GEORGIA DEPARTMENT OF NATURAL RESOURCES

Lakes Oconee and Sinclair

Proposed Criteria Technical Support Document

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1.0 INTRODUCTION

Lakes Oconee and Sinclair lie in the Oconee River watershed in central Georgia, approximately 77 miles southeast of the city of Atlanta (Figure 1-1). Lake Oconee is located in Morgan, Greene, Putnam, and a small portion of Hancock counties, and Lake Sinclair is located in Baldwin, Hancock, and Putnam counties. Lake Oconee receives the majority of its inflow from the Oconee and Apalachee Rivers. Downstream of Lake Oconee is Lake Sinclair. Lake Sinclair receives the majority of its inflow from Lake Oconee, as water is released from Wallace Dam during the day. At night, when energy costs are low, water from Lake Sinclair is pumped back into Lake Oconee, making Sinclair a “re-reg” lake. Downstream from Lake Sinclair is the Oconee River, which flows southeast into the Altamaha River.

Lakes Oconee and Sinclair are owned and operated by Georgia Power. Sinclair Dam was completed in the early 1950s and the lake became operational in 1952. Wallace Dam was completed in the later 1970s and the lake has been operational since 1979. Lakes Oconee and Sinclair are multi-use reservoirs. Uses include: flood control, hydropower generation, water supply, recreation, and fish and wildlife management.

Wallace Dam impounds water from a 1,820 square mile drainage area, and has a normal pool elevation of 436 feet mean sea level (ft MSL). The intake elevation at Wallace Dam is 345.655 ft msl, with a diameter of 25.5 ft. This means that the topmost point of the Wallace Dam intake is located at 371.155 ft msl. Courtenay O’Mara, hydrologic engineer for GA Power, explained that the dam operates with a series of four mechanical pumps, each with staggered minimum operational lake levels. Pump four can still operate at 337.2 ft msl, three at 335.5 ft msl, two at 334.5 ft msl, and the last pump can run at a minimum level of 333.8 ft msl. The lowest historical lake elevation was recorded on August 19, 1986, at 430.09 ft msl. Even at very low levels, the intake has remained appropriately submerged for operation.

Sinclair Dam impounds water from a 2,900 square mile drainage area, and has a normal pool elevation of 340 ft MSL. The intake for Sinclair Dam is located at an elevation of 279.66 feet above mean sea level (ft msl), with a diameter of 19.0 ft. This means the topmost edge of the intake is at an elevation of 298.66 ft msl. Normal full pool is 340 ft msl, with the minimum daily pond at 338.2 ft msl. Therefore, even at minimum daily pond, the intake at Sinclair Dam remains functionally submerged. The cities of Greensboro, Union Point, Madison, Bostwick, Rutledge, and Buckhead depend on the Lake Oconee for their drinking water needs and the cities of Sparta and Eatonton, as well as Hancock, Putnam, and Baldwin counties depend on the Lake Sinclair to meet their water usage needs.

Land cover in the drainage area is predominantly forested and agriculture. However, there are dense residential and commercial areas in the watershed near Athens, Georgia. The Athens area is experiencing rapid development and population growth due to the growth and expansion of the University of Georgia. This growth poses a potential impact to the environmental quality and ultimate economic sustainability of the water resources of the area. There will be a need to balance water resources and water quality protection, while allowing for smart economic development in the watershed.

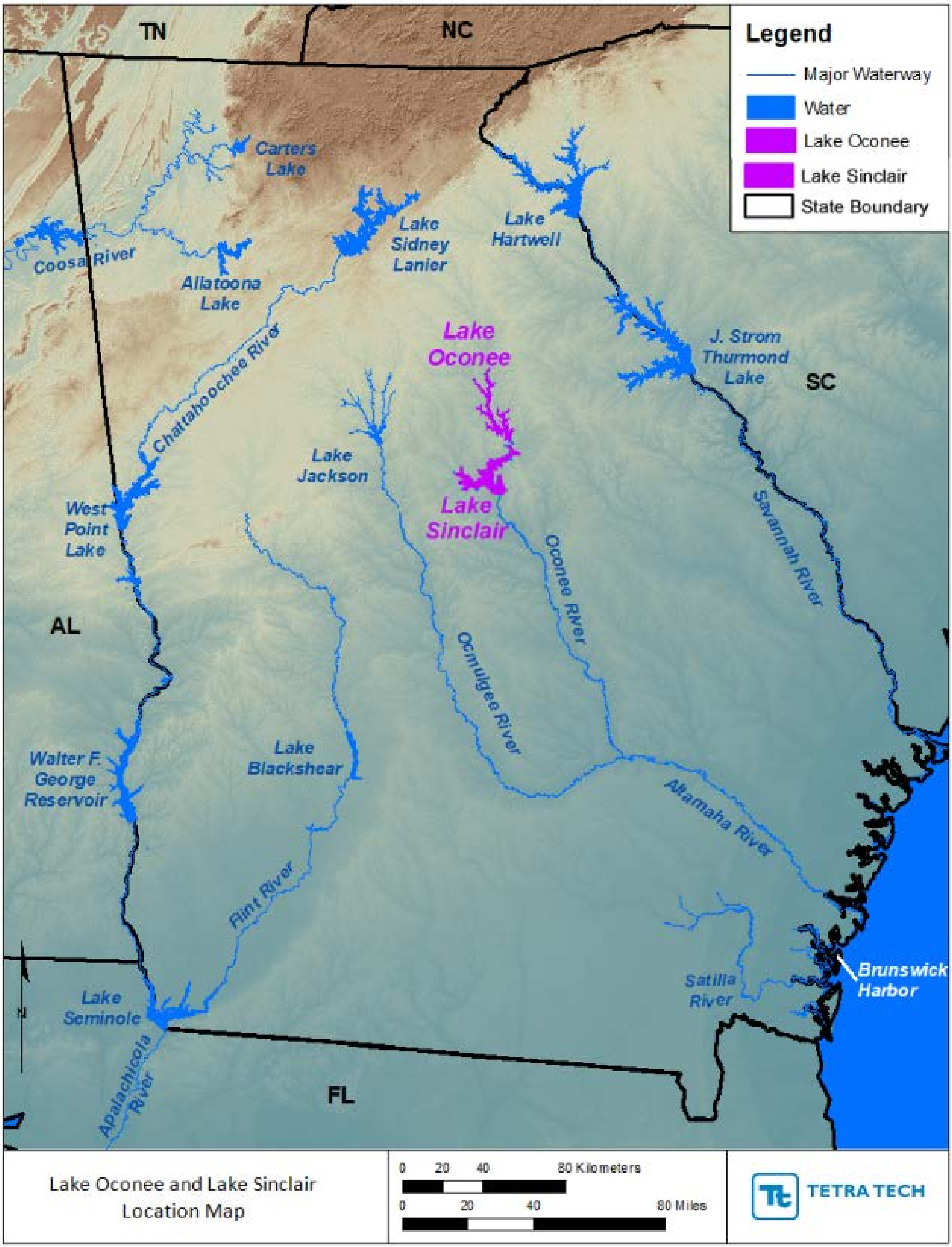


Figure 1-1. Location of Lakes Oconee and Sinclair

2.0 PROPOSED LAKE CRITERIA

Lake Oconee is the waters impounded by Wallace Dam and upstream, on the Oconee River, as well as other impounded tributaries to an elevation of 436 ft MSL, corresponding to the normal pool elevation of Lake Oconee. Lake Oconee has a volume of 400,491 acre-feet at full pool. Water quality standards have been proposed for this lake as part of the 2016 Triennial Review. Its designated uses are Recreation and Drinking Water. The proposed chlorophyll *a,* total nitrogen, and total phosphorus criteria for the lake are as follows:

Chlorophyll a: For the months of April through October, the average of monthly mid-channel photic zone composite samples shall not exceed the chlorophyll a concentrations at the locations listed below more than once in a five-year period:

1.	Oconee Arm at Highway 44	26 μg/L
2.	Richland Creek Arm	15 μg/L
3.	Upstream from the Wallace Dam Forebay	18 μg/L

Total Nitrogen: Not to exceed a growing season average of 2 mg/L as nitrogen in the photic zone.

Total Phosphorus: Not to exceed a growing season average of 0.2 mg/L in the photic zone.

Lake Sinclair is the waters impounded by Sinclair Dam and upstream, to Wallace Dam, as well as other impounded tributaries to an elevation of 340 ft MSL, corresponding to the normal pool elevation of Lake Sinclair. Lake Sinclair has a volume of 332,661 acre-feet at full pool. Water quality standards have been proposed for this lake as part of the 2016 Triennial Review. Its designated uses are Recreation and Drinking Water. The proposed chlorophyll *a,* total nitrogen, and total phosphorus criteria for the lake are as follows:

Chlorophyll a: For the months of April through October, the average of monthly mid-channel photic zone composite samples shall not exceed the chlorophyll a concentrations at the locations listed below more than once in a five-year period:

1.	Little River and Murder Creek Arm upstream from Highway 441	14 μg/L
2.	Midlake at Oconee River Arm	14 μg/L
3.	300 Meters Upstream of Sinclair Dam	10 μg/L

Total Nitrogen: Not to exceed a growing season average of 2 mg/L as nitrogen in the photic zone.

Total Phosphorus: Not to exceed a growing season average of 0.2 mg/L in the photic zone.

The chlorophyll *a* samples are collected monthly during the growing season (April through October). Each month a composite sample is collected, made up of samples collected at 1 meter depth intervals throughout the photic zone. The criteria are assessed using the monthly composite samples to obtain a growing season average. The annual growing season average criteria may not be exceeded more than once in a five year period.

The proposed chlorophyll *a*, total nitrogen, and total phosphorus criteria were derived using models, a point source nutrient management strategy, which will require point source nutrient loads to be reduced by half, and a margin of safety. The margin of safety is critical; it allows the proposed criteria not to be in violation immediately upon approval and it allows the fishery to adjust to the altered nutrient levels without disrupting the food web. The occurrence of algal blooms should decrease as nutrient levels decrease.

Other criteria being proposed that already are exist for these lakes included pH, bacteria, dissolved oxygen and temperature. The upper limit of the pH criteria is being revised from 8.5 to 9.5 to be consistent with other lake pH criteria. The specific criteria being proposed are as follows:

pH: within the range of 6.0 – 9.5 standard units.

Bacteria: E. coli shall not exceed the Recreation criterion as presented in 391-3-6-.03(6)(b)(i).

Dissolved Oxygen: A daily average of 5.0 mg/L and no less than 4.0 mg/L at all times at the depth specified in 391-3-6-.03(5)(g).

Temperature: Water temperature shall not exceed the Recreation criterion as presented in 391-3-6-.03(6)(b)(iv).

3.0 WATER QUALITY DATA

Lake Oconee and Lake Sinclair are considered by GA EPD as basin lakes that were historically sampled quarterly once every five years. In 2009, GA EPD began trying to collect water quality samples from these lakes monthly during the growing season, which is from April through October. Both lakes are sampled at three locations. Figures 3-1 and 3-2 show the locations of the Lake Oconee and Lake Sinclair water quality stations.

These data collected are used being used to calibrate water quality models and develop numeric water quality criteria for the lakes. Appendix A present the water quality data collected as part of the lake monitoring program for calendar years 2004 and 2009-2012.

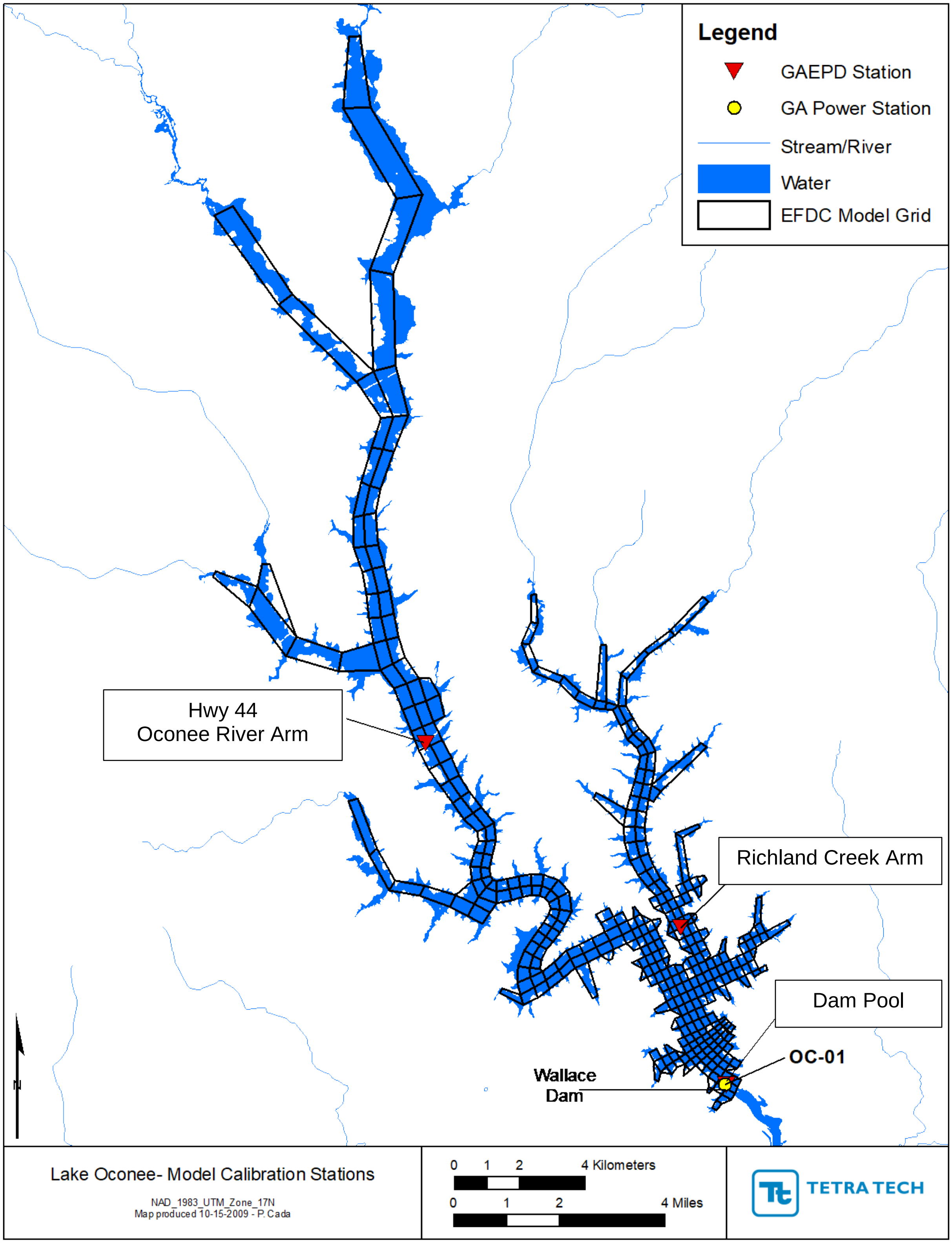


Figure 3-1. Lake Oconee Monitoring Sites

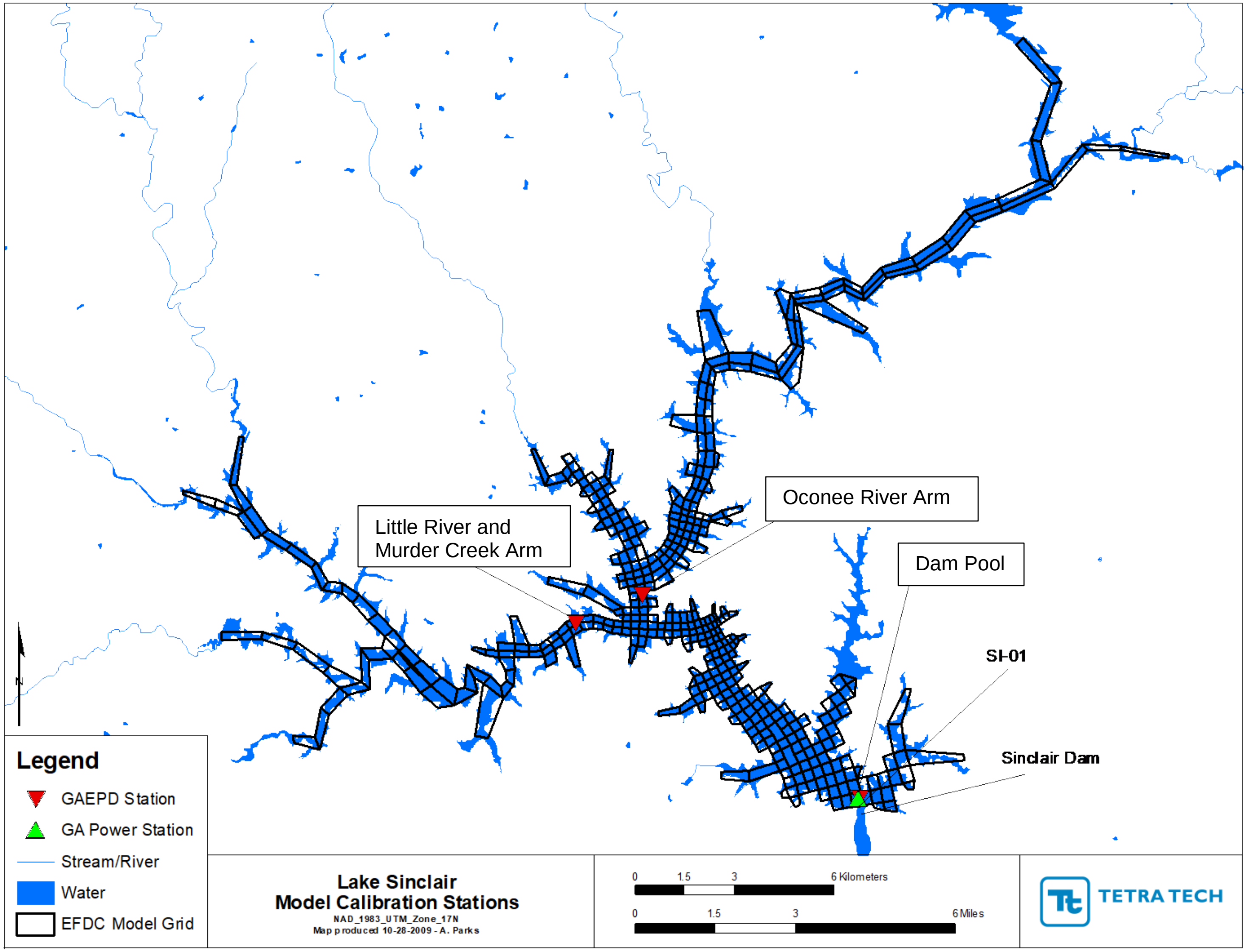


Figure 3-2. Lake Sinclair Monitoring Sites

4.0 MODEL DEVELOPMENT

The process of developing the numeric chlorophyll *a* and nutrient criteria for Lakes Oconee and Sinclair included developing computer models for the Lakes. The models were run for calendar years 2001 through 2012. During 2004, and 2009-2012, water quality data were collected in the Lakes. Watershed models of the Lakes Oconee and Sinclair watersheds were also developed, using LSPC that included all major point sources of nutrients. The watershed models simulated the effects of surface runoff on both water quality and flow and were calibrated to available data. The results of this model were used as tributary flow inputs to the hydrodynamic model EFDC. The EFDC water quality model was used to simulate the fate and transport of nutrients into and out of the lakes and the uptake by phytoplankton, where the growth and death of phytoplankton is measured through the surrogate parameter chlorophyll *a*. Figure 4-1 shows how the two models interact with one another and what outputs each model provides. The computer models used to develop these numeric criteria are described in the following sections.

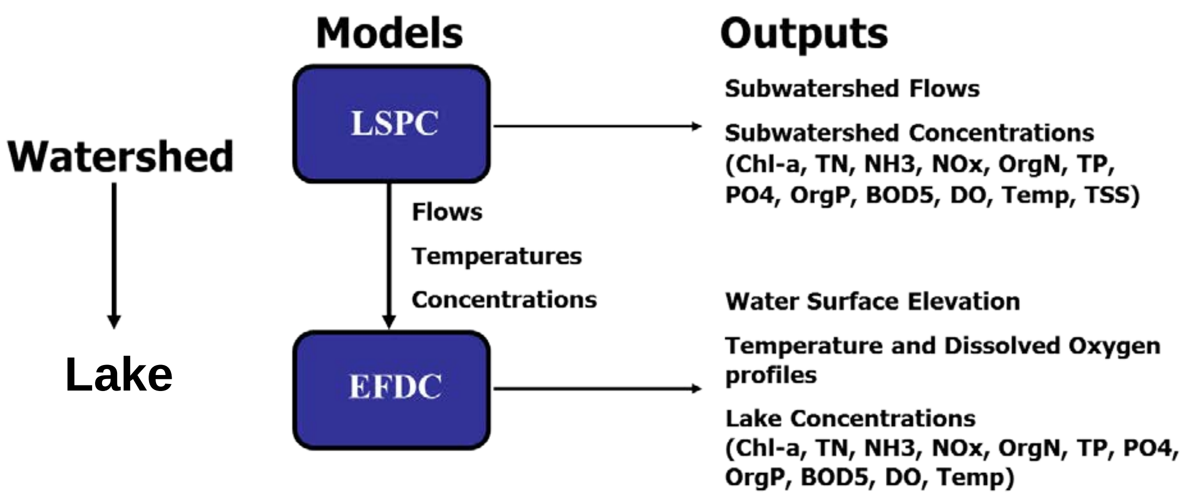


Figure 4-1. Linkage between LSPC and EFDC

4.1 Watershed Modeling (LSPC)

LSPC is a system designed to support numeric nutrient criteria 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. LSPC is a comprehensive data management and modeling system that simulates pollutant loading from nonpoint sources. LSPC utilizes the hydrologic core program of the Hydrological Simulation Program Fortran (HSPF, EPA 1996b), with a custom interface of the Mining Data Analysis System (MDAS), and modifications for non-mining applications such as nutrient and pathogen modeling.

LSPC was used to calculate runoff and hydrologic transport of pollutants based on historic precipitation data. LSPC was configured for the Lakes Oconee and Sinclair watersheds to simulate the watershed as a series of hydrologically connected sub-watersheds. Configuration of the model involved sub-dividing the Lakes Oconee and Sinclair watersheds into 279 modeling sub-watersheds, which are shown in Figure 4-2. Sub-basin delineations were based on elevation data (10 meter National Elevation Dataset from USGS), and stream connectivity from the National Hydrography Dataset.

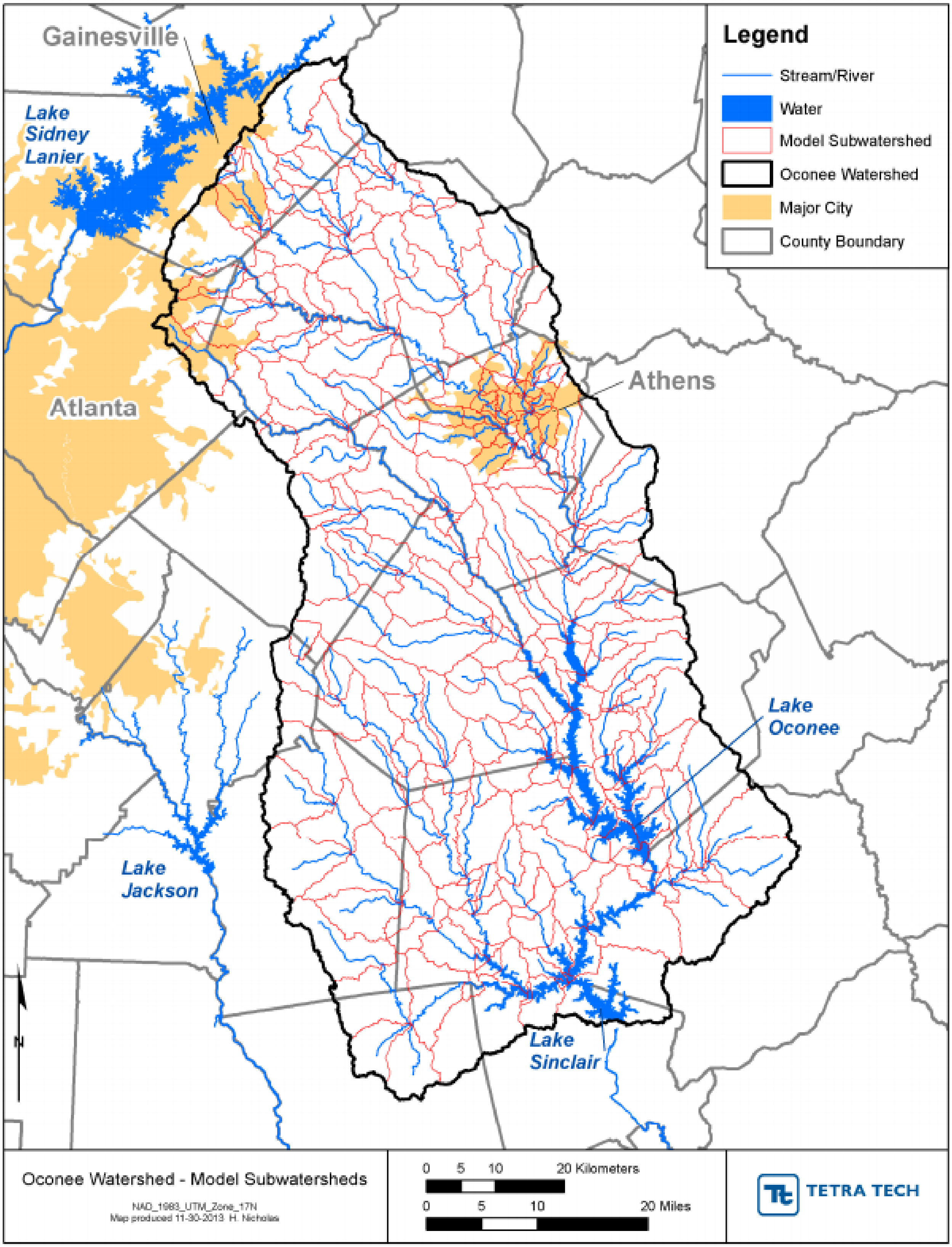


Figure 4-2. Sub-delineated 12-Digit HUC Coverage for the Lakes Oconee and Sinclair Watersheds

Potential pollutant loadings were determined from mass-balance predictions of available pollutants on the land surface for the land cover distribution in each sub-watershed.

The Lakes Oconee and Sinclair watershed LSPC models performed a continuous simulation of flow and water quality for these sub-watersheds using the following data:

- Meteorological data
- Land cover
- Soils
- Stream lengths and slopes
- Point source discharge data
- Water withdrawal data
- USGS flow data
- Water quality data

4.1.1 Meteorological Data

Nonpoint source loadings and hydrological conditions are dependent on weather conditions. Hourly data from weather stations within the boundaries of, or in close proximity to, the sub-watersheds were applied to the watershed model. An ASCII file was generated for each meteorological station used in the hydrological evaluations in LSPC. Each meteorological station file contains atmospheric data used in modeling the hydrological processes. These data include precipitation, air temperature, dew point temperature, wind speed, cloud cover, evaporation, and solar radiation. These data are used directly, or calculated from the observed data. The thirteen meteorological stations used for the Lakes Oconee and Sinclair models are listed in Table 4-1 and shown in Figure 4-3.

Table 4-1. Available Meteorological Stations in the Lakes Oconee and Sinclair Watersheds

Station ID	Station Name	Elevation (ft)	County	Latitude	Longitude
GAEMN170	Central Georgia Research and Education Center	554	Putnam	33.397	-83.488
GAEMN220	Plant Sciences Research Farm	849	Fulton	33.873	-83.535
GAEMN280	Lake Lanier	1072	Hall	34.352	-83.793
090435	Athens Ben EPPS AP	785	Clarke	33.948	-83.328
092180	Commerce 4 NW	750	Jackson	34.263	-83.486
093621	Gainesville	1170	Hall	34.301	-83.860
095195	Lexington 1 NW	760	Oglethorpe	33.882	-83.121
095874	Milledgeville	368	Baldwin	33.083	-83.250
095988	Monticello	518	Jasper	33.333	-83.698
098064	Siloam 3N	695	Greene	33.564	-83.077
098950	UGA plant science	840	Oconee	33.872	-83.536
02220900	USGS 2220900	536	Putnam	33.314	-83.437
02221525	USGS 2221525	375	Putnam	33.252	-83.481

The Lakes Oconee and Sinclair watersheds were subdivided into Thiessen polygons, using the meteorological stations as centers, to determine the meteorological station that would be used for each sub-watershed.

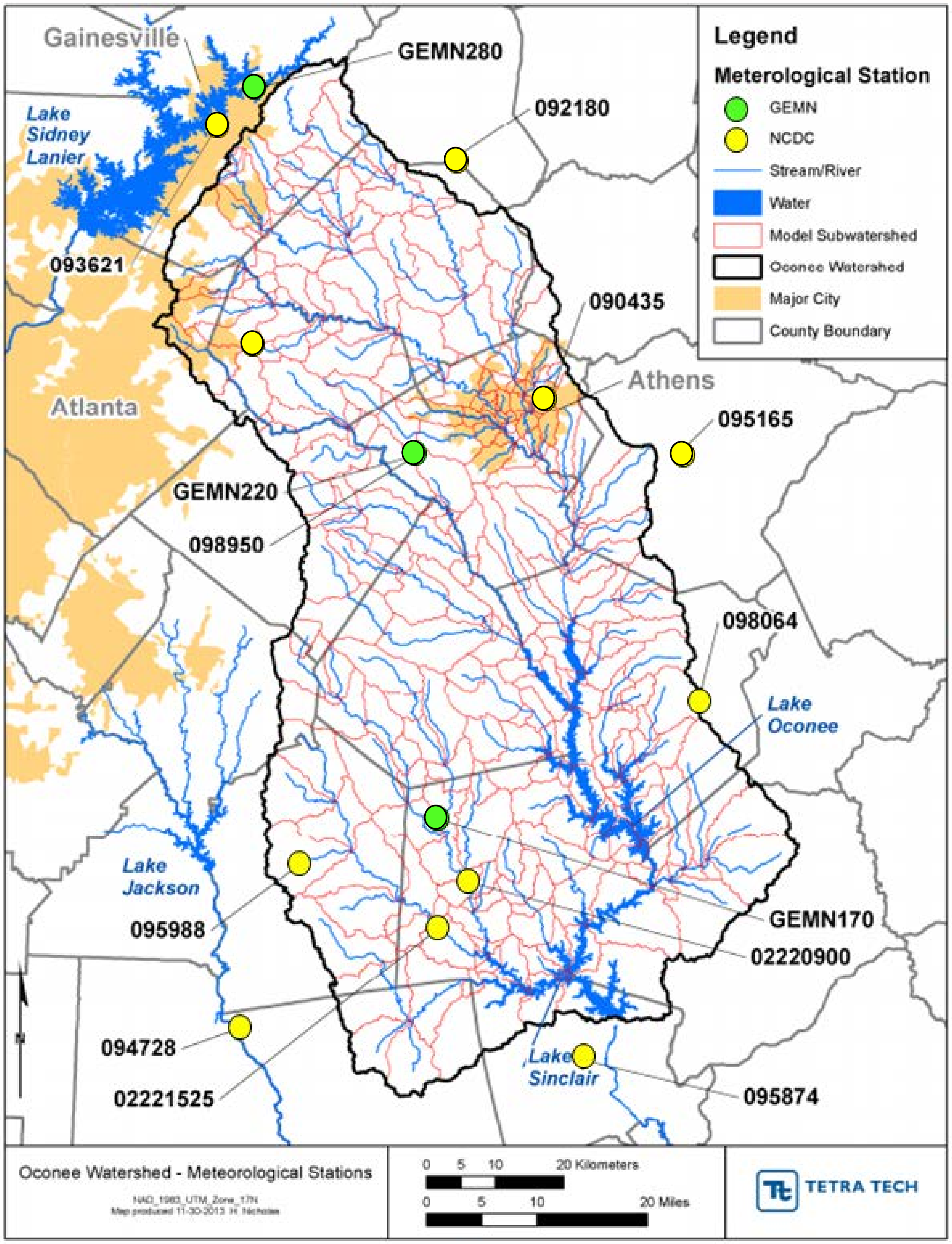


Figure 4-3. Meteorological Stations Used in the Lakes Oconee and Sinclair LSPC Models

4.1.2 Land Cover

The watershed model used land cover data as the basis for representing hydrology and nonpoint source loading. The land use data used was the 2005 and 2008 GLUT coverage. Figure 4-4 presents the distribution of land cover within the Lakes Oconee and Sinclair watersheds, and a breakdown of the watersheds by land use is given in Table 4-2.

The LSPC model requires division of land cover into pervious and impervious land units. For this, the GLUT impervious cover, Figure 4-5, was intersected with the GLUT land use cover. Any impervious areas associated with utility swaths, developed open space, and developed low intensity, were grouped together into low intensity development impervious. Impervious areas associated with medium intensity development and high intensity development, were kept separate from medium intensity development impervious and high intensity development impervious, respectively. Finally, all impervious areas not already accounted for in the three developed impervious classes were grouped together into a remaining impervious class called catch all for remaining impervious (Table 4-2). The catch all for remaining impervious class is made up of small bits of imperviousness associated with Clearcut/Sparse, Quarries/Strip Mines, Rock Outcrops, Deciduous Forest, Evergreen Forest, Mixed Forest, Golf Courses, Pasture/Hay, and Row Crops.

Table 4-2. Land Cover Percent Impervious and Pervious

Land Use Code	GLUT Land use Category	Area (acres)	%
7	Beach	3521.82	0.19
11	Open Water	37991.85	2.04
20	Utility Swaths	7509.25	0.40
21	Developed Open Space	101952.58	5.46
22	Developed Low Intensity	67024.36	3.59
222	20+21+22 Impervious	17034.20	0.91
231	Developed Medium Intensity Pervious	7810.51	0.42
232	Developed Medium Intensity Impervious	10270.27	0.55
241	Developed High Intensity Pervious	589.91	0.03
242	Developed High Intensity Impervious	6985.76	0.37
31	Clearcut/Sparse	99906.63	5.35
33	Quarries/Strip Mines	1351.94	0.07
34	Rock Outcrop	213.72	0.01
41	Deciduous Forest	464327.85	24.88
42	Evergreen Forest	469648.13	25.16
43	Mixed Forest	88753.73	4.75
73	Golf Courses	362.75	0.02
80	Pasture/Hay	376630.33	20.18
83	Row Crops	1324.96	0.07
91	Forested Wetland	85861.45	4.60
93	Non-forested Wetlands	817.74	0.04
332	Catch-all for Remaining Impervious	0.00	0.00
777	Land Application Systems	11330.81	0.61
888	Failing Septic Systems	1652.51	0.09
999	Irrigated Pasture	3671.02	0.20

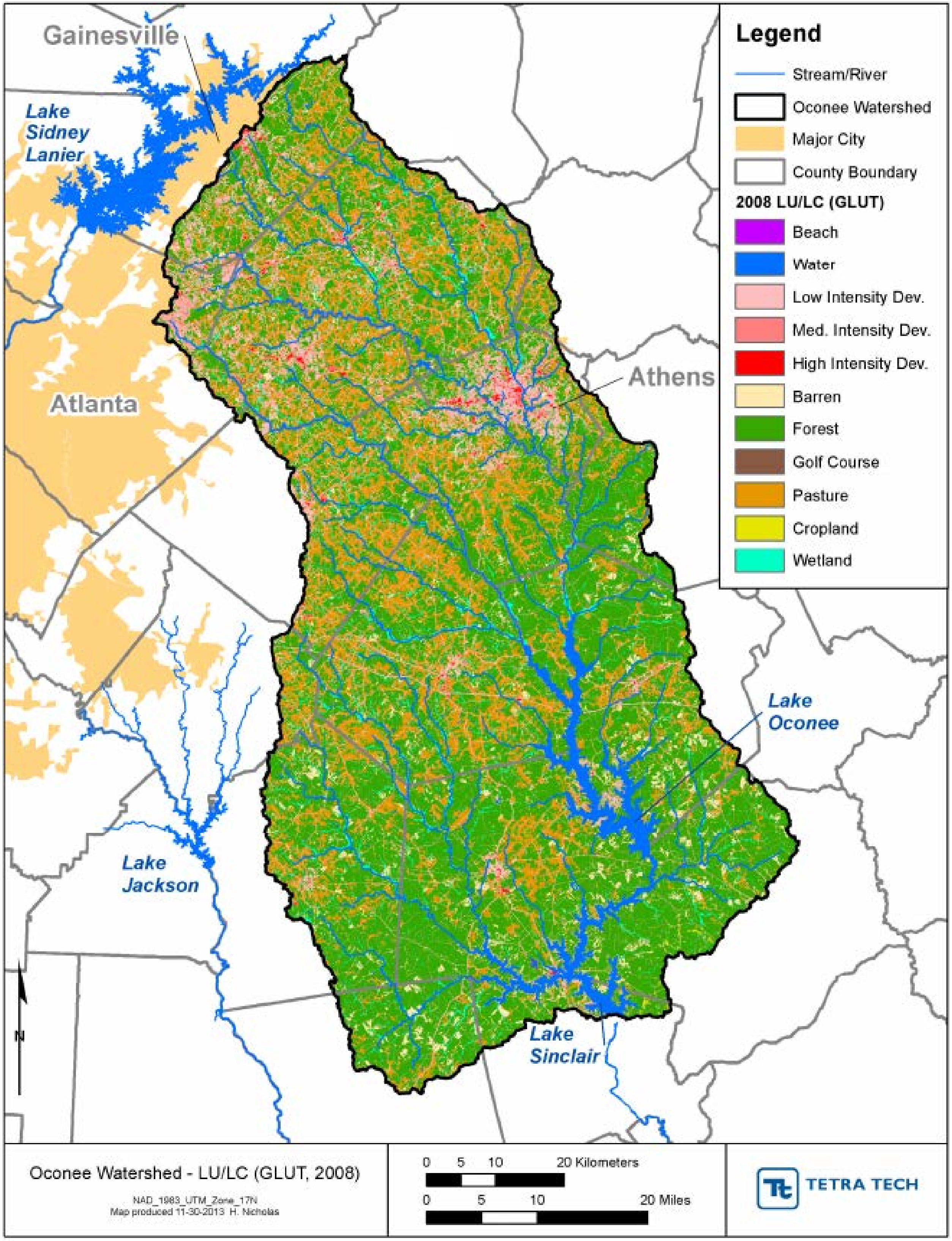


Figure 4-4. Lakes Oconee and Sinclair Watersheds Land Cover from 2008 GLUT

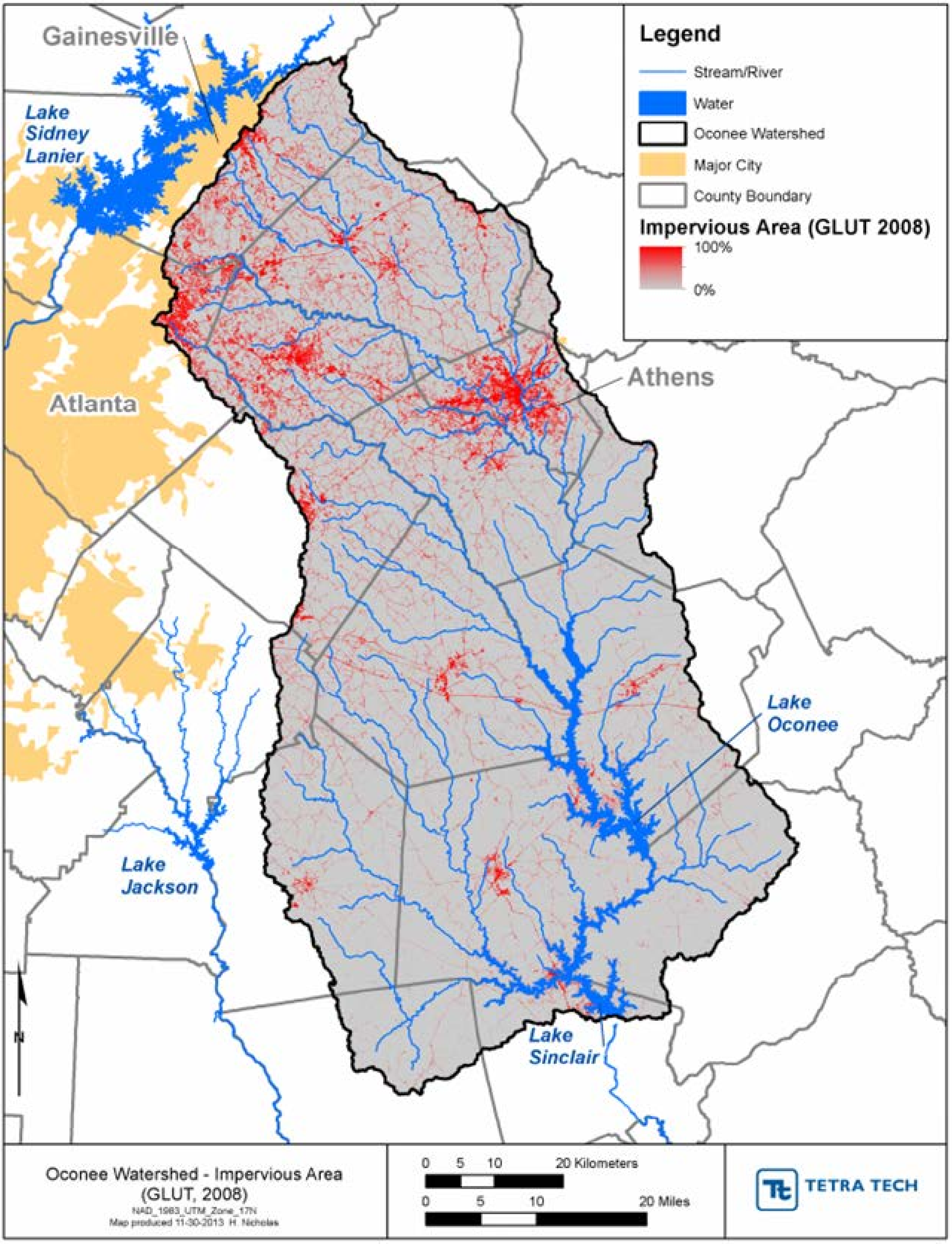


Figure 4-5. Lakes Oconee and Sinclair Watersheds Impervious Coverage from 2005 GLUT

4.1.3 Soils

Soil data for the Lakes Oconee and Sinclair watersheds were obtained from the Soil Survey Geographic Database (SSURGO). The database was produced and distributed by the Natural Resources Conservation Service (NRCS) – National Cartography and Geospatial Center (NCGS). The SSURGO data was used to determine the total area that each hydrologic soil group covered within each sub-watershed. 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 to moderately course textures.
> 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.

In LSPC, each dominant Hydrologic Soil Group within the study watershed gets assigned a default group number. A standard approach for assigning Hydrologic Soil Groups to default group numbers included: Group A equals 1, Group B equals 2, Group C equals 3 and Group D equals 4.

The sub-watersheds were represented by the hydrologic soil group that had the highest percentage of the coverage within the boundaries of the sub-watershed. There is one major Hydrologic Soil Group, Group B, in the Lakes Oconee and Sinclair watersheds. Figure 4-6 shows the soil group coverage for the watershed. The total area that each hydrologic soil group covered within each sub-watershed was determined. The hydrologic soil group that had the highest percent of coverage within each sub-watershed represented that sub-watershed in LSPC.

4.1.4 Stream Characteristics

Each sub-watershed must have a representative reach defined for it. 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 Digital Elevation Maps (DEM) and the National Hydrography Dataset (NHD). Figure 4-7 is DEM coverage for the Lakes Oconee and Sinclair watersheds. The channel geometry is described by a bank full width and depth (the main channel), a bottom width factor, a flood plain width factor, and the slope of the flood plain.

LSPC takes the attributes supplied for each reach and develops a function table, FTABLE. This table describes the hydrology of a river reach or reservoir segment by defining the functional relationship between water depth, surface area, water volume, and outflow in the segment. The assumption of a fixed depth, area, volume, and outflow relationship rules out cases where the flow reverses direction or where one reach influences another upstream of it in a time-dependent way. This routing technique falls into the class known as “storage routing” or “kinematic wave” methods. In these methods, momentum is not considered (US EPA, 2007).

For incorporating agricultural water withdrawals into the model, fictitious reaches were created to hold the irrigation water prior to being applied back onto the land. Each sub-watershed that

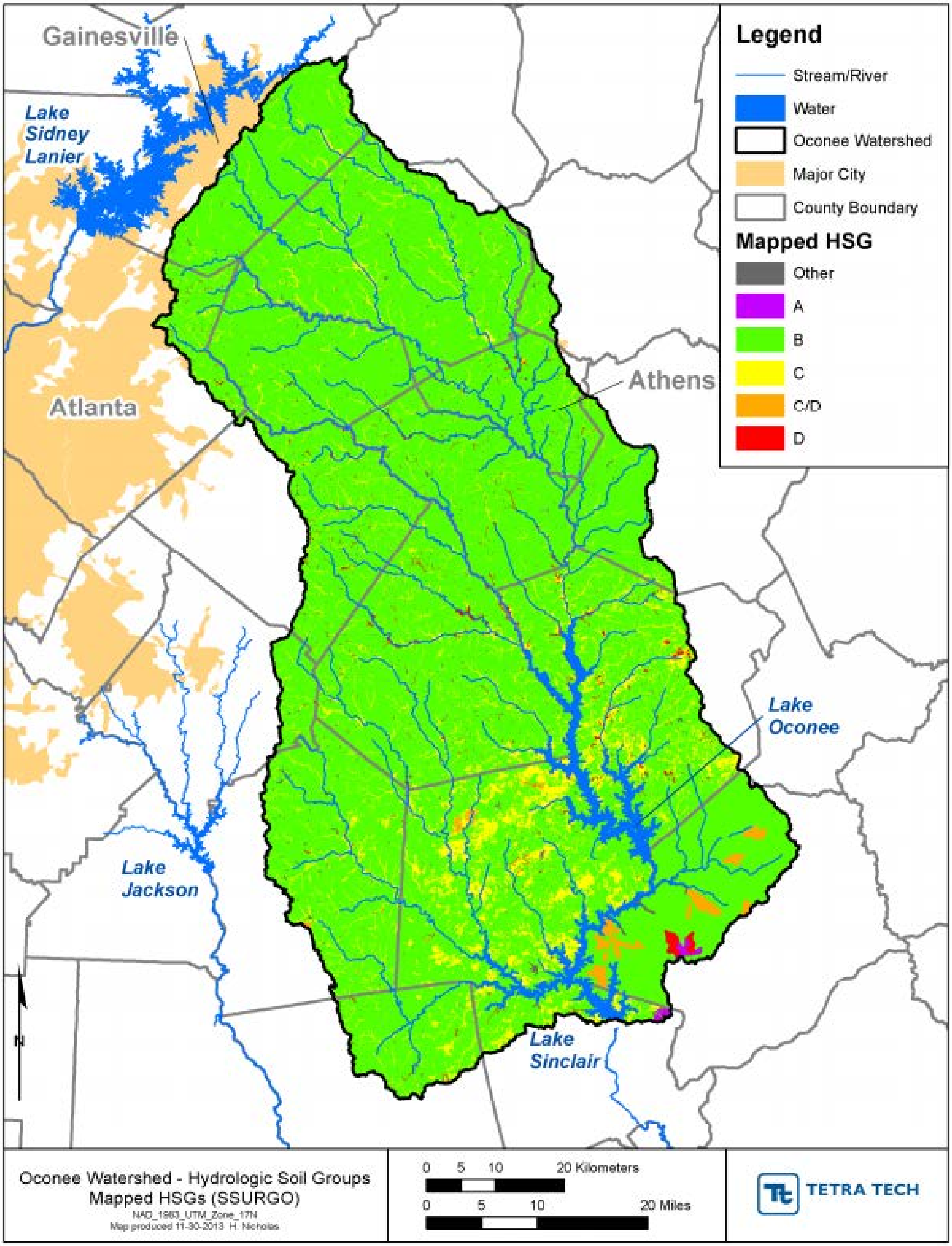


Figure 4-6. Lakes Oconee and Sinclair Watersheds Soil Hydrologic Group

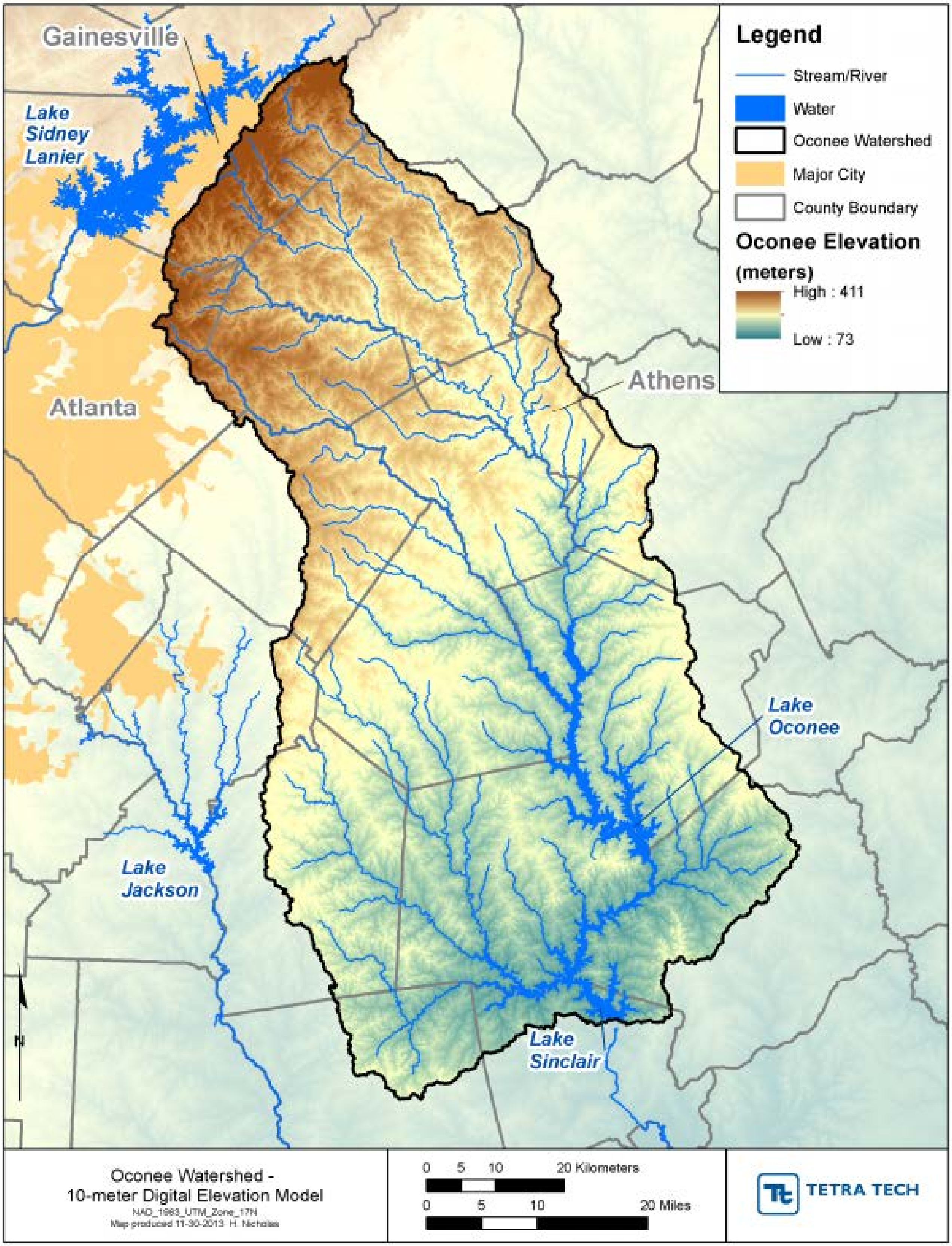


Figure 4-7. DEM Coverage for the Lakes Oconee and Sinclair Watersheds

contained irrigated land had its own fictitious reach and this reach was treated like a pot-hole lake. Each of these reaches used the same FTABLE and the outflow for each stage was held at zero. These reaches were not connected to sub-watersheds downstream and merely held water until it was applied back onto the land through the pumping of irrigation water.

4.1.5 Watershed Point Source Discharges

In general, industrial and municipal wastewater treatment facilities have NPDES permits with effluent limits. These permit limits are either based on federal and state effluent guidelines (technology-based limits) or on water quality standards (water quality-based limits).

The US Environmental Protection Agency (US EPA) has developed technology-based guidelines, which establish a minimum standard of pollution control for municipal and industrial discharges. These are based on Best Practical Control Technology Currently Available (BPT), Best Conventional Control Technology (BCT), and Best Available Technology Economically Achievable (BAT). The level of control required by each facility depends on the type of discharge and the pollutant.

The US EPA and the states have also developed numeric and narrative water quality standards. Typically, these standards are based on the results of aquatic toxicity tests and/or human health criteria and include a margin of safety. Water quality-based effluent limits are set to protect the receiving stream. These limits are based on water quality standards that have been established for a stream based on its intended use and the prescribed biological and chemical conditions that must be met to sustain that use.

Discharges from municipal and industrial wastewater treatment facilities can contribute nutrients to receiving waters. There are 39 point source discharges located in the Lakes Oconee and Sinclair watersheds that have NPDES permits. Of these point sources, 31 are municipal facilities, 6 private facilities such as schools, hospitals, rest areas and mobile home parks, and two are industrial facilities. Flows and water quality data for these point source discharges were obtained from either the Discharge Monitoring Reports (DMR) or Operating Monitoring Reports (OMR). Data obtained from these reports were input directly into the LSPC model. The sub-watershed that each facility was assigned to and the frequency of the DMR or OMR data are given in Table 4-3.

Many of the permitted dischargers did not report loads or concentrations for one or more constituents used in the LSPC model. Data from Compliance Sampling Inspection reports (CSI) was utilized in filling the missing constituents. Using these data, the following equations were applied to minor discharges (< 1.0 MGD) that did not have available orthophosphate data:

$$\text{Organic Phosphorus} = \text{Total Phosphorous} * 0.10$$
$$\text{Orthophosphate} = \text{Total Phosphorous} * 0.90$$

For major dischargers with permitted flows greater than 1.0 MGD, the average ratio of orthophosphate data to total phosphorus was 0.70. Therefore, the following equations were used for major discharges that did not have available phosphorus data:

$$\text{Organic Phosphorus} = \text{Total Phosphorous} * 0.30$$
$$\text{Orthophosphate} = \text{Total Phosphorous} * 0.70$$

Table 4-3. Summary of Point Source Discharges to the Lakes Oconee and Sinclair Watersheds

Permit Number	Facility Name	Receiving Water	Permitted Flow (MGD)
GA0002712	Jackson County Water and Sewer Authority	Middle Oconee River	0.5
GA0020141	Monticello Pond - Pearson Creek	Pearson Creek	0.17
GA0020150	Monticello Pond - White Creek	White Oak Creek	0.115
GA0021351	Greensboro - South WPCP	Town Creek	0.998
GA0021725	Athens/Clarke County - North Oconee WPCP	North Oconee River	14
GA0021733	Athens/Clarke County - Middle Oconee WPCP	Middle Oconee River	10
GA0022233	Rock Eagle 4-H Center	Glady Creek	0.155
GA0023132	Jefferson Pond	Curry Creek	1
GA0023141	Madison - Southside WPCP	Horse Branch	0.66
GA0023159	Madison - Northside WPCP	Mile Branch	0.14
GA0023191	Winder - Marburg Creek WPCP	Marburg Creek	0.6
GA0026107	Social Circle – Little River WPCP	Little River	0.65
GA0032263	Eatonton - West WPCP	Little River Tributary	0.55
GA0032271	Eatonton - East WPCP	Rooty Creek Tributary	0.55
GA0034584	Athens/Clarke County - Cedar Creek WPCP	Oconee River	4.00
GA0035980	Hoschton Pond	Mulberry River Tributary	0.10
GA0038733	Barrow County BOC - Barber Creek	Barber Creek	1.5
GA0038741	Madison I-20	Four Mile Branch	1.00
GA0038776	Winder Cedar Creek WPCP	Cedar Creek	4.00
GA0038547	Braselton WPCP	Mulberry River Tributary	1.27
GA0047171	Monroe - Jacks Creek WPCP	Jacks Creek	3.40
GA0050211	Oconee County - Calls Creek WPCP	Calls Creek Tributary	1
GA0038806	Oconee County BOC - Rocky Branch WRF	Barber Creek	1
GA0039110	Arcade WRF	Middle Oconee River	1
GA0039144	City of Crawford WPCP	Barrow Creek	0.25
GA0039314	Barrow County BOC - Tanners Bridge WRF	Apalachee River	5.0
GA0032905	Maysville WPCP	Unnamed tributary to North Oconee River	0.06
GA0047759	Mansfield WPCP	Pittman Branch	0.06
GA0033707	Crawford Westside WPCP	Barrow Creek	0.037
GA0034223	Pinewood Estates North MHP	West Fork Trail	0.044
GA0050214	Spout Springs	Lollis Creek	0.75
GA0039390	Wayne Farms	Allen Creek	Report
GA0047988	GA Pacific Wood Products	Tributary to Briar Creek	Report
GAG550000	DOT Rest Area 53	Tributary to Big Indian Ck	0.01
GAG550100	East Hall HS	Unnamed tributary to North Oconee River	0.028
GAG550159	Barnes MHP	Unnamed tributary to North Oconee River	0.005
GAG550141	Country Corners MHP	West Fork Trail Creek	0.058
GAG550143	Hallmark MHP	Tributary to East Fork Trail Creek	0.058
GAG550020	DNR Hard Labor Creek State Park	Lake Brantley	0.006

Default concentrations and temperatures shown in Table 4-4 where used when the constituent was not reported and/or was missing from the CSI reports.

Table 4-4. Assumed Water Quality Concentrations for Point Sources without Data

Parameter	Concentration (mg/L)	
	Minors (<1.0 MGD)	**Majors (≥1.0 MGD)**
Flow	Maximum found from DMR Data	Maximum found from DMR Data
Temp	Oct- March – 15 ^oC April-September – 25 ^oC	Oct- March – 15 ^oC April-September – 25 ^oC
DO	5.0	5.0
BOD5	30.0	10.0
TN	29.4	17
NH3	17.4	5.0
NO3/NO2	10.0	10.0
ORG-N	2.0	2.0
TP	5.0	1.0
PO4	4.5	0.7
ORG-P	0.5	0.3
TSS	30.00	30.00

4.1.6 Land Application Systems

Many smaller communities use land application systems (LAS) for treatment and disposal of their sanitary wastewater, including Private and Institutional Developments (PIDs). These facilities are required through LAS permits to treat all of their wastewater by land application and are to be properly operated as non-discharging systems that contribute no runoff to nearby surface waters. However, runoff during storm events may carry surface residual containing nutrients to nearby surface waters. Some of these facilities may also exceed the ground percolation rate when applying the wastewater, resulting in surface runoff from the field. If not properly bermed, this runoff, which probably contains nutrients, may be discharged to nearby surface waters.

A GIS coverage of the LAS spray fields was clipped and geo-processed with the Lakes Oconee and Sinclair sub-watersheds coverage and incorporated into the GLUT land use. The land use associated LAS acreage (under the polygon), for each sub-watershed, was subtracted from the corresponding GLUT land use and the land use associated LAS acreage was added to a new LSPC modeling unit called LAS. The GLUT land use transformation was reviewed to ensure that the LAS land use creation did not create a negative GLUT acreage and that the overall acreage of the watershed was unchanged. Figure 4-8 shows the spatial coverage of LAS spray fields and Table 4-5 provides a list of the permitted LAS in the Lakes Oconee and Sinclair watersheds. The land use that was associated with LAS acreage for each sub-watershed was subtracted from its original GLUT land use and that area was added to a new land use associated LAS. Great care was taken to ensure that the overall acreage of the watershed was unchanged. Land application system loading rates were obtained from the models developed for the Georgia State Water Plan. These land-use loading rates are quite high and were allowed to build up for 3 days before reaching their maximum storage limit.

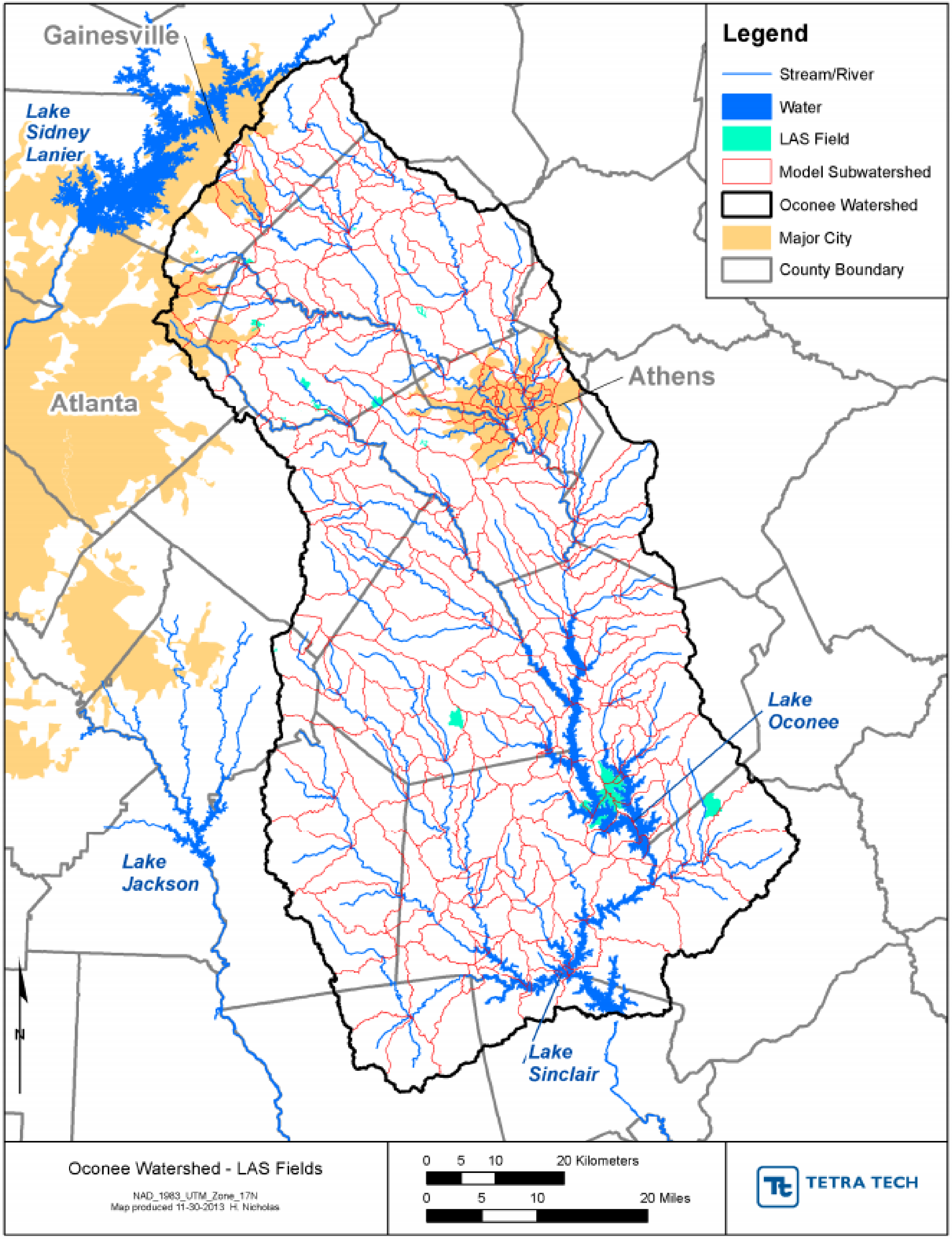


Figure 4-8. Spatial Coverage of Land Application System Spray Fields in the Lakes Oconee and Sinclair Watersheds

Table 4-5. Summary of Land Application Systems in the Upper Oconee Watershed

Permit No.	Facility name	Acres	Type	Permitted Flow (MGD)
GA01-405	INVISTA S.A.R.L.	10.8	IND	0.003
GA01-420	Sonstegard Foods	170.0	IND	0.000
GA01-461	Hyline International Inc.	1.2	IND	0.002
GA01-477	Agri-Cycle LLC	27.7	IND	0.080
GA01-532	Harrison Poultry	394.6	IND	1.300
GA01-546	Wayne Farms LLC	33.5	IND	0.850
GA02-006	Jefferson – Central City	51.2	MUN	0.380
GA02-018	Barrow County – Barber Creek WRF/LAS	559.6	MUN	0.150
GA02-072	Greatwaters at Reynolds Plantation	7.2	PID	0.070
GA02-158	Winder – Marburg Creek Reuse	308.0	MUN	0.900
GA02-176	Oconee County – Rocky Branch LAS	110.9	MUN	0.200
GA02-191	University of GA Driftmier LAS	4.6	MUN	0.010
GA02-230	Jefferson North – Opossum Creek	41.7	MUN	0.287
GA02-264	Stepan Company	46.8	IND	0.000
GA02-271	Barrow County Board of Commissioners	55.7	MUN	0.450
GA03-617	Beau Rivage	0.8	PID	0.010
GA03-632	Oconee Crossing Urban Reuse	548.8	PID	0.500
GA03-674	Robinson Farm – Rhodia	361.7	IND	0.000
GA03-700	Briar Rose Land Co. Inc.	1608.5	PID	0.060
GA03-736	Brick Store Utility Company	33.7	PID	0.035
GA03-807	Spout Springs Reclamation	30.4	MUN	1.000
GA03-809	Towler Village LAS	1.8	PID	0.010
GA03-883	Carey Station Urban Reuse Facility	629.3	PID	0.500
GA03-897	Reynolds Plantation – Linger Longer Development Co.	5022.6	PID	0.075
GA03-928	Family Life Enrichment Center	2.8	PID	0.012
GA03-942	Barrow Co. Schools – Bethlehem Elementary	3.9	PUB	0.015
GA03-965	Madison Lakes LLC	1059.5	PID	0.100
GA03-983	4W Arcade	203.5	PID	0.250

4.1.7 Septic Tanks

A portion of the nutrient contributions in the Lakes Oconee and Sinclair watersheds may be attributed to septic systems failures and illicit discharges of raw sewage. Septic tanks were considered in the watershed model. The number of septic tanks in each sub-watershed was determined through an area-weighting method. Each sub-watershed was assigned to a county based on where the outlet of the watershed lies. The ratio of the area of the sub-watershed to the area of the county was determined, and this ratio was applied to the total number of septic tanks in the county to determine a number for each sub-watershed. Not all septic tanks were considered to be contributing flow to the system. It was assumed that at any given time, 85% of the septic tanks were non-failing and 15% of the septic tanks were failing.

For the non-failing septic tanks, these were treated as a source of nutrients through subsurface flow. This was represented as a direct input into the stream, assuming a first order decay rate and an average 60-day travel time from the septic tank to the stream. To represent the non-failing septic tank flow, it was assumed that each septic tank serves a household of 2.8 people and that each person accounts for 70 gallons/day of flow in the septic tank and 15% of the water used in the house never makes it to the septic tank. The non-failing septic tanks were modeled as very small individual point sources for each sub-watershed. Table 4-6 presents the concentration of septic tank effluent, decay rates for each constituent, and the concentration after 60 days of decay. For phosphorus, it was also assumed that 90% was sorbed to sediment; therefore only 10% of the effluent concentration was used to calculate decay after 60 days.

Table 4-6. Septic Tank Water Quality Concentrations

Parameter	Effluent Concentration (mg/L)	Decay Rate (1/day)	Concentration at Stream (mg/L)**
BOD_5	105.0	0.16	0.003
Total Nitrogen	70.26	0.1	0.1263
Organic Nitrogen	0.46	0.1	0.0008
Ammonia	10.5	0.1	0.0189
Nitrate+Nitrite	59.3	0.1	0.1066
Total Phosphorus*	0.3	0.014	0.1287
Organic Phosphorus*	0.3	0.014	0.1287
Ortho-Phosphate*	0.0	0.014	0.000
TSS	10.0	0	10
Dissolved Oxygen	--	--	4
Water Temperature	--	--	GW Temp***

* It was assumed that 90% of phosphorus is sorbed to sediment.
** Assumes Septic Flow takes an average of 60 days to reach stream
***Supplied groundwater temperature from temperature component of simulation

The portion of the septic tanks that were considered failing were modeled as a “Failing Septic Tank“ land use because it was assumed that no decay occurs and raw effluent is directly applied to the land. It was determined that the average area of a septic field is 6,750 ft^2 (Inspectapedia 2009). The land use that was represented as “Failing Septic Tanks” was subtracted from the Low Intensity Urban Pervious land use for each sub-watershed. For a few of the sub-watersheds subtracting Failing Septic from Low Intensity Urban Pervious resulted in negative values. For these watersheds, all of the Failing Septic Tank area was subtracted from Developed Open Space.

4.1.8 Water Withdrawals

There are fourteen water withdrawals located in the Lakes Oconee and Sinclair watersheds that were represented in the LSPC model. Ten of them are municipal water withdrawals and four are industrial water withdrawals. The current source water, sub-watershed, and permitted withdrawal for each withdrawal are given in Table 4-7.

4.1.9 Agricultural Water Withdrawals

Agricultural irrigation systems used on Georgia farms, orchards, nurseries, and golf courses are estimated to cover 1.5 million acres. These systems are supplied with water from ground and

Table 4-7. Summary of Water Withdrawals in the Lakes Oconee and Sinclair Watersheds

Permit Number	Withdrawal	Source Water	Sub-Watershed	Permitted Withdrawal 24-Hour Limit (MGD)	Permitted Withdrawal Monthly Average (MGD)
007-0303-01	City of Winder	Mulberry River	280	6.70	5.10
007-0303-02	City of Winder – Cedar Creek and Yargo Lake	Cedar Creek and Yargo Lake	216	1.00	1.00
007-0304-04	City of Statham	NRCS Reservoir #6 at Barber Creek	258	1.00	0.80
029-0301-030	Athens – Clarke County	North Oconee River	317	34.75	25.50
029-0304-02	Athens – Clarke County	Middle Oconee River	265	16.00	16.00
066-0310-01	Feldspar Corporation – Bowdon	Bowdon Creek	371	0.50	0.40
078-0301-01	City of Jefferson	Big Curry Creek Reservoir	324	2.25	1.75
078-0304-05	Upper Oconee Basin Water Authority	Middle Oconee River	269	60.00	60.0
078-0304-06	Upper Oconee Basin Water Authority	Bear Creek Reservoir	268	79.00	58.00
079-0311-01	City of Monticello	City Water Supply Reservoir	124	0.75	0.50
079-0311-02	Feldspar Corporation – Cedar	Cedar Creek	115	1.20	1.20
104-0307-01	City of Madison – Hard Labor	Hard Labor Creek	191	1.50	1.50
104-0307-02	City of Madison	Lake Oconee	187	2.00	2.00
117-0308-01	City of Eatonton	Little River	133	1.10	1.00

surface water resources that fall under permitting requirements of the GAEPD. Most of the wells, surface water pumping stations, and ponds used in these systems, were constructed and paid for by individual land owners. In the 1988 statutes which required permits for agricultural withdrawals, these privately owned pumping systems were specifically exempt from water metering, record keeping, and reporting to GAEPD. Consequently, Georgia water planners have lacked systematic enumeration of water quantities applied in agricultural production. In 1998, GAEPD requested that the Georgia Cooperative Extension Service establish a statewide system for measurement of water application by producers and conduct a multi-year study of those water amounts. The product of the multi-year study was the Ag Water Pumping Report (Hook et al. 2004).

The Ag Water Pumping Report divided the state into four reporting regions. These regions represent Southwest Georgia, Coastal Zone, Central Coastal Plain, and North Georgia. All of the Lakes Oconee and Sinclair watersheds are located in the North Georgia Reporting Region (Figure 4-9). The data collected from the monitored irrigation systems was extensively analyzed, and they produced monthly minimum, mean, and maximum irrigations depths, for each region, by source water type. The North Georgia reporting region had monthly irrigation depths only for surface water because most of the irrigation systems in that region used surface water for their supply. For the few situations in North Georgia where groundwater was used for supply, the surface water irrigation depth was still used.

A shape file of all irrigated fields was prepared by the University of Georgia. The UGA coverage indicated each individual field's acreage and source water percent. This coverage was processed to determine the irrigated acreage supplied by both surface water and ground water

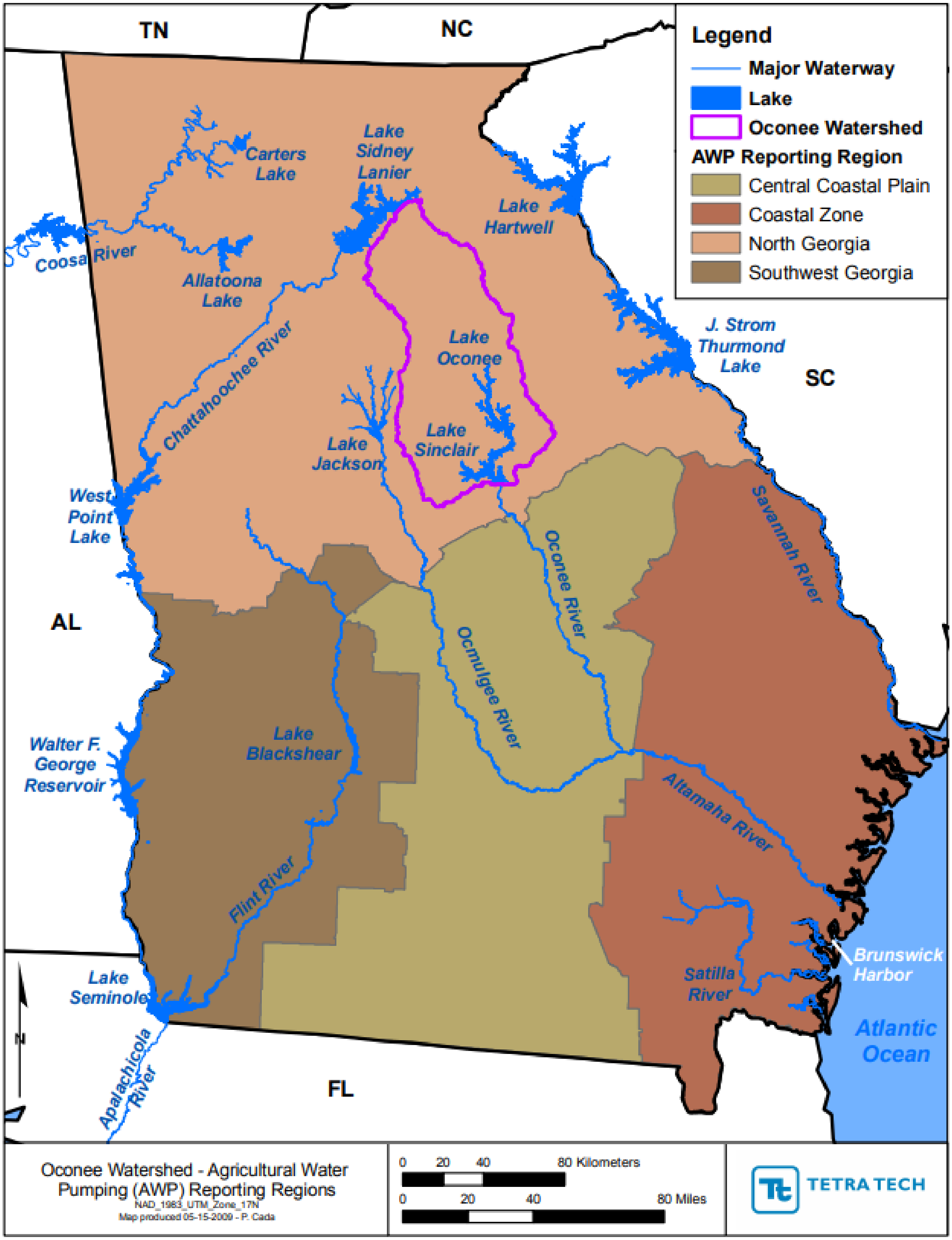


Figure 4-9. Ag Water Pumping Reporting Regions

in each sub-watershed. The irrigation shape file was also processed with the GLUT coverage and the dominant land use "covered" by irrigated land was determined for each sub-watershed. The total irrigated acreage for each sub-watershed was subtracted from the dominant land use. A new land use was created for the irrigated land. Figure 4-10 shows the locations of 3,671 irrigated acres located in the Lakes Oconee and Sinclair watersheds. To determine the volume of water extracted from groundwater and surface water sources for each sub-watershed, the source water irrigated land acreage, was multiplied by the year and source dependent, reporting region, and monthly irrigation depth. Daily, the volume of water associated with surface water was withdrawn from the reach within the sub-watershed, and transferred to a sub-watershed specific fictitious holding pond. The volume of water associated with groundwater was directed, daily, into the sub-watershed specific pond as a point source. The groundwater component needed to be handled as a point source because, unlike surface water, which can be removed from a certain reach, LSPC is not capable of withdrawing water from the lower layers of the model. Water was neither gained nor lost in the ponds holding irrigation water by atmospheric means because they were assigned to a unique air file created specifically for these ponds.

The irrigation module of LSPC is based on irrigation demand. Irrigation demand is calculated by using wither a constant or calculated value for potential evapotranspiration (PET), and an evapotranspiration coefficient (ETc). If the model calculates that irrigation demand is high, i.e., a deficit of water in the upper layers of the model, irrigation will occur until the demand is satisfied. If the holding pond was dry then no irrigation occurred. The irrigation component was built on the assumption that many places do not have irrigation water use quantified, so the model simulates almost exactly the process irrigators undertake to determine if they need to irrigate.

4.1.10 LSPC Modeling Parameters

Pollutants simulated by LSPC were biochemical oxygen demand (BOD), total nitrogen (Total N), and total phosphorus (Total P). LSPC requires land cover specific accumulation and washoff rates for each of the modeled water quality parameters. Table 4-8 provides the rates developed during model calibration for BOD, total nitrogen, and total phosphorus for each land cover type.

Table 4-8. LSPC Modeling Parameters

Land use	Water Quality Parameter	Rate of Accumulation (lbs/acre/day)	Maximum Storage (lbs/acre)	Rate Of Surface Runoff Which Will Remove 90% (in/hr)	Concentration In Interflow Outflow (mg/L)	Concentration In Active Groundwater Outflow (mg/L)
Beach	BOD	0.06417 - 0.1575	0.2567 - 0.63	0.7	1.014 - 2.184	1.248 - 1.248
	Total N	0.01273 - 0.06716	0.0509 - 0.2686	0.7	0.98904 - 1.22304	0.83304 - 1.06704
	Total P	0.0014 - 0.00875	0.0056 - 0.035	0.7	0.0156 - 0.0156	0.0156 - 0.0156
Water	BOD	0	0	0	0	0
	Total N	0	0	0	0	0
	Total P	0	0	0	0	0
Low Developed Pervious	BOD	0.06417 - 0.1575	0.2567 - 0.63	0.5	2.73 - 3.978	1.248 - 1.248
	Total N	0.01681 - 0.08865	0.0672 - 0.3546	0.4	0.98904 - 1.22304	0.83304 - 1.06704
	Total P	0.0014 - 0.00875	0.0056 - 0.035	0.6	0.01404 - 0.01404	0.01092 - 0.01092
Low	BOD	0.06417 - 0.1575	0.2567 - 0.63	0.2	0	0

Land use	Water Quality Parameter	Rate of Accumulation (lbs/acre/day)	Maximum Storage (lbs/acre)	Rate Of Surface Runoff Which Will Remove 90% (in/hr)	Concentration In Interflow Outflow (mg/L)	Concentration In Active Groundwater Outflow (mg/L)
Developed Impervious	Total N	0.01528 - 0.08059	0.0611 - 0.3224	0.2	0	0
	Total P	0.0014 - 0.00875	0.0056 - 0.035	0.2	0	0
Medium Developed Pervious	BOD	0.06417 - 0.1575	0.2567 - 0.63	0.5	2.73 - 3.978	1.248 - 1.248
	Total N	0.01681 - 0.08865	0.0672 - 0.3546	0.4	0.98904 - 1.22304	0.83304 - 1.06704
	Total P	0.0014 - 0.00875	0.0056 - 0.035	0.6	0.01404 - 0.01404	0.01092 - 0.01092
Medium Developed Impervious	BOD	0.06417 - 0.1575	0.2567 - 0.63	0.2	0	0
	Total N	0.01528 - 0.08059	0.0611 - 0.3224	0.2	0	0
	Total P	0.0014 - 0.00875	0.0056 - 0.035	0.2	0	0
High Developed Pervious	BOD	0.06417 - 0.1575	0.2567 - 0.63	0.5	2.73 - 3.978	1.248 - 1.248
	Total N	0.01681 - 0.08865	0.0672 - 0.3546	0.4	0.98904 - 1.22304	0.83304 - 1.06704
	Total P	0.0014 - 0.00875	0.0056 - 0.035	0.6	0.01404 - 0.01404	0.01092 - 0.01092
High Developed Impervious	BOD	0.06417 - 0.1575	0.2567 - 0.63	0.2	0	0
	Total N	0.01528 - 0.08059	0.0611 - 0.3224	0.2	0	0
	Total P	0.0014 - 0.00875	0.0056 - 0.035	0.2	0	0
Barren	BOD	0.06417 - 0.1925	0.2567 - 0.77	0.3	1.014 - 2.184	1.248 - 1.248
	Total N	0.01528 - 0.08059	0.0611 - 0.3224	0.3	0.702 - 0.7644	0.273 - 0.351
	Total P	0.0014 - 0.00875	0.0056 - 0.035	0.3	0.01248 - 0.01248	0.01373 - 0.01373
Forest	BOD	0.06417 - 0.1925	0.2567 - 0.77	0.7	1.014 - 2.184	1.248 - 1.248
	Total N	0.00923 - 0.06366	0.0369 - 0.2546	0.7	0.195 - 0.273	0.117 - 0.195
	Total P	0.00035 - 0.0077	0.0014 - 0.0308	0.7	0.00468 - 0.00468	0.00624 - 0.00624
Golf	BOD	0.06417 - 0.1575	0.2567 - 0.63	0.7	1.014 - 2.184	1.248 - 1.248
	Total N	0.01273 - 0.06716	0.0509 - 0.2686	0.7	0.98904 - 1.22304	0.83304 - 1.06704
	Total P	0.0014 - 0.00875	0.0056 - 0.035	0.7	0.0156 - 0.0156	0.0156 - 0.0156
Pasture	BOD	0.06417 - 0.1575	0.2567 - 0.63	0.7	1.014 - 2.964	1.248 - 1.248
	Total N	0.0294 - 0.17981	0.1176 - 0.7192	0.7	0.45864 - 0.92664	0.77064 - 1.23864
	Total P	0.00525 - 0.0105	0.021 - 0.042	0.7	0.078 - 0.0936	0.1014 - 0.1014
Crop	BOD	0.06417 - 0.42583	0.2567 - 1.7033	0.7	1.014 - 2.964	1.248 - 1.248
	Total N	0.0294 - 0.17981	0.1176 - 0.7192	0.7	0.45864 - 0.92664	0.77064 - 1.23864
	Total P	0.00525 - 0.0105	0.021 - 0.042	0.7	0.1248 - 0.1248	0.1014 - 0.1014
Forested Wetland	BOD	0.06417 - 0.1575	0.2567 - 0.63	0.7	1.014 - 2.184	1.248 - 1.248
	Total N	0.01273 - 0.06716	0.0509 - 0.2686	0.7	0.59904 - 0.63804	0.59904 - 0.63804
	Total P	0.0014 - 0.00875	0.0056 - 0.035	0.7	0.00624 - 0.00624	0.00749 - 0.00749
Non-Forested	BOD	0.06417 - 0.1575	0.2567 - 0.63	0.7	1.014 - 2.184	1.248 - 1.248

Land use	Water Quality Parameter	Rate of Accumulation (lbs/acre/day)	Maximum Storage (lbs/acre)	Rate Of Surface Runoff Which Will Remove 90% (in/hr)	Concentration In Interflow Outflow (mg/L)	Concentration In Active Groundwater Outflow (mg/L)
Wetland	Total N	0.01273 - 0.06716	0.0509 - 0.2686	0.7	0.59904 - 0.63804	0.59904 - 0.63804
	Total P	0.0014 - 0.00875	0.0056 - 0.035	0.7	0.00624 - 0.00624	0.00749 - 0.00749
Other Impervious	BOD	0.06417 - 0.1575	0.2567 - 0.63	0.2	0	0
	Total N	0.01273 - 0.06716	0.0509 - 0.2686	0.2	0	0
	Total P	0.0014 - 0.00875	0.0056 - 0.035	0.2	0	0
LAS	BOD	1.86 - 1.86	1.86 - 1.86	0	0	0
	Total N	0.43 - 0.43	0.43 - 0.43	0	0	0
	Total P	0.04 - 0.04	0.04 - 0.04	0	0	0
Failing Septic	BOD	0.309 - 0.309	0.309 - 0.309	0.7	3.276 - 3.276	1.17 - 1.17
	Total N	0.0701 - 0.0701	0.0701 - 0.0701	0.7	0.3588 - 0.3588	0.36504 - 0.36504
	Total P	0.0926 - 0.0926	0.0926 - 0.0926	0.7	0.0156 - 0.0156	0.01872 - 0.01872
Irrigated Water	BOD	0.06417 - 0.1575	0.2567 - 0.63	0.7	1.014 - 2.964	1.248 - 1.248
	Total N	0.0294 - 0.17981	0.1176 - 0.7192	0.7	0.84864 - 1.31664	0.77064 - 1.23864
	Total P	0.00525 - 0.0105	0.021 - 0.042	0.7	0.078 - 0.0936	0 - 0
Irrigated Urban	BOD	0.183333 - 0.45	0.549999 - 1.35	0.70	3.5 - 5.1	1.6 - 1.6
	Total N	0.036375 - 0.191875	0.1455 - 0.7675	0.60	1.568 - 1.868	1.268 - 1.568
	Total P	0.004 - 0.025	0.012 - 0.075	0.60	0.009 - 0.009	0.01 - 0.01
Irrigated Barren	BOD	0.183333 - 0.55	0.549999 - 1.65	0.70	1.3 - 2.8	1.6 - 1.6
	Total N	0.036375 - 0.191875	0.1455 - 0.7675	0.60	0.55 - 0.65	0.45 - 0.55
	Total P	0.004 - 0.025	0.012 - 0.075	0.60	0.008 - 0.008	0.0098 - 0.0098
Irrigated Forest	BOD	0.183333 - 0.55	0.549999 - 1.65	0.70	1.3 - 2.8	1.6 - 1.6
	Total N	0.026375 - 0.181875	0.1055 - 0.7275	0.60	0.35 - 0.45	0.25 - 0.35
	Total P	0.001 - 0.022	0.003 - 0.066	0.60	0.004 - 0.004	0.006 - 0.006
Irrigated Golf	BOD	0.183333 - 0.45	0.549999 - 1.35	0.70	1.3 - 2.8	1.6 - 1.6
	Total N	0.036375 - 0.191875	0.1455 - 0.7675	0.60	1.568 - 1.868	1.268 - 1.568
	Total P	0.004 - 0.025	0.012 - 0.075	0.60	0.005 - 0.005	0.008 - 0.008
Irrigated Pasture	BOD	0.183333 - 0.45	0.549999 - 1.35	0.70	1.3 - 3.8	1.6 - 1.6
	Total N	0.084 - 0.61375	0.336 - 2.455	0.60	1.388 - 1.988	1.188 - 1.788
	Total P	0.015 - 0.03	0.045 - 0.09	0.60	0.055 - 0.065	0.075 - 0.075
Irrigated Crop	BOD	0.183333 - 1.216667	0.5499 - 3.6500	0.70	1.3 - 3.8	1.6 - 1.6
	Total N	0.084 - 0.61375	0.336 - 2.455	0.60	1.388 - 1.988	1.188 - 1.788
	Total P	0.015 - 0.03	0.045 - 0.09	0.60	0.085 - 0.085	0.075 - 0.075
Irrigated Wetland	BOD	0.183333 - 0.45	0.549999 - 1.35	0.70	1.3 - 2.8	1.6 - 1.6
	Total N	0.036375 - 0.191875	0.1455 - 0.7675	0.60	0.768 - 0.818	0.768 - 0.818
	Total P	0.004 - 0.025	0.012 - 0.075	0.60	0.004 - 0.004	0.0058 - 0.0058

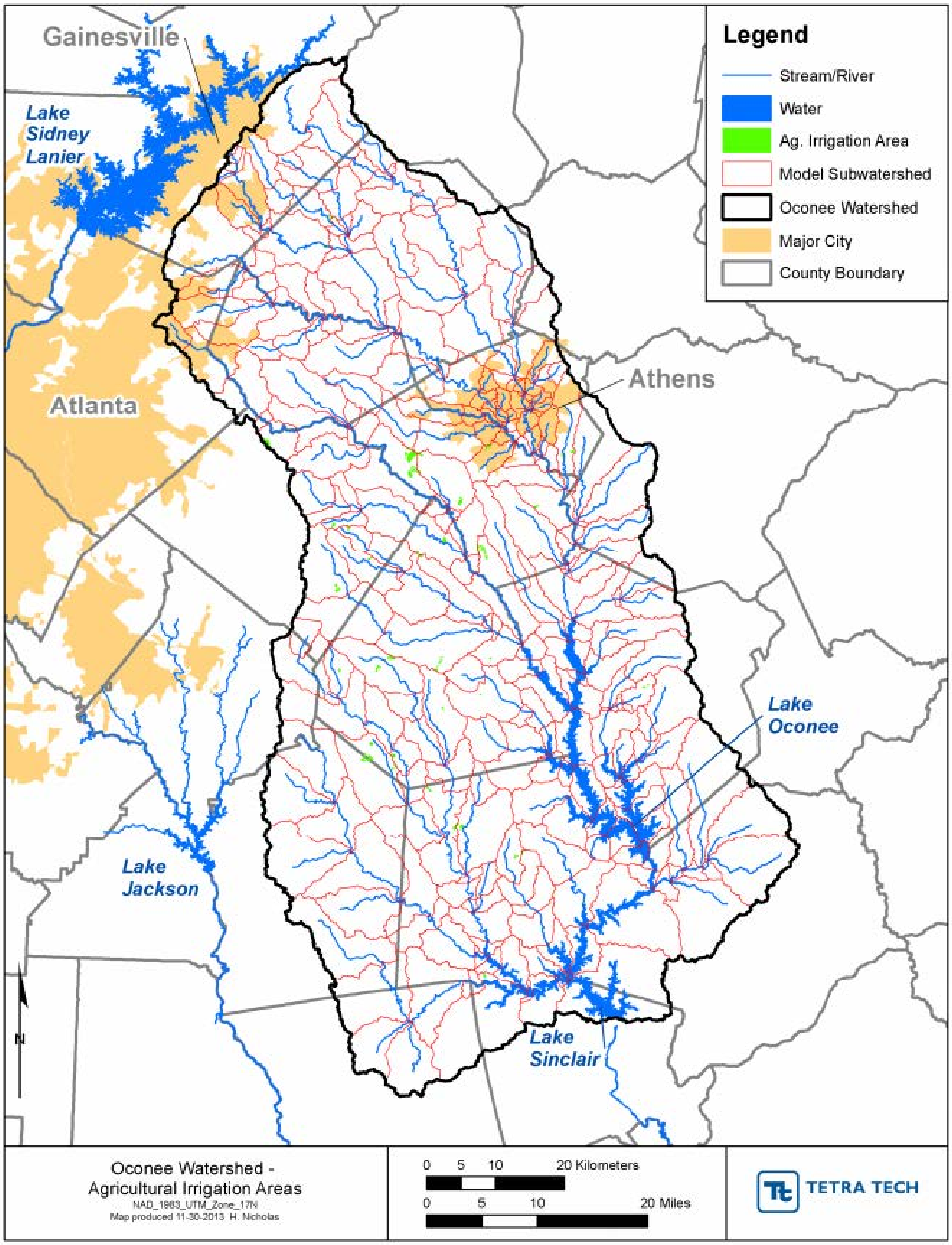


Figure 4-10. Irrigated Areas in the Lakes Oconee and Sinclair Watersheds

4.2 LSPC Model Calibration

Historical flow data collected at USGS stations located in the Lakes Oconee and Sinclair watersheds were used to calibrate and validate the LSPC watershed hydrology model. Figure 4-11 shows the location of these flow gages used for the hydrologic calibrations. Five of the gages had a complete period of record for the period from January 1, 1998 through December 31, 2012. Table 4-9 lists those stations that were used for calibration or validation.

Table 4-9. Flow Stations Used to Calibrate LSPC Hydrology

Station Name	USGS Stations	Drainage Area (mi^2)	Type	Period of Record Utilized
Wheeler Creek at Bill Creek Road, near Auburn, GA	02217274	1.16	Validation	1/1/02-12/31/12
Mulberry Creek near Winder, GA	02217297	109	Validation	1/1/08-12/31/12
Middle Oconee River near Arcade, GA	02217475	332	Calibration	1/1/98-12/31/12
Middle Oconee River near Athens, GA	02217500	398	Calibration	1/1/98-12/31/12
North Oconee River at Woodbridge Road, near Commerce, GA	02217615	99.3	Validation	1/1/10-12/31/12
North Oconee River at College Station, at Athens GA	02217770	264	Validation	1/1/03-12/31/12
Oconee River near Penfield, GA	02218300	940	Calibration	1/1/98-12/31/12
Apalachee River at Fence Road, near Dacula, GA	02218565	5.68	Validation	1/1/02-12/31/12
Apalachee River near Bostwick, GA	02219000	176	Calibration	1/1/98-12/31/12
Little River near Eatonton, GA	02220900	262	Calibration	1/1/98-12/31/12
Murder Creek below Eatonton, GA	02221525	190	Validation	1/1/98-12/31/12

During the calibration process, model parameters were adjusted based on local knowledge of soil types and groundwater conditions, within reasonable constraints as outlined in Technical Note 6 (US EPA 2000), until an acceptable agreement was achieved between simulated and observed stream flow. Key hydrologic model parameters adjusted included: evapo-transpiration, infiltration, upper and lower zone storages, groundwater recession, and losses to the deep groundwater system.

As previously mentioned, to represent watershed loadings and resulting pollutant concentrations in individual stream segments, the Lakes Oconee and Sinclair watersheds were divided into 237 sub-watersheds. Listed reaches, tributary confluences, and the locations of water quality monitoring sites defined these sub-watersheds, representing hydrologic boundaries. Delineation at water quality monitoring sites allowed comparison of model output to measured data.

Figures 4-12, 4-13 and 4-14 illustrate the calibration-validation of the hydrologic model using the results obtained at USGS station 02218300 on the Oconee River. Figure 4-12 shows the comparison between simulated and observed daily flows for the period January 1, 1998 – December 31, 2012, and the period January 1, 2005 – December 31, 2005. This figure indicates that the model satisfactorily reproduces the dynamics of the runoff events during the simulated period. Some periods exhibit better agreement between the observed and simulated data (e.g. year 2005) than others. In general, the model does a job good capturing the response of the watershed at this station. The timing and magnitude of the flows are reproduced and there is no bias in the simulated flows.

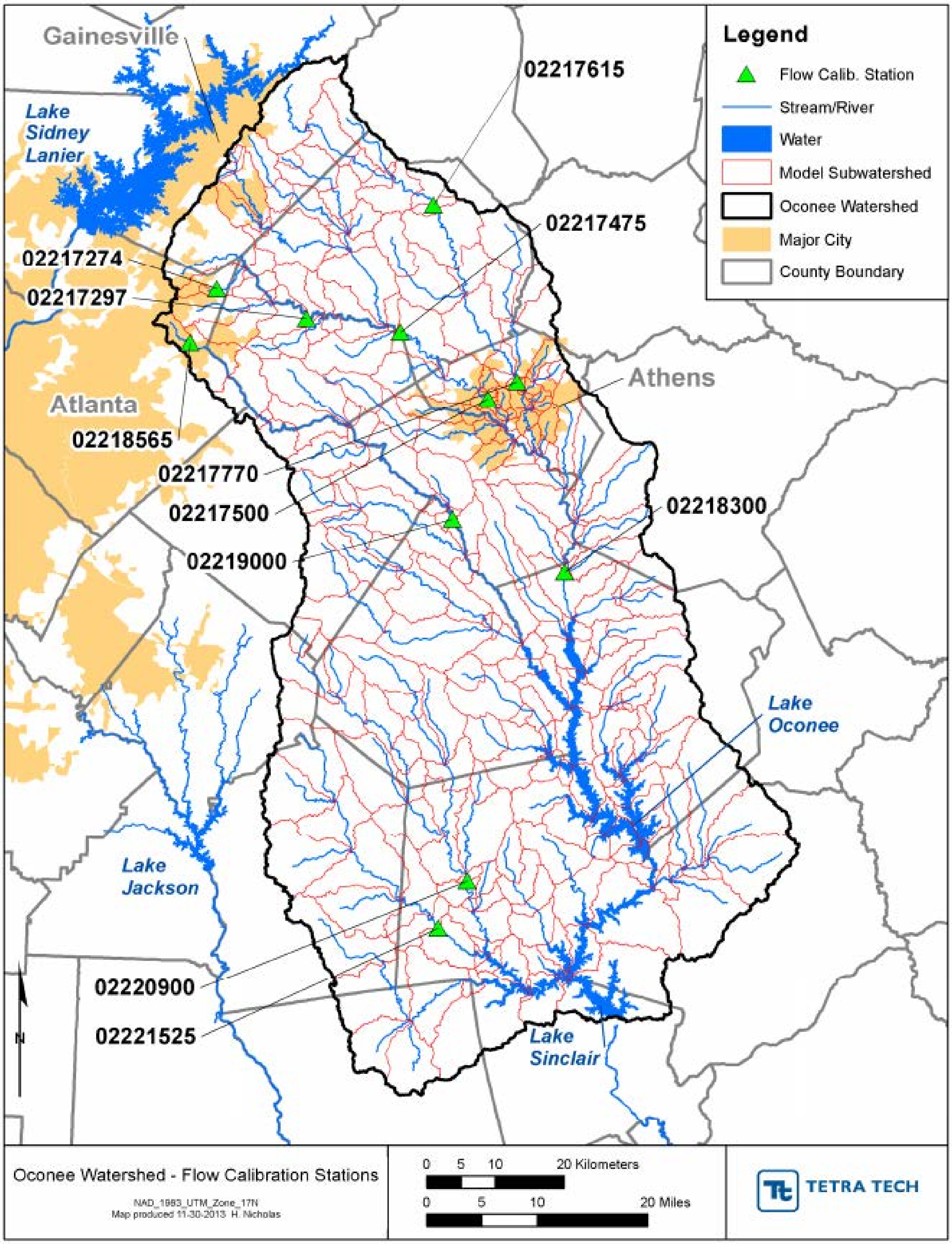
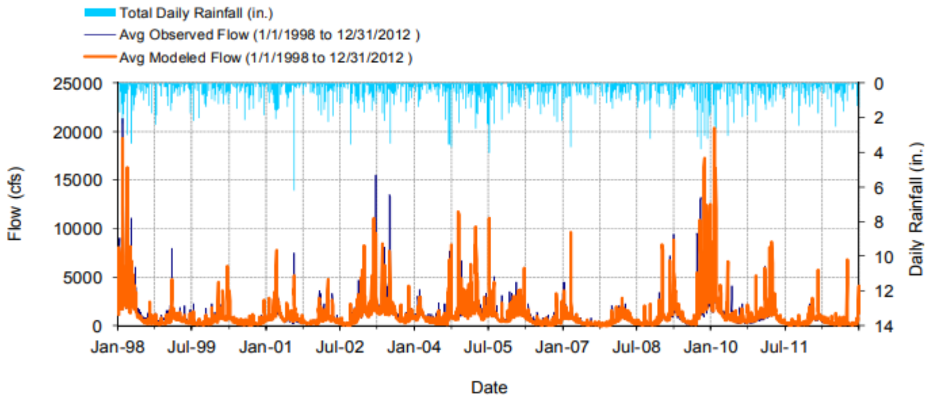
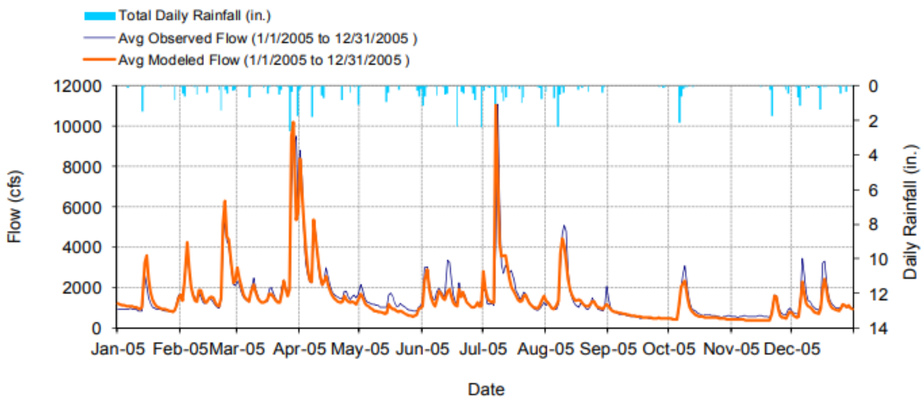


Figure 4-11. USGS Flow and Monitoring Stations Used in the Calibration of LSPC



(a)



(b)

Figure 4-12. Comparison between Observed and Predicted Flows a) 1998-2012 period, and b) 2005 year period

Figure 4-13 shows the observed and modeled flow exceedance curves for the 1998- 2012 Period at USGS stream gage 02218300 located on the Oconee River near Penfield, GA. The flow exceedance curves are an excellent means of demonstrating the effects a drainage area's impervious and pervious land coverage has on the flow.

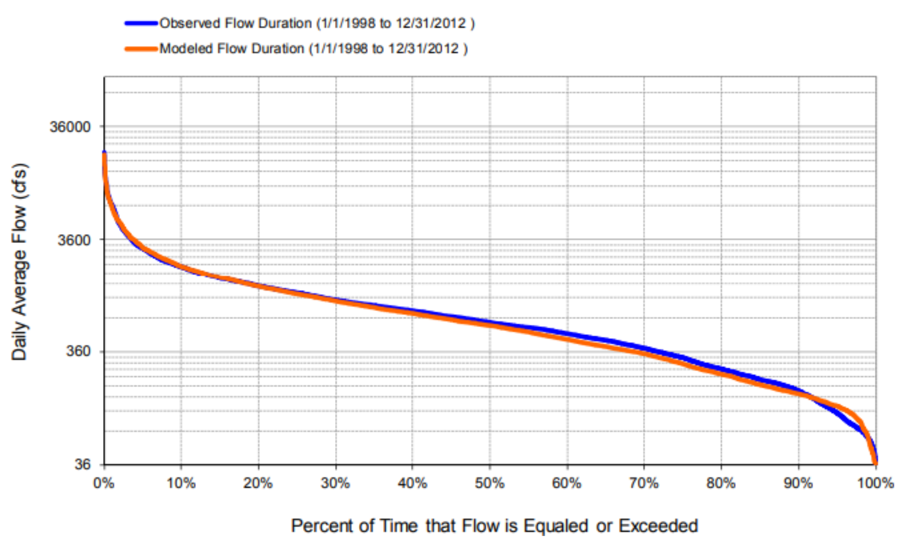


Figure 4-13. Comparison of Observed and Simulated Flow Exceedance Curves

Figure 4-14 shows the model results for the USGS gage station 02218300 located on the Oconee River near Penfield, GA on a monthly scale. The period of analysis is January 1, 1998 through December 31, 2012. This figure shows that the model does a very good job estimating the multi-annual monthly median flows, as well as the observed inter annual variability represented by the first and third quartiles.

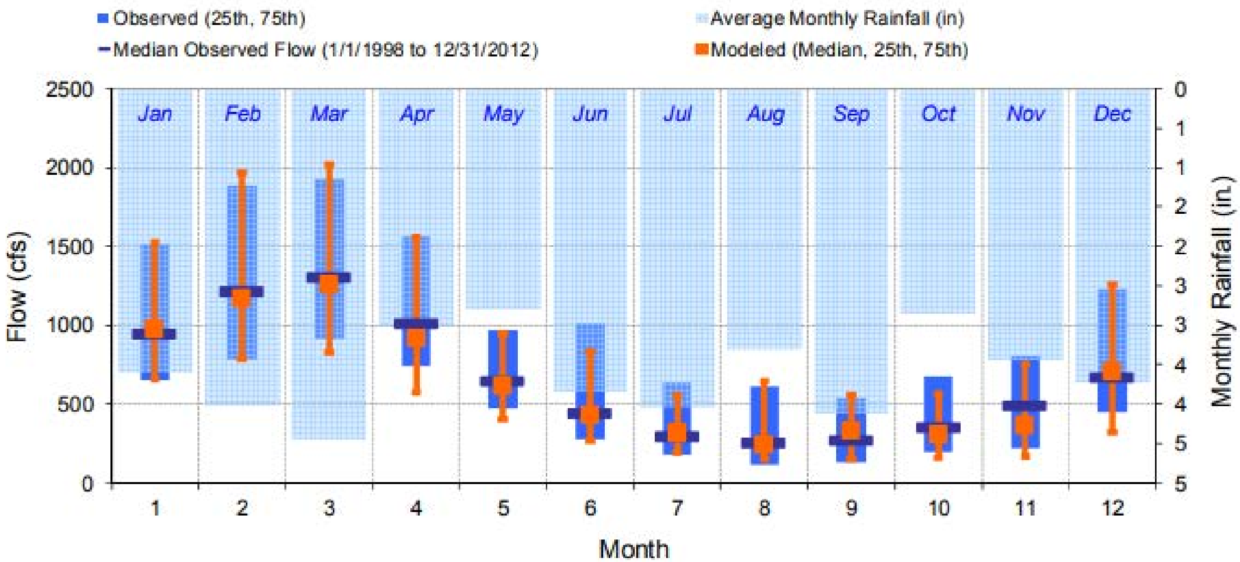


Figure 4-14. Comparison of Observed and Simulated Multiannual Monthly Mean Flows and Ranges of Variation

Each month, water quality data is collected at one location: Oconee River at Barnett Shoals Road near Athens, GA. During 2009, GA EPD conducted intensive sampling of rivers and streams in the Lakes Oconee and Sinclair watersheds. This sampling was conducted at 84 key locations throughout the watershed. The water quality data included total nitrogen, nitrate+nitrite, ammonia, total Kjeldahl nitrogen (TKN), total phosphorus, orthophosphate, BOD_5, total suspended sediment (TSS), temperature, and dissolved oxygen. The Lakes Oconee and Sinclair LSPC models were calibrated and validated to discrete instream water quality data measured. Thirteen of the stations were chosen to be calibration stations. The remaining stations were utilized as validation stations. The list of stations and how they were utilized is given in Table 4-10 and the station locations are shown in Figure 4-15.

Table 4-10. Monitoring Stations Used to Calibrate LSPC Water Quality

Station Name	Station Number	Mon Loc Number	LSPC Watershed	Calibration / Validation
Pond Fork at Greggs Road near Gainesville, GA	0301010101	RV_03_569	307	Validation
Pond Fork at Wayne Poultry Road near Pendergrass, GA	0301010201	RV_03_570	305	Validation
Allen Creek at Baker Road near Candler, GA	0301010301	RV_03_571	304	Validation
Allen Creek at Wayne Poultry Road near Pendergrass, GA	0301010302	RV_03_572	302	Validation
Allen Creek at Fuller Road near Talmo ,GA	0301010304	RV_03_779	303	Validation
E.T. Creek near Chicopee, GA	0301010401	RV_03_796	298	Validation
Walnut Creek at Tanners Mill Road (SR211) near Talmo, GA	0301010403	RV_03_574	294	Validation
Walnut Creek 319(h) nr Elachee Dr (Elachee Nature Center) near Gainesville, GA	0301010404	RV_03_812	297	Validation
Walnut Creek at Georgia Highway 332 near Winder, GA	0301010501	RV_03_575	291	Validation

Station Name	Station Number	Mon Loc Number	LSPC Watershed	Calibration / Validation
Walnut Creek at Cooper Bridge Road near Talmo ,GA	0301010502	RV_03_813	292	Validation
Middle Oconee River at Etheridge Road near Arcade, GA	0301010602	RV_03_576	274	Calibration
Mulberry River at Old Covered Bridge Road near Hoschton, GA	0301020201	RV_03_799	284	Validation
Little Mulberry River at Boss Hardy Road near Hoschton, GA	0301020301	RV_03_577	283	Validation
Cedar Creek at State Road 211 near Winder, GA	0301020402	RV_03_579	279	Validation
Mulberry River at Georgia Highway 11 near Winder, GA	0301020501	RV_03_580	275	Validation
Mulberry River at SR 319 / Etheridge Road near Arcade ,GA	0301020502	RV_03_581	273	Validation
Middle Oconee River at Georgia Highway 82 near Arcade, GA	0301030101	RV_03_582	270	Validation
Barber Creek at Barber Creek Road near Bogart ,GA	0301030401	RV_03_781	258	Validation
Barber Creek at Daniels Bridge Road near Athens, GA	0301030501	RV_03_782	256	Validation
McNutt Creek at Mal Bay Road at Athens, GA	0301030602	RV_03_584	259	Calibration
McNutt Creek at Jennings Mill Road, Athens, GA	0301030603	RV_03_585	260	Validation
Hunnicut Creek at Westchester Drive near Athens, GA	0301030701	RV_03_586	308	Validation
Brooklyn Branch at West Lake Drive near Athens, GA	0301030704	RV_03_787	309	Validation
Middle Oconee River at Macon Hwy near Athens, GA	0301030705	RV_03_589	1001	Validation
Middle Oconee River at Whitehall Road at Athens, GA	0301030707	RV_03_591	247	Validation
Calls Creek at Hickory Hill Drive near Watkinsville, GA	0301030708	RV_03_592	250	Validation
Middle Oconee River at Mitchell Bridge Road near Athens ,GA	0301030709	RV_03_593	1003	Validation
North Oconee River at Deadwyler Road near Maysville, GA	0301040201	RV_03_595	331	Validation
North Oconee River at Diamond Hill Church Road (CR266) near Maysville ,GA	0301040202	RV_03_596	332	Validation
Chandler Creek at Deadwyler Road near Maysville, GA	0301040301	RV_03_597	334	Validation
North Oconee River at Georgia Highway 82 near Maysville, GA	0301040401	RV_03_489	328	Validation
North Oconee River at State Highway 335 Near Nicholson, GA	0301040601	RV_03_490	325	Validation
North Oconee River at Newton Bridge Road near Athens ,GA	0301050101	RV_03_491	321	Validation
Sandy Creek at Highway 334 near Athens ,GA	0301050301	RV_03_492	336	Calibration
W. Fork Trail Creek at U.S. 29 near Athens, GA	0301050501	RV_03_493	341	Validation
East Fork Trail Creek Tributary (Carver Branch) at Olympic Drive near Athens, GA	0301050502	RV_03_494	342	Validation
North Oconee River - Athens Water Intake	0301050503	RV_03_495	318	Calibration
North Oconee River at East Broad Street at Athens, GA	0301050504	RV_03_496	316	Validation
Trail Creek at East Broad Street near Athens, GA	0301050505	RV_03_497	338	Validation
Carr Creek at Bailey Street near Athens, GA	0301050507	RV_03_499	345	Validation
North Oconee River at Whitehall Road near Whitehall, GA	0301050508	RV_03_500	310	Validation
Cedar Creek at Barnett Shoals Drive near Athens, GA	0301060101	RV_03_501	346	Validation
Oconee River at Barnett Shoals Road near Athens, GA	0301060102	RV_03_502	242	Calibration
Oconee River at Georgia Highway 15 near Penfield, GA	0301070101	RV_03_503	231	Calibration
Greenbriar Creek at Johnny Carson Road near Bostwick ,GA	0301070102	RV_03_792	228	Calibration
Fishing Creek at Macedonia Road near Penfield, GA	0301070301	RV_03_504	349	Validation
Fishing Creek at Conger Road near Woodville ,GA	0301070302	RV_03_505	249	Validation
Town Creek at State Road 15 near Greensboro, GA	0301070501	RV_03_507	353	Validation
Town Creek at Cold Springs Road near Greensboro, GA	0301070502	RV_03_508	352	Validation
Apalachee Riv at SR 81 nr Bethlehem, GA	0301080201	RV_03_510	219	Validation
Marburg Creek at Manning Gin Road near Bethlehem, GA	0301080301	RV_03_511	216	Validation

Station Name	Station Number	Mon Loc Number	LSPC Watershed	Calibration / Validation
Apalachee River at State Road 11 near Bethlehem, GA	0301080401	RV_03_512	217	Validation
Apalachee River at Sims Bridge Road near Bethlehem ,GA	0301080501	RV_03_780	214	Validation
Apalachee River at SR 186 / Snows Mill Road near Bishop ,GA	0301090101	RV_03_513	211	Validation
Jacks Creek at Snows Mill Road (County Road 45) near Monroe, GA	0301090301	RV_03_514	207	Validation
Jacks Creek at Bearden Road near Monroe, GA	0301090302	RV_03_515	205	Validation
Apalachee River - Near Bostwick	0301090501	RV_03_516	208	Calibration
Apalachee River at State Road 24 near Apalachee, GA	0301090601	RV_03_517	201	Calibration
Apalachee River - U.S. Highway 278	0301090701	RV_03_518	187	Validation
Sugar Creek at Seven Island Road near Madison ,GA	0301100202	RV_03_806	182	Calibration
Little Sugar Creek at Kingston Road (County Road 127) near Buckhead, GA	0301100301	RV_03_532	179	Validation
Sugar Creek at Mount Zion Road (County Road 134) near Buckhead, GA	0301100401	RV_03_533	180	Validation
Richland Creek at Ga. Hwy 15 near Greensboro, GA	0301110101	RV_03_540	364	Validation
Town Creek at Ga. Hwy 44 near Greensboro, GA	0301110102	RV_03_807	366	Validation
Town Creek at Old Covington Road County Road 39 near Greensboro, GA	0301110103	RV_03_541	365	Validation
Richland Creek at Shelby Dreyer Road near Greensboro, GA	0301110104	RV_03_542	363	Validation
Beaverdam Creek at County Road 66 near Veazey, GA	0301110301	RV_03_784	370	Validation
Big Sandy Creek at Sandy Creek Road near Bostwick, GA	0301130402	RV_03_786	199	Validation
Big Sandy Creek at Sandy Creek Road near Apalachee, GA	0301130601	RV_03_550	195	Validation
Hard Labor Creek at Lower Apalachee Road near Madison ,GA	0301130701	RV_03_793	190	Calibration
Little River at U.S. Highway 278 near Covington, GA	0301140101	RV_03_551	145	Validation
Little River at Georgia Highway 83 near Godfrey, GA	0301140401	RV_03_552	140	Validation
Little River at Little River Road (Ga. 213) near Godfrey, GA	0301140402	RV_03_553	139	Validation
Big Indian Creek at Georgia Highway 83 near Madison, GA	0301140601	RV_03_554	149	Validation
Big Indian Creek at Hearn Road near Eatonton, GA	0301140901	RV_03_555	146	Validation
Little River at State Road 16 near Eatonton, GA	0301150102	RV_03_557	132	Calibration
Glady Creek Tributary at Reids Road (Putnam County Road 17)	0301150201	RV_03_558	151	Validation
Little River at Glenwood Springs Road near Eatonton ,GA	0301150302	RV_03_560	131	Calibration
Murder Creek at New Glenwood Springs Road (FAS 777) nr Eatonton	0301160701	RV_03_561	120	Validation
Murder Creek at Hillsborough Road near Eatonton ,GA	0301160703	RV_03_563	121	Validation
Big Cedar Creek at U.S. Highway 129 near Eatonton, GA	0301170401	RV_03_567	110	Validation
Crooked Creek at Oconee Springs Road near Eatonton ,GA	0301180202	RV_03_791	161	Validation
Rooty Creek at Luther King Jr. Drive (County Road 90) near Eatonton, GA	0301180301	RV_03_599	158	Validation
Rooty Creek at County Road 89 near Eatonton, GA	0301180302	RV_03_804	157	Calibration

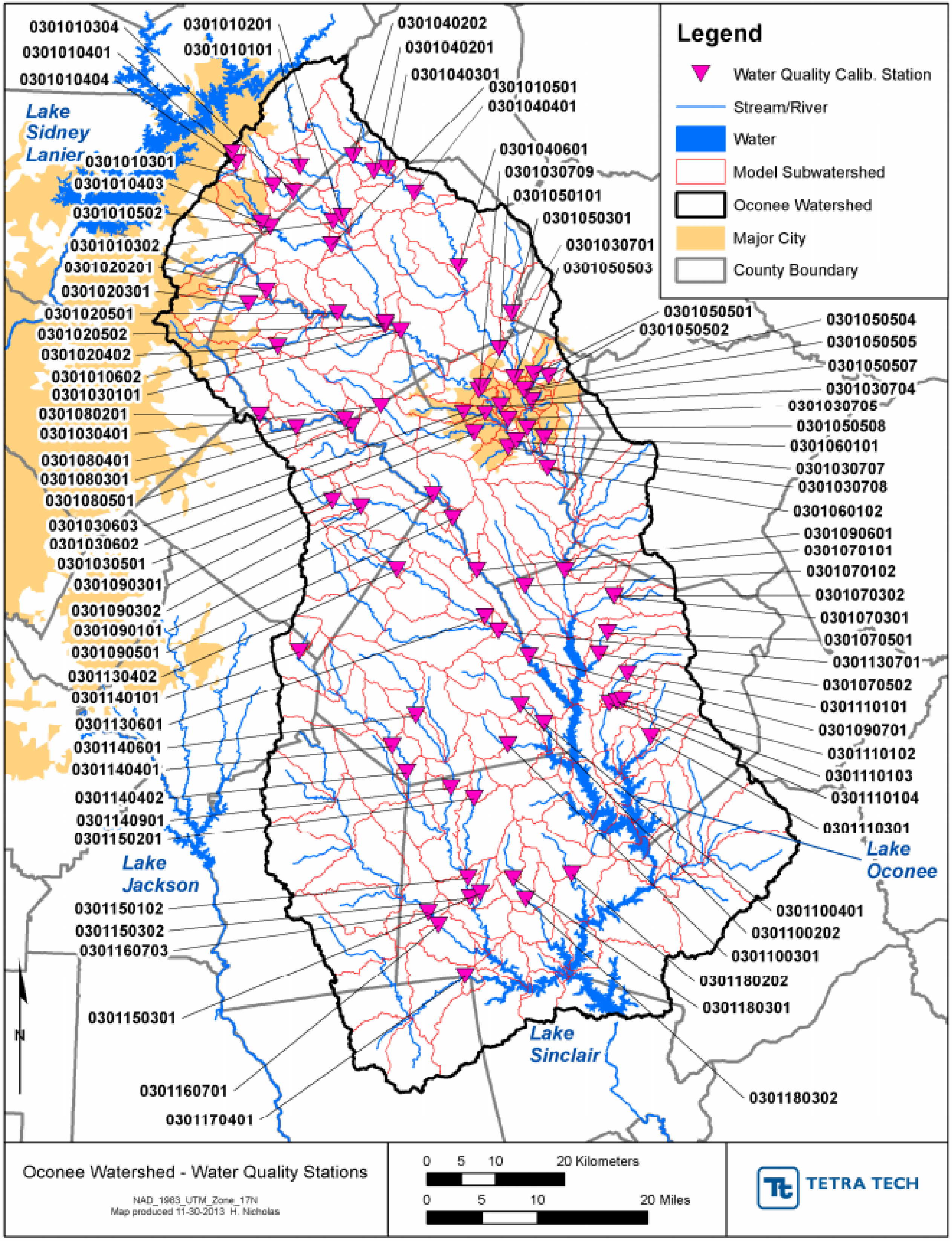
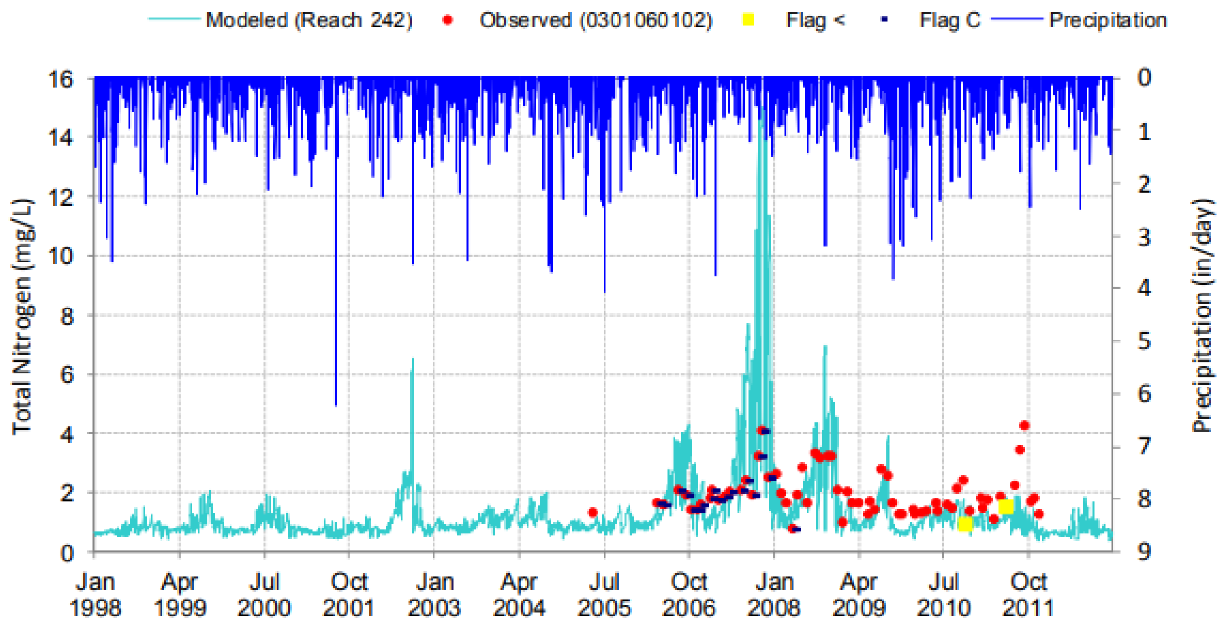
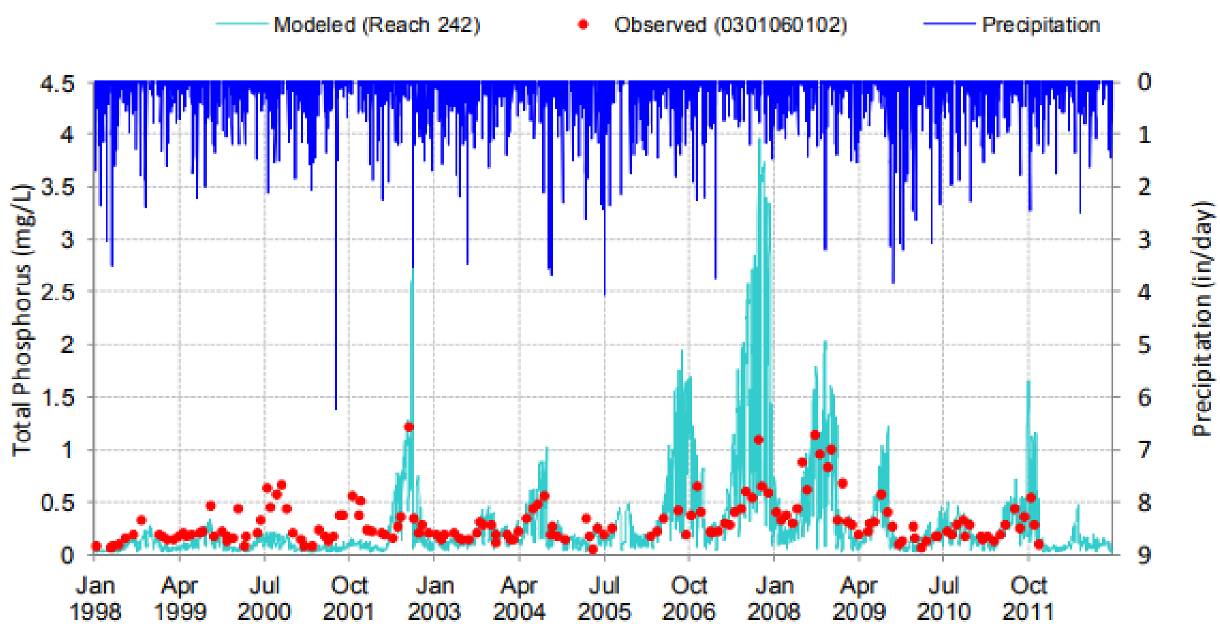


Figure 4-15. Monitoring Stations Used in the Water Quality Calibration of LSPC

Figure 4-16 shows example calibration plots for the Oconee River at Barnett Shoals Road near Athens, Georgia, for total nitrogen and total phosphorus. The simulated total nitrogen and total phosphorus model results for 1998 through 2012 are plotted against the available measured data collected during the same period. Other calibration and validation plots can be found in Appendices of the LSPC Watershed Modeling Report for Lakes Oconee and Sinclair.



(a)



(b)

Figure 4-16. Simulated vs Observed a) Total Nitrogen (mg/L) and b) Total Phosphorus (mg/L) at 0301060102 - Years 1998 through 2012

4.3 Lake Hydrodynamic Modeling (EFDC)

Bottom elevations and shoreline boundaries define the EFDC model grid. The grid for Lake Oconee covers the entire lake and includes the Oconee River up to the confluence with Fishing Creek, and the Apalachee River up to the confluence with Big Sandy Creek. Furthermore, the Richland Creek Arm was segmented into model grid cells. The grid for Lake Sinclair covers the entire lake and includes the Oconee River up to Wallace Dam. Model segmentation covers the Rooty Creek Arm just downstream of the confluence with Little Creek, and the Little River Arm just upstream of the confluence with Murder Creek. The bottom elevations for Lake Oconee and Lake Sinclair were obtained from Kingfisher Maps. Once the horizontal grid was developed, bottom elevations were interpolated for each grid cell by taking into account the total pool area and volume for each reservoir. Once the bottom elevation was determined for each cell, the elevation-area and elevation-capacity for each lake were compared.

A maximum of five uniformly distributed (equal height) vertical layers were defined along the deepest region of the main channel of each lake. This number of layers was selected to have a good resolution of the temperature stratification of the lake along the deepest part of the main channel. The average layer thickness with five layers is approximately 6 meters (m), which is roughly equal to the average photic zone thickness at each lakes forebay monitoring station. EFDC determines how many layers to assign to each cell based on a given reference maximum water surface elevation and the bathymetry of each cell. The lowest elevation in the Lake Oconee grid was set at 102 m MSL (334.6 ft MSL) and the reference maximum water surface elevation was set at 132 m MSL (433.1 ft MSL). These equate to the maximum reference depth of 30 m (98.4 ft) and reference layer thickness of 6 m (19.7 ft). The lowest elevation in the Lake Sinclair grid was set at 79 m MSL (259.2 ft MSL) and the reference maximum water surface elevation was set at 104 m MSL (341.2 ft MSL). These equate to the maximum reference depth of 25 m (82.0 ft) and reference layer thickness of 6 m (16.4 ft). For each cell, the number of layers was determined by comparing the bathymetry to a fixed interval reference bottom elevation. In short, three components are provided (maximum number of layers, reference maximum water surface elevation, and lowest elevation) and EFDC does the remaining calculation internally upon model execution.

The EFDC model requires boundary conditions to simulate circulation and transportation. These conditions include water surface elevations, dam releases, watershed tributary inflows, point source discharges, water withdrawals, and meteorological data. Data for the operation of Wallace and Sinclair Dams were provided by Georgia Power Company. Wallace Hydroelectric Plant is operated as a pump/storage system using both lakes. During times of low power demand, water is pumped into Lake Oconee from Lake Sinclair; then, during times of high power demand, that water is re-released into Lake Sinclair. The operation of the Wallace Hydroelectric Plant is not recorded, thus timing, magnitude and direction of flow are largely unknown. These flows are significant the Lake Oconee and Lake Sinclair EFDC applications. Corrective flows were used to estimate the Wallace Hydroelectric Plant’s operation. Lake Oconee was initially setup without an outflow. The corrective flow feature of EFDC was applied and timeseries of positive and negative flows were generated based on the observed water surface elevation of Lake Oconee. Negative corrective flows were adopted as flows leaving Lake Oconee and entering Lake Sinclair. Positive corrective flows were adopted as flows leaving Lake Sinclair and entering Lake Oconee. Both the positive and negative corrective flows had a 7-day moving average applied to the timeseries and were incorporated into the model setup files as operational flows for Wallace Dam. Figures 4-17 and 4-18 show daily and 7-Day moving average flows for water moving between Lakes Oconee and Sinclair.

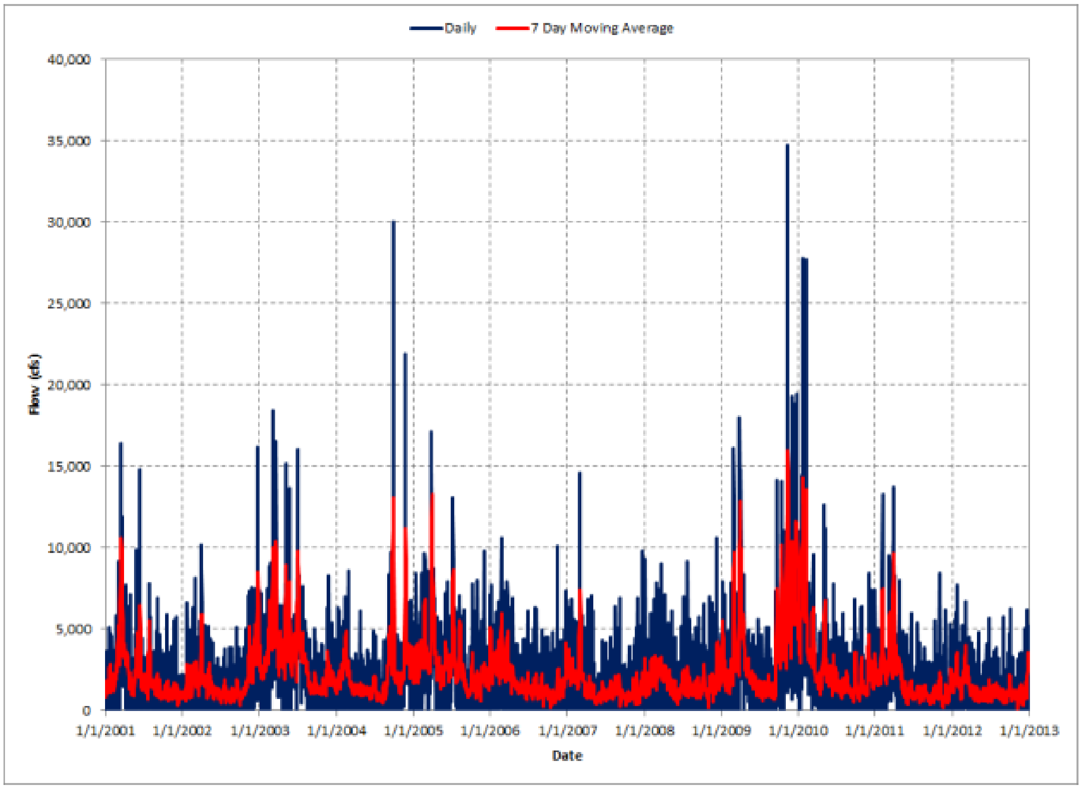


Figure 4-17. Daily Average and 7-day Moving Average Flow Released from Lake Oconee and Entering Lake Sinclair

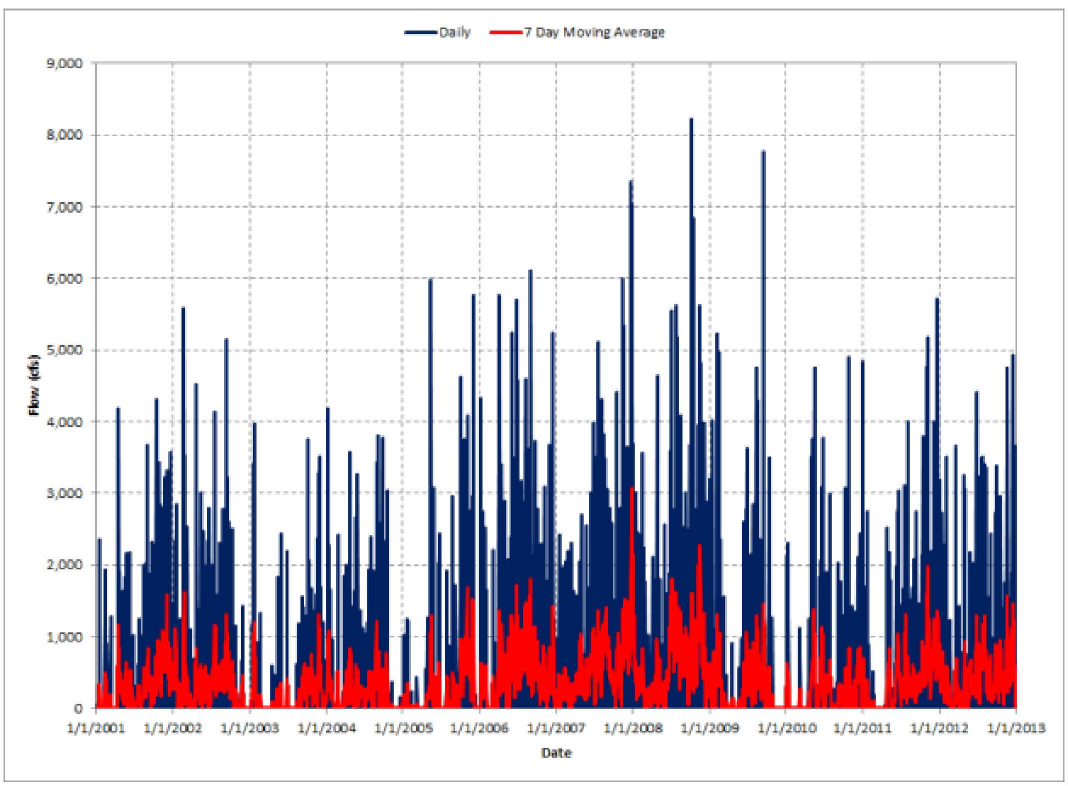


Figure 4-18. Daily Average and 7-day Moving Average Flow Released from Lake Sinclair and Entering Lake Oconee

4.3.1 Tributary Inputs

The results of the LSPC watershed model were used as tributary flow inputs to the Lake hydrodynamic model. Figures 4-19 and 4-20 show the model grids for Lakes Oconee and Sinclair and the location of the upstream boundaries and watershed inputs. The watershed flows are an important input for the flow balance of the Lakes. Table 4-11 identifies which EFDC cell each LSPC sub-watershed was input into and the flow type utilized.

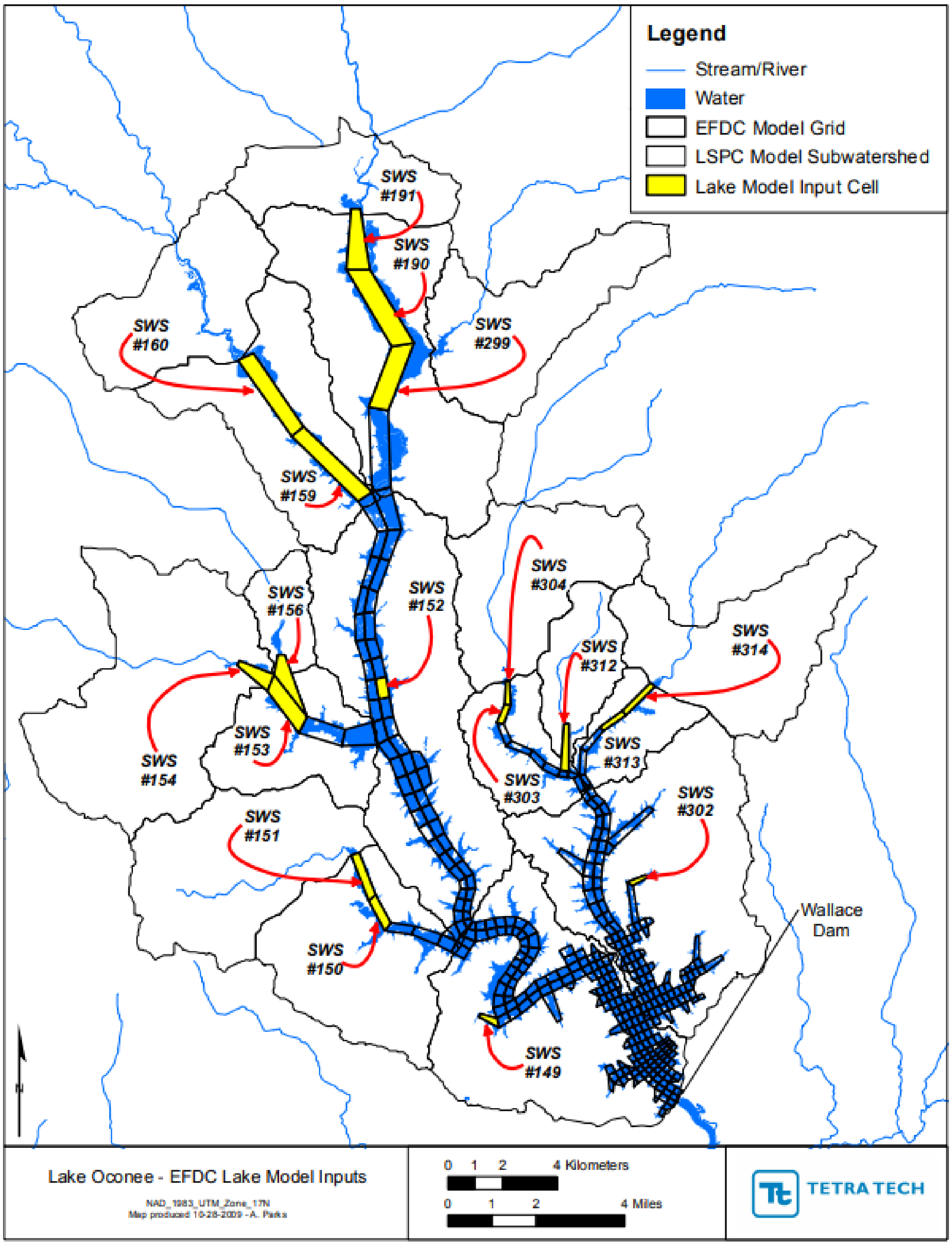


Figure 4-19. Model Grid for Lake Oconee, Showing the Location of the Upstream Boundary and Tributary Flow Inputs

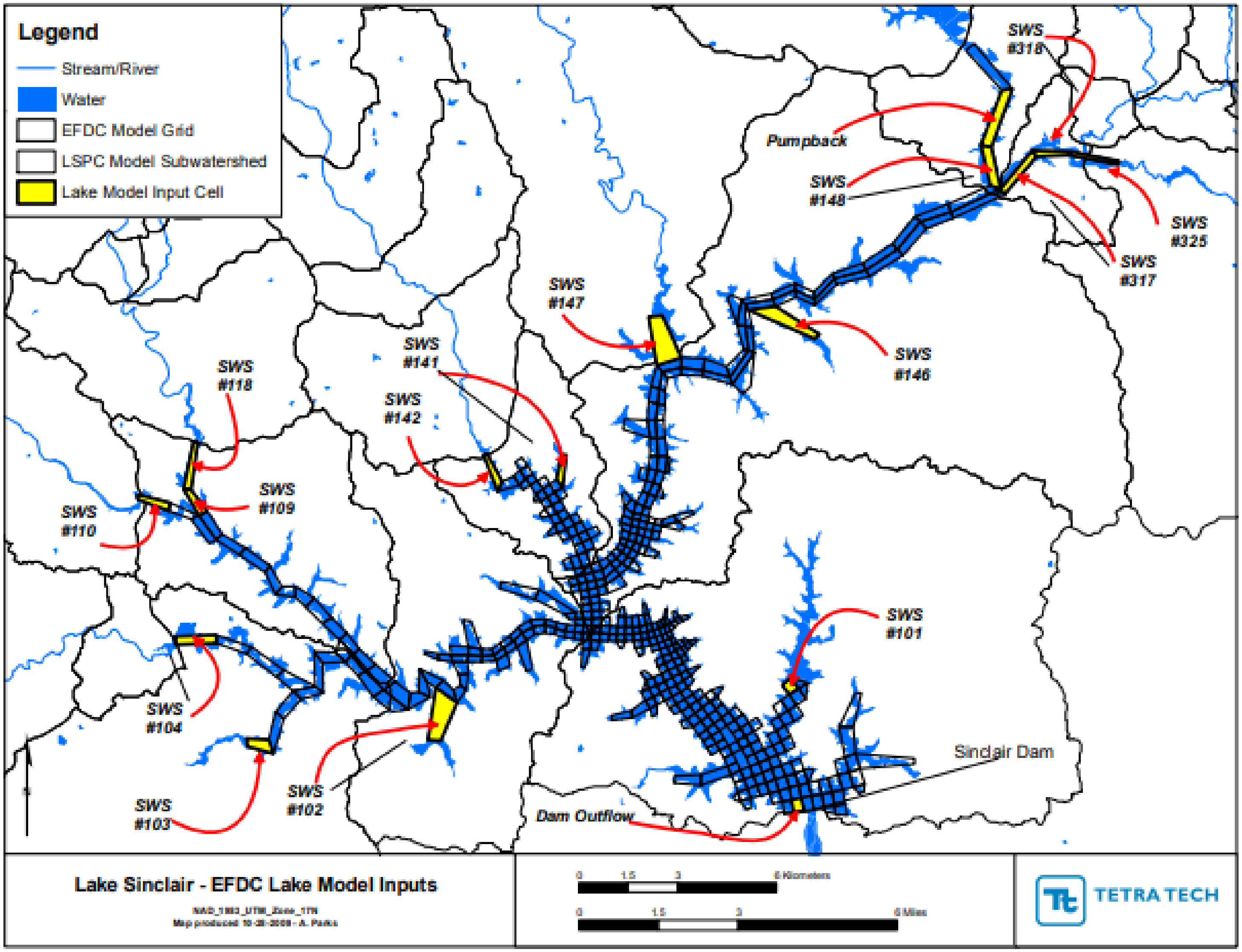


Figure 4-20. Model Grid for Lake Sinclair, Showing the Location of the Upstream Boundary and Tributary Flow Inputs

Table 4-11. LSPC Watershed Inputs

LSPC Sub-Watershed	EFDC Cell		Flow Type	Lake
	I-Value	J-Value		
360	24	48	RO	Oconee
359	25	42	RO	Oconee
358	24	47	PERO	Oconee
357	32	43	RO	Oconee
356	24	41	PERO	Oconee
355	30	35	PERO	Oconee
354	28	28	PERO	Oconee
224	17	66	RO	Oconee
223	17	68	RO	Oconee
222	17	67	PERO	Oconee
186	10	66	RO	Oconee
185	17	65	PERO	Oconee
184	10	65	PERO	Oconee
178	7	56	RO	Oconee
177	6	55	RO	Oconee
176	7	55	PERO	Oconee
175	8	55	PERO	Oconee
174	11	57	PERO	Oconee
173	9	55	PERO	Oconee
172	8	45	RO	Oconee
171	12	52	PERO	Oconee
170	8	42	PERO	Oconee
169	11	34	PERO	Oconee
168	9	24	RO	Oconee
167	34	20	PERO	Oconee
166	14	23	PERO	Oconee
165	13	11	PERO	Oconee
164	69	36	PERO	Sinclair
163	71	35	RO	Sinclair
162	68	36	PERO	Sinclair
160	60	34	PERO	Sinclair
159	54	37	RO	Sinclair
154	53	31	PERO	Sinclair
153	29	49	RO	Sinclair
118	20	7	RO	Sinclair
117	24	7	RO	Sinclair
116	20	10	PERO	Sinclair
109	24	13	RO	Sinclair
108	20	15	PERO	Sinclair
107	27	17	PERO	Sinclair
106	20	20	PERO	Sinclair
105	21	24	PERO	Sinclair
104	31	36	PERO	Sinclair
103	30	33	RO	Sinclair
102	29	28	PERO	Sinclair
101	53	13	PERO	Sinclair

4.3.2 Point Sources Discharges

There were no point sources included in the Lake Oconee EFDC model and one point source was included in the Lake Sinclair EFDC model (Table 4-12). Georgia Power Company operates a coal power plant referred to as Plant Branch on the Little River/Murder Creek arm of Lake Sinclair. Historically, Plant Branch operations required cooling water, which is withdrawn from the Little River/Murder Creek arm and discharged to Beaverdam Creek embayment. Monthly withdrawal and discharge data were input for Plant Branch for 2001 through 2012. Plant Branch closed one of its units in 2013 and the other unit closed in 2015, effectively closing the plant. Plant Branch has maintained its surface water permit and it is still withdrawing water from Lake Sinclair.

Table 4-12. Point Sources Included in the Lake Sinclair Model

Permit Number	Facility Name	Permitted Flow (MGD)	EFDC Cell
GA0026051	Georgia Power Plant Branch	No Limit, Flow Through	(30,32)

4.3.3 Water Withdrawals

There are six water withdrawals located in Lakes Oconee and Sinclair. Table 4-13 provides a summary of these facilities' water withdrawal permits. Historic monthly water withdrawal data were obtained for each of the facilities above and used in the EDFC models for each lake.

Table 4-13. Water Withdrawals Included in the Lake Oconee and Lake Sinclair Models

Withdrawal	Permit Number	Permitted Withdrawal 24-Hour Limit (MGD)	Permitted Withdrawal Monthly Average (MGD)	Lake
City of Madison	104-0307-01	1.5	1.5	Oconee
	104-0307-02	2.0	2.0	
City of Greensboro	066-0390-03	3.31	3.00	Oconee
Piedmont Water Resources	066-0390-05	2.0	2.0	Oconee
City of Sparta	070-0390-04	2.0	1.3	Sinclair
Sinclair Water Authority	117-0390-06	9.50	6.65	Sinclair
Georgia Power Plant Branch	117-0390-01	1245.0	1245.0	Sinclair

4.3.4 Meteorological Data

The meteorological inputs included precipitation, evaporation, relative humidity, air pressure, air temperature, solar radiation, cloud cover, wind speed, and wind direction. Evaporation was calculated by EFDC, and solar radiation was calculated from cloud cover. The other meteorological inputs were obtained the from the Georgia Automated Environmental Monitoring Network (GAEMN) station Eatonton (GEMN 170) due to its close proximity to lakes Oconee and Sinclair (see Figure 4-3).

4.4 Water Quality Lake Modeling (EFDC)

The water quality models developed for Lakes Oconee and Sinclair simulated different loading conditions. EFDC was also used for the water quality models. The EFDC models for Lake Oconee and Lake Sinclair were setup using the following variables:

- Organic nitrogen
- Ammonia
- Nitrate-Nitrite
- Organic phosphorus
- Orthophosphate
- Algae (2 species)
- Dissolved oxygen
- Organic carbon
- Silica

The output from the LSPC watershed models were used to represent the runoff to the Lakes. The LSPC models were calibrated for temperature, dissolved oxygen, nitrate-nitrate, ammonia, organic nitrogen, ortho-phosphorus, organic phosphorus, total suspended solids, and chlorophyll *a*. LSPC Output parameters do not directly link up with the EFDC input parameters. Therefore, the LSPC outputs were "linked" to EFDC inputs through various equations. Table 4-14 presents what LSPC parameter is used for each EFDC parameter. Note that the LSPC outputs are in English units, whereas the EFDC inputs are in metric units. Therefore, the factor of 0.4536 was used to convert all the equation from lbs/day to kg/day.

Table 4-14. Parameter Linkage for LSPC to EFDC

Parameter	LSPC Parameters	EFDC Parameter
Flow	RO or PERO	Flow
Temperature	TEMP	TEMP
Dissolved Oxygen	DOx	DO
Biochemical Oxygen Demand (5-day)	BOD5	DOC, DON, LPON, DOP, LPOP
Nitrate + Nitrite	NO3 + NO2	NOx
Ammonia	TAM	NH4
Organic Nitrogen	ORN	DON, RPON. LPON
Orthophosphate	PO4	PO4
Organic Phosphorus	ORP	DOP, RPOP, LPOP
Phytoplankton	PHYTO	Total Algae = greens (Bg) + diatoms (Bd) + Cyano (Bc)

$$DON = \left[(ORN * \%\ Dissolved) + \left[fDOx * \left[(BOD_5 * fRatio)/S_{BODu\ to\ OrgN} \right] \right] \right] * flow * C$$

$$RPON = \left[ORN * \%Particulate \right] * flow * C$$

$$LPON = \left[fLPOx * \left[(BOD_5 * fRatio)/S_{BODu\ to\ OrgN} \right] \right] * flow * C$$

$$NH4 = TAM * flow * C$$

$$NOx = \left[NO3 + NO2 \right] * flow * CBOD$$

Where:

DON = Dissolved Organic Nitrogen (kg/day)
RPON = Refractory Particulate Organic Nitrogen (kg/day)
LPON = Labile Particulate Organic Nitrogen (kg/day)
NH4 = Ammonium (kg/day)
NOx = Nitrate + Nitrite (kg/day)
ORN = Dead Refractory Organic Nitrogen Concentration from LSPC (mg/L)
BOD5 = Biochemical Oxygen Demand (5-day) Concentration from LSPC (mg/L)
TAM = Total Dissolved Ammonia Concentration from LSPC (mg/l)
NO3 = Nitrate Concentration from LSPC (mg/L)
NO2 = Nitrite Concentration from LSPC (mg/L)
% Dissolved = Percent of ORN that is Dissolved = 0.80
% Particulate = Percent of ORN that is Particulate = 0.20
fDOx = Fraction of Labile Organics in BODu that is Dissolved = 0.50
fLPOx = Fraction of Labile Organics in BODu that is Particulate = 0.50
fRatio = Factor to convert BOD5 to BODu = 3.0
S(BODu to OrgN) = Stoichiometric Value to convert BODu into Labile Organic Nitrogen = 22.90
flow = Flow from LSPC (cfs)
*C = Conversion factor from lbs/day to kg/day * 5.39 = 2.44*

$$DOP = \left[(ORP * \%\ Dissolved) + \left[fDOx * \left[(BOD_5 * fRatio)/S_{BODu\ to\ OrgP} \right] \right] \right] * flow * C$$

$$RPOP = \left[ORP * \%Particulate \right] * flow * C$$

$$LPOP = \left[fLPOx * \left[(BOD_5 * fRatio)/S_{BODu\ to\ OrgP} \right] \right] * flow * C$$

$$PO4_{EFDC} = PO4_{LSPC} * flow * C$$

Where:

DOP = Dissolved Organic Phosphorus (kg/day)
RPOP = Refractory Particulate Organic Phosphorus (kg/day)
LPOP = Labile Particulate Organic Phosphorus (kg/day)
$PO4_{EFDC}$ *= Orthophosphorus (kg/day)*
ORP = Dead Refractory Organic Phosphorus Concentration from LSPC (mg/L)
BOD_5 *= Biochemical Oxygen Demand (5-day) Concentration from LSPC (mg/L)*
$PO4_{LSPC}$ *= Orthophosphorus Concentration from LSPC (mg/L)*
% Dissolved = Percent of ORP that is Dissolved = 0.50
% Particulate = Percent of ORP that is Particulate = 0.50
fDOx = Fraction of Labile Organics in BODu that is Dissolved = 0.50
fLPOx = Fraction of Labile Organics in BODu that is Particulate = 0.50
fRatio = Factor to convert BOD5 to BODu = 3.0
$S_{(BODu\ to\ OrgP)}$ *= Stoichiometric Value to convert BODu into Labile Organic Phosphorus = 165.80*
flow = Flow from LSPC (cfs)

*C = Conversion factor from lbs/day to kg/day * 5.39 = 2.44*

$$Flow = RO\ (Instream\ Flow)\ or\ PERO\ (Overland\ Flow)$$

$$TEMP_{EFDC} = TEMP_{LSPC}$$

$$DO = DOx * flow * C$$

$$DOC = \left((BOD_5 * fRatio)/F_{(BODu\ to\ Carbon)}\right) * flow * C$$

Algae Biomass Equations

$$Bg = \left[\left(PHYTO * cphyto * \left(Green\ Algal\ Fraction\right)\right)\right] * flow * C$$

$$Bd = \left[\left(PHYTO * cphyto * \left(Diatom\ Algal\ Fraction\right)\right)\right] * flow * C$$

$$Bc = \left[\left(PHYTO * cphyto * \left(Cynobacteria\ Algal\ Fraction\right)\right)\right] * flow * C$$

Where:

Flow = Flow into EFDC (cms)
$TEMP_{EFDC}$ *= Temperature (OC)*
DO = Dissolved Oxygen (kg/day)
DOC = Dissolved Organic Carbon (kg/day)
Bg = Green Algae (kg/day)
Bd = Diatom Algae (kg/day)
Bc = Cynobacteria Algae (kg/day)
RO = Instream Flow from LSPC (cfs)
PERO = Overland Flow from LSPC (in-acre/day)
$TEMP_{LSPC}$ *= Temperature from LSPC (OC)*
DOx = Dissolved Oxygen Concentration from LSPC (mg/l)
$_{BOD5}$ *= Biochemical Oxygen Demand (5-day) Concentration from LSPC (mg/l)*
fRatio = Factor to convert BOD5 to BODu = 3.0
$F_{(BODu\ to\ Carbon)}$ *= Stoichiometric Value to convert BODu into Carbon = 2.67*
PHYTO = Phytoplankton Concentration from LSPC (mg/l)
cphyto = Coefficient of Conversion from PHYTO Biomass to Carbon = 0.49
Green Algal Fraction = Fraction of PHYTO that is Green Algal = 0.90
Diatom Algal Fraction = Fraction of PHYTO that is Diatom Algal = 0.10
Cynobacteria Algal Fraction = Fraction of PHYTO that is Cynobacteria Algal = 0.00
flow = Flow from LSPC (cfs)
*C = Conversion factor from lbs/day to kg/day * 5.39 = 2.44*

The EFDC framework allows the user to parameterize by water quality zones. Examples of information that may be used to specify water quality zone include reaeration, sediment oxygen demand, benthic nutrient flux, and more. The EFDC framework allows the user to parameterize by water quality zones. Lake Oconee and Lake Sinclair were both divided into five zones (Figures 4-21 and Figure 4-22). These five zones allowed the kinetics, SOD, and nutrient fluxes to be specified per zone in the EFDC water quality model.

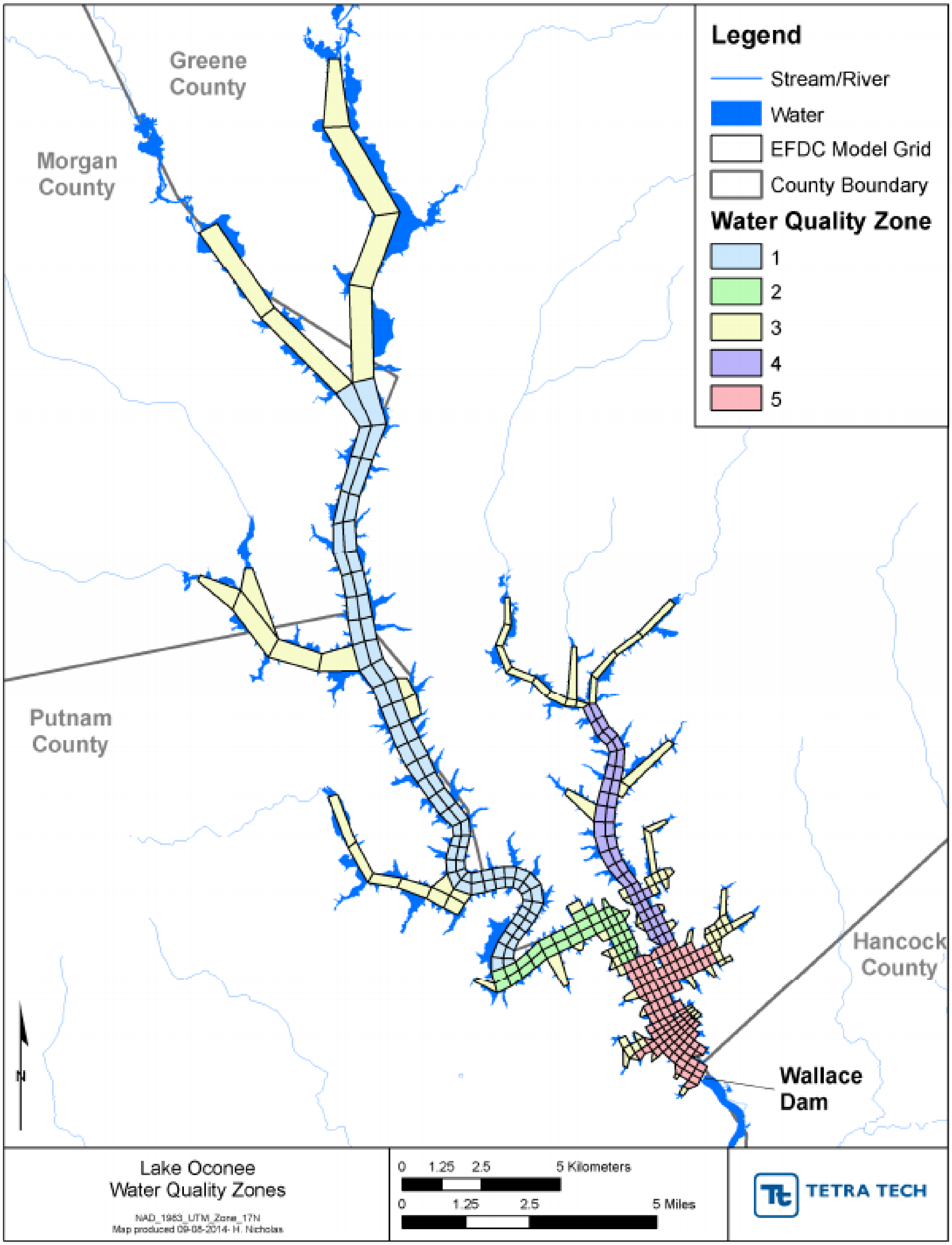


Figure 4-21. Water Quality Zones in the Lake Oconee EFDC Water Quality Model

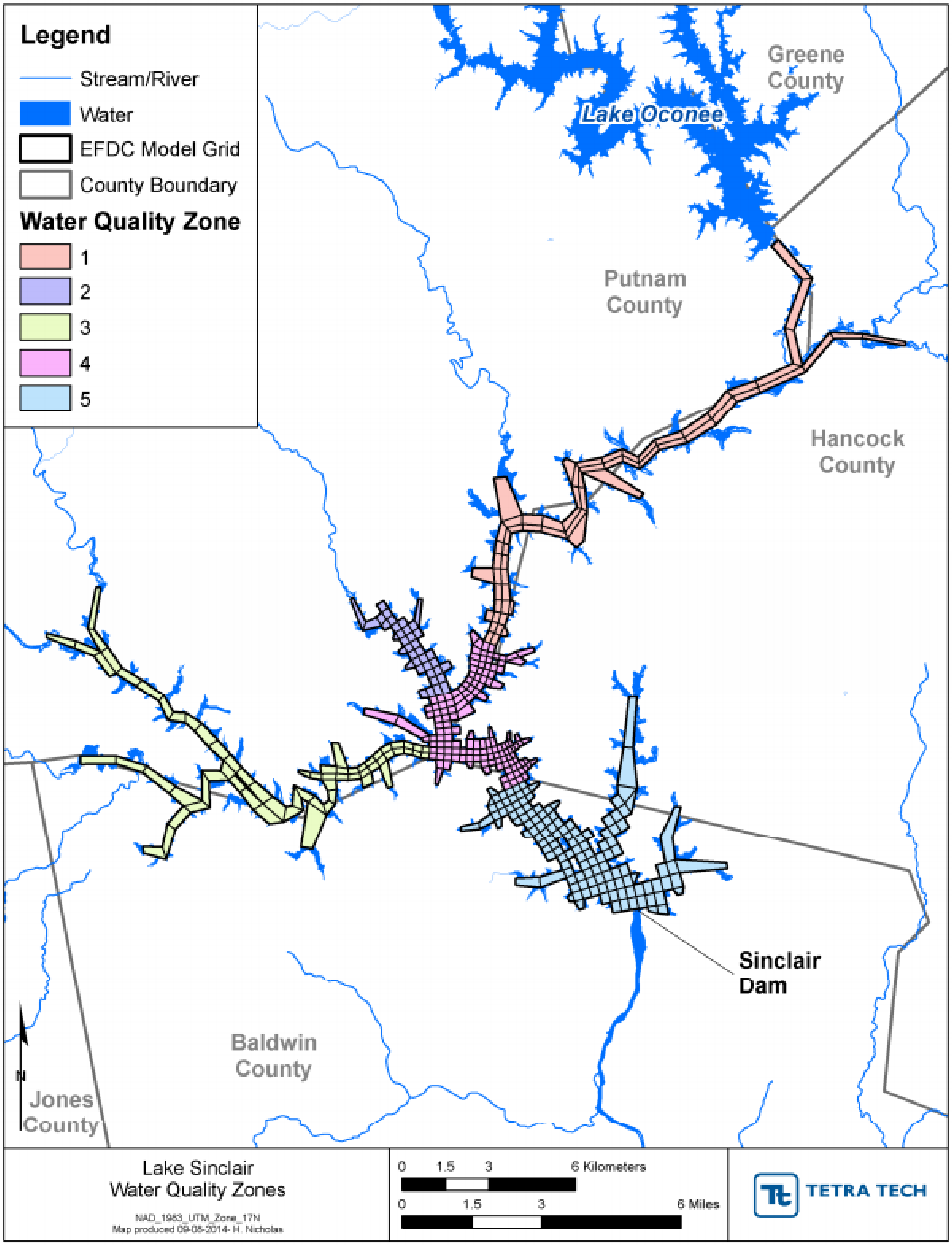


Figure 4-22. Water Quality Zones in the Lake Sinclair EFDC Water Quality Model

4.4.1 Point Sources Discharge

The operation of Plant Branch requires cooling water and it is a flow-through facility. Since no other processes are being performed with the water, the state variable assignments for the water quality of the discharge were assumed. Table 4-15 presents the assumptions used for the assignment of values to water quality parameters for Plant Branch discharge.

Table 4-15. Default Water Quality Values Used for Plant Branch Discharge

Parameter	Value
Ammonia (NH_3)	0.04 mgN/L
Nitrate+Nitrite (NO_x)	0.44 mgN/L
Organic Nitrogen (OrgN)	0.30 mgN/L
Orthophosphate (PO_4)	0.001 mgP/L
Organic Phosphorus (OrgP)	0.004 mgP/L
Chlorophyll-*a* (Chl-a)	2.0 µg/L
Dissolved Oxygen (DO)	8.0 mg/L
Dissolved Organic Carbon (DOC)	1.1 mg/L

4.4.2 Sediment Oxygen Demand

There were no reported values of observed sediment oxygen demand (SOD) for either of the lakes. The SOD was assumed to be 0.8 g O_2/m^2/day for all zones, for each of the lakes. During model calibration, if needed the SOD values were adjusted by water quality zone until the dissolved oxygen profiles and time series plots for simulated and measured data compared well.

4.4.3 Nutrient Fluxes

There were no benthic studies or reported values of observed nutrient fluxes. Table 4-16 lists the nutrient flux assumptions used in the Lakes Oconee and Sinclair applications. A 0.0015 g/m^2/day positive nutrient flux for Orthophosphate and Ammonia were added to Lake Sinclair in 2012. This was done to provide the lake enough nutrients to support an algae population that could not be supported without this positive flux amendment.

Table 4-16. Assumed Nutrient Flux Values in the Lake EFDC Application

Lake	Water Quality Zone	PO4 (g P/m^2/day)	NH4 (g N/m^2/day)	NOx (g N/m^2/day)
Oconee	1	0	0	0
	2	0	0	0
	3	0	0	0
	4	0	0	0
	5	0	0	0
Sinclair	1	0.0015 (2012 only)	0.0015 (2012 only)	0
	2	0.0015 (2012 only)	0.0015 (2012 only)	0
	3	0.0015 (2012 only)	0.0015 (2012 only)	0
	4	0.0015 (2012 only)	0.0015 (2012 only)	0
	5	0.0015 (2012 only)	0.0015 (2012 only)	0

4.4.4 Modeling Parameters

Table 4-17 provides the reaction rates and parameters used in the EFDC water quality model for the modeled algae species.

Table 4-17. EFDC Modeling Parameters

Constants and Parameters - Algae	EFDC Card	Oconee			Sinclair		
		Cyano	Diatoms	Greens	Cyano	Diatoms	Greens
Nitrogen Half-Saturation (mg/L)	08	0.02	0.02	0.02	0.02	0.02	0.02
Phosphorus Half-Saturation (mg/L)	08	0.002	0.002	0.002	0.002	0.002	0.002
Silica Half-Saturation (mg/L)	08	N/A	N/A	0.1	N/A	N/A	0.1
Carbon to Chlorophyll-*a* Ratio (mg C/ µg Chla) **	09	0.06	0.04-0.07*	0.04-0.07*	0.06	0.04-0.07*	0.04-0.07*
Optimal Depth for Growth (m)	09	1	1.2	1.5	1	1.2	1.5
Lower Optimal Temperature for Growth (^{O}C)	11	27	15	25	27	15	25
Upper Optimal Temperature for Growth (^{O}C)	11	30	17	26.5	30	17	26.5
Lower Optimal Temperature for Diatom Predation (^{O}C)	11	N/A	N/A	17	N/A	N/A	17
Upper Optimal Temperature for Diatom Predation (^{O}C)	11	N/A	N/A	20	N/A	N/A	20
Sub- Optimal Temperature Coeff. for Growth	12	0.01	0.01	0.01	0.01		0.01
Super- Optimal Temperature Coeff. for Growth	12	0.01	0.01	0.01	0.01	0.01	0.01
Sub- Optimal Temperature Coeff. for Diatom Predation	12	N/A	N/A	0.01	N/A	N/A	0.01
Super- Optimal Temperature Coeff. for Diatom Predation	12	N/A	N/A	0.01	N/A	N/A	0.01
Reference Temperature for Metabolism (^{O}C)	13	20	20	20	20	20	20
Temperature Coeff. for Metabolism	13	0.069	0.069	0.069	0.069	0.069	0.069
Carbon Dist. Coeff. for Metabolism	14	0.8	0.8	0.8	0.8	0.8	0.8
Half-Saturation Const. for DOC Excretion (gO_2/m^3)	14	0.5	0.5	0.5	0.5	0.5	0.5
Phosphorus Dist. Coeff. of RPOP for Metabolism	18	0.2	0.2	0.2	0.2	0.2	0.2
Phosphorus Dist. Coeff. of LPOP for Metabolism	18	0	0	0	0	0	0
Phosphorus Dist. Coeff. of DOP for Metabolism	20	0.6	0.6	0.6	0.6	0.6	0.6
Phosphorus Dist. Coeff. of PO4 for Metabolism	20	0.2	0.2	0.2	0.2	0.2	0.2
Nitrogen Dist. Coeff. of RPON for Metabolism	22	0.2	0.2	0.2	0.2	0.2	0.2
Nitrogen Dist. Coeff. of LPON for Metabolism	22	0	0	0	0	0	0
Nitrogen Dist. Coeff. of DON for Metabolism	24	0.6	0.6	0.6	0.6	0.6	0.6
Nitrogen Dist. Coeff. of DIN for Metabolism	24	0.2	0.2	0.2	0.2	0.2	0.2
Nitrogen to Carbon Ratio (mg N/ mg C)	24	0.15	0.15	0.15	0.15	0.15	0.15
Maximum Growth Rate (1/day)**	45	2	3.1	2.5	2	3.1	2.5
Basal Metabolism Rate (1/day)**	45	0.05	0.034-0.104*	0.05-0.13*	0.05	0.034-0.104*	0.05-0.13*
Predation Rate (1/day)**	45	0.01	0.04-0.06*	0.01-0.02*	0.01	0.04-0.06*	0.01-0.02*
Settling Velocity (m/day)	46	0.01	0.5	0.01	0.01	0.5	0.01
Settling Velocity for Refractory PON (m/day)	46	0.15			0.15		

Constants and Parameters – Light Extinction	EFDC Card	Oconee	Sinclair
Light Extinction for TSS (1/m per g/m^3)	09	0	0
Light Extinction for Total Suspended Chlorophyll KeCHL = (0.054 * $CHL^{0.6667}$) + (0.0088 * CHL) Where CHL = Total Chlorophyll Concentration (ug/L)	09	Calculated	Calculated
Background Light Extinction Coeff. (1/m)**	45	0.5	0.5
Constants and Parameters – Carbon	**EFDC Card**	**Oconee**	**Sinclair**
Carbon Dist. Coeff. for Algae Predation – RPOC	14	0.2	0.2
Carbon Dist. Coeff. for Algae Predation – LPOC	14	0	0
Carbon Dist. Coeff. for Algae Predation – DOC	14	0.8	0.8
Minimum Dissolution Rate of RPOC (1/day)	16	0.005	0.005
Minimum Dissolution Rate of LPOC (1/day)	16	0.075	0.075
Minimum Dissolution Rate of DOC (1/day)***	16	0.01	0.01
Const. Relating RPOC Dissolution Rate to Total Chla	16	0	0
Const. Relating LPOC Dissolution Rate to Total Chla	16	0	0
Const. Relating POC Dissolution Rate to Total Chla	16	0	0
Reference Temperature for Hydrolysis (^{O}C)	17	20.0	20.0
Reference Temperature for Mineralization (^{O}C)	17	20.0	20.0
Temperature effect Const. for Hydrolysis	17	0.069	0.069
Temperature effect Const. for Mineralization	17	0.069	0.069
Oxic Respiration Half-Saturation Const. for DO (gO^2/m^3)	17	0.5	0.5
Half-Saturation Const. for Denitrification (gN/m^3)	17	0.1	0.1
Ratio of Denitrification Rate to Oxic DOC Repiration Rate	17	0.5	0.5
Constants and Parameters – Phosphorus	**EFDC Card**	**Oconee**	**Sinclair**
Phosphorus Dist. Coeff. for Algae Predation – RPOP	18	0.7	0.7
Phosphorus Dist. Coeff. for Algae Predation – LPOP	18	0	0
Phosphorus Dist. Coeff. for Algae Predation – DOP	18	0.2	0.2
Phosphorus Dist. Coeff. for Algae Predation – Inorganic DOP	18	0.1	0.1
Minimum Hydrolysis Rate (1/day) of RPOP	21	0.005	0.005
Minimum Hydrolysis Rate (1/day) of LPOP	21	0	0
Minimum Hydrolysis Rate (1/day) of DOP	21	0.1	0.1
Const. Relating Hydrolysis Rate of RPOP to Algae	21	0	0
Const. Relating Hydrolysis Rate of LPOP to Algae	21	0	0
Const. Relating Hydrolysis Rate of DOP to Algae	21	0.2	0.2
Constant 1 in determining Phosphorus to Carbon Ratio	21	35	35
Constant 2 in determining Phosphorus to Carbon Ratio	21	20	20
Constant 3 in determining Phosphorus to Carbon Ratio	21	350	350

Constants and Parameters – Nitrogen	EFDC Card	Oconee	Sinclair
Nitrogen Dist. Coeff. for Algae Predation – RPOP	22	0.7	0.7
Nitrogen Dist. Coeff. for Algae Predation – LPOP	22	0	0
Nitrogen Dist. Coeff. for Algae Predation – DOP	22	0.2	0.2
Nitrogen Dist. Coeff. for Algae Predation – Inorganic DOP	22	0.1	0.1
Maximum Nitrification Rate (gN/m^3/day)	25	0.1	0.1
Nitrification Half-Saturation Const. for DO	25	1	1
Nitrification Half-Saturation Const. for NH_4	25	0.1	0.1
Reference Temperature for Nitrification (^{O}C)	25	27	27
Suboptimal Temperature Effect Const. for Nitrification	25	0.0045	0.0045
Superoptimal Temperature Effect Const. for Nitrification	25	0.0045	0.0045
Minimum Hydrolysis Rate (1/day) of RPON	26	0.005	0.005
Minimum Hydrolysis Rate (1/day) of LPON	26	0.075	0.075
Minimum Hydrolysis Rate (1/day) of DON	26	0.01	0.01
Const. Relating Hydrolysis Rate of RPON to Algae	26	0	0
Const. Relating Hydrolysis Rate of LPON to Algae	26	0	0
Const. Relating Hydrolysis Rate of DON to Algae	26	0	0
Constants and Parameters – Silica	**EFDC Card**	**Oconee**	**Sinclair**
Silica Dist. Coeff. for Diatom Predation	27	1	1
Silica Dist. Coeff. for Diatom Metabolism	27	1	1
Silica to Carbon Ratio for Algae Diatoms	27	0.36	0.36
Partition Coeff. for Sorbed/Dissolved SA	27	0.16	0.16
Dissolution Rate of Particulate Silica (PSi) (1/day)	27	0.05	0.05
Reference Temperature for PSi Dissolution (^{O}C)	27	20	20
Temperature effect on PSi Dissolution	27	0.92	0.92
Constants and Parameters – Dissolved Oxygen	**Value**	**Oconee**	**Sinclair**
Stoichiometric Algae Oxygen to Carbon (gO^2/gC)	28	2.67	2.67
Stoichiometric Algae Oxygen to Nitrogen (gO^2/gN)	28	4.33	4.33
Reaeration Constant*	28	1	1
Temperature Rate Constant for Reaeration***	28	1.014	1.024
Reaeration Adjustment Factor*	46	1	1

*Varied by year and water quality zone
** These are variable by Water Quality Zone and are found in the ALGAEGRO.INP file
*** These are variable by Water Quality Zone and are found in the KINETICS.INP file

4.5 EFDC Model Calibration and Verification

The simulation period for the hydrodynamic model EFDC was from January 1, 2001 through December 31, 2012. The model simulated water surface elevation, flows, and temperature. To help minimize the difference between simulated and measured water surface elevation, the corrective flow feature of EFDC was applied. This feature allows EFDC to calculate, at a given time scale, the amount of flow required to force a match between the calculated and observed water surface elevations. The "corrective flow," represents the error in volume associated with the model. This flow can be due to a combination of inaccurate readings of flow inputs or outputs, inaccurate estimates of watershed flow, spatial discrepancies in meteorological data, or unaccounted flow terms. Figures 4-23 and 4-24 show the water surface elevation calibrations at Wallace Dam and Sinclair Dam forebays for the period 2001 through 2012.

Temperature is simulated in EFDC using solar radiation, atmospheric temperature, heat transfer at the water surface, and the temperature of the hydraulic inputs. The Lake Oconee and Lake Sinclair EFDC models were calibrated to water temperature profile data for 2004 and 2009 through 2012 measured by GA EPD at three stations throughout the lake. The model captures the stratification very well at all the stations along the main channel of the lake, as well as in the embayment stations. The model tends to slightly under predict the bottom temperature, particularly along the deeper main stem stations. The degree of stratification between bottom and surface is also captured. Figures 4-25 and 4-26 show the temperature calibration at the Wallace Dam and Sinclair Dam forebays during 2009.

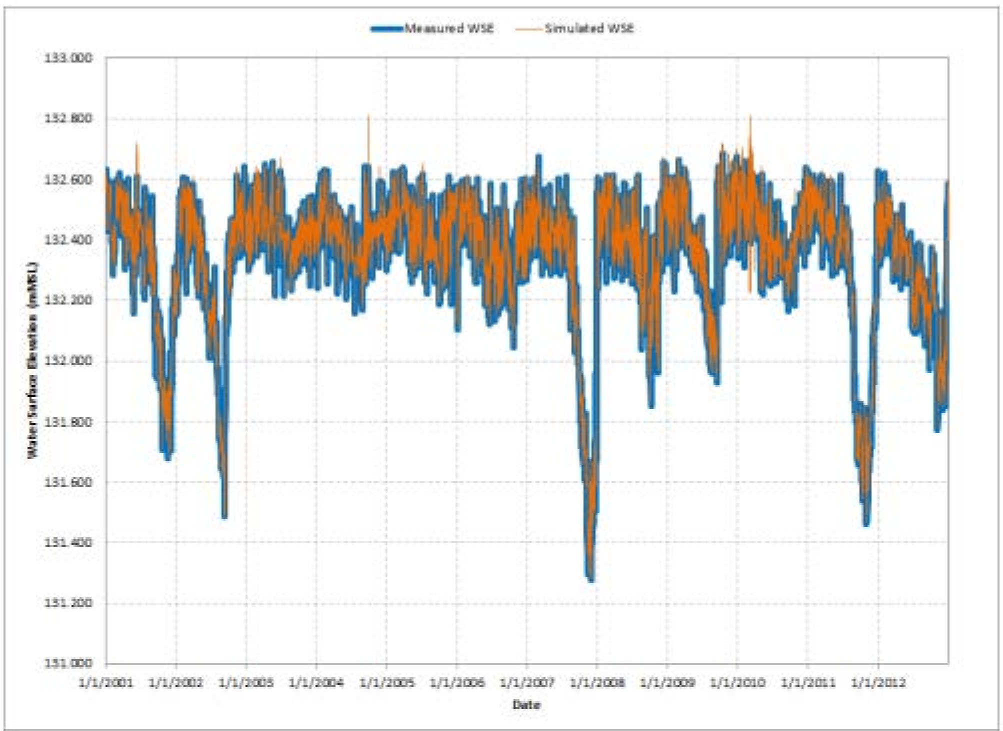


Figure 4-23. Water Surface Elevation Calibration at the Wallace Dam Forebay for the Period 2001-2012

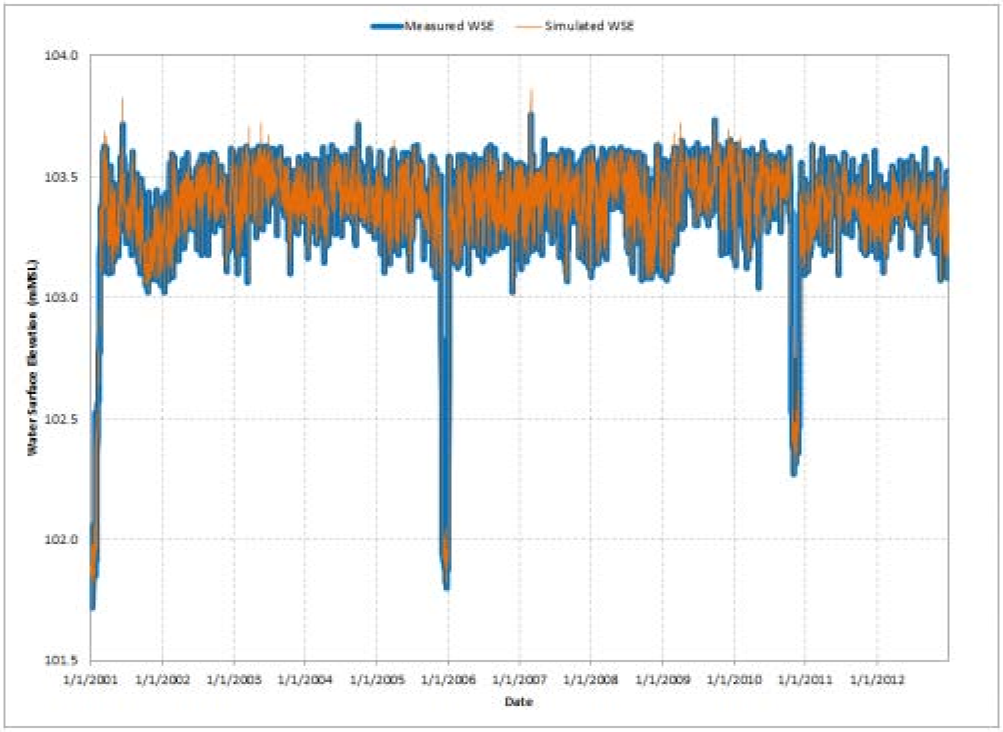


Figure 4-24. Water Surface Elevation Calibration at the Sinclair Dam Forebay for the Period 2001-2012

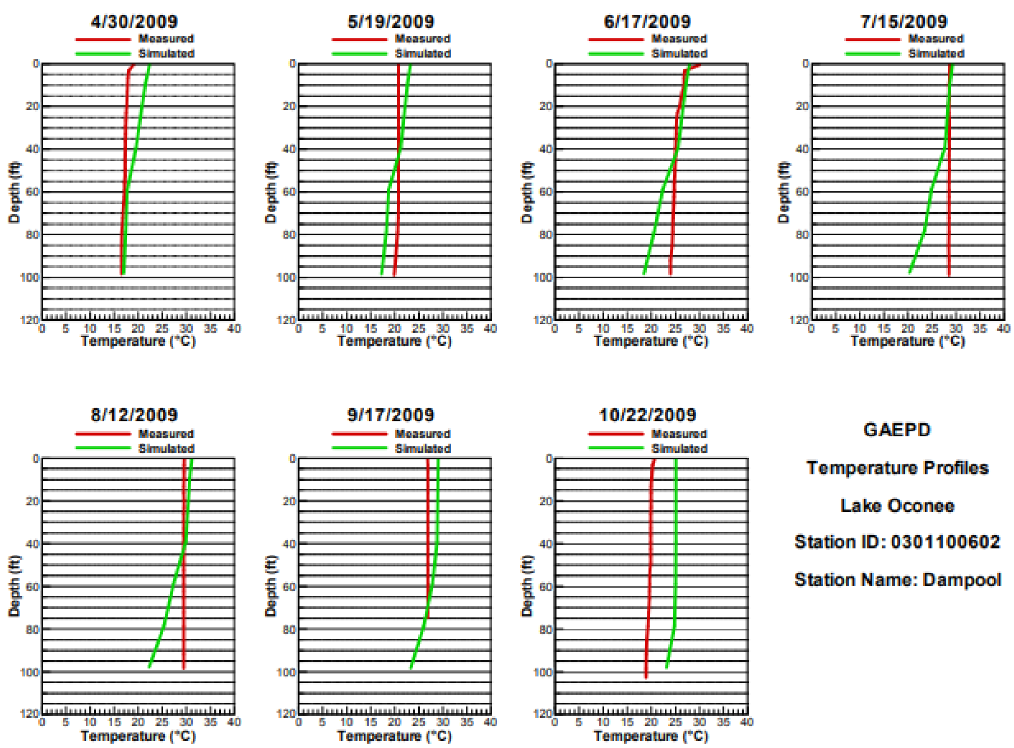


Figure 4-25. Temperature Calibration at the Wallace Dam Forebay for 2009

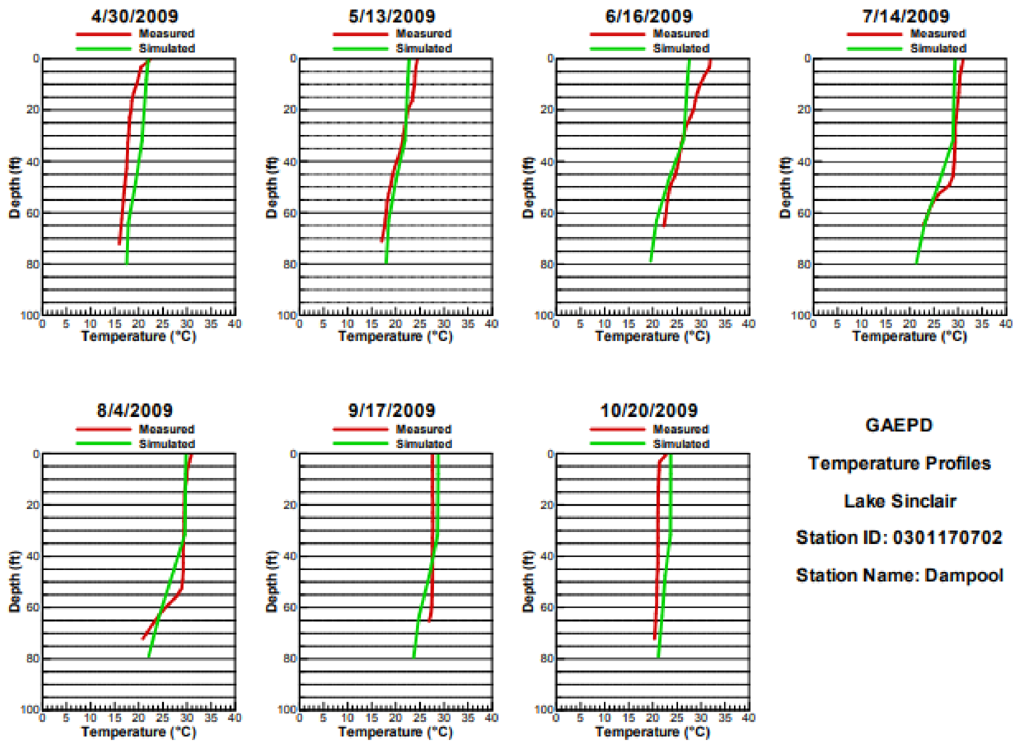


Figure 4-26. Temperature Calibration at the Sinclair Dam Forebay for 2009

The model calibration period was determined from an examination of the GA EPD 2001-2012 water quality data for the lake. The data examined included chlorophyll *a*, nitrogen components, phosphorus components, dissolved oxygen profiles, and water temperature profiles. The calibration models were run using input data for this period, including boundary conditions and meteorological data.

Measured chlorophyll *a*, ortho-phosphate, total phosphorus, total nitrogen, ammonia, and nitrate/nitrate data for the 2001 through 2012 growing seasons were used as instream targets to calibrate the model. Figures 4-27 and 4-32 show the total nitrogen, total phosphorus, and chlorophyll *a* calibration curves for the Wallace Dam and Sinclair Dam forebays for 2001-2012.

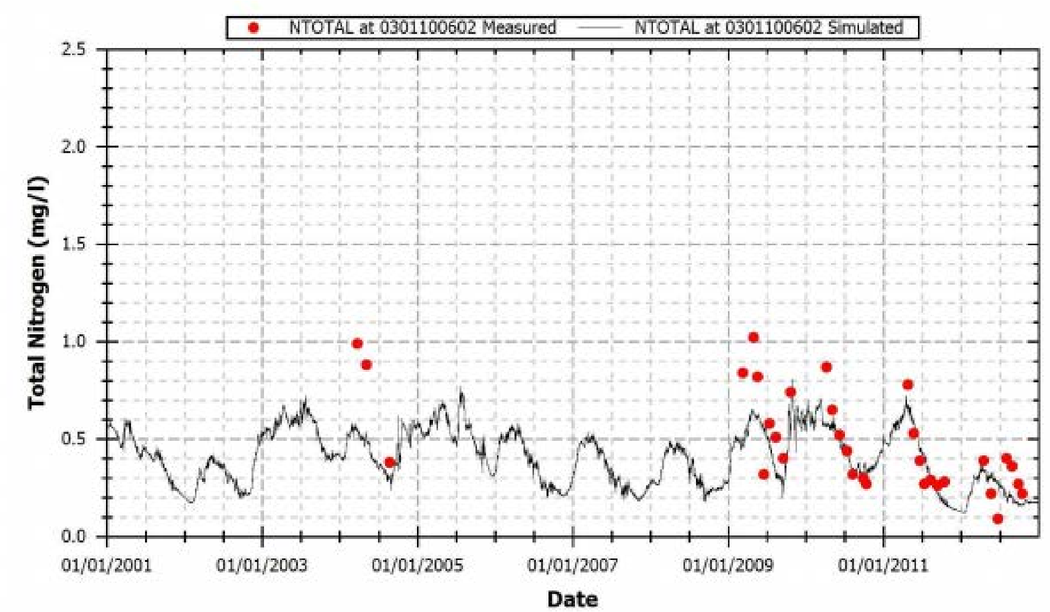


Figure 4-27. Lake Oconee Total N at Dam Pool Station 0301100602

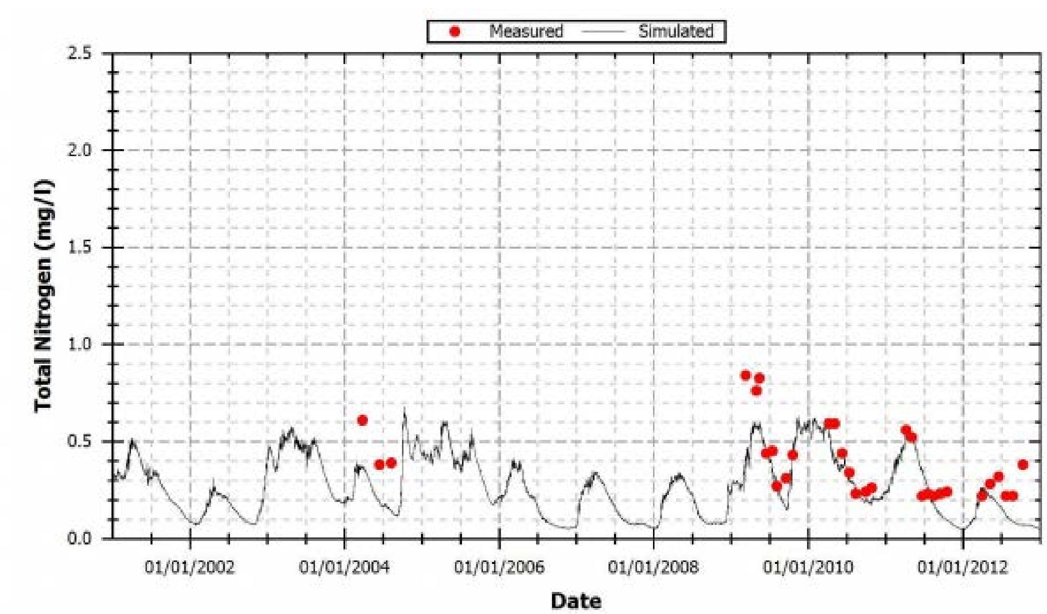


Figure 4-28. Lake Sinclair Total N at Dam Pool Station 0301170702

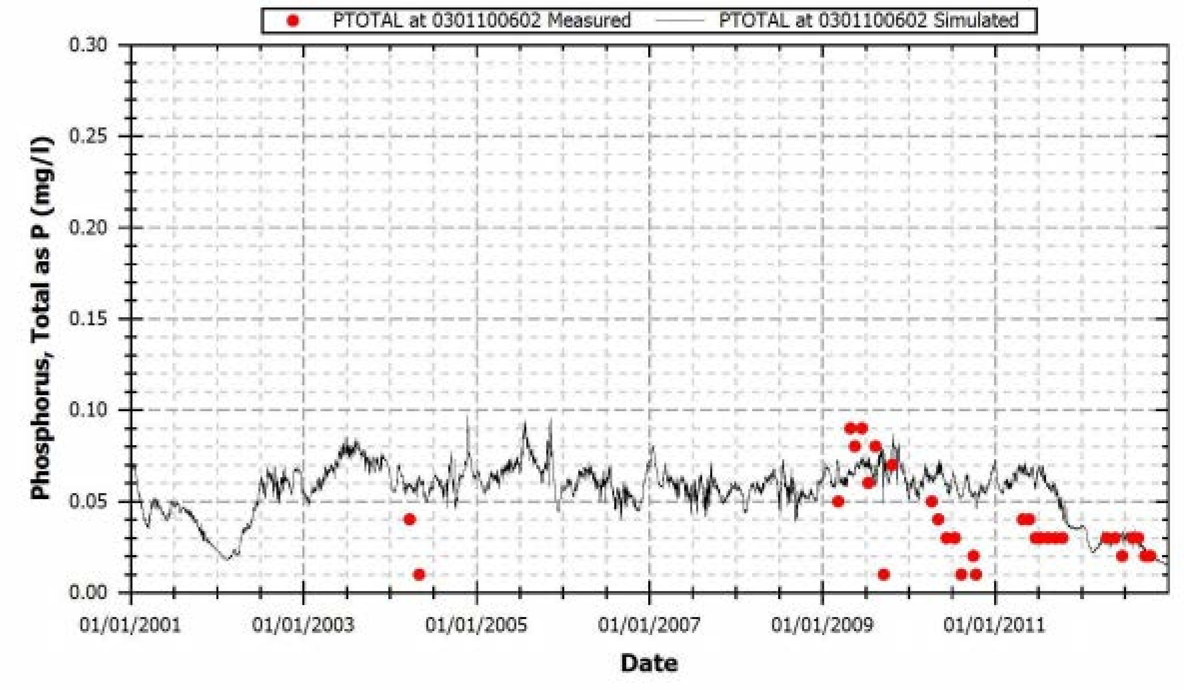


Figure 4-29. Lake Oconee Total P at Dam Pool Station 0301100602

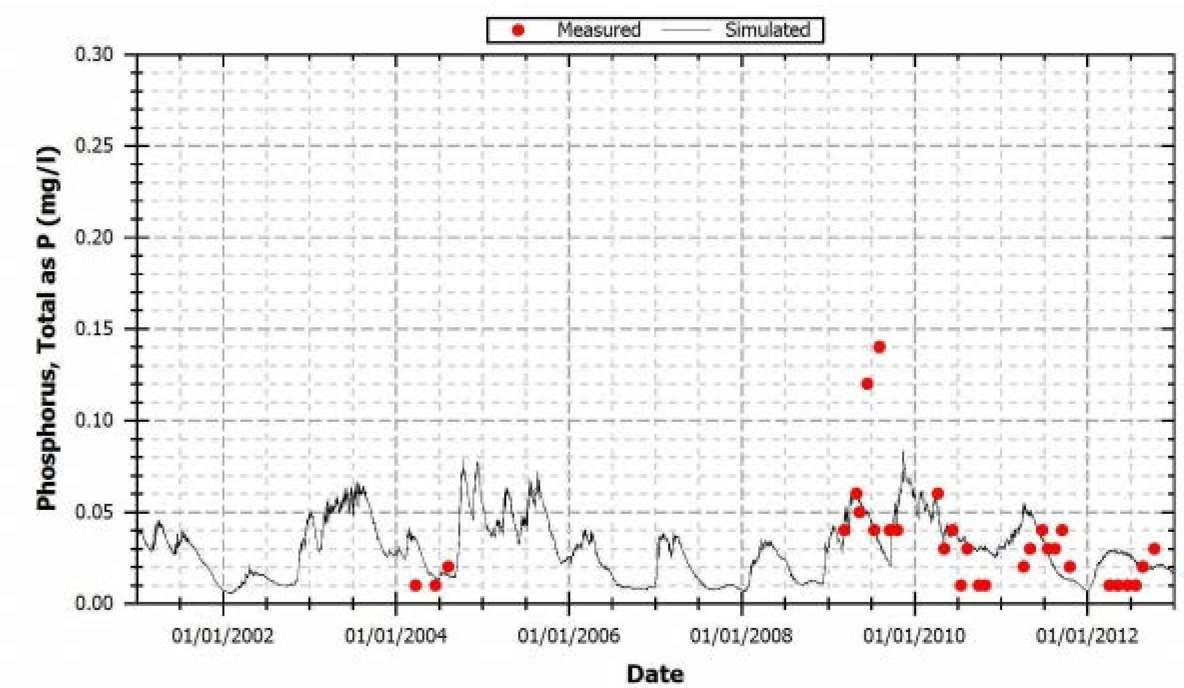


Figure 4-30. Lake Sinclair Total P at Dam Pool Station 0301170702

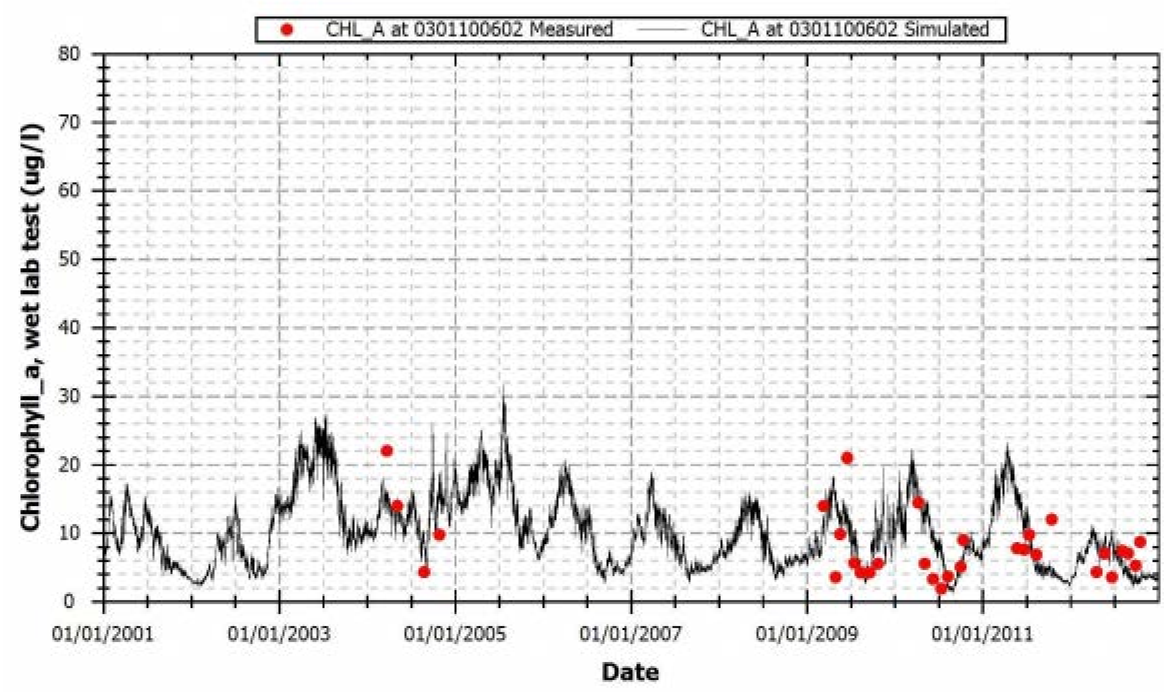


Figure 4-31. Lake Oconee Chlorophyll *a* at Dam Pool Station 0301100602

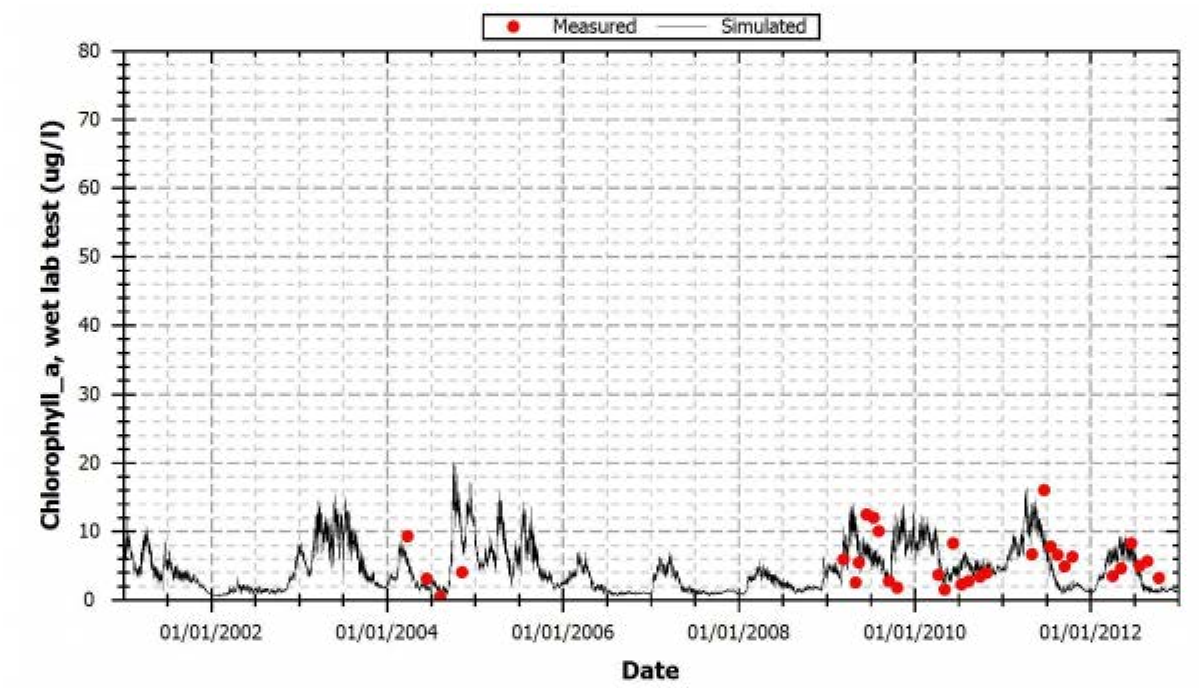


Figure 4-32. Lake Sinclair Chlorophyll *a* at Dam Pool Station 030117072

5.0 MODEL SCENARIOS

The critical conditions models were used to assess and develop the numeric nutrient and chlorophyll *a* criteria for Lakes Oconee and Sinclair. Model critical conditions were developed in accordance with GA EPD standard practices (GA EPD, 1978). The complex dynamics simulated by the models demonstrated the critical conditions for nutrient uptake and the corresponding algal growth. The critical conditions include:

- Meteorological conditions
- Available sunlight
- Watershed flows
- Retention time in the lakes
- High water temperatures
- Watershed nutrient loads

The most critical time period for excess algal growth appears to be the high-flow years when excess nutrients have been delivered to the system. The high-flow critical conditions are assumed to represent the most critical design conditions thereby providing year-round protection of water quality. During these years, the rainfall is high, sunlight can be unlimited, and nutrient fluxes may be high. The large amounts of nutrients delivered during these high-flow sunny periods can cause algae to bloom and measured chlorophyll *a* can exceed the numeric standards. High flows occurred in 2003, 2005, and 2009-2010.

Drought conditions were experienced a couple of times during the period from 2001 through 2012. This simulation period exhibited a wide variety of average flow conditions, which included low flows drought conditions in 2001-2002, 2006-2007, and 2012. Normal flows occurred in 2004, 2008, and 2011. Periods of dry weather occurred in both 2004 and 2009 followed by heavy rains, which caused some instances of high measured nutrient values.

5.1 Description of Scenarios

Seven scenarios were run using the models developed for Lakes Oconee and Sinclair to explain the sources and contributions of chlorophyll *a* levels observed, and for use in developing the chlorophyll *a* and nutrient criteria. For each scenario, both hydrology and water quality outputs from the LSPC model were examined from January 1, 1998 through December 31, 2007. Watershed flows were evaluated based on monthly and annual average flows and percentiles of daily average flows. Watershed water quality was evaluated based on annual and monthly loading, annual and monthly concentrations, and percentiles of daily average concentrations.

Watershed flows and water quality were then input into the EFDC model. In each lake, outputs for the EFDC model from 2001 through 2012 were evaluated at three monitoring locations. Results for chlorophyll *a* were evaluated based on growing season averages (April 1 through October 31). A short description of each scenario is presented below.

5.1.1 Scenario 1A (Calibration)

Scenario 1A was performed using the calibrated Lakes Oconee and Sinclair watershed hydrology and water quality model (LSPC) and the calibrated Lake Oconee and Lake Sinclair models (EFDC). The calibrated LSPC models were run using monthly flow data for watershed water withdrawals, as well as daily and/or monthly flow and water quality data from point source discharges given in the monthly Discharge Monitoring Reports (DMRs). If no data were available for the point source discharges, values were input at the permitted limits; if no permit limit existed values were used which assumed phosphorus limits using the GAEPD Phosphorus Strategy, found online at http://epd.georgia.gov/sites/epd.georgia.gov/files/related_files/site_page/Signed%20P%20Strategy.pdf.

5.1.2 Scenario 1B (All Forest)

Scenario 1B was an all forested scenario. This scenario was performed using the calibrated (Scenario 1A) Lakes Oconee and Sinclair watershed hydrology and water quality model (LSPC) and the calibrated Lake Oconee and Lake Sinclair models (EFDC) as a starting point. Point source discharges, water withdrawals, and septic tanks were then removed and all landuse was converted to forest.

5.1.3 Scenario 1C (No Point Sources – Current Landuse)

Scenario 1C was a No Point Source scenario. This scenario was performed using the calibrated (Scenario 1A) Lakes Oconee and Sinclair watershed hydrology and water quality model (LSPC) and the calibrated Lake Oconee and Lake Sinclair models (EFDC) as a starting point. The land use coverage used was the 2008 Georgia Landuse Trends (GLUT) dataset was obtained from the University of Georgia. Point source discharges and water withdrawals were then removed.

5.1.4 Scenario 1D (Current Permit)

Scenario 1D was performed using the calibrated (Scenario 1A) Lakes Oconee and Sinclair watershed hydrology and water quality model (LSPC) and the calibrated Lake Oconee and Lake Sinclair models (EFDC) as a starting point. Point source discharges and water withdrawals were then input at their current permitted limits. If no permit limits existed, then values used assumed phosphorus limits using the GAEPD Phosphorus Strategy, found online at http://epd.georgia.gov/sites/epd.georgia.gov/files/related_files/site_page/Signed%20P%20Strategy.pdf.

5.1.5 Scenario 1E (2050 Permitted Flows and Current Landuse)

Scenario 1E was a 2050 Point Source and current Landuse scenario. This scenario was performed using the calibrated (Scenario 1A) Lakes Oconee and Sinclair watershed hydrology and water quality model (LSPC) and the Lake Oconee and Lake Sinclair models (EFDC), and the 2008 landuse. Point source discharges, withdrawals, and septic tanks were set at the 2050 flows forecasted for the State Water Plan, and the current permitted or assumed total phosphorus concentration.

5.1.6 Scenario 1F (50% of P Strategy)

Scenario 1F was performed using the calibrated (Scenario 1A) Lakes Oconee and Sinclair watershed hydrology and water quality model (LSPC) and the calibrated Lake Oconee and Lake Sinclair models (EFDC) as a starting point. Point source discharges were then input at 50% of the GAEPD Phosphorus Strategy phosphorus levels. Facilities with a permitted flow $\geq$ 1 MGD were given a total phosphorus level of 0.5 mg/L, and facilities with a permitted flow < 1 MGD were given a total phosphorus load of 4.17 lbs/day or a total phosphorus level of 5 mg/L, whichever is smaller.

5.1.7 Scenario 1G (2050 Permitted Flows Maintaining Loads and Current Landuse)

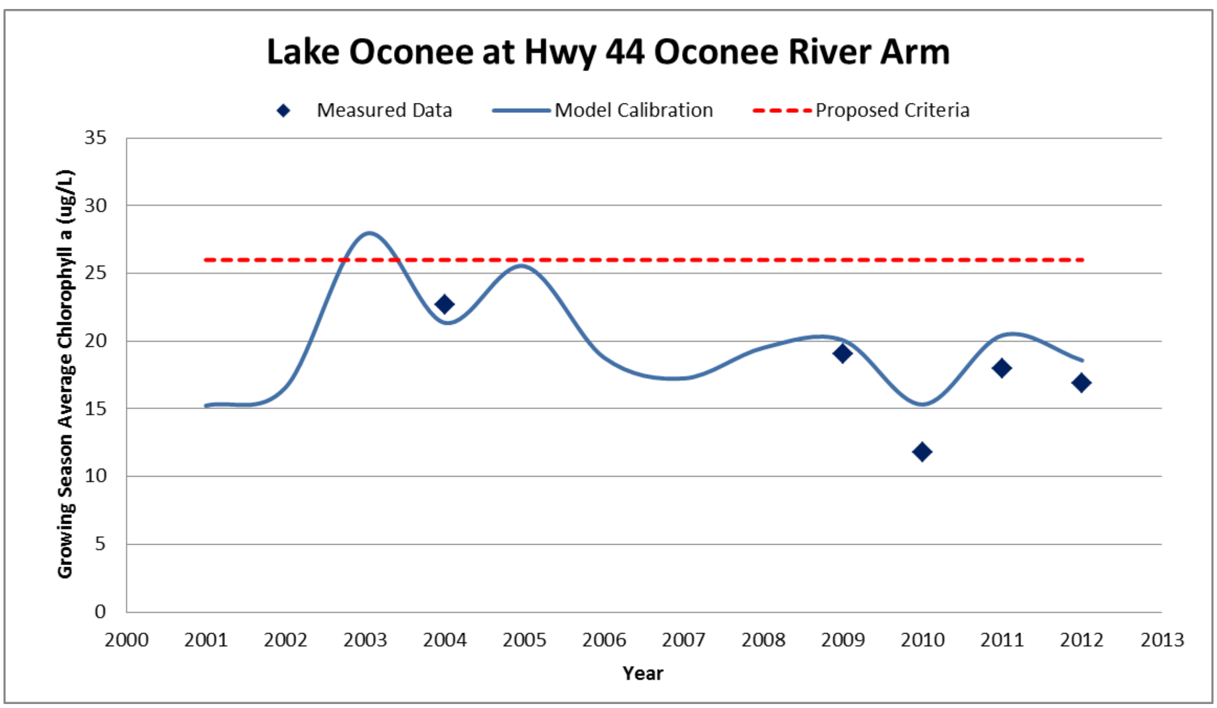
Scenario 1G was a 2050 Point Source and current Landuse scenario. This scenario was performed using the calibrated (Scenario 1A) Lakes Oconee and Sinclair watershed hydrology and water quality model (LSPC) and the Lake Oconee and Lake Sinclair models (EFDC), with the 2008 landuse. Point source discharges were set at the 2050 flows forecasted for the State Water Plan. Point source discharges were then input at the same total phosphorus load used in Scenario 1F.

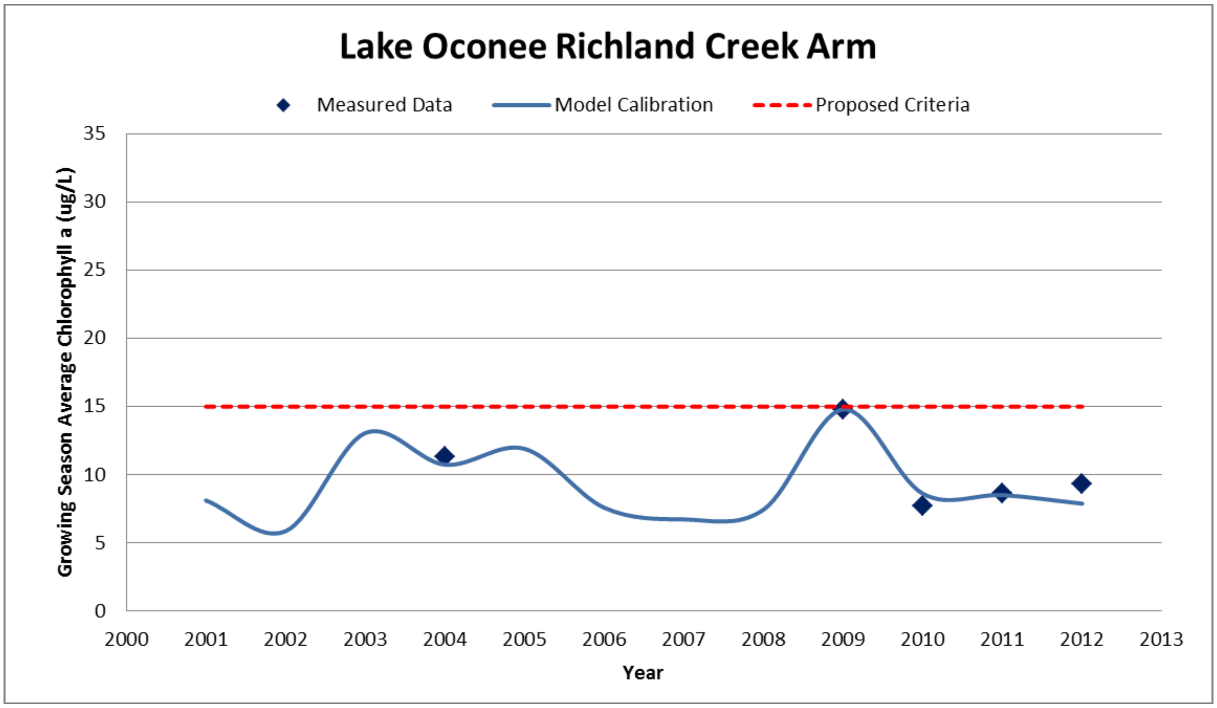
5.2 Model Calibration

The watershed and lake models were used to predict the effect various nutrient loads and sources have on lake chlorophyll *a* levels. The models predicted the growing season average chlorophyll *a* levels in the lake based on various nutrient inputs. Scenario 1A (Calibration) compared the results of this model to the measured Lake Oconee and Lake Sinclair data at EPD monitoring stations where data are available (see Figures 5-1 and 5-2).

5.2.1 Lake Oconee

In Lake Oconee, the highest measured data at Highway 44 Oconee River Arm, Richland Creek Arm, and the Dam Pool were 22.7 μg/L, 14.8 μg/L, and 12.5 μg/L, respectively.





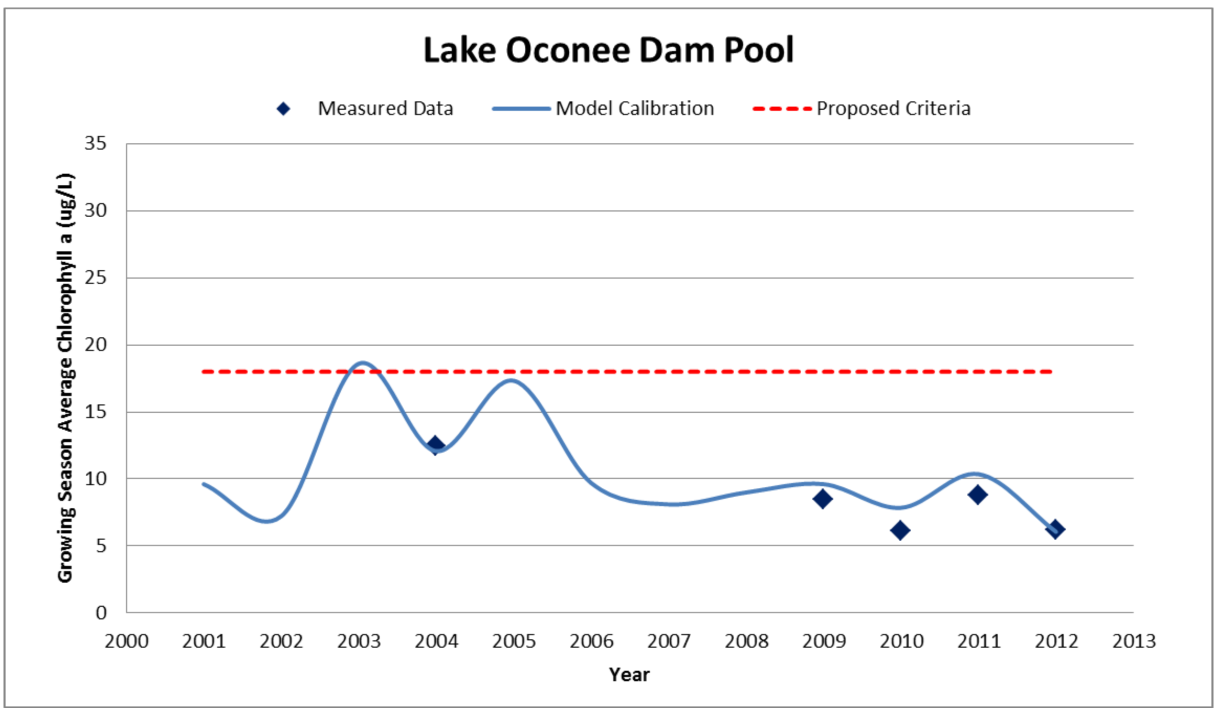
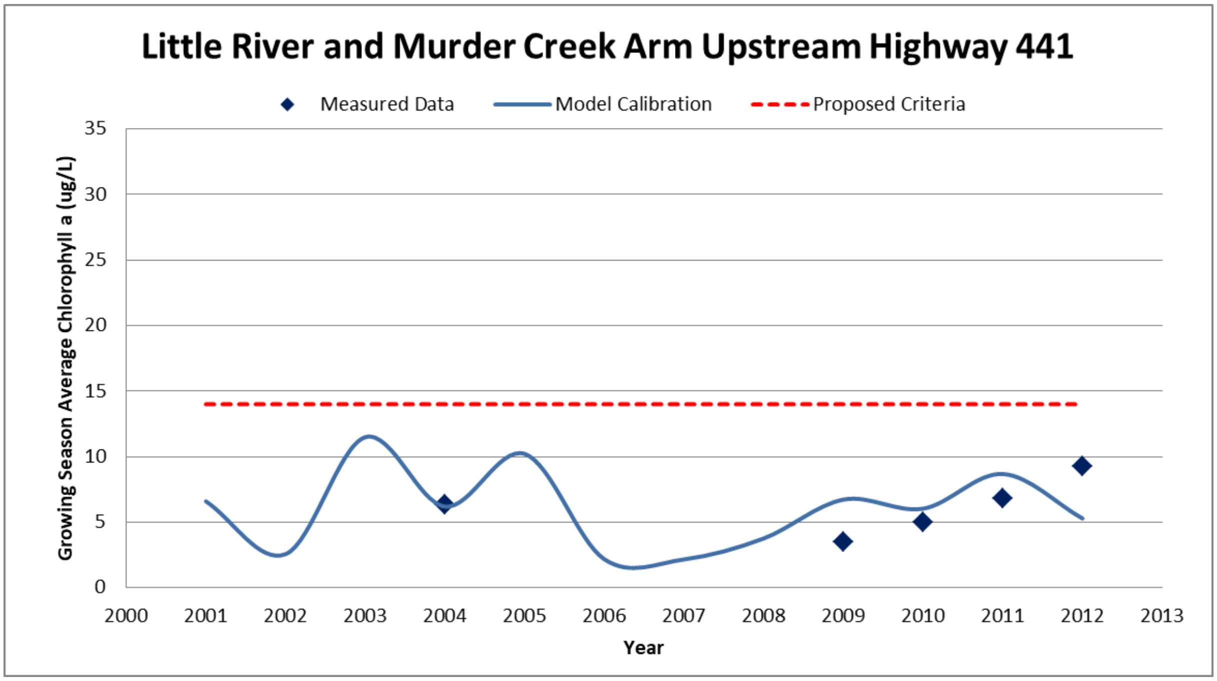
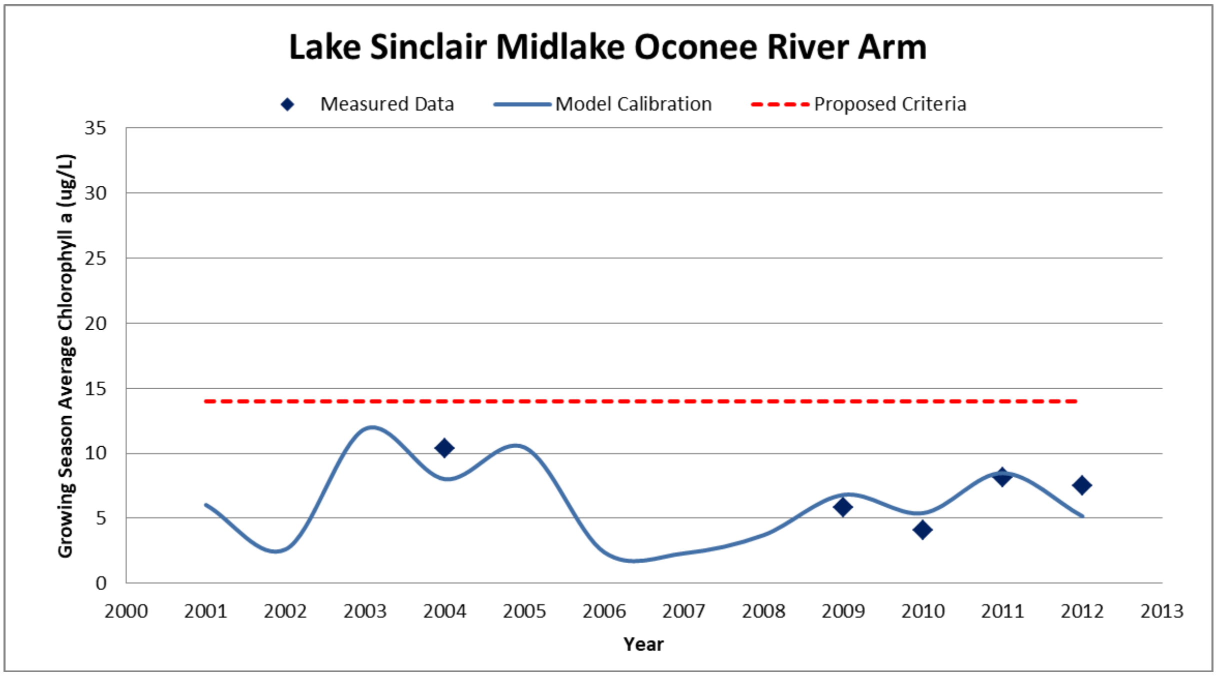


Figure 5-1. Lake Oconee Growing Season Average Chlorophyll *a* Levels from Model Scenario 1A (Calibration) compared to the Proposed Criteria and Measured Values

5.2.2 Lake Sinclair

In Lake Sinclair, the highest measured data at Little River and Murder Creek Arm Upstream Highway 441, Midlake Oconee River Arm, and the Dam Pool were 9.3 μg/L, 10.4 μg/L, and 8.1 μg/L, respectively.





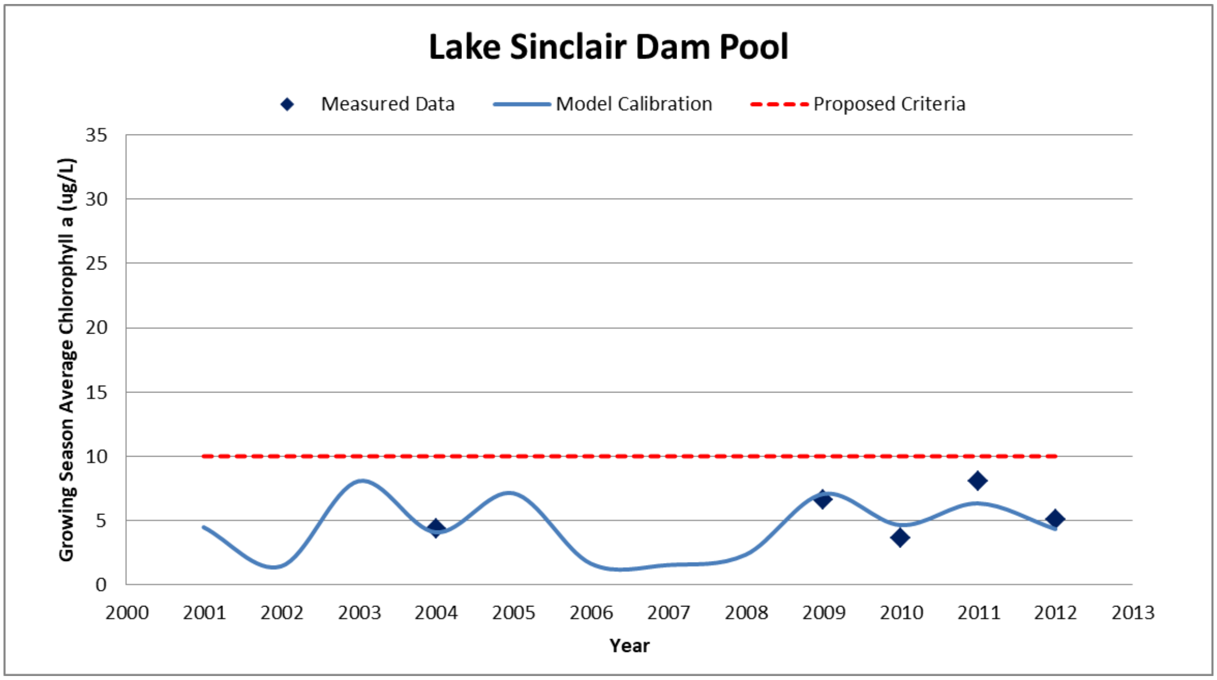


Figure 5-2. Lake Sinclair Growing Season Average Chlorophyll *a* Levels from Model Scenario 1A (Calibration) compared to the Proposed Criteria and Measured Values

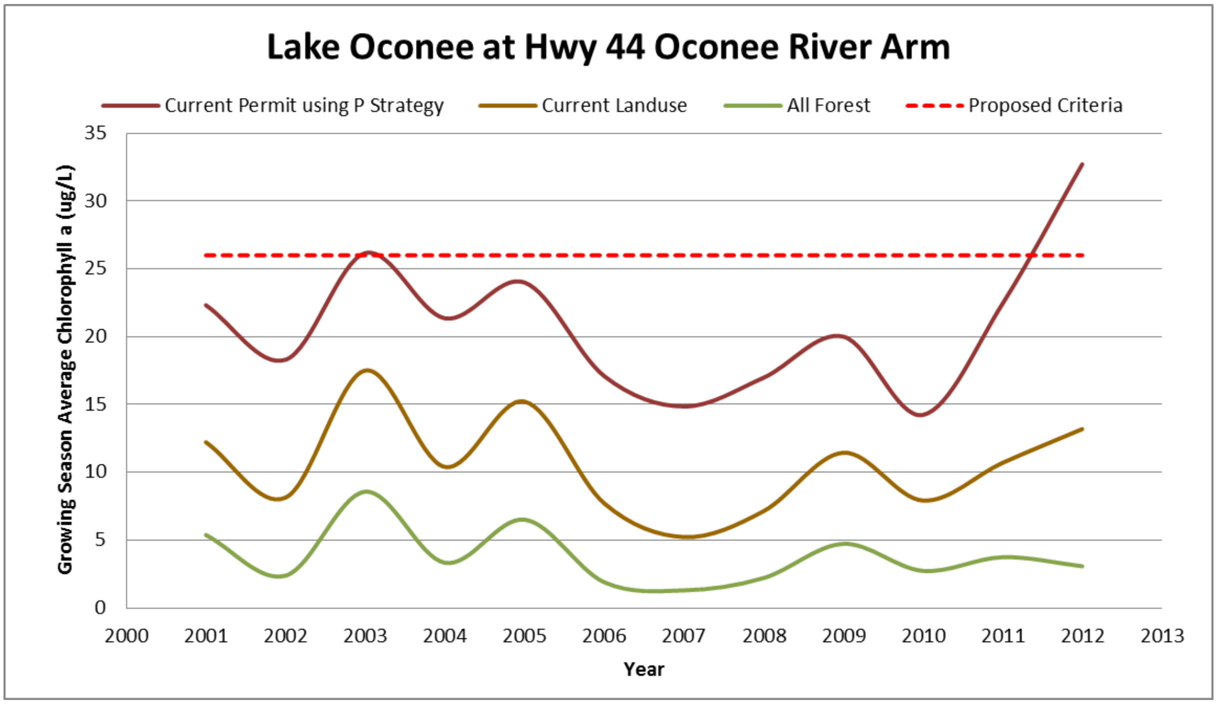
The models are considered accurate, based on the proximity of the measured values to the predicted values.

5.3 Effects of Land Use Change and Point Sources

Scenarios 1D (Current Permit), 1C (No Point Sources – Current Landuse), and 1B (All Forest) illustrate the effect discharges and landuse have on chlorophyll *a* levels in Lakes Oconee and Sinclair (see Figures 5-3 and 5-4).

<u>5.3.1 Lake Oconee</u>

At Highway 44 Oconee River Arm, the monitoring station located on the main body of the lake, the average modeled growing season average chlorophyll *a* value between 2001 and 2012 for Scenario 1D was 20.88 μg/L. The average modeled growing season average chlorophyll *a* value between 2001 and 2012 for Scenario 1C (No Point Sources – Current Landuse) was 10.57 μg/L, which indicated nearly 50% of the chlorophyll *a* is due to point sources. The average modeled growing season average chlorophyll *a* value between 2001 and 2012 for Scenario 1B (All Forest) was 3.82 μg/L, which indicated 33% of the growing season average chlorophyll *a* is due to landuse. Richland Creek Arm and the Dam Pool exhibited similar patterns when comparing these scenarios, point sources were responsible 38% of the chlorophyll *a* levels at Richland Creek Arm and 40% of the chlorophyll *a* at the Dam Pool for average value of growing season average chlorophyll *a*. Landuse contributed to 30% of the chlorophyll *a* levels at Richland Creek Arm and 46% of the chlorophyll *a* levels at the Dam Pool.



Lake Oconee at Hwy 44 Oconee River Arm
Current Permit using P Strategy
Current Landuse
All Forest
Proposed Criteria
Growing Season Average Chlorophyll a (ug/L)
0
5
10
15
20
25
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35
2000
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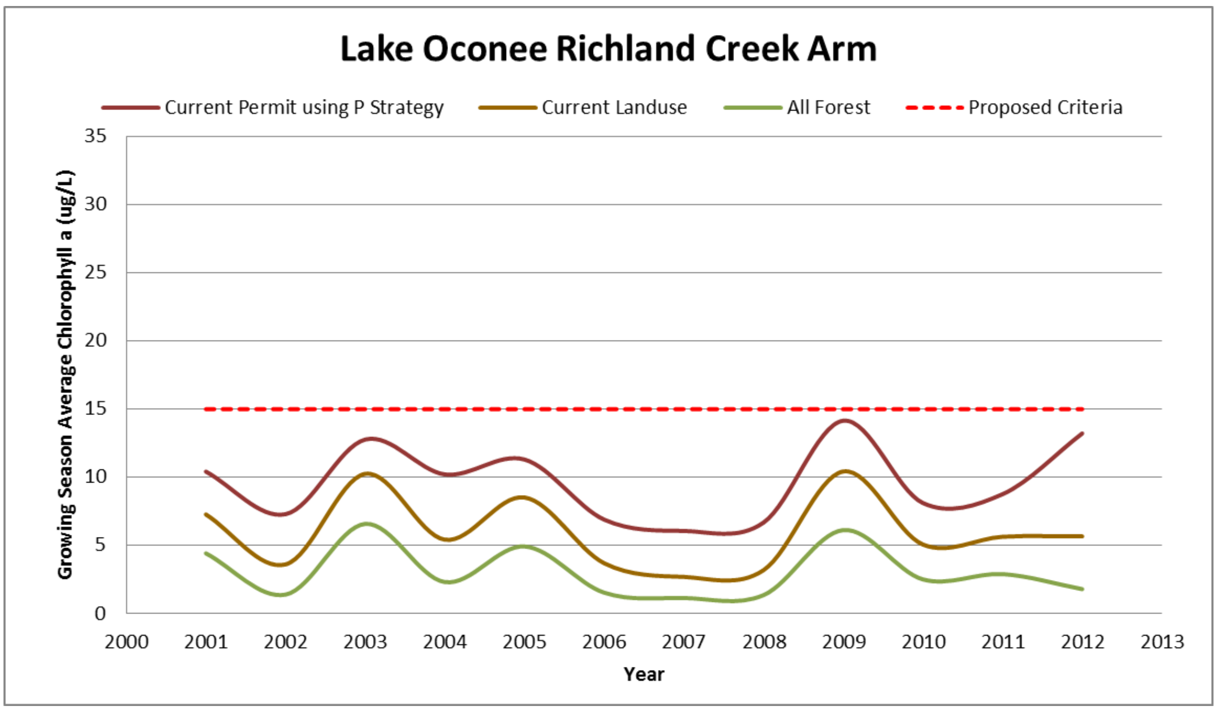

Lake Oconee Richland Creek Arm
Current Permit using P Strategy
Current Landuse
All Forest
Proposed Criteria
Growing Season Average Chlorophyll a (ug/L)
0
5
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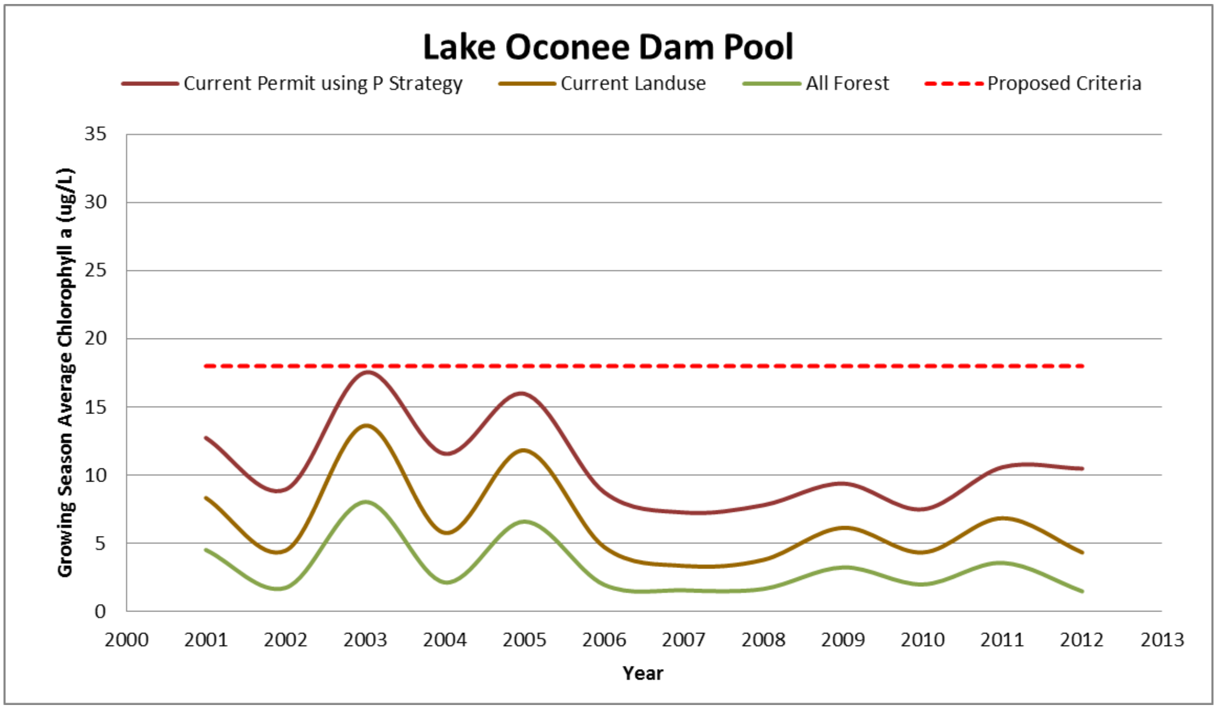
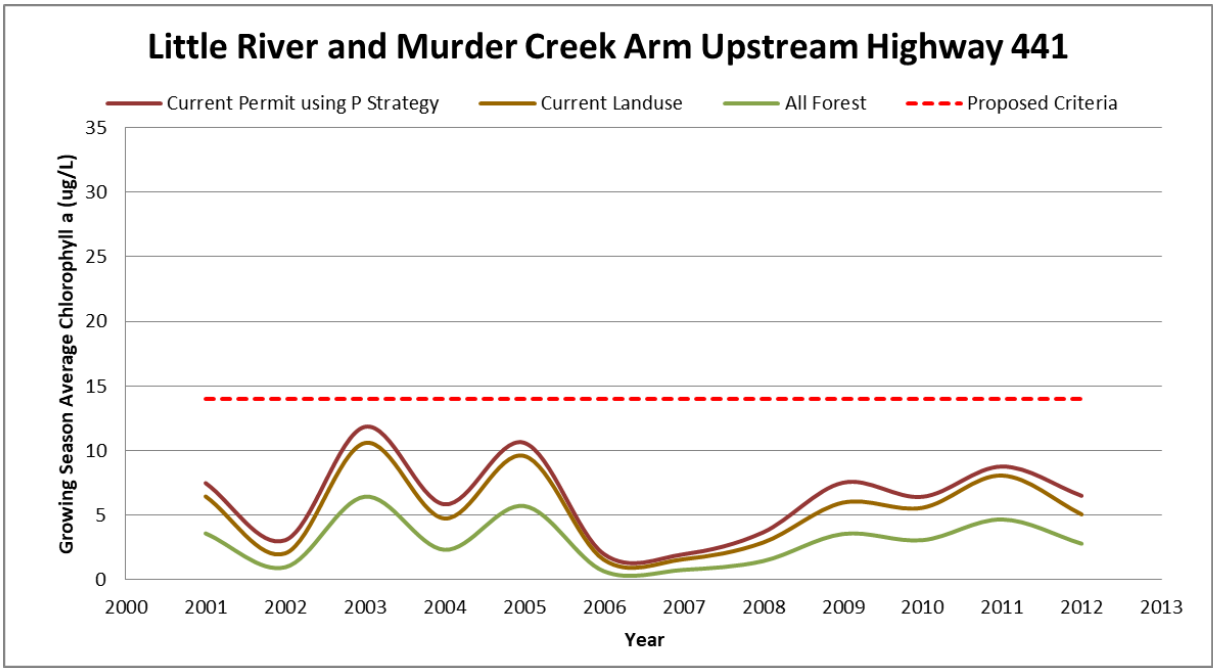


Figure 5-3. Lake Oconee Growing Season Average Chlorophyll *a* Levels for Model Scenario 1B (All Forest), Scenario 1C (Current Landuse), and Scenario 1D (Current Permit and Landuse) compared to the Proposed Criteria

5.3.2 Lake Sinclair

In Lake Sinclair, the average modeled growing season average chlorophyll *a* value between 2001 and 2012 for Scenario 1D was 6.31 µg/L at Little River and Murder Creek Arm Upstream Highway 441. The average modeled growing season average chlorophyll *a* value between 2001 and 2012 for Scenario 1C (No Point Sources – Current Landuse) was 5.35 µg/L, which indicated a 38% of growing season average chlorophyll *a* level was attributed to point sources. The average modeled growing season average chlorophyll *a* value between 2001 and 2012 for 1B (All Forest) was 3.00 µg/L, which indicated that approximately 30% of the growing season average chlorophyll *a* levels are due to landuse at the Little River and Murder Creek Arm site. The Midlake Oconee River Arm and the Dam Pool exhibited similar patterns when comparing these scenarios. Approximately 49% of the modeled average growing season average chlorophyll *a* levels at Midlake and 40% at the Dam Pool are due to point sources. Additionally, 33% of the growing season average chlorophyll *a* levels at Midlake and 46% of the growing season average chlorophyll *a* levels at the Dam Pool are the result of the landuse.


Little River and Murder Creek Arm Upstream Highway 441
Current Permit using P Strategy
Current Landuse
All Forest
Proposed Criteria
Growing Season Average Chlorophyll a (ug/L)
0
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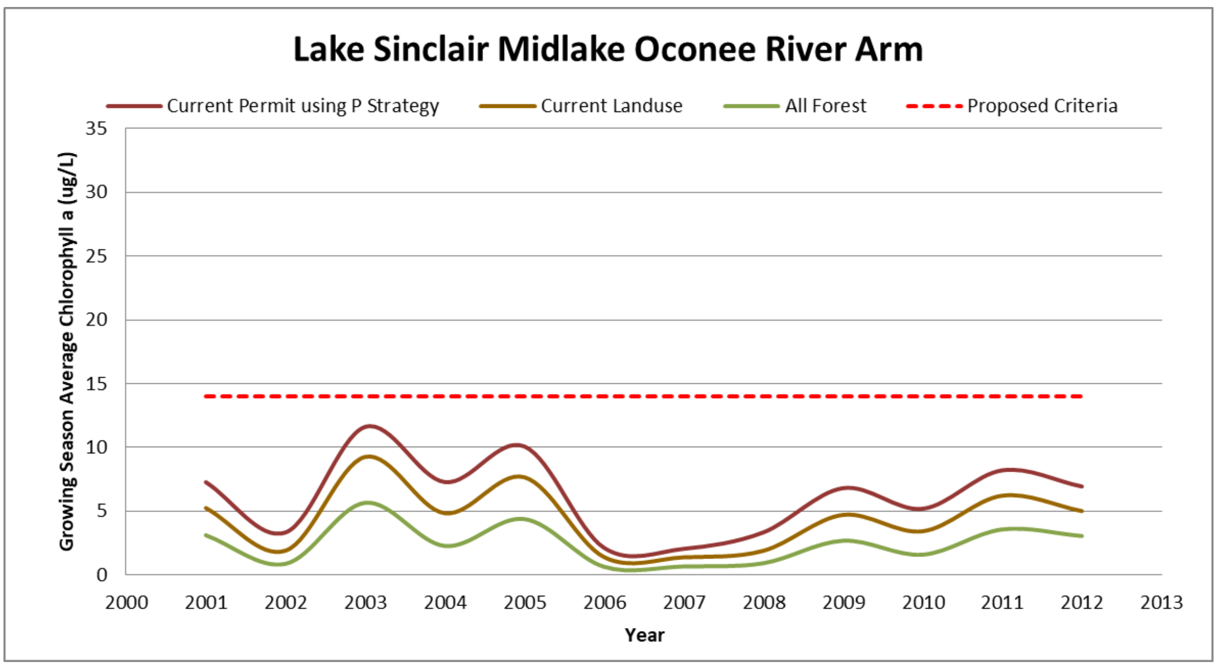
Lake Sinclair Midlake Oconee River Arm
Current Permit using P Strategy
Current Landuse
All Forest
Proposed Criteria
Growing Season Average Chlorophyll a (ug/L)
0
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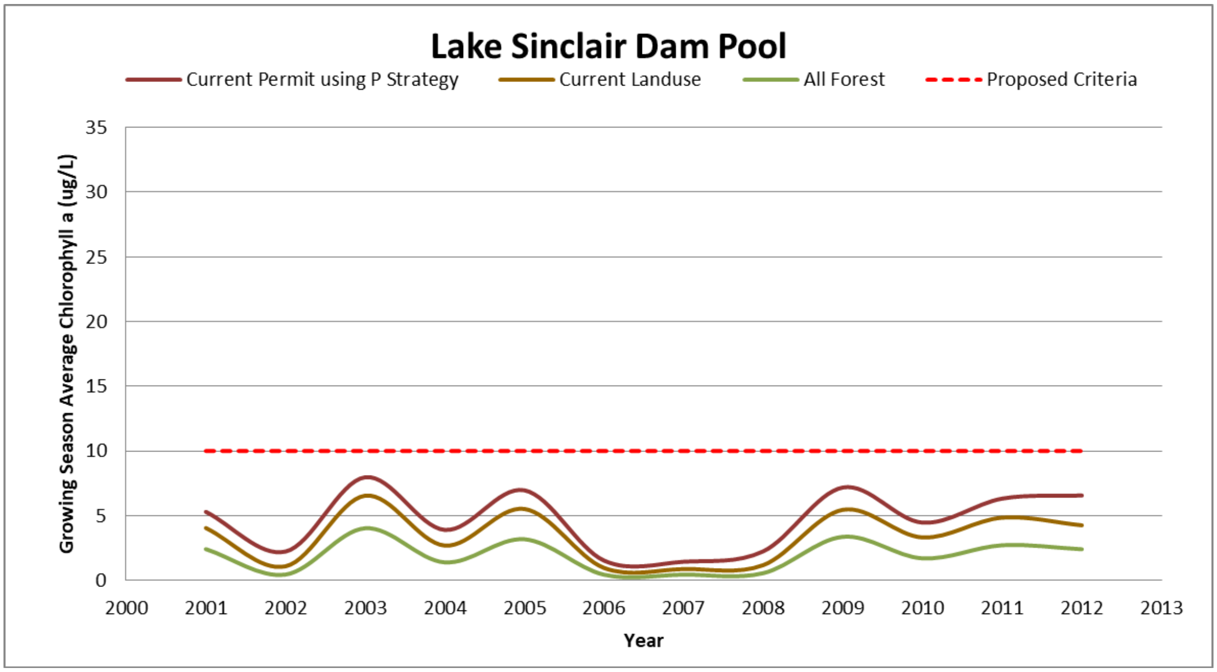


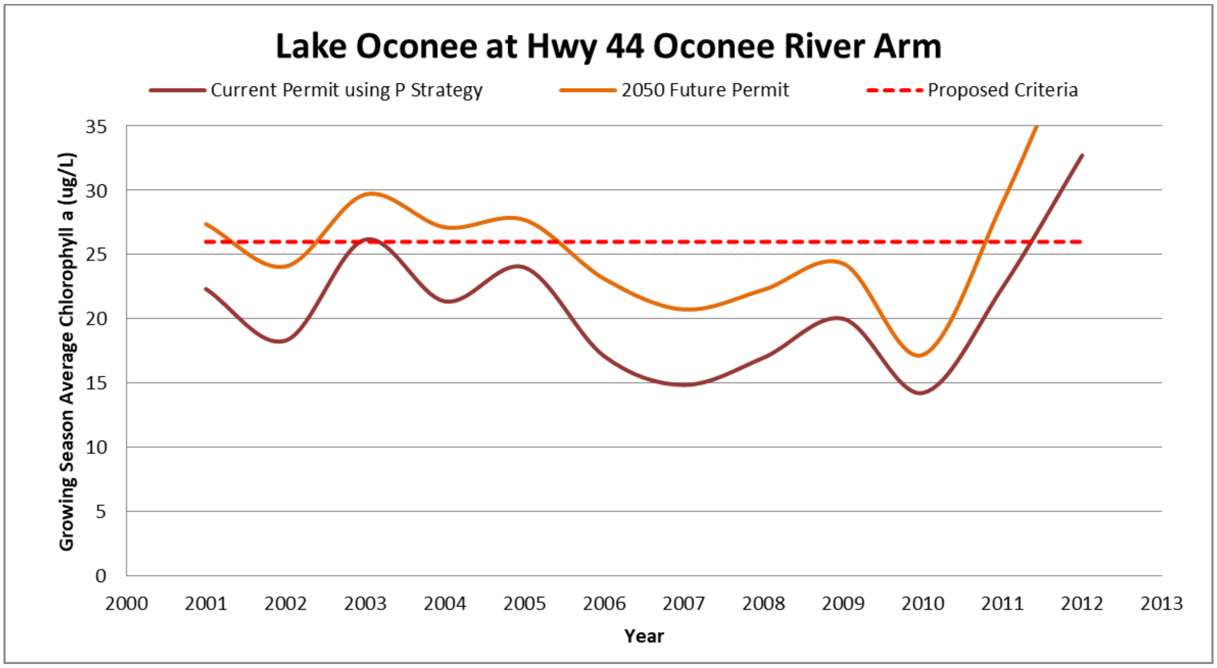
Figure 5-4. Lake Sinclair Growing Season Average Chlorophyll *a* Levels for Model Scenario 1B (All Forest), Scenario 1C (Current Landuse), and Scenario 1D (Current Permit and Landuse) compared to the Proposed Criteria

5.4 Effects of Future Permitted Flows

Scenario 1D (Current Permit) was compared with Scenario 1E (2050 Permitted Flows and Current Landuse) to determine the effect future permitted flows would have on the lake chlorophyll *a* levels if the total phosphorus concentrations remain the same (see Figures 5-5 and 5-6).

<u>5.4.1 Lake Oconee</u>

At Highway 44 Oconee River Arm, the average modeled growing season average chlorophyll *a* value between 2001 and 2012 for Scenario 1D was 20.88 μg/L. The growing season average chlorophyll *a* levels from Scenario 1E were predicted to increase by 26% compared to the current permit levels. Richland Creek Arm and the Dam Pool exhibited similar patterns when comparing these scenarios, increasing 18% at both sites by 2050 if permit concentrations remain the same.


Lake Oconee at Hwy 44 Oconee River Arm
Current Permit using P Strategy
2050 Future Permit
Proposed Criteria
Growing Season Average Chlorophyll a (ug/L)
0
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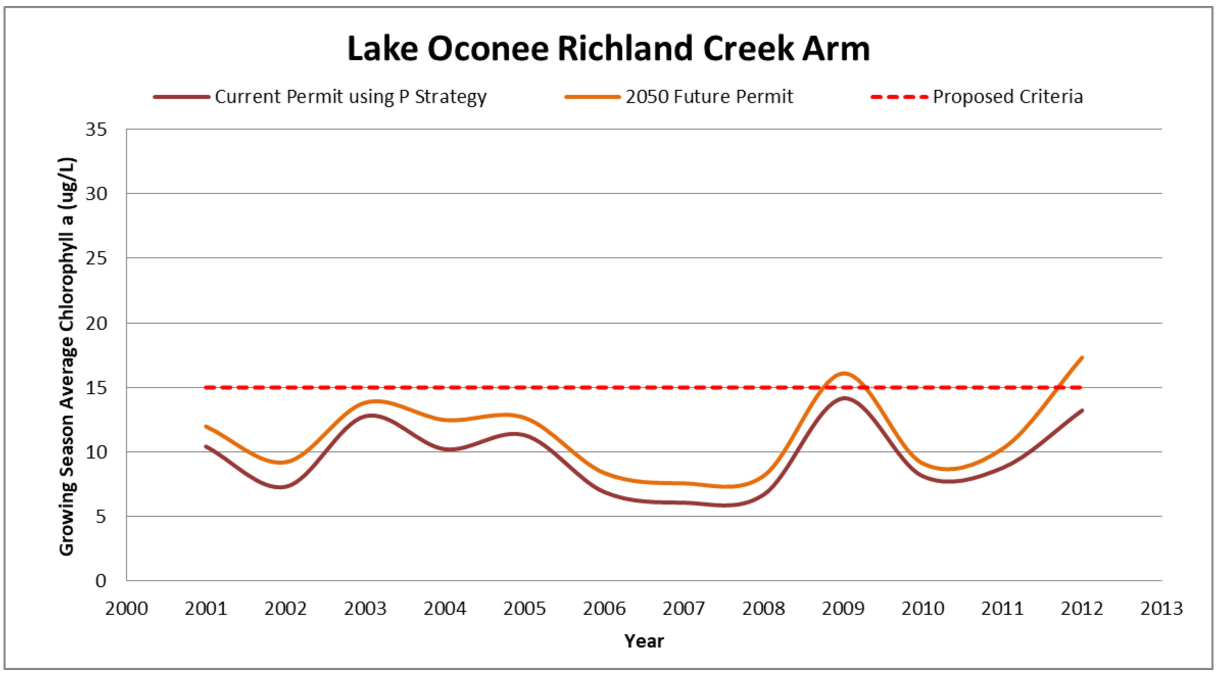
Lake Oconee Richland Creek Arm
Current Permit using P Strategy
2050 Future Permit
Proposed Criteria
Growing Season Average Chlorophyll a (ug/L)
0
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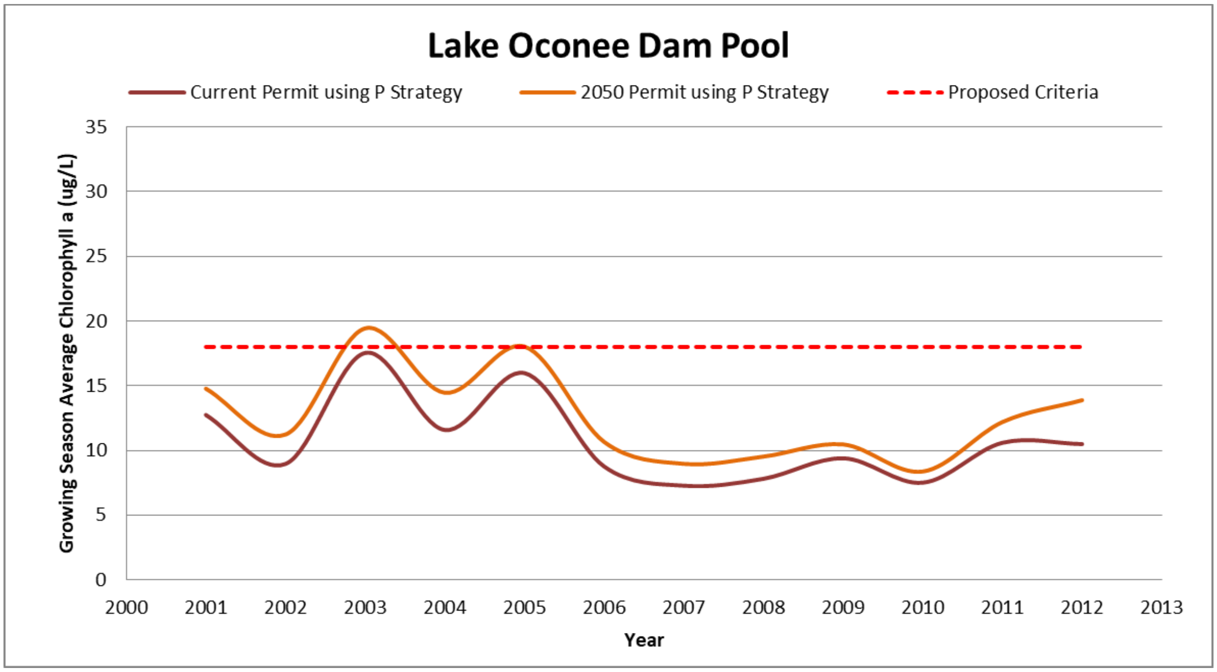
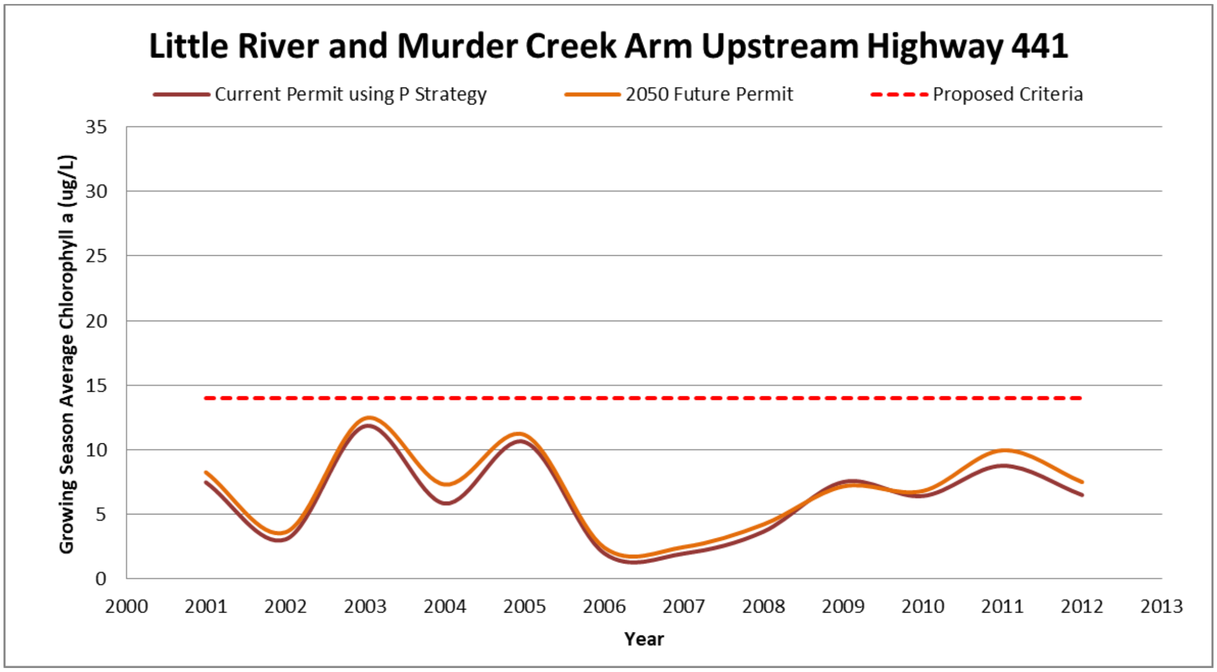


Figure 5-5. Lake Oconee Growing Season Average Chlorophyll *a* Levels for Model Scenario 1D (Current Permit) and Scenario 1E (2050 Permitted Flows and Current Landuse) compared to the Proposed Criteria

5.4.2 Lake Sinclair

At Little River and Murder Creek Arm Upstream Highway 441, the average modeled growing season average chlorophyll *a* value between 2001 and 2012 for Scenario 1D was 6.31 µg/L. The growing season average chlorophyll *a* levels for Scenario 1E were predicted to increase by 10% compared to current permit levels. Midlake Oconee River Arm and the Dam Pool exhibited similar patterns when comparing these scenarios, increasing the growing season average chlorophyll *a* levels by 12% at Midlake and 9% at the Dam Pool by 2050 if permit concentrations remain the same.


Little River and Murder Creek Arm Upstream Highway 441
Current Permit using P Strategy
2050 Future Permit
Proposed Criteria
Growing Season Average Chlorophyll a (ug/L)
0
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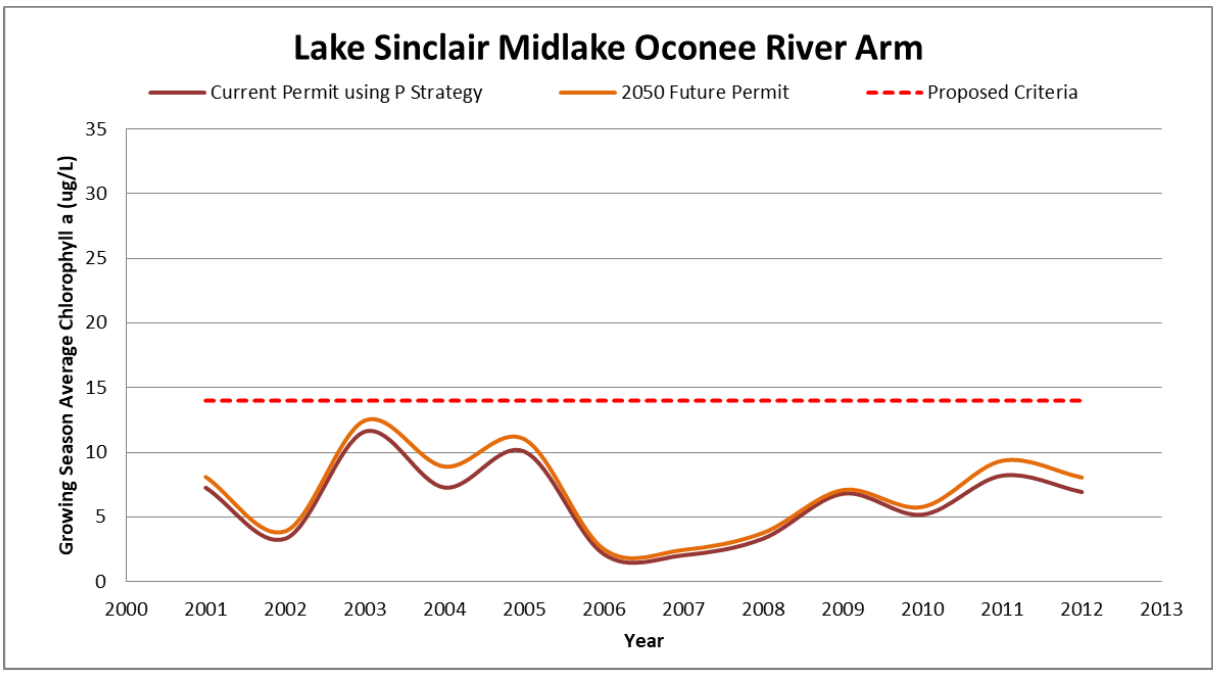
Lake Sinclair Midlake Oconee River Arm
Current Permit using P Strategy
2050 Future Permit
Proposed Criteria
Growing Season Average Chlorophyll a (ug/L)
0
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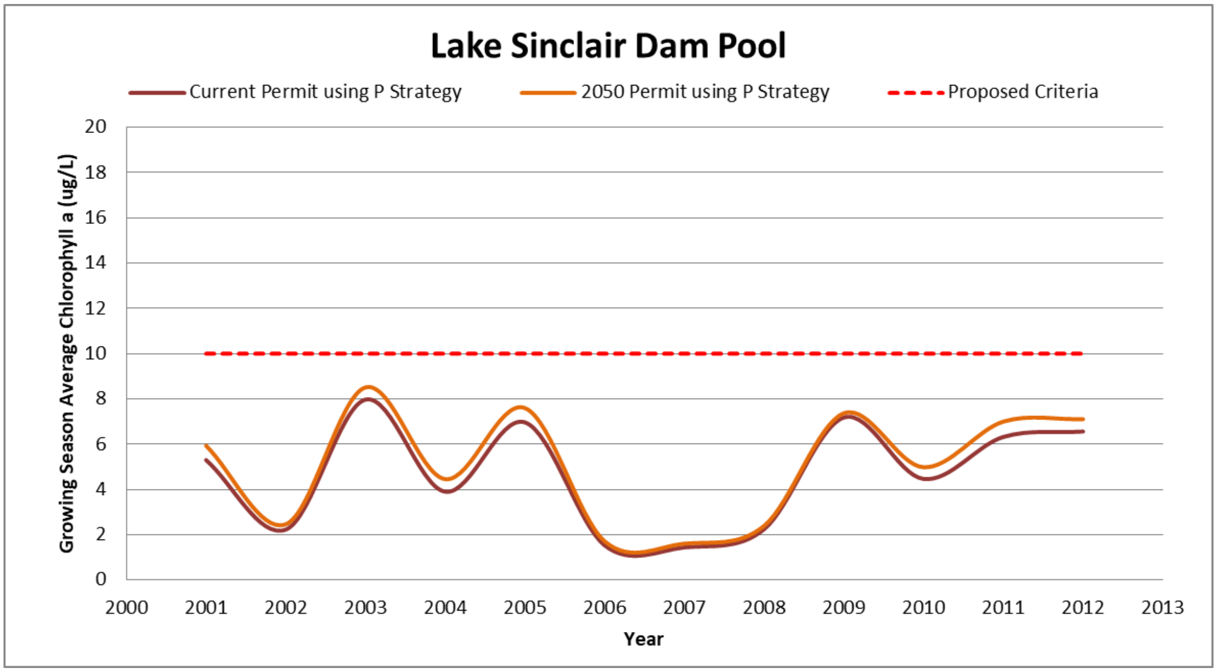


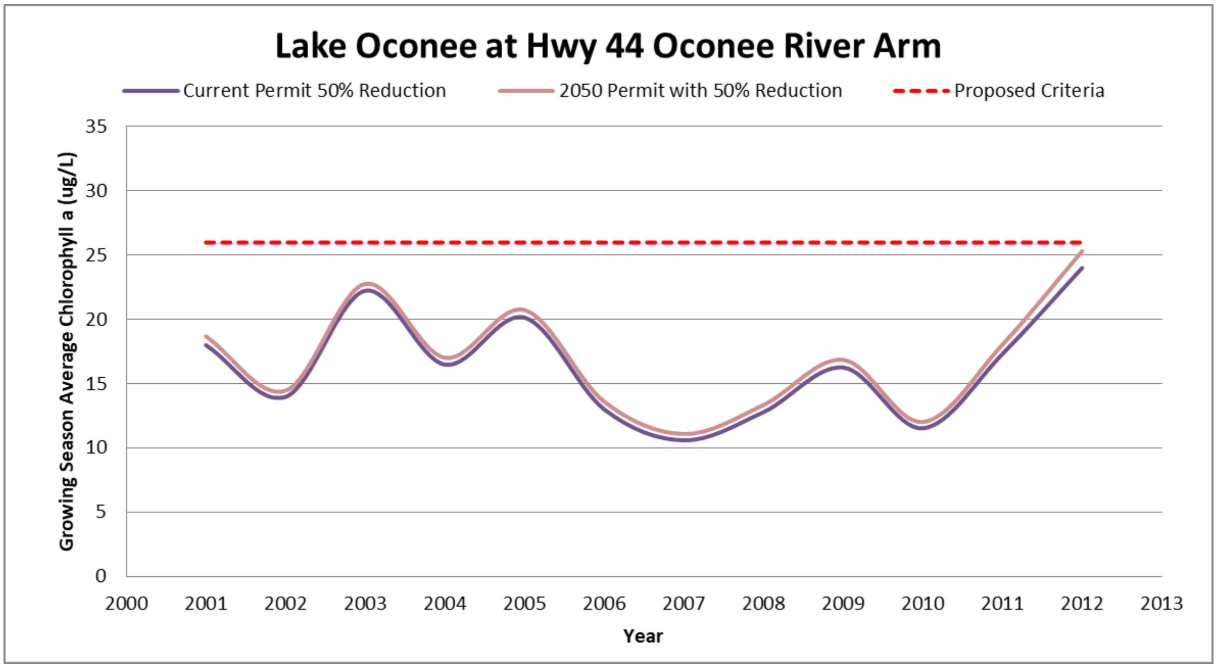
Figure 5-6. Lake Sinclair Growing Season Average Chlorophyll *a* Levels for Model Scenario 1D (Current Permit) and Scenario 1E (2050 Permitted Flows and Current Landuse) compared to the Proposed Criteria

5.5 Effects of Point Source Nutrient Management

Scenario 1F (50% of P Strategy) was compared to Scenario 1G (2050 Permitted Flows Maintaining Loads and Current Landuse) to determine the effect managing total phosphorus loads from point sources would have on the growing season average chlorophyll *a* levels in both Lakes Oconee and Sinclair (see Figures 5-7 and 5-8).

<u>5.5.1 Lake Oconee</u>

At Highway 44 Oconee River Arm, the average modeled growing season average chlorophyll *a* level between 2001 and 2012 for Scenario 1F was 16.38 μg/L. This is approximately 20% lower than the current permitted growing season average chlorophyll *a* concentration of 20.88 μg/L. The growing season average chlorophyll *a* levels from Scenario 1G were about the same, decreasing by 4% in 2050, if the permitted phosphorus loads were maintained in the future. Similar patterns were observed at the other two sites when comparing these scenarios. At Richland Creek, the average chlorophyll *a* levels from Scenario F are 7.84 μg/L compared to 9.66 μg/L for the current permitted scenario, and the proposed 2050 average chlorophyll *a* levels is predicted to be 8.82 μg/L in 2050. At the Dam Pool, the average chlorophyll a levels from Scenario F are 8.77 μg/L compared to 10.72 μg/L for the current permitted scenario, and the proposed 2050 average chlorophyll *a* levels is predicted to be 9.12 μg/L in 2050.


Lake Oconee at Hwy 44 Oconee River Arm
Current Permit 50% Reduction
2050 Permit with 50% Reduction
Proposed Criteria
Growing Season Average Chlorophyll a (ug/L)
0
5
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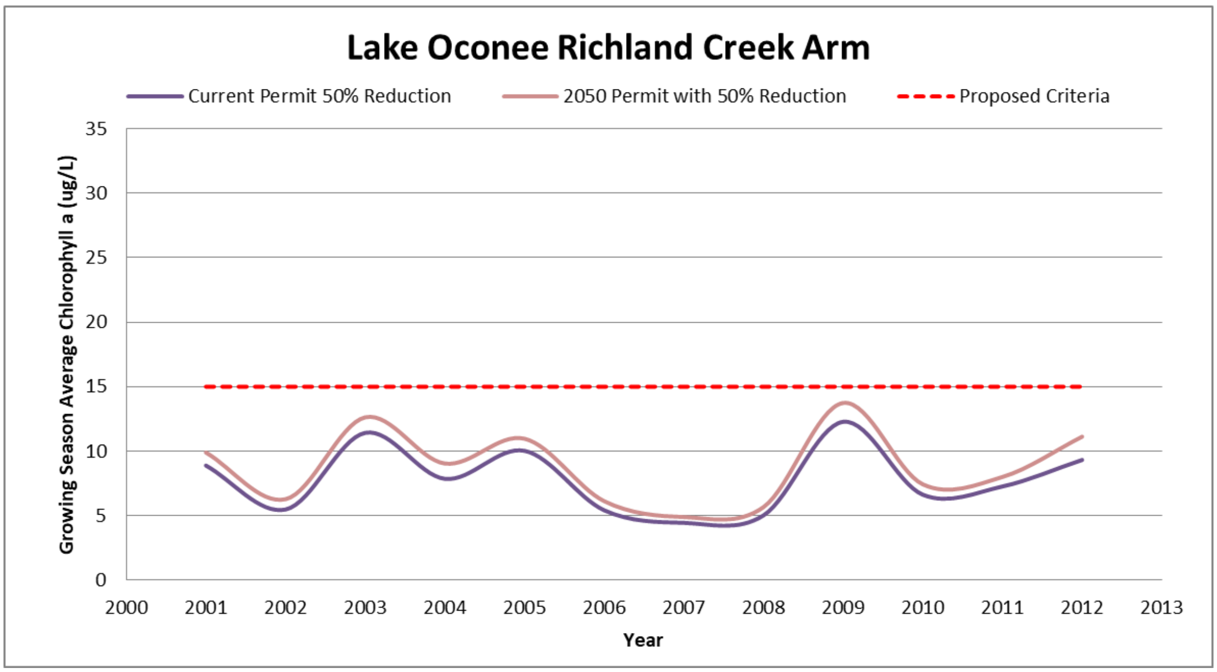
Lake Oconee Richland Creek Arm
Current Permit 50% Reduction
2050 Permit with 50% Reduction
Proposed Criteria
Growing Season Average Chlorophyll a (ug/L)
0
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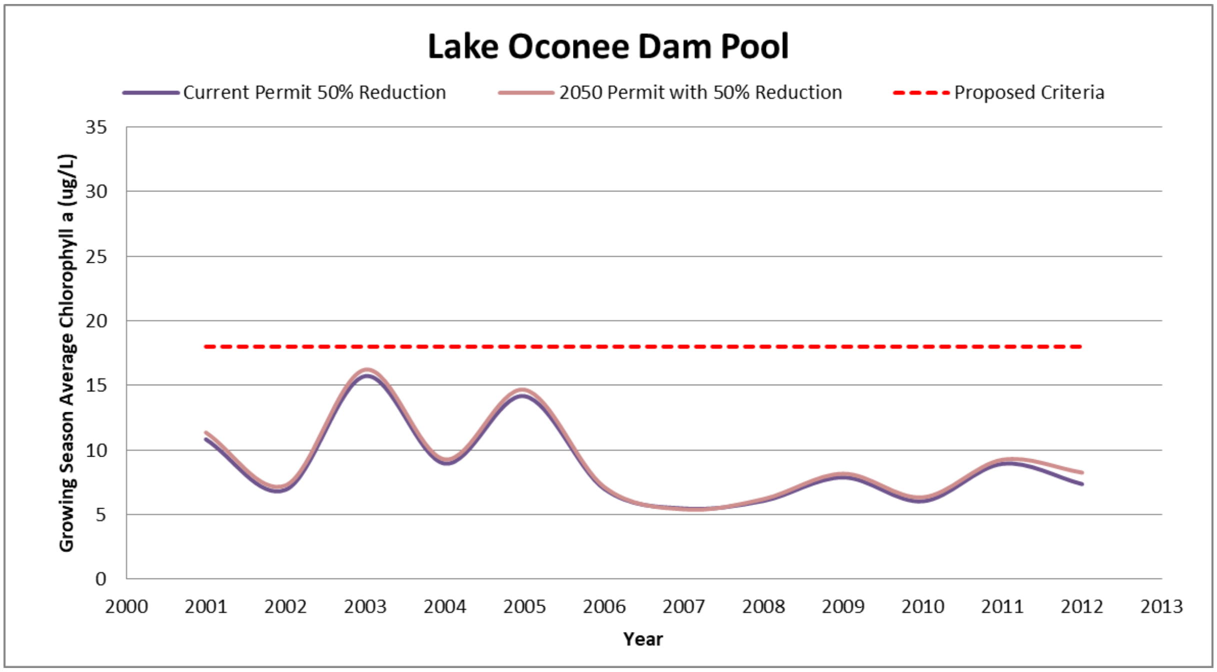
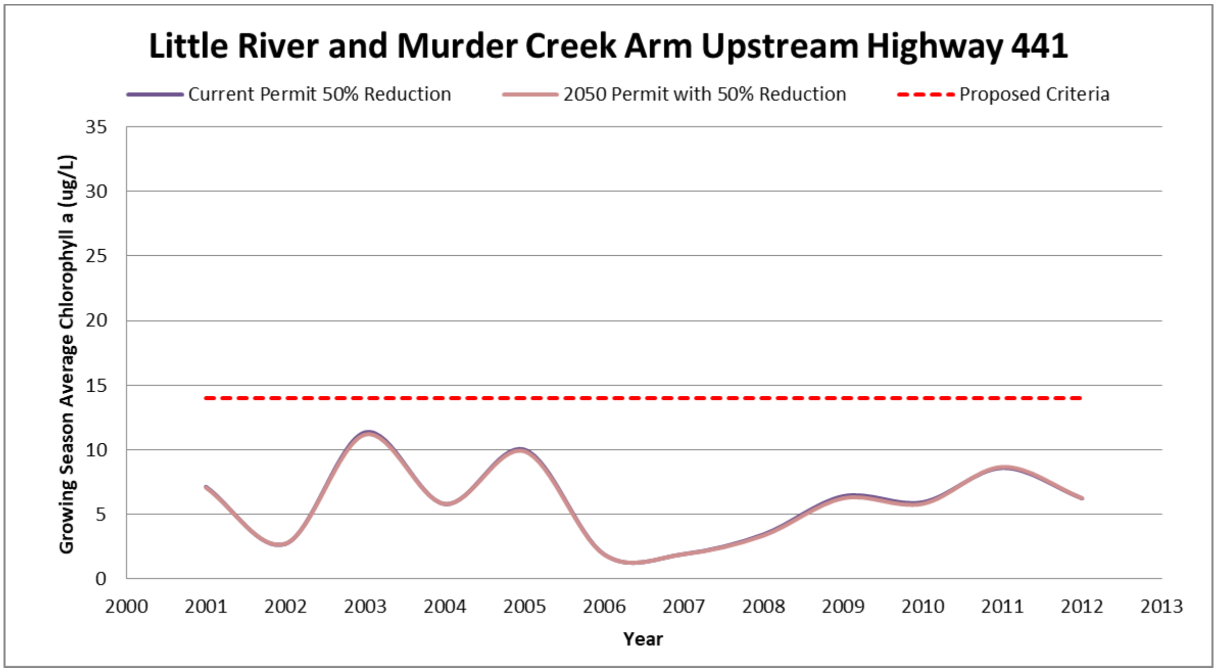


Figure 5-7. Lake Oconee Growing Season Average Chlorophyll *a* Levels for Model Scenario 1F (50% P Strategy) and Scenario 1G (2050 Permitted Flows Maintaining Loads and Current Landuse) compared to the Proposed Criteria

5.5.2 Lake Sinclair

At Little River and Murder Creek Arm Upstream Highway 441, the average modeled growing season average chlorophyll *a* value between 2001 and 2012 for Scenario 1F was 5.96 μg/L compared to 6.31 μg/L for the current permitted run. The growing season average chlorophyll *a* levels were about the same for Scenario 1G, predicted to be 5.91 μg/L in 2050. Similar patterns were observed at the other two sites when comparing these scenarios. At Midlake Oconee River Arm, the average chlorophyll *a* levels from Scenario F are 5.55 μg/L compared to 6.18 μg/L for the current permitted scenario, and the proposed 2050 average chlorophyll *a* levels is predicted to be 5.61 μg/L in 2050. At the Dam Pool, the average chlorophyll a levels from Scenario F are 4.17 μg/L compared to 4.67 μg/L for the current permitted scenario, and the proposed 2050 average chlorophyll *a* levels is predicted to be 4.20 μg/L in 2050.


Little River and Murder Creek Arm Upstream Highway 441
Current Permit 50% Reduction
2050 Permit with 50% Reduction
Proposed Criteria
Growing Season Average Chlorophyll a (ug/L)
35
30
25
20
15
10
5
0
2000
2001
2002
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2007
2008
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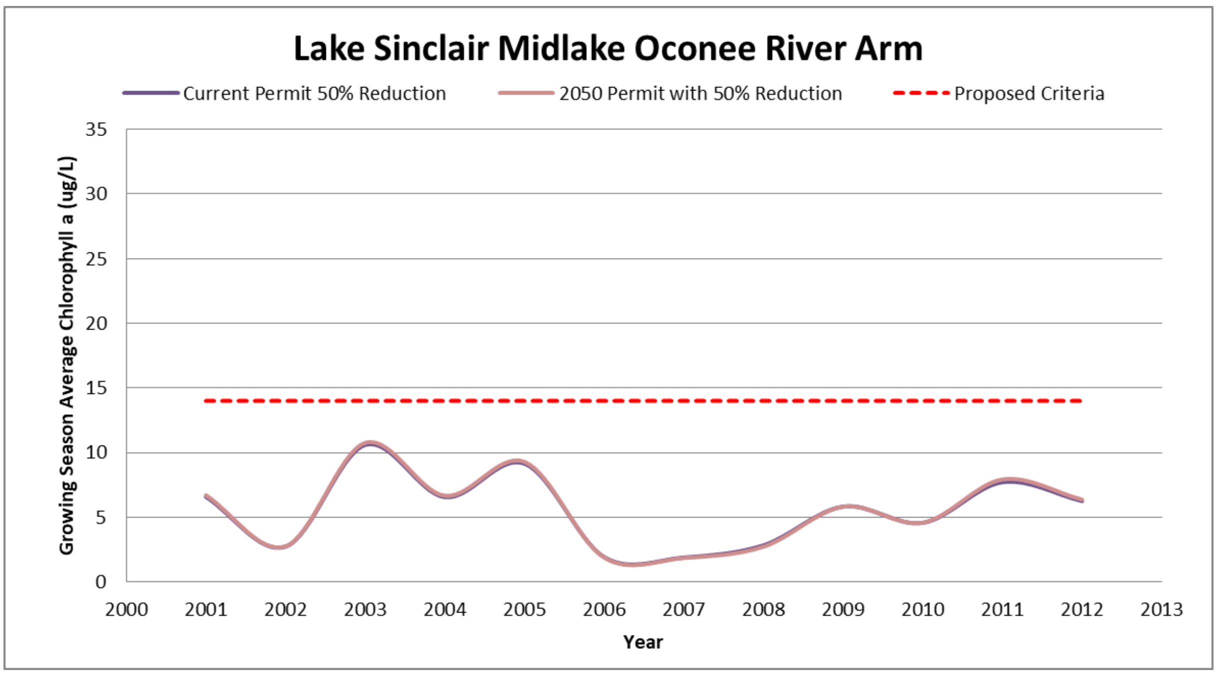
2011
2012
2013
Year


Lake Sinclair Midlake Oconee River Arm
Current Permit 50% Reduction
2050 Permit with 50% Reduction
Proposed Criteria
Growing Season Average Chlorophyll a (ug/L)
35
30
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20
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Year

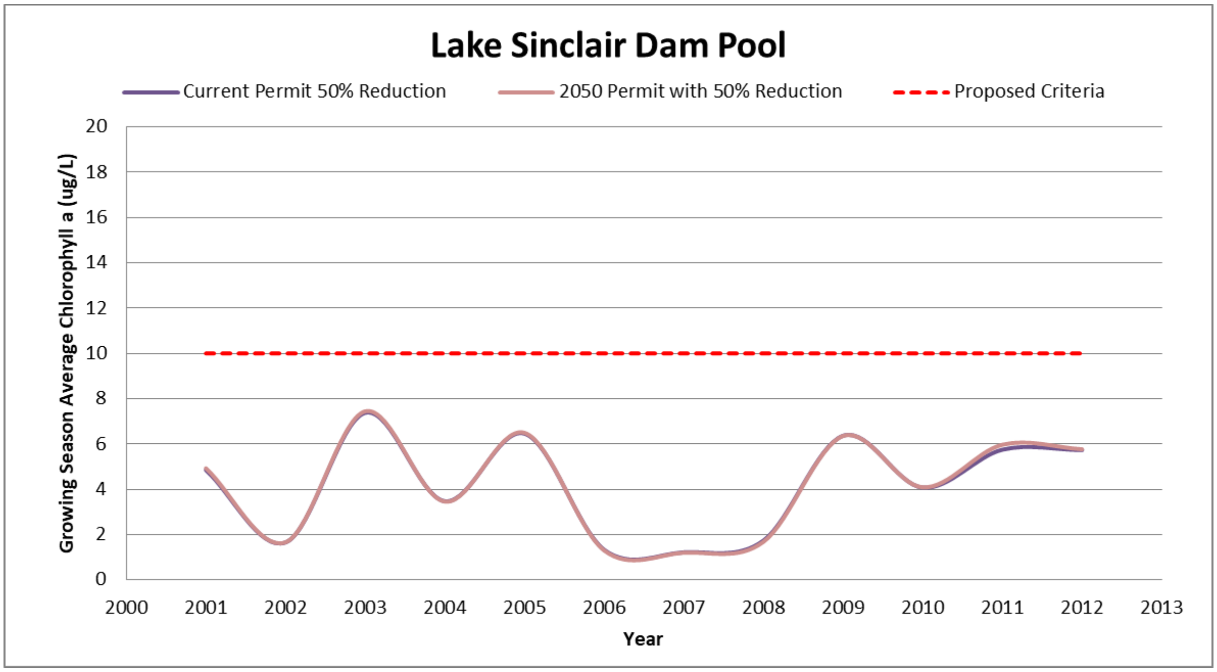


Figure 5-8. Lake Sinclair Growing Season Average Chlorophyll *a* Levels for Model Scenario 1F (50% P Strategy) and Scenario 1G (2050 Permitted Flows Maintaining Loads and Current Landuse) compared to the Proposed Criteria

5.6 Scenario Summaries

The Clean Water Act requires all permits meet water quality standards. EPD does not want to propose criteria that would be in violation upon approval; therefore, the proposed criteria allow for a reasonable margin of safety while updates to the permitted phosphorus levels take effect. This strategy will also allow time for the fishery in Lakes Oconee and Sinclair to adjust to the altered nutrient levels without disrupting the food web. Once the permitted strategy has been implemented, the lake criteria can be revised in the future.

5.6.1 Chlorophyll *a* Results

Table 5-1 provides the maximum growing season average chlorophyll *a* levels predicted during the simulation period for each scenario, at the monitoring stations on both lakes, compared to the proposed chlorophyll *a* criteria. Scenario 1D (Current Permit) has one year that violates the proposed criteria; however, all other years are predicted to be in compliance. The growing season average chlorophyll *a* concentrations for Scenarios 1F (50% of P Strategy) and 1G (2050 Permitted Flows Maintaining Loads and Current Landuse) are predicted to meet the proposed criteria. Both of these scenarios will require nutrient management. Reductions in permitted total phosphorus concentrations and/or loads will be implemented after the proposed lake criteria have been adopted.

Table 5-1. Maximum Growing Season Average Chlorophyll *a* (μg/L) for Each Scenario Compared to the Proposed Growing Season Average Chlorophyll *a* (μg/L)

Lake	Monitoring Station	Scenario							Proposed Criteria (μg/L)
		1A	1B	1C	1D	1E	1F	1G	
Lake Oconee	Highway 44 Oconee River Arm	27.9	8.6	17.5	32.7	43.4	23.0	25.3	26
	Richland Creek Arm	14.8	6.6	10.4	14.2	17.3	12.1	13.7	15
	300 Meters Upstream of Wallace Dam	18.6	8.1	13.6	17.5	19.4	15.5	16.2	18
Lake Sinclair	Little River & Murder Creek Arm Upstream Highway 441	11.5	6.4	10.6	11.8	12.4	11.1	11.2	14
	Midlake Oconee River Arm	11.9	5.7	9.3	11.6	12.5	10.4	10.8	14
	300 Meters Upstream of Sinclair Dam	8.1	4.0	6.6	8.0	8.5	7.3	7.4	10

5.6.2 Nitrogen Results

The proposed total nitrogen criterion for both Lake Oconee and Lake Sinclair is a "not to exceed" growing season average of 2 mg/L as nitrogen in the photic zone. Table 5-2 shows the maximum growing season average total nitrogen value for each scenario at each lake's monitoring stations predicted during the simulation period. Scenario 1D (Current Permit) will meet the proposed criteria at the EPD monitoring sties. Georgia Power also conducts monitoring and the highest growing season average total nitrogen levels predicted at Georgia Power's monitoring sites were 1.54 mg/L (OC-8) and 1.14 mg/L (SI-07) in Lake Oconee and Lake Sinclair, respectively.

Table 5-2. Maximum Growing Season Average Total Nitrogen (mg/L) from Each Scenario

Lake	Monitoring Station	Scenario						
		1A	1B	1C	1D	1E	1F	1G
Lake Oconee	Highway 44 Oconee River Arm	0.68	0.29	0.57	1.11	1.60	1.07	1.33
	Richland Creek Arm	0.50	0.27	0.47	0.80	1.06	0.81	1.14
	300 Meters Upstream of Wallace Dam	0.59	0.29	0.52	0.87	1.17	0.87	1.10
Lake Sinclair	Little River and Murder Creek Arm Upstream Highway 441	0.53	0.29	0.51	0.61	0.74	0.58	0.70
	Midlake Oconee River Arm	0.50	0.25	0.46	0.63	0.80	0.62	0.72
	300 Meters Upstream of Sinclair Dam	0.45	0.24	0.42	0.57	0.71	0.56	0.64

At present, discharges to the watershed only have permit limits for ammonia and do not monitor total nitrogen levels. The nitrate/nitrate and organic nitrogen levels used in the models were assumed. To ensure the proposed total nitrogen criterion is not violated upon adoption, the proposed criterion has a reasonable margin of safety. Currently, discharge permits are being revised to include total Kjeldahl nitrogen, nitrate/nitrite, and organic nitrogen monitoring. After the proposed lake criteria have been adopted, it is not anticipated that total nitrogen permit limits will be implemented, since the modeled results show the lakes are phosphorus limited. In the future, if monitoring data indicates permit limits are needed for these parameters, then permits will be modified to include numeric limits.

5.6.3 Phosphorus Results

The proposed total phosphorus criterion for both Lake Oconee and Lake Sinclair is a "not to exceed" growing season average value of 0.2 mg/L in the photic zone. Table 5-2 shows the maximum growing season average total phosphorus value for each scenario at each lake's monitoring stations predicted during the simulation period. The model results show that the proposed criteria should easily be met at the EPD monitoring stations. Growing season average total phosphorus levels were also predicted at sites where Georgia Power conducts monitoring. The highest growing season average total phosphorus levels predicted at the Georgia Power Lake Oconee and Lake Sinclair monitoring sites for Scenario 1D (Current Permit) are 0.07 mg/L and 0.14 mg/L, respectively. However, the measured data in Appendix A, indicate total phosphorus levels as high as 0.87 mg/L were measured at the Lake Oconee Dam Pool in 2004. More recently, a growing season average chlorophyll *a* concentration of 0.10 mg/L was measured at Highway 44 Bridge Oconee River Arm in 2009; whereas the predicted level for scenario 1A (Calibration) was 0.07 mg/L. Outliers have not been removed from the data set, since these data would not be removed when assessing data for compliance with water quality criteria. To ensure the proposed total phosphorus criterion is not violated upon adoption, the proposed criterion has a reasonable margin of safety.

Table 5-3. Maximum Growing Season Average Total Phosphorus (mg/L) from Each Scenario

Lake	Monitoring Station	Scenario						
		1A	1B	1C	1D	1E	1F	1G
Lake Oconee	Highway 44 Oconee River Arm	0.07	0.02	0.05	0.06	0.07	0.06	0.06
	Richland Creek Arm	0.05	0.02	0.04	0.05	0.05	0.05	0.05
	300 Meters Upstream of Wallace Dam	0.07	0.03	0.05	0.07	0.08	0.06	0.06
Lake Sinclair	Little River and Murder Creek Arm Upstream Highway 441	0.05	0.03	0.04	0.05	0.06	0.05	0.05
	Midlake Oconee River Arm	0.05	0.02	0.04	0.05	0.05	0.05	0.05
	300 Meters Upstream of Sinclair Dam	0.05	0.03	0.04	0.05	0.06	0.05	0.05

At this time, major discharges to the watershed only have total phosphorus permit limits if they expanded their discharge since 2005. All other discharges have a total phosphorus and ortho-phosphate monitoring requirement. After the proposed lake criteria have been adopted, all discharges will be given a total phosphorus limit. Figure 5-9 shows the flow contributions from various types of discharges. These include major discharges with a permitted flow $\geq$ 1 MGD (green), minor discharges with a permitted flow < 1 MGD (red), and PIDs (blue), which include mobile home parks, camps, rest areas, nursing homes, schools, hospitals, etc. Major discharges make up approximately 87.5% of the permitted flow contribution, minors make up approximate 11% of the permitted flow and PIDs contribute 1.4% of the permitted flow. If the Georgia NPDES Total Phosphorus Strategy is used to determine the contribution of the total phosphorus load, major dischargers contribute 80%, minors contribute 18%, and PIDs contribute 2% of the total phosphorus load. In the Lake Oconee and Sinclair watershed, EPD plans to implement a nutrient permitting management strategy. Facilities with a permitted flow ≥ 1 MGD were given a total phosphorus level of 0.5 mg/L, and facilities with a permitted flow < 1 MGD were given a total phosphorus load of 4.17 lbs/day or a total phosphorus level of 5 mg/L, whichever is smaller, resulting in a 46% reduction in the total phosphorus permitted load. In the future, most total phosphorus permitted loads are expected to be maintained.

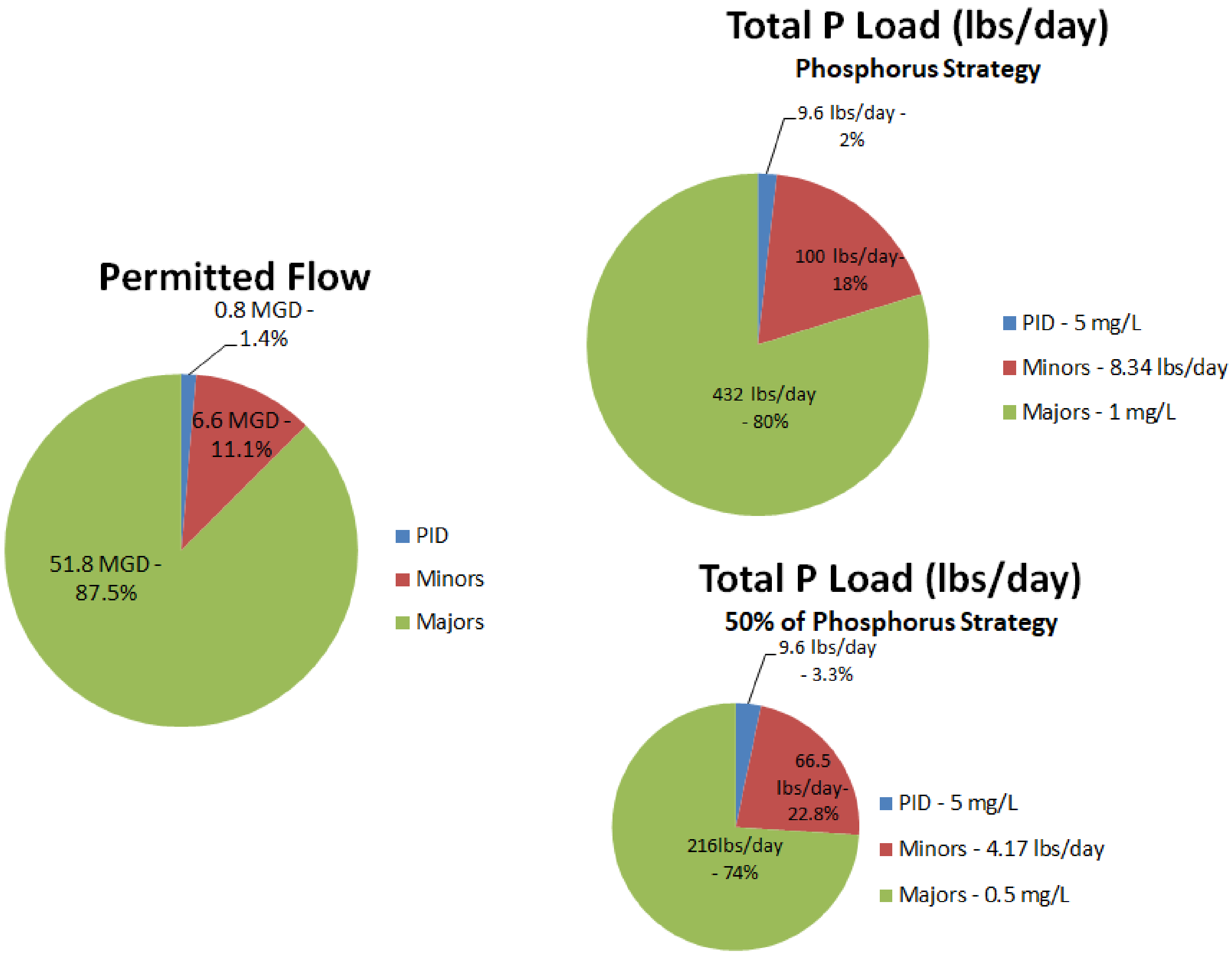


Figure 5-9. Flow and Total Phosphorus Load Contributions from Various Types of Discharges

5.6.4 pH

pH is a measure of the acidity of alkalinity of water, expressed in terms of its concentration of hydrogen ions. The pH scale ranges from 0 to 14. A pH of 7 is considered to be neutral. Substances with pH of less than 7 are acidic; substances with pH greater than 7 are basic. The term pH was derived from the manner in which the hydrogen ion concentration is calculated; it is the negative logarithm of the hydrogen ion (H+) concentration, at higher pH, there are fewer free hydrogen ions, and that a change of one pH unit reflects a tenfold change in the concentrations of the hydrogen ion.

The pH of water determines the solubility (amount that can be dissolved in the water) and biological availability (amount that can be utilized by aquatic life) of chemical constituents such as nutrients phosphorus, nitrogen, and carbon) and heavy metals (lead, copper, cadmium, etc.). It affects how much and what form a chemical is most abundant in the water, and determines whether aquatic life can use it. In the case of heavy metals, the degree to which they are soluble determines their toxicity. Metals tend to be more toxic at lower pH because they are more soluble.

In lakes, photosynthesis uses up dissolved carbon dioxide, which acts like carbonic acid (H2CO3) in water. CO2 removal, in effect, reduces the acidity of the water and so pH increases. In contrast, respiration of organic matter produces CO2, which dissolves in water as carbonic acid, thereby lowering the pH. For this reason, pH may be higher during daylight hours and during the growing season, when photosynthesis is at a maximum. Respiration and decomposition processes lower pH. Like dissolved oxygen concentrations, pH may change with depth in a lake, due again to changes in photosynthesis and other chemical reactions. There is typically a seasonal decrease in pH in the lower layers of a stratified lake because CO2 accumulates. There is no light for plants to fix CO2 and decomposition releases CO2.

Higher algal and plant growth (e.g., from increased temperature or excess nutrients), can result in increased pH levels, as allowed by the buffering capacity of the lake. Although these small changes in pH are not likely to have a direct impact on aquatic life, they can greatly influence the availability and solubility of chemical. A change in pH may increase the solubility of phosphorus, making it more available for plant growth. Fortunately, lake water is complex; it is full of chemical "shock absorbers" that prevent major changes in pH. Small or localized changes in pH are quickly modified by various chemical reactions.

In the August 28, 1996 memo from Alan Hallum (Watershed Protection Branch Chief) to Harold Reheis (EPD Director), given in Appendix B, the pH upper limit for West Point Lake was recommended to be 9.5 based on the West Point Lake Phase I Diagnostic/Feasibility Report. This criterion was adopted by the DNR Board and approved by EPA in 1995. The 1996 memo was used to support the adoption of similar criteria for other lakes.

6.0 DESIGNATED USE SUPPORT

Lakes Oconee and Sinclair have designated uses of recreation and drinking water. The proposed criteria have been modeled to protect the established designated uses for both lakes. Modeling has revealed the proposed criteria for Lakes Oconee and Sinclair, coupled with the point source nutrient management strategy, will protect existing designated uses and allows for a margin of safety. The margin of safety is critical so the proposed criteria will not be in violation immediately upon approval and to allow the fishery to adjust to the altered nutrient levels without disrupting the food web. It is believed that algal blooms will decrease as nutrient levels in discharges decrease, which will be required as part of the implementation of the point source management strategy. While there are past instances of elevated cyanobacteria cell counts, bloom events that produce toxins are rare in Georgia. Cell count alone is not a predictor of toxin production.

The downstream uses are either fishing or drinking water. At this time, the downstream waters do not have numeric nutrient criteria. However, the water quality criteria for these waters will be protected. GA EPD is currently working with the Environmental Protection Agency (EPA), the Science and Ecosystem Support Division (SESD), University of Georgia (UGA), and Coastal Resources Division (CRD) to develop a hydrodynamic water quality model that will be used to develop numeric nutrient criteria for the Altamaha Estuary, which is the terminus water downstream from Lakes Oconee and Sinclair.

6.1 Recreational Use Support

6.1.1 Lake Oconee

Lake Oconee boasts several marinas, campgrounds, recreation areas, and boat ramps. There have been no recreational closures due to algal blooms at any of the Georgia Power operated beaches (personal communication, Warren Wagner, III, Georgia Power).

In 2009, at the end of May and beginning of June, cyanobacteria blooms developed over a 600 acre area of Lake Oconee (see Figure 6-1). The bloom began in the Sugar Creek embayment, downstream of the confluence of Little Sugar Creek and Sugar Creek embayments on May 29th, spread into the main body of the lake, and began to dissipate a few days later on June 4th. Via microscopy, the bloom was observed to be Microcystis.

Figure 6-1. Lake Oconee, Sugar Creek Embayment, May 2009, Start of Bloom

Georgia Power collected phosphorus data at several locations just prior to the start of the bloom (see Figure 6-2).

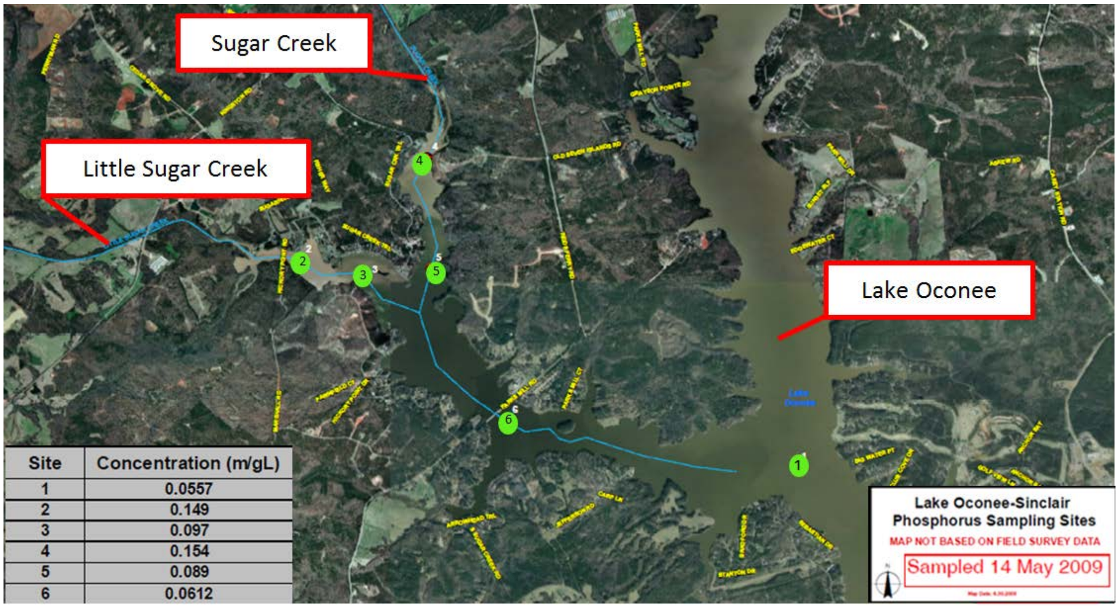


Figure 6-2. Lake Oconee Total Phosphorus Sampling Sites and Concentrations from May 2009, Just Prior to the 2009 Bloom Event

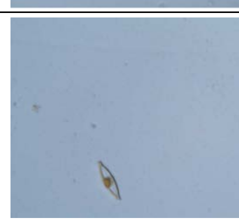
The measured phosphorus revealed that the shallowest, most upstream embayments had equally high concentration data. No source could be identified. Recreational beaches remained open during the bloom event, which did not fully dissipate for approximately a month and a half.

In September of 2011, there was an isolated, small scale event along the mid-lake to eastern shore of Lake Oconee opposite the Sugar Creek embayment. Samples were collected promptly and delivered to Dr. Kalina Manoylov of Georgia College and State University for analysis. Table 6-1 provides the results of her analysis, including algal species and count. She concluded the bloom was comprised predominantly of Microcystis aeruginosa Kutzing, followed by Anabaena species in both the linear and spiral morphologies. Additionally, Cylindrospermopsis raciborskii (Woloszynska) Seenayya et Subba-Raju, Peridinium, and two types of diatom were visualized in the samples. Based on cell density levels identified in the Guidelines for Safe Recreational Water Environments from World Health Organization (WHO), the relative probability of acute health effects for this bloom were considered high. However, WHO concludes that “measures of cyanobacterial cell density will not detect [toxicity] hazards,” meaning that cell count alone is not a predictor of toxin production. The bloom was brief and no toxins were analyzed for.

In mid-winter 2016 and 2017, a bloom was visually observed, but not sampled for toxicity testing, based on a personal communication with Anthony Dodd of Georgia Power. The bloom first began in the middle area of the Sugar Creek embayment and was identified via microscopy as Anabaena. The bloom was monitored by Georgia Power shoreline managers, who reported continuous observations until the bloom diminished.

The most recent bloom was first observed on March 17, 2017, in the Oconee Arm of the lake across from Old Salem Park (Tara Lane, Eatonton, GA). That same afternoon, Georgia Power delivered a sample to Dr. Manoylov for toxicity testing. Dr. Manoylov determined that the bloom consisted of the Cyanobacteria species Dolichospermum (Anabaena) flos-aquae (see Figure 6-3). Dolichospermum flos-aquae has been known to produce MCYST-LR in addition to anacystin

Table 6-1. Lake Oconee Algae Analysis, September 2011 Bloom Event

Name	Image (400x magnification)	Count
Microcystis aeruginosa Kutzing		482 million cells/100ml
Anabaena sp.		8 million cells/100 ml
Anabaena cf. affinis		6 million cells/100 ml
Cylindrospermopsis raciborskii (Woloszynska) Seenayya and Subba-Raju		2 million cells/100 ml
Peridinium sp. (Dinoflagellate)		> 500,000 cells/100 ml
Achnathidium minutissimum (Kutzing) Czarnecki (a diatom)		> 500,000 cells/100 ml
(Probably) Navicula sp. (a pennate diatom)		> 500,000 cells/100 ml

a. Dr. Manoylov tested for microcystin with the Abraxis kit and results indicated presence between 5 and 10 ppb, which exceeds the EPA recommended values for the recreation criteria and swimming advisories in the June 2017 document "Recommendations for Cyanobacteria and Cyanotoxin Monitoring in Recreational Waters." However, the Abraxis test is a screenoing tool only. Dolichospermum is a unique genus in that it can handle colder temperatures compared to Microcystis aeruginosa. The thought is that the cold snap, the week prior to the bloom event, gave the D. flos-aquae a competitive advantage and triggered the bloom condition.

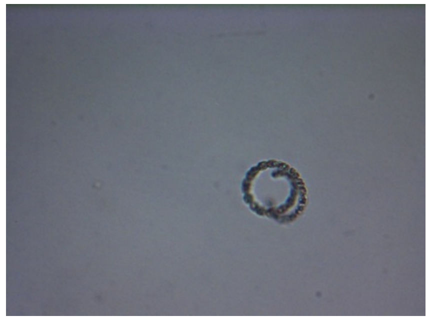


Figure 6-3. Dolichospermum (Anabaena) flos-aquae, a Type of Cyanobacteria, from the March 2017 Bloom Event

Another observation of very green water was made at the Georgia Power Company Sugar Creek boat ramp on Monday, March 20, 2017 (see Figure 6-4). The water surface showed no scum or thick film; however, a sample analyzed by Dr. Manoylov revealed the presence of D. flos-aquae in much lower numbers than previously identified (well below the recommendations from WHO for a low probability of acute health effects). This sample did contain a Haptophyte species, Prymnesium parvum, which has caused problems in Texas and Michigan. P. parvum can take over and produce toxins and has been associated with fish kills. Dr. Manoylov has documented P. parvum in Georgia twice before, both times in kaolin ponds. Fortunately, P. parvum was not abundant in the sample analyzed. According to Warren Wagner of Georgia Power, the bloom was "most intense throughout March [and exhibited] greener than usual conditions all the way through April. It wasn't until May that conditions [returned] fully back to normal." It is expected that algae will decrease as the proposed criteria are implemented.

Figure 6-4. Lake Oconee at the Sugar Creek Boat Ramp, March 2017

6.1.2 Lake Sinclair

Lake Sinclair boasts several campgrounds with beaches, including one that abuts the Sinclair National Forest. There are several marinas on the lake, as well as parks, fishing areas, and walking trails. Based on a personal communication with Warren Wagner III of Georgia Power, there have been no recreational closures due to algal blooms at any of the Georgia Power operated beaches.

Figure 6-5. Lake Sinclair, Small Cove in Oconee River Arm, August 2013, Start of Bloom

On August 21, 2013, a bloom was reported in a "pocket of water," just off of Sinclair Road, south of Scuffleboro Road, in the Oconee River Arm of Lake Sinclair (see Figure 6-5). Samples were sent to Dr. Manoylov, of Georgia College and State University and she immediately confirmed the bloom was non-toxic by finding live nematodes via microscopy. Dr. Manoylov identified the most prevalent species as Microcystis aeruginosa Kutzing (see Figure 6-6, magnified 400x), which is planktonic. Other species within the sample were identified as Chlamydomonas (a green flagellate genus of phytoplankton) and few other planktonic live taxa, together with 12 dead specimens: Botryococcus braunii Kützing (green algae colonial), Scenedesmus spinosus Chodat (green algae), Trachelomonas (Euglenophyta), and Carteria (flagellate green algae). Three genera of diatom were also found in the sample: Syneda, Gomphonema, and Fragilaria. One student on Dr. Manoylov's team described the high water mark on both sides of the stream as being stained with blue from the phycocyanin in the cyanobacterium. The student observed that a faint green line was visible from the road in the middle of the water in the cove, but that the green line in the water was not visible by boat inside of the cove. Anthony Dodd, of Georgia Power, tested for toxicity with *microcystin* strips and found the concentration of toxin less than 1 µg/L. This is well below the cyanotoxin value recommended in EPA's 2017 document and verifies Dr. Manoylov's findings that the bloom, while ugly, was not toxic. The short lived bloom began to dissipate two days later, on August 23, 2013.

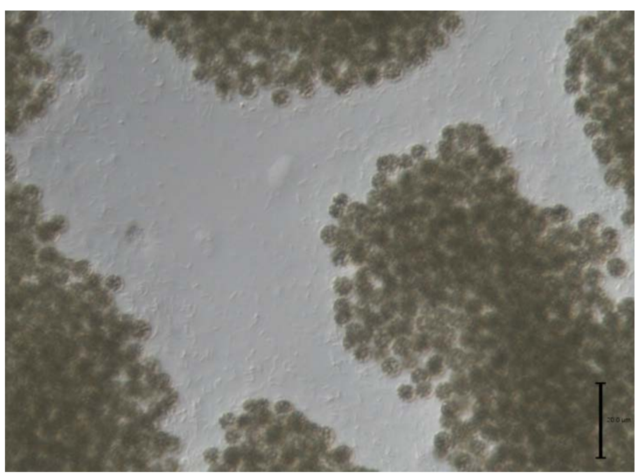


Figure 6-6. Microcystis aeruginosa Kutzing (Magnified 400x)

6.2 Fisheries Use Support

A significant decrease in nutrients and algal production could lead to a shift in the fisheries in Lakes Oconee and Sinclair. Via personal communique with Georgia Wildlife Resources Division (WRD) fisheries biologist, Brandon Baker, “Neither the sport fish nor the forage fish species in these reservoirs are considered sensitive species, biologically, and the proposed standards are within desirable ranges for sport fishes. There are, however, relationships between primary productivity and successful sport fisheries."

Ellis of WRD found gizzard shad abundance has decreased in Lake Jackson following successful efforts to reduce nutrient loading from its tributaries (Ellis, 1988). Similar findings were observed in Carter’s Lake. In 2012 Hakala of WRD observed a fish kill event that occurred after upgrades to a wastewater treatment plant upstream from the reservoir. It is believed the kill was associated with dietary deficiency related to decrease chlorophyll *a* levels (Hakala, 2012).

A shift in the black bass species from largemouth bass to spotted bass could result from a significant decrease in the nutrient levels and algal production, because spotted bass seem to have a competitive advantage over largemouth bass in clear, more infertile waters. This was seen in West Point Lake after the reduction of total phosphorus loads. It was found that largemouth bass have faster growth rates when the reservoir trophic levels increased. A similar situation exists at Lake Oconee where a small, nonnative, spotted bass population persists in the upper reaches of the lake and in the Oconee River - north to the Athens, GA area (personal communications with Chris Nelson, fisheries biologist for WRD). For additional data and references, please see Appendix C.

6.2.1 Lake Oconee Fisheries

Chris Nelson stated that “Lake Oconee is a highly productive reservoir, considering the standing stock and total biomass of fish it supports.” It is popular with anglers seeking to catch largemouth bass, black crappie, Morone species and catfish species; moreover, bass fishing tournaments and other fishing events are regular occurrences on the lake. The Fisheries section of WRD annually invests many resources, such as fish production at hatcheries for stocking, conducting fish habitat enhancement projects, and performing routine fish surveys to better understand and properly manage fish populations and their habitats in Lake Oconee.

Historical data shows that the overall profiles for temperature and dissolved oxygen are affected by dam operations, especially in the summertime due to generation and pump-backs cycles. Dam operation cycles during this time allow reservoir water to mix, resulting in warmer temperatures. This mixing, coupled with the somewhat shallow bathymetry of the reservoir, causes Oconee to lack cold-water habitats that would support any cold-water fish species. Dissolved oxygen profiles do exhibit higher saturation towards the surface and lower saturation deeper into the strata; however, dissolved oxygen concentrations remain suppressed because of reservoir mixing and its associated warmer water temperatures.

WRD Fisheries stocks both striped and hybrid bass species. The combined stocking rate for Morone species at Lake Oconee is 20 fish per acre per year, with a current ratio of 5 striped bass per acre per year and 15 hybrid-striped bass per acre per year. A shift in catfish populations have occurred over the past 15 years (see Figure 6-7). Non-native blue catfish were illegally introduced into Lake Oconee and the population increased over time. Native populations of channel and white catfish decreased. Flathead catfish, another illegally introduced non-native species, seem to have slightly increased. The establishment and continued growth of the blue catfish population is believed to be the result of blue catfish out-competing the native catfish species for resources, and predation on the native species.

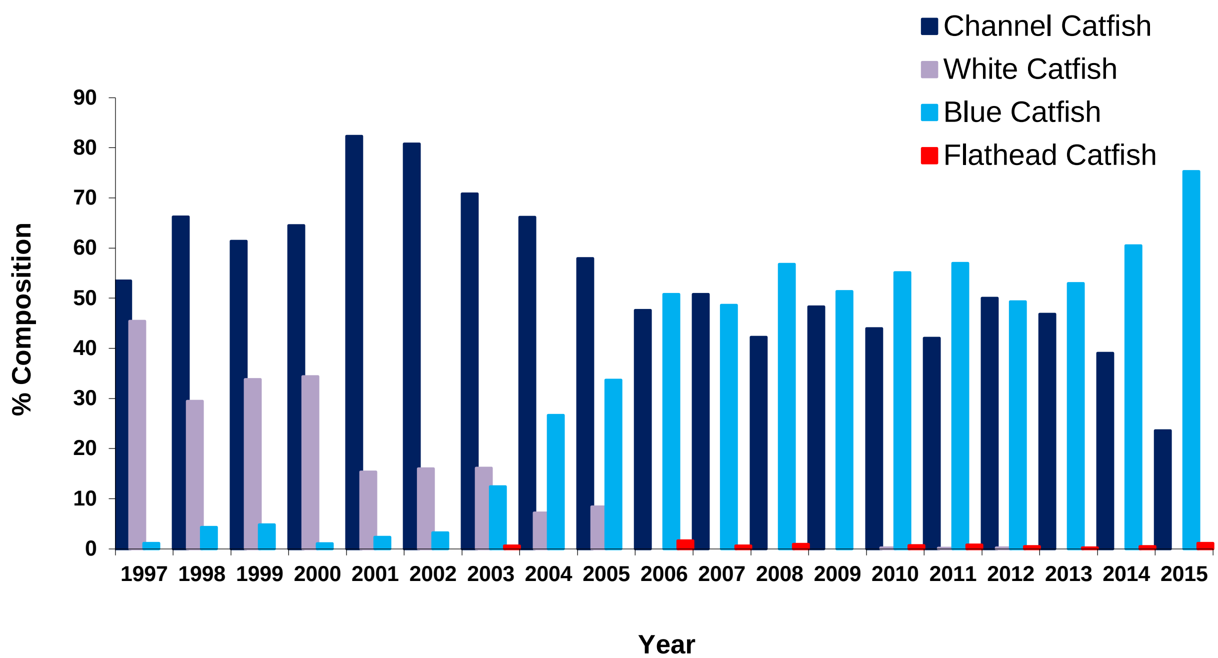


Figure 6-7. The Shift of Channel, White, Blue, and Flathead Catfish Populations in Lake Oconee between 1997 and 2015

According to Nelson, Oconee has experienced several localized fish kill events, which have occurred during the hot summer months over the past 10-15 years. Striped bass mortality during the summer months is not uncommon in lakes with limited or fluctuating refuge at depths where the water temperature is cool and dissolved oxygen is adequate. Though the events have been relatively localized and small scale, striped and hybrid bass populations can experience natural mortality events during the summer. A disease related common carp mortality event occurred in the spring of 2015. Nelson explained the event in a press release:

> "Common carp have been aggressively spawning at Lake Oconee over the last few weeks, resulting in additional energy consumption and stress, and weakening the fish's immune system allowing bacterial or viral infections to more readily occur, often causing fish death. Additionally, these spawning activities ensure that many carp are in constant contact with each other, allowing diseases to spread even more rapidly. Given that this die-off appears to affect this one species and water quality appears normal, we believe that this is a naturally occurring fish kill and of no alarm to anglers or lake visitors."

These statements are correlated by a response document generated by Georgia Power that pointed out similar events were recorded that spring (spawning time for this species) and that water quality had been checked and no concerning conditions identified, and monitoring would continue for the duration of the event.

Native plant species are being cultivated and transplanted into different, carefully chosen, areas of Lake Oconee as part of the Aquatic Plant Habitat projects. The plants incorporated into these projects include maiden cane (Panicum hemitomon), water willow (Justicia americana), pickerelweed (Pontederia cordata), potamogeton, strapleaf, American lotus (Nelumbo lutea), and others. The projects also include installation of rip-rap and spawning gravel. The goals are to improve shoreline stabilization, create fish habitat, reduce nutrients, displace and/or compete with non-native aquatic plants, and decrease sedimentation. Nelson emphasized the success of these projects over the past decade by reporting the numbers of aquatic plants planted at Lake Oconee and other numbers related to habitat and erosion control.

- Planted over 7,000 aquatic vegetation plants
- Planted over 200 bald cypress and water tupelo trees
- Installed over 1,500 tons of rip-rap
- Installed over 100 tons of fish spawning gravel

Moreover, WRD recently installed an aquatic vegetation greenhouse (via donations from Yamaha Motor Company) in Social Circle, GA which will allow an increase in native plant production.

6.2.2 Lake Sinclair Fisheries

Brandon Baker attributes the stability of the fish population at Lake Sinclair to the stable water levels. Figures 6-8 and 6-9 show proportional population size structures of black crappie and largemouth bass from 2007 and 2008, respectively, until 2017.

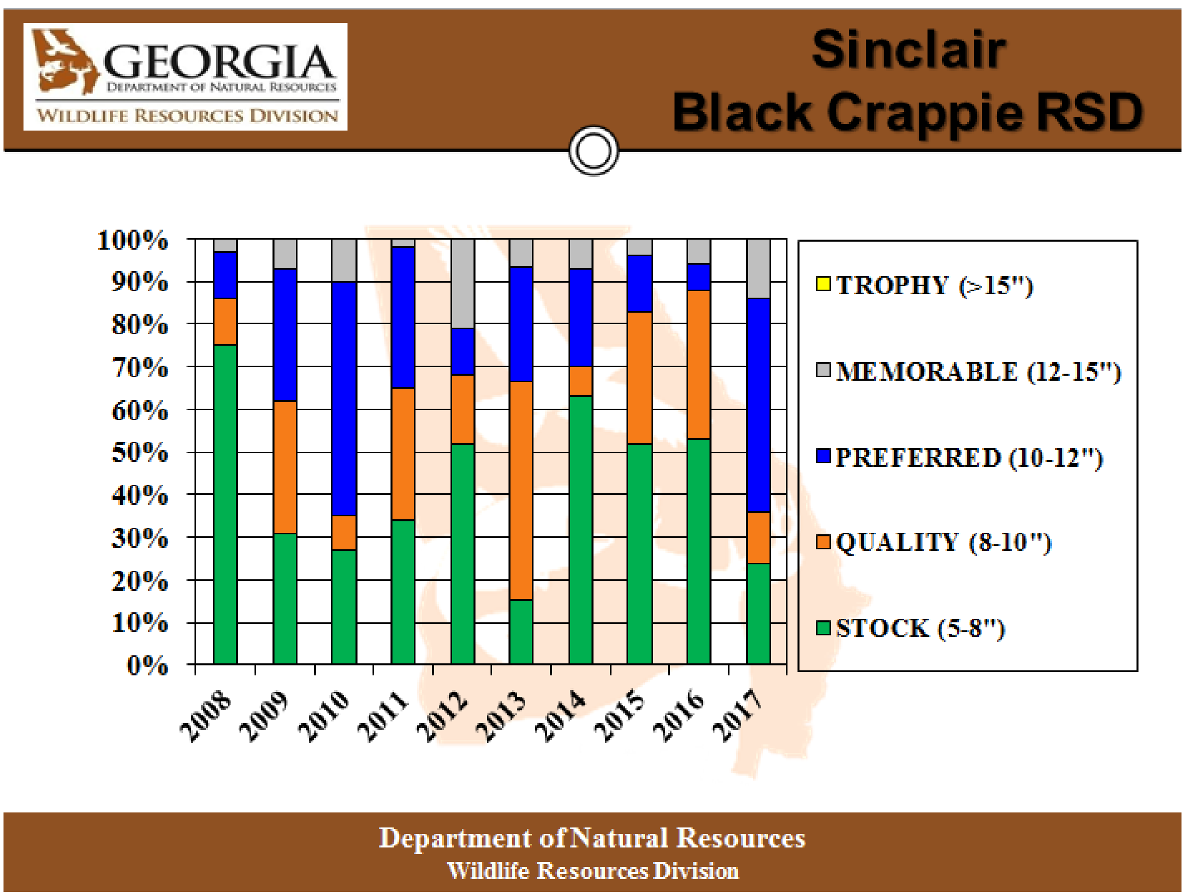


Figure 6-8. Population by Size of Black Crappie in Lake Sinclair from 2007 until 2017

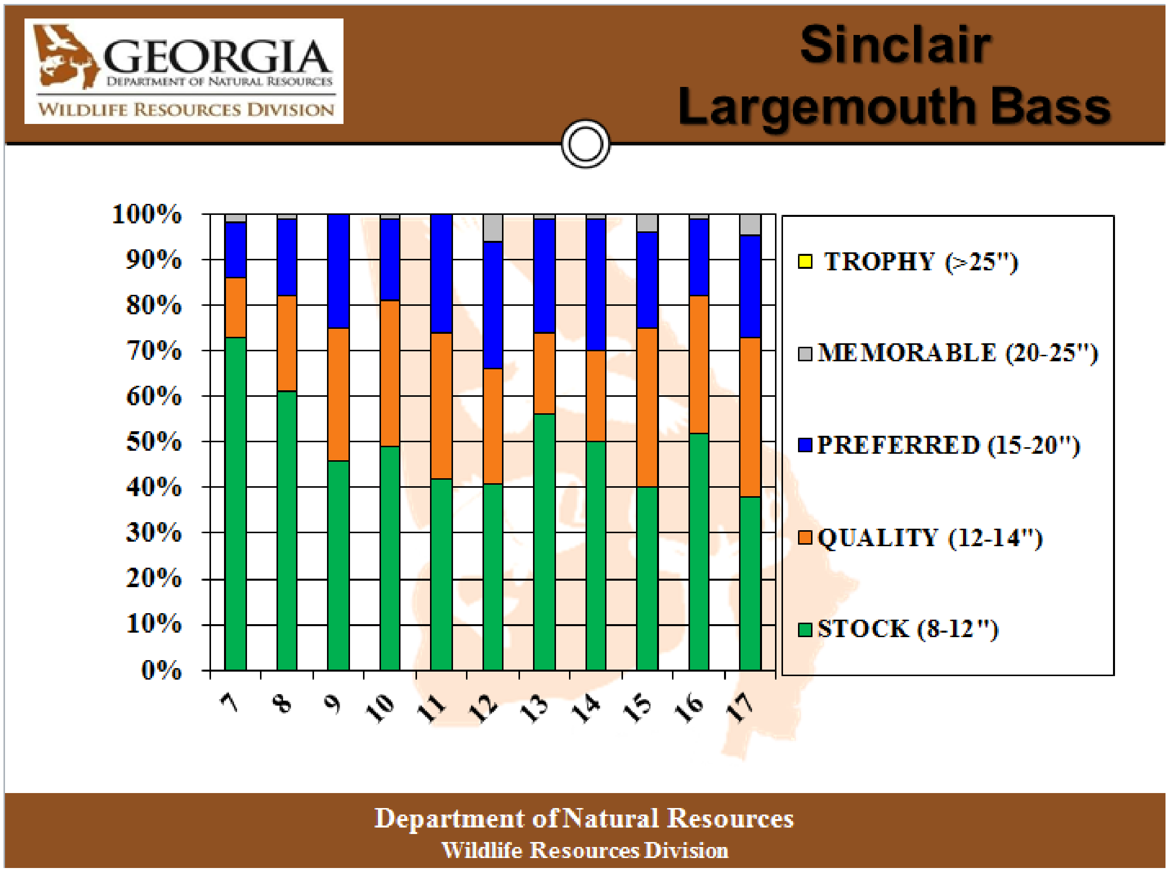


Figure 6-9. Population by Size of Largemouth Bass in Lake Sinclair from 2007 until 2017

Baker explained that crappie naturally have cyclic year classes (young of the year fish that survive), which means some years have an exceptionally high survival rate and most years are above or below the average. Approximately every three to five years, the black crappie population will have an above average spawning event where that year class of black crappie will comprise most of the lake population. Through the collection of routine standardized sampling data, fishery metric and indices are calculated to determine the status of a fish population. One of these indicators is called a condition factor, which allows a fish in one waterbody to be compared to a statewide average for a specific species. “The condition of the black crappie in Sinclair has remained close to the statewide average,” while “the largemouth bass sampled on Sinclair are, on average, slightly below the statewide average condition for largemouth bass.” Figure 6-10 shows the average sizes of bass by weight for the Georgia B.A.S.S. Chapter Federation Tournament from 1985 to 2016; average weights seem to consistently hover below two pounds, while tournament winning weights have been between 8 and 12 pounds.

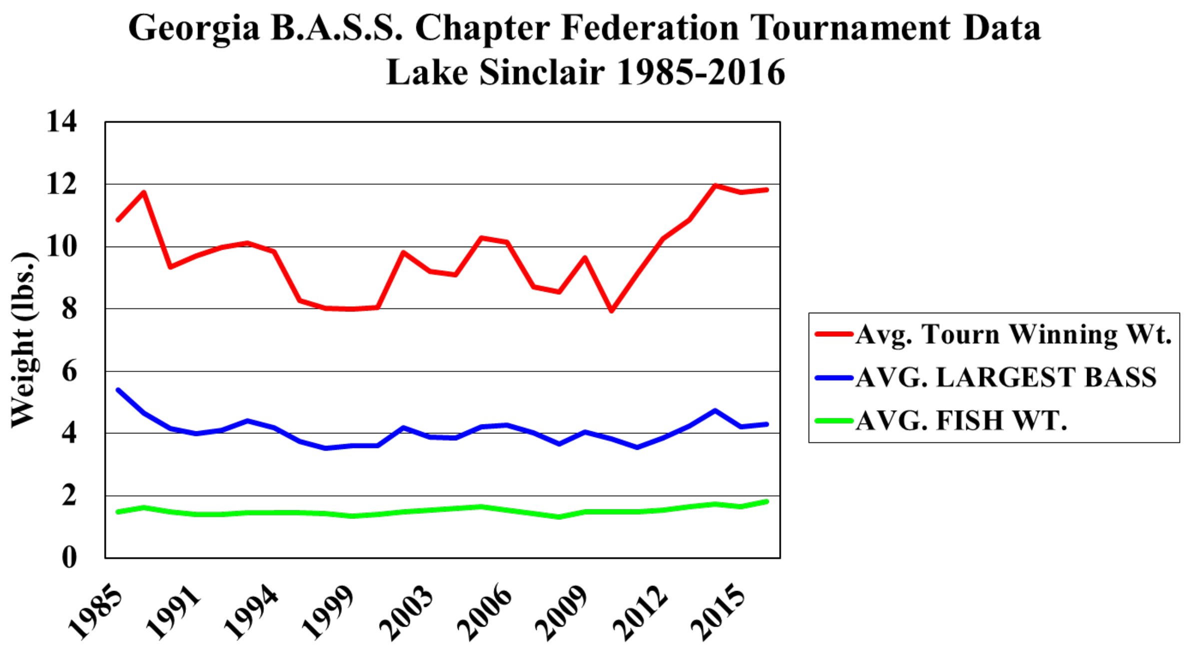


Figure 6-10. Average Sizes of Bass by Weight for the Georgia B.A.S.S. Chapter Federation Tournament from 1985 to 2016

The introduction of non-native blue catfish has affected the population of other catfish in Lake Sinclair. Baker describes blue catfish as a larger species than the native catfish. The establishment and continued growth of the blue catfish population is believed to be the result of blue catfish out-competing the native catfish species for resources, and predation on the native species. Figure 6-11 shows the blue catfish population growth, which increased dramatically from 2008 to 2010. According to Baker, the blue catfish population is believed to be stabilizing, meaning the blue catfish population is unlikely to experience another spike.

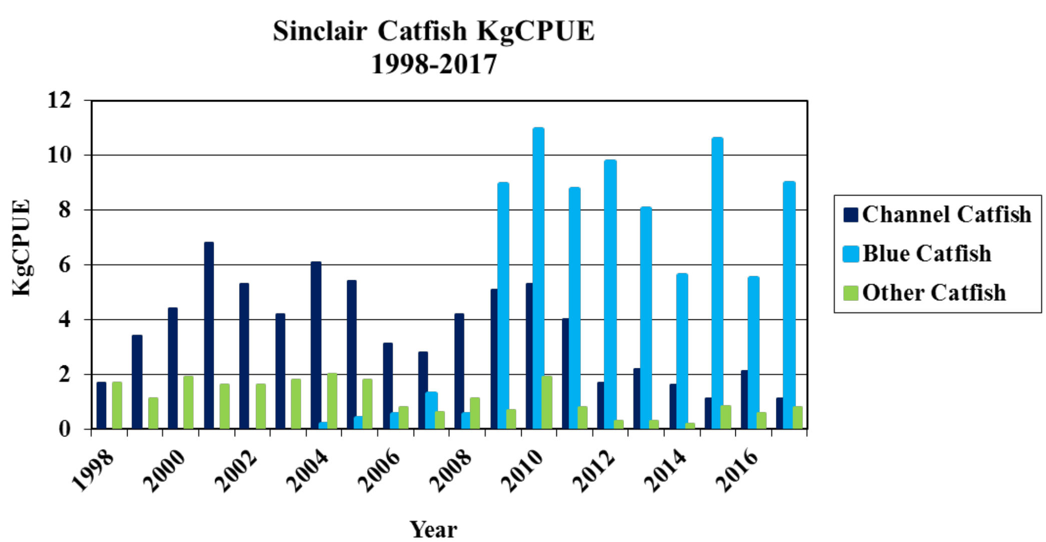


Figure 6-11. Catfish Population Shift in Lake Sinclair from 1998 to 2016

The dissolved oxygen (DO) profile on Lake Sinclair shows higher saturation towards the surface and lower saturation deeper into the strata, but only in areas located off of the mainstem. During the day, Wallace Dam releases water from Lake Sinclair into Lake Sinclair and at night, when energy costs are low, water from Lake Sinclair is pumped back into Lake Sinclair. Because of this, the areas near Sinclair Dam and the mainstem of the Sinclair Arm have consistently higher DO levels at deeper levels. Similar to Lake Oconee, Lake Sinclair is relatively shallow and lacks cold-water habitats for cold-water fish species. Baker pointed out that the fish biomass tends to follow the available nutrients in the lake, as shown in Figure 6-12. He stated that choosing the appropriate criteria for total phosphorus is critical for the health of the lake; too much of a decrease would result in a decrease in the fish biomass.

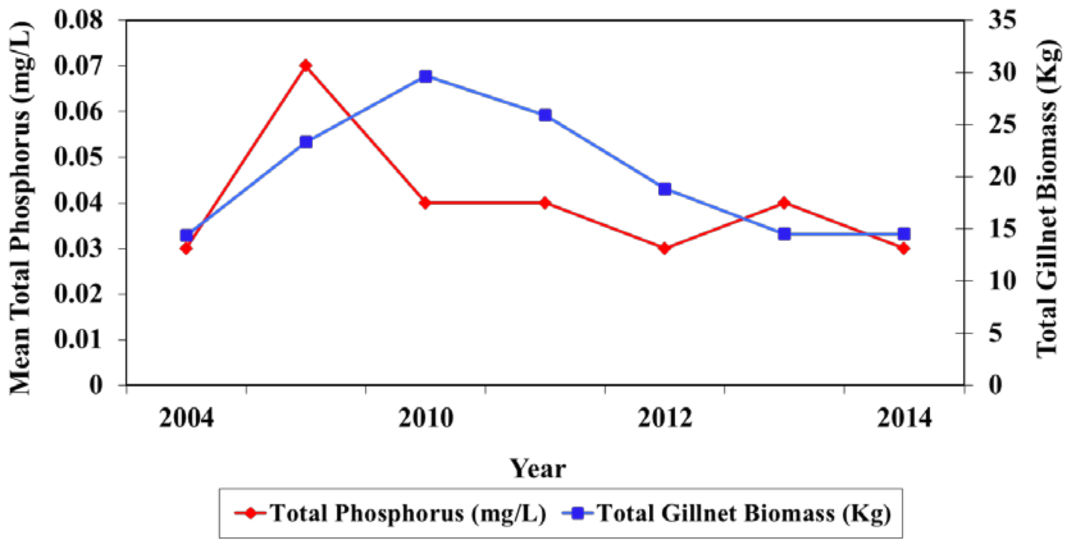


Figure 6-12. Fish Biomass Related to Available Nutrients in Lake Sinclair

WRD Fisheries stocks both striped and hybrid bass species in Lake Sinclair at a rate of 20 total fish per acre per year. Currently, the ratio is 5 striped bass per acre per year and 15 hybrid-striped bass per acre per year. The current stocking rate began in 2013 due to angler preference and recovery of native striped bass stocks in the lower Altamaha River. Over the past 13 years, WRD has stocked Lake Sinclair with 1,377,775 striped bass and 1,098,372 hybrid bass fish.

As part of the Aquatic Plant Habitat projects, native plant species are being cultivated and transplanted into Lake Sinclair to improve shoreline stabilization, create fish habitat, reduce nutrients, displace and/or compete with non-native aquatic plants, and decrease sedimentation. The plants incorporated into these projects include maiden cane (*Panicum hemitomon)*, water willow (*Justicia americana)*, pickerelweed (*Pontederia cordata)*, potamogeton, strapleaf and American lotus (*Nelumbo lutea*). According to Baker, these native plants have been introduced to different, carefully chosen, areas of Lake Sinclair. Many of the planting sites are thriving and have begun colonizing naturally since the projects began in 2005 (Figure 6-13).

Figure 6-13. Water Willow Planted by the Aquatic Plant Habitat Project

6.2.3 Appropriate Phosphorus Criteria

The maximum measured total phosphorus levels exceeding the proposed total phosphorus criteria in 2004 and 2010 informed the decision to propose a criterion of 0.2 mg/L. This proposal is supported by data from WRD Fisheries at Lakes Oconee and Sinclair which points to a clear link between total phosphorus and fish biomass; when nutrients decrease, a decrease in fish biomass follows shortly after. As the lakes are stocked and used for fishing tournaments, a decrease in fish biomass would be problematic. Moreover, WRD Fisheries is participating in Aquatic Plant Habitat projects, where native aquatic plants (natural nutrient processors) are being cultivated and planted.

Scientific literature supports the relationship between fish and total phosphorus. The Canadian Journal of Fisheries and Aquatic Sciences published a 1982 study by John Mark Hanson and William C. Leggett based on four datasets that showed a strong correlation between total phosphorus and fish biomass, compared to the relationship between macrobenthos biomass and fish biomass (Table 6-2).

Table 6-2. R2 of Total Phosphorus and Macrobenthos Biomass/Mean Depth as predictors of Fish Yield and Fish Biomass (Hanson and Leggett, 1982)

	R^2 of Total Phosphorus Concentration	R^2 of Macrobenthos Biomass/Mean Depth
Fish Yield	0.84	0.48
Fish Biomass	0.75	0.83

Total food-web health (phytoplankton, zooplankton, and fish) is also dependent on total phosphorus as a resource (Jeppesen, 2000). Jeppesen et al. published a study in Freshwater Biology that quantified the total phosphorus levels affecting species richness. The study involved examining 71 relatively shallow lakes (average depth of 3 meters) in Denmark for trophic structure, species richness, and biodiversity comparing different levels of total phosphorus. The phosphorus values were divided into five categories. Figure 6-13, shows the maximum fish biomass and species richness is found at phosphorus concentration between 0.1 – 0.2 mg/L.

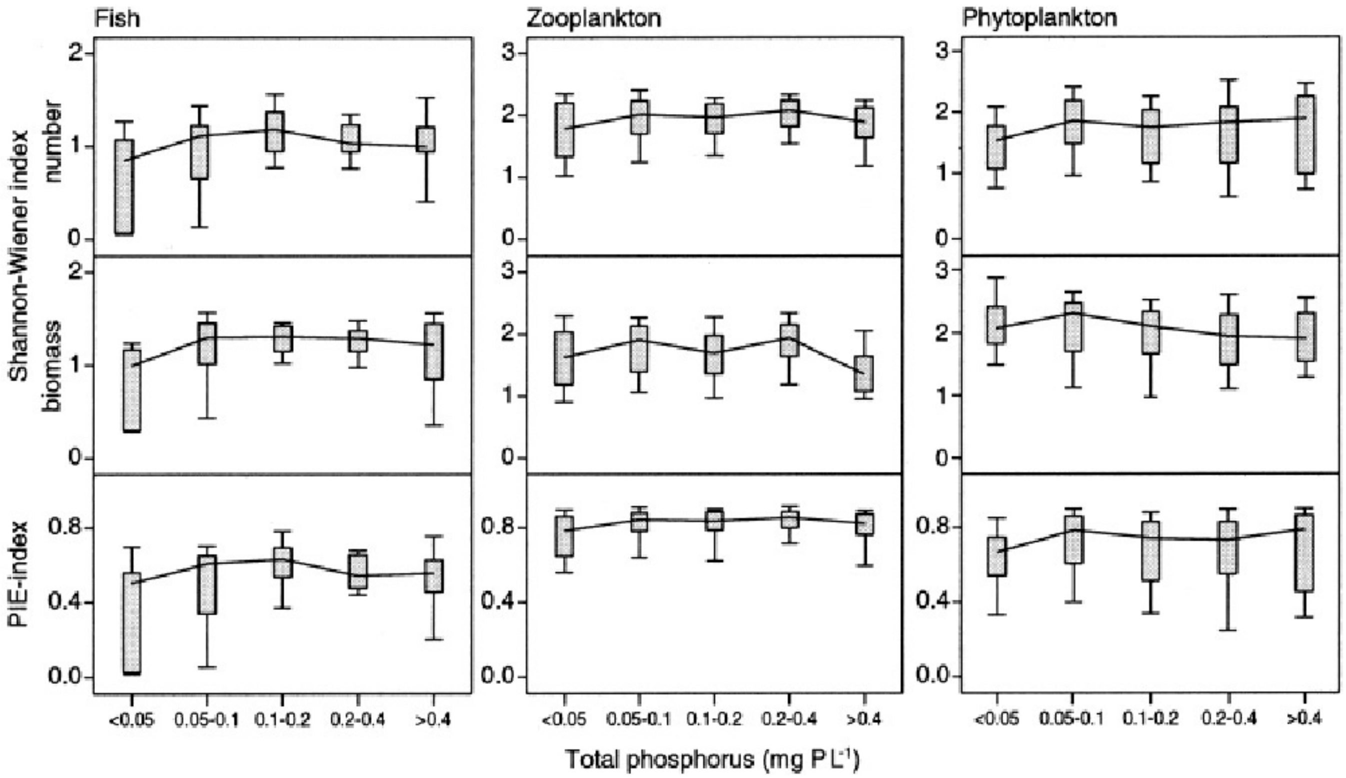


Figure 6-14. Box plot showing the Shannon–Wiener diversity index based on abundance (H′n) (middle) and biomass (H′w) (lower) and the Hurlbert PIE index (lower) for fish, zooplankton and phytoplankton (Jeppesen, 2000)

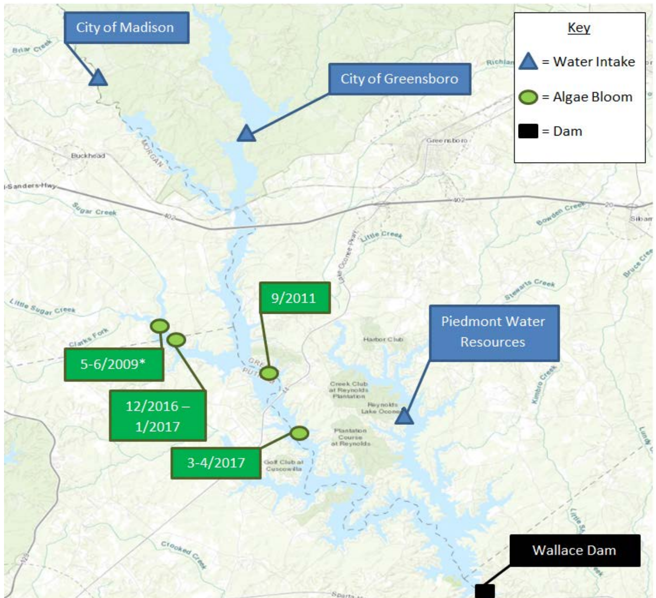
As Brandon Baker stated earlier, choosing the appropriate criteria for total phosphorus is critical for the health of the lake; too much of a decrease would result in a decrease in the fish biomass. In 2004 the average total phosphorus level measured in Lake Oconee at the Dampool exceeded 0.3 mg/L. Based on the findings from Jeppesen's study, EPD believes that the proposed criterion of 0.2 mg/L will support the lakes fisheries without causing a significant decline in fish biomass.

6.3 Drinking Water Source Use Support

6.3.1 Lake Oconee Intakes

Lake Oconee has three drinking water intakes; the City of Madison, the City of Greensboro, and Piedmont Water Resources (see Figure 6-14).

When asked about taste, color and odor problems, or increased treatment costs, none of these plants reported issues. Lamar Callaway explained that he hadn't had an issue with algae in the 33 years he has operated the Greensboro plant. Callaway mentioned that the bloom in 2011 caused him to look into treatment options, but the bloom dissipated before any action was necessary. As Lake Oconee tends to flow toward Wallace Dam, it is easy to see how each intake remained clear during each bloom event.



* The 2009 bloom encompassed Sugar Creek embayment out into the mainstem reservoir and downlake to the Cuscowilla golf course area. Before the bloom dissipated, there were bloom wind drifts throughout much of the lower reservoir to the dam.

Figure 6-15. Lake Oconee Drinking Water Intakes and Reported Algal Blooms

6.3.2 Lake Sinclair Intakes

There are two drinking water intakes in Lake Sinclair, City of Sparta and Sinclair Water Authority. The third intake is Georgia Power Plant Branch; however, according to Georgia EPD's records, the power generation ended in April 2015. The City of Sparta's intake is at 323.8 ft MSL. The minimum lake level for functionality is 331.0 ft MSL. There is a 7.2 ft MSL difference between minimum daily pond and cavitation. All three intakes are shown in Figure 6-15.

Figure 6-16. Lake Sinclair Water Intakes and the Reported Algal Bloom

When asked about issues related to algae, Joey Witcher, of Sinclair Water Authority, confirmed that warm months usually “bring on” blue-green blooms in both lakes. Direct cost increases come in the form of additional testing for cyanotoxins, as well as a one time purchase of algaecide. Witcher explained that the real cost is hidden within the price of treatment and ongoing cleaning. The Sinclair Water Authority plant operates membrane filtration, which is prone to build-up of both live and diatomaceous algae. Because of this, the Sinclair Water Authority plant has a more aggressive cleaning schedule than other water treatment plants in the area. In 2015, two Georgia College and State University students completed studies in an attempt to identify and quantify algae species in raw water samples. One student concluded that the samples contained 47% diatoms (mostly Aulacoseira), 21% green algae, and 16% cyanobacteria, while the other student’s samples consisted of 58.3% diatoms (also mostly Aulacoseira), 33.3% cyanobacteria, and 8.3% Euglenophyceae, a eukaryotic flagellate which shares characteristics of both plant and animal (see Figure 6-16). In 2017, taste and odor problems, largely caused by algae, necessitated feeding carbon into the system.

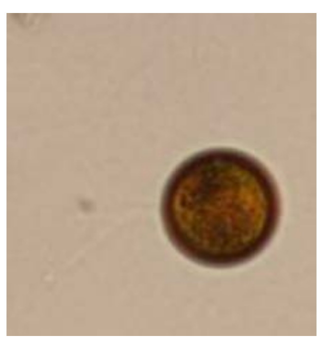


Figure 6-17. Euglenophyceae

The City of Sparta plant had significant taste and odor issues in early 2017. According to Shan Harper, who operates the water plant, the odor problems began at the end of January, and persisted in spite of repeatedly washing various filters, tanks, flushing lines, and feeding activated carbon into the system. Finally, in the middle of April, the City was able to add liquid permanganate with the accompanying feed equipment to resolve the issue. In late April, the media published an article about the incident, explaining the cause of the issue was the turning over of the lake and citing permanganate as the solution. Harper and his team checked in with the City of Milledgeville, as well as Putnam, Laurens, and Baldwin Counties. Each of the other communities said they also had taste and odor issues. Harper stated both the Sinclair River and Lake Sinclair continued to look green through the end of April.

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Fishing Use Support

GADNR WRD Fisheries Biologists (Chris Nelson; Brandon Baker) fisheries status on Lakes Oconee and Sinclair

Drinking Water Source Use Support

Greensboro Water Plant (Lamar Callaway)

Sinclair Water Authority (Joey Witcher)

City of Sparta Water Plant (Shan Harper)

EPD Watershed Protection Branch, Drinking Water Compliance and Permitting (Peter Nwogu; Lynn Ellis).

Lake Standards Designated Use Review and Assessment

This review was prepared by the DNR EPD Watershed Protection Branch, Watershed Planning & Monitoring Program. Contributors included Elizabeth Booth, Ph.D., Victoria Adams, & James Capp.

REFERENCES

GAEMN, 2009. GAEMN Homepage. 1 June 2009 http://www.griffin.uga.edu/aemn/

GA EPD, 1978. GA EPD Standard Practices. Georgia Environmental Protection Division, Atlanta, GA.

Hanson, John Mark and William C. Leggett . "Empirical Prediction of Fish Biomass and Yield." Canadian Journal of Fisheries and Aquatic Sciences, 1982, VOL. 39, NO. 2: PP. 257-263

Hook, J.E. Harrison, K.A. Hoogenboom, G. Thomas, D - Statewide irrigation monitoring, EPD cooperative agreement, 2004.

Hydological Simulation Program – FORTRAN (HSPF), 1996. HSPF Homepage. March 1997 https://www.epa.gov/ceam/hydrological-simulation-program-fortran-hspf

Inspectipedia, 2009. Septic Drainfield Design: Septic Size Requirements Guide. (http://www.inspectnyu.com/septic/fieldsize.htm).

Jeppesen, Erik, Jens Peder Jensen, Martin Søndergaard, Torben Lauridsen, and Frank Landkildehus. "Trophic structure, species richness and biodiversity in Danish lakes: changes along a phosphorus gradient." Freshwater Biology, 2000, VOL. 45, NO. 2: PP. 201-218

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Kingfisher Maps, Inc., Lake Sinclair – Map #304, Copyright © C0603304.

Tetra Tech, 2014. Watershed Hydrology and Water Quality Modeling Report for Upper Oconee Watershed, Georgia – REV2.

Tetra Tech, Inc. 2012. Hydrodynamic and Water Quality Modeling Report for Lake Oconee and Lake Sinclair, Georgia – REV1.

USEPA, 2007. BASINS Technical Note 1: Creating Hydraulic Function Tables for Reservoirs in BASINS. Office of Water, U.S. Environmental Protection Agency. Washington, DC.

USEPA, 2000. BASINS Technical Note 6. Estimating Hydrology and Hydraulic Parameters for HSPF. Office of Water, U.S. Environmental Protection Agency. Washington, DC.

USEPA, 2017. Recommendations for Cyanobacteria and Cyanotoxin Monitoring in Recreational Waters. Office of Water, U.S. Environmental Protection Agency. Washington, DC.

WHO. 2003. Guidelines for Safe Recreational Water Environments: Volume 1: Coastal and Fresh Waters. World Health Organization.

Appendix A
Water Quality Data

Lake Oconee Hwy 44 Bridge Oconee River Arm
2004 EPD Water Quality Monitoring Data

Date	Chlorophyll *a* (µg/L)	Total N (mg/L)	TKN (mg/L)	NH3 (mg/L)	NO2/NO3 (mg/L)	Total P (mg/L)	Ortho P (mg/L)	Fecal coliform (MPN/100 mL)	pH (SU)	DO (mg/L)	Water Temp (deg C)
03/23/04	20.00	1.01	0.36	<0.03	0.65	0.06	<0.04	NM	7.96	10.09	15.50
05/22/04	18.00	0.80	0.47	<0.03	0.33	0.04	<0.04	NM	7.49	8.59	21.79
08/23/04	43.00	0.60	0.57	<0.03	0.03	0.02	<0.04	<20	8.15	8.38	28.60
10/27/04	9.70	NM	NM	0.04	0.37	NM	<0.04	<20	6.80	5.80	20.59

Lake Oconee Hwy 44 Bridge Oconee River Arm
2009 EPD Water Quality Monitoring Data

Date	Chlorophyll *a* (µg/L)	Total N (mg/L)	TKN (mg/L)	NH3 (mg/L)	NO2/NO3 (mg/L)	Total P (mg/L)	Ortho P (mg/L)	Fecal coliform (MPN/100 mL)	pH (SU)	DO (mg/L)	Water Temp (deg C)
03/10/09	11.00	1.30	0.82	0.04	0.48	0.14	<0.04	20	7.47	9.46	12.68
04/30/09	9.20	1.04	0.62	0.17	0.42	0.08	<0.04	<20	6.83	7.31	20.80
05/19/09	26.00	0.84	0.76	0.15	0.08	0.09	<0.04	20	7.08	7.58	22.91
06/17/09	68.00	<0.3	<0.3	<0.03	<0.03	0.15	<0.04	<20	8.77	9.16	29.31
07/15/09	6.80	0.55	0.40	0.06	0.15	0.13	<0.04	<20	7.18	3.77	29.34
08/12/09	17.00	0.53	0.46	<0.03	0.07	0.04	<0.04	<20	6.64	6.59	30.28
09/17/09	12.00	0.41	0.41	<0.03	<0.03	0.03	<0.04	80	6.92	5.63	26.66
10/22/09	2.15	0.99	0.58	0.11	0.41	0.13	<0.04	<20	7.48	5.86	16.82

Lake Oconee Hwy 44 Bridge Oconee River Arm
2010 EPD Water Quality Monitoring Data

Date	Chlorophyll *a* (µg/L)	Total N (mg/L)	TKN (mg/L)	NH3 (mg/L)	NO2/NO3 (mg/L)	Total P (mg/L)	Ortho P (mg/L)	Fecal coliform (MPN/100 mL)	pH (SU)	DO (mg/L)	Water Temp (deg C)
04/07/10	6.47	0.91	0.34	0.04	0.57	0.04	<0.04	<20	7.23	9.72	19.77
05/05/10	12.63	<0.57	<0.2	0.20	0.37	0.05	<0.04	<20	7.80	9.79	23.07
06/08/10	14.21	0.66	0.35	0.13	0.31	0.05	<0.04	<20	7.01	6.95	27.83
07/13/10	5.57	0.47	0.32	<0.03	0.15	0.05	<0.04	20	6.72	5.29	30.99
08/10/10	7.25	0.29	0.22	0.06	0.07	0.26	<0.04	<20	7.07	5.62	31.59
09/30/10	15.06	0.33	0.26	<0.03	0.07	0.04	NM	<20	6.71	6.04	26.19
10/12/10	21.26	0.35	0.32	<0.03	0.03	<0.02	NM	<20	7.77	8.51	24.17

Lake Oconee Hwy 44 Bridge Oconee River Arm
2011 EPD Water Quality Monitoring Data

Date	Chlorophyll *a* (μg/L)	Total N (mg/L)	TKN (mg/L)	NH3 (mg/L)	NO2/NO3 (mg/L)	Total P (mg/L)	Ortho P (mg/L)	Fecal coliform (MPN/100 mL)	pH (SU)	DO (mg/L)	Water Temp (deg C)
04/26/11	4.3	0.36	0.34	<0.03	0.02	0.06	NM	<20	7.27	6.71	21.22
05/23/11	19	<0.23	<0.2	<0.03	<0.03	0.05	NM	<20	8.14	8.20	26.35
06/21/11	12	0.44	0.44	<0.03	<0.03	0.04	NM	<20	7.75	8.42	28.48
07/13/11	24	0.49	0.49	<0.03	<0.03	0.05	NM	<20	7.65	6.67	32.44
08/10/11	27	0.44	0.44	<0.03	<0.03	0.05	NM	<20	7.19	NM	29.73
09/13/11	15.06	0.41	0.41	<0.03	<0.03	0.04	NM	<20	6.83	6.53	26.22
10/13/11	17	0.4	0.40	<0.03	<0.03	0.04	NM	20	NM	NM	NM

Lake Oconee Hwy 44 Bridge Oconee River Arm
2012 EPD Water Quality Monitoring Data

Date	Chlorophyll *a* (μg/L)	Total N (mg/L)	TKN (mg/L)	NH3 (mg/L)	NO2/NO3 (mg/L)	Total P (mg/L)	Ortho P (mg/L)	Fecal coliform (MPN/100 mL)	pH (SU)	DO (mg/L)	Water Temp (deg C)
04/17/12	4.3	0.19	<0.2	<0.03	0.19	0.02	0.03	<20	6.96	6.51	20.30
05/22/12	7	<0.23	<0.2	<0.03	<0.03	<0.02	0.03	<20	6.49	5.35	23.53
06/21/12	3.57	0.36	0.3	<0.03	0.06	0.02	0.02	<20	6.67	5.93	27.15
08/01/12	7.4	0.4	0.33	<0.03	0.07	0.03	0.03	<20	7.05	5.12	30.26
08/27/12	7	0.36	0.31	<0.03	0.05	0.04	0.03	20	6.38	6.64	29.11
09/26/12	5.24	0.27	0.22	<0.03	0.05	0.02	0.02	<20	6.61	6.10	26.26
10/16/12	8.7	0.22	0.2	<0.03	0.02	0.02	0.02	<20	7.04	8.24	23.88

Lake Oconee Richland Creek Arm
2004 EPD Water Quality Monitoring Data

Date	Chlorophyll *a* (µg/L)	Total N (mg/L)	TKN (mg/L)	NH3 (mg/L)	NO2/NO3 (mg/L)	Total P (mg/L)	Ortho P (mg/L)	Fecal coliform (MPN/100 mL)	pH (SU)	DO (mg/L)	Water Temp (deg C)
03/23/04	18.00	0.70	0.44	<0.03	0.26	0.05	<0.04	NM	8.42	10.70	14.18
05/22/04	13.00	0.95	0.63	<0.03	0.32	0.03	<0.04	NM	7.61	8.42	20.99
08/23/04	4.30	0.39	0.35	<0.03	0.04	0.03	<0.04	<20	7.84	7.69	29.50
10/27/04	10.00	NM	NM	<0.03	0.28	NM	<0.04	<20	6.87	6.48	21.83

Lake Oconee Richland Creek Arm
2009 EPD Water Quality Monitoring Data

Date	Chlorophyll *a* (µg/L)	Total N (mg/L)	TKN (mg/L)	NH3 (mg/L)	NO2/NO3 (mg/L)	Total P (mg/L)	Ortho P (mg/L)	Fecal coliform (MPN/100 mL)	pH (SU)	DO (mg/L)	Water Temp (deg C)
3/10/09	16.00	1.14	0.89	0.04	0.25	0.06	<0.04	<20	8.52	11.79	15.45
4/30/09	18.00	0.99	0.83	0.17	0.16	0.06	<0.04	<20	8.47	9.69	22.55
5/19/09	12.00	0.68	0.51	0.12	0.17	0.05	<0.04	<20	6.84	7.64	21.61
6/17/09	37.00	0.60	0.60	<0.03	<0.03	0.09	<0.04	<20	9.02	9.41	29.72
7/15/09	10.00	0.45	0.38	0.04	0.07	0.11	<0.04	<20	7.56	6.51	29.62
8/12/09	12.00	0.44	0.35	<0.03	0.09	0.07	<0.04	<20	7.75	7.71	30.55
9/17/09	6.40	0.39	0.27	<0.03	0.12	0.01	<0.04	<20	6.7	5.20	27.06
10/22/09	6.8	0.60	0.3	<0.03	0.3	0.06	<0.04	<20	6.48	6.07	20.80

Lake Oconee Richland Creek Arm
2010 EPD Water Quality Monitoring Data

Date	Chlorophyll *a* (µg/L)	Total N (mg/L)	TKN (mg/L)	NH3 (mg/L)	NO2/NO3 (mg/L)	Total P (mg/L)	Ortho P (mg/L)	Fecal coliform (MPN/100 mL)	pH (SU)	DO (mg/L)	Water Temp (deg C)
04/07/10	10.44	0.72	0.30	<0.03	0.42	0.05	<0.04	<20	7.47	10.34	20.89
05/05/10	4.19	0.58	0.26	<0.03	0.32	0.04	<0.04	<20	7.72	9.82	23.89
06/08/10	9.83	0.55	0.32	<0.03	0.23	0.04	<0.04	<20	8.34	9.22	28.51
07/13/10	7.05	0.33	0.21	<0.03	0.12	<0.02	<0.04	<20	7.61	8.05	30.92
08/10/10	1.75	<0.28	<0.2	<0.03	0.08	<0.02	<0.04	<20	7.72	7.95	31.97
09/30/10	9.29	0.29	0.25	0.04	0.04	0.02	NM	<20	6.83	5.75	27.02
10/12/10	11.4	0.06	<0.2	<0.03	0.06	<0.02	NM	<20	7.18	7.54	24.75

Lake Oconee Richland Creek Arm
2011 EPD Water Quality Monitoring Data

Date	Chlorophyll *a* (µg/L)	Total N (mg/L)	TKN (mg/L)	NH3 (mg/L)	NO2/NO3 (mg/L)	Total P (mg/L)	Ortho P (mg/L)	Fecal coliform (MPN/100 mL)	pH (SU)	DO (mg/L)	Water Temp (deg C)
04/26/11	NM	0.74	0.40	<0.03	0.34	0.03	NM	<20	8.36	10.81	22.38
05/23/11	7.9	0.64	0.46	<0.03	0.18	0.06	NM	<20	8.79	13.06	26.72
06/21/11	8.9	0.41	0.29	<0.03	0.12	0.03	NM	<20	8.87	10.01	29.53
07/13/11	9	<0.24	<0.2	<0.03	0.04	0.02	NM	20	7.70	9.31	32.05
08/10/11	10	0.04	<0.2	<0.03	0.04	<0.02	NM	NM	6.74	6.47	31.19
09/13/11	12	0.33	0.29	<0.03	0.04	0.03	NM	NM	6.64	8.20	22.50
10/13/11	3.9	<0.24	<0.2	<0.03	0.04	0.02	NM	NM	6.64	7.67	22.53

Lake Oconee Richland Creek Arm
2012 EPD Water Quality Monitoring Data

Date	Chlorophyll *a* (µg/L)	Total N (mg/L)	TKN (mg/L)	NH3 (mg/L)	NO2/NO3 (mg/L)	Total P (mg/L)	Ortho P (mg/L)	Fecal coliform (MPN/100 mL)	pH (SU)	DO (mg/L)	Water Temp (deg C)
04/17/12	14	0.11	<0.2	<0.03	0.11	0.02	NM	<20	8.49	9.23	20.89
05/22/12	7.04	<0.22	<0.2	<0.03	0.03	<0.02	NM	<20	8.14	8.09	25.51
06/21/12	7.1	0.39	0.36	<0.03	0.03	0.02	NM	<20	8.23	9.37	28.96
08/01/12	5.8	0.27	0.25	<0.03	0.02	0.03	NM	<20	7.45	6.61	30.83
08/27/12	12	0.42	0.40	<0.03	0.02	0.04	NM	<20	6.38	6.64	29.11
09/26/12	9.24	0.21	0.21	<0.03	<0.03	0.02	NM	<20	6.62	6.60	26.59
10/16/12	10	0.32	0.32	<0.03	<0.03	0.02	NM	<20	NM	NM	NM

Lake Oconee Dam Pool
2004 EPD Water Quality Monitoring Data

Date	Chlorophyll *a* (µg/L)	Total N (mg/L)	TKN (mg/L)	NH3 (mg/L)	NO2/NO3 (mg/L)	Total P (mg/L)	Ortho P (mg/L)	Fecal coliform (MPN/100 mL)	pH (SU)	DO (mg/L)	Water Temp (deg C)
03/23/04	22	0.97	0.47	<0.03	0.52	0.04	<0.04	NM	8.35	11.04	13.86
05/22/04	14	0.88	0.45	<0.03	0.43	<0.02	<0.04	NM	7.34	8.45	22.00
08/23/04	4.30	0.38	0.29	<0.03	0.09	0.87	<0.04	<20	7.56	7.12	29.87
10/27/04	9.70	NM	NM	<0.03	0.38	NM	<0.04	<20	6.81	6.25	22.47

Lake Oconee Dam Pool
2009 EPD Water Quality Monitoring Data

Date	Chlorophyll *a* (µg/L)	Total N (mg/L)	TKN (mg/L)	NH3 (mg/L)	NO2/NO3 (mg/L)	Total P (mg/L)	Ortho P (mg/L)	Fecal coliform (MPN/100 mL)	pH (SU)	DO (mg/L)	Water Temp (deg C)
03/10/09	14.00	0.84	0.50	0.04	0.34	0.05	<0.04	<20	7.64	11.16	12.05
04/30/09	3.60	1.02	0.62	0.20	0.40	0.09	<0.04	<20	7.05	6.48	18.02
05/19/09	9.80	0.82	0.50	0.13	0.32	0.08	<0.04	<20	6.97	6.23	20.76
06/17/09	21.00	<0.32	<0.2	<0.03	0.12	0.09	<0.04	<20	7.79	5.53	26.88
07/15/09	5.60	0.58	0.46	0.06	0.12	0.06	<0.04	<20	6.31	3.90	28.62
08/12/09	4.20	0.51	0.31	<0.03	0.20	0.08	<0.04	<20	6.53	4.76	29.48
09/17/09	4.20	0.40	0.26	<0.03	0.14	<0.02	<0.04	<20	6.75	5.94	26.86
10/22/09	5.5	0.74	0.32	<0.03	0.42	0.07	<0.04	<20	6.46	5.79	20.24

Lake Oconee Dam Pool
2010 EPD Water Quality Monitoring Data

Date	Chlorophyll *a* (µg/L)	Total N (mg/L)	TKN (mg/L)	NH3 (mg/L)	NO2/NO3 (mg/L)	Total P (mg/L)	Ortho P (mg/L)	Fecal coliform (MPN/100 mL)	pH (SU)	DO (mg/L)	Water Temp (deg C)
4/7/10	14.42	0.87	0.30	<0.03	0.57	0.05	<0.04	<20	7.23	10.12	19.34
5/5/10	5.57	0.65	0.24	<0.03	0.41	0.04	<0.04	<20	7.71	10.16	21.89
6/8/10	3.27	0.52	0.26	<0.03	0.26	0.03	<0.04	<20	7.93	8.81	28.07
7/13/10	1.86	0.44	0.23	<0.03	0.21	0.03	<0.04	20	6.42	4.12	29.65
8/10/10	3.70	<0.32	<0.2	<0.03	0.12	<0.02	<0.04	20	6.77	5.01	31.23
9/30/10	5.03	<0.30	<0.2	<0.03	0.10	0.02	NM	40	6.92	6.08	26.85
10/12/10	8.96	<0.27	<0.2	<0.03	0.07	<0.02	NM	<20	6.92	7.36	24.35

Lake Oconee Dam Pool
2011 EPD Water Quality Monitoring Data

Date	Chlorophyll *a* (μg/L)	Total N (mg/L)	TKN (mg/L)	NH3 (mg/L)	NO2/NO3 (mg/L)	Total P (mg/L)	Ortho P (mg/L)	Fecal coliform (MPN/100 mL)	pH (SU)	DO (mg/L)	Water Temp (deg C)
04/26/11	NM	0.78	0.27	0.03	0.51	0.04	NM	<20	6.41	6.78	18.62
05/23/11	7.6	0.53	0.28	<0.03	0.25	0.04	NM	<20	8.67	11.77	27.45
06/21/11	9.7	0.39	0.21	<0.03	0.18	0.03	NM	<20	6.89	6.51	27.31
07/13/11	6.8	<0.27	<0.2	<0.03	0.07	0.03	NM	<20	7.81	9.31	32.24
08/10/11	NM	0.29	0.21	<0.03	0.08	0.03	NM	20	6.77	5.01	31.23
09/13/11	12	<0.26	<0.2	<0.03	0.06	0.03	NM	<20	6.92	6.95	27.25
10/13/11	7.8	<0.28	<0.2	<0.03	0.08	0.03	NM	<20	6.46	7.67	22.53

Lake Oconee Dam Pool
2012 EPD Water Quality Monitoring Data

Date	Chlorophyll *a* (μg/L)	Total N (mg/L)	TKN (mg/L)	NH3 (mg/L)	NO2/NO3 (mg/L)	Total P (mg/L)	Ortho P (mg/L)	Fecal coliform (MPN/100 mL)	pH (SU)	DO (mg/L)	Water Temp (deg C)
04/17/12	4.3	<0.39	<0.2	<0.03	0.19	0.02	0.03	<20	6.96	6.51	20.30
05/22/12	7	<0.22	<0.2	<0.03	<0.03	<0.02	0.03	<20	6.49	5.35	23.53
06/21/12	3.57	0.36	0.3	<0.03	0.06	0.02	0.02	<20	6.67	5.93	27.15
08/01/12	7.4	0.4	0.33	<0.03	0.07	0.03	0.03	<20	7.05	5.12	30.26
08/27/12	7	0.36	0.31	<0.03	0.05	0.04	0.03	20	6.38	6.64	29.11
09/26/12	5.24	0.27	0.22	<0.03	0.05	0.02	0.02	<20	6.61	6.10	26.26
10/16/12	8.7	0.22	0.2	<0.03	0.02	0.02	0.02	<20	7.04	8.24	23.88

Lake Sinclair Oconee River Arm
2004 EPD Water Quality Monitoring Data

Date	Chlorophyll *a* (µg/L)	Total N (mg/L)	TKN (mg/L)	NH3 (mg/L)	NO2/NO3 (mg/L)	Total P (mg/L)	Ortho P (mg/L)	Fecal coliform (MPN/100 mL)	pH (SU)	DO (mg/L)	Water Temp (deg C)
03/25/04	20	0.74	0.38	<0.03	0.36	0.03	<0.04	NM	7.80	10.02	17.40
06/15/04	13	0.39	0.25	<0.03	0.14	0.03	<0.04	NM	6.95	6.20	29.63
08/10/04	<1	0.47	0.37	<0.03	0.10	0.03	<0.04	20	6.78	5.55	31.13
11/08/04	7.4	NM	NM	0.04	0.26	NM	<0.04	20	6.90	6.63	22.38

Lake Sinclair Oconee River Arm
2009 EPD Water Quality Monitoring Data

Date	Chlorophyll *a* (µg/L)	Total N (mg/L)	TKN (mg/L)	NH3 (mg/L)	NO2/NO3 (mg/L)	Total P (mg/L)	Ortho P (mg/L)	Fecal coliform (MPN/100 mL)	pH (SU)	DO (mg/L)	Water Temp (deg C)
03/10/09	6.40	0.71	0.55	0.05	0.16	0.07	<0.04	40	7.45	9.88	15.53
04/30/09	7.20	0.82	0.5	0.08	0.32	0.08	<0.04	<20	6.72	7.23	6.72
05/13/09	8.90	0.99	0.66	0.20	0.33	0.08	<0.04	<20	6.84	5.68	24.25
06/16/09	7.40	<0.37	<0.2	<0.03	0.17	0.17	<0.04	20	6.73	5.18	30.52
07/14/09	6.00	0.43	0.28	<0.03	0.15	0.12	<0.04	<20	6.62	4.9	31.62
08/04/09	2.70	<0.35	<0.2	<0.03	0.15	0.06	0.12	40	6.84	5.06	31.50
09/17/09	3.10	0.36	0.27	<0.03	0.09	0.01	<0.04	<20	6.9	5.83	28.82
10/20/09	4.80	0.53	0.26	<0.03	0.27	0.03	<0.04	<20	6.56	5.79	21.16

Lake Sinclair Oconee River Arm
2010 EPD Water Quality Monitoring Data

Date	Chlorophyll *a* (µg/L)	Total N (mg/L)	TKN (mg/L)	NH3 (mg/L)	NO2/NO3 (mg/L)	Total P (mg/L)	Ortho P (mg/L)	Fecal coliform (MPN/100 mL)	pH (SU)	DO (mg/L)	Water Temp (deg C)
04/08/10	3.38	0.61	0.28	<0.03	0.33	0.05	<0.04	<20	6.61	8.60	19.53
05/06/10	2.43	<0.49	<0.2	<0.03	0.29	0.04	<0.04	<20	6.88	7.97	24.66
06/10/10	1.84	0.47	0.26	<0.03	0.21	0.05	<0.04	<20	6.83	6.09	29.55
07/15/10	3.36	<0.35	<0.2	<0.03	0.15	0.03	<0.04	20	7.13	5.70	32.44
08/12/10	2.31	0.38	0.28	<0.03	0.1	<0.02	<0.04	20	7.11	6.27	33.51
09/29/10	6.5	<0.25	<0.2	<0.03	0.05	<0.02	<0.04	80	6.92	6.12	29.21
10/27/10	8.8	0.25	0.25	<0.03	<0.03	<0.02	<0.04	20	6.60	7.24	24.73

Lake Sinclair Oconee River Arm
2011 EPD Water Quality Monitoring Data

Date	Chlorophyll *a* (μg/L)	Total N (mg/L)	TKN (mg/L)	NH3 (mg/L)	NO2/NO3 (mg/L)	Total P (mg/L)	Ortho P (mg/L)	Fecal coliform (MPN/100 mL)	pH (SU)	DO (mg/L)	Water Temp (deg C)
04/07/11	8.4	<0.5	<0.2	<0.03	0.3	0.04	NM	40	6.97	8.64	16.84
05/04/11	5.8	<0.44	<0.2	0.03	0.24	0.06	NM	<20	6.88	7.00	23.76
06/23/11	12	<0.33	<0.2	<0.03	0.13	0.04	NM	21	6.83	5.16	31.13
07/18/11	7.4	<0.32	<0.2	<0.03	0.12	0.04	NM	<20	7.11	5.31	33.22
08/16/11	6.3	<0.06	<0.2	<0.03	0.06	0.04	NM	NM	6.13	5.85	31.45
09/15/11	2.8	<0.02	<0.2	<0.03	0.02	0.03	NM	<20	6.79	6.64	27.80
10/18/11	5.1	0.24	0.21	<0.03	0.03	0.04	NM	<20	6.41	7.77	22.28

Lake Sinclair Oconee River Arm
2012 EPD Water Quality Monitoring Data

Date	Chlorophyll *a* (μg/L)	Total N (mg/L)	TKN (mg/L)	NH3 (mg/L)	NO2/NO3 (mg/L)	Total P (mg/L)	Ortho P (mg/L)	Fecal coliform (MPN/100 mL)	pH (SU)	DO (mg/L)	Water Temp (deg C)
04/17/12	7.5	0.06	<0.2	<0.03	0.06	0.03	NM	<20	7.29	9.44	22.24
05/22/12	6.14	0.27	0.27	<0.03	<0.03	0.03	NM	<20	7.42	7.04	26.35
06/21/12	6.4	0.33	0.33	<0.03	<0.03	0.02	NM	<20	NM	NM	NM
08/01/12	10	0.24	0.24	<0.03	<0.03	0.02	NM	<20	NM	NM	NM
08/27/12	7.8	0.35	0.35	<0.03	<0.03	0.03	NM	<20	6.56	17.38	29.94
09/26/12	NM	NM	NM	NM	NM	NM	NM	<20	6.72	92.30	28.41
10/16/12	7.1	0.29	0.29	<0.03	<0.03	0.03	NM	<20	7.01	7.76	24.80

Lake Sinclair Little River and Murder Creek Arm
2004 EPD Water Quality Monitoring Data

Date	Chlorophyll *a* (µg/L)	Total N (mg/L)	TKN (mg/L)	NH3 (mg/L)	NO2/NO3 (mg/L)	Total P (mg/L)	Ortho P (mg/L)	Fecal coliform (MPN/100 mL)	pH (SU)	DO (mg/L)	Water Temp (deg C)
03/25/04	14.0	0.66	0.32	<0.03	0.34	0.07	<0.04	NM	7.53	9.87	18.21
06/15/04	4.0	0.31	0.18	<0.03	0.13	0.03	<0.04	NM	7.57	5.46	29.88
08/10/04	4.3	0.49	0.39	<0.03	0.10	0.03	<0.04	20	6.74	5.54	30.60
11/08/04	3.1	NM	NM	0.04	0.25	NM	<0.04	20	6.82	7.05	22.48

Lake Sinclair Little River and Murder Creek Arm
2009 EPD Water Quality Monitoring Data

Date	Chlorophyll *a* (µg/L)	Total N (mg/L)	TKN (mg/L)	NH3 (mg/L)	NO2/NO3 (mg/L)	Total P (mg/L)	Ortho P (mg/L)	Fecal coliform (MPN/100 mL)	pH (SU)	DO (mg/L)	Water Temp (deg C)
03/10/09	2.70	1.01	0.8	0.1	0.21	0.09	<0.04	40	7.45	8.66	14.28
04/30/09	6.80	0.81	0.5	0.1283	0.31	0.09	<0.04	20	6.78	7.35	24.58
05/13/09	2.90	1.0	0.69	0.1971	0.31	0.1	<0.04	<20	6.85	5.48	23.37
06/16/09	3.80	<0.36	<0.2	<0.03	0.16	0.12	<0.04	<20	6.81	4.66	28.50
07/14/09	3.00	0.47	0.30	<0.03	0.16	0.1	<0.04	<20	6.66	4.63	30.82
08/04/09	3.60	<0.34	<0.2	<0.03	0.14	0.009	0.12	<20	6.97	5.23	30.18
09/17/09	2.90	0.32	0.24	<0.03	0.08	<0.02	<0.04	<20	6.94	5.94	29.42
10/20/09	2.20	0.49	0.3	<0.03	0.19	0.04	<0.04	<20	6.59	5.73	19.89

Lake Sinclair Little River and Murder Creek Arm
2010 EPD Water Quality Monitoring Data

Date	Chlorophyll *a* (µg/L)	Total N (mg/L)	TKN (mg/L)	NH3 (mg/L)	NO2/NO3 (mg/L)	Total P (mg/L)	Ortho P (mg/L)	Fecal coliform (MPN/100 mL)	pH (SU)	DO (mg/L)	Water Temp (deg C)
04/08/10	2.73	0.52	0.31	<0.03	0.21	0.04	<0.04	<20	6.48	8.00	18.05
05/06/10	13.25	0.4	0.27	<0.03	0.13	0.02	<0.04	<20	8.21	10.30	25.96
06/10/10	4.04	0.45	0.29	<0.03	0.16	0.02	<0.04	40	6.80	6.67	29.14
07/15/10	2.44	<0.32	<0.2	<0.03	0.12	0.03	<0.04	<20	7.13	5.31	31.91
08/12/10	2.33	0.3	0.21	<0.03	0.09	<0.02	<0.04	<20	6.88	5.43	32.78
09/29/10	4.42	<0.25	<0.2	<0.03	0.05	<0.02	<0.04	20	6.94	5.94	28.85
10/27/10	5.8	0.24	0.21	<0.03	0.03	<0.02	<0.04	20	6.68	6.96	23.22

Lake Sinclair Little River and Murder Creek Arm
2011 EPD Water Quality Monitoring Data

Date	Chlorophyll *a* (µg/L)	Total N (mg/L)	TKN (mg/L)	NH3 (mg/L)	NO2/NO3 (mg/L)	Total P (mg/L)	Ortho P (mg/L)	Fecal coliform (MPN/100 mL)	pH (SU)	DO (mg/L)	Water Temp (deg C)
04/07/11	8.4	<0.5	<0.2	<0.03	0.3	0.04	NM	40	6.97	8.64	16.84
05/04/11	5.8	<0.44	<0.2	0.03	0.24	0.06	NM	<20	6.88	7.00	23.76
06/23/11	12	<0.33	<0.2	<0.03	0.13	0.04	NM	21	6.83	5.16	31.13
07/18/11	7.4	<0.32	<0.2	<0.03	0.12	0.04	NM	<20	7.11	5.31	33.22
08/16/11	6.3	<0.26	<0.2	<0.03	0.06	0.04	NM	NM	6.13	5.85	31.45
09/15/11	2.8	<0.22	<0.2	<0.03	0.02	0.03	NM	<20	6.79	6.64	27.80
10/18/11	5.1	0.24	0.21	<0.03	0.03	0.04	NM	<20	6.41	7.77	22.28

Lake Sinclair Little River and Murder Creek Arm
2012 EPD Water Quality Monitoring Data

Date	Chlorophyll *a* (µg/L)	Total N (mg/L)	TKN (mg/L)	NH3 (mg/L)	NO2/NO3 (mg/L)	Total P (mg/L)	Ortho P (mg/L)	Fecal coliform (MPN/100 mL)	pH (SU)	DO (mg/L)	Water Temp (deg C)
04/02/12	6	0.08	<0.2	<0.03	0.08	0.03	NM	<20	7.06	8.50	21.35
05/08/12	5.27	0.31	0.31	<0.03	<0.03	0.03	NM	<20	7.40	7.18	26.48
06/18/12	19	0.44	0.44	<0.03	<0.03	0.04	NM	<20	NM	NM	NM
07/23/12	9.8	0	<0.2	<0.03	<0.03	0.03	NM	<20	NM	NM	NM
08/23/12	8.9	0.36	0.36	<0.03	<0.03	0.03	NM	<20	6.69	17.16	29.78
09/10/12	NM	NM	NM	NM	NM	NM	NM	<20	6.77	7.09	29.34
10/11/12	6.7	0	<0.2	<0.03	<0.03	0.03	NM	<20	6.97	7.51	24.50

Lake Sinclair Dam Pool
2004 EPD Water Quality Monitoring Data

Date	Chlorophyll *a* (µg/L)	Total N (mg/L)	TKN (mg/L)	NH3 (mg/L)	NO2/NO3 (mg/L)	Total P (mg/L)	Ortho P (mg/L)	Fecal coliform (MPN/100 mL)	pH (SU)	DO (mg/L)	Water Temp (deg C)
03/25/04	9.3	0.61	0.26	<0.03	0.35	<0.02	<0.04	NM	7.57	9.85	16.00
06/15/04	3.1	0.38	0.30	<0.03	0.08	<0.02	<0.04	NM	7.57	7.52	28.93
08/10/04	<1	0.39	0.33	<0.03	0.06	0.02	<0.04	<20	6.97	5.13	30.01
11/08/04	4.0	NM	NM	<0.03	0.24	NM	<0.04	<20	7.28	7.08	22.16

Lake Sinclair Dam Pool
2009 EPD Water Quality Monitoring Data

Date	Chlorophyll *a* (µg/L)	Total N (mg/L)	TKN (mg/L)	NH3 (mg/L)	NO2/NO3 (mg/L)	Total P (mg/L)	Ortho P (mg/L)	Fecal coliform (MPN/100 mL)	pH (SU)	DO (mg/L)	Water Temp (deg C)
03/10/09	5.90	0.84	0.78	<0.03	0.06	0.04	<0.04	50	7.5	9.8	13.97
04/30/09	2.50	0.76	0.46	0.57	0.3	0.06	<0.04	<20	6.67	6.52	20.49
05/13/09	5.40	0.83	0.58	0.16	0.24	0.05	<0.04	<20	6.93	6.91	24.14
06/16/09	12.50	<0.28	<0.2	<0.03	0.08	0.12	<0.04	<20	8.1	8.41	31.78
07/14/09	12.00	0.45	0.4	0.32	0.05	0.04	<0.04	<20	7.58	7.61	30.78
08/04/09	10.00	<0.27	<0.2	<0.03	0.07	0.14	0.11	<20	7.72	7.7	30.49
09/17/09	2.70	0.31	0.22	<0.03	0.09	0.04	<0.04	20	6.85	5.7	27.64
10/20/09	1.80	0.43	0.23	<0.03	0.2	0.04	<0.04	<20	6.60	5.66	21.34

Lake Sinclair Dam Pool
2010 EPD Water Quality Monitoring Data

Date	Chlorophyll *a* (µg/L)	Total N (mg/L)	TKN (mg/L)	NH3 (mg/L)	NO2/NO3 (mg/L)	Total P (mg/L)	Ortho P (mg/L)	Fecal coliform (MPN/100 mL)	pH (SU)	DO (mg/L)	Water Temp (deg C)
04/08/10	3.67	0.59	0.25	<0.03	0.34	0.06	<0.04	<20	6.92	9.41	19.98
05/06/10	1.5	0.59	0.27	0.04	0.32	0.03	<0.04	<20	6.54	7.48	23.36
06/10/10	8.27	0.44	0.29	<0.03	0.15	0.04	<0.04	<20	7.96	9.06	30.13
07/15/10	2.25	0.34	0.28	<0.03	0.06	<0.02	<0.04	<20	8.42	8.53	32.76
08/12/10	2.71	0.23	0.21	<0.03	0.02	0.03	<0.04	<20	7.7	7.79	32.55
09/29/10	3.41	<0.22	<0.2	<0.03	0.04	<0.02	NM	20	6.92	6.07	28.40
10/27/10	3.9	<0.22	<0.2	<0.03	0.06	<0.02	NM	<20	6.56	7.54	23.16

Lake Sinclair Dam Pool
2011 EPD Water Quality Monitoring Data

Date	Chlorophyll *a* (μg/L)	Total N (mg/L)	TKN (mg/L)	NH3 (mg/L)	NO2/NO3 (mg/L)	Total P (mg/L)	Ortho P (mg/L)	Fecal coliform (MPN/100 mL)	pH (SU)	DO (mg/L)	Water Temp (deg C)
04/07/11	NM	0.36	<0.2	0.03	0.36	0.02	NM	<20	7.06	9.67	17.23
05/04/11	6.7	0.32	<0.2	<0.03	0.32	0.03	NM	<20	6.79	8.35	23.32
06/23/11	16	<0.2	<0.2	<0.03	<0.03	0.04	NM	<20	8.7	7.85	30.95
07/18/11	7.8	<0.2	<0.2	<0.03	0.03	0.03	NM	<20	7.22	6.79	32.26
08/16/11	6.6	<0.2	<0.2	<0.03	<0.03	0.03	NM	<20	6.49	7.29	31.40
09/15/11	4.9	0.26	0.23	<0.03	0.03	0.04	NM	NM	7.36	8.28	28.07
10/18/11	6.3	<0.2	<0.2	<0.03	0.04	0.02	NM	NM	6.71	8.95	22.83

Lake Sinclair Dam Pool
2012 EPD Water Quality Monitoring Data

Date	Chlorophyll *a* (μg/L)	Total N (mg/L)	TKN (mg/L)	NH3 (mg/L)	NO2/NO3 (mg/L)	Total P (mg/L)	Ortho P (mg/L)	Fecal coliform (MPN/100 mL)	pH (SU)	DO (mg/L)	Water Temp (deg C)
04/02/12	4.3	<0.2	<0.2	<0.03	<0.03	<0.02	NM	<20	7.86	10.10	22.65
05/08/12	7	0.26	0.26	<0.03	<0.03	<0.02	NM	<20	7.99	7.90	26.24
06/18/12	3.57	0.3	0.3	<0.03	<0.03	<0.02	NM	<20	NM	NM	NM
07/23/12	7.4	<0.2	<0.2	<0.03	<0.03	<0.02	NM	<20	NM	NM	NM
08/23/12	7	<0.2	<0.2	<0.03	<0.03	0.02	NM	20	6.76	17.38	29.94
09/10/12	5.24	NM	NM	NM	NM	NM	NM	20	6.94	7.62	29.28
10/11/12	8.7	0.36	0.36	<0.03	<0.03	0.03	NM	<20	6.95	7.60	25.03

Appendix B
Proposed Water Quality Standards for West Point Lake Memo

August 28, 1996

MEMORANDUM

To: Harold F. Reheis

From: Alan W. Hallum

RE: Proposed Water Quality Standards for West Point Lake

The Water Protection Branch has reviewed the recommendations proposed in the West Point Lake Phase I Diagnostic/Feasibility Report, compared the proposals to current standards, and proposes having the attached Draft standards adopted as part of the Rules and Regulations for Water Quality Control, Paragraph 391-3-6-.03. Except for the pH standard, it is recommended that current standards (fecal coliform bacteria, dissolved oxygen, temperature, and toxics) be retained in their present format. The proposed standards would establish lake specific pH, total nitrogen, chlorophyll *a*, and phosphorus limits. A rationale for each of these is provided below. The standards are consistent with O.C.G.A. 12-5-23.1. Upon your concurrence with these proposed standards, I would recommend sending them to the Wildlife Resources Division for comment.

pH: The current pH criterion is often exceeded when algal productivity is high. At the proposed chlorophyll criterion or even at much lower chlorophyll levels, the expectation would be that a pH limit of 8.5 could not be consistently met. The proposed change is recommended in the Clean Lakes Report.

Total Nitrogen: Total Nitrogen is included in O.C.G.A. 12-5-23.1. As long as adequate phosphorus control is in place, nitrogen concentrations will have little effect on algal productivity in the lake. The proposed standard sets a level which is expected of flows of 358 MGD.

Chlorophyll *a*: The chlorophyll *a* number (27 µg/l) is that which has been utilized as our goal since 1989. This standard is also recommended in the Clean Lakes Report.

Phosphorus: The proposed loading standard represents the calculated nonpoint source loading at the time of the Clean Lakes study and the point source loading based on the 0.75 mg/l effluent limit at a flow of 358 MGD.

Dissolved Oxygen, Fecal Coliform Bacteria, and Temperature: The proposed standards retain current standards.

Tributaries: The Chattahoochee River phosphorus load standard represents the nonpoint source loading as measured during the Clean Lakes Study and a point source effluent limit of 0.75 mg/l at 358 MGD. The Yellowjacket Creek and New River loading standards are the loadings calculated in the Clean Lakes Report and rounded up to the next 1,000 pounds.

AWH/dkf
Attachment

Appendix C
Fisheries Supplemental Support Data

<u>Annotated Bibliography</u>

Allen, M. S., J. C. Greene, F. J. Snow, M. J. Maceina, and D. R. DeVries. 1999. Recruitment of largemouth bass in Alabama reservoirs: relations to trophic state and larval shad occurrence. North American Journal of Fisheries Management. 19:67-77.

- The study focused on Gizzard shad and threadfin shad abundance, primary sport fish forage sources. Found that shad abundance is positively correlated to Chl-α. Age-0 largemouth bass abundance was positively related to Chl-α.

70 ALLEN ET AL. 1999

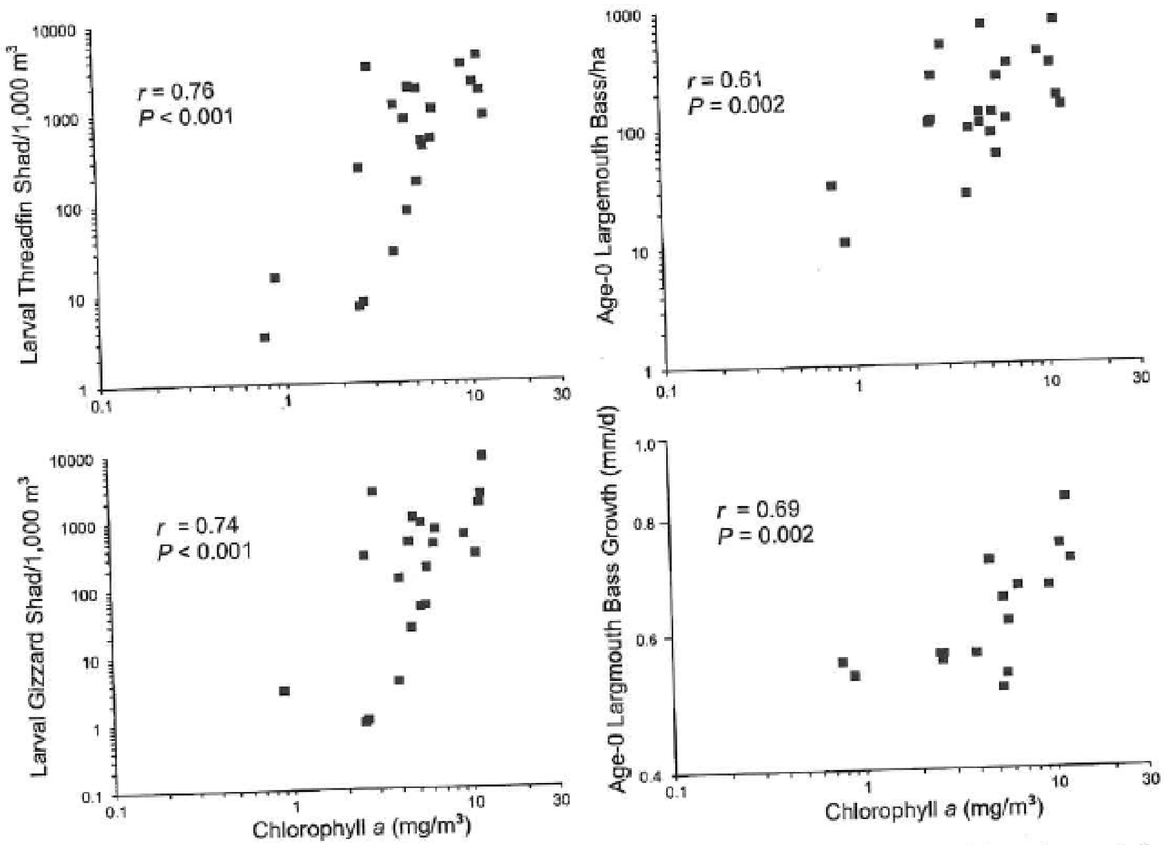


FIGURE 2.—Mean annual larval threadfin shad, gizzard shad, and age-0 largemouth bass densities and mean daily age-0 largemouth bass growth rate as a function of mean annual chlorophyll-*a* concentration (mg/m³) for each reservoir or site in nine Alabama reservoirs, 1993–1994. Larval gizzard shad were not collected at the dam forebay site of Lewis Smith Reservoir in 1994.

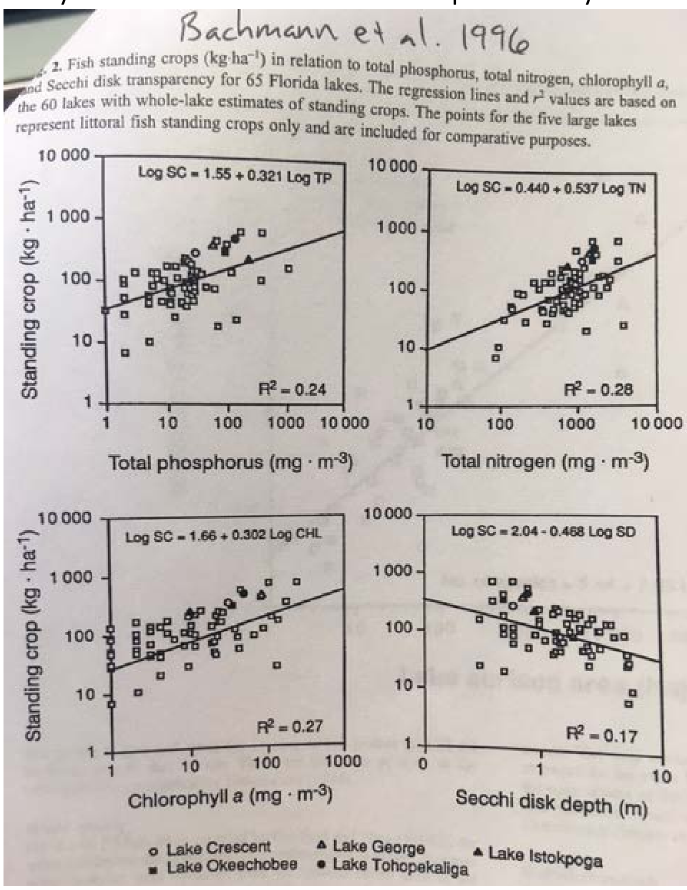
Bachmann, R. W., D. L. Bigham, M. V. Hoyer, and D. E. Canfield, Jr. 2012. Phosphorus, nitrogen, and the designated uses of Florida lakes. Lake and Reservoir Management. 28:46-58.

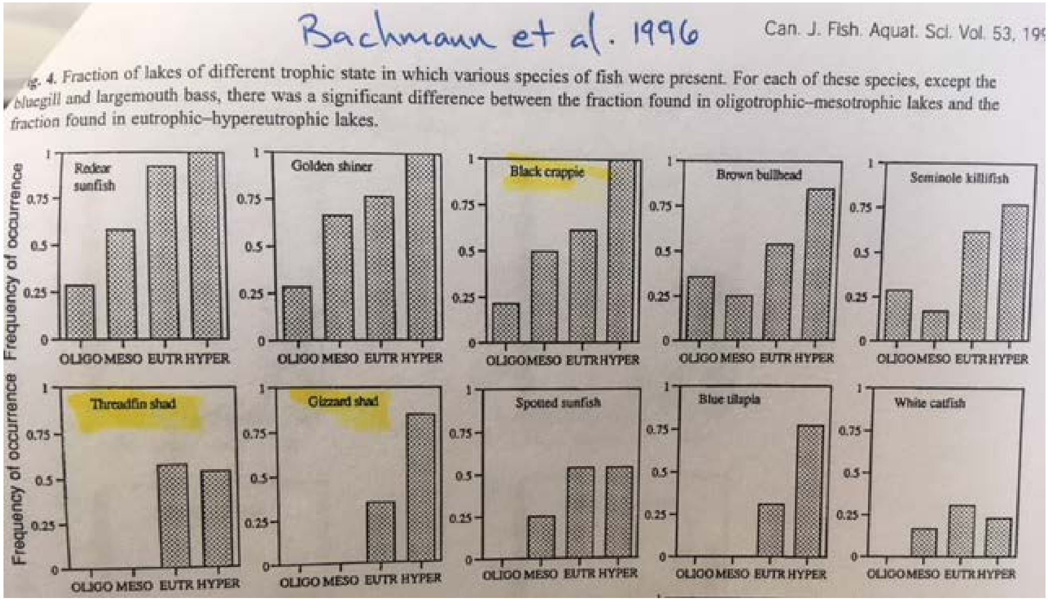
- Study shows that the top fishing lakes in Florida have higher nutrient concentrations than average Florida lakes, and many of these top fishing lakes would be labeled impaired under the USEPA (2010) nutrient criteria for Chl-α, TP, or TN. In Florida lakes, fish standing crops. increased with the concentrations of TP, TN, and Chl-α, with no absolute upper bounds using nutrient concentrations were observed in the Florida lakes studied.

- [USEPA] United State Environmental Protection Agency. 2010. Water quality standards for the state of Florida's lakes and flowing waters. Federal Register 75(131):4173-4226.

Bachmann, R. W., B. L. Jones, D. D. Fox, M. V. Hoyer, L. A. Bull, and D. E. Canfield, Jr. 1996. Relations between trophic state indicators and fish in Florida (U.S.A.) lakes. Canadian Journal of Fisheries and Aquatic Sciences. 53:842-855.

- Study demonstrates that as reservoir productivity increases, fish standing stocks will increase.





Bayne, D. R., M. J. Maceina, and W. C. Reeves. 1994. Zooplankton, fish and sport fishing quality among four Alabama and Georgia reservoirs of varying trophic status. Lake and Reservoir Management. 8(2):153-163.

- Study of four Alabama reservoirs, largemouth bass (*Micropterus salmoides*) where growth rates were substantially higher in eutrophic systems (0.05-0.1 mg/L TP) than mesotrophic systems (0.01 mg/L TP). A study in Alabama proposed that Chl-α concentrations near 15 µg/L could support quality largemouth bass and black crappie populations.

DiCenzo, J. V., M. J. Maceina, and M. R. Stimpert. 1996. Relations between reservoir trophic state and gizzard shad population characteristics in Alabama reservoirs. North American Journal of Fisheries Management. 16:888-895.

Study found in eutrophic reservoirs that gizzard shad had higher abundances and slower growth rates, which was likely attributed to density dependence mechanisms. The slower gizzard shad growth kept shad vulnerable as a prey species longer, which would suggest growth rates of piscivorous sport fishes to be a positive relationship with reservoir trophic state.

Downing, J. A., C. Plante, and S. Lalonde. 1990. Fish production correlated with primary productivity, not the morphoedaphic index. Canadian Journal of Fisheries and Aquatic Sciences. 47:1929-1936.

- As reservoir productivity increases from an increase in nutrients, fish standing stocks will increase.

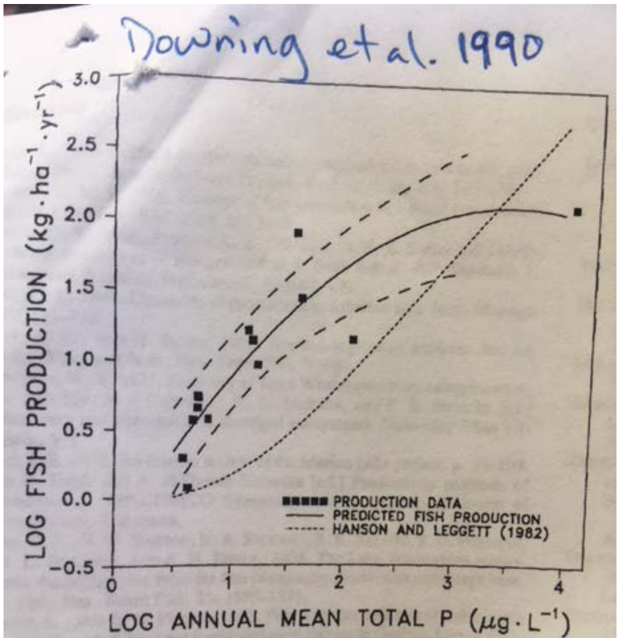


FIG. 4. The relationship between seasonal average total phosphorus concentration of the water column and the fish community production in lakes. The solid curve is predicted from Eq. (4) while the dotted curve represents predicted yields from Hanson and Leggett's (1982) Fig. 2. Dashed lines indicate approximate 95% confidence bands for predicted values of the mean $\log_{10} FP$ (Prepas 1984).

Ellis, F. S., Jr. 1988. The effect of nutrient inflow reductions on the fish populations and fishery of Lake Jackson. Georgia Department of Natural Resources, Game and Fish Division, Final Report Federal Aid Project F-33-11, 41pp.

- Gizzard shad abundance decreased in Lake Jackson, a middle Georgia reservoir, following successful efforts to reduce nutrient loading from its tributaries.

Greene, J. C. and M. J. Maceina. 2000.Influence of trophic state on spotted bass and largemouth bass spawning time and age-0 population characteristics in Alabama reservoirs. North American Journal of Fisheries Management. 20:100-108.

- Evaluated age-0 largemouth bass and spotted bass abundance with Chl-α in 6 Alabama reservoirs, they found that age-0 largemouth bass abundance was positively related to Chl-α. In contrast, age-0 spotted bass abundance increased as Chl-α decreased and visibility increased.

TROPHIC STATE EFFECTS ON LARGEMOUTH AND SPOTTED BASS 105

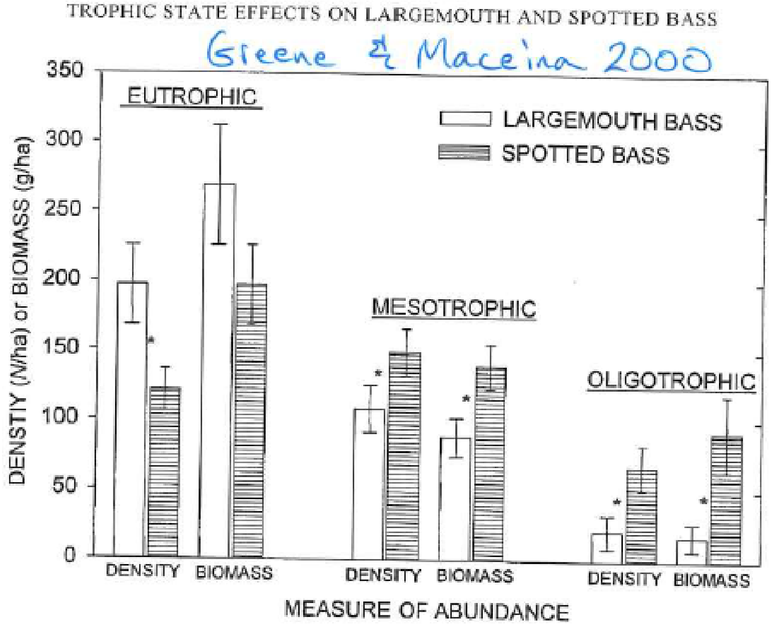


FIGURE 2.—Mean density and biomass of largemouth bass and spotted bass within trophic states in Alabama reservoirs or sites. Vertical lines represent ±SE; an asterisk indicates that mean values differed significantly ($P < 0.05$) between species.

Hakala, J. P. 2012. Natural fish kill investigation: Carters, 2012. Georgia Department of Natural Resources, Fisheries Section, Calhoun, Georgia.

- Upgrades to a waste water treatment facility in 2011 on the Coosawattee River upstream of Carters Reservoir significantly reduced TP releases to the Coosawattee River. In August 2012, there was a fish kill event on Carters and the only fish observed dying were gizzard shad. Specimens were sent to the fish disease lab at Auburn University. The result from the pathological exam found no evidence to suggest disease or parasites caused tens of thousands gizzard shad to die. The examiner believed that the kill was associated with a dietary deficiency. Chl-α levels from 2012-2017 (6.88 µg/L) were significantly lower (t-test, p=0.002) than Chl-α levels from 2007-2011 (Hakala 2018, GAEPD, unpublished data). The significant decrease in Chl-α illustrated that productivity decreased in Carters.
    - Hakala, J. P. 2015. Carters Reservoir annual report, 2014. Georgia Department of Natural Resources, Fisheries Section, Calhoun, Georgia.
    - Hakala, J. P. 2018. Carters Reservoir annual report, 2017. Georgia Department of Natural Resources, Fisheries Section, Calhoun, Georgia.

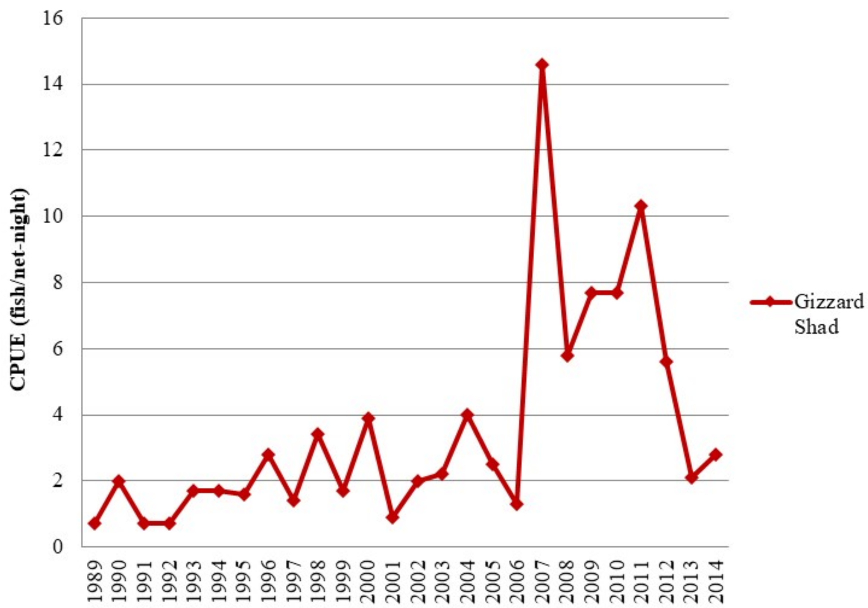


Figure 5. Gizzard shad CPUE (fish/net-night) reported during fall SARS at Carters Reservoir, 1989-2014. (Hakala 2015)

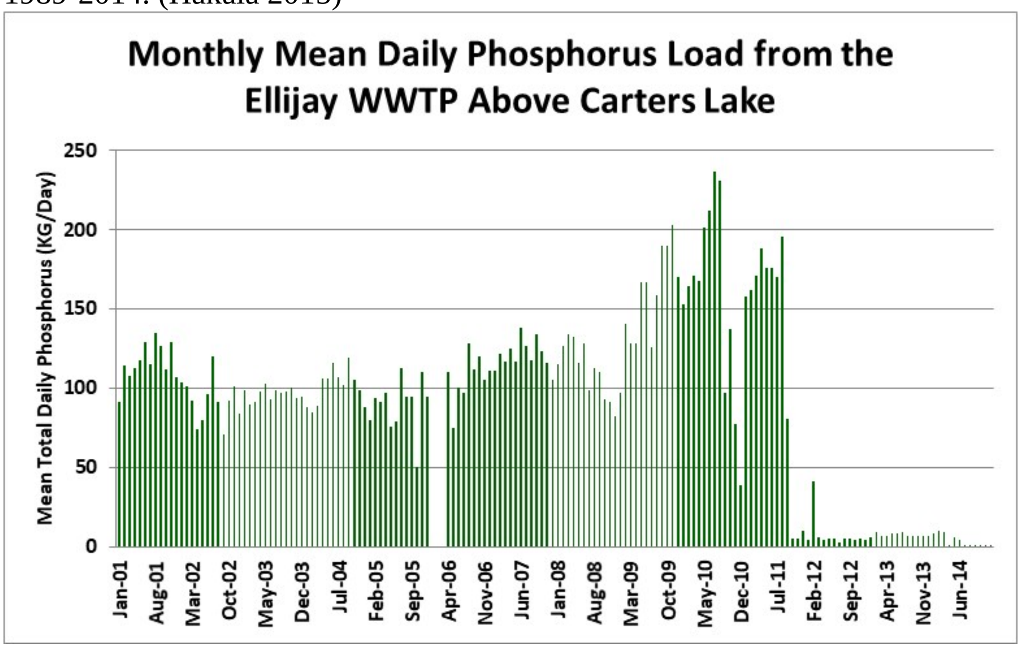


Figure 18. Mean Daily Total Phosphorus Loading From the Ellijay Waste Water Treatment Facility into the Coosawattee River above Carters Reservoir, January 2001 – December 2014. No data were available for January – March 2006. Data obtained from Steve Marchant, Hazardous Waste Management Branch, Georgia Environmental Protection Division. (Hakala 2018)

Hendricks, A. S., M. J. Maceina, and W. C. Reeves. 1995. Abiotic and biotic factors related to black bass fishing quality in Alabama. Lake and Reservoir Management. 11:47-56.

- Average black bass weight in Alabama tournament was positively related to Chl-α.

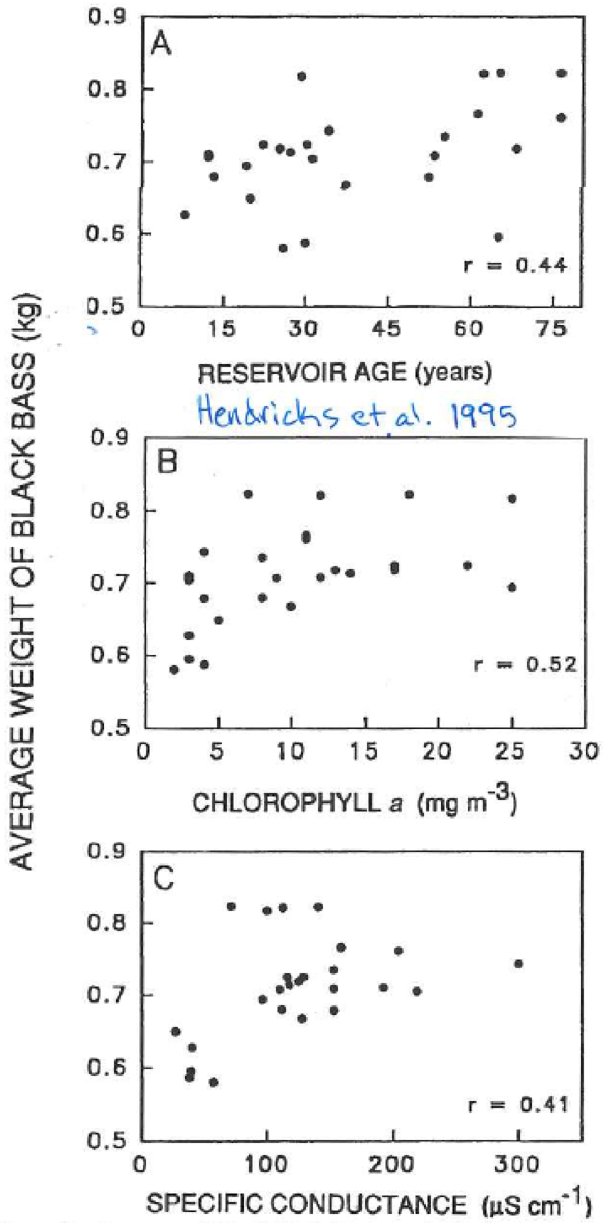


Figure 3.—Average weight of black bass caught by tournament anglers versus reservoir age (A), chlorophyll *a* concentrations (B), and specific conductance (C).

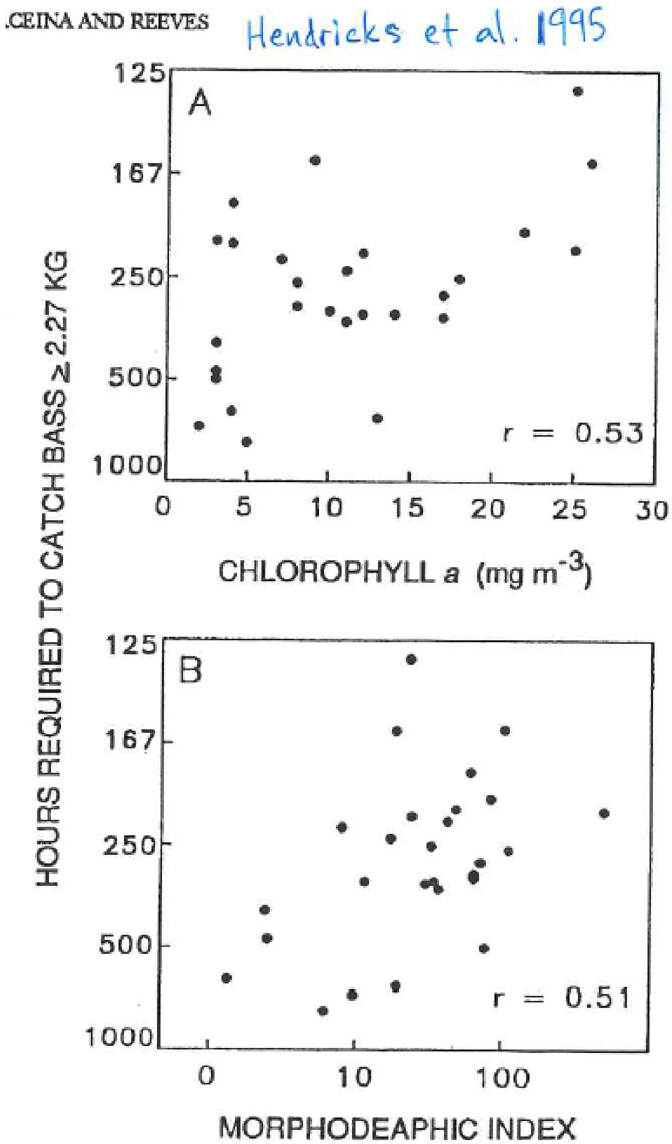
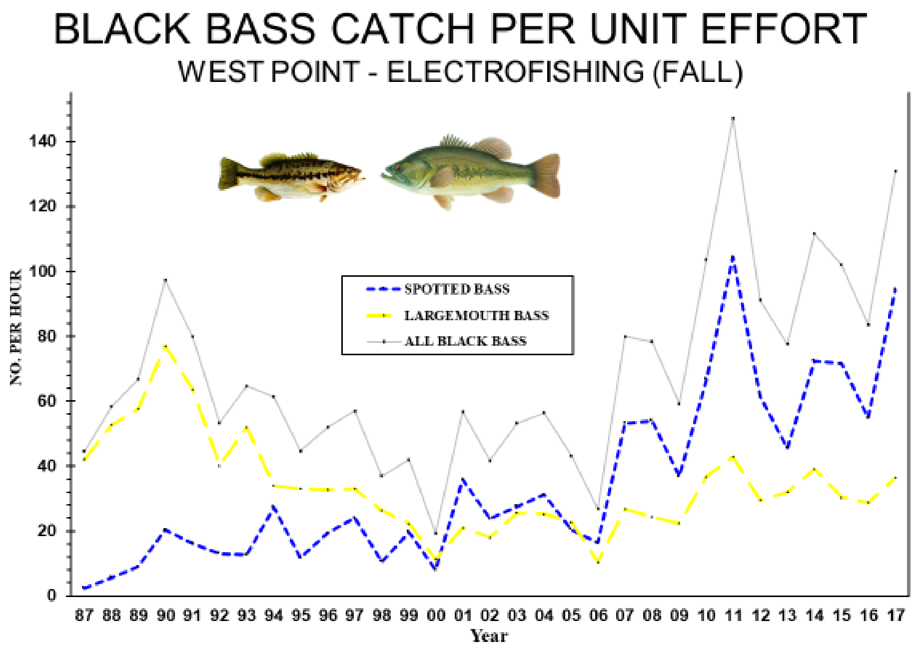


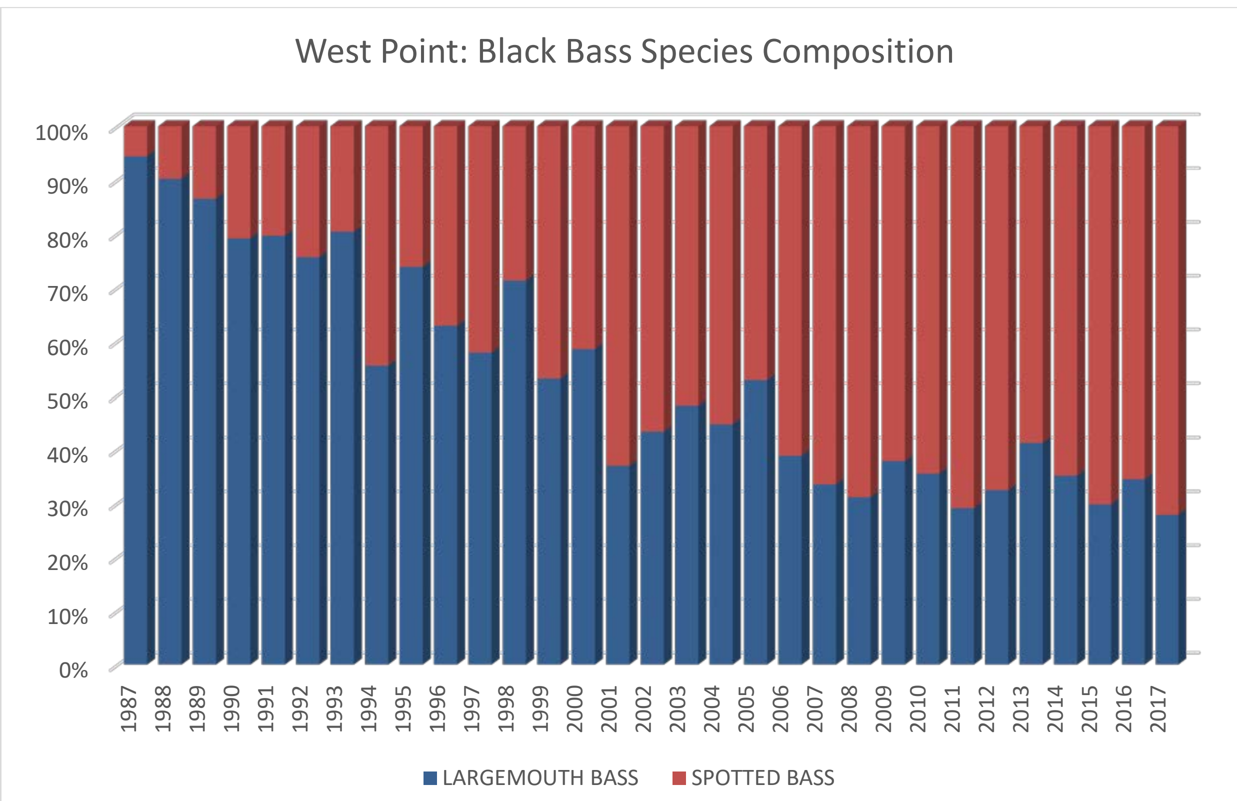
Figure 4.—Hours of effort to catch a memorable-size black bass (≥ 2.27 kg) versus chlorophyll *a* concentrations (A) and the morphoedaphic index (B). Note the scale is inverted; lower values were associated with greater catch rates of memorable-size black bass.

Hess, B. J. 2017. West Point Reservoir annual report, 2017. Georgia Department of Natural Resources, Fisheries Section, West Point, Georgia.

- Georgia DNR maintains a long-term data set, which shows the transition from a largemouth bass dominant system to a spotted bass dominant system.



(Hess 2017)



(Hess 2017)

Jones, J. R. and M. V. Hoyer. 1982. Sportfish harvest predicted by summer chlorphyll-α concentration in Midwestern lakes and reservoirs. Transactions of the American Fisheries Society. 111:176-179.

- Chl-α was found to be positively related to sport fish harvest in Midwestern lakes and reservoirs.

CHLOROPHYLL AS A PREDICTOR OF ANGLER HARVEST 177

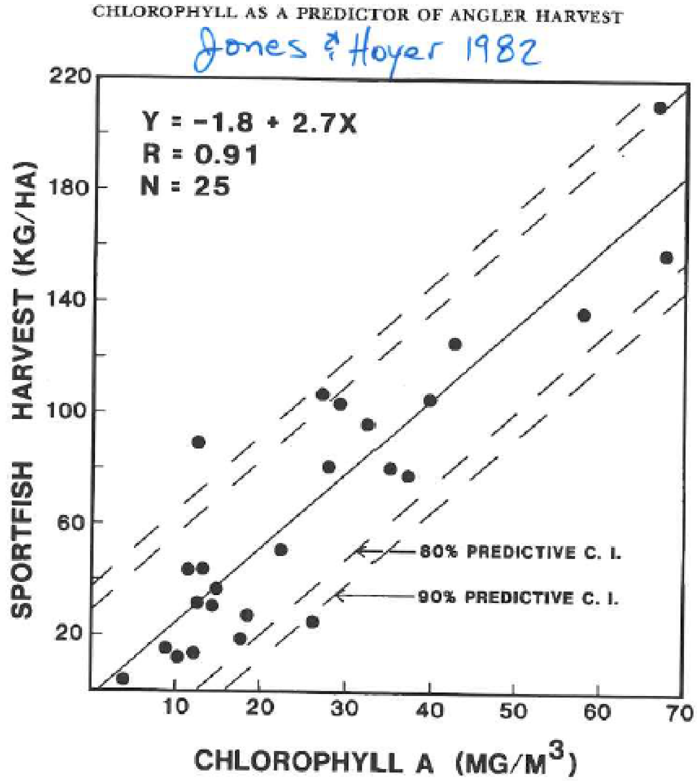


FIGURE 1.—*Angler sportfish harvest (Y, kg/hectare) as a function of mean summer chlorophyll-*a *concentrations (X, mg/m³) for water bodies in Missouri and Iowa (C. I. = confidence interval).*

Maceina, M. J., D. R. Bayne, A. S. Hendricks, W. C. Reeves, W. P. Black, and V. J. DiCenzo. 1996. Compatibility between water clarity and quality black bass and crappie fisheries in Alabama. Pages 296-305 *in* L. E. Miranda and D.R. DeVries, editors. Multidimensional approaches to reservoir fisheries management. American Fisheries Society, Symposium 16, Bethesda, Maryland.

- Found that largemouth bass had faster growth rates when reservoir trophic state increased. Proposed that quality fishing and acceptable water quality might be compatible in Alabama impoundments, however trophy largemouth bass and black crappie (*Pomoxis nigromaculatus*) would decline.

Maceina, M. J. and D. R. Bayne. 2001. Changes in the black bass community and fishery with oligotrophication in West Point Reservoir. North American Journal of Fisheries Management. 21:745-755.

- Found that Chl-α levels less than 10-15 µg/L could encumber a black bass fishery in southern reservoirs. An example of TP reductions in a Georgia reservoir occurred at West Point Reservoir. Phosphorus reductions began in the late 1980s in West Point Reservoir, which lead Maceina and Bayne (2001) to examine temporal changes to the black bass community and fishery. TP loading into West Point Reservoir from the Chattahoochee River decreased threefold between 1991-1999. Maceina and Bayne (2001) observed a decrease in largemouth bass recruitment and an increase in spotted bass recruitment. When black bass spring sampling data were examined for

1993 and 2000 in West Point Reservoir, largemouth bass between stock and quality size catch rates declined from 16.8 to 3.4 fish/h, while spotted bass catch rates increased from 2.4 to 10.2 fish/h for the same years. Aside from the reduced growth rate, the black bass species composition shifted from largemouth bass to spotted bass as the most abundant piscivore. When spotted bass became the dominant black bass species, average tournament bass weights were reduced by half from 1.5 kg in late 1980s to 0.75 kg by 1999 (Maceina and Bayne 2001). The time an angler spent to catch a largemouth bass greater than 2.27 kg was 100 h in 1986 and more than 500 h by 1999. Maceina and Bayne (2001) suggested when Chl-α criteria are proposed select a lower and upper limit, not just an upper, to safeguard black bass fisheries.

)N AND BLACK BASS 749

Maceina & Bayne 2001

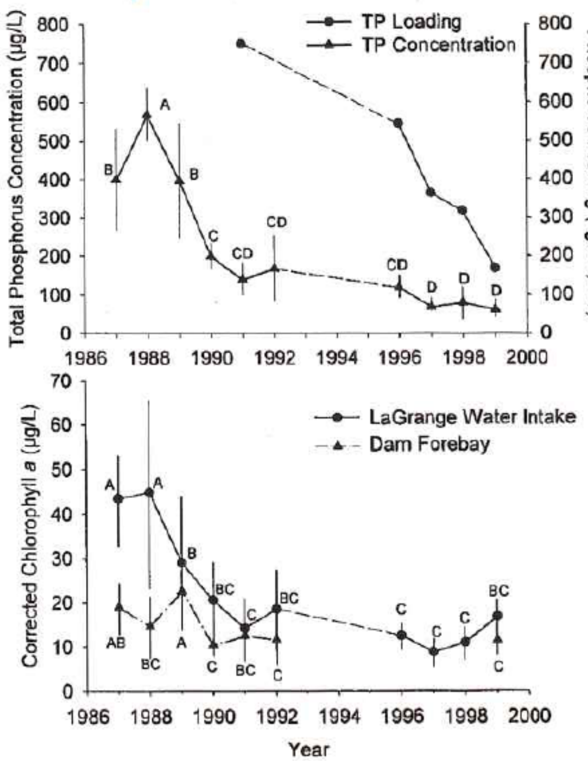


FIGURE 2.—Mean growing-season (April−October) concentrations of total phosphorus (TP) and annual TP load entering West Point Reservoir from the Chattahoochee River (top panel). Mean growing season chlorophyll-*a* concentrations at midreservoir and dam forebay locations (bottom panel). Mean values annotated by the same letter were not significantly different ($P > 0.05$). Vertical bars represent 1 SD.

Macena & Bayne 2001

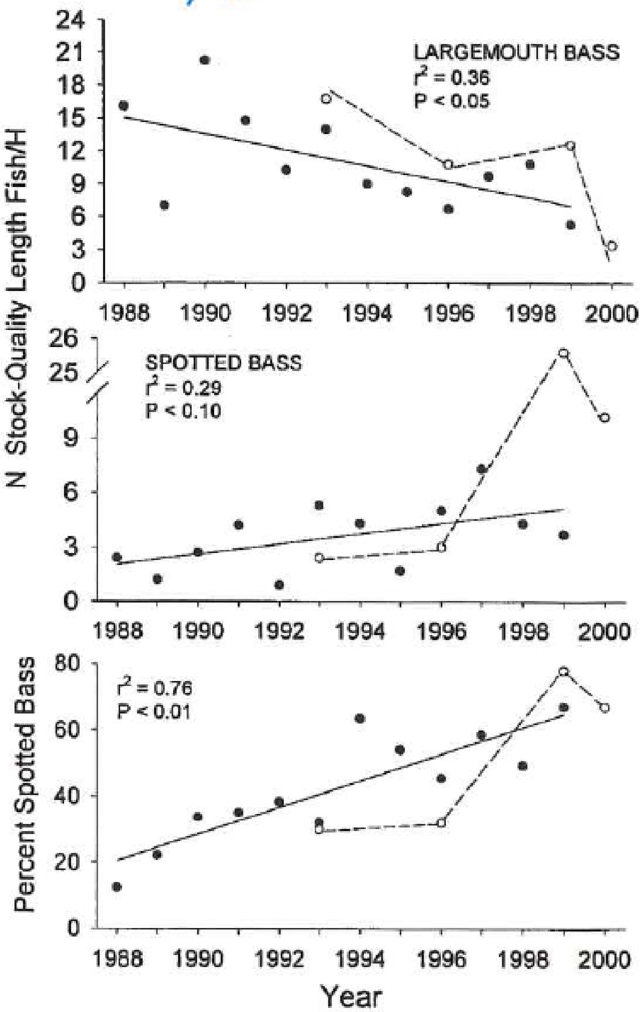


FIGURE 3.—Electrofishing catch per effort of stock-to quality-length largemouth and spotted bass and the percentage of spotted bass to total black bass caught for all fish less than 304 mm TL over time. Solid dots represent fish collected in fall 1988–1999, and solid lines present the corresponding time trend regressions for these data. Dashed lines and open circles represent data collected in spring 1993, 1996, 1999, and 2000.

Maceina & Bayne 2001

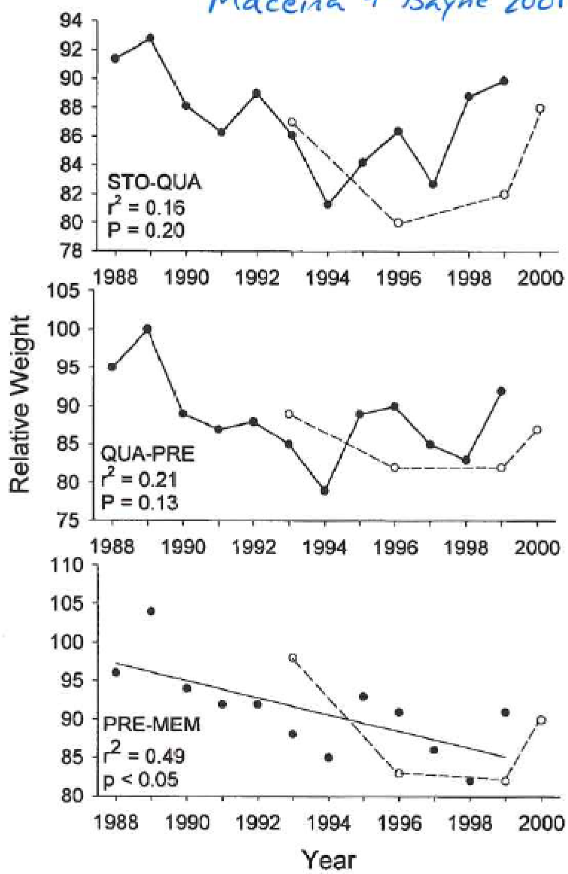


FIGURE 4.—Relative weights of the stock–quality, quality–preferred, and preferred–memorable length categories of largemouth bass over time. Solid lines and dots represent fish collected in fall 1988–1999, and a corresponding time trend regression (solid line) is presented for preferred- to memorable-length fish. Dashed lines and open circles represent data collected in spring 1993, 1996, 1999, and 2000.

752 Maceina & Bayne 2001 MACEINA A

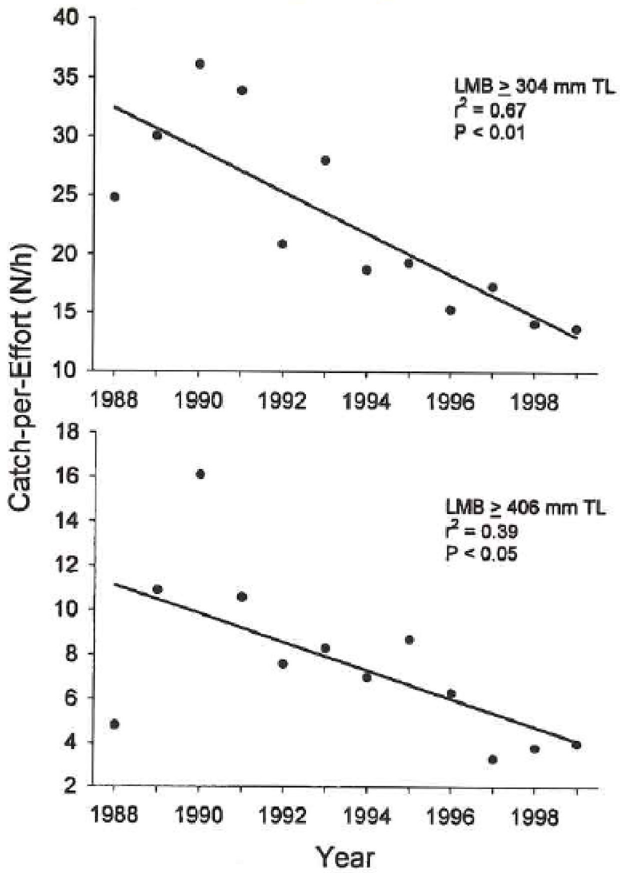


FIGURE 6.—Electrofishing catch per effort of largemouth bass longer than 304 and 406 mm from fall 1988 to 1999. Corresponding regression trend lines are shown.

Michaletz, P. H. 1998. Population characteristics of gizzard shad in Missouri reservoirs and their relation to reservoir productivity, mean depth, and sport fish growth. North American Journal of Fisheries Management. 18:114-123.

- In most southeastern reservoirs, gizzard shad (*Dorosoma cepedianum*) play an integral role in these ecosystems as a primary prey for sport fish. Shad populations can influence sport fish recruitment to a fishery depending on the strength of the shad populations and abundance of young of the year shad.

(Chris Nelson biologist with GA DNR communication)

- There is a nonnative spotted bass population that remains relatively small and appears to reside in the upper reaches of Lake Oconee and into the Oconee River north to Barnett Shoals Dam (Watkinsville, GA). This population continues upstream from Barnett Shoals Dam (Athens, GA). The reason why spotted bass have not worked their way into Lake Oconee is not clear.

Ney, J. J. 1996. Oligotrophication and its discontents: effects of reduced nutrient loading on reservoir fisheries. Pages 285-295 *in* L. E. Miranda and D.R. DeVries, editors. Multidimensional approaches to reservoir fisheries management. American Fisheries Society, Symposium 16, Bethesda, Maryland.

- Study showed that phosphorus concentrations above 0.1 mg/L will maximize sport fish biomass. Fish standing stock in southern Appalachian reservoirs showed a linear increase as total phosphorus concentration increased from 8-81 µg/L, which suggests maximum fish biomass at higher TP concentrations.

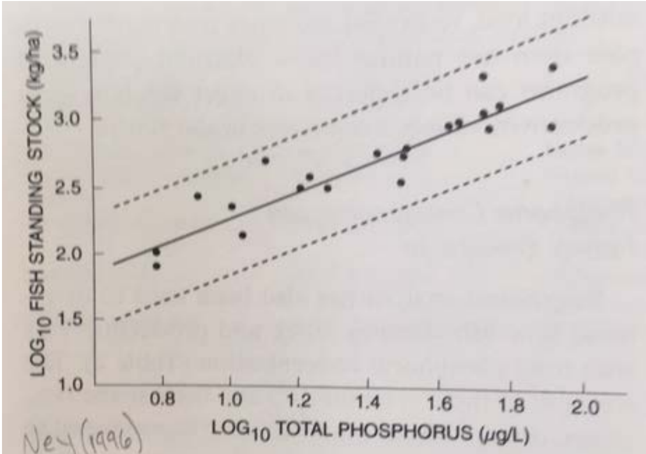


FIGURE 2.—Regression of $\log_{10}$ total fish standing stock (FSS) versus $\log_{10}$ total phosphorus (TP) concentration for 21 southern Appalachian reservoirs. $\text{Log}_{10}\text{FSS} = 1.24 + 1.02\log_{10}\text{TP}$; $r^2 = 0.84$. Dashed lines are 90% predictive limits (from Ney et al. 1990).

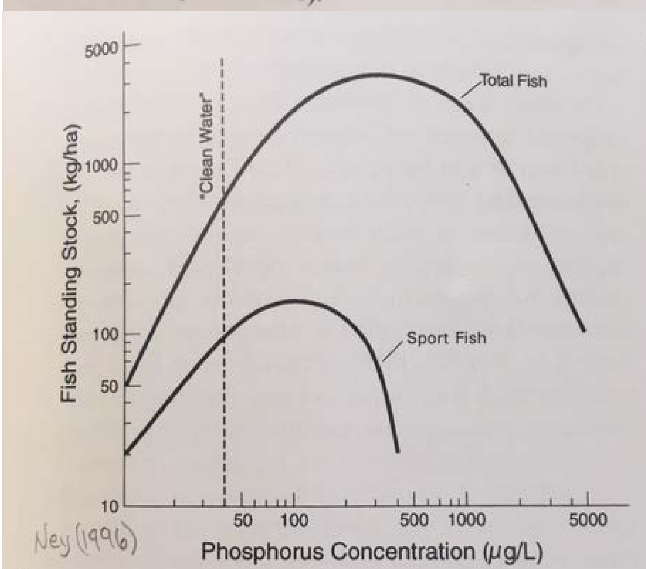


FIGURE 3.—Generalized relation of total and sport fish standing stock to total phosphorus concentration and trophic status in temperate-latitude reservoirs. Standing stock values are representative of southeastern U.S. reservoirs to 100 µg/L total phosphorus. Standing stocks at higher phosphorus concentrations are hypothetical.

Welch, E. B. 2009. Phosphorus reduction by dilution and shift in fish species in Moses Lake, WA. Lake and Reservoir Management. 25:276-283.

- Predator species shifts were also observed in Moses Lake, WA following a period of reduced TP into the lake.

Welch 2009

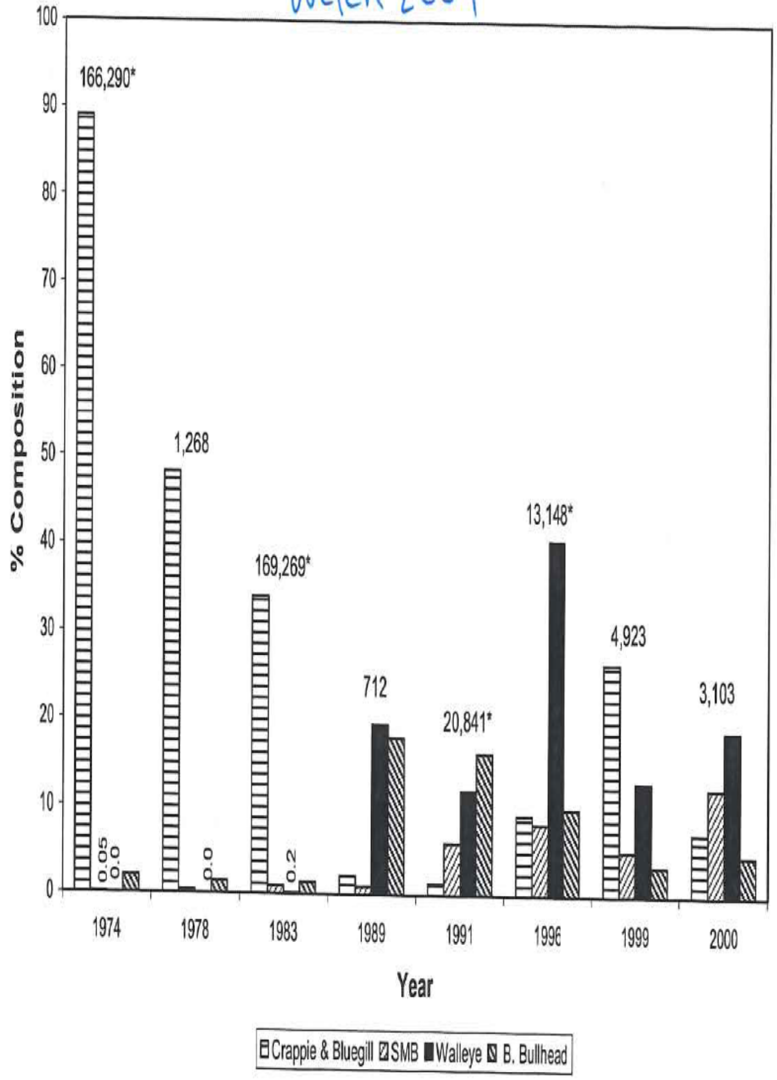


Figure 3.-Angler catch* in 1974, 1983, 1991 and 1996, and biological sampling (electrofishing and gill netting) in the other years, expressed as % of total catch, shown at the top of bars for each year (Burgess 2000, Burgess et al. 2007).

Yurk, J. J. and J. J. Ney. 1989. Phosphorus-fish community biomass relationships in southern Appalachian reservoirs: can lakes be too clean for fish? Lake and Reservoir Management. 5:83-90.

- Study showed that in freshwater systems, primary production is limited by phosphorus. Reservoirs with higher phosphorus levels are typically more productive ecosystems. Total phosphorus concentration is used to predict fishery productivity in reservoirs across the United States because there is a strong correlation. Gizzard shad averaged 40% of the total measurable fish biomass across several Appalachian reservoirs. There is a positive relationship between *Dorosoma* spp. abundance and reservoir trophic level. Age-0 gizzard shad are the most vulnerable to piscivores.

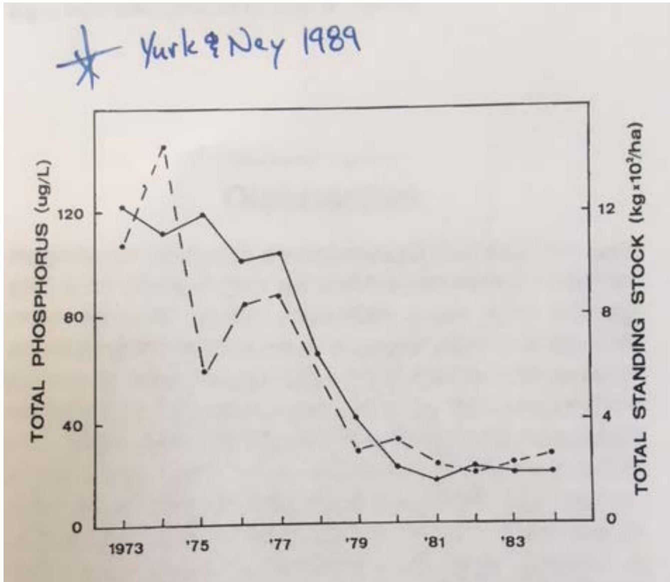


Figure 2.—Dynamics of mean total phosphorus concentration (solid line) and total fish standing stock (dashed line) in Smith Mountain Lake, Virginia 1973-84.

4.0 DESIGNATED USE SUPPORT

4.1 Recreational Use Support

West Point beaches, operated by the U.S. Army Corps of Engineers (COE), are located in the lower half of the lake. There have been no recreational closures due to algal blooms at any of the COE operated beaches (personal communication, COE).

4.2 Fisheries Use Support

There have not been any fish kills in West Point Lake associated with oxygen deficiency since standards were adopted. Following the phosphate detergent ban and phosphorus limits in NPDES permits in the early 1990's, algal productivity declined in the lake and resulted in increased water clarity. WRD Fisheries Biologists subsequently documented during standardized monitoring a shift in the dominant black bass species from largemouth bass to spotted bass. Spotted bass seem to have a competitive advantage over largemouth bass in clear, more infertile waters. The decline in the largemouth bass fishery is reflected in decreased growth and recruitment of the fish, and a reduction in angler satisfaction. A local lake advocacy group, the West Point Lake Coalition, has sponsored spotted bass fishing tournaments to offset the impact from the species shift, providing an alternative to largemouth bass tournaments. WRD has also removed the minimum length limit to encourage anglers to harvest more spotted bass.

The WRD began stocking Gulf race striped bass in West Point Lake as part of their native species restoration efforts. Striped bass, especially adults over 11 pounds, are a temperate cool water species that require at a minimum habitat having temperatures of less than 25 °C and with greater than 3 mg/L of dissolved oxygen. Water temperatures of 22 °C or less with dissolved oxygen concentrations of 5 mg/L or more are optimal for this species. Whereas the decreased algal productivity has had a negative effect on the largemouth bass sport fishery, a positive impact is expected for the restoration of the Gulf race striped bass fishery. The establishment of the Dam Forebay chlorophyll a criteria and lowering of the LaGrange Intake chlorophyll a criteria can be seen as further protecting the native fisheries in West Point Lake.

4.3 Drinking Water Source Use Support

The original City of LaGrange water intake was in the Chattahoochee River channel at an elevation of 618 feet above mean sea level (msl), and was replaced in subsequent years following lake impoundment with intakes constructed at elevations of 628, 625 and 623 feet msl. The design summer operating pool of West Point is 635 feet msl. The City has found that the depth of the epilimnion layer containing the majority of algal biomass is confined within the top 10 feet at their intake facility, and withdrawals are made using the intake below this layer when possible. With declining water levels during the summer of 2007 and somewhat higher chlorophyll a levels (as shown in Figure 4-1), the City was forced to withdraw water in the epilimnion. Water treatment costs increased and taste and odor complaints to the City became more numerous. The City has had similar problems in past dry years (e.g., 2000 and 2012) when summer lake levels were well below the design summer pool elevation and chlorophyll levels were elevated. The proposed reduction in the chlorolphyll *a* criteria should help reduce the potential for taste and odor problems due to algae in the future.

Georgia Environmental Protection Division
Atlanta, Georgia