GEORGIA DEPARTMENT OF NATURAL RESOURCES
ENVIRONMENTAL PROTECTION DIVISION

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.

Lake Sinclair is immediately downstream from Lake Oconee and 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. Both lakes have historically met and continue to meet their designated uses.

Wallace Dam impounds 29.7 miles of river to create a 19,058-acre reservoir, has an 1,820 square mile drainage area, 376 miles of shoreline, and a normal pool elevation of 436 feet mean sea level (ft MSL). The Wallace Dam intake elevation is 345.655 ft MSL, with a diameter of 25.5 ft. 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 operate at 337.2 ft MSL, three at 335.5 ft MSL, two at 334.5 ft MSL, and the last pump can operate at a minimum level of 333.8 ft MSL. The lowest historical lake elevation recorded was 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 a 15,330-acre reservoir, has a 2,900 square mile drainage area, 417 miles of shoreline, and a normal pool elevation of 340 ft MSL. The Sinclair Dam intake elevation is 279.66 ft MSL, with a diameter of 19.0 ft. The topmost 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. Below Sinclair Dam the Oconee River flows 143 miles through the Fall Line Hills District and into the Coastal Plain to join the Ocmulgee River and form the Altamaha River.

Land cover in the drainage lake areas is predominantly forested and agriculture (see Figure 1-2). However, there are dense residential and commercial areas in the watershed near Athens, Georgia.

Table 1-1 presents a breakdown of the Lake Oconee and Lake Sinclair watersheds land cover by imperviousness, which is the result of intersecting the 2005 Georgia Land Use Trend (GLUT) impervious cover (Figure 1-3) with the 2008 GLUT land use cover (Figure 1-2). The Table presents the acreage and percentage of each land cover.

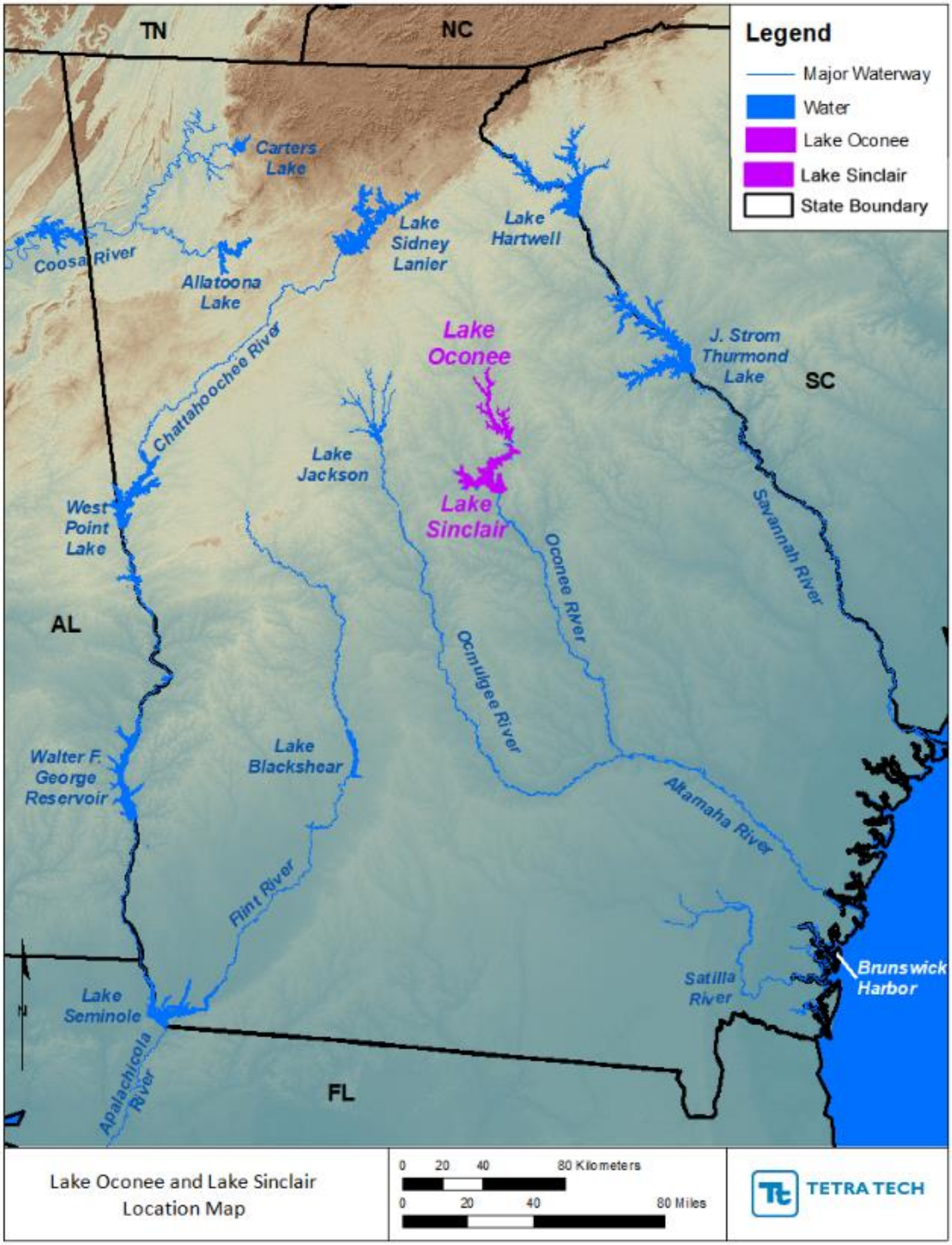

Figure 1-1. Location of Lakes Oconee and Sinclair

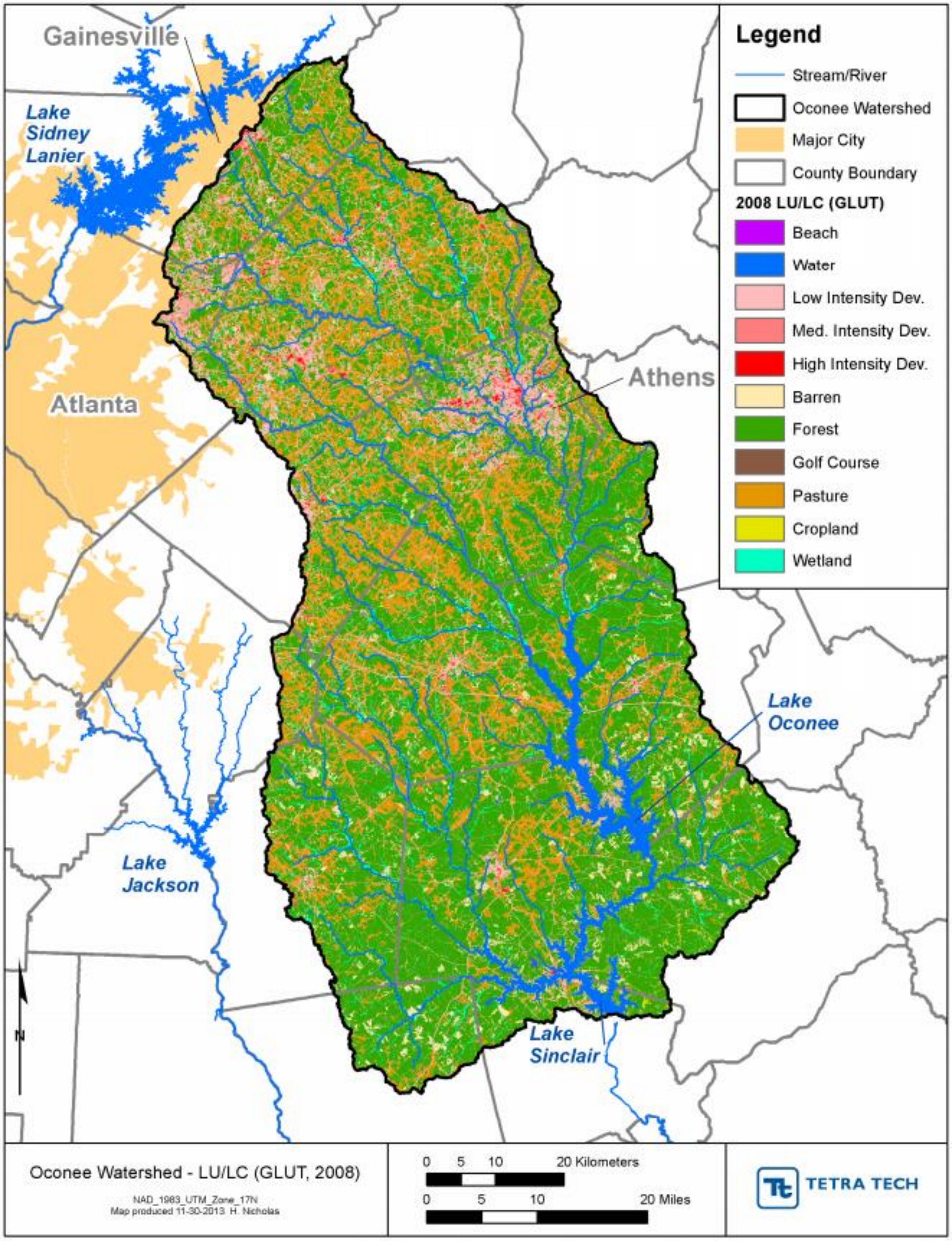

Figure 1-2. Lakes Oconee and Sinclair Watersheds Land Cover from 2008 GLUT

Table 1-1. Amount and Percentages of Land Cover and Impervious / Pervious Development

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

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.

The cities of Greensboro, Union Point, Madison, Bostwick, Rutledge, and Buckhead depend on Lake Oconee for their drinking water needs. The cities of Sparta and Eatonton, as well as Hancock, Putnam, and Baldwin counties depend on Lake Sinclair to meet their water usage needs.

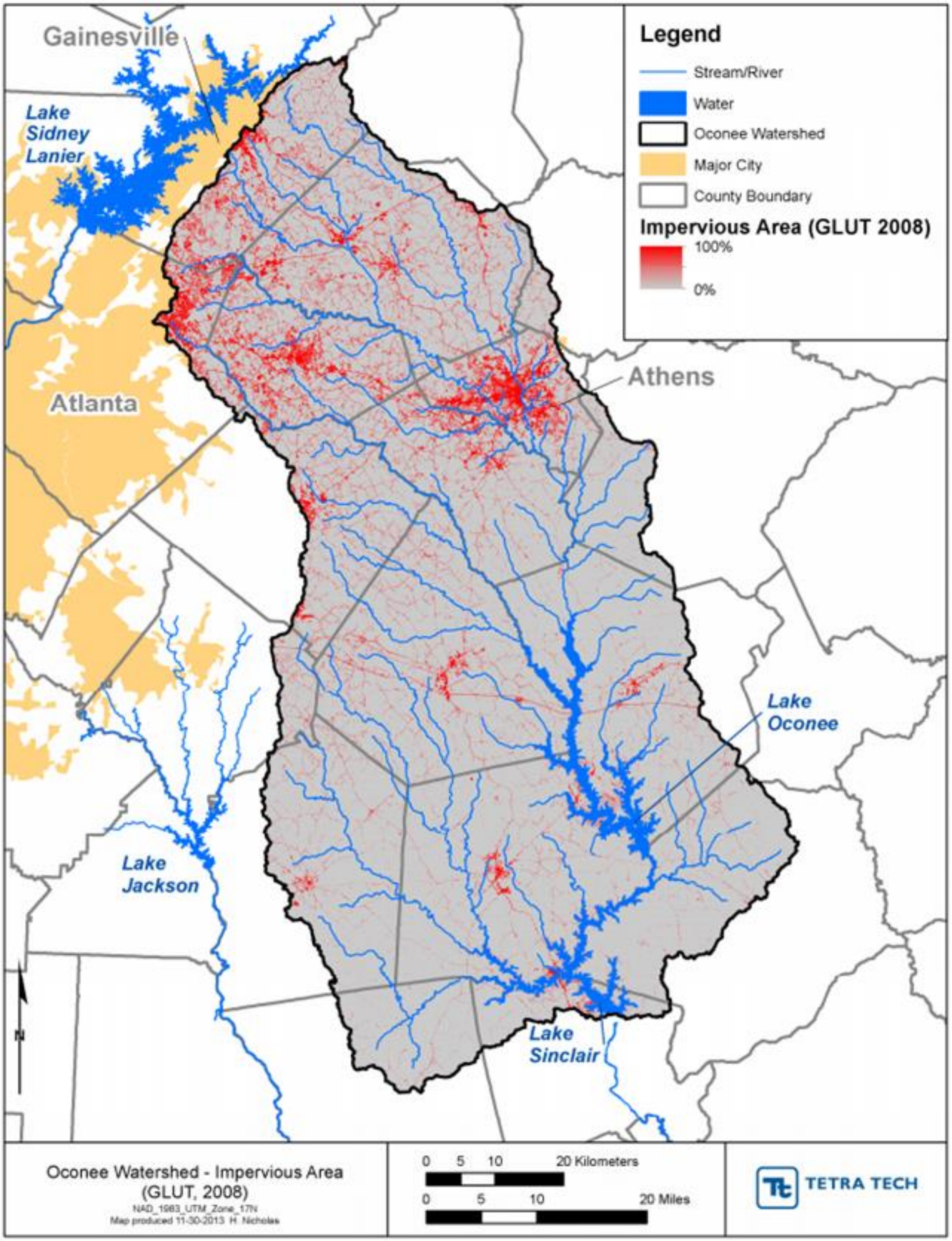

Figure 1-3. Lakes Oconee and Sinclair Watersheds Impervious Coverage from 2005 GLUT

There are 32 permitted point sources in the Lake Oconee watershed and 8 permitted point sources in the Lake Sinclair watershed. Of the 40 dischargers, only 15 have total phosphorus (Total P) permit limits. The other 25 facilities have no total phosphorus permit limits. Table 1-2 presents the Summary of Point Source Discharges to the Lakes Oconee and Sinclair Watersheds.

Table 1-2 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
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
GA0024015	Highland Mobile Home Village	North Oconee River	0.02
GA0025895	Rutledge	Little River	0.05

Many smaller communities use land application systems (LAS) for treatment and disposal of their sanitary wastewater. The LAS permits require these facilities to treat all of their wastewater by land application and properly operate the LAS 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 could 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. Table 1-3 is a list of the LAS in the Upper Oconee watershed.

Table 1-3. Summary of Land Application Systems in the Upper Oconee Watershed

Permit No.	Facility name	Acres	Type	Permitted Flow (MGD)
GAJ010518	Pilgrim's Pride Corporation		Industrial	
GAJ010532	Harrison Poultry, Inc.	394.6	Industrial	1.23
GAJ010546	Wayne Farms LLC (Pendergrass Fresh Plant)	33.5	Industrial	0.547
GAJ020006	Jefferson, City of (Central City WPCP)	51.2	Municipal	0.38
GAJ020072	Great Waters at Reynolds Plantation WRF	7.2	PID	0.07
GAJ020158	Winder, City of (Marburg Creek WRF)	308.0	Municipal	0.9
GAJ020176	Oconee County Board of Commissioners (Rocky Branch WPCP)	110.9	Municipal	0.4
GAJ020191	University of Georgia (Composting Facility)	4.6	Municipal	0.01
GAJ020230	Jefferson, City of (I85 North WPCP)	41.7	Municipal	0.287
GAJ020264	Stepah Co.	46.8	Industrial	-
GAJ020271	Barrow County Board of Commissioners (Tanners Bridge WRF)	55.7	Municipal	0.5
GAJ030632	Oconee Crossing	548.8	Municipal	0.5
GAJ030809	Towler Village WPCP	1.8	PID	0.005
GAJ030883	Carey Station Urban WRF	629.3	PID	0.500
GAJ030897	Reynolds Plantation Urban WRF	5022.6	PID	0.15
GAJ030928	High Shoals Health & Rehabilitation	2.8	PID	
GAJ030942	Bethlehem Elementary School WPCP	3.9	Municipal	0.015
GAJ030965	Madison Lakes	1059.5	Municipal	0.1
GAJ030983	Arcade Meadows (formerly, 4W ARCADE)	203.5	PID	0.25
GAJ040002	Sparta, City of (Sparta WPCP)		Municipal	0.8
GAJ040019	Walnut Grove, City of (Walnut Grove WPCP)		Municipal	0.05
GAJ040026	Hall County Board of Education (Myers Elementary School WPCP)		Municipal	
GAJ040036	Oconee County Schools (Dove Creek Elementary School WPCP)		Municipal	0.0102

The Georgia Rules require any person who is the owner of an Animal Feeding Operation (AFO) that is defined as a CAFO per 40 CFR 122 and discharges to water of the State apply for a NPDES Permit. Or, if the Division has made a case-by-case designation as a CAFO, the owner of the CAFO must apply for a NPDES permit. Otherwise, any person who is the owner of an AFO with more than 300 animal units (AUs) and uses liquid manure handling must apply for an LAS permit from the Division. Table 1-4 is a list of the AFOs LAS in the Upper Oconee watershed.

Table 1-4. Summary of Land Application Systems for Animal Feeding Operations in the Upper Oconee Watershed

Permit No.	Facility name	Number of Animal Units (AU)
GAG920015	Double Bridges Swine Center	300-1000 AU
GAG920018	Kakega LLC	300-1000 AU
GAG920030	Green Glades Farm Inc.	300-1000 AU
GAG920031	Youngs Dairy	300-1000 AU
GAG920033	T & W Farms Inc. #1	300-1000 AU
GAG920046	B&B Dairy Inc	300-1000 AU
GAG920049	R.A. Moore Dairy, Inc	300-1000 AU
GAG920061	Day Farms, Inc.	300-1000 AU
GAG920068	Key's Dairy	300-1000 AU
GAG920069	N G Purvis Farms - Stephens Farm	300-1000 AU
GAG920077	Eatonton Dairy Farm	300-1000 AU
GAG940009	Rimes Family Farm of Taliaferro	>1000 AU
GAG940015	W Dairy LLC	>1000 AU
GAG940020	Godfrey Dairy, Inc.	>1000 AU
GAG940021	Sunrise Dairy, Inc	>1000 AU
GAG940028	Cabaniss Dairy LLC	>1000 AU

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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, which corresponds to the normal pool elevation. 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 2019 Triennial Review. Its designated uses are Recreation and Drinking Water. Lake Oconee is currently meeting its designated uses. The proposed chlorophyll *a* 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

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 2019 Triennial Review. Its designated uses are Recreation and Drinking Water. Lake Sinclair is currently meeting its designated uses. The proposed chlorophyll *a* 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

Other criteria being proposed that already 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 9.0. The specific criteria being proposed are as follows:

pH: within the range of 6.0 –9.0 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

GA EPD considers Lakes Oconee and Sinclair basin lakes and historically sampled these lakes quarterly once every five years. In 2009, GA EPD began collecting water quality samples from these lakes monthly during the growing season, from April through October. Both lakes are sampled at three locations. All water quality data for the watershed and lakes can be found in GOMAS and/or WQX.

These data were used to calibrate water quality models and develop numeric water quality criteria for the lakes.

3.1 Lake Oconee

Figure 3-1 shows the locations of the Lake Oconee water quality stations: Oconee River Arm at Hwy 44; Richland Creek Arm upstream of the confluence with the Oconee River Arm; and the Wallace Dam Forebay/Dam Pool. The monitoring sites correspond to the following monitoring location IDs: Oconee River Arm at Highway 44 is LK_03_520; Richland Creek Arm is LK_03_545; and Wallace Dam Forebay/Dam Pool is LK_03_538. The location names and IDs are used interchangeably in the following figures.

Figure 3-2 shows measured chlorophyll *a* data from 2010 to 2020 at all three stations. This plot shows chlorophyll *a* levels in the lake vary throughout the growing season and the chlorophyll *a* levels decreased as you move down the lake toward Wallace Dam. The chlorophyll *a* levels have also increased over time, especially over the last three years. The fact that many of the point sources within the watershed currently do not have total phosphorus permit limits could contribute to this trend.

In addition, there was significantly more rainfall in 2018 and 2020 compared to the average monthly rainfall (Figure 3-3). This higher rainfall may have resulted in higher chlorophyll *a* levels in the lakes due to larger nutrient contributions from nonpoint source runoff. In 2019, the chlorophyll *a* levels may have been higher due to the high nutrient fluxes from the lake bottom sediments releasing nutrients into the water column as a result of higher level nutrients entering the lake in 2018.

Figures 3-4 through 3-6 show the chlorophyll *a* growing season averages measured at each station for the years 2010-2016 and 2018-2020, along with the proposed criteria. The proposed criteria are slightly less than the observed data. EPD expects that the chlorophyll *a* levels in Lake Oconee will drop when permit limits for total phosphorus are implemented.

Figure 3-7 shows measured total nitrogen data from 1986 to 2020 at all three water quality stations. Figure 3-8 shows the relationship between total nitrogen and chlorophyll *a* data. Figure 3-9 shows measured total phosphorus data from 1986 to 2020 at all three stations. Figure 3-10 shows the relationship between total phosphorus and chlorophyll *a*. These plots may indicate that the chlorophyll *a* in the lake is generally phosphorus limited. Total Nitrogen levels are relatively constant over time; whereas the total phosphorus levels appear to have decreased over time as the chlorophyll levels have increased. Both total nitrogen and total phosphorus seem to decrease moving down the lake. This may be due to the nutrients being used by the algae as they move down the lake.

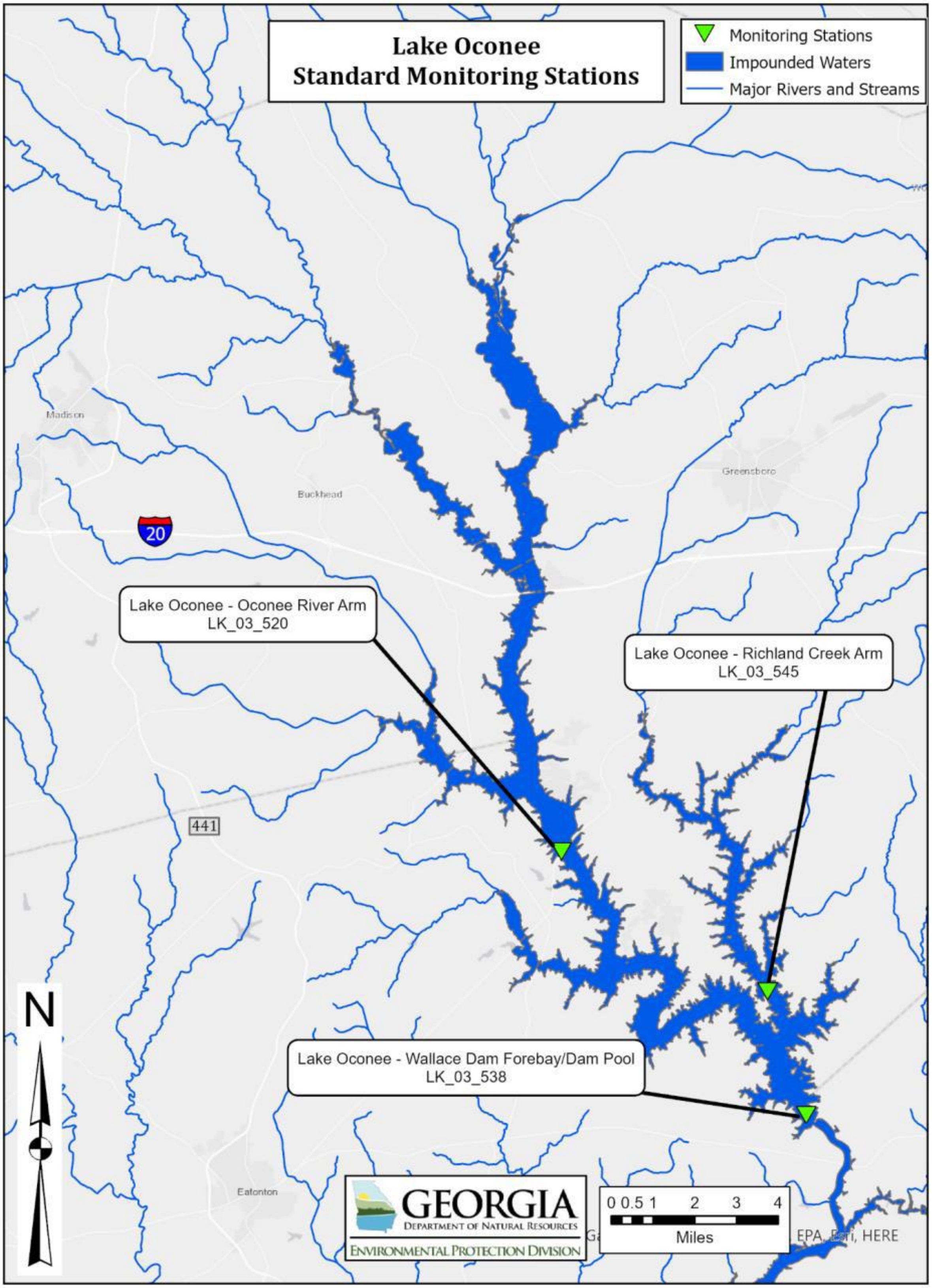

Figure 3-1. Lake Oconee Monitoring Sites

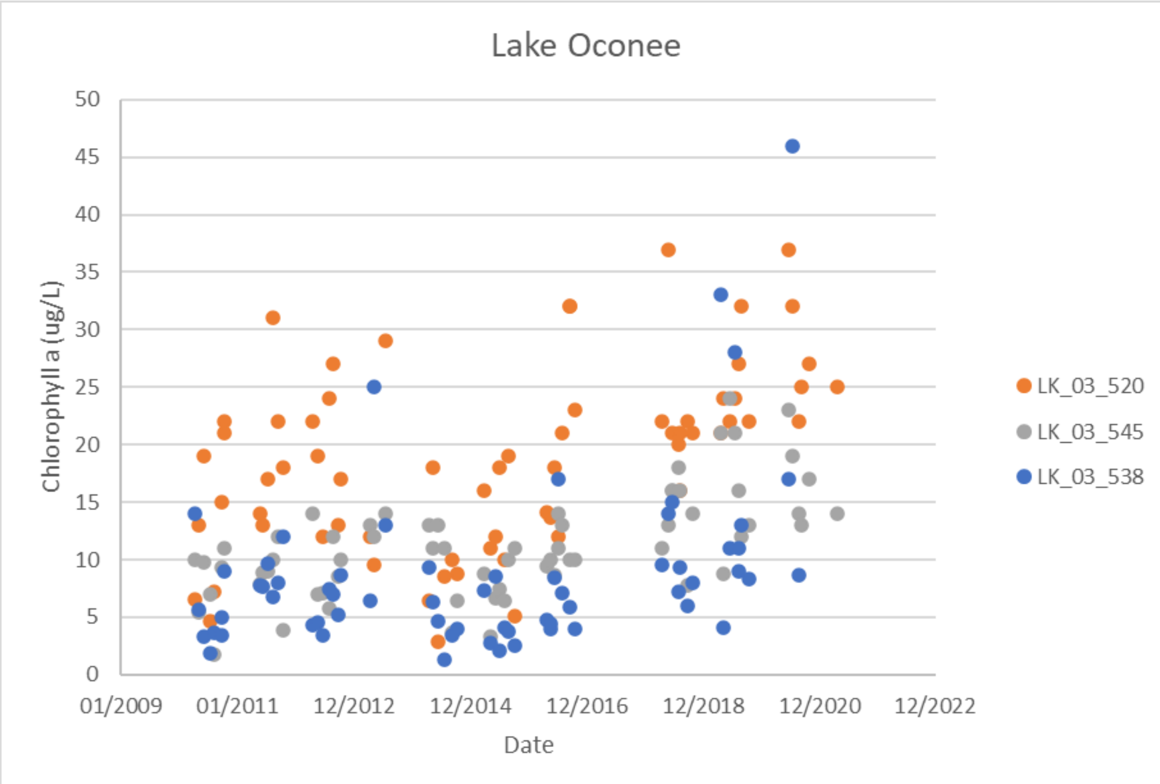

Figure 3-2. Lake Oconee Measured Chlorophyll *a* Data 2010 – 2020.

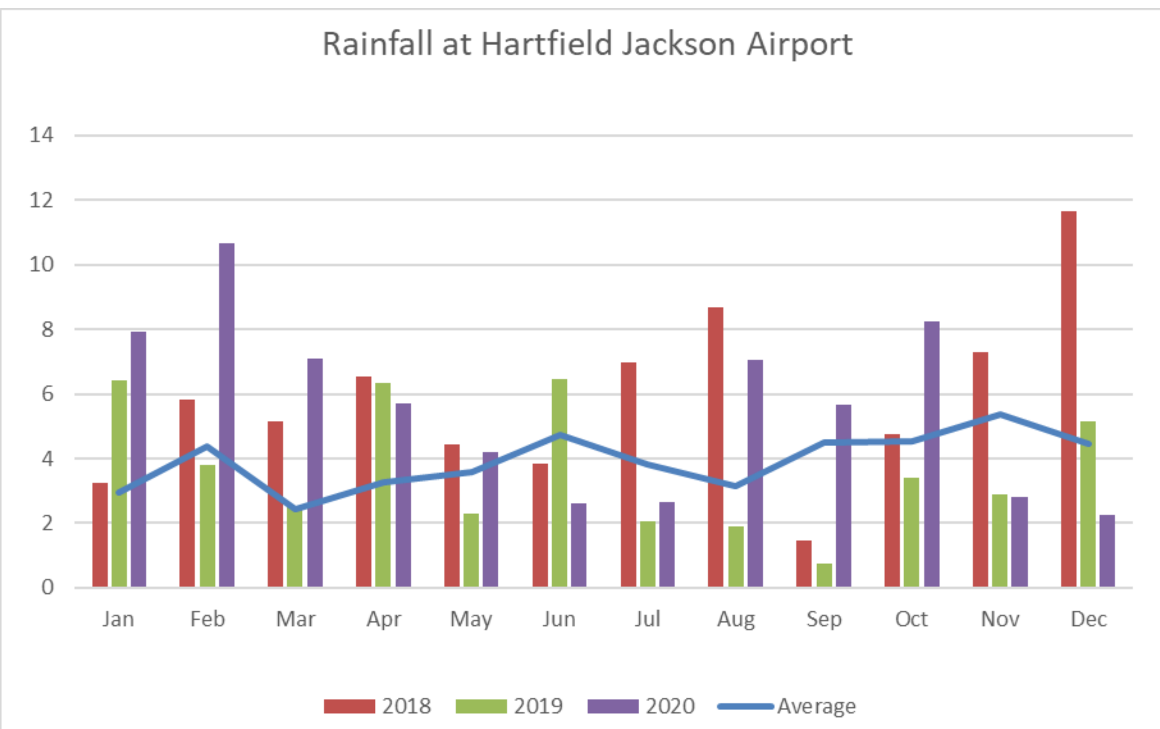

Figure 3-3. Monthly Rainfall Measured at Hartfield Jackson Airport

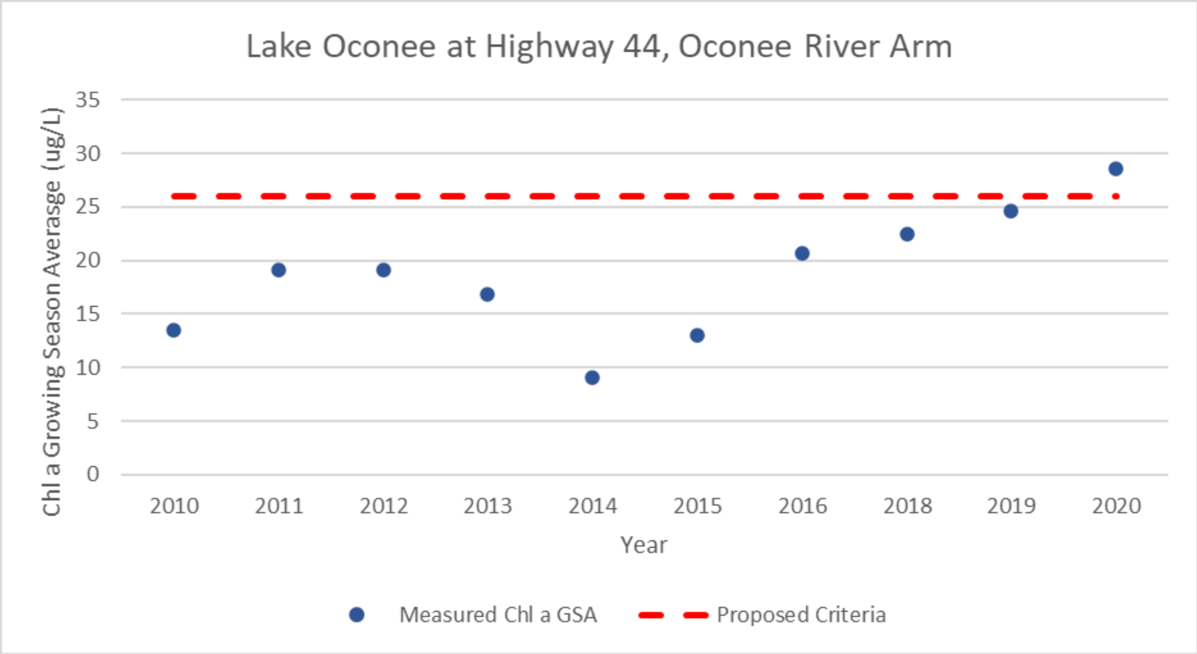

Figure 3-4. Measured Growing Season Average Chlorophyll *a* and Proposed Criteria at Highway 44, Oconee River Arm

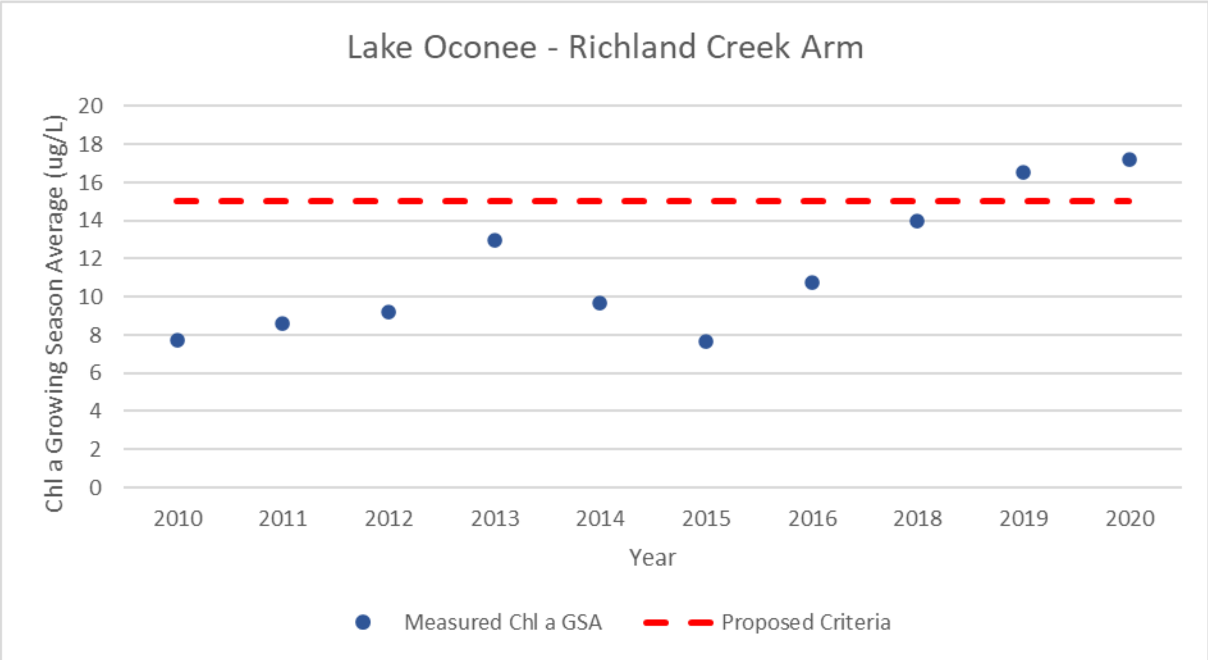

Figure 3-5. Measured Growing Season Average Chlorophyll *a* and Proposed Criteria at Richland Creek Arm.

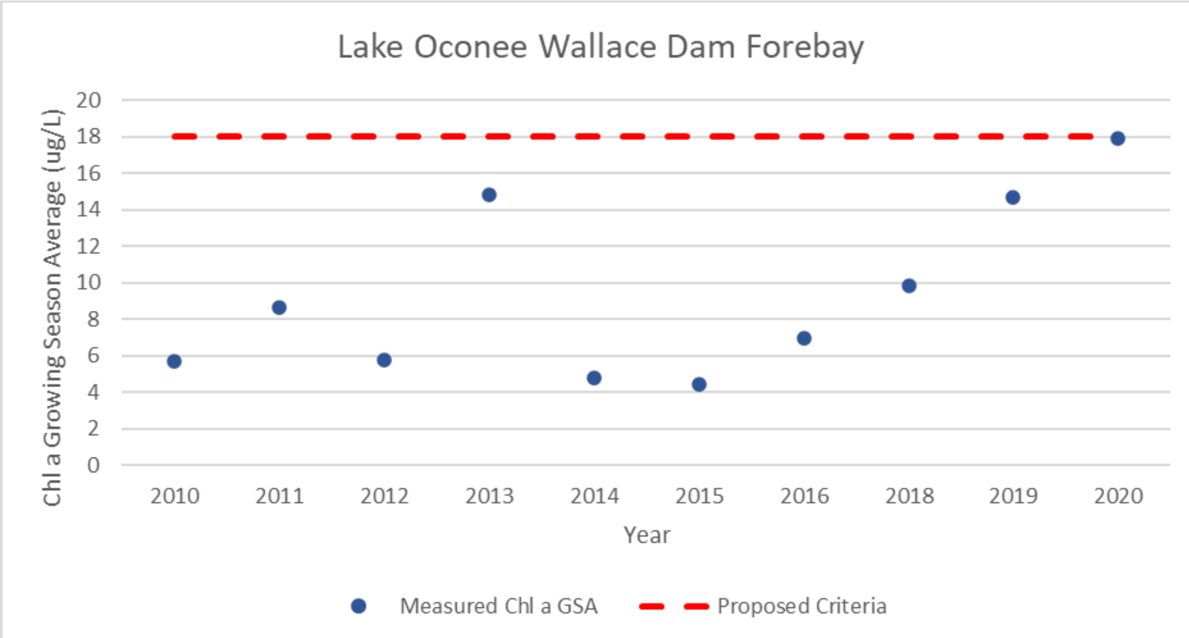

Figure 3-6. Measured Growing Season Average Chlorophyll *a* and Proposed Criteria at 300 meters upstream Wallace Dam (Dam Forebay).

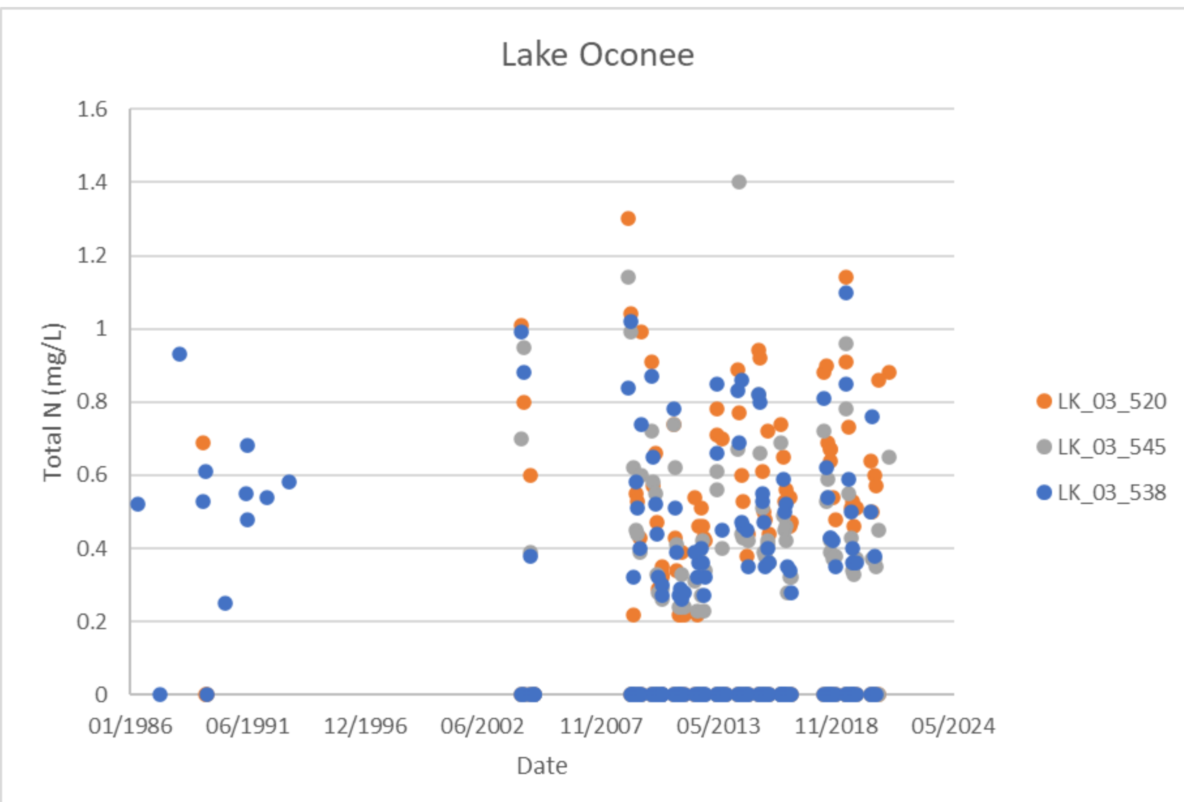

Figure 3-7. Lake Oconee Measured Total Nitrogen Data 1986 – 2020.

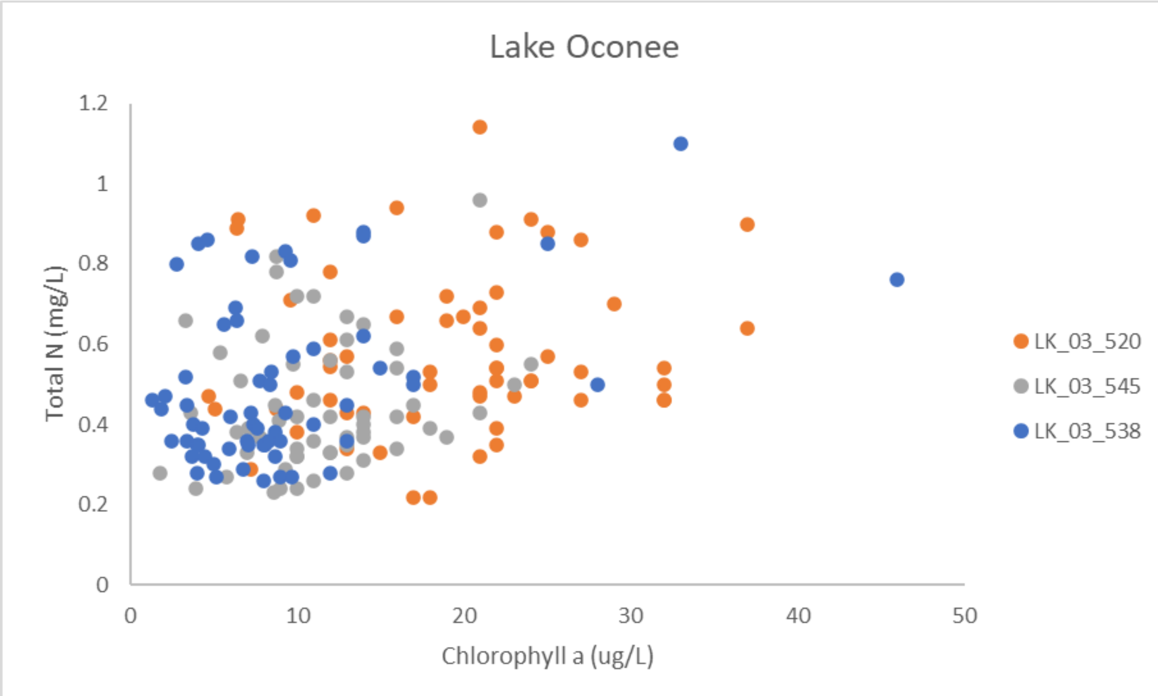

Figure 3-8. Lake Oconee Measured Chlorophyll *a* and Total Nitrogen Data.

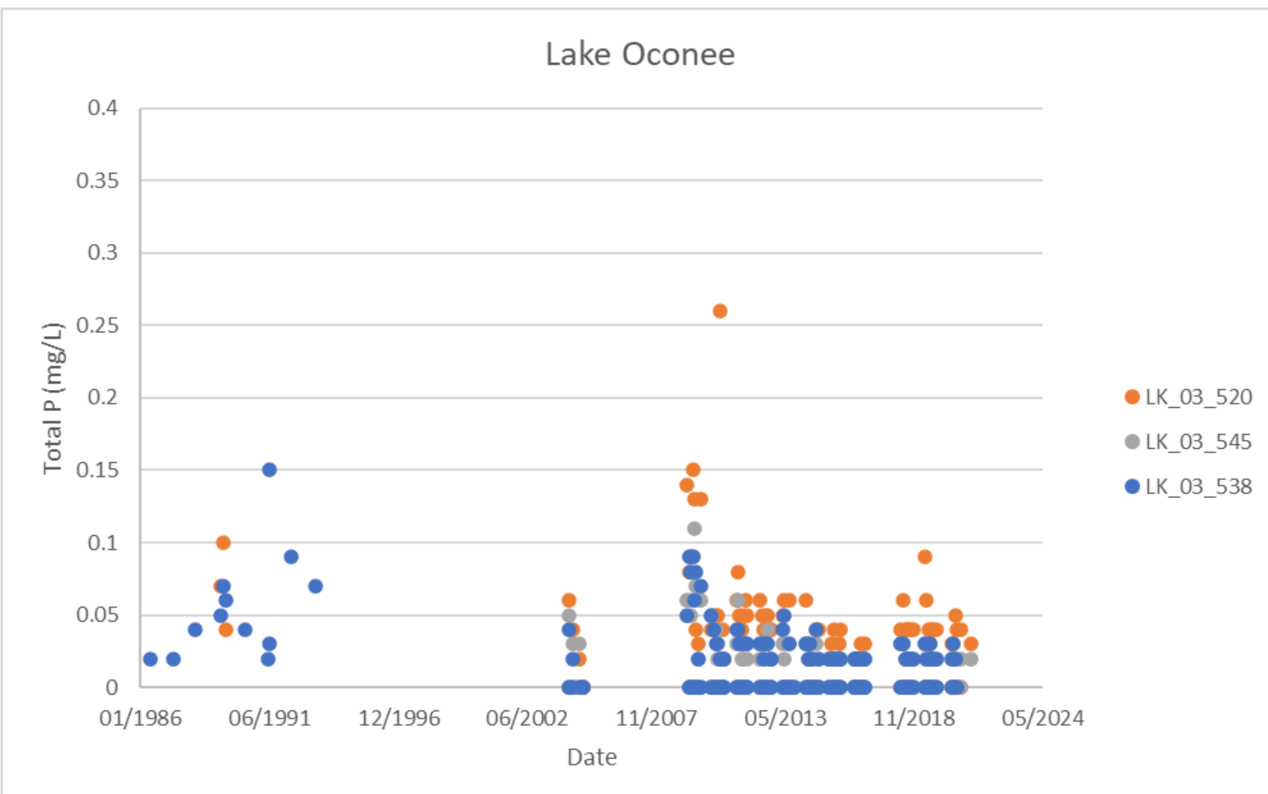

Figure 3-9. Lake Oconee Measured Total Phosphorus Data 1986 – 2020.

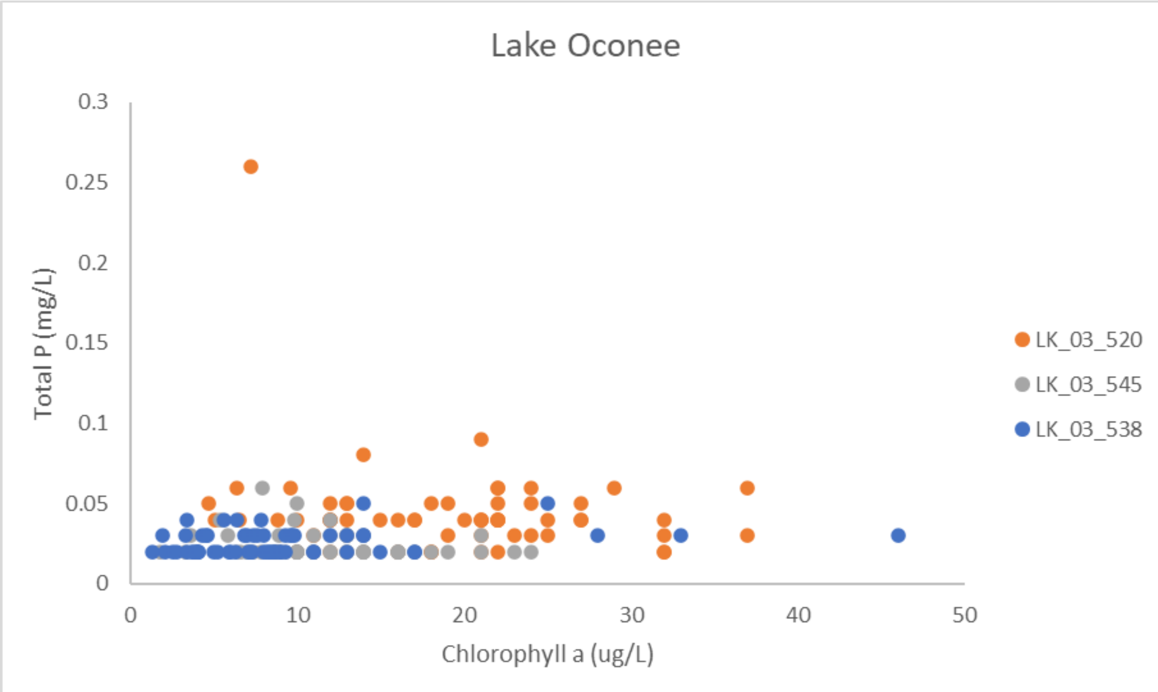

Figure 3-10. Lake Oconee Measured Chlorophyll *a* and Total Phosphorus Data.

In 2010, Algal Growth Potential Tests were performed on water collected from Lake Oconee at the three monitoring sites (Table 3-1). Lake Oconee appears to be mainly phosphorus limited, except at the Hwy 44, where the lake is nitrogen limited during the later portion of the growing season.

Table 3-1 Lake Oconee Algal Growth Potential Test - MSC (mg/L dry weight)

Station	Station Name	Date	Control	C+N	C+P	C+N+P	Limiting Nutrient
LK_03_520	Oconee River Arm-Hwy 44	5/5/2010	8.1	8.3	12.6		P
LK_03_520	Oconee River Arm-Hwy 44	9/29/2010	3.3	10.5	3.4		N
LK_03_545	Richland Creek Arm	5/5/2010	3.1	2.0	11.0		P
LK_03_545	Richland Creek Arm	9/29/2010	0.44	0.54	3.0		P
LK_03_538	Dam Pool	5/5/2010	1.2	1.4	14.0		P
LK_03_538	Dam Pool	9/29/2010	1.1	1.6	4.5		P

Figure 3-11 shows measured pH data from 1986 to 2020 at all three stations. This plot shows pH levels have been measured above 9.0, close to 9.5, and the lake is currently meeting its designated use.

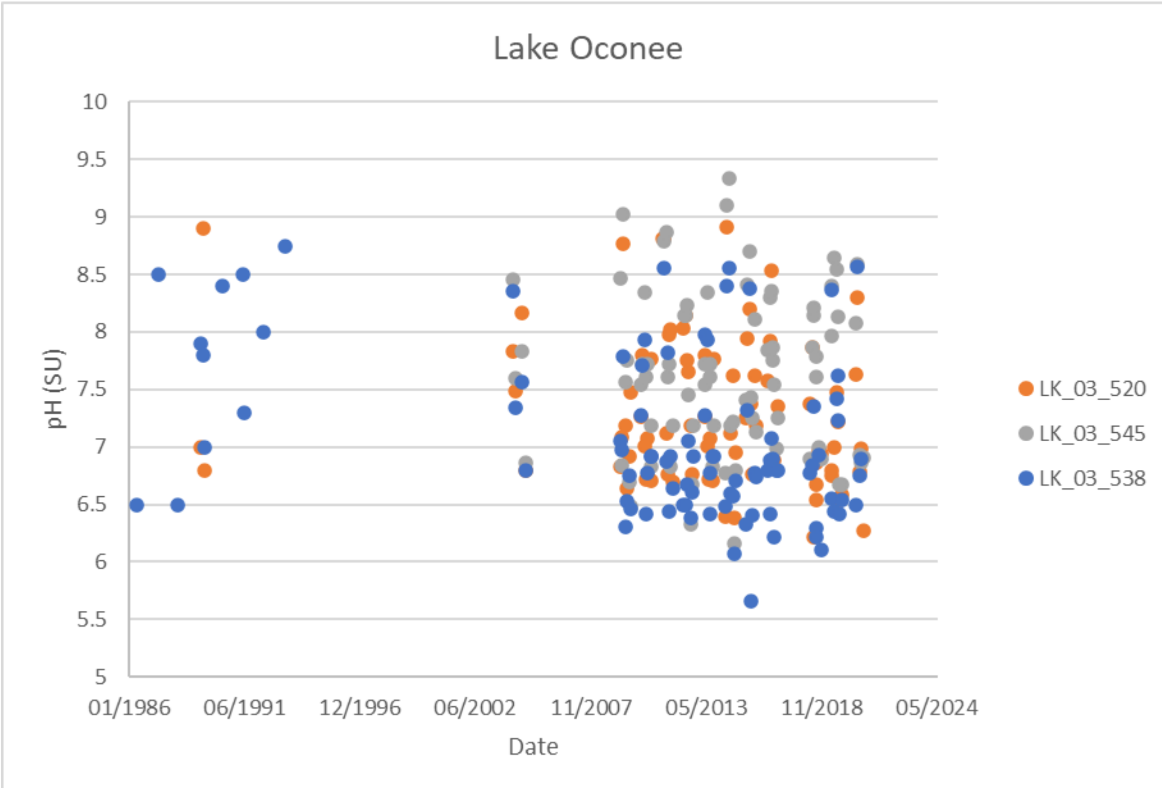

Figure 3-11. Lake Oconee Measured pH Data 1986 – 2020.

Figure 3-12 is a plot of the monthly pH depth profiles for monitoring location LK_03_545, Richland Creek Arm. Each line represents a different year. These plots show that in the photic zone at the surface of the water column where there are higher levels of algae, the pH tends to be higher. This is the result of the removal of carbon dioxide through photosynthesis. During daylight, algae remove carbon dioxide from the water as part of the sunlight-driven process of photosynthesis. The relative rates of respiration and photosynthesis within the lake determine whether there is a net addition or removal of carbon dioxide, and therefore whether pH falls or rises. Respiration rates are affected by water temperature and the biomass of the algae, plants, animals and microorganisms in the water and bottom sediment. Rates of photosynthesis are controlled primarily by sunlight intensity, plant biomass and water temperature.

During the day, photosynthesis usually exceeds respiration, so pH rises as carbon dioxide is extracted from the water. As the sun begins to set in late afternoon, photosynthesis decreases and eventually stops, so pH falls throughout the night as respiring organisms add carbon dioxide to the water. When the sun rises, plants resume photosynthesis and remove carbon dioxide from water, causing pH to rise again. The daily interplay of respiration and photosynthesis causes pH to cycle up and down during a 24-hour period. In most aquatic environments, daily photosynthesis is about equal to respiration and pH will usually remain within a range tolerated by most organisms. The summer-time bottom pH tends be between 6.0-6.5 and increase to around 7.0 in the fall and spring. On occasion, the bottom pH can drop to 5.9 or there may be temporary algae blooms where the surface pH can exceed 9.0. Even with these excursions, based on our Listing Assessment Methodology, the lake is still supporting its designated uses.

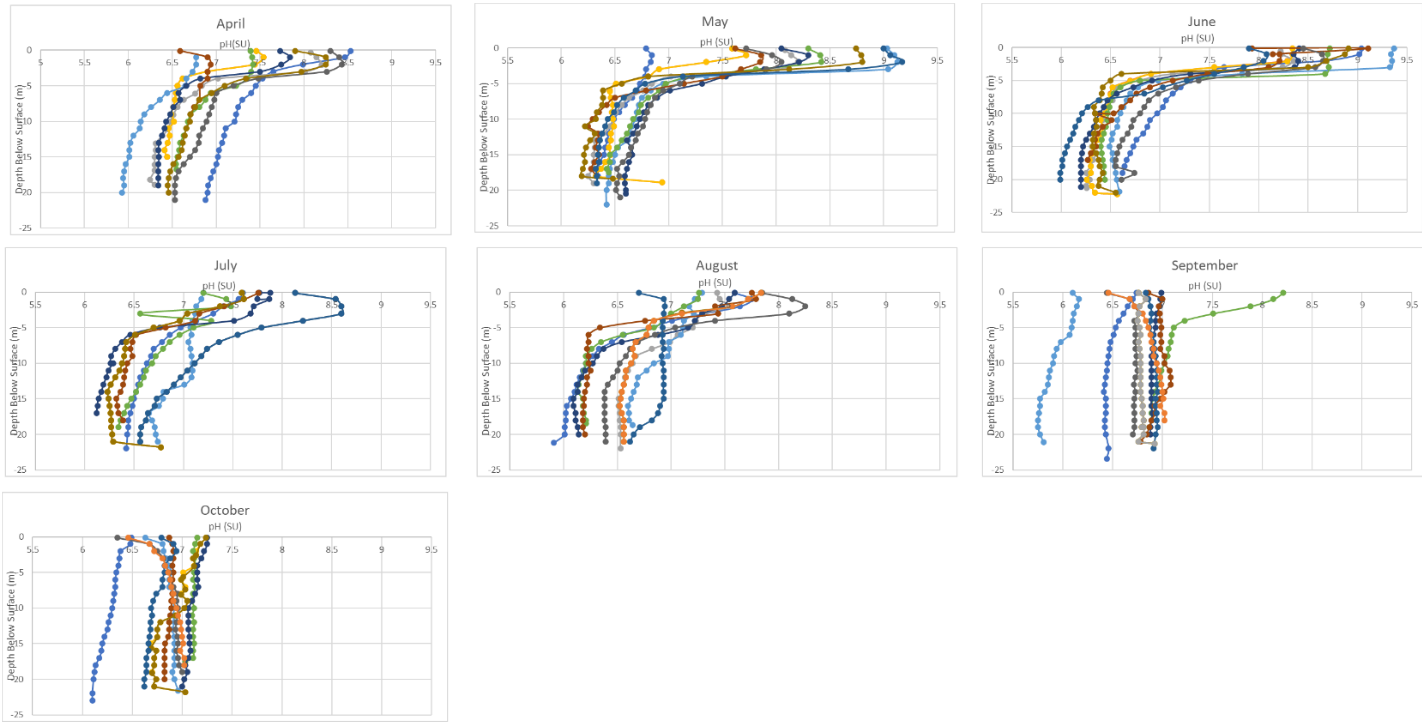

Figure 3-12. Lake Oconee pH Profile Data at Richland Creek Arm 2009 – 2020

Figure 3-13 shows the monthly temperature profiles at monitoring location LK_03_545, Richland Creek Arm. Each line represents a different year. Historical data shows that the overall profiles for temperature are affected by dam operations, especially in the summertime due to generation and pump-back cycles.

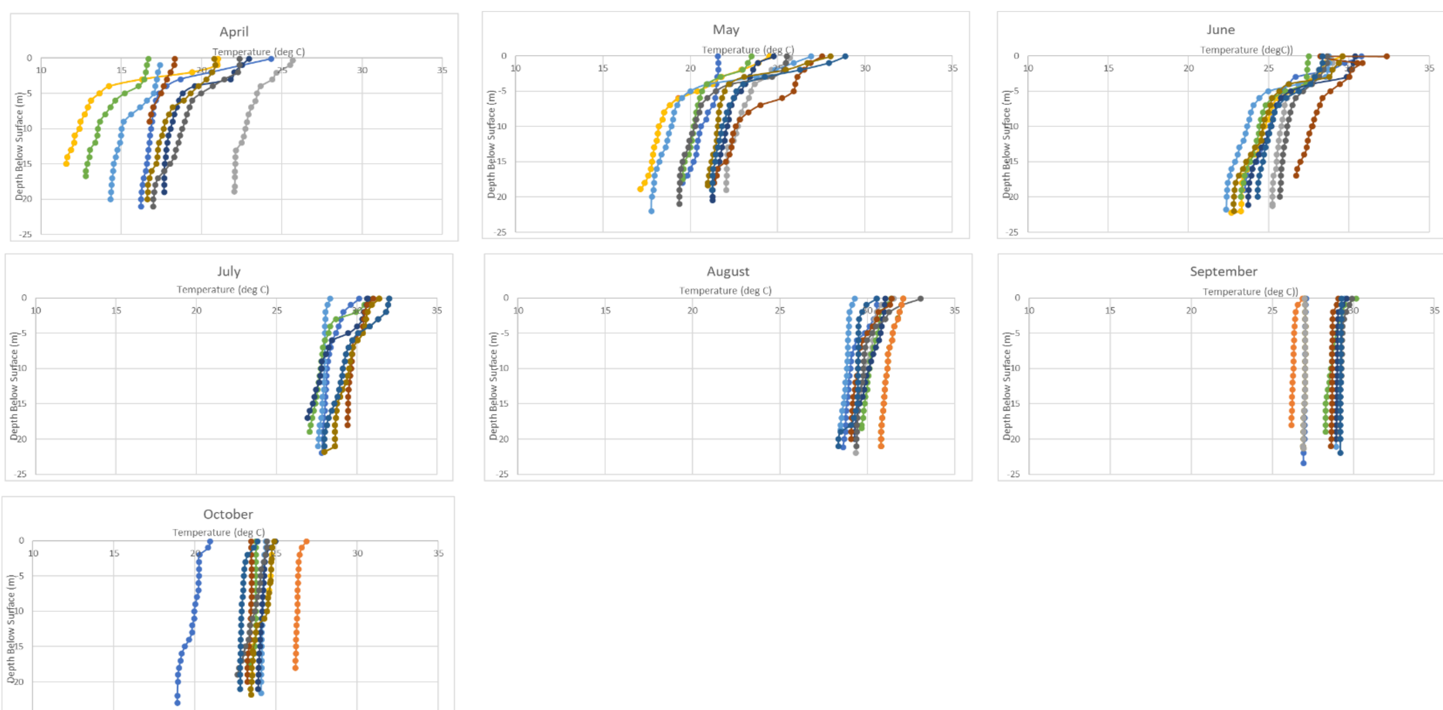

Figure 3-13. Lake Oconee Temperature Profiles Data at Richland Creek Are,1986 –2020

The temperatures are coolest in the spring (April) and increase as the summer progresses. Temperatures then begin to decrease starting in September. Typically, the temperatures do not exceed 90 deg F (32.2 Deg C) and are hotter at the water surface. There were only two days out of the 80 days sampled when the temperature in the top one meter of the lake slightly exceeded 90 deg F by 1.5 deg F. As per our Listing Methodology and because the temperature is exceeded only at the surface and the aquatic community within the lake can tolerate minor temperature excursions, the lake still supports its designated uses.

Figure 3-14 shows dissolved oxygen (DO) data measured at a depth of one meter below the water surface from 1986 to 2020. The instantaneous DO at the one-meter depth meets the DO water quality criteria of a daily average of 5 mg/L and no less than 4.0 mg/L at all times and therefore the lake is supporting its designated uses.

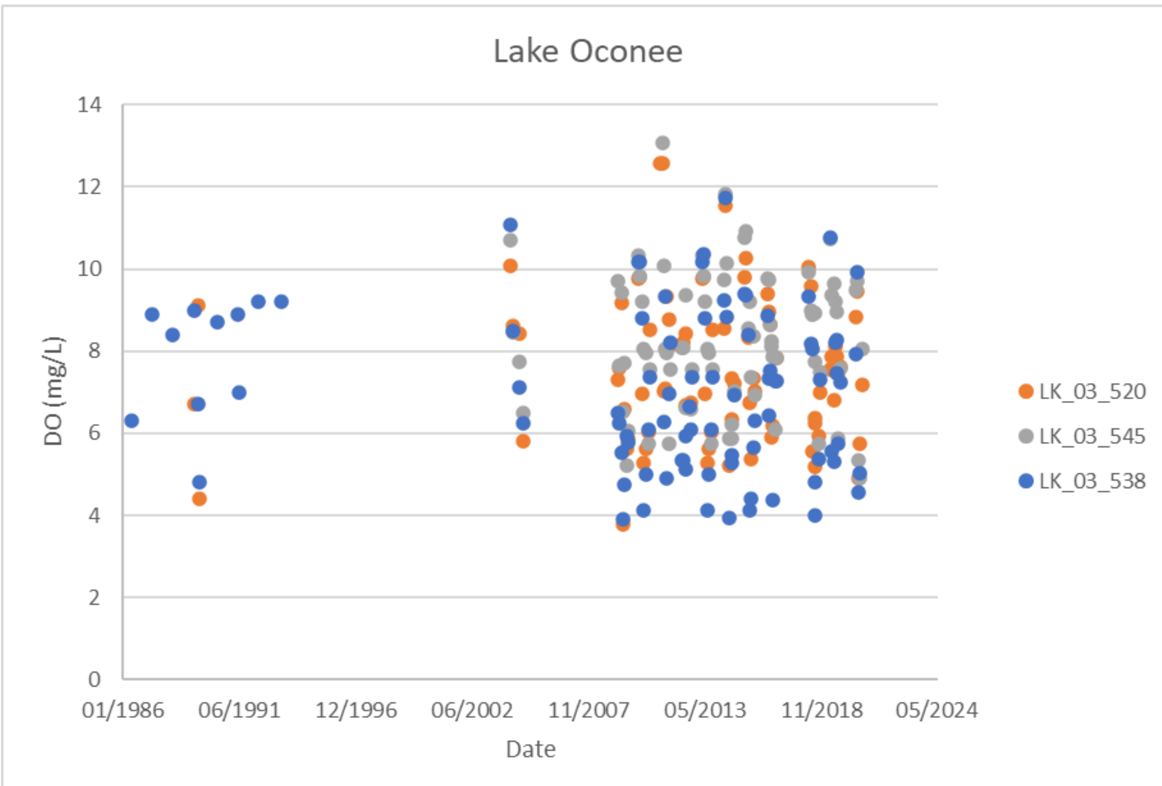

Figure 3-14. Lake Oconee Measured Dissolved Oxygen Data 1986 – 2020.

Figure 3-15 presents monthly DO depth profiles for monitoring location LK_03_545, Richland Creek Arm. Each line represents a different year. DO profiles in the lake typically exhibit higher DO at the surface and lower DO toward the bottom of the lake. DO concentrations lower in the lake remain suppressed because of the mixing resulting from the pump-back operations and the associated warmer water temperature. Historical DO data shows that the overall profiles for dissolved oxygen are affected by dam operations, especially in the summertime. Every year, in either July or August there is a time when the DO at the Dam Pool is low from top to bottom.

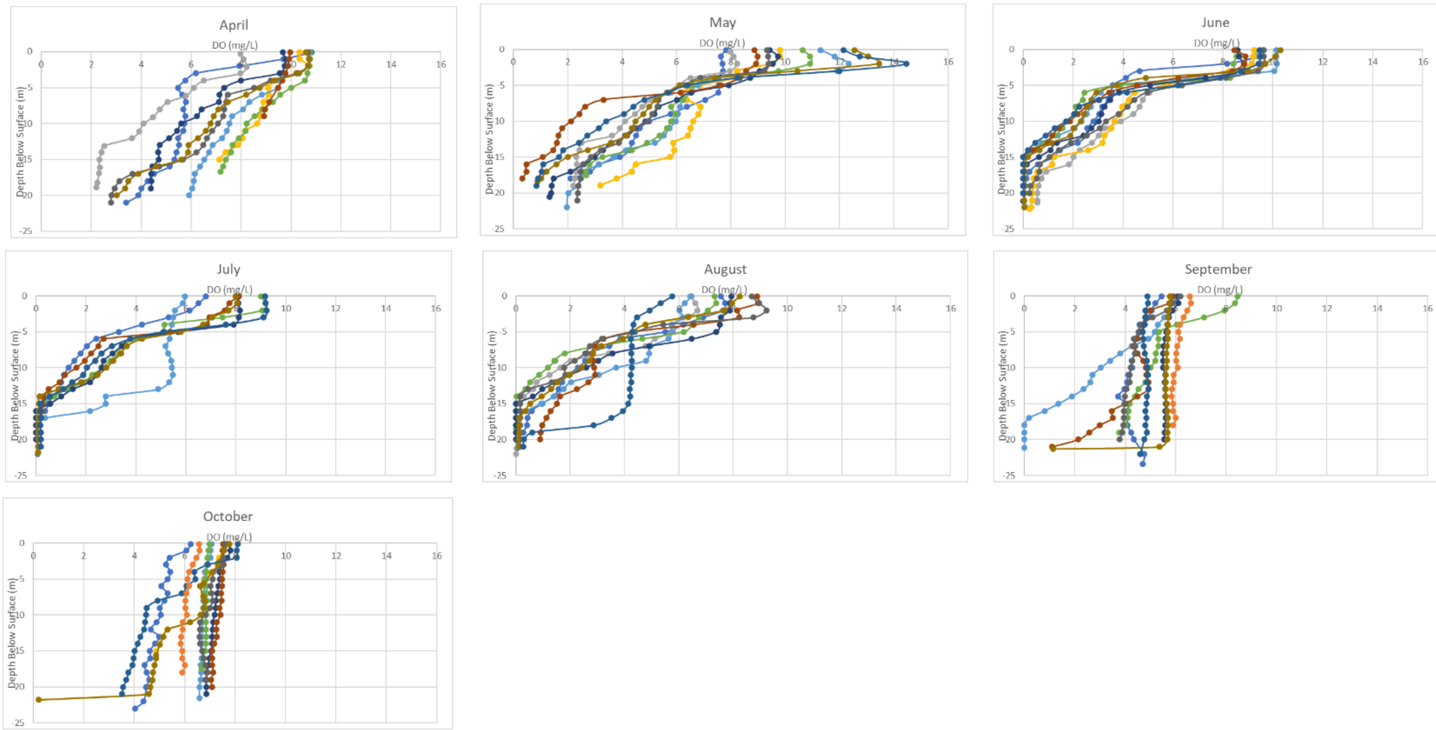

Figure 3-15. Lake Oconee Dissolved Oxygen Profile Data 2009 – 2020

Figure 3-16 is a plot of the E. coli levels measured in Lake Oconee. These data are from grab samples collected at the surface of the lake. None of these samples exceeded the 30-day geometric mean E. coli criteria (126 counts/100 mL) that supports primary recreation, which reveals that Lake Oconee is meeting its designated uses.

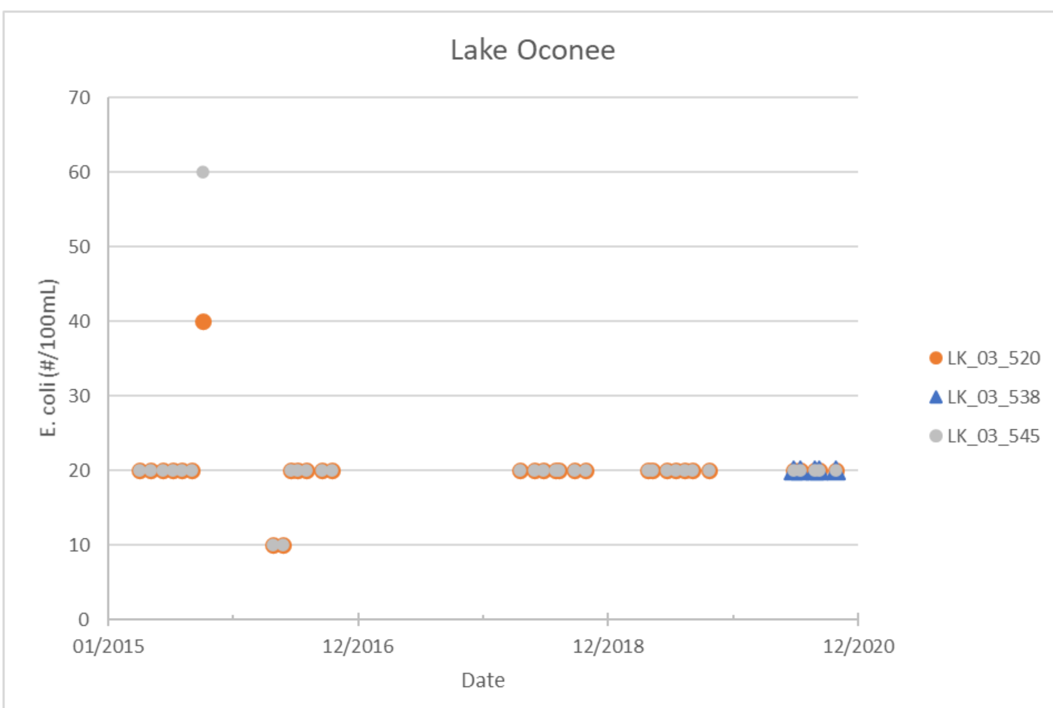

Figure 3-16. Lake Oconee Measured E. coli Data 2015 – 2020.

Figure 3-17 is a plot of fecal coliform levels measured in Lake Oconee. These data are from grab samples collected at the surface of the lake. None of these samples exceeded the 30-day geometric mean fecal coliform criteria (200 counts/100 mL) that supported primary recreation prior to the change to E. coli as the bacteria indicator for recreation designated use in 2015. These data demonstrate that Lake Oconee has historically met its designated uses.

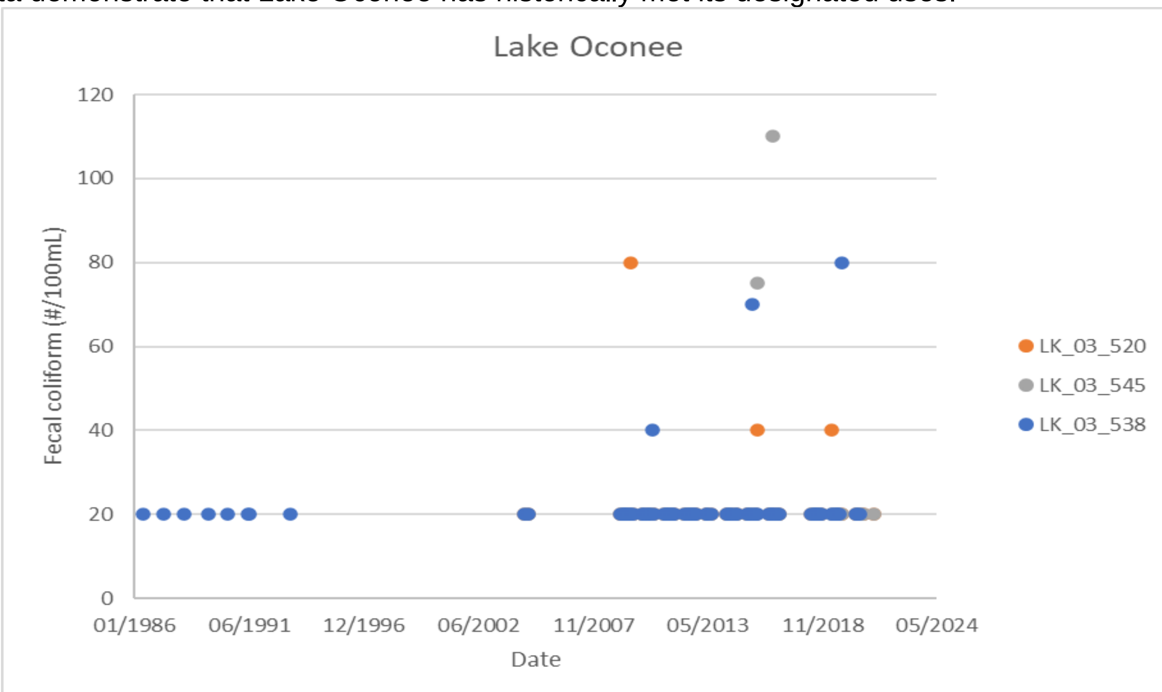

Figure 3-17. Lake Oconee Measured fecal coliform Data 1986 – 2020.

3.2 Lake Sinclair

Figure 3-18 shows the locations of the Lake Sinclair water quality stations: Oconee River Arm; Little River and Murder Creek Arm; and Dam Pool. The monitoring sites correspond to the following monitoring location IDs: Little River and Murder Creek Arm is LK_03_525; Oconee River Arm is LK_03_530; and Sinclair Dam is LK_03_526. The location names and IDs are used interchangeably in the following figures.

Figure 3-19 shows measured chlorophyll *a* data from 2010 to 2020 at all three stations. This figure shows chlorophyll *a* levels in the lake vary throughout the growing season. The chlorophyll *a* levels at the various monitoring stations are roughly the same, which may be the result of the pump back of water to Lake Oconee that occurs each night. Similar to Lake Oconee, the chlorophyll *a* levels in Lake Sinclair have increased over time. This could be due to the point sources within the watershed that currently do not have total phosphorus permit limits, as well as larger nonpoint source contributions as a result of the abnormally high rainfall in 2018 and 2020.

Figures 3-20 through 3-22 present the chlorophyll *a* growing season averages measured at each station for the years 2010-2016 and 2018-2020, along with the proposed criteria. The proposed criteria are slightly less than the observed data. It is our belief that the chlorophyll *a* levels in Lake Sinclair will drop when we implement permit limits for total phosphorus.

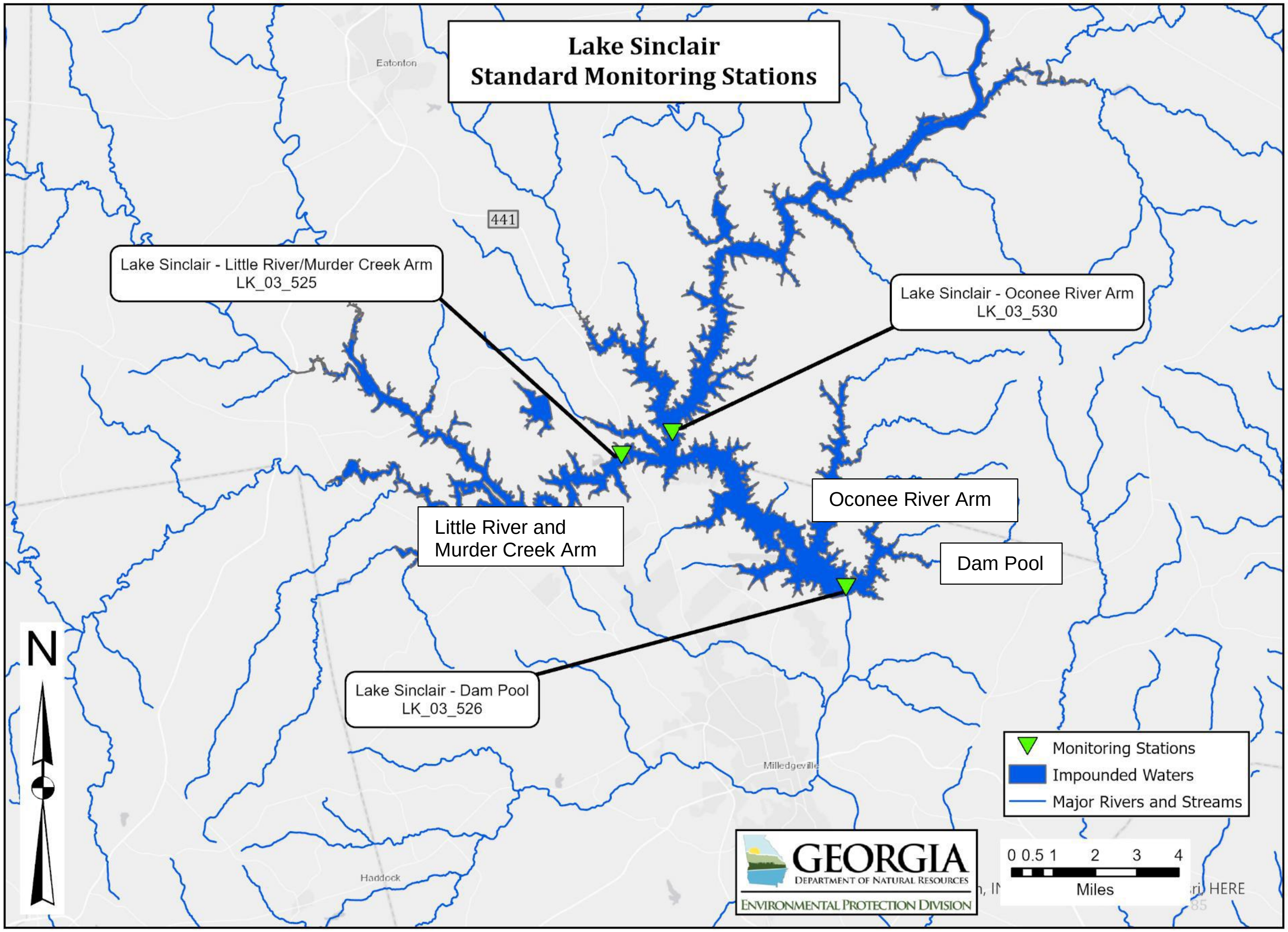

Figure 3-18. Lake Sinclair Monitoring Sites

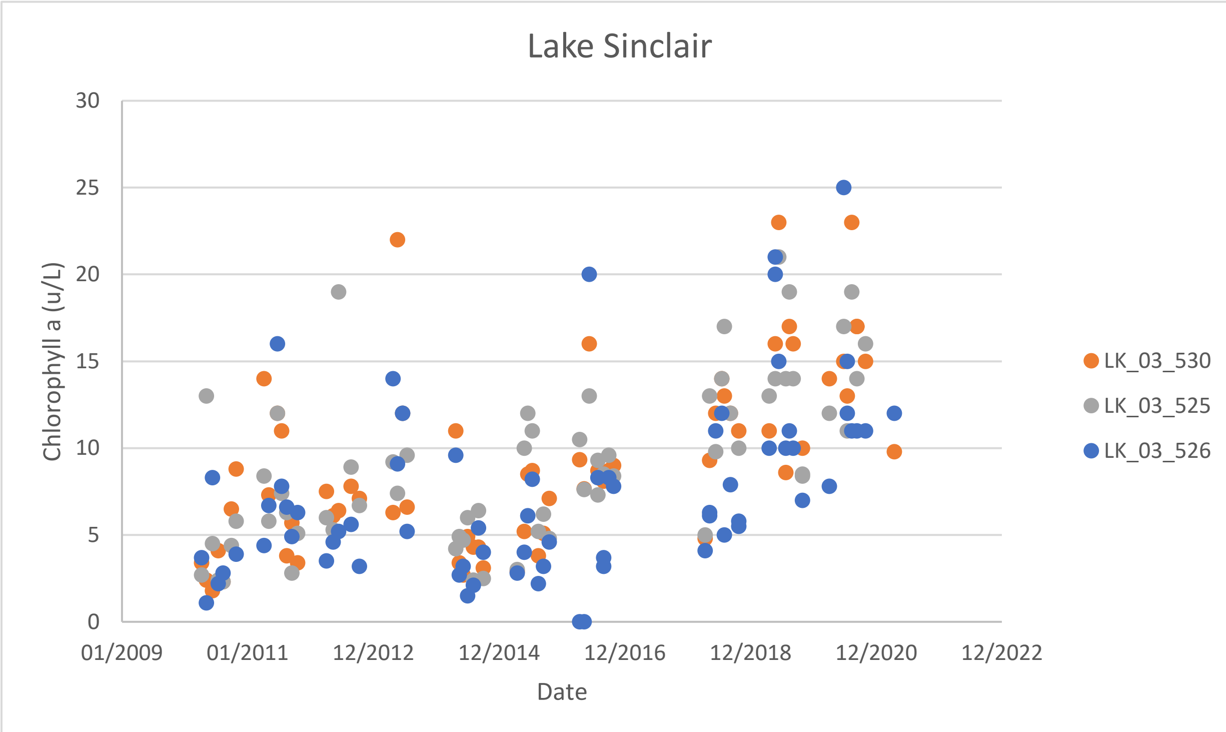

Figure 3-19. Lake Sinclair Measured Chlorophyll *a* Data 2010 – 2020.

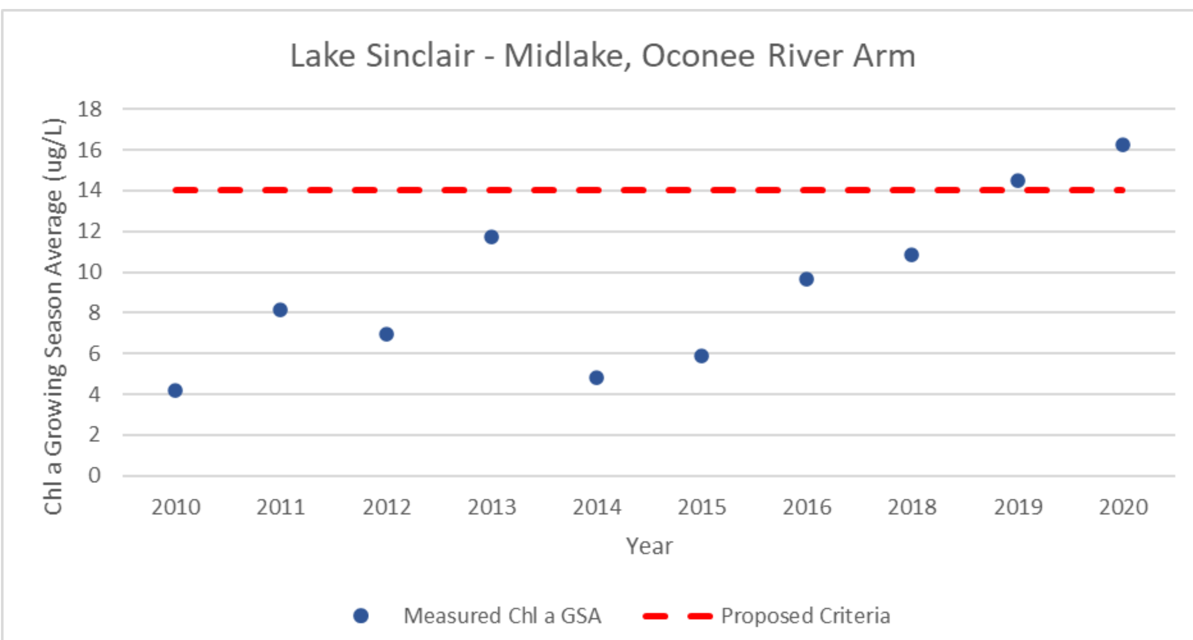

Figure 3-20. Measured Chlorophyll *a* Growing Season Average and Proposed Criteria at Midlake, Oconee River Arm.

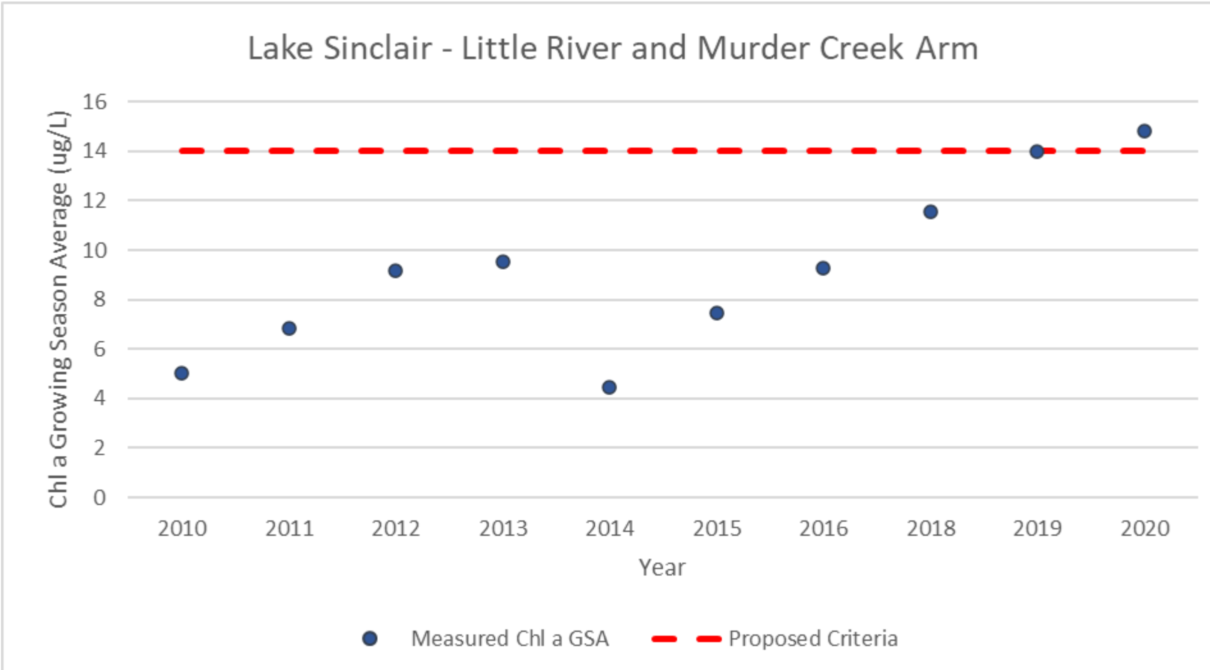

Figure 3-21. Measured Chlorophyll *a* Growing Season Average and Proposed Criteria at Little River and Murder Creek Arm.

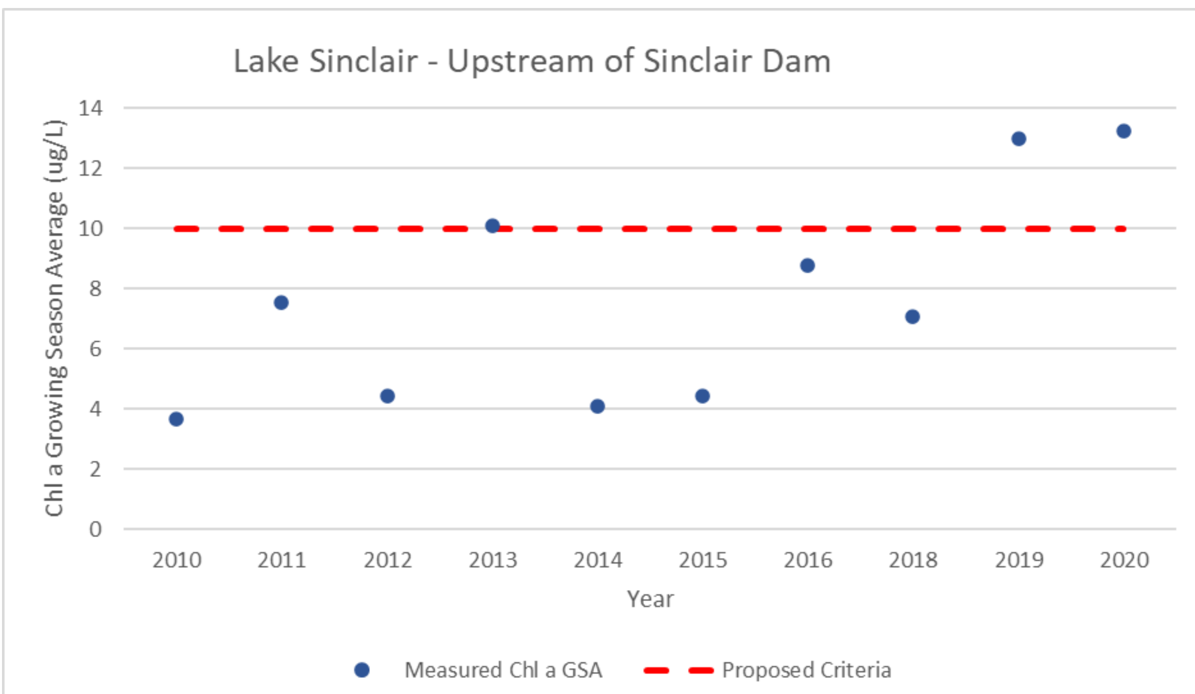

Figure 3-22. Measured Chlorophyll *a* Growing Season Average and Proposed Criteria at Sinclair Dam.

Figure 3-23 shows measured total nitrogen data from 1986 to 2020 at all three water quality stations. Figure 3-24 shows the relationship between total nitrogen and chlorophyll *a* at all three stations. Figure 3-25 shows measured total phosphorus data from 1986 to 2020 at all three stations. Figure 3-26 shows the relationship between total phosphorus and chlorophyll *a* data at all three stations. It appears that the total nitrogen and total phosphorus levels are roughly the same over time.

In 2010, Algal Growth Potential Tests were performed on water collected from Lake Sinclair at the three monitoring sites. The results of the Algal Growth Potential Test are presented in Table 3-2. Lake Sinclair appears to be nitrogen, phosphorus, and/or co-limited depending on the time of year. The lake seemed to start the growing season as phosphorus limited and became nitrogen limited as the season progressed.

Table 3-2. Lake Sinclair Algal Growth Potential Test - MSC (mg/L dry weight)

Station	Station Name	Date	Control	C+N	C+P	C+N+P	Limiting Nutrient
LK_03_525	Little River and Murder Creek Arm	5/5/2010	3.9	5.1	5.0	16	N+P
LK_03_525	Little River and Murder Creek Arm	9/29/2010	2.4	6.7	2.5		N
LK_03_530	Oconee River Arm	5/5/2010	6.5	5.7	10.5		P
LK_03_530	Oconee River Arm	9/29/2010	1.7	2.4	1.9		N
LK_03_526	Dam Pool	5/5/2010	4.4	3.9	11.8		P
LK_03_526	Dam Pool	9/29/2010	1.9	2.0	2.3	19.6	N+P

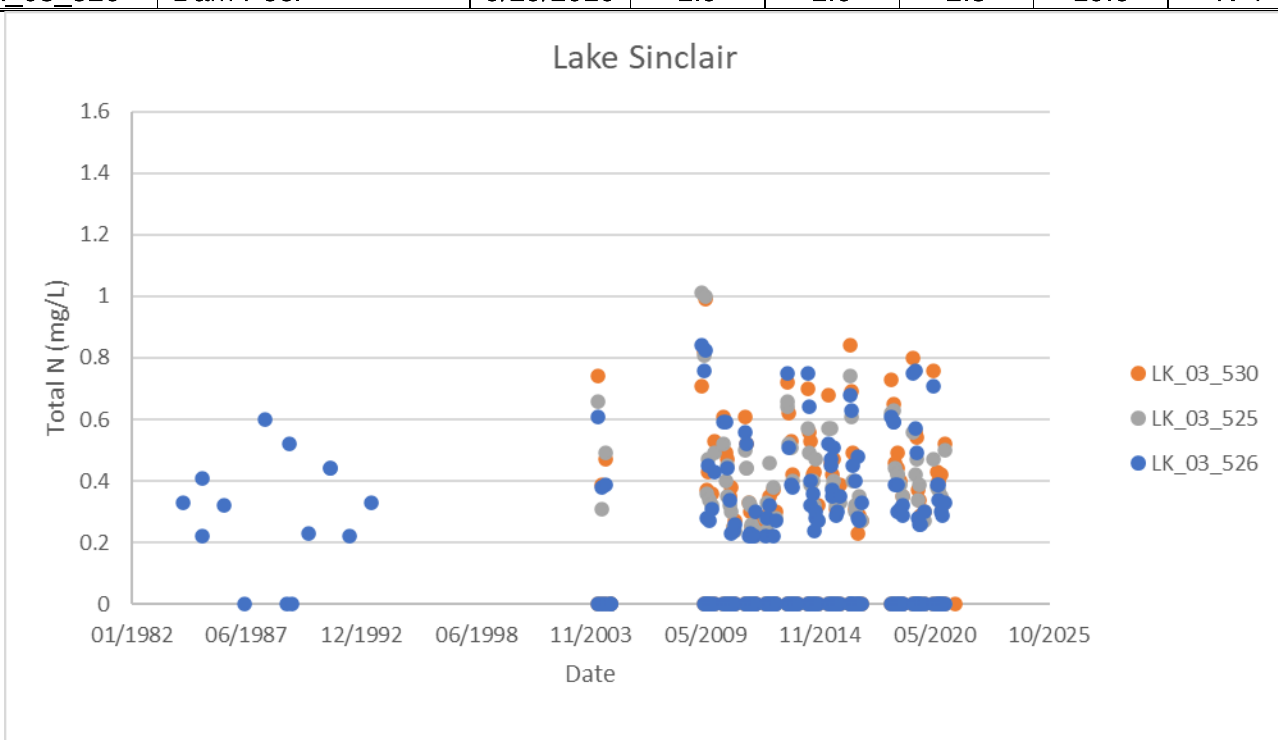

Figure 3-23. Lake Sinclair Measured Total Nitrogen Data 1986 – 2020.

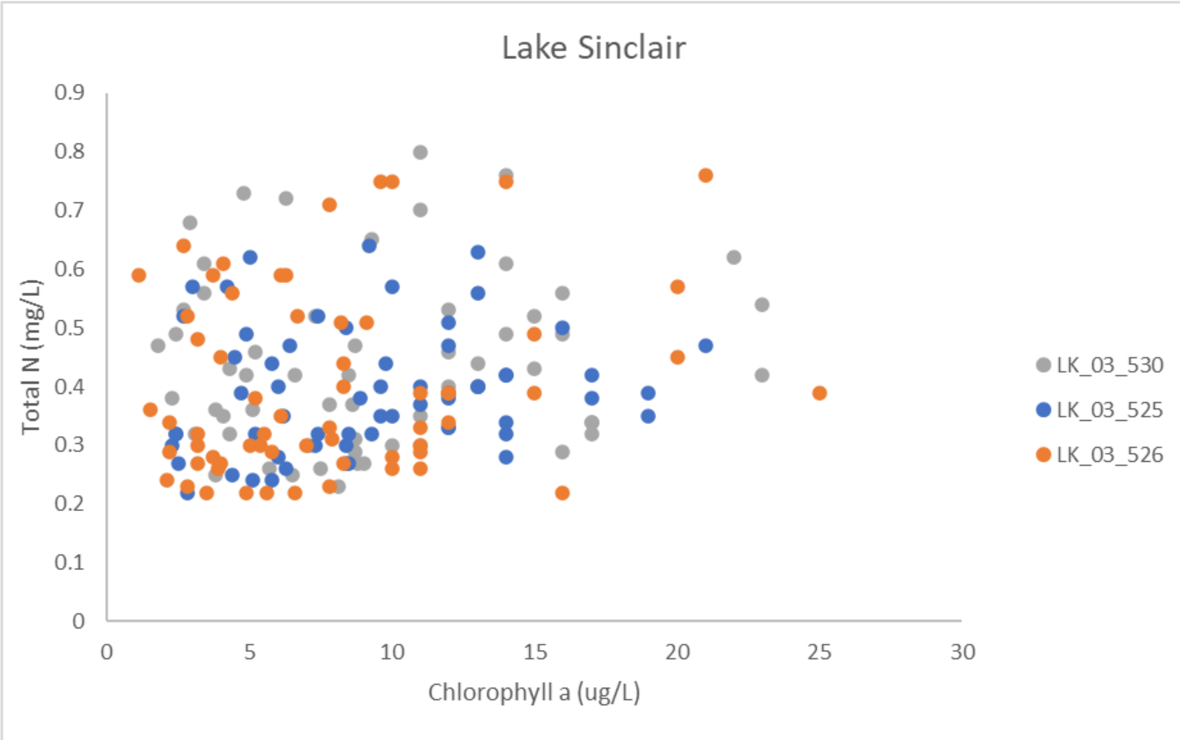

Figure 3-24. Lake Sinclair Measured Chlorophyll *a* and Total Nitrogen Data.

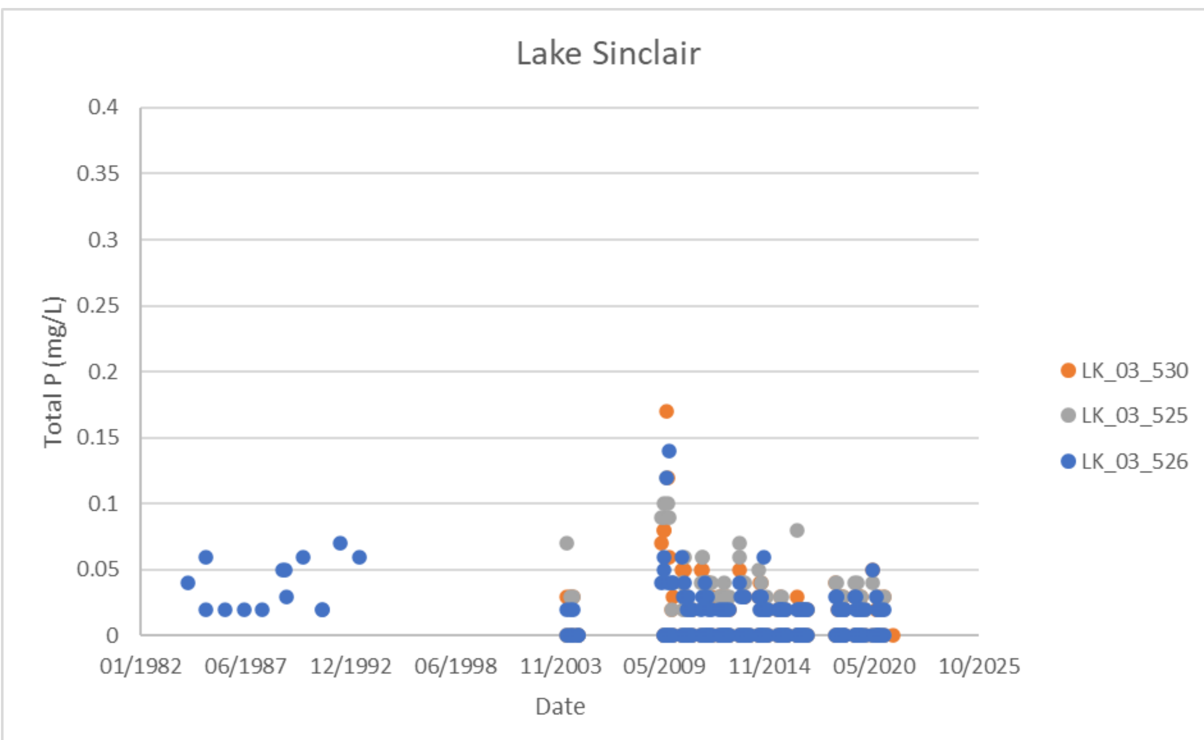

Figure 3-25. Lake Sinclair Measured Total Phosphorus Data 1986 – 2020.

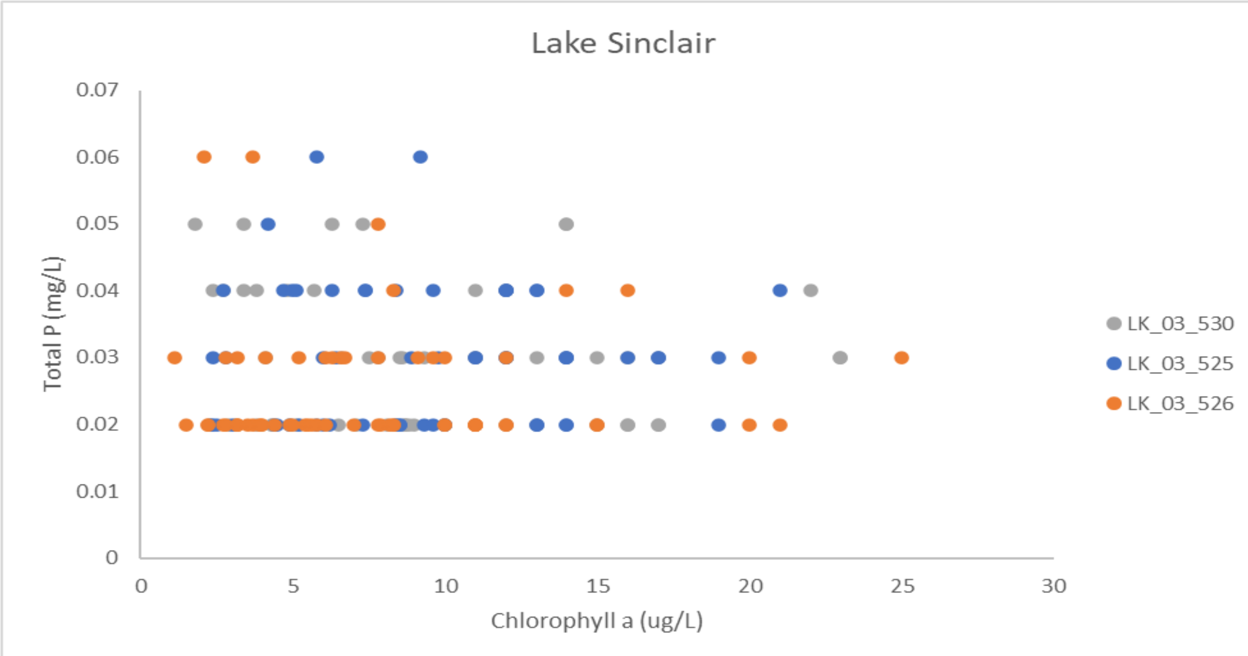

Figure 3-26. Lake Sinclair Measured Chlorophyll *a* and Total Phosphorus Data.

Figure 3-27 shows measured pH data from 1986 to 2020 at all three stations. This plot shows that most of the time the surface pH ranges between 5.5 and 9.0.

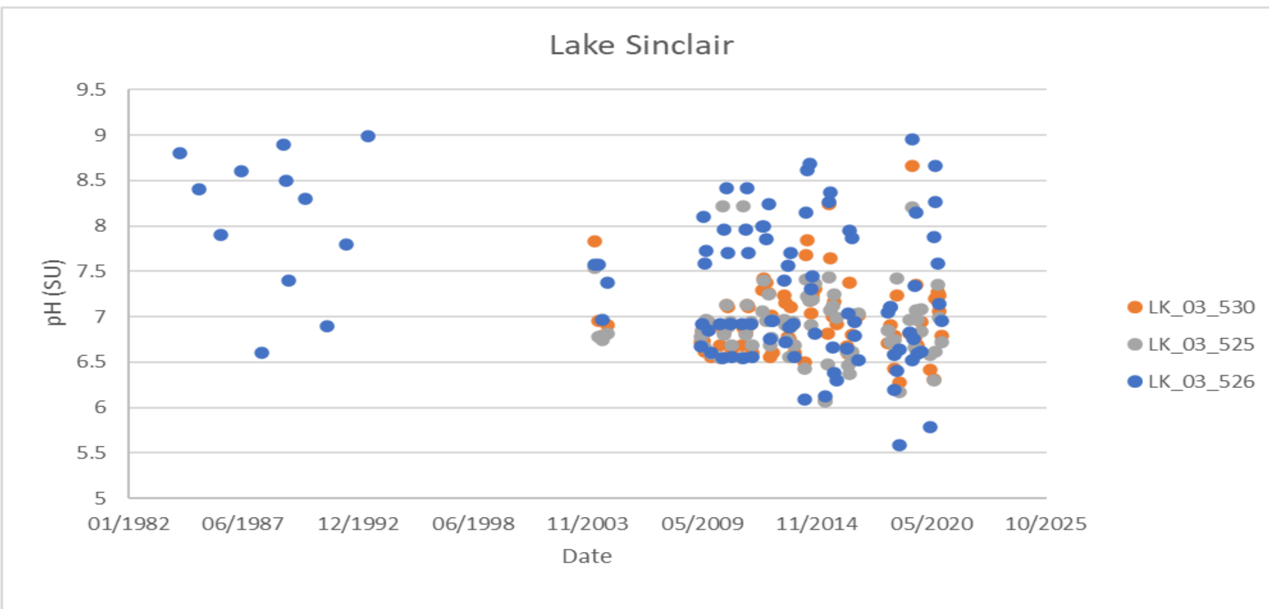

Figure 3-27. Lake Sinclair Measured pH Data 1986 – 2020.

Similar to Lake Oconee, the Lake Sinclair pH profiles show that the pH is higher at the surface and lower at the bottom (Figure 28). Figure 3-28 presents the monthly pH profiles at the Lake Sinclair Dam Pool (LK_03_526). Each line represents a different year. On occasion, the bottom pH can drop to 5.5. This may be due to the effect of the mixing that occurs in Lake Sinclair resulting from the pump back of water to Lake Oconee that occurs each night.

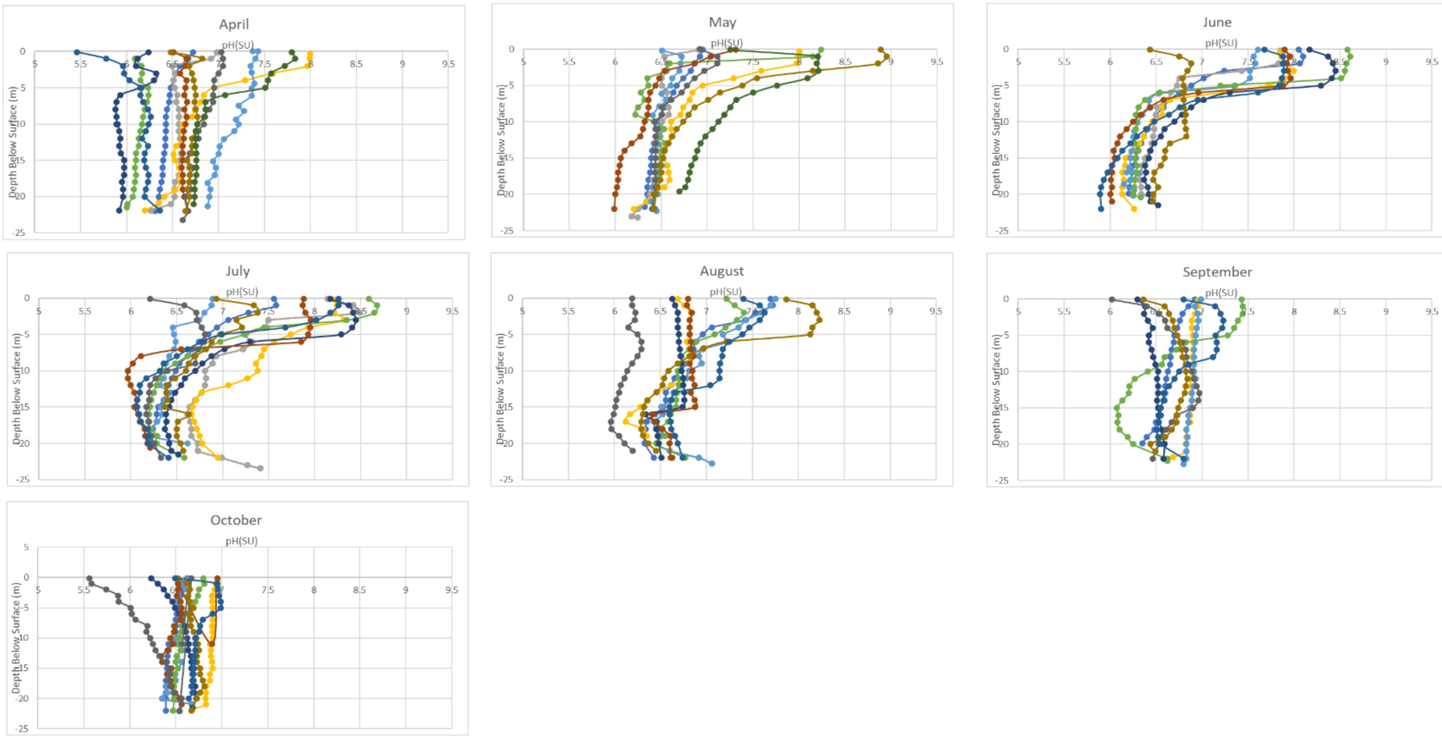

Figure 3-28. Lake Sinclair pH Profile Data at Dam Pool 2009 – 2020.

Figure 3-29 shows the temperature profile data measured in Lake Sinclair at the monitoring location ID LK_03_526, Dam Pool. Each line represents a different year. The temperature criteria of 90 deg F was often exceed throughout the water column during the summer until 2014, when Plant Branch stopped operating. After 2014, the water temperatures occasionally exceeded 90 deg F (32.2 deg C) in the top one meter and the exceedances were typically less than 1 deg F. Per our Listing Assessment Methodology and since the exceedances are limited to the surface and the fish can tolerate minor temperature excursions, the lake still supports its designated uses.

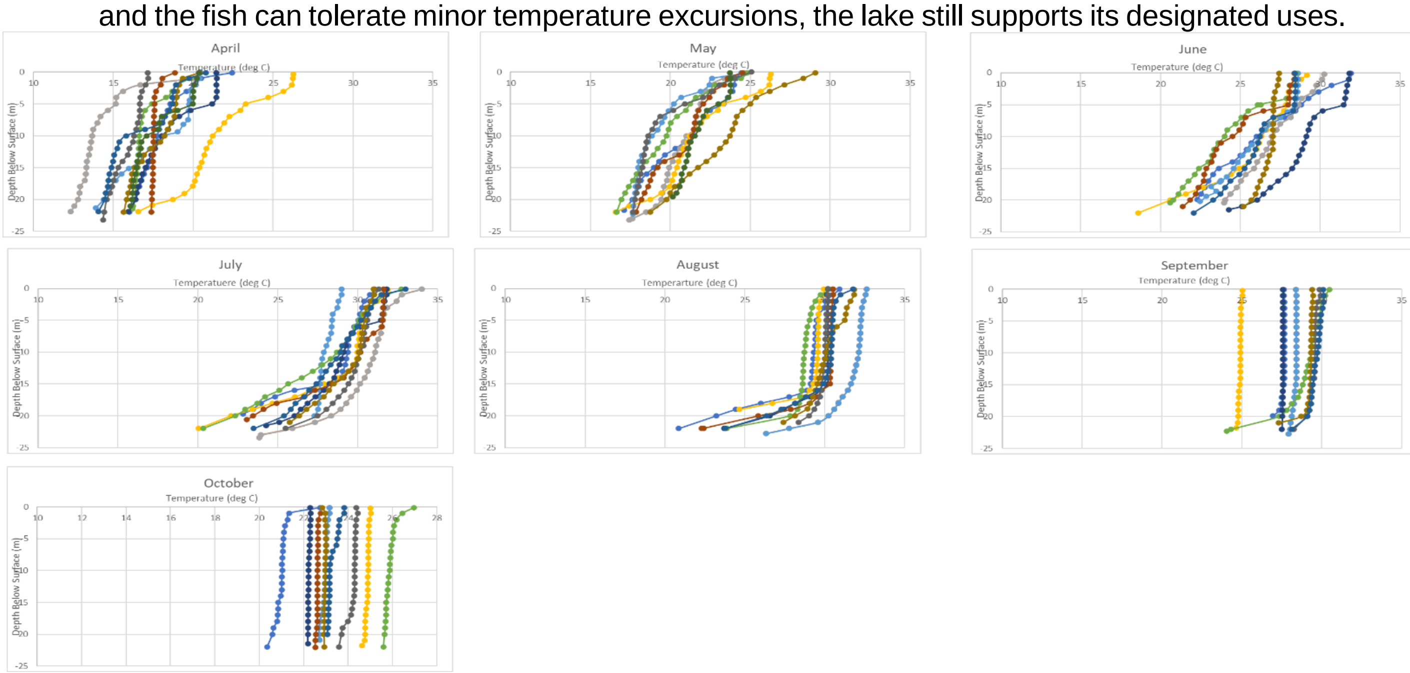

Figure 3-29 Lake Sinclair Temperature Profile Data at Dam Pool 2009 – 2020

Lake Sinclair has always met the instantaneous DO criteria of 4.0 mg/L and in most cases the measured DO is above 5.0 mg/L (Figure 3-30). Therefore, the lake is meeting its water quality criteria for DO and supporting its designated uses.

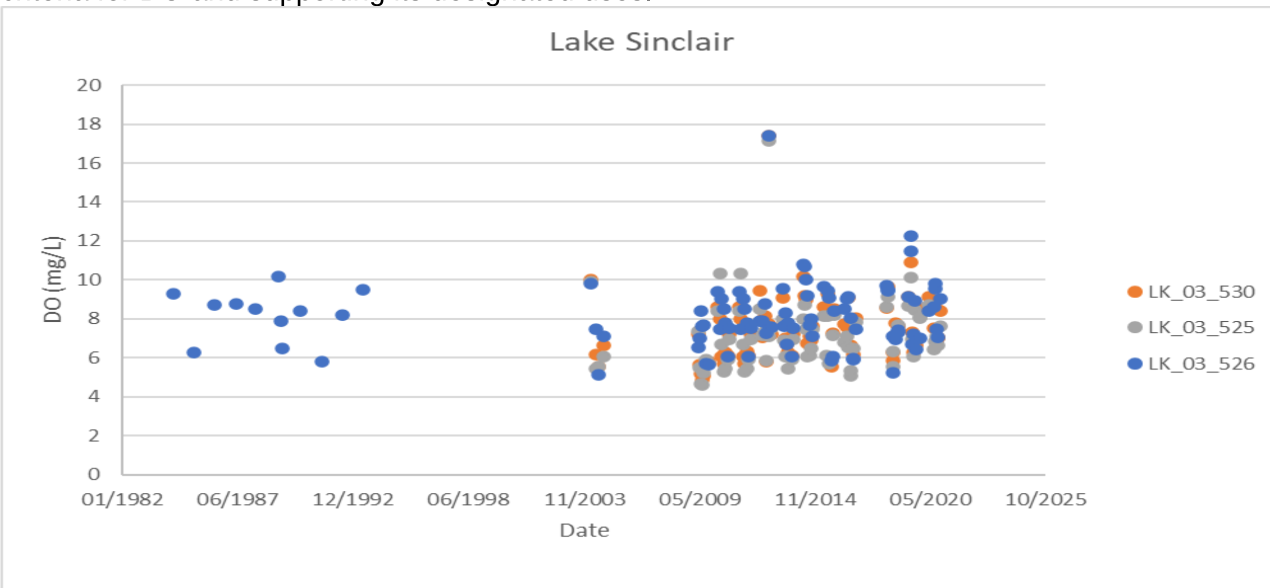

Figure 3-30. Lake Sinclair Measured Dissolved Oxygen Data 1986 – 2020.

The DO profile on Lake Sinclair shows higher DO at the surface and lower DO deeper into the strata, but only in areas located off of the mainstem (Figure 3-31). Each line represents a different year. During the day, Wallace Dam releases water from Lake Oconee into Lake Sinclair and at night, when energy costs are low, water from Lake Sinclair is pumped back into Lake Oconee. Because of this, the areas near Sinclair Dam and the mainstem of the Oconee Arm have consistently higher DO levels at increased depth. DO profiles are similar to those shown for Lake Oconee.

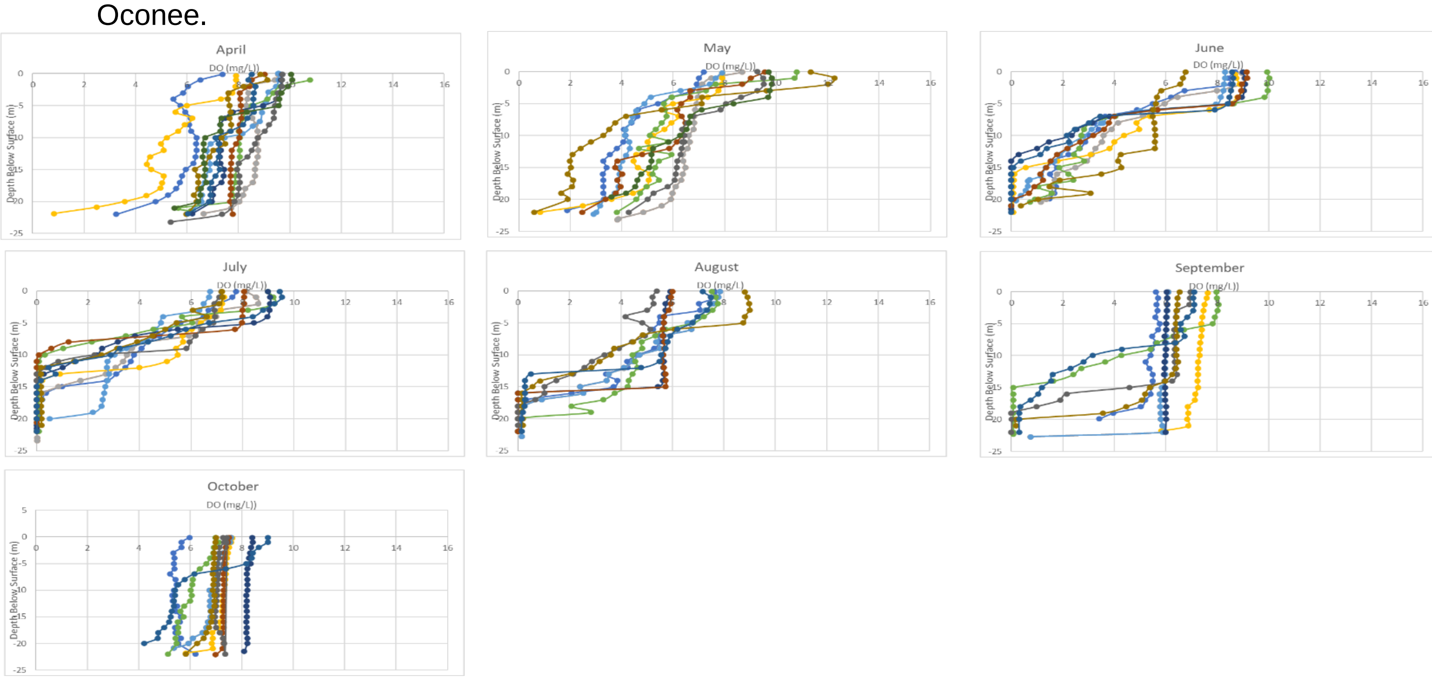

Figure 3-31 Lake Sinclair Dissolved Oxygen Profile Data at Dam Pool 2009 – 2020

None of the E coli samples taken in Lake Sinclair exceeded the 30-day geometric mean E coli criteria that supports primary recreation, which reveals that the Lake Sinclair is meeting its designated uses (Figure 3-32). These data are from grab samples collected at the surface of the lake.

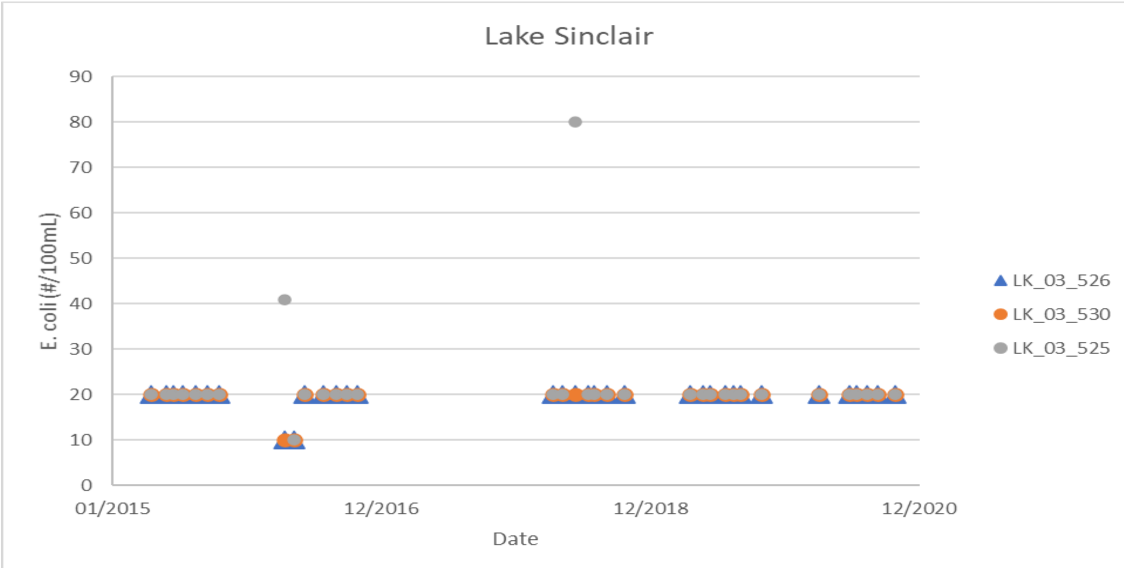

Figure 3-32. Lake Sinclair Measured E. coli Data 2015 – 2020.

Figure 3-33 is a plot of the fecal coliform levels measured in Lake Sinclair. None of these samples exceeded the 30-day geometric mean fecal coliform criteria that supported primary recreation prior to the change to E.coli as the bacteria for Recreation designated use in 2015. These data demonstrate that Lake Sinclair has historically met its designated uses. These data are from grab samples collected at the surface of the lake.

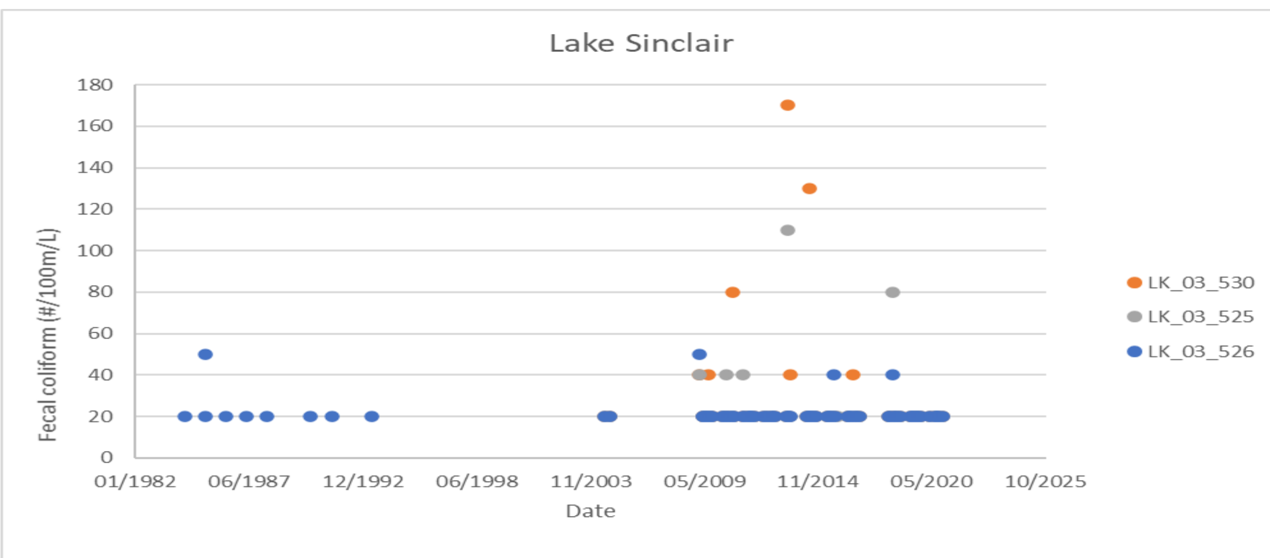

Figure 3-33. Lake Sinclair Measured Fecal Coliform Data 1986 – 2020.

4.0 DESIGNATED USE SUPPORT

Lakes Oconee and Sinclair have designated uses of recreation and drinking water, which also support fishing. The proposed criteria have been selected to protect the established designated uses for both lakes. Water quality modeling, which will be discussed in the next section, shows that the proposed criteria coupled with the point source nutrient management strategy will protect existing designated uses. EPD expects algal blooms will decrease as nutrient levels in discharges decrease, which will be required as part of the implementation of the point source nutrient management strategy.

4.1 Recreational Use Support

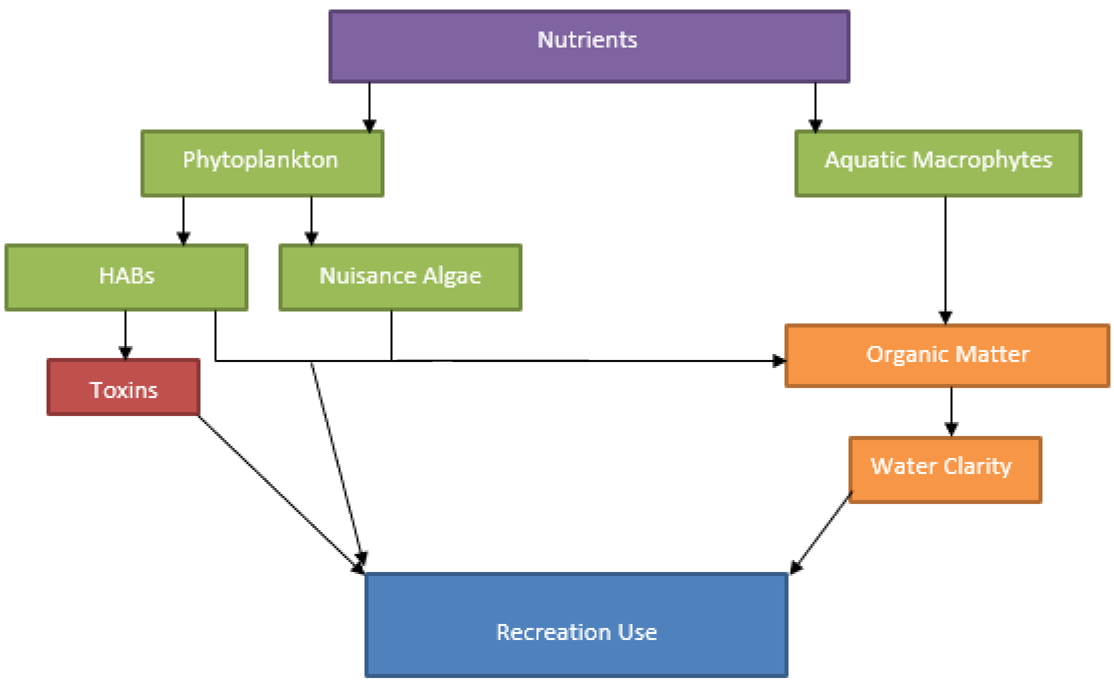

Figure 4-1. Recreation Use Schematic

Lakes Oconee and Sinclair are popular destinations for recreational activities. The lakes have numerous boat ramps, day-use parks, marinas, and campgrounds. Many people visit the lakes for the fishing, boating, hiking trails, swimming beaches, and picnic shelters. In 2016, a survey of recreational use was conducted by Georgia Power.

The most common reasons cited by users for visiting the boat ramps in March-June 2016 were boat fishing, pleasure boating, tournament fishing, bank fishing, jet skiing, and shoreline relaxation (Table 4-1). Almost half of all survey respondents (47 percent) noted that boat fishing was the primary reason for their recreation visit. Pleasure boating was the second most commonly reported reason for visiting the boat ramps (13 percent). Tournament fishing was the third most oft-cited reason (9 percent).

Table 4-1. Primary Reasons for Visits of Users Surveyed at Georgia Power Boat Ramps at Lake Oconee.

Recreational Activity	Armour Bridge	Long Shoals Boat Ramp	Sugar Creek Boat Ramp	Totals
Boat Fishing	61%	42%	46%	47%
Bank Fishing	--	5%	13%	8%
Tournament Fishing	11%	10%	8%	9%
Pleasure Boating	18%	10%	14%	13%
Pontoon Boating	--	5%	1%	2%
Water Skiing	5%	4%	1%	3%
Tubing	--	1%	4%	2%
Jet Skiing	3%	8%	2%	4%
Canoeing/kayaking	3%	1%	--	1%
Picnicking/playing	--	1%	2%	1%
Swimming/wading	--	4%	1%	2%
Shoreline relaxation	--	1%	8%	4%

On an average day, users spent approximately 6.5 hours per visit. The users surveyed averaged 4.3 trips per month to the Georgia Power boat ramps. The boat ramps were consistently rated "good" with an 87 percent respondent rate out of "good," "fair," or "poor." Survey respondents rated bank fishing access at the Georgia Power boat ramps as "good," "fair," or "poor." Of the 44 percent of total users responding, 28 percent rated the bank fishing as "good," 5 percent rated it as "fair," and 2 percent rated it as "poor," (Georgia Power, 2016).

4.1.1 Cyanobacteria Blooms

Occasionally, in Georgia waters, naturally occurring populations of algae, including blue-green algae (cyanobacteria), exhibit exponential growth patterns that result in extremely high cell densities referred to as a "bloom." Cyanobacteria (blue-green algae) are photosynthetic bacteria that share some properties with algae. When conditions are favorable, cyanobacteria can rapidly multiply, resulting in "blooms." Some species of cyanobacteria produce toxins, known as cyanotoxins. These blooms are usually temporary and typically occur during warm weather. From an ecological perspective, visible algae signify alterations in the ecosystem with potential for low dissolved oxygen levels, reduced water clarity, and high bacteria levels.

In May and June 2009, prior to the development of any cyanotoxin criteria or swim advisories, cyanobacterial blooms developed over a 600-acre area of Lake Oconee. 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. Based on the frequent observations of the bloom appearance and low particle density, the recreational beaches remained open during the bloom event even though the bloom 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. Although the bloom was brief, samples were collected promptly and delivered to Dr. Kalina Manoylov of Georgia College and

State University for analysis. Dr. Manoylov 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.

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. Samples were sent to Dr. Manoylov, and she immediately confirmed the bloom was non-toxic by finding live nematodes via microscopy. Anthony Dodd, of Georgia Power, tested for toxicity with *microcystin* strips and found the concentration of toxin to be less than 1 µg/L.

In 2015, Georgia Power developed an assessment and response protocol for blooms, which uses a visual-based cyanobacteria bloom assessment method patterned after a procedure used by the State of Vermont (Georgia Power, 2019). Georgia Power’s Regional Land Management personnel and Natural Resources personnel are trained to recognize cyanobacteria blooms. They are Georgia Power’s frontline response team for observations of potentially toxic algae blooms. Using the Visual Bloom Assessment method, Georgia Power personnel survey the lake conditions. However, initial observations of blooms or suspected blooms often come from a variety of sources including: lake recreationists, shoreline homeowners, anglers, and marina operators.

Based on the Visual Bloom Assessment, a Condition Category or stage of bloom development is assigned using a standard protocol including water clarity, color, particle density, bloom appearance, and a photo-based visual guide to aid the site investigator in determining the Condition Category of the cyanobacteria bloom. Georgia Power’s Visual Bloom Assessment can be followed by laboratory-based lake water sample analysis referred to as the Sample Assessment, if necessary (Condition Category 3). The assessment results inform decision makers with additional ecological and toxicity details of the bloom. In the event that an observed cyanobacteria bloom is shown to have toxic properties, Georgia Power, at a minimum, notifies EPD’s Watershed Protection Branch and Georgia Wildlife Resources Division (WRD) as soon as possible and a coordinated decision is made regarding beach closures and/or swim advisories.

Beaches with a history of blooms represent public-use areas that may warrant frequent monitoring. At the beginning of the summer, visual inspection, as often as possible, should be sufficient. GPC’s normal shoreline management operations result in visual inspections of parts of each Georgia Power lake for a variety of reasons on a fairly regular frequency. If dense algae blooms are noted during any of those inspections, weekly monitoring should begin. While there are past instances of elevated cyanobacteria cell counts, bloom events that produce toxins are rare in Georgia and cell count alone is not a predictor of toxin production. There have been no recreational closures due to harmful algal blooms (HAB) at any of the Georgia Power operated beaches (personal communications, Tony Dodd and Warren Wagner, III, Georgia Power).

Table 4-2 presents a summary of the algal blooms that have occurred in Lakes Oconee and Sinclair. Three of these blooms lead to water sample collections for algal species identification and after 2015, microcystin presence using the Elisa Abraxis test. Microcystin levels were not high enough to result in swim advisories and thus Lakes Oconee and Sinclair meet their recreational uses.

Table 4-2. Georgia Power's Visual Bloom Assessments

Date	Lake	Location	Category	Observations	Actions	Lab Results
1/21-22/2015	Oconee	Lick Creek	Category 3	scums and algal clumps	water sample collected	Forest Drive decaying algal debris; Franklins Condos: dominant presence Anabaena sp.
1/21/2015	Oconee	near Old Phoenix Road		small surface appearances not verified as HAB	visually monitor	
10/2/2015	Sinclair	Steel Bridge Road	Category 1	windblown particulates, no accumulations	visually monitor	
10/2/2015	Oconee	not specified	Category 1	windblown particulates, no accumulations	visually monitor	
Dec 2016 - Jan 2017	Oconee	middle sections in Sugar Ck	Category 2		visually monitor	
3/17/2017	Oconee	central part of the lake near Martin Oaks subdivision	Category 3	cloudy water	water sample collected contacted GA WRD	Anabaena density 12,300 cells/ml Abraxis test results between 5 and 10 ppb
3/20/2017	Oconee	near Old Salem Park	Category 2		visually monitor	
7/19/2019	Sinclair	Rooty Creek	Category 1		visually monitor	
8/30/2019	Sinclair	109 Meriwether	pre-bloom development		water sample collected	Microcystis aeruginosa density 5600 cells/ml; Abraxis test results between 5 and 10 ppb
9/1/2019	Oconee	102 Oak Ridge Lane, Eatonton, GA	Category 2		Data sheet observation and visually monitor	
7/9-10/2020	Sinclair	Hobb's lot, not specified	Category 1	some cloudiness and minor particulates	visually monitor	
7/9/2020	Sinclair	east side of the lake location not recorded		pre-bloom, not verified as HAB	visually monitor	
7/20/2020	Sinclair	Eastlake Community	Category 1,	intermittent appearance, pre-bloom	visually monitor	

4.2 Fishing Use Support

Lakes Oconee and Sinclair are located on the upper Oconee River in the Piedmont ecoregion. The principal fisheries inhabiting these waters are reservoir fisheries. The upper Oconee River Basin principally supports warm-water fisheries. Free flowing streams in the area are the Oconee River, Apalachee River, and other tributaries entering Lake Oconee, Island Creek, Rooty Creek, Big Cedar Creek, Little River, Murder Creek, and other tributaries entering Lake Sinclair. The upper Oconee River in the vicinity of the Lakes Oconee and Sinclair, including the free-flowing tributaries, supports about 57 species of fish (Georgia Power, 2018). The families with the most species include minnows, catfishes, sunfishes, suckers, and perches. Figure 4-2 presents a diagram of the relationship between nutrients and other factors that impact aquatic life use.

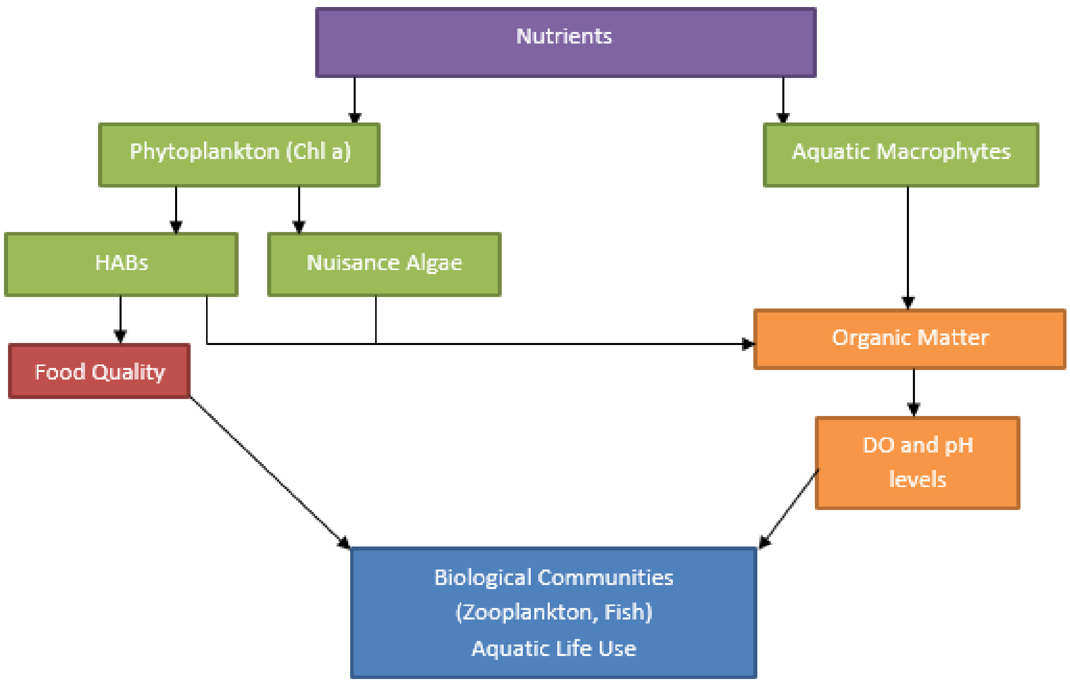

Figure 4-2. Aquatic Life Use Schematic

4.2.1 Lake Oconee Fisheries and Mussel Population

Standardized surveys conducted by Georgia DNR have documented the occurrence of at least 28 species of fish within Lake Oconee (Georgia Power, 2016a). The principal sport fishes inhabiting Lake Oconee include largemouth bass, black crappie, striped bass, white bass striped bass hybrids (hybrid bass), white bass, channel catfish, blue catfish, flathead catfish, and a variety of sunfishes.

Standing timber and fish plots (stands topped out below the surface) are distributed throughout Lake Oconee providing cover for black crappie and other sunfishes, and serving as nursery habitat for forage species, including gizzard shad and threadfin shad (FERC Study, 2019). The Wallace Dam power generation and pump-backs that occur in the summertime allows for mixing, resulting in warmer temperatures. This mixing, coupled with the somewhat shallow bathymetry of the lake, causes Lake Oconee to lack cold-water habitats that would support any cold-water fish species. There are no rare, endangered, or threatened species in Lake Oconee (Georgia Power, 2016a).

Chris Nelson, fisheries biologist for Georgia Wildlife Resources Division (WRD), stated that “Lake Oconee is a highly productive reservoir, considering the standing stock and total biomass of fish it supports.” Lake Oconee is popular with anglers. Bass fishing tournaments and other fishing events are regular occurrences on the lake. 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.

WRD stocks Lake Oconee annually with striped bass and hybrid bass. Since 2011, stocking numbers have transitioned away from a predominance of striped bass to that of hybrid bass, based on angler preferences for hybrid bass (FECR Study, 2019). Current stocking rates are about 15 hybrid bass and five striped bass per acre. These are the most sensitive species to water quality. They are temperature-sensitive and struggle with the higher temperatures in the lake.

Pelagic species (e.g., threadfin shad) are more closely tied to productivity for their diet on zooplankton. If nutrient levels are decreased significantly this will alter the food base from the bottom up. This will also affect the apex predator species, like the Morone and largemouth bass, that feed on them. If nutrient levels shift gradually, there is only a marginal change in fish population, if any at all. If nutrient levels are decreased too quickly, then certain fish species can start dying off due to starvation (O’Rouke personal communication, 2021).

Nine of the species are believed to be introduced and non-native to the Oconee River Basin, which include threadfin shad, common carp, blue catfish, flathead catfish, white bass, green sunfish, spotted bass, white crappie, and yellow perch (Georgia Power, 2016a). A shift in catfish populations has occurred over the past 15 years (see Figure 4-3). Non-native blue catfish were illegally introduced into Lake Oconee and the population has increased over time. Native populations of channel and white catfish have 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.

A small, nonnative, invasive spotted bass population persists in the upper reaches of the lake and in the Oconee River north to Athens, GA. The determining factor as to why this nonnative spotted bass population has not expanded into Lake Oconee is not clear. However, a reduction in primary productivity in Lake Oconee could be the catalyst for the invasive spotted bass expansion (personnel communication Bryant Bowen, 2021).

Currently, the native largemouth bass populations in both lakes are doing very well. Although, if nonnative spotted bass were to become established in Lake Oconee, and eventually Lake Sinclair, competition between these black bass, coupled with decreased primary production, could be detrimental to the popular native largemouth bass fisheries at these lakes. WRD will continue to evaluate sport fish populations and water quality monitoring data at lakes Oconee and Sinclair for any shifts in sport fisheries as the nutrient standards are implemented.

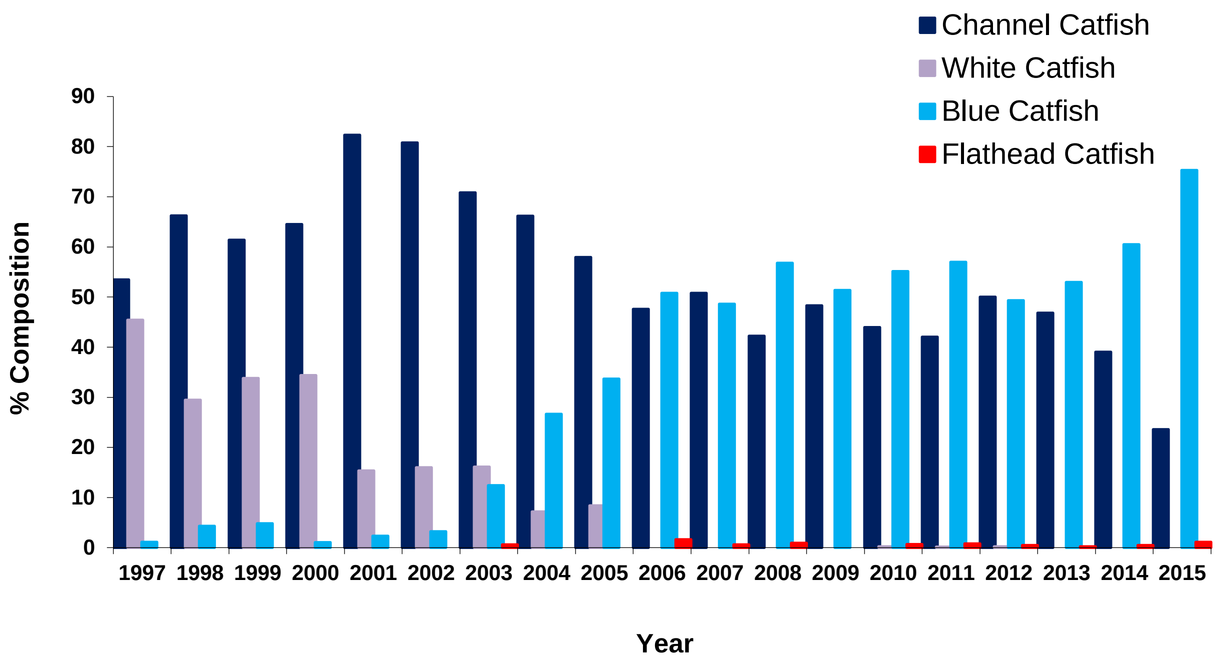

Figure 4-3. The Shift of Channel, White, Blue, and Flathead Catfish Populations in Lake Oconee Between 1997 and 2015

The proposed ranges for chlorophyll *a*are within desirable ranges for sport fishes. However, there are relationships between primary productivity and successful sport fisheries. Fish biomass is related to and tends to follow the available nutrients in the reservoir. Choosing the appropriate criteria for total phosphorus is critical for the overall health of the reservoir as too much of a decrease could result in decreases in fish biomass and condition. We do not want the base of the food chain to crash because of insufficient nutrients in the system to support primary production.

There are four native freshwater mussel species within the Lakes Oconee and Sinclair project boundary, none of which are listed as federally threatened or endangered, or state protected. The four species found in both lakes are:

- Altamaha slabshell – endemic
- Inflated floater – endemic
- Paper pondshell
- Variable spike

A Lake Oconee mussel survey yielded 355 live specimens. All four species were found in the main channel and tributary embayments. The vast majority of mussels (98.3 percent) were found downstream of I-20. The most common species was the Altamaha slabshell, which composed 71 percent of the live native mussels found in Lake Oconee, followed in relative abundance by inflated floater, paper pondshell, and variable spike. The largest number of live mussels (168) was found at a main-channel site located 1.2 miles upstream of Wallace Dam, near the reservoir forebay. This was the only site where boulders were present and the only site where all four species were found together in Lake Oconee (FERC Study, 2019).

4.2.2 Lake Sinclair Fisheries and Mussel Population

The Lake Sinclair fishery is dominated by many of the same fish species found in Lake Oconee (Georgia Power, 2018). Lake Sinclair supports a popular fishery for largemouth bass, hybrid bass, striped bass, channel catfish, blue catfish, black crappie, bluegill, and redbreast sunfish (FERC Study, 2019). Similar to Lake Oconee, Lake Sinclair is relatively shallow and lacks cold-water habitats for cold-water fish species. WRD fisheries biologist, Brandon Baker, attributes the stability of the fish population in Lake Sinclair to the stable water levels.

Crappie naturally have cyclic year classes (young of the year fish that survive), which means some years have an exceptionally high survival rate, but 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's class of black crappie will comprise most of the lake population. Brandon Baker said that "the condition of the black crappie in Sinclair has remained close to the statewide average," while "the largemouth bass sampled on Sinclair are slightly below the statewide average condition for largemouth bass."

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.

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 4-4 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.

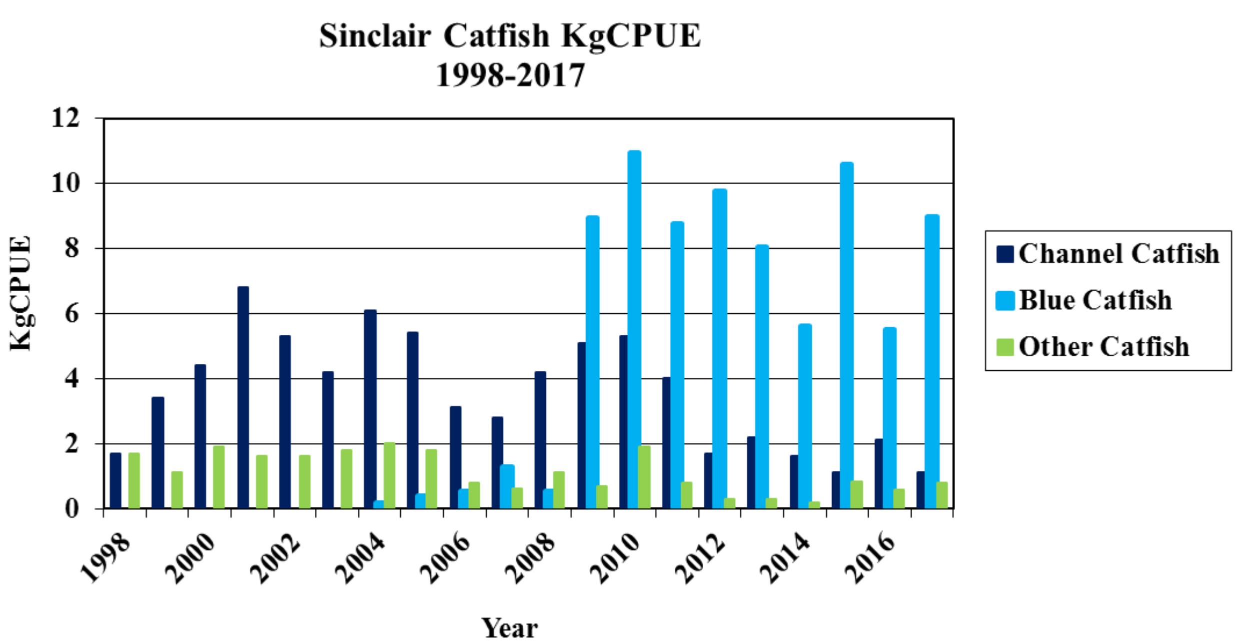

Figure 4-4. Catfish Population Shift in Lake Sinclair from 1998 to 2016

Baker pointed out that fish biomass tends to follow the available nutrients in the lake, as shown in Figure 4-5. 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. Bryant Bowen, Stream Team Program Manager of WRD, reviewed the proposed criteria and believes proposed ranges for chlorophyll *a* are within desirable ranges for sport fishes. Appendix A contains a summary of several articles regarding nutrient levels and fish biomass including an annotated bibliography that was provided by WRD.

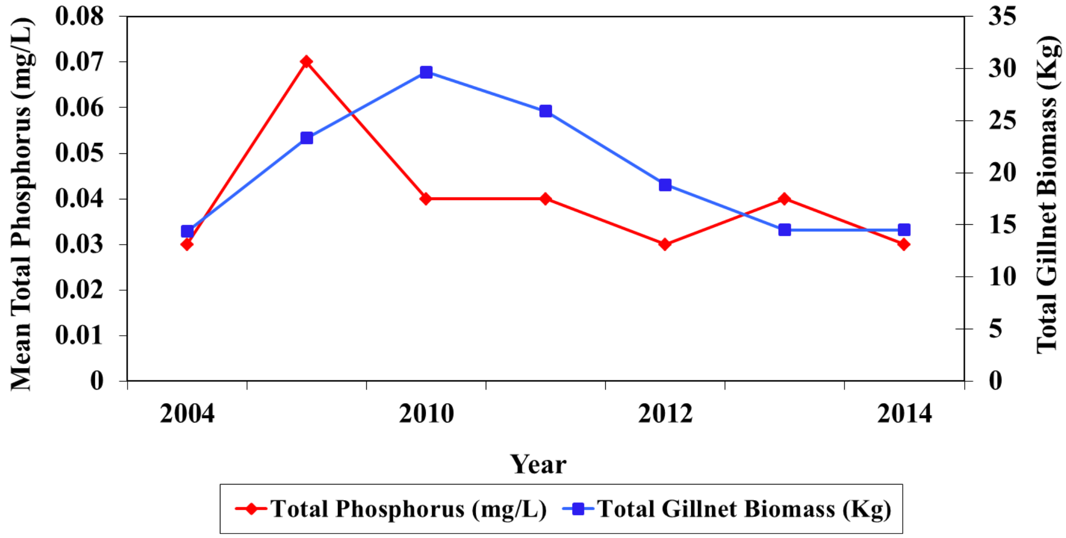

Figure 4-5. Fish Biomass Related to Available Nutrients in Lake Sinclair

The Lake Sinclair mussel survey yielded 1,479 live specimens of the following four species: Altamaha slabshell, inflated floater, paper pondshell, and variable spike. The Altamaha slabshell composed 97.5 percent of all live native mussels found, and was followed in relative abundance by variable spike, inflated floater, and paper pondshell, respectively. The vast majority of the mussels found in the tailrace area (98.2 percent) occurred in the main channel. The largest number of live mussels (501) was found in the main channel about 984 feet downstream from the powerhouse, along the east bank (FERC Study, 2019). The diversity of fish and mussel communities in both lakes indicate the aquatic life is healthy and thus the fishing use is being met.

4.3 Drinking Water Source Use Support

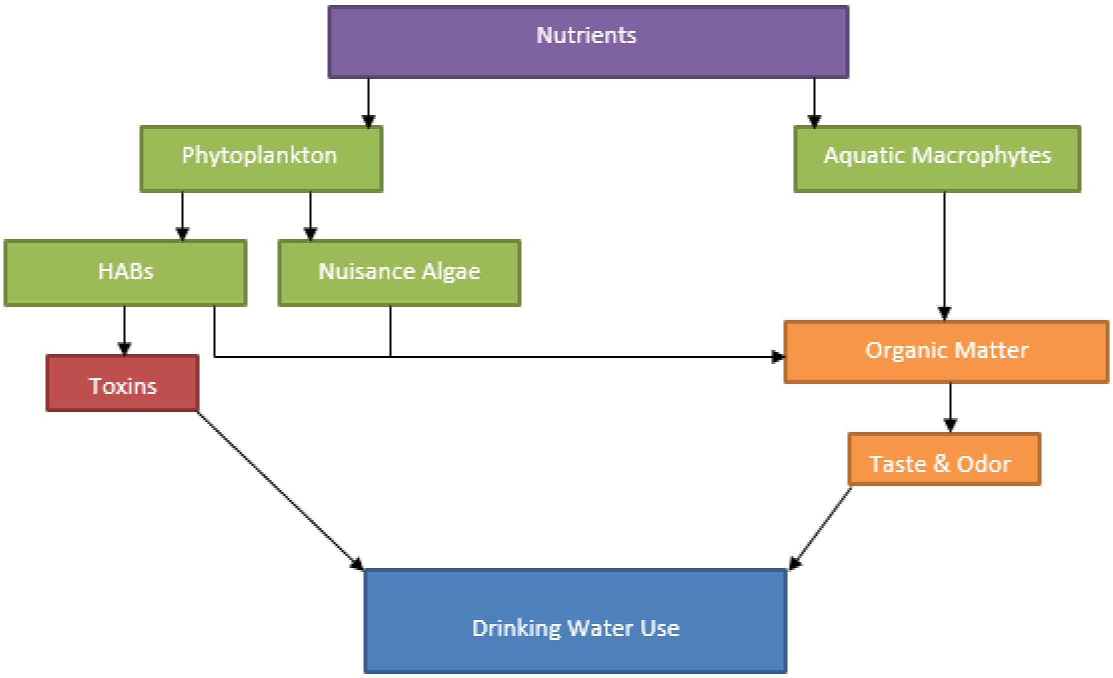

Figure 4-6. Drinking Water Use Schematic

4.3.1 Lake Oconee Intakes

Lake Oconee has three drinking water intakes: the City of Madison; the City of Greensboro; and Piedmont Water Resources. The City of Madison has an intake on Hard Labor Creek as well as an intake in Lake Oconee. Piedmont Water Resources is a ground water system that is in the process of building a surface water treatment plant with an intake in Lake Oconee.

Lake Oconee has historically met and continues to meet its drinking water use. Intakes on Lake Oconee tend to have high Total Organic Carbon (TOC) levels in the summer due to algae. When asked about taste, color and odor problems, or increased treatment costs, none of these plants reported issues. Lamar Callaway, who operates the Greensboro Plant, stated that there had been no issue with algae in the 33 years he has operated the plant. Mr. Callaway mentioned that the 2011 bloom caused him to look into treatment options, but the bloom dissipated before any action was necessary.

4.3.2 Lake Sinclair Intakes

There are two drinking water intakes in Lake Sinclair: City of Sparta and Sinclair Water Authority. The third intake, Georgia Power Plant Branch, terminated power generation 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.

When asked about issues related to algae, Joey Witcher, of Sinclair Water Authority, confirmed that warm summer months usually "bring on" blooms in both lakes. Blooms resulted in direct cost increases with additional testing for cyanotoxins, as well as a one time purchase of algaecide.Mr. Witcher explained that the real cost increase is hidden within the price of treatment and ongoing cleaning. The Sinclair Water Authority plant operates membrane filtration that 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. Taste and odor problems that are largely caused by algae may necessitate feeding carbon into the treatment system.

The City of Sparta plant had a significant taste and odor issue in early 2017 due to turn over in the lake. 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. It is natural for lakes to destratify and turn over, which periodically leads to short term taste and odor problems. However, Lake Sinclair has historically met and continues to meet its drinking water use.

The Ga EPD Drinking Water Program is unaware of any other taste and order problems in Lakes Oconee and Sinclair. There have been no complaints filed with EPD in our complaint tracking system within the last five years. Both Lakes Oconee and Sinclair are meeting the drinking water uses.

4.4 Downstream Uses

Downstream of Lakes Oconee and Sinclair, the Oconee River runs from Sinclair Dam to Altamaha River. The designated uses of this portion of the Oconee River are fishing, or drinking water and fishing. The Oconee River downstream of Lake Sinclair is supporting its designated uses. 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.

Table 4-3 shows all Oconee River segments downstream of Lake Sinclair and their assessment status. The proposed chlorophyll *a* and nutrient criteria for Lakes Oconee and Sinclair are not expected to impact downstream uses. Since the proposed lake criteria were derived based partially on historical data, and because both the lakes and the waterbodies downstream have historically met their designated uses, the proposed criteria are not expected to impact downstream uses.

At this time, there are no numeric nutrient criteria for rivers, streams, or estuaries. Each year the downstream estuary is monitored for chlorophyll *a* and nutrients. If an algal bloom should occur in the downstream estuary or chlorophyll *a* levels increase significantly such that there were a violation of our narrative standards, total nitrogen permit limits would be implemented in upstream point sources.

Eight highly migratory and/or diadromous fish species (migrate between freshwater and marine/estuarine environments to complete their life cycles) presently occur in portions of the Altamaha River Basin downstream of Lakes Oconee and Sinclair:

- Shortnose sturgeon
- Atlantic sturgeon
- American shad
- Blueback herring
- Hickory shad
- Striped bass
- American eel
- Robust redhorse

Shortnose sturgeon and Atlantic sturgeon, both listed as federally endangered species, use portions of the Altamaha River and lower Ocmulgee River and/or Oconee River downstream from Sinclair Dam for spawning runs. Critical habitat has been designated for Atlantic sturgeon, which includes the lower Oconee River downstream from Sinclair Dam (FERC Study, 2019). American shad migrate upstream as far as Sinclair Dam, and likely spawn in portions of the lower Oconee River. Blueback herring and hickory shad are currently limited in distribution to the Altamaha River and Ocmulgee River (FERC Study, 2019). American eels presently range upstream in the Oconee River Basin as far as Sinclair Dam. Robust redhorse, a Georgia endangered species, is a migratory riverine sucker that inhabits the Oconee River downstream from Lake Sinclair and the Ocmulgee River.

Table 4-3. Assessment Status of Oconee River Segments Downstream of Lake Sinclair

2020 Integrated 305(b)/303(d) List - Streams

Reach Name/ID	Reach Location/County	River Basin/ Use	Assessment/ Data Provider	Cause/ Source	Size/Unit	Category/ Priority	Notes
Oconee River	Lake Sinclair to Fishing Creek	Oconee	Supporting		5	1	
GAR030701020109	Baldwin	Drinking Water, Fishing	1		Miles		
Oconee River	Fishing Creek to Gumm Creek	Oconee	Supporting		20	1	
GAR030701020203	Baldwin	Fishing	1		Miles		
Oconee River	Gumm Creek to US Hwy 319/80	Oconee	Supporting		52	1	
GAR030701020902	Washington, Wilkinson, Laurens	Fishing, Drinking Water	1		Miles		
Oconee River	Long Branch to Turkey Creek	Oconee	Supporting		9	1	TMDL completed FC (2002 & 2007).
GAR030701020901	Laurens	Fishing	1,10		Miles		
Oconee River	Turkey Creek to Red Bluff Creek	Oconee	Not Supporting	FC	26	5	
GAR030701021201	Laurens, Treutlen, Wheeler	Fishing	1,55	NP	Miles	2020	
Oconee River	Red Bluff Creek to Altamaha River	Oconee	Supporting		38	1	
GAR030701021401	Montgomery, Wheeler	Fishing	1,55		Miles		

5.0 WATER QUALITY MODELING

The process of developing the numeric chlorophyll *a* and nutrient criteria for Lakes Oconee and Sinclair included developing computer models for the Lakes. Watershed models of the Lakes Oconee and Sinclair watersheds were also developed. The models 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 5-1 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.

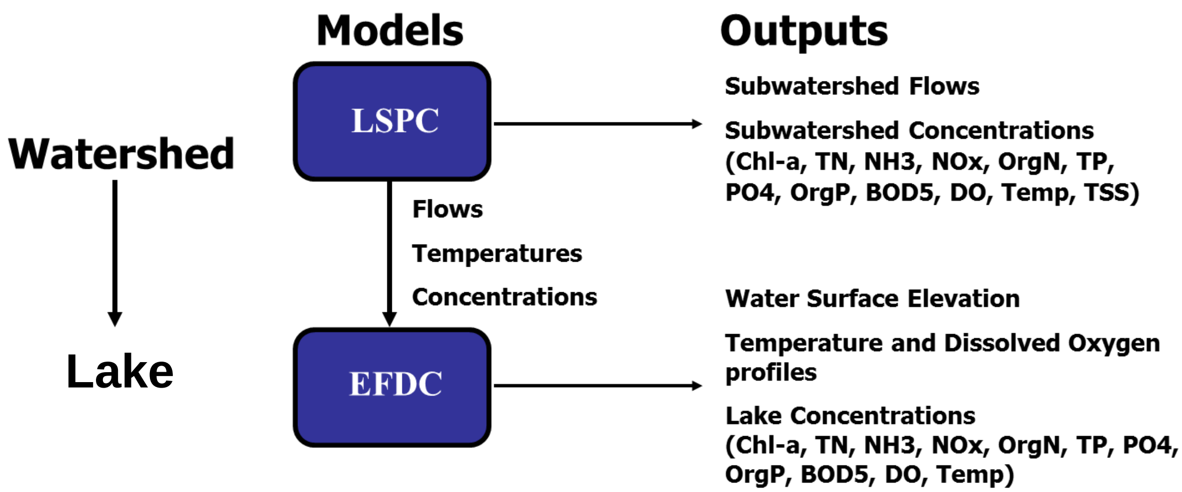

Figure 5-1. Linkage between LSPC and EFDC

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. This included five gages that had a complete period of record for the period from January 1, 1998, through December 31, 2012. During 2009, GA EPD conducted intensive sampling of rivers and streams in the Lakes Oconee and Sinclair watersheds. This sampling was conducted at 84 locations throughout the watershed. The water quality data collected included total nitrogen, nitrate plus nitrite, ammonia, total Kjeldahl nitrogen (TKN), total phosphorus, orthophosphate, BOD5, total suspended sediment (TSS), temperature, and dissolved oxygen. The Oconee and Sinclair LSPC models were calibrated and validated to these water quality data.

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 EFDC 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. The EFDC 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 results of the LSPC watershed models were used as tributary flow and water quality inputs to the Lake models.

The models were run for calendar years 2001 through 2012. During 2004, and 2009-2012, water quality data were collected in the Lakes and these data were used to calibrate the model. 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.

The models were used to assess and develop the numeric nutrient and chlorophyll *a* criteria for Lakes Oconee and Sinclair. 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 flow 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

Five scenarios were run using the models to explain the sources and contributions of chlorophyll *a* levels observed, and for use in developing the chlorophyll *a* and nutrient criteria. 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 Calibration (Scenario 1A)

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 https://epd.georgia.gov/document/publication/signed-p-strategypdf/download. This scenario represents current conditions that are currently meeting designated uses.

5.1.2 All Forested (Scenario 1B)

Scenario 1B was an all forested scenario. In this scenario, point source discharges, water withdrawals, and septic tanks were removed, and all land use was converted to forest. This model was relevant for our derivation of chlorophyll *a* criteria because it confirmed that some locations naturally have higher chlorophyll *a* concentrations without the influence of land use and point sources.

5.1.3 Lake Oconee and Sinclair Nutrient Permitting Strategy (Scenario 1C)

Scenario 1C had point source discharges input at 50% of the GAEPD Nutrient 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.

5.1.4 2050 Permitted Flows Maintaining Loads and Current Land Use (Scenario 1D)

Scenario 1D was a 2050 Point Source and current Land Use scenario. Point source discharges were set at the 2050 flows forecasted in the State Water Plan. However, the total phosphorus load was the same as in Scenario 1C.

5.1.5 Increased Permitted Nutrient Loads (Scenario 1E

Scenario 1E consisted of two model runs; one where the point source total phoshorus load used in Scenario 1C was doubled and the second where the point source total nitrogen load was doubled. These model runs were done to determine the sensitivity of the chlorophyll *a* to the nutrient levels.

5.2. 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. Figures 5-2 and 5-3 show the resulting growing season average chlorophyll *a* level for each of Scenario 1A-1D. The results of Scenario 1E indicate that both lakes are phosphorus limited as shown in Figures 5-4 and 5-5. The chlorophyll *a* levels were not affected by a doubling of the permitted total nitrogen loads but increased when the permitted total phosphorus loads were doubled.

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 (TP)	1E (TN)	
Lake Oconee	Oconee River Arm Highway 44	27.9	8.6	24.4	25.3	34.1	24.2	26
	Richland Creek Arm	14.8	6.6	12.4	13.7	13.9	12.2	15
	300 Meters Upstream of Wallace Dam	18.6	8.1	16.0	16.2	17.7	15.8	18
Lake Sinclair	Little River & Murder Creek Arm Upstream Highway 441	11.5	6.4	10.9	11.2	11.7	10.8	14
	Midlake Oconee River Arm	11.9	5.7	10.6	10.8	11.5	10.5	14
	300 Meters Upstream of Sinclair Dam	8.1	4.0	7.3	7.4	7.9	7.2	10

The Lake Oconee proposed criteria are somewhere between the Calibration and 2050 Permitted Flows Maintaining Loads and Current Land use. The proposed criteria for Lake Sinclair are closer to the historical data and these levels are within the range of typical chlorophyll *a* concentrations found in Piedmont lakes. The "All Forested" run confirms that the proposed criteria are reasonable since the relative proportions are similar. In order to meet the proposed chlorophyll *a* criteria, all NPDES permits will require total phosphorus limits. Reductions in permitted total phosphorus concentrations and/or loads will be implemented after the proposed lake criteria have been adopted.

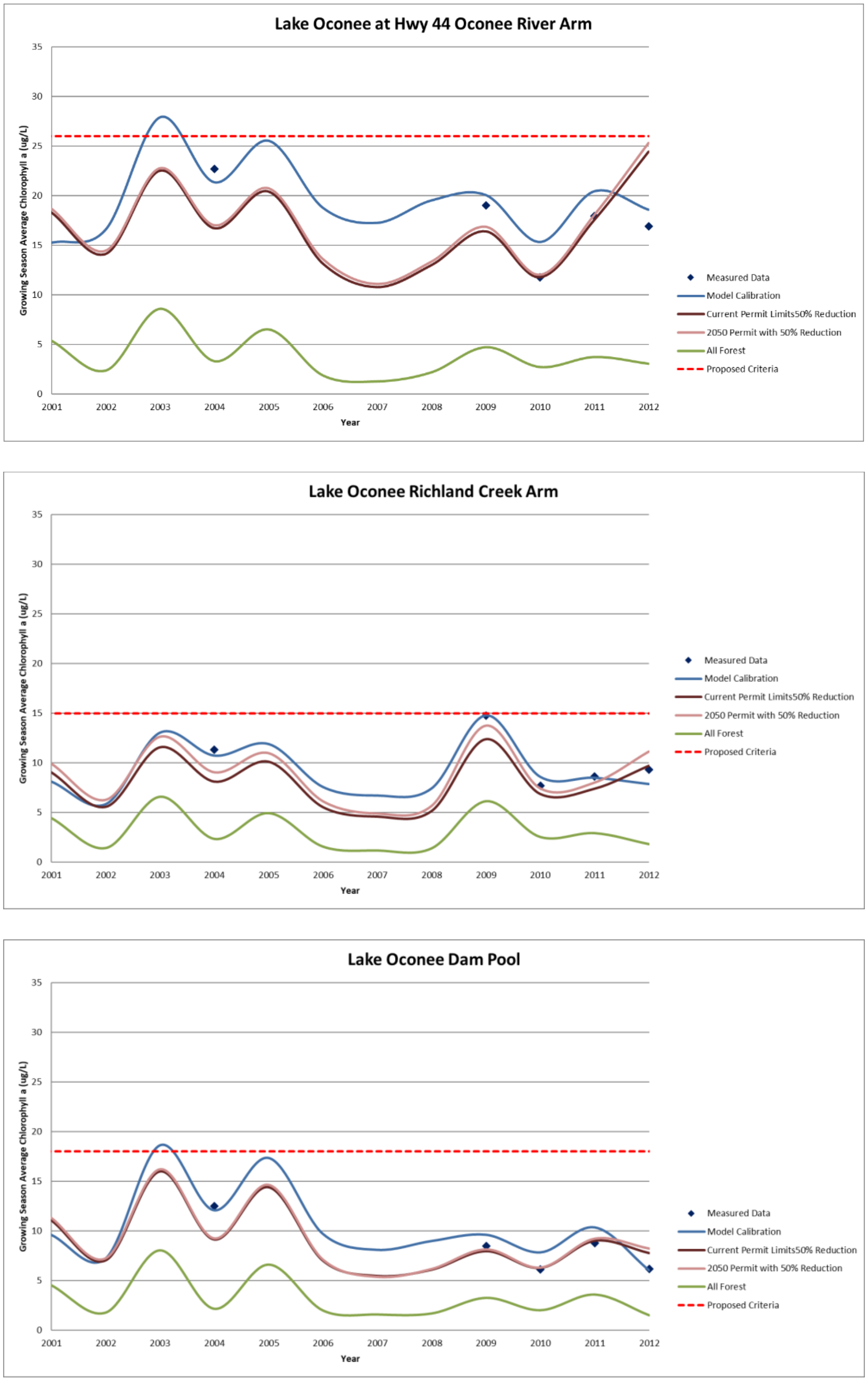

Figure 5-2. Lake Oconee Growing Season Average Chlorophyll *a* Levels from Model Scenarios 1A-1D compared to the Proposed Criteria and Measured Values

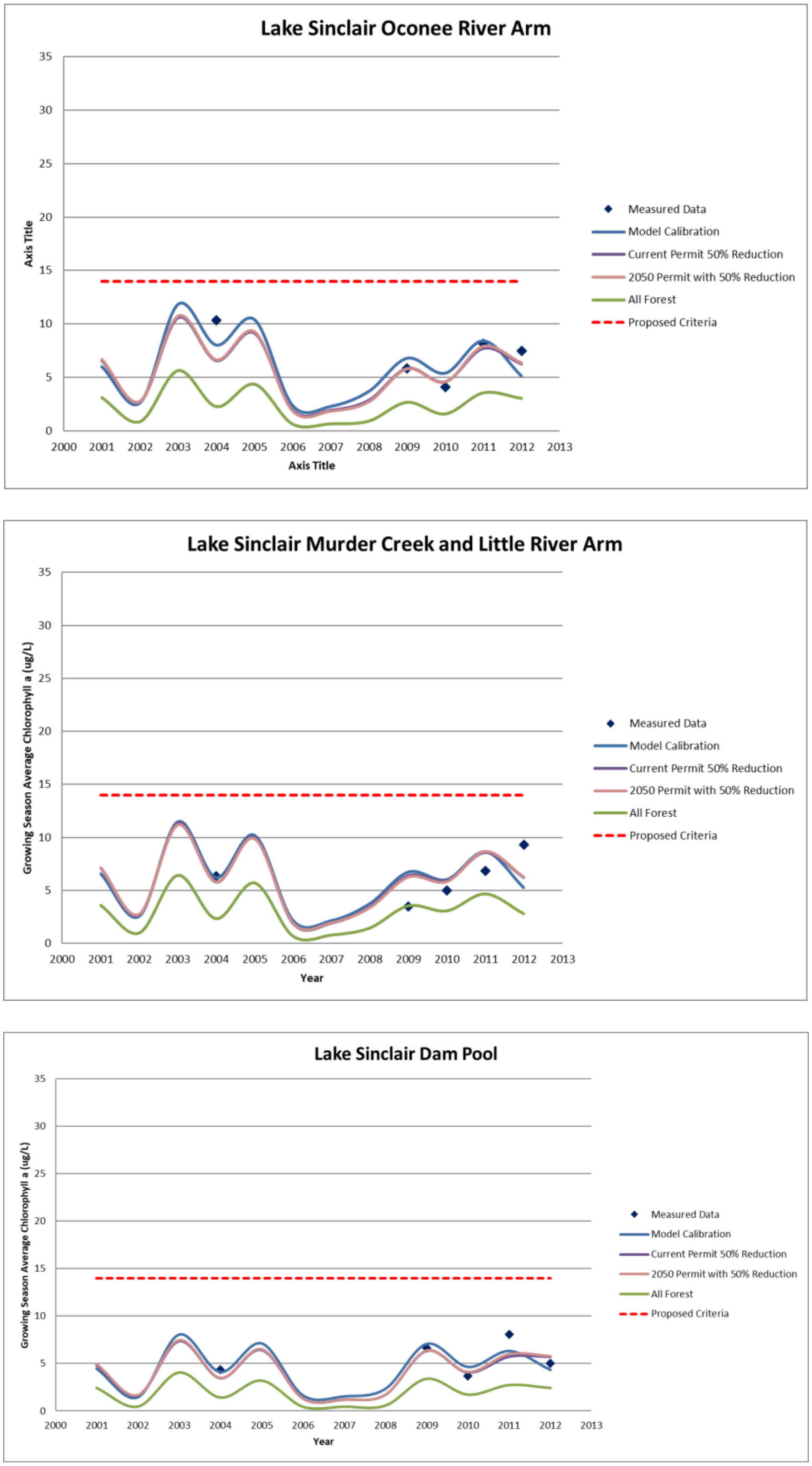

Figure 5-3. Lake Sinclair Growing Season Average Chlorophyll *a* Levels from Model Scenarios 1A-1D compared to the Proposed Criteria and Measured Values

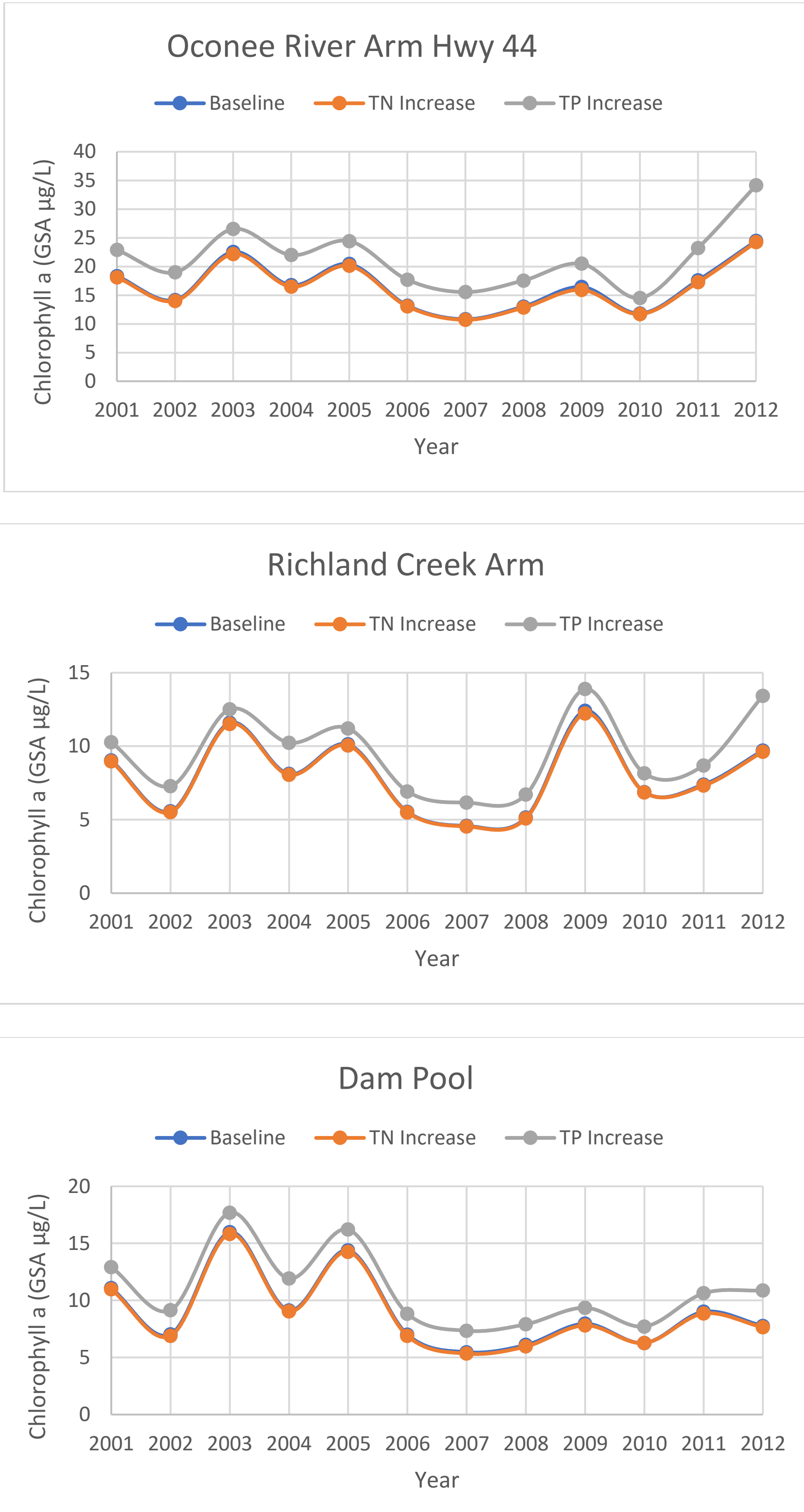

Figure 5-4. Effect of Nutrient Increases on Lake Oconee Chlorophyll *a* Levels

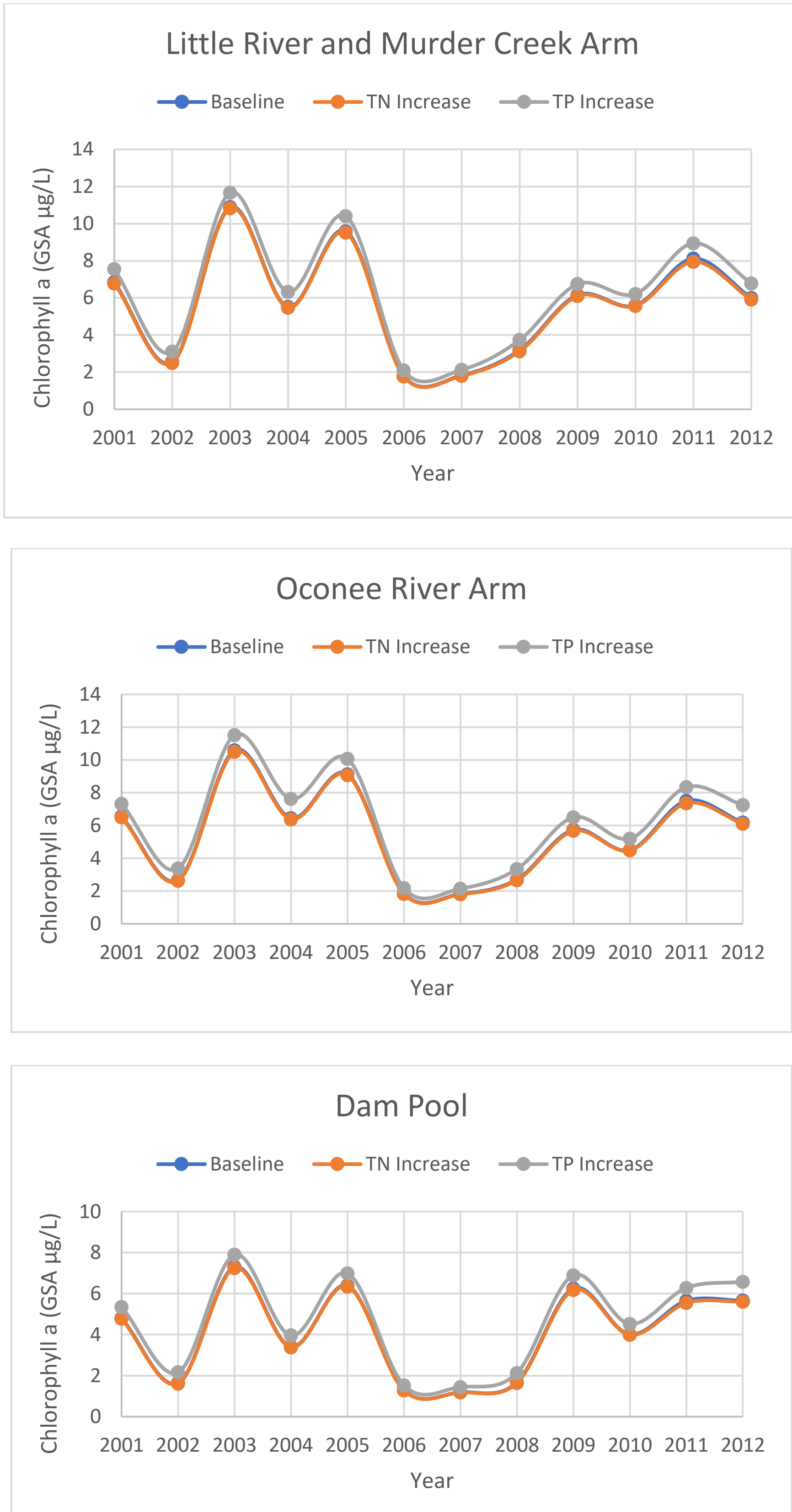

Figure 5-5. Effect of Nutrient Increases on Lake Sinclair Chlorophyll *a* Levels

5.3 Nutrient NPDES Permitting Strategy

Once EPA approves the proposed Lake Oconee and Lake Sinclair criteria, GA EPD plans to implement a nutrient NPDES permitting strategy. Assuming all facilities in the Oconee and Sinclair watershed were to discharge at the GA EPD nutrient strategy total phosphorus levels, the daily load would be 542 lbs/day. However, EPD plans to cut the existing total phosphorus limits in current permits and implement total phosphorus permit limits in the 25 facilities that currently do not have limits that would result in the total phosphorus permitted load to Lake Oconee and Lake Sinclair to be 278 lbs/day and 32 lbs/day, respectively. Most facilities will be given compliance schedules to meet these new limits. Without having permit limits in place, it is possible that total phosphorus levels may exceed any proposed total phosphorus criteria.

EPD is proposing to adopt chlorophyll *a* criteria for lakes Oconee and Sinclair and to implement appropriate phosphorus and ammonia limits in permits. EPD will not be adopting total phosphorus and nitrogen criteria at this time. This nutrient permitting strategy will also allow time for the fisheries in Lakes Oconee and Sinclair to adjust to the altered nutrient levels without disrupting the food web. Once the permitted strategy has been implemented, phosphorus and nitrogen criteria for these lakes can be adopted in the future.

Acknowledgements

Several agencies provided information for this review and are acknowledged below.

Recreational Use Support

Georgia Power Company (Anthony Dodd; Warren Wagner III; Courtenay O'Mara)

Fishing Use Support

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

Georgia Power Company (Patrick O'Rouke)

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, Gillian Gilbert-Wason, Tyler Parsons, Ania Truszczynski, & James Capp.

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Appendix A

Annotated Bibliography

Annotated Bibliography

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- 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

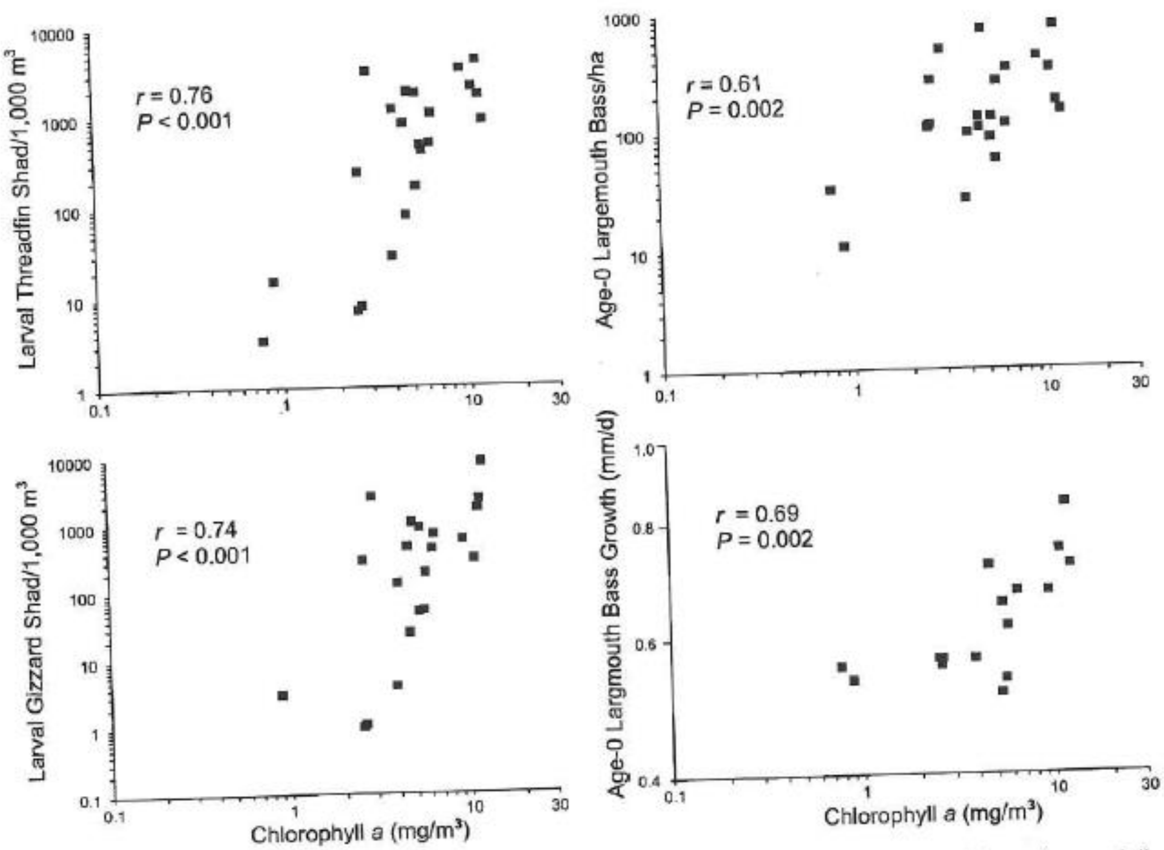

FIGURE 2.—Mean annual larval threadfin shad, gizzard shad, and age-0 largemouth bass densities and mean daily age-0 largemouth bass growth rate as a function of mean annual chlorophyll-a concentration (mg/m^3) for each reservoir or site in nine Alabama reservoirs, 1993–1994. Larval gizzard shad were not collected at the dam forebay site of Lewis Smith Reservoir in 1994.

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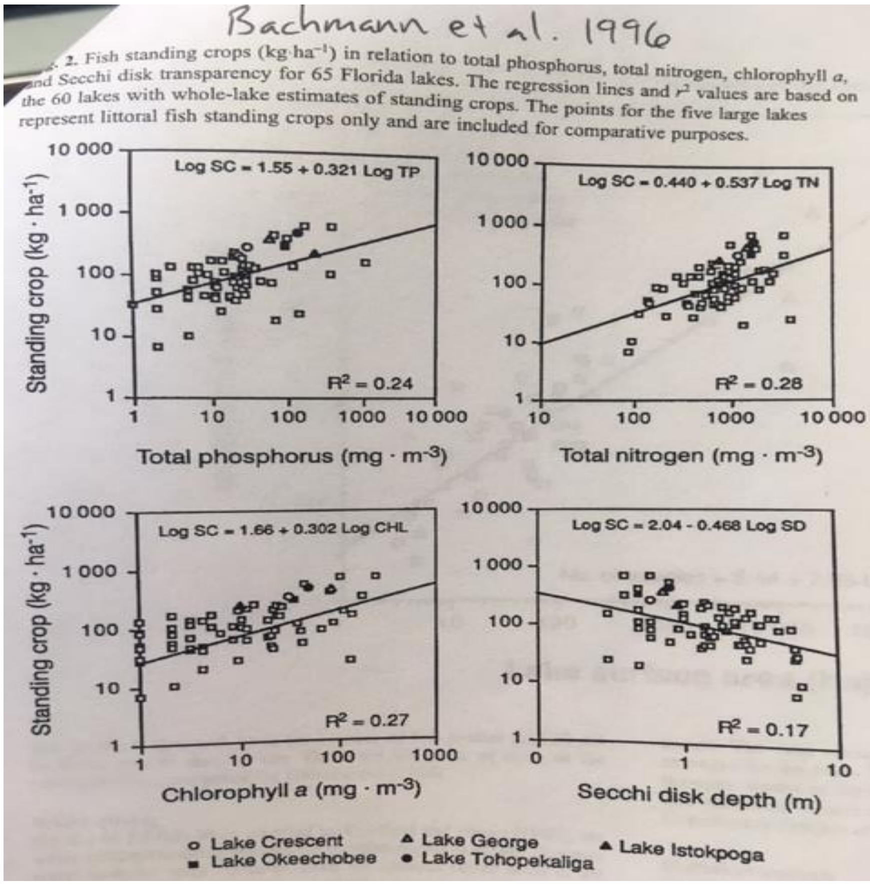
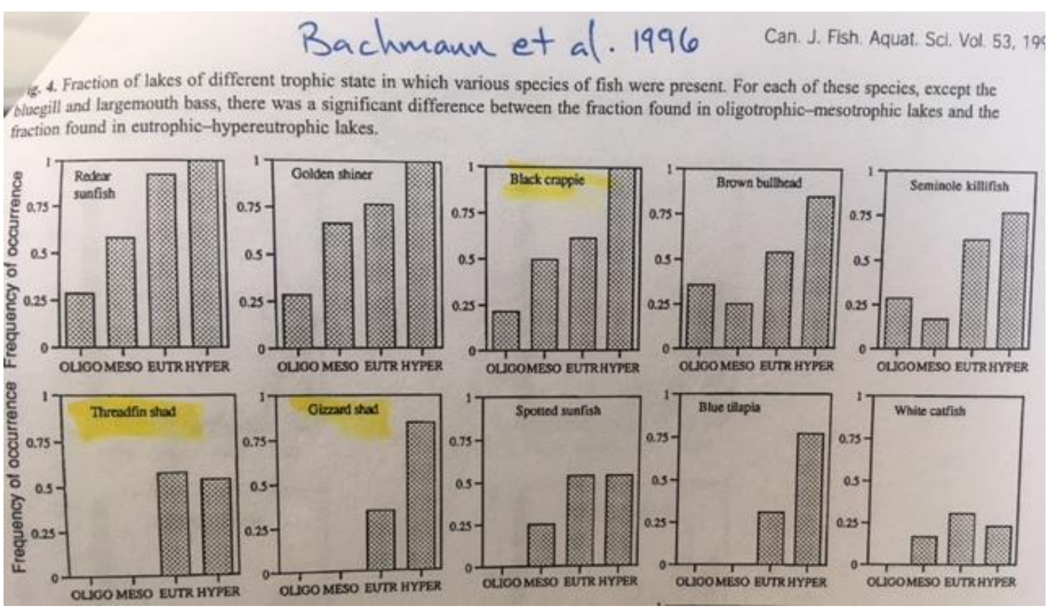
- Study demonstrates that as reservoir productivity increases, fish standing stocks will increase.





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.

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.

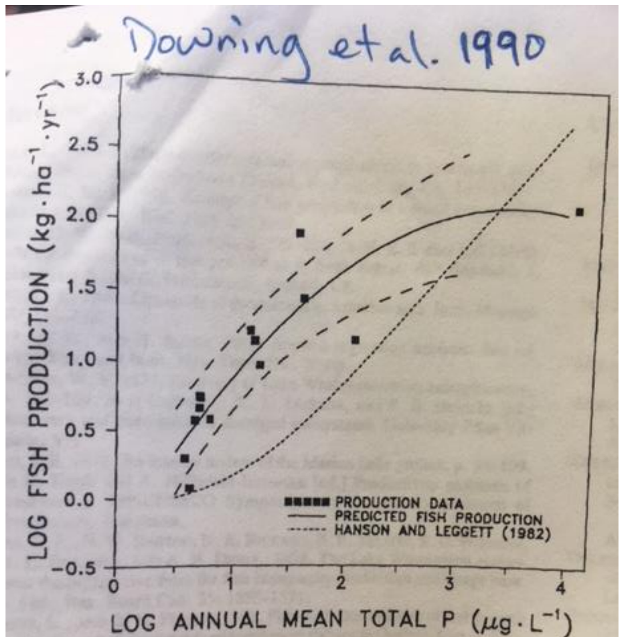


FIG. 4. The relationship between seasonal average total phosphorus concentration of the water column and the fish community production in lakes. The solid curve is predicted from Eq. (4) while the dotted curve represents predicted yields from Hanson and Leggett's (1982) Fig. 2. Dashed lines indicate 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

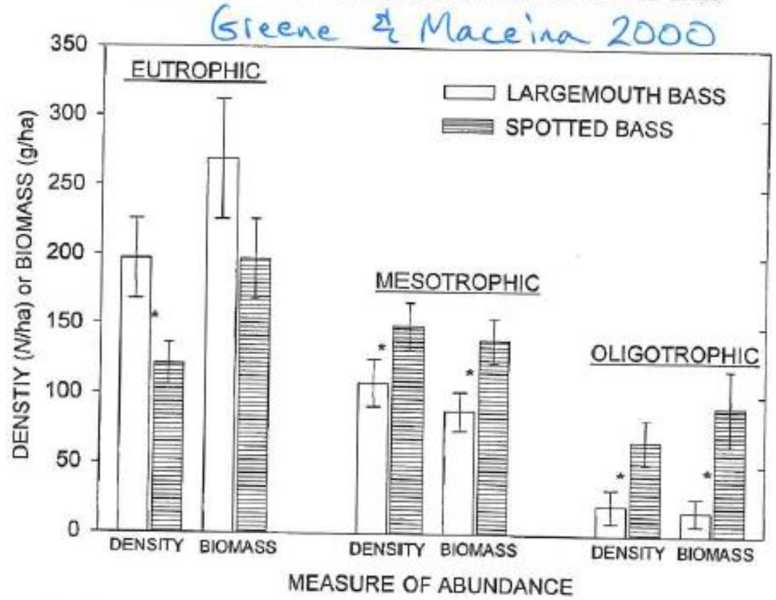


FIGURE 2.—Mean density and biomass of largemouth bass and spotted bass within trophic states in Alabama reservoirs or sites. Vertical lines represent ±SE; an asterisk indicates that mean values differed significantly ($P <$ 0.05) between species.

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

- Upgrades to a wastewater 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.

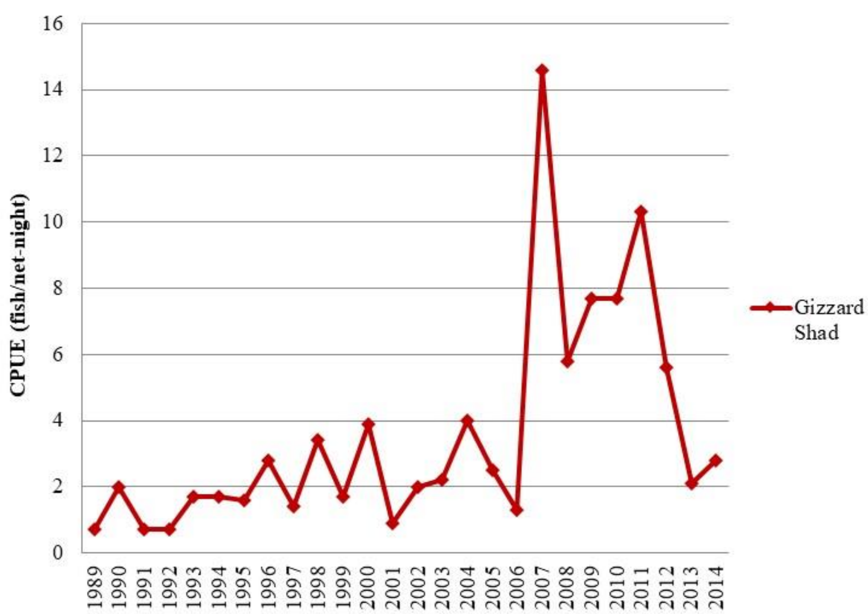


Figure 5. Gizzard shad CPUE (fish/net-night) reported during fall SARS at Carters Reservoir, 1989-2014. (Hakala 2015)

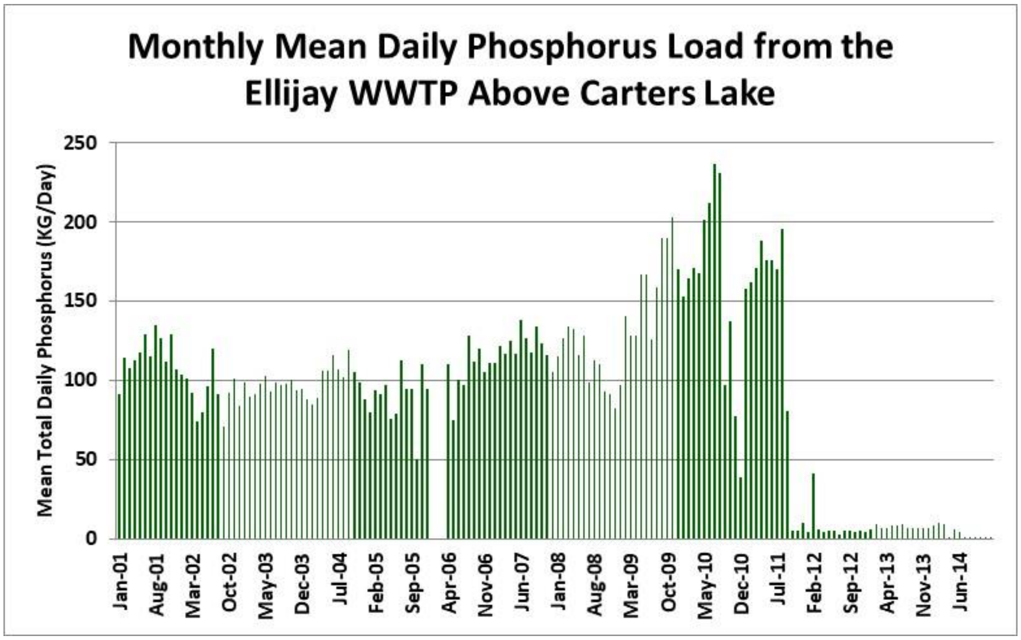


Figure 18. Mean Daily Total Phosphorus Loading from the Ellijay Wastewater Treatment Facility into the Coosawattee River above Carters Reservoir, January 2001 – December 2014. No data were available for January – March 2006. Data obtained from Steve Marchant, Hazardous Waste Management Branch, Georgia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

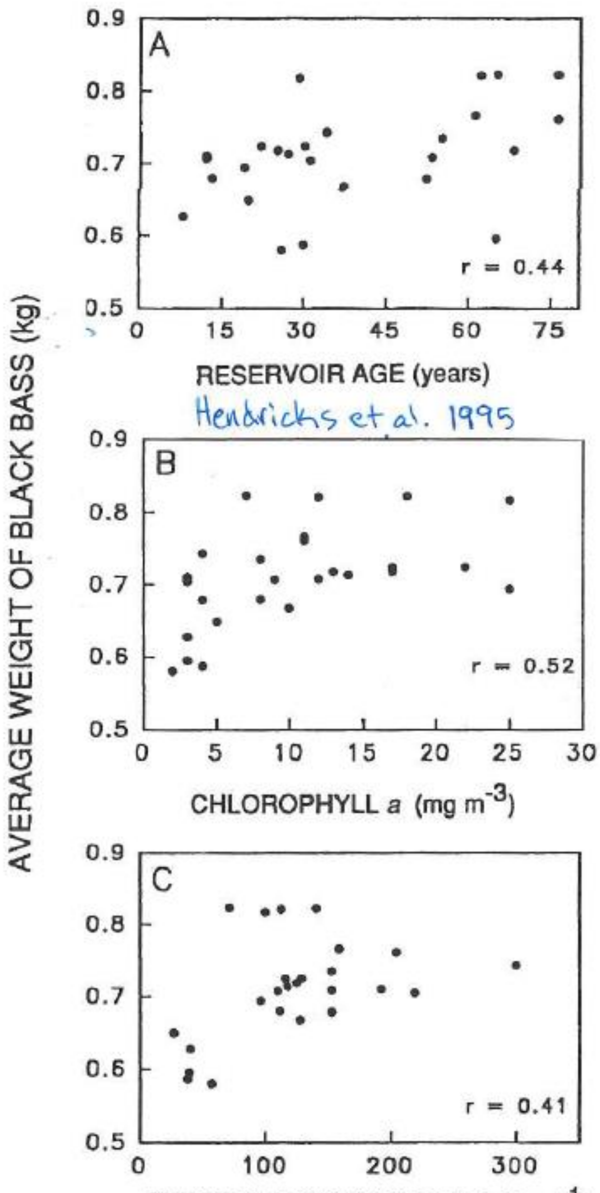


Figure 3.—Average weight of black bass caught by tournament anglers versus reservoir age (A), chlorophyll *a* concentrations (B), and specific conductance (C).

CEINA AND REEVES Hendricks et al. 1995

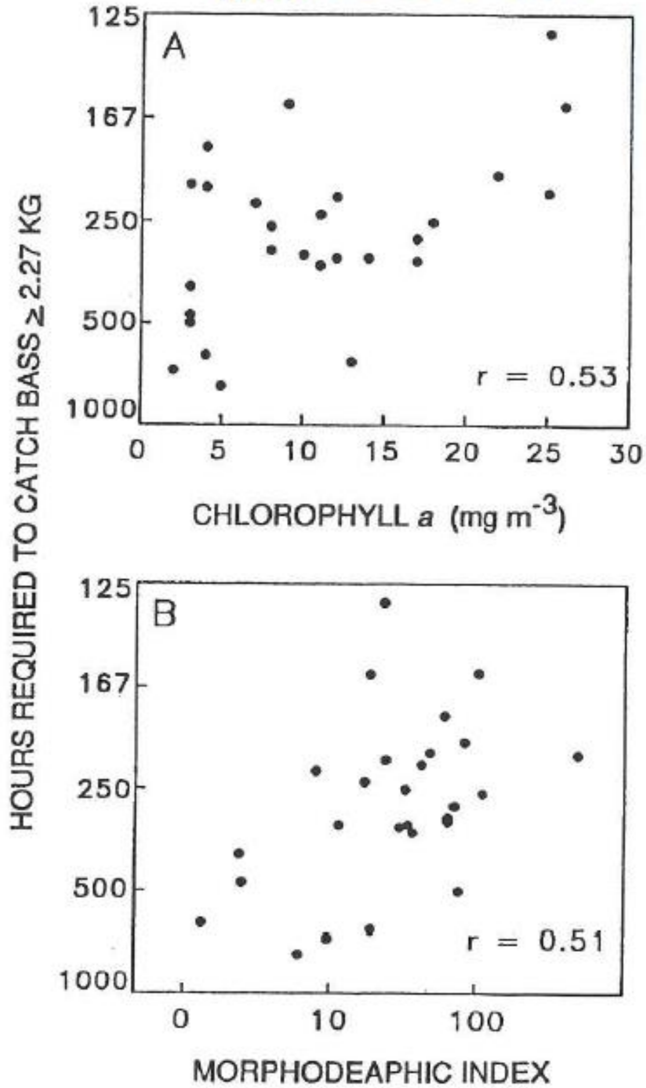
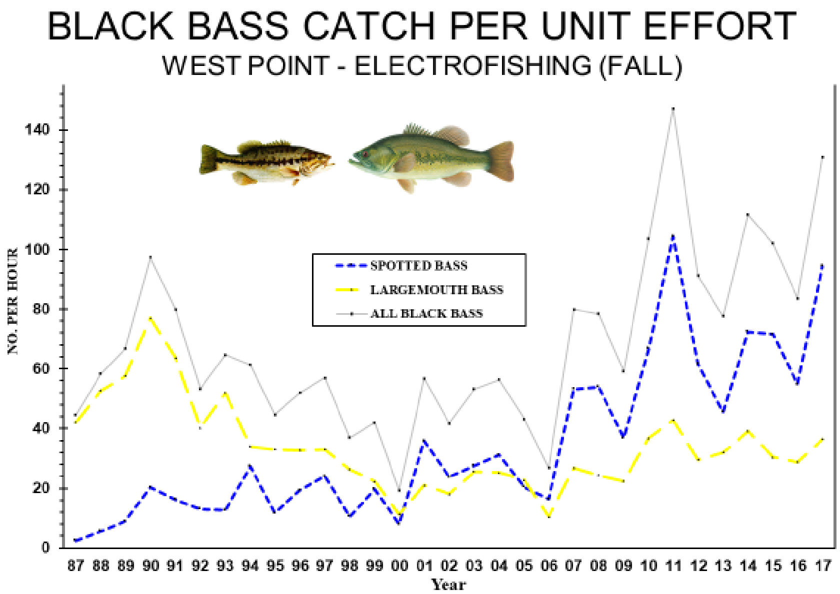


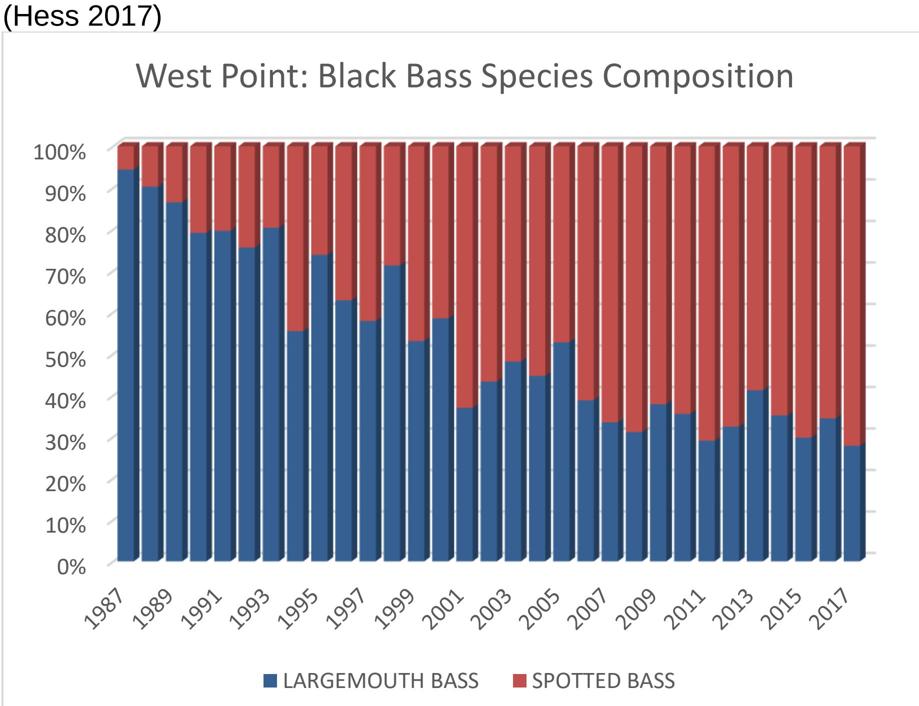
Figure 4.—Hours of effort to catch a memorable-size black bass (≥ 2.27 kg) versus chlorophyll *a* concentrations (A) and the morphoedaphic index (B). Note the scale is inverted; lower values were associated with greater catch rates of memorable-size black bass.

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 chlorophyll-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

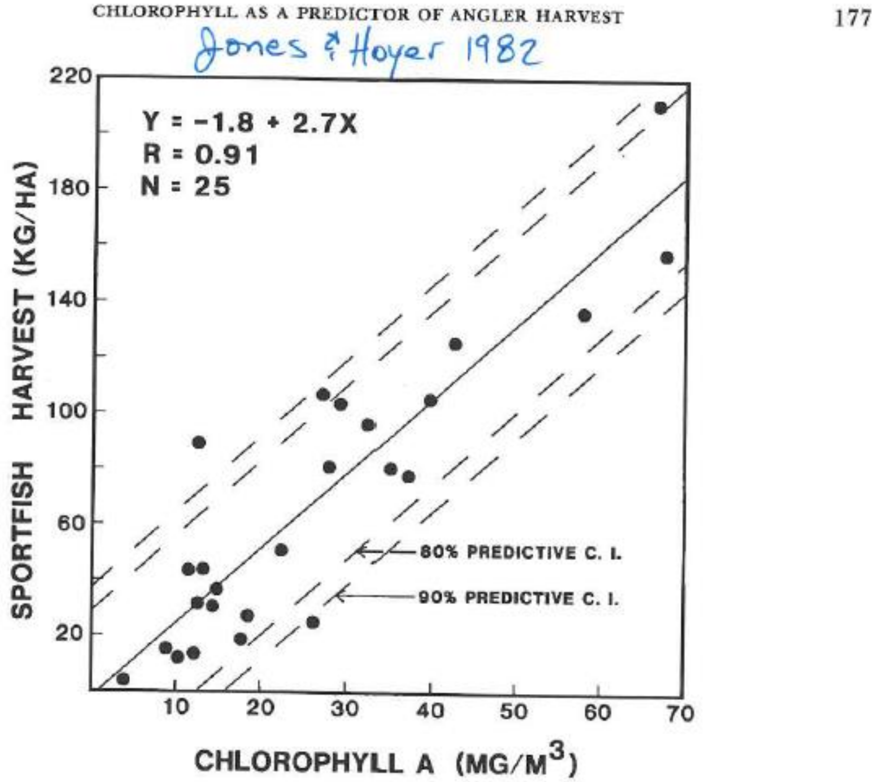


FIGURE 1.—*Angler sportfish harvest (Y, kg/hectare) as a function of mean summer chlorophyll-a concentrations (X, mg/m^3) for water bodies in Missouri and Iowa (C. I. = confidence interval).*

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.

Maceina & Bayne 2001

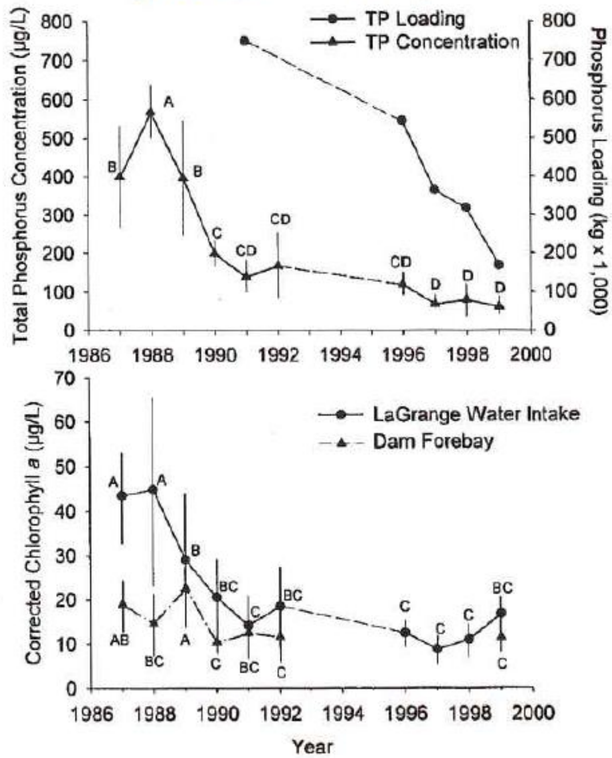


FIGURE 2.—Mean growing-season (April−October) concentrations of total phosphorus (TP) and annual TP load entering West Point Reservoir from the Chattahoochee River (top panel). Mean growing season chlorophyll-a concentrations at midreservoir and dam forebay locations (bottom panel). Mean values annotated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

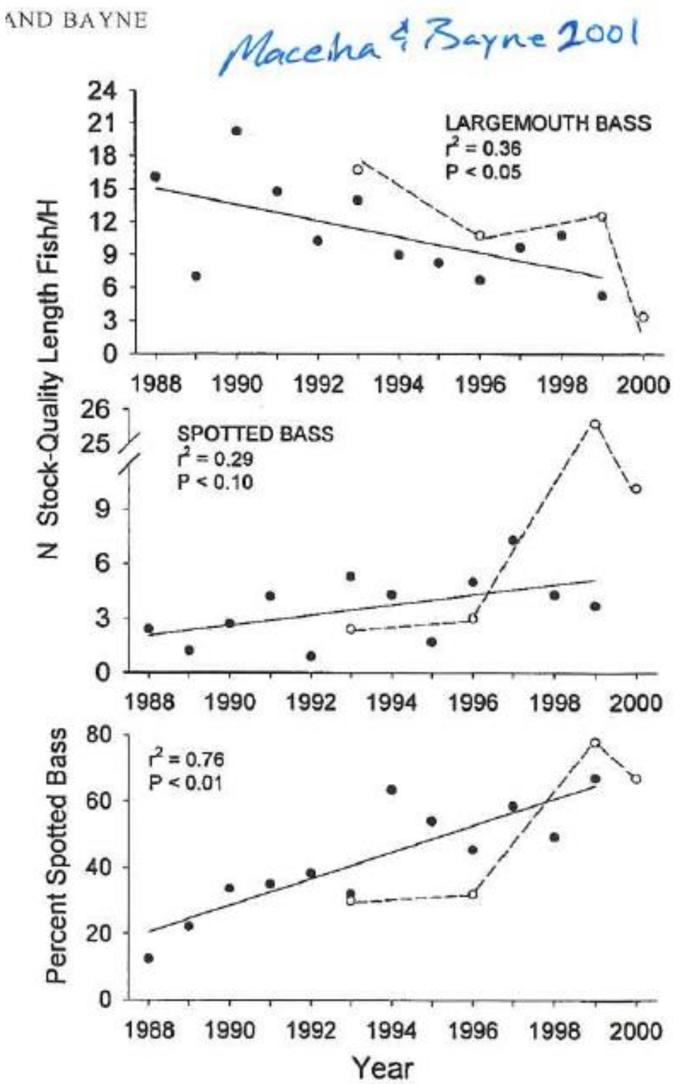


FIGURE 3.—Electrofishing catch per effort of stock-to quality-length largemouth and spotted bass and the percentage of spotted bass to total black bass caught for all fish less than 304 mm TL over time. Solid dots represent fish collected in fall 1988–1999, and solid lines present the corresponding time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

Maceina & Bayne 2001

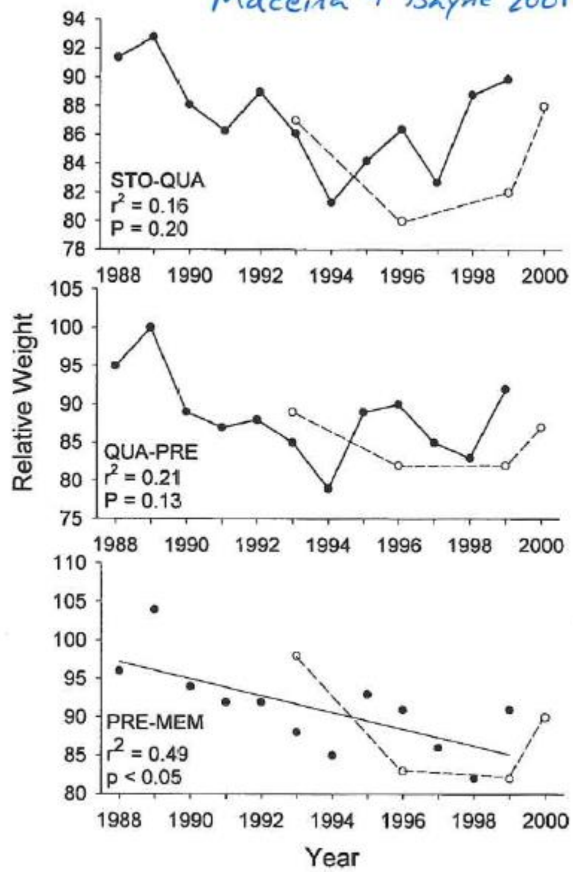


FIGURE 4.—Relative weights of the stock–quality, quality–preferred, and preferred–memorable length categories of largemouth bass over time. Solid lines and dots represent fish collected in fall 1988–1999, and a corresponding time trend regression (solid line) is presented for preferred- to memorable-length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

Maceina & Bayne 2001

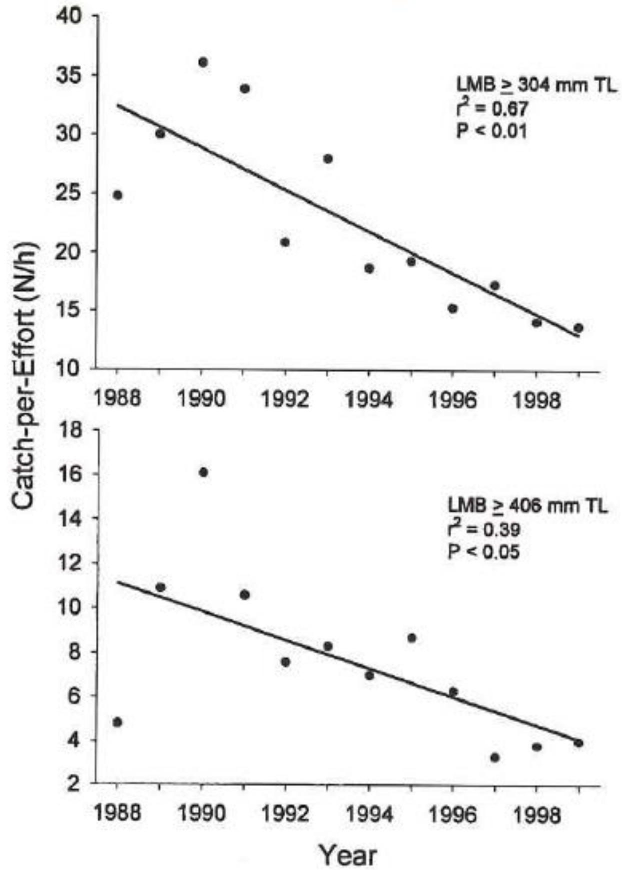


FIGURE 6.—Electrofishing catch per effort of largemouth bass longer than 304 and 406 mm from fall 1988 to 1999. Corresponding regression trend lines are shown.

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.

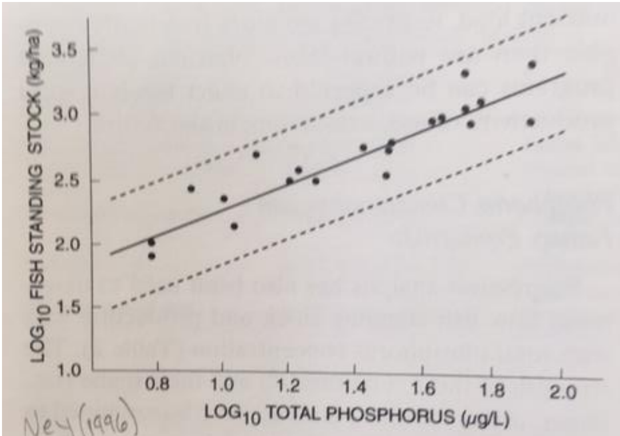


FIGURE 2.—Regression of $\log_{10}$ total fish standing stock (FSS) versus $\log_{10}$ total phosphorus (TP) concentration for 21 southern Appalachian reservoirs. $\text{Log}_{10}\text{FSS} = 1.24 + 1.02\log_{10}\text{TP}$; $r^2 = 0.84$. Dashed lines are 90% predictive limits (from Ney et al. 1990).

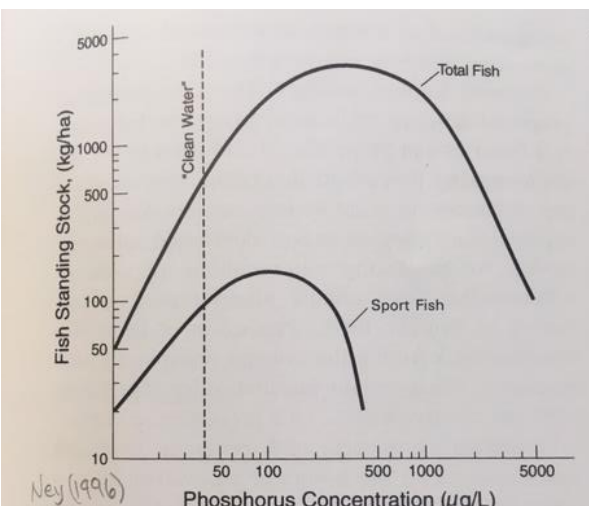


FIGURE 3.—Generalized relation of total and sport fish standing stock to total phosphorus concentration and trophic status in temperate-latitude reservoirs. Standing stock values are representative of southeastern U.S. reservoirs to 100 µg/L total phosphorus. Standing stocks at higher phosphorus concentrations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

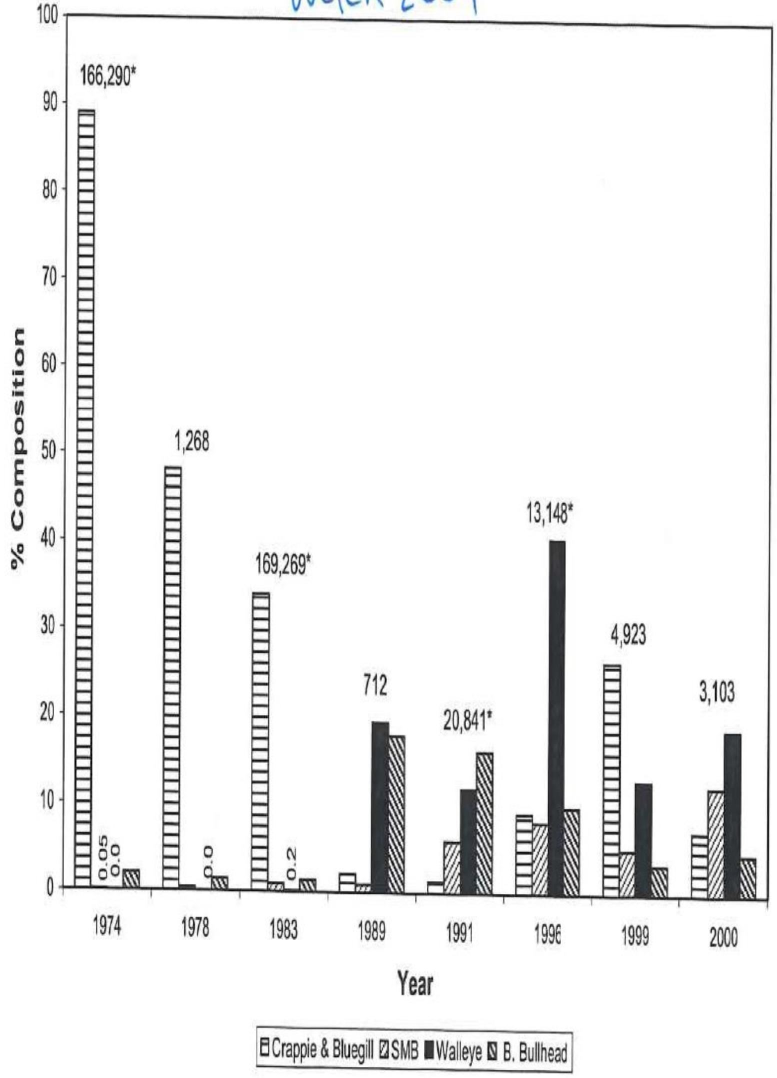


Figure 3.-Angler catch* in 1974, 1983, 1991 and 1996, and biological sampling (electrofishing and gill netting) in the other years, expressed as % of total catch, shown at the top of bars for each year (Burgess 2000, Burgess et al. 2007).

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.

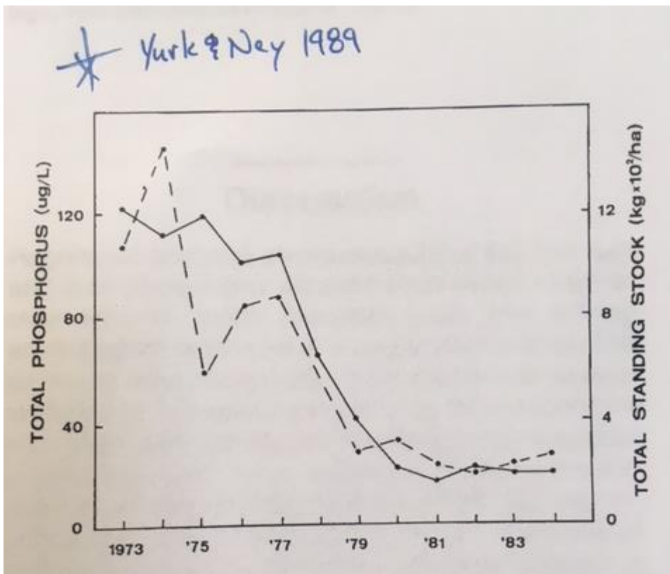


Figure 2.—Dynamics of mean total phosphorus concentration (solid line) and total fish standing stock (dashed line) in Smith Mountain Lake, Virginia 1973-84.