EVALUATION OF THE EFFECTIVENESS OF THE ALUM SEDIMENT INACTIVATION TREATMENT TO LAKE HOLDEN

Final Report
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SECTION 1

INTRODUCTION

This report provides a summary of work efforts performed by Environmental Research & Design, Inc. (ERD) for the Orange County Environmental Protection Division (OCEPD) to conduct an alum sediment inactivation treatment on Lake Holden and to evaluate the resulting impacts to water quality and sediment chemistry.

1.1 Historical Overview

Lake Holden is a 266-acre urban lake located approximately 2 miles south of downtown Orlando, FL. A general location map for Lake Holden is given on Figure 1-1, and a water depth contour map is included on Figure 1-2 (ERD, 2003). A summary of bathymetric characteristics of Lake Holden is given on Table 1-1. Lake Holden contains a total water volume of approximately 3212 ac-ft, with a mean depth of approximately 12.1 ft and a maximum water depth of more than 30 ft.

Lake Holden receives stormwater runoff from a 769-acre watershed consisting of industrial, commercial, residential, transportation, and highway land uses. An overview of sub-basin areas discharging to Lake Holden is given on Figure 1-3. Based upon the watershed area of 769 acres and a lake surface area of 266 acres, the watershed/lake area ratio for Lake Holden is approximately 2.9.

Prior to the mid-1990s, very little of the watershed area contained stormwater treatment facilities, and large portions of the drainage basin discharged untreated runoff directly into the lake. Water quality monitoring was initiated in Lake Holden during 1972 by OCEPD, and over the period from 1972-1991 Lake Holden exhibited steadily increasing concentrations for both total phosphorus and chlorophyll-a. Plots of trends in mean concentrations of total phosphorus and chlorophyll-a in Lake Holden from 1972-1991 are given in Figure 1-4, with trends in mean trophic state indices in Lake Holden from 1972-1991 illustrated on Figure 1-5. During this time, Lake Holden was consistently in a eutrophic or hypereutrophic condition, with a trend toward increasing TSI values over time. Temporary decreases in TSI values occurred during 1975 and 1980 due to significant hydrilla infestations within the lake. During the period from 1985-1991, Lake Holden ranked second only to Lake Apopka for the highest mean annual TSI value for lakes in Orange County. Aeration systems were installed within the lake during 1981 but were removed in 1984 due to a trend of declining water quality following installation of the aeration systems.

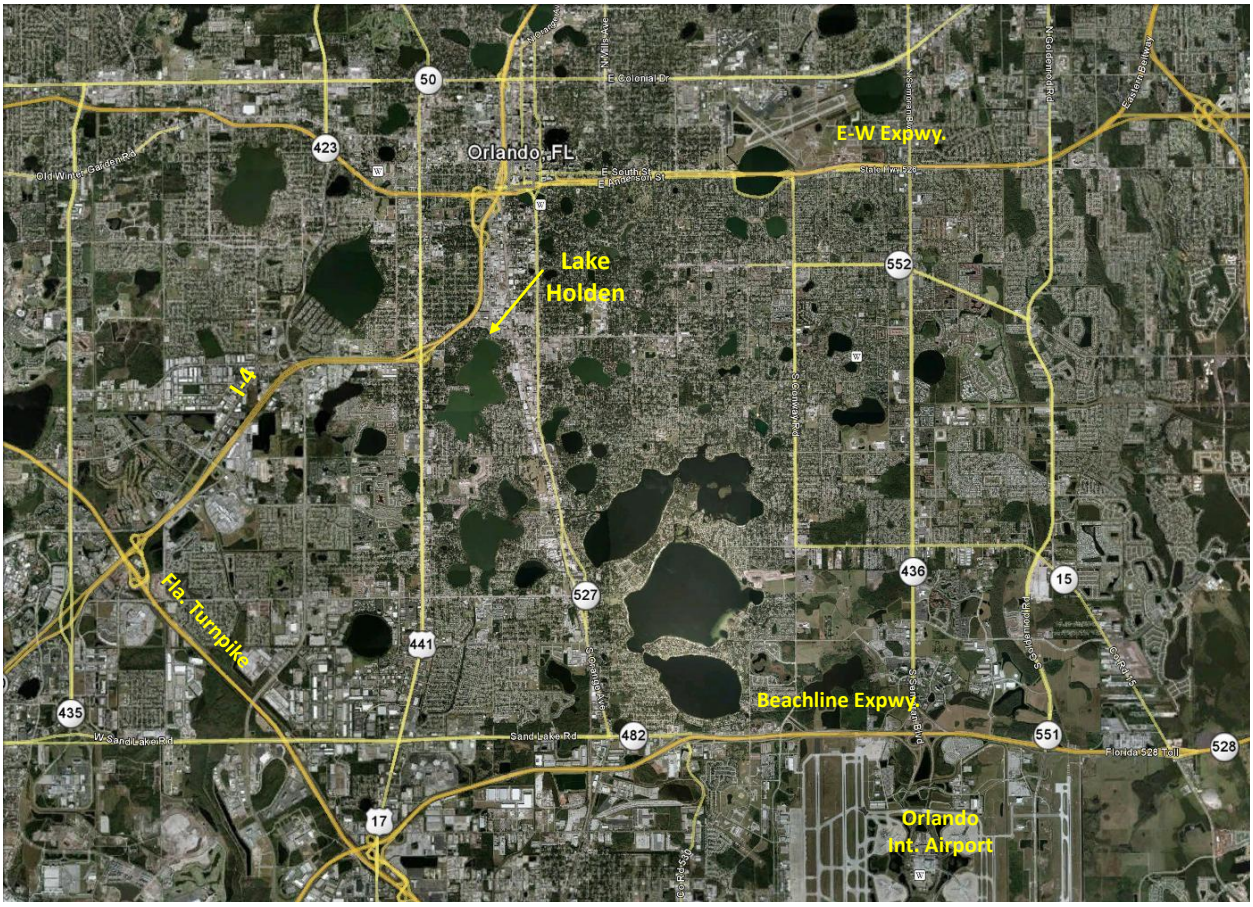


Figure 1-1. General Location Map for Lake Holden.

TABLE 1-1

BATHYMETRIC CHARACTERISTICS OF LAKE HOLDEN

BATHYMETRIC PARAMETER[1]	VALUE
Surface Area	266.2 acres
Total Volume	3212 ac-ft
Mean Depth	12.1 ft
Maximum Depth	> 30 ft
Shoreline Length	22,153 ft 4.2 miles
Shoreline Development	1.84

1. Based upon a mean water surface elevation of 91.0 ft (normal high water)

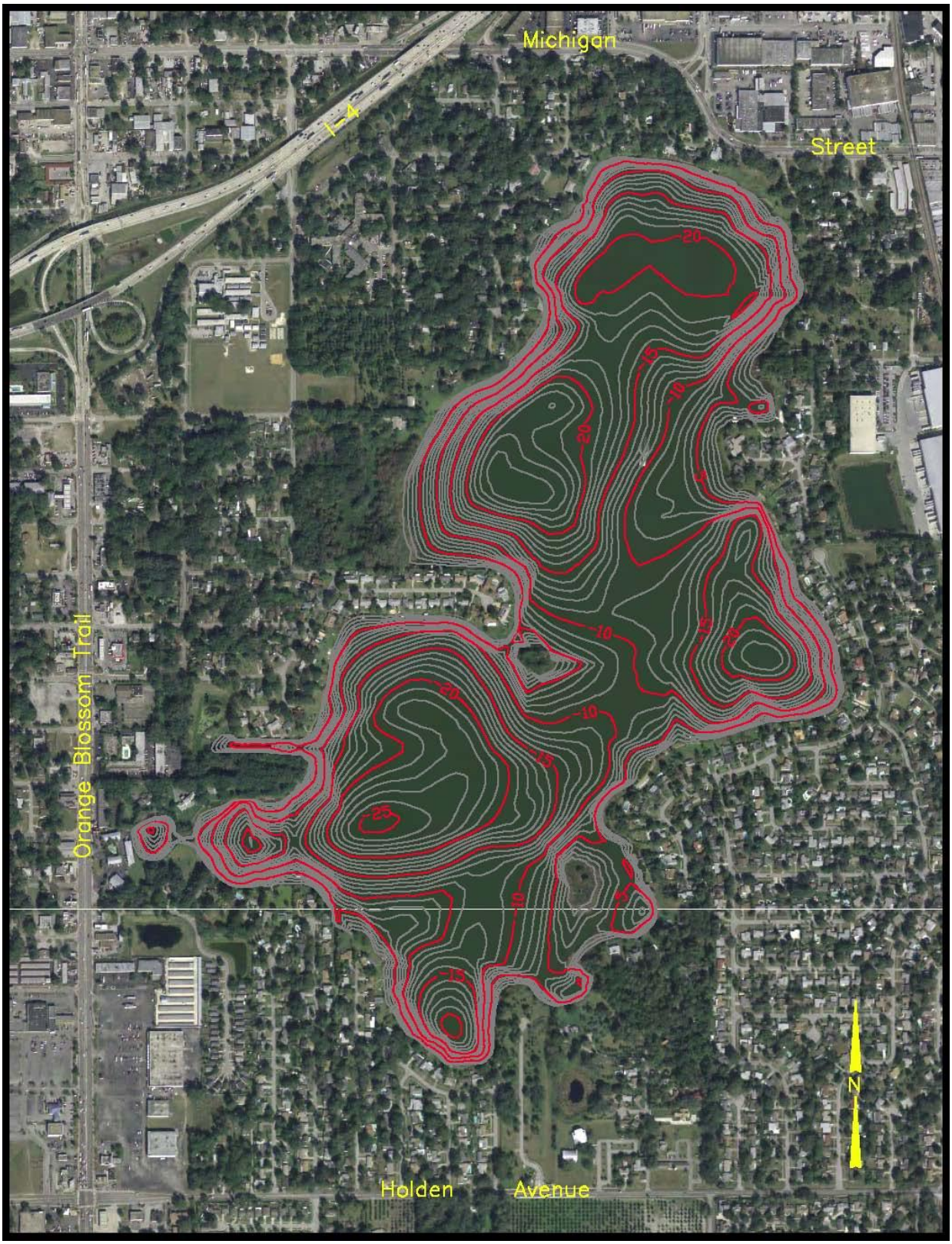


Figure 1-2. Water Depth Contours (ft) in Lake Holden (ERD, 2003).

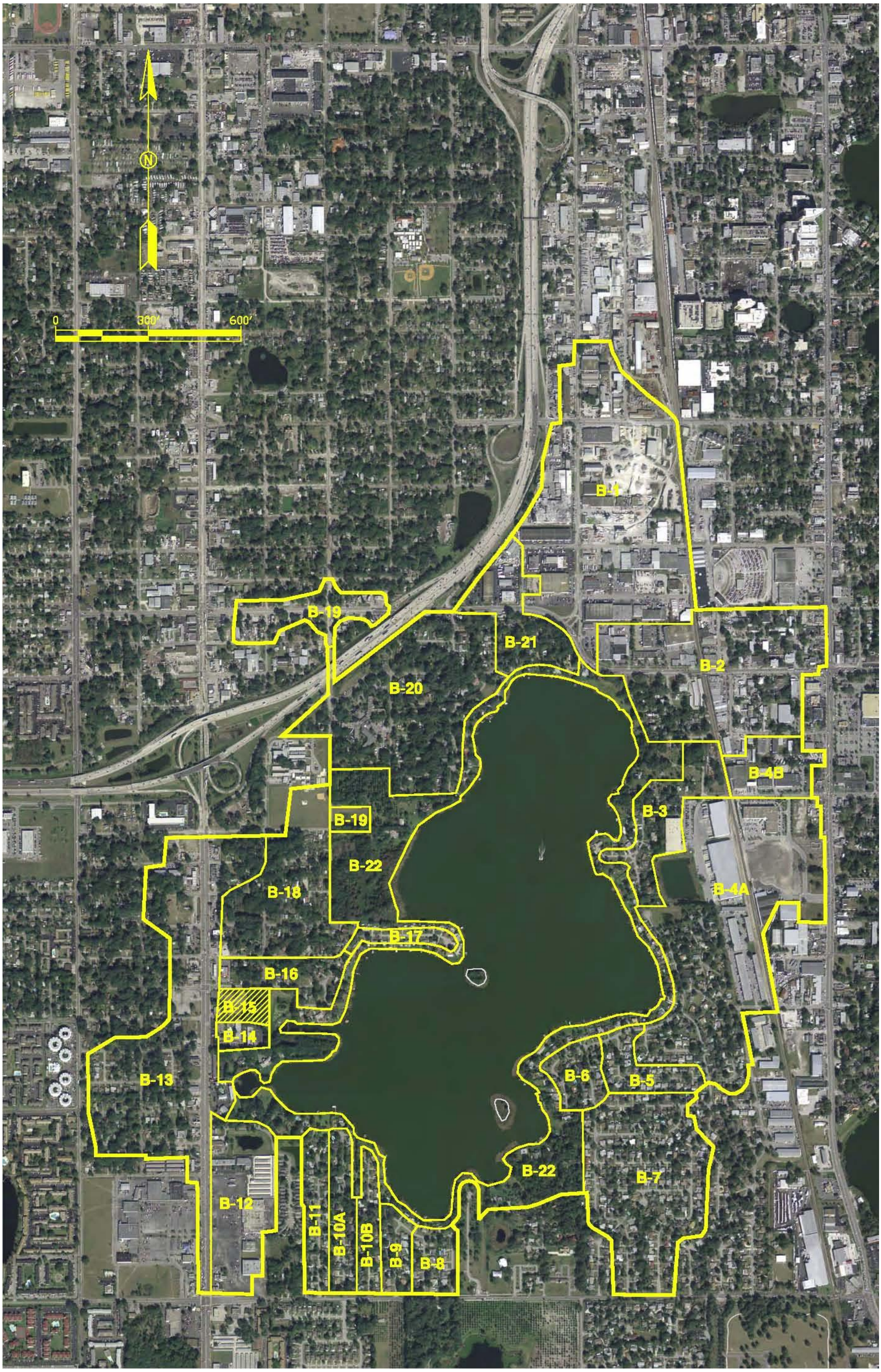
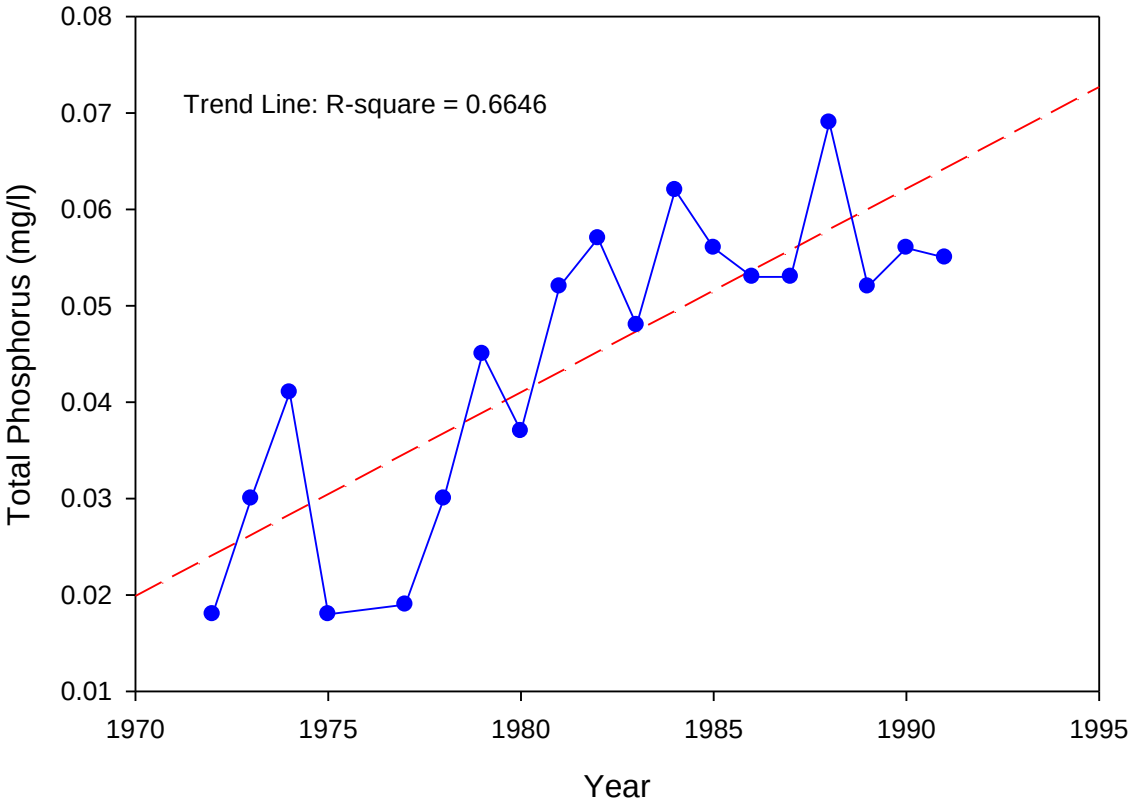


Figure 1-3. Sub-basin Areas Discharging to Lake Holden.



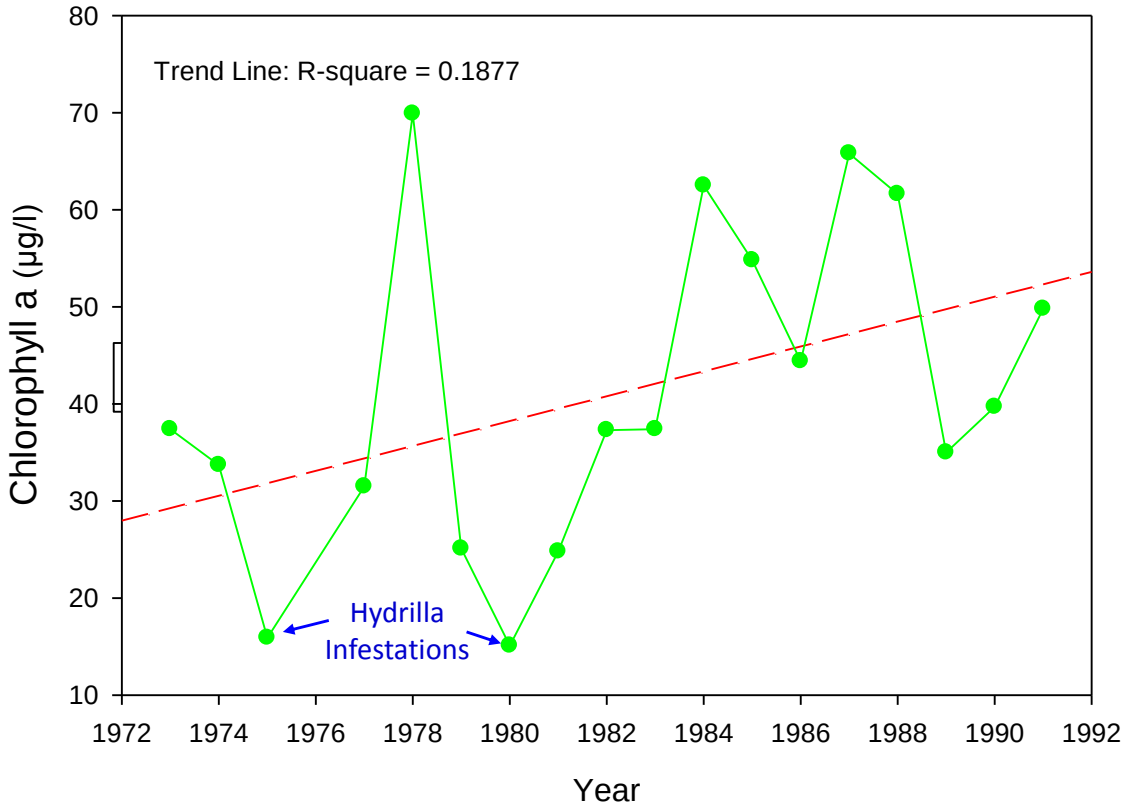


Figure 1-4. Trends in Total Phosphorus and Chlorophyll-a in Lake Holden from 1971-1991.

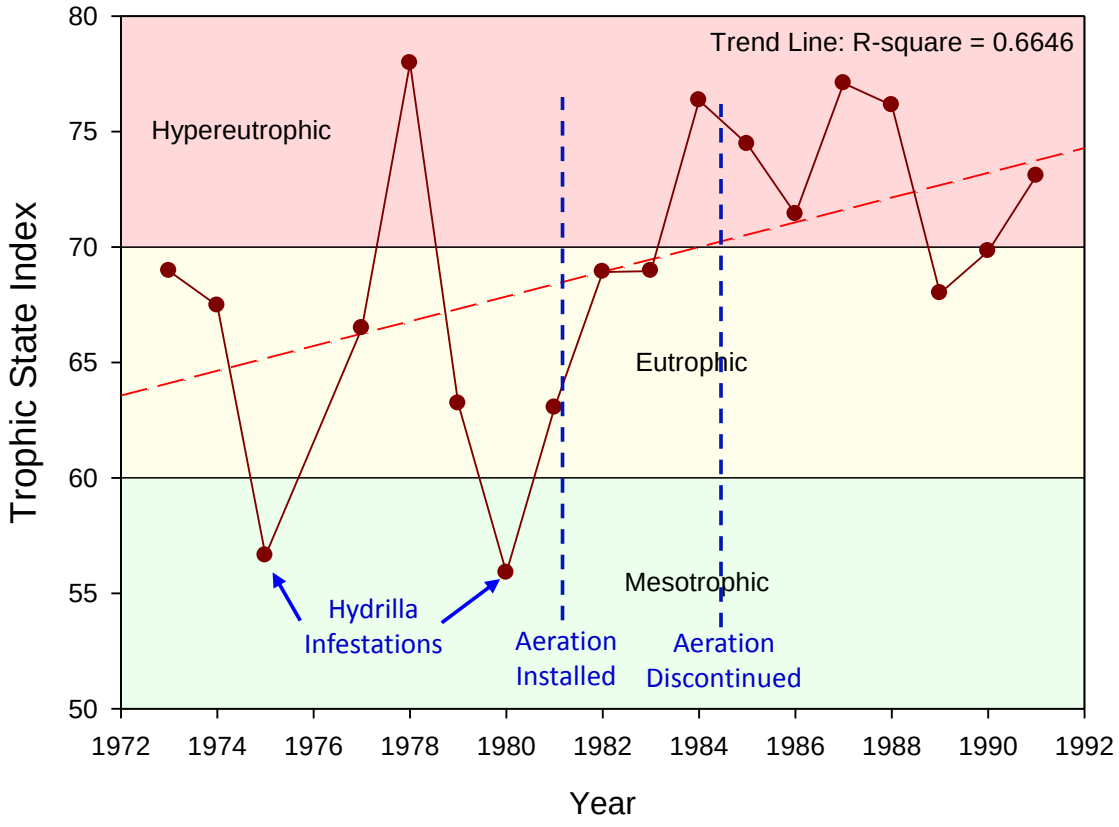


Figure 1-5. Trends in Mean Trophic State Indices in Lake Holden from 1972-1991.

During the early-1970s, the lakefront homeowners formed an association dedicated to improving water quality in Lake Holden, and in September 1973 the lakefront residents established a self-taxing unit, referred to as the Lake Holden Municipal Service Taxing Unit (MSTU). This taxing unit was established by a majority of affected parcels that submitted ballots. Currently, there are 356 parcels included in the taxing unit. The taxing unit has a millage rate of 2.5337 which generates approximately $120,000 per year or about $337 per parcel per year.

During 1975, the MSTU funded a preliminary study which estimated runoff loadings to the lake and made general water quality recommendations. This study also included an initial estimate of the drainage basin boundaries. A dry detention pond was constructed for a small basin area as a result of the recommendations from this study.

During 1991, an additional study was funded by the MSTU and managed by Orange County to identify the sources and magnitude of pollutant inputs to Lake Holden and develop cost-effective water quality improvement recommendations. This study was conducted by ERD, and a report titled "Lake Holden Water Quality and Restoration Study" was issued by ERD during June 1992. This study included an extensive review and statistical analysis of historical water quality data, water quality and sediment monitoring, stormwater monitoring and analysis at six significant outfalls, refinement of watershed and sub-basin areas, hydrologic modeling of

annual runoff inflows from sub-basin areas, development of hydrologic and nutrient budgets, ranking of hydrologic and nutrient inputs, and a water quality model to estimate impacts from proposed water quality improvement projects. The nutrient budget included inputs from bulk precipitation, stormwater runoff, and groundwater seepage which was estimated based on septic tank loadings. However, this nutrient budget did not include estimates of phosphorus loadings from internal recycling. Since very little vacant land is available within the Lake Holden basin for construction of traditional stormwater treatment facilities, alum injection systems were recommended for the three most significant runoff inputs which contributed 65% of the annual runoff loadings to the lake. A wet detention pond was also recommended for treatment of runoff generated from Sub-basin 13. Each of these recommendations was implemented during the 1990s, and water quality improvements began to occur within the lake.

During 2003, the MSTU funded an additional study, conducted by ERD, to refine the previous hydrologic and nutrient budgets to incorporate the significant projects which were constructed for treatment of stormwater runoff. This study included an updated review of historical water quality characteristics and trends, an updated bathymetric and muck depth contour maps, sediment characterization at 44 sites, sediment phosphorus speciation to evaluate phosphorus availability in sediments, installation and monitoring of seepage meters over a period of six months, re-evaluation of stormwater characteristics for each of the retrofit projects, direct measurements of internal recycling using large diameter core samples, development of revised hydrologic and nutrient budgets, and modification of the management plan based on the results of the revised study.

As part of the study, ERD conducted field monitoring of runoff characteristics for each watershed sub-basin where stormwater BMPs had been installed. The field monitoring indicated that substantial reductions had occurred in concentrations of total phosphorus in runoff generated from these basins, and the revised runoff characteristics were used to refine the previous nutrient budget for the lake. As a result of the significant reductions in stormwater related loadings, the most significant remaining source of phosphorus to Lake Holden was internal recycling of phosphorus from the lake sediments. ERD recommended that sediment inactivation be conducted in Lake Holden and provided an estimate of the volume of alum and application details for sediment inactivation. The results of these work efforts were summarized in the July 2004 final report by ERD titled "Lake Holden Revised Hydrologic/Nutrient Budget and Management Plan".

An isopleth contour map of the depth of muck sediments in Lake Holden was also generated by ERD as part of the 2004 report. An overview of muck depth contours in Lake Holden is given on Figure 1-6. Deep accumulations of organic muck were identified in northern, western-central, and western-southern portions of the lake where the depth of accumulated muck deposits exceeds 10 ft in multiple locations. Based on information provided in the July 2004 report, Lake Holden contains approximately 17,402,220 ft^3 of unconsolidated organic sediments which is sufficient in volume to cover the entire lake bottom to a depth of approximately 1.5 ft.

Implementation of the recommended sediment inactivation process began during 2005. Due to a large volume of alum required for sediment inactivation in Lake Holden, the recommended total alum volume was divided into multiple smaller applications to reduce chemical and biological impacts to the lake. Six separate applications were conducted by ERD over the period from 2005-2012, with a total of 427,377 gallons of alum applied to Lake Holden during the six treatments. The final alum application was completed during April 2012.

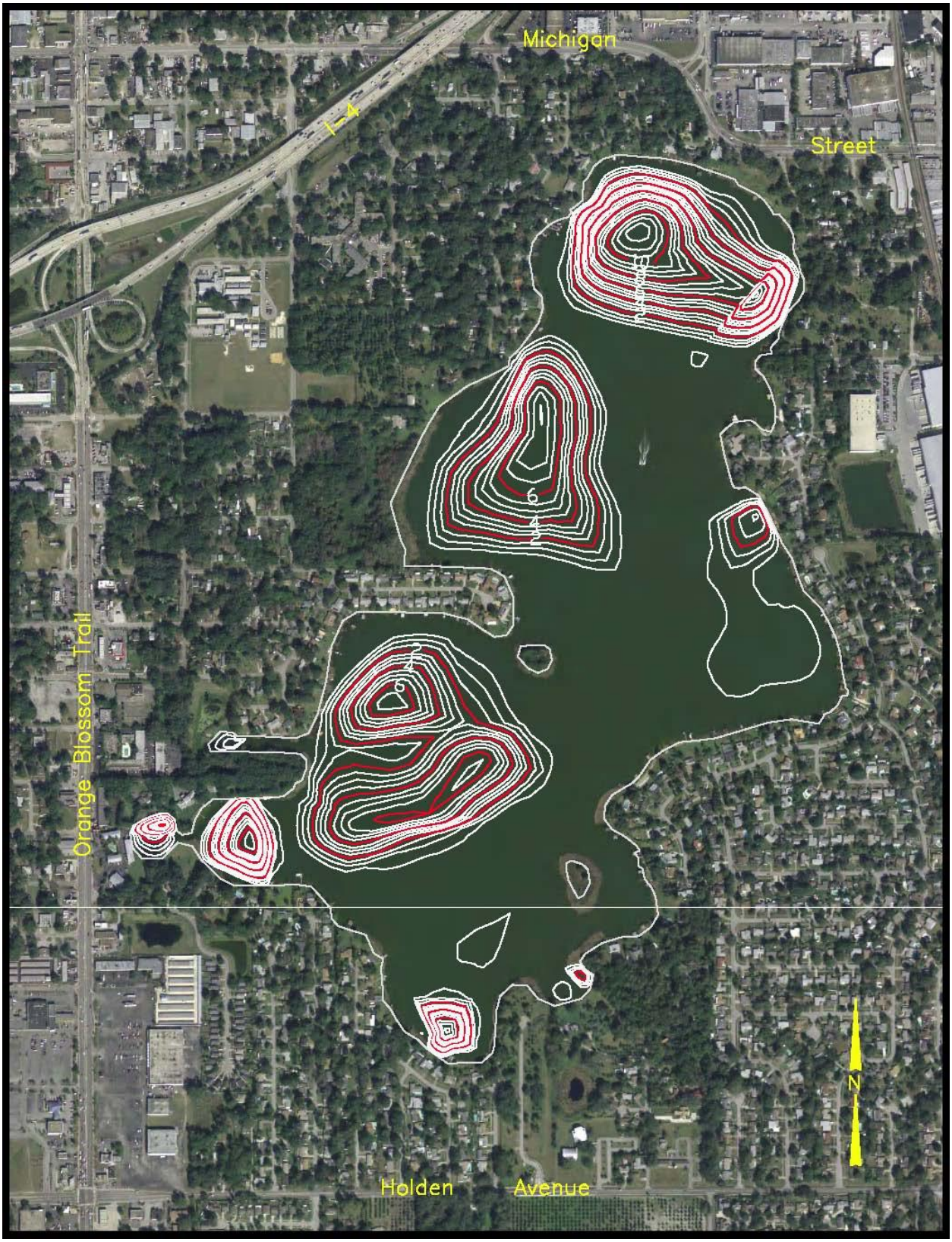


Figure 1-6. Unconsolidated Muck Depth Contours in Lake Holden (ft).

Additional details concerning water quality improvement projects conducted by the Lake Holden MSTU are included in a summary report prepared by ERD during February 2010 titled "Evaluation of the Current Status and Potential Water Quality Improvement Options for Lake Holden" which was prepared for Orange County EPD. This report provides an update of the effectiveness of existing runoff controls and provides recommendations for projects to address the remaining minor inflows.

1.2 Work Efforts Performed by ERD

Sediment monitoring was conducted by ERD in Lake Holden on four separate occasions to document changes in sediment chemistry resulting from the alum inactivation project. An initial set of sediment samples was collected in Lake Holden during September 2003 to establish pre-treatment sediment characteristics. The sediments collected on this date were also used to estimate the required alum addition necessary for sediment inactivation. Supplemental sediment monitoring was conducted by ERD during May 2007, November 2008, and March 2012 to evaluate changes in sediment chemistry during and following completion of the alum application. In addition, extensive water quality monitoring was conducted by Orange County EPD, the City of Orlando, and ERD within Lake Holden to document changes in water quality resulting from the sediment inactivation project. The results of the sediment and water quality monitoring efforts are discussed in this report and are used to evaluate the effectiveness of the sediment inactivation.

This report is divided into four separate sections for presentation of the work efforts conducted by ERD. Section 1 contains an introduction to the report, a historical summary of water quality issues and water quality improvement projects for Lake Holden, and a brief summary of work efforts conducted by ERD. Details concerning the alum treatment process, determination of alum dose, and application activities conducted by ERD are provided in Section 2. A summary of the results of the sediment and water quality monitoring efforts are provided in Section 3, along with an evaluation of the success of the inactivation project. A summary of the conclusions from the study is given in Section 4. Appendices are attached which contain historical water quality data for Lake Holden and visual sediment data collected by ERD during this project.

SECTION 2

ALUM DOSE CALCULATIONS AND APPLICATION DETAILS

This section provides a discussion of the methodology used by ERD to evaluate sediment inactivation requirements in Lake Holden, and provides information on application methods used during the inactivation process. Since the application dose is based upon the mass of available phosphorus within the sediments of Lake Holden, a discussion is provided for sediment characterization techniques, methods of analysis, and sediment speciation, along with general pre-treatment sediment characteristics.

2.1 Sediment Characterization Techniques

Sediment core samples were initially collected in Lake Holden during September 2003 to evaluate the characteristics of existing sediments and potential impacts on water quality within the lake. Sediment core samples were collected at 44 separate locations within the lake by ERD personnel. Locations of sediment sampling sites in Lake Holden are illustrated on Figure 2-1. The results of the initial sediment monitoring event were used to identify general sediment characteristics as well as to estimate bonding mechanisms for phosphorus within the lake sediments. Isopleth contour plots were developed for each of the evaluated sediment characteristics, including phosphorus speciation.

A detailed discussion of the results of this initial sediment monitoring event is provided in the July 2004 ERD report titled "Lake Holden-Revised Hydrologic/Nutrient Budget and Management Plan". This document also provides calculations of the mass of total available phosphorus within the top 0-10 cm layer of the sediments in Lake Holden and provides calculations for the quantity of alum required for sediment inactivation. The information contained in the July 2004 report is used as the basis for the subsequent sediment inactivation project.

Additional sediment monitoring was conducted by ERD in Lake Holden during May 2007, November 2008, and April 2012 to evaluate changes in sediment characteristics resulting from the recommended alum applications to the lake and document the changes in available phosphorus in the lake sediments. During each of these three supplemental sediment monitoring events, sediment core samples were collected at each of the 44 locations used for the initial sediment monitoring event, as illustrated on Figure 2-1. The results of these additional sediment monitoring events are discussed in Section 3.

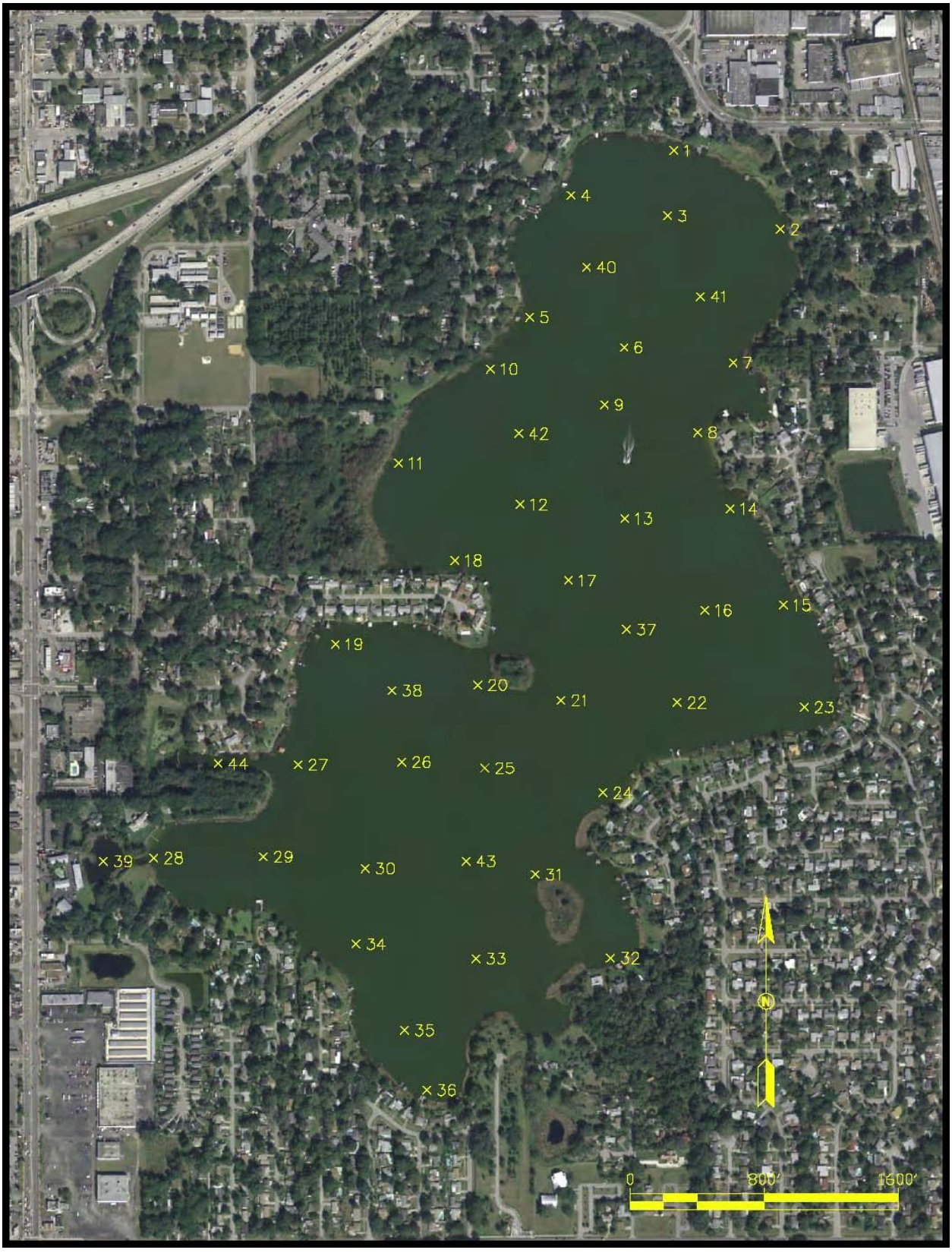


Figure 2-1. Location of Sediment Monitoring Sites in Lake Holden.

2.1.1 Sampling Techniques

Sediment samples were collected at each of the 44 monitoring sites using a stainless steel split-spoon core device, which was penetrated into the sediments at each location to a minimum distance of approximately 0.5 m. After retrieval of the sediment sample, any overlying water was carefully decanted before the split-spoon device was opened to expose the collected sample. Visual characteristics of each sediment core sample were recorded, and the 0-10 cm layer was carefully sectioned off and placed into a polyethylene container for transport to the ERD laboratory. Duplicate core samples were collected at each site, and the 0-10 cm layers were combined together to form a single composite sample for each of the 15 monitoring sites. The polyethylene containers used for storage of the collected samples were filled completely to minimize air space in the storage container above the composite sediment sample. Each of the collected samples was stored on ice and returned to the ERD laboratory for physical and chemical characterization.

2.1.2 Sediment Analysis and Speciation Techniques

Each of the 44 collected sediment core samples was analyzed for a variety of general parameters, including moisture content, organic content, sediment density, total nitrogen, and total phosphorus. Methodologies utilized for preparation and analysis of the sediment samples for these parameters are outlined in Table 2-1.

TABLE 2-1

ANALYTICAL METHODS FOR SEDIMENT ANALYSES

MEASUREMENT PARAMETER	SAMPLE PREPARATION	ANALYSIS REFERENCE	REFERENCE PREP./ANAL.*	METHOD DETECTION LIMITS (MDLs)
pH	EPA 9045	EPA 9045	3 / 3	0.01 pH units
Moisture Content	p. 3-54	p. 3-58	1 / 1	0.1%
Organic Content (Volatile Solids)	p. 3-52	pp. 3-52 to 3-53	1 / 1	0.1%
Total Phosphorus	pp. 3-227 to 3-228 (Method C)	EPA 365.4	1 / 2	0.005 mg/kg
Total Nitrogen	p. 3-201	pp. 3-201 to 3-204	1 / 1	0.010 mg/kg
Specific Gravity Density)	p. 3-61	pp. 3-61 to 3-62	1 / 1	NA

*REFERENCES:

1. Procedures for Handling and Chemical Analysis of Sediments and Water Samples, EPA/Corps of Engineers, EPA/CE-81-1, 1981.
2. Methods for Chemical Analysis of Water and Wastes, EPA 600/4-79-020, Revised March 1983.
3. Test Methods for Evaluating Solid Wastes, Physical-Chemical Methods, Third Edition, EPA-SW-846, Updated November 1990.

In addition to general sediment characterization, a fractionation procedure for inorganic soil phosphorus was conducted on each of the 44 collected sediment samples. The modified Chang and Jackson Procedure, as proposed by Peterson and Corey (1966), originally developed for agricultural soils, was used as the basis for the phosphorus fractionation. The Chang and Jackson Procedure allows the speciation of phosphorus in soils into saloid-bound phosphorus (defined as the sum of soluble plus easily exchangeable sediment phosphorus), iron-bound phosphorus, and aluminum-bound phosphorus. Although not used in this project, subsequent extractions of the Chang and Jackson procedure also provide calcium-bound and residual fractions.

The Chang and Jackson procedure was originally developed at the University of Wisconsin to evaluate phosphorus bonding in dried agricultural soils. However, drying of wet sediments will significantly impact the phosphorus speciation, particularly the soluble and iron-bound associations. Therefore, the basic Chang and Jackson method was adapted and modified by ERD during 1992 for wet sediments by adjusting solution concentrations and extraction timing to account for the liquid volume in the wet sediments and the reduced solids mass. This modified method has been used as the basis for all sediment inactivation projects which have been conducted in the State of Florida.

Saloid-bound phosphorus is considered to be available under all conditions at all times. Iron-bound phosphorus is relatively stable under aerobic environments, generally characterized by redox potentials greater than 200 mv (E_h), while unstable under anoxic conditions, characterized by redox potential less than 200 mv. Aluminum-bound phosphorus is considered to be stable under all conditions of redox potential and natural pH conditions. A schematic of the Chang and Jackson Speciation Procedure for evaluating sediment phosphorus bounding is given in Figure 2-2.

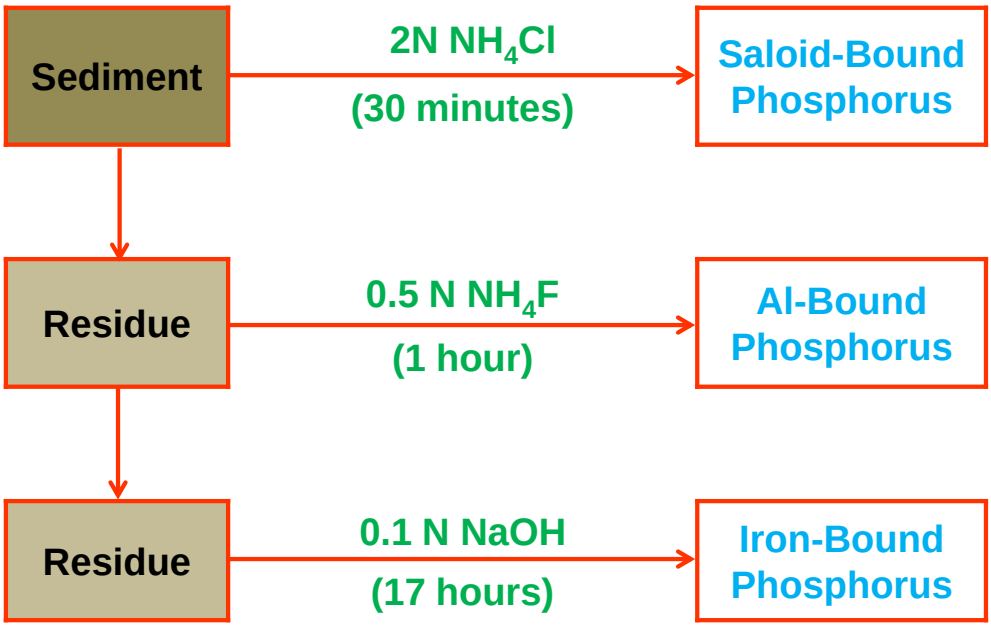


Figure 2-2. Schematic of Chang and Jackson Speciation Procedure for Evaluating Soil Phosphorus Bonding.

For purposes of evaluating release potential, ERD typically assumes that potentially available inorganic phosphorus in soils/sediments, particularly those which exhibit a significant potential to develop reduced conditions below the sediment-water interface, is represented by the sum of the soluble inorganic phosphorus and easily exchangeable phosphorus fractions (collectively termed saloid-bound phosphorus), plus iron-bound phosphorus which can become solubilized under reduced conditions. Aluminum-bound phosphorus is generally considered to be unavailable in the pH range of approximately 5.5-7.5 under a wide range of redox conditions.

2.2 Inactivation Dose Determination

2.2.1 Introduction

Sediment phosphorus inactivation is a lake restoration technique which is designed to substantially reduce sediment phosphorus release by combining available phosphorus in the sediments with a metal salt to form an insoluble inert precipitate, rendering the sediment phosphorus unavailable for release into the overlying water column. Although salts of aluminum, calcium, and iron have been used for sediment inactivation in previous projects, aluminum salts are the clear compounds of choice for most applications. Inactivation of sediment phosphorus using aluminum is a substantially less expensive option for reducing sediment phosphorus release compared with sediment removal by dredging.

Sediment phosphorus inactivation is most often performed using aluminum sulfate, commonly called alum, which is applied at the surface in a liquid form using a boat or barge. Upon entering the water column, the alum forms an insoluble precipitate of aluminum hydroxide which attracts phosphorus, bacteria, algae, and suspended solids within the water column, settling these constituents into the bottom sediments. Upon reaching the bottom sediments, the residual aluminum binds tightly with phosphorus within the sediments, forming an inert precipitate which will not be re-released under any conceivable condition of pH or redox potential which could occur in a natural lake system.

It is generally recognized that the top 10 cm layer of the sediments is the most active in terms of release of phosphorus under anoxic conditions. Therefore, the objective of a sediment inactivation project is to provide sufficient alum to bind the saloid- and iron-bound phosphorus associations in the top 10 cm of the sediments. These sediment treatments have been shown to be effective from 5-20 years, depending upon the sediment accumulation rate within the lake from the remaining phosphorus sources.

2.2.2 Calculation of Sediment Inactivation Requirements

Calculation of sediment inactivation requirements are based upon the mass of total available phosphorus which can potentially mobilize from the sediments to the overlying water column. Estimates of the mass of total available phosphorus within the top 0-10 cm layer of the sediments in Lake Holden were generated by graphically integrating the total available phosphorus isopleths presented on Figure 2-10 of the July 2004 ERD report. A copy of this map is given on Figure 2-3. The top 0-10 cm layer of the sediments is considered to be the most active layer with respect to exchange of phosphorus between the sediments and the overlying water column. Inactivation of phosphorus within the 0-10 cm layer is typically sufficient to inactivate sediment release of phosphorus within a lake.

Figure 2-3. Isopleths of Total Available Phosphorus (µg/g wet wt.) in the Top 10 cm of Sediments in Lake Holden. (September 2003 Sediment Samples)

Prior research involving sediment inactivation has indicated that an excess of aluminum is required within the sediments to cause phosphorus to preferentially bind with aluminum rather than other available competing agents. Previous sediment inactivation projects performed by ERD have been conducted at molar Al:P ratios of 2, 3, 5, and 10, with most recent sediment inactivation projects performed using a 10:1 ratio. However, due to the large amount of available phosphorus in the sediments of Lake Holden, a 5:1 ratio was used to control application costs.

A summary of estimated total available phosphorus in the sediments of Lake Holden is given in Table 2-2. The measured available phosphorus contour intervals are divided into separate ranges for each of the isopleth lines indicated on the figure. The lake surface area contained within each contour interval is then determined using GIS. The available phosphorus is calculated by multiplying the contour area times the interval mid-point for each contour interval, over a depth of 10 cm. This results in an estimate of the mass of available phosphorus contained in each contour interval within the lake which are then summed to estimate the total available phosphorus mass in the top 10 cm of the lake. The available phosphorus mass is converted into an equivalent number of moles of phosphorus based on the molecular weight of 31 g/mole. Moles of aluminum required for sediment inactivation are then calculated based upon a molar Al:P ratio of 5:1. The moles of aluminum are then converted into an equivalent volume of liquid alum.

TABLE 2-2

ESTIMATES OF AVAILABLE SEDIMENT PHOSPHORUS AND INACTIVATION REQUIREMENTS FOR LAKE HOLDEN

AVAILABLE P CONTOUR INTERVAL ($\mu g/cm^3$)	CONTOUR INTERVAL MID-POINT ($\mu g/cm^3$)	CONTOUR AREA (ac)	AVAILABLE P		ALUM REQUIREMENT Al:P Ratio = 5:1	
			kg	moles	moles of Al	gallons of alum
0-100	75	32.10	975	31,445	157,223	19,145
100-200	150	141.39	8,587	277,006	1,385,028	168,652
200-300	250	52.59	5,323	171,720	858,602	104,550
300-400	350	12.21	1,730	55,816	279,082	33,983
400-500	450	12.08	2,201	71,000	355,000	43,228
500-600	550	12.39	2,759	89,005	445,023	54,189
600-700	650	3.25	855	27,951	137,957	16,799
Total:		**266.0**	**22,431**	**723,583**	**3,617,914**	**440,545**

On a mass basis, the sediments of Lake Holden contain approximately 22,431 kg of available phosphorus in the top 10 cm, equivalent to approximately 723,583 moles of available phosphorus to be inactivated as part of the sediment inactivation process. Estimated inactivation requirements were calculated for Lake Holden based upon a molar Al:P ratio of 5:1. Prior research involving sediment inactivation has indicated that an excess of aluminum is required within the sediments to cause phosphorus to preferentially bind with aluminum rather than other available complexing agents. Based upon this ratio, inactivation of phosphorus release from sediments in Lake Holden will require approximately 3,617,914 moles of aluminum which equates to approximately 440,545 gallons of alum, equivalent to 97.9 tankers of alum containing 4,500 gallons each.

An average water column dose of alum required for sediment inactivation was calculated by dividing the required alum volume of 441,000 gallons by the overall volume of the lake. Since the alum application would occur at the surface, the overall whole-lake alum dose must be evaluated in addition to sediment requirements. Application of approximately 440,545 gallons of alum to Lake Holden into a water column volume of approximately 3211.5 ac-ft would result in an applied alum dose of 24.7 mg Al/liter, which is within the range of concentrations typically calculated for sediment inactivation projects in the Central Florida area. However, a dose in this range would substantially exceed the available buffering capacity of the lake and would need to be divided into multiple individual applications to minimize the impact on pH in the lake and eliminate the need for a supplemental buffering compound.

2.3 Alum Application Details

The total required alum volume of 440,545 gallons was divided into six separate applications which were conducted to Lake Holden over the period from 2005-2012. A summary of alum applications to Lake Holden by individual application date is given on Table 2-3. Individual alum volumes are provided for each of the tanker loads received at Lake Holden. Alum applications during the first three treatments added alum quantities ranging from 77,794-112,012 gallons. Alum additions during the final three applications were approximately 47,500 gallons each.

An overall summary of alum additions to Lake Holden is given on Table 2-4. Information is provided on the dates over which the application occurred, the total volume of alum applied, and the mean water column dose. Mean water column doses for the six applications ranged from 2.6-6.3 mg Al/liter, with an overall total of 24.0 mg Al/liter.

TABLE 2-3

SUMMARY OF ALUM APPLICATIONS TO LAKE HOLDEN BY DATE

DATE	ALUM[1] (gallons)	DATE	ALUM[1] (gallons)	DATE	ALUM[1] (gallons)	DATE	ALUM[1] (gallons)	DATE	ALUM[1] (gallons)	DATE	ALUM[1] (gallons)
4/4/2005	4,332	9/7/2005	4,502	2/22/06	4,506	1/8/10	4,324	6/1/10	4,323	1/24/12	4,322
	4,322		4,500		4,501		4,505		4,321		4,322
4/5/2005	4,321		4,493		4,502	1/11/10	4,323	6/2/10	4,321		4,322
	4,322	9/8/2005	4,501	2/23/06	4,508		4,323		4,328	1/26/12	4,324
	4,321		4,500		4,501		4,325	6/3/10	4,327		4,324
	4,321		4,501		4,501	1/12/10	4,322		4,329		4,321
4/6/2005	4,322		4,501	2/24/06	4,501		4,322	6/10/10	4,321	1/30/12	4,324
	4,321	9/9/2005	4,502		4,510		4,316	6/11/10	4,321		4,323
	4,322		4,500		4,510	1/13/10	4,315	6/25/10	4,320		4,323
	4,322		4,502		4,510		4,312	7/2/10	4,411	2/1/12	4,318
4/7/2005	4,321		4,502	2/27/06	4,510	1/14/10	4,316		4,501		4,323
	4,322	9/12/2005	4,502		4,502	**TOTAL:**	**47,701**	**TOTAL:**	**47,824**	**TOTAL:**	**47,546**
	4,322		4,501		4,510						
	4,321		4,501		4,501						
4/8/2005	4,319		4,502	2/28/06	4,502						
	4,321	9/13/2005	4,502		4,502						
	4,321		4,502		4,509						
	4,322		4,501	3/16/06	4,501						
TOTAL:	**77,794**		3,989		4,502						
		9/21/2005	4,502		4,502						
			4,502	3/17/06	4,408						
			4,502	**TOTAL:**	**94,500**						
			4,501								
		9/22/2005	4,501								
			4,502								
		TOTAL:	**112,012**								

1. Based on a density of 11.13 lbs/gallon

TABLE 2-4

OVERALL SUMMARY OF ALUM ADDITION TO LAKE HOLDEN

DATES	ALUM (gallons)	WATER COLUMN DOSE (mg Al/liter)
4/4/05 – 4/8/05	77,794	4.4
9/7/05 - 9/22/05	112,012	6.3
2/22/06 – 3/1/06	94,500	5.3
1/8/10 – 1/14/10	47,701	2.7
6/1/10 – 7/2/10	47,824	2.7
1/24/12 – 2/1/12	47,546	2.6
TOTAL:	**427,377**	**24.0**

As indicated on Figure 2-3, concentrations of available phosphorus within the sediments of Lake Holden are highly variable, and some areas of Lake Holden would require a larger volume of alum for sediment inactivation than other areas where the available phosphorus concentrations are less. An application map was developed by ERD which divides Lake Holden into four separate zones of approximately equal size. An overview of the designated zones is given on Figure 2-4. The total available phosphorus contained within each of the four zones was calculated and expressed as a percentage of the overall total available sediment phosphorus within the entire lake. Based upon the application map, Zone 1 would receive approximately 10.5% of the alum applied during each of the six individual applications, with Zone 2 receiving 25.5%, Zone 3 receiving 12.1%, and Zone 4 (located in southwestern portions of Lake Holden) receiving approximately 51.9% of the total applied alum. As a result, more than half of the total alum applied to Lake Holden during the six applications was applied within Zone 4 of the lake. The smallest amount of alum was applied in Zone 1 which receives inflows from the alum stormwater treatment systems which have already inactivated a large portion of the available phosphorus in this area.

Each of the alum applications to Lake Holden were conducted using the application boat and tanker barge combination illustrated on Figure 2-5. The smaller tank in the application boat holds approximately 500 gallons of alum, with the tanker barge holding approximately 1000 gallons of alum. The application boat and tanker barge would pull up to the shoreline area and each of the two tanks were filled with alum from the tanker delivery truck. The application boat and barge would then travel to the zone of the lake where the alum is to be applied, and the application process would begin.

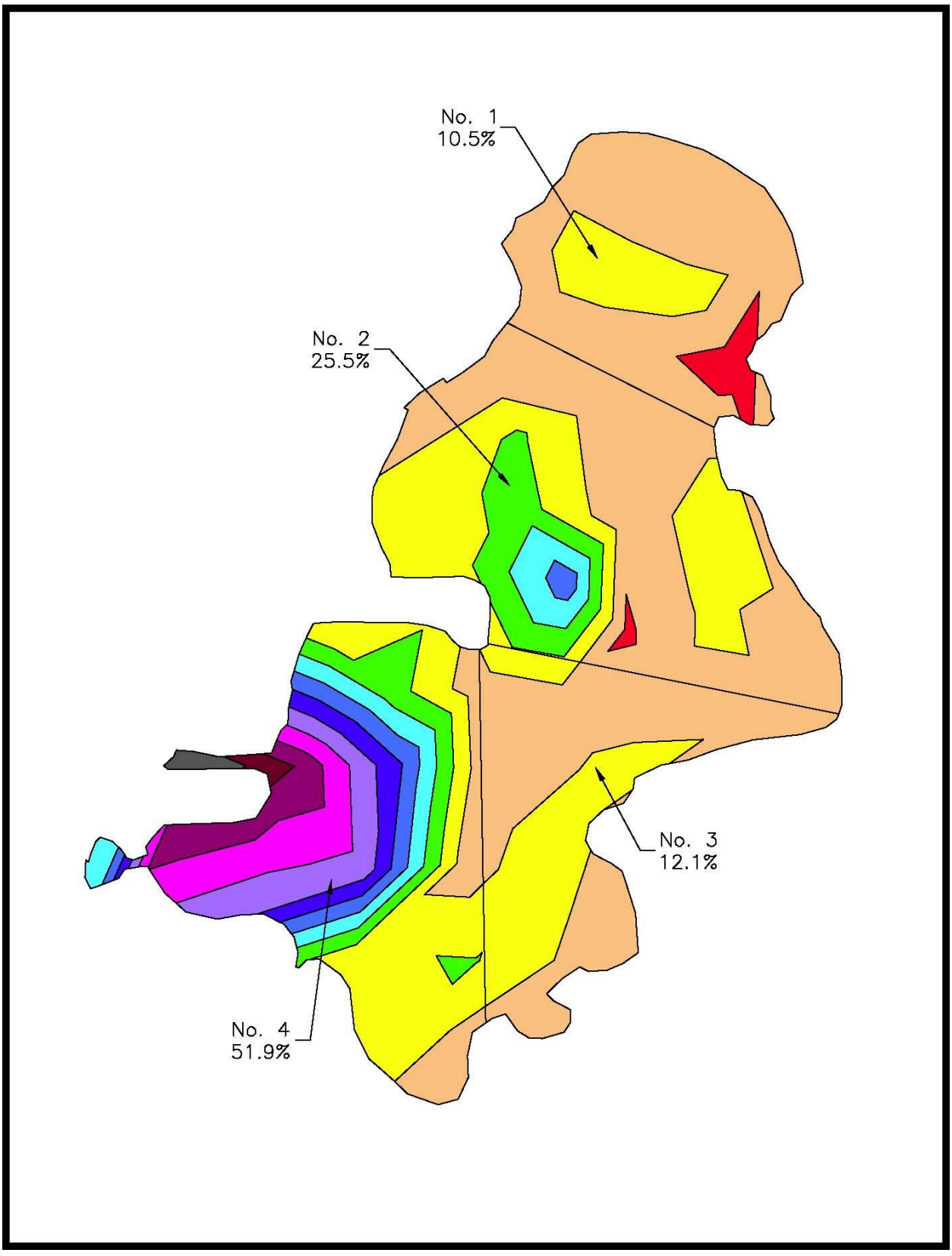


Figure 2-4. Application Map Indicating the Fraction of Total Alum to be Applied to the Identified Zones.

Figure 2-5. Application Boat and Tanker Barge Used for Alum Application in Lake Holden.

During the application, the alum is sprayed through a spreader bar located on the front of the application boat. The pumping system contains an intake for lake water, and lake water and alum were mixed in a ratio of approximately 4 parts lake water to 1 part alum before being sprayed onto the lake surface. This initial water addition helps mix the alum with the water prior to application onto the lake surface. If the alum is not initially pre-mixed with water, there is a risk that the alum (which is approximately 40% denser than water) would simply settle through the water column without adequately mixing with the lake water.

During the application process, ERD conducted field measurements of pH on an hourly basis within each zone where alum is being applied. In addition, water samples were collected on a daily basis from each of the application zones and returned to the ERD Laboratory for analysis of alkalinity to ensure that the alum addition did not reduce alkalinity levels within the water column to an undesirable range.

SECTION 3

RESULTS

This section provides a summary and analysis of changes in water quality and sediment characteristics in Lake Holden resulting from the sediment inactivation project. Changes in water quality characteristics are evaluated based upon historical water quality data collected in Lake Holden by OCEPD, the City of Orlando, LAKEWATCH, and ERD. Changes in sediment characteristics and phosphorus speciation are based upon sediment monitoring events conducted by ERD.

3.1 Changes in Water Quality Characteristics

3.1.1 Historical Water Quality Data Availability

Changes in water quality characteristics in Lake Holden are evaluated based upon a review of historical water quality data for Lake Holden collected by a variety of agencies. Relatively extensive historical water quality monitoring has been conducted in Lake Holden by the Orange County Environmental Protection Division (OCEPD), the City of Orlando (City), the LAKEWATCH volunteer program sponsored by the University of Florida, as well as ERD. A summary of available historical water quality data for Lake Holden is given in Table 3-1. Water quality monitoring by OCEPD is conducted at two separate locations in Lake Holden identified as BC-14N (located near the center of the north lobe) and BC-14S (located near the center of the south lobe). Water quality monitoring at these sites has been conducted by OCEPD on a monthly or quarterly basis from 1978 to the present. Monitoring conducted by OCEPD includes measurements of field parameters and laboratory analyses for general parameters, nutrients, microbiological parameters, and metals. A total of 257 water quality samples has been collected as part of the OCEPD monitoring program.

Surface water monitoring by the City of Orlando was initiated in Lake Holden during 2001 and has continued on a quarterly basis to the present. Monitoring is conducted by the City at two separate locations, reflecting the north and south lobes of the lake. Monitoring conducted by the City includes measurements of field parameters, general parameters, and nutrients. A total of 45 separate samples has been collected as part of the City of Orlando monitoring program.

In addition to the monitoring conducted by OCEPD and the City, surface water monitoring is also conducted by the LAKEWATCH volunteer program on approximately a monthly to bimonthly basis from 1987 to the present. The LAKEWATCH samples are collected at a single location within the lake and are shipped to the University of Florida for analysis of nutrients and chlorophyll-a. A measurement of Secchi disk depth is also conducted at the time of each monitoring event. A total of 203 separate monitoring events has been conducted as part of the LAKEWATCH program.

TABLE 3-1

SUMMARY OF AVAILABLE HISTORICAL WATER QUALITY DATA FOR LAKE HOLDEN

AGENCY	STATIONS	COLLECTION DATES	MONITORING FREQUENCY	NUMBER OF EVENTS	TYPE OF DATA
OCEPD	BC-14N BC-14S	1978-1980 1981-1987 1988-1995 1998-2000 2001-2005 2006-2007 2008-2012	Quarterly Monthly Quarterly Monthly Quarterly Monthly Quarterly	257	Field parameters, general parameters, nutrients, microbiological parameters, metals
City of Orlando	North South	2001-2002	Quarterly	45	Field parameters, general parameters, nutrients
LAKEWATCH	--	1987-2012	Monthly to bimonthly	203	Nutrients, chlorophyll-a, Secchi disk depth
ERD	North South	2005-2012	Variable	48	Field parameters, general parameters, nutrients, chlorophyll-a

Relatively extensive water quality monitoring has also been conducted in Lake Holden by ERD, with separate monitoring locations near the center of the north and south lobes. Monitoring by ERD has been conducted with a variable frequency from 2005-2012. A total of 48 separate water quality samples has been collected in Lake Holden as part of the ERD monitoring effort. Monitoring conducted by ERD includes measurements of field parameters and analysis of collected samples for general parameters, nutrients, and chlorophyll-a. A complete listing of historical water quality data collected in Lake Holden by OCEPD, the City of Orlando, LAKEWATCH, and ERD is given in Appendix A. This data set includes only significant trophic state parameters, such as total nitrogen, total phosphorus, chlorophyll-a, and Secchi disk depth.

A historical data set for Lake Holden was developed by ERD by combining the available data collected by OCEPD, the City of Orlando, LAKEWATCH, and ERD. Although water quality data for Lake Holden are available as far back as 1978, much of this earlier data suffers from poor detection limits and contains a number of potentially questionable data points. Therefore, for purposes of discussing historical water quality and water quality trends in Lake Holden, only data collected from 1985 (where available) to 2012 are included in this discussion. This provides a useable data period of more than 25 years for evaluation of historical water quality and water quality trends. The only exception to this selected data period is Secchi disk depth which is extended back to 1978 since Secchi disk measurements are not subject to the same concerns mentioned previously for laboratory measured parameters.

3.1.2 Historical Water Quality Trends

A graphical summary of measured concentrations of total phosphorus in the north and south lobes of Lake Holden from 1990-2012 is given on Figure 3-1. The data summarized in this figure includes monitoring conducted by ERD, OCEPD, and the City of Orlando. The LAKEWATCH data are not included on this figure since LAKEWATCH does not include separate monitoring locations in north and south lobes of the lake. During the early 1990s, total phosphorus concentrations in both the north and south lobes ranged primarily from 30-60 μg/l. Initiation of the stormwater treatment system occurred during 1995, and substantial reductions in total phosphorus concentrations were observed in the north and south lobes beginning in 1998. The alum sediment inactivation program was initiated during 2005, and further reductions in total phosphorus concentrations are apparent during this period. Beginning in 2005, total phosphorus concentrations in Lake Holden were reduced substantially, with the majority of measured values less than 10-20 μg/l in both the north and south lobes. It is interesting to note that the total phosphorus measured by OCEPD and ERD appear to track very closely during this period. However, phosphorus measurements conducted by the City of Orlando appear to be somewhat higher in value than measurements conducted by OCEPD and ERD.

A graphical summary of measured concentrations of total nitrogen in Lake Holden from 1990-2012 is given on Figure 3-2 based upon data collected by ERD, OCEPD, and the City of Orlando. Data collected as part of the LAKEWATCH program are not included in this figure since the LAKEWATCH monitoring does not include separate north and south monitoring stations. Unlike the trend observed for total phosphorus, measured total nitrogen concentrations reported by ERD, OCEPD, and the City of Orlando are virtually identical during periods where data collection activities overlap. Prior to 2005, measured total nitrogen concentrations in the north and south lobes ranged from approximately 1000-2500 μg/l. Implementation of the alum stormwater treatment system during 1995 did not appear to have a significant impact on measured nitrogen concentrations since alum has little affinity for removal of nitrogen species other than particulate nitrogen. However, following initiation of the alum inactivation treatments in 2005, a substantial reduction in total nitrogen concentrations was observed in both the north and south lobes, with a majority of the measured values less than 1000 μg/l. The observed reductions in nitrogen concentrations are probably related to the overall decrease in algal productivity caused by the substantial reductions in total phosphorus which reduced the amount of nitrogen contained in algal biomass within the lake.

A graphical summary of measured concentrations of chlorophyll-a in Lake Holden from 1999-2012 is given on Figure 3-3 for the north and south lobes of the lake. The range of chlorophyll-a measurements included on this figure is from 1999-2012 since chlorophyll-a data are not available from the three data sources prior to 1999. Chlorophyll-a measurements are also not included from the City of Orlando since chlorophyll-a is not routinely measured by Orlando in Lake Holden. Prior to 2001, chlorophyll-a concentrations in the north and south lobes of Lake Holden ranged from approximately 40-60 mg/m^3. An apparent decrease in chlorophyll-a concentrations occurs in both the north and south lobes beginning in 2001, with chlorophyll-a concentrations from 2001-2005 ranging from approximately 20-40 mg/m^3. These observed decreases in chlorophyll-a may be related to implementation of stormwater management projects

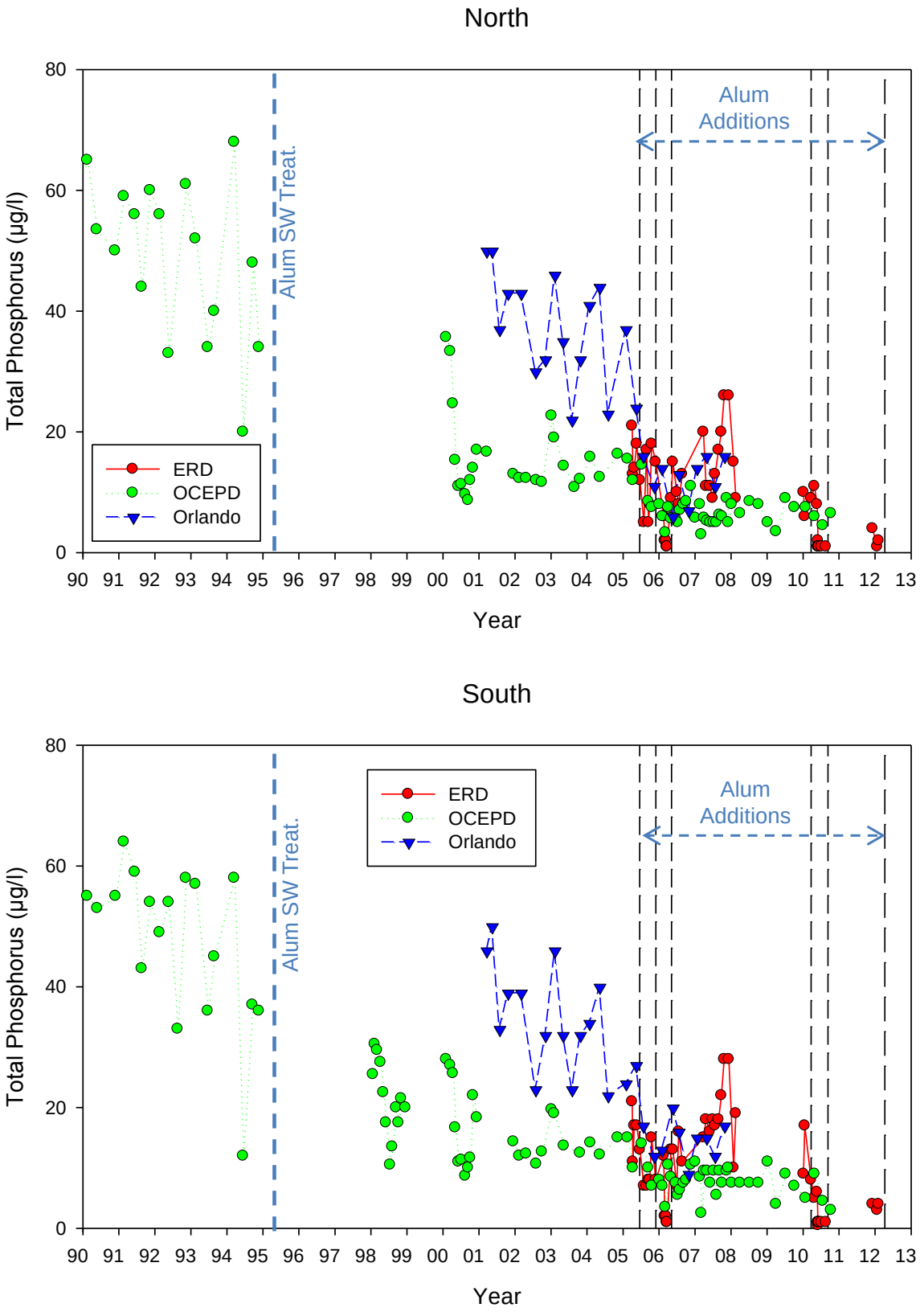


Figure 3-1. Measured Concentrations of Total Phosphorus in the North and South Lobes of Lake Holden from 1990-2012.

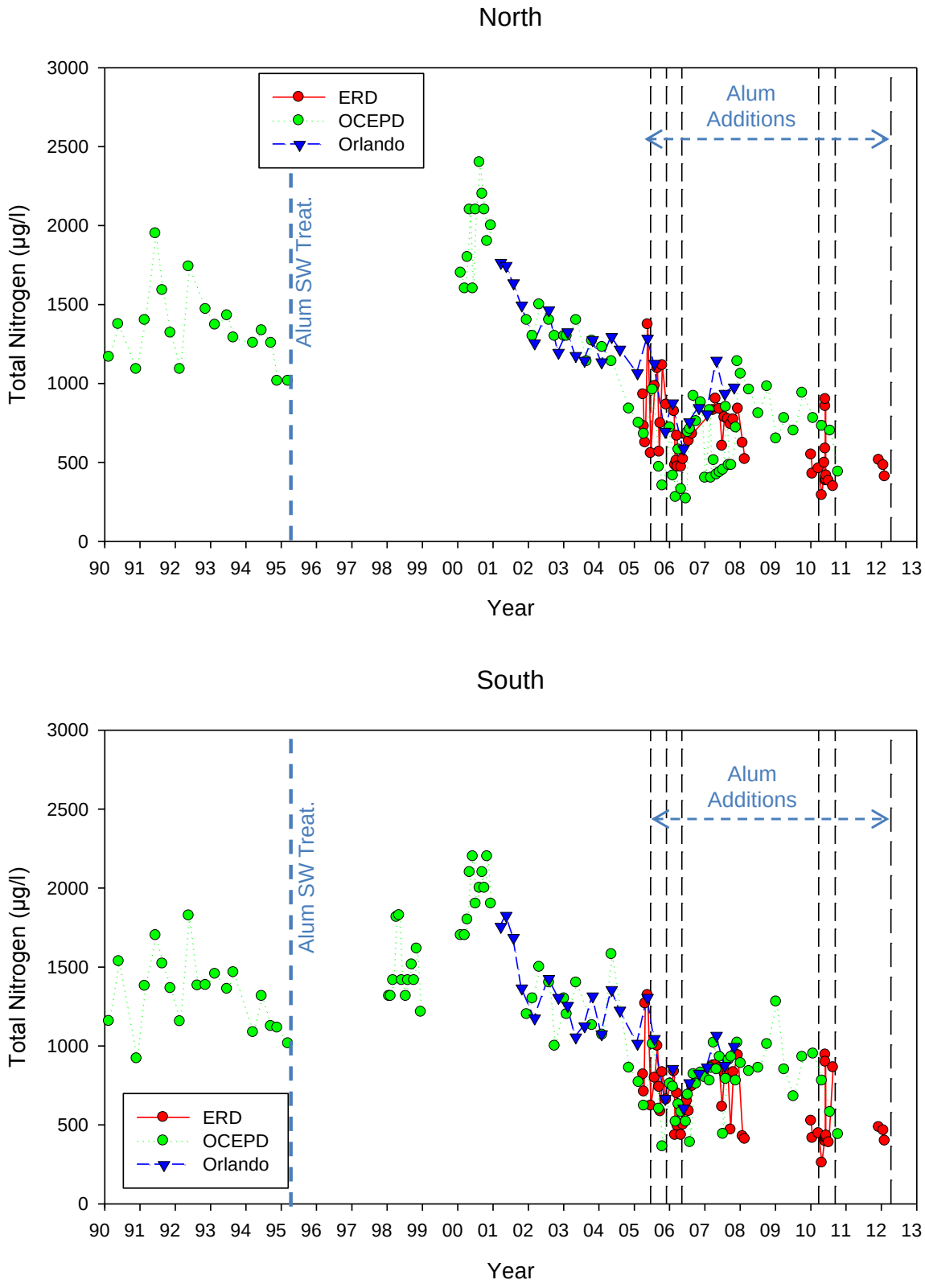


Figure 3-2. Measured Concentrations of Total Nitrogen in the North and South Lobes of Lake Holden from 1990-2012.

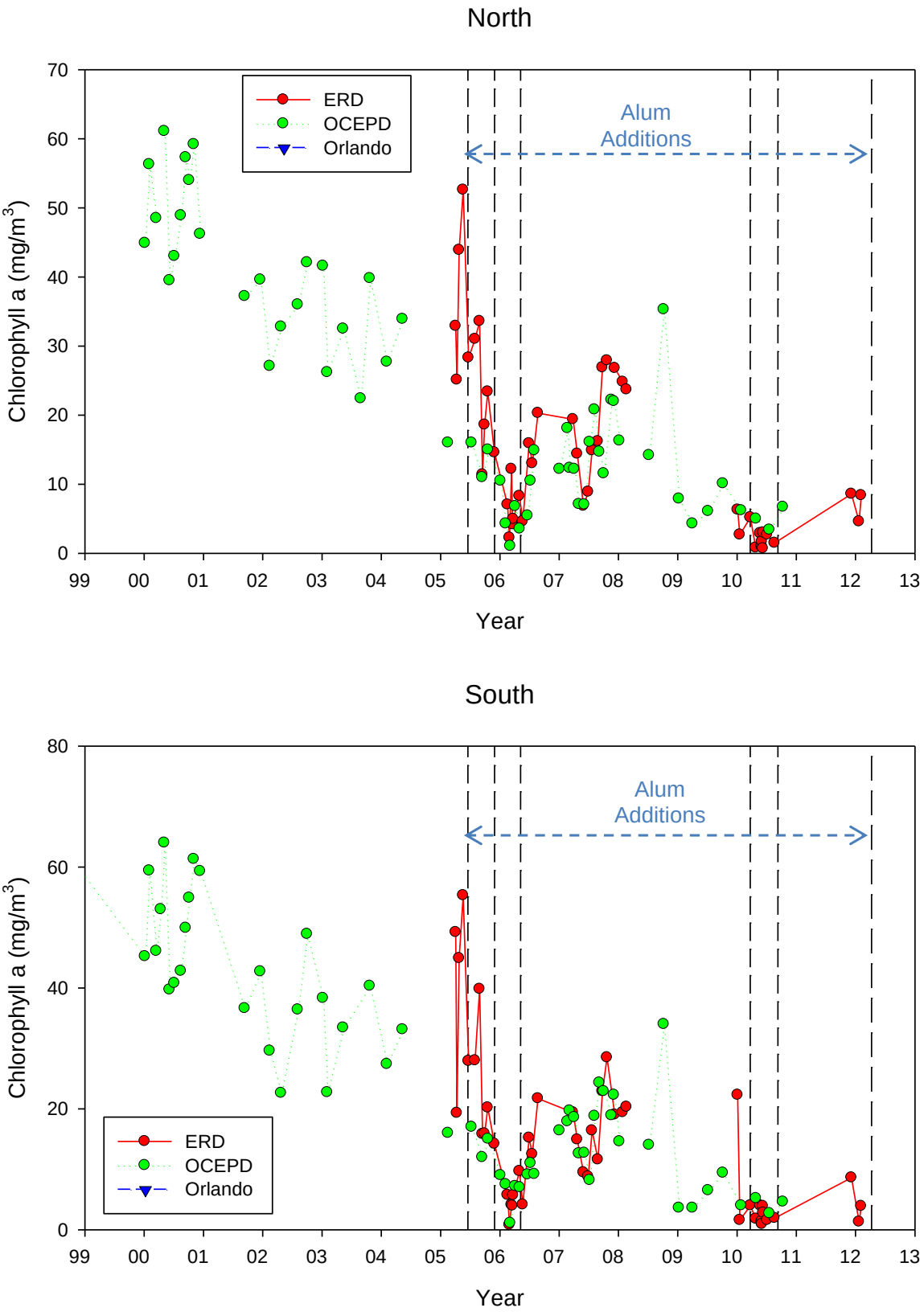


Figure 3-3. Measured Concentrations of Chlorophyll-a in the North and South Lobes of Lake Holden from 1999-2012.

within the watershed, such as the alum stormwater treatment system, construction of detention basins, installation of curb inlet baskets, and improved street sweeping activities. However, beginning in 2005, substantial reductions in chlorophyll-a concentrations occurred in both the north and south lobes as a result of the alum applications for sediment inactivation, with measured chlorophyll-a concentrations ranging from near zero to 20 mg/m^3. The observed reduction in chlorophyll-a concentrations is related to the reduced availability of phosphorus within the lake as a result of the multiple surface treatments and reduction of phosphorus release from the lake sediments.

A graphical summary of measured Secchi disk depths in Lake Holden from 1970-2012 is given on Figure 3-4. Secchi depth data is included for measurements collected as far back as 1978 since Secchi disk measurements are not subject to the same variability in measurement techniques and detection limits which occur with laboratory measured data. Prior to approximately 2005, measured Secchi disk depths in both the north and south lobes of the lake were generally approximately 1 m or less, although values as high as 2 m were recorded on several occasions. Secchi disk depths reported by ERD, OCEPD, and the City of Orlando appear to be very similar. Beginning in 2005, substantial improvements in Secchi disk depth began to occur in Lake Holden as a result of the multiple alum surface treatments and reduction in algal productivity caused by the limited phosphorus availability. Since approximately 2010, measured Secchi disk depths in Lake Holden have ranged from approximately 2-4 m, reflecting substantially enhanced water column transparency compared with pre-sediment inactivation values.

A graphical summary of calculated Florida Trophic State Index (TSI) values for Lake Holden from 1999-2012 is given on Figure 3-5. The TSI values summarized in this figure are calculated based upon the average of individual TSI calculations for nutrients, chlorophyll-a, and Secchi disk depth, as recommended by FDEP. Prior to approximately 2005, the north and south lobes of Lake Holden exhibited mesotrophic to hypereutrophic conditions which were characterized by elevated concentrations of total nitrogen, total phosphorus, chlorophyll-a, and poor water column clarity as defined by measured Secchi disk depths. However, after initiation of the sediment inactivation treatments, TSI values in the north and south lobes of Lake Holden began to decrease steadily with each of the individual alum applications. Since approximately 2009, Lake Holden has exhibited primarily oligotrophic conditions based upon the calculated TSI values. The observed substantial reductions in TSI values are a reflection of the reductions in concentrations of nutrients and chlorophyll-a combined with the observed improvements in Secchi disk depth.

A tabular summary of mean annual concentrations of significant water quality parameters in Lake Holden from 1978-2012 is given on Table 3-2. The values summarized in this table reflect mean annual average concentrations for each of the evaluated parameters, obtained as the average of measurements conducted by ERD, OCEPD, City of Orlando, and LAKEWATCH monitoring programs. On monitoring dates where multiple samples were collected within the lake, the results of the multiple samples were averaged together to generate a single value for each monitoring date. The results of each individual monitoring date were then averaged together to generate an overall average value for each parameter during each calendar year. The information summarized in Table 3-2 is used to generate graphical plots of mean annual concentrations for each of the evaluated water quality parameters which are summarized and discussed in subsequent sections.

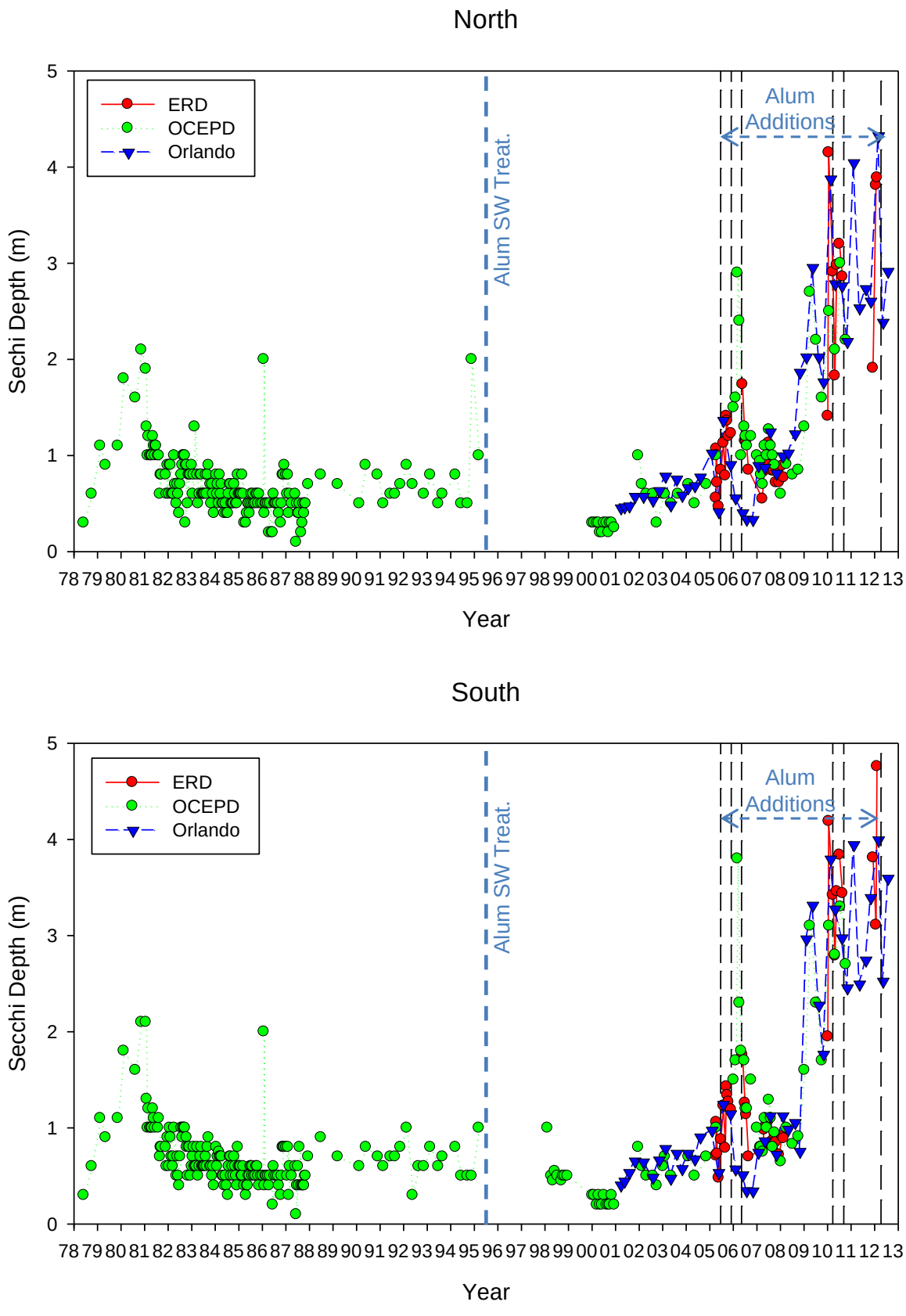


Figure 3-4. Measured Secchi Disk Depths in the North and South Lobes of Lake Holden from 1978-2012.

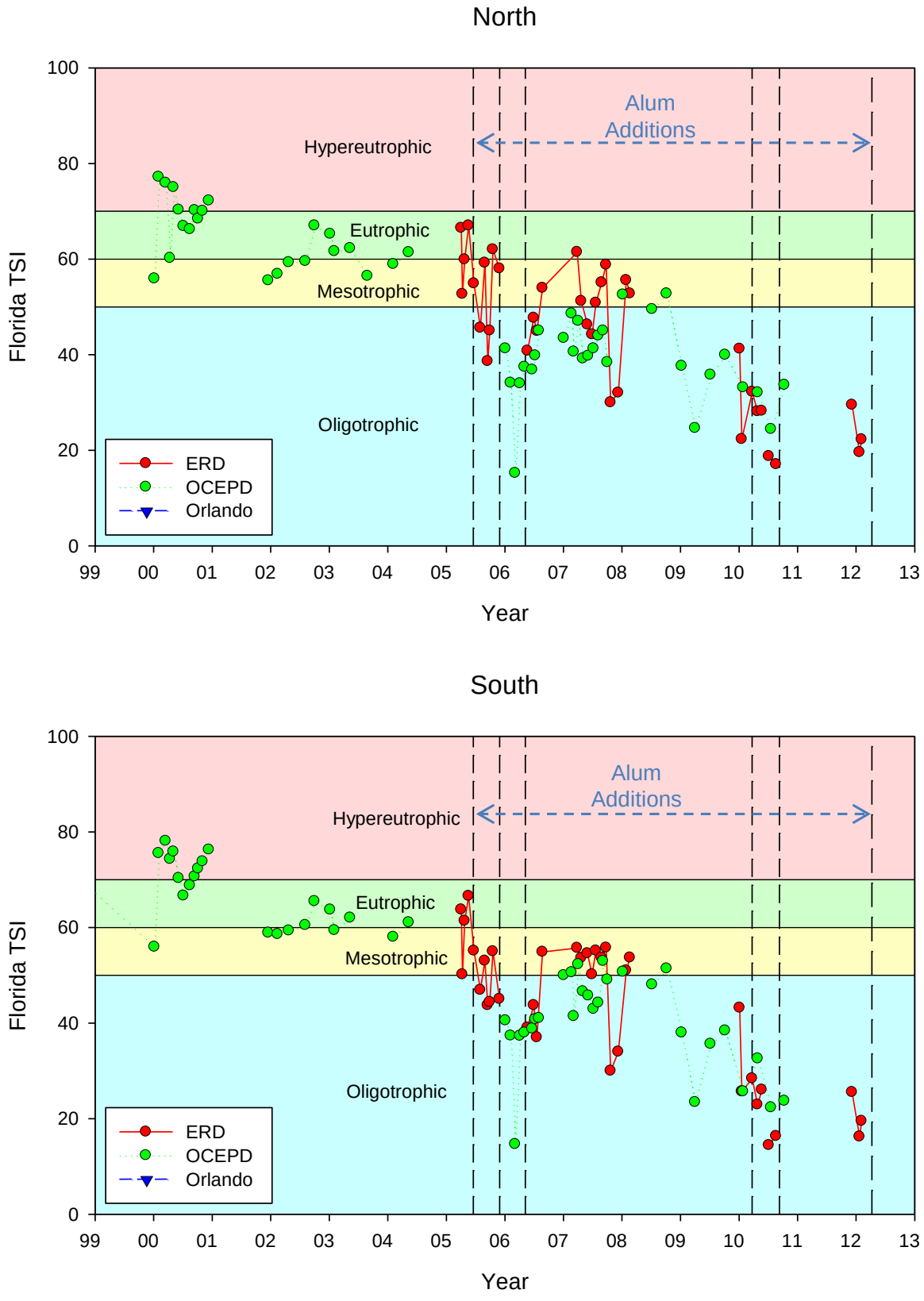


Figure 3-5. Calculated Florida TSI Values for the North and South Lobes of Lake Holden from 1999-2012.

TABLE 3-2

MEAN ANNUAL CONCENTRATIONS OF SIGNIFICANT WATER QUALITY PARAMETERS IN LAKE HOLDEN FROM 1978-2012

YEAR	CHLOROPHYLL-A (mg/m^3)	SECCHI DISK DEPTH (m)	TOTAL NITROGEN (µg/l)	TOTAL PHOSPHORUS (µg/l)	FLORIDA TSI VALUE
1978	--	0.5	1935	20	--
1979	--	1.0	926	49	--
1980	--	1.8	812	37	--
1981	--	1.0	1285	56	--
1982	--	0.7	1266	57	--
1983	--	0.7	1355	50	--
1984	--	0.6	1663	63	--
1985	--	0.5	2351	54	--
1986	--	0.6	1598	53	--
1987	72.2	0.5	1065	53	--
1988	46.8	--	901	63	--
1989	--	0.7	1708	57	--
1990	47.7	0.7	1236	49	67.0
1991	60.3	0.6	1387	50	70.8
1992	--	0.6	1499	46	--
1993	--	0.7	1395	44	--
1994	--	0.7	1188	40	--
1995	43.7	0.8	1028	53	64.4
1996	24.5	0.8	900	34	60.1
1997	49.6	0.7	1152	38	67.5
1998	52.7	0.6	1375	30	68.6
1999	54.7	0.7	1335	38	68.8
2000	57.7	0.4	1869	30	71.7
2001	48.8	0.6	1489	35	68.6
2002	38.4	0.7	1245	28	64.0
2003	35.3	0.8	1172	27	61.6
2004	34.5	0.8	1124	29	61.1
2005	23.9	1.1	873	18	54.0
2006	10.7	1.5	686	11	43.2
2007	18.0	1.0	817	16	51.5
2008	22.0	1.0	812	17	54.4
2009	7.0	2.2	719	13	38.3
2010	4.2	2.8	533	8	31.2
2011	6.6	2.7	560	12	36.8
2012	4.2	3.3	498	10	30.0

A graphical summary of mean annual concentrations of total nitrogen in Lake Holden from 1985-2012 is given on Figure 3-6. This summary includes all available total nitrogen data collected by ERD, OCEPD, City of Orlando, and LAKEWATCH. Prior to initiation of the alum sediment inactivation project in 2005, total nitrogen concentrations in Lake Holden were highly variable, ranging from approximately 900-2400 µg/l on an annual average basis. However, after initiation of the sediment inactivation project, total nitrogen concentrations within the lake decreased substantially to values ranging from 500-1000 µg/l. As discussed previously, the observed reduction in nitrogen concentrations are likely due to reductions in algal biomass and corresponding particulate nitrogen in the water column.

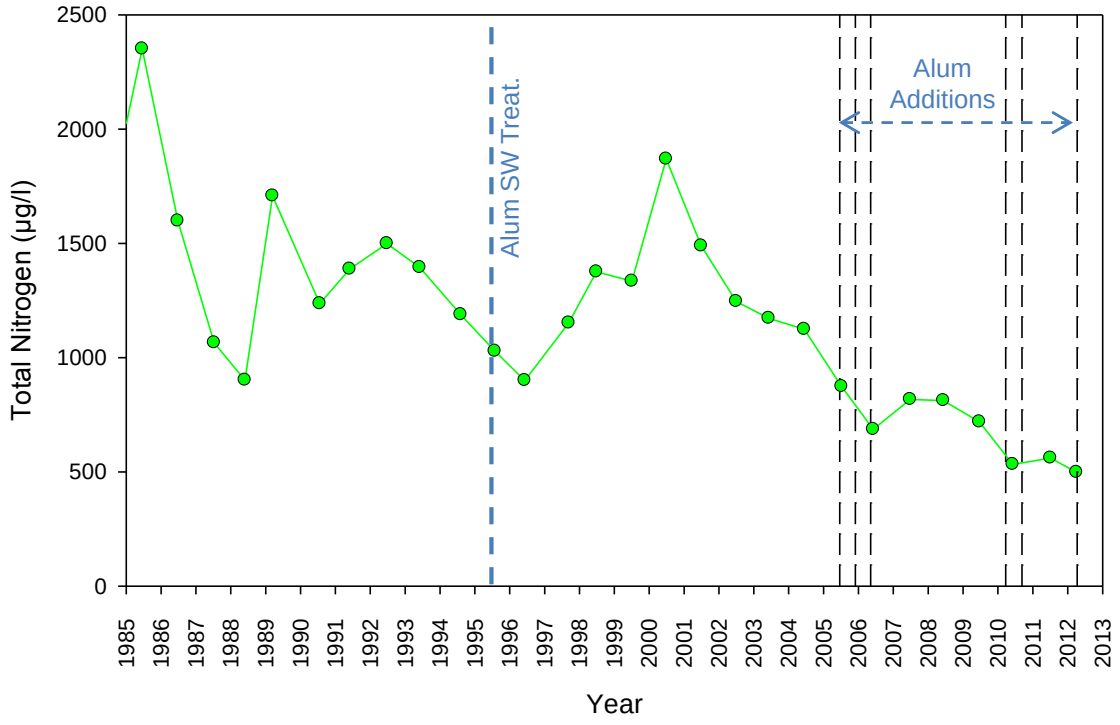


Figure 3-6. Mean Annual Concentrations of Total Nitrogen in Lake Holden from 1985-2012.

A summary of mean annual concentrations of total phosphorus in Lake Holden from 1985-2012, based upon the combined data sets from ERD, OCEPD, City of Orlando, and LAKEWATCH is given on Figure 3-7. A slight decrease in mean annual total phosphorus concentrations appears to have occurred within Lake Holden from 1985-1995 when the alum stormwater treatment systems became operational. Following implementation of the stormwater treatment systems, the steady trend of decreasing concentrations of total phosphorus continued, reaching an equilibrium total phosphorus concentration of approximately 30 µg/l. When the alum sediment inactivation project was initiated during 2005, substantial further reductions in total phosphorus concentration occurred within the lake, with new equilibrium phosphorus concentrations ranging from approximately 10-15 µg/l.

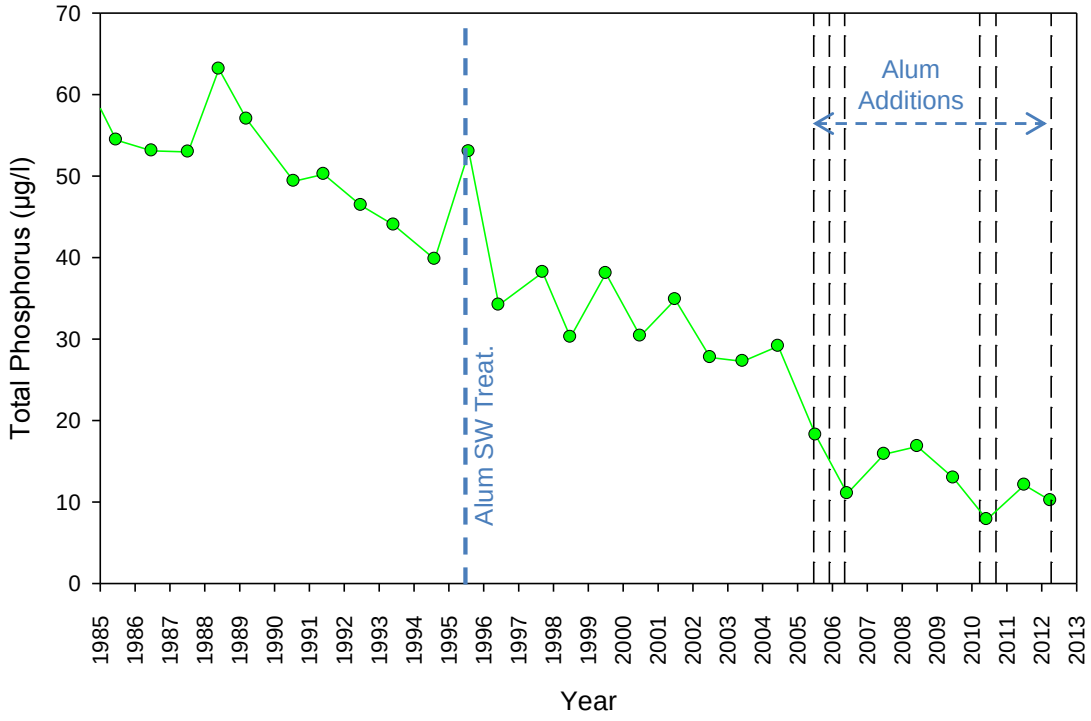


Figure 3-7. Mean Annual Concentrations of Total Phosphorus in Lake Holden from 1985-2012.

A graphical summary of mean annual concentrations of chlorophyll-a in Lake Holden from 1985-2012 is given on Figure 3-8. Chlorophyll-a data within Lake Holden has been collected on a much lower frequency than other parameters such as total nitrogen and total phosphorus. Prior to approximately 2000, mean annual chlorophyll-a concentrations in Lake Holden ranged from approximately 25-75 mg/m^3. A steady trend of decreasing chlorophyll-a concentrations began in approximately 2000 and continued until approximately 2005 when the sediment inactivation program was initiated. The observed decrease in chlorophyll-a concentration beginning in approximately 2000 is likely a delayed response from implementation of the alum stormwater treatment system and the other substantial stormwater management initiatives conducted by the MSTU. Chlorophyll-a concentrations decreased further during the sediment inactivation program, with mean annual average concentrations of approximately 7 mg/m^3 or less from 2009-2012. These chlorophyll-a values represent a significant reduction in concentration compared with chlorophyll-a values measured prior to initiation of the sediment inactivation project. The observed reductions in chlorophyll-a are a direct response to the reductions in total phosphorus within the lake.

A graphical summary of mean annual Secchi disk depths in Lake Holden from 1985-2012 is given on Figure 3-9. Prior to approximately 2000, mean annual Secchi disk depths in Lake Holden ranged from approximately 0.5-1 m, reflecting extremely poor water column clarity. Beginning in approximately 2000, steady improvement in Secchi disk depths began to occur within the lake, increasing to approximately 1.1 m at the start of the sediment inactivation project. Further increases in Secchi disk depth occurred in Lake Holden with each subsequent alum treatment to the lake. During the period from 2009-2012, mean annual Secchi disk depths in Lake Holden ranged from 2.2-3.3 m, reflecting a substantial improvement in water clarity compared with pre-sediment inactivation measurements.

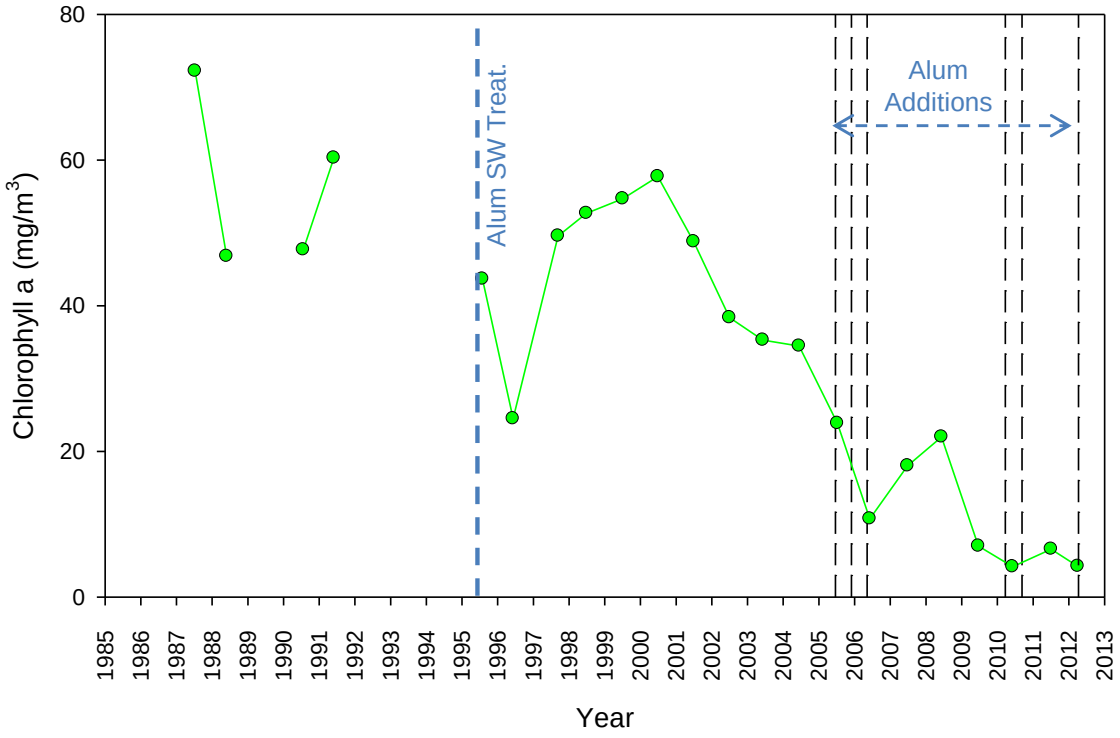


Figure 3-8. Mean Annual Concentrations of Chlorophyll-a in Lake Holden from 1985-2012.

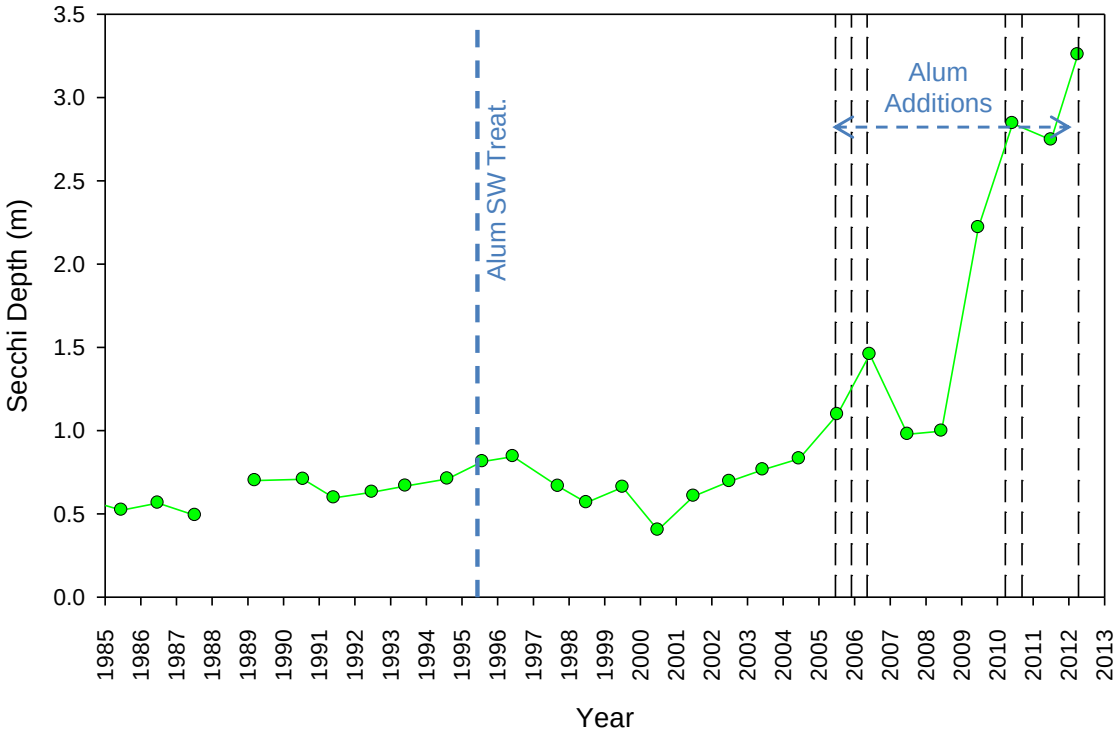


Figure 3-9. Mean Annual Concentrations of Secchi Disk Depths in Lake Holden from 1985-2012.

A graphical summary of mean annual Florida TSI values in Lake Holden from 1985-2012 is given on Figure 3-10. Prior to approximately 2000, mean annual TSI values in Lake Holden were generally in the eutrophic and hypereutrophic ranges, reflecting extremely poor water quality characteristics. Steady decreases in TSI values in Lake Holden began to occur during 2001 which continued until 2005 when Lake Holden entered the mesotrophic category. Additional reductions in annual TSI values began to occur in 2005 following initiation of the sediment inactivation program. During the period from 2009-2012, Lake Holden has maintained oligotrophic characteristics, with mean annual TSI values ranging from 30.0-38.3.

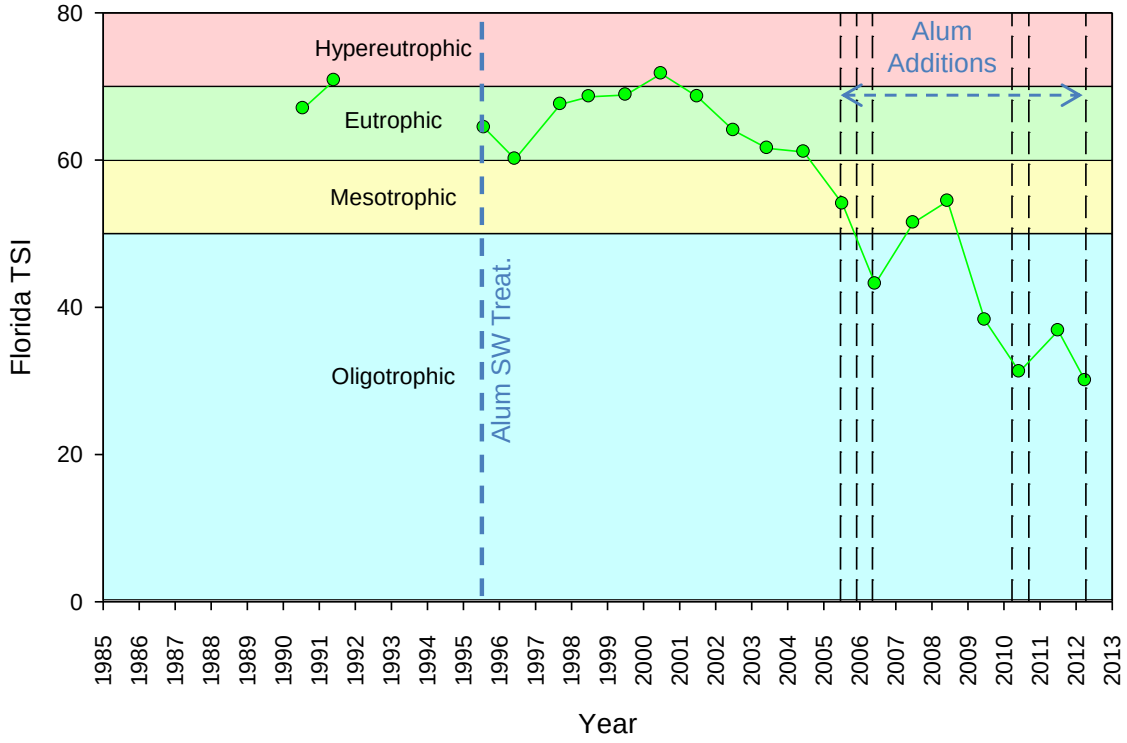


Figure 3-10. Mean Annual Florida TSI Values in Lake Holden from 1985-2012.

3.1.3 Visual Characteristics

In addition to the changes in chemical characteristics in Lake Holden discussed previously, substantial improvements in visual characteristics of the lake also occurred. Photographs of visual characteristics of Lake Holden prior to the initial alum sediment inactivation treatment are given on Figure 3-11. The water column at that time was characterized by a green color with extremely poor water column visibility and an overall unaesthetic appearance.

Photographs of Lake Holden during and following the alum sediment inactivation treatments are given on Figure 3-12. During the alum applications, the water column began to improve in appearance as algae and nutrients were removed from the water column. Lighter colored areas shown on Figure 3-12a, taken during the alum application process, indicate areas where alum floc is still settling from the water column into the sediments. Visual characteristics of Lake Holden following the sediment inactivation treatment are shown on Figure 3-12b. The water column has taken on a bluish appearance, and visibility has increased substantially.

Figure 3-11. Visual Characteristics of Lake Holden Prior to the Initial Alum Sediment Inactivation Treatment.

a. Visual water quality in Lake Holden during alum application

b. Visual water quality in Lake Holden at the completion of the alum application

Figure 3-12. Visual Characteristics of Lake Holden During and Following the Sediment Inactivation Treatments.

An aerial photograph of Lake Holden taken during January 2010, obtained from the Orange County Property Appraiser's Office, is given on Figure 3-13. The water column within the lake was exceptionally clear on the date of this photograph, with the bottom of the lake visible over approximately 75% of the lake area. Patches of submerged vegetation are also visible, including prop scars through the vegetation from boating activities.

Figure 3-13. Aerial Photo of Lake Holden in January 2010. (Source: Orange County Property Appraiser's Office).

3.1.4 Seasonal Water Quality Variability

A comparison of mean monthly total phosphorus concentrations in Lake Holden from 2000-2012 is given on Figure 3-14. Separate plots are provided for phosphorus concentrations measured from 2000-2004 prior to the sediment inactivation program, and samples collected from 2005-2012, following initiation of the sediment inactivation program. During the period from 2000-2004, a distinct seasonal variability in phosphorus concentrations was apparent, with higher phosphorus concentrations during dry season conditions than during wet season conditions. This type of pattern in phosphorus concentrations suggests that internal recycling is more significant in terms of phosphorus loadings than stormwater runoff since phosphorus concentrations are the highest during periods where rainfall is lowest. During fall, winter, and spring conditions, windy conditions often create circulation of the water column which brings phosphorus-rich water near the water-sediment interface to upper portions of the water column which increases total phosphorus concentrations and algal productivity. The pattern of total phosphorus concentrations in Lake Holden from 2000-2004 is characteristic of a lake with significant internal recycling processes.

A summary of mean monthly total phosphorus concentrations in Lake Holden is also provided for the period from 2005-2012 following initiation of the sediment inactivation process. In general, phosphorus concentrations are substantially lower in value overall compared with concentrations measured from 2000-2004. In addition, the distinct seasonal patterns of phosphorus concentrations is substantially absent, indicating that the sediment inactivation has been successful in reducing the release of phosphorus from the sediments and recirculation of this phosphorus into upper portions of the water column during circulation events within the lake. The pattern of phosphorus concentrations from 2005-2012 indicates that the sediment inactivation has been successful and has achieved the objective of reducing sediment phosphorus release.

A comparison of mean monthly concentrations of chlorophyll-a in Lake Holden before and after the sediment inactivation project is given on Figure 3-15. During the period from 2000-2004, chlorophyll-a concentrations in Lake Holden exhibited a pattern similar to the pattern exhibited by total phosphorus, with generally more elevated chlorophyll-a concentrations observed during dry season conditions compared with wet season conditions. This type of pattern suggests that nutrient sources which fuel algal growth and chlorophyll-a are more significant during non-rainy conditions than during wet season conditions. Mean monthly chlorophyll-a concentrations within the lake ranged from approximately 32-53 mg/m^3.

A comparison of mean monthly chlorophyll-a concentrations is also provided for the period from 2005-2012. In general, chlorophyll-a concentrations are substantially lower in value during this period than observed during the period from 2000-2004. Mean monthly concentrations of chlorophyll-a in Lake Holden from 2005-2012 ranged from approximately 10-20 mg/m^3. In addition, the seasonal pattern of enhanced chlorophyll-a concentrations during dry season conditions is substantially absent following the sediment inactivation process. This provides further evidence that the sediment inactivation has been successful in reducing the availability of nutrients for stimulation of algal productivity and generation of chlorophyll-a.

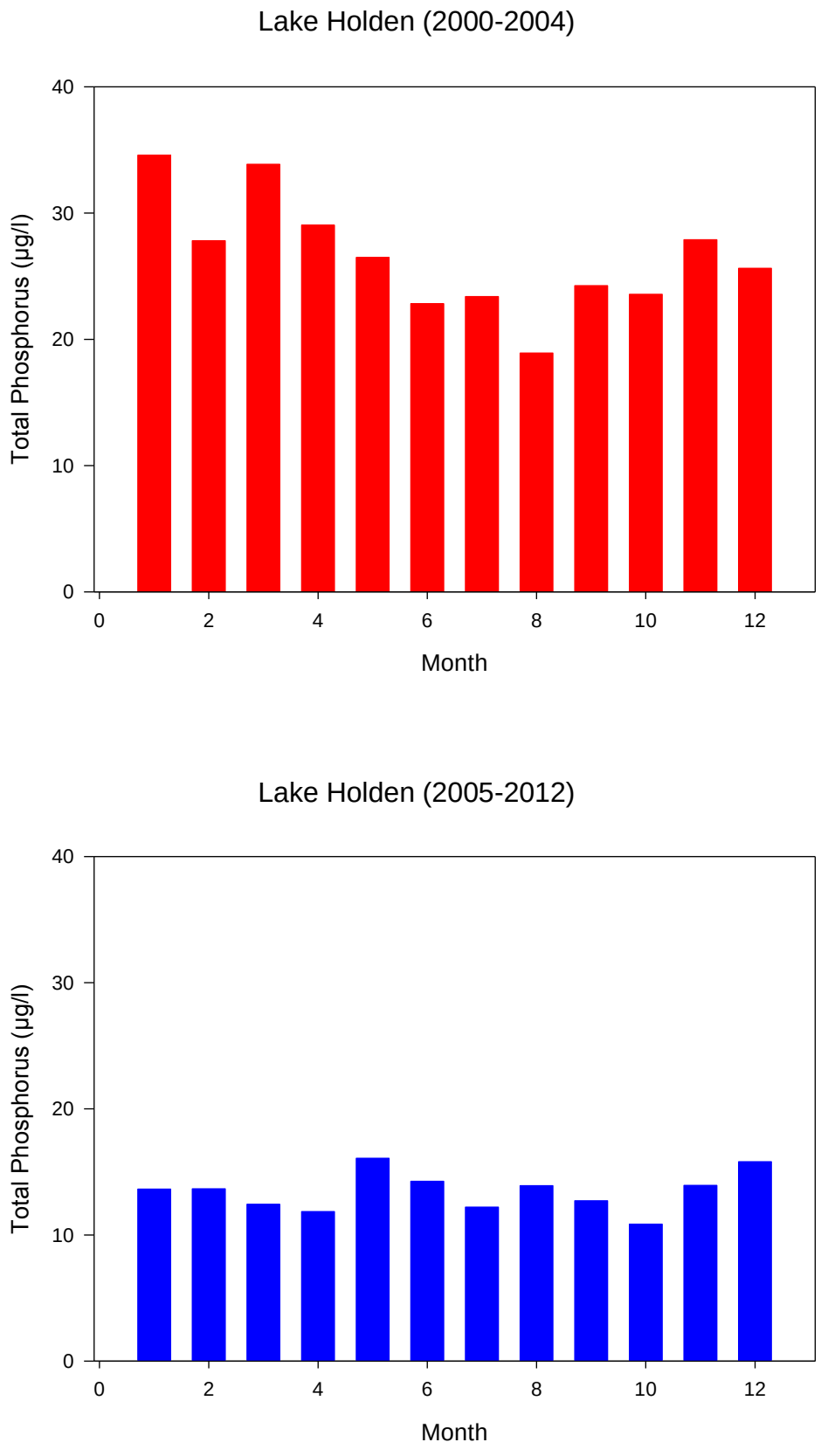


Figure 3-14. Comparison of Mean Monthly Concentrations of Total Phosphorus in Lake Holden Before and After the Sediment Inactivation Project.

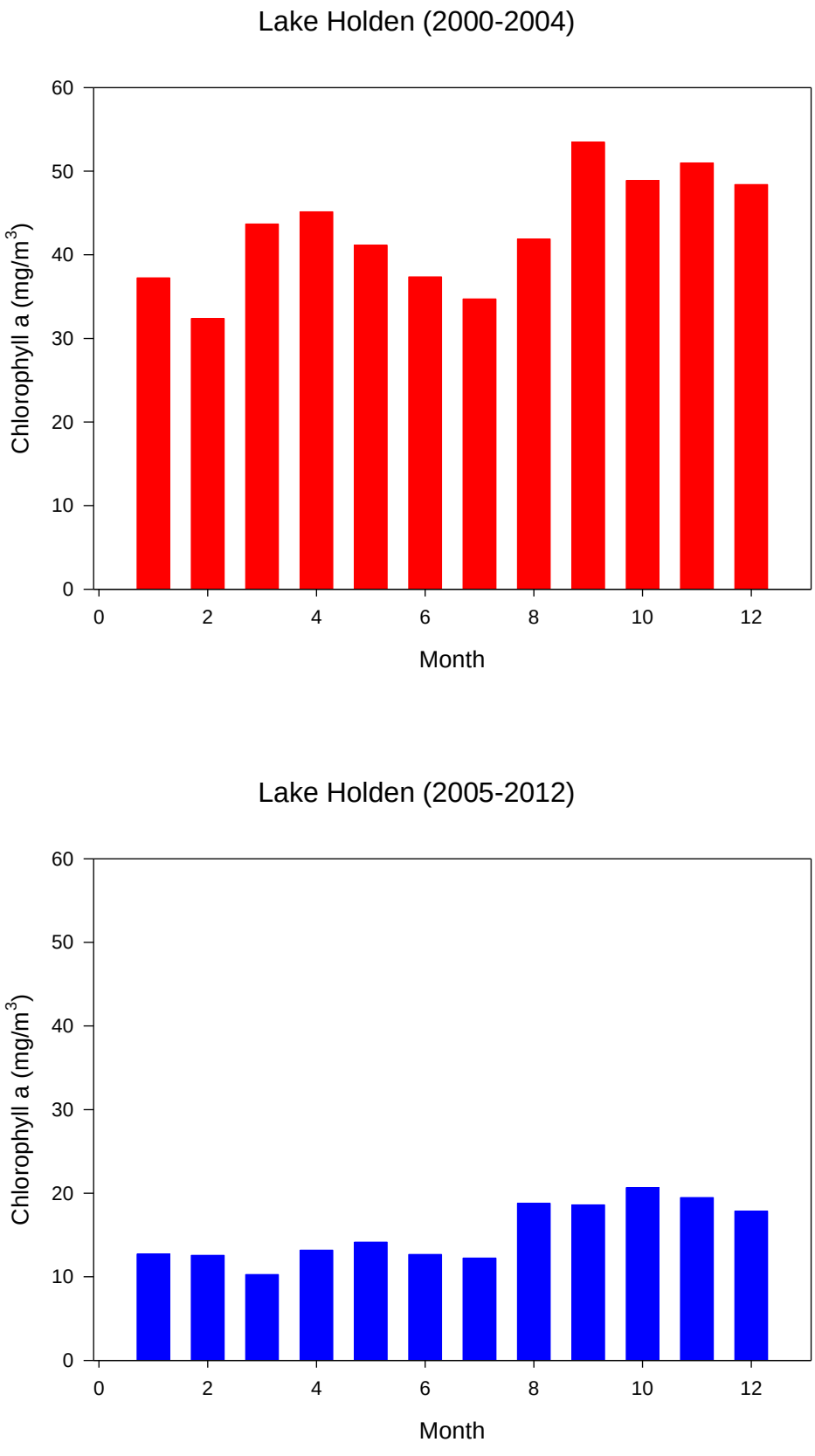


Figure 3-15. Comparison of Mean Monthly Concentrations of Chlorophyll-a in Lake Holden Before and After the Sediment Inactivation Project.

3.2 Sediment Characteristics

3.2.1 Visual Characteristics

Visual characteristics of sediment core samples were recorded for each of the 44 sediment samples collected in Lake Holden during each of the four sediment collection events. July 2011. A summary of visual characteristics of sediment core samples during the September 2003, May 2007, November 2008, and April 2012 events is given in Appendix B. In general, visual characteristics of sediment core samples collected in Lake Holden are relatively similar for a given monitoring site during each of the four sediment collection events. Shoreline areas of Lake Holden are characterized by sandy sediments with little or no visual accumulations of organic muck. The base material which forms the bottom of the lake consists primarily of light brown and dark brown fine sand, along with white sandy clay.

As water depths increase within the lake, the accumulations of unconsolidated organic muck become visible. Areas where deep deposits of organic muck have accumulated are characterized by a surface layer of unconsolidated organic muck, approximately 1-6 inches in thickness. This unconsolidated surficial muck layer is comprised primarily of fresh organic material (such as dead algal cells and detritus) which has recently accumulated onto the bottom of the lake and is easily disturbed by strong wind action or boating activities. In deeper portions of the lake, characterized by thick much deposits, the organic muck becomes more consolidated beneath the surficial layer (with a consistency similar to pudding), reflecting organic deposits which are resistant to further degradation. These layers typically do not resuspend into the water column except during vigorous and sustained wind activity on the lake.

Photographs of typical visual sediment characteristics in Lake Holden are given on Figures 3-16 and 3-17, based upon photographs collected during the May 2007 sediment collection event. Examples are provided for sediments which consist primarily of light brown to dark brown fine sand as well as organic muck. Visual evidence of alum floc is apparent in a few of the photographs collected in deeper portions of the lake.

3.2.2 General Sediment Characteristics

After return to the ERD Laboratory, the collected sediment core samples were evaluated for general sediment characteristics, including pH, moisture content, organic content, sediment density, total nitrogen, and total phosphorus. A tabular summary of general characteristics of sediment core samples collected in Lake Holden during September 2003 (prior to alum addition) is given in Table 3-3, with general characteristics of sediment core samples collected during the application process in May 2007 and November 2008, and in April 2012 (following the final alum application) are provided in Tables 3-4, 3-5, and 3-6, respectively. Geometric mean values are provided at the bottom of each table as a measure of central tendency for each of the evaluated parameters during each monitoring event.

b. Brown sand overlying white sandy clay

d. Light brown fine sand

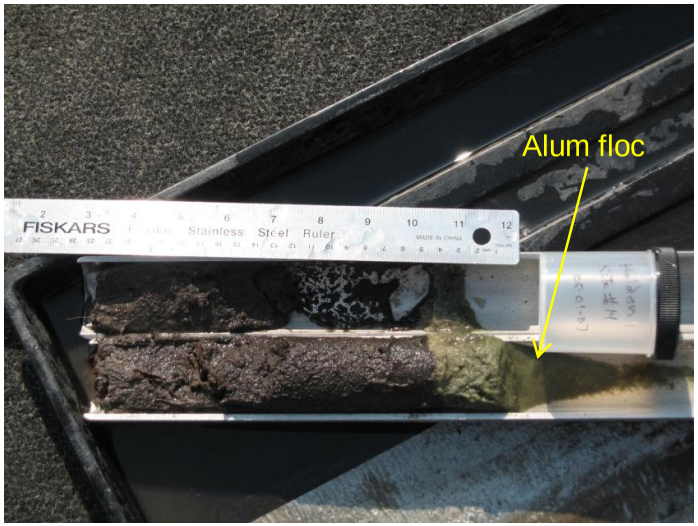
a. Light brown sand overlying dark brown sand

c. Layers of brown sands

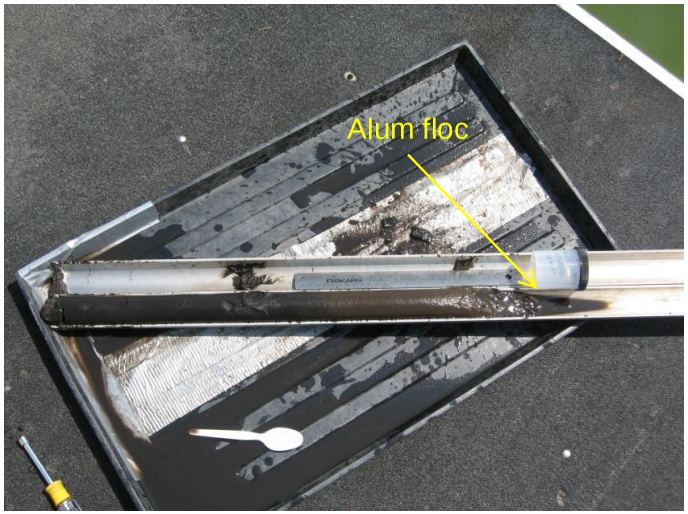
Figure 3-16. Photographs of Typical Sandy Sediments Collected in Lake Holden During May 2007.

a. Thick organic muck sediments

b. Brown sand overlying white sandy clay



c. Brown sand overlying dark brown organic mix



d. Thick organic muck with alum floc

Figure 3-17. Photographs of Typical Sandy and Organic Muck Sediments Collected in Lake Holden During May 2007.

TABLE 3-3

GENERAL CHARACTERISTICS OF SEDIMENT CORE SAMPLES COLLECTED IN LAKE HOLDEN DURING SEPTEMBER 2003

SITE	pH (s.u.)	MOISTURE CONTENT (%)	ORGANIC CONTENT (%)	DENSITY (g/cm^3)	TOTAL NITROGEN ($\mu g/cm^3$)	TOTAL PHOSPHORUS ($\mu g/cm^3$)
1	6.90	25.4	0.5	2.11	488	203
2	5.05	28.0	1.2	2.07	1,339	164
3	6.72	90.7	41.3	1.08	1,822	744
4	6.87	28.5	0.9	2.06	659	185
5	7.09	28.7	0.8	2.06	516	130
6	5.66	26.7	0.5	2.09	525	218
7	6.08	24.7	0.8	2.12	982	125
8	7.12	26.6	0.6	2.09	401	128
9	6.50	34.1	1.7	1.97	894	187
10	7.25	32.1	3.3	1.99	636	146
11	6.68	28.0	1.1	2.07	571	514
12	6.08	63.4	12.1	1.48	2,162	780
13	6.75	23.5	1.0	2.14	244	444
14	6.65	22.7	1.2	2.15	432	298
15	6.72	26.2	0.7	2.10	472	245
16	6.23	32.3	1.9	2.00	708	300
17	6.66	25.5	0.8	2.11	310	513
18	7.03	24.8	0.8	2.12	294	285
19	7.03	29.5	0.8	2.05	465	640
20	6.45	39.1	1.7	1.90	481	550
21	6.10	26.8	0.7	2.09	728	133
22	6.68	27.7	0.9	2.07	900	189
23	6.77	26.1	1.0	2.10	534	275
24	7.24	26.4	0.6	2.10	541	218
25	6.72	31.5	1.3	2.01	721	263
26	6.28	91.4	42.3	1.07	1,972	851
27	6.51	32.3	1.0	2.01	478	805
28	7.03	31.2	1.5	2.02	410	289
29	7.04	26.8	0.9	2.09	344	1,031
30	6.18	88.9	36.4	1.11	2,068	622
31	7.36	25.4	0.4	2.11	406	162
32	7.29	28.9	0.9	2.06	670	255
33	7.32	28.5	0.9	2.06	527	292
34	7.04	31.3	1.2	2.02	613	292
35	6.43	83.5	25.0	1.19	2,475	718
36	6.77	46.0	7.1	1.75	1,745	348
37	6.02	26.3	0.5	2.10	337	150
38	6.52	91.9	43.4	1.07	2,401	529
39	6.19	89.0	6.6	1.77	2,194	648
40	6.28	92.6	43.1	1.06	2,004	489
41	6.09	46.3	3.8	1.11	1,113	588
42	6.35	91.7	40.2	1.07	2,338	546
43	6.10	22.0	0.5	2.16	517	192
44	6.78	46.8	4.6	1.76	1,515	1,659
Geometric Mean	**6.59**	**36.3**	**2.1**	**1.81**	**755**	**335**

TABLE 3-4

GENERAL CHARACTERISTICS OF SEDIMENT CORE SAMPLES COLLECTED IN LAKE HOLDEN DURING MAY 2007

SITE	pH (s.u.)	MOISTURE CONTENT (%)	ORGANIC CONTENT (%)	DENSITY (g/cm^3)	TOTAL NITROGEN ($\mu g/cm^3$)	TOTAL PHOSPHORUS ($\mu g/cm^3$)
1	6.88	30.5	0.9	2.03	1,198	298
2	5.90	35.0	2.4	1.95	1,305	389
3	6.48	91.5	40.1	1.08	1,810	454
4	7.11	28.4	0.7	2.07	624	163
5	7.13	33.1	0.7	2.00	806	161
6	7.07	27.5	0.6	2.08	684	208
7	7.14	33.0	0.8	2.00	1,169	75
8	7.19	24.2	0.6	2.13	450	176
9	7.20	34.7	1.1	1.97	1,236	347
10	7.00	30.6	1.4	2.03	975	156
11	7.16	28.3	0.6	2.07	901	368
12	6.63	69.6	13.3	1.39	2,372	582
13	7.33	28.0	0.8	2.07	364	147
14	7.07	28.9	1.8	2.05	704	239
15	7.03	29.5	0.8	2.05	370	184
16	6.79	65.7	5.4	1.49	420	207
17	7.09	26.3	0.8	2.10	682	424
18	7.17	29.7	0.7	2.05	523	166
19	7.15	28.2	0.7	2.07	980	681
20	7.10	27.0	0.7	2.09	594	577
21	7.19	31.2	0.6	2.03	463	171
22	7.18	34.1	1.1	1.98	1,084	260
23	7.12	28.0	1.0	2.07	707	251
24	7.21	29.6	0.7	2.05	630	128
25	7.09	29.8	1.0	2.04	804	460
26	6.33	91.8	41.4	1.07	1,392	209
27	6.99	31.9	1.0	2.01	759	781
28	6.91	30.7	1.1	2.03	854	298
29	6.99	26.2	1.0	2.10	504	1,406
30	6.35	90.0	36.1	1.10	2,309	282
31	6.96	30.2	0.7	2.04	752	164
32	7.07	29.6	0.9	2.05	757	282
33	7.10	29.5	0.8	2.05	941	363
34	6.94	30.2	0.5	2.04	847	191
35	6.77	89.7	33.8	1.10	2,145	492
36	6.87	36.6	5.7	1.90	1,085	263
37	6.37	29.8	0.6	2.05	720	224
38	6.78	91.9	40.3	1.07	2,321	620
39	6.70	53.0	8.5	1.64	2,222	442
40	6.78	93.0	42.3	1.06	1,927	426
41	6.32	47.7	2.3	1.17	1,310	484
42	6.69	92.7	41.1	1.06	2,717	632
43	6.54	30.3	0.9	2.04	643	182
44	6.80	37.4	2.5	1.92	1,171	1,544
Geometric Mean	**6.89**	**38.2**	**2.0**	**1.78**	**930**	**305**

TABLE 3-5

GENERAL CHARACTERISTICS OF SEDIMENT CORE SAMPLES COLLECTED IN LAKE HOLDEN DURING NOVEMBER 2008

SITE	pH (s.u.)	MOISTURE CONTENT (%)	ORGANIC CONTENT (%)	DENSITY (g/cm^3)	TOTAL NITROGEN ($\mu g/cm^3$)	TOTAL PHOSPHORUS ($\mu g/cm^3$)
1	6.96	32.5	1.2	2.0	534	224
2	5.93	31.6	1.5	2.0	637	162
3	6.71	91.4	37.8	1.1	1,669	407
4	7.02	28.7	0.7	2.1	447	165
5	6.88	29.7	0.6	2.0	324	122
6	6.93	28.2	0.7	2.1	526	205
7	7.15	27.4	0.9	2.1	432	118
8	7.17	24.9	0.5	2.1	245	128
9	6.80	31.9	1.1	2.0	729	239
10	6.81	35.0	1.5	2.0	817	162
11	6.84	25.8	0.6	2.1	673	216
12	6.31	87.4	31.9	1.1	2,039	659
13	6.55	29.1	1.0	2.1	422	201
14	6.74	34.3	1.3	2.0	694	180
15	7.05	27.3	0.6	2.1	336	146
16	6.84	52.0	2.4	1.7	1,039	240
17	7.15	26.2	0.7	2.1	439	357
18	6.93	33.9	1.0	2.0	437	214
19	6.82	31.4	0.8	2.0	452	363
20	6.67	33.8	1.2	2.0	581	568
21	7.04	27.8	0.4	2.1	337	113
22	7.29	29.2	0.8	2.1	638	183
23	7.30	26.5	0.8	2.1	451	178
24	6.86	26.5	0.5	2.1	624	166
25	6.84	40.8	1.5	1.9	626	260
26	6.27	90.6	41.0	1.1	1,635	513
27	7.06	28.6	0.7	2.1	499	572
28	6.97	28.8	1.4	2.1	1,120	536
29	6.92	27.3	1.0	2.1	476	1,821
30	6.23	88.0	39.3	1.1	1,948	771
31	6.67	31.1	0.7	2.0	399	161
32	7.01	29.0	1.0	2.1	548	228
33	7.16	26.5	0.9	2.1	614	281
34	7.00	35.8	1.4	1.9	549	292
35	6.35	92.2	43.9	1.1	1,942	454
36	6.83	40.0	3.8	1.9	1,031	301
37	6.36	27.4	0.5	2.1	381	144
38	6.29	87.5	45.5	1.1	2,372	620
39	6.53	45.2	7.4	1.8	1,313	672
40	6.93	92.4	43.2	1.1	1,479	369
41	6.49	87.6	23.7	1.1	1,333	333
42	6.56	92.1	41.6	1.1	1,633	421
43	6.29	29.1	0.9	2.1	702	194
44	6.61	36.9	1.5	1.9	1,625	1,244
Geometric Mean	**6.77**	**38.5**	**2.1**	**1.78**	**715**	**285**

TABLE 3-6

GENERAL CHARACTERISTICS OF SEDIMENT CORE SAMPLES COLLECTED IN LAKE HOLDEN DURING APRIL 2012

SITE	pH (s.u.)	MOISTURE CONTENT (%)	ORGANIC CONTENT (%)	DENSITY (g/cm^3)	TOTAL NITROGEN ($\mu g/cm^3$)	TOTAL PHOSPHORUS ($\mu g/cm^3$)
1	6.45	36.0	1.2	1.95	747	246
2	5.89	37.2	2.8	1.92	848	447
3	6.38	90.5	40.2	1.08	1,710	521
4	6.63	38.0	1.1	1.92	624	148
5	6.57	37.6	0.9	1.93	748	132
6	6.34	30.3	0.6	2.04	851	263
7	6.93	25.9	0.6	2.11	791	80
8	6.88	31.9	0.9	2.01	863	132
9	6.73	29.1	0.9	2.05	843	232
10	6.76	25.9	0.7	2.10	745	169
11	6.35	36.7	0.7	2.07	835	227
12	6.45	58.2	17.6	1.58	1,941	670
13	6.53	33.3	1.2	1.99	324	215
14	6.67	33.9	1.0	1.98	705	111
15	6.75	34.4	1.1	1.97	768	178
16	6.63	42.2	2.1	1.85	883	296
17	6.64	31.5	0.8	2.02	723	372
18	6.96	29.0	0.6	2.06	556	195
19	6.73	31.0	0.9	2.03	671	407
20	6.35	31.6	1.1	2.01	613	669
21	6.85	35.7	0.7	1.96	817	122
22	6.52	28.4	0.7	2.07	802	163
23	6.43	28.7	1.0	2.06	719	168
24	6.93	31.0	0.6	2.03	338	186
25	6.95	27.3	0.9	2.08	649	258
26	6.30	92.1	37.4	1.07	1,771	645
27	6.81	37.3	1.7	1.92	983	458
28	6.61	32.6	0.9	2.00	743	291
29	6.13	31.3	1.1	2.02	736	1,476
30	6.32	89.4	28.2	1.11	1,713	563
31	6.92	35.0	0.9	1.97	786	138
32	6.58	33.5	1.4	1.98	826	271
33	6.43	33.4	0.9	1.99	900	288
34	6.51	30.0	0.7	2.04	736	242
35	6.29	88.9	42.7	1.11	1,844	499
36	6.69	35.1	3.6	1.94	1,002	356
37	6.66	28.2	0.7	2.11	488	201
38	6.27	92.7	6.4	1.10	1,799	557
39	6.47	59.0	13.0	1.54	1,778	559
40	6.26	91.8	41.8	1.07	1,741	443
41	6.81	43.7	2.0	1.83	969	327
42	6.28	92.3	40.6	1.07	1,755	249
43	6.77	28.6	1.0	2.06	811	211
44	6.58	33.2	1.5	1.99	1,895	1,473
Geometric Mean	**6.56**	**39.4**	**2.0**	**1.80**	**894**	**288**

In general, sediments in Lake Holden were found to be slightly acidic to approximately neutral in pH, with overall mean pH values ranging from 6.56-6.89 during the four monitoring events. Measurements of sediment moisture content and organic content in Lake Holden were found to be highly variable throughout the lake. Many of the collected sediment samples are characterized by a relatively low moisture content and low organic content, suggesting that these sediments are comprised primarily of fine sand. In contrast, other sediment core samples are characterized by elevated values for moisture content and organic content, suggesting areas of accumulated organic muck. Sediment moisture contents in excess of 50% are often indicative of highly organic sediments, while moisture contents less than 50% reflect either sand or mixtures of sand and muck. Sediment organic content values in excess of 20-30% are often indicative of organic muck type sediments, with values less than 20-30% representing either sand or mixtures of sand and muck. Mean sediment moisture contents were relatively similar between the four monitoring events, ranging from 36.3-39.4%. Measured sediment organic contents were also relatively similar, with mean values ranging from 2.0-2.1%.

Measured sediment density values are also useful in evaluating the general characteristics of sediments within a lake. Sediments with calculated densities between 1.0-1.5 are indicative of highly organic muck type sediments, while sediment densities of approximately 2.0 or greater are indicative of sandy sediment conditions. Sediments collected from Lake Holden exhibited a wide range of wet density values, ranging from near 1.0 to greater than 2.0 throughout the lake.

Measured concentrations of total phosphorus in Lake Holden sediments were found to be highly variable throughout the lake, with values throughout the lake ranging from near 100 to more than 1000 $\mu g/cm^3$. In general, sandy sediments are often characterized by low concentrations of total phosphorus, while highly organic muck type sediments are characterized by elevated total phosphorus concentrations. Sediment nitrogen concentrations are also highly variable throughout Lake Holden, with measured values ranging from several hundred to several thousand.

A tabular summary of mean general characteristics of sediment core samples collected in Lake Holden during 2003, 2007, 2008, and 2012 is given in Table 3-7. Mean sediment pH values are relatively similar between each of the four collection dates, ranging from 6.56-6.89. The sediment data indicate that the multiple additions of alum to Lake Holden have had little impact on sediment pH within the lake.

Sediment moisture content is also relatively similar between the four monitoring events, with mean values ranging from 36.3-39.4%. A slight trend of increasing sediment moisture content is apparent over time, although it is unlikely that the small differences are statistically significant. Mean sediment organic contents are very similar in value between the four sediment collection events. Wet sediment densities are also very similar between the four sediment collection dates, with mean wet density values ranging from 1.78-1.81 g/cm^3. Overall, the applications to Lake Holden do not appear to have had any significant impact on organic content or wet density since pre- and post-treatment measurements for these parameters are virtually identical. The small gradual increase in moisture content observed over time may be explained by the higher moisture content for alum floc compared with organic sediments, although the observed differences are likely not statistically significant.

TABLE 3-7

SUMMARY OF MEAN GENERAL CHARACTERISTICS OF SEDIMENT CORE SAMPLES COLLECTED IN LAKE HOLDEN DURING 2003, 2007, 2008, AND 2012

PARAMETER	UNITS	MEAN VALUE BY SEDIMENT COLLECTION DATE[1]			
		10/8/03	5/1/07	11/13/08	4/26/12
pH	s.u.	6.59	6.89	6.77	6.56
Moisture Content	%	36.3	38.2	38.5	39.4
Organic Content	%	2.1	2.0	2.1	2.0
Density (wet)	g/cm^3	1.81	1.78	1.78	1.80
Total Nitrogen	$\mu g/cm^3$	755	930	715	894
Total Phosphorus	$\mu g/cm^3$	335	305	285	288

1. Reflects geometric mean values

Sediment nitrogen concentrations in Lake Holden have also been relatively consistent between the four sediment collection dates, although the degree of variability between the measured values is somewhat higher than observed for moisture content, organic content, or wet density. The observed differences in measured sediment nitrogen concentrations are well within the degree of variability commonly observed in measurements of sediment nitrogen.

A much narrower range of sediment concentrations was observed for total phosphorus which ranged from 285-335 $\mu g/cm^3$ between the four sediment monitoring events. A slight decrease in sediment phosphorus concentrations is apparent from the initial event to the final sediment monitoring event, although the observed differences are not statistically significant. The observed variability in measured concentrations of both total nitrogen and total phosphorus during the four sediment monitoring events are likely a function of the inherent variability in both collection and analysis of sediment samples, since there is no conceivable process associated with the alum additions which could significantly impact concentrations of either nitrogen or phosphorus within the lake sediments.

A statistical summary of pre- and post-treatment values of pH, wet sediment density, total nitrogen, and total phosphorus in Lake Holden is given on Figure 3-18. A graphical summary of laboratory data is presented in the form of Tukey box plots, also often called “box and whisker plots”. The bottom of the box portion of each plot represents the lower quartile, with 25% of the data points falling below this value. The upper line of the box represents the 75% upper quartile, with 25% of the data falling above this value. The **blue horizontal line** within the box represents the median value, with 50% of the data falling both above and below this value, while the **red horizontal line** represents the mean value. The vertical lines, also known as "whiskers", represent the 5 and 95 percentiles for the data sets. Individual values which lie outside of the 5-95 percentile range are indicated as **red dots**.

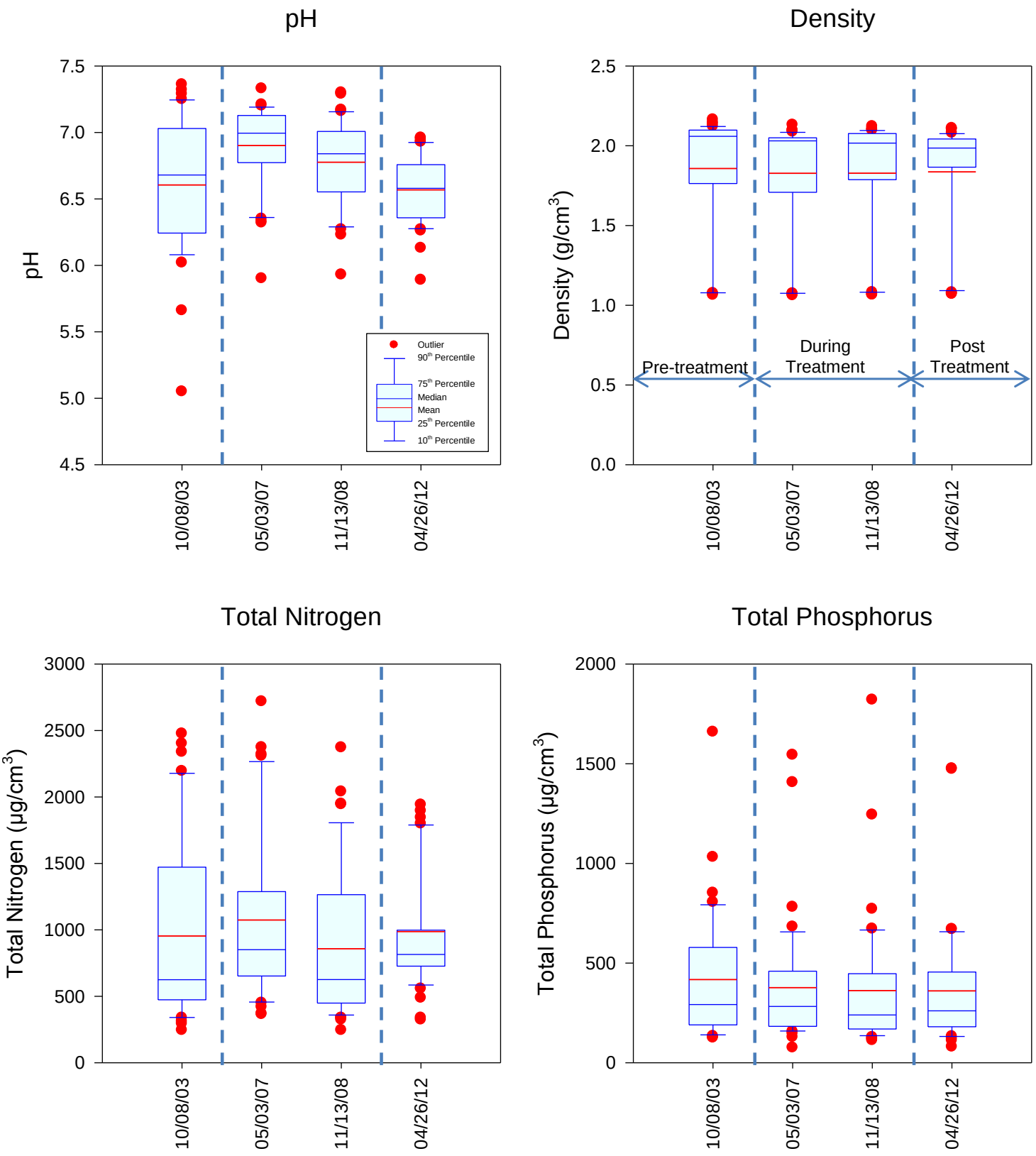


Figure 3-18. Statistical Summary of Pre- and Post-Treatment Values of pH, Density, Total Nitrogen, and Total Phosphorus in Lake Holden Sediments.

A relatively high degree of variability was observed in measured pH values in the pre-treatment sediments collected from Lake Holden, with measured sediment pH values ranging from approximately 5-7.4. As indicated on Figure 3-18, a much lower degree of variability in sediment pH values was measured during the post-treatment monitoring event. An overall increase in sediment pH of approximately 0.3 units occurred following the initial alum treatment to Lake Holden, although steady reductions in pH values were observed during subsequent applications. The median pH value measured in Lake Holden sediments following the final application was virtually identical to the median pH value observed in the pre-treatment samples, although the post-treatment pH values exhibited a much lower degree of variability. Measured sediment density values were virtually unchanged as a result of the alum treatment process.

In general, measured sediment concentrations of total nitrogen were relatively similar between the pre- and post-treatment monitoring events. The observed differences in geometric mean values for the monitoring events do not exhibit a significant trend of either increasing or decreasing concentration over time and appear to reflect normal variability in sediment nitrogen concentrations.

Similar to the trends observed for total nitrogen, no significant changes are apparent in measured sediment concentrations of total phosphorus between the pre- and post-treatment sediment monitoring period. Geometric mean concentrations of total phosphorus for each of the four sediment monitoring events are virtually identical.

3.2.3 Sediment Speciation

As discussed in Section 2.1.2, sediment core samples collected at each of the 44 monitoring sites were carried through a phosphorus fractionation procedure which allows the speciation of phosphorus into saloid-bound phosphorus (defined as the sum of soluble plus easily exchangeable phosphorus), iron-bound phosphorus, and aluminum-bound phosphorus. A tabular summary of phosphorus speciation in sediment core samples collected in Lake Holden during October 2003 (prior to alum addition) is given in Table 3-8, with phosphorus speciation in sediment core samples collected during the application process in May 2007 and November 2008, as well as in April 2012 (following the final application) provided in Tables 3-9, 3-10, and 3-11, respectively. Geometric mean values are provided at the bottom of each table as a measure of central tendency for each of the evaluated parameters during each monitoring event.

A statistical summary of pre- and post-treatment sediment phosphorus speciation in Lake Holden sediments is given on Figure 3-19. Sediment concentrations of saloid-bound phosphorus in the pre-treatment sediment samples ranged from approximately 3-23 $\mu g/cm^3$, although the majority of measured concentrations ranged from approximately 7-13 $\mu g/cm^3$. Significant reductions in saloid-bound phosphorus concentrations in Lake Holden sediments were measured during each of the three post-treatment sediment monitoring events. Saloid-bound phosphorus concentrations in the post-treatment samples ranged from near zero to 4 $\mu g/cm^3$, with median values less than 1 $\mu g/cm^3$.

TABLE 3-8

SEDIMENT SPECIATION IN SEDIMENT CORE SAMPLES COLLECTED IN LAKE HOLDEN DURING OCTOBER 2003

SITE	SALOID-P ($\mu g/cm^3$)	Al-BOUND P ($\mu g/cm^3$)	Fe-BOUND P ($\mu g/cm^3$)	TOTAL AVAILABLE P ($\mu g/cm^3$)	% AVAILABLE (%)
1	5.9	22	155	161	79
2	9.3	16	117	126	77
3	13.2	143	195	208	28
4	12.7	31	111	124	67
5	10.0	12	66	76	58
6	8.6	6	63	71	33
7	3.9	3	41	45	36
8	5.7	6	88	94	73
9	13.0	19	64	77	41
10	4.4	31	72	76	52
11	11.4	115	211	223	43
12	3.9	128	214	218	28
13	9.5	67	232	242	54
14	6.2	24	201	207	70
15	8.8	48	104	113	46
16	13.8	49	178	192	64
17	13.6	124	228	242	47
18	14.2	88	129	143	50
19	17.2	160	210	227	35
20	11.3	121	199	210	38
21	13.1	8	70	83	62
22	11.8	16	112	124	65
23	11.4	28	104	115	42
24	7.5	16	107	115	53
25	9.7	55	187	197	75
26	3.5	127	667	670	79
27	10.0	173	572	582	72
28	10.5	43	169	180	62
29	4.8	211	591	596	58
30	8.0	222	351	359	58
31	7.2	32	128	135	83
32	9.8	16	118	128	50
33	13.0	41	159	172	59
34	10.0	104	176	186	64
35	15.5	190	223	239	33
36	9.3	120	130	139	40
37	6.7	9	44	51	34
38	16.2	100	324	340	64
39	6.3	66	179	185	29
40	22.0	59	199	221	45
41	14.9	59	168	182	31
42	23.5	106	181	204	37
43	6.3	85	76	83	43
44	18.2	325	623	641	39
Geometric Mean	**9.6**	**48**	**155**	**167**	**50**

TABLE 3-9

SEDIMENT SPECIATION IN SEDIMENT CORE SAMPLES COLLECTED IN LAKE HOLDEN DURING MAY 2007

SITE	SALOID-P ($\mu g/cm^3$)	Al-BOUND P ($\mu g/cm^3$)	Fe-BOUND P ($\mu g/cm^3$)	TOTAL AVAILABLE P ($\mu g/cm^3$)	% AVAILABLE (%)
1	0.37	30	18	18	6
2	0.20	20	17	17	4
3	2.33	138	36	38	8
4	0.38	26	23	23	14
5	0.41	18	23	23	14
6	0.34	9	12	12	6
7	0.01	4	10	10	13
8	0.43	62	37	37	21
9	0.20	52	29	29	8
10	0.10	21	21	22	14
11	0.17	73	37	37	10
12	0.92	212	88	89	15
13	0.09	17	24	24	16
14	0.00	77	59	59	25
15	0.14	53	40	40	22
16	1.39	68	32	34	16
17	0.12	153	163	163	38
18	0.36	21	66	66	40
19	0.33	139	74	75	11
20	0.35	210	45	45	8
21	0.13	12	42	42	25
22	0.08	20	46	46	18
23	0.36	80	49	50	20
24	0.72	21	35	35	28
25	0.74	73	29	30	6
26	1.92	132	43	45	21
27	0.11	285	136	136	17
28	1.05	80	42	43	14
29	0.44	294	210	210	15
30	1.13	228	135	136	48
31	0.27	39	21	21	13
32	0.48	14	66	66	24
33	0.42	42	51	52	14
34	0.46	90	43	43	23
35	3.48	196	97	101	20
36	1.42	132	76	77	29
37	0.19	19	33	33	15
38	2.74	134	140	143	23
39	0.10	108	51	51	12
40	2.65	97	71	74	17
41	0.27	76	30	30	6
42	2.46	110	42	45	7
43	0.52	48	22	22	12
44	0.19	341	201	201	13
Geometric Mean	**0.4**	**59**	**45**	**45**	**15**

TABLE 3-10

SEDIMENT SPECIATION IN SEDIMENT CORE SAMPLES COLLECTED IN LAKE HOLDEN DURING NOVEMBER 2008

SITE	SALOID-P ($\mu g/cm^3$)	Al-BOUND P ($\mu g/cm^3$)	Fe-BOUND P ($\mu g/cm^3$)	TOTAL AVAILABLE P ($\mu g/cm^3$)	% AVAILABLE (%)
1	0.62	51	31	32	14
2	0.57	25	35	35	22
3	1.78	115	37	39	10
4	0.64	46	47	47	29
5	0.26	32	35	35	29
6	0.74	35	35	36	18
7	0.35	13	13	13	11
8	0.59	37	39	40	31
9	1.11	41	35	36	15
10	0.45	34	28	29	18
11	0.31	85	51	51	24
12	0.75	246	85	86	13
13	0.63	32	33	33	17
14	0.57	25	70	71	39
15	0.29	66	45	45	31
16	0.31	40	54	54	23
17	0.61	189	240	241	67
18	0.65	79	62	63	29
19	0.60	187	69	70	19
20	0.61	241	35	35	6
21	0.61	14	35	35	31
22	0.46	24	43	43	24
23	0.66	32	45	45	26
24	2.80	19	43	45	27
25	0.29	66	30	30	12
26	2.59	165	48	51	10
27	0.46	272	48	48	8
28	4.05	115	46	50	9
29	0.32	533	209	209	11
30	0.78	325	188	189	24
31	1.24	28	65	66	41
32	0.85	27	30	31	14
33	0.73	135	75	76	27
34	0.63	162	72	73	25
35	3.37	161	69	73	16
36	1.94	97	26	27	9
37	0.43	22	21	21	15
38	2.41	124	84	86	14
39	3.86	102	100	104	15
40	1.57	148	62	63	17
41	2.24	118	55	58	17
42	0.65	180	78	79	19
43	1.16	60	35	36	19
44	0.81	411	288	289	23
Geometric Mean	**0.8**	**73**	**52**	**53**	**19**

TABLE 3-11

SEDIMENT SPECIATION IN SEDIMENT CORE SAMPLES COLLECTED IN LAKE HOLDEN DURING APRIL 2012

SITE	SALOID-P ($\mu g/cm^3$)	Al-BOUND P ($\mu g/cm^3$)	Fe-BOUND P ($\mu g/cm^3$)	TOTAL AVAILABLE P ($\mu g/cm^3$)	% AVAILABLE (%)
1	0.05	43	23	23	9
2	0.15	19	29	29	7
3	0.90	145	33	34	7
4	0.20	34	35	36	24
5	0.18	21	21	21	16
6	0.40	16	23	23	9
7	0.09	10	12	12	15
8	0.28	15	20	21	16
9	0.38	28	29	29	13
10	0.30	22	24	24	14
11	0.30	60	36	36	16
12	0.56	115	62	63	9
13	0.27	24	22	22	10
14	0.38	11	44	44	40
15	0.20	31	41	41	23
16	0.20	57	33	33	11
17	0.50	24	54	54	15
18	0.41	21	34	35	18
19	0.20	79	54	54	13
20	0.30	266	32	32	5
21	0.61	10	30	31	25
22	0.40	15	33	33	20
23	0.95	45	44	45	27
24	0.89	10	36	37	20
25	0.20	38	30	30	12
26	1.00	120	29	30	5
27	0.15	157	25	25	5
28	0.48	29	40	40	14
29	0.30	141	137	137	9
30	0.74	135	102	102	18
31	0.86	12	34	35	25
32	0.77	26	27	28	10
33	0.50	23	61	61	21
34	0.08	36	27	27	11
35	1.80	201	54	56	11
36	1.16	75	16	17	5
37	0.10	41	18	18	9
38	0.82	145	61	62	11
39	0.68	150	64	65	12
40	1.20	142	54	55	12
41	1.17	66	42	43	13
42	0.76	138	69	69	28
43	0.40	92	29	29	14
44	0.60	482	250	151	10
Geometric Mean	**0.4**	**46**	**37**	**37**	**13**

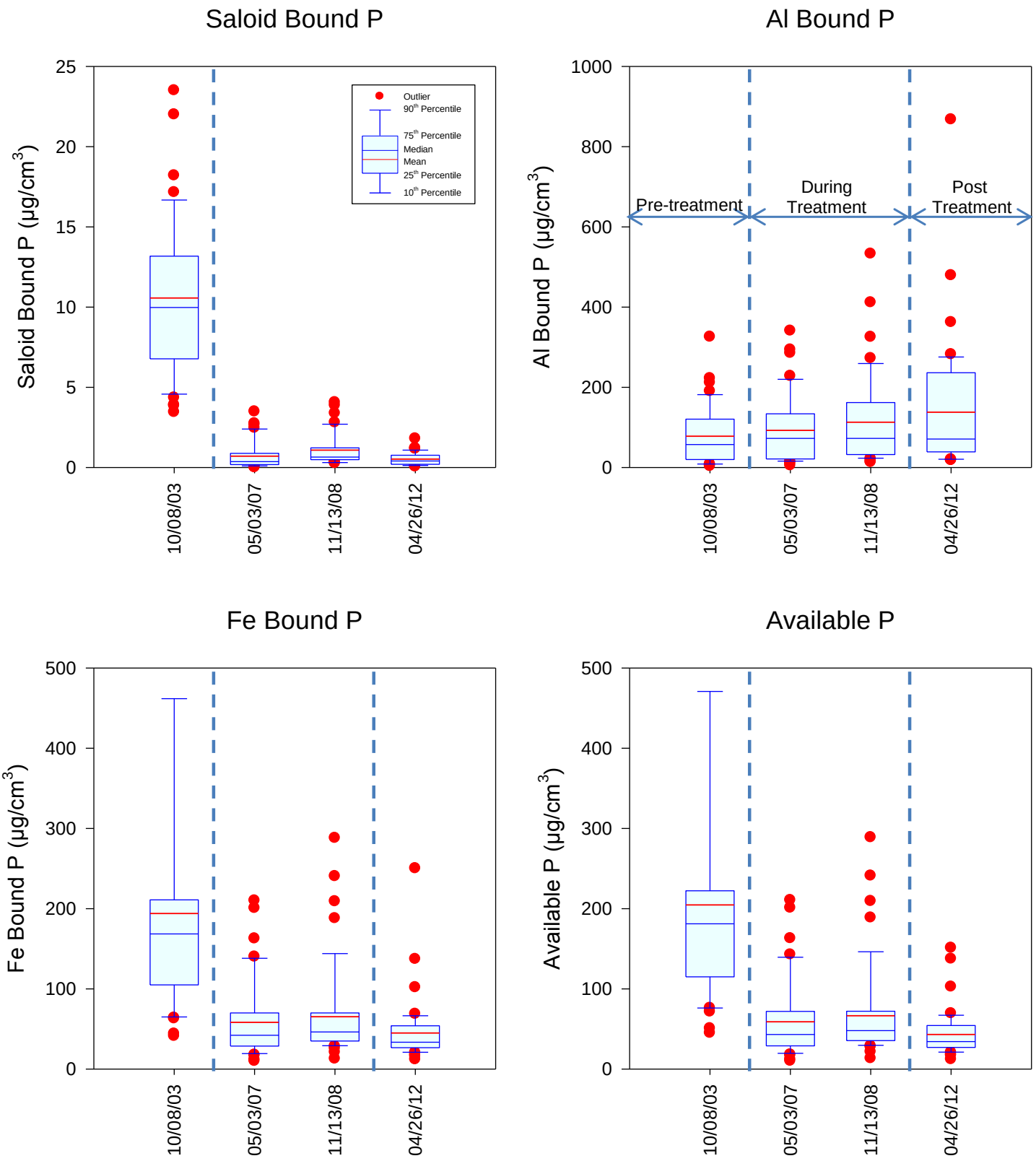


Figure 3-19. Statistical Summary of Pre- and Post-Treatment Values of Sediment Phosphorus Speciation in Lake Holden Sediments.

The pre-treatment sediment samples exhibited relatively high concentrations of iron-bound phosphorus, with measured values ranging from approximately 40 $\mu g/cm^3$ to more than 600 $\mu g/cm^3$. Substantial reductions in iron-bound phosphorus concentrations were observed during each of the three post-treatment sediment monitoring events. Iron-bound phosphorus concentrations in the post-treatment sediments exhibited a substantially lower range of values as well as substantially lower median concentrations compared with pre-treatment sediments.

Measured sediment concentrations of available phosphorus, which reflects the sum of the saloid-bound and iron-bound phosphorus fractions, follow a trend similar to the trend exhibited by iron-bound phosphorus since the iron-bound phosphorus comprises a vast majority of the calculated available phosphorus concentration. A wide range of available sediment phosphorus concentrations were observed within the pre-treatment sediment samples. Substantial reductions in both the degree of variability in measured concentrations, as well as median values, are apparent in the post-treatment samples.

The primary objective of an alum sediment inactivation project is to provide an abundance of aluminum within the sediments so that phosphorus which is released from a bonding mechanism with iron will preferentially attach to aluminum in an inert, stable state. If this process occurred within the sediments, then the measured concentrations of aluminum-bound phosphorus should increase as the iron-bound phosphorus associations decrease. As indicated on Figure 3-19, the concentrations of aluminum-bound phosphorus increased steadily throughout the application period. This trend of increasing concentrations of aluminum-bound phosphorus provides physical evidence that the sediment inactivation program has been successful in increasing the stability of phosphorus within the sediments of Lake Holden.

A summary of mean phosphorus speciation in sediment core samples collected in Lake Holden during pre- and post-treatment conditions is given on Table 3-12. The mean values provided in this table reflect geometric mean values. The pre-treatment sediments were characterized by a mean saloid-phosphorus concentration of 9.6 $\mu g/cm^3$ compared with a mean concentration of 0.4 $\mu g/cm^3$ in the post-treatment monitoring event. This corresponds to a reduction of approximately 96% in saloid-phosphorus concentrations within the sediments as a result of the inactivation project.

Pre-treatment sediment samples in Lake Holden exhibited a mean iron-bound phosphorus concentration of 155 $\mu g/cm^3$. Sediments collected at the completion of the inactivation project had a mean iron-bound phosphorus concentration of 37 $\mu g/cm^3$, reflecting a reduction of approximately 76%. Total available phosphorus decreased from a mean of 167 $\mu g/cm^3$ in the pre-treatment samples to a mean of 37 $\mu g/cm^3$ under post-treatment conditions. In addition, the percentage of the total sediment phosphorus available for release into the overlying water column decreased from 50% in the pre-treatment samples to only 13% under post-treatment conditions. As indicated on Table 3-12, mean concentrations of aluminum-bound phosphorus increased steadily during the application process, increasing from a mean of 48 $\mu g/cm^3$ in the pre-treatment samples to 86 $\mu g/cm^3$ in the post-treatment samples, an increase of approximately 79%.

TABLE 3-12

SUMMARY OF MEAN PHOSPHORUS SPECIATION IN SEDIMENT CORE SAMPLES COLLECTED IN LAKE HOLDEN DURING 2003, 2007, 2008, AND 2012

PARAMETER	UNITS	MEAN VALUE BY SEDIMENT COLLECTION DATE[1]			
		10/8/03	5/1/07	11/13/08	4/26/12
Saloid-Bound P	$\mu g/cm^3$	9.6	0.4	0.8	0.4
Fe-Bound P	$\mu g/cm^3$	155	45	52	37
Total Available P	$\mu g/cm^3$	167	45	53	37
% of Total Sediment P	%	50	15	19	13
Reduction in Available Sediment P	%	0	73	68	78
Al-Bound P	$\mu g/cm^3$	48	59	73	86

1. Reflects geometric mean values

Estimates of percent changes in available sediment phosphorus were generated by calculating the percentage reduction achieved in total available phosphorus during each of the post-treatment sediment monitoring events compared with the original pre-treatment sediment samples. During the application process, reductions in available sediment phosphorus of 73% and 68% were observed in the sediment samples collected during 2007 and 2008. However, the overall reduction of sediment phosphorus at the end of the sediment treatment process was approximately 78%. This value corresponds well with the measured increase in aluminum-bound phosphorus of 79%, indicating that the available phosphorus which was lost is now bound with aluminum.

The alum sediment inactivation project was successful in reducing approximately 78% of the available phosphorus within the sediments of Lake Holden. As a result, release of phosphorus from internal recycling should also be reduced by a similar value. However, the observed reduction in available sediment phosphorus will likely exceed 78% due to the improved water quality characteristics within the lake achieved from the alum applications which reduces the opportunity for anoxic conditions to occur which stimulate sediment phosphorus release. Not only has the amount of available phosphorus been reduced, but conditions with the lake have improved substantially which makes release of the remaining available phosphorus less likely.

SECTION 4

SUMMARY

A sediment inactivation project was initiated in Lake Holden during 2005. The objective of the sediment inactivation treatment was to inactivate available phosphorus contained within the top 10 cm of sediments in Lake Holden based upon an extensive sediment characterization study conducted during 2003. Due to the large amount of available phosphorus within the sediments, and the corresponding large volume of alum required for sediment inactivation in Lake Holden, the recommended total alum volume was divided into smaller applications to reduce chemical and biological impacts to the lake. Six separate applications were conducted by ERD over the period from 2005-2012, with a total of 427,377 gallons of alum applied to Lake Holden during the six treatments. The final alum application was completed during April 2012.

The alum applications resulted in substantial improvements in water quality characteristics within Lake Holden, with large reductions in water column concentrations of total phosphorus and substantial improvements in Secchi disk depths within the lake. Calculated TSI values in Lake Holden improved from eutrophic and hypereutrophic conditions prior to the application to primarily oligotrophic conditions following the application. During the period from 2009-2012, Lake Holden has maintained oligotrophic characteristics, with mean annual TSI values ranging from 30-38. Visual characteristics of Lake Holden have improved substantially following the sediment inactivation treatments, with improved water column appearance and visibility.

Prior to implementation of the sediment inactivation project, phosphorus concentrations within the lake exhibited a distinct seasonal variability, with higher concentrations during dry season conditions and lower concentrations during wet season conditions. Following the alum sediment inactivation, the distinct seasonal pattern of phosphorus concentrations is substantially absent, indicating that the sediment inactivation has been successful in reducing the release of phosphorus from the sediments and recirculating this phosphorus into upper portions of the water column during circulation events. A similar change in seasonal concentrations has also been observed for chlorophyll-a.

Sediment monitoring was conducted at 44 locations in Lake Holden by ERD on four separate occasions during 2003 (prior to initiation of the alum inactivation project), 2007 and 2008 (during the alum application treatment), and in 2012 (following the final alum addition). Each of the sediment samples was analyzed for general parameters, nutrient, and sediment phosphorus speciation. The alum sediment inactivation project had no significant impact on sediment concentrations for pH, moisture content, organic content, density, total nitrogen, or total phosphorus.

However, the alum sediment inactivation project resulted in significant changes in phosphorus speciation in sediment core samples, with large reductions in concentrations of saloid-bound phosphorus and iron-bound phosphorus, and increases in phosphorus bonding with aluminum. The alum sediment inactivation project was successful in inactivating approximately 78% of the available phosphorus within the sediments of Lake Holden. This value is very similar to the predicted reduction in available sediment phosphorus of 80% which was the target of the alum inactivation process.

APPENDICES

APPENDIX A

HISTORICAL WATER QUALITY DATA FOR LAKE HOLDEN

Summary of Historical Water Quality Data for Selected Parameters in Lake Holden

Data Source	Station Name	Sample Date	Chla (ugl)	Secchi (m)	Total N (ugl)	Total P (ugl)	TN/TP Ratio	Nutrient Limitation	TSI (TN)	TSI (TP)	TSI (Nut.)	TSI (Chyl-a)	TSI (SD)	FTSI (avg)	Trophic State
LAKEWATCH_V	Holden	9/2/87	52.2	x	1500	45	33	Phosphorus Limited	-------	66	66	74	x	70	Eutophic
LAKEWATCH_V	Holden	10/8/87	92.3	x	1400	40	35	Phosphorus Limited	-------	63	63	82	x	73	Hypereutrophic
LAKEWATCH_V	Holden	3/9/88	46.8	x	830	45	18	Balanced	52	52	52	72	x	62	Eutophic
LAKEWATCH_V	Holden	2/11/90	49.3	0.69	1233	53	23	Balanced	60	55	58	73	71	67	Eutophic
LAKEWATCH_V	Holden	3/18/90	52.7	0.61	1400	54	26	Balanced	63	56	59	74	75	69	Eutophic
LAKEWATCH_V	Holden	5/13/90	57.3	0.61	1533	51	30	Balanced	64	55	60	75	75	70	Eutophic
LAKEWATCH_V	Holden	6/10/90	32.0	0.91	1267	35	36	Phosphorus Limited	-------	60	60	67	63	63	Eutophic
LAKEWATCH_V	Holden	9/1/90	32.7	0.76	897	32	28	Balanced	54	46	50	67	68	62	Eutophic
LAKEWATCH_V	Holden	10/14/90	43.0	0.64	960	41	23	Balanced	55	51	53	71	73	66	Eutophic
LAKEWATCH_V	Holden	11/18/90	64.3	0.61	1433	55	26	Balanced	63	56	60	77	75	70	Hypereutrophic
LAKEWATCH_V	Holden	12/30/90	50.0	0.61	1267	48	26	Balanced	61	54	57	73	75	68	Eutophic
LAKEWATCH_V	Holden	1/13/91	58.3	0.61	1300	53	24	Balanced	61	56	58	75	75	70	Eutophic
LAKEWATCH_V	Holden	2/17/91	65.7	0.61	1367	61	23	Balanced	62	58	60	77	75	71	Hypereutrophic
LAKEWATCH_V	Holden	3/6/91	66.3	0.61	1533	60	25	Balanced	64	58	61	77	75	71	Hypereutrophic
LAKEWATCH_V	Holden	4/14/91	50.0	0.55	1267	55	23	Balanced	61	56	58	73	78	70	Eutophic
LAKEWATCH_V	Holden	6/2/91	72.0	0.46	1333	46	29	Balanced	62	53	57	78	83	73	Hypereutrophic
LAKEWATCH_V	Holden	7/7/91	50.7	0.61	1167	34	34	Phosphorus Limited	-------	60	60	73	75	69	Eutophic
LAKEWATCH_V	Holden	8/10/91	50.3	0.55	1200	38	32	Phosphorus Limited	-------	62	62	73	78	71	Hypereutrophic
LAKEWATCH_V	Holden	9/8/91	69.0	0.55	1367	35	39	Phosphorus Limited	-------	60	60	78	78	72	Hypereutrophic
LAKEWATCH_V	Holden	7/26/95	37.7	0.73	870	36	24	Balanced	53	48	51	69	69	63	Eutophic
LAKEWATCH_V	Holden	8/22/95	38.3	0.76	1083	38	28	Balanced	58	49	54	69	68	64	Eutophic
LAKEWATCH_V	Holden	11/27/95	55.0	0.76	1143	51	22	Balanced	59	55	57	75	68	66	Eutophic
LAKEWATCH_V	Holden	4/16/96	27.7	0.80	900	43	21	Balanced	54	52	53	65	67	61	Eutophic
LAKEWATCH_V	Holden	7/30/96	21.3	0.88	900	25	36	Phosphorus Limited	-------	52	52	61	64	59	Mesotrophic
LAKEWATCH_V	Holden	6/21/97	43.0	0.66	1097	35	31	Phosphorus Limited	-------	60	60	71	72	68	Eutophic
LAKEWATCH_V	Holden	7/23/97	35.0	0.56	1003	28	35	Phosphorus Limited	-------	55	55	68	77	67	Eutophic
LAKEWATCH_V	Holden	8/22/97	32.7	0.78	1043	28	38	Phosphorus Limited	-------	55	55	67	67	63	Eutophic
LAKEWATCH_V	Holden	9/29/97	60.0	0.66	1243	37	33	Phosphorus Limited	-------	62	62	76	72	70	Eutophic
LAKEWATCH_V	Holden	10/28/97	62.0	0.61	1213	48	25	Balanced	60	54	57	76	75	69	Eutophic
LAKEWATCH_V	Holden	11/29/97	64.7	0.72	1310	52	25	Balanced	61	55	58	77	70	68	Eutophic
LAKEWATCH_V	Holden	1/2/98	53.0	0.61	1237	47	26	Balanced	60	53	57	74	75	69	Eutophic
LAKEWATCH_V	Holden	1/31/98	52.7	0.55	1327	51	26	Balanced	62	55	58	74	78	70	Eutophic
LAKEWATCH_V	Holden	3/1/98	73.7	0.40	1203	49	25	Balanced	60	54	57	79	88	74	Hypereutrophic
LAKEWATCH_V	Holden	3/31/98	77.7	0.44	1483	46	32	Phosphorus Limited	-------	66	66	79	85	77	Hypereutrophic
LAKEWATCH_V	Holden	4/30/98	71.0	0.46	1557	48	32	Phosphorus Limited	-------	68	68	78	83	76	Hypereutrophic
LAKEWATCH_V	Holden	5/31/98	39.7	0.46	1407	36	39	Phosphorus Limited	-------	61	61	70	83	71	Hypereutrophic
LAKEWATCH_V	Holden	6/30/98	38.3	0.69	1203	32	38	Phosphorus Limited	-------	58	58	69	71	66	Eutophic
LAKEWATCH_V	Holden	7/30/98	32.0	0.66	1103	25	45	Phosphorus Limited	-------	52	52	67	72	64	Eutophic
LAKEWATCH_V	Holden	8/31/98	x	0.76	1143	25	45	Phosphorus Limited	-------	52	52	x	68	60	Eutophic
LAKEWATCH_V	Holden	10/1/98	71.0	0.59	1257	41	31	Phosphorus Limited	-------	64	64	78	76	73	Hypereutrophic
LAKEWATCH_V	Holden	10/29/98	63.0	0.64	1347	36	37	Phosphorus Limited	-------	61	61	76	73	70	Hypereutrophic
LAKEWATCH_V	Holden	11/23/98	60.0	0.60	1243	34	37	Phosphorus Limited	-------	59	59	76	75	70	Hypereutrophic
LAKEWATCH_V	Holden	12/20/98	62.3	0.68	1280	30	42	Phosphorus Limited	-------	57	57	76	72	68	Eutophic
LAKEWATCH_V	Holden	1/29/99	80.7	0.66	1063	39	27	Balanced	57	50	54	80	72	69	Eutophic
LAKEWATCH_V	Holden	2/23/99	49.3	0.60	1300	41	32	Phosphorus Limited	-------	64	64	73	75	71	Hypereutrophic
LAKEWATCH_V	Holden	3/18/99	52.0	0.54	1333	46	29	Balanced	62	53	57	74	79	70	Eutophic
LAKEWATCH_V	Holden	4/22/99	53.7	0.53	1480	51	29	Balanced	64	55	59	74	79	71	Hypereutrophic
LAKEWATCH_V	Holden	5/20/99	47.0	0.48	1387	39	36	Phosphorus Limited	-------	63	63	72	82	72	Hypereutrophic
LAKEWATCH_V	Holden	6/18/99	47.3	0.92	1220	36	34	Phosphorus Limited	-------	61	61	72	62	65	Eutophic
LAKEWATCH_V	Holden	7/12/99	36.0	0.69	1207	29	42	Phosphorus Limited	-------	55	55	68	71	65	Eutophic
LAKEWATCH_V	Holden	8/9/99	40.3	0.71	1257	31	41	Phosphorus Limited	-------	57	57	70	70	66	Eutophic
LAKEWATCH_V	Holden	9/20/99	64.0	0.69	1510	39	39	Phosphorus Limited	-------	62	62	77	71	70	Hypereutrophic
LAKEWATCH_V	Holden	10/18/99	63.7	0.67	1363	37	37	Phosphorus Limited	-------	62	62	77	72	70	Hypereutrophic

Summary of Historical Water Quality Data for Selected Parameters in Lake Holden

Data Source	Station Name	Sample Date	Chla (ugl)	Secchi (m)	Total N (ugl)	Total P (ugl)	TN/TP Ratio	Nutrient Limitation	TSI (TN)	TSI (TP)	TSI (Nut.)	TSI (Chyl-a)	TSI (SD)	FTSI (avg)	Trophic State
LAKEWATCH_V	Holden	11/15/99	62.0	0.73	1443	35	42	Phosphorus Limited	-------	60	60	76	69	68	Eutophic
LAKEWATCH_V	Holden	12/15/99	60.3	0.69	1453	35	42	Phosphorus Limited	-------	60	60	76	71	69	Eutophic
LAKEWATCH_V	Holden	1/23/00	59.7	0.55	1593	40	40	Phosphorus Limited	-------	63	63	76	78	72	Hypereutrophic
LAKEWATCH_V	Holden	2/13/00	43.3	0.57	1453	37	39	Phosphorus Limited	-------	61	61	71	77	70	Eutophic
LAKEWATCH_V	Holden	3/13/00	62.3	0.59	1747	45	39	Phosphorus Limited	-------	66	66	76	76	73	Hypereutrophic
LAKEWATCH_V	Holden	4/19/00	77.3	0.51	1807	45	40	Phosphorus Limited	-------	66	66	79	80	75	Hypereutrophic
LAKEWATCH_V	Holden	5/12/00	66.0	0.47	1897	45	42	Phosphorus Limited	-------	66	66	77	83	75	Hypereutrophic
LAKEWATCH_V	Holden	6/13/00	54.0	0.53	2000	36	56	Phosphorus Limited	-------	61	61	74	79	71	Hypereutrophic
LAKEWATCH_V	Holden	7/13/00	56.0	0.56	1683	37	45	Phosphorus Limited	-------	62	62	75	77	71	Hypereutrophic
LAKEWATCH_V	Holden	8/17/00	59.3	0.60	1803	37	48	Phosphorus Limited	-------	62	62	76	75	71	Hypereutrophic
LAKEWATCH_V	Holden	9/21/00	80.3	0.63	1797	39	46	Phosphorus Limited	-------	63	63	80	74	72	Hypereutrophic
LAKEWATCH_V	Holden	10/14/00	74.0	0.59	1927	45	43	Phosphorus Limited	-------	66	66	79	76	74	Hypereutrophic
LAKEWATCH_V	Holden	11/20/00	85.0	0.50	1935	52	37	Phosphorus Limited	-------	69	69	81	81	77	Hypereutrophic
LAKEWATCH_V	Holden	12/16/00	79.0	0.49	1795	48	38	Phosphorus Limited	-------	67	67	80	82	76	Hypereutrophic
LAKEWATCH_V	Holden	1/20/01	43.0	0.55	1815	62	29	Balanced	68	58	63	71	78	71	Hypereutrophic
LAKEWATCH_V	Holden	2/24/01	47.5	0.64	1455	38	39	Phosphorus Limited	-------	62	62	72	73	69	Eutophic
LAKEWATCH_V	Holden	3/18/01	61.5	0.61	1690	46	37	Phosphorus Limited	-------	66	66	76	75	72	Hypereutrophic
LAKEWATCH_V	Holden	4/4/01	36.5	0.58	1515	40	38	Phosphorus Limited	-------	63	63	69	76	69	Eutophic
LAKEWATCH_V	Holden	5/16/01	48.0	0.61	1260	38	34	Phosphorus Limited	-------	62	62	73	75	70	Eutophic
LAKEWATCH_V	Holden	6/24/01	57.5	0.56	1535	35	44	Phosphorus Limited	-------	60	60	75	77	71	Hypereutrophic
LAKEWATCH_V	Holden	7/15/01	64.5	0.55	1590	31	51	Phosphorus Limited	-------	57	57	77	78	71	Hypereutrophic
LAKEWATCH_V	Holden	8/13/01	40.5	0.62	1385	28	49	Phosphorus Limited	-------	55	55	70	74	66	Eutophic
LAKEWATCH_V	Holden	9/26/01	51.5	0.64	1200	28	43	Phosphorus Limited	-------	55	55	74	73	67	Eutophic
LAKEWATCH_V	Holden	10/16/01	53.0	0.69	1277	31	41	Phosphorus Limited	-------	57	57	74	71	68	Eutophic
LAKEWATCH_V	Holden	11/19/01	50.0	0.78	1240	37	33	Phosphorus Limited	-------	62	62	73	67	67	Eutophic
LAKEWATCH_V	Holden	12/17/01	46.3	0.74	1107	34	32	Phosphorus Limited	-------	60	60	72	69	67	Eutophic
LAKEWATCH_V	Holden	1/17/02	28.0	0.87	1237	32	38	Phosphorus Limited	-------	58	58	65	64	62	Eutophic
LAKEWATCH_V	Holden	2/24/02	25.3	0.80	1103	37	30	Phosphorus Limited	-------	61	61	63	67	64	Eutophic
LAKEWATCH_V	Holden	3/23/02	34.0	0.84	1237	37	34	Phosphorus Limited	-------	61	61	68	65	65	Eutophic
LAKEWATCH_V	Holden	4/19/02	40.3	0.62	1200	34	36	Phosphorus Limited	-------	59	59	70	74	68	Eutophic
LAKEWATCH_V	Holden	5/21/02	37.5	1.07	1455	31	48	Phosphorus Limited	-------	57	57	69	58	61	Eutophic
LAKEWATCH_V	Holden	6/18/02	44.7	0.71	1340	36	37	Phosphorus Limited	-------	61	61	72	70	68	Eutophic
LAKEWATCH_V	Holden	7/18/02	35.7	0.61	1207	27	44	Phosphorus Limited	-------	54	54	68	75	66	Eutophic
LAKEWATCH_V	Holden	8/16/02	51.3	0.71	1180	30	39	Phosphorus Limited	-------	57	57	74	70	67	Eutophic
LAKEWATCH_V	Holden	9/20/02	45.0	0.71	1153	29	40	Phosphorus Limited	-------	55	55	72	70	66	Eutophic
LAKEWATCH_V	Holden	10/21/02	43.3	0.74	1087	29	37	Phosphorus Limited	-------	56	56	71	69	65	Eutophic
LAKEWATCH_V	Holden	11/15/02	47.0	0.76	1110	35	31	Phosphorus Limited	-------	60	60	72	68	67	Eutophic
LAKEWATCH_V	Holden	12/16/02	44.0	0.86	1077	39	28	Balanced	57	50	54	71	64	63	Eutophic
LAKEWATCH_V	Holden	1/21/03	38.0	0.89	1040	42	25	Balanced	57	51	54	69	63	62	Eutophic
LAKEWATCH_V	Holden	2/28/03	40.0	0.86	1033	42	24	Balanced	57	51	54	70	64	63	Eutophic
LAKEWATCH_V	Holden	3/26/03	36.7	0.91	873	41	21	Balanced	53	51	52	69	63	61	Eutophic
LAKEWATCH_V	Holden	4/27/03	48.0	0.69	1220	39	31	Phosphorus Limited	-------	63	63	73	71	69	Eutophic
LAKEWATCH_V	Holden	5/26/03	34.7	0.89	1197	31	39	Phosphorus Limited	-------	57	57	68	63	63	Eutophic
LAKEWATCH_V	Holden	6/23/03	35.3	0.90	1043	25	42	Phosphorus Limited	-------	52	52	68	63	61	Eutophic
LAKEWATCH_V	Holden	7/27/03	22.0	1.02	1040	19	56	Phosphorus Limited	-------	45	45	61	60	55	Mesotrophic
LAKEWATCH_V	Holden	8/17/03	35.0	0.91	1133	22	52	Phosphorus Limited	-------	49	49	68	63	60	Mesotrophic
LAKEWATCH_V	Holden	10/22/03	44.3	0.90	1137	29	39	Phosphorus Limited	-------	56	56	71	63	63	Eutophic
LAKEWATCH_V	Holden	1/25/04	23.0	1.11	1160	33	35	Phosphorus Limited	-------	59	59	62	57	59	Mesotrophic
LAKEWATCH_V	Holden	2/18/04	27.7	1.02	1107	38	29	Balanced	58	49	54	65	60	59	Mesotrophic
LAKEWATCH_V	Holden	3/18/04	36.0	0.84	1147	40	29	Balanced	59	50	54	68	65	63	Eutophic
LAKEWATCH_V	Holden	5/5/04	48.0	0.71	1037	34	30	Phosphorus Limited	-------	60	60	73	70	67	Eutophic
LAKEWATCH_V	Holden	5/22/04	31.7	0.81	1340	34	39	Phosphorus Limited	-------	59	59	67	66	64	Eutophic
LAKEWATCH_V	Holden	6/25/04	6.0	1.07	890	19	47	Phosphorus Limited	-------	46	46	43	58	49	Oligotrophic

Summary of Historical Water Quality Data for Selected Parameters in Lake Holden

Data Source	Station Name	Sample Date	Chla (ugl)	Secchi (m)	Total N (ugl)	Total P (ugl)	TN/TP Ratio	Nutrient Limitation	TSI (TN)	TSI (TP)	TSI (Nut.)	TSI (Chyl-a)	TSI (SD)	FTSI (avg)	Trophic State
LAKEWATCH_V	Holden	8/9/04	30.3	1.03	1140	23	50	Phosphorus Limited	-------	50	50	66	59	58	Mesotrophic
LAKEWATCH_V	Holden	9/15/04	47.3	0.84	1080	36	30	Phosphorus Limited	-------	61	61	72	65	66	Eutophic
LAKEWATCH_V	Holden	10/17/04	57.3	0.84	1163	34	34	Phosphorus Limited	-------	60	60	75	65	67	Eutophic
LAKEWATCH_V	Holden	11/27/04	43.3	0.92	1040	40	26	Balanced	57	50	53	71	62	62	Eutophic
LAKEWATCH_V	Holden	12/13/04	36.3	1.02	980	34	29	Balanced	56	47	51	69	60	60	Mesotrophic
LAKEWATCH_V	Holden	1/25/05	21.0	1.35	927	26	35	Phosphorus Limited	-------	53	53	61	51	55	Mesotrophic
LAKEWATCH_V	Holden	2/11/05	18.3	1.55	890	28	31	Phosphorus Limited	-------	55	55	59	47	54	Mesotrophic
LAKEWATCH_V	Holden	3/24/05	25.0	1.15	900	35	26	Balanced	54	48	51	63	56	57	Mesotrophic
LAKEWATCH_V	Holden	4/23/05	28.7	0.86	913	24	39	Phosphorus Limited	-------	51	51	65	64	60	Eutophic
LAKEWATCH_V	Holden	5/28/05	39.0	0.86	1337	30	44	Phosphorus Limited	-------	57	57	70	64	64	Eutophic
LAKEWATCH_V	Holden	6/18/05	20.7	1.10	1090	24	45	Phosphorus Limited	-------	51	51	60	57	56	Mesotrophic
LAKEWATCH_V	Holden	7/17/05	13.7	1.41	803	16	49	Phosphorus Limited	-------	42	42	54	50	49	Oligotrophic
LAKEWATCH_V	Holden	8/16/05	20.0	1.05	867	23	38	Phosphorus Limited	-------	50	50	60	59	56	Mesotrophic
LAKEWATCH_V	Holden	9/11/05	30.0	1.06	923	19	48	Phosphorus Limited	-------	46	46	66	58	57	Mesotrophic
LAKEWATCH_V	Holden	10/13/05	15.3	1.73	730	15	48	Phosphorus Limited	-------	41	41	56	44	47	Oligotrophic
LAKEWATCH_V	Holden	11/13/05	13.0	1.21	620	17	36	Phosphorus Limited	-------	43	43	54	54	50	Mesotrophic
LAKEWATCH_V	Holden	12/19/05	7.3	1.52	873	18	48	Phosphorus Limited	-------	45	45	45	47	46	Oligotrophic
LAKEWATCH_V	Holden	1/22/06	8.0	1.95	953	14	70	Phosphorus Limited	-------	38	38	47	40	42	Oligotrophic
LAKEWATCH_V	Holden	2/10/06	8.0	1.68	917	14	67	Phosphorus Limited	-------	38	38	47	45	43	Oligotrophic
LAKEWATCH_V	Holden	3/11/06	5.0	2.90	880	11	80	Phosphorus Limited	-------	33	33	40	28	34	Oligotrophic
LAKEWATCH_V	Holden	4/14/06	10.0	2.51	700	17	41	Phosphorus Limited	-------	43	43	50	32	42	Oligotrophic
LAKEWATCH_V	Holden	5/19/06	7.3	1.77	623	15	41	Phosphorus Limited	-------	41	41	45	43	43	Oligotrophic
LAKEWATCH_V	Holden	6/17/06	18.3	1.47	653	20	33	Phosphorus Limited	-------	47	47	59	48	51	Mesotrophic
LAKEWATCH_V	Holden	6/22/06	11.9	x	640	12	53	Phosphorus Limited	-------	35	35	52	x	44	Oligotrophic
LAKEWATCH_V	Holden	7/20/06	24.0	1.16	740	25	29	Balanced	50	42	46	63	56	55	Mesotrophic
LAKEWATCH_V	Holden	8/11/06	19.0	1.22	867	21	41	Phosphorus Limited	-------	48	48	59	54	54	Mesotrophic
LAKEWATCH_V	Holden	9/11/06	22.7	1.10	793	19	42	Phosphorus Limited	-------	46	46	62	57	55	Mesotrophic
LAKEWATCH_V	Holden	10/8/06	22.3	1.26	800	19	41	Phosphorus Limited	-------	46	46	62	53	54	Mesotrophic
LAKEWATCH_V	Holden	11/11/06	18.3	1.40	733	16	47	Phosphorus Limited	-------	41	41	59	50	50	Oligotrophic
LAKEWATCH_V	Holden	12/10/06	18.0	1.50	863	15	56	Phosphorus Limited	-------	41	41	58	48	49	Oligotrophic
LAKEWATCH_V	Holden	1/13/07	23.0	1.07	810	17	49	Phosphorus Limited	-------	43	43	62	58	54	Mesotrophic
LAKEWATCH_V	Holden	2/11/07	20.0	1.16	847	17	49	Phosphorus Limited	-------	44	44	60	56	53	Mesotrophic
LAKEWATCH_V	Holden	3/10/07	16.3	1.17	880	19	46	Phosphorus Limited	-------	46	46	57	55	53	Mesotrophic
LAKEWATCH_V	Holden	4/22/07	15.3	0.88	1030	19	54	Phosphorus Limited	-------	46	46	56	64	55	Mesotrophic
LAKEWATCH_V	Holden	5/11/07	18.0	1.08	897	19	46	Phosphorus Limited	-------	46	46	58	58	54	Mesotrophic
LAKEWATCH_V	Holden	6/10/07	12.3	1.11	933	17	56	Phosphorus Limited	-------	43	43	53	57	51	Mesotrophic
LAKEWATCH_V	Holden	6/20/07	15.0	x	940	15	63	Phosphorus Limited	-------	40	40	56	x	48	Oligotrophic
LAKEWATCH_V	Holden	7/8/07	14.0	1.34	793	16	50	Phosphorus Limited	-------	42	42	55	51	49	Oligotrophic
LAKEWATCH_V	Holden	8/4/07	30.3	1.37	890	18	49	Phosphorus Limited	-------	44	44	66	51	54	Mesotrophic
LAKEWATCH_V	Holden	9/2/07	21.0	1.22	840	16	51	Phosphorus Limited	-------	42	42	61	54	52	Mesotrophic
LAKEWATCH_V	Holden	10/9/07	23.7	0.91	870	18	49	Phosphorus Limited	-------	44	44	62	63	56	Mesotrophic
LAKEWATCH_V	Holden	11/4/07	29.0	0.76	903	18	51	Phosphorus Limited	-------	44	44	65	68	59	Mesotrophic
LAKEWATCH_V	Holden	12/9/07	23.3	0.81	907	17	53	Phosphorus Limited	-------	43	43	62	66	57	Mesotrophic
LAKEWATCH_V	Holden	1/19/08	17.5	1.01	785	17	46	Phosphorus Limited	-------	43	43	58	60	54	Mesotrophic
LAKEWATCH_V	Holden	2/15/08	16.0	0.91	800	14	56	Phosphorus Limited	-------	39	39	57	63	53	Mesotrophic
LAKEWATCH_V	Holden	3/23/08	16.7	1.01	757	19	39	Phosphorus Limited	-------	46	46	57	60	54	Mesotrophic
LAKEWATCH_V	Holden	4/18/08	28.0	0.88	663	22	30	Phosphorus Limited	-------	49	49	65	64	59	Mesotrophic
LAKEWATCH_V	Holden	5/12/08	25.0	0.85	823	29	28	Balanced	52	44	48	63	65	59	Mesotrophic
LAKEWATCH_V	Holden	6/20/08	26.3	1.05	1033	28	37	Phosphorus Limited	-------	55	55	64	59	59	Mesotrophic
LAKEWATCH_V	Holden	7/20/08	15.0	1.33	763	15	50	Phosphorus Limited	-------	41	41	56	51	49	Oligotrophic
LAKEWATCH_V	Holden	8/15/08	22.0	1.10	770	18	44	Phosphorus Limited	-------	44	44	61	57	54	Mesotrophic
LAKEWATCH_V	Holden	9/8/08	20.0	1.13	820	19	42	Phosphorus Limited	-------	46	46	60	56	54	Mesotrophic
LAKEWATCH_V	Holden	10/13/08	31.7	0.89	857	21	41	Phosphorus Limited	-------	48	48	67	63	59	Mesotrophic

Summary of Historical Water Quality Data for Selected Parameters in Lake Holden

Data Source	Station Name	Sample Date	Chla (ugl)	Secchi (m)	Total N (ugl)	Total P (ugl)	TN/TP Ratio	Nutrient Limitation	TSI (TN)	TSI (TP)	TSI (Nut.)	TSI (Chyl-a)	TSI (SD)	FTSI (avg)	Trophic State
LAKEWATCH_V	Holden	11/9/08	29.3	1.17	977	19	52	Phosphorus Limited	-------	45	45	65	55	55	Mesotrophic
LAKEWATCH_V	Holden	12/16/08	17.7	1.05	867	24	36	Phosphorus Limited	-------	51	51	58	59	56	Mesotrophic
LAKEWATCH_V	Holden	1/10/09	5.3	1.49	1117	21	53	Phosphorus Limited	-------	48	48	41	48	46	Oligotrophic
LAKEWATCH_V	Holden	2/8/09	2.3	3.05	957	15	65	Phosphorus Limited	-------	40	40	29	27	32	Oligotrophic
LAKEWATCH_V	Holden	3/10/09	2.7	x	807	11	73	Phosphorus Limited	-------	33	33	31	x	32	Oligotrophic
LAKEWATCH_V	Holden	4/13/09	6.7	2.74	437	13	34	Phosphorus Limited	-------	36	36	44	30	37	Oligotrophic
LAKEWATCH_V	Holden	5/10/09	5.5	3.35	643	13	48	Phosphorus Limited	-------	37	37	41	24	34	Oligotrophic
LAKEWATCH_V	Holden	6/7/09	9.3	2.11	550	11	52	Phosphorus Limited	-------	32	32	49	38	40	Oligotrophic
LAKEWATCH_V	Holden	7/6/09	6.7	2.34	637	14	47	Phosphorus Limited	-------	38	38	44	35	39	Oligotrophic
LAKEWATCH_V	Holden	8/2/09	6.7	2.56	487	9	56	Phosphorus Limited	-------	27	27	44	32	34	Oligotrophic
LAKEWATCH_V	Holden	8/30/09	8.7	2.29	547	11	50	Phosphorus Limited	-------	33	33	48	35	39	Oligotrophic
LAKEWATCH_V	Holden	10/3/09	12.7	1.75	733	18	41	Phosphorus Limited	-------	44	44	53	43	47	Oligotrophic
LAKEWATCH_V	Holden	10/29/09	7.3	2.06	623	17	37	Phosphorus Limited	-------	43	43	45	38	42	Oligotrophic
LAKEWATCH_V	Holden	12/6/09	12.3	1.73	737	23	33	Phosphorus Limited	-------	50	50	53	44	49	Oligotrophic
LAKEWATCH_V	Holden	1/2/10	7.0	2.26	690	18	38	Phosphorus Limited	-------	44	44	45	36	42	Oligotrophic
LAKEWATCH_V	Holden	2/14/10	3.0	x	x	x						33		33	Oligotrophic
LAKEWATCH_V	Holden	3/7/10	3.0	x	563	9	60	Phosphorus Limited	-------	29	29	33	x	31	Oligotrophic
LAKEWATCH_V	Holden	4/11/10	5.0	3.35	447	14	31	Phosphorus Limited	-------	39	39	40	24	34	Oligotrophic
LAKEWATCH_V	Holden	5/21/10	4.8	3.05	487	14	35	Phosphorus Limited	-------	38	38	39	27	35	Oligotrophic
LAKEWATCH_V	Holden	6/6/10	4.0	3.28	467	10	45	Phosphorus Limited	-------	31	31	37	24	31	Oligotrophic
LAKEWATCH_V	Holden	7/11/10	5.8	2.59	413	10	40	Phosphorus Limited	-------	31	31	42	31	35	Oligotrophic
LAKEWATCH_V	Holden	8/8/10	6.0	2.79	437	13	34	Phosphorus Limited	-------	37	37	43	29	36	Oligotrophic
LAKEWATCH_V	Holden	9/5/10	6.2	2.51	437	12	37	Phosphorus Limited	-------	34	34	43	32	37	Oligotrophic
LAKEWATCH_V	Holden	10/3/10	8.3	2.59	503	14	36	Phosphorus Limited	-------	38	38	47	31	39	Oligotrophic
LAKEWATCH_V	Holden	11/9/10	5.3	2.44	587	13	44	Phosphorus Limited	-------	37	37	41	33	37	Oligotrophic
LAKEWATCH_V	Holden	12/8/10	4.0	2.44	607	11	54	Phosphorus Limited	-------	33	33	37	33	35	Oligotrophic
LAKEWATCH_V	Holden	1/9/11	3.0	x	600	14	44	Phosphorus Limited	-------	38	38	33	x	35	Oligotrophic
LAKEWATCH_V	Holden	2/8/11	2.7	x	677	10	65	Phosphorus Limited	-------	31	31	31	x	31	Oligotrophic
LAKEWATCH_V	Holden	3/13/11	6.3	3.25	680	16	43	Phosphorus Limited	-------	42	42	43	25	37	Oligotrophic
LAKEWATCH_V	Holden	4/10/11	6.7	2.90	633	16	39	Phosphorus Limited	-------	42	42	44	28	38	Oligotrophic
LAKEWATCH_V	Holden	6/5/11	9.0	1.91	633	11	58	Phosphorus Limited	-------	33	33	48	41	41	Oligotrophic
LAKEWATCH_V	Holden	7/2/11	12.4	2.24	520	11	46	Phosphorus Limited	-------	33	33	53	36	41	Oligotrophic
LAKEWATCH_V	Holden	7/30/11	6.2	2.90	440	14	32	Phosphorus Limited	-------	38	38	43	28	36	Oligotrophic
LAKEWATCH_V	Holden	9/4/11	5.0	2.87	437	14	32	Phosphorus Limited	-------	38	38	40	28	35	Oligotrophic
LAKEWATCH_V	Holden	10/1/11	8.0	2.72	523	14	37	Phosphorus Limited	-------	38	38	47	30	38	Oligotrophic
LAKEWATCH_V	Holden	11/6/11	5.5	2.13	493	10	51	Phosphorus Limited	-------	30	30	41	37	36	Oligotrophic
LAKEWATCH_V	Holden	12/11/11	5.5	2.26	620	13	47	Phosphorus Limited	-------	37	37	41	36	38	Oligotrophic
LAKEWATCH_V	Holden	1/10/12	4.2	3.51	537	11	50	Phosphorus Limited	-------	32	32	37	22	31	Oligotrophic
LAKEWATCH_V	Holden	2/5/12	3.2	3.81	487	13	37	Phosphorus Limited	-------	37	37	34	20	30	Oligotrophic
LAKEWATCH_V	Holden	3/18/12	2.8	x	453	12	37	Phosphorus Limited	-------	35	35	32	x	34	Oligotrophic
LAKEWATCH_V	Holden	4/22/12	5.6	2.74	540	12	44	Phosphorus Limited	-------	35	35	42	30	36	Oligotrophic
LAKEWATCH_V	Holden	5/12/12	3.8	2.59	505	12	41	Phosphorus Limited	-------	35	35	36	31	34	Oligotrophic
LAKEWATCH_V	Holden	6/10/12	5.4	2.13	517	14	38	Phosphorus Limited	-------	38	38	41	37	39	Oligotrophic
LAKEWATCH_V	Holden	7/1/12	3.9	3.12	480	12	42	Phosphorus Limited	-------	34	34	36	26	32	Oligotrophic

Summary of Historical Water Quality Data for Selected Parameters in Lake Holden

Data Source	Station Name	Sample Date	Chla (ugl)	Secchi (m)	Total N (ugl)	Total P (ugl)	TN/TP Ratio	Nutrient Limitation	TSI (TN)	TSI (TP)	TSI (Nut.)	TSI (Chyl-a)	TSI (SD)	FTSI (avg)	Trophic State
OCEPD	North	5/31/78	x	0.30	2510	x			79				96	96	Hypereutrophic
OCEPD	North	10/4/78	x	0.60	1410	20	71	Phosphorus Limited	-------	47	47	x	75	61	Eutophic
OCEPD	North	2/12/79	x	1.10	870	65	13	Balanced	53	59	56	x	57	57	Mesotrophic
OCEPD	North	5/7/79	x	0.90	920	55	17	Balanced	54	56	55	x	63	59	Mesotrophic
OCEPD	North	8/13/79	x	x	790	30	26	Balanced	51	45	48	x	x	48	Oligotrophic
OCEPD	North	11/12/79	x	1.10	1110	45	25	Balanced	58	52	55	x	57	56	Mesotrophic
OCEPD	North	2/11/80	x	1.80	750	40	19	Balanced	50	50	50	x	42	46	Oligotrophic
OCEPD	North	8/11/80	x	1.60	830	30	28	Balanced	52	45	49	x	46	47	Oligotrophic
OCEPD	North	11/10/80	x	2.10	860	40	22	Balanced	53	50	52	x	38	45	Oligotrophic
OCEPD	North	1/19/81	x	1.90	1223	77	16	Balanced	60	62	61	x	41	51	Mesotrophic
OCEPD	North	2/2/81	x	1.30	803	30	27	Balanced	52	45	48	x	52	50	Mesotrophic
OCEPD	North	2/16/81	x	1.00	1433	50	29	Balanced	63	54	59	x	60	59	Mesotrophic
OCEPD	North	3/2/81	x	1.20	1090	37	30	Balanced	58	49	53	x	55	54	Mesotrophic
OCEPD	North	3/30/81	x	1.00	2200	67	33	Phosphorus Limited	-------	75	75	x	60	68	Eutophic
OCEPD	North	4/14/81	x	1.00	1925	75	26	Balanced	69	62	65	x	60	63	Eutophic
OCEPD	North	4/27/81	x	1.00	1067	53	20	Balanced	57	56	56	x	60	58	Mesotrophic
OCEPD	North	5/11/81	x	1.20	1200	40	30	Balanced	60	50	55	x	55	55	Mesotrophic
OCEPD	North	5/26/81	x	1.10	847	50	17	Balanced	53	54	54	x	57	55	Mesotrophic
OCEPD	North	6/9/81	x	1.00	1220	40	31	Phosphorus Limited	-------	63	63	x	60	62	Eutophic
OCEPD	North	6/22/81	x	1.10	1310	50	26	Balanced	61	54	58	x	57	57	Mesotrophic
OCEPD	North	6/22/81	x	1.10	1400	50	28	Balanced	63	54	59	x	57	58	Mesotrophic
OCEPD	North	6/30/81	x	1.10	1200	50	24	Balanced	60	54	57	x	57	57	Mesotrophic
OCEPD	North	7/28/81	x	1.00	783	63	12	Balanced	51	59	55	x	60	57	Mesotrophic
OCEPD	North	8/10/81	x	1.00	1477	47	32	Phosphorus Limited	-------	67	67	x	60	63	Eutophic
OCEPD	North	8/25/81	x	0.60	1573	60	26	Balanced	65	58	61	x	75	68	Eutophic
OCEPD	North	9/8/81	x	0.80	1170	60	20	Balanced	59	58	58	x	67	63	Eutophic
OCEPD	North	9/21/81	x	0.80	1033	41	25	Balanced	57	51	54	x	67	60	Eutophic
OCEPD	North	10/5/81	x	x	950	94	10	Balanced	55	66	61	x	x	61	Eutophic
OCEPD	North	10/26/81	x	x	1067	84	13	Balanced	57	64	61	x	x	61	Eutophic
OCEPD	North	11/24/81	x	0.80	2000	50	40	Phosphorus Limited	-------	68	68	x	67	68	Eutophic
OCEPD	North	12/7/81	x	0.60	1400	56	25	Balanced	63	56	60	x	75	67	Eutophic
OCEPD	North	12/22/81	x	0.90	2000	65	31	Phosphorus Limited	-------	75	75	x	63	69	Eutophic
OCEPD	North	1/12/82	x	0.60	1067	72	15	Balanced	57	61	59	x	75	67	Eutophic
OCEPD	North	1/25/82	x	0.90	1200	63	19	Balanced	60	59	59	x	63	61	Eutophic
OCEPD	North	2/8/82	x	0.90	1100	53	21	Balanced	58	56	57	x	63	60	Mesotrophic
OCEPD	North	2/22/82	x	0.60	1867	51	36	Phosphorus Limited	-------	69	69	x	75	72	Hypereutrophic
OCEPD	North	3/15/82	x	0.60	1567	59	27	Balanced	65	57	61	x	75	68	Eutophic
OCEPD	North	3/22/82	x	0.60	1567	60	26	Balanced	65	58	61	x	75	68	Eutophic
OCEPD	North	4/5/82	x	1.00	1200	50	24	Balanced	60	54	57	x	60	58	Mesotrophic
OCEPD	North	4/19/82	x	0.70	x	x						x	71	71	Hypereutrophic
OCEPD	North	5/10/82	x	0.50	910	x						x	81	81	Hypereutrophic
OCEPD	North	5/25/82	x	0.70	290	59	5	Nitrogen Limited	33	-----	33	x	71	52	Mesotrophic
OCEPD	North	6/7/82	x	0.60	1290	54	24	Balanced	61	56	58	x	75	67	Eutophic
OCEPD	North	6/21/82	x	0.40	1070	141	8	Nitrogen Limited	61	-----	61	x	87	74	Hypereutrophic
OCEPD	North	7/6/82	x	0.70	760	161	5	Nitrogen Limited	54	-----	54	x	71	62	Eutophic
OCEPD	North	7/26/82	x	0.80	1020	54	19	Balanced	56	56	56	x	67	61	Eutophic
OCEPD	North	8/9/82	x	0.90	1100	39	28	Balanced	58	50	54	x	63	58	Mesotrophic
OCEPD	North	8/23/82	x	1.00	1700	38	45	Phosphorus Limited	-------	62	62	x	60	61	Eutophic
OCEPD	North	9/7/82	x	1.00	1500	42	36	Phosphorus Limited	-------	64	64	x	60	62	Eutophic
OCEPD	North	9/20/82	x	1.00	1100	67	16	Balanced	58	60	59	x	60	59	Mesotrophic
OCEPD	North	9/26/82	x	0.30	1910	51	37	Phosphorus Limited	-------	69	69	x	96	83	Hypereutrophic
OCEPD	North	10/4/82	x	0.90	1900	49	39	Phosphorus Limited	-------	68	68	x	63	66	Eutophic
OCEPD	North	10/18/82	x	0.90	1200	41	29	Balanced	60	51	55	x	63	59	Mesotrophic

Summary of Historical Water Quality Data for Selected Parameters in Lake Holden

Data Source	Station Name	Sample Date	Chla (ugl)	Secchi (m)	Total N (ugl)	Total P (ugl)	TN/TP Ratio	Nutrient Limitation	TSI (TN)	TSI (TP)	TSI (Nut.)	TSI (Chyl-a)	TSI (SD)	FTSI (avg)	Trophic State
OCEPD	North	11/1/82	x	0.50	770	40	19	Balanced	51	50	51	x	81	66	Eutophic
OCEPD	North	11/15/82	x	0.80	1400	41	34	Phosphorus Limited	-------	64	64	x	67	65	Eutophic
OCEPD	North	11/29/82	x	0.80	1100	52	21	Balanced	58	55	56	x	67	62	Eutophic
OCEPD	North	12/13/82	x	0.80	1100	50	22	Balanced	58	54	56	x	67	61	Eutophic
OCEPD	North	1/3/83	x	0.90	1200	45	27	Balanced	60	52	56	x	63	60	Mesotrophic
OCEPD	North	1/17/83	x	0.60	1100	33	33	Phosphorus Limited	-------	59	59	x	75	67	Eutophic
OCEPD	North	1/31/83	x	0.80	990	37	27	Balanced	56	49	52	x	67	59	Mesotrophic
OCEPD	North	2/15/83	x	1.30	x	x						x	52	52	Mesotrophic
OCEPD	North	3/28/83	x	0.80	1777	94	19	Balanced	67	66	67	x	67	67	Eutophic
OCEPD	North	4/12/83	x	0.50	1200	46	26	Balanced	60	53	56	x	81	69	Eutophic
OCEPD	North	5/3/83	x	0.60	720	x			53			x	75	75	Hypereutrophic
OCEPD	North	5/17/83	x	0.80	2180	52	42	Phosphorus Limited	-------	69	69	x	67	68	Eutophic
OCEPD	North	5/31/83	x	0.80	1380	47	29	Balanced	62	53	58	x	67	62	Eutophic
OCEPD	North	6/14/83	x	0.60	1500	52	29	Balanced	64	55	60	x	75	67	Eutophic
OCEPD	North	6/28/83	x	0.60	2110	49	43	Phosphorus Limited	-------	68	68	x	75	72	Hypereutrophic
OCEPD	North	7/11/83	x	0.60	1590	74	21	Balanced	65	62	63	x	75	69	Eutophic
OCEPD	North	7/25/83	x	0.60	x	54				-----		x	75	75	Hypereutrophic
OCEPD	North	8/9/83	x	0.80	x	44				-----		x	67	67	Eutophic
OCEPD	North	8/23/83	x	0.60	1020	41	25	Balanced	56	51	54	x	75	64	Eutophic
OCEPD	North	9/6/83	x	0.80	540	46	12	Balanced	44	53	48	x	67	58	Mesotrophic
OCEPD	North	9/20/83	x	0.90	900	30	30	Balanced	54	45	49	x	63	56	Mesotrophic
OCEPD	North	10/18/83	x	0.70	1900	58	33	Phosphorus Limited	-------	72	72	x	71	71	Hypereutrophic
OCEPD	North	11/1/83	x	0.50	1450	57	25	Balanced	63	57	60	x	81	70	Hypereutrophic
OCEPD	North	11/15/83	x	0.70	1300	61	21	Balanced	61	58	60	x	71	65	Eutophic
OCEPD	North	11/29/83	x	0.60	1250	47	27	Balanced	60	53	57	x	75	66	Eutophic
OCEPD	North	12/12/83	x	0.40	1350	50	27	Balanced	62	54	58	x	87	73	Hypereutrophic
OCEPD	North	1/18/84	x	0.80	1130	65	17	Balanced	58	59	59	x	67	63	Eutophic
OCEPD	North	1/31/84	x	0.60	1240	62	20	Balanced	60	58	59	x	75	67	Eutophic
OCEPD	North	2/8/84	x	0.70	390	65	6	Nitrogen Limited	39	-----	39	x	71	55	Mesotrophic
OCEPD	North	2/28/84	x	0.50	1360	90	15	Balanced	62	65	64	x	81	72	Hypereutrophic
OCEPD	North	3/14/84	x	0.80	820	71	12	Balanced	52	61	56	x	67	62	Eutophic
OCEPD	North	3/27/84	x	0.60	1140	56	20	Balanced	59	56	58	x	75	66	Eutophic
OCEPD	North	4/11/84	x	0.70	1080	61	18	Balanced	58	58	58	x	71	64	Eutophic
OCEPD	North	4/24/84	x	0.50	1090	63	17	Balanced	58	59	58	x	81	69	Eutophic
OCEPD	North	5/8/84	x	0.50	1650	78	21	Balanced	66	63	64	x	81	73	Hypereutrophic
OCEPD	North	5/23/84	x	0.40	2130	63	34	Phosphorus Limited	-------	74	74	x	87	81	Hypereutrophic
OCEPD	North	6/12/84	x	0.50	2210	67	33	Phosphorus Limited	-------	75	75	x	81	78	Hypereutrophic
OCEPD	North	6/26/84	x	0.40	2100	68	31	Phosphorus Limited	-------	76	76	x	87	82	Hypereutrophic
OCEPD	North	7/18/84	x	0.40	2190	57	38	Phosphorus Limited	-------	72	72	x	87	80	Hypereutrophic
OCEPD	North	7/31/84	x	0.60	2180	65	34	Phosphorus Limited	-------	75	75	x	75	75	Hypereutrophic
OCEPD	North	8/15/84	x	0.70	1620	45	36	Phosphorus Limited	-------	66	66	x	71	68	Eutophic
OCEPD	North	8/28/84	x	0.70	1890	47	40	Phosphorus Limited	-------	67	67	x	71	69	Eutophic
OCEPD	North	9/12/84	x	0.50	1597	54	30	Balanced	65	56	60	x	81	71	Hypereutrophic
OCEPD	North	9/25/84	x	0.50	2150	49	44	Phosphorus Limited	-------	68	68	x	81	74	Hypereutrophic
OCEPD	North	10/11/84	x	0.50	2700	63	43	Phosphorus Limited	-------	74	74	x	81	77	Hypereutrophic
OCEPD	North	10/23/84	x	0.70	1230	96	13	Balanced	60	66	63	x	71	67	Eutophic
OCEPD	North	11/6/84	x	0.60	2250	59	38	Phosphorus Limited	-------	72	72	x	75	74	Hypereutrophic
OCEPD	North	11/20/84	x	0.50	1740	58	30	Balanced	67	57	62	x	81	71	Hypereutrophic
OCEPD	North	12/4/84	x	0.50	1830	51	36	Phosphorus Limited	-------	69	69	x	81	75	Hypereutrophic
OCEPD	North	12/18/84	x	0.80	2500	53	47	Phosphorus Limited	-------	70	70	x	67	68	Eutophic
OCEPD	North	1/2/85	x	0.60	1560	42	37	Phosphorus Limited	-------	64	64	x	75	70	Eutophic
OCEPD	North	1/16/85	x	0.60	1560	47	33	Phosphorus Limited	-------	67	67	x	75	71	Hypereutrophic
OCEPD	North	1/30/85	x	0.60	1410	57	25	Balanced	63	57	60	x	75	68	Eutophic

Summary of Historical Water Quality Data for Selected Parameters in Lake Holden

Data Source	Station Name	Sample Date	Chla (ugl)	Secchi (m)	Total N (ugl)	Total P (ugl)	TN/TP Ratio	Nutrient Limitation	TSI (TN)	TSI (TP)	TSI (Nut.)	TSI (Chyl-a)	TSI (SD)	FTSI (avg)	Trophic State
OCEPD	North	2/13/85	x	0.60	1320	65	20	Balanced	61	59	60	x	75	68	Eutophic
OCEPD	North	2/26/85	x	0.80	2440	56	44	Phosphorus Limited	-------	71	71	x	67	69	Eutophic
OCEPD	North	3/13/85	x	0.60	1580	53	30	Balanced	65	55	60	x	75	68	Eutophic
OCEPD	North	3/27/85	x	0.30	1510	56	27	Balanced	64	56	60	x	96	78	Hypereutrophic
OCEPD	North	4/23/85	x	0.30	1440	50	29	Balanced	63	54	59	x	96	77	Hypereutrophic
OCEPD	North	5/8/85	x	0.40	2190	56	39	Phosphorus Limited	-------	71	71	x	87	79	Hypereutrophic
OCEPD	North	5/26/85	x	0.50	2210	65	34	Phosphorus Limited	-------	75	75	x	81	78	Hypereutrophic
OCEPD	North	6/5/85	x	0.50	1800	50	36	Phosphorus Limited	-------	69	69	x	81	75	Hypereutrophic
OCEPD	North	6/19/85	x	0.40	1950	58	34	Phosphorus Limited	-------	72	72	x	87	80	Hypereutrophic
OCEPD	North	7/1/85	x	0.50	1860	65	29	Balanced	68	59	64	x	81	72	Hypereutrophic
OCEPD	North	7/17/85	x	0.60	1710	47	36	Phosphorus Limited	-------	67	67	x	75	71	Hypereutrophic
OCEPD	North	7/31/85	x	0.50	1860	47	40	Phosphorus Limited	-------	67	67	x	81	74	Hypereutrophic
OCEPD	North	8/14/85	x	0.60	1800	55	33	Phosphorus Limited	-------	71	71	x	75	73	Hypereutrophic
OCEPD	North	8/27/85	x	0.50	1550	38	41	Phosphorus Limited	-------	62	62	x	81	71	Hypereutrophic
OCEPD	North	9/17/85	x	0.50	2060	57	36	Phosphorus Limited	-------	72	72	x	81	76	Hypereutrophic
OCEPD	North	10/2/85	x	0.60	1440	44	33	Phosphorus Limited	-------	66	66	x	75	70	Hypereutrophic
OCEPD	North	10/16/85	x	0.60	2040	76	27	Balanced	70	62	66	x	75	71	Hypereutrophic
OCEPD	North	10/29/85	x	0.50	4780	48	100	Phosphorus Limited	-------	68	68	x	81	74	Hypereutrophic
OCEPD	North	11/13/85	x	0.60	1950	53	37	Phosphorus Limited	-------	70	70	x	75	73	Hypereutrophic
OCEPD	North	12/10/85	x	0.50	1410	56	25	Balanced	63	56	60	x	81	70	Hypereutrophic
OCEPD	North	1/8/86	x	0.50	1660	53	31	Phosphorus Limited	-------	70	70	x	81	75	Hypereutrophic
OCEPD	North	1/22/86	x	2.00	1680	61	28	Balanced	66	58	62	x	39	51	Mesotrophic
OCEPD	North	2/5/86	x	0.40	1710	78	22	Balanced	67	63	65	x	87	76	Hypereutrophic
OCEPD	North	2/19/86	x	0.50	1680	65	26	Balanced	66	59	63	x	81	72	Hypereutrophic
OCEPD	North	3/5/86	x	0.50	1440	82	18	Balanced	63	64	63	x	81	72	Hypereutrophic
OCEPD	North	4/1/86	x	0.50	1380	35	39	Phosphorus Limited	-------	60	60	x	81	70	Hypereutrophic
OCEPD	North	4/16/86	x	0.20	1700	45	38	Phosphorus Limited	-------	66	66	x	108	87	Hypereutrophic
OCEPD	North	4/30/86	x	0.50	1530	68	23	Balanced	64	60	62	x	81	72	Hypereutrophic
OCEPD	North	5/28/86	x	0.20	1770	52	34	Phosphorus Limited	-------	69	69	x	108	89	Hypereutrophic
OCEPD	North	6/11/86	x	0.20	1860	56	33	Phosphorus Limited	-------	71	71	x	108	90	Hypereutrophic
OCEPD	North	6/25/86	x	0.60	1350	35	39	Phosphorus Limited	-------	60	60	x	75	68	Eutophic
OCEPD	North	7/9/86	x	0.50	1710	x			71			x	81	81	Hypereutrophic
OCEPD	North	7/23/86	x	0.50	1300	49	27	Balanced	61	54	58	x	81	69	Eutophic
OCEPD	North	8/6/86	x	0.50	1440	82	18	Balanced	63	64	63	x	81	72	Hypereutrophic
OCEPD	North	8/20/86	x	x	1470	47	31	Phosphorus Limited	-------	67	67	x	x	67	Eutophic
OCEPD	North	9/3/86	x	0.50	1755	37	48	Phosphorus Limited	-------	61	61	x	81	71	Hypereutrophic
OCEPD	North	9/17/86	x	0.40	2010	42	48	Phosphorus Limited	-------	64	64	x	87	76	Hypereutrophic
OCEPD	North	10/15/86	x	0.30	1290	44	29	Balanced	61	52	57	x	96	76	Hypereutrophic
OCEPD	North	10/29/86	x	0.50	1080	57	19	Balanced	58	57	57	x	81	69	Eutophic
OCEPD	North	11/12/86	x	0.80	1960	43	46	Phosphorus Limited	-------	65	65	x	67	66	Eutophic
OCEPD	North	11/25/86	x	0.80	1570	64	25	Balanced	65	59	62	x	67	64	Eutophic
OCEPD	North	12/10/86	x	0.90	1710	49	35	Phosphorus Limited	-------	68	68	x	63	66	Eutophic
OCEPD	North	1/7/87	x	0.80	1310	62	21	Balanced	61	58	60	x	67	63	Eutophic
OCEPD	North	1/21/87	x	0.60	x	76				-----		x	75	75	Hypereutrophic
OCEPD	North	2/4/87	x	0.80	1800	58	31	Phosphorus Limited	-------	72	72	x	67	69	Eutophic
OCEPD	North	2/17/87	x	0.40	x	63				-----		x	87	87	Hypereutrophic
OCEPD	North	3/4/87	x	0.60	1425	95	15	Balanced	63	66	65	x	75	70	Eutophic
OCEPD	North	3/11/87	x	x	1230	95	13	Balanced	60	66	63	x	x	63	Eutophic
OCEPD	North	4/1/87	x	0.50	931	63	15	Balanced	55	59	57	x	81	69	Eutophic
OCEPD	North	5/27/87	x	0.60	691	42	16	Balanced	49	51	50	x	75	63	Eutophic
OCEPD	North	6/10/87	x	0.10	775	48	16	Balanced	51	54	52	x	129	91	Hypereutrophic
OCEPD	North	6/24/87	x	0.50	x	49				-----		x	81	81	Hypereutrophic
OCEPD	North	7/8/87	x	0.40	846	51	17	Balanced	53	55	54	x	87	71	Hypereutrophic

Summary of Historical Water Quality Data for Selected Parameters in Lake Holden

Data Source	Station Name	Sample Date	Chla (ugl)	Secchi (m)	Total N (ugl)	Total P (ugl)	TN/TP Ratio	Nutrient Limitation	TSI (TN)	TSI (TP)	TSI (Nut.)	TSI (Chyl-a)	TSI (SD)	FTSI (avg)	Trophic State
OCEPD	North	7/22/87	x	0.40	667	29	23	Balanced	48	44	46	x	87	67	Eutophic
OCEPD	North	8/4/87	x	0.50	900	20	45	Phosphorus Limited	-------	47	47	x	81	64	Eutophic
OCEPD	North	8/26/87	x	0.20	813	44	19	Balanced	52	52	52	x	108	80	Hypereutrophic
OCEPD	North	9/15/87	x	0.30	x	42				-----		x	96	96	Hypereutrophic
OCEPD	North	9/27/87	x	0.50	951	54	18	Balanced	55	56	55	x	81	68	Eutophic
OCEPD	North	10/12/87	x	0.40	668	58	12	Balanced	48	57	52	x	87	70	Eutophic
OCEPD	North	10/27/87	x	0.50	792	60	13	Balanced	51	58	55	x	81	68	Eutophic
OCEPD	North	11/4/87	x	0.50	705	61	12	Balanced	49	58	54	x	81	67	Eutophic
OCEPD	North	12/14/87	x	0.70	593	53	11	Balanced	46	55	51	x	71	61	Eutophic
OCEPD	North	3/16/88	x		908	75	12	Balanced	54	62	58	x	-----	58	Mesotrophic
OCEPD	North	6/27/88	x	0.80	955	66	14	Balanced	55	60	57	x	67	62	Eutophic
OCEPD	North	9/28/88	x	x	x	68									Oligotrophic
OCEPD	North	3/15/89	x	0.70	1727	51	34	Phosphorus Limited	-------	69	69	x	71	70	Eutophic
OCEPD	North	2/14/90	x	0.50	1167	65	18	Balanced	59	59	59	x	81	70	Eutophic
OCEPD	North	5/22/90	x	0.90	1375	54	26	Balanced	62	56	59	x	63	61	Eutophic
OCEPD	North	11/23/90	x	0.80	1090	50	22	Balanced	58	54	56	x	67	61	Eutophic
OCEPD	North	2/20/91	x	0.50	1400	59	24	Balanced	63	57	60	x	81	70	Hypereutrophic
OCEPD	North	6/11/91	x	0.60	1950	56	35	Phosphorus Limited	-------	71	71	x	75	73	Hypereutrophic
OCEPD	North	8/21/91	x	0.60	1590	44	36	Phosphorus Limited	-------	66	66	x	75	70	Hypereutrophic
OCEPD	North	11/13/91	x	0.70	1320	60	22	Balanced	61	58	60	x	71	65	Eutophic
OCEPD	North	2/19/92	x	0.90	1090	56	19	Balanced	58	56	57	x	63	60	Eutophic
OCEPD	North	5/19/92	x	0.70	1740	33	53	Phosphorus Limited	-------	59	59	x	71	65	Eutophic
OCEPD	North	11/11/92	x	0.60	1470	61	24	Balanced	64	58	61	x	75	68	Eutophic
OCEPD	North	2/17/93	x	0.80	1370	52	26	Balanced	62	55	59	x	67	63	Eutophic
OCEPD	North	6/22/93	x	0.50	1430	34	42	Phosphorus Limited	-------	59	59	x	81	70	Hypereutrophic
OCEPD	North	8/25/93	x	0.60	1290	40	32	Phosphorus Limited	-------	63	63	x	75	69	Eutophic
OCEPD	North	3/16/94	x	0.80	1256	68	18	Balanced	61	60	60	x	67	63	Eutophic
OCEPD	North	6/13/94	x	0.50	1335	20	67	Phosphorus Limited	-------	47	47	x	81	64	Eutophic
OCEPD	North	9/19/94	x	0.50	1255	48	26	Balanced	60	54	57	x	81	69	Eutophic
OCEPD	North	11/21/94	x	2.00	1015	34	30	Balanced	56	47	52	x	39	45	Oligotrophic
OCEPD	North	3/13/95	x	1.00	1015	83	12	Balanced	56	64	60	x	60	60	Eutophic
OCEPD	North	1/6/00	44.9	0.30	x	x				-----		72	96	84	Hypereutrophic
OCEPD	North	2/2/00	56.3	0.30	1700	36	48	Phosphorus Limited	-------	61	61	75	96	77	Hypereutrophic
OCEPD	North	3/16/00	48.5	0.30	1600	33	48	Phosphorus Limited	-------	59	59	73	96	76	Hypereutrophic
OCEPD	North	4/13/00	3.0	0.30	1800	25	73	Phosphorus Limited	-------	52	52	33	96	60	Eutophic
OCEPD	North	5/5/00	61.1	0.20	2100	15	137	Phosphorus Limited	-------	41	41	76	108	75	Hypereutrophic
OCEPD	North	6/6/00	39.5	0.20	1600	11	145	Phosphorus Limited	-------	33	33	70	108	70	Hypereutrophic
OCEPD	North	7/6/00	43.0	0.30	2100	11	185	Phosphorus Limited	-------	33	33	71	96	67	Eutophic
OCEPD	North	8/15/00	48.9	0.30	2400	10	248	Phosphorus Limited	-------	30	30	73	96	66	Eutophic
OCEPD	North	9/14/00	57.3	0.20	2200	9	254	Phosphorus Limited	-------	27	27	75	108	70	Hypereutrophic
OCEPD	North	10/5/00	54.0	0.30	2100	12	175	Phosphorus Limited	-------	35	35	74	96	68	Eutophic
OCEPD	North	11/2/00	59.2	0.30	1900	14	136	Phosphorus Limited	-------	38	38	76	96	70	Hypereutrophic
OCEPD	North	12/11/00	46.2	0.25	2000	17	118	Phosphorus Limited	-------	43	43	72	102	72	Hypereutrophic
OCEPD	North	3/22/01	x	x	x	17									
OCEPD	North	9/12/01	37.2	x	x	x				-----		69	x	69	Eutophic
OCEPD	North	12/17/01	39.6	1.00	1400	13	108	Phosphorus Limited	-------	37	37	70	60	56	Mesotrophic
OCEPD	North	2/13/02	27.1	0.70	1300	12	105	Phosphorus Limited	-------	35	35	64	71	57	Mesotrophic
OCEPD	North	4/24/02	32.8	0.60	1500	12	122	Phosphorus Limited	-------	35	35	67	75	59	Mesotrophic
OCEPD	North	8/5/02	36.0	0.60	1400	12	117	Phosphorus Limited	-------	35	35	68	75	60	Mesotrophic
OCEPD	North	10/1/02	42.1	0.30	1300	12	111	Phosphorus Limited	-------	34	34	71	96	67	Eutophic
OCEPD	North	1/7/03	41.6	0.60	1300	23	57	Phosphorus Limited	-------	50	50	70	75	65	Eutophic
OCEPD	North	2/3/03	26.2	0.60	1300	19	68	Phosphorus Limited	-------	46	46	64	75	62	Eutophic
OCEPD	North	5/12/03	32.5	0.50	1400	14	98	Phosphorus Limited	-------	39	39	67	81	62	Eutophic

Summary of Historical Water Quality Data for Selected Parameters in Lake Holden

Data Source	Station Name	Sample Date	Chla (ugl)	Secchi (m)	Total N (ugl)	Total P (ugl)	TN/TP Ratio	Nutrient Limitation	TSI (TN)	TSI (TP)	TSI (Nut.)	TSI (Chyl-a)	TSI (SD)	FTSI (avg)	Trophic State
OCEPD	North	8/28/03	22.4	0.60	1140	11	105	Phosphorus Limited	-------	32	32	62	75	56	Mesotrophic
OCEPD	North	10/23/03	39.8	x	1270	12	104	Phosphorus Limited	-------	35	35	70	x	53	Mesotrophic
OCEPD	North	2/5/04	27.7	0.70	1230	16	78	Phosphorus Limited	-------	41	41	65	71	59	Mesotrophic
OCEPD	North	5/11/04	33.9	0.50	1140	13	91	Phosphorus Limited	-------	36	36	68	81	61	Eutophic
OCEPD	North	11/8/04	x	0.70	840	16	51	Phosphorus Limited	-------	42	42	x	71	56	Mesotrophic
OCEPD	North	2/16/05	16.0	x	750	16	48	Phosphorus Limited	-------	41	41	57	x	49	Oligotrophic
OCEPD	North	4/11/05	x	1.00	680	12	57	Phosphorus Limited	-------	35	35	x	60	47	Oligotrophic
OCEPD	North	7/11/05	16.0	x	960	15	66	Phosphorus Limited	-------	39	39	57	x	48	Oligotrophic
OCEPD	North	9/15/05	11.0	x	470	9	55	Phosphorus Limited	-------	27	27	51	x	39	Oligotrophic
OCEPD	North	10/20/05	15.0	x	353	8	47	Phosphorus Limited	-------	24	24	56	x	40	Oligotrophic
OCEPD	North	1/5/06	10.5	1.50	720	8	90	Phosphorus Limited	-------	25	25	51	48	41	Oligotrophic
OCEPD	North	2/6/06	4.3	1.60	415	6	69	Phosphorus Limited	-------	18	18	38	46	34	Oligotrophic
OCEPD	North	3/6/06	1.1	2.90	280	3	84	Phosphorus Limited	-------			18	28	23	Oligotrophic
OCEPD	North	4/5/06	6.8	2.40	580	8	77	Phosphorus Limited	-------	24	24	44	34	34	Oligotrophic
OCEPD	North	5/3/06	3.6	1.00	330	6	58	Phosphorus Limited	-------	17	17	35	60	37	Oligotrophic
OCEPD	North	6/21/06	5.5	1.30	270	6	48	Phosphorus Limited	-------	17	17	41	52	37	Oligotrophic
OCEPD	North	7/10/06	10.5	1.20	690	5	138	Phosphorus Limited	-------	14	14	51	55	40	Oligotrophic
OCEPD	North	8/2/06	14.9	1.10	710	7	101	Phosphorus Limited	-------	22	22	56	57	45	Oligotrophic
OCEPD	North	9/7/06	x	x	920	8	115	Phosphorus Limited	-------	25	25	x	x	25	Oligotrophic
OCEPD	North	10/4/06	x	1.20	760	9	89	Phosphorus Limited	-------	27	27	x	55	41	Oligotrophic
OCEPD	North	11/21/06	x	x	880	11	80	Phosphorus Limited	-------	33	33	x	x	33	Oligotrophic
OCEPD	North	1/4/07	12.2	1.00	402	6	70	Phosphorus Limited	-------	17	17	53	60	43	Oligotrophic
OCEPD	North	2/21/07	18.1	0.94	830	8	104	Phosphorus Limited	-------	25	25	59	62	49	Oligotrophic
OCEPD	North	3/7/07	12.3	0.80	402	3	134	Phosphorus Limited	-------	2	2	53	67	41	Oligotrophic
OCEPD	North	4/4/07	12.2	0.70	512	6	89	Phosphorus Limited	-------	17	17	53	71	47	Oligotrophic
OCEPD	North	5/3/07	7.1	1.10	422	5	80	Phosphorus Limited	-------	15	15	45	57	39	Oligotrophic
OCEPD	North	6/6/07	7.1	1.00	437	5	87	Phosphorus Limited	-------	14	14	45	60	40	Oligotrophic
OCEPD	North	7/9/07	16.1	1.27	452	5	90	Phosphorus Limited	-------	14	14	57	53	41	Oligotrophic
OCEPD	North	8/7/07	20.8	1.10	850	5	170	Phosphorus Limited	-------	14	14	61	57	44	Oligotrophic
OCEPD	North	9/6/07	14.7	1.00	482	6	77	Phosphorus Limited	-------	19	19	56	60	45	Oligotrophic
OCEPD	North	10/3/07	11.6	0.90	482	6				-----		52	63	58	Mesotrophic
OCEPD	North	11/19/07	22.2	x	720	9	80	Phosphorus Limited	-------	28	28	61	x	45	Oligotrophic
OCEPD	North	12/5/07	22.0	x	1140	5	228	Phosphorus Limited	-------	14	14	61	x	38	Oligotrophic
OCEPD	North	1/8/08	16.3	0.60	1060	8	133	Phosphorus Limited	-------	25	25	57	75	53	Mesotrophic
OCEPD	North	4/3/08	x	0.91	960	7	148	Phosphorus Limited	-------	20	20	x	63	42	Oligotrophic
OCEPD	North	7/8/08	14.2	0.80	810	9	95	Phosphorus Limited	-------	27	27	55	67	49	Oligotrophic
OCEPD	North	10/7/08	35.3	0.85	980	8	123	Phosphorus Limited	-------	25	25	68	65	53	Mesotrophic
OCEPD	North	1/8/09	7.9	1.30	650	5	130	Phosphorus Limited	-------	14	14	47	52	38	Oligotrophic
OCEPD	North	4/2/09	4.3	2.70	780	4	223	Phosphorus Limited	-------	6	6	38	30	25	Oligotrophic
OCEPD	North	7/7/09	6.1	2.20	700	9	78	Phosphorus Limited	-------	28	28	43	36	36	Oligotrophic
OCEPD	North	10/6/09	10.1	1.60	940	8	125	Phosphorus Limited	-------	24	24	50	46	40	Oligotrophic
OCEPD	North	1/27/10	6.2	2.50	780	8	104	Phosphorus Limited	-------	24	24	43	33	33	Oligotrophic
OCEPD	North	4/28/10	5.0	2.10	730	6	122	Phosphorus Limited	-------	18	18	40	38	32	Oligotrophic
OCEPD	North	7/20/10	3.4	3.00	700	5	156	Phosphorus Limited	-------	12	12	34	27	24	Oligotrophic
OCEPD	North	10/11/10	6.7	2.20	440	7	68	Phosphorus Limited	-------	20	20	44	36	34	Oligotrophic

Summary of Historical Water Quality Data for Selected Parameters in Lake Holden

Data Source	Station Name	Sample Date	Chla (ugl)	Secchi (m)	Total N (ugl)	Total P (ugl)	TN/TP Ratio	Nutrient Limitation	TSI (TN)	TSI (TP)	TSI (Nut.)	TSI (Chyl-a)	TSI (SD)	FTSI (avg)	Trophic State
OCEPD	South	5/31/78	x	0.30	2410	x			79	-----	79	x	96	87	Hypereutrophic
OCEPD	South	10/4/78	x	0.60	1410	20	71	Phosphorus Limited	-------	47	47	x	75	61	Eutophic
OCEPD	South	2/12/79	x	1.10	720	65	11	Balanced	49	59	54	x	57	56	Mesotrophic
OCEPD	South	5/7/79	x	0.90	1010	55	18	Balanced	56	56	56	x	63	60	Mesotrophic
OCEPD	South	8/13/79	x	x	1220	30	41	Phosphorus Limited	-------	56	56	x	x	56	Mesotrophic
OCEPD	South	11/12/79	x	1.10	765	45	17	Balanced	51	52	52	x	57	54	Mesotrophic
OCEPD	South	2/11/80	x	1.80	750	40	19	Balanced	50	50	50	x	42	46	Oligotrophic
OCEPD	South	8/11/80	x	1.60	820	30	27	Balanced	52	45	48	x	46	47	Oligotrophic
OCEPD	South	11/10/80	x	2.10	860	40	22	Balanced	53	50	52	x	38	45	Oligotrophic
OCEPD	South	1/19/81	x	2.10	1020	50	20	Balanced	56	54	55	x	38	47	Oligotrophic
OCEPD	South	2/2/81	x	1.30	803	30	27	Balanced	52	45	48	x	52	50	Mesotrophic
OCEPD	South	2/16/81	x	1.00	1400	50	28	Balanced	63	54	59	x	60	59	Mesotrophic
OCEPD	South	3/2/81	x	1.20	993	47	21	Balanced	56	53	54	x	55	55	Mesotrophic
OCEPD	South	3/30/81	x	1.00	1667	60	28	Balanced	66	58	62	x	60	61	Eutophic
OCEPD	South	4/14/81	x	1.00	1735	40	43	Phosphorus Limited	-------	63	63	x	60	62	Eutophic
OCEPD	South	4/27/81	x	1.00	1100	53	21	Balanced	58	56	57	x	60	58	Mesotrophic
OCEPD	South	5/11/81	x	1.20	1033	47	22	Balanced	57	53	55	x	55	55	Mesotrophic
OCEPD	South	5/26/81	x	1.10	1003	47	22	Balanced	56	53	55	x	57	56	Mesotrophic
OCEPD	South	6/9/81	x	1.00	1413	43	33	Phosphorus Limited	-------	65	65	x	60	63	Eutophic
OCEPD	South	7/28/81	x	1.00	870	67	13	Balanced	53	60	56	x	60	58	Mesotrophic
OCEPD	South	8/10/81	x	1.10	1233	47	26	Balanced	60	53	57	x	57	57	Mesotrophic
OCEPD	South	8/28/81	x	0.70	1333	53	25	Balanced	62	56	59	x	71	65	Eutophic
OCEPD	South	9/8/81	x	0.80	1140	53	21	Balanced	59	56	57	x	67	62	Eutophic
OCEPD	South	9/21/81	x	0.80	1063	46	23	Balanced	57	53	55	x	67	61	Eutophic
OCEPD	South	10/5/81	x	x	870	86	10	Balanced	53	64	59	x	x	59	Mesotrophic
OCEPD	South	10/5/81	x	x	960	108	9	Nitrogen Limited	59	-----	59	x	x	59	Mesotrophic
OCEPD	South	10/26/81	x	x	1015	95	11	Balanced	56	66	61	x	x	61	Eutophic
OCEPD	South	11/24/81	x	0.80	1467	55	27	Balanced	64	56	60	x	67	63	Eutophic
OCEPD	South	12/7/81	x	0.60	1433	63	23	Balanced	63	59	61	x	75	68	Eutophic
OCEPD	South	12/22/81	x	0.90	2000	73	28	Balanced	70	61	66	x	63	64	Eutophic
OCEPD	South	1/12/82	x	0.60	1167	71	16	Balanced	59	61	60	x	75	68	Eutophic
OCEPD	South	1/25/82	x	1.00	1100	54	20	Balanced	58	56	57	x	60	58	Mesotrophic
OCEPD	South	2/8/82	x	0.90	1267	53	24	Balanced	61	55	58	x	63	61	Eutophic
OCEPD	South	2/22/82	x	0.70	2433	53	46	Phosphorus Limited	-------	70	70	x	71	70	Hypereutrophic
OCEPD	South	3/15/82	x	0.60	1400	55	25	Balanced	63	56	59	x	75	67	Eutophic
OCEPD	South	3/22/82	x	0.70	1533	56	27	Balanced	64	56	60	x	71	66	Eutophic
OCEPD	South	4/5/82	x	1.00	1333	55	24	Balanced	62	56	59	x	60	59	Mesotrophic
OCEPD	South	5/10/82	x	0.50	1000	x			60			x	81	81	Hypereutrophic
OCEPD	South	5/25/82	x	0.70	260	50	5	Nitrogen Limited	31	-----	31	x	71	51	Mesotrophic
OCEPD	South	6/7/82	x	0.50	960	54	18	Balanced	55	56	55	x	81	68	Eutophic
OCEPD	South	6/21/82	x	0.40	970	49	20	Balanced	55	54	55	x	87	71	Hypereutrophic
OCEPD	South	7/6/82	x	0.70	740	150	5	Nitrogen Limited	53	-----	53	x	71	62	Eutophic
OCEPD	South	7/26/82	x	1.00	1350	49	28	Balanced	62	54	58	x	60	59	Mesotrophic
OCEPD	South	8/9/82	x	0.90	1300	38	34	Phosphorus Limited	-------	62	62	x	63	63	Eutophic
OCEPD	South	8/23/82	x	1.00	1200	39	31	Phosphorus Limited	-------	63	63	x	60	61	Eutophic
OCEPD	South	9/7/82	x	1.00	1600	40	40	Phosphorus Limited	-------	63	63	x	60	62	Eutophic
OCEPD	South	9/20/82	x	1.00	1300	30	43	Phosphorus Limited	-------	56	56	x	60	58	Mesotrophic
OCEPD	South	10/14/82	x	0.90	1200	47	26	Balanced	60	53	56	x	63	60	Mesotrophic
OCEPD	South	10/18/82	x	0.80	1100	44	25	Balanced	58	52	55	x	67	61	Eutophic
OCEPD	South	11/1/82	x	0.50	1700	46	37	Phosphorus Limited	-------	67	67	x	81	74	Hypereutrophic
OCEPD	South	11/15/82	x	x	1350	50	27	Balanced	62	54	58	x	x	58	Mesotrophic
OCEPD	South	11/15/82	x	0.80	1100	52	21	Balanced	58	55	56	x	67	62	Eutophic
OCEPD	South	11/29/82	x	0.80	1333	54	25	Balanced	62	56	59	x	67	63	Eutophic

Summary of Historical Water Quality Data for Selected Parameters in Lake Holden

Data Source	Station Name	Sample Date	Chla (ugl)	Secchi (m)	Total N (ugl)	Total P (ugl)	TN/TP Ratio	Nutrient Limitation	TSI (TN)	TSI (TP)	TSI (Nut.)	TSI (Chyl-a)	TSI (SD)	FTSI (avg)	Trophic State
OCEPD	South	12/13/82	x	0.50	1167	46	26	Balanced	59	53	56	x	81	68	Eutophic
OCEPD	South	1/3/83	x	0.60	1043	35	30	Balanced	57	48	52	x	75	64	Eutophic
OCEPD	South	1/17/83	x	0.70	1200	43	28	Balanced	60	51	56	x	71	63	Eutophic
OCEPD	South	1/31/83	x	0.80	1020	39	26	Balanced	56	50	53	x	67	60	Mesotrophic
OCEPD	South	2/15/83	x	0.60	1500	58	26	Balanced	64	57	61	x	75	68	Eutophic
OCEPD	South	3/1/83	x	0.60	710	58	12	Balanced	49	57	53	x	75	64	Eutophic
OCEPD	South	3/15/83	x	0.60	1120	48	23	Balanced	58	54	56	x	75	66	Eutophic
OCEPD	South	3/28/83	x	0.80	1393	52	27	Balanced	63	55	59	x	67	63	Eutophic
OCEPD	South	4/12/83	x	0.50	1260	51	25	Balanced	61	55	58	x	81	69	Eutophic
OCEPD	South	5/3/83	x	0.60	757	x			54			x	75	75	Hypereutrophic
OCEPD	South	5/17/83	x	0.70	1420	44	32	Phosphorus Limited	-------	66	66	x	71	68	Eutophic
OCEPD	South	5/31/83	x	0.80	1253	42	30	Phosphorus Limited	-------	64	64	x	67	65	Eutophic
OCEPD	South	6/14/83	x	0.60	1270	48	26	Balanced	61	54	57	x	75	66	Eutophic
OCEPD	South	6/28/83	x	0.60	1640	41	40	Phosphorus Limited	-------	64	64	x	75	70	Eutophic
OCEPD	South	7/11/83	x	0.60	1583	26	62	Phosphorus Limited	-------	53	53	x	75	64	Eutophic
OCEPD	South	7/25/83	x	0.60	x	49						x	75	75	Hypereutrophic
OCEPD	South	8/9/83	x	0.70	x	39						x	71	71	Hypereutrophic
OCEPD	South	8/23/83	x	0.60	990	43	23	Balanced	56	52	54	x	75	65	Eutophic
OCEPD	South	9/6/83	x	0.80	1140	44	26	Balanced	59	52	55	x	67	61	Eutophic
OCEPD	South	9/20/83	x	0.90	1080	32	34	Phosphorus Limited	-------	58	58	x	63	61	Eutophic
OCEPD	South	10/18/83	x	0.60	4840	55	88	Phosphorus Limited	-------	71	71	x	75	73	Hypereutrophic
OCEPD	South	11/1/83	x	0.60	1420	67	21	Balanced	63	60	61	x	75	68	Eutophic
OCEPD	South	11/15/83	x	0.50	1270	65	20	Balanced	61	59	60	x	81	70	Hypereutrophic
OCEPD	South	11/29/83	x	0.60	1420	50	28	Balanced	63	54	59	x	75	67	Eutophic
OCEPD	South	12/12/83	x	0.40	1510	99	15	Balanced	64	67	66	x	87	77	Hypereutrophic
OCEPD	South	1/18/84	x	0.80	860	52	17	Balanced	53	55	54	x	67	60	Eutophic
OCEPD	South	1/30/84	x	0.60	1630	55	30	Balanced	66	56	61	x	75	68	Eutophic
OCEPD	South	2/8/84	x	0.70	390	62	6	Nitrogen Limited	39	-----	39	x	71	55	Mesotrophic
OCEPD	South	2/29/84	x	0.75	1390	72	19	Balanced	63	61	62	x	69	65	Eutophic
OCEPD	South	3/14/84	x	0.70	820	66	12	Balanced	52	60	56	x	71	63	Eutophic
OCEPD	South	3/27/84	x	0.70	1260	51	25	Balanced	61	55	58	x	71	64	Eutophic
OCEPD	South	4/11/84	x	0.70	1020	61	17	Balanced	56	58	57	x	71	64	Eutophic
OCEPD	South	4/24/84	x	0.50	660	61	11	Balanced	48	58	53	x	81	67	Eutophic
OCEPD	South	5/8/84	x	0.50	1570	69	23	Balanced	65	60	63	x	81	72	Hypereutrophic
OCEPD	South	5/23/84	x	0.40	1770	65	27	Balanced	67	59	63	x	87	75	Hypereutrophic
OCEPD	South	6/12/84	x	0.50	1920	68	28	Balanced	69	60	64	x	81	73	Hypereutrophic
OCEPD	South	6/26/84	x	0.40	2280	73	31	Phosphorus Limited	-------	77	77	x	87	82	Hypereutrophic
OCEPD	South	7/18/84	x	0.30	2220	53	42	Phosphorus Limited	-------	70	70	x	96	83	Hypereutrophic
OCEPD	South	7/31/84	x	0.60	1950	56	35	Phosphorus Limited	-------	71	71	x	75	73	Hypereutrophic
OCEPD	South	8/15/84	x	0.70	1500	57	26	Balanced	64	57	60	x	71	66	Eutophic
OCEPD	South	8/25/84	x	x	2070	53	39	Phosphorus Limited	-------	70	70	x	x	70	Eutophic
OCEPD	South	8/28/84	x	0.70	1750	50	35	Phosphorus Limited	-------	69	69	x	71	70	Eutophic
OCEPD	South	9/2/84	x	0.50	1800	51	35	Phosphorus Limited	-------	69	69	x	81	75	Hypereutrophic
OCEPD	South	9/25/84	x	0.60	2070	58	36	Phosphorus Limited	-------	72	72	x	75	74	Hypereutrophic
OCEPD	South	10/10/84	x	0.50	2700	94	29	Balanced	76	66	71	x	81	76	Hypereutrophic
OCEPD	South	10/23/84	x	0.70	1030	63	16	Balanced	57	59	58	x	71	64	Eutophic
OCEPD	South	11/6/84	x	0.60	1500	60	25	Balanced	64	58	61	x	75	68	Eutophic
OCEPD	South	11/20/84	x	0.50	1740	59	29	Balanced	67	57	62	x	81	71	Hypereutrophic
OCEPD	South	12/4/84	x	0.40	1620	75	22	Balanced	66	62	64	x	87	76	Hypereutrophic
OCEPD	South	12/18/84	x	0.80	2250	49	46	Phosphorus Limited	-------	68	68	x	67	67	Eutophic
OCEPD	South	1/2/85	x	0.60	2010	43	47	Phosphorus Limited	-------	65	65	x	75	70	Hypereutrophic
OCEPD	South	1/16/85	x	0.60	1430	63	23	Balanced	63	59	61	x	75	68	Eutophic
OCEPD	South	1/30/85	x	0.60	1510	56	27	Balanced	64	56	60	x	75	68	Eutophic

Summary of Historical Water Quality Data for Selected Parameters in Lake Holden

Data Source	Station Name	Sample Date	Chla (ugl)	Secchi (m)	Total N (ugl)	Total P (ugl)	TN/TP Ratio	Nutrient Limitation	TSI (TN)	TSI (TP)	TSI (Nut.)	TSI (Chyl-a)	TSI (SD)	FTSI (avg)	Trophic State
OCEPD	South	2/13/85	x	0.50	1490	64	23	Balanced	64	59	61	x	81	71	Hypereutrophic
OCEPD	South	2/26/85	x	0.50	1230	54	23	Balanced	60	56	58	x	81	69	Eutophic
OCEPD	South	3/13/85	x	0.60	1320	51	26	Balanced	61	55	58	x	75	67	Eutophic
OCEPD	South	3/27/85	x	0.40	1590	64	25	Balanced	65	59	62	x	87	75	Hypereutrophic
OCEPD	South	4/23/85	x	0.30	1500	54	28	Balanced	64	56	60	x	96	78	Hypereutrophic
OCEPD	South	5/8/85	x	0.40	1890	67	28	Balanced	69	60	64	x	87	76	Hypereutrophic
OCEPD	South	5/21/85	x	0.40	2220	62	36	Phosphorus Limited	-------	74	74	x	87	81	Hypereutrophic
OCEPD	South	6/19/85	x	0.50	1950	48	41	Phosphorus Limited	-------	68	68	x	81	74	Hypereutrophic
OCEPD	South	7/1/85	x	0.60	1770	51	35	Phosphorus Limited	-------	69	69	x	75	72	Hypereutrophic
OCEPD	South	7/17/85	x	0.60	1560	31	50	Phosphorus Limited	-------	57	57	x	75	66	Eutophic
OCEPD	South	7/31/85	x	0.50	1680	55	31	Phosphorus Limited	-------	71	71	x	81	76	Hypereutrophic
OCEPD	South	8/4/85	x	0.60	1800	59	31	Phosphorus Limited	-------	72	72	x	75	74	Hypereutrophic
OCEPD	South	8/27/85	x	0.50	1600	60	27	Balanced	65	58	62	x	81	71	Hypereutrophic
OCEPD	South	9/17/85	x	0.50	2150	51	42	Phosphorus Limited	-------	69	69	x	81	75	Hypereutrophic
OCEPD	South	10/2/85	x	0.60	1530	64	24	Balanced	64	59	62	x	75	69	Eutophic
OCEPD	South	10/16/85	x	0.60	1770	53	33	Phosphorus Limited	-------	70	70	x	75	73	Hypereutrophic
OCEPD	South	10/29/85	x	0.50	24750	56	442	Phosphorus Limited	-------	71	71	x	81	76	Hypereutrophic
OCEPD	South	11/13/85	x	0.40	1710	67	26	Balanced	67	60	63	x	87	75	Hypereutrophic
OCEPD	South	12/10/85	x	0.50	1470	52	28	Balanced	64	55	59	x	81	70	Hypereutrophic
OCEPD	South	1/8/86	x	0.50	1750	33	53	Phosphorus Limited	-------	59	59	x	81	70	Eutophic
OCEPD	South	1/22/86	x	2.00	1510	46	33	Phosphorus Limited	-------	67	67	x	39	53	Mesotrophic
OCEPD	South	2/5/86	x	0.40	1500	62	24	Balanced	64	58	61	x	87	74	Hypereutrophic
OCEPD	South	2/19/86	x	0.50	1410	68	21	Balanced	63	60	61	x	81	71	Hypereutrophic
OCEPD	South	3/5/86	x	0.50	1500	73	21	Balanced	64	61	63	x	81	72	Hypereutrophic
OCEPD	South	4/1/86	x	0.50	750	40	19	Balanced	50	50	50	x	81	66	Eutophic
OCEPD	South	4/16/86	x	0.40	1620	47	34	Phosphorus Limited	-------	67	67	x	87	77	Hypereutrophic
OCEPD	South	4/30/86	x	0.50	1410	69	20	Balanced	63	60	62	x	81	71	Hypereutrophic
OCEPD	South	6/11/86	x	0.20	2070	56	37	Phosphorus Limited	-------	71	71	x	108	90	Hypereutrophic
OCEPD	South	6/25/86	x	0.60	1620	52	31	Phosphorus Limited	-------	69	69	x	75	72	Hypereutrophic
OCEPD	South	7/9/86	x	0.50	2080	x			75	-----	75	x	81	78	Hypereutrophic
OCEPD	South	8/6/86	x	0.50	1560	64	25	Balanced	65	59	62	x	81	71	Hypereutrophic
OCEPD	South	8/20/86	x	x	1530	43	36	Phosphorus Limited	-------	65	65	x	x	65	Eutophic
OCEPD	South	9/3/86	x	0.50	1470	38	39	Phosphorus Limited	-------	62	62	x	81	71	Hypereutrophic
OCEPD	South	9/17/86	x	0.40	1215	41	30	Balanced	60	50	55	x	87	71	Hypereutrophic
OCEPD	South	10/15/86	x	0.30	1320	47	28	Balanced	61	53	57	x	96	77	Hypereutrophic
OCEPD	South	10/29/86	x	0.50	1350	53	25	Balanced	62	55	59	x	81	70	Eutophic
OCEPD	South	11/12/86	x	0.80	1840	43	43	Phosphorus Limited	-------	65	65	x	67	66	Eutophic
OCEPD	South	11/25/86	x	0.80	2000	65	31	Phosphorus Limited	-------	75	75	x	67	71	Hypereutrophic
OCEPD	South	12/10/86	x	0.80	2700	46	59	Phosphorus Limited	-------	67	67	x	67	67	Eutophic
OCEPD	South	1/7/87	x	0.80	1555	57	28	Balanced	65	57	61	x	67	64	Eutophic
OCEPD	South	1/21/87	x	0.50	x	74				-----		x	81	81	Hypereutrophic
OCEPD	South	2/4/87	x	0.80	2275	57	40	Phosphorus Limited	-------	71	71	x	67	69	Eutophic
OCEPD	South	2/17/87	x	0.30	x	62				-----		x	96	96	Hypereutrophic
OCEPD	South	3/4/87	x	0.60	2025	76	27	Balanced	70	62	66	x	75	71	Hypereutrophic
OCEPD	South	3/11/87	x	x	1215	93	13	Balanced	60	66	63	x	x	63	Eutophic
OCEPD	South	4/1/87	x	0.50	1017	59	17	Balanced	56	57	57	x	81	69	Eutophic
OCEPD	South	5/27/87	x	0.60	746	45	17	Balanced	50	52	51	x	75	63	Eutophic
OCEPD	South	6/10/87	x	0.10	755	46	16	Balanced	50	53	52	x	129	90	Hypereutrophic
OCEPD	South	6/24/87	x	0.40	x	45				-----		x	87	87	Hypereutrophic
OCEPD	South	7/8/87	x	0.60	825	45	18	Balanced	52	52	52	x	75	64	Eutophic
OCEPD	South	7/22/87	x	0.40	701	27	26	Balanced	49	43	46	x	87	67	Eutophic
OCEPD	South	8/4/87	x	0.80	642	20	32	Phosphorus Limited	-------	47	47	x	67	57	Mesotrophic
OCEPD	South	8/26/87	x	0.40	839	40	21	Balanced	53	50	51	x	87	69	Eutophic

Summary of Historical Water Quality Data for Selected Parameters in Lake Holden

Data Source	Station Name	Sample Date	Chla (ugl)	Secchi (m)	Total N (ugl)	Total P (ugl)	TN/TP Ratio	Nutrient Limitation	TSI (TN)	TSI (TP)	TSI (Nut.)	TSI (Chyl-a)	TSI (SD)	FTSI (avg)	Trophic State
OCEPD	South	9/16/87	x	0.40	x	42				-----		x	87	87	Hypereutrophic
OCEPD	South	9/29/87	x	0.40	1067	49	22	Balanced	57	54	56	x	87	72	Hypereutrophic
OCEPD	South	10/12/87	x	0.40	781	70	11	Balanced	51	61	56	x	87	72	Hypereutrophic
OCEPD	South	10/27/87	x	0.50	802	51	16	Balanced	52	55	53	x	81	67	Eutophic
OCEPD	South	11/4/87	x	0.50	667	54	12	Balanced	48	56	52	x	81	66	Eutophic
OCEPD	South	11/9/87	x	x	x	57									
OCEPD	South	12/14/87	x	0.70	1630	48	34	Phosphorus Limited	-------	68	68	x	71	69	Eutophic
OCEPD	South	3/16/88	x	x	905	66	14	Balanced	54	60	57	x	x	57	Mesotrophic
OCEPD	South	6/27/88	x	0.90	977	69	14	Balanced	56	60	58	x	63	61	Eutophic
OCEPD	South	9/28/88	x	x	x	71									
OCEPD	South	3/15/89	x	0.70	1688	63	27	Balanced	66	59	63	x	71	67	Eutophic
OCEPD	South	2/14/90	x	0.60	1157	55	21	Balanced	59	56	58	x	75	66	Eutophic
OCEPD	South	5/27/90	x	0.80	1536	53	29	Balanced	64	55	60	x	67	63	Eutophic
OCEPD	South	11/27/90	x	0.70	920	55	17	Balanced	54	56	55	x	71	63	Eutophic
OCEPD	South	2/20/91	x	0.60	1380	64	22	Balanced	62	59	61	x	75	68	Eutophic
OCEPD	South	6/11/91	x	0.70	1700	59	29	Balanced	67	57	62	x	71	66	Eutophic
OCEPD	South	8/21/91	x	0.70	1520	43	35	Phosphorus Limited	-------	65	65	x	71	68	Eutophic
OCEPD	South	11/13/91	x	0.80	1365	54	25	Balanced	62	56	59	x	67	63	Eutophic
OCEPD	South	2/19/92	x	1.00	1155	49	24	Balanced	59	54	56	x	60	58	Mesotrophic
OCEPD	South	5/20/92	x	0.30	1825	54	34	Phosphorus Limited	-------	70	70	x	96	83	Hypereutrophic
OCEPD	South	8/19/92	x	0.60	1381	33	42	Phosphorus Limited	-------	59	59	x	75	67	Eutophic
OCEPD	South	11/11/92	x	0.60	1385	58	24	Balanced	62	57	60	x	75	68	Eutophic
OCEPD	South	2/17/93	x	0.80	1455	57	26	Balanced	63	57	60	x	67	63	Eutophic
OCEPD	South	6/22/93	x	0.60	1360	36	38	Phosphorus Limited	-------	61	61	x	75	68	Eutophic
OCEPD	South	8/25/93	x	0.70	1465	45	33	Phosphorus Limited	-------	66	66	x	71	68	Eutophic
OCEPD	South	3/16/94	x	0.80	1086	58	19	Balanced	58	57	57	x	67	62	Eutophic
OCEPD	South	6/13/94	x	0.50	1315	12	110	Phosphorus Limited	-------	35	35	x	81	58	Mesotrophic
OCEPD	South	9/16/94	x	0.50	1125	37	30	Phosphorus Limited	-------	61	61	x	81	71	Hypereutrophic
OCEPD	South	11/21/94	x	0.50	1115	36	31	Phosphorus Limited	-------	61	61	x	81	71	Hypereutrophic
OCEPD	South	3/13/95	x	1.00	1015	46	22	Balanced	56	53	55	x	60	57	Mesotrophic
OCEPD	South	1/21/98	63.6	x	1315	26	52	Phosphorus Limited	-------	53	53	77	x	65	Eutophic
OCEPD	South	2/9/98	70.0	1.00	1315	31	43	Phosphorus Limited	-------	57	57	78	60	65	Eutophic
OCEPD	South	3/4/98	47.8	x	1415	30	48	Phosphorus Limited	-------	56	56	72	x	64	Eutophic
OCEPD	South	4/8/98	60.3	0.50	1815	28	66	Phosphorus Limited	-------	54	54	76	81	70	Hypereutrophic
OCEPD	South	5/6/98	48.0	0.45	1827	23	81	Phosphorus Limited	-------	50	50	73	84	69	Eutophic
OCEPD	South	6/3/98	27.9	0.55	1415	18	81	Phosphorus Limited	-------	44	44	65	78	62	Eutophic
OCEPD	South	7/14/98	25.5	0.50	1315	11	125	Phosphorus Limited	-------	32	32	63	81	59	Mesotrophic
OCEPD	South	8/6/98	32.0	x	1415	14	105	Phosphorus Limited	-------	38	38	67	x	52	Mesotrophic
OCEPD	South	9/14/98	35.0	0.45	1515	20	76	Phosphorus Limited	-------	47	47	68	84	66	Eutophic
OCEPD	South	10/7/98	31.0	0.50	1415	18	81	Phosphorus Limited	-------	44	44	66	81	64	Eutophic
OCEPD	South	11/4/98	70.0	0.50	1615	22	75	Phosphorus Limited	-------	49	49	78	81	69	Eutophic
OCEPD	South	12/17/98	59.0	0.50	1215	20	61	Phosphorus Limited	-------	47	47	76	81	68	Eutophic
OCEPD	South	1/6/00	45.2	0.30	x	x				-----		72	96	84	Hypereutrophic
OCEPD	South	2/2/00	59.4	0.30	1700	28	61	Phosphorus Limited	-------	55	55	76	96	76	Hypereutrophic
OCEPD	South	3/16/00	46.1	0.20	1700	27	63	Phosphorus Limited	-------	54	54	72	108	78	Hypereutrophic
OCEPD	South	4/13/00	53.0	0.30	1800	26	70	Phosphorus Limited	-------	53	53	74	96	74	Hypereutrophic
OCEPD	South	5/5/00	64.0	0.20	2100	17	126	Phosphorus Limited	-------	43	43	77	108	76	Hypereutrophic
OCEPD	South	6/6/00	39.7	0.20	2200	11	200	Phosphorus Limited	-------	33	33	70	108	70	Hypereutrophic
OCEPD	South	7/6/00	40.8	0.30	1900	11	168	Phosphorus Limited	-------	33	33	70	96	67	Eutophic
OCEPD	South	8/15/00	42.8	0.20	2000	9	231	Phosphorus Limited	-------	27	27	71	108	69	Eutophic
OCEPD	South	9/14/00	49.9	0.20	2100	10	210	Phosphorus Limited	-------	31	31	73	108	71	Hypereutrophic
OCEPD	South	10/5/00	54.9	0.20	2000	12	171	Phosphorus Limited	-------	34	34	74	108	72	Hypereutrophic
OCEPD	South	11/2/00	61.3	0.30	2200	22	100	Phosphorus Limited	-------	49	49	76	96	74	Hypereutrophic

Summary of Historical Water Quality Data for Selected Parameters in Lake Holden

Data Source	Station Name	Sample Date	Chla (ugl)	Secchi (m)	Total N (ugl)	Total P (ugl)	TN/TP Ratio	Nutrient Limitation	TSI (TN)	TSI (TP)	TSI (Nut.)	TSI (Chyl-a)	TSI (SD)	FTSI (avg)	Trophic State
OCEPD	South	12/11/00	59.3	0.20	1900	18	104	Phosphorus Limited	-------	45	45	76	108	76	Hypereutrophic
OCEPD	South	9/12/01	36.6	x	x	x				-----		69	x	69	Eutophic
OCEPD	South	12/17/01	42.7	0.80	1200	14	84	Phosphorus Limited	-------	39	39	71	67	59	Mesotrophic
OCEPD	South	2/13/02	29.6	0.60	1300	12	108	Phosphorus Limited	-------	35	35	66	75	59	Mesotrophic
OCEPD	South	4/24/02	22.6	0.50	1500	12	122	Phosphorus Limited	-------	35	35	62	81	59	Mesotrophic
OCEPD	South	8/5/02	36.4	0.50	1400	11	131	Phosphorus Limited	-------	32	32	69	81	60	Eutophic
OCEPD	South	10/1/02	48.9	0.40	1000	13	79	Phosphorus Limited	-------	36	36	73	87	65	Eutophic
OCEPD	South	1/7/03	38.3	0.60	1300	20	66	Phosphorus Limited	-------	47	47	69	75	64	Eutophic
OCEPD	South	2/3/03	22.7	0.70	1200	19	63	Phosphorus Limited	-------	46	46	62	71	59	Mesotrophic
OCEPD	South	5/12/03	33.4	0.50	1400	14	102	Phosphorus Limited	-------	38	38	67	81	62	Eutophic
OCEPD	South	10/23/03	40.3	x	1130	13	90	Phosphorus Limited	-------	36	36	70	x	53	Mesotrophic
OCEPD	South	2/5/04	27.4	0.70	1070	14	76	Phosphorus Limited	-------	39	39	64	71	58	Mesotrophic
OCEPD	South	5/11/04	33.1	0.50	1580	12	130	Phosphorus Limited	-------	35	35	67	81	61	Eutophic
OCEPD	South	11/8/04	x	0.70	860	15	57	Phosphorus Limited	-------	40	40	x	71	55	Mesotrophic
OCEPD	South	2/16/05	16.0	x	770	15	51	Phosphorus Limited	-------	40	40	57	x	48	Oligotrophic
OCEPD	South	4/11/05	x	1.00	620	10	62	Phosphorus Limited	-------	31	31	x	60	45	Oligotrophic
OCEPD	South	7/11/05	17.0	x	1010	14	72	Phosphorus Limited	-------	38	38	58	x	48	Oligotrophic
OCEPD	South	9/15/05	12.0	x	601	10	60	Phosphorus Limited	-------	31	31	53	x	42	Oligotrophic
OCEPD	South	10/20/05	15.0	x	363	7	52	Phosphorus Limited	-------	22	22	56	x	39	Oligotrophic
OCEPD	South	1/5/06	9.0	1.50	760	8	95	Phosphorus Limited	-------	25	25	48	48	41	Oligotrophic
OCEPD	South	2/6/06	7.5	1.70	740	7	106	Phosphorus Limited	-------	22	22	46	44	37	Oligotrophic
OCEPD	South	3/6/06	1.1	3.80	520	4	149	Phosphorus Limited	-------	6	6	18	20	15	Oligotrophic
OCEPD	South	4/5/06	7.2	2.30	630	11	60	Phosphorus Limited	-------	32	32	45	35	37	Oligotrophic
OCEPD	South	5/3/06	7.0	1.80	580	9	68	Phosphorus Limited	-------	27	27	45	42	38	Oligotrophic
OCEPD	South	6/21/06	9.1	1.70	520	8	69	Phosphorus Limited	-------	24	24	49	44	39	Oligotrophic
OCEPD	South	7/10/06	11.0	1.20	690	6	125	Phosphorus Limited	-------	16	16	51	55	41	Oligotrophic
OCEPD	South	8/2/06	9.2	1.20	390	6	62	Phosphorus Limited	-------	20	20	49	55	41	Oligotrophic
OCEPD	South	9/7/06	x	x	820	8	109	Phosphorus Limited	-------	24	24	x	x	24	Oligotrophic
OCEPD	South	10/4/06	x	1.50	760	8	95	Phosphorus Limited	-------	25	25	x	48	37	Oligotrophic
OCEPD	South	11/21/06	x	x	830	11	79	Phosphorus Limited	-------	32	32	x	x	32	Oligotrophic
OCEPD	South	1/4/07	16.4	1.00	800	11	73	Phosphorus Limited	-------	33	33	57	60	50	Oligotrophic
OCEPD	South	2/21/07	17.9	0.80	780	9	92	Phosphorus Limited	-------	27	27	58	67	51	Mesotrophic
OCEPD	South	3/7/07	19.7	0.80	859	3	344	Phosphorus Limited	-------	-2	-2	60	67	41	Oligotrophic
OCEPD	South	4/4/07	18.6	0.75	1020	10	107	Phosphorus Limited	-------	29	29	59	69	52	Mesotrophic
OCEPD	South	5/3/07	12.6	1.10	850	10	89	Phosphorus Limited	-------	29	29	53	57	47	Oligotrophic
OCEPD	South	6/6/07	12.7	1.00	930	8	124	Phosphorus Limited	-------	24	24	53	60	46	Oligotrophic
OCEPD	South	7/9/07	8.2	1.29	442	10	47	Phosphorus Limited	-------	29	29	47	52	43	Oligotrophic
OCEPD	South	8/7/07	18.8	1.10	790	6	144	Phosphorus Limited	-------	16	16	59	57	44	Oligotrophic
OCEPD	South	9/6/07	24.3	0.80	910	10	96	Phosphorus Limited	-------	29	29	63	67	53	Mesotrophic
OCEPD	South	10/3/07	22.9	0.95	930	8	124	Phosphorus Limited		24	24	62	62	49	Oligotrophic
OCEPD	South	11/19/07	18.9	x	780	10	82	Phosphorus Limited	-------	29	29	59	x	44	Oligotrophic
OCEPD	South	12/5/07	22.3	x	1020	10	102	Phosphorus Limited	-------	31	31	62	x	46	Oligotrophic
OCEPD	South	1/8/08	14.6	0.65	890	8	119	Phosphorus Limited	-------	24	24	55	73	51	Mesotrophic
OCEPD	South	4/3/08	x	1.00	840	8	112	Phosphorus Limited	-------	24	24	x	60	42	Oligotrophic
OCEPD	South	7/8/08	14.0	0.83	860	8	115	Phosphorus Limited	-------	24	24	55	66	48	Oligotrophic
OCEPD	South	10/7/08	34.0	0.91	1010	8	135	Phosphorus Limited	-------	24	24	68	63	51	Mesotrophic
OCEPD	South	1/8/09	3.6	1.60	1280	11	116	Phosphorus Limited	-------	33	33	35	46	38	Oligotrophic
OCEPD	South	4/2/09	3.6	3.10	850	4	213	Phosphorus Limited	-------	9	9	35	26	23	Oligotrophic
OCEPD	South	7/7/09	6.5	2.30	680	9	76	Phosphorus Limited	-------	28	28	44	35	36	Oligotrophic
OCEPD	South	10/6/09	9.4	1.70	930	7	133	Phosphorus Limited	-------	22	22	49	44	38	Oligotrophic
OCEPD	South	1/27/10	4.0	3.10	950	5	190	Phosphorus Limited	-------	14	14	37	26	26	Oligotrophic
OCEPD	South	4/28/10	5.2	2.80	780	9	87	Phosphorus Limited	-------	28	28	41	29	33	Oligotrophic
OCEPD	South	7/20/10	2.7	3.30	580	5	129	Phosphorus Limited	-------	12	12	31	24	22	Oligotrophic

Summary of Historical Water Quality Data for Selected Parameters in Lake Holden

Data Source	Station Name	Sample Date	Chla (ugl)	Secchi (m)	Total N (ugl)	Total P (ugl)	TN/TP Ratio	Nutrient Limitation	TSI (TN)	TSI (TP)	TSI (Nut.)	TSI (Chyl-a)	TSI (SD)	FTSI (avg)	Trophic State
OCEPD	South	10/11/10	4.6	2.70	440	3	147	Phosphorus Limited	-------	2	2	39	30	24	Oligotrophic
FDEP	Center	10/2/03	x	0.80	1404	42	33	Phosphorus Limited	-------	64	64	x	67	66	Eutophic
FDEP	Center	2/2/04	x	0.90	x	x				-----		x	63	63	Eutophic
FDEP	Center	3/29/04	x	0.70	x	x				-----		x	71	71	Hypereutrophic
FDEP	Center	6/14/04	x	0.80	x	x				-----		x	67	67	Eutophic
FDEP	Center	9/13/04	x	0.70	x	x				-----		x	71	71	Hypereutrophic
FDEP	Center	6/23/09	x	1.60	615	15	41	Phosphorus Limited	-------	40	40	x	46	43	Oligotrophic
FDEP	Center	9/24/09	x	1.70	641	16	40	Phosphorus Limited	-------	42	42	x	44	43	Oligotrophic
FDEP	Center	7/7/10	x	2.50	464	12	39	Phosphorus Limited	-------	35	35	x	33	34	Oligotrophic
FDEP	Center	7/11/11	x	2.90	524	10	52	Phosphorus Limited	-------	31	31	x	28	29	Oligotrophic
FDEP	Center	1/19/12	x	x	539	10	54	Phosphorus Limited	-------	31	31	x	x	31	Oligotrophic
FDEP	Center	5/24/12	x	3.50	544	11	49	Phosphorus Limited	-------	33	33	x	22	28	Oligotrophic

Summary of Historical Water Quality Data for Selected Parameters in Lake Holden

Data Source	Station Name	Sample Date	Chla (ugl)	Secchi (m)	Total N (ugl)	Total P (ugl)	TN/TP Ratio	Nutrient Limitation	TSI (TN)	TSI (TP)	TSI (Nut.)	TSI (Chyl-a)	TSI (SD)	FTSI (avg)	Trophic State
Orlando	North	3/15/01	x	0.46	1770	50	35	Phosphorus Limited	-------	69	69	x	83	76	Hypereutrophic
Orlando	North	5/10/01	x	0.47	1750	50	35	Phosphorus Limited	-------	69	69	x	83	76	Hypereutrophic
Orlando	North	7/24/01	x	0.48	1640	37	44	Phosphorus Limited	-------	61	61	x	82	72	Hypereutrophic
Orlando	North	10/18/01	x	0.58	1500	43	35	Phosphorus Limited	-------	65	65	x	76	71	Hypereutrophic
Orlando	North	2/28/02	x	0.58	1260	43	29	Balanced	61	52	56	x	76	66	Eutophic
Orlando	North	7/25/02	x	0.54	1470	30	49	Phosphorus Limited	-------	56	56	x	78	67	Eutophic
Orlando	North	11/1/02	x	0.64	1200	32	38	Phosphorus Limited	-------	58	58	x	73	66	Eutophic
Orlando	North	2/4/03	x	0.79	1330	46	29	Balanced	62	53	57	x	67	62	Eutophic
Orlando	North	4/29/03	x	0.49	1180	35	34	Phosphorus Limited	-------	60	60	x	81	71	Hypereutrophic
Orlando	North	7/29/03	x	0.76	1150	22	52	Phosphorus Limited	-------	49	49	x	68	59	Mesotrophic
Orlando	North	10/21/03	x	0.59	1280	32	40	Phosphorus Limited	-------	58	58	x	76	67	Eutophic
Orlando	North	1/22/04	x	0.67	1140	41	28	Balanced	59	51	55	x	72	63	Eutophic
Orlando	North	5/4/04	x	0.69	1300	44	30	Balanced	61	52	57	x	71	64	Eutophic
Orlando	North	7/29/04	x	0.78	1220	23	53	Phosphorus Limited	-------	50	50	x	67	59	Mesotrophic
Orlando	North	1/27/05	x	1.03	1070	37	29	Balanced	57	49	53	x	59	56	Mesotrophic
Orlando	North	5/10/05	x	0.42	1290	24	54	Phosphorus Limited	-------	51	51	x	86	69	Eutophic
Orlando	North	7/21/05	x	1.37	1130	16	71	Phosphorus Limited	-------	42	42	x	51	46	Oligotrophic
Orlando	North	11/10/05	x	0.91	700	11	64	Phosphorus Limited	-------	33	33	x	63	48	Oligotrophic
Orlando	North	1/26/06	x	0.56	880	14	63	Phosphorus Limited	-------	38	38	x	77	58	Mesotrophic
Orlando	North	5/18/06	x	0.41	590	6	98	Phosphorus Limited	-------	18	18	x	87	53	Mesotrophic
Orlando	North	7/18/06	x	0.34	760	13	58	Phosphorus Limited	-------	37	37	x	92	64	Eutophic
Orlando	North	10/24/06	x	0.34	850	7	121	Phosphorus Limited	-------	22	22	x	93	57	Mesotrophic
Orlando	North	1/16/07	x	0.90	810	14	58	Phosphorus Limited	-------	38	38	x	63	51	Mesotrophic
Orlando	North	4/24/07	x	0.88	1150	16	72	Phosphorus Limited	-------	42	42	x	64	53	Mesotrophic
Orlando	North	7/19/07	x	1.25	940	11	85	Phosphorus Limited	-------	33	33	x	53	43	Oligotrophic
Orlando	North	10/23/07	x	0.82	980	16	61	Phosphorus Limited	-------	42	42	x	66	54	Mesotrophic
Orlando	North	1/31/08	x	1.00	x	x				-----		x	60	60	Eutophic
Orlando	North	4/22/08	x	1.03	x	x				-----		x	59	59	Mesotrophic
Orlando	North	8/7/08	x	1.23	x	x				-----		x	54	54	Mesotrophic
Orlando	North	10/21/08	x	1.87	x	x				-----		x	41	41	Oligotrophic
Orlando	North	1/29/09	x	2.03	x	x				-----		x	39	39	Oligotrophic
Orlando	North	5/7/09	x	2.96	x	x				-----		x	27	27	Oligotrophic
Orlando	North	8/11/09	x	2.03	x	x				-----		x	39	39	Oligotrophic
Orlando	North	10/22/09	x	1.77	x	x				-----		x	43	43	Oligotrophic
Orlando	North	2/11/10	x	3.88	x	x				-----		x	19	19	Oligotrophic
Orlando	North	4/20/10	x	2.79	x	x				-----		x	29	29	Oligotrophic
Orlando	North	8/5/10	x	2.77	x	x				-----		x	29	29	Oligotrophic
Orlando	North	10/26/10	x	2.19	x	x				-----		x	36	36	Oligotrophic
Orlando	North	2/3/11	x	4.05	x	x				-----		x	18	18	Oligotrophic
Orlando	North	5/3/11	x	2.54	x	x				-----		x	32	32	Oligotrophic
Orlando	North	8/9/11	x	2.74	x	x				-----		x	30	30	Oligotrophic
Orlando	North	10/26/11	x	2.61	x	x				-----		x	31	31	Oligotrophic
Orlando	North	2/21/12	x	4.33	x	x				-----		x	16	16	Oligotrophic
Orlando	North	5/1/12	x	2.39	x	x				-----		x	34	34	Oligotrophic
Orlando	North	7/17/12	x	2.92	x	x				-----		x	28	28	Oligotrophic

Summary of Historical Water Quality Data for Selected Parameters in Lake Holden

Data Source	Station Name	Sample Date	Chla (ugl)	Secchi (m)	Total N (ugl)	Total P (ugl)	TN/TP Ratio	Nutrient Limitation	TSI (TN)	TSI (TP)	TSI (Nut.)	TSI (Chyl-a)	TSI (SD)	FTSI (avg)	Trophic State
Orlando	South	3/15/01	x	0.41	1760	46	38	Phosphorus Limited	-------	67	67	x	87	77	Hypereutrophic
Orlando	South	5/10/01	x	0.45	1830	50	37	Phosphorus Limited	-------	69	69	x	84	76	Hypereutrophic
Orlando	South	7/24/01	x	0.54	1690	33	51	Phosphorus Limited	-------	59	59	x	78	69	Eutophic
Orlando	South	10/18/01	x	0.66	1370	39	35	Phosphorus Limited	-------	63	63	x	72	68	Eutophic
Orlando	South	2/28/02	x	0.65	1180	39	30	Phosphorus Limited	-------	63	63	x	73	68	Eutophic
Orlando	South	7/25/02	x	0.49	1430	23	62	Phosphorus Limited	-------	50	50	x	81	66	Eutophic
Orlando	South	11/1/02	x	0.67	1310	32	41	Phosphorus Limited	-------	58	58	x	72	65	Eutophic
Orlando	South	2/4/03	x	0.79	1260	46	27	Balanced	61	53	57	x	67	62	Eutophic
Orlando	South	4/29/03	x	0.48	1060	32	33	Phosphorus Limited	-------	58	58	x	82	70	Hypereutrophic
Orlando	South	7/29/03	x	0.74	1130	23	49	Phosphorus Limited	-------	50	50	x	69	60	Mesotrophic
Orlando	South	10/21/03	x	0.58	1320	32	41	Phosphorus Limited	-------	58	58	x	76	67	Eutophic
Orlando	South	1/22/04	x	0.74	1080	34	32	Phosphorus Limited	-------	59	59	x	69	64	Eutophic
Orlando	South	5/4/04	x	0.68	1360	40	34	Phosphorus Limited	-------	63	63	x	72	67	Eutophic
Orlando	South	7/29/04	x	0.91	1230	22	56	Phosphorus Limited	-------	49	49	x	63	56	Mesotrophic
Orlando	South	1/27/05	x	0.98	1020	24	43	Phosphorus Limited	-------	51	51	x	61	56	Mesotrophic
Orlando	South	5/10/05	x	0.54	1310	27	49	Phosphorus Limited	-------	54	54	x	78	66	Eutophic
Orlando	South	7/21/05	x	1.25	1050	17	62	Phosphorus Limited	-------	43	43	x	53	48	Oligotrophic
Orlando	South	11/10/05	x	1.15	670	12	56	Phosphorus Limited	-------	35	35	x	56	45	Oligotrophic
Orlando	South	1/26/06	x	0.58	860	13	66	Phosphorus Limited	-------	37	37	x	77	57	Mesotrophic
Orlando	South	5/18/06	x	0.52	610	20	31	Phosphorus Limited	-------	47	47	x	80	63	Eutophic
Orlando	South	7/18/06	x	0.35	770	16	48	Phosphorus Limited	-------	42	42	x	91	67	Eutophic
Orlando	South	10/24/06	x	0.35	830	9	92	Phosphorus Limited	-------	28	28	x	92	60	Mesotrophic
Orlando	South	1/16/07	x	0.75	870	15	58	Phosphorus Limited	-------	40	40	x	69	54	Mesotrophic
Orlando	South	4/24/07	x	0.87	1070	15	71	Phosphorus Limited	-------	40	40	x	64	52	Mesotrophic
Orlando	South	7/19/07	x	1.13	880	12	73	Phosphorus Limited	-------	35	35	x	56	46	Oligotrophic
Orlando	South	10/23/07	x	0.73	1000	17	59	Phosphorus Limited	-------	43		x	69	69	Eutophic
Orlando	South	1/31/08	x	1.13	x	x				-----		x	56	56	Mesotrophic
Orlando	South	4/22/08	x	0.99	x	x				-----		x	60	60	Eutophic
Orlando	South	8/7/08	x	1.06	x	x				-----		x	58	58	Mesotrophic
Orlando	South	10/21/08	x	0.76	x	x				-----		x	68	68	Eutophic
Orlando	South	1/29/09	x	2.97	x	x				-----		x	27	27	Oligotrophic
Orlando	South	5/7/09	x	3.32	x	x				-----		x	24	24	Oligotrophic
Orlando	South	8/11/09	x	2.28	x	x				-----		x	35	35	Oligotrophic
Orlando	South	10/22/09	x	1.77	x	x				-----		x	43	43	Oligotrophic
Orlando	South	2/11/10	x	3.80	x	x				-----		x	20	20	Oligotrophic
Orlando	South	4/20/10	x	3.28	x	x				-----		x	24	24	Oligotrophic
Orlando	South	8/5/10	x	2.98	x	x				-----		x	27	27	Oligotrophic
Orlando	South	10/26/10	x	2.46	x	x				-----		x	33	33	Oligotrophic
Orlando	South	2/3/11	x	3.95	x	x				-----		x	19	19	Oligotrophic
Orlando	South	5/3/11	x	2.50	x	x				-----		x	33	33	Oligotrophic
Orlando	South	8/9/11	x	2.75	x	x				-----		x	30	30	Oligotrophic
Orlando	South	10/26/11	x	3.40	x	x				-----		x	23	23	Oligotrophic
Orlando	South	2/21/12	x	4.00	x	x				-----		x	18	18	Oligotrophic
Orlando	South	5/1/12	x	2.53	x	x				-----		x	32	32	Oligotrophic
Orlando	South	7/17/12	x	3.60	x	x				-----		x	22	22	Oligotrophic

Summary of Historical Water Quality Data for Selected Parameters in Lake Holden

Data Source	Station Name	Sample Date	Chla (ugl)	Secchi (m)	Total N (ugl)	Total P (ugl)	TN/TP Ratio	Nutrient Limitation	TSI (TN)	TSI (TP)	TSI (Nut.)	TSI (Chyl-a)	TSI (SD)	FTSI (avg)	Trophic State
ERD	North	4/4/05	32.9	0.56	930	21	44	Phosphorus Limited	-------	48	48	67	77	64	Eutophic
ERD	North	4/11/05	25.1	1.07	728	13	56	Phosphorus Limited	-------	37	37	63	58	53	Mesotrophic
ERD	North	4/25/05	43.9	0.72	625	14	45	Phosphorus Limited	-------	38	38	71	70	60	Mesotrophic
ERD	North	5/20/05	52.6	0.47	1374	18	76	Phosphorus Limited	-------	44	44	74	83	67	Eutophic
ERD	North	6/22/05	28.3	0.85	558	12	47	Phosphorus Limited	-------	35	35	65	65	55	Mesotrophic
ERD	North	8/1/05	31.0	1.13	983	5	197	Phosphorus Limited	-------	14	14	66	56	46	Oligotrophic
ERD	North	8/29/05	33.6	0.79	1095	17	64	Phosphorus Limited	-------	43	43	67	67	59	Mesotrophic
ERD	North	9/16/05	11.4	1.41	566	5	113	Phosphorus Limited	-------	14	14	52	50	39	Oligotrophic
ERD	North	9/29/05	18.6	1.36	747	8	93	Phosphorus Limited	-------	25	25	59	51	45	Oligotrophic
ERD	North	10/18/05	23.4	1.20	1115	18	62	Phosphorus Limited	-------	44	44	62	55	54	Mesotrophic
ERD	North	11/28/05	14.6	1.23	865	15	58	Phosphorus Limited	-------	40	40	55	54	50	Oligotrophic
ERD	North	2/17/06	7.0	x	823	6	137	Phosphorus Limited	-------	18	18	45	x	32	Oligotrophic
ERD	North	3/1/06	2.3	x	482	2	241	Phosphorus Limited	-------	-7	-7	29	x	11	Oligotrophic
ERD	North	3/14/06	12.2	x	509	2	255	Phosphorus Limited	-------	-7	-7	53	x	23	Oligotrophic
ERD	North	3/20/06	4.2	x	667	1	667	Phosphorus Limited	-------	-24	-24	37	x	7	Oligotrophic
ERD	North	3/24/06	5.0	x	472	1	472	Phosphorus Limited	-------	-24	-24	40	x	8	Oligotrophic
ERD	North	5/2/06	8.3	x	470	9	52	Phosphorus Limited	-------	28	28	47	x	38	Oligotrophic
ERD	North	5/22/06	4.6	1.74	520	15	35	Phosphorus Limited	-------	40	40	39	43	41	Oligotrophic
ERD	North	6/30/06	15.9	1.15	670	10	67	Phosphorus Limited	-------	31	31	57	56	48	Oligotrophic
ERD	North	7/20/06	13.0	1.15	635	8	79	Phosphorus Limited	-------	25	25	54	56	45	Oligotrophic
ERD	North	8/24/06	20.3	0.85	680	13	52	Phosphorus Limited	-------	37	37	60	65	54	Mesotrophic
ERD	North	3/28/07	19.4	0.55	830	20	42	Phosphorus Limited	-------	47	47	59	78	61	Eutophic
ERD	North	4/23/07	14.4	0.83	903	11	82	Phosphorus Limited	-------	33	33	55	66	51	Mesotrophic
ERD	North	5/31/07	6.8	0.95	838	11	76	Phosphorus Limited	-------	33	33	44	62	46	Oligotrophic
ERD	North	6/29/07	8.9	1.13	604	9	67	Phosphorus Limited	-------	28	28	48	56	44	Oligotrophic
ERD	North	7/23/07	14.9	1.00	785	13	60	Phosphorus Limited	-------	37	37	56	60	51	Mesotrophic
ERD	North	8/28/07	16.2	0.84	774	17	46	Phosphorus Limited	-------	43	43	57	65	55	Mesotrophic
ERD	North	9/25/07	26.9	0.84	740	20	37	Phosphorus Limited	-------	47	47	64	65	59	Mesotrophic
ERD	North	10/23/07	27.9	0.72	771	26	30	Balanced	51	42	47	65	70	60	Eutophic
ERD	North	12/10/07	26.8	0.72	840	26	32	Phosphorus Limited	-------	53	53	64	70	62	Eutophic
ERD	North	1/28/08	24.8	0.89	623	15	42	Phosphorus Limited	-------	40	40	63	63	56	Mesotrophic
ERD	North	2/20/08	23.7	0.77	520	9	58	Phosphorus Limited	-------	28	28	62	68	53	Mesotrophic
ERD	North	1/5/10	6.3	1.41	549	10	55	Phosphorus Limited	-------	31	31	43	50	41	Oligotrophic
ERD	North	1/18/10	2.7	4.15	427	6	71	Phosphorus Limited	-------	18	18	31	17	22	Oligotrophic
ERD	North	3/24/10	5.2	2.91	461	9	51	Phosphorus Limited	-------	28	28	41	28	32	Oligotrophic
ERD	North	4/26/10	0.8	1.83	291	11	26	Balanced	32	26	29	14	42	28	Oligotrophic
ERD	North	5/24/10	2.9	2.98	497	8	62	Phosphorus Limited	-------	25	25	32	27	28	Oligotrophic
ERD	North	6/1/10	1.1	x	586	2	293	Phosphorus Limited				18	x	18	Oligotrophic
ERD	North	6/2/10	0.9	x	854	1	854	Phosphorus Limited				15	x	15	Oligotrophic
ERD	North	6/3/10	1.1	x	900	1	900	Phosphorus Limited				18	x	18	Oligotrophic
ERD	North	6/4/10	1.7	x	384	1	384	Phosphorus Limited				24	x	24	Oligotrophic
ERD	North	6/10/10	0.7	x	391	1	391	Phosphorus Limited				12	x	12	Oligotrophic
ERD	North	6/11/10	3.0	x	416	1	416	Phosphorus Limited				33	x	33	Oligotrophic
ERD	North	7/6/10	2.7	3.20	382	1	382	Phosphorus Limited				31	25	28	Oligotrophic
ERD	North	8/20/10	1.5	2.86	348	1	348	Phosphorus Limited				23	28	26	Oligotrophic
ERD	North	12/7/11	8.6	1.91	515	4	129	Phosphorus Limited	-------			48	41	44	Oligotrophic
ERD	North	1/23/12	4.6	3.81	481	1	481	Phosphorus Limited				39	20	29	Oligotrophic
ERD	North	2/6/12	8.4	3.89	409	2	205	Phosphorus Limited				47	19	33	Oligotrophic

Summary of Historical Water Quality Data for Selected Parameters in Lake Holden

Data Source	Station Name	Sample Date	Chla (ugl)	Secchi (m)	Total N (ugl)	Total P (ugl)	TN/TP Ratio	Nutrient Limitation	TSI (TN)	TSI (TP)	TSI (Nut.)	TSI (Chyl-a)	TSI (SD)	FTSI (avg)	Trophic State
ERD	South	4/4/05	49.2	0.71	818	21	39	Phosphorus Limited	-------	48	48	73	70	64	Eutophic
ERD	South	4/11/05	19.3	1.06	710	11	65	Phosphorus Limited	-------	33	33	59	58	50	Mesotrophic
ERD	South	4/25/05	44.9	0.73	1268	17	75	Phosphorus Limited	-------	43	43	72	69	61	Eutophic
ERD	South	5/20/05	55.3	0.48	1321	17	78	Phosphorus Limited	-------	43	43	75	82	67	Eutophic
ERD	South	6/22/05	27.9	0.88	621	13	48	Phosphorus Limited	-------	37	37	65	64	55	Mesotrophic
ERD	South	8/1/05	28.0	1.23	798	7	114	Phosphorus Limited	-------	22	22	65	54	47	Oligotrophic
ERD	South	8/29/05	39.8	0.79	1000	7	143	Phosphorus Limited	-------	22	22	70	67	53	Mesotrophic
ERD	South	9/16/05	15.8	1.43	739	8	92	Phosphorus Limited	-------	25	25	57	49	44	Oligotrophic
ERD	South	9/29/05	15.9	1.34	584	8	73	Phosphorus Limited	-------	25	25	57	51	44	Oligotrophic
ERD	South	10/18/05	20.2	1.27	833	15	56	Phosphorus Limited	-------	40	40	60	53	51	Mesotrophic
ERD	South	11/28/05	14.2	1.19	660	8	83	Phosphorus Limited	-------	25	25	55	55	45	Oligotrophic
ERD	South	2/17/06	5.7	x	837	12	70	Phosphorus Limited	-------	35	35	42	x	38	Oligotrophic
ERD	South	3/1/06	0.8	x	434	2	217	Phosphorus Limited	-------			14	x	14	Oligotrophic
ERD	South	3/14/06	4.1	x	519	2	260	Phosphorus Limited	-------			37	x	37	Oligotrophic
ERD	South	3/20/06	4.0	x	699	1	699	Phosphorus Limited	-------			37	x	37	Oligotrophic
ERD	South	3/24/06	5.7	x	494	1	494	Phosphorus Limited	-------			42	x	42	Oligotrophic
ERD	South	5/2/06	9.7	x	435	13	33	Phosphorus Limited	-------	37	37	49	x	43	Oligotrophic
ERD	South	5/22/06	4.2	1.76	500	13	38	Phosphorus Limited	-------	37	37	37	43	39	Oligotrophic
ERD	South	6/30/06	15.2	1.26	650	7	93	Phosphorus Limited	-------	22	22	56	53	44	Oligotrophic
ERD	South	7/20/06	12.5	1.14	587	16	37	Phosphorus Limited	-------	42	42	53	56	50	Mesotrophic
ERD	South	8/24/06	21.7	0.70	745	11	68	Phosphorus Limited	-------	33	33	61	71	55	Mesotrophic
ERD	South	3/28/07	19.4	0.78	876	15	58	Phosphorus Limited	-------	40	40	59	67	56	Mesotrophic
ERD	South	4/23/07	14.9	0.98	877	18	49	Phosphorus Limited	-------	44	44	56	61	54	Mesotrophic
ERD	South	5/31/07	9.5	1.03	859	16	54	Phosphorus Limited	-------	42	42	49	59	50	Oligotrophic
ERD	South	6/29/07	8.8	1.07	613	18	34	Phosphorus Limited	-------	44	44	48	58	50	Mesotrophic
ERD	South	7/23/07	16.4	0.84	827	17	49	Phosphorus Limited	-------	43	43	57	65	55	Mesotrophic
ERD	South	8/28/07	11.6	0.86	824	18	46	Phosphorus Limited	-------	44	44	52	65	54	Mesotrophic
ERD	South	9/25/07	22.9	0.84	469	22	21	Balanced	41	39	40	62	65	56	Mesotrophic
ERD	South	10/23/07	28.5	0.85	833	28	30	Balanced	52	44	48	65	65	59	Mesotrophic
ERD	South	12/10/07	19.0	0.72	941	28	34	Phosphorus Limited	-------	55	55	59	70	61	Eutophic
ERD	South	1/28/08	19.4	0.91	427	10	43	Phosphorus Limited	-------	31	31	59	63	51	Mesotrophic
ERD	South	2/20/08	20.3	0.89	409	19	22	Balanced	38	36	37	60	63	54	Mesotrophic
ERD	South	1/5/10	22.3	1.95	525	9	58	Phosphorus Limited	-------	28	28	62	40	43	Oligotrophic
ERD	South	1/18/10	1.6	4.19	416	17	24	Balanced	39	34	36	24	17	26	Oligotrophic
ERD	South	3/24/10	4.0	3.42	446	8	56	Phosphorus Limited	-------	25	25	37	23	28	Oligotrophic
ERD	South	4/26/10	1.8	2.79	259	5	52	Phosphorus Limited	-------	14	14	25	29	23	Oligotrophic
ERD	South	5/24/10	4.0	3.46	405	6	68	Phosphorus Limited	-------	18	18	37	23	26	Oligotrophic
ERD	South	7/6/10	1.6	3.84	389	1	389	Phosphorus Limited				24	20	22	Oligotrophic
ERD	South	8/20/10	1.9	3.44	864	1	864	Phosphorus Limited				26	23	24	Oligotrophic
ERD	South	2/6/12	3.9	4.76	399	4	100	Phosphorus Limited	-------	9	9	36	13	20	Oligotrophic
ERD	South	6/1/10	1.1	x	396	1	792	Phosphorus Limited				18	x	18	Oligotrophic
ERD	South	6/2/10	1.3	x	944	1	944	Phosphorus Limited				21	x	21	Oligotrophic
ERD	South	6/3/10	1.4	x	899	1	899	Phosphorus Limited				22	x	22	Oligotrophic
ERD	South	6/4/10	0.9	x	415	1	415	Phosphorus Limited				15	x	15	Oligotrophic
ERD	South	6/10/10	3.9	x	421	1	421	Phosphorus Limited				36	x	36	Oligotrophic
ERD	South	6/11/10	2.8	x	432	1	432	Phosphorus Limited				32	x	32	Oligotrophic
ERD	South	12/7/11	8.6	3.81	485	4	121	Phosphorus Limited	-------	9	9	48	20	26	Oligotrophic
ERD	South	1/23/12	1.3	3.11	464	3	155	Phosphorus Limited	-------	2	2	21	26	16	Oligotrophic

APPENDIX B

VISUAL CHARACTERISTICS OF SEDIMENT CORE SAMPLES COLLECTED IN LAKE HOLDEN

B-1. September 2003
B-2. May 2007
B-3. November 2008
B-4. April 2012

B-1. September 2003

VISUAL CHARACTERISTICS OF SEDIMENT CORE SAMPLES COLLECTED IN LAKE HOLDEN DURING SEPTEMBER 2003

SITE NO.	LAYER (cm)	VISUAL APPEARANCE
1	0-2	Dark brown unconsolidated organic muck with light brown sand
	2-13	Dark brown fine sand
	> 13	Dark brown consolidated organic muck with dark brown sand
2	0-6	Light brown sand with detritus
	> 6	Dark brown fine sand
3	0-18	Dark brown unconsolidated organic muck
	> 18	Dark brown consolidated organic muck
4	0 - > 10	Dark brown fine sand
5	0-2	Light green fine sand
	> 2	Light brown fine sand
6	0 - > 10	Dark brown fine sand
7	0-4	Light green fine sand
	4-7	Light brown fine sand
	> 7	Dark brown consolidated organic muck with dark brown sand
8	0-2	Light green fine sand with detritus
	> 2	Dark brown fine sand with shells
9	0-10	Dark brown fine sand with detritus
	> 10	Dark brown fine sand
10	0-7	Unconsolidated dark brown organic muck with dark brown sand
	7-11	Dark brown fine sand
	11-16	Dark brown fine sand with detritus
	> 16	Dark brown fine sand
11	0-5	Light green fine sand
	> 5	Dark brown fine sand
12	0-30	Dark brown unconsolidated organic muck
	> 30	Consolidated dark brown organic muck with dark brown sand
13	0-4	Dark brown fine sand
	> 4	Dark brown consolidated organic muck with sand
14	0-3	Light green fine sand
	3-6	Light brown fine sand
	6-17	Consolidated organic muck with dark brown fine sand
	> 17	Consolidated organic muck with light brown fine sand
15	0 - > 10	Dark brown fine sand
16	0 - > 22	Dark brown unconsolidated organic muck
17	0 - > 10	Dark brown fine sand
18	0-2	Light green fine sand
	> 2	Dark brown fine sand
19	0 - > 10	Dark brown fine sand
20	0-7	Dark brown unconsolidated organic muck
	7-15	Dark brown fine sand
	> 15	Light gray fine sand
21	0-11	Dark brown fine sand
	11-20	Light brown fine sand
	20-22	Medium gray fine sand
	> 22	Light brown fine sand
22	0-8	Dark brown fine sand
	8-14	Light gray fine sand
	> 14	Light brown fine sand

VISUAL CHARACTERISTICS OF SEDIMENT CORE SAMPLES COLLECTED IN LAKE HOLDEN DURING SEPTEMBER 2003

SITE NO.	LAYER (cm)	VISUAL APPEARANCE
23	0-6	Dark brown fine sand
	6-11	Medium gray fine sand
	11-14	Light brown fine sand
	14-16	Medium gray fine sand
	> 16	Light brown fine sand
24	0-2	Light green fine sand
	2-6	Dark brown fine sand
	6-8	Light brown fine sand
	8-13	Light gray fine sand
	> 13	Light brown fine sand
25	0-13	Dark brown fine sand
	13-15	Medium gray fine sand
	> 15	Light brown fine sand
26	0-22	Dark brown unconsolidated organic muck
	> 22	Dark brown consolidated organic muck
27	0 - > 10	Light brown fine sand
28	0-15	Dark brown fine sand
	> 15	Dark brown consolidated organic muck with detritus
29	0 - > 17	Dark brown fine sand
30	0-21	Dark brown unconsolidated organic muck
	> 21	Dark brown consolidated organic muck
31	0-2	Light green fine sand
	> 2	Light brown fine sand
32	0-2	Medium gray fine sand
	2-7	Light brown fine sand
	7-10	Medium gray fine sand
	10-13	Light brown fine sand
	13-18	Medium gray fine sand
	18-22	Light brown fine sand
	> 22	Medium gray fine sand
33	0-9	Dark brown fine sand
	9-12	Medium gray fine sand
	> 12	Light brown fine sand
34	0-6	Dark brown unconsolidated organic muck
	6-8	Dark brown fine sand
	8-11	Light gray fine sand
	> 11	Dark brown fine sand
35	0-14	Dark brown unconsolidated organic muck
	14-27	Dark brown consolidated organic muck
	> 27	Dark brown consolidated organic muck with dark brown sand
36	0-8	Dark brown unconsolidated organic muck
	8-14	Dark brown fine sand
	> 14	Dark brown consolidated organic muck
37	0-3	Dark brown unconsolidated organic muck
	3-12	Brown fine sand
	12-17	Tan/brown fine sand
	> 17	Light gray fine sand

VISUAL CHARACTERISTICS OF SEDIMENT CORE SAMPLES COLLECTED IN LAKE HOLDEN DURING SEPTEMBER 2003

SITE NO.	LAYER (cm)	VISUAL APPEARANCE
38	0-7 > 7	Brown fine sand Brown/black fine sand mix
39	0-7 > 7	Dark brown unconsolidated organic muck Dark brown consolidated organic muck
40	0-23 > 23	Dark brown unconsolidated organic muck Dark brown consolidated organic muck
41	0-7 > 7	Dark brown unconsolidated organic muck Dark brown consolidated organic muck
42	0-2 2-16 > 16	Dark brown unconsolidated organic muck Dark brown consolidated organic muck Brown/black fine sand
43	0-7 > 7	Dark brown unconsolidated organic muck Dark brown consolidated organic muck
44	0 - > 10	Brown fine sand

B-2. May 2007

VISUAL CHARACTERISTICS OF SEDIMENT CORE SAMPLES COLLECTED IN LAKE HOLDEN DURING MAY 2007

SITE NO.	LAYER (cm)	VISUAL APPEARANCE
1	0 - >26	Light brown fine sand
2	0 - >13	Light brown fine sand with detritus
3	0 – 4 4 – 23 23 - >26	Dark brown unconsolidated organic muck Dark brown consolidated muck Black consolidated muck
4	0 - >16	Light brown fine sand
5	0 - >27	Light brown fine sand
6	0 - >16	Dark brown fine sand
7	0 – 12 12 - >22	Light brown fine sand Dark brown fine sand
8	0 - >28	Light brown fine sand
9	0 – 10 10 - >32	Dark brown fine sand with detritus Light brown fine sand
10	0 - >19	Light brown fine sand
11	0 - >21	Light brown fine sand
12	0 – 2 2 – 16 16 - >31	Dark brown unconsolidated organic muck with visible floc Dark brown consolidated organic muck Light brown fine sand with organics
13	0 – 7 7- >30	Light brown fine sand Light brown fine sand with brown organics
14	0 – 3 3 – 12 12 - >22	Light brown fine sand Light brown fine sand with organics Light brown fine sand with detritus
15	0 - >31	Light brown fine sand
16	0 – 2 2 – 9 9 - >24	Dark brown unconsolidated organic muck Dark brown consolidated organic muck Light brown fine sand with organics
17	0 - >17	Light brown fine sand
18	0 – 2 2 – 13 13 - >23	Light brown fine sand with green algae Light brown fine sand Light brown fine sand with organics
19	0 – 3 3 - >31	Dark brown fine sand with green algae Dark brown fine sand
20	0 – 13 13 - >26	Dark brown fine sand Dark brown fine sand with organics
21	0 – 5 5 – 17 17 - >24	Light brown fine sand Light brown fine sand with organics Light brown fine sand
22	0 – 8 8 - >20	Light brown fine sand Light brown fine sand with organics
23	0 – 4 4 - >26	Dark brown fine sand Light brown fine sand with organics
24	0 – 7 7 - >22	Light brown fine sand Light brown fine sand with organics

VISUAL CHARACTERISTICS OF SEDIMENT CORE SAMPLES COLLECTED IN LAKE HOLDEN DURING MAY 2007

SITE NO.	LAYER (cm)	VISUAL APPEARANCE
25	0 – 9	Dark brown fine sand
	9 - >22	Light brown fine sand
26	0 – 3	Dark brown unconsolidated organic muck with visible floc
	3 – 58	Dark brown consolidated organic muck
	58 - >60	Light brown fine sand with organics
27	0 – 2	Light brown fine sand
	2 – 26	Light brown fine sand with organics
	26 - >31	Light brown fine sand
28	0 – 2	Light brown fine sand with green algae
	2 - >16	Light brown fine sand with organics
29	0 – 4	Dark brown fine sand
	4 – 10	Light brown fine sand with organics
	10 - >21	Light brown fine sand
30	0 – 5	Dark brown unconsolidated organic muck with visible floc
	5 - >51	Dark brown consolidated organic muck
31	0 – 5	Light brown fine sand with green algae
	5 - >29	Light brown fine sand
32	0 - >11	Light brown fine sand with organics
33	0 – 3	Dark brown fine sand with green algae
	3 – 9	Dark brown fine sand with organics
	9 - >31	Light brown fine sand
34	0 – 15	Light brown fine sand
	15 – 21	Light brown fine sand with organics
	21 - >32	Light brown fine sand
35	0 – 3	Dark brown unconsolidated organic muck
	3 – 31	Dark brown consolidated organic muck
	31 - >42	Dark brown fine sand with organics
36	0 – 8	Dark brown fine sand with detritus
	8 – 28	Light brown fine sand
	28 - >42	Light brown fine sand with organics
37	0 - >18	Light brown fine sand
38	0 – 20	Light brown fine sand
	20 - >31	Light brown fine sand with organics
39	0 - >23	Light brown fine sand with organics
40	0 – 1	Light brown fine sand
	1 – 21	Light brown fine sand with organics
	21 - >25	Light brown fine sand (bleached/almost white)
41	0 – 5	Dark brown unconsolidated organic muck with visible floc
	5 – 22	Dark brown consolidated organic muck with visible floc
	22 - >51	Black consolidated organic muck
42	0 – 2	Dark brown unconsolidated organic muck with visible floc
	2 - >25	Light brown fine sand with organics
43	0 – 4	Dark brown unconsolidated organic muck with visible floc
	4 – 19	Dark brown consolidated organic muck with visible floc
	19 - >51	Black consolidated organic muck
44	0 – 8	Dark brown fine sand with organics
	8 - >18	Light brown fine sand with organics

B-3. November 2008

VISUAL CHARACTERISTICS OF SEDIMENT CORE SAMPLES COLLECTED IN LAKE HOLDEN LAKE ON NOVEMBER 13, 2008

SITE NO.	LAYER (cm)	VISUAL APPEARANCE
1	0 – 0.5	Dark brown unconsolidated organic muck
	0.5 - >19	Light brown fine sand with organics
2	0 – 0.5	Dark brown unconsolidated organic muck
	0.5 - >16	Light brown fine sand with organics
3	0 – 4	Dark brown unconsolidated organic muck with visible floc
	4 – 15	Dark brown consolidated organic muck with visible floc
	15 – 29	Dark brown consolidated muck
	29 - >60	Black consolidated muck
4	0 - >18	Light brown fine sand
5	0 – >19	Light brown fine sand
6	0 - >19	Dark brown fine sand
7	0 – 0.25	Dark brown unconsolidated organic muck
	0.25 - >22	Light brown fine sand
8	0 – >21	Light brown fine sand
9	0 – >17	Dark brown fine sand
10	0 – 3	Dark brown unconsolidated organic muck
	3 - >18	Light brown fine sand
11	0 - >17	Light brown fine sand
12	0 – 6	Dark brown unconsolidated organic muck with visible floc
	6 – 8	Dark brown consolidated organic muck with visible floc
	8 – 39	Dark brown consolidated organic muck
	39 - >52	Light brown fine sand with organics
13	0 - >19	Dark brown fine sand
14	0 – 0.5	Dark brown unconsolidated organic muck with visible floc
	0.5 - >31	Light brown fine sand
15	0 - >20	Light brown fine sand
16	0 – 0.5	Dark brown unconsolidated organic muck with visible floc
	0.5 – 3	Light brown fine sand with organics and visible floc
	3 – 22	Light brown fine sand with organics
	22 - >26	Light brown fine sand
17	0 – 6	Light brown fine sand
	6 - >24	Light brown fine sand with organics
18	0 – 0.5	Dark brown unconsolidated organic muck with visible floc
	0.5 - >24	Light brown fine sand
19	0 – 15	Dark brown fine sand
	15 - >27	Dark brown fine sand with organics
20	0 - >27	Dark brown fine sand with organics
21	0 – 13	Dark brown fine sand
	13 – >34	Light brown fine sand with organics
22	0 – 4	Light brown fine sand
	4 - >21	Light brown fine sand with organics
23	0 – 5	Dark brown fine sand
	5 - >25	Dark brown fine sand with organics
24	0 - >22	Light brown fine sand
25	0 – 0.5	Dark brown fine sand with organics and visible floc
	0.5 – 10	Light brown fine sand with organics
	10 - >21	Light brown fine sand

VISUAL CHARACTERISTICS OF SEDIMENT CORE SAMPLES COLLECTED IN LAKE HOLDEN LAKE ON NOVEMBER 13, 2008

SITE NO.	LAYER (cm)	VISUAL APPEARANCE
26	0 – 4	Dark brown unconsolidated organic muck with visible floc
	4 – 18	Dark brown consolidated organic muck
	18 - >66	Black consolidated organic muck
27	0 - >31	Light brown fine sand
28	0 - >19	Light brown fine sand with organics
29	0 - >14	Dark brown fine sand
30	0 – 1	Dark brown unconsolidated organic muck with visible floc
	1 - >61	Dark brown consolidated organic muck
31	0 - >14	Light brown fine sand with green algae
32	0 - >14	Light brown fine sand with organics
33	0 – 6	Dark brown fine sand
	6 – 18	Light brown fine sand with organics
	18 - >24	Light brown fine sand
34	0 – 0.5	Dark brown unconsolidated organic muck with visible floc
	0.5 - >20	Dark brown fine sand with organics
35	0 – 13	Dark brown unconsolidated organic muck
	13 – 50	Dark brown consolidated organic muck
	50 - >74	Dark brown fine sand with organics
36	0 – 6	Dark brown fine sand
	6 - >26	Light brown fine sand with organics
37	0 – 0.5	Dark brown unconsolidated organic muck with visible floc
	0.5 – 6	Light brown fine sand with organics
	6 – 16	Light brown fine sand
	16 – 20	Light brown fine sand with organics
	20 - >22	Light brown fine sand
38	0 - 9	Dark brown fine sand
	9 - >16	White sand
39	0 - >34	Light brown fine sand with organics
40	0 – 0.5	Dark brown unconsolidated organic muck with visible floc
	0.5 – 7	Light brown fine sand with organics
	7 - >28	Light brown fine sand
41	0 – 4	Dark brown unconsolidated organic muck with visible floc
	4 – 19	Dark brown consolidated organic muck with visible floc
	19 - >60	Black consolidated organic muck
42	0 – 4	Dark brown unconsolidated organic muck with visible floc
	4 – 16	Dark brown consolidated organic muck with visible floc
	16 - >32	Light brown find sand with organics
43	0 – 5	Dark brown unconsolidated organic muck with visible floc
	5 – 20	Dark brown consolidated organic muck with visible floc
	20 - >58	Black consolidated organic muck
44	0 - >17	Brown fine sand with organics

B-4. April 2012

VISUAL CHARACTERISTICS OF SEDIMENT CORE SAMPLES COLLECTED IN LAKE HOLDEN ON APRIL 26, 2012

SITE NO.	LAYER (cm)	VISUAL APPEARANCE
1	0-0.5	Dark brown unconsolidated organic muck with floc
	0.5 - >22	Light brown fine sand with organics
2	0-0.5	Dark brown unconsolidated organic muck with floc
	0.5 - >19	Light brown fine sand with organics
3	0-5	Dark brown unconsolidated organic muck with floc
	5-22	Light brown consolidated organic muck with floc
	22 - >41	Dark brown consolidated organic muck
4	0-0.5	Dark brown unconsolidated organic muck
	0.5-15	Light brown fine sand with organics
	15 - >19	light brown fine sand
5	0-0.5	Dark brown unconsolidated organic muck
	0.5 - >21	Light brown fine sand with organics
6	0-15	Light brown fine sand with organics
	15 - >21	Light brown fine sand
7	0-4	Light brown fine sand with green algae
	4 - >22	Light brown fine sand with organics
8	0-8	Light brown fine sand with green algae
	8 - >21	Light brown fine sand with organics
9	0-8	Light brown fine sand with organics
	8 - >19	Light brown fine sand
10	0 - >18	Light brown fine sand
11	0-1	Dark brown unconsolidated organic muck with floc
	1-16	Light brown fine sand with organics
	16 - >21	Light brown fine sand
12	0-1	Dark brown unconsolidated organic muck
	1-13	Dark brown consolidated organic muck
	13 - >31	Light brown fine sand with organics
13	0-0.5	Dark brown unconsolidated organic muck
	0.5-8	Light brown fine sand
	8 - >22	Light brown fine sand with organics
14	0-0.5	Floc with green algae
	0.5-6	Light brown fine sand
	6 - >21	Light brown fine sand with organics
15	0-2	Light brown fine sand with organics and floc
	2 - >12	Light brown fine sand
16	0-0.5	Floc
	0.5 - >26	Light brown fine sand with organics
17	0-0.25	Floc
	0.25 - >11	Light brown fine sand with organics
18	0 - >14	Light brown fine sand with organics
19	0-4	Light brown fine sand with organics
	4-16	Light brown fine sand
	16-26	Light brown fine sand with organics
	26-31	light brown fine sand
	31 - >43	Light brown fine sand with organics

VISUAL CHARACTERISTICS OF SEDIMENT CORE SAMPLES COLLECTED IN LAKE HOLDEN ON APRIL 26, 2012

SITE NO.	LAYER (cm)	VISUAL APPEARANCE
20	0-5	Dark brown unconsolidated organic muck with floc
	5-36	Light brown fine sand with organics
	36 - >41	White fine sand
21	0-0.5	Dark brown unconsolidated organic muck with floc
	0.5-8	light brown fine sand
	8-14	Light brown fine sand with organics
	14 - >19	Light brown fine sand
22	0 - >14	Light brown fine sand with organics
23	0 - >17	Light brown fine sand with organics
24	0-4	Light brown fine sand
	4 - >18	Light brown fine sand with organics
25	>0≤14	Light brown fine sand with organics
26	0-4	Dark brown unconsolidated organic muck with floc
	4-22	Light brown consolidated organic muck with floc
	22 - >46	Dark brown consolidated organic muck
27	0-4	Light brown fine sand with organics
	4 0 >21	Light brown fine sand
28	0 - >13	Light brown fine sand with organics
29	0 - >14	Light brown fine sand with organics
30	0-9	Dark brown unconsolidated organic muck with floc
	9-18	Light brown consolidated organic muck with floc
	18 - >54	Dark brown consolidated organic muck
31	0-1	Dark brown unconsolidated organic muck with floc and algae
	1 - >16	Light brown fine sand
32	0 - >15	Light brown fine sand with organics
33	0-0.5	Floc
	0.5 - >12	Light brown fine sand with organics
34	0-5	Light brown fine sand with algae
	5 - >34	Light brown fine sand with organics
35	0-6	Dark brown unconsolidated organic muck with floc
	6-50	Dark brown consolidated organic muck
	50 - >57	Light brown fine sand with organics
36	0-8	Light brown fine sand with organics
	8-18	Light brown fine sand
	18 - >43	Dark brown consolidated organic muck
37	0-0.5	Algae and floc
	0.5 - >13	Light brown fine sand with organics
38	0-3	Dark brown unconsolidated organic muck with floc
	3-19	Light brown consolidated organic muck with floc
	19 - >48	Dark brown consolidated organic muck
39	0-6	Dark brown unconsolidated organic muck
	6-32	Dark brown consolidated organic muck
	32->41	Light brown fine sand with organics
40	0-3	Dark brown unconsolidated organic muck with floc
	3-31	Light brown consolidated organic muck with floc
	31 - >62	Dark brown consolidated organic muck

VISUAL CHARACTERISTICS OF SEDIMENT CORE SAMPLES COLLECTED IN LAKE HOLDEN ON APRIL 26, 2012

SITE NO.	LAYER (cm)	VISUAL APPEARANCE
41	0-1	Dark brown unconsolidated organic muck with floc
	1- >20	Light brown fine sand with organics
42	0-4	Dark brown unconsolidated organic muck with floc
	4-26	Light brown consolidated organic muck with floc
	26 - >48	Dark brown consolidated organic muck
43	0 - >9	Light brown fine sand
44	0-3	Light brown fine sand with organics
	3-12	Light brown fine sand
	12 - >41	Light brown fine sand with organics