Final 4/18/2008

FLORIDA DEPARTMENT OF ENVIRONMENTAL PROTECTION

Division of Water Resource Management, Bureau of Watershed Management

CENTRAL DISTRICT • MIDDLE ST. JOHNS BASIN

TMDL Report

Nutrient TMDLs for Spring Lake (WBID 2987A), Lake Florida (WBID 2998A), Lake Orienta (WBID 2998C), Lake Adalaide (WBID 2998E), Lake Lawne (WBID 3004C), Silver Lake (3004D), and Bay Lake (WBID 3004G) in the Wekiva Study Area

Xueqing Gao

April 18, 2008

Acknowledgments

This TMDL was developed based on modeling conducted by Camp Dresser and McKee (CDM), which was contracted by the Florida Department of Environmental Protection (the Department) to model four (Lake Lawne, Bay Lake, Silver Lake, and Spring Lake) of the seven lakes covered in this TMDL report. The Department would like to thank Mr. Richard Wagner and Mr. Daniel Reisinger of CDM, who set up the WMM and Bathtub models for the four project lakes and were very responsive to the questions and comments raised by the Department. The Department would also like to thank Ms. Danielle Honour of CDM, who provided the BMP and septic tank information for the entire Wekiva Study Area. This helped the Department develop TMDLs for the other three lakes, including Lake Forida, Lake Orienta, and Lake Adelaide. Special thanks also go to the Department's Ground Water Protection Section, specifically to Mr. Rick Hicks and Ms. Teayann Tinsley, who provided information and analyses on the nutrient contributions from ground water for this TMDL.

Editorial assistance provided by
Daryll Joyner and Jan Mandrup-Poulsen

For additional information on the watershed management approach and impaired waters in the Middle St. Johns Basin, contact
Jennifer Gihring
Florida Department of Environmental Protection
Bureau of Watershed Management
Watershed Planning and Coordination Section
2600 Blair Stone Road, Mail Station 3565
Tallahassee, FL 32399-2400
Email: Jennifer.Gihring@dep.state.fl.us
Phone: (850) 245-8418; Suncom: 205-8418
Fax: (850) 245-8434

Access to all data used in the development of this report can be obtained by contacting
Xueqing Gao
Florida Department of Environmental Protection
Bureau of Watershed Management
Watershed Assessment Section
2600 Blair Stone Road, Mail Station 3555
Tallahassee, FL 32399-2400
Email: xueqing.gao@dep.state.fl.us
Phone: (850) 245-8464, SunCom: 205-8464
Fax: (850) 245-8434

Contents

List of Tables

List of Figures

Web sites

Florida Department of Environmental Protection, Bureau of Watershed Management

Total Maximum Daily Load (TMDL) Program

http://www.dep.state.fl.us/water/tmdl/index.htm

Identification of Impaired Surface Waters Rule

http://www.dep.state.fl.us/water/tmdl/docs/AmendedIWR.pdf

STORET Program

http://www.dep.state.fl.us/water/storet/index.htm

2004 305(b) Report

http://www.dep.state.fl.us/water/docs/2004_Integrated_Report.pdf

Criteria for Surface Water Quality Classifications

http://www.dep.state.fl.us/water/wqssp/classes.htm

Basin Status Reports

http://www.dep.state.fl.us/water/tmdl/stat_rep.htm

Water Quality Assessment Reports

http://www.dep.state.fl.us/water/tmdl/stat_rep.htm

Allocation Technical Advisory Committee (ATAC) Report

http://www.dep.state.fl.us/water/tmdl/docs/Allocation.pdf

U.S. Environmental Protection Agency

Region 4: Total Maximum Daily Loads in Florida

http://www.epa.gov/region4/water/tmdl/florida/

National STORET Program

http://www.epa.gov/storet/

Chapter 1: INTRODUCTION

1.1 Purpose of Report

This report presents the Total Maximum Daily Loads (TMDLs) of nutrients for Spring Lake (WBID 2987A), Lake Florida (WBID 2998A), Lake Orienta (WBID 2998C), Lake Adelaide (WBID 2998E), Lake Lawne (WBID 3004C), Silver Lake (3004D), and Bay Lake (WBID 3004G) in the Wekiva Study Area (WSA). These lakes were verified for nutrient impairment due to elevated annual average Trophic State Index (TSI) values and were included on the Verified List of impaired waters for the Middle St. Johns River Basin that was adopted by Secretarial Order on May 27, 2004. According to the Florida Watershed Restoration Act (FWRA, Chapter 403, F.S), once a waterbody is included on the Verified List, a TMDL is required to be developed. The purpose of the TMDLs described in this report is to establish allowable loadings of pollutants to these lakes that would restore these waterbodies so that they meet their applicable water quality criteria for nutrients.

Based on the Department's basin rotation schedule, TMDLs for these lakes are not due until 2008. However, the Wekiva Parkway and Protection Act (WPPA), which was enacted in 2004 (Chapter 369, Part III, FS), requires that TMDLs be expedited for "impaired waters within the Wekiva Study area," and all of the lakes mentioned above are located within the boundary of the Wekiva Study Area defined by the WPPA.

1.2 Identification of Waterbody

The boundary of the WSA was delineated in the WPPA (2004) and encompasses 473 square miles. It is located in central Florida and includes portions of the northeastern part of Lake County, western part of Seminole County, and northwestern part of Orange County. Three of the seven lakes covered in this TMDL report, including Lake Lawne, Bay Lake, and Silver Lake, are located in the southeastern corner of the WSA, which is part of Orange County and City of Orlando. The remaining four lakes(Spring Lake, Lake Florida, Lake Orienta, and Lake Adelaide) are located along the eastern boundary of the WSA, which is in the western part of Seminole County, City of Altamonte Springs, and western part of Longwood (**Figure 1.1**). All these lakes are located in highly urbanized areas, and most of them have more than 50% of their drainage basins occupied by residential and commercial landuses.

Except for Lake Lawne, all the other six lakes are located in the Orlando Ridge region. According to Griffith et al. (1997), the Orlando Ridge lake region is an urbanized Karst area of low relief, with elevations from 75-120 feet. Phosphatic sands and clayey sand are at a shallow depth. Lakes in this region can be characterized as clear, alkaline, hard-water lakes of moderate mineral content. Most of the lakes located in this region are mesotrophic to eutrophic. Because the shallow phosphorus-rich soil and high degree of urbanization appear in the same region, it is difficult to distinguish between effects of urbanization and natural phosphatic levels.

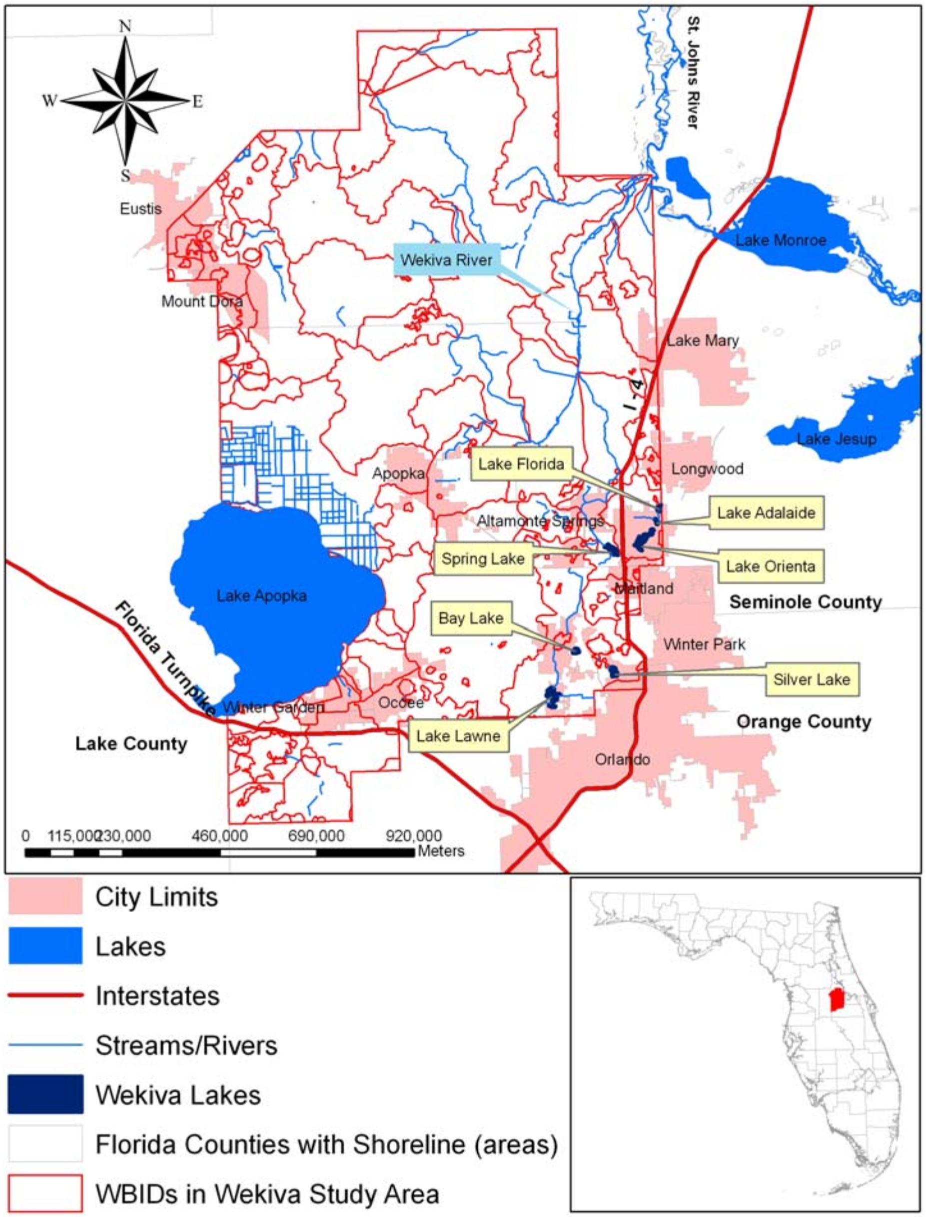

Figure 1.1. Location of the seven lakes covered in this TMDL report.

Lake Lawne is the only lake located in the Apopka Upland area. This is a region of residual sand hills, modified by karst processes and contains many small lakes with general elevations ranging from 70 – 150 feet. Longleaf pine/xerophytic oak was the natural vegetation for the region. The current land cover of the lake region consists of citrus, pasture, and urban and residential development. The physical and chemical characteristics of the lakes are varied, and lake water level can fluctuate greatly throughout drought periods. There are some acidic, clear, softwater lakes of low mineral content; some clear lakes with moderate nutrients; and some darker water lakes that still have circum neutral pH values. More detailed information regarding the hydrology, geology, and water quality conditions of these lakes can be obtained from Griffith et al. (1997) and Orange County and Seminole County's Watershed Atlas (http://maps.wateratlas.usf.edu/orange/index.asp, and http://www.seminole.wateratlas.usf.edu/).

For assessment purposes, the Department divided the Middle St. Johns Basin into water assessment polygons each with a unique waterbody identification (WBID) number for each watershed or stream reach. This TMDL report includes eight WBIDs: 2987A , 2994D, 2998A, 2998C, 2998E, 3004C, 3004D, and 3004G. **Figure 1.1** shows the locations of the WBIDs covered in this TMDL report.

1.3 Background

This report was developed as part of the Department's watershed management approach for restoring and protecting state waters and addressing TMDL Program requirements. The watershed approach, which is implemented using a cyclical management process that rotates through the state's 52 river basins over a 5-year cycle, provides a framework for implementing the TMDL Program–related requirements of the 1972 federal Clean Water Act and the FWRA.

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

This TMDL report will be followed by the development and implementation of a Basin Management Action Plan, or BMAP, to reduce the amount of nutrients that caused the verified impairment of lakes covered in this TMDL report. These activities will depend heavily on the active participation of the SJRWMD, local governments, businesses, and other stakeholders. The Department will work with these organizations and individuals to undertake or continue reductions in the discharge of pollutants and achieve the established TMDLs for impaired waterbodies.

Chapter 2: DESCRIPTION OF WATER QUALITY PROBLEM

2.1 Statutory Requirements and Rulemaking History

Section 303(d) of the Clean Water Act requires states to submit to the EPA a list of surface waters that do not meet applicable water quality standards (impaired waters) and establish a TMDL for each pollutant source in each of these impaired waters on a schedule. The Department has developed these lists, commonly referred to as 303(d) lists, since 1992. The list of impaired waters in each basin is also required by the FWRA (Subsection 403.067[4)] Florida Statutes [F.S.]), and the list is amended annually to include updates for each basin statewide.

Florida's 1998 303(d) list included 22 waterbodies in the Middle St. Johns River Basin. However, the FWRA (Section 403.067, F.S.) stated that all previous Florida 303(d) lists were for planning purposes only and directed the Department to develop, and adopt by rule, a new science-based methodology to identify impaired waters. After a long rulemaking process, the Environmental Regulation Commission adopted the new methodology as Chapter 62-303, Florida Administrative Code (F.A.C.) (Identification of Impaired Surface Waters Rule, or IWR), in April 2001 and updated in 2006. The list of waters for which impairments have been verified using the methodology in the IWR is referred to as the Verified List.

2.2 Information on Verified Impairment

The Department used the IWR to assess water quality impairments in the Middle St. Johns Basin and verified nutrient impairments for Spring Lake (WBID 2987A), Lake Florida (WBID 2998A), Lake Orienta (WBID 2998C), Lake Adalaide (WBID 2998E), Lake Lawne (WBID 3004C), Silver Lake (3004D), and Bay Lake (WBID 3004G). For Spring Lake, Lake Lawne, Silver Lake, and Bay Lake, nutrient impairments were verified based on the fact that, in the verified period (January 1, 1996, through June 30, 2003), one or more annual average TSI values exceeded the assessment threshold of 60 units**.** **Table 2.1** lists the annual average TSIs for these lakes during the Verified Period.

For Lake Florida, Lake Adalaide, and Lake Orienta, the Verified Period assessments were based primarily on LakeWatch data. According to Florida Statues, section 1004.49, Florida LAKEWATCH program:

> *" The Florida LAKEWATCH Program is hereby created within the Department of Fisheries and Aquaculture of the Institute of Food and Agricultural Sciences at the University of Florida. The purpose of the program is to provide public education and training with respect to the water quality of Florida's lakes. The Department of Fisheries and Aquaculture may, in implementing the LAKEWATCH program:*

1. *Train, supervise, and coordinate volunteers to collect water quality data from Florida's lakes.*
2. *Compile the data collected by volunteers.*
3. *Disseminate information to the public about the LAKEWATCH program.*
4. *Provide or loan equipment to volunteers in the program.*
5. *Perform other functions as may be necessary or beneficial in coordinating the LAKEWATCH program. Data collected and compiled shall be used to establish trends and general background information and shall in no instance be used in a regulatory proceeding."*

Item 5 of 1004.49 F.S clearly indicated that LakeWatch data should not be used for the regulatory proceeding and therefore could not be used for the verification assessment of water quality. Based on this regulation, LakeWatch data were excluded from the verification assessment of Lake Florida, Lake Orienta, and Lake Adalaide. Nutrient assessments for these lakes were re-conducted using water quality data from sources other than LakeWatch database. Based on more recent data collected primarily by Seminole County, these three lakes were re-verified for nutrient impairments because, for these lakes, the annual average TSIs exceed the assessment threshold of 60 units in 2005 (**Table 2.1**).

Table 2.1. Summary of annual TSI values for Spring Lake, Lake Lawne, Silver Lake, and Bay Lake in the verified period, 1996–2002, and for Lake Florida, Lake Orienta, and Lake Adelaide in 2005.

Year	Spring Lake (2987A)	Lake Lawne (3004C)	Silver Lake (3004D)	Bay Lake (3004G)	Lake Florida (2998A)	Lake Orienta (2998C)	Lake Adelaide (2998E)
1996	69.1	66.9	55.8	61.7	N/A	N/A	N/A
1997	69.3	65.6	51.2	61.8	N/A	N/A	N/A
1998	64.2	N/A	61.3	62.0	N/A	N/A	N/A
1999	68.8	N/A	41.0	67.4	N/A	N/A	N/A
2000	72.0	N/A	46.0	69.3	N/A	N/A	N/A
2001	66.7	N/A	N/A	68.4	N/A	N/A	N/A
2002	65.2	N/A	N/A	67.3	N/A	N/A	N/A
2003	N/A	N/A	N/A	N/A	N/A	N/A	N/A
2004	N/A	N/A	N/A	N/A	N/A	N/A	N/A
2005	N/A	N/A	N/A	N/A	61.5	61.0	67.2
Median TN/TP ratio	36.9	17.3	27.2	30.9	25.0	22.9	26.8
Limiting Nutrient	Phosphorus	Nitrogen and phosphorus	Nitrogen and phosphorus	Phosphorus	Nitrogen and phosphorus	Nitrogen and phosphorus	Nitrogen and phosphorus

N/A = Not enough data to calculate annual mean TSI at the time when the impairment assessment was conducted.

For the three lakes verified for nutrient impairment using only the annual average TSI of 2005, Seminole County collected data from 2004 to 2006. However, according to the IWR, to calculate the annual average TSI for a given waterbody, there has to be quarterly mean TSI from four consecutive quarters. Based on this requirement, annual average TSIs could only be calculated for 2005 for these lakes. The median TN/TP ratios were calculated based on all the data in the period of record from 2004 through 2006. The ratio in all the three lakes fell between 10 and 30, indicating that phytoplankton communities in these lakes are co-limited by both nitrogen and phosphorus.

According to the IWR, once a waterbody is verified for nutrient impairment, the limiting nutrient that controls the biomass of phytoplankton needs to be identified. The identification of the limiting nutrient is primarily based on the ratio between total nitrogen (TN) and total phosphorus (TP). If the TN/TP ratio is less than 10, the phytoplankton community is considered nitrogen limited. If TN/TP ratio is greater than 30, the phytoplankton community is considered phosphorus limited. If the ratio falls between 10 and 30, the community is considered co-limited by both nitrogen and phosphorus. As shown in **Table 2.1,** Spring Lake and Bay Lake had median TN/TP ratios greater than 30 and therefore are considered phosphorus limited. Median TN/TP ratios for all the other lakes fell between 10 and 30 and are considered co-limited by nitrogen and phosphorus.

2.3. Seasonal Dynamics of TN, TP, and *Chl a* concentrations and TSI

Seasonal trends of TN, TP, and *Chl a* concentrations and TSI were analyzed through examining the long-term monthly mean TN, TP, and *Chl a* concentrations and monthly TSI. The purpose of the seasonal trend analysis was to identify the critical season in which high nutrient concentrations are most likely to occur and effects of nutrient dynamics on algal biomass and TSI are most significant. TN, TP, and *Chl a* measurements from 1996 through 2005 were used for the seasonal analyses. For Lake Lawne and Silver Lake, TN and TP concentrations were measured both at the surface and near the bottom of these lakes. Therefore, near-the-bottom TN and TP concentrations of Lake Lawne and Silver Lake were also included in the analysis. **Figures 2.1** through **2.7** show the monthly dynamics of TN, TP, and *Chl a* concentrations and TSI in the seven lakes covered in this TMDL.

Large variations were observed in the TN, TP, and *Chl a* concentrations (**Figure 2.1** through **2.7**), however most lakes did not show a significant seasonal pattern. Bay Lake (**Figure 2.4**), Lake Florida (**Figure 2.5**), and Lake Orienta (**Figure 2.6**) showed some minor depression of TP concentration during the summer. However, there is no consistent relationship between this slight decrease of summer TP and *Chl a* values for the same time period, and it is not clear what caused the slight drop of TP during the summer. It is possible that TP levels are lower during summer because rainfall is typically higher in summer (most lakes covered in this report are seepage lakes, and evaporation during dry months may concentrate the TN and TP in these lakes). The summer drop could also be caused by aquatic plants, which stabilize the water turbulence and facilitate the deposition of particulate TP. Considering the lower solubility of TP compared to the TN compounds, aquatic plants may have more influence on the TP concentration than on the TN concentration. Another possibility for the summer low TP concentration could be that the major source of TP is internal and runoff from the watershed may dilute in-lake TP concentrations. However, based on model calibration results that will be discussed in detail in later chapters of this report, most of these lakes probably have elevated sedimentation rates, instead of significant net nutrient internal release. Therefore, a significant net internal load is not very likely. In any case, the *Chl a* concentration did not show an obvious seasonal relationship with the nutrient concentration. This suggested that managing the nutrient loadings on an annual time scale is appropriate for controlling trophic state in these lakes.

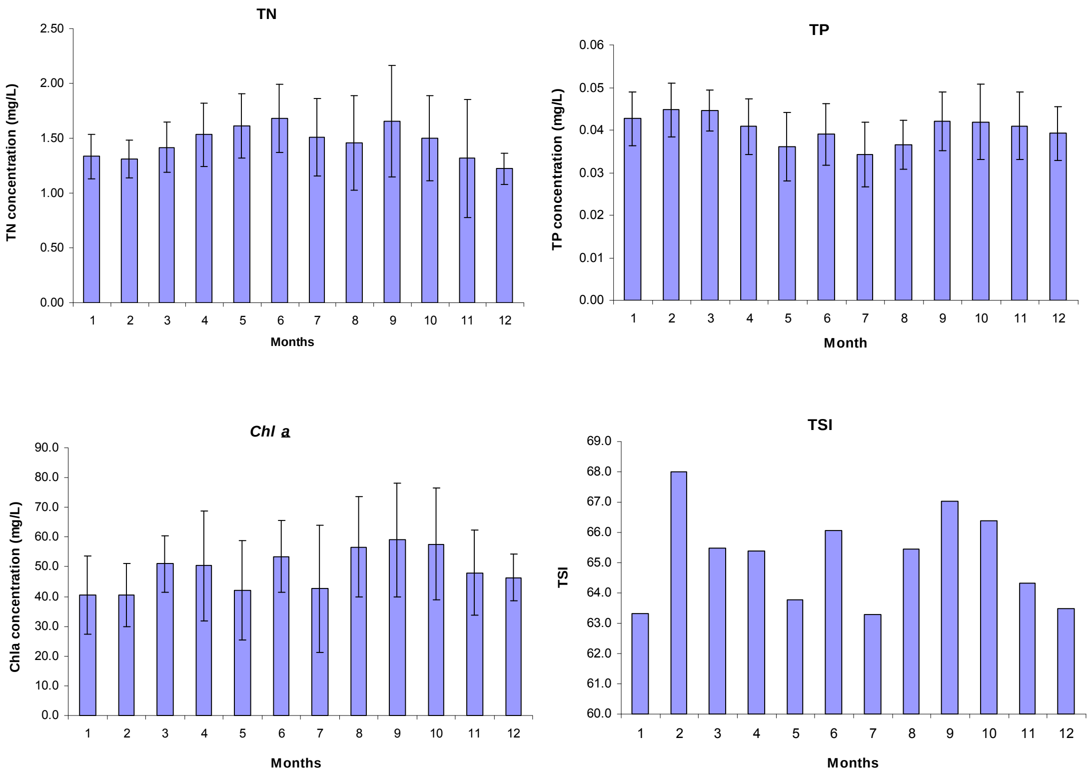

Figure 2.1. Monthly dynamics of TN, TP, and *Chl a* concentrations and TSI in Spring Lake (WBID 2987A)

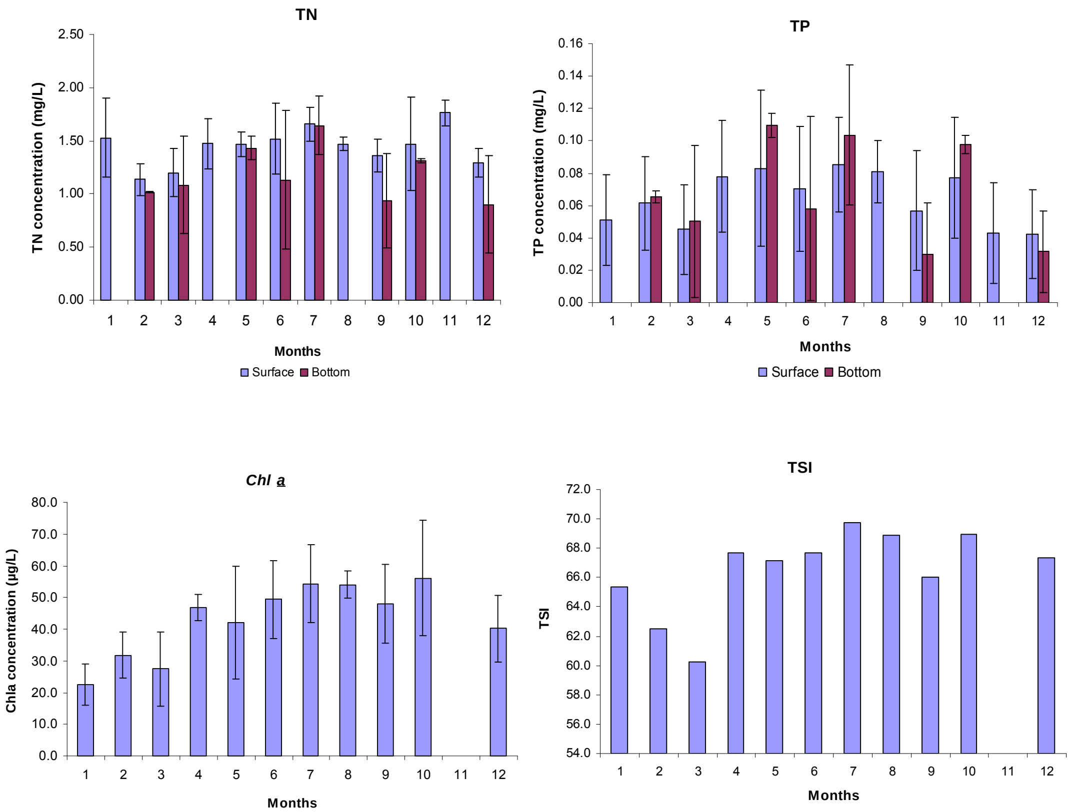

Figure 2.2. Monthly dynamics of TN, TP, and *Chl a* concentrations and TSI in Lake Lawne (WBID 3004C)

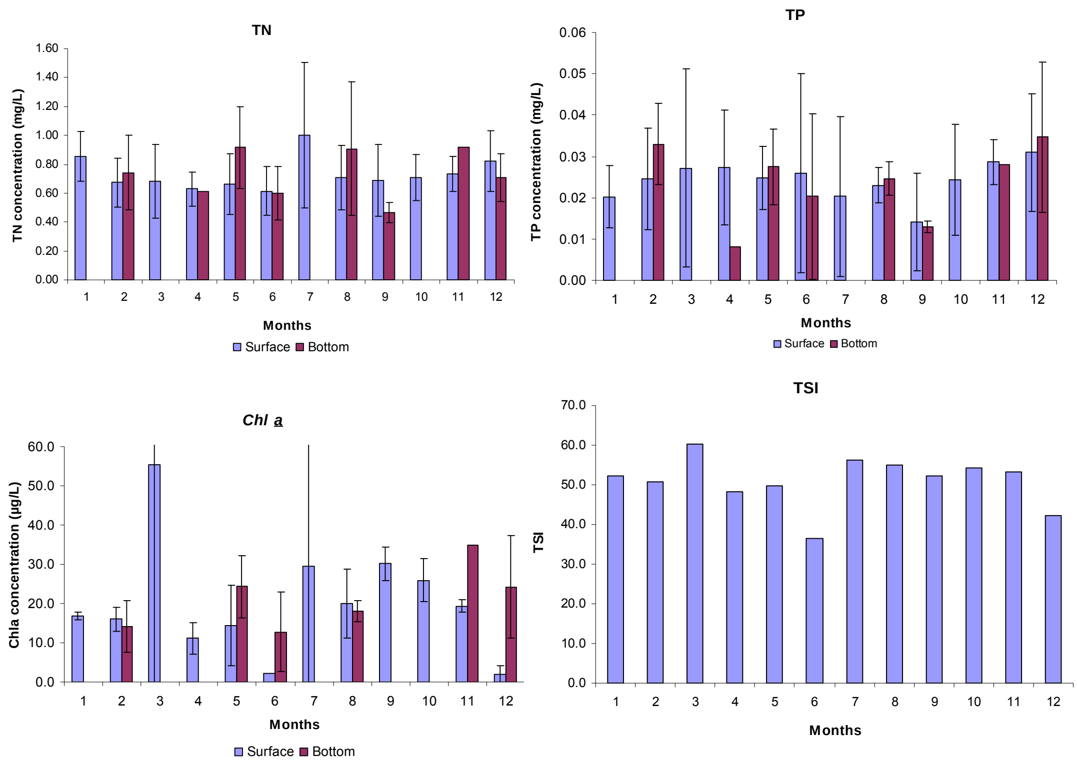

Figure 2.3. Monthly dynamics of TN, TP, and *Chl a* concentrations and TSI in Silver Lake (WBID 3004D)

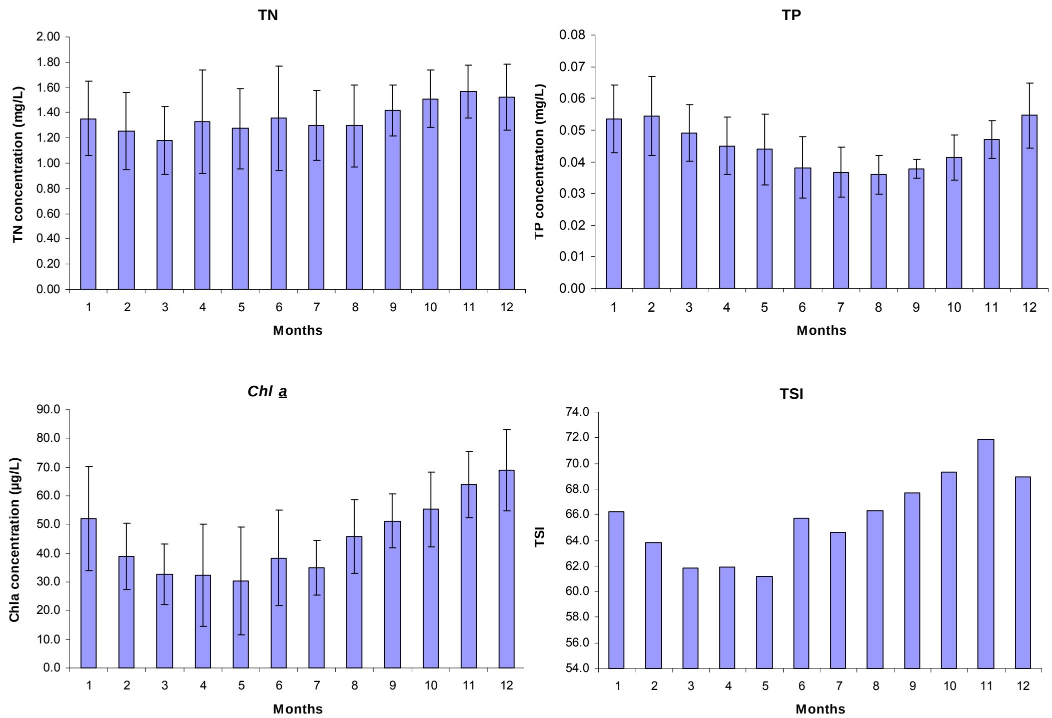

Figure 2.4. Monthly dynamics of TN, TP, and *Chl a* concentrations and TSI in Bay Lake (WBID 3004G)

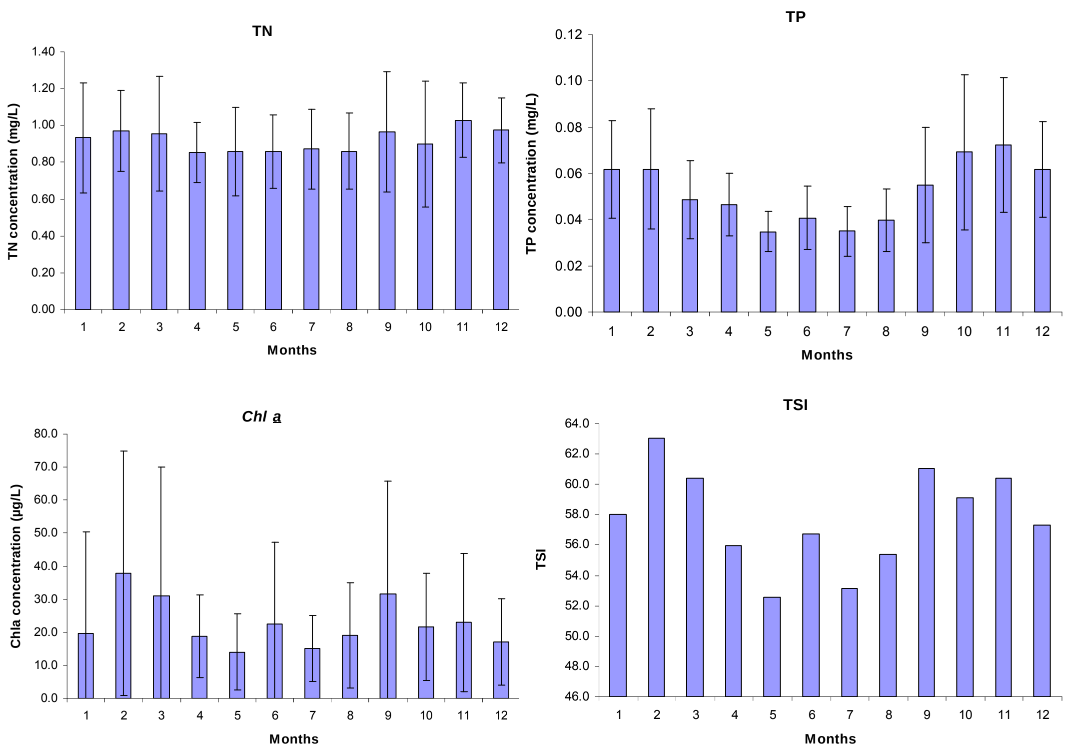

Figure 2.5. Monthly dynamics of TN, TP, and *Chl a* concentrations and TSI in Lake Florida (WBID 2998A)

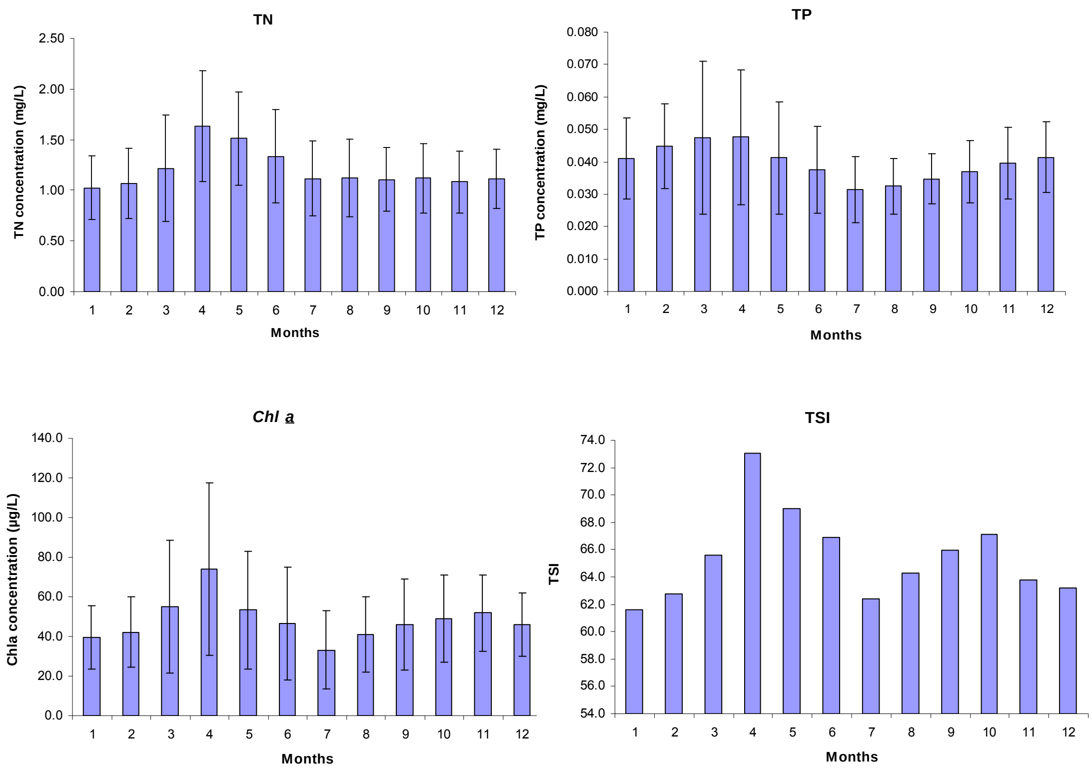

Figure 2.6. Monthly dynamics of TN, TP, and *Chl a* concentrations and TSI in Lake Orienta (WBID 2998C)

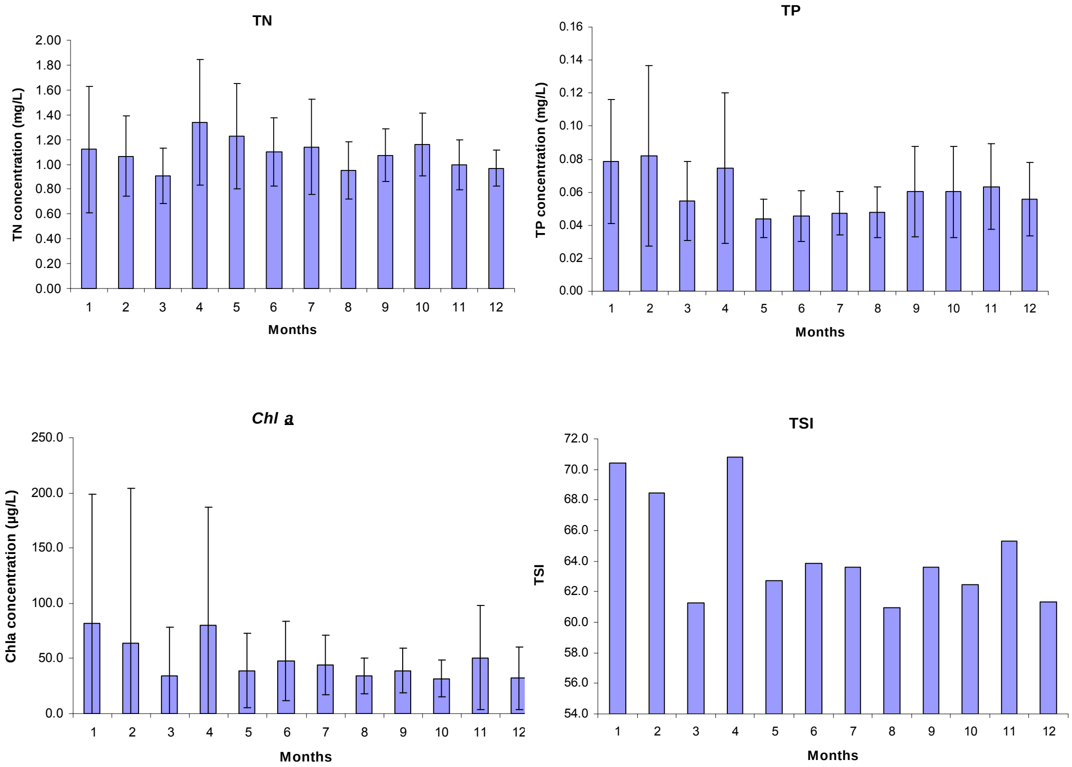

Figure 2.7. Monthly dynamics of TN, TP, and *Chl a* concentrations and TSI in Lake Adelaide (WBID 2998E)

Chapter 3. DESCRIPTION OF APPLICABLE WATER QUALITY STANDARDS AND TARGETS

3.1 Classification of the Waterbody and Criteria Applicable to the TMDL

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

Class I	**Potable water supplies**
Class II	**Shellfish propagation or harvesting**
Class III	**Recreation, propagation, and maintenance of a healthy, well-balanced population of fish and wildlife**
Class IV	**Agricultural water supplies**
Class V	**Navigation, utility, and industrial use (there are no state waters currently in this class)**

All the lakes covered in this TMDL report are Class III waterbodies, with a designated use of recreation, propagation, and maintenance of a healthy, well-balanced population of fish and wildlife. The Class III water quality criteria applicable to the impairment addressed by this TMDL are nutrients.

3.2 Applicable Water Quality Standards and Numeric Water Quality Target

Florida's nutrient criterion is narrative only—i.e., nutrient concentrations of a body of water shall not be altered so as to cause an imbalance in natural populations of aquatic flora or fauna. Accordingly, a nutrient-related target was needed to represent levels at which an imbalance in flora or fauna is expected to occur. The IWR provides assessment thresholds for nutrient impairment, which are a TSI of 60 for lakes with water color higher than 40 platinum cobalt units (PCU) and a TSI of 40 for lakes with water color lower than or equal to 40 PCU. However, these thresholds are not considered standards and need not be used as the nutrient-related water quality target for TMDLs. In fact, in recognition that the IWR threshold was developed using statewide average conditions, the IWR (Rule 62-303.450, F.A.C.) specifically allows the use of alternative, site-specific thresholds that more accurately reflect conditions beyond which an imbalance in flora or fauna occurs in a waterbody.

For this analysis, the Department established a TSI target for each lake using a modeling approach that estimated natural background TSI levels. The Watershed Management Model (WMM) developed by Camp Dresser and McKee (CDM), Inc. and the Bathtub model developed by US Army Corp of Engineering were calibrated to define the relationship between watershed loading and in-lake nutrient and *Chl a* concentrations. Later sections of this report describe the detailed model calibration and simulation. The calibrated WMM-Bathtub model set was used to simulate the background TSI, from which the final target TSI was developed.

To estimate background TSI values, the Department assumed that all human land use areas discharge TN and TP loadings in the same way as natural areas such as upland forests and wetlands. Considering the development that has already occurred in the drainage basin of these lakes, returning the water quality to the pristine background condition may not be realistic and even necessary considering the natural succession of lake communities. In addition, direct application of natural background as the target TSI would not allow for any assimilative capacity. By comparison, the IWR uses a 10 unit increase in TSI from "historical" levels as one measure to protect oligotrophic lakes. Typically, the 10 unit increase is used to represent the transition of a lake from one trophic state (say mesotrophic) to another nutrient enriched condition (eutrophic). For this TDML analyis, the Department established target TSIs for the lakes covered in this TMDL report as a 5-unit above the background TSIs. This approach allows for some increases in nutrient loading above the background condition, but prevents a significant change in trophic status of these lakes and provides an implicit margin of safety in establishing the assimilative capacity. The target TSIs developed using this approach are listed in **Table 3.1**.

Table 3.1. Target TSI for lakes covered in this TMDL report

Lake Name	Background TSI	Target TSI
Spring Lake (2987A)	49	54
Lake Florida (2998A)	44	49
Lake Orienta (2998C)	49	54
Lake Adalaide (2998E)	51	56
Lake Lawne (3004C)	55	60
Silver Lake (3004D)	38	43
Bay Lake (3004G)	43	48

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. 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, mining, discharges from failing septic systems, and atmospheric deposition.

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

To be consistent with Clean Water Act 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 TMDL).** 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. Potential Sources of pollutants in Watersheds of WRMS and RSR

4.2.1 Point Sources

4.2.1.1 Wastewater Point Sources

There are three NPDES permitted facilities that are authorized to discharge to surface waters in the watersheds of the lakes covered in this TMDL report, including Inland Materials – Orlando CBP (FLG110464), Inland Materials – Casselberry CBP (FLG110153), and Altamonte Springs Regional Water Reclamation Facility (FL003325). However, both Inland Materials facilities are concrete batch plants that operate under a general permit, and significant nutrient discharges are not expected from these facilities. The Altamonte Springs Regional Water Reclamation Facility is a domestic wastewater treatment plant that would be expected to be a source of nutrients. Although the facility is located in the watershed of Spring Lake, it directly discharges to Little Wekiva River, which does not influence the water quality of Spring Lake. Therefore, no point source dischargers were found that discharge nutrients into any of the lakes covered in this TMDL report.

4.2.1.2 Municipal Separate Storm Sewer System Permittees

Within the drainage basins of Lake Lawne and Bay Lake, Orange County has a Phase I MS4 permit (FLS000011). The Florida Department of Transportation (FDOT) District 5 and City of Maitland are co-permittees for this permit. In addition, the City of Orlando holds a separate Phase I permit (FLS000014) that covers land in the watersheds for these lakes. For drainage areas of Silver Lake, Lake Florida, Lake Orienta, and Lake Adalaide, Seminole County holds a MS4 Phase I permit (FLS000038), with FDOT District 5 and the City of Altamonte Springs being co-permittees for this permit.

4.2.2 Nonpoint Sources

Because no major conventional point sources exist in the drainage basin of any of the lakes covered in this report, the majority of the nutrient loading is from nonpoint sources or MS4s. Nonpoint sources analyzed in this TMDL primarily include loadings from surface runoff, failed septic tanks, precipitation directly onto the lake's surface and baseflow. Based on flow analyses using the data collected from two gauging stations located in the nearby Little Wekiva River, CDM concluded that there is a net discharge of water from these lakes into the ground water. Therefore, nutrient loading from the Floridan Aquifer into these lakes were not considered as a major part of the nutrient budget. This assumption was also supported by the GIS information of "Potentiometric Surfaces of the Floridan Aquifer" and "Recharge to the Floridan Aquifer (2005)" published by the St. Johns River Water Management District (SJRWMD, http://sjr.state.fl.us/programs/data.html).

Nutrient loadings through surface runoff were estimated using the Watershed Management Model (WMM) developed by the CDM. WMM is a watershed model designed to estimate annual or seasonal pollutant loadings from a given watershed and evaluate the effect of watershed management strategies on water quality (WMM User's Manual: 1998). While the strength of the model is its capability to characterize pollutant loadings from nonpoint sources, such as those through stormwater runoff, stream baseflow, and leakage of septic tanks, the model also handles point sources such as discharge from wastewater treatment facilities. Estimation of pollutant load reduction due to partial or full-scale implementation of onsite or regional best management practices (BMP) is also part of the functions of this model. The fundamental assumption of the model is that the stormwater runoff from any given landuse is in direct proportion to annual rainfall and is dictated by the portion of the landuse category that is impervious and the runoff coefficients of both pervious and impervious area. The governing equation is:

(1) $$R_L = [C_p + (C_I – C_p) IMP_L] * I$$

Where:

R_L	=	total average annual surface runoff from land use L (in/yr);
IMP_L	=	fractional imperviousness of land use L;
I	=	long-term average annual precipitation (in/yr);
C_P	=	pervious area runoff coefficient; and
C_I	=	impervious area runoff coefficient.

The model estimates pollutant loadings based on nonpoint pollution loading factors (expressed as lbs/ac/yr) that vary by land use and the percent imperviousness associated with each landuse. The pollution loading factor M_L is computed for each landuse L by the following equation:

(2) $M_L = EMC_L * R_L * K$

Where:

M_L	=	loading factor for land use L (lbs/ac/yr);
EMC_L	=	event mean concentration of runoff from land use L (mg/L); EMC varies by landuses and pollutants;
R_L	=	total average annual surface runoff from land use L computed from Equation (1) (in/yr); and
K	=	0.2266, a unit conversion constant.

In this TMDL report, WMM was used to simulate the loading from runoff, baseflow, and leakage of septic tanks. In addition, the effects of BMPs on watershed pollutant loadings were also estimated. Data required for these WMM simulations include:

- Areas of all different landuse categories in watersheds of all the lakes,
- Percent impervious area of each landuse category,
- EMC for each pollutant type and landuse category,
- Annual average baseflow and baseflow TN and TP concentrations,
- Areas served by septic tanks in watersheds of all the lakes,
- Septic tank failure rate,
- Areas with BMP implementation in watersheds of all the lakes,
- Pollutant removal efficiencies for different BMP types, and
- Annual precipitation.

4.2.2.1 Land Uses

The watershed area for each lake was delineated previously in the Little Wekiva River Watershed Stormwater Management Master Plan (CDM, 2005). In CDM's study, the hydrologic unit boundaries in general were based not only on topography, but also physical features such as roads, and presence of conveyance systems (e.g., stormwater pipes) that could alter the natural drainage patterns. Information regarding the basin delineation was also provided by Seminole County for Lake Florida, Lake Orienta, and Lake Adelaide.

The SJRWMD's year 2004 landuse shapefile was used for the WMM model simulation. Updated landuse information for Bay Lake was provided to the Department by Orange County. Most of the landuse categories used for the simulation were Florida Landuse Classification Code System (FLUCCS) Level II classification, except for "Golf Course," which is a Level III classification. The Golf Course landuse was singled out in this study because of the potential high nutrient loading from this landuse due to the fertilizer applications. In addition, percent impervious area and event mean concentrations (EMCs) specific to Golf Course were available. **Table 4.1** shows the conversion between the FLUCCS landuse and landuse categories used by WMM. **Table 4.2** shows the areas and percent areas for different landuse categories in each of the watersheds. **Figures 4.1** through **4.7** show the spatial distribution of different landuses in each watershed.

Table 4.1. FLUCCS and WMM landuse linkage

FLUCCS Land Use Category	WMM Land Use
Agricultural	Agricultural
Commercial	Commercial
Professional Services	
Golf Course	Golf Course
Institutional	Institutional
Religious	
Educational Facilities	
Government Building	
Industrial	Industrial
Utilities	
Roads and Highways	Highways
Transportation	
Railroad	
Low Density Residential	Low Density Residential
Medium Denisty Residential	Medium Denisty Residential
High Density Residential	High Density Residential
Multiple Dwelling Units	
Forest	Forest/Rural Open
Open Land	
Shrub and Brushland	
Cemetery	Urban Open
Recreation	
Water Body	Water
Stormwater Pond	
Wetlands	Wetlands

Table 4.2. Areas and percent areas of different landuses in each watershed

Unit: acre

	Spring Lake		Lake Florida		Lake Orienta		Lake Adelaide		Lake Lawne		Silver Lake		Bay Lake	
Landuse	Area	%	Area	%	Area	%	Area	%	Area	%	Area	%	Area	%
Agricultural	62	4.8	0	0	0	0	0	0	0	0	0	0	49.2	0.8
Forest/Rural Open	65	5.1	98	8.2	22	2.2	20	4.8	339	11.8	0	0	15.8	22
Urban Open	4	0.3	23	1.9	13	1.3	2	0.5	243	8.5	5	0.7	0.0	4.9
Golf Course	0	0	0	0	0	0	0	0	18	0.6	6	0.8	0.0	0
Low Density Residential	47	3.7	8	0.7	5	0.5	0	0	8	0.3	0	0	54.6	6.5
Medium Density Residential	376	29.4	566	47.2	503	49.5	126	30.1	716	25	412	57.2	0.0	15.9
High Density Residential	124	9.7	5	0.4	134	13.2	60	14.3	91	3.2	20	2.8	0.0	0
Commercial	253	19.8	232	19.3	85	8.4	112	26.7	403	14.1	77	10.7	88.4	13
Industrial	29	2.3	14	1.2	1	0.1	0	0	149	5.2	50	6.9	0.0	12.2
Highways	52	4.1	13	1.1	11	1.1	16	3.8	132	4.6	13	1.8	0.0	4.5
Institutional	12	0.9	21	1.8	36	3.5	0	0	108	3.8	63	8.8	0.3	2.8
Water	71	5.6	14	1.2	1	0.1	0	0	38	1.3	3	0.4	1.5	0.4
Wetlands	98	7.7	131	10.9	58	5.7	58	13.8	477	16.6	1	0.1	0.0	2.8
Lake Surface	86	6.7	74	6.2	147	14.5	25	6	145	5.1	70	9.7	35.0	14.2
TOTAL	1279	100	1199	100	1016	100	419	100	2867	100	720	100	244.8	100

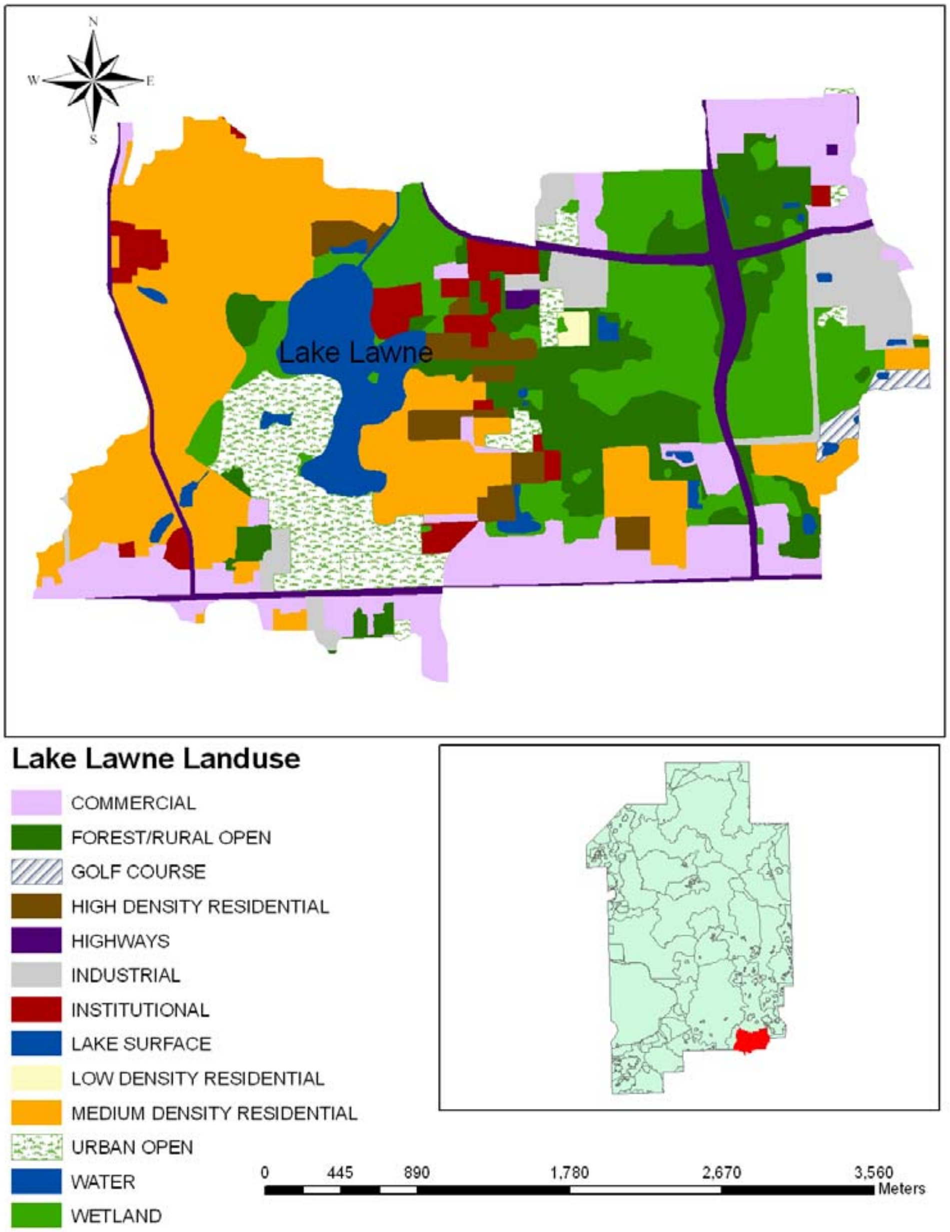

Figure 4.1. Distribution of WMM landuses in the watershed of Lake Lawne

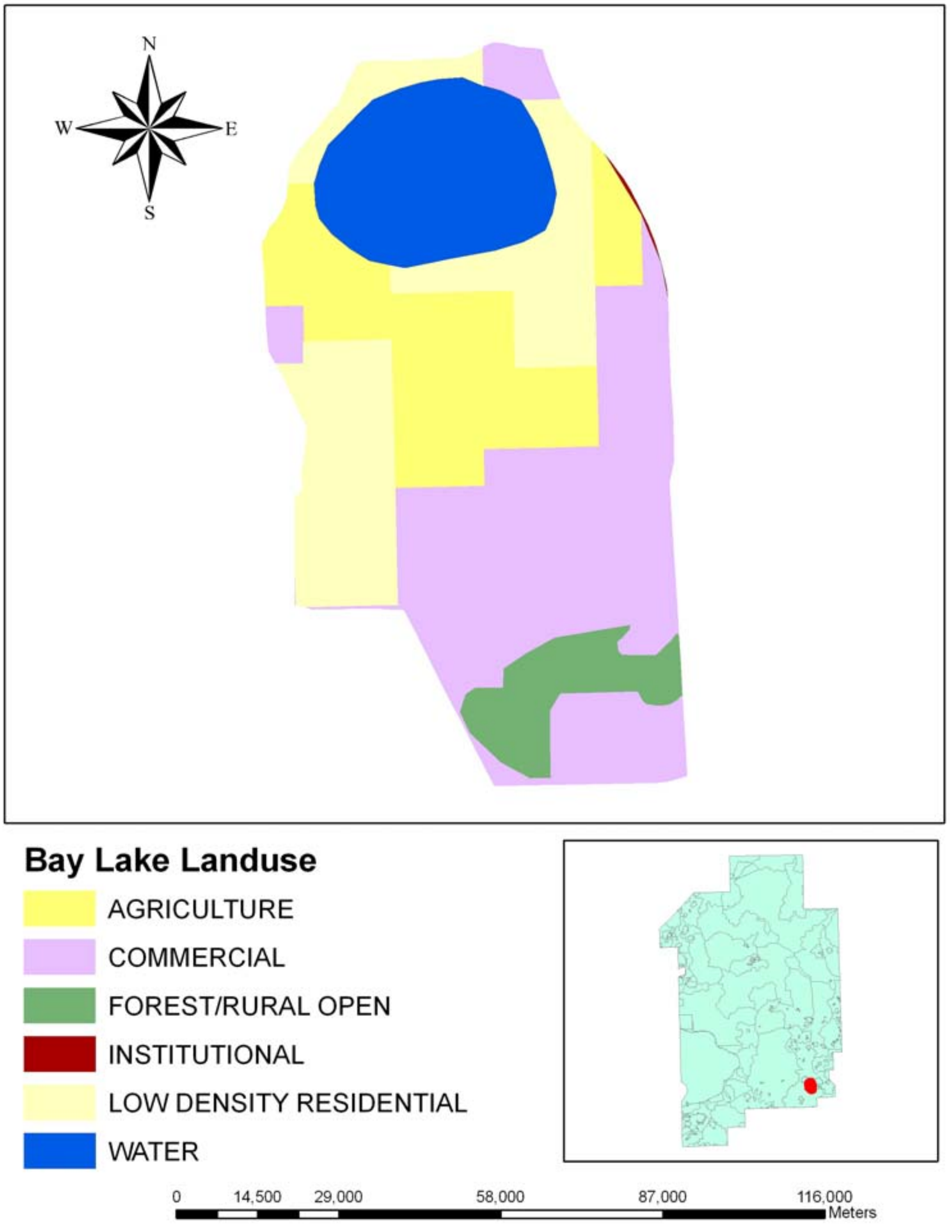

Figure 4.2. Distribution of WMM landuses in the watershed of Bay Lake

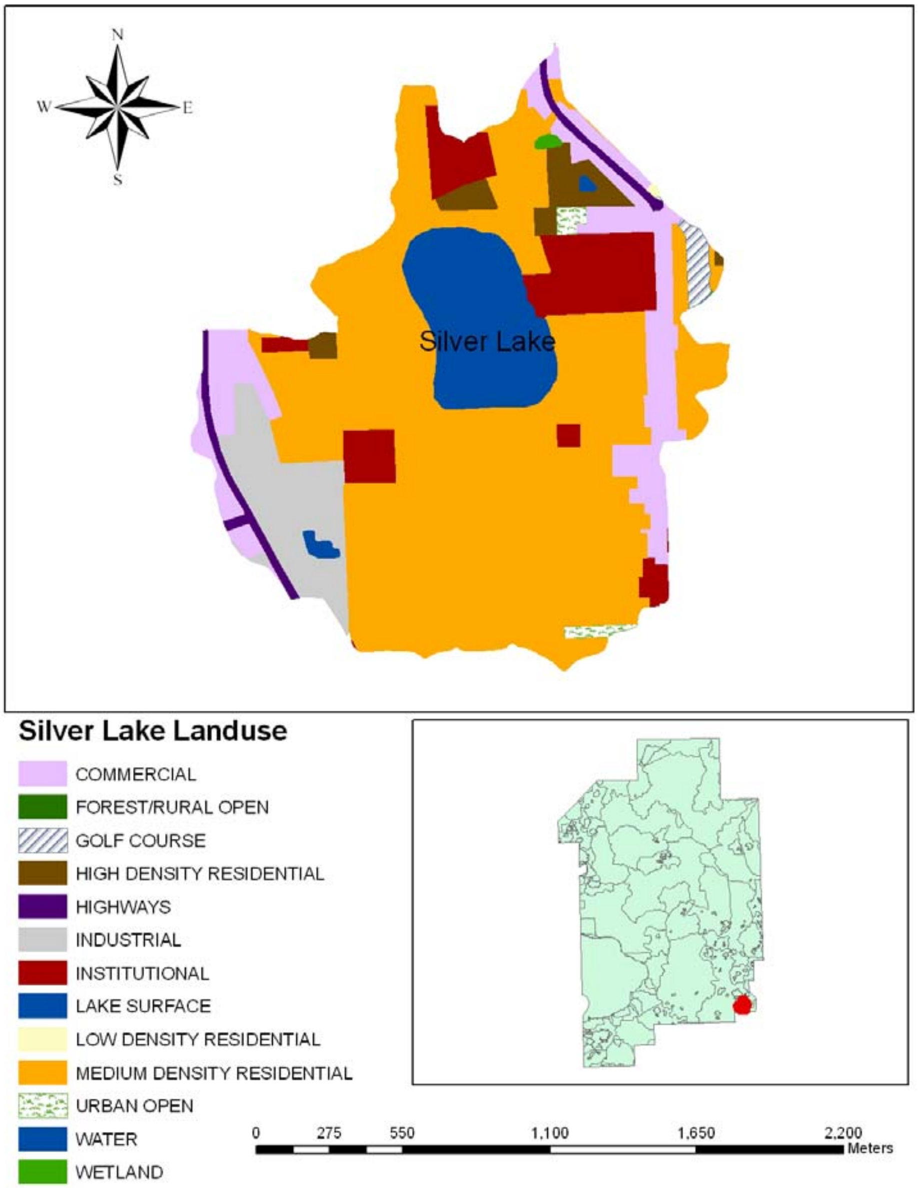

Figure 4.3. Distribution of WMM landuses in the watershed of Silver Lake

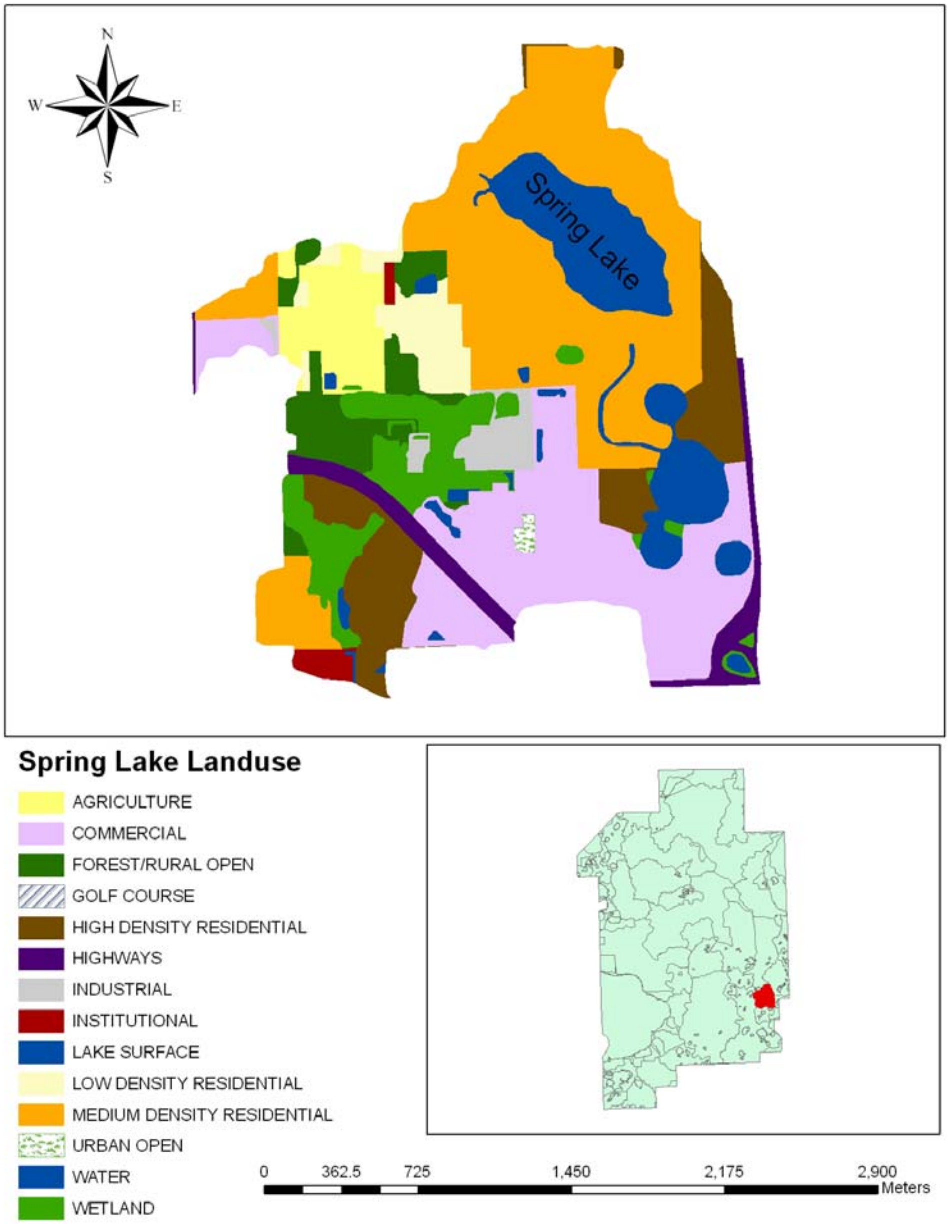

Figure 4.4. Distribution of WMM landuses in the watershed of Spring Lake

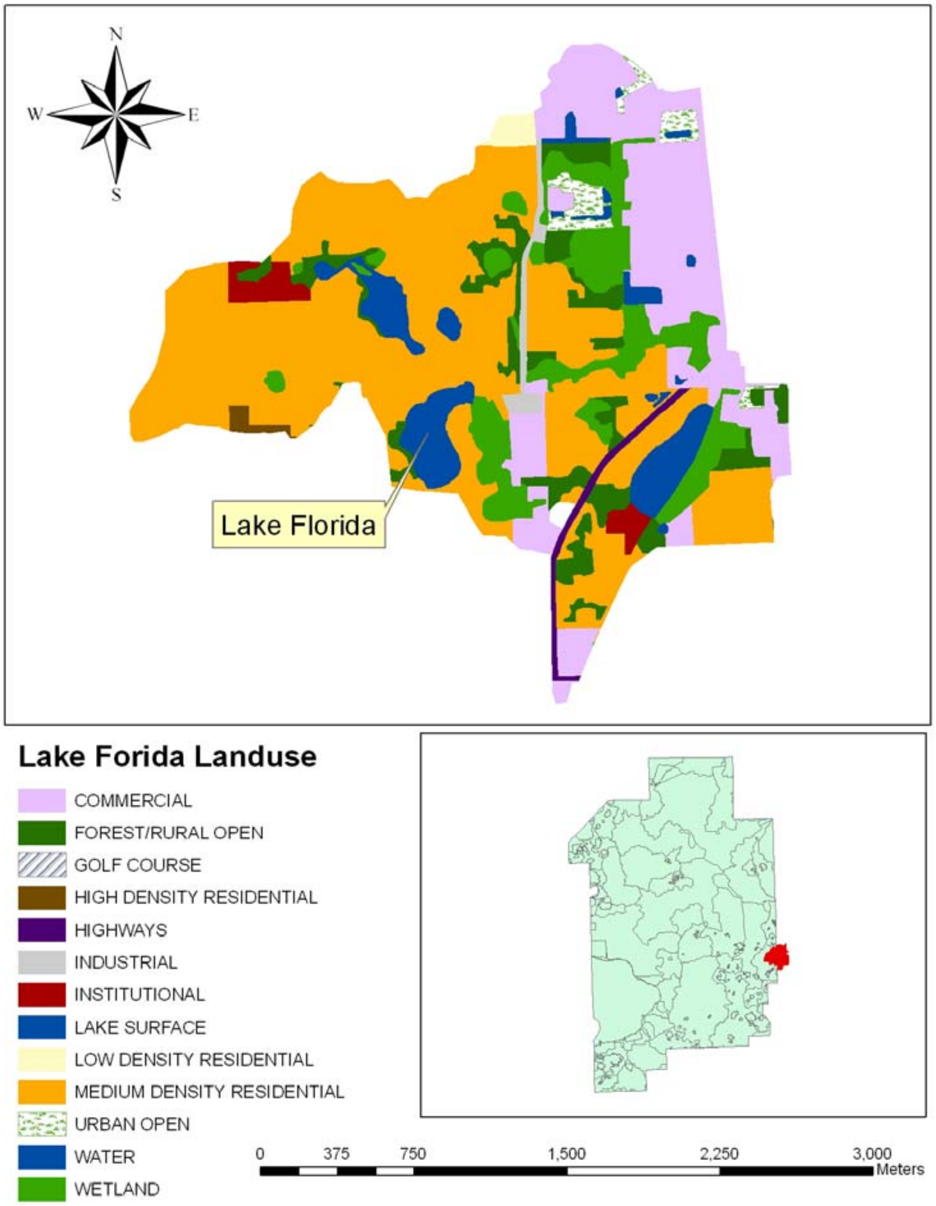

Figure 4.5. Distribution of WMM landuses in the watershed of Lake Florida

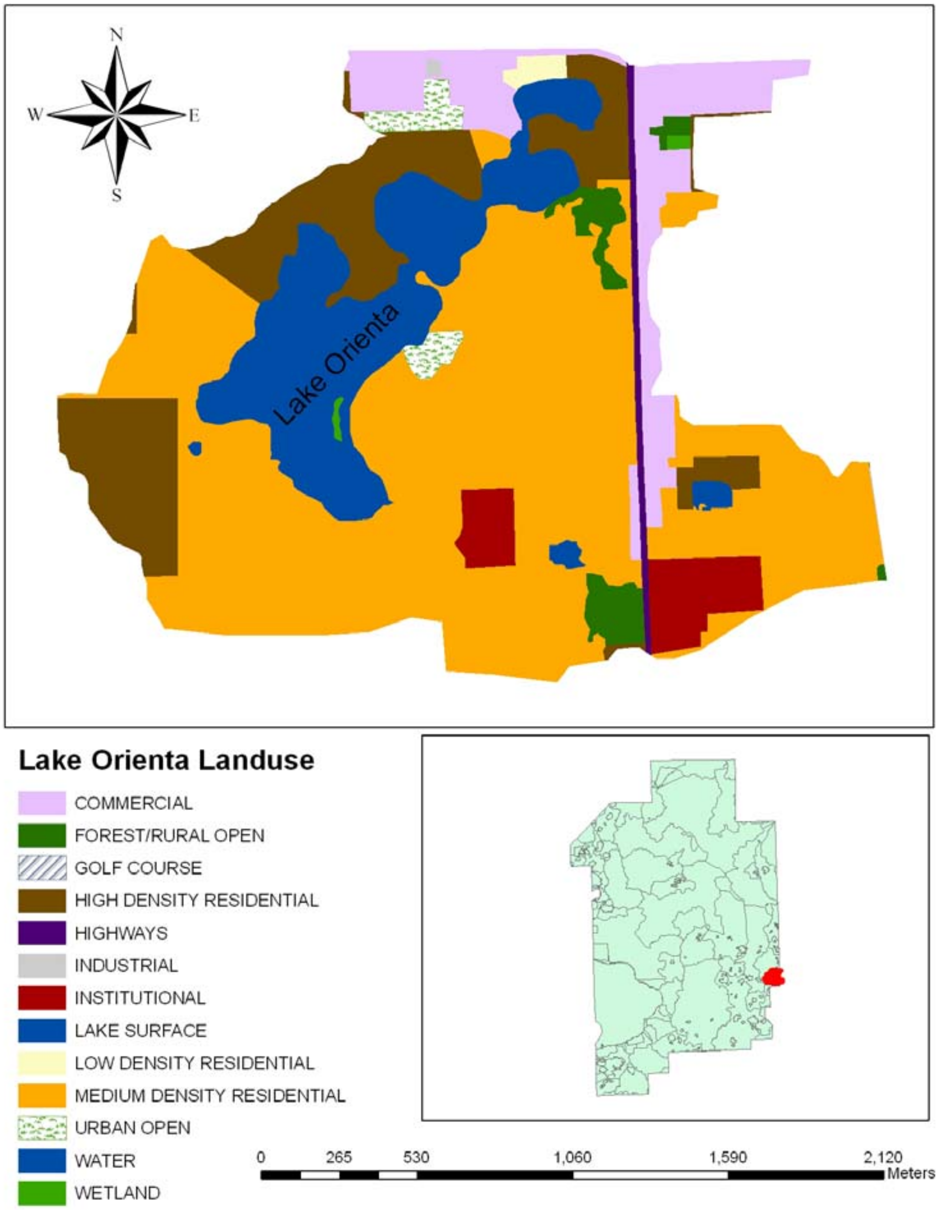

Figure 4.6. Distribution of WMM landuses in the watershed of Lake Orienta

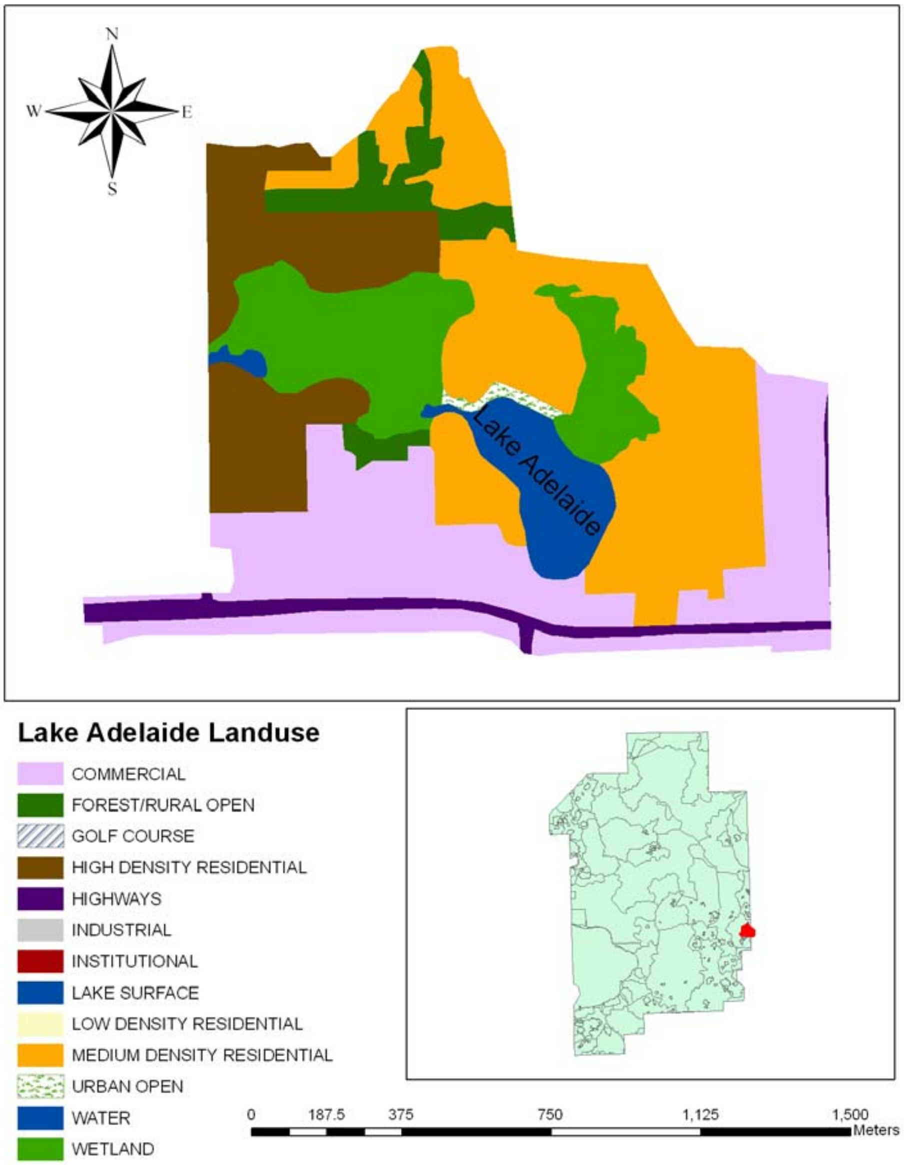

Figure 4.7. Distribution of WMM landuses in the watershed of Lake Adelaide

The total watershed area of the lakes covered in this TMDL report ranges from 245 acres for Bay Lake to 2,867 acres for Lake Lawne. All these watersheds are highly urbanized. The urban areas (including golf courses, low, median, and high density residential, commercial, industrial, institutional, and highways) account for about 67%, 72%, 76%, 75%, 57%, 89%, and 59% of watershed areas for Spring Lake, Lake Florida, Lake Orienta, Lake Adelaide, Lake Lawne, Silver Lake, and Bay Lake, respectively. Natural landuses, including water, wetlands, forest/rural open, and urban open, typically occupy less than 40% of these watersheds, such as 38% in the Lake Lawne watershed, and sometimes can be as low as 1%, such as in the Silver Lake watershed. Agricultural landuse is rare. The highest percent area of agricultural landuse was observed in the Spring Lake watershed, at about 4.8%. There were no agricultural areas in the majority of the other watersheds.

A separate category, Lake Surface, was estimated for the surface of the lakes covered in this TMDL. Surface areas of these lakes range from 25 acres (Lake Adelaide) to 147 acres (Lake Orienta). The highest lake surface to watershed area ratio was observed for Lake Orienta, which is about 15%, while the lowest ratio was found for Lake Lawne, at about 5%. When nutrient loadings from watersheds were estimated, areas of lake surface were subtracted from the total watershed. The lake's surface area was primarily used to estimate the evaporation from and rainfall directly on to the surface of these lakes.

As shown in Equations (1) and (2), three model parameters (runoff coefficients for pervious and impervious land areas, the percent impervious area of each landuse category, and event mean concentration (EMCs) of pollutants for each landuse category) are required by the WMM to simulate pollutant loadings from watersheds.

Percent impervious area of each landuse category is a very important parameter in estimating surface runoff using WMM. Nonpoint pollution monitoring studies throughout the U.S. have shown that annual "per acre" discharges of urban stormwater pollutants are positively related to the amount of imperviousness in the landuse (User's Manual: WMM 1998). Ideally, *impervious area* is considered as the area that does not allow water infiltration, and, therefore, 100% of the precipitation falling on the impervious area should become surface runoff. In practice, the runoff coefficient for impervious area typically ranges between 95 to 100%. Impervious runoff coefficients lower than this range were observed, but usually this number should not be lower than 80%. For pervious area, the runoff coefficients usually range between 10 to 20%. However, values lower than this range were also observed (User's Manual: WMM 1998). In this study, 0.15 and 0.95 (i.e., 15% and 95%) were used as the runoff coefficients for pervious and impervious areas, respectively.

It should be noted that the impervious area percentages do not necessarily represent directly connected impervious area (DCIA). Using a single family residence as an example, rain falls on rooftops, sidewalks, and driveways. The sum of these areas may represent 30% of the total lot. However, much of the rain that falls on the roof drains to the grass and infiltrates to the ground or runs off the property and thus does not run directly to the street. For WMM modeling purposes, whenever the area of the watershed that contributes to the surface runoff was considered, DCIA was used in place of impervious area. The DCIA for different landuse categories were listed in **Table 4.3**. These values were provided by CDM, and are based on the company's previous studies for the Little Wekiva River.

Pollutant EMCs were typically determined by averaging the pollutant concentrations of runoff samples collected throughout a storm event. This number is required by the WMM to estimate pollutant loadings. EMCs used for this TMDL were also provided by CDM using the company's Little Wekiva River basin study (CDM, 2005). **Table 4.3** tabulates these numbers.

Table 4.3. Percent DCIA and EMC values for different landuses

Land Use	DCIA	Event Mean Concentration (mg/l)			
		TKN	NO_X	TP	DIS P
Agricultural	1%	1.74	0.58	0.34	0.23
Forest/Rural Open	1%	1.10	0.31	0.053	0.004
Urban Open	17%	1.10	0.31	0.053	0.004
Golf Course	17%	1.74	0.58	0.34	0.23
Low Density Residential	30%	1.34	0.63	0.30	0.18
Medium Density Residential	37%	1.48	0.65	0.40	0.24
High Density Residential	71%	1.63	0.67	0.49	0.26
Commercial	85%	1.08	0.67	0.29	0.14
Industrial	71%	1.63	0.40	0.31	0.17
Highways	100%	1.61	0.40	0.34	0.19
Institutional	65%	1.24	1.05	0.15	0.08
Water	28%	0.60	0.19	0.11	0.02
Wetlands	28%	1.10	0.40	0.19	0.09

Note: TKN is total Kjeldahl nitrogen, which is the sum of ammonium and total organic nitrogen. NO_x stands for the sum of nitrate (NO_3^-) and nitrite (NO_2^-). TP is the total phosphorus and DIS P is dissolved phosphorus.

Pollutant loadings for TKN and NOx (nitrate/nitrite) were estimated separately in this study based on separate EMCs. TKN and NOx loadings were then aggregated to calculate the total nitrogen (TN) loading.

4.2.2.2. Septic Tanks

Some urbanized areas within the lake watersheds of this TMDL are served by septic tanks, rather than sanitary sewers and associated wastewater treatment plants (WWTPS). These septic tanks can produce pollutant loads to receiving waters, particularly those that are failing due to lack of maintenance, clogged drainfields, or other factors.

The WMM estimates the load impact of failing septic tanks based on the following inputs:

- Percentage of land served by septic tanks
- User-defined load multiplication factor
- Percentage of failing septic tanks

A multiplication factor is applied to the surface runoff load calculated by the WMM, and reflects the ratio of load with failing septic tanks to load without failing septic tanks. For example, if the ratio is 2, then the model presumes that the surface load from a landuse with failing septic tanks (runoff load plus failing septic tank load) is 2 times the load from surface runoff load only. **Table 4.4** lists the multiplication factors for TN and TP from failed septic tanks associated with different landuse categories. These multiplication factors were used in this report to estimate TN and TP loadings from failed septic tanks.

Table 4.4. Estimated multiplication factors for TN and TP for failed septic tanks associated with different landuses.

Land Use Type	Percent Impervious	Runoff Coefficient	Runoff (in/yr)	Runoff EMC (mg/L)	Runoff Load (lb/ac/yr)	Estimated Failing Septic Tank Load (lb/ac/yr)	Failing Septic Tank Multiplication Factor
	Total Phosphorus						
Low Density Residential	30%	0.39	19.9	0.30	1.35	0.7	1.5
Medium Density Residential	37%	0.45	22.7	0.40	2.06	2.2	2.1
High Density Residential	71%	0.72	36.6	0.49	4.07	5.9	2.4
Commercial	85%	0.83	42.3	0.29	2.78	5.9	3.1
Industrial	71%	0.72	36.6	0.31	2.57	5.9	3.3
Institutional	65%	0.67	34.2	0.15	1.16	2.9	3.5
	Total Nitrogen						
Low Density Residential	30%	0.39	19.9	1.99	9.0	11	2.2
Medium Density Residential	37%	0.45	22.7	2.13	11.0	33	4.0
High Density Residential	71%	0.72	36.6	2.3	19.1	88	5.6
Commercial	85%	0.83	42.3	1.75	16.8	88	6.2
Industrial	71%	0.72	36.6	2.03	16.8	88	6.2
Institutional	65%	0.67	34.2	2.29	17.7	44	3.5

Table 4.5 lists the percent areas of different landuse categories served with septic tanks for each of the seven lakes. These values are based on GIS coverages from the previous CDM studies (CDM, 2005), updated through coordination with the jurisdictions located in the lake tributary areas. The Spring Lake coverage used a number of sources including the Altamonte Springs Sanitary Sewer geodatabase, Orange County Sanitary Sewer Coverage, and the Septic Tank parcel coverage for the Wekiva Study Area developed by Seminole County Environmental Services, as well as the septic tank coverage originally developed as part of the Little Wekiva Watershed Stormwater Management Master Plan (CDM, 2005). The City of Orlando provided shapefiles of sanitary sewer septic lines, which were used to identify parcels expected to be served by this system. Orange County provided a coverage of parcels that are served by sanitary sewer. Areas not known to be served by sanitary sewer were presumed to be served by septic tanks.

For this analysis, the assigned value for septic tank failure rate was set at 5.9% for Lake Florida, Lake Oritenta, and Lake Adelaide. The failure rate was calculated based on the accumulative number of septic tanks in each year in Seminole County and septic tank repairs in the county published by Department of Health and assuming that failed septic tanks are not found for 5 years. (http://www.doh.state.fl.us/environment/ostds/statistics/ostdsstatistics.htm). Using the same approach, the septic tank failure rate was set at 5.4% for Spring Lake, Lake Lawne, Silver Lake, and Bay Lake (Orange County septic tank failure rate).

Table 4.5. Areas of different landuses and percent areas of each landuse category served with septic tanks

Unit: acre

	Spring Lake		Lake Florida		Lake Orienta		Lake Adelaide		Lake Lawne		Silver Lake		Bay Lake	
Landuse	Area	%*	Area	%*	Area	%*	Area	%*	Area	%*	Area	%*	Area	%*
Agricultural	62	---	0	---	0	---	0	---	0	---	0	---	49.2	---
Forest/Rural Open	65	---	98	---	22	---	20	---	339	---	0	---	15.8	---
Urban Open	4	---	23	---	13	---	2	---	243	---	5	---	0	---
Golf Course	0	---	0	---	0	---	0	---	18	---	6	---	0	---
Low Density Residential	47	23	8	95	5	0	0	0	8	96	0	0	55	98
Medium Density Residential	376	8	566	56	503	8	126	16.1	716	56	412	4	0	0
High Density Residential	124	7	5	79	134	10	60	18.3	91	12	20	8	0	0-
Commercial	253	0	232	56	85	0	112	23	403	57	77	22	88.4	57
Industrial	29	0	14	36	1	0	0	0	149	39	50	0	0	0
Highways	52	---	13	---	11	---	16	---	132	---	13	---	0	---
Institutional	12	0	21	32	36	16	0	0	108	62	63	3	0.3	88
Water	71	---	14	---	1	---	0	---	38	---	3	---	1.5	---
Wetlands	98	---	131	---	58	---	58	---	477	---	1	---	0	---
Lake Surface	86	---	74	---	147	---	25	---	145	---	70	---	35	---
TOTAL	1279	---	1199	---	1016	---	419	---	2867	---	720	---	244.8	---

*: % represents the percent area in each landuse category that is served with septic tanks.
Note: Areas served with septic tanks were only considered for low, medium, and high density residential, commercial, industrial, and institutional areas.

4.2.2.3. Best management practices (BMPs)

Some of the urbanized areas within the lake watersheds are served by structural Best Management Practices (BMPs) that capture and treat stormwater runoff. Based on input from the local jurisdictions, the coverage of BMPs in the lake tributary areas has been estimated, and is presented in **Table 4.6**.

WMM estimates the load impact (load reduction) of Best Management Practices (BMPs) based on following inputs:

- Land area treated by BMP
- Pollutant loads to BMP
- BMP removal efficiency

For a given landuse, the percentage of land area treated by the BMP is entered, and WMM uses that percentage and the total land area to calculate the acreage treated by the BMP. A separate percentage treated is specified for each landuse in the watershed area.

The data provided by the jurisdictions indicated that several different BMP types are typically present in the study area. These include the following:

- Extended dry detention
- Wet detention
- Swales

WMM is capable of assigning several different BMP types to a specific landuse category. For example, the 37% BMP coverage for industrial landuse in the Lake Lawne watershed area consists of 1% treated by swales, 14% treated by extended dry detention, and 23% treated by wet detention.

Table 4.6. Percent areas of each landuse category served with BMPs

Landuse	BMP	Percent landuse area occupied by each BMP types						
		Spring Lake	**Lake Florida**	**Lake Orienta**	**Lake Adelaide**	**Lake Lawne**	**Silver Lake**	**Bay Lake**
Agricultural	Dry Detention	0	0	0	0	0	0	0
	Swale	0	0	0	0	0	0	0
	Wet Detention	41	0	0	0	0	0	0
Forest/Rural Open		---	---	---	---	---	---	---
Urban Open		---	---	---	---	---	---	---
Golf Course	Dry Detention	0	0	0	0	0	0	0
	Swale	0	0	0	0	0	0	0
	Wet Detention	0	0	0	0	90	0	0
Low Density Residential	Dry Detention	0	0	0	0	0	0	0
	Swale	0	0	0	0	0	0	0
	Wet Detention	0.2	1.5	0	0	0	0	0
Medium Density Residential	Dry Detention	4.8	5.2	0.1	0	5.7	0.2	1
	Swale	0	0	0	0	0	0	0
	Wet Detention	7.7	1.2	0	0.2	1.3	0	0
High Density Residential	Dry Detention	0	13.3	0	0.5	0	0.4	0
	Swale	0	0	0	0	0	0	0
	Wet Detention	52.3	0	0	17	47.4	0	0
Commercial	Dry Detention	8.5	3.6	2.3	0	10	7.8	0
	Swale	0	0	0	0	0.9	0	0.3
	Wet Detention	52.4	25.1	1.7	0	7	2.2	10.5
Industrial	Dry Detention	69.8	0	0	0	13.6	0	0
	Swale	0	0	0	0	0.5	0	0
	Wet Detention	0.2	1.1	0	0	22.6	0	0
Highways	Dry Detention	1.7	22.9	0	0	0	0.1	0
	Swale	0	0	0	0	52.9	0	0
	Wet Detention	79.1	0	35.1	0	0.2	0.3	0
Institutional	Dry Detention	0	25.7	0	0	10.3	0	0
	Swale	0	0	0	0	0.8	0	1.5
	Wet Detention	71.5	0	0	0	5.6	0	10.7
Water		---	---	---	---	---	---	---
Wetlands		---	---	---	---	---	---	---
Lake Surface		---	---	---	---	---	---	---

Each of the BMPs has its own set of removal efficiency values, and the BMP removal efficiency values used in this study are presented in **Table 4.7**. These values are consistent with the values used in previous CDM studies of the Wekiva River and Little Wekiva River watersheds (CDM, 2005). Wet detention is the most effective BMP because it has multiple potential removal mechanisms (e.g, settling, biological and chemical processes). For extended dry detention, the major removal mechanism is settling, and the major removal mechanisms in swales include infiltration, filtration, and vegetative uptake of dissolved nutrients.

Table 4.7. Removal efficiencies for different type of BMPs

BMP Type	Removal Efficiency (%)			
	TKN	NOXN	TP	DIS P
Extended Dry Detention	20%	0%	30%	0%
Swales	20%	10%	40%	10%
Wet Detention	20%	60%	50%	60%

4.2.2.4. Pollutant contribution from ground water

Nutrient input from the Floridan Aquifer was considered insignificant in this TMDL based on a comparison of WMM simulated surface runoff and the surface runoff separated from the stream measured from a USGS gauging station (02234990) located in the nearby Little Wekiva River (Station name: Little Wekiva River near Altamonte Springs). During the period from 1995 through 2001, the hydrologically separated surface runoff at this gauging station was about 14.6 cfs. The drainage area for the gauge, based on the Department's USGS gauging station GIS coverage, was about 42.6 square miles. This gives a long-term annual average runoff of 4.7 inches/year for the gauge. In contrast, in a study conducted by the CDM in 2005 on the hydrology and water quality condition of the Little Wekiva River, WMM simulated runoff for the watershed that drains to this gauge was about 23 inches. Considering that the drainage basin is highly urbanized and 40-50 percent of the basin area is impervious area, 23 inches of runoff appears to be a reasonable estimate. Because the hydrologically separated runoff data based on gauge measurements were much lower than the estimated runoff from the land in the tributary area based on WMM, it seems logical to conclude that the difference (about 18 inches) is the result of the capture of runoff by the lakes in the basin and seepage from the lakes to the surficial and/or upper Floridan aquifers.

The assumption of no major Floridan aquifer input into the lakes covered in this TMDL is confirmed through comparing the surface elevations of these lakes with potentiometric heads of Floridan Aquifers in these lake areas based on data from the SJRWMD. The difference between the lake surface elevation and Floridan Aquifer potentiometric head is typically larger than 10 feet. Ground water recharge rates to the Floridan Aquifer in these lake areas ranged from 4 to 12 inches annually, which indicated that the net water flow is from these lakes to the aquifer. **Table 4.8** shows lake surface elevations and potentiometric heads of Floridan Aquifer in the areas covered by this TMDL.

Table 4.8. Lake suface elevations and potentiometric heads of Floridan Aquifer in lake areas covered by this TMDL

Lakes	Lake Elevation (ft)	Potentiometric Head of Floridan Aquifer (ft)	Annual Recharge Rates (inches/year)
Spring Lake	66	45	8
Lake Florida	56	42	4
Lake Orienta	61	44	4-8
Lake Adelaide	56	43	4
Lake Lawne	87	55	12
Silver Lake	92	51	12
Bay Lake	91	52	12

The estimated baseflow at the Altamonte Springs gage is 19.8 cfs, which translates to a unit flow of 6.3 inches per year over the tributary area. If the tributary area to this gage has an imperviousness of 40 to 50 percent (which could not directly contribute to baseflow), it is calculated that the pervious area (50 to 60 percent of the tributary area) could contribute as much as 5 to 10 inches per year of baseflow. Without detailed analyses of the lake water budget and measurements of lake stages, inflows, and outflows, it is difficult to estimate the exact contribution from the baseflow. Consequently, this TMDL assumes a baseflow of 8 inches per year. The following nitrogen and phosphorus concentrations, which were confirmed by regional ground water data, were used in simulating the baseflow nutrient inputs into these lakes.

Total P: 0.05 mg/L
Dissolved P: 0.04 mg/L
TKN: 0.6 mg/L
NOXN: 0.1 mg/L

4.2.2.5. Rainfall

Rainfall is the driving force for the simulation of surface runoff. The rainfall data used in this were from two weather stations maintained by Orange County, including a station located adjacent to Lake Orlando (28^{0}35'51"N and 81^{0}26'12"W) and a station located in Riverside Acres (28^{0}38'00"N and 81^{0}25'25"W). Period records for the Lake Orlando and Riverside Acres stations start in 1986 and 1989, respectively. A strong linear correlation of rain fall records from these two stations was identified with a slope close to 1. Because missing data records were found in both data sets, a combined annual rainfall data set was built by substituting Riverside Acres data into the Lake Orlando data set whenever the Lake Orlando data set has missing data for more than 15 days in a year and River Acre data set has the full year data. The combined data set included the annual rainfall from 1998, 1991-1995, 1997-1998, 2002-2006). Because the water quality data used in this study was for the period from 1996 through 2006, it is desirable that a long-term annual average rainfall for the same time period could be used for the model simulation. To establish the long-term annual rainfall for this time period for the combined data set, a third rainfall station was introduced into this study. This is the weather station located in Sanford, Florida (28^{0}48'N and 81^{0}16'W). The station has the full-year rainfall record for the required time period, as well as all the years that the combined data set has the full year annual rainfall data. Long-term annual average rainfalls were then calculated for both the combined data set and the Sanford data set based on annual rainfall of 1998, 1991-1995, 1997-1998, and 2002-2006. The ratio between the combined data set long-term average and Sanford data set long-term average was calculated and found to be 0.83. The long-term average annual rainfall for the Sanford station for the period from 1996 through 2006 was then calculated, which was found to be 52 inches/year. This number was multiplied by 0.83 to create the long-term average annual rainfall for the combined data set for the period from 1996 through 2006, which was determined to be 43 inches/year. This final number was used as the annual rainfall for simulating the pollutant load from the watershed in this study. Table 4.9 shows the annual rainfall from weather stations located in Lake Orlando, Riverside Acres, Sanford, and the combined data set.

4.2.2.6. WMM simulated nutrient loadings from watersheds into lakes covered in this TMDL report.

Tables 4.10 – **4.16** list total watershed areas, areas of DCIA, flow, and TN and TP loads from different landuses in the basin of each of the seven lakes covered in this TMDL report. According to **Table 4.10** – **4.16**, the total watershed area ranged from 211 to 2722 acres (total watershed area in **Table 4.2** minus lake surface area). Bay Lake has the smallest watershed area, and Lake Lawne has the largest. The percent DCIA of these watershed range from 42% to 55%. The highest percent DCIA was observed for Lake Adelaide, while the lowest percent DCIA was observed for Bay Lake.

Table 4.9. Rainfall data used in WMM runoff simulation

Annual rainfall unit: inches/year

YEAR	Lake Orlando		Riverside Acres		Combined	Sanford Station	
	# of Record	Annual rain	# of Record	Annual Rain	Data Set	# of Record	Annual Rain
1986	175	**30.1**				365	**43.90**
1987	288	**48.6**				365	**46.23**
1988	352	**46.6**			**46.6**	366	**60.05**
1989	57	**4.9**	111	**10.3**		365	**40.65**
1990	334	**39.7**	364	**36.7**	**36.7**	365	**36.36**
1991	364	**54.9**	318	**39**	**54.9**	365	**69.28**
1992	360	**48.7**	344	**23.5**	**48.7**	366	**59.88**
1993	364	**44.9**	365	**39.1**	**44.9**	365	**35.35**
1994	364	**73.5**	365	**66.8**	**73.5**	365	**71.09**
1995	365	**51.5**	365	**57.2**	**51.5**	365	**59.32**
1996	0		0			366	**62.82**
1997	365	**18.1**	365	**22.6**	**18.1**	365	**53.69**
1998	358	**28.4**	262	**18.7**	**28.4**	365	**48.83**
1999	330	**36.0**	287	**23.8**		365	**47.04**
2000	121	**2.2**	142	**0.6**		366	**32.83**
2001	261	**20.4**	264	**37.5**		365	**52.73**
2002	365	**61.9**	365	**61.5**	**61.9**	365	**66.24**
2003	365	**52.0**	365	**51.3**	**52.0**	357	**53.15**
2004	366	**47.0**	366	**54.6**	**47.0**	366	**66.71**
2005	365	**47.5**	365	**52.9**	**47.5**	365	**63.45**
2006	365	**31.7**	365	**35.0**	**31.7**	365	**37.55**

Table 4.10. Flow, TN and TP loads created from different landuses in watershed of Spring Lake

Land Use	Watershed Area (acres)	DCIA (acres)	Flow (acre-feet)	TN load (lb/yr.)	Percent TN load	TP load (lb/yr.)	Percent TP load
Agricultural	62	1	35	221	1.6%	32	1.4%
Forest/Rural Open	65	1	37	141	1.0%	5	0.2%
Urban Open	4	1	4	15	0.1%	0.6	0.0%
Golf Course	0	0	0	0	0.0%	0	0.0%
Low Density Residential	47	14	66	352	2.6%	54	2.4%
Med Density Residential	376	139	601	3480	25.3%	654	29.5%
High Density Residential	124	88	319	1995	14.5%	425	19.2%
Commercial	253	215	752	3581	26.1%	593	26.8%
Industrial	29	21	75	412	3.0%	63	2.8%
Highway	52	52	177	968	7.0%	164	7.4%
Institutional	12	8	29	179	1.3%	12	0.5%
Water	71	20	94	203	1.5%	28	1.3%
Wetland	98	27	130	530	3.9%	67	3.0%
Watershed Total	1193	587	2319	12077	87.9%	2097.6	94.7%
Septic Tanks				86	0.6%	5	0.2%
Baseflow			826	1572	11.4%	112	5.1%
BMP Removal				1487	10.8%	405	18.3%
Total before BMP	**1193**	**587**	**3145**	**13735**	100.0%	**2215**	100.0%
Total after BMP	**1193**	**587**	**3145**	**12248**	89.2%	**1810**	81.7%

Formatted Table

Table 4.11. Flow, TN and TP loads created from different landuses in watershed of Lake Florida

Land Use	Watershed Area (acres)	DCIA (acres)	Flow (acre-feet)	TN load (lb/yr.)	Percent TN load	TP load (lb/yr.)	Percent TP load
Agricultural	0	0	0	0	0.0%	0	0.0%
Forest/Rural Open	98	1	55	213	1.6%	8	0.4%
Urban Open	23	4	24	91	0.7%	3	0.2%
Golf Course	0	0	0	0	0.0%	0	0.0%
Low Density Residential	8	2	11	60	0.5%	9	0.5%
Med Density Residential	566	209	905	5239	40.0%	984	50.9%
High Density Residential	5	4	13	80	0.6%	17	0.9%
Commercial	232	197	690	3283	25.1%	544	28.1%
Industrial	14	10	36	199	1.5%	30	1.6%
Highway	13	13	44	242	1.8%	41	2.1%
Institutional	21	14	50	314	2.4%	21	1.1%
Water	14	4	19	40	0.3%	6	0.3%
Wetland	131	36	174	709	5.4%	90	4.7%
Watershed Total	1125	494	2021	10470	80.0%	1753	90.6%
Septic Tanks				1141	8.7%	78	4.0%
Baseflow			779	1484	11.3%	104	5.4%
BMP Removal				443	3.4%	106	5.5%
Total before BMP	**1125**	**494**	**2800**	**13095**	100.0%	**1935**	100.0%
Total after BMP	**1125**	**494**	**2800**	**12652**	96.6%	**1829**	94.5%

Table 4.12. Flow, TN and TP loads created from different landuses in watershed of Lake Orienta

Land Use	Watershed Area (acres)	DCIA (acres)	Flow (acre-feet)	TN load (lb/yr.)	Percent TN load	TP load (lb/yr.)	Percent TP load
Agricultural	0	0	0	0	0.0%	0	0.0%
Forest/Rural Open	22	0	12	47	0.4%	2	0.1%
Urban Open	13	2	13	51	0.5%	2	0.1%
Golf Course	0	0	0	0	0.0%	0	0.0%
Low Density Residential	5	2	7	37	0.4%	6	0.3%
Med Density Residential	503	186	804	4656	44.3%	874	50.1%
High Density Residential	134	95	345	2156	20.5%	459	26.3%
Commercial	85	72	253	1203	11.5%	199	11.4%
Industrial	1	1	3	14	0.1%	2	0.1%
Highway	11	11	37	205	2.0%	35	2.0%
Institutional	36	23	87	538	5.1%	35	2.0%
Water	1	0	1	3	0.0%	0.4	0.0%
Wetland	58	16	77	314	3.0%	40	2.3%
Watershed Total	869	408	1639	9224	87.8%	1654.4	94.8%
Septic Tanks				138	1.3%	10	0.6%
Baseflow			601	1144	10.9%	81	4.6%
BMP Removal				33	0.3%	9	0.5%
Total before BMP	**869**	**408**	**2240**	**10506**	100.0%	**1745.4**	100.0%
Total after BMP	**869**	**408**	**2240**	**10473**	99.7%	**1736.4**	99.5%

Table 4.13. Flow, TN and TP loads created from different landuse in watershed of Lake Adelaide

Land Use	Watershed Area (acres)	DCIA (acres)	Flow (acre-feet)	TN load (lb/yr.)	Percent TN load	TP load (lb/yr.)	Percent TP load
Agricultural	0	0	0	0	0.0%	0	0.0%
Forest/Rural Open	20	0	11	44	0.9%	2	0.2%
Urban Open	2	0	2	8	0.2%	0.3	0.0%
Golf Course	0	0	0	0	0.0%	0	0.0%
Low Density Residential	0	0	0	0	0.0%	0	0.0%
Med Density Residential	126	47	201	1166	22.9%	219	26.4%
High Density Residential	60	43	154	965	19.0%	206	24.8%
Commercial	112	95	333	1585	31.1%	263	31.7%
Industrial	0	0	0	0	0.0%	0	0.0%
Highway	16	16	54	297	5.8%	50	6.0%
Institutional	0	0	0	0	0.0%	0	0.0%
Water	0	0	0	0	0.0%	0	0.0%
Wetland	58	16	77	314	6.2%	40	4.8%
Watershed Total	394	217	832	4379	86.0%	780	94.0%
Septic Tanks				193	3.8%	12	1.4%
Baseflow			272	518	10.2%	38	4.6%
BMP Removal				55	1.1%	18	2.2%
Total before BMP	**394**	**217**	**1104**	**5090**	100.0%	**830**	100.0%
Total after BMP	**394**	**217**	**1104**	**5035**	98.9%	**812**	97.8%

Table 4.14. Flow, TN and TP loads created from different landuses in watershed of Lake Lawne

Land Use	Watershed Area (acres)	DCIA (acres)	Flow (acre-feet)	TN load (lb/yr.)	Percent TN load	TP load (lb/yr.)	Percent TP load
Agricultural	0	0	0	0	0.0%	0	0.0%
Forest/Rural Open	339	3	192	736	2.4%	28	0.7%
Urban Open	243	41	249	955	3.2%	36	0.9%
Golf Course	18	3	18	116	0.4%	17	0.4%
Low Density Residential	8	2	11	60	0.2%	9	0.2%
Med Density Residential	716	265	1144	6628	22.1%	1245	29.9%
High Density Residential	91	65	234	1465	4.9%	312	7.5%
Commercial	403	343	1199	5704	19.0%	945	22.7%
Industrial	149	106	383	2116	7.0%	323	7.8%
Highway	132	132	449	2456	8.2%	415	10.0%
Institutional	108	70	259	1614	5.4%	106	2.5%
Water	38	10	50	108	0.4%	15	0.4%
Wetland	477	131	632	2580	8.6%	327	7.9%
Watershed Total	2722	1171	4820	24538	81.7%	3778	90.7%
Septic Tanks				1926	6.4%	130	3.1%
Baseflow			1882	3585	11.9%	257	6.2%
BMP Removal				840	2.8%	262	6.3%
Total before BMP	**2722**	**1171**	**6702**	**30049**	100.0%	**4165**	100.0%
Total after BMP	**2722**	**1171**	**6702**	**29209**	97.2%	**3903**	93.7%

Table 4.15. Flow, TN and TP loads created from different landuses in watershed of Silver Lake

Land Use	Watershed Area (acres)	DCIA (acres)	Flow (acre-feet)	TN load (lb/yr.)	Percent TN load	TP load (lb/yr.)	Percent TP load
Agricultural	0	0	0	0	0.0%	0	0.0%
Forest/Rural Open	0	0	0	0	0.0%	0	0.0%
Urban Open	5	1	5	19	0.2%	0.74	0.1%
Golf Course	6	1	6	39	0.5%	6	0.5%
Low Density Residential	0	0	0	0	0.0%	0	0.0%
Med Density Residential	412	152	658	3814	46.4%	716	56.9%
High Density Residential	20	14	51	322	3.9%	69	5.5%
Commercial	77	65	229	1090	13.3%	181	14.4%
Industrial	50	35	129	710	8.6%	108	8.6%
Highway	13	13	44	242	2.9%	41	3.3%
Institutional	63	41	151	942	11.5%	62	4.9%
Water	3	1	4	8	0.1%	1	0.1%
Wetland	1	0	1	5	0.1%	0.68	0.1%
Watershed Total	650	323	1278	7191	87.5%	1185	94.3%
Septic Tanks				102	1.2%	6	0.5%
Baseflow			487	927	11.3%	66	5.2%
BMP Removal				22	0.3%	7	0.6%
Total before BMP	**650**	**323**	**1765**	**8220**	100.0%	**1257**	100.0%
Total after BMP	**650**	**323**	**1765**	**8198**	99.7%	**1250**	99.4%

Table 4.16. Flow, TN and TP loads created from different landuses in watershed of Bay Lake

Land Use	Watershed Area (acres)	DCIA (acres)	Flow (acre-feet)	TN load (lb/yr.)	Percent TN load	TP load (lb/yr.)	Percent TP load
Agricultural	49	0	28	176	7.4%	26	7.8%
Forest/Rural Open	16	0	9	35	1.5%	1	0.3%
Urban Open	0	0	0	0	0.0%	0	0.0%
Golf Course	0	0	0	0	0.0%	0	0.0%
Low Density Residential	55	17	77	412	17.3%	63	19.0%
Med Density Residential	0	0	0	0	0.0%	0	0.0%
High Density Residential	0	0	0	0	0.0%	0	0.0%
Commercial	88	75	263	1251	52.4%	207	62.4%
Industrial	0	0	0	0	0.0%	0	0.0%
Highway	0	0	0	0	0.0%	0	0.0%
Institutional	0	0	0.72	4	0.2%	0.29	0.1%
Water	2	0	2	4	0.2%	0.59	0.2%
Wetland	0	0	0	0	0.0%	0	0.0%
Watershed Total	211	92	380	1882	78.8%	298	89.8%
Septic Tanks				228	9.5%	15	4.5%
Baseflow			145	278	11.6%	19	5.7%
BMP Removal				56	2.3%	12	3.6%
Total before BMP	**211**	**92**	**525**	**2388**	100.0%	**332**	100.0%
Total after BMP	**211**	**92**	**525**	**2332**	97.7%	**320**	96.4%

The high percent DCIAs in these watersheds is a consequence of the urbanization. A high percentage DCIA produces high surface runoff and therefore high TN and TP loadings. Except for Bay Lake, the percent TN and TP loadings from medium density residential areas in watersheds of the other six lakes exceeded 20% of the total watershed loads. Medium density residential areas contribute 40 - 60% of the TN and TP loads in Silver Lake, Lake Florida, and Lake Orienta. Other important nutrient contributors include low and high density residential area, commercial area, and occasionally, the industrial area. Except for the Lake Orienta and Silver Lake watersheds, commercial areas in other lake watersheds contributed more than 20% of the total watershed TN and TP loadings. In addition, high density residential area contributed 10 - 20% of the TN and TP loadings in Spring Lake, Lake Orienta, and Lake Adelaide watersheds.

TP loadings from septic tanks did not constitute a significant source. Septic tank TP loadings never exceeded 10% of the total watershed loadings. The highest percent TP loadings contributed by septic tanks was observed in Bay Lake watershed, which was about 4.5%. Septic tanks contribute less than 1% of the total TP loadings in Silver Lake, Spring Lake, and Lake Orienta. Septic tanks in watersheds of Lake Lawne, Bay Lake, and Lake Florida contributed about 6.4%, 9.5%, and 8.7% of the TN. Other than in the watersheds of these lakes, septic tanks located in watersheds of other lakes typically contribute less than 5% of the TN.

Baseflow typically contributes less than 10% of TP and TN. The highest percent TP contribution from baseflow was observed in Lake Lawne, which is about 6.2%. The highest percent TN baseflow contribution was also observed in Lake Lawne, which was about 9.5%.

TN and TP loadings removed by various existing BMPs were relatively insignificant in most watersheds. The highest percent TN and TP removal were observed in the Spring Lake watershed, which accounted for 10.8% of TN and 18.3% of TP loadings from the entire watershed. The percent BMP removals were less than 1% in Silver Lake and Lake Orienta. The percent BMP removals for the other watersheds fell between 1 to 10%.

In summary, based on the current data available, the majority of the TN and TP loadings from the watershed were from several human landuse categories including low, medium, and high residential areas, commercial and industrial areas. The contribution from septic tanks is relatively minor. Nutrient removal by various BMPs is relatively insignificant compared to the total watershed loading. Because most of the lakes covered in this TMDL report are located in the ground water recharge area, contributions of nutrient from the Floridan Aquifer to the in-lake nutrient concentration was not considered.

Another source of TN and TP to lakes is by atmospheric deposition directly onto the surface of lakes. The load can be estimated by multiplying the areal loads of bulk TN and TP from the atmosphere by surface areas of lakes. The areal atmospheric TN and TP loads were provided by CDM, which are 1000 mg/m2-yr. for TN and 30 mg/m2-yr. for TP. The surface areas of the seven lakes and the TN and TP loadings that precipitate directly on to the surface of these lakes are listed on **Table 4.17**. **Table 4.18** lists the TN and TP loadings from all the sources considered in this TMDL (including surface runoff, septic tanks, baseflow, and atmospheric deposition) subtracting TN and TP loadings removed by BMPs and the percentage of atmospheric TN and TP loading in the total loadings.

Table 4.17. Atmospheric deposition of TN and TP directly onto the surface of lakes

Lake Name	Surface Area (km^2)	Areal TN atmospheric loading rate (mg/m2-yr.)	Areal TP atmospheric loading rate (mg/m2-yr.)	TN atmospheric loading (lb/year)	TP atmospheric loading (lb/year)
Spring Lake	0.36	1000	30	794	24
Lake Florida	0.10	1000	30	221	7
Lake Orienta	0.57	1000	30	1257	38
Lake Adelaide	0.09	1000	30	198	6
Lake Lawne	0.63	1000	30	1389	42
Silver Lake	0.28	1000	30	617	19
Bay Lake	0.15	1000	30	331	10

According to **Tables 4.17** and **4.18**, direct atmospheric deposition of TN onto target lakes ranged from 198 lbs/year for Lake Adelaide to 1389 lbs/year for Lake Lawne. Atmospheric TP ranged from 6 lbs/year for Adelaide to 42 lbs/year for Lake Lawne. The difference is caused by the size of lake surface areas. In the majority of cases, atmospheric direct deposition account for less than 10% of the total loadings from all sources. Percent atmospheric loadings higher than 10% were observed for Bay Lake and Lake Orienta for TN. Typically, the higher percent atmospheric load results from the larger lake surface area to watershed area ratio. The overall small percent atmospheric deposition in the total TN and TP loadings from all the sources indicates that the major nutrient contributor in these lake basins is the surface runoff from human impacted landuses.

Table 4.18. Percent atmospheric deposition of TN and TP directly onto the surface of lakes in total TN and TP loadings from all sources minus the loading removed by BMPs

Lake Name	TN atmospheric loading (lb/year)	TP atmospheric loading (lb/year)	Total TN loading from all sources (lb/year)	Total TP loading from all sources (lb/year)	Percent TN atmospheric loading in total TN loadings (%)	Percent TP atmospheric loading in total TP loadings (%)
Spring Lake	794	24	12248	1810	6.5%	1.3%
Lake Florida	221	7	12652	1829	1.7%	0.4%
Lake Orienta	1257	38	10473	1736	12.0%	2.2%
Lake Adelaide	198	6	5035	812	3.9%	0.7%
Lake Lawne	1389	42	29209	3903	4.8%	1.1%
Silver Lake	617	19	8198	1250	7.5%	1.5%
Bay Lake	331	10	2332	320	14.2%	3.1%

Chapter 5: DETERMINATION OF ASSIMILATIVE CAPACITY

5.1 Overall Approach

The goal of the TMDL development for nutrient impaired lakes in the Wekiva Study Area is to identify the maximum allowable TP and TN loadings to these lakes so that these lakes will meet the narrative water quality standard and maintain their designated uses as Class III waters. Water quality targets for lakes covered in this TMDL report are listed in **Table 3.1.** The following steps were taken to estimate the target nutrient loads that achieve these goals.

1. TP and TN loadings from watersheds of these lakes (including surface runoff, baseflow, and contribution from septic tanks were estimated using the WMM (see Chapter 4). Atmospheric loads depositing directly onto lake surfaces were also estimated. Because most of the watershed areas of these lakes are located in ground water recharge area, nutrient contributions to these lakes from Floridan Aquifer was considered insignificant. Influence on the lake nutrient concentrations from the sediment nutrient release was considered through calibrating the net nutrient deposition rate of the Bathtub eutrophication model.

2. Loading estimates from all sources were entered into the Bathtub eutrophication model to establish the relationship between TN and TP loadings and in-lake TN, TP, and Chl a concentrations. The watershed landuses were then adjusted in WMM to simulate natural background nutrient loadings. These loadings were entered into the Bathtub model to simulate background TN, TP, and Chl a concentrations and the background TSI. The target TSI for each of these lakes was established as 5-TSI units above the background TSI. The five-TSI unit increase was chosen to allow certain extent of assimilative capacity and at the same time avoid significant changes of water quality condition of the lake. A 10-TSI unit difference is typically considered a significant trophic state switch, for example, from oligotrophic to mesotrophic, or from mesotrophic to eutrophic, especially when the overall TSI is close to the mesotrophic threshold (TSI = 50).

3. After the water quality target for each lake was established, loadings to the lake were further adjusted until the TSI estimated based on TN, TP, and Chl a concentrations simulated using Bathtub achieved the target TSI. TN and TP loadings that resulted in the target TSI were considered the total nitrogen and total phosphorus (nutrient) TMDLs for the lake.

5.1.1 Entering Loading Estimates from all sources into the Bathtub Eutrophication Model

Bathtub is a suite of models developed by the U. S. Army Corps of Engineers (USACOE) Waterways Experimental Station. The primary function of these models is to estimate nutrient concentrations and algal biomass resulting from different patterns of nutrient loadings. The procedures for selection of the appropriate model(s) for a particular lake are described in the Users Manual (Walker, 1999). The model suite is composed of two types of models:

- The ***nutrient balance models*** relate in-lake nutrient concentrations to external nutrient loadings, morphometry of the lake, and watershed hydrology.
- The ***eutrophication response models*** estimate *Chl* a concentration, transparency, hypolimnetic oxygen depletion, and etc., based on in-lake nutrient concentrations established by the nutrient balance models.

The nutrient balance model adopted by Bathtub assumes that the net accumulation of nutrients in a lake is the difference between nutrient loadings into the lake from various sources and the nutrients output from the lake through outflow and losses of nutrient through whatever decay processes occur inside the lake. The major in-lake nutrient budget is described using the following mass balance equation:

(3) Net accumulation = Input - Decay - Output

In this TMDL, "input" included TN and TP loadings though surface runoff from various land use categories, baseflow, septic tanks contribution, and atmospheric deposition directly on to the surface of the lake. For the Bathtub model, no lake outlet parameters are required for model simulation. Lake outlet parameters are typically entered into model for calibration purposes.

To address nutrient decay within the lake, Bathtub provided several alternatives, depending on the inorganic/organic nutrient partitioning coefficient and reaction kinetics. The major pathway of decay for total nitrogen and total phosphorus in the model is through sedimentation to the bottom of the lake. The actual sedimentation rate estimated by Bathtub is the net difference between the gross sedimentation rate and sediment nutrient release rate.

The prediction of the eutrophication response by Bathtub involves choosing one of several alternative models, depending on whether the algal communities are limited by phosphorus or nitrogen, or co-limited by both nutrients. Scenarios that include algal communities limited by light intensity or controlled by the lake flushing rate are also included in the suite of models. In addition, the response of *Chl* a concentration to the in-lake nutrient level is characterized by two different kinetic processes: linear or exponential. The variety of models available in Bathtub allows the user to choose specific models based on the specific condition of an individual lake.

The data requirements for the Bathtub model include the following:

- The lake's physical characteristics (surface area, mean depth, length, and mixed layer depth),

- Meteorological data (precipitation and evaporation retrieved from the Climate Interactive Rapid Retrieval Users System of the National Climate Data Center),
- Measured in-lake water quality data (including TN, TP, and Chl a concentrations of the lake water and TN and TP concentrations in precipitation), and
- Loading data (flow combined with concurrent TN and TP concentrations from various sources).

One feature offered by Bathtub is the "calibration factor." The empirical models implemented in Bathtub are mathematical generalizations about lake behavior. When applied to data from a particular lake, measured data may differ from predictions by a factor of two or more. Such differences reflect data limitations (measurement or estimation errors in the average inflow and outflow concentrations), unique features of the particular lake (Walker, 1999), and unexpected processes inherent to the lake. The calibration factor offered by Bathtub provides model users with a facility to calibrate the magnitude of lake response predicted by the empirical models. The model calibrated to current conditions against measured data from the lake can then be applied to predict changes in lake conditions likely to result from specific management scenarios using the assumption that the calibration factor remains constant for all prediction scenarios.

5.1.1.1 Calculation of the Trophic State Index (TSI)

TSI values were calculated using the procedures outlined in Florida's 1996 305(b) report, as follows:

$TSI = (CHLA_{TSI} + NUTR_{TSI})/2$

Where:

$CHLA_{TSI} = 16.8 + 14.4 \times LN (CHLA)]$
$TN_{TSI} = 56 + [19.8 \times LN(TN)]$
$TN2_{TSI} = 10 \times [5.96 + 2.15 \times LN(TN + 0.0001)]$
$TP_{TSI} = [18.6 \times LN(TP \times 1000)] – 18.4$
$TP2_{TS} = 10 \times [2.36 \times LN(TP \times 1000) – 2.38]$

The procedure addresses limiting nutrient considerations by calculating $NUTR_{TSI}$:

If $TN/TP > 30$ then $NUTR_{TSI} = TP2_{TSI}$
If $TN/TP < 10$ then $NUTR_{TSI} = TN2_{TSI}$
If $10 < TN/TP < 30$ then $NUTR_{TSI} = (TP_{TSI} + TN_{TSI})/2$

5.1.1.2 TMDL Scenario Development

TMDLs for each lake were developed by evaluating TSIs for the following scenarios:

1. **The TSI for existing conditions.** TSI for the existing condition was characterized using the long-term annual average TSI calculated based on the TN, TP, and Chl a concentrations obtained from the Department's IWR database Run_26. The long-term average annual TSI was calculated based on annual mean TSI for each year. The

annual mean TSI for each year was calculated based on four quarterly TSIs for each calendar year. For TSI calculating purposes, the four quarters are designated as: 1st Quarter: January 1 through March 31; 2nd Quarter: April 1 through June 30; 3rd Quarter: July 1 through September 30; and 4th Quarter: October 1 through December 31.

2. **Natural Background TSI.** This is the TSI calculated based on the TN, TP, and Chl a concentrations result from a watershed condition at which all the human landuses, including Agriculture/Golf course, Low, Medium, and High Density Residential, Commercial, Industrial, Institution, and Transportation facilities, discharge pollutants with characteristics the same as those associated with natural landuses. In the actual modeling process, all the areas covered by human landuses were converted to Forest/Rural Open. Septic tank loading was assumed 0 when simulating the background condition. Contributions from baseflow and atmospheric deposition directly onto lake surface were kept unchanged when simulating the background condition.

3. **Target TSI.** The target TSI is considered the background TSI plus 5 TSI units.

A TMDL for each lake was set using the nutrient loads that result in meeting the target TSI in the lake.

5.1.1.3 Historical Trends of in-lake TN, TP, and Chl a concentrations and TSI

TN, TP, and *Chl a* concentrations for each lake were retrieved from the Department's IWR database Run-26. The general period of record used for this TMDL report is between 1996 to 2006. Annual average TN, TP, and *Chl a* concentrations and TSI values were calculated based on four quarterly means for each calendar year. Annual average TN, TP, and *Chl a* concentrations and TSI were not calculated when there were not enough data to calculate means for all four quarters. **Tables 5.1** lists the long-term annual means of TN, TP, and Chl a concentrations, and TSIs for all the seven lakes covered in this TMDL report. The detailed historic data used to calculate these long-terms means are listed on **Tables B-1** through **B-7** in **Appendix B**.

Table 5.1. Long-term annual average TN, TP, and Chl a concentrations and TSIs for the seven lakes covered in this TMDL report

Lakes	TN (mg/L)	TP (mg/L)	*Chl a* (mg/L)	TSI
Silver Lake	0.68	0.03	14.3	48.4
Lake Florida	0.91	0.05	22.2	55.7
Lake Orienta	1.16	0.04	46.9	63.8
Lake Adelaide	1.05	0.06	43.3	62.9
Lake Lawne	1.45	0.09	35.4	65.2
Spring Lake	1.44	0.04	44.0	66.3
Bay Lake	1.44	0.04	27.5	61.5

As shown in **Table 5.1**, the TN concentrations in these lakes ranged from 0.68 mg/L to 1.45 mg/L with the highest concentrations appearing in Lake Lawne and the lowest concentrations being observed in Silver Lake. TP concentrations ranged between 0.03 mg/L and 0.09 mg/L. Lake Lawne has the highest long-term average TP, and Silver Lake has the lowest long-term average concentration. *Chl a* concentrations ranged between 14.3 µg/L (Silver Lake) and 46.9 µg/L (Lake Orienta). The lowest long-term average annual TSI was found in Silver Lake (48.4) for its low TN, TP, and *Chl a* concentrations. The highest TSI was for Spring lake, which is 66.3. TN, TP, and *Chl a* concentrations for this lake are 1.44 mg/L, 0.04 mg/L, and 44.0 µg/L.

Long-term average TN, TP, and Chl a concentrations listed in **Table 5.1** were used for calibration of the Bathtub eutrophication model.

5.1.1.4 Bathtub Calibration

The relationship between TN and TP loadings and the in-lake TN and TP concentrations was established by fitting the Bathtub predictions with the measured TN and TP concentrations of the lake. To calibrate the model, the following data were required:

1. The lake's physical characteristics,
2. Meteorological data (precipitation and evaporation),
3. Areal atmospheric deposition of nutrient directly on to the surface of the lake,
4. Measured water quality data (TN, TP, and Chla concentrations of the lake water), and
5. Loading data (flow and TN and TP concentrations of the flow from various sources).

The major physical characteristics required by Bathtub model include lake surface area and mean depth. These parameters are used by the model to estimate the atmospheric deposition directly on to the lake surface as well as the total lake volume, which influences the pollutant concentration balance, and the water residence time, which influence the nutrient sedimentation and the time allowed for phytoplankton growth. **Table 5.2** shows surface areas and mean depths of the lakes covered in this TMDL report. For Lake Lawne, Bay Lake, Silver Lake and Spring Lake, lake surface areas and mean depths were provided by the CDM. Lake surface areas and mean depths for Lake Florida, Lake Orienta, and Lake Adelaide were obtained from the Seminole County Watershed Atlas (http://www.seminole.wateratlas.usf.edu/).

Table 5.2. Surface areas and mean depths of project lakes

Lake	Surface Area (km^2)	Mean Depth (m)
Spring Lake	0.36	1.77
Lake Florida	0.10	2.13
Lake Orienta	0.57	1.83
Lake Adelaide	0.09	2.13
Lake Lawne	0.63	1.79
Silver Lake	0.28	4.8
Bay Lake	0.15	2.39

The annual values for precipitation onto the lake surface and evaporation off of the lake surface, were set equal to 1.3 meters per year. This precipitation value is consistent with the annual rainfall (51 inches) used in WMM. Evaporation was assumed equal to precipitation.

As described in Chapter 4, atmospheric loads directly to the lake surface were 30 mg/m^2-yr. for bulk TP and 1000 mg/m^2-yr. for bulk TN. These values were provided by CDM.

Measured water quality data are listed in **Table 5.1**. Long-term average annual TN, TP, and *Chl a* concentrations were used for Bathtub calibration.

Nutrient loads were entered into Bathtub in the form of watershed hydrological input (runoff + baseflow) from each watershed and nutrient concentrations of the hydrological input. Hydrological inputs from watersheds are listed in **Table 4.10** through **4.16** with a unit of acre-feet/year. Because the unit of flow for Bathtub is hm^3/year, flow values in these tables were converted to hm^3/year and listed in **Table 5.3**. The TN and TP concentrations of the hydrological input were calculated as the quotient between the total watershed loads from all sources and total volume of surface runoff and baseflow. The units for TN and TP concentrations are ppb for Bathtub. The runoff TN and TP concentrations into each lake are also listed in **Table 5.3**.

Table 5.3. Volumes of surface runoff + baseflow from lake drainage basins and TN and TP concentrations of the flow

Lake	Area of Drainage Basin (km2)	Runoff + Baseflow (hm3/year)	TN Concentration (ppb)	TP Concentration (ppb)
Spring Lake	4.8	3.88	1432	212
Lake Florida	4.6	3.45	1662	240
Lake Orienta	3.5	2.76	1719	285
Lake Adelaide	1.6	1.36	1677	270
Lake Lawne	11.0	8.27	1603	214
Silver Lake	2.6	2.18	1708	260
Bay Lake	0.9	0.65	1633	224

Bathtub calibration was conducted based on the above model inputs. **Table 5.4** shows model calibration results. Second order decay models were originally chosen to simulate TN and TP concentrations in these lakes. Second order mass balance models are commonly used for TN and TP concentrations in lakes. These models assume that the sedimentation coefficients of TN and TP are related to the second order of in-lake TN and TP concentrations (Walker 1999). For this TMDL report, the second order decay model predicted TN concentration reasonably well. The calibration factors applied for all lakes fell within the range recommended by the Bathtub model user manual (0.3 to 3.0). However, the TP concentrations could not be calibrated using the second order model unless calibration factors much higher than those recommended by the model manual (0.5 to 2.0) were applied. **Table 5.4** shows the model simulated TP concentrations assuming calibration factors equal to 1, model simulated TP concentrations after applying calibration factors, calibration factors used in the model calibration, and long-term average TP concentrations based on measured data.

Table 5.4. TP concentration simulated using the second order decay model and the calibration factors required for the calibration.

TP concentration unit: mg/L

Lakes	Simulated TP (no calibration)	Simulated TP (calibrated)	Calibration factor	Measured TP
Spring Lake	0.124	0.04	17.0	0.04
Lake Florida	0.164	0.05	25.0	0.05
Lake Orienta	0.142	0.05	21.0	0.05
Lake Adelaide	0.148	0.06	10.0	0.06
Lake Lawne	0.131	0.09	2.9	0.09
Silver Lake	0.096	0.03	14.0	0.03
Bay Lake	0.106	0.04	10.0	0.04

While the second order decay model overestimated the in-lake TP concentrations, the model simulated TP concentrations were not unreasonably high. The simulated TP concentrations ranged from 0.096 to 0.164 mg/L when the sedimentation calibration factor was assumed equal to 1. If the highest TP sedimentation calibration factor recommended by the Bathtub user manual was applied, simulated TP concentrations for these lakes ranged from 0.072 to 0.124 mg/L. In six out of seven lakes, simulated TP concentrations with recommended TP sedimentation factors were close to or less than 0.10 mg/L. It is not uncommon for central and south Florida lakes to have TP concentrations in the range of 0.07 to 0.12 mg/L. **Table 5.5** lists several lakes that have TP concentrations in this range. Watersheds of many of these lakes are less urbanized than the lakes covered in this TMDL report.

Table 5.5. Central and south Florida lakes that have TP concentration in the range of 0.06 – 0.16 mg/L

Lake	WBIDs	Period of Record	mean TP concentration (mg/L)
Lake Griffin	2814A	1996 -- 2006	0.08
Lake Carlton	2837B	1995 -- 2006	0.07
Newnans Lake	2705B	1994 -- 2006	0.18
Lake Dora	2831B	1995 -- 2006	0.08
Lake Apopka	2835D	1995 -- 2006	0.13
Lake Helen Blazes	2893Q	1993 -- 2004	0.15
Sawgrass Lake	28931	1993 -- 2004	0.11
Lake Poinsett	2893K	1993 -- 2004	0.09
Lake Istokpoga	1856B	1993 -- 2005	0.06
Huckleberry Lake	1893	1994 -- 2004	0.16
Lake Marian	3184	3184 -- 2005	0.16
Lake Jackson (Oceola County)	3183G	1994 -- 2005	0.11

Compared to the lakes listed in **Table 5.5**, lakes in the Wekiva Study Area showed significantly lower TP concentrations while the percent watershed areas of these lakes occupied by urban landuse are all above 50% and sometimes as high as 89% (**Table 4.2**). A possible reason for this observation could be that the urban lakes covered in this TMDL have relatively high TP sedimentation rates. The possible high sedimentation rate in these lakes could be caused by several factors:

(1) The water budgets of these lakes are not dominated by major inlets and outlets that have perennial flow. Flows into these lakes are mostly driven by rainfall events. Several of these lakes do not have outlets and major water output from these lakes, other than by evaporation, would be through ground water recharge. A direct consequence of this relatively isolated hydrology would be elevated sedimentation rate in these lakes because of the long water residency time.
(2) Major inlets to some lakes, such as several inlets into Lake Lawne, may be filled with aquatic plants,. These aquatic plants may enhance the sedimentation of particulate materials from the watershed and provide habitat for periphyton, which effectively take up phosphorus from stormwater runoff and results in low TP concentration in the input water to the lake.
(3) Littoral zone vegetation and in-lake aquatic plants can also contribute to the low TP concentration by reducing the water column turbulence and increase the phosphorus sedimentation rate, stabilize the lake sediment and reduce the sediment nutrient release, and provide habitat for periphyton and remove phosphorus directly from the water column (Gasith and Hoyer 1998, Haven 2003).
(4) High phosphorus loading into these lakes may cause elevated sedimentation rates because the high content of particulate materials in the urban runoff may absorb more free phosphorus in the water and cause it to settle out of the water column (Jones and Bachmann, 1978).

Considering the above possibilities that may elevate TP sedimentation rate in urban lakes, the Department used Bachmann and Canfield's TP lake general model (Bachmann and Canfield 1981) to simulate the in-lake TP concentration instead of the second order decay model. This model was built based on 704 lakes across the United States, including natural lakes and artificial lakes. The focus of Bachmann and Canfield's 1981 study was to build a reasonable relationship between lake sedimentation coefficients and watershed phosphorus loading. The observation that stimulated Bachmann and Canfield's study was that the most commonly used phosphorus model, while capable of reasonably estimating TP concentrations in natural lakes, overestimated TP concentrations in artificial lakes by 3 to 10 times (Jones and Bachmann 1976), which is similar to what we observed in this TMDL. By using sedimentation coefficients two orders of magnitude greater than those used for natural lakes, Jones and Bachmann (1978) were able to use the Vollenweider model to calculate summer phosphorus concentrations in artificial lakes.

In building the correlation between watershed phosphorus loading and in-lake phosphorus sedimentation rate, Bachmann and Canfield observed a puzzling phenomenon – a positive correlation between phosphorus sedimentation coefficients and hydraulic flushing rates. This observation is puzzling because it is difficult to envision how a greater hydraulic flushing rate could increase the loss of phosphorus to the sediments. One might expect that a higher hydraulic flushing rate would reduce the opportunity for phosphorus to be removed by sedimentation, rather than enhance it. One possible answer to this observation was suggested by Jones and Bachmann's study (Jones and Bachmann 1978), which suggested that allochthonous inorganic particulate materials brought in by tributary streams could act as scavengers to remove phosphorus to the sediments. This was supported by the positive correlation between TP loading and total suspended sediment concentrations observed in 301 rivers located throughout the United States (U.S. Geological Survey 1997). Observations from these studies may partially explain the low TP concentrations in lakes in the Wekiva Study Area.

A strong correlation between the sedimentation coefficient and the quotient between watershed TP loading and mean depths of lakes was observed in the Bachmann and Canfield study (1981), with an R^2 = 0.83. This sedimentation model, when combined with the Vollenweider model, has the smallest 95% confidence interval compared to other commonly used phosphorus models. The model simulated TP concentrations were 31 – 288% of measured TP concentrations with a 95% confidence level. To ensure that the Bachmann and Canfield model predicted TP concentrations for lakes covered in this TMDL report fall within the 95% confidence level of the model, the ratio between the model simulated TP concentration assuming calibration factor = 1 and the measured TP concentration was estimated and listed in **Table 5.6**.

Table 5.6. TP concentrations simulated using Bachmann and Canfield's Lake General model and measured TP concentration

TP concentration unit: mg/L

Lakes	Simulated TP (no calibration)	Measured TP	Ratio of simulated/measured
Lake Lawne	0.114	0.09	127%
Bay Lake	0.079	0.04	198%
Silver Lake	0.087	0.03	290%
Spring Lake	0.087	0.04	218%
Lake Florida	0.145	0.05	290%
Lake Orienta	0.106	0.05	212%
Lake Adelaide	0.132	0.06	220%

Except for Silver Lake and Lake Florida, ratios between simulated and measured TP concentrations fall within the 95% confidence interval of the Bachmann and Canfield model. Although the ratios for Silver Lake and Lake Florida are slightly beyond the upper boundary of the 95% confidence interval, they are only different from the upper boundary of the 95% interval by less than 1%. Considering the error inherited with the data measurements, this difference can be considered as insignificant. Therefore, it is reasonable to consider that the Bachmann and Canfield model simulates the TP concentration in lakes covered in this TMDL properly.

Because specific conditions of each lake may influence its TP concentration, calibration factors were applied to the sedimentation coefficient of the model. **Table 5.7** lists calibrated TP concentrations, measured TP concentration, and calibration factors used for the calibration. No range of calibration factors for TP is recommended for the Bachmann and Canfield model by the Bathtub manual. **Table 5.7** shows that the dimension of the calibration factor required for Bachmann and Canfield model are significantly lower than those required by the second order decay model (**Table 5.10**). **Table 5.7** also lists measured and model simulated TN and *Chl a* concentrations. Because the second order decay model predicts TN concentration reasonably well, the model was used for TN simulation and the applied calibration factors for TN follows the range recommended by the Bathtub manual (0.3 – 3.0). No range of calibration factor for *Chl a* is recommended by the Bathtub user manual.

Table 5.7. Long-term annual average TN, TP, and Chla concentrations estimated based on measured data and model simulated in-lake TN, TP, and Chla concentrations

Lake	TN (mg/L)			TP (mg/L)			Chla (ug/L)		
	Measured	Modeled	Calibration factor	Measured	Modeled	Calibration factor	Measured	Modeled	Calibration factor
Lake Lawne	1.45	1.42	0.30	0.09	0.09	1.5	35.4	34.0	0.9
Bay Lake	1.44	1.42	0.30	0.04	0.04	2.5	27.5	25.0	1.4
Silver Lake	0.68	0.67	1.9	0.03	0.03	3.7	14.3	13.0	1.4
Spring Lake	1.44	1.28	0.3	0.04	0.04	4.2	44.0	40.0	2.0
Lake Florida	0.91	0.93	3.0	0.05	0.05	5.7	22.2	19.0	1.0
Lake Orienta	1.16	1.15	1.0	0.05	0.05	2.8	46.9	43.0	2.1
Lake Adelaide	1.05	1.02	1.5	0.06	0.06	3.3	43.3	39.0	1.7

Based on **Table 5.7**, factors required for calibrating TN concentration all fell within the range recommended by the Bathtub user manual, suggesting that the second order decay model predicts the in-lake TN concentration reasonably well. This may result from the high solubility of nitrogen compounds in ambient water and therefore the sedimentation rate for TN is not significantly influenced by factors discussed above that may influence the TP sedimentation rate. Although no range of calibration factors was recommended for the Bachmann and Canfield TP model, the majority of calibration factors used for in-lake TP are less than 4.0. Compared to required calibration factors listed in **Table 5.4**, Bachmann and Canfield's TP model has a better predictive power than the second order decay model. Another observation is that a calibration factor higher than 1.0 is required to calibrate in-lake TP concentration for all the lakes, suggesting that factors resulting in high sedimentation coefficient may play important roles in the phosphorus dynamics in all these lakes.

Except for Lake Lawne and Lake Florida, calibration factors higher than 1.0 were needed to calibrate the Chl a concentration in all the other lakes, suggesting that the Chl a model underpredicts the actual Chl a concentration. At this time, no information is available to the Department to explain why this the model underpredicts chlorophyll a. There are studies indicating that some algal species may contain higher Chl a concentrations than other algal species (Phlips et al. 2004). Without algal taxonomy results from these lakes, it is impossible to examine this possibility. This can be an issue addressed by future studies.

Another possible explanation of why the Chl a model underpredicts the Chl a concentration is that the model includes light limitation components. This to some extent is correct for most lakes due to either the high water color or the phytoplankton self-shading effects. However, most of the lakes covered in this TMDL report have relatively low water color. Relatively low algal biomass in these lakes also makes the phytoplankton self-shading effect insignificant. Therefore, light limitation may not be an important factor controlling the actual algal biomass in these lakes. This may result in relatively higher Chl *a* concentration compared to lakes with similar nutrient concentrations, but with relatively higher color. One recommendation based on this possibility is that the nutrient assimilative capacity of low colored lakes is relatively low because of the small chance of light limitation. Therefore, control of nutrients into these lakes is more important than for lakes with higher water color.

5.1.1.5 Evaluating natural background TSI of project lakes.

Once the Bathtub model was calibrated, the background TN and TP loadings from drainage basins were estimated using the following procedures:

1. All the man-made land use categories (agriculture/golf course, commercial area, low, medium, and high density residential area, industrial/utility, and transportation facility) were evaluated as forest/rural open.
2. The loading from septic tanks was assumed zero.
3. No BMP facilities were assumed existing under the background condition.
4. Background TN and TP loadings from the watershed were then re-estimated using the WMM with the same long-term average annual rainfall (51 inches).
5. TN and TP loadings from the atmospheric deposition were kept the same as the existing condition.
6. Background in-lake TN and TP concentrations and Chl *a* concentration were estimated using Bathtub based on the background TN and TP loadings from lake drainage basins with all the Bathtub model parameters staying the same.
7. The background TSI was calculated based on Bathtub predicted background TP, TN, and Chl *a* concentrations.

Table 5.8 lists the surface runoff + baseflow, TN and TP loadings, and TN and TP concentrations of the surface runoff + baseflow for project lakes under background conditions. **Table 5.9** lists the in-lake TN, TP, and Chl *a* concentrations and TSI under background conditions.

5.1.1.6. Evaluating target TSI, target TN, TP, and Chla concentrations, and target TN and TP loadings into project lakes

As described previously, the target TSIs for lakes covered in this TMDL (**Table 5.10**) were established as 5 TSI units above background TSIs. To achieve these target TSIs, TN and TP loadings from watersheds were reduced until the Bathtub simulated TSIs reached target TSIs. Theoretically, target TSIs can be achieved by either reducing the watershed TP, or TN, or both TP and TN. Based on TN/TP ratios of these lakes (**Table 2.1** and **2.2)**, phytoplankton communities in Bay Lake and Spring Lake are phosphorus limited and those of the remaining lakes are phosphorus and nitrogen co-limited. However, compared to other lakes, the high TN/TP ratios (greater than 30) for Bay Lake and Spring Lake occurred because of higher TN concentrations in these lakes. Therefore, instead of only requiring reducing TP loadings for these two lakes, reduction of TN and TP loadings were both required, as were required for all the other lakes covered in this TMDL.

Table 5.8. Surface runoff + baseflow, TN and TP loadings, and TN and TP concentrations of the surface runoff into project lakes under the background condition

Lake	Surface Runoff + baseflow (hm3/year)	TN load (lbs/year)	TP load (lbs/year)	TN Concentration (ppb)	TP Concentration (ppb)
Spring Lake	2.01	4522	290	1021	66
Lake Florida	1.88	4147	281	999	68
Lake Orienta	1.40	3219	187	1040	61
Lake Adelaide	0.66	1561	104	1065	71
Lake Lawne	4.71	11063	779	1066	75
Silver Lake	2.34	4326	263	837	51
Bay Lake	0.33	734	38	1019	52

Table 5.9. Background in-lake TN, TP, and Chl *a* concentrations and TSI

Lake	Background TN concentration (ppb)	Background TP concentration (ppb)	Background *Chl a* concentration (ppb)	TSI
Spring Lake	993	16	16	49
Lake Florida	563	18	6	44
Lake Orienta	844	17	14	49
Lake Adelaide	674	21	13	51
Lake Lawne	1005	37	17	55
Silver Lake	397	13	5	38
Bay Lake	1077	15	8	43

In simulating TN and TP loadings allowable by TSI targets, the hydrology of watersheds was kept at the existing condition. Loading reduction was achieved through reducing TN and TP concentrations of the Bathtub tributary input. In reducing the TN and TP tributary concentrations, existing TN and TP concentrations were compared to the background TN and TP concentration. The same percent reduction was applied to the differences between the existing and background TN and TP concentrations until target TSIs were achieved. The resulting TN and TP loadings were considered TMDLs for these lakes. **Table 5.10** also lists the in-lake TN, TP, and Chl *a* concentrations when target TSIs were achieved for these lakes using the processes described above.

Based on **Table 5.10**, the target TSIs for the seven project lakes range from 40 to 60. Lake Lawne has the highest target TSI, which is 60. Part of the reason for the high TSI target for that lake is because of the high percent wetland areas in the watershed (about 17% of the watershed area). Wetlands have relative high nutrient EMCs. Another lake, Lake Adelaide, also has a relatively high percent wetland area in the watershed (about 14%). As would be expected, this lake has the second highest target TSI, which is 56. Silver Lake has the lowest TSI target. This may be caused by the relatively large mean depth of this lake. As shown in **Table 5.8**, while most of the other lakes have a mean depth about 2 meters, Silver Lake has a mean depth of about 5 meters. High mean depth means that the lake sediment is less likely to be disturbed by wind action. Therefore the internal nutrient loading through sediment re-suspension would be low and the net sedimentation rate, which is a very important factor influencing the in-lake nutrient concentration, would be relatively low, and so will be the overall lake TSI.

Table 5.10. Target in-lake TN, TP, and Chl *a* concentrations and TSIs

Lake	Target TN concentration (ppb)	Target TP concentration (ppb)	Target Chl *a* concentration (ppb)	TSI
Spring Lake	959	21	21	54
Lake Florida	699	23	9	49
Lake Orienta	814	22	19	54
Lake Adelaide	711	27	17	56
Lake Lawne	1107	55	23	60
Silver Lake	575	15	8	43
Bay Lake	1108	19	10	48

Table 5.11 lists existing loadings, TMDLs, and required percent load reduction to achieve the target TSI for each of the seven lakes.

Table 5.11. Existing TN and TP loadings, TN and TP TMDLs, and percent load reduction required to achieve TSI targets for the seven lakes

Lake	TN loadings (lbs/year)			TP loadings (lbs/year)		
	Existing	TMDL	Percent Reduction	Existing	TMDL	Percent Reduction
Spring Lake	12248	8551	30%	1810	641	65%
Lake Florida	12656	8377	34%	1829	571	69%
Lake Orienta	10473	6092	42%	1736	451	74%
Lake Adelaide	5035	3003	40%	812	228	72%
Lake Lawne	29209	21692	26%	3903	2005	49%
Silver Lake	8198	6241	24%	1250	370	70%
Bay Lake	2332	1428	39%	320	109	66%

The overall percent reduction for TN required to achieve the water quality target ranges from 24% to 42%. The lowest required percent loading reduction is for Silver Lake, which is about 24%. The highest required percent reduction for TN is for Lake Orienta and Lake Adelaide. The required percent reductions for TP ranges from 49% to 74%. The lowest required percent reduction was for Lake Lawne, which is about 49%. This may be related to the high background TP concentration and in turn the target TP concentration established for the lake (**Table 5.6** and **5.7**). Among all the lakes covered in this TMDL report, Lake Lawne has the highest background TP concentration (0.037 mg/L) and therefore the highest target TP concentration (0.055 mg/L). The high background TP concentration may be related to the morphology of the lake. Lake Lawne has the largest lake surface area among all the lakes (**Table 5.2**), which is about 156 acres. Larger lake surface area could cause more wind induced mixing, which could reduce the overall TP sedimentation rate.

The only other lake that has a surface area similar to Lake Lawne is Lake Orienta. The surface area of this lake is 141 acres. However, the watershed area of Lake Orienta is only about one third of that of Lake Lawne. This could make the hydrological flushing in Lake Lawne significantly higher than in Lake Orienta, which again, makes the TP sedimentation rate in Lake Lawne relatively low. This is consistent with the observation that, when calibrating the Bathtub model, the lowest calibration factor is required for Lake Lawne, suggesting a relatively lower sedimentation coefficient in this lake, compared to the other lakes covered in this TMDL. In addition, the highest percent wetland areas existing in the watershed of Lake Lawne may contribute to the high target TP concentration, because the EMC for TP in wetlands is typically higher than the TP EMC of Forest/Rural Open landuse.

The percent TP reduction required to achieve the target TSI is relative similar in lakes other than Lake Lawne, ranging from 65% to 74%.

Chapter 6: DETERMINATION OF THE TMDL

6.1 Expression and Allocation of the TMDL

The objective of a TMDL is to provide a basis for allocating acceptable loads among all of 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 takes into account any uncertainty concerning the relationship between effluent limitations and water quality:

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

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

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

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 within the LA, and (2) TMDL components can be expressed in different terms (for example, the WLA for stormwater is typically expressed as a percent reduction, and the WLA for wastewater is typically expressed as mass per day).

WLAs for stormwater discharges are typically expressed as percent reduction because it is very difficult to quantify the loads from MS4s (given the numerous discharge points) and to distinguish the 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 BMPs.

This approach is consistent with federal regulations (40 CFR § 130.2[I]), which state that TMDLs can be expressed in terms of mass per time (e.g., pounds per day), toxicity, or **other appropriate measure**. TMDLs for the seven nutrient impaired lakes in the drainage basin of Wekiva Study Area are expressed in terms of maximum allowable loads and percent reduction of TN and TP, and represent the maximum long-term TN and TP loadings these lakes can assimilate and maintain a balanced aquatic flora and fauna **(Table 6.1).** Based on the recommendation from the United States Environmental Protection Agency (USEPA), TMDLs are also presented in **Table 6.1** as lbs/day. The daily loads are calculated by dividing the total annual loads by 365 days. These daily loads are only used for presentation purpose. The implementation time scale for these TMDLs should be annual average because all the nutrients discharged into the lakes covered in this TMDL report are from non-point sources, which is primarily driven by weather conditions and cannot be controlled on a daily basis.

Table 6.1. TMDL components for TN and TP loadings into the seven lakes

WBID	Parameter	TMDL (lbs/day)	$WLA_{NPDES\ wastewater}$	$WLA_{NPDES\ Stormwater}$	LA	MOS
Spring Lake (2987A)	TN	23.4	N/A	30%	30%	Implicit
	TP	1.8	N/A	65%	65%	Implicit
Lake Florida (2998A)	TN	23.0	N/A	34%	34%	Implicit
	TP	1.6	N/A	69%	69%	Implicit
Lake Orienta (2998C)	TN	16.7	N/A	42%	42%	Implicit
	TP	1.2	N/A	74%	74%	Implicit
Lake Adelaide (2998E)	TN	8.2	N/A	40%	40%	Implicit
	TP	0.6	N/A	72%	72%	Implicit
Lake Lawne (3004C)	TN	59.4	N/A	26%	26%	Implicit
	TP	5.5	N/A	49%	49%	Implicit
Silver Lake (3004D)	TN	17.1	N/A	24%	24%	Implicit
	TP	1.0	N/A	70%	70%	Implicit
Bay Lake (3004G)	TN	3.9	N/A	39%	39%	Implicit
	TP	0.3	N/A	66%	66%	Implicit

N/A in this table means not applicable.

6.2 Load Allocation

Because there are no wastewater point sources that discharge directly into any of the lakes covered in this report, the TMDLs for TN and TP were assigned to the LA (and, as discussed below, to the MS4 as well). The long-term daily average LAs for TN into Lake lawne, Bay Lake, Silver Lake, Spring Lake, Lake Florida, Lake Orienta, and Lake Adelaide are 59.4, 3.9, 17.1, 23.4, 23.0, 16.7, and 8.2 lbs/day, respectively. In comparison, the current long-term daily average TN loads for these lakes are 80.0, 6.4, 22.5, 33.6, 34.7, 28.7, and 13.8 lbs/day, respectively. These numbers include loadings from surface runoff, baseflow, and failed septic tanks after subtracting the loadings removed by various BMPs. To achieve the target TSI for each of these lakes, TN loadings need to be reduced by about 26%, 39%, 24% 30%, 34%, 42%, and 40% for Lake Lawne, Bay Lake, Silver Lake, Spring Lake, Lake Florida, Lake Orienta, and Lake Adelaide, respectively.

The long-term daily average LAs for TP into Lake lawne, Bay Lake, Silver Lake Spring Lake, Lake Florida, Lake Orienta, and Lake Adelaide are 5.5, 0.3, 1.0, 1.8, 1.6, 1.2, and 0.6 lbs/day, respectively. In comparison, the current long-term daily average TP loads for these lakes are 10.7, 0.9, 3.4, 5.0, 5.0, 4.8, and 2.2 lbs/day, respectively. Again, these figures include the loadings from surface runoff, baseflow, and failed septic tanks after subtracting the loadings removed by various BMPs. To achieve the target TSI for each of these lakes, TP loadings need to be reduced by about 49%, 66%, 70%, 65%, 69%, 74%, and 72% for Lake Lawne, Bay Lake, Silver Lake, Spring Lake, Lake Florida, Lake Orienta, and Lake Adelaide, respectively.

The Lake Lawne, Bay Lake, and Silver Lake watersheds are part of the contributing watershed that drains to the Little Wekiva Canal. The Department has developed separate TMDLs to address the nutrient and DO conditions of Little Wekiva Canal (Bailey, 2007). There is no TP reduction requirement in those TMDLs. The required percent reduction for TN to protect the nutrient and DO conditions of Little Wekiva Canal is 45%. This TN load reduction requirement is more conservative than the 26%, 24%, and 39% reduction required to protect Lake Lawne, Bay Lake, and Silver Lake. Therefore, in developing a TMDL implementation plan for the entire drainage basin of Little Wekiva Canal, 45% reduction of TN should be adopted.

6.3 Wasteload Allocation

6.3.1 National Pollutant Discharge Elimination System Wastewater Discharges

No NPDES-permitted wastewater discharges were identified as discharging to any of the lakes covered in this TMDL, and as such the WLA for wastewater is not applicable.

6.3.2 National Pollutant Discharge Elimination System Stormwater Discharges

Because no information was available to the Department at the time this analysis was conducted regarding the boundaries and locations of all the NPDES stormwater dischargers, the exact stormwater TN and TP loadings from MS4 areas were not explicitly estimated. Within the drainage basins of Lake Lawne and Bay Lake, Orange County has a Phase I MS4 permit (FLS000011). The Florida Department of Transportation (FDOT) District 5 and City of Maitland are co-permittees for this permit. In addition, City of Orlando holds a separate Phase I permit (FLS000014). For drainage areas of the other lakes, including Silver Lake, Lake Florida, Lake Orienta, and Lake Adalaide, Seminole County holds a MS4 Phase I permit (FLS000038) with FDOT District 5 and the City of Altamonte Springs being co-permittees for this permit. Percent TN and TP reduction required for all the MS4 permit holders are the same as the LA assigned to the nonpoint sources related to the watershed that discharge into each of the lakes covered in this report. The required percent reduction for TN for Lake Lawne, Silver Lake, and Bay Lake should 45% to protect the nutrient and DO conditions of the downstream Little Wekiva Canal.

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

6.4 Margin of Safety

Consistent with the recommendations of the Allocation Technical Advisory Committee (FDEP, February 2001), an implicit MOS was used in the development of this TMDL. An implicit MOS was provided by the conservative decisions associated with a number of modeling assumptions, the development of site-specific alternative water quality targets, and the development of assimilative capacity.

In this analysis, the MOS was created in several aspects of the analyses. For example, in simulating the TN and TP loadings from lake watersheds using the WMM, it was assumed that retention of TN and TP within the watershed is insignificant. This assumption tends to overestimate the existing nutrient contribution from the watershed and therefore adds to the MOS when calculating the percent load reduction required to achieve the water quality targets. In addition, when simulating the background condition, due to the lack of pre-development landuse information, it was assumed that all the existing human landuses are from the Forest and Rural Open landuse, which has relatively low nutrient event mean concentrations. This approach tends to underestimate the background nutrient loadings from the watershed under background condition because wetland, a natural landuse typically having higher nutrient event mean concentrations were not considered under the background condition. This approach tends to underestimate target TN and TP concentrations and also adds to the MOS.

6.5 Recommendations for Further Studies

As it was discussed in Chapter 5, the Bathtub model overestimated in-lake TP concentrations. Relatively high calibration factors had to be used to increase TP sedimentation coefficients in these lakes. The major assumption applied in this TMDL was that the observed difference between model simulated and measured results might result from the high TP sedimentation rates inherently associated with the hydrology, morphology, and biology of the lakes covered in this TMDL. Several factors that may cause elevated TP sedimentation rate include:

(1) The water budget of these lakes are not dominated by major inlets and outlets that show perennial flow. Flows into these lakes are mostly driven by rainfall events. Several of these lakes do not have outlets, and major water output from these lakes, other than evaporation, would be through the ground water recharge. A direct consequence of this relatively isolated hydrology would be elevated sedimentation rate in these lakes because of the long water residency time.
(2) Major inlets to some lakes are filled with aquatic plants, such as several inlets into Lake Lawne. These aquatic plants may provide habitats for periphyton, which effectively take up phosphorus from the stormwater and results in low TP concentration in the input water to the lake.
(3) Littoral zone vegetation and in-lake aquatic plants can also contribute to the low TP concentration by reducing the water column turbulence and therefore increase the phosphorus sedimentation rate, stabilize the lake sediment and therefore reduce the sediment nutrient release, and provide habitat for periphyton and remove phosphorus directly from the water column.
(4) High phosphorus loading into these lakes itself may cause elevated sedimentation rate because the high content of particulate materials in the urban runoff may absorb more free phosphorus in the water and cause it to settle out of the water column (Jones and Bachmann, 1978).

To confirmed the assumption used in developing this TMDL, the Department recommends that further studies be conducted to determine the actual TP sedimentation rates in these lakes and factors that may influence the TP sedimentation rates.

Another observation for this TMDL is that all the eutrophication models in the Bathtub model suite tends to underestimate the measured *Chl a* concentrations. The assumption made by this study is that majority of the lakes in this area are clear water lakes in which light limitation is insignificant. Therefore, the same amount of nutrients may support larger amounts of algal biomass. In addition, some algal species may have higher Chl a content than others. Further studies would be needed to confirm whether this is applicable to lakes covered in this TMDL report.

Chapter 7: NEXT STEPS: IMPLEMENTATION PLAN DEVELOPMENT AND BEYOND

7.1 Basin Management Action Plan

Following the adoption of this TMDL by rule, the next step in the TMDL process is to develop an implementation plan for the TMDL, referred to as the BMAP. This document will be developed over the next two years in cooperation with local stakeholders, who will attempt to reach consensus on detailed allocations and on how load reductions will be accomplished. The BMAP will include, among other things:

- Appropriate load reduction allocations among the affected parties,
- A description of the load reduction activities to be undertaken, including structural projects, nonstructural BMPs, and public education and outreach,
- A description of further research, data collection, or source identification needed in order to achieve the TMDL,
- Timetables for implementation,
- Confirmed and potential funding mechanisms,
- Any applicable signed agreement(s),
- Local ordinances defining actions to be taken or prohibited,
- Any applicable local water quality standards, permits, or load limitation agreements,
- Milestones for implementation and water quality improvement, and
- Implementation tracking, water quality monitoring, and follow-up measures.

An assessment of progress toward the BMAP milestones will be conducted every five years, and revisions to the plan will be made as appropriate, in cooperation with basin stakeholders.

References

Canfield, D. E. Jr., and R. W. Bachmann. 1981. Prediction of total phosphorus concentrations, chlorophyll a, and Secchi depths in natural and artifical lakes. Can. J. Fish. Aquat. Sci. 38: 414-423.

CDM. 1994. City of Jacksonville Master Stormwater Management Plan Methodology Volume Final Report.

CDM, 2005. Little Wekiva River watershed management plan (draft report). Prepared for the St. Johns River Water Management District in cooperation with Orange County, Seminole County, the City of Orlando and the City of Altamonte Springs.

Griffith, G. E., D. E. Canfield, Jr. C. A. Horsburgh, J. M. Omernik. 1997. Lake Region of Florida. Western Ecology Division, National Health and Environmental Effects Research Laboratory Office of Research and Development, U. S. Environmental Protection Agency.

Florida Administrative Code. *Chapter 62-302, Surface water quality standards.*

Florida Administrative Code. *Chapter 62-303, Identification of impaired surface waters*.

Florida Watershed Restoration Act. *Chapter 99-223, Laws of Florida.*

Florida Department of Environmental Protection. February 1, 2001. *A report to the governor and the legislature on the allocation of total maximum daily loads in Florida.* Tallahassee, Florida: Bureau of Watershed Management, Division of Water Resource Management. Available: http://www.dep.state.fl.us/water/tmdl/docs/Allocation.pdf.

Gasith, A. and M.V. Hoyer. 1998. Structuring role of macrophytes in lakes:changing influence along lake size and edpth gradients. *In*: pp. 381-292.Jeppesen, E., M. Sondergaard, M. Sondergaard and K. Christoffersen Eds. The structuring role of submerged macrophytes in lakes. Springer

Harper, H. H. and D. B. Baker. 2003. Evaluation of alternative stormwater regulations for southwest Florida. Submitted to: Water Enhancement & Restoration Coalition, Inc. Prepared by Environmental Research & Design, Inc.

Havens, K. E. 2003. Submerged aquatic vegetation correlations with depth and light attenuating materials in a shallow subtropical lake. Hydrobiologia 493: 173-186.

Jones, J. R., and R. W. Bachmann. 1976. Prediction of phosphorus and chlorophyll levels in lakes. J. Water Pollut. Contr. Fed. 48: 2176-2182.

Jones, J. R., and R. W. Bachmann. 1978. Phosphorus removal by sedimentation in some Iowa reservoirs. Verh. Int. Ver. Theoret. Angew. Limnol. 20: 1576-1580.

Phlips, E. J., J. Frost, N. Yilmaz, M. Cichra. 2004. *Factors controlling the abundance and composition of blue-green algae in Lake Griffin.* Final Report to the St. Johns River Water Management District. Project # SF669AA.

U. S. Environmental Protection Agency. 1986. Forecasting Onsite Soil Adsorption System Failure Rates.

U. S. Geological Survey. 1997. Quality of rivers of he United States, 1975 water year – based on the National stream Quality Accounting Network (NASQAN). Open-file Rep. 78-200: 436 p.

User's Manual: Watershed management model, Version 4.1 1998. Rouge River national wet weather demonstration project. Wayne County, Michigan. PRO-NPS-TM27.02.

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

Wekiva Parkway and Protection Act. 2004. Chapter 369, Part III, Florida Statutes

WSI Inc. 2004. Work Plan. Pollutant load reduction goal (PLRG) analysis for the Wekiva River and Rock Springs Run, Florida. Report prepared for the St. Johns river Water management District, Palatka, FL. Pp. variously numbered.

WSI, 2005. Pollutant load reduction goal (PLRG) analysis for the wekiva River and Rock Springs Run, Florida. Final Report. Prepared for the St. Johns River Water Management District. Wetland Solutions, Inc.

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 that are designed to achieve a specific level of treatment (i.e., performance standards) as set forth in Chapter 62-40, F.A.C. In 1994, the Department's stormwater treatment requirements were integrated with the stormwater flood control requirements of the state's water management districts, along with wetland protection requirements, into the Environmental Resource Permit regulations.

Chapter 62-40, F.A.C., also requires the water management districts to establish stormwater pollutant load reduction goals (PLRGs) and adopt them as part of a SWIM plan, other watershed plan, or rule. Stormwater PLRGs are a major component of the load allocation part of a TMDL. To date, stormwater PLRGs have been established for Tampa Bay, Lake Thonotosassa, the Winter Haven Chain of Lakes, the Everglades, Lake Okeechobee, and Lake Apopka. No PLRG had been developed for Newnans Lake when this report was published.

In 1987, the U.S. Congress established Section 402(p) as part of the federal Clean Water Act 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. These stormwater discharges include certain discharges that are associated with industrial activities designated by specific standard industrial classification (SIC) codes, construction sites disturbing 5 or more acres of land, and master drainage systems of local governments with a population above 100,000, which are better known as municipal separate storm sewer systems (MS4s). However, because the master drainage systems of most local governments in Florida are interconnected, the EPA implemented Phase I of the MS4 permitting program on a countywide basis, which brought in all cities (incorporated areas), Chapter 298 urban water control districts, and the Florida Department of Transportation throughout the 15 counties meeting the population criteria. The Department received authorization to implement the NPDES stormwater program in 2000.

An important difference between the federal NPDES and the state's stormwater/environmental resource permitting programs is that the NPDES Program covers both new and existing discharges, while the state's program focuses on new discharges only. Additionally, Phase II of the NPDES Program, implemented in 2003, expands the need for these permits to construction sites between 1 and 5 acres, and to local governments with as few as 1,000 people. While these urban stormwater discharges are now 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 all MS4 permits issued in

Florida include a re-opener clause that allows permit revisions to implement TMDLs when the implementation plan is formally adopted.

Appendix B: Historic TN, TP, and Chl a concentrations and TSI of the seven lakes covered in this TMDL report.

Table B-1. Historic TN, TP, and Chl *a* concentrations and TSI of Silver Lake

Year	Quarter	TN (mg/L)	TP (mg/L)	Chla (µg/L)	TSI
1996	1st Quarter	0.63	0.026	14.1	49.7
	2nd Quarter	0.81	0.033	25.0	56.1
	3rd Quarter	0.80	0.021	23.4	54.9
	4th Quarter	0.79	0.031	15.0	52.0
	Annual Mean	**0.76**	**0.027**	**19.4**	**53.2**
1997	1st Quarter	0.71	0.028	14.2	50.7
	2nd Quarter	0.52	0.009	12.2	40.4
	3rd Quarter	0.51	0.020	26.2	52.0
	4th Quarter	0.82	0.048	33.4	60.1
	Annual Mean	**0.64**	**0.026**	**21.5**	**50.8**
1998	1st Quarter	0.33	0.049	31.6	51.1
	2nd Quarter	0.90	0.088	41.6	64.9
	3rd Quarter	0.27	0.012	15.4	42.6
	4th Quarter	0.55	0.013	13.8	45.2
	Annual Mean	**0.51**	**0.040**	**25.6**	**50.9**
1999	1st Quarter	0.61	0.008	10.0	37.9
	2nd Quarter	0.45	0.014	8.8	43.5
	3rd Quarter	0.50	0.016	9.2	45.2
	4th Quarter	0.54	0.017	12.7	48.2
	Annual Mean	**0.53**	**0.014**	**10.2**	**43.7**
2000	1st Quarter	0.62	0.016	9.7	45.5
	2nd Quarter	0.57	0.011	5.6	37.2
	3rd Quarter	0.68	0.030	12.9	50.1
	4th Quarter	0.77	0.010	13.4	41.7
	Annual Mean	**0.66**	**0.017**	**10.4**	**43.6**
2001	1st Quarter	0.74	0.018	12.7	48.9
	2nd Quarter	0.60	0.020	----	----
	3rd Quarter	0.57	0.010	----	----
	4th Quarter	0.50	0.016	9.3	45.3
	Annual Mean	**0.60**	**0.016**	**11.0**	----
2002	1st Quarter	0.83	0.031	12.7	51.1
	2nd Quarter	0.52	0.060	11.7	48.9
	3rd Quarter	0.74	0.023	----	----
	4th Quarter	1.02	0.030	18.1	57.5
	Annual Mean	**0.78**	**0.036**	**14.2**	----
2003	1st Quarter	0.97	0.026	11.1	52.3
	2nd Quarter	0.86	0.053	3.3	44.1
	3rd Quarter	----	0.013	3.0	----
	4th Quarter	0.65	0.017	8.6	45.4
	Annual Mean	**0.83**	**0.027**	**6.5**	----
2004	1st Quarter	0.70	0.018	7.7	45.3
	2nd Quarter	0.68	0.032	4.9	43.4
	3rd Quarter	1.06	0.032	25.8	60.8
	4th Quarter	----	----	----	----
	Annual Mean	**0.81**	**0.027**	**12.8**	----
2005	1st Quarter	----	----	----	----
	2nd Quarter	----	----	----	----
	3rd Quarter	----	----	----	----
	4th Quarter	----	----	----	----
	Annual Mean	**----**	**----**	**----**	----
2006	1st Quarter	----	----	----	----
	2nd Quarter	----	----	----	----
	3rd Quarter	----	----	----	----
	4th Quarter	----	----	----	----
	Annual Mean	----	----	----	----
Long-term Mean		**0.68**	**0.03**	**14.3**	**48.4**

Table B-2. Historic TN, TP, and Chla concentrations and TSI of Lake Florida

Year	Quarter	TN (mg/L)	TP (mg/L)	Chla (µg/L)	TSI
1996	1st Quarter	1.15	0.06	43.0	64.6
	2nd Quarter	0.64	0.04	12.2	51.0
	3rd Quarter	0.65	0.05	17.0	54.2
	4th Quarter	0.77	0.09	20.8	57.2
	Annual Mean	**0.80**	**0.06**	**23.26**	**56.8**
1997	1st Quarter	0.80	0.10	11.9	53.6
	2nd Quarter	0.77	0.05	18.8	55.9
	3rd Quarter	0.73	0.04	16.2	52.8
	4th Quarter	0.77	0.05	12.0	52.7
	Annual Mean	**0.76**	**0.06**	**14.71**	**53.7**
1998	1st Quarter	0.70	0.05	15.3	53.6
	2nd Quarter	0.74	0.04	14.4	52.3
	3rd Quarter	0.67	0.03	13.7	49.9
	4th Quarter	0.73	0.03	22.0	54.9
	Annual Mean	**0.71**	**0.04**	**16.36**	**52.7**
1999	1st Quarter	0.91	0.04	17.1	55.1
	2nd Quarter	0.75	0.03	10.8	49.1
	3rd Quarter	0.73	0.03	10.4	48.5
	4th Quarter	0.99	0.06	6.3	50.4
	Annual Mean	**0.85**	**0.04**	**11.17**	**50.8**
2000	1st Quarter	1.12	0.04	23.7	58.7
	2nd Quarter	0.91	0.03	10.0	50.3
	3rd Quarter	0.79	0.03	7.9	50.0
	4th Quarter	0.82	0.03	5.2	44.4
	Annual Mean	**0.91**	**0.03**	**11.69**	**50.8**
2001	1st Quarter	0.85	0.03	7.4	47.9
	2nd Quarter	0.83	0.04	3.7	42.8
	3rd Quarter	0.91	0.04	4.2	44.1
	4th Quarter	1.17	0.11	7.3	54.9
	Annual Mean	**0.94**	**0.05**	**5.63**	**47.4**
2002	1st Quarter	1.05	0.07	20.2	59.3
	2nd Quarter	1.10	0.04	18.9	59.7
	3rd Quarter	1.05	0.05	33.1	61.4
	4th Quarter	1.30	0.08	41.6	66.1
	Annual Mean	**1.12**	**0.06**	**28.44**	**61.7**
2003	1st Quarter	0.70	0.05	10.3	51.1
	2nd Quarter	1.10	0.07	57.3	66.9
	3rd Quarter	1.46	0.05	64.1	68.1
	4th Quarter	1.09	0.06	47.6	65.1
	Annual Mean	**1.09**	**0.06**	**44.83**	**62.8**
2004	1st Quarter	0.96	0.06	54.9	65.6
	2nd Quarter	0.80	0.03	18.2	53.9
	3rd Quarter	0.90	0.06	17.9	56.9
	4th Quarter	1.06	0.09	14.9	58.4
	Annual Mean	**0.93**	**0.06**	**26.47**	**58.7**
2005	1st Quarter	1.24	0.07	82.7	70.2
	2nd Quarter	0.92	0.04	19.3	56.0
	3rd Quarter	0.94	0.06	21.7	58.6
	4th Quarter	0.90	0.06	32.5	61.5
	Annual Mean	**1.00**	**0.06**	**39.05**	**61.5**
Long-term Mean		**0.91**	**0.05**	**22.2**	**55.7**

Table B-3. Historic TN, TP, and Chla concentrations and TSI of Lake Orienta

Year	Quarter	TN (mg/L)	TP (mg/L)	Chla (µg/L)	TSI
1996	1st Quarter	0.69	0.04	26.8	57.0
	2nd Quarter	1.33	0.04	31.8	64.9
	3rd Quarter	0.85	0.03	21.1	55.2
	4th Quarter	0.96	0.04	64.8	65.3
	Annual Mean	**0.95**	**0.04**	**36.1**	**60.6**
1997	1st Quarter	0.83	0.05	45.0	62.6
	2nd Quarter	----	----	----	----
	3rd Quarter	----	----	----	----
	4th Quarter	1.51	0.05	76.7	69.6
	Annual Mean	**1.17**	**0.05**	**60.8**	----
1998	1st Quarter	----	----	----	----
	2nd Quarter	----	----	----	----
	3rd Quarter	1.10	0.04	38.4	64.8
	4th Quarter	1.13	0.04	50.7	67.0
	Annual Mean	**1.11**	**0.04**	**44.5**	----
1999	1st Quarter	1.44	0.05	67.4	68.4
	2nd Quarter	2.11	0.05	94.5	76.5
	3rd Quarter	1.53	0.04	63.6	69.6
	4th Quarter	1.33	0.05	65.1	67.0
	Annual Mean	**1.60**	**0.05**	**72.7**	**70.4**
2000	1st Quarter	1.19	0.04	43.4	63.3
	2nd Quarter	1.73	0.04	72.2	72.1
	3rd Quarter	1.62	0.04	67.4	70.0
	4th Quarter	1.71	0.06	82.0	71.1
	Annual Mean	**1.56**	**0.05**	**66.3**	**69.1**
2001	1st Quarter	1.75	0.07	80.1	72.1
	2nd Quarter	1.87	0.06	88.0	77.3
	3rd Quarter	1.23	0.04	47.1	67.2
	4th Quarter	1.01	0.04	43.3	62.1
	Annual Mean	**1.46**	**0.05**	**64.6**	**69.7**
2002	1st Quarter	1.06	0.04	36.5	61.1
	2nd Quarter	1.31	0.04	47.1	67.7
	3rd Quarter	0.97	0.03	32.2	61.7
	4th Quarter	0.92	0.03	35.3	59.5
	Annual Mean	**1.07**	**0.04**	**37.8**	**62.5**
2003	1st Quarter	0.90	0.04	36.2	59.8
	2nd Quarter	1.18	0.03	37.9	62.8
	3rd Quarter	0.86	0.03	29.1	59.4
	4th Quarter	0.86	0.03	33.1	58.2
	Annual Mean	**0.95**	**0.03**	**34.1**	**60.0**
2004	1st Quarter	0.93	0.03	33.9	59.2
	2nd Quarter	1.25	0.03	35.6	63.2
	3rd Quarter	0.95	0.03	28.0	61.1
	4th Quarter	0.91	0.03	34.4	58.9
	Annual Mean	**1.01**	**0.03**	**33.0**	**60.6**
2005	1st Quarter	0.72	0.03	30.7	57.0
	2nd Quarter	1.18	0.04	50.0	66.7
	3rd Quarter	0.86	0.03	31.4	59.6
	4th Quarter	0.94	0.03	42.0	60.9
	Annual Mean	**0.92**	**0.03**	**38.5**	**61.0**
Long-term Mean		**1.16**	**0.04**	**46.9**	**63.8**

Table B-4. Historic TN, TP, and Chla concentrations and TSI of Lake Adelaide

Year	Quarter	TN (mg/L)	TP (mg/L)	Chla (µg/L)	TSI
1996	1st Quarter	----	----	----	----
	2nd Quarter	----	----	----	----
	3rd Quarter	0.72	0.05	25.7	57.9
	4th Quarter	0.62	0.05	16.7	53.6
	Annual Mean	**0.67**	**0.05**	**21.2**	----
1997	1st Quarter	----	----	----	----
	2nd Quarter	----	----	----	----
	3rd Quarter	----	----	----	----
	4th Quarter	----	----	----	----
	Annual Mean	----	----	----	----
1998	1st Quarter	----	----	----	----
	2nd Quarter	----	----	----	----
	3rd Quarter	1.09	0.05	40.7	62.7
	4th Quarter	0.99	0.04	26.1	58.1
	Annual Mean	**1.04**	**0.04**	**33.4**	----
1999	1st Quarter	0.87	0.04	20.0	56.0
	2nd Quarter	1.41	0.04	36.5	65.5
	3rd Quarter	1.05	0.04	41.1	61.7
	4th Quarter	1.06	0.04	11.3	53.2
	Annual Mean	**1.10**	**0.04**	**27.2**	**59.1**
2000	1st Quarter	1.32	0.08	89.6	72.1
	2nd Quarter	0.86	0.04	22.6	56.7
	3rd Quarter	0.63	0.03	11.4	48.6
	4th Quarter	0.90	0.04	23.6	57.5
	Annual Mean	**0.93**	**0.05**	**36.8**	**58.7**
2001	1st Quarter	1.08	0.05	26.0	60.2
	2nd Quarter	1.21	0.05	35.3	62.3
	3rd Quarter	1.21	0.05	42.9	63.5
	4th Quarter	1.12	0.06	34.8	62.7
	Annual Mean	**1.16**	**0.05**	**34.8**	**62.2**
2002	1st Quarter	0.86	0.05	16.1	54.9
	2nd Quarter	1.05	0.05	21.0	58.0
	3rd Quarter	0.95	0.06	31.0	61.3
	4th Quarter	1.19	0.05	40.6	63.6
	Annual Mean	**1.01**	**0.05**	**27.2**	**59.5**
2003	1st Quarter	1.13	0.11	201.0	78.4
	2nd Quarter	1.40	0.09	131.0	75.5
	3rd Quarter	1.41	0.06	80.6	70.1
	4th Quarter	1.01	0.06	45.7	64.2
	Annual Mean	**1.24**	**0.08**	**114.6**	**72.0**
2004	1st Quarter	1.07	0.08	27.7	62.4
	2nd Quarter	0.80	0.04	18.2	54.8
	3rd Quarter	1.05	0.08	25.3	61.8
	4th Quarter	1.21	0.11	39.8	67.3
	Annual Mean	**1.03**	**0.08**	**27.7**	**61.6**
2005	1st Quarter	0.91	0.08	31.6	62.5
	2nd Quarter	1.90	0.07	116.0	75.1
	3rd Quarter	1.19	0.05	44.2	64.4
	4th Quarter	0.99	0.06	66.1	66.9
	Annual Mean	**1.25**	**0.07**	**64.5**	**67.2**
Long-term Mean		**1.05**	**0.06**	**43.3**	**62.9**

Table B-5. Historic TN, TP, and Chla concentrations and TSI of Lake Lawne

Year	Quarter	TN (mg/L)	TP (mg/L)	Chla (µg/L)	TSI
1996	1st Quarter	----	0.093	23.5	----
	2nd Quarter	----	0.112	48.4	----
	3rd Quarter	----	0.073	55.1	----
	4th Quarter	----	0.056	45.3	----
	Annual Mean	----	**0.08**	**43.1**	----
1997	1st Quarter	----	0.064	32.0	----
	2nd Quarter	1.31	0.111	39.3	67.5
	3rd Quarter	1.65	0.104	48.6	69.8
	4th Quarter	1.32	0.098	36.8	66.4
	Annual Mean	**1.42**	**0.09**	**39.2**	**67.9**
1998	1st Quarter	1.08	0.028	29.9	60.3
	2nd Quarter	1.68	0.047	40.9	68.5
	3rd Quarter	1.53	0.063	46.4	66.8
	4th Quarter	0.60	0.059	56.4	63.3
	Annual Mean	**1.22**	**0.05**	**43.4**	**64.7**
1999	1st Quarter	1.12	0.059	24.5	60.3
	2nd Quarter	0.92	0.073	50.3	65.5
	3rd Quarter	1.46	0.100	37.0	67.0
	4th Quarter	1.66	0.077	51.0	68.8
	Annual Mean	**1.29**	**0.08**	**40.7**	**65.4**
2000	1st Quarter	1.26	0.063	16.8	58.5
	2nd Quarter	1.69	0.111	27.4	66.1
	3rd Quarter	1.44	0.102	35.9	66.9
	4th Quarter	1.30	0.070	31.7	63.7
	Annual Mean	**1.42**	**0.09**	**27.9**	**63.8**
2001	1st Quarter	1.25	0.065	25.0	61.5
	2nd Quarter	1.60	0.099	22.2	63.8
	3rd Quarter	1.89	0.045	60.0	70.9
	4th Quarter	1.42	0.102	44.1	68.3
	Annual Mean	**1.54**	**0.08**	**37.8**	**66.1**
2002	1st Quarter	1.34	0.100	35.9	66.4
	2nd Quarter	1.39	0.119	41.6	68.5
	3rd Quarter	1.71	0.097	31.1	66.5
	4th Quarter	2.06	0.095	35.4	68.2
	Annual Mean	**1.62**	**0.10**	**36.0**	**67.4**
2003	1st Quarter	2.18	0.061	----	----
	2nd Quarter	1.42	0.072	----	----
	3rd Quarter	1.55	0.071	39.7	66.3
	4th Quarter	1.74	0.074	25.4	63.9
	Annual Mean	**1.72**	**0.07**	**32.6**	----
2004	1st Quarter	1.18	0.060	9.3	53.7
	2nd Quarter	1.26	0.081	22.7	61.9
	3rd Quarter	1.62	0.095	51.7	69.8
	4th Quarter	1.83	0.056	29.5	68.4
	Annual Mean	**1.47**	**0.07**	**28.3**	**63.4**
2005	1st Quarter	1.27	0.045	20.9	58.6
	2nd Quarter	1.37	0.075	33.9	64.8
	3rd Quarter	1.45	0.067	38.1	65.4
	4th Quarter	1.46	0.062	32.9	64.0
	Annual Mean	**1.39**	**0.06**	**31.4**	**63.2**
2006	1st Quarter	----	0.341	22.9	----
	2nd Quarter	1.57	0.080	37.3	66.4
	3rd Quarter	1.24	0.066	28.1	62.4
	4th Quarter	----	----	----	----
	Annual Mean	**1.41**	**0.16**	**29.4**	----
Long-term Mean		**1.45**	**0.09**	**35.4**	**65.2**

Table B-6. Historic TN, TP, and Chla concentrations and TSI of Spring Lake

Year	Quarter	TN (mg/L)	TP (mg/L)	Chla (µg/L)	TSI
1996	1st Quarter	1.41	0.046	51.2	70.1
	2nd Quarter	1.54	0.036	52.6	67.2
	3rd Quarter	1.58	0.033	59.3	67.2
	4th Quarter	1.59	0.047	65.3	72.1
	Annual Mean	**1.53**	**0.041**	**57.1**	**69.1**
1997	1st Quarter	1.36	0.042	49.4	68.7
	2nd Quarter	1.35	0.042	42.9	67.6
	3rd Quarter	1.63	0.037	63.9	69.1
	4th Quarter	1.55	0.046	65.2	71.7
	Annual Mean	**1.47**	**0.042**	**55.4**	**69.3**
1998	1st Quarter	1.15	0.048	49.0	64.5
	2nd Quarter	1.35	0.031	34.8	62.6
	3rd Quarter	1.37	0.038	33.8	64.8
	4th Quarter	1.40	0.031	47.2	64.8
	Annual Mean	**1.31**	**0.037**	**41.2**	**64.2**
1999	1st Quarter	1.59	0.040	54.9	68.8
	2nd Quarter	1.80	0.048	63.9	72.1
	3rd Quarter	1.21	0.037	61.3	68.9
	4th Quarter	1.30	0.045	43.1	63.9
	Annual Mean	**1.47**	**0.043**	**55.8**	**68.4**
2000	1st Quarter	1.39	0.045	41.6	68.3
	2nd Quarter	2.09	0.047	71.8	72.7
	3rd Quarter	2.33	0.047	84.9	73.9
	4th Quarter	2.07	0.047	55.4	71.0
	Annual Mean	**1.97**	**0.047**	**63.4**	**71.5**
2001	1st Quarter	1.55	0.046	39.2	68.1
	2nd Quarter	1.68	0.041	39.7	66.8
	3rd Quarter	1.28	0.037	32.4	64.1
	4th Quarter	1.30	0.039	47.6	67.5
	Annual Mean	**1.45**	**0.041**	**39.7**	**66.6**
2002	1st Quarter	1.35	0.038	38.5	65.6
	2nd Quarter	1.91	0.035	51.7	66.7
	3rd Quarter	1.31	0.031	39.3	63.4
	4th Quarter	1.40	0.036	48.2	66.6
	Annual Mean	**1.49**	**0.035**	**44.4**	**65.6**
2003	1st Quarter	1.29	0.051	32.7	62.5
	2nd Quarter	1.29	0.031	29.0	61.4
	3rd Quarter	1.22	0.037	50.8	67.4
	4th Quarter	1.36	0.043	53.0	69.4
	Annual Mean	**1.29**	**0.041**	**41.4**	**65.2**
2004	1st Quarter	1.29	0.042	37.0	66.5
	2nd Quarter	1.67	0.033	36.9	63.7
	3rd Quarter	1.64	0.031	46.5	64.7
	4th Quarter	1.28	0.023	40.0	60.1
	Annual Mean	**1.47**	**0.032**	**40.1**	**63.7**
2005	1st Quarter	1.13	0.041	25.6	59.1
	2nd Quarter	1.61	0.034	38.0	64.1
	3rd Quarter	1.70	0.024	22.3	56.4
	4th Quarter	0.96	0.043	28.9	59.3
	Annual Mean	**1.35**	**0.035**	**28.7**	**59.7**
	1st Quarter	0.88	0.030	19.5	54.3
	2nd Quarter	1.03	0.028	10.2	52.5
	3rd Quarter	1.10	0.020	20.0	53.4
	4th Quarter	----	----	----	----
	Annual Mean	**1.00**	**0.026**	**16.6**	----
Long-term Mean		**1.44**	**0.04**	**44.0**	**66.3**

Table B-7. Historic TN, TP, and Chla concentrations and TSI of Bay Lake

Year	Quarter	TN (mg/L)	TP (mg/L)	Chla (µg/L)	TSI
1996	1st Quarter	1.00	0.051	28.3	60.1
	2nd Quarter	1.00	0.040	13.8	53.8
	3rd Quarter	1.09	0.034	36.8	64.0
	4th Quarter	1.42	0.053	63.2	67.8
	Annual Mean	**1.13**	**0.044**	**35.5**	**61.5**
1997	1st Quarter	0.97	0.051	23.5	58.7
	2nd Quarter	0.95	0.055	27.5	60.1
	3rd Quarter	1.11	0.044	37.5	62.0
	4th Quarter	1.44	0.053	60.9	67.7
	Annual Mean	**1.12**	**0.051**	**37.4**	**62.1**
1998	1st Quarter	0.87	0.039	23.8	56.9
	2nd Quarter	0.91	0.042	28.0	58.7
	3rd Quarter	1.06	0.030	24.4	59.7
	4th Quarter	1.07	0.034	45.1	65.6
	Annual Mean	**0.98**	**0.036**	**30.3**	**60.2**
1999	1st Quarter	1.46	0.047	42.8	69.0
	2nd Quarter	1.35	0.048	30.3	61.8
	3rd Quarter	1.45	0.028	23.4	58.5
	4th Quarter	2.06	0.053	26.3	66.9
	Annual Mean	**1.58**	**0.044**	**30.7**	**64.1**
2000	1st Quarter	1.60	0.047	30.0	66.4
	2nd Quarter	2.17	0.057	48.1	72.1
	3rd Quarter	1.33	0.031	----	----
	4th Quarter	1.56	0.032	30.0	61.9
	Annual Mean	**1.67**	**0.042**	**36.0**	----
2001	1st Quarter	0.95	0.050	22.7	58.2
	2nd Quarter	1.51	0.044	24.6	64.2
	3rd Quarter	1.77	0.050	46.8	70.4
	4th Quarter	1.29	0.047	33.7	62.3
	Annual Mean	**1.38**	**0.048**	**32.0**	**63.8**
2002	1st Quarter	1.45	0.044	17.7	61.8
	2nd Quarter	1.92	0.058	16.8	64.7
	3rd Quarter	1.78	0.036	13.7	57.6
	4th Quarter	2.00	0.040	39.4	66.5
	Annual Mean	**1.79**	**0.045**	**21.9**	**62.7**
2003	1st Quarter	1.87	0.059	16.4	64.8
	2nd Quarter	1.36	0.038	----	----
	3rd Quarter	2.01	0.035	14.8	57.9
	4th Quarter	2.04	0.044	45.8	68.7
	Annual Mean	**1.82**	**0.044**	**25.7**	----
2004	1st Quarter	1.74	0.058	1.5	42.4
	2nd Quarter	1.52	0.045	26.9	65.1
	3rd Quarter	1.44	0.035	----	----
	4th Quarter	1.50	0.048	8.7	57.7
	Annual Mean	**1.55**	**0.047**	**12.4**	----
2005	1st Quarter	1.56	0.032	7.2	51.6
	2nd Quarter	1.54	0.050	9.7	59.1
	3rd Quarter	1.23	0.024	8.3	49.2
	4th Quarter	1.56	0.040	35.8	65.8
	Annual Mean	**1.47**	**0.037**	**15.3**	**56.4**
2006	1st Quarter	1.45	0.058	29.9	63.0
	2nd Quarter	1.61	0.040	31.2	64.8
	3rd Quarter	0.91	0.016	13.9	48.2
	4th Quarter	----	----	----	----
	Annual Mean	**1.32**	**0.038**	**25.0**	----
Long-term Mean		**1.44**	**0.043**	**27.5**	**61.5**

Florida Department of Environmental Protection
Division of Water Resource Management
Bureau of Watershed Management
2600 Blair Stone Road, Mail Station 3565
Tallahassee, Florida 32399-2400
(850) 245-8561
www2.dep.state.fl.us/water/