TOTAL MAXIMUM DAILY LOAD (TMDL) DEVELOPMENT

For

Oxygen Demanding Material/Dissolved Oxygen

In the

BRUNSWICK HARBOR SYSTEM

Listed Segments:

St. Simons Sound

And

Brunswick River

EPA United States Environmental Protection Agency

Region 4 serving the southeast

Summary Page

St. Simons Sound and Brunswick River have been placed on the State of Georgia 303(d) list for dissolved oxygen (GAEPD, 2000). As prescribed under the Clean Water Act, a Total Maximum Daily Load (TMDL) has been developed for these listed reaches and is summarized below. The TMDL represents the total mass of oxygen demanding material that can be discharged to the system under a prescribed set of critical conditions, and the water body meet its designated use. The TMDLs for Dissolved Oxygen for the two listed segments were scheduled for development in 2000 as required by Consent Decree in the Georgia TMDL Lawsuit.

Based upon the evaluation of naturally occurring dissolved oxygen within the listed reaches of St. Simons Sound and Brunswick River, it was determined that a under the critical low-flow summer period the condition exists "where natural conditions alone create dissolved oxygen concentrations less than 110 percent of the applicable criteria means or minima or both…". As the "natural" levels were between 3.3 mg/L and 4.0 mg/L, the allowable anthropogenic impact on dissolved oxygen is 0.3 mg/L. The total allowable load for anthropogenic discharges or wasteload allocation (WLA) was determined to be 47,307 lbs/day of ultimate biochemical oxygen demanding material (BODU) including the influence of Carbonaceous Biochemical Oxygen Demand (CBOD) and Nitrogenous Biochemical Oxygen Demand (NBOD). The natural background loading or load allocation (LA) for the Brunswick Harbor System from the surrounding marshes is 337,000 lbs/days. **The TMDL is the LA (337,000 lbs/days) plus WLA (47,307 lbs/day), which equals 384,307 lbs/day.**

_____ _____

Beverly H. Banister, Director Date

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Executive Summary

St. Simons Sound and Brunswick River have been placed on the State of Georgia 303(d) list for dissolved oxygen (GAEPD, 2000). As prescribed under the Clean Water Act, a Total Maximum Daily Load (TMDL) has been developed for these listed reaches and is summarized below. The TMDL represents the total mass of oxygen demanding material that can be discharged to the system under a prescribed set of critical conditions, and the water body meet its designated use. The TMDLs for Dissolved Oxygen for the two listed segments were scheduled for development in 2000 as required by Consent Decree in the Georgia TMDL Lawsuit.

Summary of TMDL Analysis

The TMDL analysis includes an evaluation of the relationship between the sources and the impact on the receiving water. Due to the many factors that dynamically influence in-stream dissolved oxygen concentrations within estuarine systems, this relationship was developed using a complex hydrodynamic and water quality model linkage. The model development is an extension of work conducted by the Georgia Environmental Protection Division (GAEPD) in the 1980s to develop a steady state, tidally averaged, waste load allocation model for the Brunswick River (GAEPD, 1984). The data, analyses, and results from the one dimensional (1-D) steady-state model were used as the framework for development of a dynamic two dimensional (2-D) model of St. Simons Sound and the Brunswick River.

The hydrodynamic model utilized was the Environmental Fluid Dynamics Code (EFDC). EFDC was developed to simulate the complex circulation and transport conditions within estuarine systems. For this TMDL analysis, the EFDC application considered the influence of tides, freshwater inflow, salt marsh retention, and salinity intrusion on the circulation and transport. The model simulated the two-dimensional, vertically averaged, dynamic tidal and non-tidal transport of material throughout the system, including all listed reaches and relevant adjacent tidal creeks and tributaries. A detailed description of the hydrodynamic model calibration is presented in a report entitled “Development of a Hydrodynamic and Water Quality Model for St. Simons Sound and Brunswick River” (EPA Region 4, 2000).

The hydrodynamic model application was linked to the Water Quality Analysis and Simulation Program (WASP) through a dynamic linkage file. The WASP water quality model simulated the two-dimensional, vertically integrated, dynamic interaction between in-stream carbonaceous biochemical oxygen demand (CBOD), net oxygen depletion through sediment oxygen demand (SOD), dynamic reaeration (driven by in-stream turbulence), net flux of CBOD and dissolved oxygen within adjacent marshes, point source discharge of CBOD, and the tidal and non-tidally driven transport of dissolved oxygen and CBOD. The water quality simulation was performed with the same resolution and spatial variation as the hydrodynamic model. A detailed description of the water quality model calibration is presented in a report entitled "Development of a Hydrodynamic and Water Quality Model for St. Simons Sound and Brunswick River" (EPA Region 4, 2000).

Applicable Water Quality Standards

The applicable dissolved oxygen water quality standard for waters in St. Simons Sound and Brunswick River is as follows:

> *Numeric*. A daily average of 5.0 mg/l and no less than 4.0 mg/l at all times for waters supporting warm water species of fish. 6.03(6)(c)(i).
>
> *Natural Water Quality - GAEPD.* It is recognized that certain natural waters of the State may have a quality that will not be within the general or specific requirements contained herein. This is especially the case for the criteria for dissolved oxygen, temperature, pH and fecal coliform. NPDES permits and best management practices will be the primary mechanisms for ensuring that the discharges will not create a harmful situation. 391-3-6-.03(7)
>
> *Note: Georgia identifies the allowable dissolved oxygen deficit based upon the natural dissolved oxygen concentrations such that the "dissolved oxygen allocated to all Permits combined in a given waterbody should be less than 10 percent of the naturally occurring dissolved oxygen". The minimum oxygen allowed after allocation of all permits should be 3.0 mg/L. The Georgia DO Permitting Strategy is presented in Appendix A.*
>
> *Natural Water Quality - EPA*. "Where natural conditions alone create dissolved oxygen concentrations less than 110 percent of the applicable criteria means or minima or both, the minimum acceptable concentration is 90 percent of the natural concentration." Ambient Aquatic Life Water Quality Criteria for Dissolved Oxygen (Freshwater). EPA440/5-86-003

Critical Condition: Dry weather, summer temperatures

MOS: Implicit; conservative assumptions include 1) running dynamic model; 2) permitted point sources are loaded into model for allocation runs (average monthly permit values); 3) critical summer low flow/high temperatures considered.

Seasonality: Evaluated under worst-case conditions. If applicable water quality standards met under these conditions, the TMDL is protective under all other conditions.

Approach: NPDES for point sources

TMDL SUMMARY
Based upon the evaluation of naturally occurring dissolved oxygen within the listed reaches of St. Simons Sound and Brunswick River, it was determined that a under the critical low-flow summer period the condition exists "where natural conditions alone create dissolved oxygen concentrations less than 110 percent of the applicable criteria means or minima or both…". As the "natural" levels were between 3.3 mg/L and 4.0 mg/L, the allowable anthropogenic impact on dissolved oxygen is 0.3 mg/L. The total allowable load for anthropogenic discharges or wasteload allocation (WLA) was determined to be 47,307 lbs/day of ultimate biochemical oxygen demanding material (BODU) including the influence of Carbonaceous Biochemical Oxygen Demand (CBOD) and Nitrogenous Biochemical Oxygen Demand (NBOD). The natural background loading or load allocation (LA) for the Brunswick Harbor System from the surrounding marshes is 337,000 lbs/days. The TMDL is the LA (337,000 lbs/days) plus WLA (47,307 lbs/day), which equals 384,307 lbs/day.

Allocation of Responsibility and Recommendations

Evaluation of the existing NPDES permits identified a total permitted BOD load of 67,583 lbs/day from the combined loads of the City of Brunswick Academy Creek Wastewater Treatment Facility and the Georgia Pacific Pulp and Paper Facility. Additionally, the Georgia Pulp and Paper Facility is required to provide 22,000 lbs/day of oxygen at its present discharge location during the critical summer low flow period (August). Evaluation of these permitted discharges identified that with oxygen injection, the net dissolved oxygen deficit is less than the allowable 0.3 mg/L. Therefore, the facilities as presently permitted (with oxygen injection) meet applicable water quality standards.

Introduction

The State of Georgia is required to develop total maximum daily loads (TMDLs) for waters not meeting water quality standards, in accordance with Section 303(d) of the Clean Water Act and the U. S. Environmental Protection Agency (EPA) Water Quality Planning and Management Regulations (40 CFR Part 130). Water quality data collected indicate that portions of St. Simons Sound and the Brunswick River do not achieve water quality standards for dissolved oxygen. The low dissolved oxygen conditions may in part be due to naturally occurring conditions. These waterbodies were listed on the Georgia 303(d) list.

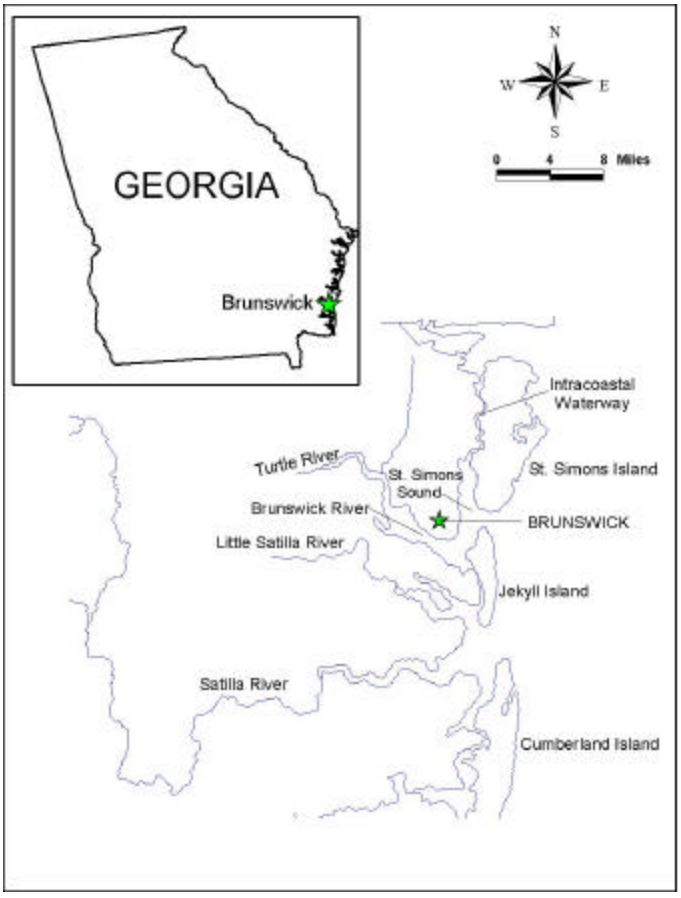

Figure 1. Location Map for St. Simons Sound and Brunswick River

Problem Definition

St. Simons Sound and Brunswick River are located in an estuary along the Atlantic Coast approximately 80 miles south of Savannah, Georgia, and 70 miles north of Jacksonville, Florida (Figure 1). The upper

portions of the estuary are made up of the Brunswick, Turtle and East Rivers. The lower portions are made up of St. Simons Sound, which empties into the Atlantic Ocean, and a series of small tidal tributaries extending north; the Back River, MacKay River, and Frederick River. In addition to these main rivers, the estuary is composed of a complex network of small streams, creeks, tidal sloughs and vast expanses of tidal salt marsh. The MacKay and Frederick Rivers flow into St. Simons Sound from the north, connecting this estuary to the Altamaha River. Jekyll Creek flows into St. Simons Sound from the south and is the connecting link to Jekyll Sound.

The drainage basin of the Turtle and South Brunswick Rivers, which are primarily tidal channels, is quite small. There are no major rivers that flow directly into the harbor area; therefore fresh water inflow is limited to that from the Altamaha River via the MacKay River. However, because of the high tidal fluctuations, the water is well mixed and there is relatively uniform salinity.

Portions of St. Simons Sound and the Brunswick River have been listed as impaired for dissolved oxygen on the State of Georgia 303(d) list. Under the Clean Water Act, a Total Maximum Daily Load (TMDL) must be determined for the parameter of concern. The TMDLs for dissolved oxygen for the 2 listed segments were scheduled for development in as required by the Consent Decree in the Georgia TMDL lawsuit.

Background and Monitoring Data

The methodology utilized in the development of the TMDLs for St. Simons Sound and the Brunswick River is an extension of previous work conducted by the State of Georgia Environmental Protection Division (GAEPD). From 1982 to 1983, under the Brunswick Harbor Project, GAEPD developed a steady-state model of the Brunswick Harbor Estuary using the Georgia Estuary Model (GAEPD, 1984). Under this study, the State of Georgia, along with various outside consultants, conducted hydrodynamic and water quality measurements within the Brunswick River, Turtle River and adjacent tributaries. This data set is the most comprehensive found to date for use in calibrating a water quality model of St. Simons Sound and the Brunswick River.

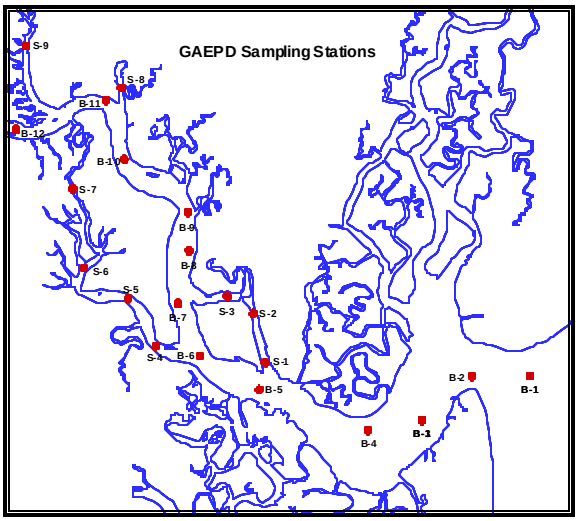

Figure 2. GAEPD Sampling Stations

Under the GAEPD study the following data were collected:

- Salinity, temperature, and dissolved oxygen profiles at four consecutive low slack and high slack water events at 20 stations throughout the system (Figure 2) on August 12 and 13, 1982.
- Discrete water quality samples at the 20 water quality stations; parameters analyzed included CBOD5, BOD5, ammonia, nitrate-nitrite,
- Measurement of the sediment oxygen demand at 15 stations throughout the listed segments and adjacent tributaries.
- Measurements of net uptake and release of dissolved oxygen and BOD from adjacent tidal marshes.
- Wastewater characterization of the Georgia Pacific Pulp and Paper Facility and the City of Brunswick Academy Creek Wastewater Treatment Plant.

The goal in the development of the EFDC model, was to utilize recent improvements in dynamic modeling capability and computer resources to enhance the GAEPD work through the development of a two-dimensional laterally averaged hydrodynamic and water quality model using the Environmental Fluid Dynamic Code (EFDC). A detailed description of the hydrodynamic model calibration is presented in a report entitled "Development of a Hydrodynamic and Water Quality Model for Brunswick Harbor" (EPA Region 4, 2000).

Water Quality Standards

St. Simons Sound and the Brunswick River been designated by the State of Georgia with a water use classification of Fishing. Georgia Water Quality Standards (Georgia EPD, 1999) have defined water quality criteria for surface waters as those that are used, or have a high potential to be used, for fishing and primary contact recreation. Georgia's water quality standards state the following criteria for measurements of dissolved oxygen with a use classification of fishing:

> *Numeric*. A daily average of 5.0 mg/l and no less than 4.0 mg/l at all times for waters supporting warm water species of fish*. A daily average of 6.0 mg/l and no less than 5.0 mg/l at all times for waters designated as trout streams by the Wildlife Resource Division.

Georgia EPD, 1999

*Waterbodies in St. Simons Sound and Brunswick are classified as supporting warm water species of fish.

Certain waters of the State may have conditions where the dissolved oxygen is naturally lower than the recommended numeric dissolved oxygen criteria. For these situations, Georgia's water quality standards state the following:

> *Natural Water Quality.* "It is recognized that certain natural waters of the State may have a quality that will not be within the general or specific requirements contained herein. This is especially the case for the criteria for dissolved oxygen, temperature, pH and fecal coliform. NPDES permits and best management practices will be the primary mechanisms for ensuring that the discharges will not create a harmful situation." 391-3-6-.03(7)

Georgia EPD, 1999

U.S. EPA guidelines supplement the Georgia guidelines for naturally low dissolved oxygen conditions by providing numeric targets:

> "Where natural conditions alone create dissolved oxygen concentrations less than 110 percent of the applicable criteria means or minima or both, the minimum acceptable concentration is 90 percent of the natural concentration." Ambient Aquatic Life Water Quality Criteria for Dissolved Oxygen (Freshwater), EPA440/5-86-003, April 1986.

EPA, 1986

Georgia identifies the allowable dissolved oxygen deficit based upon the natural dissolved oxygen concentrations such that the "dissolved oxygen allocated to all Permits combined in a given waterbody should be less than 10 percent of the naturally occurring dissolved oxygen". The minimum oxygen allowed after allocation of all permits should be 3.0 mg/L. The Georgia DO Permitting Strategy is presented in

Appendix A.

Source Assessment

An examination of permits and adjacent land uses was used to identify all potential sources of oxygen demanding substances to the listed segments. These sources (divided into point and nonpoint sources) were considered in the source loading analysis and the subsequent TMDL.

Point Sources

Potential point sources affecting in-stream dissolved oxygen concentrations include the City of Brunswick Academy Creek wastewater treatment plant, and the Georgia Pacific Pulp and Paper Facility. The Georgia Pacific Facility directly discharges organic and inorganic oxidizable substances into the Brunswick River. The City of Brunswick Academy Creek Facility discharges to an adjacent tributary that flows to the Brunswick River. The locations of the two discharges are shown in Figure 3. Pollutants that are typically monitored by facilities and should be considered in an evaluation of point source effects on in-stream dissolved oxygen concentrations include CBOD and NH3. The discharge characteristics of the two facilities are listed in Table 1.

Nonpoint Sources

Nonpoint sources of oxygen demand within St. Simons Sound and Brunswick River during the critical low flow summer period are primarily due to flooding and drying of extensive adjacent tidal saltwater marsh. These marshes are a significant source of readily oxidizable organic material and provide an influx of BOD as well as being a sink of dissolved oxygen. As this system is primarily composed of small tidal creeks the typical watershed contributions to nonpoint sources are insignificant in comparison with the marsh loadings. The natural background loading or load allocation (LA) for the Brunswick Harbor System from the surrounding marshes is 337,000 lbs/days.

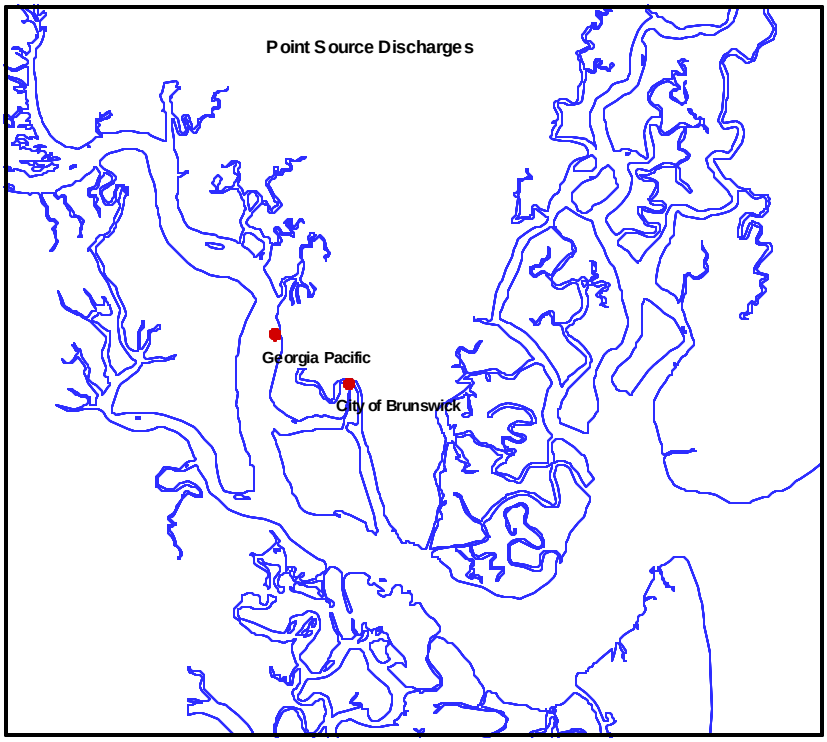

Figure 3. Locations of Point Source Discharges

Table 1. Discharge Characteristics of Point Sources

Facility Name	Receiving Water	Dissolved Oxygen (mg/L)	BOD5 (mg/L) (lb/day)*	Flow (MGD)	NH3 (mg/L)
Georgia Pacific Pulp and Paper	Brunswick River	NA	12,500*	NA	NA
City of Brunswick Academy Creek	Academy Creek	NA	20.0	13.5	17.4

*Includes oxygen injection and seasonal limits

Total Maximum Daily Load (TMDL)

Model Development

Hydrodynamic Model

The EFDC hydrodynamic application for Brunswick Harbor is a two-dimensional, vertically integrated, simulation with tidal forcing at the ocean boundary, and freshwater inflow at the upstream boundaries. The shoreline and bathymetry are represented through the use of a curvilinear grid whose boundaries are based

upon the digital National Oceanic and Atmospheric Administration (NOAA) shoreline data, and whose depths are interpolated from the NOAA digital depth data. Figure 4 presents the model grid used in the simulations.

The model calibration period was chosen based upon the work completed by GAEPD; the model is calibrated to the data collected in August of 1982. This period was chosen based upon the availability of sufficient data to calibrate the hydrodynamics and water quality model.

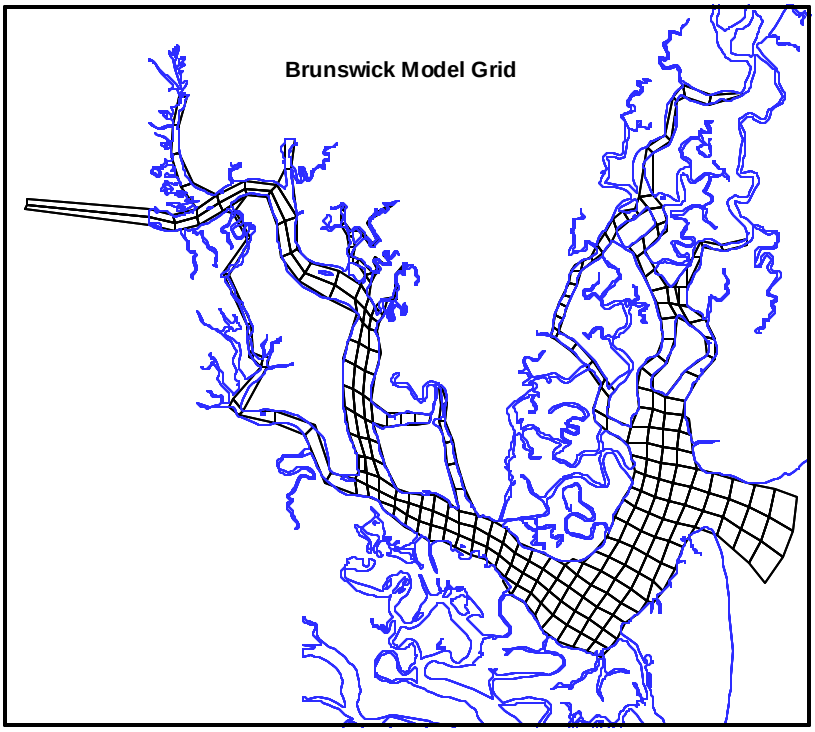

Figure 4. EFDC Model Grid

For model calibration, EFDC was forced using astronomical tide projections for July and August 1982 at the mouth of St. Simons Sound. This means that localized effects of wind and atmospheric pressure were not considered in the tidal forcing function. The model comparisons for water surface elevation and currents also used astronomical tide and current projections at interior points within the harbor and tributaries.

In order to demonstrate that the model is accurately representing the long-term net transport within the system (i.e., that driven primarily by longitudinal dispersion) the model was compared to the mean tide longitudinal distribution of salinity based upon the data collected by GAEPD on August 12, 1982. In

addition, the model was compared to the maximum and minimum (high slack and low slack tide) salinity values to provide additional verification of the tidally driven advective transport.

The determination of the freshwater inflow at the heads of the tributaries utilized the same methodology as the GAEPD study. The GAEPD study utilized the rationale method with local rainfall intensity measurements to define the freshwater inflow. The period prior to the August 12-13 measurements was relatively dry and, therefore, it was assumed that the system was at an equilibrium condition relative to the overall freshwater inflow during the preceding period.

Based upon the discussions presented above, the model was calibrated to the following:

- Propagation of the tidal wave through the system through comparison of interior water surface elevations.
- Time-dependant tidally driven flow through comparison of interior currents.
- Horizontal dispersion through comparison of the longitudinal distribution of vertically averaged mean tide salinity throughout the model domain.
- Tidally-driven advective transport through comparison of high and low slack water salinity concentrations.

Graphical, and where appropriate, harmonic and statistical comparisons were performed for each of these components. A detailed description of the hydrodynamic model calibration is presented in a report entitled "Development of a Hydrodynamic and Water Quality Model for Brunswick Harbor" (EPA Region 4, 2000).

Water Quality Model

The water quality application for Brunswick Harbor utilized the WASP component model within EFDC in a dynamic two-dimensional vertically integrated simulation. The advective and dispersive transport solutions within the WASP simulation were performed on the identical model grid used to simulate the hydrodynamics.

The primary state variable simulated was dissolved oxygen. The kinetic processes, sources, and sinks

considered within the WASP simulations that impact the mass balance of dissolved oxygen were:

- Ultimate Biochemical Oxygen Demand (BODU) decay (combined nitrogenous and carbonaceous)
- Reaeration
- Sediment Oxygen Demand
- Headwater and offshore boundary fluxes of BODU and dissolved oxygen
- Adjacent marsh sources of BODU
- Point source discharges of BODU
- Temporal and spatial variations in temperature (input file based upon ambient measurements)

Based upon the discussions presented above, the model was calibrated to the following:

- Longitudinal distribution of mean dissolved oxygen concentrations
- Temporal variations in dissolved oxygen concentrations from the model with the discrete high and low tide dissolved oxygen sampling.
- Longitudinal distribution of mean BODU concentrations

Critical Condition Determination

The determination of the critical conditions for application of the Brunswick EFDC/WASP model was based upon discussions with EPA Region. Draft guidance for critical conditions for TMDLs within estuarine systems is under development. For the Brunswick model application, the critical condition was defined as the summer/fall, low flow, and high temperature period. All inputs to the model do not change from the calibration excluding the following:

- Theoretical water surface elevation time function at the ocean boundary over a 15-day period that includes a mean spring tide and a mean neap tide.
- Low flow at the headwaters based upon critical conditions used in GAEPD model
- Temperature at the upstream and downstream boundaries set to 75 percentile of available August data (for all years available)

- Georgia Pacific Pulp and Paper Facility and City of Brunswick Academy Creek Facility at their permitted discharge (see Table 1)

Seasonal Variation

The Clean Water Act and EPA regulations require that a TMDL be established with consideration of seasonal variations. Seasonal variation was considered through modeling under the most critical period during the year for impacts to dissolved oxygen as discussed above. Therefore, if the TMDL is protective and assures that water quality standards are met during the most critical period, the TMDL is protective of all other seasonal conditions.

Margin of Safety

The margin of safety (MOS) is part of the TMDL development process. There are two basic methods for incorporating the MOS (USEPA, 1991):

- Implicitly incorporate the MOS using conservative model assumptions to develop allocations,
- Explicitly specify a portion of the total TMDL as the MOS; use the remainder for allocations.

The MOS was considered implicitly in the TMDL development process. Conservative modeling assumptions include:

- Running dynamic model
- Permitted point sources are loaded into model for allocation runs (average monthly permit values)
- Use of summer time critical conditions

TMDL Determination

Using the calibrated hydrodynamic and water quality model with the critical conditions described previously, and all point source (anthropogenic) loads removed, a baseline dissolved oxygen level was determined. The natural background loading or LA for the Brunswick Harbor System from the surrounding marshes is 337,000 lbs/days. Based upon this evaluation, within the listed reaches of St. Simons Sound and Brunswick River, it was determined that under the critical low-flow summer period the condition exists

"where natural conditions alone create dissolved oxygen concentrations less than 110 percent of the applicable criteria means or minima or both…". As the "natural" levels were between 3.3 mg/L and 4.0 mg/L, the allowable anthropogenic impact on dissolved oxygen is 0.3 mg/L.

Using the baseline critical condition model simulation, loads at the City of Brunswick Academy Creek Wastewater Treatment Facility and the Georgia Pacific Pulp and Paper Facility were increased proportional to their total permitted load until the net oxygen deficit (evaluated at a 24 hour averaging period) equaled 0.3 mg/L. Based upon this evaluation, the total allowable load for anthropogenic discharges (WLA) was determined to be 47,307 lbs/day of ultimate biochemical oxygen demanding material (BODU) including the influence of Carbonaceous Biochemical Oxygen Demand (CBOD) and Nitrogenous Biochemical Oxygen Demand (NBOD).

The TMDL is the LA (337,000 lbs/days) plus WLA (47,307 lbs/day), which equals 384,307 lbs/day.

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References

Georgia EPD. 1984. *Final Report Brunswick Estuary Modeling Project*. Environmental Protection Division. Atlanta, GA.

Georgia Environmental Protection Division. 2000. 2000 303(d) List.

Georgia EPD. 1999. *Rules and Regulations for Water Quality Control. Chapter 391-3-6*. Revised July 6th. Georgia Department of Natural Resources. Environmental Protection Division. Atlanta, GA.

USEPA. 1986. *Ambient Water Quality Criteria for Dissolved Oxygen*. EPA 440/5-86-003. U.S. Environmental Protection Agency; Office of Water, Regulations and Standards, Criteria and Standards Division, Washington, DC.

USEPA. 1991. *Guidance for Water Quality Based Decisions: The TMDL Process*. EPA 440/4-91-001. U.S. Environmental Protection Agency; Assessment and Watershed Protection Division, Washington, DC.

USEPA Region 4. 2000. Development of a Hydrodynamic and Water Quality Model for St. Simons Sound and Brunswick River.

APPENDIX A – **Ga EPD Coastal DO Permitting Strategy**

ENVIRONMENTAL PROTECTION DIVISION
Department of Natural Resources
Atlanta, Georgia
March 1993
Coastal DO Permitting Strategy

For the "Fishing" Use Classification

For Natural DO Values:		Maximum Allowable
Greater than or Equal to, (mg/L)	And Less than, (mg/L)	DO Deficit (mg/L)
0.0	2.1	0.0
2.1	3.1	0.1
3.1	3.3	(See Note)
3.3	4.1	0.3
4.1	5.1	0.4
5.1	5.5	0.5
5.5	---	(See Note)

"Maximum Allowable DO Deficit" equals the maximum amount of dissolved oxygen that may be allocated to all Permits combined, both point and non-point source, which affect DO levels in a given waterbody." Since the local value for Maximum Allowable Deficit depends on the local value of Natural DO, the numeric value of Maximum Allowable Deficit may vary from point-to-point as Natural DO varies from point-to-point.

If Natural DO is >= 3.1 mg/L and < 3.3 mg/L, then dissolved oxygen in the water column should not be allowed to drop below 3.0 mg/L.

If Natural DO is >= 5.5 mg/L, then dissolved oxygen in the water column should not be allowed to drop below 5.0 mg/L.

NOTE: All values for Natural DO and Maximum Allowable Deficit for a given waterbody are based on "critical conditions" established specifically for that waterbody.