Total Maximum Daily Load for Total Phosphorus for Lake Carlton Lake County, Florida

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1.0 Introduction

1.1 Purpose of Report

This report presents a Total Maximum Daily Load (TMDL) for Total Phosphorus (TP) for Lake Carlton and describes the projected impact of proposed TP reductions on the concentration of un-ionized ammonia in the lake. Using the methodology to identify and verify water quality impairments described in Chapter 62-303, Florida Administrative Code, (Identification of Impaired Surface Waters, which is commonly referred to as the Impaired Waters Rule, or IWR), the lake was verified as impaired by nutrients, and was included on the verified list of impaired waters for the Ocklawaha Basin that was adopted by Secretarial Order on August 28, 2002. The TMDL process quantifies the amount of a pollutant that can be assimilated in a waterbody, identifies the sources of the pollutant, and recommends regulatory or other actions to be taken to achieve compliance with applicable water quality standards based on the relationship between pollution sources and in-stream water quality conditions.

1.2 Identification of Waterbody

Lake Carlton, located in central Florida approximately 30 miles northwest of Orlando, is part of the Upper Ocklawaha River Basin (UORB) and is a sub basin to Lake Beauclair (Figure 1). It has a drainage basin of approximately 3,217 acres (Fulton personal communication, 2003). According to the Lakewatch website, the lake has a surface area of approximately 161 ha (397 acres) and an average depth of 3 m (9.8 ft). Surface outflow from the lake is toward Lake Beauclair.

For assessment purposes, the watersheds within the Ocklawaha River Basin have been broken out into smaller watersheds, with a unique **w**ater**b**ody **id**entification (WBID) number for each watershed. The Lake Carlton watershed was called Lake Carlton Outlet and had been assigned WBID 2837 in the assessment for the 1998 303(d) list, but the lake was reassigned WBID 2837B for the 2002 assessment.

2.0 Statement of Problem

The UORB is located primarily in a large lowland area between the Mount Dora Ridge to the east and the Ocala Uplift District to the west. In many areas, the valley floor intersects the potentiometric surface resulting in numerous springs and spring-fed lakes. Karst terrains are present throughout the area due to the soluble carbonate rock and the nutrient rich soils have combined to produce naturally productive hardwater lakes.

During the 1800s, resources were developed for tourism, agricultural, and commercial industry. According to the SWIM Plan (Fulton, 1995), impacts of urban development within the basin were first documented in the late 1940s. Eutrophication of surface waters was accelerated by the direct discharge of domestic, industrial, and agricultural wastes. In addition, construction of control structures and channelization of the system along with destruction of aquatic habits contributed to declines in water quality.

In 1987, the Florida Legislature adopted the Surface Water Improvement and Management (SWIM) Act, which directed Water Management Districts to adopt methodologies to identify waters in need of restoration and/or preservation. In 1989, the St. Johns River Water Management District (SJRWMD) adopted a SWIM plan for the restoration of the UORB.

In 1995, the SJRWMD developed an interim Pollutant Load Reduction Goal (PLRG) for phosphorus (Fulton, 1995) based upon trophic state modeling for the major lakes. Lake Carlton was included as a contributing sub basin to Lake Beauclair. PLRGs represent estimated reductions in pollutant loadings from stormwater needed to preserve or restore beneficial uses of receiving waters. The 1995 interim PLRG reported that, based upon land use activities over the 1984 –1990 period, discharges from Lake Apopka through the Apopka – Beauclair Canal represented about ninety percent of the phosphorus loading to Lake Beauclair. Muck farm and other agricultural discharges within the immediate Lake Beauclair drainage basin accounted for less than ten percent of the phosphorus loading.

Plots of key water quality parameters in Lake Carlton over the 1989 – 2002 period indicate that sampling for certain water quality parameters has been sporadic. Total nitrogen, total phosphorus, and Chlorophyll a measurements since 1998 illustrate seasonal fluctuations and some increases in total nitrogen and Chlorophyll a since 1999 (Figures 2[1] and 3[2]). Table 1 summarizes the DO, un-ionized ammonia, and Trophic State Index (TSI) annual averages used to assess Lake Carlton under the IWR. Statistical summaries of key water quality parameters are presented for the lake in Table 2.

In recent years, blue-green algal (cyanobacteria) blooms have become a concern in the UORB. Burns, et al. (2001) reported the presence of *Cylindrospermopsis sp.* and *Microcystis sp.* in samples collected in Lake Carlton during the summer of 1999. Measurable levels of microcystins (a cyanotoxin) were also reported in some samples. The *Cylindrospermopsis* genera represents a filamentous bloom-forming cyanobacteria that can fix nitrogen from the atmosphere. The *Microcystis* genera is a non-filamentous bloom-forming cyanobacteria that has not been demonstrated to have the ability to fix nitrogen.

3.0 Description of the Applicable Water Quality Standards and Numeric Water Quality Target

Lake Carlton is a Class III waterbody with designated uses of recreation, propagation and maintenance of a healthy, well balanced population of fish and wildlife. Class III water quality criteria applicable to the observed impairment is the narrative nutrient criterion (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). Because the nutrient criterion is narrative only, a nutrient related target was needed to represent levels at which imbalance in flora or fauna are expected to occur.

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[1] Figure 2 presents water quality information on an annual basis and suggests some increase in ranges for total nitrogen and Chlorophyll a over time.
[2] Figure 3 presents the individual observations over time.

As part of the ongoing SWIM Program assessments of the lake, the SJRWMD developed a new interim PLRG for phosphorus in Lake Beauclair that considered two approaches to determine an appropriate phosphorus target. The first approach involved modeling both the external loading and resultant lake water quality under historic (natural background) conditions. In the second approach, an appropriate TP target was determined using reference conditions from lakes in the region based upon three estimates (state lake ecoregion data, SJRWMD ecoregion dataset, and a selection of lakes with similar morphology and hydrology). All of these methods relied upon information and/or relationships developed from long-term datasets or steady state conditions (Fulton et al., 2003). Subsequently, Dr. Fulton (personal communication) has provided additional information on the Lake Carlton sub basin that has been used to develop a phosphorus TMDL for Lake Carlton similar to the process used for Lake Beauclair. In this case, the TP target developed for Lake Beauclair by the SJRWMD (32 ppb) as part of the current PLRG development for Lake Beauclair was used as the TP target for Lake Carlton.

It should be noted that the IWR provides a threshold of impairment for nutrients in lakes based on a Trophic State Index (TSI). While the IWR thresholds were not used as the water quality target for this TMDL (they are not water quality criteria), resultant changes in the TSI for the lake are included in the document to demonstrate that reductions in TP would be expected to result in decreases in lake chlorophyll a levels that would be consistent with a non-impaired lake.

Reductions in TP loading are also expected to result in additional benefits with respect to other water quality parameters, including dissolved oxygen, un-ionized ammonia, turbidity, and total suspended solids. Reductions in phosphorus will result in lower algal biomass levels in the lake, and lower algal biomass levels will mean smaller diurnal fluctuations in dissolved oxygen, less algal based total suspended solids and turbidity, and lower pH levels in the lake. Since the fraction of ammonia that is un-ionized is directly related to pH, lower pH levels will also result in fewer exceedances of the un-ionized criterion (Table 3).

The expectation that reductions in phosphorus loading will provide improvements in other parameters is supported by statistical evaluation of the Lake Carlton data. Based on Pearson correlation coefficients (Table 4) for this data set, Total phosphorus is positively correlated with turbidity, pH, corrected chlorophyll a, uncorrected chlorophyll a, ammonia, NO_2NO_3, nitrate, and dissolved oxygen. The correlation is negative between TKN, organic nitrogen and total phosphorus. The simple linear regression of total phosphorus versus uncorrected chlorophyll a was significant at an alpha level of 0.05.

This positive correlation between pH and chlorophyll a reflects changes to the carbonate balance in the water column as CO_2 is used in algal photosynthesis. Reductions in pH in response to lower algal biomass and lower overall photosynthesis will reduce the occurrence of un-ionized ammonia exceedances even without a reduction in ammonia. For example, at a temperature of 20 ^{o}C, a pH reduction from 8.5 to 8 s.u. changes the total ammonia that would result in an un-ionized exceedance from 0.15 to 0.5 mg/l, respectively.

Additional treatment in the watershed to achieve the phosphorus reduction will also result in additional nitrogen removal. Fulton et al.'s (2003) summary of 13 storm water treatment systems in Florida suggested a mean treatment efficiency of 42% for nitrogen. Those same treatment systems had a mean treatment efficiency of 63% for phosphorus.

Both the PLRG and this TMDL establish the allowable load for phosphorus only, and not nitrogen. Fulton et al. (2003) reported that ratios of nitrogen to phosphorus in the UORB suggest that algal production is potentially limited by phosphorus availability, except in lakes where excessive phosphorus loading has led to potential nitrogen or co-limitation of nitrogen and phosphorus. Total nitrogen to total phosphorus values less than 10 indicate nitrogen limitation, while ratios greater than 30 indicate phosphorus limitation. Figure 4 illustrates the distribution of this ratio for measurements in Lake Carlton over the 1996 – 2002 period. The ratio is typically above 30, indicating phosphorus limitation.

Loehr et al. (1980) point out that due to the ability of various cyanobacterial species to fix gaseous nitrogen, it is very difficult to control eutrophication problems in freshwater systems through limitations on nitrogen input. They indicate that phosphorus inputs must be lowered to the point where phosphorus replaces nitrogen as the limiting factor, and then further reduced so that the growth and yield of algal forms is reduced.

Whitton and Potts (2000) cite a study by Sas (1989) where phytoplankton and cyanobacterial components responded to phosphorus reduction in four stages:

- Stage 1: no biomass reduction because phosphorus is in excess of algal requirements
- Stage 2: declining amount of unused phosphorus results in a small reduction in Algal biomass
- Stage 3: phytoplankton biomass falls, with minimal unused phosphorus remaining
- Stage 4: further decline in biomass and changes in composition of the phytoplankton.

4.0 Assessment of Sources

4.1 Types of Sources

An important part of the TMDL analysis is the identification of source categories, source subcategories, or individual sources of phosphorus 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, runoff from agriculture, runoff from silviculture, runoff from 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 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 from a wide variety of industries (see Appendix A for background information about the State and Federal 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 (see Section 7). 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 Source Loads

Fulton et al. (2003) describes the process followed to quantify point and nonpoint source contributions to UORB lakes. Following the procedure used by Fulton (personal communication, 2003), average annual nitrogen and phosphorus loads to Lake Carlton were estimated from a variety of sources over the 1991 – 2000 period (Table 5). Figure 5 illustrates the major land uses in the Lake Carlton watershed. Loads are presented to the nearest 0.1 kg to illustrate the magnitude of some of the smaller sources that were evaluated. Sources included runoff from land uses such as residential, commercial, industrial, mining, openland/recreational, muck farms, pastures, croplands, silviculture, wetlands, and other agriculture (Table 6). Atmospheric contributions from wet and dry deposition directly on the lake surface were accounted for based upon measurements in the basin. One possible contribution that has not been quantified at this time is the possible exchange between Lake Beauclair and Lake Carlton under certain hydrologic conditions (Dr. Fulton, personal communication, 2003). Permit files from the DEP Central District were also reviewed to develop loading estimates from domestic and wastewater spills at any facilities within the watershed.

The mean annual TP load over this period was estimated at 216.2 kg. The three major sources for phosphorus within the watershed were dry deposition (14.2%), septic tanks (14.1%), and low density residential (13.5%). Total nitrogen was estimated at 4,086.7 kg/year. Wet and dry atmospheric contributions accounted for approximately 25 % of both the nitrogen and phosphorus total loads. The contributions from septic tanks were estimated assuming a drainage area ratio based upon the Lake Carlton sub basin and Lake Beauclair and warrants further investigation.

5.0 Loading Capacity – Linking Water Quality and Pollutant Sources

Based upon available data (Table 2), the mean TP concentration in Lake Carlton over the 1995 – 2002 period was 78 ug/l. The proposed TP target of 32 ug/l for Lake Beauclair was also assumed to be appropriate for Lake Carlton. Following the simplifying assumption used by the SJRWMD that phosphorus concentrations in the lakes are directly proportional to external loading, the ratio of the target TP concentration to the observed mean concentration indicated that a 59 percent reduction in annual phosphorus loading to the lake is needed.

As discussed earlier, the IWR uses a TSI to assess possible nutrient impairments in lakes. The TSI represents the average of a $Chla_{TSI}$ and $Nutrient_{TSI}$. Assuming an average TP of 78 ug/l, the $Nutrient_{TSI}$ would be 79.0, and using a long-term average chlorophyll a of 189 ug/l, the $Chla_{TSI}$ would be 92.3. Thus, the long-term average TSI under current conditions is approximately 85.6. Reducing the in-lake phosphorus concentration to 32 ug/l would result in a $Nutrient_{TSI}$ of 58. Fulton (2003a) provided a preliminary evaluation of the effects of the interim PLRG and predicted a mean chlorophyll a of 30 ug/l for Lake Beauclair. Assuming that a similar mean Chla is achieved in Lake Carlton, the $Chla_{TSI}$ would drop to less than 65.7 and the overall TSI would drop to 61.8.

6.0 Critical Conditions

As described in the IWR, nutrient enrichment in lakes is evaluated using a TSI and at least one sample from each season is required in any given year in order to calculate the TSI. Proposed phosphorus reductions were based upon long-term average conditions (a 10-year average phosphorus load to Lake Carlton). Nitrogen loads to the lake were also based upon a 10-year average. Rainfall over this period averaged 47.2 inches, which is approximately 7 % below the long-term annual average of 50.5 inches. Reduced rainfall would be expected to result in less surface runoff to the lake (except perhaps for areas that are irrigated), however, this is also likely to increase the lake flushing time and increase residence time of pollutants (and concentrations) in the lake.

The TMDL was based on long-term average conditions 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) we are generally more concerned with the net change in overall primary productivity, which is better addressed on an annual basis, and c) the methodology used to determine impairment is based upon an annual average and requires data from all four quarters of a calendar year.

7.0 Determination of TMDL

The objective of a TMDL is to provide a basis for allocating acceptable loads among all of the known pollutant sources in a watershed so that appropriate control measures can be implemented and water quality standards achieved. A TMDL is expressed as the sum of all point source loads (Waste Load Allocations), nonpoint source loads (Load Allocations), and an appropriate margin of safety (MOS), which takes into account any uncertainty concerning the relationship between effluent limitations and water quality:

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

As mentioned in Section 4.1, the WLA is broken out into separate subcategories for wastewater discharges and stormwater discharges regulated under the NPDES Program:

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

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 Carlton (Table 6) is expressed in terms of pounds per year, and represent the annual load the lake can assimilate and maintain the narrative nutrient criterion. The LA includes the atmospheric contribution (118 lbs/year).

Table 7. TMDL Components

WBID	Parameter	WLA		LA (lbs/year)	MOS	TMDL (lbs/year)	Percent Reduction
		Wastewater (lbs/year)	NPDES Stormwater (% Reduction)				
2837B	TP	N/A	59%	195	Implicit	195	59[1]

[1] Note that this percent reduction was based upon the total annual average load which included atmospheric contributions

7.1 Load Allocations (LAs)

The allowable LA is 195 lbs/year for TP. This LA represents a 59% reduction in phosphorus load from long-term average loadings, nonpoint sources will need to be reduced by 281 lbs/year. As noted earlier, atmospheric contributions represent nearly 25 % of the existing load followed by septic tanks (14.1%) and low density residential runoff (13.5 %). It should be noted that the LA includes loading from stormwater discharges regulated by the Department and the Water Management Districts that are not part of the NPDES Stormwater Program (see Appendix A).

7.2 Wasteload Allocations (WLAs)

NPDES Stormwater Discharges

As noted previously, load from stormwater discharges permitted under the NPDES Stormwater Program are placed in the WLA, rather than the LA. This includes loads from municipal separate storm sewer systems (MS4). Based on the 2000 census, the Lake Carlton watershed includes areas that will be covered by the MS4 Program, and the WLA for stormwater discharges is an 59 percent reduction of current loading from the MS4. It should be noted that any MS4 permittees 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.

NPDES Wastewater Discharges

There are no wastewater facilities authorized to discharge wastewater or stormwater to Lake Carlton, and the WLA for this TMDL is therefore not applicable.

7.3 Relationship between Lake Carlton and Lake Beauclair TMDLs

It should also be noted with respect to possible reductions in either the WLA or LA to achieve the TMDL, Lake Carlton is a sub-basin to Lake Beauclair and a draft TMDL for Lake Beauclair specified a 85% reduction in phosphorus loading to Lake Beauclair. Consequently, reductions in phosphorus loading to and from the Lake Carlton sub-basin will also become a factor in how the TMDL for Lake Beauclair is met.

7.4 Margin of Safety (MOS)

An implicit margin of safety is assumed based upon a long-term (10-year) annual load budget. Calculations of storm water runoff also assumed that there was no storm water treatment for lands already developed in 1987, while lands developed after 1987 were assumed to provide storm water treatment at levels equal to the average of 13 studies in Florida. Finally, in the determination of the target phosphorus concentration, the SJRWMD used the 25th percentile value from each estimate, which is considered a conservative level.

8.0 Seasonal Variation

As discussed earlier, potential nutrient impairments in lakes are based upon calculated annual TSI values. The IWR requires that water quality data from all four quarters of the calendar year in order to calculate a TSI.

With respect to un-ionized ammonia, the fraction of total ammonia that is un-ionized is a function of water temperature and pH. While both water temperature and pH vary seasonally, summer is the most likely period where both increased water temperature and pH are most likely occur together and result in a low allowable total ammonia concentration.

9.0 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 Ocklawaha Basin. 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 (B-MAP) 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.

10. References

Fulton, R.S. III, C. Schluter, T.A. Keller, S. Nagrid, W. Godwin, D. Smith, D. Clapp, A. Karama, J.Richmond. 2003. Interim Pollutant Load Reduction Goals for Seven Major Lakes in the Upper Ocklawaha River Basin. St. Johns River Water Management District. Draft.

Fulton, R.S. III. 2003a. Preliminary Evaluation of the Effects and Feasibility of the Proposed Interim Pollutant Load Reduction Goals for the Seven Major Lakes in the Upper Ocklawaha River Basin. St. Johns River Management District. Draft.

Fulton, R.S. III. 1995. External Nutrient Budget and Trophic State Modeling for Lakes in the Upper Ocklawaha River Basin. St. Johns River Management District. Tech Pub SJ95-6.

Fulton, R.S. III. 1995. SWIM Plan for the Upper Ocklawaha River Basin. St. Johns River Water Management District.

Loehr, R.C., C.S. Marlin, W. Rast, editors. 1980. Phosphorus Management Strategies for Lakes. Proceedings of the 1979 Conference. Ann Arbor Science Publishers, Inc.

Sas, H. 1989. Lake restoration by reduction of nutrient loading; expectations, experiences, extrapolations. Academia Verlag Richarz, St. Augustin p 497.

Williams, C.D., J. Burns, A. Chapman, L. Flewelling, M. Pawlowicz, W. Carmichael. 2001. Assessment of Cyanotoxins in Florida's Lakes, Reservoirs, and Rivers. St. Johns River Water Management District.

Whitton, Brian and Malcolm Potts, editors. 2000. The Ecology of Cyanobacteria. Kluwer Academic Publishers.

Figure 1. Upper Ocklawaha River Chain of Lakes

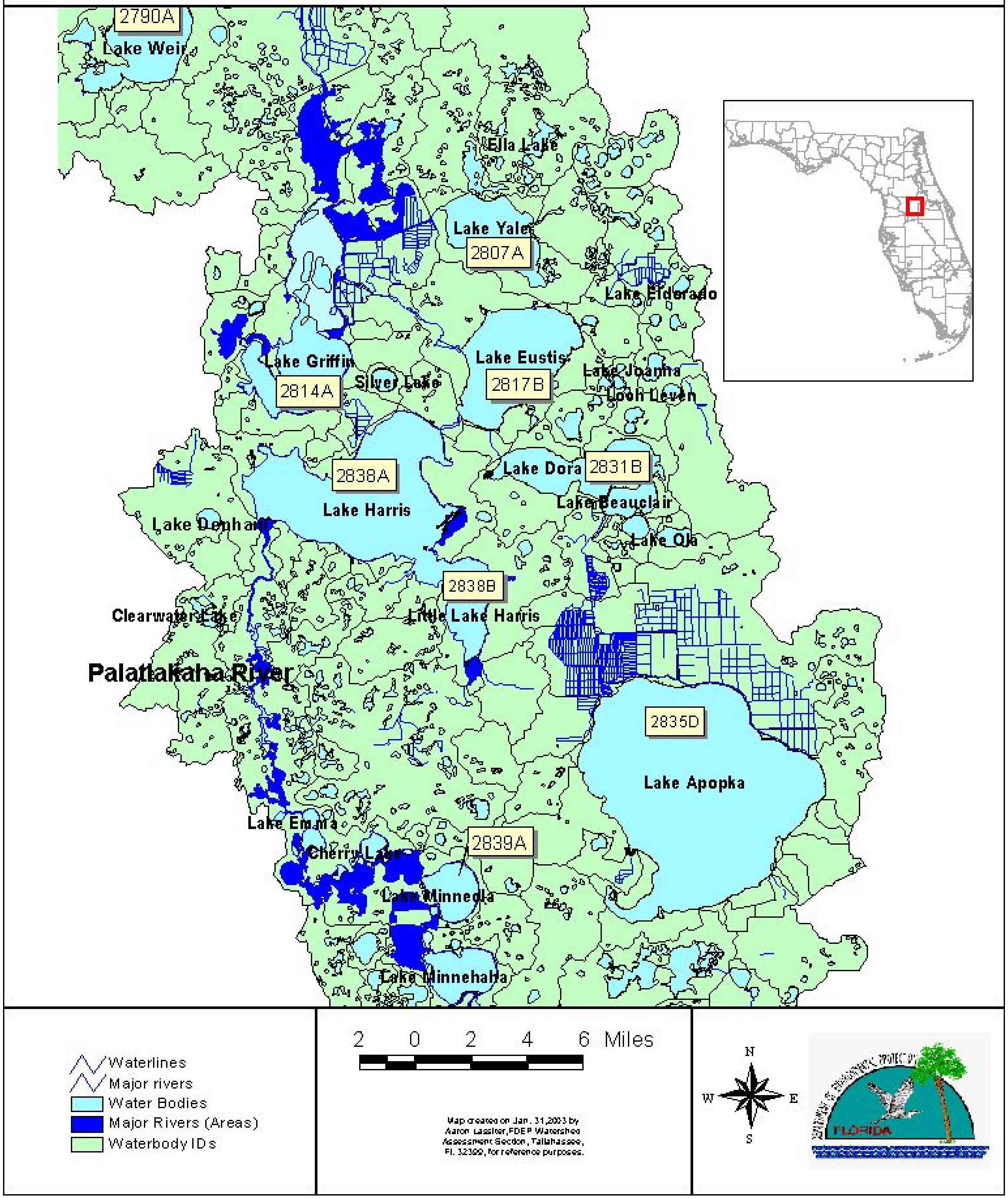


Figure 2. Boxplots of water quality by year in Lake Carlton (WBID 2837B) over the 1989 - 2002 period.

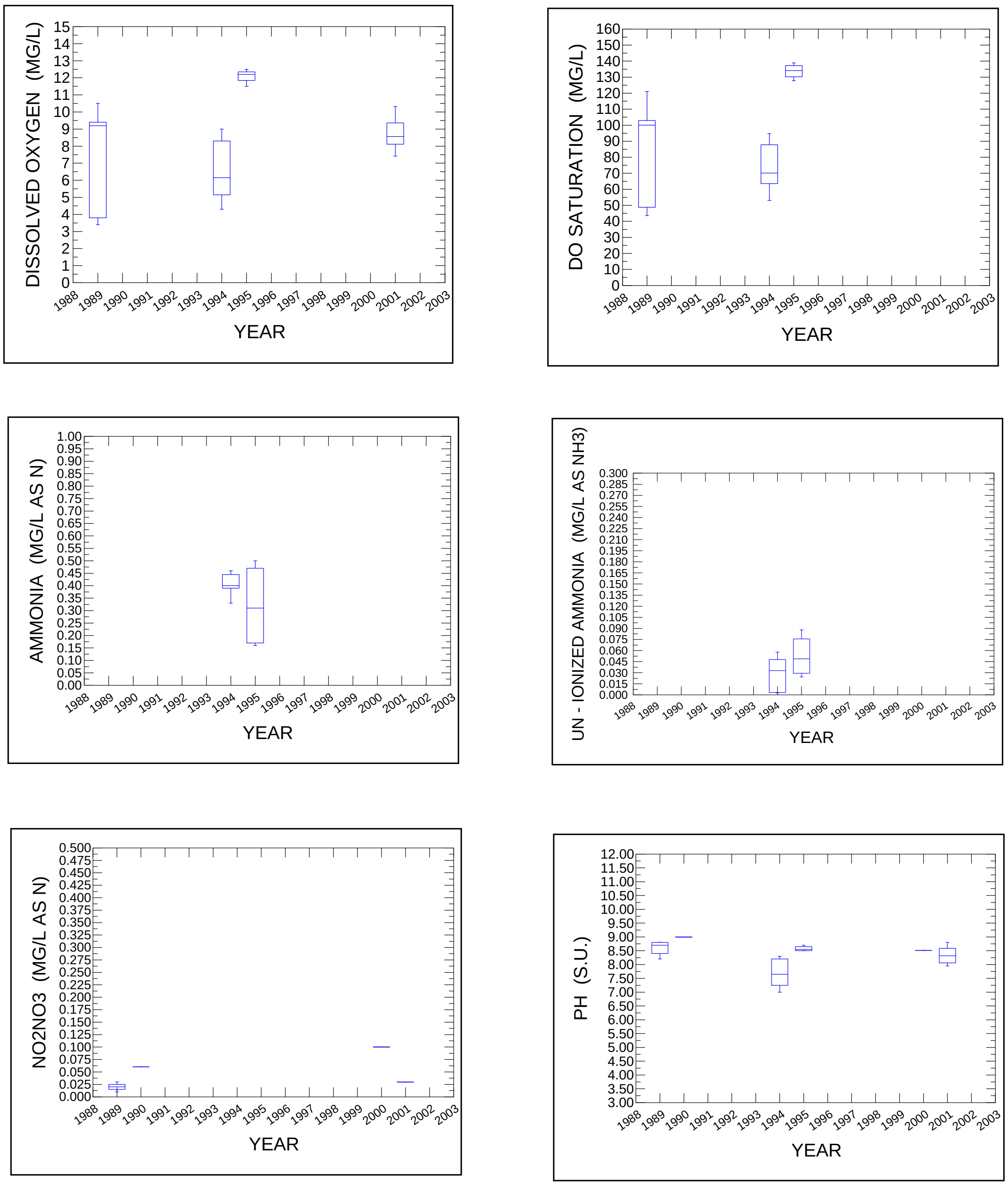
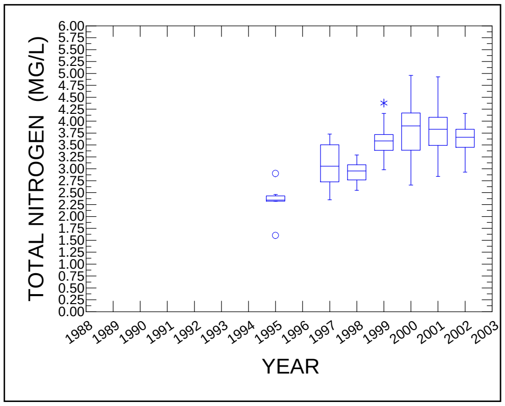
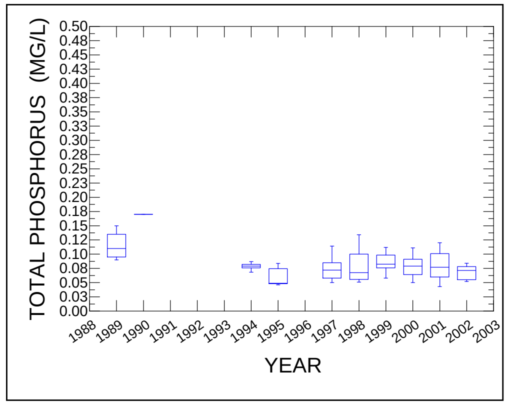
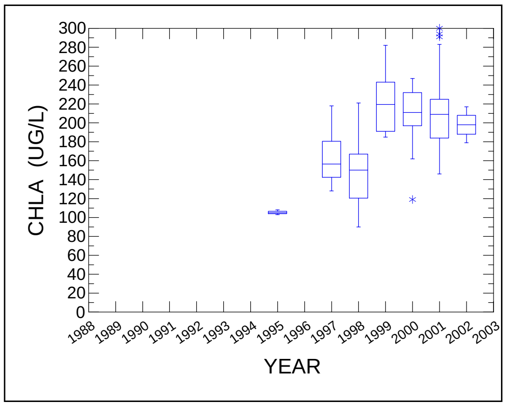


Figure 2. Continued.







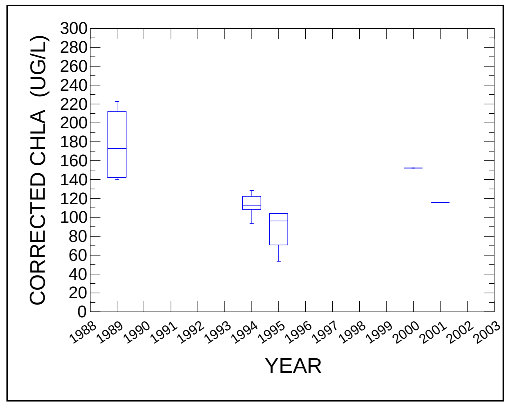


FIGURE 3. PLOTS OF WATER QUALITY FOR LAKE CARLTON FOR THE 1989-2002 PERIOD.

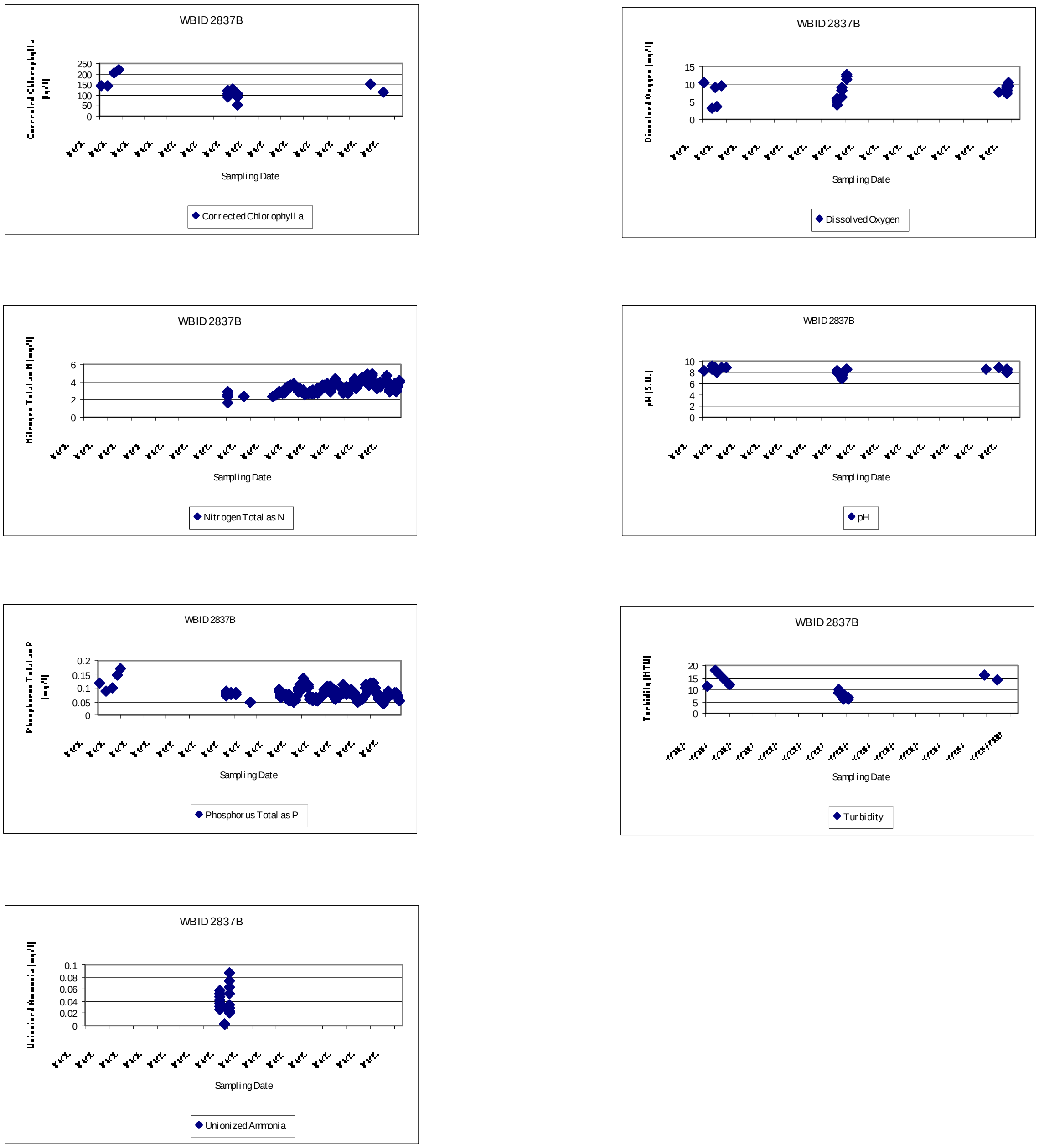


Figure 4. TN/TP ratio plot for Lake Carlton (2837B) for the January 1996 – December 2002 period.

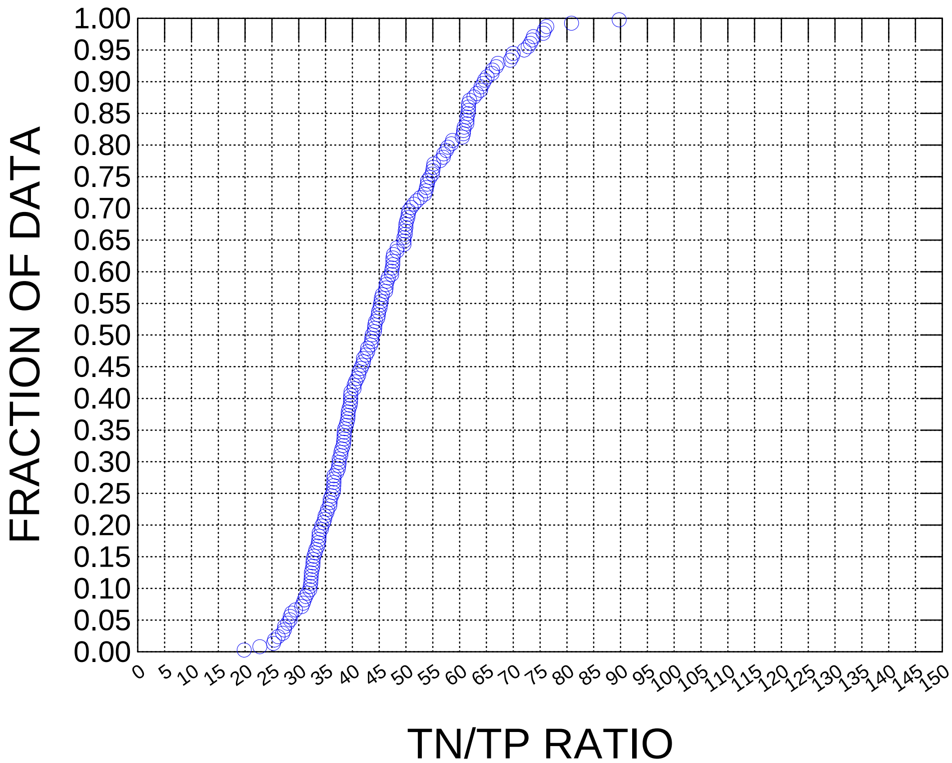
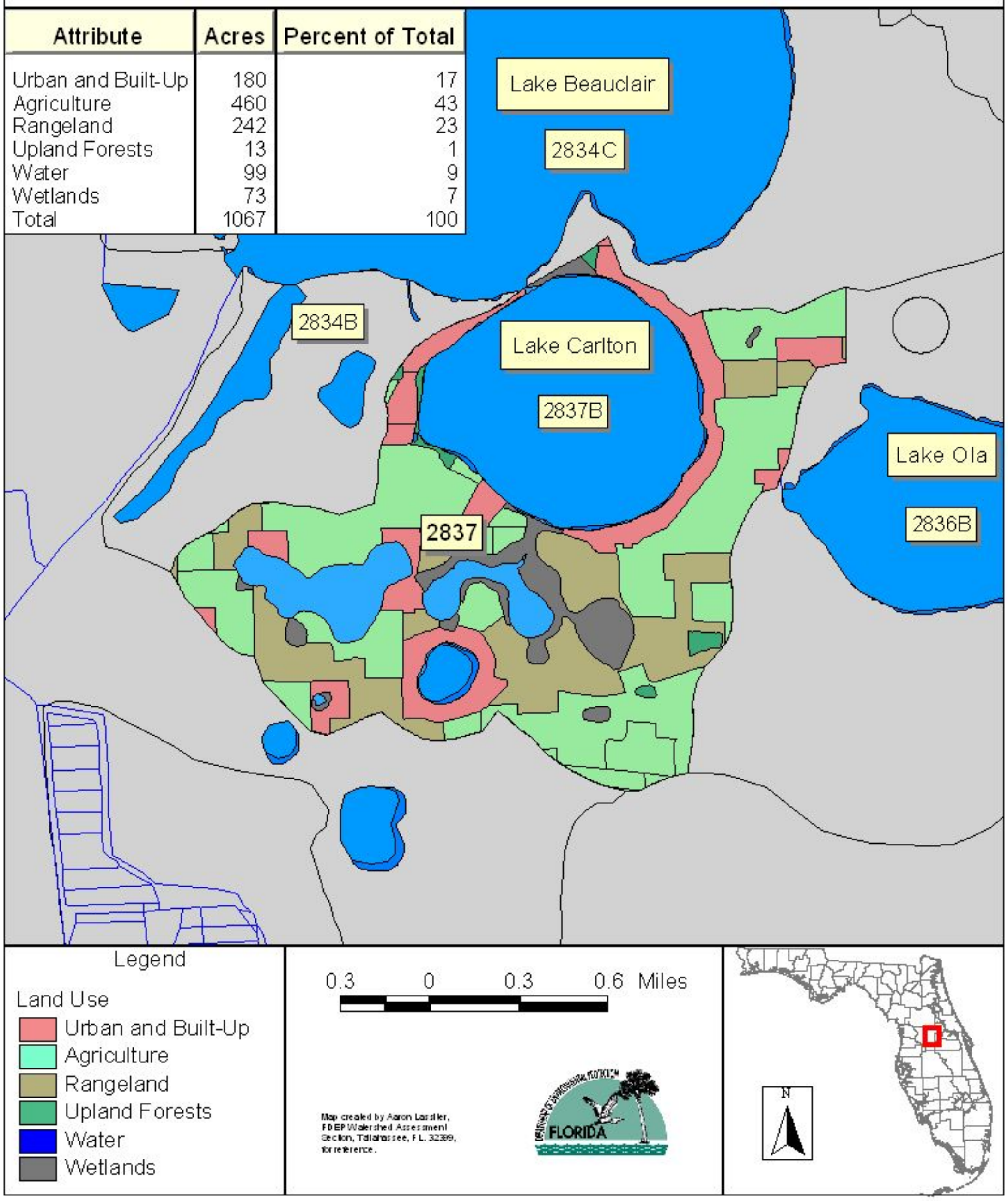


Figure 5: Lake Carlton Landuse



Attribute	Acres	Percent of Total
Urban and Built-Up	180	17
Agriculture	460	43
Rangeland	242	23
Upland Forests	13	1
Water	99	9
Wetlands	73	7
Total	1067	100

Table 1. Lake Carlton dissolved oxygen, un-ionized ammonia, and TSI assessments under the IWR.

Parameter of concern	Lake Carlton
Annual Chlorophyll a or TSI	Trophic State Index
1989	NA
1990	NA
1991	NA
1992	NA
1993	NA
1994	NA
1995	NA
1996	NA
1997	83.6
1998	81.5
1999	87.7
2000	86.0
2001	86.3
Dissolved Oxygen	PP – 4/17 Potentially Impaired VP – 0/17 Insufficient data
Un-ionized Ammonia	PP – 8/11 Insufficient data VP – 4/4 Insufficient data
PP – Planning Period which was the January 1989 through December 1998 period. VP – Verified Period which was the January 1995 through June 2002 period.	

Table 2. Summary statistics of key water quality parameters for Lake Carlton (WBID 2837B) over 1989 – 2002.

	CHLA	CHLAC	DO	DOSAT	NH4
N of cases	201	18	30	17	11
Minimum	90.000	53.400	3.400	43.608	0.160
Maximum	302.000	222.680	12.500	138.889	0.500
Median	192.000	113.750	8.480	88.421	0.400
Mean	189.647	124.052	8.375	90.712	0.376
Standard Dev	42.941	39.199	2.416	32.020	0.112

	NO2	NO3	NO2O3	ORGN	PH
N of cases	0	12	7	11	28
Minimum	.	0.000	0.010	1.140	7.000
Maximum	.	0.040	0.100	3.400	9.000
Median	.	0.020	0.030	2.720	8.360
Mean	.	0.018	0.039	2.646	8.255
Standard Dev	.	0.013	0.031	0.632	0.519

	PO4	TKN	TN	TP	TURBIDITY
N of cases	12	7	392	404	19
Minimum	0.000	3.300	1.600	0.043	6.000
Maximum	0.190	4.860	4.960	0.170	18.000
Median	0.070	3.760	3.450	0.077	9.000
Mean	0.068	3.854	3.431	0.079	10.147
Standard Dev	0.061	0.524	0.565	0.021	3.853

	UNNH4	TNTPRATIO
N of cases	11	387
Minimum	0.003	22.761
Maximum	0.088	89.767
Median	0.034	44.343
Mean	0.037	46.774
Standard Dev	0.028	13.181

Table 3. Ammonia Concentration (in mg/l as N) that results in un-ionized ammonia of 0.02 mg/l as NH_3

PH (s.u.)	Water Temperature (^{0} C)				
	10	15	20	25	30
6.0	88.71	60.22	41.56	29.00	20.50
6.5	28.20	19.08	13.20	9.17	6.50
7.0	8.87	6.04	4.17	2.91	2.06
7.5	2.24	1.92	1.33	0.93	0.66
8.0	0.90	0.64	0.50	0.31	0.22
8.5	0.30	0.21	0.15	0.11	0.08
9.0	0.10	0.08	0.06	0.04	0.04

Note: At a given pH, as water temperature increases, the un-ionized ammonia fraction increases.
At a fixed water temperature, as pH increases, the un-ionized ammonia fraction increases.

Table 4. Pearson correlation matrix for Lake Carlton (WBID 2837B).

	YEAR	MONTH	CHLA	CHLAC	DO
YEAR	1.000				
MONTH	-0.046	1.000			
CHLA	0.520	0.016	1.000		
CHLAC	-0.496	0.361	.	1.000	
DO	0.247	-0.317	.	-0.494	1.000
DOSAT	0.275	-0.564	.	-0.530	0.978
NH4	-0.401	0.348	.	0.397	-0.507
NO2	.	.	.	.	.
NO3	-0.046	0.278	.	0.331	0.332
NO2O3	0.572	0.339	.	1.000	-0.041
ORGN	-0.798	0.663	.	0.496	-0.822
PH	-0.061	-0.562	.	-0.255	0.218
PO4	0.501	-0.484	.	-0.622	0.457
TKN	0.333	0.391	.	1.000	-0.730
TN	0.634	0.222	0.720	1.000	.
TP	-0.069	-0.289	0.497	0.319	0.075
TURBIDITY	-0.239	0.069	.	0.547	-0.564
UNNH4	0.448	-0.633	.	-0.236	0.149
TNTPRATIO	0.292	0.376	-0.080	-1.000	.

	DOSAT	NH4	NO2	NO3	NO2O3
DOSAT	1.000				
NH4	-0.505	1.000			
NO2	.	.	.		
NO3	0.256	-0.063	.	1.000	
NO2O3	-0.038	.	.	.	1.000
ORGN	-0.817	0.177	.	-0.197	.
PH	0.313	-0.254	.	-0.525	0.211
PO4	0.479	-0.493	.	-0.258	.
TKN	-0.817	.	.	.	0.609
TN	.	.	.	.	1.000
TP	0.010	0.351	.	0.312	0.058
TURBIDITY	-0.592	0.356	.	-0.436	0.116
UNNH4	0.239	0.355	.	-0.241	.
TNTPRATIO	.	.	.	.	-1.000

	ORGN	PH	PO4	TKN	TN
ORGN	1.000				
PH	-0.337	1.000			
PO4	-0.376	0.332	1.000		
TKN	.	-0.499	.	1.000	
TN	.	-1.000	.	1.000	1.000
TP	-0.058	0.383	0.183	-0.381	0.219
TURBIDITY	0.611	0.463	-0.363	0.512	1.000
UNNH4	-0.186	0.787	0.003	.	.
TNTPRATIO	.	1.000	.	-1.000	0.383

	TP	TURBIDITY	UNNH4	TNTPRATIO
TP	1.000			
TURBIDITY	0.380	1.000		
UNNH4	0.109	0.197	1.000	
TNTPRATIO	-0.783	-1.000	.	1.000

Table 4. Continued. Pairwise frequency table

	YEAR	MONTH	CHLA	CHLAC	DO
YEAR	426				
MONTH	426	426			
CHLA	201	201	201		
CHLAC	18	18	0	18	
DO	30	30	0	13	30
DOSAT	17	17	0	12	17
NH4	11	11	0	11	11
NO2	0	0	0	0	0
NO3	12	12	0	12	12
NO2O3	7	7	0	2	5
ORGN	11	11	0	11	11
PH	28	28	0	14	26
PO4	12	12	0	12	12
TKN	7	7	0	2	5
TN	392	392	201	2	1
TP	404	404	201	14	17
TURBIDITY	19	19	0	14	17
UNNH4	11	11	0	11	11
TNTPRATIO	387	387	201	2	1

	DOSAT	NH4	NO2	NO3	NO2O3
DOSAT	17				
NH4	11	11			
NO2	0	0	0		
NO3	12	11	0	12	
NO2O3	4	0	0	0	7
ORGN	11	11	0	11	0
PH	17	11	0	12	7
PO4	12	11	0	12	0
TKN	4	0	0	0	7
TN	0	0	0	0	2
TP	16	11	0	12	7
TURBIDITY	16	11	0	12	7
UNNH4	11	11	0	11	0
TNTPRATIO	0	0	0	0	2

	ORGN	PH	PO4	TKN	TN
ORGN	11				
PH	11	28			
PO4	11	12	12		
TKN	0	7	0	7	
TN	0	2	0	2	392
TP	11	19	12	7	387
TURBIDITY	11	19	12	7	2
UNNH4	11	11	11	0	0
TNTPRATIO	0	2	0	2	387

	TP	TURBIDITY	UNNH4	TNTPRATIO
TP	404			
TURBIDITY	19	19		
UNNH4	11	11	11	
TNTPRATIO	387	2	0	387

TABLE 5. ESTIMATED AVERAGE ANNUAL TOTAL PHOSPHORUS AND TOTAL NITROGEN LOADING TO LAKE CARLTON, 1991-2000

Nutrient Source	Lake Carlton Mean TP load 1991-2000		Lake Carlton Mean TN load 1991-2000	
	kg/year	%	kg/year	%
Low density residential	29.2	13.5%	396.4	9.7%
Medium density residential	17.0	7.9%	172.1	4.2%
High density residential	0.0	0.0%	0.0	0.0%
Low density commercial	2.6	1.2%	29.6	0.7%
High density commercial	11.5	5.3%	76.9	1.9%
Industrial	0.0	0.0%	0.0	0.0%
Mining	0.0	0.0%	0.0	0.0%
Openland/recreational	0.1	0.05%	2.1	0.05%
Pasture	1.4	0.6%	12.4	0.3%
Cropland	7.0	3.2%	67.6	1.6%
Tree crops	28.1	13.0%	525.3	12.8%
Feeding Operations	0.0	0.0%	0.0	0.0%
Other agriculture	0.9	0.4%	8.4	0.2%
Forest/rangeland	9.4	4.3%	268.1	6.6%
Water	12.0	5.6%	580.5	14.2%
Wetlands	13.0	6.0%	371.8	9.1%
Septic tanks[1]	30.6	14.1%	540.8	13.2%
Precipitation	22.7	10.5%	805.2	19.7%
Dry deposition	30.7	14.2%	229.5	5.6%
Total	216.2	100.00%	4,086.7	100.00%

[1] The septic tank contribution was estimated based upon multiplying the septic tank loads calculated by Fulton et al., 2003 for Lake Beauclair by the fraction of drainage area of the Lake Carlton watershed to the Lake Beauclair drainage area.

Table 6. LAKE CARLTON LAND USE SUMMARY.

LAND USE TYPE	TOTAL (HECTARES)
Low Density Residential	201.88
Medium Density Residential	47.61
High Density Residential	0.0
Low Density Commercial	10.35
High Density Commercial	6.34
Industrial	0.0
Mining	0.0
Open Land/Recreation	3.33
Pasture	7.07
Cropland	16.25
Tree Crops	286.68
Feeding Operation	0.0
Other Agriculture	7.64
Forest/Range Land	280.52
Water	384.18
Wetlands	49.71
Spray Fields	0.0
Muck Farms	0.0
Lakes	0.0
TOTAL	**1301.56**

Appendix A

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, Florida Statutes (F.S.), was established as a technology-based program that relies upon 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, Florida Administrative Code (F.A.C.).

The rule requires 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, Winter Haven Chain of Lakes, the Everglades, Lake Okeechobee, and Lake Apopka. No PLRG has been developed for Newnans Lake at the time this study was conducted.

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 to designate certain stormwater discharges as "point sources" of pollution. 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, EPA has implemented Phase 1 of the MS4 permitting program on a county-wide basis, which brings in all cities (incorporated areas), Chapter 298 urban water control districts, and the DOT (Department of Transportation) throughout the 15 counties meeting the population criteria.

An important difference between the federal and the state stormwater permitting programs is that the federal program covers both new and existing discharges while the state program focuses on new discharges. Additionally, Phase 2 of the NPDES stormwater permitting program will expand the need for these permits to construction sites between one and five acres, and to local governments with as few as 10,000 people. These revised rules require that these additional activities obtain permits by 2003. 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 can not be easily collected and treated by a central treatment facility similar to other point sources of pollution, such as domestic and industrial wastewater discharges. The DEP recently accepted delegation from EPA for the stormwater part of the NPDES program. It should be noted that most MS4 permits issued in Florida include a re-opener clause that allows permit revisions to implement TMDLs once they are formally adopted by rule.