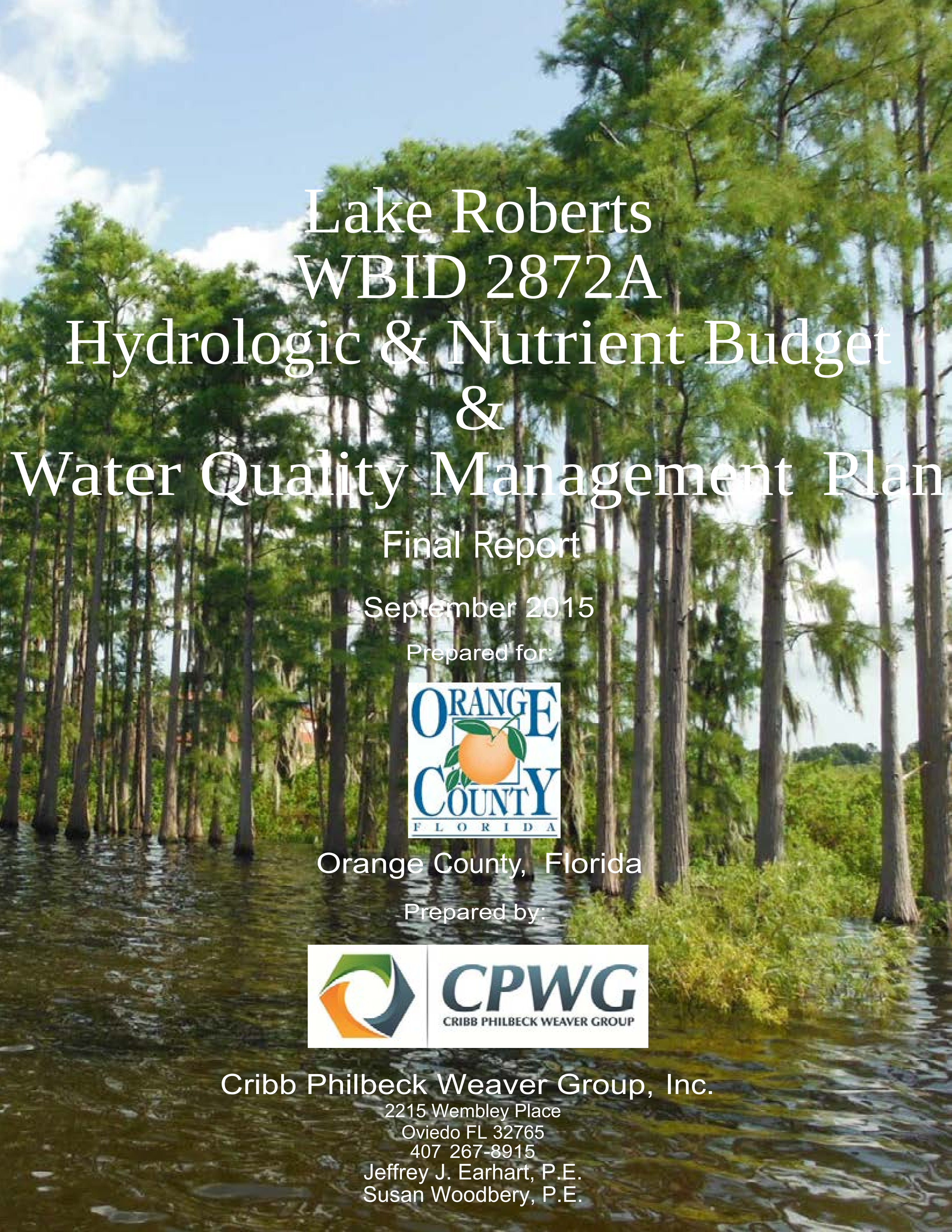

Lake Roberts
WBID 2872A
Hydrologic & Nutrient Budget
&
Water Quality Management Plan

Final Report

September 2015

Prepared for:

Orange County, Florida

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ACKNOWLEDGMENTS

A report of this magnitude requires the cooperation of many people to bring it to a successful completion. The continued interest and support of the Board of County Commissioners is gratefully acknowledged. The direction, assistance and guidance of the Environmental Protection Division, specifically the Water Sciences Section, throughout the project development were greatly appreciated.

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EXECUTIVE SUMMARY

Lake Roberts is a 108-acre urban lake located approximately 10 miles southwest of downtown Orlando and just southwest of the City of Winter Garden. This study reviews existing water quality information, estimates hydrologic flows, estimates nutrient inputs and outputs, and provides recommendation to reduce nutrient accumulation in Lake Roberts. This watershed study was completed for the Orange County Environmental Protection Division by Cribb Philbeck Weaver Group (CPWG), Team Engineering (TEAM) and Environmental Research & Design, Inc. (ERD).

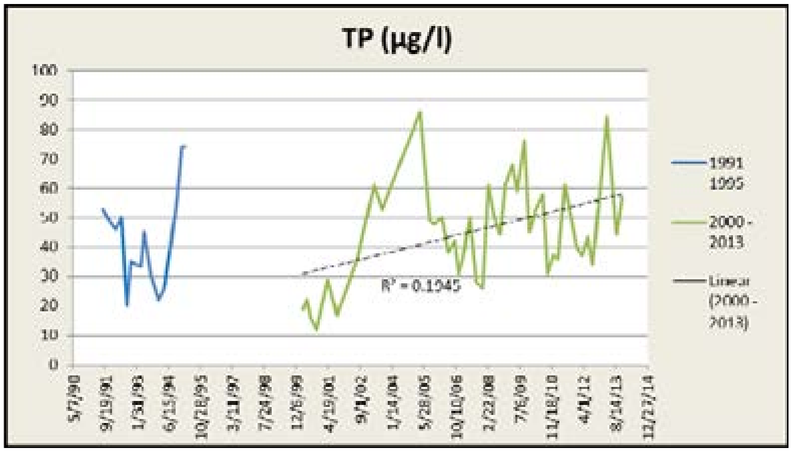
The watershed areas surrounding the lake are somewhat developed, with mostly residential and wetland land uses. Lake Reaves to the north flows through a wetland tussock into Lake Roberts. Lake Roberts discharges to the west through a pipe and through a wetland system before flowing into Lake Tilden and Black Lake. A summary of Lake Roberts' bathymetric characteristics are presented below.

Bathymetric Characteristics of Lake Roberts

Bathymetric Parameter[1]	Value
Surface Area	108 acres
Total Volume	1,066 ac-ft
Mean Depth	9.8 ft
Maximum Depth	19.7 ft.
Shoreline Length	12,010 ft / 2.27 miles
Shoreline Development	8,500 ft / 1.61 miles

1. Based upon a water surface elevation of 108.98 ft. (NAVD)

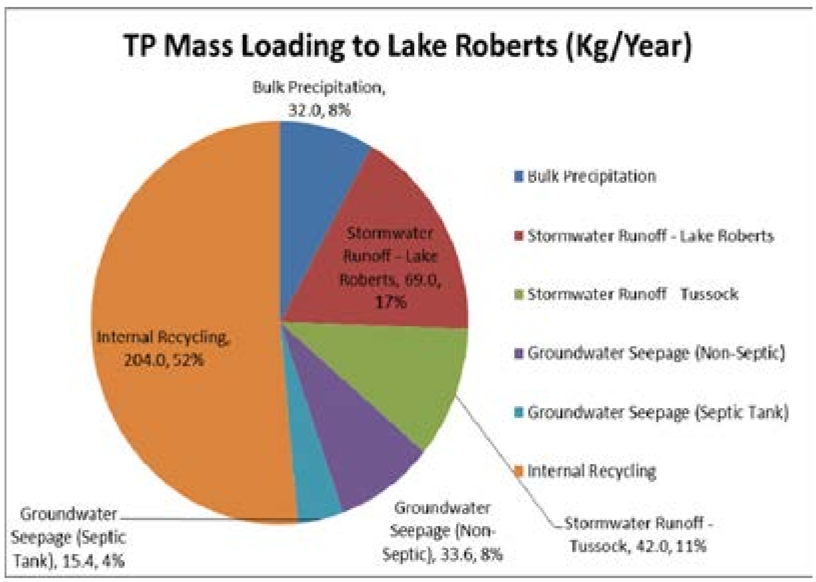
Lake Roberts has evidenced increased nutrient levels during the past several years, as illustrated in the Total Phosphorus (TP) graph below. These higher nutrient levels have contributed to several algae blooms within Lake Roberts. Historical water quality in Lake Roberts has been somewhat variable, but primarily characteristic of a eutrophic lake.



Section 303(d) of the Clean Water Act (CWA) requires states to submit lists of surface waterbodies that do not meet applicable water quality standards. Lake Roberts was verified as impaired for nutrients due to elevated annual average Trophic State Index (TSI) values (exceedance of the annual average TSI threshold of 60), and was included on the Verified List of impaired waters for the Ocklawaha River Basin that was adopted by the FDEP Secretarial Order on February 12, 2013. Lake Roberts was initially verified for nutrient impairment by FDEP based on TSI (exceedance of the annual average TSI threshold of 60). The Numeric Nutrient Criteria (NNC) was adopted in Florida on July 3, 2012, to further assess the impairment of inland waters. The numeric nutrient criteria maximum annual mean value within a high colored lake for impairment (Lake Roberts color exceeds 40 PCU) is 0.16 mg/l for TP, 2.23 mg/l, for TN and 20 μg/l for chlorophyll a. Historical values of TP and chlorophyll-a exceeded the NNC values established for lakes. Therefore, the FDEP will continue to classify Lake Roberts as impaired. The impairment was based on elevated TSI for the years 2005 and 2007 through 2010, inclusive. According to the 1999 Florida Watershed Restoration Act (FWRA), Chapter 99-223, Laws of Florida, once a waterbody is included on the Verified List, a TMDL must be developed. The purpose of the TMDL is to establish the allowable loadings of pollutants to Lake Roberts that would restore the waterbody so that it meets its applicable water quality criteria for nutrients. Based on the March 5, 2015 Florida Department of Environmental Protections' Report entitled "TMDL Report Nutrient TMDL for Lake Roberts (WBID 2871A) and Documentation in Support of the Development of Site Specific Numeric Interpretations of the Narrative Nutrient Criteria," the TN and TP concentration targets for Lake

Roberts are 0.959 mg/l and TP 0.041 mg/l, respectively. As of this writing, the Florida Department of Environmental Protection has not formally accepted these concentration targets.

Work efforts were initiated on this project by CPWG during September 2013 to assist in developing an action plan for the forthcoming Lake Roberts' TMDL. The primary objective of this project is to quantify pollutant loadings to the lake and identify areas or opportunities where nutrient load reductions could be achieved to improve water quality within the lake. A field monitoring program was conducted from September 2013 through December 2014 to collect hydrologic and water quality data for use in developing hydrologic and nutrient budgets for the lake. The hydrologic budget includes estimated inputs from precipitation, stormwater runoff, and groundwater seepage. The nutrient budget includes inputs from bulk precipitation, stormwater runoff, groundwater seepage, and internal recycling. A detailed evaluation of sediment characteristics in Lake Roberts was also conducted which included physical and chemical characterization of surficial sediments and evaluation of internal phosphorus recycling. The distribution of Total Phosphorus entering Lake Roberts is presented below.



Specific nutrient load reduction projects were evaluated and recommended to reduce nutrients entering the lake and to improve water quality.

Recommendations

Water quality maintenance and improvement options for Lake Roberts are summarized in the following paragraphs and are summarized in the table at the end of this section. The evaluated water quality improvement options are designed to target sources which have been identified as significant contributors of nutrient loadings to the lake. The evaluated options include both structural and non-structural approaches to controlling and reducing pollutant inputs into Lake Roberts.

Alum Treatments

Sediment inactivation in Lake Roberts would involve addition of liquid aluminum-based coagulants at the water surface. Upon entering the water, the coagulants form insoluble precipitants with phosphorus in the water column. These precipitants then settle onto the lake bottom clarifying the water column within the lake. The coagulant also combines with phosphorus within the sediments, forming saloid- and iron-bound complexes, making phosphorus within the sediment unavailable to the overlying water column. 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 aluminum to bind the saloid- and iron-bound phosphorus associations in the top 10 cm of the sediments.

Sanitary Sewer Installation

A majority of the existing homes around Lake Roberts are serviced by on-site sewage treatment and disposal systems, commonly known as septic tanks. Based on a literature review, an average septic tank will leach 15.4 kg/year of TP and 447 kg/year of TN to the lake. There are over 200 homes utilizing septic tanks within the Lake Roberts watershed. The loading above are only based on the 57 houses that are directly adjacent to Lake Roberts. This alternative is to replace the existing septic systems with a central sewer system.

Septic Tank Maintenance / Upgrading Septic System

Failing or unmaintained septic system can contribute substantially more nutrients to waterbodies than well maintained septic systems. The EPA's "A Homeowner's Guide to Septic Systems" is presented in Appendix 6-1. The document discusses: 1) Your septic system is your responsibility, 2) How does is work?, 3) Why should I maintain my septic system?, 4) How do I maintain my septic system?, and 5) What can make my system fail? A septic tank inspection may include: locating the system, uncovering access holes, flushing toilets, checking for signs of back up, measuring scum and sludge layers, identifying any leaks, inspecting mechanical components, and pumping the tank if necessary.

Rear Yard Swales and Berms

Runoff originating from lawns and landscaped areas has the potential to contribute significant loadings of both nutrients and pesticides into Lake Roberts. Untreated stormwater runoff from lawns and landscaped areas contains total phosphorus concentrations which are often 25-50 times greater than concentrations commonly observed in Lake Roberts. As a result, a relatively small volume of untreated rear yard runoff can impact a large quantity of adjacent water. Runoff originating from direct overland flow into Lake Roberts contributes approximately 28% of the annual phosphorus loadings to the lake.

Berm and swale systems are a relatively inexpensive method of reducing direct discharges of runoff into Lake Roberts. The anticipated capital cost for this option is relatively small compared with costs normally associated with lake restoration projects. The proposed berm and swale systems would provide stormwater treatment for a large portion of the currently untreated areas which discharge directly into the lake. Therefore, it is recommended that rear yard swales and berms be implemented, to the extent practicable.

Landscape Activities

Improper landscape and lawn maintenance activities which included blowing lawn clippings, leaves, and other vegetation debris onto paved or roadway surfaces, or directly into a waterbody, as well as improper application of both granular and liquid fertilizers to impervious surfaces and roadways are another source of pollutants to Lake Roberts. When grass clippings and fertilizers are introduced onto impervious surfaces, they become available for mobilization by stormwater runoff during rain events, causing them to be deposited into the nearest waterbody during storm events. These types of lawn maintenance practices have the potential to significantly increase nutrient loadings to Lake Roberts.

Floating Wetlands

Floating wetland islands are a combination of plants floating on platforms in a lake or pond. These floating wetlands have been used to reduce nitrogen and phosphorus concentrations in lakes through uptake of nutrients by the plant material in the islands. Floating wetlands remove pollutants by directly assimilating them into their macrophytes as well as providing a suitable environment for microorganisms to decompose or transform pollutants to the gas phase, which reduced their concentrations in pond water. The islands can be allowed to float across the lake, or be anchored in a stationary spot. These systems can be combined with aeration and circulation system to increase pollutant removal efficiencies.

Vegetated Shorelines Wetlands

The shoreline areas surrounding Lake Roberts exhibit a wide variety of both species and density of aquatic vegetation which range from natural vegetated shorelines, to planted shorelines, to cleared and bare shorelines. Several of the shoreline residents have removed virtually all aquatic vegetation from shoreline areas adjacent to their properties. Many areas exist where the rear lawn extends to the water's edge with no shoreline vegetation at all. It is recommended that shoreline vegetation be maintained over 80% of the shoreline.

Harvest and Dredge Stationary Wetland Tussock

Based on the collected data, the wetland tussock between Lake Roberts and Lake Reaves is acting as a pollutant source to Lake Roberts. This alternative is to harvest or prescribe burn the wetland tussock. This would remove the biomass, as well as, influx of nutrients from the floating wetland tussock.

Golf Course Treatment and Outfall Enhancement

The northwest portion of the Windermere Country Club Golf Course currently drains to a generally dry depressional area before discharging directly to Lake Roberts. Two BMPs are recommended at this location, one being a wet detention pond and the second being a bioretention area.

Inlet Baskets

Installation of curb and grate inlet filters within the Lake Roberts watershed would collect leaves, trash, large sand, and other debris present in the generated stormwater runoff prior to discharge into the lake or the wet detention pond. Curb inlet baskets (CIBs) and grate inlet baskets (GIBs), also referred to as catch basin basket inserts (or inlet baskets), are a retrofit-type BMP designed to filter pollutants, leaf litter, and sediments from stormwater before the pollutants enter the stormsewer system. These units are installed in individual inlets or grate inlets and are made of durable material, such as stainless steel and high-strength plastic.

Baffle Boxes

Nutrient separating baffle boxes, on average, remove 16% for TP and 19% for TN. Bold and Gold or other media can be added to baffle boxes to increase their nutrient removal efficiencies. Three locations within the Lake Roberts watershed are included as baffle box location alternatives: 1) Lake Roberts Court on the eastern shoreline 2) Water Point Boulevard on the southwestern shoreline and 3) Windermere Golf Course Outfall on the eastern shore.

Other non-structure techniques that can reduce nutrient loads to Lake Roberts include: Florida Yards and Neighborhoods Program, Street Sweeping, Public Education, and Boating Restrictions

Recommended Management Options for Lake Roberts

Option	Description	TP *** Percent Reduction	TN *** Percent Reduction	TP Removed (kg/yr)	TN Removed (kg/yr)	Required TP Reduction* (kg/yr)	Required TN Reduction* (kg/yr)	% of Goal	% of Goal	Cost
1	Sediment Inactivation (soil)**	90	50	1,464.0	0.0	46	321	3,182.6%	0.0%	$223,736
2	Sediment Inactivation (groundwater)**	90	50	49.0	0.0	46	321	106.5%	0.0%	$7,489
3	Sanitary Sewer Installation	100	100	7,866.0	25,479.0	46	321	17,100.0%	7937.4%	$3,000,000
4	Septic Tank Maintenance/Upgrading Septic System	NA	NA	NA	NA	46	321	NA	NA	$570,000
5	Rear Yard Swales and Berms	52	52	4.2	31.1	46	321	9.1%	NA	$285,000
6	Vegetated Shorelines	NA	NA	NA	NA	46	321	NA	NA	NA
7	Landscape Activities	NA	NA	NA	NA	46	321	NA	NA	NA
8	Floating Wetlands	12	12	8.0	158.0	46	321	17.4%	49.2%	$1,398,276
9	Harvest and Dredge Wetland Area****	100	100	23.2	152.0	46	321	50.4%	47.4%	$600,000
10	Golf Course Treatment Bioretention	25	40	0.2	2.9	46	321	0.4%	0.9%	$93,000
11	Golf Course Treatment Wet Pond	50	30	0.4	2.2	46	321	0.9%	0.7%	$185,000
12	Inlet Baskets	NA	NA	42.5	116.5	46	321	92.4%	36.3%	$85,000
13	Baffle Box - Water Point Blvd.	16	19	0.7	6.6	46	321	1.4%	2.1%	$70,000
14	Baffle Box - Lake Roberts Court	16	19	1.1	13.3	46	321	2.4%	4.1%	$70,000
15	Baffle Box - Windermere Golf Course Outfall	16	19	0.1	1.4	46	321	0.2%	0.4%	$70,000
16	Baffle Box with Bold and Gold- Water Point Blvd.	79	67	3.2	23.4	46	321	7.0%	7.3%	$75,500
17	Baffle Box with Bold and Gold- Lake Roberts Court	79	67	5.5	46.9	46	321	12.0%	14.6%	$75,500
18	Baffle Box with Bold and Gold - Windermere Golf Course Outfall	79	67	0.6	4.8	46	321	1.3%	1.5%	$75,500
19	Street Sweeping	NA	NA	3.6	57.0	46	321	7.8%	17.8%	$40,352
20	Public Education	NA	NA	NA	NA	46	321	NA	NA	NA
21	Boating Impacts	NA	NA	NA	NA	46	321	NA	NA	NA

* Based on pollutant removal targets in FDEP's "TMDL Report Nutrient TMDL for Lake Roberts (WBID 2872A)", March 5, 2015 Draft Version
** Based on one complete application –successive applications do not apply. Cost assumes items 1 and 2 are performed at the same time
*** Based on Basin Management Action Plan for Lake Okeechobee and other sources as sited in the report
**** Only assumes removal of nutrient released from the wetland. The actual TP and TN reduction due to biomass removal may be much greater.

1.0 INTRODUCTION

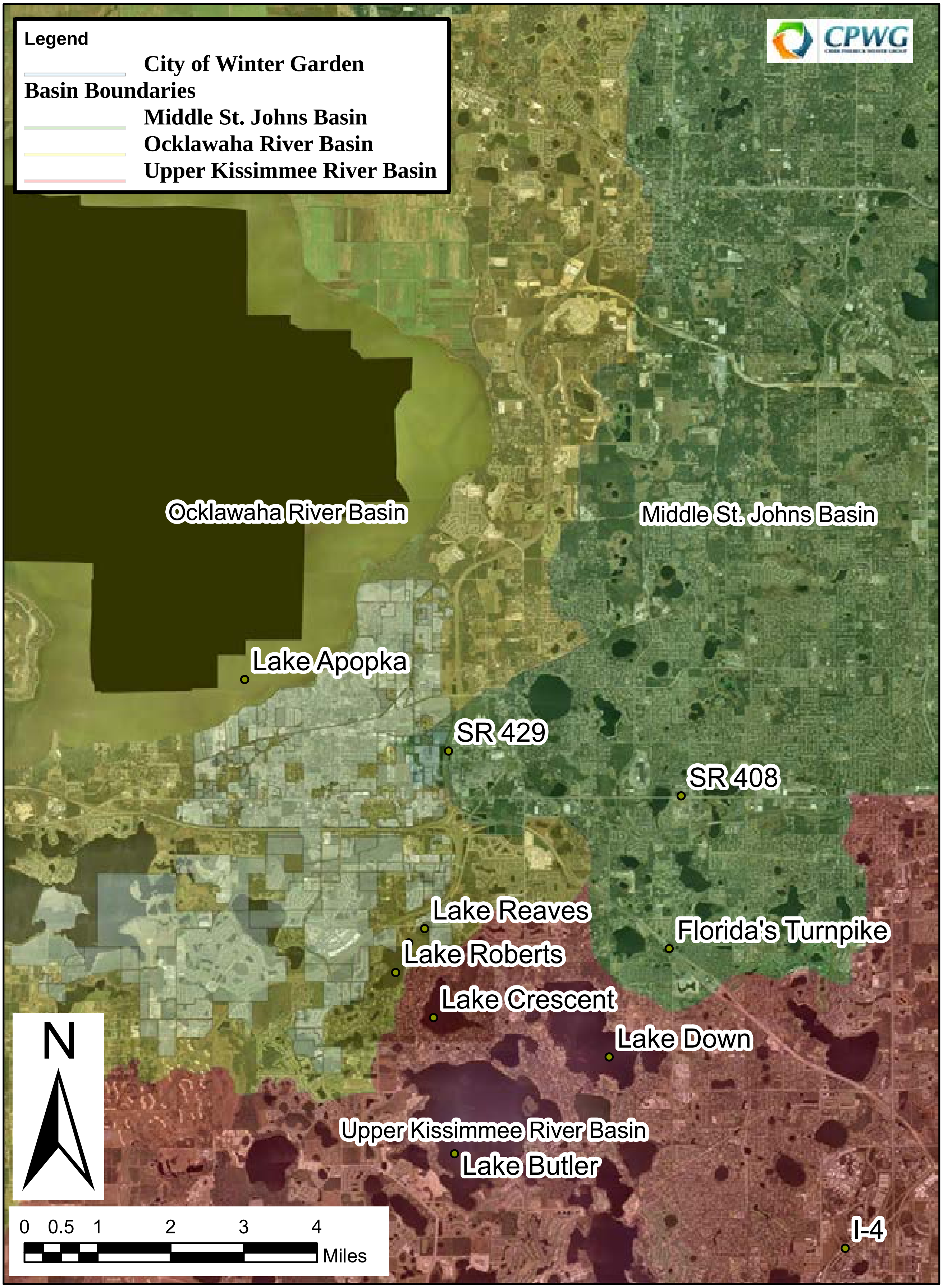
1.1 GENERAL DESCRIPTION

This report provides a summary of work efforts performed by Cribb Philbeck Weaver Group (CPWG), Team Engineering (TEAM) and Environmental Research & Design, Inc. (ERD) (NELAP #E1031026) for the Orange County Environmental Protection Division (OCEPD) (NELAP #53398) to develop hydrologic and nutrient budgets, along with a water quality management plan, for Lake Roberts. Lake Roberts is a 108-acre urban lake located approximately 10 miles southwest of downtown Orlando and just southwest of the City of Winter Garden. A location map for Lake Roberts is provided in Figure 1-1.

The watershed areas surrounding the lake are somewhat developed, with mostly residential and wetland land use activities. Three subdivisions, representing a minority of the watershed, contain stormwater treatment areas. The remaining subdivisions on the east, south and west side of the lake were constructed prior to implementation of regulations requiring stormwater treatment and discharge untreated or minimally treated runoff directly into Lake Roberts. Historical water quality in Lake Roberts has been somewhat variable, but primarily within the eutrophic range. A eutrophic lake has high biological productivity. Due to excessive nutrients, especially nitrogen and phosphorus, these water bodies are able to support an abundance of aquatic plants. Usually the water body will be dominated either by aquatic plants or algae.

1.2 IMPAIRED WATERS DESIGNATION

Section 303(d) of the Clean Water Act (CWA) requires states to submit lists of surface waterbodies that do not meet applicable water quality standards. These waterbodies are defined as “impaired waters” and Total Maximum Daily Loads (TMDLs) must be established for these waters on a prioritized schedule. The Florida Department of Environmental Protection (FDEP) has established a series of guidelines to identify impaired waters which may require the establishment of TMDLs. Waterbodies within the State of Florida have been divided into five separate groups for planning purposes, with Lake Roberts located in the Ocklawaha River Basin in Group 1.



Lake Roberts Location Map

Figure 1-1

The lake was verified as impaired for nutrients due to elevated annual average Trophic State Index (TSI) values, and was included on the Verified List of impaired waters for the Ocklawaha River Basin that was adopted by the Secretarial Order on February 12, 2013. The impairment was based on elevated TSI between 2000-2012. According to the 1999 Florida Watershed Restoration Act (FWRA), Chapter 99-223, Laws of Florida, once a waterbody is included on the Verified List, a TMDL must be developed. The purpose of the TMDL is to establish the allowable loadings of pollutants to Lake Roberts that would restore the waterbody so that it meets its applicable water quality criteria for nutrients. For assessment purposes, the Florida Department of Environmental Protection (Department) has divided the Ocklawaha River Basin into water assessment polygons with a unique waterbody identification (WBID) number for each watershed or stream reach. Lake Roberts is WBID 2872A.

Based upon available historical water quality data for Lake Roberts, the lake is characterized as a high color, co-limited system. Therefore, control of both phosphorus and nitrogen loadings to the lake is essential for improvement of water quality.

1.3 PREVIOUS STUDIES

One previous study was conducted on Lake Roberts to evaluate various issues related to water quality and stormwater inputs. A summary of the study is given below:

1.3.1 LAKE ROBERTS DRAINAGE STUDY BY PBS&J (November 2000):

The purpose of this study was to analyze the sub-basins contributing to Lake Roberts and to evaluate alternative lake outfall designs to reduce the period of high water levels. The proposed alternatives include the "no change" condition to determine the current flood stages, improving the conveyance to the west and reopening (reinstalling) the drain well. The improvements proposed were to avoid parcel acquisition. An addendum to the report was included that discussed impact that the proposed (now constructed) SR 429 would have on the outfall alternatives.

1.4 WORK EFFORTS PERFORMED

Work efforts were initiated on this project by CPWG during September 2013. The primary objective of this project is to quantify pollutant loadings to the lake and identify areas or opportunities where nutrient load reductions could be achieved to improve water quality within the lake. A field monitoring program was conducted by Team and ERD from September 2013-December 2014 to collect hydrologic and water quality data for use in developing hydrologic and nutrient budgets for the lake. The hydrologic budget includes estimated inputs from precipitation, stormwater runoff, and groundwater seepage. The nutrient budget includes inputs from bulk precipitation, stormwater runoff, groundwater seepage, and internal recycling. A detailed evaluation of sediment characteristics in Lake Roberts was also conducted which included physical and chemical characterization of surficial sediments and evaluation of internal phosphorus recycling. Specific nutrient load reduction projects were evaluated and recommended to maximize load reductions to the lake and improve water quality.

This report has been divided into six separate sections for presentation of the work efforts performed by CPWG. Section 1 contains an introduction to the report and provides a general overview of the work efforts performed. Current characteristics of Lake Roberts are discussed in Section 2, including lake bathymetry, sediment accumulation and characteristics, and water quality. A discussion of the drainage basin area is given in Section 3, and the hydrologic budget is presented in Section 4. A nutrient budget, which includes inputs from total nitrogen, total phosphorus, and TSS, is given in Section 5. Alternatives for management of water quality in Lake Roberts are discussed in Section 6. Appendices are also attached which contain technical data and analyses used to support the information contained within the report

2.0 LAKE ROBERTS' PHYSICAL AND CHEMICAL CHARACTERISTICS

The physical and chemical characteristics of Lake Roberts discussed in this section include bathymetry, sediment characterization, and a discussion of historical and current water quality characteristics.

2.1 PHYSICAL CHARACTERISTICS

An aerial view of Lake Roberts and the surrounding area is shown in Figure 2-1. Lake Roberts is shaped similar to an hourglass with distinct north and south lobes. A wetland tussock is located along the northeast border of the lake connecting Lake Roberts and Lake Reaves. The general nomenclature illustrated in Figure 2-1 is used throughout this report to describe areas within the lake.

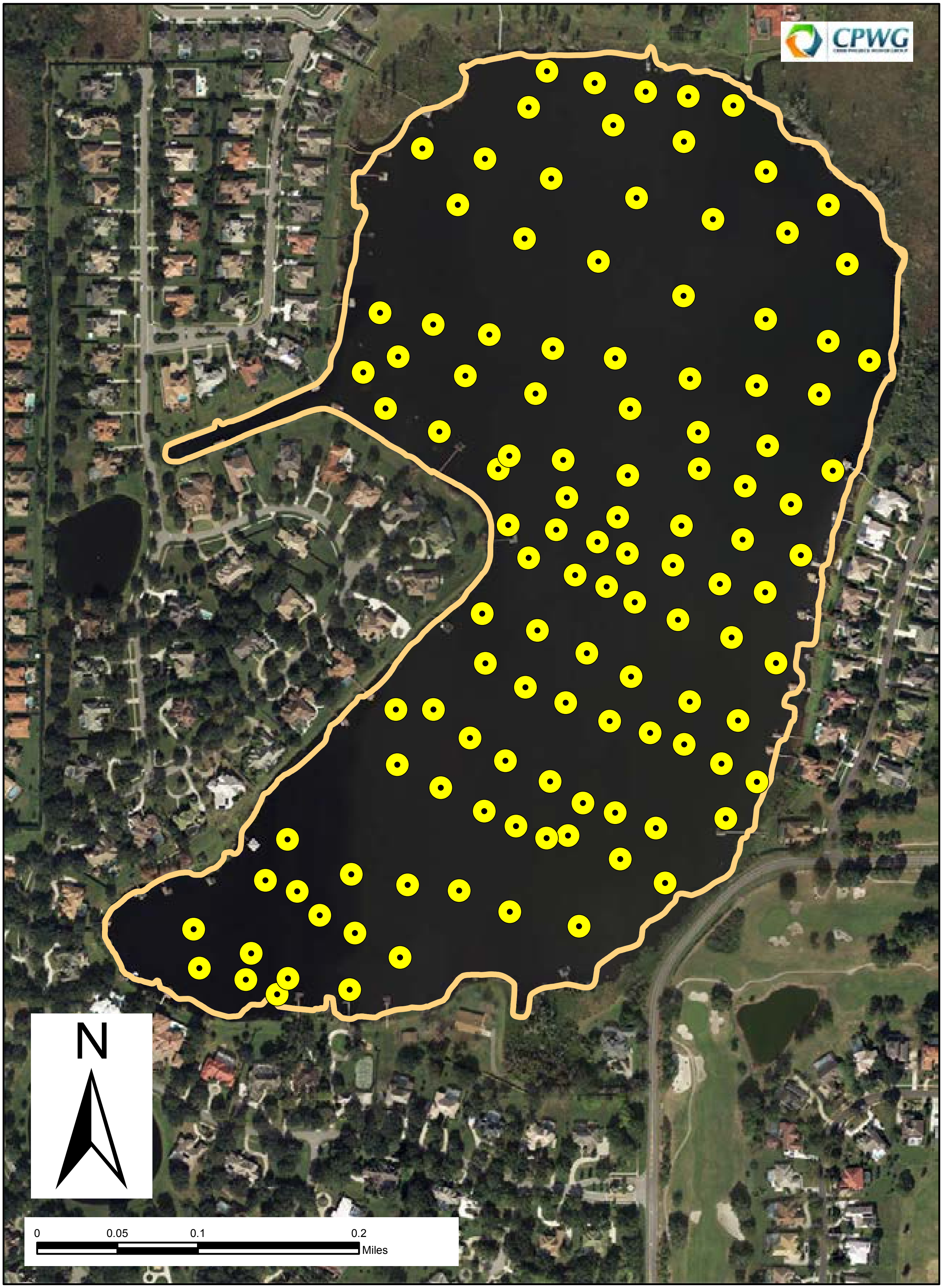
A bathymetric survey of Lake Roberts was performed by CPWG on December 30 and 31, 2013 to evaluate the water column depth as well as thickness of unconsolidated sediments within the lake. Measurements of water depth and sediment thickness were conducted at 121 individual sites (see Figure 2-2). The longitude and latitude coordinates of each depth measurement site was identified using a portable GPS (TopCon GRS-1). The staff gauge in Lake Roberts was not installed at the time of the bathymetric survey. However, the staff gauge was installed in January 2014. The surface water elevation of Lake Roberts on January 24, 2014 was approximately 108.98 ft, NAVD. Based on this surface water elevation reading, it is assumed that the elevation of Lake Roberts during the bathymetric survey was approximately 109 ft.

Water depth at each of the data collection sites was determined by lowering a 30-cm diameter stainless steel disk welded to a survey rod with graduated measurement lines until resistance from the sediment layer was encountered. The depth on the graduated line corresponding to the water surface was recorded in the dedicated field book and is defined as the water depth at each site. After measurement of the water depth at each site, a 5-pound weight tied to non-elastic rope was lowered into the water column at the same location and allowed to sink through the sediment until reaching a firm bottom material. The difference between the depth to the firm lake bottom and the water depth at each site is defined as the depth of unconsolidated sediments.

The generated field data was converted into bathymetric maps for both water depth and unconsolidated sediment depth in Lake Roberts using ArcGIS 10. Estimates of water volume and unconsolidated sediment volume within Lake Roberts were generated using ArcGIS 10.

Lake Roberts General Overview Map

Figure 2-1



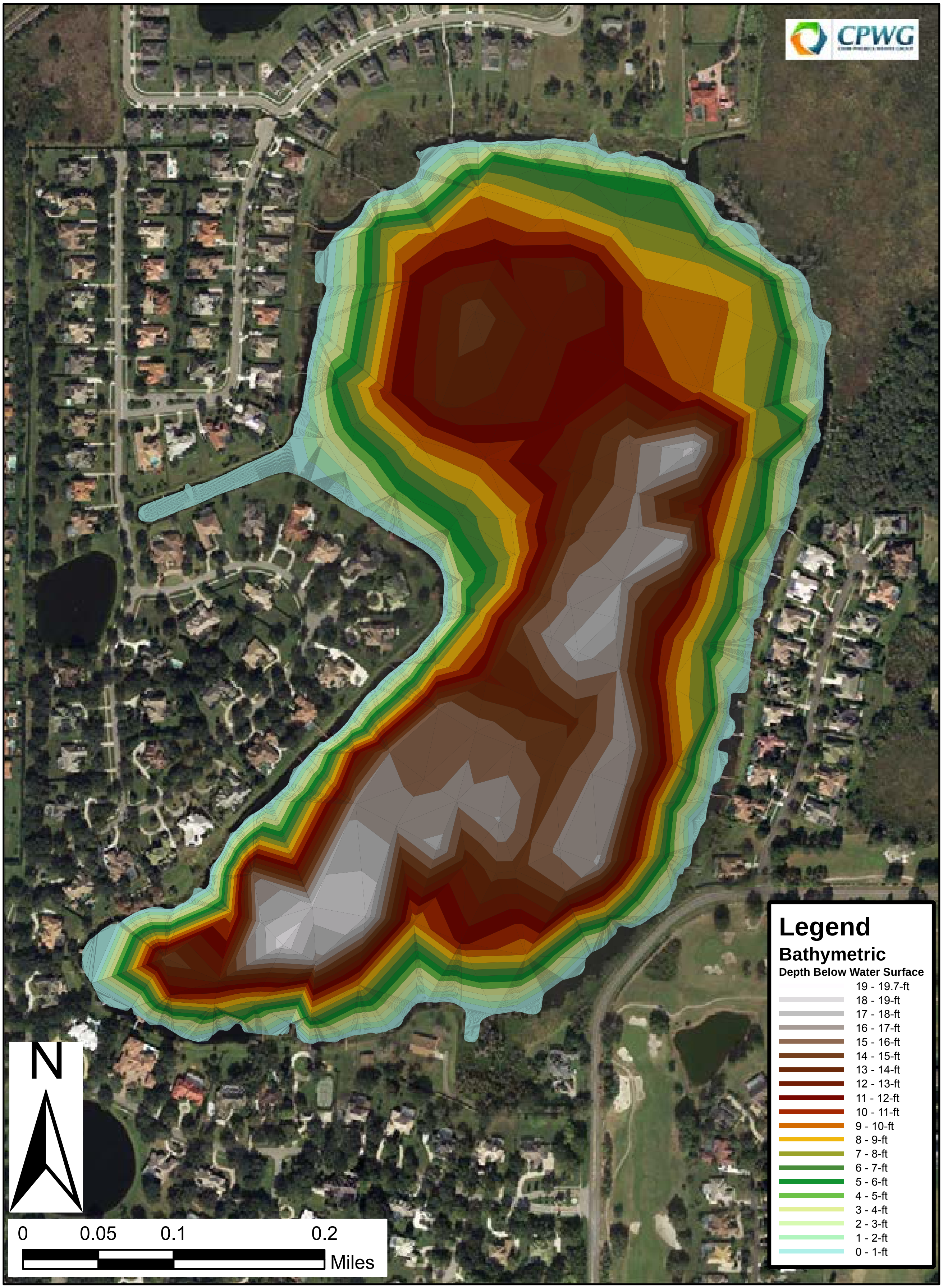
Lake Roberts Probe Locations
for Water and Muck Depths

Figure
2-2

A water depth contour map for Lake Roberts based on the field data collected by CPWG is shown on Figure 2-3. The bottom bathymetry in Lake Roberts is irregular, with areas ranging from relatively shallow to greater than 18 feet deep. The deepest areas within the lake are located in the south lobe with a water depth greater than 19 feet and in the southern portion of the north lobe with a water depth that extends between 17 and 18 feet. The bathymetric signature of Lake Roberts indicated on Figure 2-3 suggests that the lake originated as a result of independent sinkhole features which became hydraulically interconnected.

Water level elevations in Lake Roberts are regulated by an outfall pipe located in a man-made canal discharging from the western boundary of the north lobe. Flow from the man-made canal discharges through a series of pipes located in 2 subdivisions (Waterford Pointe and Bronson's Landing), through an altered wetland, through drainage pipes under the Western Beltway (SR 429) and outfalls at Lake Tilden and then flows to Black Lake and beyond. The invert elevation for the outfall pipe is approximately 106.8 feet. Further downstream of the outfall pipe, the invert in the drainage system rises to elevation 109 feet which appears to control the water level in Lake Roberts.

Stage-area-volume relationships for Lake Roberts are summarized in Table 2-1 based upon the bathymetric survey performed by CPWG. The lake surface area is approximately 108 acres based on a surface water elevation of 108.98 measured on January 24, 2015. The lake volume at this surface area is 1,066 ac-ft which corresponds to a mean water depth of approximately 9.8 feet. A summary of bathymetric characteristics of Lake Roberts is given in Table 2-2



Lake Roberts Water Depth Contours Map
(Water Elevation = 108.98-ft NAVD88)

Figure 2-3

TABLE 2-1
Depth-Area-Volume Relationships for Lake Roberts
(Elev. 108.98 ft NAVD88)

Depth Below Water Surface (ft)	Area (acres)	Incremental Volume (ac-ft)	Cumulative Volume (ac-ft)
0	108.0	106	1,066
1	103.3	101	961
2	98.6	96	860
3	93.9	92	763
4	90.1	88	671
5	86.2	84	583
6	81.7	79	499
7	76.5	73	420
8	70.1	67	347
9	63.7	60	280
10	56.7	54	220
11	50.6	47	166
12	42.7	38	120
13	33.8	30	81
14	26.8	24	51
15	20.3	16	27
16	11.7	8	11
17	3.9	3	3
18	1.4	1	1
19	0.1	0	0
19.7	0.0	0	0

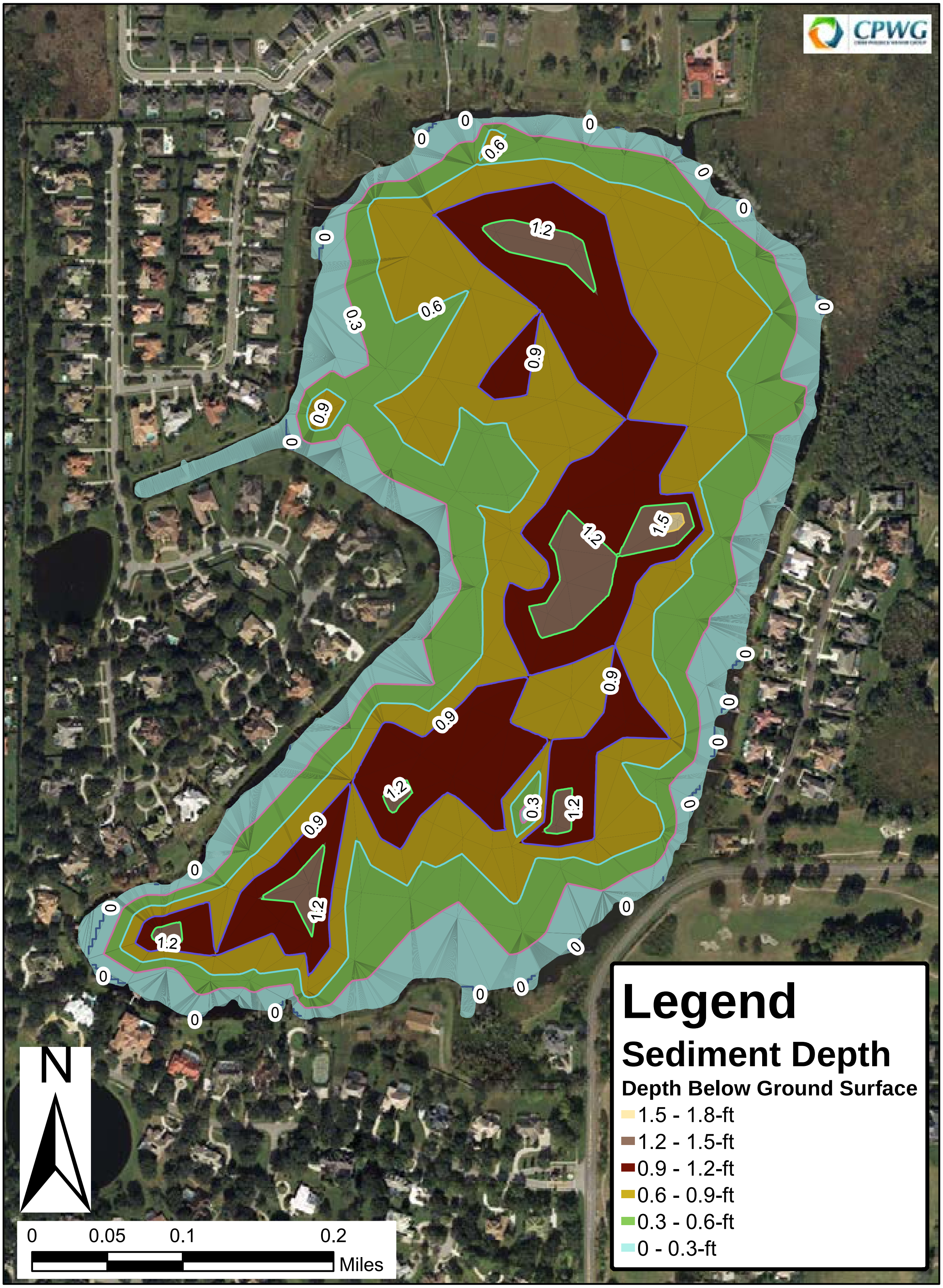
TABLE 2-2
Bathymetric Characteristics of Lake Roberts

Bathymetric Parameter[1]	Value
Surface Area	108 acres
Total Volume	1,066 ac-ft
Mean Depth	9.8 ft
Maximum Depth	19.7 ft.
Shoreline Length	12,010 ft / 2.27 miles
Shoreline Development	8,500 ft / 1.61 miles

1. Based upon a water surface elevation of 108.98 ft. (NAVD)

The shoreline length (lake perimeter) is presented in Table 2-2. This value is used to calculate the shoreline development index which is a measure of the regularity of the lake shoreline. The shoreline development index is a ratio of the perimeter of the lake to the perimeter of a lake with the same area that is a perfect circle. Lakes which exhibit a high degree of irregularity in the shoreline provide a higher degree of habitat for aquatic organisms and often display a higher degree of diversity in the aquatic community. Shoreline development indices of approximately 2 or more are often considered to provide a high degree of habitat. As indicated on Table 2-2, the shoreline development index for Lake Roberts is 1.61, indicating a fairly regular shoreline area and a medium degree of habitat compared with a lake with a regular circular shoreline.

A bathymetric contour map of the depth of unconsolidated organic sediments in Lake Roberts is shown on Figure 2-4. Accumulation of organic muck primarily occurs in the lower elevations within the lake in the north and south lobes. Muck depths range from 0.1 feet along the perimeter of the lake to approximately 2 feet in the deeper sections of the lake. The accumulated organic muck within the lake appears to be comprised primarily of dead algal cells and other partially decomposed vegetation as well as solids which have entered the lake from the adjacent wetland tussock. The shallow areas around the shoreline of the lake appear to have relatively little muck accumulation, with muck depths ranging from 0 to 0.3 feet



Lake Roberts Muck Depth Contours Map

Figure 2-4

Estimates of area-volume relationships for organic muck accumulations in Lake Roberts are given in Table 2-3. Approximately 21.5 acres (20%) of the lake area around the shoreline has less than 0.3 feet of existing muck accumulation on the lake bottom. The majority of the deeper muck accumulation ranges from 0.6 to 1.7 feet in depth and are located in the deeper portion of the north and south lobes. Overall, Lake Roberts contains approximately 67.49 ac-ft (2,939,864 ft^3) of unconsolidated organic sediments.

TABLE 2-3
Depth-Area-Volume Relationships for Organic Muck in Lake Roberts

Muck Depth (ft)	Area (acres)	Incremental Volume (ac-ft)	Cumulative Volume (ac-ft)
0	108.0	9.72	67.49
0.1	86.5	17.29	57.76
0.3	86.4	22.05	40.47
0.6	60.6	13.09	18.42
0.9	26.7	4.65	5.33
1.2	4.3	0.67	0.68
1.5	0.1	0.01	0.01
1.7	0.0	0.00	0.00

2.2 SEDIMENT CHARACTERISTICS

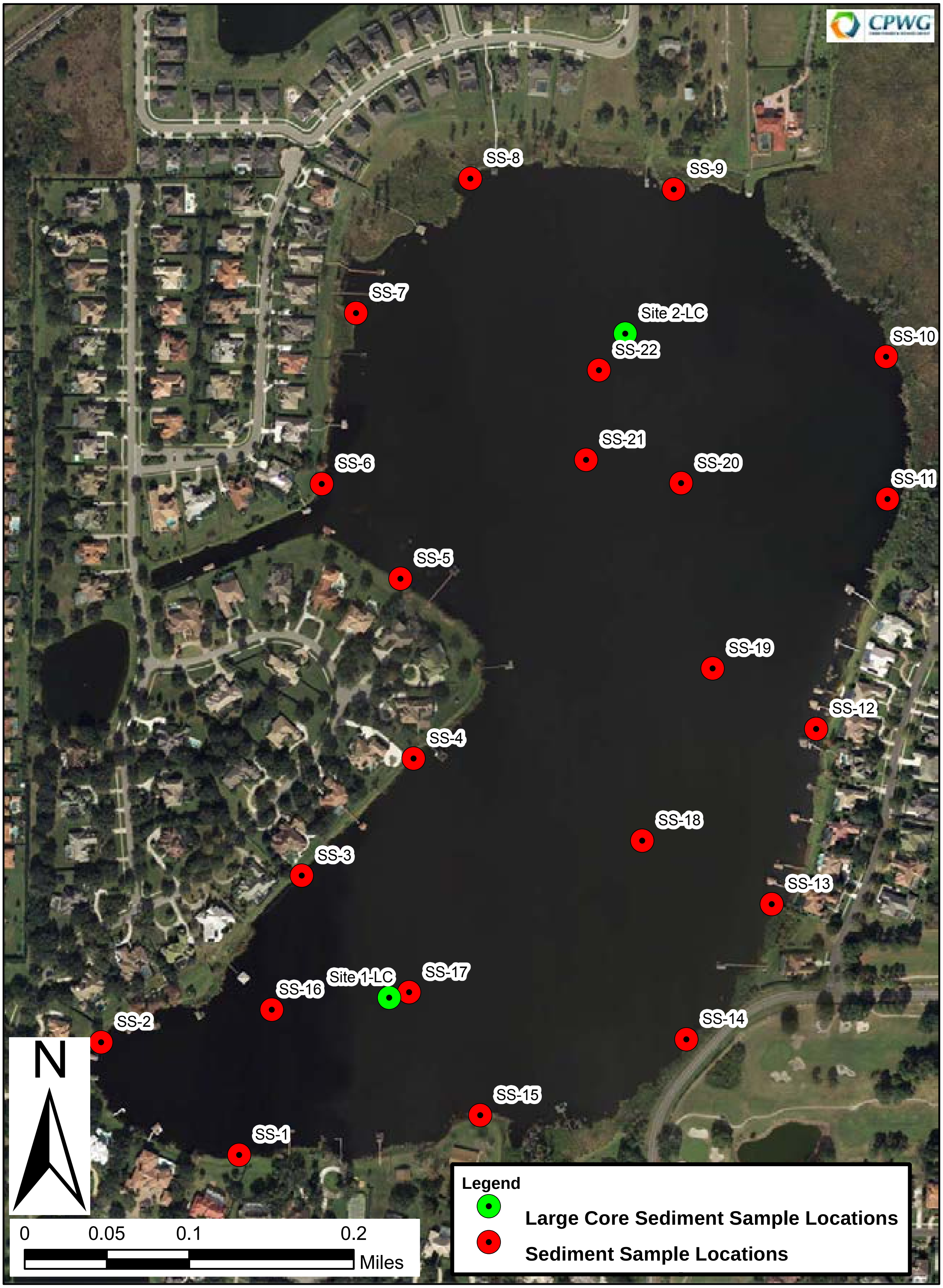
Sediment core sampling within Lake Roberts was performed in partnership with the Orange County EPD and FDEP. The FDEP goal was to examine the particle size distribution of the sediment deposited in Lake Roberts in order to estimate the hydraulic conductivity of the lake sediment, an important parameter for modeling the ground water seepage rate of the lake. Particle size distribution also has direct impact on the calibration of the ArcNLET model which is used by FDEP to simulate the septic tank nitrogen loads entering the lake. Samples collected for Orange County EPD were collected to evaluate the phosphorus and nitrogen content of existing sediments and the potential impacts on water quality within the lake.

Sediment core samples were collected for FDEP and Orange County EPD from 15 sites across Lake Roberts on April 24 and April 29, 2014. An additional 7 sediment core samples were collected for Orange County EPD April 29, 2014. Locations of sediment sampling sites in Lake Roberts are illustrated on Figure 2-5. Based on the lake surface area of 108 acres, sediment samples were collected at a rate of one sample for every 4.9 acres of lake area.

2.2.1 SAMPLING TECHNIQUES

Sediment samples for Orange County EPD were collected at each of the 22 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 decanted before the split-spoon device was opened to expose the collected sample. Visual characteristics of each sediment core sample were recorded in a dedicated field book. The 0-10 cm layer was sectioned off and placed into a polyethylene container for transport to the ERD laboratory for analysis. The polyethylene containers used for storage of the collected samples were filled completely to minimize air space in the storage container above the sediment sample. The collected samples were stored on ice and transported to the ERD laboratory within 24 hours of collection for physical and chemical characterization.

Sediment samples for FDEP were collected using a 12-inch long, 2-inch diameter split spoon core sampler with a vertically split cylinder. Twelve-inch clear, plastic liners were placed in the sampler to collect relatively undisturbed soil cores. End caps were placed on each end of the plastic liner before storing in a cooler on ice. Coolers at the end of the April 24 and April 29 sampling events were shipped overnight to the FDEP Central Laboratory located in Tallahassee, Florida for analysis. Each sediment sample was brought to the boat from the lake bottom and photographed. A visual description of each the sediment layers was recorded in a dedicated field book.



Lake Roberts Sediment Sampling Sites Figure 2-5

2.2.2 SEDIMENT CHARACTERIZATION AND SPECIATION TECHNIQUES

Each of the 22 sediment core samples was analyzed for a variety of general parameters, including moisture content, organic content, sediment density, total nitrogen, and total phosphorus. Methodologies used for preparation and analysis of the sediment samples for these parameters are outlined in Table 2-4.

In addition to general sediment characterization, a fractionation procedure for inorganic soil phosphorus was conducted on the 22 collected sediment samples. The modified Chang and Jackson Procedure, as proposed by Peterson and Corey (1966), was used for phosphorus fractionation. The Chang and Jackson Procedure allows the speciation of sediment phosphorus into saloid-bound phosphorus (defined as the sum of soluble plus easily exchangeable sediment phosphorus), iron-bound phosphorus, and aluminum-bound phosphorus.

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 (Eh), 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 soil phosphorus bounding is given in Figure 2-6.

For purposes of evaluating the sediment release potential, the potentially available inorganic phosphorus in soils/sediments 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.

TABLE 2-4
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.

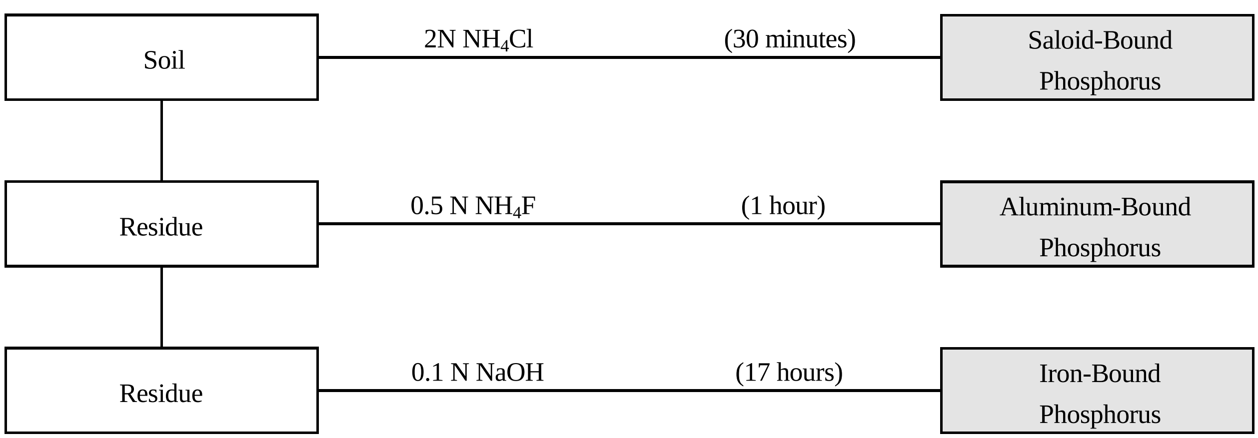


Figure 2-6. Schematic of Chang and Jackson Speciation Procedure for Evaluating Soil Phosphorus Bonding.

2.2.3 SEDIMENT CHARACTERISTICS

2.2.3.1 VISUAL CHARACTERISTICS

Visual characteristics of sediment core samples were recorded for each of the 22 sediment samples collected in Lake Roberts during April 2014. A summary of visual characteristics of the sediment core samples is presented in Table 2-5. In general, 15 sediment samples were collected near the perimeter of lake (in conjunction with FDEP) and 7 sediment samples were collected in the deeper areas of the lake (north and south lobes). A surficial layer of unconsolidated organic muck was observed in 4 of the 15 shallow sites with measured depths ranging from 0-5 cm. Three additional shallow sites had mucky mottling in the surficial layer of sediment. A surficial layer of unconsolidated organic muck was observed in 6 of the 7 deep sites with measured depths ranging from 0 to 20 cm. The organic muck at the shallow sites included root mass and detritus. In deeper portions of the lake, the organic muck appears to be more consolidated beneath the surficial layer, with a consistency similar to pudding. These layers, which reflect older organic deposits that are resistant to further degradation, are referred to as consolidated organic muck and typically do not resuspend into the water column except during relatively vigorous wind or boating activity on the lake. Shallow and shoreline areas of the lake are characterized by various types of brown fine sand which is the parent soil layer which forms the original lake bottom. Photographs of some of the sediment characteristics are shown below.

2.2.3.2 GENERAL SEDIMENT CHARACTERISTICS

ERD Laboratory was used to analyze the collected sediment core samples for general sediment characteristics, including pH, moisture content, organic content, sediment density, total nitrogen, and total phosphorus. A summary of general characteristics measured in each of the 22 collected sediment core samples is given in Table 2-6. Isopleths were developed for the general sediment characteristics using the measurements shown in Table 2-6 to evaluate patterns occurring within Lake Roberts. The isopleths and descriptions are presented below.

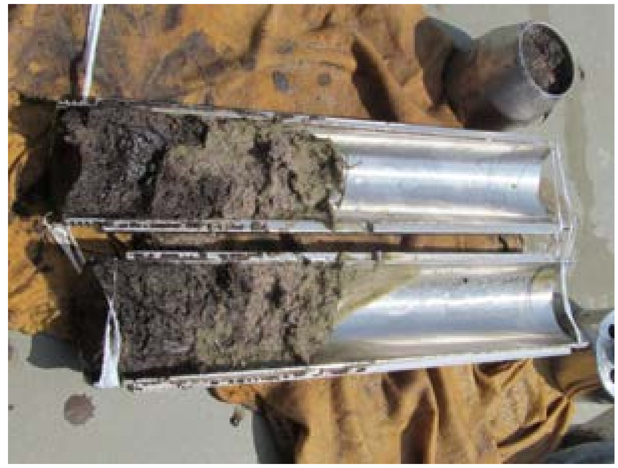
In general, sediments in Lake Roberts were found to be acidic in pH, with measured pH values ranging from 4.90 to 6.69 and a median value of 6.19. These values are typical of pH measurements commonly observed in eutrophic urban lakes. Isopleths of pH in the top 10 cm of sediments in Lake Roberts are illustrated on Figure 2-7. The majority of areas within Lake Roberts are characterized by pH values ranging from approximately 5.8 (in the shoreline areas) to 6.4 (deeper areas). The lower pH values were observed in the western shoreline of the northern lobe, with measured pH values ranging from approximately 5.0 to 5.6, which are slightly lower than commonly observed in urban lakes. The reason for the reduced pH values measured in this area is not known.

TABLE 2-5
Visual Characteristics of Sediment Core Samples Collected in Lake Roberts on April 24 & 29, 2014

Site Number	Layer (cm)	Visual Description of Sediment
SS-1	0 - 5	Dark mucky sediment
	5 - 18	Dark brown coarse sand
	18 - 30	Light brown medium-coarse sand
SS-2	0 - 5	Dark mucky sediment
	5 - 13	Dark brown coarse sand
	13 -18	Light brown medium-coarse sand
	18 - 30	Dark brown mucky medium-coarse sand
SS-3	0 - 5	Loose, loamy type light brown sand
	5 - 30	Dark brown mucky sand
SS-4	Surface	Algae growing at surface
	0 - 5	Dark brown mucky fine sand
	5 - 15	Medium brown medium-coarse sand
	15 - 30	Dark brown medium-coarse sand with muck tendencies
SS-5	0 - 10	Loose, loamy type light brown sand
	10 - 15	Greenish brown sand with mottling
	15 - 23	Medium dark brown medium-coarse sand
	23 - 30	Dark brown medium-coarse sand with some muck
SS-6	0 - 8	Greenish brown loamy fine sand
	8 - 15	Dark brown medium-coarse sand with much mottling
	15 - 30	Dark brown medium-coarse sand with muck
SS-7	0 - 3	Light brown medium-coarse sand
	3 - 15	Dark brown medium-coarse sand with muck consistency
	15 - 20	Medium brown medium-coarse sand with muck consistency
SS-8	0 - 7	Root mass, Dark brown with muck mottling
	7 - 30	Very dark brown, medium-coarse sand with muck
SS-9	0 - 5	Dark brown fine sand with muck and roots
	5 - 10	Light brown medium-coarse sand
	10 - 18	Very dark brown coarse sand
SS-10	0 - 18	Root mass with muck
	18 - 25"	Yellowish brown medium-coarse sand
	25 - 30	Grey brown medium-coarse sand
SS-11	0 - 5	Mucky fine sand with detritus
	5 - 30	Dark grey medium-coarse sand
SS-12	0 - 5	Yellow brown loamy type sand
	5 - 15	Dark brown mucky fine sand
	15 - 23	Dark brown mucky sand with yellow brown mottling
	23 - 30	Dark grey medium-coarse sand

Site Number	Layer (cm)	Visual Description of Sediment
SS-13	0 - 3	Light grey medium-coarse sand with detritus
	3 -5	Light grey medium-coarse sand
	5 - 20	Dark grey medium-coarse sand
	20 - 30	Medium dark grey medium-coarse sand
SS-14	0 - 8	Mucky fine sand with detritus
	8 - 18	Medium dark grey medium-coarse sand
	18 - 30	Light brown grey medium-coarse sand
SS-15	0 - 8	Light grey medium-fine sand
	8 - 18	Dark brown mucky fine sand
	18 - 30	Medium brown medium-fine sand with reddish hue
SS-16	0 - 5	Medium dark brown coarse sand
	5 - 8	Light Grey sand with mottling of medium dark brown sand
	8 - 13	Dark brown medium-coarse sand
SS-17	0 - 10	Very dark brown muck - loose
	10 - 25	Very dark brown muck
	25 - 28	Very dark brown mucky sand
SS-18	0 - 20	Dark brown mucky fine sand
	20 - 25	Dark brown fine sand w/ muck & mottling of yellow/brown sand
SS-19	0 - 10	Dark brown mucky fine sand
	10 - 13	Dark brown fine sand w/ muck & mottling of yellow/brown sand
	13 - 18	Light brown medium-coarse sand
	18 - 20	Medium brown medium-coarse sand
SS-20	0 -3	Dark brown muck - loose
	3 - 8	Dark brown fine sand w/ muck & mottling of yellow/brown sand
	8 - 10	Dark brown medium-coarse sand
SS-21	0 - 5	Dark brown muck - loose
	5 - 10	Dark brown mucky medium-coarse sand
	10 - 13	Dark brown fine sand w/ muck & mottling of yellow/brown sand
	13 - 18	Dark brown medium-coarse sand
SS-22	0 - 13	Dark brown mucky fine sand
	13 - 25	Dark grey brown medium-coarse sand

Photograph of Sandy Sediments
SS-10



Photograph of Sandy/Muck Sediments
SS-5

Photograph of Sandy Sediments with Muck Layer
SS-21

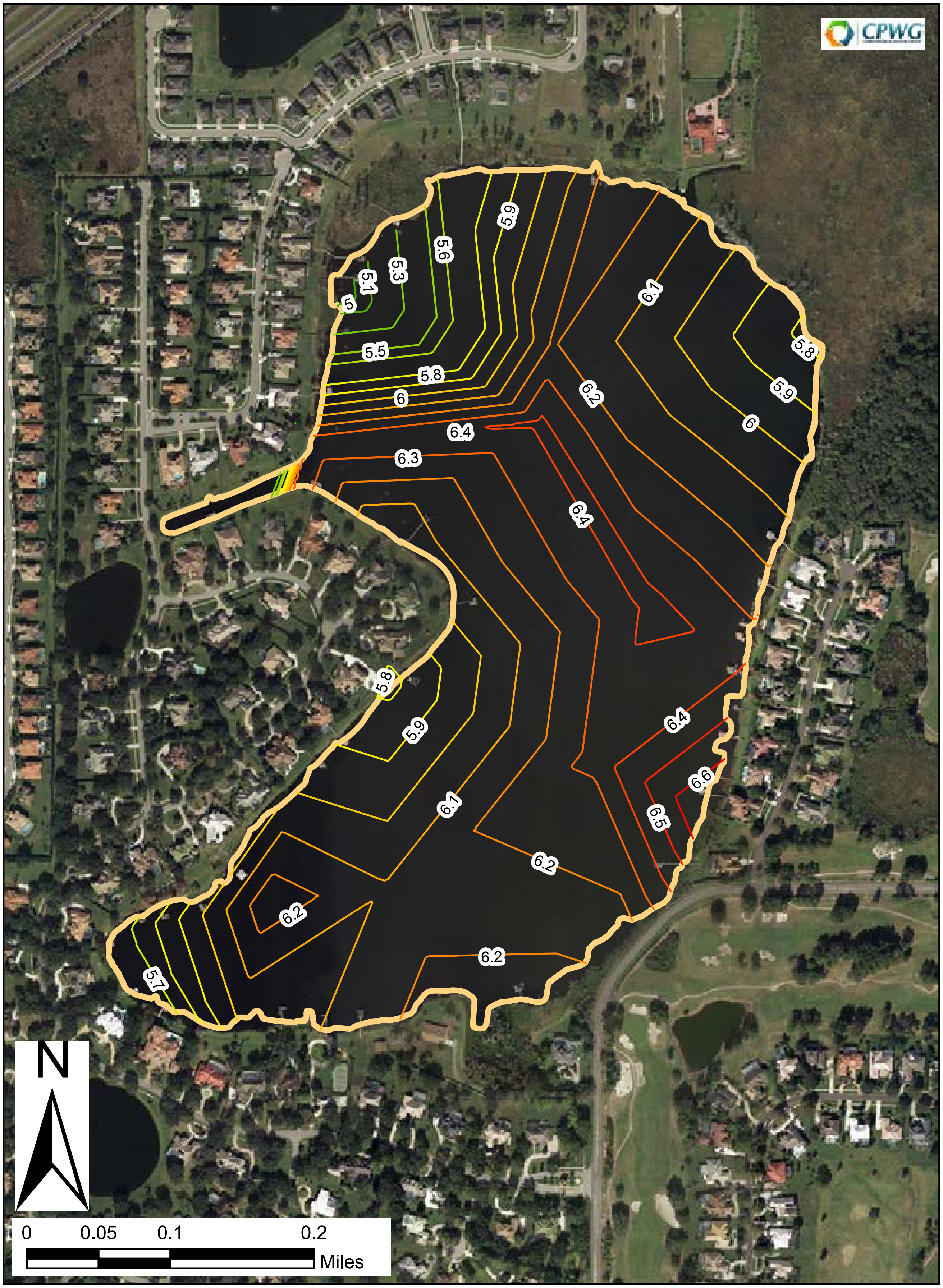
Photograph of Muck Sediments
SS-17

Photographs of Sediment Characteristics in Lake Roberts

TABLE 2-6
General Characteristics of Sediment Core Samples Collected in Lake Roberts During April 2014

Site	Date	pH (s.u.)	Moisture Content (%)	Organic Content[1] (%)	Wet Density (g/cm^3)	Total Nitrogen ($\mu g/cm^3$)	Total Phosphorus ($\mu g/cm^3$)
SS1	4/24/14	5.99	21.7	0.5	2.17	215	80
SS2	4/24/14	5.64	37.7	3.9	1.90	854	61
SS3	4/24/14	5.99	29.0	2.1	2.04	786	142
SS4	4/24/14	5.77	35.4	2.7	1.94	991	129
SS5	4/24/14	6.01	22.5	0.3	2.16	388	28
SS6	4/24/14	6.37	23.5	2.5	2.12	762	78
SS7	4/24/14	4.90	32.5	3.9	1.97	473	50
SS8	4/24/14	5.61	62.6	13.1	1.49	1,030	210
SS9	4/24/14	6.28	49.2	3.8	1.73	672	62
SS10	4/29/14	5.78	93.1	40.6	1.02	796	170
SS11	4/29/14	5.99	35.1	2.0	1.95	429	44
SS12	4/29/14	6.37	31.7	3.3	1.99	807	42
SS13	4/29/14	6.69	36.3	2.4	1.93	910	44
SS14	4/29/14	6.17	40.5	4.6	1.85	1,039	185
SS15	4/29/14	6.25	27.0	3.0	2.06	639	23
SS16	4/29/14	6.27	24.7	0.8	2.12	353	81
SS17	4/29/14	6.11	82.6	23.4	1.14	682	154
SS18	4/29/14	6.32	33.0	2.9	1.98	638	172
SS19	4/29/14	6.43	35.4	3.5	1.94	629	82
SS20	4/29/14	6.21	30.0	1.3	2.04	519	77
SS21	4/29/14	6.42	38.3	2.7	1.90	726	178
SS22	4/29/14	6.21	34.2	2.6	1.96	591	104
Minimum		**4.90**	**21.7**	**0.3**	**1.02**	**215**	**23**
Maximum		**6.69**	**93.1**	**40.6**	**2.17**	**1,039**	**210**
Median		**6.19**	**34.7**	**2.8**	**2.0**	**677**	**81**

1. Dry wt. basis



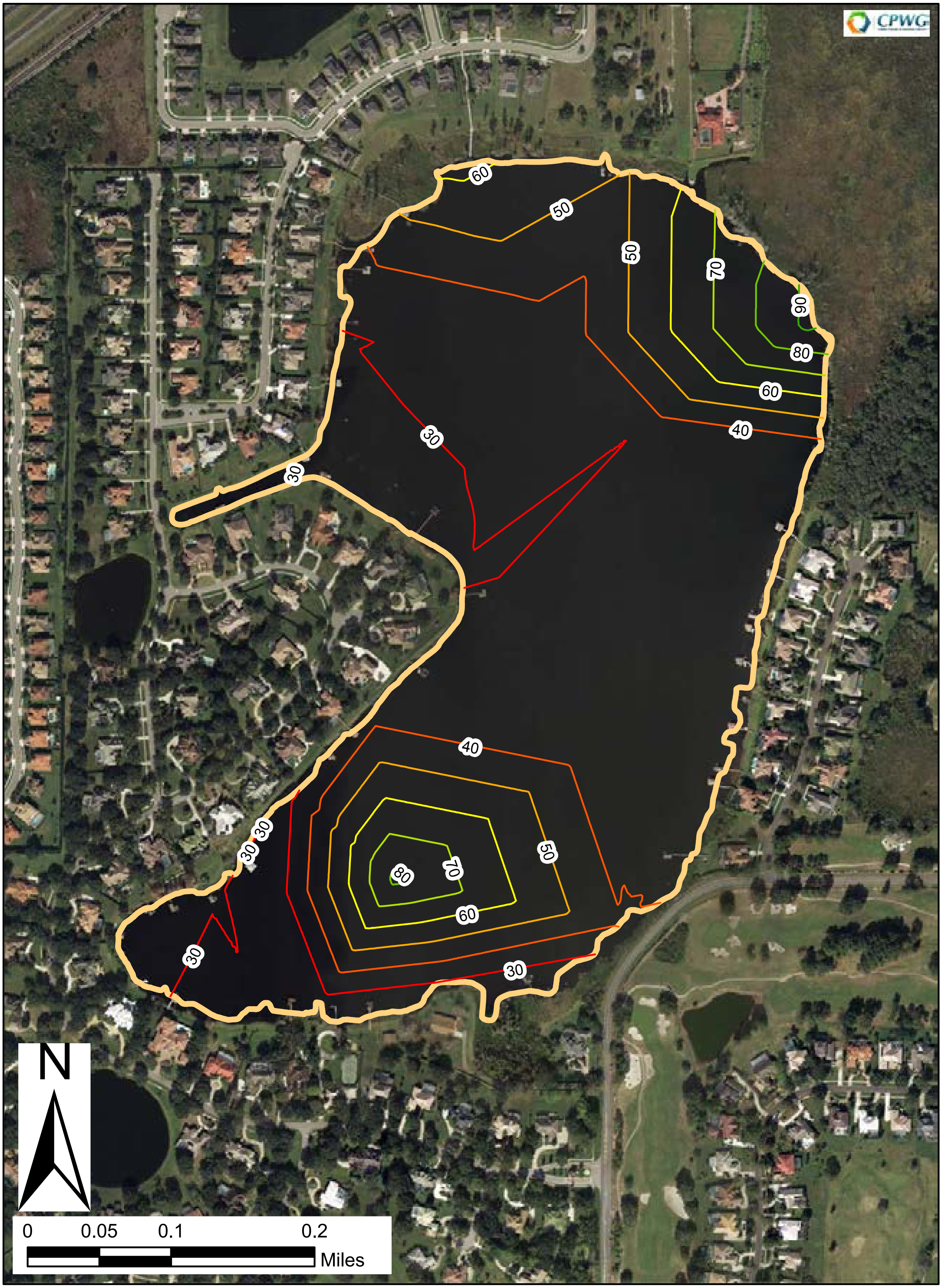
Lake Roberts Isopleth of pH (s.u.)
in Top 10 cm of Sediment

Figure
2-7

Measurements of sediment moisture content and organic content in Lake Roberts were variable throughout the lake; however, the isopleths of these two measurements were very similar in their overall pattern. Isopleths of sediment moisture content in Lake Roberts are illustrated in Figure 2-8. Areas of elevated moisture content are present in the area immediately adjacent to the wetland tussock along the northeast shore of Lake Roberts and in the deepest portion of the south lobe. Sediment moisture contents in excess of 50% are often indicative of highly organic sediments, while moisture contents less than 50% reflect mixtures of sand and muck. The areas with elevated moisture contents in the south lobe correspond well with the areas of accumulated muck shown on Figure 2-4. However, the moisture content in the deeper area of the north lobe is below 50% where there is accumulated muck. The highest percentage of moisture content found in the lake sediments is adjacent to the wetland tussock, even though the accumulated muck depth adjacent to the wetland tussock is low.

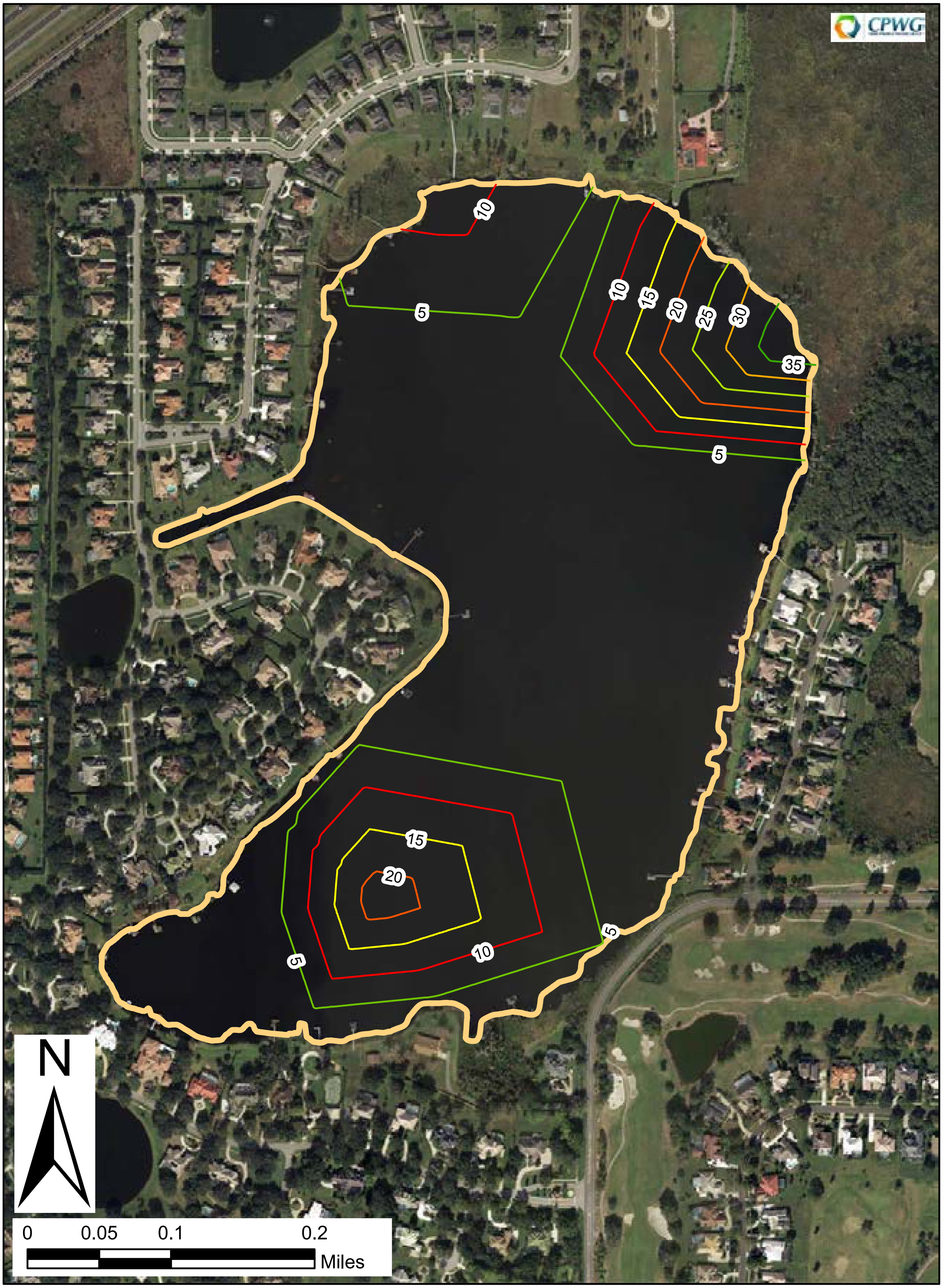
Isopleths of sediment organic content (dry wt. basis) in Lake Roberts are illustrated on Figure 2-9. Sediment organic content percentages in excess of 20% to 30% are generally indicative of organic muck type sediments. Values less than this range typically represent sand or a mixture of sand with muck. The highest percentage of organic content in the Lake Roberts sediments was found in the area nearest the wetland tussock where only small amounts of muck were measured during the bathymetric survey. Higher concentrations of organic content were also found in the deeper areas of the south lobe. The measured sediment organic content within Lake Roberts ranges from 0.3% to 40.6%, with an overall median value of 2.8%.

Measured sediment density values are useful in evaluating the presence of muck in sediments within a lake. Isopleths of wet density in Lake Roberts' sediments are presented in Figure 2-10. Sediments with calculated wet densities from 1.0 g/cm^3 to 1.25 g/cm^3 generally indicate organic muck type sediments, 1.25 g/cm^3 to 2.0 g/cm^3 indicate a sand/muck mixture and greater than 2.0 g/cm^3 indicate sandy sediment conditions. The sediment density values measured in Lake Roberts' sediments range from 1.02 g/cm^3 to 2.17 g/cm^3, with a median value of 2.0 g/cm^3. The areas of low density measurements occur in the deeper areas of the north and south lobes, and in areas near the wetland tussock. Sediments characterized by high densities are indicative of sandy sediments which are located along the shoreline and the western portions of the north lobe.



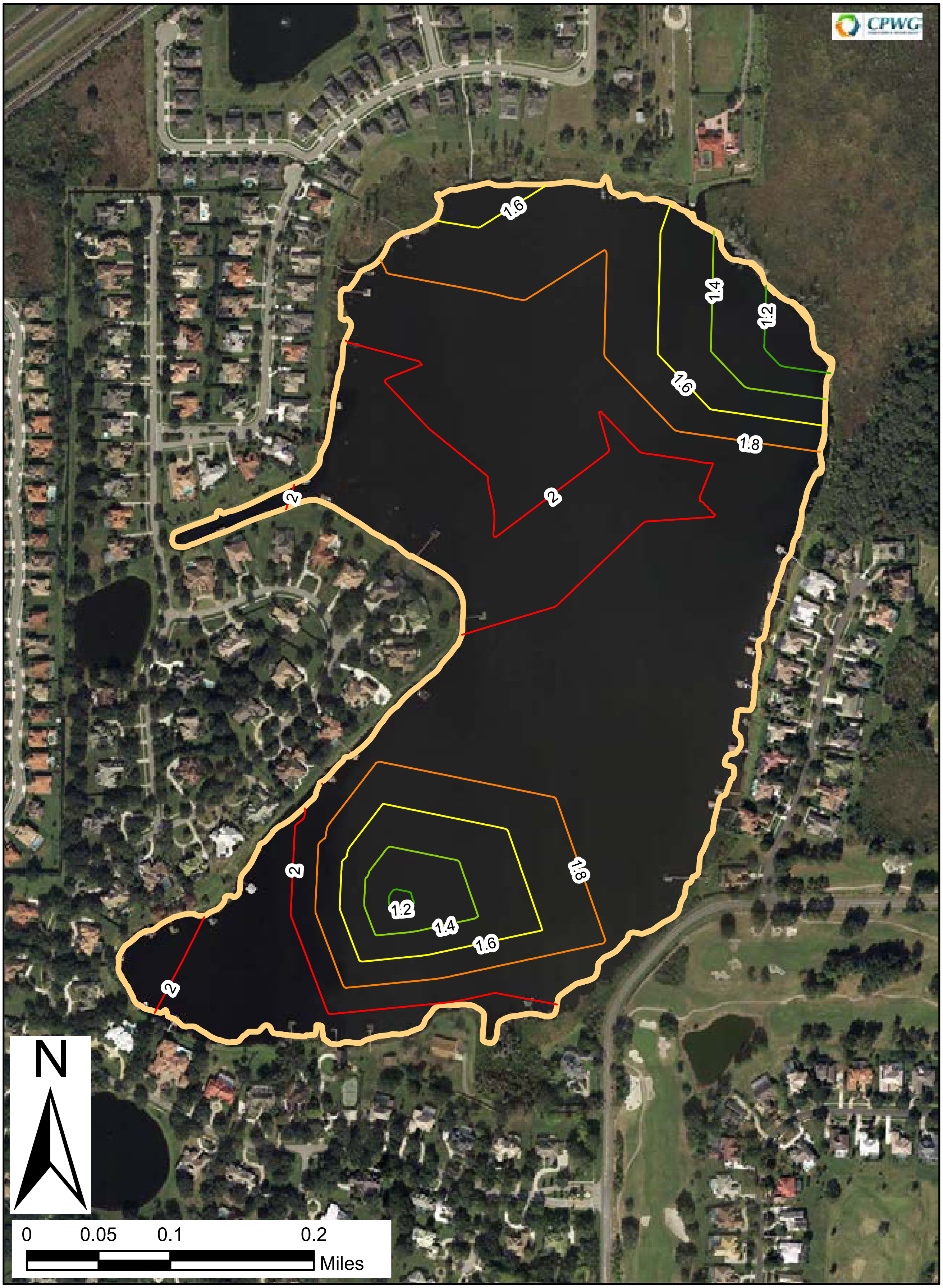
Lake Roberts Isopleth of Moisture Content (%) in Top 10 cm of Sediment

Figure 2-8



Lake Roberts Isopleth of Organic Content (% dry wt.) in Top 10 cm of Sediment

Figure 2-9



Lake Roberts Isopleth of Wet Density (g/cm^3) in Top 10 cm of Sediment

Figure 2-10

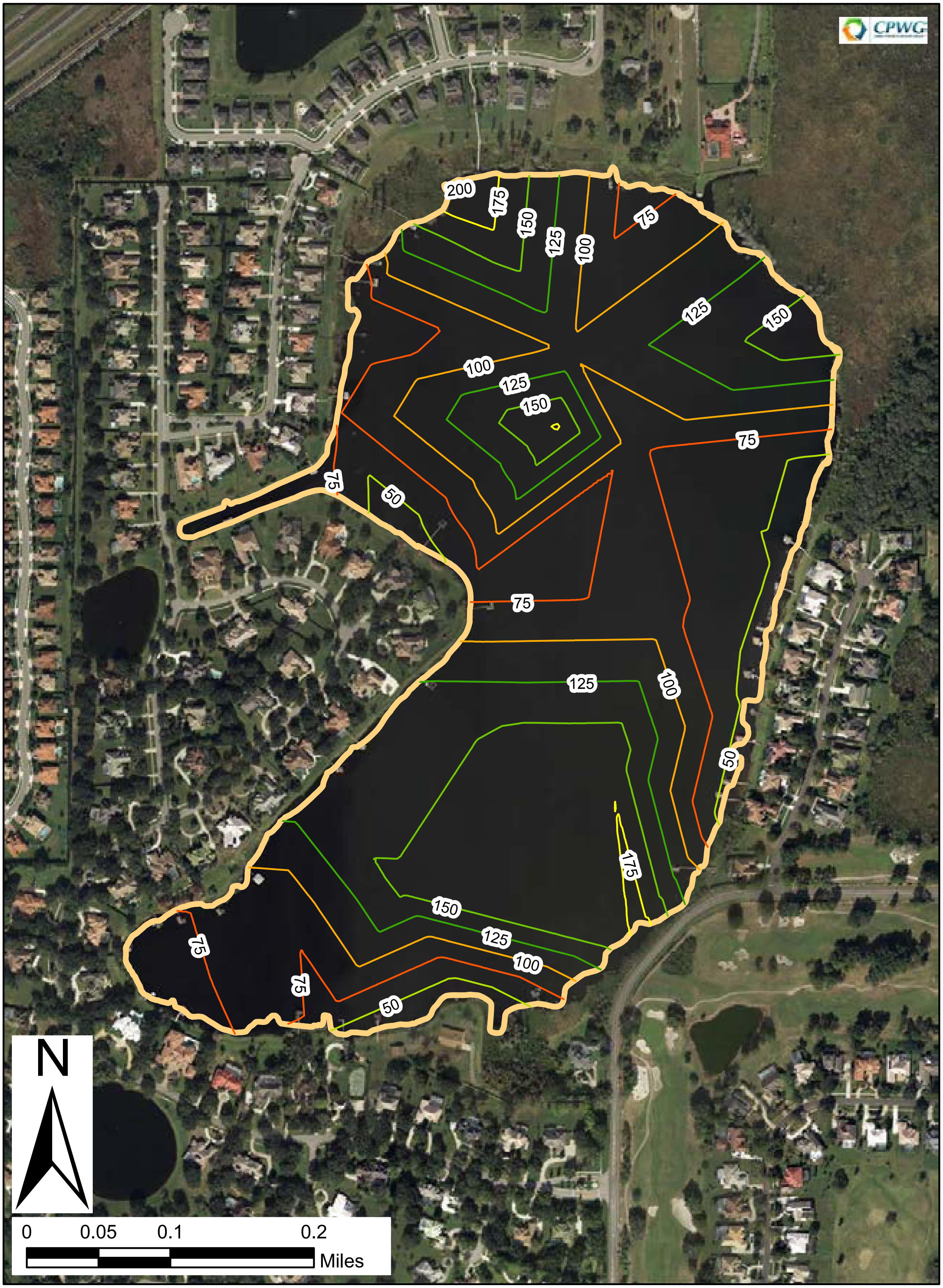
Total phosphorus concentrations were measured in the Lake Roberts sediments. Values ranged from 23 μg/cm^3 to 210 μg/cm^3 with a median value of 81 μg/cm^3. In general, sandy sediments are often characterized by low total phosphorus concentrations, while highly organic muck type sediments are characterized by elevated total phosphorus concentrations. Isopleths of sediment phosphorus concentrations in Lake Roberts are presented on Figure 2-11. The areas with the highest total phosphorus concentrations are observed in the deeper areas of the north and south lobes and along the shoreline adjacent to the wetland tussock.

Nitrogen concentrations measured in the lake sediments had values ranging from 215 μg/cm^3 to 1,039 μg/cm^3 with a median value of 677 μg/cm^3. Isopleths of sediment nitrogen concentrations in Lake Roberts are illustrated on Figure 2-12. In general, areas of elevated nitrogen concentrations are similar to the patterns exhibited by total phosphorus, with elevated concentrations present in areas of accumulated organic muck, along the shoreline of the wetland tussock and also along the western shoreline of the south lobe.

2.2.3.3 PHOSPHORUS SPECIATION

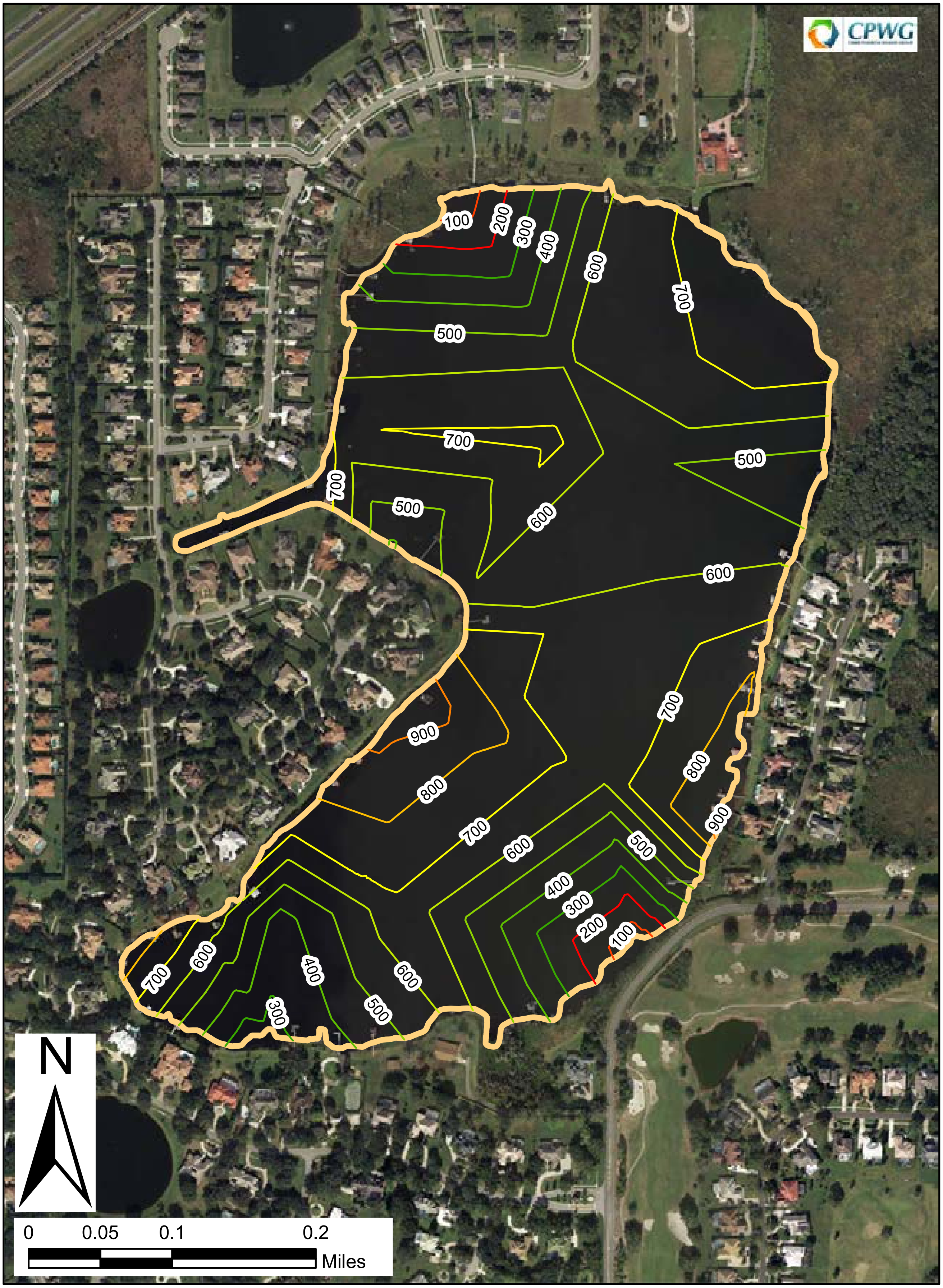
As previously discussed, each of the sediment core samples was evaluated for phosphorus speciation based upon the Chang and Jackson procedure. This procedure allows us to assess the amount of phosphorus in a sediment sample and its chemical form. The results allow us to assess the stability of phosphorus in the sediments and the potential for release of phosphorus under anoxic and oxidizing conditions.

A summary of phosphorus speciation in sediment core samples collected from Lake Roberts during April 2014 is presented in Table 2-7. Saloid-bound phosphorus represents sediment phosphorus which is either soluble or easily exchangeable and is typically considered readily available for release from the sediments into the overlying water column. Measured values for saloid-bound sediment phosphorus range from 0.5 μg/cm^3 to 2.0 μg/cm^3, with a median value of 0.7 μg/cm^3. The saloid-bound phosphorus concentrations appear to be relatively low in value and fairly uniform throughout the sediments of Lake Roberts. Isopleths of saloid-bound phosphorus in the top 10 cm of sediments in Lake Roberts are illustrated on Figure 2-13. Areas of elevated saloid-bound phosphorus are apparent in the northeastern, western, and southern portions of the lake and appear to correspond roughly with areas of accumulated muck deposits.



Lake Roberts Isopleth of Total Phosphorus ($\mu g/cm^3$) in Top 10 cm of Sediment

Figure 2-11



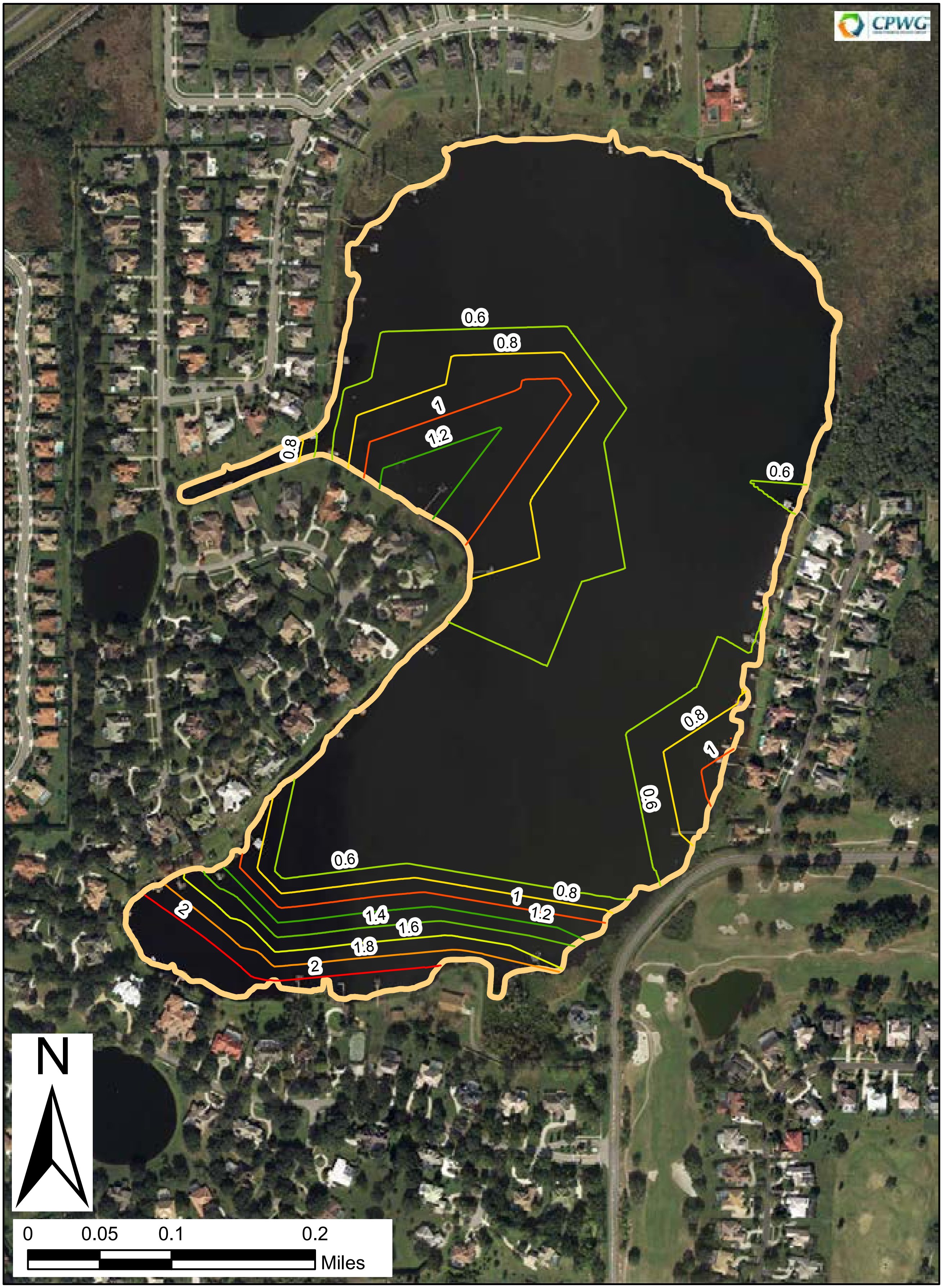
Lake Roberts Isopleth of Total Nitrogen ($\mu g/cm^3$) in Top 10 cm of Sediment

Figure 2-12

Table 2-7
Phosphorus Speciation in Sediment Core Samples Collected in Lake Roberts During April 2014

Site	Saloid-Bound P (µg/cm³ wet wt.)	Iron-Bound P (µg/cm³ wet wt.)	Available P (µg/cm³ wet wt.)	Percent of Sediment P Which is Available by Weight (%)	Al- Bound P (µg/cm³ wet wt.)
SS-1	2.2	21	23	17	3
SS-2	2.1	33	36	58	3
SS-3	0.1	25	26	18	3
SS-4	0.1	25	26	20	3
SS-5	1.4	5	6	22	3
SS-6	0.1	24	25	32	14
SS-7	0.1	33	34	67	14
SS-8	0.6	28	28	13	12
SS-9	0.4	22	23	36	2
SS-10	0.1	37	37	22	2
SS-11	0.7	9	9	21	3
SS-12	0.5	30	30	71	17
SS-13	1.1	8	9	20	3
SS-14	0.1	25	25	14	12
SS-15	2.0	6	8	36	3
SS-16	0.6	9	10	12	3
SS-17	0.3	78	79	51	19
SS-18	0.2	50	50	29	14
SS-19	0.5	31	32	39	14
SS-20	0.7	22	22	29	14
SS-21	1.1	39	40	23	13
SS-22	0.8	36	37	35	14
Minimum	**0.1**	**5**	**6**	**12**	**2**
Maximum	**2.2**	**78**	**79**	**71**	**19**
Median	**0.4**	**22**	**23**	**27**	**6**

Note: MDL for Saloid Bound P = 0.1 µg/cm³. Values are listed and full MDL.



Lake Roberts Isopleth of Saloid-Bound Phosphorus ($\mu g/cm^3$ wet wt) in Top 10 cm of Sediment

Figure 2-13

Analytical results indicate that the iron-bound phosphorus associations in the sediments of Lake Roberts appear to be an order of magnitude higher that the saloid-bound phosphorus. Iron-bound sediment phosphorus is relatively stable under oxidized conditions, but becomes unstable under a reduced environment, causing the iron-phosphorus bonds to separate and release the bound phosphorus directly into the water column. Iron-bound phosphorus concentrations in the sediments of Lake Roberts range from 5 to 78 μg/cm3, with a median value of 22 μg/cm3. Since iron-bound phosphorus can be released under anoxic conditions, large portions of Lake Roberts may have conditions favorable for release of iron-bound sediment phosphorus into the water column. Isopleths of iron-bound phosphorus in the sediments of Lake Roberts are illustrated on Figure 2-14. The area of highest iron-bound phosphorus levels is located in the deeper portion of the south lobe.

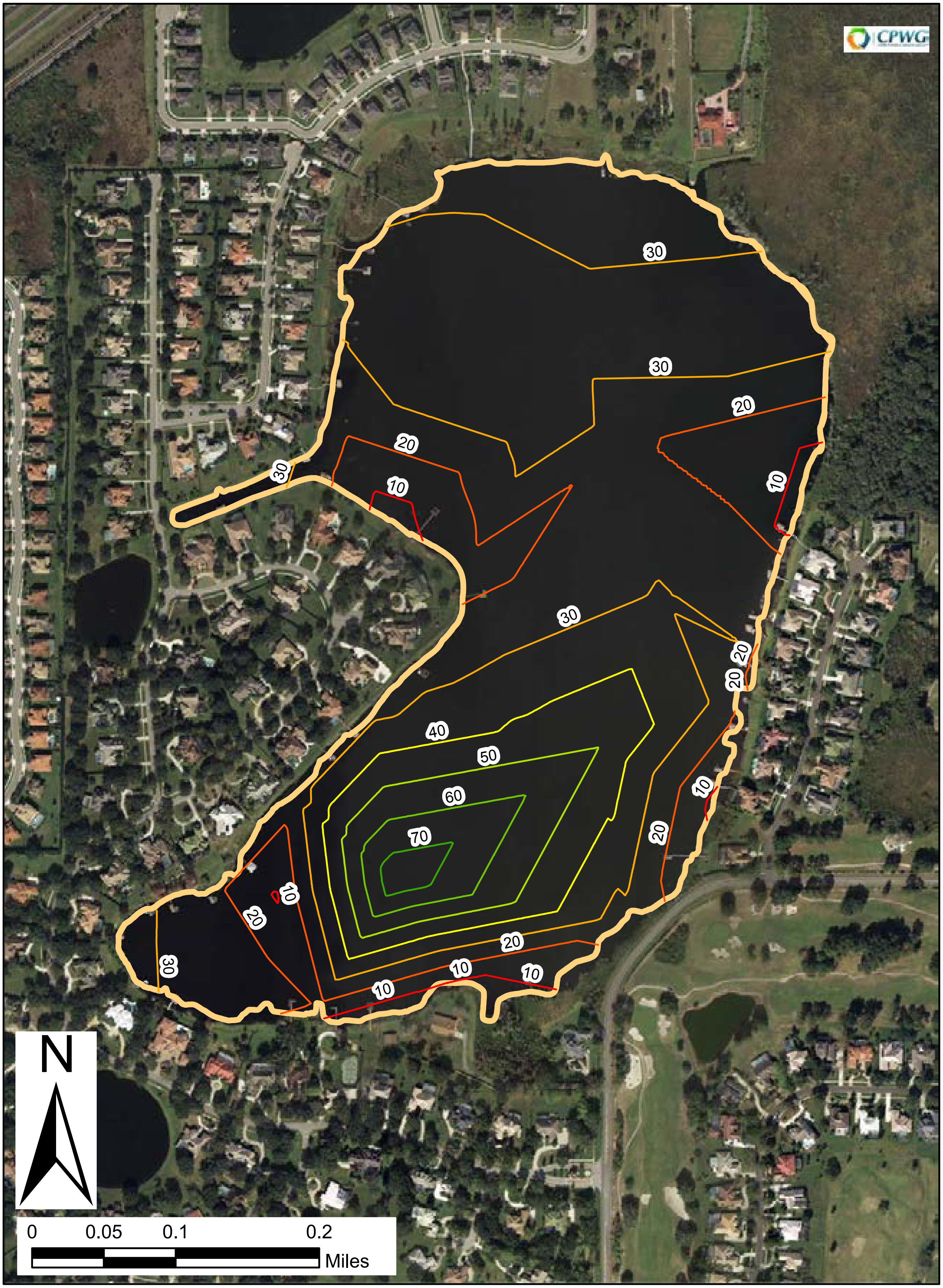
Total available phosphorus represents the sum of the saloid-bound phosphorus and iron-bound phosphorus associations in each sediment core sample. The saloid-bound phosphorus is immediately available and the iron-bound phosphorus is available under reduced conditions; therefore, the sum of these speciations represents the total phosphorus which is potentially available within the sediments. This information can be utilized as a guide for future sediment inactivation projects. A summary of total available phosphorus in each of the 22 collected sediment core samples is presented in Table 2-7. Total available phosphorus concentrations within the lake sediments range from 6 μg/cm3 to 79 μg/cm3, with a median value of 79 μg/cm3.

Isopleths of total available phosphorus in the top 10 cm of sediments in Lake Roberts are illustrated on Figure 2-15. The area of highest total phosphorus levels is located in the deeper portion of the south lobe. The total available phosphorus isopleths can be used directly as a guide for future sediment inactivation activities.

Available sediment phosphorus can also be expressed as a percentage of total phosphorus concentrations within the sediments. The percentage of available phosphorus within the sediments of Lake Roberts ranges from 12% to 17%, with a median value of 27%. This suggests that, on an average basis, approximately 27% of the existing accumulation of phosphorus within the lake is potentially available for release into the overlying water column as a result of sediment agitation or anoxic conditions.

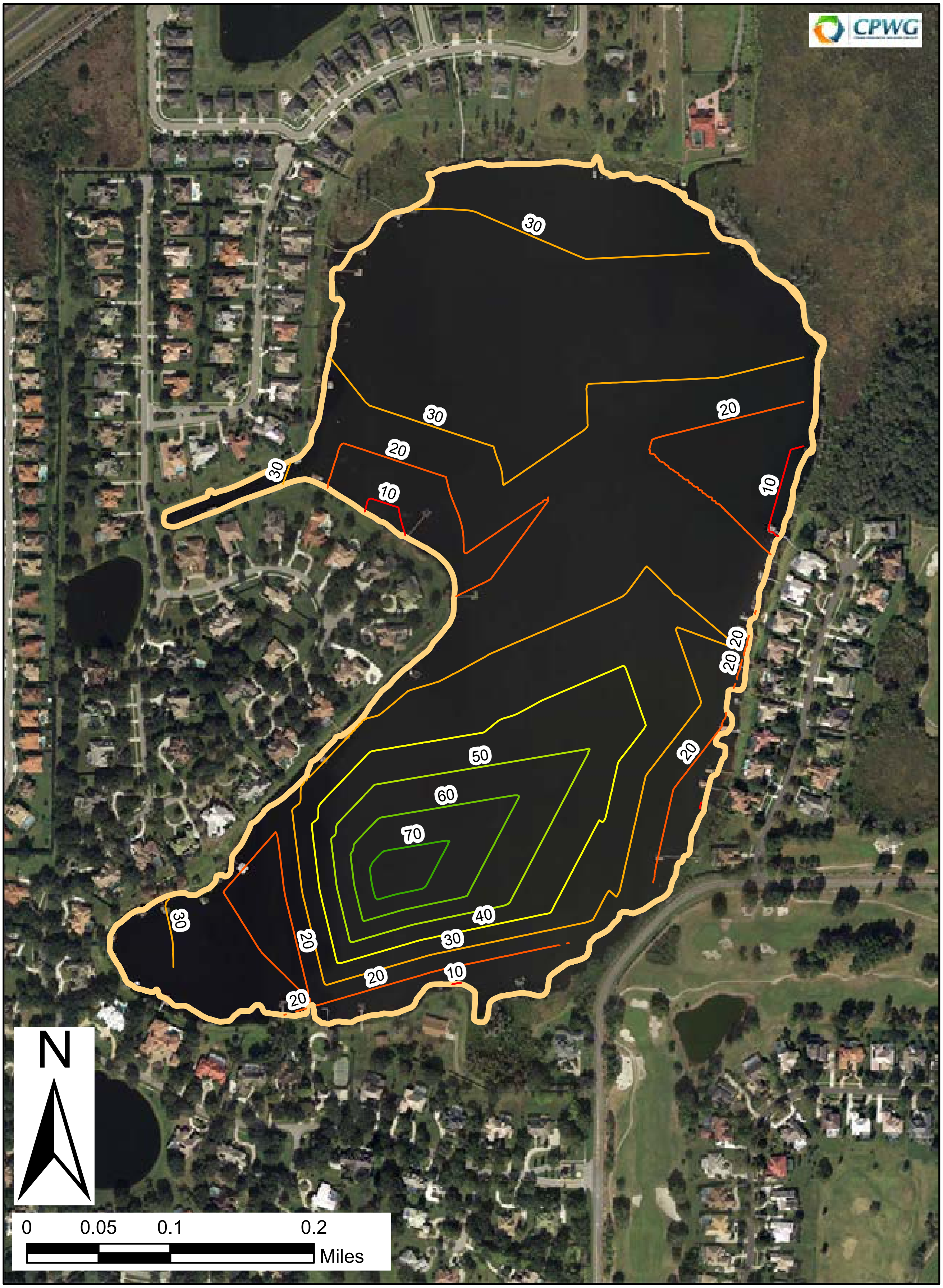
Aluminum-bound phosphorus represents an unavailable species of phosphorus within the lake sediments. Phosphorus bound with aluminum is typically considered to be inert under a wide range of pH and redox conditions within lake sediments. Aluminum-bound phosphorus concentrations in Lake Roberts range from 2 to 19 μg/cm^3, with a median value of 6 μg/cm^3.

These values are lower than aluminum-bound phosphorus concentrations observed in other lake systems. The median aluminum-bound phosphorus concentration of 6 μg/cm^3 suggests that approximately 30% of the existing phosphorus within the sediments is bound in sediment associations which are considered to be unavailable.



Lake Roberts Isopleth of Iron-Bound Phosphorus ($\mu g/cm^3$ wet wt) in Top 10 cm of Sediment

Figure 2-14



Lake Roberts Isopleth of Total Available Phosphorus (µg/cm^3 wet wt) in Top 10 cm of Sediment

Figure 2-15

2.3 WATER QUALITY CHARACTERISTICS

2.3.1 HISTORICAL WATER QUALITY

Historical water quality monitoring has been conducted in Lake Roberts by the Orange County Environmental Protection Division (OCEPD) since February 1991. A summary of available historical water quality data for Lake Roberts is presented in Table 2-8. Measurements were conducted on the collected samples for general characteristics, nutrients, chlorophyll-a, heavy metals and a measurement of Secchi disk depth. Historical data was collected at 0.5 meters below the surface.

TABLE 2-8
Summary of Available Historical Water Quality Data for Lake Roberts

Data Source	Period of Record	Station ID	Location	Number of Samples	Monitoring Frequency	Parameters Measured
OCEPD	1991 - 2005	A33	Center area of lake between north and south lobe at 0.5 meters below water surface	25	Between 1 and 3 samples per year	General Parameters, Nutrients, Microbiological Parameters, Metals
	2006 - 2013	A33	Center area of lake between north and south lobe at 0.5 meters below water surface	34	Quarterly	

Historical water quality data was collected at Station ID A33, which is located in the central area of the lake between the North and South Lobes. Available historical data from Station ID A33 was downloaded from the Orange County Water Atlas and indicates that quarterly samples were collected and analyzed for total phosphorus (TP), total nitrogen (TN), chlorophyll-a, Secchi disk depth, the TN/TP ratio, and TSI (Chl-a) during the period of record indicated in Table 2-8.

A graph of total nitrogen concentrations in samples collected in Lake Roberts from 1991 to 2013 is presented on Figure 2-16. Total nitrogen concentrations over the 23 year sampling period have ranged between 500 µg/l and 2000 µg/l. A simple linear regression method was used to develop a trend line for the graphed data. While there are cyclic variations where decreases in total nitrogen are observed, an overall trend of increasing values is observed over the 23 years of data collection.

A graphical summary of historical trends in total phosphorus concentrations in Lake Roberts is presented on Figure 2-17. The measured total phosphorus concentrations vary widely over the monitoring period ranging from approximately 10 µg/l to 90 µg/l. Peaks in phosphorus concentrations in the lake were observed in 1995 and 2005. An overall trend of increasing total phosphorus concentrations is observed over the 23 years monitoring period.

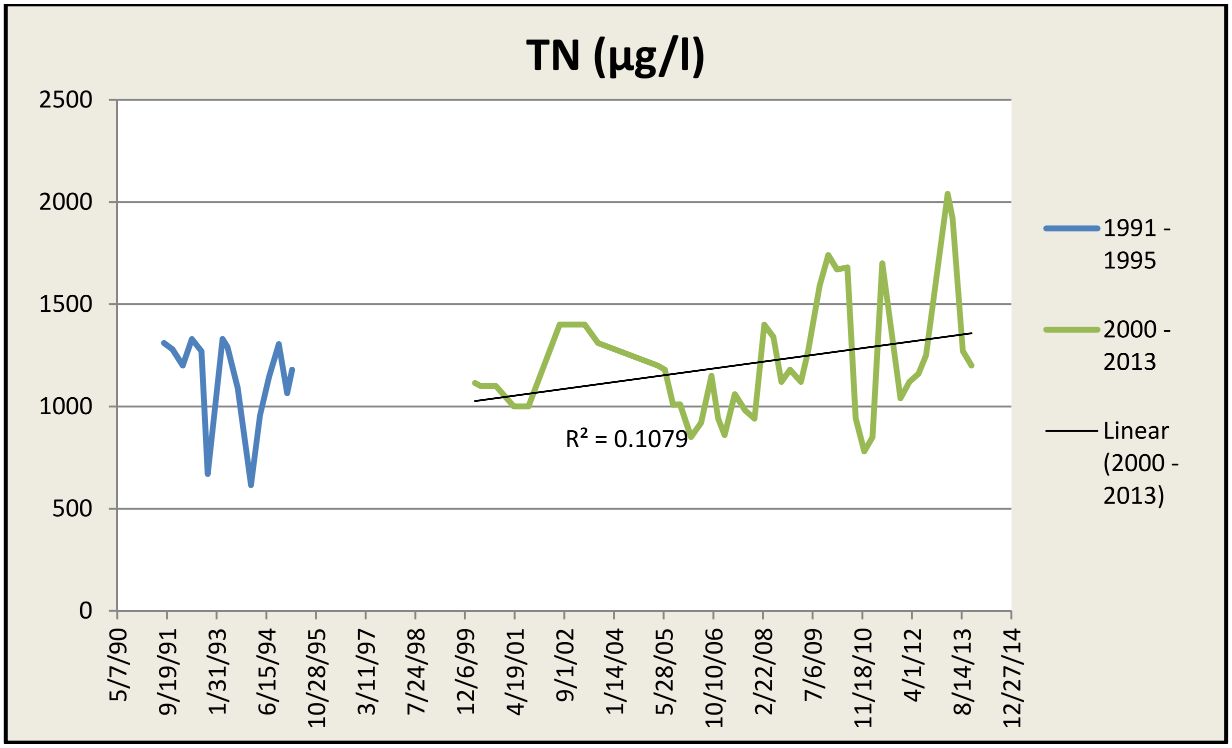


Figure 2-16. Estimated Trends in Total Nitrogen Concentrations in Lake Roberts from 1991-2013 at Sample Site A33.
(note that samples collected between March 1995 and March 2000 were not analyzed for TN)

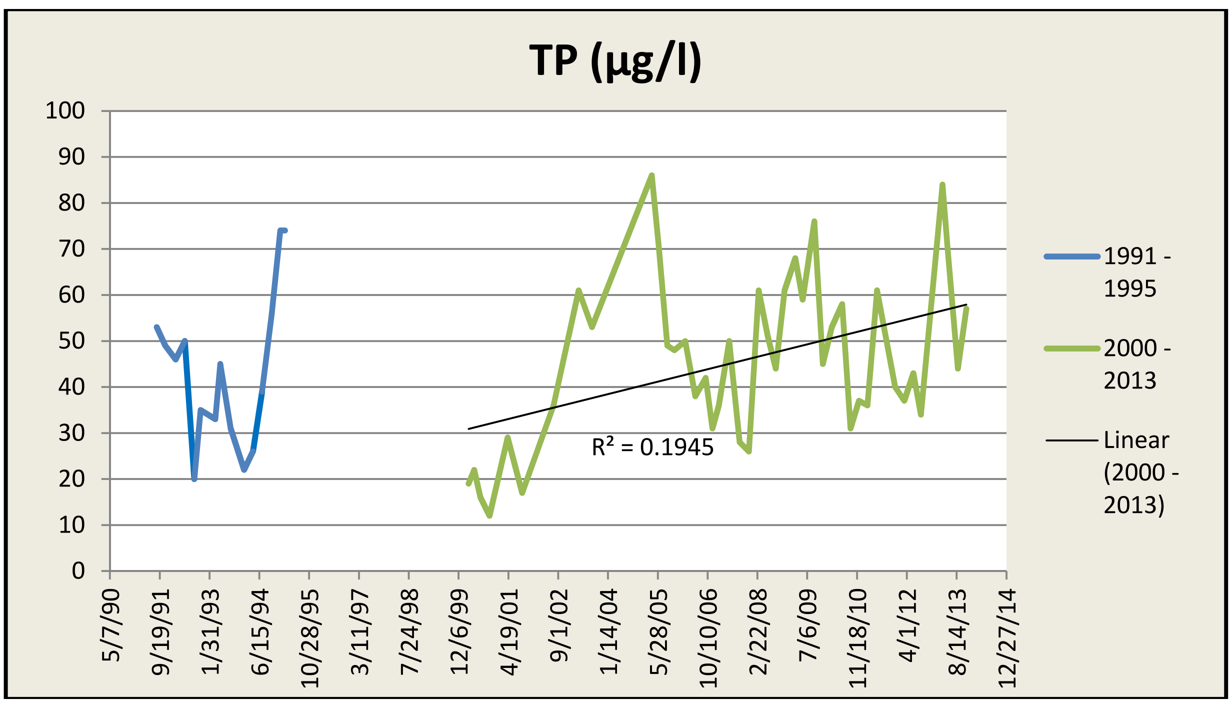


Figure 2-17. Estimated Trends in Total Phosphorus Concentrations in Lake Roberts from 1991-2013 at Sample Site A33.
(note that samples collected between March 1995 and March 2000 were not analyzed for TP)

A graphical summary of historical concentrations of chlorophyll-a concentrations in Lake Roberts is presented on Figure 2-18. Values for chlorophyll-a were available from 2000 to 2013. The measured chlorophyll-a concentrations ranged from less than 5 µg/l to approximately 60 µg/l with a couple of peaks greater than 120 µg/l. These peaks were observed in July 2000 and September 2009. An overall trend of increasing chlorophyll-a concentrations is observed during the monitoring period.

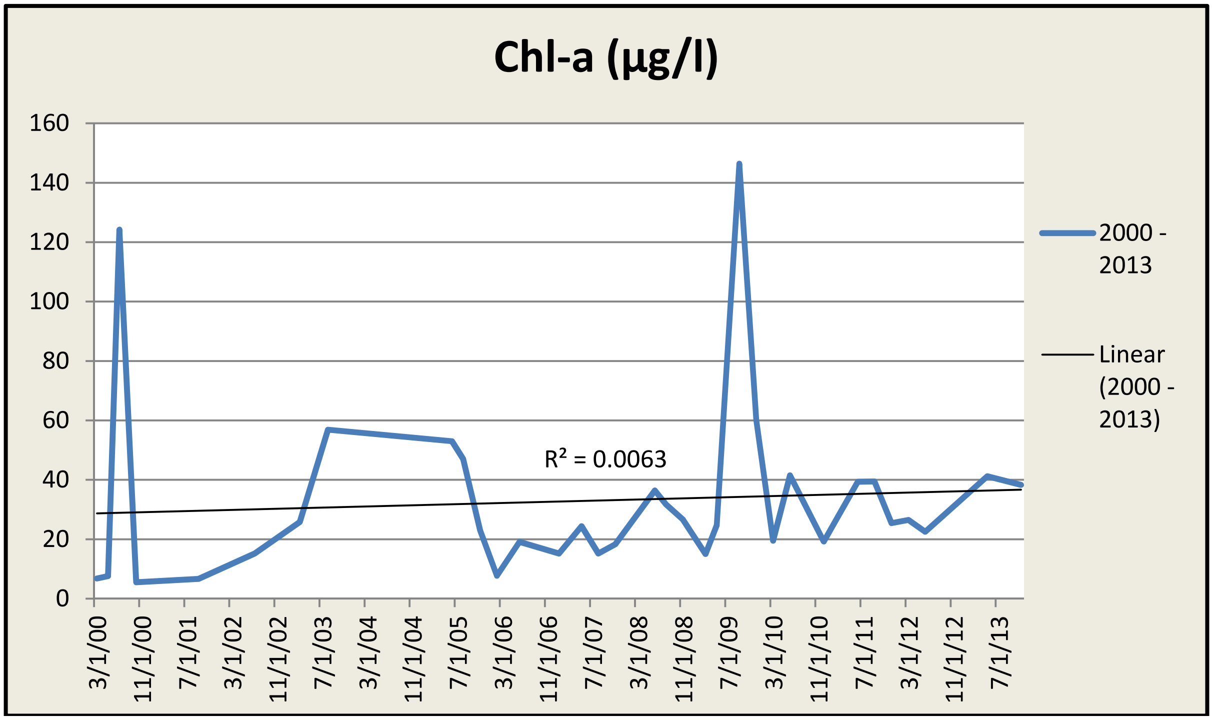


Figure 2-18. Estimated Trends in Chlorophyll-a Concentrations in Lake Roberts from 2000-2013 at Sample Site A33.

A graphical summary of measured Secchi disk depths in Lake Roberts from 1991-2013 is presented on Figure 2-19. The Secchi disk depth measurements ranged between 0.5 meters and 1.8 meters with the highest transparency observed during the early 1990's. An overall trend of decreasing Secchi disk depth is observed in the lake.

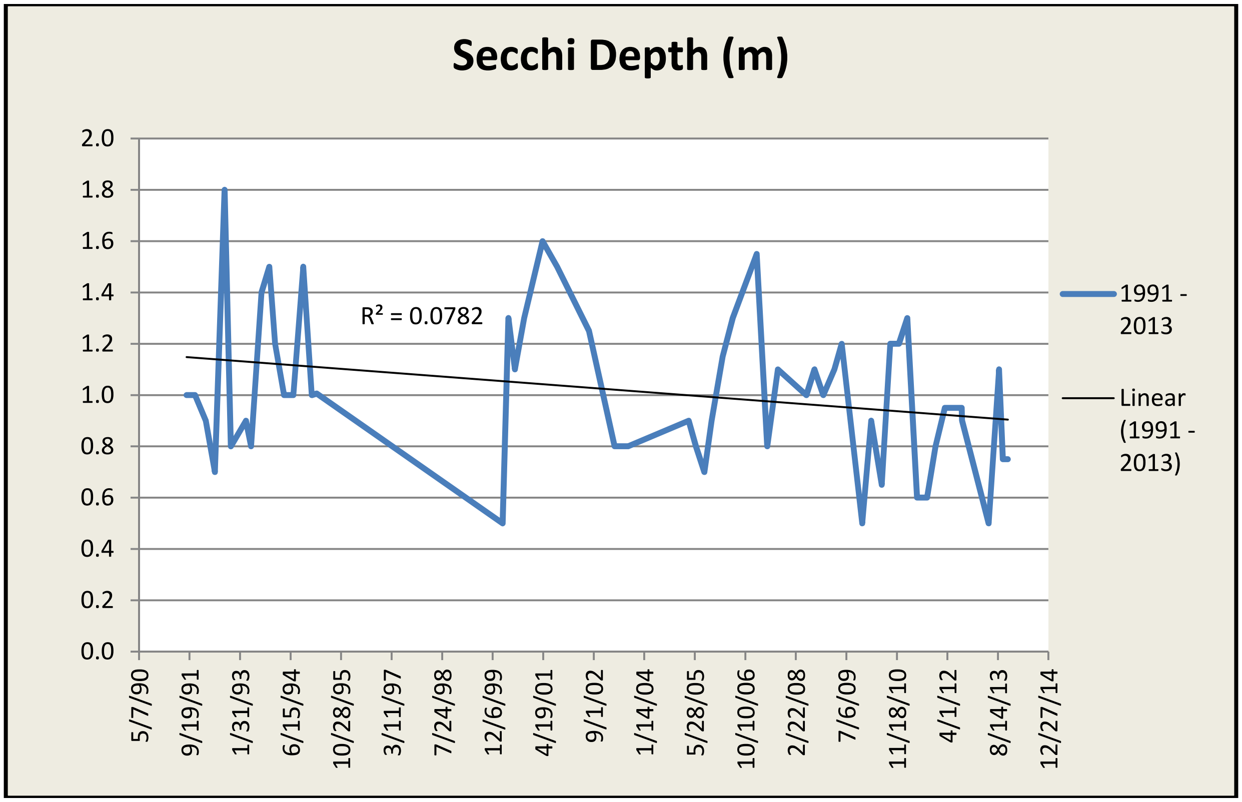


Figure 2-19. Estimated trends in Secchi Disk Depth in Lake Roberts from 1991-2013 at Sample Site A33.

Nutrient limitation in a waterbody is often evaluated using the total nitrogen/total phosphorus (TN/TP) ratio. The calculated TN/TP ratio is a numerical ratio of the measured water column concentrations of total nitrogen and total phosphorus. This ratio is useful in evaluating the relative significance of nitrogen and phosphorus in regulating primary productivity (algal growth) in a waterbody. Measured TN/TP ratios less than 10 are considered to indicate nitrogen-limited conditions, suggesting that phosphorus is relatively abundant and nitrogen is the element which limits primary productivity and the growth of algae within the lake system. Calculated TN/TP ratios between 10 and 30 indicate nutrient-balanced conditions, with both nitrogen and phosphorus considered important for limiting aquatic growth. Calculated TN/TP ratios in excess of 30 indicate phosphorus-limited conditions, which suggests that nitrogen is abundant within the system and algal growth is limited by the availability of phosphorus. This is the typical situation observed in many lakes in the Central Florida area. This condition indicates that inputs of phosphorus into the lake system should be controlled to regulate the growth of algal biomass within the lake.

A summary of total nitrogen/total phosphorus (TN/TP) ratios in Lake Roberts from 1991-2013 is presented in Figure 2-20. Although the TN/TP ratios vary widely, it appears that the Lake

Roberts data in recent years has begun to fluctuate near the value that indicates the lake is phosphorus limited.

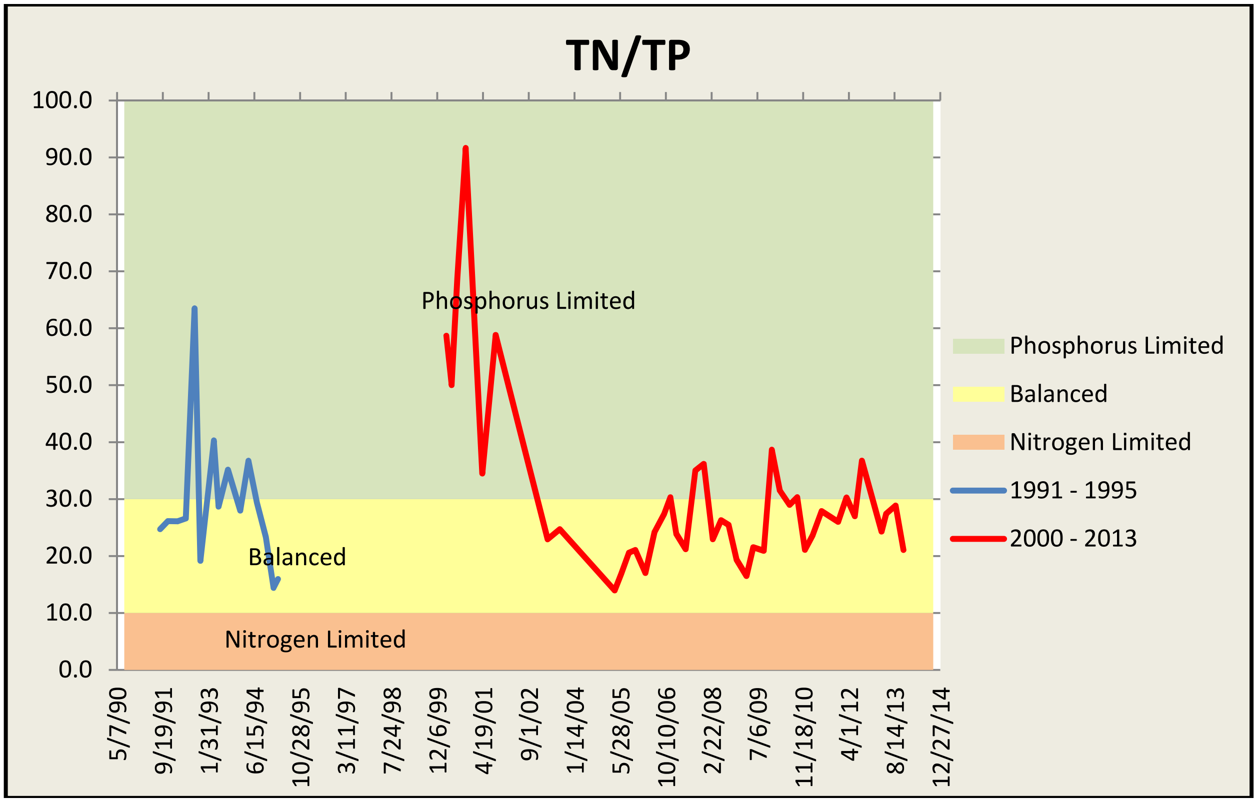


Figure 2-20. Calculated TN/TP Ratios in Lake Roberts from 1991-2013 at Sample Site A33.

Florida Trophic State Index (TSI) is a summary statistic which incorporates measured concentrations of significant parameters in lake systems and is often considered the best overall indicator of the health of a lake system. Calculated TSI values less than 50 indicate oligotrophic conditions, representing lakes with low nutrient loadings and good to excellent water quality characteristics. TSI values ranging between 50 and 60 indicate mesotrophic conditions, representing fair water quality characteristics. TSI values ranging between 60 and 70 indicate eutrophic conditions, representing poor water quality characteristics. TSI values in excess of 70 indicate hypereutrophic conditions, reflecting very poor water quality.

The TSI index was developed by Carlson (1977) as a relative measure of the degree of biological productivity in lakes. The TSI concept incorporates forcing functions such as nutrient supplies, light availability, seasonality, and other factors. Since the TSI value is intended to reflect the level of biological productivity, the best estimator for productivity is chlorophyll-a. Some calculations also incorrectly include concentrations of nutrients and Secchi disk depth in addition to chlorophyll-a. However, nutrients and Secchi disk depth should only be included as surrogates for biological productivity when chlorophyll-a data are not available. TSI calculations were performed for Lake Roberts' historical data from 200 to 2013 using measured concentrations of chlorophyll-a according to the following relationship:

$$\text{TSI (chl-a)} = 10\left(6 - \frac{(2.04 - 0.68 * \ln \text{chl-a})}{\ln 2}\right) \quad (\text{mg/m}^3)$$

Calculated TSI values in Lake Roberts from 2000 to 2013 are summarized on Figure 2-21. TSI conditions in Lake Roberts have ranged from slightly oligotrophic to hypereutrophic conditions with the highest peaks observed in 2001 and 2010. Water quality within the lake has been highly variable during the monitoring period. However, the data suggests a trend of increasing TSI values over time.

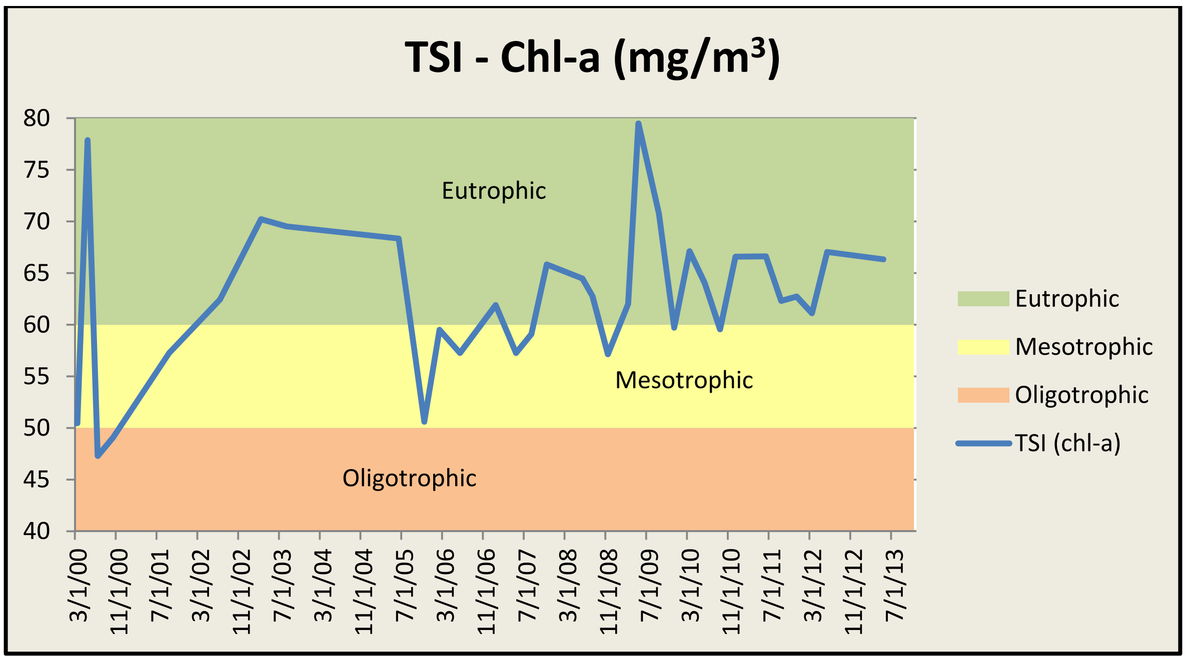


Figure 2-21. Calculated TSI Conditions in Lake Roberts from 2000-2013 at Sample Site 33.

Lake Roberts was initially verified for nutrient impairment by FDEP based on TSI (exceedance of the annual average TSI threshold of 60). The Numeric Nutrient Criteria (NNC) was adopted in Florida on 7/3/12 to further assess the impairment of inland waters. The NNC maximum annual mean value within a high colored lake for impairment (Lake Roberts color exceeds 40 PCU) is 0.16 mg/l for TP, 2.23 mg/l, for TN and 20 μg/l for chlorophyll a. Historical values of TP and chlorophyll-a exceed the NNC established values for lakes. Therefore, the FDEP will continue to classify Lake Roberts as impaired.

Mean monthly concentrations were calculated for total phosphorus, total nitrogen, chlorophyll-a, and TN/TP ratios for the available data to evaluate seasonal variations in water quality.

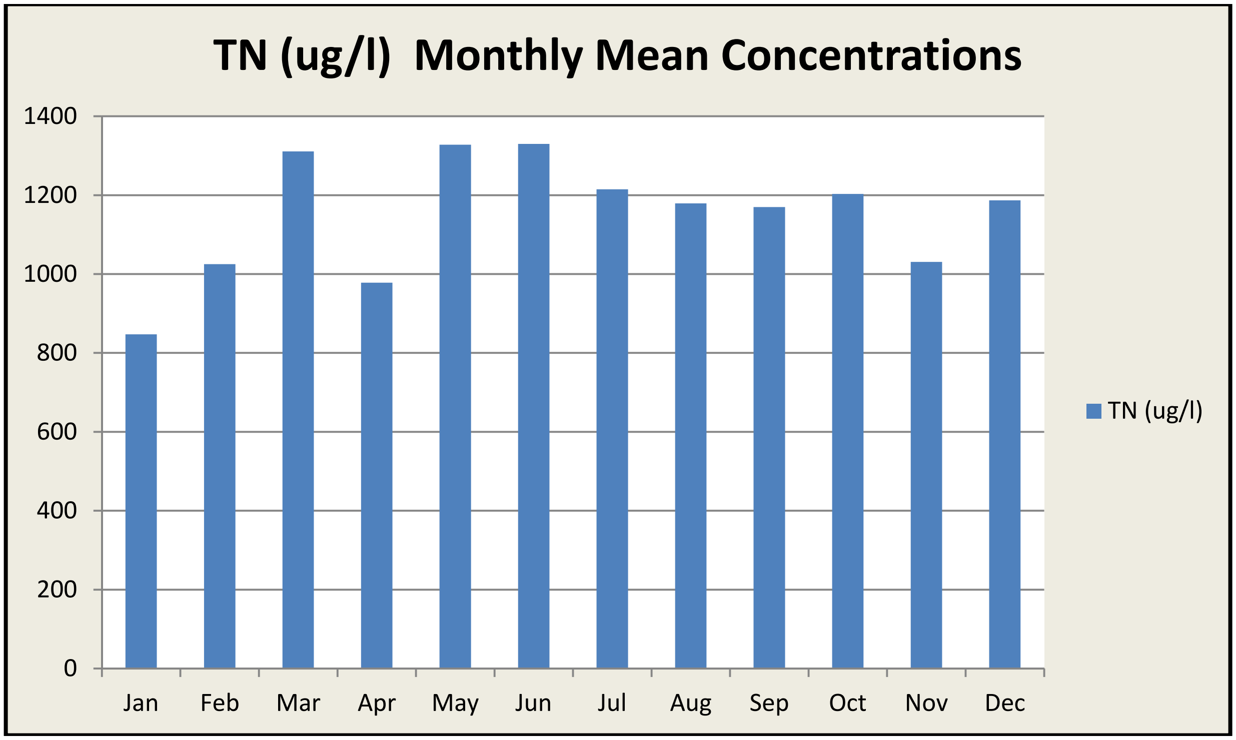
A chart of the mean monthly concentrations of total nitrogen in Lake Roberts from 1995 to 2013 is presented on Figure 2-22. Total nitrogen concentrations in Lake Roberts appear to be greatest during the spring, summer, and fall months, with lowest concentrations during January and February. Nitrogen can be released from anoxic bottom sediments, primarily in the form of ammonia, which may be partially responsible for the patterns of total nitrogen indicated on Figure 2-22.

A chart of mean monthly concentrations of TP for available data is also presented on Figure 2-22. In general, it appears that mean monthly phosphorus concentrations in Lake Roberts are lowest during late-spring and late-summer and highest in value during the late fall, winter, and early-spring months (although the April value was the lowest average concentration). Since the fall, winter, and spring months are generally characterized by low rainfall and reduced runoff inputs, the increases in phosphorus concentrations observed during this period suggest that phosphorus sources in addition to stormwater runoff are impacting water quality in Lake Roberts.

The general pattern of monthly phosphorus concentrations exhibited in Figure 2-22 suggests that internal recycling may be occurring in Lake Roberts. During late-spring through early-fall, lakes in Central Florida typically become stratified, with anoxic conditions developing in lower portions of the lake. These anoxic conditions accelerate the release of phosphorus from the bottom sediments which begin to accumulate in the lower isolated portions of the waterbody. When water temperatures cool during late-fall and winter, the water column begins to circulate and accumulated phosphorus concentrations in lower layers of the lake can be distributed throughout the entire water column, resulting in increases in phosphorus levels within the lake.

A comparison of mean monthly concentrations of chlorophyll-a in Lake Roberts from 1995 to 2013 is presented on Figure 2-23. The monthly chlorophyll-a concentrations within the lake appear to exhibit a pattern similar to that observed for total phosphorus, with the most elevated concentrations observed during mid-summer and fall and lower concentrations observed during winter and early-spring.

Average monthly TN/TP ratios in Lake Roberts from 1991 to 2013 are also illustrated on Figure 2-23. Historical data indicates that Lake Roberts has exhibited phosphorus-limited conditions during the spring, summer and early fall.



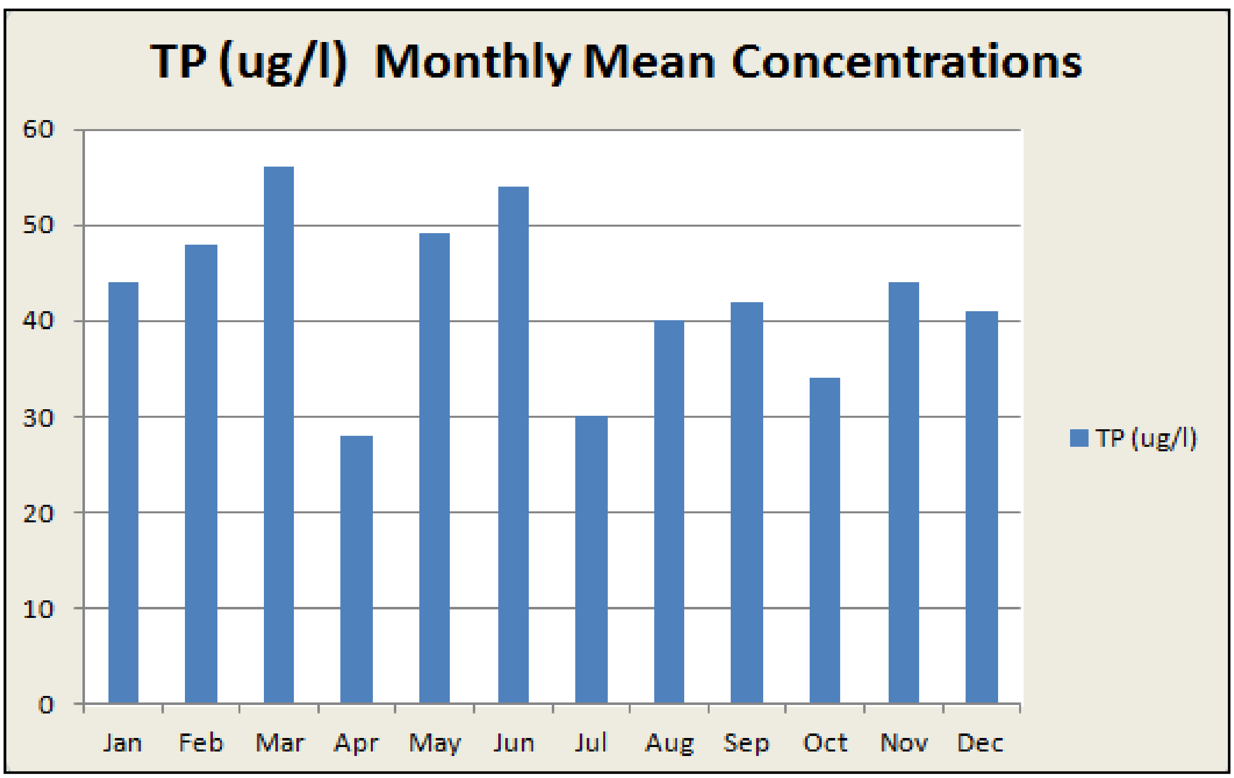


Figure 2-22. Mean Monthly Concentrations of Total Nitrogen and Total Phosphorus in Lake Roberts from 1991 to 2013.

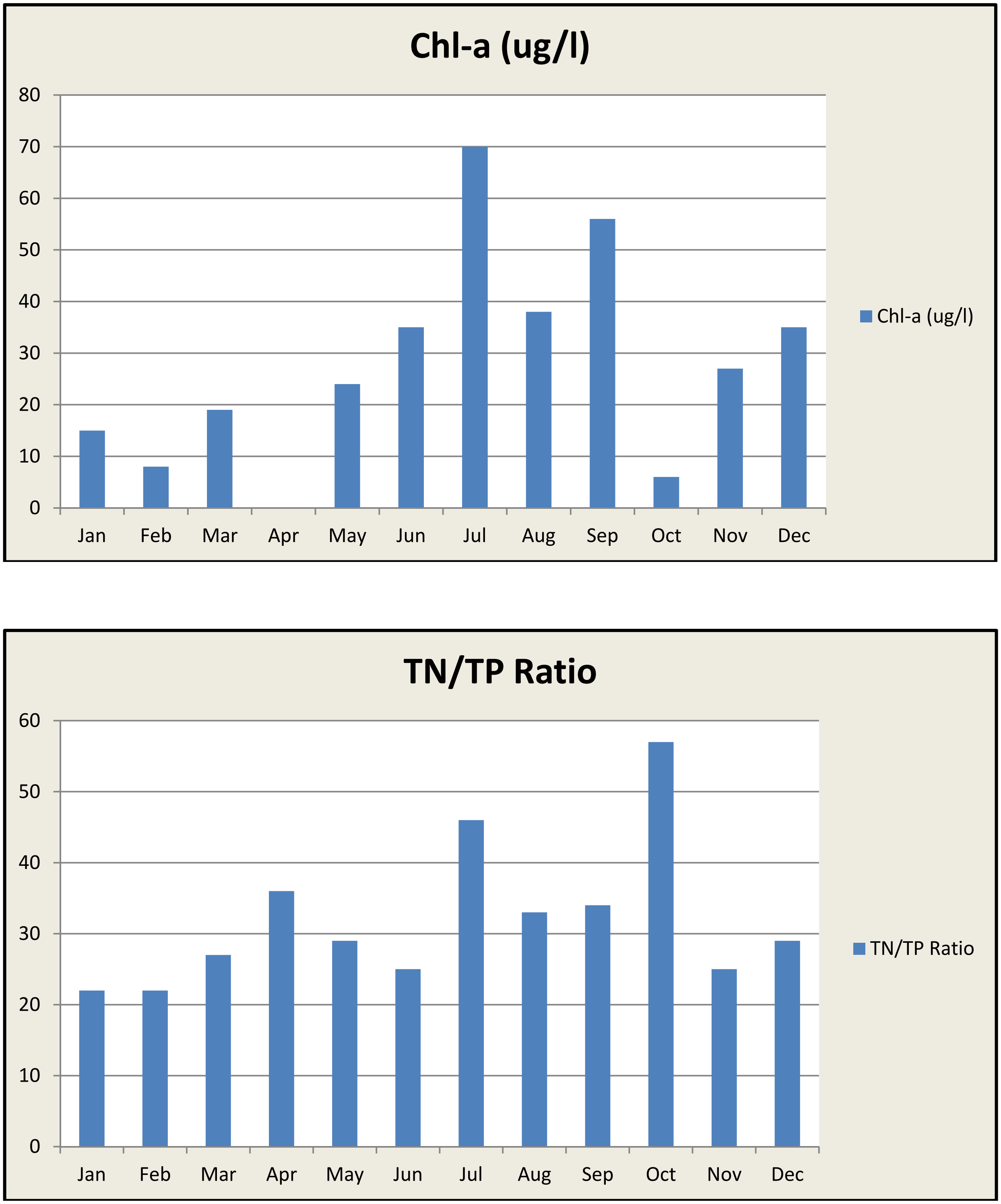


Figure 2-23. Mean Monthly Concentrations of Chlorophyll-a and TN/TP Ratio in Lake Roberts from 1991 to 2013.

A summary of historical water quality characteristics of Lake Roberts from 1991 to 2013 is given in Table 2-9 for significant water quality parameters based upon the OCEPD data set. Median values are provided for each of the listed parameters since the data sets are not normally distributed, and the median provides a better indication of central tendency than an arithmetic mean value.

Table 2-9
Summary of Historical Water Quality Characteristics of Lake Roberts from 1991 to 2013[1]

Parameter	Units	Median Value Center Area
pH	s.u.	7.1
Alkalinity	mg/l	33
Conductivity	μmho/cm	204
Total N	μg/l	1,155
Total P	μg/l	44.5
Chlorophyll-a	mg/m^3	25.6
Secchi Depth	m	1.0
TSI	--	62.4

1. OCEPD data

2.3.2 CURRENT WATER QUALITY CHARACTERISTICS

2.3.2.1 MONITORING ACTIVITIES

A monthly surface water quality monitoring program was conducted in Lake Roberts, Lake Reaves and the wetland between them during the period September 2013 and August 2014. Samples were collected at three fixed monitoring locations within Lake Roberts, one fixed location in the wetland tussock along the northeast boundary of the lake, and one location in Lake Reaves located northeast of the wetland tussock. Approximate locations of the surface water monitoring sites in Lake Roberts are indicated on Figure 2-24. Site location S2 shown on Figure 2-24 is the same location as Site A33 described in the Orange County Water Atlas. The water quality monitoring sites were selected to allow evaluation of horizontal variability in water quality characteristics, vertical variability in deep areas of Lake Roberts and general information on ambient water quality characteristics. Water quality monitoring was performed monthly with eight monitoring events performed by CPWG (analysis performed by ERD laboratories) and four monitoring events performed by Orange County EPD (analysis by OCEPD laboratories).

Location of Surface Water Monitoring Sites

Figure 2-24

Monitoring and sampling was performed in accordance with FDEP's standard operating procedures outlined in DEP-SOP-001/01 titled "Department of Environmental Protection Standard Operating Procedures for Field Activities". Surface water samples were collected using a Van Dorn sampler consisting of a plexiglas cylinder closed at both ends by rubber force cups. The cups are locked outside the cylinder to open the sampler. Once the desired depth of sample was reached, a weight was lowered to release the cups, retaining the sample in the cylinder. Surface samples (0.5 meters below water surface) and bottom samples (0.5 meters above the bottom sediment) were collected from the three Lake Roberts sites. Surface samples were collected from the wetland tussock and Lake Reaves. Samples were preserved as appropriate for the parameter to be analyzed, stored on ice, and returned to the laboratory for chemical analyses. Laboratory measurements performed is shown in Table 2-10, along with a summary of analytical methods and laboratory detection limits.

TABLE 2-10
Analytical Methods and Detection Limits for Laboratory Analyses

Measurement Parameter		Method[1]	Method Detection Limits (MDLs)[2&3]
General Parameters	Hydrogen Ion (pH)	SM-21, Sec. 4500-H^+ B	N/A
	Alkalinity	SM-21, Sec. 2320 B	2 mg/l
	TSS	SM-21, Sec. 2540 D	0.1 mg/l
	Color	SM-21, Sec. 2120 C	2 Pt-Co Unit
	Specific Conductivity	SM-21, Sec. 2510 B	0.2 µmho/cm
	Turbidity	SM-21, Sec. 2130 B	0.1 NTU
Nutrients	Ammonia-N (NH_3-N) Nitrate	SM-21, Sec. 4500-NH3 G	0.004 mg/l
	+ Nitrite (NO_x-N) Total	SM-21, Sec. 4500-NO3 F	0.005 mg/l
	Nitrogen	SM-21, Sec. 4500-N C	0.005 mg/l
	SRP (Orthophosphorus)	SM-21, Sec. 4500-P F	0.003 mg/l
	Total Phosphorus	SM-21, Sec. 4500-P B.5	0.003 mg/l
Biological Parameters	Chlorophyll-a	SM-19, Sec. 10200 H.1.3	0.003 mg/m^3

1. Standard Methods for the Examination of Water and Wastewater, 21st Ed., 2005.
2. MDLs are calculated based on the EPA method of determining detection limits. Actual value may vary with different laboratories. Values reported in table are from Orange County EPD laboratory.
3. ERD Laboratory reports different MDL than EPD. Differences include 0.6 mg/l as MDL for Alkalinity, 0.005 mg/l as MDL for Ammonia, 0.025 mg/l as MDL for TN, 0.002 mg/l as MDL for TP and 0.2 mg/m^3.as MDL for chlorophyll-a.

During each monitoring event, vertical profiles of pH, temperature, conductivity, dissolved oxygen, ORP, and turbidity were conducted at each site. Field measurements were collected at water depths of 0.5 meters and at 0.5 meter intervals to the bottom of each sampling site. All field measurements were performed using YSI Data Sonde. A measurement of Secchi disk depth was also performed at each site.

2.3.2.2 FIELD PROFILES

A listing of vertical field profiles collected in Lake Roberts, the wetland tussock and Lake Reaves from September 2013 - August 2014 is given in Appendix B.1. A discussion of vertical field profiles collected at each of the five monitoring sites is given in the following sections.

2.3.2.2.1 NORTH LOBE

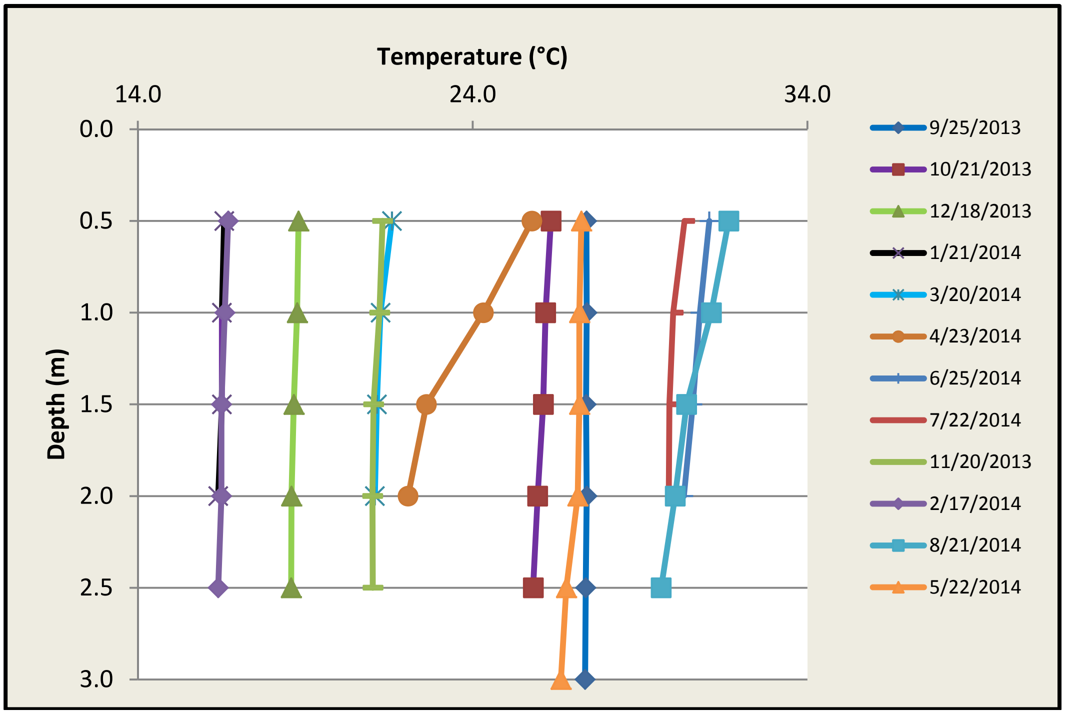
The North Lobe monitoring site is near the edge of the wetland tussock in the North Lobe and is relatively shallow. The vertical field profile measurements for temperature, pH, conductivity, and dissolved oxygen collected during the monthly monitoring event at the North Lobe monitoring site were graphed to show variations during different seasons and at different depths in the lake. These graphs are presented as Figure 2-25A and Figure 2-25B.

Temperature measurements were relatively uniform throughout the water column with temperature differences less than 1°C between top and bottom measurements observed during most of the monitoring events. No significant thermal stratification was observed at this site during the monitoring events.

Field measured pH values were relatively uniform in upper portions of the water column during the monitoring events to a depth of approximately 2 meters except during spring and summer months. Below this depth, pH measurements began to decrease with increasing water depth. During spring and summer conditions, water column pH varied from 8.00 to almost 9.0 near the surface, decreasing to approximately 6.5-7.0 at the water-sediment interface. During the colder months of the year, a pH difference of approximately 1 unit or less was observed between top and bottom measurements.

Measured conductivity values were relatively uniform throughout the water column during the monitoring events. Increases in conductivity were observed during the warmer months.

Dissolved oxygen concentrations were collected during each of the monitoring events to a depth of approximately 2-3 meters, depending upon sample date. Surface concentrations appeared to be uniform to 1 meter below the surface and then generally decreased with increasing water depth. Only one sampling event showed concentrations reaching anoxic conditions at the water-sediment interface. It appears that there is minimal internal recycling occurring in this area of the lake.



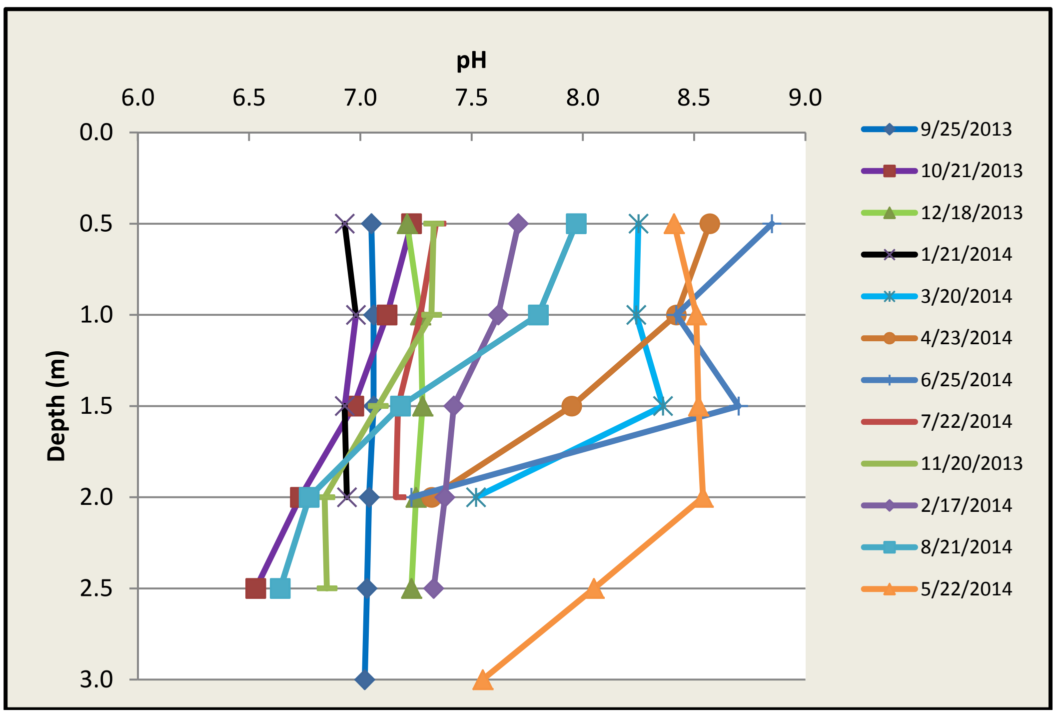
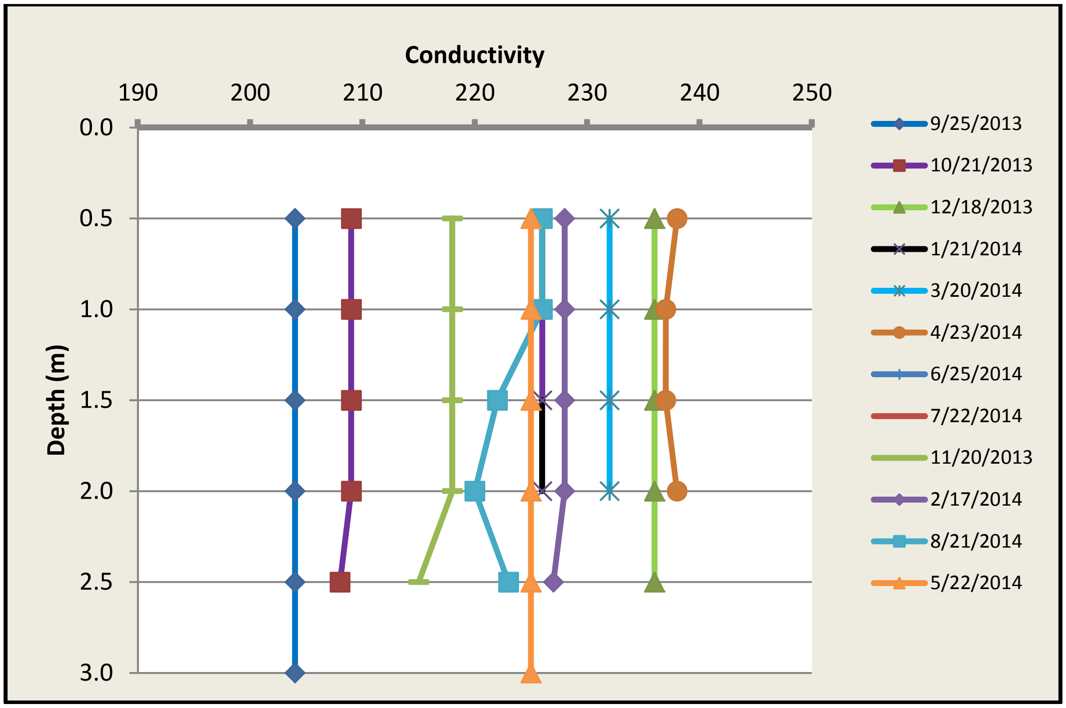


Figure 2-25A. Vertical Field Profiles of Temperature, pH, Conductivity, and Dissolved Oxygen Measured at the North Lobe in Lake Roberts from September 2013-August 2014.



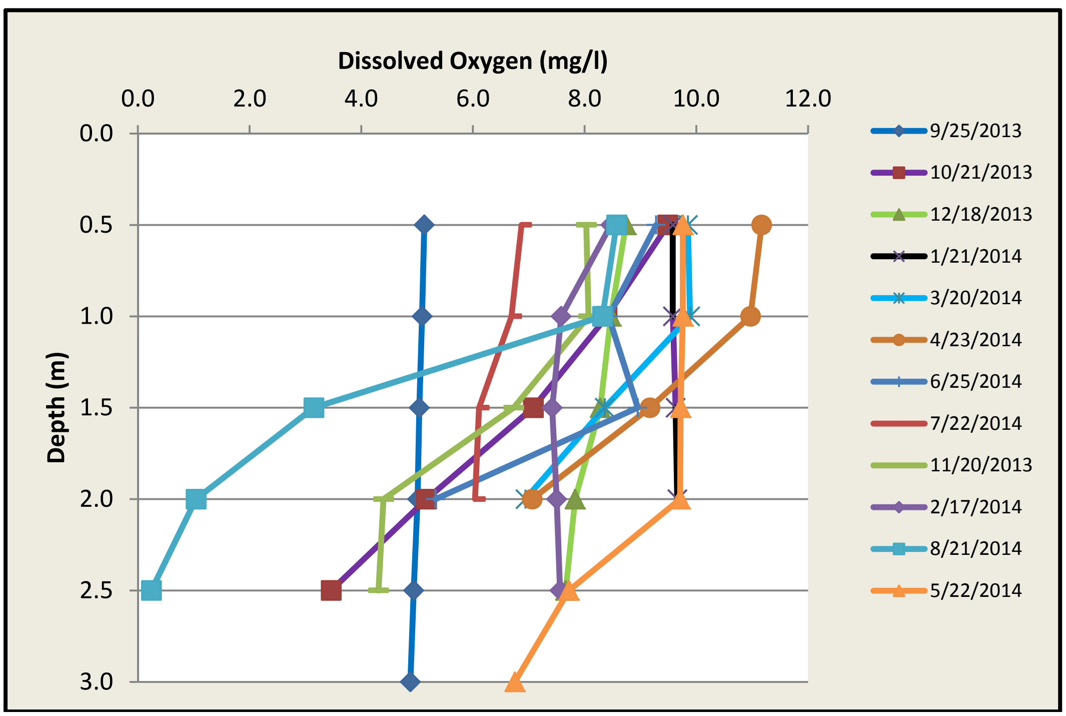


Figure 2-25B. Vertical Field Profiles of Temperature, pH, Conductivity, and Dissolved Oxygen Measured at the North Lobe in Lake Roberts from September 2013-August 2014.

2.3.2.2.2 WETLAND TUSSOCK

Initial investigation of the wetland tussock located to the northeast of Lake Roberts and between Lake Roberts and Lake Reaves indicated that the area is a large floating tussock. The water levels under the tussock were approximately 1 meter throughout the year. The predominant vegetation observed in the tussock was shallow marsh species growing on top of the water, and cattails and primrose willow growing through to the sediment below the water. Measurements of the depth of sediment in the wetland tussock monitoring site were collected during several monitoring events indicating the sediment depth to be approximately 0.33 meters deep.

A path was cut through cattails and primrose willows along the edge of the tussock to establish a permanent monitoring site within the tussock. Floating vegetation was removed from the monitoring site and a PVC pole was installed to mark the location. A surface sample (0.5 meters below surface) was collected and temperature, pH, conductivity, and dissolved oxygen were measured during most monitoring events. Temperature, pH, conductivity and dissolved oxygen measurements in the tussock were generally lower than Lake Roberts and Lake Reaves. Dissolved oxygen measurements indicate anoxic conditions in the water under the tussock during 9 of the 10 monitoring events.

2.3.2.2.3 CENTER AREA

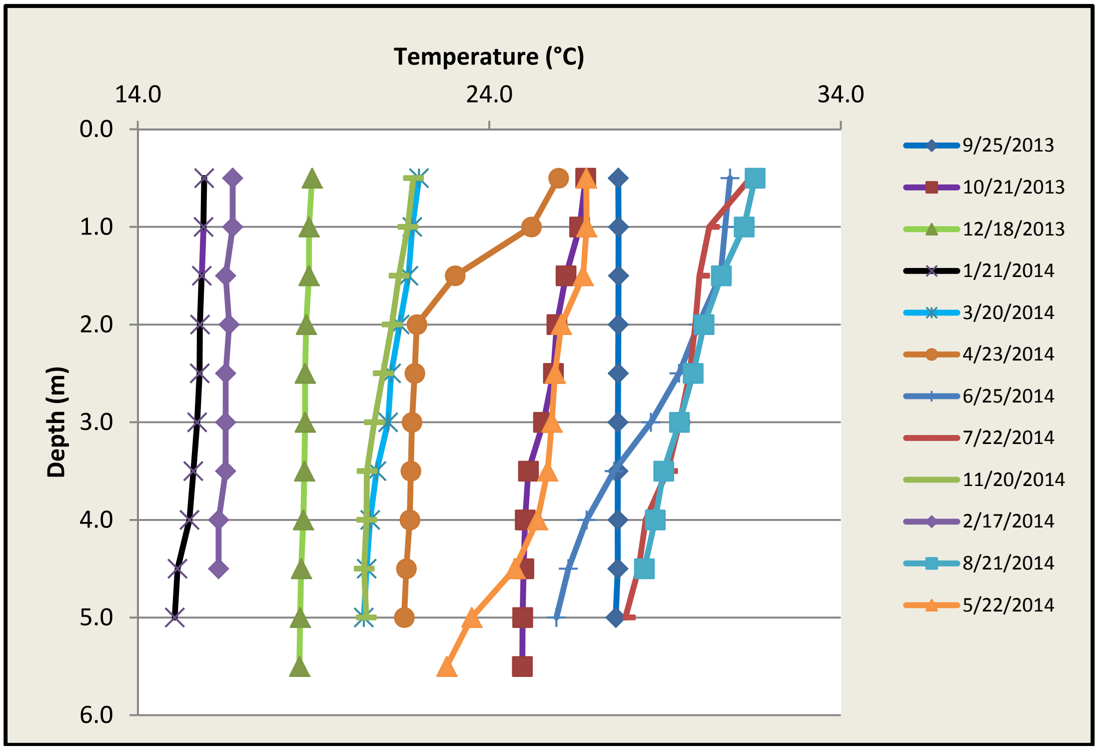
The Center Area is located in the middle of Lake Roberts where the North and South Lobes are pinched, making the lake resemble an hourglass shape. The total depth of the Center Area monitoring site is approximately 6 meters. The vertical field profile measurements for temperature, pH, conductivity, and dissolved oxygen collected during the monthly monitoring events at the Center Area monitoring site were graphed to show variations during different seasons and at different depths in the lake. These graphs are presented as Figure 2-26A and Figure 2-26B.

Relatively uniform temperature measurements were observed throughout the entire water column at this site during cooler months. During the warmer months, decreases in temperature with increasing water depth were observed. However, evidence of a classic thermocline was not observed during any of the monitoring events.

Measured pH values were higher in the top meter of the water column with values ranging from approximately 7 during the cooler months to almost 9 during the warmer months. The pH decreased with increasing water depth in each measured monitoring event.

Conductivity measurements in the Center Area site were uniform within the water column to a depth of approximately 3 meters during the monitoring events. Below this depth, increases in conductivity were observed with increasing water depth, particularly during spring and summer conditions. The significant increases in conductivity observed in lower portions of the water column are indicative of release of ions from bottom sediments.

Surface dissolved oxygen measurements ranged from approximately 8 to 12 mg/l except during the September 2013 monitoring event. Dissolved oxygen measurements gradually decreased within the water column during the cooler months. During the warmer months, dissolved oxygen measurements decreased gradually to a depth of 3 meters followed by a relatively rapid decrease in dissolved oxygen until reaching the water-sediment interface. Anoxic conditions, defined as dissolved oxygen concentrations <1 mg/l, were observed during 5 monitoring events. The areas of low dissolved oxygen correlate well with the areas of elevated conductivity measurements, further supporting the theory of significant internal recycling at this site.



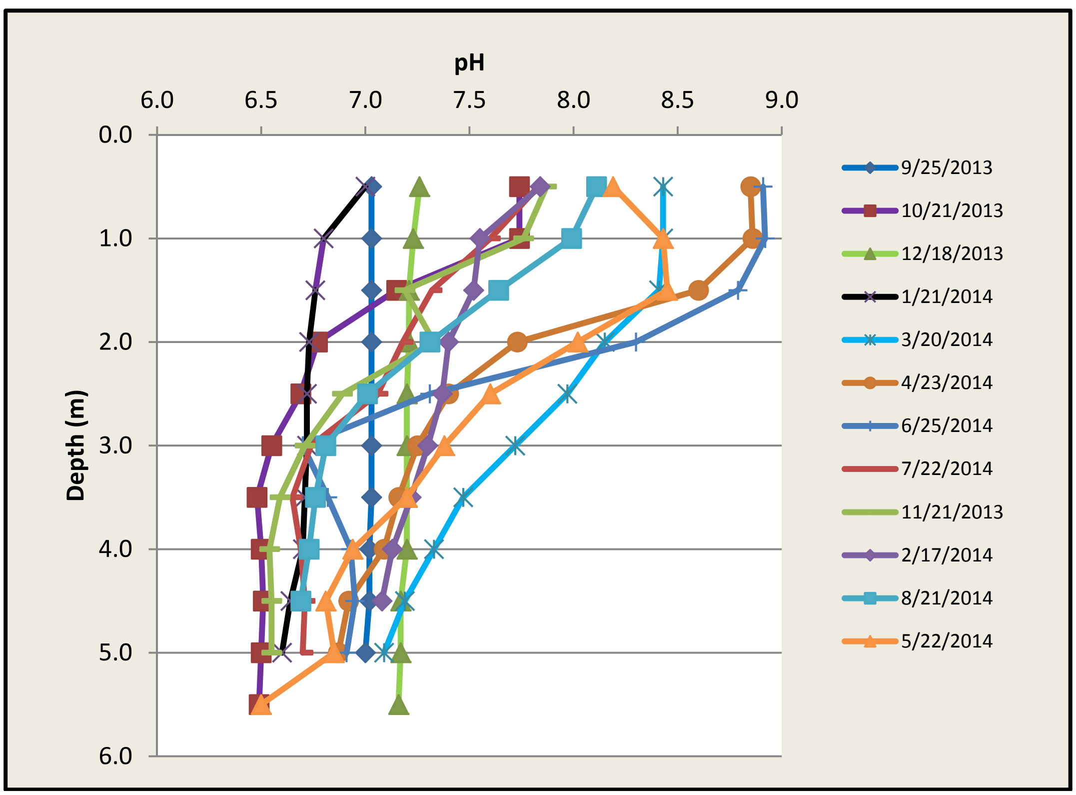
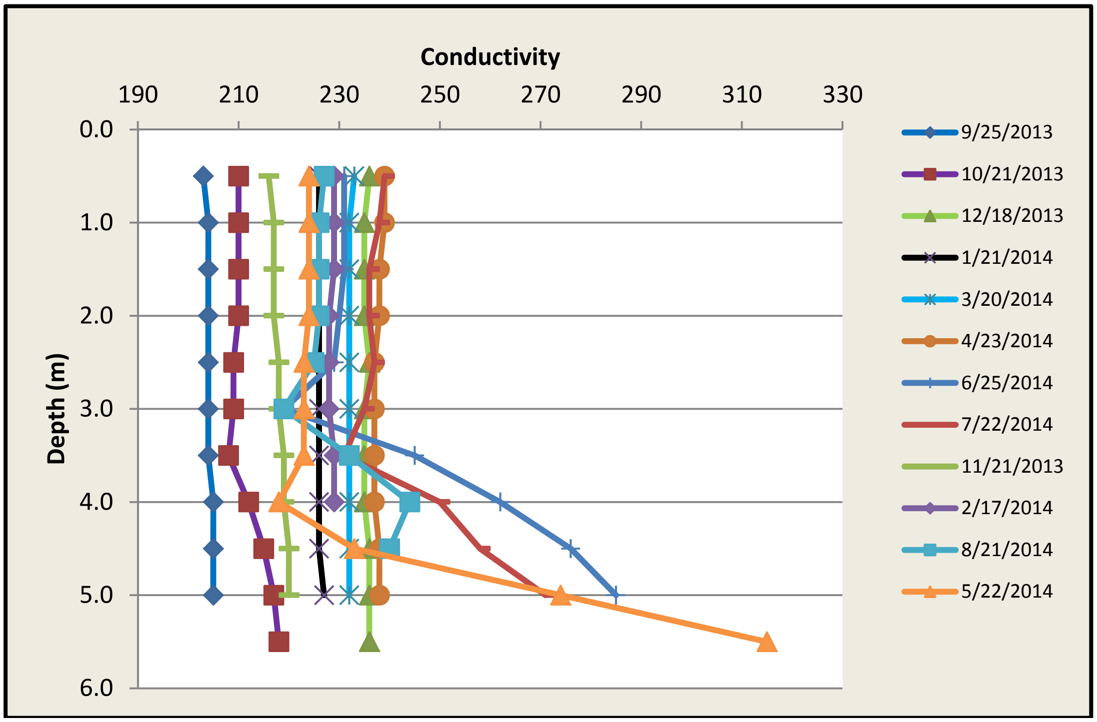


Figure 2-26A. Vertical Field Profiles of Temperature, pH, Conductivity, and Dissolved Oxygen Measured at the Center Area in Lake Roberts from September 2013-August 2014.



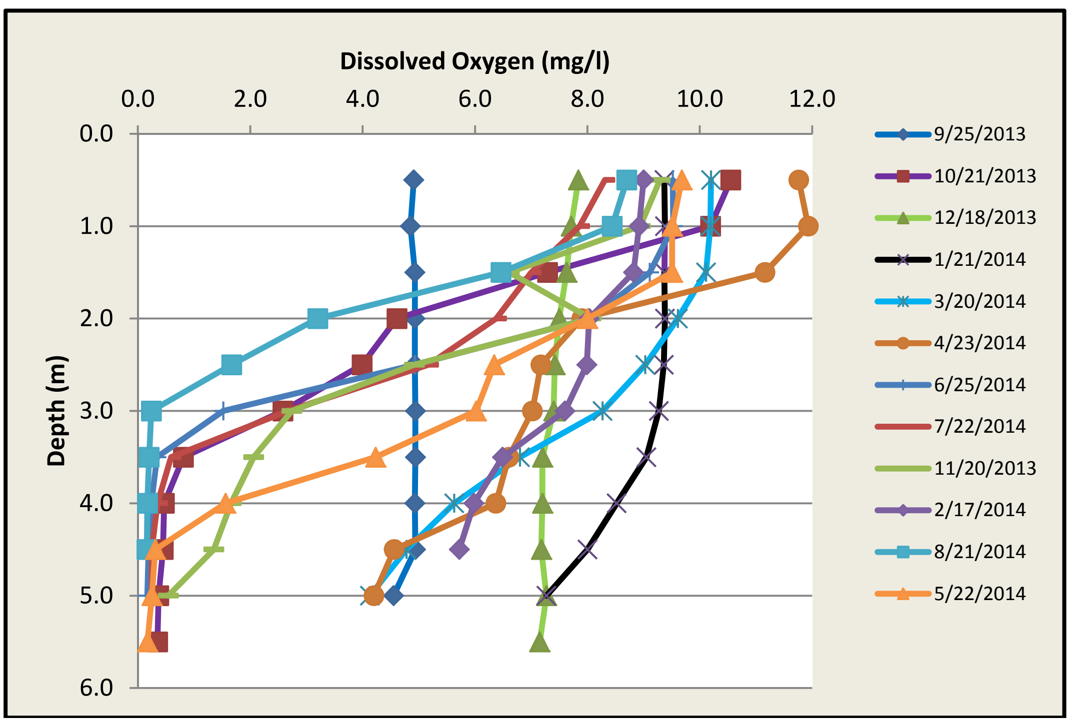


Figure 2-26B. Vertical Field Profiles of Temperature, pH, Conductivity, and Dissolved Oxygen Measured at the Center Area in Lake Roberts from September 2013-August 2014.

2.3.2.2.4 SOUTH LOBE

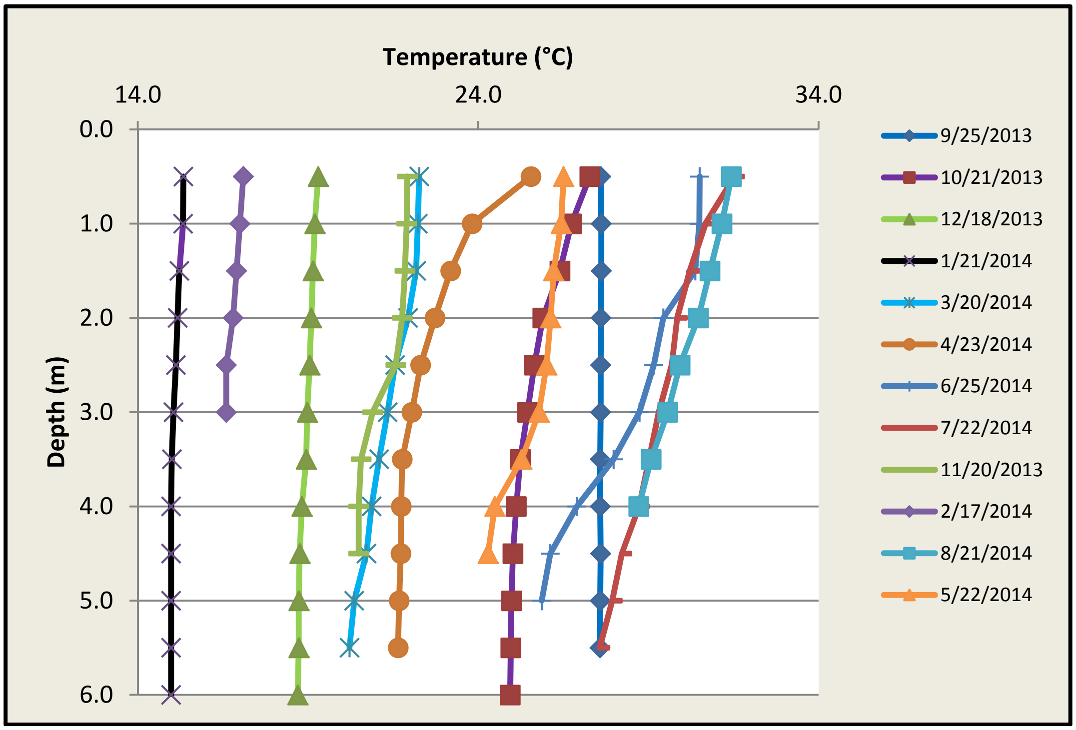
The South Lobe monitoring site is in the middle of the southern portion of the lake in one of the deepest areas of the lake, approximately 6 meters (20 feet) deep. The vertical field profile measurements for temperature, pH, conductivity, and dissolved oxygen collected during the monthly monitoring event at the South Lobe monitoring site were graphed to show variations during different seasons and at different depths in the lake. These graphs are presented as Figure 2-27A and Figure 2-27B.

Relatively uniform temperature measurements were observed throughout the entire water column at this site during cooler months. During the warmer months, decreases in temperature with increasing water depth were observed. However, evidence of a classic thermocline was not observed during any of the monitoring events.

Measured pH values were higher in the top meter of the water column with values ranging from approximately 6.5 during the cooler months to greater than 9 during the warmer months. The pH decreased with increasing water depth in each measured monitoring event.

Conductivity measurements in the South Lobe site were uniform within the water column to a depth of approximately 3.5 meters during the monitoring events. Below this depth, increases in conductivity were observed with increasing water depth, particularly during spring and summer conditions. The significant increases in conductivity observed in lower portions of the water column are indicative of a release of ions from bottom sediments. Increases of conductivity in the water-sediment interface zone are often an indication of internal recycling within the area due to released ions from the sediments.

Surface dissolved oxygen measurements ranged from approximately 8 to 12 mg/l except during the September 2013 monitoring event. Dissolved oxygen measurements gradually decreased within the water column during the cooler months. During the warmer months, dissolved oxygen measurements decreased gradually to a depth of approximately 3 meters followed by a relatively rapid decrease in dissolved oxygen until reaching the water-sediment interface. Anoxic conditions, defined as dissolved oxygen concentrations <1 mg/l, were observed during 5 monitoring events. The areas of low dissolved oxygen correspond well with the areas of elevated conductivity measurements, further supporting the theory of significant internal recycling at this site.



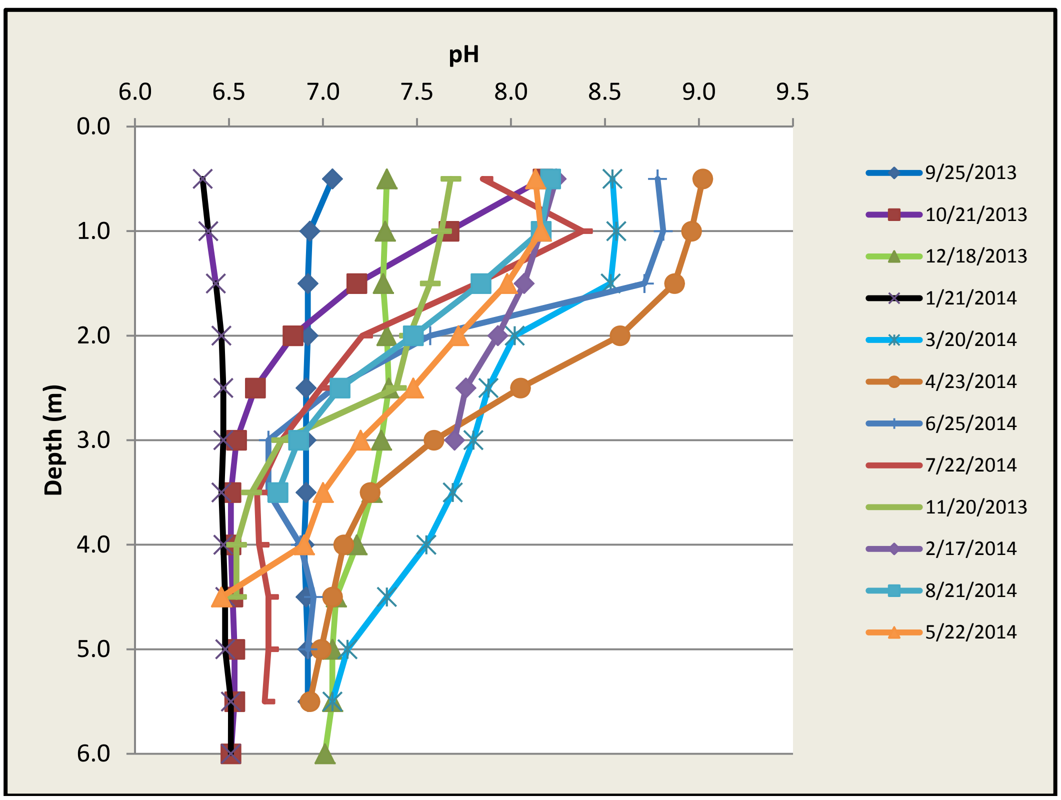
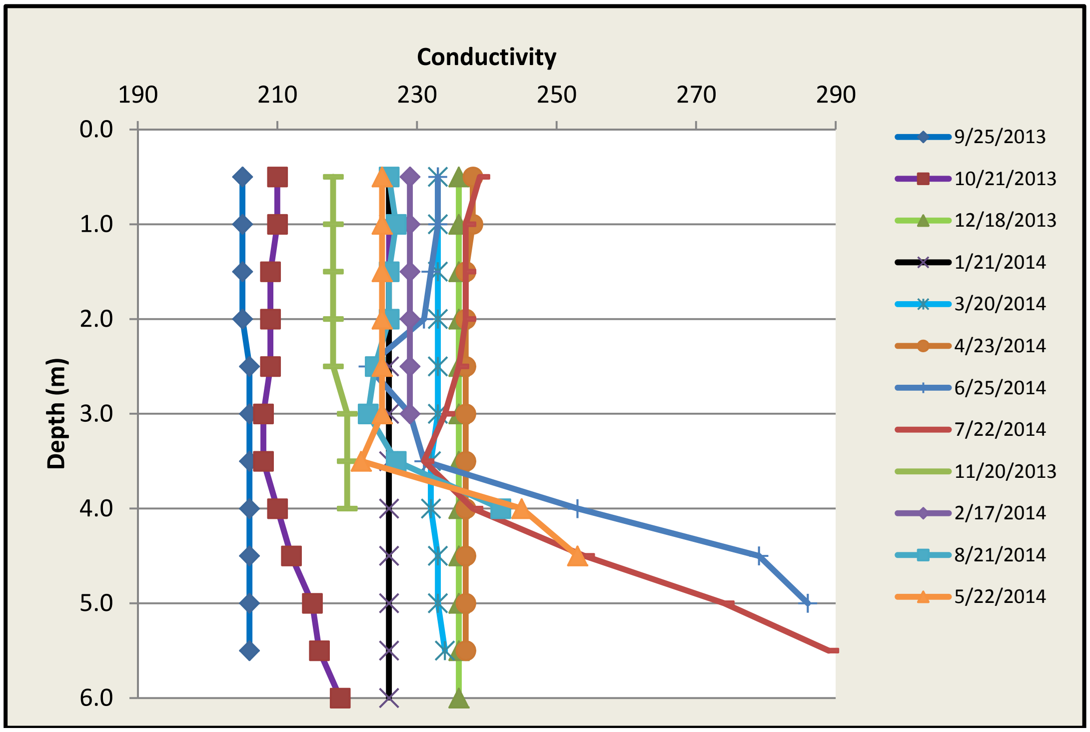


Figure 2-27A. Vertical Field Profiles of Temperature, pH, Conductivity, and Dissolved Oxygen Measured at the South Lobe in Lake Roberts from September 2013-August 2014.



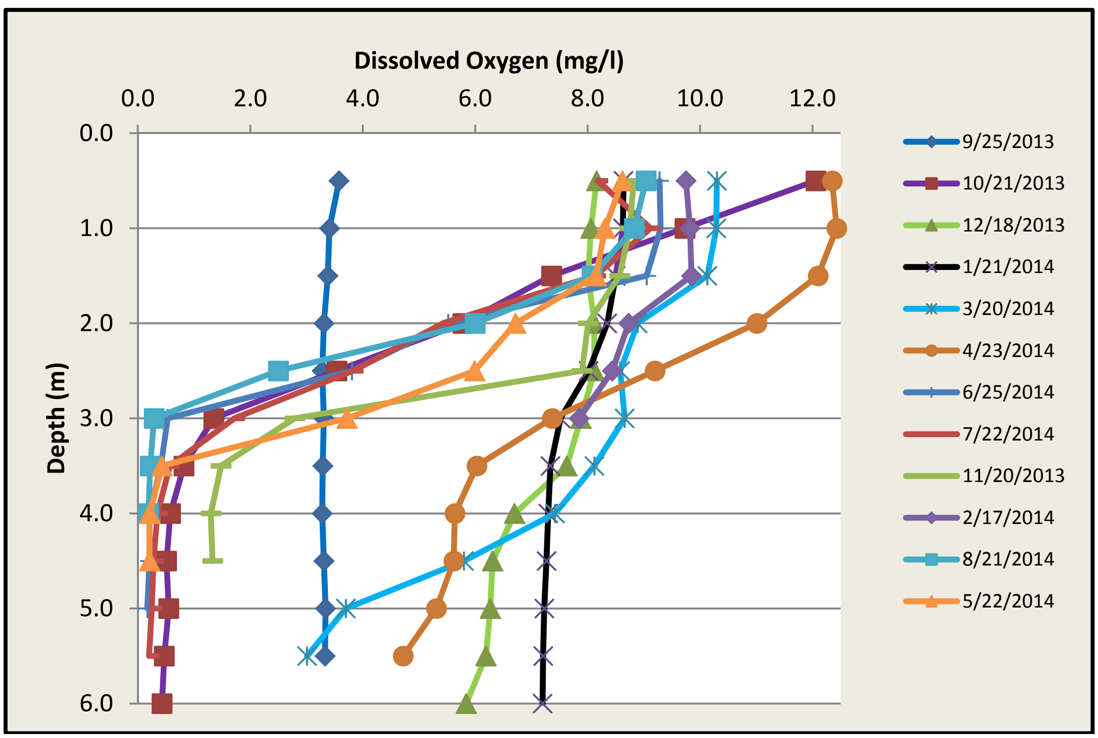


Figure 2-27B. Vertical Field Profiles of Temperature, pH, Conductivity, and Dissolved Oxygen Measured at the South Lobe in Lake Roberts from September 2013-August 2014.

2.3.2.2.5 LAKE REAVES

Lake Reaves is located northeast of Lake Roberts with a wetland tussock separating the two lakes. Discharge from Lake Reaves flows through the wetland tussock into Lake Roberts. Throughout the project, water hyacinth mats covered approximately two-thirds of the surface water in Lake Reaves. The mats consist of water hyacinth, sedges and primrose willow move across the lake depending on wind direction. Water hyacinth mats damage surface waters by blocking photosynthesis which lowers dissolved oxygen concentrations in surface water. Water hyacinth mats can deposit as much as 500 tons per acre of decomposing plant material on the lake bottom further damaging submerged plants and potentially increasing nutrients in the waterbody.

The Lake Reaves monitoring site was primarily located on the west side of the lake near the wetland tussock. On two occasions when the water hyacinths were covering the west side of the lake, the monitoring site was moved to the east side of the lake. The vertical field profile measurements for temperature, pH, conductivity, and dissolved oxygen collected during monthly monitoring events were graphed to show variations during different seasons and at different depths in the lake. These graphs are presented as Figure 2-28A and Figure 2-28B.

Overall temperatures observed in Lake Reaves were lower than those observed in Lake Roberts. During cooler months, relatively uniform temperature measurements were observed throughout the entire water column at this site. During the warmer months, decreases in temperature with increasing water depth were observed. Evidence of a classic thermocline was not observed during any of the monitoring events.

Measured pH values were tenfold less in Lake Reaves than in Lake Roberts during most monitoring events. The pH values were higher in the top meter of the water column with values ranging from approximately 5.5 during the cooler months to greater than 7 during the warmer months. The pH generally decreased with increasing water depth in each measured monitoring event.

Conductivity measurements in Lake Reaves were uniform within the water column to a depth of approximately 2 meters during the monitoring events. Below this depth, increases in conductivity were observed with increasing water depth, particularly during spring and summer conditions. The significant increases in conductivity observed in lower portions of the water column are indicative of a release of ions from bottom sediments. Increases of conductivity in the water-sediment interface zone are often an indication of internal recycling within the area due to released ions from the sediments.

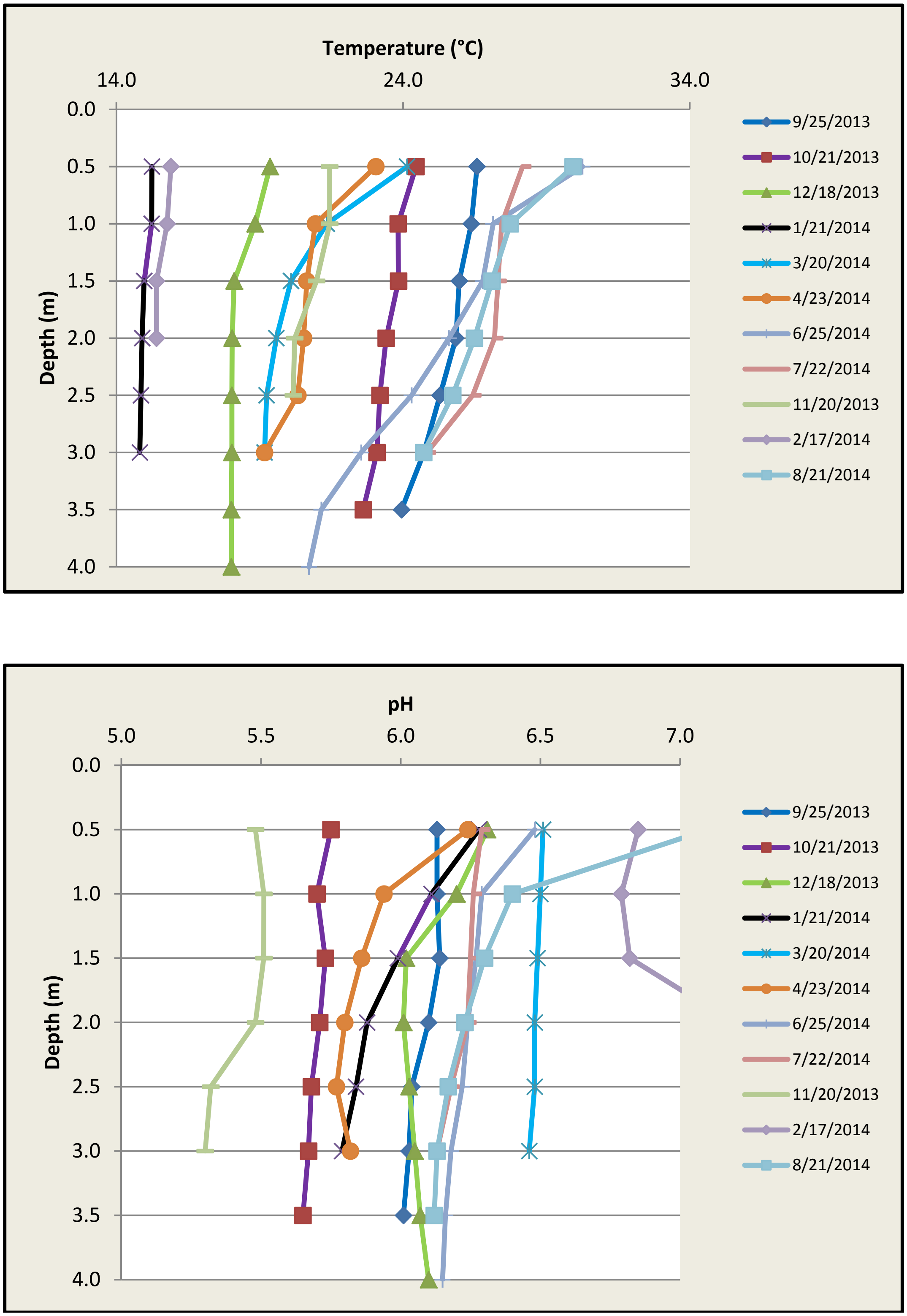
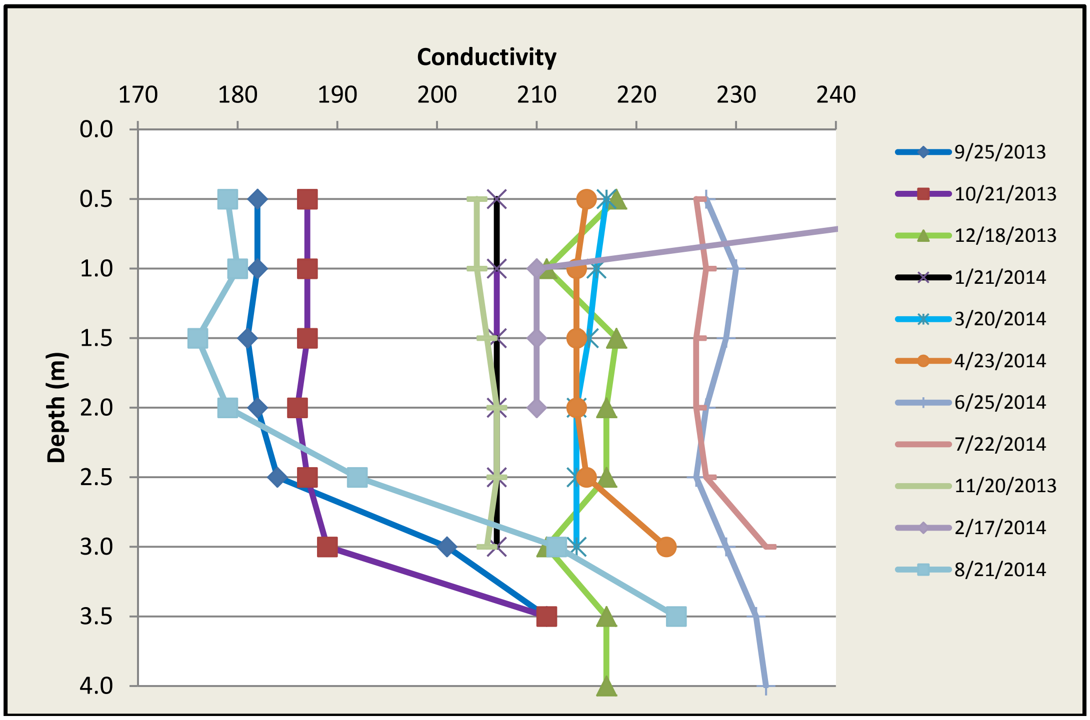


Figure 2-28A. Vertical Field Profiles of Temperature, pH, Conductivity, and Dissolved Oxygen Measured in Lake Reaves from September 2013-August 2014.



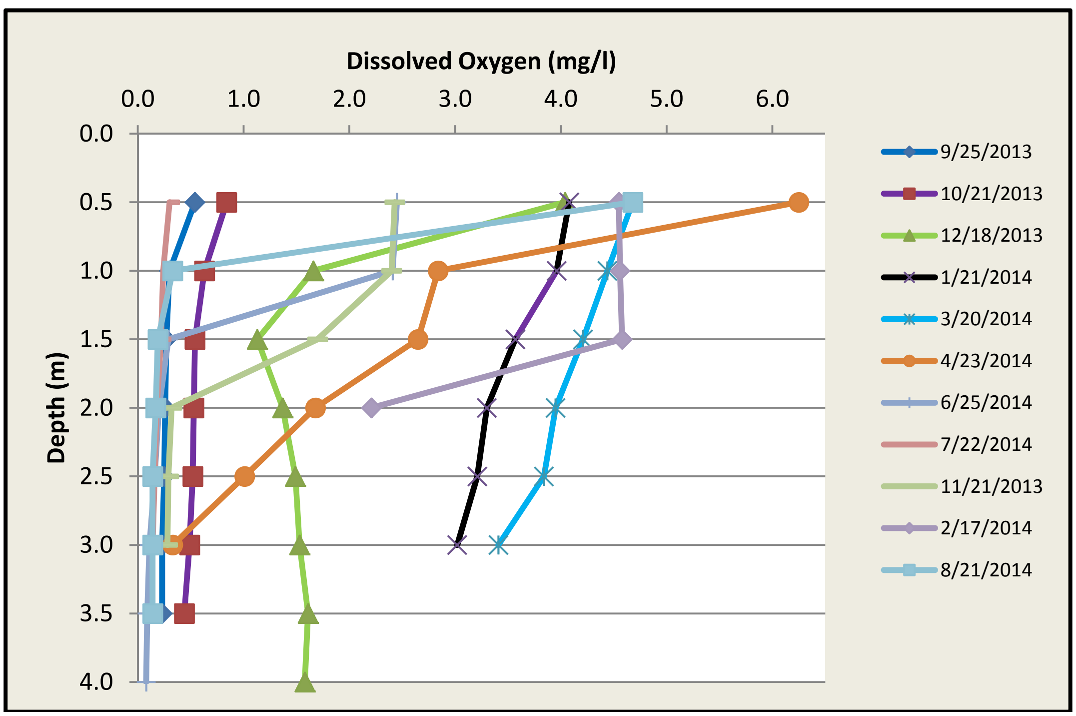


Figure 2-28B. Vertical Field Profiles of Temperature, pH, Conductivity, and Dissolved Oxygen Measured in Lake Reaves from September 2013-August 2014.

Surface dissolved oxygen measurements ranged from less than 1 to 6 mg/l. Dissolved oxygen measurements gradually decreased within the water column during most monitoring events. Anoxic conditions were observed during 7 monitoring events. The areas of low dissolved oxygen correspond well with the areas of elevated conductivity measurements, further supporting the theory of internal recycling at this site.

2.3.2.2.6 SECCHI DISK MEASUREMENTS

A Secchi disk depth measurement was collected at each of the five monitoring sites during most monitoring events. A chart of the depths for each monitoring site was prepared as shown on Figure 2-29. Secchi disk depths within the 3 monitoring sites in Lake Roberts were consistent with greater transparency occurring during the cooler months. Substantially lower Secchi disk measurements were observed in Lake Reaves and the wetland tussock.

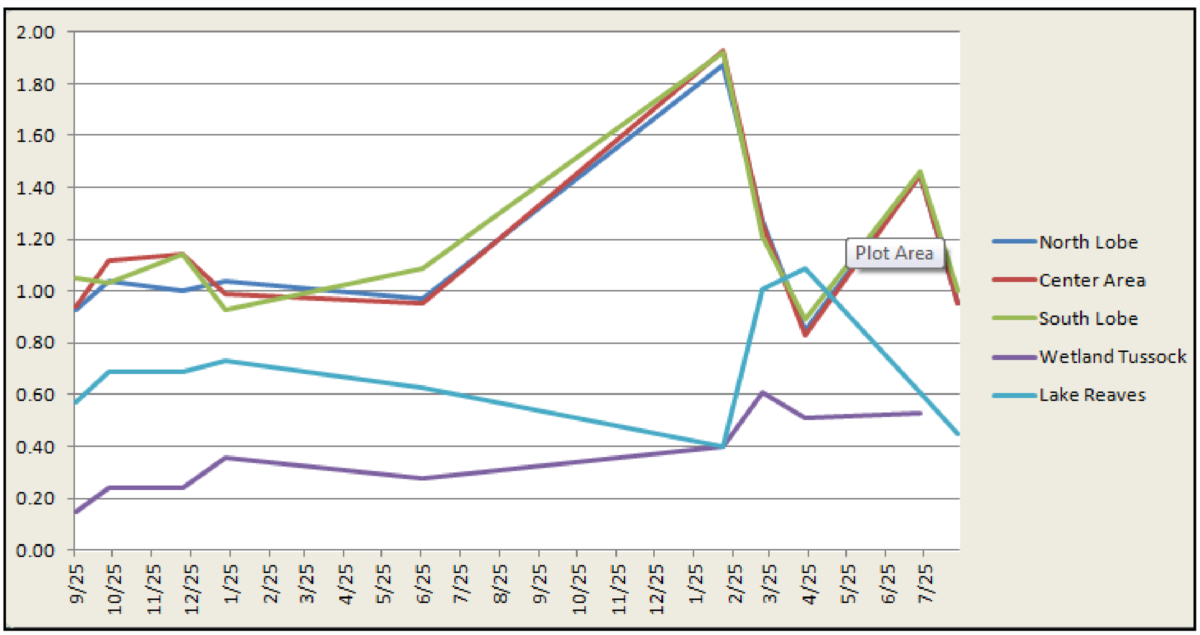


Figure 2-29. Measured Secchi Disk Depths at the Lake Roberts Monitoring Sites.

2.3.2.3 WATER QUALITY CHARACTERISTICS

Surface water monitoring was conducted in Lake Roberts on a monthly basis during the 12-month monitoring program at each of the five monitoring sites indicated on Figure 2-24. Two separate water samples were collected at the three monitoring sites in Lake Roberts, one at approximately 0.5 meters below the water surface (top sample) and the second at approximately 0.5 meters above the water-sediment interface (bottom" sample). Surface samples were collected from the monitoring sites in the wetland tussock and in Lake Reaves. A total of 12 top and 12 bottom samples was collected at each of the three monitoring sites in Lake Roberts and a total of 12 top samples collected in Lake Reaves. A total of 10 top samples was collected in the wetland tussock. A listing of water quality characteristics measured at each of the five monitoring sites between September 2013 and August 2014 is given in Appendix B.2.

A summary of mean water quality characteristics at each of the five monitoring sites in Lake Roberts between September 2013 and August 2014 is presented in Table 2-11. The values summarized in this table reflect the mean values for the data collected at each site. Separate mean values are provided for the surface and bottom samples at the three Lake Roberts sites.

Table 2-11
Summary of Mean Water Quality Characteristics Lake Roberts, Wetland Tussock and Lake Reaves September 2013 to August 2014

Parameter	Units	North Lobe (S1)		Center Area (S2)		South Lobe (S3)		Lake Reaves (S5)	Wetland Tussock (S4)
		Surface	Bottom	Surface	Bottom	Surface	Bottom	Surface	Surface
pH	s.u.	7.7	7.1	7.9	6.8	7.9	6.8	6.3	6.0
Alkalinity	mg/l	44.9	45.8	44.2	52.0	45.4	51.2	36.7	23.1
Conductivity	µmho/cm	226	226	226	243	227	239	212	163
NH_3	µg/l	33	38	35	132	36	159	57	101
NO_x	µg/l	22	9	8	8	8	10	10	9
Diss. Organic N	µg/l	751	762	707	954	755	781	807	934
Particulate N	µg/l	201	288	251	827	222	231	145	502
Total N	µg/l	1,006	1,096	1,001	1,921	1,021	1,180	1,016	1,545
SRP	µg/l	4	5	5	8	4	4	6	12
Diss. Organic P	µg/l	8	14	9	12	8	9	6	11
Particulate P	µg/l	38	43	28	85	34	37	20	89
Total P	µg/l	51	61	42	105	46	50	32	113
Turbidity	NTU	2.5	7.7	2.2	7.3	2.4	6.7	1.0	50.8
Color	PCU	52	55	54	58	51	52	223	232
TSS	mg/l	5	6	18	24	5	7	4	74
Chlorophyll-a	mg/m^3	23.1	--	26.9	--	23.2	--	11.9	53.1

Measured pH values at the three Lake Roberts monitoring sites are slightly higher than neutral in value, with mean pH values ranging from 7.65 to 7.88. The measured pH values in the wetland tussock and Lake Reaves are lower than neutral, with mean pH values at 5.97 and 6.23, respectively. Measured pH values in the bottom samples were lower than the surface samples with mean values ranging from 6.82 to 7.12. Measured alkalinity values in the three Lake Roberts surface water samples ranged from 44.2 mg/l to 45.4 mg/l, reflecting relatively poorly buffered water characteristics. The measured alkalinity values in the wetland tussock and Lake Reaves are lower than Lake Roberts with values of 23.1 mg/l and 36.7 mg/l, respectively. The measured alkalinity in the bottom samples were slightly higher with values ranging from 45.8 mg/l to 52 mg/l. Mean surface conductivity values ranged from 226 μmho/cm to 227 μmho/cm which is considered typical of values commonly measured in urban lakes. However, the conductivity values for the wetland tussock and Lake Reaves were lower with values of 163 μmho/cm and 215 μmho/cm, respectively.

Low levels of both ammonia and NOx (nitrite + nitrate) were observed at surface samples collected in Lake Roberts with higher levels observed in the wetland tussock and Lake Reaves. Elevated levels of ammonia were observed in the bottom samples of the two deeper sites in Lake Roberts. The dominant nitrogen species measured at all five monitoring sites is dissolved organic nitrogen which comprises approximately 70 to 75% of the total nitrogen measured at the surface sites in Lake Roberts and the bottom sample in the North Lobe (shallow). The dissolved organic nitrogen in the two deep Lake Roberts sites were approximately 60% to 65% of the total nitrogen, while the wetland tussock was 60% and Lake Reaves was 80%. Particulate nitrogen comprises approximately 20%-30% of the total nitrogen measured at each site. The mean total nitrogen concentrations in the surface sites of Lake Roberts ranged from 995 to 1,021 μg/l and the bottom sites ranged from 1,096 to 1,921 μg/l. The TN concentrations measured in the wetland tussock and Lake Reaves were 1,545 μg/l and 1,016 μg/l, respectively.

Low levels of SRP (soluble reactive phosphorus) and dissolved organic phosphorus were observed in both surface and bottom samples in Lake Roberts and in Lake Reaves, with values near or below detection limits except in the wetland tussock. Levels observed in the wetland tussock were twice as high as in the lakes. The dominant phosphorus species at all five monitoring sites is particulate phosphorus with higher concentrations measured in the Center Area monitoring site of Lake Roberts (surface and bottom) and the wetland tussock. The total mean phosphorus concentrations in the surface samples of Lake Roberts ranged from 46 μg/l to 110 μg/l with the highest value in the Center Area. The total mean phosphorus concentrations in the bottom samples of Lake Roberts ranged from 50 μg/l to 105 μg/l with the highest value also in the Center Area. Total mean phosphorus concentration in Lake Reaves was the lowest in value at 32 μg/l while the highest value of 113 μg/l was observed in the wetland tussock.

Measured color concentrations in the lake were high enough in value that Lake Roberts will be classified as a high color lake. Mean surface color concentrations in Lake Roberts ranged from 45 PCU to 46 PCU and mean bottom color concentrations ranged from 52 PCU to 59 PCU.

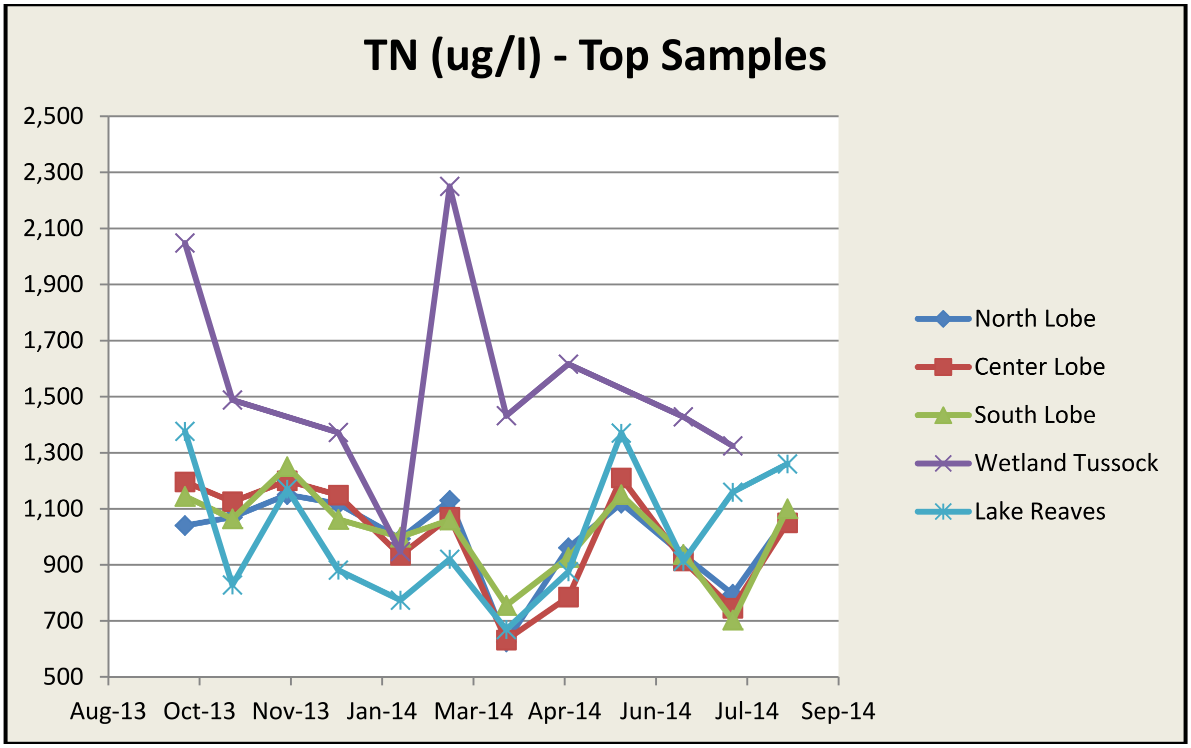
Mean surface color concentrations in the wetland tussock and Lake Reaves were measured to be 232 PCU and 190 PCU, respectively.

Mean chlorophyll-a concentrations in the three monitoring sites in Lake Roberts were similar ranging from 24.4 mg/m^3 to 26.9 mg/m^3. The mean chlorophyll-a concentrations in the wetland tussock and Lake Reaves were 53.1 mg/m^3 and 11.6 mg/m^3, respectively.

A graphical comparison of variability in measured surface concentrations of total nitrogen and total phosphorus at each of the three monitoring sites in Lake Roberts, in the wetland tussock and Lake Reaves from September 2013 to August 2014 is presented in Figure 2-30. There was no distinct seasonal pattern in the measured total nitrogen concentrations during the 12-month monitoring program. However, the measured total nitrogen concentrations in the wetland tussock are significantly higher than Lake Roberts or Lake Reaves. A distinct seasonal pattern is not apparent for total phosphorus, although concentrations historically seem to be slightly higher in the cooler months, and during May and June. The measured total phosphorus concentrations in the wetland tussock are significantly higher than Lake Roberts or Lake Reaves. The contribution of phosphorus to Lake Roberts from the wetland tussock could mask seasonal variations.

A graphical summary of variability in measured surface concentrations of chlorophyll-a in each of the three monitoring sites in Lake Roberts, in the wetland tussock and Lake Reaves from September 2013 to August 2014 is presented in Figure 2-31. A distinct seasonal pattern is not apparent in Lake Roberts. The measured chlorophyll-a levels in the wetland tussock are significantly higher than either Lake Roberts or Lake Reaves, while the levels in Lake Reaves were very low compared to Lake Roberts. Long term elevated concentrations of chlorophyll can indicate the presence of algae blooms. The presence of excess nutrients can also stimulate algal growth. Based on the measured surface concentrations of chlorophyll-a, it appears that the wetland tussock is contributing to the chlorophyll-a levels in Lake Roberts.

A graphical comparison of variability in TN/TP ratios at each of the five monitoring sites during the field monitoring program is given in Figure 2-32. In general, each of the sites appears to exhibit either nutrient-balanced or phosphorus-limited conditions throughout most of the year. The Center Area, the wetland tussock and Lake Reaves appear to be more severely phosphorus-limited than other portions of the lake.



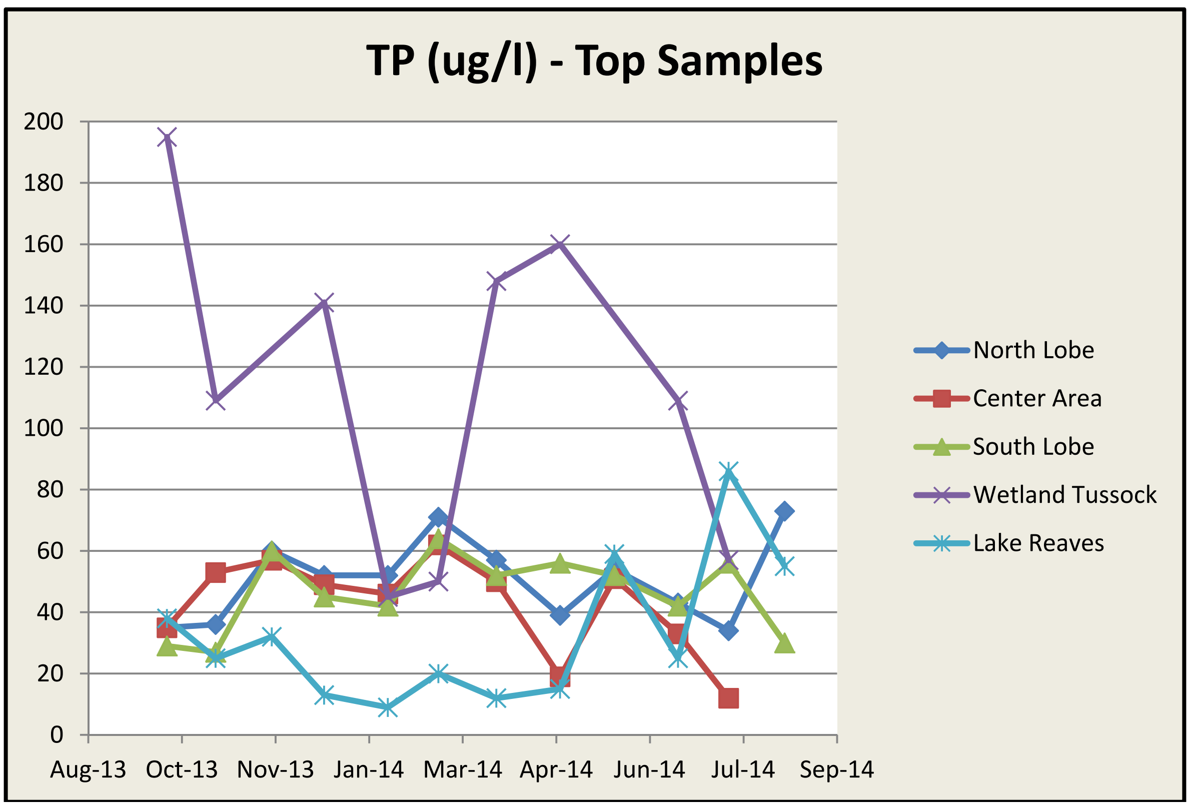


Figure 2-30. Variability in Measured Surface Concentrations of Total Nitrogen and Total Phosphorus in Lake Roberts from September 2013 to August 2014.

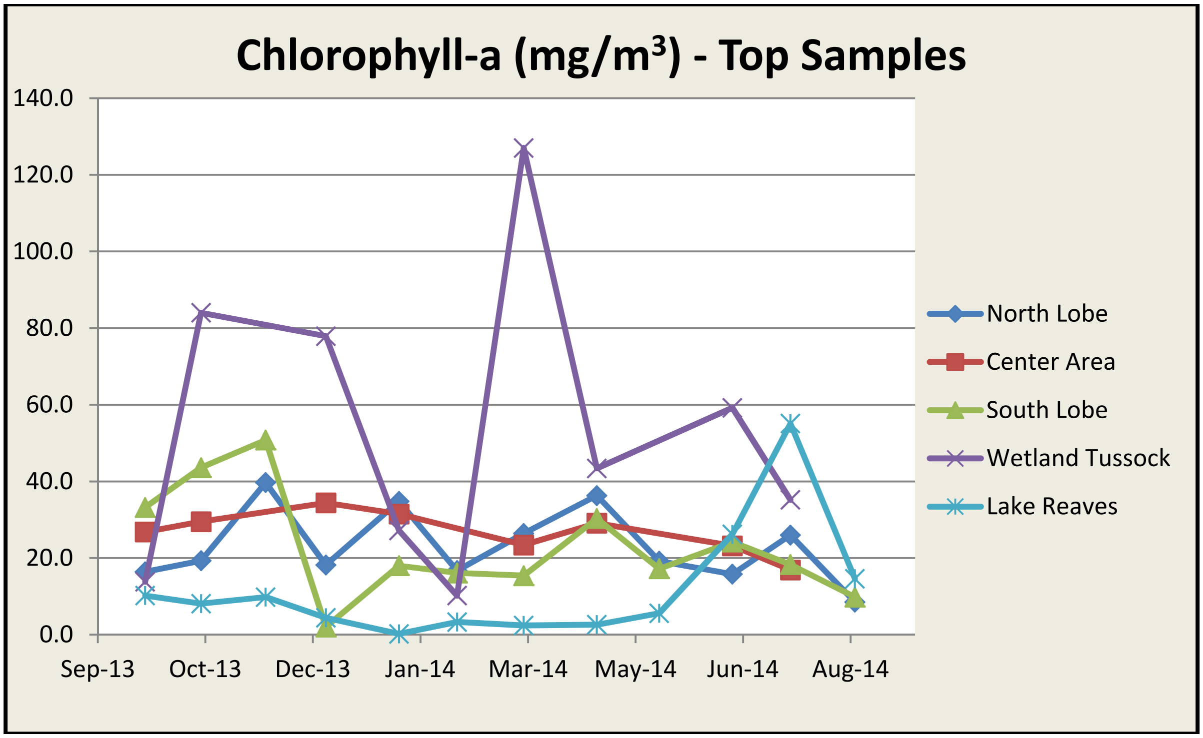


Figure 2-31. Variability in Measured Surface Concentrations of Chlorophyll-a in Lake Roberts from September 2013-August 2014.

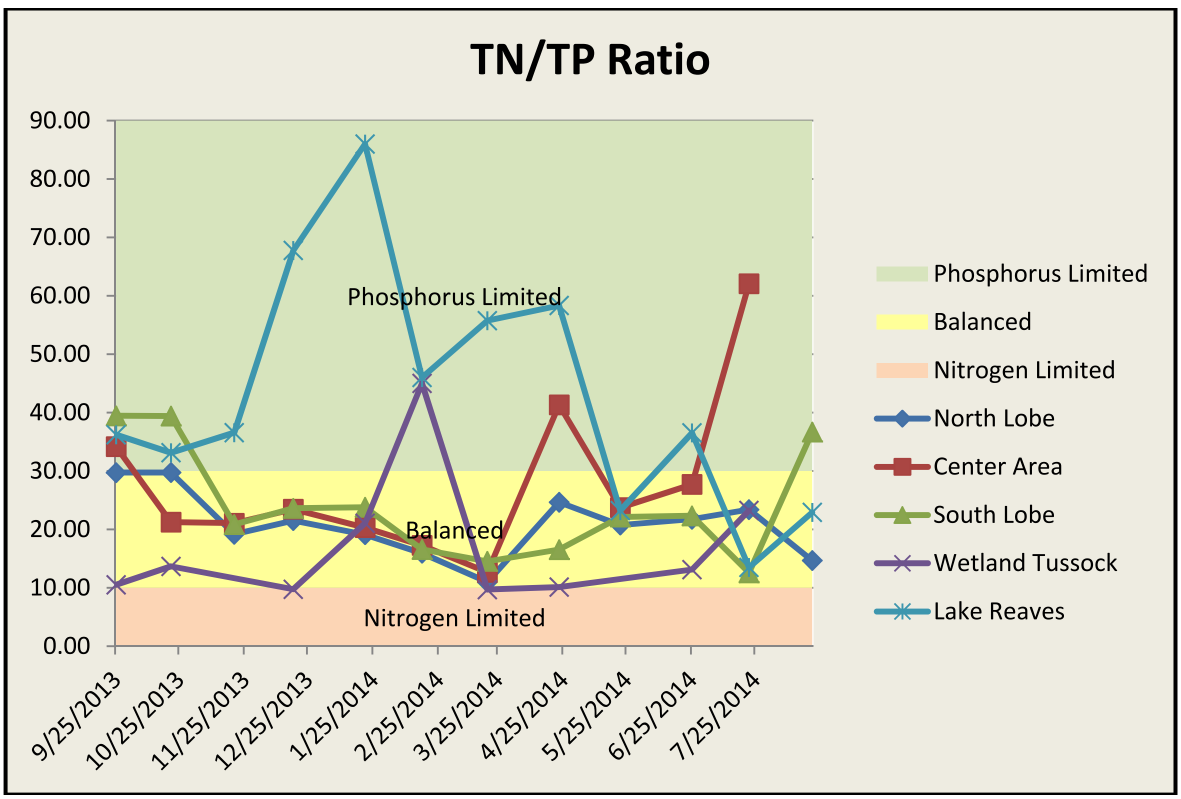


Figure 2-32. Variability in TN/TP Ratios in Measured Surface Concentrations in Lake Roberts.

A graphical comparison of variability in TSI values based on chlorophyll-a at each of the five surface water monitoring sites in Lake Roberts, the wetland tussock and Lake Reaves during the 12-month field monitoring program is shown on Figure 2-33. The North Lobe and Central Area of Lake Roberts exhibited predominantly eutrophic conditions with a few monitoring events showing mesotrophic conditions. The South Lobe exhibited predominately mesotrophic conditions, even though a few monitoring events exhibited oligotrophic and eutrophic conditions. TSI values in the wetland tussock exhibited primarily eutrophic conditions. TSI values in Lake Reaves exhibited primarily oligotrophic values, although some monitoring events suggest mesotrophic and eutrophic conditions.

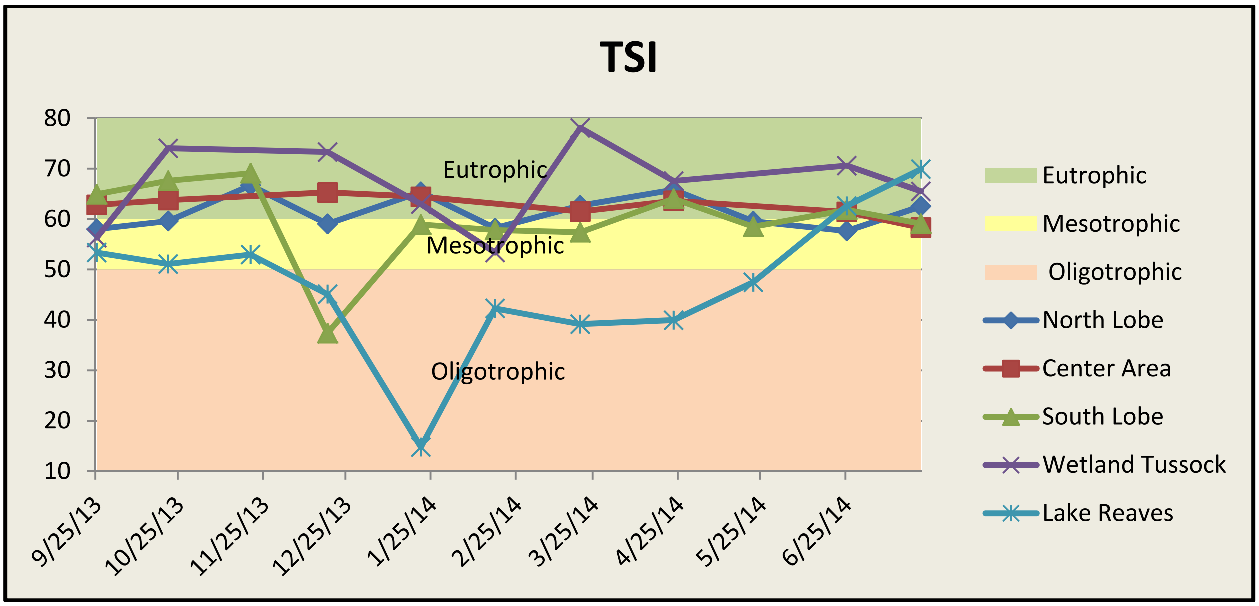


Figure 2-33. Variability in Trophic State Index (TSI) in Measured Surface Concentrations in Lake Roberts, the Wetland Tussock and Lake Reaves.

2.3.2.4 SUMMARY

The recent water quality monitoring conducted by CPWG provided water quality characteristics within Lake Roberts (surface and bottom), the wetland tussock and Lake Reaves. The historical water quality monitoring was limited to the Center Area within Lake Roberts (surface sample only). The historical water column concentrations of total nitrogen, total phosphorus, and chlorophyll-a in Lake Roberts appear to be higher in value than mean values observed in other Central Florida urban lake systems. Historical data for Lake Roberts indicates an overall trend in increased values of TP, TN and chlorophyll-a and current data supports the historical trend. Based on Trophic State Index calculations, Lake Roberts is showing signs of eutrophic conditions and poor water quality characteristics. Lake Reaves exhibits signs of TN concentrations higher than mean values observed in other Florida urban lake systems, but exhibits lower TP and chlorophyll-a values. The TN, TP and chlorophyll-a values within the wetland tussock are higher than both Lake Roberts and Lake Reaves. Evidence of internal recycling is apparent in the Center Area and South Lobe of Lake Roberts during periods of low dissolved oxygen.

Based on the historical water quality, Lake Roberts exhibits symptoms of a eutrophic lake, which TSI calculations for current lake conditions support.

2.4 WATER LEVELS

Discharge from Lake Roberts is regulated by a high point in the outfall pipe at the end of the outfall canal located on the west side of the lake. A photograph of the outfall structure is presented on Figure 2-34. The outfall structure consists of a 45"x 28" ERCP at elevation 106.8, NAVD. The outfall pipe is surrounded by a fish gate that does not impede flow. Further downstream of the outfall pipe, the invert in the drainage system rises to elevation 109 feet which appears to control the water level in Lake Roberts. The wetland area at the outfall of the drainage system appears to have an elevation between 109 and 110 feet. Therefore, for purposes of estimating the outfall volume of Lake Roberts, a 1-foot long weir at elevation 109.75 is assumed.

Figure 2-34. Outfall Structure for Lake Roberts with fish grates

Historical water level elevations have been recorded in Lake Roberts by Orange County on approximately a monthly basis from 1991 to 2004. A graphical summary of recorded surface water elevations available on the Orange County Water Atlas is presented on Figure 2-35. Water elevations in Lake Roberts appear to fluctuate between 107 and 112 feet much of the year. Two levels of approximately 100 feet are recorded during the winter of 1996 and 2004.

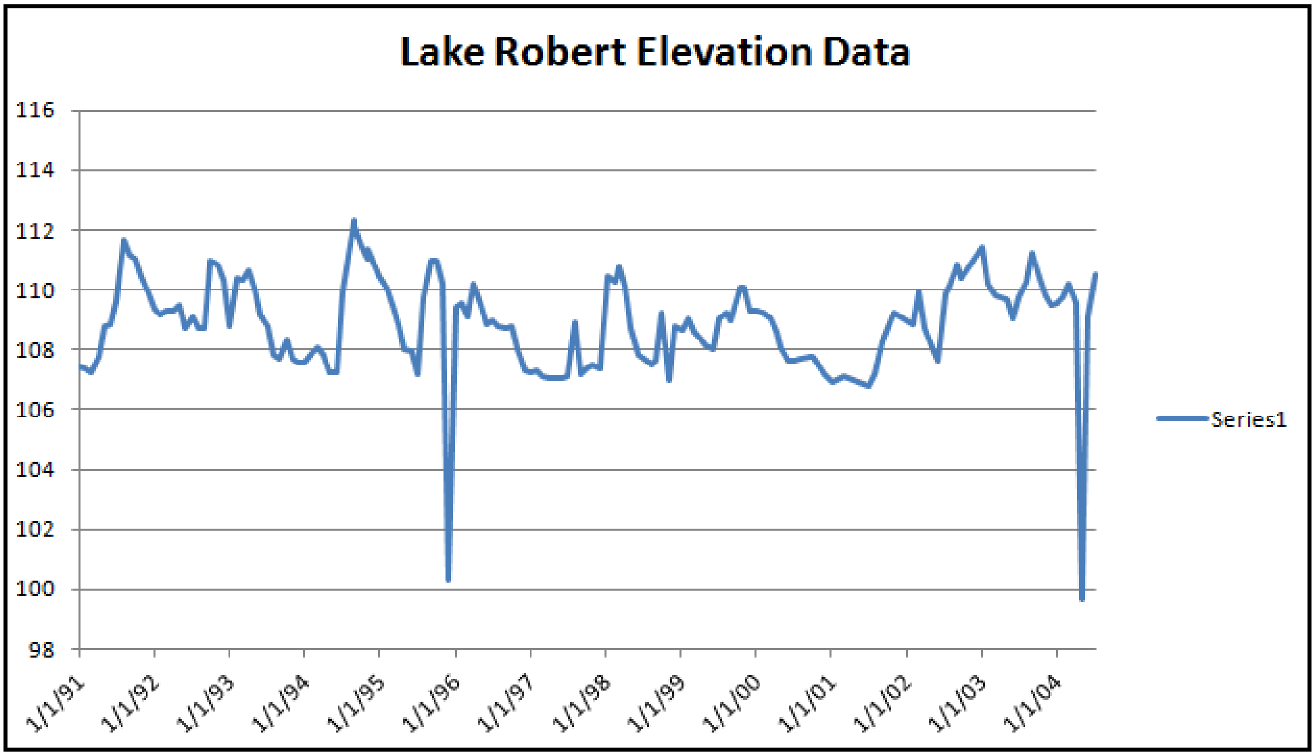


Figure 2-35. Recorded Water Surface Elevations in Lake Roberts from 1991-2004. (Source: OCEPD)

During January 2014, staff gauges were installed in Lake Roberts and Lake Reaves to further understand water level correlation between the two lakes. Current water level data collected in the two lakes is shown in Table 2-12.

Table 2-12
Water Levels in Lake Roberts and Lake Reaves

Date	Water Levels (feet – NAVD88)	
	Lake Roberts	Lake Reaves
1/24/2014	108.98	109.2
1/28/2014	109.12	109.22
2/6/2014	109.28	109.33
2/13/2014	109.32	109.38
2/17/2014	109.28	109.36
2/27/2014	109.36	109.42
3/20/2014	109.4	109.44
4/2/2014	109.44	109.48
4/23/2014	109.38	109.4
5/6/2014	110.02	110
5/22/2014	109.6	109.58
6/25/2014	109.29	109.36
7/22/2014	109.72	109.69
11/13/2014	109.49	109.55
11/18/2014	109.55	109.63
12/4/2014	110.11	110.08
3/23/2015	109.41	109.51

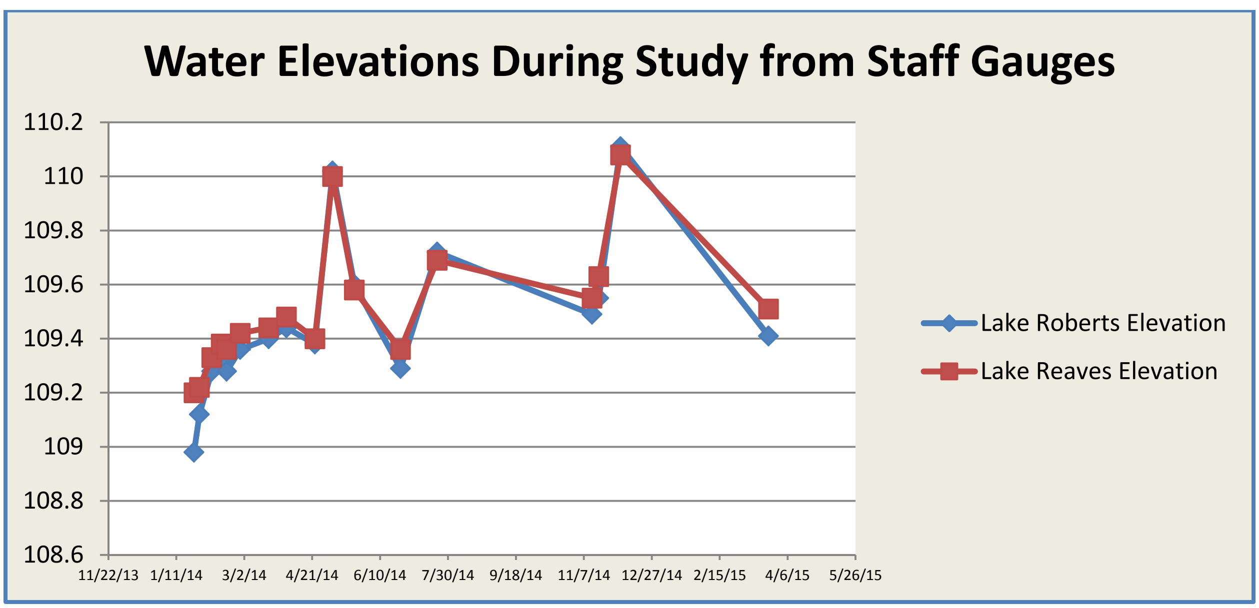


Figure 2-36. Surface Water Elevations in Lake Roberts from January 2014 to March 2015

3.0 CHARACTERISTICS OF THE LAKE ROBERTS DRAINAGE BASIN

Characteristics of the drainage basin area for Lake Roberts are summarized in this section, including information on drainage sub-basin delineation, topography, land use characteristics, soil types, stormwater treatment areas, and sewage disposal. A discussion of each of these elements is given in the following sections.

3.1 WATERSHED CHARACTERISTICS

A delineation of sub-basins contributing drainage to Lake Roberts was conducted by *Post, Buckley, Schuh, & Jernigan, Inc.* (PBS&J), as part of the November 2000 report, "Lake Roberts Drainage Study." These drainage sub-basin delineations were obtained and used as a preliminary drainage basin boundary map. The basin boundaries were then modified, as appropriate, by reviewing available 1-ft LIDAR elevation contour maps provided by Orange County, field reconnaissance, discussions with area residents, and observation of drainage patterns during significant rain events. The study was performed prior to the construction of SR-429 and the construction of several subdivisions within the basin. Therefore, major changes to the basin delineation were performed and SR-429 became the basin divide to the northwest. Waterford Point Subdivision, located on the southwest side of Lake Roberts, was field-reviewed to confirm that only the lots directly on Lake Roberts and that portion of the subdivision that drains to the internal lake discharge to Lake Roberts. It was further confirmed that a small portion of the golf course at Butler Bay on the southeast side of the lake also discharges to Lake Roberts. Windermere Road is the drainage basin divide to the northeast. Stoneybrook West is the basin boundary to the north. The inlets and pipes constructed within the basin were also used to determine flow paths and basin divides. An overview of the updated drainage basin delineation for Lake Roberts/Lake Reaves is illustrated in Figure 3-1. A summary of areas discharging to Lake Roberts is given on Table 3-1.

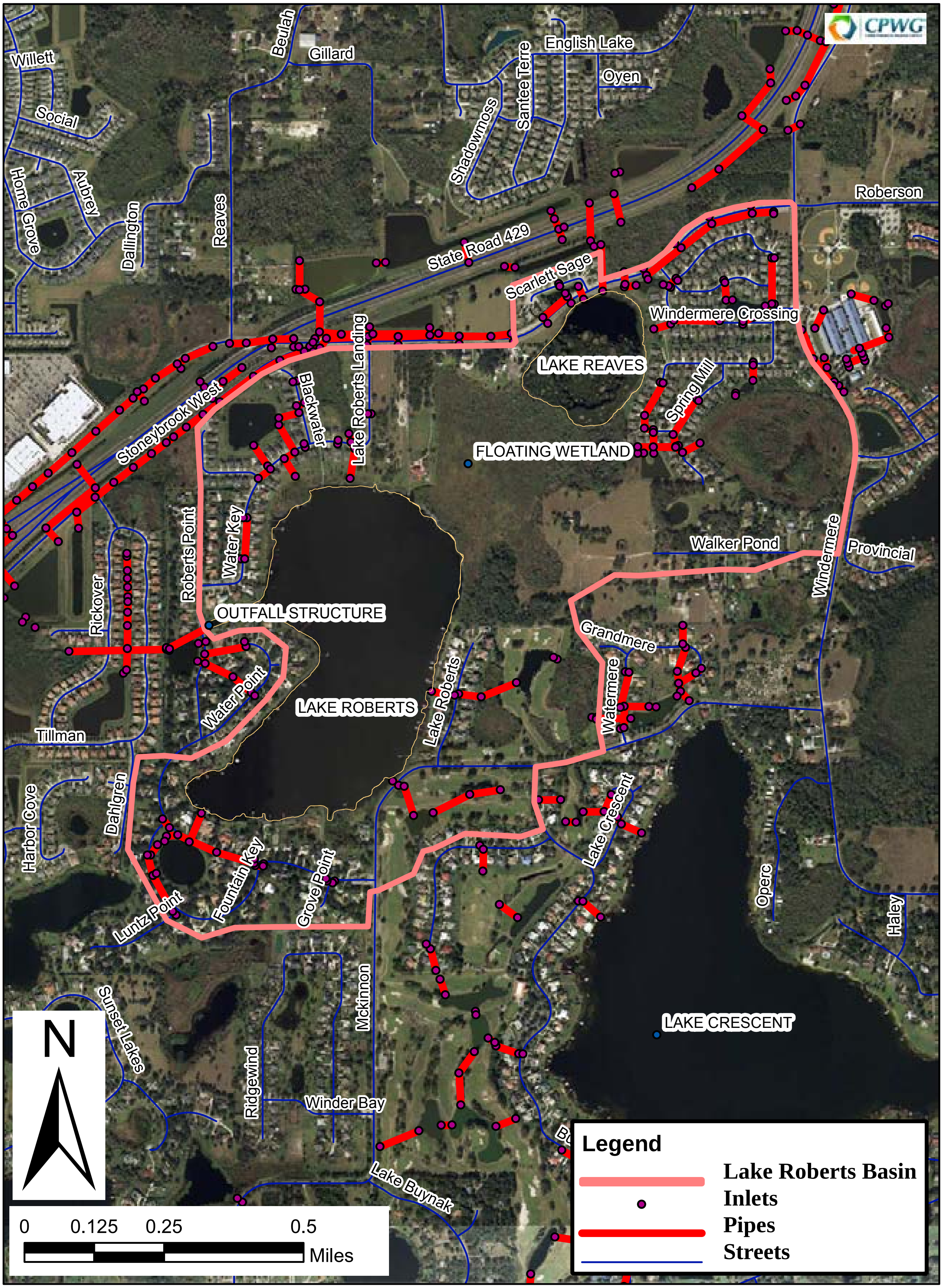
Table 3-1
Lake Roberts Drainage Basin Area

Watershed Name	Basin Area (Acres)	Lake Area (Acres)	Lake/Basin Ratio
Lake Roberts	595.16	108	5.5

The lake area used only included Lake Roberts, the floating wetland and Lake Reaves were not included in this area to be consistent with the FDEP TMDL report. Drainage basin/lake area ratios are often useful in evaluating the potential for runoff inputs that have a significant impact on water quality within a waterbody. In general, drainage basin/lake area ratios less than 7 indicate lakes where nonpoint source pollution should have minimal impacts on lake water quality, while drainage basin/lake area ratios substantially in excess of 7 indicate waterbodies where nonpoint source runoff may have a significant impact on water quality. Based on the calculated drainage basin/lake area ratios summarized in Table 3-1, Lake Roberts/Lake Reaves should have relatively minimal impacts on water quality from adjacent watershed areas.

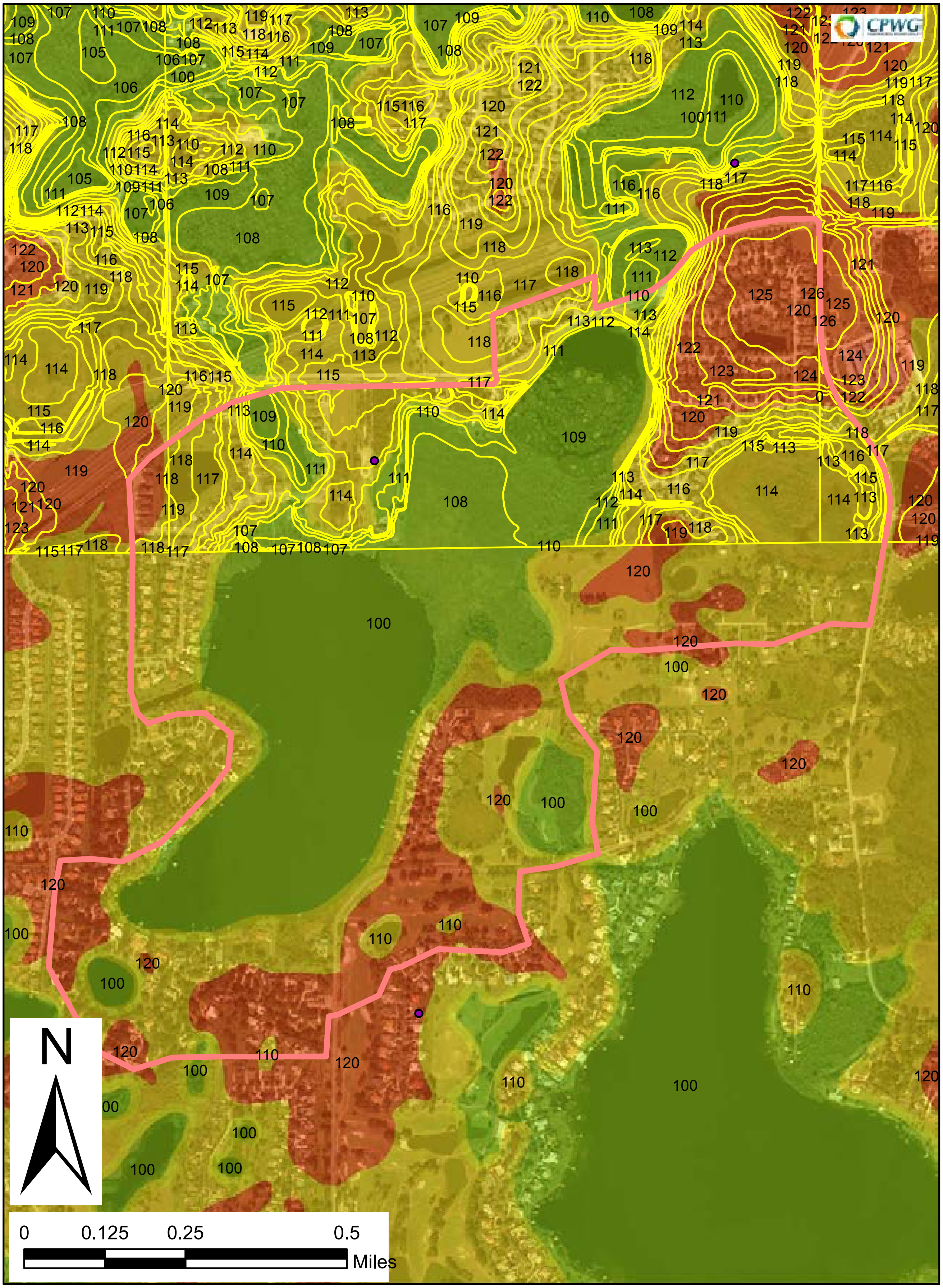
Elevation contours in the vicinity of Lake Roberts are indicated on Figure 3-2 based upon the 1-ft contour LIDAR data and 5-ft contour data provided by Orange County. The 1-ft contours are shown via contour lines. The 5-ft contours are shown via shaded areas. In general, land surfaces within the drainage basin are characterized by relatively mild slopes. The maximum elevation within the watershed is approximately 126 ft NAVD 1988, in the northeast portions of the basin which is 16 ft higher than the water surface elevation of 110 ft NAVD 1988 in Lake Roberts.

Governmental jurisdictions in the Lake Roberts watersheds are illustrated on Figure 3-3. Jurisdiction within the watershed areas is split between the City of Winter Garden and unincorporated Orange County. The portions in the northeast and northwest corners of the drainage basin are located in the City of Winter Garden, with the remainder of the basin located in unincorporated Orange County.



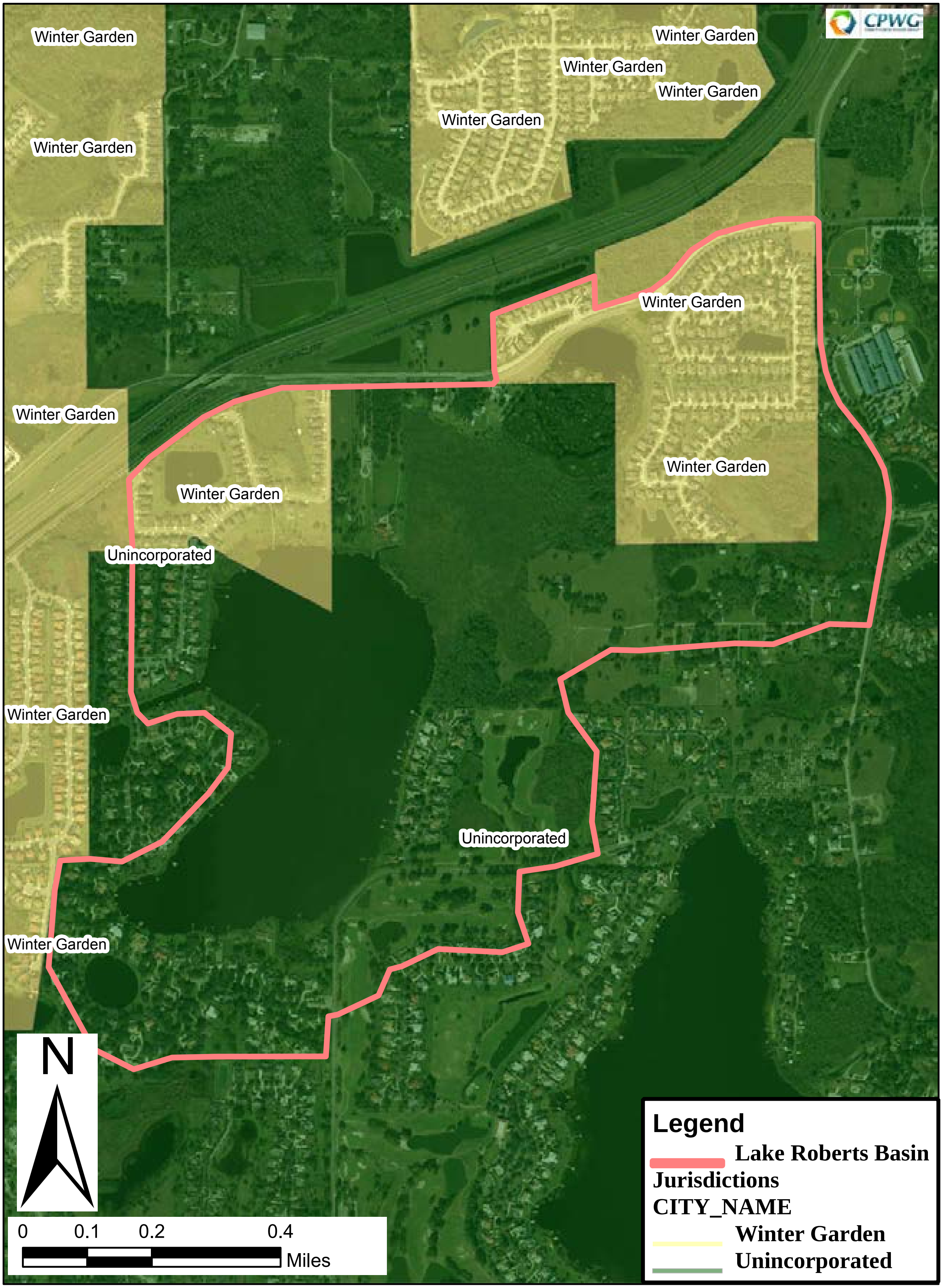
Lake Roberts Basin Map

Figure 3-1



Lake Roberts Elevation Contours

Figure 3-2



Lake Roberts Governmental Jurisdications

Figure 3-3

3.2 LAND USE

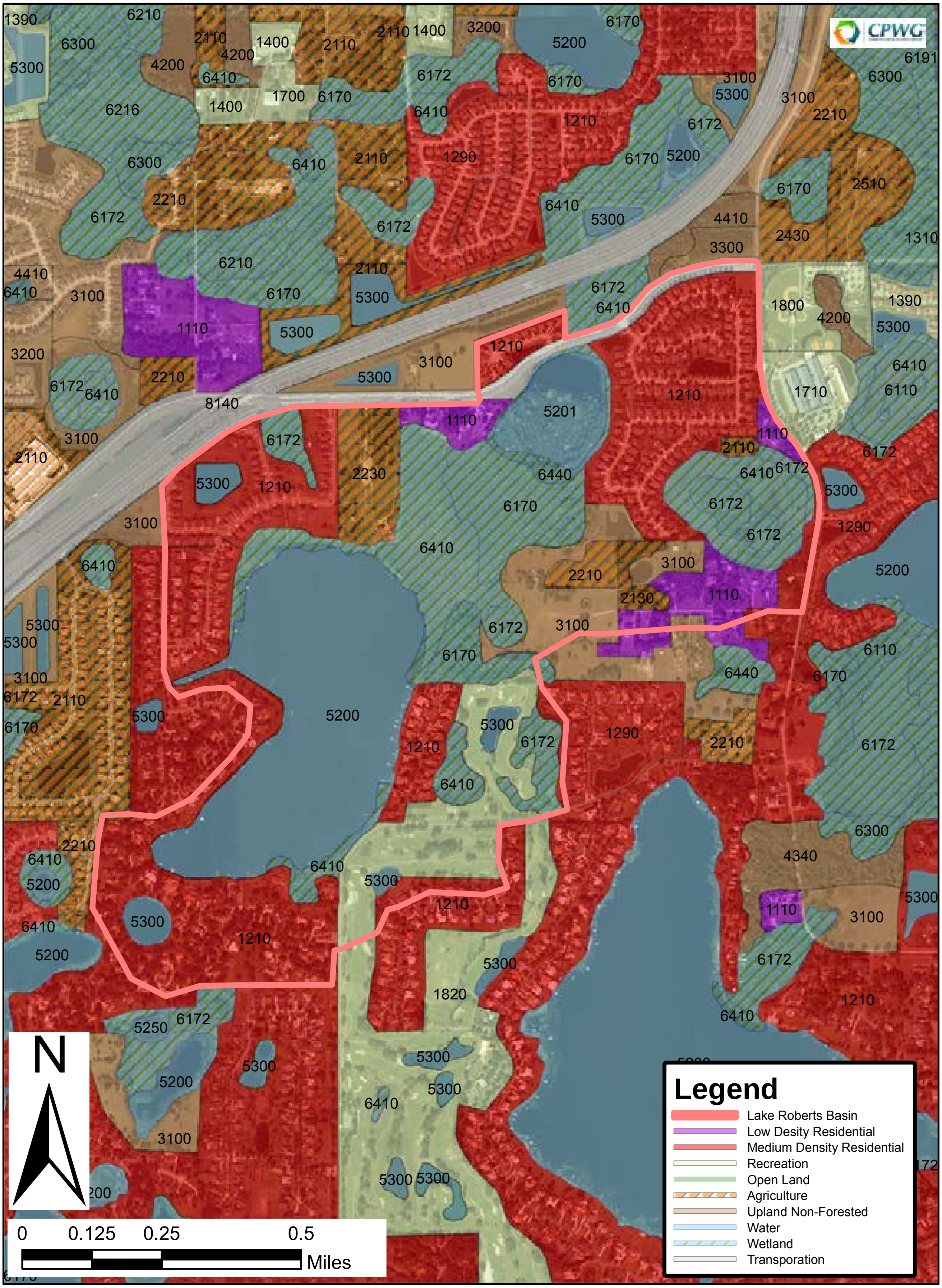
Land use information for Lake Roberts watershed was obtained from the South Florida Water Management District's Land Cover Land Use 2008 GIS coverage. This information was used as a base map, and changes to the land use characterization data were identified using a combination of aerial photography and field reconnaissance. Land use within the basin was allocated to a series of general land use categories for which runoff characterization data are typically available. The resulting land use summary reflects conditions which currently exist within the Lake Roberts drainage basin.

An overview of current general land use categories in the Lake Roberts drainage basin is given on Figure 3-4. The dominant land use within the basin is medium-density residential, with a large wetland area and some smaller areas of low density residential, open space and recreation/golf course.

A tabular summary of current land use in the watershed is given on Table 3-2. Medium-density residential is the dominant land use category, covering 34.9% of the total basin area. Approximately 43.8% of the watershed is covered with wetlands or waterbodies, about 6.6% of the basin is covered by recreational land/golf course and about 4.8% is agricultural (pasture/orange grove).

Table 3-2
Land Use

Land Use Description	Area (acres)	Percent Land Use
Low Density Residential	24.02	4.0%
Medium Density Residential	207.63	34.9%
Recreation	39.14	6.6%
Agriculture	28.81	4.8%
Upland Non-Forested	26.09	4.4%
Water	134.39	22.6%
Wetland	126.19	21.2%
Transportation	8.89	1.5%
Total	**595.16**	**100.0%**



Lake Roberts Land Use

Figure 3-4

3.3 SOILS

Information on soil types within the Lake Roberts drainage basin was obtained from the St. Johns River Water Management District GIS database. Soil information was extracted in the form of Hydrologic Soil Groups (HSG) which classifies soil types with respect to runoff-producing characteristics. Using this system, soils are classified into one of five groups for evaluation and modeling purposes. The chief consideration in each of the soil group types is the inherent capacity of bare soil to permit infiltration. A summary of the characteristics of each hydrologic soil group is given in Table 3-3.

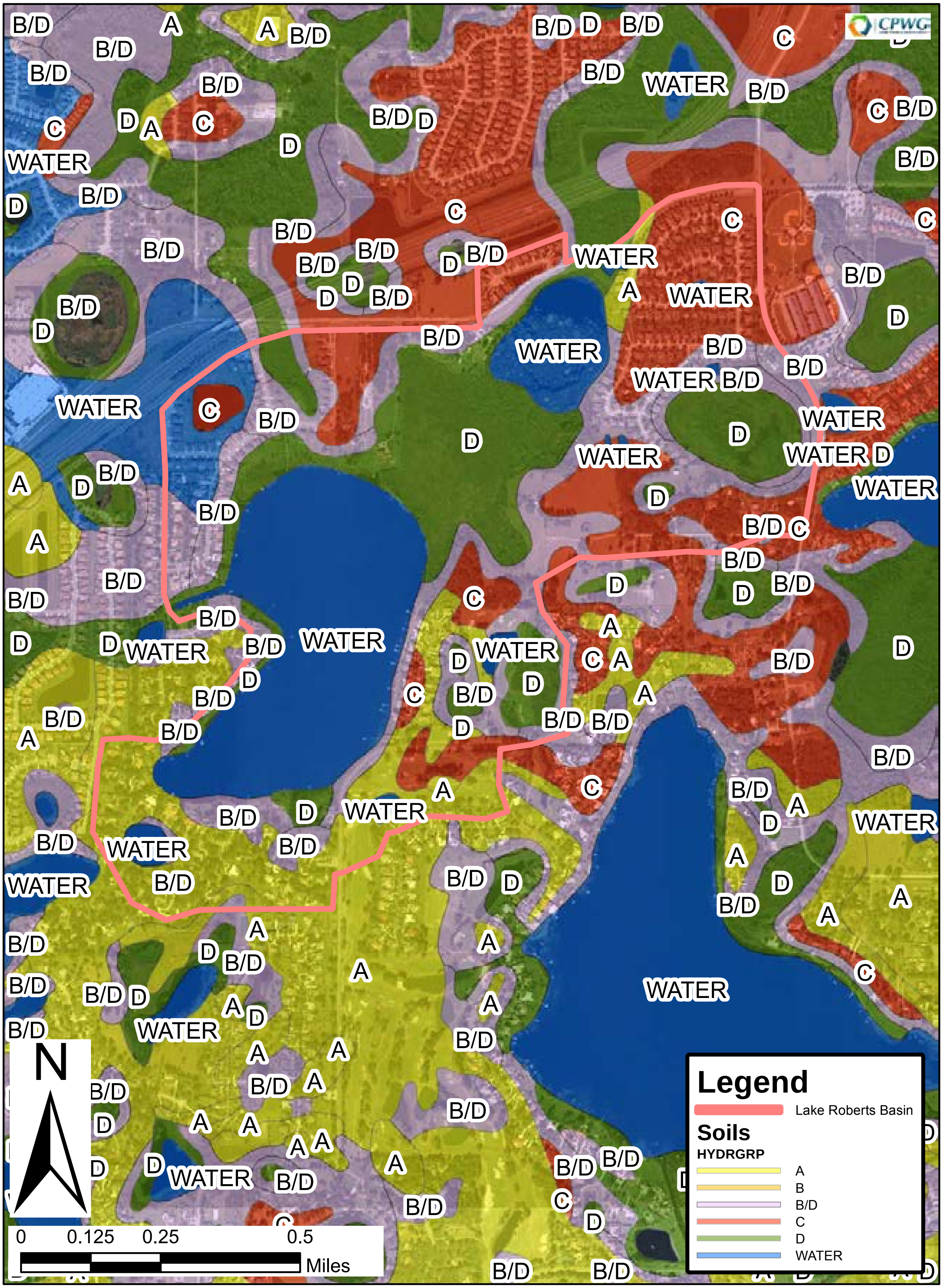
A graphical depiction of hydrologic soil groups in drainage basin areas for Lake Roberts is given in Figure 3-5. A tabular summary of soil groups is given in Table 3-4. 42% of the basin is Hydrologic Soil Group B/D or D, indicating a relatively high runoff potential.

Table 3-3
Characteristics of SCS Hydrologic Soil Group Classification

Soil Group	Description	Runoff Potential	Infiltration Rate
A	Deep sandy soils	Very low	High
B	Shallow sandy soils over low permeability layer	Low	Moderate
C	Sandy soil with high clay or organic content	Medium to high	Low
D	Clayey soils	Very high	Low to none
W	Wetland or hydric soils	--	--
B / D	Shallow sandy soils with high water table under undeveloped conditions	Very high in undeveloped Low in developed	Moderate - limited by water table in undeveloped condition

Table 3-4
Soils

Soils Hydrologic Group	Area (acres)	Percent Soil
A	75.58	12.7%
B/D	126.91	21.3%
C	113.41	19.1%
D	123.37	20.7%
WATER	155.89	26.2%
Total	**595.16**	**100.0%**



Lake Roberts Hydrologic Soils Group

Figure 3-5

3.4 HYDROLOGIC CHARACTERISTICS

In addition to land use characteristics, information on hydrologic characteristics of the Lake Roberts drainage basin areas was developed for use in modeling inputs of stormwater runoff. The initial step in evaluating hydrologic characteristics involved a review of the impervious area within the basin. There is limited directly connected impervious area within the basin and therefore all impervious area was assumed to be non-directly connected impervious area.

A composite curve number for the basin was obtained by using "Urban Hydrology of Small Watershed –TR-55" as published by United Stated Department of Agriculture. An intersection of land use, soils and basin data was used to develop the summary of hydrologic characteristics presented in Appendix 3-1.

The composite curve number value (CCN) is calculated by:

$$CCN = \frac{\sum_{1}^{n}\left(CN_{n,m} * \sum_{m=1}^{m} Area_{n,m}\right)}{\sum_{1}^{n}\left(\sum_{m=1}^{m} Area_{n,m}\right)} \qquad \text{Equation 1}$$

where:

CCN = Composite Curve Number,
CN_n = Curve Number for given land use, n, and HSG, m,
$Area_n$ = area (acres) for land use, n, and HSG, m,
n = number of different land uses within the area, and
m = number of different HSGs within the area.

An area-weighted runoff coefficient is a computation that takes into account all the various land use and soil types within an area. The application determines the area associated with each land use/hydrologic soil group combination within the area, sums these up, and divides by the total area, as shown below. This value is computed for the basin.

$$C = \frac{\sum_{1}^{n}\left(C_{n,m} * \sum_{m=1}^{m} Area_{n,m}\right)}{\sum_{1}^{n}\left(\sum_{m=1}^{m} Area_{n,m}\right)} \qquad \text{Equation 2}$$

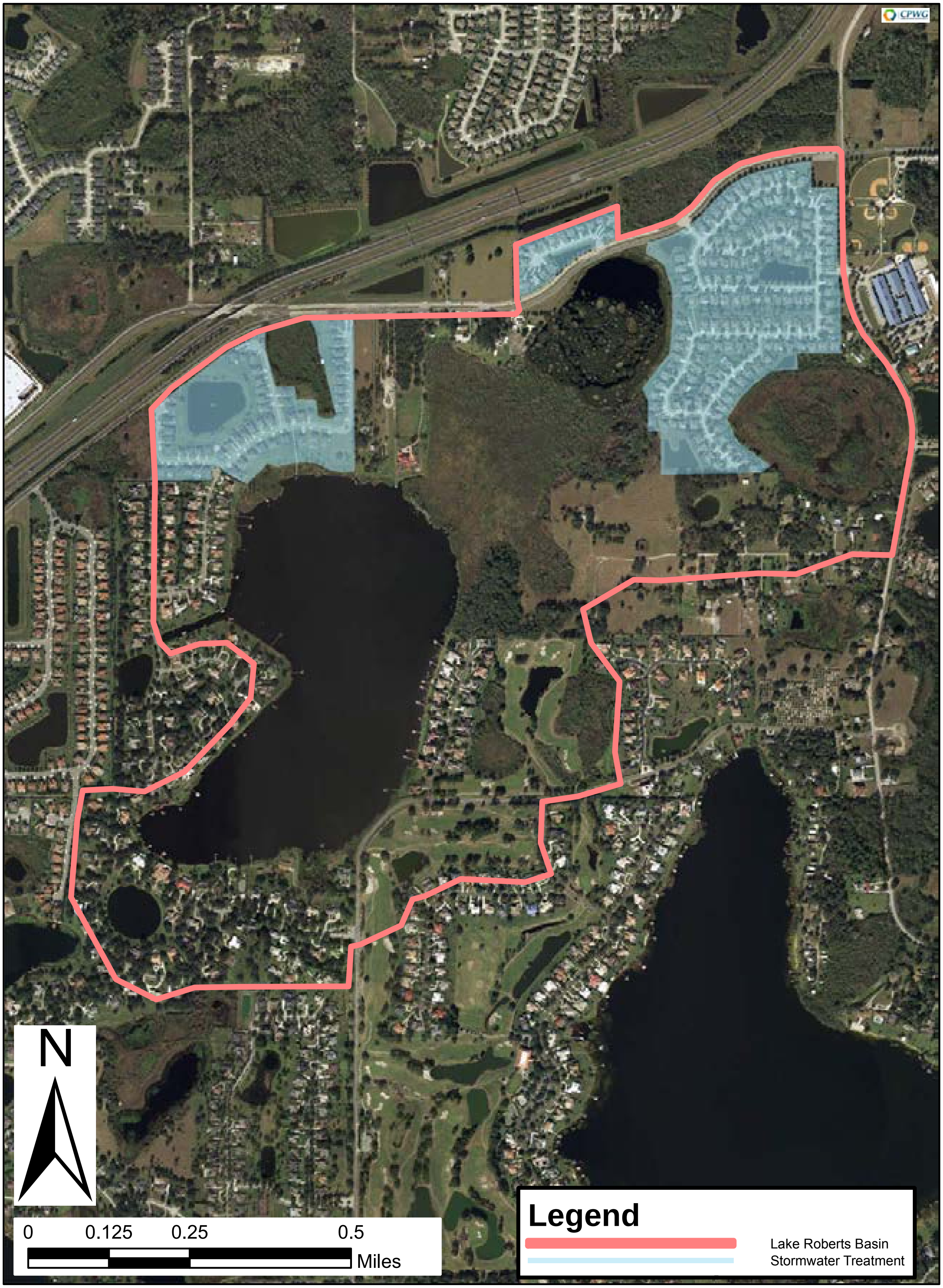
where:

C = area-weighted runoff coefficient,
C_n = area-weighted runoff coefficient for a given land use, n,
$Area_n$ = area (acres) for land use, n, and HSG, m,
n = number of different land uses within the area, and
m = number of different HSGs within the area.

3.5 STORMWATER TREATMENT

Watershed areas which currently provide stormwater treatment within the Lake Roberts watershed were identified using a combination of aerial photography and field reconnaissance. A summary of the results of these evaluations is given in Figure 3-6. Existing parcels with stormwater treatment are located primarily on newer developments in the northwest portion of the drainage basin including, Cambridge Crossing Subdivision located to the north and east of Lake Reaves and in Lake Roberts Lands located at the northwest corner of Lake Roberts. Stormwater treatment at both of these subdivisions is provided via wet detention.

The remaining portion of the watershed was constructed prior to implementation of requirements for stormwater treatment systems and discharge untreated stormwater runoff directly into the lake. The information summarized on Figure 3-6 was utilized in Sections 4 and 5 for estimation of hydrologic inputs and mass loadings from stormwater runoff entering the evaluated lakes.



Lake Roberts Stormwater Treatment Areas

Figure 3-6

3.6 SEWAGE DISPOSAL

Disposal of sanitary sewage within the Lake Roberts and Lake Reaves watersheds occurs using a combination of on-site septic tank systems and a central sanitary sewer system. Existing sanitary sewer lines in the vicinity of Lake Roberts/Lake Reaves are indicated on Figure 3-7. Central sewer systems are available in Cambridge Crossing Subdivision located at the north end of Lake Reaves and in Lake Roberts Landings located at the northwest corner of Lake Roberts. The remaining portion of the watershed is serviced by septic tanks including: Waterford Point (southwest corner), Reserve at Waterford Point (central west) and Butler Bay (southeast near golf course). Existing parcels with sewage disposal using septic tanks in the vicinity of Lake Roberts/Lake Reaves are illustrated on Figure 3-8 based on GIS shape files provided by the County. The coverage assumes that if central sewer is available the parcel is serviced by the central sewer system. Conversely, if no central sewer system is available, it is assumed the structure is serviced by a septic system. Parcels using septic tanks are located primarily along the west, south and southeast portions of Lake Roberts. Use of reclaimed wastewater for irrigation purposes does not occur within the Lake Roberts watershed.

An estimated 111.6 acres (18.7%) within the Lake Roberts and Lake Reaves watershed are covered with parcels that use septic tanks for wastewater deposal. The remaining area 483.6 acres (81.3%) is either vacant, golf course or serviced by central sewer. These areas are based upon the information illustrated on Figure 3-8.

The nutrient loading from septic tanks to receiving waterbodies is varied and is dependent on the number of people using the system, inputs to the system, water table elevation and/or groundwater potential elevation, and soil characteristics. The “Nutrient and Unionized Ammonia TMDLs for Lake Jesup (WBIDs 2981 and 2981A)” (March 2006) reported the nutrient load for household wastewater discharge into septic tanks as 1.46 kilograms/capita/ year for total phosphorus (TP) and 4.61 kilograms/capita/year for total nitrogen (TN). The “Preliminary Evaluation of Septic Tank Influences on Nutrient Loading to the Lower St. Johns River and Its Tributaries” (June 2011) report concentrations of TP and TN in groundwater downstream of septic tanks to be 0.75 milligrams/liter (mg/l) and 7.687 mg/l, respectively. The University of Florida IFAS

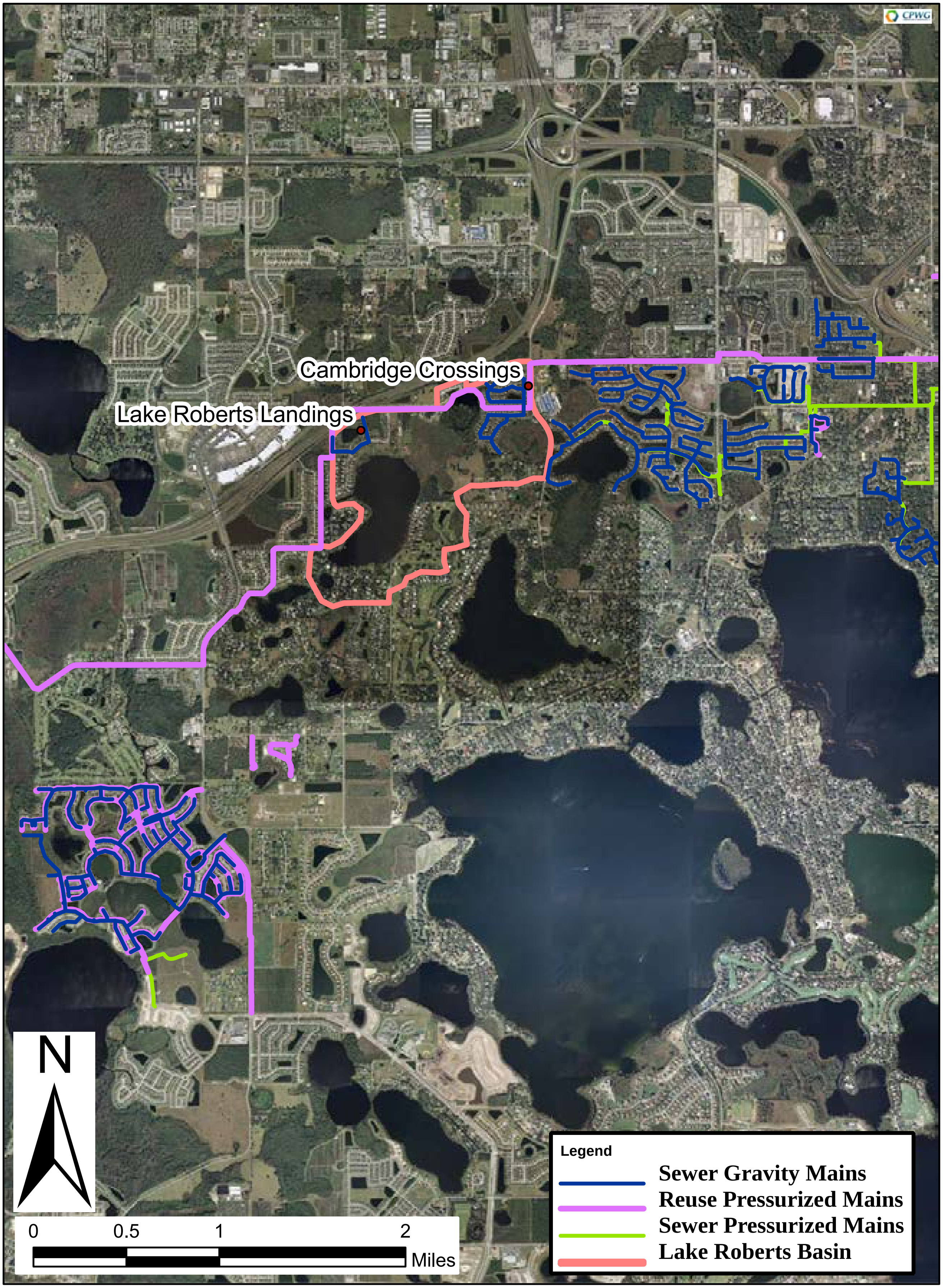
Extension reported 2.7 grams/capita/day of TP discharging into the septic system in "Onsite Sewage Treatment and Disposal Systems: Phosphorus" (July 2011). The University of Florida IFAS Extension reported 11.2 grams/capita/day of TN discharging into the septic system in "Onsite Sewage Treatment and Disposal Systems: Nitrogen" (June 2011) These same two IFAS studies report that TP removal is generally 90% to 99% and TN removal is 10% to 50%. The IFAS data is incorporated in this study in order to estimate the nutrient pollutant load from the septic tanks located within 100 meters of the lake's shoreline. It should be noted that current Orange County ordinances required a 150-ft septic tank setback from the normal high water elevation for all surface water bodies and 75-ft setback for the control elevation of all artificial water bodies. The assumed loading rates, removal rates and resulting loadings are presented in Table 3-5.
These are averages reported by the IFAS report. The actual loading at Lake Roberts could be higher or lower depending on such characteristics as surrounding soil types, groundwater depths, per capita assumptions, distance of system from the shoreline, and septic system maintenance.

Table 3-5
Nutrient Loadings from Septic Tanks

Description	Amount
TP Loading	2.7 grams/capita/day
TN Loading	11.2 grams/capita/day
Number of Septic Tanks	57 houses
Capita per Septic Tank	2.74 people/house
TP Removal Rate	90%
TN Removal Rate	30%
TP Loading to Septic Tank	154 Kg/year
TP Removed	138.6 Kg/Year
TP Loading to Lake Roberts	15.4 Kg/year (34.0 lbs/Year)
TN Loading to Septic Tank	638 Kg/Year
TN Removed	191 Kg/Year
TN Loading to Lake Roberts	447 Kg/Year (985 lbs/Year)

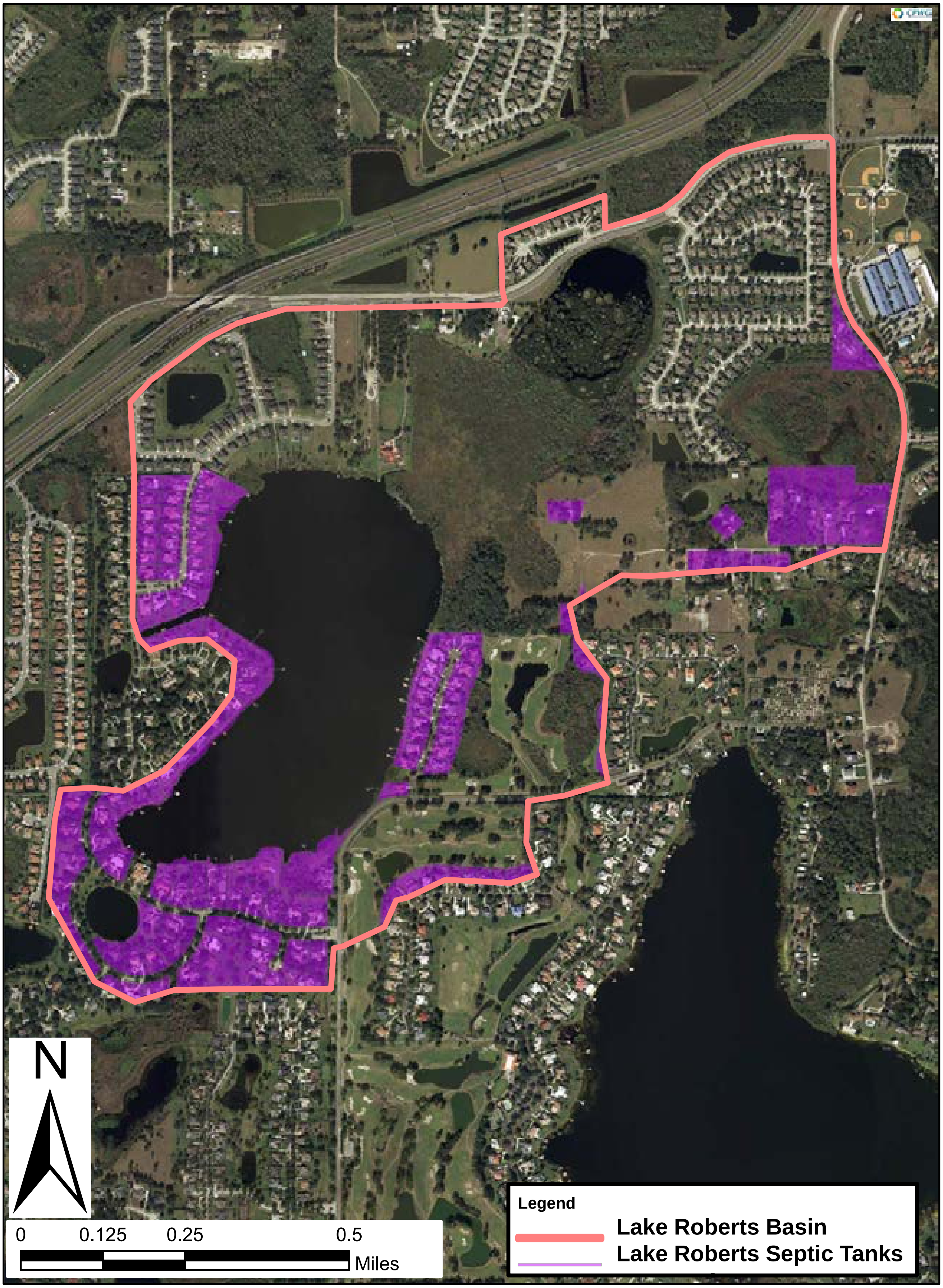
Notes:

1. Loading Rates and Removal Rates from University of Florida IFAS Extension report *"Onsite Sewage Treatment and Disposal Systems: Nitrogen" (June 2011) and "Onsite Sewage Treatment and Disposal Systems: Phosphorus" (July 2011)*
2. *Number of houses based on lots within 100 meters of the water's edge*
3. *2.74 people/house based on Orange County census average for data between 2008 and 2012*



Lake Roberts - Wastewater and Reuse Lines

Figure 3-7



Lake Roberts Septic Tank Map

Figure 3-8

4.0 HYDROLOGIC INPUTS AND LOSSES

An average annual hydrologic budget was developed for Lake Roberts which includes inputs from direct precipitation, stormwater runoff, and groundwater seepage. Hydrologic losses are estimated for evaporation, deep recharge, and discharges through the outfall structure. The hydrologic budget is used as an input for development of a nutrient budget as well as estimation of hydraulic residence time. A conceptual schematic of evaluated hydrologic inputs and losses in Lake Roberts is given on Figure 4-1. A discussion of identified hydrologic inputs and losses for Lake Roberts is given in the following sections.

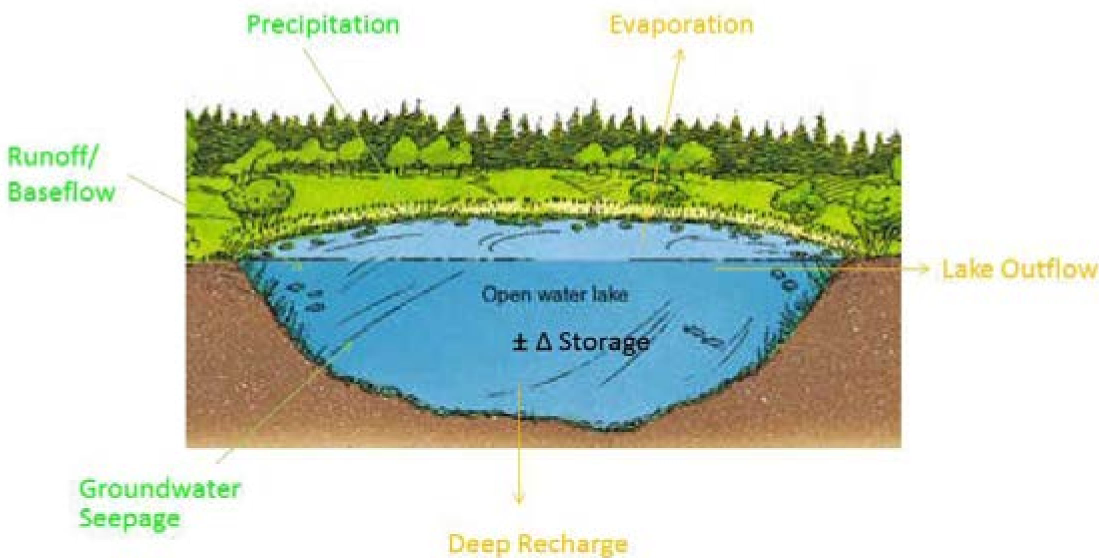


Figure 4-1: Conceptual Schematic of Evaluated Hydrologic Inputs and Losses for Lake Roberts

4.1 HYDROLOGIC INPUTS

4.1.1 DIRECT PRECIPITATION

4.1.1.1 RAINFALL CHARACTERISTICS

Hydrologic inputs from direct precipitation to Lake Roberts are calculated based upon historical mean monthly precipitation for the Lake Roberts area. Estimates of mean monthly precipitation were generated based upon historical radar rainfall data from the St. Johns River Water Management District over the period from 2000-2012.

A summary of mean monthly rainfall at Lake Roberts as provided from this radar data is given in Table 4-1. Mean monthly rainfall depths range from a low of 1.11 inches during November to a high of 8.23 inches in June, with an annual total of approximately 47.45 inches.

Table 4-1
Summary of Mean Monthly Rainfall in the Lake Roberts Area from 2000-2012

Month	Rainfall Depth (inches)
January	1.95
February	1.71
March	2.94
April	2.03
May	3.25
June	8.23
July	7.13
August	8.6
September	5.46
October	2.56
November	1.11
December	2.48
TOTAL	**47.45**

For comparison purposes estimates of mean monthly precipitation based upon historical monthly rainfall at the Orlando International Airport (OIA) meteorological station over the period from 1942-2005 are given in Table 4-2.

Table 4-2
Summary of Mean Monthly Rainfall in the Orlando Area from 1942-2005

Month	Rainfall Depth (inches)
January	2.35
February	2.47
March	3.77
April	2.68
May	3.45
June	7.58
July	7.27
August	7.13
September	6.06
October	3.31
November	2.17
December	2.58
TOTAL	**50.82**

4.1.1.2 HYDROLOGIC INPUTS

Estimated monthly hydrologic inputs from direct precipitation into Lake Roberts were calculated by multiplying the mean monthly rainfall at Lake Robert (as summarized in Table 4-1) times the assumed lake surface area of 108.27 acres for Lake Roberts. A summary of estimated mean monthly hydrologic inputs to Lake Roberts from direct precipitation is given in Table 4-3. During an average annual rainfall year, direct precipitation contributes approximately 428 acre-feet of water to Lake Roberts.

Table 4-3
Estimated Mean Monthly Hydrologic Input to Lake Roberts from Direct Precipitation from 2000-2012

Month	Monthly Rainfall (inches)	Hydrologic Inputs (ac-ft/month)
January	1.95	17.59
February	1.71	15.43
March	2.94	26.53
April	2.03	18.32
May	3.25	29.32
June	8.23	74.26
July	7.13	64.33
August	8.6	77.59
September	5.46	49.26
October	2.56	23.10
November	1.11	10.01
December	2.48	22.38
TOTALS	**47.45**	**428.12**

4.1.2 STORMWATER RUNOFF

Estimates of hydrologic inputs to Lake Roberts from stormwater runoff were calculated based upon mean rainfall characteristics from 2000-2012. Since Lake Roberts acts as one waterbody only one basin was used to develop both the hydrologic and nutrient budgets for the lake. Details of evaluation methods and results of the runoff modeling efforts are given in the following sections.

4.1.2.1 COMPUTATION METHODS

Estimates of volumetric inputs from direct stormwater runoff were generated for the areas discharging into Lake Roberts. The estimated runoff volumes were calculated for average annual rainfall conditions based upon hydrologic modeling of individual rain events. A runoff simulation model was developed and the historical rainfall data were used as the precipitation input data. This model provides an estimate of runoff inputs to Lake Roberts based on average rainfall conditions over the period from 2000-2012.

The SCS curve number methodology was used to provide estimates of the runoff volumes generated within the drainage basin area for average historical rain events from 2000-2012. The SCS methodology utilizes the hydrologic characteristics of the drainage basin, including impervious area, directly connected impervious area, and soil curve numbers to estimate runoff volumes for modeled storm events. Hydrologic characteristics of the basin areas were determined based upon aerial photography and a field reconnaissance of the watershed areas. This information was discussed previously in Section 3.

After estimating the hydrologic characteristics of each basin area, the runoff volume is calculated by adding the rainfall excess from the non-directly connected impervious area (non-DCIA) portion of the watershed to the rainfall excess created from the DCIA portion of the watershed. Rainfall excess from the non-DCIA areas is calculated using the following set of equations:

$$Soil\ Storage, S = \{\frac{1000}{nDCIA\ CN} - 10\}$$

$$nDCIA\ CN = \frac{[CN * (100 - IMP) + 98\ (IMP - DCIA)]}{100 - DCIA}$$

$$Q_{nDCIAi} = \frac{[(P_i - 0.2S)^2]}{[(P_i + 0.8S)]}$$

Where:

CN	=	Curve number for pervious area
IMP	=	Percent impervious area
DCIA	=	Percent directly connected impervious area
nDCIA CN	=	Curve number for non-DCIA area

P_i = Rainfall event depth (inches)

Q_{nDCIAi} = Rainfall excess for non-DCIA for rainfall event (inches)

For the DCIA portion, rainfall excess is calculated using the following equation:

$$Q_{DCIA_i} = (P_i - 0.1)$$

When Pi is less than 0.1, QDCIAi is equal to zero.

The methodology outlined above provides an estimate of the "generated" runoff volume for rainfall events in the basin over the 13-year period from 2000-2012. However, significant portions of the generated runoff volume may be attenuated during migration through stormwater management systems. If the stormwater management system provides dry retention treatment, a large portion of the runoff volume may be infiltrating into the ground and not reach the receiving water as a surface flow. If the stormwater system provides wet detention treatment, a portion of the generated runoff volume may be lost due to evaporation within the pond or infiltration through the pond bottom.

The watershed model includes estimates of the types of stormwater management systems utilized within each basin area and the amount of developed area treated by each stormwater management type. The runoff volume discharging to wet or dry stormwater treatment systems is reduced or attenuated for likely volumetric removal processes in the wet or dry treatment systems. Estimates of the amount of generated runoff volume attenuated by each type of stormwater management system are included in the model, and the attenuated volume is subtracted from the generated volume within the basin. The result is an estimate of the runoff volume which actually discharges into the receiving waterbody from each basin area.

A summary of estimated volumetric removal efficiencies for stormwater management systems in the Lake Roberts sub-basins is given in Table 4-4. These volumetric removals are based on research performed by ERD on the performance efficiencies of stormwater management systems used in the State of Florida. Developed areas treated by dry retention are assumed to have a volumetric loss of approximately 80% for runoff inputs due to infiltration and evaporation within the pond. Wet detention ponds are assumed to have a volumetric loss of approximately 20%, due primarily to evaporation and infiltration through the pond bottom. The information summarized in Table 4-4 is combined with information on stormwater management systems (Figure 3-6) to assist in calculation of estimated runoff inflow from sub-basin areas into the lake.

TABLE 4-4
Estimated Volumetric Removal Efficiencies for Stormwater Management Systems

System Type	Volume Reduction (%)
Dry Retention Pond	80
Wet Detention Pond	20

A summary of estimated runoff volumes which discharge into Lake Roberts on an average annual basis is given in Appendix 4-1. The generated runoff volume represents the modeled runoff volume within each sub-basin prior to volume reduction in stormwater management systems. Estimates of the volume removed in dry retention ponds and wet detention ponds are also included, based upon the volumetric removal efficiencies summarized in Table 4-4. The resulting value represents the observed runoff volume which is actually discharged into Lake Roberts. Estimates of the generated and observed runoff coefficients (C value) are also provided for each drainage sub-basin.

The single largest runoff contribution is from the wetland tussock. The wetland tussock contributes 44% of the annual runoff inputs into the lake. The second largest contribution is from medium density residential, which contributes 28% of the annual runoff inputs into the lake. The third largest contribution is from direct precipitation on Lake Reaves at 12% (which flows through the wetland tussock into Lake Roberts). The remaining land uses contribute approximately 16% of the annual runoff into the lake.

4.1.3 SHALLOW GROUNDWATER SEEPAGE

Field investigations were performed by CPWG and ERD to evaluate the quantity and quality of shallow groundwater seepage entering Lake Roberts during the monitoring period from October 2013-December 2014. Groundwater seepage was quantified using a series of underwater seepage meters installed at locations throughout the lake. Seepage meters provide a mechanism for direct measurement of groundwater inflow into a lake by isolating a portion of the lake bottom so that groundwater seeping up through the bottom sediments into the lake can be collected and characterized. Use of the direct seepage meter measurement technique avoids errors, assumptions, and extensive input data required when indirect techniques are used, such as the Gross Water Budget or Subtraction Method, as well as computer modeling and flow net analyses.

The seepage meter technique has been recommended by the U.S. Environmental Protection Agency (EPA) and has been established as an accurate and reliable technique in field and tank test studies (Lee, 1977; Erickson, 1981; Cherkauer and McBride, 1988; Belanger and Montgomery, 1992). With installation of adequate numbers of seepage meters and proper placement, seepage meters are a very effective tool to estimate groundwater-surface water interactions. One distinct advantage of seepage meters is that seepage meters can provide estimates of both water quantity and quality entering a lake system, whereas estimated methods can only provide information on water quantity.

4.1.3.1 SEEPAGE METER CONSTRUCTION AND LOCATIONS

A schematic of a typical seepage meter installation used in Lake Roberts is given in Figure 4-2. Seepage meters were constructed from a 2-foot diameter aluminum container with a closed top and open bottom. Each seepage meter isolated a sediment area of approximately 3.14 ft^2. Seepage meters were inserted into the lake sediments to a depth of approximately 8-12 inches, isolating a portion of the lake bottom. Approximately 3-6 inches of water was trapped inside the seepage meter above the lake bottom.

A 0.75-inch PVC fitting was threaded into the top of each aluminum container. The 0.75-inch PVC fitting was attached to a female quick-disconnect PVC camlock fitting. A flexible polyethylene bag, with an approximate volume of 40 gallons, was attached to the seepage meters using a quick-disconnect PVC male camlock fitting with a terminal ball valve. Each of the collection bags was constructed of black polyethylene to prevent light penetration into the bag. Light could potentially stimulate photosynthetic activity within the sample prior to collection and result in an undesirable alteration of the chemical characteristics of the sample.

Prior to attachment to the seepage meter, all air was removed from inside the polyethylene collection bag, and the PVC ball valve was closed so that lake water would not enter the collection container prior to attachment to the seepage meter. A diver then connected the collection bag to the seepage meter using the PVC camlock fitting. After attaching the collection bag to the seepage meter, the PVC ball valve was then opened. As groundwater influx occurs into the open bottom of the seepage meter, it is collected inside the flexible polyethylene bag.

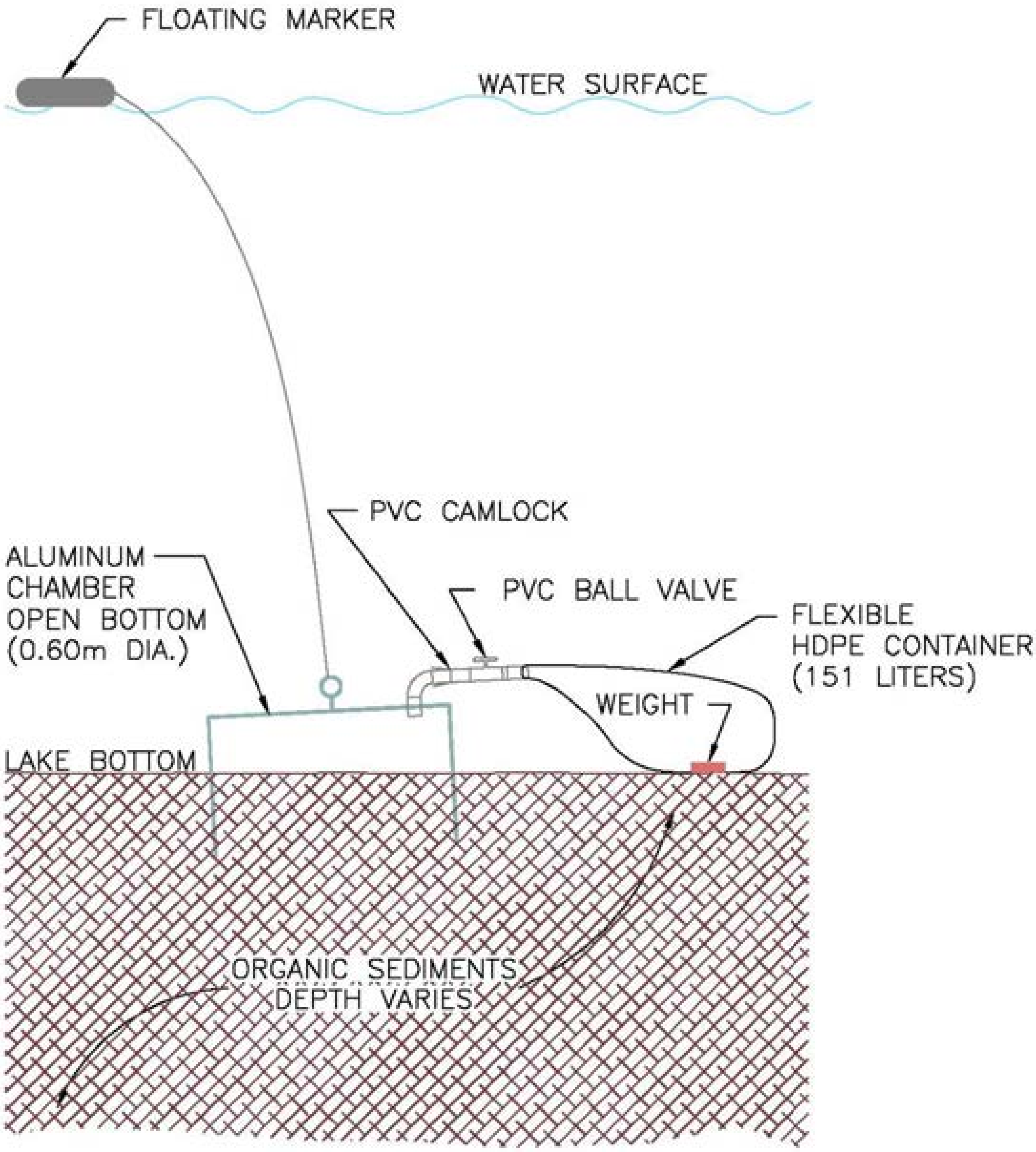
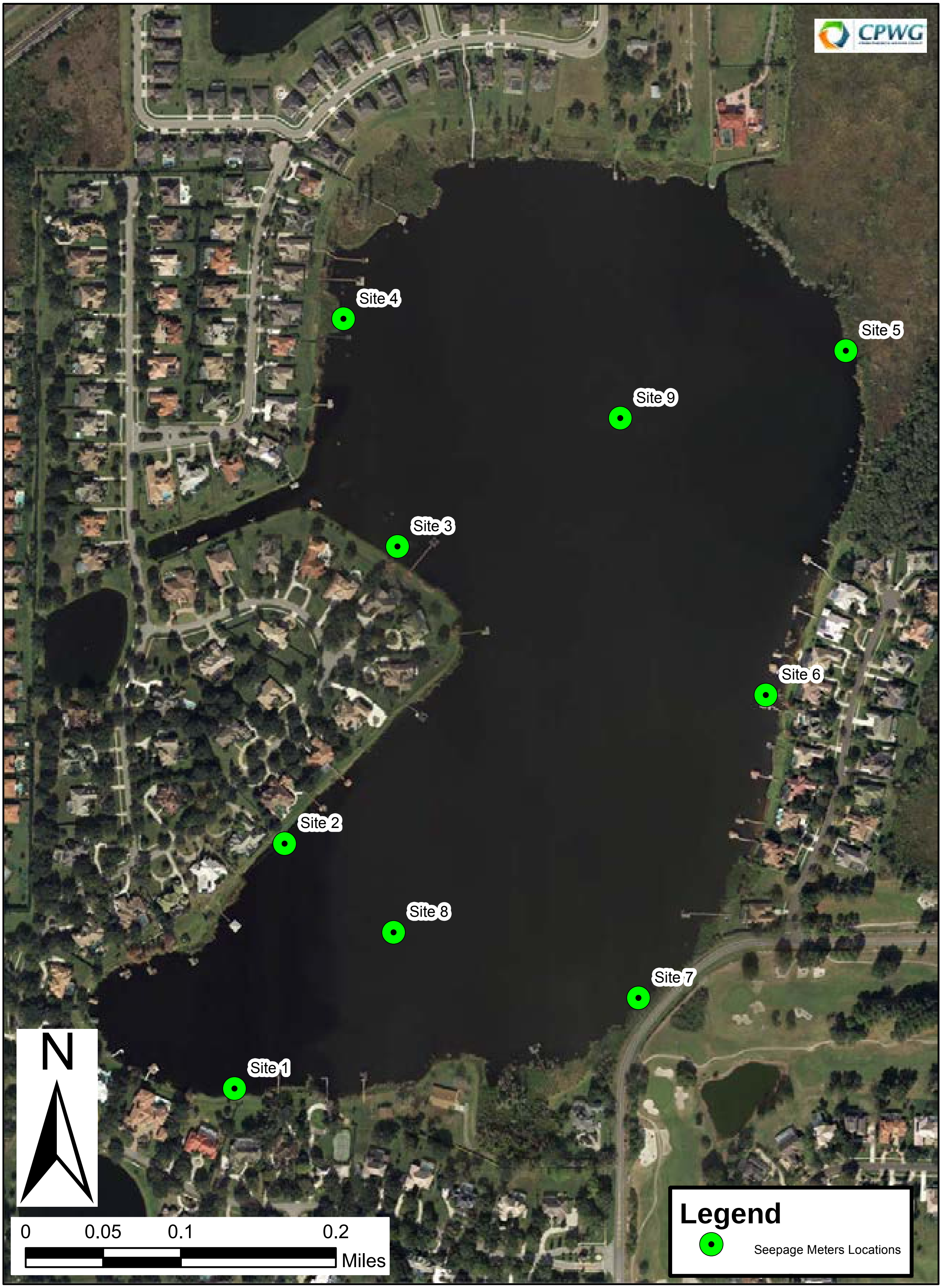


Figure 4-2. Typical Seepage Meter Installation.

Each seepage meter was installed with a slight tilt toward the outlet point so that any gases which may be generated inside the seepage meter would exit into the collection container. A plastic-coated fishing weight was placed inside each of the collection bags to prevent the bags from floating up towards the water surface as a result of trapped gases. The location of each seepage meter was indicated by a floating marker in the lake which was attached to the seepage meter using a coated wire cable.

Nine (9) seepage meters were installed in Lake Roberts on September 18, 2013. Locations for the seepage meters are indicated on Figure 4-3. Since seepage inflow is often most variable around the perimeter of a lake, the majority of the seepage meters were installed around the perimeter of the lake at a uniform water depth of approximately 5 ft. Seepage meters were also installed in central portions of the lake.

Collection bags were installed on each of the seepage meters at the time of installation, and the monitoring program was initiated. Each of the seepage meters was monitored on approximately a monthly to bi-monthly basis, depending on rainfall, from October 2013-December 2014. During the initial monitoring event, the volume of seepage collected was recorded, and the sample was discarded since the water within the collection bag represented a combination of seepage and the initial lake water trapped at the time of installation. During all subsequent events, samples were collected for analysis of seepage characteristics. Ten separate seepage monitoring events were conducted for evaluation of seepage quantity, with nine events conducted to evaluate seepage quality at each of the monitoring sites. A total of 78 samples were collected between the 9 sites over the 441-day monitoring program.



Lake Roberts Seepage Meter Location Map Figure 4-3

4.1.3.2 SEEPAGE METER SAMPLING PROCEDURES

After the initial installation of collection bags, site visits were performed at monthly (or bi-monthly) intervals to collect the seepage samples. During the collection process, a diver was used to close the PVC ball valve and remove the collection bag from the seepage meter using the quick-disconnect camlock fitting. The collection bag was placed onto the boat and the contents were emptied into a polyethylene container. The volume of seepage collected in the container was measured using either a 4-liter graduated cylinder or a 20-liter graduated polyethylene bucket, depending on the collected volume.

Following the initial purging, seepage meter samples were collected for return to the laboratory for chemical analysis. On many occasions, seepage meter samples were found to contain turbidity or particles originating from the sediments isolated within the seepage meter. Since these contaminants are not part of the seepage flow, all seepage meter samples collected for chemical analyses were field-filtered using a 0.45 micron disposable glass fiber filter typically used for filtration of groundwater samples. A new filter was used for each seepage sample. Seepage samples were filtered immediately following collection using a battery operated peristaltic pump at a flow rate of approximately 0.25 liter/minute. The filtered seepage sample was placed on ice for return to the laboratory for further chemical analyses.

A summary of field measurements of seepage inflow over the monitoring period from October 2013-December 2014 is given in Appendix 5-2. During collection of the seepage samples, information was recorded on the time of sample collection, the total volume of seepage collected at each site, and general observations regarding the condition of the seepage collection bags and replacement/repair details. The seepage flow rate at each location is calculated by dividing the total collected seepage volume (liters) by the area of the seepage meter (0.27 m^2) and the time (days) over which the seepage sample was collected.

As shown in Appendix 5-2, Site 1 (southwest shoreline) and Site 9 (northeast center of lake) contain missing data for one or more events as a result of missing or damaged collection bags and seepage meters. Two data point are missing from Site 1 and one data point is missing from Site 9. The damaged seepage meters were repaired or replaced at the time of the monitoring event.

4.1.3.3 SEEPAGE INFLOW

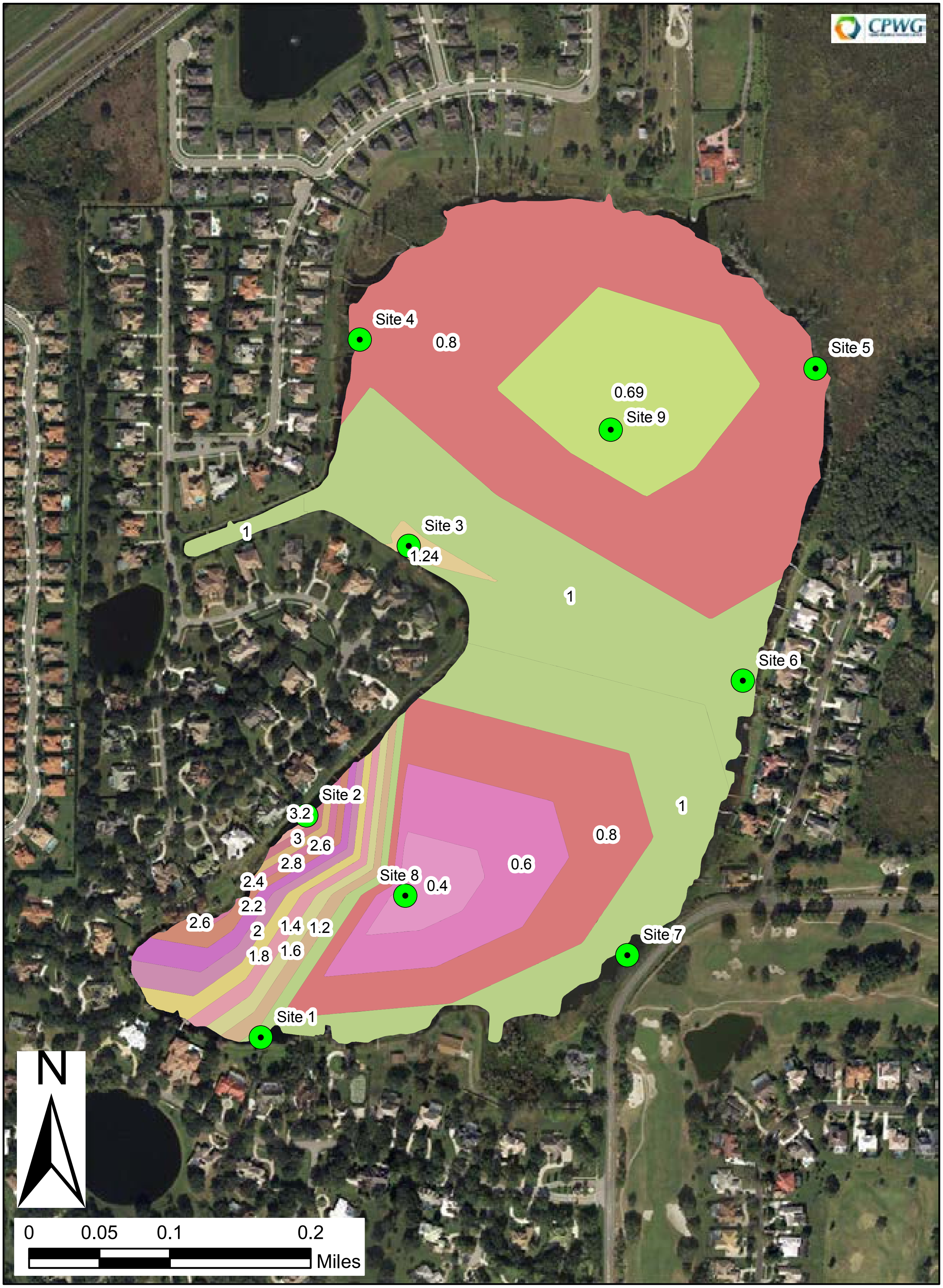
A statistical summary of seepage inflow measurements is given in Table 4-5. In general, mean seepage values measured at the monitoring sites range from 0.32 to 4.83 liters/m^2-day. However, the majority of mean values range from approximately 0.32 to 0.88 liters/m^2-day.

TABLE 4-5
Statistical Summary of Seepage Inflow Measurements in Lake Roberts
October 2013 – December 2014

SITE	Number of Samples	Minimum Value (liters/m^2-day)	Maximum Value (liters/m^2-day)	Mean Value (liters/m^2-day)
1	7	0.42	1.33	0.89
2 (TP)*	9	0.74	7.85	3.26
2 (TN)*	8	0.74	7.85	3.20
3	9	0.40	2.19	1.24
4	9	.42	1.67	0.93
5	9	0.55	1.22	0.84
6	9	0.60	1.70	1.10
7	9	0.50	1.43	0.95
8	9	0.06	0.37	0.21
9	8	0.19	1.22	0.69

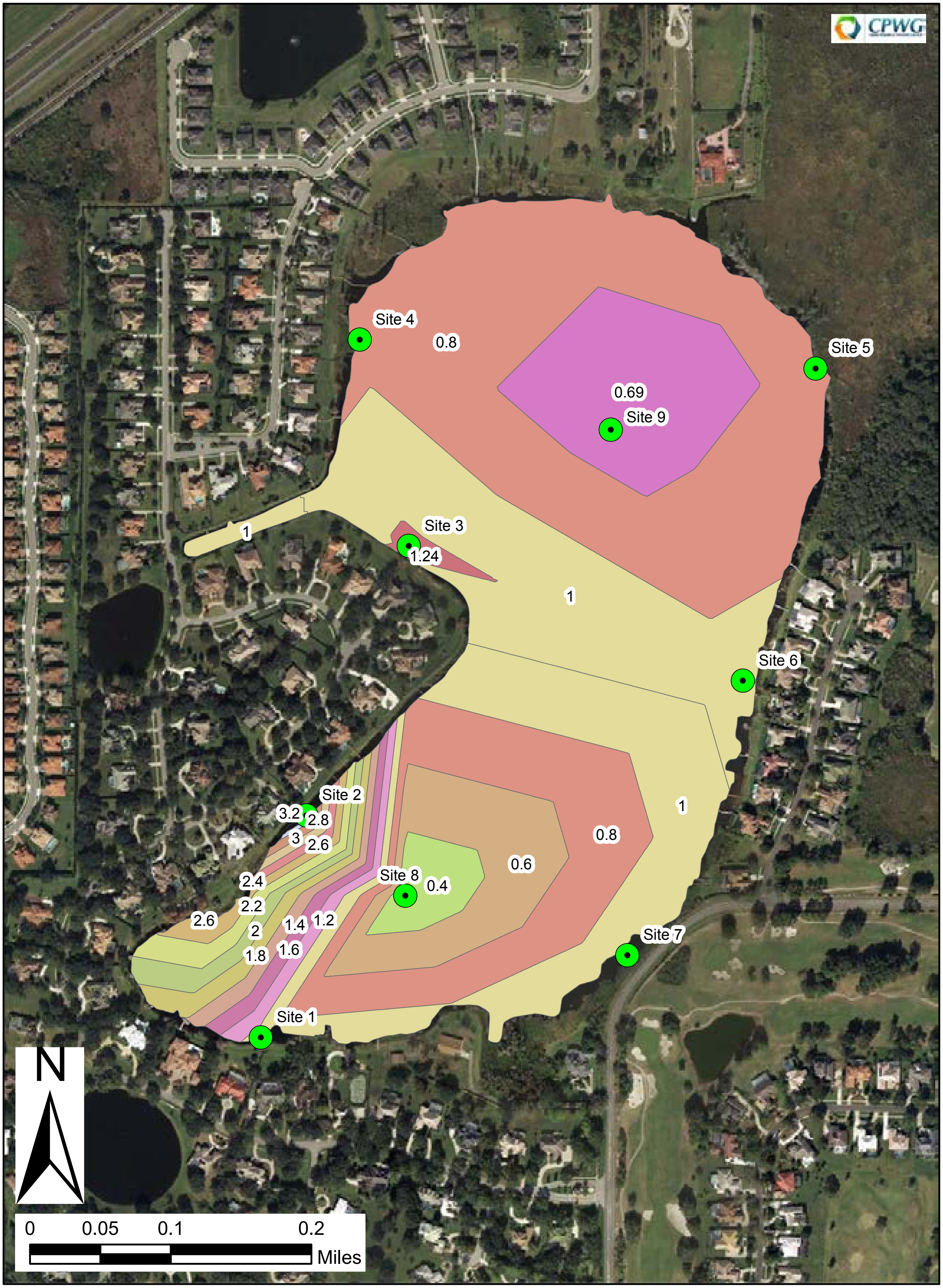
** Mean Value for TN is lower because May 2013 result tested positive as an outlier using the Dickson Q test*

The mean seepage values summarized in Table 4-5 were combined with the geographic coordinates for each site to generate an isopleth contour map for mean seepage inflow into Lake Roberts using GIS. Isopleths of mean seepage inflow into Lake Roberts from October 2013-December 2014 for TP and TN are given in Figure 4-4 and Figure 4-5, respectively.



Lake Roberts Isopleths of Mean Seepage Inflow for TP Liters/Meter^2-day

Figure 4-4



Lake Roberts Isopleths of Mean Seepage Inflow for TN Liters/Meter^2-day

Figure 4-5

The range of seepage values indicated on this figure is from <1 to 4.8 liter/m^2-day. Much of the area within Lake Roberts appears to exhibit relatively low seepage inflow, with large portions of the lake area (approximately 97 acres) indicating seepage of approximately 0.4 to 1.4 liter/m^2-day or less. Areas of elevated seepage inflow were observed along the southwest shoreline of the lake, with seepage rates increasing to as high as 18 liter/m^2-day. The one site with the high seepage rates is adjacent to an existing subdivision. While the rates are consistently higher at this location, the one reading of 18 liter/m^2-day may be in outlier.

The seepage isopleths shown on Figures 4-4 and 4-5were graphically integrated to obtain estimates of mean daily seepage influx into Lake Roberts. A summary of the results of this analysis is given in Table 4-6. The mean seepage influx to Lake Roberts during the field monitoring program was 0.932 liters/m^2-day for TP and 0.929 liters/m^2-day for TN. The flow rates are different because certain outlier data points were removed.

TABLE 4-6
Estimated Seepage Inflow to Lake Roberts from
October 2013 – December 2014

Parameter	Units	TP Value	TN Value
Lake Area	acres	108	108
Mean Seepage Inflow	liters/m^2-day ac-ft/day ac-ft/year	0.932 0.330 120.495	0.929 0.329 120.173
Seepage/Surface Area Ratio	ft/yr	1.116	1.113

4.2 HYDROLOGIC LOSSES

Hydrologic losses from Lake Roberts occur as a result of evaporation from the lake surface, discharge through the outfall structure, and discharge from deeper portions of the lake bottom to underground aquifers. Estimated losses from each of these sources are discussed in the following sections.

4.2.1 EVAPORATION LOSSES

Estimates of monthly evaporation from Lake Roberts were generated based upon mean monthly evaporation data collected at the US Weather Bureau Lisbon Station over the 65-year period from 1948-2012. The Lisbon Station is at Burrell Lock and Dam on Haines Creek near Fruitland Park, Florida, approximately 28 miles northwest of Lake Roberts and appears to be the closest long-term evaporation monitoring site to the Central Florida area. A summary of mean monthly potential evaporation (PET) for this site is given in Table 4-7. For purposes of this project, the mean evaporation measured at the Lisbon site is assumed to be similar to evaporation at Lake Roberts.

TABLE 4-7
Mean Monthly Lake Evaporation at Lisbon Experimental Station Site

Month	Mean Pan Evaporation (inches)
January	2.50
February	2.88
March	4.31
April	5.28
May	6.30
June	6.26
July	6.34
August	5.86
September	4.70
October	3.75
November	2.76
December	2.34
Total	**53.29**

A summary of estimated evaporation losses from Lake Roberts is given in Table 4-8. The values summarized in this table were obtained by multiplying the lake surface area of 108.23 acres times the estimated monthly lake evaporation values. Lake evaporation in Lake Roberts ranges from 21.11 ac-ft/month in December to 57.23 ac-ft/month in July. Overall, evaporation losses from Lake Roberts remove approximately 480 ac-ft of water each year.

TABLE 4-8
Estimate of Annual Hydrologic Losses from Lake Roberts as a Result of Surface Evaporation

Month	Lake Evaporation (inches)	Lake Evaporation (ac-ft)
January	2.50	22.57
February	2.88	26.02
March	4.31	38.92
April	5.28	47.60
May	6.30	56.85
June	6.26	56.50
July	6.34	57.23
August	5.86	52.87
September	4.70	42.45
October	3.75	33.82
November	2.76	24.88
December	2.34	21.11
Total	**53.29**	**480.82**

4.2.2 OUTFALL LOSSES

Discharge from Lake Robert is regulated by a high point in the pipe system downstream of the outfall pipe which flows west from the outfall canal located on the northwest side of Lake Roberts. A photograph of the outfall structure is shown on Figure 2-34. The outfall structure consists of a 45”x28” ERCP at elevation 106.8, NAVD. The outfall pipe is surrounded by fish grates that do not appear to impede flow. Downstream of the outfall, the pipe invert rises to elevation 109 feet. Water levels within the lake and the associated wetland tussock are controlled by this elevation with lake levels fluctuating between 109 and 110 feet. For purposes of estimating the outfall volume a 1-ft long weir at elevation 109.75 feet is assumed.

Estimates of annual discharges through the outfall pipe were performed using the historical water surface elevation data summarized on Figures 2-35 and 2-36. Discharges through the outfall pipe were modeled using a standard horizontal weir equation and the water surface elevations included in the historical data set. A summary of calculated outfall discharges from Lake Robert over the period from 1991-2004 is given on Figure 4-6 which reflects the most recent 14 years of consistent data for the lake. Mean annual discharges during this period range from approximately 0-12 cfs, although the vast majority of discharges appear to be less than 4 cfs. Many years over the period from 1991-2004 had no discharge at all through the outfall structure. On an overall basis, the mean discharge through the outfall structure is approximately 0.8 cfs which is equivalent to an average annual discharge of approximately 579 ac-ft/yr. This number is used for estimation of the hydrologic budget for Lake Roberts.

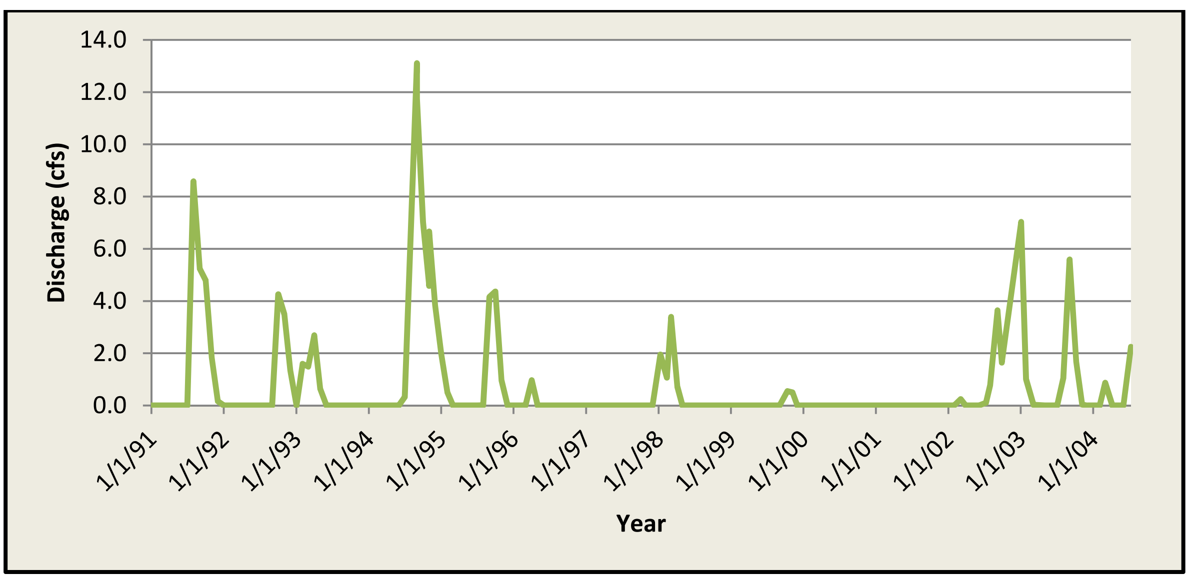


Figure 4-6. Calculated Outfall Discharges from Lake Roberts from 1991 - 2004

4.2.3 DEEP RECHARGE

Deep recharge from Lake Roberts occurs through deeper areas of the lake which have maintained a hydrologic connection to deeper underground aquifers. Water continuously seeps through these deeper areas which result in significant annual losses of water from the lake. Specific measurements of deep recharge were not conducted as part of this project. Therefore, losses of water due to deep recharge are calculated as the difference between the identified inputs and outputs for the lake.

4.3 HYDROLOGIC BUDGET

A summary of identified hydrologic inputs to Lake Roberts on an average annual basis is given in Table 4-9. The largest annual hydrologic input to Lake Roberts is stormwater runoff which contributes approximately 51% of the annual hydrologic inputs. Approximately 37% of the annual hydrologic inputs are contributed by direct rainfall and 12% by groundwater seepage.

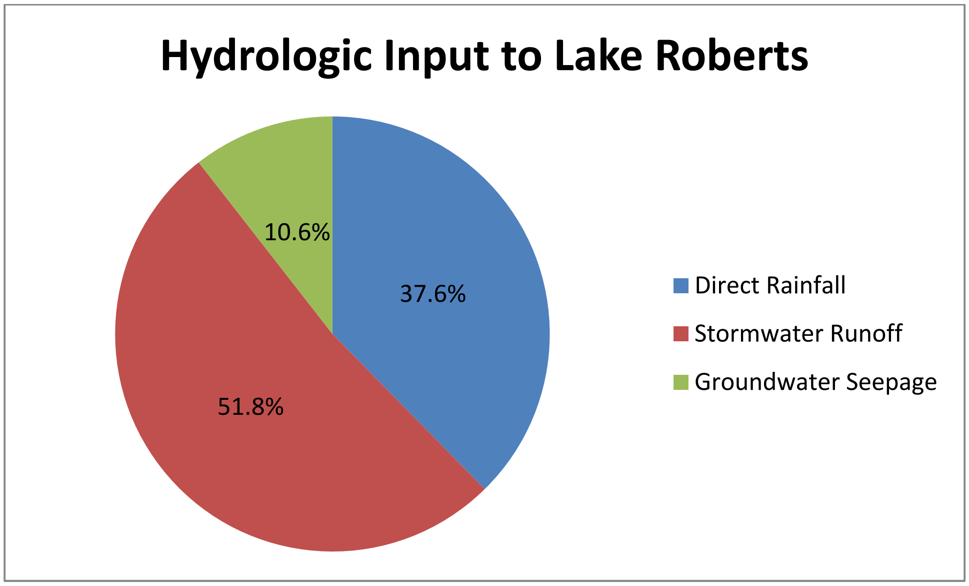
A summary of mean annual hydrologic losses from Lake Roberts is given in Table 4-10. Approximately 42% of the hydrologic losses occur as a result of surface evaporation, with an additional 50% lost as a result of outfall discharges. Approximately 8% of the annual hydrologic inputs are lost to deep recharge in deeper areas of the lake. A graphical comparison of hydrologic inputs and losses to Lake Roberts is given in Figure 4-7.

TABLE 4-9
Mean Annual Hydrologic Inputs to Lake Robert

Parameter	Volume (ac-ft.)	Percent of Total
Direct Rainfall	428	37.6%
Stormwater Runoff	589	51.8%
Groundwater Seepage	120	10.6%
Total	**1,137**	**100%**

TABLE 4-10
Mean Annual Hydrologic Losses from Lake Roberts

Parameter	Volume (ac-ft.)	Percent of Total
Evaporation	481	42.3%
Outfall Discharge	579	50.9%
Deep Recharge	77	6.8%
Total:	**1,137**	**100.0%**



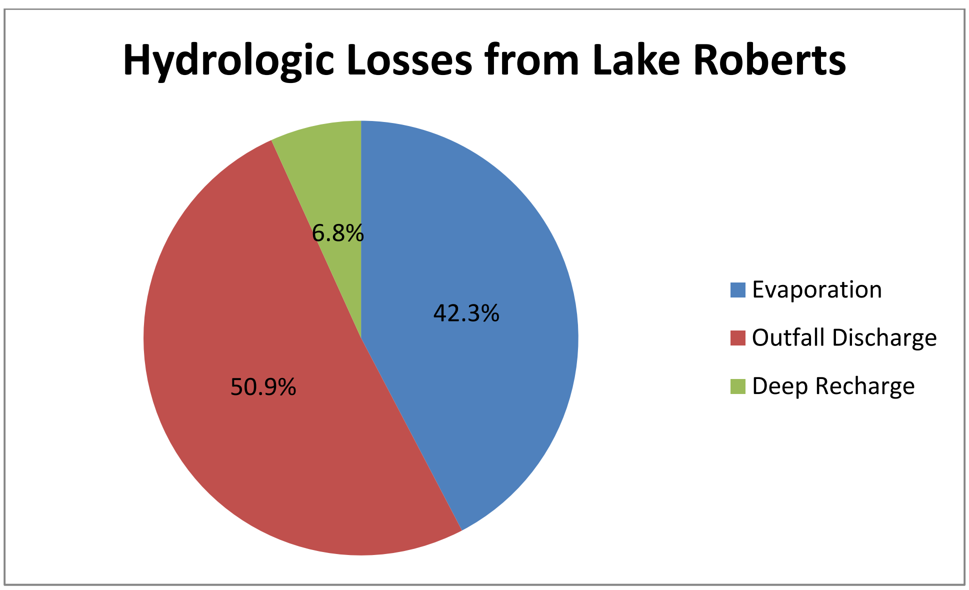


Figure 4-7. Summary of Mean Annual Hydrologic Inputs and Losses to Lake Roberts

4.4 WATER RESIDENCE TIME

Mean annual water residence time was calculated for Lake Robert by dividing the estimated water volume for the lake (summarized in Table 2-1) by the calculated mean annual hydrologic inputs (summarized in Table 4-9). A summary of this information is given in Table 4-11. Based upon this analysis, the calculated residence time in Lake Roberts is approximately 0.93 years or 339 days. This value is typical of residence times commonly observed in Central Florida urban lakes.

Table 4-11
Calculated Mean Annual Residence Time in Lake Roberts

Lake Volume (ac-ft.)	Annual Hydrologic Inputs (ac-ft.)	Residence Time	
		Year	Days
1,066	1,137	0.938	342

5.0 NUTRIENT INPUTS AND LOSSES

Lake Roberts receives nutrient inputs from a variety of sources which include bulk precipitation, stormwater runoff, shallow groundwater seepage, and internal recycling. A discussion of these inputs, along with calculated mass loadings, is given in the following sections. Information from each of these sources is used to generate an annual average nutrient budget for total nitrogen, total phosphorus and TSS in Lake Roberts. A conceptual schematic of evaluated nutrient sources and sinks in Lake Roberts is given in Figure 5-1.

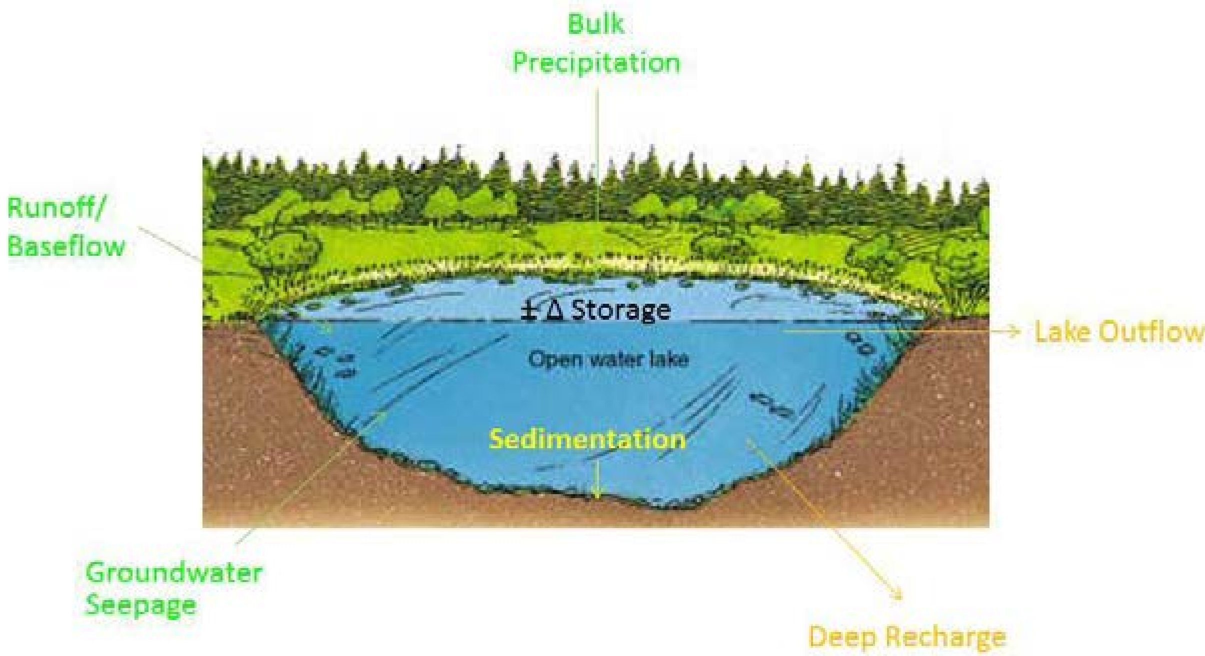


Figure 5-1: Conceptual Schematic of Evaluated Nutrient Inputs and Losses for Lake Roberts

5.1 CHARACTERISTICS OF NUTRIENT INPUTS

5.1.1 BULK PRECIPITATION

5.1.1.1 CHEMICAL CHARACTERISTICS

The chemical characteristics of bulk precipitation in the Central Florida area are based on the Butler Chain-of-Lakes study (ERD, 2005). A summary of the mean characteristics of measured concentrations for nitrogen, phosphorus, and TSS in bulk precipitation at the Butler Chain-of-Lakes monitoring site is given in Table 5-1. For purposes of this evaluation, it is assumed that the bulk precipitation characteristics summarized in Table 5-1 are similar to bulk precipitation which falls on Lake Roberts.

Table 5-1
Mean Characteristics of Bulk Precipitation in the Central Florida Area

Parameter	Units	Concentration
Nitrogen	μg/l	770
Phosphorus	μg/l	61
TSS	mg/l	17.3

5.1.1.2 MASS LOADING

Estimates of annual mass loadings from bulk precipitation to Lake Roberts were calculated for total nitrogen, total phosphorus, and TSS based upon the assumed characteristics listed in Table 5-1 and the estimated annual average volumetric inputs from direct precipitation listed in Table 4-3. A summary of estimated mean annual loadings to Lake Roberts from bulk precipitation is given in Table 5-2.

Table 5-2
Estimated Mean Annual Loading to Lake Roberts from Bulk Precipitation

Parameter	Mass Loading (kg/yr)
Total Nitrogen	406.6
Total Phosphorus	32.2
TSS	9.1

5.1.2 STORMWATER RUNOFF

This section describes the procedures, calculations, and assumptions used to calculate the watershed's contribution to pollutant load to Lake Roberts.

5.1.2.1 POLLUTANT LOAD COMPUTATION

There are a number of steps needed to compute the pollutant load discharged to Lake Roberts. First, one must determine the potential for the watershed to generate runoff and pollutant loads by computing the area-weighted Runoff Coefficient, C, and Event Mean Concentrations (EMC) based on the watershed area, as discussed in Section 4 of this report.

5.1.2.2 AREA-WEIGHTED RUNOFF COEFFICENT, C

The area-weighted runoff coefficient is a computation that takes into account all the various land use and soil types within an area. The application determines the area associated with each land use/hydrologic soil group combination within the area, sums these up, and divides by the total area, as shown below. This value is computed for each project.

$$C = \frac{\sum_{1}^{n}\left(C_{n,m} * \sum_{m=1}^{m} Area_{n,m}\right)}{\sum_{1}^{n}\left(\sum_{m=1}^{m} Area_{n,m}\right)} \qquad \text{Equation 1}$$

where:

C = area-weighted runoff coefficient,
C_n = area-weighted runoff coefficient for a given land use, n,
$Area_n$ = area (acres) for land use, n, and HSG, m,
n = number of different land uses within the area, and
m = number of different HSGs within the area.

The curve number based runoff coefficients are shown in Table 5-3.

Table 5-3
Annual Runoff C-Factors

Curve Number	Annual Runoff C-Factor
39	0.0006
40	0.0008
41	0.0010
42	0.0013
43	0.0017
44	0.0021
45	0.0025
46	0.0031
47	0.0037
48	0.0044
49	0.0051
50	0.0060
51	0.0069
52	0.0079
53	0.0090
54	0.0102
55	0.0116
56	0.0130

Curve Number	Annual Runoff C-Factor
57	0.0146
58	0.0164
59	0.0182
60	0.0202
61	0.0223
62	0.0246
63	0.0270
64	0.0297
65	0.0327
66	0.0359
67	0.0393
68	0.0430
69	0.0469
70	0.0511
71	0.0556
72	0.0603
73	0.0654
74	0.0709
75	0.0769
76	0.0834
77	0.0906
78	0.0983
79	0.1067
80	0.1157
81	0.1255
82	0.1360
83	0.1474
84	0.1596
85	0.1727
86	0.1869
87	0.2023
88	0.2188
89	0.2368
90	0.2573
91	0.2815
92	0.3101
93	0.3440
94	0.3846
95	0.4334
96	0.4934
97	0.5687

Curve Number	Annual Runoff C-Factor
98	0.6665
99	0.8005
100	1.0000

5.1.2.3 AREA-WEIGHTED EMC

The area-weighted EMC computation is one that takes into account all the various land uses within a project's watershed. One determines the area associated with each land use within the area, sums these up, and divides them by the total area, as shown below. This value is computed for each project.

$$EMC_X = \frac{\sum_{1}^{n}(EMC_n * Area_n)}{\sum_{1}^{n} Area_n} \qquad \text{Equation 2}$$

where:

EMC_X = area-weighted EMC for the project for pollutant X(mg/L),
n = number of land uses within the area,
EMC_n = EMC (mg/L) for a given land use, and
$Area_n$ = area (acres) for a given land use (the total area, A, could also be used here).

EMCs used in this study are presented in Table 5-4.

Table 5-4
Event Mean Concentration for Various Land Uses

Land Use	TN (mg/l)	TP (mg/l)	TSS (mg/l)
Golf Course	2.00	0.306	33.0
Groves	2.05	0.140	15.5
Herbaceous upland nonforested	1.25	0.057	7.8
Institutional	1.98	0.339	69.7
Lake	0.49	0.013	0.0
Low Density Residential	1.77	0.177	20.4
Medium Density Residential	2.29	0.306	33
Pasture Land	2.48	0.387	94.3
Wetland/Tussock	1.55	0.113	7.8

The EMC values were obtained primarily from Harper, H.H. (1999). Stormwater Chemistry and Water Quality: Estimating Pollutant Loadings and Evaluation of Best Management Practices for Water Quality Improvements. The wetland/tussock EMC values were provide by FDEP as part of the Lake Robert TMDL development process.

5.1.2.4 ANNUAL POLLUTANT LOADS

The annual pollutant load model spreadsheet based on land uses and EMC values can be found in Appendix 5-1. Table 5-5 summarizes the pollutant load from runoff within the watershed.

Table 5-5
Stormwater Runoff Pollutant Load

Watershed	TP (kg/yr)	TN (kg/yr)	TSS (kg/yr)
Lake Robert	111	1,139	12,985

An alternate method to determine the pollutant load to Lake Roberts from the watershed was explored. The land use/EMC values for the watershed that flows into Lake Roberts other than the wetland tussock was used as previously described. However, Lake Reaves discharges through the wetland tussock directly into Lake Roberts. Therefore, the analytical data for the samples collected from within the wetland were averaged and used to calculate pollutant load into Lake Roberts from the Lake Reaves watershed.

Pollutant load to Lake Roberts due to direct land runoff from the Lake Roberts sub-basins is presented in Table 5-6. This load calculation excludes runoff due to overland flow from the Lake Reave's sub-basin and the wetland tussock area between the two lakes.

Table 5-6
Stormwater Pollutant Load to Lake Roberts without Lake Reaves Contribution

Watershed	TP (kg/yr)	TN (kg/yr)	TSS (kg/yr)
Lake Robert	69	579	7,419

The overland flow and stormwater runoff to Lake Reaves and wetland tussock is estimated to be 322 ac-ft/year. There is no outfall from Lake Reaves except through the wetland tussock into Lake Roberts. Multiple surface water samples were taken within the wetland tussock from September 2013 to July 2014. The average concentrations measured in the wetland tussock were 0.113 mg/l, 1.545 mg/l, 73.87 mg/l for total phosphorous, total nitrogen and total suspended solids, respectively. The pollutant load to Lake Roberts from the Lake Reaves sub-basin is calculated by multiplying the volume of water flowing through the wetland tussock by the average pollutant concentrations. Based on this alternative analysis, an additional load of 3 kg TP, 53 kg of TN and 23,744 kg of TSS is discharged to Lake

Roberts from the wetland tussock. The wetland tussock essentially acts like a tea bag and releases nutrients into the flowing water column under the vegetative mat. A summary of these results are presented in Table 5-7.

Table 5-7
Stormwater Runoff Pollutant Load for Both Calculation Methods

Watershed	TP (kg/yr)	TN (kg/yr)	TSS (kg/yr)
Lake Roberts Sub-Basin	69	579	7,419
Lake Reaves/Wetland Sub-Basin	42	560	5,566
Total Based on Land-use EMCs	**111**	**1,139**	**12,985**
Lake Reaves/Wetland Load Based on Wetland Analytical Data	45	614	29,340
Difference Between the Two Calculation Methods	3	54	23,774
Percent Difference	7.1%	9.4%	427%

5.1.3 GROUNDWATER SEEPAGE

5.1.3.1 CHEMICAL CHARACTERISTICS

Nutrient influx from groundwater seepage was quantified using a total of 9 underwater seepage meters installed at various locations throughout Lake Roberts. A discussion of the hydrologic inputs resulting from groundwater seepage is given in Section 4. Each of the collected groundwater seepage samples was laboratory analyzed for pH, alkalinity, conductivity, total nitrogen, and total phosphorus. A listing of laboratory measurements conducted on seepage samples collected at each of the 9 sites is presented in Appendix 5-2.

A summary of mean chemical characteristics of seepage samples collected in Lake Roberts from November 2013 to December 2014 is presented in Table 5-8. The data from October 2013 was omitted as the first flow and concentrations measurements are inaccurate due to the installation procedure. The mean values listed in Table 5-8 reflect log-normal mean values since the data exhibited a log-normal distribution, as shown on Figure 5-2. Seepage collected from Lake Roberts was found to be slightly basic to neutral in pH, with measured conductivity values slightly higher than commonly observed in urban runoff. A wide range of nitrogen concentrations was observed in seepage samples, with mean measured values ranging from 1,479 to 7,425 µg/l. Mean total phosphorus concentrations in groundwater seepage were also highly variable, ranging from 77 to 998 µg/l between the various sites.

Table 5-8
Mean Characteristic of Groundwater Seepage Samples Collected in Lake Roberts from November 2013 – December 2014

Site	Number of Samples	pH (s.u.)	Alkalinity (mg/l)	Conductivity (µmho/cm)	Total N (µg/l)	Total P (µg/l)
1	7*	7.54	98	343	3,638	258
2	9	6.24	14	225	894**	77
3	9	7.16	71	279	2,781	312
4	9	7.28	81	323	2,698	215
5	9	7.23	95	349	7,425	800
6	9	7.31	55	276	2,293	163
7	9	7.40	63	283	3,675	113
8	9	7.32	132	370	7,341	998
9	8	7.32	83	305	6,178	515

Note: * Seepage Meter Site 1 is based on 7 samples because sample bag was torn in May and June 2014 and therefore no data was collected
** TN for Seepage Meter Site 2 is based on 8 samples because data in May 2014 was determined to be an outlier using the Q test.

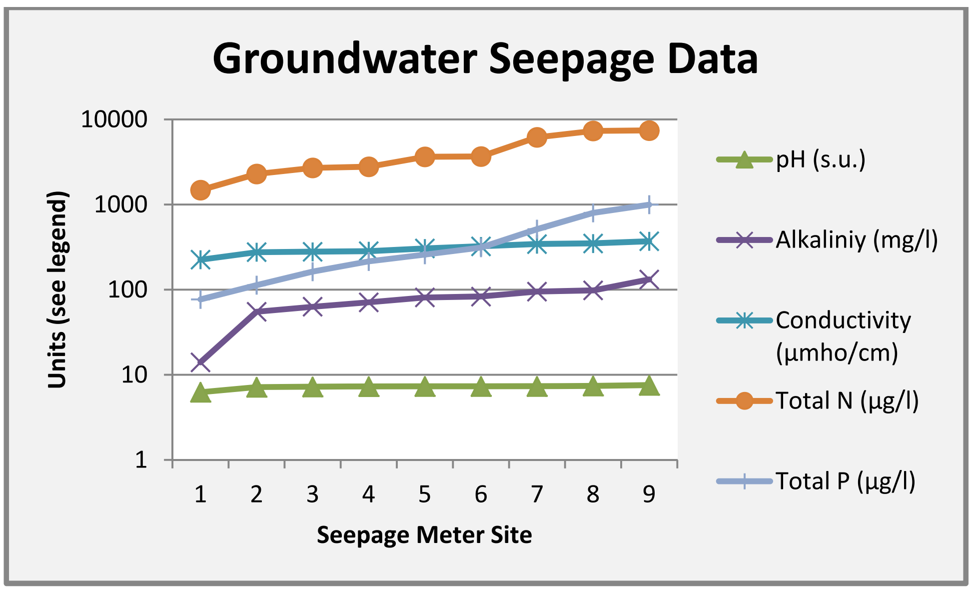


Figure 5-2 - Mean Characteristic of Groundwater Seepage Samples Collected in Lake Roberts from October 2013 to December 2014

Seepage samples collected from the lake were generally well buffered, with the majority of mean alkalinity values ranging from 55 to 132 mg/l. A substantially lower mean alkalinity value of 14 mg/l was observed at seepage site 2. This site also exhibited a substantially lower mean pH value of 6.25 and was characterized by the lowest mean conductivity value of any of the 9 seepage sites. Seepage collected at this site was also characterized by the lowest mean concentrations of total nitrogen and total phosphorus.

Isopleths of mean pH values in groundwater seepage entering Lake Roberts are illustrated on Figure 5-3. In general, the most elevated pH values (ranging from approximately 7.2 to 7.6) were observed in the north, east and south portion of Lake Roberts, with the lowest measured pH values observed on the west wide of the lake near the subdivision and the outfall canal.

Isopleths of mean alkalinity values in groundwater seepage entering Lake Roberts are illustrated on Figure 5-4. Areas of relatively elevated alkalinity were observed in the middle of the southern lobe and near the wetland tussock at the northeast end of the lake. The lowest alkalinity values were observed at the southwest portion of the lake near the subdivision.

Isopleths of mean conductivity values in groundwater seepage entering Lake Roberts are illustrated on Figure 5-5. The most elevated levels of conductivity were observed in the middle of the south lobe and near the wetland at the northeast end of the lake. The lower concentrations were generally observed along the western shoreline of Lake Roberts near the subdivision and the outfall canal.

Isopleths of mean total nitrogen concentrations in groundwater seepage entering Lake Roberts are illustrated in Figure 5-6. The most elevated levels of total nitrogen inputs were observed in the middle of the southern lobe and near the wetland tussock at the northeast end of the lake. The lowest values were generally observed along the southwestern shoreline of the lake near the subdivision.

Isopleths of mean total phosphorus concentrations in groundwater seepage entering Lake Roberts are illustrated on Figure 5-7. The most elevated levels of total phosphorus inputs were observed in the middle of the southern lobe and near the wetland tussock at the northeast end of the lake. The lowest values were generally observed along the southwest shoreline of the lake near the subdivision. The pattern of elevated total phosphorus concentrations shown on Figure 5-7 is similar to the pattern of elevated nitrogen concentrations shown on Figure 5-6.

5.1.3.2 MASS LOADING

Mean seepage isopleths for nitrogen influx, in terms of mg/m^2-day, were generated by combining the concentration isopleths for total nitrogen (provided on Figure 5-6) with the hydrologic isopleths for groundwater seepage (summarized on Figure 4-5). This procedure results in estimates of nitrogen influx in terms of mass nitrogen per square meter of lake surface per day. For purposes of this analysis, "influx" or "flux" is defined as the areal mass input or loading per unit of time.

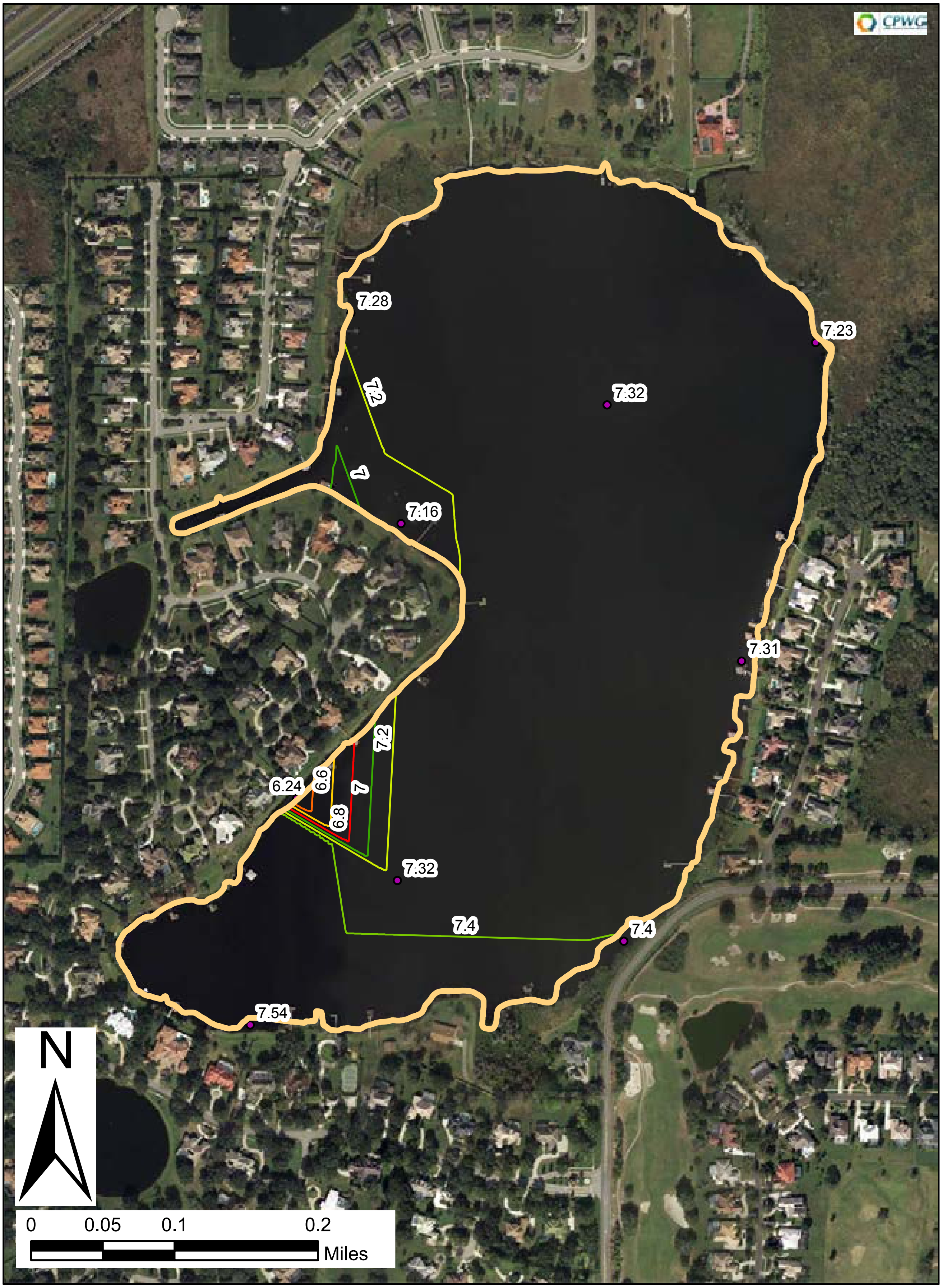
Isopleths of mean seepage influx of total nitrogen into Lake Roberts are illustrated on Figure 5-8. In general, nitrogen influx from groundwater seepage ranges from approximately 1,500 to 6,230 µg/m^2-day. The most elevated levels of nitrogen influx were observed in the northeastern portion of Lake Roberts near the wetland tussock.

Mean isopleths of phosphorus influx into Lake Roberts are illustrated on Figure 5-9. These isopleths were generated by combining the phosphorus concentration isopleths (summarized on Figure 5-7) with the seepage inflow isopleths (summarized on Figure 4-4). In general, phosphorus influx into Lake Roberts ranges from approximately 110 to 670 µg/m^2-day. The most elevated values of phosphorus influx are located in the northeast portion of Lake Roberts near the wetland tussock, similar to those exhibited on Figure 5-8 for nitrogen influx. The lowest seepage influx values were measured along the southeastern shoreline of the lake near the golf course.

The isopleths summarized on Figures 5-8 and 5-9 were integrated to develop estimates of the total influx of nitrogen and phosphorus from groundwater seepage into Lake Roberts during the field monitoring program from October 2013 to December 2014. The October flows and concentrations were not included in the analysis, as they were the first sample from the seepage meters and may have been contaminated or inaccurate. A summary of estimated annual mass loadings of total nitrogen and total phosphorus to Lake Roberts from groundwater seepage is given in Table 5-9. Overall, groundwater seepage contributes approximately 547 kg/yr of total nitrogen and 49 kg/yr of total phosphorus to Lake Roberts. Calculated areal loadings of groundwater seepage are provided at the end of Table 5-9, which reflect the mass influx divided by the lake surface area.

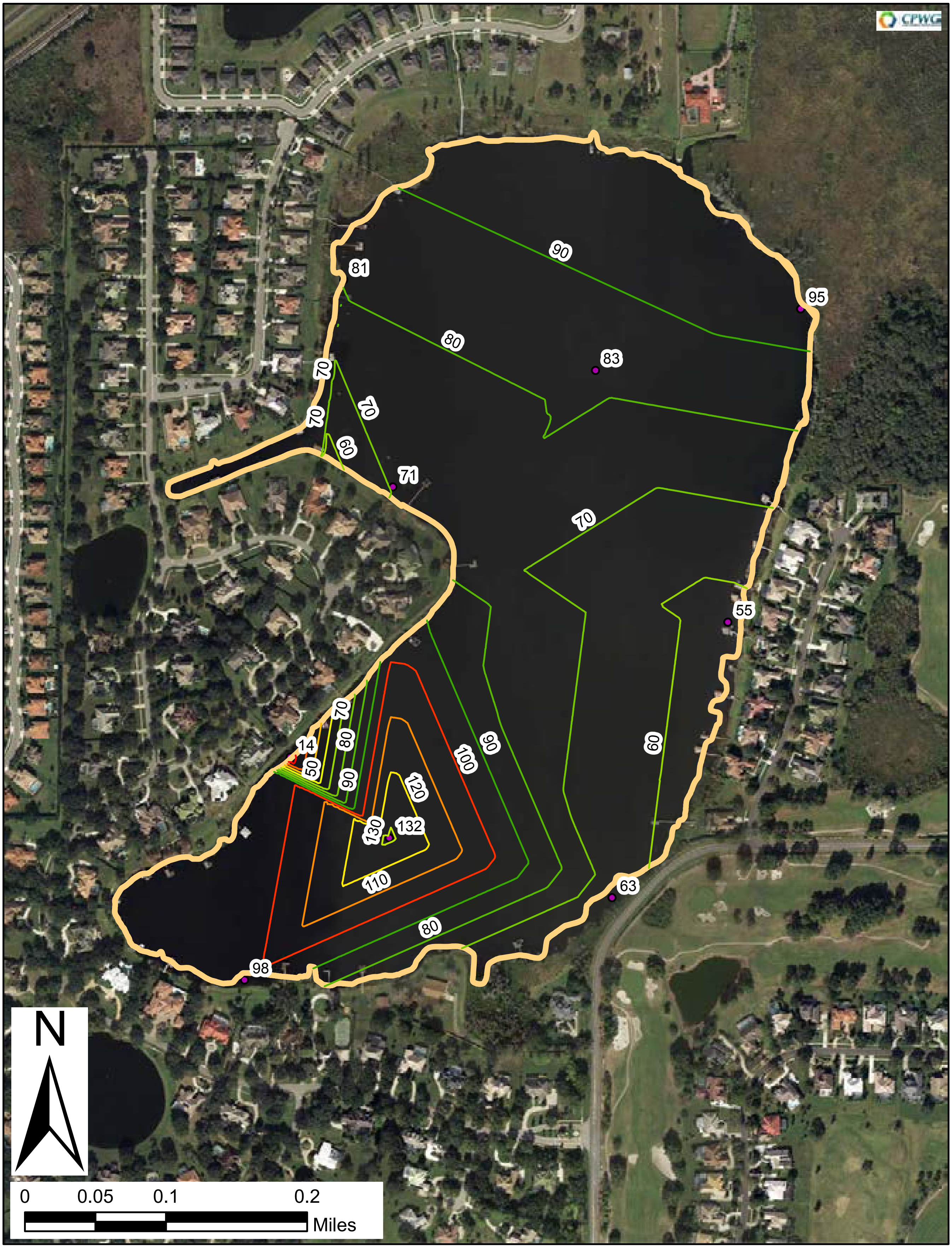
Table 5-9
Estimated Annual Mass Loading to Lake Roberts from Groundwater Seepage

Parameter	Units	Total Nitrogen	Total Phosphorus
Mean Daily Flux	mg/m^2-day	3.431	0.309
	g/day	1,499	134.8
Annual Loading	kg/yr	547	49
Areal Loading	kg/ac-yr	5.07	0.46



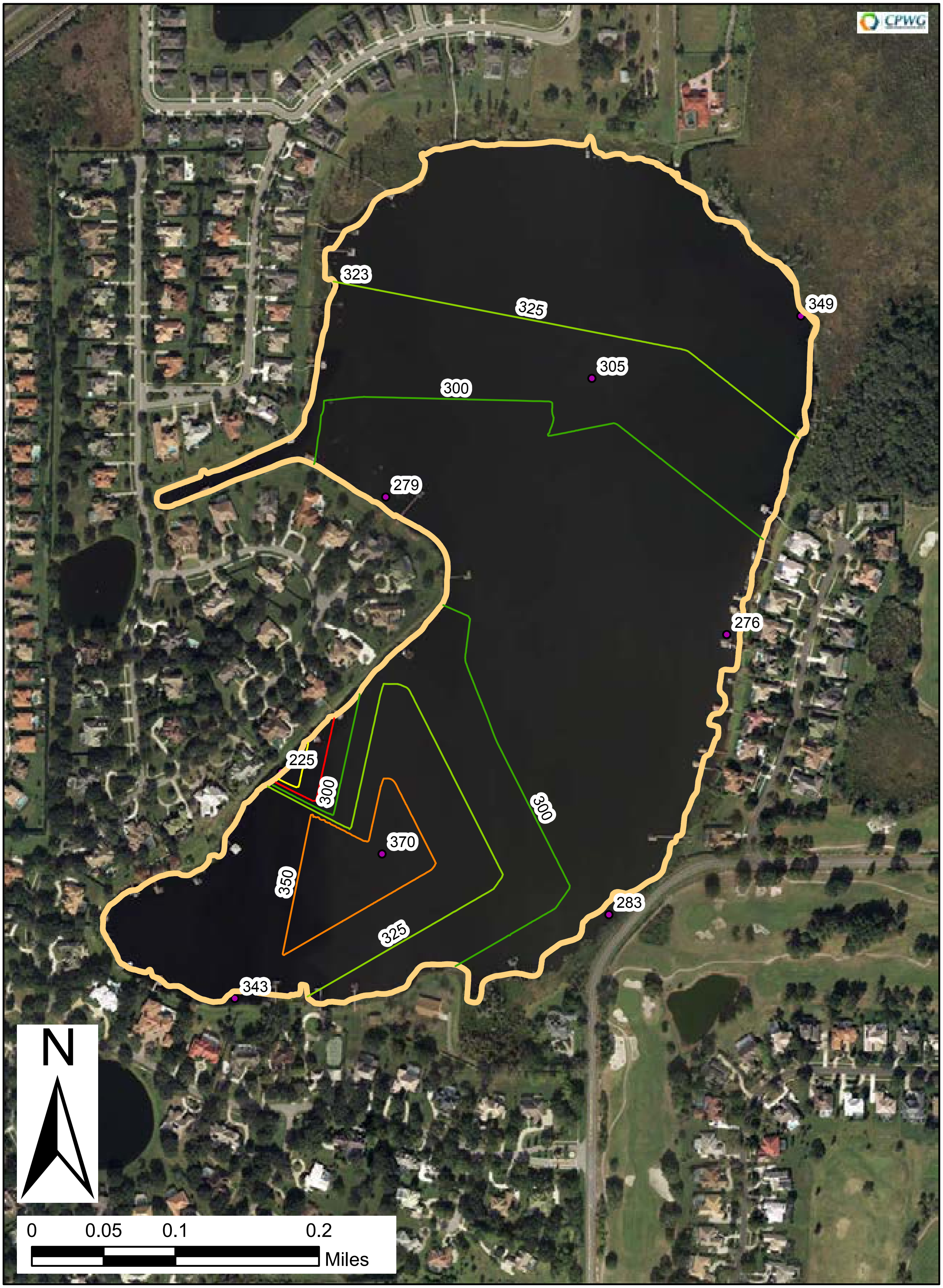
Isopleth of Mean pH (s.u.) Values in Groundwater Seepage Entering Lake Roberts

Figure 5-3



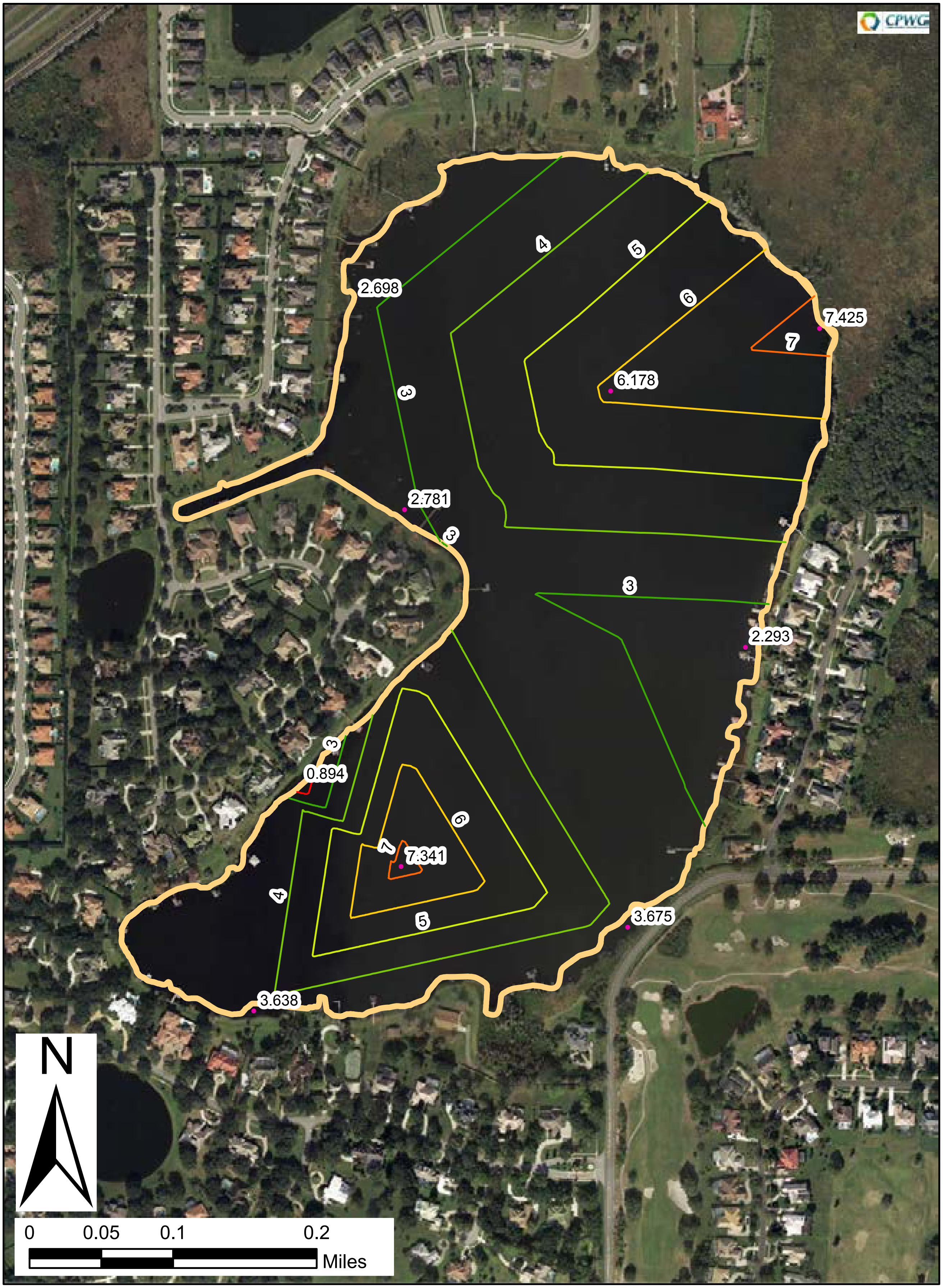
Isopleth of Mean Alkalinity (mg/l) Values in Groundwater Seepage Entering Lake Roberts

Figure 5-4



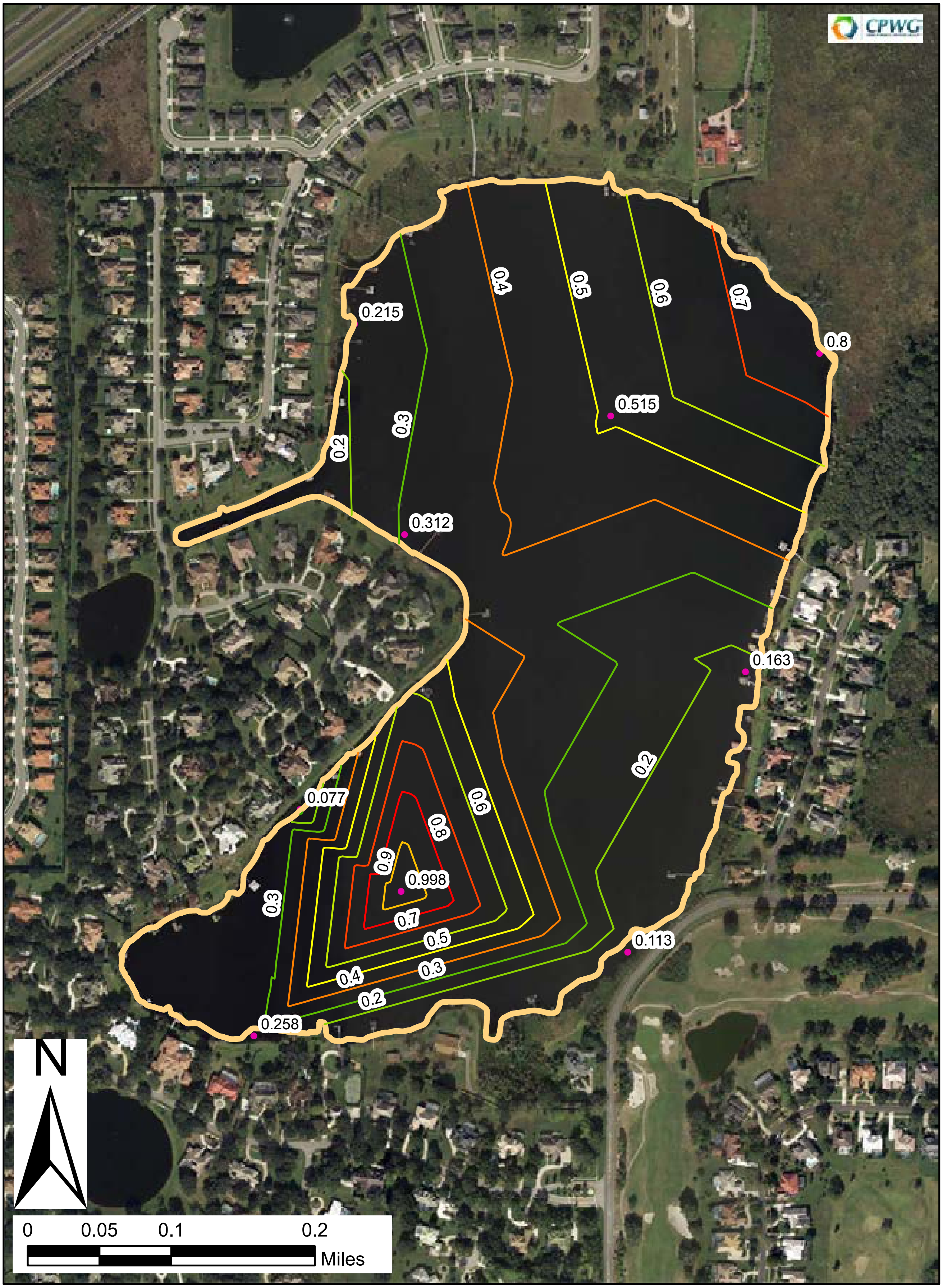
Isopleth of Mean Conductivity (µmho/cm) Values in Groundwater Seepage Entering Lake Roberts

Figure 5-5



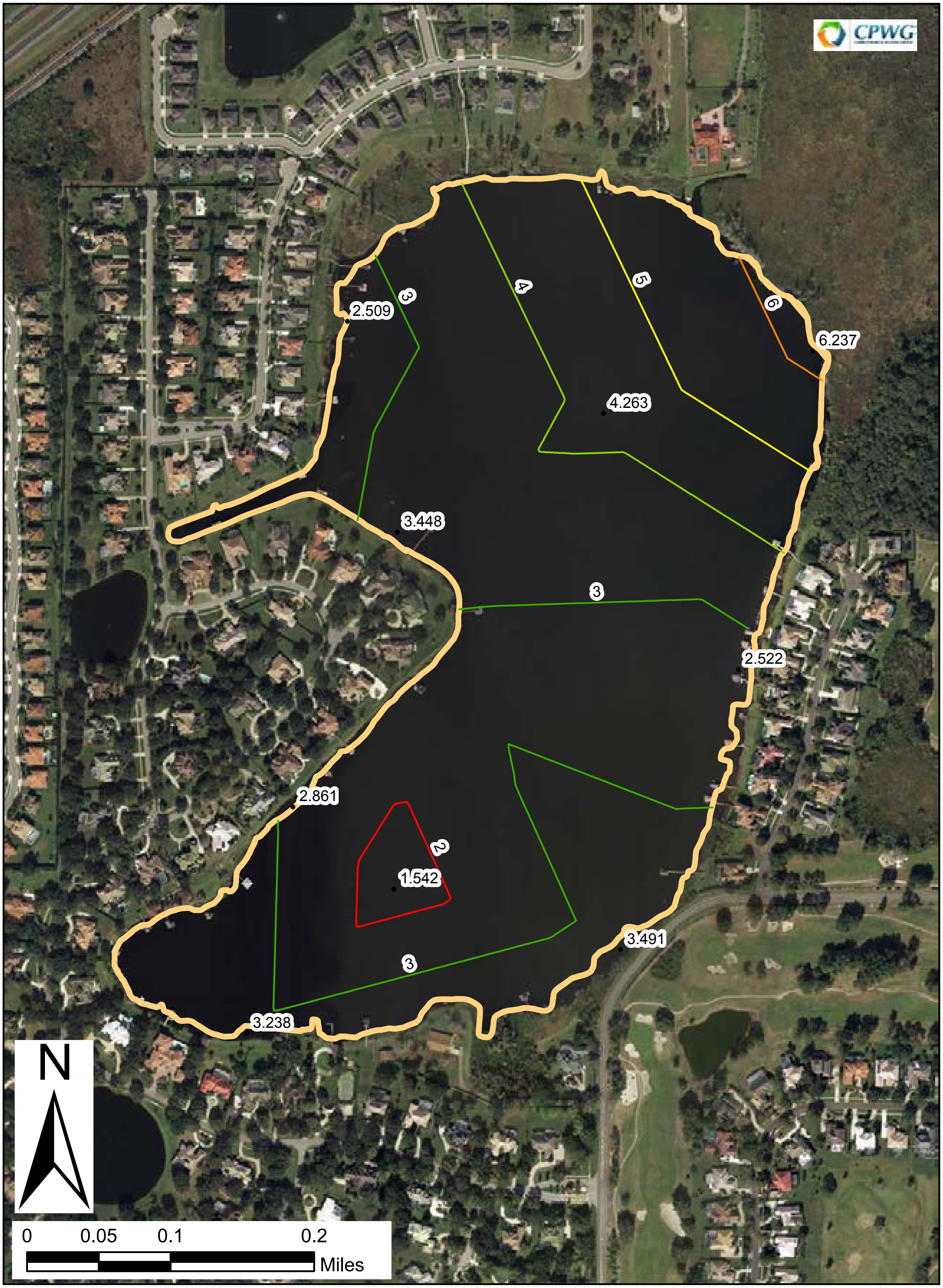
Isopleth of Mean Total Nitrogen (mg/l) Values in Groundwater Seepage Entering Lake Roberts

Figure 5-6



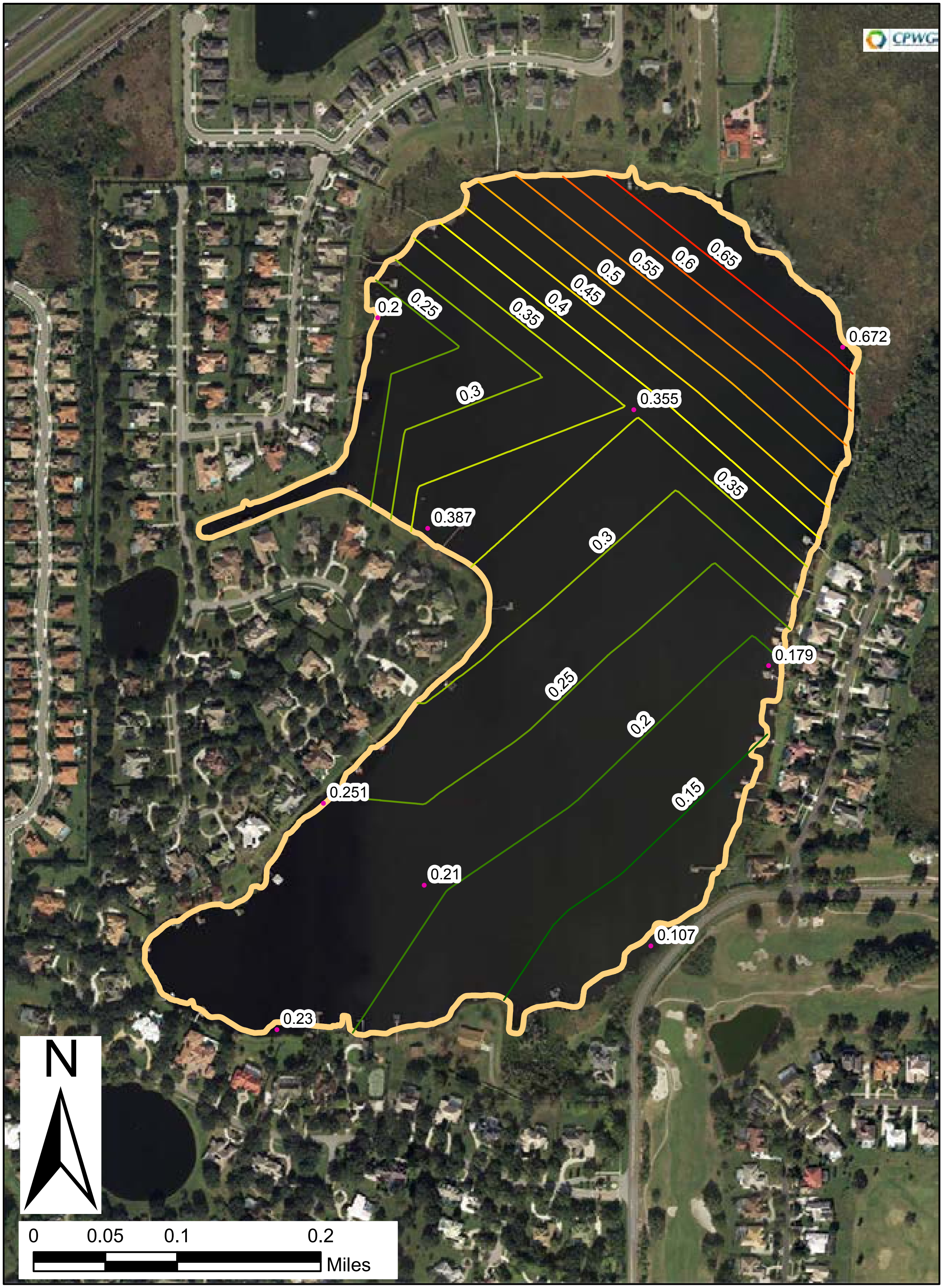
Isopleth of Mean Total Phosphorus (mg/l) Values in Groundwater Seepage Entering Lake Roberts

Figure 5-7



Isopleth of Total Nitrogen (mg/m^2-day) Influx from Groundwater Seepage to Lake Roberts

Figure 5-8



Isopleth of Total Phosphorus (mg/m^2-day) Influx from Groundwater Seepage to Lake Roberts

Figure 5-9

5.1.4 INTERNAL RECYCLING

Quantification of sediment phosphorus release as a result of internal recycling in lakes is difficult, and a variety of methods have been used by researchers to obtain this estimate. One method which has been used in reservoirs is called the Mass Balance Method. This method is best suited to a waterbody with well-defined inputs and outputs. A mass balance is then conducted on the waterbody over a one- to two-week period. An increase of phosphorus mass within the lake, after accounting for inputs and losses, would suggest that a net internal loading has occurred. However, this method appears inappropriate for use in Lake Roberts since the lake is impacted by a wide variety of hydrologic and pollutant sources.

A method which has been used extensively in deep northern lakes is to measure changes in phosphorus content in the hypolimnion of a stratified lake over an extended period of anoxia. The increase in phosphorus mass within the stratified hypolimnion can then be directly correlated with sediment release rates. However, this method also appears inappropriate for use in Lake Roberts since the lake is relatively shallow, and although a well-defined hypolimnion may develop, circulation events may be relatively common.

A third method of quantifying the internal loadings is through trophic state modeling. Using this approach, hydrologic and nutrient inputs are estimated from all quantifiable sources. A trophic state model is then developed to predict water column concentrations of total phosphorus. If the model underestimates phosphorus concentrations, then a missing phosphorus load may be present which can be attributed to internal recycling. However, this methodology can be highly inaccurate and is dependent upon the accuracy of the estimated loadings for other variables.

The final method used for quantification of internal loadings is to perform sediment nutrient release experiments. In this method, large diameter sediment cores are collected from various locations within the lake and incubated in the laboratory under a variety of conditions to simulate variability in the lake throughout the year. Changes in phosphorus concentrations are measured in the overlying sediments, and this information is extrapolated to an areal release rate within the lake. This is the only method of estimating internal loadings which provides a direct measurement of phosphorus release. This method was selected as the quantification method for Lake Roberts.

Field and laboratory investigations were performed to quantify the mass of phosphorus released as a result of internal recycling from the sediments to the overlying water column in Lake Roberts under both aerobic and anoxic conditions. Large diameter lake sediment core samples were collected at multiple locations in the lake and incubated under anoxic and aerobic conditions. Periodic measurements of phosphorus and other water quality parameters were used to estimate sediment phosphorus release under the evaluated conditions. This information is used to provide an estimate of the significance of mass loadings of phosphorus from lake sediments as part of the overall nutrient budget for the lake.

5.1.4.1 FIELD AND LABORATORY PROCEDURES

Sediment core samples were collected at two locations in Lake Roberts on March 15, 2014 using 4-inch diameter clear acrylic core tubes. Site 1-LC is located in the south lobe of the lake as Site 2-LC is located in the north lobe, as shown on Figure 5-10. The sediments at Site 1-LC consisted primarily of thick organic muck, while the sediments at Site 2-LC consisted primarily of fine sand with organics. Each of the acrylic tubes was driven into the sediments to the maximum possible depth using a large sledge hammer. A 4-inch x 4-inch wooden beam was placed on top of the acrylic core tube to evenly distribute the force of each sledge hammer blow and to prevent direct contact between the sledge hammer and the acrylic tube.

The acrylic tubes were penetrated into the sediments to depths ranging from approximately 2-6 ft, depending upon the physical characteristics of the sediments at each of the selected monitoring sites or until a firm bottom material was encountered. Each of the core tubes was retrieved intact, along with the overlying water column present at each of the collection sites. Upon retrieval, a rubber cap was attached to the bottom of each core tube to prevent loss of sediments. The collected water volume above the trapped sediments was carefully siphoned off until a water depth of 24 inches remained in each of the collected columns above the sediment-water interface. Each of the acrylic core tubes was then cut at a uniform height of 6 inches above the water level, leaving a 6-inch air space between the water level and the top of the column. A 4-inch PVC cap was then placed on the top of each collected core tube. Each of the collected core tubes was then returned to the laboratory for incubation experimentation. All samples were transported in a vertical position to avoid mixing of the sediment layers.

After return to the laboratory, each of the core samples was attached to a laboratory work bench in a vertical position. Two separate 0.25-inch diameter holes were then drilled into the PVC cap attached to the top of each core sample. A 0.25-inch diameter semi-rigid polyethylene tube was inserted through one of the holes to a depth of approximately 2-3 inches above the sediment surface. An air stone diffuser was attached to the end of the tubing inside each core tube to introduce selected gases into the core tubes to encourage aerobic or anoxic conditions.

A separate piece of polyethylene tubing was inserted into the second hole in the top of each core tube, approximately 1 inch below the level of the cap, but well above the water level contained in each tube. The other end of the tubing was connected to a water trap to minimize loss of water from each column as a result of evaporation. This tubing also provided a point of exit for gases which were bubbled into each core tube. A schematic of the sediment incubation apparatus is given in Figure 5-11.

After initial set-up of the incubation apparatus, a compressed stream of helium gas was introduced into each of the core tubes through the individual air stone diffusers. This process quickly created anoxic conditions within each of the core tubes. After anoxic conditions were established, as verified by an H_2S smell in the outflow from the water trap, the helium gas addition was reduced to 1-2 hours per day, generally in association with a sampling event to ensure completely mixed conditions within the tube. This process was continued in each of the core tubes for a period of 25 days. The gas addition was used to ensure that water within each of the core tubes was well mixed without disturbing the sediments, so that phosphorus released from the sediments could be quantified as a function of changes in phosphorus concentrations within the water column of each core tube. On approximately a 1-2 day interval, 20 ml of water was withdrawn from each of the columns using a 0.25-inch polyethylene tube and a plastic laboratory syringe. Each of the collected samples was immediately filtered using a 0.45 micron syringe type membrane filter and analyzed for orthophosphorus, total phosphorus, total nitrogen, and other significant laboratory parameters for research purposes.

At the conclusion of the experimentation under anoxic conditions, the compressed helium source was replaced with a compressed air source. Compressed air was gently bubbled through each of the columns to increase dissolved oxygen and create aerobic conditions within each tube. In general, creation of aerobic conditions, as indicated by measurements of redox potential (> 200 mv) within each of the columns, occurred after approximately 5-7 days. At the onset of aerobic conditions, sample collection was conducted at a 1-2 day interval from each of the 2 columns for a period of 22 days using the method previously outlined for anoxic conditions.

Sites for the Large Diameter Sediment Cores Used in Incubation Experiments

Figure 5-10

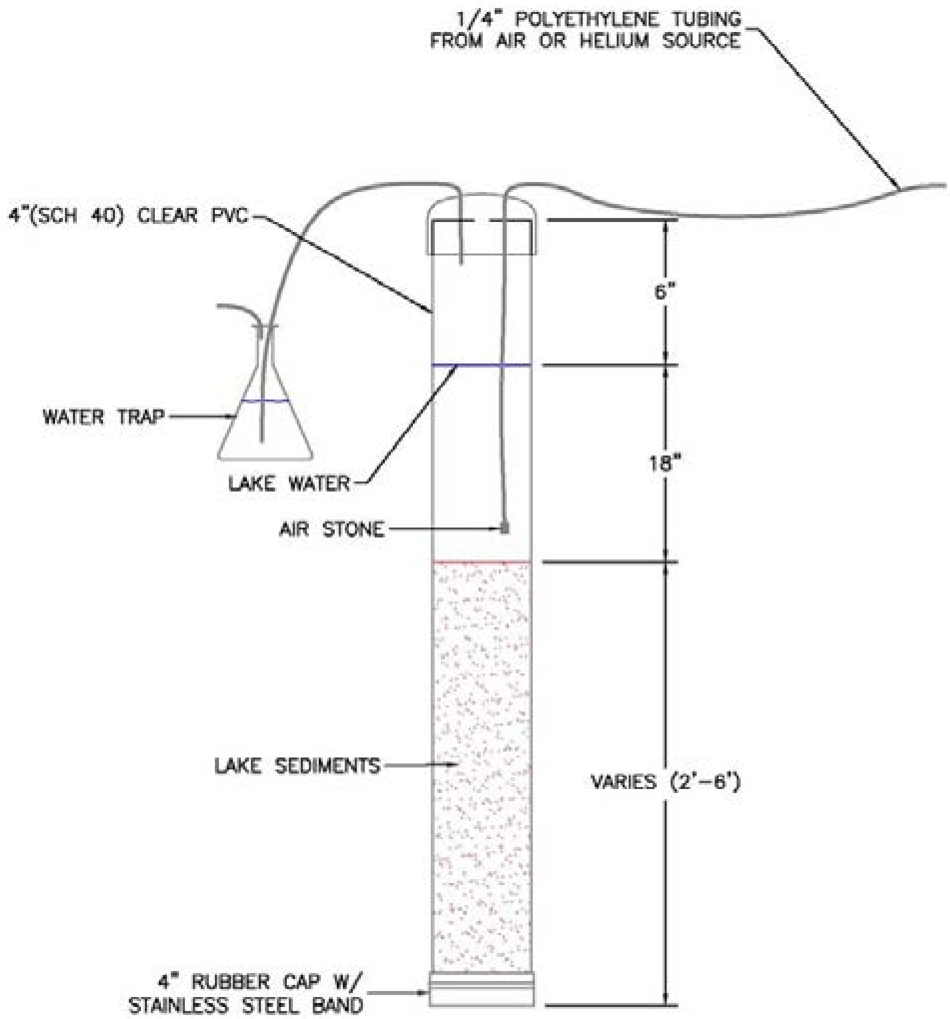


Figure 5-11. Schematic of Sediment Incubation Apparatus.

5.1.4.2 RESULTS OF LABORATORY TESTING

A graphical comparison of phosphorus release from the isolation chamber experiments under aerobic and anoxic conditions is given in Appendix 5-3. Changes in phosphorus concentrations over time are provided for each of the two isolation chamber experiments under both aerobic and anoxic conditions. Concentrations of both SRP and total phosphorus increased steadily during the first 10-14 days of the isolation chamber experiments under both aerobic and anoxic conditions, followed by a general decline in concentrations after this time. Release of SRP was about 7 times higher under anoxic conditions than aerobic conditions, while release of total phosphorus was approximately 5 times higher under anoxic compared with aerobic conditions.

5.1.4.3 MASS RELEASE

The results of the phosphorus release experiments discussed in the previous section were extrapolated to estimate sediment phosphorus release from Lake Roberts on an annual basis. The first step in this extrapolation process is to develop estimates of sediment release rates within each of the incubation chambers. The phosphorus release rate in the incubation experiments is defined as the slope of the rising limb of the SRP and total phosphorus release plots presented in Appendix 5-3. In some chambers, an initial delay in phosphorus release occurred as anoxic or aerobic conditions were established within each chamber. In these cases, the release rate is calculated using the data obtained between the start of the upward release trend and the maximum phosphorus concentrations measured within a sample. In some experiments, phosphorus concentrations began to decrease after reaching the maximum concentration, presumably due to biological uptake within the chamber. Regression relationships developed for estimation of sediment phosphorus release rates in the incubation experiments under aerobic and anoxic conditions are also included in Appendix 5-3.

Estimates of the areal extent and frequency of aerobic and anoxic conditions within the sediments of Lake Roberts were obtained from the vertical field profiles conducted in the lake from September 2013 to August 2014. These profiles (summarized in Figures 2-25 through 2-28) provide seasonal patterns of dissolved oxygen concentrations in the three significant lobes of the lake. The percentage of events indicating anoxic conditions at the water-sediment interface were calculated for each of the three monitoring sites and used to estimate the seasonal distribution of aerobic and anoxic conditions throughout the lake.

A summary of calculated sediment phosphorus release rates during the isolation chamber experiments is given in Table 5-10. Phosphorus release rates are provided for each of the two isolation chamber core samples under both aerobic and anoxic conditions, with individual release rates provided for both SRP and total phosphorus. The phosphorus release rates reflect the slope of the SRP and total phosphorus release rate plots provided in Appendix 5-3. The calculated phosphorus release rates are converted into a mass release per day by multiplying the surface area of the 4-inch diameter incubation chamber. This mass release is then converted into an areal mass release in terms of mg/m^2-day. Under aerobic conditions, the mean mass release rate for SRP was 1.01 mg/m^2-day, with a mean release rate for total phosphorus of 1.13 mg/m^2-day. Under anoxic conditions, the mass release rates increase, with a mean release rate of 1.30 mg/m^2-day for SRP and a mean release rate of 1.49 mg/m^2-day for total phosphorus.

Table 5-10
Calculated Sediment Phosphorus Release Rates During the Isolation Chamber Experiments

Condition	Site	Phosphorus (µg/l-day)		Water Volume (liters)	Mass Release (µg/day)		Mass Release (mg/m2-day)	
		SRP	Total P		SRP	Total P	SRP	Total P
Aerobic	1-LC	1.83	1.12	4.44	8.13	4.97	1.00	0.61
	2-LC	1.86	3.02	4.44	8.26	13.41	1.02	1.65
	Mean	**1.85**	**2.07**		**8.19**	**9.19**	**1.01**	**1.13**
Anoxic	1-LC	1.38	1.77	4.44	6.13	7.86	0.76	0.97
	2-LC	3.38	3.68	4.44	15.01	16.34	1.85	2.02
	Mean	**2.38**	**2.73**		**10.57**	**12.10**	**1.30**	**1.49**

A summary of calculated annual sediment phosphorus release rates in Lake Roberts is given in Table 5-11. The release is calculated using the mass release rates summarized on Table 5-10 for each of the two isolation chamber sites which is weighted by the fraction of aerobic and anoxic conditions assumed to occur within the lake, based upon the vertical field profiles summarized in Section 2. Lake Roberts exhibited anoxic conditions at the water-sediment interface during approximately 50% of the year with 50% of the year characterized by aerobic conditions. The measured aerobic and anoxic release rates are weighted by the estimated frequency of occurrence of aerobic and anoxic conditions to calculate estimates of mean annual phosphorus release for SRP and total phosphorus within each lobe (see Table 5-11). An aerial average weighing the acres of the lobes (south lobe 48-acres and north lobe 60 acres) was performed. Overall, the mean SRP release within Lake Roberts is estimated to be approximately 1.19 mg/m^2-day, with a total phosphorus release of 1.37 mg/m^2-day.

Table 5-11
Calculated Annual Sediment Phosphorus Release in Lake Roberts

Area	Frequency of Condition (%)		Weighted Phosphorus Release (mg/m2-day)	
	Aerobic	Anoxic	SRP	TP
Site 1-LC (south lobe)	50	50	0.88	0.79
Site 2-LC (north lobe)	50	50	1.43	1.83
Areal Average			**1.19**	**1.37**
Annual Load (kg/yr)			189	219
Assumed Load (kg/yr) (average of SRP and TP)			204	

Estimates of annual phosphorus loadings to Lake Roberts as a result of sediment phosphorus release are provided in Table 5-11. When extended over the entire lake surface (108 acres), the weighted SRP phosphorus release rate equates to an annual phosphorus loading of approximately 189 kg/yr, with an annual total phosphorus loading of 219 kg/yr. The estimated SRP release of 189 kg/yr in Lake Roberts probably underestimates the actual sediment release since a portion of the released SRP is likely utilized by biological activity within the isolation chamber. In contrast, the estimated annual total phosphorus release probably over-estimates phosphorus release in Lake Roberts since the measured total phosphorus will also include biological growth which occurred within the isolation chamber as a result of uptake of SRP. Even though biological growth occurred, algae were not visible in the chamber. In reality, the actual sediment phosphorus release in Lake Roberts probably lies somewhere between the annual load values for SRP and total phosphorus.

The core samples were collected in March 2014. However, the time of year the sample is collected does not affect the results. Alum or other similar treatment can be applied anytime throughout the year in Florida. There is no optimal season for application. The dosing should be performed in multiple rounds to assist in phosphorus inactivation to stay within the buffering capacity of the lake.

Research by Nurnberg (1998) has indicated that SRP comprises approximately 80% of the total phosphorus released from lake sediments, with the remaining fraction comprised primarily of organic phosphorus. As comparison, if this fraction were to be applied to SRP release in Lake Roberts, the resulting phosphorus release is calculated to be 236.25 kg/yr. This is higher than the actual TP release. Therefore, for this analysis an average of the SRP and TP release rates is used, yielding a phosphorus release from sediments of approximately 204 kg/yr.

5.2 NUTRIENT LOSSES

Nutrient losses from Lake Roberts occur primarily as a result of discharges through the outfall structure. Pollutant mass which is not discharged through the outfall structure is assumed to accumulate into the sediments of the lake. Estimates of the magnitude of losses through the outfall structure are given in the following sections.

5.2.1 OUTFALL STRUCTURE DISCHARGES

5.2.1.1 CHEMICAL CHARACTERISTICS OF OUTFALL DISCHARGES

Chemical characteristics of discharges from Lake Roberts through the outfall structure are assumed to be similar to historical water quality characteristics in Lake Roberts. A summary of water quality characteristics of Lake Roberts from 2013 to 2014 was given in Table 2-11. The characteristics of discharges through the outfall structure were assumed to be the average concentrations at the surface of the north lobe sample location, S-1. A summary of assumed mean water quality characteristics of Lake Roberts based upon this analysis is given in Table 5-12.

TABLE 5-12
Mean Water Column Characteristics of Lake Roberts

Parameter	Units	Mean Value
Total N	µg/l	1,006
Total P	µg/l	51
TSS	mg/l	4.58

5.2.1.2 MASS LOADING

Calculated mass losses through the outfall structure for Lake Roberts are summarized in Table 5-13. These values were obtained by multiplying the mean water column characteristics (summarized in Table 5-12) times a mean annual volumetric discharge through the outfall structure of 579 ac-ft/yr (summarized in Figure 4-5). The nutrients removed from Lake Roberts on an average annual basis, through the outfall structure are summarized in Table 5-13

TABLE 5-13
Calculated Mean Annual Mass Losses From Lake Roberts Through the Outfall Structure

Discharge Volume (ac-ft.)	Mass Loss (kg)		
	Total N	Total P	TSS
579	718	36.4	3,271

5.3 MEAN ANNUAL MASS BUDGETS

Estimated mean annual mass budgets were developed for total nitrogen, total phosphorus, and TSS entering Lake Roberts based upon the analyses presented in the previous sections. A discussion of estimated mass inputs and losses to Lake Roberts is given in the following sections.

5.3.1 MASS INPUTS

A summary of estimated mean annual mass loadings of total nitrogen, total phosphorus, and TSS entering Lake Roberts is given in Table 5-14. The estimated mass loadings summarized in this table are based upon the assumptions and analyses presented in previous sections. Stormwater runoff appears to be the largest contributor of nitrogen loadings to Lake Roberts on an annual basis, contributing approximately 55% of the calculated annual loadings. Of this 55%, 28% flows overland directly into Lake Roberts, while 27% flows through the wetland tussock from Lake Reaves. Approximately 26% of the annual nitrogen loadings are contributed by groundwater seepage. This 26% groundwater input can be subdivided further into 21% from septic tanks and 5% from background groundwater flow. Bulk precipitation contributes 19% of the TN.

The largest contributor of phosphorus loadings to Lake Roberts appears to be stormwater runoff (38%), followed by internal recycling (35%), groundwater seepage (16%), and bulk precipitation (11%). The stormwater runoff can be further divided into 23% from the land flowing directly into Lake Roberts and 14% flowing through the wetland tussock from Lake Reaves. The 16% groundwater contribution can be categorized as 5% from septic tanks and 11% from background groundwater flow.

Stormwater runoff appears to be the largest contributor of TSS loadings to Lake Roberts, contributing nearly 100% of the annual loadings. Overall, Lake Roberts receives approximately 2,093 kg/yr of total nitrogen, 299 kg/yr of total phosphorus, and 12,994 kg/yr of TSS.

TABLE 5-14
Estimated Mean Annual Mass Loadings of Total Nitrogen, Phosphorus and TSS to Lake Roberts

Source	Total N (kg)	Total P (kg)	TSS (kg)	Total N	Total P	TSS
Bulk Precipitation	407.0	32.0	9	19%	8%	0%
Stormwater Runoff - Lake Roberts	579.0	69.0	7,418	28%	17%	57%
Stormwater Runoff - Tussock	560.0	42.0	5,567	27%	11%	43%
Groundwater Seepage (Non-Septic)	100.0	33.6	-	5%	8%	-
Groundwater Seepage (Septic Tank)	447.0	15.4	-	21%	4%	-
Internal Recycling	-	204.0	-	-	52%	-
Total	**2,093**	**396**	**12,994**	**100%**	**100%**	**100%**

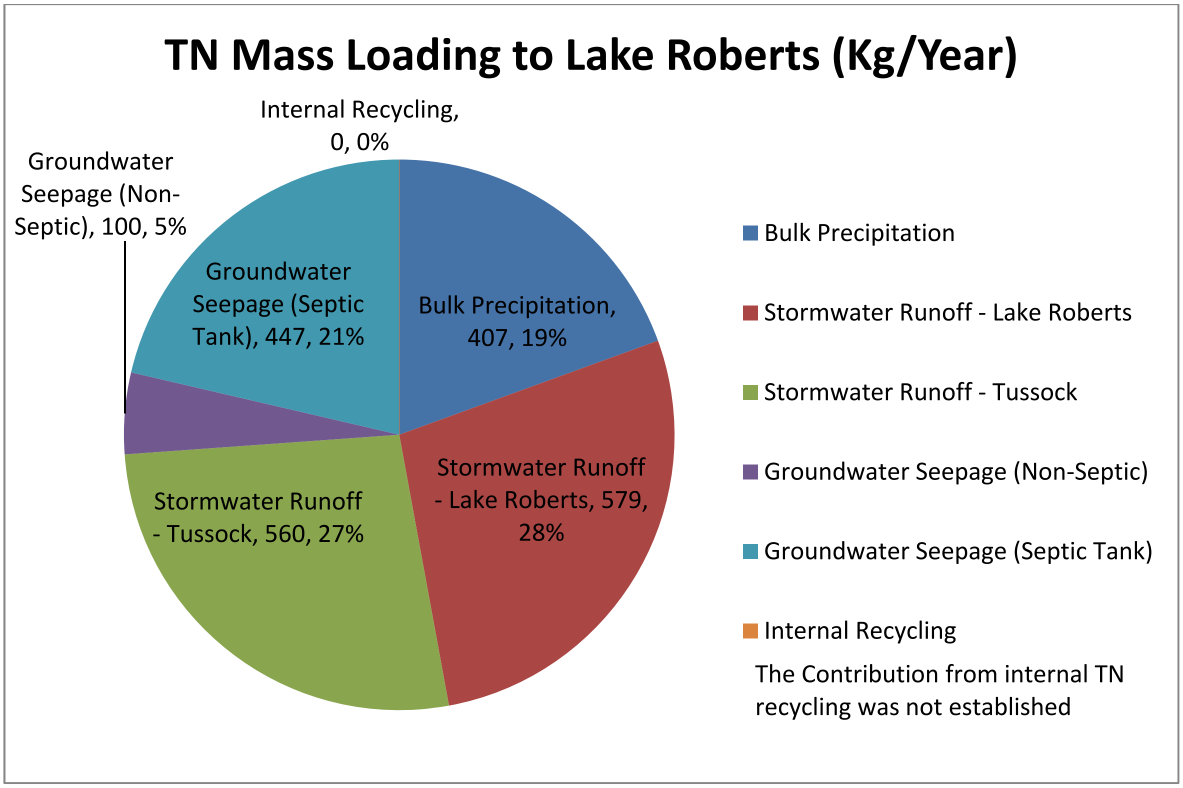
Data not available

5.3.2 MASS LOSSES

A summary of estimated annual mass losses of total nitrogen, total phosphorus, and TSS from Lake Roberts is given in Table 5-15. The vast majority of nutrient inputs into Lake Roberts are retained within the sediments of the lake, with approximately 66% of the total annual nitrogen loading, 88% of the total phosphorus loading, and 74% of the TSS loading retained within the sediments of the lake. The retained in sediment value is the difference between all the input and the calculated outfalls. It is the component that allows the mass balance of the inputs and outputs. The remaining mass loadings discharge through the outfall structure. Graphical comparisons of inputs and losses of total nitrogen, total phosphorus, and TSS in Lake Roberts are given in Figures 5-12, 5-13, and 5-14, respectively.

TABLE 5-15
Estimated Mean Annual Mass Losses from Lake Roberts

Source	Mass Loading (kg/yr)			Percent of Total (%)		
	Total N	Total P	TSS	Total N	Total P	TSS
Outfall Discharge	718	36.4	3,271	34	9	25
Retained in Sediments	1,375	359.6	9,723	66	91	75
Total:	**2,093**	**396**	**12,994**	**100**	**100**	**100**



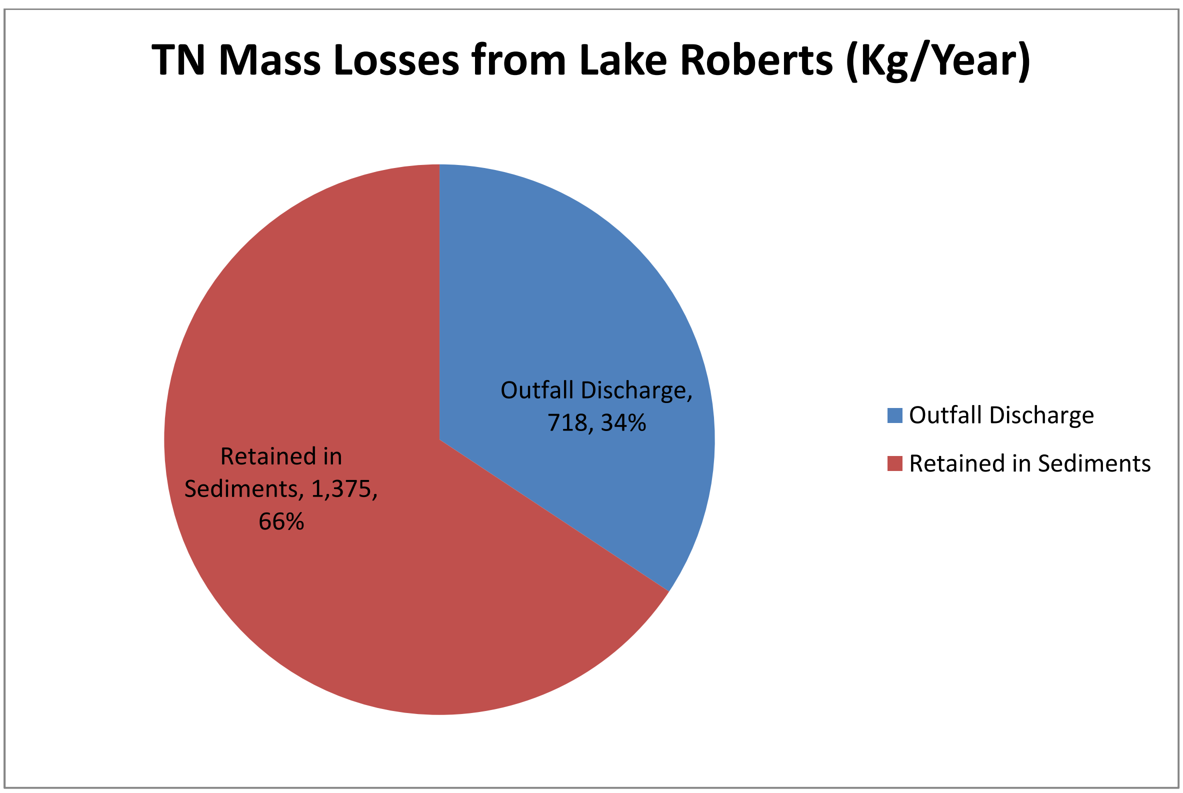
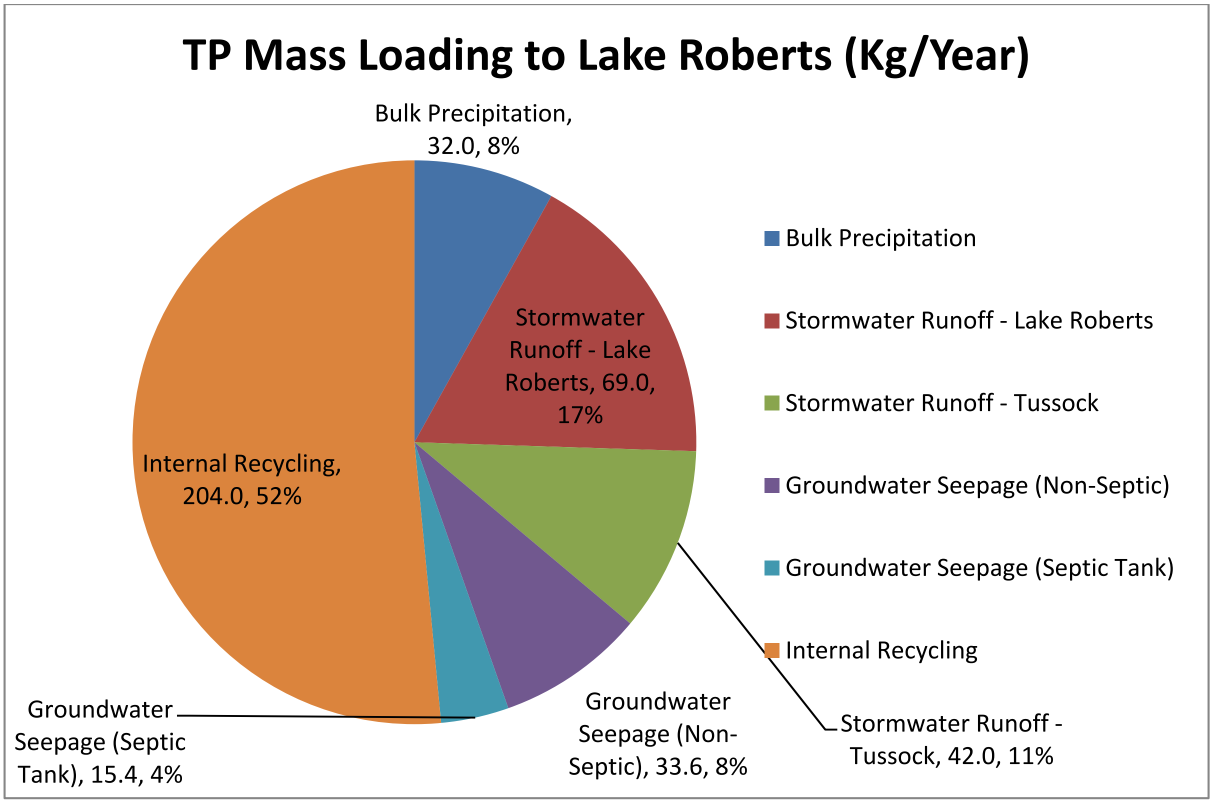


Figure 5-12: Summary of Mean Annual Mass Inputs and Losses of Total Nitrogen for Lake Roberts



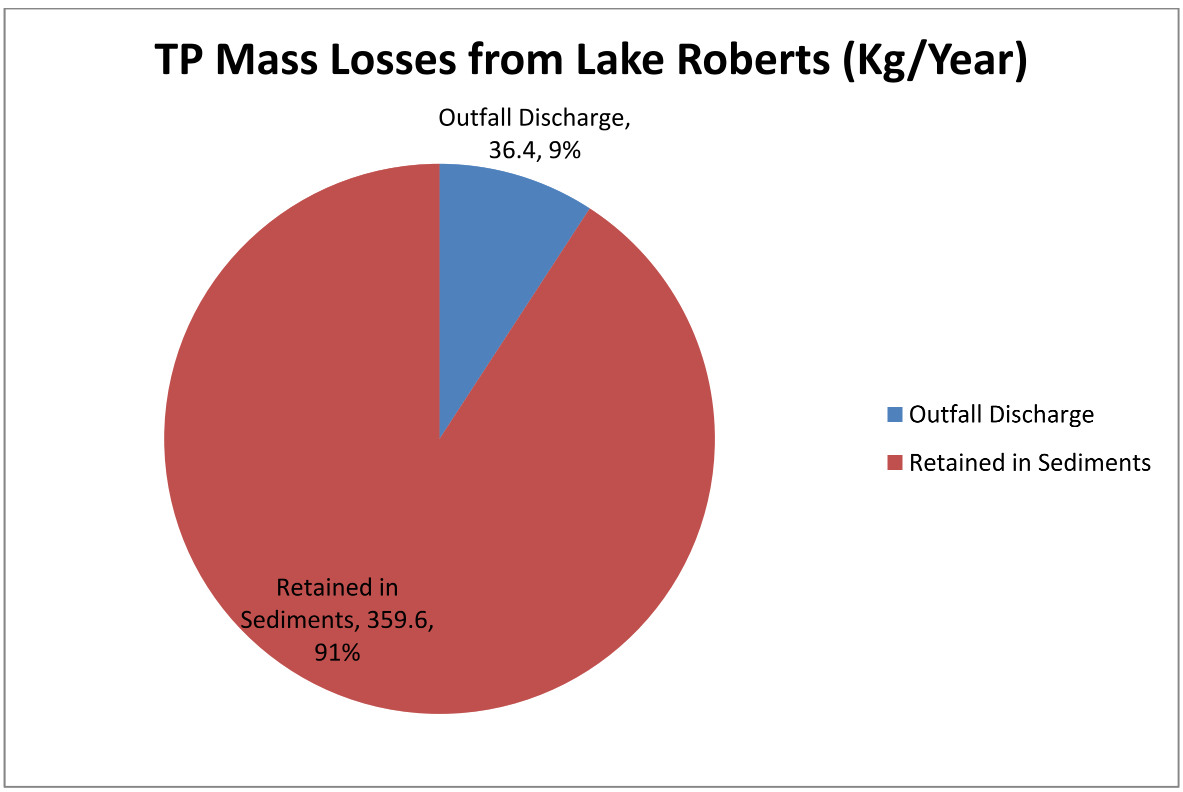
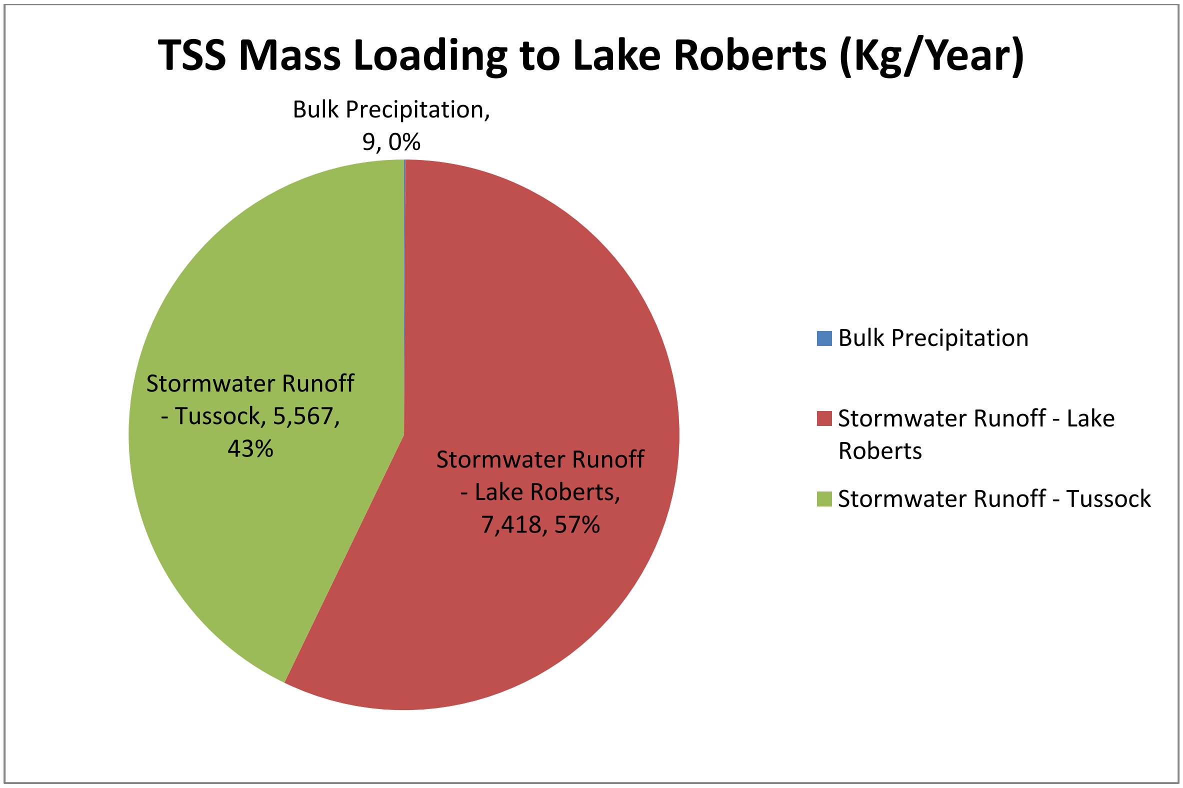


Figure 5-13: Summary of Mean Annual Mass Inputs and Losses of Total Phosphorus for Lake Roberts



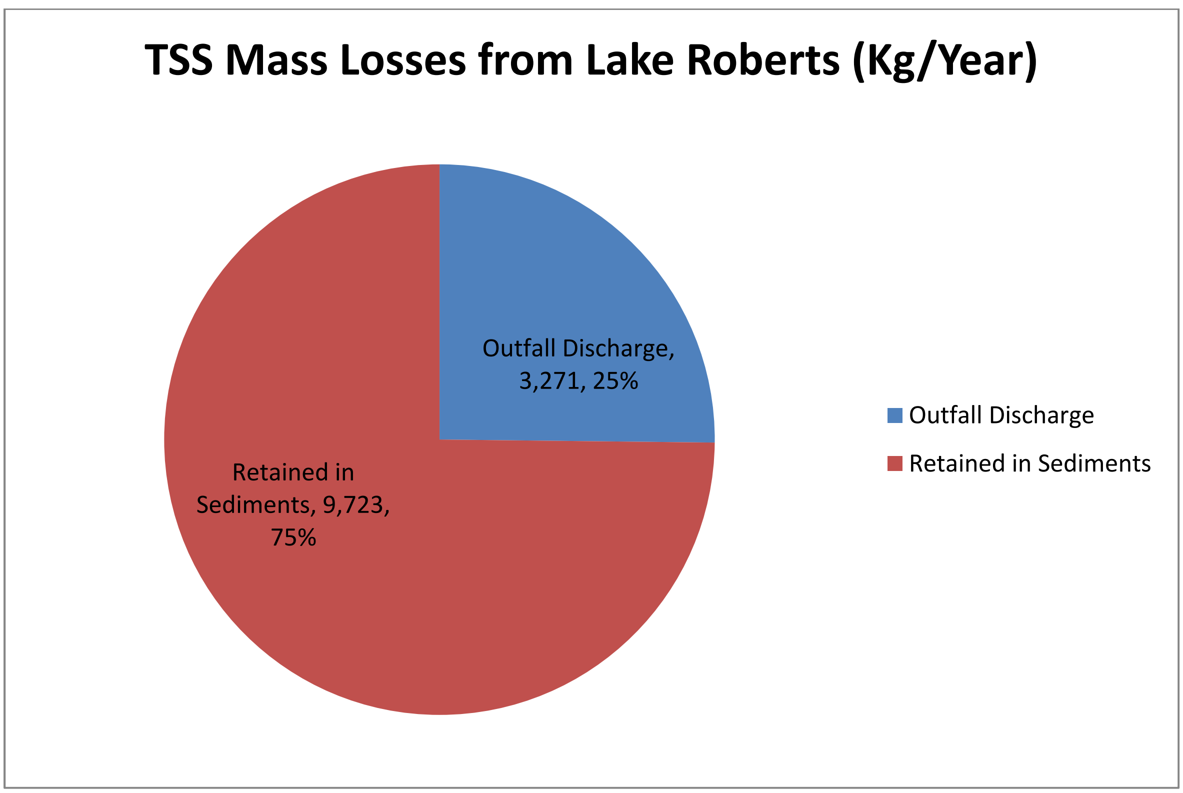


Figure 5-14: Summary of Mean Annual Mass Inputs and Losses of TSS for Lake Roberts

6.0 EVALUATION OF WATER QUALITY IMPROVEMENT OPTIONS

A discussion of water quality maintenance and improvement options for Lake Roberts is presented in this section. The evaluated water quality improvement options are designed to target sources which have been identified as significant contributors of nutrient loadings to the lake. The evaluated options include both structural and non-structural approaches to controlling and reducing pollutant inputs into Lake Roberts. A discussion of general management philosophy and recommended water quality improvement projects is given in the following sections.

6.1 MANAGEMENT PHILOSOPHY

Based upon the extensive evaluation of historical and current water quality characteristics in Lake Roberts presented in Section 2, it appears that Lake Roberts is primarily an eutrophic waterbody which is experiencing constant to declining water quality characteristics, combined with an increased frequency of visible algal blooms. It appears that declining water quality characteristics can be contributed to historical citrus activity (1950s' to 1980's), existing residential septic systems (1980's to current), and contributions from the wetland tussock. Over time, the natural ability of the lake to assimilate these nutrient loadings has diminished, resulting in a gradual degradation in water quality and the overall health of the aquatic system. Sediment accumulations in the lake have increased over time, and studies conducted as part of this project indicate that the accumulated sediments are now releasing nutrients into the overlying water column, further stimulating the growth of algae and aquatic plants.

As discussed in Section 2, Lake Roberts is a co-limited (phosphorus and nitrogen) ecosystem. This implies that all elements necessary for stimulation for algal productivity (such as carbon, magnesium, calcium, silica, sodium, potassium, and sulfur) are abundant within the water column of the lake with the exception of phosphorus and nitrogen. As phosphorus and nitrogen are added to the water column of the lake, the growth of algae responds directly to the amount of phosphorus and nitrogen added since all other elements necessary for growth are already present in abundance of the needs of the algae. As a result, the primary objective of the management options discussed in this section is to control and limit the introduction of phosphorus and nitrogen into Lake Roberts.

Phosphorus and nitrogen inputs into Lake Roberts occur through a wide variety of sources, including bulk precipitation, stormwater runoff, overland flow, groundwater seepage, and internal recycling. For many lakes located in urbanized environments, stormwater runoff represents the single largest contributor of pollutant inputs on an annual basis. However, this is not true for

Lake Roberts. Stormwater runoff contributes 28% of the TP loading. While internal recycling contributes 52% of the TP loading, nearly the twice as much as stormwater runoff. Given the wide variety of phosphorus sources impacting Lake Roberts, it creates a challenge for management efforts since a number of sources must be addressed to maintain and improve water quality.

As discussed in Sections 4 and 5, Lake Roberts also receives inflow from Lake Reaves via a wetland tussock flowway. The loadings from Lake Reaves flowing through the wetland tussock represent 11% of the total loadings entering Lake Roberts on an annual basis. This value is higher than expected because of the tea bag effect that appears to occur within the wetland tussock. When the lower concentration stormwater from Lake Reaves flows through the wetland tussock the concentration increases. The process is similar to a tea bag in clean water, that steeps and releases its favor, in this case pollutants, into the surrounding cleaner water. Treatment options are discussed in a subsequent section to address reduction of nutrient inflow to Lake Roberts.

6.2 SEDIMENT INACTIVIATION

6.2.1 GENERAL CONSIDERATIONS

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 precipitate, rendering the sediment phosphorus unavailable for release into the overlying water column. Salts of aluminum calcium and iron have been used for sediment inactivation in previous projects, aluminum salts are the clear compounds of choice for this application. Inactivation of sediment phosphorus using aluminum is a relatively inexpensive option for reducing sediment phosphorus release since removal of the existing sediments is not required.

Sediment phosphorus inactivation is most often performed using aluminum sulfate (an acidic aluminum salt commonly called alum) or sodium aluminate (an alkaline aluminum salt), which are applied at the surface in a liquid form using a boat or barge. The aluminum 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 a precipitate which remains stable under conceivable conditions of pH or redox potential which could occur in a natural lake system. These sediment treatments have been shown to be effective from between 2 and 20 years, depending upon the sediment accumulation rate within the lake from the remaining phosphorus sources. The contributions from Lake Reaves via the wetland tussock may cause the treatments to be effective for 10 years or less.

A tabular summary of the chemical and physical characteristics of alum and sodium aluminate, both of which are commonly used in lake sediment inactivation projects, is given in Table 6-1. Aluminum sulfate, commonly called alum, is the most widely used chemical for sediment inactivation, and has a density of approximately 11.12 lbs/gallon and contains 4.4% aluminum by weight. Sodium aluminate, which is often used as a pH buffer in alum treatments, has a density of 12.3 lbs/gallon and an aluminum content of 10.6% by weight, although this percentage varies slightly depending on the manufacturer.

Table 6-1
Characteristics of Common Treatment Chemicals

Chemical / Parameter		Units	Value
Alum	Density	lbs/gallon	11.12
	Aluminum Content	% Aluminum	4.4
Sodium Aluminate	Density	lbs/gallon	12.3
	Aluminum Content	% Aluminum	10.6

Based on the nutrient budget for Lake Roberts, internal recycling contributes approximately 52% of the phosphorus loading to the lake, with an additional 12% contributed by groundwater seepage. Phosphorus loadings from internal recycling and groundwater seepage can be controlled simultaneously through a carefully planned alum application. Therefore, the goal of the proposed sediment inactivation alum treatment for Lake Roberts is to provide simultaneous control for both internal recycling and groundwater seepage. Together, these sources contribute approximately 64% of the total phosphorus loading to the lake. Control of these inputs has the potential to result in substantial improvements in water quality within Lake Roberts.

6.2.2 CHEMICAL REQUIREMENTS

Sediment inactivation in Lake Roberts would involve the addition of liquid aluminum-based coagulants at the water surface. Upon entering the water, the coagulants form insoluble precipitates which settle onto the lake bottom while also clarifying the existing water column within the lake. The precipitate will combine with existing phosphorus within the sediments, primarily saloid- and iron-bound complexes, forming insoluble precipitates which will chemically bind with the phosphorus, making it unavailable for release into the overlying water column. 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 aluminum to bind the saloid- and iron-bound phosphorus complexes in the top 10 cm of the sediments.

Estimates of the mass of total available phosphorus within the top 0-10 cm layer of the sediments in Lake Roberts were generated by graphically integrating the total available phosphorus isopleths presented on Figure 6-1, generated from the phosphorus speciation conducted on the collected sediment samples. Available phosphorus concentrations in Lake Roberts sediments are generally low in value, although this does not necessarily correlate with a low phosphorus release rate. 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.

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 ions. Previous sediment inactivation projects have been conducted at molar Al:P ratios of 2, 3, 5, and 10, with recent sediment inactivation projects performed using a 10:1 ratio. However, higher Al:P ratios may be needed at lower available phosphorus concentrations to create the driving force necessary to cause binding between phosphorus and aluminum. Therefore, a slightly higher Al:P ratio of 15:1 is assumed for inactivation of sediment phosphorus in Lake Roberts.

A summary of estimated total available phosphorus in the sediments of Lake Roberts is given in Table 6-2. On a mass basis, the sediments of Lake Roberts contain approximately 1,464 kg of available phosphorus in the top 10 cm which equates to approximately 47,226 moles of available phosphorus to be inactivated as part of the sediment inactivation process. A summary of alum requirements for sediment inactivation is also provided in Table 6-2. Using an Al:P ratio of 15:1, sediment inactivation in Lake Roberts would require 708,385 moles of aluminum or approximately 86,258 gallons of alum, equivalent to approximately 20 tanker loads containing 4,500 gallons each, assuming that alum could be used as the sole inactivant without concern for pH depression. The equivalent aerial aluminum dose for this application would be 42.1 g Al/m^2.

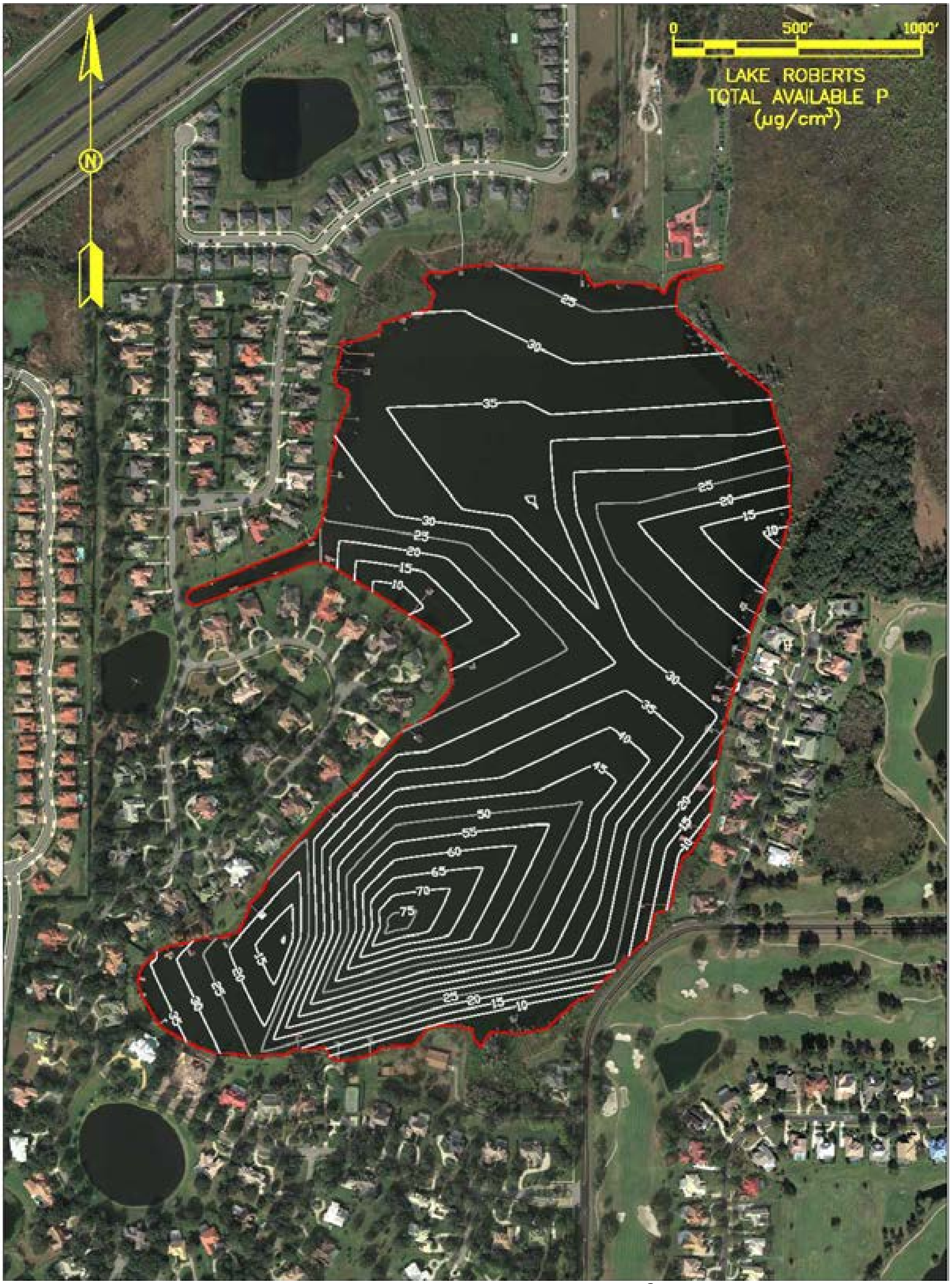


Figure 6-1. Isopleths of Total Available Phosphorus (µg/cm^3) in the Top 10 cm of Sediments in Lake Roberts.

TABLE 6-2
Lake Roberts Sediment Inactivation Requirements

Available P Contour Interval (μg/cm^3)	Contour Interval Mid-Point (μg/cm^3)	Contour Area (acres)	Available Phosphorus		Alum Requirements (Al:P Ratio = 15:1)	
			kg	moles	moles Al	gallons alum
5-10	7.5	1.94	6	190	2,857	348
10-15	12.5	4.49	23	734	11,004	1,340
15-20	17.5	8.38	59	1,915	28,730	3,498
20-25	22.5	14.02	128	4,120	61,805	7,526
25-30	27.5	21.11	235	7,583	113,738	13,850
30-35	32.5	27.69	364	11,752	176,286	21,466
35-40	37.5	15.18	231	7,435	111,532	13,581
40-45	42.5	5.14	88	2,854	42,812	5,213
45-50	47.5	4.15	80	2,575	38,630	4,704
50-55	52.5	3.32	70	2,273	34,100	4,152
55-60	57.5	2.68	62	2,010	30,150	3,671
60-65	62.5	2.04	52	1,665	24,969	3,040
65-70	67.5	1.40	38	1,236	18,539	2,258
70-75	72.5	0.76	22	724	10,861	1,323
75-80	77.5	0.16	5	158	2,370	289
Overall Totals:		**112.5**	**1,464**	**47,226**	**708,385**	**86,258**

Additional aluminum can also be added to the sediments to create an active absorption mechanism for other phosphorus inputs into the water column as a result of groundwater seepage. Inputs of phosphorus from groundwater seepage into a lake can easily exceed inputs from internal recycling in only a few annual cycles. Carefully planned applications of alum can provide an abundance of aluminum which can intercept groundwater inputs of phosphorus over a period of many years. As a result, alum applications can be used to eliminate phosphorus from the combined inputs resulting from internal recycling as well as groundwater seepage.

A summary of calculations of alum requirements for control of phosphorus loading from groundwater seepage entering Lake Roberts is given in Table 6-3. Based on the field seepage monitoring program conducted from 2013-2014, phosphorus inflow to Lake Roberts from groundwater seepage is estimated to be approximately 49 kg/yr. This analysis assumes that control of groundwater seepage is desired for a period of approximately 10 years. Therefore, the total mass of phosphorus from groundwater seepage which must be inactivated is approximately 490 kg over the 10-year period. This mass of phosphorus equates to approximately 15,161 moles of total phosphorus. Assuming an Al:P ratio of 15:1 for adequate inactivation, control of 15,161 moles of total phosphorus will require approximately 227,419 moles of aluminum, or an equivalent alum volume of 27,692 gallons.

TABLE 6-3
Alum Requirements for Control of Phosphorus
Loading From Groundwater Seepage in Lake Roberts

Parameter		Units	Value
Estimated Phosphorus Mass to be Controlled	Seepage Phosphorus Loading	g/m^2-yr	0.100
	Annual Phosphorus Loading from Seepage	kg/yr	49
	Desired Length of Control	years	10
	Total Phosphorus Mass to be Inactivated	kg	490
	Moles of Phosphorus to be Inactivated	moles	15,161
Alum Requirements	Inactivation Al:P ratio	--	15
	Moles of Aluminum Required	moles	227,419
	Alum Required	gallons	27,692

1. Based on an Al:P ratio of 15:1

Previous alum surface applications performed for inactivation of sediment phosphorus release have indicated that the greatest degree of improvement in surface water characteristics and the highest degree of inactivation of sediment phosphorus release are achieved through multiple applications of aluminum to the waterbody spaced at intervals of approximately 3-6 months. Multiple applications provide less stress on aquatic organisms and allow a gradual transition for food webs from larger concentration of TP/chlorophyll-a or a lower concentration of TP/chlorophyll-a. Each subsequent application results in additional improvements in water column quality and additional aluminum floc added to the sediments for long-term inactivation of sediment phosphorus release.

The proposed alum treatment to Lake Roberts would add sufficient alum to control both internal recycling and intercept phosphorus loadings from groundwater seepage. Assuming that approximately 86,258 gallons of alum are needed for sediment inactivation and 27,692 gallons of alum are needed for interception of groundwater seepage, the total amount of alum to be added to Lake Roberts would be 113,950 gallons. This equates to a whole-lake dose of approximately 12.3 mg Al/liter which far exceeds the available buffering capacity in the lake to withstand potential reductions in water column pH. As a result, the proposed application would need to be divided into a series of multiple applications or a buffering compound would be needed to neutralize the pH impacts from the alum addition. Due to the large quantity of alum required for Lake Roberts, three separate applications are proposed, with each application providing a whole-lake dose of approximately 4.1 mg Al/liter.

Based upon the surface water monitoring conducted during 2013-2014, the water column in Lake Roberts is poorly buffered, with measured alkalinity values ranging from approximately 30-50 mg/l, depending upon location within the lake. This level of alkalinity is insufficient to provide adequate buffering for even the relatively low estimated whole-lake dose of 4.1 mg Al/liter for each treatment. Therefore, each of the three recommended treatments will require a simultaneous application of alum and sodium aluminate.

This analysis assumes that each of the proposed treatments will require a combination of alum and sodium aluminate to provide sufficient buffering within the lake to prevent undesirable pH reduction and consumption of alkalinity. Sodium aluminate, an alkaline form of alum, is commonly used in these applications as the preferred buffering agent and is recommended for use in Lake Roberts. Sodium aluminate provides a high level of buffering, as well as supplemental aluminum ions, which reduces the total amount of alum required during the application process. If alum and sodium aluminate are used in combination, changes in pH within the lake during the application process can be easily controlled.

The specific ratio of alum and sodium aluminate required to control water column pH varies based on the characteristics of each lake and is often determined in a series of laboratory jar test experiments. However, based on previous experience in lakes with similar water quality characteristics, the simultaneous addition of 1 gallon of sodium aluminate for every 2.5 gallons of alum is often sufficient to minimize pH reductions during the application process for lakes with water quality characteristics similar to Lake Roberts. Therefore, this ratio is assumed for Lake Roberts. One gallon of alum provides approximately 8.21 moles of available aluminum for sediment inactivation, while one gallon of sodium aluminate provides 21.46 moles of aluminum. Therefore, the use of sodium aluminate not only provides pH buffering, but it can also reduce the amount of alum required for the inactivation project. The optimum alum/sodium aluminate ratio would need to be determined in a series of jar tests prior to any proposed application. The ratio may vary with each of the three proposed applications as water chemistry changes within the lake.

A summary of anticipated chemical requirements for the sediment inactivation treatments in Lake Roberts is given in Table 6-4. Assuming an alum/sodium aluminate ratio of 2.5:1, the required mass of aluminum for sediment inactivation can be achieved using approximately 67,500 gallons of alum and 27,000 gallons of sodium aluminate. When these quantities are divided into the three separate treatments, each treatment will require the addition of 22,500 gallons of alum (5 tankers) and 9,000 gallons of sodium aluminate (2.4 tankers). The applied water column dose of aluminum for each of the three treatments will be approximately 5.0 mg Al/liter.

TABLE 6-4
Chemical Requirements for Sediment Inactivation and Seepage Control in Lake Roberts

Parameter		Units	Value
Chemical Requirements	Aluminum Required	kg	29,010
	Alum/Sodium Aluminate Volume Ratio	--	2.5
	Alum	gallons	67,500
	Sodium Aluminate	gallons	27,000
	Aluminum Provided	kg	30,943
	Water Column Dose	mg Al/liter	15.0
	Areal Dose	g Al/m^2	65.9
Chemical Requirements/ Treatment	Number of Treatments	--	3
	Alum Required per Treatment	gallons tankers	22,500 5
	Sodium Aluminate Required per Treatment	gallons tankers	9,000 2.4
	Dose per Treatment	mg Al/liter	5.0

6.2.3 APPLICATION COSTS

A summary of estimated costs for the proposed sediment inactivation treatments in Lake Roberts is given in Table 6-5. Each treatment will include application of approximately 22,500 gallons of alum and 9,000 gallons of sodium aluminate. Planning and mobilization costs are estimated to be approximately $4,000 per treatment, with a chemical application fee of $1,350 per tanker or partial tanker. Field monitoring for pH and alkalinity during the application is estimated at $500, with an additional $2,400 for pre- and post-treatment laboratory analyses. The estimated overall cost for sediment inactivation in Lake Roberts is $77,075 per treatment or a total of $231,225 for the three proposed treatments.

TABLE 6-5
Estimated Costs for Sediment Inactivation and Seepage Control in Lake Roberts

Parameter		Quantity/ Treatment	Units	Unit Cost ($)	Cost/ Treatment	Total Cost ($)
Alum	Quantity	22,500	gallons	0.55	12,375	37,125
	Number of Tankers	5	tankers	--	--	--
Sodium Aluminate	Quantity	9,000	gallons	5.00	45,000	135,000
	Number of Tankers	2.4	tankers	--	--	--
Labor Costs	Planning/Mobilization	3	each	4,000	4,000	12,000
	Chemical Application	8	tankers	1,300	10,400	31,200
Monitoring/ Lab Testing	Field Monitoring	3	each	500	500	1,500
	Lab Analyses- Pre/Post	24	samples	200	4,800	14,400
				Total:	**$ 77,075**	**$ 231,225**

6.2.4 LONGEVITY OF TREATMENT

After initial application, the alum precipitate will form a visible floc layer on the surface of the sediments within the lake. This floc layer will continue to consolidate for approximately 30-90 days, reaching maximum consolidation during that time. Due to the unconsolidated nature of the sediments in much of the lake, it is anticipated that a large portion of the floc will migrate into the existing sediments rather than accumulate on the surface as a distinct layer. This process is beneficial since it allows the floc to sorb soluble phosphorus during migration through the surficial sediments. Any floc remaining on the surface will provide a chemical barrier for adsorption of phosphorus which may be released from the sediments.

At least 35 previous sediment inactivation projects have been conducted by the CPWG Team in the State of Florida since 1992. Approximately half of these waterbodies have sufficient pre- and post-water quality data to evaluate the effectiveness of the alum sediment inactivation process. None of the 20 waterbodies for which water quality data are available have shown any signs of a decrease in the effectiveness of the sediment inactivation project, some of which were conducted more than 15 years ago. As a result, it appears that a properly planned and executed alum treatment project for Lake Roberts would maintain a continuous level of effectiveness for a minimum of approximately 10-15 years. Inputs from Lake Reaves via the wetland tussock may cause the effectively to be closer to 10-years.

6.3 SANITARY SEWER INSTALLATION

A majority of the existing homes around Lake Roberts are serviced by on-site sewage facilities, commonly known as septic tanks, as shown in Figure 3-8. Based on literature review, an average septic tank will leach 138 kg/year of TP and 447 kg/year of TN. There are over 200 homes utilizing septic tanks within the Lake Roberts watershed. For purposes of calculating the potential pollutants removed by installing a central sewer system, only those 57 homes that are directly adjacent to Lake Roberts were used in the analysis. The pollutant removal estimate is presented in Table 6-6.

Table 6-6
Central Sewer Pollutant Removal Estimate

Number of Houses	57
TP Removed per House (kg/yr)	138
TN Removed per House (kg/yr)	447
Total TP Removed per Year	7,866
Total TN removed per Year	25,479
Cost per Kg of TP Removed*	$381
Cost per Kg of TN Removed*	$118

*** Assumed cost of $3,000,000**

Orange County Utilities was contacted to discuss possible connection points for the central sewer. Based on this discussion the sewer could be connected to the north at pump station PS 3963 or to the south at F3238 as shown in Figure 6-2.

The City of Winter Garden was also contacted. The City currently provides sanitary service to Lake Roberts Landing at the northwest corner of the lake and to Bronson Landing the second subdivision to the west of the lake (includes Tillman Avenue). There is a 12-inch force main along Winter Garden Vineland Road at Tillman Avenue and a 6-inch force main along Stoneybrook West Parkway, heading east from Blackwater Court. It should be noted that the City of Winter Garden requires that a force main discharges into another force main. Therefore, within the City we cannot construct a force main that discharges into the gravity sewer system.

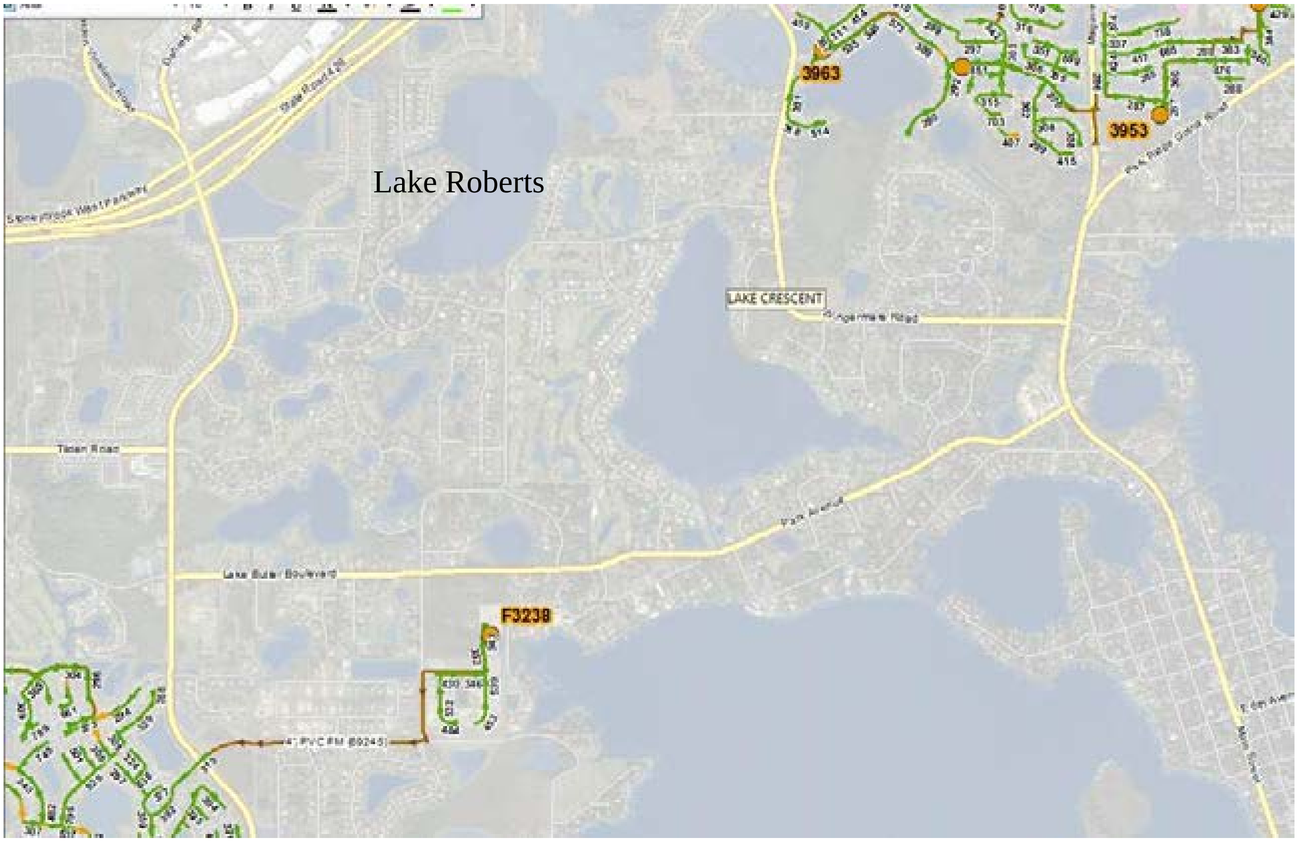
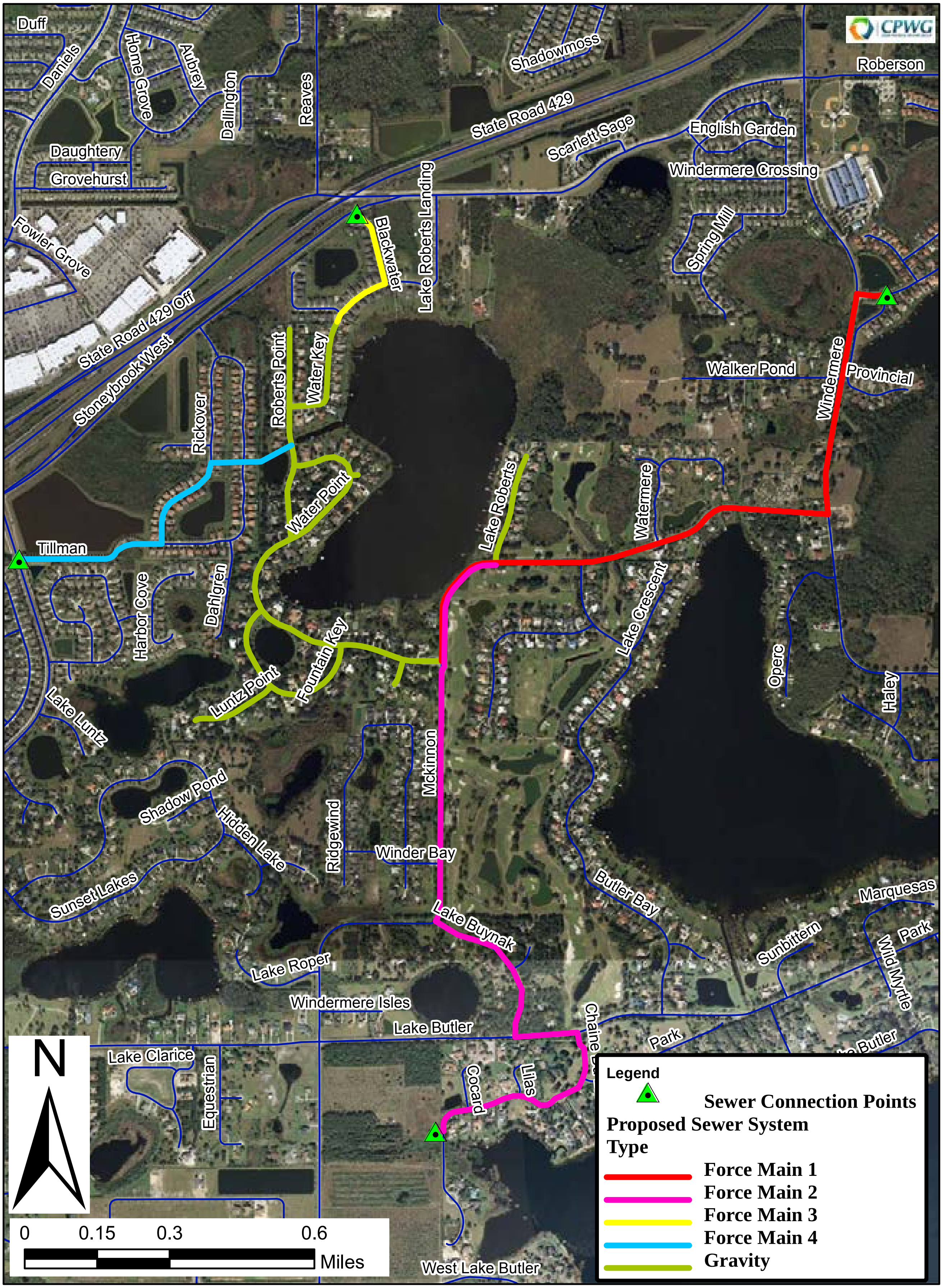


Figure 6-2 – Orange County Potential Sewer Connection Points

Four options to connect to existing force main are presented below and in Figure 6-3.

1. Connect to the northeast at PS 3963 (Orange County Utilities)
2. Connect to the south at F 3238 (Orange County Utilities)
3. Connect to the northwest (City of Winter Garden)
4. Connect to the west at Winter Garden Vineland Road and Tillman Avenue (City of Winter Garden)

The costs to connect to the City of Winter Garden system are less because their connection points are closer to the project area. The gravity sewer installation costs are the same for all four options. The gravity sewer costs include several internal lift stations and internal force mains. Easements and roadway reconstruction will be needed to construct the gravity system. The force main may be constructed with HPDE and directional drilled or open cut. Easements with property owners and agreements with either City of Winter Garden or Orange County Utilities would be needed. The costs are estimated to be between $2,000,000-$3,000,000 dollars as detailed in Table 6-7.



Sanitary Sewer Alternatives

Figure 6-3

Table 6-7
Central Sewer Cost Estimate

Alternative	Pipe Length (ft)	Unit Cost (ft)	Total	Grand Total*
Gravity System	12,990	$150	$1,948,541	
Option 1	7,967	$100	$796,700	$2,745,241
Option 2	9,199	$100	$919,900	$2,868,441
Option 3	1,551	$100	$155,100	$2,103,641
Option 4	3,686	$100	$368,600	$2,317,141

* Force Main plus constant Gravity System Costs

6.4 SEPTIC TANK MAINTAINANCE / UPGRADING SEPTIC SYSTEM

Failing or unmaintained septic system can contribute substantially more nutrients to waterbodies than well maintained septic systems. The EPA's "A Homeowner's Guide to Septic Systems" is presented in Appendix 6-1. The document discusses 1) Your septic system is your responsibility, 2) How does is work?, 3) Why should I maintain my septic system?, 4) How do I maintain my septic system, and 5) What can make my system fail. A septic tank inspection may include: locating the system, uncovering access holes, flushing toilets, checking for signs of back up, measuring scum and sludge layers, identifying any leaks, inspecting mechanical components, and pumping the tank if necessary. Steps to maintain a septic system include:

1. Inspect and pump frequently
2. Use water efficiently
3. Watch what goes down the drains
4. Care for the drainfield

If a central sewer system is not installed in the neighborhoods surrounding Lake Roberts, the existing septic systems could be replaced with advanced septic treatment system. These systems are generally pumped systems to provide additional separation between the drainfield and the groundwater elevation. Very often these systems also include a filter media which will reduce the discharge of nutrients from the septic system. Assuming 57 homes and $10,000 per home the estimate cost to replace the septic systems surrounding Lake Roberts would be $570,000 .

6.5 REAR YARD SWALES AND BERMS

Runoff originating from lawns and landscaped areas has the potential to contribute significant loadings of both nutrients and pesticides into Lake Roberts. Untreated stormwater runoff from lawns and landscaped areas contains total phosphorus concentrations which are often 25-50 times greater than concentrations commonly observed in Lake Roberts. As a result, a relatively small volume of untreated rear yard runoff can impact a large quantity of adjacent water. As shown on Table 5-14, runoff originating from direct overland flow into Lake Roberts contributes approximately 17% of the annual total phosphorus loadings to the lake.

6.5.1 EXISTING CONDITIONS AND ISSUES

A requirement for rear yard berms and swales to contain overland runoff is contained in Section 34-132 of the Orange County Municipal Code, titled "Subdivision Construction Plans". The requirement for berms and swales consists of a single sentence located in paragraph c(2) which states "… Pollution abatement swales shall be provided upland of streams and canals and the normal high water elevation in all lakes. …" However, this section provides no design criteria or guidelines for the required systems. Since the reference to berms and swales is located in a section titled "Subdivision Construction Plans", the requirement applies only to construction of new subdivisions and does not apply to pre-existing homes or new single-family homes constructed on individual lots which are not part of a designated subdivision. This provision also does not apply to redevelopment (demolition and reconstruction) of an existing single-family lot.

Design guidelines for the rear yard swale and berm systems should achieve the same level of treatment as the stormwater management systems designed for the remaining portions of the development. The design of stormwater management systems in Florida is regulated by Chapter 62-25 of the Florida Administrative Code titled "Regulation of Stormwater Discharge". This statute establishes minimum design and performance standards for stormwater management systems, including design criteria for swales which are for water quality treatment. Chapter 62-25 requires that stormwater management systems be designed "to achieve at least an 80% reduction of the average annual load of pollutants that would cause or contribute to violations of State water quality standards".

Design calculations to achieve 80% pollutant load reductions for swale and infiltration systems were developed as part of the ongoing Statewide Stormwater Rule development. As part of this process, a series of continuous simulations were conducted to evaluate retention depths necessary to achieve 80% load reductions for various combinations of curve number and directly connected impervious percentages (DCIA) for various meteorological regions within the State. To achieve as 80% removal rate 1-inch of stormwater would need to be retaining in the swale system. It is unlikely that an existing development can be retrofits to achieve 1-inch of retention of the site. The calculation herein assumes 0.5 inches of retention over the site, which would yield 52% reductions of TP and TN. These tabular values are included in both the current draft version of the Statewide Stormwater Rule as well as the 2007 report by Harper and Baker titled "Evaluation of Current Stormwater Design Criteria within the State of Florida". This methodology has been reviewed and approved by FDEP and the State's Water Management Districts. It is recommended that this methodology be used to establish volumetric requirements for rear yard berm and swale systems.

During November 2007, CDM prepared a report for OCEPD titled "Orange County Swale and Berm Design Criteria Report". This report contains many general guidelines regarding swale design concerning distance from shorelines, relationship to the seasonal high groundwater table, check dams, stability and erosion control criteria, and other general information which may be useful in designing swale and berm systems. However, volumetric requirements should be calculated using the methodology referenced previously.

The objective of a berm and swale system is to intercept runoff from the rear yard area, causing the runoff to be infiltrated into the ground rather than directly discharging into the adjacent waterbody. As the runoff migrates through the vegetation and surficial soils, a large portion of the pollutant mass is attenuated and is prevented from reaching the adjacent waterbody. Since these systems act primarily as retention areas, it is important that the area utilized for infiltration be constructed above the seasonal high groundwater table elevation. If the bottom of the infiltration area is not maintained above the seasonal high groundwater table elevation (SHGWT), the retention area will assume wetland characteristics and will gradually lose its ability to evacuate the required pollution abatement volume.

The performance efficiency of a rear yard swale or berm system for reducing loadings discharging into waterbodies is directly proportional to the volume of water retained by the system. Rear yard berm and swale systems should be designed to achieve an 80% annual load reduction if discharging to a Class III surface waterbody and 95% annual load reduction if discharging to an Outstanding Florida Water which is the same performance criteria which applies to runoff generated in other parts of a development. The resulting volume represents the amount of water which should be retained in the rear yard and dictates the design of the swale and berm. A schematic of a recommended berm and swale design is given in Figure 6-4.

One of the common criticisms of berm and swale systems concerns ongoing maintenance of the areas. Where swale systems are used, bottom portions of the swale can become wet for extended periods, making mowing and maintenance activities difficult. Mowing of bermed areas can also be difficult, particularly if the berm is constructed with steep side slopes. However, virtually all of the maintenance concerns for bermed areas can be eliminated by constructing the berm with more gradual side slopes, such as 6(H):1(V), or flatter.

The overall objective of retaining direct runoff from rear yard areas can also be achieved using decorative walls or landscaped areas, as long as the areas provide retention for the specified treatment volume. A schematic of a typical wall section which would also provide retention for rear yard runoff is given in Figure 6-5. Given the multiple methods available, it is difficult to envision how the construction or presence of a runoff collection or retention area would create a significant hardship for any lake front property owner.

A field review was conducted of the lake front properties adjacent to the Lake Roberts to determine if a berm and swale system exists along the lake shore. It was determined that while a minority of yards exhibit remnants of swales, a majority of the shoreline requires the construction or reconstruction of swales which would meet the 80% pollutant removal goal. The location of new proposed swales or existing swale to be regraded is presented in Figure 6-6. There are currently 55 waterfront parcels on Lake Roberts with a total shoreline length of 9,500 feet, all of which are in need of constructing or maintaining a berm and swale system.

Lake Roberts is on the boundary of both the SJRWMD and the SFWMD. A percentage of the northwest portion of the lakeshore and the western portion of the subdivision was permitted through the SJRWMD, while the southern portion and most of the lakeshore was permitted through the SFWMD. The SJRWMD permit application number is 40-095-0150. The SFWMD permit number is 48-0041-S. The permitted plans show a 2-foot deep retention pond/swale along the shoreline adjacent to Water Key Drive between Lake Roberts Point and the northern dead end of Water Key Drive. The area of the existing swale/retention area is basically north of the finger outfall canal. Plans for this northern section are included in Appendix 6-2. A notice of noncompliance issued in 2014 for 13013 Water Pointe Drive, in the northern section, is also included in Appendix 6-2. Based on aerial photographs it appears that the homeowner at 13013 Water Pointe Drive constructed landscaping upgrades in 2013 that filled the backyard swale. Aerial photos indicate that this same area is under construction in 2015, presumably to reestablish the swale. The available documents indicated that a shoreline swale/retention area was required by the SFWMD for the entire length of this northwestern shoreline (north of the outfall finger canal). The existing swales/retention areas in this northwest area should be cleaned and regraded to create a better opportunity for stormwater filtration.

Permits for the southwestern section could be found from neither the SFWMD, SJRWMD, nor FDEP. Aerials indicate that the roadway system for the southwest section was already constructed in 1990, with house construction underway by 1995. Given the age of the development it is possible that it was constructed prior to FDEP permitting (1982) or the permit package was misplaced over the years. Current Orange County regulations require a swale at the lakeshore. Orange County would have permitted this through the individual house construction permitting process. During our site visits swales were not evident along the shoreline for a majority of the southwestern area (south of the outfall finger canal). The construction of a swallow swale (6-inches to 12-inches) deep is recommended along the shoreline of Lake Roberts.

Berm and swale systems are an inexpensive method of reducing discharges of direct runoff from rear yards and landscaped areas into Lake Roberts. Proper construction of berm and swale systems has the potential to provide nutrient load reductions to Lake Roberts equivalent to a large structural retrofit project. Funding for construction of the berm and swale systems could be provided through an incentive program with the Lake Roberts Municipal Stormwater Benefit Unit (MSBU). A number of funding grants may also be available for this program from FDEP, SJRWMD and SFWMD.

An overview of lake front residential parcels on Lake Roberts which could be retrofitted with a new berm and swale systems or have the existing swale system regraded is also presented on Figure 6-6 as the highlighted parcels. Only a few of these parcels are known to currently have any significant berm and swale systems for treatment of overland flow discharging into the lake. The highlighted areas on Figure 6-6 include a total of 57 parcels which could be maintained or retrofitted with properly constructed berm and swale systems to provide stormwater treatment. The parcels north of the outfall finger canal have a swale with a permit through the SFWMD and this swale should be maintained. The parcels south of the outfall finger canal do not have a permit through the Water Management District or FDEP. These parcels do not have a swale system required by the Water Management District. Orange County regulations currently require swales at all lakeshore houses. These two areas encompass a large portion of the area which currently discharges to Lake Roberts with minimal existing stormwater treatment. The proposed berm and swale maintenance and retrofit will involve the installation of 9,500 linear feet of swale and berm systems along the western, eastern, and southern shorelines of Lake Roberts.

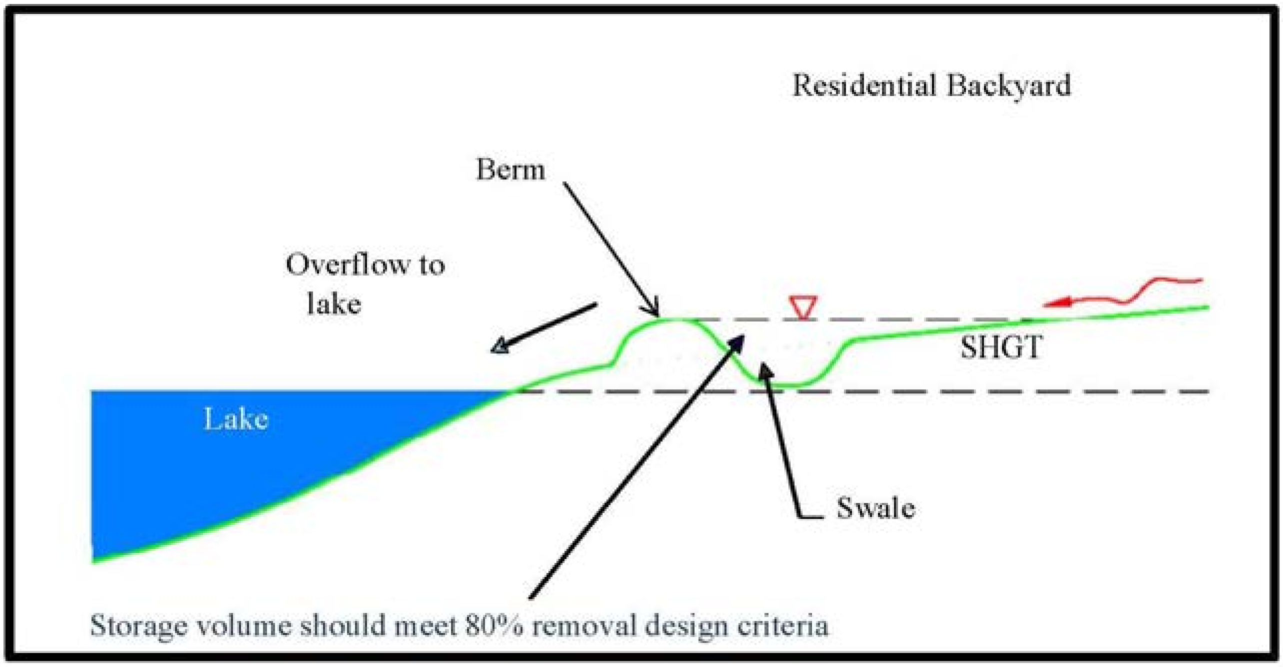


Figure 6-4. Schematic of Recommended Rear Yard Swale and Berm Design.

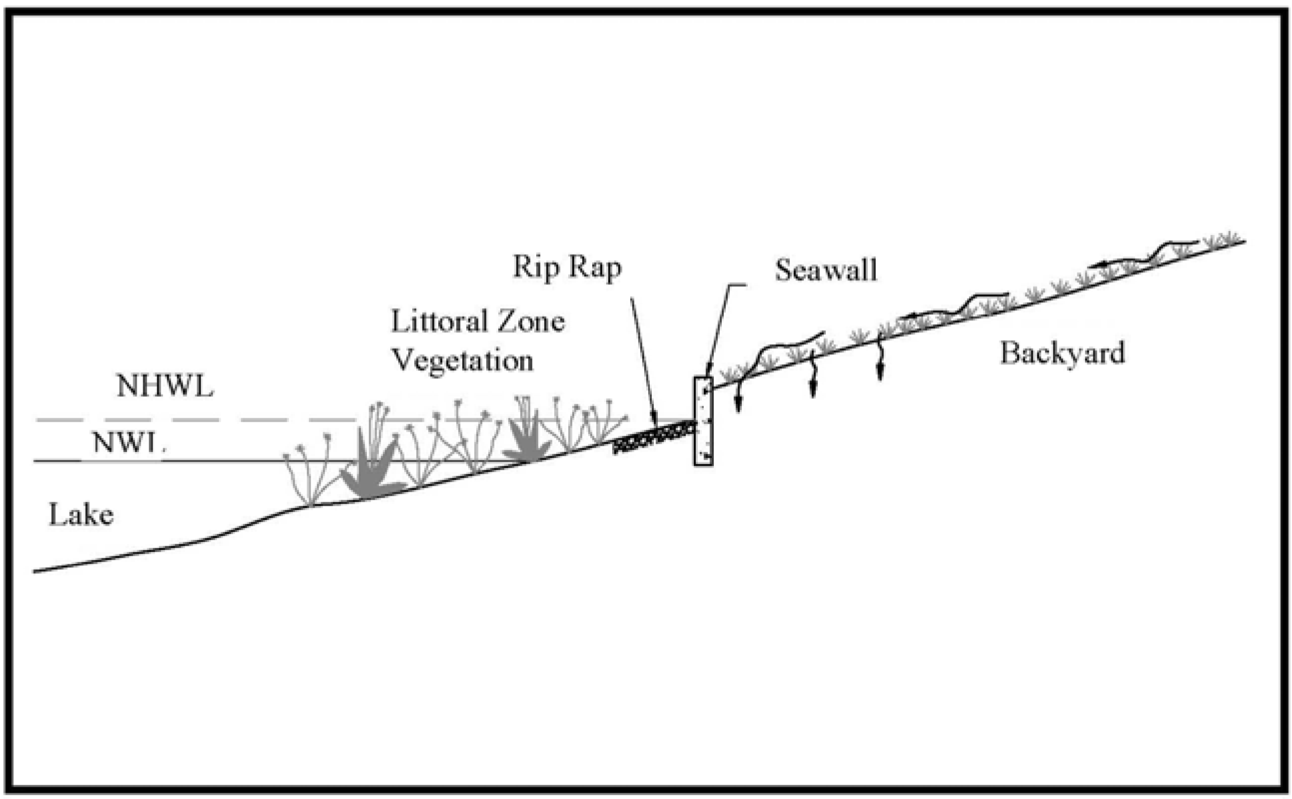
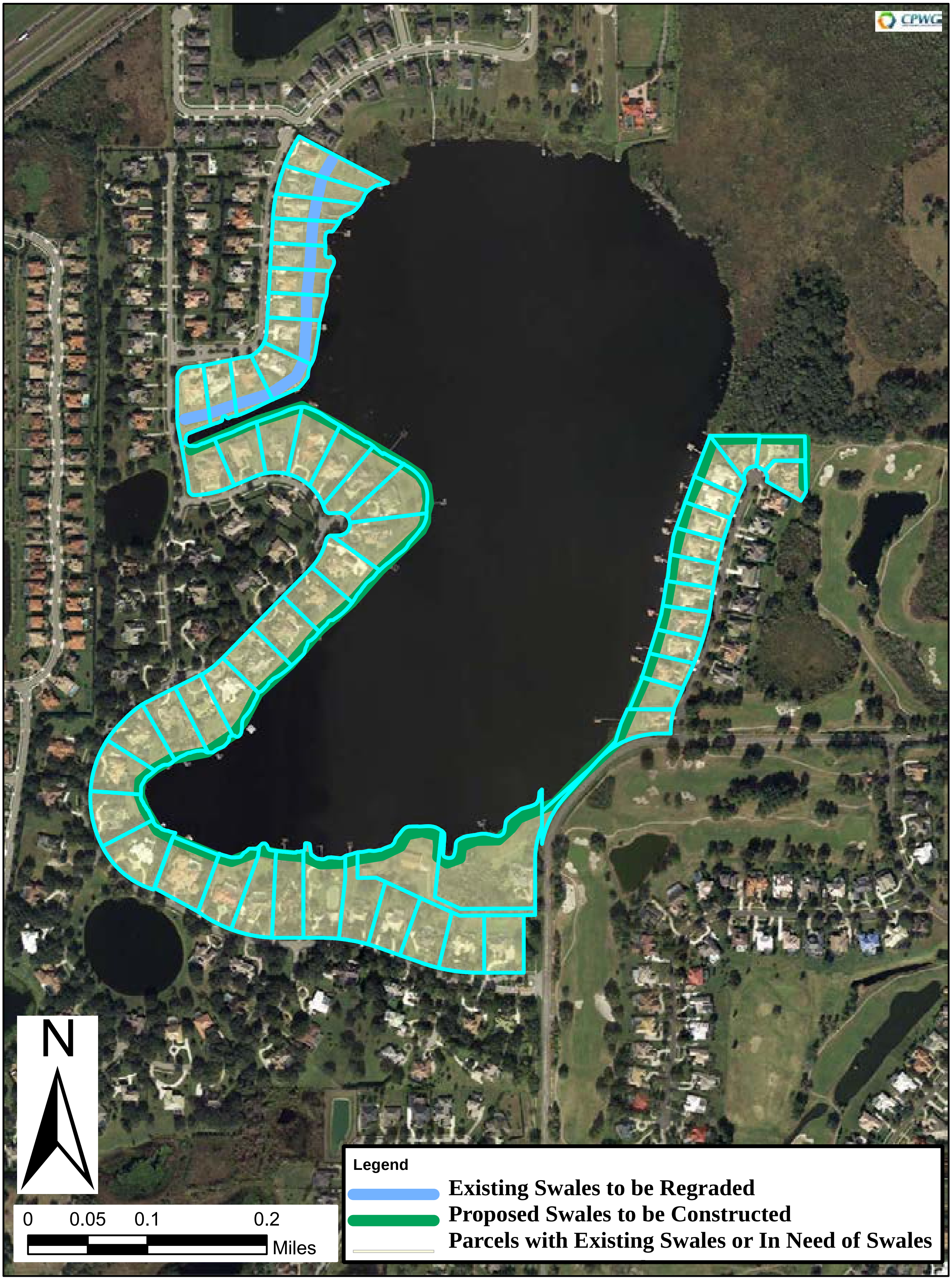


Figure 6-5. Alternative Seawall Design Used as Rear Yard Berm



New Proposed Swales and Existing Swales to be Regraded

Figure 6-6

6.5.2 ANTICIPATED ANNUAL LOAD REDUCTION AND COSTS

Construction costs for the recommended berm and swale systems will vary from lot to lot, depending upon the size of the lot, availability of access, and other issues. However, for purposes of this evaluation, a cost of approximately $30/ft. is assumed for construction of the recommended new berms and swales and the rehabilitation of existing swales. Using this unit cost, construction of berm and swale systems for each of the 57 potential parcels (9,500 ft.) would have a capital cost of approximately $285,000. A summary of anticipated construction costs for the berm and swale system is given on Table 6-8.

Table 6-8
Estimated Construction Costs for Berm and Swale Systems on Parcels Adjacent to Lake Roberts

Item	Value
Number of Parcels	57
Length	9,500 ft.
Construction Cost	$ 30/ft.
Total Cost	$ 285,000

An evaluation of potential annual mass phosphorus load reductions for the proposed berm and swale system for residential areas on Lake Roberts is presented in Table 6-9. Based upon land use and event mean concentration values,, rear yard areas discharging directly to Lake Roberts , contribute approximately 8.0 kg/yr (53.5 acres x 47.45 inches of rain x 0.1 runoff factor x 0.306 mg/l of TP x 1-ft/12-in x 1-kg/1,000,000-mg x 1233481.855 l/1-ac-ft) of total phosphorus to Lake Roberts. Likewise, the area contributes 59.8 kg/yr (53.5 acres x 47.45 inches of rain x 0.1 runoff factor x 2.29 mg/l of TN x 1-ft/12-in x 1-kg/1,000,000-mg x 1233481.855 l/1-ac-ft) of total nitrogen to Lake Roberts The proposed berm and swale system, if designed to applicable SJRWMD/SFWMD design criteria requiring a minimum of 0.50-inch of retention, would be capable of providing an annual load reduction of approximately 52% for total phosphorus and total nitrogen. This would provide an annual phosphorus and nitrogen mass removal to Lake Roberts of approximately 4.2 kg/yr and 31.1 kg/yr, respectively. .

TABLE 6-9
Estimated Phosphorus Mass Removal for Berm and Swale Systems on Parcels Adjacent to Lake Roberts

ITEM	VALUE
Total Phosphorus Load	8.0 kg/yr
Assumed Swale Removal	52%
Annual Phosphorus Removal	4.2 kg/yr

A summary of estimated phosphorus removal costs for the proposed berm and swale systems is given in Table 6-10. The 20-year present worth cost for the berm and swale systems is assumed to be $285,000 which is equal to the estimated capital construction cost. Normally, present worth costs include the initial capital construction cost plus 20 years of operation and maintenance expenses. However, it is anticipated that the operation and maintenance activities for the berm and swale systems will be conducted by each of the individual homeowners. As a result, the 20-year present worth cost only includes the initial construction cost for the systems.

TABLE 6-10
Estimated Phosphorus Removal Costs for the Proposed Berm and Swale Systems

ITEM	VALUE
20-year Present Worth Cost	$ 285,000
Phosphorus Removal	4.2 kg/yr 84 kg over 20 years
Phosphorus Removal Cost	$ 3,393/kg phosphorus removed

Phosphorus removal for the proposed berm and swale systems is estimated to be approximately 4.2 kg/yr or approximately 84 kg over the 20-year period of evaluation. The present worth per kg of phosphorus removed is calculated by dividing the present worth cost of $285,000 by the estimated 20-year phosphorus removal of 84 kg. This results in a calculated phosphorus removal cost of approximately $3,393 per kg of phosphorus removed. This mass removal cost is typical of costs associated with traditional stormwater management systems.

6.5.3 RECOMMENDATIONS

Berm and swale systems are a relatively inexpensive method of reducing direct discharges of runoff into Lake Roberts. The anticipated capital cost for this option is relatively small compared with costs normally associated with lake restoration projects. The proposed berm and swale systems would provide stormwater treatment for a large portion of the currently untreated areas which discharge directly into the lake. Therefore, it is recommended that rear yard swales and berms be implemented, to the extent practicable, for the parcels indicated on Figure 6-6. Construction of the proposed berm and swale systems has the potential to provide nutrient load reductions which are equivalent to large structural retrofit projects which could cost millions of dollars. The swale and berm system should be designed according to existing SJRWMD/SFWMD design criteria which would require retention of 0.5 inches of runoff from all parcel areas discharging directly into the lakes.

6.6 VEGETATED SHORELINES

6.6.1 EXISTING CONDITION AND ISSUES

The shoreline areas surrounding Lake Roberts exhibit a wide variety of both species and density of aquatic vegetation which range from natural vegetated shorelines, to planted shorelines, to cleared and bare shorelines. Several of the shoreline residents have removed virtually all aquatic vegetation from shoreline areas adjacent to their properties. Many areas exist where the rear lawn extends to the water's edge with no shoreline vegetation at all.

The Butler Chain-of-Lakes Study, by ERD, indicated that shoreline areas which are non-vegetated are susceptible to erosion and resuspension of sediment material as a result of wave activity caused by boats or wind. Water samples collected from non- vegetated shorelines were found to have significantly higher water column concentrations of particulate phosphorus, total phosphorus, and total suspended solids. In addition to providing protection from erosion and sediment resuspension, shoreline vegetation also contributes to a diverse ecological community which is an important factor in maintaining good water quality characteristics within the water column. Shoreline vegetation provides an extremely beneficial function in lake ecosystems and should be maintained to the maximum extent possible.

Issues related to shoreline vegetation are addressed in Article VII of the Orange County Municipal Code, titled "Lake Shore Protection". Article VII requires that a permit be obtained prior to performing any clearance of shoreline vegetation. Before permit issuance, information on the percentage of shoreline vegetation to be removed, means for minimizing and controlling erosion, methods of filtering runoff, methods for reducing the nutrient concentrations in both surface runoff and lake waters, methods for stabilizing soils, and justification for the replacement vegetation must be provided and approved by Orange County. However, these criteria are subject to a number of exemptions, including:

1. Clearing of shoreline vegetation in an area which is less than 20% or 30 ft., whichever is greater, of the shoreline area;

2. Mowing and maintenance activities; and

3. Property owners whose shoreline has been previously cleared and where the clearing is continuously maintained

6.6.2 RECOMMENDATIONS

Shoreline vegetation is essential for maintaining water quality characteristics, preventing shoreline erosion, and providing a diversity of habitat for aquatic organisms. The current clearing exemption outlined in Section 15-255 of 20% of the shoreline or 30 ft., whichever is greater, appears to be adequate to support virtually all recreational, swimming, and boating activities which may be desired by a homeowner, and it is recommended that this exemption remain in place.

However, other than the exemption referenced previously, it is recommended that vegetation be established in all shoreline areas within Lake Roberts. Although it is fully understood the desire by some homeowners to have a vegetation-free shoreline, the water quality benefits from shoreline vegetation, combined with the negative water quality conditions observed in unvegetated shoreline areas, appear to outweigh the desire of homeowners to maintain a vegetation-free shoreline. Therefore, it is recommended that all shoreline areas within Lake Roberts, other than the exception referenced previously, be re-established with natural vegetation. A period of approximately 2-5 years is recommended to allow homeowners to come into compliance with this requirement. It is recommended that exemption 5 listed under Section 15-255, which “grandfathers” existing cleared shoreline areas, be eliminated for Lake Roberts and replaced with language requiring establishment of shoreline vegetation in all areas within a specified period of time.

An apparent conflict with shoreline vegetation regulations is the desire by many homeowners to have a constructed seawall (none are currently on Lake Roberts) along the lake shoreline to protect the rear yard areas from erosion. The seawall also allows portions of the rear yard near the shoreline to be constructed at a higher elevation, eliminating many of the issues associated with vegetation maintenance in saturated soils. The requirement for establishment of shoreline vegetation is often thought to be inconsistent with the concept of a shoreline seawall. However, the objective of a vegetated shoreline does not have to be inconsistent with construction of a lake front seawall. If the seawall is constructed at or above the normal high water elevation within the lake, similar to the concept illustrated in Figure 6-5, lake and shoreline areas are still available for colonization of vegetation. The top elevation of the seawall can be raised above the land surface to create retention for rear yard runoff similar to a berm system. The design proposed in Figure 6-5 simultaneously promotes shoreline vegetation, the conveniences of a seawall, and retention for rear yard runoff. Therefore, it is recommended that a design similar to the one illustrated in Figure 6-5 be encouraged for both future and existing seawall construction within Lake Roberts.

6.7 LANDSCAPE ACTIVITIES

6.7.1 EXISTING CONDITIONIS AND ISSUES

Improper landscape and lawn maintenance activities which included blowing lawn clippings, leaves, and other vegetation debris onto paved or roadway surfaces, or directly into a waterbody, as well as improper application of both granular and liquid fertilizers to impervious surfaces and roadways are another source of pollutants to Lake Roberts. When grass clippings and fertilizers are introduced onto impervious surfaces, they become available for mobilization by stormwater runoff during rain events, causing them to be deposited into the nearest waterbody during storm events. These types of lawn maintenance practices are needless and irresponsible activities which have the potential to significantly increase nutrient loadings to Lake Roberts, as well as other waterbodies in Orange County where these activities occur. At best, these activities occur as a result of lack of information and education, while at worst, they represent a disregard for water quality consequences in a misguided attempt to reduce labor time and costs.

During 2009, Orange County enacted Ordinance No. 2009-26 titled “Fertilizer Management Ordinance” which regulates application of fertilizer to lawns and turf in Orange County. The Ordinance was codified in Chapter 15, Article XVII of the Orange County Code, Sections 15-801 through 15-812. A copy of this Ordinance is included in Appendix 6-3.

The newly adopted Fertilizer Management Ordinance places restrictions on the timing and amount of fertilizer which can be applied to turf grasses in Orange County. Fertilizer containing nitrogen or phosphorus cannot be applied to turf during a period when weather advisories have been issued or at any time during the period from June 1-September 30 of each year. Applications may not exceed 0.25 lbs of phosphorus per 1000 ft.2 per application or exceed 0.5 lbs of phosphorus per 1000 ft.2 per year. Fertilizer-free zones are established within 10 ft. of any waterbody or wetland, and it is strictly prohibited to apply fertilizer onto impervious surfaces.

Section 15-807 titled "Grass Clippings and Vegetated Material/Debris" prohibits depositing, washing, sweeping, or blowing grass clipping or any vegetated material/debris onto any impervious surface, public right-of-way, stormwater drain, ditch, conveyance, or waterbody. This section is an important addition to the Ordinance since previous research has indicated that soluble nutrients are released rapidly from yard wastes upon entering a receiving waterbody within a period of approximately 7-10 days. Discharge of yard wastes onto paved surfaces is a clear violation of surface water quality standards.

6.7.2 RECOMMENDATIONS

Discharge of yard wastes, leaves, and other vegetation debris onto paved surfaces, particularly roadways, is a needless practice since it is just as easy to blow the yard waste back onto the landscaped surfaces as it is to discharge it into the street. Although the Fertilizer Management Ordinance has been adopted and implemented in Orange County, there appear to be many homeowners and lawn care professionals who are either unaware or ignore the existing Ordinance, particularly commercial landscaping companies. This Ordinance does not appear to impose a significant hardship on landscape companies since it appears to be just as easy to blow the clippings and vegetation back onto the lawn surface rather than into the adjacent roadway or drainage system. When the yard waste is returned into the landscaped areas, it will decompose and provide additional sources of nutrients to the vegetation rather than the receiving waterbody.

The existing Fertilizer Management Ordinance, if fully observed, would virtually eliminate water quality impacts from fertilizer and landscaping activities. However, in spite of the Ordinance, instances of improper fertilizer application and discharge of vegetation debris onto paved surfaces appear to be relatively routine activities. Therefore, it is recommended that an educational pamphlet on the importance of observing the fertilizer ordinance be delivered to each homeowner living near Lake Roberts and Lake Reaves. Additionally, OCEPD staff should make a presentation during an upcoming HOA meeting to discuss issues with lake cleanup efforts and how fertilizer runoff plays an important role in the degradation of water quality.

6.8 FLOATING WETLANDS

Floating wetland islands are a combination of plants floating on platforms in a lake or pond. These floating wetlands have been used in Central Florida lakes to reduce nitrogen and phosphorus concentrations through uptake of nutrients by the plant material in the islands. Floating wetlands remove pollutants by directly assimilating them into their macrophytes as well as providing a suitable environment for microorganisms to decompose or transform pollutants to the gas phase, which reduced their concentrations in pond water. The islands can be allowed to float across the lake, or be anchored in a stationary spot.

Most of the treatment of nutrient rich water within a wetland occurs in the thin aerobic layer at the surface of the soils within plant communities. This aerobic biofilm is a result of oxygen leakage from the plant roots at the soil-water interface. In an effort to more efficiently utilize the natural ability of macrophytes to extract and store nutrients from surface water, a floating mat system to suspend native emergent plants and grasses is designed. By expanding the root zone that is in contact with the water column the thickness of the aerobic layer is increased, resulting in increased nitrification and accelerating the process in which nitrogen is cycled from the aquatic environment to the atmosphere. The greatly expanded root mass also facilitates increased uptake and storage of inorganic phosphorus in the plant tissues by creating more surface area for beneficial bacterial colonization.

Through the periodic removal of mature macrophytes from the floating plant mat, one prevents the accumulated nutrients from re-entering the aquatic ecosystem at senescence. Those plants are then composted at an upland location, allowing bacterial decomposition to release some of the organic phosphorus so it can be recycled and used as a fertilizer ingredient for growing soil mixtures. The foam and nylon parts of the floating plant mats are re-used to start a new cycle of plant growth and nutrient uptake. Beemats is one company that provides floating wetland mats.

The plants should be harvested and replaced once a year, preferably in the fall months. The plant islands should also be inspected and maintained on a monthly basis replace dead plant and to prune as needed. It is recommended the floating wetland cover up to 5% of the lake/pond area. A study performed by UCF for FDOT, “Floating Wetland Systems for Nutrient Removal in Stormwater Ponds” (September 2012) states that a 12% concentration reduction in both phosphorus and nitrogen can be achieved through the use of floating wetland systems. Additional studies report higher removal rates as detailed in Table 6-11. These removal rates assume 5% coverage of the lake/pond and annual replacement of the vegetation in the floating wetland islands.

Table 6-11
Nutrient Removal Via Beemat Floating Wetlands

Pollutant	University of Central Study FDOT Study	University of Virginia Study	University of Central Florida Study	Clemson Study
TP	12%	40%	61%	66%-87%
TN	12%	48%	53%	45%-75%

It should be noted that as part of total nitrogen, ammonia and NO_x are available for plant uptake. The surface water samples averaged 54 µg/l of ammonia and NO_x. Soluble Reactive Phosphorous (SRP), as known as ortho-phosphorus, is the portion of total phosphorus that is available for plant uptake. The surface water samples averaged 4.4 µg/l of SRP. These are somewhat low compared to the TN and TP averages, but release or transfers from other forms would be expected as the available concentration decrease.

The cost to install the floating wetland mats is approximately $6/SF and $2/SF to harvest and replace the plants on an annual basis, as presented in Table 6-12.

Table 6-12
Floating Wetland Pollutant Removal and Costs

Description	Amount
TP Available (Kg/yr)	65
TN Available (Kg/yr)	1,322
TP Removed (Kg/yr) -12%	8
TN Removed (Kr/yr) – 12%	158
SF of Wetland to Install (5% of total)	233,046
Cost Per SF To Install	$6
Construction Cost	$1,398,276
Annual Maintenance Cost $2/SF	$466,092
Monthly Maintenance Cost $0.50/SF	$116,523
TP Cost per Kg Removed (Year 1)*	$174,784
TN Cost per Kg Removed (Year1)	$8,850
TP Cost per Kg Removed (Subsequent Years)**	$80,109
TN Cost per Kg Removed (subsequent Years)**	$4,056

* Only includes construction cost
** Only includes annual and monthly maintenance costs

The floating wetland system works well at removing nutrients from the water column that flows near the wetland mat system. If the flow is limited, as in a lake system, a circulation device can assist is bringing nutrient rich water to the floating wetland. SolarBee's SB10000 V18, using solar power to circulate water from the bottom of the lake to the top of the lake at a rate of 10,000 gpm, is such a device. The circulation system can pull the nutrient ladened water from the deeper areas of the lake and bring them to be water's surface where the nutrients are available to the floating wetland system. In cases of excess available nutrients, the vegetation growth in the floating wetland system is extensive and harvesting is required twice a year, instead of the customary annual harvesting.

The circulation system has also proven to be effective at limiting Cyanobacteria, known as blue green algae. A circulation system is recommended for the southern lobe of the lake if floating wetland systems are installed where the circulation in the lake appears to be the least and historic cyanobacteria blooms have been documented.

The cost of an installed SolarBee SB10000 V18 circulation system is estimated at $60,000. It is believed the use of the circulation system will enhance nutrient removal over the floating wetland mats alone. However, enough data on the additional removal is not currently available to quantify the increased removal efficient of adding the circulation system.

6.9 HARVEST AND DREDGE STATIONARY WETLAND TUSSOCK

Generally wetlands are considered the kidneys of a natural water system by removing pollutants from stormwater runoff before it reaches a waterbody. In the case of Lake Roberts, surface water samples and seepage samples data suggest that the floating wetland tussock located along the north-northeast shore of Lake Roberts is a large contributor of TP and TN to the lake. Table 6-13 details the changes in surface water concentrations as the water flows from Lake Reaves, through the wetland, and into Lake Roberts.

Table 6-13
Mean Average Nutrient Levels in Lake Roberts, Lake Reaves and the Wetland Tussock

Pollutant	Lake Reaves (µg/l)	Wetland Tussock (µg/l)	Lake Roberts (µg/l)
TP	32	113	51
TN	1,016	1,545	1,006

By subtracting the concentration of nutrients in Lake Reaves from the wetland tussock, the nutrient loading to Lake Roberts from the wetland tussock can be implied. The resulting amount of TP loading from the wetland tussock is calculated to be 81 µg/l and the amount of TN loading is calculated to be 529 µg/l. Analytical data collected throughout the yearlong study supports the hypothesis that water from Lake Reaves is becoming nutrient enriched as it flows through the wetland tussock. It can be assumed that flow from the wetland tussock is diluted as it enters Lake Robert, reducing the TP and TN concentration. Using the concentration data and an estimated flow through the wetland tussock of 233 ac-ft/year, the nutrient load contributed to Lake Roberts by the wetland tussock, and conversely the load that would be removed if the wetland tussock was not present, can be calculated. The TP and TN loading from the wetland tussock into Lake Roberts are 23.2 kg/yr and 152 kg/yr, respectively. Table 6-14 details the estimated nutrient removal and costs that are expected to harvest the wetland tussock. Typical harvesting costs run between $5,000 and $10,000 per acre depending on access and difficulty in removing material. Total cost to harvest the 60 acre wetland tussock is estimated to be approximately $600,000 and does not include drying, hauling and disposal sites. If the material is dried and burnt on site and disposal cost is estimated at $200,000. If the material if hauled disposal costs could be as high as $3,000,000. To reduce disposal costs, an island of the tussock material could be built within the blue print of the wetland. However, as the material decomposes nutrients would be released into the lake. From a nutrient load perspective, burning the material would be preferred to creating an island of plant material.

The harvesting of the wetland tussock could be considered an adverse impact by the SJRWMD, SFWMD, and Army Corp of Engineers (ACOE). While a net benefit between the current condition and the harvested condition may be clear from a water quality perspective, the regulatory agencies may consider removal of vegetation as a net loss of habitat and could require mitigation to offset any impacts. Cost for permitting could be as high as $50,000 and mitigation costs as high as $20,000/acre or $1,200,000 for the entire wetland tussock, if required.

A prescribed burn may give some of the desired benefits; however, the vegetation is not harvested and may simply release the nutrients more quickly to the water column. There are also developed areas surrounding the wetland tussock and the likelihood of receiving permission to burn in such close proximity to houses and structures is unlikely. Based on the Orange County Property Appraisers web site, the wetland tussock is privately owned by several entities. It is also possible that the wetland tussock could be considered waters of the state. Research would need to be conducted with the Florida Department of Environmental Protect if it is waters of the state.

Table 6-14
Wetland Tussock Harvesting Pollutant Removal and Costs

Description	Amount
TP Load kg/yr	23.2
TN Load kg/yr	152.0
TP Removal Efficiency*	100%
TN Removal Efficiency*	100%
TP Removed (kg/yr)	23.2
TN Removed (kg/yr)	152.0
Harvesting Cost**	$600,000
TP Cost per Kg Removed	$25,862
TN Cost per Kg Removed	$3,947

* Assumed Future removal efficiency with plant material removed
** Does not include permitting, mitigation or restoration costs

6.10 GOLF COURSE TREATMENT AND OUTFALL ENHANCEMENT – BOLD AND GOLD

The northwest portion of the Windermere Country Club Golf Course currently drains to a generally dry depressional area before discharging directly to Lake Roberts. The existing depressional area is not maintained. Furthermore, during field investigations the outfall into the lake could not be found, and is likely buried and partially blocked by sediment and vegetation.

The recommended BMPs for this location are either a wet detention pond or a bioretention area.

Use of a bioretention area requires surface runoff to be directed into a shallow landscaped depression. The primary component of bioretention is the filter bed, which is typically comprised of a mixture of sand, soil, and organic material as the filtering media with a

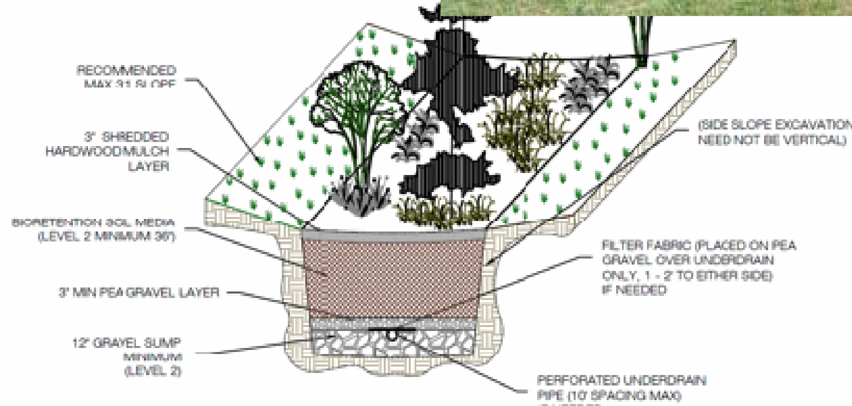


Illustration: Typical Bioretention Area

surface mulch layer. The filter media can be augmented with an absorption material such as Bold and Gold, an engineered biosorption activated media that removes solids and dissolved contaminates. During storms, runoff into the bioretention area temporarily ponds 6 to 12 inches above the mulch layer and then rapidly filters through the bed. Normally, the filtered runoff is collected in an underdrain and returned to the storm drain system. The underdrain consists of a perforated pipe in a gravel layer installed along the bottom of the filter bed. A bioretention facility with an underdrain system is commonly referred to as a Bioretention Filter.

Bioretention can also be designed to infiltrate runoff into native soils. This can be done at sites with permeable soils, a low groundwater table, and a low risk of groundwater contamination. This design features the use of a "partial exfiltration" system that promotes greater groundwater recharge. Underdrains are only installed beneath a portion of the filter bed, above a stone "sump" layer, or eliminated altogether, thereby increasing stormwater infiltration. A bioretention facility without an underdrain system, or with a storage sump in the bottom is commonly referred to as a Bioretention Basin. Based on the Virginia DRC Stormwater Design Specifications, the TP and TN removal rates are 25% and 40%, respectively.

Wet detention ponds consist of a permanent pool of standing water that promotes a better environment for gravitational settling, biological uptake and microbial activity. Runoff from each new storm enters the pond and partially displaces pool water from previous storms. The pool also acts as a barrier to re-suspension of sediments and other pollutants deposited during prior storms. When sized properly, wet ponds have a residence time that ranges from many days to several weeks, which allows numerous pollutant removal mechanisms to operate. Based on the Virginia DRC Stormwater Design Specifications the TP and TN removal rates are 50% and 30%, respectively. However, it should be noted that removal efficiently for wet ponds are highly variable and dependent on the quality of the incoming water and the resident time within the pond

Figure 6-7 illustrates the proposed location of the bioretention area or wet pond. The drainage basin area from the golf course is approximately 24 acres. The top of bank area for the proposed pond is 1.3 acres (5.4%). Bioretention is generally designed with 1-ft of storage, which would equate to treating 0.65-inches of runoff over the 24-acre site. Wet ponds are generally designed with 1.5-ft of detention volume, which would equate to treating 0.97-inches of runoff over the 24-acre basin.

A new concrete control structure should be constructed within the bio retention area/wet pond for adequate detention of runoff. A new outfall pipe from the pond to Lake Roberts should also be constructed, or the slip line the existing pipe if it is adequate condition. A new headwall design to allow for simpler on-going maintenance should also be constructed within Lake Roberts.

Tables 6-15 and 6-16 detail the estimated nutrient removal and costs that are expected with bioretention and wet ponds.

Table 6-15
Bioretention Pollutant Removal and Costs

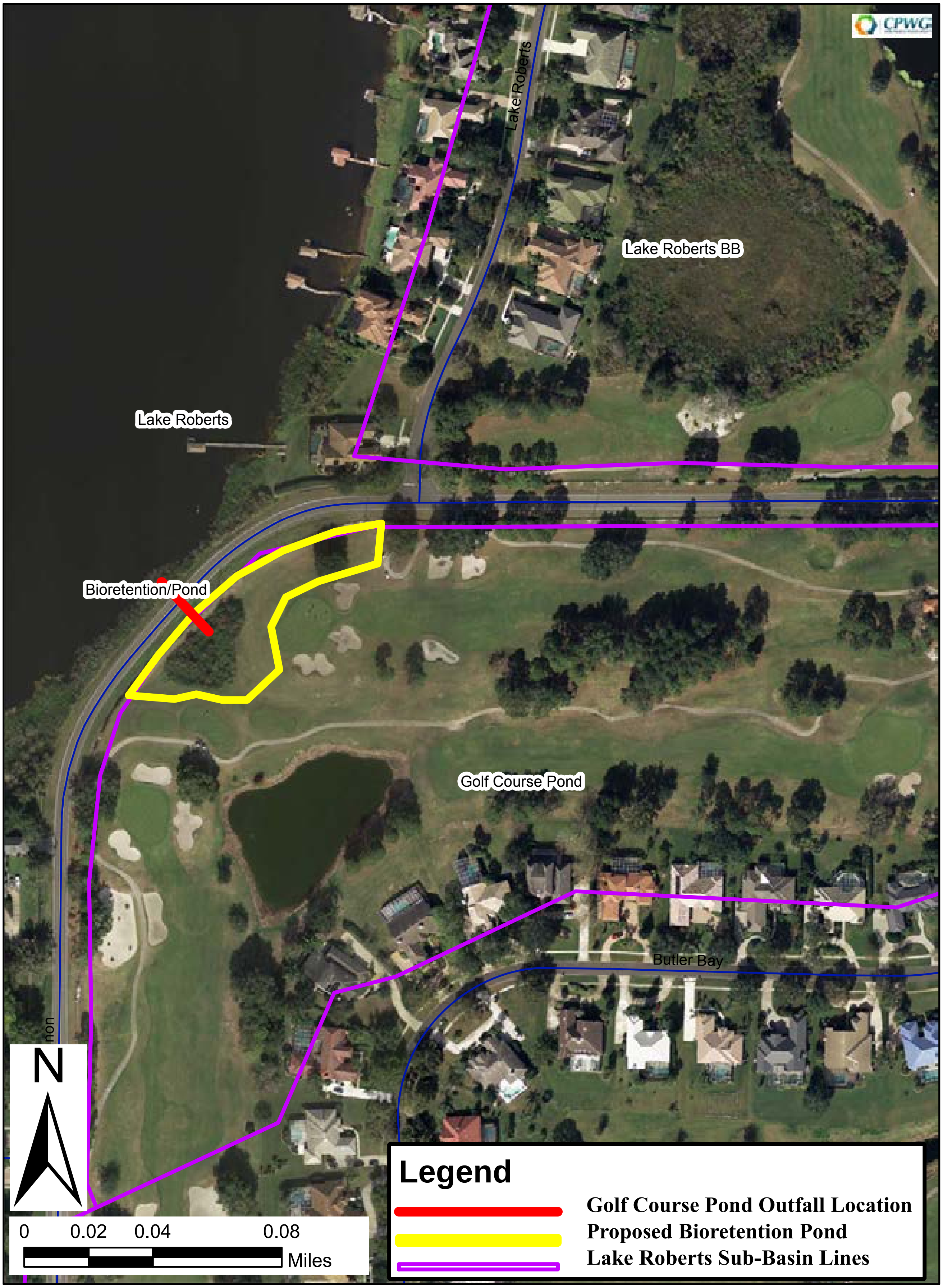
Description	Amount
TP Load kg/yr	0.8
TN Load kg/yr	7.2
TP Removal Efficiency	25%
TN Removal Efficiency	40%
TP Removed (kg/yr)	0.2
TN Removed (kg/yr)	2.9
Construction Cost	$93,000
TP Cost per Kg Removed	$448,193
TN Cost per Kg Removed	$32,202

*Not including land costs

Table 6-16
Wet Pond Pollutant Removal and Costs

Description	Amount
TP Load kg/yr	0.8
TN Load kg/yr	7.2
TP Removal Efficiency	50%
TN Removal Efficiency	30%
TP Removed (kg/yr)	0.4
TN Removed (kg/yr)	2.2
Construction Cost	$185,000
TP Cost per Kg Removed	$445,783
TN Cost per Kg Removed	$85,411

*Not including land costs



Bioretention / Wet Pond Alternative

Figure 6-7

6.11 INLET BASKETS

A majority of the subdivisions to the north of the lake have been constructed with wet detention stormwater treatment facilities that outfall to Lake Roberts. A majority of the subdivisions to the west, east and south of the lake have limited stormwater treatment.

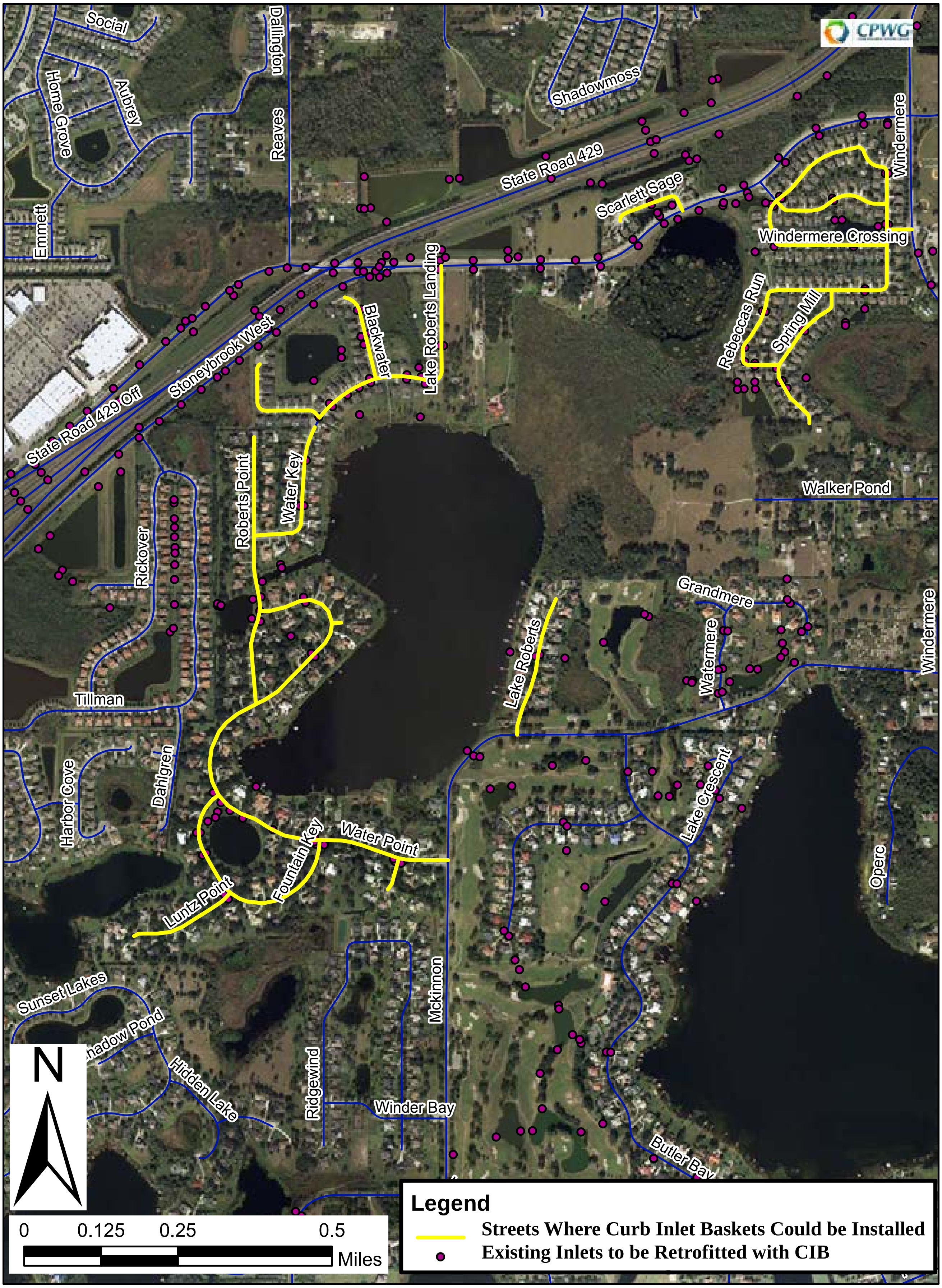
Installation of curb and grate inlet filters within the Lake Roberts watershed would collect leaves, trash, large sand, and other debris present in the generated stormwater runoff prior to discharge into the lake or the wet detention pond. Curb inlet baskets (CIBs) and grate inlet baskets (GIBs), also referred to as catch basin basket inserts (or inlet baskets), are a retrofit-type BMP designed to filter pollutants, leaf litter, and sediments from stormwater before the pollutants enter the stormsewer system. These units are installed in individual inlets or grate inlets and are made of durable material, such as stainless steel and high-strength plastic. The installed units are relatively inexpensive, with an installed cost of approximately $1,000/unit. Maintenance of the systems is relatively simple, requiring approximately 5-10 minutes to clean each unit with a vacuum-type truck. The average volumes for the CIBs and GIBs installed by OCEPD are 3.8 ft^3 and 4.3 ft^3, respectively. These units should be cleaned out on a monthly basis by the home owners association, county or a local contractor.

Locations of proposed curb and grate inlet filters in the Lake Roberts watershed are illustrated on Figure 6-8. Please note the installation of the CIBs is subject to the proposed locations meeting installation criteria. Literature values indicated a TP removal rate of 4.4kg/curb mile/year and TN removal rate of 12.0 kg/curb mile/year. Bold and Gold or another filter material can also be added to the inlet baskets to increase their pollutant removal efficiencies. Reports of Bold and Gold usage indicate removal efficiencies up to 87% for TP and 47% for TN. A pond study in Seminole County, Florida exhibited removal efficiencies of 25% for TP and 17% for TN. Most inlets, baffle boxes and outfall structures can be modified to use Bold and Gold filter material. Table 6-17 details to estimated nutrient removal and costs that are expected with inlet basket installation without Bold and Gold usage.

Table 6-17
Inlet Basket Pollutant Removal and Costs

Description	Amount
Road Length	9.7
TP Removal kg/curb mile/year	4.4
TN Removal kg/curb mile/year	12.0
TP Removed (Kg/yr)	42.5
TN Removed (Kr/yr)	116.5
Number of Inlets	85
Cost Per inlet Basket	$1,000
Construction Cost	$85,000
O&M Costs (annual)	4,250
TP Cost per Kg Removed	$19,472
TN Cost per Kg Removed	$7,100
TP Cost per Kg Removed*	$200
TN Cost per Kg Removed*	$73

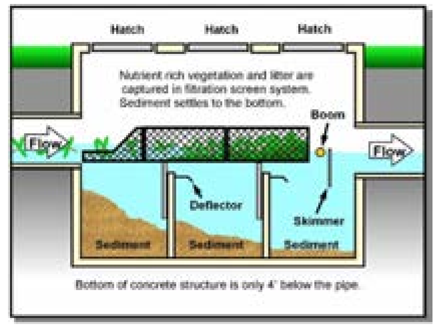
* Amortized over 20 year life cycle



Curb Inlet Basket Alternatives

Figure 6-8

6.12 BAFFLE BOXES



Baffle boxes were initially designed to collect sediment and debris. As the technology has progressed, design improvements have allowed the removal of nutrients as well. For nutrient separating baffle boxes DEP currently allows the use of the following removal efficiencies for grant applications and other uses: 16% for TP and 19% for TN. Similar to the inlet baskets, Bold and Gold or other media can be added to baffle boxes to increase their nutrient removal capabilities. The capital cost to add Bold and Gold is estimated at $6,000 per baffle box. The 2-3 cubic yards of the media in the baffle box would require replaced every five to seven years at an estimated cost of $5,500.

Three locations within the Lake Roberts watershed are included as baffle box location alternatives: 1) Lake Roberts Court on the eastern shoreline 2) Water Point Boulevard on the southwestern shoreline and 3) Windermere Golf Course Outfall on the eastern shore. The baffle box locations are shown in Figure 6-9. Tables 6-18 6-19, and 6-20 detail the estimates for pollutant removal amounts and costs both with and without the use of Bold and Gold filtration media.

Table 6-18
Baffle Box at Water Point Boulevard Pollutant Removal and Costs
(with and without the use of Bold and Gold)

Description	Amount
TP Load kg/yr	4.1
TN Load kg/yr	35.0
Without Bold and Gold	
TP Removal Efficiency	16%
TN Removal Efficiency	19%
TP Removed (kg/yr)	0.66
TN Removed (kg/yr)	6.6
Construction Cost	$70,000
Operation & Maintenance Costs (annually)	$2,000
TP Cost per Kg Removed (first year)	$109,091
TN Cost per Kg Removed (first year)	$10,909
TP Cost per Kg Removed*	$8,333
TN Cost per Kg Removed*	$833
With Bold and Gold	
TP Removal Efficiency	79%
TN Removal Efficiency	67%
TP Removed (kg/yr)	3.2
TN Removed (kg/yr)	23.4
Construction Cost	$75,500
Operation & Maintenance Costs (annually)	$2,000
Operation & Maintenance Costs (every 5 years)	$5,500
TP Cost per Kg Removed (first year)	$23,594
TN Cost per Kg Removed (first year)	$3,226
TP Cost per Kg Removed*	$2,063
TN Cost per Kg Removed*	$282

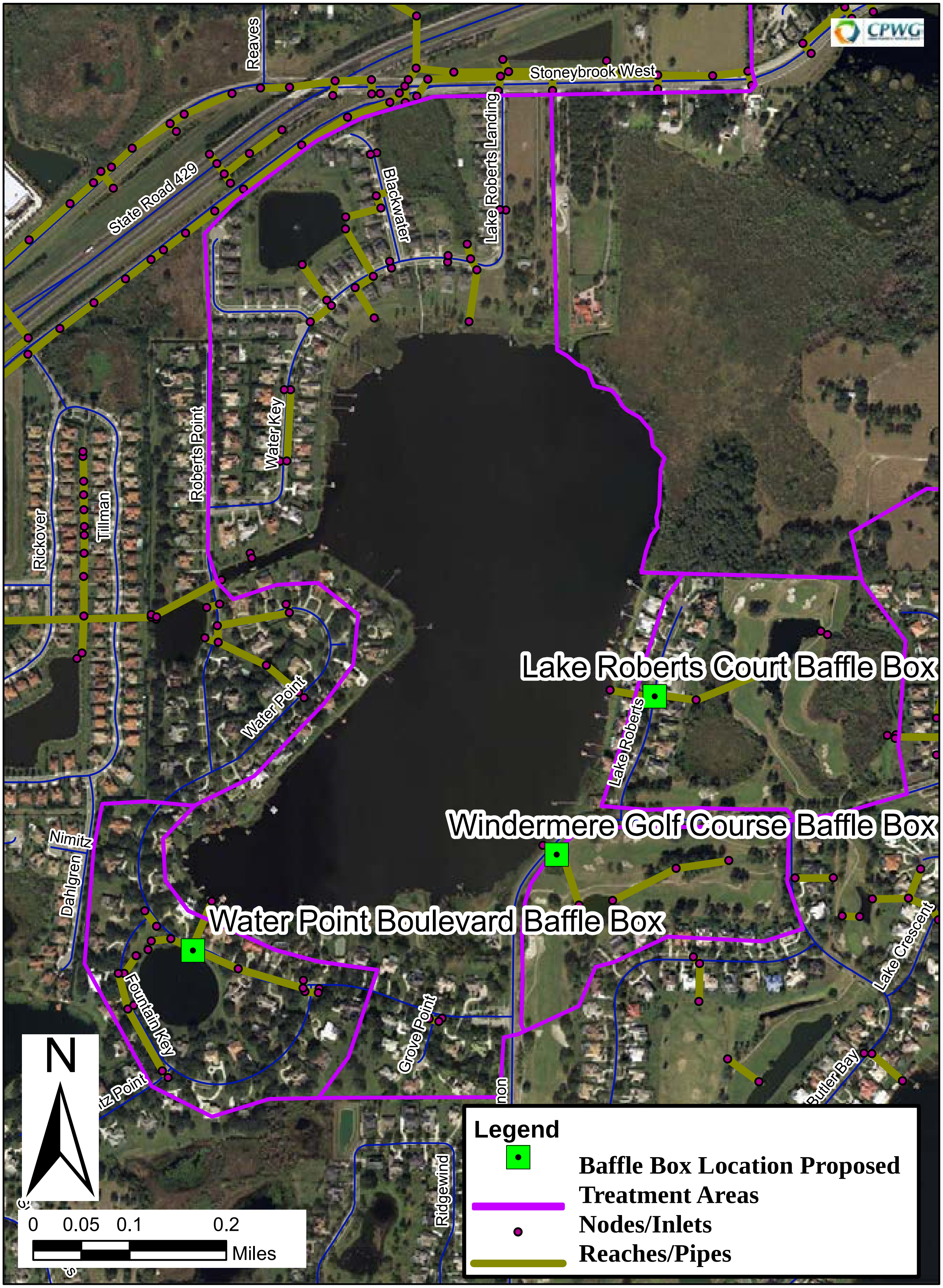
* Amortized over 20 year life cycle

Table 6-19
Baffle Box at Lake Roberts Court Pollutant Removal and Costs
(with and without the use of Bold and Gold)

Description	Amount
TP Load kg/yr	6.9
TN Load kg/yr	70.0
Without Bold and Gold	
TP Removal Efficiency	16%
TN Removal Efficiency	19%
TP Removed (kg/yr)	1.1
TN Removed (kg/yr)	13.3
Construction Cost	$70,000
Operation & Maintenance Costs (annually)	$2,000
TP Cost per Kg Removed (first year)	$65,455
TN Cost per Kg Removed (first year)	$5,414
TP Cost per Kg Removed*	$5,000
TN Cost per Kg Removed*	$414
With Bold and Gold	
TP Removal Efficiency	79%
TN Removal Efficiency	67%
TP Removed (kg/yr)	5.5
TN Removed (kg/yr)	46.9
Construction Cost	$75,500
Operation & Maintenance Costs (annually)	$2,000
Operation & Maintenance Costs (every 5 years)	$5,500
TP Cost per Kg Removed (first year)	$14,091
TN Cost per Kg Removed (first year)	$1,652
TP Cost per Kg Removed*	$1,200
TN Cost per Kg Removed*	$141

Table 6-20
Baffle Box at Windermere Golf Course Outfall Pollutant Removal and Costs
(with and without the use of Bold and Gold)

Description	Amount
TP Load kg/yr	0.8
TN Load kg/yr	7.2
Without Bold and Gold	
TP Removal Efficiency	16%
TN Removal Efficiency	19%
TP Removed (kg/yr)	0.13
TN Removed (kg/yr)	1.4
Construction Cost	$70,000
Operation & Maintenance Costs (annually)	$2,000
TP Cost per Kg Removed (first year)	$553,846
TN Cost per Kg Removed (first year)	$51,429
TP Cost per Kg Removed*	$42,307
TN Cost per Kg Removed*	$3,929
With Bold and Gold	
TP Removal Efficiency	79%
TN Removal Efficiency	67%
TP Removed (kg/yr)	0.63
TN Removed (kg/yr)	4.82
Construction Cost	$75,500
Operation & Maintenance Costs (annually)	$2,000
Operation & Maintenance Costs (every 5 years)	$5,500
TP Cost per Kg Removed (first year)	$119,048
TN Cost per Kg Removed (first year)	$16,079
TP Cost per Kg Removed*	$10,476
TN Cost per Kg Removed*	$1,369



Baffle Box Alternatives

Figure 6-9

6.13 NON-STRUCTURAL TECHNIQUES

A number of non-structural techniques are also available which have the potential to reduce phosphorus loadings entering waterbodies. Examples of non-structural techniques include enhanced regulations for erosion and sediment control, as well as stormwater management. However, a majority of the Lake Roberts drainage basin is currently developed, and opportunities for enhancing sediment and erosion control and stormwater management regulations are severely limited within the basin. Another popular non-structural technique is revegetation of shoreline areas which is addressed in Section 6.7. Another non-structural technique is a source reduction program which attempts to reduce pollutant accumulation within the watershed. These programs have a valid potential for improving the characteristics of stormwater runoff in the Lake Roberts drainage basin.

Source reduction programs have the potential to provide effective reductions in stormwater concentrations, particularly for nutrients and suspended solids. Source reduction techniques, such as street sweeping and public education, are capable of reducing loadings of pollutants entering receiving waterbodies by reducing pollutant accumulation within the watershed. If properly conducted, source reduction programs can be almost as effective as changes in stormwater regulations for reducing pollutant loadings to lakes. The two most common source reduction techniques are street sweeping and public education. These two techniques, among others, are discussed in the following sections.

6.13.1 FLORIDA YARDS AND NEIGHBORHOODS PROGRAM

The Florida Yards and Neighborhoods (FYN) Program is a project of the Florida Department of Environmental Protection and is presented by the University of Florida's IFAS extension and the Southwest Florida Water Management District. These organizations have developed the Florida-Friendly Landscaping program to educate Floridians about science-based, environmentally friendly, landscaping practices and to encourage them to conserve and protect our water resources by applying 9 basic principles:

1) <u>Right Plant, Right Place</u>: Plants selected to suit a specific site will require minimal amounts of water, fertilizers and pesticides.
2) <u>Water Efficiently</u>: Irrigate only when your lawn needs water. Efficient watering is the key to a healthy yard and conservation of limited resources.
3) <u>Fertilize Appropriately</u>: Less is often best.

4) Mulch: Maintain two to three inches of mulch to help retain soil moisture, prevent erosion and suppress weeds.
5) Attract Wildlife: Plants that provide food, water and shelter can conserve Florida's diverse wildlife.
6) Manage Yard Pests Responsibly: Unwise use of pesticides can harm people, pets, beneficial organisms and the environment.
7) Recycle: Grass clippings, leaves, and yard trimmings composted and recycled on site provide nutrients to the soil and reduce waste disposal.
8) Reduce Stormwater Runoff: Water running off the yard can carry pollutants such as fertilizer, pesticides, soil and debris that can harm water quality. Reduction of this runoff will help prevent pollution.
9) Protect the Waterfront: Waterfront property, whether on a river, stream, pond, bay or beach, is very fragile and should be carefully protected to maintain freshwater and marine ecosystems.

Landowners around Lake Roberts are encouraged to implement these principles to improve the water quality of the lake. An important aspect of the FYN program is education. If residents do not know the importance of these actives, then they cannot implement these. Distributing information in homeowner association newsletters, newspapers and other public service announcements (PSAs), such as informational pamphlets, educational presentations, and informative stormwater websites are encouraged.

6.13.2 STREET SWEEPING

Street sweeping is an effective best management practice (BMP) for reducing total suspended solids and associated pollutant wash-off from urban streets. Street sweeping is well suited to an urban environment where little land is available for installation of structural controls. Street sweeping can be extremely effective in commercial business districts, industrial sites, residential areas with significant tree cover and intensely developed areas in close proximity to receiving waters.

Street sweeping involves the use of machines that pick-up contaminants from the street surface and deposit them in a self-contained bin or hopper. Mechanical sweepers are the most commonly used sweeping devices and consist of a series of brooms which rotate at high speeds, forcing debris from the street and gutter into a collection hopper. Water is often sprayed on the surface for dust control during the sweeping process. The effectiveness of mechanical sweepers is a function of a number of factors, including: (1) particle size distribution of accumulated surface contaminants; (2) sweeping frequency; (3) number of passes during each sweeping event; (4) equipment speed; and (5) pavement conditions. Unfortunately, mechanical sweepers perform relatively poorly for collection of particle sizes <100 microns which are commonly associated with total phosphorus loadings in stormwater runoff.

Currently street sweeping is not performed in the Lake Roberts watershed.

It is recommended that street sweeping operations be expanded to include all roadway areas within the Lake Roberts drainage basin. These activities will further reduce discharges of litter, dirt, and vegetation into Lake Roberts and reduce the nutrient loadings associated with runoff inflows. Many of the areas not currently included in the existing street sweeping program do not have curb and gutter systems and use roadside swales for drainage. Mechanical broom sweepers typically require a curb and gutter system for proper operation, and therefore, vacuum-type sweepers are recommended in areas without curb and gutter systems.

The efficiency of street sweepers is highly dependent upon the sweeping interval. To achieve a 20% annual removal of TP, street sweeping should be performed twice a week. Since the average interval between storms in the Central Florida area is approximately three days, a sweeping frequency of once every three days is recommended to yield a 20% removal of TP. Orange County usually conducts sweeping operations once every six weeks, removing an estimated 5% of TP or approximately 0.35 lb/curb mile per year. Table 6-21 displays the removal efficiency of street sweeps at varying time intervals.

Table 6-21

Removal Efficiency of Street Sweeping at Various Frequencies

Street Sweep Frequency	% of Total TP Load	TP lbs/curb mile	TN lbs/curb mile
Every 6 Weeks	5%	0.35	1.46
Every 2 Weeks	10%	0.7	2.94
Weekly	15%	1.4	5.88
Twice Weekly	20%	2.81	11.8

Street sweeping activities can be particularly effective during periods of high leaf fall by removing solid leaf material and the associated nutrient loadings from roadside areas where they can easily become transported by stormwater flow. Previous research has indicated that leaves release large quantities of both nitrogen and phosphorus into surface water within 24-48 hours after becoming saturated in an aquatic environment. Loadings to waterbodies from leaf fall are often the most significant loadings during the fall and winter months. Increasing street sweeping during heavy leaf fall is recommended in the Lake Roberts watershed.

Capital costs for street sweepers range from approximately $70,000-$150,000, with the lower end of the range associated with mechanical street sweepers and the higher end of the range associated with vacuum-type sweepers. The useful life span is typically 4-8 years, with an operating cost of approximately $70/hour.

As discussed previously, the frequency of street sweeping operations is highly dependent upon the sweeping interval. Removal of 20% of TP can be achieved with a sweeping frequency of approximately twice weekly. Thus, a 20% removal of TP would require street sweeping to occur approximately once every three days, which appears to be both physically and economically infeasible. Therefore, street sweeping operations are recommended to occur at a frequency of once each week. This frequency will result in an annual reduction of approximately 15% of the mass of TP which accumulates within the watershed. Estimated pollutant removal and associated costs are presented in table 6-22.

Table 6-22
Street Sweeping Removal and Costs

Description	Amount
Road Length	9.7
TP Removal kg/curb mile/year	1.4
TN Removal kg/curb mile/year	5.88
TP Removed (kg/yr)	13.58
TN Removed (kg/yr)	57.0
Cost Per curb mile	$80
Operation Cost	$40,352
TP Cost per Kg Removed	$2,971
TN Cost per Kg Removed	$708

*Assumes weekly sweeping

6.13.3 PUBLIC EDUCATION

Public education is one of the most important nonpoint source controls which can be used in a watershed. Many residents appear to be unaware of the direct link between watershed activities and the water quality in adjacent waterbodies. The more a resident or business owner understands the relationship between nonpoint source loadings and receiving water quality, the more that person may be willing to implement source controls.

Several national studies have indicated that it is an extremely worthwhile and cost-effective activity to periodically remind property owners of the potential for water quality degradation which can occur due to misapplication of fertilizers and pesticides. Periodic information pamphlets can be distributed by hand or enclosed with water and sewer bills which will reach virtually all residents within the watershed. These educational brochures should emphasize the fact that taxpayer funds are currently being utilized to treat nonpoint source water pollution, and the homeowners have the opportunity to reduce this tax burden by modifying their daily activities. A comprehensive public education program should concentrate, at a minimum, on the following topics:

1. Relationship between land use, stormwater runoff, and pollutants
2. Functions of stormwater treatment systems
3. How to reduce stormwater runoff volume
4. Impacts of water fowl and pets on runoff characteristics and surface water quality
5. County stormwater program goals and regulations
6. Responsible use of fertilizer, pesticides and herbicides
7. Elimination of illicit connections to the stormwater system
8. Controlling erosion and turbidity
9. Proper operation and maintenance of stormwater systems

The public education program can be implemented in a variety of ways, including homeowner and business seminars, newsletters, performing special projects with local schools (elementary, middle and high schools), Earth Day celebrations, brochures, and special signage at stormwater treatment construction sites. Many people do not realize that stormsewers eventually drain to area lakes. Many cities and counties in Florida have implemented a signage program which places a small engraved plaque on each stormsewer inlet indicating "Do Not Dump, Drains to Lake". It is recommended that an aggressive public education program be implemented in the Lake Roberts watershed which incorporates all of the elements discussed previously.

Anticipated load reductions for implementation of public education programs are difficult to predict and depend highly upon the degree of implementation by the homeowners within the basin. The impacts of public education programs also depend, to a large extent, on the degree to which water quality within the Lake Roberts basin is currently being impacted by uneducated and uninformed activities by current homeowners. Several regional and national studies are currently being performed which will attempt to document the pollutant removal effectiveness of public education programs.

6.13.4 BOATING IMPACTS

Lake Roberts is used extensively for boating and recreational activities, particularly on weekends and during summer months. Several previous studies have been conducted to evaluate the impacts of boating and recreational activities on water quality in lakes. One of the first studies on the impacts of motor boats on water quality in shallow lakes was conducted by Yousef, et al. (1980). The maximum engine size used in this study was 165 HP which was one of the largest engines available at that time. The study concluded that operation of this boat and engine combination caused resuspension of bottom sediments in water as deep as 10-15 ft.

Based upon the results of the boating impact study performed by Yousef, et al., it is recommended that normal motor boating activities within Lake Roberts be restricted to water depths of approximately 10 ft. or more. These areas should be clearly outlined within the lake using buoys, with no wake restrictions in force between the buoys and the shoreline. The proposed 10-ft depth restriction for full-speed activities will also assist in minimizing human-caused shoreline erosion and impacts to beneficial vegetation within and surrounding the lake. The benefit of this restriction on aquatic flora is two-fold because it would also prevent excessive sediment resuspension; which has been shown to significantly increase phosphorous levels in lakes with high internal loading and lead to increased algae growth.

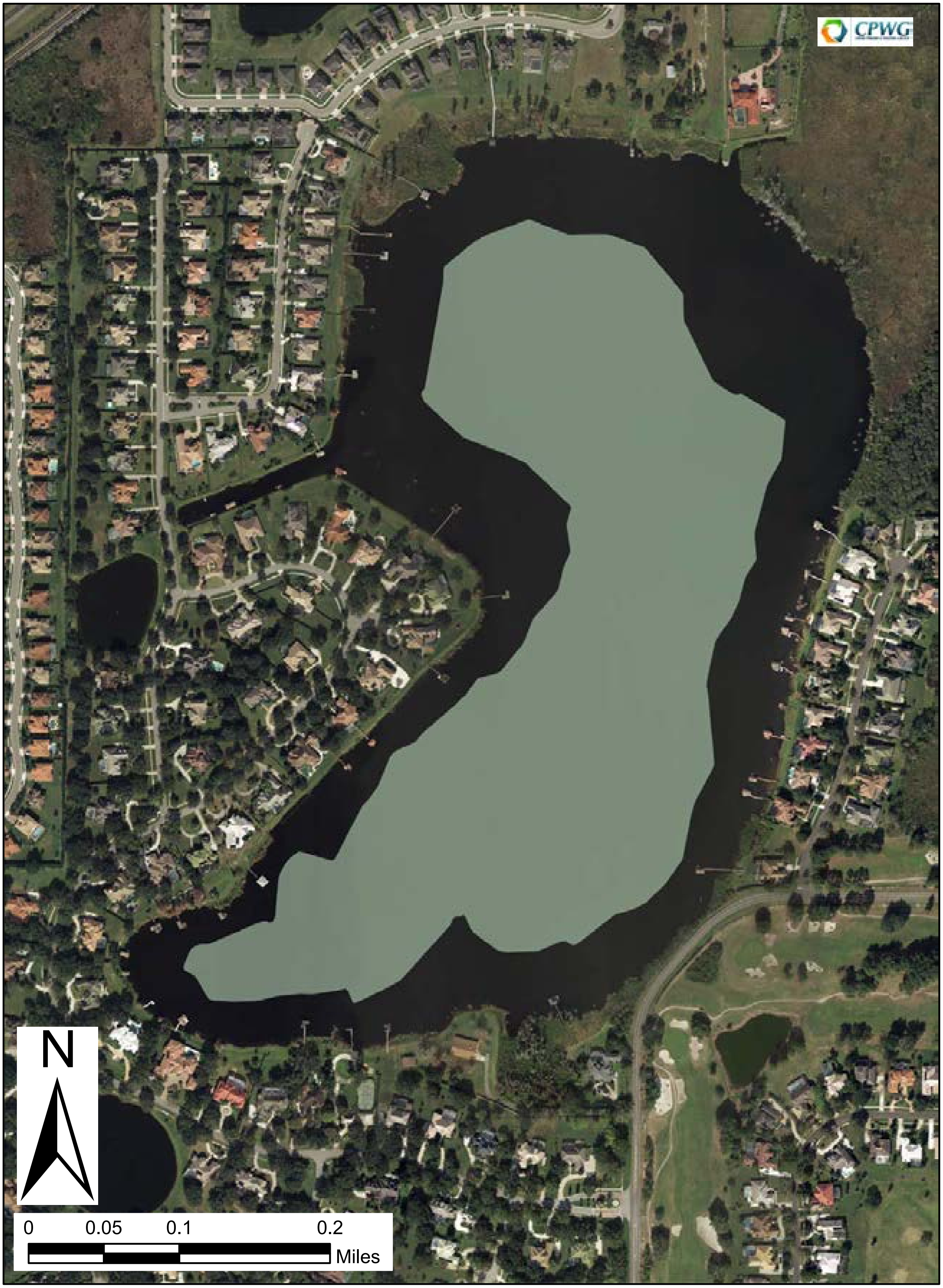
A new generation of ski and wakeboard boats which have onboard ballast tanks that can be filled with water to enhance the wake generated behind the boat have been recently introduced. These types of boats have the potential to create water column disturbances to deeper depths than occur as a result of typical motor boating activities. Therefore, it is generally recommended that normal operation using these types of boats be limited to areas where the water depth is 15 ft or more.

A diagram indicating areas within Lake Roberts which are approximately 10 ft. in depth or more are indicated on Figure 6-10. This represents the areas where normal full-speed boating activities would be allowed based upon these new recommendations. These areas include the vast majority of the central portion of the lake.

Areas of water depth of approximately 15 ft or more are indicated on Figure 6-11. The areas indicated on this figure are those which would be suitable for use by enhanced-wake boats. Areas within the lake which are suitable for this type of activity are limited to most central portion of the lake and may not be feasible to implement.

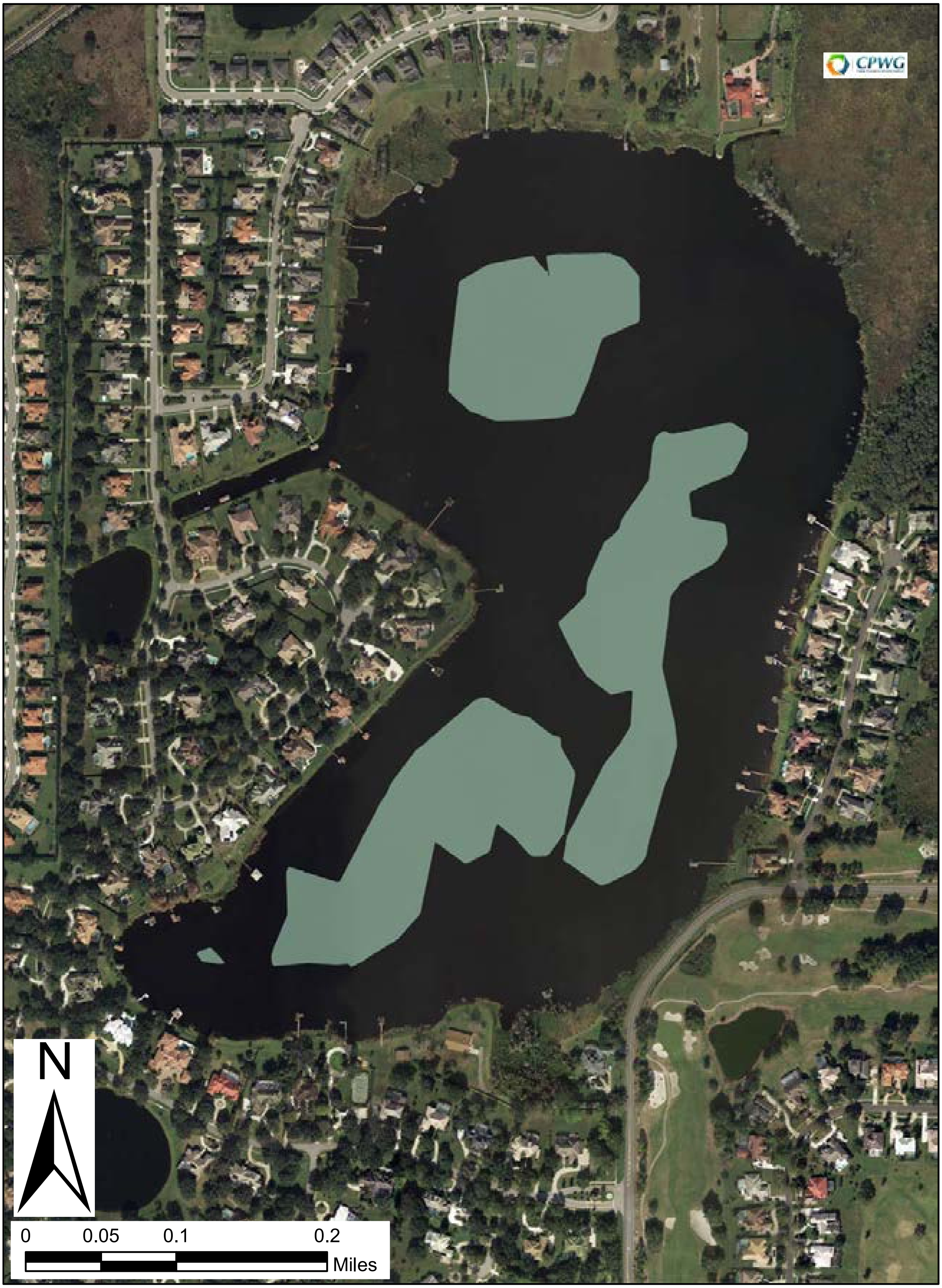
A minimum water depth of 10 ft in Lake Roberts for normal boating activities is recommended. Boating activities in water depths less than 10 ft would be limited to no-wake conditions only. Orange County Ordinance Section 8-31 designates that no wake shall be created while operating within a canal, or within 100 ft of the shoreline, docks, piers, bridges or boathouses. Areas designated for boating activities should be marked with buoys. The buoys would provide boundaries for boating zones.

The recommendations outlined previously are intended to apply to motor boats only. Personal water craft use a jet propulsion system which discharges water horizontally just below the water surface. These types of water craft create very little vertical disturbance within the water column and do not necessarily need to be limited to the same water depths recommended for traditional boats. However, even personal water crafts should not be operated in water with depths less than 5-6 ft. for both water quality and safety reasons. Therefore, it is recommended that operation of personal water craft be restricted to water depths in excess of 6 ft.



Areas of Lake Roberts with Water Depth Greater than 10-ft

Figure 6-10



Areas of Lake Roberts with Water Depth Greater than 15-ft

Figure 6-11

6.14 RECOMMENDED MANAGEMENT OPTIONS

A summary of recommended management options for Lake Roberts is given in Table 6-23. These recommendations are based upon the discussions and evaluations provided in previous sections. Many of the recommended management options have relatively low associated costs, such as developing ordinances, restricting lawn maintenance activities, public education campaigns, re-establishment of natural vegetated shorelines, and restricting boating activities in shallow areas of the lake. Each of the recommended management options have the potential to result in improvements in water quality characteristics in Lake Roberts. It is recommended that the management options be implemented as funding sources and opportunities become available.

The draft version of the Florida Department of Environmental Protection’s "TMDL Report Nutrient TMDL for Lake Roberts (WBID 2872A)", March 5, 2015 was recently published. The DEP report estimates a TP load of 138 kg/yr and calls for a 46 kg/yr (33%) reduction to meet the 0.041 mg/l TP target concentration. The DEP report estimates a TN load of 1,964 kg/yr and calls for a 321 kg/yr (16%) reduction to meet the 0.959 mg/l TN target concentration. These reduction goals, along with the percentage reduction that each option provides, are presented in Table 6-23.

Table 6-23
Recommended Management Options for Lake Roberts

Option	Description	TP *** Percent Reduction	TN *** Percent Reduction	TP Removed (kg/yr)	TN Removed (kg/yr)	Required TP Reduction* (kg/yr)	Required TN Reduction* (kg/yr)	% of Goal	% of Goal	Cost
1	Sediment Inactivation (soil)**	90	50	1,464.0	0.0	46	321	3,182.6%	0.0%	$223,736
2	Sediment Inactivation (groundwater)**	90	50	49.0	0.0	46	321	106.5%	0.0%	$7,489
3	Sanitary Sewer Installation	100	100	7,866.0	25,479.0	46	321	17,100.0%	7937.4%	$3,000,000
4	Septic Tank Maintenance/Upgrading Septic System	NA	NA	NA	NA	46	321	NA	NA	$570,000
5	Rear Yard Swales and Berms	52	52	4.2	31.1	46	321	9.1%	NA	$285,000
6	Vegetated Shorelines	NA	NA	NA	NA	46	321	NA	NA	NA
7	Landscape Activities	NA	NA	NA	NA	46	321	NA	NA	NA
8	Floating Wetlands	12	12	8.0	158.0	46	321	17.4%	49.2%	$1,398,276
9	Harvest and Dredge Wetland Area****	100	100	23.2	152.0	46	321	50.4%	47.4%	$600,000
10	Golf Course Treatment Bioretention	25	40	0.2	2.9	46	321	0.4%	0.9%	$93,000
11	Golf Course Treatment Wet Pond	50	30	0.4	2.2	46	321	0.9%	0.7%	$185,000
12	Inlet Baskets	NA	NA	42.5	116.5	46	321	92.4%	36.3%	$85,000
13	Baffle Box - Water Point Blvd.	16	19	0.7	6.6	46	321	1.4%	2.1%	$70,000
14	Baffle Box - Lake Roberts Court	16	19	1.1	13.3	46	321	2.4%	4.1%	$70,000
15	Baffle Box - Windermere Golf Course Outfall	16	19	0.1	1.4	46	321	0.2%	0.4%	$70,000
16	Baffle Box with Bold and Gold- Water Point Blvd.	79	67	3.2	23.4	46	321	7.0%	7.3%	$75,500
17	Baffle Box with Bold and Gold- Lake Roberts Court	79	67	5.5	46.9	46	321	12.0%	14.6%	$75,500
18	Baffle Box with Bold and Gold - Windermere Golf Course Outfall	79	67	0.6	4.8	46	321	1.3%	1.5%	$75,500
19	Street Sweeping	NA	NA	3.6	57.0	46	321	7.8%	17.8%	$40,352
20	Public Education	NA	NA	NA	NA	46	321	NA	NA	NA
21	Boating Impacts	NA	NA	NA	NA	46	321	NA	NA	NA

* Based on pollutant removal targets in FDEP's "TMDL Report Nutrient TMDL for Lake Roberts (WBID 2872A)", March 5, 2015 Draft Version
** Based on one complete application –successive applications do not apply. Cost assumes items 1 and 2 are performed at the same time
*** Based on Basin Management Action Plan for Lake Okeechobee and other sources as sited in the report
**** Only assumes removal of nutrient released from the wetland. The actual TP and TN reduction due to biomass removal may be much greater.

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APPENDIX 2-1

Vertical Field Profiles Collected in Lake Roberts, Wetland Tussock and Lake Reaves September 2013 through August 2014

Vertical Field Profiles collected in Lake Roberts, Wetland and Lake Reaves
September 2013 through August 2014

Location	Site	Date	Depth (meter)	Temp (^{o}C)	SpCond (umho/cm)	pH Units	DO (%)	DO (mg/l)	ORP (mV)	Turbidity (NTU)	Secchi (meter)
North	S1	9/25/2013	0.5	27.4	204	7.1	65.2	5.1	173.2	8.9	0.93
North	S1	9/25/2013	1.0	27.4	204	7.1	64.4	5.1	168.1	11.1	
North	S1	9/25/2013	1.5	27.4	204	7.1	63.8	5.0	164.8	9.5	
North	S1	9/25/2013	2.0	27.4	204	7.0	63.4	5.0	162.7	8.9	
North	S1	9/25/2013	2.5	27.4	204	7.0	62.4	4.9	159.4	10.4	
North	S1	9/25/2013	3.0	27.4	204	7.0	61.7	4.9	155.8	9.3	
Center	S2	9/25/2013	0.5	27.7	203	7.0	62.3	4.9	190.9	8.6	0.94
Center	S2	9/25/2013	1.0	27.7	204	7.0	61.6	4.9	188.0	8.7	
Center	S2	9/25/2013	1.5	27.7	204	7.0	62.5	4.9	185.7	8.4	
Center	S2	9/25/2013	2.0	27.7	204	7.0	62.6	4.9	183.8	8.3	
Center	S2	9/25/2013	2.5	27.7	204	7.0	62.6	4.9	182.1	8.3	
Center	S2	9/25/2013	3.0	27.7	204	7.0	62.8	4.9	181.2	8.2	
Center	S2	9/25/2013	3.5	27.7	204	7.0	62.8	4.9	180.7	8.7	
Center	S2	9/25/2013	4.0	27.7	205	7.0	62.7	4.9	179.4	8.6	
Center	S2	9/25/2013	4.5	27.7	205	7.0	62.5	4.9	178.6	8.4	
Center	S2	9/25/2013	5.0	27.6	205	7.0	58.2	4.6	178.1	10.3	
South	S3	9/25/2013	0.5	27.6	205	7.1	45.5	3.6	172.1	7.3	1.05
South	S3	9/25/2013	1.0	27.6	205	6.9	43.3	3.4	172.2	7.8	
South	S3	9/25/2013	1.5	27.6	205	6.9	42.9	3.4	172.3	7.2	
South	S3	9/25/2013	2.0	27.6	205	6.9	42.8	3.3	172.6	7.4	
South	S3	9/25/2013	2.5	27.6	206	6.9	41.7	3.3	173.7	7.9	
South	S3	9/25/2013	3.0	27.6	206	6.9	41.7	3.3	174.1	7.2	
South	S3	9/25/2013	3.5	27.6	206	6.9	41.7	3.3	174.7	7.3	
South	S3	9/25/2013	4.0	27.6	206	6.9	41.7	3.3	175.4	7.5	
South	S3	9/25/2013	4.5	27.6	206	6.9	41.9	3.3	175.7	7.2	
South	S3	9/25/2013	5.0	27.6	206	6.9	42.4	3.3	185.5	8.0	
South	S3	9/25/2013	5.5	27.6	206	6.9	42.3	3.3	183.5	8.3	
Wetland	S4	9/25/2013	0.5	25.1	144	5.8	12.3	0.9	-11.3	259.3	0.15
Wetland	S4	9/25/2013	1.0	25.0	143	5.8	9.2	0.7	-68.9	1770.4	
Lake Reaves	S5	9/25/2013	0.5	26.6	182	6.1	6.7	0.5	88.0	6.3	0.57
Lake Reaves	S5	9/25/2013	1.0	26.4	182	6.1	3.8	0.3	9.8	6.5	
Lake Reaves	S5	9/25/2013	1.5	26.0	181	6.1	3.4	0.3	-11.5	5.7	
Lake Reaves	S5	9/25/2013	2.0	25.8	182	6.1	3.2	0.3	-63.3	5.6	
Lake Reaves	S5	9/25/2013	2.5	25.3	184	6.0	3.0	0.3	-100.1	5.0	
Lake Reaves	S5	9/25/2013	3.0	24.7	201	6.0	2.8	0.2	-134.2	5.2	
Lake Reaves	S5	9/25/2013	3.5	24.0	211	6.0	2.7	0.2	-148.4	5.8	

Location	Site	Date	Depth (meter)	Temp (^oC)	SpCond (umho/cm)	pH Units	DO (%)	DO (mg/l)	ORP[1] (mV)	Turbidity (NTU)	Secchi (meter)
North	S1	10/21/2013	0.5	26.3	209	7.2	118.2	9.5		3.1	1.04
North	S1	10/21/2013	1.0	26.2	209	7.1	104.1	8.4		2.9	
North	S1	10/21/2013	1.5	26.1	209	7.0	88.9	7.1		3.4	
North	S1	10/21/2013	2.0	25.9	209	6.7	66.8	5.2		2.6	
North	S1	10/21/2013	2.5	25.8	208	6.5	43.6	3.5		4.3	
Center	S2	10/21/2013	0.5	26.7	210	7.7	132.3	10.6		3.0	1.12
Center	S2	10/21/2013	1.0	26.6	210	7.7	127.2	10.2		3.3	
Center	S2	10/21/2013	1.5	26.2	210	7.2	90.1	7.3		2.7	
Center	S2	10/21/2013	2.0	25.9	210	6.8	56.8	4.6		3.1	
Center	S2	10/21/2013	2.5	25.8	209	6.7	48.8	4.0		2.5	
Center	S2	10/21/2013	3.0	25.5	209	6.6	32.4	2.6		2.1	
Center	S2	10/21/2013	3.5	25.1	208	6.5	10.3	0.8		2.1	
Center	S2	10/21/2013	4.0	25.0	212	6.5	5.6	0.5		2.6	
Center	S2	10/21/2013	4.5	25.0	215	6.5	5.4	0.5		2.9	
Center	S2	10/21/2013	5.0	25.0	217	6.5	4.5	0.4		2.9	
Center	S2	10/21/2013	5.5	24.9	218	6.5	4.2	0.4		45.4	
South	S3	10/21/2013	0.5	27.3	210	8.2	152.3	12.1		3.0	1.03
South	S3	10/21/2013	1.0	26.7	210	7.7	124.0	9.7		3.3	
South	S3	10/21/2013	1.5	26.4	209	7.2	91.6	7.4		3.0	
South	S3	10/21/2013	2.0	25.9	209	6.8	71.2	5.8		2.2	
South	S3	10/21/2013	2.5	25.7	209	6.6	43.4	3.5		1.9	
South	S3	10/21/2013	3.0	25.5	208	6.5	16.8	1.4		1.9	
South	S3	10/21/2013	3.5	25.2	208	6.5	10.0	0.8		2.2	
South	S3	10/21/2013	4.0	25.1	210	6.5	7.3	0.6		2.6	
South	S3	10/21/2013	4.5	25.0	212	6.5	6.2	0.5		3.0	
South	S3	10/21/2013	5.0	25.0	215	6.5	6.6	0.6		3.1	
South	S3	10/21/2013	5.5	25.0	216	6.5	5.7	0.5		2.8	
South	S3	10/21/2013	6.0	24.9	219	6.5	5.2	0.4		5.4	
Wetland	S4	10/21/2013	0.5	22.9	164	5.8	39.4	3.3		21.8	0.24
Lake Reaves	S5	10/21/2013	0.5	24.5	187	5.8	10.2	0.8		0.5	0.69
Lake Reaves	S5	10/21/2013	1.0	23.8	187	5.7	7.5	0.6		0.2	
Lake Reaves	S5	10/21/2013	1.5	23.8	187	5.7	6.3	0.5		0.2	
Lake Reaves	S5	10/21/2013	2.0	23.4	186	5.7	6.2	0.5		0.1	
Lake Reaves	S5	10/21/2013	2.5	23.2	187	5.7	6.0	0.5		0.1	
Lake Reaves	S5	10/21/2013	3.0	23.1	189	5.7	5.6	0.5		0.1	
Lake Reaves	S5	10/21/2013	3.5	22.6	211	5.7	5.0	0.4		1304.0	

[1] ORP Values Not Recorded During this Sampling Event

Location	Site	Date	Depth (meter)	Temp (^oC)	SpCond (umho/cm)	pH Units	DO (%)	DO (mg/l)	ORP (mV)	Turbidity (NTU)	Secchi (meter)
North	S1	11/20/2013	0.5	21.3	218	7.3	90.4	8.0	-46.3	0.1	0.80
North	S1	11/20/2013	1.0	21.2	218	7.3	91.0	8.1	-46.1	0.1	
North	S1	11/20/2013	1.5	21.0	218	7.1	75.5	6.7	-31.6	0.1	
North	S1	11/20/2013	2.0	21.0	218	6.8	49.10	4.4	-17.1	0.1	
North	S1	11/20/2013	2.5	21.0	215	6.9	47.80	4.3	-18.2	0.1	
Center	S2	11/20/2013	0.5	21.8	216	7.9	106.0	9.3	-78.7	0.1	0.80
Center	S2	11/20/2013	1.0	21.7	217	7.8	101.6	8.9	-71.4	0.1	
Center	S2	11/20/2013	1.5	21.4	217	7.2	74.9	6.6	-35.9	0.1	
Center	S2	11/20/2013	2.0	21.2	217	7.3	91.40	8.1	-47.0	0.1	
Center	S2	11/20/2013	2.5	21.0	218	6.9	55.00	4.9	-19.5	0.1	
Center	S2	11/20/2013	3.0	20.7	218	6.7	30.40	2.7	-9.5	0.1	
Center	S2	11/20/2013	3.5	20.5	219	6.6	22.90	2.1	-1.2	0.1	
Center	S2	11/20/2013	4.0	20.5	219	6.5	20.50	1.7	-0.7	0.1	
Center	S2	11/20/2013	4.5	20.4	220	6.6	14.90	1.4	-0.6	0.1	
Center	S2	11/20/2013	5.0	20.5	220	6.6	6.00	0.5	-1.3	0.1	
South	S3	11/20/2013	0.5	21.9	218	7.7	101.2	8.8	-67.3	0.1	0.80
South	S3	11/20/2013	1.0	21.9	218	7.6	99.9	8.8	-64.6	0.1	
South	S3	11/20/2013	1.5	21.9	218	7.6	97.7	8.6	-61.0	0.1	
South	S3	11/20/2013	2.0	21.8	218	7.5	91.2	8.0	-53.1	0.1	
South	S3	11/20/2013	2.5	21.6	218	7.4	89.8	7.9	-50.1	0.1	
South	S3	11/20/2013	3.0	20.9	220	6.8	31.3	2.8	-13.5	0.1	
South	S3	11/20/2013	3.5	20.6	220	6.6	16.6	1.5	-3.8	0.1	
South	S3	11/20/2013	4.0	20.5	220	6.5	14.4	1.3	0.0	0.6	
South	S3	11/20/2013	4.5	20.5	220	6.5	14.7	1.3	0.0	29.3	
Wetland[2]	S4	11/20/2013									
Lake Reaves	S5	11/20/2013	0.5	21.4	204	5.5	27.4	2.4	136.1	0.1	0.50
Lake Reaves	S5	11/20/2013	1.0	21.4	204	5.5	27.2	2.4	128.0	0.1	
Lake Reaves	S5	11/20/2013	1.5	21.0	205	5.5	19.1	1.7	127.2	0.1	
Lake Reaves	S5	11/20/2013	2.0	20.2	206	5.5	3.6	0.3	134.8	0.1	
Lake Reaves	S5	11/20/2013	2.5	20.2	206	5.3	3.2	0.3	118.7	0.1	
Lake Reaves	S5	11/20/2013	3.0	20.1	205	5.3	3.1	0.3	119.0	2.7	

[2] Wetland Sample Not Collected During this Sampling Event

Location	Site	Date	Depth (meter)	Temp (^oC)	SpCond (umho/cm)	pH Units	DO (%)	DO (mg/l)	ORP (mV)	Turbidity (NTU)	Secchi (meter)
North	S1	12/18/2013	0.5	18.8	236	7.2	94.2	8.7	134.1	4.3	1.00
North	S1	12/18/2013	1.0	18.8	236	7.3	90.9	8.5	126.5	4.2	
North	S1	12/18/2013	1.5	18.7	236	7.3	88.6	8.3	124.3	4.3	
North	S1	12/18/2013	2.0	18.6	236	7.3	84.6	7.8	125.1	4.2	
North	S1	12/18/2013	2.5	18.6	236	7.2	81.9	7.7	125.0	4.6	
Center	S2	12/18/2013	0.5	19.0	236	7.3	84.4	7.8	130.6	3.6	1.14
Center	S2	12/18/2013	1.0	18.9	235	7.2	82.9	7.7	131.5	3.6	
Center	S2	12/18/2013	1.5	18.9	235	7.2	82.0	7.6	131.0	3.3	
Center	S2	12/18/2013	2.0	18.8	235	7.2	80.6	7.5	130.4	3.8	
Center	S2	12/18/2013	2.5	18.8	236	7.2	79.6	7.4	130.1	3.8	
Center	S2	12/18/2013	3.0	18.8	235	7.2	79.4	7.4	130.2	3.8	
Center	S2	12/18/2013	3.5	18.7	235	7.2	79.3	7.2	129.8	3.9	
Center	S2	12/18/2013	4.0	18.7	235	7.2	79.1	7.2	130.1	3.9	
Center	S2	12/18/2013	4.5	18.7	236	7.2	76.9	7.2	131.7	4.2	
Center	S2	12/18/2013	5.0	18.6	236	7.2	77.9	7.3	130.7	4.2	
Center	S2	12/18/2013	5.5	18.6	236	7.2	76.6	7.2	130.6	4.9	
South	S3	12/18/2013	0.5	19.3	236	7.3	88.6	8.2	136.4	3.3	1.14
South	S3	12/18/2013	1.0	19.2	236	7.3	87.3	8.1	135.2	3.6	
South	S3	12/18/2013	1.5	19.2	236	7.3	86.8	8.0	133.9	4.0	
South	S3	12/18/2013	2.0	19.1	236	7.3	87.7	8.1	132.4	3.3	
South	S3	12/18/2013	2.5	19.1	236	7.4	87.8	8.1	131.5	3.7	
South	S3	12/18/2013	3.0	19.0	236	7.3	84.8	7.9	132.5	3.7	
South	S3	12/18/2013	3.5	19.0	236	7.3	82.3	7.6	132.6	3.7	
South	S3	12/18/2013	4.0	18.8	236	7.2	71.6	6.7	135.2	3.8	
South	S3	12/18/2013	4.5	18.8	236	7.1	67.7	6.3	137.4	3.9	
South	S3	12/18/2013	5.0	18.7	236	7.1	67.4	6.3	137.4	3.9	
South	S3	12/18/2013	5.5	18.7	236	7.1	66.5	6.2	137.5	3.9	
South	S3	12/18/2013	6.0	18.7	236	7.0	62.6	5.8	138.5	8.0	
Wetland	S4	12/18/2013	0.5	17.0	169	5.3	7.7	0.7	-51.4	8.6	0.24
Lake Reaves	S5	12/18/2013	0.5	19.4	218	6.3	45.8	4.0	166.7	0.4	0.69
Lake Reaves	S5	12/18/2013	1.0	18.8	211	6.2	16.4	1.7	169.7	0.4	
Lake Reaves	S5	12/18/2013	1.5	18.1	218	6.0	12.0	1.1	176.7	0.4	
Lake Reaves	S5	12/18/2013	2.0	18.0	217	6.0	14.5	1.4	176.4	0.5	
Lake Reaves	S5	12/18/2013	2.5	18.0	217	6.0	15.8	1.5	174.0	0.3	
Lake Reaves	S5	12/18/2013	3.0	18.0	211	6.1	16.2	1.5	171.7	0.3	
Lake Reaves	S5	12/18/2013	3.5	18.0	217	6.1	17.0	1.6	169.0	0.4	
Lake Reaves	S5	12/18/2013	4.0	18.0	217	6.1	15.9	1.6	146.2	7.4	

Location	Site	Date	Depth (meter)	Temp (°C)	SpCond (umho/cm)	pH Units	DO (%)	DO (mg/l)	ORP (mV)	Turbidity (NTU)	Secchi (meter)
North	S1	1/21/2014	0.5	16.6	226	6.9	98.3	9.6	138.3	3.2	1.04
North	S1	1/21/2014	1.0	16.5	226	7.0	98.2	9.6	138.6	2.7	
North	S1	1/21/2014	1.5	16.5	226	6.9	98.5	9.6	139.9	2.4	
North	S1	1/21/2014	2.0	16.4	226	6.9	98.8	9.7	141.6	1.9	
Center	S2	1/21/2014	0.5	15.9	226	7.0	94.8	9.4	132.5	1.3	0.99
Center	S2	1/21/2014	1.0	15.9	226	6.8	94.8	9.4	136.6	6.8	
Center	S2	1/21/2014	1.5	15.8	226	6.8	94.8	9.4	137.2	1.4	
Center	S2	1/21/2014	2.0	15.8	226	6.7	94.7	9.4	136.9	1.5	
Center	S2	1/21/2014	2.5	15.8	226	6.7	94.4	9.4	136.9	1.6	
Center	S2	1/21/2014	3.0	15.7	226	6.7	93.4	9.3	136.2	1.6	
Center	S2	1/21/2014	3.5	15.6	226	6.7	91.9	9.1	136.0	1.4	
Center	S2	1/21/2014	4.0	15.5	226	6.7	85.7	8.5	136.8	1.2	
Center	S2	1/21/2014	4.5	15.1	226	6.6	79.6	8.0	137.9	1.4	
Center	S2	1/21/2014	5.0	15.1	227	6.6	72.4	7.3	139.3	2.7	
South	S3	1/21/2014	0.5	15.3	226	6.4	86.3	8.6	172.2	1.8	0.93
South	S3	1/21/2014	1.0	15.3	226	6.4	86.2	8.6	171.6	1.9	
South	S3	1/21/2014	1.5	15.2	226	6.4	84.8	8.5	171.0	1.6	
South	S3	1/21/2014	2.0	15.2	226	6.5	83.2	8.4	170.8	1.8	
South	S3	1/21/2014	2.5	15.1	226	6.5	79.9	8.0	171.2	1.5	
South	S3	1/21/2014	3.0	15.1	226	6.5	75.0	7.5	172.0	1.6	
South	S3	1/21/2014	3.5	15.0	226	6.5	72.9	7.3	171.8	1.6	
South	S3	1/21/2014	4.0	15.0	226	6.5	72.4	7.3	171.5	2.3	
South	S3	1/21/2014	4.5	15.0	226	6.5	72.2	7.3	171.1	2.5	
South	S3	1/21/2014	5.0	15.0	226	6.5	71.7	7.2	170.3	2.5	
South	S3	1/21/2014	5.5	15.0	226	6.5	71.5	7.2	170.0	2.6	
South	S3	1/21/2014	6.0	15.0	226	6.5	71.4	7.2	169.2	2.7	
Wetland	S4	1/21/2014	0.5	14.0	161	9.6	0.9	5.6	-46.2	13.5	0.36
Lake Reaves	S5	1/21/2014	0.5	15.2	206	6.3	40.8	4.1	164.7	0.1	0.73
Lake Reaves	S5	1/21/2014	1.0	15.2	206	6.1	39.7	4.0	166.2	0.1	
Lake Reaves	S5	1/21/2014	1.5	15.0	206	6.0	35.4	3.6	166.8	0.1	
Lake Reaves	S5	1/21/2014	2.0	14.9	206	5.9	32.7	3.3	167.9	0.1	
Lake Reaves	S5	1/21/2014	2.5	14.9	206	5.8	31.8	3.2	167.4	0.1	
Lake Reaves	S5	1/21/2014	3.0	14.8	206	5.8	30.6	3.0	167.2	0.1	

Location	Site	Date	Depth (meter)	Temp (°C)	SpCond (umho/cm)	pH Units	DO (%)	DO (mg/l)	ORP (mV)	Turbidity (NTU)	Secchi (meter)
North	S1	2/17/2014	0.5	16.7	228	7.7	87.0	8.5	166.0	2.1	1.87
North	S1	2/17/2014	1.0	16.6	228	7.6	78.0	7.6	169.0	2.2	
North	S1	2/17/2014	1.5	16.5	228	7.4	76.0	7.4	174.0	2.6	
North	S1	2/17/2014	2.0	16.5	228	7.4	76.0	7.5	177.0	3.2	
North	S1	2/17/2014	2.5	16.4	227	7.3	77.0	7.6	179.0	6.8	
Center	S2	2/17/2014	0.5	16.7	229	7.8	92.0	9.0	173.0	1.9	1.93
Center	S2	2/17/2014	1.0	16.7	229	7.6	92.0	8.9	189.0	2.0	
Center	S2	2/17/2014	1.5	16.5	229	7.5	90.0	8.8	194.0	2.1	
Center	S2	2/17/2014	2.0	16.6	228	7.4	82.00	8.0	198.0	2.0	
Center	S2	2/17/2014	2.5	16.5	228	7.4	82.00	8.0	204.0	2.0	
Center	S2	2/17/2014	3.0	16.5	228	7.3	78.00	7.6	207.0	1.9	
Center	S2	2/17/2014	3.5	16.5	229	7.2	67.00	6.5	207.0	1.9	
Center	S2	2/17/2014	4.0	16.3	229	7.1	61.00	6.0	210.0	1.9	
Center	S2	2/17/2014	4.5	16.3	229	7.1	58.00	5.7	212.0	1.8	
South	S3	2/17/2014	0.5	17.1	229	8.2	101.0	9.8	115.0	1.8	1.92
South	S3	2/17/2014	1.0	17.0	229	8.2	102.0	9.8	122.0	1.9	
South	S3	2/17/2014	1.5	16.9	229	8.1	98.9	9.9	128.0	1.7	
South	S3	2/17/2014	2.0	16.8	229	7.9	90.1	8.7	133.0	2.3	
South	S3	2/17/2014	2.5	16.6	229	7.8	86.8	8.4	138.0	2.4	
South	S3	2/17/2014	3.0	16.6	229	7.7	80.6	7.9	141.0	3.1	
Wetland	S4	2/17/2014	0.5	14.3	152	6.3	7.4	0.8	-34.8	4.0	0.40
Lake Reaves	S5	2/17/2014	0.5	15.9	263	6.9	46.1	4.6	23.4	1.2	0.40
Lake Reaves	S5	2/17/2014	1.0	15.8	210	6.8	46.0	4.6	96.6	1.3	
Lake Reaves	S5	2/17/2014	1.5	15.4	210	6.8	45.7	4.6	106.2	6.1	
Lake Reaves	S5	2/17/2014	2.0	15.4	210	7.2	22.2	2.2	-22.0	6.1	

Location	Site	Date	Depth (meter)	Temp (°C)	SpCond (umho/cm)	pH Units	DO (%)	DO (mg/l)	ORP (mV)	Turbidity[3] (NTU)	Secchi (meter)
North	S1	3/20/2014	0.5	21.6	232	8.3	112.2	9.9	113.6	0.1	1.27
North	S1	3/20/2014	1.0	21.3	232	8.2	111.5	9.9	113.6	0.1	
North	S1	3/20/2014	1.5	21.1	232	8.4	94.60	8.4	115.7	0.1	
North	S1	3/20/2014	2.0	21.1	232	7.5	78.10	6.9	116.5	0.1	
Center	S2	3/20/2014	0.5	22.0	233	8.4	116.7	10.2	113.1	0.1	1.26
Center	S2	3/20/2014	1.0	21.8	232	8.4	116.2	10.2	113.8	0.1	
Center	S2	3/20/2014	1.5	21.7	232	8.4	116.1	10.1	114.2	0.1	
Center	S2	3/20/2014	2.0	21.5	232	8.2	109.0	9.6	115.1	0.1	
Center	S2	3/20/2014	2.5	21.2	232	8.0	101.8	9.0	116.0	0.1	
Center	S2	3/20/2014	3.0	21.1	232	7.7	93.0	8.3	117.0	0.1	
Center	S2	3/20/2014	3.5	20.8	232	7.5	76.6	6.8	118.2	0.1	
Center	S2	3/20/2014	4.0	20.6	232	7.3	63.1	5.6	119.0	0.1	
Center	S2	3/20/2014	4.5	20.5	232	7.2	53.4	4.8	119.2	0.1	
Center	S2	3/20/2014	5.0	20.4	232	7.1	45.8	4.1	119.4	0.1	
South	S3	3/20/2014	0.5	22.3	233	8.5	118.5	10.3	143.2	0.1	1.21
South	S3	3/20/2014	1.0	22.2	233	8.6	118.3	10.3	140.4	0.1	
South	S3	3/20/2014	1.5	22.2	233	8.5	116.4	10.1	140.5	0.1	
South	S3	3/20/2014	2.0	21.9	233	8.0	101.8	8.9	142.0	0.1	
South	S3	3/20/2014	2.5	21.6	233	7.9	97.6	8.6	142.0	0.1	
South	S3	3/20/2014	3.0	21.3	233	7.8	97.8	8.7	141.8	0.1	
South	S3	3/20/2014	3.5	21.1	232	7.7	91.6	8.1	142.4	0.1	
South	S3	3/20/2014	4.0	20.9	232	7.6	83.4	7.4	142.6	0.1	
South	S3	3/20/2014	4.5	20.7	233	7.3	64.9	5.8	143.2	0.1	
South	S3	3/20/2014	5.0	20.4	233	7.1	41.3	3.7	143.9	0.1	
South	S3	3/20/2014	5.5	20.2	234	7.1	33.5	3.0	143.7	0.1	
Wetland	S4	3/20/2014	0.5	17.4	145	5.5	5.8	0.6	1.0	133.5	0.61
Lake Reaves	S5	3/20/2014	0.5	24.1	217	6.5	54.8	4.7	21.1	0.1	1.01
Lake Reaves	S5	3/20/2014	1.0	21.3	216	6.5	50.1	4.4	23.6	0.1	
Lake Reaves	S5	3/20/2014	1.5	20.1	215	6.5	46.6	4.2	24.9	0.1	
Lake Reaves	S5	3/20/2014	2.0	19.6	214	6.5	43.1	4.0	25.1	0.1	
Lake Reaves	S5	3/20/2014	2.5	19.2	214	6.5	41.8	3.8	25.6	0.1	
Lake Reaves	S5	3/20/2014	3.0	19.2	214	6.5	36.7	3.4	25.5	0.1	

[3] YSI Datasonde Probe Undetection Limit = 0.1

Location	Site	Date	Depth (meter)	Temp (^oC)	SpCond (umho/cm)	pH Units	DO (%)	DO (mg/l)	ORP (mV)	Turbidity (NTU)	Secchi (meter)
North	S1	4/23/2014	0.5	25.8	238	8.6	137.6	11.2	136.9	1.3	0.85
North	S1	4/23/2014	1.0	24.3	237	8.4	130.1	11.0	159.3	1.1	
North	S1	4/23/2014	1.5	22.6	237	8.0	107.40	9.2	184.1	0.8	
North	S1	4/23/2014	2.0	22.1	238	7.3	81.10	7.1	209.4	0.3	
Center	S2	4/23/2014	0.5	26.0	239	8.9	144.9	11.8	171.8	0.8	0.83
Center	S2	4/23/2014	1.0	25.2	239	8.9	144.9	11.9	183.4	0.7	
Center	S2	4/23/2014	1.5	23.0	238	8.6	130.5	11.2	198.1	1.2	
Center	S2	4/23/2014	2.0	21.9	238	7.7	90.7	7.9	226.8	0.1	
Center	S2	4/23/2014	2.5	21.9	237	7.4	81.9	7.2	235.9	0.2	
Center	S2	4/23/2014	3.0	21.8	237	7.3	80.1	7.0	240.7	0.0	
Center	S2	4/23/2014	3.5	21.8	237	7.2	75.5	6.6	244.4	0.2	
Center	S2	4/23/2014	4.0	21.7	237	7.1	72.7	6.4	248.3	0.3	
Center	S2	4/23/2014	4.5	21.6	238	6.9	52.1	4.6	254.0	1.3	
Center	S2	4/23/2014	5.0	21.6	238	6.9	47.6	4.2	252.3	8.1	
South	S3	4/23/2014	0.5	25.6	238	9.0	150.9	12.4	142.6	0.8	0.89
South	S3	4/23/2014	1.0	23.8	238	9.0	147.1	12.4	161.9	1.2	
South	S3	4/23/2014	1.5	23.2	237	8.9	141.7	12.1	178.6	1.3	
South	S3	4/23/2014	2.0	22.7	237	8.6	127.7	11.0	194.1	1.2	
South	S3	4/23/2014	2.5	22.3	237	8.1	107.0	9.2	216.5	0.9	
South	S3	4/23/2014	3.0	22.1	237	7.6	84.9	7.4	230.7	0.6	
South	S3	4/23/2014	3.5	21.8	237	7.3	69.1	6.0	239.9	0.5	
South	S3	4/23/2014	4.0	21.7	237	7.1	64.4	5.6	243.8	0.7	
South	S3	4/23/2014	4.5	21.7	237	7.1	64.0	5.6	248.0	0.4	
South	S3	4/23/2014	5.0	21.7	237	7.0	60.5	5.3	252.4	0.4	
South	S3	4/23/2014	5.5	21.7	237	6.9	53.8	4.7	255.4	2.0	
Wetland	S4	4/23/2014	0.5	19.6	150	4.7	13.8	1.3	-74.0	7.8	0.51
Lake Reaves	S5	4/23/2014	0.5	23.1	215	6.2	60.6	6.3	200.0	0.1	1.09
Lake Reaves	S5	4/23/2014	1.0	20.9	214	5.9	32.2	2.8	213.3	0.1	
Lake Reaves	S5	4/23/2014	1.5	20.6	214	5.9	29.5	2.7	222.0	0.1	
Lake Reaves	S5	4/23/2014	2.0	20.5	214	5.8	18.7	1.7	228.8	0.1	
Lake Reaves	S5	4/23/2014	2.5	20.3	215	5.8	11.2	1.0	235.8	0.1	
Lake Reaves	S5	4/23/2014	3.0	19.2	223	5.8	3.6	0.3	114.5	0.1	

Location	Site	Date	Depth (meter)	Temp (^oC)	SpCond (umho/cm)	pH Units	DO (%)	DO (mg/l)	ORP (mV)	Turbidity (NTU)	Secchi (meter)
North	S1	5/22/2014	0.5	27.3	225	8.4	123.1	9.8	121.6	2.6	0.70
North	S1	5/22/2014	1.0	27.2	225	8.5	123.0	9.8	125.9	2.6	
North	S1	5/22/2014	1.5	27.2	225	8.5	122.5	9.7	127.4	2.6	
North	S1	5/22/2014	2.0	27.1	225	8.5	122.20	9.7	130.4	2.7	
North	S1	5/22/2014	2.5	26.8	225	8.1	96.80	7.7	134.5	2.2	
North	S1	5/22/2014	3.0	26.6	225	7.6	83.30	6.8	105.0	55.0	
Center	S2	5/22/2014	0.5	26.8	224	8.2	121.7	9.7	114.9	2.6	0.75
Center	S2	5/22/2014	1.0	26.8	224	8.4	119.2	9.5	142.8	2.6	
Center	S2	5/22/2014	1.5	26.7	224	8.5	118.7	9.5	148.8	2.7	
Center	S2	5/22/2014	2.0	26.1	224	8.0	99.50	8.0	159.9	2.6	
Center	S2	5/22/2014	2.5	25.9	223	7.6	77.80	6.3	160.2	2.4	
Center	S2	5/22/2014	3.0	25.8	223	7.4	70.40	6.0	170.2	2.2	
Center	S2	5/22/2014	3.5	25.7	223	7.2	52.00	4.2	173.8	1.8	
Center	S2	5/22/2014	4.0	25.4	218	6.9	18.70	1.6	176.1	2.0	
Center	S2	5/22/2014	4.5	24.7	233	6.8	4.50	0.3	72.0	5.0	
Center	S2	5/22/2014	5.0	23.5	274	6.9	2.90	0.3	-23.0	9.8	
Center	S2	5/22/2014	5.5	22.8	315	6.5	2.00	0.2	-6.9	-0.7	
South	S3	5/22/2014	0.5	26.5	225	8.1	108.3	8.6	196.0	2.8	0.75
South	S3	5/22/2014	1.0	26.4	225	8.2	109.2	8.3	198.6	2.8	
South	S3	5/22/2014	1.5	26.2	225	8.0	101.0	8.2	202.2	2.7	
South	S3	5/22/2014	2.0	26.1	225	7.7	83.1	6.7	207.4	2.6	
South	S3	5/22/2014	2.5	26.0	225	7.5	73.7	6.0	211.3	2.6	
South	S3	5/22/2014	3.0	25.8	225	7.2	45.7	3.7	215.9	2.7	
South	S3	5/22/2014	3.5	25.3	222	7.0	6.3	0.4	179.0	8.3	
South	S3	5/22/2014	4.0	24.5	245	6.9	2.5	0.2	33.0	5.5	
South	S3	5/22/2014	4.5	24.3	253	6.5	2.2	0.2	-7.0	7.1	
Wetland[2]	S4	5/22/2014									
Lake Reaves	S5	5/22/2014	0.5	23.7	214	6.3	5.3	0.4	-30.0	0.7	0.45

[2] Wetland Sample Not Collected During this Sampling Event

Location	Site	Date	Depth (meter)	Temp (^oC)	SpCond (umho/cm)	pH Units	DO (%)	DO (mg/l)	ORP (mV)	Turbidity (NTU)	Secchi (meter)
North	S1	6/25/2014	0.5	31.1	232	8.9	125.1	9.3	45.7	2.1	0.97
North	S1	6/25/2014	1.0	30.8	232	8.4	113.2	8.4	57.4	2.1	
North	S1	6/25/2014	1.5	30.6	232	8.7	119.3	9.0	56.3	2.3	
North	S1	6/25/2014	2.0	30.3	232	7.2	70.80	5.3	56.4	2.2	
Center	S2	6/25/2014	0.5	30.9	231	8.9	127.9	9.5	91.3	2.0	0.95
Center	S2	6/25/2014	1.0	30.7	231	8.9	127.7	9.5	94.7	2.2	
Center	S2	6/25/2014	1.5	30.6	231	8.8	121.8	9.1	96.7	2.6	
Center	S2	6/25/2014	2.0	30.0	230	8.3	106.40	8.1	109.1	2.9	
Center	S2	6/25/2014	2.5	29.4	229	7.3	64.60	4.9	131.5	2.3	
Center	S2	6/25/2014	3.0	28.6	219	6.7	19.70	1.5	144.2	3.7	
Center	S2	6/25/2014	3.5	27.6	245	6.8	4.30	0.3	68.1	3.8	
Center	S2	6/25/2014	4.0	26.8	262	6.9	3.00	0.2	-37.4	5.6	
Center	S2	6/25/2014	4.5	26.3	276	7.0	2.30	0.2	-159.6	6.8	
Center	S2	6/25/2014	5.0	25.9	285	6.9	2.10	0.2	-205.4	7.2	
South	S3	6/25/2014	0.5	30.5	233	8.8	123.8	9.3	171.3	2.1	1.09
South	S3	6/25/2014	1.0	30.5	233	8.8	124.0	9.3	160.0	2.5	
South	S3	6/25/2014	1.5	30.4	232	8.7	120.6	9.1	157.5	2.7	
South	S3	6/25/2014	2.0	29.4	231	7.6	83.7	5.5	183.8	2.7	
South	S3	6/25/2014	2.5	29.2	223	7.1	7.4	3.8	197.6	5.1	
South	S3	6/25/2014	3.0	28.7	229	6.7	49.6	0.5	192.3	2.4	
South	S3	6/25/2014	3.5	28.0	231	6.7	4.5	0.4	123.0	3.7	
South	S3	6/25/2014	4.0	26.9	253	6.9	2.6	0.2	-61.6	4.7	
South	S3	6/25/2014	4.5	26.1	279	7.0	2.6	0.2	-144.2	7.0	
South	S3	6/25/2014	5.0	25.9	286	6.9	2.1	0.2	-183.2	7.4	
Wetland	S4	6/25/2014	0.5	24.9	191	5.8	4.8	0.4	-191.1	8.7	0.28
Lake Reaves	S5	6/25/2014	0.5	30.3	227	6.5	72.8	2.5	102.3	1.4	0.63
Lake Reaves	S5	6/25/2014	1.0	27.1	230	6.3	30.3	2.4	43.4	5.1	
Lake Reaves	S5	6/25/2014	1.5	26.8	229	6.3	3.7	0.3	-139.8	2.7	
Lake Reaves	S5	6/25/2014	2.0	25.6	227	6.2	2.4	0.2	-320.1	2.5	
Lake Reaves	S5	6/25/2014	2.5	24.3	226	6.2	1.8	0.2	-376.8	2.0	
Lake Reaves	S5	6/25/2014	3.0	22.5	229	6.2	1.3	0.1	-365.0	1.8	
Lake Reaves	S5	6/25/2014	3.5	21.2	232	6.2	1.0	0.1	-365.3	1.9	
Lake Reaves	S5	6/25/2014	4.0	20.7	233	6.2	0.8	0.1	-370.6	1.7	

Location	Site	Date	Depth (meter)	Temp (^oC)	SpCond (umho/cm)	pH Units	DO (%)	DO (mg/l)	ORP (mV)	Turbidity[3] (NTU)	Secchi (meter)
North	S1	7/22/2014	0.5	30.3	240	7.3	91.3	6.9	173.8	0.1	1.45
North	S1	7/22/2014	1.0	30.0	240	7.3	88.4	6.7	176.0	0.1	
North	S1	7/22/2014	1.5	29.9	240	7.2	80.8	6.1	178.9	0.1	
North	S1	7/22/2014	2.0	29.9	240	7.2	79.80	6.0	179.5	0.1	
Center	S2	7/22/2014	0.5	31.4	239	7.8	112.6	8.3	105.4	0.1	1.45
Center	S2	7/22/2014	1.0	30.3	238	7.6	104.6	7.9	119.2	0.1	
Center	S2	7/22/2014	1.5	30.0	236	7.3	92.8	7.0	131.4	0.1	
Center	S2	7/22/2014	2.0	29.9	236	7.2	84.30	6.4	138.0	0.1	
Center	S2	7/22/2014	2.5	29.7	237	7.1	68.10	5.2	145.2	0.1	
Center	S2	7/22/2014	3.0	29.4	235	6.7	35.40	2.7	155.7	0.1	
Center	S2	7/22/2014	3.5	29.1	231	6.7	8.10	0.6	159.0	0.1	
Center	S2	7/22/2014	4.0	28.5	250	6.7	4.60	0.4	113.3	0.1	
Center	S2	7/22/2014	4.5	28.3	258	6.7	3.30	0.3	74.8	0.1	
Center	S2	7/22/2014	5.0	27.9	271	6.7	3.10	0.3	-34.1	0.1	
South	S3	7/22/2014	0.5	31.5	239	7.9	111.1	8.2	106.2	0.1	1.46
South	S3	7/22/2014	1.0	30.7	237	8.4	121.9	9.1	106.9	0.1	
South	S3	7/22/2014	1.5	30.2	237	7.8	108.1	8.1	123.1	0.1	
South	S3	7/22/2014	2.0	29.9	237	7.2	71.7	5.4	140.9	0.1	
South	S3	7/22/2014	2.5	29.7	236	7.0	50.4	3.8	149.0	0.1	
South	S3	7/22/2014	3.0	29.3	234	6.8	22.7	1.7	155.2	0.1	
South	S3	7/22/2014	3.5	29.0	231	6.7	7.6	0.6	160.1	0.1	
South	S3	7/22/2014	4.0	28.7	238	6.7	4.6	0.4	142.9	0.1	
South	S3	7/22/2014	4.5	28.2	254	6.7	3.7	0.3	96.0	0.1	
South	S3	7/22/2014	5.0	27.9	274	6.7	3.2	0.3	-5.6	0.1	
South	S3	7/22/2014	5.5	27.6	289	6.7	2.6	0.2	-87.1	0.1	
Wetland	S4	7/22/2014	0.5	25.6	188	5.9	7.8	0.6	-130.8	0.0	0.53
Lake Reaves	S5	7/22/2014	0.5	28.2	226	6.3	3.9	0.3	77.6	0.1	0.61
Lake Reaves	S5	7/22/2014	1.0	27.4	227	6.3	3.1	0.2	-25.1	0.1	
Lake Reaves	S5	7/22/2014	1.5	27.3	226	6.3	2.7	0.2	-48.8	0.1	
Lake Reaves	S5	7/22/2014	2.0	27.2	226	6.2	2.3	0.2	-69.5	0.1	
Lake Reaves	S5	7/22/2014	2.5	26.4	227	6.2	2.0	0.2	-134.3	0.1	
Lake Reaves	S5	7/22/2014	3.0	24.8	233	6.1	1.7	0.1	-163.9	0.1	

[3] YSI Datasonde Probe Undetection Limit = 0.1

Location	Site	Date	Depth (meter)	Temp (^oC)	SpCond (umho/cm)	pH Units	DO (%)	DO (mg/l)	ORP (mV)	Turbidity (NTU)	Secchi (meter)
North	S1	8/21/2014	0.5	31.7	226	8.0	116.6	8.6	62.2		0.95
North	S1	8/21/2014	1.0	31.1	226	7.8	112.5	8.3	65.4	<0	
North	S1	8/21/2014	1.5	30.4	222	7.2	42.1	3.2	69.5	<0	
North	S1	8/21/2014	2.0	30.1	220	6.8	13.70	1.0	69.5	<0	
North	S1	8/21/2014	2.5	29.6	223	6.6	3.20	0.2	49.2	<0	
Center	S2	8/21/2014	0.5	31.6	227	8.1	118.0	8.7	68.4		0.95
Center	S2	8/21/2014	1.0	31.3	226	8.0	114.6	8.4	73.8	<0	
Center	S2	8/21/2014	1.5	30.6	226	7.6	86.6	6.5	77.2	<0	
Center	S2	8/21/2014	2.0	30.1	226	7.3	42.40	3.2	78.6	<0	
Center	S2	8/21/2014	2.5	29.8	225	7.0	22.00	1.7	79.0	<0	
Center	S2	8/21/2014	3.0	29.4	219	6.8	3.20	0.2	76.5	<0	
Center	S2	8/21/2014	3.5	29.0	232	6.8	2.60	0.2	51.0	<0	
Center	S2	8/21/2014	4.0	28.7	244	6.7	2.20	0.2	8.4	<0	
Center	S2	8/21/2014	4.5	28.4	240	6.7	2.00	0.2	-27.6	<0	
South	S3	8/21/2014	0.5	31.4	226	8.2	122.6	9.0	59.5		1.00
South	S3	8/21/2014	1.0	31.2	227	8.2	119.3	8.8	63.1	<0	
South	S3	8/21/2014	1.5	30.8	226	7.8	107.9	8.1	68.3	<0	
South	S3	8/21/2014	2.0	30.5	226	7.5	80.1	6.0	71.6	<0	
South	S3	8/21/2014	2.5	29.9	224	7.1	32.1	2.5	72.2	<0	
South	S3	8/21/2014	3.0	29.6	223	6.9	3.8	0.3	65.4	<0	
South	S3	8/21/2014	3.5	29.1	227	6.8	2.9	0.2	60.1	<0	
South	S3	8/21/2014	4.0	28.7	242	6.7	2.5	0.2	5.0	<0	
Wetland[2]	S4	8/21/2014									
Lake Reaves	S5	8/21/2014	0.5	29.9	179	7.1	63.0	4.7	54.0		0.45
Lake Reaves	S5	8/21/2014	1.0	27.7	180	6.4	3.9	0.3	47.0	<0	
Lake Reaves	S5	8/21/2014	1.5	27.1	176	6.3	2.4	0.2	66.0	<0	
Lake Reaves	S5	8/21/2014	2.0	26.5	179	6.2	2.1	0.2	81.0	<0	
Lake Reaves	S5	8/21/2014	2.5	25.7	192	6.2	2.0	0.1	93.4	<0	
Lake Reaves	S5	8/21/2014	3.0	24.7	212	6.1	1.7	0.1	96.6	<0	
Lake Reaves	S5	8/21/2014	3.5	24.0	224	6.1	1.6	0.1	102.0	<0	

[2] Wetland Sample Not Collected During this Sampling Event

APPENDIX 2-2

Characteristics of Water Samples Collected at Lake Roberts September 2013 through August 2014

Characteristics of Water Samples Collected at Lake Roberts. Lake Reaves and Wetland Tussock
September 2013 through August 2014

Sample ID	Sample Description	Site	Date Collected	pH (s.u.) (field measurement)	Alkalinity (mg/L)	Conductivity (µmho/cm) (field measurement)	Ammonia (µg/L)	NOX (µg/L)	Diss. Org. N (µg/L) (pass through 0.45 micron filter)	Part. N (µg/L)	Total N (µg/L)	SRP (µg/L)	Diss. Org. P (µg/L) (pass through 0.45 micron filter)	Part. P (µg/L)	Total P (µg/L)	Chyl- a (mg/m^3)	TSS (mg/L)	Turbidity (NTU) (field measurement)	Color (PCU)
3524	Lake Roberts	XA33 S1S	9/25/13	7.1	45.2	204	77	9	722	296	1,104	3	1	31	35	16.4	5	8.9	60
3826	Lake Roberts	XA33 S1S	10/21/13	7.2	48.0	209	5	5	748	316	1,070	5	1	30	36	19.3	6	3.1	100
3826	Lake Roberts	XA33 S1S	11/20/13	7.3	43.0	218	40	5	870	235	1,150	3	16	41	60	39.7	6	0.1	55
3826	Lake Roberts	XA33 S1S	12/18/13	7.2	43.6	236	5	5	778	330	1,118	1	1	50	52	18.2	5	4.3	48
3826	Lake Roberts	XA33 S1S	1/21/14	6.9	51.6	226	5	5	732	251	993	6	6	40	52	34.8	7	3.2	50
3826	Lake Roberts	XA33 S1S	2/17/14	7.7	43.0	228	40	5	940	145	1,130	9	37	25	71	16.7	4	2.1	50
3826	Lake Roberts	XA33 S1S	3/20/14	8.3	43.6	232	5	5	393	222	625	8	8	41	57	26.4	2	0.1	50
3826	Lake Roberts	XA33 S1S	4/23/14	8.6	48.2	238	27	92	753	89	961	1	4	34	39	36.3	6	1.3	46
3826	Lake Roberts	XA33 S1S	5/22/14	8.4	40.0	225	40	5	1,050	25	1,120	4	9	41	54	19.2	2	2.6	42
3826	Lake Roberts	XA33 S1S	6/25/14	8.9	43.2	232	33	12	684	206	935	2	6	35	43	15.8	4	2.1	36
3826	Lake Roberts	XA33 S1S	7/22/14	7.3	47.2	240	99	108	486	102	795	7	4	23	34	26.0	3	0.1	37
3826	Lake Roberts	XA33 S1S	8/21/14	8.0	42.0	226	20	4	850	196	1,070	4	3	66	73	8.5	5		55
MEAN				7.7	44.9	226	33	22	751	201	1006	4	8	38	51	23.1	5	2.5	52
MEDIAN				7.5	43.6	227	30	5	751	214	1070	4.0	5	38	52	19.3	5	2.1	50
3525	Lake Roberts	XA33 S1B	9/25/13	7.0	45.0	204	96	10	775	322	1,203	4	1	29	34		4	9.3	55
3827	Lake Roberts	XA33 S1B	10/21/13	6.5	57.4	208	59	5	706	313	1,083	3	1	33	37		4	4.3	110
3827	Lake Roberts	XA33 S1B	11/20/13	6.9	44.0	215	40	5	920	485	1,450	3	11	71	85		12	0.1	50
3827	Lake Roberts	XA33 S1B	12/18/13	7.2	45.4	236	5	5	775	283	1,068	1	1	44	46		6	4.6	50
3827	Lake Roberts	XA33 S1B	1/21/14	6.9	49.0	226	5	5	736	214	960	4	7	32	43		3	1.9	70
3827	Lake Roberts	XA33 S1B	2/17/14	7.3	46.0	227	40	5	860	235	1,140	19	44	31	94		5	6.8	55
3827	Lake Roberts	XA33 S1B	3/20/14	7.5	43.8	232	9	5	579	247	840	12	11	41	64		6	0.1	50
3827	Lake Roberts	XA33 S1B	4/23/14	7.3	47.6	238	18	8	797	404	1,227	1	11	60	72		4	0.3	44
3827	Lake Roberts	XA33 S1B	5/22/14	7.6	40.0	225	40	5	800	305	1,150	3	10	45	58		10	55.0	43
3827	Lake Roberts	XA33 S1B	6/25/14	7.2	42.6	232	8	9	731	273	1,021	1	10	33	44		5	2.2	36
3827	Lake Roberts	XA33 S1B	7/22/14	7.2	46.8	240	112	38	502	186	838	3	13	14	30		4	0.1	40
3827	Lake Roberts	XA33 S1B	8/21/14	6.6	42.0	223	20	4	960	186	1,170	4	45	82	131		5		60
MEAN				7.1	45.8	226	38	9	762	288	1,096	5	14	43	61		6	7.7	55
MEDIAN				7.2	45.2	227	30	5	775	278	1112	3.0	11	37	52		5	2.2	50
3526	Lake Roberts	XA33 S2S	9/25/13	7.0	43.6	203	77	6	779	334	1,196	8	1	26	35	26.8	3	8.6	55
3828	Lake Roberts	XA33 S2S	10/21/13	7.7	41.4	210	5	5	811	304	1,125	9	2	42	53	29.5	6	3.0	110
3828	Lake Roberts	XA33 S2S	11/20/13	7.9	47.0	216	40	5	830	325	1,200	3	15	39	57		7	0.1	
3828	Lake Roberts	XA33 S2S	12/18/13	7.3	44.6	236	5	5	768	371	1,149	3	1	45	49	34.4	5	3.6	47
3828	Lake Roberts	XA33 S2S	1/21/14	7.0	45.6	226	5	5	717	207	934	3	7	36	46	31.5	4	1.3	49
3828	Lake Roberts	XA33 S2S	2/17/14	7.8	44.0	229	4	5	810	251	1,070	10	27	25	62		3	1.9	
3828	Lake Roberts	XA33 S2S	3/20/14	8.4	45.2	233	5	5	361	261	632	6	12	32	50	23.4	3	0.1	49
3828	Lake Roberts	XA33 S2S	4/23/14	8.9	46.4	239	22	7	707	49	785	1	11	7	19	29.1	8	0.8	47
3828	Lake Roberts	XA33 S2S	5/22/14	8.2	41.0	224	40	5	730	435	1,210	5	10	36	51		9	2.6	
3828	Lake Roberts	XA33 S2S	6/25/14	8.9	41.8	231	10	3	708	193	914	1	12	20	33	23.2	3	2.0	35
3828	Lake Roberts	XA33 S2S	7/22/14	7.8	47.8	239	185	38	421	101	745	4	5	3	12	16.9	1	0.1	37
3828	Lake Roberts	XA33 S2S	8/21/14	8.1	42.0	227	20	4	840	186	1050	4	7	796*	807*		162		
MEAN				7.9	44.2	226	35	8	707	251	1,001	5	9	28	42	26.9	18	2.2	54
MEDIAN				7.9	44.3	228	15	5	749	256	1060	4.0	9	32	49	28.0	5	1.9	48

Characteristics of Water Samples Collected at Lake Roberts. Lake Reaves and Wetland Tussock
September 2013 through August 2014

Sample ID	Sample Description	Site	Date Collected	pH (s.u.) (field measurement)	Alkalinity (mg/L)	Conductivity (μmho/cm) (field measurement)	Ammonia (μg/L)	NOX (μg/L)	Diss. Org. N (μg/L) (pass through 0.45 micron filter)	Part. N (μg/L)	Total N (μg/L)	SRP (μg/L)	Diss. Org. P (μg/L) (pass through 0.45 micron filter)	Part. P (μg/L)	Total P (μg/L)	Chyl- a (mg/m^3)	TSS (mg/L)	Turbidity (NTU) (field measurement)	Color (PCU)
3527	Lake Roberts	XA33 S2B	9/25/13	7.0	42.4	205	59	6	861	339	1,265	12	1	28	41		3	10.3	60
3829	Lake Roberts	XA33 S2B	10/21/13	6.5	45.2	218	354	5	785	994	2,138	0	2	142	144		53	45.4	120
3829	Lake Roberts	XA33 S2B	11/20/13	6.6	45.0	220	200	26	1,020	454	1,700	3	14	67	84		11	0.1	60
3829	Lake Roberts	XA33 S2B	12/18/13	7.2	43.6	236	5	5	715	772	1,497	2	0	106	108		38	4.9	47
3829	Lake Roberts	XA33 S2B	1/21/14	6.6	48.6	227	5	18	778	194	995	9	6	30	45		7	2.7	50
3829	Lake Roberts	XA33 S2B	2/17/14	7.1	44.0	229	40	5	890	315	1,250	8	33	27	68		8	1.8	55
3829	Lake Roberts	XA33 S2B	3/20/14	7.1	44.0	232	44	5	493	274	816	14	10	26	50		5	0.1	45
3829	Lake Roberts	XA33 S2B	4/23/14	6.9	47.6	238	23	10	761	3,503	4,297	1	12	46	59		10	8.1	42
3829	Lake Roberts	XA33 S2B	5/22/14	6.5	59.0	315	55	5	1,990	730	2,780	32	44	241	317		98	0.1	85
3829	Lake Roberts	XA33 S2B	6/25/14	6.9	72.2	285	95	3	902	522	1,522	3	12	48	63		7	7.2	39
3829	Lake Roberts	XA33 S2B	7/22/14	6.7	68.8	271	631	5	487	219	1,342	4	3	39	46		6	0.1	42
3829	Lake Roberts	XA33 S2B	8/21/14	6.7	64.0	240	74	4	1,770	1,602	3,450	4	12	219	235		44		55
MEAN				6.8	52.0	243	132	8	954	827	1,921	8	12	85	105		24	7.3	58
MEDIAN				6.8	46.4	234	57	5	823	488	1510	4.0	11	47	66		9	2.7	53
3528	Lake Roberts	XA33 S3S	9/25/13	6.9	42.6	205	144	6	776	218	1,144	4	1	24	29	33.2	4	7.8	55
3830	Lake Roberts	XA33 S3S	10/21/13	8.2	43.8	210	6	5	802	251	1,064	0	2	25	27	43.6	6	3.0	100
3830	Lake Roberts	XA33 S3S	11/20/13	7.7	44.0	218	40	5	1,250	55	1,350	3	14	43	60	50.8	6	0..1	55
3830	Lake Roberts	XA33 S3S	12/18/13	7.3	44.4	236	5	5	753	299	1,062	1	2	42	45	2.0	5	3.3	47
3830	Lake Roberts	XA33 S3S	1/21/14	6.4	49.0	226	5	18	665	311	999	7	2	33	42	18.0	4	1.8	50
3830	Lake Roberts	XA33 S3S	2/17/14	8.2	44.0	229	40	5	780	235	1,060	3	24	37	64	16.1	3	1.8	50
3830	Lake Roberts	XA33 S3S	3/20/14	8.5	45.4	233	5	5	662	83	755	14	13	25	52	15.4	3	0.1	46
3830	Lake Roberts	XA33 S3S	4/23/14	9.0	44.6	238	31	9	588	298	926	1	12	43	56	30.3	5	0.8	47
3830	Lake Roberts	XA33 S3S	5/22/14	8.1	42.0	225	40	5	790	315	1,150	3	12	37	52	17.2	10	2.8	40
3830	Lake Roberts	XA33 S3S	6/25/14	8.8	52.0	233	33	13	674	217	937	2	7	33	42	24.2	5	2.1	36
3830	Lake Roberts	XA33 S3S	7/22/14	7.9	48.8	239	65	11	444	183	703	4	4	48	56	18.3	3	0.1	36
3830	Lake Roberts	XA33 S3S	8/21/14	8.2	44.0	226	20	4	880	196	1,100	4	6	20	30	9.8	3		50
MEAN				7.9	45.4	227	36	8	755	222	1,021	4	8	34	46	23.2	5	2.4	51
MEDIAN				8.2	44.2	228	32	5	765	227	1061	3.0	7	35	49	18.2	4	2.0	49
3529	Lake Roberts	XA33 S3B	9/25/13	6.9	44.2	206	152	6	747	193	1,098	4	2	22	28		4	8.3	55
3831	Lake Roberts	XA33 S3B	10/21/13	6.5	47.4	219	397	5	829	317	1,548	0	2	58	60		9	5.4	110
3831	Lake Roberts	XA33 S3B	11/20/13	6.2	44.0	220	160	20	1,000	250	1,430	3	13	47	63		4	29.3	55
3831	Lake Roberts	XA33 S3B	12/18/13	7.0	45.0	236	5	8	747	351	1,111	0	2	44	46		6	8.0	48
3831	Lake Roberts	XA33 S3B	1/21/14	6.5	47.8	226	5	18	750	227	1,000	9	6	40	55		8	2.7	50
3831	Lake Roberts	XA33 S3B	2/17/14	7.7	45.0	229	40	5	930	325	1,300	5	30	36	71		7	3.1	50
3831	Lake Roberts	XA33 S3B	3/20/14	7.1	44.6	234	14	5	458	113	590	7	16	30	53		4	0.1	45
3831	Lake Roberts	XA33 S3B	4/23/14	6.9	44.4	237	18	8	714	130	870	1	7	26	34		5	2.0	42
3831	Lake Roberts	XA33 S3B	5/22/14	6.5	56.0	253	140	5	980	435	1,560	5	12	65	82		16	7.1	43
3831	Lake Roberts	XA33 S3B	6/25/14	6.9	72.6	286	91	6	771	174	1,042	2	9	31	42		8	7.4	38
3831	Lake Roberts	XA33 S3B	7/22/14	6.7	75.0	274	865	24	417	67	1,373	7	4	17	28		7	0.1	39
3831	Lake Roberts	XA33 S3B	8/21/14	6.7	48.0	242	20	4	1,030	186	1,240	4	4	33	41		6		49
MEAN				6.8	51.2	239	159	10	781	231	1,180	4	9	37	50		7	6.7	52
MEDIAN				6.8	46.2	235	66	6	761	210	1176	4.0	7	35	50		7	5.4	49

Characteristics of Water Samples Collected at Lake Roberts. Lake Reaves and Wetland Tussock
September 2013 through August 2014

Sample ID	Sample Description	Site	Date Collected	pH (s.u.) (field measurement)	Alkalinity (mg/L)	Conductivity (µmho/cm) (field measurement)	Ammonia (µg/L)	NOX (µg/L)	Diss. Org. N (µg/L) (pass through 0.45 micron filter)	Part. N (µg/L)	Total N (µg/L)	SRP (µg/L)	Diss. Org. P (µg/L) (pass through 0.45 micron filter)	Part. P (µg/L)	Total P (µg/L)	Chyl- a (mg/m^3)	TSS (mg/L)	Turbidity (NTU) (field measurement)	Color (PCU)
3530	Lake Reaves	XA32 S5S	9/25/13	6.1	33.8	182	8	5	1,054	309	1,376	16	1	21	38	10.2	2	6.3	240
3832	Lake Reaves	XA32 S5S	10/21/13	5.8	34.0	187	2	5	654	167	828	6	5	14	25	8.1	2	0.5	480
3832	Lake Reaves	XA32 S5S	11/20/13	5.5	35.0	204	40	9	990	131	1,170	4	17	11	32	9.8	5	0.1	220
3832	Lake Reaves	XA32 S5S	12/18/13	6.3	33.0	218	38	5	790	48	881	6	0	7	13	4.4	1	0.4	190
3832	Lake Reaves	XA32 S5S	1/21/14	6.3	34.0	206	5	17	600	152	774	7	0	2	9	0.2	1	0.1	190
3832	Lake Reaves	XA32 S5S	2/17/14	6.9	33.0	263	40	6	860	14	920	3	11	6	20	3.3	4	1.2	190
3832	Lake Reaves	XA32 S5S	3/20/14	6.5	35.8	217	7	5	497	160	669	4	3	5	12	2.4	2	0.1	160
3832	Lake Reaves	XA32 S5S	4/23/14	6.2	33.8	215	43	5	755	72	875	4	6	5	15	2.6	4	0.1	160
3832	Lake Reaves	XA32 S5S	5/22/14	6.3	41.0	214	40	6	1,240	84	1,370	7	11	41	59	5.6	13	0.7	210
3832	Lake Reaves	XA32 S5S	6/25/14	6.5	43.8	227	24	6	730	153	913	6	6	13	25	26.2	3	1.4	150
3832	Lake Reaves	XA32 S5S	7/22/14	6.3	48.6	226	415	43	252	449	1,159	7	5	74	86	55.1	5	0.1	240
3832	Lake Reaves	XA32 S5S	8/21/14	7.1	35.0	179	20	4	1,260	0	1,260	4	8	43	55	14.6	5		240
MEAN				6.3	36.7	212	57	10	807	145	1,016	6	6	20	32	11.9	4	1.0	223
MEDIAN				6.3	34.5	215	31	6	773	142	917	6.0	6	12	25	6.9	3	0.4	200
3531	Lake Roberts	X Wetland	9/25/13	6.0	33.0	144	116	5	818	1,109	2,048	30	2	163	195	13.8	257	259.3	210
3833	Lake Roberts	X Wetland	10/21/13	6.1	30.0	164	71	5	881	531	1,488	10	3	96	109	84.0	98	21.8	400
3833	Lake Roberts	X Wetland	11/20/13																
3833	Lake Roberts	X Wetland	12/18/13	5.8	24.0	169	36	5	811	520	1,372	17	3	121	141	77.9	83	8.6	180
3833	Lake Roberts	X Wetland	1/21/14	6.1	18.6	161	5	20	765	157	947	15	2	28	45	27.2	16	13.5	220
3833	Lake Roberts	X Wetland	2/17/14	6.3	14.0	152	40	5	1,630	575	2,250	4	23	23	50	10.2	15	4.0	260
3833	Lake Roberts	X Wetland	3/20/14	6.1	14.0	145	17	5	709	701	1,432	8	14	126	148	127.0	115	133.5	280
3833	Lake Roberts	X Wetland	4/23/14	5.5	13.8	150	49	21	1,333	213	1,616	1	17	142	160	43.4	38	7.8	260
3833	Lake Roberts	X Wetland	5/22/14																
3833	Lake Roberts	X Wetland	6/25/14	5.8	27.6	191	122	8	883	415	1,428	8	20	81	109	59.2	26	8.7	120
3833	Lake Roberts	X Wetland	7/22/14	5.9	33.2	188	451	4	576	293	1,324	14	19	24	57	35.2	16	0.0	160
3833	Lake Roberts	X Wetland	8/21/14																
MEAN				6.0	23.1	163	101	9	934	502	1,545	12	11	89	113	53.1	74	50.8	232
MEDIAN				6.0	24.0	161	49	5	818	520	1432	10.0	14	96	109	43.4	38	8.7	220

Note: * (XA33S2S August 2014) Data considered to be outlier and not used in the Mean or Median Value calculation

Note: Undetected parameters are used at the full MDL

APPENDIX 3-1

Hydrologic Characteristics for Lake Roberts

Appendix 3-1
Hydrologic Characteristics for Lake Roberts

Land Use Code	Hydrologic Soil Group	Area (acres)	Curve Number	CN*Area
1110	B/D	0.67	68	45.38
1110	B/D	1.71	68	116.32
1110	B/D	1.73	68	117.63
1110	B/D	0.20	68	13.30
1110	B/D	0.01	68	0.88
1110	B/D	0.02	68	1.28
1110	B/D	2.12	68	144.28
1110	B/D	3.52	68	239.11
1110	C	9.94	79	785.50
1110	C	0.65	79	51.73
1110	C	0.24	79	19.03
1110	D	0.10	84	8.75
1110	D	0.01	84	0.65
1110	D	3.10	84	260.15
1210	A	5.83	57	332.24
1210	A	3.16	57	180.40
1210	A	39.45	57	2,248.41
1210	A	0.00	57	0.00
1210	A	1.69	57	96.42
1210	A	4.78	57	272.38
1210	B/D	0.06	72	4.33
1210	B/D	0.12	72	8.79
1210	B/D	0.23	72	16.23
1210	B/D	1.30	72	93.49
1210	B/D	2.82	72	203.37
1210	B/D	1.01	72	72.83
1210	B/D	3.28	72	236.11
1210	B/D	1.81	72	130.23
1210	B/D	9.73	72	700.59
1210	B/D	0.17	72	12.54
1210	B/D	0.00	72	0.05
1210	B/D	5.95	72	428.70

Land Use Code	Hydrologic Soil Group	Area (acres)	Curve Number	CN*Area
1210	B/D	2.68	72	193.11
1210	B/D	0.73	72	52.37
1210	B/D	1.06	72	76.61
1210	B/D	0.56	72	40.47
1210	B/D	5.64	72	405.74
1210	B/D	0.73	72	52.55
1210	B/D	3.63	72	261.54
1210	B/D	0.58	72	41.76
1210	B/D	5.75	72	414.35
1210	B/D	0.84	72	60.16
1210	B/D	8.64	72	621.92
1210	B/D	0.32	72	23.02
1210	B/D	2.16	72	155.17
1210	B/D	0.84	72	60.82
1210	C	2.94	81	238.35
1210	C	2.55	81	206.31
1210	C	0.31	81	25.07
1210	C	40.14	81	3,251.11
1210	C	1.26	81	102.39
1210	C	6.30	81	510.08
1210	C	0.02	81	1.36
1210	C	4.39	81	355.46
1210	C	0.75	81	60.47
1210	D	0.05	86	4.01
1210	D	0.25	86	21.86
1210	D	0.87	86	75.00
1210	D	1.15	86	98.88
1210	D	3.58	86	308.13
1210	D	3.42	86	293.75
1210	D	0.88	86	75.76
1210	D	2.25	86	193.18
1210	D	0.05	86	4.16
1210	WATER	0.06	86	5.16
1210	WATER	0.17	86	14.48
1210	WATER	0.36	86	30.66

Land Use Code	Hydrologic Soil Group	Area (acres)	Curve Number	CN*Area
1210	WATER	0.54	86	46.43
1210	WATER	1.31	86	112.42
1210	WATER	0.66	86	56.85
1210	WATER	0.00	86	0.16
1210	WATER	3.62	86	311.45
1210	WATER	0.14	86	12.44
1210	WATER	11.35	86	975.95
1290	B/D	1.13	72	81.00
1290	B/D	0.77	72	55.09
1290	B/D	0.55	72	39.62
1290	D	0.27	86	23.08
8140	B/D	0.02	98	2.19
8140	C	0.01	98	1.28
1820	A	0.96	39	37.49
1820	A	16.68	39	650.55
1820	B/D	0.25	80	20.21
1820	B/D	0.04	80	3.43
1820	B/D	4.00	80	319.92
1820	B/D	4.46	80	356.76
1820	C	7.76	74	574.59
1820	C	1.73	74	128.38
1820	D	0.07	80	5.95
1820	D	0.00	80	0.09
1820	D	3.15	80	252.12
1820	WATER	0.02	80	1.30
1820	WATER	0.01	80	0.44
2110	A	0.30	39	11.68
2110	B/D	0.44	80	35.58
2110	B/D	1.03	80	82.55
2110	B/D	0.00	80	0.09
2130	B/D	0.42	80	33.53
2130	B/D	0.03	80	2.40
2130	C	4.07	74	301.38
2210	A	0.07	39	2.89
2210	C	5.11	74	378.47

Land Use Code	Hydrologic Soil Group	Area (acres)	Curve Number	CN*Area
2230	B/D	1.25	80	100.23
2230	B/D	4.15	80	331.61
2230	C	7.27	74	538.16
2230	D	4.66	80	372.47
3100	B/D	3.17	80	253.46
3100	B/D	11.98	80	958.07
3100	B/D	0.08	80	6.65
3100	C	0.24	74	17.94
3100	C	0.96	74	71.38
3100	C	0.26	74	19.12
3100	C	5.16	74	382.20
3100	C	0.13	74	9.59
3100	D	0.95	80	76.07
3100	D	1.89	80	150.83
3100	WATER	0.08	80	6.13
3100	WATER	1.19	80	95.22
5200	A	0.03	39	1.19
5200	A	0.18	39	7.14
5200	B/D	0.00	80	0.25
5200	B/D	0.78	80	62.10
5200	B/D	0.00	80	0.04
5200	B/D	0.46	80	36.44
5200	D	0.18	80	14.47
5200	D	0.12	80	9.98
5200	D	0.13	80	10.77
5200	D	0.10	80	7.81
5200	D	0.16	80	12.43
5300	A	0.06	39	2.32
5300	A	0.20	39	7.80
5300	A	0.23	39	9.14
5300	B/D	0.15	80	11.67
5300	B/D	0.06	80	4.73
5300	B/D	0.28	80	22.50
5300	C	3.18	74	235.63
5300	D	0.07	80	5.55

Land Use Code	Hydrologic Soil Group	Area (acres)	Curve Number	CN*Area
5300	WATER	1.59	100	159.50
5300	WATER	0.95	100	94.65
5300	WATER	3.29	100	328.91
6170	A	0.73	98	71.80
6170	B/D	3.29	98	322.13
6170	B/D	1.64	98	161.14
6170	C	5.05	98	494.51
6170	C	0.02	98	2.33
6170	D	0.42	98	40.89
6170	D	21.23	98	2,080.83
6170	WATER	0.79	98	77.25
6172	B/D	0.62	98	60.53
6172	B/D	1.21	98	118.98
6172	B/D	0.11	98	10.51
6172	B/D	0.86	98	84.74
6172	B/D	1.22	98	120.05
6172	B/D	0.02	98	2.41
6172	B/D	0.64	98	62.86
6172	B/D	0.08	98	7.50
6172	D	2.45	98	240.34
6172	D	1.55	98	151.99
6172	D	6.26	98	613.39
6172	D	3.90	98	382.26
6172	D	4.92	98	481.99
6410	A	0.10	98	9.98
6410	B/D	0.65	98	63.24
6410	B/D	0.02	98	2.44
6410	B/D	0.02	98	2.15
6410	B/D	0.80	98	78.68
6410	B/D	2.31	98	226.00
6410	B/D	3.35	98	328.57
6410	B/D	1.25	98	122.63
6410	D	4.89	98	479.41
6410	D	27.87	98	2,730.80
6410	D	2.27	98	222.92

Land Use Code	Hydrologic Soil Group	Area (acres)	Curve Number	CN*Area
6410	D	0.73	98	72.02
6410	D	1.77	98	173.93
6410	D	13.99	98	1,370.93
6410	WATER	2.53	98	248.28
6410	WATER	1.87	98	183.39
6410	WATER	0.03	98	3.33
6440	A	0.29	98	28.33
6440	B/D	0.13	98	12.84
6440	D	1.15	98	112.66
6440	WATER	3.12	98	305.54
8140	A	0.82	98	80.31
8140	B/D	0.01	98	0.95
8140	B/D	2.54	98	249.41
8140	C	0.28	98	27.38
8140	C	2.66	98	260.49
8140	D	2.50	98	244.99
8140	WATER	0.04	98	4.26
		472.98		37,762.49

- Composite Curve Number is 80 (37,762.49/472.98).
- 103.81 acres of Lake Robert and 18.36 acres for Lake Reaves were not included in this calculation as they will be calculated based on direct precipitation.

APPENDIX 4-1

Calculated Mean Annual Runoff Inputs from Sub-Basin Areas to Lake Roberts

Appendix 4-1
Calculated Mean Annual Runoff Inputs from Sub-Basin Area to Lake Roberts

Basin	Land Use	Stormwater Treatment	Area (acres)	DCIA (%)	Non-DCIA CN Value	Runoff C Value	Generated Runoff Volume (ac-ft)	Runoff Volume Reduction Factor	Delivered Runoff Volume (ac-ft)
Lake Roberts	Low Density	No	9.94	5	77	0.1194	4.69	0	4.69
Lake Roberts	Low Density	No	0.54	5	77	0.1194	0.25	0	0.25
Lake Roberts	Low Density	No	0.24	5	77	0.1194	0.11	0	0.11
Lake Roberts	Low Density	No	0.10	5	82	0.1625	0.07	0	0.07
Lake Roberts	Low Density	No	0.67	5	82	0.1625	0.43	0	0.43
Lake Roberts	Low Density	No	0.01	5	82	0.1625	0.01	0	0.01
Lake Roberts	Low Density	No	1.71	5	82	0.1625	1.10	0	1.10
Lake Roberts	Low Density	No	1.73	5	82	0.1625	1.11	0	1.11
Lake Roberts	Low Density	No	0.20	5	82	0.1625	0.13	0	0.13
Lake Roberts	Low Density	No	0.01	5	82	0.1625	0.01	0	0.01
Lake Roberts	Low Density	No	0.02	5	82	0.1625	0.01	0	0.01
Lake Roberts	Low Density	No	2.12	5	82	0.1625	1.36	0	1.36
Lake Roberts	Low Density	No	3.50	5	82	0.1625	2.25	0	2.25
Lake Roberts	Low Density	No	3.10	5	82	0.1625	1.99	0	1.99
Lake Roberts	Medium Density	No	5.83	15	53	0.1077	2.48	0	2.48
Lake Roberts	Medium Density	No	1.33	15	53	0.1077	0.57	0	0.57
Lake Roberts	Medium Density	No	18.57	15	53	0.1077	7.91	0	7.91
Lake Roberts	Medium Density	No	1.26	15	53	0.1077	0.54	0	0.54
Lake Roberts	Medium Density	No	0.09	15	80	0.1984	0.07	0	0.07
Lake Roberts	Medium Density	No	2.94	15	80	0.1984	2.31	0	2.31
Lake Roberts	Medium Density	No	2.55	15	80	0.1984	2.00	0	2.00
Lake Roberts	Medium Density	No	0.31	15	80	0.1984	0.24	0	0.24
Lake Roberts	Medium Density	No	0.06	15	80	0.1984	0.05	0	0.05

Basin	Land Use	Stormwater Treatment	Area (acres)	DCIA (%)	Non-DCIA CN Value	Runoff C Value	Generated Runoff Volume (ac-ft)	Runoff Volume Reduction Factor	Delivered Runoff Volume (ac-ft)
Lake Roberts	Medium Density	No	0.01	15	80	0.1984	0.01	0	0.01
Lake Roberts	Medium Density	No	0.02	15	80	0.1984	0.01	0	0.01
Lake Roberts	Medium Density	No	0.60	15	80	0.1984	0.47	0	0.47
Lake Roberts	Medium Density	No	0.36	15	84	0.2356	0.34	0	0.34
Lake Roberts	Medium Density	No	0.31	15	84	0.2356	0.28	0	0.28
Lake Roberts	Medium Density	No	0.50	15	84	0.2356	0.46	0	0.46
Lake Roberts	Medium Density	No	0.02	15	84	0.2356	0.02	0	0.02
Lake Roberts	Medium Density	No	0.06	15	84	0.2356	0.06	0	0.06
Lake Roberts	Medium Density	No	0.12	15	84	0.2356	0.11	0	0.11
Lake Roberts	Medium Density	No	0.23	15	84	0.2356	0.21	0	0.21
Lake Roberts	Medium Density	No	1.30	15	84	0.2356	1.21	0	1.21
Lake Roberts	Medium Density	No	0.05	15	84	0.2356	0.04	0	0.04
Lake Roberts	Medium Density	No	2.82	15	84	0.2356	2.63	0	2.63
Lake Roberts	Medium Density	No	1.01	15	84	0.2356	0.94	0	0.94
Lake Roberts	Medium Density	No	0.41	15	84	0.2356	0.38	0	0.38
Lake Roberts	Medium Density	No	0.25	15	84	0.2356	0.24	0	0.24
Lake Roberts	Medium Density	No	1.53	15	84	0.2356	1.42	0	1.42
Lake Roberts	Medium Density	No	0.50	15	84	0.2356	0.46	0	0.46
Lake Roberts	Medium Density	No	3.47	15	84	0.2356	3.23	0	3.23
Lake Roberts	Medium Density	No	5.95	15	84	0.2356	5.55	0	5.55
Lake Roberts	Medium Density	No	1.15	15	84	0.2356	1.07	0	1.07

Basin	Land Use	Stormwater Treatment	Area (acres)	DCIA (%)	Non-DCIA CN Value	Runoff C Value	Generated Runoff Volume (ac-ft)	Runoff Volume Reduction Factor	Delivered Runoff Volume (ac-ft)
Lake Roberts	Medium Density	No	2.68	15	84	0.2356	2.50	0	2.50
Lake Roberts	Medium Density	No	3.58	15	84	0.2356	3.34	0	3.34
Lake Roberts	Medium Density	No	0.73	15	84	0.2356	0.68	0	0.68
Lake Roberts	Medium Density	No	1.06	15	84	0.2356	0.99	0	0.99
Lake Roberts	Medium Density	No	0.56	15	84	0.2356	0.52	0	0.52
Lake Roberts	Medium Density	No	3.42	15	84	0.2356	3.18	0	3.18
Lake Roberts	Medium Density	No	5.60	15	84	0.2356	5.22	0	5.22
Lake Roberts	Medium Density	No	0.73	15	84	0.2356	0.68	0	0.68
Lake Roberts	Medium Density	No	3.63	15	84	0.2356	3.38	0	3.38
Lake Roberts	Medium Density	No	0.58	15	84	0.2356	0.54	0	0.54
Lake Roberts	Medium Density	No	5.75	15	84	0.2356	5.36	0	5.36
Lake Roberts	Medium Density	No	0.79	15	84	0.2356	0.73	0	0.73
Lake Roberts	Medium Density	No	1.93	15	84	0.2356	1.80	0	1.80
Lake Roberts	Medium Density	No	0.32	15	84	0.2356	0.29	0	0.29
Lake Roberts	Medium Density	No	0.05	15	84	0.2356	0.05	0	0.05
Lake Roberts	Medium Density	No	0.06	15	98	0.6665	0.16	0	0.16
Lake Roberts	Medium Density	No	0.17	15	98	0.6665	0.44	0	0.44
Lake Roberts	Medium Density	No	0.66	15	98	0.6665	1.74	0	1.74
Lake Roberts	Medium Density	No	3.62	15	98	0.6665	9.53	0	9.53
Lake Roberts	Medium Density	No	0.06	15	98	0.6665	0.16	0	0.16
Lake Roberts	Medium Density	No	1.13	15	84	0.2356	1.05	0	1.05

Basin	Land Use	Stormwater Treatment	Area (acres)	DCIA (%)	Non-DCIA CN Value	Runoff C Value	Generated Runoff Volume (ac-ft)	Runoff Volume Reduction Factor	Delivered Runoff Volume (ac-ft)
Lake Roberts	Medium Density	No	0.77	15	84	0.2356	0.71	0	0.71
Lake Roberts	Medium Density	No	0.27	15	84	0.2356	0.25	0	0.25
Lake Roberts	Medium Density	No	0.55	15	84	0.2356	0.51	0	0.51
Lake Roberts	Institutional	No	0.00	90	98	0.6665	0.01	0	0.01
Lake Roberts	Institutional	No	0.02	90	98	0.6665	0.06	0	0.06
Lake Roberts	Golf Course	No	5.55	1	40	0.0074	0.16	0	0.16
Lake Roberts	Golf Course	No	2.77	1	74	0.0768	0.84	0	0.84
Lake Roberts	Golf Course	No	1.73	1	74	0.0768	0.53	0	0.53
Lake Roberts	Golf Course	No	0.25	1	80	0.1212	0.12	0	0.12
Lake Roberts	Golf Course	No	0.07	1	80	0.1212	0.04	0	0.04
Lake Roberts	Golf Course	No	0.00	1	80	0.1212	0.00	0	0.00
Lake Roberts	Golf Course	No	3.63	1	80	0.1212	1.74	0	1.74
Lake Roberts	Golf Course	No	4.46	1	80	0.1212	2.14	0	2.14
Lake Roberts	Golf Course	No	3.15	1	80	0.1212	1.51	0	1.51
Lake Roberts	Golf Course	No	0.02	1	98	0.6665	0.04	0	0.04
Lake Roberts	Pasture Land	No	0.30	1	40	0.0074	0.01	0	0.01
Lake Roberts	Pasture Land	No	0.44	1	80	0.1212	0.21	0	0.21
Lake Roberts	Pasture Land	No	1.03	1	80	0.1212	0.49	0	0.49
Lake Roberts	Pasture Land	No	0.00	1	80	0.1212	0.00	0	0.00
Lake Roberts	Pasture Land	No	3.96	1	74	0.0768	1.20	0	1.20
Lake Roberts	Pasture Land	No	0.42	1	80	0.1212	0.20	0	0.20
Lake Roberts	Pasture Land	No	0.03	1	80	0.1212	0.01	0	0.01
Lake Roberts	Groves	No	0.07	1	40	0.0074	0.00	0	0.00
Lake Roberts	Groves	No	5.07	1	74	0.0768	1.54	0	1.54
Lake Roberts	Groves	No	7.27	1	74	0.0768	2.21	0	2.21
Lake Roberts	Groves	No	1.25	1	80	0.1212	0.60	0	0.60
Lake Roberts	Groves	No	4.15	1	80	0.1212	1.99	0	1.99
Lake Roberts	Groves	No	4.66	1	80	0.1212	2.23	0	2.23
Lake Roberts	Herbaceous	No	0.24	1	74	0.0768	0.07	0	0.07

Basin	Land Use	Stormwater Treatment	Area (acres)	DCIA (%)	Non-DCIA CN Value	Runoff C Value	Generated Runoff Volume (ac-ft)	Runoff Volume Reduction Factor	Delivered Runoff Volume (ac-ft)
	upland nonforested								
Lake Roberts	Herbaceous upland nonforested	No	0.96	1	74	0.0768	0.29	0	0.29
Lake Roberts	Herbaceous upland nonforested	No	0.26	1	74	0.0768	0.08	0	0.08
Lake Roberts	Herbaceous upland nonforested	No	4.45	1	74	0.0768	1.35	0	1.35
Lake Roberts	Herbaceous upland nonforested	No	0.95	1	80	0.1212	0.46	0	0.46
Lake Roberts	Herbaceous upland nonforested	No	3.17	1	80	0.1212	1.52	0	1.52
Lake Roberts	Herbaceous upland nonforested	No	1.89	1	80	0.1212	0.90	0	0.90
Lake Roberts	Herbaceous upland nonforested	No	11.55	1	80	0.1212	5.54	0	5.54
Lake Roberts	Herbaceous upland nonforested	No	0.08	1	80	0.1212	0.04	0	0.04
Lake Roberts	Lakes	No	0.18	85	98	0.0000	0.00	0	0.00
Lake Roberts	Lakes	No	0.78	85	98	0.0000	0.00	0	0.00
Lake Roberts	Lakes	No	0.12	85	98	0.0000	0.00	0	0.00
Lake Roberts	Lakes	No	0.00	85	98	0.0000	0.00	0	0.00
Lake Roberts	Lakes	No	0.13	85	98	0.0000	0.00	0	0.00
Lake Roberts	Lakes	No	0.10	85	98	0.0000	0.00	0	0.00
Lake Roberts	Lakes	No	0.16	85	98	0.0000	0.00	0	0.00
Lake Roberts	Lakes	No	0.46	85	98	0.0000	0.00	0	0.00
Lake Roberts	Lakes	No	103.81	85	98	0.0000	0.00	0	0.00
Lake Roberts	Lake Reaves	No	0.03	85	98	1.0000	0.12	0	0.12
Lake Roberts	Lake Reaves	No	0.18	85	98	1.0000	0.72	0	0.72

Basin	Land Use	Stormwater Treatment	Area (acres)	DCIA (%)	Non-DCIA CN Value	Runoff C Value	Generated Runoff Volume (ac-ft)	Runoff Volume Reduction Factor	Delivered Runoff Volume (ac-ft)
Lake Roberts	Lake Reaves	No	0.00	85	98	1.0000	0.01	0	0.01
Lake Roberts	Lake Reaves	No	18.36	85	98	1.0000	72.61	0	72.61
Lake Roberts	Ponds	No	0.06	85	98	0.6665	0.16	0	0.16
Lake Roberts	Ponds	No	0.15	85	98	0.6665	0.38	0	0.38
Lake Roberts	Ponds	No	0.06	85	98	0.6665	0.16	0	0.16
Lake Roberts	Ponds	No	0.07	85	98	0.6665	0.18	0	0.18
Lake Roberts	Ponds	No	1.59	85	98	0.6665	4.20	0	4.20
Lake Roberts	Wetland	No	0.73	75	39	0.5000	1.45	0	1.45
Lake Roberts	Wetland	No	5.05	75	74	0.5176	10.33	0	10.33
Lake Roberts	Wetland	No	0.02	75	74	0.5176	0.05	0	0.05
Lake Roberts	Wetland	No	0.42	75	80	0.5288	0.87	0	0.87
Lake Roberts	Wetland	No	3.29	75	80	0.5288	6.87	0	6.87
Lake Roberts	Wetland	No	21.23	75	80	0.5288	44.40	0	44.40
Lake Roberts	Wetland	No	1.64	75	80	0.5288	3.44	0	3.44
Lake Roberts	Wetland	No	0.79	75	98	0.6665	2.08	0	2.08
Lake Roberts	Wetland	No	0.02	75	80	0.5288	0.05	0	0.05
Lake Roberts	Wetland	No	0.64	75	80	0.5288	1.34	0	1.34
Lake Roberts	Wetland	No	3.83	75	80	0.5288	8.01	0	8.01
Lake Roberts	Wetland	No	0.03	75	80	0.5288	0.06	0	0.06
Lake Roberts	Wetland	No	2.45	75	80	0.5288	5.13	0	5.13
Lake Roberts	Wetland	No	0.62	75	80	0.5288	1.29	0	1.29
Lake Roberts	Wetland	No	1.55	75	80	0.5288	3.24	0	3.24
Lake Roberts	Wetland	No	1.21	75	80	0.5288	2.54	0	2.54
Lake Roberts	Wetland	No	0.11	75	80	0.5288	0.22	0	0.22
Lake Roberts	Wetland	No	6.26	75	80	0.5288	13.09	0	13.09
Lake Roberts	Wetland	No	0.86	75	80	0.5288	1.81	0	1.81
Lake Roberts	Wetland	No	1.22	75	80	0.5288	2.56	0	2.56
Lake Roberts	Wetland	No	4.92	75	80	0.5288	10.28	0	10.28
Lake Roberts	Wetland	No	0.10	75	39	0.5000	0.20	0	0.20
Lake Roberts	Wetland	No	4.89	75	80	0.5288	10.23	0	10.23

Basin	Land Use	Stormwater Treatment	Area (acres)	DCIA (%)	Non-DCIA CN Value	Runoff C Value	Generated Runoff Volume (ac-ft)	Runoff Volume Reduction Factor	Delivered Runoff Volume (ac-ft)
Lake Roberts	Wetland	No	27.87	75	80	0.5288	58.27	0	58.27
Lake Roberts	Wetland	No	0.65	75	80	0.5288	1.35	0	1.35
Lake Roberts	Wetland	No	0.02	75	80	0.5288	0.05	0	0.05
Lake Roberts	Wetland	No	2.27	75	80	0.5288	4.76	0	4.76
Lake Roberts	Wetland	No	0.02	75	80	0.5288	0.05	0	0.05
Lake Roberts	Wetland	No	0.80	75	80	0.5288	1.68	0	1.68
Lake Roberts	Wetland	No	0.73	75	80	0.5288	1.54	0	1.54
Lake Roberts	Wetland	No	1.77	75	80	0.5288	3.71	0	3.71
Lake Roberts	Wetland	No	2.31	75	80	0.5288	4.82	0	4.82
Lake Roberts	Wetland	No	13.99	75	80	0.5288	29.25	0	29.25
Lake Roberts	Wetland	No	3.33	75	80	0.5288	6.97	0	6.97
Lake Roberts	Wetland	No	1.25	75	80	0.5288	2.62	0	2.62
Lake Roberts	Lake	No	2.53	75	98	0.0000	0.00	0	0.00
Lake Roberts	Wetland	No	1.87	75	98	0.6665	4.93	0	4.93
Lake Roberts	Wetland	No	0.29	75	39	0.5000	0.57	0	0.57
Lake Roberts	Wetland	No	1.12	75	80	0.5288	2.33	0	2.33
Lake Roberts	Wetland	No	0.13	75	80	0.5288	0.27	0	0.27
Lake Roberts	Wetland	No	3.12	75	98	0.6665	8.22	0	8.22
Lake Roberts	Roads	No	0.01	90	98	0.6665	0.03	0	0.03
Lake Roberts	Roads	No	0.48	90	98	0.6665	1.26	0	1.26
Lake Roberts	Roads	No	0.63	90	98	0.6665	1.66	0	1.66
Lake Roberts	Low Density	Wet Detention	0.12	5	77	0.1194	0.05	20	0.04
Lake Roberts	Low Density	Wet Detention	0.02	5	82	0.1625	0.01	20	0.01
Lake Roberts	Low Density	Wet Detention	0.00	5	82	0.1625	0.00	20	0.00
Lake Roberts	Medium Density	Wet Detention	20.87	15	53	0.1077	8.89	20	7.11
Lake Roberts	Medium Density	Wet Detention	0.00	15	53	0.1077	0.00	20	0.00
Lake Roberts	Medium Density	Wet Detention	0.43	15	53	0.1077	0.18	20	0.15

Basin	Land Use	Stormwater Treatment	Area (acres)	DCIA (%)	Non-DCIA CN Value	Runoff C Value	Generated Runoff Volume (ac-ft)	Runoff Volume Reduction Factor	Delivered Runoff Volume (ac-ft)
Lake Roberts	Medium Density	Wet Detention	1.83	15	53	0.1077	0.78	20	0.62
Lake Roberts	Medium Density	Wet Detention	3.69	15	80	0.1984	2.90	20	2.32
Lake Roberts	Medium Density	Wet Detention	0.75	15	80	0.1984	0.59	20	0.47
Lake Roberts	Medium Density	Wet Detention	6.30	15	80	0.1984	4.94	20	3.95
Lake Roberts	Medium Density	Wet Detention	40.07	15	80	0.1984	31.43	20	25.14
Lake Roberts	Medium Density	Wet Detention	1.25	15	80	0.1984	0.98	20	0.79
Lake Roberts	Medium Density	Wet Detention	0.04	15	84	0.2356	0.03	20	0.03
Lake Roberts	Medium Density	Wet Detention	7.49	15	84	0.2356	6.98	20	5.58
Lake Roberts	Medium Density	Wet Detention	0.01	15	84	0.2356	0.01	20	0.01
Lake Roberts	Medium Density	Wet Detention	0.38	15	84	0.2356	0.36	20	0.28
Lake Roberts	Medium Density	Wet Detention	0.31	15	84	0.2356	0.29	20	0.23
Lake Roberts	Medium Density	Wet Detention	1.84	15	84	0.2356	1.71	20	1.37
Lake Roberts	Medium Density	Wet Detention	0.82	15	84	0.2356	0.77	20	0.61
Lake Roberts	Medium Density	Wet Detention	0.00	15	84	0.2356	0.00	20	0.00
Lake Roberts	Medium Density	Wet Detention	0.84	15	84	0.2356	0.78	20	0.62
Lake Roberts	Medium Density	Wet Detention	0.17	15	84	0.2356	0.16	20	0.13
Lake Roberts	Medium Density	Wet Detention	0.00	15	84	0.2356	0.00	20	0.00
Lake Roberts	Medium Density	Wet Detention	2.87	15	84	0.2356	2.68	20	2.14
Lake Roberts	Medium Density	Wet Detention	0.28	15	84	0.2356	0.26	20	0.21
Lake Roberts	Medium Density	Wet Detention	0.38	15	84	0.2356	0.35	20	0.28
Lake Roberts	Medium Density	Wet Detention	6.26	15	84	0.2356	5.83	20	4.67

Basin	Land Use	Stormwater Treatment	Area (acres)	DCIA (%)	Non-DCIA CN Value	Runoff C Value	Generated Runoff Volume (ac-ft)	Runoff Volume Reduction Factor	Delivered Runoff Volume (ac-ft)
Lake Roberts	Medium Density	Wet Detention	0.01	15	98	0.6665	0.01	20	0.01
Lake Roberts	Medium Density	Wet Detention	11.29	15	98	0.6665	29.74	20	23.80
Lake Roberts	Medium Density	Wet Detention	0.00	15	98	0.6665	0.00	20	0.00
Lake Roberts	Medium Density	Wet Detention	0.36	15	98	0.6665	0.94	20	0.75
Lake Roberts	Medium Density	Wet Detention	0.54	15	98	0.6665	1.42	20	1.14
Lake Roberts	Medium Density	Wet Detention	1.31	15	98	0.6665	3.45	20	2.76
Lake Roberts	Institutional	Wet Detention	0.01	90	98	0.6665	0.03	20	0.02
Lake Roberts	Pasture Land	Wet Detention	0.01	1	80	0.1212	0.00	20	0.00
Lake Roberts	Pasture Land	Wet Detention	0.00	1	80	0.1212	0.00	20	0.00
Lake Roberts	Pasture Land	Wet Detention	0.12	1	74	0.0768	0.04	20	0.03
Lake Roberts	Groves	Wet Detention	0.05	1	74	0.0768	0.01	20	0.01
Lake Roberts	Herbaceous upland nonforested	Wet Detention	0.00	1	74	0.0768	0.00	20	0.00
Lake Roberts	Herbaceous upland nonforested	Wet Detention	0.72	1	74	0.0768	0.22	20	0.17
Lake Roberts	Herbaceous upland nonforested	Wet Detention	0.13	1	74	0.0768	0.04	20	0.03
Lake Roberts	Herbaceous upland nonforested	Wet Detention	0.43	1	80	0.1212	0.21	20	0.16
Lake Roberts	Herbaceous upland nonforested	Wet Detention	0.08	1	98	0.6665	0.20	20	0.16
Lake Roberts	Herbaceous upland nonforested	Wet Detention	1.19	1	98	0.6665	3.14	20	2.51
Lake Roberts	Ponds	Wet Detention	0.23	85	98	0.6665	0.62	20	0.49

Basin	Land Use	Stormwater Treatment	Area (acres)	DCIA (%)	Non-DCIA CN Value	Runoff C Value	Generated Runoff Volume (ac-ft)	Runoff Volume Reduction Factor	Delivered Runoff Volume (ac-ft)
Lake Roberts	Ponds	Wet Detention	3.18	85	98	0.6665	8.39	20	6.71
Lake Roberts	Ponds	Wet Detention	0.28	85	98	0.6665	0.74	20	0.59
Lake Roberts	Ponds	Wet Detention	3.29	85	98	0.6665	8.67	20	6.93
Lake Roberts	Wetland	Wet Detention	0.00	75	80	0.5288	0.00	20	0.00
Lake Roberts	Wetland	Wet Detention	0.07	75	80	0.5288	0.14	20	0.12
Lake Roberts	Wetland	Wet Detention	0.05	75	80	0.5288	0.10	20	0.08
Lake Roberts	Wetland	Wet Detention	0.02	75	80	0.5288	0.04	20	0.03
Lake Roberts	Wetland	Wet Detention	0.03	75	98	0.6665	0.09	20	0.07
Lake Roberts	Wetland	Wet Detention	0.01	75	80	0.5288	0.01	20	0.01
Lake Roberts	Wetland	Wet Detention	0.03	75	80	0.5288	0.06	20	0.05
Lake Roberts	Roads	Wet Detention	0.82	90	98	0.6665	2.16	20	1.73
Lake Roberts	Roads	Wet Detention	0.28	90	98	0.6665	0.74	20	0.59
Lake Roberts	Roads	Wet Detention	2.66	90	98	0.6665	7.01	20	5.60
Lake Roberts	Roads	Wet Detention	2.01	90	98	0.6665	5.29	20	4.23
Lake Roberts	Roads	Wet Detention	0.12	90	98	0.6665	0.30	20	0.24
Lake Roberts	Roads	Wet Detention	0.06	90	98	0.6665	0.15	20	0.12
Lake Roberts	Roads	Wet Detention	1.76	90	98	0.6665	4.63	20	3.70
Lake Roberts	Roads	Wet Detention	0.04	90	98	0.6665	0.11	20	0.09
Lake Roberts	Medium Density	Wetland Detention	4.78	15	53	0.1077	2.03	20	1.63
Lake Roberts	Medium Density	Wetland Detention	0.14	15	98	0.6665	0.38	20	0.31
Lake Roberts	Golf Course	Wetland Detention	0.96	1	40	0.0074	0.03	20	0.02

Basin	Land Use	Stormwater Treatment	Area (acres)	DCIA (%)	Non-DCIA CN Value	Runoff C Value	Generated Runoff Volume (ac-ft)	Runoff Volume Reduction Factor	Delivered Runoff Volume (ac-ft)
Lake Roberts	Golf Course	Wetland Detention	11.13	1	40	0.0074	0.33	20	0.26
Lake Roberts	Golf Course	Wetland Detention	4.99	1	74	0.0768	1.52	20	1.21
Lake Roberts	Golf Course	Wetland Detention	0.04	1	80	0.1212	0.02	20	0.02
Lake Roberts	Golf Course	Wetland Detention	0.36	1	80	0.1212	0.17	20	0.14
Lake Roberts	Golf Course	Wetland Detention	0.01	1	98	0.6665	0.01	20	0.01
Lake Roberts	Ponds	Wetland Detention	0.20	85	98	0.6665	0.53	20	0.42
Lake Roberts	Ponds	Wetland Detention	0.95	85	98	0.6665	2.49	20	2.00
			595.16				**620.44**		**589.00**

APPENDIX 5-1

Watershed Hydrologic and Nutrient Model for Lake Roberts

Basin	Land Use	Stormwater Treatment	Area (acres)	DCIA (%)	Non-DCIA CN Value	Runoff C Value	Generated Runoff Volume (ac-ft)	Runoff Volume Reduction Factor	Delivered Runoff Volume (ac-ft)	TP EMC (mg/l)	TN EMC (mg/l)	TSS EMC (mg/l)	TP (kg/yr)	TN (kg/yr)	TSS (kg/yr)
Lake Roberts	Low Density	No	9.94	5	77	0.1194	4.69	0	4.69	0.177	1.77	20.4	1.02	10.25	118.10
Lake Roberts	Low Density	No	0.54	5	77	0.1194	0.25	0	0.25	0.177	1.77	20.4	0.06	0.56	6.40
Lake Roberts	Low Density	No	0.24	5	77	0.1194	0.11	0	0.11	0.177	1.77	20.4	0.02	0.25	2.86
Lake Roberts	Low Density	No	0.10	5	82	0.1625	0.07	0	0.07	0.177	1.77	20.4	0.01	0.15	1.69
Lake Roberts	Low Density	No	0.67	5	82	0.1625	0.43	0	0.43	0.177	1.77	20.4	0.09	0.94	10.79
Lake Roberts	Low Density	No	0.01	5	82	0.1625	0.01	0	0.01	0.177	1.77	20.4	0.00	0.01	0.13
Lake Roberts	Low Density	No	1.71	5	82	0.1625	1.10	0	1.10	0.177	1.77	20.4	0.24	2.40	27.67
Lake Roberts	Low Density	No	1.73	5	82	0.1625	1.11	0	1.11	0.177	1.77	20.4	0.24	2.43	27.98
Lake Roberts	Low Density	No	0.20	5	82	0.1625	0.13	0	0.13	0.177	1.77	20.4	0.03	0.27	3.16
Lake Roberts	Low Density	No	0.01	5	82	0.1625	0.01	0	0.01	0.177	1.77	20.4	0.00	0.02	0.21
Lake Roberts	Low Density	No	0.02	5	82	0.1625	0.01	0	0.01	0.177	1.77	20.4	0.00	0.03	0.30
Lake Roberts	Low Density	No	2.12	5	82	0.1625	1.36	0	1.36	0.177	1.77	20.4	0.30	2.98	34.32
Lake Roberts	Low Density	No	3.50	5	82	0.1625	2.25	0	2.25	0.177	1.77	20.4	0.49	4.91	56.59
Lake Roberts	Low Density	No	3.10	5	82	0.1625	1.99	0	1.99	0.177	1.77	20.4	0.43	4.35	50.09
Lake Roberts	Medium Density	No	5.83	15	53	0.1077	2.48	0	2.48	0.306	2.29	33.0	0.94	7.01	101.01
Lake Roberts	Medium Density	No	1.33	15	53	0.1077	0.57	0	0.57	0.306	2.29	33.0	0.21	1.60	23.11
Lake Roberts	Medium Density	No	18.57	15	53	0.1077	7.91	0	7.91	0.306	2.29	33.0	2.98	22.34	321.88
Lake Roberts	Medium Density	No	1.26	15	53	0.1077	0.54	0	0.54	0.306	2.29	33.0	0.20	1.51	21.80
Lake Roberts	Medium Density	No	0.09	15	80	0.1984	0.07	0	0.07	0.306	2.29	33.0	0.03	0.20	2.88
Lake Roberts	Medium Density	No	2.94	15	80	0.1984	2.31	0	2.31	0.306	2.29	33.0	0.87	6.52	93.94
Lake Roberts	Medium Density	No	2.55	15	80	0.1984	2.00	0	2.00	0.306	2.29	33.0	0.75	5.64	81.32
Lake Roberts	Medium Density	No	0.31	15	80	0.1984	0.24	0	0.24	0.306	2.29	33.0	0.09	0.69	9.88
Lake Roberts	Medium Density	No	0.06	15	80	0.1984	0.05	0	0.05	0.306	2.29	33.0	0.02	0.14	2.04
Lake Roberts	Medium Density	No	0.01	15	80	0.1984	0.01	0	0.01	0.306	2.29	33.0	0.00	0.02	0.33
Lake Roberts	Medium Density	No	0.02	15	80	0.1984	0.01	0	0.01	0.306	2.29	33.0	0.00	0.04	0.54
Lake Roberts	Medium Density	No	0.60	15	80	0.1984	0.47	0	0.47	0.306	2.29	33.0	0.18	1.34	19.31
Lake Roberts	Medium Density	No	0.36	15	84	0.2356	0.34	0	0.34	0.306	2.29	33.0	0.13	0.95	13.68
Lake Roberts	Medium Density	No	0.31	15	84	0.2356	0.28	0	0.28	0.306	2.29	33.0	0.11	0.80	11.59
Lake Roberts	Medium Density	No	0.50	15	84	0.2356	0.46	0	0.46	0.306	2.29	33.0	0.18	1.31	18.92
Lake Roberts	Medium Density	No	0.02	15	84	0.2356	0.02	0	0.02	0.306	2.29	33.0	0.01	0.06	0.88
Lake Roberts	Medium Density	No	0.06	15	84	0.2356	0.06	0	0.06	0.306	2.29	33.0	0.02	0.16	2.28
Lake Roberts	Medium Density	No	0.12	15	84	0.2356	0.11	0	0.11	0.306	2.29	33.0	0.04	0.32	4.63
Lake Roberts	Medium Density	No	0.23	15	84	0.2356	0.21	0	0.21	0.306	2.29	33.0	0.08	0.59	8.55
Lake Roberts	Medium Density	No	1.30	15	84	0.2356	1.21	0	1.21	0.306	2.29	33.0	0.46	3.42	49.24
Lake Roberts	Medium Density	No	0.05	15	84	0.2356	0.04	0	0.04	0.306	2.29	33.0	0.02	0.12	1.77
Lake Roberts	Medium Density	No	2.82	15	84	0.2356	2.63	0	2.63	0.306	2.29	33.0	0.99	7.43	107.12
Lake Roberts	Medium Density	No	1.01	15	84	0.2356	0.94	0	0.94	0.306	2.29	33.0	0.36	2.66	38.36
Lake Roberts	Medium Density	No	0.41	15	84	0.2356	0.38	0	0.38	0.306	2.29	33.0	0.14	1.07	15.45
Lake Roberts	Medium Density	No	0.25	15	84	0.2356	0.24	0	0.24	0.306	2.29	33.0	0.09	0.67	9.64
Lake Roberts	Medium Density	No	1.53	15	84	0.2356	1.42	0	1.42	0.306	2.29	33.0	0.54	4.02	57.93
Lake Roberts	Medium Density	No	0.50	15	84	0.2356	0.46	0	0.46	0.306	2.29	33.0	0.17	1.31	18.81
Lake Roberts	Medium Density	No	3.47	15	84	0.2356	3.23	0	3.23	0.306	2.29	33.0	1.22	9.13	131.59
Lake Roberts	Medium Density	No	5.95	15	84	0.2356	5.55	0	5.55	0.306	2.29	33.0	2.09	15.67	225.78
Lake Roberts	Medium Density	No	1.15	15	84	0.2356	1.07	0	1.07	0.306	2.29	33.0	0.40	3.03	43.60
Lake Roberts	Medium Density	No	2.68	15	84	0.2356	2.50	0	2.50	0.306	2.29	33.0	0.94	7.06	101.72
Lake Roberts	Medium Density	No	3.58	15	84	0.2356	3.34	0	3.34	0.306	2.29	33.0	1.26	9.43	135.88
Lake Roberts	Medium Density	No	0.73	15	84	0.2356	0.68	0	0.68	0.306	2.29	33.0	0.26	1.91	27.59
Lake Roberts	Medium Density	No	1.06	15	84	0.2356	0.99	0	0.99	0.306	2.29	33.0	0.37	2.80	40.35
Lake Roberts	Medium Density	No	0.56	15	84	0.2356	0.52	0	0.52	0.306	2.29	33.0	0.20	1.48	21.32
Lake Roberts	Medium Density	No	3.42	15	84	0.2356	3.18	0	3.18	0.306	2.29	33.0	1.20	8.99	129.54

Basin	Land Use	Stormwater Treatment	Area (acres)	DCIA (%)	Non-DCIA CN Value	Runoff C Value	Generated Runoff Volume (ac-ft)	Runoff Volume Reduction Factor	Delivered Runoff Volume (ac-ft)	TP EMC (mg/l)	TN EMC (mg/l)	TSS EMC (mg/l)	TP (kg/yr)	TN (kg/yr)	TSS (kg/yr)
Lake Roberts	Medium Density	No	5.60	15	84	0.2356	5.22	0	5.22	0.306	2.29	33.0	1.97	14.73	212.29
Lake Roberts	Medium Density	No	0.73	15	84	0.2356	0.68	0	0.68	0.306	2.29	33.0	0.26	1.92	27.68
Lake Roberts	Medium Density	No	3.63	15	84	0.2356	3.38	0	3.38	0.306	2.29	33.0	1.28	9.56	137.76
Lake Roberts	Medium Density	No	0.58	15	84	0.2356	0.54	0	0.54	0.306	2.29	33.0	0.20	1.53	22.00
Lake Roberts	Medium Density	No	5.75	15	84	0.2356	5.36	0	5.36	0.306	2.29	33.0	2.02	15.15	218.25
Lake Roberts	Medium Density	No	0.79	15	84	0.2356	0.73	0	0.73	0.306	2.29	33.0	0.28	2.07	29.90
Lake Roberts	Medium Density	No	1.93	15	84	0.2356	1.80	0	1.80	0.306	2.29	33.0	0.68	5.08	73.25
Lake Roberts	Medium Density	No	0.32	15	84	0.2356	0.29	0	0.29	0.306	2.29	33.0	0.11	0.83	11.97
Lake Roberts	Medium Density	No	0.05	15	84	0.2356	0.05	0	0.05	0.306	2.29	33.0	0.02	0.13	1.84
Lake Roberts	Medium Density	No	0.06	15	98	0.6665	0.16	0	0.16	0.306	2.29	33.0	0.06	0.45	6.44
Lake Roberts	Medium Density	No	0.17	15	98	0.6665	0.44	0	0.44	0.306	2.29	33.0	0.17	1.25	18.07
Lake Roberts	Medium Density	No	0.66	15	98	0.6665	1.74	0	1.74	0.306	2.29	33.0	0.66	4.92	70.92
Lake Roberts	Medium Density	No	3.62	15	98	0.6665	9.53	0	9.53	0.306	2.29	33.0	3.60	26.92	387.99
Lake Roberts	Medium Density	No	0.06	15	98	0.6665	0.16	0	0.16	0.306	2.29	33.0	0.06	0.46	6.70
Lake Roberts	Medium Density	No	1.13	15	84	0.2356	1.05	0	1.05	0.306	2.29	33.0	0.40	2.96	42.67
Lake Roberts	Medium Density	No	0.77	15	84	0.2356	0.71	0	0.71	0.306	2.29	33.0	0.27	2.01	29.02
Lake Roberts	Medium Density	No	0.27	15	84	0.2356	0.25	0	0.25	0.306	2.29	33.0	0.09	0.71	10.18
Lake Roberts	Medium Density	No	0.55	15	84	0.2356	0.51	0	0.51	0.306	2.29	33.0	0.19	1.45	20.87
Lake Roberts	Instiutational	No	0.00	90	98	0.6665	0.01	0	0.01	0.339	1.98	69.7	0.00	0.02	0.58
Lake Roberts	Instiutational	No	0.02	90	98	0.6665	0.06	0	0.06	0.339	1.98	69.7	0.02	0.14	5.07
Lake Roberts	Golf Course	No	5.55	1	40	0.0074	0.16	0	0.16	0.306	2	33.0	0.06	0.40	6.65
Lake Roberts	Golf Course	No	2.77	1	74	0.0768	0.84	0	0.84	0.306	2	33.0	0.32	2.08	34.31
Lake Roberts	Golf Course	No	1.73	1	74	0.0768	0.53	0	0.53	0.306	2	33.0	0.20	1.30	21.45
Lake Roberts	Golf Course	No	0.25	1	80	0.1212	0.12	0	0.12	0.306	2	33.0	0.05	0.30	4.93
Lake Roberts	Golf Course	No	0.07	1	80	0.1212	0.04	0	0.04	0.306	2	33.0	0.01	0.09	1.45
Lake Roberts	Golf Course	No	0.00	1	80	0.1212	0.00	0	0.00	0.306	2	33.0	0.00	0.00	0.02
Lake Roberts	Golf Course	No	3.63	1	80	0.1212	1.74	0	1.74	0.306	2	33.0	0.66	4.30	70.92
Lake Roberts	Golf Course	No	4.46	1	80	0.1212	2.14	0	2.14	0.306	2	33.0	0.81	5.27	87.03
Lake Roberts	Golf Course	No	3.15	1	80	0.1212	1.51	0	1.51	0.306	2	33.0	0.57	3.73	61.50
Lake Roberts	Golf Course	No	0.02	1	98	0.6665	0.04	0	0.04	0.306	2	33.0	0.02	0.11	1.74
Lake Roberts	Pasture Land	No	0.30	1	40	0.0074	0.01	0	0.01	0.387	2.48	94.3	0.00	0.03	1.03
Lake Roberts	Pasture Land	No	0.44	1	80	0.1212	0.21	0	0.21	0.387	2.48	94.3	0.10	0.64	24.33
Lake Roberts	Pasture Land	No	1.03	1	80	0.1212	0.49	0	0.49	0.387	2.48	94.3	0.24	1.51	57.53
Lake Roberts	Pasture Land	No	0.00	1	80	0.1212	0.00	0	0.00	0.387	2.48	94.3	0.00	0.00	0.06
Lake Roberts	Pasture Land	No	3.96	1	74	0.0768	1.20	0	1.20	0.387	2.48	94.3	0.57	3.68	139.78
Lake Roberts	Pasture Land	No	0.42	1	80	0.1212	0.20	0	0.20	0.387	2.48	94.3	0.10	0.61	23.37
Lake Roberts	Pasture Land	No	0.03	1	80	0.1212	0.01	0	0.01	0.387	2.48	94.3	0.01	0.04	1.67
Lake Roberts	Groves	No	0.07	1	40	0.0074	0.00	0	0.00	0.14	2.05	15.5	0.00	0.01	0.04
Lake Roberts	Groves	No	5.07	1	74	0.0768	1.54	0	1.54	0.14	2.05	15.5	0.27	3.89	29.44
Lake Roberts	Groves	No	7.27	1	74	0.0768	2.21	0	2.21	0.14	2.05	15.5	0.38	5.59	42.24
Lake Roberts	Groves	No	1.25	1	80	0.1212	0.60	0	0.60	0.14	2.05	15.5	0.10	1.52	11.48
Lake Roberts	Groves	No	4.15	1	80	0.1212	1.99	0	1.99	0.14	2.05	15.5	0.34	5.03	37.99
Lake Roberts	Groves	No	4.66	1	80	0.1212	2.23	0	2.23	0.14	2.05	15.5	0.39	5.64	42.68
Lake Roberts	Herbaceous upland nonforested	No	0.24	1	74	0.0768	0.07	0	0.07	0.057	1.25	7.8	0.01	0.11	0.71
Lake Roberts	Herbaceous upland nonforested	No	0.96	1	74	0.0768	0.29	0	0.29	0.057	1.25	7.8	0.02	0.45	2.82
Lake Roberts	Herbaceous upland nonforested	No	0.26	1	74	0.0768	0.08	0	0.08	0.057	1.25	7.8	0.01	0.12	0.76
Lake Roberts	Herbaceous upland nonforested	No	4.45	1	74	0.0768	1.35	0	1.35	0.057	1.25	7.8	0.09	2.08	13.00
Lake Roberts	Herbaceous upland nonforested	No	0.95	1	80	0.1212	0.46	0	0.46	0.057	1.25	7.8	0.03	0.70	4.39
Lake Roberts	Herbaceous upland nonforested	No	3.17	1	80	0.1212	1.52	0	1.52	0.057	1.25	7.8	0.11	2.34	14.61
Lake Roberts	Herbaceous upland nonforested	No	1.89	1	80	0.1212	0.90	0	0.90	0.057	1.25	7.8	0.06	1.39	8.70

Basin	Land Use	Stormwater Treatment	Area (acres)	DCIA (%)	Non-DCIA CN Value	Runoff C Value	Generated Runoff Volume (ac-ft)	Runoff Volume Reduction Factor	Delivered Runoff Volume (ac-ft)	TP EMC (mg/l)	TN EMC (mg/l)	TSS EMC (mg/l)	TP (kg/yr)	TN (kg/yr)	TSS (kg/yr)
Lake Roberts	Herbaceous upland nonforested	No	11.55	1	80	0.1212	5.54	0	5.54	0.057	1.25	7.8	0.39	8.53	53.26
Lake Roberts	Herbaceous upland nonforested	No	0.08	1	80	0.1212	0.04	0	0.04	0.057	1.25	7.8	0.00	0.06	0.38
Lake Roberts	Lakes	No	0.18	85	98	0.0000	0.00	0	0.00	0.013	0.49	17.3	0.00	0.00	0.00
Lake Roberts	Lakes	No	0.78	85	98	0.0000	0.00	0	0.00	0.013	0.49	17.3	0.00	0.00	0.00
Lake Roberts	Lakes	No	0.12	85	98	0.0000	0.00	0	0.00	0.013	0.49	17.3	0.00	0.00	0.00
Lake Roberts	Lakes	No	0.00	85	98	0.0000	0.00	0	0.00	0.013	0.49	17.3	0.00	0.00	0.00
Lake Roberts	Lakes	No	0.13	85	98	0.0000	0.00	0	0.00	0.013	0.49	17.3	0.00	0.00	0.00
Lake Roberts	Lakes	No	0.10	85	98	0.0000	0.00	0	0.00	0.013	0.49	17.3	0.00	0.00	0.00
Lake Roberts	Lakes	No	0.16	85	98	0.0000	0.00	0	0.00	0.013	0.49	17.3	0.00	0.00	0.00
Lake Roberts	Lakes	No	0.46	85	98	0.0000	0.00	0	0.00	0.013	0.49	17.3	0.00	0.00	0.00
Lake Roberts	Lakes	No	103.81	85	98	0.0000	0.00	0	0.00	0.013	0.49	17.3	0.00	0.00	0.00
Lake Roberts	Lake Reaves	No	0.03	85	98	1.0000	0.12	0	0.12	0.013	0.49	17.3	0.00	0.07	2.57
Lake Roberts	Lake Reaves	No	0.18	85	98	1.0000	0.72	0	0.72	0.013	0.49	17.3	0.01	0.43	15.26
Lake Roberts	Lake Reaves	No	0.00	85	98	1.0000	0.01	0	0.01	0.013	0.49	17.3	0.00	0.01	0.26
Lake Roberts	Lake Reaves	No	18.36	85	98	1.0000	72.61	0	72.61	0.013	0.49	17.3	1.16	43.89	1,549.43
Lake Roberts	Ponds	No	0.06	85	98	0.6665	0.16	0	0.16	0.013	0.49	17.3	0.00	0.09	3.35
Lake Roberts	Ponds	No	0.15	85	98	0.6665	0.38	0	0.38	0.013	0.49	17.3	0.01	0.23	8.20
Lake Roberts	Ponds	No	0.06	85	98	0.6665	0.16	0	0.16	0.013	0.49	17.3	0.00	0.09	3.32
Lake Roberts	Ponds	No	0.07	85	98	0.6665	0.18	0	0.18	0.013	0.49	17.3	0.00	0.11	3.91
Lake Roberts	Ponds	No	1.59	85	98	0.6665	4.20	0	4.20	0.013	0.49	17.3	0.07	2.54	89.70
Lake Roberts	Wetland	No	0.73	75	39	0.5000	1.45	0	1.45	0.113	1.55	7.8	0.20	2.77	13.94
Lake Roberts	Wetland	No	5.05	75	74	0.5176	10.33	0	10.33	0.113	1.55	7.8	1.44	19.75	99.37
Lake Roberts	Wetland	No	0.02	75	74	0.5176	0.05	0	0.05	0.113	1.55	7.8	0.01	0.09	0.47
Lake Roberts	Wetland	No	0.42	75	80	0.5288	0.87	0	0.87	0.113	1.55	7.8	0.12	1.67	8.39
Lake Roberts	Wetland	No	3.29	75	80	0.5288	6.87	0	6.87	0.113	1.55	7.8	0.96	13.14	66.13
Lake Roberts	Wetland	No	21.23	75	80	0.5288	44.40	0	44.40	0.113	1.55	7.8	6.19	84.89	427.18
Lake Roberts	Wetland	No	1.64	75	80	0.5288	3.44	0	3.44	0.113	1.55	7.8	0.48	6.57	33.08
Lake Roberts	Wetland	No	0.79	75	98	0.6665	2.08	0	2.08	0.113	1.55	7.8	0.29	3.97	19.99
Lake Roberts	Wetland	No	0.02	75	80	0.5288	0.05	0	0.05	0.113	1.55	7.8	0.01	0.10	0.49
Lake Roberts	Wetland	No	0.64	75	80	0.5288	1.34	0	1.34	0.113	1.55	7.8	0.19	2.56	12.90
Lake Roberts	Wetland	No	3.83	75	80	0.5288	8.01	0	8.01	0.113	1.55	7.8	1.12	15.32	77.08
Lake Roberts	Wetland	No	0.03	75	80	0.5288	0.06	0	0.06	0.113	1.55	7.8	0.01	0.12	0.60
Lake Roberts	Wetland	No	2.45	75	80	0.5288	5.13	0	5.13	0.113	1.55	7.8	0.71	9.80	49.34
Lake Roberts	Wetland	No	0.62	75	80	0.5288	1.29	0	1.29	0.113	1.55	7.8	0.18	2.47	12.43
Lake Roberts	Wetland	No	1.55	75	80	0.5288	3.24	0	3.24	0.113	1.55	7.8	0.45	6.20	31.20
Lake Roberts	Wetland	No	1.21	75	80	0.5288	2.54	0	2.54	0.113	1.55	7.8	0.35	4.85	24.43
Lake Roberts	Wetland	No	0.11	75	80	0.5288	0.22	0	0.22	0.113	1.55	7.8	0.03	0.43	2.16
Lake Roberts	Wetland	No	6.26	75	80	0.5288	13.09	0	13.09	0.113	1.55	7.8	1.82	25.02	125.92
Lake Roberts	Wetland	No	0.86	75	80	0.5288	1.81	0	1.81	0.113	1.55	7.8	0.25	3.46	17.40
Lake Roberts	Wetland	No	1.22	75	80	0.5288	2.56	0	2.56	0.113	1.55	7.8	0.36	4.90	24.64
Lake Roberts	Wetland	No	4.92	75	80	0.5288	10.28	0	10.28	0.113	1.55	7.8	1.43	19.66	98.95
Lake Roberts	Wetland	No	0.10	75	39	0.5000	0.20	0	0.20	0.113	1.55	7.8	0.03	0.39	1.94
Lake Roberts	Wetland	No	4.89	75	80	0.5288	10.23	0	10.23	0.113	1.55	7.8	1.43	19.56	98.42
Lake Roberts	Wetland	No	27.87	75	80	0.5288	58.27	0	58.27	0.113	1.55	7.8	8.12	111.40	560.61
Lake Roberts	Wetland	No	0.65	75	80	0.5288	1.35	0	1.35	0.113	1.55	7.8	0.19	2.58	12.98
Lake Roberts	Wetland	No	0.02	75	80	0.5288	0.05	0	0.05	0.113	1.55	7.8	0.01	0.10	0.50
Lake Roberts	Wetland	No	2.27	75	80	0.5288	4.76	0	4.76	0.113	1.55	7.8	0.66	9.09	45.76
Lake Roberts	Wetland	No	0.02	75	80	0.5288	0.05	0	0.05	0.113	1.55	7.8	0.01	0.09	0.44
Lake Roberts	Wetland	No	0.80	75	80	0.5288	1.68	0	1.68	0.113	1.55	7.8	0.23	3.21	16.15
Lake Roberts	Wetland	No	0.73	75	80	0.5288	1.54	0	1.54	0.113	1.55	7.8	0.21	2.94	14.79

Basin	Land Use	Stormwater Treatment	Area (acres)	DCIA (%)	Non-DCIA CN Value	Runoff C Value	Generated Runoff Volume (ac-ft)	Runoff Volume Reduction Factor	Delivered Runoff Volume (ac-ft)	TP EMC (mg/l)	TN EMC (mg/l)	TSS EMC (mg/l)	TP (kg/yr)	TN (kg/yr)	TSS (kg/yr)
Lake Roberts	Wetland	No	1.77	75	80	0.5288	3.71	0	3.71	0.113	1.55	7.8	0.52	7.10	35.71
Lake Roberts	Wetland	No	2.31	75	80	0.5288	4.82	0	4.82	0.113	1.55	7.8	0.67	9.22	46.40
Lake Roberts	Wetland	No	13.99	75	80	0.5288	29.25	0	29.25	0.113	1.55	7.8	4.08	55.93	281.44
Lake Roberts	Wetland	No	3.33	75	80	0.5288	6.97	0	6.97	0.113	1.55	7.8	0.97	13.33	67.08
Lake Roberts	Wetland	No	1.25	75	80	0.5288	2.62	0	2.62	0.113	1.55	7.8	0.36	5.00	25.17
Lake Roberts	Lake	No	2.53	75	98	0.0000	0.00	0	0.00	0.013	0.49	17.3	0.00	0.00	0.00
Lake Roberts	Wetland	No	1.87	75	98	0.6665	4.93	0	4.93	0.113	1.55	7.8	0.69	9.43	47.45
Lake Roberts	Wetland	No	0.29	75	39	0.5000	0.57	0	0.57	0.113	1.55	7.8	0.08	1.09	5.50
Lake Roberts	Wetland	No	1.12	75	80	0.5288	2.33	0	2.33	0.113	1.55	7.8	0.33	4.46	22.46
Lake Roberts	Wetland	No	0.13	75	80	0.5288	0.27	0	0.27	0.113	1.55	7.8	0.04	0.52	2.64
Lake Roberts	Wetland	No	3.12	75	98	0.6665	8.22	0	8.22	0.113	1.55	7.8	1.15	15.71	79.06
Lake Roberts	Roads	No	0.01	90	98	0.6665	0.03	0	0.03	0.013	0.49	17.3	0.00	0.02	0.54
Lake Roberts	Roads	No	0.48	90	98	0.6665	1.26	0	1.26	0.013	0.49	17.3	0.02	0.76	26.90
Lake Roberts	Roads	No	0.63	90	98	0.6665	1.66	0	1.66	0.013	0.49	17.3	0.03	1.00	35.33
Lake Roberts	Low Density	Wet Detention	0.12	5	77	0.1194	0.05	20	0.04	0.177	1.77	20.4	0.01	0.10	1.10
Lake Roberts	Low Density	Wet Detention	0.02	5	82	0.1625	0.01	20	0.01	0.177	1.77	20.4	0.00	0.02	0.22
Lake Roberts	Low Density	Wet Detention	0.00	5	82	0.1625	0.00	20	0.00	0.177	1.77	20.4	0.00	0.00	0.00
Lake Roberts	Medium Density	Wet Detention	20.87	15	53	0.1077	8.89	20	7.11	0.306	2.29	33.0	2.68	20.08	289.36
Lake Roberts	Medium Density	Wet Detention	0.00	15	53	0.1077	0.00	20	0.00	0.306	2.29	33.0	0.00	0.00	0.00
Lake Roberts	Medium Density	Wet Detention	0.43	15	53	0.1077	0.18	20	0.15	0.306	2.29	33.0	0.06	0.42	6.01
Lake Roberts	Medium Density	Wet Detention	1.83	15	53	0.1077	0.78	20	0.62	0.306	2.29	33.0	0.24	1.76	25.39
Lake Roberts	Medium Density	Wet Detention	3.69	15	80	0.1984	2.90	20	2.32	0.306	2.29	33.0	0.87	6.55	94.33
Lake Roberts	Medium Density	Wet Detention	0.75	15	80	0.1984	0.59	20	0.47	0.306	2.29	33.0	0.18	1.32	19.07
Lake Roberts	Medium Density	Wet Detention	6.30	15	80	0.1984	4.94	20	3.95	0.306	2.29	33.0	1.49	11.16	160.84
Lake Roberts	Medium Density	Wet Detention	40.07	15	80	0.1984	31.43	20	25.14	0.306	2.29	33.0	9.49	71.03	1,023.51
Lake Roberts	Medium Density	Wet Detention	1.25	15	80	0.1984	0.98	20	0.79	0.306	2.29	33.0	0.30	2.22	32.02
Lake Roberts	Medium Density	Wet Detention	0.04	15	84	0.2356	0.03	20	0.03	0.306	2.29	33.0	0.01	0.08	1.14
Lake Roberts	Medium Density	Wet Detention	7.49	15	84	0.2356	6.98	20	5.58	0.306	2.29	33.0	2.11	15.77	227.20
Lake Roberts	Medium Density	Wet Detention	0.01	15	84	0.2356	0.01	20	0.01	0.306	2.29	33.0	0.00	0.03	0.43
Lake Roberts	Medium Density	Wet Detention	0.38	15	84	0.2356	0.36	20	0.28	0.306	2.29	33.0	0.11	0.80	11.59
Lake Roberts	Medium Density	Wet Detention	0.31	15	84	0.2356	0.29	20	0.23	0.306	2.29	33.0	0.09	0.66	9.55
Lake Roberts	Medium Density	Wet Detention	1.84	15	84	0.2356	1.71	20	1.37	0.306	2.29	33.0	0.52	3.87	55.81
Lake Roberts	Medium Density	Wet Detention	0.82	15	84	0.2356	0.77	20	0.61	0.306	2.29	33.0	0.23	1.73	24.93
Lake Roberts	Medium Density	Wet Detention	0.00	15	84	0.2356	0.00	20	0.00	0.306	2.29	33.0	0.00	0.00	0.02
Lake Roberts	Medium Density	Wet Detention	0.84	15	84	0.2356	0.78	20	0.62	0.306	2.29	33.0	0.24	1.76	25.35
Lake Roberts	Medium Density	Wet Detention	0.17	15	84	0.2356	0.16	20	0.13	0.306	2.29	33.0	0.05	0.37	5.29
Lake Roberts	Medium Density	Wet Detention	0.00	15	84	0.2356	0.00	20	0.00	0.306	2.29	33.0	0.00	0.00	0.02
Lake Roberts	Medium Density	Wet Detention	2.87	15	84	0.2356	2.68	20	2.14	0.306	2.29	33.0	0.81	6.05	87.13
Lake Roberts	Medium Density	Wet Detention	0.28	15	84	0.2356	0.26	20	0.21	0.306	2.29	33.0	0.08	0.59	8.53
Lake Roberts	Medium Density	Wet Detention	0.38	15	84	0.2356	0.35	20	0.28	0.306	2.29	33.0	0.11	0.79	11.41
Lake Roberts	Medium Density	Wet Detention	6.26	15	84	0.2356	5.83	20	4.67	0.306	2.29	33.0	1.76	13.18	189.94
Lake Roberts	Medium Density	Wet Detention	0.01	15	98	0.6665	0.01	20	0.01	0.306	2.29	33.0	0.00	0.03	0.43
Lake Roberts	Medium Density	Wet Detention	11.29	15	98	0.6665	29.74	20	23.80	0.306	2.29	33.0	8.98	67.21	968.59
Lake Roberts	Medium Density	Wet Detention	0.00	15	98	0.6665	0.00	20	0.00	0.306	2.29	33.0	0.00	0.01	0.16
Lake Roberts	Medium Density	Wet Detention	0.36	15	98	0.6665	0.94	20	0.75	0.306	2.29	33.0	0.28	2.12	30.60
Lake Roberts	Medium Density	Wet Detention	0.54	15	98	0.6665	1.42	20	1.14	0.306	2.29	33.0	0.43	3.22	46.34
Lake Roberts	Medium Density	Wet Detention	1.31	15	98	0.6665	3.45	20	2.76	0.306	2.29	33.0	1.04	7.79	112.19
Lake Roberts	Instiutational	Wet Detention	0.01	90	98	0.6665	0.03	20	0.02	0.339	1.98	69.7	0.01	0.05	1.90
Lake Roberts	Pasture Land	Wet Detention	0.01	1	80	0.1212	0.00	20	0.00	0.387	2.48	94.3	0.00	0.01	0.38
Lake Roberts	Pasture Land	Wet Detention	0.00	1	80	0.1212	0.00	20	0.00	0.387	2.48	94.3	0.00	0.00	0.01

Basin	Land Use	Stormwater Treatment	Area (acres)	DCIA (%)	Non-DCIA CN Value	Runoff C Value	Generated Runoff Volume (ac-ft)	Runoff Volume Reduction Factor	Delivered Runoff Volume (ac-ft)	TP EMC (mg/l)	TN EMC (mg/l)	TSS EMC (mg/l)	TP (kg/yr)	TN (kg/yr)	TSS (kg/yr)
Lake Roberts	Pasture Land	Wet Detention	0.12	1	74	0.0768	0.04	20	0.03	0.387	2.48	94.3	0.01	0.09	3.30
Lake Roberts	Groves	Wet Detention	0.05	1	74	0.0768	0.01	20	0.01	0.14	2.05	15.5	0.00	0.03	0.21
Lake Roberts	Herbaceous upland nonforested	Wet Detention	0.00	1	74	0.0768	0.00	20	0.00	0.057	1.25	7.8	0.00	0.00	0.00
Lake Roberts	Herbaceous upland nonforested	Wet Detention	0.72	1	74	0.0768	0.22	20	0.17	0.057	1.25	7.8	0.01	0.27	1.68
Lake Roberts	Herbaceous upland nonforested	Wet Detention	0.13	1	74	0.0768	0.04	20	0.03	0.057	1.25	7.8	0.00	0.05	0.30
Lake Roberts	Herbaceous upland nonforested	Wet Detention	0.43	1	80	0.1212	0.21	20	0.16	0.057	1.25	7.8	0.01	0.25	1.59
Lake Roberts	Herbaceous upland nonforested	Wet Detention	0.08	1	98	0.6665	0.20	20	0.16	0.057	1.25	7.8	0.01	0.25	1.55
Lake Roberts	Herbaceous upland nonforested	Wet Detention	1.19	1	98	0.6665	3.14	20	2.51	0.057	1.25	7.8	0.18	3.87	24.14
Lake Roberts	Ponds	Wet Detention	0.23	85	98	0.6665	0.62	20	0.49	0.013	0.49	17.3	0.01	0.30	10.54
Lake Roberts	Ponds	Wet Detention	3.18	85	98	0.6665	8.39	20	6.71	0.013	0.49	17.3	0.11	4.06	143.27
Lake Roberts	Ponds	Wet Detention	0.28	85	98	0.6665	0.74	20	0.59	0.013	0.49	17.3	0.01	0.36	12.65
Lake Roberts	Ponds	Wet Detention	3.29	85	98	0.6665	8.67	20	6.93	0.013	0.49	17.3	0.11	4.19	147.98
Lake Roberts	Wetland	Wet Detention	0.00	75	80	0.5288	0.00	20	0.00	0.113	1.55	7.8	0.00	0.00	0.00
Lake Roberts	Wetland	Wet Detention	0.07	75	80	0.5288	0.14	20	0.12	0.113	1.55	7.8	0.02	0.22	1.11
Lake Roberts	Wetland	Wet Detention	0.05	75	80	0.5288	0.10	20	0.08	0.113	1.55	7.8	0.01	0.15	0.75
Lake Roberts	Wetland	Wet Detention	0.02	75	80	0.5288	0.04	20	0.03	0.113	1.55	7.8	0.00	0.06	0.29
Lake Roberts	Wetland	Wet Detention	0.03	75	98	0.6665	0.09	20	0.07	0.113	1.55	7.8	0.01	0.14	0.69
Lake Roberts	Wetland	Wet Detention	0.01	75	80	0.5288	0.01	20	0.01	0.113	1.55	7.8	0.00	0.02	0.10
Lake Roberts	Wetland	Wet Detention	0.03	75	80	0.5288	0.06	20	0.05	0.113	1.55	7.8	0.01	0.09	0.44
Lake Roberts	Roads	Wet Detention	0.82	90	98	0.6665	2.16	20	1.73	0.013	0.49	17.3	0.03	1.04	36.87
Lake Roberts	Roads	Wet Detention	0.28	90	98	0.6665	0.74	20	0.59	0.013	0.49	17.3	0.01	0.36	12.57
Lake Roberts	Roads	Wet Detention	2.66	90	98	0.6665	7.01	20	5.60	0.013	0.49	17.3	0.09	3.39	119.60
Lake Roberts	Roads	Wet Detention	2.01	90	98	0.6665	5.29	20	4.23	0.013	0.49	17.3	0.07	2.56	90.37
Lake Roberts	Roads	Wet Detention	0.12	90	98	0.6665	0.30	20	0.24	0.013	0.49	17.3	0.00	0.15	5.18
Lake Roberts	Roads	Wet Detention	0.06	90	98	0.6665	0.15	20	0.12	0.013	0.49	17.3	0.00	0.07	2.61
Lake Roberts	Roads	Wet Detention	1.76	90	98	0.6665	4.63	20	3.70	0.013	0.49	17.3	0.06	2.24	79.04
Lake Roberts	Roads	Wet Detention	0.04	90	98	0.6665	0.11	20	0.09	0.013	0.49	17.3	0.00	0.06	1.96
Lake Roberts	Medium Density	Wetland Detention	4.78	15	53	0.1077	2.03	20	1.63	0.306	2.29	33.0	0.61	4.60	66.25
Lake Roberts	Medium Density	Wetland Detention	0.14	15	98	0.6665	0.38	20	0.31	0.306	2.29	33.0	0.12	0.86	12.42
Lake Roberts	Golf Course	Wetland Detention	0.96	1	40	0.0074	0.03	20	0.02	0.306	2	33.0	0.01	0.06	0.92
Lake Roberts	Golf Course	Wetland Detention	11.13	1	40	0.0074	0.33	20	0.26	0.306	2	33.0	0.10	0.65	10.67
Lake Roberts	Golf Course	Wetland Detention	4.99	1	74	0.0768	1.52	20	1.21	0.306	2	33.0	0.46	2.99	49.37
Lake Roberts	Golf Course	Wetland Detention	0.04	1	80	0.1212	0.02	20	0.02	0.306	2	33.0	0.01	0.04	0.67
Lake Roberts	Golf Course	Wetland Detention	0.36	1	80	0.1212	0.17	20	0.14	0.306	2	33.0	0.05	0.35	5.69
Lake Roberts	Golf Course	Wetland Detention	0.01	1	98	0.6665	0.01	20	0.01	0.306	2	33.0	0.00	0.03	0.48
Lake Roberts	Ponds	Wetland Detention	0.20	85	98	0.6665	0.53	20	0.42	0.013	0.49	17.3	0.01	0.25	9.00
Lake Roberts	Ponds	Wetland Detention	0.95	85	98	0.6665	2.49	20	2.00	0.013	0.49	17.3	0.03	1.21	42.59
			595.16				**620.44**		**589.00**				**111**	**1,139**	**12,985**

APPENDIX 5-2

Characteristics of Shallow Groundwater Seepage Collected in Lake Roberts

Seepage Meter Field Measurements

Location: **Lake Roberts** **Site:** **1**

Date Installed: **9/18/13** **Chamber Diameter:** **0.58 m** **Sediment Area Covered:** **0.27 m2**

Date	Time Collected	Volume Collected (liters)	Previous Collection Event		Seepage Time (days)	Seepage (liters/m^2-day)	Comments / Observations
			Date	Time			
9/18/13		-----	-----	-----	-----	-----	Seepage Meter and First Bag Installed
10/15/13	9:15	3.5	9/18/13	0:00	27.4		Measured volume, no sample collected
11/12/13	9:24	4.25	10/15/13	9:15	28.0	0.56	Measured volume, sample collected for analysis
1/10/14	9:40	21.25	11/12/13	9:24	59.0	1.33	Measured volume, sample collected for analysis
3/15/14	12:30	16.25	1/10/14	9:40	64.1	0.94	Measured volume, sample collected for analysis
5/19/14	9:15	-----	3/15/14	12:30	64.9	-----	Bag damaged, no sample collected
6/16/14	9:42	-----	5/19/14	9:15	28.0	-----	Bag damaged, no sample collected
7/11/14	9:07	8.25	6/16/14	9:42	25.0	1.22	Measured volume, sample collected for analysis
8/8/14	8:31	7.25	7/11/14	9:07	28.0	0.96	Measured volume, sample collected for analysis
9/10/14	9:14	7.25	8/8/14	8:31	33.0	0.81	Measured volume, sample collected for analysis
12/3/14	13:36	9.5	9/10/14	9:14	84.2	0.42	Measured volume, sample collected for analysis
MEAN		9.69				0.89	

Note 1: October volume not included in mean seepage rate calculation as there is no corresponding analytical data.

Note 2: Torn bag was discovered on 5/19 and 6/16: No sample was collected during either sampling event

Location: **Lake Roberts** **Site:** **2**

Date Installed: **9/18/13** **Chamber Diameter:** **0.58 m** **Sediment Area Covered:** **0.27 m2**

Date	Time Collected	Volume Collected (liters)	Previous Collection Event		Seepage Time (days)	Seepage (liters/m^2-day)	Comments / Observations
			Date	Time			
9/18/13		-----	-----	-----	-----	-----	Seepage Meter and First Bag Installed
10/15/13	9:22		9/18/13	0:00	27.4	-----	Measured volume, no sample collected
11/12/13	9:31	19.75	10/15/13	9:22	28.0	2.61	Measured volume, sample collected for analysis
1/10/14	9:47	125	11/12/13	9:31	59.0	7.85	Measured volume, sample collected for analysis
3/15/14	12:40	20.5	1/10/14	9:47	64.1	1.18	Measured volume, sample collected for analysis
5/19/14	9:22	65.75	3/15/14	12:40	64.9	3.75	Measured volume, sample collected for analysis
6/16/14	9:47	24.75	5/19/14	9:22	28.0	3.27	Measured volume, sample collected for analysis
7/11/14	9:14	21.5	6/16/14	9:47	25.0	3.19	Measured volume, sample collected for analysis
8/8/14	8:41	39.75	7/11/14	9:14	28.0	5.26	Measured volume, sample collected for analysis
9/10/14	9:21	13.5	8/8/14	8:41	33.0	1.51	Measured volume, sample collected for analysis
12/3/14	12:47	16.75	9/10/14	9:21	84.1	0.74	Measured volume, sample collected for analysis
MEAN		38.58				3.26	

Note 1: October volume not included in mean seepage rate calculation as there is no corresponding analytical data.

Location: **Lake Roberts** **Site:** **3**

Date Installed: **9/18/13** **Chamber Diameter:** **0.58 m** **Sediment Area Covered:** **0.27 m2**

Date	Time Collected	Volume Collected (liters)	Previous Collection Event		Seepage Time (days)	Seepage (liters/m^2-day)	Comments / Observations
			Date	Time			
9/18/13		-----	-----	-----	-----	-----	Seepage Meter and First Bag Installed
10/15/13	9:29	-----	9/18/13	0:00	27.4	-----	No sample collected, bag damaged, bag replaced
11/12/13	9:42	14.5	10/15/13	9:29	28.0	1.92	Measured volume, sample collected for analysis
1/10/14	9:56	13.5	11/12/13	9:42	59.0	0.85	Measured volume, sample collected for analysis
3/15/14	12:55	7.0	1/10/14	9:56	64.1	0.40	Measured volume, sample collected for analysis
5/19/14	9:31	9.5	3/15/14	12:55	64.9	0.54	Measured volume, sample collected for analysis
6/16/14	9:56	6.25	5/19/14	9:31	28.0	0.83	Measured volume, sample collected for analysis
7/11/14	9:20	14.75	6/16/14	9:56	25.0	2.19	Measured volume, sample collected for analysis
8/8/14	8:47	13.5	7/11/14	9:20	28.0	1.79	Measured volume, sample collected for analysis
9/10/14	9:29	18.5	8/8/14	8:47	33.0	2.07	Measured volume, sample collected for analysis
12/3/14	11:10	13.5	9/10/14	9:29	84.1	0.59	Measured volume, sample collected for analysis
MEAN		12.33				1.24	

Note 1: October volume not included in mean seepage rate calculation as there is no corresponding analytical data.

Seepage Meter Field Measurements

Location: Lake Roberts **Site:** 4

Date Installed: 9/18/13 **Chamber Diameter:** 0.58 m **Sediment Area Covered:** 0.27 m2

Date	Time Collected	Volume Collected (liters)	Previous Collection Event		Seepage Time (days)	Seepage (liters/m^2-day)	Comments / Observations
			Date	Time			
9/18/13		-----	-----	-----	-----	-----	Seepage Meter and First Bag Installed
10/15/13	9:33	2.75	9/18/13	0:00	27.4	-----	Measured volume, no sample collected
11/12/13	9:49	3.75	10/15/13	9:33	28.0	0.50	Measured volume, sample collected for analysis
1/10/14	10:03	7.25	11/12/13	9:49	59.0	0.46	Measured volume, sample collected for analysis
3/15/14	13:10	11.25	1/10/14	10:03	64.1	0.65	Measured volume, sample collected for analysis
5/19/14	9:36	9.75	3/15/14	13:10	64.9	0.56	Measured volume, sample collected for analysis
6/16/14	10:04	9.75	5/19/14	9:36	28.0	1.29	Measured volume, sample collected for analysis
7/11/14	9:29	11.25	6/16/14	10:04	25.0	1.67	Measured volume, sample collected for analysis
8/8/14	8:53	10.75	7/11/14	9:29	28.0	1.42	Measured volume, sample collected for analysis
9/10/14	9:35	12.75	8/8/14	8:53	33.0	1.43	Measured volume, sample collected for analysis
12/3/14	11:22	9.5	9/10/14	9:35	84.1	0.42	Measured volume, sample collected for analysis
MEAN		8.88				0.93	

Note 1: October volume not included in mean seepage rate calculation as there is no corresponding analytical data.

Location: Lake Roberts **Site:** 5

Date Installed: 9/18/13 **Chamber Diameter:** 0.58 m **Sediment Area Covered:** 0.27 m2

Date	Time Collected	Volume Collected (liters)	Previous Collection Event		Seepage Time (days)	Seepage (liters/m^2-day)	Comments / Observations
			Date	Time			
9/18/13		-----	-----	-----	-----	-----	Seepage Meter and First Bag Installed
10/15/13	9:47	2.75	9/18/13	0:00	27.4	-----	Measured volume, no sample collected
11/12/13	10:05	8.25	10/15/13	9:47	28.0	1.09	Measured volume, sample collected for analysis
1/10/14	10:12	9.75	11/12/13	10:05	59.0	0.61	Measured volume, sample collected for analysis
3/15/14	13:20	8.75	1/10/14	10:12	64.1	0.51	Measured volume, sample collected for analysis
5/19/14	9:45	11.25	3/15/14	13:20	64.9	0.64	Measured volume, sample collected for analysis
6/16/14	10:04	8.5	5/19/14	9:45	28.0	1.12	Measured volume, sample collected for analysis
7/11/14	9:35	8.25	6/16/14	10:04	25.0	1.22	Measured volume, sample collected for analysis
8/8/14	9:09	8.25	7/11/14	9:35	28.0	1.09	Measured volume, sample collected for analysis
9/10/14	9:45	6.75	8/8/14	9:09	33.0	0.76	Measured volume, sample collected for analysis
12/3/14	12:01	12.5	9/10/14	9:45	84.1	0.55	Measured volume, sample collected for analysis
MEAN		8.50				0.84	

Note 1: October volume not included in mean seepage rate calculation as there is no corresponding analytical data.

Location: Lake Roberts **Site:** 6

Date Installed: 9/18/13 **Chamber Diameter:** 0.58 m **Sediment Area Covered:** 0.27 m2

Date	Time Collected	Volume Collected (liters)	Previous Collection Event		Seepage Time (days)	Seepage (liters/m^2-day)	Comments / Observations
			Date	Time			
9/18/13		-----	-----	-----	-----	-----	Seepage Meter and First Bag Installed
10/15/13	9:52	5.25	9/18/13	0:00	27.4	-----	Measured volume, no sample collected
11/12/13	10:14	5.75	10/15/13	9:52	28.0	0.76	Measured volume, sample collected for analysis
1/10/14	10:24	22.25	11/12/13	10:14	59.0	1.40	Measured volume, sample collected for analysis
3/15/14	13:40	13.0	1/10/14	10:24	64.1	0.75	Measured volume, sample collected for analysis
5/19/14	10:00	10.5	3/15/14	13:40	64.8	0.60	Measured volume, sample collected for analysis
6/16/14	10:04	9.75	5/19/14	10:00	28.0	1.29	Measured volume, sample collected for analysis
7/11/14	9:50	11.5	6/16/14	10:04	25.0	1.70	Measured volume, sample collected for analysis
8/8/14	9:14	11.5	7/11/14	9:50	28.0	1.52	Measured volume, sample collected for analysis
9/10/14	9:53	11.5	8/8/14	9:14	33.0	1.29	Measured volume, sample collected for analysis
12/3/14	12:34	14.25	9/10/14	9:53	84.1	0.63	Measured volume, sample collected for analysis
MEAN		11.53				1.10	

Note 1: October volume not included in mean seepage rate calculation as there is no corresponding analytical data.

Seepage Meter Field Measurements

Location: Lake Roberts **Site: 7**

Date Installed: 9/18/13 **Chamber Diameter: 0.58 m** **Sediment Area Covered: 0.27 m2**

Date	Time Collected	Volume Collected (liters)	Previous Collection Event		Seepage Time (days)	Seepage (liters/m^2-day)	Comments / Observations
			Date	Time			
9/18/13		-----	-----	-----	-----	-----	Seepage Meter and First Bag Installed
10/15/13	9:57	5.5	9/18/13	0:00	27.4	-----	Measured volume, no sample collected
11/12/13	10:20	5.75	10/15/13	9:57	28.0	0.76	Measured volume, sample collected for analysis
1/10/14	10:31	8.75	11/12/13	10:20	59.0	0.55	Measured volume, sample collected for analysis
3/15/14	13:50	20.25	1/10/14	10:31	64.1	1.17	Measured volume, sample collected for analysis
5/19/14	10:06	8.75	3/15/14	13:50	64.8	0.50	Measured volume, sample collected for analysis
6/16/14	10:04	10.25	5/19/14	10:06	28.0	1.36	Measured volume, sample collected for analysis
7/11/14	9:56	6.75	6/16/14	10:04	25.0	1.00	Measured volume, sample collected for analysis
8/8/14	9:20	7.75	7/11/14	9:56	28.0	1.03	Measured volume, sample collected for analysis
9/10/14	9:59	12.75	8/8/14	9:20	33.0	1.43	Measured volume, sample collected for analysis
12/3/14	13:17	16.5	9/10/14	9:59	84.1	0.73	Measured volume, sample collected for analysis
MEAN		10.30				0.95	

Note 1: October volume not included in mean seepage rate calculation as there is no corresponding analytical data.

Location: Lake Roberts **Site: 8**

Date Installed: 9/18/13 **Chamber Diameter: 0.58 m** **Sediment Area Covered: 0.27 m2**

Date	Time Collected	Volume Collected (liters)	Previous Collection Event		Seepage Time (days)	Seepage (liters/m^2-day)	Comments / Observations
			Date	Time			
9/18/13		-----	-----	-----	-----	-----	Seepage Meter and First Bag Installed
10/15/13	10:14	9.75	9/18/13	0:00	27.4	-----	Measured volume, no sample collected
11/12/13	10:27	2.75	10/15/13	10:14	28.0	0.36	Measured volume, sample collected for analysis
1/10/14	10:37	1.5	11/12/13	10:27	59.0	0.09	Measured volume, sample collected for analysis
3/15/14	14:00	4.5	1/10/14	10:37	64.1	0.26	Measured volume, sample collected for analysis
5/19/14	10:12	6.55	3/15/14	14:00	64.8	0.37	Measured volume, sample collected for analysis
6/16/14	10:04	1.2	5/19/14	10:12	28.0	0.16	Measured volume, sample collected for analysis
7/11/14	10:05	2.25	6/16/14	10:04	25.0	0.33	Measured volume, sample collected for analysis
8/8/14	9:26	0.75	7/11/14	10:05	28.0	0.10	Measured volume, sample collected for analysis
9/10/14	10:06	1.25	8/8/14	9:26	33.0	0.14	Measured volume, sample collected for analysis
12/3/14	13:03	1.4	9/10/14	10:06	84.1	0.06	Measured volume, sample collected for analysis
MEAN		3.19				0.21	

Note 1: October volume not included in mean seepage rate calculation as there is no corresponding analytical data.

Location: Lake Roberts **Site: 9**

Date Installed: 9/18/13 **Chamber Diameter: 0.58 m** **Sediment Area Covered: 0.27 m2**

Date	Time Collected	Volume Collected (liters)	Previous Collection Event		Seepage Time (days)	Seepage (liters/m^2-day)	Comments / Observations
			Date	Time			
9/18/13		-----	-----	-----	-----	-----	Seepage Meter and First Bag Installed
10/15/13	10:06	2.75	9/18/13	0:00	27.4	-----	Measured volume, no sample collected
11/12/13	9:58	9.25	10/15/13	10:06	28.0	1.22	Measured volume, sample collected for analysis
1/10/14	10:17	16.25	11/12/13	9:58	59.0	1.02	Measured volume, sample collected for analysis
3/15/14	13:30	3.25	1/10/14	10:17	64.1	0.19	Measured volume, sample collected for analysis
5/19/14	9:52	6.25	3/15/14	13:30	64.8	0.36	Measured volume, sample collected for analysis
6/16/14	10:04	5.25	5/19/14	9:52	28.0	0.69	Measured volume, sample collected for analysis
7/11/14	9:44	6.75	6/16/14	10:04	25.0	1.00	Measured volume, sample collected for analysis
8/8/14	9:02	3.5	7/11/14	9:44	28.0	0.46	Measured volume, sample collected for analysis
9/10/14							Could not find sampler - no sample collected. New meter installed
12/3/14	11:46	13.75	9/10/14	0:00	84.5	0.60	Measured volume
MEAN		7.44				0.69	

Note 1: October volume not included in mean seepage rate calculation as there is no corresponding analytical data.

Characteristics of Groundwater Seepage Collected in Lake Roberts
from September 2013 to December 2014

Seepage Meter Analytical Data

Location: Lake Roberts **Site: 1**

Date Installed: 9/18/13

Date	Time Collected	Volume Collected (liters)	Seepage (liters/m^2-day)	pH (s.u.)	Alkalinity as ($CaCO_3$) (mg/l)	Conductivity (umho/cm)	Total Nitrogen (ug/l)	Total Phosphorus (ug/l)
9/18/13		-----	-----	-----	-----	-----	-----	-----
10/15/13	9:15	3.5	-----	-----	-----	-----	-----	-----
11/12/13	9:24	4.25	0.56	7.39	85	324	3351	217
1/10/14	9:40	21.25	1.33	7.39	64	274	2163	126
3/15/14	12:30	16.25	0.94	7.58	113	342	4672	306
5/19/14	9:15	-----	-----	-----	-----	-----	-----	-----
6/16/14	9:42	-----	-----	-----	-----	-----	-----	-----
7/11/14	9:07	8.25	1.22	7.45	96	367	3600	183
8/8/14	8:31	7.25	0.96	7.66	122	305	4108	276
9/10/14	9:14	7.25	0.81	7.77	144	446	3690	428
12/3/14	13:36	9.5	0.42	-----	65	-----	3880	270
MEAN			0.89	7.54	98	343	3638	258

Note 1: October volume not included in mean seepage rate calculation as there is no corresponding analytical data.

Note 2: Torn bag was discovered on 5/19 and 6/16: No sample was collected during either sampling event.

Location: Lake Roberts **Site: 2** **FOR ALL VALUES EXCEPT TN During the May 2014 sampling event**

Date Installed: 9/18/13

Date	Time Collected	Volume Collected (liters)	Seepage (liters/m^2-day)	pH (s.u.)	Alkalinity as ($CaCO_3$) (mg/l)	Conductivity (umho/cm)	Total Nitrogen (ug/l)	Total Phosphorus (ug/l)
9/18/13		-----	-----	-----	-----	-----	-----	-----
10/15/13	9:22	140	-----	-----	-----	-----	-----	-----
11/12/13	9:31	19.75	2.61	6.33	24	219	-----	80
1/10/14	9:47	125	7.85	6.42	15	214	-----	36
3/15/14	12:40	20.5	1.18	6.13	15	200	-----	72
5/19/14	9:22	65.75	3.75	5.45	4	226	-----	44
6/16/14	9:47	24.75	3.27	6.22	7	227	-----	21
7/11/14	9:14	21.5	3.19	6.32	19	228	-----	61
8/8/14	8:41	39.75	5.26	6.65	20	260	-----	43
9/10/14	9:21	13.5	1.51	6.39	17	228	-----	66
12/3/14	12:47	16.75	0.74	-----	6	-----	-----	267
MEAN			3.26	6.24	14	225		77

Note 1: October volume not included in mean seepage rate calculation as there is no corresponding analytical data.

Characteristics of Groundwater Seepage Collected in Lake Roberts
from September 2013 to December 2014

Seepage Meter Analytical Data

Location: Lake Roberts Site: 2 FOR TN ONLY excluding the May 2014 sampling date

Date Installed: 9/18/13

Date	Time Collected	Volume Collected (liters)	Seepage (liters/m^2-day)	pH (s.u.)	Alkalinity as ($CaCO_3$) (mg/l)	Conductivity (umho/cm)	Total Nitrogen (ug/l)	Total Phosphorus (ug/l)
9/18/13	-----	-----	-----	-----	-----	-----	-----	-----
10/15/13	9:22	140	-----	-----	-----	-----	-----	-----
11/12/13	9:31	19.75	2.61	-----	-----	-----	1320	-----
1/10/14	9:47	125	7.85	-----	-----	-----	671	-----
3/15/14	12:40	20.5	1.18	-----	-----	-----	678	-----
5/19/14	9:22	65.75	-----	-----	-----	-----	-----	-----
6/16/14	9:47	24.75	3.27	-----	-----	-----	964	-----
7/11/14	9:14	21.5	3.19	-----	-----	-----	765	-----
8/8/14	8:41	39.75	5.26	-----	-----	-----	715	-----
9/10/14	9:21	13.5	1.51	-----	-----	-----	1041	-----
12/3/14	12:47	16.75	0.74	-----	-----	-----	1000	-----
MEAN			3.20				894	

Note 1: October volume not included in mean seepage rate calculation as there is no corresponding analytical data.

Note 2: Mean value does not include May 2014 sample data. The data tested positive as an outlier using Dickson Q test

Location: Lake Roberts Site: 3

Date Installed: 9/18/13

Date	Time Collected	Volume Collected (liters)	Seepage (liters/m^2-day)	pH (s.u.)	Alkalinity as ($CaCO_3$) (mg/l)	Conductivity (umho/cm)	Total Nitrogen (ug/l)	Total Phosphorus (ug/l)
9/18/13	-----	-----	-----	-----	-----	-----	-----	-----
10/15/13	9:29	-----	-----	-----	-----	-----	-----	-----
11/12/13	9:42	14.5	1.92	7.26	87.8	302	3672	392
1/10/14	9:56	13.5	0.85	7.15	51.4	249	2166	148
3/15/14	12:55	7.0	0.40	7.11	107	277	2548	345
5/19/14	9:31	9.5	0.54	6.94	63.8	273	1244	370
6/16/14	9:56	6.25	0.83	6.94	71	278	3502	279
7/11/14	9:20	14.75	2.19	7.03	57	262	2191	235
8/8/14	8:47	13.5	1.79	7.45	73	320	3100	363
9/10/14	9:29	18.5	2.07	7.42	77	268	2684	284
12/3/14	11:10	13.5	0.59	-----	50	-----	3920	388
MEAN			1.24	7.16	71	279	2781	312

Note 1: October volume not included in mean seepage rate calculation as there is no corresponding analytical data.

Characteristics of Groundwater Seepage Collected in Lake Roberts
from September 2013 to December 2014

Seepage Meter Analytical Data

Location: Lake Roberts **Site: 4**

Date Installed: 9/18/13

Date	Time Collected	Volume Collected (liters)	Seepage (liters/m^2-day)	pH (s.u.)	Alkalinity as ($CaCO_3$) (mg/l)	Conductivity (umho/cm)	Total Nitrogen (ug/l)	Total Phosphorus (ug/l)
9/18/13		-----	-----	-----	-----	-----	-----	-----
10/15/13	9:33	2.75	-----	-----	-----	-----	-----	-----
11/12/13	9:49	3.75	0.50	7.17	58	258	3828	284
1/10/14	10:03	7.25	0.46	7.59	83	334	2163	296
3/15/14	13:10	11.25	0.65	7.06	64	258	1452	186
5/19/14	9:36	9.75	0.56	7.31	95	387	3400	186
6/16/14	10:04	9.75	1.29	7.37	97	371	1914	135
7/11/14	9:29	11.25	1.67	7.29	80	344	1456	133
8/8/14	8:53	10.75	1.42	7.38	102	304	2616	188
9/10/14	9:35	12.75	1.43	7.10	77	329	1497	120
12/3/14	11:22	9.5	0.42	-----	73	-----	5960	404
MEAN			0.93	7.28	81	323	2698	215

Note 1: October volume not included in mean seepage rate calculation as there is no corresponding analytical data.

Location: Lake Roberts **Site: 5**

Date Installed: 9/18/13

Date	Time Collected	Volume Collected (liters)	Seepage (liters/m^2-day)	pH (s.u.)	Alkalinity as ($CaCO_3$) (mg/l)	Conductivity (umho/cm)	Total Nitrogen (ug/l)	Total Phosphorus (ug/l)
9/18/13		-----	-----	-----	-----	-----	-----	-----
10/15/13	9:47	2.75	-----	-----	-----	-----	-----	-----
11/12/13	10:05	8.25	1.09	7.21	88	347	6380	900
1/10/14	10:12	9.75	0.61	7.21	87	336	6750	850
3/15/14	13:20	8.75	0.51	7.11	87	330	7870	1000
5/19/14	9:45	11.25	0.64	6.83	41	253	5270	27
6/16/14	10:04	8.5	1.12	7.24	147	454	9074	978
7/11/14	9:35	8.25	1.22	7.27	114	418	9391	1106
8/8/14	9:09	8.25	1.09	7.71	147	266	9350	1223
9/10/14	9:45	6.75	0.76	7.24	114	390	7011	772
12/3/14	12:01	12.5	0.55	-----	35	-----	5730	347
MEAN			0.84	7.23	95	349	7425	800

Note 1: October volume not included in mean seepage rate calculation as there is no corresponding analytical data.

Characteristics of Groundwater Seepage Collected in Lake Roberts
from September 2013 to December 2014

Seepage Meter Analytical Data

Location: Lake Roberts **Site: 6**

Date Installed: 9/18/13

Date	Time Collected	Volume Collected (liters)	Seepage (liters/m^2-day)	pH (s.u.)	Alkalinity as ($CaCO_3$) (mg/l)	Conductivity (umho/cm)	Total Nitrogen (ug/l)	Total Phosphorus (ug/l)
9/18/13		-----	-----	-----	-----	-----	-----	-----
10/15/13	9:52	5.25	-----	-----	-----	-----	-----	-----
11/12/13	10:14	5.75	0.76	7.28	74	354	6526	622
1/10/14	10:24	22.25	1.40	7.28	56	272	1967	100
3/15/14	13:40	13.0	0.75	7.08	56	248	1666	186
5/19/14	10:00	10.5	0.60	7.15	50	273	3296	25
6/16/14	10:04	9.75	1.29	7.30	58	297	1118	47
7/11/14	9:50	11.5	1.70	7.41	53	276	954	58
8/8/14	9:14	11.5	1.52	7.73	55	214	1086	56
9/10/14	9:53	11.5	1.29	7.25	53	272	1062	49
12/3/14	12:34	14.25	0.63	-----	39	-----	2960	325
MEAN			1.10	7.31	55	276	2293	163

Note 1: October volume not included in mean seepage rate calculation as there is no corresponding analytical data.

Location: Lake Roberts **Site: 7**

Date Installed: 9/18/13

Date	Time Collected	Volume Collected (liters)	Seepage (liters/m^2-day)	pH (s.u.)	Alkalinity as ($CaCO_3$) (mg/l)	Conductivity (umho/cm)	Total Nitrogen (ug/l)	Total Phosphorus (ug/l)
9/18/13		-----	-----	-----	-----	-----	-----	-----
10/15/13	9:57	5.5	-----	-----	-----	-----	-----	-----
11/12/13	10:20	5.75	0.76	7.24	78	329	4797	365
1/10/14	10:31	8.75	0.55	7.43	61	275	2514	153
3/15/14	13:50	20.25	1.17	7.25	49	222	936	101
5/19/14	10:06	8.75	0.50	7.73	43	248	5729	12
6/16/14	10:04	10.25	1.36	7.54	42	244	6159	31
7/11/14	9:56	6.75	1.00	7.63	152	454	8370	55
8/8/14	9:20	7.75	1.03	7.29	45	233	1009	39
9/10/14	9:59	12.75	1.43	7.09	48	256	1097	43
12/3/14	13:17	16.5	0.73	-----	52	-----	2460	220
MEAN			0.95	7.40	63	283	3675	113

Note 1: October volume not included in mean seepage rate calculation as there is no corresponding analytical data.

Seepage Meter Analytical Data

Location: Lake Roberts **Site: 8**

Date Installed: 9/18/13

Date	Time Collected	Volume Collected (liters)	Seepage (liters/m^2-day)	pH (s.u.)	Alkalinity as ($CaCO_3$) (mg/l)	Conductivity (umho/cm)	Total Nitrogen (ug/l)	Total Phosphorus (ug/l)
9/18/13		-----	-----	-----	-----	-----	-----	-----
10/15/13	10:14	9.75	-----	-----	-----	-----	-----	-----
11/12/13	10:27	2.75	0.36	7.21	89	368	6730	495
1/10/14	10:37	1.5	0.09	7.22	98	380	3310	312
3/15/14	14:00	4.5	0.26	6.86	48	232	805	192
5/19/14	10:12	6.55	0.37	7.04	60	263	6512	202
6/16/14	10:04	1.2	0.16	7.44	147	454	9450	580
7/11/14	10:05	2.25	0.33	7.60	192	449	11203	979
8/8/14	9:26	0.75	0.10	7.47	207	227	10626	987
9/10/14	10:06	1.25	0.14	7.69	228	583	12843	1483
12/3/14	13:03	1.4	0.06		117		4590	3750
MEAN			0.21	7.32	132	370	7341	998

Note 1: October volume not included in mean seepage rate calculation as there is no corresponding analytical data.

Location: Lake Roberts **Site: 9**

Date Installed: 9/18/13

Date	Time Collected	Volume Collected (liters)	Seepage (liters/m^2-day)	pH (s.u.)	Alkalinity as ($CaCO_3$) (mg/l)	Conductivity (umho/cm)	Total Nitrogen (ug/l)	Total Phosphorus (ug/l)
9/18/13		-----	-----	-----	-----	-----	-----	-----
10/15/13	10:06	2.75	-----	-----	-----	-----	-----	-----
11/12/13	9:58	9.25	1.22	7.18	52	275	5849	331
1/10/14	10:17	16.25	1.02	7.07	50	250	2884	177
3/15/14	13:30	3.25	0.19	7.12	62	290	7745	805
5/19/14	9:52	6.25	0.36	7.30	62	321	5466	600
6/16/14	10:04	5.25	0.69	7.49	133	411	9239	693
7/11/14	9:44	6.75	1.00	7.41	97	309	4741	334
8/8/14	9:02	3.5	0.46	7.65	164	276	11777	1031
9/10/14	-----	-----	-----	-----	-----	-----	-----	-----
12/3/14	11:46	13.75	0.60	-----	42	-----	1720	146
MEAN			0.69	7.32	83	305	6178	515

Note 1: October volume not included in mean seepage rate calculation as there is no corresponding analytical data.

Note 2: Site 9 seepage metere could not be found in September, no sample collected

APPENDIX 5-3

Results of Sediment Phosphorus Release Experiments Conducted on Lake Roberts Core Samples

Results of Sediment Phosphorus Release Rate Studies in Lake Roberts

Location: Lake Roberts **Site: 1**

Date Large Core Collected: 3/15/14 **Anoxic Conditions**

Date	Time Collected	SRP (ug/l)	Total P	Previous Collection Event		Time (days)	Cumulative Time (days)
				Date	Time		
03/17/2014	13:30	10	23			0.0	0.0
03/19/2014	16:40	35	47	03/17/2014	13:30	2.1	2.1
03/21/2014	07:32	41	54	03/19/2014	16:40	1.6	3.8
03/24/2014	07:10	43	57	03/21/2014	07:32	3.0	6.7
03/26/2014	14:28	49	67	03/24/2014	07:10	2.3	9.0
03/28/2014	06:54	52	69	03/26/2014	14:28	1.7	10.7
03/31/2014	05:22	54	72	03/28/2014	06:54	2.9	13.7
04/02/2014	05:30	55	75	03/31/2014	05:22	2.0	15.7
04/04/2014	05:50	61	83	04/02/2014	05:30	2.0	17.7
04/07/2014	07:02	68	86	04/04/2014	05:50	3.1	20.7
04/09/2014	8:34	54	71	04/07/2014	07:02	2.1	22.8
04/11/2014	15:34	49	68	04/09/2014	8:34	2.3	25.1

Location: Lake Roberts **Site: 1**

Date Large Core Collected: 3/15/14 **Aerobic Conditions**

Date	Time Collected	SRP (ug/l)	Total P	Previous Collection Event		Time (days)	Cumulative Time (days)
				Date	Time		
04/15/2014	11:50	10	30			0.0	0.0
04/16/2014	07:30	10	34	04/15/2014	11:50	0.8	0.8
04/17/2014	08:40	16	39	04/16/2014	07:30	1.0	1.9
04/18/2014	10:34	17	43	04/17/2014	08:40	1.1	2.9
04/21/2014	07:15	18	46	04/18/2014	10:34	2.9	5.8
04/23/2014	15:18	20	48	04/21/2014	07:15	2.3	8.1
04/25/2014	10:08	22	50	04/23/2014	15:18	1.8	9.9
04/28/2014	07:26	20	47	04/25/2014	10:08	2.9	12.8
04/30/2014	14:40	18	46	04/28/2014	07:26	2.3	15.1
05/02/2014	08:19	19	46	04/30/2014	14:40	1.7	16.9
05/07/2014	7:20	15	40	05/02/2014	08:19	5.0	21.8
05/17/2014	17:26	15	39	05/07/2014	7:20	10.4	32.2

Results of Sediment Phosphorus Release Rate Studies in Lake Roberts

Location: Lake Roberts **Site: 2**

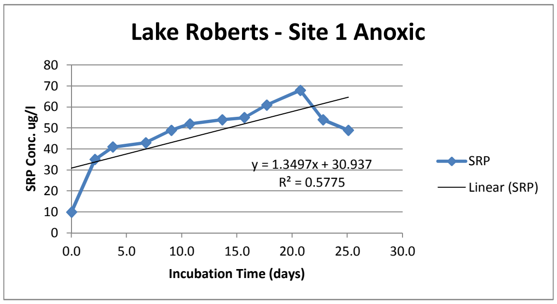
Date Large Core Collected: 3/15/14 **Anoxic Conditions**

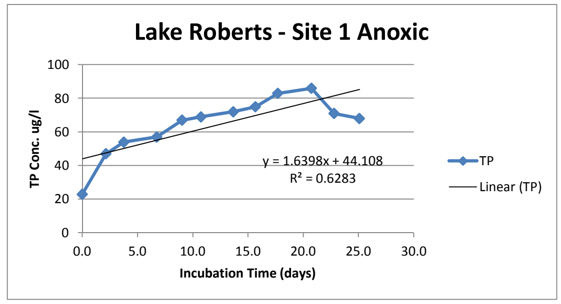
Date	Time Collected	SRP (ug/l)	Total P	Previous Collection Event		Time (days)	Cumulative Time (days)
				Date	Time		
03/17/2014	13:32	6	25			0.0	0.0
03/19/2014	16:42	18	40	03/17/2014	13:32	2.1	2.1
03/21/2014	07:34	32	56	03/19/2014	16:42	1.6	3.8
03/24/2014	07:12	36	60	03/21/2014	07:34	3.0	6.7
03/26/2014	14:30	54	78	03/24/2014	07:12	2.3	9.0
03/28/2014	06:58	62	87	03/26/2014	14:30	1.7	10.7
03/31/2014	05:24	73	97	03/28/2014	06:58	2.9	13.7
04/02/2014	05:32	76	104	03/31/2014	05:24	2.0	15.7
04/04/2014	05:52	78	107	04/02/2014	05:32	2.0	17.7
04/07/2014	07:04	72	97	04/04/2014	05:52	3.1	20.7
04/09/2014	8:36	70	95	04/07/2014	07:04	2.1	22.8
04/11/2014	15:36	66	94	04/09/2014	8:36	2.3	25.1

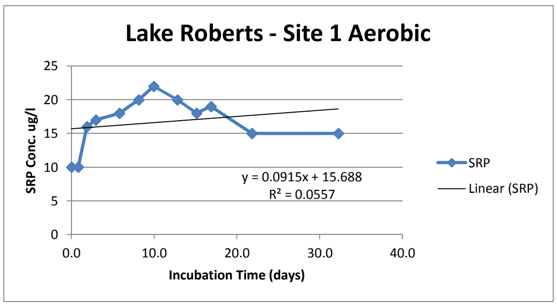
Location: Lake Roberts **Site: 2**

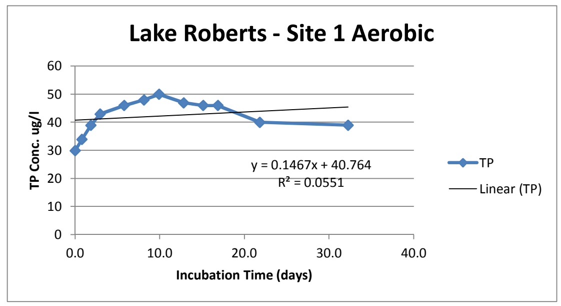
Date Large Core Collected: 3/15/14 **Aerobic Conditions**

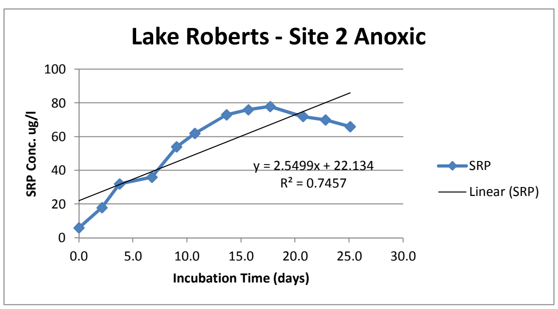
Date	Time Collected	SRP (ug/l)	Total P	Previous Collection Event		Time (days)	Cumulative Time (days)
				Date	Time		
04/15/2014	11:52	5	27			0.0	0.0
04/16/2014	07:32	7	30	04/15/2014	11:52	0.8	0.8
04/17/2014	08:42	10	36	04/16/2014	07:32	1.0	1.9
04/18/2014	10:37	12	43	04/17/2014	08:42	1.1	2.9
04/21/2014	07:15	14	46	04/18/2014	10:37	2.9	5.8
04/23/2014	18:20	21	53	04/21/2014	07:15	2.5	8.3
04/25/2014	10:10	22	59	04/23/2014	18:20	1.7	9.9
04/28/2014	07:28	31	68	04/25/2014	10:10	2.9	12.8
04/30/2014	14:42	25	63	04/28/2014	07:28	2.3	15.1
05/02/2014	08:23	24	58	04/30/2014	14:42	1.7	16.9
05/07/2014	7:22	18	48	05/02/2014	08:23	5.0	21.8
05/17/2014	17:29	19	48	05/07/2014	7:22	10.4	32.2

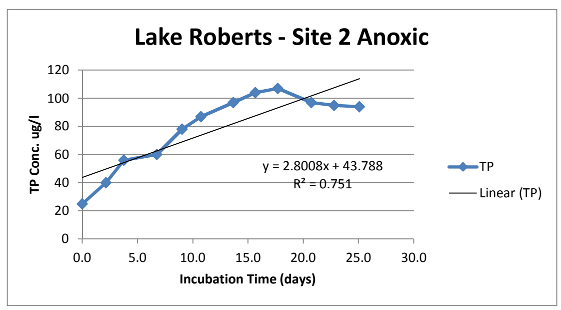

Lake Roberts - Site 1 Anoxic
SRP Conc. ug/l
Incubation Time (days)
y = 1.3497x + 30.937
R² = 0.5775
SRP
Linear (SRP)

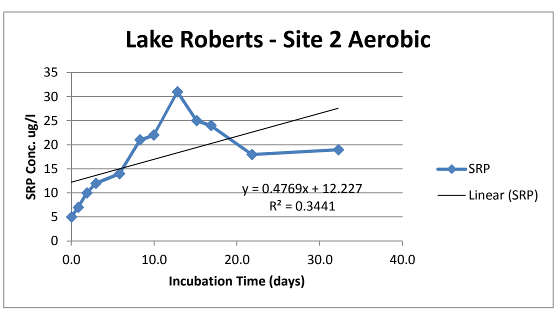

Lake Roberts - Site 1 Anoxic
TP Conc. ug/l
Incubation Time (days)
y = 1.6398x + 44.108
R² = 0.6283
TP
Linear (TP)

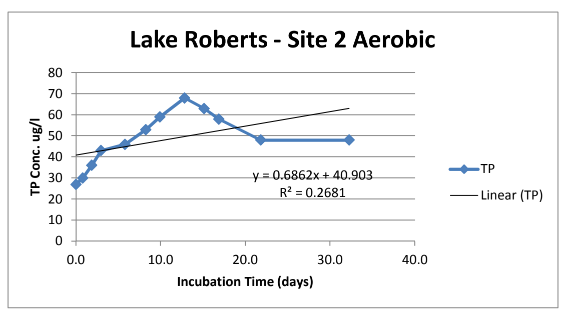

Lake Roberts - Site 1 Aerobic
SRP Conc. ug/l
Incubation Time (days)
y = 0.0915x + 15.688
R² = 0.0557
SRP
Linear (SRP)


Lake Roberts - Site 1 Aerobic
TP Conc. ug/l
Incubation Time (days)
y = 0.1467x + 40.764
R² = 0.0551
TP
Linear (TP)


Lake Roberts - Site 2 Anoxic
SRP Conc. ug/l
Incubation Time (days)
y = 2.5499x + 22.134
R² = 0.7457
SRP
Linear (SRP)


Lake Roberts - Site 2 Anoxic
TP Conc. ug/l
Incubation Time (days)
y = 2.8008x + 43.788
R² = 0.751
TP
Linear (TP)


Lake Roberts - Site 2 Aerobic
SRP Conc. ug/l
Incubation Time (days)
y = 0.4769x + 12.227
R² = 0.3441
SRP
Linear (SRP)

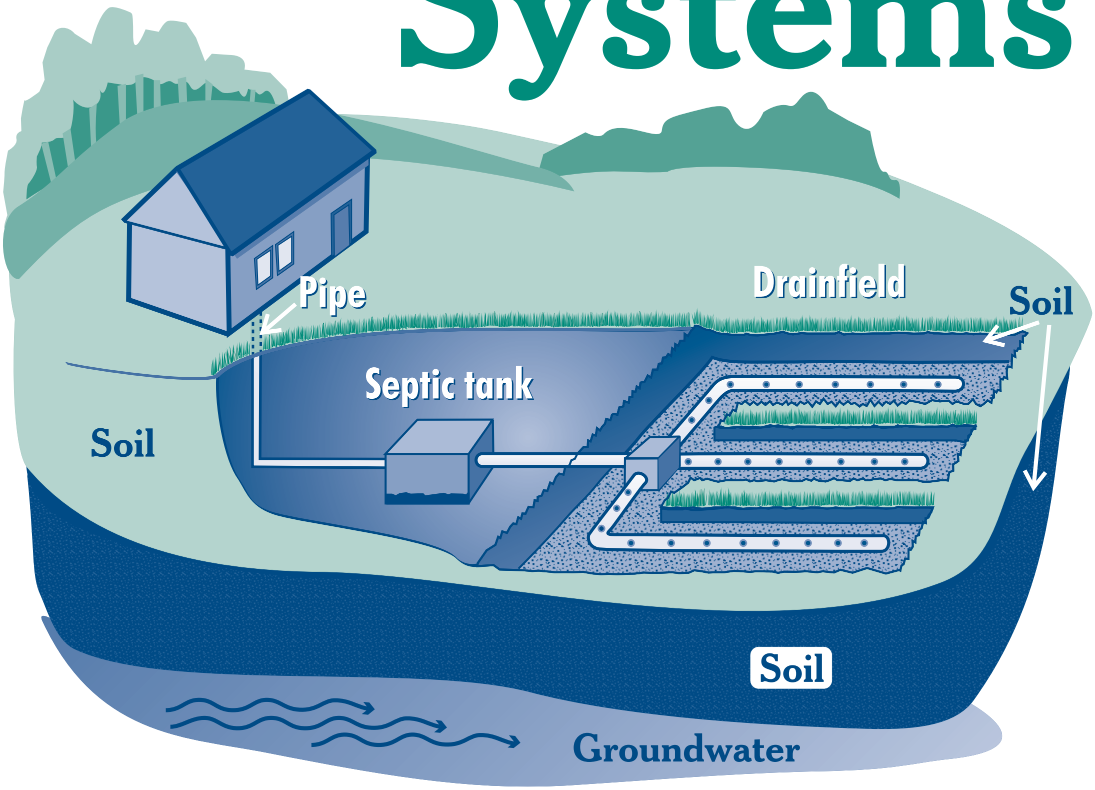

Lake Roberts - Site 2 Aerobic
TP Conc. ug/l
Incubation Time (days)
y = 0.6862x + 40.903
R² = 0.2681
TP
Linear (TP)

APPENDIX 6-1

EPA's "A Homeowner's Guide to Septic Systems"

EPA United States Environmental Protection Agency

A Homeowner's Guide to Septic Systems



What's Inside

Your Septic System is your responsibility!

Did you know that as a homeowner you're responsible for maintaining your septic system? Did you know that maintaining your septic system protects your investment in your home? Did you know that you should periodically inspect your system and pump out your septic tank?

If properly designed, constructed and maintained, your septic system can provide long-term, effective treatment of household wastewater. If your septic system isn't maintained, you might need to replace it, costing you thousands of dollars. A malfunctioning system can contaminate groundwater that might be a source of drinking water. And if you sell your home, your septic system must be in good working order.

Top Four Things You Can Do to Protect Your Septic System

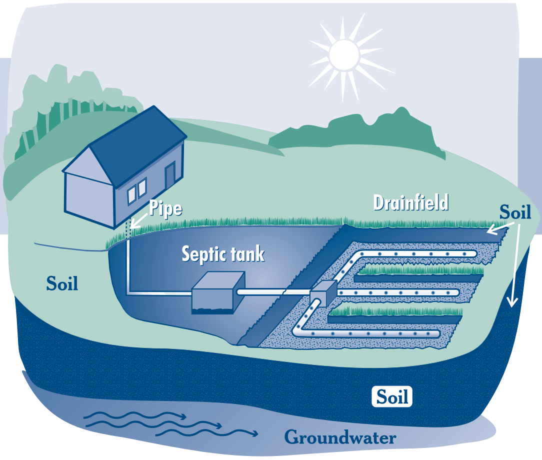
1. Regularly inspect your system and pump your tank as necessary.
2. Use water efficiently.
3. Don't dispose of household hazardous wastes in sinks or toilets.
4. Care for your drainfield.

This guide will help you care for your septic system. It will help you understand how your system works and what steps you can take as a homeowner to ensure your system will work properly. To help you learn more, consult the resources listed at the back of this booklet.

How does it work?

Components

A typical septic system has four main components: a pipe from the home, a septic tank, a drainfield, and the soil. Microbes in the soil digest or remove most contaminants from wastewater before it eventually reaches groundwater.



Typical septic system

Septic system aliases:

- On-lot system
- Onsite system
- Individual sewage disposal system
- Onsite sewage disposal system
- Onsite wastewater treatment system

Pipe from the home

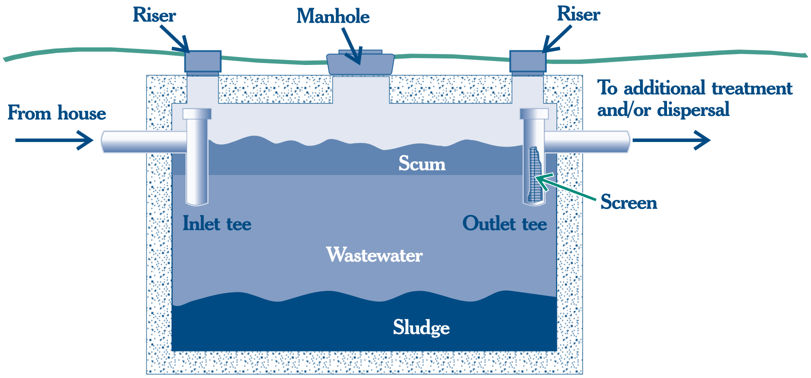
All of your household wastewater exits your home through a pipe to the septic tank.

Septic tank

The septic tank is a buried, watertight container typically made of concrete, fiberglass, or polyethylene. It holds the wastewater long enough to allow solids to settle out (forming sludge) and oil and grease to float to the surface (as scum). It also allows partial decomposition of the solid materials. Compartments and a T-shaped outlet in the septic tank prevent the sludge and scum from leaving the tank and traveling into the drainfield area. Screens are also recommended to keep solids from entering the drainfield.

Newer tanks generally have risers with lids at the ground surface to allow easy location, inspection, and pumping of the tank.

Typical single-compartment septic tank with ground-level inspection risers and screen

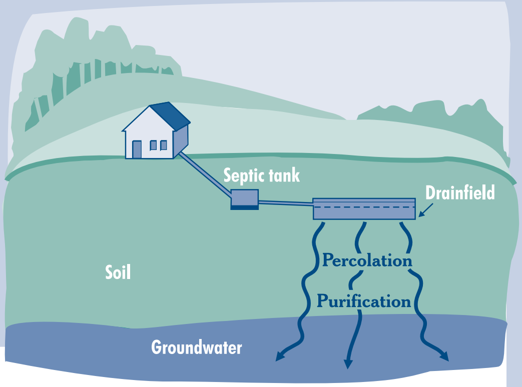


Tip

To prevent buildup, sludge and floating scum need to be removed through periodic pumping of the septic tank. Regular inspections and pumping are the best and cheapest way to keep your septic system in good working order.

Finding Your System

Your septic tank, drainfield, and reserve drainfield should be clearly designated on the "as-built" drawing for your home. (An "as-built" drawing is a line drawing that accurately portrays the buildings on your property and is usually filed in your local land records.) You might also see lids or manhole covers for your septic tank. Older tanks are often hard to find because there are no visible parts. An inspector/pumper can help you locate your septic system if your septic tank has no risers.



Drainfield

The wastewater exits the septic tank and is discharged into the drainfield for further treatment by the soil. The partially treated wastewater is pushed along into the drainfield for further treatment every time new wastewater enters the tank.

If the drainfield is overloaded with too much liquid, it will flood, causing sewage to flow to the ground surface or create backups in plumbing fixtures and prevent treatment of all wastewater.

A reserve drainfield, required by many states, is an area on your property suitable for a new drainfield system if your current drainfield fails. Treat this area with the same care as your septic system.

Soil

Septic tank wastewater flows to the drainfield, where it percolates into the soil, which provides final treatment by removing harmful bacteria, viruses, and nutrients. Suitable soil is necessary for successful wastewater treatment.

Alternative systems

Because many areas don't have soils suitable for typical septic systems, you might have or need an alternative system. You might also have or need an alternative system if there are too many typical septic systems in one area or the systems are too close to groundwater or surface waters. Alternative septic systems use new technology to improve treatment processes and might need special care and maintenance. Some alternative systems use sand, peat, or plastic media instead of soil to promote wastewater treatment. Other systems might use wetlands, lagoons, aerators, or disinfection devices. Float switches, pumps, and other electrical or mechanical components are often used in alternative systems. Alternative systems should be inspected annually. Check with your local health department or installer for more information on operation and maintenance needs if you have or need an alternative system.

Why should I maintain my septic system?

When septic systems are properly designed, constructed, and maintained, they effectively reduce or eliminate most human health or environmental threats posed by pollutants in household wastewater. However, they require regular maintenance or they can fail. Septic systems need to be monitored to ensure that they work properly throughout their service lives.

Saving money

A key reason to maintain your septic system is to save money! Failing septic systems are expensive to repair or replace, and poor maintenance is often the culprit. Having your septic system inspected regularly is a bargain when you consider the cost of replacing the entire system. Your system will need pumping depending on how many people live in the house and the size of the system. An unusable septic system or one in disrepair will lower your property value and could pose a legal liability.

Protecting health and the environment

Other good reasons for safe treatment of sewage include preventing the spread of infection and disease and protecting water resources. Typical pollutants in household wastewater are nitrogen, phosphorus, and disease-causing bacteria and viruses. If a septic system is working properly, it will effectively remove most of these pollutants.

With one-fourth of U.S. homes using septic systems, more than 4 billion gallons of wastewater per day is dispersed below the ground's surface. Inadequately treated sewage from septic systems can be a cause of groundwater contamination. It poses a significant threat to drinking water and human health because it can contaminate drinking water wells and cause diseases and infections in people and animals. Improperly treated sewage that contaminates nearby surface waters also increases the chance of swimmers contracting a variety of infectious diseases. These range from eye and ear infections to acute gastrointestinal illness and diseases like hepatitis.

How do I maintain my septic system?

Inspect and pump frequently

You should have a typical septic system inspected at least every 3 years by a professional and your tank pumped as recommended by the inspector (generally every 3 to 5 years). Alternative systems with electrical float switches, pumps, or mechanical components need to be inspected more often, generally once a year. Your service provider should inspect for leaks and look at the scum and sludge layers in your septic tank. If the bottom of the scum layer is within 6 inches of the bottom of the outlet tee or the top of the sludge layer is within 12 inches of the outlet tee, your tank needs to be pumped. Remember to note the sludge and scum levels determined by your service provider in your operation and maintenance records. This information will help you decide how often pumping is necessary.

What Does an Inspection Include?

- Locating the system.
- Uncovering access holes.
- Flushing the toilets.
- Checking for signs of back up.
- Measuring scum and sludge layers.
- Identifying any leaks.
- Inspecting mechanical components.
- Pumping the tank if necessary.

Four major factors influence the frequency of pumping: the number of people in your household, the amount of wastewater generated (based on the number of people in the household and the amount of water used), the volume of solids in the wastewater (for example, using a garbage disposal increases the amount of solids), and septic tank size.

Some makers of septic tank additives claim that their products break down the sludge in septic tanks so the tanks never need to be pumped. Not everyone agrees on the effectiveness of additives. In fact, septic tanks already contain the microbes they need for effective treatment. Periodic pumping is a much better way to ensure that septic systems work properly and provide many years of service. Regardless, every septic tank requires periodic pumping.

In the service report, the pumper should note any repairs completed and whether the tank is in good condition. If the pumper recommends additional repairs he or she can't perform, hire someone to make the repairs as soon as possible.

Use water efficiently

Average indoor water use in the typical single-family home is almost 70 gallons per person per day. Leaky toilets can waste as much as 200 gallons each day. The more water a household conserves, the less water enters the septic system. Efficient water use can improve the operation of the septic system and reduce the risk of failure.

High-efficiency toilets

Toilet use accounts for 25 to 30 percent of household water use. Do you know how many gallons of water your toilet uses to empty the bowl? Most older homes have toilets with 3.5- to 5-gallon reservoirs, while newer high-efficiency toilets use 1.6 gallons of water or less per flush. If you have problems with your septic system being flooded with household water, consider reducing the volume of water in the toilet tank if you don't have a high-efficiency model or replacing your existing toilets with high-efficiency models.

Faucet aerators and high-efficiency showerheads

Faucet aerators help reduce water use and the volume of water entering your septic system. High-efficiency shower-heads or shower flow restrictors also reduce water use.

Water fixtures

Check to make sure your toilet's reservoir isn't leaking into the bowl. Add five drops of liquid food coloring to the reservoir before bed. If the dye is in the bowl the next morning, the reservoir is leaking and repairs are needed.

A small drip from a faucet adds many gallons of unnecessary water to your system every day. To see how much a leak adds to your water usage, place a cup under the drip for 10 minutes. Multiply the amount of water in the cup by 144 (the number of minutes in 24 hours, divided by 10). This is the total amount of clean water traveling to your septic system each day from that little leak.

Use Water Efficiently!

- **Install high-efficiency showerheads**
- **Fill the bathtub with only as much water as you need**
- **Turn off faucets while shaving or brushing your teeth**
- **Run the dishwasher and clothes washer only when they're full**
- **Use toilets to flush sanitary waste only (not kitty litter, diapers, or other trash)**
- **Make sure all faucets are completely turned off when not in use**
- **Maintain your plumbing to eliminate leaks**
- **Install aerators in the faucets in your kitchen and bathroom**
- **Replace old dishwashers, toilets, and clothes washers with new, high-efficiency models.**

For more information on water conservation, please visit www.epa.gov/owm/water-efficiency/index.htm

Watch your drains

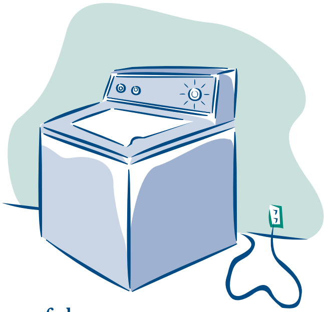
What goes down the drain can have a major impact on how well your septic system works.

Waste disposal

What shouldn't you flush down your toilet? Dental floss, feminine hygiene products, condoms, diapers, cotton swabs, cigarette butts, coffee grounds, cat litter, paper towels, and other kitchen and bathroom items that can clog and potentially damage septic system components if they become trapped. Flushing household chemicals, gasoline, oil, pesticides, antifreeze, and paint can stress or destroy the biological treatment taking place in the system or might contaminate surface waters and groundwater. If your septic tank pumper is concerned about quickly accumulating scum layers, reduce the flow of floatable materials like fats, oils, and grease into your tank or be prepared to pay for more frequent inspections and pumping.

Washing machines

By selecting the proper load size, you'll reduce water waste. Washing small loads of laundry on the large-load cycle wastes precious water and energy. If you can't select load size, run only full loads of laundry.



Doing all the household laundry in one day might seem like a time-saver, but it could be harmful to your septic system. Doing load after load does not allow your septic tank time to adequately treat wastes. You could be flooding your drainfield without allowing sufficient recovery time. Try to spread water usage throughout the week. A new Energy Star clothes washer uses 35 percent less energy and 50 percent less water than a standard model.

Care for your drainfield

Your drainfield is an important part of your septic system. Here are a few things you should do to maintain it:

- Plant only grass over and near your septic system. Roots from nearby trees or shrubs might clog and damage the drainfield.
- Don't drive or park vehicles on any part of your septic system. Doing so can compact the soil in your drainfield or damage the pipes, tank, or other septic system components.
- Keep roof drains, basement sump pump drains, and other rainwater or surface water drainage systems away from the drainfield. Flooding the drainfield with excessive water slows down or stops treatment processes and can cause plumbing fixtures to back up.

What can make my system fail?

If the amount of wastewater entering the system is more than the system can handle, the wastewater backs up into the house or yard and creates a health hazard.

You can suspect a system failure not only when a foul odor is emitted but also when partially treated wastewater flows up to the ground surface. By the time you can smell or see a problem, however, the damage might already be done.

By limiting your water use, you can reduce the amount of wastewater your system must treat. When you have your system inspected and pumped as needed, you reduce the chance of system failure.

A system installed in unsuitable soils can also fail. Other failure risks include tanks that are inaccessible for maintenance, drainfields that are paved or parked on, and tree roots or defective components that interfere with the treatment process.

Failure symptoms

The most obvious septic system failures are easy to spot. Check for pooling water or muddy soil around your septic system or in your basement. Notice whether your toilet or sink backs up when you flush or do laundry. You might also notice strips of bright green grass over the drainfield. Septic systems also fail when partially treated wastewater comes into contact with groundwater. This type of failure is not easy to detect, but it can result in the pollution of wells, nearby streams, or other bodies of water. Check with a septic system professional and the local health department if you suspect such a failure.

Stop, look, and smell!

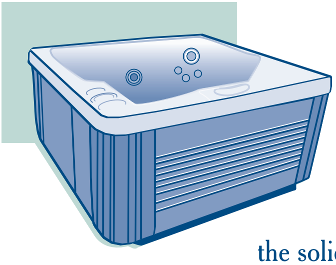
Failure causes

Household toxics

Does someone in your house use the utility sink to clean out paint rollers or flush toxic cleaners? Oil-based paints, solvents, and large volumes of toxic cleaners should not enter your septic system. Even latex paint cleanup waste should be minimized. Squeeze all excess paint and stain from brushes and rollers on several layers of newspaper before rinsing. Leftover paints and wood stains should be taken to your local household hazardous waste collection center. Remember that your septic system contains a living collection of organisms that digest and treat waste.

Household cleaners

For the most part, your septic system's bacteria should recover quickly after small amounts of household cleaning products have entered the system. Of course, some cleaning products are less toxic to your system than others. Labels can help key you into the potential toxicity of various products. The word "Danger" or "Poison" on a label indicates that the product is highly hazardous. "Warning" tells you the product is moderately hazardous. "Caution" means the product is slightly hazardous. ("Nontoxic" and "Septic Safe" are terms created by advertisers to sell products.) Regardless of the type of product, use it only in the amounts shown on the label instructions and minimize the amount discharged into your septic system.



Hot tubs

Hot tubs are a great way to relax. Unfortunately, your septic system was not designed to handle large quantities of water from your hot tub. Emptying hot tub water into your septic system stirs the solids in the tank and pushes them out into the drainfield, causing it to clog and fail. Draining your hot tub into a septic system or over the drainfield can overload the system. Instead, drain cooled hot tub water onto turf or landscaped areas well away from the septic tank and drainfield, and in accordance with local regulations. Use the same caution when draining your swimming pool.

Water Purification Systems

Some freshwater purification systems, including water softeners, unnecessarily pump water into the septic system. This can contribute hundreds of gallons of water to the septic tank, causing agitation of solids and excess flow to the drainfield. Check with your licensed plumbing professional about alternative routing for such freshwater treatment systems.

Garbage disposals

Eliminating the use of a garbage disposal can reduce the amount of grease and solids entering the septic tank and possibly clogging the drainfield. A garbage disposal grinds up kitchen scraps, suspends them in water, and sends the mixture to the septic tank. Once in the septic tank, some of the materials are broken down by bacterial action, but most of the grindings have to be pumped out of the tank. Using a garbage disposal frequently can significantly increase the accumulation of sludge and scum in your septic tank, resulting in the need for more frequent pumping.

Improper design or installation

Some soils provide excellent wastewater treatment; others don't. For this reason, the design of the drainfield of a septic system is based on the results of soil analysis. Homeowners and system designers sometimes underestimate the significance of good soils or believe soils can handle any volume of wastewater applied to them. Many failures can be attributed to having an undersized drainfield or high seasonal groundwater table. Undersized septic tanks—another design failure—allow solids to clog the drainfield and result in system failure.

If a septic tank isn't watertight, water can leak into and out of the system. Usually, water from the environment leaking into the system causes hydraulic overloading, taxing the system beyond its capabilities and causing inadequate treatment and sometimes sewage to flow up to the ground surface. Water leaking out of the septic tank is a significant health hazard because the leaking wastewater has not yet been treated.

Even when systems are properly designed, failures due to poor installation practices can occur. If the drainfield is not properly leveled, wastewater can overload the system. Heavy equipment can damage the drainfield during installation which can lead to soil compaction and reduce the wastewater infiltration rate. And if surface drainage isn't diverted away from the field, it can flow into and saturate the drainfield.

For more information

Local Health Department

EPA Onsite/Decentralized Management Homepage

www.epa.gov/owm/septic

EPA developed this Web site to provide tools for communities investigating and implementing onsite/decentralized management programs. The Web site contains fact sheets, program summaries, case studies, links to design and other manuals, and a list of state health department contacts that can put you in touch with your local health department.

National Small Flows Clearinghouse

www.nesc.wvu.edu

Funded by grants from EPA, the NSFC helps America's small communities and individuals solve their wastewater problems. Its activities include a Web site, online discussion groups, a toll-free assistance line (800-624-8301), informative publications, and a free quarterly newsletter and magazine.

Rural Community Assistance Program

www.rcap.org

RCAP is a resource for community leaders and others looking for technical assistance services and training related to rural drinking water supply and wastewater treatment needs, rural solid waste programs, housing, economic development, comprehensive community assessment and planning, and environmental regulations.

National Onsite Wastewater Recycling Association, Inc.

www.nowra.org

NOWRA is a national professional organization to advance and promote the onsite wastewater industry. The association promotes the need for regular service and educates the public on the need for properly designed and maintained septic systems.

Septic Yellow Pages

www.septicyellowpages.com

The Septic Yellow Pages provides listings by state for professional septic pumpers, installers, inspectors, and tank manufacturers throughout the United States. This Web site is designed to answer simple septic system questions and put homeowners in contact with local septic system professionals.

National Association of Wastewater Transporters

www.nawt.org

NAWT offers a forum for the wastewater industry to exchange ideas and concerns. The NAWT Web site lists state associations and local inspectors and pumpers.

EPA United States Environmental Protection Agency

EPA-832-B-02-005
December 2002
Revised March 2005

Additional copies can be obtained from:
U.S. EPA Publications Clearinghouse
P.O. Box 42419
Cincinnati, OH 45241

Telephone: 800-490-9198
Fax: 513-489-8695

Office of Water
U.S. Environmental Protection Agency

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Septic System Dos and Don'ts

(adapted from National Small Flows Clearinghouse)

Dos

- Check with the local regulatory agency or inspector/pumper if you have a garbage disposal unit to make sure that your septic system can handle this additional waste.
- Check with your local health department before using additives. Commercial septic tank additives do not eliminate the need for periodic pumping and can be harmful to the system.
- Use water efficiently to avoid overloading the septic system. Be sure to repair leaky faucets or toilets. Use high-efficiency fixtures.
- Use commercial bathroom cleaners and laundry detergents in moderation. Many people prefer to clean their toilets, sinks, showers, and tubs with a mild detergent or baking soda.
- Check with your local regulatory agency or inspector/pumper before allowing water softener backwash to enter your septic tank.
- Keep records of repairs, pumpings, inspections, permits issued, and other system maintenance activities.
- Learn the location of your septic system. Keep a sketch of it with your maintenance record for service visits.
- Have your septic system inspected and pumped as necessary by a licensed inspector/contractor.
- Plant only grass over and near your septic system. Roots from nearby trees or shrubs might clog and damage the drainfield.

Don'ts

- Your septic system is not a trash can. Don't put dental floss, feminine hygiene products, condoms, diapers, cotton swabs, cigarette butts, coffee grounds, cat litter, paper towels, latex paint, pesticides, or other hazardous chemicals into your system.
- Don't use caustic drain openers for a clogged drain. Instead, use boiling water or a drain snake to open clogs.
- Don't drive or park vehicles on any part of your septic system. Doing so can compact the soil in your drainfield or damage the pipes, tank, or other septic system components.

EPA
United States
Environmental Protection
Agency

Office of Water
Washington, DC 20460

Official Business
Penalty for Private Use
$300
EPA-832-B-02-005

APPENDIX 6-2

Waterford Pointe Subdivision
Water Management District Non-Compliance Letter
and Construction Plans

SOUTH FLORIDA WATER MANAGEMENT DISTRICT

ORLANDO SERVICE CENTER 1707 Orlando Central Parkway, Suite 200, Orlando, FL 32809
(407) 858-6100 • FL WATS 1-800-250-4250 • Suncom 358-6100 • Fax (407) 858-6121 • www.sfwmd.gov/orlando/

CON 24-05

ENVIRONMENTAL RESOURCE REGULATION

July 2, 2014

Ellyn Siviglia, President
Waterford Pointe HOA, Inc.
1801 Cook Avenue
Orlando, FL 32806

Las Bellas Canas Corp.
c/o Alberto Vasquez
11019 Ledgement Lane
Windermere, FL 34786

Dear Ms. Siviglia and Mr. Vasquez:

Subject: Notice of Noncompliance
Berm and Swale and Fill Import @ 13013 Water Point Blvd, Windermere
Permit No. 48-00411-S, Waterford Pointe (fka Dynasty Estates)
Orange County, S 1,2/T23S/R28E

On May 30, 2014, District staff met on site with Mr. Alberto Vasquez to discuss ongoing construction activities at the site. The above referenced permit requires that all lakefront lots maintain a berm and swale to reduce the amount of nutrients from entering the lake. As the Department of Environmental Protection recently designated Lake Roberts as an impaired waterbody due to high presence of nutrients, especially phosphorus, it is critical to the health of the lake for all berm and swales to function as designed.

Per the special conditions of the permit, the HOA is responsible for the operation and maintenance of the surface water management system, of which the berm and swales are an integral part.

During the site inspection, staff had difficulty determining the location and depth of the berm and swale on site as the drainage easement was severely overgrown. In addition, a large amount of fill was noted to have been placed in the back of the house. While the fill does not appear to be located in the drainage easement, the height difference between the properties does negatively impact adjacent property owners by directing rainwater runoff onto adjacent properties.

To bring the property into compliance with the District permit condition and as discussed on site with Mr. Vasquez, the following actions need to occur:

1 – Mow overgrown vegetation the width of the property line and have the surveyor stake the limits of the drainage easement, including noting the elevations of the top and bottom of the berm and swale. Staff left a copy of the permit, including a detail construction plan of the berm and swale system, with Mr. Vasquez to aid with this delineation.

In the event that the existing elevations do not match the permitted plan or there is no evidence of a berm and swale, it will be required to construct the berm and swale according to the permit conditions.

2- The fill material brought in and placed in the backyard cannot remain as is. Two alternatives were presented to Mr. Vasquez at the meeting. The first option is to remove the fill to the previous elevation such that it does not have a negative impact on the adjacent properties. This is the preferred action of the District as it will be the least costly and least time consuming, as it will not require permitting.

The second option is to submit plans for the design of an engineered retaining wall that will capture the runoff and re-direct it to the berm and swale as the original design of the lot intended. Please note, that this option will require permitting from the District as it deviates from the previously approved permit for the subdivision. In addition, the HOA as the current owner of the stormwater management system needs to sign the application as a co-applicant, along with the homeowner of the lot.

The District grants 30 days from the date of this letter to have the drainage easement staked out and to hear as to the intentions of the fill violation. At such time, the District will re-inspect the property for compliance. Should you have any questions, please contact me at 407-858-6100, ext. 3834.

Sincerely,

Andi Reyes
Regulatory Professional IV
Orlando Service Center

C: Alberto Vasquez via email (vasquez20@gmail.com)
Ellyn Siviglia, HOA President via email (esiviglia@aol.com)


LAKE SIDE RETENTION POND REGRADING
WATERFORD POINTE, PHASE III
ENGINEERING & ENVIRONMENTAL DESIGN, INC.
807 S. ORLANDO AVENUE, SUITE C
WINTER PARK, FLORIDA 32789
Engineers, Environmental and Planning Consultants
WATER KEY DRIVE
ROBERTS POINTE DRIVE
EXISTING POND TO BE FILLED W/ STOCKPILE OF BORROWED SOILS
RETENTION POND
DHW (25) = EL 112.56
DHW (100) = EL 112.60
75' GRASS WEIR
EL.=112.50
100 YEAR FLOOD PLAIN LINE (TYP.) EL=111.50
ORANGE COUNTY JURISDICTIONAL LINE (NWHL)
RETENTION POND (VARIES)
TRACT "D"
CONSERVATION AREA
LAKE ROBERTS
NHW = EL 109.0
DHW (25) = EL 110.7
DHW (100) = EL 111.5
FLAGGED WETLAND LINE (SJWMD, SFWMD, ACOE)
EXISTING POND TO BE FILLED W/ STOCKPILE SOILS
EXISTING IRRIGATION
RELOCATE STRUCTURE S21 TYPE "C" DBI (SEE DETAIL THIS SHEET)
CUT & REMOVE APPROX. 20 LF 15" RCP
EXISTING 50 LF 15" RCP
EXISTING MES INV. = 105.14
LEGEND
F.F. 114.15 - FINISHED FLOOR ELEVATION
17 - LOT NUMBER
© - LOT GRADING TYPE
FLOODPLAIN COMPENSATION STORAGE CROSS-SECTION LOCATION
SWALE DETAIL
NTS
GRASS WEIR DETAIL
NTS
FIBERGLASS BRACKET DETAIL
NTS
SECTION
NTS
PROPOSED ELEVATION
NTS
SKIMMER TOP = 113.11
SKIMMER BOTTOM = 111.40
POND BOTTOM = 111.50
WEIR EL. 111.90
TOP OF BERM EL. 113.00
EL. 110.90
4" THICK 3,000 PSI CONC. PAD
15" R.C.P. INV. EL. 106.50
*NOTE:
1. FORM AND RAISE TOP FROM 110.40 TO 111.90.
2. EXISTING CONTROL STRUCTURE S21 TYPE "C" DBI INLET PER FDOT #232.
JOB No. 9919
SCALE: NOTED
DATE: 08/18/99
SHEET NO. 1 OF 1
SEP 01 1999
H:\proj\waterfd\dwg\swale regrade\swalegrade.dwg 09/01/99 04:16:18 PM EDT

APPENDIX 6-3

Orange County Code Sections 15-801 through 15-812: Fertilizer Management Ordinance

APPENDIX 6-3

ORANGE COUNTY CODE
SECTIONS 15-801 THROUGH 15-812

"FERTILIZER MANAGEMENT ORDINANCE"

ORDINANCE NO. 2009-26

AN ORDINANCE IN ORANGE COUNTY, FLORIDA, ENACTING A "FERTILIZER MANAGEMENT ORDINANCE" REGULATING APPLICATION OF FERTILIZER TO LAWNS AND TURF IN ORANGE COUNTY; PROVIDING FOR DEFINITIONS; PROVIDING FOR SEASONAL RESTRICTIONS ON FERTILIZER APPLICATION; PROVIDING RESTRICTIONS FOR FERTILIZER CONSTITUENTS PHOSPHORUS AND NITROGEN; PROVIDING FOR RESTRICTIONS IN RATES OF FERTILIZER APPLICATION; PROVIDING FOR TRAINING REQUIREMENTS FOR COMMERCIAL APPLICATORS OF FERTILIZER; PROVIDING FOR EXEMPTIONS; PROVIDING FOR VARIANCES; PROVIDING FOR SEVERABILITY; PROVIDING FOR LIBERAL CONSTRUCTION; PROVIDING FOR INCLUSION INTO CODE; AND PROVIDING AN EFFECTIVE DATE.

WHEREAS, surface water runoff and baseflow runoff leaves residential neighborhoods, commercial centers, industrial areas, and other lands of Orange County and enters into natural and artificial stormwater and drainage conveyances and natural water bodies in Orange County; and

WHEREAS, phosphorus and nitrogen – the primary nutrients associated with the degradation of groundwater and surface water – are commonly the primary components of fertilizer for turf application; and

WHEREAS, leaching and runoff of nutrients from improper or excess fertilization practices contributes to nitrogen and phosphorus loading in Orange County's stormwater conveyances and natural water bodies and thus to the overgrowth of algae and vegetation in these waterways; and

WHEREAS, Orange County's natural and artificial stormwater and drainage conveyances regulate the flow of stormwater to prevent flooding and undesired accumulations of water; and

WHEREAS, the overgrowth of algae and vegetation in stormwater and drainage conveyances hinders the goal of flood prevention and proper water conduction; and

WHEREAS, the quality of streams, lakes, and wetlands is critical to environmental, economic, and recreational prosperity and to the health, safety, and welfare of the residents of Orange County; and

WHEREAS, recent algae blooms and accelerated growth of aquatic weeds in Orange County's water bodies have heightened community concerns about water quality and eutrophication of surrounding waters; and

WHEREAS, pursuant to Section 303(d) of the federal Clean Water Act and the resulting Florida Impaired Waters Rule (Chapter 62-303, Florida Administrative Code), the Florida Department of Environmental Protection ("FDEP") has classified specific water bodies in Orange County as "impaired" as a result of the presence of excess nutrients; and

WHEREAS, the amount of fertilizer applied to a given landscape and the method of application have potential for creating nutrient pollution; and

WHEREAS, the amount of fertilizer applied should be the minimum necessary for turf to meet initial establishment and basic growth needs; and

WHEREAS, it is generally recognized that Florida soils naturally have a suitable phosphorus content for most vegetative needs and that phosphorus is therefore rarely needed to create or maintain a vibrant landscape; and

WHEREAS, it has been recognized that the use of slow release nitrogen sources is more efficiently used by plants and less likely to leach out or wash away in stormwater runoff; and

WHEREAS, this ordinance is part of a multi-pronged effort by Orange County to reduce nutrient leaching and runoff through improved stormwater management, water conservation efforts, conversion of septic systems to central sewage treatment, public education, and updated development standards as set forth in the Orange County Code.

WHEREAS, Orange County's Environmental Protection Division has demonstrated to the Board of County Commissioners that, as part of a comprehensive program to address nonpoint sources of nutrient pollution which is science-based, and economically, and technically feasible, this ordinance contains additional or more stringent standards than those in the Florida Department of Environmental Protection's Model Ordinance for Florida-Friendly Fertilizer Use on Urban Landscapes (January 2009) which are necessary to adequately address urban fertilizer contributions to nonpoint source nutrient loading to water bodies; and

WHEREAS, in the process of adoption of this ordinance, the Board of County Commissioners has considered all relevant scientific information, including input from the Department of Environmental Protection, the Department of Agriculture and Consumer Services, and the University of Florida Institute of Food and Agricultural Sciences, to the extent provided, on the need for additional or more stringent provisions to address fertilizer as a contributor to water quality degradation; and such information is part of the public record.

BE IT ORDAINED BY THE BOARD OF COUNTY COMMISSIONERS OF ORANGE COUNTY:

Section 1. Enactment of New Fertilizer Management Ordinance. A new Fertilizer Management Ordinance, to be codified at Chapter 15, Article XVII of the Orange County Code, Section 15-801 through 15-812, is enacted to read as follows:

ARTICLE XVII
FERTILIZER MANAGEMENT ORDINANCE

Section 15-801. Definitions.

Apply or *application* means the physical deposit, placement, or release of fertilizer upon soil or turf.

Applicator means any person who applies fertilizer.

Article means Chapter 15, Article XVII of the Orange County Code of Ordinances, as amended, unless otherwise specified.

Best management practices (BMPs) means the practice or combination of practices based on research, field testing and expert review, determined to be the most effective and practicable on-location means, including economic and technological considerations, for improving water quality, conserving water supplies and protecting natural resources.

Commercial applicator means any person who applies fertilizer in exchange for money, goods, services or other valuable consideration and who is required by law, ordinance, or regulation to obtain an Orange County local business tax certificate.

County-approved best management practices training program means a program approved as such in writing by the

Manager of the Orange County Environmental Protection Division. The program shall include the most current version of "Florida Friendly Best Management Practices for Protection of Water Resources by Green Industries, December 2008." The Orange County Environmental Protection Division will maintain a publicly available list of approved training programs.

Fertilizer means any substance or mixture of substances, excluding pesticides, organic composts, and fertilizer derived from biosolids, that contains one or more recognized plant nutrients and promotes plant growth, or controls soil acidity or alkalinity, or provides other soil enrichment, or provides other corrective measures to the soil.

Guaranteed analysis means the percentage of plant nutrients or measures of neutralizing capability claimed to be present in a fertilizer.

Golf course means any public or private area of land designed and used exclusively for playing or practicing golf, including tees, fairways, greens, rough areas, hazards and driving ranges (stand-alone ranges or those associated with a golf course). A golf course shall also include the following uses if they are accessory to the above uses: clubhouses, and all facilities adjacent to and associated with the daily operations of the above-referenced areas. Golf-related structures or features on residentially zoned private land shall not constitute a golf course.

Groundcover means plants used in mass as alternative to turf or lawn and/or to create variety in landscape; usually not having a mature height over two (2) feet tall.

Person means any person, natural or artificial, individual, firm, association, organization, partnership, business trust, corporation, company, agent, employee, or any other legal entity, the United States of America, and the state of Florida and all political subdivisions, regions, districts, municipalities, and public agencies.

Restricted season means the period from June 1st through September 30th.

Slow release means nitrogen in a form which delays its availability for plant uptake and use for an extended period after application, or which extends its availability to the plant longer than a readily available, rapid or quick-release product. This definition includes the terms "controlled release," "timed release," "slowly available," and "water insoluble."

Turf, sod, or *lawn* means a mat layer of monocotyledonous plants, including but not limited to, Bahia, Bermuda, Centipede, Paspalum, St. Augustine, and Zoysia, or other groundcover.

Section 15-802. Applicability.

Consistent with Section 704 of the Orange County Charter, this ordinance shall be applicable throughout all of Orange County, except in municipalities that have minimum standards for the regulation of fertilizer application that are no less strict than those in this article.

Section 15-803. Weather and Seasonal Restrictions.

(a) No fertilizer containing nitrogen or phosphorus shall be applied to turf during a period for which the National Weather Service has issued any of the following advisories for any portion Orange County: a severe thunderstorm warning or watch, flood warning or watch, tropical storm warning or watch, hurricane warning or watch, or a three-day cone of uncertainty.

(b) No person, except applicators certified pursuant to Section 15-809 herein, shall apply fertilizer containing nitrogen or phosphorus to turf during the restricted season from June 1st through September 30th.

Section 15-804. Fertilizer Content; Application Rate.

(a) All fertilizer shall be labeled in accordance with state law.

(b) No fertilizer containing phosphorus shall be applied to turf. Provided, however, where phosphorus deficiency has been demonstrated in the soil underlying the turf by a soil analysis test performed by a State of Florida-certified laboratory, phosphorus may be applied to turf at a rate no greater than one-quarter of one pound (0.25 lb.) of phosphorus per 1,000 square feet per application, not to exceed one-half pound (0.5 lb.) of phosphorus per 1,000 square feet per year. Any person who obtains such a soil analysis test showing a phosphorus deficiency and who wishes to apply phosphorus to turf shall mail a copy of the test results to Orange County Environmental Protection Division, Attention: Manager, 800 Mercy Drive, Orlando, Florida 32808 within 30 days of receipt of results. In addition, phosphorus may be applied at the foregoing rate to newly installed turf, regardless of whether a soil deficiency test has been performed, for a period of sixty (60) days following installation.

(c) No fertilizer containing nitrogen shall be applied to turf unless at least fifty (50) percent of its nitrogen content is slow release as indicated on the Guaranteed Analysis label, with no more than one pound (1 lb.) total nitrogen per 1,000 square feet of area per application.

(d) Notwithstanding subsection 15-804(c), commercial applicators may apply fertilizer to turf at a rate that does not exceed one-half of one pound (0.5 lb.) of readily available nitrogen per 1,000 square feet of area, provided, however, that any application that exceeds one-half of one pound (0.5 lb.) of nitrogen shall conform to subsection 15-804 (c).

(e) Notwithstanding any other provision of this section 15-804, no fertilizer shall be applied to turf at a rate that exceeds the limits per plant species set forth below:

Plant Species/ Nitrogen limit:
Bahia grass: 2-4 pounds of nitrogen per 1,000 square feet per year.
Bermuda grass: 4-6 pounds of nitrogen per 1,000 square feet per year.
Centipede grass: 2-3 pounds of nitrogen per 1,000 square feet per year.
St. Augustine grass: 2-5 pounds of nitrogen per 1,000 square feet per year.
Zoysia grass: 3-6 pounds of nitrogen per 1,000 square feet per year.

Section 15-805. Fertilizer-Free Zones.

(a) No fertilizer shall be applied within ten (10) feet of any lake, pond, stream, water body, water course or canal. Additionally, no fertilizer shall be applied within ten (10) feet of any wetland as defined by the Florida Department of Environmental Protection (Chapter 62-340, Florida Administrative Code, as it may be amended or superseded).

(b) No fertilizer shall be deposited, washed, swept, or blown off – intentionally or inadvertently – onto any impervious surface, public right-of-way, public property, stormwater drain, ditch, conveyance, or water body.

(c) A low-maintenance zone is strongly recommended – though not required – for all areas within six (6) feet of the normal high water elevation of any lake, pond, stream, water body, water course or canal, or any wetland. Low-maintenance zones should be planted and managed in such a way as to minimize the need for watering, mowing, and other active maintenance.

Section 15-806. Mode of Application.

Broadcast spreaders applying fertilizers must be equipped with deflector shields positioned to deflect fertilizer from all impervious surfaces, rights-of-way, stormwater drains, ditches, conveyances, and water bodies.

Section 15-807. Grass Clippings and Vegetative Material/Debris.

Grass clippings and/or vegetative material/debris shall not be deposited, washed, swept, or blown off – intentionally or inadvertently – onto any impervious surface, public right-of-way, stormwater drain, ditch, conveyance, or water body.

Section 15-808. Exemptions; exceptions.

(a) Sections 15-805 through 15-810 of this article shall not apply to golf courses; provided, however, fertilizer shall not be applied to golf courses in excess of the provisions of the Florida Department of Environmental Protection ("FDEP") document, *BMPs for the Enhancement of Environmental Quality on Florida Golf Courses, January 2007.*

(b) This article shall not apply to any bona fide farm operation that Orange County is without authority to regulate with regard to fertilizer application pursuant to the Florida Right to Farm Act, Sec. 823.14, *et seq.*, Florida Statutes (2007), or other applicable state law.

(c) This article shall not apply to sports turf areas at parks and athletic fields.

Section 15-809. Commercial Training Requirements; Proof of Compliance.

(a) No commercial applicator shall cause fertilizer to be applied, except at his or her own residence, without proof of successful completion of a County-approved best management practices training program within the previous three years, unless he or she is under the direct physical supervision of a person who has proof of successful completion of such a training program.

(b) Each commercial applicator shall ensure that each applicator he or she employs has successfully completed a County-approved best management practices training program within 180 days of initial employment and shall ensure that prior to the successful completion of said program, each employee applicator shall work under the direct physical supervision of a person who has successfully completed said program.

(c) Possession of a valid limited certification for urban landscape commercial fertilizer application from the Florida Department of Agriculture and Consumer Services shall suffice as evidence of completion of a County-approved best management practices training program.

Section 15-810. Commercial Applicators; Business Tax Certificate.

Prior to obtaining or renewing an Orange County local business tax certificate for a business that provides landscape services, each commercial applicator provide proof of successful completion from a County-approved best management practices training program within the previous three years. Commercial applicators who hold an Orange County local business tax certificate as of the effective date of this article shall provide such certificate of completion to the Orange County Tax Collector's office no later than March 1, 2010. Possession of a valid limited certification for urban landscape commercial fertilizer application from the Florida Department of Agriculture and Consumer Services shall suffice as evidence of completion of a County-approved best management practices training program.

Section 15-811. Variances.

(a) All requests for a variance(s) from the requirements of this article shall be made in writing to the Manager of the Orange County Environmental Protection Division. The Manager may require the applicant for a variance to provide such information as necessary to carry out the purpose of this article. The Manager may approve, approve with conditions or deny requests for variances. A variance may be granted if strict application of the Orange County Fertilizer Management Ordinance would lead to unreasonable or unfair results in particular instances, provided that the applicant demonstrates with particularity that compliance will result in a substantial economic, health or other hardship on the applicant requesting the variance or those served by the applicant.

(b) Variances may be issued by the Manager only upon satisfaction of the following:

(1) A showing of good and sufficient cause by the applicant and that the cause is not self-imposed, and

(2) A determination by the Manager that the variance is the minimum necessary to afford relief, and

(3) A determination by the Manager that failure to grant the variance would result in a practical difficulty or a physical hardship affecting the applicant's economic use of the property, and

(4) A determination by the Manager that the granting of the variance will not result in threats to the health, safety and welfare of the residents of the County or conflict with existing local laws or ordinances.

(c) Any person aggrieved by the decision of the Manager may appeal pursuant to the provisions of section 15-38.

Section 15-812. Enforcement and Penalty.

(a) It shall be unlawful for any person to violate any provision of this article, or any provision of any resolution enacted pursuant to the authority of this article. Every code enforcement officer is authorized to enforce the provisions of this article. Any person who violates any provision of this article, or any provision of any resolution enacted pursuant to the authority of this article, shall be subject to the following penalties:

(i) First violation: written notice.
(ii) Second violation: written notice.

(iii) Third violation: Fine of fifty dollars ($50.00).

(iv) Fourth and subsequent violations: Fine of one hundred dollars ($100.00).

(b) In addition to the enforcement provisions provided, the county may avail itself of any other legal or equitable remedy available to it including, without limitation, injunctive relief, in the enforcement of any provision of this article or any provision of any resolution enacted pursuant to the authority of this article. Any person violating this article shall be held liable for all costs incurred by the county in connection with enforcing this article, or any resolution enacted pursuant to the authority of this article including, but not limited to, attorney's fees.

Section 2. Severability. If any section, subsection, sentence, clause, phrase or word of this article is for any reason, held or declared to be unconstitutional, inoperative, or void, such holding of invalidity shall not affect the remaining portions of this article; and it shall be construed to have been the intent to adopt this article without such unconstitutional, invalid, or inoperative part therein; and the remainder of this article, after the exclusion of such part or parts, shall be deemed to be held valid as if such part or parts had not been included herein.

Section 3. Liberal Construction. The provisions of this ordinance shall be liberally construed to effectuate its purposes.

Section 4. Inclusion in the Orange County Code. It is the intention of the board of county commissioners hereby provided that the provisions of this ordinance shall be made a part of the Orange County Code; that the sections of this ordinance may be renumbered or re-lettered to accomplish such intention; and that the word "ordinance" may be changed to "section," "article," or other appropriate designation.

Section 5. Effective Date. This ordinance shall take effect pursuant to general law; provided, however, no citations, notices to appear, notices of violation or other enforcement procedures shall be instituted until March 1, 2010.

ADOPTED THIS _______ DAY OF October, 2009.

ORANGE COUNTY, FLORIDA
By: Board of County Commissioners

By:________________________________
Richard T. Crotty,
Orange County Mayor

ATTEST: Martha O. Haynie, County Comptroller
As Clerk of the Board of County Commissioners

By:_____________________________
Deputy Clerk

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