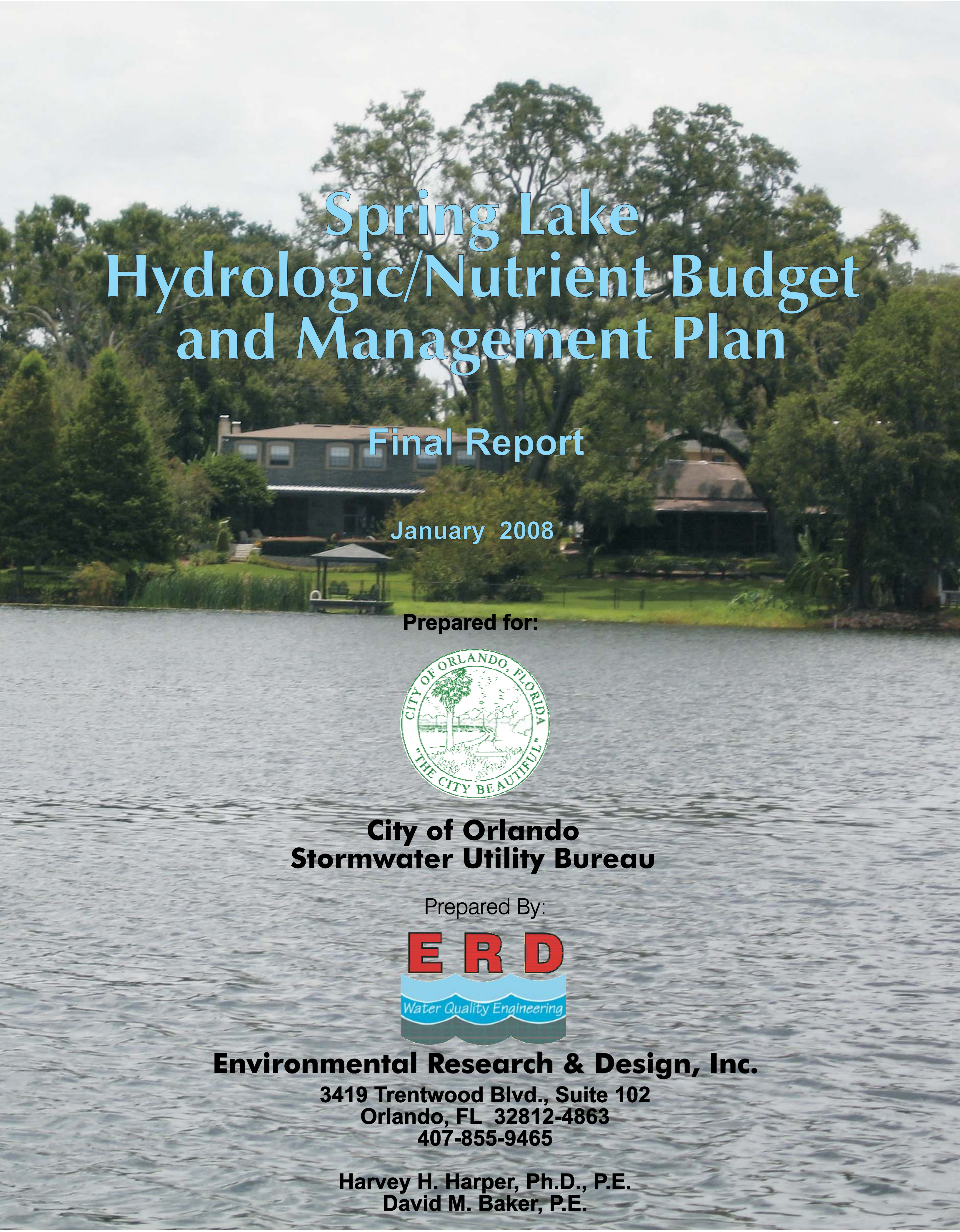

Spring Lake Hydrologic/Nutrient Budget and Management Plan

Final Report

January 2008

Prepared for:

City of Orlando
Stormwater Utility Bureau

Prepared By:

ERD
Water Quality Engineering

Environmental Research & Design, Inc.

3419 Trentwood Blvd., Suite 102
Orlando, FL 32812-4863
407-855-9465

Harvey H. Harper, Ph.D., P.E.
David M. Baker, P.E.

NOTE: This is Part 1 of the Spring Lake Hydrologic/Nutrient Budget and Management Final Report, January 2008. It contains Sections 1 - 4 of 7. For Sections 5 - 7 and the Appendices, see Spring Lake Hydrologic/Nutrient Budget and Management Final Report Part 2 (Sections 5 - 7 of 7; Appendices), also located on the Orange County Water Atlas.

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SECTION 1

INTRODUCTION

1.1 General Description

This report provides a summary of work efforts performed by Environmental Research & Design, Inc. (ERD) for the City of Orlando (City) to develop hydrologic and nutrient budgets, along with water quality improvement options, for Spring Lake. Spring Lake is a 38.24-acre urban lake located approximately 2 miles northwest of downtown Orlando. A location map for Spring Lake is given in Figure 1-1. The watershed areas surrounding the lake are highly developed, with a mixture of residential, golf course, highway, and commercial land use activities. Many of these areas were constructed prior to implementation of regulations requiring stormwater treatment and discharge untreated runoff directly into the lake. Historical water quality in Spring Lake has been highly variable, ranging from oligotrophic to near-hypereutrophic conditions over the available period of record.

Figure 1-1. Location Map for Spring Lake.

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 for the designated uses for the waterbody. 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 Spring Lake located in the Middle St. Johns Basin in Group 2.

During September 2003, the draft verified list of impaired waterbodies for the Middle St. Johns Basin was released by FDEP and included Spring Lake as an impaired waterbody due to elevated trophic state index (TSI) values and elevated nutrient concentrations during the verified period from January 1996-December 2002. Based upon available historical water quality data for Spring Lake, the lake is characterized as a low color, phosphorus-limited or nutrient-balanced system. Since control of nitrogen loadings is difficult, control of phosphorus loadings to the lake is essential for improvement of water quality.

1.3 Work Efforts Performed by ERD

Work efforts were initiated on this project by ERD during March 2006. The primary objectives of this project are to develop hydrologic and nutrient budgets for Spring 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 ERD from August 2006-May 2007 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, inflow from interconnected ponds, and groundwater seepage. The nutrient budget includes inputs from bulk precipitation, stormwater runoff, inflow from interconnected ponds, and groundwater seepage. A detailed evaluation of sediment characteristics in Spring Lake 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. The work efforts described in this report were funded by the City of Orlando Streets and Stormwater Division under Service Authorization No. 06-0619 J-3.

This report has been divided into eight separate sections for presentation of the work efforts performed by ERD. Section 1 contains an introduction to the report and provides a general overview of the work efforts performed by ERD. Current and historical characteristics of Spring Lake are discussed in Section 2, including lake bathymetry, sediment characteristics, and water quality. A discussion of the drainage basin area is given in Section 3. 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. A water quality model for Spring Lake is presented in Section 6. Alternatives for management of water quality in Spring Lake are discussed in Section 7. Cited references are listed in Section 8. Appendices are also attached which contain technical data and analyses used to support the information contained within the report.

SECTION 2

PHYSICAL AND CHEMICAL CHARACTERISTICS OF SPRING LAKE

2.1 Physical Characteristics

A hydrographic survey of Spring Lake was conducted by the City of Orlando during February 2003. The survey information includes a bathymetric map, stage/volume/area relationships, and a summary of calculated physical characteristics of the lake. The water level within Spring Lake at the time of the survey was approximately 86.6 ft (NAVD 88), 1.5 ft below the water control elevation for the lake. A copy of the hydrographic survey conducted by the City is given in Appendix A.

A water depth contour map for Spring Lake, based upon the hydrographic survey performed by the City, is given in Figure 2-1. As seen in Figure 2-1, Spring Lake appears to consist of two interconnected lobes. The larger lobe, which comprises the southern and central portions of the lake, is characterized by relatively modest side slopes which extend to a deep central area at water depths ranging from 18-19 ft. The smaller lobe, comprising the eastern portion of the lake, is characterized by relatively steep side slopes which extend rapidly to a maximum depth of approximately 16-17 ft. The bathymetric signatures indicated on Figure 2-1 suggest that Spring Lake originated as a result of two independent sinkhole features which became interconnected.

The water level in Spring Lake is regulated by two separate structures with a water control elevation of 88.1 ft. An 18-inch diameter drainwell structure is located on the southeast side of the lake which provides water level control under normal conditions. According to information provided by the City, the drainwell has an intake invert of 88.1 ft. In addition, an outfall weir structure is located on the northeast side of the lake which allows water to discharge to Lake Adair under high level conditions. The discharge invert of this structure is also set at elevation 88.1 ft. As a result, the effective water level control elevation for Spring Lake is approximately 88.1 ft. These structures are discussed in more detail in a subsequent section.

Stage-storage relationships for Spring Lake are summarized in Table 2-1 based on the hydrographic survey provided by the City. At the water surface elevation of 86.6 ft present on February 24, 2003, the lake surface area is approximately 38.24 acres. The lake volume at this surface area is 388.1 ac-ft which corresponds to a mean water depth of approximately 10.2 ft. This value is relatively common for a Central Florida lake. Since the control elevation for Spring Lake is approximately 88.1 ft, the lake was approximately 1.5 ft below control elevation at the time of the hydrographic survey conducted on February 24, 2003. As a result, the estimated lake surface area and lake volume, summarized in Table 2-1, will under-estimate values for these parameters when the lake elevation is at the control water level. A summary of bathymetric characteristics of Spring Lake is given in Table 2-2.

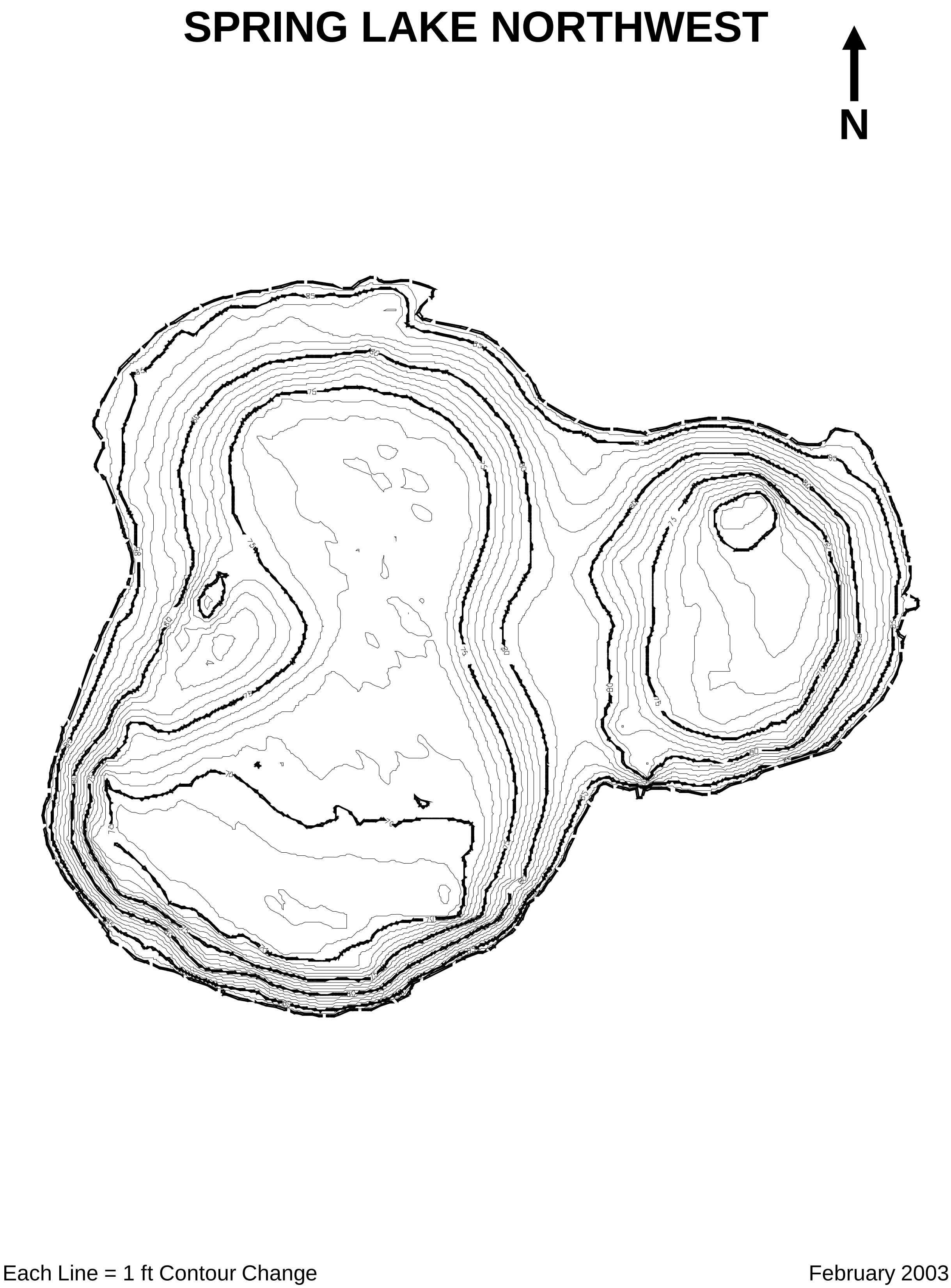


Figure 2-1. Water Depth Contours (ft) for Spring Lake on February 24, 2003. (Water Elevation = 86.6 ft)

TABLE 2-1

DEPTH-AREA-VOLUME RELATIONSHIPS FOR SPRING LAKE (Elev. 86.6 ft)

ELEVATION (ft, NAVD 88)	AREA (acres)	CUMULATIVE VOLUME (ac-ft)	ELEVATION (ft, NAVD 88)	AREA (acres)	CUMULATIVE VOLUME (ac-ft)
86.6	38.24	388.1	76.0	19.82	81.1
86.0	37.43	366.9	75.0	18.19	62.1
85.0	35.95	330.2	74.0	16.41	44.8
84.0	34.29	295.0	73.0	13.85	29.6
83.0	32.33	261.7	72.0	9.59	17.8
82.0	30.58	230.3	71.0	6.46	9.83
81.0	28.19	200.9	70.0	4.17	4.63
80.0	26.41	173.6	69.0	2.43	1.29
79.0	24.85	148.0	68.0	0.22	0.05
78.0	23.11	124.0	67.0	0.00	0.00
77.0	21.40	101.7			

TABLE 2-2

BATHYMETRIC CHARACTERISTICS OF SPRING LAKE

BATHYMETRIC PARAMETER[1]	VALUE
Surface Area	38.24 acres
Total Volume	388.1 ac-ft
Mean Depth	10.2 ft
Maximum Depth	~ 19 ft
Shoreline Length	5461 ft 1.03 miles

1. Based upon a water surface elevation of 86.6 ft (NAVD 88) on February 24, 2003

2.2 Sediment Characteristics

Sediment core samples were collected in Spring Lake by ERD to evaluate the characteristics of existing sediments and potential impacts on water quality within the lake. Sediment core samples were collected at 27 separate locations within the lake during August 2006 by ERD personnel. Locations of sediment sampling sites in Spring Lake are illustrated on Figure 2-2. Based on the lake surface area of 38.24 acres, sediment samples were collected at a rate of one sample for every 1.42 acres of lake area.

2.2.1 Sampling Techniques

Sediment samples were collected at each of the 27 monitoring sites using a stainless steel split-spoon core device, which was penetrated into the sediments at each location to a minimum distance of approximately 0.5 m. After retrieval of the sediment sample, any overlying water was carefully decanted before the split-spoon device was opened to expose the collected sample. Visual characteristics of each sediment core sample were recorded, and the 0-10 cm layer was carefully sectioned off and placed into a polyethylene container for transport to the ERD laboratory. Duplicate core samples were collected at each site, and the 0-10 cm layers were combined together to form a single composite sample for each of the 27 monitoring sites. The polyethylene containers utilized for storage of the collected samples were filled completely to minimize air space in the storage container above the composite sediment sample. Each of the collected samples was stored on ice and returned to the ERD laboratory for physical and chemical characterization.

2.2.2 Sediment Characterization and Speciation Techniques

Each of the 27 collected sediment core samples was analyzed for a variety of general parameters, including moisture content, organic content, sediment density, total nitrogen, and total phosphorus. Methodologies utilized for preparation and analysis of the sediment samples for these parameters are outlined in Table 2-3.

In addition to general sediment characterization, a fractionation procedure for inorganic soil phosphorus was conducted on each of the 27 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. Although not used in this project, subsequent extractions of the Chang and Jackson procedure also provide calcium-bound and residual fractions.

Saloid-bound phosphorus is considered to be available under all conditions at all times. Iron-bound phosphorus is relatively stable under aerobic environments, generally characterized by redox potentials greater than 200 mv (E_h), while unstable under anoxic conditions, characterized by redox potential less than 200 mv. Aluminum-bound phosphorus is considered to be stable under all conditions of redox potential and natural pH conditions. A schematic of the Chang and Jackson Speciation Procedure for evaluating soil phosphorus bounding is given in Figure 2-3.

Figure 2-2. Location of Sediment Monitoring Sites in Spring Lake.

TABLE 2-3

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.

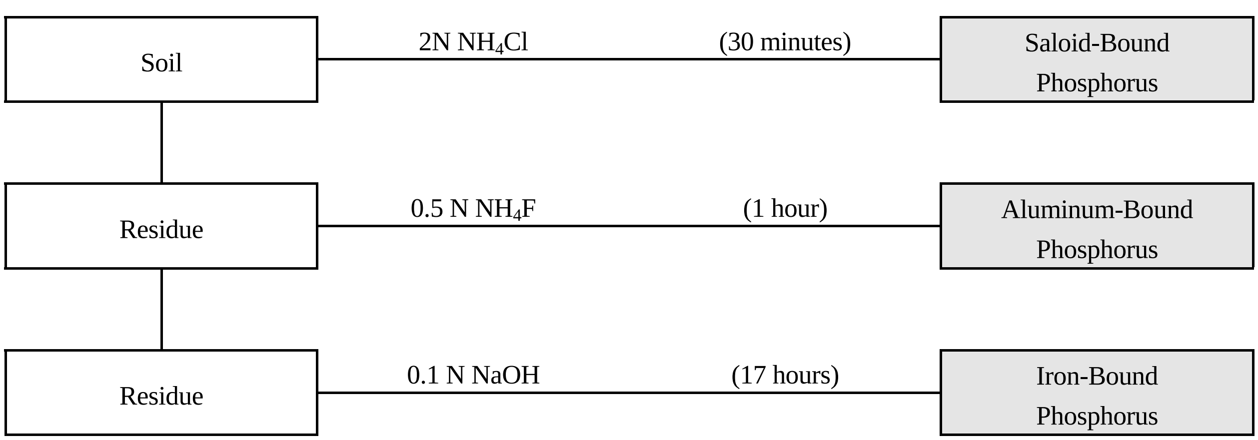


Figure 2-3. Schematic of Chang and Jackson Speciation Procedure for Evaluating Soil Phosphorus Bonding.

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

2.2.3 Sediment Characteristics

2.2.3.1 Visual Characteristics

Visual characteristics of sediment core samples were recorded for each of the 27 sediment samples collected in Spring Lake during August 2006. A summary of visual characteristics of sediment core samples is given in Table 2-4. In general, a surficial layer of unconsolidated organic muck was observed in Spring Lake at 17 of the 27 monitoring sites, with measured depths ranging from 0-6 cm. This unconsolidated surficial layer is comprised primarily of fresh organic material (such as dead algal cells) and detritus which has recently accumulated onto the bottom of the lake. A photograph of a typical core sample with unconsolidated organic sediments is given in Figure 2-4a. This organic material is easily disturbed by wind action or boating activities. In deeper portions of the lake, characterized by thick muck deposits, the organic muck becomes more consolidated beneath the surficial layer, with a consistency similar to pudding. These layers reflect older organic deposits which are somewhat resistant to further degradation. These layers typically do not resuspend into the water column except during relatively vigorous wind activity on the lake. Shallow and shoreline areas of the lake are characterized by surficial layers of fine sand, with little accumulation of organic muck. A photograph of a typical core sample with sandy sediments is given in Figure 2-4b.

TABLE 2-4

VISUAL CHARACTERISTICS OF SEDIMENT CORE SAMPLES COLLECTED IN SPRING LAKE DURING AUGUST 2006

SITE NO.	LAYER (cm)	VISUAL APPEARANCE
1	0 – 1 1 – 5 5 - <36	Light brown fine sand with algae Light brown fine sand Brown fine sand with organics
2	0 – 1 1 - < 47	Light brown fine sand Brown fine sand with organics
3	0 – 1 1 - <35	Brown fine sand with organics with live vegetation Brown fine sand with organics
4	0 – 3 3 – 26 26 - <43	Dark brown unconsolidated organic muck Dark brown consolidated organic muck Brown fine sand with organics
5	0 – 6 6 - <61	Dark brown unconsolidated organic muck Dark brown consolidated organic muck

TABLE 2-4 -- CONTINUED

VISUAL CHARACTERISTICS OF SEDIMENT CORE SAMPLES COLLECTED IN SPRING LAKE DURING AUGUST 2006

SITE NO.	LAYER (cm)	VISUAL APPEARANCE
6	0 – 9	Light brown fine sand with algae
	9 – 28	Light brown fine sand
	28 - <30	Dark gray clay
7	0 – 1	Light brown fine sand with algae
	1 – 3	Light brown fine sand
	3 - <28	Brown fine sand with organics
8	0 – 1	Dark brown unconsolidated organic muck
	1 - <32	Brown fine sand with organics
9	0 – 1	Dark brown unconsolidated organic muck
	1 0 <18	Brown fine sand with organics with shells/mussels
10	0 – 1	Dark brown unconsolidated organic muck
	1 - <29	Brown fine sand with organics
11	0- 2	Dark brown unconsolidated organic muck
	2 – 30	Dark brown consolidated organic muck
	30 - <41	Brown fine sand with organics
12	0 – 6	Brown fine sand with organics with algae
	6 - <19	Brown fine sand with organics
13	0 – 5	Dark brown unconsolidated organic muck
	5 – 15	Dark brown consolidated organic muck
	15 - <36	Brown fine sand with organics
14	0 – 6	Dark brown unconsolidated organic muck
	6 - <76	Dark brown consolidated organic muck
15	0 – 1	Dark brown unconsolidated organic muck
	1 - <22	Brown fine sand with organics
16	0 – 1	Light brown fine sand
	1 – 6	Light brown fine sand
	6 - <31	Brown fine sand with organics
17	0 – 1	Light brown fine sand
	1 - <31	Brown fine sand with organics
18	0 – 3	Dark brown unconsolidated organic muck
	3 - <62	Dark brown consolidated organic muck
19	0 – 6	Brown fine sand with organics with algae
	6 - <19	Brown fine sand with organics
20	0 – 1	Dark brown unconsolidated organic muck
	1 - <26	Brown fine sand with organics
21	0 – 1	Dark brown unconsolidated organic muck
	1 - <31	Brown fine sand with organics
22	0 – 1	Dark brown unconsolidated organic muck
	1 – 6	Light brown fine sand with algae
	6 - <19	Brown fine sand with organics
23	0 – 3	Dark brown unconsolidated organic muck
	3 – 46	Dark brown consolidated organic muck
	46 - <60	Brown fine sand with organics
24	0 – 3	Dark brown unconsolidated organic muck
	3 - <66	Dark brown consolidated organic muck
25	0 – 1	Dark brown unconsolidated organic muck
	1 – 6	Light brown fine sand with algae
	6 - <17	Brown fine sand with organics
26	0 – 1	Light brown fine sand
	1 – 2	Light brown fine sand
	2 - <17	Dark brown fine sand with organics
27	0 – 1	Dark brown unconsolidated organic muck
	1 - <27	Brown fine sand with organics

Figure 2-4a. Core Sample with Unconsolidated Organic Sediments.

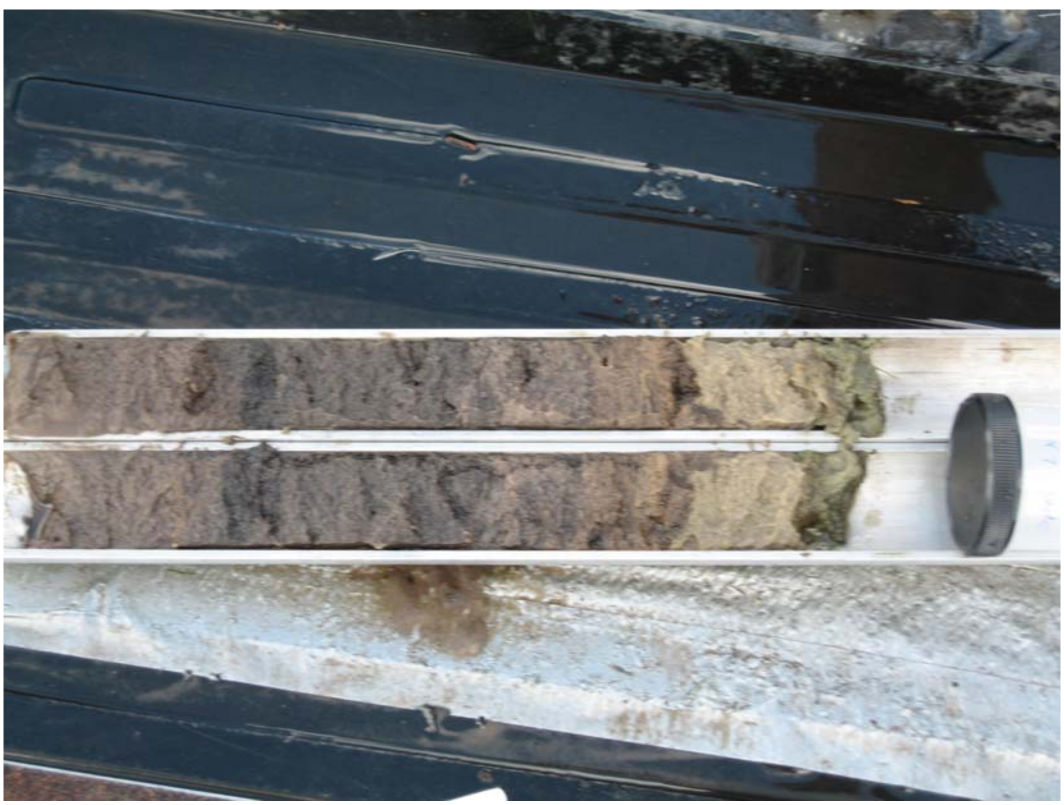


Figure 2-4b. Core Sediment Sample with Fine Sand Sediments.

2.2.3.2 General Sediment Characteristics

After return to the ERD Laboratory, the collected sediment core samples were evaluated for general sediment characteristics, including pH, moisture content, organic content, sediment density, total nitrogen, and total phosphorus. A summary of general characteristics measured in each of the 27 collected sediment core samples is given in Table 2-5. In general, sediments in Spring Lake were found to be slightly acidic in pH, with measured pH values ranging from 5.99-6.97 and an overall mean of 6.47. These values are typical of pH measurements commonly observed in eutrophic urban lakes.

TABLE 2-5

GENERAL CHARACTERISTICS OF SEDIMENT CORE SAMPLES COLLECTED IN SPRING LAKE DURING AUGUST 2006

SITE	pH (s.u.)	MOISTURE CONTENT (%)	ORGANIC CONTENT (%)	WET DENSITY (g/cm^3)	TOTAL NITROGEN (µg/cm^3)	TOTAL PHOSPHORUS (µg/cm^3)
1	6.28	31.9	1.2	2.01	639	404
2	6.32	38.8	1.6	1.90	633	163
3	6.50	37.5	2.3	1.92	565	327
4	6.24	91.8	38.3	1.08	1801	271
5	6.11	92.4	41.1	1.07	1952	409
6	6.62	32.4	1.2	2.00	771	241
7	6.77	31.0	1.0	2.03	733	161
8	6.00	39.7	1.8	1.89	936	224
9	6.84	35.6	2.1	1.95	789	179
10	6.65	33.3	1.3	1.99	636	216
11	6.26	93.1	38.2	1.06	1322	234
12	6.87	30.7	0.8	2.03	678	229
13	5.99	64.4	6.3	1.50	1596	327
14	6.43	92.1	41.0	1.07	2050	460
15	6.97	43.0	6.6	1.80	1545	233
16	6.79	30.2	0.9	2.04	632	84
17	6.16	35.6	1.4	1.95	792	199
18	6.00	91.0	38.6	1.08	1574	437
19	6.77	28.0	0.7	2.07	724	267
20	6.76	31.8	1.0	2.01	762	173
21	6.35	36.3	1.5	1.94	923	197
22	6.73	34.9	1.3	1.96	787	184
23	6.24	92.3	39.9	1.07	1826	293
24	6.01	92.0	38.7	1.07	1578	429
25	6.77	29.4	1.0	2.05	686	239
26	6.57	31.5	1.2	2.02	692	119
27	6.61	29.1	1.1	2.05	950	283
MEAN	**6.47**	**50.0**	**11.6**	**1.73**	**1058**	**259**

Isopleths of pH in the top 10 cm of sediments in Spring Lake are illustrated on Figure 2-5, based upon the information provided in Table 2-5. The majority of areas within Spring Lake are characterized by pH values ranging from approximately 6.2-6.8. In general, pH values of approximately 6.2 or less were observed in areas of deep organic muck within the lake, although pH values equal to this or less were also observed in shoreline areas along the northeastern shore of the lake adjacent to U.S. 441.

Measurements of sediment moisture content and organic content in Spring Lake were found to be highly variable throughout the lake. Many of the collected sediment samples are characterized by a relatively low moisture content and low organic content, suggesting that these surficial sediments are comprised primarily of fine sand. In contrast, other sediment core samples are characterized by elevated values for both moisture content and organic content, suggesting areas of accumulated organic muck.

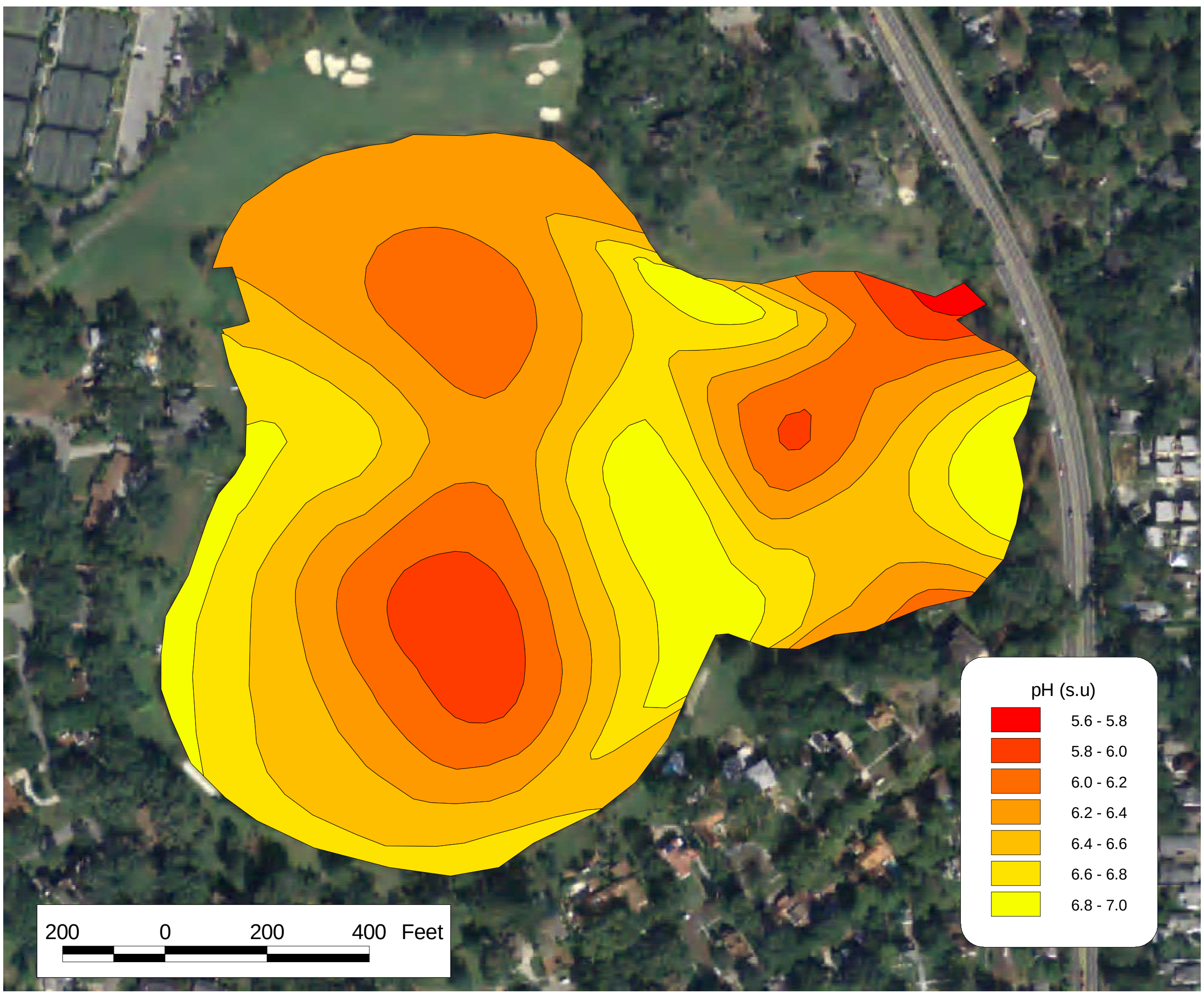


Figure 2-5. Isopleths of pH in the top 10 cm of Sediments in Spring Lake.

Isopleths of sediment moisture content in Spring Lake are summarized in Figure 2-6 based upon the information provided in Table 2-6. Areas of elevated moisture content are present in central and eastern portions of the lake. 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.

Isopleths of sediment organic content in Spring Lake are illustrated on Figure 2-7 based upon the information provided in Table 2-5. In general, sediment organic content values in excess of 20-30% are often indicative of organic muck type sediments, with values less than 20-30% representing either sand or mixtures of muck and sand. Based upon these criteria, areas of concentrated organic muck are apparent in central and eastern portions of Spring Lake. Measured sediment organic content within Spring Lake ranges from 0.7-41.1%, with an overall mean of 11.6%. The mean sediment organic content of 11.6% in Spring Lake is 38% greater than the mean organic content of 8.4% in measured Lake Holden sediments.

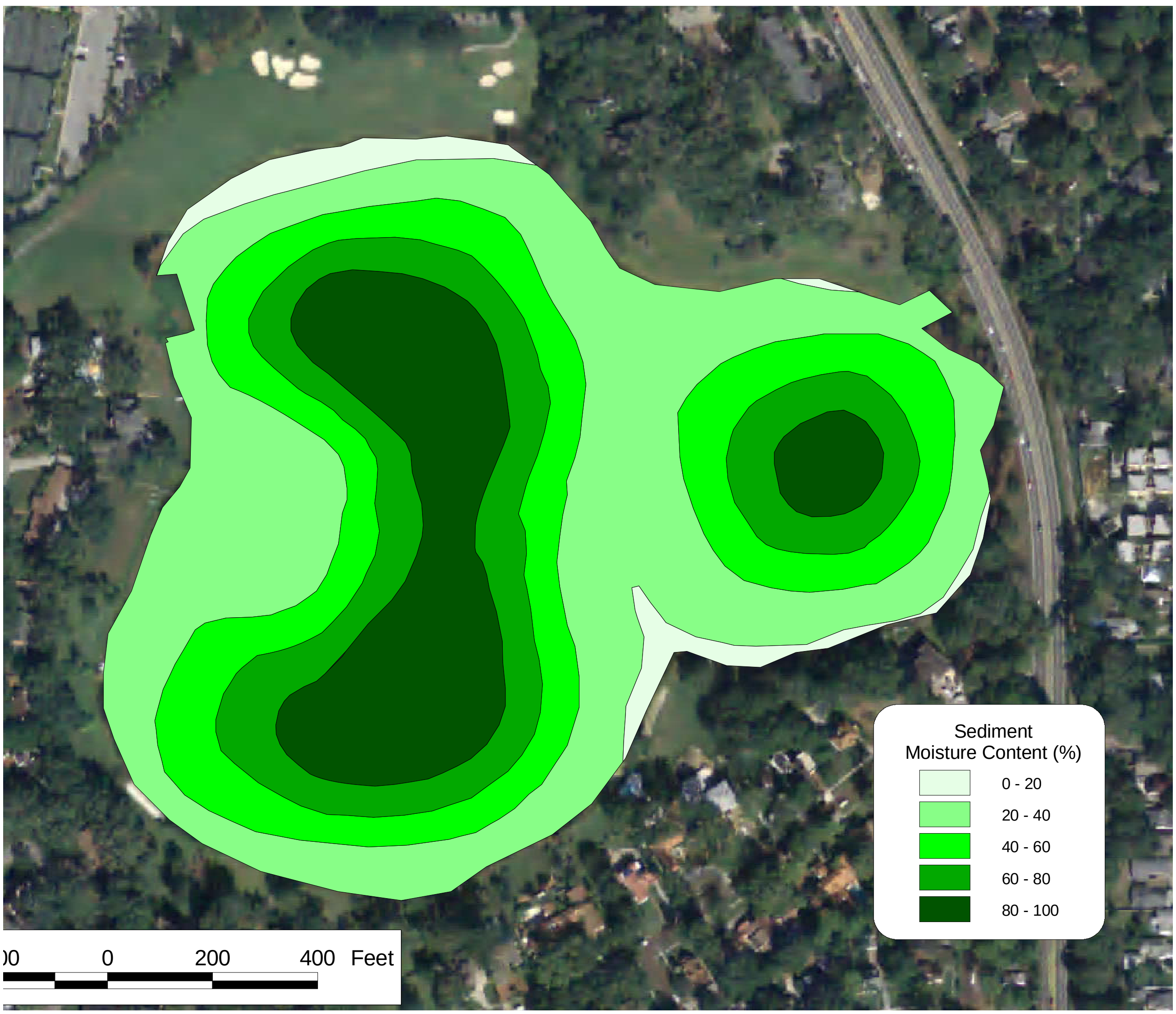


Figure 2-6. Isopleths of Moisture Content in the top 10 cm of Sediments in Spring Lake.

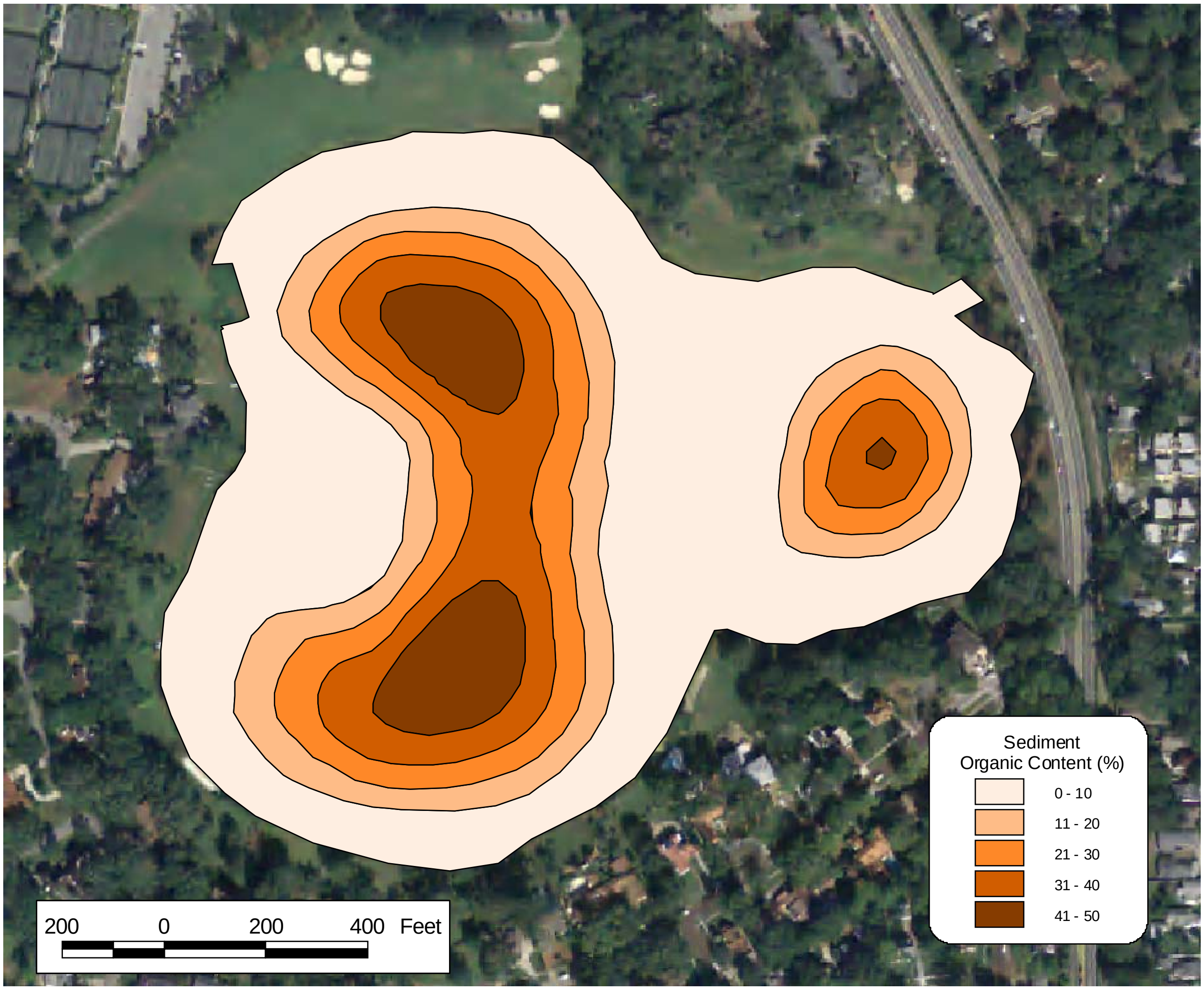


Figure 2-7. Isopleths of Organic Content in the top 10 cm of Sediments in Spring Lake.

Measured sediment density values are also useful in evaluating the general characteristics of sediments within a lake. Sediments with calculated wet densities between 1.0 g/cm^3 and 1.25 g/cm^3 are indicative of highly organic muck type sediments, while sediment densities of approximately 2.0 or greater are indicative of sandy sediment conditions. Values between 1.25 g/cm^3 and 2.0 g/cm^3 indicate mixtures of sand muck. Measured sediment density values in Spring Lake range from 1.06-2.07 g/cm^3, with an overall mean of 1.73 g/cm^3.

Measured concentrations of total phosphorus in Spring Lake sediments were found to be highly variable throughout the lake. Measured total phosphorus concentrations range from 84-460 µg/cm^3, with an overall mean of 259 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. The mean sediment phosphorus concentration of 259 µg/cm^3 in Spring Lake is 41% less than the sediment phosphorus concentration of 439 µg/cm^3 measured in Lake Holden.

Isopleths of sediment phosphorus concentrations in Spring Lake are presented on Figure 2-8, based on information contained in Table 2-5. Areas of elevated sediment phosphorus concentrations are present in the southern portions of the lake, similar to the areas of elevated moisture and organic content illustrated on Figures 2-6 and 2-7, respectively. In general, overall total phosphorus concentrations observed in Spring Lake appear to be similar to phosphorus sediment concentrations typically observed in urban lakes.

Similar to the trends observed for sediment phosphorus concentrations, sediment nitrogen concentrations are also variable throughout Spring Lake. Measured sediment nitrogen concentrations in the lake range from 565-2050 $\mu g/cm^3$, with an overall mean of 1058 $\mu g/cm^3$. Measured sediment nitrogen concentrations in Spring Lake appear to be similar to values normally observed in urban lakes. The mean sediment nitrogen concentration of 1058 $\mu g/cm^3$ in Spring Lake is similar to the mean of 1198 $\mu g/cm^3$ measured by ERD in Lake Holden during September 2003.

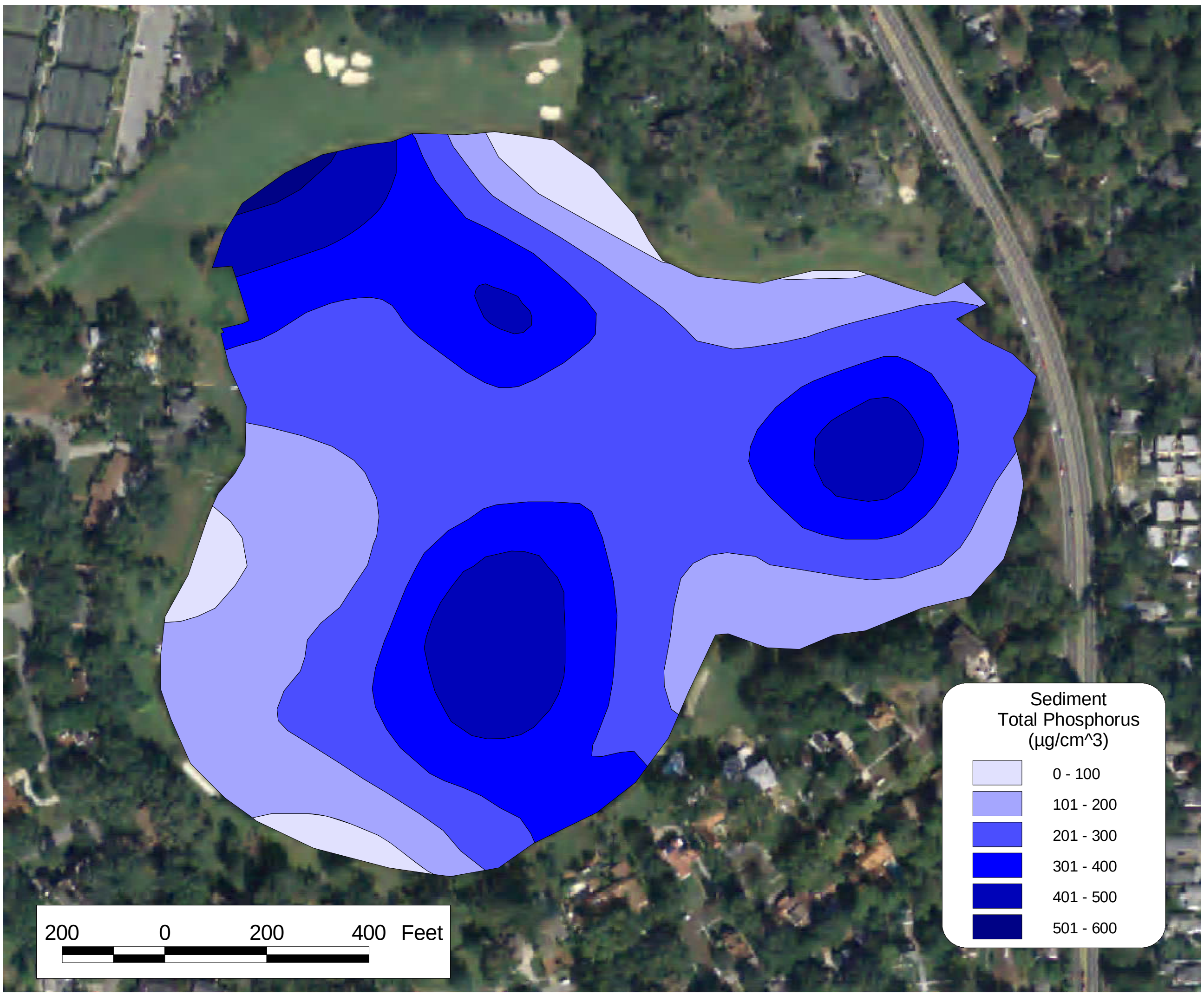


Figure 2-8. Isopleths of Total Phosphorus in the top 10 cm of Sediments in Spring Lake.

Isopleths of sediment nitrogen concentrations in Spring Lake are illustrated on Figure 2-9. In general, patterns of elevated nitrogen concentrations are similar to the patterns exhibited by total phosphorus.

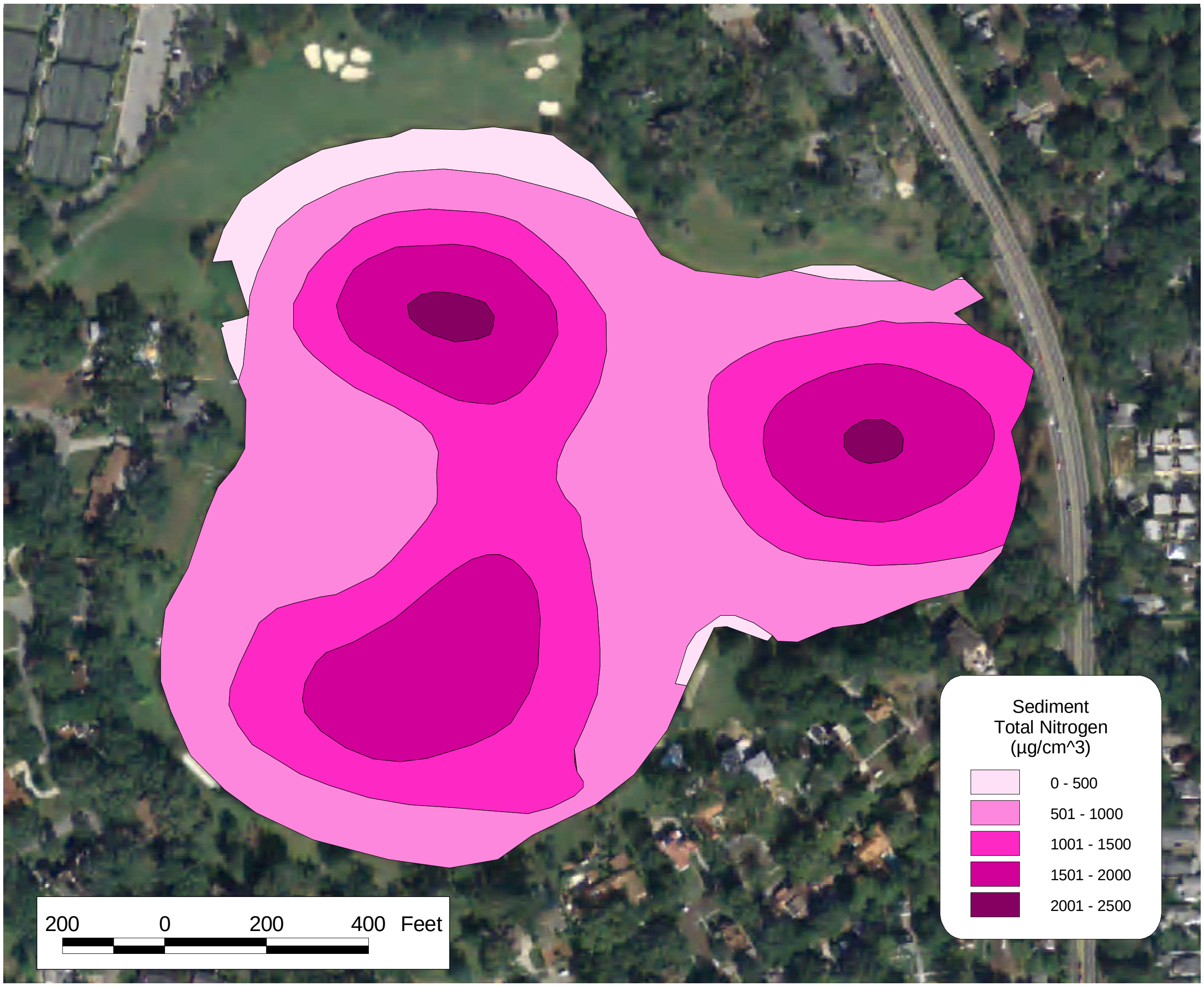


Figure 2-9. Isopleths of Total Nitrogen in the top 10 cm of Sediments in Spring Lake.

2.2.3.3 Phosphorus Speciation

As discussed in Section 2.2.2, each of the collected sediment core samples was evaluated for phosphorus speciation based upon the Chang and Jackson speciation procedure. This procedure allows phosphorus within the sediments to be speciated with respect to bonding mechanisms within the sediments. This information is useful in evaluating the stability of phosphorus in the sediments and the potential for release of phosphorus from the sediments under anoxic or other conditions.

A summary of phosphorus speciation in sediment core samples collected from Spring Lake during August 2006 is given in Table 2-6. Saloid-bound phosphorus represents sediment phosphorus which is either soluble or easily exchangeable and is typically considered to be readily available for release from the sediments into the overlying water column. As seen in Table 2-6, saloid-bound phosphorus concentrations appear to be fairly uniform throughout the sediments of Spring Lake. Measured values for saloid-bound phosphorus range from 1-17 $\mu g/cm^3$, with an overall mean of 6.8 $\mu g/cm^3$.

In general, iron-bound phosphorus associations in the sediments of Spring Lake appear to be moderate in value. Iron-bound phosphorus is relatively stable under oxidized conditions, but becomes unstable under a reduced environment, causing the iron-phosphorus bonds to separate, releasing the bound phosphorus directly into the water column. Iron-bound phosphorus concentrations in the sediments of Spring Lake range from 8-60 $\mu g/cm^3$, with an overall mean of 19 $\mu g/cm^3$. Since iron-bound phosphorus can be released under anoxic conditions, large portions of Spring Lake may have conditions favorable for release of iron-bound sediment phosphorus into the water column throughout much of the year. The iron-bound phosphorus concentrations summarized in Table 2-6 appear to be similar to values commonly observed in urban lake systems.

Total available phosphorus represents the sum of the saloid-bound phosphorus and iron-bound phosphorus associations in each sediment core sample. Since the saloid-bound phosphorus is immediately available, and the iron-bound phosphorus is available under reduced conditions, 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 procedures.

A summary of total available phosphorus in each of the 27 collected sediment core samples is given in Table 2-6. Total available phosphorus concentrations within the lake range from 10-61 $\mu g/cm^3$, with an overall mean of 26 $\mu g/cm^3$. The mean sediment total available phosphorus in Spring Lake is less than half of the mean sediment available phosphorus measured in Lake Holden.

Isopleths of total available phosphorus in the top 10 cm of sediments in Spring Lake are illustrated on Figure 2-10. Areas of elevated total available phosphorus are apparent in the central, southern, and eastern portions of the lake. The isopleths presented on Figure 2-10 can be utilized directly as a guide for future sediment inactivation activities.

TABLE 2-6

PHOSPHORUS SPECIATION IN SEDIMENT CORE SAMPLES COLLECTED IN SPRING LAKE DURING MARCH 2006

SITE	SALOID-BOUND P (µg/cm^3 wet wt.)	Fe-BOUND P (µg/cm^3 wet wt.)	AVAILABLE P (µg/cm^3 wet wt.)	PERCENT OF SEDIMENT P WHICH IS AVAILABLE (%)	Al-BOUND P (µg/cm^3 wet wt.)
1	4	13	18	4.3	42
2	7	8	15	9.3	21
3	11	32	42	12.9	168
4	10	18	28	10.4	80
5	9	21	30	7.4	103
6	4	12	15	6.3	17
7	2	12	14	8.5	13
8	17	21	37	16.7	43
9	3	19	22	12.0	61
10	6	34	41	18.8	73
11	11	15	27	11.4	45
12	2	16	18	7.8	47
13	11	21	32	9.7	72
14	13	27	40	8.7	92
15	14	19	33	14.0	67
16	1	9	10	11.4	9
17	9	13	22	11.1	39
18	5	39	45	10.2	159
19	2	9	12	4.5	18
20	5	11	16	9.1	41
21	7	12	19	9.5	42
22	9	8	17	9.0	16
23	7	29	36	12.2	128
24	8	19	27	6.4	90
25	5	10	15	6.3	40
26	2	10	13	10.8	20
27	1	60	61	21.5	202
Mean	**7**	**19**	**26**	**10.4**	**65**

Figure 2-10. Isopleths of Total Available Phosphorus in the top 10 cm of Sediments in Spring Lake.

Available sediment phosphorus is also expressed as a percentage of total phosphorus concentrations within the sediments. The percentage of available phosphorus within the sediments of Spring Lake ranges from approximately 4-22%, with an overall mean of 10%. This suggests that approximately 10% 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.

Isopleths of percentage availability of phosphorus within the sediments of Spring Lake are given on Figure 2-11. Areas of elevated sediment phosphorus available are apparent in western, southern, and northeastern portions of the lake.

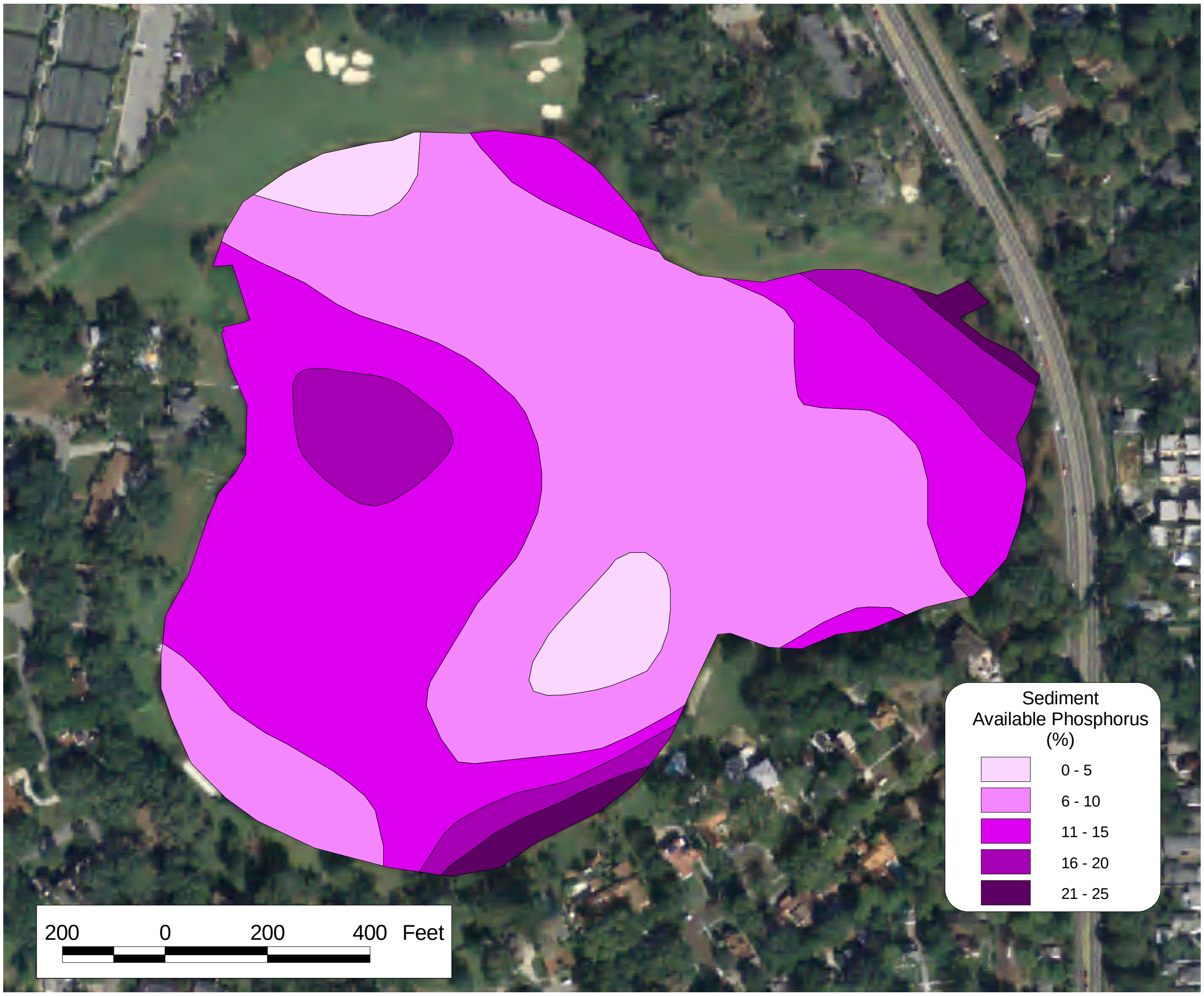


Figure 2-11. Isopleths of Percent Available Phosphorus in the top 10 cm of Sediments in Spring Lake.

2.3 Water Quality Characteristics

2.3.1 Data Collection

Historical water quality monitoring has been conducted in Spring Lake by the City of Orlando since 1988. In general, water quality monitoring is conducted by the City at a single location near the geographic center of the lake. Single monitoring events were conducted during 1988 and 1989. Three separate monitoring events were conducted during 1990, 1991, and 1992. Beginning in 1993, monitoring was conducted on approximately a quarterly basis from 1993 to the present. Collection of vertical field profiles of temperature, pH, specific conductivity, TDS, dissolved oxygen, turbidity, and redox potential at specified intervals within the water column was initiated by the City during August 1994 and has been conducted as part of each monitoring event since that time.

A complete listing of field and laboratory data collected in Spring Lake by the City of Orlando is given in Appendix B. Vertical field profiles are summarized in Appendix B.1, with laboratory data summarized in Appendix B.2. The collected surface water samples were analyzed for general parameters (alkalinity, TSS, VSS, TDS, and color), nutrients, fecal coliform bacteria, and chlorophyll-a. Trophic state index (TSI) values are also calculated for significant trophic state indicators.

2.3.2 Vertical Profiles

A comparison of generalized field profiles collected in Spring Lake from 1994-2006 is given in Figure 2-12. The information summarized in this figure represents the mean of vertical field profiles collected by the City of Orlando. For evaluation purposes, the vertical profiles have been averaged on a seasonal basis to provide a general indication of seasonal conditions within Spring Lake. "Fall" conditions are assumed to occur during the months of September, October, and November. "Winter" conditions are assumed to occur during December, January, and February. "Spring" conditions are assumed to occur during March, April, and May, with "summer" conditions during June, July, and August. Vertical profiles collected during each of these periods were averaged together to develop the generalized patterns indicated on Figure 2-12.

In general, significant thermal stratification was observed in Spring Lake during fall, spring, and summer conditions. The general pattern summarized on Figure 2-12 suggests the presence of thermal stratification within the first meter during fall, spring, and summer conditions. In general, a temperature difference of approximately 6-10^{o}C was observed between top and bottom layers during these periods of the year. In contrast, no significant thermal stratification was observed in Spring Lake during winter conditions, with a difference of approximately 2^{o}C (on average) between surface and bottom measurements.

During spring, summer, and winter conditions, relatively elevated pH levels were observed near the water surface in Spring Lake, with mean pH values ranging from 8.3-9.3. A steady decrease in pH from the water surface to the bottom was observed during these periods, with bottom pH measurements ranging from approximately 6.5-7.5. In contrast, during fall conditions, the surface pH appears to average approximately 7.5, with a slight increase in pH occurring during the first 1-2 m of the water column. This behavior suggests a metalimnetic algal bloom within the lake during fall conditions which results in maximum algal production and maximum pH beneath the water surface rather than at the surface. After the metalimnetic layer, a gradual decrease in pH is observed during fall conditions.

In general, relatively isograde conductivity conditions were observed within the lake to water depths of 4 m or less during fall, spring, summer, and winter conditions. However, increases in specific conductivity were observed in the water-sediment interface during fall, spring, and summer conditions. This increase is not observed during the winter period when dissolved oxygen concentrations are typically higher. The increase in specific conductivity near the water-sediment interface suggests the presence of internal recycling within the lake during spring through fall conditions.

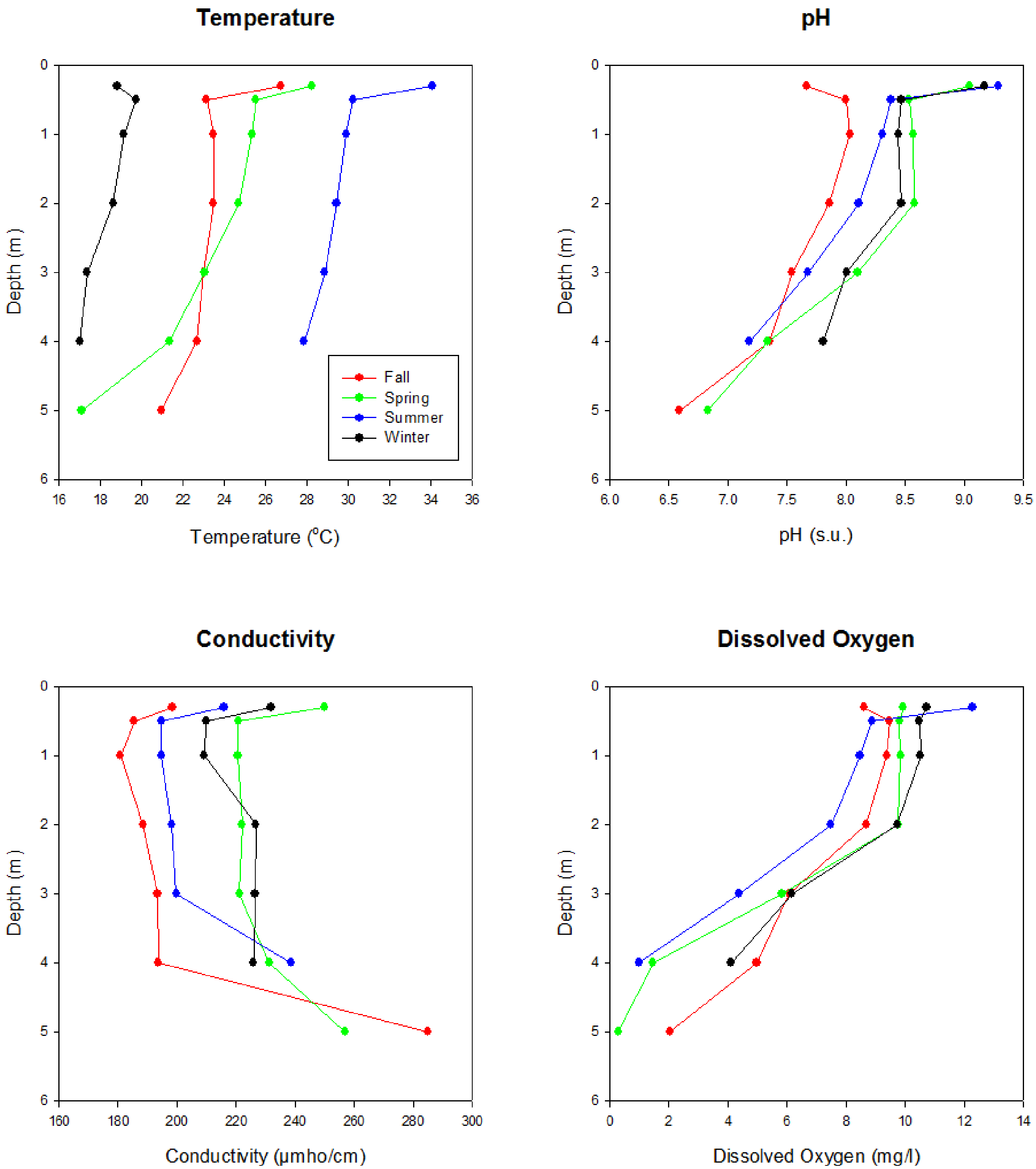


Figure 2-12. Generalized Vertical Field Profiles Collected in Spring Lake from 1994-2006.

In general, saturated to super-saturated dissolved oxygen concentrations were observed within the first meter of the water column in Spring Lake during all seasons. A gradual decrease in dissolved oxygen concentrations was observed with increasing depth, with concentrations approaching anoxic conditions at water depths of 4 m or more during fall, spring, and summer conditions. In contrast, aerobic conditions appear to be maintained throughout the water column during winter conditions. The decreases in dissolved oxygen observed near the water-sediment interface during fall, spring, and summer conditions correspond closely to measured increases in conductivity during the same periods.

In general, vertical field profiles measured in Spring Lake are typical of profiles commonly observed in a eutrophic urban lake. Lower layers of the water column exhibit anoxic conditions during at least portions of the fall, spring, and summer conditions. Evidence of significant internal recycling is present, particularly during the summer and fall conditions. Recycling appears to be less significant during winter and spring conditions.

2.3.3 Laboratory Data

Historical water quality characteristics in Spring Lake were evaluated by ERD based upon an examination of the results of individual monitoring events conducted by the City of Orlando as well as mean annual concentrations for total phosphorus, total nitrogen, chlorophyll-a, Secchi disk depth, TN/TP ratio, and TSI. A summary of historical trends in total phosphorus and total nitrogen in Spring Lake from 1988-2006 is given in Figure 2-13. Mean annual average concentrations for these parameters are superimposed over the individual historical data to provide an evaluation of both seasonal and annual variability in water quality characteristics and trends within the lake.

A trend line is also provided on each plot to assist in identifying significant water quality trends. This line is obtained using linear regression techniques. The calculated probability value (p value) is also provided which indicates the level of significance associated with each regression model. A model which is significant at a 95% confidence level would be associated with a p value of 0.05. However, lakes exhibit normal seasonal cyclic variations in water quality which can reduce the statistical significance of the regression model. Therefore, for evaluating water quality trends in lakes, a p value of 0.2 or less is generally considered to indicate a significant statistical trend, while p values greater than 0.2 suggest an insignificant trend.

Measured total phosphorus concentrations in Spring Lake over the period from 1988-2006 have ranged from 20-132 μg/l, with mean annual concentrations ranging from approximately 40-80 μg/l. A peak in total phosphorus concentrations within the lake occurred during the mid-1990s, followed by a gradual decline in phosphorus concentrations until approximately 2001, when concentrations began to exhibit a gradual increase. However, based upon the regression trend line and calculated p value of 0.058, a significant trend of decreasing phosphorus concentrations appears to have occurred in Spring Lake over the period of record. However, this apparent trend is impacted by the elevated total phosphorus concentrations measured during the mid-1990s. If the data were evaluated over the past 8-10 years, a significant upward trend in phosphorus concentrations would be apparent.

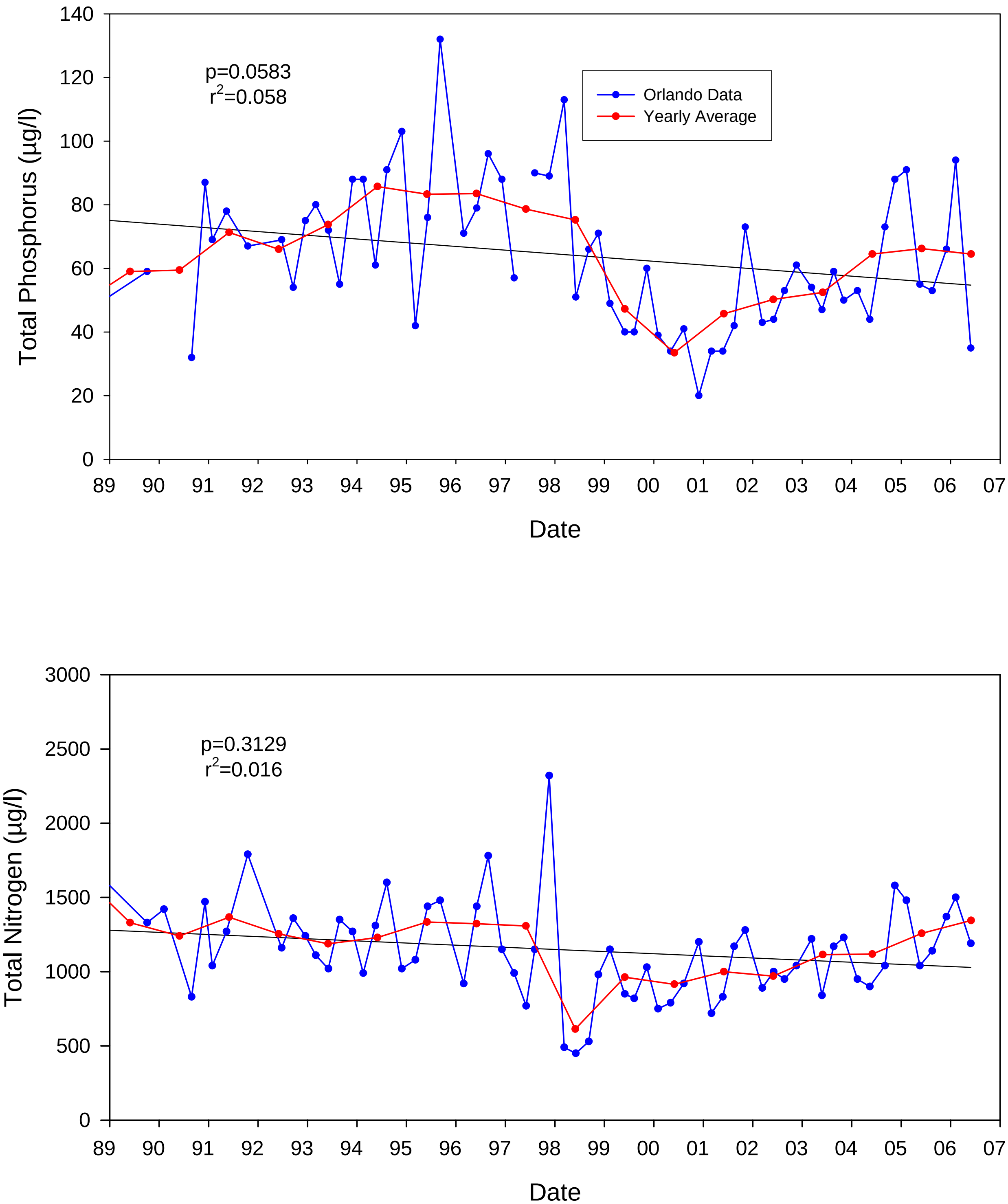


Figure 2-13. Summary of Trends in Total Phosphorus and Total Nitrogen in Spring Lake from 1988-2006.

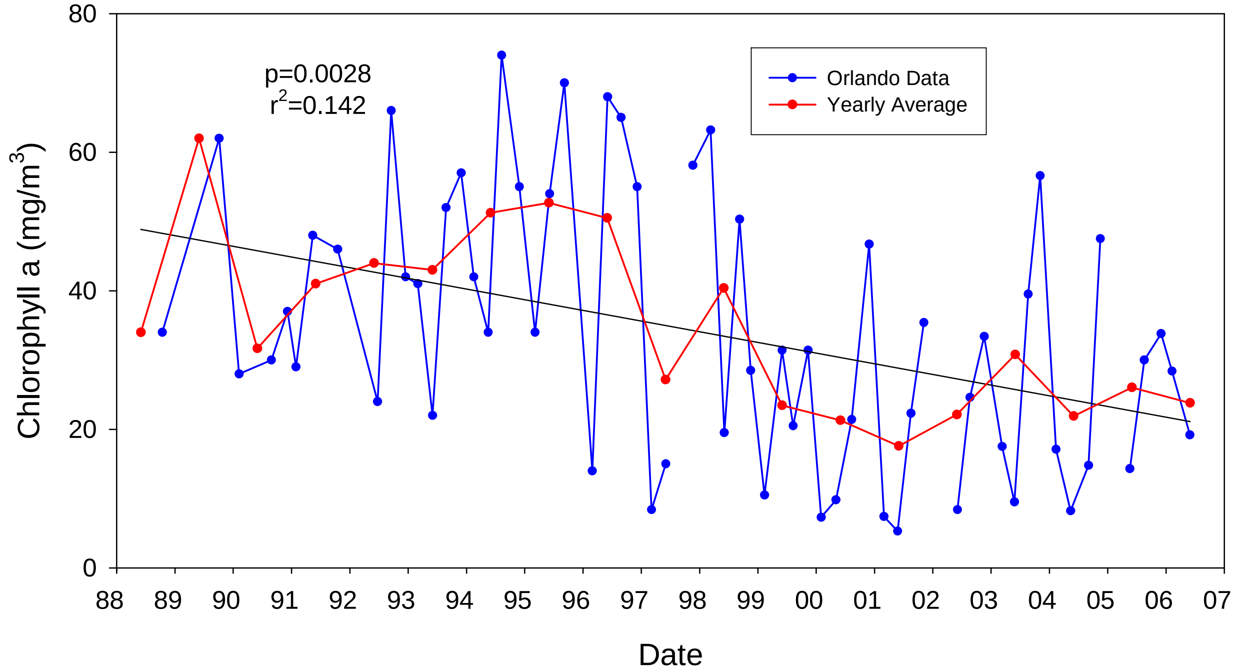
A summary of measured total nitrogen concentrations in Spring Lake is also provided in Figure 2-13. Measured concentrations of total nitrogen within the lake have ranged from 450-2320 μg/l over the period of record, although the majority of values appear to fall between approximately 750-1500 μg/l. In contrast to the apparent trend exhibited by total phosphorus, total nitrogen does not appear to exhibit a trend of either decreasing or increasing concentrations over time. The calculated p value confirms the lack of a significant trend.

Variations in measured concentrations of chlorophyll-a and Secchi disk in Spring Lake from 1988-2006 are illustrated on Figure 2-14. Measured chlorophyll-a concentrations in Spring Lake have ranged from 5.3-74.0 mg/m^3 over the monitoring period, although the majority of values appear to range from approximately 10-60 mg/m^3. Measured concentrations of chlorophyll-a in Spring Lake have been highly variable, with large differences in concentrations often observed between consecutive monitoring events. Similar to the trend observed for total phosphorus, a peak in chlorophyll-a concentrations was observed during the 1990s, followed by a gradual decline until approximately 2001, with relatively constant concentrations since that time. The calculated trend line suggests a statistically significant trend of decreasing chlorophyll-a concentrations over time. However, if the trend had been calculated over the past 8-10 years, a steady or perhaps upward trend in concentration would be observed.

Variability in measured Secchi disk depths in Spring Lake is also illustrated on Figure 2-14. Measured Secchi disk depths in the lake have ranged from 0.5-1.5 m over the monitoring program, with the majority of values ranging from approximately 0.6-1.0 m. The calculated trend line suggests a slight trend of increasing Secchi disk depth within the lake over the available period of record. However, when evaluated over the past 8-10 years, a sharp downward trend in Secchi disk depth is apparent.

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 regulates primary productivity and the growth of algae within the lake system. Calculated TN/TP ratios between 10-30 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 trends in mean annual TN/TP ratios in Spring Lake from 1988-2006 is given in Figure 2-15. Based upon the mean annual TN/TP ratios indicated on this figure, it appears that Spring Lake exists primarily in a nutrient-balanced condition much of the time. The trend line for changes in TN/TP ratios over time is insignificant, suggesting no significant trend toward either nitrogen or phosphorus limitation.



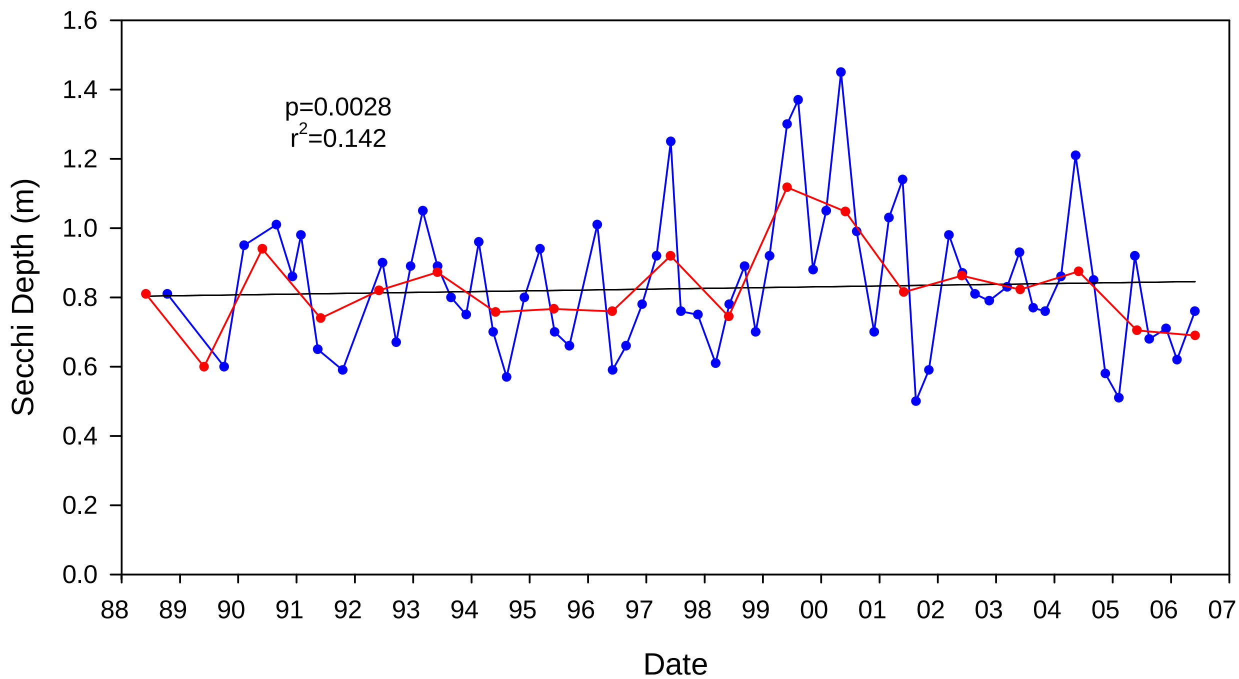
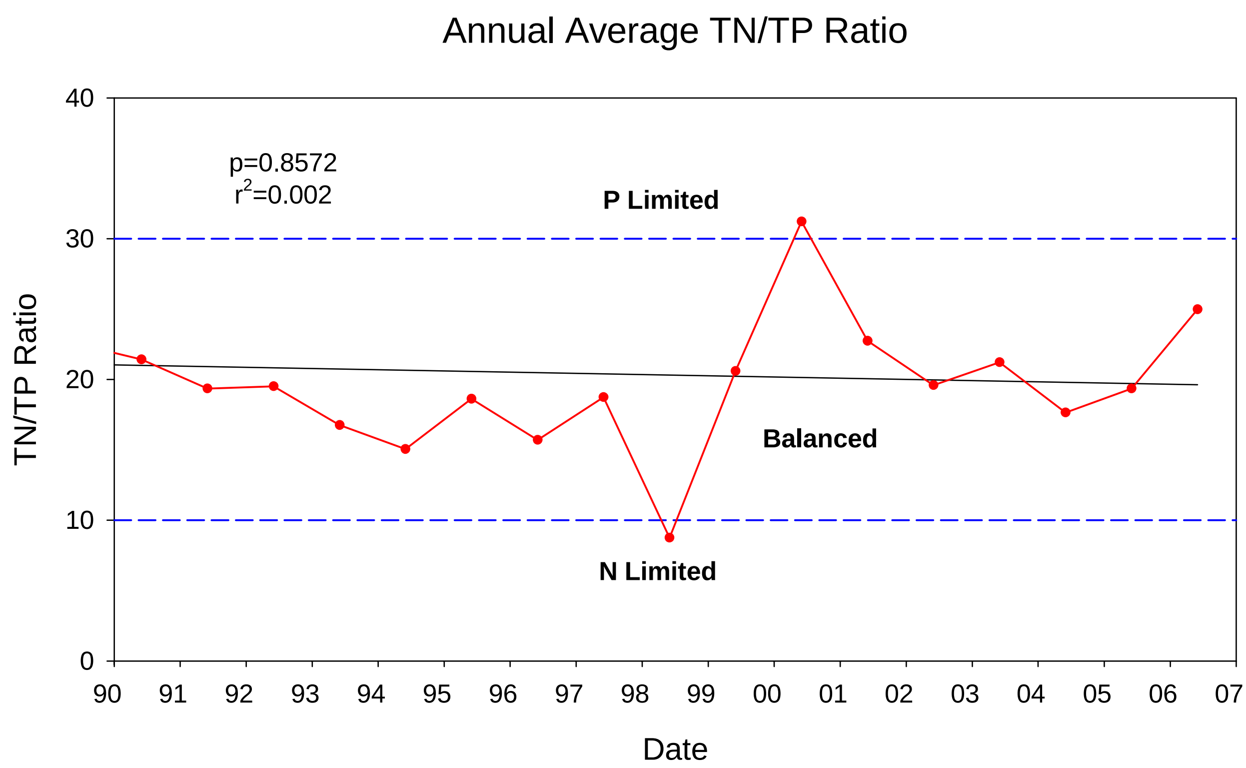


Figure 2-14. Summary of Trends in Chlorophyll-a and Secchi Disk Depth in Spring Lake from 1988-2006.



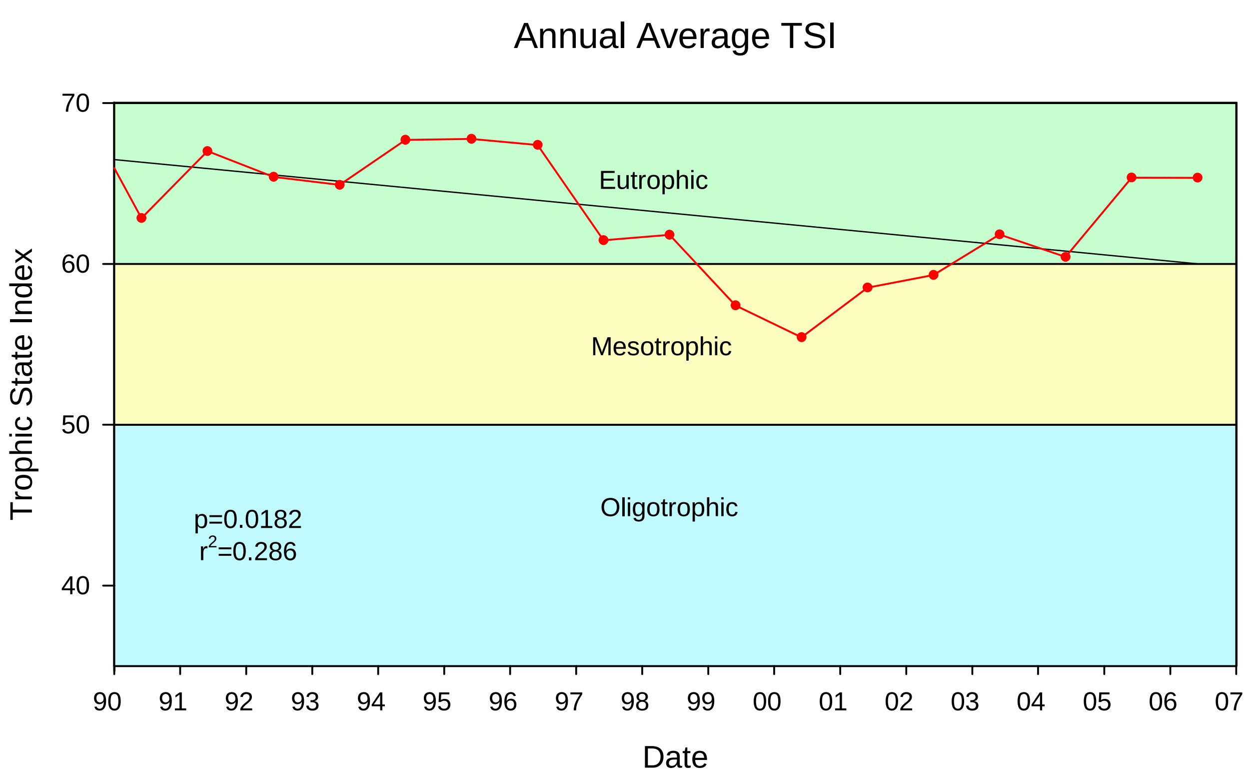


Figure 2-15. Summary of Trends in TN/TP Ratios and TSI Values in Spring Lake from 1988-2006.

TSI is a summary statistic which incorporates measured concentrations of significant parameters in lake systems, including total phosphorus, total nitrogen, Secchi disk depth, and chlorophyll-a. Since this index summarizes information obtained from several separate measured parameters, it is often considered the best overall indicator of the health and productivity 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. Calculated TSI values from 50-60 indicate mesotrophic or fair water quality characteristics. Calculated TSI values between 60-70 indicate eutrophic or poor water quality characteristics, with hypereutrophic conditions indicated by TSI values in excess of 70.

Individual TSI values were calculated for each monitoring event based on measured concentrations of chlorophyll-a and nutrients. The Secchi disk depth is not included by ERD as part of the TSI calculation due to the relatively subjective nature of this measurement, variability in measurement techniques, and statistical irregularities which often arise when evaluating this parameter. If phosphorus-limited conditions were present at the time of the monitoring event, indicated by TN/TP ratios >30, the TSI value was calculated using the following relationships:

$$\text{TSI (chl-a)} = 16.8 + 14.4 \ln \text{chl-a (mg/m}^3\text{)}$$

$$\text{TSI (TP)} = 23.6 \ln \text{TP } (\mu\text{g/l}) - 23.8$$

$$\text{TSI (Avg.)} = \tfrac{1}{2}\,[\text{TSI (chl-a)} + \text{TSI (TP)}]$$

If nutrient-balanced conditions occurred at the time of the monitoring event, the TSI value was calculated based on the following relationships involving chlorophyll-a, total nitrogen, and total phosphorus:

$$\text{TSI (chl-a)} = 16.8 + 14.4 \ln \text{chl-a (mg/m}^3\text{)}$$

$$\text{TSI(TN)} = 56 + 19.8 \ln \text{TN } (\mu\text{g/l})$$

$$\text{TSI (TP)} = 18.6 \ln \text{TP } (\mu\text{g/l}) - 18.4$$

$$\text{TSI (Avg.)} = \tfrac{1}{2} \left\{ [\text{TSI (chl-a)}] + \{0.5\,[\text{TSI (TP)} + \text{TSI (TN)}]\} \right\}$$

Mean annual TSI values in Spring Lake from 1988-2006 are also summarized in Figure 2-15. Spring Lake has primarily exhibited eutrophic water quality characteristics over the period of record except for the period from 1999-2002 when mesotrophic conditions were observed within the lake. A statistically significant trend of decreasing TSI value is apparent based upon the historical data, although a steady increase in TSI has been observed within the lake over the past 8-10 years.

Additional evaluations were performed to examine seasonal variations in water quality in Spring Lake. For this evaluation, mean monthly concentrations were calculated for total phosphorus, total nitrogen, chlorophyll-a, and TN/TP ratios over the period of record from 1988-2006 using the City of Orlando data. A comparison of mean monthly concentrations of total phosphorus in Spring Lake from 1988-2006 is given in Figure 2-16. No data are available for the months of April and July since no monitoring events were conducted during these months. However, in general, it appears that total phosphorus concentrations within the lake may be slightly lower during the summer months than during fall and spring conditions. 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 Spring Lake. The trend of monthly phosphorus concentrations in Spring Lake is very similar to the trend of monthly phosphorus concentrations in Lake Holden (ERD, 2004).

The general pattern of monthly phosphorus concentrations exhibited in Figure 2-16 suggests that internal recycling of phosphorus may be occurring in Spring Lake. 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 are distributed throughout the entire water column, resulting in increases in phosphorus levels within the lake. The trend exhibited by total phosphorus for Spring Lake suggests that significant internal recycling, fueled by upwelling of high phosphorus water during circulating events, may be occurring within the lake.

Average monthly concentrations of total nitrogen in Spring Lake from 1988-2006 are also indicated on Figure 2-16. Similar to the trends observed for total phosphorus, total nitrogen concentrations in Spring Lake also appear to be somewhat lower during the summer months than observed during other times of the year. However, this trend is not as apparent as observed for total phosphorus. Nitrogen can also 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 2-16.

A comparison of mean monthly concentrations of chlorophyll-a in Spring Lake from 1988-2006 is given in Figure 2-17. 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 fall and winter conditions, and lower concentrations observed during the summer months. Average monthly TN/TP ratios in Spring Lake from 1988-2006 are also illustrated on Figure 2-17. No seasonal trend is apparent in nutrient limitation patterns within the lake.

A summary of historical water quality characteristics in Spring Lake from 1988-2006 is given in Table 2-7 for significant water quality parameters based on the City of Orlando data set. In general, measured values for pH, alkalinity, and conductivity are similar to values commonly observed in urban lakes. However, measured values for total phosphorus, BOD, TSS, and chlorophyll-a appear to be higher than commonly observed in urban lakes. The mean Secchi disk depth of 0.8 m also appears to be worse than average for urban lakes.

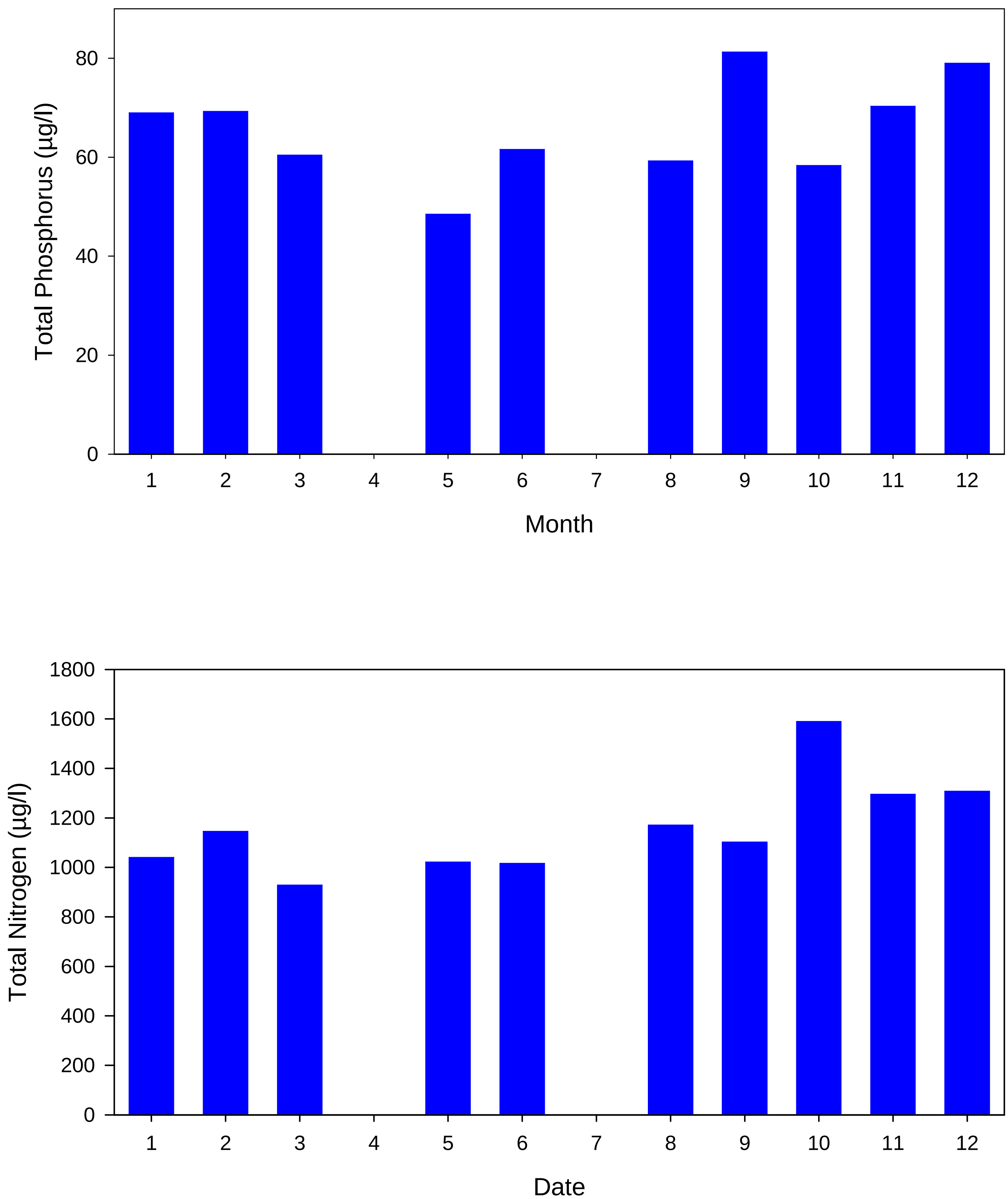


Figure 2-16. Mean Monthly Concentrations of Total Phosphorus and Total Nitrogen in Spring Lake from 1988-2006.

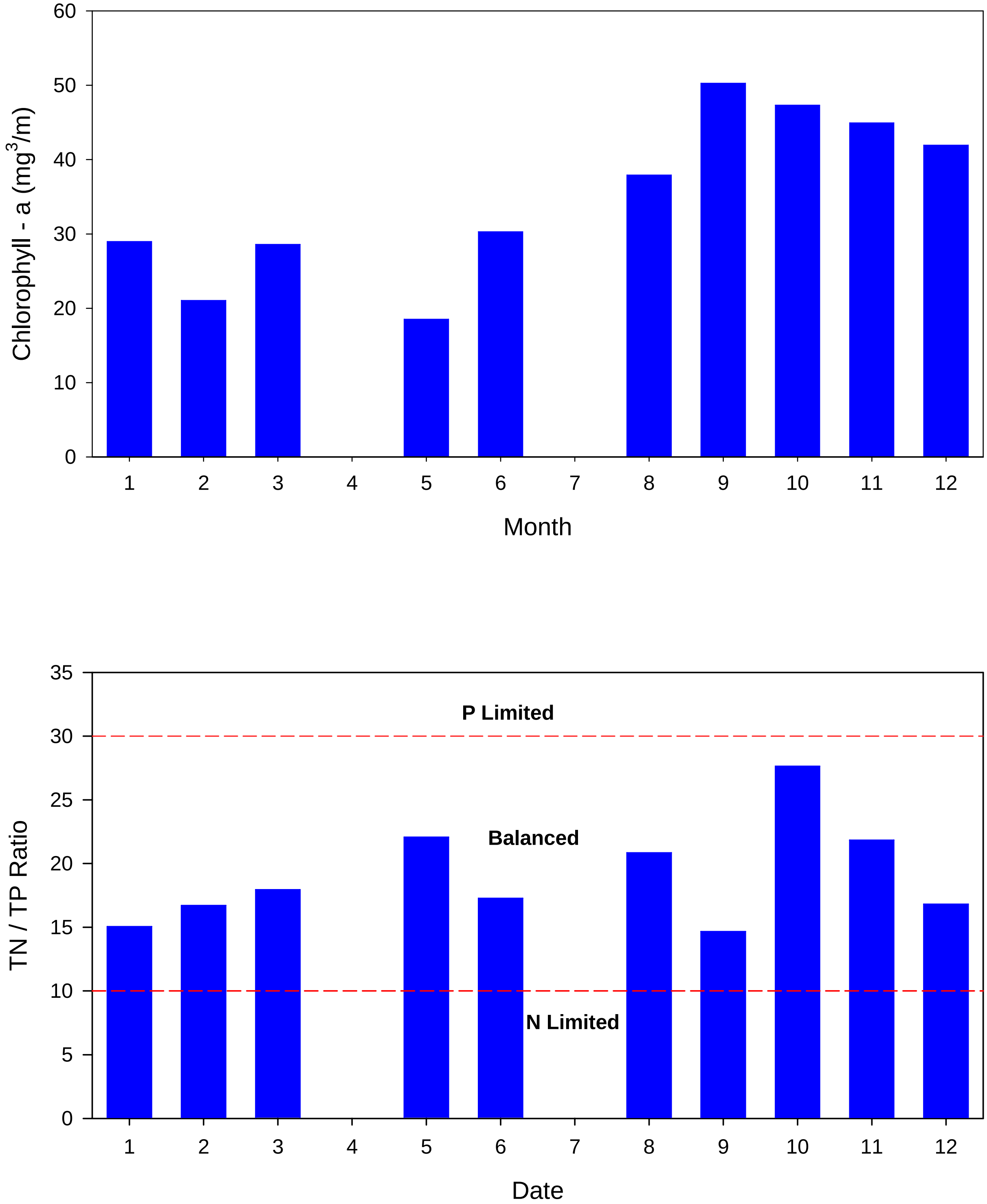


Figure 2-17. Mean Monthly Concentrations of Chlorophyll-a and TN/TP Ratio in Spring Lake from 1988-2006.

TABLE 2-7

SUMMARY OF HISTORICAL WATER QUALITY CHARACTERISTICS OF SPRING LAKE FROM 1988-2006[1]

PARAMETER	UNITS	MEAN VALUE	RANGE OF VALUES	NUMBER OF SAMPLES
pH	s.u.	8.33	6.60 – 9.48	63
Alkalinity	mg/l	49.4	8.0 – 114	64
Conductivity	μmho/cm	206	134 – 269	51
Total N	μg/l	1130	450 – 2320	64
Total P	μg/l	64	20 – 132	62
BOD	mg/l	4.6	2.1 – 8.4	17
TSS	mg/l	8.1	< 1 - 17.0	64
Chlorophyll-a	mg/m^3	33.7	5.3 – 74.0	61
Secchi Disk	m	0.84	0.5 – 1.45	64
TSI	--	63	49 – 74	64

1. City of Orlando data

2.3.4 Visual Characteristics

Visual characteristics of Spring Lake water quality were recorded by ERD field personnel, as field notes and photographically, during routine monitoring activities. In general, the water column of the lake exhibited a noticeable green tint with relatively poor clarity. Excessive growth of hydrilla was observed in many shoreline areas. However, eel-grass, a desirable aquatic species, was also relatively abundant in shoreline areas. Many of the shoreline areas also had thick accumulations of floating filamentous algae which, in many areas, was several inches thick. Expanding areas of cattails were observed along the east shoreline of the lake adjacent to U.S. 441. Photographs of shoreline areas in Spring Lake are included in Figure 2-18. The orange floats seen in several of the pictures are used to mark the locations of seepage meters installed by ERD.

a. Filamentous Algae

b. Combination of Water Lilies, Hydrilla, and Filamentous Algae

Figure 2-18. Photographs of Shoreline Areas in Spring Lake.

c. Area of Thick Hydrilla with Floating Filamentous Algae

d. Area of Eel-grass with Floating Filamentous Algae

Figure 2-18. Photographs of Shoreline Areas in Spring Lake (continued).

e. Yellow Water Lilies and Eel-grass

f. Expanding Growth of Cattails

Figure 2-18. Photographs of Shoreline Areas in Spring Lake (continued).

SECTION 3

CHARACTERISTICS OF THE SPRING LAKE DRAINAGE BASIN

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

3.1 Watershed Characteristics

A delineation of contributing drainage areas to Spring Lake was conducted by ERD as part of this project. Preliminary drainage basin boundaries were established based upon information contained in the City of Orlando Urban Stormwater Management Manual (OUSWMM). The basin boundaries were modified, as appropriate, by reviewing 1-ft contour elevation maps provided by the St. Johns River Water Management District (SJRWMD) for the drainage basin, field reconnaissance, and observation of drainage patterns during significant storm events. Individual sub-basin areas were also delineated to further identify specific areas discharging through each stormsewer inflow into Spring Lake.

An overview of the drainage basin delineation and sub-basin areas discharging into Spring Lake is given in Figure 3-1. Eleven separate sub-basin areas were identified which discharge stormwater runoff into Spring Lake through individual stormsewer systems.

A summary of sub-basin areas discharging to Spring Lake is given in Table 3-1. Drainage basin areas which discharge directly to Spring Lake through individual stormsewer systems are identified as Sub-basins 1-10. Sub-basin 11 represents areas which discharge to Spring Lake as a result of overland flow. Drainage sub-basin areas discharging to Spring Lake range from approximately 3.67-72.59 ac, with a total drainage basin area of 363.66 ac. Approximately 28.8% of the overall drainage basin area is contained within Sub-basin 4, with approximately 20.0% contained in Sub-basin 1 and 12.8% in Sub-basin 2. The remaining sub-basin areas contribute approximately 10% or less of the overall drainage basin area.

Drainage basin/lake area ratios are often useful in evaluating the potential for runoff inputs to have a significant impact on water quality within a waterbody. Some researchers have suggested that drainage basin/lake area ratios substantially 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 direct drainage basin area of 363.66 ac and a lake surface area of 38.24 ac for Spring Lake, the calculated watershed/lake area ratio for this lake is 9.5. Based upon this ratio, Spring Lake has a potential to have significant water quality impacts from nonpoint source inputs within the adjacent watershed area.

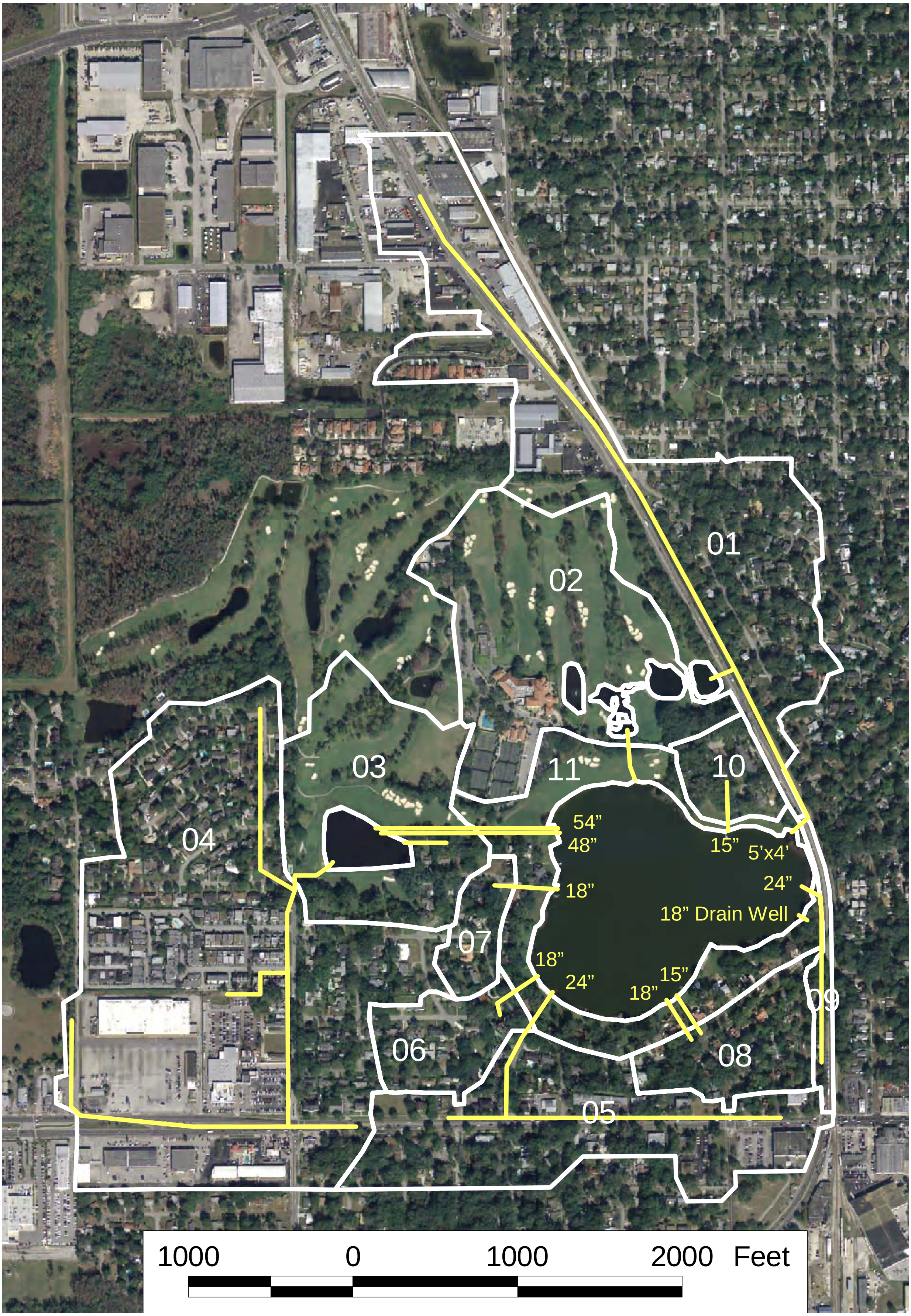


Figure 3-1. Overview of the Drainage Basin and Sub-basin Areas Discharging into Spring Lake.

TABLE 3-1

SUMMARY OF SUB-BASIN AREAS DISCHARGING TO SPRING LAKE

SUB-BASIN NO.	AREA (acres)	PERCENT OF TOTAL (%)	DRAINAGE INPUT
1	72.59	20.0	5-ft x 3-ft CBC
2	46.42	12.8	18-inch RCP
3	34.07	9.3	48- and 54-inch RCP
4	104.76	28.8	48- and 54-inch RCP
5	38.99	10.7	24-inch RCP
6	10.79	3.0	18-inch RCP
7	5.76	1.6	18-inch RCP
8	13.46	3.7	15- and 18-inch RCP
9	3.67	1.0	24-inch RCP
10	6.83	1.9	15-inch RCP
11	26.31	7.2	Direct overland flow
TOTAL:	**363.66**		

Elevation contours in the vicinity of Spring Lake are indicated on Figure 3-2 based upon information obtained from the 1-ft contour elevation maps obtained from SJRWMD. In general, upland portions of the drainage basin are characterized by relatively mild slopes, with land surface elevations ranging from approximately 110-98 ft. Contour elevations become much steeper in the immediate vicinity of Spring Lake, with an elevation decrease of approximately 10 ft or more within approximately 200-300 ft around the perimeter of the lake.

3.2 Land Use

Land use information for Spring Lake was initially obtained from the 2004 Land Use Inventory conducted by the Florida Department of Environmental Protection (FDEP). This information was utilized by ERD as a baseline, 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 developed by ERD reflects conditions which currently exist within the Spring Lake drainage basin.

An overview of general land use categories in the Spring Lake drainage basin is given in Figure 3-3. The dominant land use within the basin appears to be single-family residential followed by commercial, recreational, and multi-family residential. A small area of undeveloped forested land exists along the west side of U.S. 441.

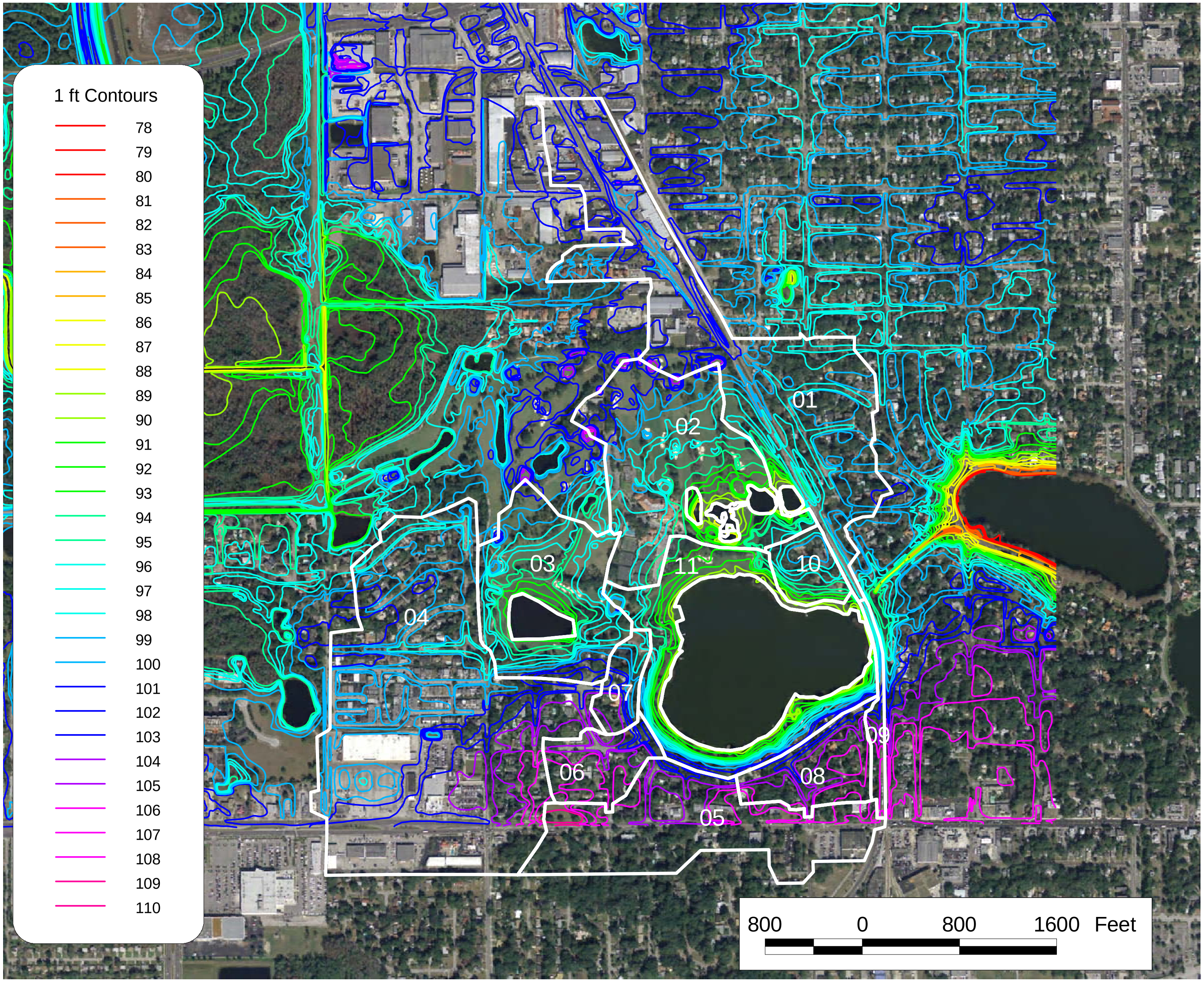


Figure 3-2. Elevation Contours in the Spring Lake Drainage Basin.

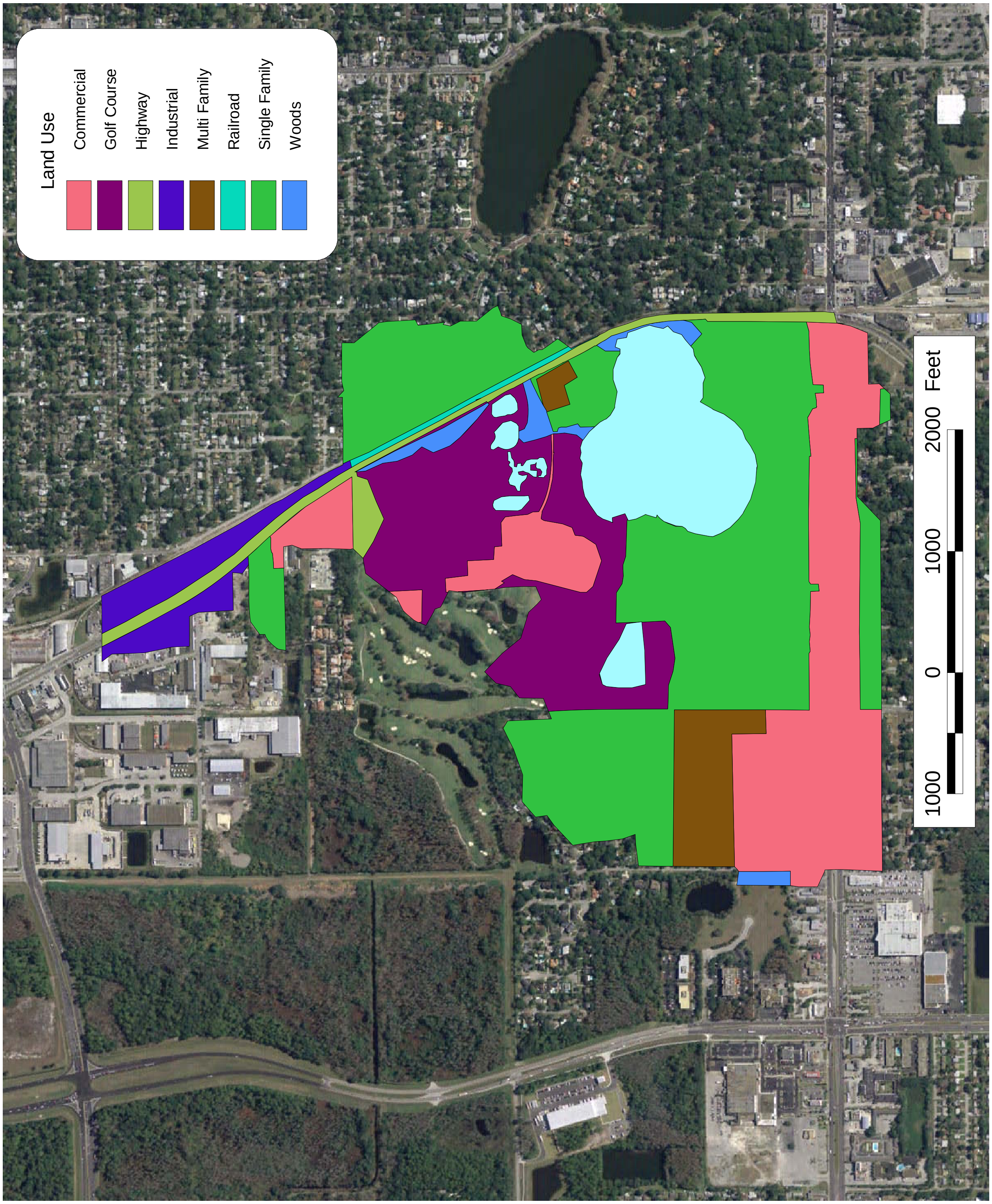


Figure 3-3. Land Use in the Spring Lake Drainage Basin.

A summary of land use characteristics in the Spring Lake drainage basin is given in Table 3-2. The single largest land use category in the Spring Lake drainage basin is single-family residential which occupies approximately 41.4% of the basin. Approximately 23.8% of the drainage basin is covered with commercial land use, with 4.8% in multi-family residential, 17.8% in recreational, 4.3% in industrial, 3.7% in highway, and 1.8% in ponds.

TABLE 3-2

CURRENT LAND USE IN THE SPRING LAKE DRAINAGE BASIN[1]

LAND USE CATEGORY	AREA (acres)	PERCENT OF TOTAL (%)
Commercial	86.46	23.8
Recreational (golf course)	64.73	17.8
Highway	13.50	3.7
Single-Family Residential	150.66	41.4
Multi-Family Residential	17.52	4.8
Wooded Areas	6.50	1.8
Ponds	6.64	1.8
Industrial	15.62	4.3
Railroad	2.01	0.6
TOTAL:	**363.66**	**100.0**

1. Excluding Spring Lake

3.3 Soil Characteristics

Information on soil types within the Spring Lake 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 soil group identified as "X" is also sometimes included. This group is referred to as "urban land". HSG classifications for this group could not be performed at the time of the original soil cover since the soil has been disturbed or covered by urban development. 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 Spring Lake is given in Figure 3-4, and a tabular summary of soil groups is given in Table 3-4. The vast majority of soils within the drainage basin appear to be classified in Hydrologic Soil Group (HSG) A, which includes deep sandy soils with a very low runoff potential, and in HSG C, which includes sandy soil with clay or organic content and a moderate to high runoff potential. A pocket of HSG D soils is located east of Spring Lake. This information is used to generate input data for hydrologic modeling of runoff inputs from each of the sub-basin areas. Areas with soils classified as urban land are assigned to soil groups based on characteristics of soils in adjacent areas.

TABLE 3-3

CHARACTERISTICS OF SCS HYDROLOGIC SOIL GROUP CLASSIFICATIONS

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
B/D	Shallow sandy soils over low permeability layer	Very high in natural state; low after development	Low in natural state; moderate following development

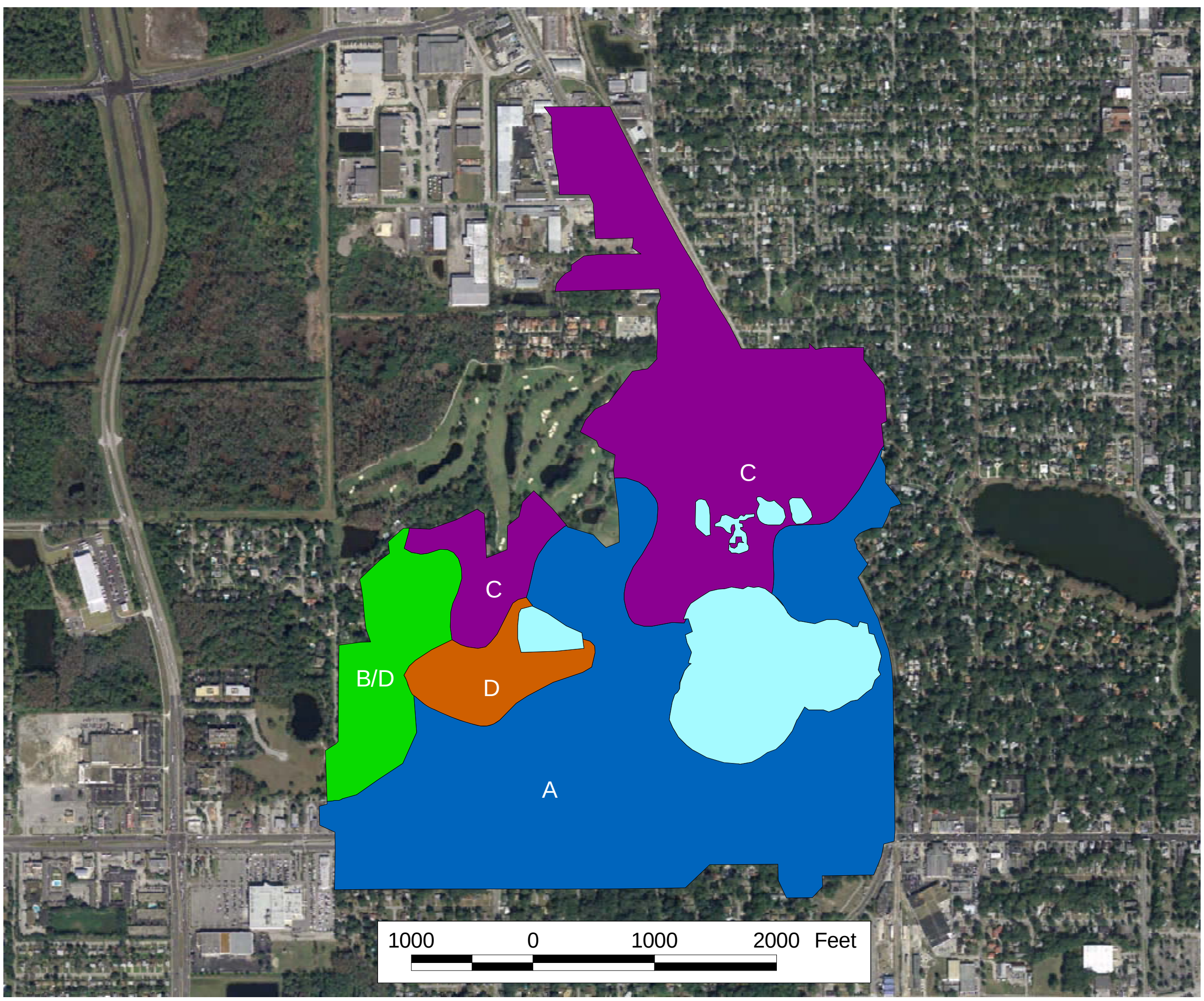


Figure 3-4. Hydrologic Soil Groups in Drainage Basin Areas for Spring Lake.

TABLE 3-4

HYDROLOGIC SOIL GROUPS IN THE SPRING LAKE DRAINAGE BASIN

HYDROLOGIC SOIL GROUP	AREA (acres)	PERCENT OF TOTAL
A	183.72	50.5
B/D	30.00	8.2
C	126.88	34.9
D	16.42	4.6
W	6.64	1.8
TOTAL:	**363.66**	**100.0**

3.4 Hydrologic Characteristics

In addition to land use characteristics, information on hydrologic characteristics of the drainage sub-basin areas was developed by ERD for use in modeling inputs of stormwater runoff to Spring Lake. The initial step in evaluating hydrologic characteristics involves delineating all pervious and impervious areas within the drainage basin. Aerial photography of the drainage basin areas was obtained from FDEP in the form of digital orthoquad photography, dated 2004. All impervious areas within the drainage basin boundaries were then digitally outlined using GIS. The remaining land areas are assumed to represent pervious areas.

A tabular summary of hydrologic characteristics of drainage basin areas discharging to Spring Lake is given in Table 3-5. Hydrologic characteristics are provided for each individual land use category within each sub-basin area. In addition to the total area for each land use category, information is also provided on the percentage of directly connected impervious areas (DCIA) within the basin. An area is considered to be directly connected if the drainage from the area discharges directly into the primary stormsewer system for the basin. In non-directly connected areas, the runoff from the impervious surface first migrates over a pervious area prior to entering the stormsewer system. This pervious area provides additional opportunities for soil infiltration of the runoff prior to reaching the receiving waterbody. The DCIA and non-DCIA areas are modeled separately when performing estimates of runoff inputs from modeled storm events. A non-DCIA curve number value (CN) is also provided for each basin and land use category. This value is used to represent the runoff potential for the pervious areas as well as impervious areas which are not directly connected.

TABLE 3-5

HYDROLOGIC CHARACTERISTICS OF DRAINAGE BASIN AREAS FOR SPRING LAKE[1]

SUB-BASIN NUMBER	LAND USE	HYDROLOGIC PARAMETER		
		TOTAL AREA (acres)	DCIA (%)	NON-DCIA CURVE NUMBER
1	Single-Family residential	32.25	21.6	76.3
	Highway	10.50	90.0	84.2
	Commercial	5.97	40.0	82.0
	Industrial	15.62	59.3	85.5
	Railroad	2.01	0.0	65.0
	Golf Course	3.19	0.0	74.7
	Woods	2.39	0.0	74.0
2	Commercial	11.68	82.4	75.9
	Golf Course	30.33	0.0	74.0
	Woods	1.79	0.0	47.7
3	Single-Family Residential	7.72	18.2	61.3
	Commercial	0.18	90.0	39.0
	Golf Course	22.84	0.0	60.0
4	Commercial	40.96	83.4	63.7
	Golf Course	0.09	0.0	80.9
	Multi-Family Residential	15.70	75.0	68.2
	Woods	0.56	0.0	61.0
	Single-Family Residential	47.45	20.0	67.9
5	Commercial	26.99	38.1	57.1
	Highway	0.23	90.0	68.5
	Single-Family Residential	11.77	19.7	53.5
6	Single-Family Residential	10.79	19.4	53.2
7	Single-Family Residential	5.76	17.4	51.3
8	Single-Family Residential	13.46	18.7	52.6
9	Highway	2.77	90.0	68.5
	Single-Family Residential	0.90	20.0	53.8
10	Multi-Family Residential	1.84	40.0	58.7
	Single-Family Residential	4.99	11.7	46.8
11	Golf Course	8.28	0.0	70.7
	Commercial	0.70	90.0	71.3
	Single-Family Residential	15.58	9.3	45.0
	Woods	1.76	0.0	40.4

1. Excludes water features and ponds

3.5 Stormwater Treatment

Watershed areas which currently receive stormwater treatment were identified by ERD within the Spring Lake drainage basin using a combination of aerial photography and field reconnaissance. A summary of the results of these evaluations is given on Figure 3-5. Stormwater treatment within the Spring Lake drainage basin consists primarily of dry retention and wet detention. Developed areas which receive stormwater treatment by one of these two common mechanisms are indicated on Figure 3-5. Dry retention is a treatment mechanism which emphasizes infiltration of the runoff into the onsite soils, while wet detention provides stormwater treatment in a wet pond setting.

In general, existing stormwater treatment is provided for portions of the commercial land use activities immediately adjacent to Colonial Drive, along with a small portion of the multi-family and commercial areas along U.S. 441. However, no significant traditional stormwater treatment is provided for the remaining single-family or multi-family residential areas which currently discharge into Spring Lake. Runoff generated in Sub-basins 3 and 4 is treated in a 3.4-acre wet detention pond, located near the center of Sub-basin 3, prior to discharge into Spring Lake. In addition, stormwater treatment is also provided for two of the commercial parcels located in Sub-basin 4 on the north side of Colonial Drive. The information summarized on Figure 3-5 is utilized in Sections 4 and 5 for estimation of hydrologic inputs and mass loadings from stormwater runoff entering the lake.

During 2004, the City of Orlando modified an existing baffle box structure to include a nutrient separating screen system to enhance nutrient removal from runoff generated in the single-family residential areas in Sub-basin 8. The pre-existing baffle box is located at the intersection of Spring Lake Drive and Springdale Road in line with the 18-inch RCP which discharges from Sub-basin 8 into Spring Lake. The location of the baffle box structure is indicated on Figure 3-6.

A schematic of the Spring Lake baffle box nutrient separating screen system is given on Figure 3-7. The baffle box structure modification was designed and installed by Suntree Technologies, Inc. in Cocoa, Florida. The baffle box utilizes a screening system to collect leaves and other debris from the stormwater flow, allowing this collected litter to be stored under dry conditions. Previous research has indicated that submerged leaves and vegetation can release substantial quantities of nutrients within a relatively short period of time. This enhanced baffle box design is intended to prevent this nutrient release from occurring by maintaining the collected leaves under non-submerged conditions.

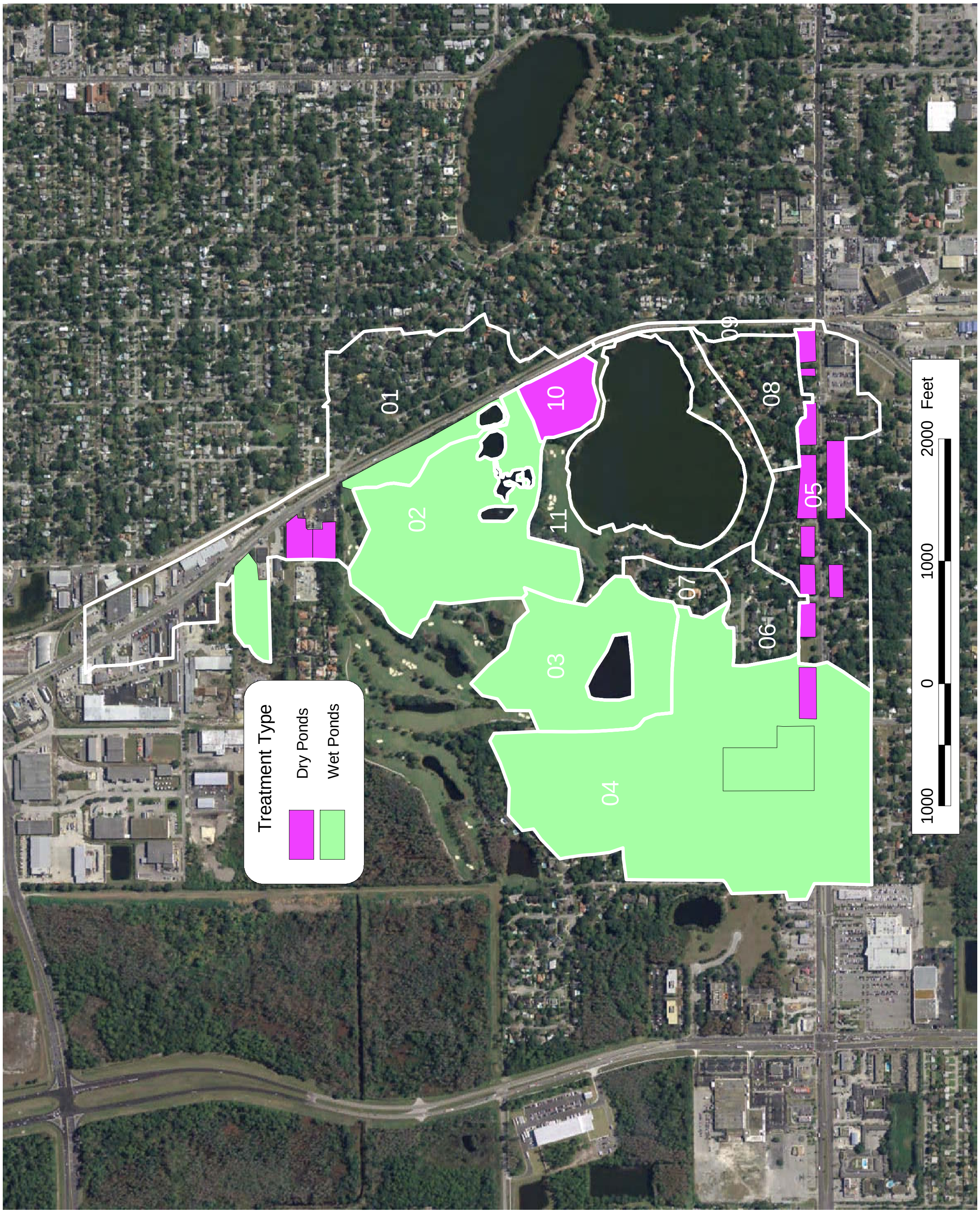


Figure 3-5. Locations of Typical Stormwater Treatment Systems.

Figure 3-6. Location of the Baffle Box Structure.

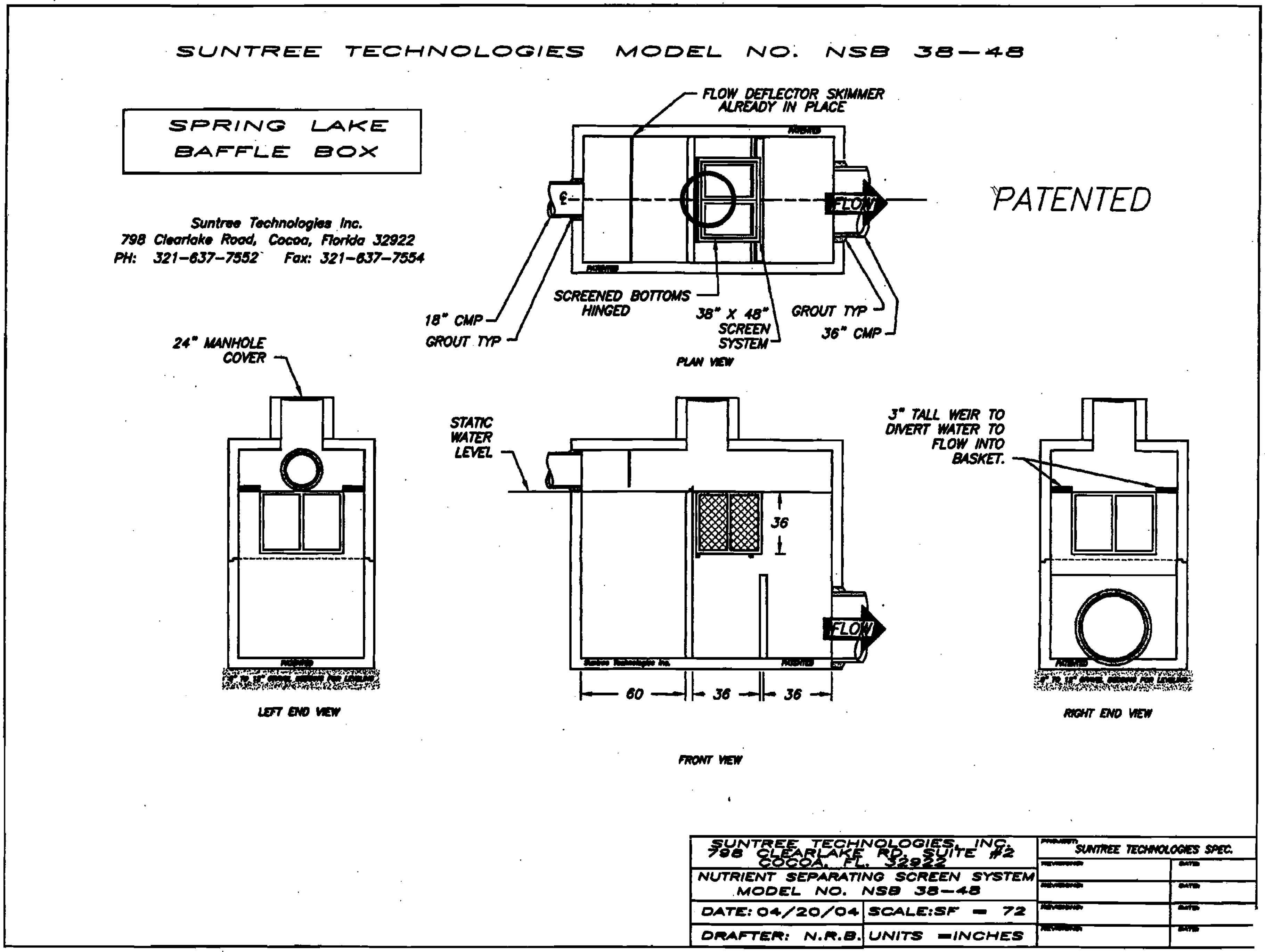


Figure 3-7. Schematic of the Baffle Box Structure (Suntree Technologies, Inc.).

SECTION 4

HYDROLOGIC INPUTS AND LOSSES

An annual hydrologic budget was developed for Spring Lake which includes inputs from direct precipitation, stormwater runoff, and groundwater seepage. Hydrologic losses are estimated for evaporation and discharges to existing drainage wells and downstream lakes. The hydrologic budget is used as an input for development of a nutrient budget and water quality model for Spring Lake, as well as for estimation of a hydraulic residence time within the lake. A discussion of identified hydrologic inputs and losses for Spring Lake is given in the following sections.

4.1 Hydrologic Inputs

4.1.1 Direct Precipitation

Estimated monthly hydrologic inputs from direct precipitation into Spring Lake were calculated by multiplying the mean monthly rainfall for the Orlando area times the assumed lake surface area of 38.24 ac. Mean monthly rainfall characteristics for the Orlando area were obtained from the National Climatic Data Center (NCDC) over the period from 1942-2005. Over this period, mean monthly rainfall depths in the Orlando area ranged from 1.97 inches during November to 7.76 inches during July, with a total annual mean rainfall depth of 50.02 inches.

A summary of calculated monthly hydrologic inputs to Spring Lake from direct precipitation is given in Table 4-1. On an average annual basis, direct precipitation contributes approximately 159.4 ac-ft of water to Spring Lake each year. This information is utilized in subsequent sections for development of a nutrient budget for the lake.

TABLE 4-1

CALCULATED MONTHLY HYDROLOGIC INPUTS TO SPRING LAKE FROM DIRECT PRECIPITATION

MONTH	MEAN RAINFALL[1] (inches)	HYDROLOGIC INPUTS[2] (ac-ft)	MONTH	MEAN RAINFALL[1] (inches)	HYDROLOGIC INPUTS[2] (ac-ft)
January	2.24	7.14	July	7.76	24.73
February	2.71	8.64	August	6.92	22.05
March	3.55	11.31	September	6.27	19.98
April	2.55	8.13	October	3.46	11.03
May	3.33	10.61	November	1.97	6.28
June	7.07	22.53	December	2.19	6.98
			TOTAL:	**50.02**	**159.40**

1. Mean monthly rainfall at the Orlando International Airport from 1942-2005
2. Based on a water surface area of 38.24 acres

4.1.2 Stormwater Runoff

Estimates of annual hydrologic inputs to Spring Lake from stormwater runoff were calculated for each identified sub-basin area based upon a frequency distribution of the historical rainfall data for the City of Orlando. Individual estimates of runoff inputs were generated for each of the sub-basin areas discharging to Spring Lake and are utilized for development of both 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 Computational Methods

Estimates of volumetric inputs from stormwater runoff were generated for each of the identified sub-basin areas discharging into Spring Lake. Hydrologic modeling was conducted based upon estimates of runoff volumes generated by common ordinary rain events and a statistical distribution of rain events occurring in the Orlando area during the 64-year period from 1942-2005. Rainfall amounts for single rain events during the 64-year period were divided into a total of 19 rainfall event intervals, and the number of annual rain events which occur within each of the selected interval ranges was estimated. The median rainfall event in each interval was also calculated. A statistical summary of rain events in the Orlando area from 1942-2005 is given in Table 4-2, based on an average annual rainfall of 50.03 inches and an average of 127 rain events per year. During this period, approximately 43.3% of all rain events were 0.10 inch or less, 57.9% were 0.20 inch or less, and 76.0% were 0.50 inch or less.

TABLE 4-2

FREQUENCY DISTRIBUTION OF RAIN EVENTS IN THE ORLANDO AREA FROM 1942-2005

RAINFALL EVENT RANGE (inches)	NUMBER OF ANNUAL EVENTS IN RANGE	MEDIAN INTERVAL RAINFALL DEPTH (inches)	RAINFALL EVENT RANGE (inches)	NUMBER OF ANNUAL EVENTS IN RANGE	MEDIAN INTERVAL RAINFALL DEPTH (inches)
0.00-0.10	54.85	0.041	3.01-3.50	0.39	3.271
0.11-0.20	18.52	0.152	3.51-4.00	0.31	3.721
0.21-0.30	10.37	0.252	4.01-4.50	0.18	4.218
0.31-0.40	6.79	0.353	4.51-5.00	0.06	4.703
0.41-0.50	5.79	0.456	5.01-6.00	0.20	5.485
0.51-1.00	16.39	0.716	6.01-7.00	0.03	6.255
1.01-1.50	7.03	1.225	7.01-8.00	0.04	7.590
1.51-2.00	3.24	1.725	8.01-9.00	0.02	8.190
2.01-2.50	1.65	2.228	> 9.00	0.03	12.310
2.51-3.00	0.82	2.702			

The SCS curve number methodology was used to provide estimates of the runoff volumes generated within each delineated drainage sub-basin area for the common rainfall events summarized in Table 4-2. 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 sub-basin areas are summarized in Table 3-5 and are also provided in the watershed model, summarized in Appendix C.

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

$$Soil\ \ Storage,\ S\ =\ \left(\frac{1000}{nDCIA\ \ CN}\ -\ 10\right)$$

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

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

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 P_i is less than 0.1, Q_{DCIAi} is equal to zero. This methodology is used to estimate the generated runoff volume within each of the delineated sub-basin areas for each of the rainfall events listed in Table 4-2.

The methodology outlined above provides an estimate of the "generated" runoff volume for each sub-basin area. However, significant portions of the generated runoff volume may be attenuated during migration through stormwater management systems within individual sub-basin areas. 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 sub-basin area and the amount of developed area treated by each stormwater management type. Estimates of the amount of generated runoff volume which is attenuated by each type of stormwater management system are included in the model, and the attenuated volume is subtracted from the generated volume within each sub-basin. The result is an estimate of the runoff volume which actually discharges into the receiving waterbody from each sub-basin area as a surface inflow.

A summary of estimated volumetric removal efficiencies for stormwater management systems in the Spring Lake drainage basins is given in Table 4-3. These volumetric removals are based on previous 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 4-3 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. A volumetric loss is not assumed for the large wet pond located in Sub-basin 3 since this pond is largely filled in and currently has a relatively short detention period. This issue is discussed in more detail in Section 7.

TABLE 4-3

ESTIMATED VOLUMETRIC REMOVAL EFFICIENCIES FOR STORMWATER MANAGEMENT SYSTEMS IN THE SPRING LAKE DRAINAGE BASIN

SYSTEM TYPE	VOLUME REDUCTION (%)
Dry Retention Pond	80
Wet Detention Pond	20

A summary of estimated annual runoff volumes which discharge from the 363.66-acre drainage basin area into Spring Lake during an "average" water year is given in Table 4-4. 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 4-3. The resulting value represents the observed runoff volume which actually discharged into Spring Lake. Estimates of the generated and observed runoff coefficients (C value) are provided for each drainage sub-basin area.

TABLE 4-4

CALCULATED ANNUAL RUNOFF INPUTS FROM SUB-BASIN AREAS TO SPRING LAKE DURING AN AVERAGE WATER YEAR

SUB-BASIN NO.	GENERATED RUNOFF VOLUME (ac-ft)	GENERATED C VALUE	VOLUME REMOVED IN DRY RETENTION PONDS (ac-ft)	VOLUME REMOVED IN WET RETENTION PONDS (ac-ft)	OBSERVED RUNOFF VOLUME (ac-ft)	OBSERVED C VALUE	PERCENT OF TOTAL (%)
1	142.20	0.470	4.68	2.12	135.40	0.447	27.2
2	53.96	0.279	0.00	10.79	43.17	0.223	8.7
3	10.93	0.077	0.00	0.00	10.93	0.077	2.2
4	243.71	0.558	1.88	28.25	213.57	0.489	43.0
5	56.16	0.346	11.9	0.00	44.26	0.272	8.9
6	9.46	0.210	0.00	0.00	9.46	0.210	1.9
7	4.52	0.188	0.00	0.00	4.52	0.188	0.9
8	11.39	0.203	0.00	0.00	11.39	0.203	2.3
9	11.29	0.738	0.00	0.00	11.29	0.738	2.3
10	5.86	0.206	4.69	0.00	1.17	0.041	0.2
11	12.07	0.110	0.00	0.00	12.07	0.110	2.4
Total:	**561.55**	**0.370**[1]	**23.15**	**41.16**	**497.24**	**0.328**[1]	**100.0**

1. Weighted average value

Approximately 70% of the runoff inputs to Spring Lake originate from Sub-basins 1 and 4. As indicated in Figure 3-1, these sub-basins include portions of the Colonial Drive and U.S. 441 corridors, including adjacent commercial and residential land uses. Runoff inputs from the remaining sub-basin areas contribute approximately 9% or less of the annual runoff inflow to Spring Lake. Observed runoff coefficients for sub-basin areas range from a low of 0.041 in Sub-basin 10, to a high of 0.738 in Sub-basin 9. The overall weighted runoff coefficient for sub-basins discharging to Spring Lake during an average rainfall year is approximately 0.328, indicating that approximately 32.8% of the total rainfall entered the lake as runoff.

4.1.3 Dry Weather Baseflow

During the field monitoring program conducted by ERD, measurable baseflow was observed only in the 48-inch RCP stormsewer line from Sub-basin 1 and includes a total of 72.59 ac. Continuous flow records were maintained at this site by the flow monitoring equipment installed as part of the stormwater monitoring program discussed in Section 5. Periodic baseflow was also observed discharging through the 24-inch RCP from Sub-basin 8 on the southeast side of the lake, although this flow appeared to be highly intermittent and does not appear to represent a significant hydrologic input into the lake.

The observed baseflow at the sub-basin monitoring site is due primarily to drawdown of a wet pond located on the west side of U.S. 441, as well as groundwater infiltration into the stormsewer system. This monitoring site and adjacent areas are discussed in more detail in Section 5. Flow monitoring conducted by ERD from October 2006-May 2007 indicated typical baseflow discharges ranging from approximately 0.02-0.06 cfs, with an average of approximately 0.04 cfs during wet season conditions from October-December 2006. No significant baseflow was observed over the period from January-May 2007. For purposes of this analysis, it is assumed that measurable baseflow occurs approximately 50% of the year at this site. Based upon an average discharge of 0.04 cfs over a period of six months, dry weather baseflow contributes approximately 14.28 ac-ft of water from Sub-basin 1 each year.

A summary of estimated inputs from stormwater and baseflow in Sub-basin 1 is given in Table 4-5. Based on the hydrologic modeling summarized in Section 4.1.2, direct stormwater runoff is estimated to contribute 135.4 ac-ft, with baseflow contributing 14.28 ac-ft, for a total input of 149.68 ac-ft/yr from this sub-basin.

TABLE 4-5

ESTIMATED INPUTS FROM STORMWATER AND BASEFLOW IN SUB-BASIN 1

PARAMETER	VALUE (ac-ft/yr)
Stormwater	135.4
Baseflow	14.28
TOTAL:	**149.68**

4.1.4 Shallow Groundwater Seepage

Field investigations were performed by ERD to evaluate the quantity and quality of shallow groundwater seepage entering Spring Lake during the monitoring period from October 2006-May 2007. Groundwater seepage was quantified using a series of underwater seepage meters installed at selected 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.

4.1.4.1 Seepage Meter Construction and Locations

A schematic of a typical seepage meter installation used in Spring Lake is given in Figure 4-1. Seepage meters were constructed from a 2-ft 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 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.

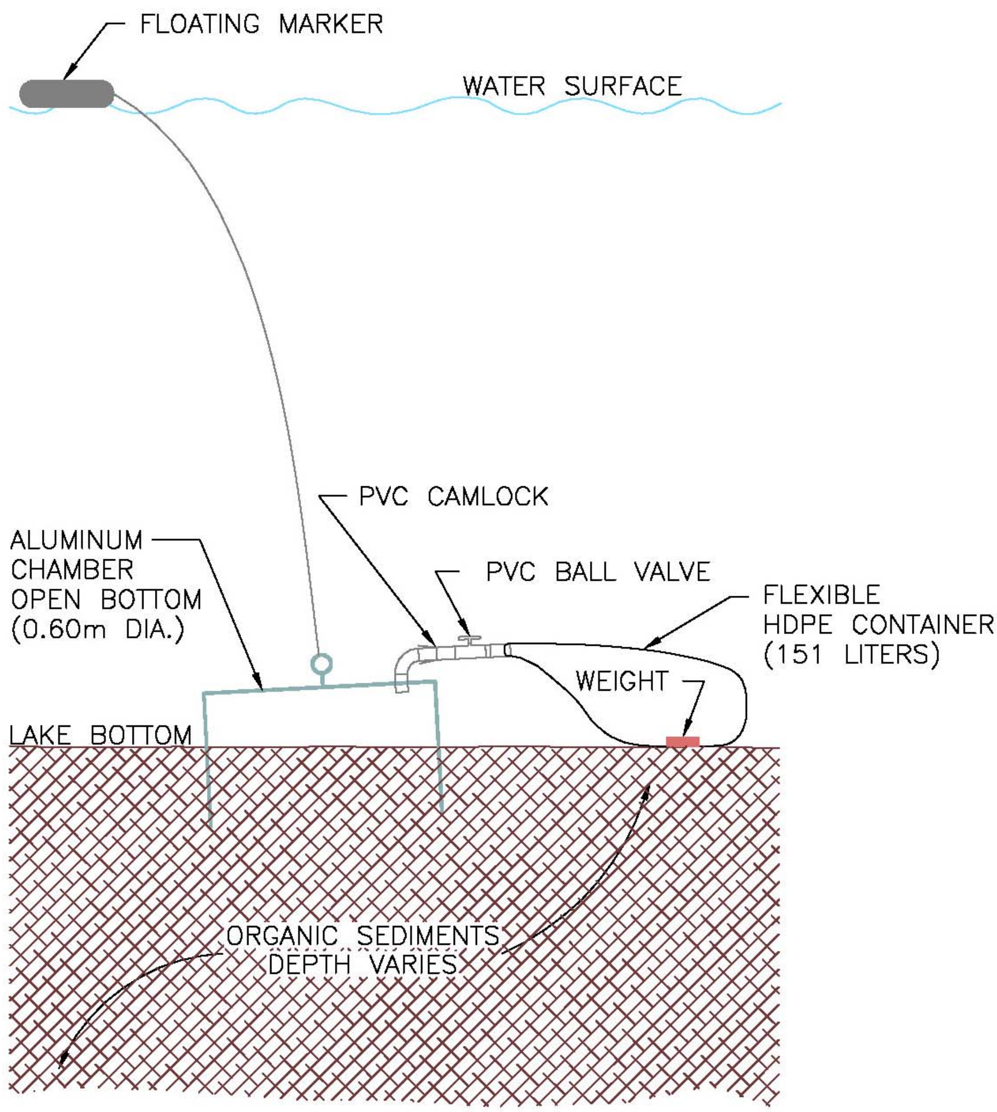


Figure 4-1. Typical Seepage Meter Installation.

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.

Eleven (11) seepage meters were installed in Spring Lake on August 14, 2006. Locations for the seepage meters are indicated on Figure 4-2. 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 the central portion of the lake in areas of maximum water depth.

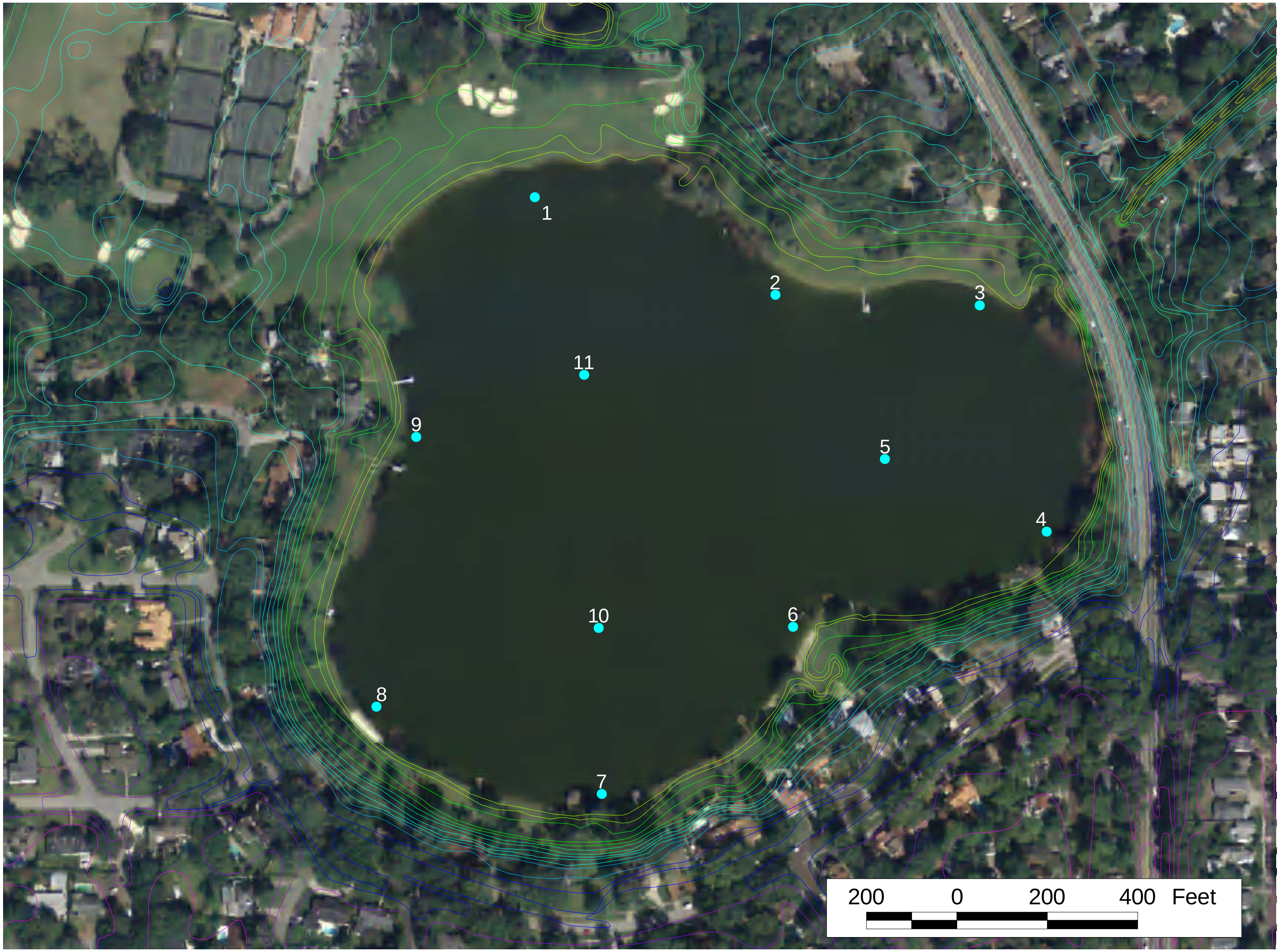


Figure 4-2. Seepage Meter Monitoring Locations in Spring Lake.

Each of the 11 seepage meters was allowed to equilibrate from August 14-September 19, 2006. Collection bags were installed on each of the seepage meters on September 19th, and the monitoring program was initiated. Each of the 11 seepage meters was monitored on approximately a monthly basis from October 2006-May 2007. Six (6) separate seepage monitoring events were conducted for evaluation of quantity and quality at each of the monitoring sites, with a total of 66 samples collected between the 11 sites.

4.1.4.2 Seepage Meter Sampling Procedures

After the initial installation of collection bags, site visits were performed at 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 ERD laboratory for further chemical analyses. Damaged seepage meters were repaired or replaced at the time of the monitoring event.

A summary of field measurements of seepage inflow over the monitoring period from October 2006-May 2007 is given in Appendix D.1. 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.

4.1.4.3 Seepage Inflow

A statistical summary of seepage inflow measurements is given in Table 4-6. In general, mean seepage values measured at the monitoring sites range from 0.45-7.43 liters/m^2-day. However, the majority of mean values range from approximately 0.5-2.0 liters/m^2-day.

The mean seepage values summarized on Table 4-6 were combined with the geographic coordinates for each site to generate an isopleth contour map for mean seepage inflow into the lake using the Autodesk Land Desktop 2007 Module for AutoCAD. Isopleths of mean seepage inflow into Spring Lake from October 2006-May 2007 are given in Figure 4-3. The range of seepage values indicated on this figure is from <1 to 7 liter/m^2-day. Much of the area within Spring Lake

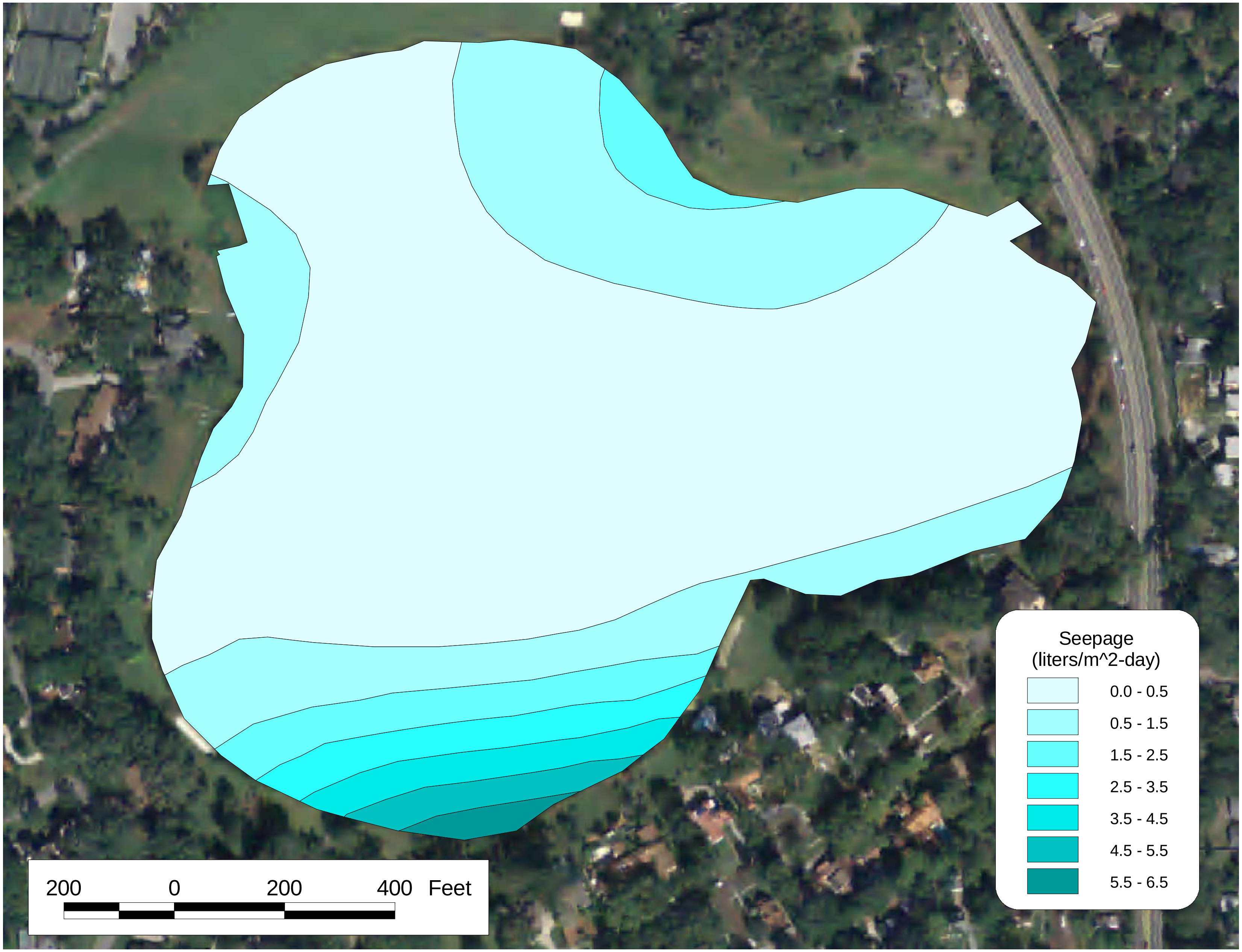


Figure 4-3. Isopleths of Mean Seepage Inflow into Spring Lake from October 2006-May 2007.

appears to exhibit relatively low seepage inflow, with large portions of the lake area indicating seepage of approximately 1-2 liter/m^2-day or less. Areas of elevated seepage inflow were observed along the southern and northern shorelines of the lake, with seepage rates increasing to as high as 4-7 liter/m^2-day. Most of the areas with elevated seepage inflow are located adjacent to sub-basin areas with permeable soils and a relatively steep topography which enhances the potential for migration of groundwater into the adjacent receiving waterbodies.

TABLE 4-6

STATISTICAL SUMMARY OF SEEPAGE INFLOW MEASUREMENTS FROM OCTOBER 2006-MAY 2007

SITE	MEAN VALUE (liters/m^2-day)	MINIMUM VALUE (liters/m^2-day)	MAXIMUM (liters/m^2-day)	NUMBER OF SAMPLES
1	0.65	0.41	1.29	6
2	2.00	0.77	3.21	6
3	0.97	0.80	1.14	6
4	1.04	0.16	2.08	6
5	0.45	0.15	1.03	6
6	1.35	0.73	1.86	6
7	7.43	4.87	10.95	6
8	1.69	0.49	4.23	6
9	1.18	0.50	1.72	6
10	0.46	0.13	1.38	6
11	0.53	0.15	1.34	6

The seepage isopleths indicated on Figure 4-3 were graphically integrated to obtain estimates of mean daily seepage influx into the lake. Calculations used for estimating daily and total seepage influx to Spring Lake are given in Appendix D.2. Based on this analysis, the mean seepage inflow is estimated to be 0.586 ac-ft/day. Since the seepage monitoring program covered both wet and dry season conditions, this value is assumed to be an average annual inflow rate. This mean value was converted into an estimated annual seepage volume by multiplying the mean daily value by 365 days. A summary of estimated seepage inputs into Spring Lake is given in Table 4-7. Annual seepage inputs to Spring Lake are estimated to be 213.8 ac-ft.

TABLE 4-7

ESTIMATED ANNUAL SEEPAGE INFLOW TO SPRING LAKE

SURFACE AREA (acres)	SEEPAGE INFLOW (ac-ft)	SEEPAGE / SURFACE AREA RATIO (ft)
38.24	213.8	5.59

The calculated seepage/surface area ratio for Spring Lake is provided in the final column of Table 4-7. This value provides an estimate of seepage inflow in terms of a water depth over the entire lake surface and provides a method for comparing relative seepage inflow within the lake without consideration of lake area. In general, seepage inflow to Spring Lake appears to be slightly higher than observed by ERD in other Central Florida lakes. The seepage inflow listed on Table 4-7 is utilized in subsequent sections for development of an overall hydrologic budget for the lake.

4.2 Hydrologic Losses

Hydrologic losses were estimated for Spring Lake resulting from evaporation and lake outflow as a result of discharges to the existing drainage well structure and outflow to Lake Adair. Estimated losses from evaporation and outflow discharges are summarized in the following sections.

4.2.1 Evaporation Losses

Estimates of monthly evaporation from Spring Lake were generated based upon mean monthly evaporation data collected at the Lake Alfred Experimental Station over the 30-year period from 1965-1994. The Lake Alfred Station is located approximately 35 miles southwest of Spring Lake and appears to be the closest long-term evaporation monitoring site to the Central Florida area. A summary of mean monthly evaporation for this site is given in Table 4-8. For purposes of this project, the mean evaporation measured at the Lake Alfred site is assumed to be similar to evaporation at Spring Lake. The recorded data at the Lake Alfred site reflects pan evaporation, with lake evaporation assumed to be equal to 70% of the pan evaporation values.

A summary of annual estimated evaporation losses from Spring Lake is given in Table 4-9. The values summarized in this table were obtained by multiplying the lake surface area summarized in Table 2-2 times the monthly estimated lake evaporation. The overall annual lake evaporation is 49.98 inches, equivalent to a total volume of 159.27 ac-ft. This information is utilized for estimation of the hydrologic budget for the lake.

TABLE 4-8

MEAN MONTHLY LAKE EVAPORATION AT THE LAKE ALFRED EXPERIMENTAL STATION SITE

MONTH	MEAN PAN EVAPORATION (inches)	LAKE EVAPORATION[1] (inches)	MONTH	MEAN PAN EVAPORATION (inches)	LAKE EVAPORATION[1] (inches)
January	3.47	2.43	July	7.57	5.30
February	4.21	2.95	August	7.16	5.01
March	6.26	4.38	September	6.28	4.40
April	7.60	5.32	October	5.51	3.86
May	8.47	5.93	November	3.98	2.79
June	7.65	5.36	December	3.22	2.25
			TOTAL:	**71.38**	**49.98**

1. Assumed to be 70% of pan evaporation

TABLE 4-9

ESTIMATED MONTHLY EVAPORATION LOSSES FROM SPRING LAKE

MONTH	LAKE EVAPORATION (inches)	EVAPORATION LOSSES (ac-ft)
January	2.43	7.74
February	2.95	9.40
March	4.38	13.96
April	5.32	16.95
May	5.93	18.90
June	5.36	17.80
July	5.30	16.89
August	5.01	15.97
September	4.40	14.02
October	3.86	12.30
November	2.79	8.89
December	2.25	7.17
TOTAL:	**49.98**	**159.27**

4.2.2 Regulation of Water Level

Measurements of water surface elevations in Spring Lake have been conducted by both the City of Orlando and Orange County on a routine basis from approximately 1960 until the present. A graphical summary of available water surface elevation data for Spring Lake is given in Figure 4-4. In general, very close agreement appears to exist between measurements performed by the City of Orlando and the County.

In general, water level elevations within Spring Lake varied within a range of approximately 1-2 ft during the period from 1960-1985. However, beginning in approximately 1985, more rapid changes in water surface elevations in Spring Lake began to occur, with water level fluctuations of approximately 3-4 ft during many years. A horizontal line is included on Figure 4-4 at an elevation of approximately 88.1 ft which represents the water level control elevation for the lake. During the period from 1960-1980, discharges from Spring Lake were relatively rare, and the vast majority of inputs were retained within the lake system. Beginning in approximately 1980, discharges from the lake became much more common, with virtually constant discharges occurring during many years.

Regulation of water level elevations in Spring Lake is achieved using two separate devices which include a drainage well and outfall structure. Approximate locations of the two water level control structures are shown in Figure 4-5. A discussion of each of the water regulation devices is given in the following sections.

4.2.2.1 Drainage Well Losses

A schematic of a typical drainage well structure is given on Figure 4-6. When the water level within the waterbody exceeds a certain elevation, excess water is discharged through a horizontal culvert into a drainage well structure located adjacent to the lake. The drainage well structure typically consists of a 12- to 24-inch diameter steel casing which extends approximately 300-450 ft downward into an intermediate aquifer. Water from the lake enters the connecting culvert and is conveyed to the drainwell structure. Drainwells often include mechanisms to prevent trash and large debris from discharging into the drainwell. These devices may include a skimmer within the lake to prevent floating debris from entering the drainwell structure, a vertical birdcage consisting of metal bars to limit the size of objects which can enter the drainwell, or a horizontal grate over the top of the drainwell opening.

The approximate location of the drainwell structure in Spring Lake is indicated on Figure 4-5. The 18-inch diameter drainage well, designated as Drainage Well 23 by the City of Orlando, is located along the eastern shore of the lake adjacent to U.S. 441 in Spring Lake Park. A photograph of the exterior of the drainwell is given in Figure 4-7. Water is conveyed from Spring Lake to the drainwell through an 18-inch corrugated metal pipe. A photograph of the interior of Drainage Well 23 is given on Figure 4-8. This well does not have a traditional birdcage structure to filter larger solids from entering the well. A circular metal plate is visible which is used to temporarily restrict inflow into the well.

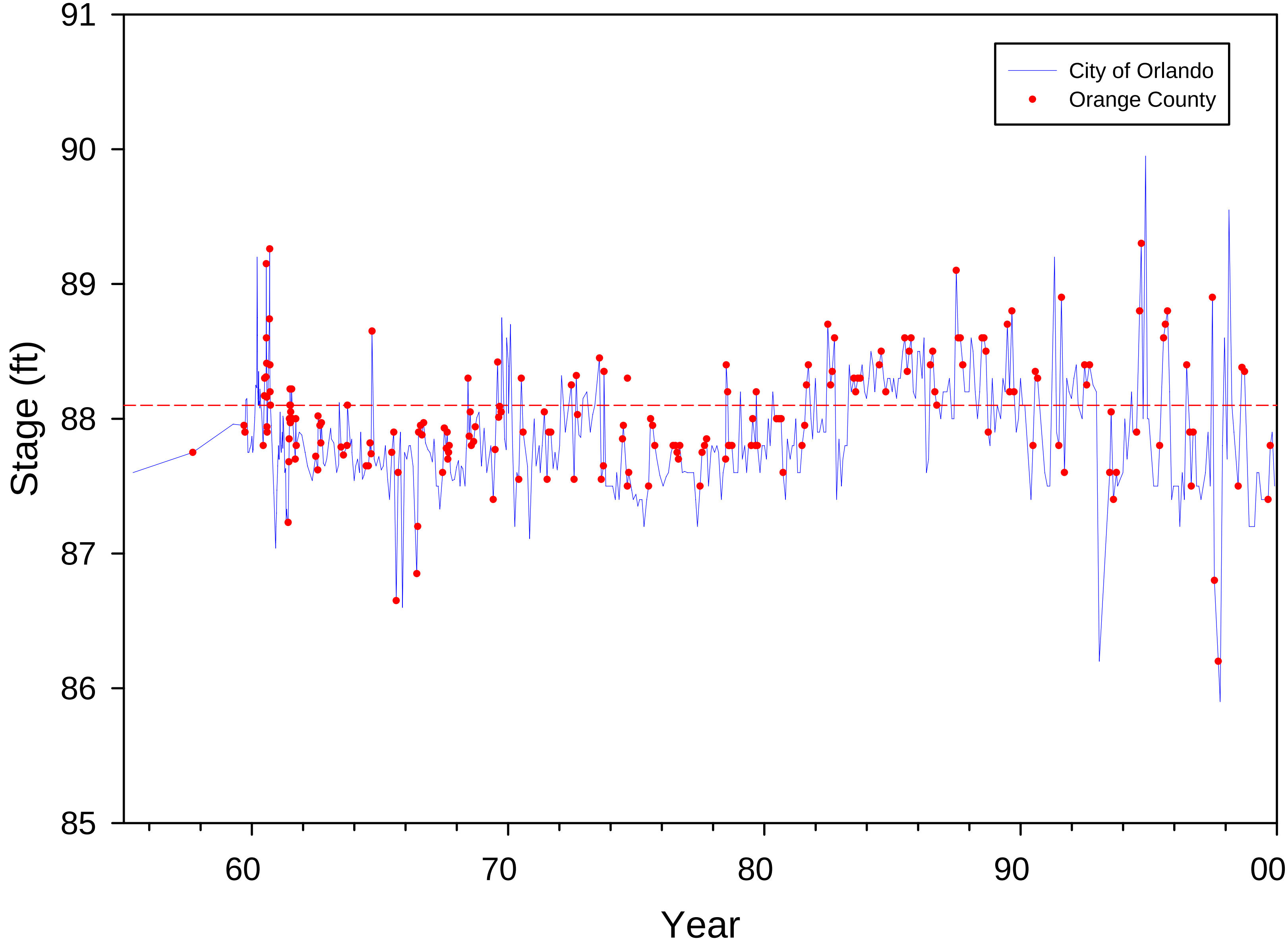


Figure 4-4. Historical Water Surface Elevations in Spring Lake.

Figure 4-5. Location of the Water Level Control Structures in Spring Lake.

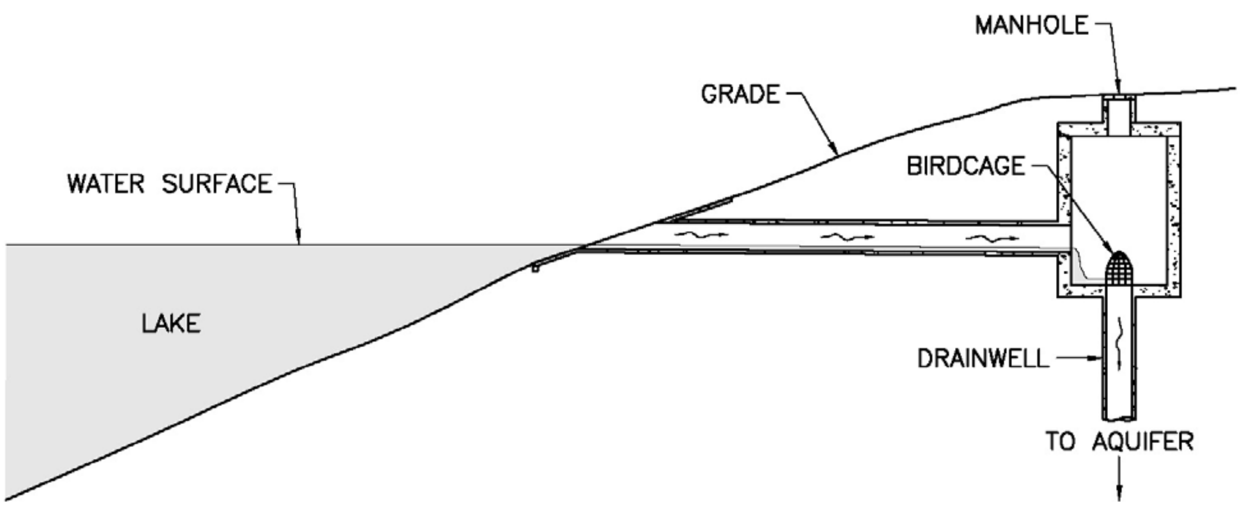


Figure 4-6. General Schematic of a Typical Drainage Well.

Figure 4-7. Entrance Structure to Drainage Well 23.

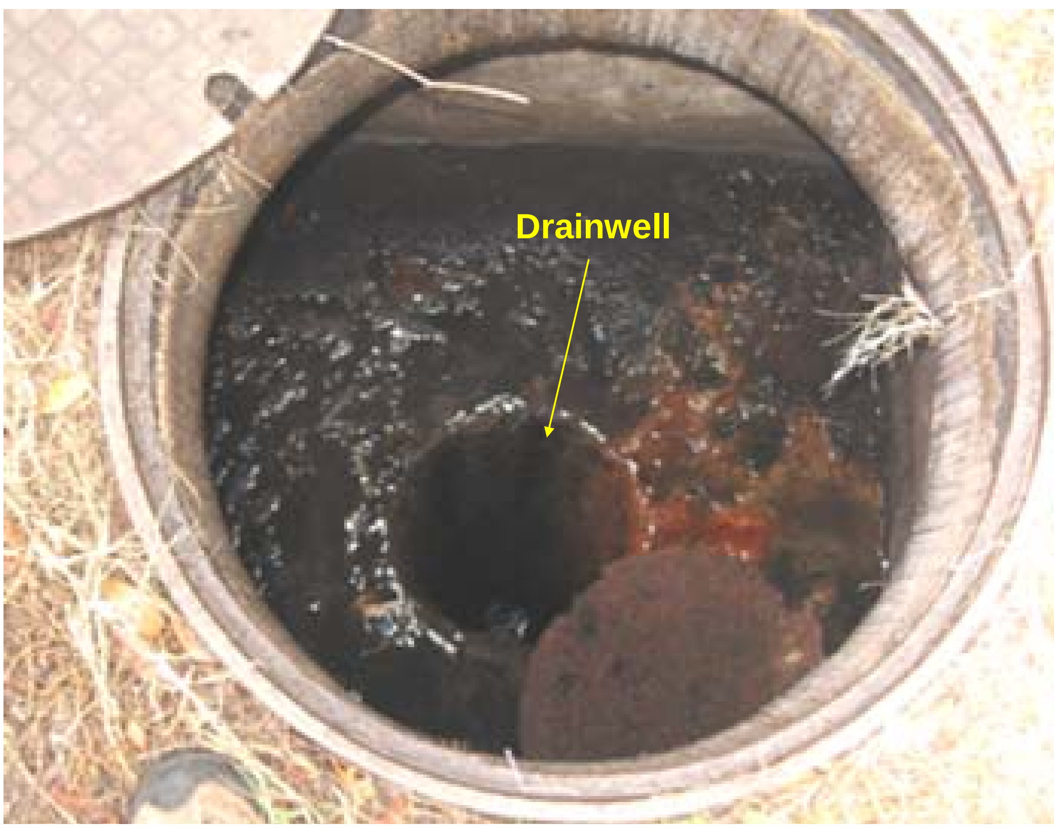


Figure 4-8. Interior of Drainage Well 23.

According to the City of Orlando drainage well information report, the Spring Lake drainage well was constructed in 1958 by Meredith Brothers Drillers. The total well depth is 456 ft, with the top 137 ft lined with an 18-inch steel casing. The well is stated to be in "good" condition. The invert elevation for the drainage well is 88.1 ft and discharges to the well only occur when the lake water level exceeds this value. Stage-discharge relationships for the drainage well are summarized in Table 4-10 based on information provided by the City of Orlando. Since the water level elevation in Spring Lake rarely exceeds 89.0 ft, discharges to the drainwell typically range from 0-10 cfs.

TABLE 4-10

STAGE-DISCHARGE RELATIONSHIPS FOR THE SPRING LAKE DRAINAGE WELL (Source: City of Orlando)

ELEVATION (feet)	WELL DISCHARGE (cfs)
88.1	0.0
89	8.1
90	11.7
91	14.5
92	16.8
93	18.8

4.2.2.2 Outflow to Lake Adair

In addition to the drainage well structure discussed in the previous section, discharges from Spring Lake also occur through an outfall structure, located on the east side of the lake, adjacent to U.S. 441. This outfall structure consists of a 5-ft x 4-ft concrete box culvert which discharges beneath U.S. 441 into a deep vegetated ravine, commonly referred to as Overbrook Ditch, which outfalls to Lake Adair. The 5-ft x 4-ft box culvert is also used as a point of inflow for stormwater runoff generated within Sub-basin 1. A concrete weir is located within the box culvert, with a weir crest elevation of 88.1 ft, identical to the control elevation of the drainage well. As long as the water elevation within Spring Lake is less than the weir elevation of 88.1 ft, discharges from Spring Lake do not occur through the outfall structure, and stormwater runoff generated in Sub-basin 1 discharges directly into the lake. However, when the elevation of the lake exceeds 88.1 ft, excess water from Spring Lake begins to discharge over the weir and downstream to Overbrook Ditch and Lake Adair. Under these conditions, portions of runoff generated within Sub-basin 1 may also discharge directly over the weir toward Lake Adair. However, the vast majority of runoff inputs from Sub-basin 1 will continue to discharge into Spring Lake. Photographs of the Spring Lake outfall structure are given in Figure 4-9.

Figure 4-9. Photographs of the Spring Lake Outfall Box Culvert Structure.

Stage-discharge relationships for the box culvert outfall structure are summarized in Table 4-11 based on information provided by the City of Orlando. Discharges through the box culvert structure appear to be substantially greater for a given water level elevation than the discharge relationships for the drainage well indicated in Table 4-10. As a result, the majority of water which is discharged from Spring Lake leaves through the box culvert rather than through the drainage well.

TABLE 4-11

STAGE-DISCHARGE RELATIONSHIPS FOR THE BOX CULVERT OUTFLOW TO LAKE ADAIR (Source: City of Orlando)

ELEVATION (feet)	WELL DISCHARGE (cfs)
88.1	0.0
89	35.1
90	79.3
91	131
92	190
93	255

An evaluation was conducted by ERD to examine the magnitude of relative water losses which occur as a result of outflow to Lake Adair and discharge through the drainwell structure. The stage discharge relationships summarized in Table 4-10 for the drainage well and in Table 4-11 for the box culvert outflow were combined with the water surface elevation data (summarized in Figure 4-4) to compute anticipated discharges through the two outfall mechanisms on an average annual basis. This analysis was conducted on a continuous basis for the 41 years of available water surface elevation data for Spring Lake. The results of this evaluation indicate that, on an annual basis, approximately 75% of the lake outflow occurs through the outfall to Lake Adair and 25% discharges to the drainage well.

However, based on discussions with City of Orlando personnel, it appears likely that the analysis conducted by ERD substantially underestimates the water volume discharging into the drainwell structure and overestimates the lake discharge to Lake Adair. According to the City, sandbars accumulate periodically within Overbrook Ditch which increase the water elevation required for discharges to occur from Spring Lake to Lake Adair. Under these conditions, the majority of water discharging from Spring Lake goes to the drainwell structure. In addition, the structure which regulates the discharge of water from Spring Lake into the drainage well has several leaks which allows water to discharge through the structure at elevations less than the normal water level of 88.1 ft. The City of Orlando was performing repairs to this structure during the field monitoring program conducted by ERD. These repair activities are evident in Figure 4-7.

As a result of the previous discussion, it is difficult to quantify the relative magnitudes of water losses from Spring Lake through the various outflow mechanisms. Therefore, for purposes of developing hydrologic and nutrient budgets, the water loss from the lake is simply referred to as "outflow" which includes the combined discharges to the drainwell and outfall structure to Overbrook Ditch.

4.3 Hydrologic Budget

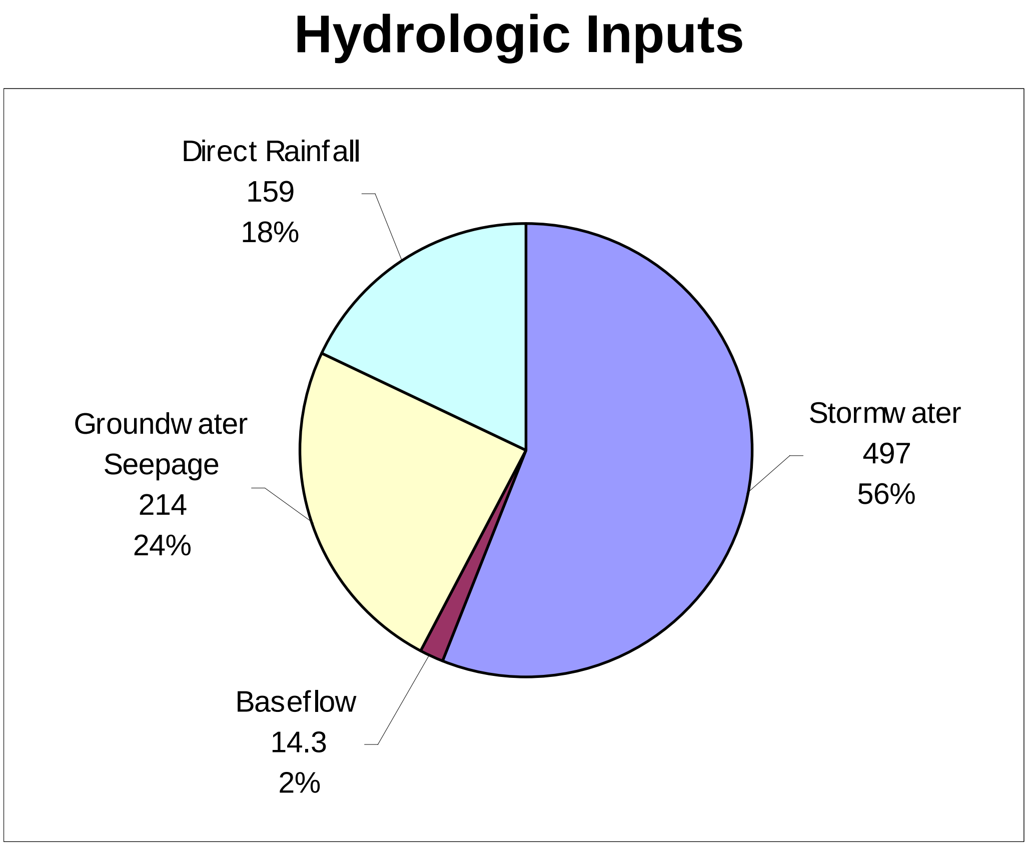
A summary of estimated annual hydrologic inputs to Spring Lake is given in Table 4-12. The largest hydrologic input to Spring Lake is stormwater runoff which contributes approximately 56.2% of the annual hydrologic inputs. An additional 1.6% is contributed by baseflow. Approximately 24.2% of the hydrologic inputs originate from groundwater seepage, with 18.0% from direct rainfall. A graphical comparison of hydrologic inputs to Spring Lake is given on Figure 4-10.

TABLE 4-12

ESTIMATED ANNUAL HYDROLOGIC INPUTS TO SPRING LAKE

PARAMETER	VOLUME (ac-ft)	PERCENT OF TOTAL
Stormwater	497.2	56.2
Baseflow	14.3	1.6
Groundwater Seepage	213.8	24.2
Direct Rainfall	159.4	18.0
TOTAL:	**884.7**	**100.0**

A summary of estimated annual hydrologic losses from Spring Lake is given in Table 4-13. As summarized in Table 4-9, mean annual evaporation losses from Spring Lake are estimated to be approximately 159.3 ac-ft/yr. The remaining losses from the lake occur as a result of discharges through the outfall structure and into the drainwell. In order to maintain a balanced annual water budget, inputs and losses from Spring Lake must be approximately equal. After accounting for evaporation losses, an additional 725.4 ac-ft of water must be discharged from Spring Lake each year as outflow. Based upon this analysis, approximately 18.0% of the annual hydrologic losses occur as a result of evaporation, with 82.0% of the annual losses occurring as a result of discharges through the outfall structure and discharges through the drainwell structure. A graphical comparison of hydrologic losses from Spring Lake is also given on Figure 4-10.



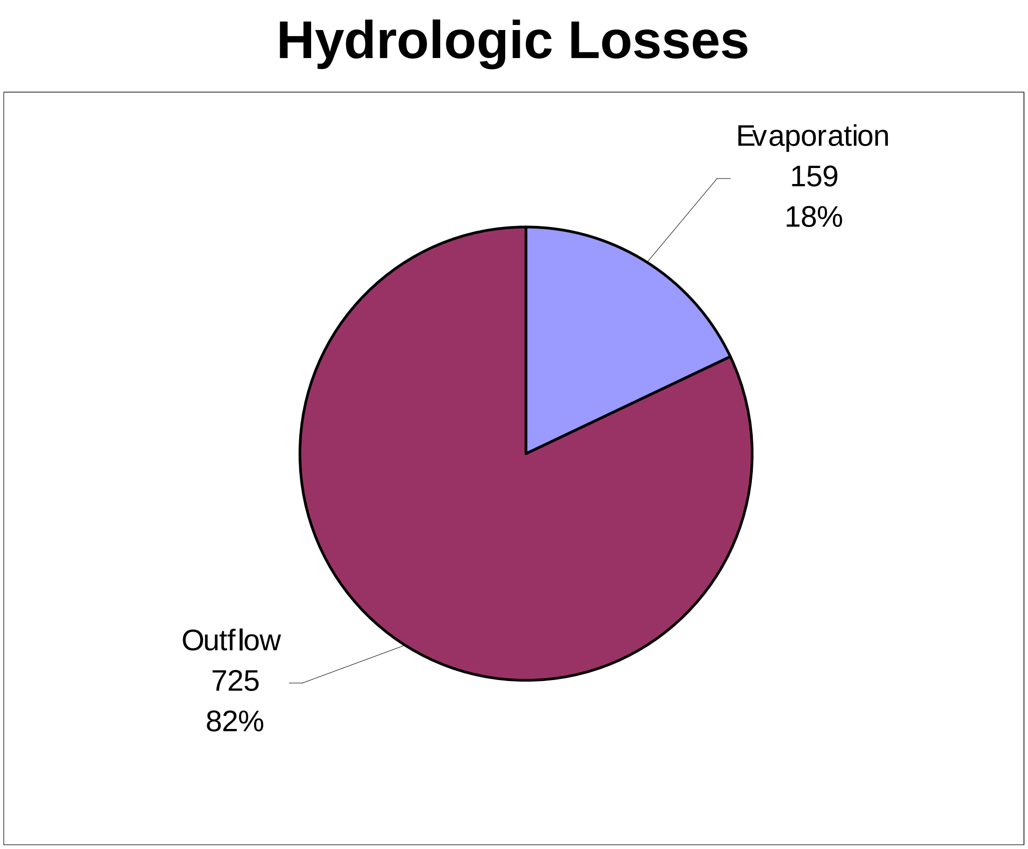


Figure 4-10. Comparison of Mean Annual Hydrologic Inputs and Losses to Spring Lake.

TABLE 4-13

ESTIMATED ANNUAL HYDROLOGIC LOSSES FROM SPRING LAKE

PARAMETER	VOLUME (ac-ft)	PERCENT OF TOTAL
Evaporation	159.3	18.0
Outflow	725.4	82.0
TOTAL:	**884.7**	**100.0**

4.4 Water Residence Time

Annual water residence time was calculated for Spring Lake by dividing the estimated water volume for the lake (summarized in Table 2-2) by the calculated total annual hydrologic inputs (summarized in Table 4-12). A summary of this information is given in Table 4-14. Based upon this analysis, the calculated residence time in Spring Lake is approximately 0.44 years or 160 days.

TABLE 4-14

CALCULATED ANNUAL RESIDENCE TIME IN SPRING LAKE

LAKE VOLUME (ac-ft)	HYDROLOGIC INPUTS (ac-ft)[1]	RESIDENCE TIME	
		YEARS	DAYS
388.1	884.7	0.44	160