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FLORIDA DEPARTMENT OF ENVIRONMENTAL PROTECTION

Division of Water Resource Management, Bureau of Watershed Management

SOUTHWEST DISTRICT • LAKE HANCOCK BASIN • PEACE RIVER PLANNING UNIT

TMDL Report

Nutrient TMDL For Lake Lena

WBID 1501

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Acknowledgments

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Identification of Impaired Surface Waters Rule

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

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Chapter 1: INTRODUCTION

1.1 Purpose of Report

This report presents the TMDL for nutrients for Lake Lena, located in the Lake Hancock Basin. Lake Lena discharges to Lake Lena Run/Creek which is a contributing outfall to Lake Hancock and thus, has a direct impact on water quantity and quality to Lake Hancock and subsequent waterbodies. Lake Lena was verified as impaired by excessive nutrients using the methodology in the Identification of Impaired Surface Waters Rule (IWR, Rule 62-303, Florida Administrative Code), and was included on the Verified List of impaired waters for the Lake Hancock Basin that was adopted by Secretarial Order on June 17, 2005. The TMDL establishes the allowable loadings to the lake that would restore the waterbody so that it meets its applicable water quality narrative criteria for nutrients.

1.2 Identification of Waterbody

Lake Lena is located in Polk County, Auburndale, Florida. The estimated surface area of the lake is 207 acres and the average depth is 10 ft (3.1 m) with a maximum depth of 14 ft (4.3 m). The Lake Lena watershed has a surface water drainage area of approximately 8.1 square miles or 5,175 acres (see **Figure 1.1**). The watershed's land use designations are primarily low, medium, and high density residential. The majority of this residential area is associated with the City of Auburndale and the Inwood area of Winter Haven. Significant waterbodies in the Lake Lena watershed include Lakes Ariana, Arietta, and Whistler. The normal pool topographic elevation of the water surface is 133.6 feet National Geodetic Vertical Datum (NGVD) (Polk County Natural Resources Division, 2002). There are no major tributaries (non-canal) flowing into the lake. However, there are a number of small stormwater conduits that discharge local runoff into the lake.

For assessment purposes, the Department has divided the Lake Hancock Basin into water assessment polygons with a unique **w**ater**b**ody **id**entification (WBID) number for each watershed or stream reach. Lake Lena has been given the WBID number of 1501.
The Lake Lena WBID and its sampling/monitoring stations are illustrated in **Figure 1.2**.

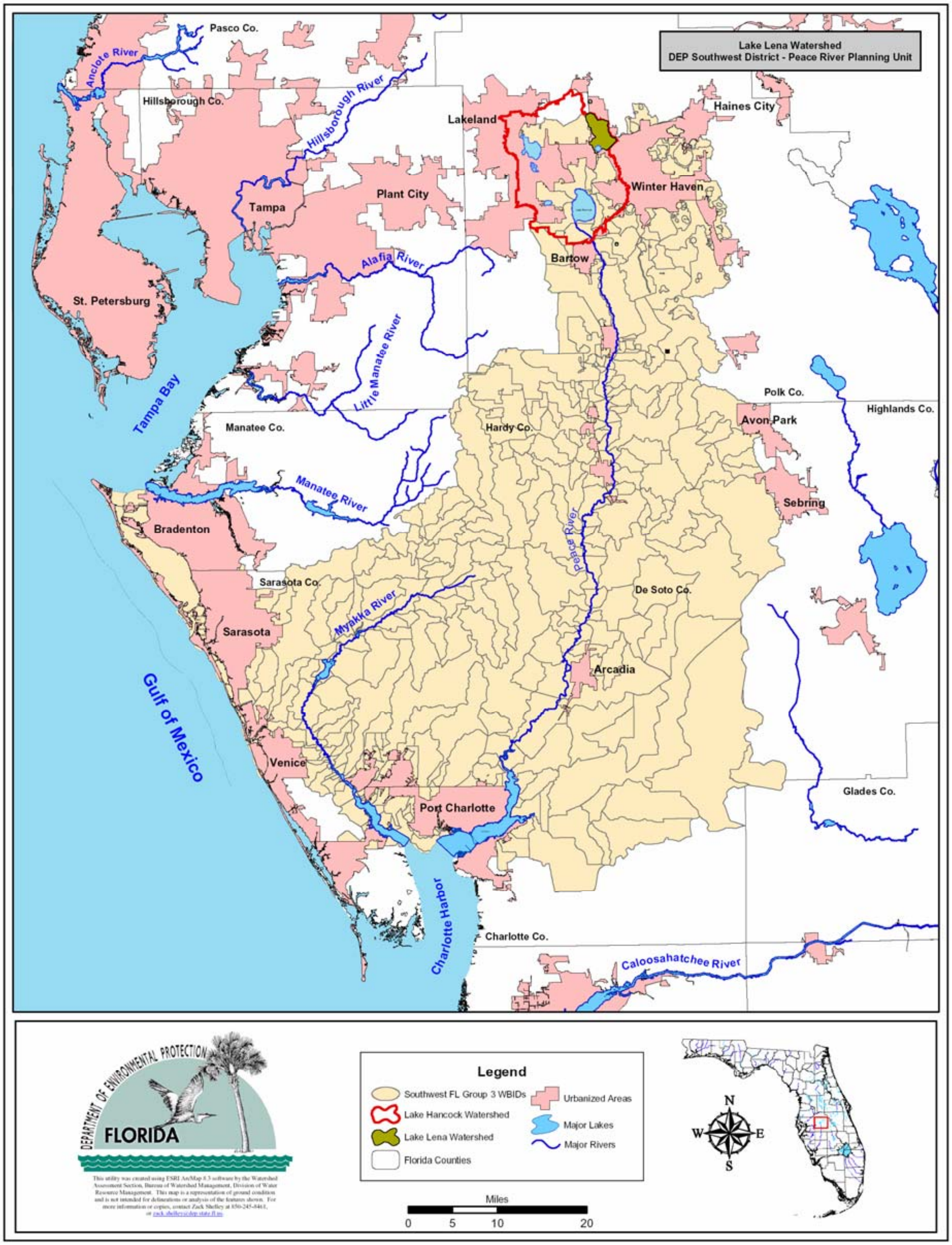


Figure 1.1 Southwest Florida Group 3 WBIDs and Major Metropolitan Areas Surrounding the Lake Hancock Watershed and the Lake Lena Watershed

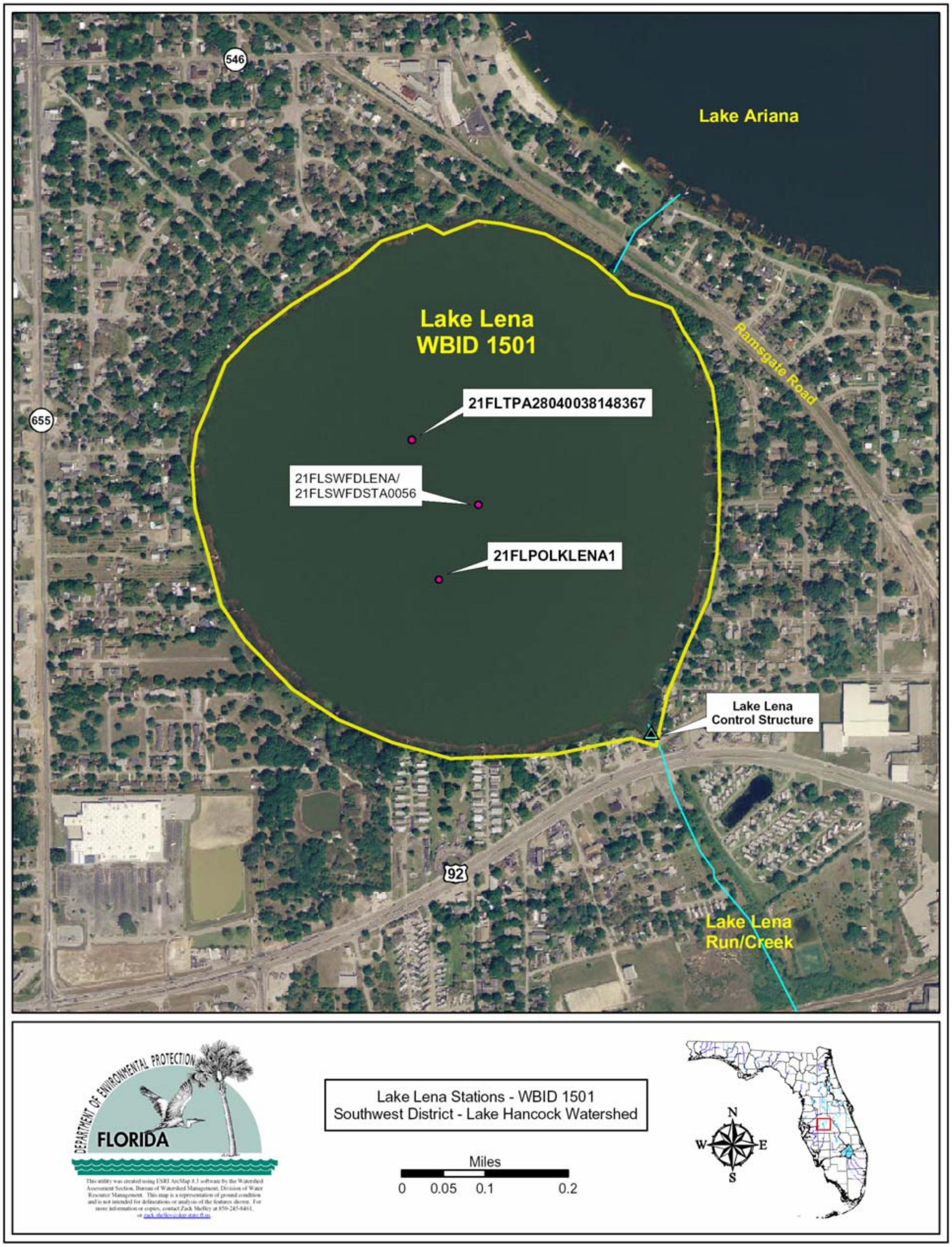


Figure 1.2 Lake Lena WBID 1501 and Monitoring Stations

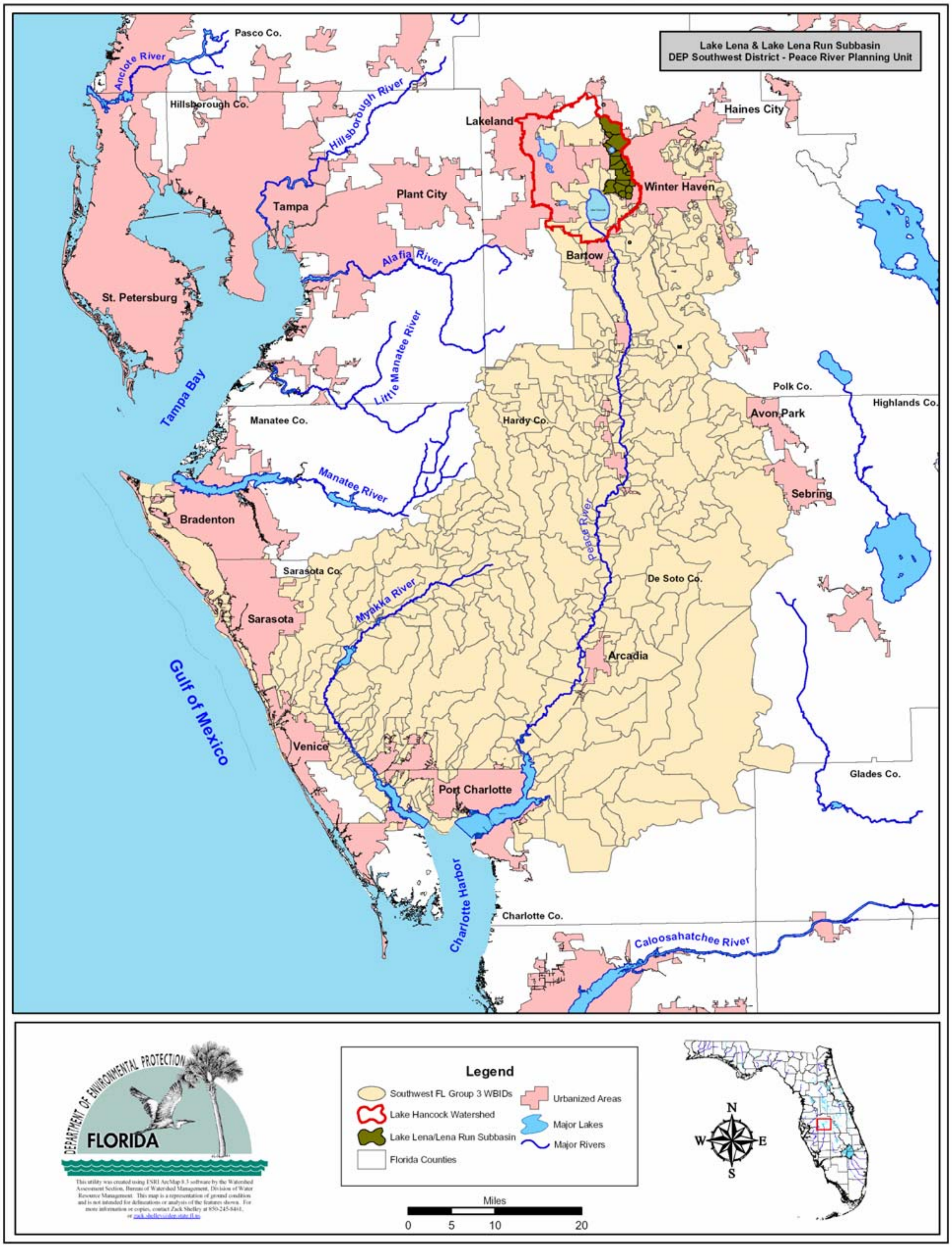
1.3 Background Information

The Lake Lena and Lake Lena Run sub-basin has a surface water drainage area of approximately 20.4 square miles or 13,059 acres (see **Figure 1.3**). The Lake Lena watershed includes interconnected lakes Ariana, Arietta, and Whistler. Lake Lena is directly connected to upstream Lake Ariana via a canal. Lake Ariana is connected to Lake Whistler and Whistler to Lake Arietta via canals. Lake Lena discharge is controlled by SWFWMD Structure P-1 (see **Figure 4.1**). The Lake Lena and Lake Lena Run sub-basin also includes Lake Thomas and the interconnected lakes of Sears, Spirit, Grassy, and Dinner. Lake Thomas is a 'closed basin' with no outfall structure. Grassy Lake was formerly a 'closed basin,' but was recently modified with a pumping station and piping to discharge under near-flood conditions to Dinner Lake, which discharges over a weir and through a channel to wetlands that drain into Lena Run. Spirit Lake was similarly a part of a 'closed basin' that included Sears Lake, until the system was recently modified to discharge through underground pipes to the wetlands north and downstream of Dinner Lake (BCI Engineers and Scientists, Inc., 2005). Water in Lake Lena discharges to Lake Lena Run which flows into Lake Hancock. Thus, the water quality and quantity in Lake Lena directly affects water quality and quantity of downstream receiving waterbodies such as Lake Hancock, the Peace River, and ultimately, Charlotte Harbor and the Gulf of Mexico. (**Figure 1.1**).

The TMDL Report for Lake Lena is part of the implementation of the Florida Department of Environmental Protection's (Department) watershed management approach for restoring and protecting water resources and addressing Total Maximum Daily Load (TMDL) Program requirements. The watershed approach, which is implemented using a cyclical management process that rotates through the state's fifty-two river basins over a five-year cycle, provides a framework for implementing the requirements of the 1972 federal Clean Water Act and the 1999 Florida Watershed Restoration Act (Chapter 99-223, Laws of Florida).

A TMDL represents the maximum amount of a given pollutant that a waterbody can assimilate and still meet the waterbody's designated uses. A waterbody that does not meet its designated uses is defined as impaired. TMDLs must be developed and implemented for each of the state's impaired waters, unless the impairment is documented to be a naturally occurring condition that cannot be abated by a TMDL or unless a management plan already in place is expected to correct the problem.

The development and implementation of a Basin Management Action Plan, or BMAP, to reduce the amount of pollutants that caused the impairment will follow this TMDL Report. These activities will depend heavily on the active participation of Polk County, the water management district, local governments, local 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 the impaired Lake.



This utility was created using ESRI ArcMap 8.3 software by the Watershed Assessment Section, Bureau of Watershed Management, Division of Water Resource Management. This map is a representation of ground condition and is not intended for delineations or analysis of the features shown. For more information or copies, contact Zack Shelley at 850-245-8461, or zack.shelley@dep.state.fl.us

Figure 1.3 Southwest Florida Group 3 WBIDs and Major Metropolitan Areas Surrounding the Lake Hancock Watershed and the Lake Lena and Lake Lena Run Sub-basin

Chapter 2: STATEMENT OF WATER QUALITY PROBLEM

2.1 Legislative and Rulemaking History

Section 303(d) of the federal 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 causing the impairment of the listed waters on a schedule. The Department has developed such lists, commonly referred to as 303(d) lists, since 1992. The list of impaired waters in each basin, referred to as the Verified List, is also required by the Florida Watershed Restoration Act (Subsection 403.067[4)] Florida Statutes [F.S.]), and the state's 303(d) list is amended annually to include basin updates.

Florida's 1998 303(d) list included 52 waterbodies in the Peace River Planning Unit, with 11 of those waterbodies in the Lake Hancock 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. 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.

2.2 Information on Verified Impairment

The Department used the IWR to assess water quality impairments in Lake Lena. The lake was verified as impaired for nutrients based on an elevated annual average Trophic State Index (TSI) value over the verification period (the Verified Period for the Group 3 basins is from January 1, 1997 to June 30, 2004). The IWR methodology uses the water quality variables total nitrogen (TN), total phosphorus (TP), and chlorophyll a (a measure of algal mass, corrected and uncorrected) in calculating annual TSI values and in interpreting Florida's narrative nutrient threshold. For Lake Lena, data were available for the three water quality variables for all seasons for only one year (2003) during the verified period. The resulting annual average TSI value for this year was 67.1. Following IWR methodology, exceeding 60 in any one year of the verified period is sufficient in determining the impairment for a lake for nutrients. Annual average color values for the verified period for the lake were 11.7 (1997), 16.7 (1998), 5 (1999), 5 (2000), 12 (2002), and 43.2 (2003). The annual average color value for years in the verified period was 15.6.

The TSI is calculated based on concentrations of TP, TN, and chlorophyll a as follows:

$CHLA_{TSI} = 16.8 + 14.4 * LN(Chl\ a)$ Chlorophyll a in µg/L
$TN_{TSI} = 56 + 19.8 * LN(N)$ Nitrogen in mg/L
$TN2_{TSI} = 10 * [5.96 + 2.15 * LN(N + 0.0001)]$ Phosphorus in mg/L
$TPTSI = 18.6 * LN(P * 1000) – 18.4$
$TP2_{TSI} = 10 * [2.36 * LN(P * 1000) – 2.38]$

If $N/P > 30$, *then* $NUTR_{TSI} = TP2_{TSI}$
If $N/P < 10$, *then* $NUTR_{TSI} = TN2_{TSI}$
if $10 < N/P < 30$, *then* $NUTR_{TSI} = (TP_{TSI} + TN_{TSI})/2$

$TSI = (CHLA_{TSI} + NUTR_{TSI})/2$ Note: TSI has no units

For modeling purposes, the analysis of the eutrophication-related data for Lake Lena used “all” of the available data from 1993 – 2004 for which records of TP, TN, and Chlorophyll a were sufficient to calculate seasonal and annual average conditions. However, as noted in the previous paragraph, to calculate the TSI for a given year under the IWR, there must be at least one sample of TN, TP, and Chlorophyll a taken within the same quarter (each season) of the year. The absence of data from all four seasons for the planning and verified periods caused the elimination of the years 1992 to 2002 from the analysis of TSI for Lake Lena.

Figure 2.1 displays annual average TSI values for all data from 1993 to 2004 (includes Lakewatch data) and the IWR verified period TSI value from 2003 (does not include Lakewatch data). Additionally, as the verified period ends in June of 2004, annual averages were not calculated for 2004 but are displayed in **Figure 2.1** for review. The verified period annual average TSI value exceeded the IWR threshold level of 60 in 2003 with a mean TSI result of 67.1.

Monthly and annual average TN results for Lake Lena from 1993 to 2004 are displayed in **Figures 2.2** and **2.3**, respectively. Monthly and annual average TP results from 1993 to 2004 are displayed in **Figures 2.4** and **2.5**. Monthly and annual average chlorophyll a results from 1993 to 2004 are displayed in **Figures 2.6** and **2.7**. Values from all stations for TN for Lake Lena from 1993 to 2004 were typically highest during the months of May and November. Values for TP were typically low but had higher values in the month of May. Values for Chlorophyll a were highest during the months of May and November.

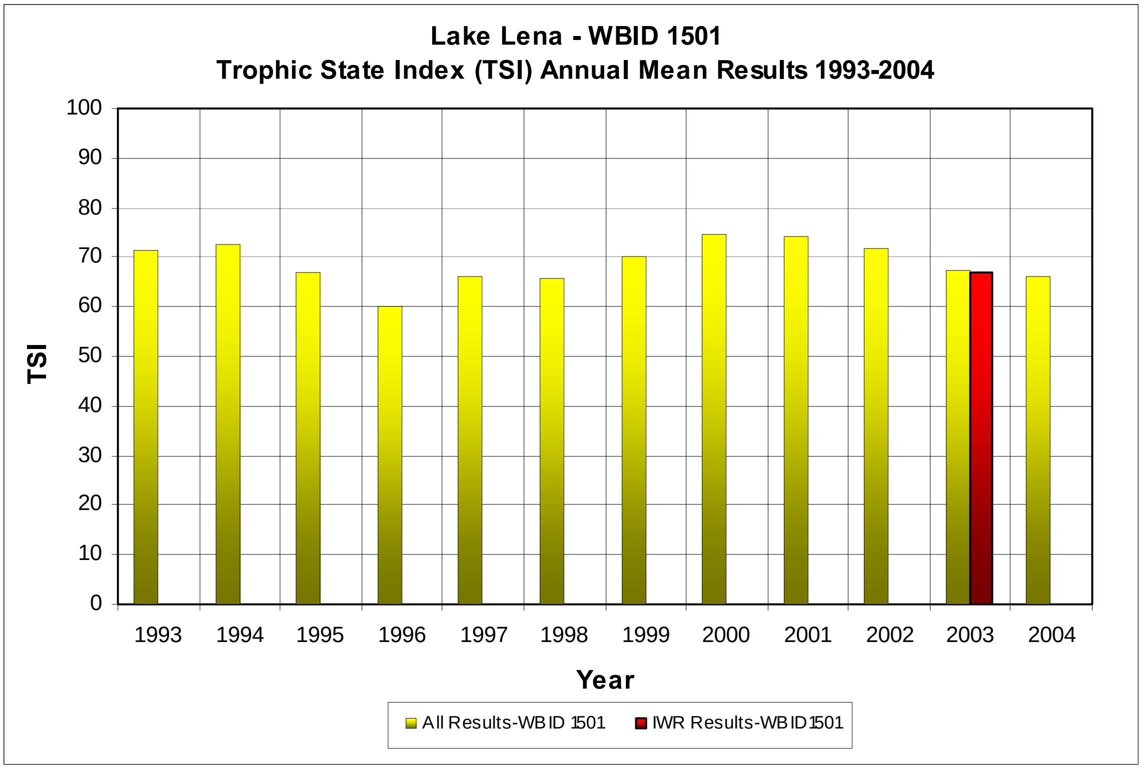


Figure 2.1 TSI Results for Lake Lena Calculated from Annual Average Concentrations of TP, TN, and Chlorophyll a from 1993 to 2004

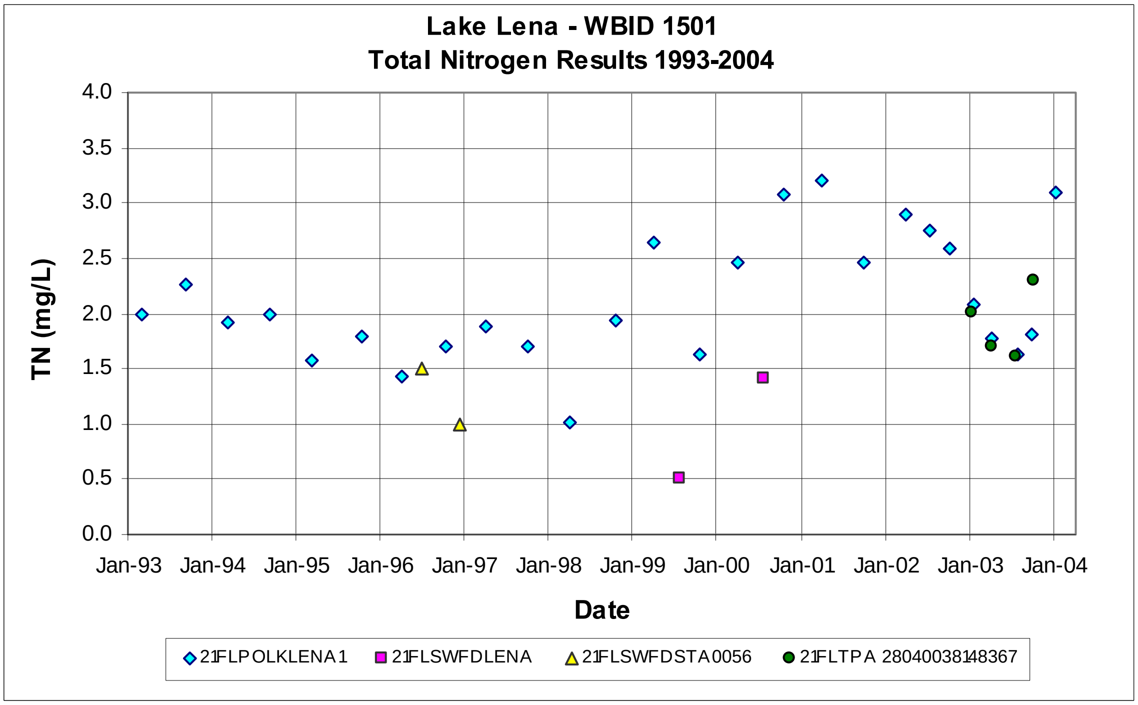


Figure 2.2 Total Nitrogen Monthly Results for Lake Lena from 1993 to 2004

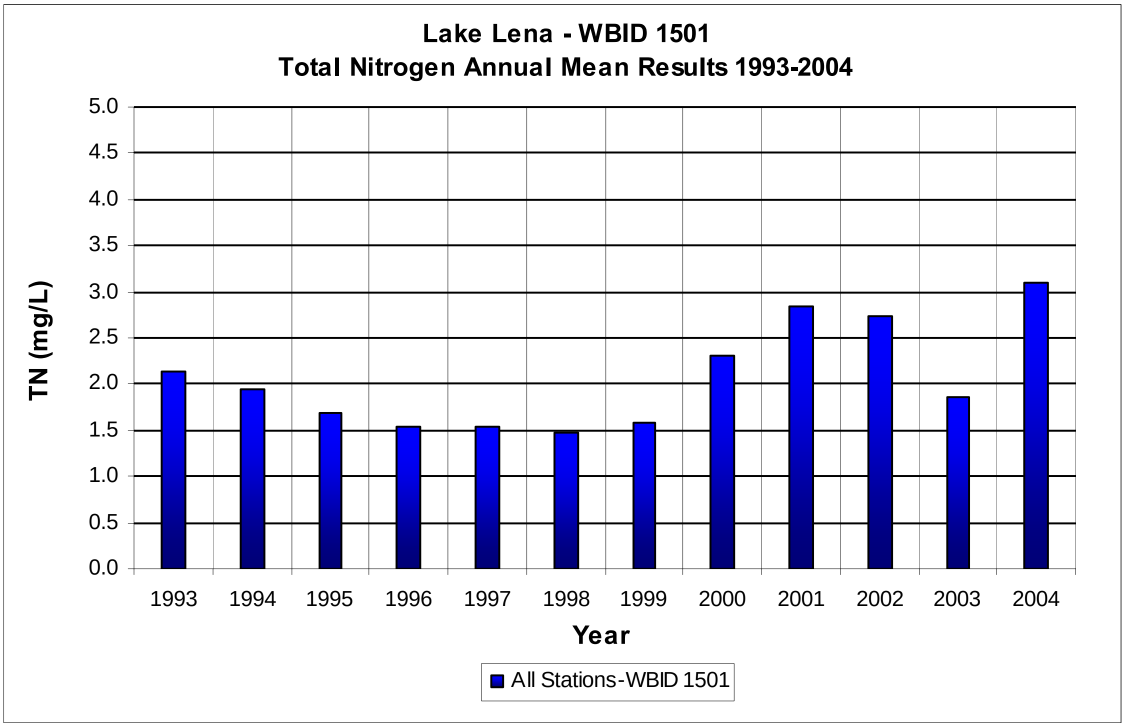


Figure 2.3 Total Nitrogen Annual Mean Results for Lake Lena from 1993 to 2004

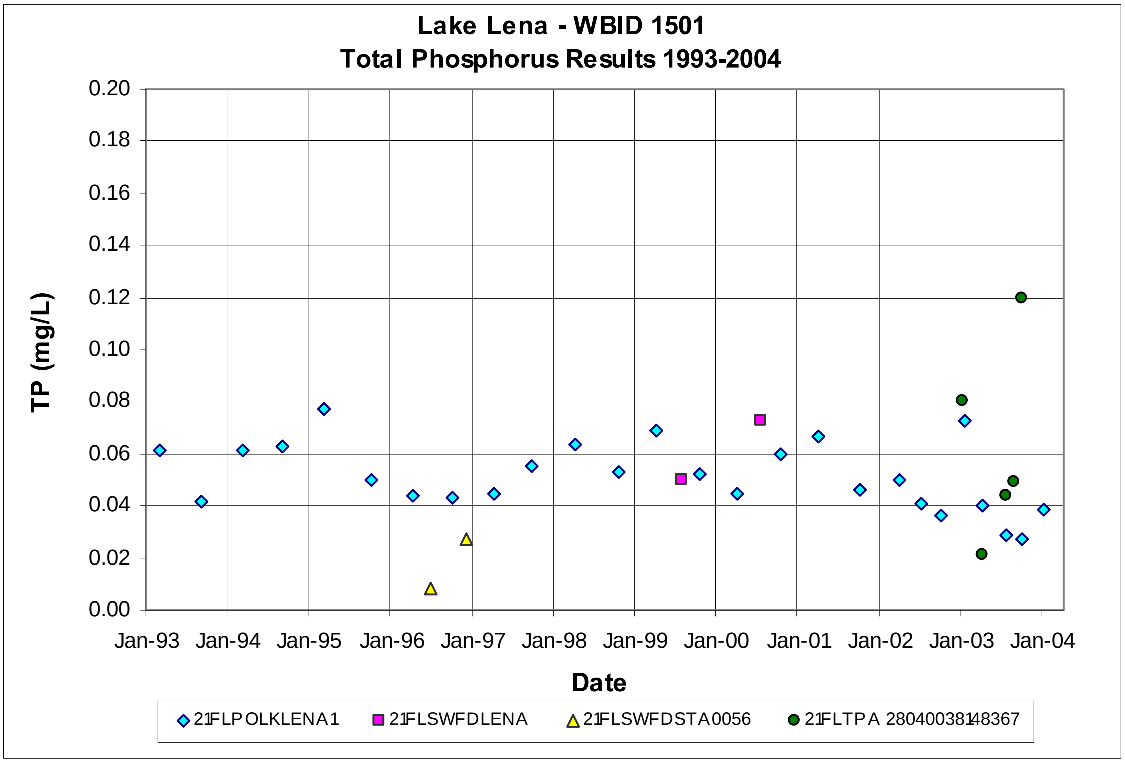


Figure 2.4 Total Phosphorus Monthly Results for Lake Lena from 1993 to 2004

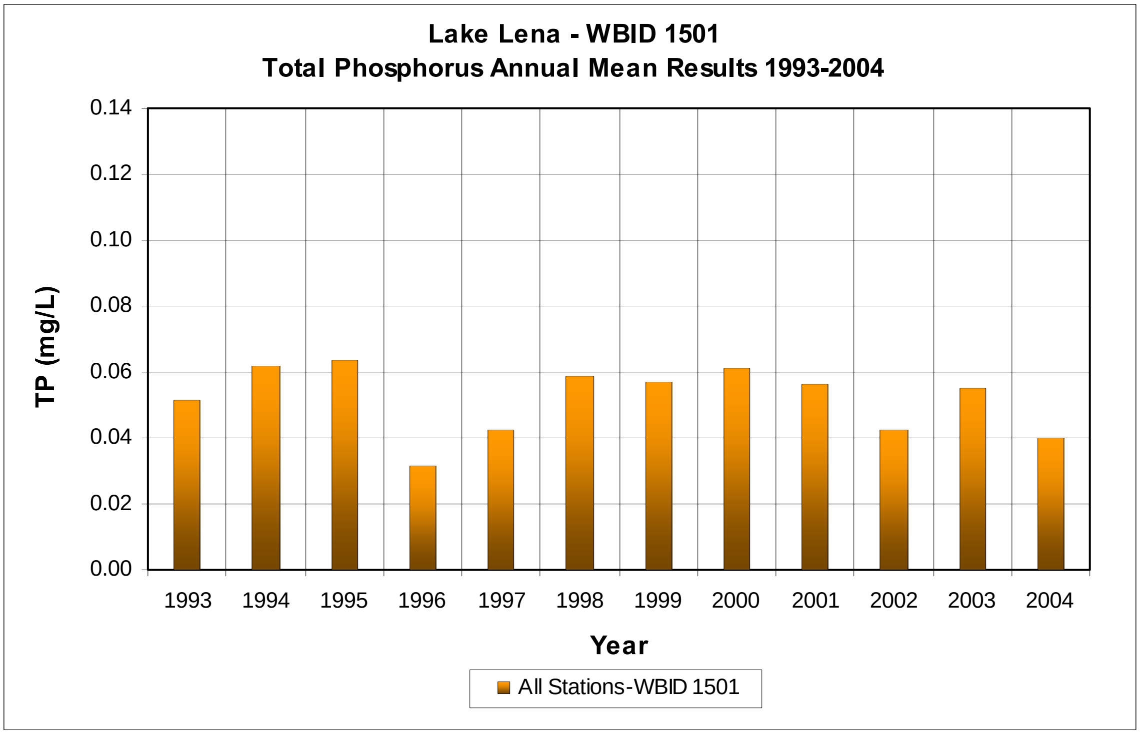


Figure 2.5 Total Phosphorus Annual Mean Results for Lake Lena from 1993 to 2004

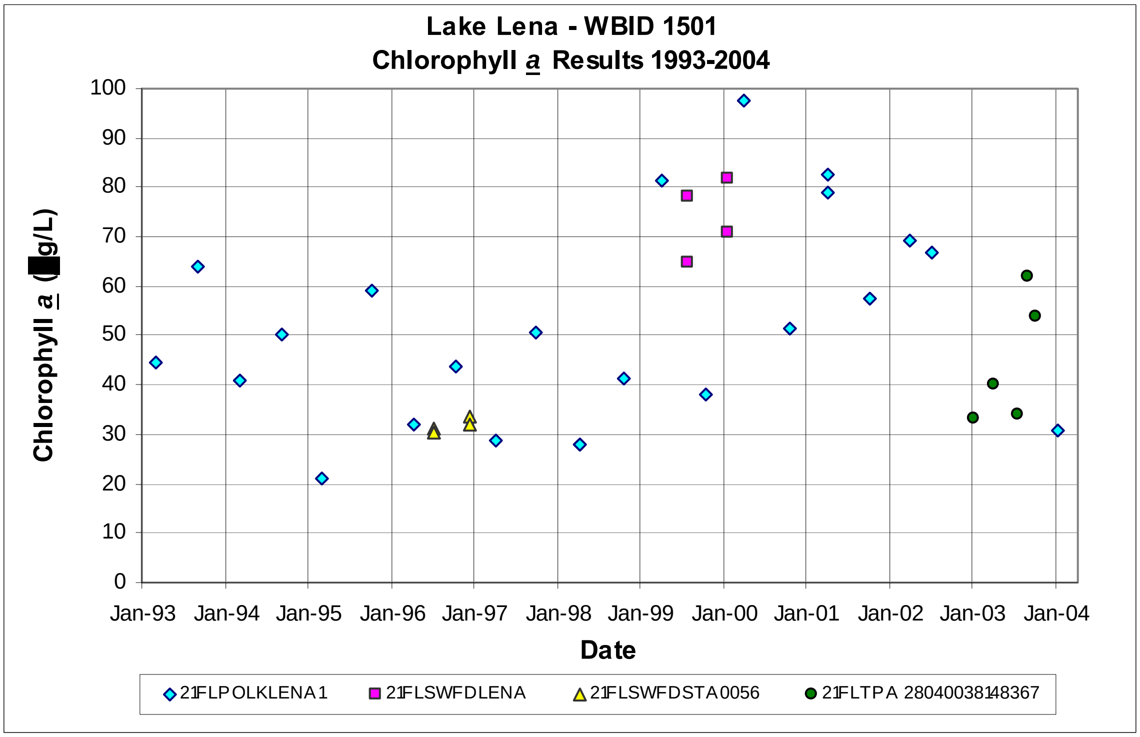


Figure 2.6 Chlorophyll a Monthly Results for Lake Lena from 1993 to 2004

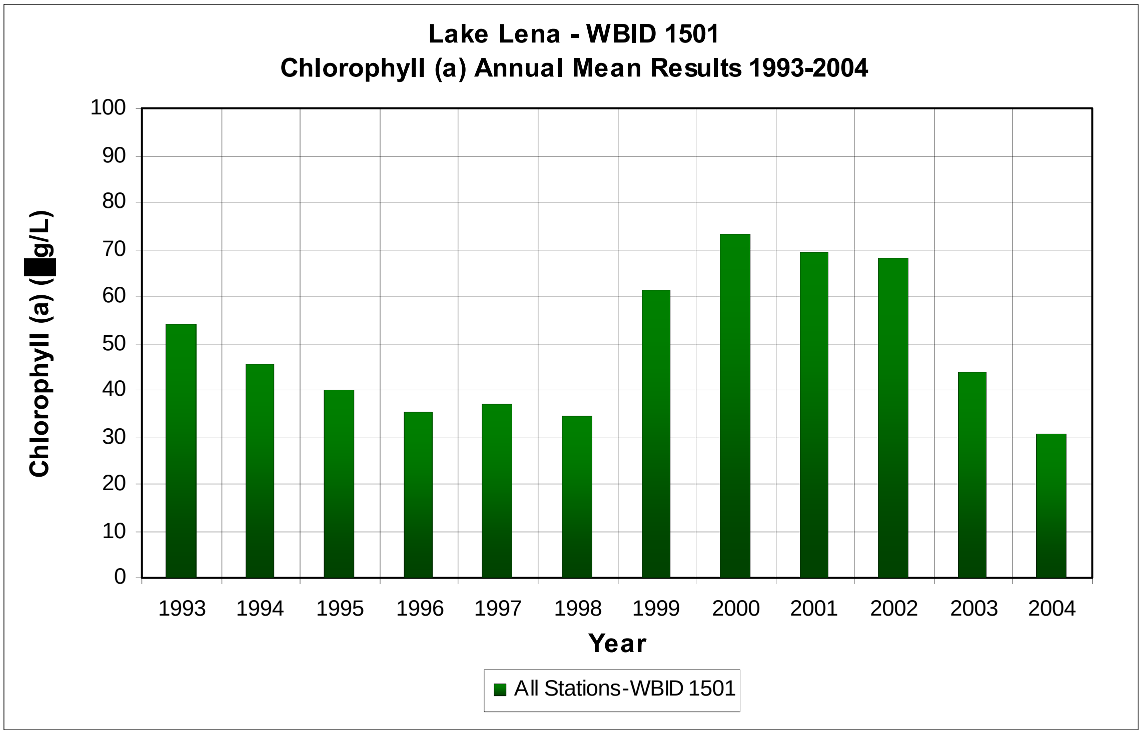


Figure 2.7 Chlorophyll a Annual Mean Results for Lake Lena from 1993 to 2004

Table 2.1 provides summary statistics for the lake for TN, TP, and chlorophyll a from 1993 to 2004. Individual water quality measurements (raw data) for TN, TP, and chlorophyll a used in the assessment are provided in **Appendix B.**

Table 2.1 Water Quality Summary Statistics for TN, TP, and Chlorophyll a from 1993 to 2004 for Lake Lena (WBID 1501)

Waterbody	Water Variable	# of Samples	Minimum	Mean	Median	Maximum
Lake Lena	Total Nitrogen (mg/L)	34	0.50	1.98	1.90	3.21
Lake Lena	Total Phosphorus (mg/L)	35	0.01	0.05	0.05	0.12
Lake Lena	Chlorophyll a (µg/L)	30	20.90	49.95	47.32	97.46

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 water is 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)**

Lake Lena is classified as Class III freshwater waterbody, with a designated use of recreation, propagation and maintenance of a healthy, well-balanced population of fish and wildlife. The Class III water quality criterion applicable to the observed impairment for Lake Lena is the state of Florida's narrative nutrient criterion [Rule 62-302.530(48) (b), FAC].

3.2 Interpretation of the Narrative Nutrient Criterion for Lakes

To place a waterbody segment on the Verified List for nutrients, the Department must identify the limiting nutrient or nutrients causing impairment as required by the IWR. The following method is used to identify the limiting nutrient(s) in streams and lakes:

The individual ratios over the entire verified period (i.e., January 1997 to June 2004) are evaluated to determine the limiting nutrient(s). If all the sampling event ratios are less than 10, nitrogen is identified as the limiting nutrient, and if all the ratios are greater than 30, phosphorus is identified as the limiting nutrient. Both nitrogen and phosphorus are identified as limiting nutrients if the ratios are between 10 and 30. For Lake Lena, the median TN/TP ratio was 41.02 mg/L for the verified period, clearly indicating that TP is the limiting nutrient for the lake.

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. While the IWR provides a threshold for nutrient impairment for lakes based on annual average TSI levels, these thresholds are not standards and are not required to be used as the nutrient-related water quality target for TMDLs. In recognition that the IWR thresholds were developed using statewide average conditions, the IWR (Subsection 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 the waterbody.

The TSI originally developed by R. E. Carlson (1977) was calculated based on Secchi depth, chlorophyll concentration, and total phosphorus concentration and was used to describe a lake's trophic state. Carlson's TSI was developed based on the assumption that the lakes were all phosphorus limited. In Florida, because the local geology produced a phosphorus rich soil, nitrogen can be the sole or co-limiting factor for phytoplankton population in some lakes. In addition, because of the existence of dark-water lakes in the state, using Secchi depth as an index to represent lake trophic state can produce misleading results.

Therefore, the TSI was revised to be based on total nitrogen, total phosphorus, and chlorophyll *a* concentrations. This revised calculation for TSI now contains a TN -TSI, TP -TSI, and Chlorophyll *a* -TSI. As a result, there are three different ways of calculating a final in-lake TSI. If the TN to TP ratio is equal to or greater than 30, the lake is considered phosphorus limited and the final TSI is the average of the TP -TSI and the Chlorophyll *a* -TSI. If the TN to TP ratio is 10 or less, the lake is considered nitrogen limited and the final TSI is the average of the TN -TSI and the Chlorophyll *a* -TSI. If the TN to TP ratio is between 10 and 30, the lake is considered co-limited and the final TSI is the result of averaging the Chlorophyll *a* -TSI with the average of the TN and TP TSI's.

The Florida-specific TSI was determined based on the analysis of data from 313 Florida lakes. The index was adjusted so that a chlorophyll *a* concentration of 20 μg/L was equal to a Chlorophyll *a* -TSI value of 60. The final TSI for any lake may be higher or lower than 60 depending on the TN -TSI and the TP -TSI values. A TSI of 60 was then set as the threshold for nutrient impairment for most lakes (for those with a color higher than 40 platinum cobalt units) because, generally, the phytoplankton may switch to communities dominated by blue-green algae at chlorophyll *a* levels above 20 μg/L. These blue-green algae are often an unfavorable food source to zooplankton and many other aquatic animals. Some blue-green algae may even produce toxins, which could be harmful to fish and other animals. In addition, excessive growth of phytoplankton and the subsequent death of these algae may consume large quantities of dissolved oxygen and result in anaerobic conditions in lakes, which makes conditions in the impacted lake unfavorable for fish and other wildlife. All of these processes may negatively impact the health and balance of native fauna and flora.

Because of the amazing diversity and productivity of Florida lakes, some lakes have a natural background TSI that is different from 60. In recognition of this natural variation, the IWR allows for the use of a lower TSI (40) in very clear lakes, a higher TSI if paleolimnological data indicate the lake was naturally above 60, and the development of site-specific thresholds that better represent the levels at which nutrient impairment occurs.

For the Lake Lena TMDL, the Department applied the Watershed Assessment Model (WAM) (Soil and Water Engineering Technology, Inc., 2005) and the BATHTUB model (Quantitative Environmental Analysis, LLC, 2005) to simulate water quality discharges and eutrophication processes to determine the appropriate nutrient target. The WAM model was used to estimate existing conditions in the Lake Lena watershed and Lake Lena Run sub-basin and the natural background TSI by setting land uses to natural or forested land, and then compare the resulting TSI to the IWR thresholds. If the natural background TSI can be determined, then an increase of 5 TSI units above natural background will be used as the water quality target for the TMDL. Otherwise, the IWR threshold TSI of 60 will be established as the target for TMDL development. The estimated natural background TSI for Lake Lena is 60.01 with a target TMDL TSI of 65.01.

3.3 Narrative Nutrient Criteria Definitions

Chlorophyll *a*

Chlorophyll is a green pigment found in plants and is an essential component in the process of converting light energy into chemical energy. Chlorophyll is capable of channeling the energy of sunlight into chemical energy through the process of photosynthesis. In photosynthesis, the energy absorbed by chlorophyll transforms carbon dioxide and water into carbohydrates and oxygen. The chemical energy stored by photosynthesis in carbohydrates drives biochemical reactions in nearly all living organisms. Thus, chlorophyll is at the center of the photosynthetic oxidation-reduction reaction between carbon dioxide and water.

There are several types of chlorophyll; however, the predominant form is chlorophyll *a*. The measurement of chlorophyll *a* in a water sample is a useful indicator of phytoplankton biomass, especially when used in conjunction with analysis concerning algal growth potential and species abundance. The greater the abundance of chlorophyll *a*, typically the greater the abundance of algae. Algae are the primary producers in the aquatic food web, and thus are very important in characterizing the productivity of lakes and streams. As noted earlier, chlorophyll *a* measurements are also used to estimate the trophic conditions of lakes and lentic waters.

Nitrogen Total as N (TN)

Total nitrogen is the combined measurement of nitrate (NO^3), nitrite (NO^2), ammonia, and organic nitrogen found in water. Nitrogen compounds function as important nutrients to many aquatic organisms and are essential to the chemical processes that exist between land, air, and water. The most readily bio-available forms of nitrogen are ammonia and nitrate. These compounds, in conjunction with other nutrients, serve as an important base for primary productivity.

The major source of excessive amounts of nitrogen in surface water are the effluent from municipal treatment plants and runoff from agricultural sites. When nutrient concentrations consistently exceed natural levels, the resulting nutrient imbalance can cause undesirable changes in a waterbody's biological community and drive an aquatic system into an accelerated rate of eutrophication. Usually, the eutrophication process is observed as a change in the structure of the algal community and includes severe algal blooms that may cover large areas for extended periods. Large algal blooms are generally followed by a depletion in dissolved oxygen concentrations as a result of algal decomposition.

Phosphorus Total as P (TP)

Phosphorus is one of the primary nutrients that regulates algal and macrophyte growth in natural waters, particularly in fresh water. Phosphate, the form in which almost all phosphorus is found in the water column, can enter the aquatic environment in a number of ways. Natural processes transport phosphate to water through atmospheric deposition, ground water percolation, and terrestrial runoff. Municipal treatment plants, industries, agriculture, and domestic activities also contribute to phosphate loading through direct discharge and natural transport mechanisms. The very high levels of phosphorus in some of Florida's streams and estuaries are usually caused by phosphate mining and fertilizer processing activities.

High phosphorus concentrations are frequently responsible for accelerating the process of eutrophication, or accelerated aging, of a waterbody. Once phosphorus and other important nutrients enter the ecosystem, they are extremely difficult to remove. They become tied up in biomass or deposited in sediments. Nutrients, particularly phosphates, deposited in sediments generally are redistributed to the water column. This type of cycling compounds the difficulty of halting the eutrophication process.

Chapter 4: ASSESSMENT OF SOURCES

4.1 Overview of Modeling Process

The Lake Lena watershed and the Lake Lena Run sub-basin are a part of a larger network of lakes and streams that drain to Lake Hancock, which discharges to Lower Saddle Creek, the Peace River, and ultimately, Charlotte Harbor and the Gulf of Mexico. As there are several other lakes in the network for which TMDLs are being developed, the Department modeled the entire Lake Hancock Basin. A primary basin setup was used to create an ArcView project file for Lake Hancock, which was designated the primary basin. The term ‘primary basin’ in the Watershed Assessment Model (WAM), refers to a collection of sub-basins or basins that discharge to a single receiving water body. The primary basin setup procedure used to model Lake Lena, Lake Lena Run, and ultimately, Lake Hancock is described in detail in “The WAM Watershed Assessment Final Report of the Lake Hancock Basin” (see **Appendix C**). The WAM model was then linked to the BATHTUB model. The BATHTUB model simulates nutrients in reservoirs and lakes based on annual average inputs. This model is described in detail in “The BATHTUB Framework for the Lake Hancock Basin, Florida, Final Report” (see **Appendix D**).

The external load assessment conducted by the WAM and BATHTUB models was intended to determine the loading characteristics of the various sources of pollutants to Lake Lena and Lake Lena Run. Assessing the external load entailed assessing land use patterns, soils, topography, hydrography, point sources, service area coverages, climate, and rainfall to determine the volume, concentration, timing, location, and underlying nature of the point, nonpoint, and atmospheric sources of nutrients to the lake and creek.

WAM is a tool that has been shown to be useful in the assessment of watershed-related properties. WAM was developed to allow engineers and planners to assess the water quality of both surface water and ground water. The model simulates the primary physical processes important for watershed hydrologic and pollutant transport. The model assesses the hydrology of the watershed using imbedded models including “Ground Water Loading Effects of Agricultural Management Systems” (GLEAMS; Knisel, 1993), “Everglades Agricultural Area Model” (EAAMod; Bottcher et al., 1998; SWET, 1999), and two submodels written specifically for WAM to handle wetland and urban landscapes. Dynamic routing of flows is accomplished through the use of an algorithm that uses a Manning’s flow equation based technique (Jacobson et al., 1998). BATHTUB is a U. S. Army Corps of Engineers steady-state model. The model incorporates several empirical equations of nutrient settling and algal growth to predict steady-state nutrient and chlorophyll a concentrations based on waterbody characteristics, hydraulic characteristics, and nutrient loadings. BATHTUB is capable of predicting concentrations of chlorophyll a, total nitrogen (TN), total phosphorus (TP) and transparency in a waterbody under different loading conditions (QEA, LLC, 2005).

4.2 Potential Sources of Nutrients in the Lake Lena Watershed

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 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, and 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 National Pollutant Discharge Elimination Program (NPDES). 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" will be used to describe traditional point sources (such as domestic and industrial wastewater discharges) and stormwater systems requiring an NPDES stormwater permit when allocating pollutant load reductions required by a TMDL. However, the methodologies used to estimate nonpoint source loads do not distinguish between NPDES stormwater discharges and non-NPDES stormwater discharges, and as such, this source assessment section does not make any distinction between the two types of stormwater.

4.2.1 Point Sources

There are no permitted wastewater treatment facilities or industrial wastewater facilities that discharge directly to Lake Lena. However, two active National Pollutant Discharge Elimination System (NPDES) permitted facilities are located within the Lake Lena Run/Creek watershed (which is a part of the Lake Lena and Lena Run sub-basin modeled for Lake Hancock); the City of Auburndale Allred Waste Water Treatment Facility (WWTF) (NPDES FL0021466) and the Florida Distillers Company – Auburndale (NPDES FL0003051).

The Auburndale WWTF is an existing 1.4 million gallon a day (MGD) annual average daily flow complete mix extended oxidation ditch domestic wastewater treatment facility. The facility is operated to achieve secondary treatment with basic disinfection for land application of effluent and/or advanced secondary treatment with basic disinfection and dechlorination prior to discharging to Lake Lena Run, the outflow tributary from Lake Lena. Effluent disposal consists of a 0.65 MGD monthly average daily flow permitted surface water discharge (D001) to Lake Lena Run (see **Figure 4.1**).

The Florida Distillers facility is a citrus and cane molasses fermentation and bottling plant with a 2.6 MGD design capacity. The facility is involved in the manufacture of brandy, rum, and grain whiskey from cane, citrus, and grains. The materials are mashed with water, pasteurized, fermented, concentrated, and subsequently distilled, blended, and bottled. The liquid waste stream is evaporation condensate, cleaning water, cooling water and sanitary wastewater. The wastewater undergoes neutralization, flow equalization and biological treatment through an activated sludge plant. The effluent is chlorinated, aerated and discharged through Outfall D002. Effluent disposal consists of a 0.5 MGD monthly average daily flow permitted surface water discharge to Lake Lena Run, the outflow tributary from Lake Lena (see **Figure 4.1).**

The discharges from the Auburndale WWTP and Florida Distillers facility were considered significant enough, in terms of volumes and concentrations, to affect modeling results and as a result, were incorporated into the WAM model and in determining TMDL point source loads for Lake Hancock.

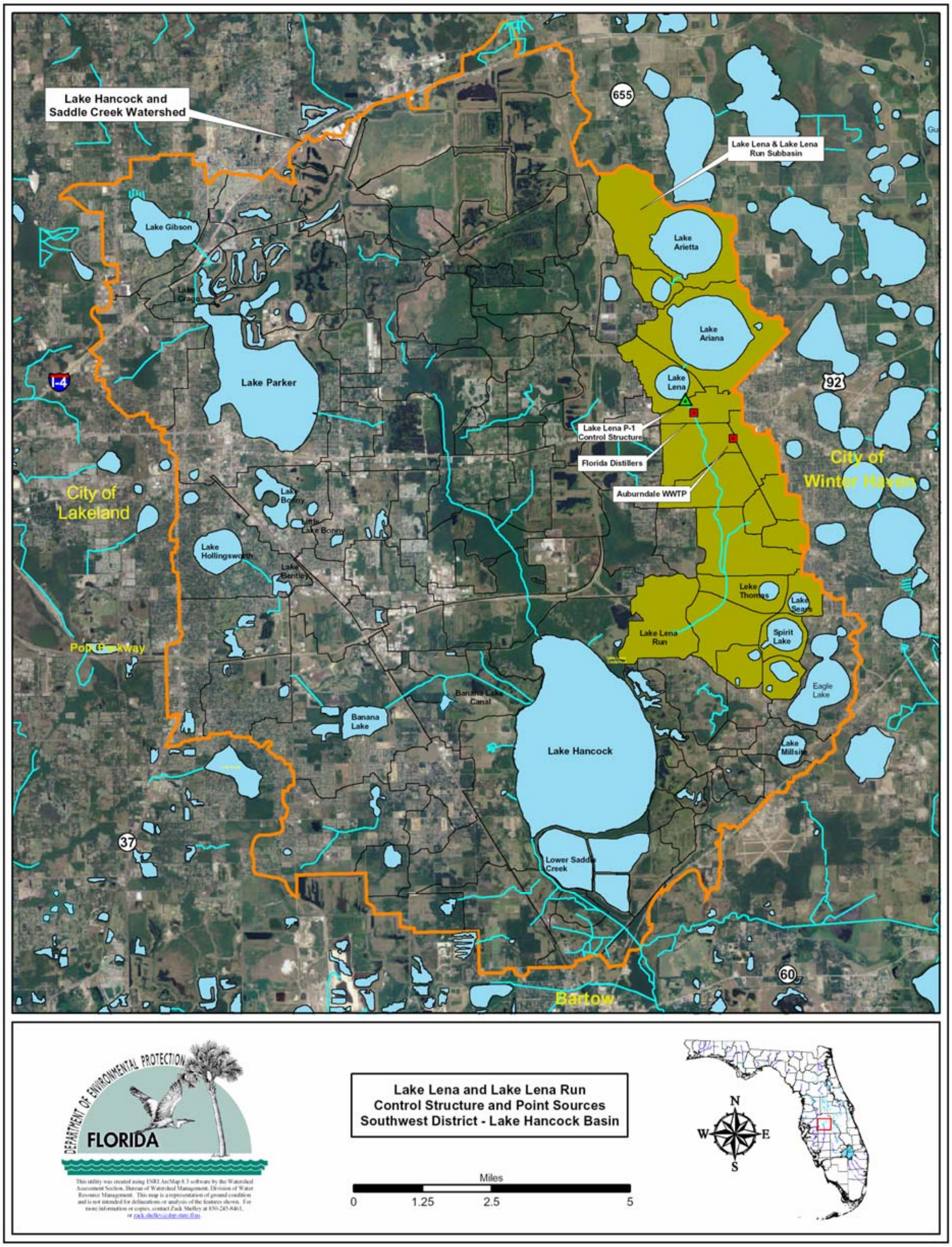


Figure 4.1 Lake Lena and Lake Lena Run Sub-basin Lake Control Structure and NPDES Point Sources Contributing to Lake Hancock and Lower Saddle Creek

Municipal Separate Storm Sewer System Permittees

Municipal separate storm sewer systems (MS4s) may discharge nutrients to waterbodies in response to storm events. To address stormwater discharges, the EPA developed the National Pollutant Discharge Elimination System (NPDES) stormwater permitting program in two phases. Phase I, promulgated in 1990, addresses large and medium MS4s located in incorporated places and counties with populations of 100,000 or more. Phase II permitting began in 2003. Regulated Phase II MS4s, which are defined in Section 62-624.800, F.A.C., typically cover urbanized areas serving jurisdictions with a population of at least 10,000 or discharge into Class I or Class II waters, or Outstanding Florida Waters.

The stormwater collection systems in the Lake Lena and Lake Lena Run sub-basin, which are owned and operated by Polk County in conjunction with the Florida Department of Transportation (FDOT), are covered by a NPDES Phase I MS4 permit. The Lake Lena and Lake Lena Run sub-basin is located within the Lake Hancock watershed. The Lake Hancock watershed is situated between the cities of Lakeland, Winterhaven, Auburndale, and Bartow. All of theses cities are Phase I MS4 co-permittees with City of Lakeland having portions of their jurisdiction located within the segment. At this time, it is unknown if local governments in the Lake Lena and Lake Lena Run sub-basin have applied for coverage under the Phase II NPDES MS4 permit. Currently, there are no known Polk County stormwater Capital Improvement Projects (CIPs) in the Lake Lena watershed or the Lake Lena Run sub-basin.

4.2.2 Nonpoint Sources and Land Uses

Unlike traditional point source effluent loads, nonpoint source loads enter at so many locations and exhibit such large temporal variation that a direct monitoring approach is often infeasible. For the Lake Lena TMDL, all nonpoint sources were evaluated by use of a watershed and lake modeling approach. **Table 4.1** shows the existing area of the various land use categories in the Lake Lena watershed. **Table 4.2** shows the existing area of the various land use categories examined and modeled for the Lake Lena and Lake Lena Run sub-basin. **Figure 4.2** shows the drainage area of Lake Lena and the spatial distribution of the land uses shown in **Table 4.1. Figure 4.3** shows the drainage area of the Lake Lena and Lake Lena Run sub-basin and the spatial distribution of the land uses is shown in **Table 4.2.**

The predominant land coverages for the Lake Lena watershed include low, medium, and high density residential areas (31.8%). Commercial and industrial related areas account for only 2.3 percent of the land use. Lakes and interconnected waterways account for 42.4 percent of the watershed. The areas occupied by anthropogenic land uses account for 42.9 percent of the watershed.

The predominant land coverages for the Lake Lena and Lake Lena Run sub-basin include low, medium, and high density residential (25.5%); followed by agriculture, pastures, and undeveloped land (23.9%); and commercial, industrial, and transportation (9.3%). These coverages account for 58.8 percent of the land use in the sub-basin. The lakes, creek, and interconnected waterways/streams/wetlands etc. account for 28.3 percent of the sub-basin. The areas occupied by anthropogenic land uses account for 59.4 percent of the watershed.

Land use coverages in the watershed and sub-basin were aggregated using the Florida Land Use, Cover and Forms Classification System (FLUCCS, 1999). The spatial distribution and acreage of different land use categories for WAM were identified using the 1999 land use coverage (scale 1:24,000) provided by the Southwest Florida Water Management District

(SWFWMD) contained in the Lake Hancock Basin WAM model developed by Soil and Water Engineering Technology, Inc. (2005).

Table 4.1 Lake Lena Watershed Existing Land Use Description

FLUCCS ID	Lake Lena Watershed Existing Land Use Coverage	Acres	Sq Miles	Percent
5201	Interconnected Lakes	2,040.64	3.189	39.44%
1200	Medium Density Residential, Fixed Single Family Units	1,297.84	2.028	25.08%
2100	Pastures and Fields	383.10	0.599	7.40%
2210	Citrus Groves	336.18	0.525	6.50%
2600	Old Field	253.21	0.396	4.89%
1100	Low Density Residential, Fixed Single Family Units	237.71	0.371	4.59%
1300	High Density Residential, Fixed Single Family Units	109.38	0.171	2.11%
1900	Undeveloped Land	96.73	0.151	1.87%
1400	Commercial and Services	94.22	0.147	1.82%
1700	Educational Facilities	82.18	0.128	1.59%
6300	Wetland Forested Mixed	61.40	0.096	1.19%
5200	Lakes	41.49	0.065	0.80%
6410	Freshwater Marshes	30.79	0.048	0.60%
7400	Barren Land	26.45	0.041	0.51%
4340	Hardwood - Conifer Mixed	20.71	0.032	0.40%
6150	Stream and Lake Swamps (Bottomland)	17.30	0.027	0.33%
8100	Transportation	17.26	0.027	0.33%
2410	Tree Nurseries	12.36	0.019	0.24%
8300	Utilities	7.41	0.012	0.14%
1800	Recreation	4.88	0.008	0.09%
6440	Emergent Aquatic Vegetation	2.47	0.004	0.05%
1500	Industrial	0.72	0.001	0.01%
8200	Communications	0.13	0.000	0.00%
Sum		**5,174.6**	**8.1**	**100%**

FLUCCS: Florida Land Use, Cover, and Forms Classification System, 1999.

Table 4.2 Lake Lena and Lake Lena Run Sub-basin Existing Land Use Description

FLUCCS ID	Lake Lena and Lake Lena Run/Creek Sub-basin Existing Land Use Coverage	Acres	Sq Miles	Percent
5201	Interconnected Lakes	2,421.6	3.784	18.54%
1200	Medium Density Residential, Fixed Single Family Units	2,367.3	3.699	18.13%
2100	Pastures and Fields	1,131.7	1.768	8.67%
1900	Undeveloped Land	963.7	1.506	7.38%
6150	Stream and Lake Swamps (Bottomland)	916.8	1.432	7.02%
1500	Industrial	662.2	1.035	5.07%
1100	Low Density Residential, Fixed Single Family Units	632.6	0.988	4.84%
2210	Citrus Groves	590.6	0.923	4.52%
1400	Commercial and Services	489.3	0.764	3.75%
4110	Pine Flatwoods	430.0	0.672	3.29%
2600	Old Field	427.5	0.668	3.27%
1300	High Density Residential, Fixed Single Family Units	333.6	0.521	2.55%
8300	Utilities	168.0	0.263	1.29%
6300	Wetland Forested Mixed	143.3	0.224	1.10%
3200	Prairies	131.0	0.205	1.00%
1700	Educational Facilities	126.0	0.197	0.96%
6410	Freshwater Marshes	126.0	0.197	0.96%
4340	Hardwood - Conifer Mixed	123.6	0.193	0.95%
1600	Extractive-Phosphorus Mining	121.1	0.189	0.93%
5200	Lakes	118.6	0.185	0.91%
3100	Herbaceous	111.2	0.174	0.85%
1800	Recreation	91.4	0.143	0.70%
7400	Barren Land	91.4	0.143	0.70%
5300	Reservoirs	76.6	0.120	0.59%
6200	Wetland Coniferous Forest	76.6	0.120	0.59%
8100	Transportation	64.2	0.100	0.49%
6430	Wet Prairies	37.1	0.058	0.28%
4200	Upland Hardwood Forest	34.6	0.054	0.26%
4100	Upland Coniferous Forests	24.7	0.039	0.19%
2410	Tree Nurseries	12.4	0.019	0.09%
6210	Cypress	4.9	0.008	0.04%
2140	Row Crops	2.5	0.004	0.02%
6440	Emergent Aquatic Vegetation	2.5	0.004	0.02%
6530	Inland Shores/Ephemeral Ponds	2.5	0.004	0.02%
8200	Communications	2.5	0.004	0.02%
Sum		**13,059.4**	**20.41**	**100%**

FLUCCS: Florida Land Use, Cover, and Forms Classification System, 1999.

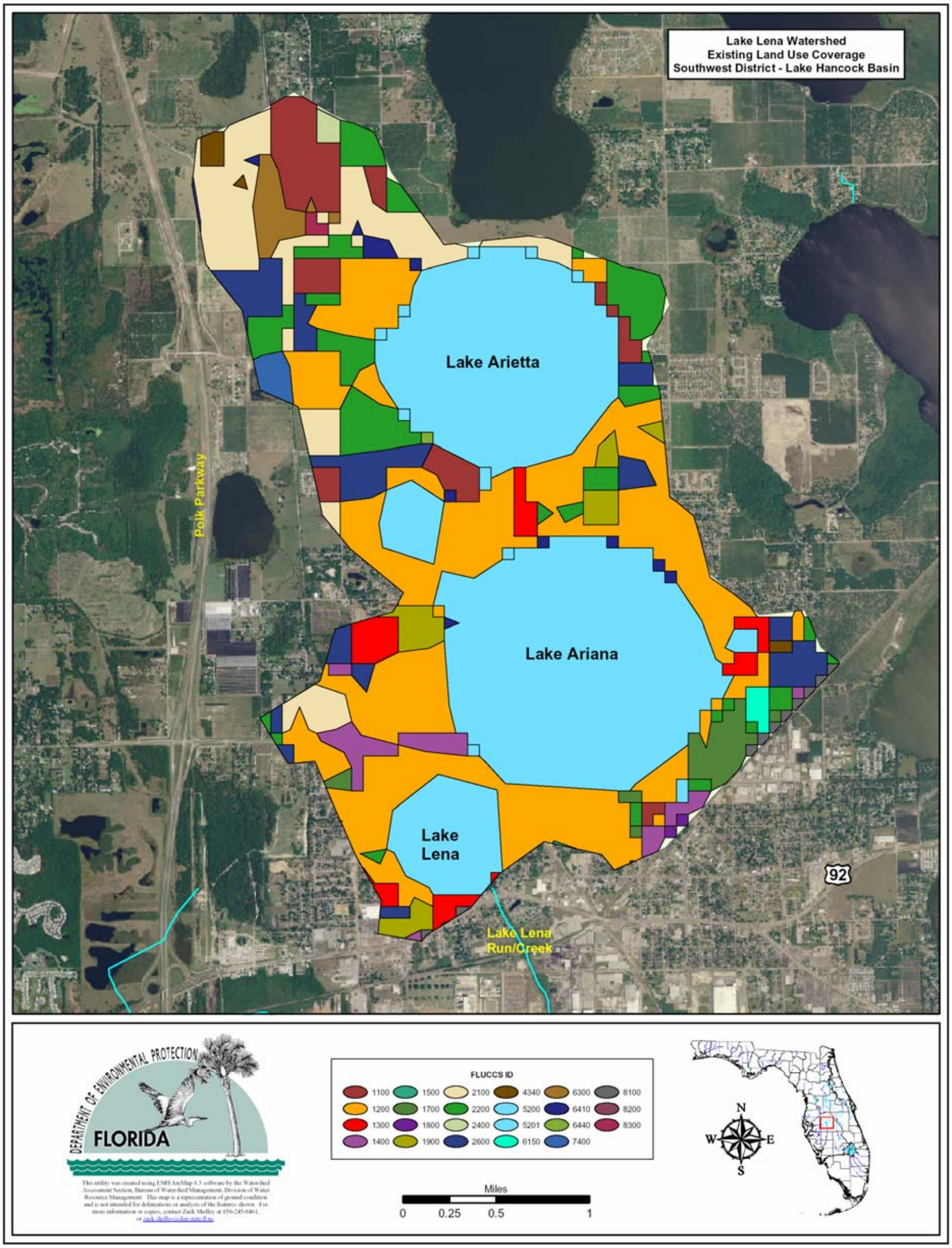


Figure 4.2 Lake Lena Watershed Existing Land Use Coverage

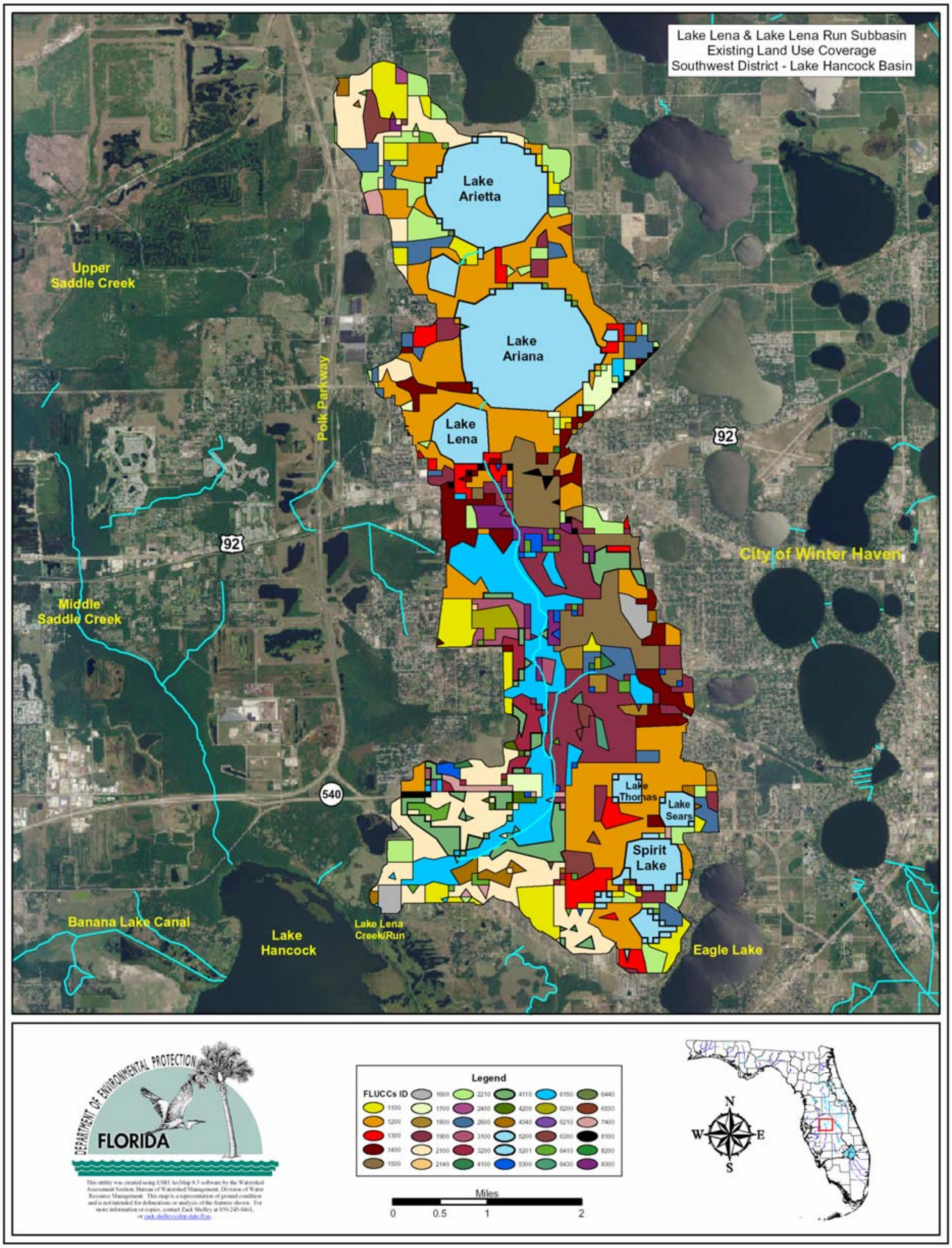


Figure 4.3 Lake Lena and Lake Lena Run/Creek Sub-basin Existing Land Use Coverage

Polk County Population

According to the U.S Census Bureau, the population density in Polk County, in the year 2000, was at or less than 258.2 people per square mile. The Census Bureau reports that the total population in 2000 for Polk County, which includes (but is not exclusive to) the Lake Lena watershed and sub-basin, was 483,924, with 226,376 housing units. Polk County occupies an area of approximately 2,009 square miles. For all of Polk County, the Bureau reported a housing density of 120.8 houses per square mile. Polk County is just below the average housing density for Florida counties with 134.3 housing units per square mile. (U. S. Census Bureau Web site, 2004).

Polk County Septic Tanks

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

As of 2001, Polk County had a cumulative registry of 112,848 septic systems. Data for septic tanks are based on 1970 – 2001 census results, with year-by-year additions based on new septic tank construction. The data do not reflect septic tanks that have been removed going back to 1970. From fiscal years 1993–2004, 1,151 permits for repairs were issued in Polk County (Florida Department of Health, 2004). Based on the number of permitted septic tanks and housing units (226,376) located in the county, approximately 50 percent of the housing units are connected to a central sewer line (i.e., wastewater treatment facility), with the remaining 50 percent utilizing septic tank systems.

4.3 Estimating Point and Nonpoint Source Loadings

Model Approach

The Watershed Assessment Model (WAM) was utilized to estimate the nutrient loads within and discharged from the Lake Hancock Basin. WAM is a Geographic Information System (GIS) based model that allows the Department to interactively simulate and assess the environmental effects of various land use changes and associated land use practices.

WAM utilizes ESRI^{TM} ArcView 3.2 with Spatial Analyst 2.0 to analyze and display model input and output using grids. Grid datasets, as opposed to polygon datasets, spatially represent geographic data as a collection of raster cells. Each cell contains attributes of the dataset, e.g. land use code numbers that can be overlaid with cells of other grids. The benefits of using grids over polygons include computational speed and output resolution. Output can be displayed by grid cell as opposed to by sub-basin polygon. The cell size is dependant on the desired resolution. A grid cell size of one hectare was chosen with the intent that this would adequately characterize the land use and capture linear features such as highways (SWET, 2005).

The water quality parameters (impact parameters) simulated within the model for Lake Lena and Lake Lena Run include: Water quantity, soluble nitrogen (N) forms (ammonia, soluble organic, nitrate), particulate N, ground water N, soluble phosphorus (P), particulate P, ground water P, sediment, 5-day biochemical oxygen demand (BOD_5), and land sourced dissolved oxygen. GIS datasets of land use, soils and rainfall are used to calculate the combined impact of the watershed characteristics for a given grid cell. Once the combined impact for each unique cell within a watershed is determined, the cumulative impact for the entire watershed is determined by attenuating the constituent to the sub-basin outlets. Constituents are attenuated based upon the flow distances (overland to nearest water body, through wetlands or depressions and within streams to the sub-basin outlet), flow rates in each related flow path and the type of wetland or depression encountered. **Figure 4.4** shows the conceptual routing schemes and flow distances that are calculated for each cell (SWET, 2005).

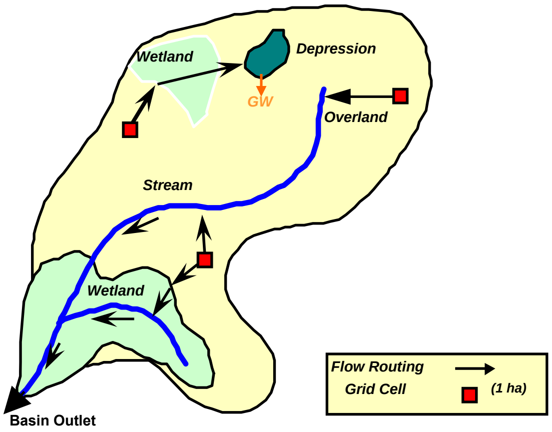


Figure 4.4 WAM Conceptual Routing Diagram (SWET, 2005)

A portion of the flow in each cell is converted to ground water based on the soil type and amount of imperviousness estimated for each land use. Surface flow that enters depressions is also converted to ground water. Ground water is routed to the nearest stream unless directed otherwise.

The hydrologic contaminant transport modeling is accomplished by first simulating all of the unique grid cell combinations of land use, soils, and rainfall by using one of several source cell models including GLEAMS (Knisel, 1993), EAAMOD (Bottcher et al., 1998; SWET, 1999), a wetland module, and an urban module. The time series outputs for each grid cell are then routed and attenuated to the nearest stream and then through the entire stream network of the watershed. Dynamic routing of flows is accomplished through the use of an algorithm, BLASROUTE.exe, that uses a non-linear reservoir technique (Jacobson et al., 1998). **Figure 4.5** shows a flow diagram of the hydrologic contaminant transport modeling component of the overall WAM model.

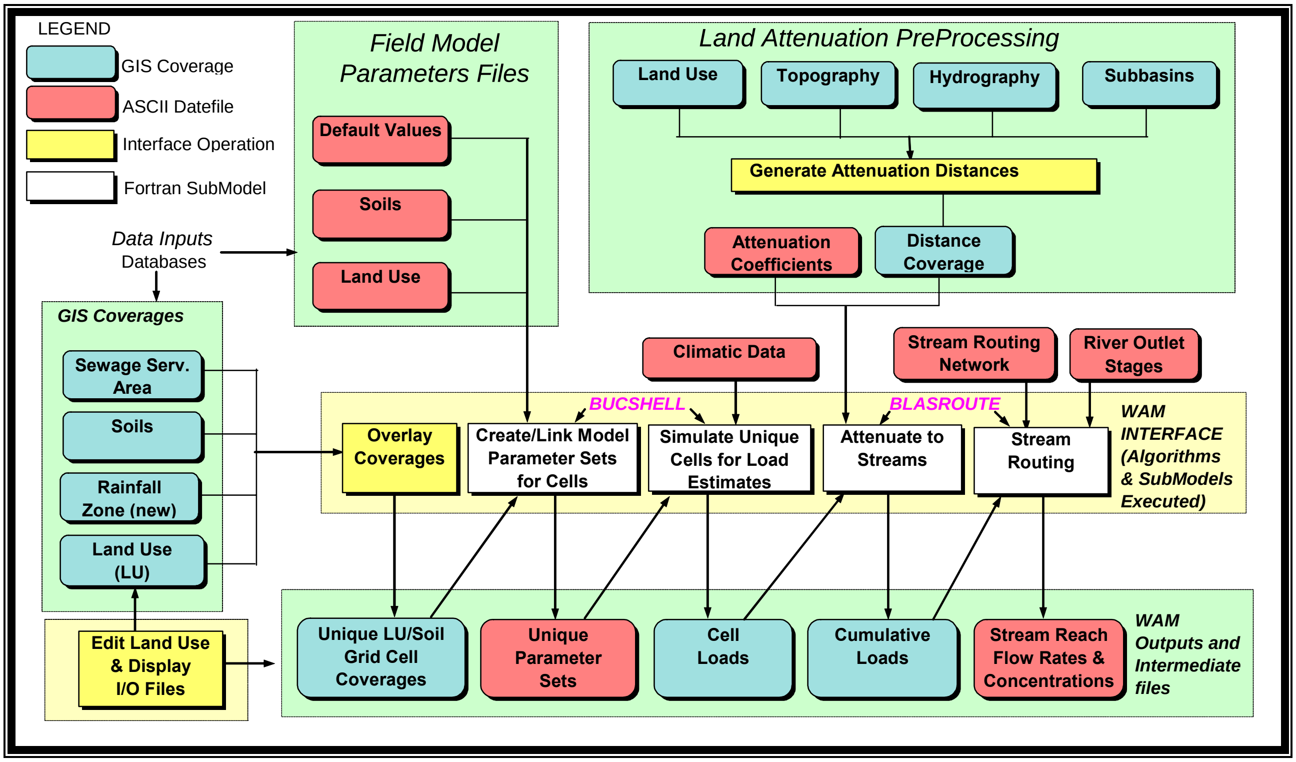


Figure 4.5 Dynamic Modeling Approach (SWET, 2005)

While BATHTUB has the capability to simulate large, sinuous reservoirs and lakes using multiple model cells, the size and nature of the eleven lakes evaluated supported the designation of one BATHTUB segment for each lake. However, because of the interconnectedness of the eleven lakes, all eleven lakes, including Lake Lena, were incorporated into a single BATHTUB model framework containing eleven linked segments. The outflow from each lake enters the next lake downstream. Surface water and ground water inputs are designated as tributaries in the model (one set to each lake). These inputs are provided by WAM, which was explicitly set up to output the incremental surface water and ground water quantity and quality flowing into each of the BATHTUB-simulated lakes. That is, the tributaries designated in the BATHTUB model have flows and concentrations that reflect their local upstream (between lakes) sources only. Ground water seepage from each lake is simulated using BATHTUB's channels. A schematic of the model framework is shown in **Figure 4.6**. All flows that do not point to a lake represent flows that are lost to the system. Daily WAM results were computed for he time period 1994 to 2003. The WAM results were averaged on annual basis to develop eleven separate BATHTUB model scenarios, one for each year (QEA, LLC, 2005).

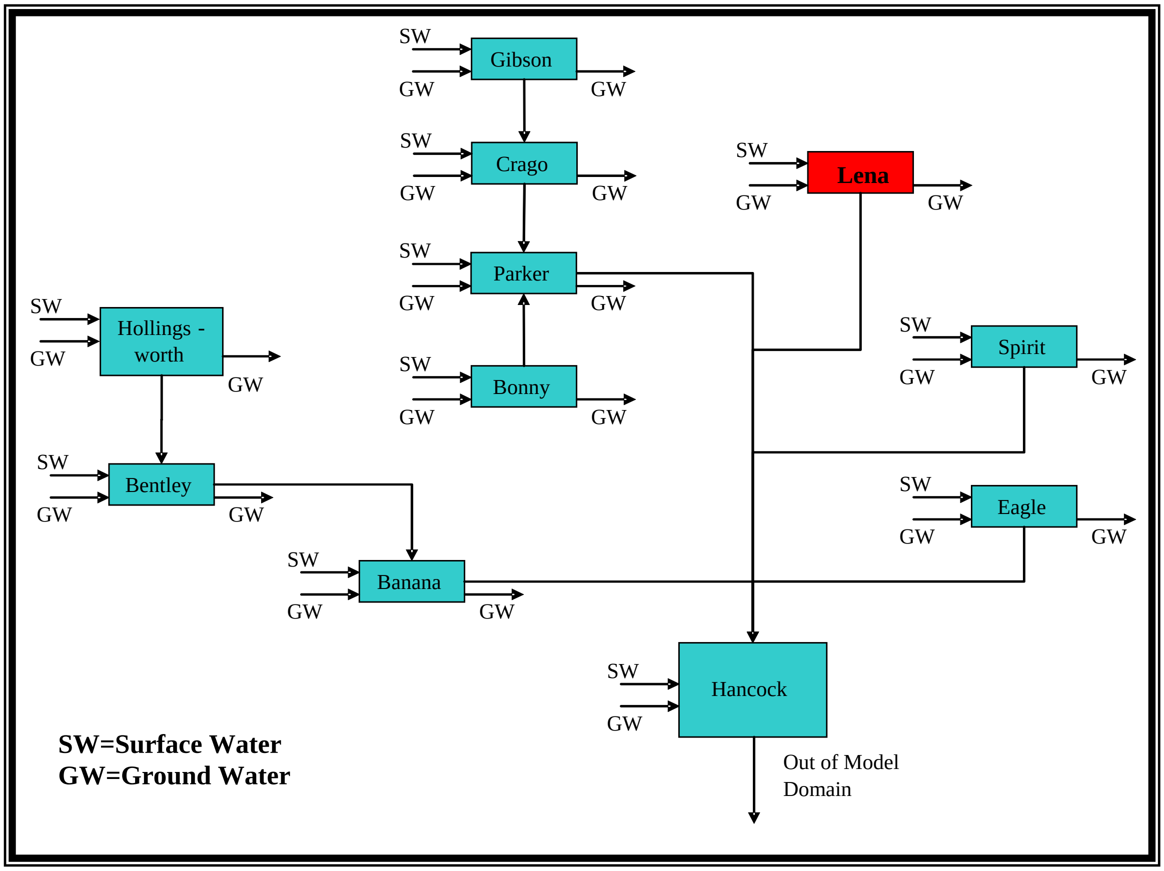


Figure 4.6 Model Schematic Depicting the Interconnected Eleven Lakes Modeled for The Lake Hancock Watershed (QEA, 2005)

GIS and model data set inputs for WAM included land use, soils, topography and depressions, hydrography, USGS gage and flow data, septic tanks, water use pumpage, point sources, rainfall, ground water, atmospheric deposition, solar radiation, control structures, attenuation distances, and stream reaches.

Inputs required for the BATHTUB model included annual data for rainfall (amount and TN and TP concentrations), evaporation, surface water inflow volumes and TN and TP loads, ground water inflow volumes and TN and TP loads, and leakage volume. Because BATHTUB is unable to vary the rainfall rate between lakes, it was decided that WAM would include rain inputs as part of its surface reach loads, so that the rain zones could be represented. Therefore, BATHTUB inputs show no rainfall. BATHTUB has been set up to simulate Lake Lena and its upstream watershed and lakes. The flow routing to and between lakes is built into both WAM and BATHTUB. Bathtub will route flow and constituents between lakes, but requires WAM to provide all flow and constituents generated above and between lakes (SWET, 2005).

Lake Lena Existing Land Use Loadings

The total loadings of nitrogen and phosphorus for Lake Lena were estimated using the WAM and BATHTUB models. Modeling frameworks were designed to simulate the period 1994 through 2003. This represented the planning and verified periods for Group 3 waterbodies located in the Lake Hancock Basin.

Based on the hydrology, and lake and stream interconnected reaches, nine major sub-basins were delineated in making up the Lake Hancock and Saddle Creek watershed. The nine sub-basins include Banana Lake and Banana Lake Canal, Cabbage Branch, Eagle Lake, K-Ville Branch, Lake Lena and Lake Lena Run/Creek, Lake Parker, Lower Saddle Creek, Middle Saddle Creek, and Upper Saddle Creek. Within the nine sub-basins making up the Lake Hancock watershed, eleven lakes were targeted and modeled based on nutrient impairment and the interconnected nature of the waterbodies contributing runoff and loadings to Lake Hancock and Lower Saddle Creek. The eleven lakes are Lake Gibson, Lake Crago, Lake Bonny, Lake Parker, Lake Lena, Lake Hollingsworth, Lake Bentley, Banana Lake, Spirit Lake, Eagle Lake, and Lake Hancock.

The eleven lakes are impaired for nutrients based on the Department’s Impaired Waters Rule (IWR) methodology. Each lake was modeled separately to determine individual contributions to Lake Hancock. **Table 4.3** illustrates the total water volume and loadings for TN and TP going into Lake Lena from 1994 to 2003 based on the WAM and BATHTUB model results under current/existing land use conditions. Loads were estimated based on lake surface rainfall, surface water inflow, ground water inflow and septic inflow. Ground water loss/leakage from each lake was also calculated and subtracted from the total inflow volume.

Table 4.3 Lake Lena Existing Land Use Water Volume and Loadings for TN and TP from 1994 to 2003

Lake Lena Loadings					
Year	**Water** (hm^3)	**TN** (kg)	**TN** (lbs)	**TP** (kg)	**TP** (lbs)
1994	3.091	4,862.648	10,720.306	380.469	838.792
1995	4.698	9,690.187	21,363.210	637.030	1,404.411
1996	1.915	1,550.221	3,417.653	229.254	505.419
1997	4.559	10,021.931	22,094.579	732.385	1,614.633
1998	5.603	9,849.340	21,714.081	794.594	1,751.781
1999	1.394	1,861.005	4,102.815	163.607	360.691
2000	1.113	2,326.550	5,129.166	126.907	279.783
2001	1.381	2,823.895	6,225.623	204.521	450.891
2002	2.829	3,903.195	8,605.074	374.815	826.326
2003	6.150	11,515.956	25,388.342	887.805	1,957.275
94-03 mean	3.3	5,840.5	12,876.1	453.1	999.0
94-03 totals	32.7	58,404.9	128,760.8	4,531.4	9,990.0

hm^3: Cubic Hectometers
kg: Kilograms
lbs: Pounds

Chapter 5: DETERMINATION OF ASSIMILATIVE CAPACITY

5.1 Determination of Loading Capacity

Nutrient enrichment and the resulting problems related to eutrophication tend to be widespread and are frequently manifested far (in both time and space) from their source. Addressing eutrophication involves relating water quality and biological effects (such as photosynthesis, decomposition, and nutrient recycling), as acted upon by hydrodynamic factors (including flow, wind, tide, and salinity) to the timing and magnitude of constituent loads supplied from various categories of pollution sources. The assimilative capacity should be related to some specific hydro-meteorological condition such as an ‘average’ during a selected time span or to cover some range of expected variation in these conditions.

As discussed in Chapter 4, the WAM model was selected as the watershed model. It was run dynamically through the ten-year period of record with all the lakes linked together in their current configuration. BATHTUB was selected as the lake model. It was set up with all the lakes linked together and the model calibrated based on the annual average output from WAM and run year-by-year (1994 – 2003) for all eleven lakes.

5.1.1 Rainfall

The long-term average for the two rainfall gages used in the model [Bartow (COOP: 080478) and Lakeland (COOP: 084797 and COOP: 084802) National Weather Service stations] was 52.01 inches/year. The 10-year average rainfall for the study period (1994 – 2003) was 55.23 inches for Lakeland (60th percentile of the Lakeland long-term record) and 55.19 inches for Bartow (71st percentile of the Bartow long-term record) (see **Table 5.1**). Therefore, the study period represented a wetter than average period. However, it contained a very dry year, the year 2000, that was the driest year with 38.3 inches of rain recorded in Lakeland (10th percentile of the long-term record) and with 35.9 inches recorded at Bartow (~ the 1st percentile of the long-term record). For the year 2000, evaporation exceeded rainfall. This created a year with very high in-lake concentrations in both the current condition and natural land use background scenario.

Table 5.1 Bartow and Lakeland, Florida, Rainfall Stations used for Model Loading and Calibration

Rainfall from Bartow and Lakeland		
Bartow	1900-2004 average = 53.7”	
Lakeland	1949-2004 average = 50.33”	
Year	**Lakeland**	**Bartow**
1994	67.13	60
1995	48.47	60.31
1996	52.85	46.1
1997	58.14	60.2
1998	54.41	62.33
1999	48.66	42.29
2000	38.26	35.87
2001	57.67	49.56
2002	66.58	71.44
2003	60.13	63.83
94-03 Average	55.23”	55.19”

Note: Lakeland stations missing data from September and October 1995.

5.1.2 Model Calibration

Watershed Assessment Model (WAM)

WAM was calibrated by consultants for conditions in the years 1994 – 2003. Calibration consisted of a water balance approach to match the measured in-lake stages and flows at flow measuring points. An ACCSESS database tool was created to aggregate the daily predictions for surface water and ground water (flows and TN, TP concentrations) up to annual average conditions in a format compatible with the requirements of the BATHTUB model. For details on the WAM model see “WAM Watershed Assessment Model, Model Documentation and Users Manual,” Soil and Water Engineering Technology, Inc., 2005 (**Appendix C**). For details on the model calibration see the WAM Final Report September 2005 (**Appendix D**).

BATHTUB Model

The consultant provided the Department with copies of ten BATHTUB input decks (one for each year 1994- 2003) set up for current conditions but not calibrated. The Department calibrated the BATHTUB model which consisted of running each model year through all of the model options to determine which set of models provided the best uncalibrated fit to the measured data. As a result of running through these models, it became apparent that for many of the lake/year combinations the watershed model was not delivering enough mass to match the measured data for either TN or TP. However, in other lake/year combinations, there was too much mass. Once a set of models was selected the primary calibration for TN and TP was achieved by invoking BATHTUBs internal loading rate functions for both TN and TP to match the measured in-lake mass. This Internal Loading rate (IL) integrates all of the missing mass. It is not proposed that the IL rate represents only those in-lake processes that either recycle mass within the lake or fix nitrogen from the atmosphere; it also includes all other missing mass. As such, it will be referred to as the ‘missing mass.’ Chlorophyll a was calibrated using the BATHTUB calibration coefficient. Each lake/year combination was calibrated individually, but once the chlorophyll a calibration was set, it remained unchanged for all other BATHTUB simulations (background and TMDL development).

The phosphorous model that best fit Lake Lena was Model 4. The nitrogen model selected was Model 1, Second-Order, Available N model. The chlorophyll a mode selected was Model 1, for P, N, Light and Flushing. Details regarding the selected modes can be found in the BATHTUB Users Manual (U.S. Army Corps of Engineers, 1999; Walker, W.W., 2004). **Figures 5.1 through 5.4** illustrate the measured data and calibrated data for TN, TP, Chlorophyll a, and TSI respectively for Lake Lena for the ten-year modeled period (1994 – 2003).

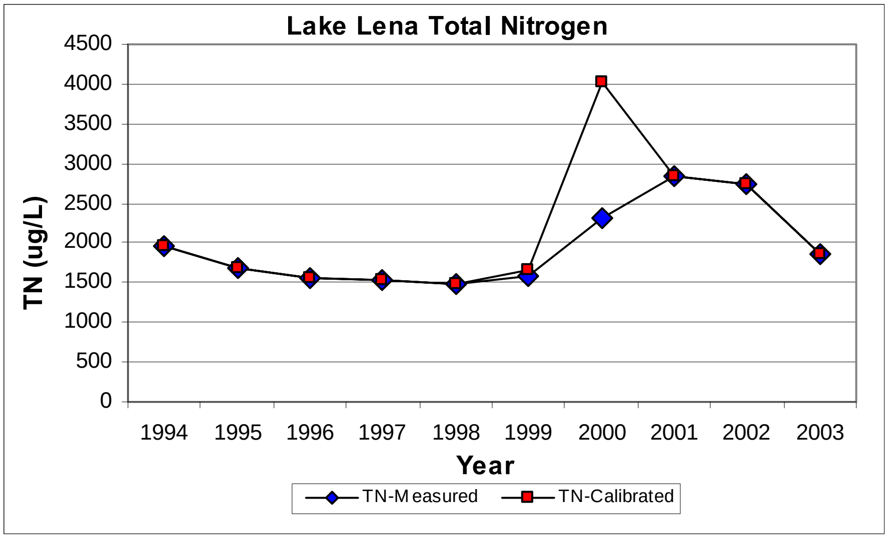


Figure 5.1 Lake Lena Total Nitrogen Measured and Calibrated Data from 1994 to 2003

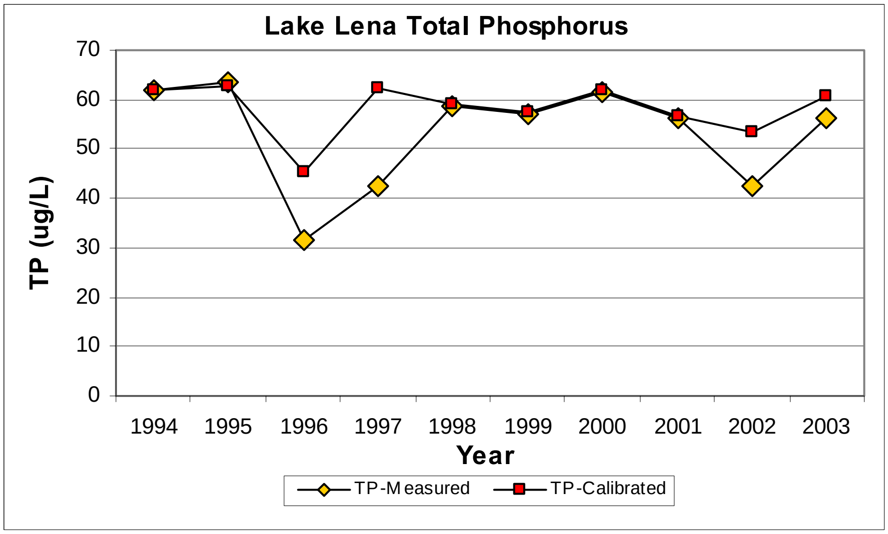


Figure 5.2 Lake Lena Total Phosphorus Measured and Calibrated Data from 1994 to 2003

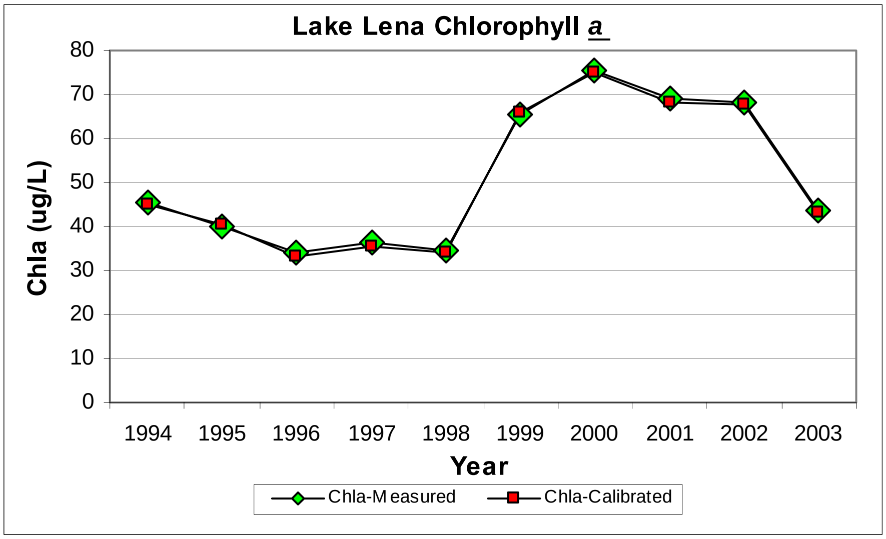


Figure 5.3 Lake Lena Chlorophyll *a* Measured and Calibrated Data from 1994 to 2003

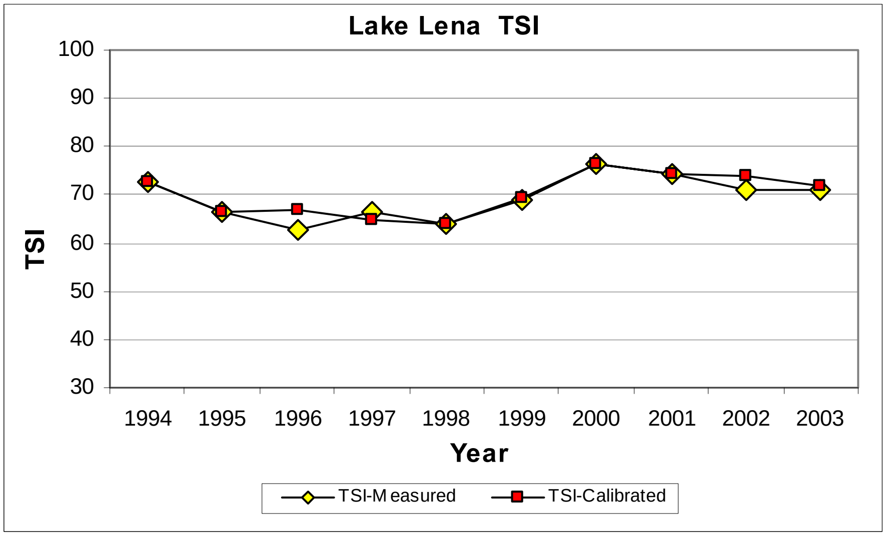


Figure 5.4 Lake Lena TSI Measured and Calibrated Data from 1994 to 2003

5.1.3 Background Conditions

WAM Model

WAM was used to describe and evaluate the “natural land use background condition” for the entire Lake Hancock watershed. For this simulation all current land uses were ‘reassigned’ to a mixture of Herbaceous, Prairies, Other Shrubs and Brush, Upland Coniferous Forest, Pine Flatwoods, Upland Hardwoods Forest, Hardwood Conifer Mix (the majority), Lakes, Interconnected Lakes, Reservoirs, Mixed Wetland Hardwoods, Streams and Lakes Swamps (bottomlands), Wetland Coniferous Forest, Cypress, Wetland Forested Mix, Freshwater Marshes, Wet Prairies, Emergent Aquatic Vegetation, Inland Shores and Ephemeral Ponds. The current condition was maintained for all waterbody physical characteristics. From this point forward, the natural land use background will be referred to as “background.”

At first, the WAM was run with current rates of seepage around waterbodies and leakance from inside waterbodies. This resulted in such a large reduction in the total water flowing into the lakes that even with the significant reduction in external watershed loading, several lake/year combinations had higher concentrations of TN, TP, and chlorophyll a than under current conditions as the evaporation of 1.32 meters nearly exceeded inflow and the lakes dried up. To account for this water loss in the background condition, seepage around the lakes was adjusted back to background conditions in the model and leakance was adjusted down (50 percent of current rate) until the lake stages and surface areas approximated current conditions. Even under this scenario the total water inflowing to the lakes under the background scenario was less than current conditions, particularly in the drier years (1996 and 2000). Again, this resulted in concentrations for some lake/year combinations being as great as they are under current conditions. In other words, the watershed model is indicating that under ‘natural landuse’ dry conditions the lakes would have a trophic state similar to that of today. Conversely, under average or wet conditions the natural land use trophic states were significantly less than current conditions.

BATHTUB Model

After achieving acceptable WAM background results, the BATHTUB model was run with no reduction in the total amount of missing mass (internal loading rate). As expected with the reduction in total flow for the background condition and with no attenuation of the missing mass, many of the lake/year combinations did not improve. In fact, for the dry years the background condition was still worst than the current condition. In an effort to find the natural background, reductions in the missing mass were made. First, the BATHTUB model was used to identify the total external load of TN and TP under both the current condition and the background condition. Then the ratio of the change in external load between the background condition and the current condition (background/current) was applied to the missing mass (internal loading rate). This was called the attenuated case (A). This brought the in-lake trophic states down in the average and wet years, but many of the dry year lake trophic states remained higher in the background condition than in the current condition. As a result, the remaining missing mass was reduced until the worst case dry year trophic state was below the current conditions. This required an additional 75 percent reduction in the missing mass remaining after attenuation.

The modeling abbreviations used in the tables, figures and report are explained below:

<u>Abbreviations Used</u>

L 100 = leakance at current conditions (calibrated model)
L50 = leakance reduced from current conditions by 50 percent
L0 = leakance reduced to near zero (0.01 m)
PC = results from calibrated BATHTUB model
IL = missing mass (used internal loading rate to achieve mass balance in model calibration)
ILA = missing mass changed by the ratio of the change in external mass of background/current condition.
IL50 = ILA plus an additional 50 percent reduction in missing mass
IL75 = ILA plus an additional 75 percent reduction in missing mass
ILNIL = all missing mass eliminated (loading rate = 0.0)

5.2 Selection of the TMDL Target

It should be recognized that the direct application of natural background as the target TSI would not allow for any assimilative capacity. The IWR uses as one measure of impairment in lakes, a 10 unit change in TSI from “historical” levels. This 10 unit increase is assumed to represent the transition of a lake from one trophic state (say mesotrophic) to another nutrient enriched condition (eutrophic). The Department has assumed that allowing a 5 unit increase in TSI over the natural background condition would prevent a lake from becoming impaired (changing trophic states) and reserve 5 TSI units to allow for future changes in the basin and as part of the implicit margin of safety in establishing the assimilative capacity.

After examining all the background runs for Lake Lena, it was decided that the scenario with leakance set at 50 percent of the current condition and the attenuated missing mass reduced by an additional 75 percent represented the natural land use background condition. These conditions resulted in a TSI of 60.01. As has been Department practice, when acceptable background conditions can be established the target for TMDL development becomes the background TSI plus 5 TSI units. This raises the target TSI for Lake Lena to 65.01 (60.1 + 5 TSI units).

Based on achieving the TMDL targets for each year of the ten-year period of record, a long-term annual average TMDL for TSI was set at 64.5. The range in TSI TMDL targets was between 60.4 and 72.1. Once the target TSI was established (a TSI of 65.01), BATHTUB was rerun with decreasing loads until the target TSI was met.

The required annual average percent reduction for TN coming into Lake Lena was 45.3 percent with an allowable long-term annual average loading of 7,036.2 kg/year (15,512.2 lbs/year). The required annual average percent reduction for TP coming into the lake was 26.6 with an allowable long-term annual average loading of 397.4 kg/year (876.1 lbs/year). The annual percent reductions ranged between 33 and 67 for TN and between 13 and 52 for TP. These reductions correspond to a range in loadings of 893.3 kg/year (1,969.4 lbs/year) to 14,838.3 kg/year (32,712.9 lbs/year) for TN and between 129.2 kg/year (284.8 lbs/year) to 728 kg/year (1,604.9 lbs/year) for TP. Maintaining the long-term annual average loadings for TN and TP established in this TMDL should result in attaining the annual average TSI of 64.5.

Table 5.2 shows the TSI for the calibrated model (PC), the background model (IL75), the TMDL Target TSI, TMDL-TSI, and the percent reduction. **Table 5.3** shows the mass for TN and TP for the calibrated model, TMDL, and percent reductions. **Table 5.4** shows the annual average concentrations for TN, TP, and chlorophyll a. **Figures 5.5** through **5.8** illustrate the TMDL target, calibrated data, and L50-IL75 for TN, TP, Chlorophyll a, and TSI respectively for Lake Lena for the ten-year modeled period (1994 – 2003).

Table 5.2 TSI for PC, Background, TMDL Target, and TSI-Unit Reduction

Lake Lena TSI for PC, Background, TMDL Target, TMDL, and TSI-unit reduction Based on Background L50-IL75

Year	PC	Background IL75	Target IL75+5	TMDL	TN % Reduction	TP % Reduction
1994	72.5	60.28	65.28	65.03	41	13
1995	66.31	57.84	62.84	62.79	45	18
1996	66.69	57.76	62.76	60.43	33	18
1997	64.84	55.81	60.81	60.74	44	25
1998	64.07	56.07	61.07	61.03	34	20
1999	69.3	58.14	63.14	63.13	52	52
2000	76.24	67.11	72.11	72.1	42	42
2001	74.49	64.27	69.27	69.29	45	45
2002	73.75	63.85	68.85	67	67	15
2003	71.99	58.93	63.93	63.19	50	18
Minimum	64.07	55.81	60.81	60.43	33	13
Maximum	76.24	67.11	72.11	72.1	67	52
Average	70.02	60.01	65.01	64.47	45.3	26.6

Table 5.3 Mass for TN and TP for Calibrated Model, TMDL, and Percent Reduction

Lake Lena Mass for TN and TP for Calibrated Model and TMDL, with mass percent reductions (kg/year)

Year	TN-MASS Calibrated	TN-MASS TMDL	TN-MASS % Reduction	TP-MASS Calibrated	TP-MASS TMDL	TP-MASS % Reduction
1994	15,225.1	8,982.8	41	566.1	492.5	13
1995	19,333.9	10,633.7	45	776.6	636.8	18
1996	4,681.8	3,136.8	33	229.3	188.0	18
1997	15,377.8	8,611.6	44	732.4	549.3	25
1998	18,579.7	12,262.6	34	794.6	635.7	20
1999	1,861.0	893.3	52	290.0	139.2	52
2000	2,326.6	1,349.4	42	270.7	157.0	42
2001	4,203.1	2,311.7	45	235.0	129.2	45
2002	22,247.5	7,341.7	67	374.8	318.6	15
2003	29,676.6	14,838.3	50	887.8	728.0	18
Minimum	1,861.0	893.3	33	229.3	129.2	13
Maximum	29,676.6	14,838.3	67	887.8	728.0	52
Average	13,351.3	7,036.2	45.3	515.7	397.4	26.6

Table 5.4 Lake Lena Annual Average Concentrations for TN, TP, and Chlorophyll a

Lake Lena Annual Average Concentrations for TN, TP, and Chlorophyll a (µg/L)												
Year	Measured TN	Calibrated TN	TMDL TN	Background TN	Measured TP	Calibrated TP	TMDL TP	Background TP	Measured Chl a	Calibrated Chl a	TMDL Chl a	Background Chl a
1994	1954.8	1955.3	1437.8	798.8	62	61.9	57.4	57.1	45.5	44.8	40.3	31.2
1995	1690	1690.8	1176	678.7	63.5	62.9	56	55.7	40	40.5	34.4	25.3
1996	1546.8	1546.7	1224.5	847.4	31.7	45.3	40.9	40.7	34.3	33.4	29.5	26.3
1997	1527.5	1527.1	1066.9	633.7	42.3	62.3	52.5	52.2	36.4	35.7	28.8	20.9
1998	1479.5	1479	1143.4	661.3	58.5	58.9	51.3	50.4	34.5	34	29.1	21.5
1999	1590.3	1655.8	1077.7	650.5	57	57.6	41.4	38	65.6	57.9	46.5	34.8
2000	2305	4020.6	3057	1937	61.7	62.1	49.6	38.6	75.4	68.9	60.9	45.8
2001	2832.5	2832.1	2025.7	1673.5	56.3	56.6	43.1	33.5	69.2	64.4	52	39
2002	2743.3	2743.4	1444.2	963.5	42.3	53.4	48.7	48.6	68.2	59	58.6	50.1
2003	1867.1	1867	1222.5	750.9	56.1	60.7	53.6	52.4	43.8	43.1	36.4	28.6
Minimum	1479.5	1479	1066.9	633.7	31.7	45.3	40.9	33.5	34.3	33.4	28.8	20.9
Maximum	2832.5	4020.6	3057	1937	63.5	62.9	57.4	57.1	75.4	68.9	60.9	50.1
Average	1953.7	2131.8	1487.6	959.5	53.1	58.2	49.4	46.7	51.3	48.2	41.6	32.3

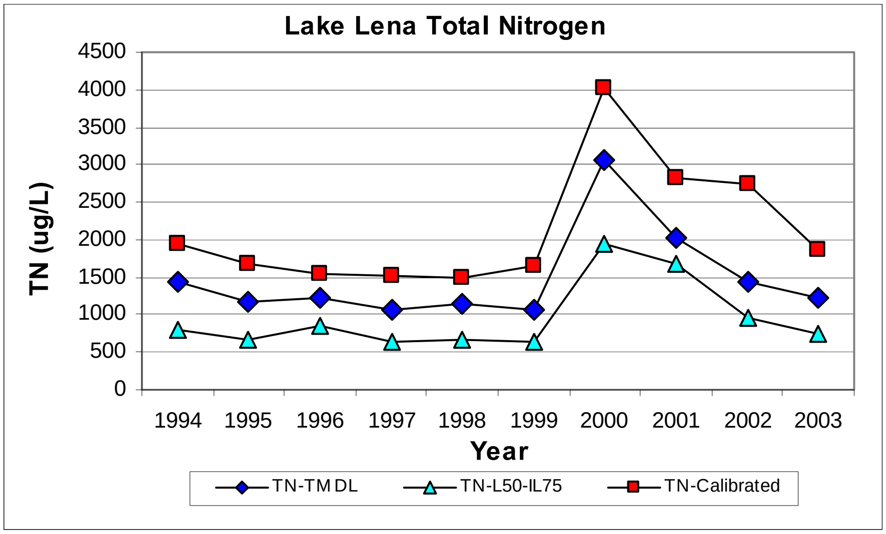


Figure 5.5 Lake Lena Total Nitrogen Target TMDL, Background Calibration, and L50-IL75 from 1994 to 2003

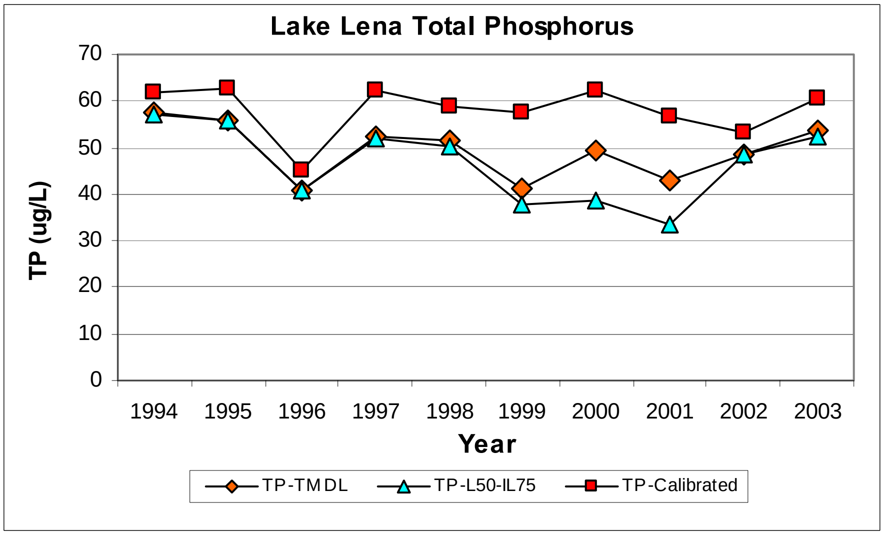


Figure 5.6 Lake Lena Total Phosphorus Target TMDL, Background Calibration, and L50-IL75 from 1994 to 2003

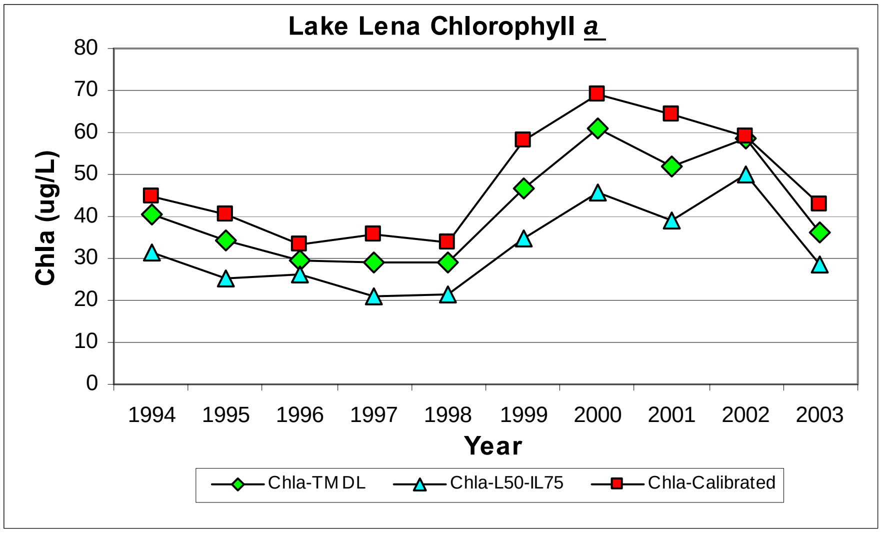


Figure 5.7 Lake Lena Chlorophyll *a* Target TMDL, Background Calibration, and L50-IL75 from 1994 to 2003

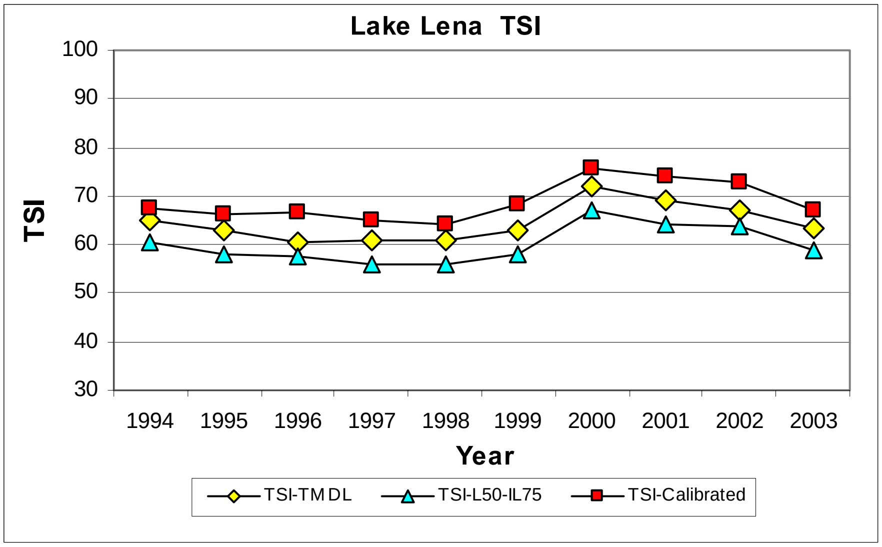


Figure 5.8 Lake Lena TSI Target TMDL, Background Calibration, and L50-IL75 from 1994 to 2003

5.3 Critical Conditions

The estimated assimilative capacity was based on annual average conditions (i.e., values from all four seasons in calendar year 2003) rather than critical/seasonal conditions because (a) the methodology used to determine the assimilative capacity does not lend itself very well to short-term assessments, (b) the Department is generally more concerned with the net change in overall primary productivity in the segment, which is better addressed on an annual basis, and (c) the methodology used to determine impairment is based on an annual average and requires data from all four quarters of a calendar year.

Chapter 6: DETERMINATION OF THE TMDL

6.1 Expression and Allocation of the TMDL

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

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

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

It should be noted that the various components of the TMDL equation may not sum up to the value of the TMDL because a) the WLA for NPDES stormwater is typically based on the percent reduction needed for nonpoint sources and is accounted for within the LA, and b) 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 a mass per day].

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

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**. The TMDL for Lake Lena is expressed in terms of pounds per year (converted from kilograms per year as shown in Chapter 5) and percent reductions, and represent the long-term annual average load of TN and TP the waterbody can assimilate and maintain the Class III narrative nutrient criterion (**see Table 6.1).**

Table 6.1 Lake Lena TMDL Load Allocations

WBID	Parameter	WLA		LA (lbs/year)	MOS	TMDL (lbs/year)	Percent Reduction
		Wastewater (lbs/year)	Stormwater (% reduction)				
1501	TN	NA	45.3	15,512.2	Implicit	15,512.2	45.3
1501	TP	NA	26.6	876.1	Implicit	876.1	26.6

6.2 Load Allocation (LA)

The allowable LA is 15,512.2 lbs/year for TN and 876.1 lbs/year for TP. This corresponds to reductions from the existing loadings of 45.3 percent for TN and 26.6 percent for TP. It should be noted that the LA may include loading from stormwater discharges regulated by the Department and the Water Management District that are not part of the NPDES Stormwater Program **(see Appendix A).**

6.3 Wasteload Allocation (WLA)

NPDES Wastewater Discharges

As noted in Chapter 4, Section 4.2.1, there are two active National Pollutant Discharge Elimination System (NPDES) permitted facilities located within the Lake Lena Run/Creek watershed. Lake Lena Run is a part of the Lake Lena and Lake Lena Run sub-basin modeled for Lake Hancock. However, the $\text{WLA}_{\text{wastewater}}$ for the Lake Lena TMDL is not applicable because there are no wastewater or industrial wastewater NPDES facilities that discharge directly to Lake Lena or its watershed.

NPDES Stormwater Discharges

The wasteload allocation for stormwater discharges is a 45.3 percent reduction in loading for TN and 26.6 percent reduction in loading for TP, which is the required percent reductions in nonpoint sources. It should be noted that any MS4 permittee will only be responsible for reducing the loads associated with stormwater outfalls for which it owns or otherwise has responsible control, and is not responsible for reducing other nonpoint source loads within its jurisdiction.

6.4 Margin of Safety (MOS)

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

The MOS can either be implicitly accounted for by choosing conservative assumptions about loading or water quality response, or explicitly accounted for during the allocation of loadings. Consistent with the recommendations of the Allocation Technical Advisory Committee (Florida Department of Environmental Protection, February 2001), an implicit margin of safety (MOS) was used in the development of the Lake Parker TMDL. An implicit MOS was used because the TMDL was based on the conservative decisions associated with a number of the modeling assumptions and allowing for a10 TSI unit increase (5 TSI units above natural background conditions and an additional 5 TSI units to allow for future changes in the watershed) in determining the assimilative capacity (i.e., loading and water quality response) for Lake Lena.

Chapter 7: NEXT STEPS: IMPLEMENTATION PLAN DEVELOPMENT AND BEYOND

Following adoption of this TMDL by rule, the next step in the TMDL process is to develop an implementation plan for the TMDL, which will be a component of the Basin Management Action Plan for the Lake Lena watershed. This document will be developed in cooperation with local stakeholders and will attempt to reach consensus on more detailed allocations and on how load reductions will be accomplished.

The Basin Management Action Plan (BMAP) will include:

- Appropriate allocations among the affected parties.
- A description of the load reduction activities to be undertaken.
- Timetables for project implementation and completion.
- Funding mechanisms that may be utilized.
- Any applicable signed agreements.
- Local ordinances defining actions to be taken or prohibited.
- Local water quality standards, permits, or load limitation agreements.
- Monitoring and follow-up measures.

It should be noted that TMDL development and implementation is an iterative process, and this TMDL will be re-evaluated during the BMAP development process and subsequent Watershed Management cycles. The Department acknowledges the uncertainty associated with TMDL development and allocation, particularly in estimates of nonpoint source loads and allocations for NPDES stormwater discharges, and fully expects that it may be further refined or revised over time. If any changes in the estimate of the assimilative capacity AND/OR allocation between point and nonpoint sources are required, the rule adopting this TMDL will be revised, thereby providing a point of entry for interested parties.

References

Abtew, Wossenu, 1992. *An Atlas of the Lower Kissimmee and Lake Istokpoga Surface Water Management Basins*. South Florida Water Management District (SFWMD) Technical Memorandum DRE # 313.

Baniukiewicz, A. and D. Gilbert, 2004. *Nutrients Total Maximum Daily Load for Lake Hunter, Polk County, Florida.* Florida Department of Environmental Protection, Division of Water Resource Management, Watershed Assessment Section, Tallahassee, Florida, September, 2004.

BCI Engineers & Scientists, Inc. 2005. *Lake Hancock Lake Level Modification Preliminary Evaluation, Final Report*. Prepared for the Southwest Florida Water Management District, Brooksville, Florida.

Bottcher, A.B, N.B. Pickering, and A.B. Cooper, 1998. *EAAMOD-FIELD: A Flow and Phosphorous Model for High Water Tables*. Proceedings of the 7th Annual Drainage Symposium. American Society of Agricultural Engineers, St. Joseph, MI.

Bottcher, A.B., J.G. Hiscock, and B.M. Jacobson, 2002. *Watershed Assessment Model (WAM), a Geographic Information System (GIS) Approach to Watershed Assessment Modeling*. Proceeding of the Watershed 2002 Pre-Conference Modeling Workshop. Ft. Lauderdale, FL. Publisher: Water Environment Federation. Alexandria, VA.

Camp, Dresser, & McKee, 2002. *Lake Hancock Restoration Management Plan, Final Report.* Prepared for the Polk County Board of Commissioners and Florida Department of Environmental Protection. Prepared by CDM, January, 2002.

City of Lakeland, 2001. *City of Lakeland Lakes Water Quality Report, 1988 to 2000.* Prepared by the City of Lakeland, Public Works Department, Lakes and Stormwater Division, Lakeland, Florida, August 2001. Web site available at http://www.lakelandgov.net/publicworks/lakes/files/CC61F2B4E0FF48779DC9B308EFCF5B2E.pdf.

City of Lakeland, 2005. *Lakeland 2005 Capitol Improvement Projects.* Prepared by the City of Lakeland, Public Works Department, Lakes and Stormwater Division, Lakeland, Florida. Available at http://www.lakelandgov.net/publicworks/lakes/files/023793F01E65428D9DBEBA1E0F14A82B.pdf.

Environmental Research & Design, Inc., 2005. *Physical and chemical characterization of Lake Hancock surface water*. Prepared for Parsons Water and Infrastructure. Prepared by ERD, Orlando, Florida, March, 2005.

Environmental Research & Design, Inc., 2002. *Lake Morton Water Quality Diagnostic Evaluation*. Prepared by ERD, Orlando, Florida, December, 2002.

Florida Department of Environmental Protection, February 2001. *A Report to the Governor and the Legislature on the Allocation of Total Maximum Daily Loads in Florida.* Florida Department of Environmental Protection, Allocation Technical Advisory Committee, Division of Water Resource Management, Bureau of Watershed Management, Tallahassee, Florida.

—, April 2001. Chapter 62-302, *Surface Water Quality Standards,* Florida Administrative Code (*F.A.C.*), Florida Department of Environmental Protection, Division of Water Resource Management, Bureau of Watershed Management, Tallahassee, Florida.

—, April 2001. *Chapter 62-303, Identification of Impaired Surface Waters Rule (IWR), Florida Administrative Code*. Florida Department of Environmental Protection, Division of Water Resource Management, Bureau of Watershed Management, Tallahassee, Florida.

—, June 2004. Division of Water Resource Management, Bureau of Information Systems, Geographic Information Systems Section, Florida Department of Environmental Protection, Tallahassee, Florida. Available at http://www.dep.state.fl.us/gis/contact.htm

—, October 2004. *Group 3 Sarasota Bay and Peace and Myakka Rivers Water Quality Assessment Report.* Florida Department of Environmental Protection, Division of Water Resource Management, Watershed Assessment Section, Southwest District, Group 3 Basin, Tallahassee, Florida.

—, June 2005. *Wastewater Facility Regulation (WAFR), Facility Detail Report.* Division of Water Resource Management, Florida Department of Environmental Protection, Tallahassee, Florida. Available at http://www.dep.state.fl.us/water/wastewater/index.htm.

Florida Department of Health, July 2004. Florida Department of Health web site. Available at http://www.doh.state.fl.us/
; or http://www.doh.state.fl.us/environment/OSTDS/statistics/ostdsstatistics.htm.

Florida Department of Transportation, 1999. *Florida Land Use, Cover and Forms Classification Systen (FLUCCS)*. Florida Department of Transportation Thematic Mapping Section.

Friedemann, M. and Hand, J., 1989. *Typical Water Quality Values for Florida Lakes, Streams, and Estuaries.* Florida Department of Environmental Regulation, Bureau of Surface Water Management, Standards and Monitoring Section, Tallahassee, Florida.

FWRA, 1999. *Florida Watershed Restoration Act,* Chapter 99-223, Laws of Florida.

Gao, X., D. Gilbert, and W. Magley, 2005. *Nutrient Total Maximum Daily Load for Alachua Sink, Alachua County, Florida*. Florida Department of Environmental Protection, Division of Water Resource Management, Watershed Assessment Section, Tallahassee, Florida, February, 2005.

Gao, X., 2005. *Nutrient and Unionized Ammonia Total Maximum Daily Loads for Lake Jesup, Seminole County, Florida*. Florida Department of Environmental Protection, Division of Water Resource Management, Watershed Assessment Section, Tallahassee, Florida, August, 2005.

Guardo, Mariano, 1992. *An Atlas of the Upper Kissimmee Surface Water Management Basins*. Southwest Florida Water Management District (SWFWMD) Technical Memorandum DRE # 309.

Harper, H.H., 1994. *Stormwater Loading Rate Parameters for Central and South Florid.* Environmental Research and Design, Inc., Orlando, Florida, October, 1994.

Harper, H.H. and Baker, D. M., 2003. *Evaluation of Alternative Stormwater Regulations for Southwest Florida, Final Report.* Environmental Research and Design, Inc., Orlando, Florida, September, 2003.

Harper, H.H., J.L. Herr, and D.M. Baker. 1999. *Lake Hancock Water and Nutrient Budget and Water Quality Improvement Project.* Final Report to the Southwest Florida Water Management District. Environmental Research and Design, Inc., Orlando, Florida, December, 1999.

Keith and Schnars, 2003. *Saddle Creek Watershed Management Program Task II - Watershed Management Plan*. Polk County Board of County Commissioners and the Southwest Florida Water Management District, Lakeland, Florida.

Jacobson, Barry M., Adelbert B. Bottcher, Nigel B. Pickering, and Jeffrey G. Hiscock, 1998. Unique routing algorithm for watershed assessment model. ASAE Paper No. 98-2237. Am. Soc. of Agr. Eng., St. Joseph, MI 49085.

Knisel, W. G., 1993. “GLEAMS: *Ground Water Loading Effects of Agricultural Management Systems.”* UGA-CPES-BAED Publication no. 5.

National Weather Service, 2004. National Weather Service, National Climatic Data Center, Climate Interactive Rapid Retrieval User System (CIRRUS) Database hosted by the Southeast Regional Climate Center web site. Available at http://www.dnr.state.sc.us/pls/cirrus/cirrus.login.

Polk County, 2002. *Polk County 2002 Annual Lake and Stream Report*. Prepared for the Polk County Board of County Commissioners. Published by the Environmental Services Department, Natural Resources Division, Polk County, Florida. Available at http://www.polk.wateratlas.usf.edu/upload/documents/2002Lk_StrRpt.pdf.

___, 2005. Polk County Water Atlas Homepage. Available at http://www.polk.wateratlas.usf.edu/.

QEA, LLC, 2005. *BATHTUB Model Framework for the Lake Hancock Basin, Polk County, Florida.* Prepared for Soil and Water Engineering Technology, Inc. Published by Quantitative Environmental Analysis, LLC, Austin, Texas, June, 2005.

Roehl, J. W., 1962. Sediment Source Areas, Delivery Ratios, and Influencing Morphological Factors. International association of Scientific Hydrology. 59: 202-213. Symposium of Bari, October 1-8, 1962.

Shelley, Z. and K. Petrus, 2004. *Nutrient Total Maximum Daily Load for Lower Sweetwater Creek, Hillsborough County, Florida*. Florida Department of Environmental Protection, Division of Water Resource Management, Watershed Assessment Section, Tallahassee, Florida, September, 2004.

SWET. 1999. *EAAMOD Technical and User Manuals*. Final Reports to the Everglades Research and Education Center, University of Florida, Belle Glade, Florida.

___, 2002. *WAM Training Manual*. Developed for EPA Region IV Training. Published by: Soil and Water Engineering Technology, Inc., Gainesville, FL.

___, 2005. *Watershed Assessment Model (WAM), Model Documentation and Users/Training Manual.* Developed for the Florida Department of Environmental Protection, Division of Water Resource Management, Watershed Assessment Section. Published by Soil and Water Engineering Technology, Inc., Gainesville, Florida, May, 2005.

___, 2005. *Watershed Assessment Model (WAM) of the Lake Hancock Basin Final Report.* Developed for the Florida Department of Environmental Protection, Division of Water Resource Management, Watershed Assessment Section. Published by Soil and Water Engineering Technology, Inc., Gainesville, Florida, September, 2005.

U. S. Environmental Protection Agency, April 1991. *Guidance for Water Quality – Based Decisions: The TMDL Process.* U. S. Environmental Protection Agency, Office of Water, Washington, D.C. EPA-440/4-91-001.

—, November 1999. *Protocol for Developing Nutrient TMDLs.* U. S. Environmental Protection Agency, Office of Water, Washington, D.C. EPA841-B-99-007.

—, July 2003. *40 CFR 130.2(I),* Title 40 – Protection of the Environment, Chapter I – U.S. Environmental Protection Agency, Part 130 – Water Quality Planning and Management, U.S. Environmental Protection Agency, Washington, D.C.

Walker, W. W., 2004. *Simplified Procedures for Eutrophication Assessment and Prediction: User Manual, BATHTUB Version 6.1.* Instruction Report W-96-2. U. S. Army Corps of Engineers, Waterways Experiment Station, Vicksburg, Mississippi, April, 2004.

U. S. Census Bureau Web Site. 2004. Available at http://www.census.gov/; or http://factfinder.census.gov/servlet/GCTTable?_bm=y&-geo_id=04000US12&-_box_head_nbr=GCT-PH1&-ds_name=DEC_2000_SF1_U&-_lang=en&-format=ST-2&-_sse=on.

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.

The rule requires the state's water management districts (WMDs) 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. To date, no PLRG has been developed for Lake Lena.

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 implementation of 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 five 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 fifteen counties meeting the population criteria. The Department received authorization to implement the NPDES stormwater program in 2000.

An important difference between the NPDES and other state stormwater permitting programs is that the NPDES program covers both new and existing discharges, while the other state programs focus on new discharges. Additionally, Phase II of the NPDES Program, implemented in 2003, expands the need for these permits to construction sites between one and five 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 similar to 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: TN, TP, and Chlorophyll a Raw Data Used in the TMDL Analysis for Lake Lena

Lake Lena Total Nitrogen Data

WBID	Station	Date	Time	Depth	Storet Code	TN	R-Code
1501	21FLPOLKLENA1	3/29/1993	1245	2.00	600	2.00	
1501	21FLPOLKLENA1	10/4/1993	1210	4.00	600	2.26	
1501	21FLPOLKLENA1	4/6/1994	1130	1.80	600	1.92	
1501	21FLPOLKLENA1	10/3/1994	1120	2.00	600	1.99	
1501	21FLPOLKLENA1	4/3/1995	1210	2.00	600	1.58	
1501	21FLPOLKLENA1	11/6/1995	1212	2.00	600	1.80	
1501	21FLPOLKLENA1	5/6/1996	1115	2.00	600	1.43	
1501	21FLSWFDSTA0056	8/1/1996	1310	0.50	600	1.50	
1501	21FLPOLKLENA1	11/7/1996	1140	1.90	600	1.71	
1501	21FLSWFDSTA0056	1/7/1997	2500	0.50	600	1.00	+
1501	21FLPOLKLENA1	5/5/1997	1133	1.90	600	1.88	
1501	21FLPOLKLENA1	10/28/1997	855	2.00	600	1.70	
1501	21FLPOLKLENA1	5/4/1998	908	2.00	600	1.02	
1501	21FLPOLKLENA1	11/16/1998	1000	2.00	600	1.94	
1501	21FLPOLKLENA1	5/3/1999	915	1.80	600	2.64	
1501	21FLSWFDLENA	8/25/1999	1430	.	600	0.50	J
1501	21FLPOLKLENA1	11/16/1999	903	0.90	600	1.63	
1501	21FLPOLKLENA1	5/1/2000	1348	1.50	600	2.47	
1501	21FLSWFDLENA	8/16/2000	1330	.	600	1.42	+
1501	21FLPOLKLENA1	11/14/2000	1225	1.60	600	3.01	
1501	21FLPOLKLENA1	5/1/2001	1025	0.50	600	3.21	
1501	21FLPOLKLENA1	11/1/2001	1240	0.50	600	2.46	
1501	21FLPOLKLENA1	5/1/2002	935	0.50	600	2.89	
1501	21FLPOLKLENA1	8/7/2002	1020	0.50	600	2.75	
1501	21FLPOLKLENA1	11/6/2002	1010	0.50	600	2.59	
1501	21FLTPA 28040038148367	2/5/2003	1130	0.20	600	2.00	+
1501	21FLPOLKLENA1	2/20/2003	820	0.50	600	2.08	
1501	21FLTPA 28040038148367	5/6/2003	930	0.20	600	1.70	+
1501	21FLPOLKLENA1	5/7/2003	1025	0.50	600	1.78	
1501	21FLTPA 28040038148367	8/18/2003	1055	0.20	600	1.61	+
1501	21FLPOLKLENA1	8/26/2003	1055	0.50	600	1.63	
1501	21FLPOLKLENA1	10/30/2003	950	0.50	600	1.81	
1501	21FLTPA 28040038148367	11/3/2003	1335	0.20	600	2.31	+
1501	21FLPOLKLENA1	2/5/2004	820	0.50	600	3.10	+

J: Estimated; Value shown is not a result of analytical measurement.
+: Calculated value.

Lake Lena Total Phosphorus Data

WBID	Station	Date	Time	Depth	Storet Code	TP	R-Code
1501	21FLPOLKLENA1	3/29/1993	1245	2.00	665	0.061	
1501	21FLPOLKLENA1	10/4/1993	1210	4.00	665	0.042	
1501	21FLPOLKLENA1	4/6/1994	1130	1.80	665	0.061	
1501	21FLPOLKLENA1	10/3/1994	1120	2.00	665	0.063	
1501	21FLPOLKLENA1	4/3/1995	1210	2.00	665	0.077	
1501	21FLPOLKLENA1	11/6/1995	1212	2.00	665	0.050	
1501	21FLPOLKLENA1	5/6/1996	1115	2.00	665	0.044	
1501	21FLSWFDSTA0056	8/1/1996	1310	0.50	665	0.008	T
1501	21FLPOLKLENA1	11/7/1996	1140	1.90	665	0.043	
1501	21FLSWFDSTA0056	1/7/1997	2500	0.50	665	0.027	
1501	21FLPOLKLENA1	5/5/1997	1133	1.90	665	0.045	
1501	21FLPOLKLENA1	10/28/1997	855	2.00	665	0.055	
1501	21FLPOLKLENA1	5/4/1998	908	2.00	665	0.064	
1501	21FLPOLKLENA1	11/16/1998	1000	2.00	665	0.053	
1501	21FLPOLKLENA1	5/3/1999	915	1.80	665	0.069	
1501	21FLSWFDLENA	8/25/1999	1430	.	665	0.050	
1501	21FLPOLKLENA1	11/16/1999	903	0.90	665	0.052	
1501	21FLPOLKLENA1	5/1/2000	1348	1.50	665	0.045	
1501	21FLSWFDLENA	8/16/2000	1330	.	665	0.073	
1501	21FLPOLKLENA1	11/14/2000	1230	0.50	665	0.065	
1501	21FLPOLKLENA1	5/1/2001	1025	0.50	665	0.067	
1501	21FLPOLKLENA1	11/1/2001	1240	0.50	665	0.046	
1501	21FLPOLKLENA1	5/1/2002	935	0.50	665	0.050	
1501	21FLPOLKLENA1	8/7/2002	1020	0.50	665	0.041	
1501	21FLPOLKLENA1	11/6/2002	1010	0.50	665	0.036	
1501	21FLTPA 28040038148367	2/5/2003	1130	0.20	665	0.080	A
1501	21FLPOLKLENA1	2/20/2003	820	0.50	665	0.073	
1501	21FLTPA 28040038148367	5/6/2003	930	0.20	665	0.021	I
1501	21FLPOLKLENA1	5/7/2003	1025	0.50	665	0.040	
1501	21FLTPA 28040038148367	8/18/2003	1055	0.20	665	0.044	
1501	21FLPOLKLENA1	8/26/2003	1055	0.50	665	0.029	
1501	21FLTPA 28040038148367	9/30/2003	1235	0.20	665	0.049	
1501	21FLPOLKLENA1	10/30/2003	950	0.50	665	0.027	
1501	21FLTPA 28040038148367	11/3/2003	1335	0.20	665	0.120	
1501	21FLPOLKLENA1	2/5/2004	820	0.50	665	0.039	

A: Value reported is the mean of two or more determinations.

I: The value reported is less than the practical quantitation limit and greater than or equal to the method detection limit.

T: The value reported is less than the criteria of detection.

Lake Lena Chlorophyll *a* Data

WBID	Station	Date	Time	Depth	Storet Code	Chl(a)	R-Code
1501	21FLPOLKLENA1	3/29/1993	1245	6.56	32210	44.57	
1501	21FLPOLKLENA1	10/4/1993	1210	13.12	32210	63.77	
1501	21FLPOLKLENA1	4/6/1994	1130	5.90	32210	40.87	
1501	21FLPOLKLENA1	10/3/1994	1120	6.56	32210	50.07	
1501	21FLPOLKLENA1	4/3/1995	1210	6.56	32210	20.90	
1501	21FLPOLKLENA1	11/6/1995	1212	6.56	32210	59.06	
1501	21FLPOLKLENA1	5/6/1996	1115	6.56	32210	31.94	
1501	21FLSWFDSTA0056	8/1/1996	1310	0.50	32211	30.40	
1501	21FLPOLKLENA1	11/7/1996	1140	6.23	32210	43.65	
1501	21FLSWFDSTA0056	1/7/1997	2500	0.50	32211	32.04	
1501	21FLPOLKLENA1	5/5/1997	1133	6.23	32210	28.93	
1501	21FLPOLKLENA1	10/28/1997	855	6.56	32210	50.73	
1501	21FLPOLKLENA1	5/4/1998	908	2.00	32210	27.77	
1501	21FLPOLKLENA1	11/16/1998	1000	6.56	32210	41.16	
1501	21FLPOLKLENA1	5/3/1999	915	1.80	32223	81.44	
1501	21FLSWFDLENA	8/25/1999	1430	.	32211	64.70	
1501	21FLPOLKLENA1	11/16/1999	903	0.90	32223	38.05	
1501	21FLSWFDLENA	2/14/2000	1330	.	32211	70.90	
1501	21FLPOLKLENA1	5/1/2000	1348	1.50	32223	97.46	
1501	21FLPOLKLENA1	11/14/2000	1230	0.50	32223	51.60	
1501	21FLPOLKLENA1	5/1/2001	1025	0.50	32223	80.80	
1501	21FLPOLKLENA1	11/1/2001	1240	0.50	32223	57.67	
1501	21FLPOLKLENA1	5/1/2002	935	0.50	32223	69.42	
1501	21FLPOLKLENA1	8/7/2002	1020	0.50	32223	66.93	
1501	21FLTPA 28040038148367	2/5/2003	1130	0.20	32209	33.00	
1501	21FLTPA 28040038148367	5/6/2003	930	0.20	32209	40.00	
1501	21FLTPA 28040038148367	8/18/2003	1055	0.20	32209	34.00	
1501	21FLTPA 28040038148367	9/30/2003	1235	0.20	32209	62.00	
1501	21FLTPA 28040038148367	11/3/2003	1335	0.20	32209	54.00	
1501	21FLPOLKLENA1	2/5/2004	820	0.50	32210	30.59	

Appendix C: SWET Watershed Assessment Model (WAM) Final Report for the Lake Hancock and Saddle Creek Basin (available upon request)

Appendix D: QEA, LLC, BATHTUB Model Final Report for the Lake Hancock and Saddle Creek Basin (available upon request)