Total Maximum Daily Load for Total Phosphorus For Lake Yale and Yale Canal Lake County, Florida

Wayne Magley, Ph.D, P.E.

Florida Department of Environmental Protection
Watershed Assessment Section
September 19, 2003

Table of Contents

List of Figures

List of Tables

Phosphorus TMDL for Lake Yale

1.0 Introduction

1.1 Purpose of Report

This report presents a Total Maximum Daily Load (TMDL) for Total Phosphorus (TP) for Lake Yale and Lake Yale Canal 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 (Identification of Impaired Surface Waters, which is commonly referred to as the Impaired Waters Rule, or IWR), Florida Administrative Code, the lake and canal were verified as impaired nutrients, and both waters were 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 Yale, located in central Florida approximately 30 miles northwest of Orlando, is part of the Upper Ocklawaha River Basin (UORB (Figure 1). It has a drainage basin of approximately 15,394 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 1,627 ha (4,020 acres) and an average depth of 3.73 m (12.2 ft). Surface outflow from the lake is through the Yale Canal into Lake Griffin. Discharge and water elevation is partially controlled by a fixed crest weir

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 Yale had been assigned WBID 2807A and Lake Yale Canal has been assigned WBID 2807.

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) for lakes in the UORB based upon trophic state modeling. PLRGs represent estimated reductions in pollutant loadings from stormwater needed to preserve or restore beneficial uses of receiving waters. Fulton (1995) found that nutrient loadings were divided among a number of sources, with no single dominant source. He identified runoff from upland agriculture as a major source of both nitrogen and phosphorus loading to Lake Yale. In the 1984-85 period, the agricultural loadings were primarily from pasture and citrus. However, following freezes in the mid 1980's, the citrus acreage declined and other upland agricultural loadings increased. However, runoff from natural areas was also identified as a major source of nutrients to the lake.

Plots of key water quality parameters over the 1989 – 2002 period indicate that water quality has declined over this period and some parameters suggest a fluctuating pattern over time, perhaps reflecting changes in water level elevation and residence time (Figures 2[1] and 3[2]).). Table 1 summarizes the DO, un-ionized ammonia, and Chlorophyll a and/or Trophic State Index (TSI) annual averages used to assess Lake Yale and Yale Canal under the IWR. Statistical summaries of key water quality parameters are presented for both WBIDs 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 Yale 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 Yale. 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 and August 2002, but that microcystin levels have declined from the peak levels in December 2001.

[1]). Figure 2 presents water quality information on an annual basis and suggests some fluctuations or cycles 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 were positive, suggesting declining water quality with time.

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

Lake Yale and Lake Yale Canal are Class III waterbodies with designated uses 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 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.

As part of the ongoing SWIM Program assessments of the lake, the SJRWMD developed a new interim PLRG for phosphorus in Lake Yale 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 20 ppb for Lake Yale.

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 Yale data. Based on Pearson correlation coefficients for this data set (Table 4), Total phosphorus is positively correlated with turbidity, pH, corrected chlorophyll a, uncorrected chlorophyll a, ammonia, total nitrogen and TKN. The correlation is negative between dissolved oxygen and total phosphorus. The simple linear regressions of total phosphorus versus ammonia, turbidity, corrected Chla, uncorrected Chla, 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 ^{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.

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 proposed 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 Yale 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 Yale, Fulton et al. (2003) estimated average annual nitrogen and phosphorus loads to Lake Yale 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. 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 1,432.4 kg. The three major sources for phosphorus were dry deposition (25.94%), precipitation (19.74%), and wetlands (14.59%). In this evaluation, pasture, cropland, feeding operations, and other agricultural activities represented approximately 5% of the annual average phosphorus. Total nitrogen was estimated at 23,078.7 kg/year, with precipitation accounting for approximately 42% of the total load. Permitted industrial or domestic wastewater sources represented less than 4% of the phosphorus load and less than 2% of the nitrogen load to the lake.

5.0 Loading Capacity – Linking Water Quality and Pollutant Sources

Fulton et al. (2003) calculated a mean TP of 22 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 Yale was 20 ug/l. Fulton estimated that a 10 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 (20 ug/l) to the existing phosphorus concentration (22 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 22 ug/l, the $Nutrient_{TSI}$ would be 49.1, and using a long-term average Chla of 29 ug/l, the $Chla_{TSI}$ would be 65.3. Thus, the long-term average TSI under current conditions is approximately 57. Reducing the in-lake phosphorus concentration to 20 ug/l would result in a $Nutrient_{TSI}$ of 47. Fulton (2003a) provided a preliminary evaluation of the effects of the interim PLRG and predicted a mean Chla of 14 ug/l. At this concentration, the $Chla_{TSI}$ would drop to less than 55 and the TSI would be 51.

6.0 Critical Conditions

Phosphorus reductions proposed by the SJRWMD were based upon a 10-year average phosphorus load to Lake Yale. 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:

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

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:

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

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 Yale (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 (1,442 lbs/year).

Table 6. TMDL Components

WBID	Parameter	WLA		LA (lbs/year)	MOS	TMDL (lbs/year)	Percent Reduction
		Wastewater (lbs/year)	NPDES Stormwater (% Reduction)				
2807A	TP	N/A	10%	2,844	Implicit	2,844	10[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 2,844 lbs/year for TP. This corresponds to reductions from the existing loadings of 10 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).

Since precipitation and dry deposition represent two of the largest sources of phosphorus load to the lake, reductions from remaining sources will be greater than 10%.

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 Yale watershed includes areas that will be covered by the MS4 Program, and the WLA for stormwater discharges is a 10 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

The weak waste discharge from Golden Gem Growers was the only wastewater facility authorized to discharge wastewater to Lake Yale. According to the permitting system database, this facility was purchased by Citrus World, Inc. in 2000 and is now called Florida Natural Growers. Since 2000, the operation and permit conditions have been modified such that discharge of non-contact cooling water up to 0.133 MGD to a ditch that flows into Lake Yale represents a conditional backup option. The facility is not processing fresh citrus and is required to notify the Department if it plans to resume that operation and address a possible surface discharge. There is a non-contact storm water pond located at the facility that may overflow into the ditch.

7.3 Relationship between Lake Yale and Lake Griffin TMDLs

The proposed TMDL for Lake Griffin estimated that discharge from Lake Yale currently represents a very small contribution of the total annual phosphorus load for Lake Griffin. Reductions in phosphorus loading to and from Lake Yale as a result of this TMDL will ensure that Lake Yale does not become a factor in the future with respect to water quality problems in Lake Griffin.

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.

Since DO is a gas, its saturation level is a function of water temperature and salinity. Increased water temperatures and/or salinities reduce the amount of oxygen that can remain in solution. Salinity is not a factor in Lake Yale. Consequently, summer and early fall would represent periods of highest water temperature where DO saturation and DO would be expected to be lower. Algal production during these periods can increase oxygen levels during the day, however, the increased respiration will result in lower levels at night and the possibility of large diurnal fluctuations. Reductions in the algal biomass will reduce these fluctuations.

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

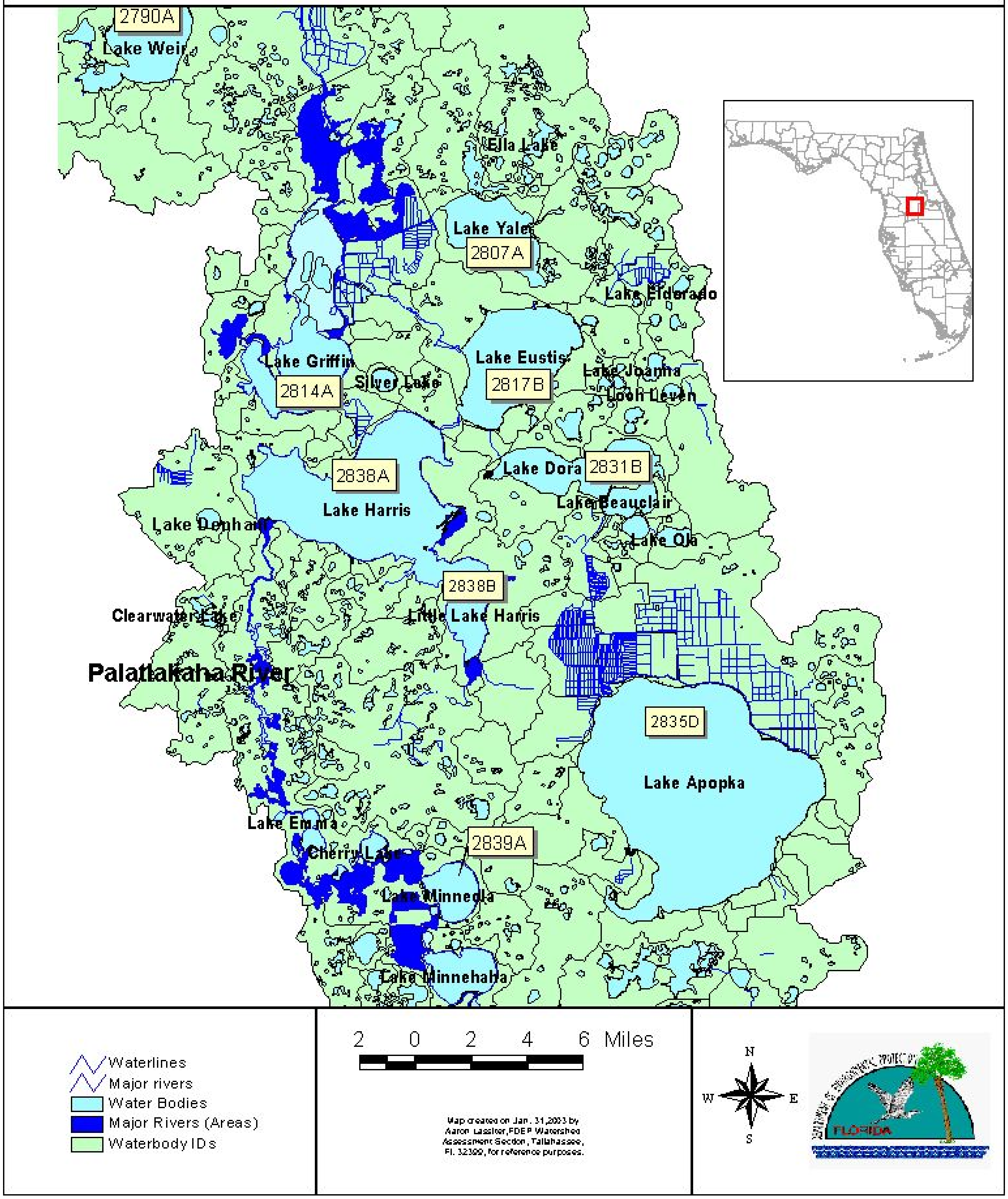


Figure 2a. Boxplots of water quality by year in Lake Yale (WBID 2807A) for the 1989 - 2002 period.

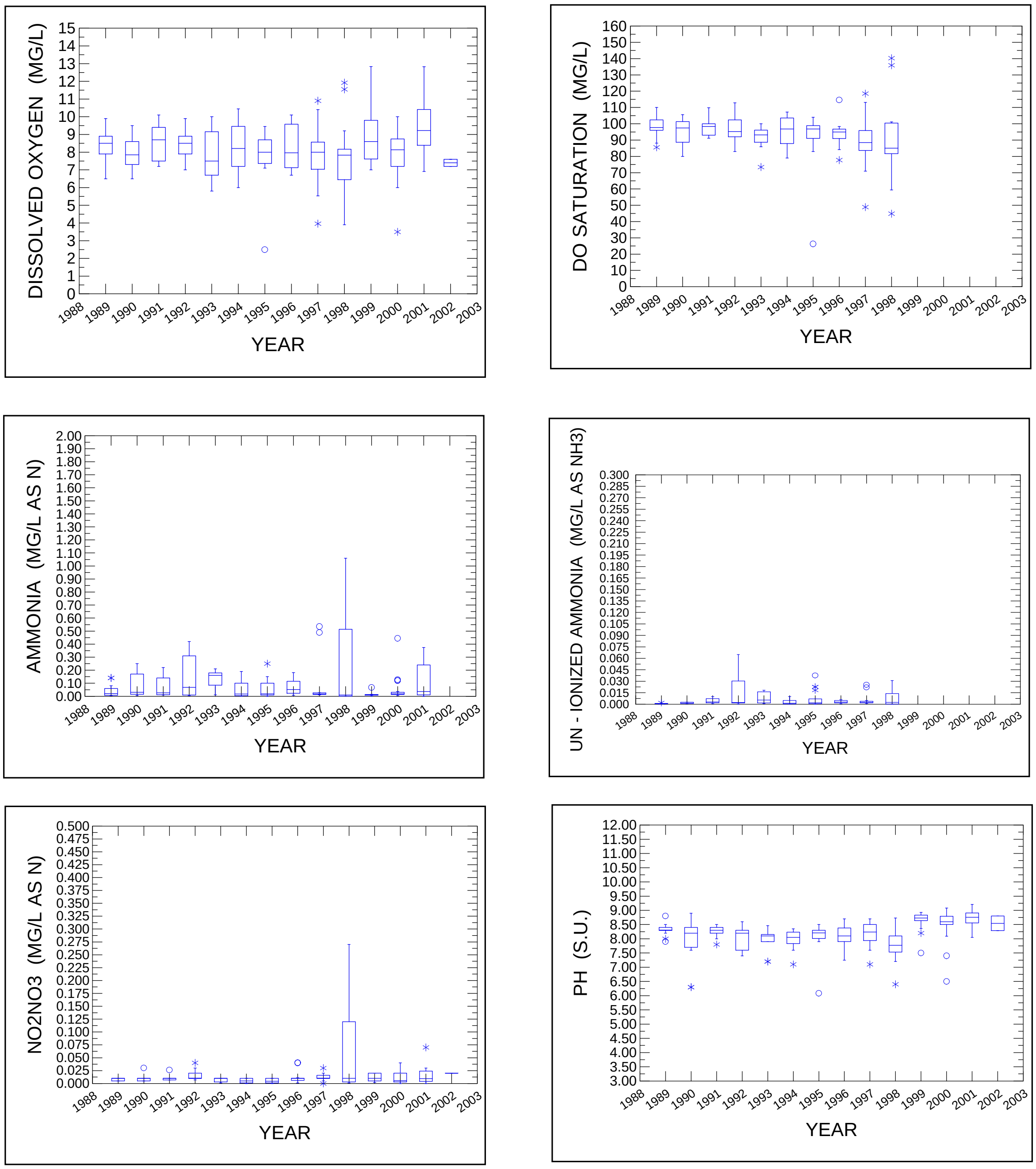
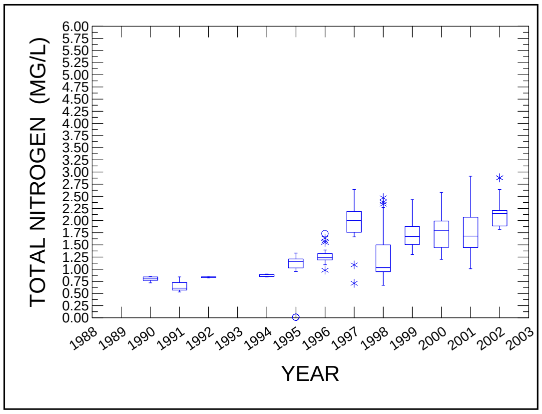
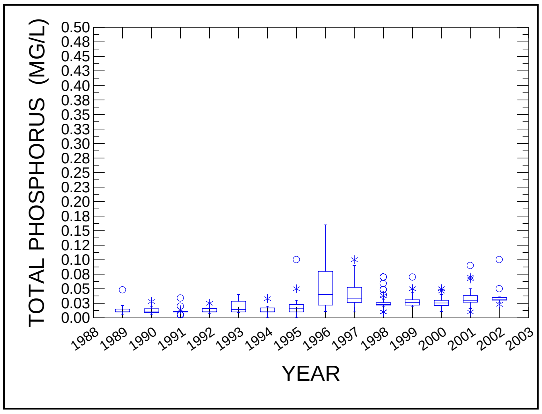
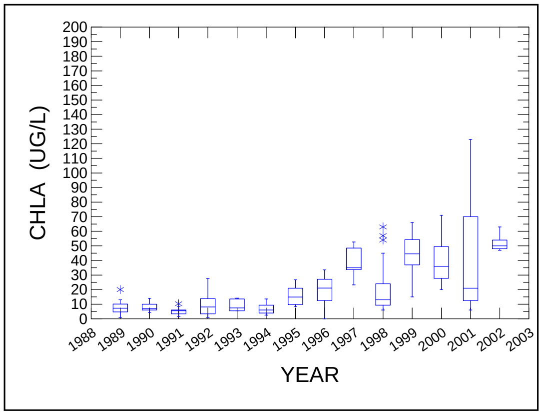


Figure 2a. Continued.







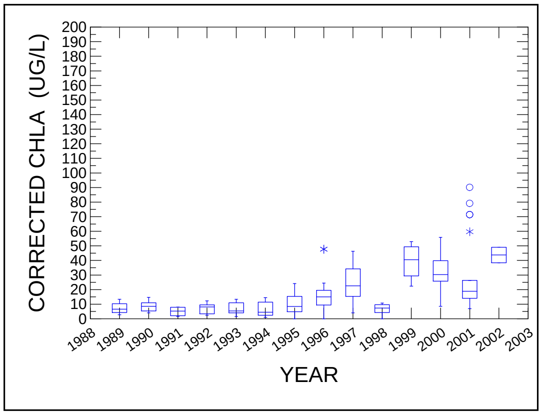


Figure 2b. Boxplots of water quality by year in Lake Yale Canal (WBID 2807) for the 1989 - 2002 period.

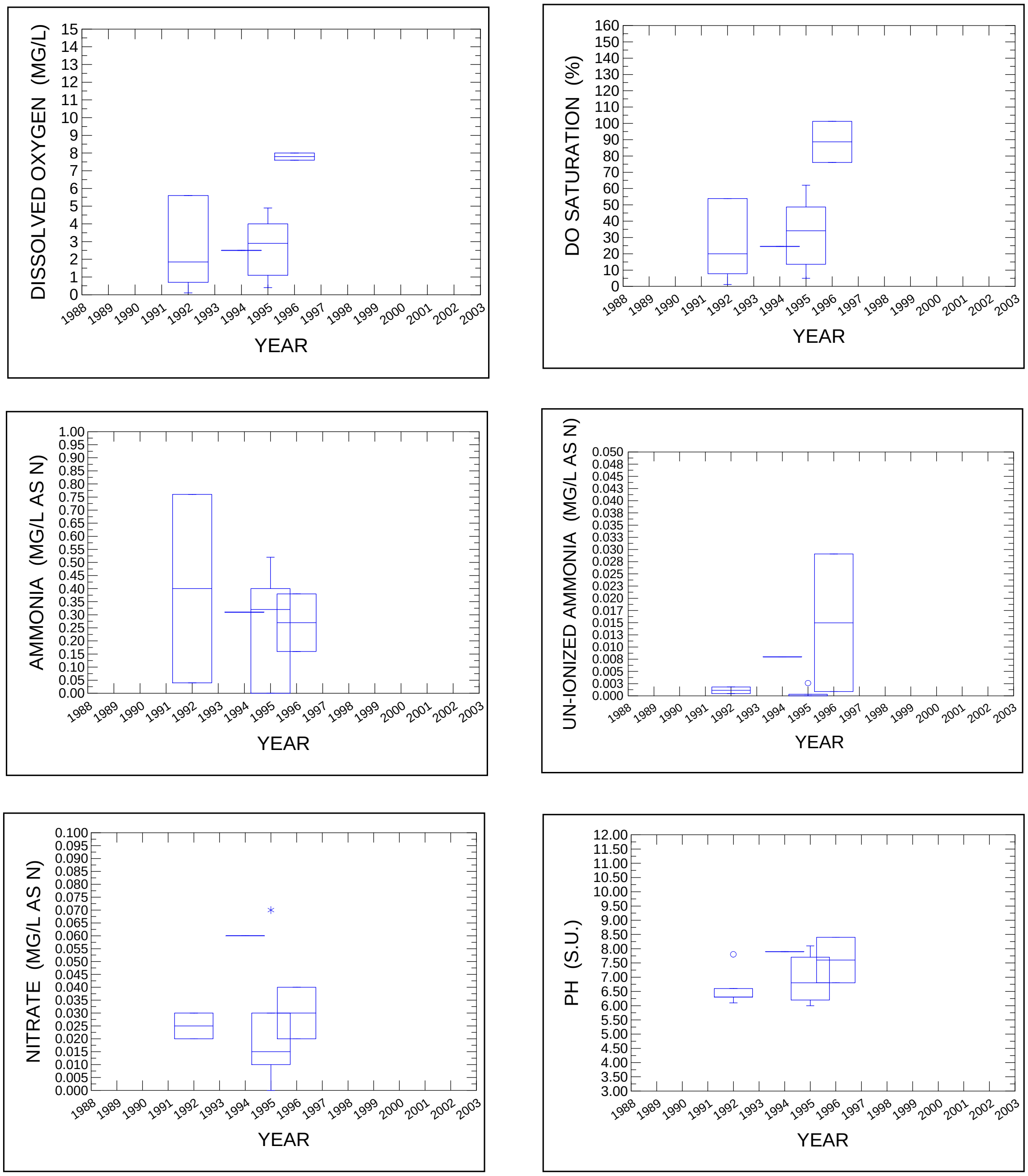


Figure 2b. Continued.

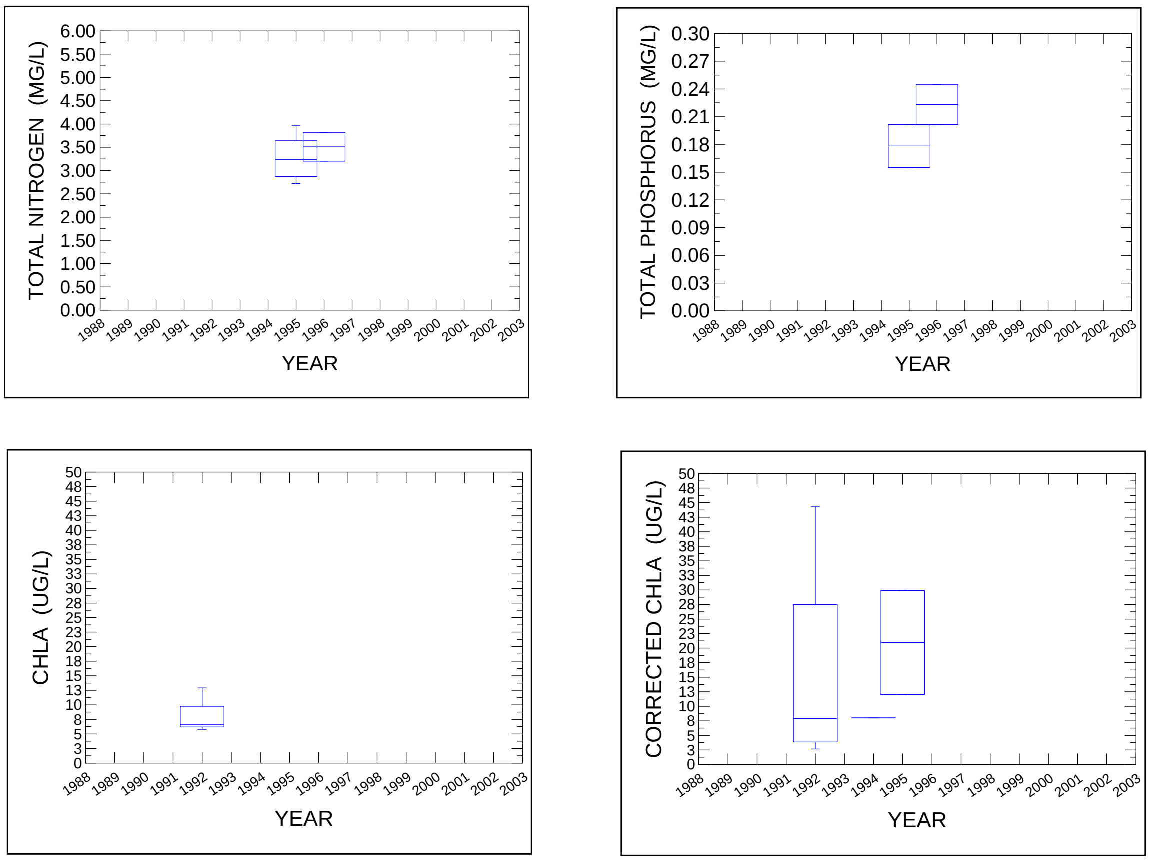
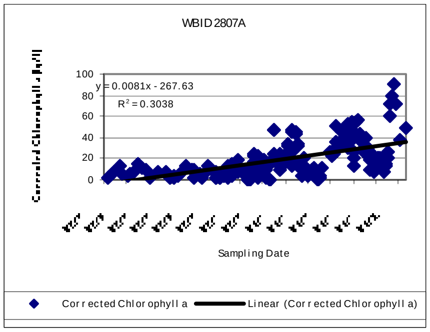
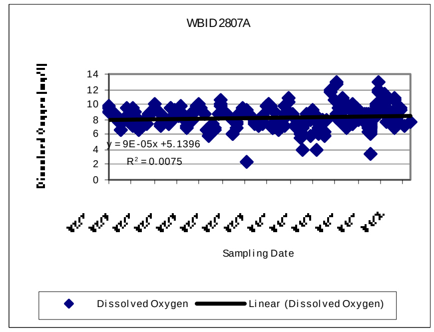
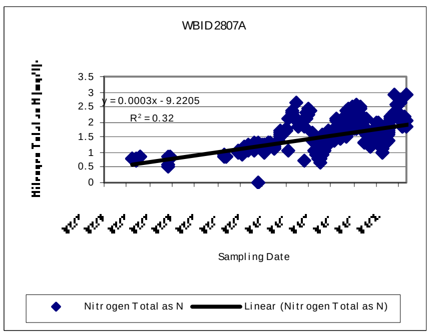
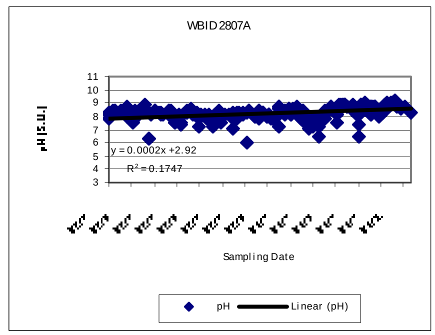


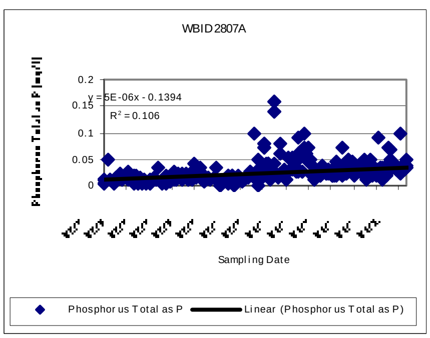
FIGURE 3. PLOTS OF WATER QUALITY IN LAKE YALE FOR THE 1989-2002 PERIOD WITH TRENDLINES.

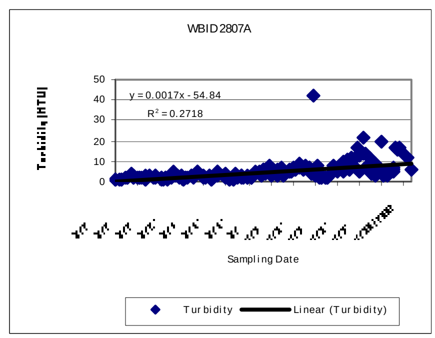












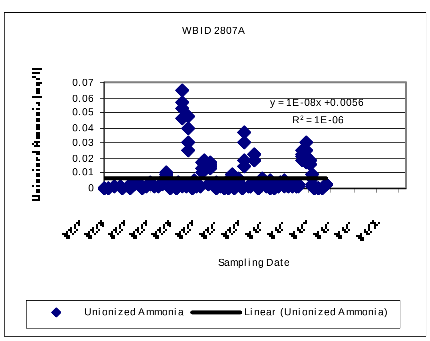


Figure 4. Cyanobacteria levels (biovolumes) in Lake Yale from Lake County Water Authority

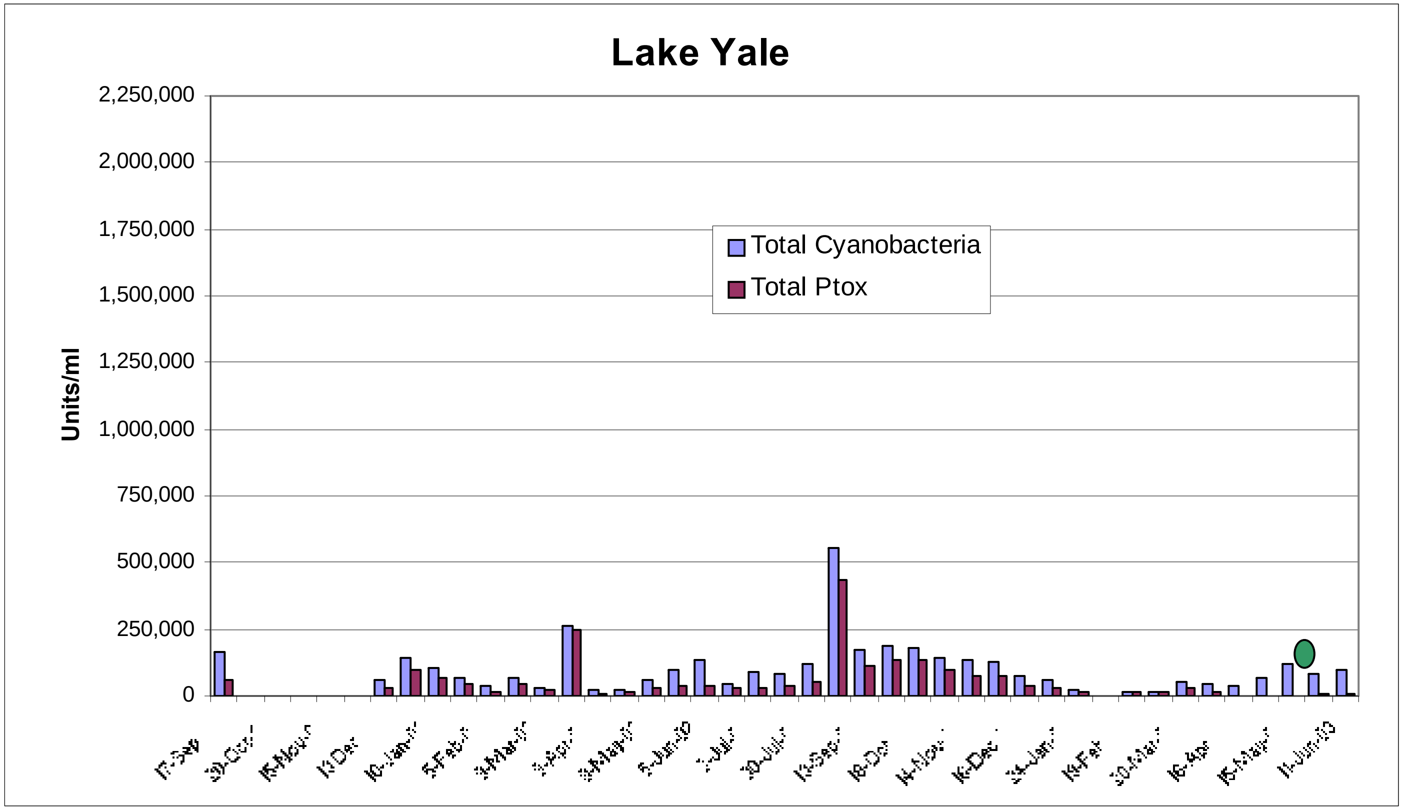


Figure 5. Microcystin levels in Lake Yale from Lake County Water Authority.

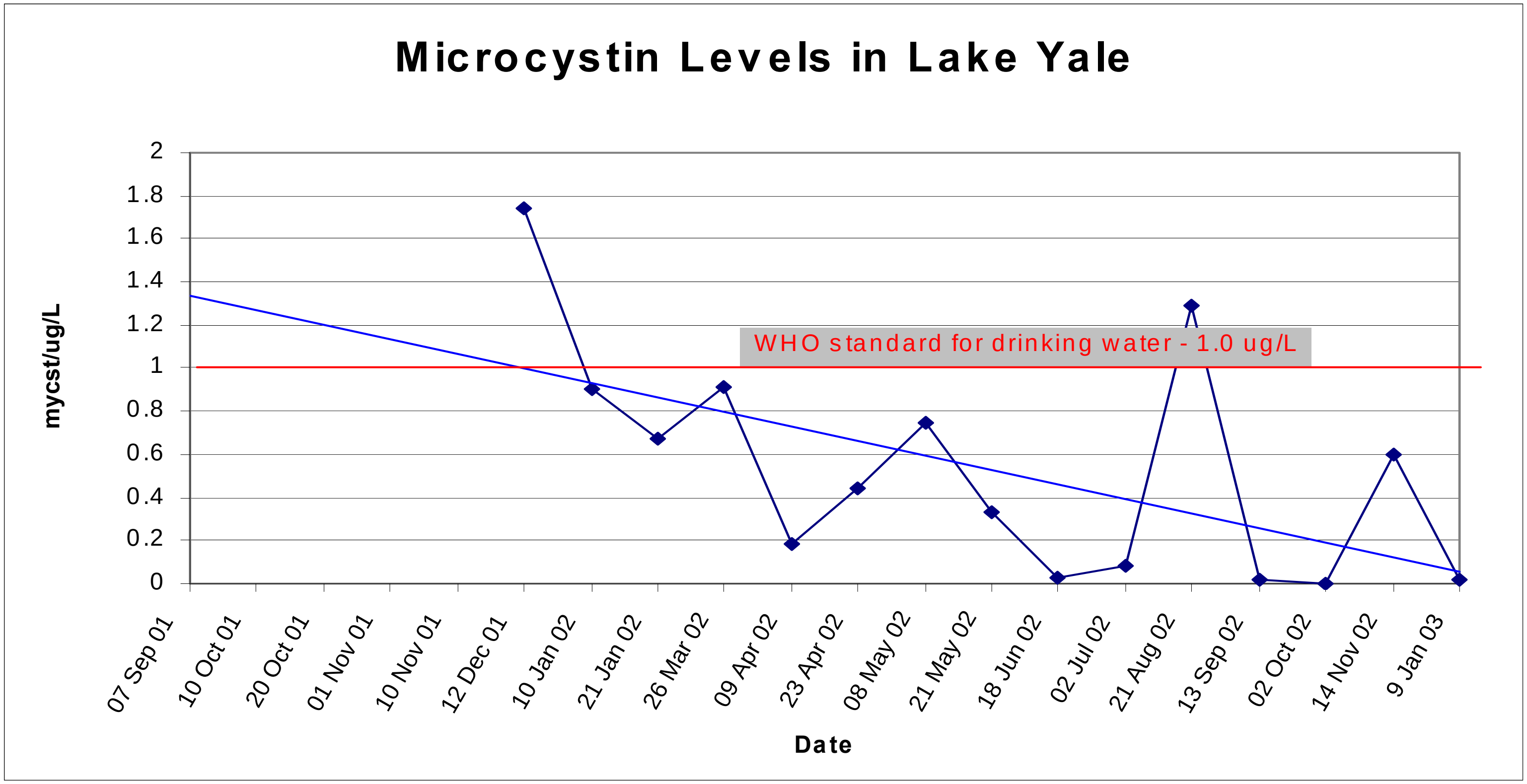


Figure 6. TN/TP cumulative frequency distribution for measurements in Lake Yale over the 1989 – 2002 period.

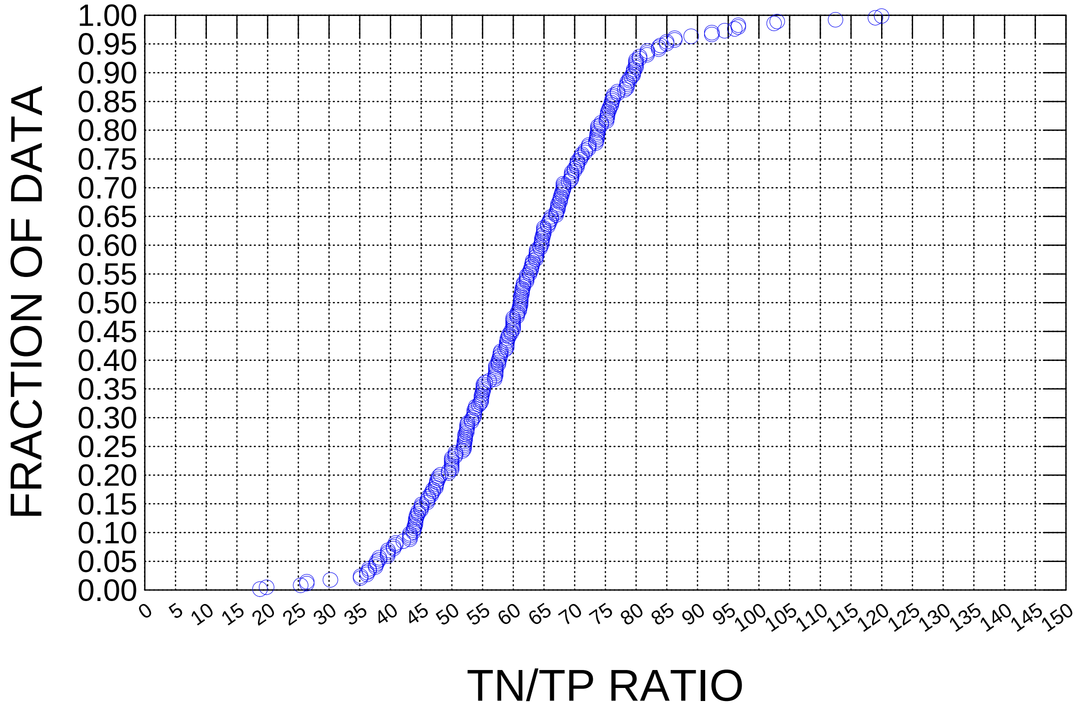


Figure 7: Lake Yale Landuse

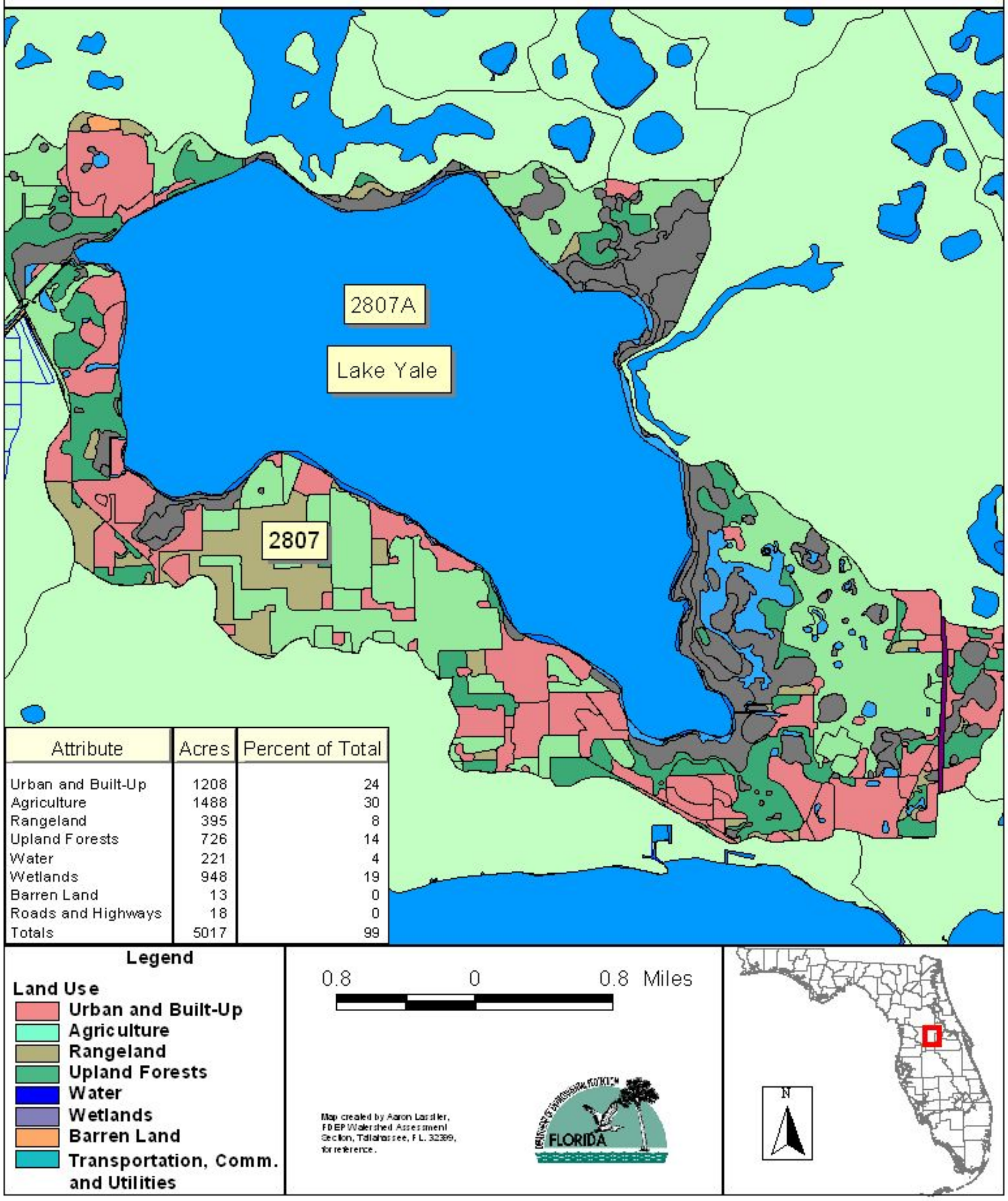


Table 1. Lake Yale and Yale Canal dissolved oxygen, un-ionized ammonia, Chlorophyll a and/or TSI assessments under the IWR.

Parameter of concern	Yale Canal	Lake Yale
Annual Chlorophyll a or TSI	Chlorophyll a (ug/l))	Trophic State Index
1989		37.5
1990		40.2
1991		35.9
1992		42.2
1993		45.6
1994		40.2
1995	78.9	46.9
1996		58.4
1997		62.8
1998		54.8
1999		62.6
2000		61.2
2001		61.9
Dissolved Oxygen	PP – 11/14 Potentially impaired VP – 2/8 Insufficient data	PP - 0/158 Not Impaired VP – 0/156 Not Impaired
Un-ionized Ammonia	PP – 0/10 Not impaired VP – 1/7 Insufficient data	PP – 11/106 Not impaired VP – 7/51 Not impaired
PP – Planning Period which was the January 1989 thru December 1998 period VP – Verified Period which was the January 1995 thru June 2002 period		

Table 2a. Summary statistics of key water quality parameters for Lake Yale (2807A) over the 1980 – 2002 period.

	CHLA	CHLAC	DO	DOSAT	NH4
N of cases	328	197	307	147	186
Minimum	0.010	-19.989	2.490	26.218	-0.001
Maximum	123.000	90.033	12.830	140.279	1.060
Median	23.000	14.000	8.200	95.223	0.020
Mean	28.906	19.259	8.308	93.593	0.089
Standard Dev	23.212	17.059	1.400	12.934	0.148

	NO2	NO3	NO2O3	ORGN	PH
N of cases	0	0	234	52	308
Minimum	.	.	-0.001	0.000	6.080
Maximum	.	.	16.700	1.450	9.210
Median	.	.	0.010	0.845	8.400
Mean	.	.	0.150	0.796	8.322
Standard Dev	.	.	1.459	0.281	0.494

	PO4	TKN	TN	TP	TURBIDITY
N of cases	0	186	452	536	219
Minimum	.	0.660	0.010	0.001	0.800
Maximum	.	2.900	2.913	0.160	42.000
Median	.	1.375	1.620	0.025	3.500
Mean	.	1.507	1.605	0.027	4.760
Standard Dev	.	0.515	0.460	0.018	4.316

	UNNH4	TNTPRATIO
N of cases	107	312
Minimum	0.000	18.778
Maximum	0.065	120.000
Median	0.002	61.213
Mean	0.007	61.469
Standard Dev	0.011	15.304

Table 2b. Summary statistics of key water quality parameters for Yale Canal (WBID 2807) over the 1989 – 2002 period.

	TEMP	TRANSM	COLOR	DO	DOSAT
N of cases	15	9	3	15	15
Minimum	12.800	0.200	50.000	0.100	1.220
Maximum	29.000	1.400	50.000	8.000	101.266
Median	22.000	0.490	50.000	2.500	24.510
Mean	21.907	0.602	50.000	3.333	37.052
Standard Dev	6.031	0.379	0.000	2.553	28.926

	PH	TN	ORGN	AMMONIA	UNNH3
N of cases	13	8	11	11	10
Minimum	6.000	2.720	1.910	0.000	0.000
Maximum	8.400	3.970	3.960	0.760	0.029
Median	6.800	3.275	2.760	0.310	0.001
Mean	7.000	3.338	2.846	0.292	0.004
Standard Dev	0.855	0.445	0.571	0.233	0.009

	NO3	TP	CHLA	CHLAC	TURBIDITY
N of cases	11	8	3	14	14
Minimum	0.000	0.155	5.804	2.673	1.000
Maximum	0.070	2.945	12.923	244.300	32.000
Median	0.020	0.450	6.583	49.400	7.500
Mean	0.028	1.142	8.437	59.408	11.543
Standard Dev	0.021	1.229	3.905	63.907	11.855

	TNTPRATIO
N of cases	8
Minimum	1.138
Maximum	19.702
Median	10.192
Mean	9.683
Standard Dev	8.192

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 4a. Pearson correlation matrix for Lake Yale (WBID 2807A).

	YEAR	MONTH	CHLA	CHLAC	DO
YEAR	1.000				
MONTH	0.006	1.000			
CHLA	0.603	0.218	1.000		
CHLAC	0.532	0.208	0.958	1.000	
DO	0.106	-0.258	-0.072	-0.086	1.000
DOSAT	-0.214	0.080	-0.069	-0.187	0.797
NH4	0.041	-0.185	-0.047	-0.128	-0.028
NO2	.	.	.	.	.
NO3	.	.	.	.	.
NO2O3	-0.042	-0.040	-0.127	-0.109	-0.000
ORGN	-0.167	-0.147	-0.155	.	0.088
PH	0.399	0.220	0.452	0.465	0.243
PO4	.	.	.	.	.
TKN	0.623	-0.020	0.825	0.712	-0.020
TN	0.577	-0.072	0.814	0.781	-0.304
TP	0.309	0.020	0.579	0.266	-0.054
TURBIDITY	0.524	0.007	0.637	0.553	0.054
UNNH4	-0.005	0.069	0.065	-0.086	-0.171
TNTPRATIO	-0.158	-0.122	0.022	-0.037	-0.355

	DOSAT	NH4	NO2	NO3	NO2O3
DOSAT	1.000				
NH4	-0.245	1.000			
NO2	.	.	.		
NO3	.	.	.	.	
NO2O3	0.058	-0.055	.	.	1.000
ORGN	0.198	0.339	.	.	0.185
PH	0.469	-0.254	.	.	-0.015
PO4	.	.	.	.	.
TKN	-0.189	0.281	.	.	-0.133
TN	.	.	.	.	0.092
TP	-0.097	0.151	.	.	-0.058
TURBIDITY	-0.069	0.239	.	.	-0.083
UNNH4	-0.121	0.654	.	.	-0.053
TNTPRATIO	.	.	.	.	0.033

	ORGN	PH	PO4	TKN	TN
ORGN	1.000				
PH	0.072	1.000			
PO4	.	.	.		
TKN	.	0.289	.	1.000	
TN	.	-0.108	.	1.000	1.000
TP	-0.095	0.162	.	0.219	0.589
TURBIDITY	-0.127	0.262	.	0.622	0.757
UNNH4	0.258	0.139	.	0.452	.
TNTPRATIO	.	-0.039	.	-0.012	0.164

	TP	TURBIDITY	UNNH4	TNTPRATIO
TP	1.000			
TURBIDITY	0.200	1.000		
UNNH4	0.016	0.117	1.000	
TNTPRATIO	-0.554	-0.180	.	1.000

Table 4a. Continued. Pairwise frequency table

	YEAR	MONTH	CHLA	CHLAC	DO
YEAR	828				
MONTH	828	828			
CHLA	328	328	328		
CHLAC	197	197	126	197	
DO	307	307	131	160	307
DOSAT	147	147	85	73	147
NH4	186	186	140	125	154
NO2	0	0	0	0	0
NO3	0	0	0	0	0
NO2O3	234	234	137	166	201
ORGN	52	52	8	0	30
PH	308	308	129	158	305
PO4	0	0	0	0	0
TKN	186	186	133	170	175
TN	452	452	167	14	14
TP	536	536	308	170	205
TURBIDITY	219	219	124	152	187
UNNH4	107	107	84	72	107
TNTPRATIO	312	312	167	14	14

	DOSAT	NH4	NO2	NO3	NO2O3
DOSAT	147				
NH4	108	186			
NO2	0	0	0		
NO3	0	0	0	0	
NO2O3	111	182	0	0	234
ORGN	30	52	0	0	52
PH	146	152	0	0	199
PO4	0	0	0	0	0
TKN	85	134	0	0	182
TN	0	0	0	0	14
TP	115	186	0	0	234
TURBIDITY	114	168	0	0	215
UNNH4	107	107	0	0	103
TNTPRATIO	0	0	0	0	14

	ORGN	PH	PO4	TKN	TN
ORGN	52				
PH	30	308			
PO4	0	0	0		
TKN	0	173	0	186	
TN	0	14	0	14	452
TP	52	203	0	186	312
TURBIDITY	52	186	0	167	14
UNNH4	30	107	0	77	0
TNTPRATIO	0	14	0	14	312

	TP	TURBIDITY	UNNH4	TNTPRATIO
TP	536			
TURBIDITY	219	219		
UNNH4	107	106	107	
TNTPRATIO	312	14	0	312

Table 4b. Pearson correlation matrix for Yale Canal (WBID 2807).

	TEMP	TRANSM	COLOR	DO	DOSAT
TEMP	1.000				
TRANSM	-0.621	1.000			
COLOR	.	.	.		
DO	-0.207	-0.513	.	1.000	
DOSAT	-0.029	-0.544	.	0.979	1.000
PH	0.234	-0.438	.	0.494	0.580
TN	.	.	.	.	.
ORGN	0.468	-0.510	.	0.220	0.312
AMMONIA	-0.476	0.453	.	-0.073	-0.203
UNNH3	0.233	-0.671	.	0.472	0.579
NO3	-0.116	-0.578	.	0.232	0.262
TP	.	.	.	.	.
CHLA	0.724	-0.873	.	-0.687	-0.734
CHLAC	0.345	-0.599	.	0.651	0.724
TURBIDITY	0.107	-0.603	.	0.565	0.582
TNTPRATIO	.	.	.	.	.

	PH	TN	ORGN	AMMONIA	UNNH3
PH	1.000				
TN	.	1.000			
ORGN	0.256	.	1.000		
AMMONIA	-0.737	.	-0.417	1.000	
UNNH3	0.549	.	0.301	-0.159	1.000
NO3	0.355	.	-0.431	0.019	0.489
TP	.	0.008	.	.	.
CHLA	-0.739	.	.	.	.
CHLAC	0.478	.	0.596	-0.080	0.820
TURBIDITY	0.474	.	0.229	-0.086	0.396
TNTPRATIO	.	0.221	.	.	.

	NO3	TP	CHLA	CHLAC	TURBIDITY
NO3	1.000				
TP	.	1.000			
CHLA	.	.	1.000		
CHLAC	0.116	.	0.981	1.000	
TURBIDITY	-0.014	.	0.890	0.564	1.000
TNTPRATIO	.	-0.877	.	.	.

	TNTPRATIO
TNTPRATIO	1.000

Table 4b. Continued. Pairwise frequency table

	TEMP	TRANSM	COLOR	DO	DOSAT
TEMP	15				
TRANSM	9	9			
COLOR	3	3	3		
DO	15	9	3	15	
DOSAT	15	9	3	15	15
PH	13	9	3	13	13
TN	0	0	0	0	0
ORGN	11	6	0	11	11
AMMONIA	11	6	0	11	11
UNNH3	10	6	0	10	10
NO3	11	6	0	11	11
TP	0	0	0	0	0
CHLA	3	3	3	3	3
CHLAC	14	9	3	14	14
TURBIDITY	14	9	3	14	14
TNTPRATIO	0	0	0	0	0

	PH	TN	ORGN	AMMONIA	UNNH3
PH	13				
TN	0	8			
ORGN	10	0	11		
AMMONIA	10	0	11	11	
UNNH3	10	0	10	10	10
NO3	10	0	11	11	10
TP	0	8	0	0	0
CHLA	3	0	0	0	0
CHLAC	13	0	11	11	10
TURBIDITY	13	0	11	11	10
TNTPRATIO	0	8	0	0	0

	NO3	TP	CHLA	CHLAC	TURBIDITY
NO3	11				
TP	0	8			
CHLA	0	0	3		
CHLAC	11	0	3	14	
TURBIDITY	11	0	3	14	14
TNTPRATIO	0	8	0	0	0

	TNTPRATIO
TNTPRATIO	8

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

	Lake Yale		**Lake Yale**	
	Mean TP load 1991-2000		**Mean TN load 1991-2000**	
Nutrient Source	**kg/year**	**%**	**kg/year**	**%**
Low density residential	14.2	0.99%	142.3	0.62%
Medium density residential	37.2	2.60%	283.9	1.23%
High density residential	86.3	6.03%	426.5	1.85%
Low density commercial	13.8	0.96%	108.6	0.47%
High density commercial	59.9	4.18%	394.5	1.71%
Industrial	50.5	3.53%	291.8	1.26%
Mining	0.1	0.01%	0.6	0.00%
Openland/recreational	0.5	0.04%	11.5	0.05%
Pasture	37.2	2.60%	238.4	1.03%
Cropland	29.3	2.04%	200.3	0.87%
Tree crops	7.9	0.55%	115.2	0.50%
Feeding Operations	1.7	0.12%	20.9	0.09%
Other agriculture	2.7	0.19%	15.7	0.07%
Forest/rangeland	14.9	1.04%	330.0	1.43%
Water	24.1	1.68%	700.0	3.03%
Wetlands	209.0	14.59%	4,624.9	20.04%
Septic tanks	132.3	9.23%	2,335.1	10.12%
Precipitation	282.8	19.74%	9,744.6	42.22%
Dry deposition	371.5	25.94%	2,717.4	11.77%
Umatilla WWTP runoff	6.9	0.48%	119.8	0.52%
Golden Gem weak waste discharge	49.4	3.45%	256.5	1.11%
Total	**1,432.4**	**100.00%**	**23,078.7**	**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.