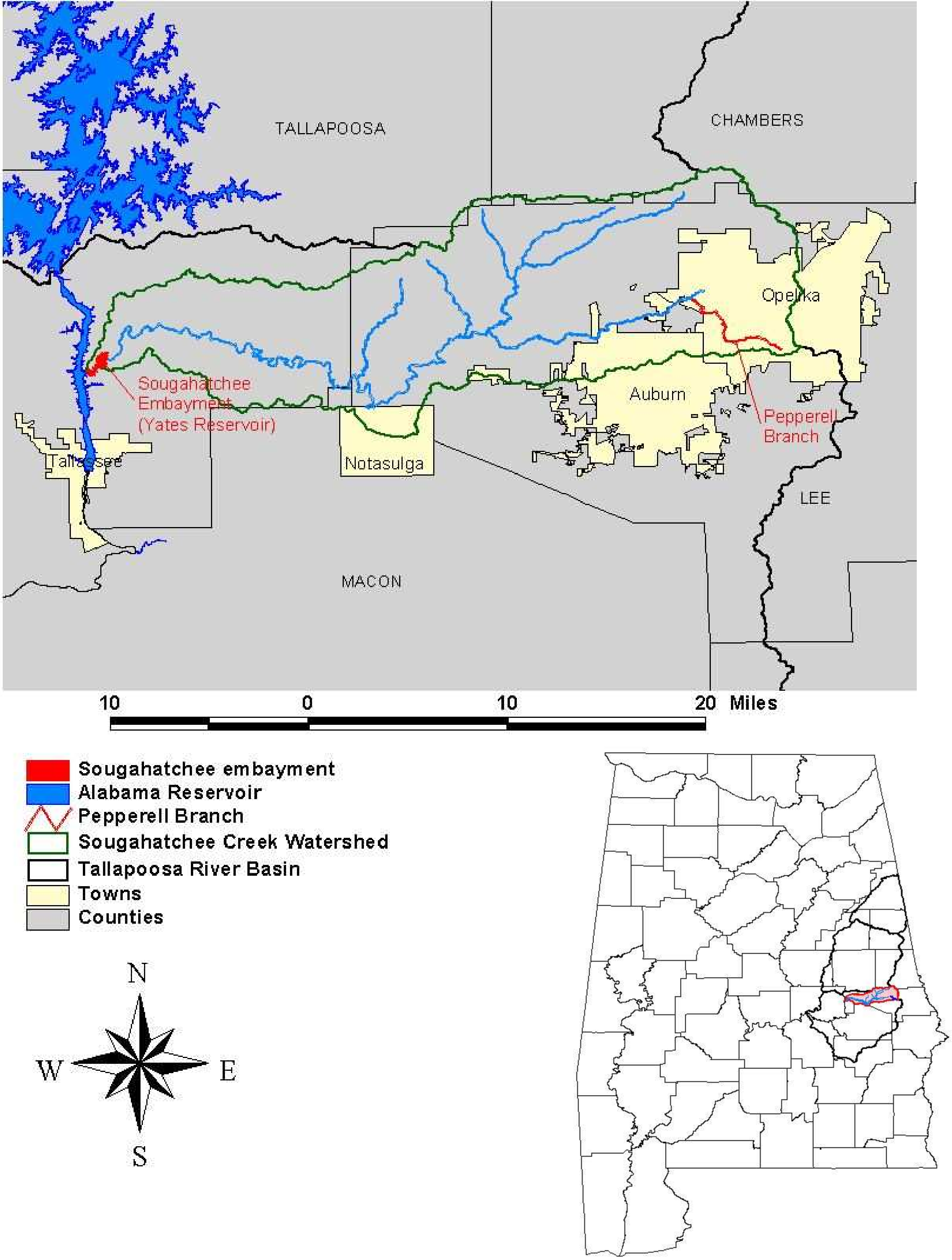
Final
Total Maximum Daily Load
Nutrients & OE/DO

Pepperell Branch
AL03150110-0201-700
Nutrients

Sougahatchee Creek Embayment
(Yates Reservoir)
AL03150110-0204-101
Nutrients & OE/DO

Alabama Department of Environmental Management
Water Quality Branch
Water Division
April 2008

Sougahatchee Creek Watershed in the Tallapoosa River Basin



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1.0 Executive Summary

The Alabama Department of Environmental Management (ADEM) has identified two segments within the Sougahatchee Creek watershed of the Lower Tallapoosa River basin as being impaired for nutrients and organic enrichment/dissolved oxygen and requires development of a TMDL to address these water quality impairments. Sougahatchee Creek embayment, a tributary to Yates Reservoir, is currently on the State of Alabama's §303(d) list of impaired waters for nutrients and organic enrichment/dissolved oxygen (OE/DO). Pepperell Branch, a tributary to Sougahatchee Creek, is currently on the State of Alabama's §303(d) list of impaired waters for nutrients. Shown in Table 1-1, below, are the causes and sources of impairment for each of the §303(d) listed segments within the Sougahatchee Creek watershed.

Table 1-1 §303(d) Listed Segments of the Sougahatchee Creek Watershed within the Lower Tallapoosa River Basin

Waterbody ID	Waterbody Name	County	Uses	Causes	Sources	Size	Support Status
AL0315011-0204-101	Sougahatchee Creek Embayment	Tallapoosa	Public Water Supply (PWS), Swimming (S), Fish and Wildlife (F&W)	Nutrients and Organic Enrichment/ Dissolved Oxygen (OE/DO)	Industrial, Municipal, Nonirrigated crop production, and Pasture Grazing	203.78 acres	Non
AL0315011-0201-700	Pepperell Branch	Lee	Fish and Wildlife (F&W)	Nutrients	Industrial	6.67 miles	Non

The Department's approach to the development of the TMDL for these two impaired segments is to develop a TMDL for the entire Sougahatchee Creek watershed. Pepperell Branch does not appear to have nutrient impairments itself due to its hydrology; a continuously flowing stream with large elevation changes and few pools. The 2004 bioassessment study performed on Pepperell Branch by ADEM supports this assumption. The data provided by the bioassessment study can be found in Appendix A. However, because of the significant point source of phosphorus on Pepperell Branch, this stream segment appears to be a contributing factor to the nutrient impairment within the Sougahatchee Creek embayment. By addressing the nutrient impairment in the Sougahatchee Creek embayment with a watershed TMDL, nutrient loading from Pepperell Branch will be reduced and should no longer be a significant source of nutrients in the Sougahatchee Creek embayment.

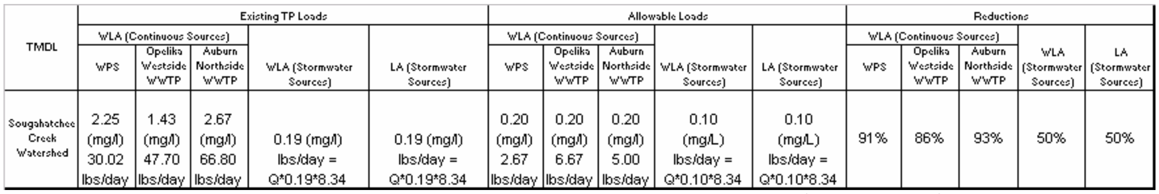
The pollutants of concern listed for the impaired segments are OE/DO and nutrients. OE includes the sources of carbonaceous biochemical oxygen demand (CBOD) that consume dissolved oxygen. Nutrients are of concern due to their ability to promote algal growth, which in turn affects the dissolved oxygen balance through photosynthesis, respiration, and the regeneration of organic materials.

According to ADEM's Nutrient Criteria Implementation Plan (September 2007), chlorophyll *a* (algal growth indicator) has been chosen as the primary variable for addressing cultural eutrophication and will be used as the primary tool for protecting designated uses of lakes and reservoirs from nutrient over-enrichment. Chlorophyll *a* was chosen as the candidate variable because of its wide acceptance among federal/state agencies, limnologists and scientists as being a good surrogate for estimating phytoplankton biomass. Chlorophyll *a* is also considered a good early indicator of nutrient enrichment and is relatively easy and inexpensive to collect and analyze. The Sougahatchee Creek watershed nutrient target, expressed as a growing season average chlorophyll *a* concentration of 12 µg/L in the Sougahatchee Creek embayment, specifically at Station Yates 2. The target was developed using a "reference condition" approach for determining the appropriate levels of nutrients necessary to support the designated uses of waters within the Sougahatchee Creek watershed.

To address the diverse conditions and listed pollutants within the Sougahatchee Creek watershed, a system of models was developed that provided simulation of the overland flow, instream hydrodynamics, and instream water quality. The system design was such that flow and water quality conditions experienced within the Sougahatchee Creek watershed during the 2000 and 2002 growing season could be simulated using one set of tools. These time periods were chosen because they include a period of critical conditions, and a period during which monthly data is available for Sougahatchee Creek embayment including chlorophyll *a*, nutrients, and water column profile data for dissolved oxygen and temperature.

The TMDL results necessary to meet water quality standards for the Sougahatchee Creek Watershed are presented below in Table 1-2 and in Table 1-3. West Point Stevens has an active NPDES permit for a process water discharge to Pepperell Branch; however, as of July 2007 the facility has currently halted production. Table 1-3 presents an alternate TMDL scenario which excludes the West Point Stevens WLA should the NPDES permit be withdrawn and the discharge be permanently removed. Considering the TP reductions included in the TMDL and the corresponding reduction in algal biomass production, the existing $CBOD_5$ loading is expected to achieve natural DO conditions within the Sougahatchee Creek embayment. The existing $CBOD_5$ loads, expressed as a TMDL, are shown in Table 1-4.

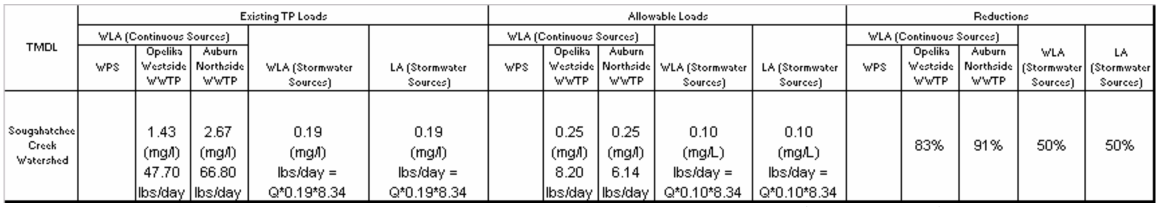
Table 1-2 Growing Season (April-October) Total Phosphorus TMDL Results for the Sougahatchee Creek Watershed



TMDL	Existing TP Loads					Allowable Loads					Reductions				
	WLA (Continuous Sources)			WLA (Stormwater Sources)	LA (Stormwater Sources)	WLA (Continuous Sources)			WLA (Stormwater Sources)	LA (Stormwater Sources)	WLA (Continuous Sources)			WLA (Stormwater Sources)	LA (Stormwater Sources)
	WPS	Opelika Westside WWTP	Auburn Northside WWTP			WPS	Opelika Westside WWTP	Auburn Northside WWTP			WPS	Opelika Westside WWTP	Auburn Northside WWTP		
Sougahatchee Creek Watershed	2.25 (mg/l) 30.02 lbs/day	1.43 (mg/l) 47.70 lbs/day	2.67 (mg/l) 66.80 lbs/day	0.19 (mg/l) lbs/day = Q*0.19*8.34	0.19 (mg/l) lbs/day = Q*0.19*8.34	0.20 (mg/l) 2.67 lbs/day	0.20 (mg/l) 6.67 lbs/day	0.20 (mg/l) 5.00 lbs/day	0.10 (mg/L) lbs/day = Q*0.10*8.34	0.10 (mg/L) lbs/day = Q*0.10*8.34	91%	86%	93%	50%	50%

*Existing TP concentrations were determined using Point Source DMR data (April-October) for the period of 2000 and 2002
*Point source TP mass loadings were calculated utilizing TP concentrations times design flows times 8.34
*Q is equal to flow in MGD

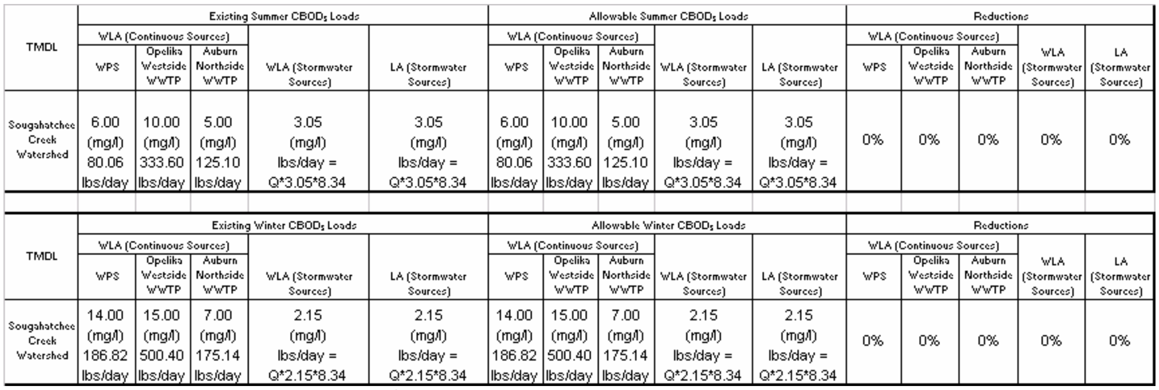
Table 1-3 Growing Season (April-October) Total Phosphorus TMDL Results for the Sougahatchee Creek Watershed with the West Point Stevens Discharge Removed from Pepperell Branch



TMDL	Existing TP Loads					Allowable Loads					Reductions				
	WLA (Continuous Sources)			WLA (Stormwater Sources)	LA (Stormwater Sources)	WLA (Continuous Sources)			WLA (Stormwater Sources)	LA (Stormwater Sources)	WLA (Continuous Sources)			WLA (Stormwater Sources)	LA (Stormwater Sources)
	WPS	Opelika Westside WWTP	Auburn Northside WWTP			WPS	Opelika Westside WWTP	Auburn Northside WWTP			WPS	Opelika Westside WWTP	Auburn Northside WWTP		
Sougahatchee Creek Watershed		1.43 (mg/l) 47.70 lbs/day	2.67 (mg/l) 66.80 lbs/day	0.19 (mg/l) lbs/day = Q*0.19*8.34	0.19 (mg/l) lbs/day = Q*0.19*8.34		0.25 (mg/l) 8.20 lbs/day	0.25 (mg/l) 6.14 lbs/day	0.10 (mg/L) lbs/day = Q*0.10*8.34	0.10 (mg/L) lbs/day = Q*0.10*8.34		83%	91%	50%	50%

*Existing TP concentrations were determined using Point Source DMR data (April-October) for the period of 2000 and 2002
*Existing point source TP mass loadings were calculated utilizing TP concentrations times design flows times 8.34
*Q is equal to flow in MGD
*Allowable point source TP mass loadings calculated by distributing allowable WPS TP mass loading in Table 1-2 proportional to facility design capacities (ex. Auburn lb/day = 5 lbs/day + 2.67 lbs/day * 3 MGD / 7MGD = 6.14 lbs/day)
*Note: Auburn Northside WWTP Design Capacity = 3 MGD; Opelika Westside WWTP Design Capacity = 4 MGD

Table 1-4 CBOD$_5$ TMDL Results for the Sougahatchee Creek Watershed



TMDL	Existing Summer CBOD$_5$ Loads					Allowable Summer CBOD$_5$ Loads					Reductions				
	WLA (Continuous Sources)			WLA (Stormwater Sources)	LA (Stormwater Sources)	WLA (Continuous Sources)			WLA (Stormwater Sources)	LA (Stormwater Sources)	WLA (Continuous Sources)			WLA (Stormwater Sources)	LA (Stormwater Sources)
	WPS	Opelika Westside WWTP	Auburn Northside WWTP			WPS	Opelika Westside WWTP	Auburn Northside WWTP			WPS	Opelika Westside WWTP	Auburn Northside WWTP		
Sougahatchee Creek Watershed	6.00 (mg/l) 80.06 lbs/day	10.00 (mg/l) 333.60 lbs/day	5.00 (mg/l) 125.10 lbs/day	3.05 (mg/l) lbs/day = Q*3.05*8.34	3.05 (mg/l) lbs/day = Q*3.05*8.34	6.00 (mg/l) 80.06 lbs/day	10.00 (mg/l) 333.60 lbs/day	5.00 (mg/l) 125.10 lbs/day	3.05 (mg/l) lbs/day = Q*3.05*8.34	3.05 (mg/l) lbs/day = Q*3.05*8.34	0%	0%	0%	0%	0%

TMDL	Existing Winter CBOD$_5$ Loads					Allowable Winter CBOD$_5$ Loads					Reductions				
	WLA (Continuous Sources)			WLA (Stormwater Sources)	LA (Stormwater Sources)	WLA (Continuous Sources)			WLA (Stormwater Sources)	LA (Stormwater Sources)	WLA (Continuous Sources)			WLA (Stormwater Sources)	LA (Stormwater Sources)
	WPS	Opelika Westside WWTP	Auburn Northside WWTP			WPS	Opelika Westside WWTP	Auburn Northside WWTP			WPS	Opelika Westside WWTP	Auburn Northside WWTP		
Sougahatchee Creek Watershed	14.00 (mg/l) 186.82 lbs/day	15.00 (mg/l) 500.40 lbs/day	7.00 (mg/l) 175.14 lbs/day	2.15 (mg/l) lbs/day = Q*2.15*8.34	2.15 (mg/l) lbs/day = Q*2.15*8.34	14.00 (mg/l) 186.82 lbs/day	15.00 (mg/l) 500.40 lbs/day	7.00 (mg/l) 175.14 lbs/day	2.15 (mg/l) lbs/day = Q*2.15*8.34	2.15 (mg/l) lbs/day = Q*2.15*8.34	0%	0%	0%	0%	0%

*Existing CBOD$_5$ concentrations were taken from NPDES Permits
*Point source CBOD$_5$ mass loadings were calculated utilizing CBOD$_5$ concentrations times design flows times 8.34
*Q is equal to flow in MGD
*The estimated CBOD$_5$ allocations for stormwater (WLA and LA Stormwater Sources) represent the maximum allowable stormwater loads at Lovelady Bridge including point source contributions. The CBOD$_5$ TMDL allocations for stormwater sources should be dictated by the 0% reduction.

2.0 Basis for §303(d) Listing

2.1 Introduction

Section 303(d) of the Clean Water Act (CWA), as amended by the Water Quality Act of 1987, and EPA's Water Quality Planning and Management Regulations [(Title 40 of the Code of Federal Regulations (CFR), Part 130)] require states to identify waterbodies which are not meeting water quality standards applicable to their designated uses and to determine the total maximum daily load (TMDL) for pollutants causing use impairment. The TMDL process establishes the allowable loading of pollutants for a waterbody based on the relationship between pollution sources and in-stream water quality conditions, so that states can establish water-quality based controls to reduce pollution from both point and non-point sources and restore and maintain the quality of their water resources (USEPA, 1991).

Pepperell Branch was originally placed on the State of Alabama's 1992 and 1994 §303(d) lists for unknown toxicity, OE/DO, and thermal modification. In 1996, nutrients were added to the listing for Pepperell Branch. In 1998, EPA approved TMDLs for OE/DO and delistings for unknown toxicity and thermal modification. Pepperell Branch has remained on the State of Alabama's 1998, 2000, 2002, 2004, 2006 and 2008 §303(d) lists for nutrients. Pepperell Branch had a use classification of Agricultural and Industrial Water Supply (A&I); however, in April 2002, ADEM upgraded its use classification to Fish and Wildlife (F&W). West Point Stevens, a textile manufacturing facility, is permitted to discharge treated process wastewater to Pepperell Branch approximately 3.8 miles upstream of its confluence with Sougahatchee Creek.

Sougahatchee Creek embayment was placed on the State of Alabama's 1996, 1998, 2000, 2002, 2004, 2006 and 2008 §303(d) lists for OE/DO and nutrients. Sougahatchee Creek embayment has a use classification of Public Water Supply (PWS), Swimming (S), and Fish and Wildlife (F&W). From the embayment to Sougahatchee Lake, a water supply for the City of Opelika, Sougahatchee Creek is classified as F&W. From Sougahatchee Lake to its source, Sougahatchee Creek is classified as Public Water Supply (PWS) and F&W. The City of Opelika discharges treated wastewater to Sougahatchee Creek near its confluence with Pepperell Branch at stream mile 8.4 and the City of Auburn discharges treated wastewater to Sougahatchee Creek at stream mile 16.0.

2.2 Problem Definition

Waterbody Impaired:	Pepperell Branch; Sougahatchee Creek to Its Source
Waterbody Length:	6.67 miles
Waterbody Drainage Area:	14.5 mi^2
Water Quality Standard Violation:	Nutrients
Pollutant of Concern:	Total Phosphorus
Water Use Classification:	Fish and Wildlife (F&W)

Waterbody Impaired:	Sougahatchee Creek embayment; Tallapoosa River to End of Embayment
Waterbody Size:	203.78 acres
Waterbody Drainage Area:	216 mi^2
Water Quality Standard Violation:	Nutrients, Dissolved Oxygen
Pollutant of Concern:	Total Phosphorus, Organic Enrichment
Water Use Classification:	Fish and Wildlife (F&W) Swimming (S) Public Water Supply (PWS)

Usage of waters in the Fish and Wildlife category is described as follows in ADEM Admin. Code R. 335-6-10-.09(5) (a), (b), (c), and (d).

> (a) Best usage of waters: Fishing, propagation of fish, aquatic life, and wildlife, and any other usage except for swimming and water-contact sports or as a source of water supply for drinking or food processing purposes.
>
> (b) Conditions related to best usage: The waters will be suitable for fish, aquatic life and wildlife propagation. The quality of salt and estuarine waters to which this classification is assigned will also be suitable for the propagation of shrimp and crabs.

(c) Other usage of waters: It is recognized that the waters may be used for incidental water contact and recreation during June through September, except that water contact is strongly discouraged in the vicinity of discharges or other conditions beyond the control of the Department or the Alabama Department of Public Health.

(d) Conditions related to other usage: The waters, under proper sanitary supervision by the controlling health authorities, will meet accepted standards of water quality for outdoor swimming places and will be considered satisfactory for swimming and other whole body water-contact sports.

Usage of waters in the Swimming category is described as follows in ADEM Admin. Code R. 335-6-10-.09(3) (a) and (b).

(a) Best usage of waters: swimming and other whole body water-contact sports*

*NOTE: In assigning this classification to waters intended for swimming and water-contact sports, the Commission will take into consideration the relative proximity of discharges of wastes and will recognize the potential hazards involved in locating swimming areas close to waste discharges. The Commission will not assign this classification to waters, the bacterial quality of which is dependent upon adequate disinfection of waste and where the interruption of such treatment would render the water unsafe for bathing.

(b) Conditions related to best usage: the waters, under proper sanitary supervision by the controlling health authorities, will meet accepted standards of water quality for outdoor swimming places and will be considered satisfactory for swimming and other whole body water-contact sports. The quality of waters will also be suitable for the propagation of fish, wildlife, and aquatic life. The quality of salt waters and estuarine waters to which this classification is assigned will be suitable for the propagation and harvesting of shrimp and crab.

Usage of waters in the Public Water Supply category is described in ADEM Admin. Code R. 335-6-10-.09(2) (a), (b), (c), and (d).

(a) Best usage of waters: source of water supply for drinking or food-processing purposes.*

*NOTE: In determining the safety or suitability of waters for use as sources of water supply for drinking or food-processing purposes after approved treatment, the Commission will be guided by the physical and chemical standards specified by the Department.

(b) Conditions related to best usage: the waters, if subjected to treatment approved by the Department equal to coagulation, sedimentation, filtration and disinfection, with additional treatment if necessary to remove naturally present impurities, and which meet the requirements of the Department, will be considered safe for drinking or food-processing purposes.

(c) Other usage of waters: it is recognized that the waters may be used for incidental water contact and recreation during June through September, except that water contact is strongly discouraged in the vicinity of discharges or other conditions beyond the control of the Department or the Alabama Department of Public Health.

(d) Conditions related to other usage: the waters, under proper sanitary supervision by the controlling health authorities, will meet accepted standards of water quality for outdoor swimming places and will be considered satisfactory for swimming and other whole body water-contact sports.

2.3 Water Quality Criteria

2.3.1. Dissolved Oxygen

Alabama’s water quality criteria for the Swimming, Public Water Supply, and Fish and Wildlife use classifications (ADEM Admin. Code R. 335-6-10-.09-(3)(c)(4) and ADEM Admin. Code R. 335-6-10-.09-(5)(e)(4)) state that for a diversified warm water biota, including game fish, daily dissolved oxygen concentrations, shall not be less than 5.0 mg/l at all times; except under extreme conditions due to natural causes, it may range between 5.0 mg/l and 4.0 mg/l, provided that the water quality is favorable in all other parameters. The application of dissolved oxygen criteria referred to above, shall be measured at a depth of 5 feet in waters 10 feet or greater in depth; and for those waters less than 10 feet in depth, dissolved oxygen criteria will be applied at mid-depth. Furthermore, Alabama’s water quality standards recognize that “[n]atural waters may, on occasion, have characteristics outside the limits established by these criteria. The criteria…relate to the condition of waters as affected by the discharge of sewage, industrial wastes or other wastes, not to conditions resulting from natural forces.” (ADEM Admin. Code R. 335-6-10-.05(4)).

2.3.2 Nutrients

ADEM’s decision to list Pepperell Branch and Sougahatchee Creek embayment as being impaired for nutrients was authorized under ADEM’s Water Quality Standards Program, which employs both numeric and narrative criteria to ensure adequate protection of designated uses for surface waters of the State. Numeric criteria typically have quantifiable endpoints for a given parameter, such as pH, dissolved oxygen, or a toxic pollutant, whereas narrative criteria are qualitative statements that establish a set of desired conditions for all State waters. These narrative criteria are more commonly referred to as “free from” criteria and provide States with a regulatory avenue to address pollutants or problems that may be causing or contributing to a use impairment that otherwise cannot be evaluated against any numeric criteria. Typical pollutants that fall under this category are nutrients and sediment. Historically, in the absence of established numeric nutrient criteria, ADEM and/or EPA would use available data and information coupled with best professional judgment to determine overall use support for a given waterbody. Narrative criteria continue to serve as a basis for determining use attainability and subsequently listing/delisting of waters from Alabama's 303(d) List. ADEM's Narrative Criteria, as shown in ADEM's Administrative Code 335-6-10-.06, are as follows:

335-6-10-.06 **Minimum Conditions Applicable to All State Waters**. *The following minimum conditions are applicable to all State waters, at all places and at all times, regardless of their uses:*

(a) State waters shall be free from substances attributable to sewage, industrial wastes or other wastes that will settle to form bottom deposits which are unsightly, putrescent or interfere directly or indirectly with any classified water use.

(b) State waters shall be free from floating debris, oil, scum, and other floating materials attributable to sewage, industrial wastes or other wastes in amounts sufficient to be unsightly, or which interfere directly or indirectly with any classified water use.

(c) State waters shall be free from substances attributable to sewage, industrial wastes or other wastes in concentrations or combination, which are toxic or harmful to human, animal, or aquatic life to the extent commensurate with the designated usage of such waters.

3.0 Technical Basis for TMDL Development

3.1 Applicable Water Quality Criteria

3.1.1. Organic Enrichment/Dissolved Oxygen (OE/DO)

ADEM identified organic enrichment and nutrient loads as the potential causes of low dissolved oxygen observed in Sougahatchee Creek embayment. Nitrogen and phosphorus, in the presence of ample sunlight, support the growth of algae in an embayment. Over time, the growth and decay of algae contribute organic material to the system. As this material decomposes, oxygen is consumed and nutrients stored in the biomass are released and used to support additional algal growth. In an unimpaired system, this cycle is fairly stable and oxygen levels remain high enough to support other life forms in the waterbody. Excessive nutrient loads that lead to algal blooms, however, disturb the equilibrium, and can cause oxygen concentrations to drop below 5.0 mg/l. As a general rule, oxygen concentrations below this level are stressful to aquatic organisms (Thomann and Mueller, 1987). However, dissolved oxygen levels in some waterbodies may occasionally fall below 5.0 mg/l due to natural conditions; in such cases, TMDLs target the natural conditions as the water quality endpoint.

3.1.2. Nutrients

ADEM continues its efforts to develop comprehensive numeric nutrient criteria for all surface waters throughout Alabama, including rivers/streams, lakes/reservoirs, wetlands, and coastal/estuarine waters. However, until numeric nutrient criteria or some form of quantitative interpretations of ADEM's narrative criteria are developed, the Department will continue to use all available data and information coupled with best professional judgment to make informed decisions regarding overall use support and to establish targets for TMDLs.

Typically, development of a water quality criterion for a given pollutant involves extensive research using information from many areas of aquatic toxicology. For example, development of numeric criteria for toxic pollutants, such as mercury, involves numerous toxicological studies such as dose/response relationships, bioaccumulation studies, fate and transport studies, and an understanding of both the acute and chronic effects to aquatic life. As part of the toxicological evaluations, EPA performs uncertainty analysis to help guide selection of the recommended water quality criterion for a given pollutant. For toxic pollutants, the more uncertainty revealed during the evaluation, the more conservative (i.e. the lower the value) the recommended criterion becomes.

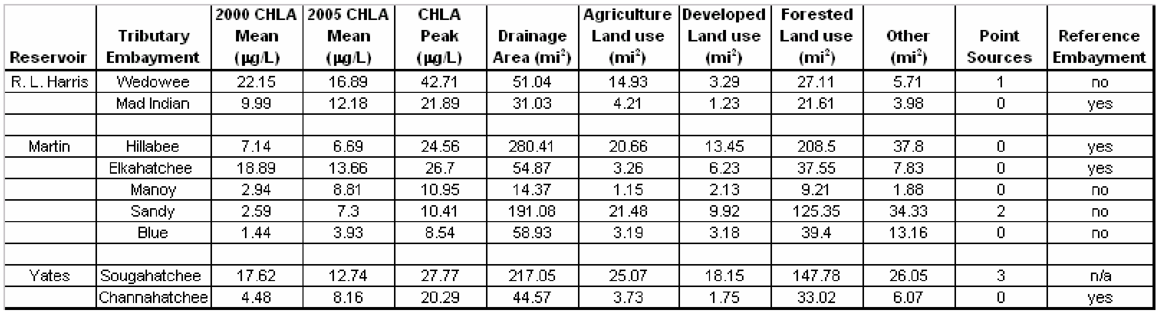
Nutrients such as phosphorus and nitrogen are essential elements to aquatic life, but can be undesirable when present at sufficient concentrations to stimulate excessive plant growth. Even though these pollutants are generally considered nontoxic (the exception being un-ionized ammonia toxicity to aquatic life), they can impact aquatic life due to their indirect effects on water quality, either when in overabundance or when availability is limited.

ADEM's water quality criteria applying to nutrients are narrative, therefore a numerical translator is needed to define the TMDL target. Based on the historical data collected within the Sougahatchee Creek Watershed, there is evidence that designated uses are impaired by nutrient over-enrichment, but some uncertainty remains in the exact quantification of the nutrient target due to the complexity of the relationship of cause and effect and the state of the science. This is a very common dilemma in nutrient water quality management, and often warrants an alternate approach. EPA recommends, in the absence of sufficient "effects-based" information, a reference condition approach for determining protective nutrient criteria. With this approach, a numerical value can be empirically developed that can be assumed to inherently protect uses supported in the reference waters. This approach can provide an initial target while continuing studies will allow further evaluation of the cause and effect relationships that might result in refinement of the initial target.

In developing a nutrient target for the Sougahatchee Creek Watershed Nutrient TMDL, a “reference condition” approach for determining the appropriate levels of nutrients necessary to support designated uses was utilized. This approach is based on using ambient water quality data from candidate reference tributary embayments that are located in characteristically similar regions of Alabama known as ecoregions. An ecoregion is defined as a similar and comparable relatively homogeneous area defined by similar climate, landform, soil, potential natural vegetation, hydrology and other ecologically relevant variables (USEPA, 2000). “Reference embayments” are defined as waterbodies that have been relatively undisturbed or minimally-impacted that can serve as examples of the natural biological integrity of a particular ecoregion. These “reference embayments” can be monitored over time to establish a baseline to which other waters can be compared. Reference embayments are not necessarily pristine or undisturbed by humans, however they do represent waters within Alabama that are healthy and fully support their designated uses, to include protection of aquatic life. The “reference condition” approach used to determine appropriate nutrient targets for the Sougahatchee Creek TMDL is reasonable, scientifically defensible, protective of designated uses, and consistent with USEPA guidance.

An evaluation of several watershed characteristics was performed to gain an understanding of the current condition of the Sougahatchee Creek watershed, as well as, the several selected reference tributary embayments. Table 3-1, below, provides the summary statistics of the tributary embayments that were considered in developing the nutrient target for the Sougahatchee Creek Watershed Nutrient TMDL. Maps of the embayments listed in Table 3-1 may be found in Appendix C.

Table 3-1 Summary Statistics for the Sougahatchee Creek Watershed and Selected Reference Tributary Embayments within the Tallapoosa River Basin



Reservoir	Tributary Embayment	2000 CHLA Mean (µg/L)	2005 CHLA Mean (µg/L)	CHLA Peak (µg/L)	Drainage Area (mi^2)	Agriculture Land use (mi^2)	Developed Land use (mi^2)	Forested Land use (mi^2)	Other (mi^2)	Point Sources	Reference Embayment
R. L. Harris	Wedowee	22.15	16.89	42.71	51.04	14.93	3.29	27.11	5.71	1	no
	Mad Indian	9.99	12.18	21.89	31.03	4.21	1.23	21.61	3.98	0	yes
Martin	Hillabee	7.14	6.69	24.56	280.41	20.66	13.45	208.5	37.8	0	yes
	Elkahatchee	18.89	13.66	26.7	54.87	3.26	6.23	37.55	7.83	0	yes
	Manoy	2.94	8.81	10.95	14.37	1.15	2.13	9.21	1.88	0	no
	Sandy	2.59	7.3	10.41	191.08	21.48	9.92	125.35	34.33	2	no
	Blue	1.44	3.93	8.54	58.93	3.19	3.18	39.4	13.16	0	no
Yates	Sougahatchee	17.62	12.74	27.77	217.05	25.07	18.15	147.78	26.05	3	n/a
	Channahatchee	4.48	8.16	20.29	44.57	3.73	1.75	33.02	6.07	0	yes

Phosphorus has commonly been considered the primary limiting nutrient governing algal growth in most freshwater stream systems in North America, particularly in freshwater lakes, in contrast with nitrogen-limited estuarine ecosystems (e.g., Correll, 1998). Case studies cited in EPA guidance demonstrated that control of nutrient concentrations can limit the growth of filamentous algae (USEPA, 2000; Sosiak, 2002). Recent evidence suggests that nutrient limitation by nitrogen or phosphorus may be seasonal and that nitrogen limitation has been observed in some streams (Dodds et al., 2000). An appropriate initial strategy to controlling algal growth in the Sougahatchee Creek watershed is to effectively control phosphorus loadings in the system. A model simulation with a 30% reduction of TN, in addition to the reduced TP loading, yielded an insignificant change in the chlorophyll *a* value of Sougahatchee Creek embayment as shown in Figure 5-1, and ADEM also has no current evidence that nitrogen exported from the system contributes to any known nutrient enrichment problems downstream. Therefore, controlling nitrogen in the system should be unnecessary because phosphorus will be managed to prevent nitrogen from becoming the limiting nutrient.

Based on the aforementioned, a nutrient target, expressed as a growing season average chlorophyll *a* concentration of 12 µg/L in the Sougahatchee Creek embayment at Station Yates 2, was established. A detailed explanation of the determination of the nutrient target is included in Appendix C.

3.2 Source Assessment

3.2.1. General Sources of Organic Enrichment/Dissolved Oxygen and Nutrients

Both point and non-point sources may contribute organic enrichment to a given waterbody. Dissolved oxygen depletion likewise occurs as the result of oxygen consumption from organisms which consume organic material found either on or within stream sediments, referred to as Sediment Oxygen Demand (SOD). This SOD component is ultimately derived from discharges and runoff in combination with additional organic material produced by phytoplankton within the waterbody. Potential sources of organic loading are numerous and often occur in combination. In rural areas, storm runoff from row crops, livestock pastures, animal waste application sites, and feedlots can transport significant loads of organic pollutants. Poorly or inadequately treated municipal sewage comprises a major source of organic compounds that, when hydrolyzed, create additional organic loading. Urban storm water runoff, sanitary sewer overflows, and combined sewer overflows may similarly result in considerable significant sources of organic loading.

Non-point source pollution to surface waters occurs as the result of natural erosion and weathering of soils, rocks, and uncultivated land; as the result of erosion from large agriculturally cultivated land areas and pasture lands with unconfined grazing livestock which lessen or reduce normal vegetative ground cover and promote stream bank damage when allowed direct access to streams; as the result of urban erosion from cleared or barren construction sites and wash-off of accumulated dust and litter from impervious street and roadway surfaces; and as the result of erosion from unpaved or dirt roadways.

Potential sources of organic loading in the watershed were identified based on an evaluation of current land use/cover information on watershed activities (e.g., agricultural management activities). The source assessment was used as the basis of development of the model and ultimate analysis of the TMDL allocations. The organic loading within the watershed included both point and non-point sources.

3.2.2. NPDES Construction Activities and Municipal Separate Storm Sewer Systems

Certain construction activities (those disturbing areas of 1 acre or more) and Municipal Separate Storm Sewer Systems (MS4s) permits required for populated metropolitan areas with populations greater than 100,000 people (Phase I) or less than 100,000 (Phase II) are currently regulated by the State's NPDES program.

Pollutant loadings from MS4s enter surface waters in response to storm events. MS4s discharge to waterbodies during storm events by way of road drainage systems, curb and gutter systems, ditches, and storm drains. Such systems convey urban runoff from barren surfaces as well as wash-off of accumulated street dust and litter from impervious roadway surfaces during rain events. The purpose of the NPDES permits is to either eliminate or minimize the extent of pollutant discharges. Wasteload allocations applied to regulate construction activities and MS4s will be addressed through NPDES permits in the form of Best Management Practices (BMPs).

3.2.3. Non-point Sources

Shown in Table 3-2, below, is a summary of the land usage in the Sougahatchee Creek watershed. The land use map of the watershed is presented in Figure 3-1. The predominant land uses within the watershed are forest (includes shrub/grassland), agriculture (cropland + pasture), and urban. Their respective percentages of the total watershed are 76.8%, 11.7%, and 8.4%, respectively (NLCD, 2001).

Table 3-2 Land use in the Sougahatchee Creek Watershed

LAND USE	PERCENTAGE (%)	ACRES
Forest	76.8	106,620
Wetlands	1.5	2,098
Urban	8.4	11,670
Agriculture	11.7	16,172
Open Water	0.9	1301
Other	0.7	914
TOTAL	**100%**	**138,775**

Each land use has the potential to contribute to the organic loading in the watershed due to organic material on the land surface that can be washed off into the receiving waters of the watershed. Information on agricultural and management activities and watershed characteristics were obtained through coordination with the ADEM Mining and Non-point Source Section in the Field Operations Division, the Alabama Cooperative Extension System, and the USDA-Natural Resources Conservation Service (NRCS).

The major sources of organic enrichment from non-point sources within the Sougahatchee Creek watershed are nutrients and organic material from agricultural and urban lands. Other non-point source contributions could be failing septic tanks. Compared to other land uses, organic enrichment from forested land is normally considered to be small. This is because forested land tends to serve as a filter of pollution originating within its drainage areas. Runoff from pastures, animal operations, improper land application of animal wastes, fertilizer application, and animals with access to streams are all mechanisms that can introduce organic loading to waterbodies.

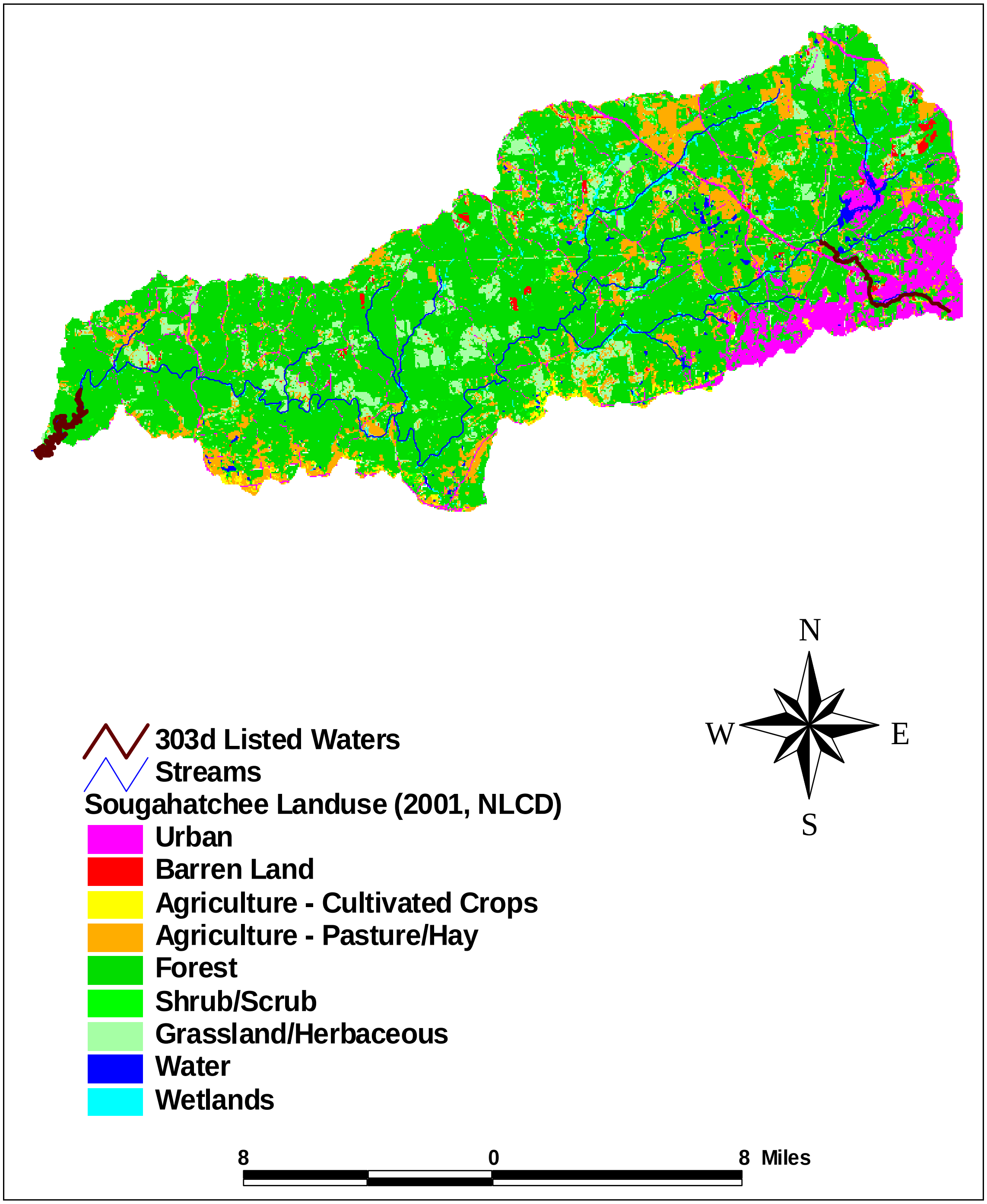


Figure 3-1 Land use Map for the Sougahatchee Creek Watershed

3.2.4. Point Sources

Point source considerations typically represent discharge from wastewater treatment plants, industrial operations, concentrated flows, and more. These operations generally result in some type of loading to the receiving water body. The loadings could be temperature, nutrients, organic matter, and more. Specific to this modeling effort, the loadings of interest include the following:

- Ammonia (NH_3)
- Nitrate+Nitrite (NOx)
- Organic Nitrogen (OrgN)
- Orthophosphate (PO_4)
- Organic Phosphorus (OrgP)
- Chlorophyll *a* (Chla)
- Biochemical Oxygen Demand (BOD)
- Dissolved Oxygen (DO)
- Flows (Q)
- Temperature (T)

Generally, a point source discharger does not measure all of these parameters. The NPDES permit dictates what parameters are to be measured based on the type of operation. When possible, parameters that are measured can be used in model applications.

A list of point sources identified in the Sougahatchee Creek watershed is presented in Table 3-3. Of these point sources, two municipalities, Opelika Westside WWTP and Auburn Northside WWTP, and one industrial facility, West Point Stevens Finishing Plant, were considered in the water quality modeling for this TMDL. The above mentioned dischargers are currently permitted to discharge oxygen consuming waste and contribute the majority of the wastewater flow to Pepperell Branch and Sougahatchee Creek. These facilities do not currently have total phosphorus limits.

Table 3-3 Point Sources in the Sougahatchee Creek Watershed

**Facility	Permit	Type	Discharge Type	Receiving Water
Opelika Westside WWTP	AL 0050130	Municipal	Process Water	Sougahatchee Creek
Auburn Northside WWTP	AL 0050245	Municipal	Process Water	Sougahatchee Creek
*The Colony Apartments	AL 0045641	SPP	Process Water	UT to Sougahatchee Creek
West Point Stevens Grifftex Chem	AL 0001074	Industrial (Minor)	Stormwater	Pepperell Branch
Quantegy, Inc	AL 0003310	Industrial (Minor)	Stormwater	Pepperell Branch
West Point Stevens Filter Plant	AL 0024198	Industrial (Minor)	Stormwater	Pepperell Branch
West Point Stevens Finishing Plant***	AL 0002968	Industrial (Major)	Process Water	Pepperell Branch

*Discharge currently inactive

**Stormwater discharges include and may not be limited to construction activities, mining activities, and MS4 discharges and are included in the TMDL as a percent reduction equal to the LA reduction (See Table 1-2)

***Active NPDES permit but currently not discharging

3.3 Data Availability and Analysis

In 2000-2002, Auburn University, Department of Fisheries and Allied Aquacultures, collected data at a total of twenty-four stations located throughout the Sougahatchee Creek watershed to include, but not limited to, Sougahatchee Creek main stem and its tributaries, such as Pepperell Branch and Loblockee Creek. ADEM also collected data throughout the Sougahatchee Creek watershed in 2000 and 2002 on Pepperell Branch, Sougahatchee Creek main stem and embayment, and Yates Reservoir at a total of thirteen stations. Listed in Table 3-4 are the sampling stations within the Sougahatchee Creek watershed along with a brief location description, followed by a map depicting these locations within the watershed presented in Figure 3-2.

Table 3-4 Sougahatchee Creek Watershed Sampling Locations

StationID	Description	Latitude	Longitude	Agency
SOGL-1	Sougahatchee Creek @ Lee Co. Rd 188	32.6267	85.588	ADEM
SOGL-2	Sougahatchee Creek @ Lee Co. Rd 65	32.6194	85.6336	ADEM
SOGL-3	Sougahatchee Creek @ Roxana Rd	32.605	85.693	ADEM
SOGL-4	Sougahatchee Creek @ Hayes Mill Road	32.6148	85.7268	ADEM
SOGL-5	Sougahatchee Creek @ Alabama Highway 49	32.6318	85.7983	ADEM
SOGL-6	Sougahatchee Creek @ Lovelady Road	32.6402	85.8446	ADEM
PPLL-1	Pepperell Branch @ Thomason Road	32.6328	85.4051	ADEM
PPLL-2	Pepperell Branch @ US Highway 29	32.6347	85.4254	ADEM
PPLL-3	Pepperell Branch @ US Highway 80	32.6446	85.4257	ADEM
PPLL-4	Pepperell Branch@ a New Street Upstream of Waverly Parkway	32.6494	85.4298	ADEM
PPLL-5	Pepperell Branch Upstream of Sougahatchee Creek Confluence (behind Opelika Westside WWTP	32.6603	85.4487	ADEM
YATES 2	Deepest Point of Main Creek Channel of Sougahatchee Creek Embayment; 1.6 miles upstream of Tallapoosa River confluence	32.6132	85.8766	ADEM
YATES 1	Dam Forebay Reservoir River Mile 0-1.0 (In the vicinity and below Sougahatchee Creek Embayment	32.5777	85.8901	ADEM
1	West point Stevens	32.6294	85.4181	AU
2	WestSide WWTP-Opelika	32.6607	85.4505	AU
3	Northside WWTP-Auburn	32.6306	85.5426	AU
4	Sougahatchee Creek upstream of Sougahatchee Lake	32.7012	85.4170	AU
5	Sougahatchee Lake Spillway	32.6657	85.4386	AU
6	Sougahatchee Creek @ Hwy 280	32.6575	85.4596	AU
7	Sougahatchee Creek @ North Donahue	32.6423	85.5044	AU
8	Sougahatchee Creek @ Lee Co. Rd 188	32.6267	85.5880	AU
9	Sougahatchee Creek @ Lee Co. Rd 65	32.6193	85.6335	AU
10	Sougahatchee Creek @ Lee Co. Rd 217	32.6050	85.6931	AU
11	Sougahatchee Creek @ Hayes Mill Rd	32.6147	85.7268	AU
12	Sougahatchee Creek @ Lovelady Road	32.6402	85.8447	AU
13	Unnamed Tributary upstream of Sougahatchee Lake	32.6848	85.4045	AU
14	Opelika City Park Stream	32.6586	85.4262	AU
15	Pepperell Branch upstream of West Point Stevens outfall	32.6288	85.4177	AU
16	Pepperell Branch downstream of West Point Stevens outfall	32.6512	85.4304	AU
17	AU Fisheries Station Stream	32.6466	85.4885	AU
18	N. Auburn Stream	32.6355	85.4908	AU
19	Auburn University Club pond/stream	32.6325	85.5109	AU
20	Unnamed Tributary to Loblockee @ Lee Co. Rd 188	32.6556	85.5756	AU
21	Loblockee Creek @ Lee Co. Rd 188	32.6581	85.5839	AU
22	Cane Creek @ Lee Co. Rd 217	32.6252	85.6886	AU
23	Sycamore Creek	32.6325	85.7477	AU
24	Buck Creek	32.6521	85.8325	AU

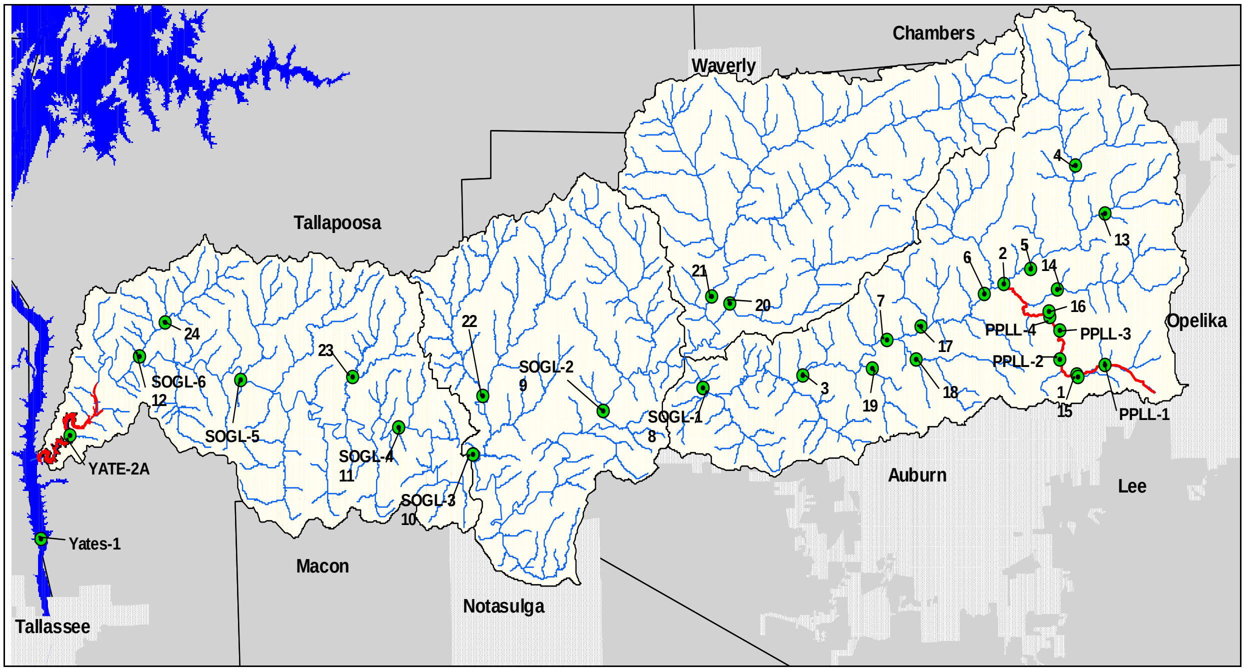


Figure 3-2 Sougahatchee Creek Watershed Sampling Locations Map

Parameters that were collected at the sampling stations varied; however, the following parameters were consistently sampled at all stations and all the sample data used for this TMDL may be found in Appendix A:

- Date
- Time
- Depth
- DO
- NH3
- TP
- TN
- $CBOD_5$

This wide range of data and information was used to characterize the watershed and the in-stream conditions. The categories of data used include physiographic data that describe the physical conditions of the watershed and environmental monitoring data that identify potential pollutant sources and their respective loading contribution, and in-stream water quality monitoring data. ADEM Reservoir Water Quality Monitoring (RWQM) data demonstrated chlorophyll *a* concentrations greater than the established target in the Sougahatchee Creek embayment, represented by Figure 3-3, and low dissolved oxygen levels, shown in Table 3-5.

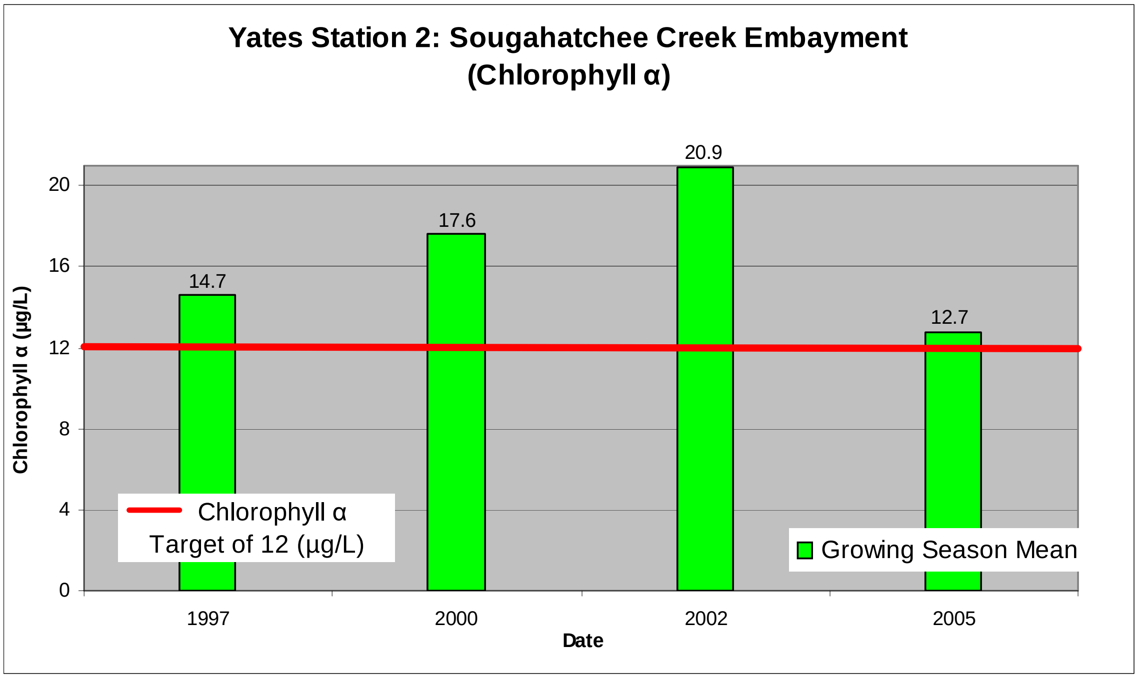
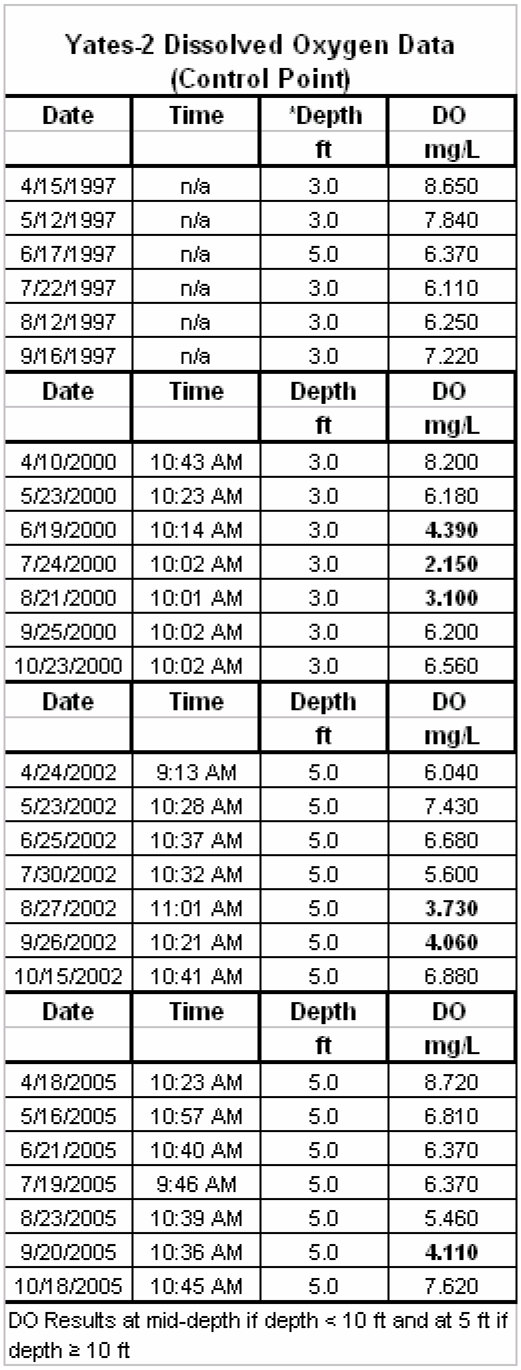


Figure 3-3 **Yates 2 Sougahatchee Creek Embayment Station Chlorophyll *a* Data**

Table 3-5 Yates 2 Sougahatchee Creek Embayment Station Dissolved Oxygen Data



Yates-2 Dissolved Oxygen Data
(Control Point)

Date	Time	*Depth	DO
		ft	mg/L
4/15/1997	n/a	3.0	8.650
5/12/1997	n/a	3.0	7.840
6/17/1997	n/a	5.0	6.370
7/22/1997	n/a	3.0	6.110
8/12/1997	n/a	3.0	6.250
9/16/1997	n/a	3.0	7.220
Date	**Time**	**Depth**	**DO**
		ft	**mg/L**
4/10/2000	10:43 AM	3.0	8.200
5/23/2000	10:23 AM	3.0	6.180
6/19/2000	10:14 AM	3.0	**4.390**
7/24/2000	10:02 AM	3.0	**2.150**
8/21/2000	10:01 AM	3.0	**3.100**
9/25/2000	10:02 AM	3.0	6.200
10/23/2000	10:02 AM	3.0	6.560
Date	**Time**	**Depth**	**DO**
		ft	**mg/L**
4/24/2002	9:13 AM	5.0	6.040
5/23/2002	10:28 AM	5.0	7.430
6/25/2002	10:37 AM	5.0	6.680
7/30/2002	10:32 AM	5.0	5.600
8/27/2002	11:01 AM	5.0	**3.730**
9/26/2002	10:21 AM	5.0	**4.060**
10/15/2002	10:41 AM	5.0	6.880
Date	**Time**	**Depth**	**DO**
		ft	**mg/L**
4/18/2005	10:23 AM	5.0	8.720
5/16/2005	10:57 AM	5.0	6.810
6/21/2005	10:40 AM	5.0	6.370
7/19/2005	9:46 AM	5.0	6.370
8/23/2005	10:39 AM	5.0	5.460
9/20/2005	10:36 AM	5.0	**4.110**
10/18/2005	10:45 AM	5.0	7.620

DO Results at mid-depth if depth < 10 ft and at 5 ft if depth ≥ 10 ft

4.0 Model Development

Establishing the relationship between in-stream water quality and source loading is an important component of TMDL development. It allows the determination of the relative contribution of sources to total pollution loading and the evaluation of potential changes to water quality resulting from implementation of various management options. This relationship can be developed using a variety of techniques ranging from qualitative assumptions based on scientific principles to numerical computer modeling. In this section, the numerical modeling techniques developed to simulate the loading of organic material and nutrients, as well as, the resulting in-stream response are summarized.

A watershed model was constructed to simulate loading of pollutants from nonpoint sources on the land surface. The Loading Simulation Program C++ (LSPC) was used to calculate runoff based on precipitation records. Hydrologic output from the watershed model was then used as input to a hydrodynamic model, the Environmental Fluid Dynamics Code (EFDC). The EFDC model was used to simulate the hydrology of the Sougahatchee Creek watershed. The simulated reservoir was the Sougahatchee Creek embayment. The EFDC simulated hydrodynamics were used as a basis for the dynamic water quality simulation using the Water Quality Analysis Simulation Program (WASP).

WASP calculates the interaction of eight water quality constituents based on interspecies kinetics and user-defined rates, as a function of water temperature. The eight state variables are ammonia, orthophosphate, nitrates, chlorophyll, dissolved oxygen, biochemical oxygen demand (BOD), organic nitrogen, and organic phosphorus. WASP includes consideration of sediment oxygen demand (SOD) and instream reaeration.

4.1 Watershed Modeling

Hydrologic response and pollutant loading model calibrations must occur to determine the watershed loads to the receiving waters. First, the model is calibrated for the hydrologic response of the watershed to rainfall and background source flows. During periods of precipitation, the rainfall will govern hydrology and subsequent loads of oxygen consuming waste. During dry periods, past events and their associated deposition within the system, and background inflows will govern the system hydrology and water quality response. In each case, there is a corresponding load that will be carried from the watershed to the instream model. Loads washed into the system will pass through and/or react during dry periods if the loads still remain in the water column. In addition, build up of organic material in the listed reaches from past high flow events can create increased sediment oxygen demand that exerts itself during low flow periods. In each case, the development of a TMDL that accounts for the storm water impacts upon the system requires the quantification of the total load and its distribution.

Based on analysis of the sampled data, review of the literature, and past modeling experience, the Loading Simulation Program C++ (LSPC) was used to represent the pollutant source-instream response linkage in the Sougahatchee Creek watershed. LSPC is a comprehensive data management and modeling system that simulates pollutant loading from nonpoint sources. LSPC utilizes the hydrologic core program of the Hydrologic Simulation Program Fortran (HSPF, EPA 1996b), with a custom interface of the Mining Data Analysis System (MDAS), with modification for non-mining applications such as nutrients modeling.

4.1.1 Hydrology Model Set Up and Calibration

LSPC is a system designed to support TMDL development for areas impacted by both point and nonpoint sources. It is capable of simulating land-to-stream transport of flow, sediment, metals, nutrients, and other conventional pollutants, as well as temperature and pH. The comprehensive watershed model is used to simulate watershed hydrology and pollutant transport as well as stream hydraulics and instream water quality. LSPC was configured to simulate the Sougahatchee Creek watershed as a series of hydrological connected sub-watersheds that contribute loads to various lengths of the listed reaches. Configuration of the model involved subdivision of the watershed into modeling units and continuous simulation of flow and water quality for these units using meteorological, land use, and stream data. Total phosphorus was the pollutant simulated. Appendix B contains the Sougahatchee Creek watershed model report which describes the configuration process and key components of the model in more detail.

The Sougahatchee Creek watershed was divided into 43 sub-watersheds to represent watershed loadings, hydrological boundaries and resulting concentrations of total phosphorus to the stream segments. Figure 4-1 presents the sub-watershed breakdown in LSPC. The division was based on elevation data from the 30 meter resolution, National Elevation Dataset (NED) from USGS, stream connectivity from the National Hydrography Dataset (NHD) stream coverage, and the locations of sampling stations.

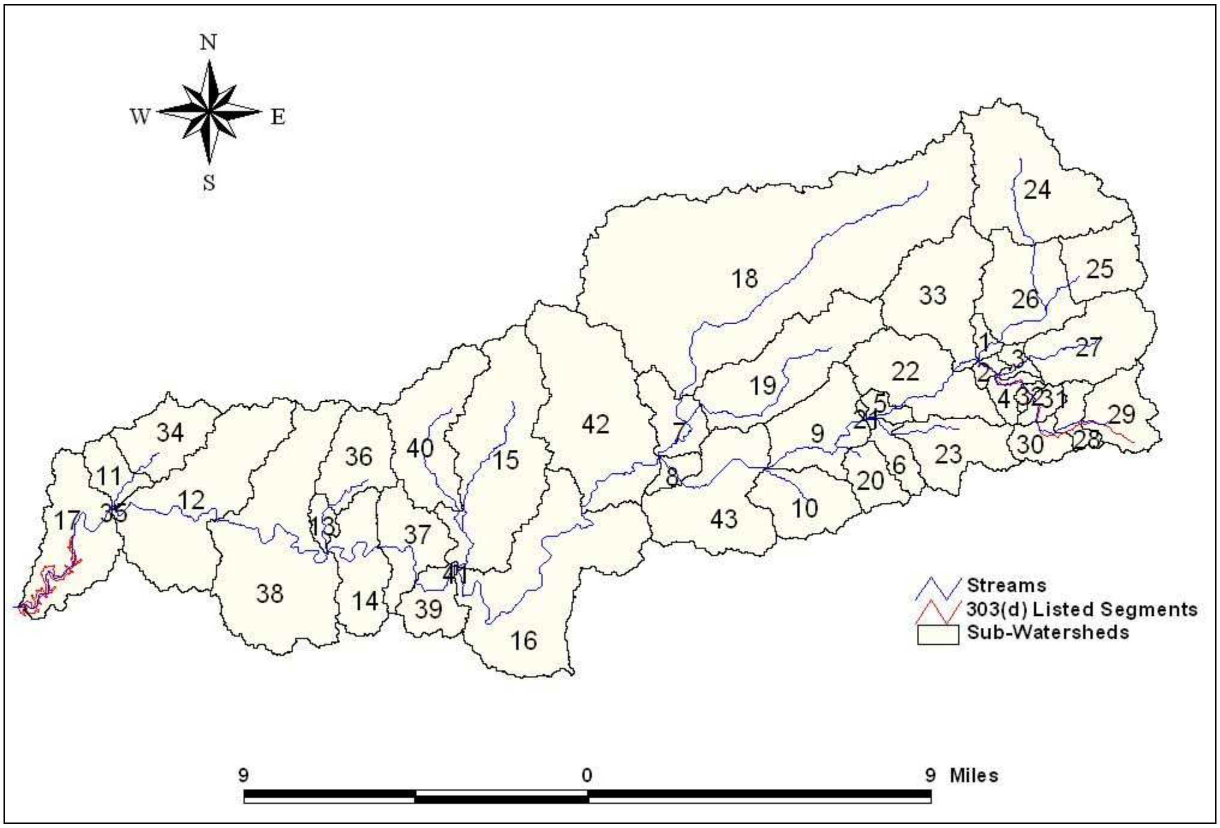


Figure 4-1 LSPC Subwatershed Delineation of Sougahatchee Creek Watershed

The hydrology of the LSPC model was calibrated for the period of record 1/1/2000-12/30/2002 at USGS station 02418230 on Sougahatchee Creek at Lee Co. Rd 188. The hydrology calibration was performed prior to water quality calibration and involved adjustment of the model parameters used to represent the hydrologic cycle until an acceptable correspondence between the simulated flows and the USGS Gage 02418230 measured flows was obtained. Some of the model parameters adjusted for the hydrologic calibration include: evapotranspiration, infiltration, upper and lower zone storage, groundwater storage, recession, losses to the deep groundwater system, and interflow discharge. Figure 4-2 represents the Sougahatchee Creek watershed hydrology calibration for the years of 2000 and 2002.

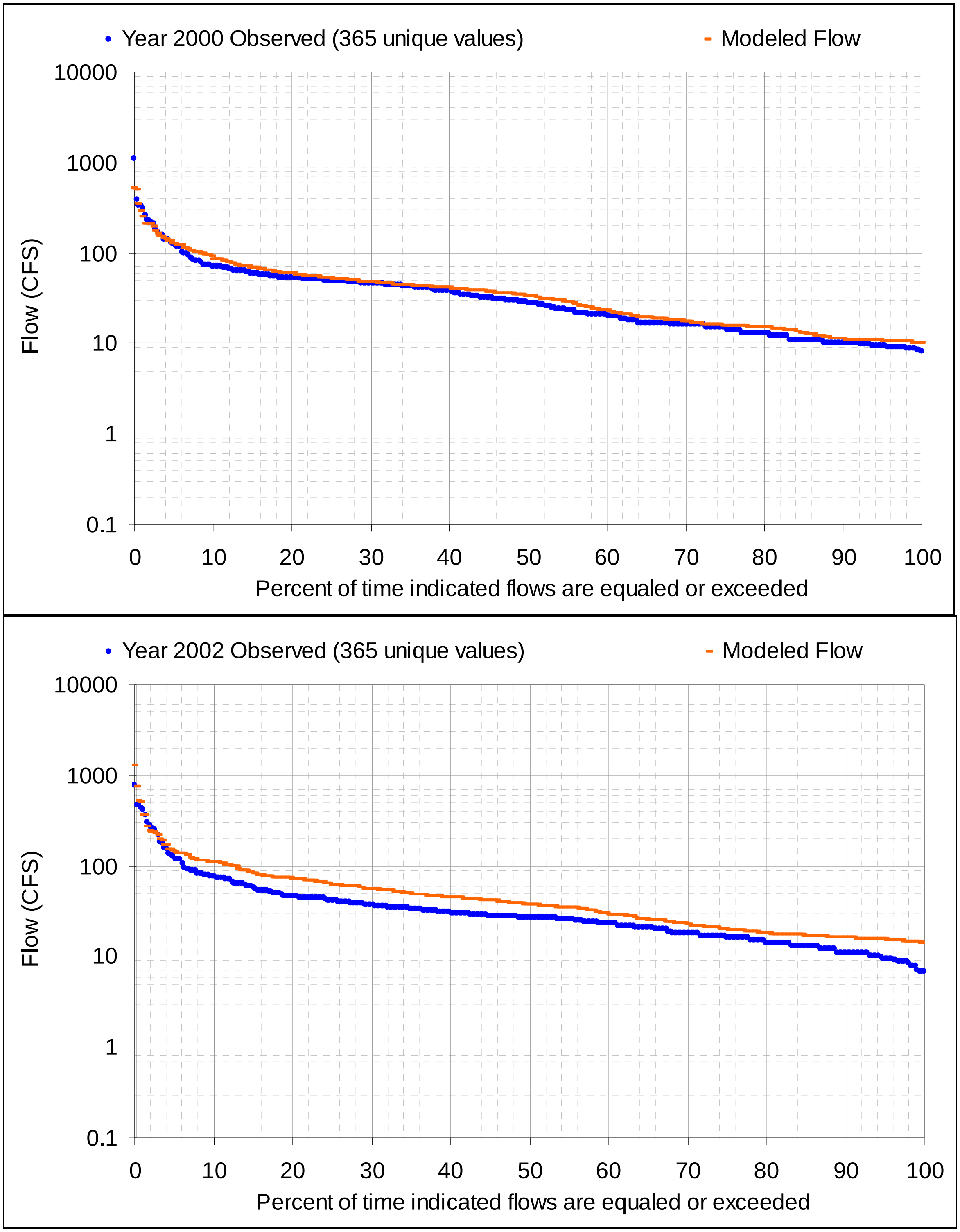


Figure 4-2 **LSPC 2000 and 2002 Sougahatchee Creek Hydrology Calibration**

4.1.2 Water Quality Model Set Up and Calibration

A dynamic computer model was selected for total phosphorus analysis in order to:

- simulate the time varying nature of deposition on land surfaces and transport to receiving waters
- incorporate seasonal effects on the production and fate of total phosphorus

For modeling purposes, sources of total phosphorus are represented by the following components: runoff loads from land uses (build-up and wash-off due to runoff) and point source discharges. Typically, watershed sources are characterized by buildup and wash-off processes. These sources can be represented in the model as land-based runoff from the land use categories to account for their contribution to form loading within the watersheds. Accumulation rates (mass per acre per day) can be calculated for each land use based on all sources contributing total phosphorus to the surface of the land use.

The LSPC model is a build-up and wash-off model that represents the pollutant by accumulating the pollutant over time, storing the pollutant to some maximum limit, and then transporting the pollutant via overland flow to the stream. The model represents these processes with an accumulation rate (ACQOP) and the storage limit (SQOLIM). WSQOP is defined as the rate of surface runoff (inches per hour) that results in ninety percent wash-off in one hour. The lower the value, the more easily wash-off occurs. The parameter is user-defined and was determined for each land use by USEPA recommended ranges. The ACQOP and SQOLIM can be varied monthly or be a constant through the simulation. For the Sougahatchee Creek watershed model, the ACQOP and SQOLIM rates were input as constant values.

Following hydrology calibration, the water quality constituent was calibrated. Modeled versus observed instream concentrations for total phosphorus were directly compared during model calibration. The water quality calibration consisted of executing the watershed model, comparing water quality time series output to available water quality observation data, and adjusting user-defined parameters within a reasonable range. The parameters that were adjusted to obtain a calibrated model were the build-up and wash-off of total phosphorus from the land use and the direct loads such as point sources.

Water quality calibration of the LSPC watershed model focused on matching trends such as low flow, mean flow, and storm peaks identified during the water quality analysis. Daily average instream concentrations from the model were compared directly to the measured data collected by ADEM and Auburn University.

The model simulation was developed for the 2000 and 2002 time period. This time period was chosen because it not only represents critical conditions, but monthly data is also available for the Sougahatchee Creek embayment including chlorophyll *a*, nutrients, and water column profile data for dissolved oxygen and temperature. The model was calibrated for both years. For each water quality station, model results were plotted against the respective sampled data to assess the model's response to spatial variation of loading sources. Below, in Figure 4-3, is the calibration for total phosphorus at Lovelady Bridge. Appendix B provides the Sougahatchee Creek watershed modeling report describing in more detail the model set up and calibration along with model inputs, outputs and critical parameters.

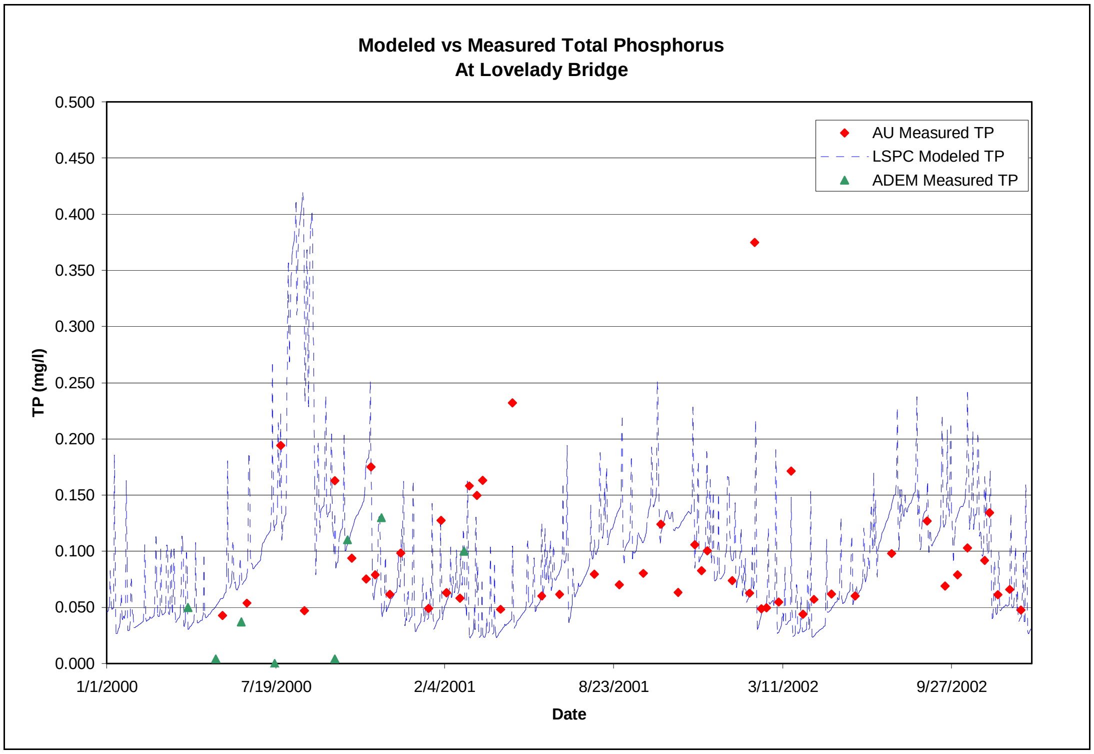


Figure 4-3 LSPC Total Phosphorus Calibration at Lovelady Bridge

4.2 Hydrodynamic Modeling

The receiving water models take the pollutant loads from the watershed model (LSPC) along with available information on the point source loads from the watershed system, and provide for the fate and transport of the material as it moves through the system.

In order to simulate the flow and transport within the listed segments, a hydrodynamic model, namely, the Environmental Fluid Dynamics Code (EFDC) was used. EFDC is a general purpose modeling package for simulating 1-D, 2-D, and 3-D flow and transport in surface water systems including rivers, lakes, estuaries, reservoirs, wetlands, and near shore to shelf-scale coastal regions. Inputs to each EFDC hydrodynamic model include the following:

- Model grid and geometry
- Hourly upstream boundary discharges
- Monthly temperatures from the upstream boundary
- Meteorological data from Auburn, Alabama
- Flows from the upstream boundary

The model grid was developed based upon USGS topographic maps and cross-sectional information from EPA, ADEM and Alabama Power Company. The Sougahatchee Creek embayment grid contained 24 grid cells, each with four vertical layers. Each cell was 400 meters (0.25 miles) apart for a total length of 9600 meters (6 miles). The grid coverage extends from the mouth of Sougahatchee Creek at Tallapoosa River (Yates Reservoir) upstream to the bridge crossing (Lovelady Bridge) located on Lovelady Road. Figure 4-4 presents the model grid utilized for Sougahatchee Creek embayment. Further explanation of model development and setup can be found in Appendix B.

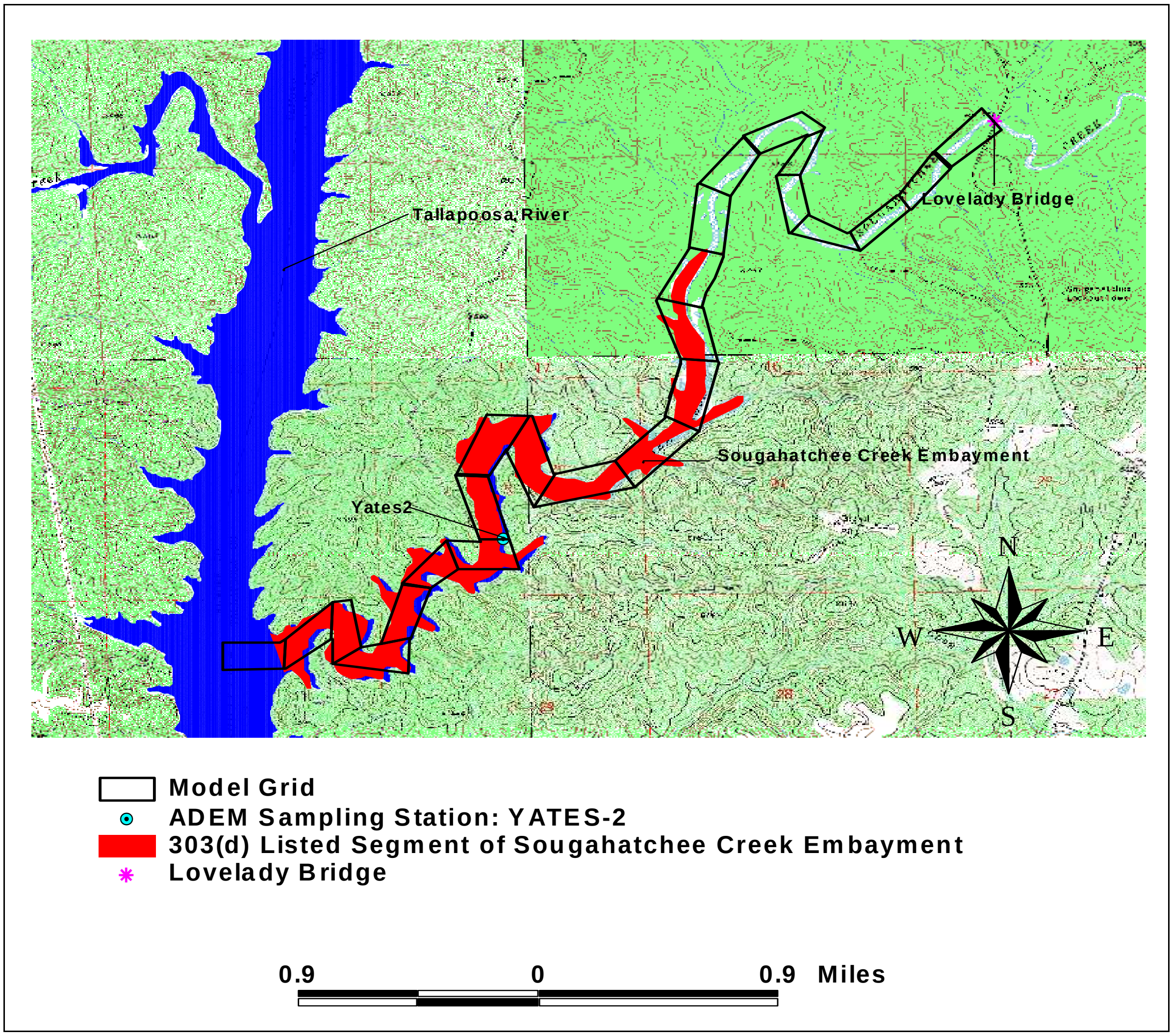


Figure 4-4 Sougahatchee Creek Embayment Model Grid

4.3 Water Quality Modeling

In order to simulate the temporal and spatial concentrations of nutrients, dissolved oxygen, and chlorophyll *a*, a dynamic water quality model was utilized which simulates the full eutrophication kinetics, to include phosphorus and nitrogen cycle, oxidation of organic material, SOD, and reaeration across the water surface.

For simulation of the water quality model, the EFDC model was externally linked to the Water Quality Analysis Simulation Program (WASP) through a hydrodynamic forcing file that contains the flows, volumes, and exchange coefficients between adjacent cells. WASP 6.1 is a dynamic compartment model for aquatic systems including both the water column and the underlying benthos. The time varying processes of advection, dispersion, point and diffuse mass loading, and boundary exchange are represented in the basic program.

Water quality processes are represented in special kinetic subroutines that are either chosen from a library or written by the user. WASP is structured to permit easy substitution of kinetic subroutines into the overall package to form problem-specific models. WASP permits the modeler to structure one, two, and three-dimensional models; allows the specification of time-variable exchange coefficients, advective flows, waste loads, and water quality boundary conditions; and permits tailored structuring of the kinetic process, all within the larger modeling framework without having to write or rewrite large sections of computer code.

For the Sougahatchee Creek watershed simulations, the WASP model was run under full eutrophication kinetics with the following state variables simulated:

- Dissolved Oxygen (DO)
- Ultimate Carbonaceous Biochemical Oxygen Demand (CBODu)
- Ammonia as Nitrogen (NH_3-N)
- Nitrate/Nitrite as Nitrogen (NO_3NO_2-N)
- Organic Nitrogen (ON)
- Organic Phosphorus (OP)
- Orthophosphate (PO_4-P)
- Chlorophyll *a*

In order to perform the full eutrophication simulations, the following general input conditions were required:

- Boundary flows and concentrations for all 8 state variables where flow enters the model (i.e. watershed inputs)
- Meteorological inputs
- Model input coefficients

Boundary flows and concentrations were obtained from the LSPC simulations. Sediment oxygen demand (SOD) measurements were taken from data collected by the USEPA during a special 2003 Sougahatchee Creek study. Meteorological data used in the WASP model was from the Columbus Metropolitan Airport and the AWIS Weather Services, Inc (Auburn University Mesonet, Station Auburn_CR10). Solar radiation and average air temperature values were obtained from AWIS and the wind speed data came from the Columbus Metropolitan Airport. For the WASP model, hourly weather data was utilized for the inputs to establish diurnal fluctuations in the system.

The WASP model input coefficients reflect the best available literature values, and where available site-specific values were utilized. The best fit between the WASP model simulations and the measured data was obtained by variation of critical parameters within the range of acceptable literature values. Where site-specific measured values were used, no adjustment of those coefficients was made.

The WASP model was calibrated to chlorophyll *a*, dissolved oxygen, and nutrients (total phosphorus) during the 2000 and 2002 growing seasons (April through October). The measurements of chlorophyll *a*, dissolved oxygen, and nutrients (total phosphorus) were taken at ADEM station, Yates 2, within Sougahatchee Creek embayment for the corresponding years. Appendix B provides the Sougahatchee Creek watershed modeling report describing in more detail the model set up and calibration plots along with model inputs and critical parameters.

5.0 Total Maximum Daily Load Development for the Sougahatchee Creek Watershed

This section presents the TMDL developed to address both nutrients and OE/DO for the listed segments in the Sougahatchee Creek watershed. A TMDL is the total amount of a pollution load that can be assimilated by the receiving water while still achieving water quality standards. TMDLs can be expressed in terms of mass per time or by other appropriate measures. TMDLs are comprised of the sum of individual waste load allocations (WLAs) for point sources, load allocations (LAs) for non-point sources, and natural background levels. In addition, the TMDL must include a margin of safety (MOS), either implicitly or explicitly, that accounts for the uncertainty in the relationship between pollutant loads and the quality of the receiving waterbody. Conceptually, this definition is denoted by the following equation:

$$\text{TMDL} = \Sigma\text{WLAs} + \Sigma\text{LAs} + \text{MOS}$$

In order to develop the TMDL, the following steps will be defined:

- Numeric Target for TMDL
- Existing/Baseline Conditions
- Critical Conditions
- Margin of Safety
- Seasonal Variation
- TMDL Results

5.1 TMDL Numeric Targets

The TMDL endpoints represent the in-stream water quality target used in quantifying the load reduction that maintains water quality standards. The TMDL endpoints can be a combination of water quality standards, both numeric and narrative, and surrogate parameters that would ensure the standards are being met. The following presents the endpoints used for each of the parameters selected.

5.1.1 Nutrients

The Sougahatchee Creek Watershed nutrient target, expressed as a growing season average chlorophyll *a* concentration of 12 µg/L in the Sougahatchee Creek embayment, specifically at Station Yates 2, was developed using a “reference condition” approach for determining the appropriate levels of nutrients necessary to support the designated uses of waters within the Sougahatchee Creek watershed.

5.1.2 OE/DO

According to ADEM’s Water Quality Criteria (Administrative Code 335-6-10), the minimum dissolved oxygen concentration for waters classified as F&W, S, and PWS is 5.0 mg/l. For the purpose of this TMDL, a minimum dissolved oxygen level of 5.0 mg/l will be implemented, except where natural conditions cause the value to be depressed.

5.2 Existing/Baseline Conditions

The results of the calibrated model provide the existing condition for Sougahatchee Creek. Existing conditions represent the existing non-point source loading and the permitted point source discharge conditions.

The models were run during the 2000 and 2002 growing seasons to establish the existing conditions for Sougahatchee Creek for both chlorophyll *a* and dissolved oxygen. Predicted in-stream concentrations of both chlorophyll *a* and dissolved oxygen for the listed segments were compared directly to the TMDL targets. This comparison allowed for evaluation of Sougahatchee Creek under its present nutrient loading (namely phosphorus) and the associated in-stream response of chlorophyll *a* and dissolved oxygen.

5.3 Critical Conditions

A TMDL must be protective of water quality over a range of possible conditions that might occur within the listed segment. EPA’s Nutrient Criteria Technical Guidance Manual: Rivers and Streams (EPA, 2000) states that ‘Nutrient and algal problems are frequently seasonal in streams and rivers, so sampling periods can be targeted to the seasonal periods associated with nuisance problems.’ It has been determined that the seasonal period associated with nutrient enrichment that results in nuisance algal problems for the Sougahatchee Creek watershed is the growing season of April through October. Typically, critical conditions specify a flow that will represent an extreme low flow regime or a loading that represents a high possible value. The models are then run under these critical conditions, and the resulting in-stream target concentration, the growing season average of chlorophyll *a*, is compared directly to the TMDL endpoint at the compliance point (Station Yates 2). If the growing season average chlorophyll *a* concentration is less than the target concentration, then the total phosphorus loading to the system is said to be protective of water quality. However, if the growing season average chlorophyll *a* concentration is greater than the target, then the total phosphorus loading must be reduced until the target concentration is met.

For the listed segments in the Sougahatchee Creek watershed, two phosphorus loading conditions were defined to establish critical conditions. The 2000 and 2002 growing seasons were selected as they represent a wide range of conditions that are expected in this system.

Growing season months (April - October) generally represent the critical conditions of an embayment for instream dissolved oxygen concentrations as a result of lower precipitation and higher temperatures which lead to shallower stream depths, slower velocities, increased residence time, and decreased re-aeration. Increased residence time allows for additional decay which further depletes stream dissolved oxygen. Reaction rates for CBODu and NBOD (i.e., organic loading) are temperature dependent and thereby increase with higher temperatures.

Low intensity rains typically occur with greater frequency in winter months with the absence of land surface build-up of organic material, resulting in a more uniform load distribution. Higher flows in connection with lower temperatures effectively result in less residence time and lower decay rates such that waterbodies are capable of assimilating larger organic loads.

5.4 Margin of Safety

There are two methods for incorporating a MOS in the analysis: a) by implicitly incorporating the MOS using conservative model assumptions to develop allocations; b) by explicitly specifying a portion of the TMDL as the MOS and using the remainder for allocations.

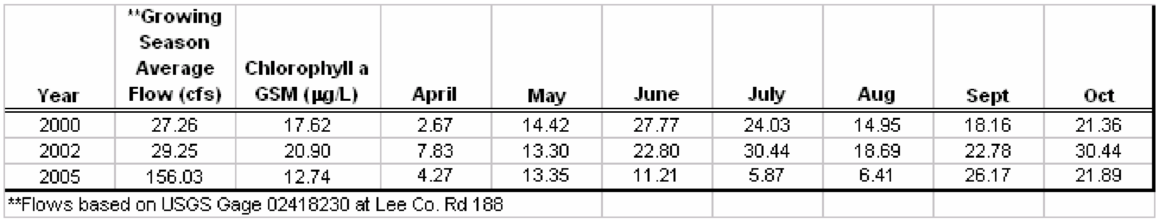
An implicit MOS was incorporated in this TMDL since this TMDL was developed based on worst-case conditions. Also, this implicit MOS includes conservative modeling assumptions and a continuous simulation that incorporates a range of meteorological events. The conservative modeling assumptions that were used include: setting point sources at permitted design flows, conservative estimates of instream decay, and all land areas considered to be connected directly to streams. Organic material loss on the land surface is not computed in the model; therefore, the loads delivered to the model do not account for decay and are conservative.

Also, by using minimally-impacted reference embayments within the Tallapoosa River basin, the target TP concentration is expected to support good habitat and biology with normal algal growth. This approach is conservative and recommended by EPA guidance and was used in the development of the Sougahatchee Creek Watershed TMDL Nutrient Target. The established TP target was calculated based upon the 75th percentile of the chlorophyll *a* data from the selected minimally-impacted reference embayments. Normally, ADEM prefers to utilize the 90th percentile; however, since the reference data set was limited in this specific case (4 reference embayments), the 75th percentile was deemed more appropriate.

5.5 Seasonal Variation

Seasonal variation was considered in the development of the TMDL by evaluating the Sougahatchee Creek embayment data (Growing Season: April-October) during the time periods of 2000 and 2002, relatively dry seasons, and the time period of 2005, a wet season. As shown in Table 5-1, the 2005 data indicates the embayment was less eutrophic (Growing Season Mean (GSM) for CHLA = 12.5 ug/L) during that time period, as opposed to the dry year (2000) when the GSM = 17.6 ug/L. Therefore, it can be said that critical conditions for this system are during drought conditions, which appears reasonable because retention time increases and phosphorus concentrations increase as the stream becomes more effluent dominated. For the purpose of this TMDL, the year 2000 was selected as the critical condition for the Sougahatchee Creek watershed, and the 2002 data was used for validation.

Table 5-1 Growing Season (April-October) Chlorophyll a and Flow Results for ADEM Station Yates 2



Year	**Growing Season Average Flow (cfs)	Chlorophyll a GSM (µg/L)	April	May	June	July	Aug	Sept	Oct
2000	27.26	17.62	2.67	14.42	27.77	24.03	14.95	18.16	21.36
2002	29.25	20.90	7.83	13.30	22.80	30.44	18.69	22.78	30.44
2005	156.03	12.74	4.27	13.35	11.21	5.87	6.41	26.17	21.89

**Flows based on USGS Gage 02418230 at Lee Co. Rd 188

The numeric chlorophyll *a* (total phosphorus driven) target is representative of the range of values measured over multiple-year growing seasons at the designated reference sites. Therefore, application and interpretation of the nutrient target for the Sougahatchee Creek embayment accounts for varying ambient chlorophyll *a* concentrations that may exceed the target at times while still maintaining conditions similar to those in streams that fully support the designated use of aquatic life, as long as the growing season average concentration does not exceed the target. Application of the proposed nutrient target of 12 µg/l of chlorophyll *a* must consider the methodology of the ecoregion reference embayment approach that was used to develop the number. Ecoregion reference embayment site data were assessed on a growing-season basis that accounts for natural variability. Therefore, it would be inappropriate to expect the Sougahatchee Creek not to exhibit natural variability during the growing season including higher, as well as lower, levels of chlorophyll *a* while attaining the growing season average target value. The April-October growing season was determined to be the appropriate time frame for managing TP to control algae in the Sougahatchee Creek embayment. It was determined that requiring compliance with the target in the winter (i.e., non-growing season) would not be necessary since high flows, cool temperatures, and low availability of substrate and light limit algal production during these months.

5.6 TMDL Results

5.6.1 Total Phosphorus

As mentioned previously, the year 2000 was chosen as the critical condition year based on applicable data. The data for the year 2002 was used to validate this assumption. Therefore, the TMDL results will be based on the worst-case or critical condition scenario: a low flow period with high temperatures as in the year 2000. As predicted based upon modeling tools, in order to meet the chlorophyll *a* target of 12 µg/l, a growing season (April-October) total phosphorus limit of 0.20 mg/l will need to be met by point sources (WLA continuous sources) and a fifty percent total phosphorus reduction will be needed for stormwater sources (MS4 and LA) within the watershed. Table 5-2 presents the TMDL results for total phosphorus necessary to meet water quality standards. West Point Stevens has an active NPDES permit for a process water discharge to Pepperell Branch; however, as of July 2007 the facility has currently halted production. An alternate TMDL scenario has been developed which excludes the West Point Stevens WLA should the NPDES permit be withdrawn and the discharge be permanently removed. Table 5-3 presents the total phosphorus TMDL results necessary to meet water quality standards for the Sougahatchee Creek Watershed with the West Point Stevens discharge removed from Pepperell Branch.

Table 5-2 Growing Season (April-October) Total Phosphorus TMDL Results for the Sougahatchee Creek Watershed

TMDL	Existing TP Loads					Allowable Loads					Reductions				
	WLA (Continuous Sources)			WLA (Stormwater Sources)	LA (Stormwater Sources)	WLA (Continuous Sources)			WLA (Stormwater Sources)	LA (Stormwater Sources)	WLA (Continuous Sources)			WLA (Stormwater Sources)	LA (Stormwater Sources)
	WPS	Opelika Westside WWTP	Auburn Northside WWTP			WPS	Opelika Westside WWTP	Auburn Northside WWTP			WPS	Opelika Westside WWTP	Auburn Northside WWTP		
Sougahatchee Creek Watershed	2.25 (mg/l) 30.02 lbs/day	1.43 (mg/l) 47.70 lbs/day	2.67 (mg/l) 66.80 lbs/day	0.19 (mg/l) lbs/day = Q*0.19*8.34	0.19 (mg/l) lbs/day = Q*0.19*8.34	0.20 (mg/l) 2.67 lbs/day	0.20 (mg/l) 6.67 lbs/day	0.20 (mg/l) 5.00 lbs/day	0.10 (mg/L) lbs/day = Q*0.10*8.34	0.10 (mg/L) lbs/day = Q*0.10*8.34	91%	86%	93%	50%	50%

*Existing TP concentrations were determined using Point Source DMR data (April-October) for the period of 2000 and 2002
*Point source TP mass loadings were calculated utilizing TP concentrations times design flows times 8.34
*Q is equal to flow in MGD

Table 5-3 Growing Season (April-October) Total Phosphorus TMDL Results for the Sougahatchee Creek Watershed with the West Point Stevens Discharge Removed from Pepperell Branch

TMDL	Existing TP Loads					Allowable Loads					Reductions				
	WLA (Continuous Sources)			WLA (Stormwater Sources)	LA (Stormwater Sources)	WLA (Continuous Sources)			WLA (Stormwater Sources)	LA (Stormwater Sources)	WLA (Continuous Sources)			WLA (Stormwater Sources)	LA (Stormwater Sources)
	WPS	Opelika Westside WWTP	Auburn Northside WWTP			WPS	Opelika Westside WWTP	Auburn Northside WWTP			WPS	Opelika Westside WWTP	Auburn Northside WWTP		
Sougahatchee Creek Watershed		1.43 (mg/l) 47.70 lbs/day	2.67 (mg/l) 66.80 lbs/day	0.19 (mg/l) lbs/day = Q*0.19*8.34	0.19 (mg/l) lbs/day = Q*0.19*8.34		0.25 (mg/l) 8.20 lbs/day	0.25 (mg/l) 6.14 lbs/day	0.10 (mg/L) lbs/day = Q*0.10*8.34	0.10 (mg/L) lbs/day = Q*0.10*8.34		83%	91%	50%	50%

*Existing TP concentrations were determined using Point Source DMR data (April-October) for the period of 2000 and 2002
*Existing point source TP mass loadings were calculated utilizing TP concentrations times design flows times 8.34
*Q is equal to flow in MGD
*Allowable point source TP mass loadings calculated by distributing allowable WPS TP mass loading in Table 1-2 proportional to facility design capacities (ex. Auburn lb/day = 5 lbs/day + 2.67 lbs/day * 3 MGD / 7MGD = 6.14 lbs/day)
*Note: Auburn Northside WWTP Design Capacity = 3 MGD; Opelika Westside WWTP Design Capacity = 4 MGD

An appropriate initial strategy to controlling algal growth in the Sougahatchee Creek watershed, is to effectively control phosphorus loadings in the system. Therefore, controlling nitrogen in the system should be unnecessary because phosphorus will be managed to prevent nitrogen from becoming the limiting nutrient. **“**Based on available literature, including EPA guidance summarizing evidence that phosphorus often limits stream algae (EPA 2000), control of total phosphorus rather than total nitrogen should be effective as an initial strategy to manage algal productivity.” Since Yates forebay, downstream of the impaired Sougahatchee Creek embayment, represents full use support with no nitrogen-caused nutrient impairment, targeting only phosphorus will be protective of downstream waterbodies. Furthermore, it is expected that phosphorus reductions achieved through improved wastewater and stormwater treatment will also help achieve reductions in biologically available nitrogen. A model run simulation with a 30% reduction of TN, in addition to the reduced TP loading, yielded an insignificant change in the chlorophyll *a* value of Sougahatchee Creek embayment as shown in Figure 5-1, and ADEM also has no current evidence that nitrogen exported from the system contributes to any known nutrient enrichment problems downstream.

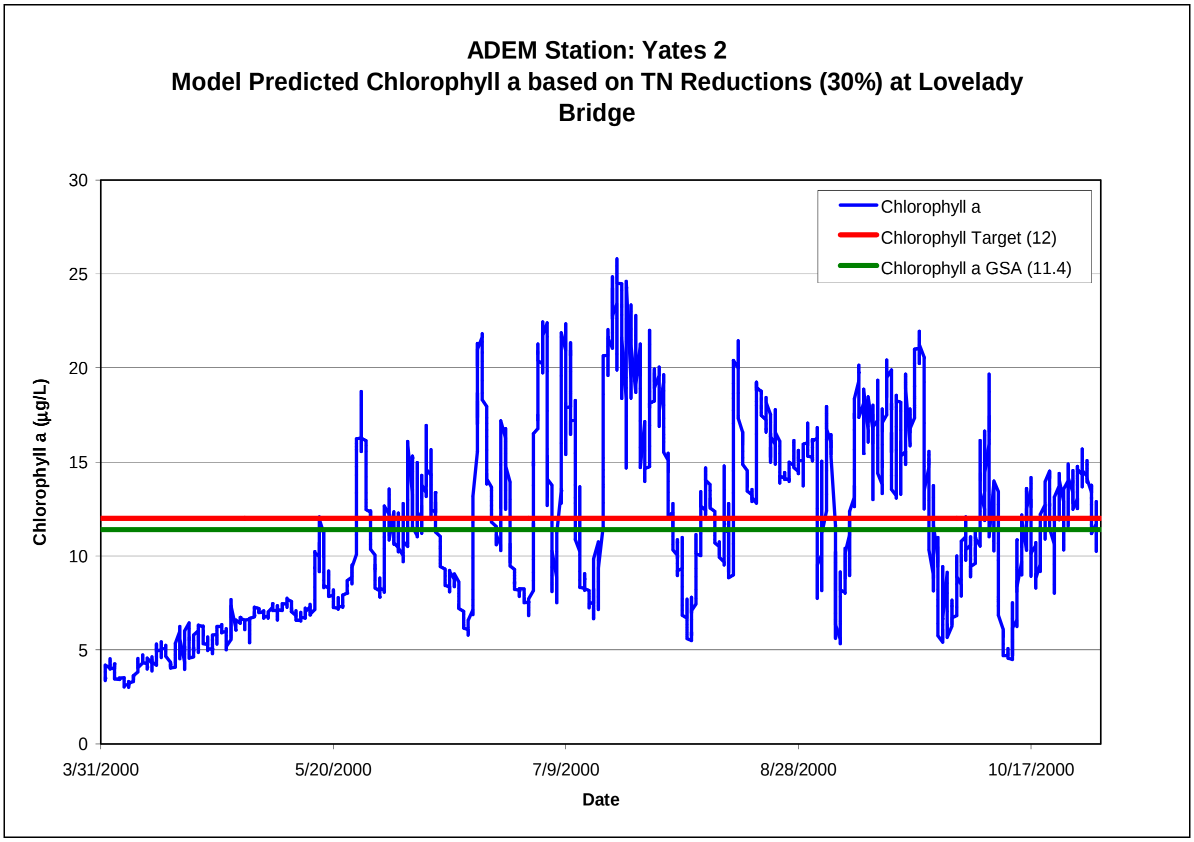


Figure 5-1 Chlorophyll *a* Concentrations Resulting from Thirty Percent Nitrogen and Fifty Percent Phosphorus Loading Reduction to Sougahatchee Creek Embayment

5.6.2 Dissolved Oxygen

Nutrients are of concern due to their ability to promote algal growth, which in turn affects the dissolved oxygen balance through photosynthesis, respiration, and the regeneration of organic materials. Therefore, the subject total phosphorus reductions are expected to improve the dissolved oxygen levels in the watershed. However, the model predicted that the total phosphorus reductions alone did not restore the dissolved oxygen levels in the Sougahatchee Creek embayment above the water quality criterion of 5.0 mg/l. Using the WASP model, it was determined that achieving the water quality criterion for DO of 5.0 mg/L throughout the year could only be accomplished by reducing sediment oxygen demand (SOD) to extremely low levels that would be unrealistic in a natural system. Furthermore, it was determined that even by removing all point sources, under nominal background conditions there would still be occasions that the DO would fall below 5.0 mg/L in a critical conditions year such as 2000.

SOD was measured by USEPA field staff in the Sougahatchee embayment at a value of 1.6 g/m^2/day. During low stream flow and high temperature periods, a SOD of this magnitude is the main cause of low dissolved oxygen in the embayment. The relationship between sediment oxygen demand and its source, organic carbon loading, was investigated by the use of a spreadsheet model tool developed by Dr. James Martin at Mississippi State University. Using a typical relationship between carbon and CBOD-ultimate, it became apparent that it would be impossible to reduce SOD to extremely low values by reducing allochthonous CBOD. With the TP reductions required by the allocations, an overall reduction of more than fifty percent will result in significant reductions in algal biomass levels which in turn will leave less organic material on the bottom substrate during critical periods; such reductions over time are expected to result in significantly lower levels of SOD. Therefore, in the WASP model, a SOD value of 0.8 g/m^2/day was estimated to correspond to a “natural condition.”

The WASP model results for dissolved oxygen in the “natural condition” (i.e., no point sources) scenario and with the existing point sources included are shown in Figure 5-2. The “natural condition” assumes a CBOD-ultimate concentration of 2.0 mg/L and SOD of 0.8 g/m^2/day. In the critical condition year of 2000, the “natural condition” scenario had 12 days with minor excursions of the dissolved oxygen criterion.

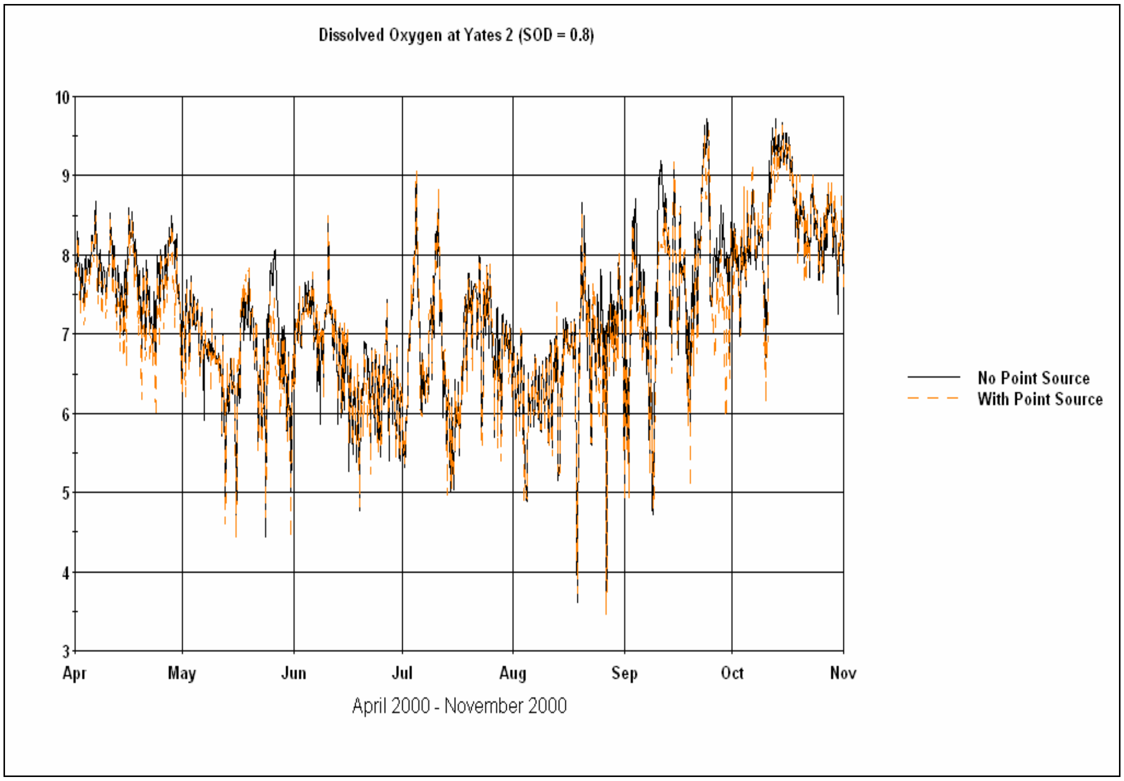
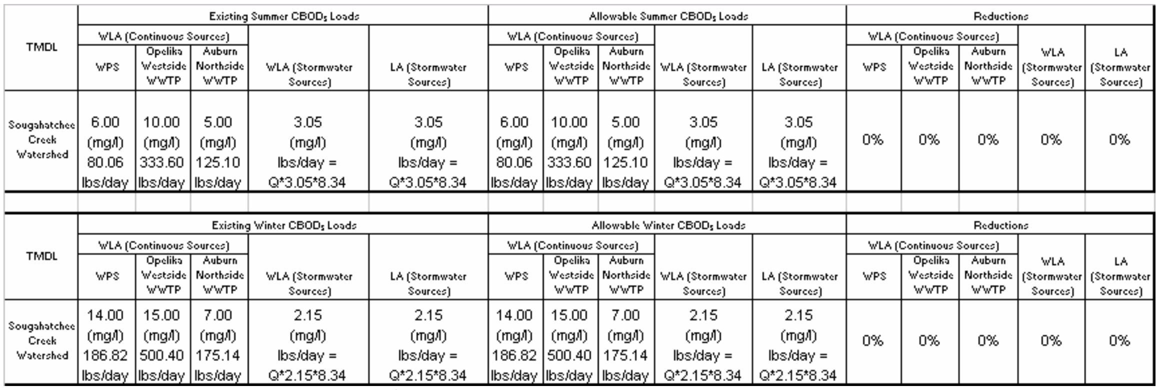


Figure 5-2 WASP results for “natural conditions” and with point sources added

In order to demonstrate the additional impact of point sources on the system under the TMDL allocation scenarios, the point source contribution of CBOD-ultimate was estimated and added to the WASP model. Based on TMDL allocations at current permit limits for CBOD, the additional CBOD-ultimate contribution from point sources was determined as a function of stream flow, time-of-travel, and temperature-corrected instream attenuation (data shown in Appendix C). The additional point source contribution was added to the assumed 2.0 mg/L CBOD-ultimate of the natural condition.

With the additional flows of the point sources, there occurred 15 days with DO excursions, however, the additional impact was only a mean deviation of -0.13 mg/L from the natural conditions. For the days when DO levels of less than 5.0 mg/L occurred, the mean deviation was -0.17 mg/L. The mean deviations are well within the margin of error associated with the predictive capabilities of the calibrated models used in the analysis. Therefore, WASP model results show that point source impacts compared to the natural conditions scenario are negligible. This is consistent with observations that CBOD sensitivity of the system is low compared to the impact of SOD. Considering the TP reductions included in the TMDL and the corresponding reduction in algal biomass production, the existing $CBOD_5$ loading is expected to achieve natural DO conditions within the Sougahatchee Creek embayment. These existing $CBOD_5$ loads, expressed as a TMDL, are shown in Table 5-4. Model comparison statistics of the "natural condition" and with existing point sources added are shown in Table 5-5.

Table 5-4 $CBOD_5$ TMDL Results for the Sougahatchee Creek Watershed



TMDL	Existing Summer $CBOD_5$ Loads					Allowable Summer $CBOD_5$ Loads					Reductions				
	WLA (Continuous Sources)			WLA (Stormwater Sources)	LA (Stormwater Sources)	WLA (Continuous Sources)			WLA (Stormwater Sources)	LA (Stormwater Sources)	WLA (Continuous Sources)			WLA (Stormwater Sources)	LA (Stormwater Sources)
	WPS	Opelika Westside WWTP	Auburn Northside WWTP			WPS	Opelika Westside WWTP	Auburn Northside WWTP			WPS	Opelika Westside WWTP	Auburn Northside WWTP		
Sougahatchee Creek Watershed	6.00 (mg/l) 80.06 lbs/day	10.00 (mg/l) 333.60 lbs/day	5.00 (mg/l) 125.10 lbs/day	3.05 (mg/l) lbs/day = Q*3.05*8.34	3.05 (mg/l) lbs/day = Q*3.05*8.34	6.00 (mg/l) 80.06 lbs/day	10.00 (mg/l) 333.60 lbs/day	5.00 (mg/l) 125.10 lbs/day	3.05 (mg/l) lbs/day = Q*3.05*8.34	3.05 (mg/l) lbs/day = Q*3.05*8.34	0%	0%	0%	0%	0%

TMDL	Existing Winter $CBOD_5$ Loads					Allowable Winter $CBOD_5$ Loads					Reductions				
	WLA (Continuous Sources)			WLA (Stormwater Sources)	LA (Stormwater Sources)	WLA (Continuous Sources)			WLA (Stormwater Sources)	LA (Stormwater Sources)	WLA (Continuous Sources)			WLA (Stormwater Sources)	LA (Stormwater Sources)
	WPS	Opelika Westside WWTP	Auburn Northside WWTP			WPS	Opelika Westside WWTP	Auburn Northside WWTP			WPS	Opelika Westside WWTP	Auburn Northside WWTP		
Sougahatchee Creek Watershed	14.00 (mg/l) 186.82 lbs/day	15.00 (mg/l) 500.40 lbs/day	7.00 (mg/l) 175.14 lbs/day	2.15 (mg/l) lbs/day = Q*2.15*8.34	2.15 (mg/l) lbs/day = Q*2.15*8.34	14.00 (mg/l) 186.82 lbs/day	15.00 (mg/l) 500.40 lbs/day	7.00 (mg/l) 175.14 lbs/day	2.15 (mg/l) lbs/day = Q*2.15*8.34	2.15 (mg/l) lbs/day = Q*2.15*8.34	0%	0%	0%	0%	0%

*Existing $CBOD_5$ concentrations were taken from NPDES Permits

*Point source $CBOD_5$ mass loadings were calculated utilizing $CBOD_5$ concentrations times design flows times 8.34

*Q is equal to flow in MGD

*The estimated $CBOD_5$ allocations for stormwater (WLA and LA Stormwater Sources) represent the maximum allowable stormwater loads at Lovelady Bridge including point source contributions. The $CBOD_5$ TMDL allocations for stormwater sources should be dictated by the 0% reduction.

Table 5-5 Comparison of WASP model results for "natural conditions" and point sources added.

Scenario	Mean DO (mg/L)	Minimum DO (mg/L)	Mean Deviation (mg/L)	Mean Deviation when DO<5.0 mg/L
Natural Conditions	7.72	3.6	---	---
With Point Sources	7.59	3.5	-0.13	-0.17

According to ADEM's Water Quality Criteria (Administrative Code 335-6-10), the minimum dissolved oxygen concentration for waters classified as F&W, S, and PWS is 5.0 mg/l, except when such levels cannot be achieved as a result of natural conditions. For the purpose of this TMDL, a minimum dissolved oxygen level of 5.0 mg/l cannot be implemented at all times, due to natural conditions as demonstrated by the aforementioned dissolved oxygen data analysis. During the occasions when dissolved oxygen concentrations would naturally be less than 5.0 mg/l, the TMDL allocations are expected to result in the attainment of the natural dissolved oxygen levels.

5.7 Adaptive Management

It is possible during the implementation of this TMDL that further evaluation of instream conditions within the Sougahatchee Creek watershed, including biological and chemical monitoring, will reveal trends of improvement in water quality and biological conditions. If so, any required implementation in the future may be revised according to the best available science at that time. Adaptive management, in conjunction with the implementation schedule as determined by ADEM's NPDES permitting program, will allow the TMDL target to be validated or adjusted as necessary based on additional data that becomes available in the future.

6.0 Follow Up Monitoring

ADEM has adopted a basin approach to water quality management; an approach that divides Alabama's fourteen major river basins into five groups. Each year, the ADEM water quality resources are concentrated in one of the basin groups. The goal is to continue to monitor §303(d) listed waters. This monitoring will occur in each basin according to the schedule in Table 6-1:

Table 6-1 Monitoring Schedule for Alabama's Major River Basins

River Basin Group	Schedule
Cahaba/Black Warrior	2007
Tennessee	2008
Choctawhatchee/Chipola / Perdido-Escambia/Chattahoochee	2009
Tallapoosa/Alabama/ Coosa	2010
Escatawpa/Upper Tombigbee/Lower Tombigbee/Mobile	2011

Monitoring will help further characterize water quality conditions resulting from the implementation of reduced waste load allocations and best management practices in the watershed.

7.0 Public Participation

As part of the public participation process, this TMDL was placed on public notice and made available for review and comment. The public notice was prepared and published in the four major daily newspapers in Montgomery, Huntsville, Birmingham, and Mobile, as well as submitted to persons who have requested to be on ADEM's postal and electronic mailing distributions. In addition, the public notice and subject TMDL was made available on ADEM's Website: www.adem.state.al.us. The public can also request paper or electronic copies of the TMDL by contacting Mr. Chris Johnson at 334-271-7827 or clj@adem.state.al.us. The public was given an opportunity to review the TMDL and submit comments to the Department in writing. At the end of the public review period, all written comments received during the public notice period became part of the administrative record. ADEM considered all comments received by the public prior to finalization of this TMDL and subsequent submission to EPA Region 4 for final review and approval.

8.0 References

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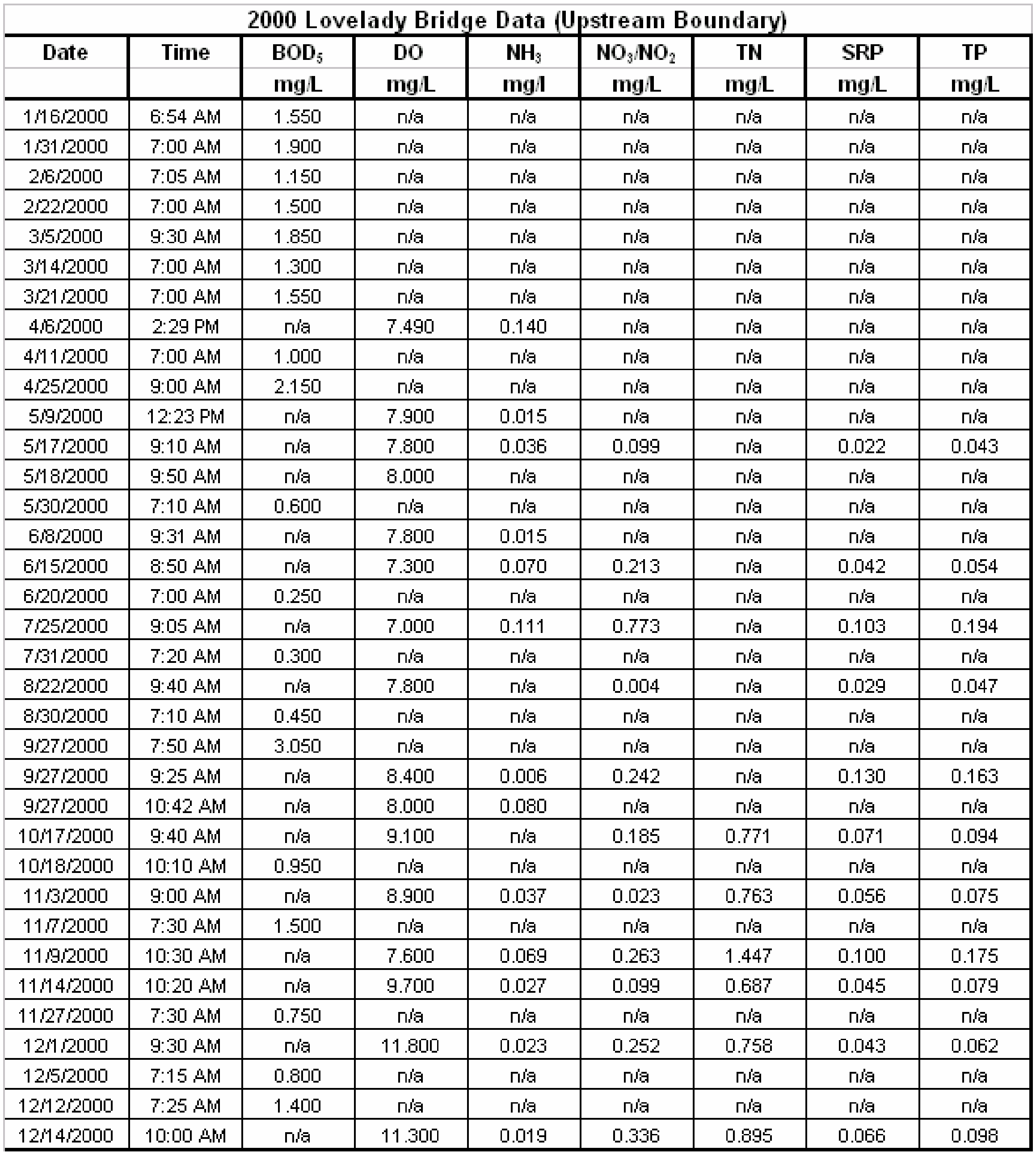
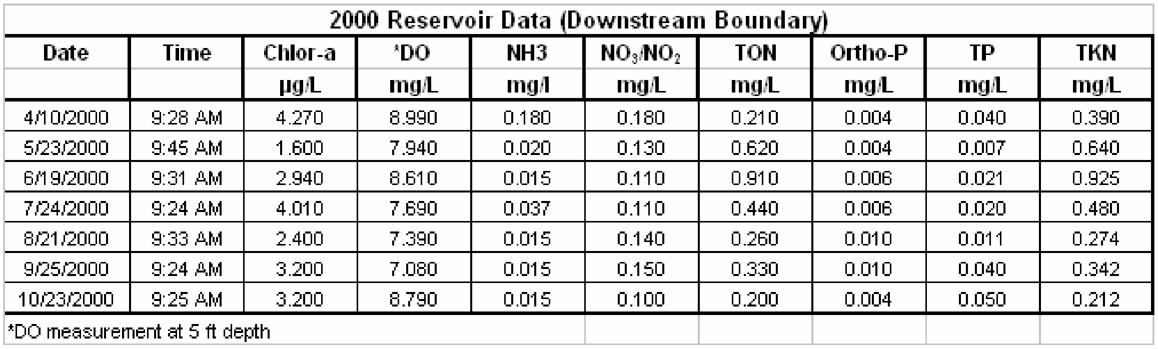
APPENDIX A: WATER QUALITY DATA



2000 Lovelady Bridge Data (Upstream Boundary)

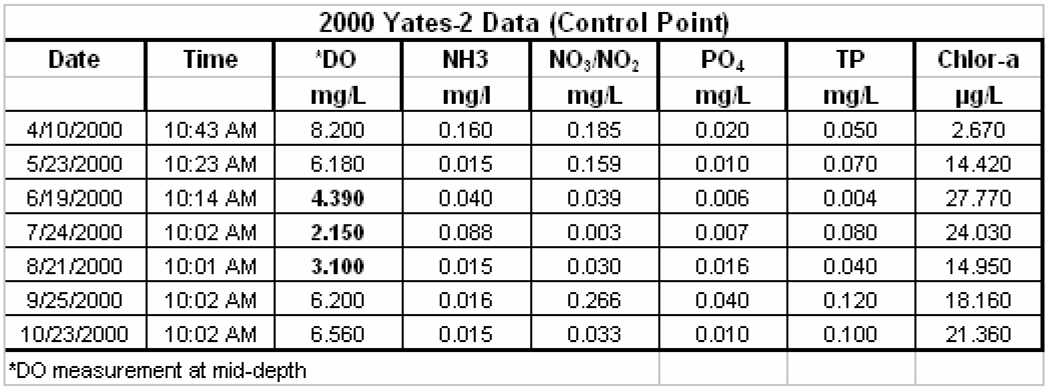
Date	Time	BOD_5	DO	NH_3	NO_3/NO_2	TN	SRP	TP
		mg/L	mg/L	mg/l	mg/L	mg/L	mg/L	mg/L
1/16/2000	6:54 AM	1.550	n/a	n/a	n/a	n/a	n/a	n/a
1/31/2000	7:00 AM	1.900	n/a	n/a	n/a	n/a	n/a	n/a
2/6/2000	7:05 AM	1.150	n/a	n/a	n/a	n/a	n/a	n/a
2/22/2000	7:00 AM	1.500	n/a	n/a	n/a	n/a	n/a	n/a
3/5/2000	9:30 AM	1.850	n/a	n/a	n/a	n/a	n/a	n/a
3/14/2000	7:00 AM	1.300	n/a	n/a	n/a	n/a	n/a	n/a
3/21/2000	7:00 AM	1.550	n/a	n/a	n/a	n/a	n/a	n/a
4/6/2000	2:29 PM	n/a	7.490	0.140	n/a	n/a	n/a	n/a
4/11/2000	7:00 AM	1.000	n/a	n/a	n/a	n/a	n/a	n/a
4/25/2000	9:00 AM	2.150	n/a	n/a	n/a	n/a	n/a	n/a
5/9/2000	12:23 PM	n/a	7.900	0.015	n/a	n/a	n/a	n/a
5/17/2000	9:10 AM	n/a	7.800	0.036	0.099	n/a	0.022	0.043
5/18/2000	9:50 AM	n/a	8.000	n/a	n/a	n/a	n/a	n/a
5/30/2000	7:10 AM	0.600	n/a	n/a	n/a	n/a	n/a	n/a
6/8/2000	9:31 AM	n/a	7.800	0.015	n/a	n/a	n/a	n/a
6/15/2000	8:50 AM	n/a	7.300	0.070	0.213	n/a	0.042	0.054
6/20/2000	7:00 AM	0.250	n/a	n/a	n/a	n/a	n/a	n/a
7/25/2000	9:05 AM	n/a	7.000	0.111	0.773	n/a	0.103	0.194
7/31/2000	7:20 AM	0.300	n/a	n/a	n/a	n/a	n/a	n/a
8/22/2000	9:40 AM	n/a	7.800	n/a	0.004	n/a	0.029	0.047
8/30/2000	7:10 AM	0.450	n/a	n/a	n/a	n/a	n/a	n/a
9/27/2000	7:50 AM	3.050	n/a	n/a	n/a	n/a	n/a	n/a
9/27/2000	9:25 AM	n/a	8.400	0.006	0.242	n/a	0.130	0.163
9/27/2000	10:42 AM	n/a	8.000	0.080	n/a	n/a	n/a	n/a
10/17/2000	9:40 AM	n/a	9.100	n/a	0.185	0.771	0.071	0.094
10/18/2000	10:10 AM	0.950	n/a	n/a	n/a	n/a	n/a	n/a
11/3/2000	9:00 AM	n/a	8.900	0.037	0.023	0.763	0.056	0.075
11/7/2000	7:30 AM	1.500	n/a	n/a	n/a	n/a	n/a	n/a
11/9/2000	10:30 AM	n/a	7.600	0.069	0.263	1.447	0.100	0.175
11/14/2000	10:20 AM	n/a	9.700	0.027	0.099	0.687	0.045	0.079
11/27/2000	7:30 AM	0.750	n/a	n/a	n/a	n/a	n/a	n/a
12/1/2000	9:30 AM	n/a	11.800	0.023	0.252	0.758	0.043	0.062
12/5/2000	7:15 AM	0.800	n/a	n/a	n/a	n/a	n/a	n/a
12/12/2000	7:25 AM	1.400	n/a	n/a	n/a	n/a	n/a	n/a
12/14/2000	10:00 AM	n/a	11.300	0.019	0.336	0.895	0.066	0.098



2000 Reservoir Data (Downstream Boundary)

Date	Time	Chlor-a	*DO	NH3	NO$_3$/NO$_2$	TON	Ortho-P	TP	TKN
		µg/L	mg/L	mg/l	mg/L	mg/L	mg/L	mg/L	mg/L
4/10/2000	9:28 AM	4.270	8.990	0.180	0.180	0.210	0.004	0.040	0.390
5/23/2000	9:45 AM	1.600	7.940	0.020	0.130	0.620	0.004	0.007	0.640
6/19/2000	9:31 AM	2.940	8.610	0.015	0.110	0.910	0.006	0.021	0.925
7/24/2000	9:24 AM	4.010	7.690	0.037	0.110	0.440	0.006	0.020	0.480
8/21/2000	9:33 AM	2.400	7.390	0.015	0.140	0.260	0.010	0.011	0.274
9/25/2000	9:24 AM	3.200	7.080	0.015	0.150	0.330	0.010	0.040	0.342
10/23/2000	9:25 AM	3.200	8.790	0.015	0.100	0.200	0.004	0.050	0.212

*DO measurement at 5 ft depth



2000 Yates-2 Data (Control Point)

Date	Time	*DO	NH3	NO$_3$/NO$_2$	PO$_4$	TP	Chlor-a
		mg/L	mg/l	mg/L	mg/L	mg/L	µg/L
4/10/2000	10:43 AM	8.200	0.160	0.185	0.020	0.050	2.670
5/23/2000	10:23 AM	6.180	0.015	0.159	0.010	0.070	14.420
6/19/2000	10:14 AM	**4.390**	0.040	0.039	0.006	0.004	27.770
7/24/2000	10:02 AM	**2.150**	0.088	0.003	0.007	0.080	24.030
8/21/2000	10:01 AM	**3.100**	0.015	0.030	0.016	0.040	14.950
9/25/2000	10:02 AM	6.200	0.016	0.266	0.040	0.120	18.160
10/23/2000	10:02 AM	6.560	0.015	0.033	0.010	0.100	21.360

*DO measurement at mid-depth

2002 Lovelady Bridge Data (Upstream Boundary)

Date	Time	BOD_5	DO	NH_3	NO_3/NO_2	TN	SRP	TP
		mg/L	mg/L	mg/l	mg/L	mg/L	mg/L	mg/L
1/10/2002	7:30 AM	0.900	14.050	0.075	0.691	0.949	0.039	0.074
1/31/2002	7:40 AM	1.050	9.900	0.048	0.367	0.769	0.063	0.063
2/6/2002	10:24 AM	2.600	11.200	0.320	0.413	2.836	0.027	0.375
2/14/2002	7:20 AM	1.100	12.000	0.034	0.298	0.520	0.026	0.048
2/20/2002	1:00 PM	1.150	11.000	0.010	0.191	0.553	0.026	0.050
3/6/2002	7:10 AM	0.750	12.400	0.043	0.002	0.720	0.012	0.055
3/21/2002	9:20 AM	1.850	9.100	0.227	0.054	1.339	0.015	0.171
4/4/2002	7:15 AM	0.600	9.250	0.061	0.132	0.718	0.023	0.044
4/17/2002	7:18 AM	0.650	8.300	0.084	0.270	0.654	0.020	0.057
5/8/2002	7:05 AM	0.450	7.800	0.067	0.558	0.927	0.028	0.062
6/5/2002	7:20 AM	0.400	6.200	0.041	0.182	0.666	0.033	0.060
7/18/2002	7:15 AM	0.850	6.000	0.025	0.780	1.299	0.063	0.098
8/27/2002	9:40 AM	n/a	6.800	n/a	n/a	n/a	n/a	n/a
8/29/2002	7:20 AM	0.350	6.400	0.025	0.177	0.788	0.038	0.127
8/30/2002	12:55 PM	n/a	7.200	0.064	n/a	n/a	n/a	n/a
9/19/2002	7:20 AM	0.250	6.500	0.042	0.367	1.899	0.052	0.069
10/4/2002	7:40 AM	n/a	6.800	n/a	0.350	0.895	0.056	0.079
10/16/2002	9:10 AM	0.860	8.200	0.049	0.312	1.187	0.073	0.103
11/5/2002	7:20 AM	0.650	8.300	0.063	0.137	0.685	0.066	0.092
11/11/2002	1:55 PM	1.270	8.800	0.057	0.477	1.226	0.050	0.134
11/21/2002	8:15 AM	0.920	10.000	0.054	0.475	0.860	0.034	0.061
12/5/2002	7:30 AM	1.060	11.200	0.031	0.339	1.086	0.041	0.066
12/18/2002	7:30 AM	0.440	11.200	0.043	0.569	0.909	0.025	0.048

2002 Reservoir Data (Downstream Boundary)

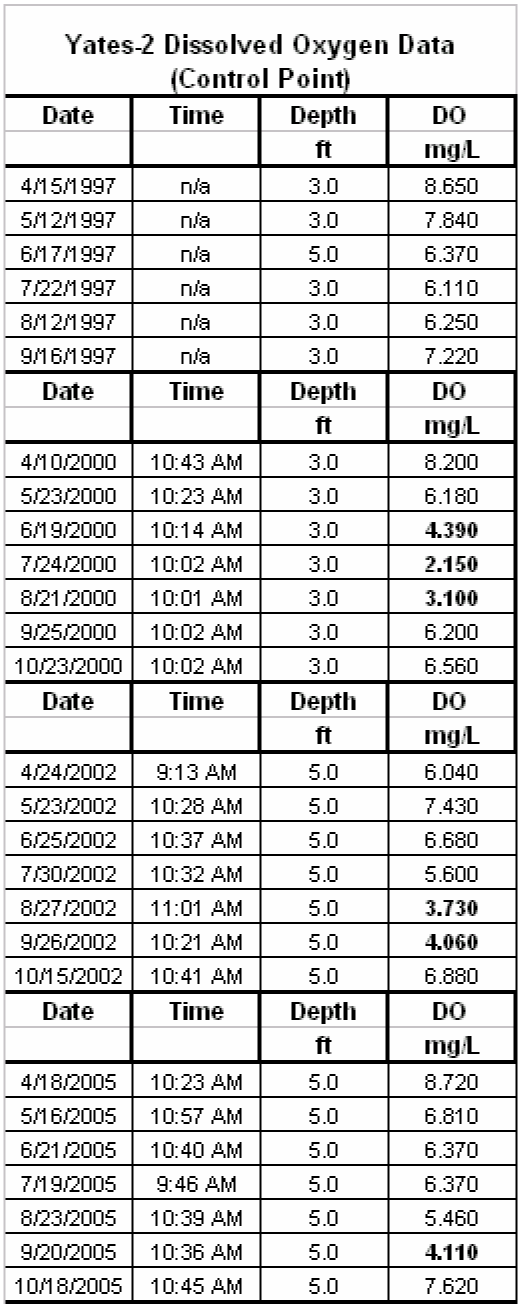
Date	Time	Chlor-a	*DO	NH3	NO_3/NO_2	TON	Ortho-P	TP	TKN
		µg/L	mg/L	mg/l	mg/L	mg/L	mg/L	mg/L	mg/L
4/24/2002	8:23 AM	6.940	8.920	0.020	0.090	0.140	0.020	0.030	0.390
5/23/2002	9:58 AM	2.400	8.690	0.020	0.120	0.140	0.010	0.030	0.640
6/25/2002	10:01 AM	2.940	8.870	0.020	0.140	0.670	0.010	0.040	0.925
7/30/2002	10:00 AM	3.740	7.210	0.020	0.160	0.330	0.010	0.070	0.480
8/27/2002	9:37 AM	4.540	8.210	0.060	0.140	0.100	0.010	0.050	0.274
9/26/2002	9:40 AM	2.940	8.180	0.190	0.160	0.010	0.020	0.040	0.342
10/15/2002	10:03 AM	37.740	7.670	0.050	0.150	0.100	0.010	0.030	0.212

*DO measurement at 5 ft depth

2002 Yates-2 Data (Control Point)

Date	Time	*DO	NH3	NO_3/NO_2	PO_4	TP	Chlor-a
		mg/L	mg/l	mg/L	mg/L	mg/L	µg/L
4/24/2002	9:13 AM	6.040	0.015	0.190	0.024	0.050	7.830
5/23/2002	10:28 AM	7.430	0.015	0.213	0.008	0.050	13.300
6/25/2002	10:37 AM	6.680	0.015	0.151	0.004	0.061	22.800
7/30/2002	10:32 AM	5.600	0.015	0.338	0.013	0.096	30.440
8/27/2002	11:01 AM	3.730	0.064	0.022	0.014	0.072	18.690
9/26/2002	10:21 AM	4.060	0.124	0.159	0.017	0.039	22.790
10/15/2002	10:41 AM	6.880	0.028	0.110	0.022	0.061	30.440

*DO measurement at 5 ft depth



Yates-2 Dissolved Oxygen Data (Control Point)

Date	Time	Depth ft	DO mg/L
4/15/1997	n/a	3.0	8.650
5/12/1997	n/a	3.0	7.840
6/17/1997	n/a	5.0	6.370
7/22/1997	n/a	3.0	6.110
8/12/1997	n/a	3.0	6.250
9/16/1997	n/a	3.0	7.220
Date	**Time**	**Depth ft**	**DO mg/L**
4/10/2000	10:43 AM	3.0	8.200
5/23/2000	10:23 AM	3.0	6.180
6/19/2000	10:14 AM	3.0	**4.390**
7/24/2000	10:02 AM	3.0	**2.150**
8/21/2000	10:01 AM	3.0	**3.100**
9/25/2000	10:02 AM	3.0	6.200
10/23/2000	10:02 AM	3.0	6.560
Date	**Time**	**Depth ft**	**DO mg/L**
4/24/2002	9:13 AM	5.0	6.040
5/23/2002	10:28 AM	5.0	7.430
6/25/2002	10:37 AM	5.0	6.680
7/30/2002	10:32 AM	5.0	5.600
8/27/2002	11:01 AM	5.0	**3.730**
9/26/2002	10:21 AM	5.0	**4.060**
10/15/2002	10:41 AM	5.0	6.880
Date	**Time**	**Depth ft**	**DO mg/L**
4/18/2005	10:23 AM	5.0	8.720
5/16/2005	10:57 AM	5.0	6.810
6/21/2005	10:40 AM	5.0	6.370
7/19/2005	9:46 AM	5.0	6.370
8/23/2005	10:39 AM	5.0	5.460
9/20/2005	10:36 AM	5.0	**4.110**
10/18/2005	10:45 AM	5.0	7.620

ADEM 2004 Pepperell Branch Bioassessment Study

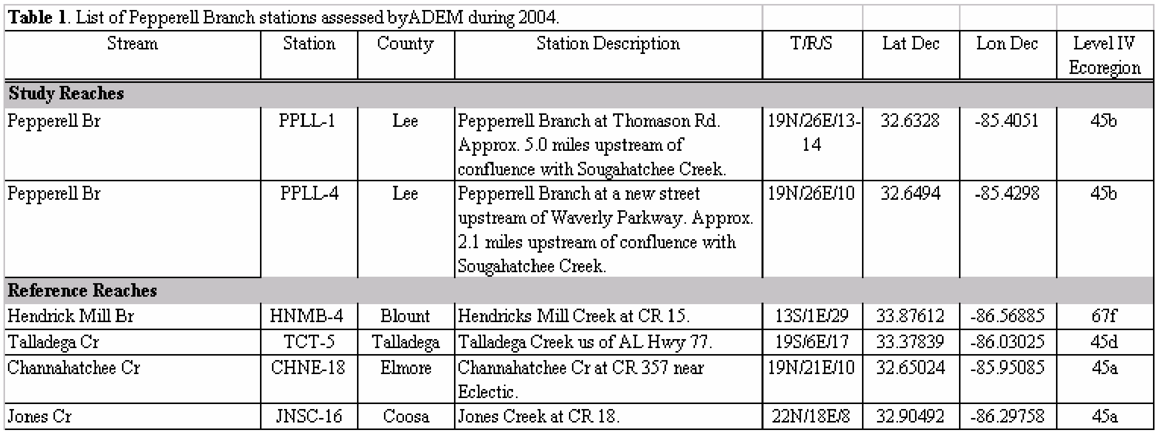


Table 1. List of Pepperell Branch stations assessed byADEM during 2004.

Stream	Station	County	Station Description	T/R/S	Lat Dec	Lon Dec	Level IV Ecoregion
Study Reaches							
Pepperell Br	PPLL-1	Lee	Pepperrell Branch at Thomason Rd. Approx. 5.0 miles upstream of confluence with Sougahatchee Creek.	19N/26E/13-14	32.6328	-85.4051	45b
Pepperell Br	PPLL-4	Lee	Pepperrell Branch at a new street upstream of Waverly Parkway. Approx. 2.1 miles upstream of confluence with Sougahatchee Creek.	19N/26E/10	32.6494	-85.4298	45b
Reference Reaches							
Hendrick Mill Br	HNMB-4	Blount	Hendricks Mill Creek at CR 15.	13S/1E/29	33.87612	-86.56885	67f
Talladega Cr	TCT-5	Talladega	Talladega Creek us of AL Hwy 77.	19S/6E/17	33.37839	-86.03025	45d
Channahatchee Cr	CHNE-18	Elmore	Channahatchee Cr at CR 357 near Eclectic.	19N/21E/10	32.65024	-85.95085	45a
Jones Cr	JNSC-16	Coosa	Jones Creek at CR 18.	22N/18E/8	32.90492	-86.29758	45a

Table 2. Summary of assessment results.

Station		HNMB-4	TCT-5	CHNE-18	JNSC-16	PPLL-1	PPLL-4
Level IV Ecoregion		67f	45d	45a	45a	45b	45b
Drainage Area (mi^2)		7	70	36	6	5	7
Macroinvertebrate Assessment Results							
Date (yymmdd)		040623	040629	040625	040625	040624	040624
# EPT Families		18	14	11	15	2	3
EPT Assessment		Excellent	Good	Good	Good	Poor	Poor
Periphyton Assessment Results							
Date (yymmdd)		040805	040726	040721	040726	040721	040719
Periphyton Chlorophyll *a* (mg/m^2)		6.53	9.61	1.41	1.36	25.25	9.2
Periphyton Assessment		---	---	---	---	Very Enriched	Slightly Enriched
AGPT (mg/L)		---	---	---	---	---	---
Limiting nutrient		---	---	---	---	---	---
Physical Characateristics[b]							
Width (ft)		10	45	14	10	12	18
Canopy cover[c]		S	MO	S	50/50	MO	50/50
Depth (ft)	Riffle	0.3	0.5	0.3	0.2	0.4	0.6
	Run	0.6	1.5	1.5	0.8	0.8	1.5
	Pool	1.0	3.0	2.0	1.2	1.5	1.5
Substrate (%)	Bedrock	40	30	5	6	15	30
	Boulder	7	20	3	3	0	20
	Cobble	20	20	15	20	5	15
	Gravel	15	10	10	20	15	15
	Sand	8	17	45	36	53	14
	Silt	0	1	10	3	10	2
	Detritus	10	2	9	12	0	4
	Clay	0	0	1	0	2	0
	Organic silt	0	0	2	0	0	0
Habitat Assessments[b]							
Form[d,e]		RR	RR	RR	RR	RR	RR
Habitat survey (% maximum)							
	Instream habitat quality	84	81	63	74	35	90
	Sediment deposition	78	79	55	51	44	60
	Sinuosity	82	30	68	80	23	95
	Bank and vegetative stability	53	71	44	64	43	88
	Riparian measurements	99	53	91	43	28	85
Habitat assessment score		193	171	164	158	87	201
% Maximum		80	71	68	66	36	84
Habitat Assessment[e]		Excellent	Good	Good	Good	Poor	Excellent

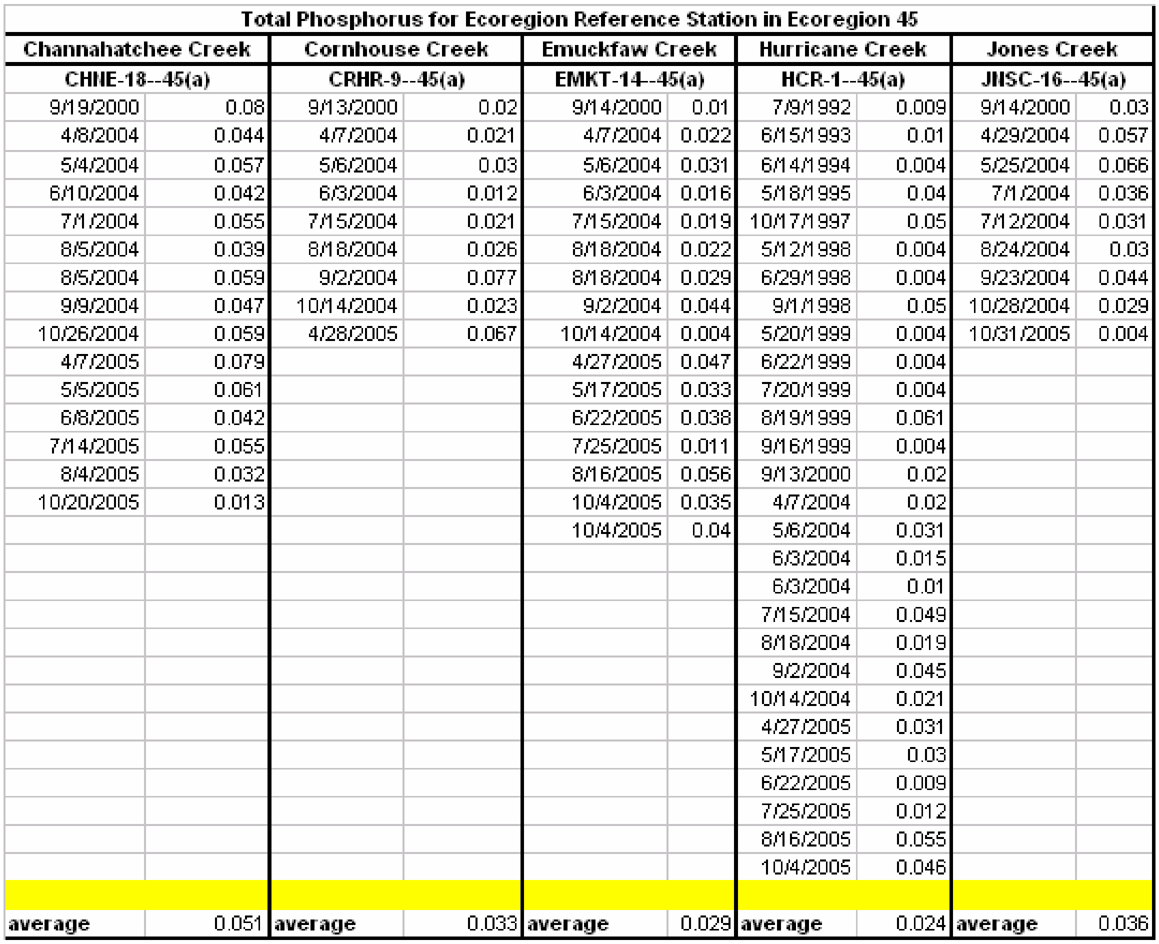
a. Completed during periphyton assessment

b. Completed during macroinvertebrate assessment

c. Canopy cover: S=shaded; MS=mostly shaded; 50/50=50% shaded; MO=mostly open; O=open

d. Habitat assessment form: RR=riffle/run (Barbour et al. 1999); GP=glide/pool (Barbour et al. 1999)

e. Assessment guidelines based on data collected at reference sites, 1991-2003



Total Phosphorus for Ecoregion Reference Station in Ecoregion 45									
Channahatchee Creek		**Cornhouse Creek**		**Emuckfaw Creek**		**Hurricane Creek**		**Jones Creek**	
CHNE-18--45(a)		**CRHR-9--45(a)**		**EMKT-14--45(a)**		**HCR-1--45(a)**		**JNSC-16--45(a)**	
9/19/2000	0.08	9/13/2000	0.02	9/14/2000	0.01	7/9/1992	0.009	9/14/2000	0.03
4/8/2004	0.044	4/7/2004	0.021	4/7/2004	0.022	6/15/1993	0.01	4/29/2004	0.057
5/4/2004	0.057	5/6/2004	0.03	5/6/2004	0.031	6/14/1994	0.004	5/25/2004	0.066
6/10/2004	0.042	6/3/2004	0.012	6/3/2004	0.016	5/18/1995	0.04	7/1/2004	0.036
7/1/2004	0.055	7/15/2004	0.021	7/15/2004	0.019	10/17/1997	0.05	7/12/2004	0.031
8/5/2004	0.039	8/18/2004	0.026	8/18/2004	0.022	5/12/1998	0.004	8/24/2004	0.03
8/5/2004	0.059	9/2/2004	0.077	8/18/2004	0.029	6/29/1998	0.004	9/23/2004	0.044
9/9/2004	0.047	10/14/2004	0.023	9/2/2004	0.044	9/1/1998	0.05	10/28/2004	0.029
10/26/2004	0.059	4/28/2005	0.067	10/14/2004	0.004	5/20/1999	0.004	10/31/2005	0.004
4/7/2005	0.079			4/27/2005	0.047	6/22/1999	0.004		
5/5/2005	0.061			5/17/2005	0.033	7/20/1999	0.004		
6/8/2005	0.042			6/22/2005	0.038	8/19/1999	0.061		
7/14/2005	0.055			7/25/2005	0.011	9/16/1999	0.004		
8/4/2005	0.032			8/16/2005	0.056	9/13/2000	0.02		
10/20/2005	0.013			10/4/2005	0.035	4/7/2004	0.02		
				10/4/2005	0.04	5/6/2004	0.031		
						6/3/2004	0.015		
						6/3/2004	0.01		
						7/15/2004	0.049		
						8/18/2004	0.019		
						9/2/2004	0.045		
						10/14/2004	0.021		
						4/27/2005	0.031		
						5/17/2005	0.03		
						6/22/2005	0.009		
						7/25/2005	0.012		
						8/16/2005	0.055		
						10/4/2005	0.046		
average	0.051	**average**	0.033	**average**	0.029	**average**	0.024	**average**	0.036

Total Phosphorus for Ecoregion Reference Station in Ecoregion 45									
Paint Creek		Cheaha Creek		Choccolocco Creek		Shoal Creek		Talledega Creek	
PNTC-11--45(a)		CHEC-6--45(d)		CHOC-2--45(d)		SHLC-3--45(d)		TCT-5 45(d)	
9/14/2000	0.02	9/14/2000	0.03	9/18/2000	0.03	9/18/2000	0.04	6/16/1993	0.019
4/10/2003	0.019	4/6/2004	0.022	4/6/2004	0.03	9/18/2000	0.02	6/16/1993	0.012
5/8/2003	0.083	5/5/2004	0.029	5/5/2004	0.054	4/6/2004	0.023	5/16/1995	0.07
6/9/2003	0.034	6/2/2004	0.021	6/2/2004	0.026	5/5/2004	0.06	5/12/1998	0.007
7/10/2003	0.026	7/14/2004	0.021	7/14/2004	0.053	6/2/2004	0.02	7/27/1998	0.004
8/4/2003	0.039	8/17/2004	0.023	8/17/2004	0.059	7/14/2004	0.049	9/1/1998	0.004
9/4/2003	0.029	9/1/2004	0.046	9/1/2004	0.049	8/17/2004	0.058	9/14/2000	0.01
10/16/2003	0.042	10/13/2004	0.007	10/13/2004	0.021	9/1/2004	0.047	4/9/2003	0.032
4/7/2005	0.053	4/6/2005	0.033	10/13/2004	0.031	10/13/2004	0.029	5/1/2003	0.007
5/4/2005	0.065	5/4/2005	0.024	4/7/2005	0.024	4/7/2005	0.019	6/5/2003	0.029
6/7/2005	0.042	6/7/2005	0.004	5/4/2005	0.064	5/4/2005	0.061	7/17/2003	0.054
7/13/2005	0.043	7/13/2005	0.014	6/8/2005	0.041	6/9/2005	0.04	8/6/2003	0.038
8/3/2005	0.042	8/3/2005	0.041	7/20/2005	0.046	7/21/2005	0.016	10/2/2003	0.004
10/18/2005	0.011	10/24/2005	0.004	8/24/2005	0.004	8/25/2005	0.004	10/22/2003	0.043
								4/6/2004	0.02
								5/5/2004	0.0291
								6/2/2004	0.022
								7/14/2004	0.052
								8/17/2004	0.024
								9/1/2004	0.044
								10/13/2004	0.022
								4/11/2005	0.047
								5/3/2005	0.035
								6/7/2005	0.009
								7/13/2005	0.008
								8/2/2005	0.03
								10/24/2005	0.004
average	0.039	average	0.023	average	0.038	average	0.035	average	0.025

Station	Growing Season Average (GSA) TP (mg/L)
All Eco-Reference Stations (Level III)	0.03
Pepperell Branch (PPLL-1) (50% reduction to NPS and 91% reduction to WPS)	0.03
Pepperell Branch (PPLL-4) (50% reduction to NPS and 91% reduction to WPS)	0.03

PPLL-1 is located near the headwaters of Pepperell Branch. PPLL-4 is a station that is located just downstream of a major industrial point source, West Point Stevens. According to the data provided by the Pepperell Branch bioassessment, the periphyton assessment at PPLL-4 is only slightly enriched with a relatively low chlorophyll *a* value of 9.2 mg/m^2. Comparing PPLL-4 periphyton assessment to the periphyton assessment of a Level III Ecoregion (45) reference stream, Talladega Creek (TCT-5), PPLL-4 has a lower chlorophyll *a* value. The macroinvertebrate was poor at PPLL-4; however, this poor score does not appear to be the result of nutrient impairment, but caused by other contributing sources, such as sediment and/or chlorides discharged within the stream. The habitat assessment at PPLL-4 is excellent. Based on this data, and coupled with a fifty percent reduction in non-point total phosphorus and a ninety one percent reduction in West Point Stevens total phosphorus, nutrient loading from Pepperell Branch will be reduced and should no longer be a significant source of nutrients in the Sougahatchee Creek embayment.

APPENDIX B: MODEL CALIBRATION REPORT

Appendix B provides a detailed description of the modeling development in support of the Sougahatchee Creek watershed TMDL. The model development includes the setup, calibration, and confirmation of a dynamic watershed model, a dynamic instream hydraulic model, and an instream kinetic water quality model for Sougahatchee Creek watershed.

Technical Approach

In order to address the conditions within the watershed, a system of models was developed that provided simulation of the overland flow, instream hydrodynamics, and instream water quality. The system design was such that all flow and water quality conditions experienced within the Sougahatchee Creek watershed could be simulated using one set of tools.

A watershed model was constructed to simulate instream loading of pollutants from the land surface. The upper portion of the watershed is within an NPDES Stormwater Phase II Municipal Separate Storm Sewer System (MS4). What was traditionally considered as nonpoint source loads, are now considered the responsibility of the municipalities under an MS4 permit and therefore included in the TMDL as a wasteload. The Loading Simulation Program C++ (LSPC) was used to calculate stormwater runoff and hydrologic transport of pollutants based on historic precipitation records.

The watershed model was calibrated to flows collected at USGS gage 02418230 on Sougahatchee Creek at Lee Co. Rd 188. Hydrologic output from the watershed model was then used as input to an instream hydrodynamic model, the Environmental Fluid Dynamics Code (EFDC).

Total phosphorus loadings were also simulated using LSPC. Data collected by Auburn University and ADEM were used to calibrate total phosphorus in the watershed. Water quality output from the watershed model was then used as input to the instream water quality model Water-quality Analysis Simulation Program (WASP).

The EFDC model was used to simulate the hydraulics of the Sougahatchee Creek watershed and these simulated hydrodynamics were used as the basis for the WASP dynamic water quality simulation.

The final component in the series of models is WASP. WASP calculates the interaction of eight water quality constituents based on interspecies kinetics and user-defined rates, as a function of water temperature. The eight state variables are ammonia, orthophosphate, nitrates, chlorophyll *a*, DO, biochemical oxygen demand (BOD), organic nitrogen, and organic phosphorus. WASP includes consideration of sediment oxygen demand (SOD) and instream reaeration.

The water quality model was used to establish conditions during periods critical to management decisions for the TMDL and future use. Model scenarios were run from January 2000 to December 2002 to represent seasonal trends in the model.

Watershed Modeling

The Loading Simulation Program C++ (LSPC) was used to represent the hydrologic conditions and nutrient loadings from land activities in the Sougahatchee Creek watershed. LSPC is a comprehensive data management and modeling system that simulates pollutant loading from nonpoint sources. LSPC utilizes the hydrologic core program of the Hydrologic Simulation Program Fortran (HSPF, EPA 1996b), with custom interface of the Mining Data Analysis System (MDAS), with modifications for non-mining applications such as nutrient and pathogen modeling.

LSPC is a system designed to support TMDL development for areas impacted by both point and nonpoint sources. It is capable of simulating land-to-stream transport of flow, sediment, metals, nutrients, and other conventional parameters, as well as temperature and pH.

Model Development

The watershed model represented the variability of nonpoint source contributions through dynamic representation of hydrology and land practices. The watershed model included nonpoint source contributions and point source contributions. Key components of the watershed modeling included:

- Watershed segmentation
- Meteorological Data
- Stream flow Data
- Soils
- Land use Representation
- Reach Characteristics
- Point Source Discharges
- Hydrological Representation
- Water Quality Representation
- Simulation Data

Watershed Segmentation

In order to evaluate the sources contributing to the impaired waterbody and to represent their spatial variability in the watershed model, the contributing drainage area was represented by a series of watersheds. The Sougahatchee Creek watershed was delineated for appropriate hydrological connectivity and representation. The sub-watersheds were delineated using the National Elevation Dataset (NED), the National

Hydrography Dataset (NHD), National Land Coverage Data NLCD (2001), and various Geographic Information Systems (GIS) coverage. The delineated sub-watersheds and watershed elevations are shown in Figure B-1, below, and Figure B-2, on the next page.

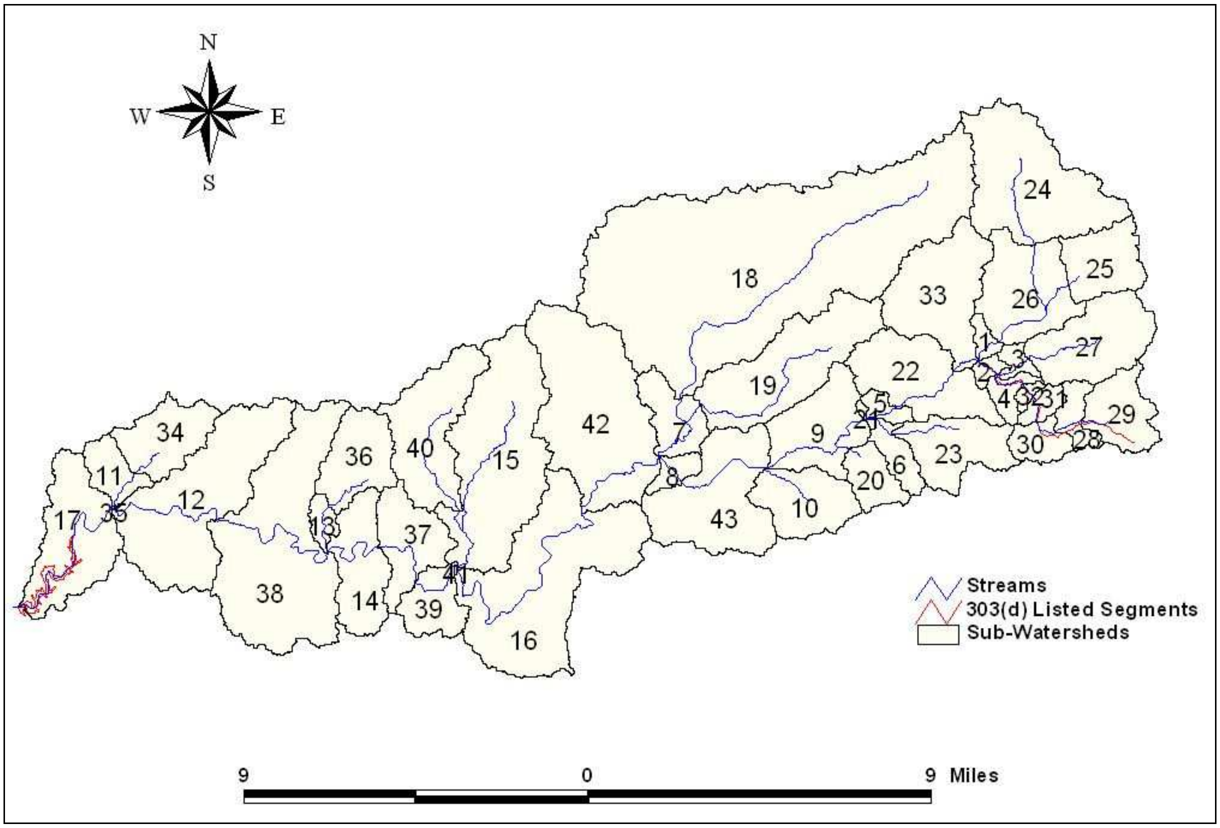


Figure B-1 Delineated Sub-watersheds in the Sougahatchee Creek Watershed

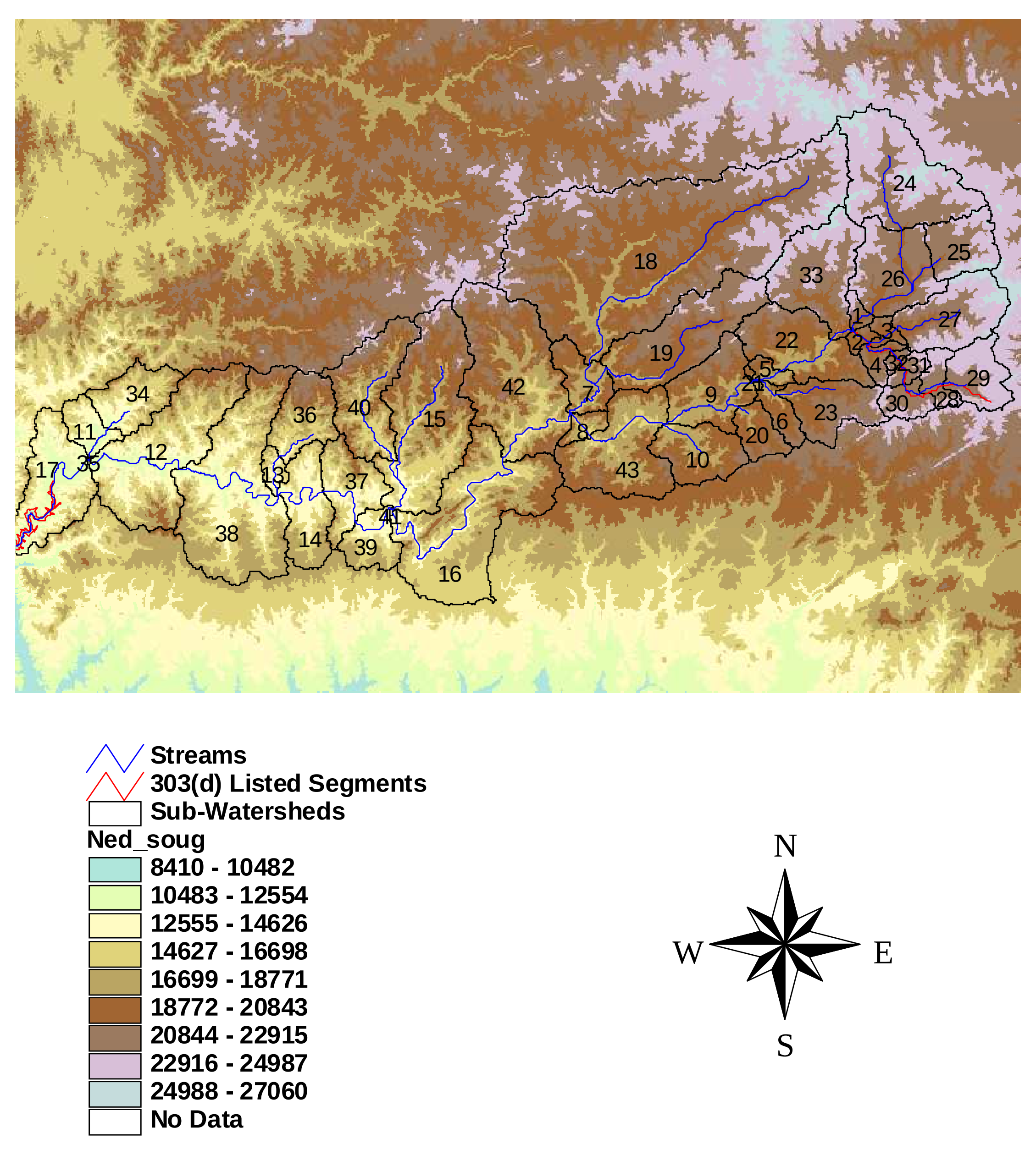


Figure B-2 NED in the Sougahatchee Creek Watershed

Meteorological Data

Nonpoint source loadings and hydrological conditions are dependent upon weather conditions. Weather data provided by Auburn University as well as rainfall from various precipitation stations within the watershed was applied to the model. An ASCII file was generated for each meteorological station. Each meteorological station file contains precipitation, and potential evapo-transpiration data used in modeling hydrological processes.

Stream flow Data

Measured stream flows are necessary to calibrate and validate modeled values. The USGS has collected continuous stream flow at USGS gage 02418230 on Sougahatchee Creek at Lee Co. Rd 188 since September 1999. Thus, the USGS collected daily average stream flow on Sougahatchee Creek (Gage 02418230) from January 2000 to December 2002 was used for this TMDL.

Soils

Soil data for the watershed were obtained from the State Soil Geographic Data Base (STATSGO). There are four main Hydrologic Soil Groups (Group A, B, C, and D). The different soil groups range from soils that have a low runoff potential to soils that have a high runoff potential. The four soils groups are described below:

> Group A Soils Low runoff potential and high infiltration rates even when wet. They consist chiefly of sand and gravel and are well to excessively drained.
>
> Group B Soils Moderate infiltration rates when wet and consist chiefly of soils that are moderately deep to deep, moderately to well drained, and moderately fine to fine texture.
>
> Group C Soils Low infiltration rates when wet and consist chiefly of soils having a layer that impedes downward movement of water with moderately fine to fine texture.
>
> Group D Soils High runoff potential, very low infiltration rates and consist chiefly of clay soils.

The total area that each hydrologic soil group covered within each sub-watershed was determined. In the Sougahatchee Creek watershed, Group B soil was dominate.

Land Use Representation

The National Land Coverage Data (NLCD, 2001) was used to provide the land use distribution utilized in the watershed model to develop the relative loads from urban, forested, agricultural, and other areas. The predominant land uses within the watershed are forest (includes shrub/grassland), agriculture (cropland + pasture), and urban. Their respective percentages of the total watershed are 76.8%, 11.7%, and 8.4%, respectively (NLCD, 2001). Figure B-3 represents the Sougahatchee Creek land use.

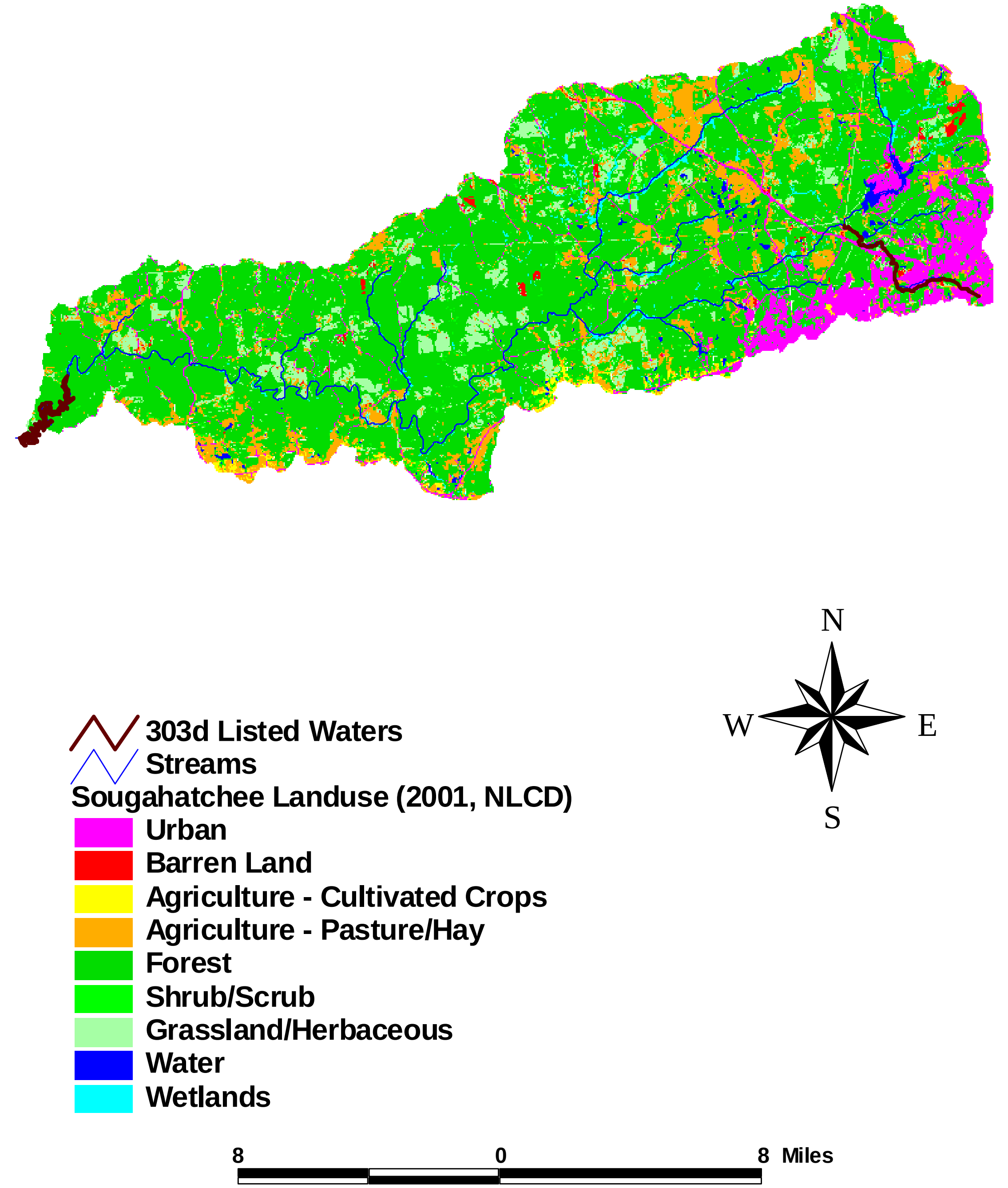


Figure B-3 **Sougahatchee Creek Watershed Land use**

Reach Characteristics

The LSPC model must have a representative reach defined for each sub-watershed. The characteristics for each reach include the length and slope of the reach, the channel geometry, and the connectivity between the sub-watersheds. Length and slope data for each reach was obtained using the National Elevation Dataset (NED) and the National Hydrography Dataset (NHD). The channel geometry was described by bank full width and depth (the main channel), a bottom width factor, a flood plain width factor and slope of the flood plain. Reach details are provided in Table B-1.

Table B-1 Sougahatchee Creek Reach Characteristics

Sub-Watershed	Area (m^2)	Length (meters)	Slope of Reach	Minimum Elevation (ft)	Maximum Elevation (ft)	Elevation Difference (ft)	Upstream Right Sub-watershed	Upstream Left Sub-watershed	Downstream Sub-watershed
1	5017.05	1461.02	0.0094	187.1	200.8	13.7	26	N/A	33
2	3717.63	1123.68	0.0027	186.5	189.5	3	3	4	33
3	1585.89	1670.96	0.0026	189.5	193.9	4.4	27	N/A	2
4	2012.49	1883.12	0.0063	188.5	200.3	11.8	32	N/A	2
5	12204.99	1421.55	0.0021	174	177	3	22	N/A	21
6	1389.78	1441.29	0.0074	172.8	183.4	10.6	23	N/A	21
7	12289.86	4255.61	0.0036	155.6	171.1	15.5	18	19	42
8	18615.15	1512.82	0.0065	154.6	164.4	9.8	43	N/A	42
9	15391.89	6159.27	0.0018	163.9	174.8	10.9	21	20	43
10	1011.42	2558.31	0.0055	163.5	177.5	14	N/A	N/A	43
11	1406.79	2080.68	0.0043	106.8	115.8	9	34	N/A	35
12	53048.79	6323.82	0.0013	106.6	114.6	8	38	N/A	35
13	1185.30	2250.40	0.0053	125.1	137.1	12	36	N/A	38
14	45258.66	4451.03	0.0012	123.5	128.9	5.4	37	N/A	38
15	4830.21	9186.14	0.0059	130.6	184.5	53.9	40	N/A	41
16	37690.92	13570.37	0.0012	130.4	146.9	16.5	42	N/A	41
17	56151.36	9344.33	0.0007	102.2	108.8	6.6	35	N/A	N/A
18	9483.03	17163.42	0.0024	170.5	211.7	41.2	N/A	N/A	7
19	2133.90	8439.06	0.0038	170.8	202.8	32	N/A	N/A	7
20	483.93	685.52	0.0117	170.6	178.6	8	N/A	N/A	9
21	13632.12	127.28	0.0071	174.8	175.7	0.9	5	6	9
22	12020.22	3564.34	0.0016	176.9	182.6	5.7	33	N/A	5
23	1033.29	3275.10	0.0040	180.5	193.7	13.2	N/A	N/A	6
24	2503.26	4421.49	0.0033	205.3	219.9	14.6	N/A	N/A	26
25	895.05	632.76	0.0013	206.8	207.6	0.8	N/A	N/A	26
26	4873.32	5885.88	0.0012	200.8	207.6	6.8	24	25	1
27	1420.65	3862.87	0.0045	193.6	210.8	17.2	N/A	N/A	3
28	1106.19	1316.11	0.0040	212.3	217.5	5.2	29	N/A	30
29	780.75	1255.48	0.0021	217.5	220.1	2.6	N/A	N/A	28
30	1481.22	1199.14	0.0056	207.4	214.1	6.7	28	N/A	31
31	1686.33	1398.83	0.0034	203.1	207.8	4.7	30	N/A	32
32	1770.30	706.70	0.0052	199.4	203.1	3.7	31	N/A	4
33	10479.69	1273.69	0.0041	182	187.2	5.2	1	2	22
34	944.73	1640.58	0.0093	114.3	129.6	15.3	N/A	N/A	11
35	54457.11	42.43	0.0165	107.2	107.9	0.7	11	12	17
36	981.99	2458.94	0.0083	131.3	151.6	20.3	N/A	N/A	13
37	44145.54	3282.79	0.0008	126.4	129	2.6	39	N/A	14
38	50163.66	8755.08	0.0017	113.2	128.3	15.1	13	14	12
39	43161.12	2855.52	0.0025	127.7	134.8	7.1	41	N/A	37
40	1683.81	6040.87	0.0057	141.5	176.1	34.6	N/A	N/A	15
41	42525.36	84.86	0.0141	133.5	134.7	1.2	15	16	39
42	34134.75	5395.60	0.0026	142.6	156.8	14.2	7	8	16
43	18386.82	4347.72	0.0012	160.8	165.8	5	9	10	8

Point Source Dischargers

Two municipalities, Opelika WWTP and Auburn Northside WWTP, and one industrial facility, West Point Stevens Finishing Plant, were considered in the modeling of this TMDL. The above mentioned dischargers are currently permitted to discharge oxygen consuming waste and contribute the majority of the wastewater flow to Pepperell Branch and Sougahatchee Creek. These facilities do not currently have total phosphorus limits. Discharge monitoring reports for these facilities provided inputs to the LSPC model.

Facility	Permit	Type	Receiving Water
Opelika Westside WWTP	AL 0050130	Municipal	Sougahatchee Creek
Auburn Northside WWTP	AL 0050245	Municipal	Sougahatchee Creek
*The Colony Apartments	AL 0045641	SPP	UT to Sougahatchee Creek
West Point Stevens Finish	AL 0002968	Industrial (Major)	Pepperell Branch

*Discharge currently inactive

Figure B-4, below, shows the point source location within the delineated sub-watershed.

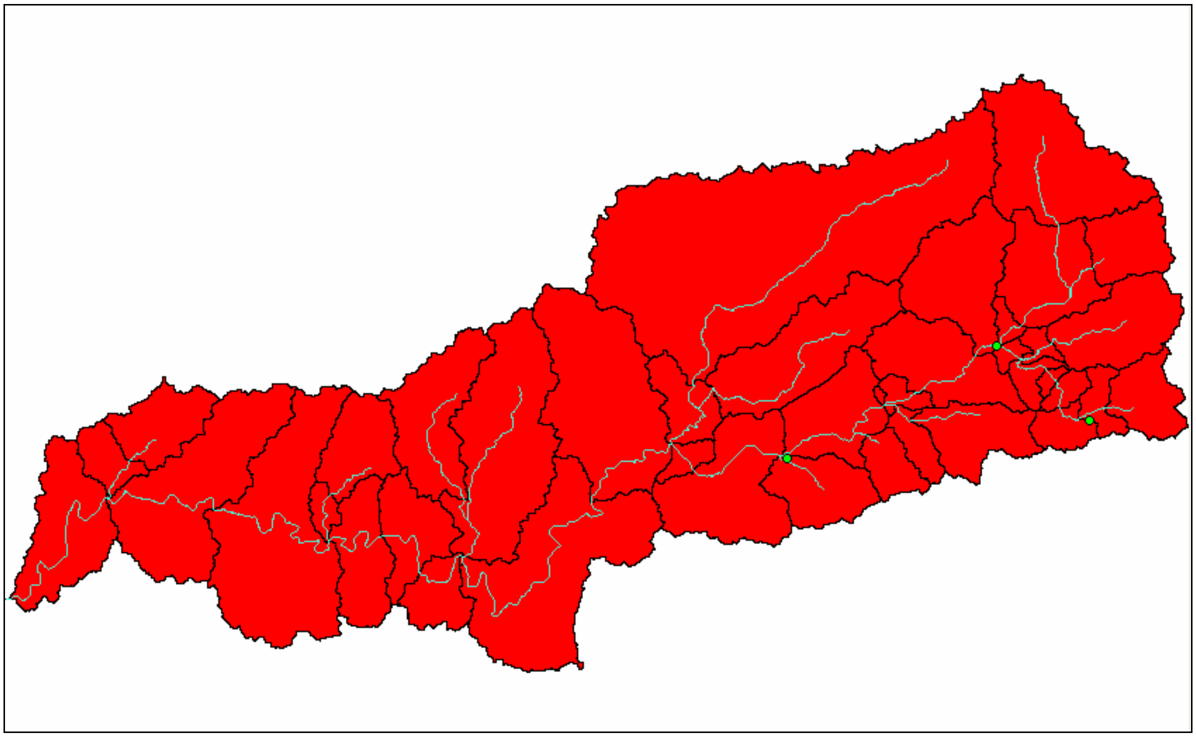


Figure B-4 Point Sources in Sougahatchee Creek Watershed

Hydrological Representation

LSPC allows the user to define various components of the water budget to represent hydrologic conditions in the watershed. User defined parameters representing the water budget include rates for evaporation, interception storage, overland flow, interflow, upper and lower zone storage, groundwater storage, and deep fraction groundwater storage. These parameters can be held constant or may vary seasonally, by soil type or land use. Table B-2 represents water budget variables in LSPC and the rates calibrated and validated for the Sougahatchee Creek watershed. More specific calculations used in the model to equate flows can be found in the HSPF User's Manual (Bicknell et al., 1996).

Table B-2 Watershed Model Parameters for Hydrologic Representation

Parameter ID	Parameter Description	Values
agwetp	Fraction of Remaining Potential ET that can be Satisfied from Active Groundwater	0.023
agwrc	Base Groundwater Recession	0.988
agws	Initial Active Groundwater Storage	0.01
basetp	Fraction of Remaining Potential ET that can be Satisfied from Baseflow	0.023
ceps	Initial Interception	0.01
cepsc	Interception Storage Capacity (inches)	0.1
deepfr	Fraction of Groundwater Inflow that will Enter Deep Groundwater	0.0
gwvs	Initial Index to Groundwater Slope	0.01
ifws	Initial Interflow Storage	0.01
infexp	Exponent in the Infiltration Equation	3.0
infild	Ratio between the Maximum and Mean Infiltration Capacities Over the PLS	2.0
infilt*	Index to the Infiltration Capacity of the Soil (in/hr)	0.11
intfw	Interflow Inflow Parameter	1.5
irc	Interflow Recession Parameter	0.6
kvary	Variable Groundwater Recession (1/in)	0.5
lzetp	Lower Zone ET Parameter	0.6
lzs	Initial Lower Zone Storage	6-8.0
lzsn	Lower Zone Nominal Soil Moisture Storage (inches)	6-12.0
nsur	Manning's for the Assumed Overland Flow Plane	0.2
petmax	Air Temperature below which ET is Reduced (˚F)	40
petmin	Air Temperature below which ET is Zero (˚F)	35
surs	Initial Surface (Overland Flow) Storage	0.01
uzs	Initial Upper Zone Storage	1.0
uzsn	Upper Zone Nominal Storage (in)	0.5

*The infiltration capacity is dependent on the Land use activity. Therefore, a highly impervious, urban area would be assigned a value of 0.01 and a wetland area a value of 0.6.

Water Quality Representation

The water quality representation of the watershed in LSPC was based on land based pollutant controls including rates of accumulation, wash off, and storage. Rates may be held constant, vary monthly, or by land use. Table B-3 represents water quality parameters in LSPC and the rates calibrated for the Sougahatchee Creek watershed. More specific calculations used in the model to determine pollutant concentrations and loads can be found in the HSPF User's Manual (Bicknell et al., 1996).

Table B-3 Watershed Model Parameters for Water Quality Representation

Parameter ID	Parameter Description	TP
QUALID	General Quality ID (QUAL)	
DECAY	General First Order Instream Loss Rate of Qual by Group (1/day)	0.7
SQO	Initial Storage of QUAL on Surface (m/acre)	0.0 -1.2
POTFW	Washoff Potency Factor (when sediment associated qsdfg >0) (m/ton)	0.0-0.017
POTFS	Scour Potency Factor (when sediment associated qsdf > 0) (m/ton)	0.0-0.017
ACQOP	Accumulation Rate of QUAL on Surface (m/acre/day)	0.0-0.80
SQOLIM	Maximum Storage of QUAL on Surface (m/acre)	0.0-7.20
WSQOP	Rate of Surface Runoff that Removes 90% of Stored QUAL (in/hr)	0.0-2.0
IOQC	Concentration of Constituents in Interflow Outflow (mg/l)	0.0-1.0
AOQC	Concentration of Constituents in Groundwater Outflow (mg/l)	0.0-1.0

Simulated Period

The LSPC was simulated on Sougahatchee Creek from January 1, 2000 through December 30, 2002. The USGS has collected flow on Sougahatchee Creek since 1999. The modeled flows were compared to the data collected by USGS from January 2000 through December 2002. To allow the model plenty of “spin-up” time, the model was run for four months (September 1999-December 1999) before the simulation period.

Watershed Model Calibration and Validation

The watershed model was calibrated for hydrologic and water quality parameters. Model calibration involved comparing simulated stream flows and nutrient (total phosphorus) concentrations with historic data collected on Sougahatchee Creek. The data used in calibration included data collected by Auburn University, ADEM, and USGS.

The hydrology calibration of the watershed model involved comparing simulated stream flows to historic stream flow from a USGS station for the same period of time. The hydrological parameters were calibrated using the continuous record at USGS station 02418230, Sougahatchee Creek at Lee Co. Rd 188. The calibration of the hydrological parameters includes the period from January 1, 2000 to December 30, 2002. Figure B-5 represents the 2000 hydrologic calibration of Sougahatchee Creek and 2002 hydrologic validation, respectively.

The water quality calibration of the watershed model involved comparing simulated total phosphorus concentrations to measured total phosphorus concentrations, by Auburn University and ADEM, at Sougahatchee Creek station: Lovelady Bridge. The model results for total phosphorus are shown in Figure B-6.

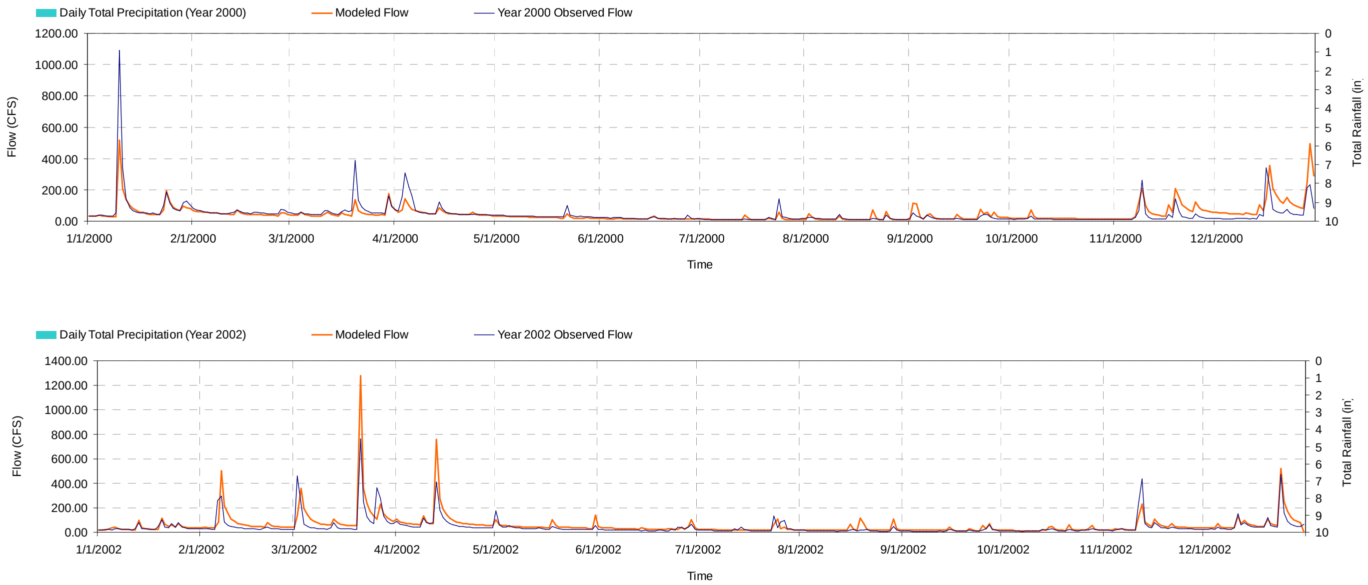


Figure B-5 2000 Hydrology Calibration and 2002 Validation for Sougahatchee Creek watershed

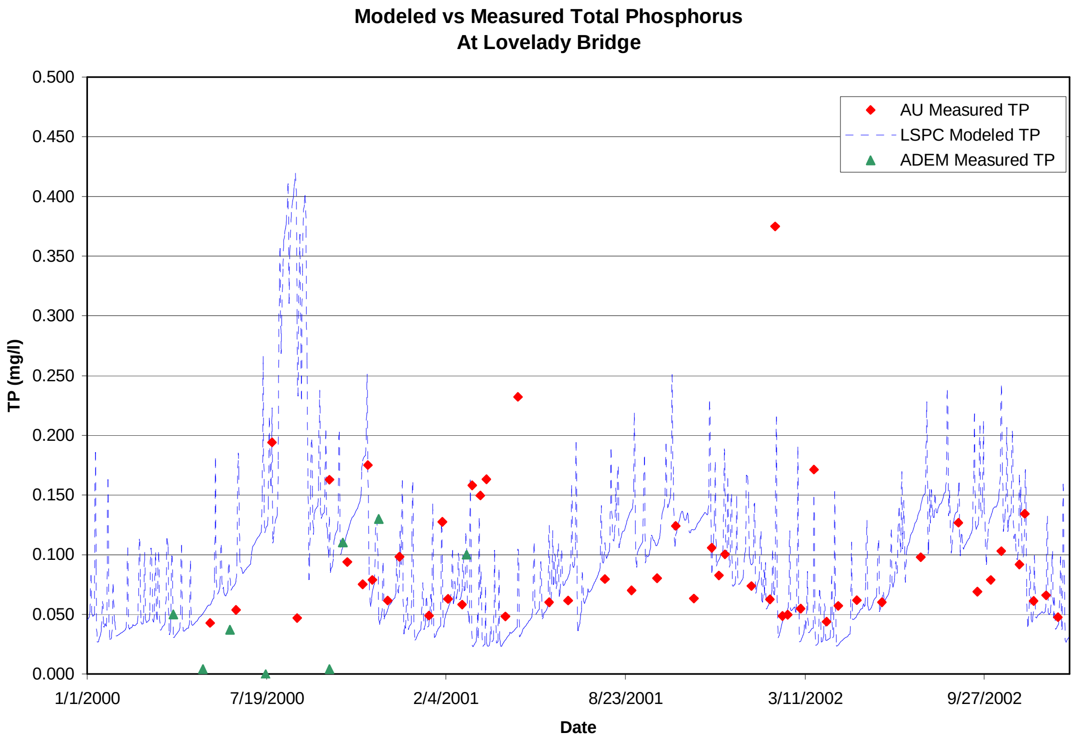


Figure B-6 Calibration of Total Phosphorus in Sougahatchee Creek at Lovelady Bridge

Hydrodynamic Modeling

The receiving water models take the pollutant loads from the watershed model (LSPC) along with available information on the point source loads from the watershed system, and provide for the transport and transformation of the material as it moves through the system.

In order to simulate the flow and transport within the listed segments, a hydrodynamic model called the Environmental Fluid Dynamics Code (EFDC) was used. EFDC is a general purpose modeling package for simulating 1-D, 2-D, and 3-D flow and transport in surface water systems including rivers, lakes, estuaries, reservoirs, wetlands, and near shore to shelf-scale coastal regions.

Lake Morphometry and Segmentation

The Sougahatchee Creek watershed TMDL model comprises the Sougahatchee Creek embayment, between the Tallapoosa River (Yates Reservoir) and Lovelady Bridge. This portion of the creek is narrow at the upstream boundary, Lovelady Bridge, and gradually widens to the mouth as it flows downstream to the Tallapoosa River. This section of the creek, the embayment, may be represented by a string of model cells, extending from Lovelady Bridge to Yates Reservoir, that are one-dimensional in the lateral (cross-flow) dimension.

EFDC performs calculations on a finite-difference grid, which is a representation of the embayment as a set of discrete cells on a regular spacing. The first step of the model setup is the definition of the model grid. The grid must provide a good approximation of the actual physical dimensions (morphometry) of the water body; however, specification of too complex a grid results in very long and inefficient simulations. EFDC is set up to use a curvilinear-orthogonal grid in the horizontal plane, consisting of an orthogonal grid that is stretched to provide a realistic representation of the curvature of the actual water body. Vertical structure is represented by specification of a fixed number of vertical subdivisions for each lateral grid cell. Different vertical cells thus have different thicknesses and elevations, depending on the bottom contours of the lake and water level simulation.

The EFDC grid was created in an Arcview environment by placing cell nodes along the creek at approximately 400-m intervals in the upstream direction beginning at the downstream boundary (Yates Reservoir). This spacing was selected based on preliminary analysis of stability criteria. Because the width of Sougahatchee Creek embayment is fairly constant, that is, wide at the mouth with a gradual narrowing moving upstream, the EFDC grid was arranged with one cell width representing the cross-section. Therefore, the model is primarily two-dimensional: longitudinal and vertical. The entire grid is made up of 24 cells that are each modeled in 4 layers. The Sougahatchee Creek embayment grid is shown in Figure B-7.

Vertical segmentation of the EFDC is accomplished by specifying the relative thickness of model layers. EFDC uses a sigma grid in which a fixed number of vertical layers are distributed across all lateral cells. Vertical layers thus do not have a fixed depth, but rather vary according to the depth of a given segment at a given time. This can present some problems in matching model results to a DO criterion that is specified at a fixed depth of 5 feet. A total of four layers were used in the simulations. These were specified such that the top layer will approximately coincide with the 5-foot compliance depth in the portion of the embayment at station, Yates 2. The relative proportion of the vertical scale assigned to the four layers were (from surface to bottom) 0.25, 0.25, 0.25, and 0.25.

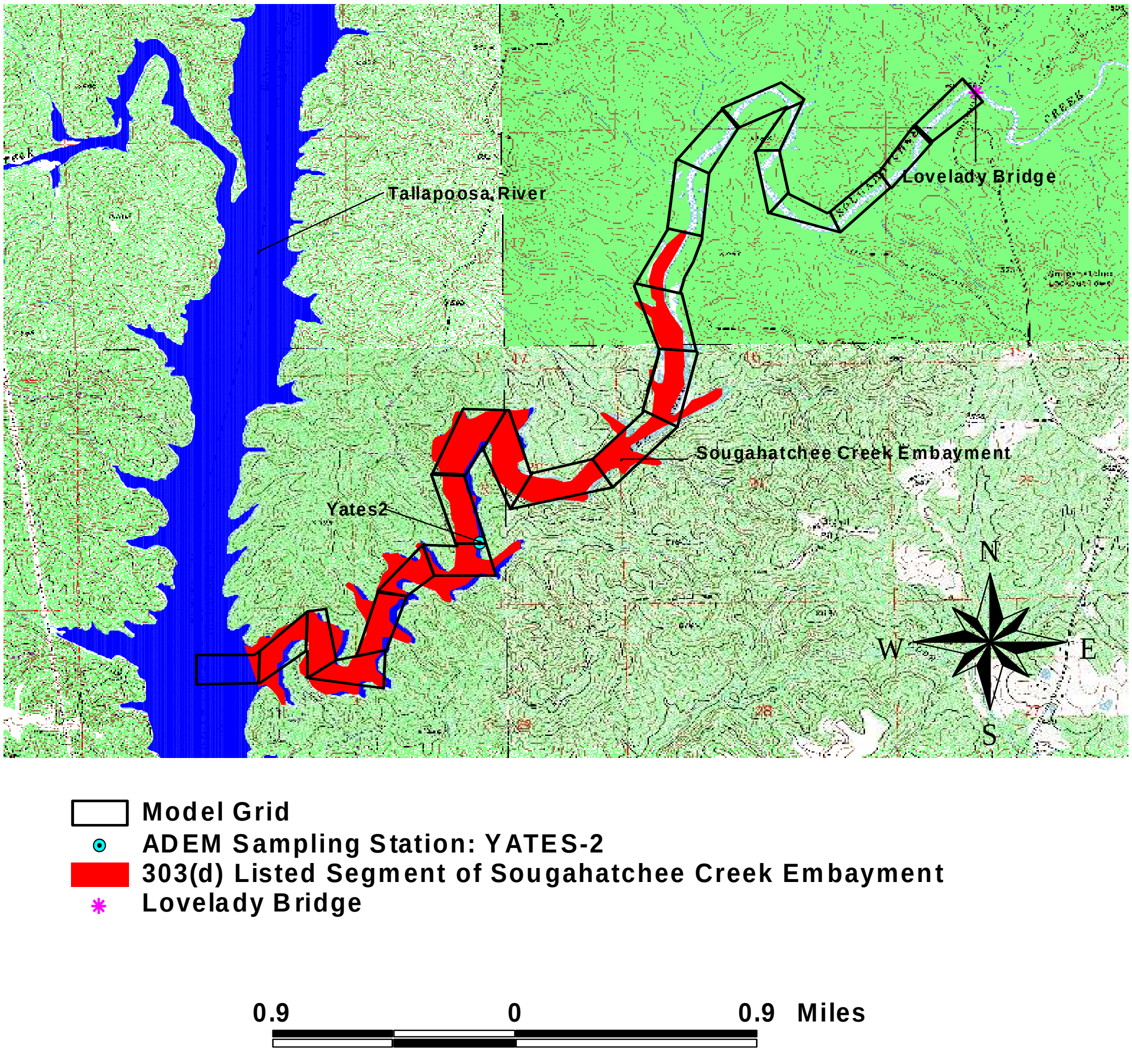


Figure B-7 EFDC and WASP Model Grid Representing the Sougahatchee Creek Embayment

External Forcing Functions

The EFDC simulation requires specification of a number of external data series to implement the hydrodynamic and thermal simulation, including flows, precipitation, temperature, etc. These series are documented below.

Flows

All flows must be specified in the file “Qser.inp.” Daily flow rates measured at Yates Dam were used for the lake boundary flow. Flows at the upstream boundary, Lovelady Bridge, were provided by LSPC. Figure B-8 shows the calibrated flows at Lovelady Bridge.

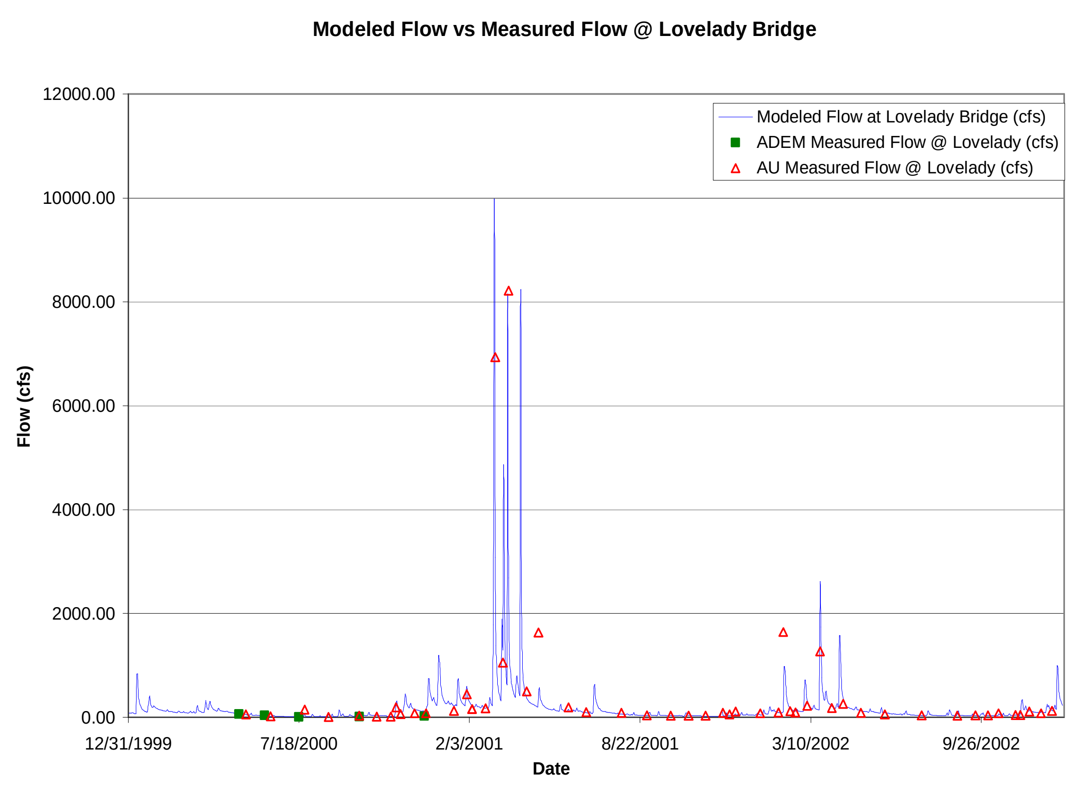


Figure B-8 **Calibrated Sougahatchee Creek Flows at Lovelady Bridge**

Air temperature

The air temperature that was used in the simulation was obtained from AWIS Weather Services, Inc., Auburn University Mesonet station Auburn_CR10.

Solar Radiation

Solar radiation data was obtained from AWIS Weather Services, Inc., Auburn University Mesonet station Auburn_CR10.

Atmospheric Pressure

Atmospheric pressure data were obtained from the Columbus, Georgia Metropolitan Airport.

Wind Movement

Daily wind movement (converted to m/s) and average wind direction were input as daily averages. These data were also obtained from the Columbus, Georgia Metropolitan Airport.

Influent Water Temperature

Water temperature data was measured data from both Auburn University, Department of Fisheries and Allied Aquacultures, and the Alabama Department of Environmental Management (ADEM).

Initial Conditions

EFDC simulations were implanted on a yearly basis, commencing on January 1. Initial conditions must be specified for lake surface elevation and water temperature. The elevations were set at the start of each year from the Alabama Power Company with the assumption that the lake surface was level. Starting temperatures for the simulation were assigned 9 degrees Centigrade throughout (no thermal stratification), which is assumed to be a typical condition for that time of year.

EFDC Calibration and Validation Approach

Results from the EFDC model are strongly determined by the specification of external forcings and water body morphometry. Because the physics of flow and water temperature are well understood, there are only a few parameters that are likely to be varied during calibration. Instead, the calibration procedure largely consists of confirming that the simulation provides an adequate match to observed data. Initial EFDC model calibration was undertaken for year 2000. Once satisfactory results were obtained for 2000, the model was validated with similar procedures for the year 2002. These years were selected for application due to the presence of substantial amount of data as well as seasonal variation for water quality model application.

Water Quality Modeling

The EFDC hydrodynamic simulation is used to drive the WASP/EUTRO water quality model. WASP was operated on the same spatial grid shown in Figure B-7 with the same number of layers used to run EFDC.

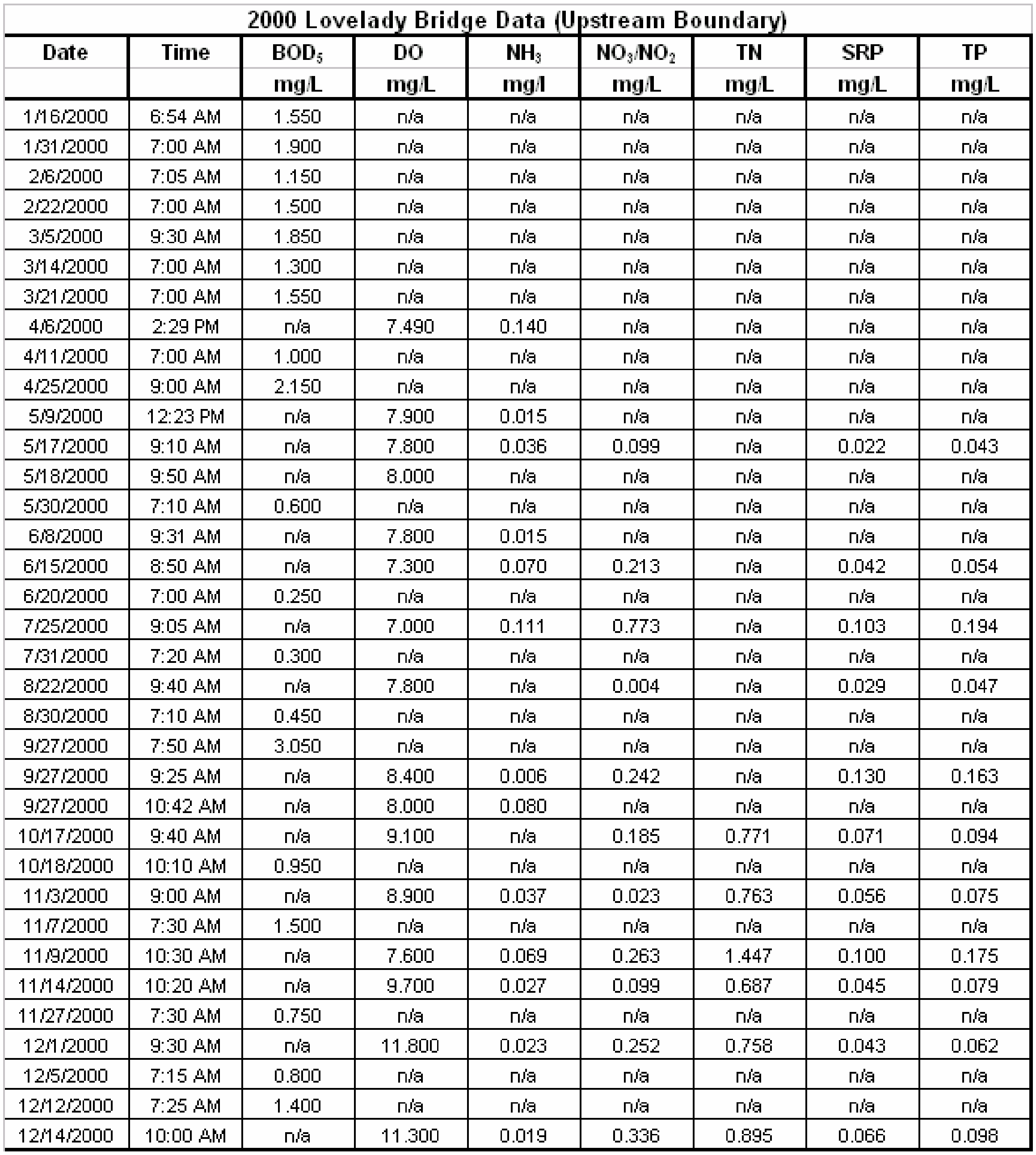
An external hydrodynamic file (".hyd" file) output by EFDC was used to input hydrodynamic parameters needed by WASP. Volume, depth, velocity, and flow at each cell or between cells are written to the ".hyd" file.

Input Concentrations

The simulations with WASP are driven primarily by flows and concentrations from upstream and downstream water levels. Upstream concentrations were obtained from measured data by Auburn University, Department of Fisheries and Allied Aquacultures, and ADEM with the exception of total phosphorus which was provided by LSPC.

Upstream boundary, Lovelady Bridge, data was provided by the Auburn University 2000/2002 Sougahatchee Creek watershed study and ADEM's 303(d) Monitoring Program (2000). The combined data sets are shown in Table B-4 as the Lovelady Bridge boundary concentrations. Table B-5 presents the Lovelady Bridge boundary 2002 data. Table B-6 represents the total phosphorus at Lovelady Bridge simulated by LSPC.

Table B-4



2000 Lovelady Bridge Data (Upstream Boundary)

Date	Time	BOD$_5$	DO	NH$_3$	NO$_3$/NO$_2$	TN	SRP	TP
		mg/L	mg/L	mg/l	mg/L	mg/L	mg/L	mg/L
1/16/2000	6:54 AM	1.550	n/a	n/a	n/a	n/a	n/a	n/a
1/31/2000	7:00 AM	1.900	n/a	n/a	n/a	n/a	n/a	n/a
2/6/2000	7:05 AM	1.150	n/a	n/a	n/a	n/a	n/a	n/a
2/22/2000	7:00 AM	1.500	n/a	n/a	n/a	n/a	n/a	n/a
3/5/2000	9:30 AM	1.850	n/a	n/a	n/a	n/a	n/a	n/a
3/14/2000	7:00 AM	1.300	n/a	n/a	n/a	n/a	n/a	n/a
3/21/2000	7:00 AM	1.550	n/a	n/a	n/a	n/a	n/a	n/a
4/6/2000	2:29 PM	n/a	7.490	0.140	n/a	n/a	n/a	n/a
4/11/2000	7:00 AM	1.000	n/a	n/a	n/a	n/a	n/a	n/a
4/25/2000	9:00 AM	2.150	n/a	n/a	n/a	n/a	n/a	n/a
5/9/2000	12:23 PM	n/a	7.900	0.015	n/a	n/a	n/a	n/a
5/17/2000	9:10 AM	n/a	7.800	0.036	0.099	n/a	0.022	0.043
5/18/2000	9:50 AM	n/a	8.000	n/a	n/a	n/a	n/a	n/a
5/30/2000	7:10 AM	0.600	n/a	n/a	n/a	n/a	n/a	n/a
6/8/2000	9:31 AM	n/a	7.800	0.015	n/a	n/a	n/a	n/a
6/15/2000	8:50 AM	n/a	7.300	0.070	0.213	n/a	0.042	0.054
6/20/2000	7:00 AM	0.250	n/a	n/a	n/a	n/a	n/a	n/a
7/25/2000	9:05 AM	n/a	7.000	0.111	0.773	n/a	0.103	0.194
7/31/2000	7:20 AM	0.300	n/a	n/a	n/a	n/a	n/a	n/a
8/22/2000	9:40 AM	n/a	7.800	n/a	0.004	n/a	0.029	0.047
8/30/2000	7:10 AM	0.450	n/a	n/a	n/a	n/a	n/a	n/a
9/27/2000	7:50 AM	3.050	n/a	n/a	n/a	n/a	n/a	n/a
9/27/2000	9:25 AM	n/a	8.400	0.006	0.242	n/a	0.130	0.163
9/27/2000	10:42 AM	n/a	8.000	0.080	n/a	n/a	n/a	n/a
10/17/2000	9:40 AM	n/a	9.100	n/a	0.185	0.771	0.071	0.094
10/18/2000	10:10 AM	0.950	n/a	n/a	n/a	n/a	n/a	n/a
11/3/2000	9:00 AM	n/a	8.900	0.037	0.023	0.763	0.056	0.075
11/7/2000	7:30 AM	1.500	n/a	n/a	n/a	n/a	n/a	n/a
11/9/2000	10:30 AM	n/a	7.600	0.069	0.263	1.447	0.100	0.175
11/14/2000	10:20 AM	n/a	9.700	0.027	0.099	0.687	0.045	0.079
11/27/2000	7:30 AM	0.750	n/a	n/a	n/a	n/a	n/a	n/a
12/1/2000	9:30 AM	n/a	11.800	0.023	0.252	0.758	0.043	0.062
12/5/2000	7:15 AM	0.800	n/a	n/a	n/a	n/a	n/a	n/a
12/12/2000	7:25 AM	1.400	n/a	n/a	n/a	n/a	n/a	n/a
12/14/2000	10:00 AM	n/a	11.300	0.019	0.336	0.895	0.066	0.098

Table B-5 2002 Lovelady Bridge Data (Upstream Boundary)

Date	Time	BOD_5 mg/L	DO mg/L	NH_3 mg/l	NO_3/NO_2 mg/L	TN mg/L	SRP mg/L	TP mg/L
1/10/2002	7:30 AM	0.900	14.050	0.075	0.691	0.949	0.039	0.074
1/31/2002	7:40 AM	1.050	9.900	0.048	0.367	0.769	0.063	0.063
2/6/2002	10:24 AM	2.600	11.200	0.320	0.413	2.836	0.027	0.375
2/14/2002	7:20 AM	1.100	12.000	0.034	0.298	0.520	0.026	0.048
2/20/2002	1:00 PM	1.150	11.000	0.010	0.191	0.553	0.026	0.050
3/6/2002	7:10 AM	0.750	12.400	0.043	0.002	0.720	0.012	0.055
3/21/2002	9:20 AM	1.850	9.100	0.227	0.054	1.339	0.015	0.171
4/4/2002	7:15 AM	0.600	9.250	0.061	0.132	0.718	0.023	0.044
4/17/2002	7:18 AM	0.650	8.300	0.084	0.270	0.654	0.020	0.057
5/8/2002	7:05 AM	0.450	7.800	0.067	0.558	0.927	0.028	0.062
6/5/2002	7:20 AM	0.400	6.200	0.041	0.182	0.666	0.033	0.060
7/18/2002	7:15 AM	0.850	6.000	0.025	0.780	1.299	0.063	0.098
8/27/2002	9:40 AM	n/a	6.800	n/a	n/a	n/a	n/a	n/a
8/29/2002	7:20 AM	0.350	6.400	0.025	0.177	0.788	0.038	0.127
8/30/2002	12:55 PM	n/a	7.200	0.064	n/a	n/a	n/a	n/a
9/19/2002	7:20 AM	0.250	6.500	0.042	0.367	1.899	0.052	0.069
10/4/2002	7:40 AM	n/a	6.800	n/a	0.350	0.895	0.056	0.079
10/16/2002	9:10 AM	0.860	8.200	0.049	0.312	1.187	0.073	0.103
11/5/2002	7:20 AM	0.650	8.300	0.063	0.137	0.685	0.066	0.092
11/11/2002	1:55 PM	1.270	8.800	0.057	0.477	1.226	0.050	0.134
11/21/2002	8:15 AM	0.920	10.000	0.054	0.475	0.860	0.034	0.061
12/5/2002	7:30 AM	1.060	11.200	0.031	0.339	1.086	0.041	0.066
12/18/2002	7:30 AM	0.440	11.200	0.043	0.569	0.909	0.025	0.048

Table B-6 2000 and 2002 Total Phosphorus at Lovelady Bridge

datetime	TP	datetime	TP
1/1/00 12:00	0.0455	1/1/02 12:00	0.081036
1/2/00 12:00	0.0464	1/2/02 12:00	0.094962
1/3/00 12:00	0.0472	1/3/02 12:00	0.099545
1/4/00 12:00	0.0523	1/4/02 12:00	0.108879
1/5/00 12:00	0.0826	1/5/02 12:00	0.166356
1/6/00 12:00	0.0536	1/6/02 12:00	0.165108
1/7/00 12:00	0.0485	1/7/02 12:00	0.145578
1/8/00 12:00	0.0490	1/8/02 12:00	0.101676
1/9/00 12:00	0.0504	1/9/02 12:00	0.095062
1/10/00 12:00	0.1854	1/10/02 12:00	0.091539
1/11/00 12:00	0.0896	1/11/02 12:00	0.092166
1/12/00 12:00	0.0270	1/12/02 12:00	0.093398
1/13/00 12:00	0.0270	1/13/02 12:00	0.114736
1/14/00 12:00	0.0289	1/14/02 12:00	0.141708
1/15/00 12:00	0.0309	1/15/02 12:00	0.068143
1/16/00 12:00	0.0329	1/16/02 12:00	0.071773
1/17/00 12:00	0.0376	1/17/02 12:00	0.074878
1/18/00 12:00	0.0608	1/18/02 12:00	0.077425
1/19/00 12:00	0.0401	1/19/02 12:00	0.079695
1/20/00 12:00	0.0391	1/20/02 12:00	0.109403
1/21/00 12:00	0.0421	1/21/02 12:00	0.119233
1/22/00 12:00	0.0406	1/22/02 12:00	0.061933
1/23/00 12:00	0.0536	1/23/02 12:00	0.060236
1/24/00 12:00	0.1626	1/24/02 12:00	0.08742
1/25/00 12:00	0.0882	1/25/02 12:00	0.065926
1/26/00 12:00	0.0295	1/26/02 12:00	0.093468
1/27/00 12:00	0.0293	1/27/02 12:00	0.054544
1/28/00 12:00	0.0306	1/28/02 12:00	0.055363
1/29/00 12:00	0.0418	1/29/02 12:00	0.057399
1/30/00 12:00	0.0752	1/30/02 12:00	0.059303
1/31/00 12:00	0.0453	1/31/02 12:00	0.061225
2/1/00 12:00	0.0434	2/1/02 12:00	0.063669
2/2/00 12:00	0.0318	2/2/02 12:00	0.069692
2/3/00 12:00	0.0319	2/3/02 12:00	0.103284
2/4/00 12:00	0.0325	2/4/02 12:00	0.069802
2/5/00 12:00	0.0330	2/5/02 12:00	0.066239
2/6/00 12:00	0.0334	2/6/02 12:00	0.082972
2/7/00 12:00	0.0339	2/7/02 12:00	0.215428
2/8/00 12:00	0.0345	2/8/02 12:00	0.07879
2/9/00 12:00	0.0350	2/9/02 12:00	0.030118
2/10/00 12:00	0.0356	2/10/02 12:00	0.031745
2/11/00 12:00	0.0361	2/11/02 12:00	0.034919
2/12/00 12:00	0.0368	2/12/02 12:00	0.038164
2/13/00 12:00	0.0374	2/13/02 12:00	0.041229
2/14/00 12:00	0.0494	2/14/02 12:00	0.04397
2/15/00 12:00	0.1058	2/15/02 12:00	0.046272
2/16/00 12:00	0.0405	2/16/02 12:00	0.04822
2/17/00 12:00	0.0377	2/17/02 12:00	0.049794
2/18/00 12:00	0.0382	2/18/02 12:00	0.051047
2/19/00 12:00	0.0387	2/19/02 12:00	0.052259
2/20/00 12:00	0.0393	2/20/02 12:00	0.053606
2/21/00 12:00	0.0416	2/21/02 12:00	0.067977
2/22/00 12:00	0.0406	2/22/02 12:00	0.120144
2/23/00 12:00	0.0405	2/23/02 12:00	0.054604
2/24/00 12:00	0.0411	2/24/02 12:00	0.052992
2/25/00 12:00	0.0419	2/25/02 12:00	0.054074
2/26/00 12:00	0.0426	2/26/02 12:00	0.055067
2/27/00 12:00	0.0526	2/27/02 12:00	0.055596
2/28/00 12:00	0.1125	2/28/02 12:00	0.056094
2/29/00 12:00	0.0792	3/1/02 12:00	0.051983

Table B-6 2000 and 2002 Total Phosphorus at Lovelady Bridge (cont)

datetime	TP	datetime	TP
3/1/00 12:00	0.0440	3/2/02 12:00	0.077423
3/2/00 12:00	0.0416	3/3/02 12:00	0.190364
3/3/00 12:00	0.0421	3/4/02 12:00	0.078082
3/4/00 12:00	0.0512	3/5/02 12:00	0.027106
3/5/00 12:00	0.1021	3/6/02 12:00	0.027465
3/6/00 12:00	0.0472	3/7/02 12:00	0.02918
3/7/00 12:00	0.0433	3/8/02 12:00	0.030967
3/8/00 12:00	0.0438	3/9/02 12:00	0.032612
3/9/00 12:00	0.0445	3/10/02 12:00	0.035106
3/10/00 12:00	0.0451	3/11/02 12:00	0.044774
3/11/00 12:00	0.0530	3/12/02 12:00	0.037821
3/12/00 12:00	0.1047	3/13/02 12:00	0.059266
3/13/00 12:00	0.0968	3/14/02 12:00	0.085673
3/14/00 12:00	0.0464	3/15/02 12:00	0.035008
3/15/00 12:00	0.0436	3/16/02 12:00	0.035131
3/16/00 12:00	0.0526	3/17/02 12:00	0.036348
3/17/00 12:00	0.1017	3/18/02 12:00	0.037255
3/18/00 12:00	0.0520	3/19/02 12:00	0.037952
3/19/00 12:00	0.0455	3/20/02 12:00	0.038719
3/20/00 12:00	0.0824	3/21/02 12:00	0.148237
3/21/00 12:00	0.1002	3/22/02 12:00	0.061077
3/22/00 12:00	0.0370	3/23/02 12:00	0.023965
3/23/00 12:00	0.0367	3/24/02 12:00	0.024037
3/24/00 12:00	0.0380	3/25/02 12:00	0.025308
3/25/00 12:00	0.0393	3/26/02 12:00	0.026755
3/26/00 12:00	0.0405	3/27/02 12:00	0.070021
3/27/00 12:00	0.0414	3/28/02 12:00	0.069294
3/28/00 12:00	0.0455	3/29/02 12:00	0.026843
3/29/00 12:00	0.0702	3/30/02 12:00	0.027281
3/30/00 12:00	0.1131	3/31/02 12:00	0.028288
3/31/00 12:00	0.1069	4/1/02 12:00	0.033806
4/1/00 12:00	0.0335	4/2/02 12:00	0.059311
4/2/00 12:00	0.0329	4/3/02 12:00	0.028396
4/3/00 12:00	0.0393	4/4/02 12:00	0.028174
4/4/00 12:00	0.0977	4/5/02 12:00	0.028565
4/5/00 12:00	0.0783	4/6/02 12:00	0.029057
4/6/00 12:00	0.0305	4/7/02 12:00	0.029574
4/7/00 12:00	0.0308	4/8/02 12:00	0.030204
4/8/00 12:00	0.0320	4/9/02 12:00	0.049776
4/9/00 12:00	0.0329	4/10/02 12:00	0.082332
4/10/00 12:00	0.0338	4/11/02 12:00	0.030111
4/11/00 12:00	0.0349	4/12/02 12:00	0.03254
4/12/00 12:00	0.0360	4/13/02 12:00	0.152453
4/13/00 12:00	0.0368	4/14/02 12:00	0.071768
4/14/00 12:00	0.0513	4/15/02 12:00	0.023676
4/15/00 12:00	0.1078	4/16/02 12:00	0.023536
4/16/00 12:00	0.0519	4/17/02 12:00	0.024117
4/17/00 12:00	0.0364	4/18/02 12:00	0.025097
4/18/00 12:00	0.0362	4/19/02 12:00	0.026102
4/19/00 12:00	0.0367	4/20/02 12:00	0.02707
4/20/00 12:00	0.0373	4/21/02 12:00	0.02794
4/21/00 12:00	0.0379	4/22/02 12:00	0.028578
4/22/00 12:00	0.0383	4/23/02 12:00	0.029105
4/23/00 12:00	0.0387	4/24/02 12:00	0.029754
4/24/00 12:00	0.0470	4/25/02 12:00	0.03035
4/25/00 12:00	0.0947	4/26/02 12:00	0.030839
4/26/00 12:00	0.0445	4/27/02 12:00	0.031289
4/27/00 12:00	0.0408	4/28/02 12:00	0.032051
4/28/00 12:00	0.0412	4/29/02 12:00	0.032876
4/29/00 12:00	0.0418	4/30/02 12:00	0.033541
4/30/00 12:00	0.0426	5/1/02 12:00	0.056165
5/1/00 12:00	0.0435	5/2/02 12:00	0.110448
5/2/00 12:00	0.0443	5/3/02 12:00	0.046234
5/3/00 12:00	0.0453	5/4/02 12:00	0.045386
5/4/00 12:00	0.0465	5/5/02 12:00	0.046062
5/5/00 12:00	0.0475	5/6/02 12:00	0.046795
5/6/00 12:00	0.0482	5/7/02 12:00	0.047713
5/7/00 12:00	0.0488	5/8/02 12:00	0.049031
5/8/00 12:00	0.0496	5/9/02 12:00	0.05027
5/9/00 12:00	0.0506	5/10/02 12:00	0.051424
5/10/00 12:00	0.0517	5/11/02 12:00	0.052661
5/11/00 12:00	0.0530	5/12/02 12:00	0.0539
5/12/00 12:00	0.0544	5/13/02 12:00	0.054517

Table B-6 2000 and 2002 Total Phosphorus at Lovelady Bridge (cont)

datetime	TP	datetime	TP
5/13/00 12:00	0.0556	5/14/02 12:00	0.054913
5/14/00 12:00	0.0567	5/15/02 12:00	0.058666
5/15/00 12:00	0.0574	5/16/02 12:00	0.05677
5/16/00 12:00	0.0577	5/17/02 12:00	0.057556
5/17/00 12:00	0.0578	5/18/02 12:00	0.077676
5/18/00 12:00	0.0589	5/19/02 12:00	0.128843
5/19/00 12:00	0.0609	5/20/02 12:00	0.06014
5/20/00 12:00	0.0630	5/21/02 12:00	0.053278
5/21/00 12:00	0.0636	5/22/02 12:00	0.053595
5/22/00 12:00	0.0825	5/23/02 12:00	0.054489
5/23/00 12:00	0.1805	5/24/02 12:00	0.055758
5/24/00 12:00	0.0787	5/25/02 12:00	0.057543
5/25/00 12:00	0.0671	5/26/02 12:00	0.059756
5/26/00 12:00	0.0682	5/27/02 12:00	0.061724
5/27/00 12:00	0.0695	5/28/02 12:00	0.063212
5/28/00 12:00	0.0754	5/29/02 12:00	0.064367
5/29/00 12:00	0.1076	5/30/02 12:00	0.065486
5/30/00 12:00	0.0811	5/31/02 12:00	0.090365
5/31/00 12:00	0.0715	6/1/02 12:00	0.111822
6/1/00 12:00	0.0729	6/2/02 12:00	0.052634
6/2/00 12:00	0.0670	6/3/02 12:00	0.05501
6/3/00 12:00	0.0654	6/4/02 12:00	0.057377
6/4/00 12:00	0.0669	6/5/02 12:00	0.059825
6/5/00 12:00	0.0680	6/6/02 12:00	0.068488
6/6/00 12:00	0.0717	6/7/02 12:00	0.062926
6/7/00 12:00	0.0919	6/8/02 12:00	0.061903
6/8/00 12:00	0.0804	6/9/02 12:00	0.062527
6/9/00 12:00	0.0703	6/10/02 12:00	0.063848
6/10/00 12:00	0.0711	6/11/02 12:00	0.065124
6/11/00 12:00	0.0724	6/12/02 12:00	0.066813
6/12/00 12:00	0.0734	6/13/02 12:00	0.068932
6/13/00 12:00	0.0743	6/14/02 12:00	0.076976
6/14/00 12:00	0.0757	6/15/02 12:00	0.120824
6/15/00 12:00	0.0776	6/16/02 12:00	0.078856
6/16/00 12:00	0.0951	6/17/02 12:00	0.072734
6/17/00 12:00	0.1834	6/18/02 12:00	0.075305
6/18/00 12:00	0.1693	6/19/02 12:00	0.079479
6/19/00 12:00	0.0998	6/20/02 12:00	0.09428
6/20/00 12:00	0.0893	6/21/02 12:00	0.084511
6/21/00 12:00	0.0882	6/22/02 12:00	0.084594
6/22/00 12:00	0.0842	6/23/02 12:00	0.119274
6/23/00 12:00	0.0848	6/24/02 12:00	0.138926
6/24/00 12:00	0.0858	6/25/02 12:00	0.101966
6/25/00 12:00	0.0867	6/26/02 12:00	0.103359
6/26/00 12:00	0.0877	6/27/02 12:00	0.169564
6/27/00 12:00	0.0887	6/28/02 12:00	0.105329
6/28/00 12:00	0.0896	6/29/02 12:00	0.145414
6/29/00 12:00	0.0905	6/30/02 12:00	0.093883
6/30/00 12:00	0.0915	7/1/02 12:00	0.076899

Table B-6 2000 and 2002 Total Phosphorus at Lovelady Bridge (cont)

datetime	TP	datetime	TP
7/1/00 12:00	0.0924	7/2/02 12:00	0.099882
7/2/00 12:00	0.0997	7/3/02 12:00	0.105025
7/3/00 12:00	0.1053	7/4/02 12:00	0.108198
7/4/00 12:00	0.1071	7/5/02 12:00	0.109711
7/5/00 12:00	0.1085	7/6/02 12:00	0.112777
7/6/00 12:00	0.1100	7/7/02 12:00	0.116243
7/7/00 12:00	0.1113	7/8/02 12:00	0.118231
7/8/00 12:00	0.1127	7/9/02 12:00	0.119492
7/9/00 12:00	0.1139	7/10/02 12:00	0.121667
7/10/00 12:00	0.1152	7/11/02 12:00	0.124528
7/11/00 12:00	0.1164	7/12/02 12:00	0.126309
7/12/00 12:00	0.1176	7/13/02 12:00	0.127677
7/13/00 12:00	0.1188	7/14/02 12:00	0.129964
7/14/00 12:00	0.1511	7/15/02 12:00	0.132742
7/15/00 12:00	0.2661	7/16/02 12:00	0.134932
7/16/00 12:00	0.1414	7/17/02 12:00	0.137422
7/17/00 12:00	0.1187	7/18/02 12:00	0.140877
7/18/00 12:00	0.1218	7/19/02 12:00	0.144523
7/19/00 12:00	0.1236	7/20/02 12:00	0.147203
7/20/00 12:00	0.1250	7/21/02 12:00	0.14912
7/21/00 12:00	0.1426	7/22/02 12:00	0.150581
7/22/00 12:00	0.2141	7/23/02 12:00	0.151967
7/23/00 12:00	0.1633	7/24/02 12:00	0.175979
7/24/00 12:00	0.1579	7/25/02 12:00	0.226062
7/25/00 12:00	0.2222	7/26/02 12:00	0.101545
7/26/00 12:00	0.1106	7/27/02 12:00	0.106457
7/27/00 12:00	0.1169	7/28/02 12:00	0.154204
7/28/00 12:00	0.1262	7/29/02 12:00	0.126372
7/29/00 12:00	0.1292	7/30/02 12:00	0.154701
7/30/00 12:00	0.1312	7/31/02 12:00	0.134817
7/31/00 12:00	0.1331	8/1/02 12:00	0.131037
8/1/00 12:00	0.1795	8/2/02 12:00	0.131193
8/2/00 12:00	0.3250	8/3/02 12:00	0.149567
8/3/00 12:00	0.3558	8/4/02 12:00	0.138644
8/4/00 12:00	0.2713	8/5/02 12:00	0.134949
8/5/00 12:00	0.2943	8/6/02 12:00	0.137157
8/6/00 12:00	0.3417	8/7/02 12:00	0.139606
8/7/00 12:00	0.3611	8/8/02 12:00	0.141268
8/8/00 12:00	0.3684	8/9/02 12:00	0.142287
8/9/00 12:00	0.3735	8/10/02 12:00	0.143456
8/10/00 12:00	0.3780	8/11/02 12:00	0.145207
8/11/00 12:00	0.3918	8/12/02 12:00	0.147664
8/12/00 12:00	0.4088	8/13/02 12:00	0.150242
8/13/00 12:00	0.3115	8/14/02 12:00	0.152008
8/14/00 12:00	0.3528	8/15/02 12:00	0.154036

Table B-6 2000 and 2002 Total Phosphorus at Lovelady Bridge (cont)

datetime	TP	datetime	TP
8/15/00 12:00	0.3804	8/16/02 12:00	0.179861
8/16/00 12:00	0.3903	8/17/02 12:00	0.237007
8/17/00 12:00	0.3964	8/18/02 12:00	0.134582
8/18/00 12:00	0.4015	8/19/02 12:00	0.154099
8/19/00 12:00	0.4084	8/20/02 12:00	0.128851
8/20/00 12:00	0.4194	8/21/02 12:00	0.101928
8/21/00 12:00	0.3957	8/22/02 12:00	0.106173
8/22/00 12:00	0.2996	8/23/02 12:00	0.12433
8/23/00 12:00	0.2336	8/24/02 12:00	0.12961
8/24/00 12:00	0.3383	8/25/02 12:00	0.132215
8/25/00 12:00	0.3670	8/26/02 12:00	0.134552
8/26/00 12:00	0.2753	8/27/02 12:00	0.135667
8/27/00 12:00	0.2308	8/28/02 12:00	0.136156
8/28/00 12:00	0.3372	8/29/02 12:00	0.155917
8/29/00 12:00	0.3867	8/30/02 12:00	0.159677
8/30/00 12:00	0.3938	8/31/02 12:00	0.100255
8/31/00 12:00	0.4011	9/1/02 12:00	0.116786
9/1/00 12:00	0.3721	9/2/02 12:00	0.115965
9/2/00 12:00	0.2625	9/3/02 12:00	0.106116
9/3/00 12:00	0.1619	9/4/02 12:00	0.104591
9/4/00 12:00	0.0804	9/5/02 12:00	0.106635
9/5/00 12:00	0.0950	9/6/02 12:00	0.108556
9/6/00 12:00	0.1516	9/7/02 12:00	0.110227
9/7/00 12:00	0.1960	9/8/02 12:00	0.111452
9/8/00 12:00	0.1545	9/9/02 12:00	0.112485
9/9/00 12:00	0.1177	9/10/02 12:00	0.113937
9/10/00 12:00	0.1325	9/11/02 12:00	0.115867
9/11/00 12:00	0.1371	9/12/02 12:00	0.11774
9/12/00 12:00	0.1386	9/13/02 12:00	0.11836
9/13/00 12:00	0.1397	9/14/02 12:00	0.125063
9/14/00 12:00	0.1407	9/15/02 12:00	0.172738
9/15/00 12:00	0.1592	9/16/02 12:00	0.21809
9/16/00 12:00	0.2377	9/17/02 12:00	0.127353
9/17/00 12:00	0.1395	9/18/02 12:00	0.121395
9/18/00 12:00	0.1310	9/19/02 12:00	0.123761
9/19/00 12:00	0.1332	9/20/02 12:00	0.125346
9/20/00 12:00	0.1344	9/21/02 12:00	0.140464
9/21/00 12:00	0.1354	9/22/02 12:00	0.208139
9/22/00 12:00	0.1583	9/23/02 12:00	0.1432
9/23/00 12:00	0.2041	9/24/02 12:00	0.130921
9/24/00 12:00	0.1260	9/25/02 12:00	0.149872
9/25/00 12:00	0.1199	9/26/02 12:00	0.211767
9/26/00 12:00	0.0977	9/27/02 12:00	0.14051
9/27/00 12:00	0.1315	9/28/02 12:00	0.125872
9/28/00 12:00	0.0852	9/29/02 12:00	0.09225
9/29/00 12:00	0.0884	9/30/02 12:00	0.107322
9/30/00 12:00	0.0901	10/1/02 12:00	0.115114

Table B-6 2000 and 2002 Total Phosphorus at Lovelady Bridge (cont)

datetime	TP	datetime	TP
10/1/00 12:00	0.0976	10/2/02 12:00	0.12581
10/2/00 12:00	0.1085	10/3/02 12:00	0.129939
10/3/00 12:00	0.1152	10/4/02 12:00	0.131805
10/4/00 12:00	0.1173	10/5/02 12:00	0.133825
10/5/00 12:00	0.1196	10/6/02 12:00	0.136232
10/6/00 12:00	0.1217	10/7/02 12:00	0.13831
10/7/00 12:00	0.1446	10/8/02 12:00	0.139573
10/8/00 12:00	0.2027	10/9/02 12:00	0.13994
10/9/00 12:00	0.1001	10/10/02 12:00	0.13983
10/10/00 12:00	0.1012	10/11/02 12:00	0.140948
10/11/00 12:00	0.1039	10/12/02 12:00	0.143666
10/12/00 12:00	0.1065	10/13/02 12:00	0.148388
10/13/00 12:00	0.1086	10/14/02 12:00	0.158833
10/14/00 12:00	0.1108	10/15/02 12:00	0.16915
10/15/00 12:00	0.1138	10/16/02 12:00	0.241376
10/16/00 12:00	0.1162	10/17/02 12:00	0.172717
10/17/00 12:00	0.1183	10/18/02 12:00	0.119985
10/18/00 12:00	0.1212	10/19/02 12:00	0.126483
10/19/00 12:00	0.1241	10/20/02 12:00	0.13179
10/20/00 12:00	0.1263	10/21/02 12:00	0.153878
10/21/00 12:00	0.1284	10/22/02 12:00	0.206259
10/22/00 12:00	0.1304	10/23/02 12:00	0.119966
10/23/00 12:00	0.1317	10/24/02 12:00	0.125722
10/24/00 12:00	0.1326	10/25/02 12:00	0.132412
10/25/00 12:00	0.1338	10/26/02 12:00	0.132294
10/26/00 12:00	0.1355	10/27/02 12:00	0.142407
10/27/00 12:00	0.1371	10/28/02 12:00	0.202195
10/28/00 12:00	0.1386	10/29/02 12:00	0.180219
10/29/00 12:00	0.1407	10/30/02 12:00	0.113991
10/30/00 12:00	0.1427	10/31/02 12:00	0.117389
10/31/00 12:00	0.1442	11/1/02 12:00	0.10909
11/1/00 12:00	0.1501	11/2/02 12:00	0.096722
11/2/00 12:00	0.1704	11/3/02 12:00	0.095735
11/3/00 12:00	0.1784	11/4/02 12:00	0.106621
11/4/00 12:00	0.1805	11/5/02 12:00	0.166224
11/5/00 12:00	0.1821	11/6/02 12:00	0.131064
11/6/00 12:00	0.1833	11/7/02 12:00	0.15624
11/7/00 12:00	0.1996	11/8/02 12:00	0.107437
11/8/00 12:00	0.2509	11/9/02 12:00	0.097851
11/9/00 12:00	0.1753	11/10/02 12:00	0.102
11/10/00 12:00	0.0897	11/11/02 12:00	0.130113
11/11/00 12:00	0.0626	11/12/02 12:00	0.169757
11/12/00 12:00	0.0568	11/13/02 12:00	0.07158
11/13/00 12:00	0.0632	11/14/02 12:00	0.039945
11/14/00 12:00	0.0688	11/15/02 12:00	0.041908
11/15/00 12:00	0.0731	11/16/02 12:00	0.065648
11/16/00 12:00	0.0768	11/17/02 12:00	0.090315

Table B-6 2000 and 2002 Total Phosphorus at Lovelady Bridge (cont)

datetime	TP	datetime	TP
11/17/00 12:00	0.1036	11/18/02 12:00	0.047923
11/18/00 12:00	0.1286	11/19/02 12:00	0.043606
11/19/00 12:00	0.1308	11/20/02 12:00	0.045719
11/20/00 12:00	0.0946	11/21/02 12:00	0.057554
11/21/00 12:00	0.0487	11/22/02 12:00	0.099293
11/22/00 12:00	0.0414	11/23/02 12:00	0.048074
11/23/00 12:00	0.0451	11/24/02 12:00	0.046957
11/24/00 12:00	0.0487	11/25/02 12:00	0.048113
11/25/00 12:00	0.0718	11/26/02 12:00	0.049174
11/26/00 12:00	0.0927	11/27/02 12:00	0.049997
11/27/00 12:00	0.0465	11/28/02 12:00	0.050482
11/28/00 12:00	0.0482	11/29/02 12:00	0.051066
11/29/00 12:00	0.0504	11/30/02 12:00	0.051942
11/30/00 12:00	0.0522	12/1/02 12:00	0.051837
12/1/00 12:00	0.0542	12/2/02 12:00	0.050959
12/2/00 12:00	0.0568	12/3/02 12:00	0.051544
12/3/00 12:00	0.0580	12/4/02 12:00	0.052276
12/4/00 12:00	0.0590	12/5/02 12:00	0.068429
12/5/00 12:00	0.0600	12/6/02 12:00	0.132347
12/6/00 12:00	0.0610	12/7/02 12:00	0.052813
12/7/00 12:00	0.0621	12/8/02 12:00	0.04963
12/8/00 12:00	0.0632	12/9/02 12:00	0.050571
12/9/00 12:00	0.0643	12/10/02 12:00	0.051534
12/10/00 12:00	0.0692	12/11/02 12:00	0.093371
12/11/00 12:00	0.0965	12/12/02 12:00	0.102655
12/12/00 12:00	0.0698	12/13/02 12:00	0.047998
12/13/00 12:00	0.0680	12/14/02 12:00	0.063908
12/14/00 12:00	0.0896	12/15/02 12:00	0.037626
12/15/00 12:00	0.1198	12/16/02 12:00	0.038227
12/16/00 12:00	0.0929	12/17/02 12:00	0.039824
12/17/00 12:00	0.1621	12/18/02 12:00	0.041213
12/18/00 12:00	0.0760	12/19/02 12:00	0.042404
12/19/00 12:00	0.0342	12/20/02 12:00	0.067305
12/20/00 12:00	0.0406	12/21/02 12:00	0.097413
12/21/00 12:00	0.0388	12/22/02 12:00	0.037527
12/22/00 12:00	0.0616	12/23/02 12:00	0.037731
12/23/00 12:00	0.0640	12/24/02 12:00	0.158499
12/24/00 12:00	0.0378	12/25/02 12:00	0.081471
12/25/00 12:00	0.0394	12/26/02 12:00	0.029414
12/26/00 12:00	0.0410	12/27/02 12:00	0.026405
12/27/00 12:00	0.0425	12/28/02 12:00	0.027946
12/28/00 12:00	0.1127	12/29/02 12:00	0.029561
12/29/00 12:00	0.1606	12/30/02 12:00	0.031089
12/30/00 12:00	0.0630		
12/31/00 12:00	0.0284		

Meteorological Forcing Functions

Solar Radiation

Solar radiation data used in WASP was provided by the Auburn University Mesonet AWIS station.

Light Extinction Coefficients

Availability of light for photosynthesis is an important limiting factor on algal growth in Sougahatchee Creek embayment. High levels of dissolved organic material, fine suspended solids, and color, all scatter light and limit the zone in which algae can grow. Observed Secchi disk depths (the depth to which a standard optical target is visible from the surface) are on average less than 1 meter.

WASP models the light available for photosynthesis from the incident solar radiation at the water surface and the rate of light attenuation or “extinction” in the water column. Light extinction is represented by an extinction coefficient (Ke), such that light remaining at depth z is equal to e-Ke*z.

The model estimates Ke as the combined effects of algal self-shading, which can be important under bloom conditions, and a non-algal component, represented through a user-supplied extinction coefficient (Ke’) that can vary in time and space. The non-algal component was estimated by Di Toro’s equation (Di Toro, 1978) that considers both Secchi depth (SD (meters)) and chlorophyll *a* (µg/l):

$$Ke' = 1.8 / (SD) - 0.031 * \text{Chl } a$$

Measured Secchi depth and chlorophyll *a* from ADEM’s Monthly (April-October) Lake Monitoring for 2000/2002 was used for the simulation period. Interpolation was done to provide numbers for the months that data was not collected.

Air Temperature

Average air temperature was provided by Auburn University Mesonet AWIS station, AU10.

Daily Average Wind Velocity

WASP uses wind velocity to estimate reaeration of the water column; the effects of wind stress on water movement are calculated separately in the hydrodynamic model. A daily time series for wind speed was created using data for wind speed (m/sec) from the Columbus Georgia Metropolitan Airport.

Water Temperature

Water temperature is important in water quality modeling as many reaction rates are temperature dependent. At present, water temperatures are not transferred from EFDC to WASP via the "hyd" file and must be input into WASP as a time series in the input file.

Fraction Daily Light

WASP uses the fraction of daily light to distribute the daily solar radiation over the fraction of daylight hours for each day. The fraction of daily light was calculated every 14 days by computing the declination and time between sunrise and sunset. The declination of the Sun varies between about -23 and +23 degrees throughout the year, with the negative values corresponding to winter and the positive values to summer. The declination for Sougahatchee Creek was calculated using the following equation:

$$\delta = \frac{23.45\pi}{180}\cos(\frac{2\pi}{365}(172 - D_y)$$

D_y is the day of the year. $D_y = 1$ corresponds to January 1st. The fraction of daily light is the time between sunrise and sunset divided by 24. The fraction of daily light for Sougahatchee Creek was calculated using the following equation, where θ is the latitude in degrees:

$$\frac{(t_{ss} - t_{sr})}{24} = \frac{1}{\pi}\cos^{-1}\left[\frac{\sin\left(\frac{\pi\theta}{180}\right)\sin(\delta)}{\cos\left(\frac{\pi\theta}{180}\right)\cos(\delta)}\right]$$

Sediment Oxygen Demand

The decomposition of organic material in benthic sediment can have profound effects on the concentrations of oxygen in the overlying waters. The decomposition of organic material results in the exertion of an oxygen demand at the sediment-water interface. As a result, the aerial fluxes from the sediment can be substantial oxygen sinks to the overlying water column. The USEPA conducted sediment oxygen demand (SOD) measurements on Sougahatchee Creek in 2003 with values ranging from 1.3 to 1.6 $g/m^2/day$.

WASP Model Scenarios

In the context of this TMDL, the primary need from the model is to provide an accurate representation of dissolved oxygen and sources of DO depletion as well as the simulation of nutrient species and chlorophyll *a* within model segments. In keeping with this objective, the primary target for calibration will be ADEM’s Reservoir Monitoring station, Yates 2.

In contrast to the hydrodynamic model, the WASP water quality model contains a large number of parameters that are typically determined through calibration. The general strategy adopted was to achieve a chlorophyll *a* target of 12 μg/l for the Sougahatchee Creek embayment by reducing total phosphorus.

WASP Calibration

The WASP model was calibrated to dissolved oxygen, total phosphorus, and chlorophyll *a* during the 2000 and 2002 growing seasons (April through October). The calibration points were measurements of DO, TP, and chlorophyll *a* obtained at ADEM station: Yates 2, located in Sougahatchee embayment for the corresponding years (Figure B-7). Figure B-9 presents the DO calibration, Figure B-10 presents the chlorophyll *a* calibration, and Figure B-11 presents the total phosphorus calibration for the Sougahatchee Creek embayment.

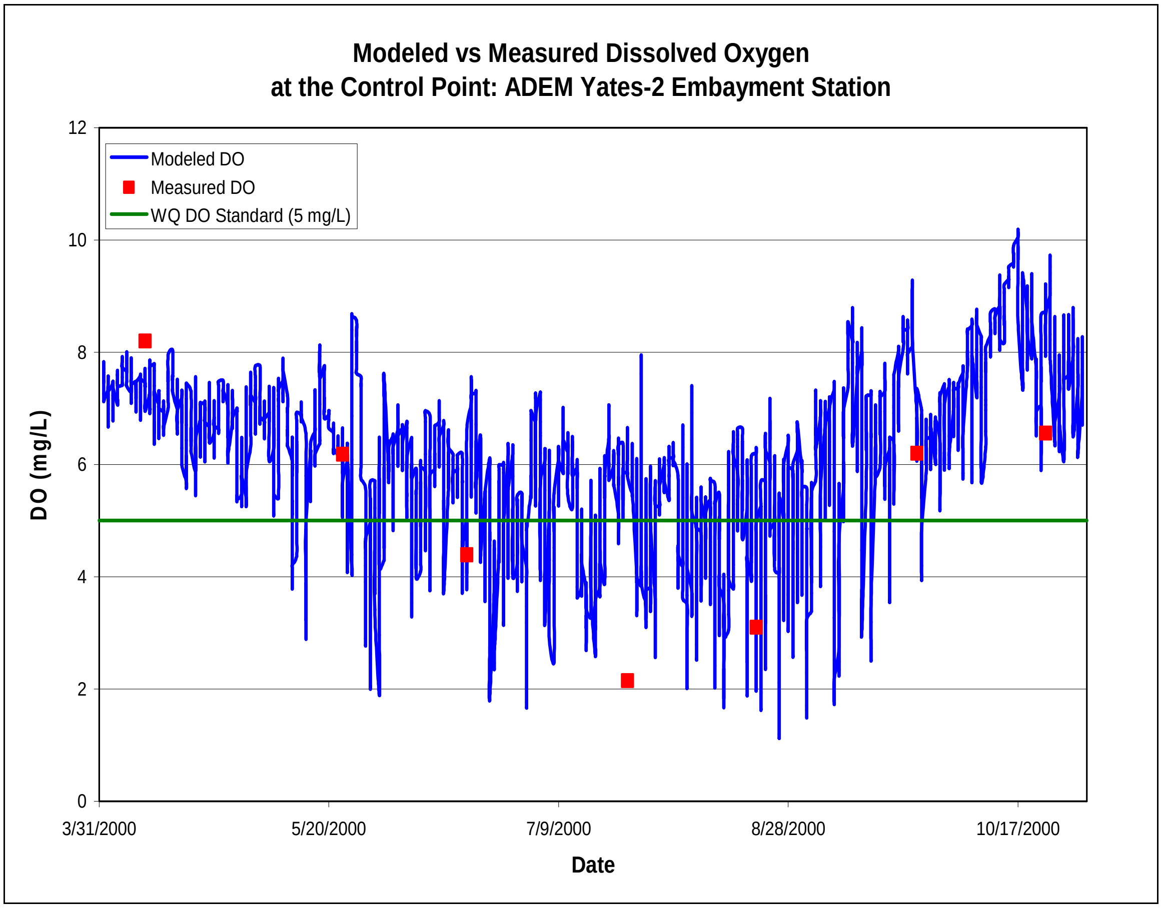


Figure B-9 **DO Calibration at Yates 2 in Sougahatchee Creek embayment**

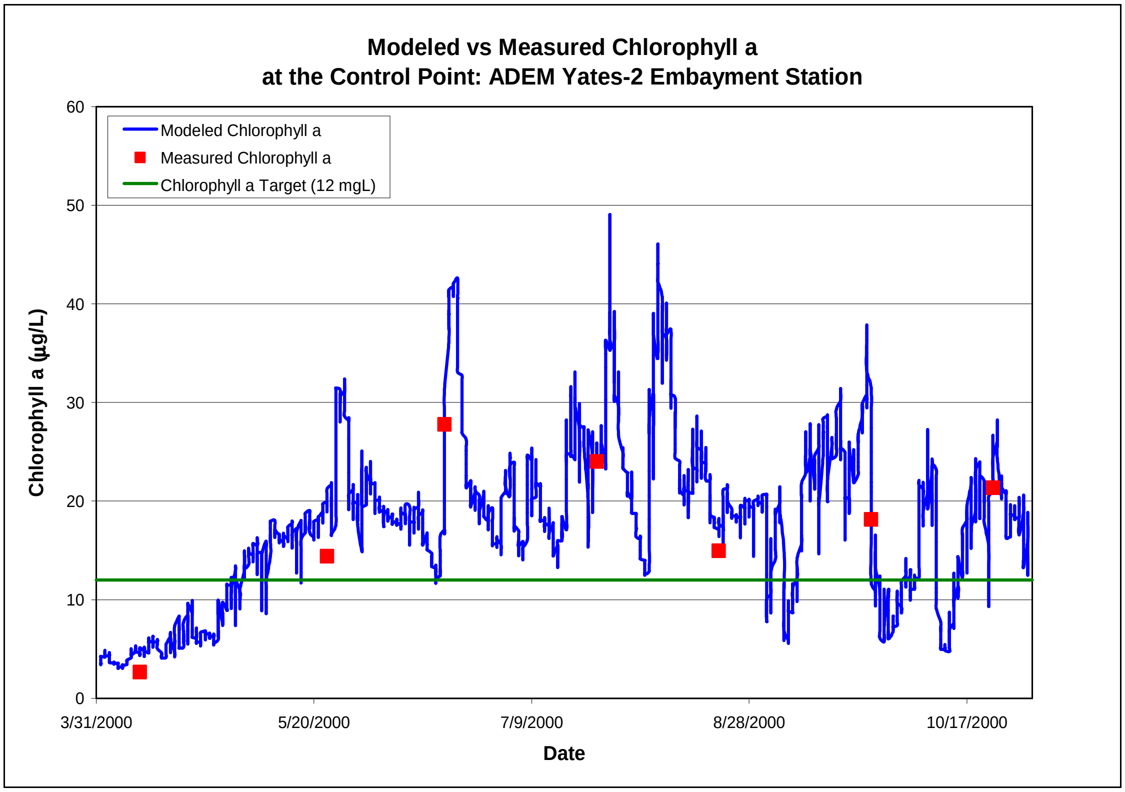


Figure B-10 **Chlorophyll *a* Calibration at Yates 2 in Sougahatchee Creek embayment**

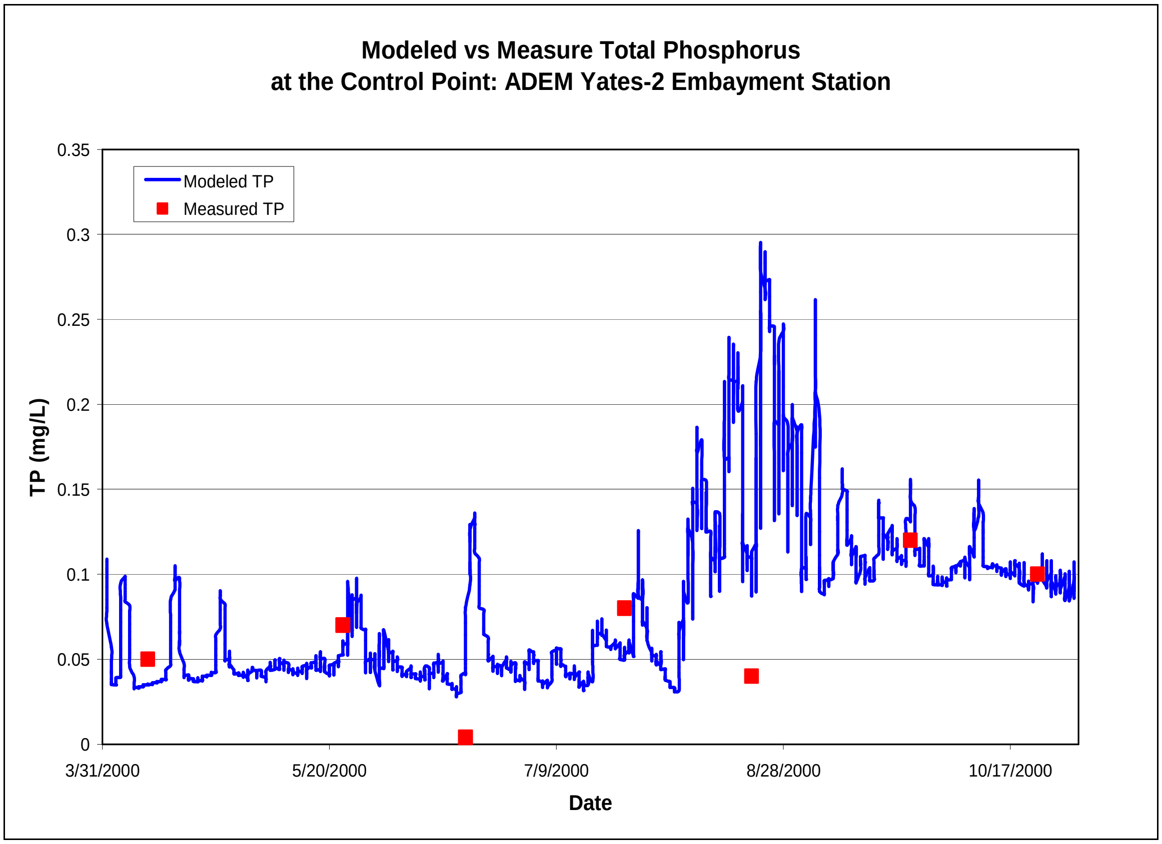


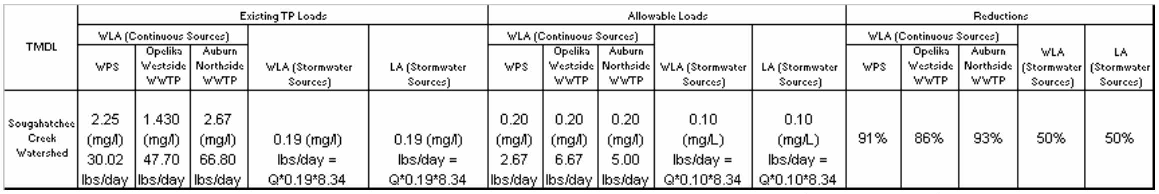
Figure B-11 Total Phosphorus Calibration at Yates 2 in Sougahatchee Creek embayment

TMDL Results

Total Phosphorus

As mentioned previously, the year 2000 was chosen as the critical condition year based on applicable data. The data for the year 2002 was used to validate this assumption. Therefore, the TMDL results will be based on the worst-case or critical condition scenario: a low flow period with high temperatures as in the year 2000. As predicted based upon modeling tools, in order to meet the chlorophyll *a* target of 12 µg/l, a growing season (April-October) total phosphorus limit of 0.20 mg/l will need to be met by point sources (WLA continuous sources) and a fifty percent total phosphorus reduction will be needed for stormwater sources (MS4 and LA) within the watershed. Table B-7 represents the TMDL results for total phosphorus. West Point Stevens has an active NPDES permit for a process water discharge to Pepperell Branch; however, the facility has currently halted production. An alternate TMDL scenario has been developed which excludes the West Point Stevens WLA should the discharge be permanently removed. Table B-8 represents the TMDL results for the Sougahatchee Creek Watershed with the West Point Stevens discharge removed from Pepperell Branch.

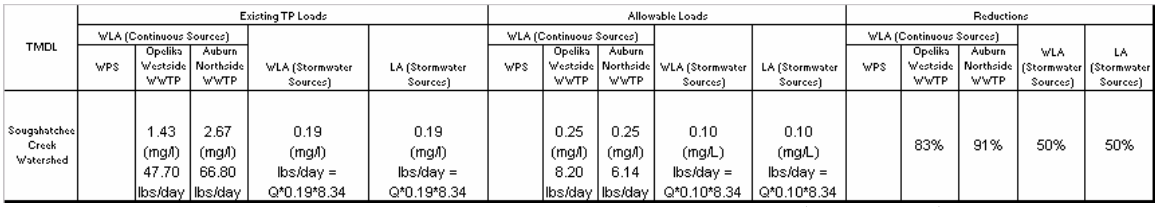
Table B-7 Growing Season (April-October) Total Phosphorus TMDL Results for the Sougahatchee Creek Watershed



TMDL	Existing TP Loads					Allowable Loads					Reductions				
	WLA (Continuous Sources)			WLA (Stormwater Sources)	LA (Stormwater Sources)	WLA (Continuous Sources)			WLA (Stormwater Sources)	LA (Stormwater Sources)	WLA (Continuous Sources)			WLA (Stormwater Sources)	LA (Stormwater Sources)
	WPS	Opelika Westside WWTP	Auburn Northside WWTP			WPS	Opelika Westside WWTP	Auburn Northside WWTP			WPS	Opelika Westside WWTP	Auburn Northside WWTP		
Sougahatchee Creek Watershed	2.25 (mg/l) 30.02 lbs/day	1.430 (mg/l) 47.70 lbs/day	2.67 (mg/l) 66.80 lbs/day	0.19 (mg/l) lbs/day = Q*0.19*8.34	0.19 (mg/l) lbs/day = Q*0.19*8.34	0.20 (mg/l) 2.67 lbs/day	0.20 (mg/l) 6.67 lbs/day	0.20 (mg/l) 5.00 lbs/day	0.10 (mg/L) lbs/day = Q*0.10*8.34	0.10 (mg/L) lbs/day = Q*0.10*8.34	91%	86%	93%	50%	50%

*Existing TP concentrations were determined using Point Source DMR data (April-October) for the period of 2000 and 2002
*Point source TP mass loadings were calculated utilizing TP concentrations times design flows times 8.34
*Q is equal to flow in MGD

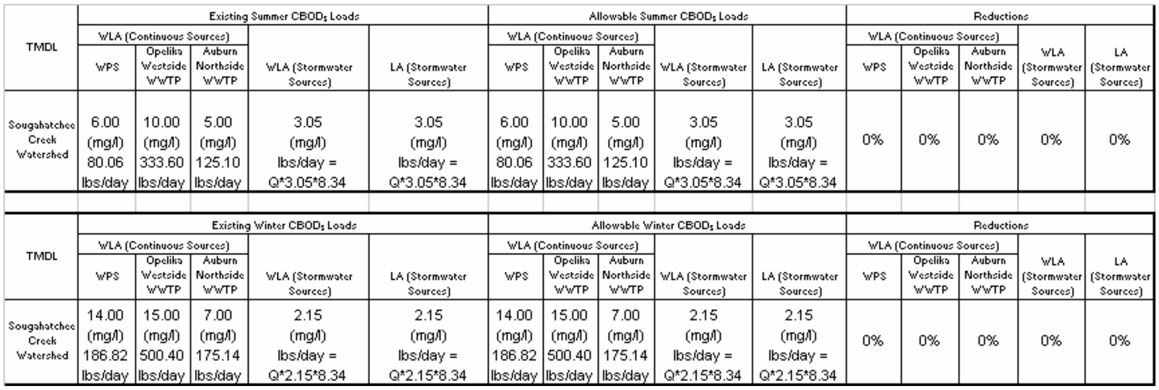
Table B-8 Growing Season (April-October) Total Phosphorus TMDL Results for the Sougahatchee Creek Watershed with the West Point Stevens Discharge Removed From Pepperell Branch



TMDL	Existing TP Loads					Allowable Loads					Reductions				
	WLA (Continuous Sources)			WLA (Stormwater Sources)	LA (Stormwater Sources)	WLA (Continuous Sources)			WLA (Stormwater Sources)	LA (Stormwater Sources)	WLA (Continuous Sources)			WLA (Stormwater Sources)	LA (Stormwater Sources)
	WPS	Opelika Westside WWTP	Auburn Northside WWTP			WPS	Opelika Westside WWTP	Auburn Northside WWTP			WPS	Opelika Westside WWTP	Auburn Northside WWTP		
Sougahatchee Creek Watershed		1.43 (mg/l) 47.70 lbs/day	2.67 (mg/l) 66.80 lbs/day	0.19 (mg/l) lbs/day = Q*0.19*8.34	0.19 (mg/l) lbs/day = Q*0.19*8.34		0.25 (mg/l) 8.20 lbs/day	0.25 (mg/l) 6.14 lbs/day	0.10 (mg/L) lbs/day = Q*0.10*8.34	0.10 (mg/L) lbs/day = Q*0.10*8.34		83%	91%	50%	50%

*Existing TP concentrations were determined using Point Source DMR data (April-October) for the period of 2000 and 2002
*Existing point source TP mass loadings were calculated utilizing TP concentrations times design flows times 8.34
*Q is equal to flow in MGD
*Allowable point source TP mass loadings calculated by distributing allowable WPS TP mass loading in Table 1-2 proportional to facility design capacities (ex. Auburn lb/day = 5 lbs/day + 2.67 lbs/day * 3 MGD / 7MGD = 6.14 lbs/day)
*Note: Auburn Northside WWTP Design Capacity = 3 MGD; Opelika Westside WWTP Design Capacity = 4 MGD

Table B-9 CBOD$_5$ TMDL Results for the Sougahatchee Creek Watershed



TMDL	Existing Summer CBOD$_5$ Loads					Allowable Summer CBOD$_5$ Loads					Reductions				
	WLA (Continuous Sources)			WLA (Stormwater Sources)	LA (Stormwater Sources)	WLA (Continuous Sources)			WLA (Stormwater Sources)	LA (Stormwater Sources)	WLA (Continuous Sources)			WLA (Stormwater Sources)	LA (Stormwater Sources)
	WPS	Opelika Westside WWTP	Auburn Northside WWTP			WPS	Opelika Westside WWTP	Auburn Northside WWTP			WPS	Opelika Westside WWTP	Auburn Northside WWTP		
Sougahatchee Creek Watershed	6.00 (mg/l) 80.06 lbs/day	10.00 (mg/l) 333.60 lbs/day	5.00 (mg/l) 125.10 lbs/day	3.05 (mg/l) lbs/day = Q*3.05*8.34	3.05 (mg/l) lbs/day = Q*3.05*8.34	6.00 (mg/l) 80.06 lbs/day	10.00 (mg/l) 333.60 lbs/day	5.00 (mg/l) 125.10 lbs/day	3.05 (mg/l) lbs/day = Q*3.05*8.34	3.05 (mg/l) lbs/day = Q*3.05*8.34	0%	0%	0%	0%	0%

TMDL	Existing Winter CBOD$_5$ Loads					Allowable Winter CBOD$_5$ Loads					Reductions				
	WLA (Continuous Sources)			WLA (Stormwater Sources)	LA (Stormwater Sources)	WLA (Continuous Sources)			WLA (Stormwater Sources)	LA (Stormwater Sources)	WLA (Continuous Sources)			WLA (Stormwater Sources)	LA (Stormwater Sources)
	WPS	Opelika Westside WWTP	Auburn Northside WWTP			WPS	Opelika Westside WWTP	Auburn Northside WWTP			WPS	Opelika Westside WWTP	Auburn Northside WWTP		
Sougahatchee Creek Watershed	14.00 (mg/l) 186.82 lbs/day	15.00 (mg/l) 500.40 lbs/day	7.00 (mg/l) 175.14 lbs/day	2.15 (mg/l) lbs/day = Q*2.15*8.34	2.15 (mg/l) lbs/day = Q*2.15*8.34	14.00 (mg/l) 186.82 lbs/day	15.00 (mg/l) 500.40 lbs/day	7.00 (mg/l) 175.14 lbs/day	2.15 (mg/l) lbs/day = Q*2.15*8.34	2.15 (mg/l) lbs/day = Q*2.15*8.34	0%	0%	0%	0%	0%

*Existing CBOD$_5$ concentrations were taken from NPDES Permits
*Point source CBOD$_5$ mass loadings were calculated utilizing CBOD$_5$ concentrations times design flows times 8.34
*Q is equal to flow in MGD
*The estimated CBOD$_5$ allocations for stormwater (WLA and LA Stormwater Sources) represent the maximum allowable stormwater loads at Lovelady Bridge including point source contributions. The CBOD$_5$ TMDL allocations for stormwater sources should be dictated by the 0% reduction.

An appropriate initial strategy to controlling algal growth in the Sougahatchee Creek watershed, is to effectively control phosphorus loadings in the system. Therefore, controlling nitrogen in the system should be unnecessary because phosphorus will be managed to prevent nitrogen from becoming the limiting nutrient. "Based on available literature, including EPA guidance summarizing evidence that phosphorus often limits stream algae (EPA 2000), control of total phosphorus rather than total nitrogen should be effective as an initial strategy to manage algal productivity." Since Yates forebay, downstream of the impaired Sougahatchee Creek embayment, represents full use support with no nitrogen-caused nutrient impairment, targeting only phosphorus will be protective of downstream waterbodies. Furthermore, it is expected that phosphorus reductions achieved through improved wastewater and stormwater treatment will also help achieve reductions in biologically available nitrogen. A model run simulation with a 30% reduction of TN, in addition to the reduced TP loading, yielded an insignificant change in the chlorophyll *a* value of Sougahatchee Creek embayment as shown in Figure B-12.

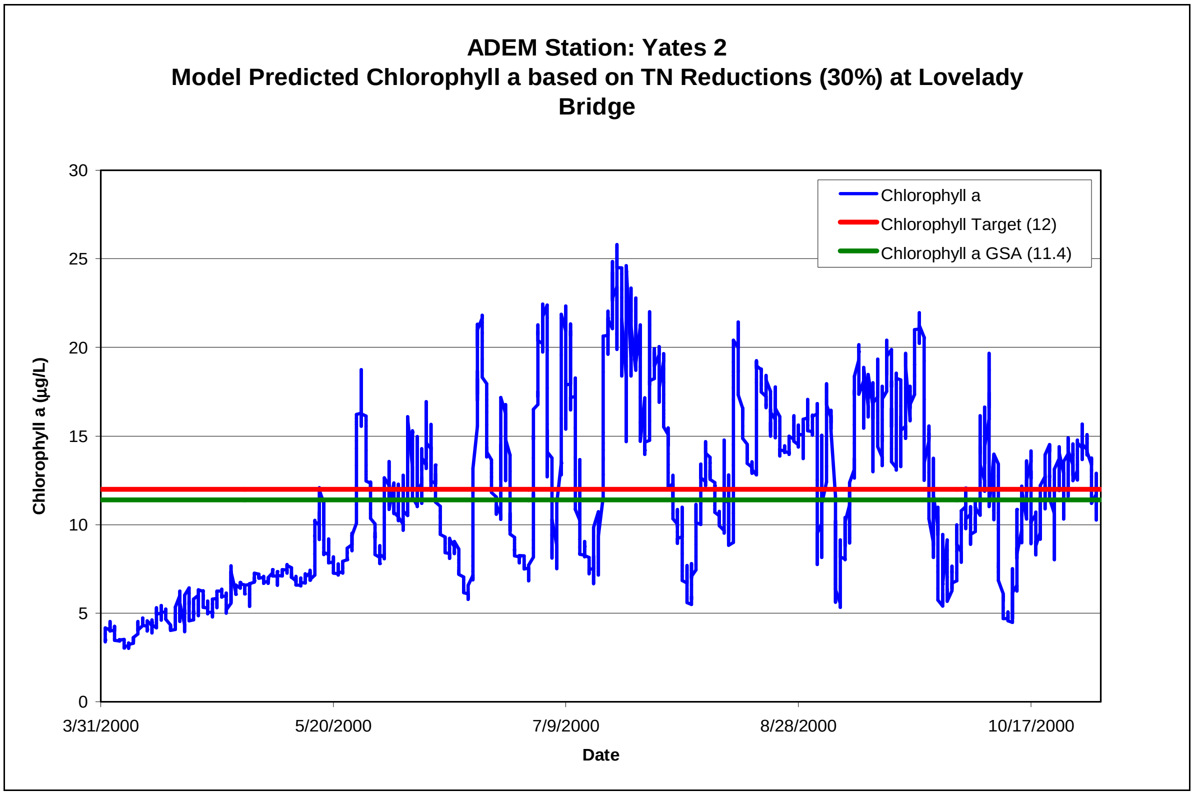


Figure B-12 Chlorophyll *a* Concentrations Resulting from a Thirty Percent Nitrogen and Fifty Percent Phosphorus Loading Reduction to Sougahatchee Creek Embayment

Dissolved Oxygen

Estimation of point source delivery to Sougahatchee embayment at Yates Reservoir

In order to demonstrate the potential impact of point source CBOD on dissolved oxygen in the Sougahatchee embayment at Yates Reservoir, estimates of transported CBOD were made and compared to the assumed natural condition of 2.0 mg/L CBOD-ultimate.

Instream attenuation (decay) of point source CBOD is assumed to occur as a first order exponential decay. The decay rate was chosen as the same CBOD decay rate used in WASP of 0.35/day. As in common practice, the decay rate is temperature-corrected as $k(T) = k * \theta^{(T-20)}$.

An example of instream decay for summer conditions, 8/19/2000 with an instream flow of 9 CFS, estimated velocity of 3.3 miles / day, and temperature of 21.4 deg C is shown on the next page.

Table B-10: Kcbod and temperature corrected decay rate

Kcbod	theta	temp (degC)	temp corrected K(T)
0.35	**1.07**	**21.4**	**0.38**

Table B-11: Estimated instream attenuation of CBOD in Sougahatchee Creek

WWTP	distance (mi)	discharge (MGD)	summer CBOD (mg/L)	summer CBOD (lb/day)	travel time @3.3 mi/day	attenuation [1-e^(-k*t)]	Net CBOD (lb/day)
Auburn-Northside	31	1.6	9	120	9.4	0.97	3.2
Opelika-Westside	38	4.0	10	333	11.5	0.99	4.0
West Point-Stevens	42.5	1.6	6	80.1	12.9	0.99	0.6
						SUM:	**7.8**
						Net delivered:	**1.5%**

Since it is summertime, at low flow and high temperature, this estimate is a very low value. At higher flows and velocities, and lower temperatures, more CBOD is transported downstream. Using daily values for flow, estimated velocity and time-of-travel, daily estimates of transported CBOD can be calculated.

The relationship between stream flow and time-of-travel is shown in Figure B-13.

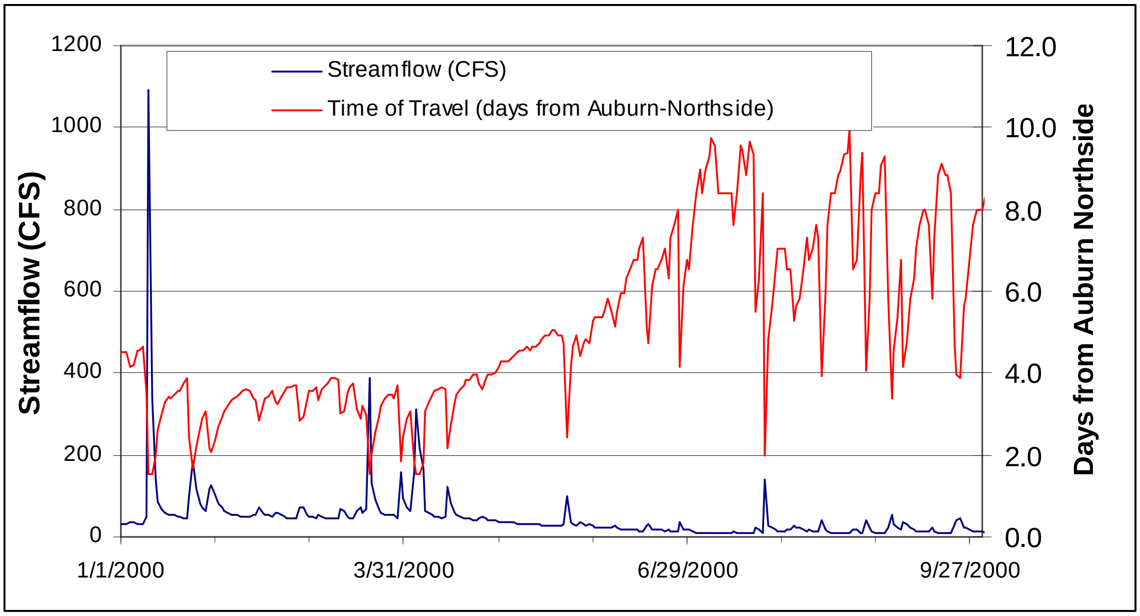


Figure B-13 **Stream flow and time-of travel for CBOD in Sougahatchee Creek**

The daily time-of-travel and temperature for each of the three major point sources were used to calculate the temperature-corrected attenuation rates for the year 2000. These attenuation rates are shown in Figure B-14 below.

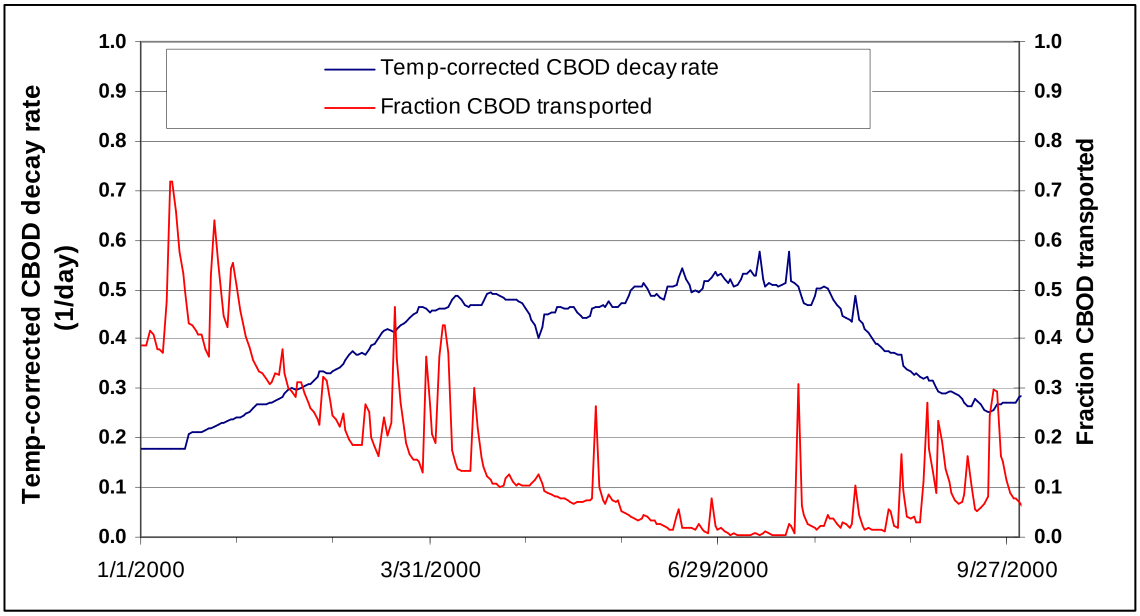


Figure B-14 **Temperature-corrected CBOD decay rate and percent transported.**

The total mass of CBOD from the point sources delivered to the embayment was converted to a concentration as a function of the total stream flow for each day. The $CBOD_u/CBOD_5$ ratio is assumed to be 3.5.

Baseline $CBOD_U$ for the natural condition is assumed to equal 2.0 mg/L. Adding the additional point source contribution for the summer allocation scenario results in the values shown in Figure B-15.

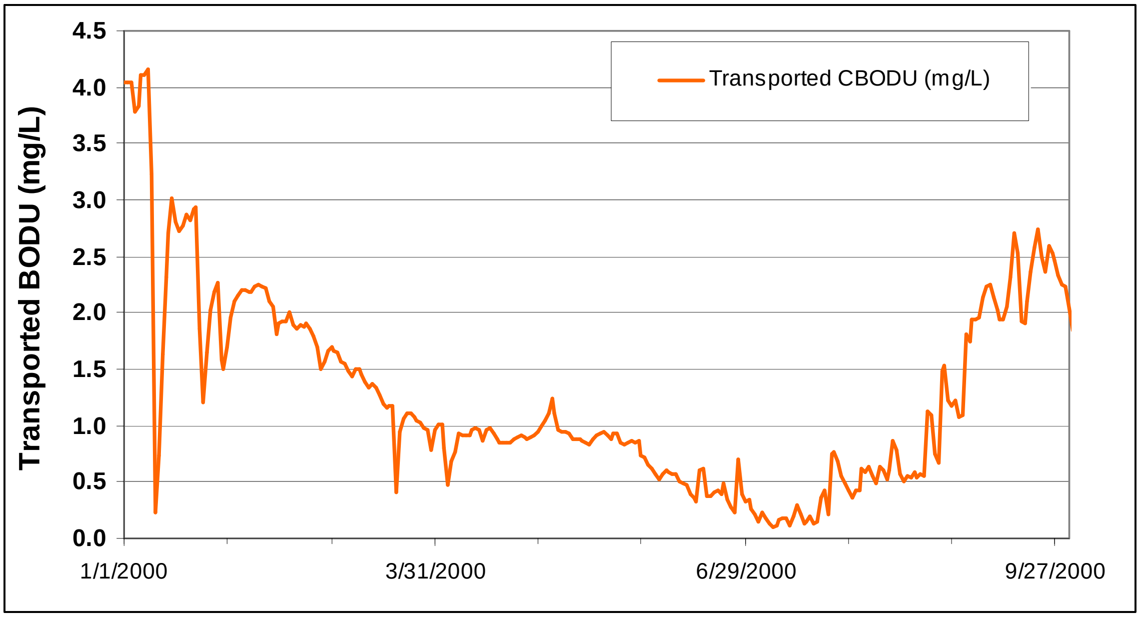


Figure B-15 **Transported CBOD-ultimate**

APPENDIX C: NUTRIENT TARGET DEVELOPMENT

ADEM continues its efforts to develop comprehensive numeric nutrient criteria for all surface waters throughout Alabama, including rivers/streams, lakes/reservoirs, wetlands, and coastal/estuarine waters. However, until numeric nutrient criteria or some form of quantitative interpretations of ADEM's narrative criteria are developed, the Department will continue to use all available data and information coupled with best professional judgment to make informed decisions regarding overall use support and when establishing targets for TMDLs.

Typically, development of a water quality criterion for a given pollutant involves extensive research using information from many areas of aquatic toxicology. For example, development of numeric criteria for toxic pollutants, such as mercury, involves numerous toxicological studies such as dose/response relationships, bioaccumulation studies, fate and transport studies, and an understanding of both the acute and chronic effects to aquatic life. As part of the toxicological evaluations, EPA performs uncertainty analysis to help guide selection of the recommended water quality criterion for a given pollutant. For toxic pollutants, the more uncertainty revealed during the evaluation, the more conservative (i.e. the lower the value) the recommended criterion becomes.

Nutrients such as phosphorus and nitrogen are essential elements to aquatic life, but can be undesirable when present at sufficient concentrations to stimulate excessive plant growth. Even though these pollutants are generally considered nontoxic (the exception being un-ionized ammonia toxicity to aquatic life), they can impact aquatic life due to their indirect effects on water quality, either when in overabundance or when availability is limited.

ADEM's water quality criteria applying to nutrients are narrative except in the reservoirs where numeric criteria have been adopted and nutrient loadings from tributaries must support the reservoir criteria. Therefore, a numerical translator is needed to define the TMDL target. Based on the historical data collected within the Sougahatchee Creek Watershed, there is evidence that designated uses are impaired by nutrient over-enrichment, but some uncertainty remains in the exact quantification of the nutrient target due to the complexity of the relationship of cause and effect and the state of the science. This is a very common dilemma in nutrient water quality management, and often warrants an alternate approach. EPA recommends, in the absence of sufficient "effects-based" information, a reference condition approach for determining protective nutrient criteria is suitable provided that truly similar and comparable waters with reference conditions can be identified. With this approach, a numerical value can be empirically developed that can be assumed to inherently protect uses supported in the reference waters. This approach can provide an initial target while continuing studies will allow further evaluation of the cause and effect relationships that might result in refinement of the initial target.

In developing a nutrient target for the Sougahatchee Creek Watershed Nutrient TMDL, ADEM has chosen to use a “reference condition” approach for determining the appropriate levels of nutrients necessary to support designated uses. This approach is based on using ambient water quality data from candidate reference tributary embayments that are located in characteristically similar regions of Alabama known as ecoregions. An ecoregion is defined as a relatively homogeneous area defined by similar climate, landform, soil, potential natural vegetation, hydrology and other ecologically relevant variables (USEPA, 2000). “Reference embayments” are defined as reasonably similar and comparable waterbodies that have been relatively undisturbed or minimally-impacted that can serve as examples of the natural biological integrity of a particular ecoregion. These “reference embayments” can be monitored over time to establish a baseline to which other waters can be compared. Reference embayments are not necessarily pristine or undisturbed by humans, however they do represent waters within Alabama that are healthy and fully support their designated uses, to include protection of aquatic life. The “reference condition” approach used to determine appropriate nutrient targets for the Sougahatchee Creek TMDL is reasonable, scientifically defensible, protective of designated uses, and consistent with USEPA guidance.

An evaluation of several watershed characteristics was performed to gain an understanding of the current condition of the Sougahatchee Creek Watershed as well as the several selected reference tributary embayments. Table C-1, below, provides the summary statistics of the tributary embayments that were considered in developing the nutrient target for the Sougahatchee Creek Watershed Nutrient TMDL.

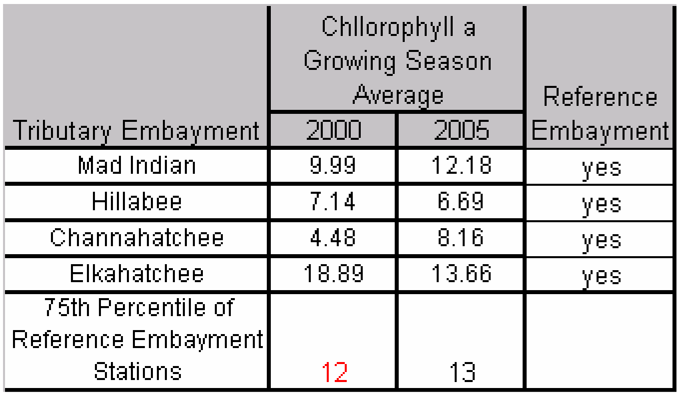
Table C-1 Summary Statistics for the Sougahatchee Creek Watershed and Selected Reference Tributary Embayments within the Tallapoosa River Basin

Reservoir	Tributary Embayment	2000 CHLA Mean (µg/L)	2005 CHLA Mean (µg/L)	CHLA Peak (µg/L)	Drainage Area (mi^2)	Agriculture Land use (mi^2)	Developed Land use (mi^2)	Forested Land use (mi^2)	Other (mi^2)	Point Sources	Reference Embayment
R. L. Harris	Wedowee	22.15	16.89	42.71	51.04	14.93	3.29	27.11	5.71	1	no
	Mad Indian	9.99	12.18	21.89	31.03	4.21	1.23	21.61	3.98	0	yes
Martin	Hillabee	7.14	6.69	24.56	280.41	20.66	13.45	208.5	37.8	0	yes
	Elkahatchee	18.89	13.66	26.7	54.87	3.26	6.23	37.55	7.83	0	yes
	Manoy	2.94	8.81	10.95	14.37	1.15	2.13	9.21	1.88	0	no
	Sandy	2.59	7.3	10.41	191.08	21.48	9.92	125.35	34.33	2	no
	Blue	1.44	3.93	8.54	58.93	3.19	3.18	39.4	13.16	0	no
Yates	Sougahatchee	17.62	12.74	27.77	217.05	25.07	18.15	147.78	26.05	3	n/a
	Channahatchee	4.48	8.16	20.29	44.57	3.73	1.75	33.02	6.07	0	yes

Phosphorus has commonly been considered the primary limiting nutrient governing algal growth in most freshwater stream systems in North America, particularly in freshwater lakes, in contrast with nitrogen-limited estuarine ecosystems (e.g., Correll, 1998). Case studies cited in EPA guidance demonstrated that control of nutrient concentrations can limit the growth of filamentous algae (USEPA, 2000; Sosiak, 2002). Recent evidence suggests that nutrient limitation by nitrogen or phosphorus may be seasonal and that nitrogen limitation has been observed in some streams (Dodds et al., 2000). An appropriate initial strategy to controlling algal growth in the Sougahatchee Creek watershed, is to effectively control phosphorus loadings in the system. A model simulation with a 30% reduction of TN, in addition to the reduced TP loading, yielded an insignificant change in the chlorophyll *a* value as shown in Figure 5-1. Therefore, controlling nitrogen in the system should be unnecessary because phosphorus will be managed to prevent nitrogen from becoming the limiting nutrient.

Based on the summary statistics listed in Table C-1, a nutrient target, expressed as a growing season chlorophyll *a* concentration of 12 µg/L, in the Sougahatchee Creek embayment, specifically at Station Yates 2, was established. This target was derived using the 75th percentile of the chlorophyll a growing season average of the chosen reference embayments (Table C-2). Normally, ADEM prefers to utilize the 90th percentile; however, since the reference data set in this specific case was limited, the 75th percentile was deemed more appropriate.

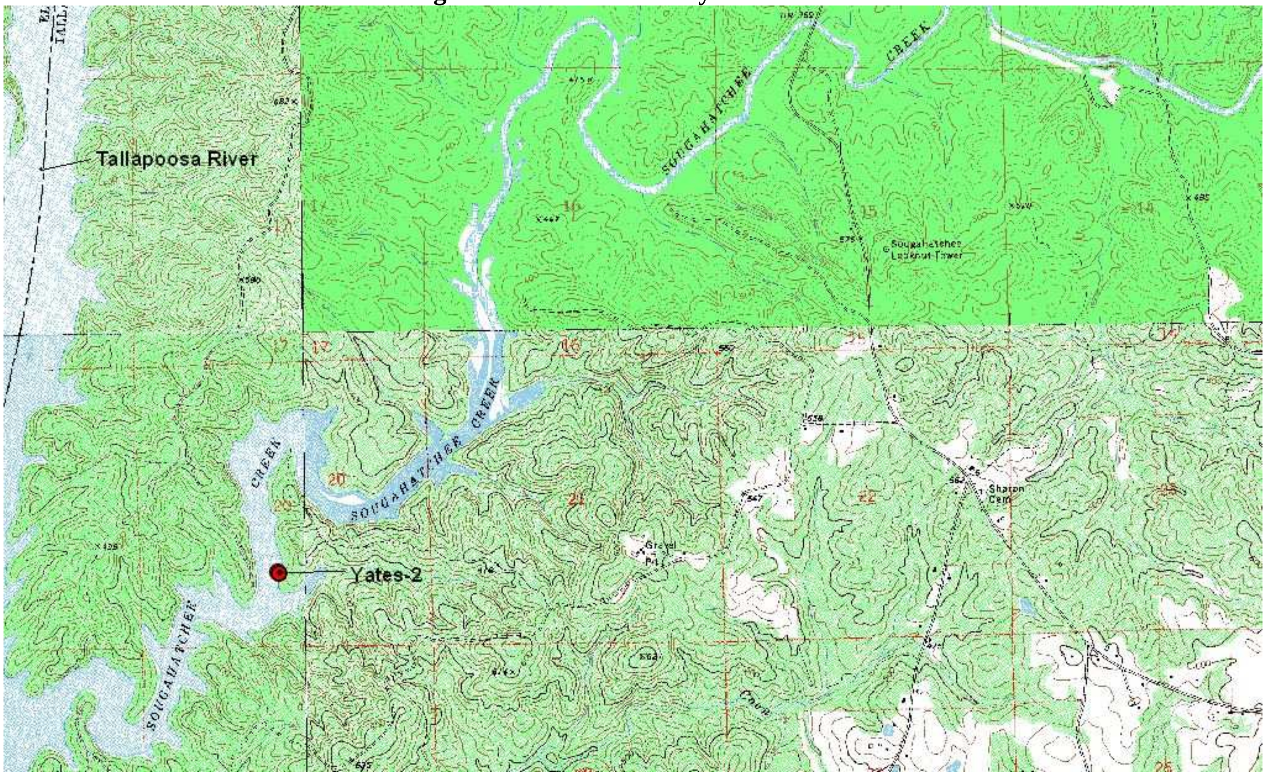
Table C-2 Chlorophyll a Target Calculation for Selected Reference Tributary Embayments within the Tallapoosa River Basin



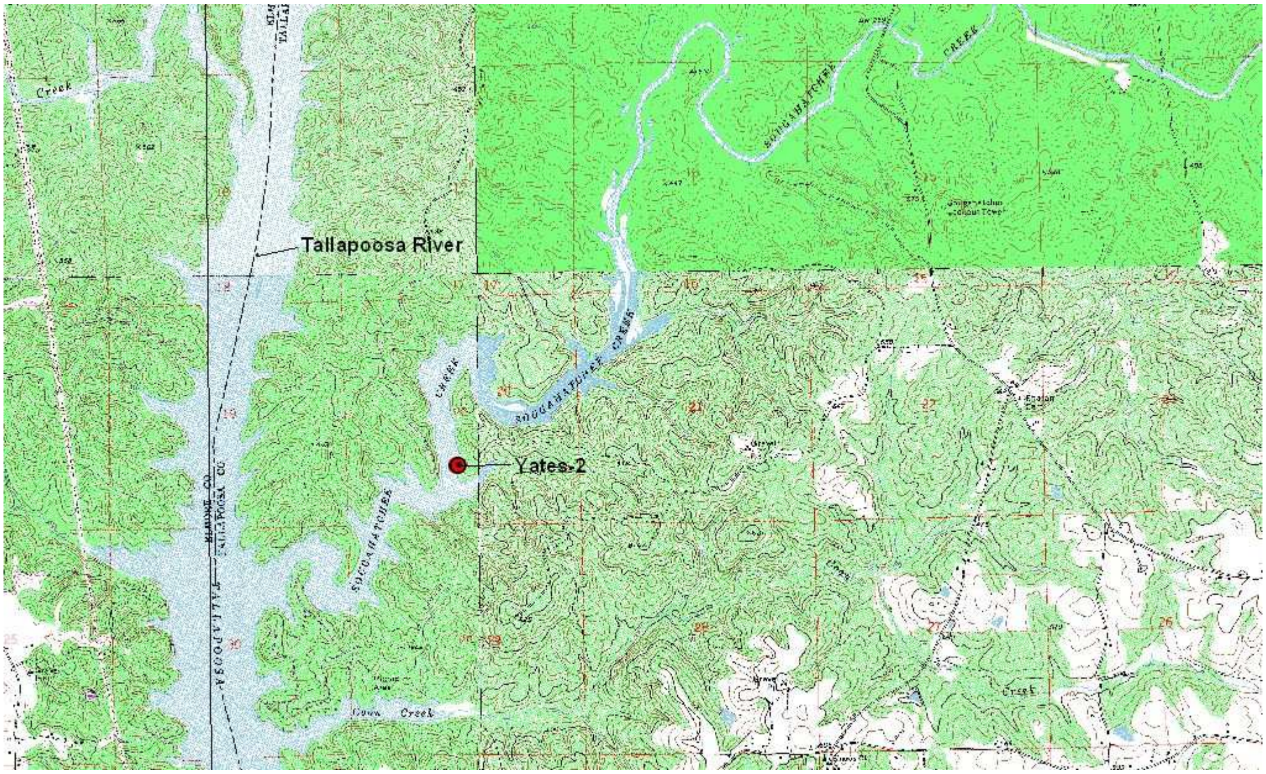
Tributary Embayment	Chllorophyll a Growing Season Average		Reference Embayment
	2000	2005	
Mad Indian	9.99	12.18	yes
Hillabee	7.14	6.69	yes
Channahatchee	4.48	8.16	yes
Elkahatchee	18.89	13.66	yes
75th Percentile of Reference Embayment Stations	12	13	

Mad Indian, Hillabee, Channahatchee, and Elkahatchee Creeks were chosen as reference embayments based on the relative location of their sampling stations and the absence of significant nutrient sources within the watershed. The sampling points within these embayments are considered to be the most representative locations to capture the expression of nutrients entering the embayment and in this respect are most similar to the Yates 2 sampling location in the Sougahatchee Creek embayment. Other embayments within the Tallapoosa River reservoirs are much larger and their sampling stations are more representative of main stem reservoir conditions. The Wedowee Creek embayment on R.L. Harris Reservoir was not considered since there is a point source located a short distance upstream of the sampling point. The 2000 sampling season was chosen as the critical period and is the data set from which the nutrient target was derived.

Sougahatchee Creek Embayment

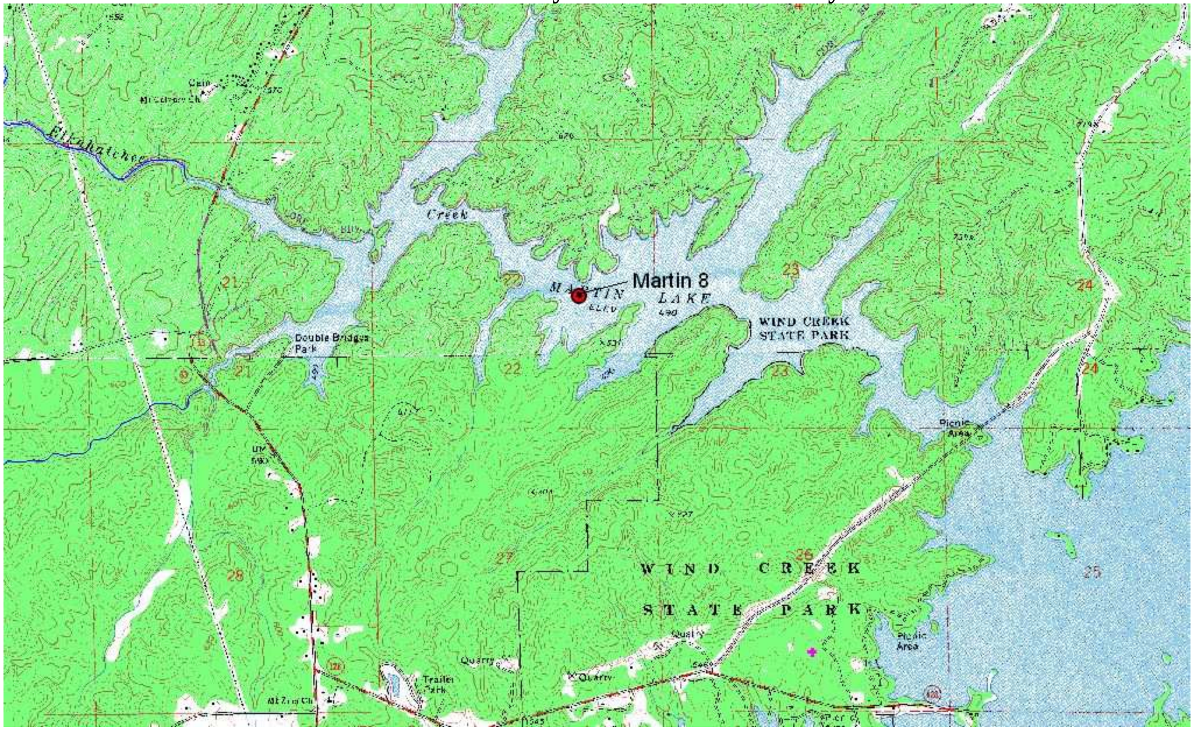


Sougahatchee Creek Embayment

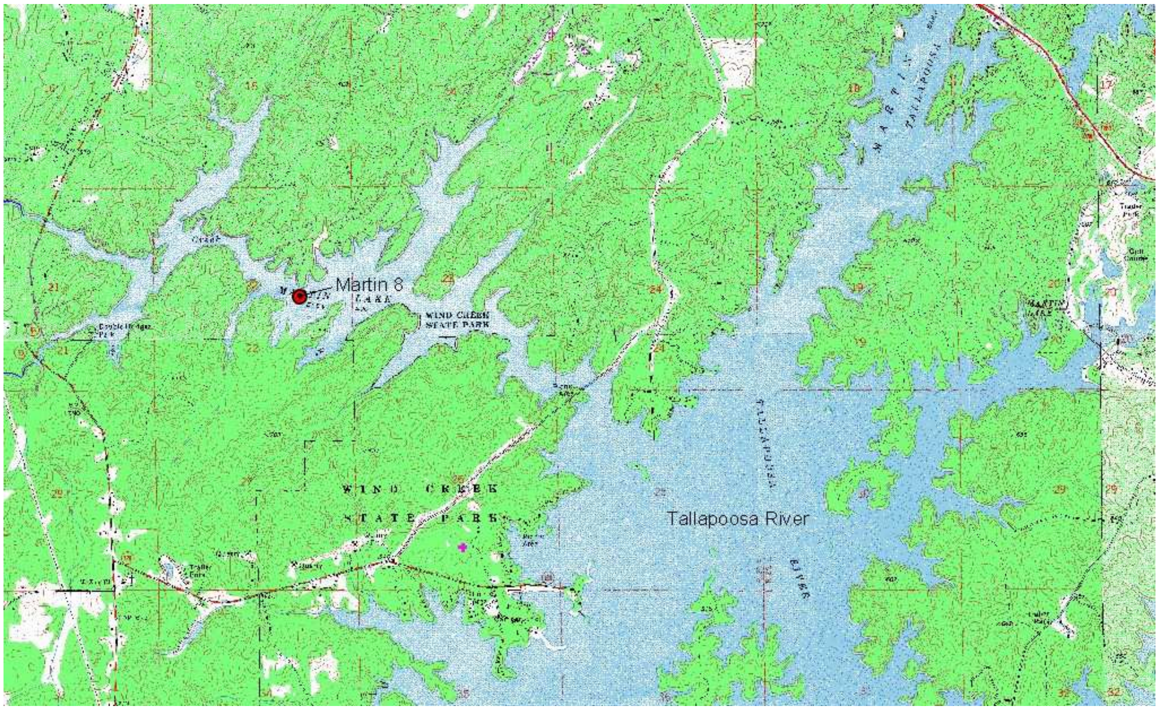


Overview of Sougahatchee Creek Embayment

Elkahatchee Creek Embayment: Reference Embayment

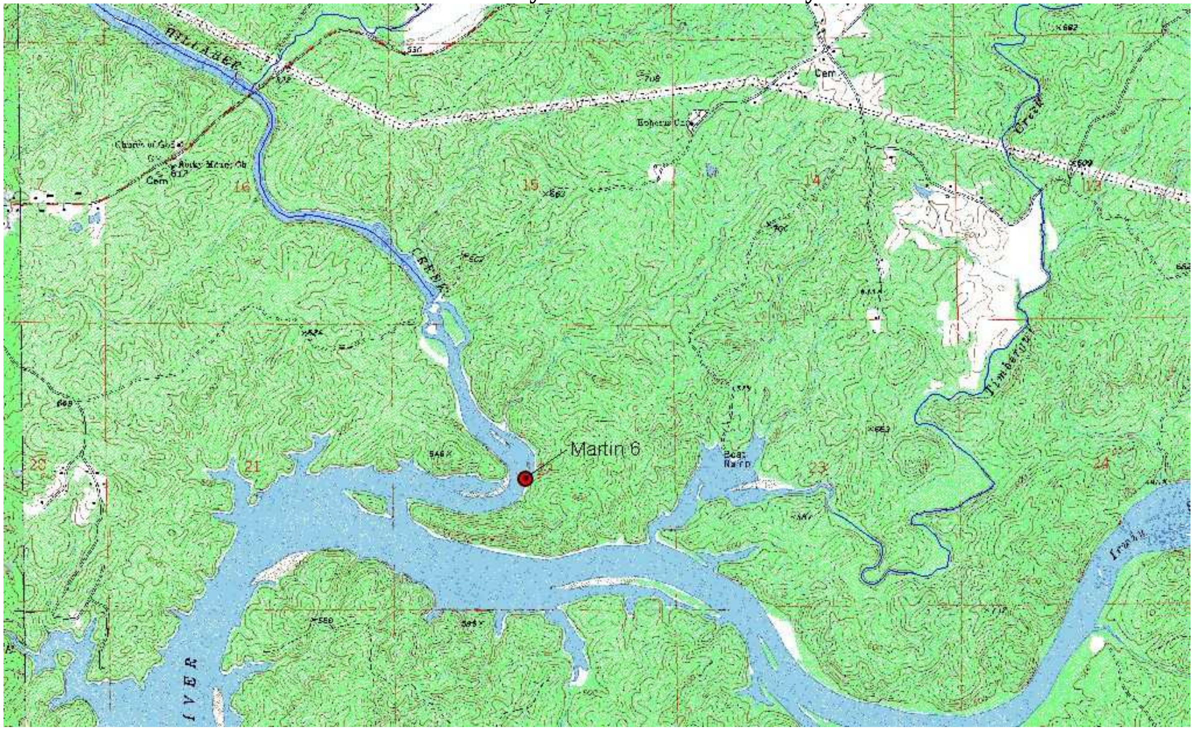


Elkahatchee Creek Embayment



Overview of Elkahatchee Creek Embayment

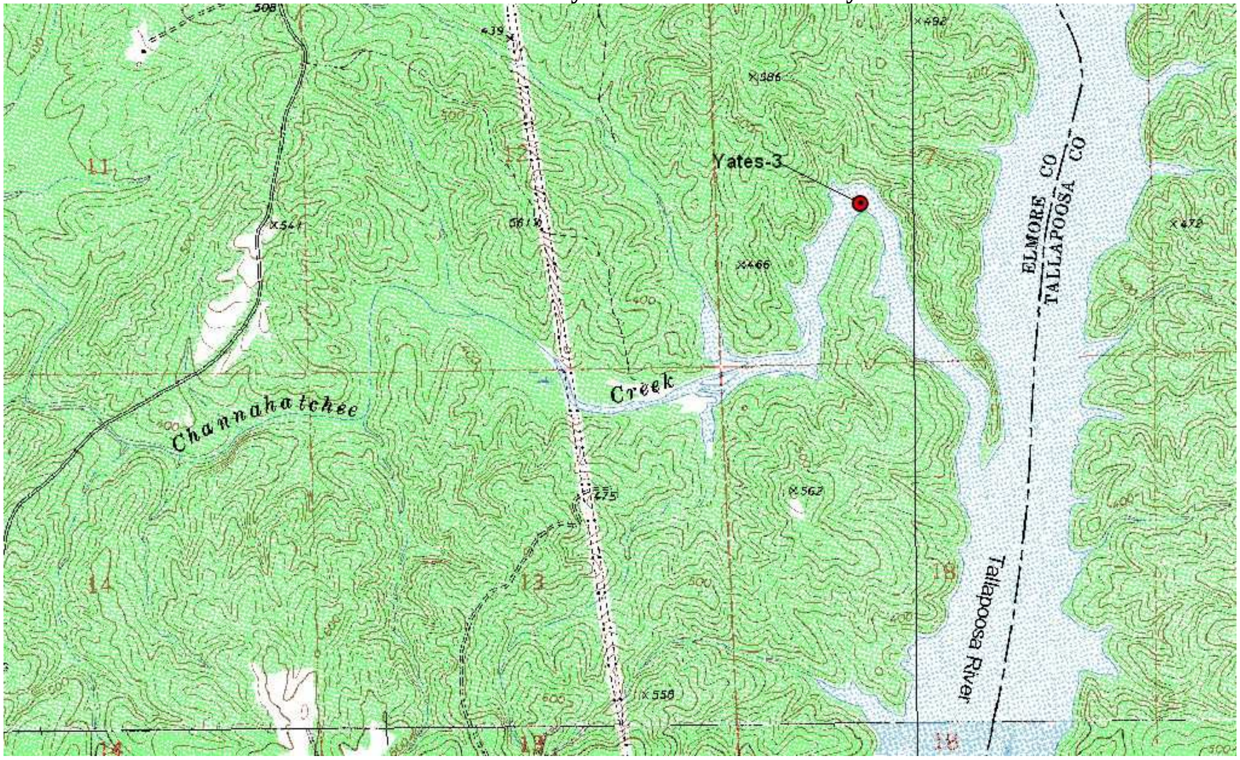
Hillabee Creek Embayment: Reference Embayment



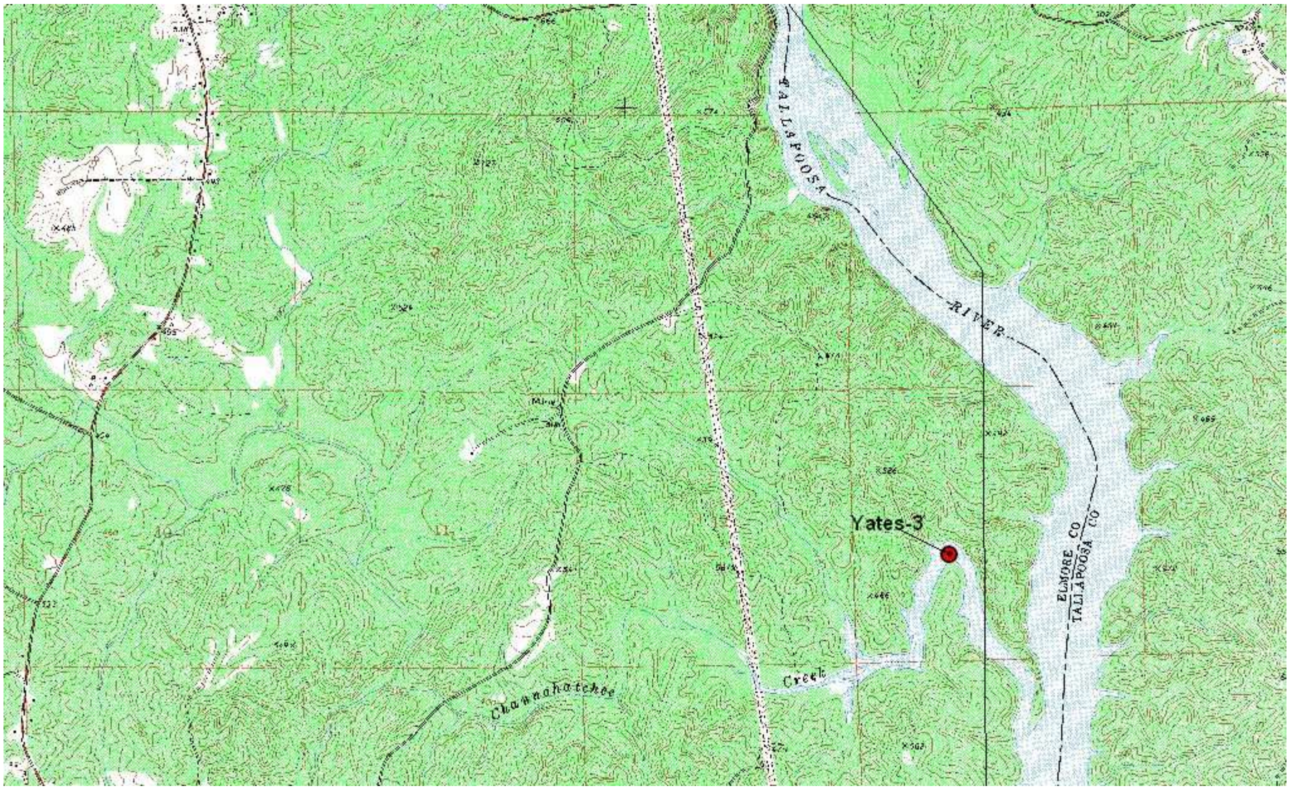
Hillabee Creek Embayment

Overview of Hillabee Creek Embayment

Channahatchee Creek Embayment: Reference Embayment

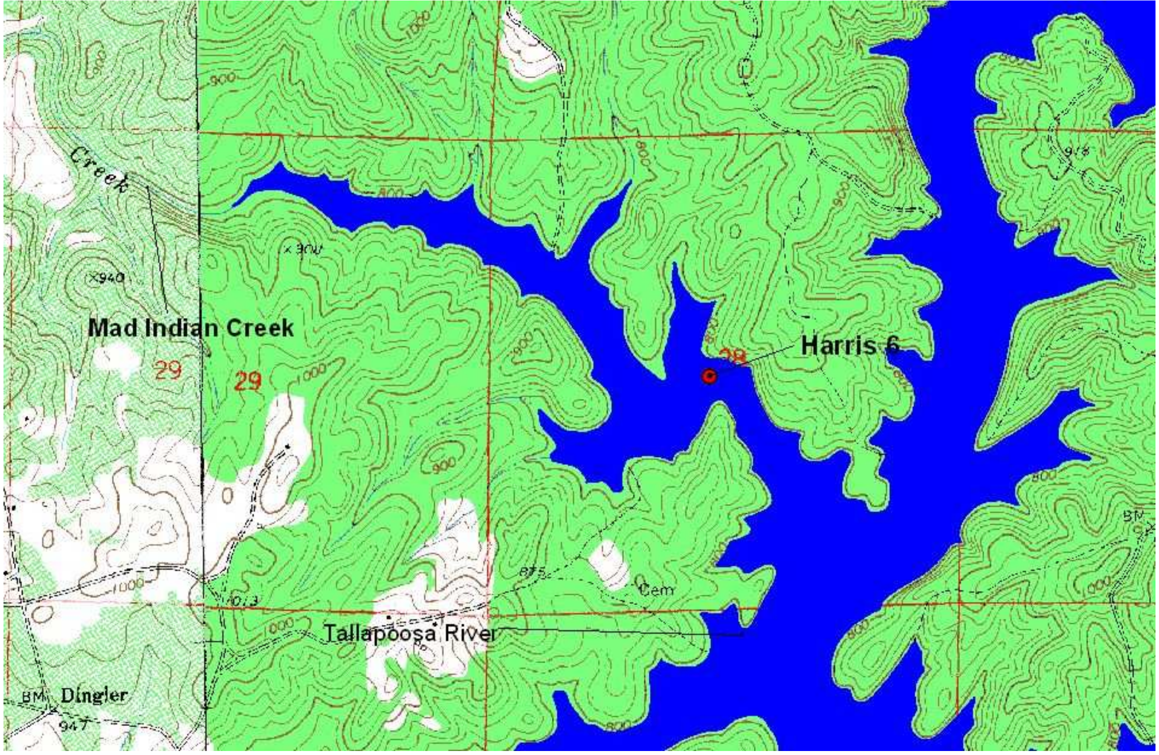


Channahatchee Creek Embayment

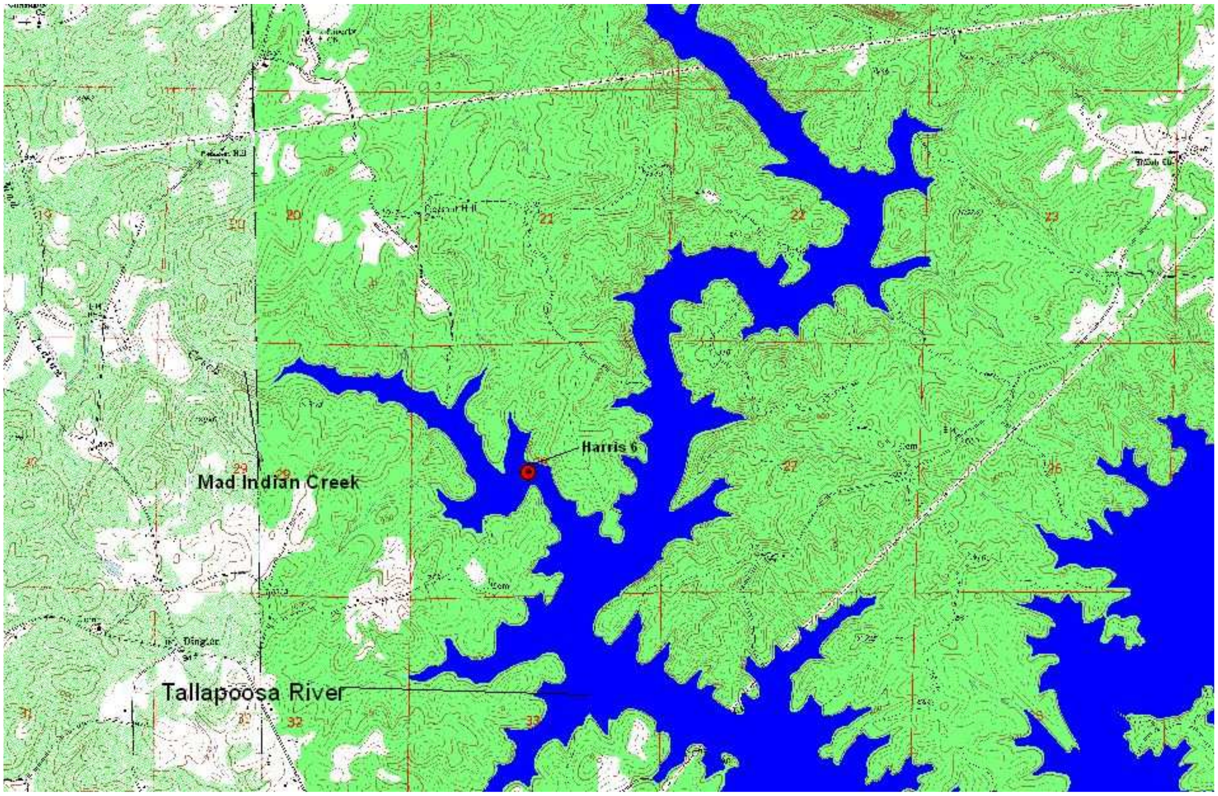


Overview of Channahatchee Creek Embayment

Mad **Indian Creek Embayment: Reference Embayment**

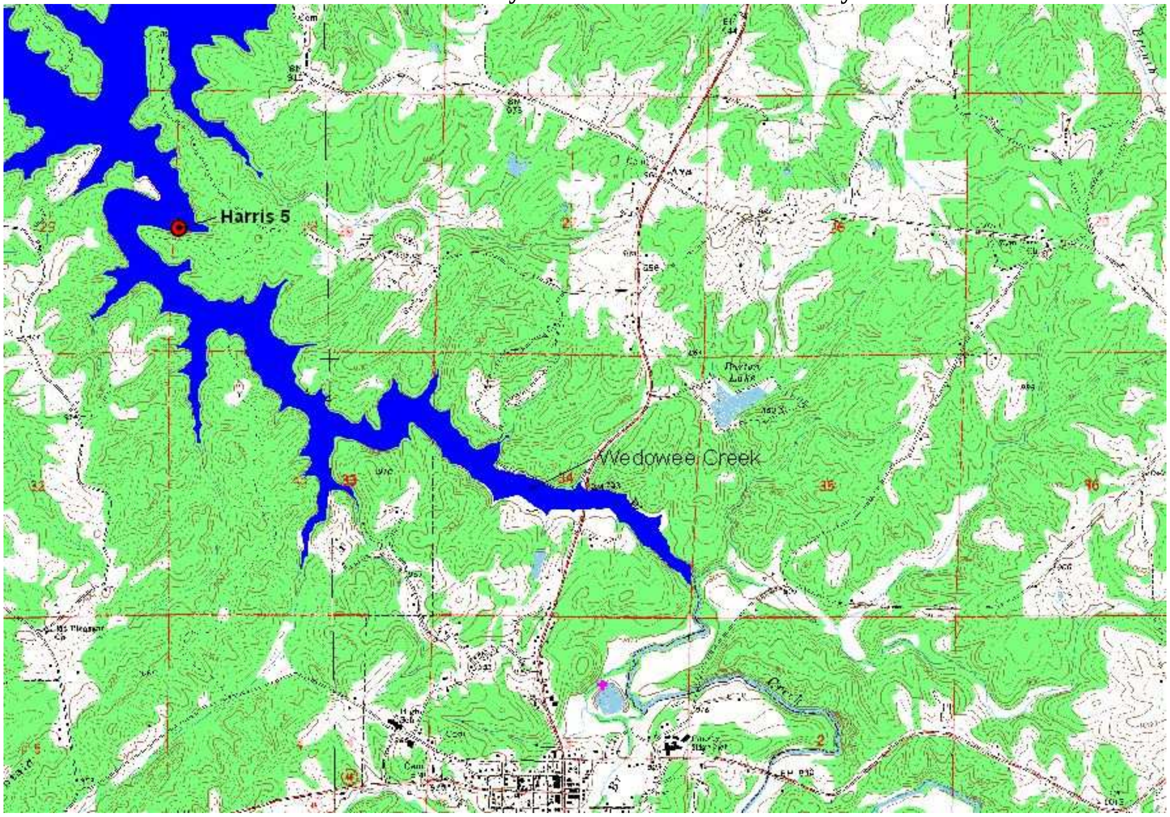


Mad Indian Creek Embayment

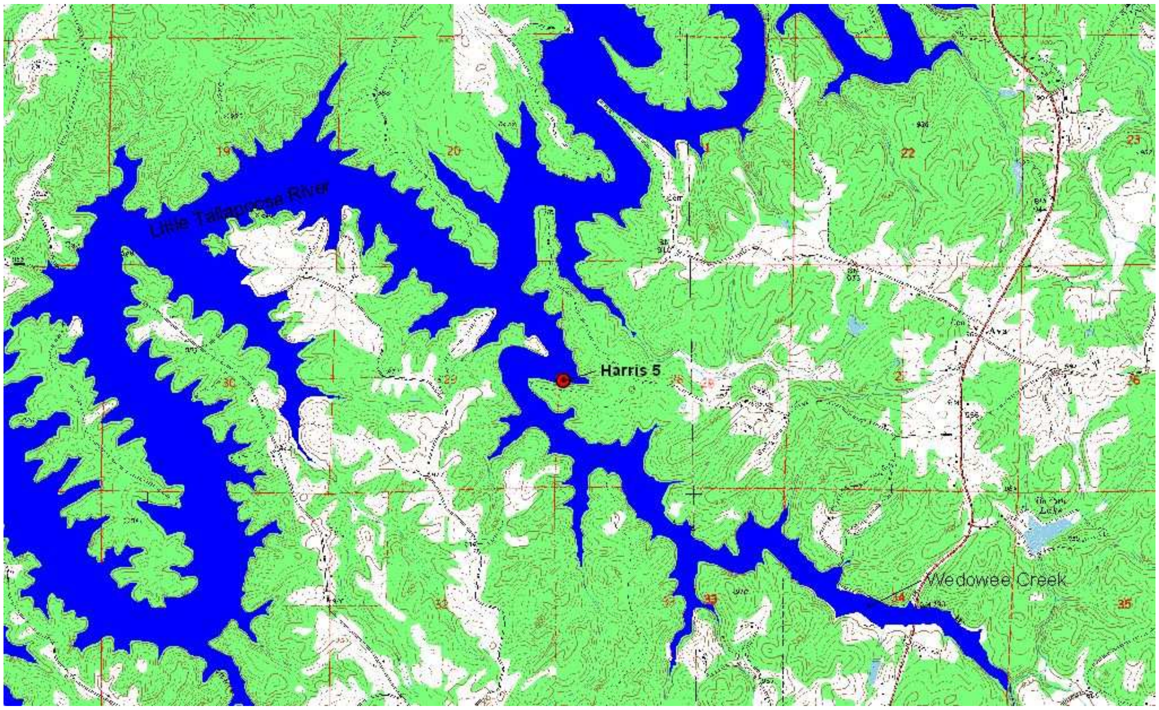


Overview of Mad Indian Creek Embayment

Wedowee Creek Embayment: Non-Reference Embayment

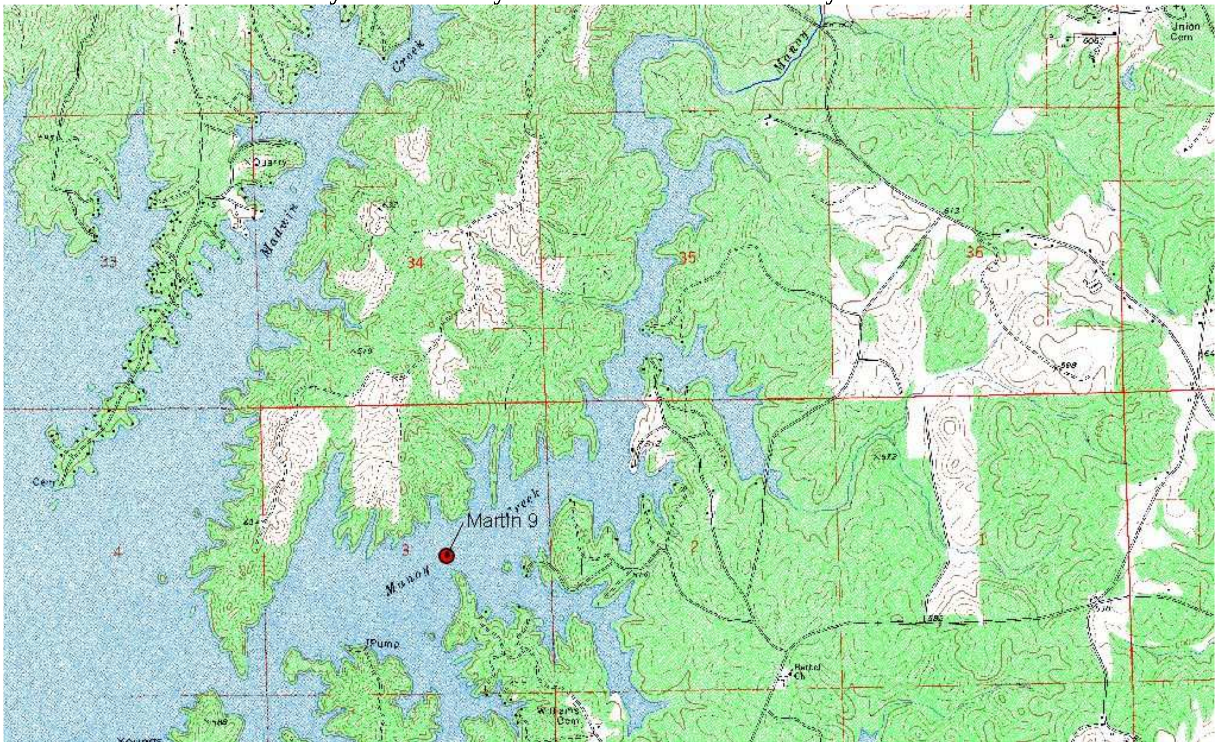


Wedowee Creek Embayment

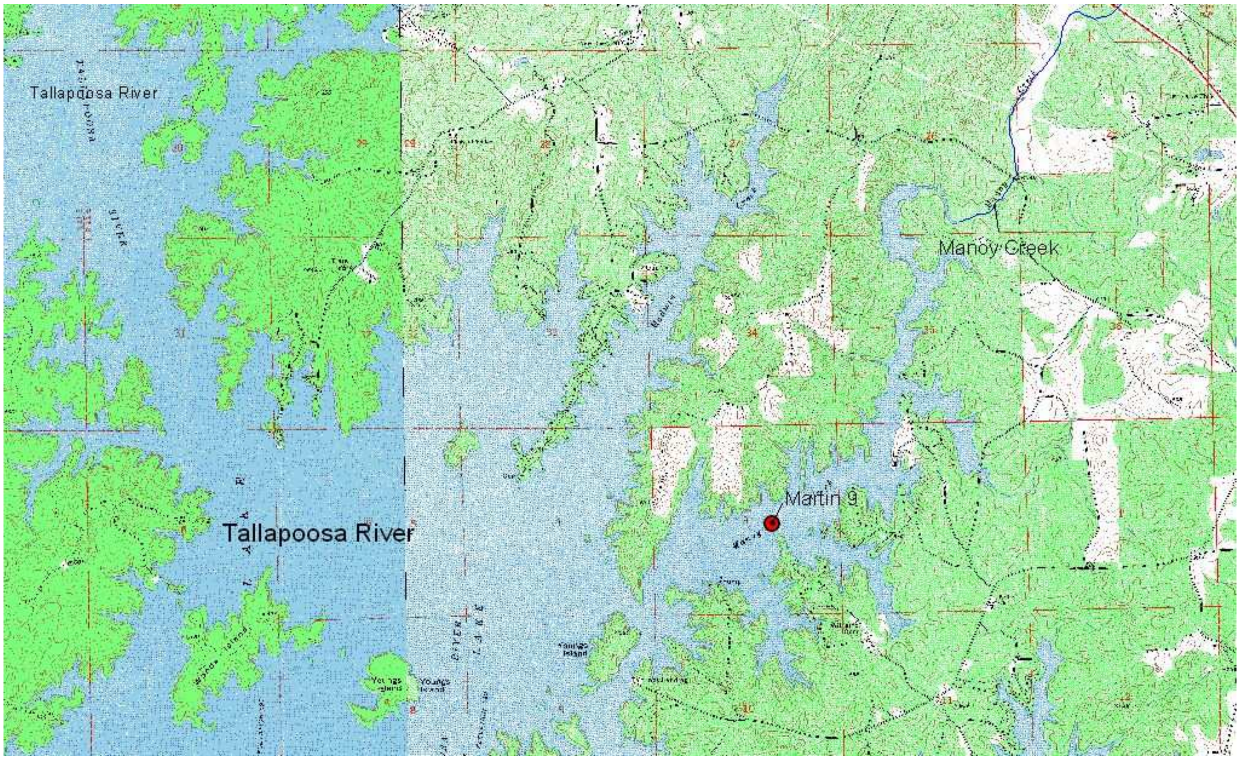


Overview of Wedowee Creek Embayment

Manoy Creek Embayment: Non-Reference Embayment

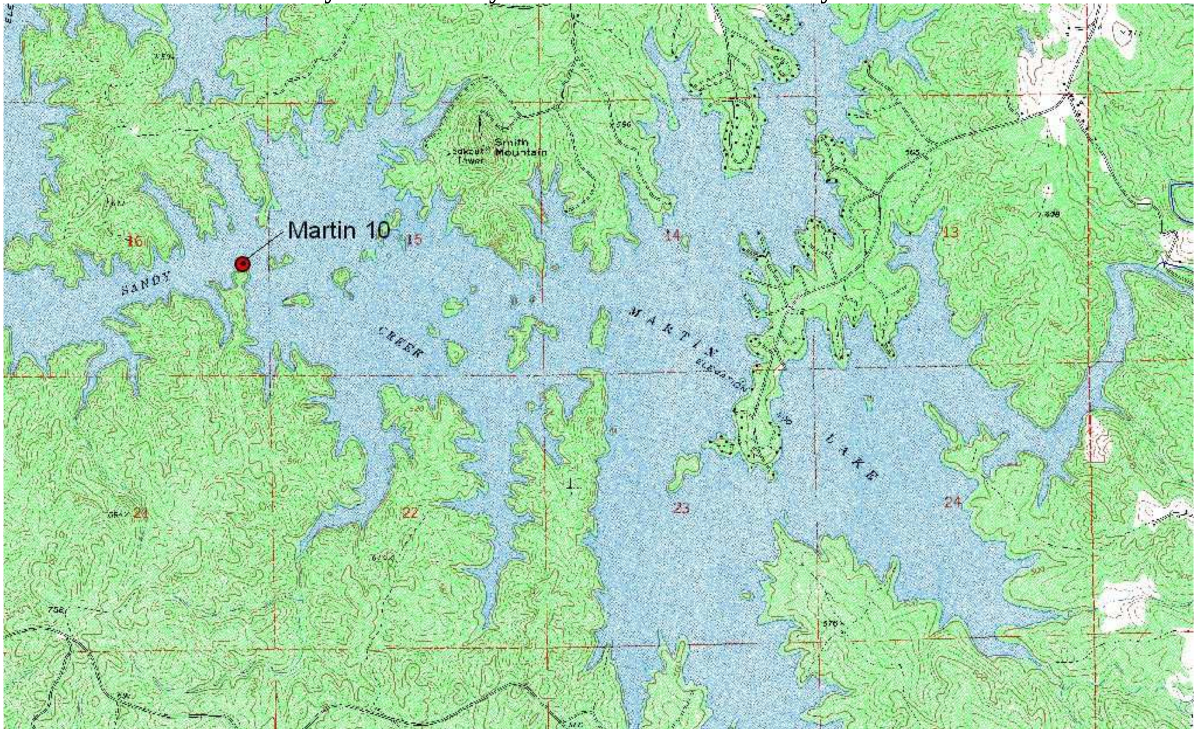


Manoy Creek Embayment

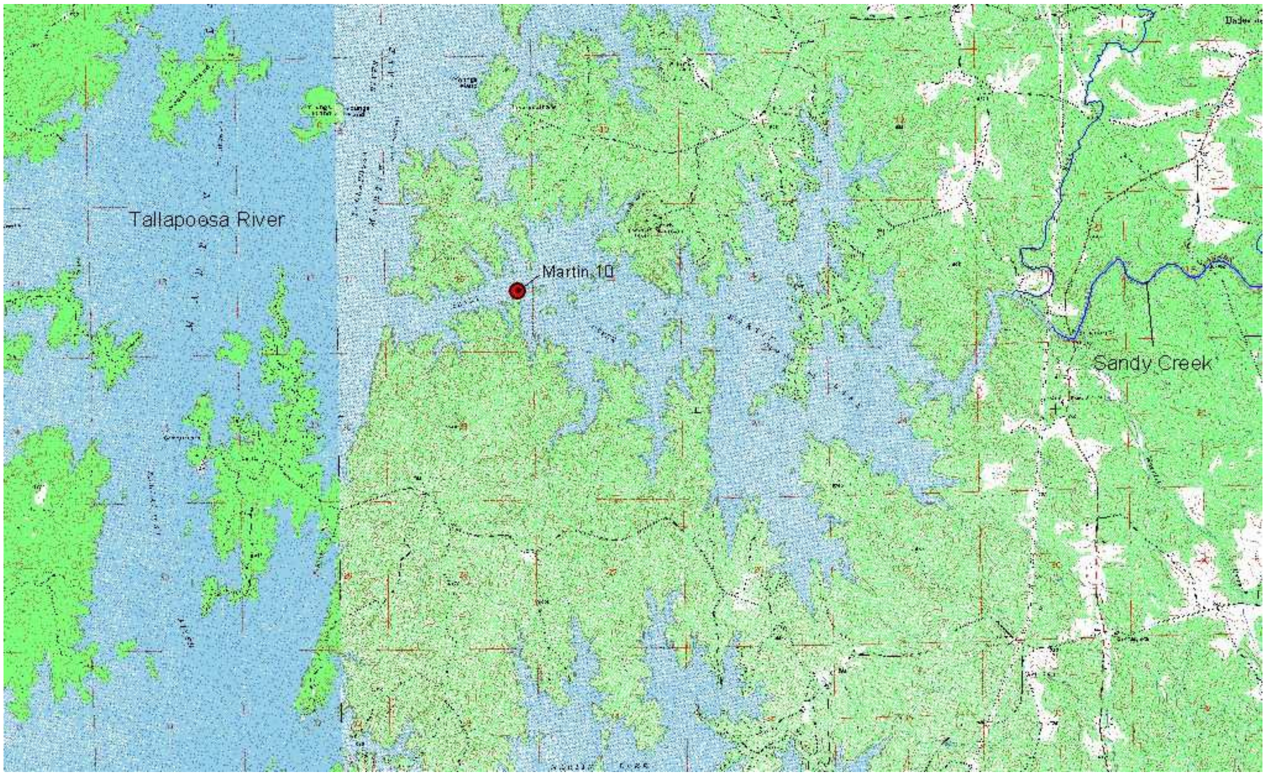


Overview of Manoy Creek Embayment

Sandy Creek Embayment: Non-Reference Embayment

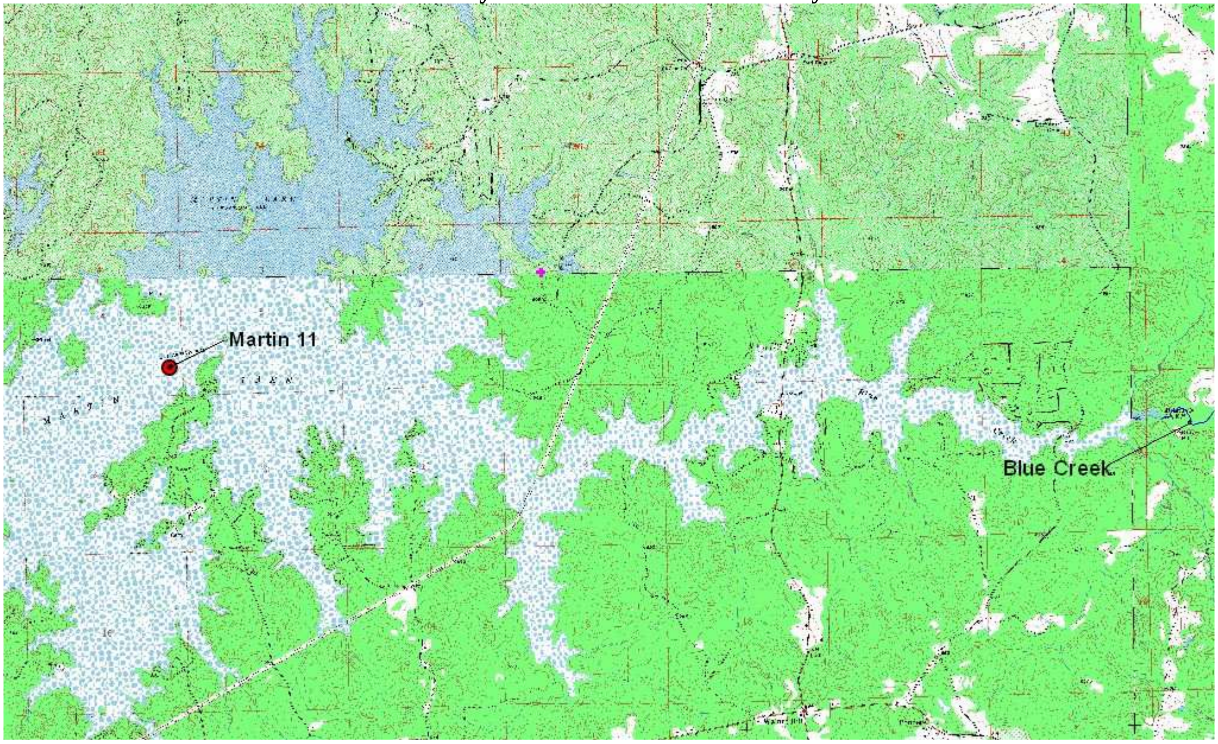


Sandy Creek Embayment

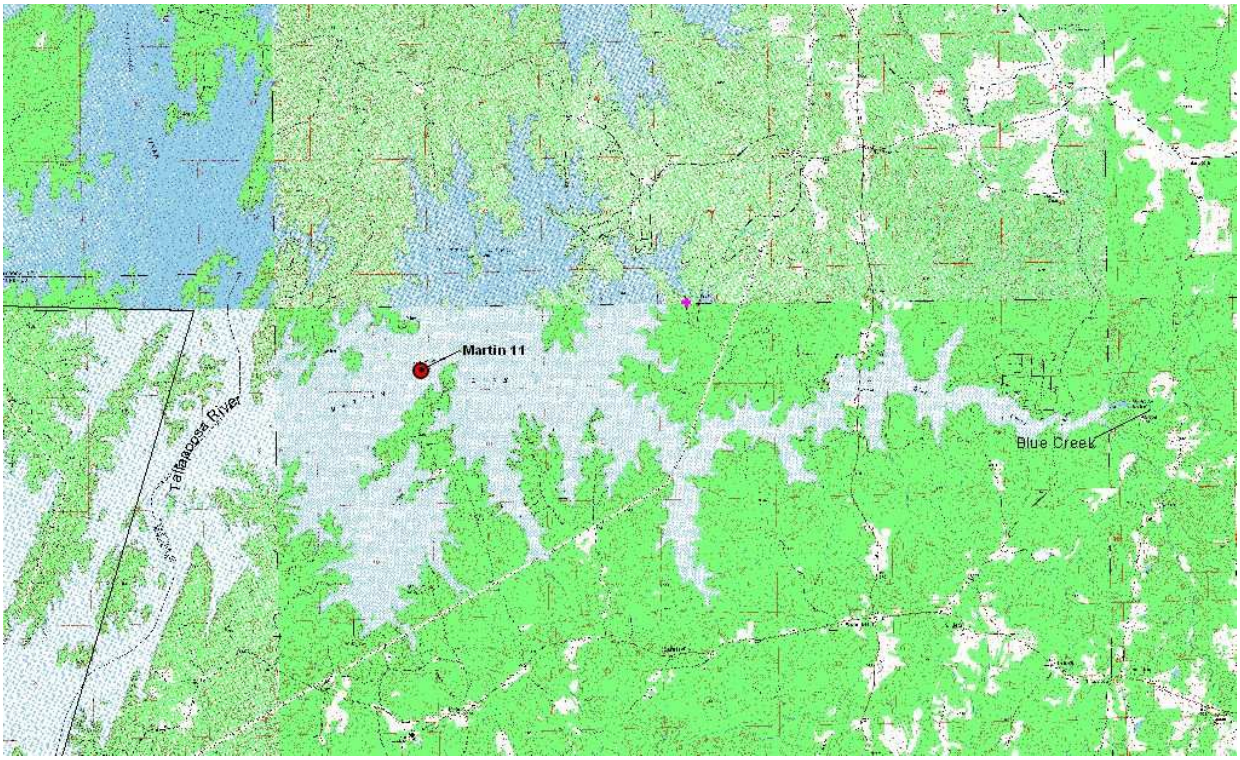


Overview of Sandy Creek Embayment

Blue Creek Embayment: Non-Reference Embayment



Blue Creek Embayment



Overview of Blue Creek Embayment