St. Marys River Basin Dissolved Oxygen TMDLs

Submitted to:

U.S. Environmental Protection Agency
Region 4
Atlanta, Georgia

Submitted by:

Georgia Department of Natural Resources
Environmental Protection Department
Atlanta, Georgia

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TMDL Executive Summary

Basin Name: **St. Marys River**

Table 1: Listed Segments

Segment Number	Name	Priority Ranking	Use Classification	Size (miles)	Location
Segment #1	Boone Creek	2	Fishing	6	Upstream St. Marys River (Charlton Co.)
Segment #2	Corn House Creek	2	Fishing	7	Upstream St. Marys River (Charlton Co.)
Segment #3	Horsepen Creek	2	Fishing	4	Headwaters to St. Marys River (Camden Co.)
Segment #4	St. Marys Tributary 5	2	Fishing	3	Upstream St. Marys River (Charlton Co.)
Segment #5	**N. Prong St. Marys River**	2	Fishing	19	Headwaters to Cedar Cr. (Charlton Co.)
Segment #6	**St. Marys River**	2	Fishing	15	Upstream Cabbage Bend to Catfish Cr. (Camden Co.)
Segment #7	**Spanish Creek**	2	Fishing	2.5	Long Branch to St. Marys River

Summary of TMDL Analysis and the TMDLs for Listed Segments

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, this relationship was developed using a complex model linkage. Impaired waterbodies were modeled using both a dynamic receiving water model and a dynamic watershed model. The linkage of these models permitted representation of major processes associated with dissolved oxygen concentration variability. By developing a linked watershed-receiving water model, the impacts of various factors (including all nonpoint and point source loads) on in-stream dissolved oxygen were evaluated. Ultimately, the loading capacity of the waterbody for each critical pollutant affecting the dissolved oxygen concentration was determined. The required source-based loading reduction required to meet the in-stream standard was also calculated. This approach permitted assessment of point source and nonpoint source contributions (including both watershed and leaf litterfall, etc.).

Applicable Water Quality Standards

The applicable dissolved oxygen water quality criteria for waters in the St. Marys River Basin 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. 391-3-6-.03 (c) (l)
>
> _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)
>
> _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: June – July, 1998 (low flow and high temperature).

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) running model with real flow and temperature during summer instead of 7Q10 and 75% temperature; 4) assumed 41% saturation for upstream DO (Meyer, 1992).

Seasonality: Evaluated for all seasons, including high flow winter and low flow summer conditions.

Monitoring: Follow-up monitoring according to 5-year River Basin Planning cycle (Georgia EPD, 1996).

Approach: NPDES for point sources; Best management practices for nonpoint sources.

Date Submitted: Draft - June 2000, Final – December 2001.

Table 2: Summary of TMDLs for Listed Segments

Listed Segments	TMDL – TOC (lbs/yr)	TMDL – TN (lbs/yr)	TMDL – TP (lbs/yr)
Boone Creek - Segment #1	2,283,779	57,095	3,482
Corn House Creek - Segment #2	3,666,509	68,381	6,049
Horsepen Creek - Segment #3	1,298,778	22,170	1,533
St. Mary's Tributary 5 - Segment #4	1,281,612	35,168	1,824
N. Prong St. Mary's River - Segment #5	28,033,979	785,946	56,802
St. Mary's River - Segment #6	106,266,655	3,564,579	263,927
Spanish Creek - Segment #7	7,050,984	338,413	25,868

Appendix D presents the Waste Load Allocations (WLAs) and the Load Allocations (LAs) as annual loads for the loads contributing to the dissolved oxygen in the impaired segments in the St. Marys River Basin.

1.0 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 in 1998 indicate that a number of waterbodies in the St. Marys River Basin did not achieve water quality standards for dissolved oxygen. The low dissolved oxygen conditions may be due to naturally occuring conditions. These waterbodies were listed on the Georgia 2000-303(d) list. This document presents the dissolved oxygen TMDLs for the listed waterbodies in the St. Marys River Basin, which is located in southeastern Georgia (Figure 1-1).

Four river basins, the Ochlockonee, Suwannee, Satilla, and the St. Marys are the focus of TMDL development in Georgia in 2000. The four river basins are shown in Figure 1-1.

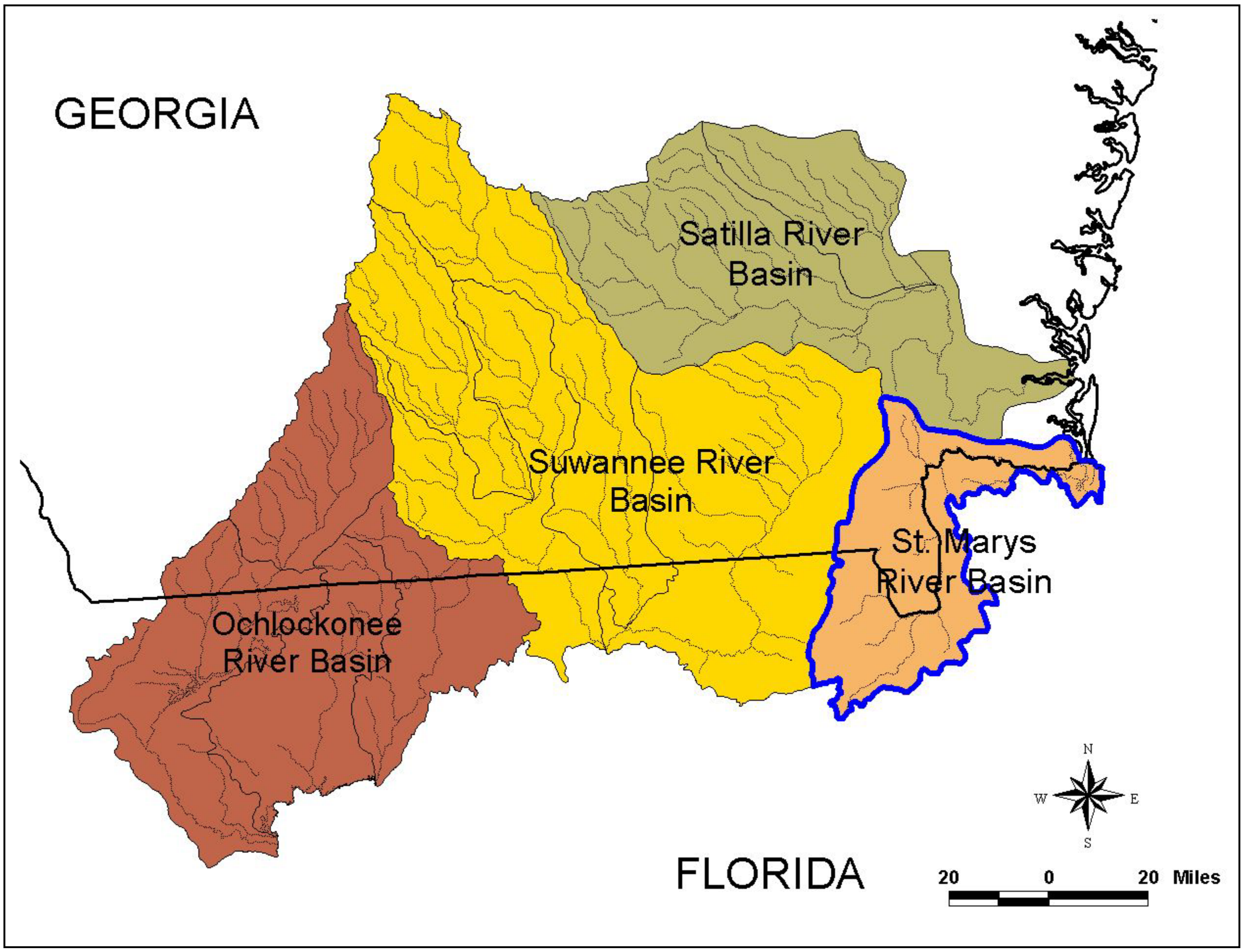

Figure 1-1. Southern Four Georgia Basins Requiring Dissolved Oxygen TMDL Development (Ochlockonee, Suwannee, Satilla, and St. Marys River Basins)

2.0 Problem Understanding

The St Marys River is the border between Florida and Georgia and its headwaters are located in the Okefenokee Swamp in Georgia. The river basin covers an area of approximately 1,451 mi^2. The major Georgia cities in the St Marys River Basin are Kingsland, St. Marys, Homeland, and Folkston shown in the location map in Figure 2-1. For the purpose of developing TMDLs in southern Georgia for the low dissolved oxygen segments, the St Marys River Basin will refer to portions of the river basins that are located within the Georgia state border.

The St Marys River Basin contains 7 waterbody segments that are violating Georgia's dissolved oxygen standards of a daily average of 5.0 mg/l and no less than 4.0 mg/l (Figure 2-2 and see Listed Segments table on page 3). Each of these 7 listed segments contained at least one monitoring station in 1998 used for impairment listing purposes (Figure 2-2), the North Prong of the St Marys River contains 2 stations.

The GAEPD established water quality monitoring stations for the Ochlockonee, Suwannee, Satilla, and St. Marys River Basins as a part of the Georgia River Basin Planning Program (GAEPD, 1996). There were 138 stations established and sampled in the four river basins in 1998. Ten of the sampling stations were in the St. Marys River Basin. The monitoring work was conducted as a cooperative effort between the GAEPD and the United States Geologic Survey (USGS). The four river basins will be monitored again in 2003. It should be noted that core stations in the four basins are monitored each year. During 1998, the USGS measured gage height, water temperature, pH, and dissolved oxygen on-site and collected water samples for laboratory analyses. The laboratory water quality parameters included turbidity, five-day biological oxygen demand (BOD5), ammonia, nitrate-nitrite, total phosphorus, total organic carbon, and fecal coliform. In addition, samples for metals analyses were collected at each station. These data were used to assess compliance with water quality standards and the assessment results were used by the GAEPD in the development of the 2000-303(d) list.

The assessment indicated that 7 waterbody segments were not achieving compliance with water quality standards for dissolved oxygen (Figure 2-2 and see Listed Segments table on page 3). Low dissolved oxygen conditions in the St. Marys River basin may be in part due to naturally occuring conditions. Each of the 7 listed segments contained at least one monitoring site in 1998. The North Prong of the St. Marys River listed segment had 2 USGS stations (USGS02228500 and USGS 02229350). The TMDLs for dissolved oxygen for the 7 listed segments were scheduled for development in 2000 and for presentation for public comment in June 2000. This report presents the TMDLS for dissolved oxygen for the listed segments in the St. Marys River Basin. A summary of selected water quality data and a map of station locations are presented in Appendix A.

The St. Marys River Basin is predominantly forested and wetland (88%) with a large wetland contribution from the Okefenokee Swamp in the northwestern portion and the St. Marys River Estuary in the northeastern portion of the basin. The USGS MRLC land use distribution for the early to mid 1990's is shown in Figure 2-3 for the entire basin.

Typical precipitation in this area is 51 inches per year based on examination of nearby precipitation stations in Folkston 3 SW (GA3460) and Brunswick (GA1340). A summary of the precipitation data and a map of stations in southern Georgia are included in Appendix A.

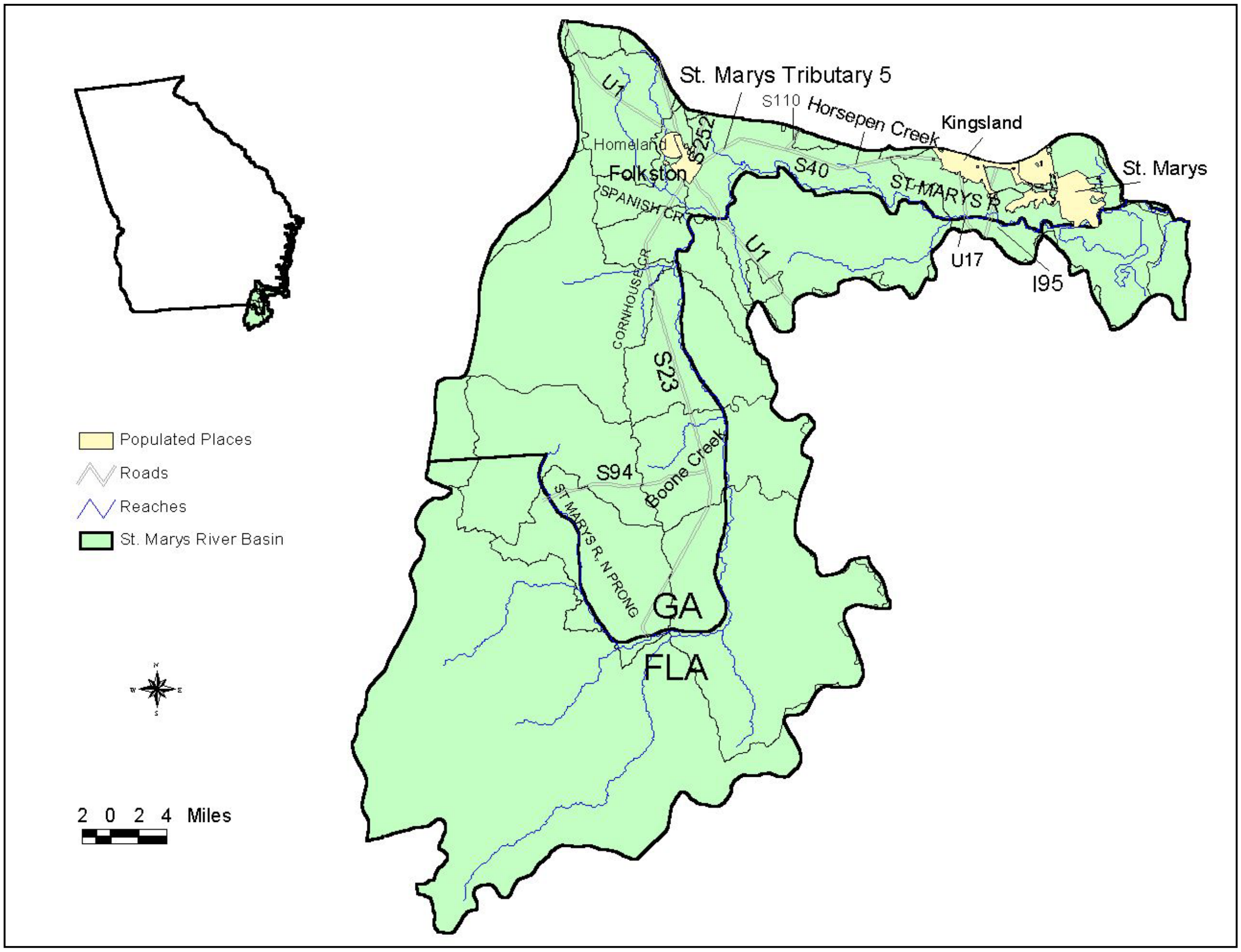

Figure 2-1. Location Map of the St. Marys River Basin

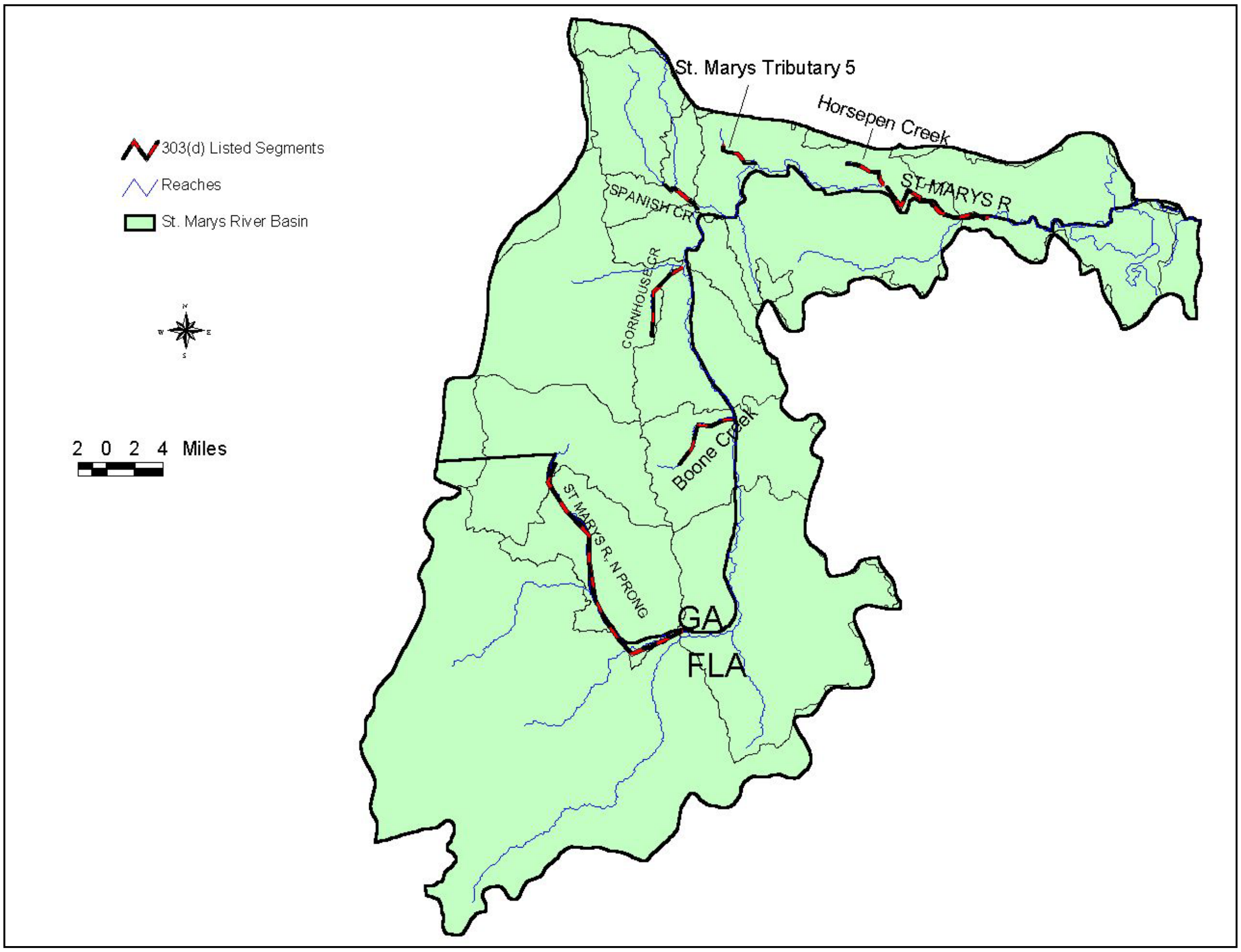

Figure 2-2. 303(d) Listed Segments for Dissolved Oxygen in the St. Marys River Basin

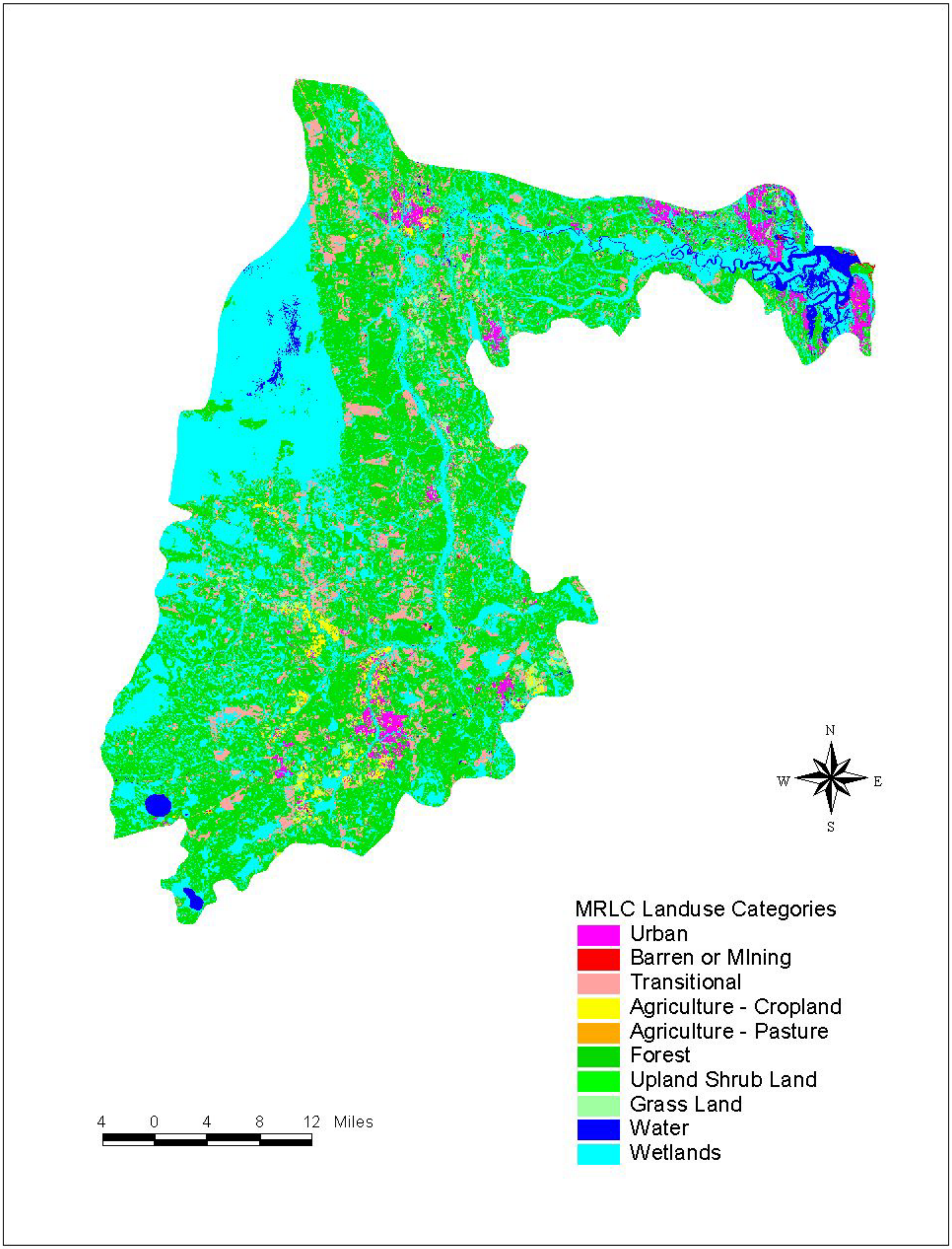

Figure 2-3. Land Use Representation in the St. Marys River Basin

3.0 Water Quality Standards

All dissolved oxygen impaired waterbodies in the St. Marys River Basin are designated by the State of Georgia with a water use classification of fishing. Georgia Water Quality Standards (GAEPD, 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.

GAEPD, 1999

*Waterbodies in the St. Marys River Basin are assumed to be 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 and cannot meet the numeric criteria unless reductions in the natural nutrient and carbon loads are obtained. This reduction in the natural forest or wetland contributions is not feasible, practicable or desirable, therefore the EPA Dissolved Oxygen Criteria was instituted and dissolved oxygen target limits were identified for TMDL development. The target limits were identified as 90% of the minimum naturally occurring concentration for impaired waterbodies.

> *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)

GAEPD, 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.

USEPA, 1986

Dissolved oxygen violation analyses were performed for all 10 water quality stations in the basin by comparing observation values to numeric water quality standards. The analyses confirmed that the water quality standards were violated for the listed segments.

4.0 Source Assessment

The 303(d) listing for the impaired segments identified nonpoint sources as the primary contributors to dissolved oxygen impairment. An examination of permits and land use information for the watershed was used to identify all potential sources of oxygen demanding substances in the basin. 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 wastewater treatment plants, industrial facilities (e.g., food processing facilities), combined sewer overflows, sanitary sewer overflows, and stormwater runoff. Point sources directly discharge organic and inorganic oxidizable substances into a waterbody, which ultimately affects dissolved oxygen concentrations. 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 BOD, NH3, and TSS. Point sources contributing to the listed waters are listed in Table 4-1 and their corresponding discharge characteristics are listed in Table 4-2. The locations of the point sources are shown in Figure 4-1.

Table 4-1. Point Sources Contributing to Impaired Waterbodies in the St. Marys River Basin

PERMIT ID	Point Source	Receiving Water
GA0027189	Folkston Pond	Clay Branch
GA0037613	Folkston WPCP	Clay Branch
GA0021547	Kingsland WPCP	Little Catfish Creek

Table 4-2. Point Sources in Watersheds Contributing to Impaired Segments

			Permitted (MAX / AVG)					
NPDES	GA 12-Digit Watershed ID	Receiving Water	Season	DO (mg/L)	BOD-5	Flow (mgd)	NH3	TSS
GA0027189	3070204006	Clay Branch		--	45 / 30 mg/L	--	--	120 / 90 mg/L
GA0037613	3070204006	Clay Branch	0	--	45 / 30 mg/L	0.32 / 0.26	15 / 10 mg/L	45 / 30 mg/L
			1	5	30 / 20 mg/L	--	7.5 / 5 mg/L	--
GA0021547	3070204004	Little Catfish Creek		5	22.5 / 15 mg/L	--	7.5 / 5 mg/L	45 / 30 mg/L

Notes: -- Denotes situations where permitted data are not available.
Season 0 = winter, Nov - Apr
Season 1 = summer, May - Oct

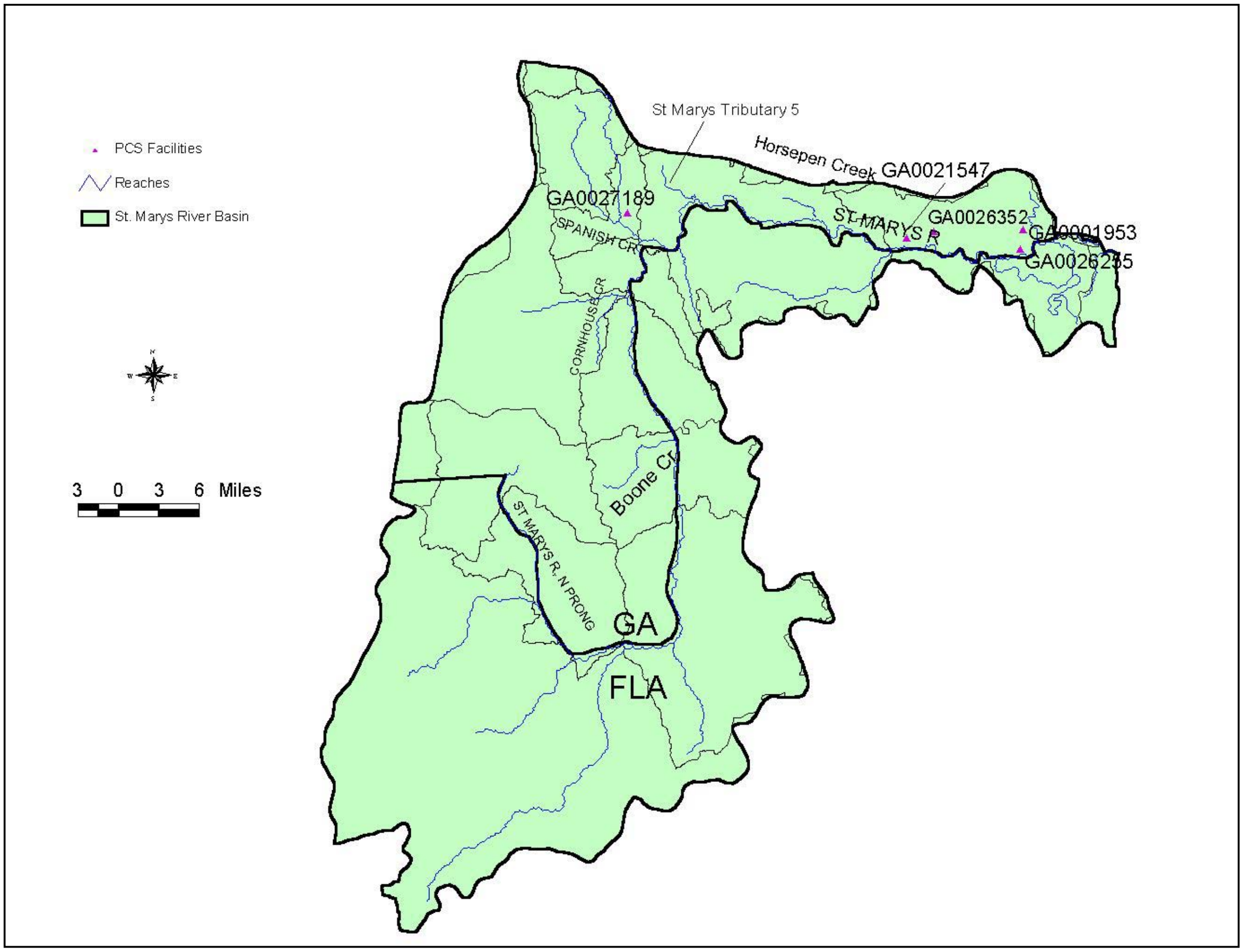

Figure 4-1. Point Sources in the St. Marys River Basin Contributing to Impaired Waterbodies

Nonpoint Sources

Nonpoint sources of oxygen demanding substances are typically separated into urban and rural components. In urban or suburban settings, important sources of loading are surface storm runoff, failing septic systems, and leakage and overflows from sanitary sewer systems. In rural areas, sources of oxygen demanding substances may include diffuse runoff of agricultural fertilizer and animal wastes (from manure application or grazing animals), erosion of sediments, and runoff from concentrated animal operations.

Based on a landuse assessment and review of the literature, nonpoint source contributions from urban, agriculture, and forested areas are all likely in the St. Marys River Basin. Croplands, pasture, forest, urban (or built-up) areas, and wetlands were all identified in the basin. The land use distribution for the Georgia 12-digit watersheds contributing to the impaired segments is displayed in Appendix A. Figure 2-3 graphically displays the land use distribution within the study area.

In addition to the aforementioned nonpoint sources of oxygen demanding substances, many southern Georgia streams receive significant contributions of oxygen demanding organic materials from local wetlands and forested stream corridors. In particular, the following sources of organic materials have been identified:

- adjacent wetland/swampy areas that have organically rich bottom sediments
- direct leaf litterfall onto the water surface from overhanging trees and vegetation
- lateral leaf litterfall that has fallen into the floodplains

Leaf litterfall plays a major role in the amount of carbon in the stream water column. The riparian areas of the watershed are the primary source of litterfall. At higher flows, the leaf litterfall in the floodplains are picked up and transported laterally into the stream. Many streams in southern Georgia are referred to as "blackwater" streams due to the humic substances leached from surrounding watersheds that impart color to the water (Meyer, 1992). Low dissolved oxygen in blackwater streams is common in the summer months when the temperatures are high and the flows are low.

5.0 Summary of the Technical Approach

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, this relationship was developed using a complex model linkage.

Impaired waterbodies were modeled using both a dynamic receiving water model and a dynamic watershed model. The linkage of these models permitted representation of major processes associated with dissolved oxygen concentration variability, including:

- Input and oxidation of carbonaceous waste material
- Input and oxidation of nitrogenous waste material
- Input and oxygen demand of sediments in the water body

- Use of oxygen through aquatic plant respiration
- Reaeration
- Oxygen production through photosynthesis

By developing a linked watershed-receiving water model, the impacts of various factors (including all nonpoint and point source loads) on in-stream dissolved oxygen were evaluated. Ultimately, the loading capacity of the waterbody for each critical pollutant affecting the dissolved oxygen concentration was determined. The required source-based loading reduction required to meet the in-stream standard was also calculated. This approach permitted assessment of point source and nonpoint source contributions (including both watershed and leaf litterfall, etc.).

The technical approach is summarized in the following sections:
- Model selection
- Source representation
- In-stream representation
- Model testing

Model Selection

The Hydrologic Simulation Program Fortran (HSPF), a dynamic watershed model capable of simulating a wide range of water quality parameters, was selected to represent nonpoint source pollutant contributions (and point source contributions as necessary) to the impaired waterbodies. The impaired waterbodies themselves were modeled using the Environmental Fluid Dynamics Code (EFDC), a 3-D hydrodynamic and water quality model capable of simulating dissolved oxygen and a full suite of dissolved oxygen interactions. Output from the HSPF was applied directly to the EFDC, in order to provide the linkage between source and waterbody response.

Source Representation

Nonpoint and point sources were both represented in the linked models. The watershed model was primarily implemented to represent upstream nonpoint source contributions to the impaired waterbody. Direct contributions of leaf litter (representation of organic materials contributed by overhanging trees and vegetation) to each impaired waterbody were represented in the receiving water model.

Point sources were represented in both the receiving water model and the watershed model. Facilities discharging within the same 12-digit subwatershed as a modeled impaired waterbody were represented in the receiving water model. Facilities discharging to unimpaired reach segments that affect impaired waterbodies, but were not explicitly modeled with the receiving water model, were represented in the watershed model.

Nonpoint Source Representation

Nonpoint source pollutants likely to impact dissolved oxygen include nutrients, BOD, and sediment. These pollutants have a direct impact on oxygen reducing procedures, including oxidation of carbonaceous and nitrogenous materials and exertion of oxygen demand by sediments. They also affect oxygen replenishment through plant respiration and photosynthesis production.

The watershed model represents the variability of nonpoint source contributions through dynamic representation of hydrology and land practices. In a number of situations, the watershed model additionally accounts for point source contributions (where point sources are located on major streams contributing to an impaired waterbody that are not represented explicitly in the receiving water model). Key components of the watershed model include:

- Watershed segmentation
- Meteorological data
- Simulation period
- Landuse representation
- Hydrologic representation
- Water quality representation

Watershed Segmentation

In order to evaluate the sources contributing to an impaired waterbody and to represent the spatial variability of these sources within the watershed model, the contributing drainage area was represented by a series of subwatersheds. These subwatersheds were represented using the Georgia 12-digit watershed data layer. In some situations, the 12-digit data layer required further subdivision for appropriate hydrologic connectivity and representation.

The watershed model was run for all subwatersheds contributing to each impaired waterbody. Figure 5-1 presents the subwatersheds used in the watershed modeling process. Table 5-1 presents the subwatersheds contributing to individual impaired waterbodies.

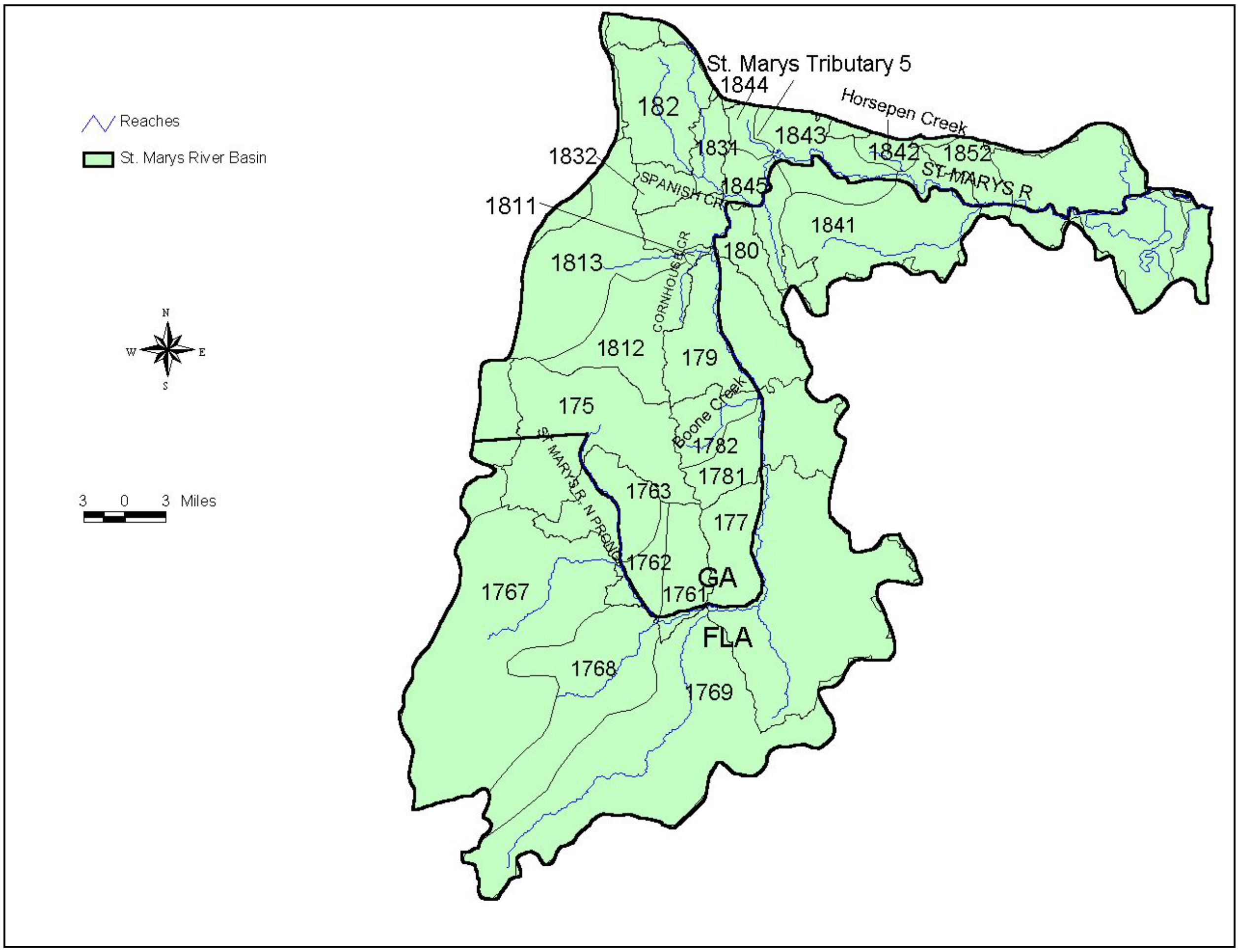

Figure 5-1. Subwatersheds Used in the Watershed Modeling Process (Contributing to Listed Waterbodies)
Note: Subwatersheds are labeled by their model Ids - refer to Table 5-1 for corresponding 12-digit Ids.
Some subwatersheds were further divided to support proper hydrologic representation.

Table 5-1. Subwatersheds Contributing to the Impaired Waterbodies.

Name	Contributing Watersheds (Model ID)	Contributing Subwatersheds (12-Digit HUC)
Boone Creek Segment #1	178-2	030702040202(b)
Corn House Creek Segment #2	181-2	030702040302(b)
Horsepen Creek Segment #3	184-2	030702040401(b)
St. Marys Tributary 5 Segment #4	184-4	030702040401(d)
N. Prong St. Marys River Segment #5	175, 176-1, 176-2, 176-3, 176-7, 176-8,	030702040101, 030702040102(a), 030702040102(b), 030702040102(c), 030702040102(g), 030702040102(h)
St. Marys River Segment #6	175, 176-1, 176-2, 176-3, 176-7, 176-8, 176-9, 177, 178-1, 178-2, 179, 180, 181-1, 181-2, 181-3, 182, 183-1, 183-2, 184-1, 184-2, 184-3, 184-4, 184-5, 185-2	030702040101, 030702040102(a), 030702040102(b), 030702040102(c), 030702040102(g), 030702040102(h), 030702040102(i), 030702040201, 030702040202(a), 030702040202(b), 030702040203, 030702040301, 030702040302(a), 030702040302(b), 030702040302(c), 030702040303, 030702040304(a), 030702040304(b), 030702040401(a), 030702040401(b), 030702040401(c), 030702040401(d), 030702040401(e), 030702040402(b)
Spanish Creek Segment #7	182, 183-1, 183-2	030702040303, 030702040304(a), 030702040304(b)

Note: Contributing Subwatersheds (GA 12-digit) and Corresponding Watershed Model Ids are listed in the same order for each segment. Model Ids are presented for the purpose of visually displaying the subwatersheds in Figure 5-1.

Meteorological Data

Nonpoint source loadings and hydrologic conditions are dependent on weather conditions. Weather parameters required to simulate various components of hydrology and water quality include precipitation, air temperature, dew point, wind speed, solar radiation, and percent cloud cover. Hourly data from weather stations within the boundaries of or in close proximity to the subwatersheds being modeled, were applied to the watershed model.

Weather stations used to represent the St. Marys River Basin include Folkston 3 SW (GA3460) and Brunswick (GA1340). Appendix A presents the locations of the weather stations with respect to the modeled subwatersheds.

Examination of the precipitation at these stations shows that the wettest months are typically January, February, March, and July. The driest month is typically October. Monthly and annual patterns are similar for all stations. Appendix A presents rainfall characteristics, including monthly mean and annual total precipitation for each station.

Simulation Period

Selection of an appropriate simulation period is important in nonpoint source modeling due to the variability of hydrologic and source loading conditions over time. The year 1998 was selected as the simulation period. This time period was selected due to its coverage of a wide range of hydrologic conditions, including heavy rainfall and drought conditions. Additionally, this period contained the most extensive monitoring data, which is necessary for model calibration.

The HSPF model was run for 10 years to examine the watershed water quality loading over an extended period of time. The 1998 watershed load was also compared directly to the 1997 loading year to see if there were any anomalies in the loading rates. For some cases, particularly for subwatershed 031200020101 (model ID 322), the 1997 load was double the 1998 load. In this case, the in-stream model was run during 1997 through 1998 to account for any build-up in the sediment oxygen demand from the higher 1997 loads.

Land Use Representation

The watershed model uses land use data as the basis for representing hydrology and nonpoint source loading. Land use categories for modeling were selected based on the USGS Multi-Resolution Land Classification (MRLC) data set, and included built-up, forest, cropland, pasture, and wetlands. The USGS data represents conditions in the early to middle 1990's. The modeling categories and their corresponding USGS classifications are presented in Table 5-2. The land use representation for the Georgia 12-digit watersheds used in modeling are presented in Appendix A.

Table 5-2. Land Use Representation

Land Categories Represented in the Model	MRLC Land Use Code	MRLC Land Use Classes	% Impervious
Built-up	21	Low Intensity Residential	19
	22	High Intensity Residential	65
	23	High Intensity Comm./Ind./Trans.	80
	33	Transitional	10
Forest	31	Bare Rock/Sand/Clay	0
	32	Quarries/Strip Mines/Gravel Pits	0
	41	Deciduous Forest	0
	42	Evergreen Forest	0
	43	Mixed Forest	0
	51	Deciduous Shrubland	0
	52	Evergreen Shrubland	0
	53	Mixed Shrubland	0
	71	Grassland/Herbaceous	0
	85	Other Grasses	0
Wetland	91	Woody Wetlands	0
	92	Emergent Herbaceous Wetlands	0
Cropland	61	Planted/Cultivated	0
	82	Row Crops	0
	83	Small Grains	0
	84	Bare Soil	0
Pasture	81	Pasture/Hay	0

The HSPF model requires division of land uses in each subwatershed into separate pervious and impervious land units. For each land use, this division can be made based on typical imperviousness percentages from individual land use categories, such as those used in the Soil

Conservation Service's TR-55 method. For modeling purposes, the percent imperviousness of a give land category can be calculated as an area-weighted average of land use classes encompassing the modeling land category.

Hydrologic Representation

Watershed hydrology plays an important role in the determination of nonpoint source flow and ultimately nonpoint source loadings to a waterbody. The watershed model must appropriately represent the spatial and temporal variability of hydrologic characteristics within a watershed. Key hydrologic characteristics include interception storage capacities, infiltration properties, evaporation and transpiration rates, and watershed slope and roughness. The HSPF modules used to represent watershed hydrology for TMDL development include PWATER (water budget simulation for pervious land units) and IWATER (water budget simulation for impervious land units). A detailed description of relevant hydrologic algorithms is presented in the HSPF User's Manual.

Water Quality Representation

A total of four water quality parameters were simulated using the watershed model: biochemical oxygen demand (BOD,) total nitrogen (TN), total phosphorus (TP), and total suspended solids (TSS). These parameters (either directly or indirectly) constitute the primary nonpoint sources contributing to dissolved oxygen depletion and/or replenishment. The buildup and washoff of these pollutants were represented using the PQUAL (simulation of quality constituents for pervious land segments) and IQUAL (simulation of quality constituents for impervious land segments) modules in HSPF. Different buildup and washoff rates were used to represent the different land categories (e.g. fertilizer and manure application generally result in a higher nutrient buildup and washoff from cropland than from urban lands). Upon application to the receiving water model, many of parameters simulated in the watershed model were converted into more applicable constituents for in-stream modeling.

Leaf Litterfall Representation

Loadings of leaf litterfall were assumed to be consistent with a study performed on the Ogeechee River in southern Georgia (Meyer et al. 1997). The direct leaf litterfall was reported as 843 $g/m^2/yr$ and lateral leaf litterfall was reported as 3,520 $g/m^2/yr$. The surface area of the stream channel was used to derive loading rates into the model. The lateral leaf litterfall was flow dependent to simulate the loading increase when the flows are large enough to inundate the floodplains. During the higher flows, the organic material deposited in the floodplain is picked up and transported into the stream.

The leaf litterfall loading was only applied to the receiving water model grid segments (during simulation of each impaired river segment). Loadings from the HSPF model (particularly BOD, which was ultimately converted to TOC) were assumed to account for residual leaf litterfall from upstream segments (transported to the impaired segment). The majority of leaf litter was assumed to be deposited on the stream bottom within each segment, thus forming an organic-enriched bed.

Point Source Representation

After identifying all point source facility locations in the subwatersheds contributing to the impaired waterbodies, appropriate facilities were represented in the linked models. Depending on location, point sources were either represented in the watershed model or the receiving water model. Facilities discharging within a Georgia 12-digit subwatershed containing an impaired waterbody were represented as direct inputs into the receiving water model. Facilities discharging within a subwatershed representing an unimpaired waterbody were represented in the watershed model.

In the later case, the facilities discharge into waterbodies that eventually feed into an impaired waterbody, and thus must be considered in the source representation. Due to their indirect impact on the impaired waterbody, however, their contributions are subject to fate and transport in the watershed model through a stream system leading to the impaired waterbody.

Point source facilities were represented in both the watershed and receiving water models using a constant flow and pollutant loading. DMR data (flow and pollutant concentrations or loads) were represented in the models to simulate existing conditions – for calibration. Permitted flows and loads were used to represent initial conditions for TMDL development. The monthly average permitted conditions were loaded into the in-stream model for the allocation runs. For example, where BOD5 is permitted at a maximum of 45 mg/L and an average of 30 mg/L, the average of 30 mg/L would be multiplied by the average daily, permitted flow to produce a daily mass loading (lbs/day). The monthly average permitted values, versus the monthly maximum, are more representative in determining assimilative capacity in the system. In special circumstances, such as a major point source discharge, a step-function would be implemented so that the waterbody would receive a maximum daily load during the month, but still maintain the permitted monthly average. Water quality constituents represented include BOD, TN, TSS, and TP. BOD and TSS values were represented using DMR and permitted values. TN values were based on monitored NH3 values for the facilities. TP values were assumed to be 5 mg/L for municipal facilities (due to the absence of DMR data and permitted values). Refer to Table 4-1 for point source flows and loads used in the modeling process.

In-stream Representation

The receiving water model, EFDC, was used to simulate all in-stream dissolved oxygen processes for the impaired waterbodies. Impaired waterbodies received flow and water quality output from the corresponding HSPF model (which represented watershed contributions). Unimpaired waterbodies located in stream networks contributing to impaired waterbodies were not represented explicitly using EFDC, but instead were represented using HSPF in-stream algorithms. Key components of the in-stream representation include:

- Hydrodynamic representation
- Water quality configuration
- Unimpaired waterbody representation

Hydrodynamic Representation

Independent grid systems were developed to represent impaired waterbodies using EFDC, except in the case where multiple impaired waterbodies were connected. In these situations extended grids representing the entire impaired system were developed. The longitudinal extent of each waterbody impairment, as defined in the Georgia 303(d) list, was used to determine the grid coverage. In general, the grid for each impairment was extended to the waterbody's intersection with the nearest up- and down-stream Georgia 12-digit subwatershed boundary. This standardized the grid development processes, as well as the watershed model-receiving water model linkage. Under this configuration, the entire extent of each impairment was fully represented.

The extent of impairments in the St. Marys River Basin ranged from 2.5 miles to over 19 miles (when considering connected impairments). Due to the variability in impairment length, each grid was configured using a different number of cells and different cell dimensions. Each cell was rectangular and represented a single vertical water layer (one dimension). Cells were typically on the order of 1 km (0.62 mi) to 3.22 km (2 mi) in length. Lateral dimensions were derived from USGS cross-sectional data obtained from USGS monitoring stations located on each of the impaired segments.

Tributary inflows, point sources, and nonpoint source contributions were applied directly to applicable cells in the grid. For impaired headwaters, the total flow from the contributing 12-digit subwatershed was divided into two portions. The first portion (typically 20% of the flow) was applied directly into the most upstream cell, while the remaining portion (typically 80%) was divided equally among the remaining cells to represent nonpoint source inflows.

For downstream impairments, upstream inflows (represented in the watershed model) were applied directly to the most upstream cell in the grid. Flow from the 12-digit subwatershed(s) in immediate vicinity of the impaired waterbody (also represented in the watershed model) were distributed evenly among the cells. Flow from incoming tributaries (represented as stream networks in the watershed model) and point sources were applied directly to the most appropriate cell in the configuration. Figure 5-2 presents an example of the in-stream configuration for an impaired headwater and its linkage to the watershed model.

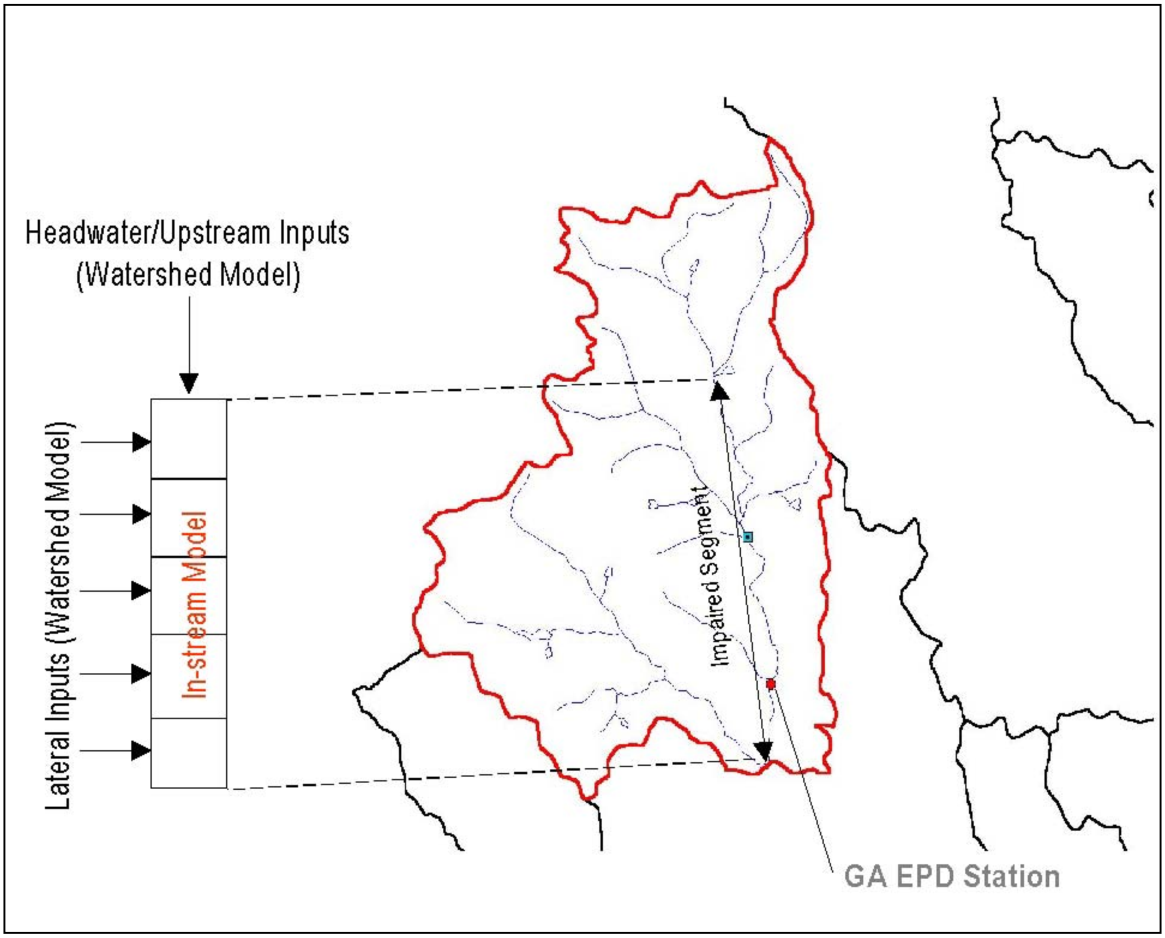

Figure 5-2. Diagram of In-stream Model Configuration

The hydrodynamic portion of the EFDC model is designed to solve three-dimensional, vertically hydrostatic, free surface, turbulent averaged equations of motion for a variable-density fluid. The model uses stretched or sigma vertical coordinates and Cartesian or curvilinear, orthogonal horizontal coordinates. Dynamically-coupled transport equations for turbulent kinetic energy, turbulent length scale, salinity and temperature are also solved. The two turbulence parameter transport equations implement the Mellor-Yamada level 2.5 turbulence closure scheme (Mellor & Yamada, 1982) as modified by Galperin et al (1988). The EFDC model also simultaneously solves an arbitrary number of Eulerian transport-transformation equations for dissolved and suspended materials. The EFDC model allows for drying and wetting in shallow areas by a mass conservation scheme. A number of alternatives are in place in the model to simulate general discharge control structures such as weirs, spillways and culverts. The theoretical and computational basis for the model is documented in Hamrick (1992a).

Water Quality Configuration

Simulation of dissolved oxygen in the receiving water model considered a large suite of model state variables and kinetic processes. The EFDC model simulates the interactions between up to 21 state variables including dissolved oxygen, suspended algae (3 groups), various components of carbon, nitrogen, phosphorus and silica cycles, and fecal coliform bacteria. The kinetic processes included in this model use the Chesapeake Bay three-dimensional water quality model, CE-QUAL.ICM (Cevco & Cole, 1994). Figure 5-3 is a schematic diagram of the EFDC water column water quality model.

The primary sources and sinks of oxygen represented in the EFDC model are:

- algal photosynthesis and respiration
- nitrification
- heterotrophic respiration of dissolved organic carbon
- oxidation of chemical oxygen demand
- surface reaeration
- sediment oxygen demand
- external loads

Refer to *A Three-Dimensional Hydrodynamic-Eutrophication Model (HEM-3D): Description of Water Quality and Sediment Process Submodels (EFDC Water Quality Model)* for a full description of relevant equations and formulations.

In order to represent all sources and sinks of dissolved oxygen, the water quality model required temperature representation and inputs of water quality parameters from the watershed model and point source discharges. For calibration purposes, in-situ temperature data measured concurrently with dissolved oxygen was input into the model. For the allocation model runs, a representative, seasonal distribution of temperature was created for the entire southern four basins. The data used to create the seasonal pattern in the model was collected by the USGS at the 5 monitoring sites in Georgia. The monitoring site that was the closest to the southern four basins in Georgia was at USGS02213700 on the Ocmulgee River near Warner Robbins, Georgia. A sinsusoidal function was fit to the daily maximum and minimum from the Ocmulgee River station to create the representative temperature for the allocation runs.

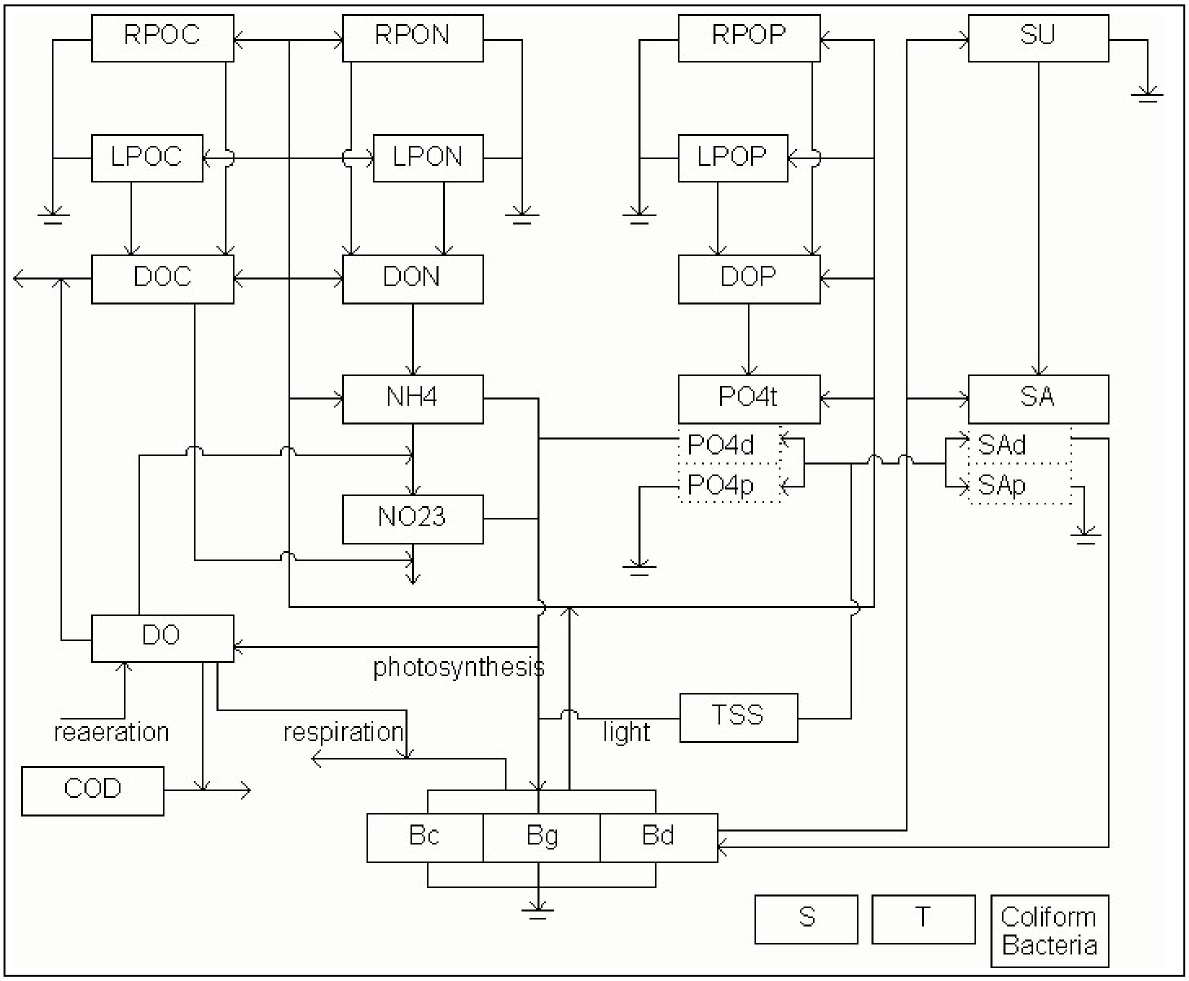

Figure 5-3. EFDC water column water quality model schematics diagram

Water quality parameters were input to cells in the grid using the same procedure as for flow. All upstream inputs, tributary inputs, point sources, and nonpoint source contributions in immediate vicinity of the impaired waterbody were accounted for. Specific parameters transferred from the watershed model (and point sources) to the receiving water model included TSS, BOD, TN, and TP.

BOD5 to Total Organic Carbon

The HSPF subwatershed model runs were calibrated primarily to 5-day biochemical oxygen demand (BOD5) and total suspended solids (TSS). Due to the inherent solutions of the water quality models, it was necessary to convert the BOD5 from the point and nonpoint sources to TOC. The watershed loads simulated by HSPF are with respect to BOD5, TN, TP, and TSS. EFDC is a carbon-based water quality model, and therefore, the model simulates organic matter as carbon rather than BOD. Therefore, to put the watershed loads into the in-stream model, BOD5 had to be converted to TOC. By breaking the ratio down into a BODU/BOD5 and TOC/BODU components, the multiplier was justified by a typical in-stream f-ratio (ratio of ultimate BOD to a 5-day BOD) of 4.0 and literature value for converting ultimate BOD to TOC of 2.7 (Thomann and Mueller, 1987). Therefore, an 11.0 (sensitivity ranged from 10.8 to 11.2) multiplier was initially used to convert BOD5 to TOC.

Two cases were initially setup for the in-stream water quality calibrations. A human-impacted subwatershed and a natural subwatershed were selected to be the range of conditions found in the 4 basins, excluding the effect of point sources. The human-impacted subwatershed selected was the headwater of the Ochlockonee River (SWSID 322). This watershed had almost 70% agricultural land uses, a small urban component, no point sources, and exhibited low flow due its headwater location in the watershed. The natural subwatershed was on the Suwannoochee River (SWSID 203) in the Suwannee River Basin. This subwatershed had over 90% forested and wetland areas and no point sources. The EFDC model was setup for both segments and an attempt was made to create one common input file containing load multipliers, kinetic rates, and coefficients that could be used for all subwatershed types that were within the range that was established for SWSIDs 322 and 203. It became apparent that the two subwatersheds exhibited completely different characteristics of organic loading into the system. From examining measured data for BOD5 and TOC, it became obvious the differences between a carbon load in a watershed with primarily agricultural contributions versus one with primarily forest or wetland contributions. The TOC measured data were an in-stream value that would include all of the contributions of oxygen consuming material, point and nonpoint sources. From examination of the data by predominant landuse, a landuse-based multiplier was derived for each landuse type. The multipliers are listed in Table 5-3.

Table 5-3. Landuse-based Multipliers to Convert BOD5 to TOC.

Landuse	TOC/BOD5
Forest/Wetland	20
Agriculture	7.5
Urban	2.3

Unimpaired Waterbody Representation

Unimpaired waterbodies contributing to impaired segments were represented as a component of the watershed model. The RCHRES and GQUAL HSPF modules were used to simulate in-stream flow and general water quality. Flow determination using HSPF required development of rating curves for each stream modeled. Rating curves were developed for streams using cross-sectional dimensions estimated from regional watershed area-bankfull channel dimension curves (Rosgen, 1996). No explicit water quality interactions were represented using the GQUAL module. General first-order decay was used to represent all processes typically influencing the fate of water quality parameters, e.g. transformation, settling, etc.

Model Testing

After developing the watershed and receiving water models to represent source contributions and in-stream response, the models were tested for validity. This testing is typically referred to as model calibration, and it involves the comparison of simulated results to observed data and the subsequent adjustment of model parameter values. Calibration of the linked models was performed for the year 1998, due to the availability of monitoring data. Hydrology and water quality were first calibrated for the watershed model. Once the preliminary calibration results from the watershed model were applied to the receiving water model, calibration of the receiving water model ensued. Calibration of the receiving water model additionally required further calibration of the watershed model, and thus an iterative approach to calibration was taken.

Watershed Model Hydrology Calibration

Hydrologic calibration involved an adjustment of parameters related to all components of the hydrologic cycle including overland flow, infiltration, groundwater flow, and evapotranspiration. Adjustments were made during a comparison of in-stream flow monitoring data to modeled in-stream flow at a representative location for the region. The location selected was Little Satilla River near Offerman, GA (USGS02227500). The entire drainage area contributing to flow at this station was modeled and results were compared to the monitoring data. After making appropriate adjustments, the model results showed a good correlation with the observed values. The resulting hydrology parameters were validated at two additional stations in the region; Withlacoochee River at McMillan Road near Bemiss, Georgia and Okapilco Creek at Route 33 near Quitman, Georgia. A summary of calibration and validation results for these locations are presented in Appendix B. Once hydrologic parameters were calibrated and validated, the values were applied to the remaining subwatersheds in the basin.

Watershed Model Water Quality Calibration

Once hydrology was calibrated and validated for the watershed model, calibration of water quality parameters was necessary. Water quality calibration consisted of adjusting TSS, BOD, TN, and TP buildup and washoff parameters within a reasonable range to achieve a good match between model output and in-stream water quality observations. Key considerations in the water quality calibration for the watershed model were baseflow concentrations, background concentrations, seasonal variations, and stormflow concentrations.

Initial buildup and washoff parameters were based on past studies in the southeast, including the *Nonpoint Source Pollutant Loading Evaluation - ACT and ACF Water Allocation Formula - Environmental Impact Statements* and *Water-Quality Improvements in the Lower Mississippi River Valley – Analysis of Nutrient Loadings in the Yazoo River Basin*. Each landuse category was represented by a different buildup and washoff rate, in order to simulate the variability between load contributions from different sources. The parameters were adjusted through a comparison of model output to typical loading rates from various landuses and monitoring data at the 18 water quality monitoring stations. As with the hydrology parameters, water quality parameter values were additionally applied to the remaining subwatersheds in the basin.

Receiving Water Model Calibration

Calibration of the receiving water model focused on adjustment of kinetic parameters during a comparison of model output and monitoring data for 1998. Preliminary calibration was performed at station USGS02228500 – North Prong St. Marys River at Moniac, GA, and the resulting parameter values were applied to the remaining impaired waterbodies. In some situations the preliminary calibrated parameters required further change. Calibration results for dissolved oxygen at station USGS02327170 are presented in Appendix C. The remaining modeled waterbodies exhibited similar results.

Kinetic parameters that required adjustment included reaeration formula, ratios for nutrient splits, leaf litterfall nutrient split, and density of periphyton. For the in-stream, EFDC model runs, the primary water quality parameters for evaluating a calibrated model were dissolved oxygen and TOC. Secondary parameters include ammonia, nitrate-nitrite, total nitrogen, and total phosphorus. SOD and COD benthic flux were also examined to see how much oxygen demand was derived by the sediment. In addition to the water quality calibration, flow, velocity, and depth were examined to ensure proper calibration of the hydrodynamics.

6.0 Loading Capacity

The tested model was ultimately used to identify the allowable loading capacity for the listed segments. The first step in the process was to determine naturally occurring dissolved oxygen concentrations for the impaired waterbodies. By doing so, the applicable water quality standard used for TMDL development was identified.

To determine the naturally occurring dissolved oxygen concentrations, the in-stream models were run using watershed model input representing pristine conditions (entirely forest and wetland contributions) and leaf litterfall. The resultant in-stream dissolved oxygen concentrations represented natural conditions. The minimum daily average dissolved oxygen concentration observed during the critical summer period was compared to the water quality standards. The range of values was representative of naturally low dissolved oxygen concentrations and was below 110% of the state water quality standard, therefore the EPA criteria was instituted and dissolved oxygen target limits were identified for TMDL development. The target limits were identified as 90% of the minimum naturally occurring concentration for impaired waterbodies.

After identifying the dissolved oxygen target limits, the models were run to determine the loading capacity of the waterbody. This was done through a series of simulations aimed at meeting the dissolved oxygen target limit by varying source contributions. The final acceptable scenario represented the TMDL (and loading capacity of the waterbody). Subsequent sections of this report present components of the TMDL.

Confirmation of Waterbodies Reaching Dry Conditions

An analysis of USGS daily discharge data at selected gaging stations located throughout the southern four Georgia basins suggests that many streams in the region actually exhibit no-flow conditions for extended periods of time. Several of the impaired waterbodies dry for significant periods of time throughout the year. Analysis of water quality is virtually impossible during no-flow conditions and situations where streams contain no flow or pooled non flowing water. Seven stations were selected for the analysis. Each station is located on a unique waterbody representing a drainage area between 139 and 1,260 mi^2 (Table 6-1).

Table 6-1. USGS Gaging Stations and Characteristics

USGS Gaging Station ID	Drainage Area (mi^2)	Waterbody	Basin	Period of Record
02227000	139	Hurricane Creek	Satilla	10/1/51 - 10/8/71
02227500	646	Little Satilla River	Satilla	1/27/51 - 9/30/98
02314500	1,260	Suwannee River	Suwannee	4/20/37 - 9/30/98
02316000	663	Alapaha River	Suwannee	4/26/37 - 9/30/76
02317755	537	Withlacoochee River	Suwannee	10/20/76 - 1/4/90
02318000	577	Little River	Suwannee	6/12/40 - 9/30/71
02318700	269	Okapilco Creek	Suwannee	12/21/79 - 9/30/98

The three stations representing the smallest drainage areas (02227000, 02317755, and 02318700) had no-flow days more than 9% of the time. The remaining stations, representing larger watersheds, exhibited no-flow conditions less than 1% of the time. Although the timing of no-flow conditions varied from one waterbody to the next, the most common months exhibiting no-flow conditions were October, November, and June. Precipitation data for the basin supports these trends in that October and November are typically the driest months, and June often exhibits lower rainfall totals (compared to other months). Refer to Appendix A for detailed information regarding precipitation at appropriate weather stations in the basin. Table 6-2 presents information, by station, related to no-flow time periods.

Table 6-2. No-Flow Characteristics for Selected USGS Gaging Stations

USGS Gaging Station ID	Days with No Flow	Total Days	% of Days with No Flow	Month with Most No-Flow Days
02227000	745	7306	10.20	June
02227500	50	17414	0.29	October
02314500	74	22,444	0.33	November
02316000	106	14403	0.74	October
02317755	142	1233	11.52	November
02318000	17	11433	0.15	June
02318700	683	6859	9.96	October

Under no-flow conditions, the development or determination of an appropriate naturally occurring dissolved oxygen water quality standard is not possible or appropriate. Therefore, when using the models to identify minimum dissolved oxygen concentrations under natural conditions, no-flow periods were not considered. The minimum dissolved oxygen concentrations and related loadings were identified only during periods when there was flow in the stream.

7.0 Waste Load and Load Allocations

Two critical components of the TMDL are the Waste Load Allocations (WLAs) and the Load Allocations (LAs). The WLAs represent the load allocations to point source facilities contributing to impaired waterbodies, while the LAs represent load allocations to the nonpoint source contributions. LAs are assumed to represent all watershed and leaf litterfall loads to the impaired waterbody. The LAs are divided into subwatersheds (representing all subwatersheds contributing to an impaired waterbody).

The WLAs and LAs presented in Appendix D represent successful allocation scenarios (in which the dissolved oxygen target limit is met). WLAs and LAs sum to represent the entire TMDL, because MOS is implicitly considered through model assumptions.

The partitioning of allocations between point (WLA) and nonpoint (LA) sources was based on modeling results and professional judgment to meet the TMDL. The WLAs may be modified by GAEPD during the NPDES permitting process. The TMDLs will be used to assess the permit renewals in the impaired segments.

8.0 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, and
- 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), taking into account the daily maximum loads,
- Running model with actual flow and temperature during one or more annual cycles including a critical summer period, and
- 41% saturation for upstream dissolved oxygen (Meyer, 1992).

9.0 Seasonal Variation

The Statute and regulations require that a TMDL be established with consideration of seasonal variations. Seasonal variation was considered through dynamic representation of a full calendar year. The model simulations included a wide range of hydrologic and pollutant loading scenarios and led to development of a TMDL corresponding to these scenarios.

10.0 Monitoring Plan

The GAEPD has adopted a basin approach to water quality management; an approach that divides Georgia's major river basins into five groups. Each year the GAEPD water quality monitoring resources are concentrated in one of the basin groups. One goal is to continue to monitor 303(d) listed waters. This monitoring will occur in the next monitoring cycle for the St. Marys in 2003 and will help further characterize water quality conditions resulting from the implementation of best management practices in the watershed.

11.0 Point and Nonpoint Source Approaches

Permitted discharges will be regulated through the NPDES permitting process described in this report. The total organic carbon nonpoint source loading to the streams in the St. Marys River is made up of a combination of naturally occuring leaf litter and anthropogenic non-point source loads. Because most, if not all, total organic carbon loading to streams in the St. Marys River Basin is the result of nonpoint sources, the implementation goal for nonpoint sources will be to reduce the total organic carbon loading from anthropogenic non-point source loads. The reduction in anthropogenic non-point source loading should lead to the attainment of water quality standards. To ensure that anthropogenic non-point source load reductions occur in the Satilla River Basin, Georgia EPD will work with the Natural Resource Conservation Service (NRCS), the Georgia Soil and Water Conservation Commission (GSWCC), and the Georgia Forestry Commission to implement best management practices (BMPs) to reduce anthropogenic nonpoint source loading of total organic carbon. Implementation of BMPs to reduce anthropogenic non-point source loading of total organic carbon is expected to lead to the attainment of water quality standards.

12.0 Public Participation

A sixty-day public notice was provided for this TMDL. During that time the availability of the TMDL was public noticed, a copy of the TMDL was provided as requested, and the public was invited to provide comments on the TMDL.

13.0 References

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Appendix A

Data Used in TMDL Analyses

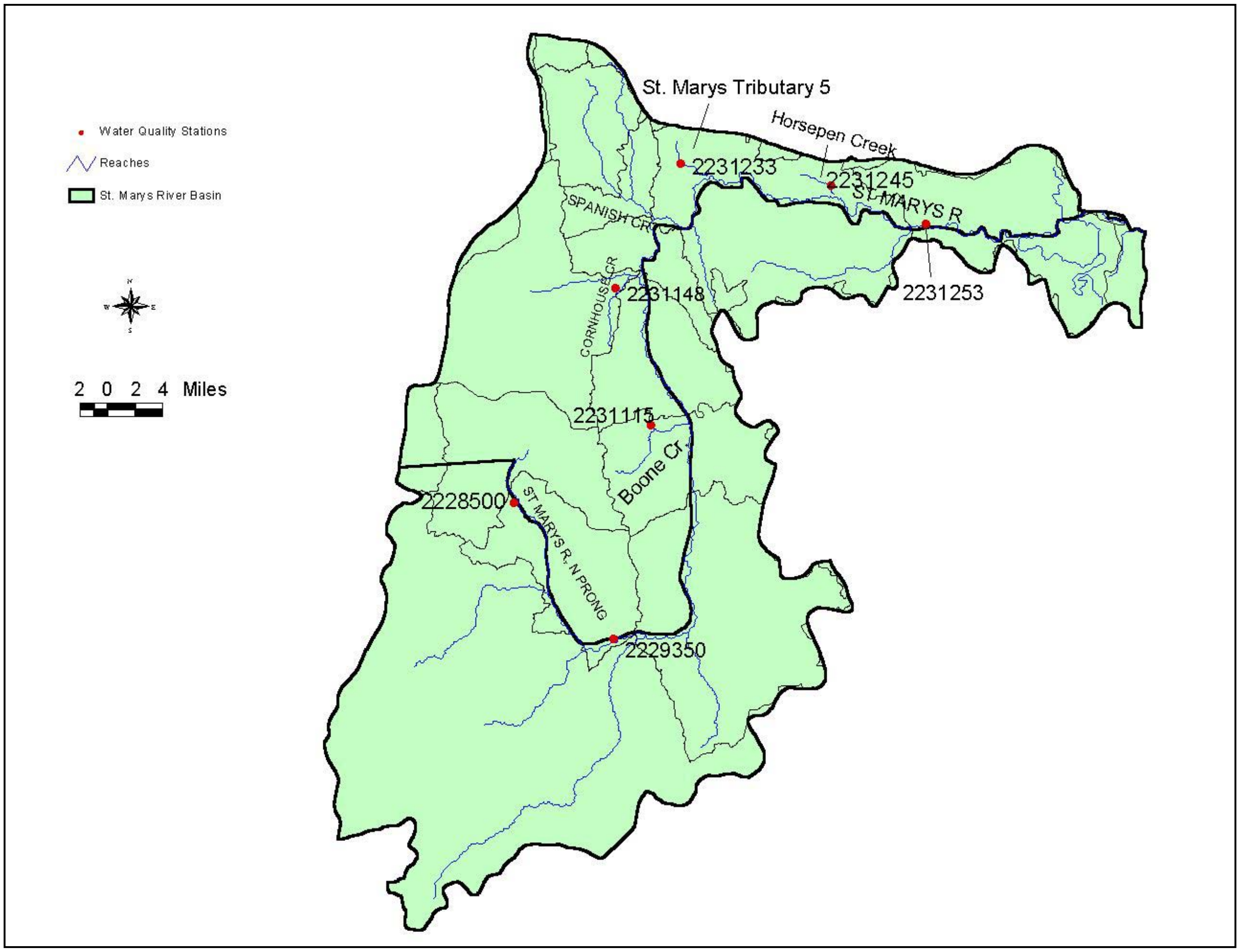


Figure A-1. Water Quality Stations in the St Marys River Basin

Table A-1. Summary of Dissolved Oxygen Data from Monitoring Stations for 1998

USGS ID NO	Station Description	USGS 12-digit HUC	Dissolved Oxygen (mg/L)			No of Meas.
			min	max	mean	
02228500	NORTH PRONG ST MARYS RIVER AT MONIAC, GA.	030702040102	1.8	8.4	5.4	22
02229350	NORTH PRONG ST MARYS R (SR 121) NR MACCLENNY, FLA	030702040102	4.2	9.4	6.3	22
02231100	ST. MARYS RIVER (SR 94) AT ST. GEORGE, GA.	030702040202	4.7	8.1	6.1	22
02231115	BOONE CREEK NEAR ST GEORGE, GA	030702040202	0.2	8	4.0	22
02231148	CORNHOUSE CREEK (SR 121) NEAR ST GEORGE, GA.	030702040302	2.8	7.3	4.4	22
02231200	SPANISH CREEK NEAR FOLKSTON, GA.	030702040304	3.4	9.1	5.2	22
02231220	ST. MARYS RIVER AT BOULOGNE, FLA.	030702040401	4.0	8.2	5.5	22
02231233	ST. MARYS RIVER TRIB 5 (SR 40) AT FOLKSTON, GA.	030702040401	0.9	8.7	4.6	23
02231245	HORSEPEN CREEK (CR 55) NEAR KINGSLAND, GA.	030702040401	1.7	5.7	3.2	23
02231253	ST MARYS RIVER NEAR GROSS, FL.	030702040402	3.0	7.8	4.9	23

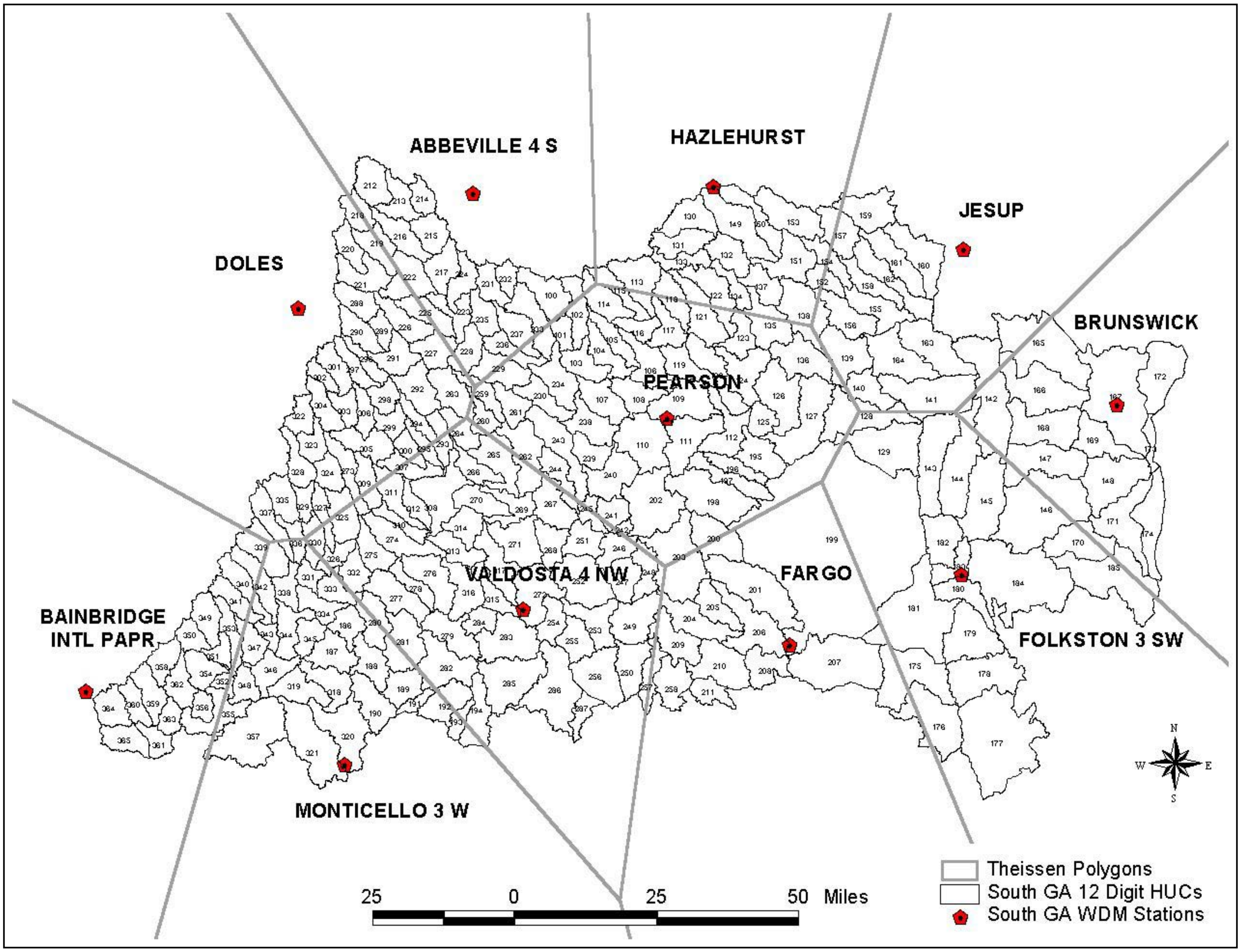


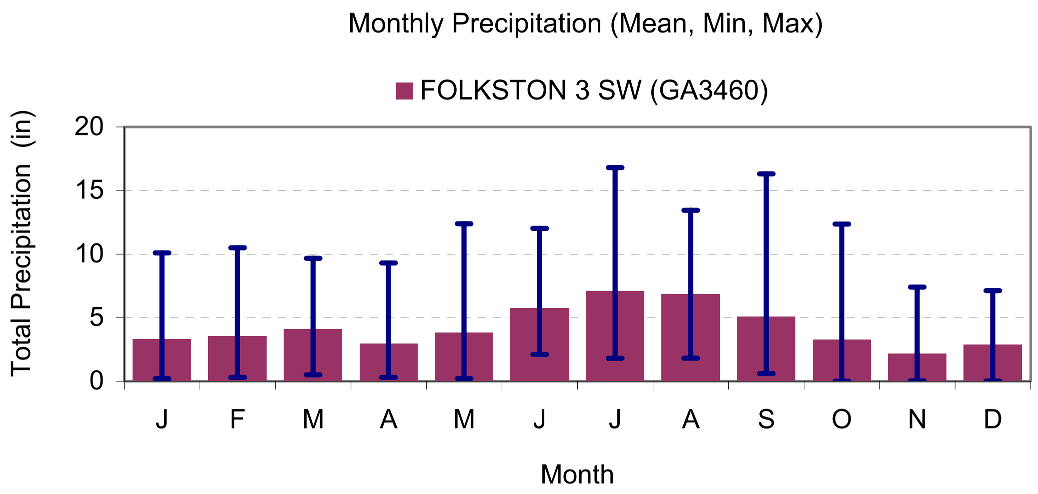
Figure A-2. Meteorological Stations for Southern 4 Basins Used in Watershed Model

TOTAL MONTLY PRECIPITATION (IN)

Station: FOLKSTON 3 SW (GA3460)

Analysis Period: 50 years (from July, 1948 to June, 1998)

Month	Count	Mean	Min	Max	St Dev	Median	25th	75th
January	50	3.29	0.20	10.10	2.26	3.11	1.55	4.55
February	50	3.54	0.30	10.50	2.12	3.20	2.22	4.51
March	50	4.11	0.50	9.67	2.59	3.98	1.95	5.05
April	50	2.97	0.30	9.30	2.26	2.30	1.31	3.96
May	50	3.81	0.20	12.39	2.63	3.07	2.12	5.34
June	50	5.75	2.10	12.02	2.16	6.02	3.78	7.16
July	50	7.07	1.80	16.80	3.18	6.45	4.77	8.94
August	50	6.85	1.81	13.44	3.12	5.99	4.52	9.48
September	50	5.07	0.60	16.31	3.42	4.27	2.64	6.46
October	50	3.25	0.00	12.36	2.62	2.65	1.46	4.79
November	50	2.20	0.02	7.40	1.55	1.78	1.10	3.23
December	50	2.87	0.01	7.12	1.83	2.34	1.46	4.57



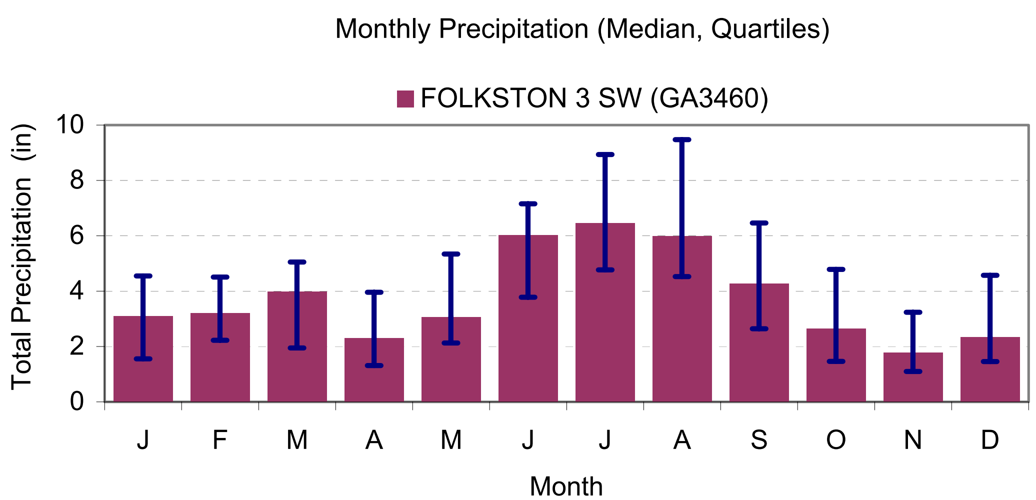


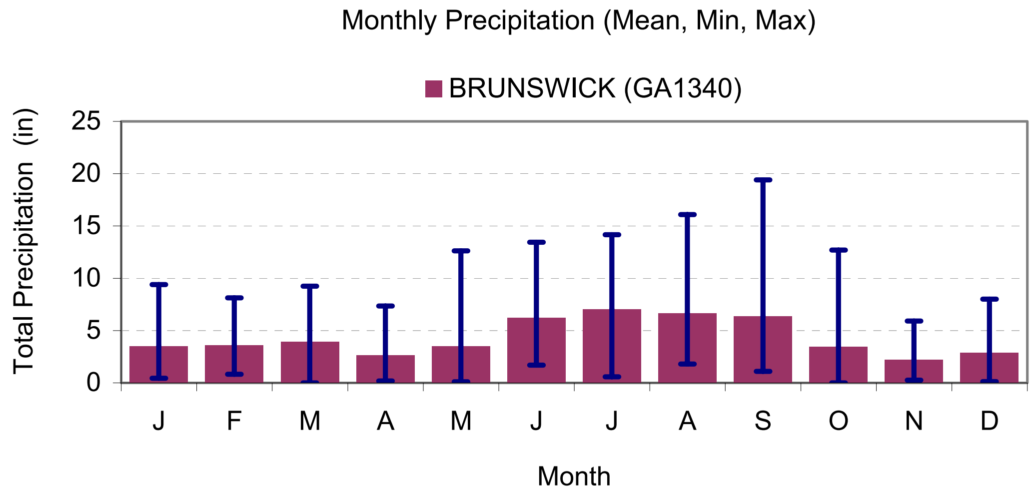
Figure A-3. Average Monthly Mean Precipitation for Folkston 3 SW (GA3460)

TOTAL MONTLY PRECIPITATION (IN)

Station: BRUNSWICK (GA1340)

Analysis Period: 34 years (from July, 1964 to November, 1998)

Month	Count	Mean	Min	Max	St Dev	Median	25th	75th
January	34	3.52	0.45	9.40	2.23	3.20	1.47	5.45
February	34	3.60	0.83	8.13	1.90	3.34	2.20	4.51
March	34	3.96	0.00	9.24	2.35	3.94	2.23	4.82
April	34	2.68	0.18	7.35	1.83	2.35	1.10	3.78
May	34	3.50	0.10	12.62	2.73	2.94	1.67	4.40
June	34	6.23	1.70	13.44	3.03	6.16	3.55	7.98
July	35	7.05	0.58	14.17	3.55	6.49	4.80	10.31
August	35	6.65	1.80	16.09	3.33	6.12	4.47	7.85
September	35	6.37	1.10	19.41	4.18	5.97	3.73	7.57
October	35	3.48	0.00	12.70	2.70	3.06	1.58	4.66
November	35	2.23	0.26	5.92	1.69	1.60	0.76	3.42
December	34	2.90	0.12	8.00	1.82	2.42	1.59	4.19



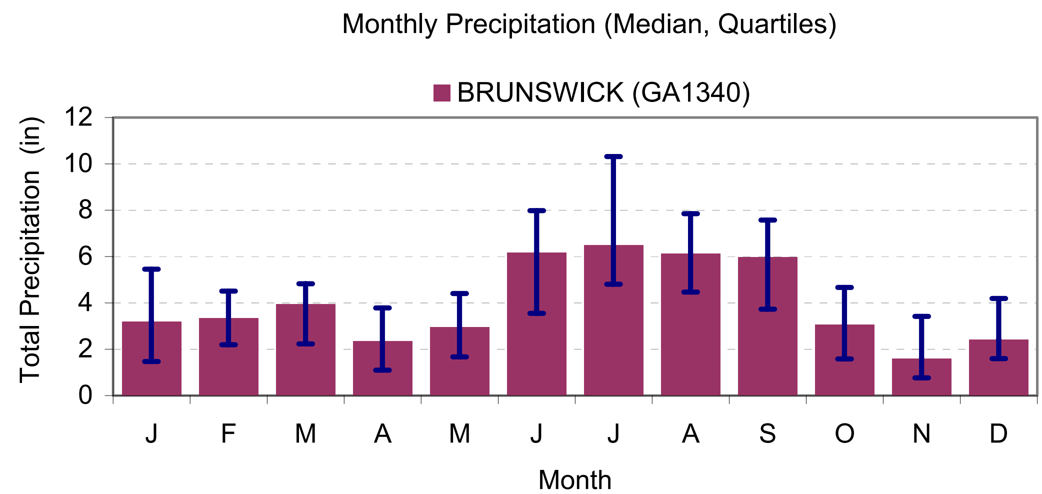


Figure A-4. Average Monthly Mean Precipitation for Brunswick (GA1340)

Table A-2: Land Use Distribution for Impaired Segments

GA 12-digit Watershed ID	Built-up Impervious (acres)	Built-up Pervious (acres)	Cropland (acres)	Forest/Wetland (acres)	Pasture (acres)	TOTAL (acres)
30702010101	290	2419	302	59461	11	62483
30702040102	4793	31121	8373	287674	723	332684
30702010103	1657	11754	1079	103844	300	118635
30702040201	764	5786	68	46882	104	53605
30702040202	572	4732	8	40798	40	46150
30702040301	348	2898	4	21272	40	24562
30702040302	340	2969	4	91100	0	94414
30702040303	671	5570	447	24851	32	31570
30702040304	719	3947	528	12179	34	17408
30702040401	1631	9912	726	99642	169	112080
30702040402	1566	3597	335	29450	22	34972

Source: USGS MRLC – 1990's
Note: Built-up includes low and high residential, high and low commercial and barren land uses.

Appendix B

Hydrology Calibration and Validations

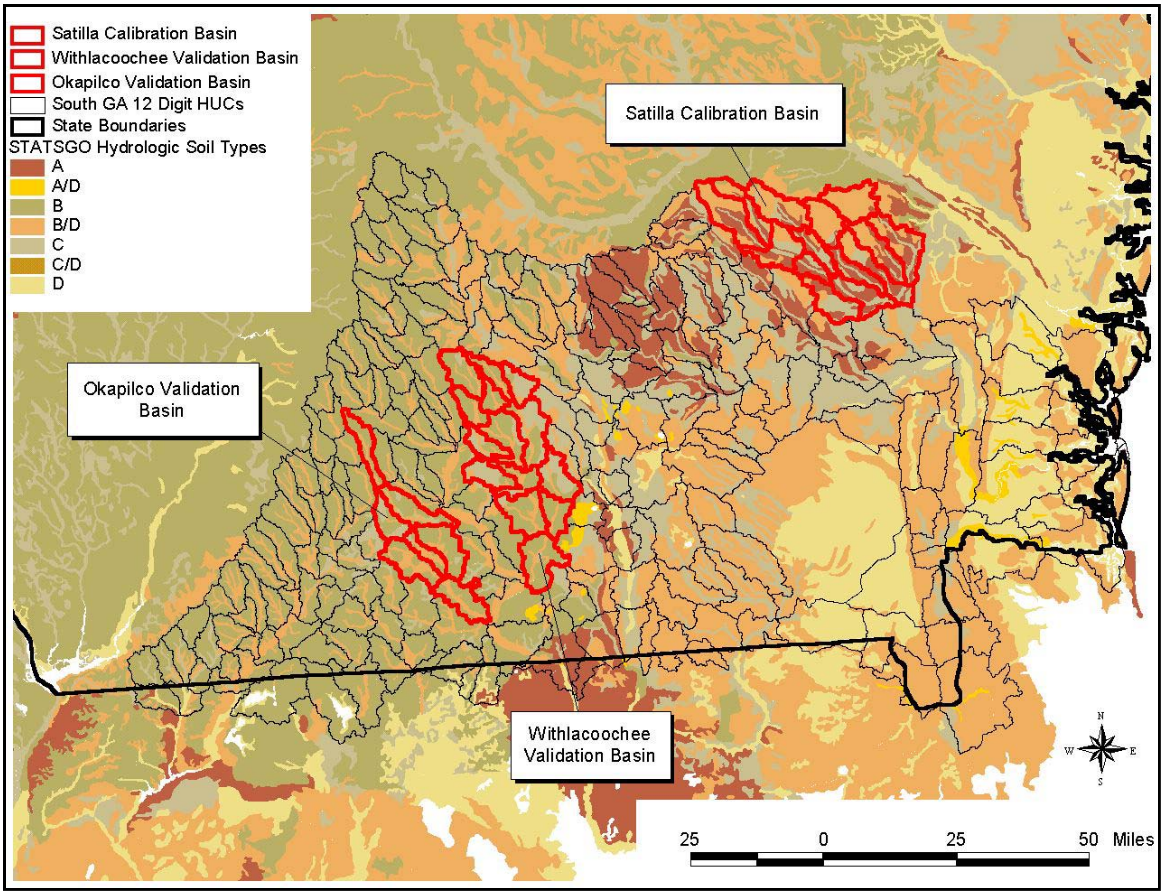


Figure B-1. Location of hydrology calibration and validation basins.

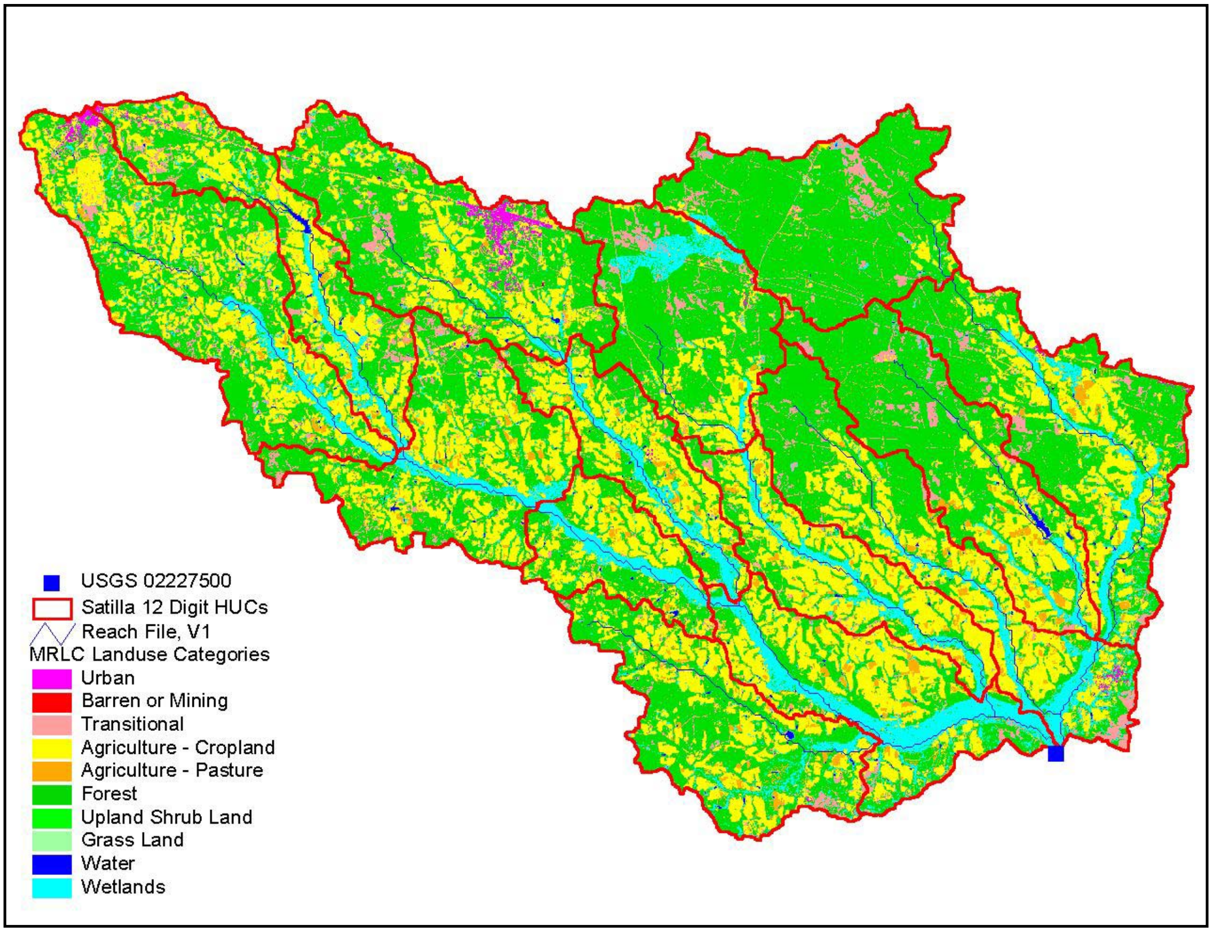


Figure B-2. Hydrology calibration drainage basin, Little Satilla River near Offerman, GA.

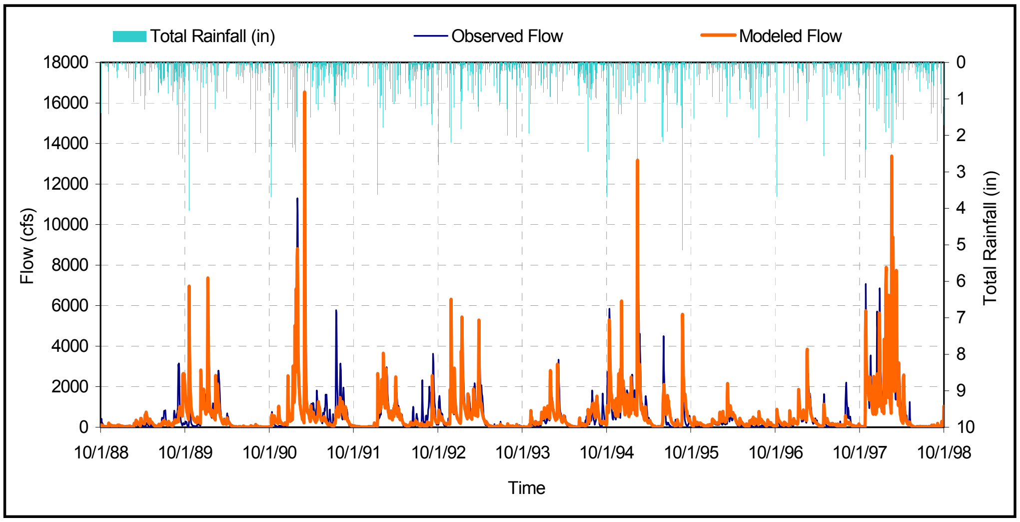


Figure B-3. 10-year calibration (daily flow) at Little Satilla River near Offerman, GA

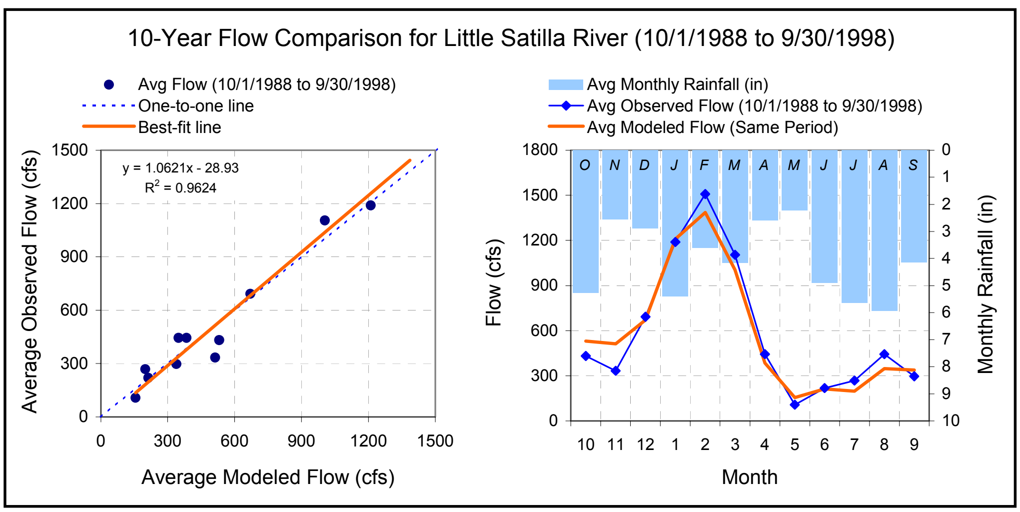


Figure B-4. 10-year calibration (monthly average) at Little Satilla River near Offerman, GA.

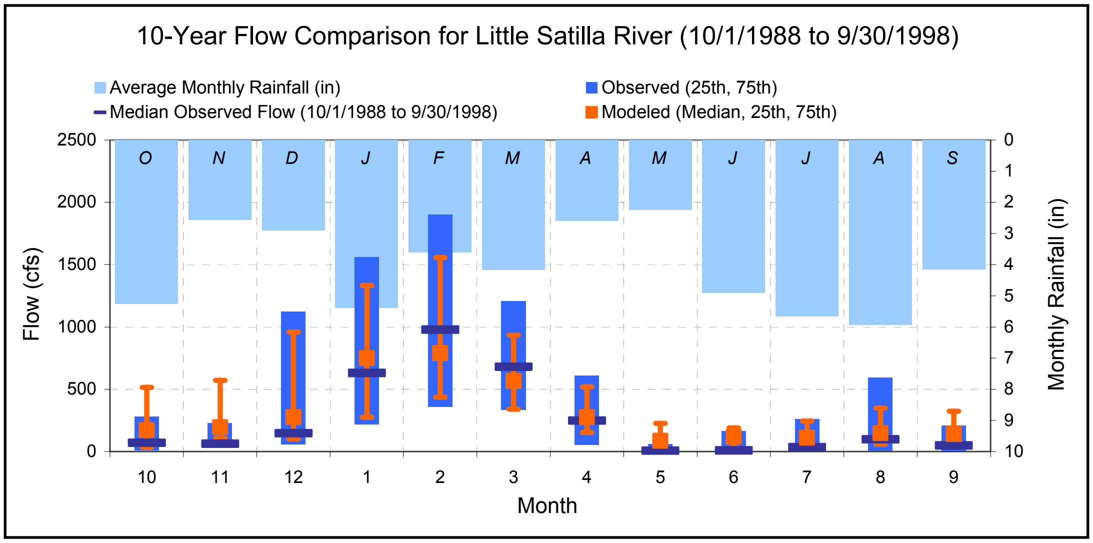


Figure B-5. 10-year calibration (monthly medians), Little Satilla River near Offerman, GA.

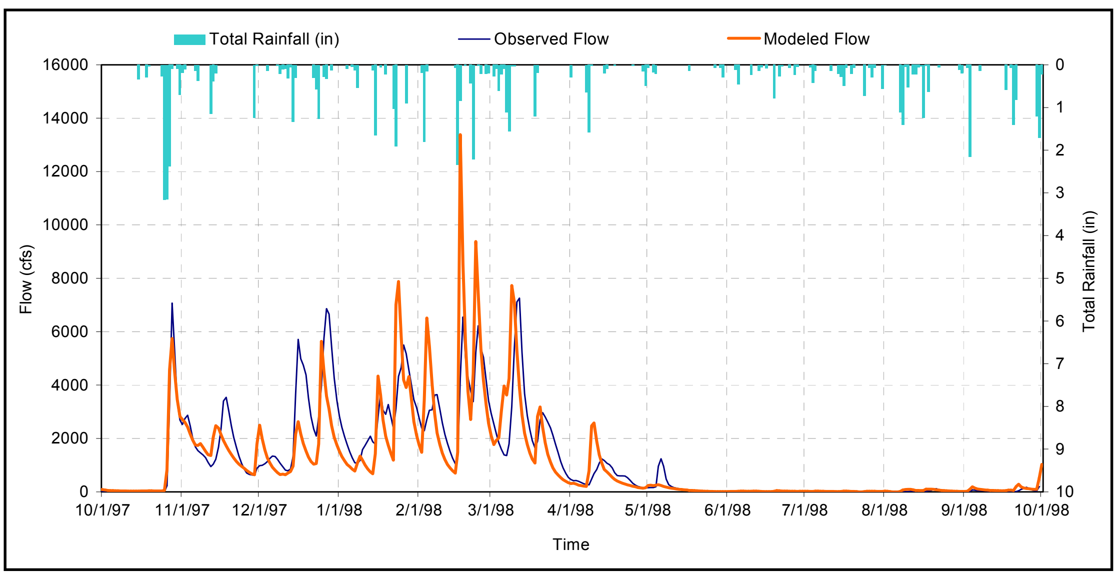


Figure B-6. Water year 1998 (daily flow), Little Satilla River near Offerman, GA.

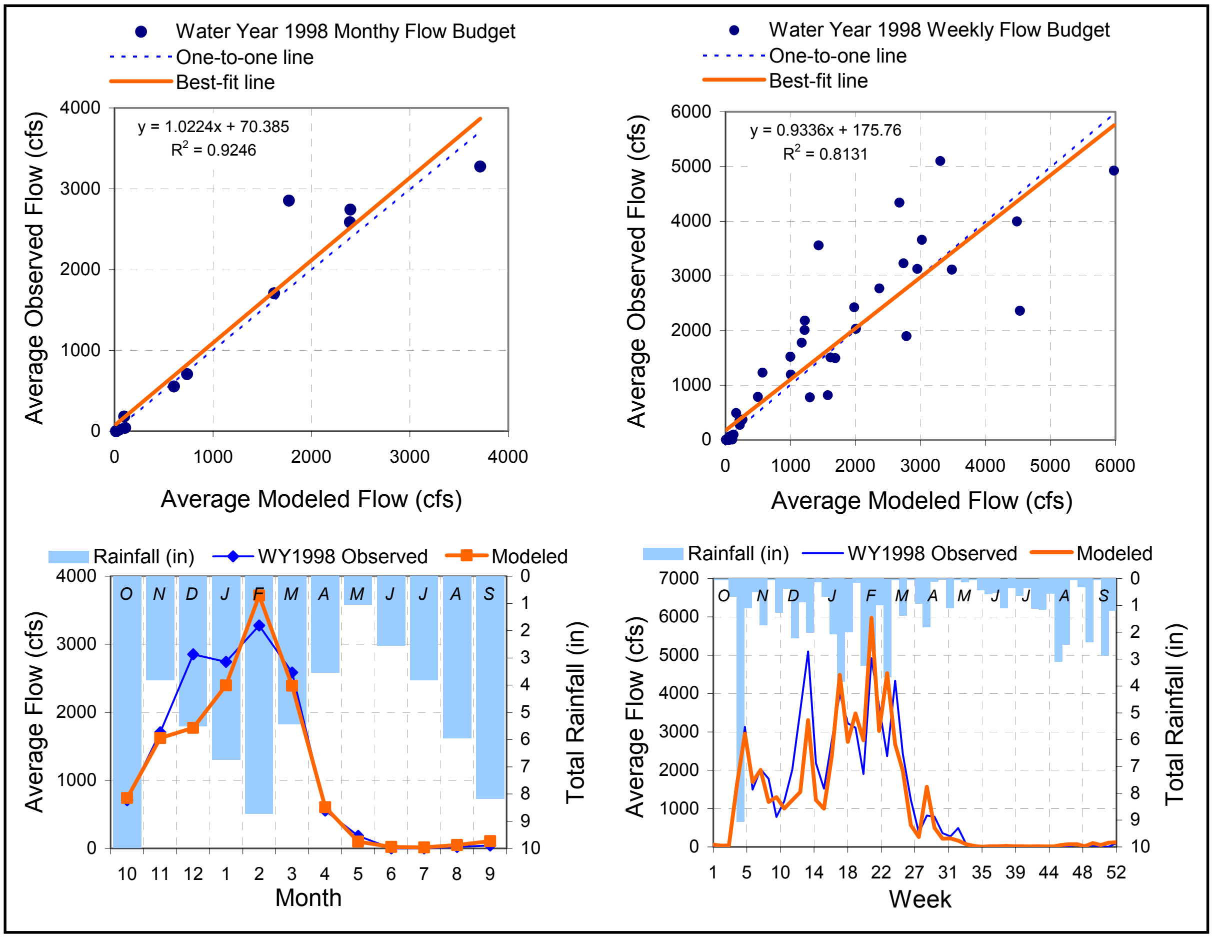


Figure B-7. Water year 1998 (monthly & weekly), Little Satilla River near Offerman, GA.

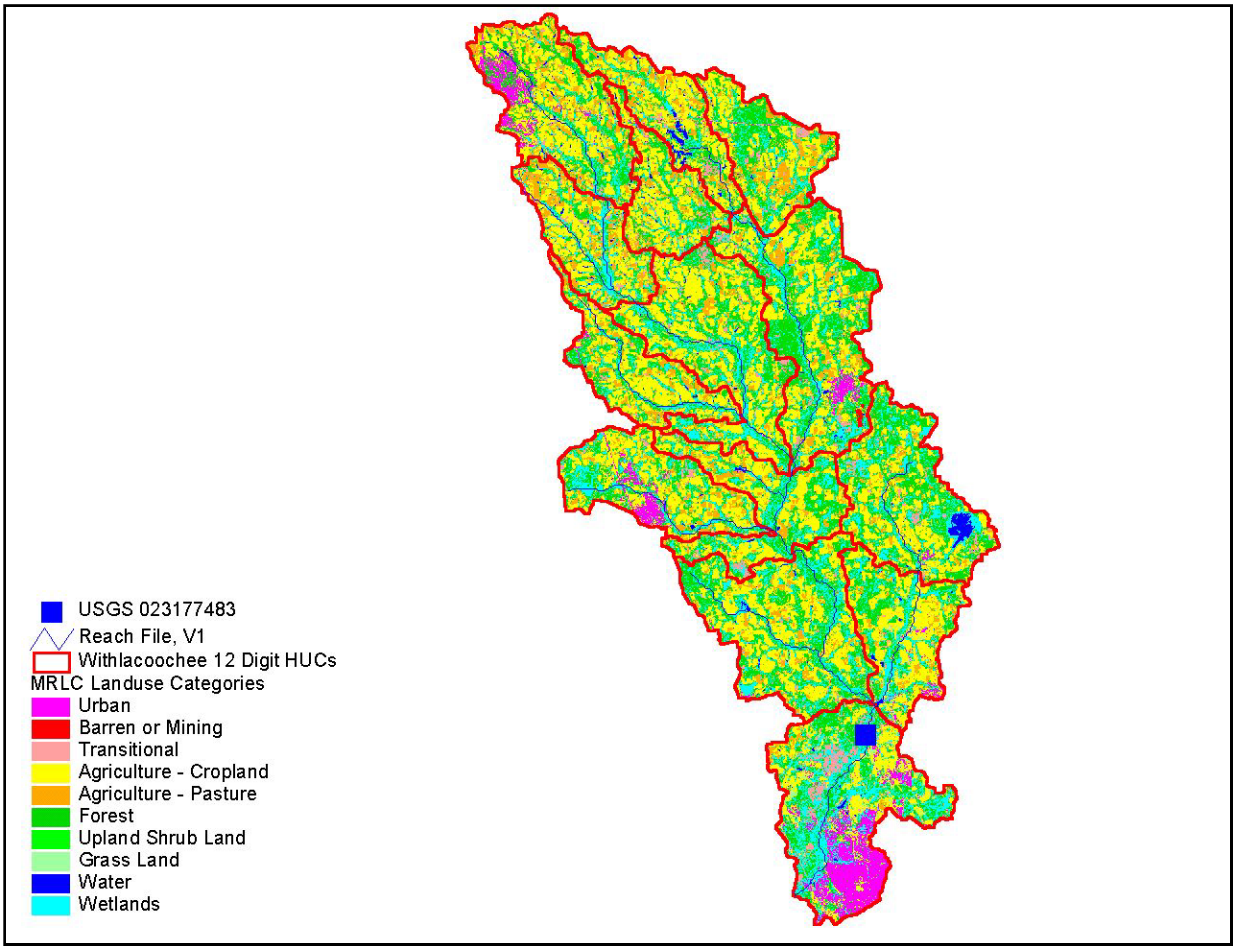


Figure B-8. Hydrology validation 1 drainage basin, Withlacoochee River at McMillan Rd near Bemiss, GA.

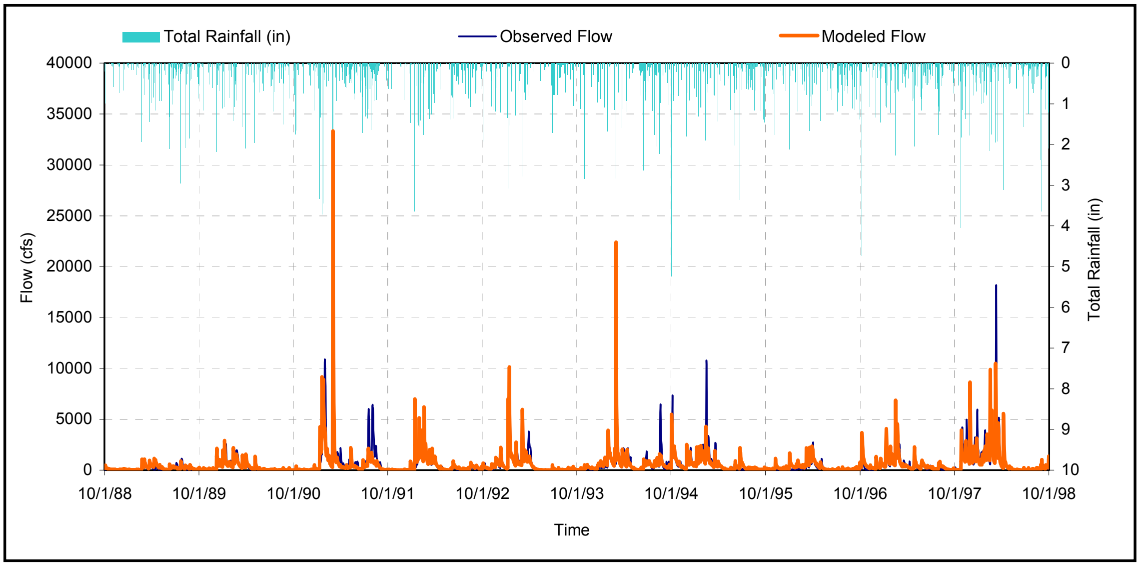


Figure B-9. 10-year validation (daily flow), Withlacoochee River at McMillan Rd near Bemiss, GA.

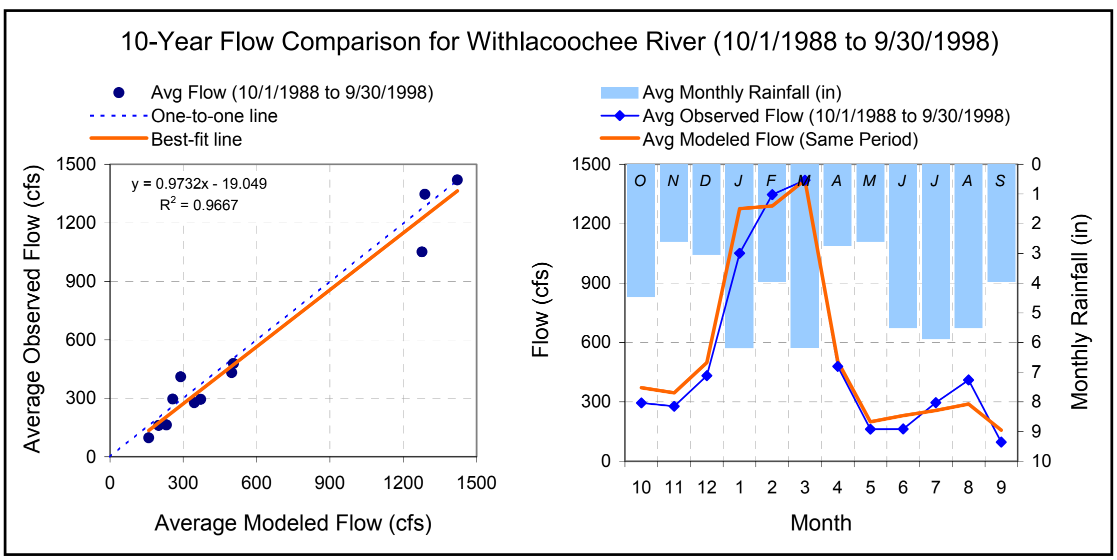


Figure B-10. 10-year validation (monthly average), Withlacoochee River at McMillan Rd near Bemiss, GA.

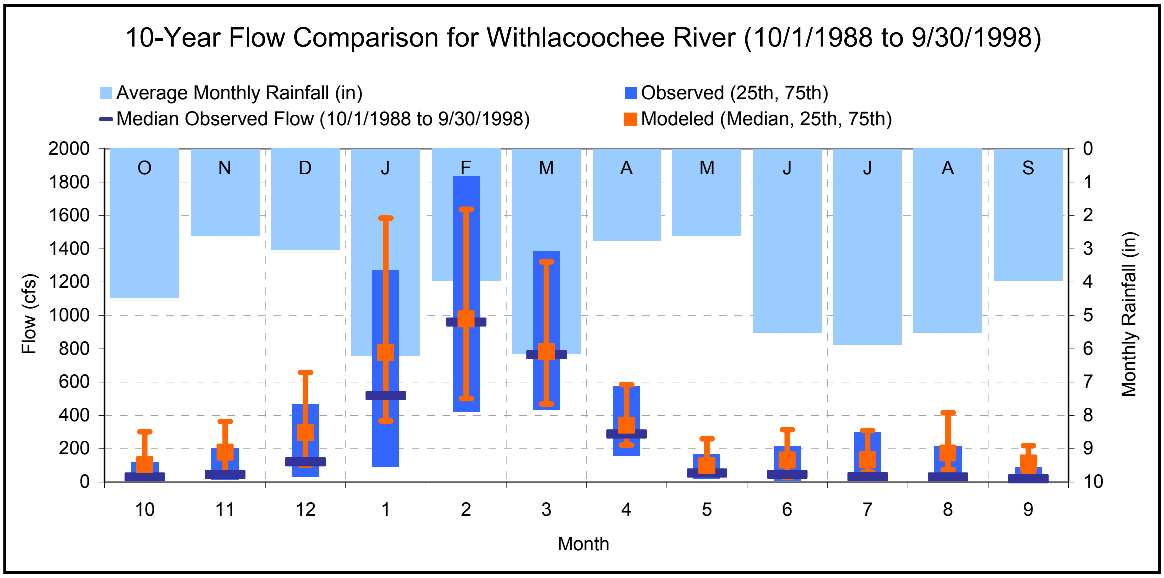


Figure B-11. 10-year validation (monthly medians), Withlacoochee River at McMillan Rd near Bemiss, GA.

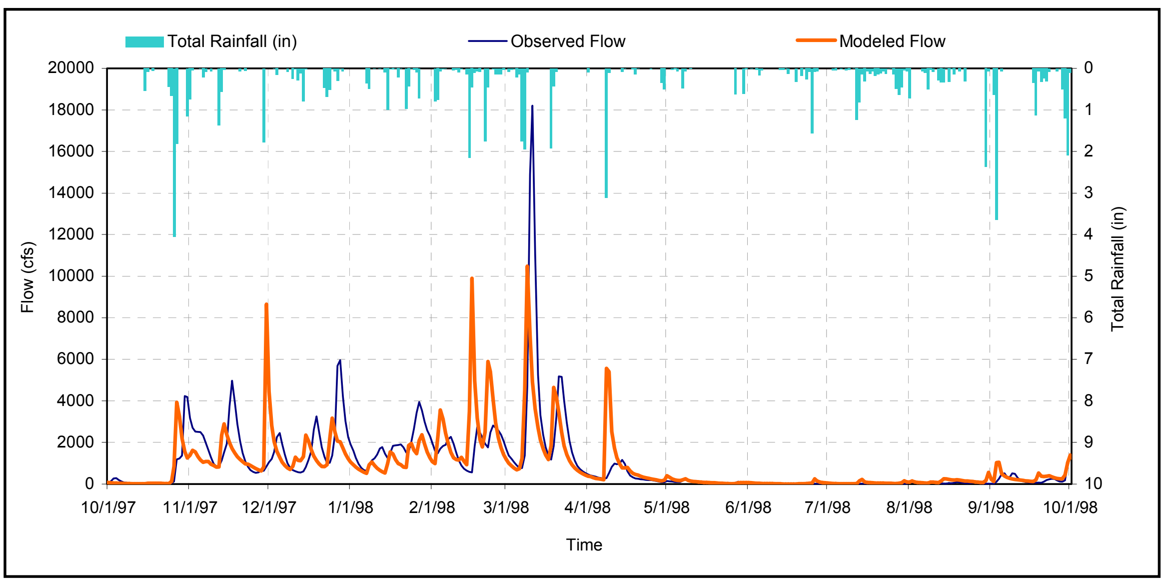


Figure B-12. Water year 1998 (daily flow), Withlacoochee River at McMillan Rd near Bemiss, GA.

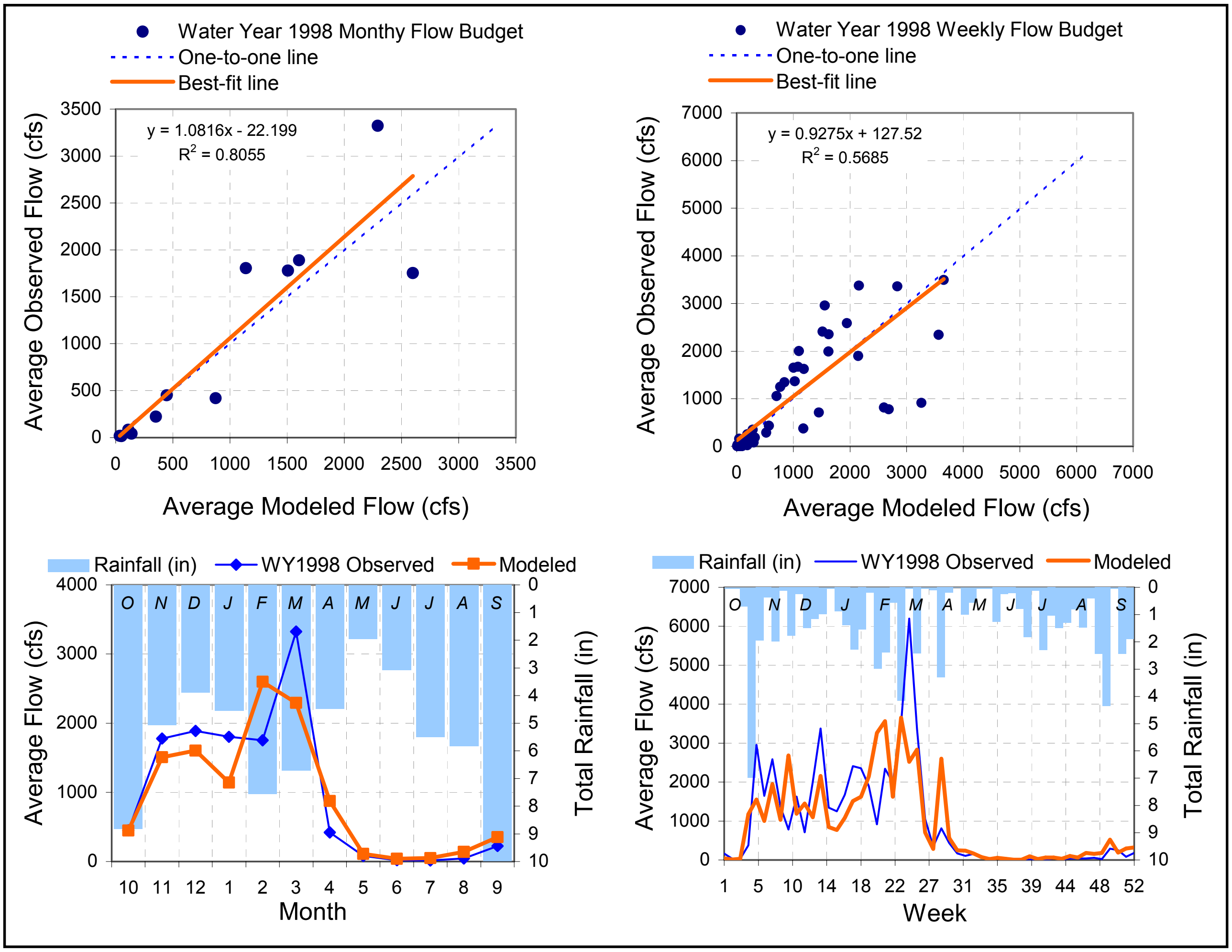


Figure B-13. Water year 1998 (monthly & weekly), Withlacoochee River at McMillan Rd near Bemiss, GA.

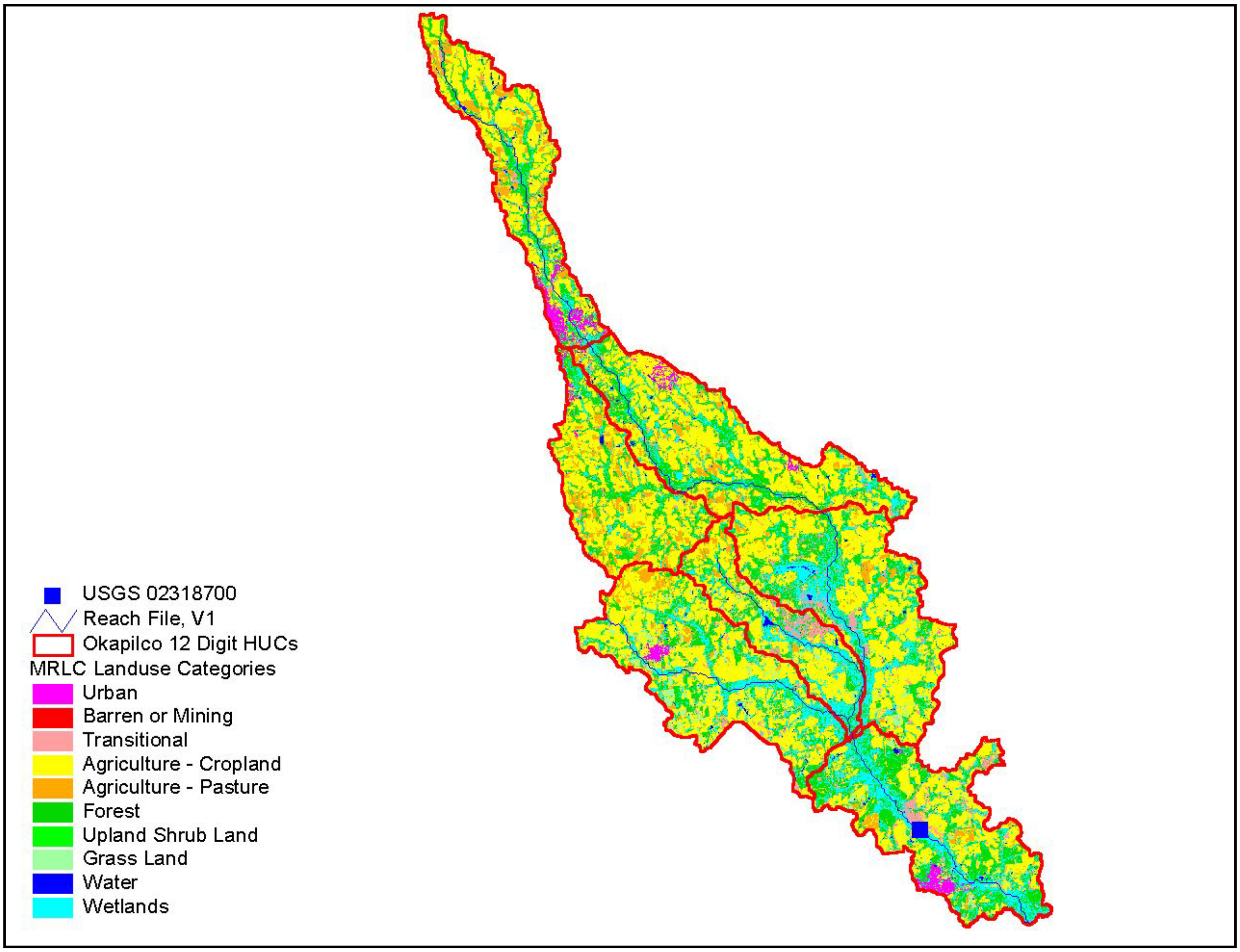


Figure B-14. Hydrology validation 2 drainage basin, Okapilco Creek at RT 33 near Quitman, GA.

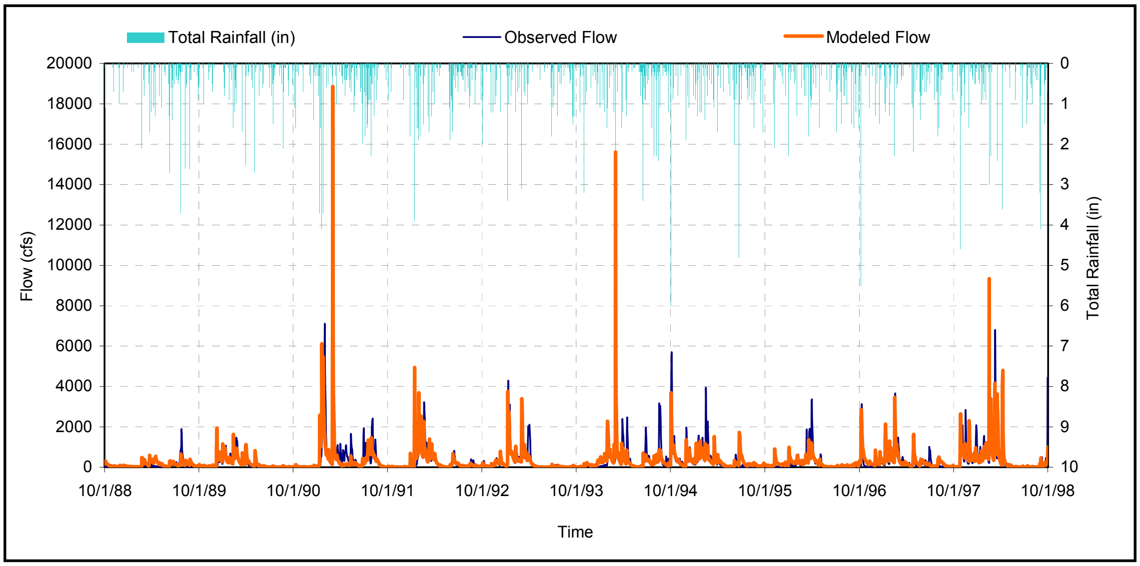


Figure B-15. 10-year validation (daily flow), Okapilco Creek at ST RT 33 near Quitman, GA.

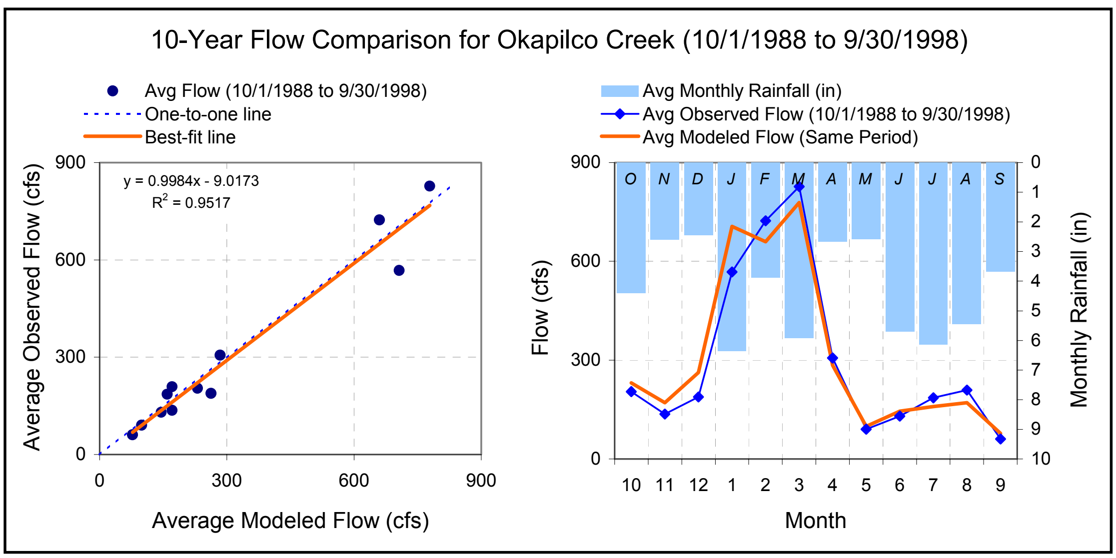


Figure B-16. 10-year validation (monthly average), Okapilco Creek at ST RT 33 near Quitman, GA.

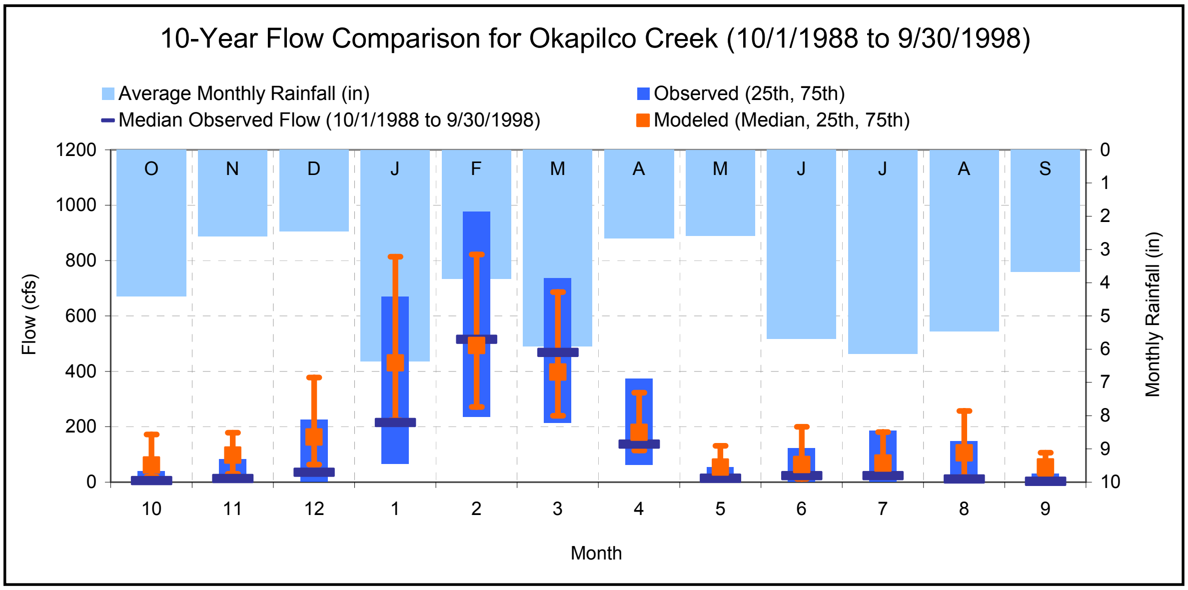


Figure B-17. 10-year validation (monthly medians), Okapilco Creek at ST RT 33 near Quitman, GA.

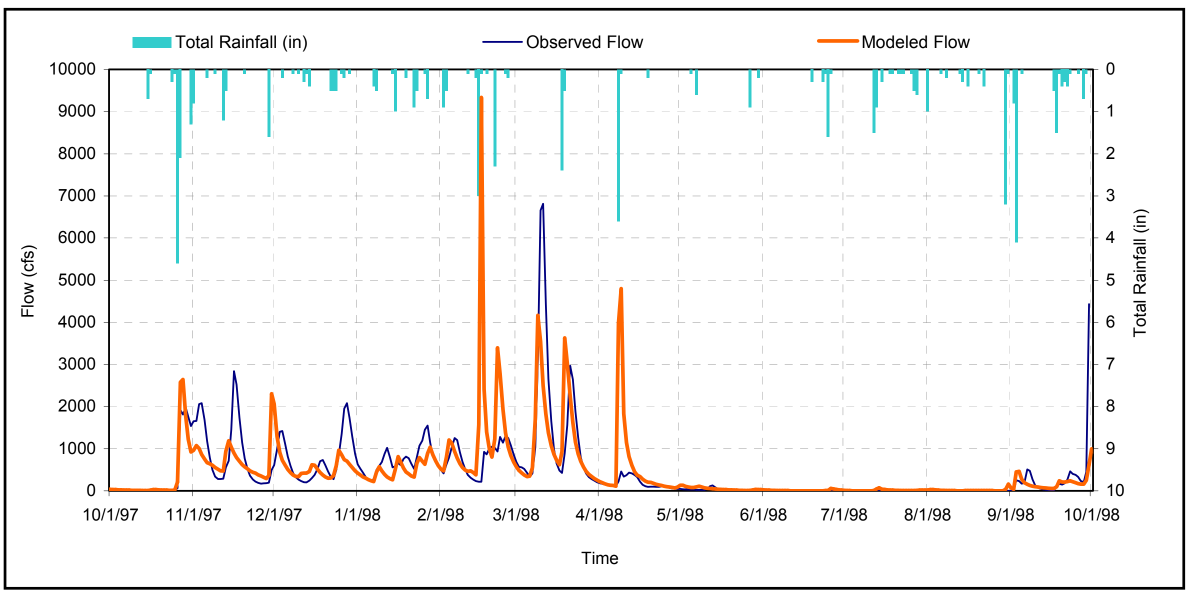


Figure B-18. Water year 1998 (daily flow), Okapilco Creek at ST RT 33 near Quitman, GA.

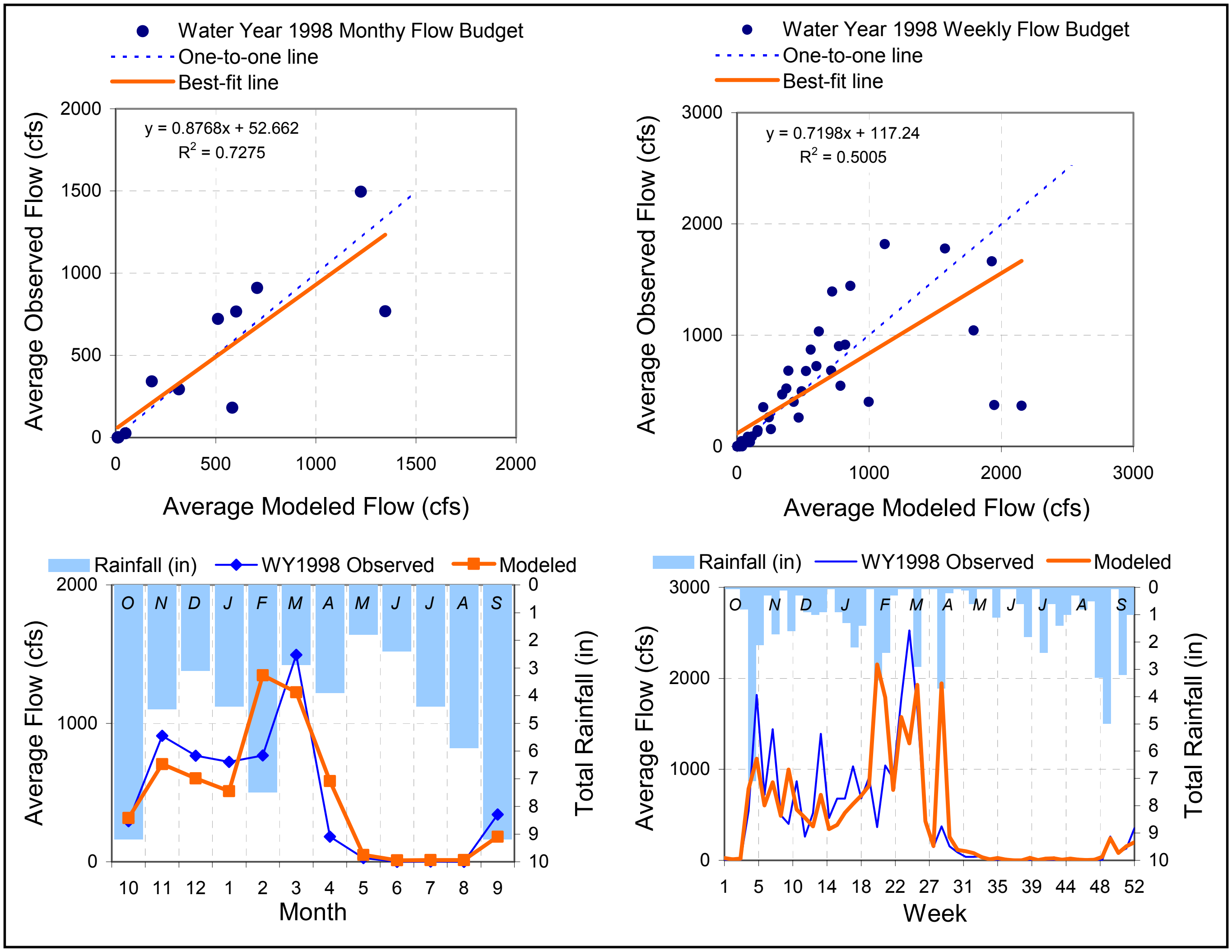


Figure B-19. Water year 1998 (monthly & weekly), Okapilco Creek at ST RT 33 near Quitman, GA.

Appendix C

In-Stream Dissolved Oxygen Calibration

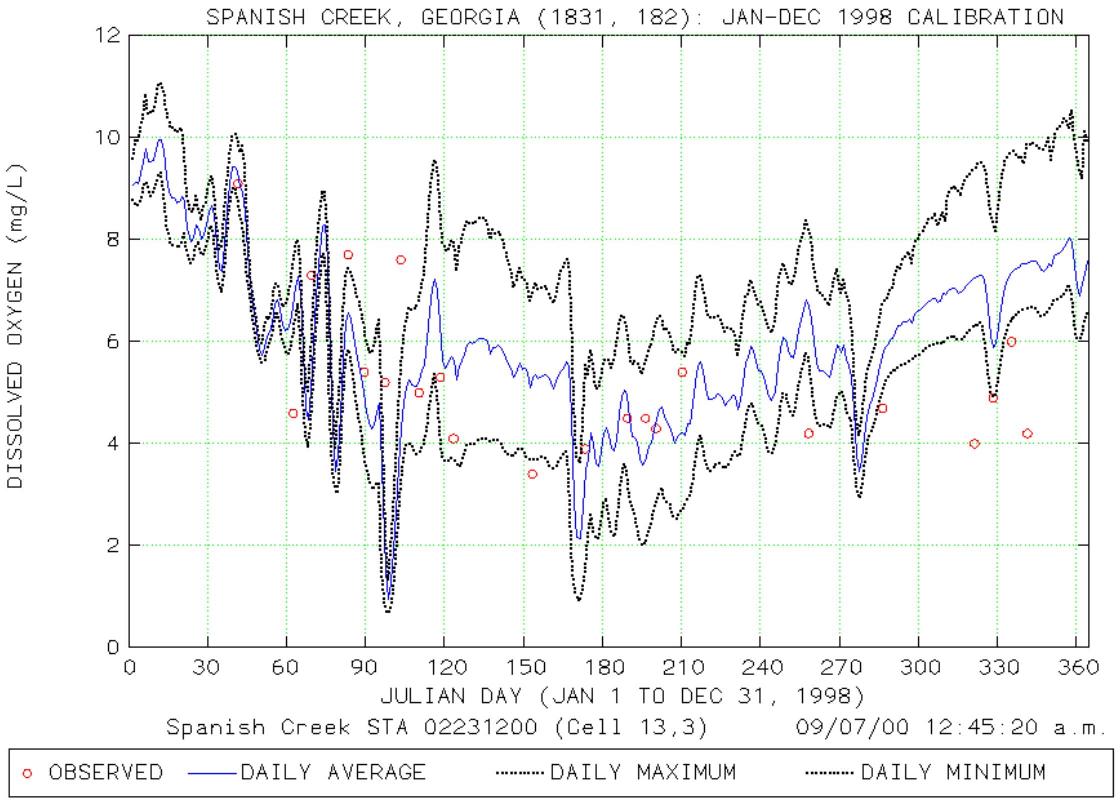


Figure C-1: In-Stream Water Quality Calibration for DO at USGS0231200 – Spanish Creek near Folkston, GA (Subwatershed 183).

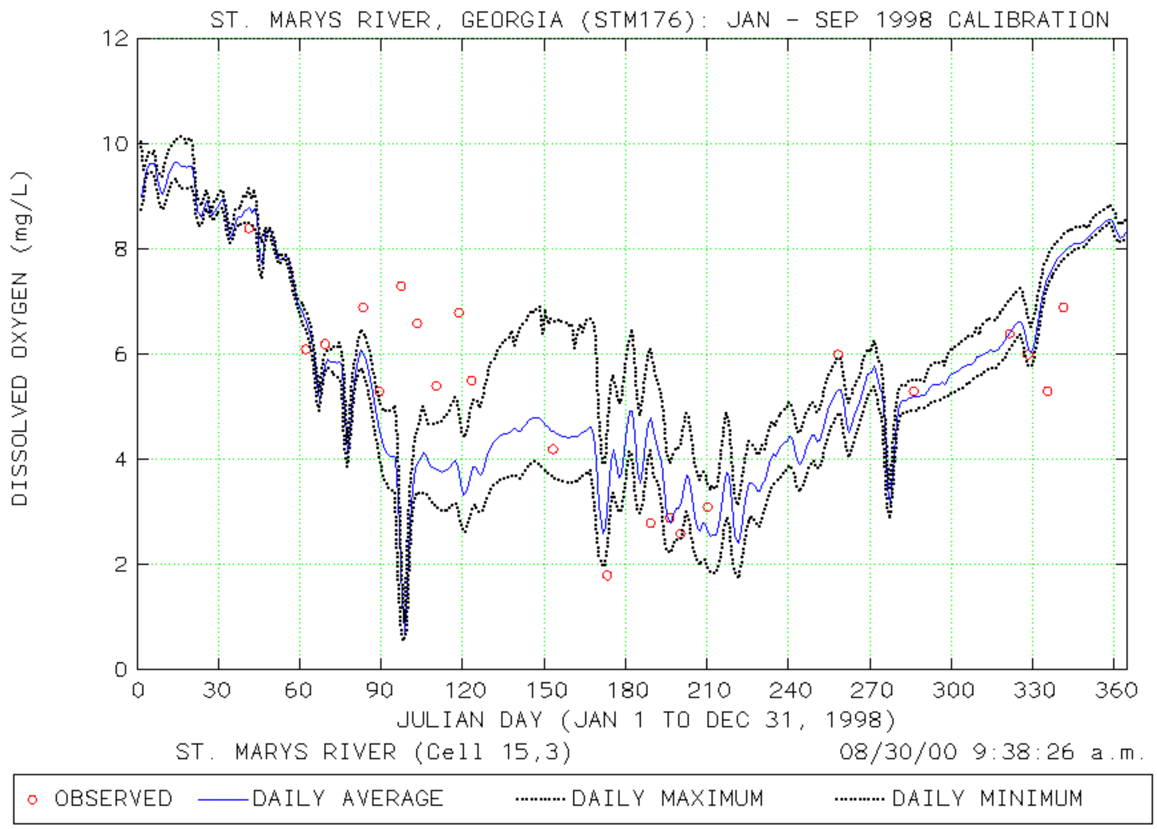


Figure C-2: In-Stream Water Quality Calibration for DO at USGS02229350 – North Prong of St. Marys River at SR 121 near Macclenny, FL (Subwatershed 176).

Appendix D

TMDL Components

Table D-1

Boone Creek - Segment #1				TMDL = WLA + LA					
				TOC(lb/yr)	TN(lb/yr)	TP(lb/yr)			
				2,283,779	57,095	3,482			
Nonpoint Sources (LA)	TOC(lb/yr)	TN(lb/yr)	TP(lb/yr)	TOC(lb/yr)	TN(lb/yr)	TP(lb/yr)	TOC(lb/yr)	TN(lb/yr)	TP(lb/yr)
Contributing Subwatersheds	Existing Loads			Allocation Loads (LA)			% Reduction		
030702040202(b)	2,283,779	57,095	3,482	2,283,779	57,095	3,482	0.00	0.00	0.00
Total	2,283,779	57,095	3,482	2,283,779	57,095	3,482	0.00	0.00	0.00

Table D-2

Corn House Creek - Segment #2				TMDL = WLA + LA					
				TOC(lb/yr)	TN(lb/yr)	TP(lb/yr)			
				3,666,509	68,381	6,049			
Nonpoint Sources (LA)	TOC(lb/yr)	TN(lb/yr)	TP(lb/yr)	TOC(lb/yr)	TN(lb/yr)	TP(lb/yr)	TOC(lb/yr)	TN(lb/yr)	TP(lb/yr)
Contributing Subwatersheds	Existing Loads			Allocation Loads (LA)			% Reduction		
030702040302	3,666,509	68,381	6,049	3,666,509	68,381	6,049	0.00	0.00	0.00
Total	3,666,509	68,381	6,049	3,666,509	68,381	6,049	0.00	0.00	0.00

Table D-3

Horsepen Creek - Segment #3				TMDL = WLA + LA					
				TOC(lb/yr)	TN(lb/yr)	TP(lb/yr)			
				1,298,778	22,170	1,533			
Nonpoint Sources (LA)	TOC(lb/yr)	TN(lb/yr)	TP(lb/yr)	TOC(lb/yr)	TN(lb/yr)	TP(lb/yr)	TOC(lb/yr)	TN(lb/yr)	TP(lb/yr)
Contributing Subwatersheds	Existing Loads			Allocation Loads (LA)			% Reduction		
030702040401(b)	1,396,244	23,834	1,648	1,298,778	22,170	1,533	6.98	6.98	6.98
Total	1,396,244	23,834	1,648	1,298,778	22,170	1,533	7	7	7

Table D-4

St. Mary's Tributary 5 - Segment #4				TMDL = WLA + LA					
				TOC(lb/yr)	TN(lb/yr)	TP(lb/yr)			
				1,281,612	35,168	1,824			
Nonpoint Sources (LA)	TOC(lb/yr)	TN(lb/yr)	TP(lb/yr)	TOC(lb/yr)	TN(lb/yr)	TP(lb/yr)	TOC(lb/yr)	TN(lb/yr)	TP(lb/yr)
Contributing Subwatersheds	Existing Loads			Allocation Loads (LA)			% Reduction		
030702040401(d)	1,355,898	37,206	1,930	1,281,612	35,168	1,824	5.48	5.48	5.48
Total	1,355,898	37,206	1,930	1,281,612	35,168	1,824	5.48	5.48	5.48

Table D-5

N. Prong St. Mary's River - Segment #5				TMDL = WLA + LA					
				TOC(lb/yr)	TN(lb/yr)	TP(lb/yr)			
				28,033,979	785,946	56,802			
Nonpoint Sources (LA)	TOC(lb/yr)	TN(lb/yr)	TP(lb/yr)	TOC(lb/yr)	TN(lb/yr)	TP(lb/yr)	TOC(lb/yr)	TN(lb/yr)	TP(lb/yr)
Contributing Subwatersheds	Existing Loads			Allocation Loads (LA)			% Reduction		
030702040101	6,966,479	134,096	12,123	4,846,163	93,282	8,433	30.44	30.44	30.44
030702040102(a)	2,347,388	81,048	5,065	2,347,388	81,048	5,065	0.00	0.00	0.00
030702040102(b)	2,816,167	76,826	5,533	2,393,668	65,300	4,703	15.00	15.00	15.00
030702040102(c)	3,950,284	141,420	7,725	2,988,114	106,975	5,843	24.36	24.36	24.36
030702040102(d)	13,392,976	313,068	25,520	9,112,500	213,010	17,364	31.96	31.96	31.96
030702040102(e)	6,346,146	226,332	15,394	6,346,146	226,332	15,394	0.00	0.00	0.00
Total	35,819,440	972,790	71,360	28,033,979	785,946	56,802	21.74	19.21	20.40

Table D-6

St. Mary's River - Segment #6				TMDL = WLA + LA					
				TOC(lb/yr)	TN(lb/yr)	TP(lb/yr)			
				106,266,655	3,564,579	263,927			
Nonpoint Sources (LA)	TOC(lb/yr)	TN(lb/yr)	TP(lb/yr)	TOC(lb/yr)	TN(lb/yr)	TP(lb/yr)	TOC(lb/yr)	TN(lb/yr)	TP(lb/yr)
Contributing Subwatersheds	**Existing Loads**			**Allocation Loads (LA)**			**% Reduction**		
030702040101	6,966,479	134,096	12,123	4,846,163	93,282	8,433	30.44	30.44	30.44
030702040102(a)	2,347,388	81,048	5,065	2,347,388	81,048	5,065	0.00	0.00	0.00
030702040102(b)	2,816,167	76,826	5,533	2,393,668	65,300	4,703	15.00	15.00	15.00
030702040102(c)	3,950,284	141,420	7,725	2,988,114	106,975	5,843	24.36	24.36	24.36
030702040102(d)	13,392,976	313,068	25,520	9,112,500	213,010	17,364	31.96	31.96	31.96
030702040102(e)	6,346,146	226,332	15,394	6,346,146	226,332	15,394	0.00	0.00	0.00
030702040102(f)	12,640,964	564,792	36,148	12,640,964	564,792	36,148	0.00	0.00	0.00
030702040201	13,207,669	511,296	31,911	13,207,669	511,296	31,911	0.00	0.00	0.00
030702040202(a)	4,502,005	187,464	10,825	4,502,005	187,464	10,825	0.00	0.00	0.00
030702040202(b)	2,283,779	57,095	3,482	2,283,779	57,095	3,482	0.00	0.00	0.00
030702040203	5,987,095	200,762	11,923	5,987,095	200,762	11,923	0.00	0.00	0.00
030702040301	3,083,158	120,172	6,765	3,083,158	120,172	6,765	0.00	0.00	0.00
030702040302(a)	201,719	6,664	344	201,719	6,664	344	0.00	0.00	0.00
030702040302(b)	3,666,509	68,381	6,049	3,666,509	68,381	6,049	0.00	0.00	0.00
030702040302(c)	6,422,758	100,667	10,485	6,422,758	100,667	10,485	0.00	0.00	0.00
030702040303	4,505,388	221,127	11,344	3,862,387	189,568	9,725	14.27	14.27	14.27
030702040304(a)	1,742,113	84,300	4,407	1,539,571	74,499	3,895	11.63	11.63	11.63
030702040304(b)	1,369,849	71,810	3,373	1,203,370	63,083	2,963	12.15	12.15	12.15
030702040401(a)	6,265,388	173,607	12,447	6,265,388	173,607	12,447	0.00	0.00	0.00
030702040401(b)	1,396,244	23,834	1,648	1,298,778	22,170	1,533	6.98	6.98	6.98
030702040401(c)	4,058,163	98,959	6,479	4,058,163	98,959	6,479	0.00	0.00	0.00
030702040401(d)	1,355,898	37,206	1,930	1,281,612	35,168	1,824	5.48	5.48	5.48
030702040401(e)	2,199,805	106,954	6,010	2,199,805	106,954	6,010	0.00	0.00	0.00
030702040402(b)	3,709,693	163,237	10,225	3,709,693	163,237	10,225	0.00	0.00	0.00
Total	114,417,636	3,771,117	247,153	105,448,401	3,530,485	229,833	7.84	6.38	7.01
Point Sources (WLA)	**Existing Loads**			**Allocation Loads (WLA)**			**% Reduction**		
Kingsland WPCP (GA0021547)	818,254	34,094	34,094	818,254	34,094	34,094	0.0	0.0	0.0
Total	818,254	34,094	34,094	818,254	34,094	34,094	0	0	0

Table D-7

Spanish Creek - Segment #7				TMDL = WLA + LA					
				TOC(lb/yr)	TN(lb/yr)	TP(lb/yr)			
				7,050,984	338,413	25,868			
Nonpoint Sources (LA)	TOC(lb/yr)	TN(lb/yr)	TP(lb/yr)	TOC(lb/yr)	TN(lb/yr)	TP(lb/yr)	TOC(lb/yr)	TN(lb/yr)	TP(lb/yr)
Contributing Subwatersheds	**Existing Loads**			**Allocation Loads (LA)**			**% Reduction**		
030702040303	4,505,388	221,127	11,344	3,862,387	189,568	9,725	14.27	14.27	14.27
030702040304(a)	1,742,113	84,300	4,407	1,539,571	74,499	3,895	11.63	11.63	11.63
030702040304(b)	1,369,849	71,810	3,373	1,203,370	63,083	2,963	12.15	12.15	12.15
Total	7,617,350	377,236	19,125	6,605,327	327,150	16,583	13	13	13
Point Sources (WLA)	**Existing Loads**			**Allocation Loads (WLA)**			**% Reduction**		
Folkston Pond (GA0027189)	350,680	7,306	7,306	350,680	7,306	7,306	0.0	0.0	0.0
Folkston WPCP (GA0037613)	94,976	3,957	1,979	94,976	3,957	1,979	0.0	0.0	0.0
Total	445,656	11,263	9,285	445,656	11,263	9,285	0	0	0