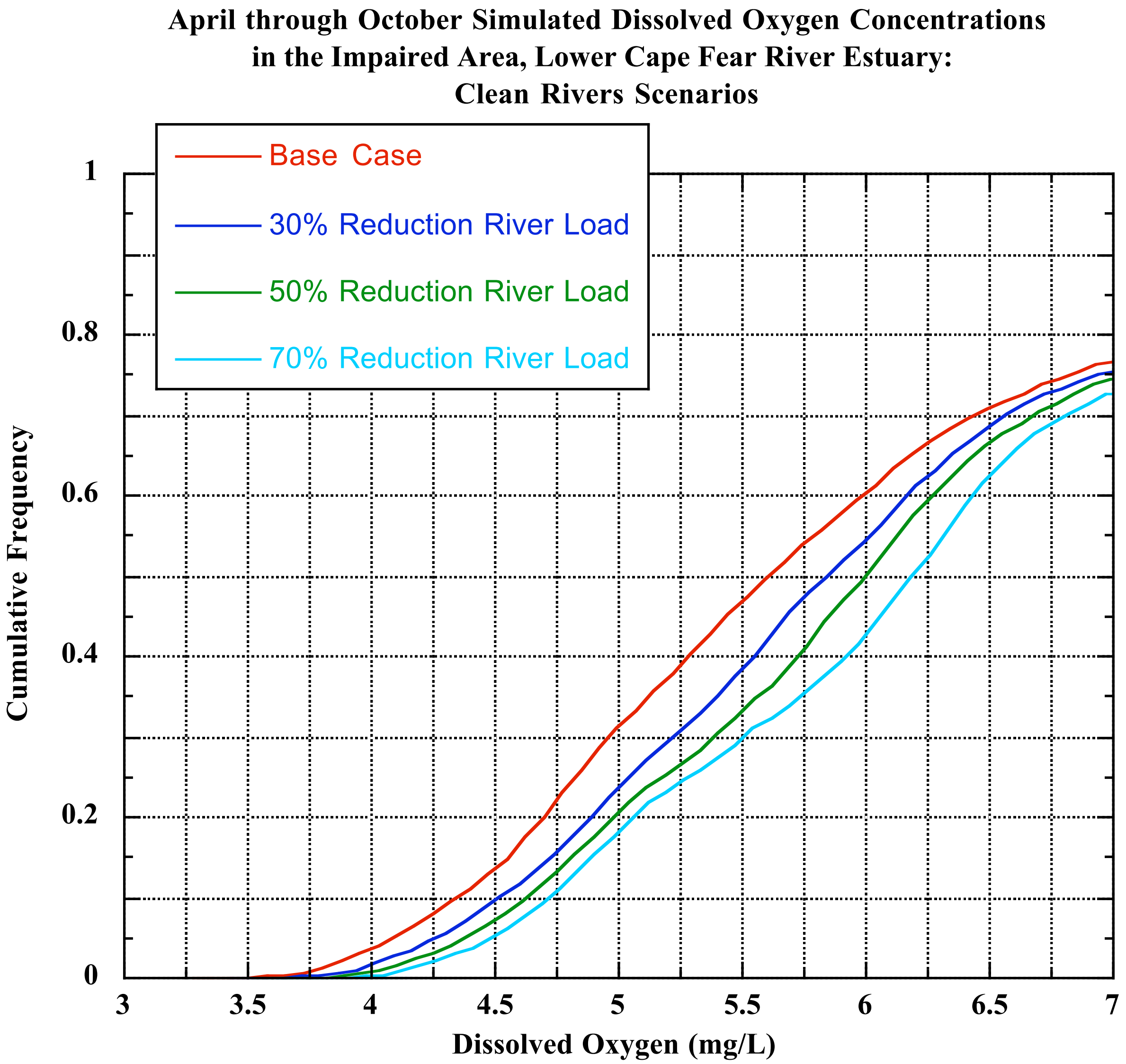


Figure 80. Percentile Plot of Model Predicted Dissolved Oxygen Concentrations During the Summer 2004 for the Base Case and two Scenarios that Reduce Loading from Rivers and Creeks by 30%, 50%, and 70%. The y-axis indicates the fraction of values below the corresponding DO concentration (mg/L) indicated on the x-axis.

6.4 Effect of Changing Sediment Oxygen Demand

Additional water quality model runs were conducted to investigate the sensitivity of the results to the choice of model kinetic parameters. Because of its relative importance in determining dissolved oxygen concentrations, the sensitivity analysis focused on the impact of various choices for the sediment oxygen demand. During calibration it was found that this parameter had a significant impact on dissolved oxygen concentrations in the estuary. In addition to the calibrated SOD value (0.4 $g/m^2/d$ at 20° C), runs were made at a lower value (0.3 $g/m^2/d$ at 20° C) and a higher value (0.5 $g/m^2/d$ at 20° C). Model fit to the observed data set was compared for these three cases. All three cases (SOD @ 20 deg C = 0.3, 0.4, 0.5) had similar correlation r^2 values (83.4%, and 84.5%, and 83.4%), but on average the low SOD case overpredicted DO concentrations by 0.11 mg/L, while the high SOD case underpredicted DO concentrations by a similar amount (0.09 mg/L).

The impact of turning off the organic matter and ammonia loadings from all wastewater treatment plants was investigated for each of these three SOD cases. Each scenario produced a very similar change in DO concentration when all point sources were turned off (Figure 81). Even though DO concentrations were changed with the different SOD cases, in each scenario, turning off the sources increased DO concentrations by approximately 0.25 mg/L at the 10th percentile level (Figure 81). Likewise the percentage of DO values below 5.0 mg/L decreased by a similar amount using the three different sediment oxygen demand values. For the base case SOD value (0.4 $g/m^2/d$ at 20° C) turning off the wastewater sources decreased the percentage of DO values below 5.0 mg/L from 45% to 40%. For the lower SOD value (0.3 $g/m^2/d$ at 20° C), removing the wastewater sources decreased the percentage of values below 5.0 mg/L from 37% to 29%. Using the higher SOD value (0.5 $g/m^2/d$ at 20° C) removing the wastewater sources decreased the percentage of values below 5.0 mg/L from 54% to 49% (Figure 81). The magnitude of change in the percentage of values below 5.0 mg/L changes only slightly for these three SOD values. It is expected that changes in other model parameters would have a qualitatively similar result. Although absolute concentrations are affected by changes in parameter values, relative changes in concentration are less affected by changing parameter values.

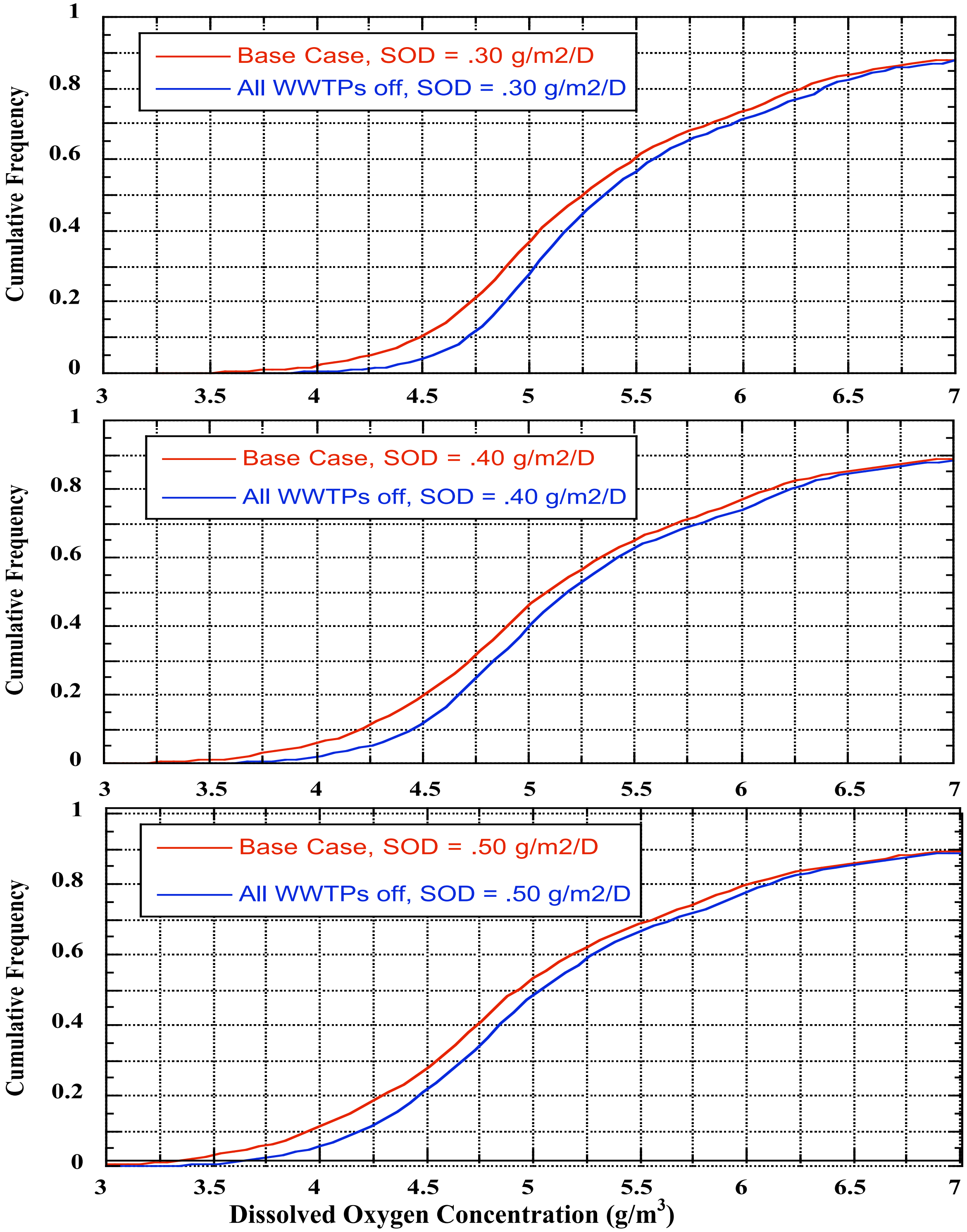


Figure 81. Percentile Plot of Model Predicted Dissolved Oxygen Concentrations During the Summer 2004 for the Base Case and a No WWTP Loading Scenario for Three Different Values of Sediment Oxygen Demand. The y-axis indicates the fraction of values below the corresponding DO concentration (mg/L) indicated on the x-axis.

6.5 Cumulative Effect of Lower Sediment Oxygen Demand and Reduced Loadings from Rivers, Creeks, and Wetlands

It has been shown (section 6.3) that even a 70% loading reduction in the organic matter inputs from rivers, creeks, and wetlands sources is not enough to completely eliminate violations of the state water quality standard of 5.0 mg/L (see Figure 80), even though these sources constitute the majority of inputs of oxygen demanding wastes into the Lower Cape Fear Estuary (see Figures 42 and 43). In this scenario we examine what conditions would be necessary to produce summertime DO concentrations above 5.0 mg/L. In addition, one limitation of the analysis done previously is that it ignores possible changes that might occur in the benthos if organic matter loadings were reduced. For instance, it is likely that a reduction of 30% or 50% or 70% in organic matter loading would in the long-term also result in lower sediment oxygen demands. The cumulative effect of decreasing both organic matter loading and sediment oxygen demand are examined in this scenario.

In this scenario a total of six additional runs were made and compared to the base case. As done previously, three runs assumed that the oxygen demanding wastes (organic matter and ammonia) from the three rivers (Cape Fear, Black, Northeast Cape Fear) and from the fourteen creek and wetland inputs to the estuary were reduced by 30%, 50%, or 70%. These reductions were made by holding steady the freshwater inflows while reducing the concentrations by the appropriate amount. For these three runs, wastewater inputs and the sediment oxygen demand were held at the values used in the base case. Three additional runs were made that assumed 30%, 50%, or 70% reductions both in the oxygen demanding waste input and the sediment oxygen demands. These reductions in sediment oxygen demand were made by assuming a constant percentage reduction in sediment oxygen demand while retaining the assumed time variations in these values. As described in the calibration section of the report, sediment oxygen demand was assumed to vary seasonally, with higher values in the summer when the benthic layer is warmer and the biota more active as compared with the winter months.

As expected reducing the sediment oxygen demand along with the waste inputs had a larger effect than when only the waste inputs were reduced. For the case with a 30% reduction in SOD and loadings from rivers, creeks, and wetlands, the percentage of summertime DO concentrations below 5.0 mg/L was reduced to 22%, as compared to 45% for the base case and 33% when only the oxygen demanding wastes are decreased (Figure 82). The 50% reduction case had an even lower rate of water quality violations, but these were not completely eliminated. With both SOD and oxygen demanding wastes decreased, approximately 7% of summertime DO concentrations in the impaired region are below 5.0 mg/L, as compared to 27% when only the oxygen demanding wastes are decreased (Figure 82). There is also a large increase in the minimum predicted DO concentration for this case. The base case had a minimum predicted DO concentration of approximately 3.2 mg/L, whereas the minimum when SOD and oxygen demanding wastes are reduced by 50% is approximately 4.6 mg/L (Figure 82). A decrease in SOD of 70% and a reduction in river load of 70%, however, does almost completely eliminate dissolved oxygen concentrations below 5.0 mg/L (Figure 82). For this case, only about 1% of the predicted dissolved oxygen concentrations are below the water quality standard value.

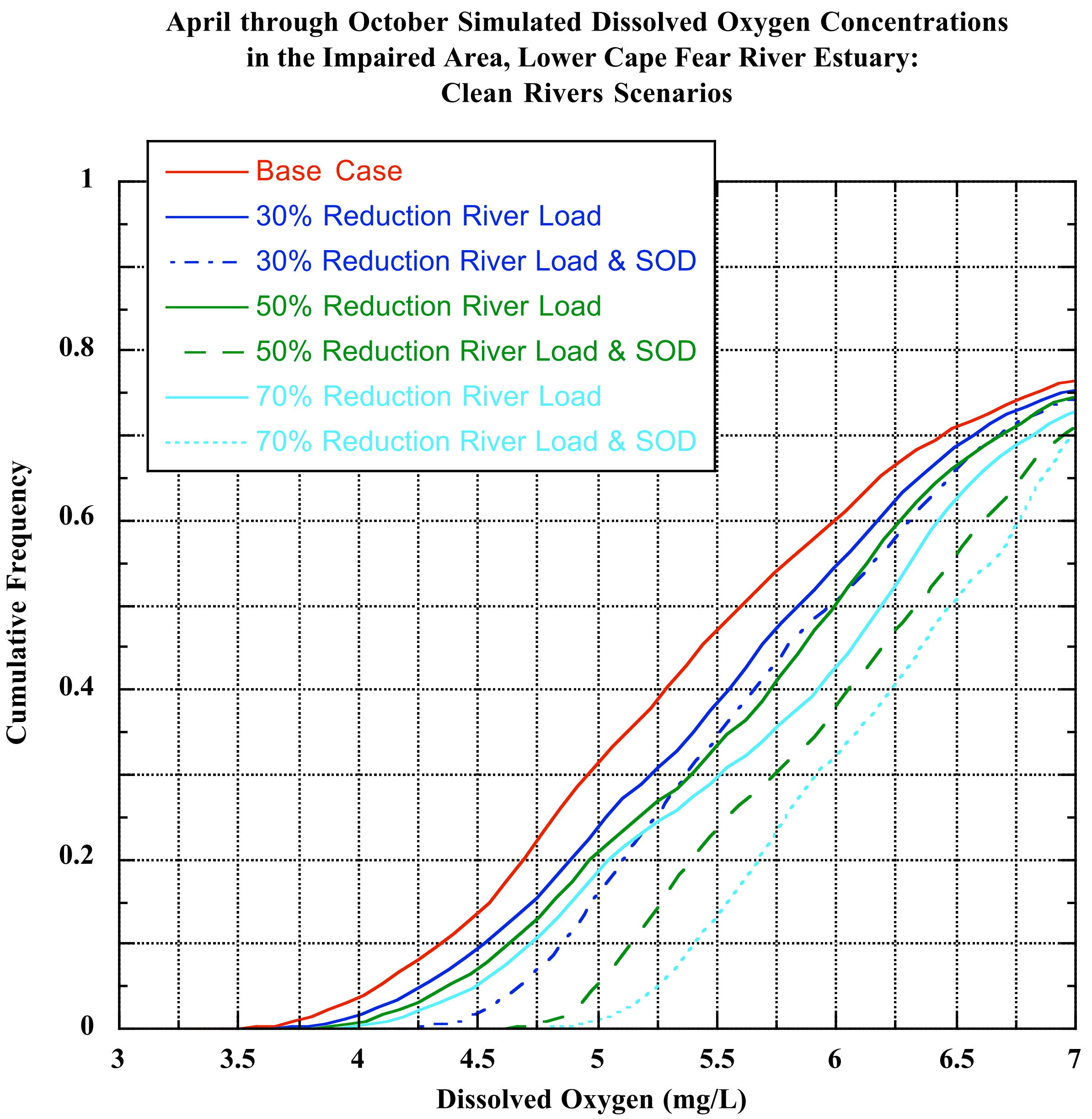


Figure 82. Percentile Plot of Model Predicted Dissolved Oxygen Concentrations During the Summer 2004 for the Base Case and two Scenarios that Reduce Loading from Rivers and Creeks by 30% and 50%. The dashed lines show the corresponding changes in dissolved oxygen when SOD is also reduced by 30% or 50%. The y-axis indicates the fraction of values below the corresponding DO concentration (mg/L) indicated on the x-axis.

6.6 Effect of Eliminating Ammonia Inputs from Wastewater Point Sources

A fifth scenario considered eliminating the ammonia loading for all wastewater treatment plants. As for the other scenarios, loading reductions were achieved by decreasing the effluent concentrations, while keep the discharges at that specified in the base case. For this scenario the ammonia concentration in all twenty wastewater point sources was set to zero. The wastewater loadings from all other constituents was held constant, as was the loading from the seventeen other point sources that provided contributions from the rivers, creeks, and wetlands that discharge directly to the estuary.

This scenario produced an increase in dissolved oxygen concentrations that was detectable but not dramatic. As expected, the magnitude of the increase was less than when both the organic matter and ammonia loadings were eliminated from wastewater sources. At the 10th percentile level, dissolved oxygen concentrations increased by about 0.1 mg/L, from about 4.3 mg/L for the base case to about 4.4 mg/L when the ammonia loading was eliminated (Figure 83). The magnitude of the increase generally decreased for higher percentile values. For instance, the median dissolved oxygen concentration in the base case (5.6 mg/L) increased by only about 0.05 mg/L, with concentrations in the upper part of the distribution (> 6.0 mg/L) increasing by an even lesser amount. A small, but detectable drop in percentage of DO concentrations less than 5.0 mg/L was seen when ammonia discharges from wastewater treatment plants was eliminated. In the base case approximately 32% of summertime DO concentrations in the impaired region are below the water quality standard of 5.0 mg/L, whereas approximately 30% are below 5.0 mg/L when ammonia discharges are eliminated (Figure 83).

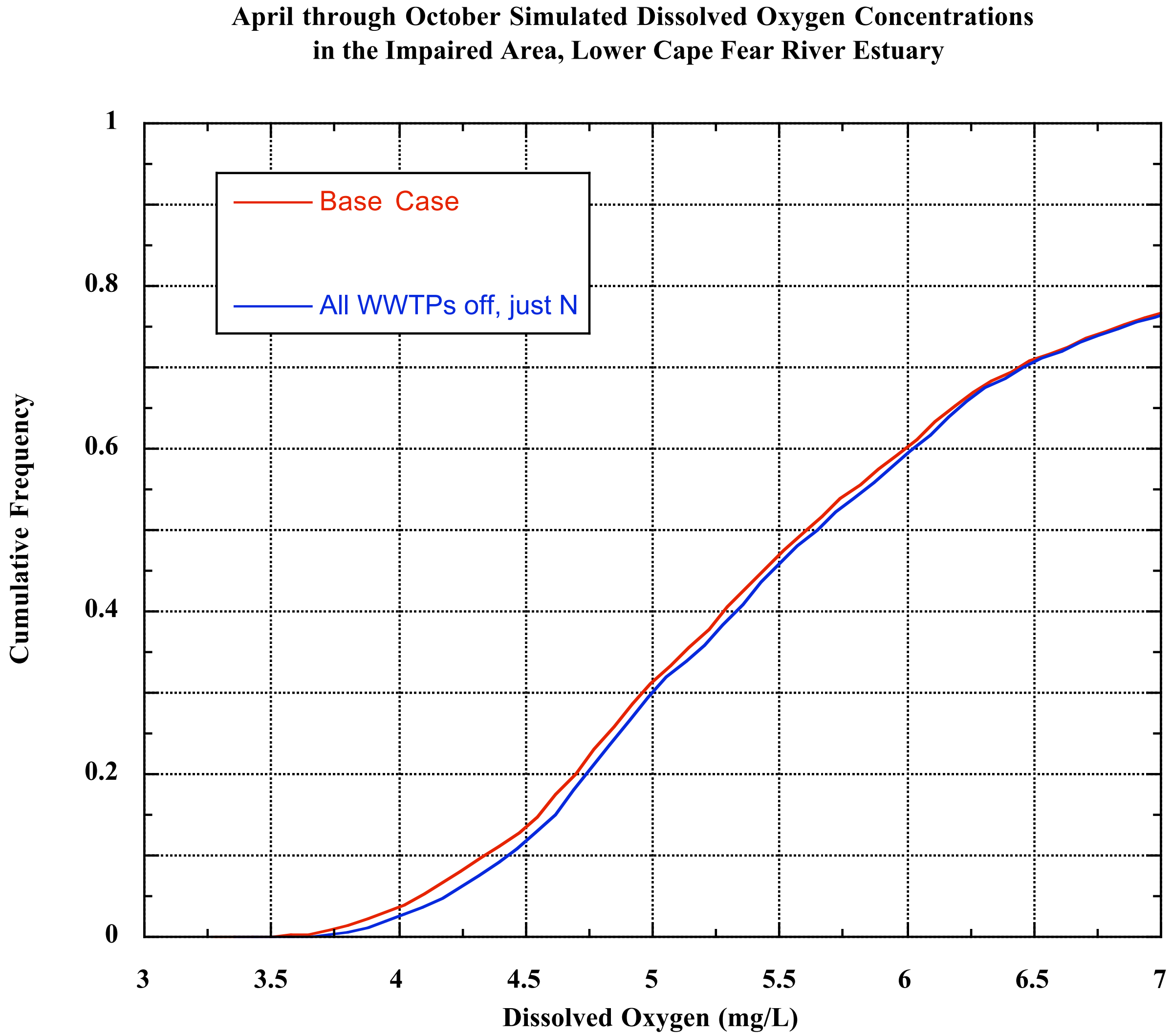


Figure 83. Percentile Plot of Model Predicted Dissolved Oxygen Concentrations During the Summer 2004 for the Base Case and a no Ammonia Loading Scenario. The y-axis indicates the fraction of values below the corresponding DO concentration (mg/L) indicated on the x-axis.

6.7 Effect of Increasing Wastewater Inputs to Maximum Permitted Values

The base case scenario used facility discharge monitoring records to establish the loadings of oxygen demanding wastes from each of the twenty wastewater point sources that discharge directly to the Lower Cape Fear Estuary. In several instances, the actual loadings were considerably below permitted maximum values. Of interest is how increasing all 20 wastewater inputs to the permitted maximum values would affect the dissolved oxygen conditions in the estuary. In this scenario, those permitted maximum discharges are assumed for each of the sources where that information is available.

Of the twenty wastewater point sources in the model, thirteen had maximum permitted discharges for either BOD, flow, or ammonia that exceeded the loadings in the base case (Table 23). For each of these sources, modifications were made to the EFDC water quality point source input file (WQPSL.INP) to simulate a continuous discharge at the maximum permitted value. The permit limits for these thirteen sources (Table 24) were provided by the NC Division of Water Quality (DWQ). In keeping with the DWQ's rules for these permits, winter limits were used for five months (January, February, March, November, December) and summer limits for the remaining seven months. In creating the scenario all other sources and parameters were held at the base case levels.

Table 23. Model Point Sources That Were Adjusted to Maximum Permitted Values

Source No.	NPDES Permit No.	Name of Source
1	NC0000663	Dupont-Wilmington/Brunswick, Outfall 1
5	NC0001112	Arteva Specialties-Wilmington, Outfall 2
6	NC0003298	International Paper
7	NC0021334	Southport, Town-WWTP/Southport
8	NC0023256	Carolina Beach, Town-WWTP
9	NC0023965	Wilmington-Northside WWTP
10	NC0023973	Wilmington-Southside WWTP
11	NC0025763	Kure Beach WWTP, Town Of
12	NC0027065	Archer Daniels Midland Co.
13	NC0059234	Takeda Chemical Products USA
16	NC0075540	Belville, Town – WWTP
17	NC0082295	Fortron Industries
35	NC0086819	Brunswick Co. WWTP

The scenario with the thirteen wastewater sources at their permitted maximum values produced dissolved oxygen concentrations that were slightly lower than the corresponding base values by approximately 0.1 mg/L (Figure 84). This decrease of approximately 0.1 mg/L was seen throughout the distributions, with both the 10th percentile DO concentration value and the median value decrease by a similar amount. More low DO concentrations were predicted for the maximum permit case as opposed to the base case. The percentage of DO concentration below the water quality permit value of 5.0 mg/L increased from 32% to approximately 34% for the maximum permit case (Figure 84). Approximately 4% of the base case DO concentrations in the impaired region during the Summer were expected to be below 4.0 mg/L, while the maximum permit case had approximately 7% below 4.0 mg/L (Figure 84).

Table 24. Total Maximum Monthly Permitted Values for the Point Sources in the Lower Cape Fear Estuary**.**

Permit #	Constituents	Outfall 1		Outfall 2		Outfall 3		Outfall 4	
		Monthly	Unit	Monthly	Unit	Monthly	Unit	Monthly	Unit
NC0000663	Flow	3.5	MGD						
1	BOD, 5-Day (20 Deg. C)	493.3	lbs/day						
	Solids, Total Suspended	786	lb/day	75	mg/L				
NC0001112	Flow			1.25	MGD				
5 (2)	BOD, 5-Day (20 Deg. C) Summer			215.7	lb/day				
	Solids, Total Suspended	30	mg/L	329	lb/day				
NC0003298	Flow	50	MGD						
6	BOD, 5-Day (20 Deg. C) Winter	10,000	lbs/day						
	BOD, 5-Day (20 Deg. C) Summer	5,000	lbs/day						
	Solids, Total Suspended	65,720	lbs/day	30	mg/L				
NC0021334	Flow	0.8	MGD						
7	BOD, 5-Day (20 Deg. C)	30	mg/L						
	Solids, Total Suspended	30	mg/L						
NC0023256	Flow	3	MGD						
8	BOD, 5-Day (20 Deg. C) Winter	10	mg/L						
	BOD, 5-Day (20 Deg. C) Summer	5	mg/L						
	Nitrogen, Ammonia Total (as N) winter	4	mg/L						
	Nitrogen, Ammonia Total (as N) summer	2	mg/L						
NC0023965	Flow	16	MGD						
9	BOD, 5-Day (20 Deg. C)	30	mg/L						
	Solids, Total Suspended	30	mg/L						
	Nitrogen, Ammonia Total (as N) winter	2	mg/L						
	Nitrogen, Ammonia Total (as N) summer	1	mg/L						

NC0023973	Flow	12	MGD						
10	BOD, Carbonaceous 05 Day, 20 deg C	25	mg/L						
	Solids, Total Suspended	30	mg/L						
NC0025763	Flow	0.285	MGD						
11	BOD, 5-Day (20 Deg. C) All Yr	30	mg/L						
	Solids, Total Suspended	30	mg/L						
NC0027065	Flow	3.502	MGD	0.008	MGD				
12	BOD, 5-Day (20 Deg. C)	25,171	lbs/day	30	mg/L				
	COD, Oxygen Demand, Chem. (High Level)	14,451	lbs/day						
	Solids, Total Suspended	42,791	lbs/day	30	mg/L				
	Nitrogen, Total (as N)		lbs/day						
NC0059234	Flow								
13	BOD, 5-Day (20 Deg. C)	9	lbs/day						
	COD, Oxygen Demand, Chem. (High Level)	2.8	lbs/day						
	Solids, Total Suspended	15.4	lbs/day						
NC0075540	Flow	0.8	MGD						
16	BOD, 5-Day (20 Deg. C) Winter	10	mg/L						
	BOD, 5-Day (20 Deg. C) Summer	5	mg/L						
	Solids, Total Suspended	30	mg/L						
	Nitrogen, Ammonia Total (as N) winter	4	mg/L						
	Nitrogen, Ammonia Total (as N) summer	2	mg/L						
NC0082295	Flow	0.834	MGD						
17	BOD, 5-Day (20 Deg. C)	102.4	lbs/day						
	Solids, Total Suspended	331	lbs/day						
NC0086819	Flow	1.65	mgd	0.31	mgd				
35	BOD, 5-Day (20 Deg. C) All Yr			10	mg/L				
	BOD, 5-Day (20 Deg. C) Winter	10	mg/L						
	BOD, 5-Day (20 Deg. C) Summer	5	mg/L						
	COD, Oxygen Demand, Chem. (High Level)								
	Solids, Total Suspended	30	mg/L	5	mg/L				
	Nitrogen, Ammonia Total (as N)			4	mg/L				
	Nitrogen, Ammonia Total (as N) winter	2	mg/L						
	Nitrogen, Ammonia Total (as N) summer	1	mg/L						

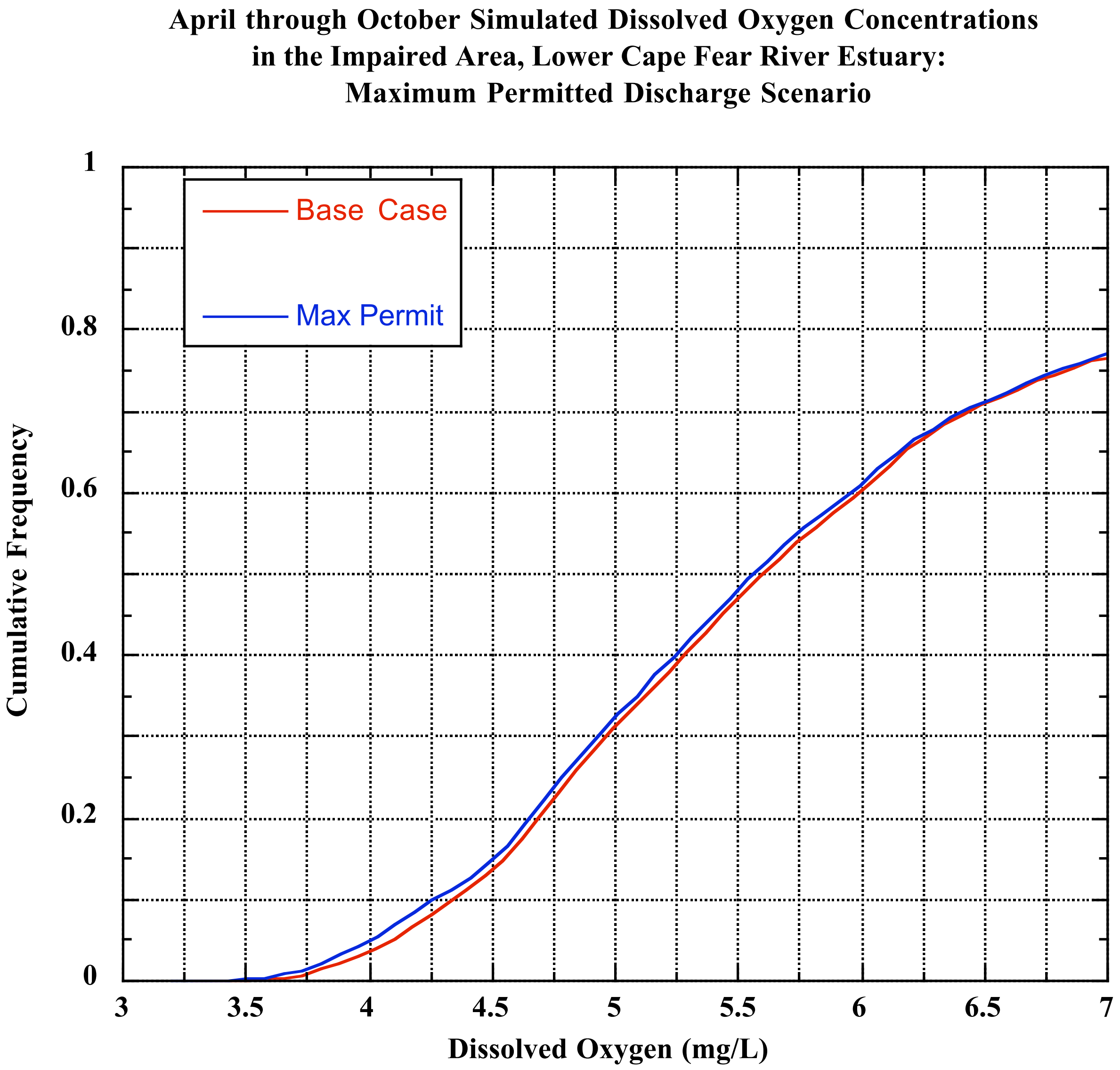


Figure 84. Percentile Plot of Model Predicted Dissolved Oxygen Concentrations During the Summer 2004 for the Base Case and a Scenario Where all WWTP's are Set to the Their Maximum Permitted Discharge. The y-axis indicates the fraction of values below the corresponding DO concentration (mg/L) indicated on the x-axis.

6.8 Effect of Deepening of the Navigation Channel

An ongoing navigation channel deepening project is underway in the Lower Cape Fear River Estuary. This project is being conducted by the Wilmington district of the US Army Corps of Engineers. The Wilmington Harbor Project will deepen 37 miles of channel by 4 feet in the Cape Fear River up to the State Port of Wilmington, and into the Northeast Cape Fear River. Project information is available www.saw.usace.army.mil/wilmington-harbor/main.htm. Information from this site was used to modify the water depths given in the EFDC grid file DXDY.INP. Each grid cell in the navigation channel was deepened according to the plan described by the Army Corps of Engineers. No other changes were made from the base case values in defining the various input files needed to run the model.

The channel deepening had a noticeable, and slightly negative effect on dissolved oxygen concentrations during the summertime in the Lower Cape Fear River Estuary. Deepening of the channel slightly decreased dissolved oxygen concentrations. The reduction in dissolved oxygen concentrations was similar across the distribution of dissolved oxygen values. At the 10th percentile value, the dissolved oxygen was decreased by about 0.2 mg/L, from 4.3 mg/L to 4.1 mg/L. Near the median dissolved oxygen concentration, the dissolved oxygen decreased by about 0.1 mg/L, from 5.6 mg/L to 5.5 mg/L (Figure 85). The effect of deepening the channel is also seen when comparing the frequency of DO concentrations below 5.0 mg/L. For the base case the percentage below 5.0 mg/L was 32%, for the deepened channel the percentage was approximately 34%. Thus there is an effect with the channel deepening, which slightly lowers dissolved oxygen concentrations, but the magnitude of the effect is small (< 0.2 mg/L difference, > 5% difference in DO concentrations below a particular value).

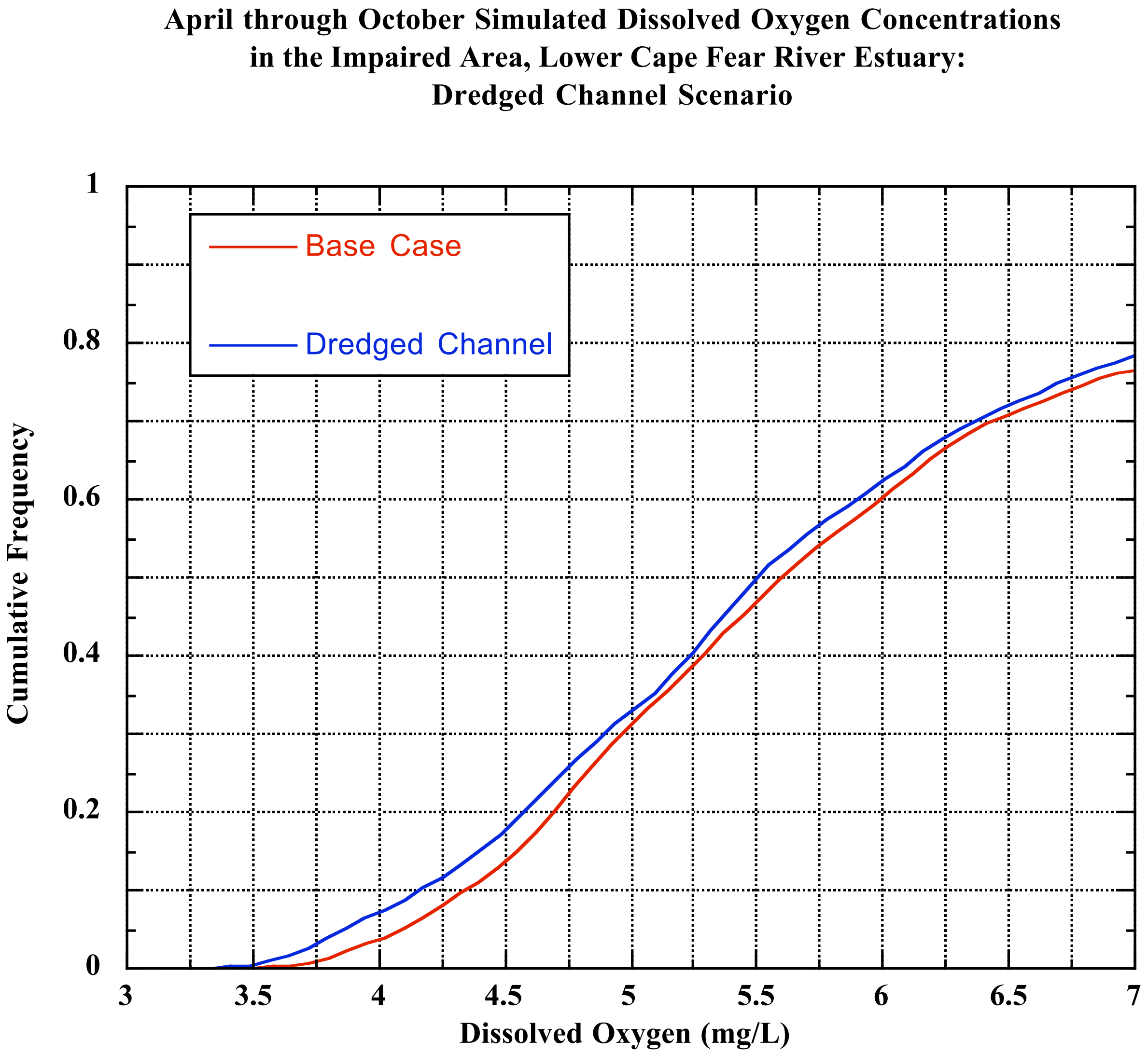


Figure 85. Percentile Plot of Model Predicted Dissolved Oxygen Concentrations During the Summer 2004 for the Base Case and a Scenario Where the Navigation Channel is Deepened by Dredging. The y-axis indicates the fraction of values below the corresponding DO concentration (mg/L) indicated on the x-axis.

6.9 Effect of Changing Brunswick County Wastewater Loadings

Three model scenarios considered the impact of changing the wastewater flow of a single discharger (Brunswick County wastewater treatment plant). Based on the discharge monitoring reports for the model period (2003-2005), the base condition had a time-averaged flow of 0.38 MGD. The three alternate scenarios tested had time-averaged flows of 1.65, 4.65 and 15 MGD. These scenarios therefore represented the effect of changing the wastewater treatment flow by factors of 4.3, 12.1, and 39.1. In these alternate loading scenarios, each discharge flow was increased by a constant factor. All concentrations were assumed to be constant. Thus the wastewater loadings had identical patterns of time variation, but had time-averaged flows that equaled the values given above. As for the other scenarios, twice daily dissolved oxygen concentrations were collected and compared to the base case at eighteen sites within the impaired region, from all eight layers of the model and from every day within the summertime period (April 1 – October 31, 2004).

Despite the relatively large changes in the assumed wastewater flow, there were only very small differences in the predicted dissolved oxygen concentrations, for summertime conditions in the impaired region. Across the entire range of dissolved oxygen concentrations, the differences between the base case and each of the three scenarios was always less than 0.05 mg/L (Figure 86). Thus there was essentially no effect of changing the wastewater flow. One limitation of this analysis is the assumption that loading would increase solely by increasing the flow. Since the organic matter concentrations were only slightly higher than the receiving waters, it is not surprising that changing the loading by holding effluent concentrations constant while increasing the flows had a very small effect on dissolved oxygen concentrations.

April through October Simulated Dissolved Oxygen Concentrations in the Impaired Area, Lower Cape Fear River Estuary

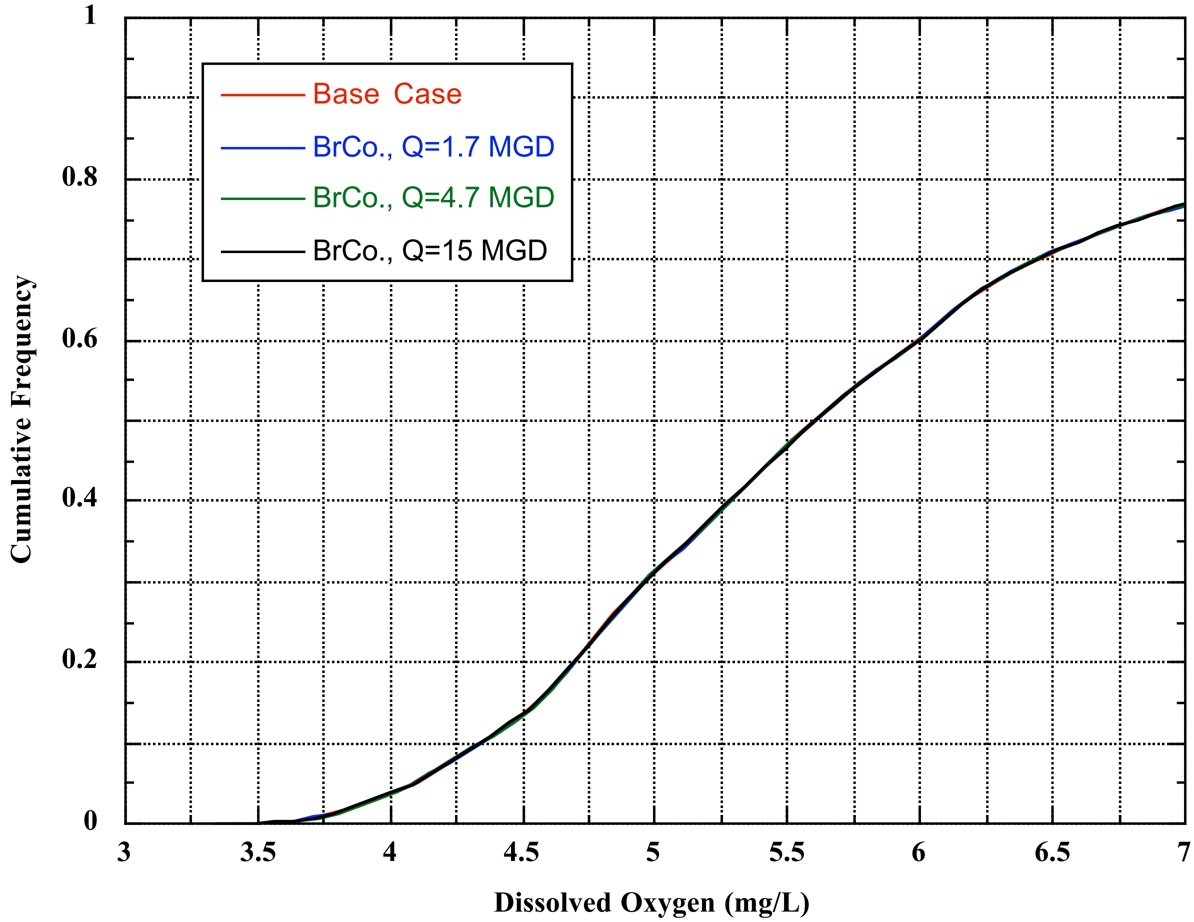


Figure 86. Percentile Plot of Model Predicted Dissolved Oxygen Concentrations During the Summer 2004 for the Base Case and Three Brunswick County WWTP Loading Scenarios. The y-axis indicates the fraction of values below the corresponding DO concentration (mg/L) indicated on the x-axis.

6.10 Analysis of the Summer Dissolved Oxygen Deficit in the Impaired Region

One conclusion that results from the previous scenarios is that depressed summertime dissolved oxygen concentrations in the Lower Cape Fear River Estuary can possibly be the result from one or more processes. Sediment oxygen demand, water-column decomposition of organic matter, or oxidation of ammonia can all result in dissolved oxygen depletion. Furthermore, there are several sources of organic matter in the water column (e.g. wastewater point sources, riverine inputs, inputs from creeks and rivers). An important consideration in the analysis of water quality in the Lower Cape Fear River Estuary is the relative importance of these various sources and processes to the dissolved oxygen concentrations in the impaired region of the Estuary.

To investigate the relative importance of these sources and processes, an analysis was performed to quantitatively compare the rates of oxygen consumption in the water-column due to riverine, estuarine, and wastewater sources, and to compare this consumption to sediment oxygen demand. The analysis focused on three sites within the impaired region where monitoring data were available: Cape Fear at Navassa (see Figure 6, Station NAV), Northeast Cape Fear River at Wilmington (see Figure 7, USGS Station 02108690), and Cape Fear River at Horseshoe Bend (see Figure 6, Station HB). Twice daily model predicted dissolved oxygen concentration, temperature, and salinity values were recorded near the surface (layer 7 of 8) at these three stations. Temperature and salinity values were used to calculate dissolved oxygen saturation concentration (Chapra 1997), and then the DO concentrations were plotted as a fraction of the DO saturation concentration (Figure 87) for a fourteen-month period beginning December 1, 2003. At all three stations, the DO saturation fraction is highest during the winter months and lowest during the summer months, probably as a result of temperature related differences in the consumption rate of water-column dissolved oxygen. At all three stations DO saturation percentages peak at about 90% in early March but then decline steady until August, when DO saturation percentages are less than 60% at all three stations. Beginning in early April, DO saturation values go below 70% at all stations, and do go back above 70% until late October (Figure 87).

Clearly oxygen consumption and under-saturated DO concentrations are a persistent feature during the summer at these three stations within the impaired region of the Lower Cape Fear Estuary, but what is the relative importance of the processes that produce this under saturation of dissolved oxygen in the water-column? To investigate this question, a first-order sensitivity analysis was performed to determine the relative importance of these three processes:

1. Discharge of oxygen demanding wastes by the 20 wastewater treatment plants that discharge directly to the estuary,
2. Discharge of oxygen demanding wastes by the three rivers in the basin (Cape Fear, Black, Northeast Cape Fear) as well as the creek and wetlands areas that discharge directly to the estuary, and
3. Sediment oxygen demand.

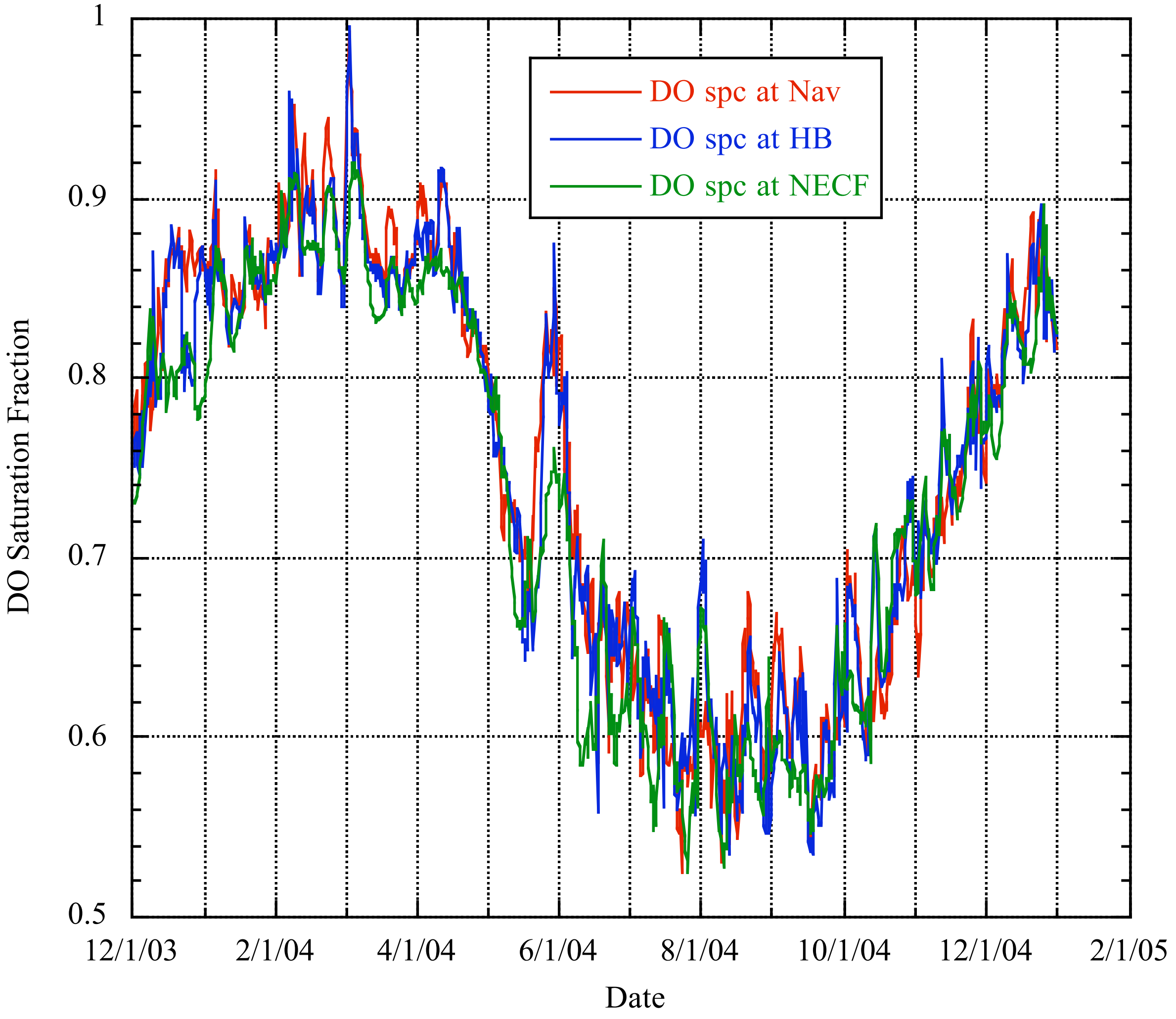


Figure 87. Model Predicted Dissolved Oxygen Concentrations in the Surface Waters as a Percentage of Saturation Concentration at Two Cape Fear Locations (Navassa and Horseshoe Bend) and one NE Cape Fear Station (Wilmington).

Three separate runs were made to determine the sensitivity of the time-averaged DO concentration at the three test sites to changes in one of the processes listed above. In each run, a prescribed relative change (e.g. 10% of the base case) in one of the loadings or the sediment oxygen demand rate was made, while holding all other rates and parameters at the values set in the base case. These three runs were then compared to the base case and the relatively sensitivity of each process was determined by comparing the change in dissolved oxygen concentration between the cases. The time-averaged mean oxygen depletion at each site was then apportioned based upon the relative sensitivity of the three processes.

There were slight differences in the magnitudes of the oxygen depletion attributable to the three different factors at the three different sites (Figure 88). In general, however, the dissolved oxygen deficit caused by SOD and the river loadings of organic matter were significantly greater than that caused by the WWTP loadings. Time averaged dissolved oxygen concentrations were slightly different at the three sites, ranging from 5.65 mg/L at Navassa to 5.45 mg/L at the Northeast Cape Fear at Wilmington site. At each site the time-averaged dissolved oxygen saturation concentration was approximately 8.2 mg/L, thus each site had a time-averaged dissolved oxygen depletion of approximately 2.7 mg/L. Of the three processes compared, the wastewater treatment plant discharges had by far the smallest dissolved oxygen depletion effect. At each wastewater treatment plants accounted for approximately 0.2 mg/L of the total dissolved oxygen depletion. This amount of depletion represents approximately 7 to 9% of the total depletion. Of the remaining DO depletion (approximately 2.5 mg/L, which is more than 90% of the total), roughly similar amounts could be attributable to SOD or riverine loadings of organic matter. The exception to this was the Northeast Cape Fear at Wilmington site, where more of the depletion (56% vs. 37%) was due to the SOD. These findings are consistent with earlier estimates of organic matter loading that show that rivers, creeks, and wetlands are the dominant sources of oxygen demanding wastes to the estuary (e.g. see Figures 43, 44, and 45).

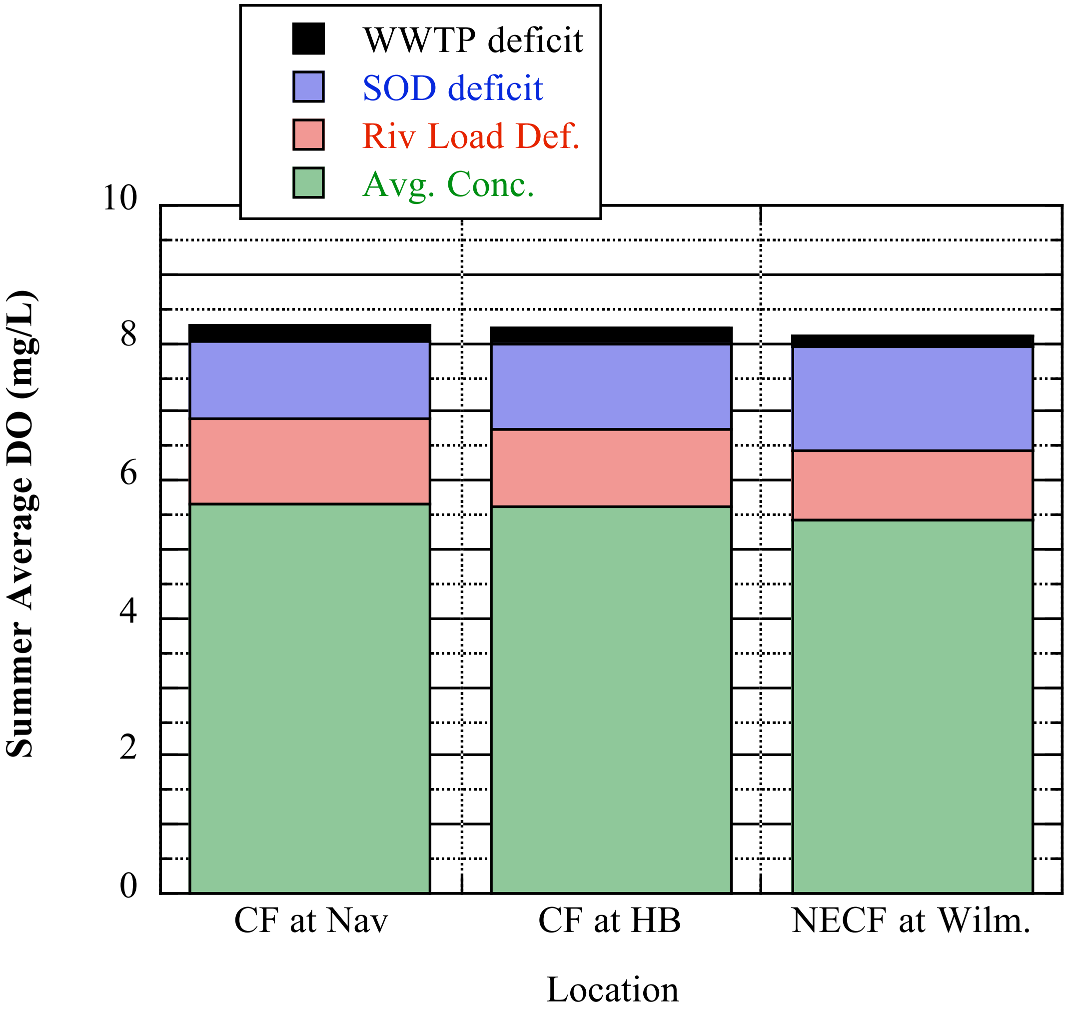


Figure 88. Bar Graphs of Summer Season (April through October) Time-Averaged Model Predicted Dissolved Oxygen Concentrations (green) and the Dissolved Oxygen Deficit Caused by Wastewater Treatment Plants (black) Riverine Discharges (blue), and Sediment Oxygen Demand (pink) at Two Cape Fear Locations (Navassa and Horseshoe Bend) and one NE Cape Fear Station (Wilmington).

7. SUMMARY, DISCUSSION, AND CONCLUSIONS

The three-dimensional water quality model EFDC (Environmental Fluid Dynamics Code) was applied to simulate hydrodynamic and water conditions for the Lower Cape Fear River Estuary, North Carolina. The model region included the tidally affected portions of the Cape Fear, Black, and Northeast Cape Fear Rivers near Wilmington, North Carolina, and extended southward to the mouth of the Cape Fear River near Southport, North Carolina. A multi-agency monitoring program was used to gather the necessary data to run and calibrate the model. A fourteen-month period from November 2003 until January 2005 was used for model calibration. The model was created in such a way so that it separately accounted for the oxygen demanding loadings to the estuary from the three major rivers, tidal creeks and fringing wetlands within the estuary, wastewater treatment plant discharges, and sediment oxygen demand within the estuary. A phased multi-objective calibration procedure was implemented that sought to maximize the model's fit to multiple water quality constituents. The calibration phasing was accomplished in such a way that recognized the primary importance of dissolved oxygen prediction. The calibrated model simulated well the temporal and spatial patterns of dissolved oxygen concentration within the estuary. Model confirmation testing was performed for a twelve-month period from January 2005 to January 2006. The model's ability to simulate dissolved oxygen during the confirmation run was similar to that for the calibration period.

The model was used to investigate the effects of various organic matter and ammonia load reduction scenarios on the dissolved oxygen concentrations within the estuary. Various scenarios investigated the system response to reductions in wastewater and watershed loadings. Of the three primary constituents that contribute to oxygen depletion, only ammonia had a load that was contributed primarily from the wastewater sources. For organic matter loadings, the majority of the load was contributed by the incoming rivers and local tidal creeks and wetlands discharging directly to the estuary. Reducing these watershed loads had a significant impact on the dissolved concentrations within the estuary. Despite the sensitivity of the system to changes in these loadings, elimination of violations of the water quality standard for dissolved oxygen (5 mg/L) would require a 70% reduction both in riverine loadings but also a similar reduction in sediment oxygen demand.

Reducing wastewater loads generally had a smaller, but still noticeable impact on dissolved oxygen concentrations. Generally the magnitude of the increase in dissolved oxygen concentration followed the relative importance of the discharge to the overall loading to the estuary. An additional scenario tested the degree to which parameter variation, in this case sediment oxygen demand, could change the system's sensitivity to load reductions. This case demonstrated that the change in DO concentrations for a particular load reduction did not vary appreciably as the SOD used by the model was changed. Other scenarios investigated the system's sensitivity, with regard to dissolved oxygen concentrations to changes in the estuary that might result from dredging of the navigation channel or increases in wastewater treatment plant loadings up to the maximum permitted values. These two scenarios had a relatively minor effect on dissolved oxygen concentrations.

The model was designed to allow for relatively simple specification of additional scenarios. The results of the scenario tests, strategic choices made in creating the model, and results from previous modeling work on the estuary (e.g. Tetra Tech 2001), indicate that further refinement of the benthic flux model is justified. Both this study and the previous modeling effort demonstrate the significance of benthic fluxes to the overall dissolved oxygen budget. While special efforts were undertaken to rationally specify the temporal and spatial variation in SOD, the method by which benthic fluxes are prescribed rather than predicted from a sediment diagenesis model does limit the predictive ability of this model. For instance, it was recognized that reductions in river loading would probably also reduce sediment oxygen demand in the long-term, but with the prescribed SOD there was no way to predict the magnitude of the changes in SOD, or the time scale of those changes. Also, the monitoring data indicated that spatial differences in SOD probably exist within the estuary, but the DO monitoring data alone don't provide sufficient information to rationally prescribe the spatial variation in sediment quality.

The results of the analysis are qualitatively similar to that of the previous modeling study (Tetra Tech 2001), despite the conceptual differences in the two models. Both models indicate the importance of the wetland areas within the estuary, even though conceptualization of this portion of the water body differs between the two models. The previous model only considered the wetlands to be a sink of dissolved oxygen; consideration of organic matter loadings from these areas was not considered. In the model described here, the tidal creeks and wetlands were considered sinks of dissolved oxygen as well as a source of organic matter and freshwater. In the previous modeling work the "marsh effect" was estimated by completely removing these cells from the model, which had both water quality and circulation effects. In the modeling work described here, the effects of the wetlands were lumped together with that of the major rivers that drain to the estuary. These effects were quantified by varying the loadings from the all of the riverine and non-point sources, and then observing the resulting effects on dissolved oxygen concentrations within the estuary. With the analysis done this way, it is not possible to distinguish between the effect caused by the riverine sources and that from the wetlands and tidal creeks. One good aspect of this model, however, is that a scenario that looks separately at the effects of the rivers and the wetlands could be easily formulated and may be warranted in the future.

It is hoped that the model will be used as a tool for the rational water quality management of the system. The model was created with the objective of considering all sources of oxygen demanding waste to the estuary. A second objective was to quantify these sources in such way so that additional scenario testing would not be overly burdensome. Considering the complexity of the system, the importance of the natural resource, and the importance of the economy supported by the estuary's resources, further analysis in the future using this model seems warranted.

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Parameters Used to Calculate Loads

Name	Value	Units	Notes
Starting Day	37257	days	Day 0 = 1/1/2002
Sample Day	15.5	days	Noon on the 15th of the month

Load Calculation Matrix (to get results in kg/day)

Multiply by Flow to get Daily Load?

Each constituent value is linearly related to the following 7 measurements, which are given either as loads, concentrations, or flow. Each column gives weighting factors for each constituent

	Bc	Bd	Bg	RPOC	LPOC	DOC	RPOP	LPOP	DOP	PTO4	RPON	LPON	DON	NH4	NO3	SU	SA	COD	DO	TAM	FCB	Flow
Multiply by Flow to get Daily Load?	no	no	no	no	no	no	no	no	no	no	no	no	no	no	no	no	no	no	yes	no	no	no
00300 - DO, Oxygen, Dissolved, g/m3	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	3.79	0.00	0.00	0.00
00310 - BOD, 5-Day (20 Deg_ C) lb/day	0.00	0.00	0.00	0.00	**0.00**	**0.32**	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
00530 - Solids, Total Suspended, lb/day	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
00600 - Nitrogen, Total (as N), lb/day	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	**0.0157**	**-0.0157**	0.00	0.00	**0.1134**	0.00	**0.3402**	0.00	0.00	0.00	0.00	0.00	0.00	0.00
00610 - Nitrogen, Ammonia Total (as N), lb/day	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	**-0.0157**	**0.0157**	0.00	0.00	**-0.1134**	**0.45**	**-0.3402**	0.00	0.00	0.00	0.00	0.00	0.00	0.00
00665 - Phosphorus, Total (as P), lb/day	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	**0.45**	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
50050 - Flow, in conduit or thru treatment plant, MGD	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	1.00

Parameters Used to Get Values Above (each coefficient is the product of the numbers below it)

Kg to lb ratio	0.4536	0.4536	0.4536	0.4536	0.4536	0.4536	0.4536	
BOD5 to BODU scaleup	1.9	1.9						
C to O2 molecular weight ratio (12/32)	0.3745	0.3745						
kilograms per gram								0.001
m3 per million gallon								3786.2
fraction of non-ammonia nitrogen that is DON			**0.25**	**0.25**	**0.25**			
fraction of non-ammonia nitrogen that is NOX							**0.75**	
P to N mass ratio			**0.1389**	**0.1389**				
LPOC/DOC split (see jdb_1485)	0.0%	100.0%						
Fraction Remaining	100%	100%	100%	100%	100%	**100%**	100%	100%
Resulting Unit in Computed Data		kg/d	kg/d	kg/d	kg/d	kg/d	kg/d	kg/MG

Assumptions

DOC = BODu * C to O2 molecular weight ratio

DON = (TN - NH4) * .25

NO3 = (TN - NH4) * 0.75

DOP = DON * (Redfield P to N mass ratio)

PO4T = TP - DOP

Parameters Used to Calculate Loads

Name	Value	Units	Notes
Starting Day	37257	days	Day 0 = 1/1/2002
Sample Day	15.5	days	Noon on the 15th of the month

Load Calculation Matrix (to get results in kg/day)

Multiply by Flow to get Daily Load?

Each constituent concentration is linearly related to the following 8 measurements (6 loads, 1 conc. (DO), 1 flow) Each column gives weighting factors for each constituent

	Bc	Bd	Bg	RPOC	LPOC	DOC	RPOP	LPOP	DOP	PTO4	RPON	LPON	DON	NH4	NO3	SU	SA	COD	DO	TAM	FCB
Multiply by Flow to get Daily Load?	no	no	no	no	no	no	no	no	no	no	no	no	no	no	no	no	no	no	yes	no	no
00300 - DO, Oxygen, Dissolved	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
00310 - BOD, 5-Day (20 Deg_ C) lb/day	0.00	0.00	0.00	0.00	0.00	**0.32**	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
00530 - Solids, Total Suspended	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
00600 - Nitrogen, Total (as N)	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	**0.0157**	**-0.0157**	0.00	0.00	**0.11**	0.00	**0.34**	0.00	0.00	0.00	0.00	0.00	0.00
00610 - Nitrogen, Ammonia Total (as N)	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	**-0.0157**	**0.0157**	0.00	0.00	**-0.11**	**0.45**	**-0.34**	0.00	0.00	0.00	0.00	0.00	0.00
00665 - Phosphorus, Total (as P)	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	**0.45**	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
50050 - Flow, in conduit or thru treatment plant	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
DO * flow (g/m3 MGD)	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	**3.79**	0.00	0.00

Parameters Used to Get Values Above (each coefficient is the product of the numbers below it)

	DOC	DOP	PTO4	DON	NH4	NO3	DO
Kg to lb ratio	0.4536	0.4536	0.4536	0.4536	0.4536	0.4536	
BOD5 to BODU scaleup	1.9						
C to O2 molecular weight ratio (12/32)	0.3745						
kilograms per gram							0.001
m3 per million gallon							3786.2
fraction of non-ammonia nitrogen that is DON		**0.25**	**0.25**	**0.25**			
fraction of non-ammonia nitrogen that is NOX						**0.75**	
P to N mass ratio		**0.1389**	**0.1389**				
Fraction Remaining	100%			100%	**100%**		

Assumptions

DOC = BODu * C to O2 molecular weight ratio
DON = (TN - NH4) * .25
NO3 = (TN - NH4) * 0.75
DOP = DON * (Redfield P to N mass ratio)
PO4T = TP - DOP

Parameters Used to Calculate Loads

Name	Value	Units	Notes
Starting Day	37257	days	Day 0 = 1/1/2002
Sample Day	15.5	days	Noon on the 15th of the month

Load Calculation Matrix (to get results in kg/day)

Multiply by Flow to get Daily Load?

Each constituent concentration is linearly related to the following 8 measurements (6 loads, 1 conc. (DO), 1 flow) Each column gives weighting factors for each constituent

	Bc	Bd	Bg	RPOC	LPOC	DOC	RPOP	LPOP	DOP	PTO4	RPON	LPON	DON	NH4	NO3	SU	SA	COD	DO	TAM	FCB
Multiply by Flow to get Daily Load?	no	no	no	no	no	no	no	no	no	no	no	no	no	no	no	no	no	no	yes	no	no
00300 - DO, Oxygen, Dissolved	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
00310 - BOD, 5-Day (20 Deg_ C) lb/day	0.00	0.00	0.00	0.00	0.00	**0.32**	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
00530 - Solids, Total Suspended	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
00600 - Nitrogen, Total (as N)	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	**0.0157**	**-0.0157**	0.00	0.00	**0.11**	0.00	**0.34**	0.00	0.00	0.00	0.00	0.00	0.00
00610 - Nitrogen, Ammonia Total (as N)	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	**-0.0157**	**0.0157**	0.00	0.00	**-0.11**	**0.45**	**-0.34**	0.00	0.00	0.00	0.00	0.00	0.00
00665 - Phosphorus, Total (as P)	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	**0.45**	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
50050 - Flow, in conduit or thru treatment plant	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
DO * flow (g/m3 MGD)	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	**3.79**	0.00	0.00

Parameters Used to Get Values Above (each coefficient is the product of the numbers below it)

	DOC	DOP	PTO4	DON	NH4	NO3	DO
Kg to lb ratio	0.4536	0.4536	0.4536	0.4536	0.4536	0.4536	
BOD5 to BODU scaleup	1.9						
C to O2 molecular weight ratio (12/32)	0.3745						
kilograms per gram							0.001
m3 per million gallon							3786.2
fraction of non-ammonia nitrogen that is DON		**0.25**	**0.25**	**0.25**			
fraction of non-ammonia nitrogen that is NOX						**0.75**	
P to N mass ratio		**0.1389**	**0.1389**				
Fraction Remaining	100%			100%	**100%**		

Assumptions

DOC = BODu * C to O2 molecular weight ratio
DON = (TN - NH4) * .25
NO3 = (TN - NH4) * 0.75
DOP = DON * (Redfield P to N mass ratio)
PO4T = TP - DOP

Parameters Used to Calculate Loads

Name	Value	Units	Notes
Starting Day	37257	days	Day 0 = 1/1/2002
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Load Calculation Matrix (to get results in kg/day)

Multiply by Flow to get Daily Load?

Each constituent concentration is linearly related to the following 8 measurements (6 loads, 1 conc. (DO), 1 flow) Each column gives weighting factors for each constituent

	Bc	Bd	Bg	RPOC	LPOC	DOC	RPOP	LPOP	DOP	PTO4	RPON	LPON	DON	NH4	NO3	SU	SA	COD	DO	TAM	FCB	Flow
Multiply by Flow to get Daily Load?	no	no	no	no	no	no	yes	yes	yes	yes	yes	yes	yes	yes	yes	no	no	no	yes	no	no	no
00300 - DO, Oxygen, Dissolved, g/m3	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	3.79	0.00	0.00	0.00
00310 - BOD, 5-Day (20 Deg_ C), lb/day	0.00	0.00	0.00	0.00	0.00	**0.32**	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
00530 - Solids, Total Suspended, lb/day	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
00600 - Nitrogen, Total (as N), g/m3	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	**0.1315**	**-0.1315**	0.00	0.00	**0.95**	0.00	**2.84**	0.00	0.00	0.00	0.00	0.00	0.00	0.00
00610 - Nitrogen, Ammonia Total (as N), g/m3	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	**-0.1315**	**0.1315**	0.00	0.00	**-0.95**	**3.79**	**-2.84**	0.00	0.00	0.00	0.00	0.00	0.00	0.00
00665 - Phosphorus, Total (as P), g/m3	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	**3.79**	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
50050 - Flow, in conduit or thru treatment plant, mg/D	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	1.00

Parameters Used to Get Values Above (each coefficient is the product of the numbers below it)

	DOC	DOP	PTO4	DON	NH4	NO3	DO
Kg to lb ratio	0.4536						
BOD5 to BODU scaleup	1.9						
C to O2 molecular weight ratio (12/32)	0.3745						
kilograms per gram		0.001	0.001	0.001	0.001	0.001	0.001
m3 per million gallon		3786.2	3786.2	3786.2	3786.2	3786.2	3786.2
fraction of non-ammonia nitrogen that is DON		**0.25**	**0.25**	**0.25**			
fraction of non-ammonia nitrogen that is NOX						**0.75**	
P to N mass ratio		**0.1389**	**0.1389**				
Fraction Remaining	100%			100%	**100%**		

Assumptions

DOC = BODu * C to O2 molecular weight ratio

DON = (TN - NH4) * .25

NO3 = (TN - NH4) * 0.75

DOP = DON * (Redfield P to N mass ratio)

PO4T = TP - DOP

0 0.3228

Parameters Used to Calculate Loads

Name	Value	Units	Notes
Starting Day	37257	days	Day 0 = 1/1/2002
Sample Day	15.5	days	Noon on the 15th of the month

Load Calculation Matrix (to get results in kg/day)

Multiply by Flow to get Daily Load?

Each constituent concentration is linearly related to the following 8 measurements (6 loads, 1 conc. (DO), 1 flow) Each column gives weighting factors for each constituent

	Bc	Bd	Bg	RPOC	LPOC	DOC	RPOP	LPOP	DOP	PTO4	RPON	LPON	DON	NH4	NO3	SU	SA	COD	DO	TAM	FCB	Flow
Multiply by Flow to get Daily Load?	no	no	no	no	no	no	yes	yes	yes	yes	yes	yes	yes	yes	yes	no	no	no	yes	no	no	no
00300 - DO, Oxygen, Dissolved, g/m3	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	3.79	0.00	0.00	0.00
00310 - BOD, 5-Day (20 Deg_ C), lb/day	0.00	0.00	0.00	0.00	0.00	0.32	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
00530 - Solids, Total Suspended, lb/day	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
00600 - Nitrogen, Total (as N), g/m3	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.1315	-0.1315	0.00	0.00	0.95	0.00	2.84	0.00	0.00	0.00	0.00	0.00	0.00	0.00
00610 - Nitrogen, Ammonia Total (as N), g/m3	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	-0.1315	0.1315	0.00	0.00	-0.95	3.79	-2.84	0.00	0.00	0.00	0.00	0.00	0.00	0.00
00665 - Phosphorus, Total (as P), g/m3	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	3.79	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
50050 - Flow, in conduit or thru treatment plant, mg/D	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	1.00

Parameters Used to Get Values Above (each coefficient is the product of the numbers below it)

Kg to lb ratio	0.4536						
BOD5 to BODU scaleup	1.9						
C to O2 molecular weight ratio (12/32)	0.3745						
kilograms per gram		0.001	0.001	0.001	0.001	0.001	0.001
m3 per million gallon		3786.2	3786.2	3786.2	3786.2	3786.2	3786.2
fraction of non-ammonia nitrogen that is DON		0.25	0.25	0.25			
fraction of non-ammonia nitrogen that is NOX						0.75	
P to N mass ratio		0.1389	0.1389				
Fraction Remaining	100%			100%	100%		

Assumptions

DOC = BODu * C to O2 molecular weight ratio
DON = (TN - NH4) * .25
NO3 = (TN - NH4) * 0.75
DOP = DON * (Redfield P to N mass ratio)
PO4T = TP - DOP

0 0.3228

Parameters Used to Calculate Loads

Name	Value	Units	Notes
Starting Day	37257	days	Day 0 = 1/1/2002
Sample Day	15.5	days	Noon on the 15th of the month

Load Calculation Matrix (to get results in kg/day)

Each constituent concentration is linearly related to the following 8 measurements (6 loads, 1 conc. (DO), 1 flow) Each column gives weighting factors for each constituent

	Bc	Bd	Bg	RPOC	LPOC	DOC	RPOP	LPOP	DOP	PTO4	RPON	LPON	DON	NH4	NO3	SU	SA	COD	DO	TAM	FCB	Flow
Multiply by Flow to get Daily Load?	no	no	no	no	no	no	yes	yes	yes	yes	yes	yes	yes	yes	yes	no	no	no	yes	no	no	no
00300 - DO, Oxygen, Dissolved, g/m3	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	**3.79**	0.00	0.00	0.00
00310 - BOD, 5-Day (20 Deg_ C), lb/day	0.00	0.00	0.00	**0.78**	0.00	**0.26**	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
00530 - Solids, Total Suspended, lb/day	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
00600 - Nitrogen, Total (as N), g/m3	0.00	0.00	0.00	0.00	0.00	0.00	**0.10**	0.00	**0.03**	**-0.13**	**0.71**	0.00	**0.24**	0.00	**2.84**	0.00	0.00	0.00	0.00	0.00	0.00	0.00
00610 - Nitrogen, Ammonia Total (as N), g/m3	0.00	0.00	0.00	0.00	0.00	0.00	**-0.10**	0.00	**-0.03**	**0.13**	**-0.71**	0.00	**-0.24**	**3.79**	**-2.84**	0.00	0.00	0.00	0.00	0.00	0.00	0.00
00665 - Phosphorus, Total (as P), g/m3	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	**3.79**	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
50050 - Flow, in conduit or thru treatment plant, mg/D	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	1.00

Parameters Used to Get Values Above (each coefficient is the product of the numbers below it)

	RPOC	LPOC	DOC	RPOP	LPOP	DOP	PTO4	RPON	LPON	DON	NH4	NO3	SU	SA	COD	DO
Kg to lb ratio	0.4536		0.4536													
BOD5 to BODU scaleup	6.11		6.11													
C to O2 molecular weight ratio (12/32)	0.3745		0.3745													
kilograms per gram				0.001		0.001	0.001	0.001		0.001	0.001	0.001				0.001
m3 per million gallon				3786.2		3786.2	3786.2	3786.2		3786.2	3786.2	3786.2				3786.2
fraction of non-ammonia nitrogen that is ON				**0.25**		**0.25**	**0.25**	**0.25**		**0.25**						
fraction of non-ammonia nitrogen that is NOX												**0.75**				
P to N mass ratio				**0.1389**		**0.1389**	**0.1389**									
LPOC/DOC split (see jdb_1485)	75.0%		25.0%	75.0%		25.0%		75.0%		25.0%						
Fraction Remaining	100%		100%	100%		100%	100%	100%		100%	**100%**	100%				100%

Assumptions

DOC = BODu * C to O2 molecular weight ratio
DON = (TN - NH4) * .25
NO3 = (TN - NH4) * 0.75
DOP = DON * (Redfield P to N mass ratio)
PO4T = TP - DOP

0 1.038

Parameters Used to Calculate Loads

Name	Value	Units	Notes
Starting Day	37257	days	Day 0 = 1/1/2002
Sample Day	15.5	days	Noon on the 15th of the month

Load Calculation Matrix (to get results in kg/day)

Each constituent concentration is linearly related to the following 8 measurements (6 loads, 1 conc. (DO), 1 flow) Each column gives weighting factors for each constituent

	Bc	Bd	Bg	RPOC	LPOC	DOC	RPOP	LPOP	DOP	PTO4	RPON	LPON	DON	NH4	NO3	SU	SA	COD	DO	TAM	FCB	Flow
Multiply by Flow to get Daily Load?	no	no	no	no	no	yes	yes	yes	yes	yes	yes	yes	yes	yes	yes	no	no	no	yes	no	no	no
00300 - DO, Oxygen, Dissolved, g/m3	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	3.79	0.00	0.00	0.00
00310 - BOD, 5-Day (20 Deg_ C), mg/L	0.00	0.00	0.00	0.00	0.00	2.69	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
00530 - Solids, Total Suspended, g/m3	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
00600 - Nitrogen, Total (as N), g/m3	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.1315	-0.1315	0.00	0.00	0.95	0.00	2.84	0.00	0.00	0.00	0.00	0.00	0.00	0.00
00610 - Nitrogen, Ammonia Total (as N), g/m3	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	-0.1315	0.1315	0.00	0.00	-0.95	3.79	-2.84	0.00	0.00	0.00	0.00	0.00	0.00	0.00
00665 - Phosphorus, Total (as P), g/m3	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	3.79	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
50050 - Flow, in conduit or thru treatment plant, mg/D	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	1.00

Parameters Used to Get Values Above (each coefficient is the product of the numbers below it)

	Bc	Bd	Bg	RPOC	LPOC	DOC	RPOP	LPOP	DOP	PTO4	RPON	LPON	DON	NH4	NO3	SU	SA	COD	DO	TAM	FCB	Flow
Kg to lb ratio																						
BOD5 to BODU scaleup						1.9																
C to O2 molecular weight ratio (12/32)						0.3745																
kilograms per gram						0.001			0.001	0.001			0.001	0.001	0.001				0.001			
m3 per million gallon						3786.2			3786.2	3786.2			3786.2	3786.2	3786.2				3786.2			
fraction of non-ammonia nitrogen that is DON									0.25	0.25			0.25									
fraction of non-ammonia nitrogen that is NOX															0.75							
P to N mass ratio									0.1389	0.1389												
Fraction Remaining						100%							100%	100%								

Assumptions

DOC = BODu * C to O2 molecular weight ratio
DON = (TN - NH4) * .25
NO3 = (TN - NH4) * 0.75
DOP = DON * (Redfield P to N mass ratio)
PO4T = TP - DOP

Parameters Used to Calculate Loads

Name	Value	Units	Notes
Starting Day	37257	days	Day 0 = 1/1/2002
Sample Day	15.5	days	Noon on the 15th of the month

Load Calculation Matrix (to get results in kg/day)

Multiply by Flow to get Daily Load?

Each constituent concentration is linearly related to the following 8 measurements (6 loads, 1 conc. (DO), 1 flow) Each column gives weighting factors for each constituent

	Bc	Bd	Bg	RPOC	LPOC	DOC	RPOP	LPOP	DOP	PTO4	RPON	LPON	DON	NH4	NO3	SU	SA	COD	DO	TAM	FCB	Flow
Multiply by Flow to get Daily Load?	no	no	no	no	no	yes	yes	yes	yes	yes	yes	yes	yes	yes	yes	no	no	no	yes	no	no	no
00300 - DO, Oxygen, Dissolved, g/m3	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	3.79	0.00	0.00	0.00
00310 - BOD, 5-Day (20 Deg_ C), mg/L	0.00	0.00	0.00	0.00	0.00	2.69	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
00530 - Solids, Total Suspended, g/m3	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
00600 - Nitrogen, Total (as N), g/m3	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	**0.1315**	**-0.1315**	0.00	0.00	**0.95**	0.00	**2.84**	0.00	0.00	0.00	0.00	0.00	0.00	0.00
00610 - Nitrogen, Ammonia Total (as N), g/m3	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	**-0.1315**	**0.1315**	0.00	0.00	**-0.95**	**3.79**	**-2.84**	0.00	0.00	0.00	0.00	0.00	0.00	0.00
00665 - Phosphorus, Total (as P), g/m3	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	**3.79**	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
50050 - Flow, in conduit or thru treatment plant, mg/D	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	1.00

Parameters Used to Get Values Above (each coefficient is the product of the numbers below it)

	DOC	DOP	PTO4	DON	NH4	NO3	DO
Kg to lb ratio							
BOD5 to BODU scaleup	1.9						
C to O2 molecular weight ratio (12/32)	0.3745						
kilograms per gram	0.001	0.001	0.001	0.001	0.001	0.001	0.001
m3 per million gallon	3786.2	3786.2	3786.2	3786.2	3786.2	3786.2	3786.2
fraction of non-ammonia nitrogen that is DON		**0.25**	**0.25**	**0.25**			
fraction of non-ammonia nitrogen that is NOX						**0.75**	
P to N mass ratio		**0.1389**	**0.1389**				
Fraction Remaining	100%			100%	**100%**		

Assumptions

DOC = BODu * C to O2 molecular weight ratio
DON = (TN - NH4) * .25
NO3 = (TN - NH4) * 0.75
DOP = DON * (Redfield P to N mass ratio)
PO4T = TP - DOP

Parameters Used to Calculate Loads

Name	Value	Units	Notes
Starting Day	37257	days	Day 0 = 1/1/2002
Sample Day	15.5	days	Noon on the 15th of the month

Load Calculation Matrix (to get results in kg/day)

Multiply by Flow to get Daily Load?

Each constituent concentration is linearly related to the following 8 measurements (6 loads, 1 conc. (DO), 1 flow) Each column gives weighting factors for each constituent

	Bc	Bd	Bg	RPOC	LPOC	DOC	RPOP	LPOP	DOP	PTO4	RPON	LPON	DON	NH4	NO3	SU	SA	COD	DO	TAM	FCB	Flow
Multiply by Flow to get Daily Load?	no	no	no	yes	no	yes	yes	yes	yes	yes	yes	yes	yes	yes	yes	no	no	no	yes	no	no	no
00300 - DO, Oxygen, Dissolved, g/m3	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	3.79	0.00	0.00	0.00
00310 - BOD, 5-Day (20 Deg_ C), mg/L	0.00	0.00	0.00	0.00	0.00	4.98	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
00530 - Solids, Total Suspended, g/m3	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
00600 - Nitrogen, Total (as N), g/m3	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.13	-0.1315	0.00	0.00	0.95	0.00	2.84	0.00	0.00	0.00	0.00	0.00	0.00	0.00
00610 - Nitrogen, Ammonia Total (as N), g/m3	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	-0.13	0.1315	0.00	0.00	-0.95	3.79	-2.84	0.00	0.00	0.00	0.00	0.00	0.00	0.00
00665 - Phosphorus, Total (as P), g/m3	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	3.79	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
50050 - Flow, in conduit or thru treatment plant, mg/D	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	1.00

Parameters Used to Get Values Above (each coefficient is the product of the numbers below it)

	Bc	Bd	Bg	RPOC	LPOC	DOC	RPOP	LPOP	DOP	PTO4	RPON	LPON	DON	NH4	NO3	SU	SA	COD	DO	TAM	FCB	Flow
Kg to lb ratio																						
BOD5 to BODU scaleup				3.51		3.51																
C to O2 molecular weight ratio (12/32)				0.3745		0.3745																
kilograms per gram				0.001		0.001	0.001		0.001	0.001	0.001		0.001	0.001	0.001				0.001			
m3 per million gallon				3786.2		3786.2	3786.2		3786.2	3786.2	3786.2		3786.2	3786.2	3786.2				3786.2			
fraction of non-ammonia nitrogen that is DON							0.25		0.25	0.25	0.25		0.25									
fraction of non-ammonia nitrogen that is NOX															0.75							
P to N mass ratio							0.1389		0.1389	0.1389												
RPOC/DOC split (see jdb_1485)				0.0%		100.0%	0.0%		100.0%		0.0%		100.0%									
Fraction Remaining				100%		100%	100%		100%	100%	100%		100%	100%	100%				100%			

Assumptions

DOC = BODu * C to O2 molecular weight ratio
DON = (TN - NH4) * .25
NO3 = (TN - NH4) * 0.75
DOP = DON * (Redfield P to N mass ratio)
PO4T = TP - DOP

Parameters Used to Calculate Loads

Name	Value	Units	Notes
Starting Day	37257	days	Day 0 = 1/1/2002
Sample Day	15.5	days	Noon on the 15th of the month

Load Calculation Matrix (to get results in kg/day)

Multiply by Flow to get Daily Load?

Each constituent concentration is linearly related to the following 8 measurements (6 loads, 1 conc. (DO), 1 flow) Each column gives weighting factors for each constituent

	Bc	Bd	Bg	RPOC	LPOC	DOC	RPOP	LPOP	DOP	PTO4	RPON	LPON	DON	NH4	NO3	SU	SA	COD	DO	TAM	FCB	Flow
	no	no	no	yes	no	yes	yes	yes	yes	yes	yes	yes	yes	yes	yes	no	no	no	yes	no	no	no
00300 - DO, Oxygen, Dissolved, g/m3	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	**3.79**	0.00	0.00	0.00
00310 - BOD, 5-Day (20 Deg_ C), mg/L	0.00	0.00	0.00	**0.00**	0.00	**2.69**	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
00530 - Solids, Total Suspended, g/m3	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
00600 - Nitrogen, Total (as N), g/m3	0.00	0.00	0.00	0.00	0.00	0.00	**0.00**	0.00	**0.13**	**-0.13**	**0.00**	0.00	**0.95**	0.00	**2.84**	0.00	0.00	0.00	0.00	0.00	0.00	0.00
00610 - Nitrogen, Ammonia Total (as N), g/m3	0.00	0.00	0.00	0.00	0.00	0.00	**0.00**	0.00	**-0.13**	**0.13**	**0.00**	0.00	**-0.95**	**3.79**	**-2.84**	0.00	0.00	0.00	0.00	0.00	0.00	0.00
00665 - Phosphorus, Total (as P), g/m3	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	**3.79**	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
50050 - Flow, in conduit or thru treatment plant, mg/D	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	1.00

Parameters Used to Get Values Above (each coefficient is the product of the numbers below it)

	RPOC	LPOC	DOC	RPOP	LPOP	DOP	PTO4	RPON	LPON	DON	NH4	NO3	SU	SA	COD	DO
Kg to lb ratio																
BOD5 to BODU scaleup	1.9		1.9													
C to O2 molecular weight ratio (12/32)	0.3745		0.3745													
kilograms per gram	0.001		0.001	0.001	0.001	0.001	0.001	0.001		0.001	0.001	0.001				0.001
m3 per million gallon	3786.2		3786.2	3786.2	3786.2	3786.2	3786.2	3786.2		3786.2	3786.2	3786.2				3786.2
fraction of non-ammonia nitrogen that is DON				**0.25**	**0.25**	**0.25**	**0.25**	**0.25**		**0.25**						
fraction of non-ammonia nitrogen that is NOX												**0.75**				
P to N mass ratio				**0.1389**	**0.1389**	**0.1389**	**0.1389**									
RPOC/DOC split (see jdb_1615)	0.0%		100.0%	0.0%		100.0%		0.0%		100.0%						
Fraction Remaining	100%		100%	100%	100%	100%	100%	100%		100%	**100%**	100%				100%

Assumptions

DOC = BODu * C to O2 molecular weight ratio

DON = (TN - NH4) * .25

NO3 = (TN - NH4) * 0.75

DOP = DON * (Redfield P to N mass ratio)

PO4T = TP - DOP

Parameters Used to Calculate Loads

Name	Value	Units	Notes
Starting Day	37257	days	Day 0 = 1/1/2002
Sample Day	15.5	days	Noon on the 15th of the month

Load Calculation Matrix (to get results in kg/day)

Multiply by Flow to get Daily Load?

Each constituent concentration is linearly related to the following 8 measurements (6 loads, 1 conc. (DO), 1 flow) Each column gives weighting factors for each constituent

	Bc	Bd	Bg	RPOC	LPOC	DOC	RPOP	LPOP	DOP	PTO4	RPON	LPON	DON	NH4	NO3	SU	SA	COD	DO	TAM	FCB	Flow
Multiply by Flow to get Daily Load?	no	no	no	yes	no	yes	yes	yes	yes	yes	yes	yes	yes	yes	yes	no	no	no	yes	no	no	no
00300 - DO, Oxygen, Dissolved, g/m3	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	3.79	0.00	0.00	0.00
00310 - BOD, 5-Day (20 Deg_ C), mg/L	0.00	0.00	0.00	**0.00**	0.00	**2.69**	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
00530 - Solids, Total Suspended, g/m3	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
00600 - Nitrogen, Total (as N), g/m3	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	**0.1315**	**-0.1315**	0.00	0.00	**0.95**	0.00	**2.84**	0.00	0.00	0.00	0.00	0.00	0.00	0.00
00610 - Nitrogen, Ammonia Total (as N), g/m3	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	**-0.1315**	**0.1315**	0.00	0.00	**-0.95**	**3.79**	**-2.84**	0.00	0.00	0.00	0.00	0.00	0.00	0.00
00665 - Phosphorus, Total (as P), g/m3	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	**3.79**	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
50050 - Flow, in conduit or thru treatment plant, mg/D	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	1.00

Parameters Used to Get Values Above (each coefficient is the product of the numbers below it)

	RPOC	DOC	DOP	PTO4	DON	NH4	NO3	DO
Kg to lb ratio								
BOD5 to BODU scaleup	1.9	1.9						
C to O2 molecular weight ratio (12/32)	0.3745	0.3745						
kilograms per gram	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001
m3 per million gallon	3786.2	3786.2	3786.2	3786.2	3786.2	3786.2	3786.2	3786.2
fraction of non-ammonia nitrogen that is DON			**0.25**	**0.25**	**0.25**			
fraction of non-ammonia nitrogen that is NOX							**0.75**	
P to N mass ratio			**0.1389**	**0.1389**				
LPOC/DOC split (see jdb_1485)	0.0%	100.0%						
Fraction Remaining	100%	100%	100%	100%	100%	**100%**	100%	100%

Assumptions

DOC = BODu * C to O2 molecular weight ratio
DON = (TN - NH4) * .25
NO3 = (TN - NH4) * 0.75
DOP = DON * (Redfield P to N mass ratio)
PO4T = TP - DOP

Parameters Used to Calculate Loads

Name	Value	Units	Notes
Starting Day	37257	days	Day 0 = 1/1/2002
Sample Day	15.5	days	Noon on the 15th of the month

Load Calculation Matrix (to get results in kg/day)

Multiply by Flow to get Daily Load?

Each constituent concentration is linearly related to the following 8 measurements (6 loads, 1 conc. (DO), 1 flow) Each column gives weighting factors for each constituent

	Bc	Bd	Bg	RPOC	LPOC	DOC	RPOP	LPOP	DOP	PTO4	RPON	LPON	DON	NH4	NO3	SU	SA	COD	DO	TAM	FCB	Flow
Multiply by Flow to get Daily Load?	no	no	no	no	no	no	no	no	no	no	no	no	no	no	no	no	no	no	yes	no	no	no
00300 - DO, Oxygen, Dissolved, g/m3	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	3.79	0.00	0.00	0.00
00310 - BOD, 5-Day (20 Deg_ C), lb/day	0.00	0.00	0.00	0.00	0.00	**0.32**	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
00530 - Solids, Total Suspended, lb/day	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
00600 - Nitrogen, Total (as N), lb/day	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	**0.11**	0.00	**0.34**	0.00	0.00	0.00	0.00	0.00	0.00	0.00
00610 - Nitrogen, Ammonia Total (as N), lb/day	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	**-0.11**	**0.45**	**-0.34**	0.00	0.00	0.00	0.00	0.00	0.00	0.00
00665 - Phosphorus, Total (as P), g/m3	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	1.89	1.89	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
50050 - Flow, in conduit or thru treatment plant, mg/D	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	1.00

Parameters Used to Get Values Above (each coefficient is the product of the numbers below it)

	DOC	DOP	PTO4	DON	NH4	NO3	DO
Kg to lb ratio	0.4536			0.4536	0.4536	0.4536	
BOD5 to BODU scaleup	1.9						
C to O2 molecular weight ratio (12/32)	0.3745						
kilograms per gram		0.001	0.001				0.001
m3 per million gallon		3786.2	3786.2				3786.2
fraction of non-ammonia nitrogen that is DON				**0.25**			
fraction of non-ammonia nitrogen that is NOX						**0.75**	
fraction of TP that is PO4 or DOP		**0.5**	**0.5**				
Fraction Remaining	100%			100%	**100%**		

Assumptions

DOC = BODu * C to O2 molecular weight ratio
DON = (TN - NH4) * .25
NO3 = (TN - NH4) * 0.75
DOP = 1/2 TP
PO4 = 1/2 TP

Parameters Used to Calculate Loads

Name	Value	Units	Notes
Starting Day	37257	days	Day 0 = 1/1/2002
Sample Day	15.5	days	Noon on the 15th of the month

Load Calculation Matrix (to get results in kg/day)

Multiply by Flow to get Daily Load?

Each constituent concentration is linearly related to the following 8 measurements (6 loads, 1 conc. (DO), 1 flow) Each column gives weighting factors for each constituent

	Bc	Bd	Bg	RPOC	LPOC	DOC	RPOP	LPOP	DOP	PTO4	RPON	LPON	DON	NH4	NO3	SU	SA	COD	DO	TAM	FCB	Flow
Multiply by Flow to get Daily Load?	no	no	no	no	no	no	yes	yes	yes	yes	yes	yes	yes	yes	yes	no	no	no	yes	no	no	no
00300 - DO, Oxygen, Dissolved, g/m3	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	3.79	0.00	0.00	0.00
00310 - BOD, 5-Day (20 Deg_ C), lb/day	0.00	0.00	0.00	0.00	0.00	**0.32**	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
00530 - Solids, Total Suspended, lb/day	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
00600 - Nitrogen, Total (as N), g/m3	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	**0.1315**	**-0.1315**	0.00	0.00	**0.95**	0.00	**2.84**	0.00	0.00	0.00	0.00	0.00	0.00	0.00
00610 - Nitrogen, Ammonia Total (as N), g/m3	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	**-0.1315**	**0.1315**	0.00	0.00	**-0.95**	**3.79**	**-2.84**	0.00	0.00	0.00	0.00	0.00	0.00	0.00
00665 - Phosphorus, Total (as P), g/m3	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	**3.79**	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
50050 - Flow, in conduit or thru treatment plant, mg/D	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	1.00

Parameters Used to Get Values Above (each coefficient is the product of the numbers below it)

Kg to lb ratio	0.4536						
BOD5 to BODU scaleup	1.9						
C to O2 molecular weight ratio (12/32)	0.3745						
kilograms per gram		0.001	0.001	0.001	0.001	0.001	0.001
m3 per million gallon		3786.2	3786.2	3786.2	3786.2	3786.2	3786.2
fraction of non-ammonia nitrogen that is DON		**0.25**	**0.25**	**0.25**			
fraction of non-ammonia nitrogen that is NOX						**0.75**	
P to N mass ratio		**0.1389**	**0.1389**				
Fraction Remaining	100%			100%	**100%**		

Assumptions

DOC = BODu * C to O2 molecular weight ratio
DON = (TN - NH4) * .25
NO3 = (TN - NH4) * 0.75
DOP = DON * (Redfield P to N mass ratio)
PO4T = TP - DOP

Parameters Used to Calculate Loads

Name	Value	Units	Notes
Starting Day	37257	days	Day 0 = 1/1/2002
Sample Day	15.5	days	Noon on the 15th of the month

Load Calculation Matrix (to get results in kg/day)

Multiply by Flow to get Daily Load?

Each constituent concentration is linearly related to the following 8 measurements (6 loads, 1 conc. (DO), 1 flow) Each column gives weighting factors for each constituent

	Bc	Bd	Bg	RPOC	LPOC	DOC	RPOP	LPOP	DOP	PTO4	RPON	LPON	DON	NH4	NO3	SU	SA	COD	DO	TAM	FCB	Flow
	no	no	no	no	no	no	yes	yes	yes	yes	yes	yes	yes	yes	yes	no	no	no	yes	no	no	no
00300 - DO, Oxygen, Dissolved, g/m3	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	3.79	0.00	0.00	0.00
00310 - BOD, 5-Day (20 Deg_ C), lb/day	0.00	0.00	0.00	0.00	0.00	0.32	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
00530 - Solids, Total Suspended, lb/day	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
00600 - Nitrogen, Total (as N), g/m3	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.1315	-0.1315	0.00	0.00	0.95	0.00	2.84	0.00	0.00	0.00	0.00	0.00	0.00	0.00
00610 - Nitrogen, Ammonia Total (as N), g/m3	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	-0.1315	0.1315	0.00	0.00	-0.95	3.79	-2.84	0.00	0.00	0.00	0.00	0.00	0.00	0.00
00665 - Phosphorus, Total (as P), g/m3	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	3.79	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
50050 - Flow, in conduit or thru treatment plant, mg/D	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	1.00

Parameters Used to Get Values Above (each coefficient is the product of the numbers below it)

Kg to lb ratio	0.4536						
BOD5 to BODU scaleup	1.9						
C to O2 molecular weight ratio (12/32)	0.3745						
kilograms per gram		0.001	0.001	0.001	0.001	0.001	0.001
m3 per million gallon		3786.2	3786.2	3786.2	3786.2	3786.2	3786.2
fraction of non-ammonia nitrogen that is DON		0.25	0.25	0.25			
fraction of non-ammonia nitrogen that is NOX						0.75	
P to N mass ratio		0.1389	0.1389				
Fraction Remaining	100%			100%	100%		

Assumptions

DOC = BODu * C to O2 molecular weight ratio

DON = (TN - NH4) * .25

NO3 = (TN - NH4) * 0.75

DOP = DON * (Redfield P to N mass ratio)

PO4T = TP - DOP

Parameters Used to Calculate Loads

Name	Value	Units	Notes
Starting Day	37257	days	Day 0 = 1/1/2002
Sample Day	15.5	days	Noon on the 15th of the month

Load Calculation Matrix (to get results in kg/day)

Multiply by Flow to get Daily Load?

Each constituent concentration is linearly related to the following 8 measurements (6 loads, 1 conc. (DO), 1 flow) Each column gives weighting factors for each constituent

	Bc	Bd	Bg	RPOC	LPOC	DOC	RPOP	LPOP	DOP	PTO4	RPON	LPON	DON	NH4	NO3	SU	SA	COD	DO	TAM	FCB	Flow
Multiply by Flow to get Daily Load?	no	no	no	no	no	yes	yes	yes	yes	yes	yes	yes	yes	yes	yes	no	no	no	yes	no	no	no
00300 - DO, Oxygen, Dissolved, g/m3	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	3.79	0.00	0.00	0.00
00310 - BOD, 5-Day (20 Deg_ C), mg/L	0.00	0.00	0.00	0.00	0.00	**2.69**	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
00530 - Solids, Total Suspended, g/m3	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
00600 - Nitrogen, Total (as N), g/m3	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	**0.1315**	**-0.1315**	0.00	0.00	**0.95**	0.00	**2.84**	0.00	0.00	0.00	0.00	0.00	0.00	0.00
00610 - Nitrogen, Ammonia Total (as N), g/m3	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	**-0.1315**	**0.1315**	0.00	0.00	**-0.95**	**3.79**	**-2.84**	0.00	0.00	0.00	0.00	0.00	0.00	0.00
00665 - Phosphorus, Total (as P), g/m3	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	**3.79**	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
50050 - Flow, in conduit or thru treatment plant, mg/D	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	1.00

Parameters Used to Get Values Above (each coefficient is the product of the numbers below it)

Kg to lb ratio							
BOD5 to BODU scaleup	1.9						
C to O2 molecular weight ratio (12/32)	0.3745						
kilograms per gram	0.001	0.001	0.001	0.001	0.001	0.001	0.001
m3 per million gallon	3786.2	3786.2	3786.2	3786.2	3786.2	3786.2	3786.2
fraction of non-ammonia nitrogen that is DON		**0.25**	**0.25**	**0.25**			
fraction of non-ammonia nitrogen that is NOX						**0.75**	
P to N mass ratio		**0.1389**	**0.1389**				
Fraction Remaining	100%			100%	**100%**		

Assumptions

DOC = BODu * C to O2 molecular weight ratio
DON = (TN - NH4) * .25
NO3 = (TN - NH4) * 0.75
DOP = DON * (Redfield P to N mass ratio)
PO4T = TP - DOP

Parameters Used to Calculate Loads

Name	Value	Units	Notes
Starting Day	37257	days	Day 0 = 1/1/2002
Sample Day	15.5	days	Noon on the 15th of the month

Load Calculation Matrix (to get results in kg/day)

Multiply by Flow to get Daily Load?

Each constituent concentration is linearly related to the following 8 measurements (6 loads, 1 conc. (DO), 1 flow) Each column gives weighting factors for each constituent

	Bc	Bd	Bg	RPOC	LPOC	DOC	RPOP	LPOP	DOP	PTO4	RPON	LPON	DON	NH4	NO3	SU	SA	COD	DO	TAM	FCB	Flow
	no	no	no	no	no	yes	yes	yes	yes	yes	yes	yes	yes	yes	yes	no	no	no	yes	no	no	no
00300 - DO, Oxygen, Dissolved, g/m3	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	3.79	0.00	0.00	0.00
00310 - BOD, 5-Day (20 Deg_ C), mg/L	0.00	0.00	0.00	0.00	0.00	**2.69**	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
00530 - Solids, Total Suspended, g/m3	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
00600 - Nitrogen, Total (as N), g/m3	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	**0.1315**	**-0.1315**	0.00	0.00	**0.95**	0.00	**2.84**	0.00	0.00	0.00	0.00	0.00	0.00	0.00
00610 - Nitrogen, Ammonia Total (as N), g/m3	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	**-0.1315**	**0.1315**	0.00	0.00	**-0.95**	**3.79**	**-2.84**	0.00	0.00	0.00	0.00	0.00	0.00	0.00
00665 - Phosphorus, Total (as P), g/m3	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	**3.79**	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
50050 - Flow, in conduit or thru treatment plant, mg/D	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	1.00

Parameters Used to Get Values Above (each coefficient is the product of the numbers below it)

Kg to lb ratio							
BOD5 to BODU scaleup	1.9						
C to O2 molecular weight ratio (12/32)	0.3745						
kilograms per gram	0.001	0.001	0.001	0.001	0.001	0.001	0.001
m3 per million gallon	3786.2	3786.2	3786.2	3786.2	3786.2	3786.2	3786.2
fraction of non-ammonia nitrogen that is DON		**0.25**	**0.25**	**0.25**			
fraction of non-ammonia nitrogen that is NOX						**0.75**	
P to N mass ratio		**0.1389**	**0.1389**				
Fraction Remaining	100%			100%	**100%**		

Assumptions

DOC = BODu * C to O2 molecular weight ratio
DON = (TN - NH4) * .25
NO3 = (TN - NH4) * 0.75
DOP = DON * (Redfield P to N mass ratio)
PO4T = TP - DOP

Parameters Used to Calculate Loads

Name	Value	Units	Notes
Starting Day	37257	days	Day 0 = 1/1/2002
Sample Day	15.5	days	Noon on the 15th of the month

Load Calculation Matrix (to get results in kg/day)

Multiply by Flow to get Daily Load?

Each constituent concentration is linearly related to the following 8 measurements (6 loads, 1 conc. (DO), 1 flow) Each column gives weighting factors for each constituent

	Bc	Bd	Bg	RPOC	LPOC	DOC	RPOP	LPOP	DOP	PTO4	RPON	LPON	DON	NH4	NO3	SU	SA	COD	DO	TAM	FCB	Flow
Multiply by Flow to get Daily Load?	no	no	no	no	no	no	yes	yes	yes	yes	yes	yes	yes	yes	yes	no	no	no	yes	no	no	no
00300 - DO, Oxygen, Dissolved, g/m3	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	3.79	0.00	0.00	0.00
00310 - BOD, 5-Day (20 Deg_ C), lb/day	0.00	0.00	0.00	0.00	0.00	0.32	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
00530 - Solids, Total Suspended, g/m3	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
00600 - Nitrogen, Total (as N), g/m3	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.1315	-0.1315	0.00	0.00	0.95	0.00	2.84	0.00	0.00	0.00	0.00	0.00	0.00	0.00
00610 - Nitrogen, Ammonia Total (as N), g/m3	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	-0.1315	0.1315	0.00	0.00	-0.95	3.79	-2.84	0.00	0.00	0.00	0.00	0.00	0.00	0.00
00665 - Phosphorus, Total (as P), g/m3	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	3.79	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
50050 - Flow, in conduit or thru treatment plant, mg/D	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	1.00

Parameters Used to Get Values Above (each coefficient is the product of the numbers below it)

Kg to lb ratio	0.4536						
BOD5 to BODU scaleup	1.9						
C to O2 molecular weight ratio (12/32)	0.3745						
kilograms per gram		0.001	0.001	0.001	0.001	0.001	0.001
m3 per million gallon		3786.2	3786.2	3786.2	3786.2	3786.2	3786.2
fraction of non-ammonia nitrogen that is DON		0.25	0.25	0.25			
fraction of non-ammonia nitrogen that is NOX						0.75	
P to N mass ratio		0.1389	0.1389				
Fraction Remaining	100%			100%	100%		

Assumptions

DOC = BODu * C to O2 molecular weight ratio
DON = (TN - NH4) * .25
NO3 = (TN - NH4) * 0.75
DOP = DON * (Redfield P to N mass ratio)
PO4T = TP - DOP

Parameters Used to Calculate Loads

Name	Value	Units	Notes	
Starting Day	37257	days	Day 0 = 1/1/2002	1
Sample Day	15.5	days	Noon on the 15th of the month	

Load Calculation Matrix (to get results in kg/day)

Multiply by Flow to get Daily Load?

Each constituent concentration is linearly related to the following 8 measurements (6 loads, 1 conc. (DO), 1 flow) Each column gives weighting factors for each constituent

	Bc	Bd	Bg	RPOC	LPOC	DOC	RPOP	LPOP	DOP	PTO4	RPON	LPON	DON	NH4	NO3	SU	SA	COD	DO	TAM	FCB	Flow
Multiply by Flow to get Daily Load?	no	no	no	no	no	yes	yes	yes	yes	yes	yes	yes	yes	yes	yes	no	no	no	yes	no	no	no
00300 - DO, Oxygen, Dissolved, g/m3	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	3.8E+00	0.0E+00	0.0E+00	0.0E+00
00310 - BOD, 5-Day (20 Deg_ C), g/m3	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	**2.7E+00**	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00
00530 - Solids, Total Suspended, g/m3	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00
00600 - Nitrogen, Total (as N), g/m3	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	**1.3E-01**	**-1.3E-01**	0.0E+00	0.0E+00	**9.5E-01**	0.0E+00	**2.8E+00**	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00
00610 - Nitrogen, Ammonia Total (as N), g/m3	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	**-1.3E-01**	**1.3E-01**	0.0E+00	0.0E+00	**-9.5E-01**	**3.8E+00**	**-2.8E+00**	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00
00665 - Phosphorus, Total (as P), g/m3	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	**3.8E+00**	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00
50050 - Flow, in conduit or thru treatment plant, mg/D	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	1.0E+00

Parameters Used to Get Values Above (each coefficient is the product of the numbers below it)

	DOC	DOP	PTO4	DON	NH4	NO3	DO
Kg to lb ratio							
BOD5 to BODU scaleup	1.9						
C to O2 molecular weight ratio (12/32)	0.3745						
kilograms per gram	0.001	0.001	0.001	0.001	0.001	0.001	0.001
m3 per million gallon	3786.2	3786.2	3786.2	3786.2	3786.2	3786.18	3786.2
fraction of non-ammonia nitrogen that is DON		**0.25**	**0.25**	**0.25**			
fraction of non-ammonia nitrogen that is NOX						**0.75**	
P to N mass ratio		**0.1389**	**0.1389**				
Fraction Remaining	100%			100%	**100%**		

Assumptions

DOC = BODu * C to O2 molecular weight ratio

DON = (TN - NH4) * .25

NO3 = (TN - NH4) * 0.75

DOP = DON * (Redfield P to N mass ratio)

PO4T = TP - DOP

Parameters Used to Calculate Loads

Name	Value	Units	Notes
Starting Day	37257	days	Day 0 = 1/1/2002
Sample Day	15.5	days	Noon on the 15th of the month

1

Load Calculation Matrix (to get results in kg/day)

Multiply by Flow to get Daily Load?

Each constituent concentration is linearly related to the following 8 measurements (6 loads, 1 conc. (DO), 1 flow) Each column gives weighting factors for each constituent

	Bc	Bd	Bg	RPOC	LPOC	DOC	RPOP	LPOP	DOP	PTO4	RPON	LPON	DON	NH4	NO3	SU	SA	COD	DO	TAM	FCB	Flow
Multiply by Flow to get Daily Load?	no	no	no	no	no	yes	yes	yes	yes	yes	yes	yes	no	no	no	no	no	no	yes	no	no	no
00300 - DO, Oxygen, Dissolved, g/m3	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	3.8E+00	0.0E+00	0.0E+00	0.0E+00
00310 - BOD, 5-Day (20 Deg_ C), g/m3	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	2.7E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00
00530 - Solids, Total Suspended, lb/day	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00
00600 - Nitrogen, Total (as N), lb/day	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	1.3E-01	-1.3E-01	0.0E+00	0.0E+00	1.1E-01	0.0E+00	3.4E-01	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00
00610 - Nitrogen, Ammonia Total (as N), lb/day	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	-1.3E-01	1.3E-01	0.0E+00	0.0E+00	-1.1E-01	4.5E-01	-3.4E-01	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00
00665 - Phosphorus, Total (as P), g/m3	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	3.8E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00
50050 - Flow, in conduit or thru treatment plant, mg/D	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	1.0E+00

Parameters Used to Get Values Above (each coefficient is the product of the numbers below it)

	DOC	DOP	PTO4	DON	NH4	NO3	DO
Kg to lb ratio				0.4536	0.4536	0.4536	
BOD5 to BODU scaleup	1.9						
C to O2 molecular weight ratio (12/32)	0.3745						
kilograms per gram	0.001	0.001	0.001				0.001
m3 per million gallon	3786.2	3786.2	3786.2				3786.2
fraction of non-ammonia nitrogen that is DON		0.25	0.25	0.25			
fraction of non-ammonia nitrogen that is NOX						0.75	
P to N mass ratio		0.1389	0.1389				
Fraction Remaining	100%	100%	100%	100%	100%	100%	100%

Assumptions

DOC = BODu * C to O2 molecular weight ratio
DON = (TN - NH4) * .25
NO3 = (TN - NH4) * 0.75
DOP = DON * (Redfield P to N mass ratio)
PO4T = TP - DOP

Parameters Used to Calculate Loads

Name	Value	Units	Notes	
Starting Day	37257	days	Day 0 = 1/1/2002	1
Sample Day	15.5	days	Noon on the 15th of the month	

Load Calculation Matrix (to get results in kg/day)

Multiply by Flow to get Daily Load?

Each constituent concentration is linearly related to the following 8 measurements (6 loads, 1 conc. (DO), 1 flow) Each column gives weighting factors for each constituent

	Bc	Bd	Bg	RPOC	LPOC	DOC	RPOP	LPOP	DOP	PTO4	RPON	LPON	DON	NH4	NO3	SU	SA	COD	DO	TAM	FCB	Flow
Multiply by Flow to get Daily Load?	no	no	no	no	no	yes	yes	yes	yes	yes	yes	yes	yes	yes	yes	no	no	no	yes	no	no	no
00300 - DO, Oxygen, Dissolved, g/m3	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	3.8E+00	0.0E+00	0.0E+00	0.0E+00
00310 - BOD, 5-Day (20 Deg_ C), g/m3	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	**2.7E+00**	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00
00530 - Solids, Total Suspended, g/m3	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00
00600 - Nitrogen, Total (as N), g/m3	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	**1.3E-01**	**-1.3E-01**	0.0E+00	0.0E+00	**9.5E-01**	0.0E+00	**2.8E+00**	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00
00610 - Nitrogen, Ammonia Total (as N), g/m3	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	**-1.3E-01**	**1.3E-01**	0.0E+00	0.0E+00	**-9.5E-01**	**3.8E+00**	**-2.8E+00**	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00
00665 - Phosphorus, Total (as P), g/m3	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	**3.8E+00**	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00
50050 - Flow, in conduit or thru treatment plant, mg/D	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	1.0E+00

Parameters Used to Get Values Above (each coefficient is the product of the numbers below it)

	DOC	DOP	PTO4	DON	NH4	NO3	DO
Kg to lb ratio							
BOD5 to BODU scaleup	1.9						
C to O2 molecular weight ratio (12/32)	0.3745						
kilograms per gram	0.001	0.001	0.001	0.001	0.001	0.001	0.001
m3 per million gallon	3786.2	3786.2	3786.2	3786.2	3786.2	3786.18	3786.2
fraction of non-ammonia nitrogen that is DON		**0.25**	**0.25**	**0.25**			
fraction of non-ammonia nitrogen that is NOX						**0.75**	
P to N mass ratio		**0.1389**	**0.1389**				
Fraction Remaining	100%			100%	**100%**		

Assumptions

DOC = BODu * C to O2 molecular weight ratio

DON = (TN - NH4) * .25

NO3 = (TN - NH4) * 0.75

DOP = DON * (Redfield P to N mass ratio)

PO4T = TP - DOP

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C cell.inp file, i columns and j rows, for Cape Fear River
C              1         2         3         4
C    12345678901234567890123456789012345678901234567890123456
C
 99  00000000000000000000000000000000000000000000000000000000
 98  00000000000000000000000000000000000000000000000000099990
 97  00000000000000000000000000000000000000000000000000095590
 96  00000000000000000000000000000000000000000000000000095590
 95  00000000000000000000000000000000000000000000000000095590
 94  00000000000000000000000000000000000000000000000000095590
 93  00000000000000000000000000000000000000000000000000095590
 92  00000000000000000000000000000000000000000000000000095590
 91  00000000000000000000000000000000000000000000000000095590
 90  00000000000000000000000000000000000000000000000000095590
 89  00000000000000000000000000000000000000000000000000095590
 88  00000000000000000000000000000000000000000000000000095590
 87  00000000000000000000000000000000000000000000000000095590
 86  00999900000000000000000000000000000000000000000000095590
 85  00955900000000000000000000000000000000000000000000095590
 84  00955900000000000000000000000000000000000000000000095590
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 82  00955900000000000009999990000000000000000000000000095590
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C dxdy.inp file, in free format across columns
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ZROUGH  VEG TYPE
C
     30    5    528.85    580.93      4.50     -4.20      0.015
     31    5    498.24    594.57      7.50     -7.20      0.015
     32    5    518.20    604.75     10.50    -10.20      0.015
     33    5    592.94    615.96     13.30    -13.00      0.015
     30    6    492.08    506.28      4.50     -4.20      0.015
     31    6    478.97    511.64      7.50     -7.20      0.015
     32    6    482.89    517.41     13.30    -13.00      0.015
     33    6    503.19    529.03     13.30    -13.00      0.015
      4    7    150.00    688.47      7.00     -6.70      0.015
      5    7   1000.00    688.47      0.30      0.00      0.035
     24    7    343.40    343.39      2.50     -2.20      0.015
     25    7    301.41    355.30      2.50     -2.20      0.015
     26    7    377.25    350.60      2.50     -2.20      0.015
     30    7    471.21    457.79      7.50     -7.20      0.015
     31    7    456.40    451.89     10.50    -10.20      0.015
     32    7    448.45    447.44     13.30    -13.00      0.015
     33    7    455.71    423.62     13.30    -13.00      0.015
      4    8    150.00    706.12      7.00     -6.70      0.015
      5    8   1000.00    706.12      0.30      0.00      0.035
     24    8    315.90    376.14      2.50     -2.20      0.015
     25    8    316.12    358.25      2.50     -2.20      0.015
     26    8    361.08    363.58      2.50     -2.20      0.015
     27    8    403.12    381.77      2.50     -2.20      0.015
     30    8    471.40    379.09     10.50    -10.20      0.015
     31    8    440.39    409.90     10.50    -10.20      0.015
     32    8    420.66    423.09     13.50    -13.20      0.015
     33    8    387.87    430.16     10.50    -10.20      0.015
      4    9    150.00    637.80      7.00     -6.70      0.015
      5    9   1000.00    637.80      0.30      0.00      0.035
     24    9    301.27    332.29      2.50     -2.20      0.015
     25    9    299.34    347.79      2.96     -2.66      0.015
     26    9    367.67    354.97     11.50    -11.20      0.015
     27    9    416.54    350.16     11.85    -11.55      0.015
     28    9    426.36    362.20     12.04    -11.74      0.015
     29    9    415.95    376.67     12.31    -12.01      0.015
     30    9    458.98    378.65     12.50    -12.20      0.015
     31    9    425.34    389.37     13.50    -13.20      0.015
     32    9    405.59    400.23     13.50    -13.20      0.015
     33    9    384.84    399.03     10.50    -10.20      0.015
      4   10    150.00    481.44      7.00     -6.70      0.015
      5   10    514.08    481.44      0.30      0.00      0.035
     23   10    308.45    383.19      7.50     -7.20      0.015
     24   10    272.89    400.25     11.50    -11.20      0.015
     25   10    232.70    381.49     12.76    -12.46      0.015
     26   10    402.96    339.18     11.50    -11.20      0.015
     27   10    424.18    320.70      6.44     -6.14      0.015
     28   10    406.80    333.02      6.81     -6.51      0.015
     29   10    450.81    336.48      7.10     -6.80      0.015
     30   10    435.38    358.01      8.71     -8.41      0.015
     31   10    404.65    369.54      6.38     -6.08      0.015
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 32   10    396.96    388.02      4.83     -4.53       0.015
 33   10    401.39    402.40      4.00     -3.70       0.015
  3   11    102.96    519.71      4.00     -3.70       0.015
  4   11    102.96    519.71      6.50     -6.20       0.015
  5   11    952.46    519.71      0.30      0.00       0.035
 23   11    308.45    565.33      6.65     -6.35       0.015
 24   11    224.53    549.10     12.62    -12.32       0.015
 25   11    231.61    553.22      7.84     -7.54       0.015
 26   11    389.53    547.83      3.08     -2.78       0.015
 27   11    406.39    518.22      3.50     -3.20       0.015
 28   11    425.67    506.80      3.50     -3.20       0.015
 29   11    444.94    495.38      3.50     -3.20       0.015
 30   11    422.60    496.68      3.50     -3.20       0.015
 31   11    397.62    507.27      3.04     -2.74       0.015
 32   11    395.98    499.86      3.00     -2.70       0.015
 33   11    396.09    488.63      3.00     -2.70       0.015
  4   12    150.75    524.62      6.50     -6.20       0.015
  5   12    943.54    524.62      0.30      0.00       0.035
 23   12    273.34    598.81      9.55     -9.25       0.015
 24   12    189.10    603.06     12.50    -12.20       0.015
 25   12    293.87    594.69      4.29     -3.99       0.015
 27   12    371.39    591.58      3.00     -2.70       0.015
 28   12    390.67    580.90      3.00     -2.70       0.015
 29   12    409.95    570.22      3.00     -2.70       0.015
 30   12    408.75    562.23      3.00     -2.70       0.015
 31   12    400.95    556.47      2.67     -2.37       0.015
 32   12    400.20    556.03      2.50     -2.20       0.015
 33   12    402.23    563.44      2.50     -2.20       0.015
  4   13    141.42    672.68      6.50     -6.20       0.015
  5   13    735.86    672.68      0.30      0.00       0.035
 23   13    252.41    613.21      6.29     -5.99       0.015
 24   13    189.10    623.44     12.50    -12.20       0.015
 25   13    304.58    623.26      5.18     -4.88       0.015
 26   13    345.10    606.82      2.50     -2.20       0.015
 27   13    345.10    606.82      2.50     -2.20       0.015
 28   13    365.60    605.64      2.50     -2.20       0.015
 29   13    351.93    606.43      2.50     -2.20       0.015
 30   13    358.77    606.03      2.50     -2.20       0.015
 31   13    393.13    597.25      2.50     -2.20       0.015
 32   13    395.63    597.47      2.74     -2.44       0.015
 33   13    397.70    603.03      2.00     -1.70       0.015
  4   14    185.00    600.19      6.98     -6.68       0.015
  5   14    824.74    600.19      0.30      0.00       0.035
 23   14    252.41    585.68      3.63     -3.33       0.015
 24   14    189.10    575.05     12.54    -12.24       0.015
 25   14    292.16    568.85      6.93     -6.63       0.015
 26   14    305.24    580.07      2.00     -1.70       0.015
 27   14    323.03    593.24      2.00     -1.70       0.015
 28   14    341.53    604.50      2.00     -1.70       0.015
 29   14    357.97    612.25      1.90     -1.60       0.015
 30   14    370.67    616.44      1.82     -1.52       0.015
 31   14    379.72    618.02      2.00     -1.70       0.015
 32   14    386.09    617.78      2.11     -1.81       0.015
 33   14    389.81    613.75      1.50     -1.20       0.015
 34   14    398.29    590.09      1.71     -1.41       0.015
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   4   15     70.71    514.78      6.98     -6.68      0.015
   5   15    961.58    514.78      0.30      0.00      0.035
  23   15    232.72    518.62      3.48     -3.18      0.015
  24   15    203.73    519.01     12.50    -12.20      0.015
  25   15    267.28    527.85      7.38     -7.08      0.015
  26   15    287.84    567.41      1.74     -1.44      0.015
  27   15    307.36    591.25      1.70     -1.40      0.015
  28   15    325.26    606.47      1.70     -1.40      0.015
  29   15    341.16    616.62      3.00     -2.70      0.015
  30   15    354.76    623.64      2.00     -1.70      0.015
  31   15    366.10    628.97      1.50     -1.20      0.015
  32   15    375.52    633.99      1.50     -1.20      0.015
  34   15    391.31    651.94      1.50     -1.20      0.015
  35   15    362.71    665.69      1.50     -1.20      0.015
  36   15    345.64    649.55      1.50     -1.20      0.015
  37   15    410.70    617.62      1.50     -1.20      0.015
  43   15    175.40    625.58      9.50     -9.20      0.015
   4   16    111.80    585.23      7.31     -7.01      0.015
   5   16    845.82    585.23      0.30      0.00      0.035
  23   16    213.90    573.56      4.69     -4.39      0.015
  24   16    181.95    606.08     12.50    -12.20      0.015
  25   16    265.58    631.76      7.57     -7.27      0.015
  26   16    285.37    618.71      2.33     -2.03      0.015
  27   16    301.78    614.69      1.70     -1.40      0.015
  28   16    316.24    615.38      1.74     -1.44      0.015
  29   16    316.24    615.38      1.74     -1.44      0.015
  31   16    352.89    627.91      1.50     -1.20      0.015
  32   16    363.04    634.16      1.50     -1.20      0.015
  35   16    373.09    661.76      1.50     -1.20      0.015
  36   16    372.83    678.98      1.50     -1.20      0.015
  37   16    409.99    701.91      1.50     -1.20      0.015
  42   16    173.30    664.97      2.47     -2.17      0.015
  43   16    178.85    690.47      8.50     -8.20      0.015
  44   16   1200.00    690.47      0.30      0.00      0.035
   4   17    152.40    619.05      6.00     -5.70      0.015
   5   17   1200.00    619.05      0.30      0.00      0.035
  22   17    277.60    558.33      1.50     -1.20      0.015
  23   17    208.15    576.02      5.38     -5.08      0.015
  24   17    142.13    569.94     12.71    -12.41      0.015
  25   17    283.37    576.10      7.21     -6.91      0.015
  26   17    290.40    586.29      2.20     -1.90      0.015
  27   17    299.13    593.15      2.20     -1.90      0.015
  28   17    308.69    598.64      1.50     -1.20      0.015
  29   17    318.78    603.66      1.50     -1.20      0.015
  31   17    340.33    613.76      1.50     -1.20      0.015
  32   17    351.86    619.24      1.93     -1.63      0.015
  33   17    363.60    625.06      1.72     -1.42      0.015
  34   17    374.06    631.04      1.50     -1.20      0.015
  35   17    379.64    639.75      1.50     -1.20      0.015
  36   17    357.64    645.77      1.50     -1.20      0.015
  42   17    163.91    628.06      6.45     -6.15      0.015
  43   17    175.85    615.84      8.50     -8.20      0.015
  44   17   1200.00    615.84      0.30      0.00      0.035
   4   18    103.08    689.66      5.00     -4.70      0.015
   5   18   1200.00    689.66      0.30      0.00      0.035
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22   18    256.33    572.13      1.50     -1.20      0.015
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24   18    142.13    569.94     12.50    -12.20      0.015
25   18    294.34    571.37      6.83     -6.53      0.015
26   18    292.72    574.87      3.07     -2.77      0.015
27   18    295.64    579.22      2.87     -2.57      0.015
28   18    301.17    583.82      1.99     -1.69      0.015
29   18    308.49    588.38      1.50     -1.20      0.015
30   18    317.43    592.80      1.50     -1.20      0.015
31   18    328.33    597.05      1.50     -1.20      0.015
32   18    342.06    600.95      1.50     -1.20      0.015
34   18    382.56    595.98      1.50     -1.20      0.015
35   18    369.92    536.08      1.50     -1.20      0.015
42   18    147.00    548.72      4.15     -3.85      0.015
43   18    181.02    574.22      8.50     -8.20      0.015
44   18   1100.00    574.22      0.30      0.00      0.035
 4   19    143.96    561.89      4.00     -3.70      0.015
 5   19   1100.00    561.89      0.30      0.00      0.035
20   19   1200.00    606.11      0.30      0.00      0.035
21   19    268.74    591.33      1.50     -1.20      0.015
22   19    242.74    575.98      1.50     -1.20      0.015
23   19    214.36    572.58      7.41     -7.11      0.015
24   19    160.70    587.76     13.03    -12.73      0.015
25   19    290.92    595.87      5.56     -5.26      0.015
26   19    288.52    582.50      1.69     -1.39      0.015
27   19    289.64    578.92      3.44     -3.14      0.015
28   19    292.95    579.41      2.73     -2.43      0.015
29   19    298.09    581.74      1.74     -1.44      0.015
30   19    305.21    585.07      1.55     -1.25      0.015
31   19    315.05    589.42      1.60     -1.30      0.015
32   19    329.66    596.24      1.50     -1.20      0.015
33   19    355.08    611.71      1.50     -1.20      0.015
34   19    391.49    599.21      2.27     -1.97      0.015
42   19    160.82    683.53      2.49     -2.19      0.015
43   19    187.33    706.38      8.50     -8.20      0.015
44   19    700.76    706.38      0.30      0.00      0.035
 4   20    125.00    497.02      4.00     -3.70      0.015
 5   20    497.97    497.02      0.30      0.00      0.035
19   20    522.22    544.85      0.30      0.00      0.035
20   20    520.46    563.13      0.30      0.00      0.035
21   20    247.16    578.30      1.50     -1.20      0.015
22   20    232.22    589.15      1.50     -1.20      0.015
23   20    217.55    599.84      6.54     -6.24      0.015
24   20    177.84    570.44     12.50    -12.20      0.015
25   20    272.68    548.08      5.51     -5.21      0.015
26   20    278.30    566.47      1.50     -1.20      0.015
27   20    280.92    573.68      1.97     -1.67      0.015
28   20    283.23    577.77      3.64     -3.34      0.015
29   20    286.59    581.73      2.37     -2.07      0.015
30   20    291.66    586.42      1.73     -1.43      0.015
31   20    298.83    591.48      1.52     -1.22      0.015
32   20    308.33    594.99      1.50     -1.20      0.015
33   20    321.25    592.33      1.50     -1.20      0.015
43   20    179.96    493.03      7.50     -7.20      0.015
44   20    980.00    493.03      0.30      0.00      0.035
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   4    21     163.48     636.97       4.00      -3.70        0.015
   5    21     777.12     636.97       0.30       0.00        0.035
  18    21     543.88     559.19       0.30       0.00        0.035
  19    21     924.48     545.94       0.30       0.00        0.035
  21    21     238.38     558.01       1.50      -1.20        0.015
  22    21     226.86     564.47       1.50      -1.20        0.015
  23    21     214.85     568.55       5.19      -4.89        0.015
  24    21     161.25     588.38      12.50     -12.20        0.015
  25    21     279.99     595.49       6.85      -6.55        0.015
  26    21     274.83     580.73       3.94      -3.64        0.015
  27    21     272.02     577.38       2.00      -1.70        0.015
  28    21     270.92     579.52       2.75      -2.45        0.015
  29    21     271.63     585.15       2.84      -2.54        0.015
  30    21     274.38     594.03       1.50      -1.20        0.015
  31    21     279.21     607.06       1.50      -1.20        0.015
  32    21     285.25     625.55       1.50      -1.20        0.015
  33    21     307.14     640.88       1.50      -1.20        0.015
  43    21     159.14     686.53       6.50      -6.20        0.015
  44    21    1200.00     686.53       0.30       0.00        0.035
   4    22     125.00     548.29       4.00      -3.70        0.015
   5    22     902.80     548.29       0.30       0.00        0.035
  17    22     482.46     505.75       0.30       0.00        0.035
  18    22     482.46     505.75       0.30       0.00        0.035
  20    22     482.54     516.75       0.30       0.00        0.035
  21    22     235.11     523.47       2.04      -1.74        0.015
  22    22     227.95     530.67       1.50      -1.20        0.015
  23    22     218.67     534.34       3.13      -2.83        0.015
  24    22     142.84     534.77      12.50     -12.20        0.015
  25    22     287.61     540.45       9.28      -8.98        0.015
  26    22     268.32     552.92       5.09      -4.79        0.015
  27    22     259.86     565.91       2.45      -2.15        0.015
  28    22     255.71     577.68       2.46      -2.16        0.015
  29    22     253.83     587.67       2.34      -2.04        0.015
  30    22     254.30     596.42       1.56      -1.26        0.015
  31    22     259.21     606.91       1.50      -1.20        0.015
  32    22     267.68     615.01       1.50      -1.20        0.015
  43    22     133.14     474.05       5.50      -5.20        0.015
  44    22     900.00     474.05       0.30       0.00        0.035
   4    23     145.77     637.38       4.00      -3.70        0.015
   5    23     776.62     637.38       0.30       0.00        0.035
  17    23     485.30     419.43       0.30       0.00        0.035
  21    23     333.07     467.21       1.50      -1.20        0.015
  22    23     236.64     486.00       1.50      -1.20        0.015
  23    23     250.57     515.23       1.96      -1.66        0.015
  24    23     142.84     534.77      12.50     -12.20        0.015
  25    23     254.17     543.71      10.15      -9.85        0.015
  26    23     248.18     565.59       5.56      -5.26        0.015
  27    23     245.71     589.65       2.42      -2.12        0.015
  28    23     243.18     611.71       2.46      -2.16        0.015
  29    23     238.70     629.28       1.90      -1.60        0.015
  30    23     228.74     627.96       1.50      -1.20        0.015
  31    23     236.34     639.74       1.50      -1.20        0.015
  32    23     290.26     652.64       1.50      -1.20        0.015
  43    23     160.08     656.22       4.50      -4.20        0.015
  44    23    1300.00     656.22       0.30       0.00        0.035
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  4   24    175.00    654.31     4.00    -3.70     0.015
  5   24   1000.00    654.31     0.30     0.00     0.035
 17   24    552.30    324.88     0.30     0.00     0.035
 21   24    329.94    434.94     1.50    -1.20     0.015
 23   24    255.88    468.59     1.56    -1.26     0.015
 24   24    160.70    490.37    12.50   -12.20     0.015
 25   24    216.28    532.57    11.08   -10.78     0.015
 26   24    229.52    582.31     5.39    -5.09     0.015
 27   24    238.30    621.92     3.02    -2.72     0.015
 28   24    243.31    654.04     2.01    -1.71     0.015
 29   24    244.31    677.03     1.50    -1.20     0.015
 43   24    201.56    638.85     4.00    -3.70     0.015
 44   24   1200.00    638.85     0.30     0.00     0.035
  4   25    206.16    667.08     4.00    -3.70     0.015
  5   25   1200.00    667.08     0.30     0.00     0.035
 17   25    546.10    363.99     0.30     0.00     0.035
 21   25    228.08    481.03     1.50    -1.20     0.015
 23   25    220.85    548.87     2.20    -1.90     0.015
 24   25    146.29    578.54    12.50   -12.20     0.015
 25   25    218.41    602.23    10.98   -10.68     0.015
 26   25    229.55    626.21     5.65    -5.35     0.015
 27   25    241.98    657.39     2.68    -2.38     0.015
 28   25    253.89    694.36     1.65    -1.35     0.015
 29   25    267.85    730.59     1.74    -1.44     0.015
 30   25    237.07    769.45     1.89    -1.59     0.015
 31   25    280.18    793.17     1.50    -1.20     0.015
 43   25    237.17    617.45     4.00    -3.70     0.015
 44   25    801.68    617.45     0.30     0.00     0.035
  4   26    201.56    627.00     4.00    -3.70     0.015
  5   26   1200.00    627.00     0.30     0.00     0.035
 17   26    800.00    442.85     0.30     0.00     0.035
 21   26    231.49    534.05     1.50    -1.20     0.015
 23   26    211.17    596.25     4.28    -3.98     0.015
 24   26    112.25    611.44    12.50   -12.20     0.015
 25   26    214.55    618.01    12.58   -12.28     0.015
 26   26    229.21    631.30     3.87    -3.57     0.015
 27   26    249.96    640.47     1.90    -1.60     0.015
 28   26    278.35    639.12     1.50    -1.20     0.015
 43   26    227.71    613.88     4.00    -3.70     0.015
 44   26   1200.00    613.88     0.30     0.00     0.035
  4   27    180.28    631.59     4.00    -3.70     0.015
  5   27   1200.00    631.59     0.30     0.00     0.035
 18   27    907.14    457.00     0.30     0.00     0.035
 19   27    504.02    485.41     0.30     0.00     0.035
 20   27    497.56    513.00     0.30     0.00     0.035
 21   27    244.65    543.95     1.50    -1.20     0.015
 22   27    221.05    564.90     1.77    -1.47     0.015
 23   27    210.12    573.31     7.07    -6.77     0.015
 24   27    127.57    608.89    12.50   -12.20     0.015
 25   27    196.57    649.51    10.84   -10.54     0.015
 26   27    227.48    664.59     2.33    -2.03     0.015
 27   27    260.00    677.77     1.66    -1.36     0.015
 28   27    300.82    699.04     1.50    -1.20     0.015
 29   27    369.52    732.80     1.50    -1.20     0.015
 43   27    196.47    693.18     4.00    -3.70     0.015
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44   27   1200.00    693.18      0.30      0.00      0.035
 4   28    180.28    758.22      4.00     -3.70      0.015
 5   28   1300.00    758.22      0.30      0.00      0.035
22   28    220.33    556.60      2.87     -2.57      0.015
23   28    201.66    595.76      9.07     -8.77      0.015
24   28    139.75    587.33     12.50    -12.20      0.015
25   28    236.87    573.35      9.32     -9.02      0.015
26   28    258.18    598.68      1.50     -1.20      0.015
27   28    287.31    619.34      1.50     -1.20      0.015
28   28    326.60    638.21      1.50     -1.20      0.015
29   28    382.93    655.65      1.50     -1.20      0.015
30   28    537.69    682.65      1.50     -1.20      0.015
43   28    222.99    690.015      4.00     -3.70      0.015
44   28   1200.00    690.015      0.30      0.00      0.035
 4   29    125.00    703.58      4.00     -3.70      0.015
 5   29   1300.00    703.58      0.30      0.00      0.035
21   29    237.07    616.81      2.51     -2.21      0.015
22   29    222.71    584.61      6.02     -5.72      0.015
23   29    212.54    566.87      8.25     -7.95      0.015
24   29    134.63    560.24     12.50    -12.20      0.015
25   29    300.91    558.19      7.62     -7.32      0.015
26   29    301.39    561.70      1.50     -1.20      0.015
27   29    320.51    573.01      1.50     -1.20      0.015
28   29    355.82    585.93      1.50     -1.20      0.015
29   29    412.04    596.97      1.50     -1.20      0.015
30   29    495.77    597.43      1.50     -1.20      0.015
31   29    364.42    592.89      1.50     -1.20      0.015
43   29    276.09    789.45      4.00     -3.70      0.015
44   29   1300.00    789.45      0.30      0.00      0.035
 4   30    191.64    580.28      4.00     -3.70      0.015
 5   30   1100.00    580.28      0.30      0.00      0.035
20   30    227.49    531.80      5.20     -4.90      0.015
21   30    225.31    519.01      7.46     -7.16      0.015
22   30    221.45    535.00      2.64     -2.34      0.015
23   30    217.91    522.32      3.81     -3.51      0.015
24   30    152.07    538.11     12.50    -12.20      0.015
25   30    322.64    570.13      6.90     -6.60      0.015
26   30    325.67    572.98      1.50     -1.20      0.015
27   30    340.06    571.48      1.50     -1.20      0.015
28   30    366.83    569.34      1.50     -1.20      0.015
29   30    412.52    563.71      1.50     -1.20      0.015
30   30    499.28    538.03      1.50     -1.20      0.015
43   30    302.08    575.54      4.00     -3.70      0.015
44   30   1100.00    575.54      0.30      0.00      0.035
 4   31    176.71    666.13      4.00     -3.70      0.015
 5   31   1300.00    666.13      0.30      0.00      0.035
20   31    235.34    770.17      8.26     -7.96      0.015
21   31    231.35    726.78      7.02     -6.72      0.015
22   31    225.06    711.81      1.75     -1.45      0.015
23   31    215.77    720.88      2.87     -2.57      0.015
24   31    162.50    728.36     12.50    -12.20      0.015
25   31    325.08    685.99      5.92     -5.62      0.015
26   31    335.30    625.33      1.50     -1.20      0.015
27   31    335.30    625.33      1.50     -1.20      0.015
28   31    366.85    584.47      1.50     -1.20      0.015
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  29   31    397.56    590.72      1.50     -1.20      0.015
  30   31    510.41    612.57      1.50     -1.20      0.015
  43   31    214.71    733.55      4.00     -3.70      0.015
  44   31   1400.00    733.55      0.30      0.00      0.035
   4   32     90.14    548.29      4.00     -3.70      0.015
   5   32   1080.00    548.29      0.30      0.00      0.035
  20   32    235.44    611.75      6.75     -6.45      0.015
  21   32    228.95    601.48      6.05     -5.75      0.015
  22   32    223.75    592.29      4.71     -4.41      0.015
  23   32    219.85    583.35      5.29     -4.99      0.015
  24   32    152.15    554.19     12.50    -12.20      0.015
  25   32    331.01    536.81      5.62     -5.32      0.015
  26   32    334.64    550.15      1.50     -1.20      0.015
  28   32    434.64    600.15      1.50     -1.20      0.015
  29   32    399.67    618.24      1.50     -1.20      0.015
  30   32    399.67    618.24      1.50     -1.20      0.015
  43   32    131.24    627.00      4.00     -3.70      0.015
  44   32   1200.00    627.00      0.30      0.00      0.035
   4   33    176.78    637.38      4.00     -3.70      0.015
   5   33   1200.00    637.38      0.30      0.00      0.035
  19   33    249.63    512.48      3.93     -3.63      0.015
  20   33    226.63    497.43      8.50     -8.20      0.015
  21   33    220.16    496.84      3.39     -3.09      0.015
  22   33    217.70    490.62      1.50     -1.20      0.015
  23   33    222.09    479.36      2.31     -2.01      0.015
  24   33    134.82    467.11     12.50    -12.20      0.015
  25   33    327.40    478.91      6.58     -6.28      0.015
  26   33    322.66    511.83      1.50     -1.20      0.015
  28   33    399.13    544.22      1.50     -1.20      0.015
  29   33    399.13    544.22      1.50     -1.20      0.015
  30   33    338.54    550.21      1.50     -1.20      0.015
  43   33    143.96    508.94      4.00     -3.70      0.015
  44   33   1000.00    508.94      0.30      0.00      0.035
   4   34    106.07    686.04      4.00     -3.70      0.015
   5   34   1300.00    686.04      0.30      0.00      0.035
  19   34    255.29    434.56      8.39     -8.09      0.015
  20   34    232.33    468.82      6.01     -5.71      0.015
  21   34    218.89    489.13      1.50     -1.20      0.015
  22   34    211.57    502.76      1.50     -1.20      0.015
  23   34    210.35    512.93      2.55     -2.25      0.015
  24   34    123.31    519.82     12.50    -12.20      0.015
  25   34    279.83    533.34      7.64     -7.34      0.015
  26   34    296.11    568.27      1.50     -1.20      0.015
  28   34    459.92    646.01      1.50     -1.20      0.015
  29   34    401.90    617.07      1.50     -1.20      0.015
  30   34    404.01    618.20      1.50     -1.20      0.015
  43   34    200.06    752.08      4.00     -3.70      0.015
  44   34   1400.00    752.08      0.30      0.00      0.035
   4   35    158.11    707.74      4.00     -3.70      0.015
   5   35   1400.00    707.74      0.30      0.00      0.035
  19   35    280.38    507.76      6.02     -5.72      0.015
  20   35    237.79    518.99      2.58     -2.28      0.015
  21   35    214.96    549.70      1.50     -1.20      0.015
  22   35    198.12    589.87      1.50     -1.20      0.015
  23   35    182.35    636.76      3.34     -3.04      0.015
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24   35    134.54     661.85      12.50     -12.20       0.015
25   35    186.65     662.57      12.50     -12.20       0.015
26   35    244.99     662.91       3.73      -3.43       0.015
27   35    403.62     643.10       1.50      -1.20       0.015
28   35    459.92     646.01       1.50      -1.20       0.015
29   35    434.88     689.59       1.50      -1.20       0.015
30   35    405.87     741.94       1.50      -1.20       0.015
43   35    154.03     642.83       4.00      -3.70       0.015
44   35   1200.00     642.83       0.30       0.00       0.035
 4   36    182.00     594.24       4.00      -3.70       0.015
19   36    271.75     432.19       3.24      -2.94       0.015
20   36    233.35     466.32       4.99      -4.69       0.015
21   36    211.96     484.98       1.50      -1.20       0.015
22   36    198.55     493.62       1.79      -1.49       0.015
23   36    191.37     490.80       4.34      -4.04       0.015
24   36    127.57     512.62      12.50     -12.20       0.015
25   36    158.41     553.88       9.76      -9.46       0.015
26   36    200.015     580.32       4.10      -3.80       0.015
27   36    476.04     637.67       1.50      -1.20       0.015
28   36    486.04     637.67       1.50      -1.20       0.015
29   36    478.18     665.86       1.50      -1.20       0.015
30   36    398.21     716.00       1.50      -1.20       0.015
43   36    164.92     626.26       4.00      -3.70       0.015
44   36   1200.00     626.26       0.30       0.00       0.035
 4   37    150.00     500.00       4.00      -3.70       0.015
 5   37    750.42     375.00       4.00      -3.70       0.015
 6   37    627.00     201.56       4.00      -3.70       0.015
 7   37    400.00     200.00       4.00      -3.70       0.015
20   37    227.35     480.86      10.46     -10.16       0.015
21   37    214.29     487.70       8.12      -7.82       0.015
22   37    207.59     495.04       4.70      -4.40       0.015
23   37    209.05     500.69       5.79      -5.49       0.015
24   37    126.00     504.00      12.50     -12.20       0.015
25   37    194.49     505.31       6.39      -6.09       0.015
26   37    177.01     506.07       3.08      -2.78       0.015
27   37    151.51     520.49       1.50      -1.20       0.015
28   37    269.56     510.51       1.50      -1.20       0.015
30   37    287.10     513.43       1.50      -1.20       0.015
31   37    458.65     517.80       1.50      -1.20       0.015
43   37    217.83     647.65       4.00      -3.70       0.015
44   37   1200.00     647.65       0.30       0.00       0.035
 4   38    152.07     682.37       4.00      -3.70       0.015
 7   38    254.95     471.70       4.00      -3.70       0.015
 8   38   1399.20     471.70       0.30       0.00       0.035
21   38    209.45     602.09       2.96      -2.66       0.015
22   38    205.82     591.46       4.32      -4.02       0.015
23   38    203.09     582.59       5.79      -5.49       0.015
24   38    126.00     581.00      12.50     -12.20       0.015
25   38    199.45     582.66       6.18      -5.88       0.015
26   38    178.19     587.13       2.68      -2.38       0.015
27   38    151.51     590.49       1.50      -1.20       0.015
28   38    269.56     587.51       1.50      -1.20       0.015
29   38    262.32     582.20       1.50      -1.20       0.015
30   38    334.06     587.41       1.50      -1.20       0.015
31   38    396.13     598.20       1.50      -1.20       0.015
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  32   38    328.00    605.56      1.50     -1.20      0.015
  43   38    195.26    811.25      4.00     -3.70      0.015
  44   38   1400.00    811.25      0.30      0.00      0.035
   4   39    155.24    869.60      4.00     -3.70      0.015
   5   39    999.00    869.60      0.30      0.00      0.035
   7   39    151.33    615.55      4.00     -3.70      0.015
   8   39   1072.22    615.55      0.30      0.00      0.035
  22   39    202.11    562.70      1.50     -1.20      0.015
  23   39    201.60    575.19      3.88     -3.58      0.015
  24   39    126.00    580.00     12.50    -12.20      0.015
  25   39    184.55    578.93      7.32     -7.02      0.015
  26   39    192.10    577.31      3.26     -2.96      0.015
  27   39    205.95    579.39      1.50     -1.20      0.015
  28   39    234.43    585.48      1.50     -1.20      0.015
  29   39    268.40    588.73      1.50     -1.20      0.015
  30   39    317.31    584.27      1.50     -1.20      0.015
  31   39    388.41    567.45      1.50     -1.20      0.015
  32   39    328.00    605.56      1.50     -1.20      0.015
  43   39    145.77    617.45      4.00     -3.70      0.015
  44   39   1068.92    617.45      0.30      0.00      0.035
   4   40     91.24    723.30      4.00     -3.70      0.015
   5   40    999.00    723.30      0.30      0.00      0.035
   7   40    202.24    637.89      4.00     -3.70      0.015
   8   40   1200.00    637.89      0.30      0.00      0.035
  23   40    201.50    605.00      4.29     -3.99      0.015
  24   40    126.50    605.00     12.50    -12.20      0.015
  25   40    179.16    608.68      6.49     -6.19      0.015
  26   40    194.24    612.52      1.61     -1.31      0.015
  27   40    211.95    610.54      1.59     -1.29      0.015
  28   40    234.60    604.35      2.32     -2.02      0.015
  29   40    265.08    593.56      1.71     -1.41      0.015
  30   40    311.23    575.37      1.50     -1.20      0.015
  31   40    396.48    534.45      1.50     -1.20      0.015
  43   40    168.00    592.22      4.00     -3.70      0.015
  44   40   1114.46    592.22      0.30      0.00      0.035
   4   41    102.96    652.76      4.00     -3.70      0.015
   5   41    900.00    652.76      0.30      0.00      0.035
   7   41    125.00    450.69      4.00     -3.70      0.015
   8   41    732.21    450.69      0.30      0.00      0.035
  23   41    201.50    707.00      7.60     -7.30      0.015
  24   41    114.00    707.12     12.50    -12.20      0.015
  25   41    192.42    694.87      4.82     -4.52      0.015
  26   41    206.01    670.20      1.50     -1.20      0.015
  28   41    239.39    622.55      1.50     -1.20      0.015
  29   41    264.90    601.93      2.61     -2.31      0.015
  30   41    310.28    591.34      1.50     -1.20      0.015
  31   41    430.95    576.15      1.66     -1.36      0.015
  43   41    168.00    733.64      4.00     -3.70      0.015
  44   41    899.62    733.64      0.30      0.00      0.035
   4   42    127.48    571.18      4.00     -3.70      0.015
   5   42    750.00    571.18      0.30      0.00      0.035
   7   42    134.63    536.77      4.00     -3.70      0.015
   8   42    614.79    536.77      0.30      0.00      0.035
  22   42    278.08    735.33      2.40     -2.10      0.015
  23   42    189.50    707.00      7.26     -6.96      0.015
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24   42    116.22    682.03     12.52    -12.22      0.015
25   42    224.51    647.62      3.31     -3.01      0.015
26   42    228.81    627.93      1.50     -1.20      0.015
28   42    248.37    588.73      1.50     -1.20      0.015
29   42    266.94    566.00      2.54     -2.24      0.015
30   42    300.32    534.15      1.50     -1.20      0.015
43   42    134.63    770.15      4.00     -3.70      0.015
44   42    856.98    770.15      0.30      0.00      0.035
 4   43    130.00    715.89      4.00     -3.70      0.015
 5   43    999.00    715.89      0.30      0.00      0.035
 7   43    125.00    419.08      4.00     -3.70      0.015
 8   43    787.44    419.08      0.30      0.00      0.035
23   43    189.50    616.05      5.46     -5.16      0.015
24   43    124.23    616.05     12.50    -12.20      0.015
25   43    248.72    606.75      6.05     -5.75      0.015
26   43    245.29    595.90      1.50     -1.20      0.015
27   43    247.72    588.13      1.50     -1.20      0.015
28   43    255.01    581.60      1.89     -1.59      0.015
29   43    267.24    575.40      2.11     -1.81      0.015
30   43    284.14    568.12      1.50     -1.20      0.015
31   43    295.31    569.01      2.05     -1.75      0.015
43   43    150.33    741.69      4.00     -3.70      0.015
44   43    889.86    741.69      0.30      0.00      0.035
 4   44    183.44    649.04      4.00     -3.70      0.015
 5   44    900.00    649.04      0.30      0.00      0.035
 7   44    201.56    340.035      4.00     -3.70      0.015
 8   44    970.47    340.035      0.30      0.00      0.035
23   44    183.45    569.01      2.93     -2.63      0.015
24   44    126.62    556.71     12.50    -12.20      0.015
25   44    251.81    600.98      5.83     -5.53      0.015
26   44    251.29    602.14      1.50     -1.20      0.015
27   44    253.29    602.81      1.50     -1.20      0.015
28   44    258.96    604.81      2.69     -2.39      0.015
29   44    269.61    609.51      2.04     -1.74      0.015
30   44    269.33    606.01      1.98     -1.68      0.015
31   44    269.33    606.01      1.98     -1.68      0.015
33   44    300.00    300.00      4.20     -3.90      0.015
34   44   1300.00    100.00      4.20     -3.90      0.015
35   44   1300.00    100.00      4.20     -3.90      0.015
43   44    176.14    660.015      4.00     -3.70      0.015
44   44    999.96    660.015      0.30      0.00      0.035
 4   45    161.25    657.65      4.00     -3.70      0.015
 5   45    900.00    657.65      0.30      0.00      0.035
 7   45    160.08    347.31      4.00     -3.70      0.015
 8   45    950.16    347.31      0.30      0.00      0.035
22   45    326.01    645.54      1.50     -1.20      0.015
23   45    193.07    682.91      4.29     -3.99      0.015
24   45    126.62    680.27     12.50    -12.20      0.015
25   45    261.68    637.43      6.38     -6.08      0.015
26   45    255.11    639.18      1.50     -1.20      0.015
27   45    252.40    644.54      2.00     -1.70      0.015
28   45    253.08    652.54      2.39     -2.09      0.015
29   45    266.07    660.45      1.50     -1.20      0.015
30   45    266.07    660.45      1.50     -1.20      0.015
43   45    237.12    661.23      4.00     -3.70      0.015
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 44   45    998.14    661.23      0.30      0.00       0.035
  4   46    131.53    634.11      4.00     -3.70       0.015
  5   46    900.00    634.11      0.30      0.00       0.035
  7   46    145.77    382.43      4.00     -3.70       0.015
  8   46    862.90    382.43      0.30      0.00       0.035
 22   46    290.60    624.83      1.50     -1.20       0.015
 23   46    250.88    591.85      3.24     -2.94       0.015
 24   46    101.83    611.92     12.50    -12.20       0.015
 25   46    268.16    659.53      7.89     -7.59       0.015
 26   46    255.09    683.69      2.72     -2.42       0.015
 27   46    248.08    710.82      3.29     -2.99       0.015
 28   46    225.96    719.10      1.50     -1.20       0.015
 43   46    201.56    665.68      4.00     -3.70       0.015
 44   46    991.46    665.68      0.30      0.00       0.035
  4   47    122.58    677.66      4.00     -3.70       0.015
  5   47    900.00    677.66      0.30      0.00       0.035
  7   47    230.49    654.31      4.00     -3.70       0.015
  8   47   1008.70    654.31      0.30      0.00       0.035
 22   47    286.12    586.77      1.50     -1.20       0.015
 23   47    275.88    649.52      2.20     -1.90       0.015
 24   47    116.22    683.86     12.50    -12.20       0.015
 25   47    236.80    697.98      9.06     -8.76       0.015
 26   47    240.86    723.27      3.57     -3.27       0.015
 27   47    241.82    746.05      2.00     -1.70       0.015
 43   47    111.80    538.52      4.00     -3.70       0.015
 44   47    612.79    538.52      0.30      0.00       0.035
  4   48    133.14    719.81      4.00     -3.70       0.015
  5   48    900.00    719.81      0.30      0.00       0.035
  7   48    195.26    529.74      4.00     -3.70       0.015
  8   48    622.95    529.74      0.30      0.00       0.035
 21   48    303.16    601.49      1.50     -1.20       0.015
 22   48    287.20    642.65      1.50     -1.20       0.015
 23   48    267.57    687.69      1.81     -1.51       0.015
 24   48    114.19    698.39     12.50    -12.20       0.015
 25   48    238.08    691.62      8.72     -8.42       0.015
 26   48    239.88    701.04      2.10     -1.80       0.015
 27   48    241.58    710.49      1.80     -1.50       0.015
 28   48    251.32    724.31      1.50     -1.20       0.015
 43   48    175.00    760.35      4.00     -3.70       0.015
 44   48   1200.00    760.35      0.30      0.00       0.035
  4   49    166.51    691.47      4.00     -3.70       0.015
  5   49    900.00    691.47      0.30      0.00       0.035
  7   49    103.08    477.62      4.00     -3.70       0.015
  8   49    690.93    477.62      0.30      0.00       0.035
 21   49    303.24    669.34      1.50     -1.20       0.015
 22   49    291.88    671.42      1.50     -1.20       0.015
 23   49    280.39    667.05      2.40     -2.10       0.015
 24   49    113.50    662.55     12.50    -12.20       0.015
 25   49    266.06    666.79      7.37     -7.07       0.015
 26   49    250.68    674.29      1.50     -1.20       0.015
 27   49    241.30    678.15      1.97     -1.67       0.015
 28   49    228.74    698.43      1.50     -1.20       0.015
 43   49    160.08    691.47      4.00     -3.70       0.015
 44   49   1300.00    691.47      0.30      0.00       0.035
  4   50    183.98    678.12      4.00     -3.70       0.015
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 5   50    900.00    678.12      0.30      0.00      0.035
 7   50    160.08    427.93      4.00     -3.70      0.015
 8   50    771.15    427.93      0.30      0.00      0.035
21   50    321.20    721.48      1.50     -1.20      0.015
22   50    302.75    713.41      1.50     -1.20      0.015
23   50    289.30    714.29      1.70     -1.40      0.015
24   50    126.00    717.64     12.50    -12.20      0.015
25   50    285.19    713.74      6.35     -6.05      0.015
26   50    250.09    712.00      1.50     -1.20      0.015
27   50    222.49    715.63      1.50     -1.20      0.015
28   50    222.49    715.63      1.50     -1.20      0.015
43   50    127.48    480.88      4.00     -3.70      0.015
44   50    686.24    500.00      0.30      0.00      0.035
 4   51    167.63    659.24      4.00     -3.70      0.015
 5   51    900.00    678.12      0.30      0.00      0.035
 7   51    127.48    395.28      4.00     -3.70      0.015
 8   51    834.85    395.28      0.30      0.00      0.035
21   51    340.15    764.48      1.50     -1.20      0.015
22   51    304.35    721.37      1.50     -1.20      0.015
23   51    276.82    683.32      2.45     -2.15      0.015
24   51    138.50    663.05     12.50    -12.20      0.015
25   51    300.43    656.66      5.25     -4.95      0.015
27   51    242.78    620.65      1.50     -1.20      0.015
28   51    242.78    620.65      1.50     -1.20      0.015
43   51    141.42    509.90      4.00     -3.70      0.015
44   51    970.78    509.90      0.30      0.00      0.035
 4   52    175.00    550.015     4.00     -3.70      0.015
 5   52    600.00    550.015     0.30      0.00      0.035
 7   52    167.71    648.56      4.00     -3.70      0.015
 8   52   1017.64    648.56      0.30      0.00      0.035
21   52    344.26    732.63      1.50     -1.20      0.015
22   52    300.63    725.85      1.50     -1.20      0.015
23   52    263.39    716.70      2.88     -2.58      0.015
24   52    151.00    711.00     12.50    -12.20      0.015
25   52    313.52    689.92      3.01     -2.71      0.015
27   52    264.23    622.67      1.50     -1.20      0.015
28   52    264.23    622.67      1.50     -1.20      0.015
43   52    115.00    601.02      4.00     -3.70      0.015
44   52   1100.00    601.02      0.30      0.00      0.035
 4   53    191.64    659.34      4.00     -3.70      0.015
 5   53    900.00    659.34      0.30      0.00      0.035
 7   53    145.77    728.87      4.00     -3.70      0.015
 8   53    905.52    728.87      0.30      0.00      0.035
20   53    737.40    618.99      0.30      0.00      0.035
21   53    339.51    639.88      2.65     -2.35      0.015
22   53    304.13    665.46      1.50     -1.20      0.015
23   53    275.04    696.38      1.78     -1.48      0.015
24   53    151.56    699.79     12.50    -12.20      0.015
25   53    324.27    693.28      4.56     -4.26      0.015
26   53    282.14    712.66      1.50     -1.20      0.015
27   53    252.88    744.61      1.50     -1.20      0.015
28   53    252.88    744.61      1.50     -1.20      0.015
43   53     99.25    578.66      4.00     -3.70      0.015
44   53   1100.00    578.66      0.30      0.00      0.035
 4   54    140.00    542.31      4.00     -3.70      0.015
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    5   54    750.00    542.31      0.30      0.00      0.035
    7   54    160.08    585.77      4.00     -3.70      0.015
    8   54   1126.72    585.77      0.30      0.00      0.035
   20   54    742.66    409.16      0.30      0.00      0.035
   21   54    742.66    409.16      0.30      0.00      0.035
   24   54    126.00    584.53     12.50    -12.20      0.015
   25   54    316.45    637.57      3.83     -3.53      0.015
   26   54    290.22    674.67      1.50     -1.20      0.015
   27   54    275.62    672.76      1.50     -1.20      0.015
   43   54    111.80    570.09      4.00     -3.70      0.015
   44   54   1100.00    570.09      0.30      0.00      0.035
    4   55    100.00    602.08      4.00     -3.70      0.015
    5   55    800.00    602.08      0.30      0.00      0.035
    7   55    176.78    807.00      4.00     -3.70      0.015
    8   55    613.38    807.00      0.30      0.00      0.035
   20   55    702.32    439.24      0.30      0.00      0.035
   21   55    702.32    439.24      0.30      0.00      0.035
   24   55    107.62    739.19     12.50    -12.20      0.015
   25   55    301.07    803.61      8.09     -7.79      0.015
   26   55    296.45    926.21      1.50     -1.20      0.015
   27   55    292.41   1095.30      1.50     -1.20      0.015
   43   55    100.00    471.70      4.00     -3.70      0.015
   44   55    524.70    500.00      0.30      0.00      0.035
    4   56     87.46    728.87      4.00     -3.70      0.015
    5   56    900.00    728.87      0.30      0.00      0.035
    7   56    167.71    627.00      4.00     -3.70      0.015
    8   56    789.48    627.00      0.30      0.00      0.035
   20   56   2600.00    507.24      0.30      0.00      0.035
   21   56    322.59    545.33      1.69     -1.39      0.015
   22   56    334.89    591.26      1.50     -1.20      0.015
   23   56    368.54    648.71      1.50     -1.20      0.015
   24   56    118.73    692.69     12.50    -12.20      0.015
   25   56    314.73    720.21      7.40     -7.10      0.015
   26   56    317.38    748.33      1.50     -1.20      0.015
   27   56    286.57    765.79      1.50     -1.20      0.015
   43   56    111.80    602.08      4.00     -3.70      0.015
   44   56   1100.00    602.08      0.30      0.00      0.035
    4   57     77.62    499.52      4.00     -3.70      0.015
    5   57    700.00    499.52      0.30      0.00      0.035
    7   57    134.63    783.02      4.00     -3.70      0.015
    8   57    632.16    783.02      0.30      0.00      0.035
   20   57   2600.00    596.43      0.30      0.00      0.035
   21   57    304.70    620.97      1.50     -1.20      0.015
   22   57    300.81    660.73      1.53     -1.23      0.015
   23   57    300.55    706.79      1.58     -1.28      0.015
   24   57    154.55    725.96     12.50    -12.20      0.015
   25   57    313.78    735.26      6.06     -5.76      0.015
   26   57    274.30    777.83      1.50     -1.20      0.015
   43   57     70.71    626.50      4.00     -3.70      0.015
   44   57    790.10    626.50      0.30      0.00      0.035
    4   58    100.00    670.30      4.00     -3.70      0.015
    5   58    900.00    670.30      0.30      0.00      0.035
    7   58    145.77    649.04      4.00     -3.70      0.015
    8   58    762.66    649.04      0.30      0.00      0.035
   20   58   2600.00    728.30      0.30      0.00      0.035
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  21   58    263.49    728.27      1.50     -1.20      0.015
  22   58    263.96    690.15      1.50     -1.20      0.015
  23   58    257.00    644.65      2.32     -2.02      0.015
  24   58    171.71    625.42     12.50    -12.20      0.015
  25   58    272.94    617.26      3.98     -3.68      0.015
  26   58    245.19    571.37      1.50     -1.20      0.015
  43   58    125.00    760.35      4.00     -3.70      0.015
  44   58   1200.00    760.35      0.30      0.00      0.035
   4   59     90.00    606.71      4.00     -3.70      0.015
   5   59    800.00    606.71      0.30      0.00      0.035
   7   59    145.77    571.18      4.00     -3.70      0.015
   8   59    866.62    571.18      0.30      0.00      0.035
  20   59   2400.00    640.74      0.30      0.00      0.035
  21   59    241.35    640.74      1.50     -1.20      0.015
  22   59    253.27    629.91      1.50     -1.20      0.015
  23   59    152.32    630.25      1.50     -1.20      0.015
  24   59    157.54    606.79     12.50    -12.20      0.015
  25   59    260.57    570.62      4.56     -4.26      0.015
  26   59    282.40    557.67      1.84     -1.54      0.015
  27   59    349.95    531.00      1.50     -1.20      0.015
  43   59    125.00    548.29      4.00     -3.70      0.015
  44   59   1000.00    548.29      0.30      0.00      0.035
   4   60     90.00    629.36      4.00     -3.70      0.015
   5   60    900.00    629.36      0.30      0.00      0.035
   7   60    106.07    617.45      4.00     -3.70      0.015
   8   60    801.68    617.45      0.30      0.00      0.035
  21   60   1000.00    520.78      0.30      0.00      0.035
  22   60    233.22    520.78      1.50     -1.20      0.015
  23   60    152.32    509.49      1.50     -1.20      0.015
  24   60    147.15    532.78     12.50    -12.20      0.015
  25   60    276.16    553.69      5.14     -4.84      0.015
  26   60    293.30    534.01      1.50     -1.20      0.015
  27   60    317.05    518.21      1.97     -1.67      0.015
  28   60    287.74    494.07      1.50     -1.20      0.015
  43   60    167.71    742.04      4.00     -3.70      0.015
  44   60    667.08    742.04      0.30      0.00      0.035
   4   61    100.00    618.47      4.00     -3.70      0.015
   5   61    900.00    618.47      0.30      0.00      0.035
   7   61    103.08    682.37      4.00     -3.70      0.015
   8   61    725.42    682.37      0.30      0.00      0.035
  21   61   1100.00    556.15      0.30      0.00      0.035
  22   61    219.82    556.16      1.50     -1.20      0.015
  23   61    276.79    533.25      1.50     -1.20      0.015
  24   61    153.97    499.11     12.50    -12.20      0.015
  25   61    285.54    478.25      3.83     -3.53      0.015
  27   61    292.58    472.78      1.50     -1.20      0.015
  28   61    291.38    485.85      1.73     -1.43      0.015
  29   61    291.38    485.85      1.73     -1.43      0.015
  43   61    145.77    637.38      4.00     -3.70      0.015
  44   61    517.74    637.38      0.30      0.00      0.035
   4   62    100.00    701.78      4.00     -3.70      0.015
   5   62   1000.00    701.78      0.30      0.00      0.035
   7   62    103.08    581.49      4.00     -3.70      0.015
   8   62    851.26    581.49      0.30      0.00      0.035
  21   62   1200.00    618.07      0.30      0.00      0.035
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22   62    243.07     618.06      1.50     -1.20      0.015
23   62    227.88     569.34      2.05     -1.75      0.015
24   62    135.47     532.57     12.50    -12.20      0.015
25   62    329.32     490.13      4.66     -4.36      0.015
27   62    284.02     390.73      1.50     -1.20      0.015
28   62    301.69     313.49      1.88     -1.58      0.015
29   62    301.69     313.49      1.88     -1.58      0.015
43   62    175.00     654.31      4.00     -3.70      0.015
44   62    504.34     654.31      0.30      0.00      0.035
 4   63     87.32     754.80      4.00     -3.70      0.015
 5   63    900.00     754.80      0.30      0.00      0.035
 7   63    103.08     682.37      4.00     -3.70      0.015
 8   63    725.42     682.37      0.30      0.00      0.035
21   63   1600.00     814.38      0.30      0.00      0.035
22   63    228.48     814.38      1.50     -1.20      0.015
23   63    213.04     738.12      1.88     -1.58      0.015
24   63    113.19     673.54     12.50    -12.20      0.015
25   63    319.79     579.71      3.70     -3.40      0.015
26   63    288.26     494.28      1.50     -1.20      0.015
27   63    285.07     428.07      1.50     -1.20      0.015
28   63    309.26     350.09      1.57     -1.27      0.015
43   63    150.00     626.50      4.00     -3.70      0.015
44   63    526.74     626.50      0.30      0.00      0.035
 4   64    120.42     596.41      4.00     -3.70      0.015
 5   64    800.00     596.41      0.30      0.00      0.035
 7   64    100.00     694.62      4.00     -3.70      0.015
 8   64    712.62     694.62      0.30      0.00      0.035
22   64   1200.00     622.28      0.30      0.00      0.035
23   64    203.11     622.29      2.19     -1.89      0.015
24   64    158.75     622.29     12.50    -12.20      0.015
25   64    234.32     619.28      5.12     -4.82      0.015
26   64    271.12     595.81      1.50     -1.20      0.015
27   64    297.73     556.52      1.63     -1.33      0.015
28   64    310.33     522.29      1.50     -1.20      0.015
43   64    106.07     664.27      4.00     -3.70      0.015
44   64    496.78     664.27      0.30      0.00      0.035
 4   65    122.98     659.34      4.00     -3.70      0.015
 5   65    900.00     659.34      0.30      0.00      0.035
 7   65    103.08     673.15      4.00     -3.70      0.015
 8   65    735.34     673.15      0.30      0.00      0.035
22   65   1200.00     625.13      0.30      0.00      0.035
23   65    192.29     625.13      1.99     -1.69      0.015
24   65    165.40     638.07     12.50    -12.20      0.015
25   65    198.69     660.10      7.73     -7.43      0.015
26   65    283.05     662.64      1.83     -1.53      0.015
27   65    200.00     520.00      1.83     -1.53      0.015
43   65    145.77     675.46      4.00     -3.70      0.015
44   65    488.56     675.46      0.30      0.00      0.035
 4   66    147.14     686.48      4.00     -3.70      0.015
 5   66    900.00     686.48      0.30      0.00      0.035
 7   66    125.00     800.39      4.00     -3.70      0.015
 8   66    618.44     800.39      0.30      0.00      0.035
19   66   1000.00     536.71      0.30      0.00      0.035
20   66    215.46     536.71      6.00     -5.70      0.015
21   66    303.07     538.75      6.00     -5.70      0.015
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 22   66    252.31    551.62     6.00    -5.70      0.015
 23   66    195.15    561.99     6.00    -5.70      0.015
 24   66    152.01    547.83     6.00    -5.70      0.015
 25   66    189.45    547.32     6.00    -5.70      0.015
 43   66    111.80    626.50     4.00    -3.70      0.015
 44   66    526.74    626.50     0.30     0.00      0.035
  4   67    150.08    678.40     4.00    -3.70      0.015
  5   67    900.00    678.40     0.30     0.00      0.035
  7   67    111.80    570.09     4.00    -3.70      0.015
  8   67    868.28    570.09     0.30     0.00      0.035
 18   67   1400.00    742.71     0.30     0.00      0.035
 19   67    210.42    755.70     6.00    -5.70      0.015
 20   67    239.33    774.61     6.00    -5.70      0.015
 23   67    600.00    495.63     0.30     0.00      0.035
 24   67    164.97    521.85    12.50   -12.20      0.015
 25   67    163.50    534.32     6.54    -6.24      0.015
 43   67    140.00    551.45     4.00    -3.70      0.015
 44   67    598.42    551.45     0.30     0.00      0.035
  4   68    108.17    617.41     4.00    -3.70      0.015
  5   68    900.00    617.41     0.30     0.00      0.035
  7   68    100.00    715.89     4.00    -3.70      0.015
  8   68    691.44    715.89     0.30     0.00      0.035
 18   68   1500.00    798.26     0.30     0.00      0.035
 19   68    400.00    798.26     6.00    -5.70      0.015
 24   68    177.00    762.64    12.50   -12.20      0.015
 43   68    166.88    590.64     4.00    -3.70      0.015
 44   68    558.72    590.64     0.30     0.00      0.035
  4   69     95.53    584.23     4.00    -3.70      0.015
  5   69    800.00    584.23     0.30     0.00      0.035
  7   69    134.63    800.39     4.00    -3.70      0.015
  8   69    618.44    800.39     0.30     0.00      0.035
 17   69    653.04    757.99     0.30     0.00      0.035
 18   69   1500.00    757.99     0.30     0.00      0.035
 19   69    400.00    757.99     6.00    -5.70      0.015
 23   69    386.50    486.34     0.30     0.00      0.035
 24   69    185.63    510.73    12.50   -12.20      0.015
 43   69    167.71    583.63     4.00    -3.70      0.015
 44   69    565.42    583.63     0.30     0.00      0.035
  4   70     97.08    301.04     4.00    -3.70      0.015
  5   70    400.00    301.04     0.30     0.00      0.035
  7   70    160.08    687.84     4.00    -3.70      0.015
  8   70    719.64    687.84     0.30     0.00      0.035
 17   70    650.92    760.46     0.30     0.00      0.035
 18   70   1500.00    760.46     0.30     0.00      0.035
 19   70    400.00    760.46     6.00    -5.70      0.015
 23   70    214.62    555.64     2.26    -1.96      0.015
 24   70    175.41    556.18    12.50   -12.20      0.015
 43   70    180.28    756.90     4.00    -3.70      0.015
 44   70    435.98    756.90     0.30     0.00      0.035
  4   71     99.25    472.07     4.00    -3.70      0.015
  5   71    700.00    472.07     0.30     0.00      0.035
  7   71    111.80    750.00     4.00    -3.70      0.015
  8   71    660.00    750.00     0.30     0.00      0.035
 17   71    626.62    789.96     0.30     0.00      0.035
 18   71   1500.00    789.96     0.30     0.00      0.035
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 19   71    400.00     789.96      6.00     -5.70       0.015
 23   71    223.32     539.75      2.97     -2.67       0.015
 24   71    169.02     503.35     12.50    -12.20       0.015
 43   71    167.71     706.77      4.00     -3.70       0.015
 44   71    700.36     706.77      0.30      0.00       0.035
  4   72    129.03     637.38      4.00     -3.70       0.015
  5   72    800.00     637.38      0.30      0.00       0.035
  7   72    103.08     608.79      4.00     -3.70       0.015
 18   72   1400.00     768.70      0.30      0.00       0.035
 19   72    400.00     768.70      6.00     -5.70       0.015
 23   72    212.06     465.57      5.72     -5.42       0.015
 24   72    188.46     450.09     12.50    -12.20       0.015
 43   72    158.11     583.10      4.00     -3.70       0.015
 44   72    848.92     583.10      0.30      0.00       0.035
  4   73    138.29     593.49      4.00     -3.70       0.015
  5   73    750.00     593.49      0.30      0.00       0.035
 18   73   1500.00     920.98      0.30      0.00       0.035
 19   73    350.00     939.24      6.00     -5.70       0.015
 23   73    192.25     446.72      6.42     -6.12       0.015
 24   73    183.46     456.84     12.50    -12.20       0.015
 43   73    142.21     730.56      4.00     -3.70       0.015
 44   73    677.56     730.56      0.30      0.00       0.035
  4   74     86.02     539.07      4.00     -3.70       0.015
  5   74    750.00     539.07      0.30      0.00       0.035
 19   74    150.00     550.00      6.00     -5.70       0.015
 23   74    162.53     456.30      5.62     -5.32       0.015
 24   74    158.40     459.66     12.50    -12.20       0.015
 43   74    142.21     733.30      4.00     -3.70       0.015
 44   74    675.04     733.30      0.30      0.00       0.035
  4   75    129.03     675.02      4.00     -3.70       0.015
  5   75    900.00     675.02      0.30      0.00       0.035
 18   75   1200.00     659.62      0.30      0.00       0.035
 19   75    150.00     659.62      5.50     -5.20       0.015
 23   75    132.19     420.70      3.03     -2.73       0.015
 24   75    137.18     418.01     12.50    -12.20       0.015
 43   75    190.39     617.45      4.00     -3.70       0.015
 44   75    801.68     617.45      0.30      0.00       0.035
  4   76    180.28     570.09      4.00     -3.70       0.015
  5   76    800.00     570.09      0.30      0.00       0.035
 18   76    898.26     551.06      0.30      0.00       0.035
 19   76    150.00     551.06      5.50     -5.20       0.015
 23   76    262.26     513.46      0.30      0.00       0.035
 24   76    153.09     506.97     11.50    -11.20       0.015
 43   76    201.56     665.68      4.00     -3.70       0.015
 44   76    743.60     665.68      0.30      0.00       0.035
  4   77    145.77     664.27      4.00     -3.70       0.015
  5   77    800.00     664.27      0.30      0.00       0.035
 18   77    704.64     702.49      0.30      0.00       0.035
 19   77    150.00     702.49      5.00     -4.70       0.015
 23   77    282.80     489.27      0.30      0.00       0.035
 24   77    164.28     527.01     10.50    -10.20       0.015
 43   77    176.78     649.04      4.00     -3.70       0.015
 44   77    762.66     649.04      0.30      0.00       0.035
  4   78    117.05     530.75      4.00     -3.70       0.015
  5   78    700.00     530.75      0.30      0.00       0.035
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 19   78    150.00    649.44      4.50     -4.20      0.015
 24   78    139.11    489.98     10.50    -10.20      0.015
 43   78    180.28    721.11      4.00     -3.70      0.015
 44   78    686.44    721.11      0.30      0.00      0.035
  4   79    120.42    701.78      4.00     -3.70      0.015
  5   79    900.00    701.78      0.30      0.00      0.035
 22   79    113.15    522.62      6.00     -5.70      0.015
 23   79    151.91    529.39      8.00     -7.70      0.015
 24   79    140.83    508.50      8.00     -7.70      0.015
 43   79    223.61    610.33      4.00     -3.70      0.015
 44   79    847.22    610.33      0.30      0.00      0.035
  4   80    107.35    634.05      4.00     -3.70      0.015
  5   80    800.00    634.05      0.30      0.00      0.035
 21   80    914.48    541.29      0.30      0.00      0.035
 22   80    150.00    541.29      6.50     -6.20      0.015
 24   80    140.83    587.83     10.50    -10.20      0.015
 43   80    201.56    638.85      4.00     -3.70      0.015
 44   80    501.56    638.85      4.00     -3.70      0.015
  4   81    120.21    607.82      4.00     -3.70      0.015
  5   81    800.00    607.82      0.30      0.00      0.035
 21   81   1000.00    589.82      0.30      0.00      0.035
 22   81    150.00    589.82      7.00     -6.70      0.015
 24   81    157.98    583.93     10.50    -10.20      0.015
 43   81    201.56   1038.85      4.00     -3.70      0.015
 44   81   1003.12   1038.85      0.30      0.00      0.035
  4   82    105.95    685.00      4.00     -3.70      0.015
  5   82    675.00    685.00      0.30      0.00      0.035
 43   82    201.56   2300.00      4.00     -3.70      0.015
 44   82   1003.12   2300.00      0.30      0.00      0.035
  4   83    105.95    603.92      4.00     -3.70      0.015
  5   83    600.00    603.92      0.30      0.00      0.035
 43   83    201.56    700.00      4.00     -3.70      0.015
 44   83   1003.12    700.00      0.30      0.00      0.035
  4   84    103.08    589.94      4.00     -3.70      0.015
  5   84    600.00    589.94      0.30      0.00      0.035
 43   84    201.56   1650.00      4.00     -3.70      0.015
 44   84   1003.12   1650.00      0.30      0.00      0.035
  4   85    134.54    628.01      4.00     -3.70      0.015
  5   85    525.00    628.01      0.30      0.00      0.035
 43   85    201.56   2140.00      4.00     -3.70      0.015
 44   85    800.00   2140.00      0.30      0.00      0.035
 43   86    201.56   1820.00      4.00     -3.70      0.015
 44   86   1000.00   1820.00      0.30      0.00      0.035
 43   87    201.56   2570.00      4.00     -3.70      0.015
 44   87   1400.00   2570.00      0.30      0.00      0.035
 43   88    201.56   2160.00      4.00     -3.70      0.015
 44   88   1600.00   2160.00      0.30      0.00      0.035
 43   89    101.56   2500.00      4.00     -3.70      0.015
 44   89    903.12   2500.00      0.30      0.00      0.035
 43   90    101.56   2100.00      4.00     -3.70      0.015
 44   90    603.12   2100.00      0.30      0.00      0.035
 43   91    101.56   1900.00      4.00     -3.70      0.015
 44   91    903.12   1900.00      0.30      0.00      0.035
 43   92    101.56   2360.00      4.00     -3.70      0.015
 44   92   1403.12   2360.00      0.30      0.00      0.035
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43   93    101.56   2000.00      4.00     -3.70      0.015
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43   95     71.56   1220.00      4.00     -3.70      0.015
44   95    603.12   1220.00      0.30      0.00      0.035
43   96     71.56   1550.00      4.00     -3.70      0.015
44   96    603.12   1550.00      0.30      0.00      0.035
43   97     71.56    710.00      4.00     -3.70      0.015
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27   22     34.5530     12.2070   0.7088799   0.7053292  -0.7053292   0.7088799  -1.0000000
28   22     34.7340     12.0240   0.7266873   0.6869684  -0.6869684   0.7266873  -1.0000000
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32   22     35.5120     11.3520   0.8066753   0.5909949  -0.5909949   0.8066753  -1.0000000
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21   23     33.9500     13.5840   0.7322029   0.6810866  -0.6810866   0.7322029  -1.0000000
22   23     34.1220     13.4230   0.7334517   0.6797416  -0.6797416   0.7334517  -1.0000000
23   23     34.3010     13.2580   0.7152382   0.6988808  -0.6988808   0.7152382  -1.0000000
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25   23     34.5820     12.9800   0.6942698   0.7197148  -0.7197148   0.6942698  -1.0000000
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 29   34     37.7710     18.7470   0.9842117   0.1769952  -0.1769952   0.9842117  -1.0000000
 30   34     38.1590     18.6400   0.9710875   0.2387238  -0.2387238   0.9710875  -1.0000000
 43   34     32.3220     56.0250  -0.1465520  -0.9892030   0.9892030  -0.1465520  -1.0000000
 44   34     32.3220     56.0250  -0.1465520  -0.9892030   0.9892030  -0.1465520  -0.0100000
  4   35     27.6750     55.3350   0.3562477  -0.9343916   0.9343916   0.3562477  -1.0000000
  5   35     27.6750     55.3350   0.3562477  -0.9343916   0.9343916   0.3562477  -0.0100000
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 20   35     35.5350     19.7310   0.9873909   0.1583007  -0.1583007   0.9873909  -1.0000000
 21   35     35.7580     19.6940   0.9878280   0.1555502  -0.1555502   0.9878280  -1.0000000
 22   35     35.9620     19.6610   0.9898052   0.1424280  -0.1424280   0.9898052  -1.0000000
 23   35     36.1500     19.6320   0.9928368   0.1194780  -0.1194780   0.9928368  -1.0000000
 24   35     36.3020     19.5940   0.9732487   0.2297542  -0.2297542   0.9732487  -1.0000000
 25   35     36.4570     19.5540   0.9968849   0.0788707  -0.0788707   0.9968849  -1.0000000
 26   35     36.6710     19.5300   0.9998183  -0.0190645   0.0190645   0.9998183  -1.0000000
 27   35     36.9940     19.5020   0.9999999   0.0004214  -0.0004214   0.9999999  -1.0000000
 28   35     37.4240     19.4570   0.9961948   0.0871549  -0.0871549   0.9961948  -1.0000000
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 30   35     38.2780     19.3100   0.9802942   0.1975432  -0.1975432   0.9802942  -1.0000000
 43   35     31.6420     55.9750   0.1915226  -0.9814882   0.9814882   0.1915226  -1.0000000
 44   35     31.6420     55.9750   0.1915226  -0.9814882   0.9814882   0.1915226  -0.0100000
  4   36     27.0750     55.5880   0.3271701  -0.9449654   0.9449654   0.3271701  -1.0000000
 19   36     35.3340     20.2400   0.9949861   0.1000137  -0.1000137   0.9949861  -1.0000000
 20   36     35.5860     20.2200   0.9981602   0.0606322  -0.0606322   0.9981602  -1.0000000
 21   36     35.8080     20.2080   0.9990488   0.0436072  -0.0436072   0.9990488  -1.0000000
 22   36     36.0140     20.1990   0.9989846   0.0450535  -0.0450535   0.9989846  -1.0000000
 23   36     36.2080     20.1930   0.9972126   0.0746120  -0.0746120   0.9972126  -1.0000000
 24   36     36.3670     20.1770   0.9842031   0.1770432  -0.1770432   0.9842031  -1.0000000
 25   36     36.5080     20.1570   0.9914514   0.1304767  -0.1304767   0.9914514  -1.0000000
 26   36     36.6870     20.1450   0.9923452   0.1234950  -0.1234950   0.9923452  -1.0000000
 27   36     37.0000     20.1205   0.9961115   0.0881021  -0.0881021   0.9961115  -1.0000000
 28   36     37.4850     20.0960   0.9961115   0.0881021  -0.0881021   0.9961115  -1.0000000
 29   36     37.9660     20.0630   0.9942500   0.1070836  -0.1070836   0.9942500  -1.0000000
 30   36     38.4020     20.0280   0.9928061   0.1197332  -0.1197332   0.9928061  -1.0000000
 43   36     31.4300     56.3200   0.9572459   0.2892753  -0.2892753   0.9572459  -1.0000000
 44   36     31.4300     56.3200   0.9572459   0.2892753  -0.2892753   0.9572459  -0.0100000
  4   37     26.5500     55.7000   0.0000000  -1.0000000   1.0000000   0.0000000  -1.0000000
  5   37     26.4870     56.1500   0.0166598  -0.9998612   0.9998612   0.0166598  -1.0000000
  6   37     26.5250     56.8380   0.1019175  -0.9947929   0.9947929   0.1019175  -1.0000000
  7   37     26.5500     57.3500   0.0000000  -1.0000000   1.0000000   0.0000000  -1.0000000
 20   37     35.5990     20.6940   0.9999930   0.0037393  -0.0037393   0.9999930  -1.0000000
 21   37     35.8190     20.6940   0.9999934  -0.0036145   0.0036145   0.9999934  -1.0000000
 22   37     36.0300     20.6930   0.9999002   0.0141315  -0.0141315   0.9999002  -1.0000000
 23   37     36.2390     20.6870   0.9996251   0.0273795  -0.0273795   0.9996251  -1.0000000
 24   37     36.4060     20.6820   1.0000000   0.0000000   0.0000000   1.0000000  -1.0000000
 25   37     36.5660     20.6830   0.9998916   0.0147209  -0.0147209   0.9998916  -1.0000000
 26   37     36.7520     20.6830   0.9996842   0.0251325  -0.0251325   0.9996842  -1.0000000
 27   37     36.9220     20.6830   0.9996842   0.0251325  -0.0251325   0.9996842  -1.0000000
 28   37     37.1320     20.6830   0.9996842   0.0251325  -0.0251325   0.9996842  -1.0000000
 30   37     37.6580     20.6780   0.9998260   0.0186575  -0.0186575   0.9998260  -1.0000000
 31   37     38.0310     20.6760   0.9984464   0.0557206  -0.0557206   0.9984464  -1.0000000
 43   37     31.7180     56.8820   0.8378644   0.5458784  -0.5458784   0.8378644  -1.0000000
 44   37     31.7180     56.8820   0.8378644   0.5458784  -0.5458784   0.8378644  -0.0100000
  4   38     25.9620     55.7500   0.1554819  -0.9878387   0.9878387   0.1554819  -1.0000000
  7   38     26.2500     57.4750   0.3690618  -0.9294049   0.9294049   0.3690618  -1.0000000
  8   38     26.2500     57.4750   0.3690618  -0.9294049   0.9294049   0.3690618  -0.0100000
 21   38     35.8290     21.2390   0.9999892   0.0046539  -0.0046539   0.9999892  -1.0000000
 22   38     36.0370     21.2370   0.9996812   0.0252500  -0.0252500   0.9996812  -1.0000000
 23   38     36.2410     21.2290   0.9997902   0.0204827  -0.0204827   0.9997902  -1.0000000
 24   38     36.4050     21.2250   0.9999996  -0.0008606   0.0008606   0.9999996  -1.0000000
 25   38     36.5680     21.2260   0.9997911  -0.0204365   0.0204365   0.9997911  -1.0000000
 26   38     36.7570     21.2290   0.9998496  -0.0173443   0.0173443   0.9998496  -1.0000000
 27   38     36.9220     21.2290   0.9989399   0.0460324  -0.0460324   0.9989399  -1.0000000
 28   38     37.1320     21.2270   0.9980754   0.0620122  -0.0620122   0.9980754  -1.0000000
 29   38     37.3980     21.2250   0.9993327   0.0365269  -0.0365269   0.9993327  -1.0000000
 30   38     37.6960     21.2270   0.9994706   0.0325357  -0.0325357   0.9994706  -1.0000000
 31   38     38.0620     21.2330   0.9999999   0.0002705  -0.0002705   0.9999999  -1.0000000
 32   38     38.4240     21.2390   0.9997694  -0.0214729   0.0214729   0.9997694  -1.0000000
 43   38     32.1250     57.4870   0.8012773   0.5982931  -0.5982931   0.8012773  -1.0000000
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 4   39     25.2700     55.8500   0.1554819  -0.9878387   0.9878387   0.1554819  -1.0000000
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 7   39     25.8400     57.8250   0.4584127  -0.8887394   0.8887394   0.4584127  -1.0000000
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23   39     36.2410     21.8070   0.9999337   0.0115199  -0.0115199   0.9999337  -1.0000000
24   39     36.4050     21.8050   1.0000000   0.0000000   0.0000000   1.0000000  -1.0000000
25   39     36.5600     21.8070   0.9999191  -0.0127214   0.0127214   0.9999191  -1.0000000
26   39     36.7490     21.8110   0.9999030  -0.0139281   0.0139281   0.9999030  -1.0000000
27   39     36.9470     21.8130   0.9999957   0.0029346  -0.0029346   0.9999957  -1.0000000
28   39     37.1680     21.8120   0.9999439   0.0105946  -0.0105946   0.9999439  -1.0000000
29   39     37.4190     21.8100   0.9999998  -0.0006578   0.0006578   0.9999998  -1.0000000
30   39     37.7120     21.8120   0.9998754  -0.0157842   0.0157842   0.9998754  -1.0000000
31   39     38.0650     21.8160   0.9998900  -0.0148300   0.0148300   0.9998900  -1.0000000
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 7   40     25.3150     58.0000  -0.1525558  -0.9882948   0.9882948  -0.1525558  -1.0000000
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23   40     36.2410     22.3970   0.9999999  -0.0004132   0.0004132   0.9999999  -1.0000000
24   40     36.4050     22.3970   0.9999999  -0.0004132   0.0004132   0.9999999  -1.0000000
25   40     36.5570     22.4010   0.9997835  -0.0208103   0.0208103   0.9997835  -1.0000000
26   40     36.7440     22.4060   0.9998882  -0.0149534   0.0149534   0.9998882  -1.0000000
27   40     36.9470     22.4080   0.9999945  -0.0033126   0.0033126   0.9999945  -1.0000000
28   40     37.1710     22.4060   0.9999669   0.0081378  -0.0081378   0.9999669  -1.0000000
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24   41     36.3980     23.0530   0.9999577  -0.0091924   0.0091924   0.9999577  -1.0000000
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22   42     36.0260     23.7720   0.9954726   0.0950491  -0.0950491   0.9954726  -1.0000000
23   42     36.2590     23.7600   0.9996480   0.0265299  -0.0265299   0.9996480  -1.0000000
24   42     36.4100     23.7470   0.9907788   0.1354895  -0.1354895   0.9907788  -1.0000000
25   42     36.5780     23.7220   0.9942727   0.1068730  -0.1068730   0.9942727  -1.0000000
26   42     36.8030     23.6930   0.9900991   0.1403699  -0.1403699   0.9900991  -1.0000000
28   42     37.2720     23.6180   0.9834660   0.1810931  -0.1810931   0.9834660  -1.0000000
29   42     37.5260     23.5750   0.9819075   0.1893611  -0.1893611   0.9819075  -1.0000000
30   42     37.8060     23.5300   0.9843979   0.1759569  -0.1759569   0.9843979  -1.0000000
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 4   43     23.8000     56.8750   0.9944351  -0.1053515   0.1053515   0.9944351  -1.0000000
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 7   43     25.1120     58.5500   0.9885548   0.1508618  -0.1508618   0.9885548  -1.0000000
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24   43     36.4860     24.3910   0.9547542   0.2973960  -0.2973960   0.9547542  -1.0000000
25   43     36.6650     24.3430   0.9835840   0.1804507  -0.1804507   0.9835840  -1.0000000
26   43     36.9070     24.2960   0.9797590   0.2001808  -0.2001808   0.9797590  -1.0000000
27   43     37.1480     24.2450   0.9768392   0.2139748  -0.2139748   0.9768392  -1.0000000
28   43     37.3940     24.1910   0.9750853   0.2218301  -0.2218301   0.9750853  -1.0000000
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  5   46     22.2000     57.6950   0.3963514  -0.9180989   0.9180989   0.3963514  -0.0100000
  7   46     24.4130     59.0880   0.1706729  -0.9853277   0.9853277   0.1706729  -1.0000000
  8   46     24.4130     59.0880   0.1706729  -0.9853277   0.9853277   0.1706729  -0.0100000
 22   46     36.4310     26.2920   0.9851137   0.1719037  -0.1719037   0.9851137  -1.0000000
 23   46     36.6960     26.2360   0.9772605   0.2120425  -0.2120425   0.9772605  -1.0000000
 24   46     36.8690     26.2010   0.9822542   0.1875545  -0.1875545   0.9822542  -1.0000000
 25   46     37.0520     26.1730   0.9820345   0.1887013  -0.1887013   0.9820345  -1.0000000
 26   46     37.3100     26.1330   0.9848358   0.1734891  -0.1734891   0.9848358  -1.0000000
 27   46     37.5590     26.0970   0.9860556   0.1664166  -0.1664166   0.9860556  -1.0000000
 28   46     37.7930     26.0550   0.9820862   0.1884321  -0.1884321   0.9820862  -1.0000000
 43   46     34.1750     60.6380   0.5301558   0.8479002  -0.8479002   0.5301558  -1.0000000
 44   46     34.1750     60.6380   0.5301558   0.8479002  -0.8479002   0.5301558  -0.0100000
  4   47     21.6120     57.9200   0.1464948  -0.9892114   0.9892114   0.1464948  -1.0000000
  5   47     21.6120     57.9200   0.1464948  -0.9892114   0.9892114   0.1464948  -0.0100000
  7   47     24.2630     59.3750   0.9562553  -0.2925336   0.2925336   0.9562553  -1.0000000
  8   47     24.2630     59.3750   0.9562553  -0.2925336   0.2925336   0.9562553  -0.0100000
 22   47     36.5060     26.8930   0.9929683   0.1183803  -0.1183803   0.9929683  -1.0000000
 23   47     36.7830     26.8490   0.9917006   0.1285683  -0.1285683   0.9917006  -1.0000000
 24   47     36.9760     26.8380   0.9980386  -0.0626007   0.0626007   0.9980386  -1.0000000
 25   47     37.1510     26.8430   0.9975356   0.0701625  -0.0701625   0.9975356  -1.0000000
 26   47     37.3890     26.8300   0.9992295   0.0392482  -0.0392482   0.9992295  -1.0000000
 27   47     37.6300     26.8190   0.9997009   0.0244566  -0.0244566   0.9997009  -1.0000000
 43   47     34.5500     60.5750  -0.9122413   0.4096533  -0.4096533  -0.9122413  -1.0000000
 44   47     34.5500     60.5750  -0.9122413   0.4096533  -0.4096533  -0.9122413  -0.0100000
  4   48     20.9380     58.0750   0.4587257  -0.8885779   0.8885779   0.4587257  -1.0000000
  5   48     20.9380     58.0750   0.4587257  -0.8885779   0.8885779   0.4587257  -0.0100000
  7   48     24.2120     59.9500   0.8217237  -0.5698861   0.5698861   0.8217237  -1.0000000
  8   48     24.2120     59.9500   0.8217237  -0.5698861   0.5698861   0.8217237  -0.0100000
 21   48     36.2130     27.4910   0.9973906  -0.0721946   0.0721946   0.9973906  -1.0000000
 22   48     36.5080     27.5060   0.9982136  -0.0597467   0.0597467   0.9982136  -1.0000000
 23   48     36.7850     27.5160   0.9985209  -0.0543693   0.0543693   0.9985209  -1.0000000
 24   48     36.9750     27.5260   0.9949672  -0.1002008   0.1002008   0.9949672  -1.0000000
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 28   48     37.8770     27.5540   0.9998484  -0.0174091   0.0174091   0.9998484  -1.0000000
 43   48     34.5880     59.9500  -0.9965926  -0.0824812   0.0824812  -0.9965926  -1.0000000
 44   48     34.5880     59.9500  -0.9965926  -0.0824812   0.0824812  -0.9965926  -0.0100000
  4   49     20.3370     58.4250   0.7024830  -0.7117006   0.7117006   0.7024830  -1.0000000
  5   49     20.3370     58.4250   0.7024830  -0.7117006   0.7117006   0.7024830  -0.0100000
  7   49     23.8880     60.1750  -0.1740423  -0.9847382   0.9847382  -0.1740423  -1.0000000
  8   49     23.8880     60.1750  -0.1740423  -0.9847382   0.9847382  -0.1740423  -0.0100000
 21   49     36.1360     28.1210   0.9899129  -0.1416776   0.1416776   0.9899129  -1.0000000
 22   49     36.4310     28.1580   0.9909456  -0.1342640   0.1342640   0.9909456  -1.0000000
 23   49     36.7150     28.1890   0.9932561  -0.1159412   0.1159412   0.9932561  -1.0000000
 24   49     36.9120     28.2040   0.9987404  -0.0501760   0.0501760   0.9987404  -1.0000000
 25   49     37.1010     28.2130   0.9976012  -0.0692236   0.0692236   0.9976012  -1.0000000
 26   49     37.3590     28.2280   0.9984771  -0.0551680   0.0551680   0.9984771  -1.0000000
 27   49     37.6050     28.2400   0.9982271  -0.0595206   0.0595206   0.9982271  -1.0000000
 28   49     37.8380     28.2630   0.9915454  -0.1297605   0.1297605   0.9915454  -1.0000000
 43   49     34.7870     59.3500  -0.7189829   0.6950278  -0.6950278  -0.7189829  -1.0000000
 44   49     34.7870     59.3500  -0.7189829   0.6950278  -0.6950278  -0.7189829  -0.0100000
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  8   50     23.6250     59.9380  -0.8744090  -0.4851896   0.4851896  -0.8744090  -0.0100000
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 22   50     36.3280     28.8420   0.9919519  -0.1266151   0.1266151   0.9919519  -1.0000000
 23   50     36.6230     28.8740   0.9926128  -0.1213249   0.1213249   0.9926128  -1.0000000
 24   50     36.8290     28.8890   0.9973666  -0.0725246   0.0725246   0.9973666  -1.0000000
 25   50     37.0350     28.9000   0.9950978  -0.0988962   0.0988962   0.9950978  -1.0000000
 26   50     37.3020     28.9190   0.9965158  -0.0834041   0.0834041   0.9965158  -1.0000000
 27   50     37.5370     28.9340   0.9957656  -0.0919290   0.0919290   0.9957656  -1.0000000
 28   50     37.7570     28.9340   0.9957656  -0.0919290   0.0919290   0.9957656  -1.0000000
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 22   51     36.2490     29.5550   0.9984819  -0.0550818   0.0550818   0.9984819  -1.0000000
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 24   51     36.7470     29.5740   0.9988502  -0.0479403   0.0479403   0.9988502  -1.0000000
 25   51     36.9660     29.5820   0.9980040  -0.0631503   0.0631503   0.9980040  -1.0000000
 27   51     37.5020     29.5990   0.9999764   0.0068682  -0.0068682   0.9999764  -1.0000000
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  8   52     23.1250     60.2370   0.8905388  -0.4549073   0.4549073   0.8905388  -0.0100000
 21   52     35.9040     30.2900   0.9997537   0.0221955  -0.0221955   0.9997537  -1.0000000
 22   52     36.2260     30.2780   0.9997140   0.0239155  -0.0239155   0.9997140  -1.0000000
 23   52     36.5080     30.2660   0.9996815   0.0252368  -0.0252368   0.9996815  -1.0000000
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 25   52     36.9470     30.2540   0.9996598   0.0260798  -0.0260798   0.9996598  -1.0000000
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  4   53     18.1880     58.9950  -0.2255335  -0.9742354   0.9742354  -0.2255335  -1.0000000
  5   53     18.1880     58.9950  -0.2255335  -0.9742354   0.9742354  -0.2255335  -1.0000000
  7   53     22.8370     60.8620   0.8944252  -0.4472176   0.4472176   0.8944252  -1.0000000
  8   53     22.8370     60.8620   0.8944252  -0.4472176   0.4472176   0.8944252  -0.0100000
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 21   53     35.9150     30.9760   0.9997212   0.0236134  -0.0236134   0.9997212  -1.0000000
 22   53     36.2370     30.9730   0.9999347   0.0114232  -0.0114232   0.9999347  -1.0000000
 23   53     36.5270     30.9720   0.9995725   0.0292360  -0.0292360   0.9995725  -1.0000000
 24   53     36.7390     30.9640   0.9969051   0.0786149  -0.0786149   0.9969051  -1.0000000
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28   53     37.7660     30.9030   0.9978903   0.0649225  -0.0649225   0.9978903  -1.0000000
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44   53     36.2870     59.2320  -0.8934140   0.4492344  -0.4492344  -0.8934140  -0.0100000
 4   54     17.6250     58.9950   0.1975061  -0.9803017   0.9803017   0.1975061  -1.0000000
 5   54     17.6250     58.9950   0.1975061  -0.9803017   0.9803017   0.1975061  -1.0000000
 7   54     22.4750     61.3880   0.6324716  -0.7745836   0.7745836   0.6324716  -1.0000000
 8   54     22.4750     61.3880   0.6324716  -0.7745836   0.7745836   0.6324716  -0.0100000
20   54     35.5520     31.5130   0.9975114  -0.0705053   0.0705053   0.9975114  -1.0000000
21   54     36.2370     31.5130   0.9975114  -0.0705053   0.0705053   0.9975114  -1.0000000
24   54     36.7770     31.6050   0.9997712   0.0213893  -0.0213893   0.9997712  -1.0000000
25   54     36.9980     31.6090   0.9998575  -0.0168831   0.0168831   0.9998575  -1.0000000
26   54     37.3010     31.6150   0.9999893  -0.0046180   0.0046180   0.9999893  -1.0000000
27   54     37.5840     31.6110   0.9992100   0.0397417  -0.0397417   0.9992100  -1.0000000
43   54     36.4250     58.6750  -0.9341418   0.3569020  -0.3569020  -0.9341418  -1.0000000
44   54     36.4250     58.6750  -0.9341418   0.3569020  -0.3569020  -0.9341418  -0.0100000
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 5   55     17.0750     59.0750  -0.0415583  -0.9991361   0.9991361  -0.0415583  -1.0000000
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 8   55     22.1380     61.9630   0.8607903  -0.5089598   0.5089598   0.8607903  -0.0100000
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21   55     36.2370     31.9310   0.9681812  -0.2502502   0.2502502   0.9681812  -1.0000000
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25   55     36.9090     32.3200   0.9685498  -0.2488196   0.2488196   0.9685498  -1.0000000
26   55     37.1960     32.4030   0.9680122  -0.2509030   0.2509030   0.9680122  -1.0000000
27   55     37.4790     32.4810   0.9709209  -0.2394007   0.2394007   0.9709209  -1.0000000
43   55     36.7000     58.2750  -0.2756825   0.9612488  -0.9612488  -0.2756825  -1.0000000
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 4   56     16.5870     58.7370  -0.7071068  -0.7071068   0.7071068  -0.7071068  -1.0000000
 5   56     16.5870     58.7370  -0.7071068  -0.7071068   0.7071068  -0.7071068  -1.0000000
 7   56     22.0500     62.6620   0.9816423  -0.1907311   0.1907311   0.9816423  -1.0000000
 8   56     22.0500     62.6620   0.9816423  -0.1907311   0.1907311   0.9816423  -0.0100000
20   56     35.3380     32.3790   0.9203100  -0.3911899   0.3911899   0.9203100  -1.0000000
21   56     35.6330     32.5100   0.9101977  -0.4141740   0.4141740   0.9101977  -1.0000000
22   56     35.9310     32.6480   0.9006951  -0.4344518   0.4344518   0.9006951  -1.0000000
23   56     36.2470     32.8030   0.8816995  -0.4718114   0.4718114   0.8816995  -1.0000000
24   56     36.4610     32.9180   0.8514692  -0.5244046   0.5244046   0.8514692  -1.0000000
25   56     36.6480     33.0280   0.8733473  -0.4870980   0.4870980   0.8733473  -1.0000000
26   56     36.9210     33.1880   0.8755207  -0.4831806   0.4831806   0.8755207  -1.0000000
27   56     37.1750     33.3510   0.8494966  -0.5275940   0.5275940   0.8494966  -1.0000000
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21   57     35.3580     33.0230   0.8524539  -0.5228024   0.5228024   0.8524539  -1.0000000
22   57     35.6130     33.1860   0.8306066  -0.5568597   0.5568597   0.8306066  -1.0000000
23   57     35.8610     33.3560   0.7877274  -0.6160241   0.6160241   0.7877274  -1.0000000
24   57     36.0460     33.4890   0.7843815  -0.6202787   0.6202787   0.7843815  -1.0000000
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43   57     37.0000     59.0250   0.8006779   0.5990951  -0.5990951   0.8006779  -1.0000000
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 7   58     21.9380     64.0370   0.9910745  -0.1333093   0.1333093   0.9910745  -1.0000000
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23   58     35.4490     33.8910   0.8186513  -0.5742909   0.5742909   0.8186513  -1.0000000
24   58     35.6230     34.0160   0.8090318  -0.5877649   0.5877649   0.8090318  -1.0000000
25   58     35.8050     34.1440   0.8011975  -0.5984000   0.5984000   0.8011975  -1.0000000
26   58     36.0190     34.2900   0.8027360  -0.5963345   0.5963345   0.8027360  -1.0000000
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5   59     15.1000     57.9850  -0.0743757  -0.9972303   0.9972303  -0.0743757  -1.0000000
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 21   59     34.6680     34.1940   0.8854092  -0.4648124   0.4648124   0.8854092  -1.0000000
 22   59     34.8880     34.3060   0.8782620  -0.4781798   0.4781798   0.8782620  -1.0000000
 23   59     35.1630     34.4620   0.8703567  -0.4924219   0.4924219   0.8703567  -1.0000000
 24   59     35.2960     34.5360   0.8771753  -0.4801702   0.4801702   0.8771753  -1.0000000
 25   59     35.4790     34.6370   0.8807117  -0.4736528   0.4736528   0.8807117  -1.0000000
 26   59     35.7190     34.7630   0.8987764  -0.4384074   0.4384074   0.8987764  -1.0000000
 27   59     35.9950     34.9160   0.8831446  -0.4691010   0.4691010   0.8831446  -1.0000000
 43   59     37.6880     58.8250   0.6672976   0.7447912  -0.7447912   0.6672976  -1.0000000
 44   59     37.6880     58.8250   0.6672976   0.7447912  -0.7447912   0.6672976  -0.0100000
  4   60     14.5000     57.8450  -0.1527375  -0.9882668   0.9882668  -0.1527375  -1.0000000
  5   60     14.5000     57.8450  -0.1527375  -0.9882668   0.9882668  -0.1527375  -1.0000000
  7   60     21.6380     65.1370   0.7839124  -0.6208714   0.6208714   0.7839124  -1.0000000
  8   60     21.6380     65.1370   0.7839124  -0.6208714   0.6208714   0.7839124  -0.0100000
 21   60     34.3250     34.8170   0.8981718  -0.4396447   0.4396447   0.8981718  -1.0000000
 22   60     34.6250     34.8170   0.8981718  -0.4396447   0.4396447   0.8981718  -1.0000000
 23   60     34.9010     34.9680   0.8881603  -0.4595336   0.4595336   0.8881603  -1.0000000
 24   60     35.0370     35.0430   0.8816512  -0.4719016   0.4719016   0.8816512  -1.0000000
 25   60     35.2260     35.1390   0.9049813  -0.4254515   0.4254515   0.9049813  -1.0000000
 26   60     35.4850     35.2570   0.9074348  -0.4201930   0.4201930   0.9074348  -1.0000000
 27   60     35.7610     35.3860   0.8922241  -0.4515930   0.4515930   0.8922241  -1.0000000
 28   60     36.0310     35.5220   0.8705022  -0.4921645   0.4921645   0.8705022  -1.0000000
 43   60     38.0750     59.3380   0.8695643   0.4938197  -0.4938197   0.8695643  -1.0000000
 44   60     38.0750     59.3380   0.8695643   0.4938197  -0.4938197   0.8695643  -0.0100000
  4   61     13.9000     57.6750  -0.1221857  -0.9925073   0.9925073  -0.1221857  -1.0000000
  5   61     13.9000     57.6750  -0.1221857  -0.9925073   0.9925073  -0.1221857  -1.0000000
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  8   61     21.1380     65.3500   0.0489322  -0.9988021   0.9988021   0.0489322  -0.0100000
 21   61     34.1650     35.3040   0.9083694  -0.4181688   0.4181688   0.9083694  -1.0000000
 22   61     34.3950     35.3040   0.9083694  -0.4181688   0.4181688   0.9083694  -1.0000000
 23   61     34.6210     35.4050   0.9023107  -0.4310863   0.4310863   0.9023107  -1.0000000
 24   61     34.8100     35.5070   0.8565553  -0.5160553   0.5160553   0.8565553  -1.0000000
 25   61     35.0050     35.6050   0.9167880  -0.3993741   0.3993741   0.9167880  -1.0000000
 27   61     35.5390     35.8280   0.9083964  -0.4181101   0.4181101   0.9083964  -1.0000000
 28   61     35.8020     35.9550   0.8976976  -0.4406120   0.4406120   0.8976976  -1.0000000
 29   61     36.0810     36.0500   0.8976976  -0.4406120   0.4406120   0.8976976  -1.0000000
 43   61     38.4870     59.8880   0.6370447   0.7708268  -0.7708268   0.6370447  -1.0000000
 44   61     38.4870     59.8880   0.6370447   0.7708268  -0.7708268   0.6370447  -0.0100000
  4   62     13.2500     57.5750  -0.0356462  -0.9993645   0.9993645  -0.0356462  -1.0000000
  5   62     13.2500     57.5750  -0.0356462  -0.9993645   0.9993645  -0.0356462  -1.0000000
  7   62     20.5380     65.4250   0.0995512  -0.9950324   0.9950324   0.0995512  -1.0000000
  8   62     20.5380     65.4250   0.0995512  -0.9950324   0.9950324   0.0995512  -0.0100000
 21   62     33.9500     35.8500   0.9598657  -0.2804601   0.2804601   0.9598657  -1.0000000
 22   62     34.1840     35.8500   0.9598657  -0.2804601   0.2804601   0.9598657  -1.0000000
 23   62     34.4110     35.9140   0.9555624  -0.2947889   0.2947889   0.9555624  -1.0000000
 24   62     34.5830     35.9700   0.9160641  -0.4010320   0.4010320   0.9160641  -1.0000000
 25   62     34.8030     36.0450   0.9329047  -0.3601233   0.3601233   0.9329047  -1.0000000
 27   62     35.3740     36.2270   0.9485602  -0.3165967   0.3165967   0.9485602  -1.0000000
 28   62     35.6510     36.3240   0.9442009  -0.3293700   0.3293700   0.9442009  -1.0000000
 29   62     35.9310     36.3940   0.9442009  -0.3293700   0.3293700   0.9442009  -1.0000000
 43   62     39.0250     60.0880  -0.0574046   0.9983510  -0.9983510  -0.0574046  -1.0000000
 44   62     39.0250     60.0880  -0.0574046   0.9983510  -0.9983510  -0.0574046  -0.0100000
  4   63     12.5250     57.5920   0.1711236  -0.9852496   0.9852496   0.1711236  -1.0000000
  5   63     12.5250     57.5920   0.1711236  -0.9852496   0.9852496   0.1711236  -1.0000000
  7   63     19.9380     65.5000  -0.1947787  -0.9808472   0.9808472  -0.1947787  -1.0000000
  8   63     19.9380     65.5000  -0.1947787  -0.9808472   0.9808472  -0.1947787  -0.0100000
 21   63     33.8800     36.5530   0.9998210   0.0189193  -0.0189193   0.9998210  -1.0000000
 22   63     34.1050     36.5530   0.9998210   0.0189193  -0.0189193   0.9998210  -1.0000000
 23   63     34.3260     36.5530   0.9999964   0.0026806  -0.0026806   0.9999964  -1.0000000
 24   63     34.4890     36.5470   0.9965425   0.0830845  -0.0830845   0.9965425  -1.0000000
 25   63     34.7040     36.5580   0.9988645  -0.0476422   0.0476422   0.9988645  -1.0000000
 26   63     35.0060     36.5930   0.9943762  -0.1059052   0.1059052   0.9943762  -1.0000000
 27   63     35.2910     36.6250   0.9950503  -0.0993730   0.0993730   0.9950503  -1.0000000
 28   63     35.5870     36.6470   0.9975940  -0.0693269   0.0693269   0.9975940  -1.0000000
 43   63     39.6250     60.2000   0.2470855   0.9689937  -0.9689937   0.2470855  -1.0000000
 44   63     39.6250     60.2000   0.2470855   0.9689937  -0.9689937   0.2470855  -0.0100000
  4   64     11.9050     57.8050   0.6183338  -0.7859156   0.7859156   0.6183338  -1.0000000
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  7   64     19.3000     65.2750  -0.2609794  -0.9653444   0.9653444  -0.2609794  -1.0000000
  8   64     19.3000     65.2750  -0.2609794  -0.9653444   0.9653444  -0.2609794  -0.0100000
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 25   64     34.7620    37.1530   0.9909816   0.1339979  -0.1339979   0.9909816  -1.0000000
 26   64     35.0140    37.1350   0.9971902   0.0749107  -0.0749107   0.9971902  -1.0000000
 27   64     35.2980    37.1150   0.9952444   0.0974089  -0.0974089   0.9952444  -1.0000000
 28   64     35.6000    37.0810   0.9932615   0.1158948  -0.1158948   0.9932615  -1.0000000
 43   64     40.0130    60.0370  -0.8443334   0.5358183  -0.5358183  -0.8443334  -1.0000000
 44   64     40.0130    60.0370  -0.8443334   0.5358183  -0.5358183  -0.8443334  -0.0100000
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  7   65     18.6880    65.2250   0.3076707  -0.9514929   0.9514929   0.3076707  -1.0000000
  8   65     18.6880    65.2250   0.3076707  -0.9514929   0.9514929   0.3076707  -0.0100000
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 25   65     34.8450    37.7860   0.9948414   0.1014425  -0.1014425   0.9948414  -1.0000000
 26   65     35.0840    37.7610   0.9941316   0.1081773  -0.1081773   0.9941316  -1.0000000
 27   65     35.3040    37.6610   0.9941316   0.1081773  -0.1081773   0.9941316  -1.0000000
 43   65     40.1120    59.3880   0.9684899  -0.2490529   0.2490529   0.9684899  -1.0000000
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 21   66     34.0540    38.4830   0.9937400   0.1117173  -0.1117173   0.9937400  -1.0000000
 22   66     34.3310    38.4640   0.9956812   0.0928388  -0.0928388   0.9956812  -1.0000000
 23   66     34.5510    38.4320   0.9826409   0.1855181  -0.1855181   0.9826409  -1.0000000
 24   66     34.7210    38.4010   0.9961902   0.0872063  -0.0872063   0.9961902  -1.0000000
 25   66     34.8910    38.3880   0.9976149   0.0690250  -0.0690250   0.9976149  -1.0000000
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 44   66     40.3750    58.9000  -0.4631031   0.8863044  -0.8863044  -0.4631031  -0.0100000
  4   67     11.2550    59.3880   0.6386882  -0.7694656   0.7694656   0.6386882  -1.0000000
  5   67     11.2550    59.3880   0.6386882  -0.7694656   0.7694656   0.6386882  -1.0000000
  7   67     17.6750    66.1250   0.9341418  -0.3569020   0.3569020   0.9341418  -1.0000000
  8   67     17.6750    66.1250   0.9341418  -0.3569020   0.3569020   0.9341418  -0.0100000
 18   67     33.3940    39.1580   0.9992611  -0.0384342   0.0384342   0.9992611  -1.0000000
 19   67     33.5960    39.1650   0.9992186  -0.0395252   0.0395252   0.9992186  -1.0000000
 20   67     33.8200    39.1620   0.9998428   0.0177342  -0.0177342   0.9998428  -1.0000000
 23   67     34.5950    38.9590   0.9913591   0.1311760  -0.1311760   0.9913591  -1.0000000
 24   67     34.7650    38.9340   0.9972720   0.0738143  -0.0738143   0.9972720  -1.0000000
 25   67     34.9290    38.9280   0.9993833   0.0351133  -0.0351133   0.9993833  -1.0000000
 43   67     40.9250    58.7700   0.0362918   0.9993412  -0.9993412   0.0362918  -1.0000000
 44   67     40.9250    58.7700   0.0362918   0.9993412  -0.9993412   0.0362918  -0.0100000
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 19   68     33.5270    39.9440   0.9935773  -0.1131556   0.1131556   0.9935773  -1.0000000
 24   68     34.8080    39.5750   0.9994620   0.0327986  -0.0327986   0.9994620  -1.0000000
 43   68     41.4870    58.8570   0.1893369   0.9819122  -0.9819122   0.1893369  -1.0000000
 44   68     41.4870    58.8570   0.1893369   0.9819122  -0.9819122   0.1893369  -0.0100000
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  5   69     10.1580    59.9550   0.6740256  -0.7387080   0.7387080   0.6740256  -1.0000000
  7   69     17.4620    67.5000   0.9847905  -0.1737459   0.1737459   0.9847905  -1.0000000
  8   69     17.4620    67.5000   0.9847905  -0.1737459   0.1737459   0.9847905  -0.0100000
 17   69     33.1970    40.6920   0.9840309  -0.1779976   0.1779976   0.9840309  -0.0100000
 18   69     33.1970    40.6920   0.9840309  -0.1779976   0.1779976   0.9840309  -1.0000000
 19   69     33.3990    40.7230   0.9837608  -0.1794844   0.1794844   0.9837608  -1.0000000
 23   69     34.6400    40.2230   0.9997077   0.0241757  -0.0241757   0.9997077  -1.0000000
 24   69     34.8290    40.2100   0.9999974  -0.0022844   0.0022844   0.9999974  -1.0000000
 43   69     41.9870    59.1250   0.5723556   0.8200055  -0.8200055   0.5723556  -1.0000000
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  5   70      9.7900    60.1620   0.5019256  -0.8649108   0.8649108   0.5019256  -1.0000000
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19   70     33.2310     41.4620   0.9806373  -0.1958329   0.1958329   0.9806373  -1.0000000
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24   70     34.8080     40.7430   0.9997869  -0.0206469   0.0206469   0.9997869  -1.0000000
43   70     42.4750     59.5850   0.6230873   0.7821523  -0.7821523   0.6230873  -1.0000000
44   70     42.4750     59.5850   0.6230873   0.7821523  -0.7821523   0.6230873  -0.0100000
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 5   71      9.4325     60.0620   0.1084285  -0.9941043   0.9941043   0.1084285  -1.0000000
 7   71     17.0250     68.8500   0.6407458  -0.7677531   0.7677531   0.6407458  -1.0000000
 8   71     17.0250     68.8500   0.6407458  -0.7677531   0.7677531   0.6407458  -0.0100000
17   71     32.8710     42.1890   0.9917078  -0.1285131   0.1285131   0.9917078  -0.0100000
18   71     32.8710     42.1890   0.9917078  -0.1285131   0.1285131   0.9917078  -1.0000000
19   71     33.0910     42.2150   0.9929819  -0.1182664   0.1182664   0.9929819  -1.0000000
23   71     34.6290     41.2900   0.9954019   0.0957862  -0.0957862   0.9954019  -1.0000000
24   71     34.8240     41.2710   0.9938225   0.1109816  -0.1109816   0.9938225  -1.0000000
43   71     43.0620     60.0100   0.4570889   0.8894210  -0.8894210   0.4570889  -1.0000000
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 7   72     16.5130     69.2500   0.2858175  -0.9582841   0.9582841   0.2858175  -1.0000000
18   72     32.6880     42.9430   0.9531692  -0.3024376   0.3024376   0.9531692  -1.0000000
19   72     32.8960     43.0000   0.9531636  -0.3024552   0.3024552   0.9531636  -1.0000000
23   72     34.7090     41.7850   0.9730717   0.2305028  -0.2305028   0.9730717  -1.0000000
24   72     34.9040     41.7400   0.9762105   0.2168251  -0.2168251   0.9762105  -1.0000000
43   72     43.6250     60.3250   0.4178606   0.9085112  -0.9085112   0.4178606  -1.0000000
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19   73     32.5130     43.8000   0.8829616  -0.4694452   0.4694452   0.8829616  -1.0000000
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24   73     34.9950     42.1840   0.9786102   0.2057235  -0.2057235   0.9786102  -1.0000000
43   73     44.2370     60.5200   0.1495430   0.9887552  -0.9887552   0.1495430  -1.0000000
44   73     44.2370     60.5200   0.1495430   0.9887552  -0.9887552   0.1495430  -0.0100000
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19   74     32.0570     44.4290   0.8754952  -0.4832268   0.4832268   0.8754952  -1.0000000
23   74     34.9240     42.6660   0.9686953   0.2482525  -0.2482525   0.9686953  -1.0000000
24   74     35.0820     42.6340   0.9829894   0.1836624  -0.1836624   0.9829894  -1.0000000
43   74     44.9630     60.6200   0.1629133   0.9866404  -0.9866404   0.1629133  -1.0000000
44   74     44.9630     60.6200   0.1629133   0.9866404  -0.9866404   0.1629133  -0.0100000
 4   75      8.2275     61.6380   0.9511582  -0.3087040   0.3087040   0.9511582  -1.0000000
5    75      8.2275     61.6380   0.9511582  -0.3087040   0.3087040   0.9511582  -1.0000000
18   75     31.8430     44.9810   0.9966757  -0.0814712   0.0814712   0.9966757  -0.0100000
19   75     31.8430     44.9810   0.9966757  -0.0814712   0.0814712   0.9966757  -1.0000000
23   75     35.0350     43.0900   0.9773861   0.2114628  -0.2114628   0.9773861  -1.0000000
24   75     35.1680     43.0650   0.9813164   0.1924011  -0.1924011   0.9813164  -1.0000000
43   75     45.6120     60.7870   0.3792095   0.9253109  -0.9253109   0.3792095  -1.0000000
44   75     45.6120     60.7870   0.3792095   0.9253109  -0.9253109   0.3792095  -0.0100000
 4   76      7.9500     61.9000   0.1601805  -0.9870877   0.9870877   0.1601805  -1.0000000
 5   76      7.9500     61.9000   0.1601805  -0.9870877   0.9870877   0.1601805  -1.0000000
18   76     31.7810     45.5770   0.9644126  -0.2644018   0.2644018   0.9644126  -0.0100000
19   76     31.7810     45.5770   0.9644126  -0.2644018   0.2644018   0.9644126  -1.0000000
23   76     35.1350     43.5460   0.9788923   0.2043765  -0.2043765   0.9788923  -1.0000000
24   76     35.2740     43.5150   0.9694539   0.2452736  -0.2452736   0.9694539  -1.0000000
43   76     46.1750     61.0880   0.5301558   0.8479002  -0.8479002   0.5301558  -1.0000000
44   76     46.1750     61.0880   0.5301558   0.8479002  -0.8479002   0.5301558  -0.0100000
 4   77      7.5625     62.1380   0.7725407  -0.6349652   0.6349652   0.7725407  -1.0000000
 5   77      7.5625     62.1380   0.7725407  -0.6349652   0.6349652   0.7725407  -1.0000000
18   77     31.8620     46.1610   0.9407222   0.3391779  -0.3391779   0.9407222  -0.0100000
19   77     31.8620     46.1610   0.9407222   0.3391779  -0.3391779   0.9407222  -1.0000000
23   77     35.2170     44.0410   0.9972686   0.0738612  -0.0738612   0.9972686  -1.0000000
24   77     35.3680     44.0220   0.9868888   0.1614020  -0.1614020   0.9868888  -1.0000000
43   77     46.7630     61.3620   0.5048463   0.8632092  -0.8632092   0.5048463  -1.0000000
44   77     46.7630     61.3620   0.5048463   0.8632092  -0.8632092   0.5048463  -0.0100000
 4   78      7.2700     62.6450   0.5539256  -0.8325662   0.8325662   0.5539256  -1.0000000
5   78     7.2700     62.6450   0.5539256  -0.8325662   0.8325662   0.5539256  -1.0000000
19   78     32.0820     46.7960   0.9803649   0.1971922  -0.1971922   0.9803649  -1.0000000
24   78     35.3280     44.5190   0.9819896  -0.1889350   0.1889350   0.9819896  -1.0000000
43   78     47.2750     61.7500   0.8320503   0.5547002  -0.5547002   0.8320503  -1.0000000
44   78     47.2750     61.7500   0.8320503   0.5547002  -0.5547002   0.8320503  -0.0100000
 4   79      6.7950     62.6500  -0.3218375  -0.9467949   0.9467949  -0.3218375  -1.0000000
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5   79      6.7950     62.6500  -0.3218375  -0.9467949   0.9467949  -0.3218375  -1.0000000
22   79     34.9190     44.8930   0.9080355  -0.4188932   0.4188932   0.9080355  -1.0000000
23   79     35.0390     44.9500   0.9217742  -0.3877271   0.3877271   0.9217742  -1.0000000
24   79     35.1770     44.9940   0.9677365  -0.2519643   0.2519643   0.9677365  -1.0000000
43   79     47.6500     62.3000   0.8591530   0.5117188  -0.5117188   0.8591530  -1.0000000
44   79     47.6500     62.3000   0.8591530   0.5117188  -0.5117188   0.8591530  -1.0000000
 4   80      6.2000     62.5620   0.3957258  -0.9183687   0.9183687   0.3957258  -1.0000000
 5   80      6.2000     62.5620   0.3957258  -0.9183687   0.9183687   0.3957258  -1.0000000
21   80     34.5790     45.2610   0.3922861  -0.9198433   0.9198433   0.3922861  -0.0100000
22   80     34.5790     45.2610   0.3922861  -0.9198433   0.9198433   0.3922861  -1.0000000
24   80     35.1270     45.5270   0.9896071   0.1437977  -0.1437977   0.9896071  -1.0000000
43   80     47.9870     62.8250   0.8646075   0.5024480  -0.5024480   0.8646075  -1.0000000
44   80     47.9870     62.8250   0.8646075   0.5024480  -0.5024480   0.8646075  -1.0000000
 4   81      5.8175     62.9580   0.8627293  -0.5056661   0.5056661   0.8627293  -1.0000000
 5   81      5.8175     62.9580   0.8627293  -0.5056661   0.5056661   0.8627293  -1.0000000
21   81     34.0510     45.3300   0.0077300  -0.9999701   0.9999701   0.0077300  -1.0000000
22   81     34.0510     45.3300   0.0077300  -0.9999701   0.9999701   0.0077300  -1.0000000
24   81     35.2770     46.0860   0.8954697   0.4451226  -0.4451226   0.8954697  -1.0000000
43   81     48.1570     63.6050   1.0000000   0.0000000  -0.0000000   1.0000000  -1.0000000
44   81     48.1570     63.6050   1.0000000   0.0000000  -0.0000000   1.0000000  -1.0000000
 4   82      5.3925     63.2500   0.1675430  -0.9858648   0.9858648   0.1675430  -1.0000000
 5   82      5.3925     63.2500   0.1675430  -0.9858648   0.9858648   0.1675430  -1.0000000
43   82     47.5570     65.0350  -0.8443334   0.5358183  -0.5358183  -0.8443334  -1.0000000
44   82     47.5570     65.0350  -0.8443334   0.5358183  -0.5358183  -0.8443334  -1.0000000
 4   83      4.7575     63.1750  -0.2896261  -0.9571398   0.9571398  -0.2896261  -1.0000000
 5   83      4.7575     63.1750  -0.2896261  -0.9571398   0.9571398  -0.2896261  -1.0000000
43   83     46.9900     66.4000   1.0000000   0.0000000  -0.0000000   1.0000000  -1.0000000
44   83     46.9900     66.4000   1.0000000   0.0000000  -0.0000000   1.0000000  -1.0000000
 4   84      4.1875     63.2000   0.2911504  -0.9566773   0.9566773   0.2911504  -1.0000000
 5   84      4.1875     63.2000   0.2911504  -0.9566773   0.9566773   0.2911504  -1.0000000
43   84     46.4300     67.2800  -0.7189829   0.6950278  -0.6950278  -0.7189829  -1.0000000
44   84     46.4300     67.2800  -0.7189829   0.6950278  -0.6950278  -0.7189829  -1.0000000
 4   85      3.7200     63.5500   0.7358159  -0.6771816   0.6771816   0.7358159  -1.0000000
 5   85      3.7200     63.5500   0.7358159  -0.6771816   0.6771816   0.7358159  -1.0000000
43   85     45.7200     68.9000   0.9884899  -0.1512869   0.1512869   0.9884899  -1.0000000
44   85     45.7200     68.9000   0.9884899  -0.1512869   0.1512869   0.9884899  -1.0000000
43   86     45.5500     70.8500   1.0000000   0.0000000  -0.0000000   1.0000000  -1.0000000
44   86     45.4500     70.8500   1.0000000   0.0000000  -0.0000000   1.0000000  -1.0000000
43   87     45.3000     72.9700   0.9684899  -0.2490529   0.2490529   0.9684899  -1.0000000
44   87     45.4500     72.9700   1.0000000   0.0000000  -0.0000000   1.0000000  -1.0000000
43   88     45.6700     75.0500   0.7587842   0.6513421  -0.6513421   0.7587842  -1.0000000
44   88     45.6700     75.0500   0.7587842   0.6513421  -0.6513421   0.7587842  -1.0000000
43   89     46.4100     77.1600   1.0000000   0.0000000  -0.0000000   1.0000000  -1.0000000
44   89     46.4100     77.1600   1.0000000   0.0000000  -0.0000000   1.0000000  -1.0000000
43   90     47.2800     79.0800   0.6587842   0.7523320  -0.7523320   0.6587842  -1.0000000
44   90     47.2800     79.0800   0.6587842   0.7523320  -0.7523320   0.6587842  -1.0000000
43   91     47.5800     80.5800  -0.8443334   0.5358183  -0.5358183  -0.8443334  -1.0000000
44   91     47.5800     80.5800  -0.8443334   0.5358183  -0.5358183  -0.8443334  -1.0000000
43   92     47.5700     82.4800   0.9219567   0.3872930  -0.3872930   0.9219567  -1.0000000
44   92     47.5500     82.4800   0.9219567   0.3872930  -0.3872930   0.9219567  -1.0000000
43   93     46.9700     83.5300   0.0669665   0.9977552  -0.9977552   0.0669665  -1.0000000
44   93     46.9700     83.6300   0.0669665   0.9977552  -0.9977552   0.0669665  -1.0000000
43   94     45.5100     83.9000  -0.6443334   0.7647447  -0.7647447  -0.6443334  -1.0000000
44   94     45.5100     83.9000  -0.6443334   0.7647447  -0.7647447  -0.6443334  -1.0000000
43   95     44.4500     84.6000  -0.4443334   0.8958615  -0.8958615  -0.4443334  -1.0000000
44   95     44.4500     84.6000  -0.4443334   0.8958615  -0.8958615  -0.4443334  -1.0000000
43   96     43.1300     84.8000   0.0669665   0.9977552  -0.9977552   0.0669665  -1.0000000
44   96     43.1300     84.8000   0.0669665   0.9977552  -0.9977552   0.0669665  -1.0000000
43   97     42.1100     84.9700  -0.6443334   0.7647447  -0.7647447  -0.6443334  -1.0000000
44   97     42.1100     84.9700  -0.6443334   0.7647447  -0.7647447  -0.6443334  -1.0000000
```

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 -------------------------------------------------------------------------------
C71B FOOD CHAIN MODEL OUTPUT CONTROL
C
     ISFDCH: 1 TO WRITE OUTPUT FOR HOUSATONIC RIVER FOOD CHAIN MODEL
     NFDCHZ: NUMBER OF SPATIAL ZONES
     HBFDCH: AVERAGING DEPTH FOR TOP PORTION OF BED (METERS)
     TFCAVG: TIME AVERAGING INTERVAL FOR FOOD CHAIN OUTPUT (SECONDS)
C
C71B ISFDCH   NFDCHZ   HBFDCH    TFCAVG
     0         5       0.1524    86400.
-------------------------------------------------------------------------------C72
CONTROLS FOR HORIZONTAL SURFACE ELEVATION OR PRESSURE CONTOURING          |
C72 CONTROLS FOR HORIZONTAL SURFACE ELEVATION OR PRESSURE CONTOURING          |
 C                                                                             |
       ISPPH:  1 TO WRITE FILE FOR SURF ELEVATION CONTOURING                   |
|
               2 WRITE ONLY DURING LAST REFERENCE TIME PERIOD                  |
|
       NPPPH:    NUMBER OF WRITES PER REFERENCE TIME PERIOD                    |
       ISRPPH: 1 TO WRITE FILE FOR RESIDUAL SURFACE ELEVATION  CONTOURNG IN    |
                 HORIZONTAL PLANE                                              |
       IPPHXY: 0 DOES NOT WRITE I,J,X,Y IN surfplt.out and rsurfplt.out FILES  |
               1 WRITES I,J ONLY IN surfplt.out and rsurfplt.out FILES         |
               2 WRITES I,J,X,Y  IN surfplt.out and rsurfplt.out FILES         |
               3 WRITES EFDC EXPLORER BINARY FORMAT FILES                      |
 C                                                                              |
 C72 ISPPH   NPPPH   ISRPPH     IPPHXY                                         |
     0       4       0          0
 -------------------------------------------------------------------------------
 C73 CONTROLS FOR HORIZONTAL PLANE VELOCITY VECTOR PLOTTING                    |
 C                                                                             |
       ISVPH:  1 TO WRITE FILE FOR VELOCITY PLOTTING IN HORIZONTAL PLANE       |
               2 WRITE ONLY DURING LAST REFERENCE TIME PERIOD                  |
       NPVPH:    NUMBER OF WRITES PER REFERENCE TIME PERIOD                    |
       ISRVPH: 1 TO WRITE FILE FOR RESIDUAL VELOCITY PLOTTIN IN                |
                 HORIZONTAL PLANE                                              |
       IVPHXY: 0 DOES NOT WRITE I,J,X,Y IN velplth.out and rvelplth.out FILES  |
               1 WRITES I,J ONLY IN velplth.out and rvelplth.out FILES         |
               2 WRITES I,J,X,Y  IN velplth.out and rvelplth.out FILES         |
               3 WRITES EFDC EXPLORER BINARY FORMAT FILES                      |
 C                                                                             |
 C73 ISVPH   NPVPH   ISRVPH  IVPHXY                                             |
     0       24      0        3
 -------------------------------------------------------------------------------
 C74 CONTROLS FOR VERTICAL PLANE SCALAR FIELD CONTOURING                       |
 C                                                                             |
       ISECSPV:  N AN INTEGER NUMBER OF VERTICAL SECTIONS (N.LE.9) TO WRITE    |
                   N FILES FOR SCALAR  FIELD CONTOURING                        |
       NPSPV:      NUMBER OF WRITES PER REFERENCE TIME PERIOD                  |
       ISSPV:    1 TO ACTIVATE INSTANTANEOUS SCALAR FIELDS                     |
                 2 TO WRITE ONLY DURING LAST REFERENCE TIME PERIOD
       ISRSPV:   1 TO ACTIVATE FOR RESIDUAL SCALAR FIELDS                      |
       ISHPLTV:  1 FOR VERTICAL PLANE PLOTTING FOR MSL DATUMS, ZERO OTHERWISE  |
       DATA LINE REPEATS 7 TIMES FOR SAL,TEM,DYE,SFL,TOX,SED,SND               |
       ISECSPV IS DETERMINED FOR ALL 7 VARIABLES BY VALUE ON FIRST DATA LINE   |
 C                                                                             |
 C74 ISECSPV   NPSPV  ISSPV  ISRSPV  ISHPLTV                                    |
     1          6      0      0       1          !SAL
     0          6      0      0       1          !TEM
     0          6      0      0       1          !DYE
     0          6      0      0       1          !SFL
     0          6      0      0       1          !TOX
     0          6      0      0       1          !SED
```

```
    0          6      0      0       1          !SND
-------------------------------------------------------------------------------
C75 MORE CONTROLS FOR VERTICAL PLANE SCALAR FIELD CONTOURING                  |
C                                                                             |
      ISECSPV:  SECTION NUMBER                                                |
      NIJSPV:   NUMBER OF CELLS OR I,J PAIRS IN SECTION                       |
      SEC ID:   CHARACTER FORMAT SECTION TITLE                                |
C                                                                             |
C75 ISECSPV NIJSPV  SEC ID
    1       10      'test n-s printout'
|
-------------------------------------------------------------------------------
C76 I,J LOCATIONS FOR VERTICAL PLANE SCALAR FIELD CONTOURING                  |
C                                                                             |
      ISECSPV: SECTION NUMBER                                                 |
      ISPV:    I CELL                                                         |
      JSPV:    J CELL                                                         |
C                                                                             |
C76 ISECSPV ISPV    JSPV
    1       32      5
    1       32      6
    1       32      7
    1       32      8
    1       32      9
    1       32      10
    1       32      11
    1       32      12
    1       32      13
    1       32      14
-------------------------------------------------------------------------------
C77 CONTROLS FOR VERTICAL PLANE VELOCITY VECTOR PLOTTING                      |
C                                                                             |
      ISECVPV:  N AN INTEGER NUMBER (N.LE.9) OF VERTICAL SECTIONS             |
                  TO WRITE N FILES FOR VELOCITY PLOTTING                      |
      NPVPV:      NUMBER OF WRITES PER REFERENCE TIME PERIOD                  |
      ISVPV:    1 TO ACTIVATE INSTANTANEOUS VELOCITY                          |
                2 TO WRITE ONLY DURING LAST REFERENCE TIME PERIOD             |
      ISRSPV:   1 TO ACTIVATE FOR RESIDUAL VELOCITY                           |
C                                                                             |
C77 ISECVPV   NPVPV  ISVPV  ISRSPV                                            |
    0         6      0      0
-------------------------------------------------------------------------------
C78 MORE CONTROLS FOR VERTICAL PLANE VELOCITY VECTOR PLOTTING                 |
C                                                                             |
      ISCEVPV:  SECTION NUMBER                                                |
      NIJVPV:   NUMBER IS CELLS OR I,J PAIRS IN SECTION                       |
      ANGVPV:   CCW POSITIVE ANGLE FROM EAST TO SECTION NORMAL                |
      SEC ID:   CHARACTER FORMAT SECTION TITLE                                |
C                                                                             |
C78 ISECVPV   NIJVPV  ANGVPV  SEC ID                                          |
-------------------------------------------------------------------------------
C79 CONTROLS FOR VERTICAL PLANE VELOCITY PLOTTING                             |
C                                                                             |
      ISECVPV:  SECTION NUMBER (REFERENCE USE HERE)                           |
      IVPV:     I CELL INDEX                                                  |
      JVPV:     J CELL INDEX                                                  |
C                                                                             |
C79 ISECVPV IVPV    JVPV                                                      |
-------------------------------------------------------------------------------
C80 CONTROLS FOR 3D FIELD OUTPUT                                              |
C                                                                             |
      IS3DO:  1 TO WRITE TO 3D ASCI INTEGER FORMAT FILES, JS3Dvar.LE.2     SEE|
              1 TO WRITE TO 3D ASCI FLOAT POINT FORMAT FILES, JS3Dvar.EQ.3 C57|
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              2 TO WRITE TO 3D CHARACTER ARRAY FORMAT FILES (NOT ACTIVE)      |
              3 TO WRITE TO 3D HDF IMAGE FORMAT FILES (NOT ACTIVE)            |
              4 TO WRITE TO 3D HDF FLOATING POINT FORMAT FILES (NOT ACTIVE)   |
      ISR3DO:   SAME AS IS3DO EXCEPT FOR RESIDUAL VARIABLES                   |
      NP3DO:    NUMBER OF WRITES PER LAST REF TIME PERIOD FOR INST VARIABLES  |
      KPC:      NUMBER OF UNSTRETCHED PHYSICAL VERTICAL LAYERS                |
      NWGG:     IF NWGG IS GREATER THAN ZERO, NWGG DEFINES THE NUMBER OF !2877|
                WATER CELLS IN CARTESIAN 3D GRAPHICS GRID OVERLAY OF THE      |
                CURVILINEAR GRID. FOR NWGG>0 AND EFDC RUNS ON A CURVILINEAR   |
                GRID, I3DMI,I3DMA,J3DMI,J3DMA REFER TO CELL INDICES ON THE    |
                ON THE CARTESIAN GRAPHICS GRID OVERLAY DEFINED BY FILE        |
                gcell.inp.  THE FILE gcell.inp IS NOT USED BY EFDC, BUT BY    |
                THE COMPANION GRID GENERATION CODE GEFDC.F.  INFORMATION      |
                DEFINING THE OVERLAY IS READ BY EFDC.F FROM THE FILE          |
                gcellmp.inp. IF NWGG EQUALS 0, I3DMI,I3DMA,J3DMI,J3DMA REFER  |
                TO INDICES ON THE EFDC GRID DEFINED BY cell.inp.              |
                ACTIVATION OF THE REWRITE OPTION I3DRW=1 WRITES TO THE FULL   |
                GRID DEFINED BY cell.inp AS IF cell.inp DEFINES A CARTESIAN   |
                GRID.  IF NWGG EQ 0 AND THE EFDC COMP GRID IS CO, THE REWRITE |
                OPTION IS NOT RECOMMENDED AND A POST PROCESSOR SHOULD BE USED |
                TO TRANSFER THE SHORT FORM, I3DRW=0, OUTPUT TO AN APPROPRIATE |
                FORMAT FOR VISUALIZATION. CONTACT DEVELOPER FOR MORE DETAILS  |
      I3DMI:    MINIMUM OR BEGINNING I INDEX FOR 3D ARRAY OUTPUT              |
      I3DMA:    MAXIMUM OR ENDING I INDEX FOR 3D ARRAY OUTPUT                 |
      J3DMI:    MINIMUM OR BEGINNING J INDEX FOR 3D ARRAY OUTPUT              |
      J3DMA:    MAXIMUM OR ENDING J INDEX FOR 3D ARRAY OUTPUT                 |
      I3DRW:  0 FILES WRITTEN FOR ACTIVE CO WATER CELLS ONLY                  |
              1 REWRITE FILES TO CORRECT ORIENTATION DEFINED BY gcell.inp     |
                AND gcellmp.inp FOR CO WITH NWGG.GT.O OR BY cell.inp IF THE   |
                COMPUTATIONAL GRID IS CARTESIAN AND NWGG.EQ.0                 |
      SELVMAX:  MAXIMUM SURFACE ELEVATION FOR UNSTRETCHING (ABOVE MAX SELV )  |
      BELVMIN:  MINIMUM BOTTOM ELEVATION FOR UNSTRETCHING (BELOW MIN BELV)    |
C                                                                             |
C80 IS3DO ISR3DO NP3DO KPC NWGG I3DMI I3DMA J3DMI J3DMA I3DRW SELVMAX BELVMIN |
    0     0      0     1   0    1     42    1     118   0     15.0     -315.
-------------------------------------------------------------------------------
C81 OUTPUT ACTIVATION AND SCALES FOR 3D FIELD OUTPUT                          |
C                                                                             |
      VARIABLE:      DUMMY VARIBLE ID (DO NOT CHANGE ORDER)                   |
      IS3(VARID):  1 TO ACTIVATE THIS VARIBLES                                |
      JS3(VARID):  0 FOR NO SCALING OF THIS VARIABLE                          |
                   1 FOR AUTO SCALING OF THIS VARIABLE OVER RANGE 0<VAL<255   |
                     AUTO SCALES FOR EACH FRAME OUTPUT IN FILES out3d.dia AND |
                     rout3d.dia  OUTPUT IN I4 FORMAT                          |
                   2 FOR SCALING SPECIFIED IN NEXT TWO COLUMNS WITH OUTPUT    |
                     DEFINED OVER RANGE  0<VAL<255 AND WRITTEN IN I4 FORMAT   |
                   3 FOR MULTIPLIER SCALING BY MAX SCALE VALUE WITH OUTPUT    |
                     WRITTEN IN F7.1 FORMAT (IS3DO AND ISR3DO MUST BE 1)      |
C                                                                             |
C81 VARIABLE    IS3D(VARID)  JS3D(VARID)   MAX SCALE VALUE  MIN SCALE VALUE   |
    'U VEL'     1            3              100.0             -1.0
    'V VEL'     1            3              100.0             -1.0
    'W VEL'     0            0             1000.0          -1.0E-3
    'SALINITY'  1            3                1.0              0.0
    'TEMP'      1            3                1.0             10.0
    'DYE'       0            0             1000.0              0.0
    'COH SED'   1            3             1000.0              0.0
    'NCH SED'   1            3             1000.0              0.0
    'TOX CON'   1            3             1000.0              0.0
-------------------------------------------------------------------------------
C82 INPLACE HARMONIC ANALYSIS PARAMETERS                                      |
C                                                                             |
      ISLSHA:  1 FOR IN PLACE LEAST SQUARES HARMONIC ANALYSIS                 |
```

```
      MLLSHA:  NUMBER OF LOCATIONS FOR LSHA                                  |
      NTCLSHA: LENGTH OF LSHA IN INTEGER NUMBER OF REFERENCE TIME PERIODS    |
      ISLSTR:  1 FOR TREND REMOVAL                                           |
      ISHTA :  1 FOR SINGLE TREF PERIOD SURFACE ELEV ANALYSIS                |
C                    90                                                      |
C82 ISLSHA  MLLSHA   NTCLSHA  ISLSTR  ISHTA                                  |
    1       7        29       0       0
-------------------------------------------------------------------------------
C83 HARMONIC ANALYSIS LOCATIONS AND SWITCHES                                 |
C                                                                            |
      ILLSHA:   I CELL INDEX                                                 |
      JLLSHA:   J CELL INDEX                                                 |
      LSHAP:  1 FOR ANALYSIS OF SURFACE ELEVATION                            |
      LSHAB:  1 FOR ANALYSIS OF SALINITY                                     |
      LSHAUE: 1 FOR ANALYSIS OF EXTERNAL MODE HORIZONTAL VELOCITY            |
      LSHAU:  1 FOR ANALYSIS OF HORIZONTAL VELOCITY IN EVERY LAYER           |
      CLSL:     LOCATION AS A CHARACTER VARIALBLE                            |
C                                                                            |
C83 ILLSHA   JLLSHA   LSHAP  LSHAB  LSHAUE LSHAU  CLSL                       |
      4      84       1      1      0      0     'Lock and Dam 1'
      7      67       1      1      0      0     'Black at Currie'
      43     97       1      1      0      0     'NECF at Burgaw'
      4      11       1      1      0      0     '02107576, CF @ Nav'         |1
      43     15       1      1      0      0     '02108692, NECF @ Wilm'      |2
      25     47       1      1      0      0     '02108820  M12'              |3
      33     5        1      1      0      0     '02108894  Cape Fear at mouth'
-------------------------------------------------------------------------------
C84 CONTROLS FOR WRITING TO TIME SERIES FILES                                |
C                                                                            |
      ISTMSR:  1 OR 2 TO WRITE TIME SERIES OF SURF ELEV, VELOCITY, NET       |
               INTERNAL AND EXTERNAL MODE VOLUME SOURCE-SINKS, AND           |
               CONCENTRATION VARIABLES,  2 APPENDS EXISTING TIME SERIES FILES |
      MLTMSR:  NUMBER HORIZONTAL LOCATIONS TO WRITE TIME SERIES OF SURF ELEV, |
               VELOCITY, AND CONCENTRATION VARIABLES,  MAXIMUM LOCATIONS = 9  |
      NBTMSR:  TIME STEP TO BEGIN WRITING TO TIME SERIES FILES               |
      NSTMSR:  TIME STEP TO STOP WRITING TO TIME SERIES FILES                |
      NWTSER:  WRITE INTERVAL FOR WRITING TO TIME SERIES FILES               |
     NTSSTSP:  NUMBER OF TIME SERIES START-STOP SCENARIOS,  1 OR GREATER     |
      TCTMSR:  UNIT CONVERSION FOR TIME SERIES TIME.  FOR SECONDS, MINUTES,  |
               HOURS,DAYS USE 1.0, 60.0, 3600.0, 86400.0 RESPECTIVELY        |
        IDUM:  2 DUMMY INTEGER VARIABLES REQUIRED, BOTH = 0                  |
C           13                        1728                                   |
C84 ISTMSR  MLTMSR  NBTMSR  NSTMSR  NWTMSR  NTSSTSP  TCTMSR   IDUM  IDUM      |
    1       21       1      2000000  2160    1       86400.   0     0
-------------------------------------------------------------------------------
C85 CONTROLS FOR WRITING TO TIME SERIES FILES                                |
C                                                                            |
     ITSSS:    START-STOP SCENARIO NUMBER 1.GE.ISSS.LE.NTSSTSP               |
   MTSSTSP:    NUMBER OF STOP-START PAIRS FOR SCENARIO ISSS                  |
C                                                                            |
C85 ITSSS  MTSSTSP                                                           |
      1      1    !FULL SAVE
-------------------------------------------------------------------------------
C86 CONTROLS FOR WRITING TO TIME SERIES FILES                                |
C                                                                            |
     ITSSS:    START-STOP SCENARIO NUMBER 1.GE.ISSS.LE.NTSSTSP               |
     MTSSS:    NUMBER OF STOP-START PAIRS FOR SCENARIO ISSS                  |
    TSSTRT:    STARTING TIME FOR SCENARIO ITSSS, SAVE INTERVAL MTSSS         |
    TSSTOP:    STOPING TIME FOR SCENARIO ITSSS, SAVE INTERVAL MTSSS          |
C                  -1000.                                                    |
C86 ISSS   MTSSS    TSSTRT    TSSTOP     USER COMMENT                        |
      1      1      700       10000.     ! FULL SAVE
-------------------------------------------------------------------------------
```

```
C87 CONTROLS FOR WRITING TO TIME SERIES FILES                                 |
C                                                                             |
      ILTS:    I CELL INDEX                                                   |
      JLTS:    J CELL INDEX                                                   |
    NTSSSS:    WRITE SCENARIO FOR THIS LOCATION                               |
      MTSP:  1 FOR TIME SERIES OF SURFACE ELEVATION                           |
      MTSC:  1 FOR TIME SERIES OF TRANSPORTED CONCENTRATION VARIABLES         |
      MTSA:  1 FOR TIME SERIES OF EDDY VISCOSITY AND DIFFUSIVITY              |
      MTSUE: 1 FOR TIME SERIES OF EXTERNAL MODE HORIZONTAL VELOCITY           |
      MTSUT: 1 FOR TIME SERIES OF EXTERNAL MODE HORIZONTAL TRANSPORT          |
      MTSU:  1 FOR TIME SERIES OF HORIZONTAL VELOCITY IN EVERY LAYER          |
      MTSQE: 1 FOR TIME SERIES OF NET EXTERNAL MODE VOLUME SOURCE/SINK        |
      MTSQ:  1 FOR TIME SERIES OF NET EXTERNAL MODE VOLUME SOURCE/SINK        |
      CLTS:    LOCATION AS A CHARACTER VARIALBLE                              |
C                                                                             |
C87 ILTS JLTS NTSSSS MTSP MTSC MTSA MTSUE MTSUT MTSU MTSQE MTSQ  CLTS         |
      4  84    1     1    1    0     0     0    0    0     0    'USGS, L&D1'  1
      4  80    1     0    1    0     0     0    0    0     0    'NC11'        2
      7  67    1     1    1    0     0     0    0    0     0    '02107544'    3
      7  66    1     0    1    0     0     0    0    0     0    ' B210'       4
      4  60    1     0    1    0     0     0    0    0     0    'AC, CF'      5
      4  25    1     0    1    0     0     0    0    0     0    'IC, CF'      6
     43  97    1     1    1    0     0     0    0    0     0    'NE Burhaw'   7
     43  66    1     0    1    0     0     0    0    0     0    'NCF117'      8
     44  27    1     0    1    0     0     0    0    0     0    'NCF6'        9
      4  11    1     1    1    0     0     0    0    0     0    '02107576 '  10
      4  10    1     0    1    0     0     0    0    0     0    'Nav, CF@Nav'11
     22  81    1     0    1    0     0     0    0    0     0    'HB, CF'     12
     43  15    1     1    1    0     0     0    0    0     0    'NECF Wilm'  13
     18  72    1     0    1    0     0     0    0    0     0    'Brnsk R.'   14
     24  68    1     0    1    0     0     0    0    0     0    'CF, M61'    15
     24  58    1     0    1    0     0     0    0    0     0    'CF, M54'    16
     25  49    1     0    1    0     0     0    0    0     0    'CF, M42'    17
     25  47    1     1    1    0     0     0    0    0     0    'CF, M12'    18
     26  40    1     0    1    0     0     0    0    0     0    'CF, M35'    19
     23  21    1     0    1    0     0     0    0    0     0    'CF, M23'    20
     24  11    1     1    1    0     0     0    0    0     0    'CF, M18'    21
-------------------------------------------------------------------------------
C88 CONTROLS FOR EXTRACTING INSTANTANEOUS VERTICAL SCALAR FIELD PROFILES       |
C                                                                             |
      ISVSFP: 1 FOR EXTRACTING INSTANTANEOUS VERTICAL FIELD PROFILES          |
      MDVSFP:   MAXIMUM NUMBER OF DEPTHS FOR SAMPLING VALUES                  |
      MLVSFP:   NUMBER OF HORIZONTAL SPACE-TIME LOCATION PAIRS TO BE SAMPLED  |
      TMVSFP:   MULTIPLIER TO CONVERT SAMPLING TIMES TO SECONDS               |
      TAVSFP:   ADDITIVE ADJUSTMENT TO SAMPLING TIME BEFORE CONVERSION TO SEC |
C          200max   1600max                                                   |
C88 ISVSFP  MDVSFP  MLVSFP  TMVSFP  TAVSFP                                     |
      0       0     0       86400.  0.0
-------------------------------------------------------------------------------
C89 SAMPLING DEPTHS FOR EXTRACTING INST VERTICAL SCALAR FIELD PROFILES        |
C                                                                             |
      MMDVSFP:  Mth SAMPLING DEPTH                                            |
      DMSFP:    SAMPLING DEPTH BELOW SURFACE, IN METERS                       |
C                                                                             |
C89 MMDVSFP  DMVSFP                                                           |
-------------------------------------------------------------------------------
C90 HORIZONTAL SPACE-TIME LOCATIONS FOR SAMPLING                              |
C                                                                             |
      MMLVSFP:  Mth SPACE TIME SAMPLING LOCATION                              I
      TIMVSFP:  SAMPLING TIME                                                 |
      IVSFP:    I HORIZONTAL LOCATON INDEX                                    |
      JVSFP:    J HORIZONTAL LOCATON INDEX                                    |
C                                                                             |
```

```
C90 MMLVSFP  TIMVSFP  IVSFP  JVSFP                                              |
********************************************************************************
********************************************************************************
********************************************************************************
```

```
# <-- set first character to "#" to use extended annotation in this file
C------------------------------------------------------------------------------
C01  MAIN TITLE CARDS
C
C  TITLE(M), M=1,3
C
C01 THREE TITLE CARDS FOLLOW:
': Cape Fear River Water Quality Model'
': Variable stream flow and variable NPDES discharges'
': using tetratech input files'
C------------------------------------------------------------------------------
C02 I/O CONTROL VARIABLE CARD
C
C02 ONE TITLE CARD FOLLOWS:
$$ C02 I/O control variables $$
C02
C  IWQLVL = kinetic complexity level
C           1  WASP5 LEVEL KINETICS (SINGLE ORGANIC CARBON, PHOSPHOROUS, AND
C              NITROGEN CLASSES + REACTIVE DOC/CBOD VARIABLE)
C           2  INTERMEDIATE LEVEL KINETICS (TOTAL REFRACTORY AND TOTAL LABILE
C              ORGANIC CARBON, PHOSPHOROUS, AND NITROGEN CLASSES
C              + REACTIVE DOC/CBOD)
C           3  CE-QUAL-ICM (ORIGINAL CHES BAY VARIABLES)
C           4  EXTENDED CE-QUAL-ICM (4 ORGANIC CARBON, PHOSPHOROUS, AND
C              NITROGEN CLASSES + REACTIVE DOC/CBOD VARIABLE)
C    NWQV = number of water quality water column variables
C    NWQZ = max. number of spatial zones having varying water quality parameters
C   NWQPS = max. number of water quality point source locations
C   NWQTD = number of data points in the temperature lookup table
C   NWQTS = max. number of water quality time-series output locations
C  NTSWQV = max. number of water quality time-series output variables
C    NSMG = number of sediment model groups (= 3)
C    NSMZ = max. number of sediment model spatial variation zones
C  NTSSMV = max. number of sediment model time-series output variables
C   NSMTS = not used
C NWQKDPT = number of kinetic updates per transport update
C
C02 IWQLVL NWQV NWQZ NWQPS NWQTD NWQTS NTSWQV NSMG NSMZ NTSSMV NSMTS NWQKDPT
      3    21   1    38    551   22     21     1    1    3      30    1
C------------------------------------------------------------------------------
C02A TRANSPORT BYPASS FLAGS
C   B  B  B  R  L  D  R  L  D  P  R  L  D  N  N  S  S  C  D  T  F
C   c  d  g  P  P  O  P  P  O  O  P  P  O  H  O  U  A  O  O  A  C
C            O  O  C  O  O  P  4  O  O  N  4  3        D     M
C            C  C     P  P     t  N  N
    1  1  1  1  1  1  1  1  1  1  1  1  1  1  1  1  1  1  1  0  0
C------------------------------------------------------------------------------
C03
C  IWQDT   = number of water quality time steps per hydrodynamic time step
C             =1 for 2 time level hydrodynamic and =2 for three time level
C  IWQM    = full or reduced model switch (1=full model; 2=reduced model)
C  IWQBEN  = benthic flux model switch (0=specified flux; 1=predictive flux, 2
predictive flux w/ time and space variation)
C  IWQSI   = switch to activate silica state variables (0=off; 1=activated)
C  IWQFCB  = switch to activate fecal coliform bacteria (0=off; 1=activated)
C  IWQSRP  = switch for sediment sorption (1=TAM sorption; 2=sediment sorption)
C  IWQSTOX = cyanobacteria salinity toxicity switch (0=no toxicity; 1=toxicity)
C  IWQKA   = reaeration option
C          = 0, constant reaeration (WQKRO), no wind reaeration
C          = 1, constant reaeration (WQKRO) plus wind reaeration
C          = 2, use O'Connor-Dobbins (1958) formula
C          = 3, use Owens & Gibbs (1964) formula
C          = 4, modified Owens & Gibbs (1964) formula (for Christina River)
```

```
C  IWQVLIM = option for velocity limitation of macroalgae growth
C          = 0, macroalgae growth is not limited by stream velocity
C          = 1, macroalgae growth limited using Michaelis-Menton formula
C          = 2, macroalgae growth limited using 5-parameter Logistic Function
C
C03 IWQDT   IWQM    IWQBEN  IWQSI   IWQFCB  IWQSRP  IWQSTOX  IWQKA IWQVLIM
     1       1       2       0       0       0       1        2     0
C-----------------------------------------------------------------------------
C04
C     IWQZ = number of zones for spatially varying WQ parameters
C    IWQNC = switch to save negative concentrations to WQ3DNC.LOG (0=OFF; 1=ON)
C   IWQRST = switch to save WQ restart data to WQWCRST.OUT (0=OFF; 1=ON)
C    NDMWQ = number of horizontal spatial domains for decomposition calc. (=1)
C    LDMWQ = number of horizontal cells in the WQ computational domain (=LC-2)
C  NDDOAVG = no longer used
C  NDLTAVG = no longer used
C IDNOTRVA = ID number of macroalgae water quality variable
C
C04 IWQZ    IWQNC   IWQRST  NDMWQ   LDMWQ   NDDOAVG  NDLTAVG IDNOTRVA
    1       0       1       1       1050     0        0      0
C-----------------------------------------------------------------------------
C05
C   IWQICI = initial condition switch
C            0=spatially constant initial conditions (card C44)
C            1=read initial condition file ICIFN (see card C51)
C            2=read initial conditions from restart file WQWCRST.INP
C   IWQAGR = algae growth kinetics switch
C            0=use constant kinetics on card C45
C            1=read spatial/time-varying kinetics from file AGRFN (card C51)
C   IWQSTL = settling velocity switch
C            0=use spatially/temporally constant settling velocities (card C46)
C            1=use spatial/time-varying settling vel. from STLFN (card C51)
C   IWQSUN = solar radiation switch
C            0=use constant solar radiation (I0) and FD from card C10
C            1=use daily average solar rad. and FD from file SUNDAY.INP
C            2=use hourly solar rad. from ASER.INP file
C   IWQPSL = point source load switch
C            0=use constant point source loads
C            1=use time-variable point source loads from file WQPSL.INP
C   IWQNPL = not used
C isDIURDO = switch for saving diurnal D.O. data
C            0=do not save diurnal D.O. data to file
C            1=save diurnal D.O. data to binary file WQDIURDO.BIN
C              if WQDIURDO.BIN already exists, delete it
C            2=save diurnal D.O. data to binary file WQDIURDO.BIN
C              if WQDIURDO.BIN already exists, append to it
C  WQDIUDT = time interval for writing to diurnal D.O. file (hours)
C   IWQKIN = switch for using spatially-varying kinetic rate constants
C            0=do not use spatially-varying kinetics
C            1=use spatially-varying kinetics in file KINETICS.INP
C              Only applies to IWQKA, KRO, KTR, REAC, KDC, KDCALGm, KHRm
C              DOPTm, KCD, and KHCOD.
C
C05 IWQICI  IWQAGR  IWQSTL  IWQSUN  IWQPSL  IWQNPL  isDIURDO WQDIUDT IWQKIN
     0       0       0       2       1       0       0       24.0     0
C-----------------------------------------------------------------------------
C06
C    IWQTS = number of time-series locations to output to ASCII file WQWCTS.OUT
C   TWQTSB = beginning time for recording time-series data (Julian Day)
C   TWQTSE = ending    time for recording time-series data (Julian Day)
C   WQTSDT = write interval (hours), also averaging interval for binary files
C            use 24.0 hours for daily averages (solar day)
C            use 24.8412 hours to average over the M2 tide period (lunar day)
```

```
C  isWQAVG = switch to save WQ averages to binary file WQWCAVG.BIN
C            0=OFF; 1=ON, overwrite existing file; 2=ON, append to existing file
C  isWQMIN = switch to save WQ minimums to binary file WQWCMIN.BIN
C            0=OFF; 1=ON, overwrite existing file; 2=ON, append to existing file
C  isWQMAX = switch to save WQ minimums to binary file WQWCMAX.BIN
C            0=OFF; 1=ON, overwrite existing file; 2=ON, append to existing file
C   isCOMP = switch to save DO components to file WQDOCOMP.BIN
C            0=OFF; 1=ON, overwrite existing file; 2=ON, append to existing file
C   17
C06 IWQTS   TWQTSB  TWQTSE  WQTSDT  isWQAVG isWQMIN isWQMAX  isCOMP
     14      0000.0  10000.0 12.4206     0       0       0        0
C-----------------------------------------------------------------------------
C07  TIME-SERIES WRITE CONTROLS
C    CHL = total chlorophyll
C    TOC = total organic carbon
C    DOC = dissolved organic carbon
C     TP = total phosphorus
C    DOP = dissolved organic phosphorus
C   PO4t = total orthophosphate
C   PO4d = dissolved orthophosphate
C    APC = algae phosphorus-to-carbon ratio
C     TN = total nitrogen
C    DON = dissolved organic nitrogen
C    NH4 = ammonia nitrogen
C    NO3 = nitrite + nitrate nitrogen
C    TSI = total silica
C     SU = unavailable dissolved silica
C     SA = total available biogenic dissolved silica
C    SAd = dissolved available biogenic dissolved silica
C    COD = chemical oxygen demand
C    TAM = total active metal
C   TAMp = total active metal
C    FCB = fecal coliform bacteria
C     Fm = macroalgae
C
C   ICWQTS(NW,M), NW=1,NTSWQV, M=1,IWQTS
C
C07  Two title cards follow:
$I   J    CHL  TOC  DOC  TP   DOP  PO4t PO4d APC  TN   DON  NH4  NO3  TSI
$         SU   SA   SAd  COD  O2   TAM  TAMp FCB  Fm
 4  80    1    1    1    1    1    1    1    1    1    1    1    1    1
          1    1    1    1    1    0    0    0    0                          ! NC11
  7 66    1    1    1    1    1    1    1    1    1    1    1    1    1
          1    1    1    1    1    0    0    0    0                          ! B210
 4  60    1    1    1    1    1    1    1    1    1    1    1    1    1
          1    1    1    1    1    0    0    0    0                          ! AC
 4 25     1    1    1    1    1    1    1    1    1    1    1    1    1
          1    1    1    1    1    0    0    0    0                          ! IC
 44 27    1    1    1    1    1    1    1    1    1    1    1    1    1
          1    1    1    1    1    0    0    0    0                          ! NCf6
  4 10    1    1    1    1    1    1    1    1    1    1    1    1    1
          1    1    1    1    1    0    0    0    0                          ! Nav
 22 81    1    1    1    1    1    1    1    1    1    1    1    1    1
          1    1    1    1    1    0    0    0    0                          ! HB
 18 72    1    1    1    1    1    1    1    1    1    1    1    1    1
          1    1    1    1    1    0    0    0    0                          ! Bruns.
River
 24 68    1    1    1    1    1    1    1    1    1    1    1    1    1
          1    1    1    1    1    0    0    0    0                          ! M61
 24 58    1    1    1    1    1    1    1    1    1    1    1    1    1
          1    1    1    1    1    0    0    0    0                          ! M54
 25 49    1    1    1    1    1    1    1    1    1    1    1    1    1
          1    1    1    1    1    0    0    0    0                          ! M42
```

```
 26 40    1    1    1    1    1    1    1    1    1    1    1    1    1
          1    1    1    1    1    0    0    0    0                          ! M35
 23 21    1    1    1    1    1    1    1    1    1    1    1    1    1
          1    1    1    1    1    0    0    0    0                          ! M23
 24 11    1    1    1    1    1    1    1    1    1    1    1    1    1
          1    1    1    1    1    0    0    0    0                          ! M18
C------------------------------------------------------------------------------
C08 ONE TITLE CARD FOLLOWS:
$$ C08 constant parameters for ALGAE (see Table 3-1) $$
C08
C    KHNc = nitrogen half-saturation for cyanobacteria (mg/L)
C    KHNd = nitrogen half-saturation for algae diatoms (mg/L)
C    KHNg = nitrogen half-saturation for algae greens algae (mg/L)
C    KHNm = nitrogen half-saturation for macroalgae (mg/L)
C    KHPc = phosphorus half-saturation for cyanobacteria (mg/L)
C    KHPd = phosphorus half-saturation for algae diatoms (mg/L)
C    KHPg = phosphorus half-saturation for algae greens algae (mg/L)
C    KHPm = phosphorus half-saturation for macroalgae (mg/L)
C     KHS = silica half-saturation for algae diatoms (mg/L)
C    STOX = salinity at which microsystis growth is halved for cyanobacteria
C   0.030  0.030  0.030  0.030  0.003  0.003  0.003  0.003  0.035 1.0
C08 KHNc   KHNd   KHNg   KHNm   KHPc   KHPd   KHPg   KHPm   KHS   STOX
    0.010  0.010  0.010  0.010  0.001  0.001  0.001  0.001  0.035 2.0
C------------------------------------------------------------------------------
C09 constant parameters for ALGAE (see Table 3-1)
C   KeTSS = light extinction for total suspended solids (1/m per g/m3)
C   KeCHL = light extinction for total suspended chlorophyll (1/m per g/m3)
C     Note: if KeCHL is negative, the Riley (1956) formula is used to
C           compute the extinction coefficient due to chlorophyll:
C             KeCHL = 0.054*CHL^0.6667 + 0.0088*CHL
C             where CHL = total chloryphyll concentration (ug/L)
C   CChlc = carbon-to-chlorophyll ratio for cyanobacteria (mg C / ug Chl)
C   CChld = carbon-to-chlorophyll ratio for algae diatoms (mg C / ug Chl)
C   CChlg = carbon-to-chlorophyll ratio for algae greens (mg C / ug Chl)
C   CChlm = carbon-to-chlorophyll ratio for macroalgae (mg C / ug Chl)
C   DOPTc = optimal depth (m) for cyanobacteria growth
C   DOPTd = optimal depth (m) for algae diatoms growth
C   DOPTg = optimal depth (m) for algae greens growth
C   DOPTm = optimal depth (m) for macroalgae growth
C          0.041  0.060  0.060  0.060
C09 KeTSS  KeChl  CChlc  CChld  CChlg  CChlm  DOPTc  DOPTd DOPTg DOPTm
    0.015  0.017  0.060  0.060  0.060  0.060  1.0    1.0   1.0   0.10
C------------------------------------------------------------------------------
C10 constant parameters for ALGAE (see Table 3-1)
C      I0 = initial solar radiation (Langley/day) at water surface
C   IsMIN = minimum optimum solar radiation (Langley/day)
C      FD = fraction of day that is daylight
C     CIa = weighting factor for solar radiation at current day
C     CIb = weighting factor for solar radiation at (-1) days
C     CIc = weighting factor for solar radiation at (-2) days
C     CIm = not used
C     Rea = global reaeration adjustment factor
C  PARadj = solar radiation multiplied by this factor to get the
C           photoactive available radiation (PAR) for algae growth
C           4.6
C10  I0    IsMIN  FD     CIa    CIb    CIc    CIm    Rea   PARadj
     28.0  40.0  0.5     0.7    0.2    0.1    0.7    1.00   0.43
C------------------------------------------------------------------------------
C11 constant parameters for ALGAE (see Table 3-1)
C    TMc1 = lower optimal temperature for cyanobacteria growth (degC)
C    TMc2 = upper optimal temperature for cyanobacteria growth (degC)
C    TMd1 = lower optimal temperature for algae diatoms growth (degC)
C    TMd2 = upper optimal temperature for algae diatoms growth (degC)
```

```
C    TMg1 = lower optimal temperature for algae greens growth (degC)
C    TMg2 = upper optimal temperature for algae greens growth (degC)
C    TMm1 = lower optimal temperature for macroalgae growth (degC)
C    TMm2 = upper optimal temperature for macroalgae growth (degC)
C    TMp1 = lower optimal temperature for diatom predation (degC)
C    TMp2 = upper optimal temperature for diatom predation (degC)
C
C11 TMc1  TMc2   TMd1   TMd2   TMg1   TMg2   TMm1   TMm2   TMp1   TMp2
    27.5  32.5   17.0   20.0   20.0   30.0    1.0    1.0    2.0   29.0
C-------------------------------------------------------------------------------
C12 constant parameters for ALGAE (see Table 3-1)
C   KTG1c = suboptimal   temperature effect coef. for cyanobacteria growth
C   KTG2c = superoptimal temperature effect coef. for cyanobacteria growth
C   KTG1d = suboptimal   temperature effect coef. for algae diatoms growth
C   KTG2d = superoptimal temperature effect coef. for algae diatoms growth
C   KTG1g = suboptimal   temperature effect coef. for algae greens growth
C   KTG2g = superoptimal temperature effect coef. for algae greens growth
C   KTG1m = suboptimal   temperature effect coef. for macroalgae growth
C   KTG2m = superoptimal temperature effect coef. for macroalgae growth
C   KTG1p = suboptimal   temperature effect coef. for diatom predation growth
C   KTG2p = superoptimal temperature effect coef. for diatom predation growth
C  0.0080 0.0100 0.0040 0.0060 0.0080 0.0200 0.001  0.001 0.0001 0.0001
0.0100
C12 KTG1c KTG2c  KTG1d  KTG2d  KTG1g  KTG2g  KTG1m  KTG2m  KTG1p  KTG2p
   0.0080 0.0100 0.0040 0.0060 0.0080 0.0200 0.001  0.001 0.0001 0.0001
C-------------------------------------------------------------------------------
C13 constant parameters for ALGAE (see Table 3-1)
C     TRc = reference temperature for cyanobacteria metabolism (degC)
C     TRd = reference temperature for algae diatoms metabolism (degC)
C     TRg = reference temperature for algae greens metabolism (degC)
C     TRm = reference temperature for macroalgae metabolism (degC)
C    KTBc = temperature effect coef. for cyanobacteria metabolism
C    KTBd = temperature effect coef. for algae diatoms metabolism
C    KTBg = temperature effect coef. for algae greens metabolism
C    KTBm = temperature effect coef. for macroalgae metabolism
C
C13 TRc   TRd   TRg   TRm   KTBc   KTBd   KTBg   KTBm
    20.0  20.0  20.0  20.0  0.069  0.069  0.069  0.069
C-------------------------------------------------------------------------------
C14 ONE TITLE CARD FOLLOWS:
$$ C14 constant parameters for CARBON (see Table 3-2) $$
C14
C    FCRP = carbon distribution coef. for algae predation: refractory POC
C    FCLP = carbon distribution coef. for algae predation: labile POC
C    FCDP = carbon distribution coef. for algae predation: DOC
C    FCDc = carbon distribution coef. for cyanobacteria metabolism
C    FCDd = carbon distribution coef. for algae diatoms metabolism
C    FCDg = carbon distribution coef. for algae greens metabolism
C    KHRc = half-sat. constant (gO2/m3) for cyanobacteria DOC excretion
C    KHRd = half-sat. constant (gO2/m3) for algae diatoms DOC excretion
C    KHRg = half-sat. constant (gO2/m3) for algae greens  DOC excretion
C Note:  FCRP + FCLP + FCDP = 1.0
C
C14 FCRP   FCLP   FCDP   FCDc  FCDd   FCDg   KHRc  KHRd  KHRg
    0.35   0.55   0.10   0.0   0.0    0.0    0.5   0.5   0.5
C-------------------------------------------------------------------------------
C15 ONE TITLE CARD FOLLOWS:
$$ C15 constant parameters for CARBON (macroalgae)
C15
C   FCRPm = carbon distribution coef. for macroalgae predation: refractory POC
C   FCRPm = carbon distribution coef. for macroalgae predation: labile POC
C   FCRPm = carbon distribution coef. for macroalgae predation: DOC
C    FCDm = carbon distribution coef. for macroalgae metabolism
```

```
C    KHRm = half-sat. constant (gO2/m3) for macroalgae DOC excretion
C Note:  FCRPm + FCLPm + FCDPm = 1.0
C
C15 FCRPm  FCLPm  FCDPm  FCDm  KHRm
    0.25   0.25   0.50   0.0   0.5
C-----------------------------------------------------------------------------
C16 constant parameters for CARBON (see Table 3-2)
C     KRC = minimum dissolution rate (1/day) of refractory POC
C     KLC = minimum dissolution rate (1/day) of labile POC
C     KDC = minimum dissolution rate (1/day) of DOC
C  KRCalg = constant relating refractory POC dissolution rate to total chla
C  KLCalg = constant relating labile POC dissolution rate to total chla
C  KDCalg = constant relating DOC dissolution rate to total chla
C KDCalgm = constant relating DOC dissolution rate to macroalgae
C   0.020   0.150   0.300
C16 KRC     KLC     KDC     KRCalg  KLCalg  KDCalg KDCalgm
    0.03   0.075   0.150   0.0     0.0     0.2    0.000
C-----------------------------------------------------------------------------
C17 constant parameters for CARBON (see Table 3-2)
C   TRHDR = reference temperature for hydrolysis (degC)
C   TRMNL = reference temperature for mineralization (degC)
C   KTHDR = temperature effect constant for hydrolysis
C   KTMNL = temperature effect constant for mineralization
C  KHORDO = oxic respiration half-sat. constant for D.O. (gO2/m3)
C   KHDNN = half-sat. constant for denitrification (gN/m3)
C   AANOX = ratio of denitrification rate to oxic DOC respiration rate
C                                   0.1
C17 TRHDR   TRMNL   KTHDR   KTMNL   KHORDO  KHDNN   AANOX
    20.0    20.0    0.069   0.069   0.5     0.1     0.7
C-----------------------------------------------------------------------------
C18 ONE TITLE CARD FOLLOWS:
$$ C18 constant parameters for PHOSPHORUS (see Table 3-3) $$
C18
C    FPRP = phos. distribution coef. for algae predation: refractory POP
C    FPLP = phos. distribution coef. for algae predation: labile POP
C    FPDP = phos. distribution coef. for algae predation: DOP
C    FPIP = phos. distribution coef. for algae predation: Inorganic P
C    FPRc = phos. distribution coef. of RPOP for cyanobacteria metabolism
C    FPRd = phos. distribution coef. of RPOP for algae diatoms metabolism
C    FPRg = phos. distribution coef. of RPOP for algae greens metabolism
C    FPLc = phos. distribution coef. of LPOP for cyanobacteria metabolism
C    FPLd = phos. distribution coef. of LPOP for algae diatoms metabolism
C    FPLg = phos. distribution coef. of LPOP for algae greens metabolism
C Note, the following must sum to 1.0:
C         FPRP + FPLP + FPDP + FPIP = 1.0
C         FPRc + FPLc + FPDc + FPIc = 1.0
C         FPRd + FPLd + FPDd + FPId = 1.0
C         FPRg + FPLg + FPDg + FPIg = 1.0
C   0.30 0.30  0.20  0.20             0.3            0.2
C18 FPRP FPLP  FPDP  FPIP  FPRc  FPRd FPRg FPLc FPLd FPLg
    0.10 0.20  0.50  0.20  0.0   0.0  0.0  0.0  0.0  0.0
C-----------------------------------------------------------------------------
C19 ONE TITLE CARD FOLLOWS:
$$ C19 constant parameters for PHOSPHORUS (macroalgae)
C19
C   FPRPM = phos. distribution coef. for macroalgae predation: RPOP
C   FPLPM = phos. distribution coef. for macroalgae predation: LPOP
C   FPDPM = phos. distribution coef. for macroalgae predation: DOP
C   FPIPM = phos. distribution coef. for macroalgae predation: Inorganic P
C    FPRm = phos. distribution coef. of RPOP for macroalgae metabolism
C    FPLm = phos. distribution coef. of LPOP for macroalgae metabolism
C    APCM = factor to modify APC for macroalgae
C Note, the following must sum to 1.0:
```

```
C         FPRPM + FPLPM + FPDPM + FPIPM = 1.0
C         FPRm + FPLm + FPDm + FPIm = 1.0
C
C19 FPRPM  FPLPM  FPDPM  FPIPM   FPRm   FPLm   APCM
    0.40   0.40   0.1    0.1     0.2    0.3    0.50
C-----------------------------------------------------------------------------
C20 constant parameters for PHOSPHORUS (see Table 3-3)
C    FPDc = phosphorus distribution coef. of DOP for cyanobacteria metabolism
C    FPDd = phosphorus distribution coef. of DOP for algae diatoms metabolism
C    FPDg = phosphorus distribution coef. of DOP for algae greens metabolism
C    FPDm = phosphorus distribution coef. of DOP for macroalgae metabolism
C    FPIc = phosphorus distribution coef. of P4T for cyanobacteria metabolism
C    FPId = phosphorus distribution coef. of P4T for algae diatoms metabolism
C    FPIg = phosphorus distribution coef. of P4T for algae greens metabolism
C    FPIm = phosphorus distribution coef. of P4T for macroalgae metabolism
C   KPO4p = partition coefficient for sorbed/dissolved PO4
C
C Notes, the following must sum to 1.0:
C         FPRc + FPLc + FPDc + FPIc = 1.0
C         FPRd + FPLd + FPDd + FPId = 1.0
C         FPRg + FPLg + FPDg + FPIg = 1.0
C                 0.4                          0.1
C20 FPDc   FPDd   FPDg   FPDm    FPIc   FPId   FPIg   FPIm   KPO4p
    1.0    1.0    1.0    1.0     0.0    0.0    0.0    0.0     1.00
C-----------------------------------------------------------------------------
C21 constant parameters for PHOSPHORUS (see Table 3-3)
C     KRP = minimum hydrolysis rate (1/day) of RPOP
C     KLP = minimum hydrolysis rate (1/day) of LPOP
C     KDP = minimum hydrolysis rate (1/day) of DOP
C  KRPalg = constant relating hydrolysis rate of RPOP to algae
C  KLPalg = constant relating hydrolysis rate of LPOP to algae
C  KDPalg = constant relating hydrolysis rate of DOP to algae
C  CPprm1 = constant used in determining algae Phos-to-Carbon ratio
C  CPprm2 = constant used in determining algae Phos-to-Carbon ratio
C  CPprm3 = constant used in determining algae Phos-to-Carbon ratio
C                 0.100                 0.2
C21 KRP    KLP    KDP    KRPalg  KLPalg KDPalg CPprm1 CPprm2 CPprm3
    0.03  0.075  0.150  0.0     0.0    0.5    15.0    35.0   350.0
C-----------------------------------------------------------------------------
C22 ONE TITLE CARD FOLLOWS:
$$ C22 constant parameters for NITROGEN (see Table 3-4) $$
C22
C    FNRP = nitrogen distribution coef. for algae predation: RPON
C    FNLP = nitrogen distribution coef. for algae predation: LPON
C    FNDP = nitrogen distribution coef. for algae predation: DON
C    FNIP = nitrogen distribution coef. for algae predation: Inorganic N
C    FNRc = nitrogen distribution coef. of RPON for cyanobacteria metabolism
C    FNRd = nitrogen distribution coef. of RPON for algae diatoms metabolism
C    FNRg = nitrogen distribution coef. of RPON for algae greens  metabolism
C    FNLc = nitrogen distribution coef. of LPON for cyanobacteria metabolism
C    FNLd = nitrogen distribution coef. of LPON for algae diatoms metabolism
C    FNLg = nitrogen distribution coef. of LPON for algae greens  metabolism
C   0.3   0.5   0.1   0.1               0.2              0.4
C22 FNRP  FNLP  FNDP  FNIP  FNRc  FNRd  FNRg FNLc  FNLd  FNLg
    0.35  0.55   0.1   0.0   0.0   0.0   0.0  0.0   0.0   0.0
C-----------------------------------------------------------------------------
C23 ONE TITLE CARD FOLLOWS:
$$ C23  constant parameters for NITROGEN (MACROALGAE)
C23
C   FNRPM = nitrogen distribution coef. for marcoalgae predation: RPON
C   FNLPM = nitrogen distribution coef. for marcoalgae predation: LPON
C   FNDPM = nitrogen distribution coef. for marcoalgae predation: DON
C   FNIPM = nitrogen distribution coef. for marcoalgae predation: Inorganic N
```

```
C    FNRm = nitrogen distribution coef. of RPON for macroalgae metabolism
C    FNLm = nitrogen distribution coef. of LPON for macroalgae metabolism
C
C23 FNRPM FNLPM  FNDPM  FNIPM  FNRm  FNLm
    0.4   0.5    0.1    0.0    0.2   0.4
C-----------------------------------------------------------------------------
C24 constant parameters for NITROGEN (see Table 3-4)
C    FNDc = nitrogen distribution coef. of DON for cyanobacteria metabolism
C    FNDd = nitrogen distribution coef. of DON for algae diatoms metabolism
C    FNDg = nitrogen distribution coef. of DON for algae greens  metabolism
C    FNDm = nitrogen distribution coef. of DON for macroalgae    metabolism
C    FNIc = nitrogen distribution coef. of DIN for cyanobacteria metabolism
C    FNId = nitrogen distribution coef. of DIN for algae diatoms metabolism
C    FNIg = nitrogen distribution coef. of DIN for algae greens  metabolism
C    FNIm = nitrogen distribution coef. of DIN for macroalgae    metabolism
C    ANCc = nitrogen-to-carbon ratio for cyanobacteria
C    ANCd = nitrogen-to-carbon ratio for algae diatoms
C    ANCg = nitrogen-to-carbon ratio for algae greens
C    ANCm = nitrogen-to-carbon ratio for macroalgae
C Note: FNRx + FNLx + FNDx + FNIx = 1.0
C   1.0   1.0   1.0   1.0   0.0   0.0   0.0   0.0   0.100 0.100 0.100 0.100
C24 FNDc  FNDd  FNDg  FNDm  FNIc  FNId  FNIg  FNIm  ANCc  ANCd  ANCg  ANCm
    1.0   1.0   1.0   1.0   0.0   0.0   0.0   0.0   0.17 0.17 0.17 0.050
C-----------------------------------------------------------------------------
C25 constant parameters for NITROGEN (see Table 3-4)
C    ANDC = mass NO3 reduces per DOC oxidized (gN/gC)
C   rNitM = maximum nitrification rate (gN/m3/day)
C KHNitDO = nitrification half-sat. constant for D.O.
C  KHNitN = nitrification half-sat. constant for NH4
C    TNit = reference temperature for nitrification (degC)
C   KNit1 = suboptimal temperature effect constant for nitrification
C   Knit2 = superoptimal temperature effect constant for nitrification
C
C           0.25    0.1     0.1     20.0
C25 ANDC    rNitM   KHNitDO KHNitN  TNit    KNit1   KNit2 changed rNitM from 0.99
baker
    0.933   0.11    0.1    0.1     27.0    0.0045  0.0045
C-----------------------------------------------------------------------------
C26 constant parameters for NITROGEN (see Table 3-4)
C     KRN = minimum hydrolysis rate (1/day) of RPON
C     KLN = minimum hydrolysis rate (1/day) of LPON
C     KDN = minimum hydrolysis rate (1/day) of DON
C  KRNalg = constant relating hydrolysis rate of RPON to algae
C  KLNalg = constant relating hydrolysis rate of LPON to algae
C  KDNalg = constant relating hydrolysis rate of DON to algae
C   0.005   0.075   0.600   0.0     0.0     0.0
C26 KRN     KLN     KDN     KRNalg  KLNalg  KDNalg
    0.03   0.075   0.150   0.0     0.0     0.0
C-----------------------------------------------------------------------------
C27 ONE TITLE CARD FOLLOWS:
$$ C27 constant parameters for SILICA (see Table 3-5) $$
C27
C    FSPP = silica distribution coef. for diatom predation
C    FSIP = silica distribution coef. for diatom predation
C    FSPd = silica distribution coef. for diatom metabolism
C    FSId = silica distribution coef. for diatom metabolism
C    ASCd = silica-to-carbon ratio for algae diatoms
C    KSAp = partition coef. for sorbed/dissolved SA
C     KSU = dissolution rate (1/day) of particulate silica (PSi)
C   TRSUA = reference temperature (degC) for PSi dissolution
C   KTSUA = temperature effect on PSi dissolution
C
C27 FSPP    FSIP    FSPd    FSId    ASCd    KSAp    KSU     TRSUA   KTSUA
```

```
    1.0     0.0     1.0     0.0     0.36    0.16    0.05    20.0    0.092
C-----------------------------------------------------------------------------
C28 ONE TITLE CARD FOLLOWS:
$$ C28 constant parameters for COD & DO (see Table 3-6) $$
C28
C    AOCR = stoichiometric algae oxygen-to-carbon ratio (gO2/gC)
C    AONT = stoichiometric algae oxygen-to-nitrate ratio (gO2/gN)
C     KRO = reaeration constant (3.933 for OConnor-Dobbins; 5.32 for Owen-Gibbs)
C     KTR = temperature rate constant for reaeration
C   KHCOD = oxygen half-saturation constant for COD decay (mg/L O2)
C     KCD = COD decay rate (per day)
C   TRCOD = reference temperature for COD decay (degC)
C   KTCOD = temperature rate constant for COD decay
C  AOCRpm = macroalgae photosynthesis oxygen-to-carbon ratio
C  AOCRrm = macroalgae respiration oxygen-to-carbon ratio
C                   1.25
C28 AOCR    AONT    KRO     KTR     KHCOD   KCD     TRCOD   KTCOD AOCRpm AOCRrm
    2.67    4.33    3.933   1.024   1.5     1.00    20.0    0.041 0.041   0.041
C-----------------------------------------------------------------------------
C29 ONE TITLE CARD FOLLOWS:
$$ C29 constant parameters for TAM & FCB (see Table 3-7) $$
C29
C   KHbmf = D.O. concentration where TAM release is half the anoxic rate
C   BFTAM = anoxic release rate of TAM (mol/m2/day)
C    Ttam = reference temperature for TAM release (degC)
C    Ktam = temperature effect constant for TAM release
C  TAMdmx = TAM solubility at anoxic conditions (mol/m3)
C  Kdotam = constant relating TAM solubility to D.O.
C    KFCB = first-order fecal coliform bacteria decay rate (1/day)
C    TFCB = temperature effect constant for KFCB decay rate
C
C29 KHbmf   BFTAM   Ttam    Ktam    TAMdmx  Kdotam  KFCB    TFCB
    0.5     0.1     20.0    0.2     0.015   1.0     0.5     1.07
C-----------------------------------------------------------------------------
C30 SIX TITLE CARDS FOLLOW:
$$ C30 CONCENTRATION TIME SERIES DATA $$
$$ NUMBER OF TIME SERIES FOR EACH STATE VARIABLE
$  B  B  B  R  L  D  R  L  D  P  R  L  D  N  N  S  S  C  D  T  F
$  c  d  g  P  P  O  P  P  O  O  P  P  O  H  O  U  A  O  O  A  C
$           O  O  C  O  O  P  4  O  O  N  4  3        D     M
$           C  C     P  P     t  N  N
   1  1  1  0  0  0  0  0  0  1  0  0  0  1  1  0  0  0  1  0  0
C-----------------------------------------------------------------------------
C31 ONE TITLE CARD FOLLOWS:
$$ C31 parameters for OPEN BDRY CONDITIONS $$
C31
C  NWQOBS = number of WQ open boundary cells on SOUTH boundary
C  NWQOBW = number of WQ open boundary cells on WEST boundary
C  NWQOBE = number of WQ open boundary cells on EAST boundary
C  NWQOBN = number of WQ open boundary cells on NORTH boundary
C
C31 NWQOBS  NWQOBW  NWQOBE  NWQOBN
    4       0        1       0
C-----------------------------------------------------------------------------
C32 SIX TITLE CARDS FOLLOW:
$$ C32 SOUTH OPEN BOUNDARY $$
$$ TIME SERIES ID'S FOR EACH STATE VARIABLE
$  I   J   B  B  B  R  L  D  R  L  D  P  R  L  D  N  N  S  S  C  D  T  F
$          c  d  g  P  P  O  P  P  O  O  P  P  O  H  O  U  A  O  O  A  C
$                   O  O  C  O  O  P  4  O  O  N  4  3        D     M
$                   C  C     P  P     t  N  N
  30   5   1  1  1  0  0  0  0  0  0  1  0  0  0  1  1  0  0  0  1  0  0
  31   5   1  1  1  0  0  0  0  0  0  1  0  0  0  1  1  0  0  0  1  0  0
```

```
  32   5   1  1  1  0  0  0  0  0  0  1  0  0  0  1  1  0  0  0  1  0  0
  33   5   1  1  1  0  0  0  0  0  0  1  0  0  0  1  1  0  0  0  1  0  0
C------------------------------------------------------------------------------
C33 FIVE TITLE CARDS FOLLOW:
$$ C33 SOUTH OPEN BOUNDARY $$
$$ CONSTANT BOTTOM CONCENTRATION BC'S
$  I   J   Bc      Bd      Bg      RPOC    LPOC    DOC
$          RPOP    LPOP    DOP     PO4t    RPON    LPON    DON
$          NH4     NO3     SU      SA      COD     DO      TAM     FCB
     30      5 0.0000 0.0000 0.0000 1.6504 0.0000 0.7790
               0.0076 0.0000 0.0076 0.0000 0.2659 0.0000 0.1432
               0.0000 0.0000 0.0000 0.0000 0.0000 0.0000 0.0000 0.0000
     31      5 0.0000 0.0000 0.0000 1.6504 0.0000 0.7790
               0.0076 0.0000 0.0076 0.0000 0.2659 0.0000 0.1432
               0.0000 0.0000 0.0000 0.0000 0.0000 0.0000 0.0000 0.0000
     32      5 0.0000 0.0000 0.0000 1.6504 0.0000 0.7790
               0.0076 0.0000 0.0076 0.0000 0.2659 0.0000 0.1432
               0.0000 0.0000 0.0000 0.0000 0.0000 0.0000 0.0000 0.0000
     33      5 0.0000 0.0000 0.0000 1.6504 0.0000 0.7790
               0.0076 0.0000 0.0076 0.0000 0.2659 0.0000 0.1432
               0.0000 0.0000 0.0000 0.0000 0.0000 0.0000 0.0000 0.0000
C------------------------------------------------------------------------------
C34 FIVE TITLE CARDS FOLLOW:
$$ C34 SOUTH OPEN BOUNDARY $$
$$ CONSTANT SURFACE CONCENTRATION BC'S
$  I   J   Bc      Bd      Bg      RPOC    LPOC    DOC
$          RPOP    LPOP    DOP     PO4t    RPON    LPON    DON
$          NH4     NO3     SU      SA      COD     DO      TAM     FCB
     30      5 0.0000 0.0000 0.0000 1.6504 0.0000 0.7790
               0.0076 0.0000 0.0076 0.0000 0.2659 0.0000 0.1432
               0.0000 0.0000 0.0000 0.0000 0.0000 0.0000 0.0000 0.0000
     31      5 0.0000 0.0000 0.0000 1.6504 0.0000 0.7790
               0.0076 0.0000 0.0076 0.0000 0.2659 0.0000 0.1432
               0.0000 0.0000 0.0000 0.0000 0.0000 0.0000 0.0000 0.0000
     32      5 0.0000 0.0000 0.0000 1.6504 0.0000 0.7790
               0.0076 0.0000 0.0076 0.0000 0.2659 0.0000 0.1432
               0.0000 0.0000 0.0000 0.0000 0.0000 0.0000 0.0000 0.0000
     33      5 0.0000 0.0000 0.0000 1.6504 0.0000 0.7790
               0.0076 0.0000 0.0076 0.0000 0.2659 0.0000 0.1432
               0.0000 0.0000 0.0000 0.0000 0.0000 0.0000 0.0000 0.0000
C------------------------------------------------------------------------------
C35 SIX TITLE CARDS FOLLOW:
$$ C35 WEST OPEN BOUNDARY $$
$$ TIME SERIES ID'S FOR EACH STATE VARIABLE
$  I   J   B  B  B  R  L  D  R  L  D  P  R  L  D  N  N  S  S  C  D  T  F
$          c  d  g  P  P  O  P  P  O  O  P  P  O  H  O  U  A  O  O  A  C
$                   O  O  C  O  O  P  4  O  O  N  4  3        D     M
$                   C  C     P  P     t  N  N
C------------------------------------------------------------------------------
C36 FIVE TITLE CARDS FOLLOW:
$$ C36 WEST OPEN BOUNDARY $$
$$ CONSTANT BOTTOM CONCENTRATION BC'S
$  I   J   Bc      Bd      Bg      RPOC    LPOC    DOC
$          RPOP    LPOP    DOP     PO4t    RPON    LPON    DON
$          NH4     NO3     SU      SA      COD     DO      TAM     FCB
C------------------------------------------------------------------------------
C37 FIVE TITLE CARDS FOLLOW:
$$ C37 WEST OPEN BOUNDARY $$
$$ CONSTANT SURFACE CONCENTRATION BC'S
$  I   J   Bc      Bd      Bg      RPOC    LPOC    DOC
$          RPOP    LPOP    DOP     PO4t    RPON    LPON    DON
$          NH4     NO3     SU      SA      COD     DO      TAM     FCB
C------------------------------------------------------------------------------
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C38 SIX TITLE CARDS FOLLOW:
$$ C38 EAST OPEN BOUNDARY $$
$$ TIME SERIES ID'S FOR EACH STATE VARIABLE
$  I   J   B  B  B  R  L  D  R  L  D  P  R  L  D  N  N  S  S  C  D  T  F
$          c  d  g  P  P  O  P  P  O  O  P  P  O  H  O  U  A  O  O  A  C
$                   O  O  C  O  O  P  4  O  O  N  4  3        D     M
$                   C  C     P  P     t  N  N
  35  44   0  0  0  0  0  0  0  0  0  0  0  0  0  0  0  0  0  0  1  0  0
C-----------------------------------------------------------------------------
C39 FIVE TITLE CARDS FOLLOW:
$$ C39 EAST OPEN BOUNDARY $$
$$ CONSTANT BOTTOM CONCENTRATION BC'S
$  I   J   Bc      Bd      Bg      RPOC    LPOC    DOC
$          RPOP    LPOP    DOP     PO4t    RPON    LPON    DON
$          NH4     NO3     SU      SA      COD     DO      TAM     FCB
  35  44   0.0     0.0     0.3     0.1     0.0     0.1
           0.05    0.0     0.05    0.1     0.2     0.0     0.2
           0.04    0.08    0.0     0.0     0.0     0.0     0.0     0.0
C-----------------------------------------------------------------------------
C40 FIVE TITLE CARDS FOLLOW:
$$ C40 EAST OPEN BOUNDARY $$
$$ CONSTANT SURFACE CONCENTRATION BC'S
$  I   J   Bc      Bd      Bg      RPOC    LPOC    DOC
$          RPOP    LPOP    DOP     PO4t    RPON    LPON    DON
$          NH4     NO3     SU      SA      COD     DO      TAM     FCB
  35  44   0.0     0.0     0.3     0.1     0.0     0.1
           0.05    0.0     0.05    0.1     0.2     0.0     0.2
           0.04    0.08    0.0     0.0     0.0     0.0     0.0     0.0
C-----------------------------------------------------------------------------
C41 SIX TITLE CARDS FOLLOW:
$$ C41 NORTH OPEN BOUNDARY $$
$$ TIME SERIES ID'S FOR EACH STATE VARIABLE
$  I   J   B  B  B  R  L  D  R  L  D  P  R  L  D  N  N  S  S  C  D  T  F
$          c  d  g  P  P  O  P  P  O  O  P  P  O  H  O  U  A  O  O  A  C
$                   O  O  C  O  O  P  4  O  O  N  4  3        D     M
$                   C  C     P  P     t  N  N
C-----------------------------------------------------------------------------
C42 FIVE TITLE CARDS FOLLOW:
$$ C42 NORTH OPEN BOUNDARY $$
$$ CONSTANT BOTTOM CONCENTRATION BC'S
$  I   J   Bc      Bd      Bg      RPOC    LPOC    DOC
$          RPOP    LPOP    DOP     PO4t    RPON    LPON    DON
$          NH4     NO3     SU      SA      COD     DO      TAM     FCB
C-----------------------------------------------------------------------------
C43 FIVE TITLE CARDS FOLLOW:
$$ C43 NORTH OPEN BOUNDARY $$
$$ CONSTANT SURFACE CONCENTRATION BC'S
$  I   J   Bc      Bd      Bg      RPOC    LPOC    DOC
$          RPOP    LPOP    DOP     PO4t    RPON    LPON    DON
$          NH4     NO3     SU      SA      COD     DO      TAM     FCB
C-----------------------------------------------------------------------------
C44 ONE TITLE CARD FOLLOWS:
$$ C44 constant ICs (g/m^3): TAM(mol/m^3), FCB(MPN/100mL) $$
C44
C Definitions:
C   Bc = cyanobacteria
C   Bd = algae diatoms
C   Bg = algae greens
C RPOC = refractory particulate carbon
C LPOC = labile particulate carbon
C  DOC = dissolved organic carbon
C RPOP = refractory particulate organic phosphorus
C LPOP = labile particulate organic phosphorus
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C  DOP = dissolved organic phosphorus
C PO4t = total orthophosphate
C RPON = refractory particulate organic nitrogen
C LPON = labile particulate organic nitrogen
C  DON = dissolved organic nitrogen
C  NH4 = ammonia nitrogen
C  NO3 = nitrite + nitrate nitrogen
C   SU = unavailable silica
C   SA = available biogenic silica
C  COD = chemical oxygen demand
C   DO = dissolved oxygen
C  TAM = total active metal
C  FCB = fecal coliform bacteria
C   Bm = macroalgae
C Bmin = minimum macroalgae biomass
C
C  Bc      Bd      Bg      RPOC    LPOC    DOC
C  RPOP    LPOP    DOP     PO4t    RPON    LPON    DON
C  NH4     NO3     SU      SA      COD     DO      TAM     FCB   Bm  Bmin
   0.05    0.05    0.05    1.0     0.1     1.0
   0.025   0.01    0.025   0.05    0.14    0.07    0.14
   0.05    0.10    0.0     0.0     0.0     10.0    0.0     0.0   0.0  0.0
C-----------------------------------------------------------------------------
C45 ONE TITLE CARD FOLLOWS:
$$ C45 spatially/temporally constant ALGAL PARAMETERS (/d except Keb in /m) $$
C45
C    PMc = max. growth rate for cyanobacteria (1/day)
C    PMd = max. growth rate for algae diatoms (1/day)
C    PMg = max. growth rate for algae greens  (1/day)
C    PMm = max. growth rate for macroalgae    (1/day)
C   BMRc = basal metabolism rate for cyanobacteria (1/day)
C   BMRd = basal metabolism rate for algae diatoms (1/day)
C   BMRg = basal metabolism rate for algae greens  (1/day)
C   BMRm = basal metabolism rate for macroalgae    (1/day)
C   PRRc = predation rate on cyanobacteria (1/day)
C   PRRd = predation rate on algae diatoms (1/day)
C   PRRg = predation rate on algae greens  (1/day)
C   PRRm = predation rate on macroalgae    (1/day)
C    Keb = background light extinction coefficient (1/m)
C    0.0  0.0  3.0  2.0  0.05  0.01  0.02  0.10 0.28  0.10  0.10  0.33 0.475
C45  PMc  PMd  PMg  PMm  BMRc  BMRd  BMRg  BMRm PRRc  PRRd  PRRg  PRRm Keb
     1.1  0.7  0.9  0.0  0.01  0.01  0.02  0.10  0.10  0.10  0.10  0.0  0.475
C-----------------------------------------------------------------------------
C46 ONE TITLE CARD FOLLOWS:
$$ C46 spatially/temporally constant SETTLING VELOCITIES (m/d) $$
C46
C    WSc = settling velocity for cyanobacteria (m/day)
C    WSd = settling velocity for algae diatoms (m/day)
C    WSg = settling velocity for algae greens  (m/day)
C   WSrp = settling velocity for refractory POM (m/day)
C   WSlp = settling velocity for labile POM (m/day)
C    WSs = settling velocity for particles sorbed to TAM (m/day)
C    WSM = settling velocity for macroalgae (m/day = 0.0)
C   REAC = reaeration adjustment factor
C   0.0     0.10    0.10    0.12    0.12    0.10    1.0   1.00
C46 WSc     WSd     WSg     WSrp    WSlp    WSs     WSM   REAC
    0.05    0.10    0.10    0.00    0.10    0.10    1.0   1.00
C-----------------------------------------------------------------------------
C47 ONE TITLE CARD FOLLOWS:
$$ C47 constant benthic flux rates (g/m^2/d) $$
C47
C   FPO4 = benthic flux rate of phosphate
C   FNH4 = benthic flux rate of ammonia nitrogen
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```
C   FNO3 = benthic flux rate of nitrite+nitrite nitrogen
C   FSAD = benthic flux rate of silica
C   FCOD = benthic flux rate of chemical oxygen demand
C    SOD = sediment oxygen demand rate
C
C47  FPO4    FNH4    FNO3    FSAD    FCOD    SOD
     0.000   0.000   -0.05   0.000  0.000   -0.50
C-----------------------------------------------------------------------------
C48 ONE TITLE CARD FOLLOWS:
$$ C48 const PS (kg/d): PSQ(m^3/s),DO(g/m^3),TAM(kmol/d),FCB(MPN/100mL)
C48
C   IWQPS = number of point sources
C NPSTMSR = number of point source time series
C
C48 const PS (kg/d): PSQ(m^3/s),DO(g/m^3),TAM(kmol/d),FCB(MPN/100mL)
C IWQPS   NPSTMSR
C IWQPS   NPSTMSR
  38     38
C  I   J   K   N   PSQ     Bc      Bd      Bg      RPOC    LPOC    DOC
C              S   RPOP    LPOP    DOP     PO4t    RPON    LPON    DON
C              R   NH4     NO3     SU      SA      COD     DO      TAM     FCB
   4   32  0   1   0.0     0.0     0.0     0.0     0.0     0.0     0.0   ! DUPONT-
WILMINGTON/BRUNSWICK
                   0.0     0.0     0.0     0.0     0.0     0.0     0.0
                   0.0     0.0     0.0     0.0     0.0     0.0     0.0     0.0
   4   32  0   2   0.0     0.0     0.0     0.0     0.0     0.0     0.0   ! DUPONT-
WILMINGTON/BRUNSWICK
                   0.0     0.0     0.0     0.0     0.0     0.0     0.0
                   0.0     0.0     0.0     0.0     0.0     0.0     0.0     0.0
   4   32  0   3   0.0     0.0     0.0     0.0     0.0     0.0     0.0   ! DUPONT-
WILMINGTON/BRUNSWICK
                   0.0     0.0     0.0     0.0     0.0     0.0     0.0
                   0.0     0.0     0.0     0.0     0.0     0.0     0.0     0.0
   4   27  0   4   0.0     0.0     0.0     0.0     0.0     0.0     0.0   ! ARTEVA
SPECIALTIES-WILMINGTON
                   0.0     0.0     0.0     0.0     0.0     0.0     0.0
                   0.0     0.0     0.0     0.0     0.0     0.0     0.0     0.0
   4   27  0   5   0.0     0.0     0.0     0.0     0.0     0.0     0.0   ! ARTEVA
SPECIALTIES-WILMINGTON
                   0.0     0.0     0.0     0.0     0.0     0.0     0.0
                   0.0     0.0     0.0     0.0     0.0     0.0     0.0     0.0
   4   63  0   6   0.0     0.0     0.0     0.0     0.0     0.0     0.0   ! FEDERAL
PAPER BD CO-RIEGELWD
                   0.0     0.0     0.0     0.0     0.0     0.0     0.0
                   0.0     0.0     0.0     0.0     0.0     0.0     0.0     0.0
  23   10  0   8   0.0     0.0     0.0     0.0     0.0     0.0     0.0   ! SOUTHPORT,
TOWN-WWTP/SOUTHPORT
                   0.0     0.0     0.0     0.0     0.0     0.0     0.0
                   0.0     0.0     0.0     0.0     0.0     0.0     0.0     0.0
  31   39  0   9   0.0     0.0     0.0     0.0     0.0     0.0     0.0   ! CAROLINA
BEACH, TOWN-WWTP
                   0.0     0.0     0.0     0.0     0.0     0.0     0.0
                   0.0     0.0     0.0     0.0     0.0     0.0     0.0     0.0
  24   79  0  10    0.0     0.0     0.0     0.0     0.0     0.0     0.0   !
WILMINGTON-NORTHSIDE WWTP
                   0.0     0.0     0.0     0.0     0.0     0.0     0.0
                   0.0     0.0     0.0     0.0     0.0     0.0     0.0     0.0
  28   63  0  11    0.0     0.0     0.0     0.0     0.0     0.0     0.0   !
WILMINGTON-SOUTHSIDE WWTP   17   64
                   0.0     0.0     0.0     0.0     0.0     0.0     0.0
                   0.0     0.0     0.0     0.0     0.0     0.0     0.0     0.0
  30   33  0  12    0.0     0.0     0.0     0.0     0.0     0.0     0.0   ! KURE BEACH
WWTP
```

```
                   0.0     0.0     0.0     0.0     0.0     0.0     0.0
                   0.0     0.0     0.0     0.0     0.0     0.0     0.0      0.0
  23   18  0  13    0.0     0.0     0.0     0.0     0.0     0.0     0.0    ! ARCHER
DANIELS MIDLAND CO.
                   0.0     0.0     0.0     0.0     0.0     0.0     0.0
                   0.0     0.0     0.0     0.0     0.0     0.0     0.0      0.0
   4   31  0  14    0.0     0.0     0.0     0.0     0.0     0.0     0.0    ! TAKEDA
CHEMICAL PRODUCTS
                   0.0     0.0     0.0     0.0     0.0     0.0     0.0
                   0.0     0.0     0.0     0.0     0.0     0.0     0.0      0.0
   4   31  0  14    0.0     0.0     0.0     0.0     0.0     0.0     0.0    ! TAKEDA
CHEMICAL PRODUCTS, number 2
                   0.0     0.0     0.0     0.0     0.0     0.0     0.0
                   0.0     0.0     0.0     0.0     0.0     0.0     0.0      0.0
   4   15  0  15    0.0     0.0     0.0     0.0     0.0     0.0     0.0    ! LELAND
INDUSTRIAL PARK WWTP
                   0.0     0.0     0.0     0.0     0.0     0.0     0.0
                   0.0     0.0     0.0     0.0     0.0     0.0     0.0      0.0
  18   72  0  16    0.0     0.0     0.0     0.0     0.0     0.0     0.0    ! BELVILLE,
TOWN - WWTP
                   0.0     0.0     0.0     0.0     0.0     0.0     0.0
                   0.0     0.0     0.0     0.0     0.0     0.0     0.0      0.0
   4   27  0  17    0.0     0.0     0.0     0.0     0.0     0.0     0.0    ! FORTRON
INDUSTRIES
                   0.0     0.0     0.0     0.0     0.0     0.0     0.0
                   0.0     0.0     0.0     0.0     0.0     0.0     0.0      0.0
   4   85  0  18    0.0     0.0     0.0     0.0     0.0     0.0     0.0    ! cape fear
river
                   0.0     0.0     0.0     0.0     0.0     0.0     0.0
                   0.0     0.0     0.0     0.0     0.0     0.0     0.0      0.0
   7   72  0  19    0.0     0.0     0.0     0.0     0.0     0.0     0.0    ! black
river
                   0.0     0.0     0.0     0.0     0.0     0.0     0.0
                   0.0     0.0     0.0     0.0     0.0     0.0     0.0      0.0
  43   97  0  20    0.0     0.0     0.0     0.0     0.0     0.0     0.0    ! ne cape
fear river
                    0.0     0.0     0.0     0.0     0.0     0.0     0.0
                    0.0     0.0     0.0     0.0     0.0     0.0     0.0      0.0
  43   21  0  21    0.0     0.0     0.0     0.0     0.0     0.0     0.0    ! NE Cape
Fear, estuary 1
                    0.0     0.0     0.0     0.0     0.0     0.0     0.0
                    0.0     0.0     0.0     0.0     0.0     0.0     0.0      0.0
  43   35  0  22    0.0     0.0     0.0     0.0     0.0     0.0     0.0    ! NE Cape
Fear, estuary 2
                    0.0     0.0     0.0     0.0     0.0     0.0     0.0
                    0.0     0.0     0.0     0.0     0.0     0.0     0.0      0.0
  43   93  0  23    0.0     0.0     0.0     0.0     0.0     0.0     0.0    ! NE Cape
Fear, estuary 3
                    0.0     0.0     0.0     0.0     0.0     0.0     0.0
                    0.0     0.0     0.0     0.0     0.0     0.0     0.0      0.0
  43   87  0  24    0.0     0.0     0.0     0.0     0.0     0.0     0.0    ! NE Cape
Fear, estuary 4
                    0.0     0.0     0.0     0.0     0.0     0.0     0.0
                    0.0     0.0     0.0     0.0     0.0     0.0     0.0      0.0
  43   47  0  25    0.0     0.0     0.0     0.0     0.0     0.0     0.0    ! NE Cape
Fear, estuary 5
                    0.0     0.0     0.0     0.0     0.0     0.0     0.0
                    0.0     0.0     0.0     0.0     0.0     0.0     0.0      0.0
  43   79  0  26    0.0     0.0     0.0     0.0     0.0     0.0     0.0    ! NE Cape
Fear, estuary 6
                    0.0     0.0     0.0     0.0     0.0     0.0     0.0
                    0.0     0.0     0.0     0.0     0.0     0.0     0.0      0.0
```

```
   7   58  0  27    0.0     0.0     0.0     0.0     0.0     0.0     0.0   ! Black
River, estuary 1
                    0.0     0.0     0.0     0.0     0.0     0.0     0.0
                    0.0     0.0     0.0     0.0     0.0     0.0     0.0     0.0
   7   41  0  28    0.0     0.0     0.0     0.0     0.0     0.0     0.0   ! Black
River, estuary 2
                    0.0     0.0     0.0     0.0     0.0     0.0     0.0
                    0.0     0.0     0.0     0.0     0.0     0.0     0.0     0.0
   4   63  0  29    0.0     0.0     0.0     0.0     0.0     0.0     0.0   ! Cape Fear,
upper estuary 1
                    0.0     0.0     0.0     0.0     0.0     0.0     0.0
                    0.0     0.0     0.0     0.0     0.0     0.0     0.0     0.0
   4   42  0  30    0.0     0.0     0.0     0.0     0.0     0.0     0.0   ! Cape Fear,
upper estuary 2
                    0.0     0.0     0.0     0.0     0.0     0.0     0.0
                    0.0     0.0     0.0     0.0     0.0     0.0     0.0     0.0
   4   17  0  31    0.0     0.0     0.0     0.0     0.0     0.0     0.0   ! Cape Fear,
upper estuary 3
                    0.0     0.0     0.0     0.0     0.0     0.0     0.0
                    0.0     0.0     0.0     0.0     0.0     0.0     0.0     0.0
   20  57  0  32    0.0     0.0     0.0     0.0     0.0     0.0     0.0   ! Cape Fear,
lower estuary 1
                    0.0     0.0     0.0     0.0     0.0     0.0     0.0
                    0.0     0.0     0.0     0.0     0.0     0.0     0.0     0.0
   27  55  0  33    0.0     0.0     0.0     0.0     0.0     0.0     0.0   ! Cape Fear,
lower estuary 2
                    0.0     0.0     0.0     0.0     0.0     0.0     0.0
                    0.0     0.0     0.0     0.0     0.0     0.0     0.0     0.0
   22  42  0  34    0.0     0.0     0.0     0.0     0.0     0.0     0.0   ! Cape Fear,
lower estuary 3
                    0.0     0.0     0.0     0.0     0.0     0.0     0.0
                    0.0     0.0     0.0     0.0     0.0     0.0     0.0     0.0
   4   15  0  35    0.0     0.0     0.0     0.0     0.0     0.0     0.0   ! Brunswick
Co. WWTP, NC0086819
                    0.0     0.0     0.0     0.0     0.0     0.0     0.0
                    0.0     0.0     0.0     0.0     0.0     0.0     0.0     0.0
   43  28  0  36    0.0     0.0     0.0     0.0     0.0     0.0     0.0   ! GE -
Wilmington, NC0001228
                    0.0     0.0     0.0     0.0     0.0     0.0     0.0
                    0.0     0.0     0.0     0.0     0.0     0.0     0.0     0.0
   43  72  0  37    0.0     0.0     0.0     0.0     0.0     0.0     0.0   ! Occidental
Chemical, NC0003875
                    0.0     0.0     0.0     0.0     0.0     0.0     0.0
                    0.0     0.0     0.0     0.0     0.0     0.0     0.0     0.0
   4   63  0  38    0.0     0.0     0.0     0.0     0.0     0.0     0.0   ! DO
injection, IP
                    0.0     0.0     0.0     0.0     0.0     0.0     0.0
                    0.0     0.0     0.0     0.0     0.0     0.0     0.0     0.0
C-------------------------------------------------------------------------------
C49 FOUR TITLE CARDS FOLLOW:
$$ C49 Constant Dry Atmospheric Deposition (g/m2/day; MPN/m2/day)
$ DSQ       Bc        Bd        Bg        RPOC      LPOC      DOC
$ RPOP      LPOP      DOP       PO4t      RPON      LPON      DON
$ NH4       NO3       SU        SA        COD       DO        TAM       FCB
  0.0       0.0       0.0       0.0       0.0       0.0       0.0
  0.0       0.0       0.0       0.0       0.0       0.0       0.0
  0.0       0.0       0.0       0.0       0.0       0.0       0.0       0.0
C-------------------------------------------------------------------------------
C50 FOUR TITLE CARDS FOLLOW:
$$ C50 Wet Atmospheric Deposition concentrations (mg/L; MPN/L)
$           Bc        Bd        Bg        RPOC      LPOC      DOC
$ RPOP      LPOP      DOP       PO4t      RPON      LPON      DON
$ NH4       NO3       SU        SA        COD       DO        TAM       FCB
```

```
            0.0       0.0       0.0       0.0       0.0       0.0
  0.0       0.0       0.0       0.0       0.0       0.0       0.0
  0.0       0.0       0.0       0.0       0.0       0.0       0.0       0.0
C------------------------------------------------------------------------------
C51 ONE TITLE CARD FOLLOWS:
$$ C51 File names for spatially/temporally varying parameters: lower case only $$
Restart file for end spatial distribution = wq3drst.out
File for initial conditions (ICIFN)       = NONE ICIFN.INP
File for algal growth, resp, pred (AGRFN) = NONE AGRFN.INP
File for settling of algae, POM (STLFN)   = NONE STLFN.INP
Input file for Io, FD, KT, Te (SUNFN)     = NONE SUNFN.INP
Input file for benthic fluxes (BENFN)     = benflux_tser.inp
Input file for point source input (PSLFN) = NONE PSLFN.INP
File for NPS input inc/atm input (NPLFN)  = NONE NPLFN.INP
Diagnostic file-negative conc. (NCOFN)    = NONE wq3dnc.log
```

```
#   Variable Benthic Flux, By Jim Bowen, Feb 2008, number of zones
#   date to begin new set of values
#    iwqz  FPO4  FNH4  FNO3  FSAD  FCOD  FSOD
  2
365.00
1      0.0   0.0   -0.0075     0.0   0.0   -0.188
2      0.0   0.0   -0.0113     0.0   0.0   -0.281
395.42
1      0.0   0.0   -0.0080     0.0   0.0   -0.199
2      0.0   0.0   -0.0119     0.0   0.0   -0.298
425.83
1      0.0   0.0   -0.0095     0.0   0.0   -0.237
2      0.0   0.0   -0.0142     0.0   0.0   -0.355
456.25
1      0.0   0.0   -0.0134     0.0   0.0   -0.336
2      0.0   0.0   -0.0202     0.0   0.0   -0.504
486.67
1      0.0   0.0   -0.0180     0.0   0.0   -0.449
2      0.0   0.0   -0.0270     0.0   0.0   -0.674
517.08
1      0.0   0.0   -0.0241     0.0   0.0   -0.601
2      0.0   0.0   -0.0300     0.0   0.0   -0.902
547.50
1      0.0   0.0   -0.0278     0.0   0.0   -0.696
2      0.0   0.0   -0.0300     0.0   0.0   -1.044
577.92
1      0.0   0.0   -0.0255     0.0   0.0   -0.638
2      0.0   0.0   -0.0300     0.0   0.0   -0.956
608.33
1      0.0   0.0   -0.0214     0.0   0.0   -0.535
2      0.0   0.0   -0.0300     0.0   0.0   -0.803
638.75
1      0.0   0.0   -0.0180     0.0   0.0   -0.449
2      0.0   0.0   -0.0270     0.0   0.0   -0.674
669.17
1      0.0   0.0   -0.0134     0.0   0.0   -0.336
2      0.0   0.0   -0.0202     0.0   0.0   -0.504
699.58
1      0.0   0.0   -0.0089     0.0   0.0   -0.223
2      0.0   0.0   -0.0134     0.0   0.0   -0.335
730.00
1      0.0   0.0   -0.0075     0.0   0.0   -0.188
2      0.0   0.0   -0.0113     0.0   0.0   -0.281
760.42
1      0.0   0.0   -0.0080     0.0   0.0   -0.199
2      0.0   0.0   -0.0119     0.0   0.0   -0.298
790.83
1      0.0   0.0   -0.0095     0.0   0.0   -0.237
2      0.0   0.0   -0.0142     0.0   0.0   -0.355
821.25
1      0.0   0.0   -0.0134     0.0   0.0   -0.336
2      0.0   0.0   -0.0202     0.0   0.0   -0.504
851.67
1      0.0   0.0   -0.0180     0.0   0.0   -0.449
2      0.0   0.0   -0.0270     0.0   0.0   -0.674
882.08
1      0.0   0.0   -0.0241     0.0   0.0   -0.601
2      0.0   0.0   -0.0300     0.0   0.0   -0.902
```

```
912.50
1      0.0    0.0    -0.0278      0.0    0.0    -0.696
2      0.0    0.0    -0.0300      0.0    0.0    -1.044
942.92
1      0.0    0.0    -0.0255      0.0    0.0    -0.638
2      0.0    0.0    -0.0300      0.0    0.0    -0.956
973.33
1      0.0    0.0    -0.0214      0.0    0.0    -0.535
2      0.0    0.0    -0.0300      0.0    0.0    -0.803
1003.75
1      0.0    0.0    -0.0180      0.0    0.0    -0.449
2      0.0    0.0    -0.0270      0.0    0.0    -0.674
1034.17
1      0.0    0.0    -0.0134      0.0    0.0    -0.336
2      0.0    0.0    -0.0202      0.0    0.0    -0.504
1064.58
1      0.0    0.0    -0.0089      0.0    0.0    -0.223
2      0.0    0.0    -0.0134      0.0    0.0    -0.335
1095.00
1      0.0    0.0    -0.0075      0.0    0.0    -0.188
2      0.0    0.0    -0.0113      0.0    0.0    -0.281
1125.42
1      0.0    0.0    -0.0080      0.0    0.0    -0.199
2      0.0    0.0    -0.0119      0.0    0.0    -0.298
1155.83
1      0.0    0.0    -0.0095      0.0    0.0    -0.237
2      0.0    0.0    -0.0142      0.0    0.0    -0.355
1186.25
1      0.0    0.0    -0.0134      0.0    0.0    -0.336
2      0.0    0.0    -0.0202      0.0    0.0    -0.504
1216.67
1      0.0    0.0    -0.0180      0.0    0.0    -0.449
2      0.0    0.0    -0.0270      0.0    0.0    -0.674
1247.08
1      0.0    0.0    -0.0241      0.0    0.0    -0.601
2      0.0    0.0    -0.0300      0.0    0.0    -0.902
1277.50
1      0.0    0.0    -0.0278      0.0    0.0    -0.696
2      0.0    0.0    -0.0300      0.0    0.0    -1.044
1307.92
1      0.0    0.0    -0.0255      0.0    0.0    -0.638
2      0.0    0.0    -0.0300      0.0    0.0    -0.956
1338.33
1      0.0    0.0    -0.0214      0.0    0.0    -0.535
2      0.0    0.0    -0.0300      0.0    0.0    -0.803
1368.75
1      0.0    0.0    -0.0180      0.0    0.0    -0.449
2      0.0    0.0    -0.0270      0.0    0.0    -0.674
1399.17
1      0.0    0.0    -0.0134      0.0    0.0    -0.336
2      0.0    0.0    -0.0202      0.0    0.0    -0.504
1429.58
1      0.0    0.0    -0.0089      0.0    0.0    -0.223
2      0.0    0.0    -0.0134      0.0    0.0    -0.335
1465.00
1      0.0    0.0    -0.0075      0.0    0.0    -0.188
2      0.0    0.0    -0.0113      0.0    0.0    -0.281
```