Final TMDL Report

Nutrient TMDLs for Lake George (WBID 2893A), St. Johns River below Lake George (WBID 2893A5), and St. Johns River above Ocklawaha River (WBID 2213O)

and Documentation in Support of the Development of Site-Specific Numeric Interpretations of the Narrative Nutrient Criterion

Wayne Magley, Ph.D.
Water Quality Evaluation and TMDL Program
Division of Environmental Assessment and Restoration
Florida Department of Environmental Protection

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2600 Blair Stone Road
Tallahassee, FL 32399-2400
www.dep.state.fl.us

Executive Summary

Lake George (WBID 2893A), located in northeast Florida, covers an area of approximately 46,000 acres and is the second largest lake in the state. The lake is 11 miles long and has a maximum width of 6 miles, with the St. Johns River flowing through the center from south to north.

Lake George was verified as impaired for nutrients during the Cycle 1 assessment for the Middle St. Johns River Basin based on elevated TSI values and was included on the Verified List of impaired waters adopted by Secretarial Order on May 27, 2004. The Cycle 1 Verified List also included nutrient impairments based on elevated chlorophyll *a* levels for two St. Johns River segments downstream of the lake: St. Johns River below Lake George (WBID 2893A1) and St. Johns River above Ocklawaha River (WBID 2213O).

For the Cycle 3 assessment period, Lake George was verified impaired for nutrients based on exceedances of adopted numeric nutrient criteria for chlorophyll *a* and total phosphorus (TP) that went into effect on October 27, 2014. The St. Johns River below Lake George segment, now designated as WBID 2893A5, was included on the Cycle 3 Verified List for chlorophyll *a*. WBID 2213O remains on the 303(d) Verified List based on the Cycle 1 assessment.

Individual total maximum daily loads (TMDLs) for total nitrogen (TN) and TP have been developed for Lake George and both St. Johns River segments, and supporting information for the TMDLs is listed below in **Table EX-1**. These TMDLs were developed in accordance with Section 303(d) of the federal Clean Water Act and guidance developed by the U.S. Environmental Protection Agency.

Table EX-1: Summary of TMDL supporting information for Lake George, St. Johns River below Lake George, and St. Johns River above Ocklawaha River

Type of Information	Description
Waterbody name/ Segment with waterbody identification (WBID) number	Lake George (WBID 2893A) St. Johns River below Lake George (WBID 2893A5) St. Johns River above Ocklawaha River (WBID 2213O)
Hydrologic Unit Code (HUC) 8	Upper St. Johns River Basin (03080101)
Use classification/ Waterbody designation	Class III/Freshwater
Targeted beneficial uses	Fish consumption; recreation, propagation and maintenance of a healthy, well-balanced population of fish and wildlife
303(d) listing status	Verified List of impaired waters for the Group 2 basins (Middle St. Johns River Basin) adopted via Secretarial Order dated May 27, 2004.
TMDL pollutants	TN and TP
Water quality targets	**Lake George (WBID 2893A):** **Chlorophyll *a*:** 23 micrograms per liter (µg/L), expressed as an annual geometric mean (AGM) concentration not to be exceeded. **TN:** 4,132,773 kilograms per year (kg/yr), expressed as a 7-year average of annual loads not to be exceeded. **TP:** 219,324 kg/yr, expressed as a 7-year average of annual loads not to be exceeded. **St. Johns River below Lake George (WBID 2893A5):** **Chlorophyll *a*:** 23 µg/L, expressed as an AGM concentration not to be exceeded. **TN:** 4,132,773 kg/yr, expressed as a 7-year average of annual loads not to be exceeded. **TP:** 219,324 kg/yr, expressed as a 7-year average of annual loads not to be exceeded. **St. Johns River above Ocklawaha River (WBID 2213O):** **Chlorophyll *a*:** 22 µg/L, expressed as an AGM concentration not to be exceeded. **TN:** 4,132,773 kg/yr, expressed as a 7-year average of annual loads not to be exceeded. **TP:** 219,324 kg/yr, expressed as a 7-year average of annual loads not to be exceeded.
TMDL goal	**WBID 2893A**: 7 % TN reduction and 29 % TP reduction to achieve a chlorophyll *a* target of 23 µg/L, expressed as an AGM concentration not to be exceeded. **WBID 2893A5**: 7 % TN reduction and 29 % TP reduction to achieve a chlorophyll *a* target of 23 µg/L, expressed as an AGM concentration not to be exceeded. **WBID 2213O**: 7 % TN reduction and 29 % TP reduction to achieve a chlorophyll *a* target of 22 µg/L, expressed as an AGM concentration not to be exceeded.

Acknowledgments

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For additional information on the watershed management approach and impaired waters in the Middle St. Johns River Basin, contact:

Moira Homann
Florida Department of Environmental Protection
Water Quality Restoration Program Watershed Planning and Coordination Section
2600 Blair Stone Road, Mail Station 3565
Tallahassee, FL 32399-2400
Email: Moira Homann
Phone: (850) 245–8460

Access to all data used in the development of this report can be obtained by contacting:

Kevin Petrus
Florida Department of Environmental Protection
Water Quality Evaluation and TMDL Program
Watershed Evaluation and TMDL Section
2600 Blair Stone Road, Mail Station 3555
Tallahassee, FL 32399-2400
Email: Kevin Petrus
Phone: (850) 245–8459

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Chapter 1: Introduction

1.1 Purpose of Report

This report describes the analysis carried out to develop nutrient total maximum daily loads (TMDLs) for 3 segments with waterbody identification (WBID) numbers—Lake George, St. Johns River below Lake George, and St. Johns River above Ocklawaha River—to assess the impact of proposed nutrient reductions on chlorophyll *a* levels. Lake George (WBID 2893A), located in Northeast Florida, covers an area of 46,000 acres and is the second largest lake in the state. Its watershed spans portions of 4 counties (Lake, Volusia, Marion, and Putnam) (**Figure 1.1**). Lake George was verified as impaired for nutrients during the Cycle 1 assessment for the Middle St. Johns River Basin based on elevated Trophic State Index (TSI) values and was included on the Verified List of impaired waters adopted by Secretarial Order on May 27, 2004. The Cycle 1 Verified List also included nutrient impairments based on chlorophyll *a* levels for the St. Johns below Lake George stream segment (WBID 2893A1) and the St. Johns River above Ocklawaha River stream segment (WBID 2213O).

The Cycle 3 assessment considered the numeric nutrient criteria (NNC) that went into effect on October 27, 2014. Lake George (WBID 2893A) was on the Delist List adopted by Secretarial Order on October 21, 2016, for nutrients (TSI) since the TSI is no longer used to assess impairments. The Verified List, however, included Lake George for chlorophyll *a* and total phosphorus (TP) based on the adopted NNC. WBID 2893A1 was retired, and all associated data were reassigned to WBID 2893A5 (St. Johns below Lake George). WBID 2893A5 was placed on the Cycle 3 Verified List for chlorophyll *a*. WBID 2213O remains on the 303(d) Verified List based on the Cycle 1 assessment.

According to Section 303(d) of the federal Clean Water Act (CWA) and the Florida Watershed Restoration Act (FWRA), Chapter 403.067, Florida Statutes (F.S.), the Florida Department of Environmental Protection (DEP) is required to submit to the U.S. Environmental Protection Agency (EPA) on a recurring basis lists of surface waters that do not meet applicable water quality standards (impaired waters). The methodologies used by the state for determining impairment are established in Chapter 62-303, Identification of Impaired Surface Waters (IWR), Florida Administrative Code (F.A.C.).

Once a waterbody or waterbody segment has been verified as impaired and referenced in the Secretarial Order Adopting the Verified List of Impaired Waters, work on establishing the TMDL begins. The TMDL process establishes the allowable loadings of pollutants or other quantifiable parameters for a waterbody based on the relationship between pollutants and in-stream water quality conditions, so that states can establish water quality–based controls to reduce pollution from both point and nonpoint sources and restore and maintain the quality of their water resources (EPA 1991).

These TMDLs will constitute the site-specific numeric interpretations of the narrative nutrient criterion set forth in Paragraph 62-302.530(90)(b), F.A.C., that will replace the otherwise applicable NNC in Subsection 62-302.531(2), F.A.C., for these particular waterbodies.

1.2 Identification of Waterbody

Lake George is a 46,000-acre lake in the northeast corner of Florida (**Figure 1.1**). The lake is 11 miles long, has a maximum width of 6 miles, with the St. Johns River flowing through the center from south to north. The average lake depth is 11 feet (ft). The Lake George Watershed includes portions of 4 counties (Lake, Marion, Putnam, and Volusia). Fifty-nine percent of the watershed is identified as conservation or managed lands under a number of county, state, or federal entities. This includes 53,972 acres of the Ocala National Forest. Seventeen springs have been identified in the watershed, including Silver Glen, a first magnitude spring (discharge >100 cubic feet per second [cfs]), and 5 second magnitude springs (discharge > 10 to 100 cfs).

There are approximately 10.5 river miles between Drayton Island at the northern end of Lake George and the confluence of the St. Johns River with the Ocklawaha River. A portion of the St. Johns River south of the confluence with the Ocklawaha River appears on topographic maps as Little Lake George.

Lake George is located in the area known as the St. Johns Offset subprovince of the Central Lake physiographic region. Seventy-five percent of the watershed is characterized as having Type A and A/D soils and a relatively low elevation gradient surrounding the lake (**Figure 1.2**).

Lake George (WBID 2893A), the St. Johns below Lake George segment (WBID 2893A5) and the St. Johns River above Ocklawaha River segment (WBID 2213O) are part of the Lake George Planning Unit. Planning units are groups of smaller watersheds (WBIDs) that are part of a larger basin unit, in this case the Middle St. Johns Basin. The Lake George Planning Unit consists of 31 WBIDs. **Figure 1.3** shows the locations of the three WBIDs in the planning unit.

1.3 Background

This report is part of DEP's watershed management approach for restoring and protecting state waters under TMDL Program requirements. The watershed approach looks at waterbodies in a larger geographic context of 52 river basins. It is implemented by organizing the basins into 5 groups, with an individual basin group evaluated during a given single year; all basins are assessed during a 5-year cycle. The TMDL Program implements the requirements of the 1972 federal CWA and the 1999 FWRA (Chapter 99-223, Laws of Florida).

A TMDL represents the maximum amount of a given pollutant that a waterbody can assimilate and still meet water quality standards, specifically its applicable water quality criteria and its designated uses. TMDLs are developed for waterbodies that are verified as not meeting their water quality standards, as set by the state. They provide important water quality restoration goals that will guide restoration activities.

This TMDL report will be followed by the development and implementation of a restoration plan designed to reduce the nutrient levels in Lake George. These activities will solicit and include the active participation of local citizen groups, as well as local and regional political entities such as the St. Johns River Water Management District (SJRWMD), municipal governments, businesses, and other stakeholders. DEP will work with these organizations and individuals to undertake or continue reductions in the discharge of pollutants and achieve the established TMDLs for the impaired waterbodies.

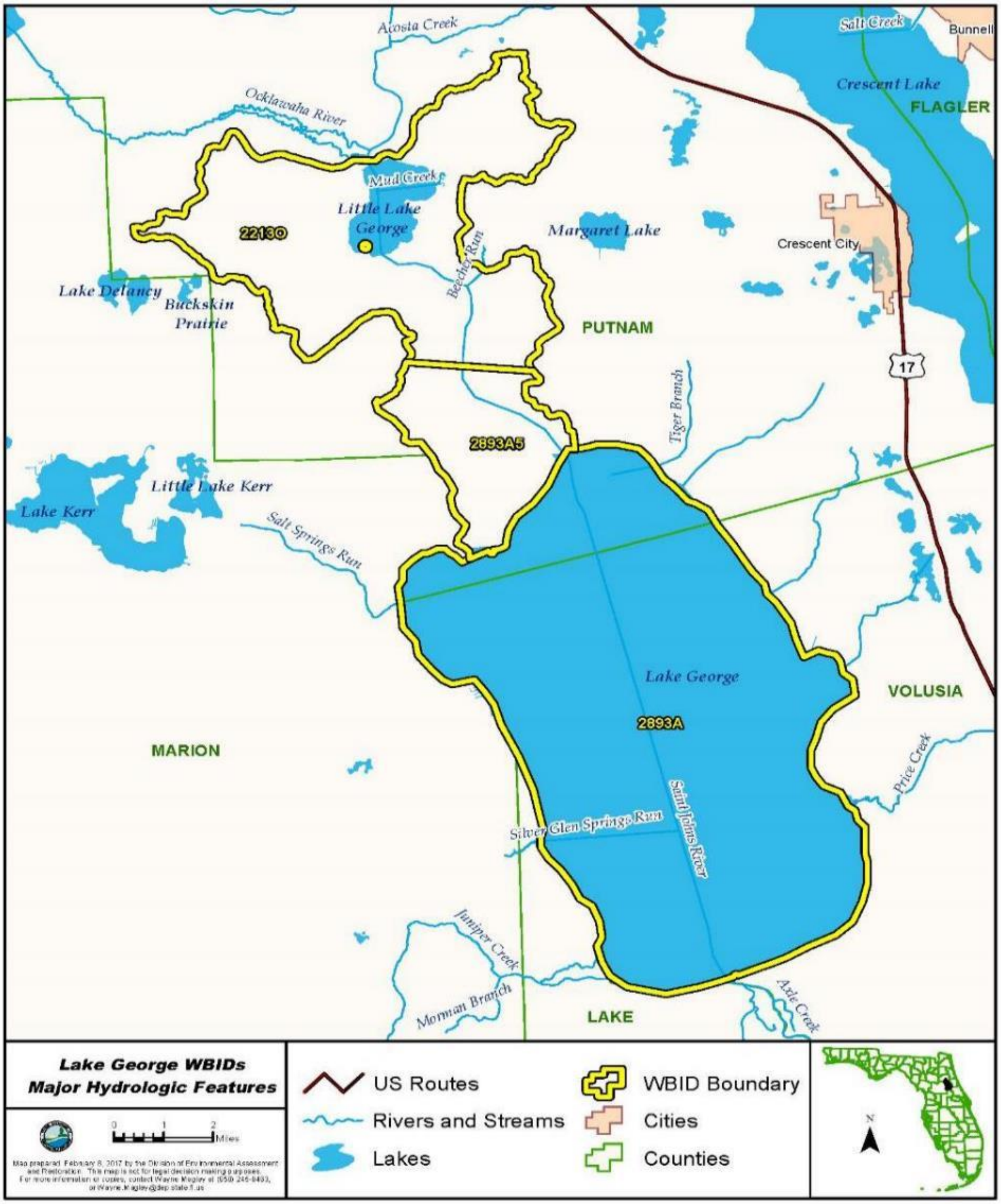

Figure 1.1. Location of the Lake George (WBID 2893A), St. Johns below Lake George (WBID 2893A5), and St. Johns River above Ocklawaha River (WBID 2213O) Water Segments in Northeast Florida and major hydrologic features in the area

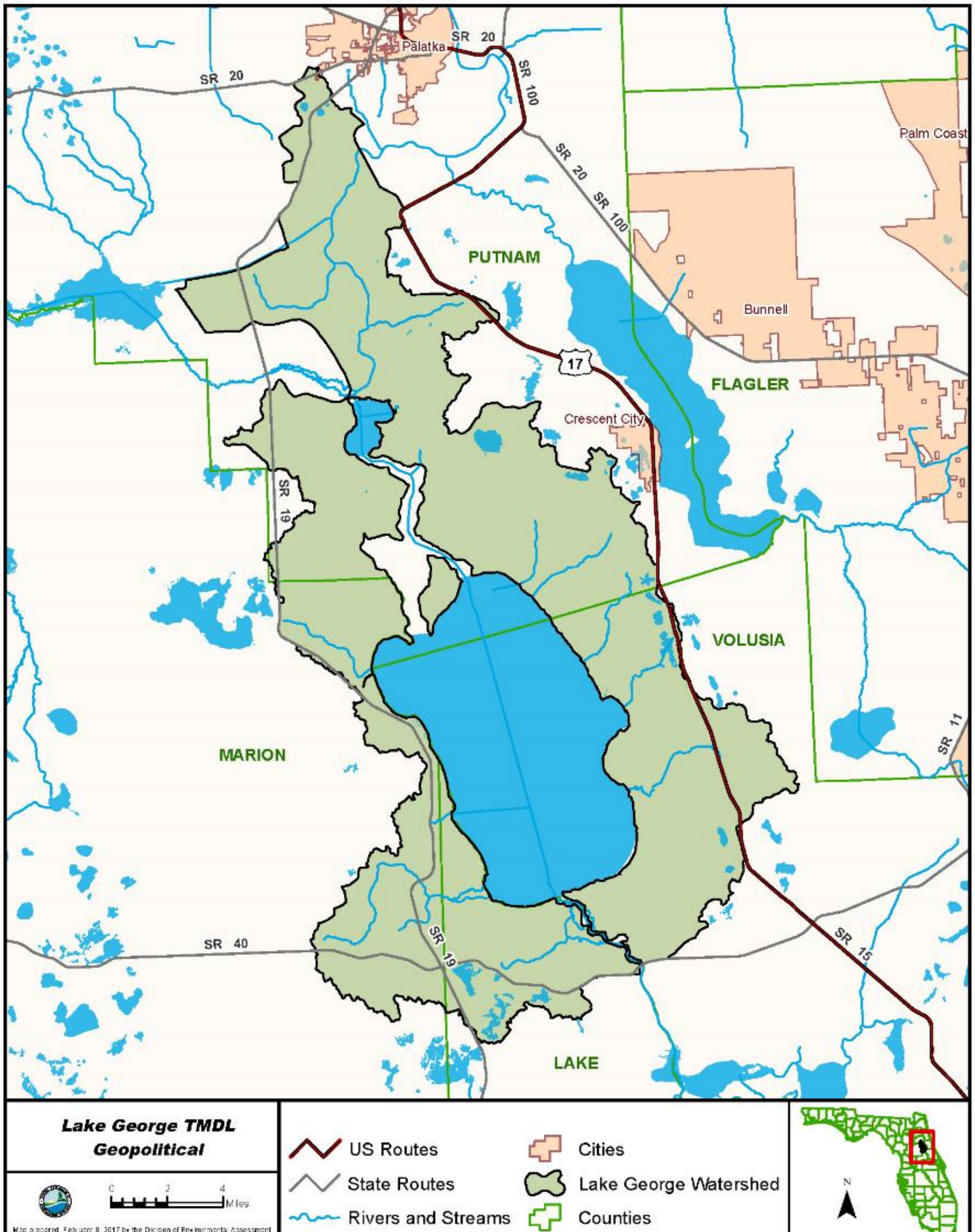

Figure 1.2. Location of the Lake George Watershed in the Middle St. Johns River Basin and major geopolitical and hydrologic features in the area

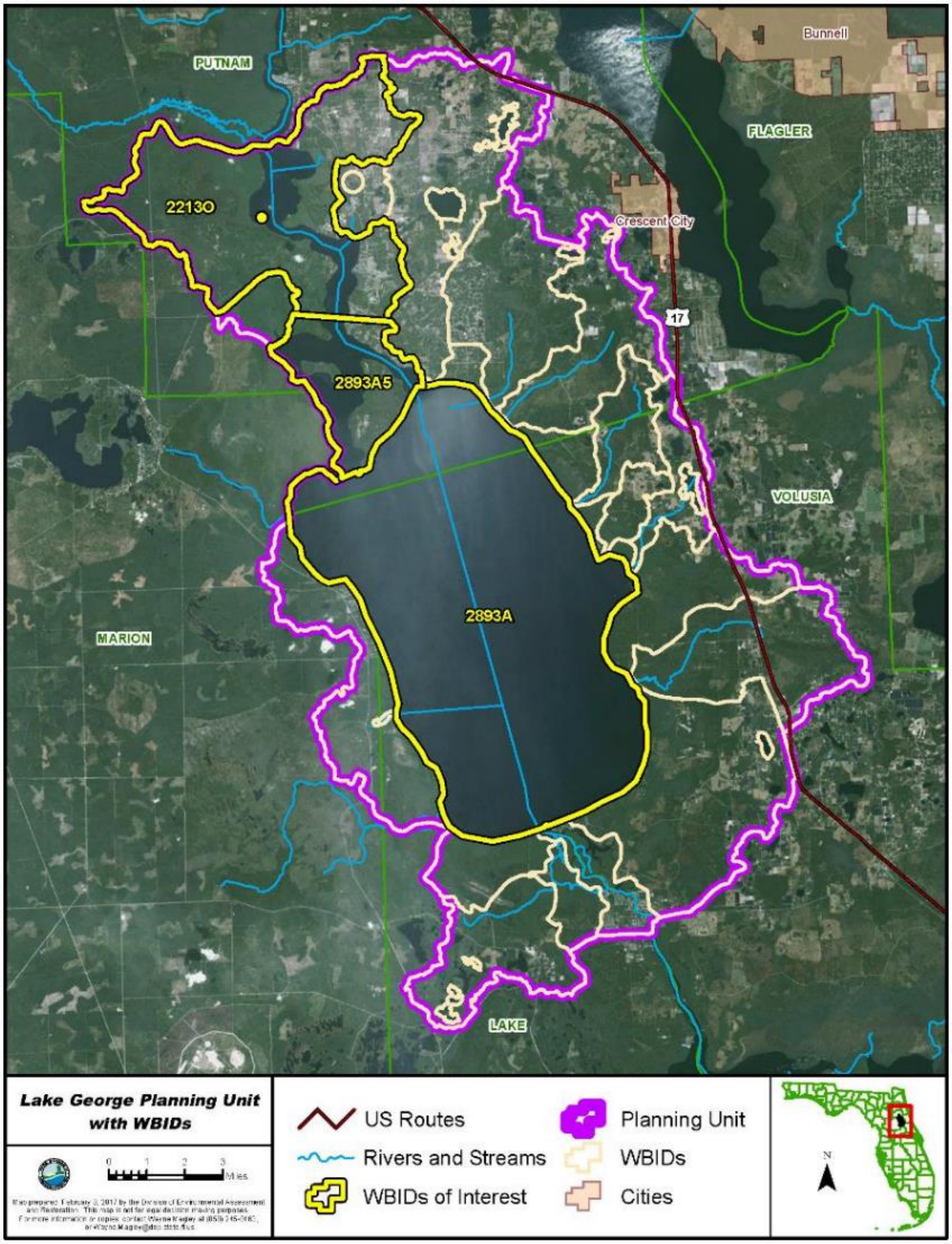

Figure 1.3. Location of the Lake George (WBID 2893A), St. Johns River below Lake George (WBID 2893A5), and St. Johns River above Ocklawaha River (WBID 2213O) Watersheds in the Lake George Planning Unit

Chapter 2: Description of Water Quality Problem

2.1 Statutory Requirements and Rulemaking History

Section 303(d) of the federal CWA requires states to submit to the EPA lists of surface waters that do not meet applicable state water quality standards (impaired waters) and establish a TMDL for each pollutant causing the impairment of listed waters on a schedule. DEP has developed such lists, commonly referred to as 303(d) lists, since 1992. The list of impaired waters in each basin, referred to as the Verified List, is also required by the FWRA. The state's 303(d) list is amended annually to include basin updates.

Florida placed 41 waterbodies in the Ocklawaha Basin on the 1998 303(d) list of impaired waters. However, the FWRA stated that all Florida 303(d) lists created before the adoption of the FWRA were for planning purposes only and directed DEP to develop, and adopt by rule, a new science-based methodology to identify impaired waters. After an extended rulemaking process, the Environmental Regulation Commission adopted the new methodology as Chapter 62-303, F.A.C. (Identification of Impaired Surface Waters Rule, or IWR), in April 2001; the rule was modified in 2006, 2007, 2012, and 2013.

2.2 Information on Verified Impairment

DEP used the IWR to assess water quality impairments in Lake George and segments of the St. Johns River below Lake George. The lake was verified as impaired for nutrients based on elevated annual average TSI values during the Cycle 1 verified period (the verified period for the Group 2 basins was January 1, 1996, to June 30, 2003). When the Cycle 1 assessment was performed, the IWR methodology used the water quality variables total nitrogen (TN), total phosphorus (TP), and chlorophyll *a* (a measure of algal mass, corrected and uncorrected) in calculating annual TSI values, which was used to interpret Florida's narrative nutrient criterion. The TSI is calculated based on concentrations of TP, TN, and chlorophyll *a*. The TSI threshold (60 for lakes with color higher than 40 platinum cobalt units [PCU]) was exceeded in Lake George in multiple years during the verified period and was sufficient to identify the lake as impaired for nutrients. The Cycle 1 assessment also identified 2 other segments—St. Johns River below Lake George (WBID 2893A1) and St. Johns River above Ocklawaha River (WBID 2213O)—as impaired for nutrients based on exceeding an annual mean chlorophyll *a* threshold of 20 µg/L during multiple years during the verified period.

In the Cycle 2 verified period (January 1, 2001, to June 30, 2008), the annual mean TSI values continued to exceed the listing thresholds in Lake George, and WBIDs 2213O and 2893A1 were still impaired for nutrients based on annual chlorophyll *a* means exceeding 20 µg/L. The Cycle 2 Verified List included an impairment for un-ionized ammonia in WBID 2213O and a dissolved oxygen (DO) impairment for a segment identified as Lake George Leftover (WBID 2893A3).

Florida adopted NNC for lakes, spring vents, and streams in 2011 that were approved by the EPA in 2012. Pursuant to Chapter 2013-71, Laws of Florida, the criteria went into effect on October 27, 2014. It is envisioned that these standards, in combination with the related bioassessment tools, will facilitate the assessment of designated use attainment for the state's waters and provide a better means to protect them from the adverse effects of nutrient overenrichment. The lake NNC, which are set forth in Subparagraph 62-302.531(2)(b)1., F.A.C., are expressed as annual geometric mean (AGM) values for chlorophyll *a*, TN, and TP, further described in **Chapter 3**.

The Cycle 3 assessment (verified period January 1, 2007, to June 30, 2014) incorporated changes in Chapters 62-302 and 62-303, F.A.C., for DO criteria and NNC. Lake George was delisted for nutrients based on the TSI, since this index was no longer used to assess nutrient impairment. Based on the NNC for lakes, Lake George was placed on the Verified List for both chlorophyll *a* and TP, since AGMs for both exceeded nutrient criteria more than once in a 3-year period during the verified period. The lake is not impaired for DO.

WBID 2893A1, which was on the Verified List based on the Cycle 1 assessment, was delisted because the WBID had been retired, and all associated data were reassigned to WBID 2893A5 (St. Johns River below Lake George). WBID 2893A5, which was created from portions of the retired WBID 2893A1 and the extant WBID 2893A3, was verified impaired for nutrients based on AGM chlorophyll *a* concentrations exceeding the nutrient threshold of 20 µg/L more than once in a 3-year period during the verified period. There were insufficient data for WBID 2213O in the verified period to asses un-ionized ammonia, and so it remained impaired based on the previous assessment. Both St. Johns River WBIDs immediately downstream of Lake George are not impaired for DO.

Tables 2.1 through **2.3** summarize chlorophyll *a*, TN, and TP AGMs for Lake George (WBID 2893A), St. Johns below Lake George (WBID 2893A1) and St. Johns River above Ocklawaha River (WBID 2213O), respectively.

Table 2.1. Summary of AGMs for corrected chlorophyll *a*, TN, and TP for Lake George (WBID 2893A)

mg/L = Milligrams per liter

Note: Values shown in boldface type and shaded yellow are greater than the new NNC for lakes. Subparagraph 62-302.531(2)(b)1., F.A.C., states that the applicable numeric interpretations for TN, TP, and chlorophyll *a* shall not be exceeded more than once in any consecutive three-year period.

Year	Corrected chlorophyll *a* AGM (µg/L)	TN AGM (mg/L)	TP AGM (mg/L)
1990	**37**	1.23	0.03
1991	**21**	**1.28**	0.03
1992	**21**	1.25	0.03
1993	**34**	1.14	0.03
1994	17	1.16	0.03
1995	15	1.35	0.06
1996	13	1.33	0.07
1997	20	1.05	0.03
1998	12	0.84	0.03
1999	**36**	1.15	0.05
2000	**24**	0.93	0.04
2001	**24**	1.12	0.04
2002	15	1.15	0.07
2003	9	0.93	0.07
2004	13	0.74	0.05
2005	4	1.16	0.07
2006	**35**	0.77	0.04
2007	**46**	0.89	0.04
2008	**30**	1.27	**0.05**
2009	20	1.12	**0.06**
2010	**32**	1.04	0.04
2011	**55**	1.13	0.04
2012	**25**	0.98	0.04
2013	11	0.98	0.03
2014	19	1.19	0.07
2015	20	1.19	**0.07**
2016	**23**	**1.36**	0.05

Table 2.2. Summary of AGMs for corrected chlorophyll *a*, TN, and TP for St. Johns River below Lake George (WBID 2893A5)

Note: Values shown in boldface type and shaded yellow are greater than the new NNC for streams. Subparagraph 62-302.531(2)(c)2., F.A.C., states that the applicable numeric interpretations for TN and TP shall not be exceeded more than once in any consecutive three-year period.

Year	Corrected chlorophyll *a* AGM (µg/L)	TN AGM (mg/L)	TP AGM (mg/L)
1993	18	1.37	0.04
1994	15	1.38	0.06
1995	**24**	**1.74**	0.06
1996	20	1.46	0.06
1997	**32**	1.27	0.06
1998	18	**1.58**	0.06
1999	**32**	**1.69**	0.06
2000	**28**	1.41	0.05
2001	**23**	**1.75**	0.06
2002	16	1.39	0.09
2003	20	1.33	0.08
2004	16	1.47	0.08
2005	15	1.34	0.07
2006	**26**	1.28	0.06
2007	**30**	1.34	0.03
2008	14	1.42	0.07
2009	**27**	1.41	0.09
2010	**26**	1.36	0.07
2011	**34**	1.54	0.07
2012	**23**	1.27	0.04
2013	**27**	1.33	0.06
2014	**21**	0.93	0.07
2015	**22**	1.08	0.05
2016	**23**	1.39	0.06

Table 2.3. Summary of AGMs for corrected chlorophyll *a*, TN, and TP for St. Johns River above Ocklawaha River (WBID 2213O)

ID = Insufficient data to calculate geometric means per the requirements of Chapter 62-303, F.A.C.
ND = No data
Note: Values shown in boldface type and shaded yellow are greater than the new NNC for streams. Subparagraph 62-302.531(2)(c)2., F.A.C., states that the applicable numeric interpretations for TN and TP shall not be exceeded more than once in any consecutive three-year period.

Year	Corrected Chlorophyll *a* AGM (µg/L)	TN AGM (mg/L)	TP AGM (mg/L)
1990	ID	ID	ID
1991	ND	**1.85**	0.06
1992	ND	1.50	0.08
1993	ND	1.26	0.02
1994	ND	1.31	0.04
1998	**22**	**1.67**	0.07
1999	**28**	**1.66**	0.07
2000	**21**	1.35	0.05
2001	19	0.56	0.03
2002	16	1.52	0.09
2003	20	1.32	0.08
2004	**30**	1.45	0.07

In Florida waterbodies, nitrogen and phosphorus are most often the limiting nutrients. The limiting nutrient is defined as the nutrient that limits plant growth (both macrophytes and algae) when it is not available in sufficient quantities. A limiting nutrient is a chemical necessary for plant growth, but available in quantities smaller than those needed for algae, represented by chlorophyll *a*, and macrophytes to grow.

In the past, management activities to control lake eutrophication focused on phosphorus reduction, as phosphorus was generally recognized as the limiting nutrient in freshwater systems. Recent studies, however, have supported the reduction of both nitrogen and phosphorus as necessary to control algal growth in aquatic systems (Conley et al. 2009; Paerl 2009; Lewis et al. 2011; Paerl and Otten 2013). Furthermore, the analysis used in the development of the Florida lake NNC supports this idea, as statistically significant relationships were found between chlorophyll *a* values and both nitrogen and phosphorus concentrations (DEP 2012a).

Chapter 3. Description of Applicable Water Quality Standards and Targets

3.1 Classification of the Waterbody and Criterion Applicable to the TMDL

Florida's surface waters are protected for six designated use classifications, as follows:

Class I	**Potable Water Supplies**
Class I-Treated	**Treated Potable Water Supplies**
Class II	**Shellfish Propagation or Harvesting**
Class III	**Fish Consumption; Recreation, Propagation, and Maintenance of a Healthy, Well-Balanced Population of Fish and Wildlife**
Class III-Limited	**Fish Consumption; Recreation or Limited Recreation; and/or Propagation and Maintenance of a Limited Population of Fish and Wildlife**
Class IV	**Agricultural Water Supplies**
Class V	**Navigation, Utility, and Industrial Use (there are no state waters currently in this class)**

Lake George and the two St. Johns River segments are Class III (freshwater) waterbodies, with a designated use of recreation, propagation, and maintenance of a healthy, well-balanced population of fish and wildlife. The Class III water quality criteria applicable to the verified impairments (nutrients) for these waters are Florida's nutrient criterion in Paragraph 62-302.530(90)(b), F.A.C., and the adopted lake criteria for TN, TP, and chlorophyll *a* (Subparagraph 62-302.531[2][b]1., F.A.C.) and stream criteria for TN and TP (Paragraph 62-302.531[2][c], F.A.C.).

3.2 Applicable Water Quality Standards and Numeric Water Quality Target

<u>Generally Applicable Numeric Nutrient Criteria</u>

The NNC for inland waters were adopted in Florida on December 8, 2012, and have been effective since October 27, 2014.

NNC rule language for lakes in Paragraph 62-302.531(2)(b), F.A.C., states:

> 1. For lakes, the applicable numeric interpretations of the narrative nutrient criterion in paragraph 62-302.530(90)(b), F.A.C., for chlorophyll *a* are shown in the table below. The applicable interpretations for TN and TP will vary on an annual basis, depending on the availability of chlorophyll *a* data and the concentrations of nutrients and chlorophyll a in the lake, as described below. The applicable numeric interpretations for TN, TP, and chlorophyll *a* shall not be exceeded more than once in any consecutive three year period.

a. If there are sufficient data to calculate the annual geometric mean chlorophyll *a* and the mean does not exceed the chlorophyll *a* value for the lake type in the table below, then the TN and TP numeric interpretations for that calendar year shall be the annual geometric means of lake TN and TP samples, subject to the minimum and maximum limits in the table below. However, for lakes with color > 40 PCU in the West Central Nutrient Watershed Region, the maximum TP limit shall be the 0.49 mg/L TP streams threshold for the region; or

b. If there are insufficient data to calculate the annual geometric mean chlorophyll *a* for a given year or the annual geometric mean chlorophyll *a* exceeds the values in the table below for the lake type, then the applicable numeric interpretations for TN and TP shall be the minimum values in the table below (see **Table 3.1)**.

Table 3.1. Corrected chlorophyll *a*, TN, and TP criteria for Florida lakes (Subparagraph 62-302.531[2][b]1., F.A.C.)

$CaCO_3$ = Calcium carbonate
[1] For lakes with color > 40 PCU in the West Central Nutrient Watershed Region, the maximum TP limit shall be the 0.49 mg/L TP streams threshold for the region.

Long-Term Geometric Mean Lake Color and Alkalinity	AGM Chlorophyll *a*	Minimum Calculated AGM TP NNC	Minimum Calculated AGM TN NNC	Maximum Calculated AGM TP NNC	Maximum Calculated AGM TN NNC
>40 PCU	20 µg/L	0.05 mg/L	1.27 mg/L	0.16 mg/L[1]	2.23 mg/L
≤ 40 PCU and > 20 mg/L $CaCO_3$	20 µg/L	0.03 mg/L	1.05 mg/L	0.09 mg/L	1.91 mg/L
≤ 40 PCU and ≤ 20 mg/L $CaCO_3$	6 µg/L	0.01 mg/L	0.51 mg/L	0.03 mg/L	0.93 mg/L

Based on the long-term geometric mean color of 67 PCU (964 observations), Lake George is a high color lake, and the generally applicable chlorophyll *a* criterion for the lake is an AGM of 20 µg/L. For years when the 20 µg/L annual chlorophyll *a* was exceeded, the applicable TN and TP criteria are the minimum calculated AGM values of 1.27 and 0.05 mg/L, respectively. These criteria were exceeded in several years (shown in boldface type and yellow highlighting in Table 2.1).

The nutrient standard for streams in Paragraph 62-302.531(2)(c), F.A.C., states:

(c) For streams, if a site specific interpretation pursuant to paragraph 62-302.531(2)(a) or (2)(b), F.A.C., has not been established, biological information shall be used to interpret the narrative nutrient criterion in combination with Nutrient Thresholds. The narrative nutrient criterion in paragraph 62-302.530(90)(b), F.A.C., shall be interpreted as being achieved in a stream segment where information on chlorophyll *a* levels, algal mats or blooms, nuisance macrophyte growth, and changes in algal species composition indicates there are no imbalances in flora or fauna, and either:

1. The average score of at least two temporally independent SCIs [Stream Condition Index assessments] performed at representative locations and times is 40 or higher, with neither of the two most recent SCI scores less than 35, or

2. The nutrient thresholds set forth in the table below (see **Table 3.2**) are achieved.

Table 3.2. TN and TP criteria for Florida streams (Subparagraph 62-302.531[2][c]2., F.A.C.)

[1]These values are AGM concentrations not to be exceeded more than once in any three calendar years.

Nutrient Watershed Region	TP Nutrient Threshold[1]	TN Nutrient Threshold[1]
Panhandle West	0.06 mg/L	0.67 mg/L
Panhandle East	0.18 mg/L	1.03 mg/L
North Central	0.30 mg/L	1.87 mg/L
Peninsular	0.12 mg/L	1.54 mg/L
West Central	0.49 mg/L	1.65 mg/L
South Florida	No numeric nutrient threshold. The narrative criterion in Paragraph 62-302.530(90)(b), F.A.C., applies.	No numeric nutrient threshold. The narrative criterion in Paragraph 62-302.530(90)(b), F.A.C., applies.

Since the segments of the St. Johns River between Lake George and the confluence with the Ocklawaha River are located in the Peninsular nutrient region, the generally applicable TN and TP criteria are 1.54 mg/L and 0.12 mg/L, respectively. According to Rule 62-303.450(1), F.A.C., a stream without applicable numeric criteria in Subsection 62-302.531(2), F.A.C., shall be placed on the Verified List if AGM chlorophyll *a* concentrations exceed 20 µg/L more than once in a 3-year period.

Site-specific Interpretations of the Narrative Nutrient Criterion

The nutrient TMDLs presented in this report, upon adoption into Chapter 62-304, F.A.C., will constitute site-specific numeric interpretations of the narrative nutrient criterion set forth in Paragraph 62-302.530(90)(b), F.A.C., that will replace the otherwise applicable NNC in Subsection 62-302.531(2), F.A.C., for Lake George and the St. Johns River between Lake George and the confluence with the Ocklawaha. **Appendix B** summarizes the relevant TMDL information that supports establishing the TMDL and associated nutrient targets as the site-specific numeric interpretations of the narrative nutrient criterion, including information demonstrating that the TMDL provides for the attainment and maintenance of water quality standards in downstream waters (pursuant to Subsection 62-302.531[4], F.A.C.).

Because the department does not intend to abate natural background conditions, a comparison of those criteria with possible natural background nutrient conditions—established through a model-based prediction of natural background conditions—was made to ensure that the proposed criteria were not lower than background conditions (**Appendix E**).

In addition to evaluating natural background nutrient conditions, the department also reviewed the ecological analysis conducted by Hendrickson et al. 2017, which included recommended nutrient targets for Lake George of 40 µg/L, not to be exceeded more than 40 consecutive days (see Section 5.2).

The department concluded the chlorophyll *a* target recommended by Hendrickson et al. was protective of designated uses of the lake because it will increase algal community diversity and zooplankton abundance, which will improve the upward transfer of primary production carbon in the food web, leading to well-balanced populations of fish and wildlife. A series of model simulations were then conducted with incremental reductions in anthropogenic nutrient source external loads to determine nutrient loads that attained the recommended chlorophyll *a* target in Lake George. As described in Section 5.4.2, this target is equivalent to a chlorophyll *a* criterion of 23 µg/L as an AGM, which is not to be exceeded. Algal growth is a natural feature of Florida lakes, although historically far less extreme than current conditions. To allow some flexibility for natural drought related changes to algal communities, which may enhance algal growth, the TN and TP criteria are expressed as maximum long-term (seven-year) averages of annual loads identified to meet the chlorophyll *a* target. Table 3.3 summarizes the proposed site-specific interpretation of narrative nutrient criteria for Lake George. For informational purposes only, the TN and TP concentrations corresponding to the chlorophyll *a* criteria of 23 µg/L and the loading criteria are 1.14 mg/L and 0.06 mg/L, respectively. These concentrations are AGMs not to be exceeded when the site-specific criteria for TN and TP loads are met. The nutrient loads and concentrations were determined using the U.S. Army Corps of Engineers [USACE] Quality Integrated Compartment Model [CE-QUAL-ICM]) model, as described in **Chapter 5**. The new water quality standard will incorporate the chlorophyll a criteria of 23 µg/L and the associated loads comprising the TMDLs described in **Chapter 6**.

Table 3.3. Chlorophyll *a*, TN, and TP Criteria for Lake George

[1] Maximum long-term 7-year average of annual loads.
[2] AGM concentration.

Approach	TN Criteria (kg/yr)[1]	TP Criteria (kg/yr)[1]	Chlorophyll *a* Criteria (µg/L)[2]
Water Quality Model	4,132,773	219,324	23

The predominant nutrient loads to the two St. Johns River segments below Lake George are from the lake. On average, less than 1 percent of the TN load and less than 2 percent of the TP load are from direct runoff from the adjacent watersheds of the river segments, **Table 3.4**. Since the flow and nutrient loads of the St. Johns River below Lake George are dominated by the outflow from the lake, the nutrient criteria developed for the lake determine the appropriate nutrient targets and criteria for these downstream river segments. The nutrient criteria were set at the same loading-based values as those for Lake George, while the chlorophyll *a* criteria for the downstream river segments are based on the model estimated chlorophyll *a* levels for each river segment that result from the load-based nutrient criteria and chlorophyll a NNC for Lake George. As the natural condition of the river immediately downstream of the lake is dominated by the lake outflow, it is protective to apply the lake TN and TP criteria to the river segments.

Table 3.5 summarizes the proposed site-specific interpretation of the narrative nutrient criterion for the two St. Johns River stream segments downstream of Lake George. The TN and TP criteria are expressed as maximum long-term (seven-year) average loads. For reference purposes, the TN and TP concentrations corresponding to the chlorophyll a criteria and the loading criteria are as follows: St. Johns River below Lake George - 1.09 mg/L TN and 0.05 mg/L TP; St. Johns River above Ocklawaha River – 1.04 mg/L TN and 0.06 mg/L TP. These reference concentrations are AGMs not to be exceeded when the site-specific criteria for TN and TP loads are met.

Table 3.4. Nutrient Load Contributions to the St. Johns River Segments Downstream of Lake George

Year	Lake George Watershed TN Load (kg)	Direct Runoff TN Load to St. Johns River Segments (kg)	Watershed Runoff TN Load to St. Johns River Segments (kg)	St. Johns River Segments Direct Runoff TN Load (%)	Lake George Watershed TP Load (kg)	Direct Runoff TP Load to St. Johns River Segments (kg)	Watershed Runoff TP Load to St. Johns River Segments (kg)	St. Johns River Segments Direct Runoff TP Load (%)
2003	5,151,061	13,585	5,164,646	0.3	308,010	4,163	312,173	1.3
2004	5,852,090	12,359	5,864,450	0.2	457,700	4,044	461,744	0.9
2005	5,675,377	13,748	5,689,125	0.2	374,724	4,379	379,103	1.2
2006	2,049,109	6,802	2,055,911	0.3	108,460	2,647	111,107	2.4
2007	1,869,318	6,585	1,875,902	0.4	104,308	2,405	106,712	2.3
2008	6,264,665	12,237	6,276,901	0.2	511,080	3,883	514,962	0.8
2009	3,509,779	12,107	3,521,886	0.3	286,563	3,723	290,286	1.3
2010	2,559,923	9,398	2,569,321	0.4	174,061	3,092	177,152	1.7
2011	2,953,767	8,241	2,962,008	0.3	186,732	2,736	189,468	1.4
2012	2,902,481	9,630	2,912,111	0.3	157,230	2,990	160,220	1.9
2013	2,737,270	8,790	2,746,060	0.3	173,992	2,813	176,805	1.6
Average	3,774,985	10,316	3,785,302	0.3	258,442	3,352	261,794	1.3

Table 3.5. Chlorophyll *a*, TN, and TP Criteria for the St. Johns River segments downstream of Lake George

[1] Maximum long-term 7-year average.
[2] AGM concentration.

Stream Segment	Approach	TN Criteria (kg/yr)[1]	TP Criteria[1] (kg/yr)[1]	Corrected Chlorophyll *a* Criteria (µg/L)[2]
St. Johns River below Lake George	Water Quality Model	4,132,773	219,324	23
St. Johns River above Ocklawaha River	Water Quality Model	4,132,773	219,324	22

Average depths in these St. Johns River segments are over 6.5 ft, with seventy-five percent of the river stretch over 5.5 ft. As described in Section 4.2.4, monthly mean discharge at Astor and Buffalo Bluff are 2,534 and 3,898 cfs, respectively. This portion of the St. Johns River is not a wadeable stream.

Assessment of submerged aquatic vegetation (SAV) in the Lower St. Johns (Sagan, 2007) in Ecozone 3 (river mile 70 to river mile 100 (just above confluence with Ocklawaha)) indicated the SAV had extremely short beds (mean linear coverage 4.3 m) that appeared to be caused by factors other than water quality. The report described Ecozone 3 as a narrow, deeper, and faster flowing river (relative to downstream ecozones), with a steeply sloping bottom that was often littered with underwater snags, leaf and tree litter, and other detritus. Bottom sediments were described as often mucky, mucky-clay, or a thick spongy peat layer often with an overlying detrital layer.

Given the physical and hydrologic characteristics of this portion of the St. Johns River, the evaluation of stream floral metrics as described in Implementation of Florida's Numeric Nutrient Standard (DEP, 2013a) are inappropriate for the two river segments downstream of the lake. Therefore, the chlorophyll *a* criteria are most representative of the waterbody, and given that they have been demonstrated to be protective of designated uses, they will replace the stream floral metrics used in the generally applicable numeric nutrient standards for streams.

3.3 Downstream Protection

The two river segments (WBID 2893A5 and 2213O) of the St. Johns River between Lake George and the confluence with the Ocklawaha River are on the Verified List for chlorophyll *a* impairments. Water quality in both segments is dominated by the discharge and loads from Lake George. Achieving the TMDL nutrient reductions in Lake George will result in an estimated average reduction of 21 % to 25 % in chlorophyll AGMs in downstream segments.

The Lower St. Johns River nutrient TMDL was approved under subparagraph 62-302.531(2)(a)1.a., F.A.C., as a site-specific numeric interpretation of the narrative nutrient criteria. That TMDL required a 30 % reduction in anthropogenic nitrogen and phosphorus loads upstream of Buffalo Bluff. Buffalo Bluff represented a downstream model boundary condition in the Lake George TMDL, and both St. Johns River segments included in this analysis are located in the Lake George simulated watershed. The Lake George TMDL nutrient reductions meet or exceed the reduction goals for the Lower St. Johns River nutrient TMDL.

The reductions in nutrient loads prescribed in the Lake George TMDL are not expected to cause nutrient impairments downstream and will actually result in water quality improvements in the immediate downstream segments of the St. Johns River and waters farther downstream by reducing algal biomass and associated nutrients transported downstream.

3.4 Endangered Species Consideration

The U.S. Fish and Wildlife Service online Information for Planning and Conservation (IPaC) tool, https://ecos.fws.gov/ipac/, identifies the threatened West Indian manatee (Trichechus manatus latirostris) and the endangered Shortnose Sturgeon (Acipenser brevirostrum) as species that are potentially affected by activities in the area of Lake George.

The manatee (Trichechus manatus latirostris) inhabits the waters of the St. Johns River throughout the year. Manatees are generally most abundant in the lower St. Johns River from late April through August, with few manatees observed during the winter months (December to February). Blue Spring Run, a tributary to the St. Johns River upstream of Lake George is recognized by the Manatee Sanctuary Act of 1978 (Rule 68C-22-.012, Florida Administrative Code [F.A.C.]) as important manatee habitat, provides the primary warm-water winter refuge for manatees on the St. Johns River. Park records indicate that the winter manatee population has increased since counts began in the early 1970s, from about 20 manatees counted in the spring run during the winter of 1975 to 1976 to over 320 manatees during the winter of 2012 to 2013. This information suggests that the existing water quality in the St. Johns River downstream of Blue Spring Run does not inhibit manatees from utilizing this refuge area.

The shortnose sturgeon (Acipenser brevirostrum) is an endangered fish species that occurs in large coastal rivers and estuaries of eastern North America. It is an anadromous fish living mainly in the slower moving riverine waters or nearshore marine waters along the east coast of North America, and migrating periodically into faster moving freshwater areas to spawn. Shortnose sturgeon, unlike other anadromous species, do not appear to make long distance offshore migrations. They are benthic feeders. Juveniles are believed to feed on benthic insects and crustaceans. Mollusks and large crustaceans are the primary food of adult shortnose sturgeon.

Based on records provided by the SJRWMD, only one shortnose sturgeon has been captured in Lake George, and this occurred in 1949. The St. Johns River represents the southern extent of the range for the shortnose sturgeon and evidence suggests that the sturgeon occurring in the St. Johns River are transient individuals that do not spawn in the St. Johns (DEP 2013). As part of the state's development of revised DO Criteria for Fresh and Marine Waters, the DEP established alternative DO criteria, in conjunction with the US Fish and Wildlife Service and NOAA, to assure potential shortnose sturgeon spawning habitat is protected (DEP 2013). The alternative criteria to protect sturgeon applies to the portion of the St. Johns River between the U.S. Highway 17 Bridge in Palatka north to Shands Bridge (U.S. Highway 16) near Green Cove Springs, which is downstream of the area that is covered by the nutrient TMDLs. This river area includes WBIDs 2213M, 2213L, 2213K, 2213J, and 2213I; all of which are not impaired for DO based on the results in the IWR Run 53 database. Since there are no DO impairments in Lake George, the two St. Johns River segments immediately downstream of the lake, and the river segments with alternate DO criteria to protect sturgeon, the existing water quality is not impacting the sturgeon spawning habitat. The TMDL nutrient loadings are expected to result in further improvement of water quality conditions in the lake and the downstream St. Johns River area.

The site specific nutrient criteria are fully protective of threatened and endangered aquatic species in the area of Lake George.

Chapter 4: Assessment of Sources

4.1 Types of Sources

An important part of the TMDL analysis is the identification of pollutant sources within categories, source subcategories, or individual sources of pollutants in the impaired waterbody and the amount of pollutant loadings contributed by each of these sources. Sources are broadly classified as either “point sources” or “nonpoint sources.” Historically, the term “point sources” has meant discharges to surface waters that typically have a continuous flow via a discernable, confined, and discrete conveyance, such as a pipe. Domestic and industrial wastewater treatment facilities (WWTFs) are examples of traditional point sources. In contrast, the term “nonpoint sources” was used to describe intermittent, rainfall-driven, diffuse sources of pollution associated with everyday human activities, including runoff from urban land uses, agriculture, silviculture, and mining; discharges from failing septic systems; and atmospheric deposition.

However, the 1987 amendments to the CWA redefined certain nonpoint sources of pollution as point sources subject to regulation under the EPA’s National Pollutant Discharge Elimination System (NPDES) Program. These nonpoint sources included certain urban stormwater discharges, such as those from local government master drainage systems, construction sites over five acres, and a wide variety of industries (see **Appendix A** for background information on the federal and state stormwater programs).

To be consistent with CWA definitions, the term “point source” will be used to describe traditional point sources (such as domestic and industrial wastewater discharges) **and** stormwater systems requiring an NPDES stormwater permit when allocating the pollutant load reductions required by a TMDL (see **Section 6.1**). However, the methodologies used to estimate nonpoint source loads do not distinguish between NPDES stormwater discharges and non-NPDES stormwater discharges, and as such, this source assessment section does not make any distinction between the two types of stormwater.

4.2 Potential Sources of Nutrient Loads in the Lake George Watershed

The contributing basin area to Lake George consists of the adjacent watershed, which is the lake watershed area downstream of the U.S. Geological Survey gaging station at Astor on the St. Johns River (**Figure 4.1**), and the watershed area upstream of the gaging station, referred to as the watershed above Lake George. The following provides a detailed accounting of the sources in the Lake George adjacent watershed and identifies, where appropriate, other sources in the watershed above the lake that contribute runoff to the St. Johns River.

4.2.1 Point Sources

4.2.1.1 Wastewater Point Sources

There are no NPDES-permitted wastewater facilities in the Lake George adjacent watershed.

4.2.1.2 Municipal Separate Storm Sewer System (MS4) Permittees

Marion County (FLR04E021), Lake County (FLR04E106), and Volusia County (FLR04E033) all have Phase II-C MS4 permits, and the Florida Department of Transportation (FDOT) District 5 has an MS4 permit (FLR04E024) that covers these counties. Based on the 2010 Topologically Integrated Geographic Encoding and Referencing (TIGER) Census urbanized area coverage data (**Figure 4.1**), no portion of the Lake George adjacent watershed is in any urbanized area of these counties.

There are six counties in the watershed area above Lake George that have MS4 permits. Seminole County (FLS000038) and Orange County (FLS000011) have Phase I-C MS4 permits. The counties of Brevard (FLR04E052), Osceola (FLR04E012), Indian River (FLR04E068), and St. Lucie (FLR04E029) have Phase II-C MS4 permits. Additionally, portions of FDOT District 4 (FLR04E083) and Florida's Turnpike Enterprise (FLR04E049) are located in the watershed area above the lake and are covered by MS4 permits.

4.2.2 Land Uses and Nonpoint Sources

4.2.2.1 2009 SJRWMD Land Use

The Lake George Watershed encompasses an area of 159,747 acres, or 250 square miles (**Figure 4.2**). Acreages associated with WBIDs 2893A, 2893A5, and 2213O are 43,097.9 acres, 5,978.6 acres, and 18,866 acres, respectively. Within the watershed, 75 % (120,296 acres) is classified as upland forest and wetlands. Agricultural land uses account for 13 % (20,434 acres), while urban-related land uses represent 8 % (13,119 acres). **Table 4.1** lists the 2009 land use categories in the Lake George Watershed. **Appendix C** contains figures and land use summaries for each sub-basin in the watershed.

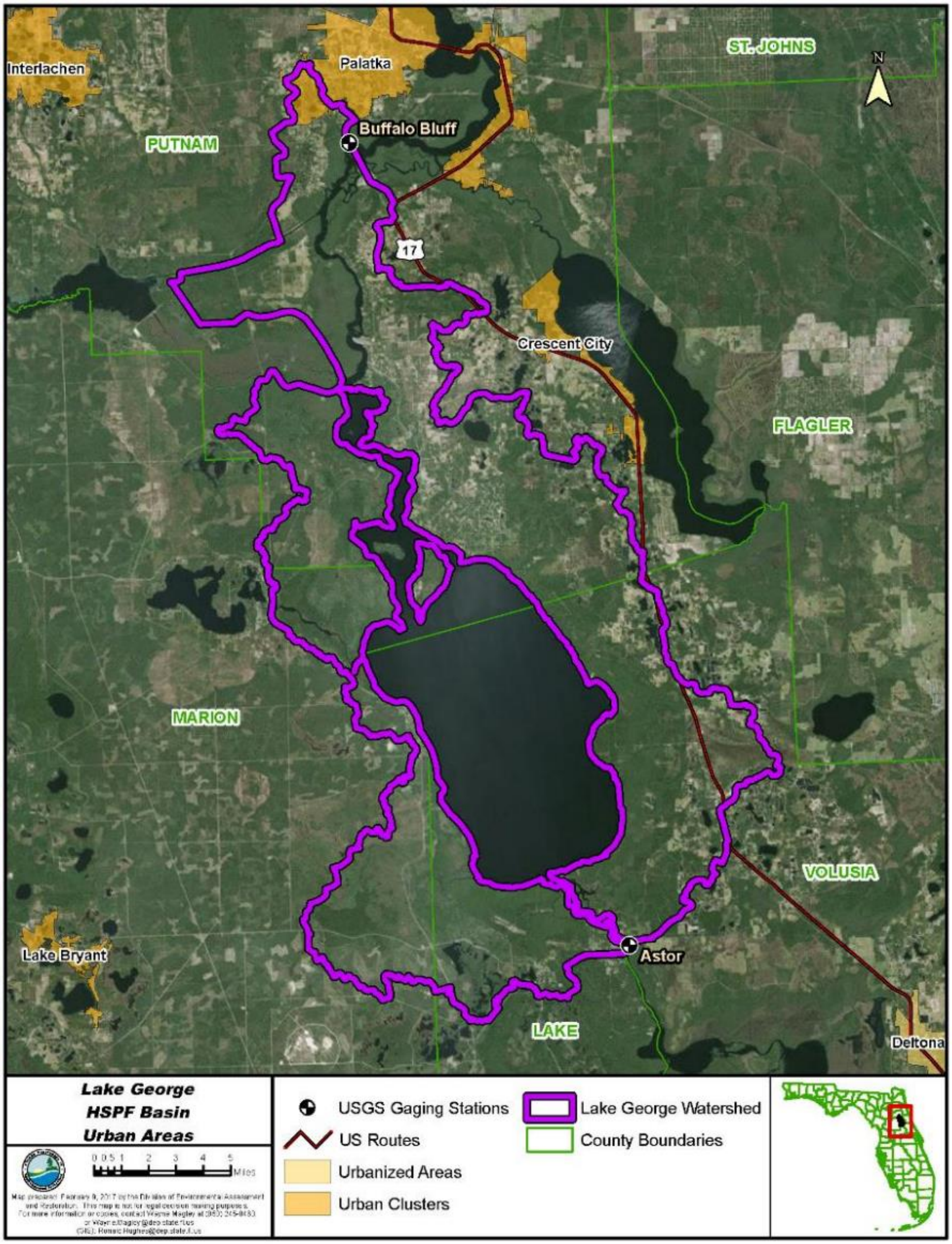

Figure 4.1. Urbanized areas in the Lake George Watershed based on TIGER 2010 Census information

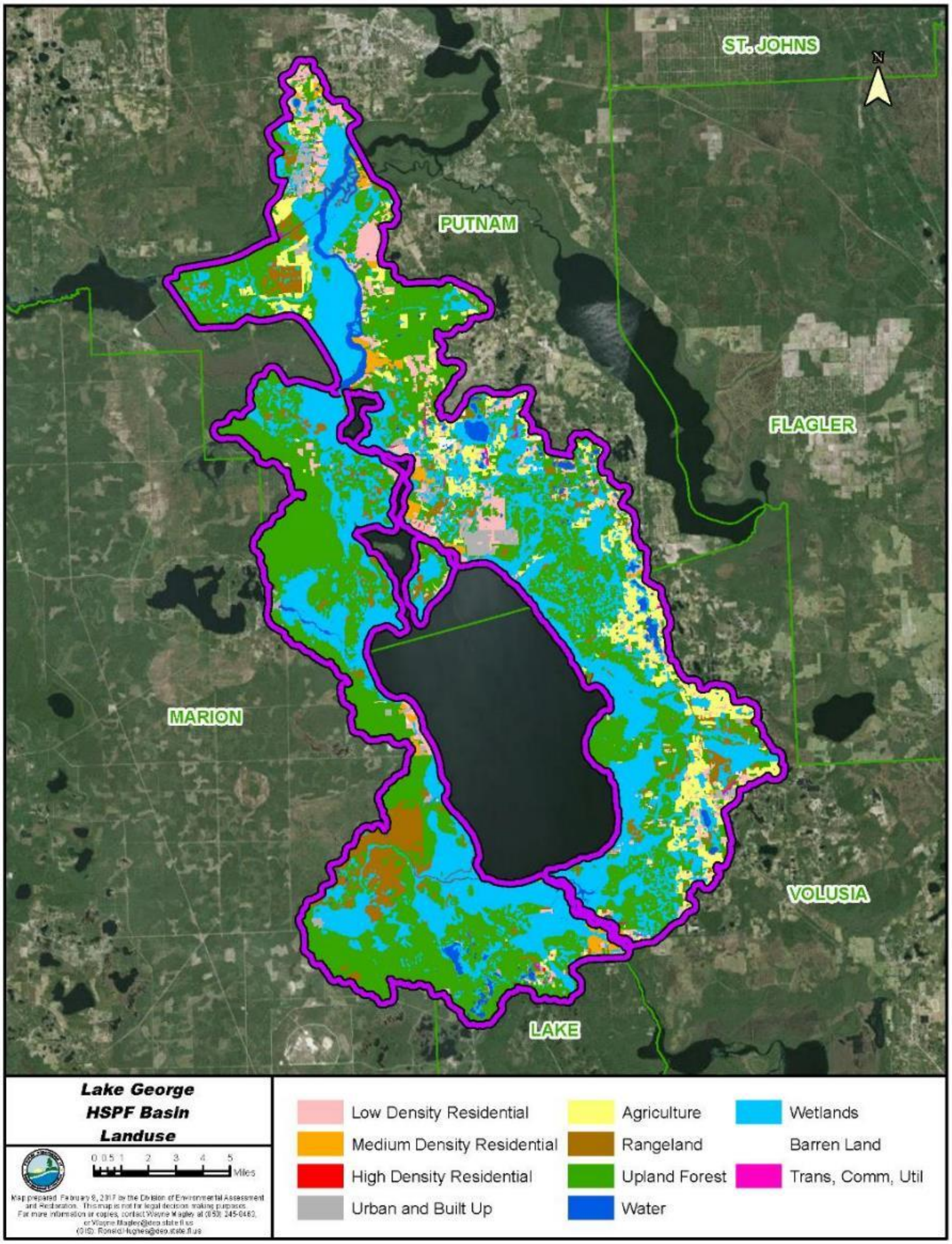

Figure 4.2. Principal land uses in the Lake George Watershed

Table 4.1. Classification of 2009 SJRWMD land use categories in the Lake George Watershed

Land Use Code	Land Use Classification	Acres	% of Total
1100	Residential, low density – less than 2 dwelling units/acre	5,354.17	3.35
1180	Rural residential	2,775.43	1.74
1190	Low density under construction	4.43	0.00
1200	Residential, medium density – 2-5 dwelling units/acre	1,822.36	1.14
1290	Medium density under construction	57.99	0.04
1300	Residential, high density – 6 or more dwelling units/acre	67.13	0.04
1400	Commercial and services	228.47	0.14
1480	Cemeteries	19.29	0.01
1550	Other light industrial	61.71	0.04
1561	Ship building and repair	27.73	0.02
1620	Sand and gravel pits	33.75	0.02
1650	Reclaimed lands	14.05	0.01
1660	Holding ponds	10.64	0.01
1700	Institutional	258.02	0.16
1730	Military	8.30	0.01
1820	Golf courses	92.66	0.06
1840	Marinas and fish camps	92.14	0.06
1850	Parks and zoos	182.99	0.11
1860	Community recreational facilities	51.80	0.03
1890	Other Recreational <Riding stables, go-cart tracks, skeet ranges, etc.>	104.00	0.07
1900	Open land	39.93	0.02
1920	Inactive land with street pattern but no structures	1,493.75	0.94
2110	Improved pastures (monocult, planted forage crops)	4,684.25	2.93
2120	Unimproved pastures	393.80	0.25
2130	Woodland pastures	767.36	0.48
2140	Row crops	58.38	0.04
2150	Field crops	858.66	0.54
2200	Tree crops	15.42	0.01
2210	Citrus Groves <Orange, grapefruit, tangerines, etc.>	187.04	0.12
2240	Abandoned groves	2.22	0.00
2400	Nurseries and vineyards	18.22	0.01
2410	Tree nurseries	52.56	0.03
2420	Sod farms	117.01	0.07
2430	Ornamentals	167.28	0.10
2431	Shade ferns	1,651.34	1.03
2432	Hammock ferns	1,725.02	1.08
2510	Horse farms	379.03	0.24
2540	Aquiculture	153.43	0.10
2600	Other open lands – rural	41.26	0.03
2610	Fallow cropland	18.57	0.01
3100	Herbaceous upland nonforested	533.32	0.33
3200	Shrub and brushland (wax myrtle or saw palmetto, occasionally scrub)	7,031.52	4.40

Land Use Code	Land Use Classification	Acres	% of Total
3300	Mixed upland nonforested/Mixed rangeland	1,577.83	0.99
4110	Pine flatwoods	14,316.57	8.96
4120	Longleaf pine – xeric oak	2376.78	1.49
4130	Sand pine	16,027.91	10.03
4200	Upland hardwood forests	303.29	0.19
4210	Xeric oak	459.13	0.29
4340	Upland mixed coniferous/hardwood	8,970.88	5.62
4410	Coniferous pine	16,789.87	10.51
4430	Forest regeneration areas	7,309.65	4.58
5100	Streams and waterways	2,571.37	1.61
5200	Lakes	2,445.59	1.53
5250	Open water within a freshwater marsh/Marshy lakes	172.11	0.11
5300	Reservoirs – pits, retention ponds, dams	197.11	0.12
5500	Major springs	224.94	0.14
6110	Bay swamps	2,701.58	1.69
6170	Mixed wetland hardwoods	18,121.26	11.34
6181	Cabbage palm hammock	399.80	0.25
6210	Cypress	3,973.78	2.49
6220	Pond pine	39.06	0.02
6250	Hydric pine flatwoods	5,617.45	3.52
6300	Wetland forested mixed	13,308.63	8.33
6410	Freshwater marshes	2,562.40	1.60
6420	Saltwater marshes	35.52	0.02
6430	Wet prairies	517.84	0.32
6440	Emergent aquatic vegetation	914.32	0.57
6460	Treeless hydric savanna/Mixed scrub-shrub wetland	5,550.07	3.47
7200	Sand other than beaches	3.30	0.00
7400	Disturbed land	28.10	0.02
7410	Rural land in transition without positive indicators of intended activity	239.17	0.15
7430	Spoil areas	16.69	0.01
8110	Airports	71.41	0.04
8140	Roads and highways (divided 4-lanes with medians)	20.11	0.01
8150	Port facilities	2.49	0.00
8160	Canals and locks	12.07	0.01
8200	Communications	11.53	0.01
8310	Electrical power facilities	8.21	0.01
8320	Electrical power transmission lines	133.18	0.08
8330	Water supply plants	9.09	0.01
8340	Sewage treatment	31.73	0.02
8350	Solid waste disposal	5.15	0.00
8370	Surface water collection basins	13.49	0.01
	Sum	**159,746.88**	**100.00**

4.2.2.2 Population

The 2010 U.S. Census Bureau block data were used to estimate the human population in the Lake George Watershed. Total population data for Census blocks covering the watershed were clipped using geographic information system (GIS) layers to estimate the population, based on the fraction of the block contained in the watershed. This yielded an estimated population of 12,423 in the Lake George Watershed. According to the 2010 Census, average household sizes for the 4 counties in the watershed ranged between 2.31 and 2.48, with a simple average of 2.39.

4.2.2.3 Septic Tanks

Onsite sewage treatment and disposal systems (OSTDS), including septic tanks, are commonly used where providing central sewer service is not cost-effective or practical. When properly sited, designed, constructed, maintained, and operated, OSTDS are a safe means of disposing of domestic waste. The effluent from a well-functioning OSTDS is comparable to secondarily treated wastewater from a sewage treatment plant. When not functioning properly, however, OSTDS can be a source of nutrients (nitrogen and phosphorus), pathogens, and other pollutants to both groundwater and surface water.

In November 2016 the Florida Department of Health (FDOH) completed the Florida Onsite Sewage Treatment and Disposal Systems Inventory and provided GIS shapefiles by county of septic tanks. Files for Lake, Marion, Putnam, and Volusia Counties were clipped using GIS to estimate the number of septic systems in the watershed. There were 7,916 systems (**Figure 4.3**).

Buffers of 200, 500, and 1,000 meters (m) around Lake George and surface waters in the watershed were created to estimate the number of septic systems in each buffer zone using the FDOH 2016 inventory of estimated septics (**Table 4.2**).

Using an estimate of 70 gallons/day/person (EPA 1999), and septic tank effluent TN and TP concentrations of 57 and 10 mg/L, respectively (Toor et al. 2011; Lusk et al. 2011), potential annual groundwater loads of TN and TP were calculated for septic systems in each of the buffer areas. This was a screening-level calculation, and soil types, the age of the system, vegetation, proximity to a receiving water, and other factors would influence the degree of attenuation of this load (**Table 4.3**).

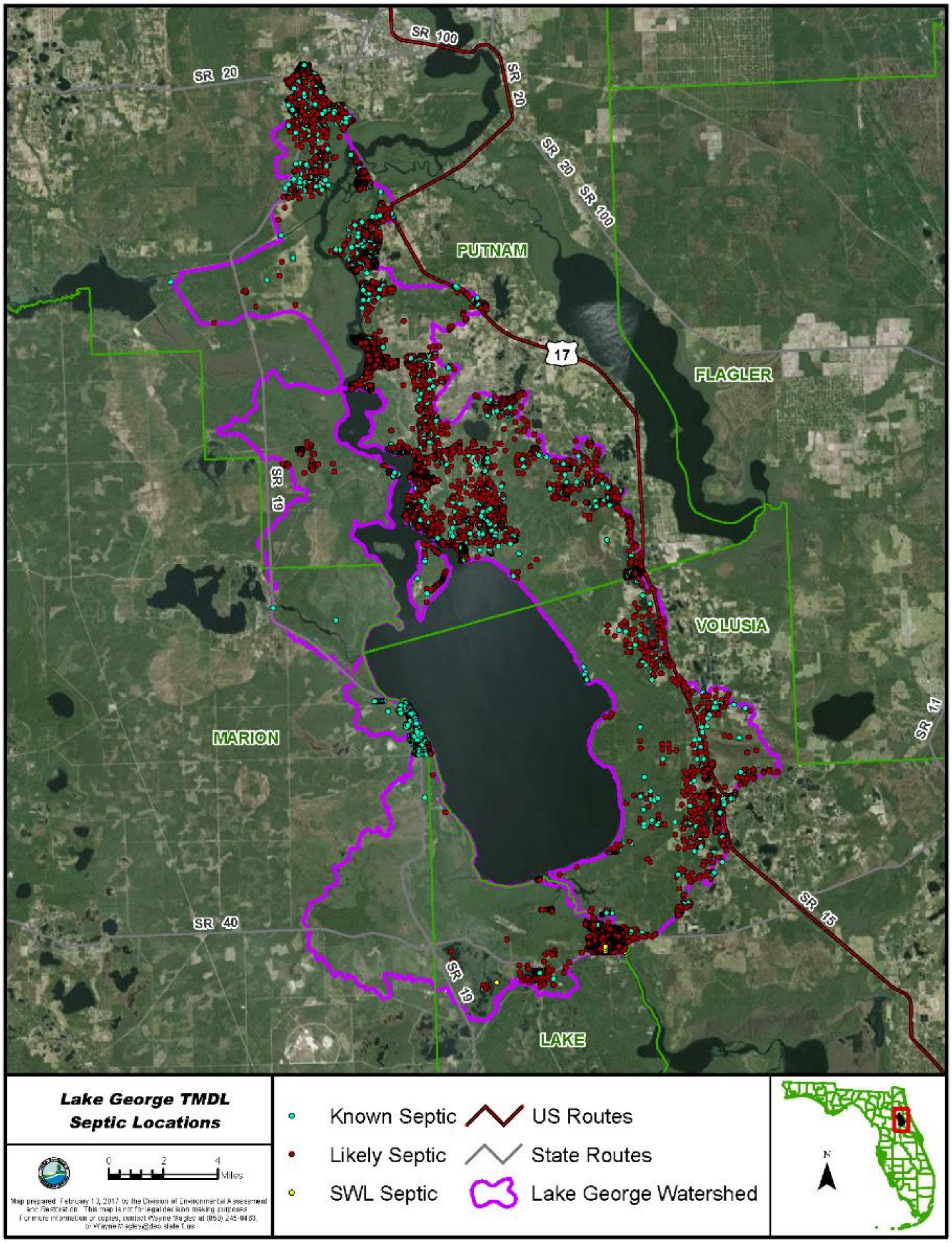

Figure 4.3. FDOH septic tank locations in the Lake George Watershed (November 2016)

Table 4.2. Estimated septics within 200 m, 500 m, and 1000 m buffers around surface waters in the Lake George Watershed

Category	200 m Buffer	500 m Buffer	1000 m Buffer
Known Septic	788	903	1,065
Likely Septic	3,804	4,230	4,806
Static Water Level (SWL) Septic	19	19	19
Sum	**4,611**	**5,152**	**5,890**

Table 4.3. Estimated nitrogen and phosphorus annual loadings from septic tanks in the Lake George Watershed for different buffer areas around surface waters

lbs/yr = Pounds per year
[1] U.S. Census Bureau
[2] EPA 1999

Estimated Number of Households on Septic	Estimated Number of People Per Household[1]	Gallons Per Person Per Day[2]	TN in Drainfield (mg/L)	TP in Drainfield (mg/L)	Estimated Annual TN Load (lbs/yr)	Estimated Annual TP Load (lbs/yr)
4,611 (200 m)	2.39	70	57	10	133,947	23,499
5,152 (500 m)	2.39	70	57	10	149,663	26,257
5,890 (1,000 m)	2.39	70	57	10	171,101	30,018

4.2.3 Springs in the Lake George Watershed

Springs occur in areas where the Floridan potentiometric elevation is above the land surface. Seventeen springs have been identified in the Lake George Watershed (**Figure 4.4**). Silver Glen Springs is a first magnitude spring (> 100 cfs). There are 5 second magnitude springs (> 10 cfs < 100 cfs) and another 5 third magnitude springs (>1 cfs < 10 cfs).

4.2.4 St. Johns River Inflow – Watershed Above Lake George

The St. Johns River enters the southern end of Lake George just north of Astor and represents the major source of nutrient loading to the lake. **Figure 4.5** shows the monthly mean daily discharge measured at the U.S. Geological Survey gaging station at Astor. The watershed area upstream of the gaging station is 3,330 square miles. The 25th percentile, median, and 75th percentile of monthly mean discharges were approximately 1,342, 2,534, and 4,267 cfs, respectively. Sucsy et al. (2016) estimated that 94 % of the total phosphorus load and 96 % of the total nitrogen load to Lake George enters from the St. Johns River. **Figures 4.6** through **4.8** contain graphs of TN, TP, and corrected chlorophyll *a* concentrations observed in the St. Johns near Astor from February 1990 to February 2016. The 25th percentile, median, and 75th percentile of TN were 1.10, 1.28, and 1.48 mg/L, respectively. The 25th percentile, median, and 75th percentile of TP were 0.061, 0.076, and 0.09 mg/L, respectively. The 25th percentile, median, and 75th percentile of corrected chlorophyll *a* were 2.67, 9.3, and 22 µg/L, respectively.

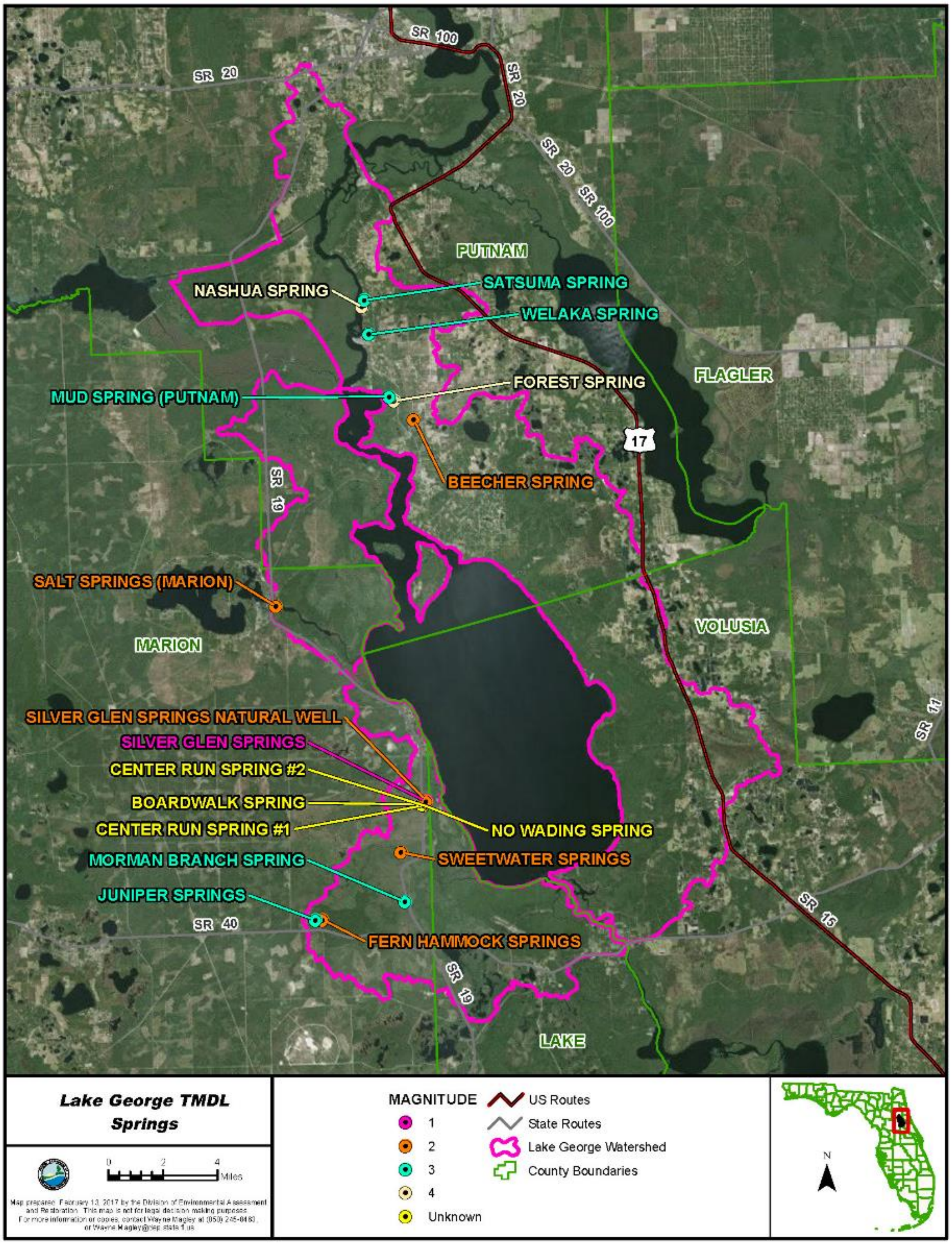

Figure 4.4. Springs in the Lake George Watershed

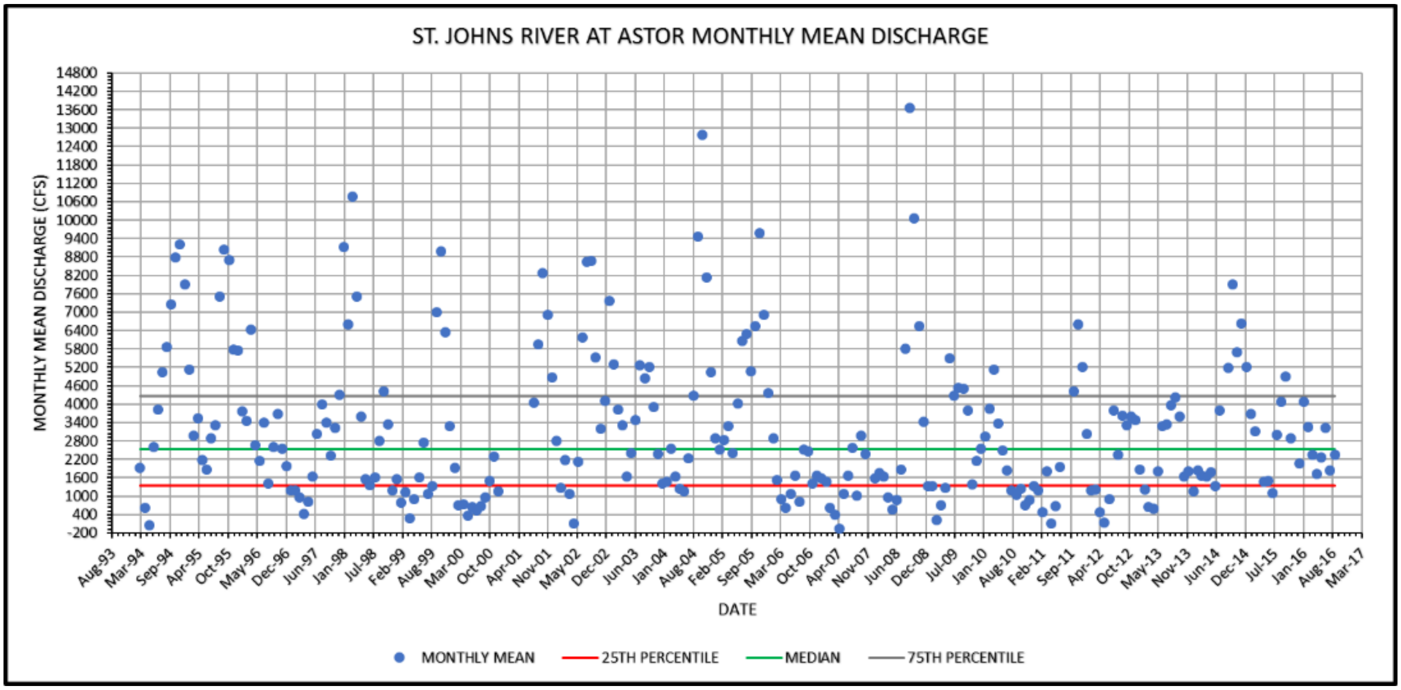

Figure 4.5. Monthly mean discharge in the St. Johns River at Astor

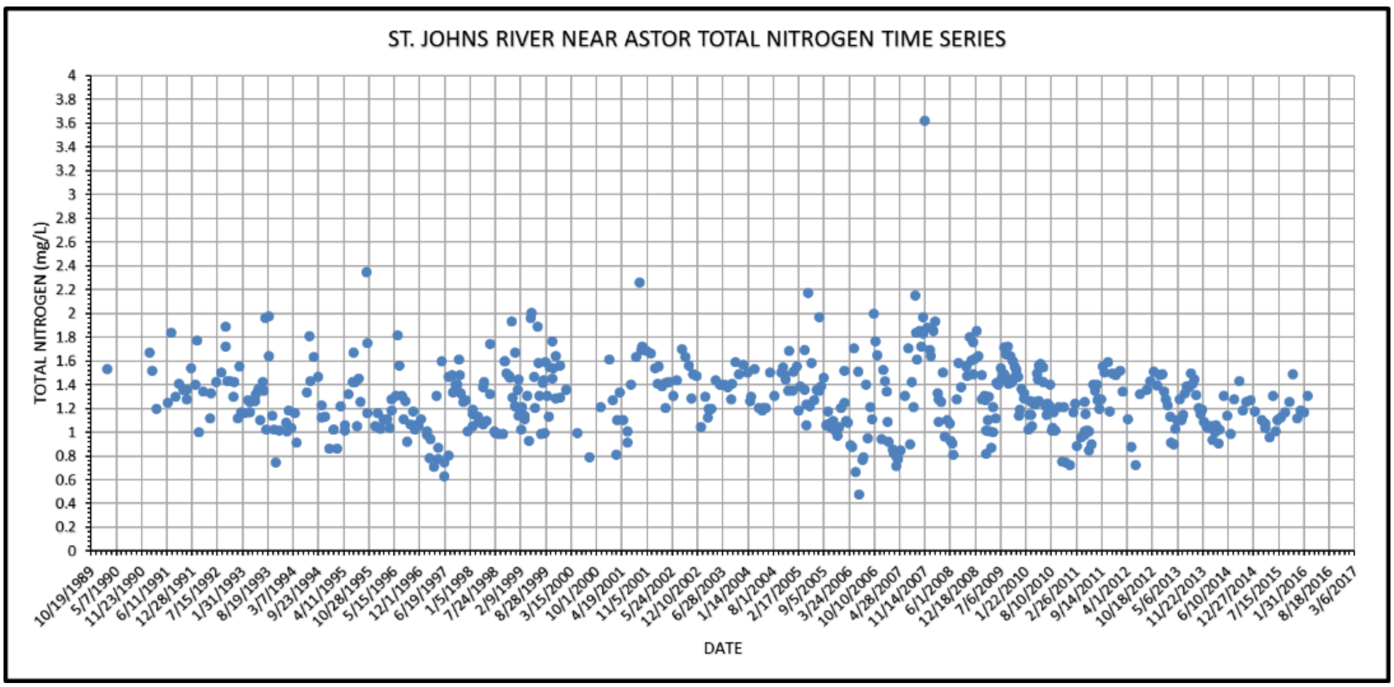

Figure 4.6. TN observations in the St. Johns River near Astor

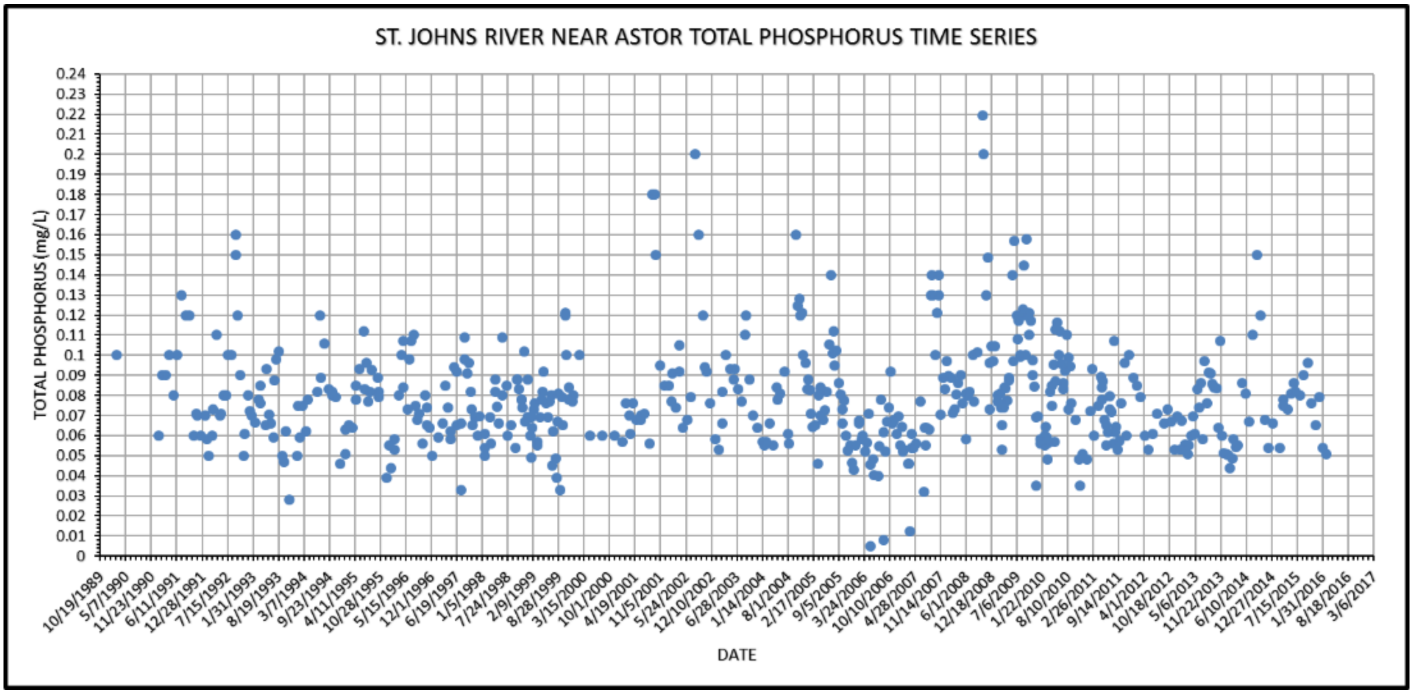

Figure 4.7. TP observations in the St. Johns River near Astor

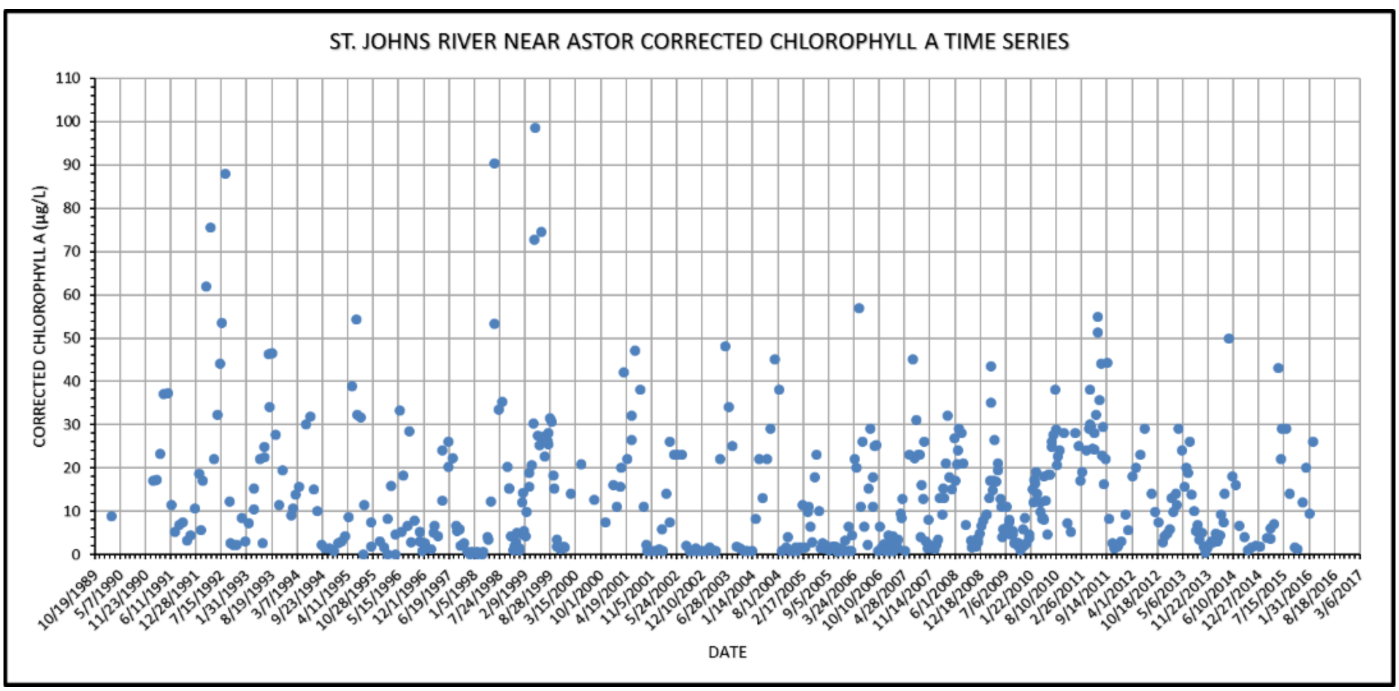

Figure 4.8. Corrected chlorophyll *a* observations in the St. Johns River near Astor

Sucsy et al. (2016) discuss the propagation of ocean tides up to Palatka and a rapid reduction between Palatka and Lake George. The astronomical tidal range in Lake George is only about 0.8 inches. However, lake water levels can be more variable (amplitudes of 0.75 ft) as the result of low-frequency ocean-level variability caused by winds over the Atlantic Shelf. The St. Johns River at Buffalo Bluff was used as a downstream boundary condition in modeling the Lake George system. **Figure 4.9** shows monthly mean daily discharge at Buffalo Bluff. The 25th percentile, median, and 75th percentile of monthly mean discharges were approximately 2,296, 3,898, and 6,436 cfs, respectively. Less than 2 % of the monthly mean calculated discharges over the February 1993 to November 2016 period were negative (indicating net upstream transport).

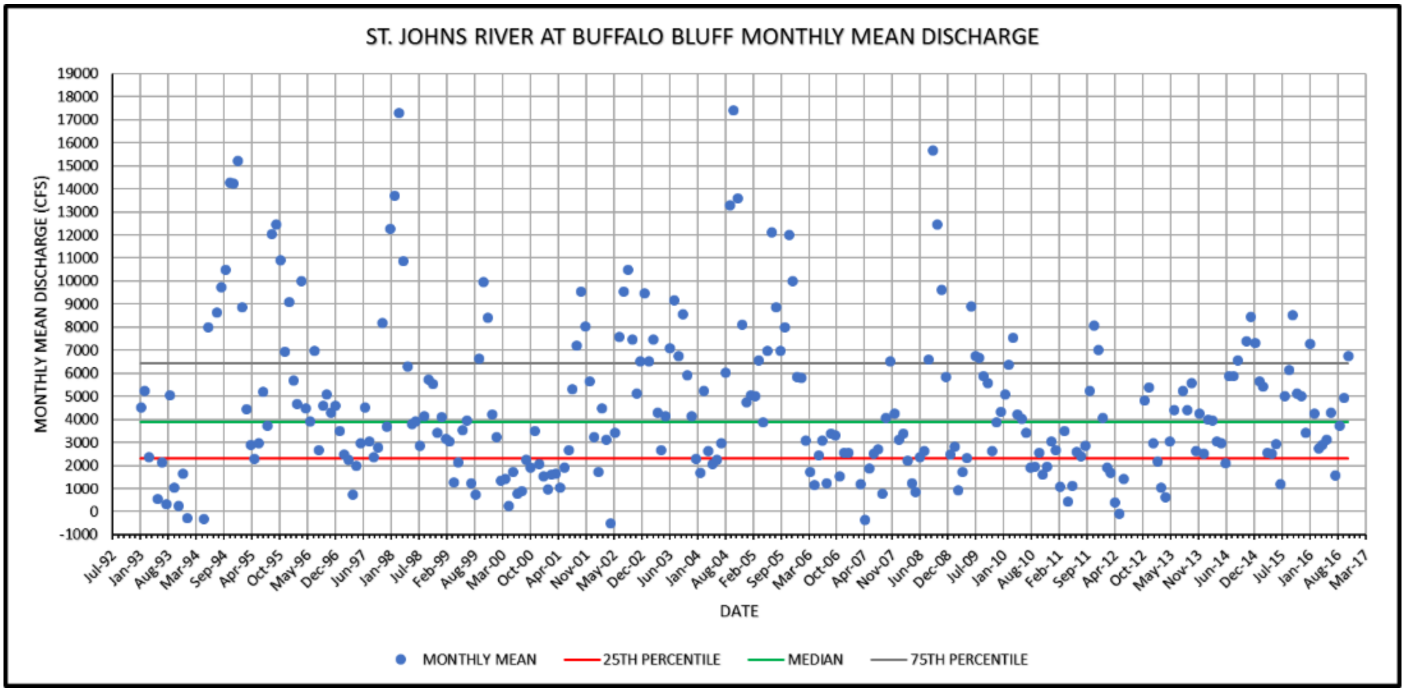

Figure 4.9. Monthly mean discharge in the St. Johns River at Buffalo Bluff

Chapter 5: Determination of Assimilative Capacity

5.1 Analysis of Water Quality Data

A list of water quality stations sampled for corrected chlorophyll *a*, TN, and TP in Lake George and the St. Johns River between Lake George and the confluence with the Ocklawaha River over the 1980–2016 period is provided in **Appendix D**. **Figures 5.1** and **5.2** show the station locations. Data can be provided on request.

5.1.1 Lake George Water Quality

Figure 5.3 displays the historical corrected chlorophyll *a* observations over time. The simple linear regression of corrected chlorophyll *a* versus sampling date in **Figure 5.3** was not significant at an alpha (α) level of 0.05. As seen in the figure, chlorophyll levels can exceed 60 µg/L during the spring and remain elevated for sustained periods.

Figure 5.4 graphs the time series for TN. Although the R^2 was small, the simple linear regression of TN versus sampling date in the figure was significant at an alpha (α) level of 0.05 (over 1,800 values) and indicated a slight decreasing trend in TN. Temporal patterns in TN concentrations were similar to those seen for corrected chlorophyll *a*.

Figure 5.5 contains a graph of TP observations. The simple linear regression of TP versus sampling date in the figure was significant at an alpha (α) level of 0.05 (R^2 = 0.043) and indicated an increasing trend in TP. Although there were temporal patterns in TP concentrations, they were not as pronounced as those seen in the corrected chlorophyll *a* and TN time series.

The state-adopted NNC for lakes discussed in **Chapter 3** are related to the long-term geometric mean color and alkalinity of a lake. The long-term geometric means for color and alkalinity in Lake George were 67 PCU and 66.8 mg/L as $CaCO_3$, respectively. **Figure 5.6** shows a time series graph of color. **Table 5.1** summarizes the distribution of key water quality parameters in Lake George based on measurements over the 1980–2016 period.

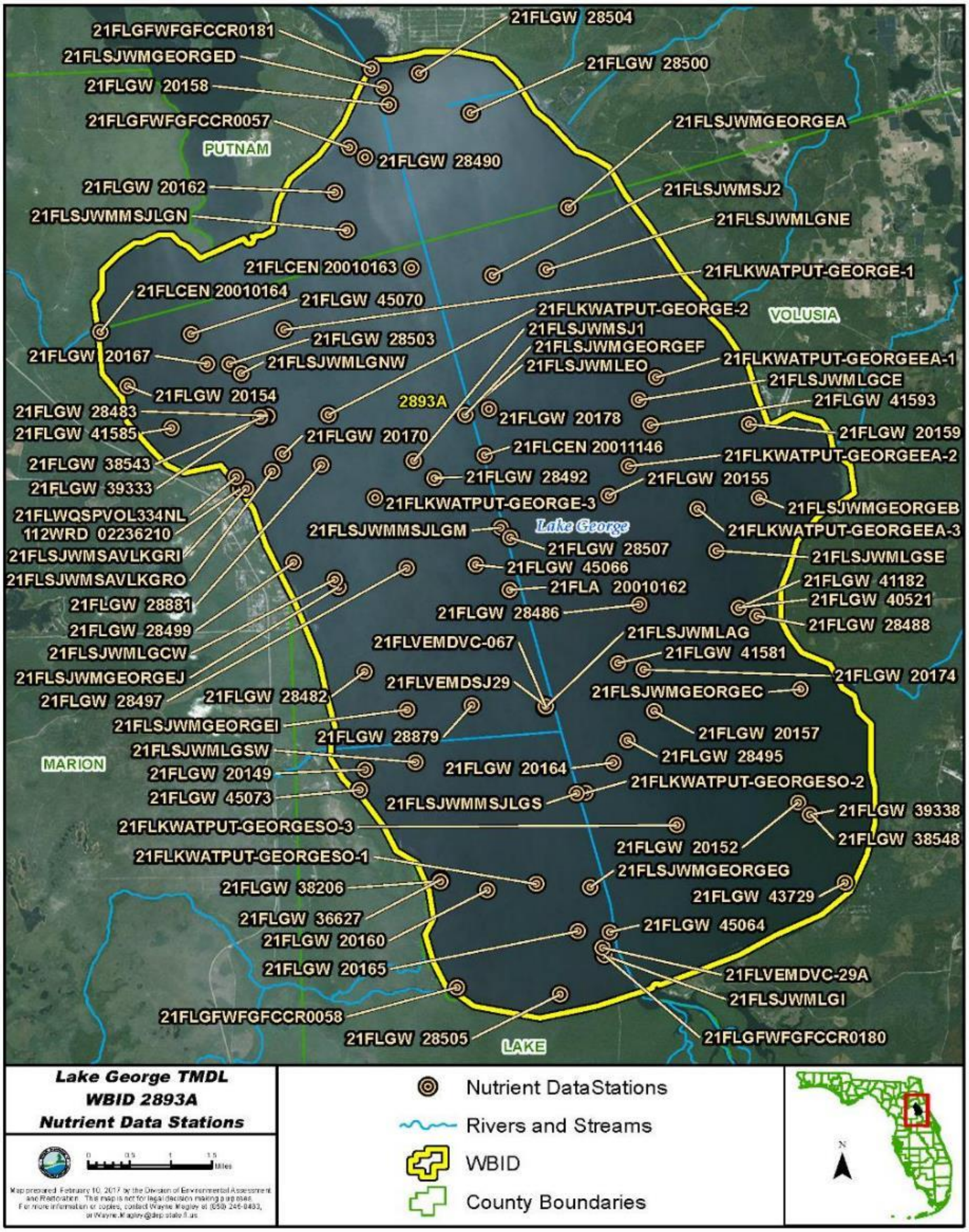

Figure 5.1. Lake George water quality sampling stations

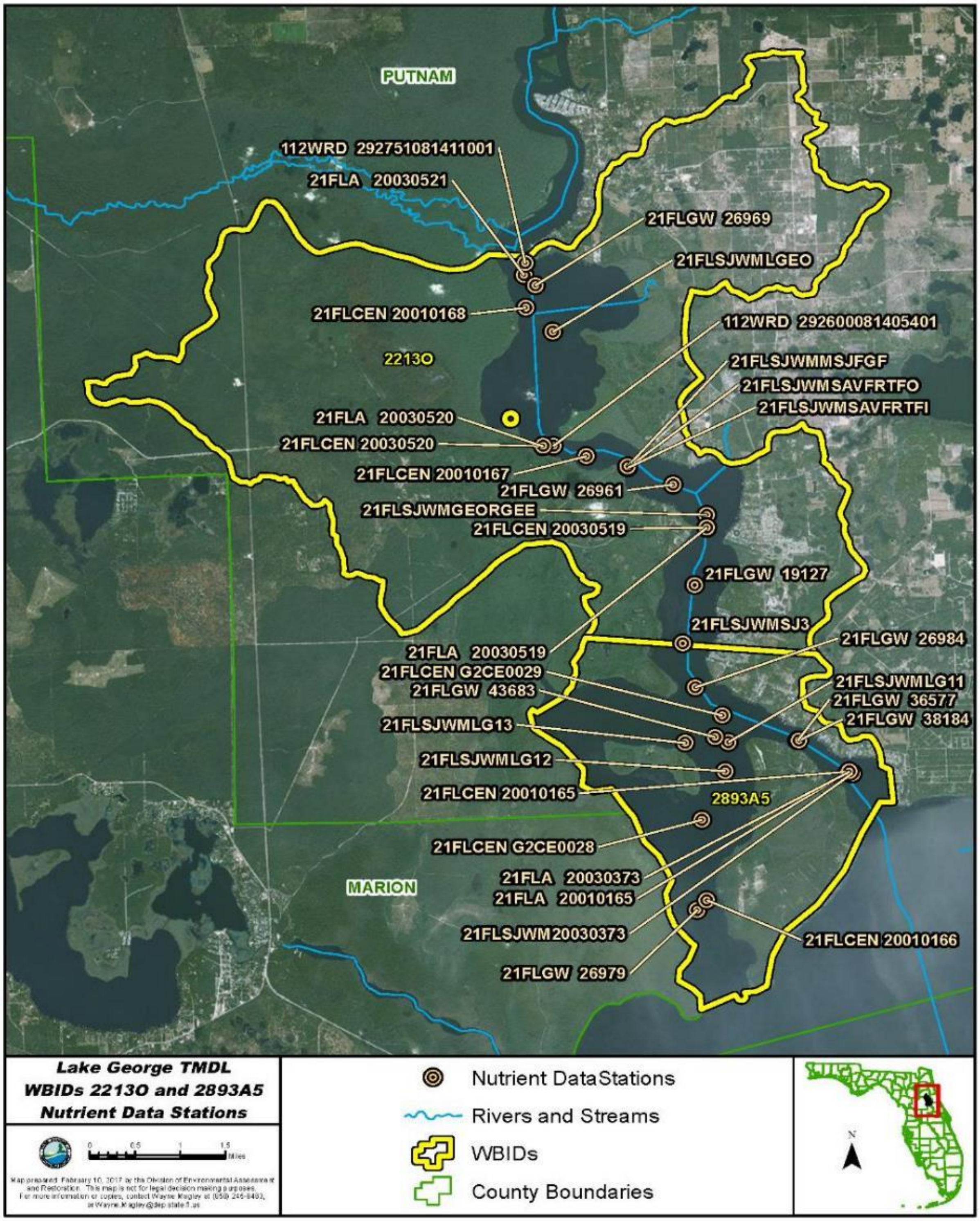

Figure 5.2. Water quality sampling stations in the St. Johns River between Lake George and the confluence of the Ocklawaha River

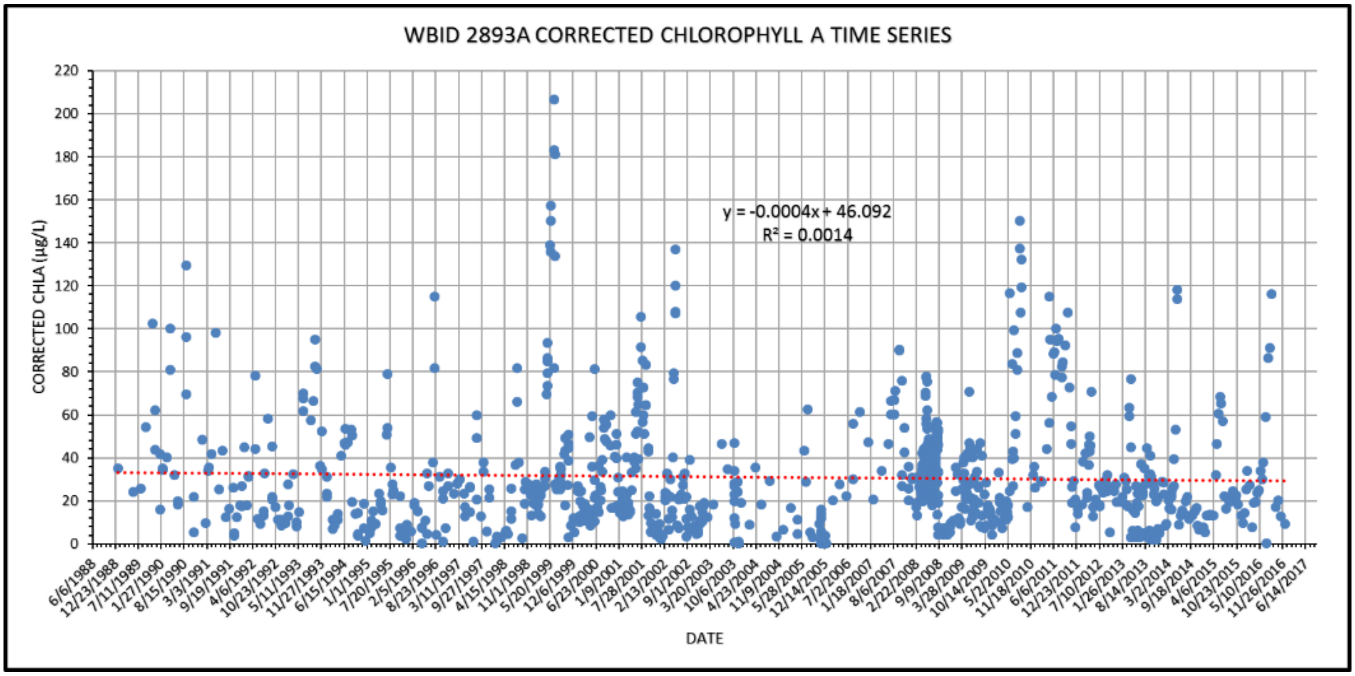

Figure 5.3. Corrected chlorophyll *a* time series for Lake George

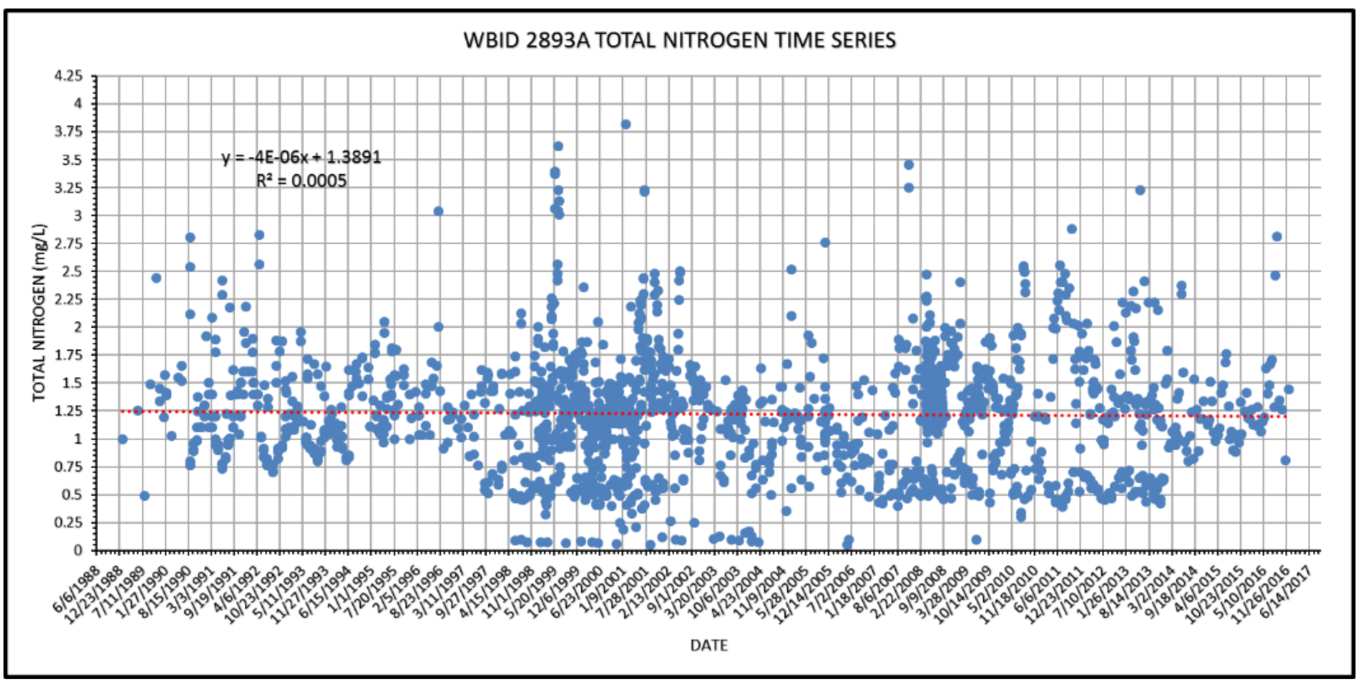

Figure 5.4. TN time series for Lake George

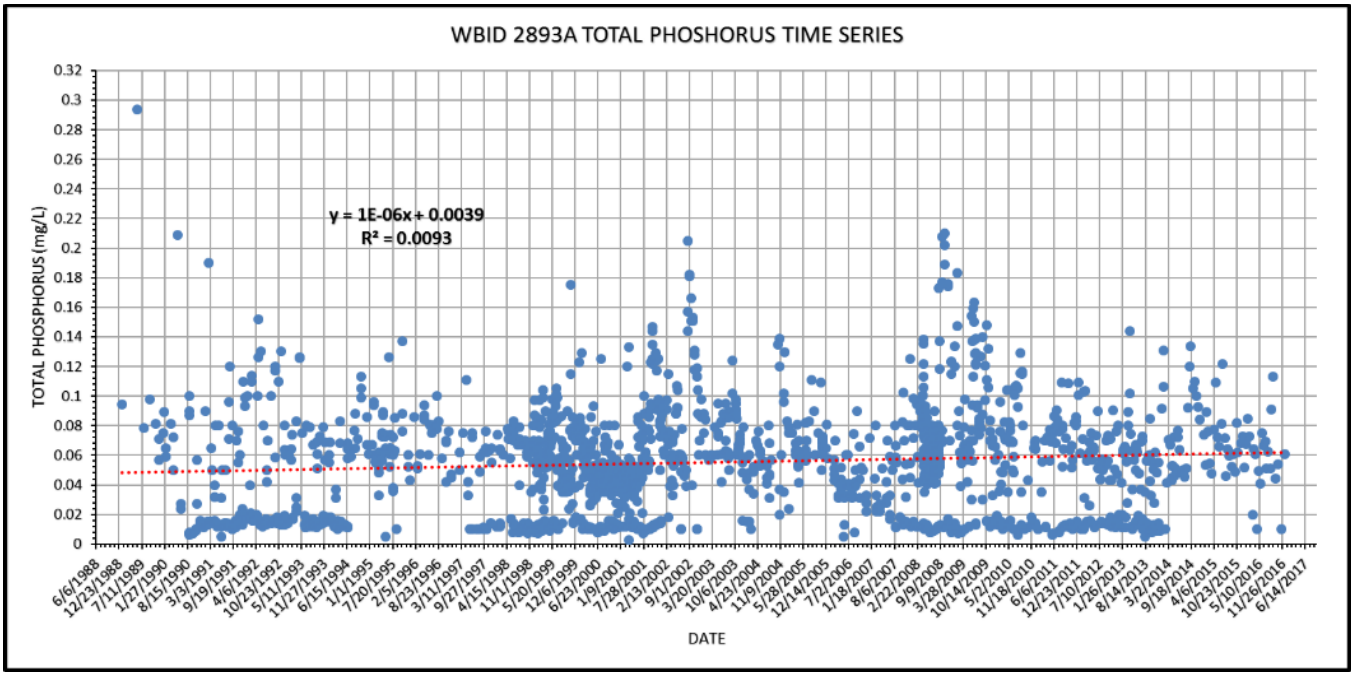

Figure 5.5. TP time series for Lake George

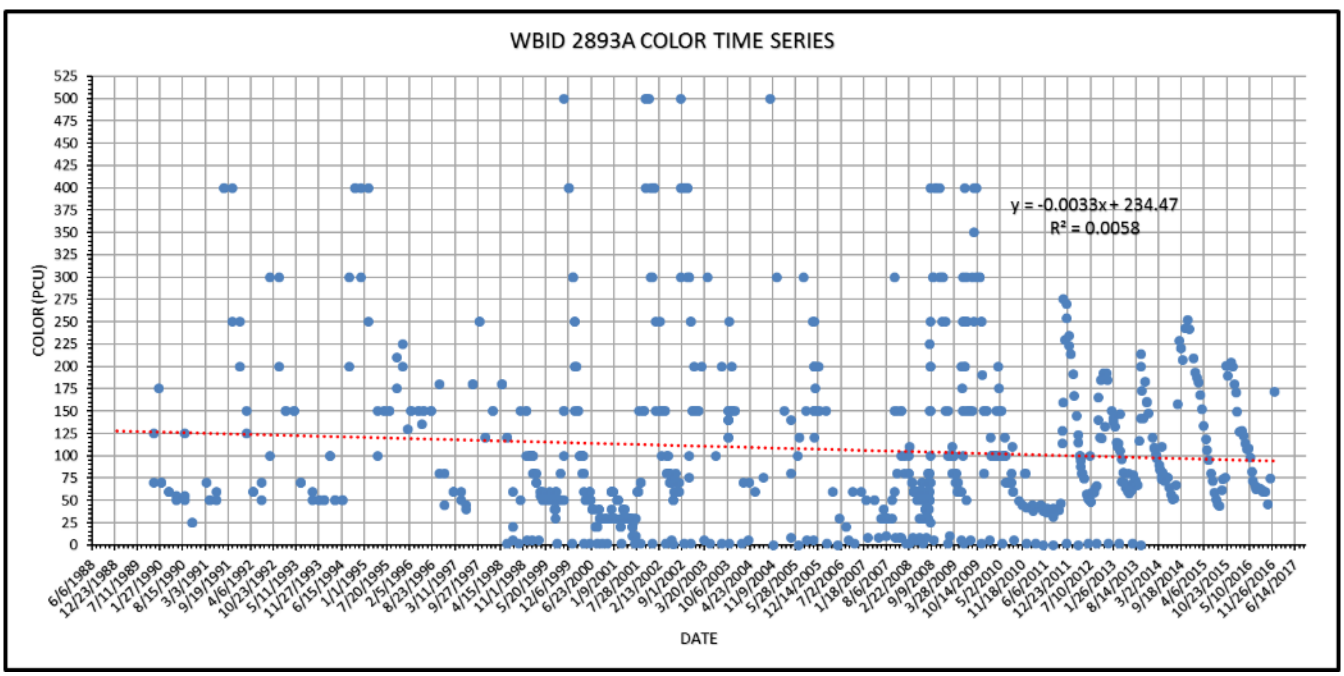

Figure 5.6. Color time series for Lake George

Table 5.1. Summary statistics for key water quality parameters in Lake George

µmhos/cm = Micromhos per centimeter; su = Standard units; NTU = Nephelometric turbidity units

Parameter	N	Min	25th	Median	Mean	75th	Max
Alkalinity (mg/L as $CaCO_3$)	515	8.1	59.5	69.7	68.0	77.2	120.0
Biochemical Oxygen Demand (BOD) (mg/L)	408	0.5	1.4	1.8	2.1	2.5	6.4
Uncorrected chlorophyll *a* (µg/L)	1,603	0.0	9.8	23.9	30.2	40.2	212.5
Corrected chlorophyll *a* (µg/L)	1,036	0.0	14.2	25.2	31.3	40.0	206.7
Chloride (mg/L)	1,071	0	220	291	297	364	731
Color (PCU)	964	0	50	70	107	150	500
Conductance (µmhos/cm)	1,161	1	925	1216	1229	1513	14400
DO (mg/L)	1,170	0.20	6.68	7.90	7.59	9.03	16.58
DOSAT (percent)	1,150	0.60	77.70	91.12	84.76	99.60	182.12
Ammonium (NH_4) (mg/L)	1,040	0.00	0.01	0.01	0.04	0.03	0.64
Nitrate+nitrite (NO_3O_2) (mg/L)	1,076	0.00	0.01	0.02	0.08	0.08	1.10
pH (su)	1,156	6.40	7.60	8.06	8.06	8.57	9.54
Secchi Depth (m)	1,653	0.05	0.50	0.65	1.02	0.92	50.00
Water Temperature (^{0}C)	1,279	7.00	20.59	23.67	23.67	28.00	35.09
TN (mg/L)	1,858	0.05	0.90	1.23	1.23	1.50	3.82
Total Organic Carbon (TOC) (mg/L)	717	0.1	15.2	17.5	18.0	20.5	32.8
TP (mg/L)	1,887	0.003	0.035	0.057	0.060	0.078	0.336
Total Suspended Solids (TSS) (mg/L)	967	1	8	13	14	18	69
Turbidity (NTU)	1,081	0.3	3.8	6.0	8.1	8.9	66.0

In addition to algal biomass measurements, the SJRWMD collects samples at Stations 21FLSJWMLEO and 21FLSJWMLG12 for phytoplankton and zooplankton species enumeration. Phytoplankton and zooplankton taxa are identified to species level if possible. Total biovolume for samples collected between October 1993 and November 2015 were grouped at the division level, and the relative fraction in each phytoplankton division was calculated. **Table 5.2** summarizes the relative contribution by phytoplankton by division over the sampling period. Cyanophycota (blue-green algae) dominated in most of the samples, with a median percentage of 67.2 %, and comprised more than 50 % of the algal biovolume in 175 of 276 sampling events (63 %). Bacillariophyta (diatoms) exceeded 50 % of the total biovolume for 66 sampling events (24 %). **Figure 5.7** shows a time series of relative biovolume by division (divisions with a median contribution of less than 20 % were not included).

Table 5.2. Summary statistics for phytoplankton biovolumes by division in Lake George

Division	Number of Cases	Min	Max	Median	Mean
Bacillariophyta	276	0.57	95.53	21.87	30.48
Chlorophyta	276	0.10	60.80	3.60	5.41
Chrysophyta	66	0.00	16.56	0.34	0.78
Cryptophycophyta	252	0.01	55.02	1.42	3.51
Cyanophycota	276	0.60	98.71	67.23	59.02
Dinophyta	1	0.07	0.07	0.07	0.07
Euglenophycota	225	0.00	16.58	0.22	0.78
Haptophyta	57	0.08	4.51	0.38	0.71
Orchophyta	1	0.01	0.01	0.01	0.01
Pyrrophycophyta	134	0.01	21.03	1.05	1.85
Xanthophyta	8	0.00	0.88	0.08	0.29

As part of the analysis of phytoplankton communities in Lake George, Hendrickson et al. (2017) aggregated phytoplankton taxa into three groups: eukaryotic (y-E), nitrogen-fixing cyanobacteria (NF-BG), and non-nitrogen fixing cyanobacteria (BG). **Figures 5.8** and **5.9** illustrate the relative biovolume fraction of each group at Stations 21FLSJWMLEO and 21FLSJRWMLG12, respectively. The graphs include chlorophyll *a* measured during sampling events.

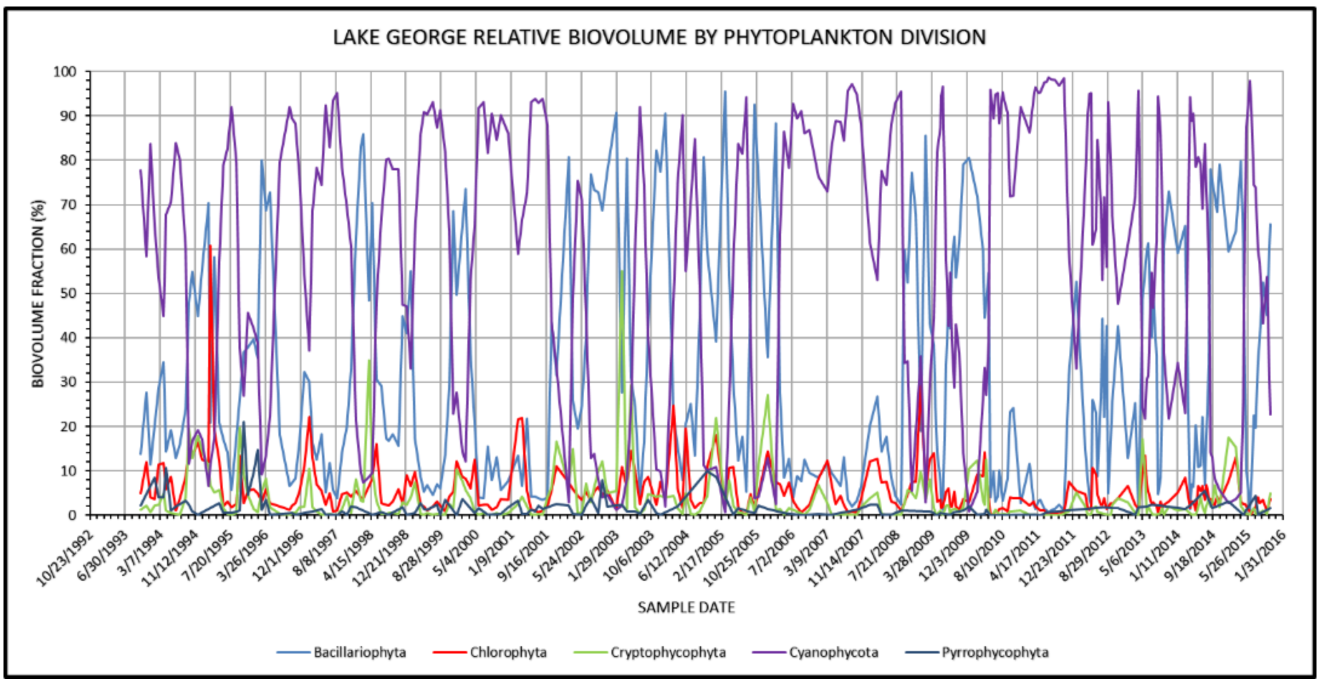

Figure 5.7. Composition of algal species based on biovolumes by division

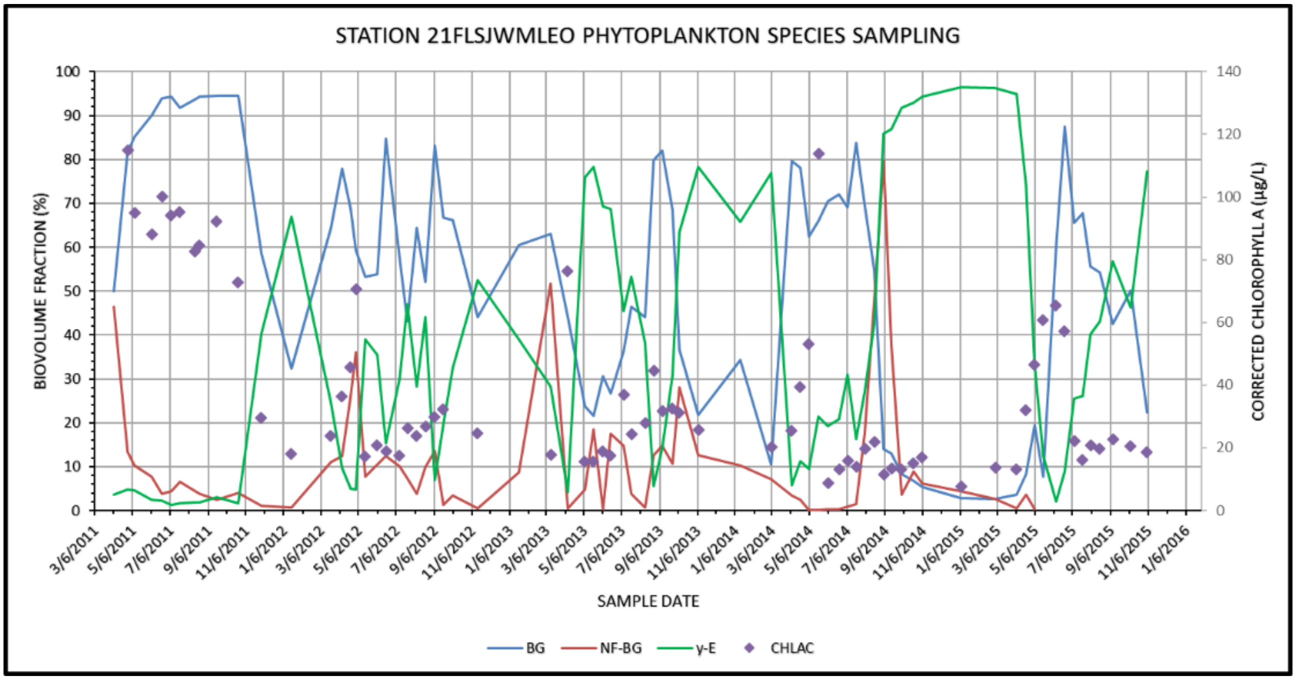

Figure 5.8. Composition of eukaryotic (y-E), N-fixing cyanobacteria (NF-BG), and non-N fixing cyanobacteria (BG) algal groups at Station 21FLSJWNLEO

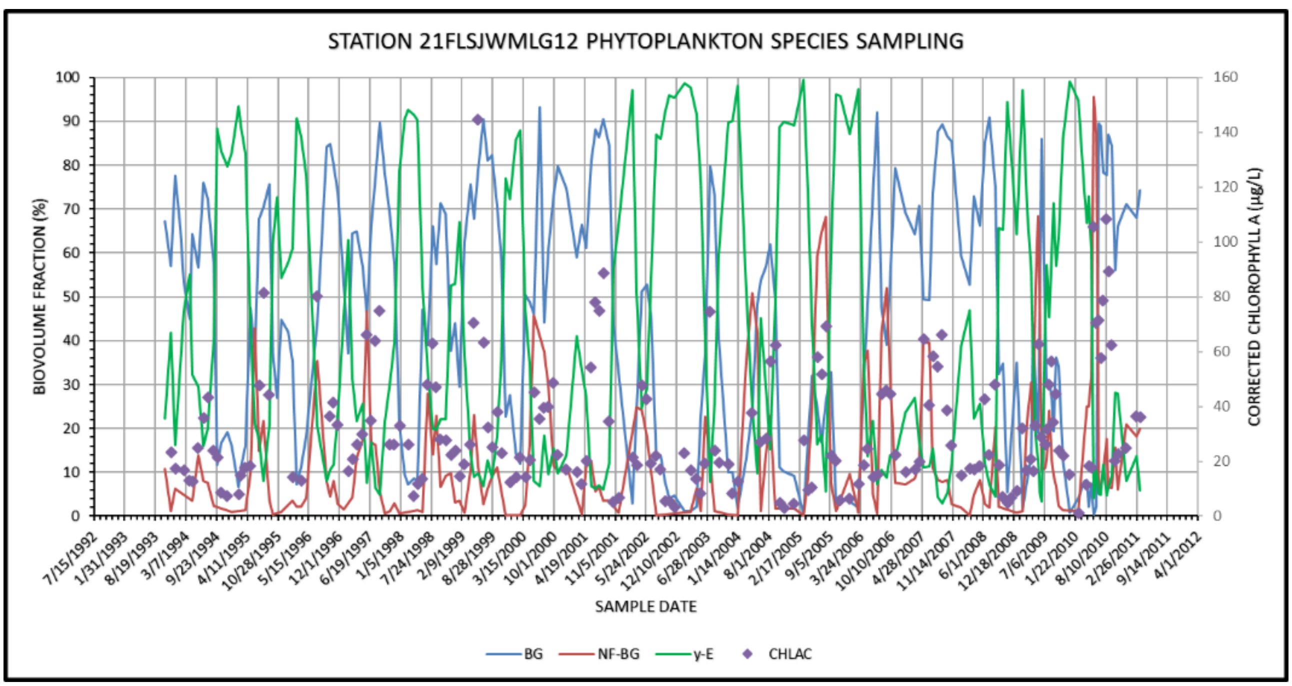

Figure 5.9. Composition of eukaryotic (y-E), N-fixing cyanobacteria (NF-BG), and non-N fixing cyanobacteria (BG) algal groups at Station 21FLSJWNLG12

Blue-green species capable of fixing nitrogen (e.g., Anabaena, Cylindrospermopsis, and Aphanizomenon) were present in 231 of 276 sampling dates (84 %). Based on the list of known or potentially harmful algal bloom (HAB) species in Florida (Abbott et al. 2009, Appendix D), at least 1 of 3 HABs (*Anabaena circinalis*, *Anabaena spiroides*, and *Microcystis aeruginosa*) occurred on 101 of the 276 sampling dates (36 %).

Table 2.1 summarizes the chlorophyll *a*, TN, and TP AGMs for Lake George. **Figures 5.10** through **5.12** show the values, along with the minimum and maximum TN and TP NNC AGMs (red lines).

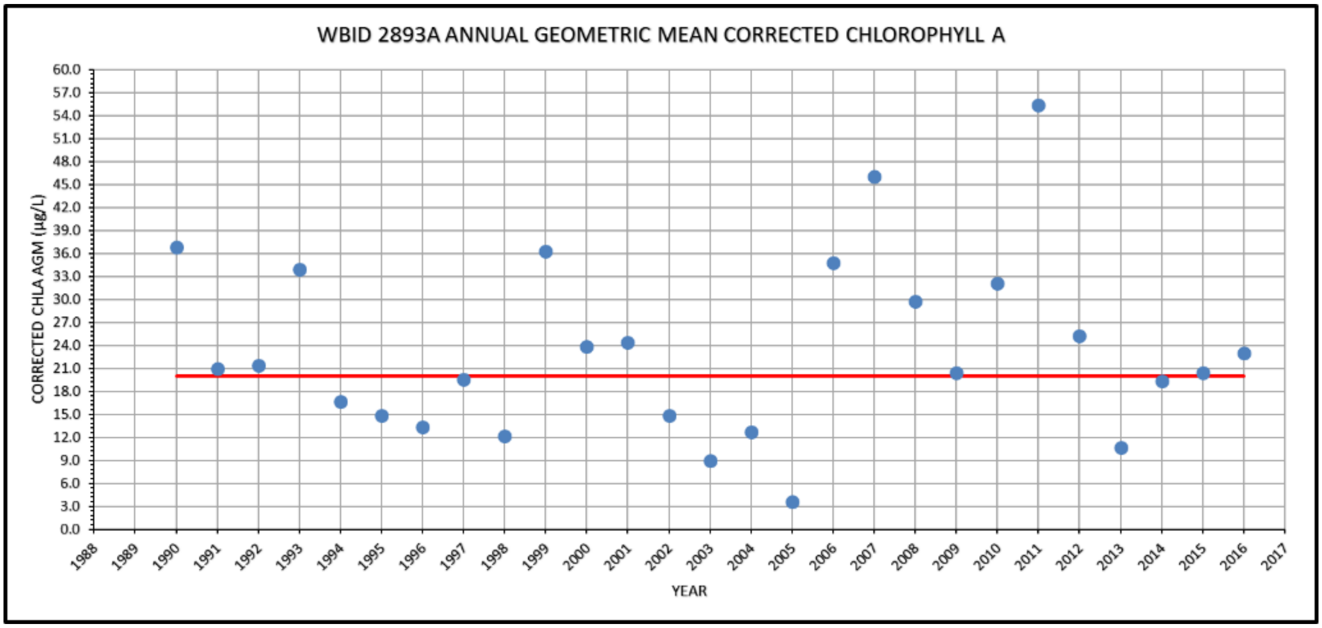

Figure 5.10. Chlorophyll *a* AGMs for Lake George

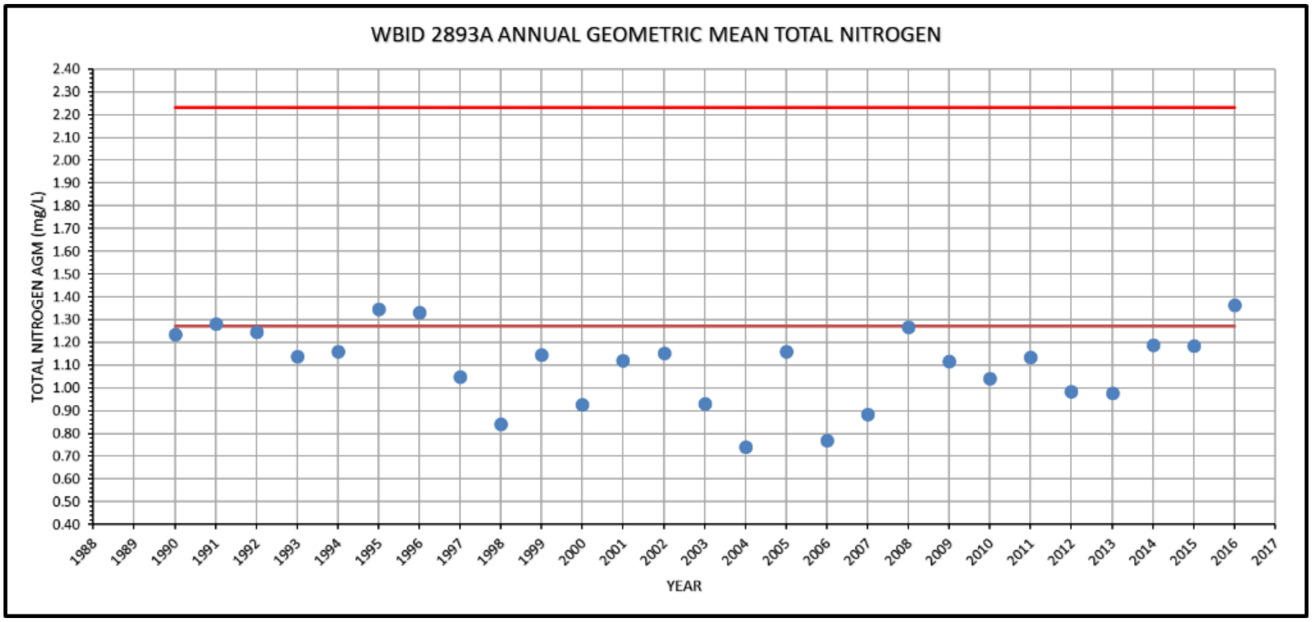

Figure 5.11. TN AGMs for Lake George

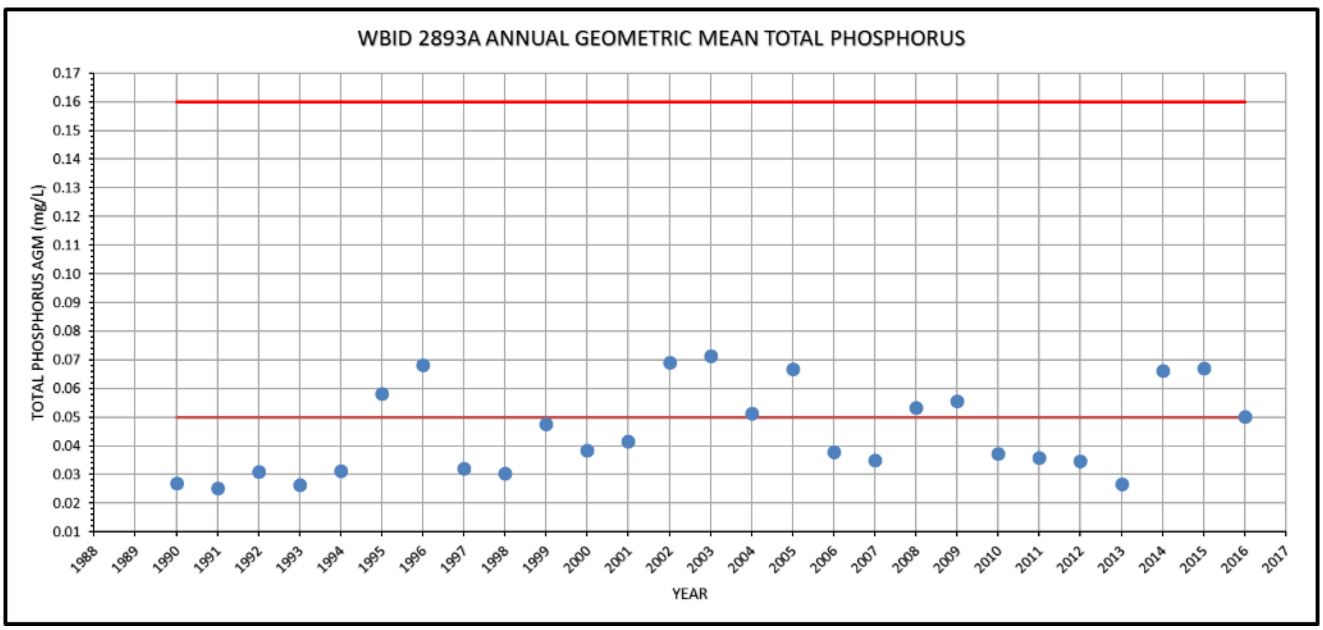

Figure 5.12. TP AGMs for Lake George

5.1.2 Water Quality in St. Johns River Below Lake George

Figure 5.13 displays the historical corrected chlorophyll *a* observations over time for this segment of the St. Johns River. The simple linear regression of corrected chlorophyll *a* versus sampling date in the figure was not significant at an alpha (α) level of 0.05. As might be expected, chlorophyll patterns are very similar to those seen in Lake George.

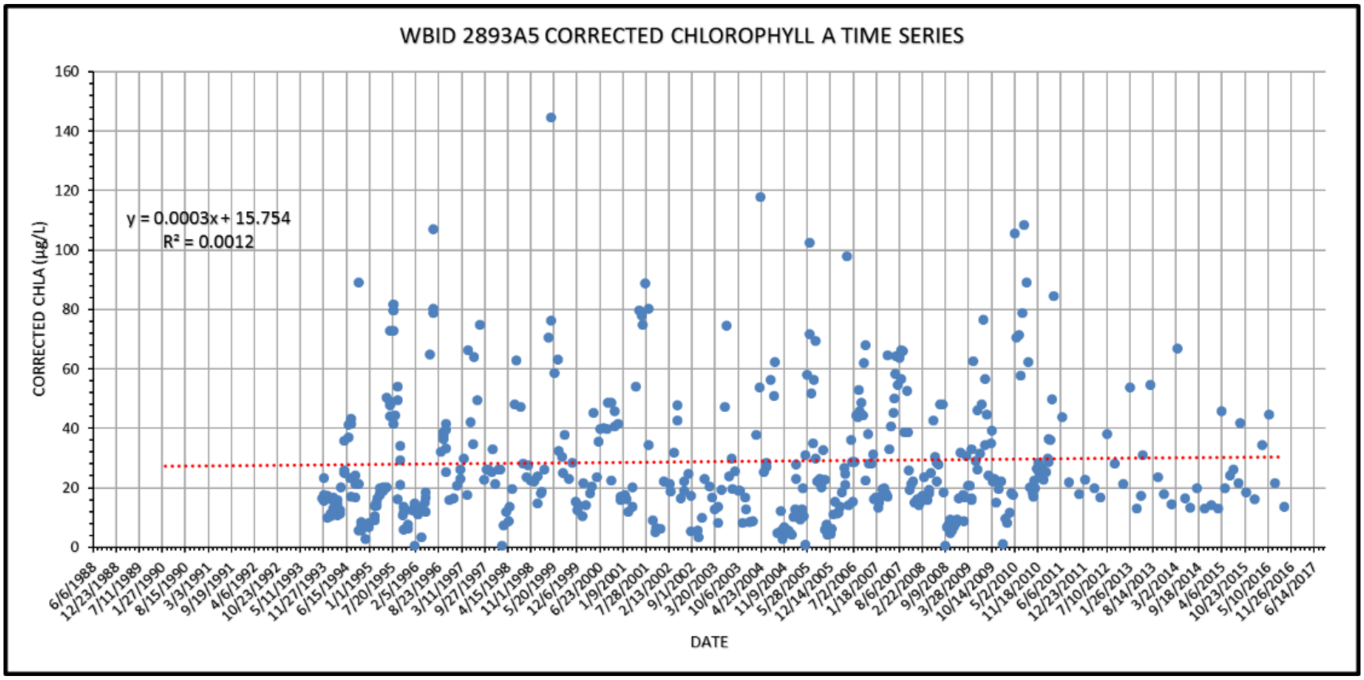

Figure 5.13. Corrected chlorophyll *a* time series for St. Johns River below Lake George

Figure 5.14 graphs the time series for TN. Although the R^2 was small, the simple linear regression of TN versus sampling date in the figure was significant at an alpha (α) level of 0.05 (over 5,000 values) and indicated a slight decreasing trend in TN.

Figure 5.15 graphs the TP observations. The simple linear regression of TP versus sampling date in the figure was significant at an alpha (α) level of 0.05 and indicated an increasing trend in TP.

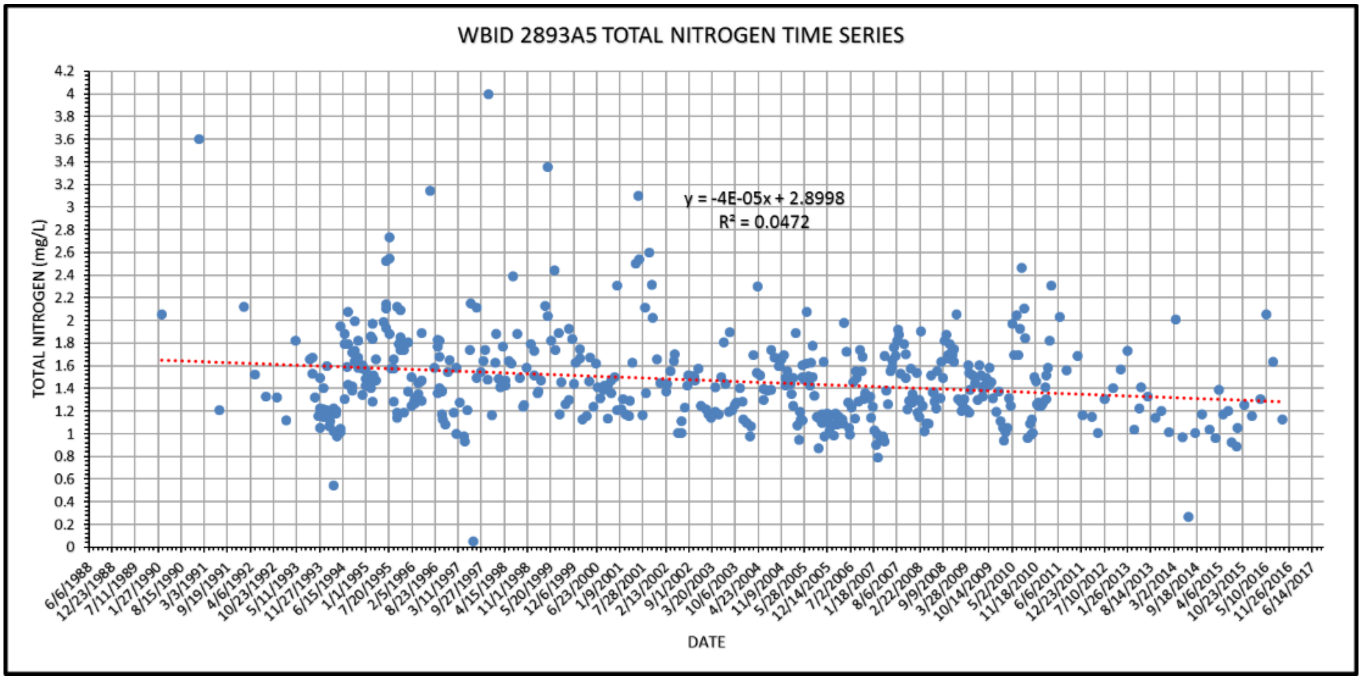

Figure 5.14. TN time series for St. Johns River below Lake George

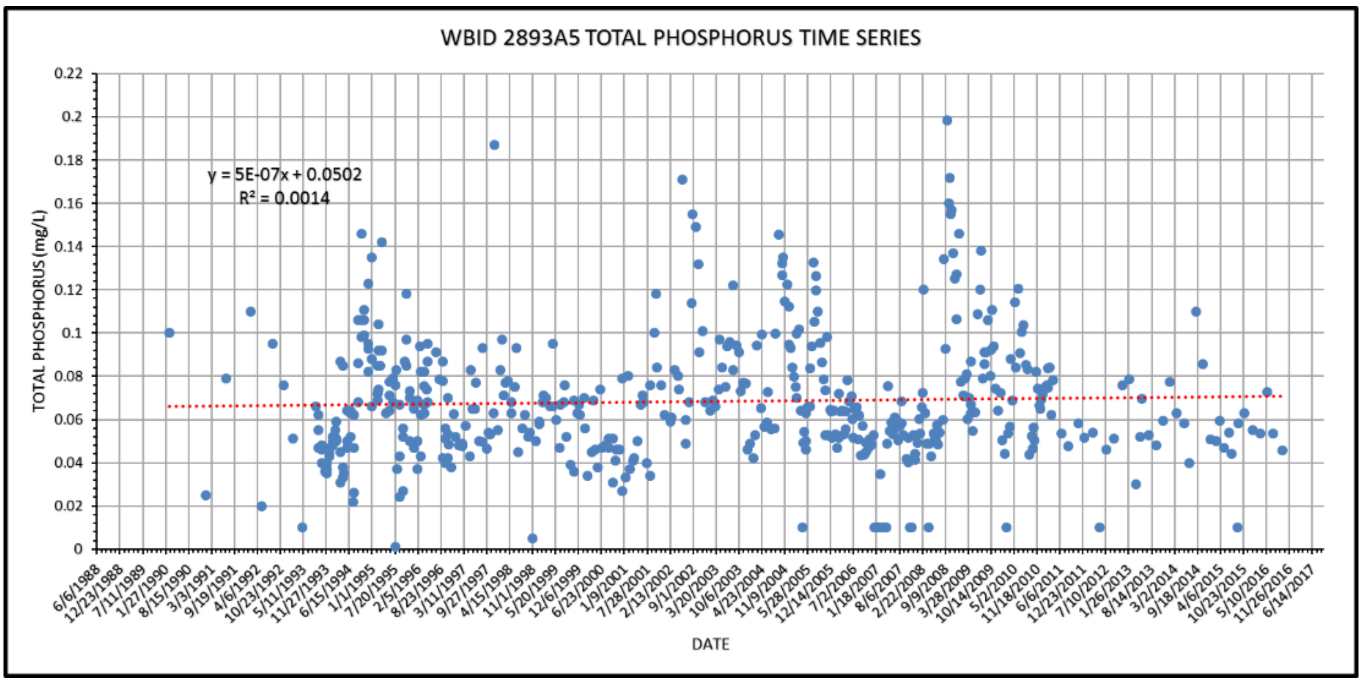

Figure 5.15. TP time series for St. Johns River below Lake George

Table 2.2 summarizes the chlorophyll *a*, TN, and TP AGMs for St. Johns River below Lake George. **Figures 5.16** through **5.18** show the values, along with the stream TN and TP NNC AGMs (red line).

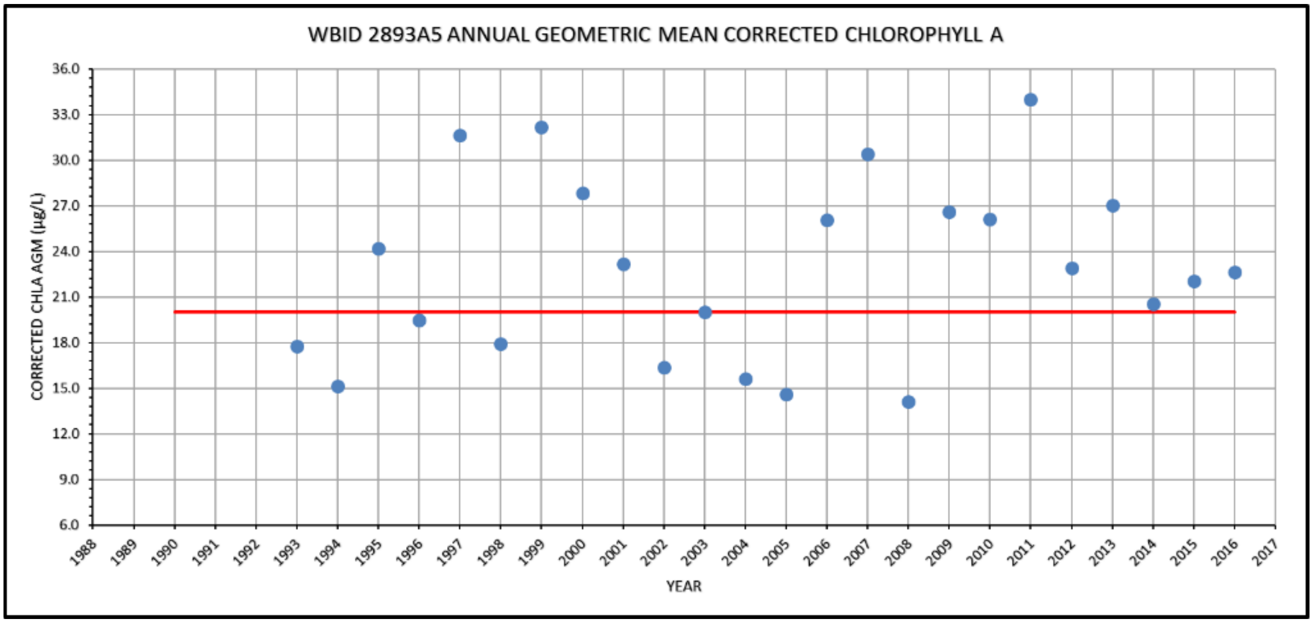

Figure 5.16. Chlorophyll *a* AGMs for St. Johns River below Lake George

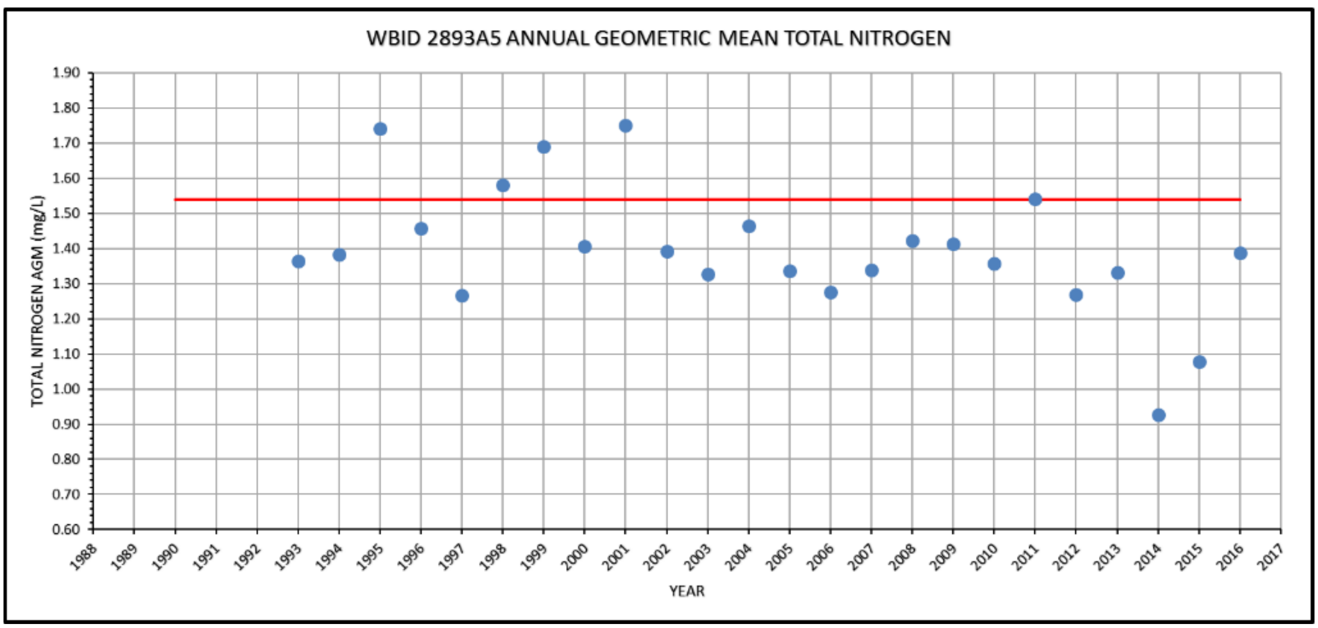

Figure 5.17. TN AGMs for St. Johns River below Lake George

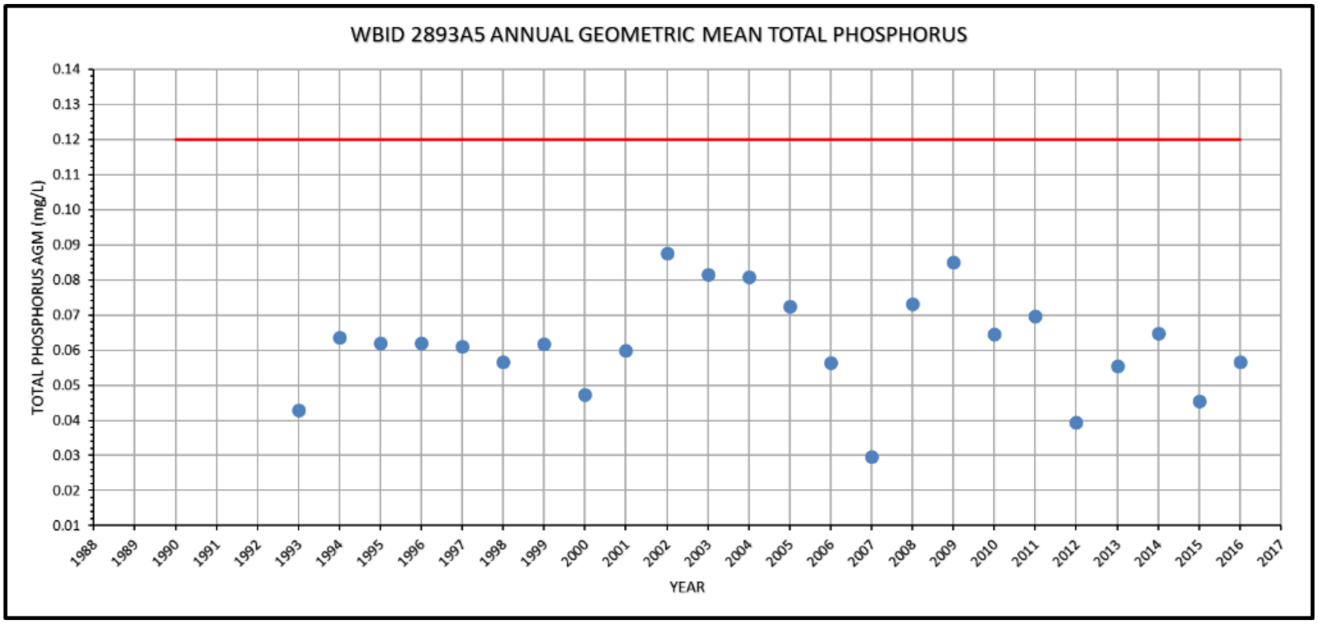

Figure 5.18. TP AGMs for St. Johns River below Lake George

5.1.3 Water Quality in St. Johns River Above Ocklawaha River

Figure 5.19 displays the historical corrected chlorophyll *a* observations over time for this segment of the St. Johns River. The simple linear regression of corrected chlorophyll *a* versus sampling date in the figure was not significant at an alpha (α) level of 0.05.

Figure 5.20 graphs the times series for TN. The simple linear regression of TN versus sampling date in the figure was not significant at an alpha (α) level of 0.05.

Figure 5.21 graphs TP observations. The simple linear regression of TP versus sampling date in the figure was significant at an alpha (α) level of 0.05 and indicated an increasing trend in TP. As seen in the graphs, this segment of the St. Johns River has not been routinely monitored since early 2005.

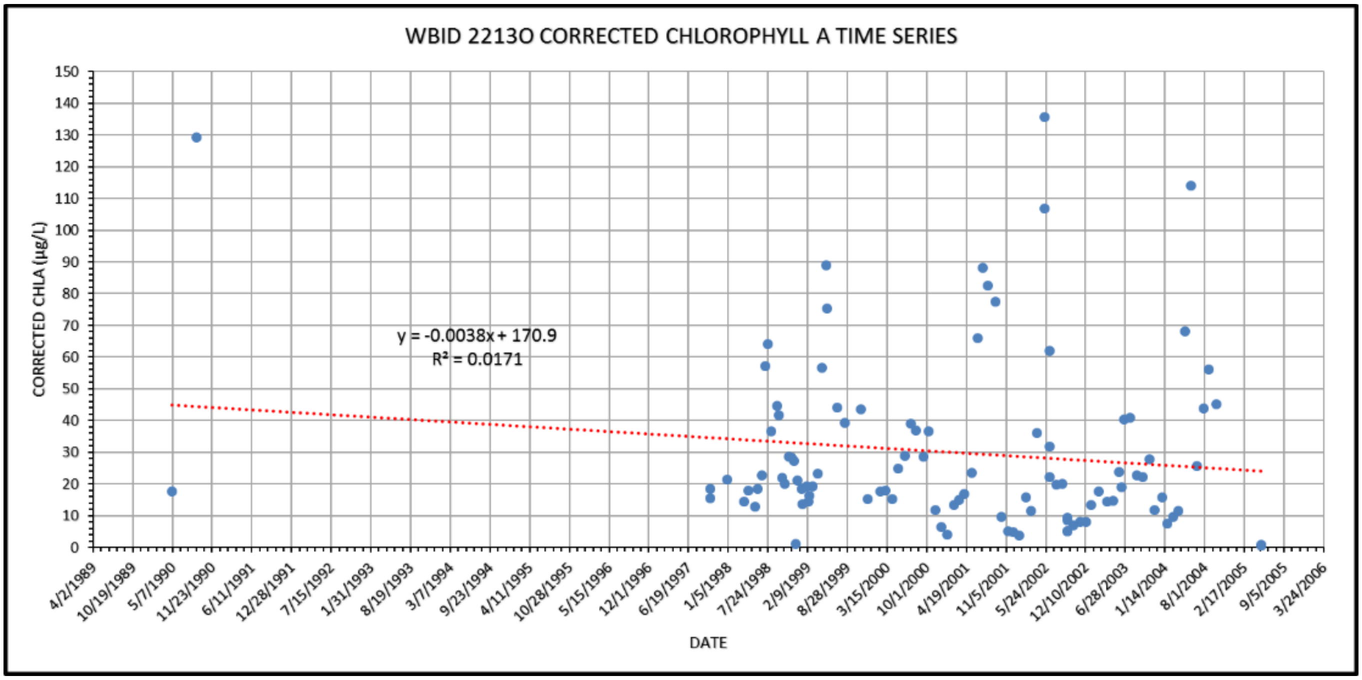

Figure 5.19. Corrected chlorophyll *a* time series for St. Johns River above Ocklawaha River

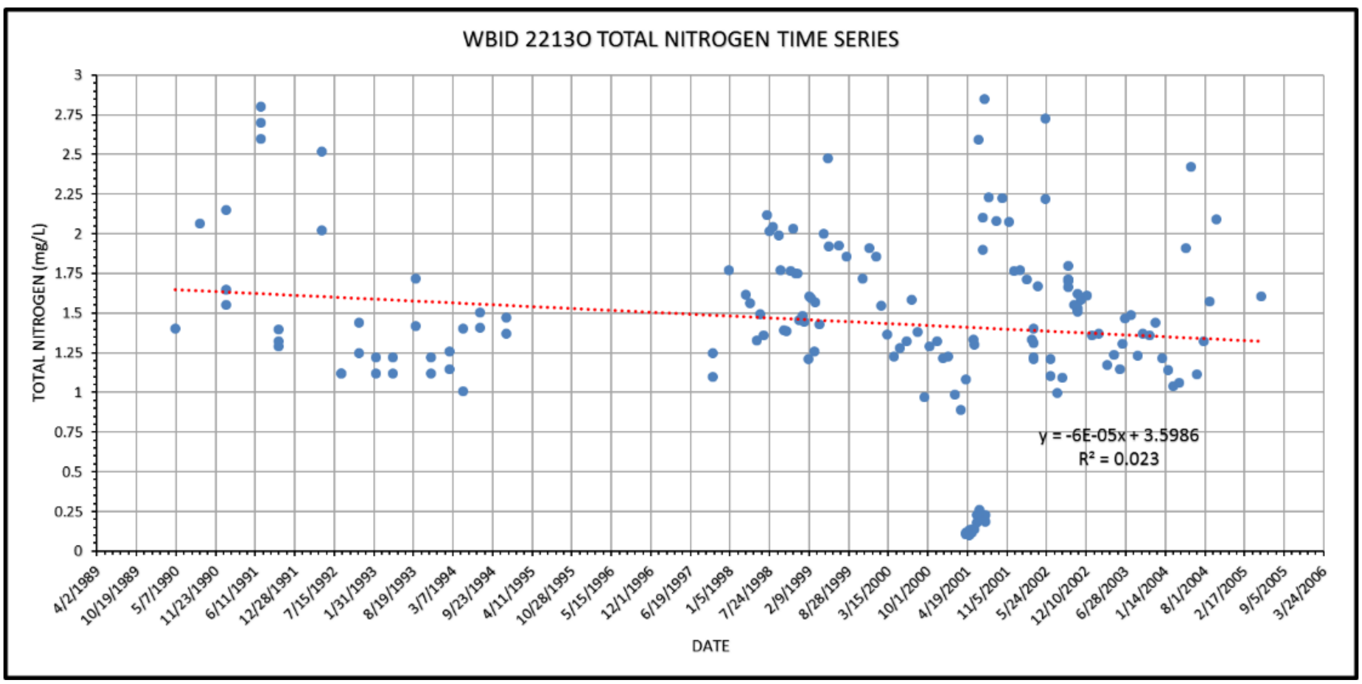

Figure 5.20. TN time series for St. Johns River above Ocklawaha River

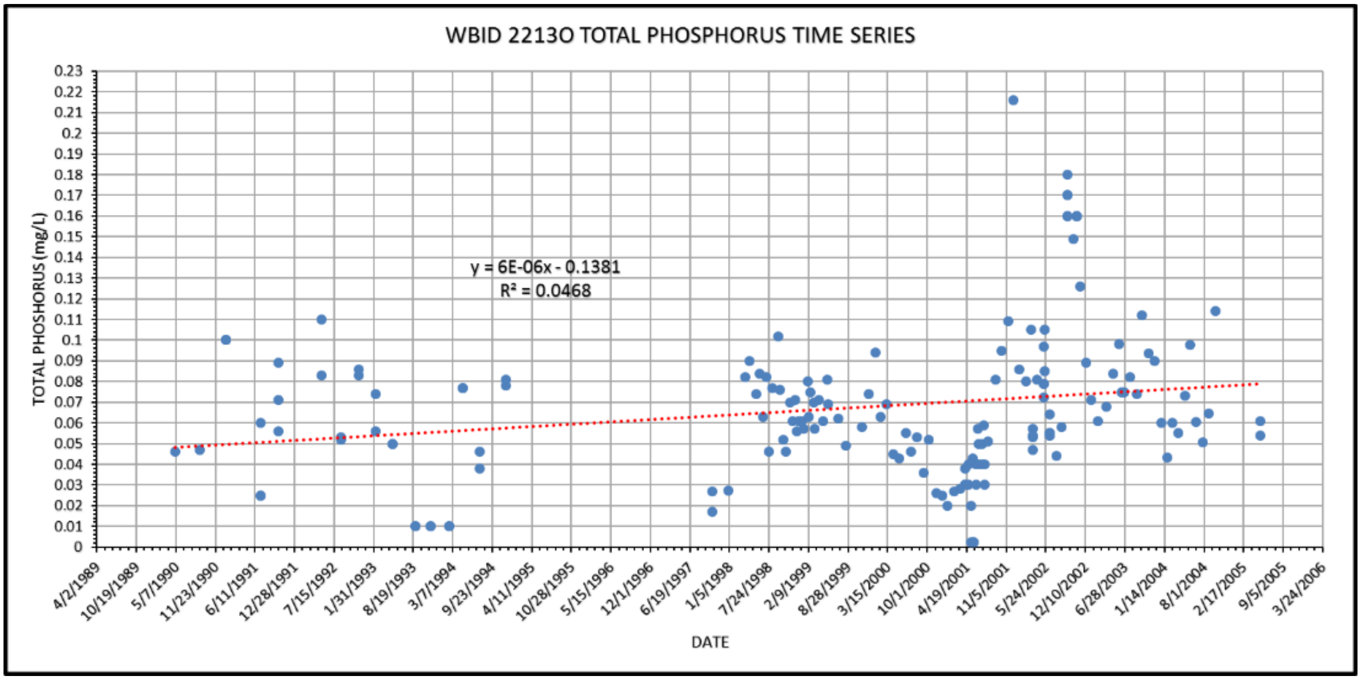

Figure 5.21. TP time series for St. Johns River above Ocklawaha River

Table 2.3 summarizes the chlorophyll *a*, TN, and TP AGMs for St. Johns River above Ocklawaha River. **Figures 5.22** through **5.24** show values along with the stream TN and TP NNC AGMs (red line).

Since water quality in the two St. Johns River segments is highly influenced by water quality conditions in Lake George, the remainder of this document focuses on Lake George and the development of targets necessary to restore designated uses. Water quality improvements in the lake should directly impact these two stream segments.

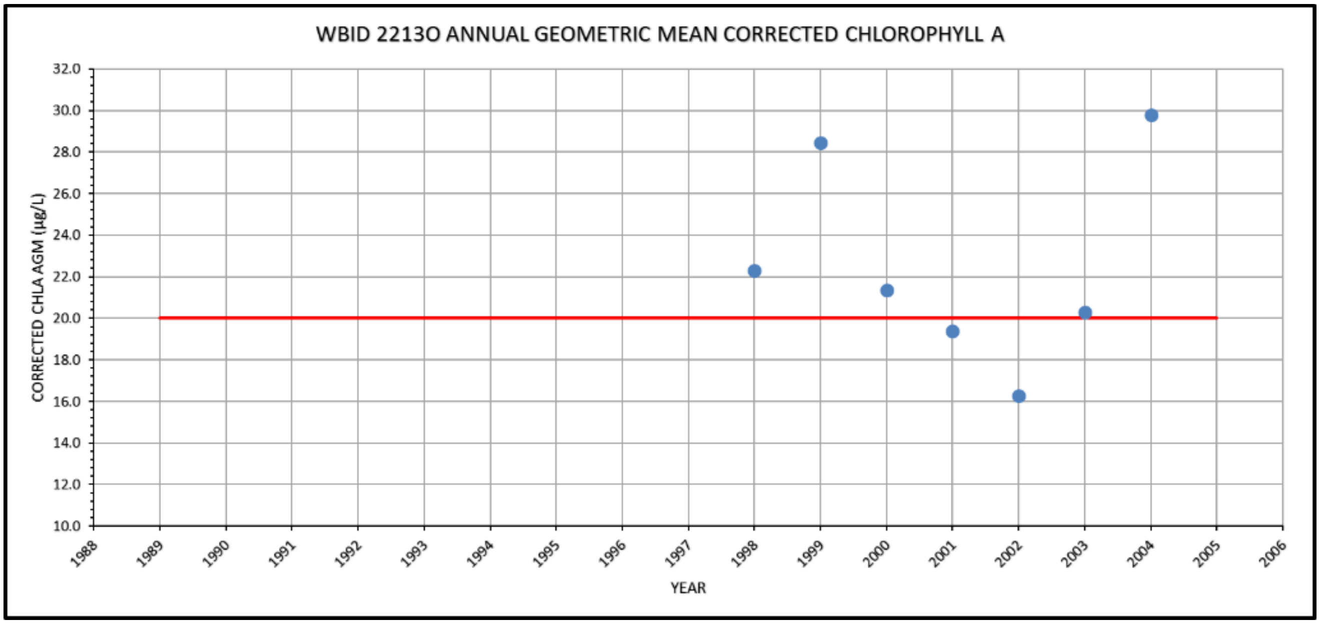

Figure 5.22. Chlorophyll *a* AGMs for St. Johns River above Ocklawaha River

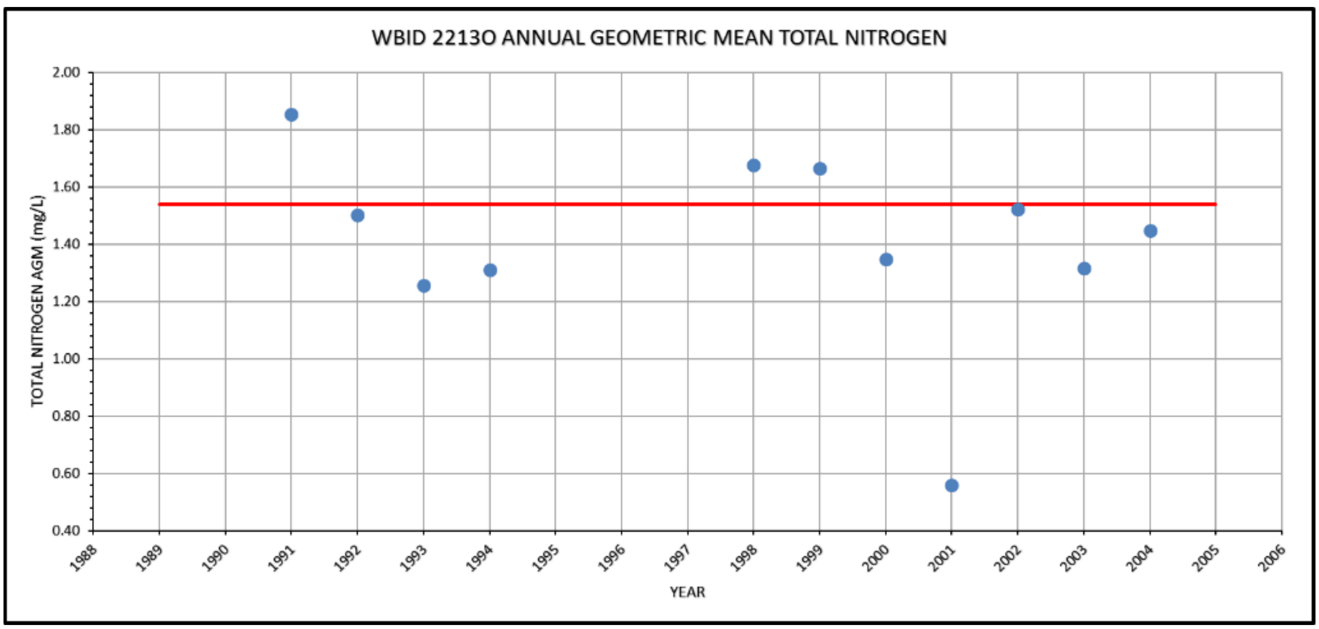

Figure 5.23. TN AGMs for St. Johns River above Ocklawaha River

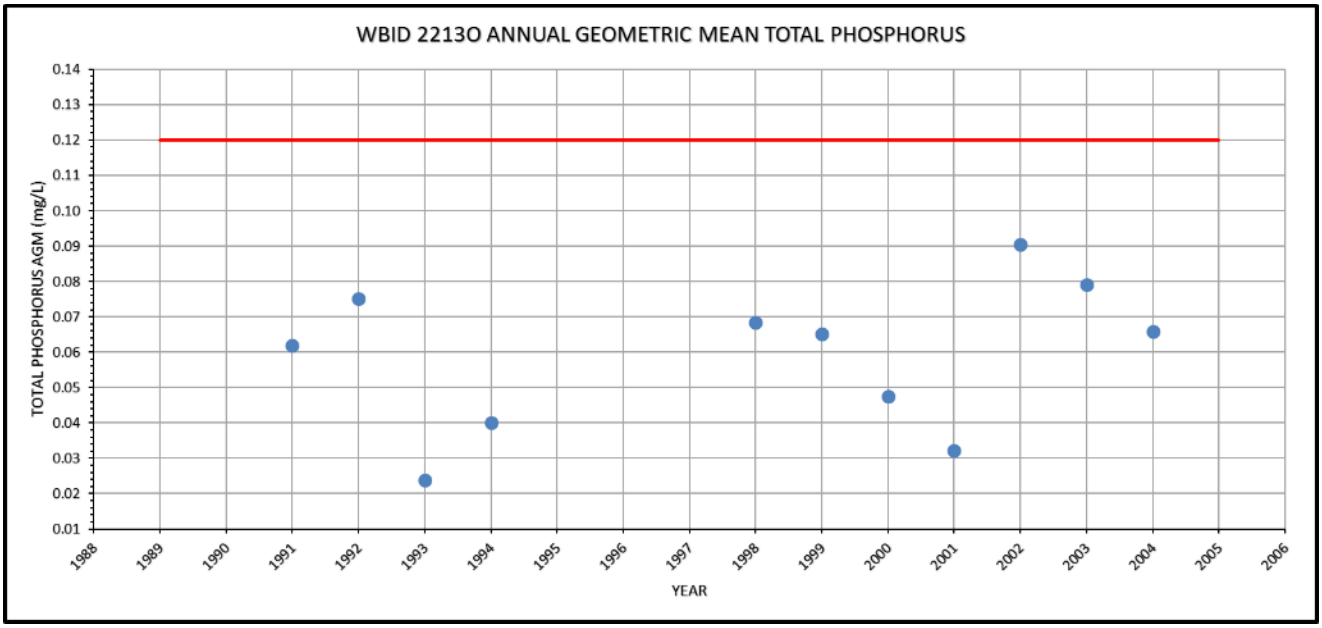

Figure 5.24. TP AGMs for St. Johns River above Ocklawaha River

5.2 TMDL Development Process—Establishing Nutrient Targets

Hendrickson et al. (2017) conducted a comprehensive analysis of the ecological setting and cultural eutrophication changes that have occurred since naturalist William Bartram made his observations in traveling across Florida in 1792. The lake is at the head of tide for the St. Johns River Estuary, attenuating tide, and converts bioavailable nitrogen and phosphorus delivered from the upper and middle portions of the St. Johns River Basin into predominantly phytoplankton biomass. Rooted submerged aquatic vegetation is limited to shoreline margins, and floating macrophytes are constrained by aquatic weed spraying. As seen in **Figures 5.3**, **5.13**, and **5.19**, phytoplankton blooms occur nearly annually in Lake George and are transported downstream.

Historical accounts of Lake George (and the freshwater St. Johns River estuary) indicate it was a naturally mesotrophic aquatic ecosystem, supporting primary productivity in rooted and floating macrophytes and phytoplankton. Water quality data collected in Little Lake George in 1939-40 (Pierce, 1947), indicate that Secchi depth was twice and TN approximately half that of current conditions. Due to the analysis method used in this study (albuminoid organic N), it is likely that TN reported is less than would have been measured had the Kjeldahl method been used. Furthermore, it is likely that a greater fraction of TN (and TP) at this time were partitioned into floating macrophytes. The exotic floating aquatic water hyacinth (*Eichhornia crassipes*) was introduced to Florida in Lake George in the late 1800s, and soon it displaced the native dominant floating macrophyte water lettuce (*Pistia stratiotes*). A protracted effort by the U. S. Army Corps of Engineers to control this invasive species ultimately succeeded in the early 1970's, and since then primary production in the lake has been partitioned almost exclusively in the phytoplankton. The targets proposed herein for Lake George presume a phytoplankton-dominated pelagic ecosystem, meaning one in which a greater amount of TN and TP are partitioned into the water column.

Between the 1948–1953 and 1967–1969 periods, fisheries sampling in Lake George indicated that gizzard shad abundance had nearly tripled to 74 % of the total catch. In 2012 the SJRWMD initiated a rough fish harvest program in the lake with 3 objectives: (1) the direct removal of in-lake phosphorus in fish biomass, (2) increased phosphorus sediment burial by reduction in fish responsible for bioturbation, and (3) reduction in grazing pressure by zooplanktiverous fish.

Figure 5.3 illustrates the long-term and seasonal cycle of algal production in Lake George. Phytoplankton species composition by division, summarized in **Table 5.2** and plotted in **Figure 5.7,** demonstrated that cyanobacteria species dominated the phytoplankton community, followed by diatoms. Grouping species into eukaryotic, nitrogen-fixing cyanobacteria, and non-nitrogen fixing cyanobacteria at the 2 sampling stations (**Figures 5.8** and **5.9**) showed shifts in the phytoplankton community and diversity. As chlorophyll *a* concentrations increase, cyanobacteria become an increasing relative fraction of the total phytoplankton biomass. As shown in **Figure 5.25**, above a chlorophyll *a* concentration of 20 µg/L there is a sharp increase in the relative cyanobacteria biovolume fraction.

In addition to the phytoplankton species composition sampling at Stations 21FLSJWMLEO and 21FLSJWMLG12, samples were also collected for zooplankton species composition. Hendrickson et al. (2017) discuss research studies that found cyanobacteria are of poorer nutritional quality than eukaryotic algae and some cyanobacterial genera can disrupt zooplankton grazing. The potential impact of toxic metabolites produced by some cyanobacterial species to zooplankton is an area of ongoing research and, as noted earlier, 3 known HAB species were found in 36 % of the samples. Hendrickson et al. (2017) described changes in Cladoceran zooplankton in response to the consecutive severe bloom years of 2010 and 2011 (**Figure 5.26**). Bloom conditions were defined as a chlorophyll *a* concentration in excess of 40 µg/L. The rationale to select 40 µg/L as a bloom threshold is based on the fact that it is a generally recognized level indicative of both visible appearance and ecosystem impact (Havens, 2003), and it is the same chlorophyll-*a* threshold applied for the downstream freshwater Lower St. Johns River TMDL.

The number of zooplankton organisms were also arranged into major groups and plotted as a function of bloom duration (**Figure 5.27**). Hendrickson et al. (2017) plotted the cumulative sum for the rolling, 5-event 95th percentile for bloom length, sorted by increasing duration. Peaks represent the change point where zooplankton numbers are decreasing with increased bloom duration. Cladoceran zooplankton appeared to be the most adversely affected by persistent bloom conditions, but copepod and rotifer numbers also declined. Change points ranged between 37 and 45 days among the 4 groups.

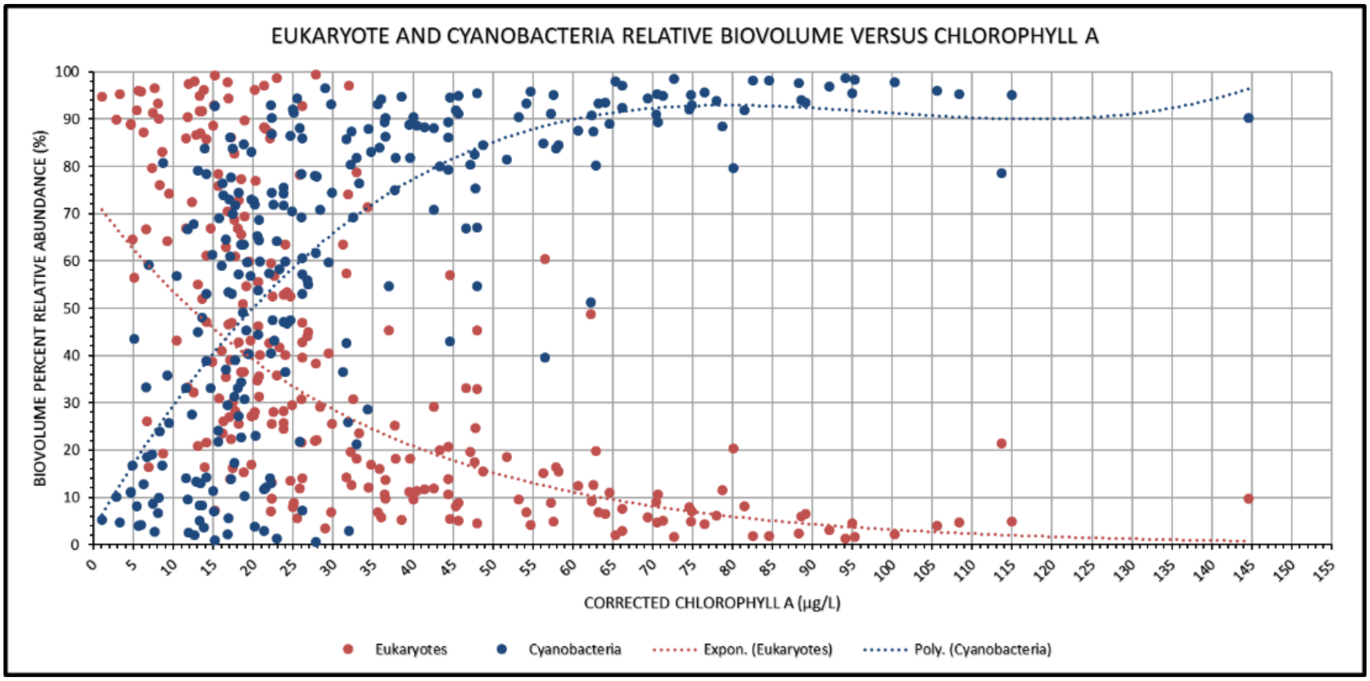

Figure 5.25. Eukaryote and cyanobacteria biovolume fractions versus chlorophyll *a* in Lake George

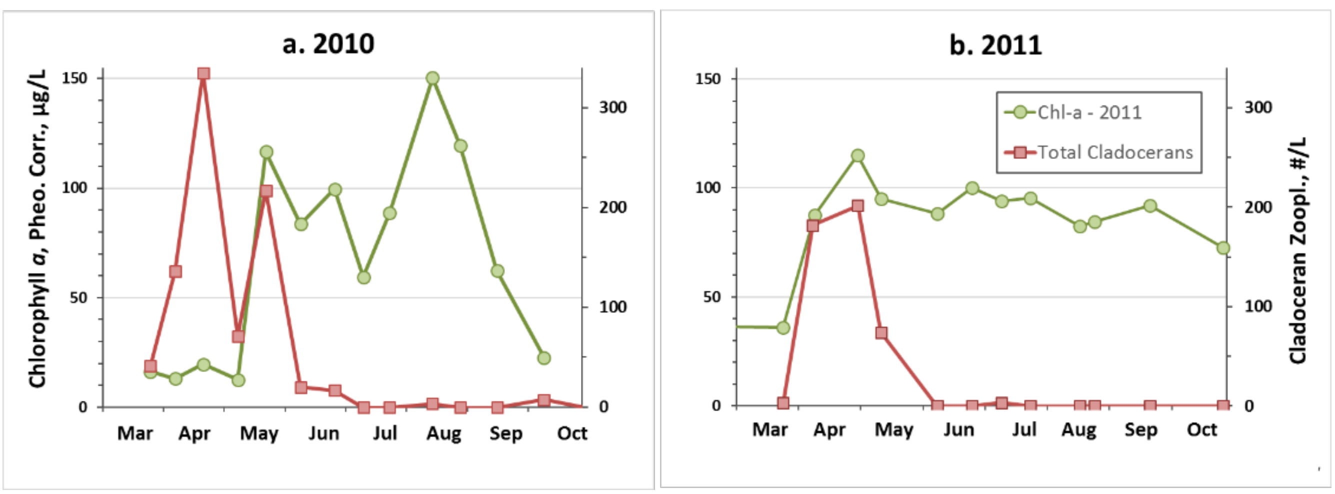

Figure 5.26. Change in Cladoceran numbers with increasing cyanobacteria bloom duration in Lake George (Hendrickson et al. 2017; used with permission)

As the phytoplankton community shifts from a dominance of eukaryotic algae (primarily diatoms) in the winter and early spring to cyanobacteria from late spring through early fall, when available forms of nitrogen become limiting, there is a competitive advantage for nitrogen-fixing cyanobacteria species (**Figures 5.8** and **5.9**). Hendrickson et al. (2017) suggest that this occurs at an algal biomass of around 40 µg/L as chlorophyll *a*. Under this condition, cyanobacteria biomass will continue to increase until the available phosphorus becomes limiting. An algal organic phosphorus concentration of 0.05 mg/L appears to be the threshold above which nitrogen becomes limiting to growth.

According to Hendrickson et al. (2017), during the April through September period, cyanobacteria such as *Anabaena*, *Aphanizomenon*, and *Cylindrospermopsis* average 18 % of the community biomass. Bioassays conducted in 2004 (Paerl et al. 2005) measured peak daily N-fixation rates of 0.05 µg N/µg chlorophyll *a*/hr, with daily average rates from 3 bioassays at 0.028 µg N/µg chlorophyll *a*/day. As a result of N-fixation, Lake George exports more nitrogen than enters the lake as an external load. Daily mean inflow and outflow TN concentrations and the difference between cumulative TN inlet and outlet loads were calculated in Hendrickson et.al. (2017) (see **Figure 11**). Over the 2004–13 period, they estimated a mean annual increase of 571 metric tons per year (MT/yr) in the TN outflow load (an increase of 16 %).

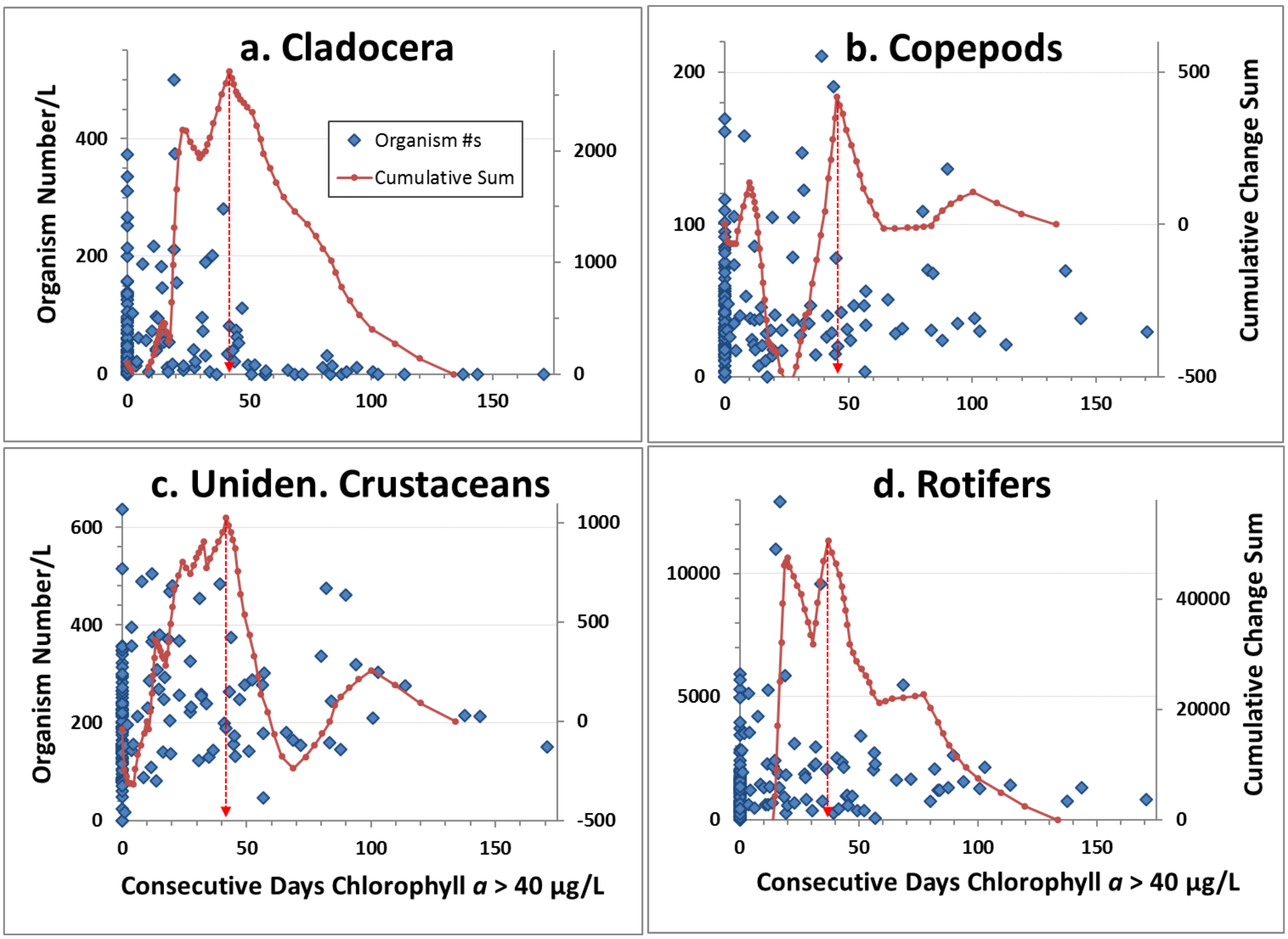

Figure 5.27. Change in zooplankton group mean abundance as a function of algal bloom duration in Lake George (Hendrickson et al. 2017; used with permission)

Algal blooms can also impact DO conditions over the water column, particularly if the water column becomes stratified and mixing is inhibited. Following phosphorus limitation there can be rapid senescence and sharp oxygen declines from algal respiration and bacterial decomposition. A comparison of continuous phycocyanin and DO sensors located at Channel Markers 4 and 5 in the northern half of Lake George (Hendrickson et al. 2017) showed a strong correlation between the daily rate of chlorophyll decline and the degree of oxygen depletion. The transport of residual lake phytoplankton biomass at the end of the growth season can also contribute to oxygen depression downstream.

Temperature-based density stratification during high algal productivity periods and associated bottom water anoxia can also be a significant factor in the internal cycling of phosphorus from lake sediments. As described by Hendrickson et al. 2017, vertical migration patterns are discernible in the phycocyanin pigment sensor. The sequestration of bottom water phosphorus (PO_4) released by sediments during anoxic periods would provide a mechanism to sustain bloom conditions by N-fixing cyanobacteria when available nitrogen has been depleted in the photic zone.

The SJRWMD's ecological studies in Lake George, summarized in this section (see Hendrickson et al. 2017 for a more detailed analysis), document a chlorophyll *a* target of 40 µg/L not to be exceeded more than 40 consecutive days. This target would (1) maintain the diversity of the plankton community, (2) facilitate the upward transfer of primary production to higher trophic levels (and maintain zooplankton diversity), and (3) minimize the potential dominance of detrimental algal species and the production of algal toxins. The chlorophyll *a* target identified by the SJRWMD is protective of designated uses.

Above chlorophyll *a* concentrations of 35 to 40 µg/L, N-fixing cyanobacterial species represent a significant fraction of the algal biomass and increase the annual downstream export of nitrogen on average by 571 MT/yr. Reducing the supply of external phosphorus to Lake George to levels stoichiometrically equivalent to the upper range of external loads of bioavailable N that becomes limiting will limit the magnitude and duration of cyanobacterial blooms. The threshold is an annual average TP concentration of 0.063 mg/L.

5.3 TMDL Development Process—Application of Hydrodynamic and Water Quality Models

Chapter 3 described the generally applicable NNC. However, in order to avoid abating the natural condition, DEP examined the nutrient concentrations established using a model-based prediction of natural background conditions. Consistent with EPA (2000) technical guidance, additional analyses were conducted to confirm that proposed site-specific nutrient targets (TN and TP) for the lake were appropriate.

The SJRWMD assembled an interconnected suite of basinwide hydrologic, hydrodynamic, and water quality models to develop this TMDL. The suite of models includes the following: (1) a hydrologic model that calculates seasonal runoff and nutrient loads for each sub-basin in the

Lake George Watershed (Hydrologic Simulation Program Fortran [HSPF] and Pollution Load Simulation Program [PLSM]); (2) a hydrodynamic model of Lake George and segments of the St. Johns River that simulates the mixing and transport of nutrients (Environmental Fluid Dynamics Code [EFDC]); and (3) a water quality model that simulates the transformation of nutrients and processes affecting eutrophication in the lake and river segments (U.S. Army Corps of Engineers [USACE] Quality Integrated Compartment Model [CE-QUAL-ICM]).

5.3.1 External Load Models

Figure 5.28 shows the results for the Lake George Watershed and individual sub-basins. Nutrient concentrations based on land use and soils were based on the application of the PLSM (Adamus and Bergman 1995; Hendrickson and Konwinski 1998; Hendrickson et al. 2002) and HSPF for flows. The PLSM uses a computer-driven GIS framework to develop aggregate whole-basin loads of relevant water quality constituents. The computational approach of the PLSM calculates constituent load as the product of concentration and runoff water volume, using nonpoint source pollutant export concentrations specific to 1 of 15 different land use classes, and water quantity through a hybrid of the Soil Conservation Service (SCS) curve number method. As part of the *St. Johns River Water Supply Impact Study* (WSIS) (Lowe et al. 2012) a set of HSPF hydrologic models was developed, and they were used in this TMDL analysis to determine surface runoff and surficial groundwater flow from sub-basins. **Appendix E** provides a more detailed explanation of the methods used to simulate the external nutrient loads.

5.3.2 Hydrodynamic Model

EFDC is a finite-difference, three-dimensional hydrodynamic that solves the hydrostatic Navier-Stokes equations, together with a continuity equation, and transport equations for salinity, temperature, turbulent kinetic energy, and turbulent macroscale. The equations are solved horizontally on a curvilinear, orthogonal grid and vertically on a stretched sigma-grid.

Figure 5.29 illustrates the grid used for both the hydrodynamic and water quality models. The model grid is a subset of the EFDC Water Supply Impact Study (WSIS) hydrodynamic model grid (Sucsy et al. 2012). This Lake George model contains the portion of the EFDC WSIS model between Astor and Buffalo Bluff. There are 567 horizontal cells and 6 equally spaced vertical layers. The mean cell length is 600 meters, and the maximum achievable time-step for stability of the hydrodynamics simulation is approximately 30 seconds. The model was modified to include a heat budget to simulate periods of temperature stratification.

5.3.3 Water Quality Model

The three-dimensional, time-variable water quality process model code used was the USACE Quality Integrated Compartment Model (CE-QUAL-ICM), Version 2 (Cerco and Cole 1995), with some modifications. CE-QUAL-ICM is among the most sophisticated water quality process models in existence and was originally developed for the Chesapeake Bay Program to examine factors leading to bay hypoxia.

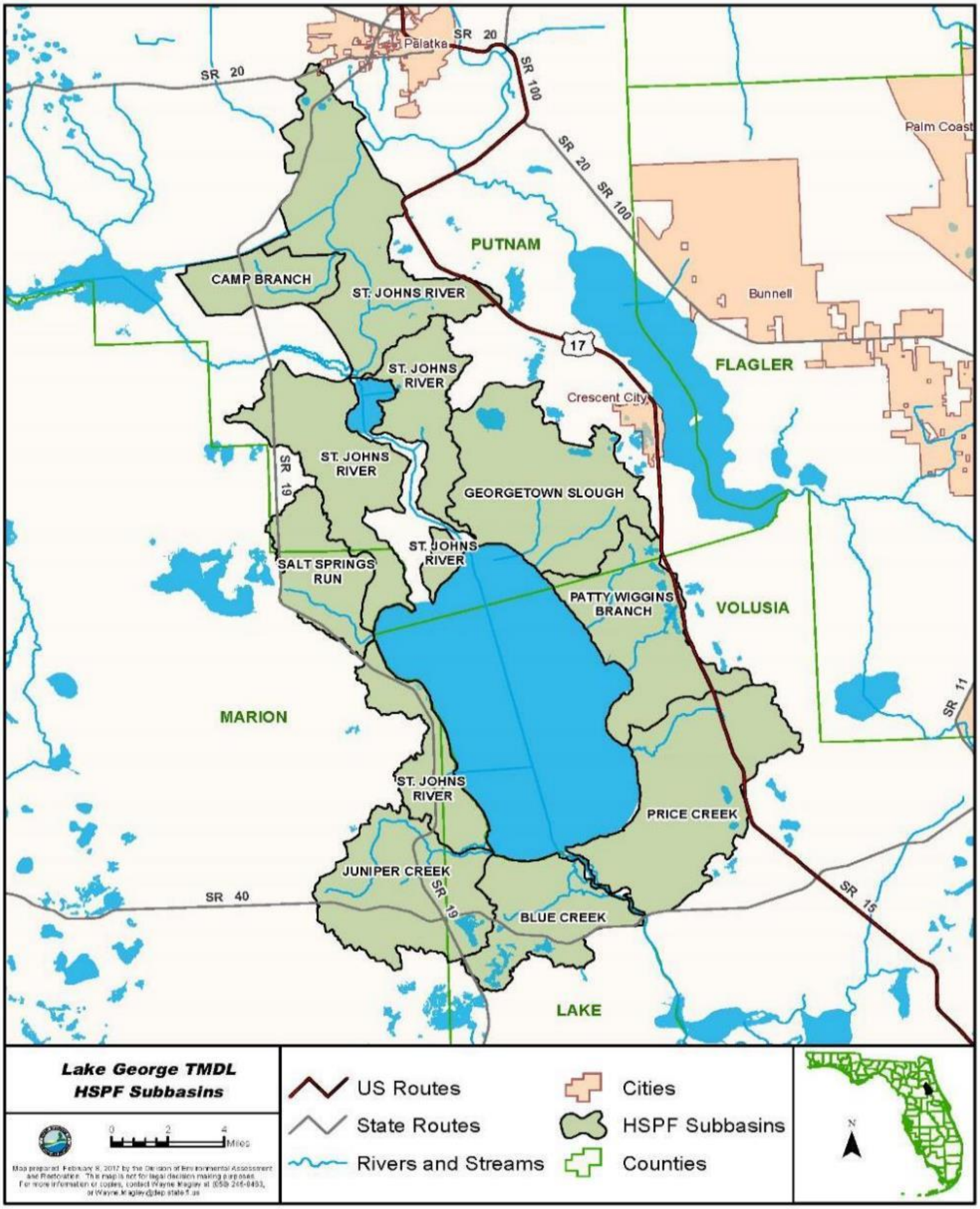

Figure 5.28. HSPF sub-basins in the Lake George Watershed

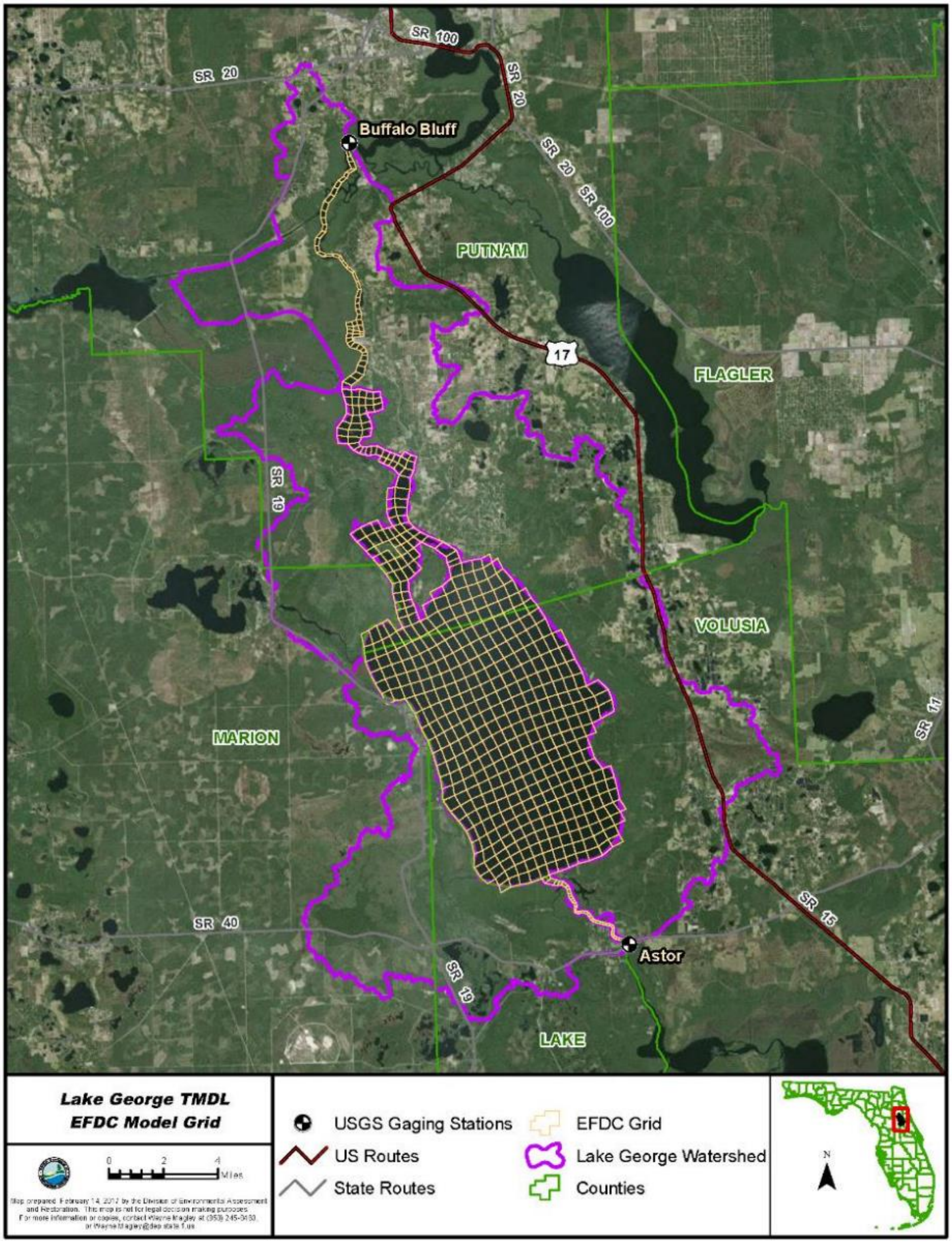

Figure 5.29. EFDC and CE-QUAL-ICM model grid

Table 5.3 summarizes the 26 state variables included in the LSJR version of the CE-QUAL-ICM model. The LSJR version included 2 algal carbon groups: (1) cyanobacteria, and (2) all eukaryotes. A benthic sediment diagenesis submodel was dynamically coupled with the water column to produce sediment oxygen demand and nutrient fluxes. The sediment diagenesis submodel uses an additional 17 state variables (**Table 5.4**). Sucsy et al. (2016) provide a more detailed explanation of the modifications made to the model code for application to Lake George.

Table 5.3. State variables included in the CE-QUAL-ICM model for Lake George

ppt = Parts per thousand

State Variable	Model Acronym	Units
Temperature	T	ºC
Salinity	S	ppt
Inorganic Suspended Solids	TSS	mg/L
Cyanobacteria	Cyano	mg/L Carbon
Eukaryotes	Euk	mg/L Carbon
Labile Dissolved Organic Carbon	LDOC	mg/L
Refractory Dissolved Organic Carbon	RDOC	mg/L
Labile Particulate Organic Carbon	LPOC	mg/L
Refractory Particulate Organic Carbon	RPOC	mg/L
Ammonium	NH3	mg/L
Nitrite+Nitrate	Nox	mg/L
Labile Dissolved Organic Nitrogen	LDON	mg/L
Refractory Dissolved Organic Nitrogen	RDON	mg/L
Labile Particulate Organic Nitrogen	LPON	mg/L
Refractory Particulate Organic Nitrogen	RPON	mg/L
Total Phosphate	PO4	mg/L
Labile Dissolved Organic Phosphorus	LDOP	mg/L
Refractory Dissolved Organic Phosphorus	RDOP	mg/L
Labile Particulate Organic Phosphorus	LPOP	mg/L
Refractory Particulate Organic Phosphorus	RPOP	mg/L
Chemical Oxygen Demand	COD	mg/L
Dissolved Oxygen	D.O.	mg/L
Particulate Silica	Psi	mg/L
Dissolved Silica	Dsi	mg/L
Cyanobacteria Phosphorus	IntP1	mg/L
Eukaryote Phosphorus	IntP2	mg/L

Table 5.4. State variables included in the CE-QUAL-ICM sediment diagenesis submodel for Lake George

State Variable	Model Acronym	Units
Sediment Temperature	CTEMP	°C
Particulate Organic Carbon G1 Class	POC1	mgC/m^3 bulk volume
Particulate Organic Carbon G2 Class	POC2	mgC/m^3 bulk volume
Particulate Organic Carbon G3 Class	POC3	mgC/m^3 bulk volume
Particulate Organic Nitrogen G1 Class	PON1	mgN/m^3 bulk volume
Particulate Organic Nitrogen G2 Class	PON2	mgN/m^3 bulk volume
Particulate Organic Nitrogen G3 Class	PON3	mgN/m^3 bulk volume
Particulate Organic Phosphorus G1 Class	POP1	mgP/m^3 bulk volume
Particulate Organic Phosphorus G2 Class	POP2	mgP/m^3 bulk volume
Particulate Organic Phosphorus G3 Class	POP3	mgP/m^3 bulk volume
Particulate Biogenic Silica	PSI	mgSi/m^3 bulk volume
Sulfide/Methane in Aerobic Layer	HST1	gO2/m^3 bulk volume
Sulfide/Methane in Anaerobic Layer	HST2	gO2/m^3 bulk volume
Ammonia in Aerobic Layer	NH4T1	mgN/m^3 bulk volume
Ammonia in Anaerobic Layer	NH4T2	mgN/m^3 bulk volume
Nitrate in Aerobic Layer	NO3T1	mgN/m^3 bulk volume
Nitrate in Anaerobic Layer	NO3T2	mgN/m^3 bulk volume
Phosphate in Aerobic Layer	PO4T1	mgP/m^3 bulk volume
Phosphate in Anaerobic Layer	PO4T2	mgP/m^3 bulk volume
Available Silica in Aerobic Layer	SI1	mgSi/m^3 pore water volume
Available Silica in Anaerobic Layer	SIT2	mgSi/m^3 bulk volume

5.3.4 Water Quality Model System Calibration and Confirmation

The hydrodynamic and water quality models were set up to simulate the 2002–13 period. Sucsy et al. (2016) provide an overview of observed datasets compiled for model setup and calibration. The six-year period from 2003 to 2008 represented the model calibration period. Model calibration was evaluated by applying the coefficient of determination, the Nash-Sutcliffe Modeling Efficiency coefficient, the average relative error, the average absolute error, and the mean difference to matched pairs of simulated and observed time series. In addition to comparisons with testing model state variables, derived variables TN, TP, TSS, chlorophyll *a*, carbon:chlorophyll ratio, and color time series were evaluated. The following section summarizes the modeling approach used to establish TN and TP targets under natural conditions.

Model calibration required aligning simulated and observed data in both time and space. Vertical stratification was assessed by comparing time series of surface concentrations with vertically-averaged concentrations for a given state variable at a given horizontal location. Diurnal variability was assessed by calculating the average relative variation of each model state variable for each day. Four stations had sufficient data available for comparison. Sucsy et al. *(*2016) provide a detailed discussion of the statistical comparisons for each state variable. Comparison of cumulative distributions for all simulated state variables with the observed distribution was acceptable. Good temporal variability was achieved for TP, phosphate, dissolved silica, chlorophyll, DO, and TSS. Temporal variability was poorer for TN, ammonium, and nitrate, reflecting the difficulty of simulating biologically controlled sources (nitrogen fixation) and sinks (denitrification). Overall the calibration was acceptable.

The 2009–13 period was used for model confirmation. Seasonal rainfall during the confirmation period was generally below average and include two unusually cold winters (2009 and 2010). The highest annual average chlorophyll *a* occurred during the confirmation period. Chlorophyll *a* was underpredicted in the summers of 2010 and 2011, as was TN in the summer of 2011. The underprediction was likely because the model was unable to predict the fraction of the phytoplankton population that was actively fixing nitrogen. With the exception noted above, the statistical comparisons between observed and simulated state variables for the confirmation period were similar to those in the calibration period.

The sediment diagenesis submodel simulation of average porewater phosphate concentrations agreed well with the range reported by Cerco and Noel (2007), while the range in porewater ammonia was slightly less than the observed range. Sediment flux ranges for phosphate and ammonia between the sediment and water column compared well with observed ranges. Simulated sediment denitrification rates were generally about one-half of observed mean rates. Part of the difference in denitrification rates may be caused by the considerable difficulty in measuring denitrification in the field. Given measurement uncertainties, a match within a factor of two for denitrification rates was acceptable. Finally, sediment oxygen demand rates were in close agreement with observed ranges.

5.3.5 Water Quality Model Simulation of Existing Conditions

Once the model calibration and validation process was completed, existing conditions over the 2003–13 period were simulated. Model output from individual cells was postprocessed to obtain daily lakewide average concentrations of chlorophyll *a*, TN, and TP. Annual average and AGM concentrations for chlorophyll *a*, TN, and TP were calculated from the respective daily time series. **Tables 5.5** through **5.7** summarize the existing conditions simulation for chlorophyll *a*, TN, and TP, respectively for Lake George. **Appendix F** lists the annual external nutrient loads associated with each year.

Table 5.5. Chlorophyll *a* summary statistics for Lake George under existing conditions

Year	Minimum (µg/L)	Maximum (µg/L)	Arithmetic Mean (µg/L)	Geometric Mean (µg/L)	Maximum Consecutive Days Chlorophyll *a* > 40 µg/L
2003	10	60	25	22	60
2004	4	74	32	23	157
2005	9	72	26	21	66
2006	12	68	37	33	112
2007	16	64	35	32	149
2008	5	59	24	20	59
2009	9	62	26	23	62
2010	14	65	38	34	181
2011	10	58	33	30	133
2012	14	36	23	22	0
2013	13	39	23	22	0

Table 5.6. TN summary statistics for Lake George under existing conditions

Year	Minimum (mg/L)	Maximum (mg/L)	Arithmetic Mean (mg/L)	Geometric Mean (mg/L)
2003	1.04	1.51	1.22	1.22
2004	0.94	1.72	1.40	1.38
2005	0.95	1.79	1.26	1.24
2006	0.96	1.73	1.29	1.27
2007	0.91	1.61	1.29	1.27
2008	1.09	1.64	1.34	1.33
2009	1.01	1.60	1.29	1.29
2010	0.89	1.68	1.36	1.33
2011	1.02	1.55	1.29	1.28
2012	0.96	1.33	1.15	1.14
2013	0.88	1.22	1.09	1.09

Table 5.7. TP summary statistics for Lake George under existing conditions

Year	Minimum (mg/L)	Maximum (mg/L)	Arithmetic Mean (mg/L)	Geometric Mean (mg/L)
2003	0.040	0.109	0.071	0.068
2004	0.041	0.145	0.085	0.078
2005	0.042	0.201	0.087	0.079
2006	0.040	0.099	0.069	0.066
2007	0.042	0.124	0.073	0.069
2008	0.057	0.159	0.092	0.087
2009	0.053	0.172	0.089	0.084
2010	0.040	0.164	0.091	0.083
2011	0.044	0.131	0.074	0.070
2012	0.052	0.096	0.066	0.065
2013	0.041	0.121	0.066	0.063

As shown in **Table 5.5**, the longest duration of consecutive days with chlorophyll *a* above 40 µg/L occurred in 2010. Monthly mean discharges at Astor (**Figure 4.5**) from October 2009 to February 2010 were between the 25th percentile and median. Following July 2010, monthly mean discharges throughout the rest of 2010 were below the 25th percentile. Sucsy et al. (2016) (**Figure 4.4**) graphed average net rainfall and illustrated an extended dry period for the July–December 2010 period. The winter of 2010 (January–March) was also unusually cold, and the authors discuss the influence of thermal stratification on sediment fluxes of inorganic nutrients and enhanced algal biomass production by cyanobacteria. The combination of increased residence time, reduced supply of external nutrients, a cold winter, and subsequent thermal stratification all contributed to an early and sustained bloom of cyanobacteria in 2010.

Output from the existing conditions simulation was postprocessed in a similar manner to obtain segment daily averaged concentrations for the two river segments of chlorophyll *a*, TN, and TP. Annual average and AGM concentrations for chlorophyll *a*, TN, and TP were calculated from the respective daily time series. **Tables 5.8** through **5.13** summarize the existing conditions simulation for chlorophyll *a*, TN, and TP, respectively, for the St. Johns River below Lake George and St. Johns River above Ocklawaha River segments.

Table 5.8. Chlorophyll *a* summary statistics for St. Johns River below Lake George under existing conditions

Year	Minimum (µg/L)	Maximum (µg/L)	Arithmetic Mean (µg/L)	Geometric Mean (µg/L)
2003	11	66	27	24
2004	5	83	33	26
2005	11	88	30	25
2006	13	84	39	34
2007	17	76	40	36
2008	5	83	26	21
2009	14	69	30	27
2010	13	79	43	37
2011	14	56	33	32
2012	15	33	23	23
2013	13	54	25	23

Table 5.9. TN summary statistics for St. Johns River below Lake George under existing conditions

Year	Minimum (mg/L)	Maximum (mg/L)	Arithmetic Mean (mg/L)	Geometric Mean (mg/L)
2003	0.92	1.60	1.16	1.15
2004	0.86	1.93	1.35	1.32
2005	0.91	2.01	1.22	1.19
2006	0.86	2.09	1.32	1.28
2007	0.84	1.73	1.35	1.33
2008	1.05	1.73	1.30	1.29
2009	0.95	1.62	1.23	1.22
2010	0.83	1.92	1.42	1.38
2011	1.01	1.56	1.27	1.26
2012	0.92	1.29	1.08	1.08
2013	0.81	1.35	1.06	1.06

Table 5.10. TP summary statistics for St. Johns River below Lake George under existing conditions

Year	Minimum (mg/L)	Maximum (mg/l)	Arithmetic Mean (mg/L)	Geometric Mean (mg/L)
2003	0.033	0.094	0.063	0.060
2004	0.001	0.100	0.048	0.034
2005	0.001	0.099	0.051	0.044
2006	0.034	0.098	0.068	0.064
2007	0.000	0.100	0.060	0.043
2008	0.000	0.100	0.053	0.038
2009	0.000	0.099	0.061	0.049
2010	0.002	0.099	0.044	0.034
2011	0.000	0.100	0.061	0.054
2012	0.045	0.083	0.061	0.060
2013	0.001	0.099	0.059	0.054

Table 5.11. Chlorophyll *a* summary statistics for St. Johns River above Ocklawaha River under existing conditions

Year	Minimum (µg/L)	Maximum (µg/L)	Arithmetic Mean (µg/L)	Geometric Mean (µg/L)
2003	10	56	23	21
2004	5	81	30	23
2005	5	83	27	23
2006	11	82	35	31
2007	11	81	38	33
2008	5	75	25	21
2009	11	58	29	26
2010	7	73	36	32
2011	11	52	31	29
2012	11	34	22	22
2013	11	86	27	25

Table 5.12. TN summary statistics for St. Johns River above Ocklawaha River under existing conditions

Year	Minimum (mg/L)	Maximum (mg/L)	Arithmetic Mean (mg/L)	Geometric Mean (mg/L)
2003	0.91	1.52	1.12	1.12
2004	0.85	1.88	1.25	1.23
2005	0.89	1.91	1.19	1.16
2006	0.83	1.97	1.18	1.16
2007	0.75	1.93	1.24	1.21
2008	0.98	1.61	1.24	1.23
2009	0.88	1.51	1.15	1.13
2010	0.80	1.75	1.24	1.21
2011	0.91	1.44	1.15	1.15
2012	0.91	1.37	1.08	1.08
2013	0.78	1.55	1.05	1.04

Table 5.13. TP summary statistics for St. Johns River above Ocklawaha River under existing conditions

Year	Minimum (mg/L)	Maximum (mg/L)	Arithmetic Mean (mg/L)	Geometric Mean (mg/L)
2003	0.037	0.088	0.061	0.059
2004	0.001	0.100	0.056	0.041
2005	0.000	0.100	0.051	0.040
2006	0.036	0.094	0.061	0.059
2007	0.000	0.100	0.057	0.046
2008	0.000	0.100	0.057	0.044
2009	0.001	0.100	0.062	0.054
2010	0.000	0.100	0.057	0.044
2011	0.030	0.090	0.058	0.056
2012	0.035	0.079	0.058	0.057
2013	0.003	0.099	0.059	0.056

5.4 Calculation of the TMDL

5.4.1 TMDL Scenario

Once the nutrient targets were identified, incremental reductions in anthropogenic nutrient source external loads were made and the simulations were rerun. Output from each reduction scenario was postprocessed using the same process described earlier. The number of consecutive days that chlorophyll *a* in Lake George exceeded 40 µg/L in each year was compared among reduction scenarios. As discussed in the previous section, 2010 was an anomalous year because of a number of factors, and the target of less than 40 consecutive days with chlorophyll below 40 µg/L could not be met with any of the evaluated reduction scenarios. The scenario of a 30 % reduction in anthropogenic nitrogen with a 70 % reduction in anthropogenic phosphorus (30 % TN 70 % TP scenario) met the target for all years (with the exception of 2010). Note that the 30% reduction in TN were applied to the nitrogen model state variables at each inflow point. The actual overall TN load reduction applied in the model varies between annual percent reductions of approximately 32% and 40%, resulting in a long-term average reduction of 35%, because nitrogen and phosphorus contained in the model state variables for algae were reduced proportionally at the St. Johns River model inflow point. The 70% reduction was applied to both nitrogen and phosphorus in the algal component of the model, in order to maintain the relative proportions of nutrients in algae between the different model scenarios. The anthropogenic percent reductions are equivalent to total lake load reductions of 7% for TN and 29% for TP.

Tables 5.14 through **5.16** summarize the results for the 30 % TN 70 % TP reduction scenario simulation for chlorophyll *a*, TN, and TP, respectively for Lake George. Results for the 35 % TN 70 % TP reduction scenario simulation for chlorophyll *a*, TN, and TP, are summarized in **Tables 5.17-5.19**, for the St. Johns River below Lake George segment, and **Tables 5.20-5.22** for the St. Johns River above Ocklawaha River segment.

Table 5.14. Chlorophyll *a* summary statistics for Lake George under the 30 % TN 70 % TP anthropogenic reduction scenario

Year	Minimum (µg/L)	Maximum (µg/L)	Arithmetic Mean (µg/L)	Geometric Mean (µg/L)	Maximum Consecutive Days Chlorophyll *a* > 40 µg/L
2003	9	41	19	18	1
2004	3	52	23	18	38
2005	8	48	20	17	32
2006	10	43	25	23	15
2007	13	40	25	23	1
2008	4	41	18	16	1
2009	8	40	20	19	0
2010	12	50	28	26	85
2011	9	33	21	20	0
2012	12	26	18	18	0
2013	12	29	19	18	0

Table 5.15. TN summary statistics for Lake George under the 30 % TN 70 % TP anthropogenic reduction scenario

Year	Minimum (mg/L)	Maximum (mg/L)	Arithmetic Mean (mg/L)	Geometric Mean (mg/L)
2003	0.99	1.22	1.10	1.10
2004	0.88	1.36	1.19	1.18
2005	0.91	1.41	1.13	1.12
2006	0.82	1.35	1.01	1.00
2007	0.74	1.33	1.03	1.01
2008	0.92	1.51	1.16	1.15
2009	0.95	1.29	1.15	1.14
2010	0.82	1.36	1.13	1.12
2011	0.79	1.26	0.95	0.95
2012	0.74	1.24	1.01	1.00
2013	0.82	1.13	0.98	0.97

Table 5.16. TP summary statistics for Lake George under the 30 % TN 70 % TP anthropogenic reduction scenario

Year	Minimum (mg/L)	Maximum (mg/L)	Arithmetic Mean (mg/L)	Geometric Mean (mg/L)
2003	0.030	0.073	0.050	0.048
2004	0.031	0.101	0.059	0.055
2005	0.030	0.155	0.062	0.057
2006	0.029	0.063	0.046	0.045
2007	0.031	0.081	0.051	0.048
2008	0.042	0.117	0.067	0.064
2009	0.040	0.126	0.065	0.062
2010	0.030	0.115	0.064	0.058
2011	0.030	0.074	0.047	0.045
2012	0.037	0.064	0.047	0.046
2013	0.031	0.088	0.048	0.046

Table 5.17. Chlorophyll *a* summary statistics for St. Johns River below Lake George under the 30 % TN 70 % TP anthropogenic reduction scenario

Year	Minimum (µg/L)	Maximum (µg/L)	Arithmetic Mean (µg/L)	Geometric Mean (µg/L)
2003	10	43	21	19
2004	5	56	24	20
2005	10	57	23	20
2006	11	51	25	23
2007	14	47	28	26
2008	5	55	19	17
2009	13	45	23	22
2010	11	57	30	27
2011	13	31	21	20
2012	13	27	18	18
2013	12	42	20	19

Table 5.18. TN summary statistics for St. Johns River below Lake George under the 30 % TN 70 % TP anthropogenic reduction scenario

Year	Minimum (mg/L)	Maximum (mg/L)	Arithmetic Mean (mg/L)	Geometric Mean (mg/L)
2003	0.88	1.19	1.02	1.02
2004	0.80	1.43	1.13	1.11
2005	0.84	1.47	1.07	1.06
2006	0.71	1.39	0.98	0.97
2007	0.73	1.32	1.04	1.03
2008	0.89	1.51	1.11	1.09
2009	0.90	1.24	1.08	1.08
2010	0.77	1.50	1.14	1.12
2011	0.74	1.22	0.91	0.90
2012	0.70	1.21	0.94	0.93
2013	0.74	1.24	0.93	0.93

Table 5.19. TP summary statistics for St. Johns River below Lake George under the 30 % TN 70 % TP anthropogenic reduction scenario

Year	Minimum (mg/L)	Maximum (mg/L)	Arithmetic Mean (mg/L)	Geometric Mean (mg/L)
2003	0.025	0.064	0.045	0.044
2004	0.028	0.091	0.055	0.052
2005	0.030	0.127	0.058	0.054
2006	0.025	0.063	0.046	0.044
2007	0.033	0.079	0.053	0.051
2008	0.040	0.116	0.063	0.060
2009	0.039	0.121	0.062	0.060
2010	0.027	0.096	0.058	0.054
2011	0.029	0.061	0.043	0.042
2012	0.035	0.057	0.044	0.044
2013	0.030	0.082	0.046	0.044

Table 5.20. Chlorophyll *a* summary statistics for St. Johns River above Ocklawaha River under the 30 % TN 70 % TP anthropogenic reduction scenario

Year	Minimum (µg/L)	Maximum (µg/L)	Arithmetic Mean (µg/L)	Geometric Mean (µg/L)
2003	9	36	18	17
2004	5	57	23	19
2005	8	53	21	19
2006	10	52	24	22
2007	12	57	28	25
2008	5	49	19	17
2009	12	43	23	21
2010	10	50	27	24
2011	10	44	22	21
2012	11	30	18	18
2013	12	64	22	20

Table 5.21. TN summary statistics for St. Johns River above Ocklawaha River under the 30 % TN 70 % TP anthropogenic reduction scenario

Year	Minimum (mg/L)	Maximum (mg/l)	Arithmetic Mean (mg/L)	Geometric Mean (mg/L)
2003	0.85	1.18	1.00	1.00
2004	0.76	1.39	1.07	1.05
2005	0.84	1.43	1.05	1.04
2006	0.69	1.36	0.93	0.92
2007	0.69	1.42	1.00	0.98
2008	0.76	1.48	1.07	1.05
2009	0.77	1.22	1.01	1.00
2010	0.73	1.33	1.02	1.01
2011	0.70	1.20	0.89	0.89
2012	0.71	1.29	0.96	0.95
2013	0.70	1.43	0.92	0.91

Table 5.22. TP summary statistics for St. Johns River above Ocklawaha River under the 30 % TN 70 %TP anthropogenic reduction scenario

Year	Minimum (mg/L)	Maximum (mg/l)	Arithmetic Mean (mg/L)	Geometric Mean (mg/L)
2003	0.029	0.068	0.047	0.046
2004	0.031	0.088	0.055	0.053
2005	0.030	0.112	0.059	0.056
2006	0.026	0.059	0.045	0.044
2007	0.024	0.083	0.052	0.050
2008	0.041	0.111	0.062	0.060
2009	0.041	0.112	0.061	0.059
2010	0.029	0.086	0.053	0.051
2011	0.032	0.061	0.043	0.043
2012	0.035	0.058	0.045	0.045
2013	0.033	0.086	0.048	0.046

5.4.2 TMDL and Site-Specific Numeric Nutrient Interpretation Expressions

As described in **Section 5.2**, the chlorophyll *a* target of 40 µg/L not to be exceeded more than 40 consecutive days is protective of the designated use. Achieving this target in the lake required load reductions of 30% TN and 70 % TP from anthropogenic sources in the model simulation.

In order to express this target as a water quality standard in a manner consistent with the NNC, the 80th percentile of the chlorophyll *a* AGM concentrations for the TMDL model simulation was determined and expressed as criteria which will have the same duration and frequency components as the NNC. Therefore, the site-specific criterion for Lake George is an AGM concentration of 23 µg/L.

Rolling 7-year averages for external TN and TP loads to Lake George were calculated based on the 30 % TN and 70 % TP anthropogenic reduction scenario. **Table 5.23** and **5.24** present the existing, natural background, and TMDL condition TN and TP annual loads to the lake, respectively. The TN and TP annual loadings for each source used in the model simulations are provided in **Appendix F**. A 7-year period is consistent with the time frame used to assess waters for impairment of designated uses (Chapter 62-303, F.A.C.). The nutrient TMDLs and site-specific numeric nutrient interpretation expression for Lake George are the maximum of the 7-year averages of annual loads applied in the load reduction model scenario (**Table 5.25**).

Table 5.23. Annual TN Loads to Lake George for the Exiting, Natural Background, and TMDL Conditions

1 - Represents a long-term average 35% anthropogenic TN load reduction in watershed runoff to the lake.

Year	Existing Condition TN Load (KG)	Natural Background TN Load (KG)	Existing Anthropogenic TN Load (KG)	TN Load Reduction (KG)[1]	TMDL TN Load (KG)
2003	5,266,845	4,146,492	1,120,353	384,821	4,882,024
2004	5,967,874	4,706,178	1,261,697	430,118	5,537,756
2005	5,791,161	4,704,484	1,086,677	352,740	5,438,422
2006	2,164,893	1,712,621	452,272	157,607	2,007,286
2007	1,985,102	1,716,699	268,402	106,803	1,878,299
2008	6,380,449	4,601,297	1,779,152	572,627	5,807,821
2009	3,625,563	2,876,553	749,010	247,763	3,377,800
2010	2,675,707	2,131,766	543,941	209,922	2,465,785
2011	3,069,551	2,399,562	669,989	246,231	2,823,320
2012	3,018,265	2,398,814	619,451	226,596	2,791,669
2013	2,853,054	2,272,677	580,377	206,273	2,646,782
Maximum 7 Year Average (2003-2009)					4,132,773

Table 5.24. Annual TP Loads to Lake George for the Exiting, Natural Background, and TMDL Conditions

1 - Represents a 70% anthropogenic TP load reduction in watershed runoff to the lake.

Year	Existing Condition TP Load (KG)	Natural Background TP Load (KG)	Existing Anthropogenic TP Load (KG)	TP Load Reduction (KG)[1]	TMDL TP Load (KG)
2003	309,380	184,370	125,010	87,507	221,872
2004	459,070	266,878	192,192	134,534	324,532
2005	376,094	210,473	165,621	115,935	260,158
2006	109,830	67,054	42,776	29,943	79,886
2007	105,678	68,307	37,371	26,159	79,517
2008	512,450	300,121	212,329	148,630	363,816
2009	287,933	170,159	117,774	82,442	205,490
2010	175,431	105,538	69,893	48,925	126,504
2011	188,102	112,806	75,295	52,707	135,402
2012	158,600	95,053	63,548	44,483	114,122
2013	175,362	104,925	70,436	49,305	126,057
Maximum 7 Year Average (2003-2009)					219,324

Table 5.25. TMDL and site-specific nutrient interpretation for Lake George

[1] AGM concentration.
[2] Represents a maximum long-term (7-year) average of annual loads.

Chlorophyll *a* AGM (µg/L)[1]	TN Load (kg)[2]	TP Load (kg)[2]
23	4,132,773	219,324

The chlorophyll *a* targets and nutrient TMDLs for St. Johns River below Lake George and St. Johns River above Ocklawaha River are calculated and expressed similar to the values for Lake George. As Lake George outflow represents the majority of the nutrient loads to the downstream river segments, the lake TMDL loadings are assigned to the two river segments. The chlorophyll *a* criteria for the river segments are the conditions achieved under the TMDL loading scenario. **Tables 5.26** and **5.27** identify the expressions of the site-specific nutrient interpretations for St. Johns River below Lake George and St. Johns River above Ocklawaha River, respectively.

Table 5.26. TMDL and site-specific nutrient interpretation for St. Johns River below Lake George

[1] AGM concentration.
[2] Represents a maximum long-term (7-year) average of annual loads.

Chlorophyll *a* AGM (µg/L)[1]	TN Load (kg)[2]	TP Load (kg)[2]
23	4,132,773	219,324

Table 5.27. TMDL and site-specific nutrient interpretation for St. Johns River above Ocklawaha River

[1] AGM concentration.
[2] Represents a maximum long-term (7-year) average of annual loads.

Chlorophyll *a* AGM (µg/L)[1]	TN Load (kg)[2]	TP Load (kg)[2]
22	4,132,773	219,324

5.5 Critical Conditions/Seasonality

The estimated assimilative capacity is based on annual conditions, rather than critical/seasonal conditions, because (1) the methodology used to determine assimilative capacity does not lend itself very well to short-term assessments; (2) DEP is generally more concerned with the net change in overall primary productivity in the segment, which is better addressed on an annual basis; and (3) the methodology used to determine impairment is based on annual conditions (AGMs or arithmetic means).

Chapter 6: Determination of the TMDL

6.1 Expression and Allocation of the TMDL

A TMDL can be expressed as the sum of all point source loads (wasteload allocations or WLAs), nonpoint source loads (load allocations or LAs), and an appropriate margin of safety (MOS) that takes into account any uncertainty about the relationship between effluent limitations and water quality:

As mentioned previously, the WLA is broken out into separate subcategories for wastewater discharges and stormwater discharges regulated under the NPDES Program:

$$\mathbf{TMDL} \cong \sum \square \mathbf{WLAs}_{\mathbf{wastewater}} + \sum \square \mathbf{WLAs}_{\mathbf{NPDES\ Stormwater}} + \sum \square \mathbf{LAs} + \mathbf{MOS}$$

It should be noted that the various components of the TMDL equation may not sum up to the value of the TMDL because (1) the WLA for NPDES stormwater is typically based on the percent reduction needed for nonpoint sources and is accounted for within the LA, and (2) TMDL components can be expressed in different terms (for example, the WLA for stormwater is typically expressed as a percent reduction and the WLA for wastewater is typically expressed as mass per day).

WLAs for stormwater discharges are typically expressed as “percent reduction” because it is very difficult to quantify the loads from MS4s (given the numerous discharge points) and to distinguish loads from MS4s from other nonpoint sources (given the nature of stormwater transport). The permitting of stormwater discharges is also different than the permitting of most wastewater point sources. Because stormwater discharges cannot be centrally collected, monitored and treated, they are not subject to the same types of effluent limitations as wastewater facilities, and instead are required to meet a performance standard of providing treatment to the “maximum extent practical” through the implementation of best management practices (BMPs).

This approach is consistent with federal regulations (40 Code of Federal Regulations § 130.2[I]), which state that TMDLs can be expressed in terms of mass per time (e.g., pounds per day), toxicity, or other appropriate measure. The TMDLs for Lake George are expressed in terms of the maximum long-term average annual nutrient loads for nonpoint sources necessary to meet the chlorophyll a target (**Table 6.1**). The TMDLs for the St. Johns River below Lake George and St. Johns River above Ocklawaha River stream segments are likewise expressed in terms of the maximum long-term average annual loads for nonpoint sources necessary to attain the TMDLs for Lake George (**Table 6.2**). The majority of the nutrient loads to the two downstream segments are from Lake George. The TMDLs will constitute the site-specific numeric interpretation of the narrative nutrient criterion set forth in Paragraph 62-302.530(90)(b), F.A.C., that will replace the otherwise applicable NNC in Subsection 62-302.531(2), F.A.C., for these particular waters.

Table 6.1. TMDL components for Lake George

[1] The TMDL represents a long-term average annual load; dividing by 365 days yields daily TMDL loads of 9,564.4 kg TN/day and 507.4 kg TP/day, which complies with EPA requirements to express the TMDL on a daily basis. The loads result in a chlorophyll *a* AGM concentration of 23 µg/L.
[2] The percent reductions are for the existing total load to the lake. This equates to a long-term average 35% anthropogenic TN load reduction and a 70% anthropogenic TP load reduction.
NA = Not applicable

WBID	Parameter	TMDL (kg/yr)[1]	WLA Wastewater (kg/yr)	WLA NPDES Stormwater (% Reduction)[2]	LA (% Reduction)[2]	MOS
2893A	TN	4,132,773	NA	7	7	Implicit
2893A	TP	219,324	NA	29	29	Implicit

Table 6.2. TMDL components for St. Johns River below Lake George and St. Johns River above Ocklawaha

[1] The TMDL represents a long-term average annual load; dividing by 365 days yields daily TMDL loads of 9,564.4 kg TN/day and 507.4 kg TP/day, which complies with EPA requirements to express the TMDL on a daily basis. The loads result in a chlorophyll *a* AGM concentration of 23 µg/L for WBID 2893A5 and 22 µg/L for WBID 2213O.
[2] [2] The percent reductions are for the existing total load to the lake. This equates to a long-term average 35% anthropogenic TN load reduction and a 70% anthropogenic TP load reduction.
NA = Not applicable

WBID	Parameter	TMDL (kg/yr)[1]	WLA Wastewater (kg/yr)	WLA NPDES Stormwater (% Reduction)[2]	LA (% Reduction)[2]	MOS
2893A5	TN	4,132,773	NA	7	7	Implicit
2893A5	TP	219,324	NA	29	29	Implicit
2213O	TN	4,132,773	NA	7	7	Implicit
2213O	TP	219,324	NA	29	29	Implicit

6.2 Load Allocation (LA)

The modeling results identify that a 7% reduction in aggregate TN loads and a 29% reduction in aggregate TP loads are required to achieve the chlorophyll a target AGM of 23 µg/L, not to be exceeded. It should be noted that the load allocation includes loading from stormwater discharges that are not part of the NPDES Stormwater Program.

During the implementation phase of this TMDL, nutrient reductions for projects included in adopted BMAP areas upstream of the lake shall be taken into account when identifying reductions needed to meet the TMDLs.

6.3 Wasteload Allocation (WLA)

6.3.1 NPDES Wastewater Discharges

There are no NPDES wastewater facilities that discharge directly to Lake George, its adjacent watershed, or the two St. Johns River segments. As such, a WLA for wastewater discharges is not applicable.

6.3.2 NPDES Stormwater Discharges

Marion County (FLR04E021), Lake County (FLR04E106), and Volusia County (FLR04E033) all have Phase II-C MS4 permits, and FDOT District 5 has an MS4 permit (FLR04E024) that covers these counties. Based on the 2010 TIGER Census data, none of the urbanized areas covered by the MS4 permits is located in the Lake George adjacent watershed (including the two St. Johns River segments).

In the watershed area above Lake George, there are six counties that have MS4 permits. Seminole County (FLS000038) and Orange County (FLS000011) have Phase I-C MS4 permits. The counties of Brevard (FLR04E052), Osceola (FLR04E012), Indian River (FLR04E068), and St. Lucie (FLR04E029) have Phase II-C MS4 permits. Additionally, portions of FDOT District 4 (FLR04E083) and Florida's Turnpike Enterprise (FLR04E049) are located in the watershed area above the lake and are covered by MS4 permits.

Areas within the jurisdictions of MS4 permittees may be responsible for a 7% reduction in TN loads and a 29% reduction in TP loads in order to meet the TMDLs.

It should be noted that any MS4 permittee is only responsible for reducing the anthropogenic loads associated with stormwater outfalls that it owns or otherwise has responsible control over, and it is not responsible for reducing other nonpoint source loads in its jurisdiction.

During the implementation phase of this TMDL, nutrient reductions for projects included in adopted BMAP areas upstream of the lake shall be taken into account when identifying reductions needed to meet the TMDLs.

6.4 Margin of Safety (MOS)

TMDLs must address uncertainty issues by incorporating an MOS into the analysis. The MOS is a required component of a TMDL and accounts for the uncertainty about the relationship between pollutant loads and the quality of the receiving waterbody (CWA, Section 303[d][1][c]). Considerable uncertainty is usually inherent in estimating nutrient loading from nonpoint sources, as well as predicting water quality response. The effectiveness of management activities (e.g., stormwater management plans) in reducing loading is also subject to uncertainty.

The MOS can either be implicitly accounted for by choosing conservative assumptions about loading or water quality response, or explicitly accounted for during the allocation of loadings.

Consistent with the recommendations of the Allocation Technical Advisory Committee (DEP 2001), an implicit MOS was used in the development of these TMDLs because of the following conservative assumptions that were applied.

1. The water quality model used the fraction of nitrogen fixing cyanobacteria within the total cyanobacteria population as an indicator of the relative proportion of nitrogen fixation that could occur under nitrogen-limiting conditions. This parameter was input to the model as a time series developed from observations of phytoplankton community composition. This parameter was unaltered for the nutrient reduction scenarios. It is likely, however, that the nutrient reductions required to meet the TMDL would shift the composition of the phytoplankton community away from its present dominance by cyanobacteria and more towards diatoms and other eukaryotes. This shift would then lower community nitrogen fixation and increase nitrogen-limitation on growth, thus decreasing phytoplankton biomass and chlorophyll relative to the model predictions.

2. The model assumes that grazing rates on cyanobacteria are linearly proportional to cyanobacteria biomass with a constant proportionality constant. Both these assumptions are premised on the status of zooplankton grazers under present water quality conditions. However, as water quality improves, the zooplankton community will likely become more robust and increase relative grazing pressure on the declining phytoplankton. The greater grazing pressure under lower nutrient load scenarios would result in lower chlorophyll than predicted by the model.

3. The SJRWMD began a program of shad harvesting in Lake George in 2012. In other lakes (notably Lake Apopka) shad harvesting has been shown to improve water quality by direct removal of phosphorus, reduction of sediment recycling, and trophic level alterations. However, no assumptions were made regarding the potential for water quality improvement in Lake George due to shad harvesting for determining the assimilative capacity of the lake. If shad harvesting proves equally effective for improving water quality in Lake George as for Lake Apopka, then water quality targets could be possible at lower nutrient reductions than predicted by the model.

Chapter 7: Next Steps: Implementation Plan Development and Beyond

7.1 Implementation Mechanisms

Following the adoption of a TMDL, implementation takes place through various measures. Implementation of TMDLs may occur through specific requirements in NPDES wastewater and MS4 permits, and, as appropriate, through local or regional water quality initiatives or basin management action plans.

Facilities with NPDES permits that discharge to the TMDL waterbody must respond to the permit conditions that reflect target concentrations, reductions, or wasteload allocations identified in the TMDL. NPDES permits are required for Phase I and Phase II MS4s as well as domestic and industrial wastewater facilities. MS4 Phase I permits require that a permit holder prioritize and take action to address a TMDL unless the management actions are already defined in a BMAP. MS4 Phase II permit holders must also implement responsibilities defined in a BMAP.

7.2 Basin Management Action Plans

BMAPs are discretionary and are not initiated for all TMDLs. A BMAP is a TMDL implementation tool that integrates the appropriate management strategies applicable through existing water quality protection programs. DEP or a local entity may develop a BMAP that addresses some or all of the contributing areas to the TMDL waterbody.

Section 403.067, F.S. (FWRA) provides for the development and implementation of BMAPs. BMAPs are adopted by the DEP Secretary and are legally enforceable. BMAPs describe the management strategies that will be implemented as well as funding strategies, project tracking mechanisms, and water quality monitoring, as well as fair and equitable allocations of pollution reduction responsibilities to the sources in the watershed. BMAPs also identify mechanisms to address potential pollutant loading from future growth and development.

The most important component of a BMAP is the list of management strategies to reduce the pollution sources, as these are the activities needed to implement the TMDL. The local entities that will conduct these management strategies are identified and their responsibilities are enforceable. Management strategies may include wastewater treatment upgrades, stormwater improvements, and agricultural BMPs. Additional information about BMAPs is available online.

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Appendices

Appendix A: Background Information on Federal and State Stormwater Programs

In 1982, Florida became the first state in the country to implement statewide regulations to address the issue of nonpoint source pollution by requiring new development and redevelopment to treat stormwater before it is discharged. The Stormwater Rule, as authorized in Chapter 403, F.S., was established as a technology-based program that relies on the implementation of BMPs designed to achieve a specific level of treatment (i.e., performance standards), as set forth in Chapter 62-40, F.A.C. In 1994, the DEP stormwater treatment requirements were integrated with the stormwater flood control requirements of the water management districts, along with wetland protection requirements, into the Environmental Resource Permit regulations, as authorized under Part IV of Chapter 373, F.S.

Chapter 62-40, F.A.C., also requires the state's water management districts to establish stormwater pollutant load reduction goals (PLRGs) and adopt them as part of a Surface Water Improvement and Management (SWIM) Program plan, other watershed plan, or rule. Stormwater PLRGs are a major component of the load allocation part of a TMDL. To date, stormwater PLRGs have been established for Tampa Bay, Lake Thonotosassa, the Winter Haven Chain of Lakes, the Everglades, Lake Okeechobee, and Lake Apopka.

In 1987, the U.S. Congress established Section 402(p) as part of the federal CWA Reauthorization. This section of the law amended the scope of the federal NPDES permitting program to designate certain stormwater discharges as "point sources" of pollution. The EPA promulgated regulations and began implementing the Phase I NPDES stormwater program in 1990 to address stormwater discharges associated with industrial activity, which includes 11 categories of industrial activity, construction activities disturbing 5 or more acres of land, large and medium MS4s located in incorporated places, and counties with populations of 100,000 or more.

However, because the master drainage systems of most local governments in Florida are physically interconnected, the EPA implemented Phase I of the MS4 permitting program on a countywide basis, which brought in all cities (incorporated areas), Chapter 298 special districts; community development districts, water control districts, and the FDOT throughout the 15 counties meeting the population criteria. DEP received authorization to implement the NPDES stormwater program in October 2000. Its authority to administer the program is set forth in Section 403.0885, F.S.

The Phase II NPDES stormwater program, promulgated in1999, addresses additional sources, including small MS4s and small construction activities disturbing 1 and 5 acres, and urbanized areas serving a minimum resident population of at least 1,000 individuals. While these urban stormwater discharges are technically referred to as "point sources" for the purpose of regulation, they are still diffuse sources of pollution that cannot be easily collected and treated by a central treatment facility, as are other point sources of pollution such as domestic and industrial wastewater discharges. It should be noted that Phase I MS4 permits issued in Florida include a reopener clause that allows permit revisions to implement TMDLs when the implementation plan is formally adopted.

Appendix B: Information in Support of Site-Specific Interpretations of the Narrative Nutrient Criterion

Table B-1. Spatial extent of the numeric interpretation of the narrative nutrient criterion

Waterbody Location Information	Description of Waterbody Location Information
Waterbody name	Lake George, St. Johns River between Lake George, and St. Johns River above Ocklawaha River
Waterbody type(s)	Lake George: freshwater lake St. Johns River between Lake George and St. Johns River above Ocklawaha River: freshwater stream
Waterbody ID (WBID)	WBIDs 2893A, 2893A5 and 2213O (see **Figure 1.1** of this report)
Description	Lake George is located in northeast Florida along the St. Johns River between Astor and Welaka (south of Palatka). The surface area of the lake is 46,000 acres, and the watershed encompasses 159,747 acres. The mean lake residence time is 62.4 days. The average depth of the lake is 11.2 ft. The St. Johns River flows through the lake, entering the southern portion of the lake just above Astor. The river exits the lake at Drayton Island. The St. Johns River represents the primary inlet and outlet for the lake and represents approximately 95 % of the external nutrient load to the lake. The St. Johns River segments between Drayton Island and the confluence with the Ocklawaha River are dominated by conditions in Lake George. These segments represent a distance of 10.5 river miles. Flow is predominantly northward toward Jacksonville. However, there are periods of net upstream transport (toward Lake George) because of low-frequency ocean-level variability caused by winds over the Atlantic Shelf.
Specific location (latitude/longitude or river miles)	The center of Lake George is located at N: 170 40’28”/ W: -810 36’5.01”. The St. Johns River enters the southern portion of the lake just north of Astor and exits in the northern portion of the lake at Drayton Island. Drayton Island is approximately 110 miles upstream from the mouth of the St. Johns, and Buffalo Bluff is 89 miles upstream of the mouth. The two St. Johns River segments immediately downstream of Lake George are located in the 10.5 mile reach between Drayton Island and the confluence of the St. Johns River with the Ocklawaha River.
Map	**Figure 1.1** of this report shows the general location of Lake George and its watershed, and **Figure 4.2** shows land uses in the watershed.
Classification(s)	Lake George: Class III freshwater, colored, high-alkalinity lake St. Johns River between Lake George and the confluence with the Ocklawaha River: Class III freshwater stream
Basin name (Hydrologic Unit Code [HUC] 8)	Upper St. Johns River Basin (03080101)

Table B-2. Description of the numeric interpretation of the narrative nutrient criterion

Numeric Interpretation of Narrative Nutrient Criterion	Parameter Information Related to Numeric Interpretation of the Narrative Nutrient Criterion
NNC summary: Default classification (if applicable) and corresponding NNC	Because the long-term geometric mean color of Lake George exceeds 40 PCU, the lake is classified as a high-color lake, and the generally applicable NNC, which are expressed as AGM concentrations not to be exceeded more than once in any consecutive 3-year period, are chlorophyll a of 20 µg/L, TN of 1.27 to 2.23 mg/L, and TP of 0.05 to 0.16 mg/L. The St. Johns River between Lake George and the confluence with the Ocklawaha River is located in the peninsular part of the state. The stream NNC require no observable imbalance with corrected chlorophyll a, algal mats or blooms, nuisance macrophyte growth, and algal species composition, and either benthic invertebrate communities are healthy or AGM TN and TP concentrations measured in the stream do not exceed nutrient thresholds in more than 1 of any 3 continuous calendar years. Nutrient thresholds for this part of the state are 0.12 mg/L of TP and 1.54 mg/L of TN.
Proposed TN, TP, chlorophyll *a* (magnitude, duration, and frequency)	Numeric interpretations of the narrative nutrient criterion for Lake George: TN load of 4,132,773 kg/yr and TP load of 219,324 kg/yr, expressed as long-term average (7-year) annual loads not to be exceeded. For assessment purposes, the long-term average annual loads will be calculated using the annual loads of the most recent 7 years in the verified period. The nutrient loads resulted in a AGM lake chlorophyll *a* of 23 µg/L, and the department set the chlorophyll a criterion at 23 µg/L, expressed as an AGM concentration target not to be exceeded. Numeric interpretations of the narrative nutrient criterion for St. Johns River below Lake George: Since discharge from Lake George represents most of the loading to this segment, simulation results from the Lake George TMDL scenario were used to determine the nutrient TMDL for this segment: TN load of 4,132,773 kg/yr and TP load of 219,324 kg/yr, expressed as long-term average (7-year) annual loads not to be exceeded. These nutrient loads result in a AGM chlorophyll *a* level of 23 µg/L, and the department set the chlorophyll *a* criterion at 23 µg/L, expressed as an AGM concentration target not to be exceeded. Numeric interpretations of the narrative nutrient criterion for St. Johns River above Ocklawaha: Since discharge from Lake George represents most of the loading to this segment, simulation results from the Lake George TMDL scenario were used to determine the nutrient TMDL for this segment: TN load of 4,132,773 kg/yr and TP load of 219,324 kg/yr, expressed as long-term average (7-year) annual loads not to be exceeded. These nutrient loads result in a AGM chlorophyll *a* level of 22 µg/L, and the department set the chlorophyll *a* criterion at 22 µg/L, expressed as an AGM concentration target not to be exceeded. **Section 5.4.2** provides additional details.
Period of record used to develop the numeric interpretations of the narrative nutrient criterion for TN and TP criteria	The proposed TN and TP TMDLs were based on the hydrology records from 2003 through 2013 and the SJRWMD's 2009 land use GIS information.

Numeric Interpretation of Narrative Nutrient Criterion	**Parameter Information Related to Numeric Interpretation of the Narrative Nutrient Criterion**
Indicate how criteria developed are spatially and temporally representative of the waterbody or critical condition.	Simulations with the EFDC and CE-QUAL-ICM models spanned the 2002–13 period, which included both wet and dry years. Mean annual rainfall over the period was 53.7 inches, which was similar to the long-term average of 51 inches (1961–1990). Rainfall was below average in 2006, 2010, and 2011. The years 2004, 2005, and 2009 were wet. **Figures 5.1 and 5.2** show the sampling stations in Lake George and the St. Johns River segments. Stations are distributed across the lake and along the river segments. **Chapter 5** contains graphs showing water quality data for variables relevant to TMDL development.

Table B-3. Designated use, verified impairment, and approach to establish protective restoration targets

Designated Use Requirements	Information Related to Designated Use Requirements
History of assessment of designated use support	Lake George (WBID 2893A) was initially verified as impaired during the Cycle 1 assessment (verified period January 1, 1996, to June 30, 2003) for excessive nutrients because the TSI threshold of 60 was exceeded using the methodology in the IWR (Chapter 62-303, F.A.C.). As a result, the lake was included on the Cycle 1 Verified List of impaired waters for the Middle St. Johns River Basin adopted by Secretarial Order on May 27, 2004. During the Cycle 2 assessment (verified period January 1, 2001, to June 30, 2008), the impairment for nutrients was documented as continuing, as the TSI threshold of 60 was exceeded. The Cycle 3 assessment (verified period January 1, 2007, to June 30, 2014) applied the adopted NNC for lakes and the lake was placed on the verified list for both chlorophyll *a* and phosphorus. The St. Johns River below Lake George (WBID 2893A1) and the St. Johns River above Ocklawaha River (WBID 2213O) segments were on the Cycle 1 Verified List for nutrients based on exceedances of the stream chlorophyll *a* threshold of 20 µg/L. The impairment for nutrients was reaffirmed in the Cycle 2 assessment. WBID 2213O was also placed on the Verified List for un-ionized ammonia. In Cycle 3, WBID 2893A1 was retired, and associated data were reassigned to WBID 2893A5 (St. Johns River below Lake George). Based on the adopted NNC, WBID 2893A5 was verified impaired for nutrients based on chlorophyll *a* AGMs that exceeded the nutrient threshold of 20 µg/L more than once in a 3-year period. There were insufficient data for WBID 2213O in the Cycle 3 verified period to assess un-ionized ammonia, and so it remained impaired based on the previous assessment.
Basis for use support	DEP evaluated a site-specific interpretation of the narrative nutrient criterion for Lake George and 2 segments of the St. Johns River downstream from Lake George, taking into account ecological studies conducted by the SJRWMD in Lake George. The SJRWMD has recommended (**Section 5.2**) a chlorophyll *a* target of 40 µg/L not to be exceeded more than 40 consecutive days. This target would (1) maintain the diversity of the plankton community, (2) facilitate the upward transfer of primary production to higher trophic levels (and maintain zooplankton diversity), and (3) minimize the potential dominance of detrimental algal species and the production of algal toxins. Based on a model simulation using the site-specific data, DEP determined site-specific AGM chlorophyll *a* target concentrations, expressed as not to be exceeded, and long-term average nutrient loads that would attain the target chlorophyll a concentration recommended by the SJRWMD. When these criteria are achieved in Lake George, the nutrient loads entering the two downstream river segments will be protective of designated uses. As described in **Section 5.4.2**, this portion of the Lower St. Johns River is not representative of a wadeable stream, and the chlorophyll *a* targets established through TMDL development are most representative of the waterbody and will replace all other default stream floral metrics.
Summarize approach used to develop criteria and how it protects uses	The numeric interpretations of the narrative nutrient criteria for TN and TP were based on model simulations of lake conditions that reduced external anthropogenic nutrient loads to attain a protective ecological endpoint (the chlorophyll *a* target recommended by SJRWMD). TN and TP loads and the associated in-lake chlorophyll *a* concentrations attained by the TMDL will become the site-specific interpretation of the narrative nutrient criterion.

Designated Use Requirements	Information Related to Designated Use Requirements
	Because discharge from Lake George dominates conditions in the two immediate downstream segments of the St. Johns River, results from the Lake George TMDL simulation determined the nutrient TMDLs and site specific interpretations of TN, TP, and chlorophyll *a* for these segments. Because these nutrient criteria were based on an ecological endpoint that considered both floral and faunal components of the biological community in Lake George, they are inherently protective of the designated uses of the waterbodies.
How the TMDL will ensure that nutrient-related parameters are attained to demonstrate that the TMDL will not negatively impact other water quality criteria	Since the nutrient concentration targets are based on an ecological endpoint that is protective of both flora and fauna, other water quality criteria will not be adversely impacted and designated uses will be maintained. DEP notes that there were no impairments for DO or un-ionized ammonia in the lake. The proposed reductions in nutrient inputs will result in further improvements in water quality. Model simulations reflect water quality results from both high- and low-rainfall years as well as average and abnormally cold winters during a period when lake chlorophyll *a* concentrations and composition tended to be inversely related to rainfall. The implementation of the nutrient TMDL reductions for Lake George to achieve proposed criteria is expected to address the nutrient impairments in the two immediate downstream St. Johns River stream segments, since discharge from Lake George dominates conditions in these segments.

Table B-4. Documentation of the means to attain and maintain water quality standards in downstream waters

Downstream Waters Protection and Monitoring Requirements	Information Related to Downstream Waters Protection and Monitoring Requirements
Identification of downstream waters	The primary outlet from Lake George is the St. Johns River. Two segments (WBID 2893A5 and 2213O) of the St. Johns River between Lake George and the confluence with the Ocklawaha River are on the Verified List for chlorophyll *a* impairments. WBID 2213O was also on the Verified List for un-ionized ammonia. Water quality in both segments is dominated by discharge from Lake George. Achieving the TMDL nutrient reductions in Lake George will result in an estimated average reduction of 21 % to 25 % in chlorophyll AGMs in downstream segments (**Tables 5.8** and **5.17** and **Tables 5.11 through 5.20**). The Lower St. Johns River nutrient TMDL was approved under subparagraph 62-302.531(2)(a)1.a., F.A.C., as a site-specific numeric interpretation of the narrative nutrient criteria. That TMDL required a 30 % reduction in anthropogenic nitrogen and phosphorus loads upstream of Buffalo Bluff. Buffalo Bluff represented a downstream model boundary condition in the Lake George TMDL, and both St. Johns River segments included in this analysis are located in the Lake George simulated watershed. The Lake George TMDL nutrient reductions meet or exceed the reduction goals for the Lower St. Johns River nutrient TMDL. The reductions in nutrient loads prescribed in the Lake George TMDL are not expected to cause nutrient impairments downstream and will actually result in water quality improvements in the immediate downstream segments of the St. Johns River and waters farther downstream by reducing algal biomass and associated nutrients transported downstream.
Summary of existing monitoring and assessment related to implementation of Subsection 62-302.531(4), F.A.C., and trends tests in Chapter 62-303, F.A.C.	The SJRWMD conducts routine bimonthly monitoring at one station in Lake George and one station in the St. Johns River below Lake George. Other organizations (including DEP) sample these waterbodies as part of a strategic monitoring program. The frequency of sampling of these waterbodies meets the minimum sampling requirements for future assessments, including trend tests.

Table B-5. Documentation of Endangered Species Consideration

Administrative Requirements	Information for Administrative Requirements
Endangered Species Consideration	The U.S. Fish and Wildlife Service, identifies the threatened West Indian manatee (Trichechus manatus latirostris) and the endangered Shortnose Sturgeon (Acipenser brevirostrum) as species that are potentially affected by activities in the area of Lake George. As described in **Section 3.4**, the existing water quality in Lake George and the two downstream river segments does not appear to be negatively affecting the threatened and endangered aquatic species. The nutrient TMDLs will serve to improve the water quality conditions in the waterbodies.

Table B-6. Documentation to demonstrate administrative requirements are met

Administrative Requirements	Information for Administrative Requirements
Notice and comment notifications	A rule development public workshop was noticed on June 14, 2017 and held on July 17, 2017. Public comments were received on the TMDLs during the public review period which ended on July 28, 2017. DEP has prepared a responsiveness summary for these comments.
Hearing requirements and adoption format used; responsiveness summary	Following the publication of the Notice of Proposed Rule, DEP will provide a 21-day challenge period and a public hearing that will be noticed no less than 45 days prior.
Official submittal to the EPA for review and General Counsel certification	If DEP does not receive a rule challenge, the certification package for the rule will be prepared by the DEP program attorney. DEP will prepare the TMDLs and submittal package for the TMDLs to be considered a site-specific interpretation of the narrative nutrient criterion, and submit these documents to the EPA.

Appendix C. Lake George Sub- basin 2009 Land Uses

Available on request.

Appendix D: Water Quality Stations Sampled for Nutrients in WBIDs 2893A, 2893A6, and 2213O over the 1980–2016 Period

Available on request.

Appendix E: Lake George External Nutrient Loads Methodology

Available on request.

Appendix F: External Loads under Existing and TMDL Conditions and NNC Calculations

Available on request.

Appendix G: Important Links

Cover Page:
DEP website: www.dep.state.fl.us

Acknowledgments:
Email address for Moira Homann – moira,homann@dep.state.fl.us
Email address for Kevin Petrus – kevin.petrus@dep.state.fl.us

Websites:
DEP TMDL Program – http://www.dep.state.fl.us/water/tmdl/index.htm
DEP Identification of Impaired Surface Waters Rule –
http://www.dep.state.fl.us/legal/Rules/shared/62-303/62-303.pdf
Florida STORET Program – http://www.dep.state.fl.us/water/storet/index.htm
2016 Integrated Report – http://www.dep.state.fl.us/water/docs/2016-Integrated-Report.pdf
Criteria for Surface Water Quality Classifications –
http://www.dep.state.fl.us/legal/Rules/shared/62-302/62-302.pdf
Surface Water Quality Standards –
https://www.flrules.org/gateway/ChapterHome.asp?Chapter=62-302
EPA Region 4 – https://archive.epa.gov/pesticides/region4/water/tmdl/web/html/index-2.html
EPA National STORET Program – https://www.epa.gov/waterdata/storage-and-retrieval-and-water-quality-exchange

Chapter 4:
Florida Onsite Sewage Treatment and Disposal Systems Inventory –
http://www.floridahealth.gov/environmental-health/onsite-sewage/research/FLWMI/details.html

References:
Lusk, Toor, and Obreza, 2011 – http://edis.ifas.ufl.edu/ss551
Toor, Lusk, and Obreza, 2011 – https://edis.ifas.ufl.edu/ss550
U.S. Census Bureau *QuickFacts: Polk County, Florida* –
https://www.census.gov/quickfacts/table/PST045213/12105/embed/accessible

Chapter 7:
DEP BMAP website – http://www.dep.state.fl.us/water/watersheds/bmap.htm