Total Maximum Daily Load for Total Phosphorus
For Lake Griffin, Lake County, Florida

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Phosphorus TMDL for Lake Griffin

1.0 Introduction

1.1 Purpose of Report

This report presents a Total Maximum Daily Load (TMDL) for Total Phosphorus (TP) for Lake Griffin and describes the projected impact of proposed TP reductions on the concentration of unionized 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 un-ionized ammonia and nutrients, and was included on the verified list of impaired waters for the Ocklawaha Basin that was adopted by Secretarial Order on August 26, 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 Griffin, located in central Florida approximately 30 miles northwest of Orlando, is part of the Upper Ocklawaha River Basin (UORB) and the headwater lake of the Ocklawaha River (Figure 1). It has a drainage basin of approximately 50,575 acres (Fulton et al., 2003). At a lake surface elevation of 59 ft National Geodetic Vertical Datum (NGVD), the lake has a surface area of approximately 3,809 ha (9,412 acres) and an average depth of 2.36 m (7.7 ft). Surface outflow from the lake is through the Moss Bluff Lock and Dam, which is operated by the SJRWMD in accordance with regulations prescribed by the U.S. Army Corps of Engineers to maintain water levels in Lake Griffin. The regulation schedule maintains an elevation range of 58 to 59.5 feet NGVD in Lake Griffin.

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. Lake Griffin had been assigned WBID 2814A in the assessment for the 1998 303(d) list, but the lake has been reassigned WBID 2814.

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. PLRGs represent estimated reductions in pollutant loadings from stormwater needed to preserve or restore beneficial uses of receiving waters. Restoration of muck farms within the UORB was predicted to reduce equilibrium total phosphorus (TP) concentrations by about fifty percent in Lake Griffin.

Plots of key water quality parameters over the 1989 – 2002 period indicate that water quality has slightly declined over this period, but that the ranges for some parameters have decreased over time (Figures 2[1] and 3[2])). Table 1 summarizes the Trophic State Index (TSI) annual averages used to assess Lake Griffin under the IWR. Statistical summaries of key water quality parameters are presented for the lake in Table 2.

In recent years, additional attention has been focused on blue-green algal (cyanobacteria) blooms in Florida lakes. Burns, et al. (2001) reported the presence of *Cylindrospermopsis sp.* and *Microcystis sp.* in samples collected in Lake Griffin 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.

In response to the blue-green algal blooms, the Lake County Water Authority (LCWA) funded a monitoring program that measures cyanobacteria abundance and microcystin levels in lakes in the UORB, including Lake Griffin. Results of the monitoring to date are shown in Figures 4 and 5 (provided by Mr. Mike Perry, personal communication of the LCWA). Figure 5 indicates that microcystin levels were temporarily above the World Health Institute threshold for drinking water in December 2001, but that microcystin levels have declined from the peak levels in December 2001.

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

Lake Griffin 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 include the un-ionized ammonia

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[1] . Figure 2 presents water quality information on an annual basis and suggests some reduction in ranges for some parameters over time.

[2] Figure 3 presents the individual observations over time and includes trendlines. Although the r^2 values were low, slopes (with the exception of dissolved oxygen, and un-ionized ammonia) were positive, suggesting declining water quality with time.

criterion (0.02 mg/l) and 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.

As part of the ongoing SWIM Program assessments of the lake, the SJRWMD developed a new interim PLRG for phosphorus in Lake Griffin 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. These approaches yielded a TP target of 32 ppb for Lake Griffin.

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 nonimpaired lake.

Reductions in TP loading are also expected to result in additional benefits with respect to other parameters of concern, 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 Griffin 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 and TKN. The correlation is negative between dissolved oxygen and total phosphorus. The simple linear regressions of total phosphorus versus un-ionized ammonia, turbidity, corrected Chla, uncorrected Chla, NO_2NO_3, or pH were 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 $^{\circ}$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.

Proposed reductions in phosphorus will also result in a smaller input of nitrogen from nitrogen fixation by cyanobacteria that gets recycled in the lake through processes such as grazing and settling. In addition, additional treatment in the watershed to achieve the 66 percent 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 6 illustrates the distribution of this ratio for measurements in Lake Griffin over the 1989 – 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

As part of the development of a phosphorus PLRG for Lake Griffin, Fulton et al. (2003) estimated average annual nitrogen and phosphorus loads to Lake Griffin from a variety of sources over the 1991 – 2000 period (Table 5). 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 (Figure 7). Atmospheric contributions from wet and dry deposition directly on the lake surface were accounted for based upon measurements in the basin. Inputs from tributaries to the lake such as from the Haines Creek Reach (Lake Eustis) and Yale Canal (Lake Yale) were also incorporated into the nitrogen and phosphorus loading estimates. Permit files from the DEP Central District were also reviewed to develop loading estimates from domestic and wastewater spill at facilities within the watershed.

The mean annual TP load over this period was estimated at 33,328.7 kg. The three major sources for phosphorus were muck farms (29.15%), the Emeralda Marsh Conservation Area (30.6%), and Haines Creek (28.67%). Total nitrogen was estimated at 523,138.4 kg/year with Haines Creek accounting for nearly 83% of the total load. Permitted industrial or domestic wastewater sources represented less than 0.04% of either the phosphorus or nitrogen load to the lake.

5.0 Loading Capacity – Linking Water Quality and Pollutant Sources

Fulton et al. (2003) calculated a mean lake TP concentration of 94 ug/l over the 1991 – 2000 period. Based upon results from the two approaches used to determine a target TP, the proposed TP target for Lake Griffin was 32 ug/l. Fulton estimated that a 66 percent reduction in annual phosphorus loading to the lake was needed to meet this TP target. This was based upon the ratio of the target phosphorus concentration (32 ug/l) to the existing phosphorus concentration (94 ug/l). Fulton et al. (2003) made the simplifying assumption that the phosphorus concentration in the lakes is directly

proportional to external loading. Consequently, the ratio was then applied to the long-term annual phosphorus load to determine an allowable load and percent reduction necessary to achieve the TP target.

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 94 ug/l, the $Nutrient_{TSI}$ would be 83.4, and using a long-term average Chla of 135 ug/l, the $Chla_{TSI}$ would be 87.4Thus, the long-term average TSI under current conditions is approximately 85. 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 Chla of 30 ug/l. At this concentration, the $Chla_{TSI}$ would drop to less than 66.

6.0 Critical Conditions

Phosphorus reductions proposed by the SJRWMD were based upon a 10-year average phosphorus load to Lake Griffin. Nitrogen loads to the lake were also based upon a 10-year average. Fulton et al. (2003) note that the phosphorus load reduction goals should be treated as long-term average annual loads and that there is substantial year-to-year variation in the phosphorus load to the UORB lakes. They also pointed out that the estimated external phosphorus load was lower than the reduction goal in at least one of the years 1991-2001 in all of the lakes, except for Lake Griffin.

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:

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

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:

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

It should be noted that the various components of the 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 Griffin (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 (3,815 lbs/year).

Table 6. TMDL Components

| WBID | Parameter | WLA | | LA (lbs/year) | MOS | TMDL (lbs/year) | Percent Reduction |
		Wastewater (lbs/year)	NPDES Stormwater (% Reduction)				
2814A	TP	N/A	66%	26,901	Implicit	26,901	66[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 26,901 lbs/year for TP. This corresponds to reductions from the existing loadings of 66 percent for TP. 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).

As noted earlier, the three largest existing sources are the Emeralda Marsh Conservation Area (30.06%), muck farms (29.15%), and Haines Creek (28.67%). Since TMDLs are being developed for the upstream lakes, there should be a significant reduction in the Haines Creek Reach and Yale Canal discharges to Lake Griffin.

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 Griffin watershed includes areas that will be covered by the MS4 Program, and the WLA for stormwater discharges is an 66 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. In addition, implementation of TMDLs for upstream waterbodies that flow into Lake Griffin will also influence the percent reduction that MS4 areas will need to meet for the TMDL for the lake to be achieved.

NPDES Wastewater Discharges

The only wastewater facility authorized to discharge wastewater to Lake Griffin is the Cutrale Citrus processing facility. The load of TN and TP discharged from the facility is very small, and the discharges represents only 0.02% of the load to the lake. According to the permitting system database, this facility reuses the cooling water and should no longer have a routine surface water discharge.

7.3 Relationship between Lake Eustis, Lake Eustis, and Lake Griffin TMDLs

It should also be noted with respect to possible reductions in either the WLA or LA to achieve the TMDL, discharge from Lake Eustis via the Haines Creek Reach currently represents nearly 29 percent of the annual load of phosphorus to Lake Griffin. A TMDL has been proposed for Lake Eustis that specifies a significant phosphorus load reduction. Although the current contribution from Lake Yale via the Yale Canal is small, a TMDL for phosphorus loading to Lake Yale has also been proposed. Consequently, implementation of these TMDLs will reduce their contributions to Lake Griffin and assist in achieving the TMDL for the lake.

Lake Griffin represents the headwaters for the Ocklwaha River which has been verified impaired for nutrients. A TMDL is currently being developed for the segments immediately downstream of Lake Griffin. Reductions in phosphorus loading to and from Lake Griffin as a result of this TMDL will also become a factor in how the TMDL for the Ocklawaha River 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.

10.0 References

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Figure 1. Upper Ocklawaha River Chain of Lakes

Lake Weir — 2790A
Ella Lake
Lake Yale — 2807A
Lake Eldorado
Lake Griffin — 2814A
Silver Lake
Lake Eustis — 2817B
Lake Joanna
Loch Leven
Lake Dora — 2831B
Lake Harris — 2838A
Lake Denham
Lake Beauclair
Lake Ola
Little Lake Harris — 2838B
Clearwater Lake
Palatlakaha River
Lake Apopka — 2835D
Lake Emma
Cherry Lake — 2839A
Lake Minneola
Lake Minnehaha

Waterlines
Major rivers
Water Bodies
Major Rivers (Areas)
Waterbody IDs

2   0   2   4   6 Miles

Map created on Jan. 31,2003 by
Aaron Lassiter, FDEP Watershed
Assessment Section, Tallahassee,
Fl. 32399, for reference purposes.
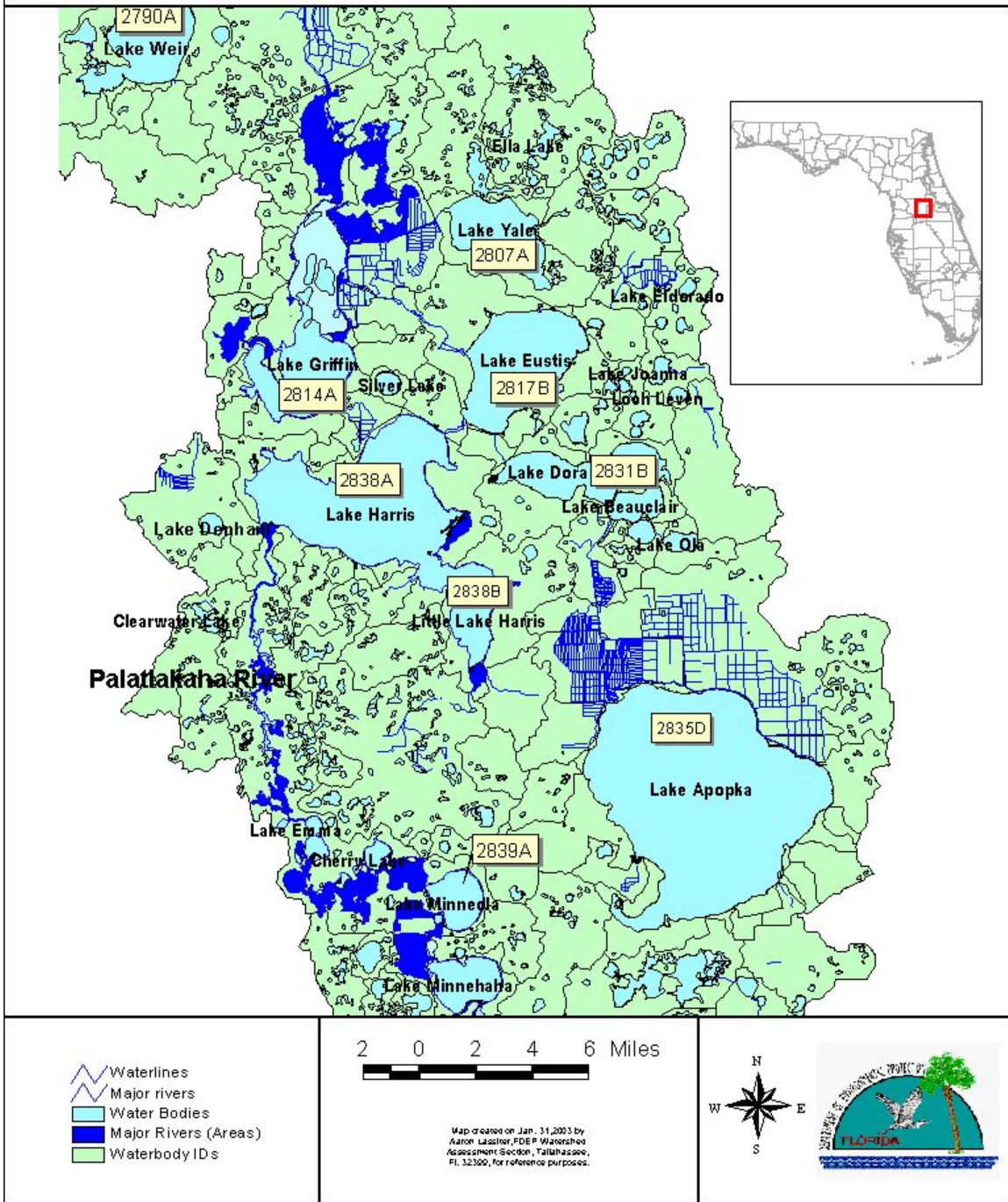
N
W   E
S

FLORIDA

Figure 2. Boxplots of water quality by year in Lake Griffin (WBID 2814A) for the 1989 - 2002 period.
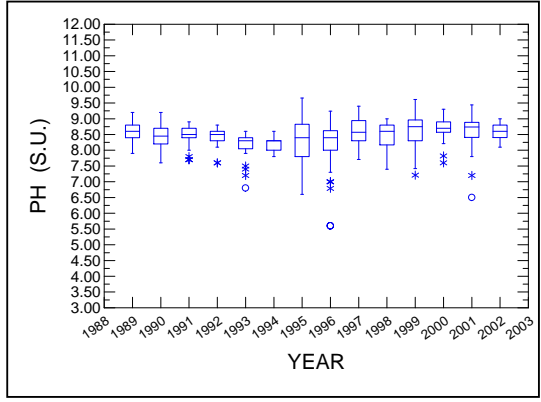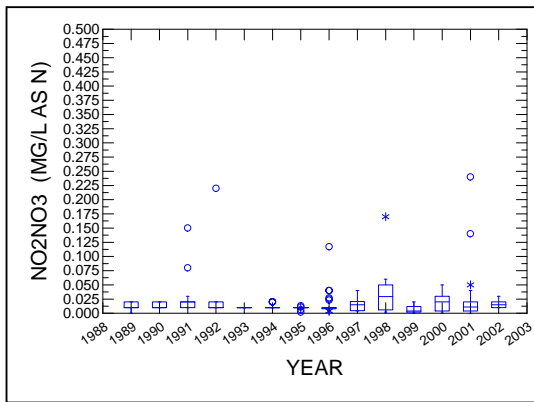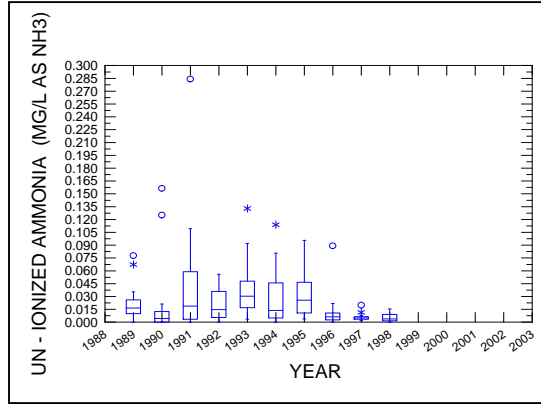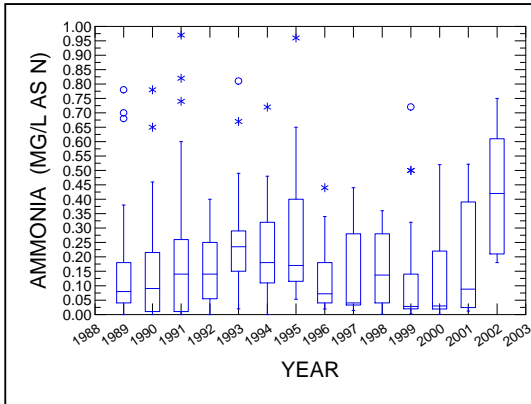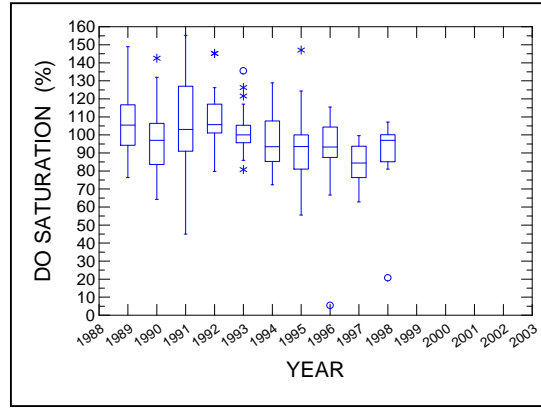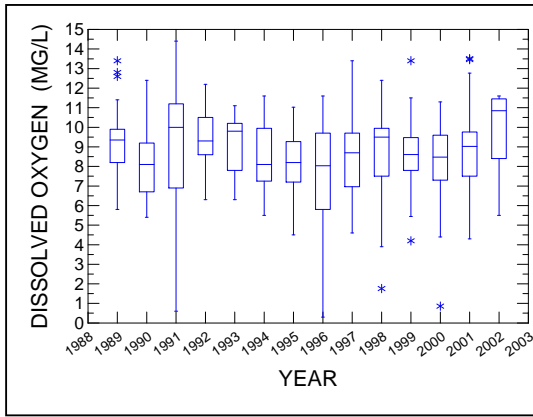
Figure 2. Continued.
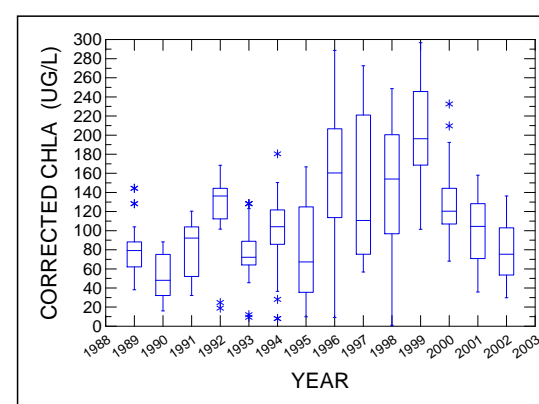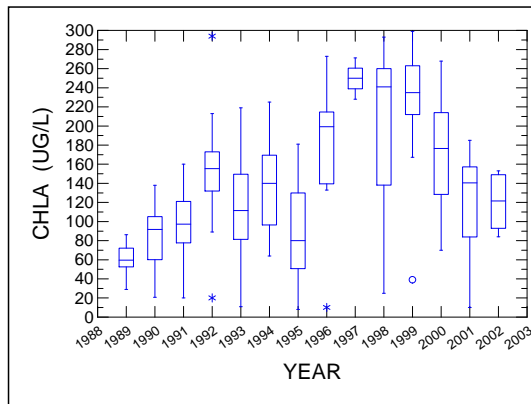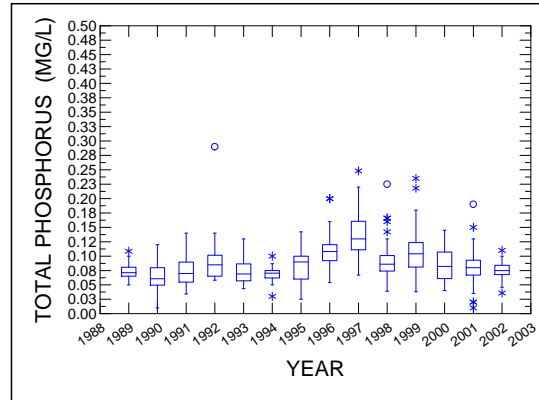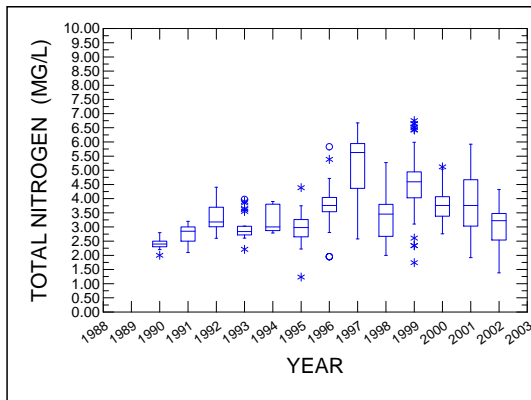
FIGURE 3. PLOTS OF WATER QUALITY IN LAKE GRIFFIN FOR THE 1989-2002 PERIOD WITH TRENDLINES.

WBID 2814A — Corrected Chlorophyll a

$y = 0.0245x - 725.88$
$R^2 = 0.13$

WBID 2814A — Dissolved Oxygen

$y = -0.0001x + 12.21$
$R^2 = 0.0048$

WBID 2814A — Nitrogen Total as N

$y = 0.0003x - 8.4881$
$R^2 = 0.1698$

WBID 2814A — pH

$y = 3E-05x + 7.3223$
$R^2 = 0.0085$

WBID 2814A — Phosphorus Total as P

$y = 1E-05x - 0.3488$
$R^2 = 0.0088$

WBID 2814A — Turbidity

$y = 0.0006x + 5.1405$
$R^2 = 0.0037$

WBID 2814A — Unionized Ammonia

$y = -5E-06x + 0.1835$
$R^2 = 0.0192$
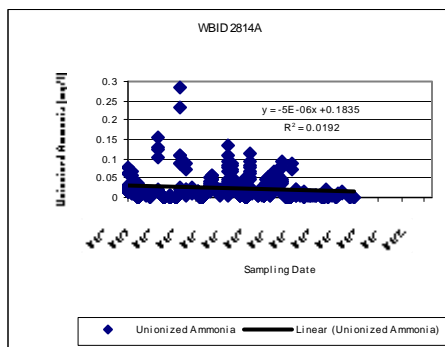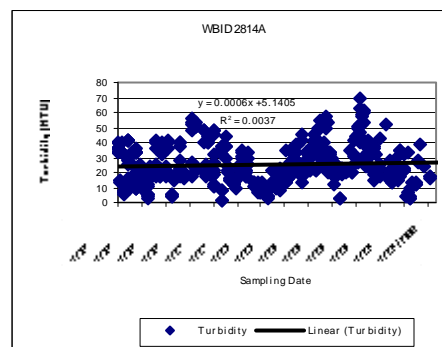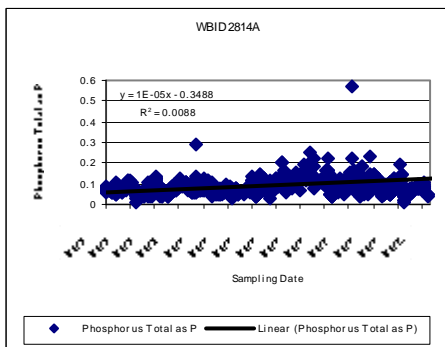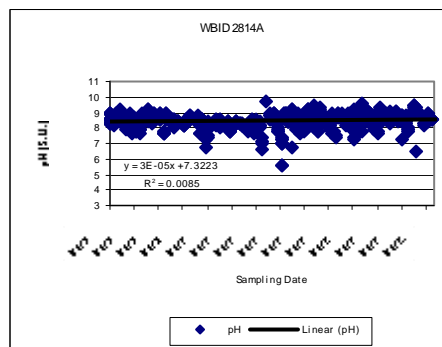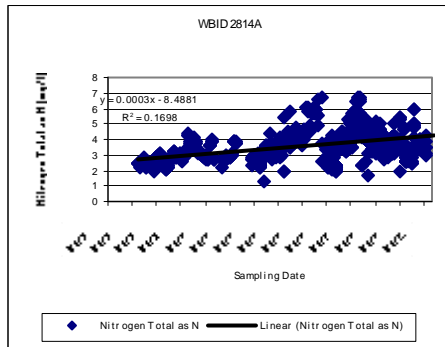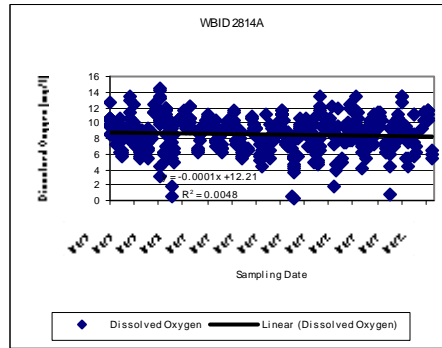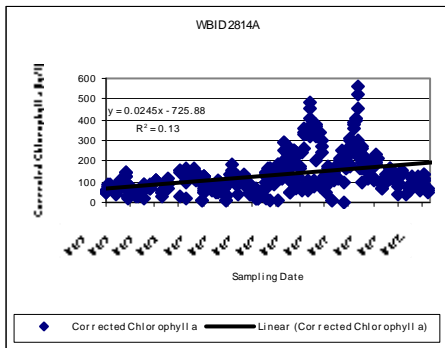
Figure 4. Cyanobacteria levels (biovolumes) in Lake Griffin
from Lake County Water Authority
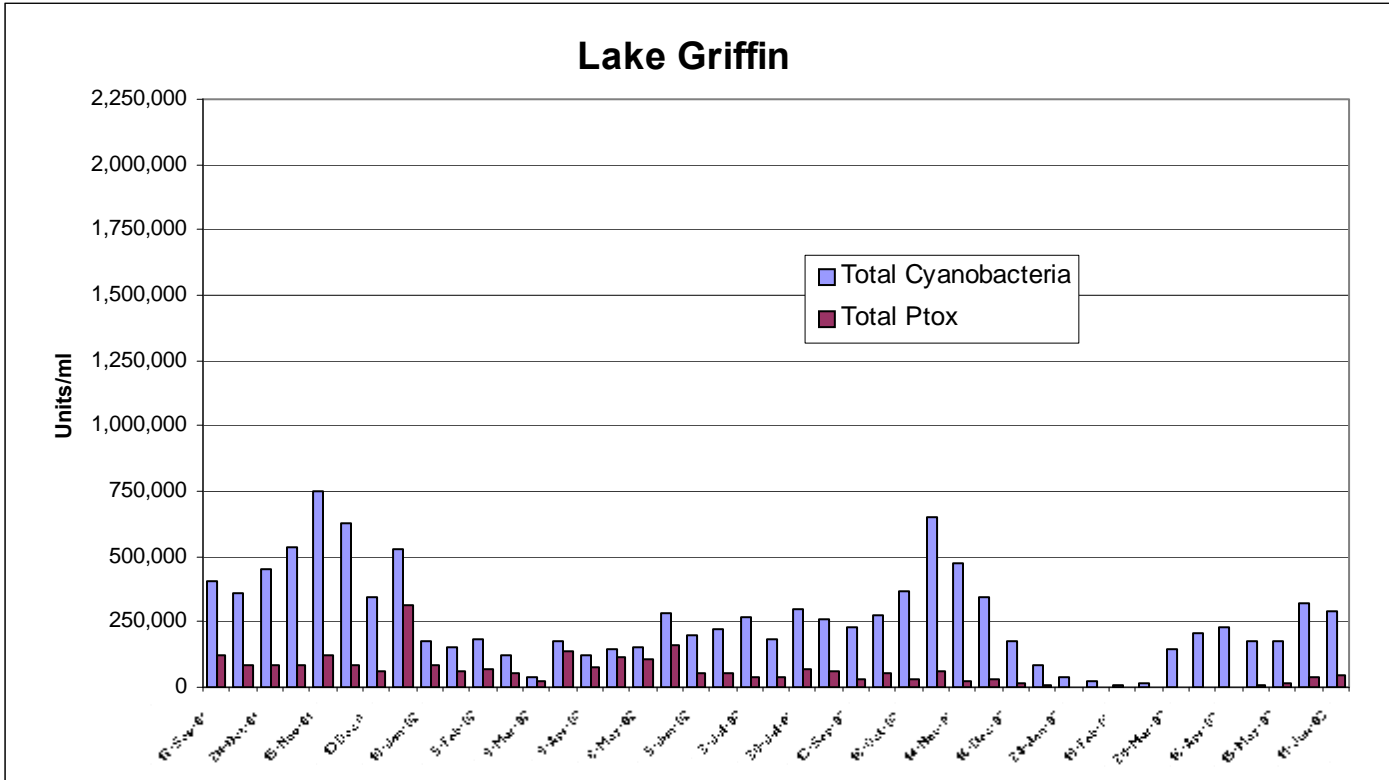
Figure 5. Microcystin levels in Lake Griffin from Lake County Water Authority.

Microcystin Levels in Lake Griffin

WHO standard for drinking water - 1.0 ug/L
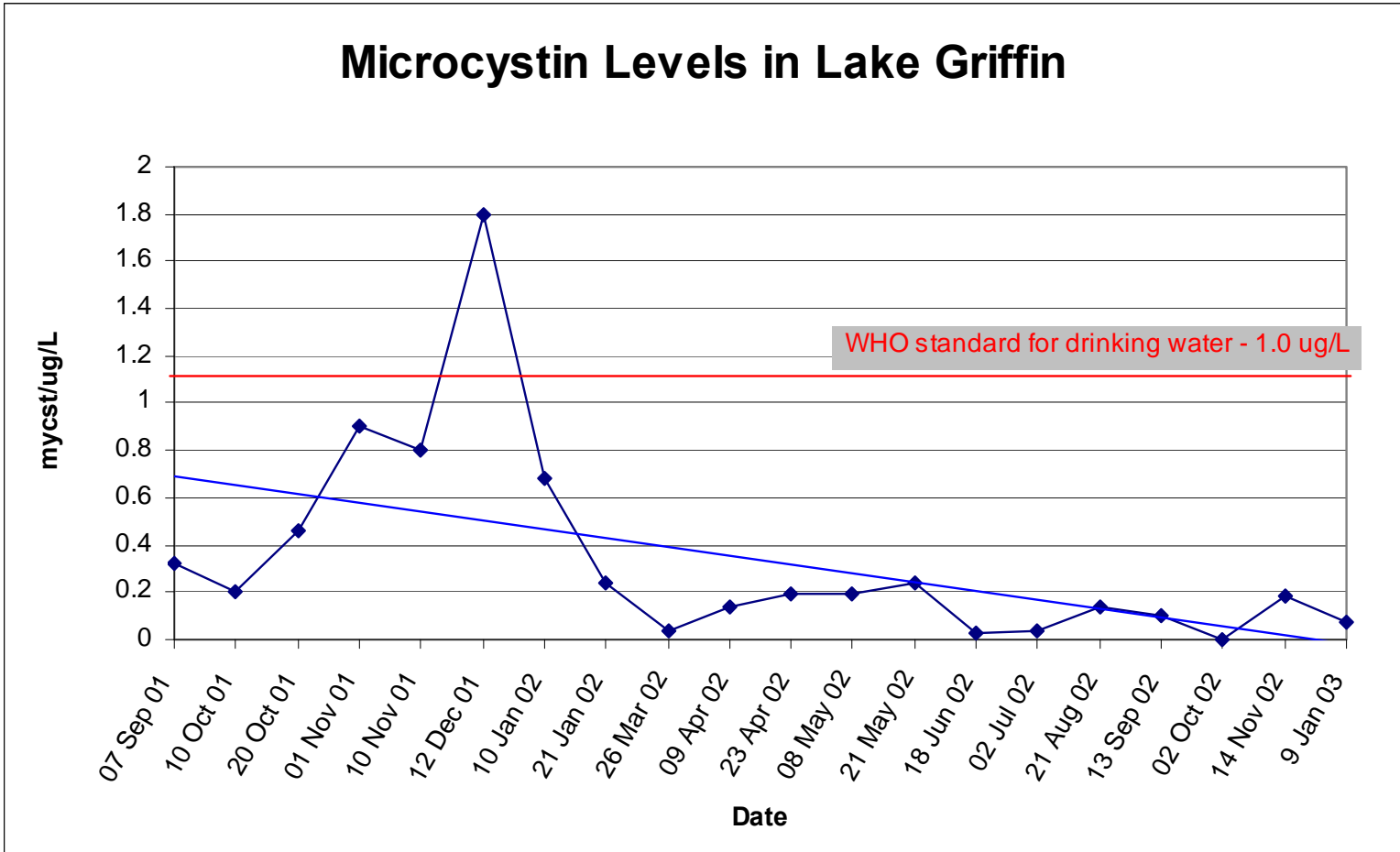
Figure 6. TN/TP cumulative frequency distribution for measurements in Lake Griffin over the 1989 – 2002 period.

Lake Griffin Landuse

Attribute	Acres	Percent of Total
Urban and Built-Up	2924	22
Agriculture	2035	15
Rangeland	787	6
Upland Forests	2302	17
Water	904	7
Wetlands	4470	33
Barren Land	8	0
Roads and Highways	79	0
Totals	13509	100

Lake Yale

Lake Eustis

2814

2814A
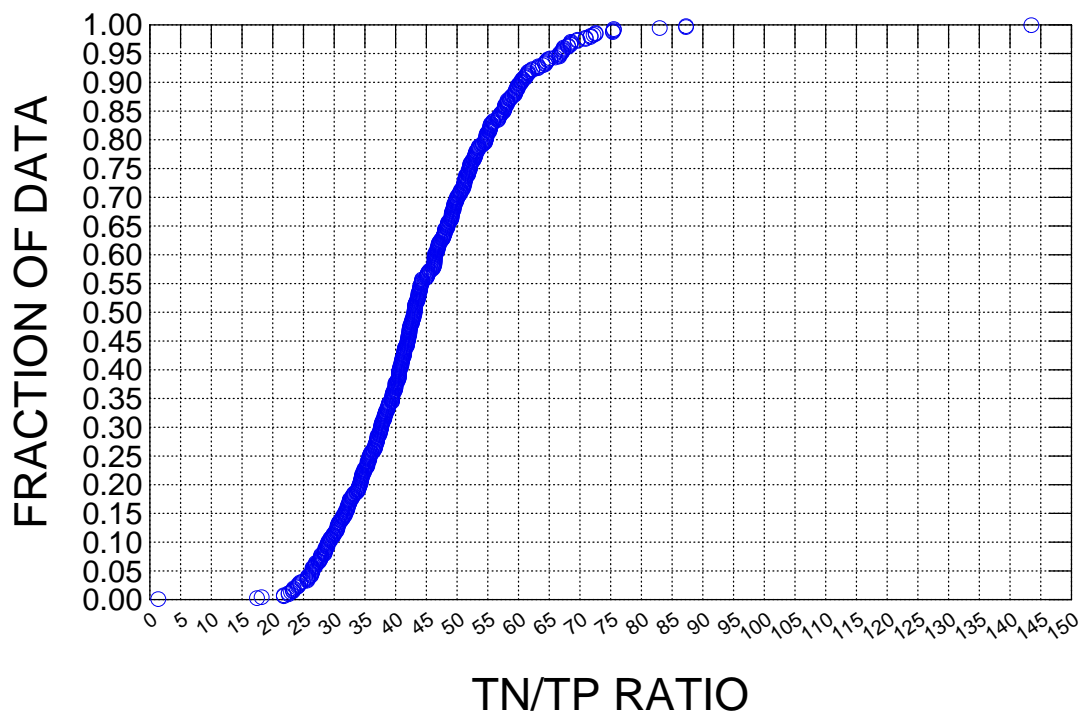
Lake Griffin
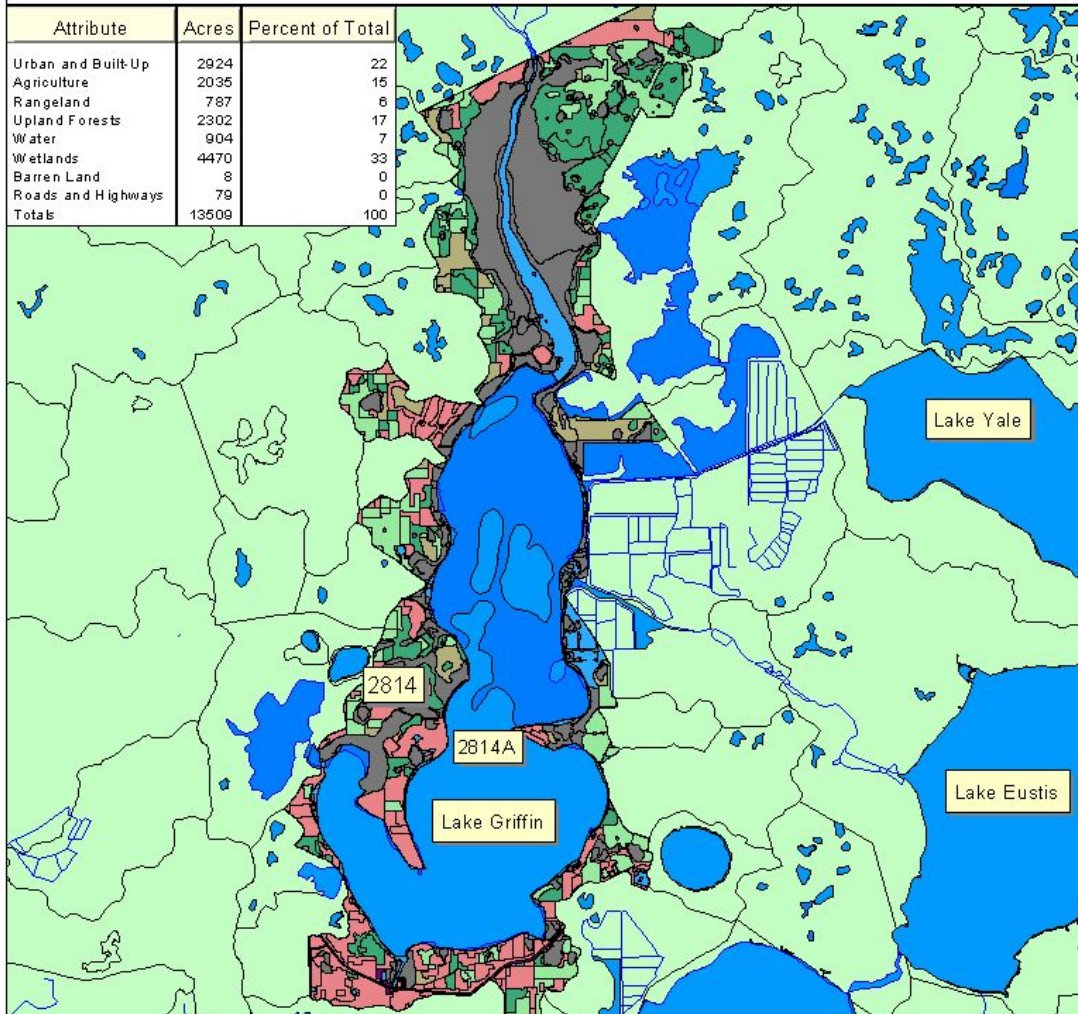
Legend

Land Use
- Urban and Built-Up
- Agriculture
- Rangeland
- Upland Forests
- Water
- Wetlands
- Barren Land
- Transportation, Comm. and Utilities

0.8 0 0.8 1.6 2.4 3.2 4 Miles

Map created by Aaron Lardler,
FDEP Watershed Assessment
Section, Tallahassee, FL 32399,
for reference.

FLORIDA

N

Table 1. Lake Griffin un-ionized ammonia TSI assessments under the IWR.

Parameter of concern	Lake Griffin
Annual TSI	Trophic State Index
1989	78.7
1990	73.8
1991	77.9
1992	85.3
1993	79.5
1994	
1995	79.7
1996	89.1
1997	94.2
1998	85.4
1999	92.0
2000	85.6
2001	84.1
Un-ionized Ammonia	PP – 63/185 Potentially impaired VP – 18/66 Verified

Table 2. Summary statistics of key water quality parameters for Lake Griffin (WBID 2814A) over the 1989 – 2002 period.

	CHLA	CHLAC	DO	DOSAT	NH4
N of cases	483	417	524	304	385
Minimum	8.000	1.000	0.300	5.385	0.000
Maximum	571.180	565.106	14.400	155.263	1.220
Median	154.000	114.900	8.800	98.070	0.120
Mean	169.519	134.655	8.648	98.805	0.188
Standard Dev	97.698	92.727	2.126	19.433	0.210

	NO2	NO3	NO2O3	ORGN	PH
N of cases	0	193	285	286	468
Minimum	.	0.000	-0.002	0.120	5.600
Maximum	.	0.290	2.540	6.870	9.660
Median	.	0.020	0.010	3.000	8.500
Mean	.	0.032	0.026	3.120	8.448
Standard Dev	.	0.043	0.152	0.875	0.514

	PO4	TKN	TN	TP	TURBIDITY
N of cases	126	187	763	1038	455
Minimum	0.000	1.230	1.232	0.010	1.000
Maximum	0.350	6.750	6.751	4.250	69.800
Median	0.030	3.890	3.620	0.084	22.000
Mean	0.049	3.999	3.643	0.092	25.043
Standard Dev	0.051	1.228	0.934	0.134	12.926

	UNNH4	TNTPRATIO
N of cases	187	590
Minimum	0.000	1.393
Maximum	0.284	278.000
Median	0.012	43.107
Mean	0.025	45.151
Standard Dev	0.035	16.516

Table 3. Ammonia Concentration (in mg/l as N) that results in un-ionized
ammonia of 0.02 mg/ 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 Griffin (WBID 2814A).

	YEAR	MONTH	CHLA	CHLAC	DO
YEAR	1.000				
MONTH	-0.000	1.000			
CHLA	0.513	0.025	1.000		
CHLAC	0.352	0.122	0.993	1.000	
DO	-0.055	-0.214	-0.167	-0.018	1.000
DOSAT	-0.298	-0.046	-0.299	-0.279	0.863
NH4	-0.035	-0.135	-0.345	-0.274	-0.113
NO2	.	.	.	.	.
NO3	-0.048	-0.329	.	-0.104	0.105
NO2O3	0.083	0.032	-0.050	-0.285	-0.081
ORGN	0.488	0.178	-0.600	0.878	0.094
PH	0.087	0.214	0.143	0.198	0.150
PO4	0.018	-0.038	.	-0.213	-0.073
TKN	0.268	-0.042	0.740	0.729	-0.016
TN	0.417	0.016	0.825	0.836	0.357
TP	0.092	-0.023	0.477	0.463	-0.047
TURBIDITY	0.062	-0.005	0.783	0.505	0.159
UNNH4	-0.149	0.075	-0.347	-0.247	-0.072
TNTPRATIO	0.112	0.233	-0.063	0.340	-0.244

	DOSAT	NH4	NO2	NO3	NO2O3
DOSAT	1.000				
NH4	-0.226	1.000			
NO2	.	.	.		
NO3	-0.167	-0.033	.	1.000	
NO2O3	0.067	0.148	.	.	1.000
ORGN	-0.032	-0.215	.	-0.105	0.011
PH	0.363	-0.322	.	-0.252	-0.306
PO4	-0.050	0.174	.	-0.168	.
TKN	-0.524	-0.027	.	.	-0.064
TN	.	.	.	.	0.531
TP	-0.056	0.051	.	0.100	0.969
TURBIDITY	0.193	-0.467	.	-0.060	0.038
UNNH4	0.178	0.460	.	-0.169	-0.084
TNTPRATIO	.	.	.	.	-0.192

	ORGN	PH	PO4	TKN	TN
ORGN	1.000				
PH	0.179	1.000			
PO4	-0.205	-0.140	1.000		
TKN	.	0.092	.	1.000	
TN	.	-0.249	.	0.869	1.000
TP	0.054	-0.188	-0.045	0.039	0.190
TURBIDITY	0.335	0.316	-0.107	0.755	0.799
UNNH4	-0.116	0.232	-0.062	-0.206	.
TNTPRATIO	.	-0.120	.	-0.028	0.149

	TP	TURBIDITY	UNNH4	TNTPRATIO
TP	1.000			
TURBIDITY	0.100	1.000		
UNNH4	-0.178	-0.243	1.000	
TNTPRATIO	-0.194	-0.388	.	1.000

Table 4. Continued. Pairwise frequency table

	YEAR	MONTH	CHLA	CHLAC	DO
YEAR	1434				
MONTH	1434	1434			
CHLA	483	483	483		
CHLAC	417	417	87	417	
DO	524	524	111	313	524
DOSAT	304	304	58	141	304
NH4	385	385	88	259	323
NO2	0	0	0	0	0
NO3	193	193	0	188	181
NO2O3	285	285	88	135	229
ORGN	286	286	8	182	231
PH	468	468	107	306	455
PO4	126	126	0	122	114
TKN	187	187	80	135	174
TN	763	763	342	25	28
TP	1038	1038	430	323	410
TURBIDITY	455	455	83	305	390
UNNH4	187	187	29	113	186
TNTPRATIO	590	590	342	25	28

	DOSAT	NH4	NO2	NO3	NO2O3
DOSAT	304				
NH4	201	385			
NO2	0	0	0		
NO3	114	187	0	193	
NO2O3	113	198	0	0	285
ORGN	164	286	0	187	99
PH	271	314	0	172	235
PO4	113	121	0	126	0
TKN	58	100	0	0	187
TN	0	1	0	0	31
TP	227	384	0	193	284
TURBIDITY	234	352	0	180	265
UNNH4	186	187	0	95	92
TNTPRATIO	0	1	0	0	31

	ORGN	PH	PO4	TKN	TN
ORGN	286				
PH	222	468			
PO4	121	105	126		
TKN	1	180	0	187	
TN	1	31	0	31	763
TP	286	406	126	186	590
TURBIDITY	268	387	125	172	31
UNNH4	150	187	94	37	0
TNTPRATIO	1	31	0	31	590

	TP	TURBIDITY	UNNH4	TNTPRATIO
TP	1038			
TURBIDITY	444	455		
UNNH4	187	185	187	
TNTPRATIO	590	31	0	590

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

Nutrient Source	Lake Griffin Mean TP load 1991-2000		Lake Griffin Mean TN load 1991-2000	
	kg/year	%	kg/year	%
Low density residential	61.2	0.17%	669.2	0.13%
Medium density residential	228.0	0.65%	1,750.5	0.33%
High density residential	179.8	0.51%	1,075.5	0.21%
Low density commercial	41.6	0.12%	339.6	0.06%
High density commercial	436.1	1.23%	3,101.7	0.59%
Industrial	89.4	0.25%	535.8	0.10%
Mining	0.8	0.00%	6.8	0.00%
Openland/recreational	9.8	0.03%	224.6	0.04%
Muck farms	10,298.5	29.15%	13,115.3	2.51%
Pasture	56.2	0.16%	367.4	0.07%
Cropland	66.6	0.19%	529.9	0.10%
Tree crops	3.9	0.01%	57.5	0.01%
Feeding Operations	3.8	0.01%	71.0	0.01%
Other agriculture	11.0	0.03%	71.3	0.01%
Forest/rangeland	30.5	0.09%	719.3	0.14%
Water	24.5	0.07%	718.1	0.14%
Wetlands	439.0	1.24%	9,838.3	1.88%
Emeralda Marsh Conservation Area	10,619.1	30.06%	7,055.6	1.35%
Septic tanks	857.4	2.43%	15,135.0	2.89%
Precipitation	732.7	2.07%	26,242.3	5.02%
Dry deposition	997.8	2.82%	7,449.2	1.42%
Haines Creek discharge	10,127.5	28.67%	433,903.3	82.94%
Lake Yale discharge	1.0	0.00%	59.6	0.01%
Cutrale weak waste discharges	6.9	0.02%	44.3	0.01%
Cutrale spray/fields runoff	5.1	0.01%	56.3	0.01%
Cutrale spills	0.2	0.00%	0.1	0.00%
Domestic WWTP spills	0.2	0.00%	1.0	0.00%
Total	**35,328.7**	**100.00%**	**523,138.4**	**100.00%**

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.