Northeast District • Suwannee Basin Group• Withlacoochee River Basin

Final Report

Nutrient TMDLs for Lake Francis (WBID 3366A) and Documentation in Support of the Development of Site-Specific Numeric Interpretations of the Narrative Nutrient Criterion

Kyeongsik Rhew
Division of Environmental Assessment and Restoration
Florida Department of Environmental Protection

January 2026

2600 Blair Stone Road
Mail Station 3000
Tallahassee, FL 32399-2400
https://floridadep.gov

Executive Summary

This report presents the total maximum daily loads (TMDLs) developed to address the nutrient impairment of Lake Francis (WBID 3366A), located in the Withlacoochee River Basin that is part of the larger Suwannee Basin Group.

Lake Francis was identified as impaired for nutrients based on elevated chlorophyll *a* and total phosphorus (TP) concentrations exceeding the numeric nutrient criteria (NNC) in Subsection 62-302.531(2), Florida Administrative Code (F.A.C.). The lake was verified as impaired for nutrients and was included on the Verified List of Impaired Waters for the Suwannee Basin Group 1 in Assessment Cycle 4, adopted by Secretarial Order in October 2019.

TMDLs for TN and TP have been developed. **Table EX-1** lists supporting information for the TMDLs. Pursuant to Paragraph 62-302.531(2)(a), Florida Administrative Code (F.A.C.), these TMDLs will constitute the site-specific numeric interpretations of the narrative nutrient criterion set forth in Paragraph 62-302.530(48)(b), F.A.C., that will replace the otherwise applicable NNC in Subsection 62-302.531(2), F.A.C. The 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 Francis.

Type of Information	Description
Waterbody name (WBID)	Lake Francis (WBID 3366A)
Hydrologic Unit Code (HUC) 8	03110203 (Withlacoochee River Basin)
Use classification/ Waterbody designation	Class III Freshwater
Targeted beneficial uses	Fish consumption, recreation and propagation and maintenance of a healthy, well-balanced population of fish and wildlife
303(d) listing status	Placed on the Verified List of Impaired Waters for the Suwannee Group 1 Basin adopted via Secretarial Order in October 2019.
TMDL pollutants	Total nitrogen (TN) and total phosphorus (TP)
TMDLs and site-specific interpretations of the narrative nutrient criterion	**Lake Francis (WBID 3366A):** **Chlorophyll *a*:** 20 micrograms per liter (µg/L), expressed as an annual geometric mean (AGM) concentration not to be exceeded more than once in any 3-year period. **TN:** 896 kilograms per year (kg/yr), expressed as a 5-year rolling average load not to be exceeded. **TP:** 73 kg/yr, expressed as a 5-year rolling average load not to be exceeded.
Load reductions required to meet the TMDLs	**WBID 3366A:** A 48 % TN reduction and a 53 % TP reduction to achieve the applicable AGM chlorophyll *a* criterion for low-color, high-alkalinity lakes.
Concentration-based lake restoration targets (for informational purposes only)	**WBID 3366A:** The nutrient concentrations corresponding to the applicable chlorophyll *a* numeric nutrient criterion and the loading-based criteria are a TN AGM of 0.80 milligrams per liter (mg/L) and a TP AGM of 0.05 mg/L, not to be exceeded in any year.

Acknowledgments

This analysis was accomplished thanks to significant contributions from staff in the Florida Department of Environmental Protection (DEP) Division of Environmental Assessment and Restoration, specifically the Watershed Services Program, Watershed Assessment Section, Standards Development Section, Water Quality Restoration Program and Watershed Evaluation and TMDL Section. DEP also recognizes the Suwannee River Water Management District and Madison County for their contributions towards understanding the issues, history and processes at work in the Lake Francis watershed.

For additional information regarding the development of this report, contact the Division of Environmental Assessment and Restoration office at:

2600 Blair Stone Road
Mail Station 3000
Tallahassee, FL 32399-2400
Phone: (850) 245–8668

Contents

List of Figures

List of Tables

List of Acronyms and Abbreviations

µg/L	Micrograms Per Liter
µmhos/cm	Micromhos/Centimeter
ac-ft	Acre-Feet
ac-ft/yr	Acre-Feet Per Year
AGM	Annual Geometric Mean
AMC	Antecedent Moisture Condition
$ASRC_{wb}$	Average Stormwater Runoff Coefficient
BMAP	Basin Management Action Plan
BMP	Best Management Practice
$CaCO_3$	Calcium Carbonate
CDM	Camp Dresser McKee
CFR	Code of Federal Regulations
Chl*a*	Chlorophyll *a*
cm	Centimeter
CWA	Clean Water Act
DCIA	Directly Connected Impervious Area
DEP	Florida Department of Environmental Protection
DO	Dissolved Oxygen
EMC	Event Mean Concentration
EPA	U.S. Environmental Protection Agency
° F.	Degrees Fahrenheit
F.A.C.	Florida Administrative Code
DOH	Department of Health
DOT	Department of Transportation
FL	Florida
F.S.	Florida Statutes
FWRA	Florida Watershed Restoration Act
FWS	U.S. Fish and Wildlife Service
GIS	Geographic Information System
hm^3/yr	Cubic Hectometers Per Year
HUC	Hydrologic Unit Code
IPaC	Information for Planning and Conservation
IWR	Impaired Surface Waters Rule
LA	Load Allocation
lbs	Pounds
kg/yr	Kilogram Per Year
m	Meter
m/yr	Meters Per Year

mg/L	Milligrams Per Liter
$mg/m^2/yr$	Milligrams Per Square Meter Per Year
MOS	Margin of Safety
MS4	Municipal Separate Storm Sewer System
NA	Not Applicable
ND	No Data
NDCIA	Nondirectly Connected Impervious Area
NLDAS	North American Land Data Assimilation System
NMFS	National Marine Fisheries Service
NNC	Numeric Nutrient Criteria
NOAA	National Oceanic and Atmospheric Administration
NPDES	National Pollutant Discharge Elimination System
NRCS	Natural Resources Conservation Service
OSTDS	Onsite Sewage Treatment and Disposal System
PCU	Platinum Cobalt Unit
PLRG	Pollutant Load Reduction Goal
PO_4	Orthophosphate
POR	Period of Record
PRC	Proportional Runoff Coefficient
ROC	Runoff Coefficient
SJRWMD	St. Johns River Water Management District
SRWMD	Suwannee River Water Management District
SWIM	Surface Water Improvement and Management (Program)
TDN	Total Dissolved Nitrogen
TDP	Total Dissolved Phosphorus
TIGER	Topologically Integrated Geographic Encoding and Referencing
TMDL	Total Maximum Daily Load
TN	Total Nitrogen
TP	Total Phosphorus
USACE	U.S. Army Corps of Engineers
WBID	Waterbody Identification (Number)
WDMutil	Watershed Data Management Utility Program
WLA	Wasteload Allocation
WQS	Water Quality Standards
WRF	Weighted Runoff Coefficient
WWTF	Wastewater Treatment Facility

Chapter 1: Introduction

1.1 Purpose of Report

This report presents the total maximum daily loads (TMDLs) developed to address the nutrient impairment of Lake Francis, located in the Withlacoochee River Basin which is part of the Suwannee Basin Group. Pursuant to paragraph 62-302.531(2)(a), Florida Administrative Code (F.A.C.), the TMDLs will also constitute the site-specific numeric interpretations of the narrative nutrient criterion set forth in paragraph 62-302.530(48)(b), F.A.C., that will replace the otherwise applicable numeric nutrient criteria (NNC) in subsection 62-302.531(2), F.A.C. The waterbody was verified as impaired for nutrients using the methodology in the Identification of Impaired Surface Waters Rule (IWR) (Chapter 62-303, F.A.C.) and included on the Verified List of Impaired Waters for the Suwannee Basin that was adopted by Secretarial Order in October 2019.

The TMDL process quantifies the amount of a pollutant that can be assimilated in a waterbody, identifies the sources of the pollutant, and provides water quality targets needed to comply with applicable water quality criteria based on the relationship between pollutant sources and water quality in the receiving waterbody. The TMDLs establish the allowable loadings to Lake Francis that would restore the waterbody so that it meets the applicable water quality criteria for nutrients.

1.2 Identification of Waterbody

Lake Francis is a 25-acre lake located in the city of Madison. The lake drains a watershed of about 510 acres (0.78 square miles). There are no major inlet streams to the lake. The major sources of water to the lake include surface runoff from the watershed, seepage flow from ground water, and direct rainfall onto the lake. The lake flows southeast through a drainpipe to a wetland in Norton Creek watershed.

For assessment purposes, the Florida Department of Environmental Protection (DEP) divided the Withlacoochee River Basin (Hydrologic Unit Code [HUC] 8 – 03110203) into watershed assessment polygons with a unique **w**ater**b**ody **id**entification (WBID) number for each watershed or surface water segment. Lake Francis is WBID 3366A. **Figure 1.1** shows the location of the waterbody in the basin and major geopolitical and hydrologic features in the region. **Figure 1.2** contains a more detailed map of the Lake Francis Watershed.

Figure 1.1. Location of the Lake Francis (WBID 3366A) Watershed in the Tampa Bay Tributaries Basin Group and major geopolitical features in the area.

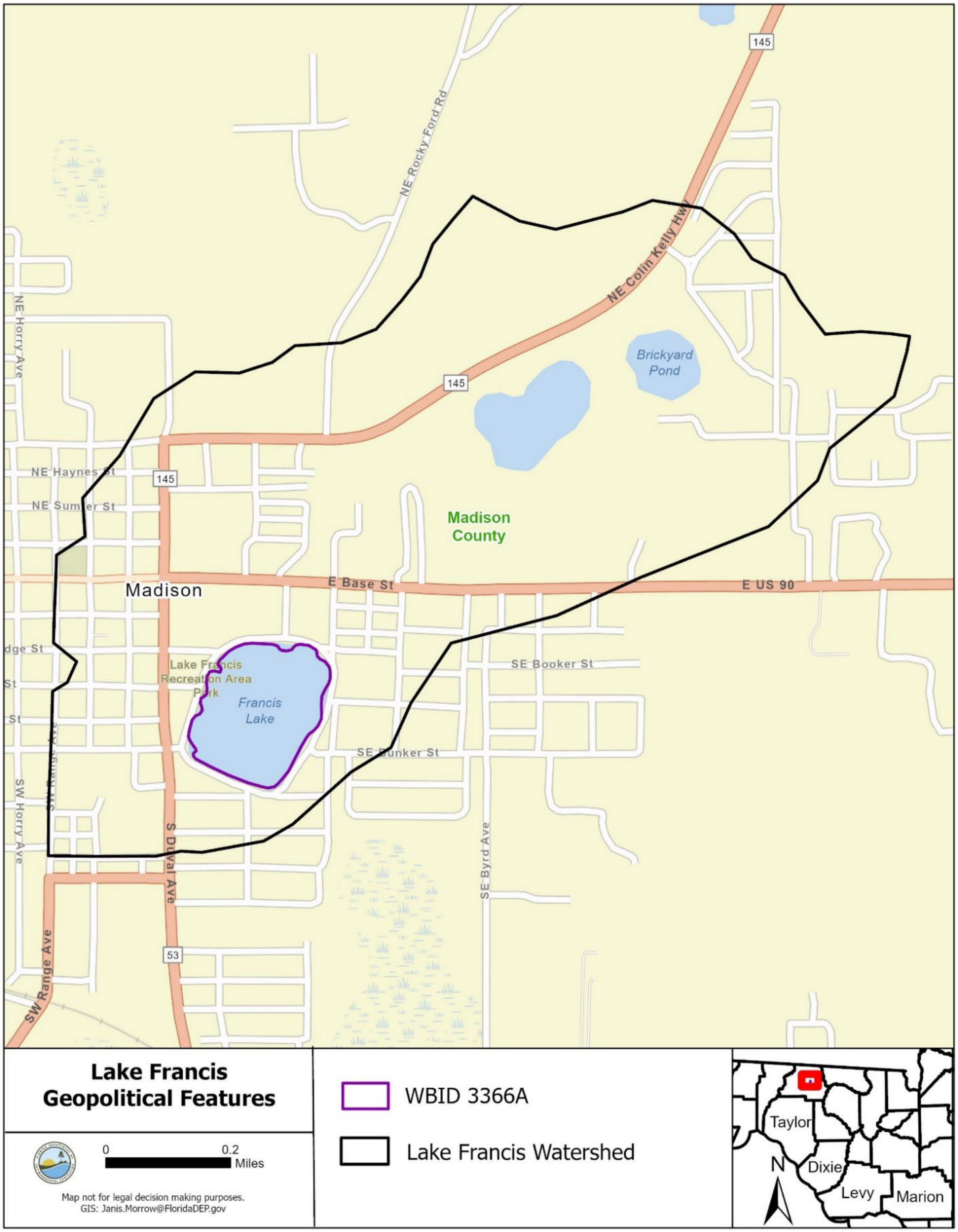


Figure 1.2. Lake Francis (WBID 3366A) Watershed and major hydrologic and geopolitical features in the area.

1.3 Watershed Information

1.3.1 Population and Geopolitical Setting

Lake Francis watershed is in the City of Madison, Florida within Madison County. According to data available from the U.S. Census Bureau (2023), the population of Madison County is 18,228, with a density of 26 people per square mile. The county occupies an area of 697 square miles and contains 8,497 housing units, with a housing density of 12 houses per square mile. The City of Madison has a population of 2,960 (2022).

1.3.2 Topography

Lake Francis lies in the Northern Peninsular Karst Plains Lake Region (Region 65-06), This region is also called the Suwannee Limestone Plains which are relatively well-drained flat to rolling karst upland (Griffith et al. 1997). The region has lakes that are somewhat acidic with moderate alkalinity. Nutrient levels in the region are variable, but phosphorus levels are high. The elevations in the Lake Francis Watershed range from 150 to 190 ft.

1.3.3 Hydrogeological Setting

The Lake Francis Watershed is located in a humid subtropical climate zone characterized by hot and humid summers, mild winters and a wet season between June and September. The watershed's long-term average rainfall was 51.7 inches per year (in/yr) from 1910 to 2016. Rainfall data were obtained from the Northeast Regional Climate Center Online Weather Data (2022) at Madison Station. The annual average temperature was 68.3 degrees Fahrenheit (° F.).

The hydrologic characteristics of soil can significantly influence the capability of a watershed to hold rainfall or produce surface runoff. Soils are generally classified as one of four major types based on their hydrologic characteristics (Viessman et al. 1989). Type A soils have high infiltration rates even if thoroughly wetted. They consist chiefly of deep, well-drained to excessively drained sands or gravels. These soils have a high rate of water transmission. Type B soils have moderate infiltration rates if thoroughly wetted. They consist chiefly of moderately deep to deep, moderately well-drained to well-drained soils with moderately fine to moderately coarse textures. These soils have a moderate rate of water transmission. Type C soils have slow infiltration rates if thoroughly wetted. They consist chiefly of soils with a layer that impedes the downward movement of water, or soils with moderately fine to fine texture. These soils have a slow rate of water transmission. Type D soils have very slow infiltration rates if thoroughly wetted. They consist chiefly of clay soils with a high swelling potential, soils with a permanent high-water table, soils with a clay pan or clay layer at or near the surface, and shallow soils over nearly impervious materials. These soils have a very slow rate of water transmission. When unsaturated, Group A/D, B/D and C/D soils are characteristic of Group A, B and C soils, respectively, and when saturated they are more characteristic of Group D soils.

Table 1.1 lists the soil hydrologic groups in the Lake Francis Watershed. Type A and B soils predominate in the watersheds, occupying about 80%. Unclassified represents the lake bottom soils. **Figure 1.3** contains detailed maps of the soil hydrologic groups in the watershed.

Table 1.1. Acreage of hydrologic soil groups in the Lake Francis Watershed.

Hydrologic Soil Group	Area (acres)	%
A	348.4	68
A/D	12.9	3
B	68.0	13
B/D	3.5	1
C	32.2	6
Unclassified	44.8	9
Total	**509.8**	**100.0**

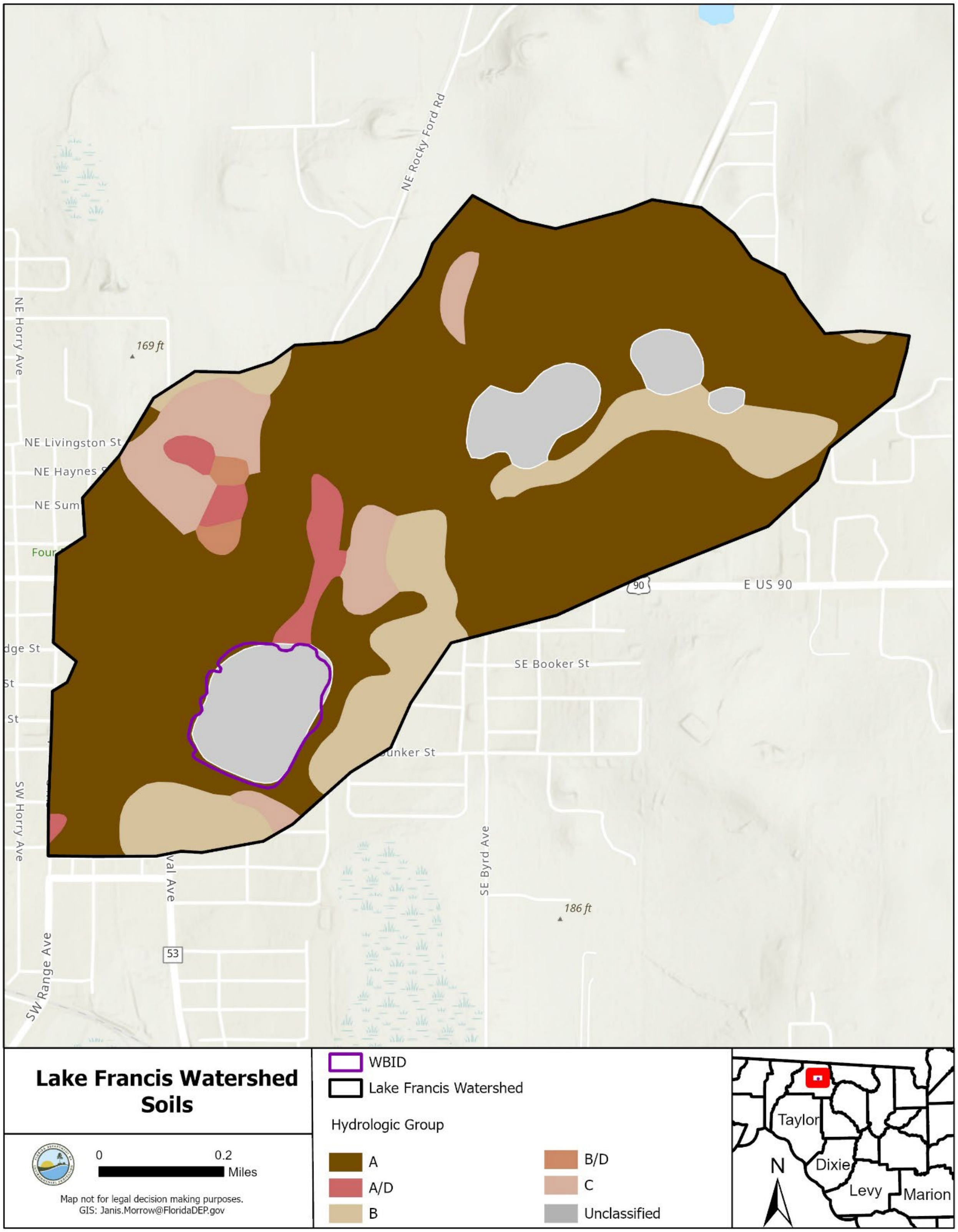


Figure 1.3. Hydrologic soil groups in the Lake Francis Watershed.

Chapter 2: Water Quality Assessment and Identification of Pollutants of Concern

2.1 Statutory Requirements and Rulemaking History

Section 303(d) of the federal Clean Water Act (CWA) requires states to submit to the U.S. Environmental Protection Agency (EPA) lists of surface waters that do not meet applicable 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 Florida Watershed Restoration Act (FWRA) (section 403.067, Florida Statutes [F.S.]) directed DEP to develop, and adopt by rule, a science-based methodology to identify impaired waters. The Environmental Regulation Commission adopted the methodology as Chapter 62-303, F.A.C. (the IWR), in 2001. The rule was last amended in 2016.

The list of impaired waters in each basin, referred to as the Verified List, is also required by the FWRA (subsection 403.067[4], F.S.). In the past, the state's 303(d) list has been amended annually to include basin updates for 20% of the state every year, conducted as part of a rotating basin approach to cover the whole state every five years. Beginning with the 2022 biennial assessment, the state's 303(d) list is amended biennially and will consist of a statewide assessment every two years.

2.2 Classification of the Waterbody and Applicable Water Quality Standards

Lake Francis is a Class III (fresh) waterbody, with a designated use of fish consumption, recreation and propagation and maintenance of a healthy, well-balanced population of fish and wildlife. The Class III water quality criteria applicable to the verified impairments for these waterbodies are Florida's nutrient criteria in paragraph 62-302.530(48)(b), F.A.C. Florida adopted NNC for lakes, spring vents and streams in 2011. These were approved by the EPA in 2012 and became effective in 2014.

The applicable lake NNC are dependent on alkalinity, measured in milligrams per liter (mg/L) as calcium carbonate ($CaCO_3$) and true color (color), measured in platinum cobalt units (PCU), based on long-term period of record (POR) geometric means. For the purpose of subparagraph 62-302.531(2)(b)1., F.A.C., color is assessed as true color and should be free from turbidity. Lake color and alkalinity are based on a minimum of ten data points over at least three years with at least one data point in each year. Based on available color and alkalinity results (**Table 2.1),** Lake Francis is characterized as low-color (≤ 40 PCU), high-alkalinity (> 20 mg/L $CaCO_3$). The POR data for the lakes are from IWR Database Run 66.

Table 2.1. Long-term geometric means for color and alkalinity for the POR in Lake Francis.

Waterbody	POR for Color	# of Years of Color Data	# of Color Samples	Long-Term Geometric Mean Color (PCU)	POR for Alkalinity	# of Years of Alkalinity Data	# of Alkalinity Samples	Long-Term Geometric Mean Alkalinity (mg/L $CaCO_3$)
Lake Francis	1971–2023	14	66	14	1971–2023	13	59	69

Table 2.2 lists the NNC for Florida lakes specified in Subparagraph 62-302.531(2)(b)1., F.A.C. The relevant row for Lake Francis is the middle row corresponding to low-color, high-alkalinity lakes (color ≤ 40 PCU; alkalinity > 20 mg/L $CaCO_3$). The chlorophyll *a* NNC for low-color, high-alkalinity lakes is an annual geometric mean (AGM) value of 20 µg/L, not to be exceeded more than once in any consecutive 3-year period.

The associated total nitrogen (TN) and total phosphorus (TP) criteria for a lake can vary annually, depending on the availability of data for chlorophyll *a* and the concentrations of chlorophyll *a* in the lake. If there are sufficient data to calculate an AGM for chlorophyll *a* and the AGM does not exceed the chlorophyll *a* criterion for the lake type listed in **Table 2.2**, then the corresponding numeric interpretations for TN and TP are the maximum values. If there are insufficient data to calculate the AGM for chlorophyll *a* for a given year, or the AGM for chlorophyll *a* exceeds the values in the table for the lake type, then the corresponding numeric interpretations for TN and TP are the minimum values.

Table 2.2. Chlorophyll *a*, TN and TP criteria for Florida lakes (subparagraph 62-302.531(2)(b)1., F.A.C.).

[a] 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.
Note: Values shown in boldface type and shaded represent the relevant NNC for Lake Francis

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

2.3 Determination of the Pollutant of Concern

2.3.1 Data Providers

The data providers for Lake Francis include DEP and Suwannee River Water Management District (SRWMD). **Table 2.3** lists the data providers for Lake Francis, including corresponding stations and monitoring beginning and ending dates. DEP was the primary data provider for the assessment that identified the nutrient impairment. **Figure 2.1** shows the lake sampling locations.

Table 2.3. Lake Francis data provider.

Sampling Station	Data Provider	Activity Beginning Date	Activity Ending Date
21FLA 21020056	DEP	1971	2012
21FLA 21020057	DEP	1971	2012
21FLA 21020058	DEP	1971	2012
21FLGW 36282	DEP	2009	2009
21FLGW 37339	DEP	2009	2009
21FLGW 39673	DEP	2011	2011
21FLGW 40387	DEP	2011	2011
21FLGW 42437	DEP	2012	2012
21FLGW 44297	DEP	2013	2013
21FLGW 50083	DEP	2016	2016
21FLGW 54225	DEP	2018	2018
21FLGW 59254	DEP	2021	2021
21FLGW 63235	DEP	2023	2023
21FLSUW 129251	SRWMD	2020	2023
21FLSUW FRA001C1	SRWMD	1998	2003
21FLTLHRG1TLHR0022	DEP	2016	2016
21FLTLHRG1TLHR0045	DEP	2017	2018
21FLTLHRHAB_062220_0003	DEP	2020	2020
21FLWQA BLOOM30	DEP	2019	2019
21FLWQSP21020123	DEP	2007	2008
21FLWQSPMAD152UL	DEP	2005	2006

The individual water quality measurements discussed in this report are available in IWR Run 65 and are available on request.

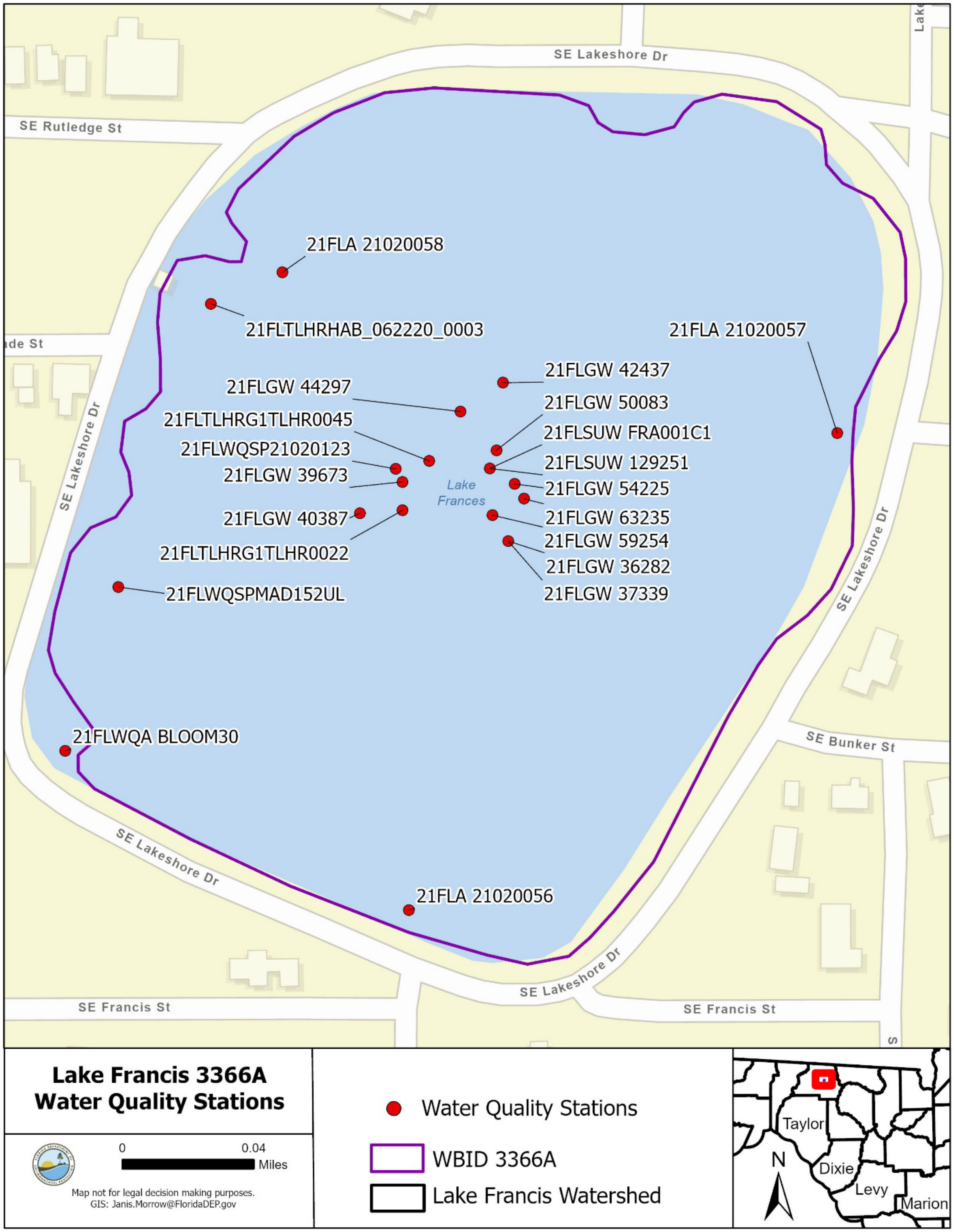


Figure 2.1. Water quality monitoring stations in Lake Francis.

2.3.2 Information on Verified Impairment

Lake Francis (WBID 3366A) was assessed for nutrients as part of the Group 1, Cycle 4 IWR assessment. The verified period was January 1, 2011, to June 30, 2018. Data for the Group 1, Cycle 4 IWR assessment are stored in the IWR Run 56 Access Database. The lake was identified as nutrient impaired (Category 5) and was included on the Verified List of Impaired Waters.

Table 2.4 lists the lake AGM values for chlorophyll *a*, TN and TP for the 2011–18 verified period and AGM results for subsequent years, calculated using the most recent results found in the IWR Run 66 Database. To be assessed as impaired (Category 5) for nutrients, AGMs for a particular nutrient had to have exceeded the NNC more than once in a three-year period.

Table 2.4. Lake Francis AGM values for the 2011–23 period.

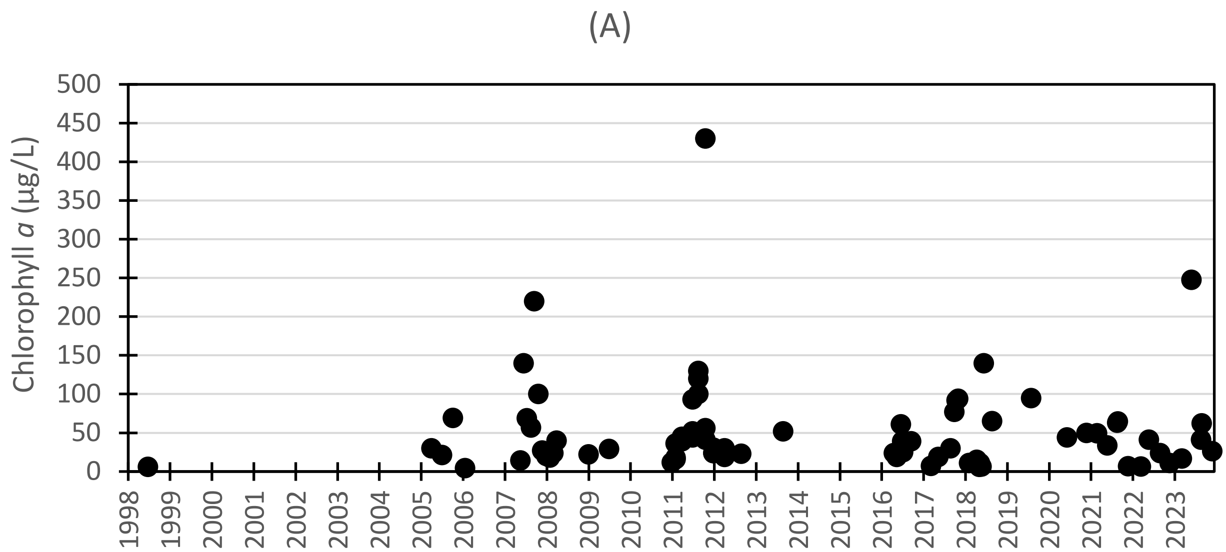
ID = Insufficient data

Note: Values shown in boldface type and shaded are greater than the NNC for lakes. Rule 62-302.531, 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	Chlorophyll *a* (µg/L)	TN (mg/L)	TP (mg/L)
2011	**52**	**1.72**	**0.09**
2012	ID	ID	ID
2013	ID	ID	ID
2014	ND	ND	ND
2015	ND	ND	ND
2016	**32**	0.88	**0.14**
2017	**38**	**1.37**	**0.07**
2018	18	0.90	0.09
2019	ID	ID	ID
2020	ID	ID	ID
2021	**34**	**1.57**	**0.11**
2022	16	1.26	**0.12**
2023	**49**	**1.33**	**0.11**

2.3.3 Historical Variation in Water Quality Variables

For Lake Francis (WBID 3366A), water quality data have been collected at 21 sampling stations starting in 1971 (**Table 2.3** and **Figure 2.1**). Prior to 2007, the limited amount of data available for the lake are insufficient to calculate AGM values. **Figures 2.2** through **2.5** show the chlorophyll *a*, TN and TP data collected at all the stations in the waterbody using (a) individual samples and (b) AGMs in the POR from the IWR Database (IWR Run 66).



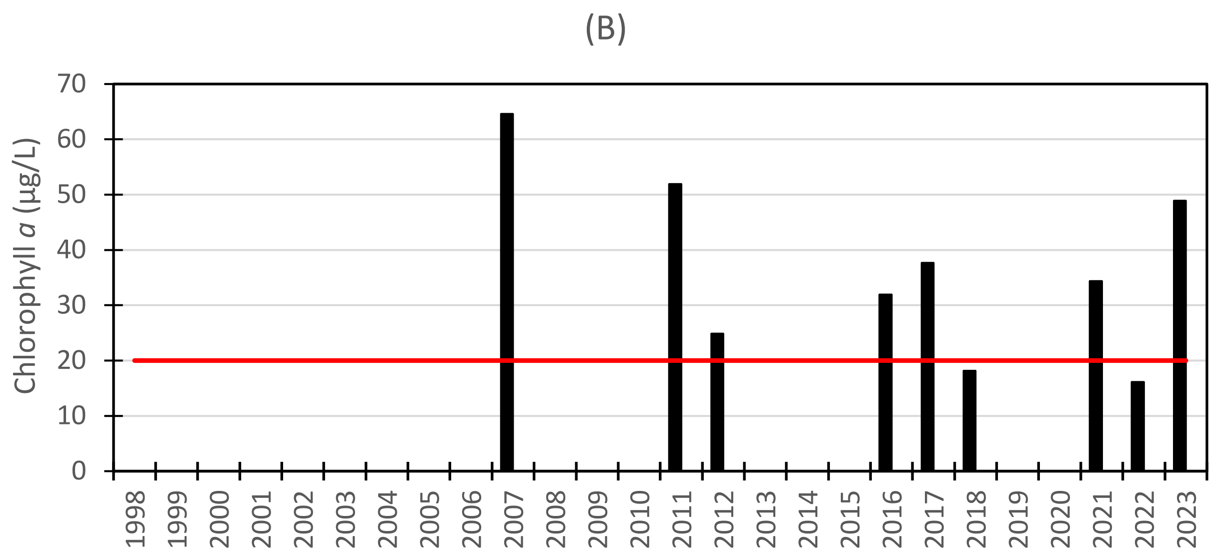


Figure 2.2. Chlorophyll *a* corrected measured in WBID 3366A: (a) individual sampling results, (b) AGMs in the POR. Red line represents the chlorophyll *a* NNC value of 20 µg/L, expressed as an AGM.

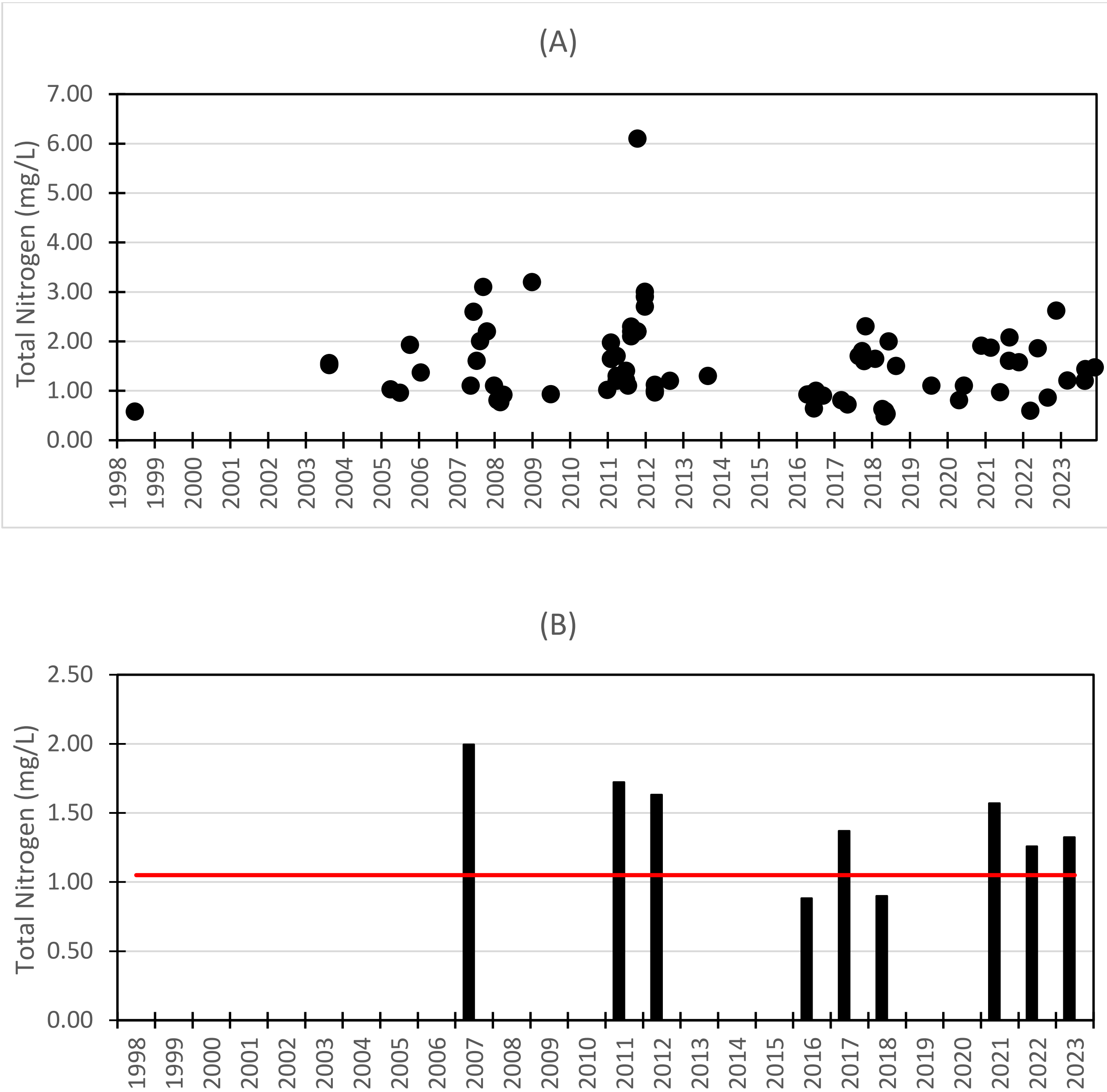


Figure 2.3. TN measured in WBID 3366A: (a) individual sampling results, (b) AGMs in the POR. Red line represents the TN minimum NNC value of 1.05 mg/L, expressed as an AGM.

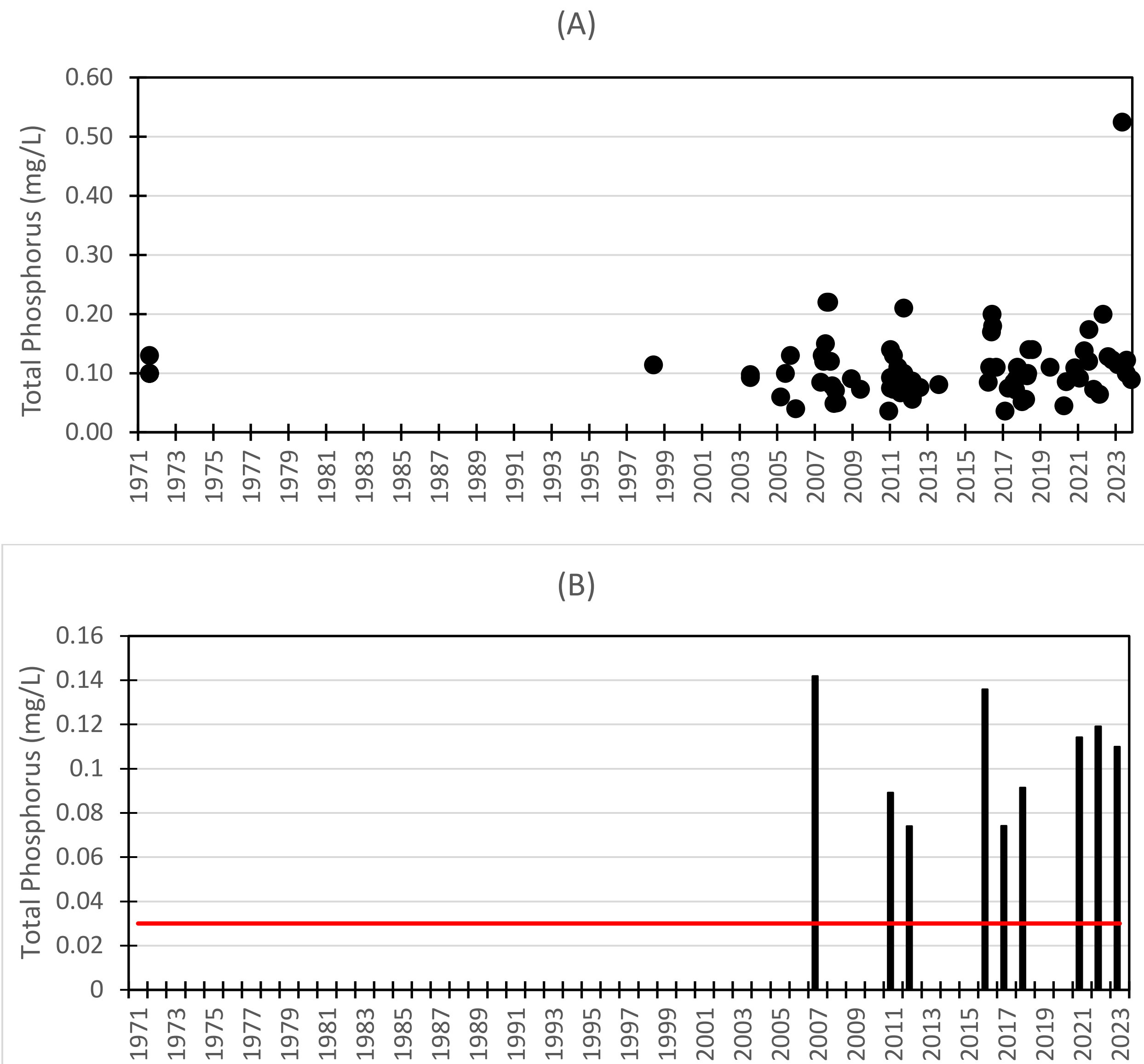


Figure 2.4. TP measured in WBID 3366A: (a) individual sampling results, (b) AGMs in the period of record. Red line represents the TP minimum NNC value of 0.03 mg/L, expressed as an AGM.

2.3.4 Relationships Between Water Quality Variables

For Lake Francis, simple linear regression analyses were used to evaluate the relationships between the pollutant variables (TN and TP) and the response variable (chlorophyll *a*). **Figures 2.5** and **2.6** show the relationships between chlorophyll *a* and TN AGM values, and chlorophyll *a* and TP AGM values from 2007 to 2023.

There was a marginally significant relationship between chlorophyll *a* and TN ($R^2 = 0.4535$, $p = 0.047$), but not significant between chlorophyll *a* and TP ($R^2 = 0.0822$, $p = 0.455$).

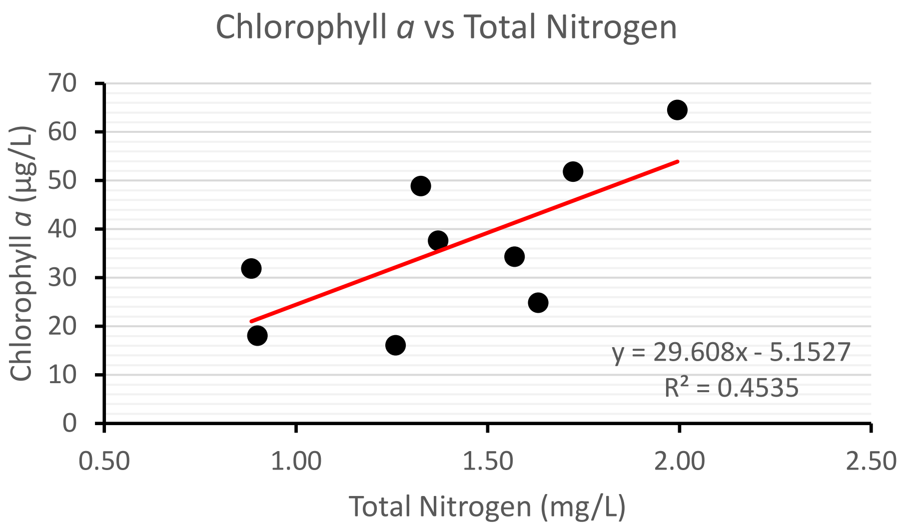


Figure 2.5. Lake Francis chlorophyll *a* AGMs vs. TN AGMs.

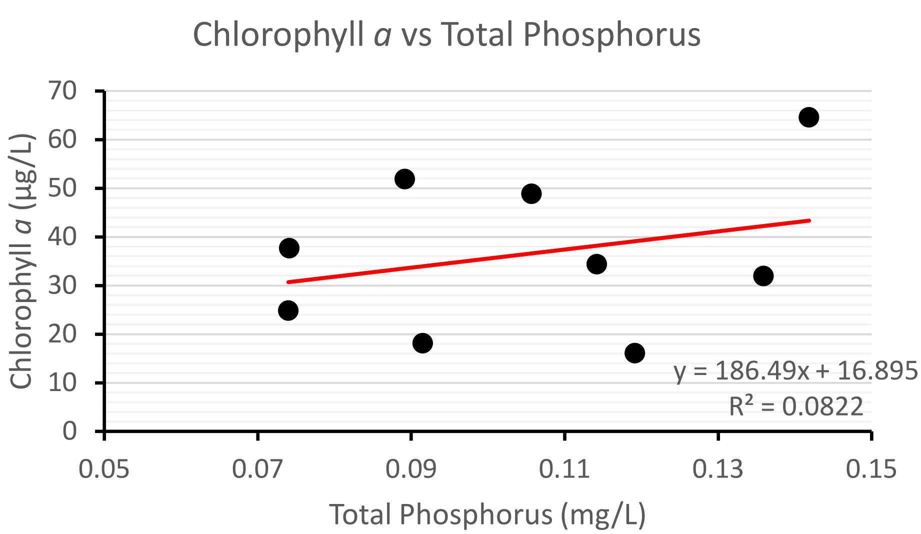


Figure 2.6. Lake Francis chlorophyll *a* AGMs vs. TP AGMs.

Chapter 3: Site-Specific Numeric Interpretation of the Narrative Nutrient Criterion

3.1 Establishing the Site-Specific Interpretation

Pursuant to paragraph 62-302.531(2)(a), F.A.C., the nutrient TMDLs presented in this report, upon adoption into Chapter 62-304.505, F.A.C., will constitute the site-specific numeric interpretations of the narrative nutrient criterion set forth in paragraph 62-302.530(48)(b), F.A.C., and will replace the otherwise applicable NNC from subparagraph 62-302.531(2)(b)1., F.A.C. **Table 3.1** lists the elements of the nutrient TMDLs that constitute the site-specific numeric interpretations of the narrative nutrient criterion. **Appendix B** summarizes the relevant details to support the determination that the TMDLs provide for the protection of Lake Francis for the attainment and maintenance of water quality standards in downstream waters (pursuant to subsection 62-302.531(4), F.A.C.), and to support using the nutrient TMDLs as the site-specific numeric interpretations of the narrative nutrient criterion.

When developing TMDLs to address nutrient impairment, it is essential to address those nutrients that typically contribute to excessive plant growth. In Florida waterbodies, nitrogen and phosphorus are most often the limiting nutrients. A limiting nutrient is a chemical that is 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 a better approach to controlling 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 2012).

3.2 Site-Specific Response Variable Target Selection

The generally applicable chlorophyll *a* criteria for lakes were established by taking into consideration an analysis of lake chlorophyll *a* concentrations statewide, comparisons with a smaller population of select reference lakes, paleolimnological studies, expert opinions, user perceptions and biological responses. Based on these resources, DEP concluded that an annual geometric mean chlorophyll *a* of 20 µg/L in high-color and low-color, high-alkalinity lakes is protective of the designated uses of recreation and aquatic life support (DEP 2012). Color and alkalinity were used as morphoedaphic factors to predict the natural trophic status of lakes. DEP developed a chlorophyll *a* criterion of 20 µg/L for both high-color (> 40 PCU) lakes and low-color (≤ 40 PCU), high-alkalinity (≥ 20 $CaCO_3$) lakes.

There are no available data suggesting that Lake Francis differs from the lakes used to develop the NNC. Therefore, DEP has determined that the generally applicable chlorophyll *a* NNC for a low-color, high-alkalinity lake is the most appropriate TMDL restoration target for the lake (and will remain the applicable water quality criterion).

3.3 Expression of the Site-Specific Numeric Interpretations

Site-specific numeric interpretations of the narrative nutrient standard for Lake Francis were determined for TN and TP using the modeling approach discussed in **Chapter 5** to determine the nutrient loads that resulted in the lake attaining the chlorophyll *a* criterion. The modeling related annual watershed TN and TP loading to in-lake chlorophyll *a*, TN and TP concentrations. For Lake Francis, nutrient and chlorophyll concentrations were simulated from 2016 to 2023.

The model was used to determine the annual TN and TP loads necessary to attain the chlorophyll *a* target. The chlorophyll *a* target was based on the applicable criterion of 20 µg/L as an AGM not to be exceeded more than once in any consecutive 3-year period. DEP calculated a rolling 5-year average loading for each parameter. The site-specific interpretations of the narrative nutrient criterion were then set for each parameter at the maximum 5-year rolling average load for Lake Francis. **Section 5.5** discusses in more detail the method used to determine these loading values.

Site-specific interpretations for Lake Francis are expressed as a 5-year rolling annual average load not to be exceeded. **Table 3.1** summarizes the site-specific interpretations for TN and TP for Lake Francis.

Table 3.1. Lake Francis site-specific numeric interpretations of the narrative nutrient criterion.

kg/yr = Kilograms per year

Waterbody	WBID	5-Year Annual Average TN (kg/yr)	5-Year Annual Average TP (kg/yr)
Lake Francis	3366A	896	73

DEP also calculated the in-lake TN and TP concentrations corresponding to the load-based TN and TP site-specific interpretations of the narrative criterion that attain the target chlorophyll *a* concentration of 20 µg/L. For Lake Francis, the TN and TP AGM concentrations of 0.80 and 0.05 mg/L, respectively, are not to be exceeded in any year. These concentration-based restoration targets are provided for informational purposes only and will be used to help evaluate the effectiveness of restoration activities. The loads listed in **Table 3.1** are the site-specific interpretations of the narrative criterion for the lake.

3.4 Downstream Protection

Lake Francis discharges into a wetland in WBID 3366 (Norton Creek), a Class III freshwater stream. Based on the most recent assessment, Norton Creek is not verified impaired for nutrients.

As evidenced by their healthy existing condition, the existing loads from Lake Francis to the downstream waters have not led to impairments. Furthermore, the nutrient criteria for Norton Creek are TN and TP AGM concentrations of 1.87 and 0.3 mg/L, respectively. In comparison, the target concentrations of Lake Francis for TN and TP are 0.80 and 0.05 mg/L, respectively. Since the nutrient targets for Lake Francis are lower than nutrient criteria for Norton Creek, the TMDLs for Lake Francis are protective of the downstream creek. Therefore, the reductions in nutrient loads prescribed in the TMDLs for Lake Francis are not expected to cause nutrient impairments downstream.

3.5 Endangered Species Consideration

Section 7(a)(2) of the Endangered Species Act requires each federal agency, in consultation with the services (i.e., U.S. Fish and Wildlife Service [FWS] and National Oceanic and Atmospheric Agency [NOAA] National Marine Fisheries Service [NMFS]), to ensure that any federal action authorized, funded, or carried out is not likely to jeopardize the continued existence of listed species or result in the destruction or adverse modification of designated critical habitat. The EPA must review and approve changes in water quality standards (WQS) such as setting site-specific criteria.

Prior to approving WQS changes for aquatic life criteria, the EPA will prepare an Effect Determination summarizing the direct or indirect effects of an action on the species or critical habitat, together with the effects of other activities that are interrelated or interdependent with that action. The EPA categorizes potential effect outcomes as either (1) "no effect," (2) "may affect, not likely to adversely affect," or (3) "may affect: likely to adversely affect."

The service(s) must concur on the Effect Determination before the EPA approves a WQS change. A finding and concurrence by the service(s) of "no effect" will allow the EPA to approve an otherwise approvable WQS change. However, findings of either "may affect, not likely to adversely affect" or "may affect: likely to adversely affect" will result in a longer consultation process between the federal agencies and may result in a disapproval or a required modification to the WQS change.

The FWS online Information for Planning and Conservation (IPaC) tool (see **Appendix B**) identifies terrestrial species potentially affected by activities in the watershed. DEP is not aware of any aquatic, amphibious, or anadromous endangered species present in the Lake Francis Watershed. Furthermore, it is expected that restoration efforts and subsequent water quality improvements will positively affect aquatic species living in the lake and its watershed.

Chapter 4: Assessment of Sources

4.1 Types of Sources

An important part of the TMDL analysis is the identification of pollutant source categories, source subcategories, or individual sources of the pollutant of concern in the target watershed and the amount of pollutant loading 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. Point sources also include 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). 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 septic systems; and atmospheric deposition.

To be consistent with CWA definitions, the term "point source" is used to describe traditional point sources (such as domestic and industrial wastewater discharges) and stormwater systems requiring an NPDES stormwater permit when allocating pollutant load reductions required by a TMDL (see **Section 6.1** on **Expression and Allocation of the TMDLs**). However, the methodologies used to estimate nonpoint source loads do not distinguish between NPDES 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 Point Sources

4.2.1 Wastewater Point Sources

There are no NPDES-permitted wastewater facilities discharging to Lake Francis or to its watershed.

4.2.2 Municipal Separate Storm Sewer System (MS4) Permittees

Municipal separate storm sewer systems (MS4s) may also discharge pollutants to waterbodies in response to storm events. To address stormwater discharges, the EPA developed the NPDES stormwater permitting program in two phases. Phase 1, promulgated in 1990, addresses large and medium-size MS4s located in incorporated areas and counties with populations of 100,000 or more. Phase 2 permitting began in 2003. Regulated Phase 2 MS4s are defined in Rule 62-624.800, F.A.C., and typically cover urbanized areas serving jurisdictions with a population of at least 10,000 or discharging into Class I or Class II waters, or into Outstanding Florida Waters (OFWs). There are no NPDES Phase I or Phase II MS4 permits in the Lake Francis watershed.

For more information on MS4s in the watersheds, send an email to NPDES-stormwater@dep.state.fl.us.

4.3 Nonpoint Sources

Nutrient loadings to Lake Francis are primarily generated from nonpoint sources. Nonpoint sources addressed in this analysis mainly include loadings from surface runoff based on land use, onsite sewage treatment and disposal systems (OSTDS), groundwater seepage entering the lake and precipitation directly onto the lake surface (atmospheric deposition).

4.3.1 Land Uses

Land use is one of the most important factors in determining nutrient loadings from the Lake Francis Watershed. Nutrients can be flushed into a receiving water through surface runoff and stormwater conveyance systems during stormwater events. Both human land use areas and natural land areas generate nutrients. However, human land uses typically generate more nutrient loads per unit of land surface area than natural lands can produce. **Table 4.1** lists land use in the watershed based on the statewide land use land cover dataset (including the land use dataset from SRWMD 2019-20). **Figure 4.1** shows the information graphically.

Table 4.1 and **Figure 4.1** show the breakdown of the various land use categories in the Lake Francis Watershed. Urban land uses—including low, medium, high density commercial\ institutional, and transportation –predominate with 58 % coverage. Natural land uses are followed with Forest (22%), Water (8%) and wetlands (3%). There are some portions of agricultural land (8%).

Table 4.1. Land use in the Lake Francis Watershed, 2019-20 (SRWMD).

Land Use Type	Area (acres)	%
Low-density residential	43.2	9
Medium-density residential	103.5	20
High-density residential	12.4	2
Low-density commercial/institutional	36.8	7
High-density commercial	81.3	16
Transportation	22.9	4
Open land/recreational	4.3	1
Pasture	8.1	2
Cropland	28.2	6
Forest/rangeland	110.3	22
Water	41.4	8
Wetlands	17.4	3
	509.8	**100**

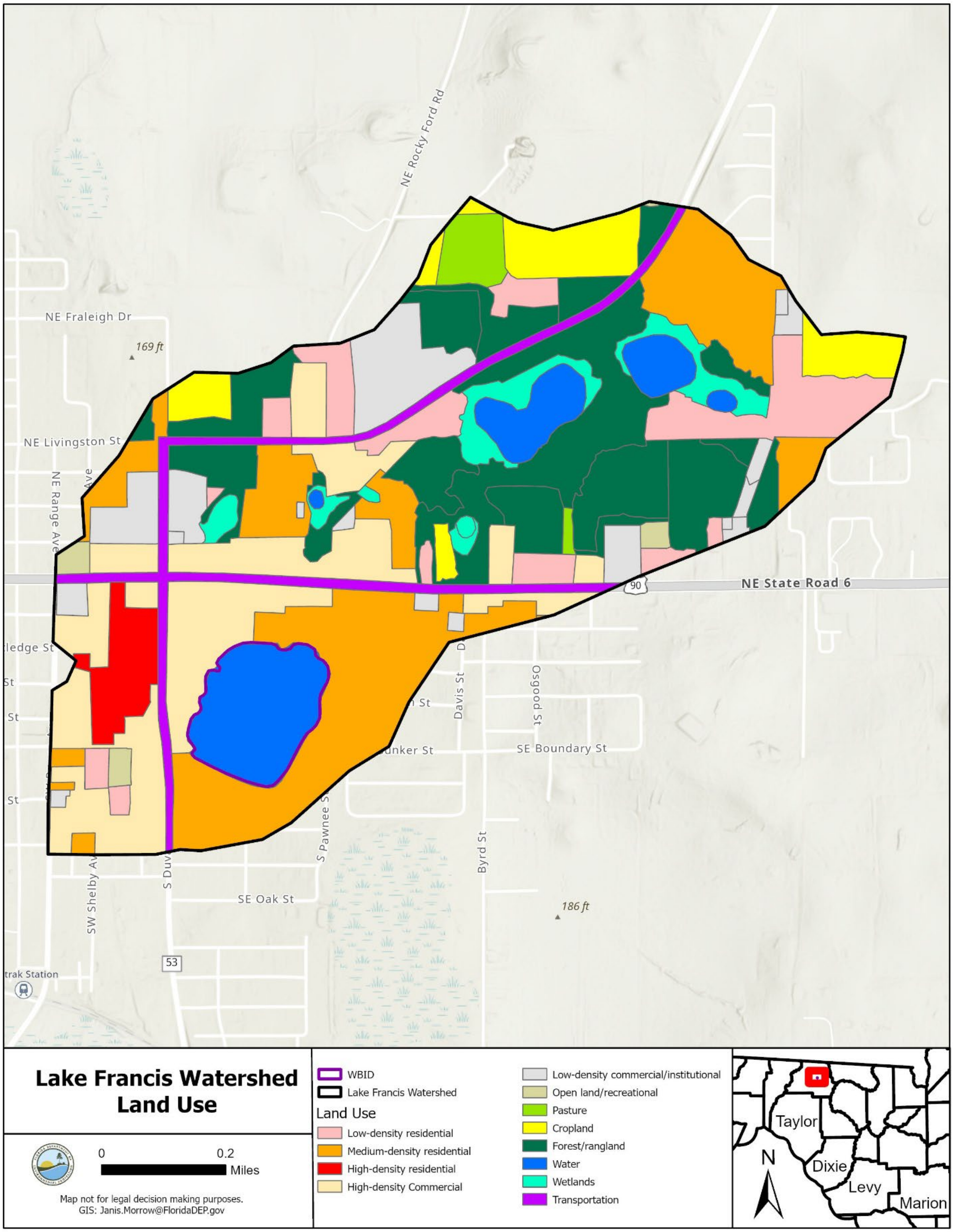


Figure 4.1. Land use in the Lake Francis Watershed, 2019-20.

4.3.2 OSTDS

OSTDS, including septic systems, 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. OSTDS can be a source of nutrients (nitrogen and phosphorus), pathogens and other pollutants to both groundwater and surface water.

The Florida Department of Health (FDOH) maintains a list of septic systems by county, and the FDOH Florida Water Management Inventory dataset was used to determine the number of septic systems in the area. **Figure 3.2** shows the approximate locations of OSTDS in the watershed based on centroids of parcels with known, likely, or somewhat likely septic systems. There are 117 septic systems in the Lake Francis Watershed.

4.3.3 Atmospheric Deposition

Nutrient loadings from the atmosphere are an important component of the nutrient budget in many Florida lakes. Nutrients are delivered through two pathways: wet atmospheric deposition with precipitation and dry particulate-driven deposition. Atmospheric deposition to terrestrial portions of the Lake Francis Watershed is assumed to be accounted for in the loading rates used to estimate the watershed loading from land. There are no known complete atmospheric deposition data for Lake Francis. Lake Apopka, the closest deposition measuring site, located about 165 miles southeast of Lake Francis, is the only site to include deposition data for both phosphorus and nitrogen. Therefore, loading from atmospheric deposition directly onto the water surface was estimated based on the St. Johns River Water Management District (SJRWMD) data collected in Lake Apopka. These included both wet and dry atmospheric deposition data.

The dry deposition portion is expressed as a per area loading rate (areal loading rate) on an annual scale. Wet deposition is delivered by precipitation, and annual wet deposition is therefore expressed as a concentration of solutes in precipitation multiplied by the total volume of precipitation. Both the wet and dry components of the calculated atmospheric nutrient deposition (**Table 4.2**) were added to the waterbody model for Lake Francis. The table also shows annual TN and TP atmospheric loads to the lake surface.

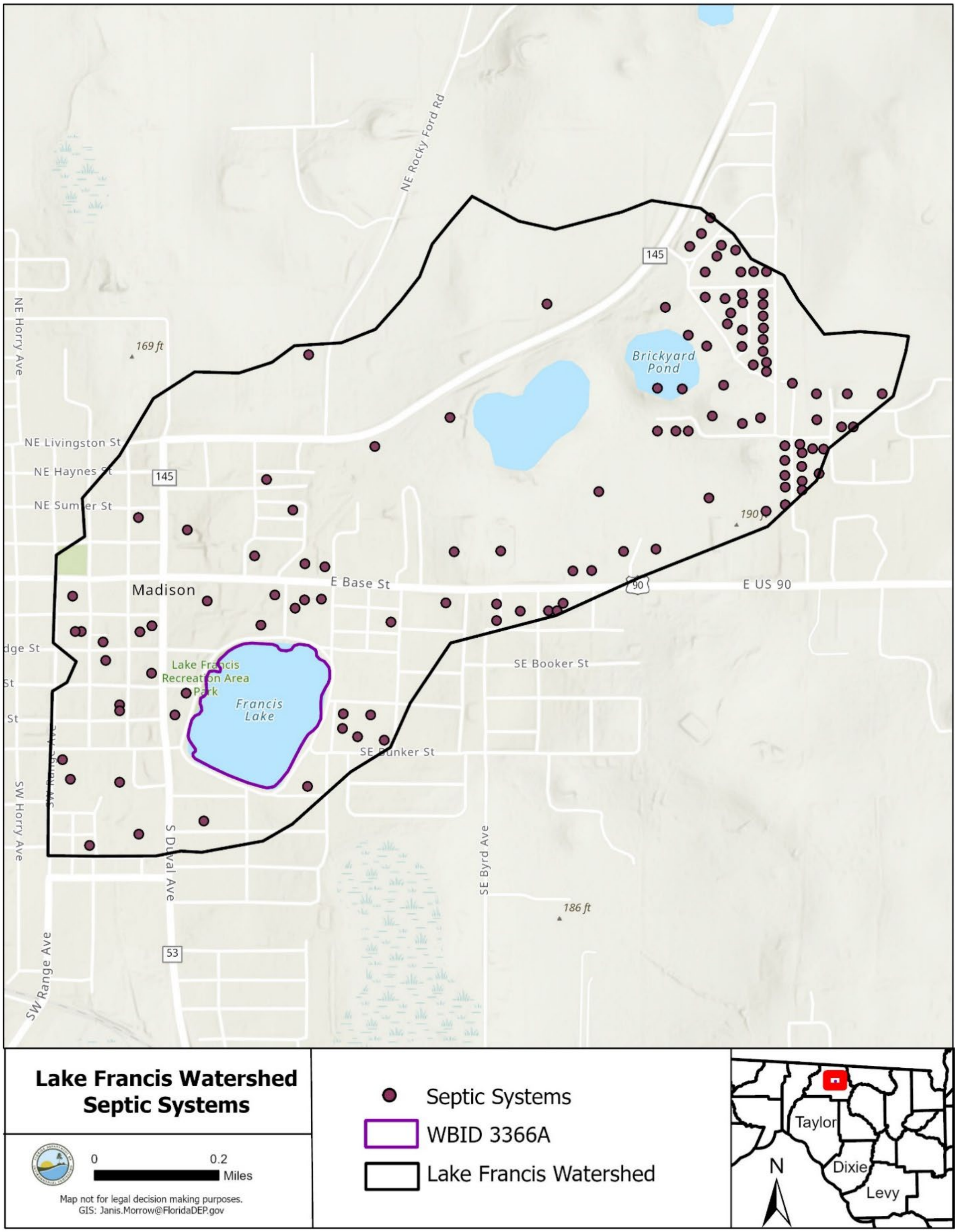


Figure 4.2. OSTDS in the Lake Francis Watershed.

Table 4.2. Calculated atmospheric deposition in Lake Francis based on field measurements in Lake Apopka, 2016–23.

mg/m^2/yr = Milligrams per square meter per year
kg/yr = Kilograms per year

Year	Dry Deposition TN (mg/m^2/yr)	Dry Deposition TP (mg/m^2/yr)	Wet Deposition TN (mg/m^2/yr)	Wet Deposition TP (mg/m^2/yr)	Total Deposition TN (mg/m^2/yr)	Total Deposition TP (mg/m^2/yr)	TN loads to Lake surface (kg/yr)	TP loads to Lake surface (kg/yr)
2016	170	24	540	17	710	41	71	4
2017	244	32	437	14	681	46	68	5
2018	129	16	536	16	665	32	66	3
2019	159	28	423	15	582	44	58	4
2020	143	38	638	31	781	68	78	7
2021	184	52	726	31	910	83	91	8
2022	142	23	501	21	643	44	64	4
2023	151	30	619	23	770	53	77	5

4.4 Estimating Watershed Loadings

To simulate nutrient loading from the Lake Francis Watershed, the Natural Resources Conservation Service (NRCS) curve number model approach was used, following the SJRWMD procedure in Fulton et al. (2004) (**Appendix C**). This approach estimates runoff volume by taking into consideration the land use type, soil type, imperviousness of the watershed and antecedent moisture condition of the soil. Curve numbers from 20 to 100 are assigned to different land use–soil combinations to represent different runoff potentials.

Rainfall is the driving force of the curve number simulation. The stormwater runoff volume was estimated using the same spreadsheet model created by the SJRWMD. The annual runoff volume in the Lake Francis Watershed ranged from 0.538 to 0.801 cubic hectometers per year (hm^3/yr, one cubic hectometer is equal to 1,000,000 cubic meters.) from 2016 through 2023 (**Table 4.3**). The long-term average annual runoff is 0.621 hm^3/yr.

The nutrient loads from the watershed were calculated by multiplying land use specific runoff volumes by land use TN and TP event mean concentrations (EMCs), and also by taking into account the dissolved fraction of these nutrients and flow path distance to the lake (**Appendix C**). EMCs were based on general land use descriptions and spatially averaged data from studies in Florida (Harper 1994; 2012). **Table 4.4** list the stormwater runoff TN and TP loads from the Lake Francis Watershed estimated using the procedures described in **Appendix C**.

Table 4.3. Runoff volume (hm^3/yr) from the Lake Francis watershed.

Land use	2016	2017	2018	2019	2020	2021	2022	2023	Average
low density residential	0.015	0.015	0.021	0.017	0.033	0.012	0.015	0.016	0.018
medium density residential	0.087	0.085	0.110	0.086	0.137	0.078	0.081	0.099	0.095
high density residential	0.016	0.015	0.019	0.015	0.020	0.015	0.015	0.018	0.016
low density commercial	0.074	0.072	0.087	0.067	0.088	0.069	0.068	0.086	0.076
high density commercial	0.182	0.177	0.212	0.165	0.213	0.172	0.166	0.213	0.188
transportation	0.051	0.050	0.060	0.047	0.061	0.048	0.047	0.060	0.053
open land / recreational	0.001	0.001	0.001	0.001	0.002	0.000	0.001	0.001	0.001
pasture	0.001	0.001	0.002	0.002	0.005	0.001	0.001	0.001	0.002
cropland	0.005	0.005	0.008	0.007	0.017	0.003	0.005	0.005	0.007
forest/rangeland	0.020	0.020	0.036	0.028	0.075	0.013	0.021	0.019	0.029
water	0.069	0.068	0.080	0.062	0.077	0.066	0.063	0.081	0.071
wetlands	0.064	0.062	0.074	0.057	0.072	0.061	0.058	0.075	0.065
Total Runoff Volume	**0.585**	**0.569**	**0.710**	**0.554**	**0.801**	**0.538**	**0.541**	**0.674**	**0.621**

Table 4.4. Runoff TP annual loads (kg/yr) from the Lake Francis watershed.

Sources	2016	2017	2018	2019	2020	2021	2022	2023	Average
low density residential	1.7	1.7	2.4	1.9	3.8	1.4	1.7	1.9	2.1
medium density residential	16.7	16.3	21.1	16.5	26.2	15.0	15.6	19.0	18.3
high density residential	5.0	4.9	5.9	4.6	6.3	4.7	4.6	5.8	5.2
low density commercial	7.6	7.4	8.9	6.9	9.1	7.1	7.0	8.9	7.9
high density commercial	37.5	36.5	43.7	34.1	43.9	35.4	34.3	43.8	38.7
transportation	7.9	7.7	9.2	7.2	9.3	7.4	7.2	9.2	8.1
open land/recreational	0.1	0.1	0.2	0.2	0.4	0.1	0.1	0.1	0.2
pasture	0.7	0.6	1.2	0.9	2.4	0.4	0.7	0.6	0.9
cropland	1.6	1.6	2.9	2.3	6.1	1.1	1.7	1.6	2.4
forest/rangeland	0.7	0.7	1.3	1.0	2.6	0.4	0.7	0.7	1.0
water	0.6	0.6	0.7	0.6	0.7	0.6	0.6	0.7	0.6
wetlands	2.3	2.2	2.6	2.0	2.5	2.1	2.1	2.6	2.3
Total Runoff Load	**82.4**	**80.3**	**100.1**	**78.2**	**113.3**	**75.7**	**76.3**	**94.9**	**87.7**

Table 4.5. Runoff TN annual loads (kg/yr) from the Lake Francis watershed.

Sources	2016	2017	2018	2019	2020	2021	2022	2023	Average
low density residential	18.6	18.2	26.3	20.6	41.0	15.3	18.1	20.3	22.3
medium density residential	133.3	129.9	168.3	131.5	209.7	119.5	124.9	151.7	146.1
high density residential	27.2	26.5	32.3	25.2	34.3	25.3	25.0	31.6	28.4
low density commercial	59.4	57.7	69.5	54.2	71.1	55.7	54.3	69.2	61.4
high density commercial	333.0	323.7	388.0	302.3	389.7	313.7	304.3	388.9	342.9
transportation	65.1	63.2	76.0	59.2	77.0	61.2	59.5	75.9	67.1
open land/recreational	0.9	0.9	1.6	1.2	3.2	0.6	0.9	0.9	1.3
pasture	4.1	4.0	7.3	5.7	15.1	2.7	4.3	4.0	5.9
cropland	10.7	10.6	19.2	15.1	40.0	7.0	11.3	10.5	15.6
forest/rangeland	18.7	18.5	33.8	26.6	71.2	12.0	19.8	18.1	27.3
water	28.6	27.7	32.9	25.6	31.7	27.1	26.0	33.5	29.1
wetlands	61.5	59.8	70.9	55.2	68.9	58.3	56.1	72.1	62.9
Total Runoff Load	**761.1**	**740.7**	**926.1**	**722.4**	**1052.9**	**698.4**	**704.5**	**876.7**	**810.3**

4.4.1 Estimating Septic Tank Flow Rate and Nutrient Loadings

The amount of TN and TP contributed by OSTDS was simulated using ArcNLET-Py (ArcGIS-based Nutrient Load Estimation Toolbox – Python version) that is a tool used to estimate nutrient loads, including nitrogen and phosphorus, to groundwater and surface water. The tool simulates the transformation and transport of nitrogen species (nitrate (NO_3-N) and ammonium (NH_4-N)) and phosphorus (PO_4-P) from septic systems to nearby waterbodies (ArcNLET-Py: https://github.com/ArcNLET-Py/ArcNLET-Py).

The simulated TN and TP loads from septic effluent through seepage were 146 and 1 kg/yr, respectively. **Table 4.6** lists the estimated TN and TP loads from septic tank contributions.

Table 4.6. OSTDS loads from the Lake Francis watershed.

Flow Rate (hm^3/yr)	TN Concentration (mg/L)	TP Concentration (mg/L)	TN Load (kg/yr)	TP Load (kg/yr)
0.05872	2.493	0.019	146	1

4.4.2 Estimating groundwater Nutrient Loadings

Because of the lack of information on ground water flow rate when these TMDLs were developed, DEP used a relationship between watershed surface water and seepage flow rate from the Lake Roberts nutrient TMDL development (DEP 2017). In the study, the surface water flows were positively related to seepage flows and on average, the latter occupied 22 % of the former. For Lake Francis, groundwater flow rate was estimated to be 22% of the watershed surface water flow rate (**Table 4.7**). TN and TP concentrations in the BATHTUB model to simulate ground water loadings were 0.96 mg/L for TN and 0.226 mg/L for TP from ground water samples collected from wells located in Madison County (WBID 3329 Devils Woodyard Slough). **Table 4.7** lists the estimated nutrient loads to Lake Francis from groundwater.

Table 4.7. Nutrient loads to Lake Francis from groundwater.

Year	Groundwater flow (hm3/yr)	Groundwater TN concentration (mg/L)	Groundwater TP concentration (mg/L)	TN Load (kg/yr)	TP Load (kg/yr)
2016	0.129	0.96	0.226	124	29
2017	0.125	0.96	0.226	120	28
2018	0.156	0.96	0.226	150	35
2019	0.122	0.96	0.226	117	28
2020	0.176	0.96	0.226	169	40
2021	0.118	0.96	0.226	114	27
2022	0.119	0.96	0.226	114	27
2023	0.148	0.96	0.226	142	34

4.5 Summary of the Nutrient Loadings to the Lake from Nonpoint Sources

Based on calculated estimates and model simulations, the long-term mean of annual TN loading from external sources to Lake Francis was 1,159 kg/yr (**Table 4.8**). The watershed surface runoff to the lake was the largest nitrogen loading source, representing 70 % of long-term total TN loading, followed by septic systems, groundwater and atmospheric deposition (**Table 4.8**).

As shown in **Table 4.9**, the long-term mean of the total annual TP loading from external sources to Lake Francis was 125 kg/yr. Watershed surface runoff was the largest source of phosphorus loading to Lake Francis, representing 70 % of long-term total TP loading, followed by groundwater, atmospheric deposition and septic systems (**Table 4.9**).

Table 4.8. Long-term mean annual TN loading from nonpoint sources to Lake Francis, 2016–23 (unit: kg/yr).

Value	Atmospheric Deposition	Surface Runoff	Ground water	Septic Load	Total
Long-term mean annual	72	810	131	146	1,159
%	6	70	11	13	100

Table 4.9. Long-term mean annual TP loading from nonpoint sources to Lake Francis, 2016–23 (unit: kg/yr).

Value	Atmospheric Deposition	Surface Runoff	Ground water	Septic Load	Total
Long-term mean annual	5	88	31	1	125
%	4	70	25	1	100

Chapter 5: Determination of Assimilative Capacity

5.1 Determination of Loading Capacity

Nutrient enrichment and the resulting problems related to eutrophication tend to be widespread and are frequently manifested far (in both time and space) from their sources. Addressing eutrophication involves relating water quality and biological effects such as photosynthesis, decomposition and nutrient recycling as acted on by environmental factors (rainfall, point source discharge, etc.) to the timing and magnitude of constituent loads supplied from various categories of pollution sources. Assimilative capacity should be related to some specific hydrometeorological condition during a selected period or to some range of expected variation in these conditions.

The goal of this TMDL analysis is to determine the assimilative capacity of Lake Francis and to identify the maximum allowable TN and TP loadings from the watershed, so that the waterbody will meet the TMDL targets and thus maintain its function and designated uses as a Class III water.

5.2 Evaluation of Water Quality Conditions

Annual Arithmetic Means (AAMs) were used for the water quality modeling for TMDL development. For the purpose of this modeling, AAMs were calculated using a minimum of four sample results per year, except for 2020 when had 2 samples of chlorophyll *a* and 3 samples of TN and TP, with at least one of the samples collected in the May to September period and at least one sample collected from other months. Values with an "I" qualifier code were used as reported. Values with "U" or "T" qualifier codes were changed to the minimum detection limit (mdl) divided by the square root of 2. Values with "G" or "V" qualifier codes were removed from the analysis for quality control purposes. Negative values and zero values were also removed. Multiple sample results collected on the same day at the same station were averaged.

From 2016 to 2023, Lake Francis chlorophyll *a* AAMs varied from 20.5 µg/L in 2022 to 78.8 µg/L in 2023 (**Figure 5.2**). TP AAMs ranged from 0.078 mg/L in 2017 to 0.190 mg/L in 2023 (**Figure 5.3**). TN AAMs ranged from 0.89 mg/L in 2016 to 2.18 mg/L in 2023 (**Figure 5.4**).

5.3 Critical Conditions and Seasonal Variation

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, (3) the chlorophyll *a* criterion used as the TMDL target is expressed as an AGM and (4) the methodology used to determine impairment is based on annual conditions (AGM values).

5.4 Water Quality Modeling to Determine Assimilative Capacity

To represent water quality processes occurring in Lake Francis, the U.S. Army Corps of Engineers (USACE) BATHTUB model was used (Walker 1987; 1999). The model simulates steady-state lake conditions and is set up to simulate water quality for long-term receiving water conditions. It is designed to represent reservoirs and other large waterbodies with relatively stable water levels.

5.4.1 Water Quality Model Description

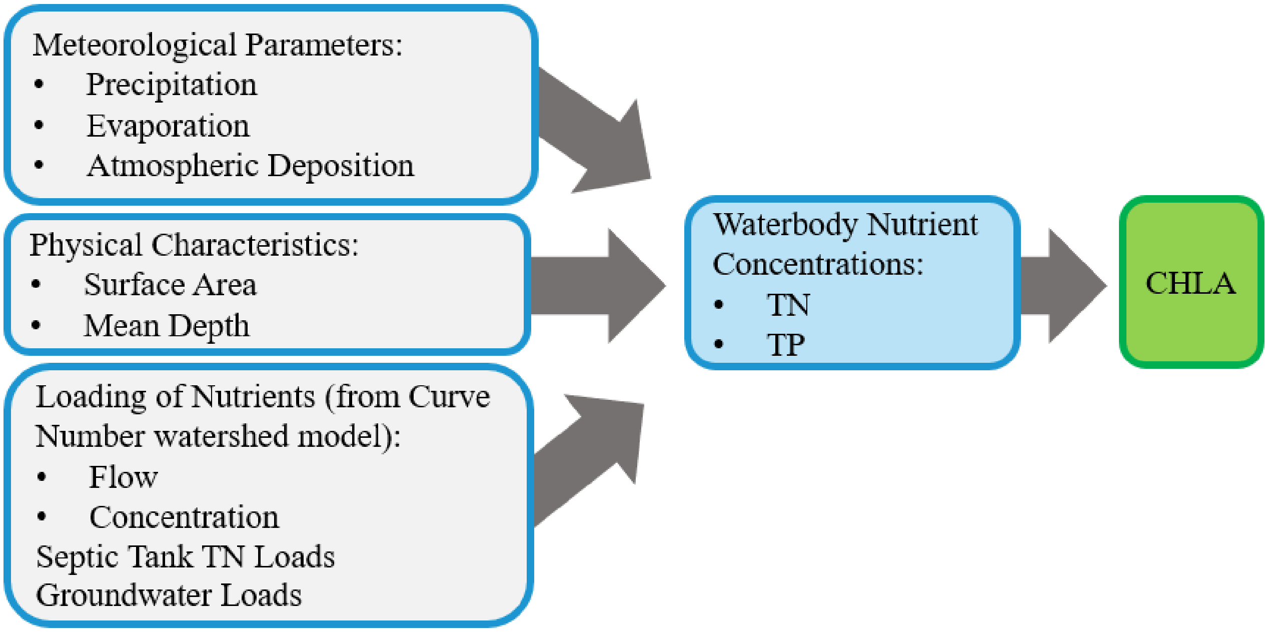
The BATHTUB model runs on a modeling framework that uses empirical relationships between nutrient loading, meteorological conditions and physical parameters to estimate algal growth. The model's framework includes lake and lake segments morphometry, which may be directly or indirectly connected, as well as inputs of rainfall, atmospheric nutrient deposition, nutrient loads from the surrounding watershed and internal loading of nutrients.

The primary goal of the BATHTUB model is to estimate in-lake nutrient concentrations and algal biomass (represented by chlorophyll *a* concentrations) as they relate to nutrient loadings. Walker (1999) describes methods for choosing the appropriate models for producing these nutrient estimates for different waterbodies. Two categories of models are used to empirically predict lake eutrophication, and this process usually occurs in two stages. The nutrient balance model describes the relationships between nutrient concentrations in the lake to external nutrient loadings, morphometry and lake hydraulics. The eutrophication response model relates eutrophication indicators in the lake, including nutrient levels, chlorophyll *a*, hypolimnetic oxygen depletion and transparency (Walker 1999).

The nutrient models in BATHTUB assume that the net accumulation of nutrients in a lake is the difference between nutrient loadings into the lake from various sources and nutrients carried out through outflow, and nutrient losses through whatever decay processes occur in the lake. BATHTUB includes a suite of phosphorus and nitrogen sedimentation, chlorophyll *a* and Secchi depth models.

Figure 5.1 shows the scheme used to relate these various models in BATHTUB. According to this scheme, external nutrient loadings, physical characteristics and meteorological parameters are all applied to simulate in-lake nutrient concentrations. The physical, chemical and biological response of the lake to the level of nutrients then produces waterbody nutrient concentrations, which are used to predict algal biomass. In BATHTUB, chlorophyll models are available to account for nitrogen, phosphorus, light, or flushing, as limiting factors to algal growth.

Lake Francis was represented as one waterbody in the BATHTUB model because the lake is relatively small and is spatially homogeneous because of its geometry. The waterbody was modeled on a yearly basis, with inputs including the watershed nutrient delivery derived from the curve number approach, atmospheric deposition, groundwater contributions and septic tank flux (see **Sections 4.3** and **4.4**).



CHLA = Chlorophyll *a*

Figure 5.1. BATHTUB concept scheme.

5.4.2 Morphologic Inputs

The physical characteristics of the lake were input for each year into BATHTUB. Two processes—residence time and nutrient fate and transport—vary based on these physical features. Lake Francis has an average depth of 1.38 meters (m), a surface area of 0.1 square kilometers (km^2) and a lake length of 0.4 kilometers (km).

5.4.3 Meteorological Data

Rainfall

Rainfall data (2016–23) used in the TMDL analyses such as input on the lake surface area and flow rates were obtained from the North American Land Data Assimilation System (NLDAS) meteorological data at X332Y043 (Madison, FL) (**Table 5.1**). NLDAS is currently running operationally on a 1/8th degree grid with an hourly timestep over Central North America (25-53 North). Weather Processor V 2.05 (EPA website: https://www.epa.gov/hydrowq/basins-download-and-installation#download) was used to extract NLDAS meteorological data in the Lake Francis area. **Table 5.1** shows annual rainfall totals for the model simulation period. The annual average rainfall in this area was 1.345 m. During the simulation period, wetter than average conditions occurred in 2018, 2020 and 2023, while drier than average conditions were present in 2017, 2019, 2021 and 2022.

Evaporation

Hamon potential evapotranspiration was computed by the Watershed Data Management Utility Program (WDMutil) using the NLDAS meteorological data (2016–23) (**Table 5.1**).

Table 5.1 lists the annual rainfall and lake evaporation values used in calibrating the BATHTUB model for Lake Francis.

Table 5.1. Annual rainfall and lake evaporation rates in Madison County for the Lake Francis BATHTUB model.

m/yr = Meters per year

Year	Annual Rainfall (m/yr)	Lake Evaporation (m/yr)
2016	1.328	1.074
2017	1.290	1.069
2018	1.514	1.057
2019	1.179	1.087
2020	1.415	1.085
2021	1.267	1.031
2022	1.207	1.072
2023	1.562	1.075

Atmospheric Deposition

Atmospheric deposition rates (total deposition of TN and TP) to the lake surface area were applied in the BATHTUB model. These rates were calculated based on data collected by the SJRWMD in Lake Apopka (see **Section 4.3.3**) that included both wet and dry atmospheric deposition rates (see **Table 4.2**).

5.4.4 Watershed Nutrient Inputs

The curve number approach was used to simulate watershed surface runoff (see **Section 4.4**). Annual loading rates from this approach were entered as watershed tributary inputs in the BATHTUB model for simulating yearly conditions. Annual loading rates from septic tank and groundwater contributions (see **Section 4.4**) were also entered as watershed tributary inputs in the model.

5.4.5 BATHTUB Model Calibration

The BATHTUB model was set up to simulate in-lake TN, TP and chlorophyll *a* concentrations. Lake AAMs for chlorophyll *a,* TN and TP were input into the model as observed values from 2016 – 2018 and 2020 – 2023. AAMs for chlorophyll *a,* TN and TP were calculated using results from a minimum of 4 sampling events per year, except for 2020 when 2 to 3 samples were available, but from both growing and non-growing seasons included. There were no observed AAMs available for the year 2019. The observed AAM values were used to calibrate the BATHTUB model and guided the selection of the appropriate nitrogen, phosphorus and chlorophyll *a* models to apply.

For the model calibration, Model Option 08 (Canf & Bach, Lakes) was used for TP, Model Option 03 (2nd Order, Fixed) was used for TN and Model Option 01 (P, N, Light, Flushing) was used for chlorophyll *a*. The Option 01 chlorophyll *a* model assumes that phytoplankton growth is limited by not only both phosphorus and nitrogen but also light. To edit tributaries in the BATHTUB model, the non-point Inflow (type 2) was selected to enter land use specific information to the land use tab and export coefficients, based on the simulated watershed data obtained from the watershed model. Calibration factors of 1.2, 0.7 and 1 were applied for TP, TN and chlorophyll *a*, respectively to fit the Lake Francis model predictions to all modeling years.

Additionally, calibrations for TN and TP were achieved by applying the internal loading rate functions for both TN and TP to approximate the measured in-lake mass. The internal loading rates account for in-lake processes that recycle nutrients from the lake bottom sediments by resuspension and inputs of nitrogen (N_2) through nitrogen fixation by cyanobacteria. According to a Lake Francis survey conducted in 2002, the lake bottom was covered with thick sediments reaching up to 5 feet in the middle of the lake (**Appendix D,** FWC, personal communication). Additionally, sampling since the 1990s indicates that cyanobacteria (blue-green algae) are common in the lake, and some of the blue-green algae taxa capable of fixing atmospheric nitrogen, including *Anabaena* spp., *Aphanizomenon* spp., *Dolichospermum circinale* and *Cylindrospermopsis raciborskii*, have been observed in Lake Francis (**Appendix E**). The high concentrations of the measured nutrients, chlorophyll *a* and the analyses of the phytoplankton composition indicate that these internal processes may occur in the lake.

The high lake TP concentrations occurred in 2016, 2021, 2022 and 2023 (**Figure 5.3**). It is hypothesized that these increased nutrient concentrations were released from resuspended sediments. To account for these possible processes, higher internal loading rates than other years were applied in the model to estimate the higher in-lake concentrations of TP observed in these years (**Table 5.2**). The high lake TN concentrations occurred in 2017, 2021, 2022 and 2023 (**Figure 5.4**) probably due to the resuspended sediments and/or nitrogen fixation. To account for these possible processes, high internal loading rates were applied in the model to estimate the in-lake concentrations of TN observed in these years (**Table 5.2**).

Table 5.2. Internal load inputs for TN and TP.

Year	TP Internal load (mg/m2/day)	TN Internal load (mg/m2/day)
2016	1.5	1.0
2017	0.5	20.0
2018	0.5	1.0
2019	0.4	3.0
2020	0.3	10.0
2021	1.0	25.0
2022	1.5	5.0
2023	1.2	32.0

Figures 5.2 through **5.4** show the model-predicted results and observed concentrations for chlorophyll *a*, TP and TN, respectively, for Lake Francis. To evaluate model performance, the difference between both the mean and median simulated and observed values over the modeling period were calculated and are shown in **Table 5.3**. The percent differences in mean values for the modeling period of predicted and observed chlorophyll *a*, TN and TP, were 8 %, 8 % and 12 %, respectively. The percent differences in median values for the modeling period of predicted and observed chlorophyll *a*, TN and TP were 3 %, 16 % and 11 %, respectively.

The annual average concentrations of chlorophyll *a*, TN and TP in the model-predicted existing condition are tabulated in **Table 5.4.a**.

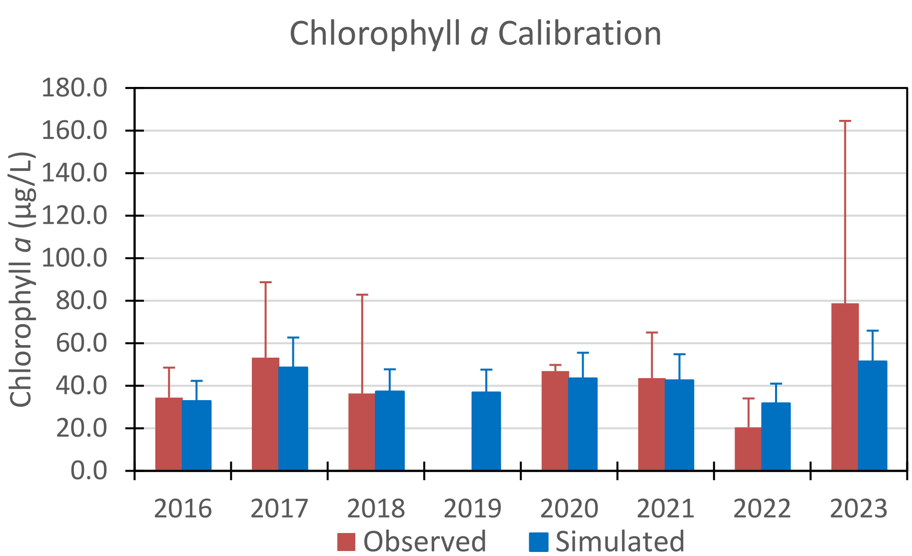


Figure 5.2. Lake Francis chlorophyll *a* observed and BATHTUB-simulated annual average results with standard deviation, 2016–23.

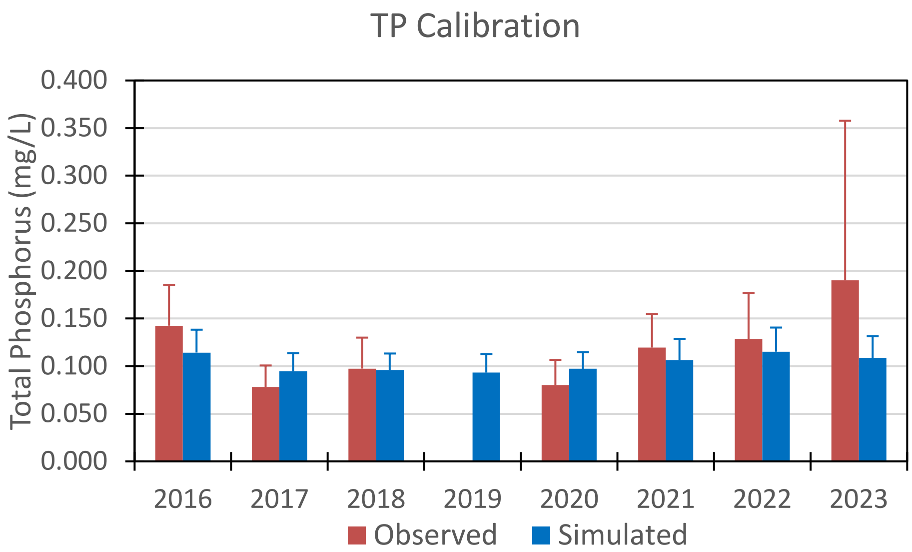


Figure 5.3. Lake Francis TP observed and BATHTUB-simulated annual average results, with standard deviation, 2016–23.

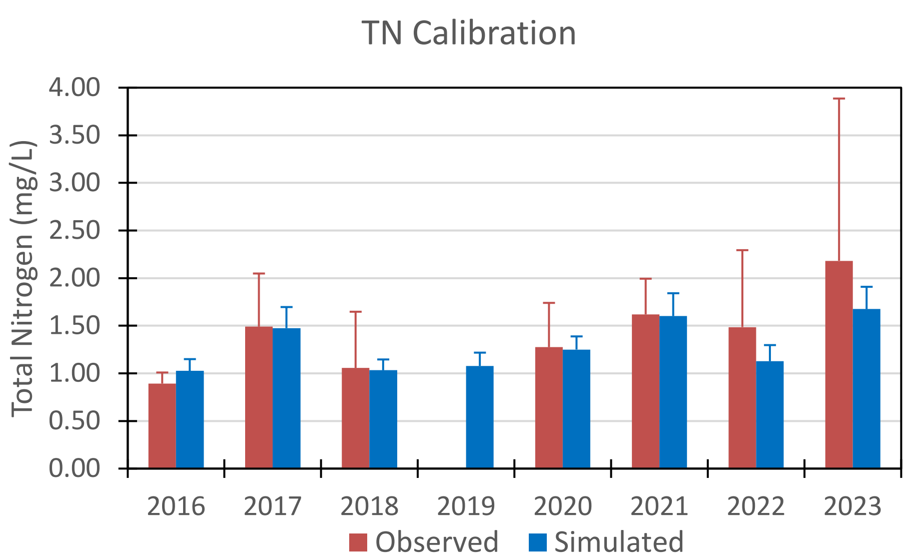


Figure 5.4. Lake Francis TN observed and BATHTUB-simulated annual average results, with standard deviation, 2016–23.

Table 5.3. Performance statistics for model simulated parameters.

Chl *a* = Chlorophyll *a*

Statistics	Measured Chl *a* (µg/L)	Simulated Chl *a* (µg/L)	Measured TN (mg/L)	Simulated TN (mg/L)	Measured TP (mg/L)	Simulated TP (mg/L)
Mean	45	41	1.43	1.31	0.119	0.105
% Difference		8		8		12
Median	44	43	1.49	1.25	0.119	0.106
% Difference		3		16		11

5.4.6 Natural Background Conditions and TMDL Scenario Run

To ensure that the site-specific restoration target would not abate natural background conditions, a Lake Francis natural background condition model scenario was developed. To estimate the natural background nutrient loading conditions, all anthropogenic land uses applied in the existing condition scenario were converted to forest land in the BATHTUB model. Wetland and water land uses remained unchanged in the model for the natural background condition. Additionally, the septic tank loading estimates and internal loads were removed as inputs in the BATHTUB model. The atmospheric deposition and groundwater loadings in the model were kept the same as in the existing condition scenario.

Simulated annual average concentrations of Chlorophyll *a*, TN and TP for the natural background condition were converted to AGMs for each year using the linear relationships between annual average concentrations and AGM from the lake dataset used in developing the NNC (Ken Weaver, DEP, personal communication). The regression equations used for conversion from annual average to AGM are as follows:

TP AGM = 0.9328 x TP annual average

TN AGM = 0.9654 x TN annual average

Chlorophyll a AGM = 0.8805 x Chlorophyll a annual average

For Lake Francis, the model simulated annual average chlorophyll *a* concentrations under the natural background loading condition were slightly higher than 20 µg/L in 2017 and 2020 (**Figure 5.5; Table 5.4.b**). However, when the annual averages were converted to AGMs, all chlorophyll *a* concentrations during the modeling period did not exceed chlorophyll *a* criterion (20 µg/L in AGM). The DEP has demonstrated that the chlorophyll *a* criterion of 20 µg/L is protective of designated uses and maintains a balanced aquatic flora and fauna for low-color, high-alkalinity lakes (DEP 2012). Therefore, 20 µg/L of chlorophyll *a* AGM is appropriate to use as the restoration target for Lake Francis.

The TMDL nutrient loading scenario was developed by iteratively reducing the anthropogenic loadings in the BATHTUB model until the simulated chlorophyll *a* AGM concentrations did not exceed 20 µg/L more than once in any consecutive 3-year period. The BATHTUB simulated in-lake annual averages of the chlorophyll *a*, TN and TP results for the TMDL loading scenario are displayed in **Figures 5.5** to **5.7**, respectively. **Table 5.4.c** also includes AGM concentrations of the chlorophyll *a*, TN and TP converted from annual average in the TMDL scenario run. The AGMs of in-lake TN concentration, 0.8 mg/L and TP concentrations, 0.05 mg/L (not to be exceeded in any year) in the TMDL scenario serve as concentration-based restoration targets to assist in evaluating the effectiveness of restoration activities. These nutrient concentration targets are for informational purposes only.

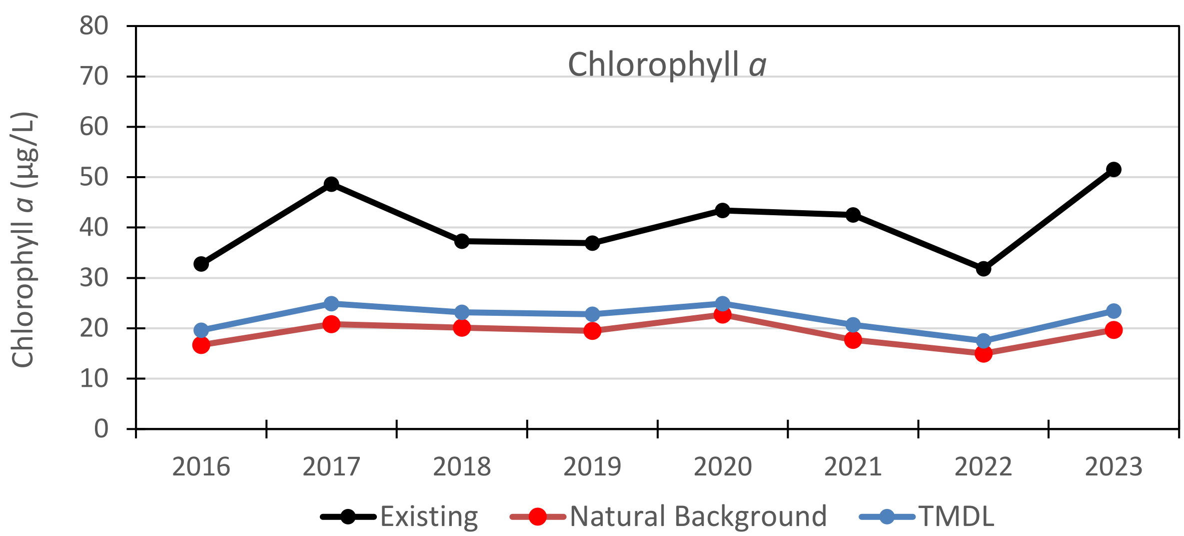


Figure 5.5. Chlorophyll *a* concentrations in existing, natural background and TMDL target conditions in Lake Francis during the BATHTUB modeling period, 2016–23.

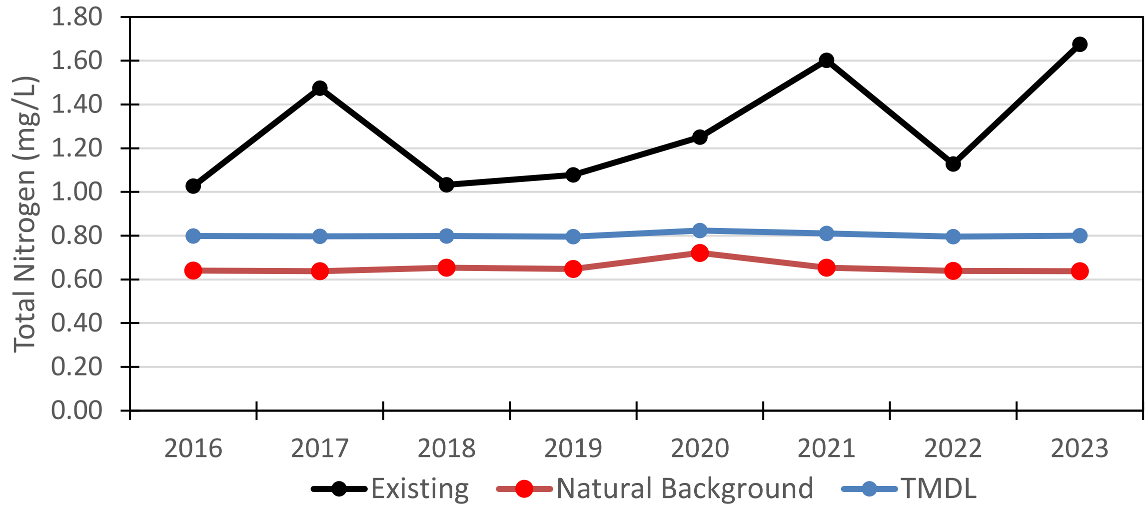


Figure 5.6. TN concentrations in existing, natural background and TMDL target conditions in Lake Francis during the BATHTUB modeling period, 2016–23.

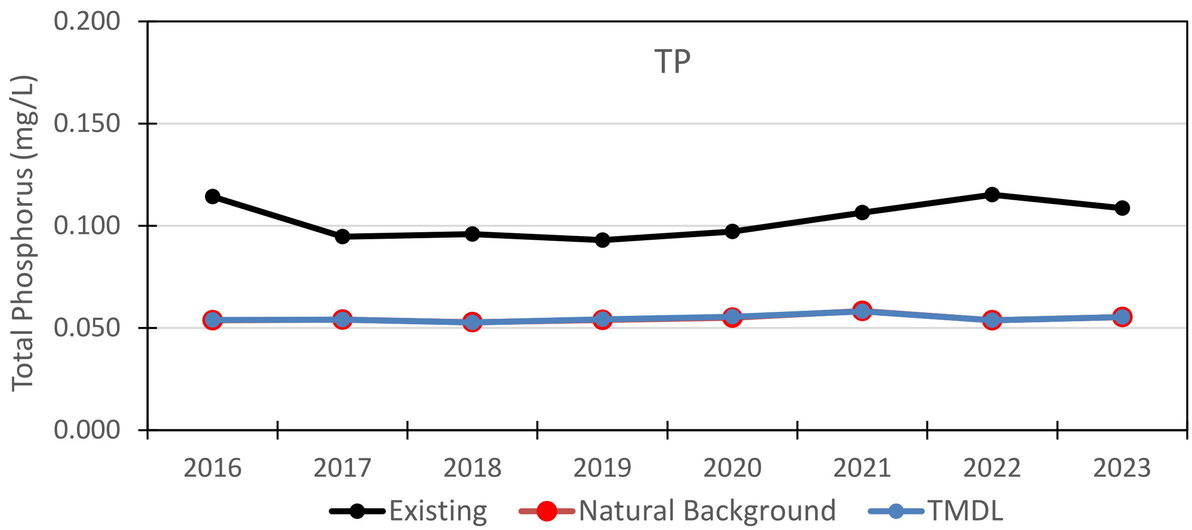


Figure 5.7. TP concentrations in existing, natural background and TMDL target conditions in Lake Francis during the BATHTUB modeling period, 2016–23.

Table 5.4. Chlorophyll *a*, TP and TN concentrations in (a) existing, (b) natural background and (c) TMDL conditions during the simulation period and target concentrations.

a. Existing Condition (Annual Average)

Year	Chlorophyll *a* Annual Average (µg/L)	TN Annual Average (mg/L)	TP Annual Average (mg/L)
2016	33	1.03	0.114
2017	49	1.48	0.095
2018	37	1.03	0.096
2019	37	1.08	0.093
2020	43	1.25	0.097
2021	43	1.60	0.106
2022	32	1.13	0.115
2023	52	1.67	0.109

b. Natural Background Condition (Annual Average and Converted AGMs)

Year	Chlorophyll *a* Annual Average (µg/L)	Chlorophyll *a* AGM (µg/L)	TN Annual Average (mg/L)	TN AGM (mg/L)	TP Annual Average (mg/L)	TP AGM (mg/L)
2016	17	15	0.64	0.62	0.054	0.050
2017	21	18	0.64	0.62	0.054	0.050
2018	20	18	0.65	0.63	0.053	0.049
2019	19	17	0.65	0.63	0.054	0.050
2020	23	20	0.72	0.70	0.055	0.051
2021	18	16	0.65	0.63	0.058	0.054
2022	15	13	0.64	0.62	0.054	0.050
2023	20	17	0.64	0.62	0.055	0.052

c. TMDL Condition (Annual Average and Converted AGMs)

Year	Chlorophyll *a* Annual Average (µg/L)	Chlorophyll *a* AGM (µg/L)	TN Annual Average (mg/L)	TN AGM (mg/L)	TP Annual Average (mg/L)	TP AGM (mg/L)
2016	20	17	0.80	0.77	0.054	0.050
2017	25	22	0.80	0.77	0.054	0.050
2018	23	20	0.80	0.77	0.053	0.049
2019	23	20	0.80	0.77	0.054	0.050
2020	25	22	0.82	0.80	0.055	0.051
2021	21	18	0.81	0.78	0.058	0.054
2022	17	15	0.80	0.77	0.054	0.050
2023	23	21	0.80	0.77	0.055	0.052

5.5 Calculation of the TMDLs

The nutrient loadings for the TMDL scenario are the loadings where the annual in-lake chlorophyll *a* concentrations do not exceed 20 µg/L more than once in any consecutive 3-year time frame during the modeling period (2016–23). **Table 5.3** lists the nutrient loads input to the BATHTUB model for Lake Francis, including the TN and TP existing loads, the loads that achieve the criterion of 20 µg/L chlorophyll *a* (TMDL condition) and their maximum 5-year averages.

The final reductions to establish the TMDLs for Lake Francis were calculated by using the maximum 5-year average of both the existing and TMDL condition TN and TP loads. The maximum 5-year averages for TN existing loads and TMDL condition loads for the lake are 1,709 and 896 kg/yr, respectively. The maximum 5-year averages for TP existing loads and TMDL condition loads for the lake are 157 and 73 kg/yr, respectively (**Table 5.3**). The general equation used to calculate the percent reductions based on maximum 5-year averages is as follows:

$$\frac{\textbf{[Maximum Existing Load – Maximum TMDL Condition Load]}}{\textbf{Maximum Existing Load}} \textbf{ x 100}$$

To meet the TMDL loads for Lake Francis, the required percent reductions for the TN and TP existing loads are 48 % and 53 %, respectively (**Table 5.5**). The TN and TP TMDLs of 896 and 73 kg/yr, respectively, which are expressed as a 5-year average load, not to be exceeded, address the anthropogenic nutrient inputs contributing to the exceedances of the chlorophyll *a* restoration target.

Table 5.5. Lake Francis TMDL condition nutrient loads, 2016–23.

Note: Values shown in boldface type and shaded cells represent the maximum 5-year averages, the 5-year loads used for the calculations, and percent reductions.

Year	Modeled Existing Condition TN Loads (kg/yr)	5-Year Rolling Average TN Loads (kg/yr)	Modeled TMDL Condition TN Loads (kg/yr)	5-Year Rolling Average TN Loads (kg/yr)	Modeled Existing Condition TP Loads (kg/yr)	5-Year Rolling Average TP Loads (kg/yr)	Modeled TMDL Condition TP Loads (kg/yr)	5-Year Rolling Average TP Loads (kg/yr)
2016	1,139		832		171		68	
2017	1,804		810		132		67	
2018	1,325		969		158		77	
2019	1,154		784		126		65	
2020	1,811	1,447	1,086	**896**	172	152	88	73
2021	1,960	1,611	798	889	148	147	70	**73**
2022	1,212	1,492	775	882	163	153	63	73
2023	2,408	**1,709**	937	876	178	**157**	79	73
Maximum 5-Year Average		**1,709**		**896**		**157**		**73**
% Reduction				48				53

Chapter 6: Determination of Loading Allocations

6.1 Expression and Allocation of the TMDL

The objective of a TMDL is to provide a basis for allocating loads to all the known pollutant sources in a watershed so that appropriate control measures can be implemented and water quality standards achieved. A TMDL is 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), which accounts for uncertainty in the relationship between effluent limitations and water quality:

$$\mathbf{TMDL = \sum WLAs + \sum LAs + MOS}$$

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

$$\mathbf{TMDL \cong \sum WLAs_{wastewater} + \sum WLAs_{NPDES\ Stormwater} + \sum LAs + MOS}$$

It should be noted that the various components of the revised 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 also accounted for in 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). Stormwater reductions are included in both the MS4 WLA and LA, as applicable. However, in determining the overall stormwater reductions needed, DEP does not differentiate between the MS4 WLA and LA, and instead applies the same overall reductions to both as if the two categories were a single category source, unless otherwise specified.

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 also differs from 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, which state that TMDLs can be expressed in terms of mass per time (e.g., pounds per day), toxicity, or other appropriate measure—see 40 Code of Federal Regulations (CFR) § 130.2(i). The TMDLs for Lake Francis are expressed in terms of kg/yr and percent reduction of TN and TP and represent the loads of TN and TP that the waterbody can assimilate while maintaining balanced communities of aquatic flora and fauna (see **Table 6.1**). These TMDLs are based on 5-year rolling averages of simulated loads from 2016 to 2023. For the TMDLs, the restoration goal is to achieve the generally applicable chlorophyll *a* criterion of 20 µg/L, which is expressed as an AGM not to be exceeded more than once in any consecutive 3-year period, thus meeting the water quality criteria and protecting designated uses for Lake Francis.

Table 6.1 lists the TMDLs for the Lake Francis Watershed. The TN and TP loads for the lake will constitute the site-specific numeric interpretations of the narrative nutrient criterion set forth in paragraph 62-302.530(48)(b), F.A.C., that will replace the otherwise applicable NNC in subsection 62-302.531(2), F.A.C., for the lake. Site-specific interpretations for Lake Francis are expressed as a 5-year rolling annual average load not to be exceeded.

Table 6.1. TMDL components for nutrients in Lake Francis (WBID 3366A).

Note: The LA and TMDL daily load for TN is 2.45 kg/day and for TP 0.2 kg/day.
NA = Not applicable
* The required percent reductions listed in this table represent the reduction from all sources.

Waterbody (WBID)	Parameter	TMDL (kg/yr)	WLA Wastewater (% reduction)	WLA NPDES Stormwater (% reduction)*	LA (% reduction)*	MOS
3366A	TN	896	NA	NA	48	Implicit
3366A	TP	73	NA	NA	53	Implicit

6.2 Load Allocation

To achieve the LA for Lake Francis, 48 % and 53 % reductions in existing TN and TP loads, respectively, will be required. Load reductions were calculated from 896 kg/yr for TN and 73 kg/yr for TP, based on the highest five-year average load from the 2016 – 2023 period. Reductions may need to be adjusted to meet the TMDLs in the future based on future loadings.

The TMDLs are based on the percent reduction in total watershed loading of TN and TP from all anthropogenic sources. However, it is not DEP's intent to abate natural conditions. It should be noted that the LA includes loading from stormwater discharges regulated by DEP and the water management district that are not part of the NPDES stormwater program (see **Appendix A**).

6.3 Wasteload Allocation

6.3.1 NPDES Wastewater Discharges

As noted in **Chapter 4**, no active NPDES-permitted facilities in the Lake Francis Watershed discharge into either the lake or the watershed. Therefore, a WLA for wastewater discharges is not applicable.

6.3.2 NPDES Stormwater Discharges

There are no NPDES Phase I or Phase II MS4 permits in the Lake Francis watershed.

6.4 MOS

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. 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)). An implicit MOS was used because the TMDLs were based on the conservative decisions associated with a number of the modeling assumptions in determining assimilative capacity (i.e., loading and water quality response). The TMDLs were developed using the maximum five-year averages for TN and TP existing loads to calculate the percent reductions and requiring the TMDL loads not to be exceeded in any one year.

Chapter 7: Implementation Plan Development and Beyond

7.1 Implementation Mechanisms

Following the adoption of a TMDL, implementation may take place through various measures, including specific requirements in NPDES wastewater and MS4 permits, and as appropriate, local or regional water quality initiatives or basin management action plans (BMAPs).

Facilities with NPDES permits that discharge to the TMDL waterbody must implement the permit conditions that reflect target concentrations, reductions, or WLAs 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 a permit holder to prioritize and act to address a TMDL unless management actions to achieve that particular TMDL are already defined in a BMAP. MS4 Phase II permit holders must also implement the responsibilities defined in a BMAP or other form of restoration plan (e.g., a reasonable assurance plan).

7.2 BMAPs

Information on the development and implementation of BMAPs is found in Section 403.067, F.S. (the FWRA). DEP or a local entity may initiate and develop a BMAP that addresses some or all of the contributing areas to the TMDL waterbody. BMAPs are adopted by the DEP Secretary and are legally enforceable.

BMAPs can describe the fair and equitable allocations of pollution reduction responsibilities to the sources in the watershed, as well as the management strategies that will be implemented to meet those responsibilities, funding strategies, mechanisms to track progress and water quality monitoring. Local entities—such as wastewater facilities, industrial sources, agricultural producers, county and city stormwater systems, military bases, water control districts, state agencies and individual property owners—usually implement these strategies. BMAPs can also identify mechanisms to address potential pollutant loading from future growth and development.

7.3 Implementation Considerations for the Waterbody

Existing nutrient reduction and management infrastructure and plans should be included in any future pollutant mitigation strategies. In addition to addressing reductions in watershed pollutant contributions to impaired waters during the implementation phase, it may also be necessary to consider the impacts of internal sources (e.g., sediment nutrient fluxes or the presence of nitrogen-fixing cyanobacteria) and the results of any associated remediation projects on surface water quality. Approaches for addressing these potential factors should be included in a comprehensive management plan for the lake.

Additionally, the current water quality monitoring of the lake should continue and be expanded, as necessary, during the implementation phase to ensure that adequate information is available for tracking restoration progress. Consideration should be given to expanding monitoring to include likely sources of nutrients to the waterbodies to better guide restoration activities. BMPs and other projects have been implemented to reduce nutrient loading to lake in the basin. Madison County and SRWMD have conducted projects and educational and outreach efforts in the area to help reduce nutrient loading. Projects include sediment controls, detention ponds and street sweeping. Educational and outreach efforts include the illicit discharge program, landscaping, irrigation, fertilizer and pet waste management ordinances, public service announcements and website development.

In fact, the Department of Transportation (DOT), SRWMD and the City of Madison initiated a joint project to address sediment control of contaminants entering Lake Francis from water run-off, flowing from the storm water drains off of U.S. Highway 90, also known as Base Street in 2020. The project was a pilot program and based upon its effectiveness, future plans might be considered to address other sediment control measures.

In 2022, The sediment control system, also referred to as a baffling system was installed off of Lake Shore Drive, as it intersects with Priest Street, to remove sediment, suspended particles, and pollutants from stormwater runoff entering Lake Francis. The storm water drains collect all the water run-off that is accumulated off of Base Street and is funneled into Lake Francis. The sediment control system would also collect rubbish, such as plastic bottles, paper residue, Styrofoam cups, leaves, moss, limbs and other like items of debris before it enters the lake.

References

Conley, D.J., H.W. Paerl, R.W. Howarth, D.F. Boesch, S.P. Seitzinger, K.E. Havens, C. Lancelot, and G.E. Likens. 2009. *Controlling eutrophication: Nitrogen and phosphorus. Science* 323: 1014–1015.

Florida Department of Environmental Protection. 2001. *A report to the Governor and the Legislature on the allocation of total maximum daily loads in Florida.* Tallahassee, FL: Bureau of Watershed Management.

———. 2012. *Development of numeric nutrient criteria for Florida lakes, spring vents, and streams.* Technical support document. Tallahassee, FL: Division of Environmental Assessment and Restoration, Standards and Assessment Section.

———. 2017. *Nutrient TMDLs for Lake Roberts (WBID 2872A).* TMDL report. Tallahassee, FL

Fulton, R.S. III. 1995. *External Nutrient Budget and Trophic State Modeling for Lakes in the Upper Ocklawaha River Basin*. Technical Publication SJ1995-6. Palatka, FL.: St. Johns River Water Management District.

Fulton, R.S. III, C. Schluter, T.A. Keller, S. Nagid, and W. Godwin et al. 2004. *Pollutant load reduction goals for seven major lakes in the Upper Ocklawaha River Basin.* Technical Publication SJ2004-5. Palatka, FL.: St. Johns River Water Management District.

Griffith, G.E., D.E. Canfield, Jr., C.A. Horsburgh, and J.M. Omernik. 1997. *Lake regions of Florida.* EPA/R-97/127. Corvallis, OR: U.S. Environmental Protection Agency.

Harper, H. 1994. *Stormwater loading rate parameters for central and south Florida.* Orlando, FL: Environmental Research and Design, Inc.

———. 2012. *BMPTRAINS MODEL: Rainfall characteristics*. PowerPoint slides.

Lewis, W.M., W.A. Wurtsbaugh, and H.W. Paerl. 2011. *Rationale for control of anthropogenic nitrogen and phosphorus in inland waters. Environmental Science and Technology* 45: 10300–10305.

Northeast Regional Climate Center. 2021. *Online weather data.* Accessed September 1, 2021.

Paerl, H.W. 2009. *Controlling eutrophication along the freshwater-marine continuum: Dual nutrient (N and P) reductions are essential. Estuaries and Coasts* 32: 593–601.

Paerl, H.W., and T.G. Otten. 2013. *Harmful cyanobacterial blooms: Causes, consequences and controls. Microbial Ecology* 65: 995–1010.

U.S. Census Bureau. 2023. QuickFacts

Walker, W.W., Jr. 1987. *Empirical methods for predicting eutrophication in impoundments. Report 4, Phase III: Application manual.* Technical report E-81-9. Vicksburg, MS: U.S. Army Corps of Engineers, Waterways Experiment Station.

———. 1999. *Simplified procedures for eutrophication assessment and prediction: User manual.* Instruction Report W-96-2. Washington, DC: U.S. Army Corps of Engineers.

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, 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, they 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, including 11 categories of industrial activity, construction activities disturbing 5 or more acres of land, and 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 FDOT throughout the 15 counties meeting the population criteria. DEP received authorization to implement the NPDES stormwater program in 2000. The authority to administer the program is set forth in Section 403.0885, F.S.

The Phase II NPDES stormwater program, promulgated in 1999, addresses additional sources, including small MS4s and small construction activities disturbing between 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.

Location	Description
Waterbody name	Lake Francis
Waterbody type(s)	Lake
WBID	Lake Francis (WBID 3366A) (see **Figure 1.1** of this report)
Description	Lake Francis is located in the City of Madison, FL within Madison County, The lake and its surrounding watershed cover an area of 510 acres. Lake Francis has a surface area of 25 acres, with an average depth of 4.3 feet. Urban land use predominates in the Lake Francis Watershed, with 58% coverage. **Chapter 1** of this report describes the Lake Francis system in more detail.
Specific location (latitude/longitude or river miles)	The center of Lake Francis is located at N: 30°27'58"/W: -83°24'27." The site-specific criteria apply as a spatial average for the lake, as defined by WBID 3366A.
Map	**Figures 1.1** and **1.2** show the general location of Lake Francis and its associated watershed, and **Figure 4.1** shows the land uses in the watershed.
Classification(s)	Class III Freshwater
Basin name (HUC 8)	Withlacoochee River Basin (03110203)

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

Numeric Interpretation of Narrative Nutrient Criterion	Information on Parameters Related to Numeric Interpretation of the Narrative Nutrient Criterion
NNC summary: Generally applicable lake classification (if applicable) and corresponding NNC	Lake Francis is a low-color, high-alkalinity lake, and the generally applicable NNC, expressed as AGM concentrations not to be exceeded more than once in any 3-year period, are chlorophyll *a* of 20 µg/L, TN of 1.05 to 1.91 mg/L and TP of 0.03 to 0.09 mg/L.
Proposed TN, TP, chlorophyll *a*, and/or nitrate + nitrite concentrations (magnitude, duration, and frequency)	**Numeric interpretations of the narrative nutrient criterion:** For Lake Francis the 5-year rolling average TN and TP loads are 896 and 73 kg/yr, respectively. Nutrient concentrations are provided for informational purposes only. The in-lake TN and TP AGM concentrations for Lake Francis at the allowable TMDL loading are 0.80 and 0.05 mg/L, respectively, not to be exceeded in any year. These restoration concentrations represent the in-lake concentrations that would still meet the target chlorophyll *a* concentration of 20 µg/L with a 1-in-3-year exceedance rate.
Period of record used to develop numeric interpretations of the narrative nutrient criterion for TN and TP	The criteria were developed based on the application of the curve number method and the BATHTUB model, which simulated hydrology and water quality conditions from 2016 to 2023 for Lake Francis. The primary datasets for this period include water quality data from IWR Run 66, Madison County Weather Data from NLDAS and 2019-2020 SRWMD land use coverage. **Chapters 4** and **5** of this report provide a complete description of the data used in the derivation of the proposed site-specific criteria.
How the criteria developed are spatially and temporally representative of the waterbody or critical condition	The BATHTUB model was used to simulate lake conditions in the 2016–23 period. The period included wet and dry years. The annual average rainfall in this area was 1.345 m during the simulation period. Wetter than average conditions occurred in 2018, 2020 and 2023, while drier than average conditions were present in 2017, 2019, 2021 and 2022. This period captures the hydrologic variability of the system. The curve number approach model simulated loads generated in the watershed to evaluate how changes in watershed loads impact lake nutrient and chlorophyll *a* concentrations. **Figure 2.1** shows the locations of the sampling stations in Lake Francis. Monitoring stations were located throughout the lake and represent the spatial distribution of nutrient dynamics in the lake.

Table B-3. Summary of how designated use(s) are protected by the criterion.

Designated Use Requirements	Information Related to Designated Use Requirements
History of assessment of designated use support	DEP used the IWR Database to assess water quality impairments in Lake Francis (WBID 3366A). Lake Francis (WBID 3366A) was assessed for nutrients as part of the Group 1, Cycle 4 IWR assessment. The verified period was January 1, 2011, to June 30, 2018. Data for the Group 1, Cycle 4 IWR assessment are stored in the IWR Run 56 Access Database. Lake Francis was determined to be verified impaired for chlorophyll *a* and TP. **Table 2.4** lists the AGM values for chlorophyll *a*, TN and TP during the verified period for the waterbody.
Basis for use support	The basis for use support is the NNC chlorophyll *a* concentration of 20 µg/L, which is protective of designated uses for low-color, high-alkalinity lakes. Based on the available information, there is nothing unique about Lake Francis that would make the use of the chlorophyll *a* threshold of 20 µg/L inappropriate for the lake.
Approach used to develop criteria and how it protects uses	For the Lake Francis nutrient TMDLs, DEP created loading-based criteria using the curve number method to simulate loading from the Lake Francis Watershed, and this information and other loading data from atmospheric deposition, OSTDS and groundwater to the lake were inputs into BATHTUB. DEP established the site-specific TN and TP loadings using the calibrated models to achieve an in-lake chlorophyll *a* AGM concentration of 20 µg/L. The maximum of the 5-year rolling averages of TN and TP loadings to achieve the chlorophyll *a* target was determined by decreasing TN and TP loads from anthropogenic sources into the lake until the chlorophyll *a* target was achieved. **Chapter 3** of this report describes the derivation of the TMDLs and criteria.
How the TMDL analysis will ensure that nutrient-related parameters are attained to demonstrate that the TMDLs will not negatively impact other water quality criteria	Model simulations indicated that the target chlorophyll *a* concentration (20 µg/L) in the lake will be attained at the TMDL loads for TN and TP. DEP notes that no other impairments were verified for Lake Francis that may be related to nutrients (such as dissolved oxygen [DO] or un-ionized ammonia). Reducing the nutrient loads entering the lake will not negatively affect other water quality parameters in the lake.

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

Protection of Downstream Waters and Monitoring Requirements	Information Related to Protection of Downstream Waters and Monitoring Requirements
Identification of downstream waters: List receiving waters and identify technical justification for concluding downstream waters are protected	Lake Francis discharges into a wetland in WBID 3366 (Norton Creek), a Class III freshwater stream. Based on the most recent assessment, Norton Creek is not verified impaired for nutrients. As evidenced by their healthy existing condition, the existing loads from Lake Francis to the downstream waters have not led to impairments. Furthermore, the nutrient criteria for Norton Creek are TN and TP AGM concentrations of 1.87 and 0.3 mg/L, respectively. In comparison, the target concentrations of Lake Francis for TN and TP are 0.92 and 0.053 mg/L, respectively. Since the nutrient targets for Lake Francis are lower than nutrient criteria for Norton Creek, the TMDLs for Lake Francis are protective of the downstream creek. Therefore, the reductions in nutrient loads prescribed in the TMDLs for Lake Francis are not expected to cause nutrient impairments downstream.
Summary of existing monitoring and assessment related to the implementation of Subsection 62-302.531(4), F.A.C., and trends tests in Chapter 62-303, F.A.C.	SRWMD and DEP conduct routine monitoring of Lake Francis. The data collected through these monitoring activities will be used to evaluate the effect of BMPs implemented in the watershed on lake TN and TP loads in subsequent water quality assessment cycles.

Table B-5. Documentation of endangered species consideration.

Administrative Requirements	Information for Administrative Requirements
Endangered species consideration	DEP is not aware of any aquatic, amphibious, or anadromous endangered species present in the Lake Francis Watershed. Furthermore, it is expected that restoration efforts and subsequent water quality improvements will positively affect aquatic species living in the lake and its watershed.

Table B-6. Documentation that administrative requirements are met.

Administrative Requirements	Information for Administrative Requirements
Notice and comment notifications	DEP published a Notice of Development of Rulemaking on June 2, 2024, to initiate TMDL development for impaired waters in the Tampa Bay Tributaries Basin. A rule development public workshop for the TMDLs was held on July 24, 2025.
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 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 as site-specific interpretations of the narrative nutrient criterion and will submit these documents to the EPA.

Appendix C. Estimating the Runoff Volume and Nutrient Loads from the Lake Francis Watershed

A. NRCS Curve Number Approach

The stormwater runoff volume for these TMDLs was estimated, using the same spreadsheet model created by SJRWMD (Fulton et al. 2004). The key function of this spreadsheet model is to estimate the annual average runoff coefficient (ROC) for each land use–soil type combination for each year. Once the ROC is decided, the runoff volume can be calculated as the product of rainfall, ROC and acreage of the land use–soil type combination.

SJRWMD's runoff volume spreadsheet model was built based on a land use classification with 15 categories. Each land use was associated with 4 soil hydrologic groups (Types A, B, C and D), resulting in a total of 60 land use–soil type combinations. To calculate the runoff volume for the entire Lake Francis Watershed and, at the same time, quantify the runoff contribution from each land use area, the ROC for each land use–soil type combination must be estimated. SJRWMD's runoff model achieved this goal by estimating a watershed-basin average stormwater runoff coefficient ($ASRC_{wb}$) first, and then deriving the ROC for land use–soil type combination.

The NRCS curve number approach estimates the runoff volume from a given land surface using **Equation 1**:

$$Q = \frac{(P - 0.2 * S)^2}{P + 0.8 * S} \qquad \textbf{Equation 1}$$

Where,

Q = Runoff volume (inches).
P = Rainfall amount (inches).
S = Potential soil storage (inches), which can be calculated using **Equation 2**:

$$S = \frac{1000}{CN} - 10 \qquad \textbf{Equation 2}$$

Where,

CN = Curve number.

The curve number is a dimensionless value ranging from 0 to 100. It is used in the runoff equation to characterize the runoff potential for different land use–soil combinations. Specific curve numbers are assigned to different combinations. In addition, curve numbers are influenced by the antecedent moisture condition (AMC) of the soil. **Table C-1** lists the curve numbers used in developing these TMDLs. These numbers were cited in Suphunvorranop (1985) and were also used by SJRWMD in developing the nutrient PLRG for the Upper Ocklawaha Chain of Lakes.

The curve numbers listed in **Table C-1** are established for the average soil AMC, which is commonly referred to as AMC II. The low and high soil AMCs are usually referred to as AMC I and AMC III, respectively. In the curve number approach, the soil AMC status is judged by comparing the total amount of rainfall a given watershed area received for a total of five days with a set of five-day threshold rainfall values in either the dormant season or the growth season. **Table C-2** lists the five-day threshold rainfall values used to determine the soil AMC for these TMDLs. **Table C-3** lists the curve numbers under the AMC I and AMC III corresponding to each curve number value under the AMC II condition.

Table C-1. Curve numbers by hydrologic soil groups and land use types.

Land Use	Soil Group A	Soil Group B	Soil Group C	Soil Group D
Low-density residential	51	68	79	84
Medium-density residential	57	72	81	86
High-density residential	77	85	90	92
Low-density commercial	77	85	90	92
High-density commercial	89	92	94	95
Transportation	89	92	94	95
Mining	32	58	72	79
Open land/recreational	49	69	79	84
Pasture	47	67	81	88
Cropland	64	75	82	84
Tree crops	32	58	72	79
Other agriculture	59	74	82	86
Forest/rangeland	36	60	73	79
Water	98	98	98	98
Wetlands	89	89	89	89

Table C-2. Threshold five-day antecedent rainfall volume (inches) for AMC classification.

Soil AMC Classification	Dormant Season (November–March)	Growth Season (April–October)
I	< 0.5	< 1.4
II	0.5 – 1.1	1.4 – 2.1
III	> 1.1	> 2.1

Table C-3. Relationship between curve numbers under AMCs I, II and III.

AMC I	AMC II	AMC III
0	0	0
2	5	17
4	10	26
7	15	33
9	20	39
12	25	45
15	30	50
19	35	55
23	40	60
27	45	65
31	50	70
35	55	75
40	60	79
45	65	83
51	70	87
57	75	91
63	80	94
70	85	97
78	90	98
87	95	99
100	100	100

One common practice to calculate runoff volume from a given watershed using the curve number approach is to calculate the runoff from the pervious and impervious areas, and then add the runoff volumes from these two areas together to determine total watershed runoff. To apply this method, the impervious areas are usually divided into two types: directly connected impervious area (DCIA) and non-directly connected impervious area (NDCIA). The DCIA represents the areas that are directly connected to the stormwater drainage system. It is typically assumed that 90 % of the rainfall onto the DCIA will become runoff.

In contrast, the runoff created from the NDCIA will reach the pervious area and contribute to pervious area runoff. Therefore, the NDCIA typically is not considered as part of the impervious area but as part of the pervious area. **Table C-4** lists the percent areas occupied by DCIA, NDCIA and pervious areas for each land use type used in developing the TMDLs. SJRWMD used these percent area values in developing the nutrient PLRG for the Upper Ocklawaha Chain of Lakes. The values included in the table were assembled by Camp Dresser and McKee (CDM) (1994).

The total runoff from a watershed can be represented using **Equation 3**:

$$Q = Q_{Pervious} + Q_{DCIA}$$ **Equation 3**

Where,

Q = Total runoff from the watershed area (centimeters [cm]).
$Q_{Pervious}$ = Runoff from the pervious area (cm).
Q_{DCIA} = Runoff from the DCIA (cm).

Table C-4. Land use–specific percent DCIA, NDCIA and pervious area.

Note: This table was cited from SJRWMD's nutrient PLRG for the Upper Ocklawaha River Basin. Data were assembled by CDM (1994).

Land Use	DCIA	NDCIA	Pervious Area	Sum of NDCIA and Pervious Area
Low-density residential	5	10	85	95
Medium-density residential	15	20	65	85
High-density residential	25	40	35	75
Low-density commercial	40	40	20	60
High-density commercial	45	35	20	55
Transportation	45	35	20	55
Mining	1	1	98	99
Open land/recreational	1	1	98	99
Pasture	1	1	98	99
Cropland	1	1	98	99
Tree crops	1	1	98	99
Other agriculture	1	1	98	99
Forest/rangeland	1	1	98	99
Water	85	15	0	15
Wetland	75	0	25	25

Q_{DCIA} can be calculated using **Equation 4**:

$$Q_{DCIA} = P * 0.9 * (\frac{DCIA}{TotalArea})$$ **Equation 4**

Where,

P = Rainfall (cm).
$DCIA$ = Area of DCIA.
$TotalArea$ =Total watershed area.

$Q_{Pervious}$ can be calculated using **Equation 5**:

$$Q_{Pervious} = \frac{(P' - 0.2 * S)^2}{P' + 0.8 * S} * (\frac{PerviousArea}{TotalArea}) \qquad \textbf{Equation 5}$$

Where,

P' = Adjusted rainfall (centimeters [cm]).
S = Potential soil storage of rainfall (cm).
PerviousArea = Acreage of the pervious area in the watershed.

Measured rainfall was adjusted in **Equation 5** to account for rain falling in the NDCIA. It was assumed that rainfall on these areas would reach and uniformly spread out onto the pervious area. To account for rainfall to the NDCIA, the measured rainfall was adjusted using **Equation 6**.

$$P' = \frac{P * PerviousArea + P * NDCIA}{PerviousArea} \qquad \textbf{Equation 6}$$

Where,

NDCIA = Area of NDCIA.

Equation 6 can be simplified to **Equation 7**:

$$P' = P * (1 + \frac{NDCIA}{PerviousArea}) \qquad \textbf{Equation 7}$$

The potential soil storage can be calculated using **Equation 8**:

$$S = \frac{1000}{CNpervious} - 10 \qquad \textbf{Equation 8}$$

Where,

$CN_{Pervious}$ = Curve number for the pervious area.

$CN_{Pervious}$ can be derived from the watershed average curve number, calculated using **Equation 9**:

$$CN_{Watershed} = \frac{\sum (Area * CN)}{TotalArea} \qquad \textbf{Equation 9}$$

Where,

$CN_{Watershed}$ = Watershed average curve number.
CN = Land use–soil combination specific curve number listed in **Table 4.3**.
$Area$ = Area occupied by a specific land use–soil combination.
$TotalArea$ = Total area of the entire watershed.

$CN_{Watershed}$ can also be represented using **Equation 10**:

$$CN_{Watershed} = \frac{(CN_{DCIA} * Area_{DCIA}) + (CN_{Pervious} * Area_{Pervious})}{TotalArea}$$ **Equation 10**

Where,

CN_{DCIA} = Curve number of the DCIA.
$Area_{DCIA}$ = Acreage occupied by the DCIA.
$Area_{Pervious}$ = Acreage of the watershed occupied by both the NDCIA and pervious area.

Equation 10 can be rewritten to solve for $CN_{Pervious}$ as **Equation 11**:

$$CN_{Pervious} = \frac{(CN_{Watershed} * TotalArea) - (CN_{DCIA} * Area_{DCIA})}{Area_{Pervious}}$$ **Equation 11**

With all the above equations, the watershed runoff volume Q defined in **Equation 4** can be calculated. The watershed-basin average $ASRC_{wb}$ can be calculated as the quotient between the watershed runoff volume and rainfall to the watershed.

$ASRC_{wb}$ can also be represented using **Equation 12**:

$$ASRC_{wb} = \frac{(DCIA * 0.9) + (PerviousArea * WRC_{Pervious})}{TotalArea}$$ **Equation 12**

Equation 12 can be rewritten to solve for the weighted runoff coefficient (WRF) for the pervious area (**Equation 13**):

$$WRC_{Pervious} = \frac{(ASRC_{wb} * TotalArea) - (DCIA * 0.9)}{PerviousArea}$$ **Equation 13**

When developing the nutrient PLRG for the Upper Ocklawaha Chain of Lakes, SJRWMD assumed that Type D soil would have four times the runoff compared with Type A (Fulton et al.

2004). This assumption was made based on the typical depth to groundwater and the resultant soil storage (**Table C-5**).

Table C-5. Groundwater depth and soil runoff potential.

PRC = Proportional runoff coefficient

Soil Type	Depth to Groundwater (m)	Runoff Ratio	Soil Type Coefficient
A	>1.2	1	PRC
B	0.9	2	2*PRC
C	0.6	3	3*PRC
D	0.3	4	4*PRC

Based on this assumption, $WRC_{Pervious}$ can also be represented using **Equation 14**:

$$WRC_{Pervious} = \frac{PRC * Area_{Asoil} + 2PRC * Area_{Bsoil} + 3PRC * Area_{Csoil} + 4PRC * Area_{Dsoil}}{PerviousArea}$$

Equation 14

Where,

PRC = Proportional runoff coefficient.
$AreaAsoil$ = Area occupied by Type A soil.
$AreaBsoil$ = Area occupied by Type B soil.
$AreaCsoil$ = Area occupied by Type C soil.
$AreaDsoil$ = Area occupied by Type D soil.

Equation 14 can be rewritten to solve for PRC (**Equation 15**):

$$PRC = \frac{PerviousArea * WRC_{Pervious}}{Area_{Asoil} + 2 * Area_{Bsoil} + 3 * Area_{Csoil} + 4 * Area_{Dsoil}}$$ **Equation 15**

The final area WRF for each land use–soil combination ($ASRC_{LS}$) is calculated using **Equation 16**:

$$ASRC_{LS} = \frac{(DCIA_{LS} * 0.9) + (PerviousArea_{LS} * n * PRC)}{TotalArea_{LS}}$$ **Equation 16**

Where,

$DCIA_{LS}$ = DCIA occupied by a specific land use–soil type combination.

PerviousArea$_{LS}$ = Pervious area (including the NDCIA) occupied by a specific land use–soil type combination.

n = Runoff ratio listed in **Table C-5**. The n values for Type A, B, C and D soils are 1, 2, 3 and 4, respectively.

TotalArea$_{LS}$ = Total area occupied by a specific land use–soil type combination.

Rainfall data from the Madison County (NLDAS, X332Y043) were used in calculating the ROC and runoff volume for the TMDLs. **Table 5.1** summarizes the annual rainfall to the Lake Francis Watershed for each year from 2016 to 2023. **Table C-6** lists the ROCs for each land use–soil type combination for each year from 2016 to 2023. **Table 4.3** lists the annual runoff volume from the Lake Francis Watershed in each year.

Table C-6. Runoff coefficient for different land use–soil type combinations for each year, 2016–23.

NA = Not applicable because there is no such land use or soil type.

Land Use	Soil	2016	2017	2018	2019	2020	2021	2022	2023
Low-density residential	A	0.061	0.061	0.073	0.074	0.116	0.054	0.064	0.057
Low-density residential	B	0.076	0.077	0.101	0.102	0.187	0.062	0.084	0.069
Low-density residential	C	0.092	0.093	0.130	0.131	0.258	0.071	0.103	0.081
Low-density residential	D	0.108	0.109	0.158	0.160	0.328	0.080	0.122	0.093
Medium-density residential	A	0.149	0.149	0.160	0.161	0.198	0.143	0.152	0.146
Medium-density residential	B	0.163	0.164	0.185	0.186	0.262	0.150	0.169	0.156
Medium-density residential	C	0.177	0.178	0.211	0.212	0.325	0.158	0.187	0.167
Medium-density residential	D	0.191	0.192	0.236	0.237	0.389	0.166	0.204	0.178
High-density residential	A	0.237	0.238	0.247	0.248	0.281	0.232	0.240	0.234
High-density residential	B	NA	NA	NA	NA	NA	NA	NA	NA
High-density residential	C	NA	NA	NA	NA	NA	NA	NA	NA
High-density residential	D	NA	NA	NA	NA	NA	NA	NA	NA
Low-density commercial	A	0.370	0.370	0.378	0.378	0.405	0.365	0.372	0.368
Low-density commercial	B	0.380	0.380	0.396	0.396	0.450	0.371	0.384	0.375
Low-density commercial	C	0.390	0.390	0.413	0.414	0.494	0.376	0.397	0.383
Low-density commercial	D	0.400	0.401	0.431	0.432	0.539	0.382	0.409	0.390
High-density commercial	A	0.414	0.414	0.421	0.422	0.446	0.410	0.416	0.412
High-density commercial	B	0.423	0.424	0.438	0.438	0.487	0.415	0.427	0.419
High-density commercial	C	0.432	0.433	0.454	0.455	0.528	0.420	0.438	0.426
High-density commercial	D	0.441	0.442	0.470	0.471	0.569	0.425	0.450	0.433
Transportation	A	0.414	0.414	0.421	0.422	0.446	0.410	0.416	0.412
Transportation	B	0.423	0.424	0.438	0.438	0.487	0.415	0.427	0.419
Transportation	C	0.432	0.433	0.454	0.455	0.528	0.420	0.438	0.426
Transportation	D	0.441	0.442	0.470	0.471	0.569	0.425	0.450	0.433
Mining	A	NA	NA	NA	NA	NA	NA	NA	NA
Mining	B	NA	NA	NA	NA	NA	NA	NA	NA
Mining	C	NA	NA	NA	NA	NA	NA	NA	NA
Mining	D	NA	NA	NA	NA	NA	NA	NA	NA

Land Use	Soil	2016	2017	2018	2019	2020	2021	2022	2023
Open land/recreational	A	0.025	0.026	0.038	0.039	0.083	0.018	0.029	0.021
Open land/recreational	B	NA	NA	NA	NA	NA	NA	NA	NA
Open land/recreational	C	NA	NA	NA	NA	NA	NA	NA	NA
Open land/recreational	D	NA	NA	NA	NA	NA	NA	NA	NA
Pasture	A	0.025	0.026	0.038	0.039	0.083	0.018	0.029	0.021
Pasture	B	NA	NA	NA	NA	NA	NA	NA	NA
Pasture	C	0.058	0.059	0.097	0.099	0.231	0.036	0.069	0.046
Pasture	D	NA	NA	NA	NA	NA	NA	NA	NA
Cropland	A	0.025	0.026	0.038	0.039	0.083	0.018	0.029	0.021
Cropland	B	0.042	0.042	0.068	0.069	0.157	0.027	0.049	0.034
Cropland	C	0.058	0.059	0.097	0.099	0.231	0.036	0.069	0.046
Cropland	D	NA	NA	NA	NA	NA	NA	NA	NA
Tree crop	A	NA	NA	NA	NA	NA	NA	NA	NA
Tree crop	B	NA	NA	NA	NA	NA	NA	NA	NA
Tree crop	C	NA	NA	NA	NA	NA	NA	NA	NA
Tree crop	D	NA	NA	NA	NA	NA	NA	NA	NA
Other agriculture	A	NA	NA	NA	NA	NA	NA	NA	NA
Other agriculture	B	NA	NA	NA	NA	NA	NA	NA	NA
Other agriculture	C	NA	NA	NA	NA	NA	NA	NA	NA
Other agriculture	D	NA	NA	NA	NA	NA	NA	NA	NA
Forest/rangeland	A	0.025	0.026	0.038	0.039	0.083	0.018	0.029	0.021
Forest/rangeland	B	0.042	0.042	0.068	0.069	0.157	0.027	0.049	0.034
Forest/rangeland	C	0.058	0.059	0.097	0.099	0.231	0.036	0.069	0.046
Forest/rangeland	D	0.074	0.076	0.126	0.128	0.304	0.045	0.089	0.059
Water	A	0.767	0.768	0.769	0.770	0.776	0.766	0.768	0.767
Water	B	0.770	0.770	0.774	0.774	0.787	0.768	0.771	0.769
Water	C	NA	NA	NA	NA	NA	NA	NA	NA
Water	D	0.775	0.775	0.783	0.783	0.810	0.770	0.777	0.773
Wetland	A	0.679	0.679	0.682	0.683	0.694	0.677	0.680	0.678
Wetland	B	0.683	0.683	0.690	0.690	0.712	0.680	0.685	0.681
Wetland	C	NA	NA	NA	NA	NA	NA	NA	NA
Wetland	D	0.691	0.692	0.705	0.705	0.750	0.684	0.695	0.688

B. Estimating Runoff Nutrient Loads

The runoff nutrient loads from a watershed are calculated by multiplying the runoff volume from the land use area by runoff TN and TP concentrations specific to the land use type. These runoff nutrient concentrations are commonly referred to as EMCs. EMCs can be determined through stormwater studies, in which both runoff volume and runoff nutrient concentrations are measured during the phases of a given stormwater event. The EMC for the stormwater event is then calculated as the mean concentration weighted for the runoff volume. The TN and TP EMCs (**Table C-7**) used in this TMDL analysis were based on general land use descriptions and were spatially averaged data in Florida (Harper 1994; 2012).

Table C-7. EMCs of TN and TP for different land use types.

Land Use	TP EMC (mg/L)	TN EMC (mg/L)
Low-density residential	0.178	1.51
Medium-density residential	0.301	1.87
High-density residential	0.497	2.10
Low-density commercial	0.179	1.07
High-density commercial	0.248	2.2
Transportation	0.184	1.52
Mining	0.150	1.18
Pasture	0.621	3.30
Tree crops	0.152	2.07
Cropland	0.489	2.46
Other agriculture	1.050	3.24
Open land/recreational	0.301	1.87
Forest/rangeland	0.055	1.15
Wetlands	0.055	1.15
Water	0.025	0.716

Another aspect of the nutrient load simulation was the effective delivery of nutrients to the receiving water after going through the overland transport process. In this TMDL analysis, all dissolved components of TN and TP were considered to reach the receiving water without any loss, while particulate fractions of TN and TP were considered subject to loss through the overland transport process. Therefore, the amount of nutrients eventually reaching the receiving water includes two components: the unattenuated dissolved fraction (T) and the particulate fraction that is attenuated through the overland transport process. The portion of the nutrients that eventually reaches the receiving water can be represented using **Equation 7**, which is a function established in the Reckhow et al. (1989) analyses.

$$D = (1 - T) * e^{(1.01 - 0.34 * \ln(L))} + T$$ **Equation 17**

Where,

D = Amount of nutrients that eventually reaches the receiving water.
T = Dissolved fraction of the total nutrient (TN and TP) concentrations.
(1-T) = Particulate fraction of the total nutrient (TN and TP) concentrations.
The exponential portion of the equation represents the delivery ratio of the particulate nutrients.
L = Length of the overland flow path.

The percent dissolved TN and TP concentrations for different land uses used in this TMDL analysis were cited from SJRWMD's Upper Ocklawaha Chain of Lakes PLRG report (Fulton et al. 2004). These numbers were created by comparing concentrations of TN, TP, orthophosphate (PO_4), total dissolved phosphorus (TDP) and total dissolved nitrogen (TDN) from several studies on stormwater runoff conducted in Florida (Dierberg 1991; Fall 1990; Fall and Hendrickson 1988; German 1989; Harper and Miracle 1993; Hendrickson 1987; Izuno et al. 1991). **Table C-8** lists the percent concentration of dissolved phosphorus and nitrogen for different land uses.

The length of the overland flow path was estimated by randomly picking 20 transects of the watershed and measuring the distance between the boundary of the watershed and the boundary of the lake. The final length of the overland flow path was calculated as the mean values of the lengths of these 20 transect measurements. For the Lake Francis Watershed, the average length of the overland flow path was estimated this way as 872 m.

Table 4.4 lists the stormwater runoff TN and TP loads from the Lake Francis Watershed estimated using the procedures described above.

Table C-8. Dissolved fraction of TN and TP concentrations for different land uses.

Land Use	Dissolved Phosphorus (%)	Dissolved Nitrogen (%)
Low-density residential	50.1	75.3
Medium-density residential	50.1	75.3
High- density residential	50.1	75.3
Low-density commercial	41.4	65.7
High- density commercial	76.7	76.7
Transportation	76.7	76.7
Mining	46.7	65.7
Pasture	72.2	90.8
Tree crop	62.9	90.8
Cropland	60.0	90.8
Other agriculture	68.7	90.8
Open land/recreational	50.1	75.3
Forest/rangeland	50.1	75.3
Wetlands	50.7	77.5
Water	11.8	41.3

References

Camp Dresser and McKee Inc. 1994. *City of Jacksonville master stormwater management plan methodology volume.* Final report for the city of Jacksonville and St. Johns River Water Management District. Jacksonville, FL.

Dierberg, F.E. 1991. *Nonpoint source loadings of nutrients and dissolved organic carbon from an agricultural-suburban watershed in east central Florida. Water Research* 25:363–74.

Fall, C. 1990. *Characterization of agricultural pump discharge quality in the Upper St. Johns River Basin.* Technical Publication SJ90-1. Palatka, FL: St. Johns River Water Management District.

Fall, C., and J. Hendrickson. 1988. *An investigation of the St. Johns Water Control District: Reservoir water quality and farm practices.* Technical Publication SJ88-5. Palatka, FL: St. Johns River Water Management District.

Fulton, R.S., III., C. Schluter, T.A. Keller, S. Nagid, and W. Godwin et al. 2004. *Pollutant load reduction goals for seven major lakes in the Upper Ocklawaha River Basin.* Technical Publication SJ2004-5. Palatka, FL: St. Johns River Water Management District.

German, E.R. 1989. *Quantity and quality of stormwater runoff recharged to the Floridan aquifer system through two drainage wells in the Orlando, Florida, area.* U.S. Geological Survey Water-Supply Paper 2344. Denver, CO.

Harper, H.H. Revised 1994. *Stormwater loading rate parameters for central and south Florida.* Orlando, FL: Environmental Research and Design, Inc.

———. 2012. BMPTRAINS MODEL: *Rainfall characteristics.* PowerPoint slides.

Harper, H.H., and D.E. Miracle. 1993. *Treatment efficiencies of detention with filtration systems.* Special Publication SJ93-SP12. Palatka, FL: St. Johns River Water Management District.

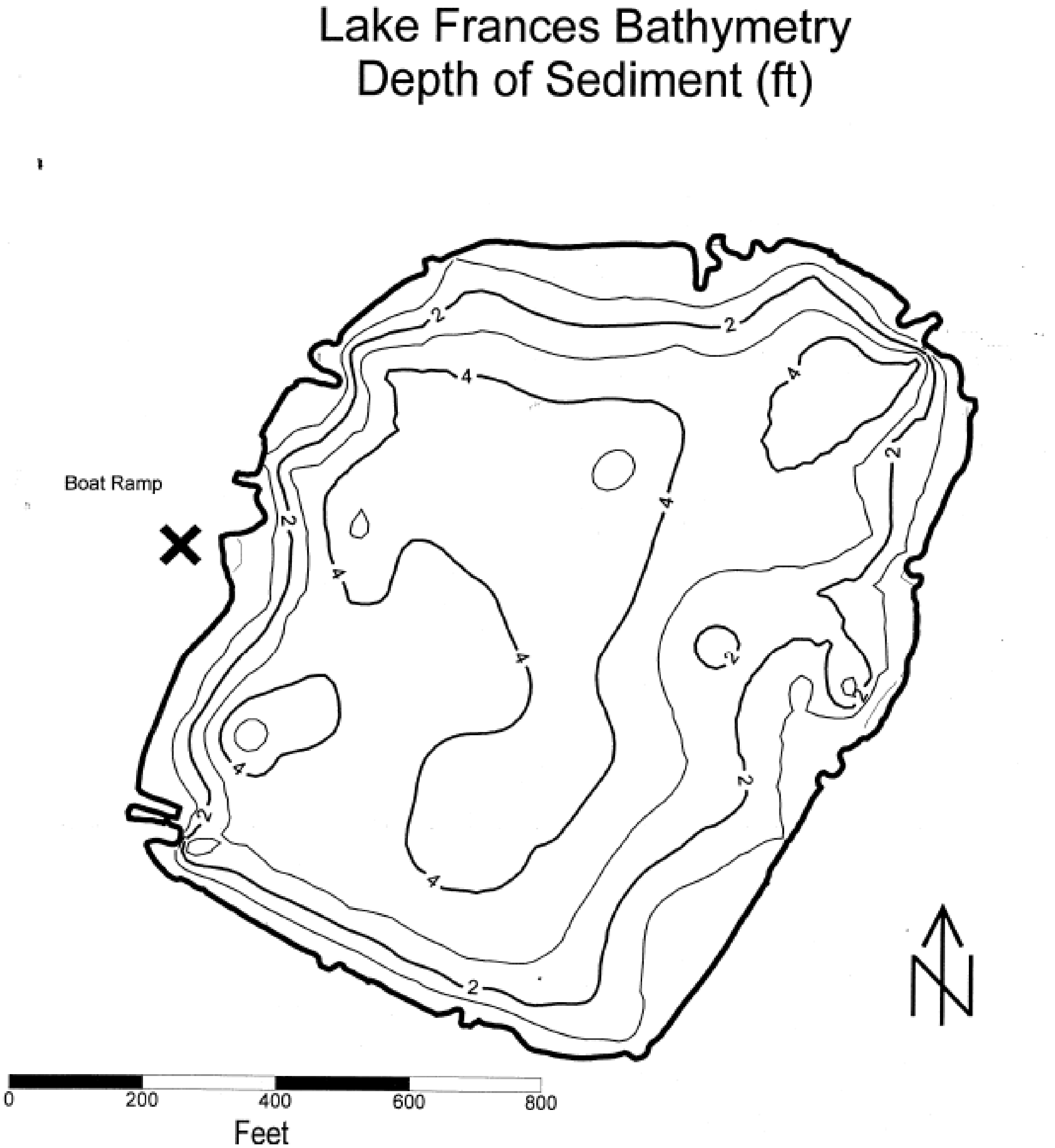
Hendrickson, J. 1987. *Effect of the Willowbrook Farms detention basin on the quality of agricultural runoff.* Report to the Florida Department of Environmental Regulation and St. Johns River Water Management District. Palatka, FL.

Izuno, F.T., C.A. Sanchez, F.J. Coale, A.B. Bottcher, and D.B. Jones. 1991. *Phosphorus concentrations in drainage water in the Everglades agricultural area. Journal of Environmental Quality* 20:608–19.

Reckhow, K.H., J.P. Hartigan, and S. Coffey. 1989. *Lake nutrient budget development for state-level applications.* In: *Proceedings of a national conference on enhancing states' lakes management programs* (Washington, DC: North American Lake Management Society).

Suphunvorranop, T. 1985. *A guide to SCS runoff procedures*. Technical Publication SJ 85-5. Palatka, FL: St. Johns River Water Management District.

Appendix D. Lake Bottom Sediment depth in Lake Francis.



Appendix E. Algal composition and unit density collected in Lake Francis.

Sample Date	Station	Taxon Name	Density (Unit/mL)	Phylum
9/4/1996	21020056	*Anabaena*	186.7	Cyanophycota
9/4/1996	21020056	*Chlamydomonas*	186.7	Chlorophycota
9/4/1996	21020056	*Microcystis*	373.4	Cyanophycota
9/4/1996	21020056	*Oscillatoria*	10268.62	Cyanophycota
10/7/2003	21020056	*Anabaena*	45869	Cyanophycota
10/7/2003	21020056	*Ankistrodesmus falcatus*	1014	Chlorophycota
10/7/2003	21020056	*Bacillariophyceae*	3041	Bacillariophyta
10/7/2003	21020056	*Ceratium*	253	Pyrrophycophyta
10/7/2003	21020056	*Chlorella*	2027	Chlorophycota
10/7/2003	21020056	*Cosmarium abbreviatum minus*	2788	Chlorophycota
10/7/2003	21020056	*Cyanobium planctium*	1774	Cyanophycota
10/7/2003	21020056	*Oocystis*	1774	Chlorophycota
10/7/2003	21020056	*Scenedesmus*	253	Chlorophycota
10/7/2003	21020056	*Scenedesmus bijuga*	760	Chlorophycota
10/7/2003	21020056	*Selenastrum*	4815	Chlorophycota
10/7/2003	21020056	*Staurastrum gracile coronulatum*	11657	Chlorophycota
10/7/2003	21020056	*Tetraedron gracile*	1014	Chlorophycota
11/15/2006	21020123	*Amphora*		Bacillariophyta
11/15/2006	21020123	*Ankistrodesmus falcatus*	6356	Chlorophycota
11/15/2006	21020123	*Aulacoseira*		Bacillariophyta
11/15/2006	21020123	*Bacillariophyceae*		Bacillariophyta
11/15/2006	21020123	*Bacillariophyta*	5018	Bacillariophyta
11/15/2006	21020123	*Chlorella*	5018	Chlorophycota
11/15/2006	21020123	*Cocconeis placentula*		Bacillariophyta
11/15/2006	21020123	*Cylindrospermopsis raciborskii*	669	Cyanophycota
11/15/2006	21020123	*Dictyosphaerium pulchellum*	9701	Chlorophycota
11/15/2006	21020123	*Fragilaria*		Bacillariophyta
11/15/2006	21020123	*Fragilaria pinnata*		Bacillariophyta
11/15/2006	21020123	*Fragilariaceae*		Bacillariophyta
11/15/2006	21020123	*Geitlerinema*	50177	Cyanophycota
11/15/2006	21020123	*Golenkinia paucispina*	1004	Chlorophycota
11/15/2006	21020123	*Gomphonema*		Bacillariophyta
11/15/2006	21020123	*Jaaginema*	4683	Cyanophycota
11/15/2006	21020123	*Kirchneriella contorta*	335	Chlorophycota
11/15/2006	21020123	*Microcystis aeruginosa*	335	Cyanophycota
11/15/2006	21020123	*Navicula cryptocephala*		Bacillariophyta
11/15/2006	21020123	*Nitzschia*		Bacillariophyta
11/15/2006	21020123	*Oocystis*	1338	Chlorophycota
11/15/2006	21020123	*Pediastrum duplex*	669	Chlorophycota

11/15/2006	21020123	*Pediastrum simplex*	335	Chlorophycota
11/15/2006	21020123	*Planktolyngbya*	1004	Cyanophycota
11/15/2006	21020123	*Pseudanabaena mucicola*	1004	Cyanophycota
11/15/2006	21020123	*Rhabdogloea*	5352	Cyanophycota
11/15/2006	21020123	*Scenedesmus*	335	Chlorophycota
11/15/2006	21020123	*Scenedesmus quadricauda*	2342	Chlorophycota
11/15/2006	21020123	*Schroederia setigera*	669	Chlorophycota
11/15/2006	21020123	*Selenastrum*	1673	Chlorophycota
11/15/2006	21020123	*Selenastrum gracile*	335	Chlorophycota
11/15/2006	21020123	*Sellaphora*		Bacillariophyta
11/15/2006	21020123	*Synechocystis*	2007	Cyanophycota
11/15/2006	21020123	*Tetraedron minimum*	669	Chlorophycota
11/15/2006	21020123	*Tetraedron pentaedricum*	335	Chlorophycota
6/19/2007	21020123	*Achnanthes minutissima*		Bacillariophyta
6/19/2007	21020123	*Anabaena planctonica*	11475	Cyanophycota
6/19/2007	21020123	*Aphanizomenon*	239	Cyanophycota
6/19/2007	21020123	*Aphanocapsa*	80	Cyanophycota
6/19/2007	21020123	*Aulacoseira*		Bacillariophyta
6/19/2007	21020123	*Aulacoseira granulata*		Bacillariophyta
6/19/2007	21020123	*Bacillariophyceae*		Bacillariophyta
6/19/2007	21020123	*Bacillariophyta*	478	Bacillariophyta
6/19/2007	21020123	*Ceratium hirundinella*	80	Pyrrophycophyta
6/19/2007	21020123	*Chlamydomonas*	2948	Chlorophycota
6/19/2007	21020123	*Chlorella*	637	Chlorophycota
6/19/2007	21020123	*Chlorococcum*	80	Chlorophycota
6/19/2007	21020123	*Chlorophyceae*	159	Chlorophycota
6/19/2007	21020123	*Chroococcus minutus*	159	Cyanophycota
6/19/2007	21020123	*Cocconeis placentula*		Bacillariophyta
6/19/2007	21020123	*Coelastrum cambricum*	239	Chlorophycota
6/19/2007	21020123	*Cosmarium subretusiforme*	159	Chlorophycota
6/19/2007	21020123	*Craticula*		Bacillariophyta
6/19/2007	21020123	*Cryptomonas*	159	Cryptophycophyta
6/19/2007	21020123	*Cyclotella pseudostelligera*		Bacillariophyta
6/19/2007	21020123	*Cyclotella stelligera*		Bacillariophyta
6/19/2007	21020123	*Diadesmis confervacea*		Bacillariophyta
6/19/2007	21020123	*Dictyosphaerium pulchellum*	398	Chlorophycota
6/19/2007	21020123	*Encyonema*		Bacillariophyta
6/19/2007	21020123	*Eunotia*		Bacillariophyta
6/19/2007	21020123	*Fragilaria*		Bacillariophyta
6/19/2007	21020123	*Fragilaria pinnata*		Bacillariophyta
6/19/2007	21020123	*Fragilariaceae*		Bacillariophyta
6/19/2007	21020123	*Gloeocystis*	2072	Chlorophycota
6/19/2007	21020123	*Gomphonema gracile*		Bacillariophyta

6/19/2007	21020123	*Gomphonema parvulum*		Bacillariophyta
6/19/2007	21020123	*Jaaginema*	80	Cyanophycota
6/19/2007	21020123	*Microcystis wesenbergii*	80	Cyanophycota
6/19/2007	21020123	*Navicula*		Bacillariophyta
6/19/2007	21020123	*Nitzschia*		Bacillariophyta
6/19/2007	21020123	*Oocystis*	319	Chlorophycota
6/19/2007	21020123	*Pediastrum duplex*	319	Chlorophycota
6/19/2007	21020123	*Pediastrum simplex*	159	Chlorophycota
6/19/2007	21020123	*Pediastrum tetras*	80	Chlorophycota
6/19/2007	21020123	*Planktosphaeria*	398	Chlorophycota
6/19/2007	21020123	*Planktothrix*	558	Cyanophycota
6/19/2007	21020123	*Radiococcus*	239	Chlorophycota
6/19/2007	21020123	*Scenedesmus*	80	Chlorophycota
6/19/2007	21020123	*Scenedesmus bijuga*	159	Chlorophycota
6/19/2007	21020123	*Scenedesmus dimorphus*	239	Chlorophycota
6/19/2007	21020123	*Scenedesmus quadricauda*	159	Chlorophycota
6/19/2007	21020123	*Selenastrum*	159	Chlorophycota
6/19/2007	21020123	*Sellaphora laevissima*		Bacillariophyta
6/19/2007	21020123	*Sellaphora pupula*		Bacillariophyta
6/19/2007	21020123	*Sphaerocystis*	159	Chlorophycota
6/19/2007	21020123	*Staurastrum*	80	Chlorophycota
6/19/2007	21020123	*Staurastrum anatinum anatinum*	159	Chlorophycota
6/19/2007	21020123	*Staurastrum curviceps*	80	Chlorophycota
6/19/2007	21020123	*Staurastrum depressiceps depressiceps*	159	Chlorophycota
6/19/2007	21020123	*Synechocystis*	478	Cyanophycota
6/19/2007	21020123	*Synedra acus angustissima*		Bacillariophyta
6/19/2007	21020123	*Tetraedron gracile*	159	Chlorophycota
6/19/2007	21020123	*Tetraedron limneticum*	80	Chlorophycota
6/19/2007	21020123	*Trachelomonas*	319	Euglenophycota
7/18/2007	21020123	*Achnanthes minutissima*		Bacillariophyta
7/18/2007	21020123	*Anabaena planctonica*	136	Cyanophycota
7/18/2007	21020123	*Ankistrodesmus falcatus*	271	Chlorophycota
7/18/2007	21020123	*Aphanizomenon flosaquae*	10042	Cyanophycota
7/18/2007	21020123	*Aulacoseira*		Bacillariophyta
7/18/2007	21020123	*Aulacoseira granulata*		Bacillariophyta
7/18/2007	21020123	*Bacillariophyceae*		Bacillariophyta
7/18/2007	21020123	*Bacillariophyta*	1628	Bacillariophyta
7/18/2007	21020123	*Chlamydomonas*	543	Chlorophycota
7/18/2007	21020123	*Chlorella*	1764	Chlorophycota
7/18/2007	21020123	*Chlorococcum*	271	Chlorophycota
7/18/2007	21020123	*Closterium gracile gracile*	543	Chlorophycota
7/18/2007	21020123	*Cocconeis placentula*		Bacillariophyta
7/18/2007	21020123	*Coelastrum cambricum*	136	Chlorophycota

7/18/2007	21020123	*Coelastrum microporum*	814	Chlorophycota
7/18/2007	21020123	*Cosmarium anisochondrum tetrachondrum*	950	Chlorophycota
7/18/2007	21020123	*Cryptomonas*	679	Cryptophycophyta
7/18/2007	21020123	*Cyclotella*		Bacillariophyta
7/18/2007	21020123	*Cyclotella meneghiniana*		Bacillariophyta
7/18/2007	21020123	*Diadesmis confervacea*		Bacillariophyta
7/18/2007	21020123	*Fragilaria*		Bacillariophyta
7/18/2007	21020123	*Fragilaria pinnata*		Bacillariophyta
7/18/2007	21020123	*Fragilariaceae*		Bacillariophyta
7/18/2007	21020123	*Gloeocystis*	543	Chlorophycota
7/18/2007	21020123	*Gloeocystis gigas*	4207	Chlorophycota
7/18/2007	21020123	*Gomphonema gracile*		Bacillariophyta
7/18/2007	21020123	*Gomphonema parvulum*		Bacillariophyta
7/18/2007	21020123	*Kirchneriella contorta*	271	Chlorophycota
7/18/2007	21020123	*Microcystis wesenbergii*	2171	Cyanophycota
7/18/2007	21020123	*Navicula*		Bacillariophyta
7/18/2007	21020123	*Navicula minima*		Bacillariophyta
7/18/2007	21020123	*Nitzschia*		Bacillariophyta
7/18/2007	21020123	*Nitzschia amphibia*		Bacillariophyta
7/18/2007	21020123	*Oocystis*	3528	Chlorophycota
7/18/2007	21020123	*Pediastrum duplex*	271	Chlorophycota
7/18/2007	21020123	*Pediastrum simplex*	1357	Chlorophycota
7/18/2007	21020123	*Planktosphaeria*	3528	Chlorophycota
7/18/2007	21020123	*Pseudanabaena mucicola*	543	Cyanophycota
7/18/2007	21020123	*Scenedesmus quadricauda*	1493	Chlorophycota
7/18/2007	21020123	*Sellaphora*		Bacillariophyta
7/18/2007	21020123	*Sellaphora pupula*		Bacillariophyta
7/18/2007	21020123	*Staurastrum*	679	Chlorophycota
7/18/2007	21020123	*Tetraedron minimum*	4614	Chlorophycota
9/19/2007	21020123	*Achnanthes exigua*		Bacillariophyta
9/19/2007	21020123	*Amphora*		Bacillariophyta
9/19/2007	21020123	*Anabaena*	16491	Cyanophycota
9/19/2007	21020123	*Asterionella*		Bacillariophyta
9/19/2007	21020123	*Asterionella formosa*		Bacillariophyta
9/19/2007	21020123	*Aulacoseira*		Bacillariophyta
9/19/2007	21020123	*Aulacoseira granulata*		Bacillariophyta
9/19/2007	21020123	*Bacillariophyceae*		Bacillariophyta
9/19/2007	21020123	*Bacillariophyta*	1499	Bacillariophyta
9/19/2007	21020123	*Chlamydomonas*	5997	Chlorophycota
9/19/2007	21020123	*Chlorella*	5997	Chlorophycota
9/19/2007	21020123	*Chlorococcum*	7496	Chlorophycota
9/19/2007	21020123	*Cocconeis placentula*		Bacillariophyta
9/19/2007	21020123	*Coelastrum microporum*	1499	Chlorophycota

9/19/2007	21020123	*Craticula*		Bacillariophyta
9/19/2007	21020123	*Cryptomonas*	5997	Cryptophycophyta
9/19/2007	21020123	*Diadesmis confervacea*		Bacillariophyta
9/19/2007	21020123	*Encyonema*		Bacillariophyta
9/19/2007	21020123	*Fragilaria capucina*		Bacillariophyta
9/19/2007	21020123	*Fragilariaceae*		Bacillariophyta
9/19/2007	21020123	*Golenkinia paucispina*	5997	Chlorophycota
9/19/2007	21020123	*Gomphonema*		Bacillariophyta
9/19/2007	21020123	*Gomphonema affine*		Bacillariophyta
9/19/2007	21020123	*Gomphonema gracile*		Bacillariophyta
9/19/2007	21020123	*Gomphonema parvulum*		Bacillariophyta
9/19/2007	21020123	*Gomphonema subclavatum*		Bacillariophyta
9/19/2007	21020123	*Mallomonas*	1499	Chrysophyta
9/19/2007	21020123	*Microcystis aeruginosa*	4498	Cyanophycota
9/19/2007	21020123	*Microcystis wesenbergii*	11994	Cyanophycota
9/19/2007	21020123	*Navicula*		Bacillariophyta
9/19/2007	21020123	*Navicula cryptotenella*		Bacillariophyta
9/19/2007	21020123	*Nitzschia*		Bacillariophyta
9/19/2007	21020123	*Nitzschia amphibia*		Bacillariophyta
9/19/2007	21020123	*Pediastrum simplex*	8995	Chlorophycota
9/19/2007	21020123	*Planktosphaeria*	5997	Chlorophycota
9/19/2007	21020123	*Pseudanabaena mucicola*	5997	Cyanophycota
9/19/2007	21020123	*Scenedesmus bijuga*	2998	Chlorophycota
9/19/2007	21020123	*Scenedesmus quadricauda*	7496	Chlorophycota
9/19/2007	21020123	*Selenastrum*	1499	Chlorophycota
9/19/2007	21020123	*Sellaphora*		Bacillariophyta
9/19/2007	21020123	*Sellaphora laevissima*		Bacillariophyta
9/19/2007	21020123	*Sellaphora pupula*		Bacillariophyta
9/19/2007	21020123	*Staurosira elliptica*		Bacillariophyta
9/19/2007	21020123	*Staurosirella pinnata*		Bacillariophyta
9/19/2007	21020123	*Synedra acus angustissima*		Bacillariophyta
9/19/2007	21020123	*Tetraedron minimum*	350818	Chlorophycota
4/3/2008	21020123	*Achnanthes*		Bacillariophyta
4/3/2008	21020123	*Achnanthes lanceolata*		Bacillariophyta
4/3/2008	21020123	*Anabaena planctonica*	1388	Cyanophycota
4/3/2008	21020123	*Ankistrodesmus falcatus*	58	Chlorophycota
4/3/2008	21020123	*Aphanizomenon*	173	Cyanophycota
4/3/2008	21020123	*Aulacoseira*		Bacillariophyta
4/3/2008	21020123	*Bacillariophyta*	810	Bacillariophyta
4/3/2008	21020123	*Ceratium hirundinella*	116	Pyrrophycophyta
4/3/2008	21020123	*Chlamydomonas*	1561	Chlorophycota
4/3/2008	21020123	*Chlorella*	1851	Chlorophycota
4/3/2008	21020123	*Chlorococcum*	58	Chlorophycota

4/3/2008	21020123	*Chlorophyceae*	289	Chlorophycota
4/3/2008	21020123	*Chroomonas*	116	Cryptophycophyta
4/3/2008	21020123	*Closterium gracile gracile*	405	Chlorophycota
4/3/2008	21020123	*Cocconeis*		Bacillariophyta
4/3/2008	21020123	*Cocconeis placentula*		Bacillariophyta
4/3/2008	21020123	*Coelastrum microporum*	405	Chlorophycota
4/3/2008	21020123	*Coscinodiscophyceae*		Bacillariophyta
4/3/2008	21020123	*Cosmarium*	58	Chlorophycota
4/3/2008	21020123	*Cryptomonas*	231	Cryptophycophyta
4/3/2008	21020123	*Cyclostephanos invisitatus*		Bacillariophyta
4/3/2008	21020123	*Cyclotella*		Bacillariophyta
4/3/2008	21020123	*Cyclotella meneghiniana*		Bacillariophyta
4/3/2008	21020123	*Cyclotella pseudostelligera*		Bacillariophyta
4/3/2008	21020123	*Dictyosphaerium pulchellum*	289	Chlorophycota
4/3/2008	21020123	*Elakatothrix viridis*	58	Chlorophycota
4/3/2008	21020123	*Fragilaria capucina*		Bacillariophyta
4/3/2008	21020123	*Fragilariaceae*		Bacillariophyta
4/3/2008	21020123	*Gloeocystis gigas*	58	Chlorophycota
4/3/2008	21020123	*Gomphonema*		Bacillariophyta
4/3/2008	21020123	*Gomphonema parvulum*		Bacillariophyta
4/3/2008	21020123	*Navicula*		Bacillariophyta
4/3/2008	21020123	*Navicula cryptocephala*		Bacillariophyta
4/3/2008	21020123	*Nitzschia*		Bacillariophyta
4/3/2008	21020123	*Nitzschia acicularis*		Bacillariophyta
4/3/2008	21020123	*Oocystis*	1272	Chlorophycota
4/3/2008	21020123	*Pediastrum duplex*	58	Chlorophycota
4/3/2008	21020123	*Pediastrum obtusum*	58	Chlorophycota
4/3/2008	21020123	*Pediastrum simplex*	463	Chlorophycota
4/3/2008	21020123	*Pediastrum tetras*	58	Chlorophycota
4/3/2008	21020123	*Planktosphaeria*	116	Chlorophycota
4/3/2008	21020123	*Scenedesmus abundans*	173	Chlorophycota
4/3/2008	21020123	*Scenedesmus bijuga*	173	Chlorophycota
4/3/2008	21020123	*Scenedesmus quadricauda*	1388	Chlorophycota
4/3/2008	21020123	*Schroederia setigera*	231	Chlorophycota
4/3/2008	21020123	*Selenastrum*	405	Chlorophycota
4/3/2008	21020123	*Sellaphora pupula*		Bacillariophyta
4/3/2008	21020123	*Staurastrum*	231	Chlorophycota
4/3/2008	21020123	*Staurosirella pinnata*		Bacillariophyta
4/3/2008	21020123	*Synechocystis*	289	Cyanophycota
4/3/2008	21020123	*Synedra*		Bacillariophyta
4/3/2008	21020123	*Synedra acus angustissima*		Bacillariophyta
4/3/2008	21020123	*Synura*	58	Chrysophyta
4/3/2008	21020123	*Tetraedron minimum*	4453	Chlorophycota

4/3/2008	21020123	*Trachelomonas*	116	Euglenophycota
6/22/2020	21020058	*Aphanocapsa incerta*		Cyanophycota
6/22/2020	21020058	*Botryococcus braunii*		Chlorophycota
6/22/2020	21020058	*Cuspidothrix issatschenkoi*		Cyanophycota
6/22/2020	21020058	*Dolichospermum circinale*		Cyanophycota
6/22/2020	21020058	*Dolichospermum planctonicum*		Cyanophycota
6/22/2020	21020058	*Kirchneriella*		Chlorophycota
6/22/2020	21020058	*Microcystis*		Cyanophycota
6/22/2020	21020058	*Microcystis wesenbergii*		Cyanophycota
6/22/2020	21020058	*Pediastrum*		Chlorophycota
6/22/2020	21020058	*Scenedesmus bijuga*		Chlorophycota
6/22/2020	21020058	*Snowella*		Cyanophycota
6/22/2020	21020058	*Staurastrum*		Chlorophycota
6/22/2020	21020058	*Tetraedron gracile*		Chlorophycota