Spring Lake Hydrologic/Nutrient Budget and Management Plan

Final Report

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Prepared for:

City of Orlando
Stormwater Utility Bureau

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

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SECTION 5

NUTRIENT INPUTS AND LOSSES

Spring Lake receives nutrient inputs from a variety of sources which include stormwater runoff, baseflow, shallow groundwater seepage, and bulk precipitation. Characteristics of stormwater runoff, baseflow, and groundwater seepage were measured directly by ERD during the period from October 2006-May 2007. A discussion of these inputs, along with calculated mass loadings, is given in the following sections. Nutrient inputs from bulk precipitation were not measured directly by ERD as part of this project. These inputs are estimated based upon previous monitoring of bulk precipitation performed in the Central Florida area. Information from each of these sources is used to generate annual average nutrient budgets for total nitrogen, total phosphorus and TSS in Spring Lake.

5.1 Characteristics of Nutrient Inputs

5.1.1 Bulk Precipitation

5.1.1.1 Chemical Characteristics

ERD has performed several evaluations of the characteristics of bulk precipitation in the Central Florida area. The most recent of these evaluations was conducted as part of the Butler Chain-of-Lakes evaluation. Bulk precipitation samples were collected by ERD on a continuous basis from December 2004-November 2005 at a monitoring site located adjacent to the Keene's Point boat ramp on Lake Isleworth. Twenty-nine bulk precipitation samples were collected at the monitoring site and analyzed for general parameters, nutrients, and TSS. A summary of the mean characteristics of measured concentrations for nitrogen, phosphorus, and TSS in bulk precipitation at the Butler Chain-of-Lakes monitoring site is given in Table 5-1. For purposes of this evaluation, it is assumed that the bulk precipitation characteristics summarized in Table 5-1 are similar to bulk precipitation which falls on Spring Lake.

TABLE 5-1

MEAN CHARACTERISTICS OF BULK PRECIPITATION IN THE CENTRAL FLORIDA AREA

PARAMETER	UNITS	CONCENTRATION
Nitrogen	μg/l	770
Phosphorus	μg/l	61
TSS	mg/l	17.3

5.1.1.2 Mass Loadings

Estimates of annual mass loadings from bulk precipitation to Spring Lake were calculated for total nitrogen, total phosphorus, and TSS based upon the assumed characteristics listed in Table 5-1 and the estimated annual volumetric inputs from direct precipitation listed on Table 4-1. A summary of estimated loadings to Spring Lake from bulk precipitation is given in Table 5-2. On an annual basis, inputs from bulk precipitation contribute approximately 151.4 kg of total nitrogen, 11.99 kg of total phosphorus, and 3401kg of TSS.

TABLE 5-2

ESTIMATED LOADINGS TO SPRING LAKE FROM BULK PRECIPITATION

PARAMETER	MASS LOADINGS (kg)
Total N	151.4
Total P	11.99
TSS	3401

5.1.2 Stormwater Runoff

5.1.2.1 Evaluation Methodology

Field monitoring was conducted by ERD from December 2006-June 2007 to evaluate the chemical characteristics of stormwater runoff entering Spring Lake from four major drainage sub-basin areas. Approximate locations of the stormwater monitoring sites in the Spring Lake drainage basin are indicated on Figure 5-1. Physical characteristics of the monitored drainage sub-basins are summarized in Table 5-3. The monitored sub-basin areas were selected to include each of the significant land use types within the drainage basin. The monitored areas include significant commercial and highway areas along Colonial Drive and U.S. 441, as well as residential areas along the southern side of the lake and golf course areas north and east of the lake. The four drainage sub-basin areas monitored by ERD have a combined area of 271.3 acres which is approximately 75% of the total drainage basin area discharging to Spring Lake. The modeled annual runoff volume for these sub-basins is 428.7 ac-ft, including baseflow, which represents 84% of the annual surface inflow which discharges to the lake.

An overview of the Sub-basin 1 monitoring site and details of adjacent land use and drainage features is given in Figure 5-2. Stormwater monitoring at this site was conducted in the 5-ft x 4-ft concrete box culvert (CBC) which discharges from Sub-basin 1 into the northeast side of Spring Lake. This sub-basin area includes primarily U.S. 441, along with commercial and golf course areas west of U.S. 441 and residential areas east of U.S. 441. Few stormwater treatment systems currently exist within this sub-basin. A small wet detention pond is located in Sub-basin 1D which provides partial treatment for portions of the golf course in the vicinity of this pond prior to discharging into the FDOT drainage system. This small detention pond is primarily responsible for creating a continuous baseflow through the stormsewer system following significant storm events due to slow bleed-down of the pond water into the stormsewer system. Stormwater monitoring at this site was conducted approximately 10 ft inside the 5-ft x 4-ft CBC upstream of the point of discharge into Spring Lake.

Figure 5-1. Stormwater Monitoring Locations for Spring Lake.

TABLE 5-3

CHARACTERISTICS OF SUB-BASIN AREAS USED FOR COLLECTION OF STORMWATER RUNOFF IN THE SPRING LAKE DRAINAGE BASIN

SUB-BASIN NO.	SUB-BASIN AREA (acres)	RUNOFF VOLUME (ac-ft/yr)	SUB-BASIN DESCRIPTION
1	72.59	149.68[1]	Commercial activities, residential, heavily traveled 4-lane roadway
2	46.42	43.17	Golf course, club house parking
3 and 4	138.8	224.5	Golf course, commercial, multi-family residential, single-family residential, and heavily traveled 4-lane roadway
8	13.46	11.39	Single-family residential, commercial, and heavily-traveled 4-lane roadway
TOTAL:	**271.3 (74.6% of total)**	**428.7 (83.8% of total)**	

1. Includes baseflow volume

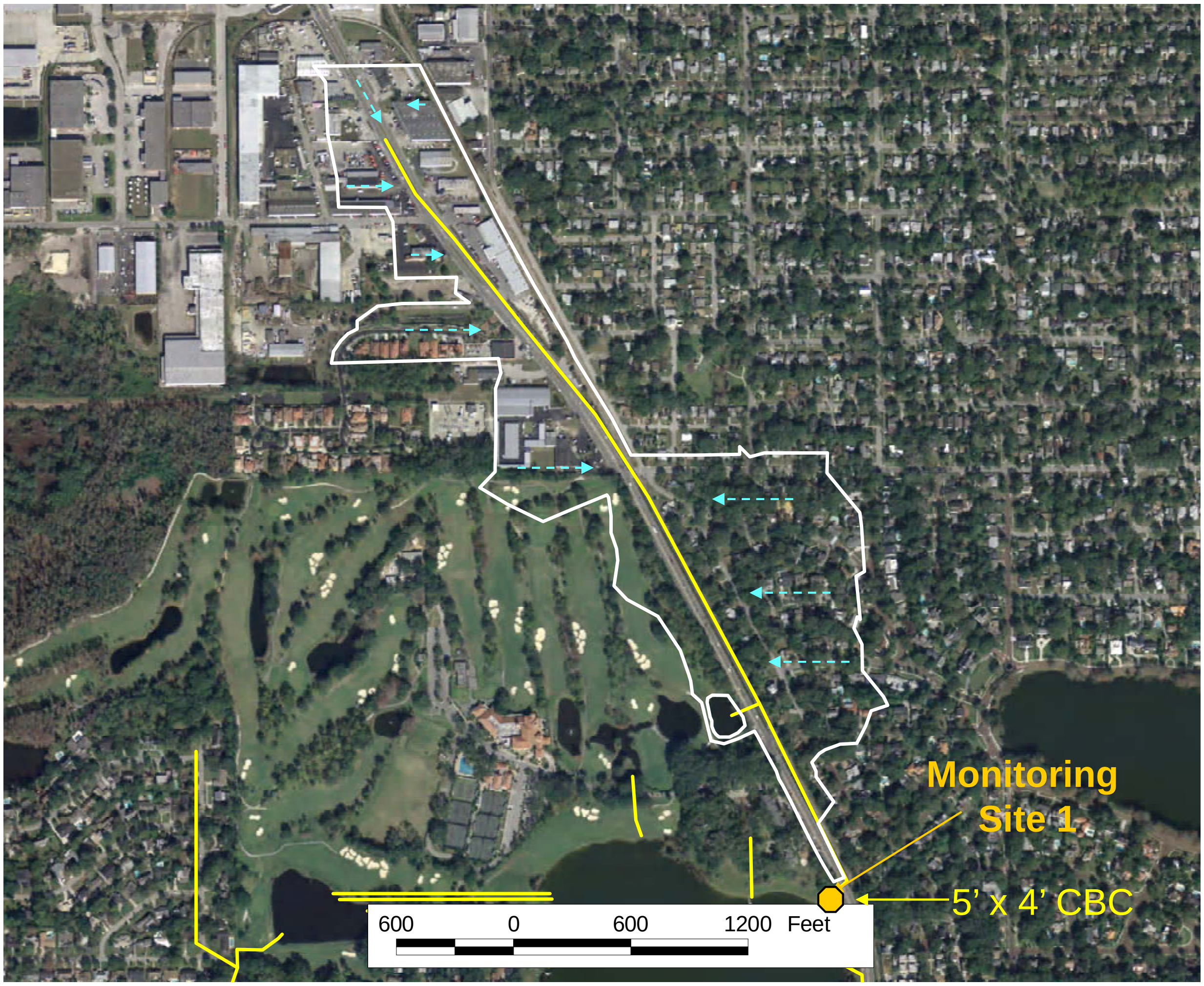


Figure 5-2. Overview of the Spring Lake Sub-basin 1 Monitoring Site (Site 1).

Details of the Sub-basin 1 monitoring site are indicated on Figure 5-3. An automatic sampler was housed inside an aluminum equipment shelter with cables and tubing extending approximately 10 ft into the 5-ft x 4-ft CBC.

An overview of the Sub-basin 8 monitoring site (Site 2) and details of the adjacent land use and drainage features is given on Figure 5-4. This sub-basin area is located on the southeast side of Spring Lake in an area of upscale single-family homes. Runoff generated within the sub-basin flows along the brick roadways and discharges into one of two adjacent stormsewer lines which convey runoff from this sub-basin into Spring Lake.

The specific location of the Sub-basin 08 (Site 2) monitoring site is indicated on Figure 5-5. The automatic sampler was placed inside the manhole cover indicated on Figure 5-5. Sample tubing was extended from this location to a point downstream from the baffle box structure so that the collected stormwater samples reflected water quality impacts from the baffle box system.

Figure 5-3. Monitoring Equipment for Sub-basin 1.

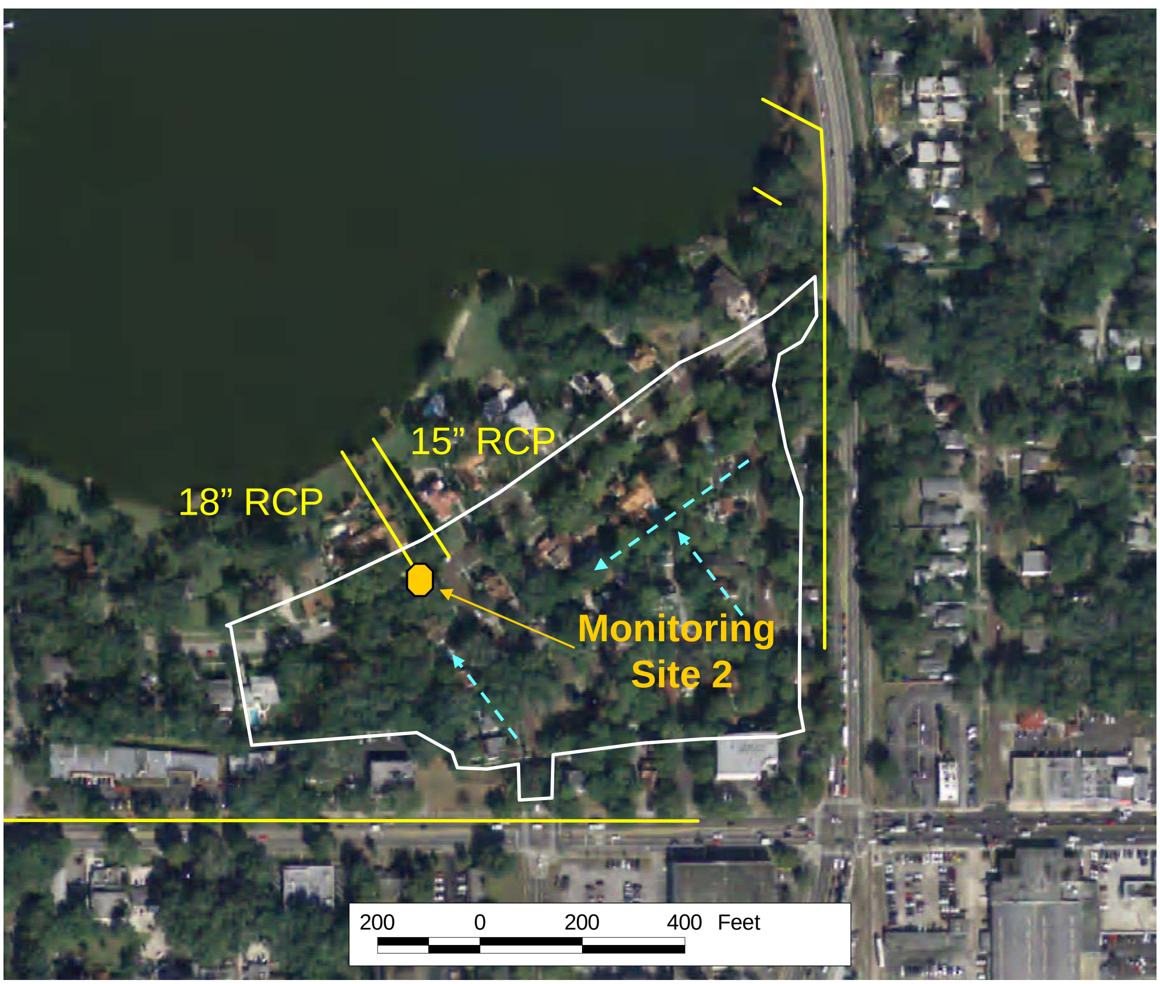


Figure 5-4. Overview of the Sub-basin 08 Monitoring Site (Site 2).

Figure 5-5. Location of the Sub-basin 08 (Site 2) Monitoring Site.

An overview of the Sub-basin 3 monitoring site (Site 3) is given on Figure 5-6. Monitoring at this site was conducted to evaluate discharges from the wet detention pond which receives runoff inputs from Sub-basins 3 and 4, with a combined drainage basin area of 137.6 ac. Under existing conditions, two separate stormsewers discharge from the wet detention pond into Spring Lake. A photograph of the two outfall structures is given on Figure 5-7. It appears that the outfall structure identified as "secondary outflow" on Figure 5-7 was the initial discharge structure from the pond. This outfall structure discharges through a 24-inch RCP into Spring Lake. A second larger discharge was added at a later date which is indicated as the "primary outflow" for this site. The primary outflow is connected to a 54-inch RCP which discharges to Spring Lake.

The specific location of the monitoring site for Site 3 is indicated on Figure 5-8. An automatic sampler was installed adjacent to the outfall structure connected to the 54-inch RCP. This autosampler provided continuous sampling for all discharges from the pond to Spring Lake during the monitoring program.

An overview of land use and drainage features in the vicinity of monitoring Site 4 is given in Figure 5-9. This site is designed to evaluate discharges from a series of interconnected golf course ponds which collect runoff generated in Sub-basin 2.

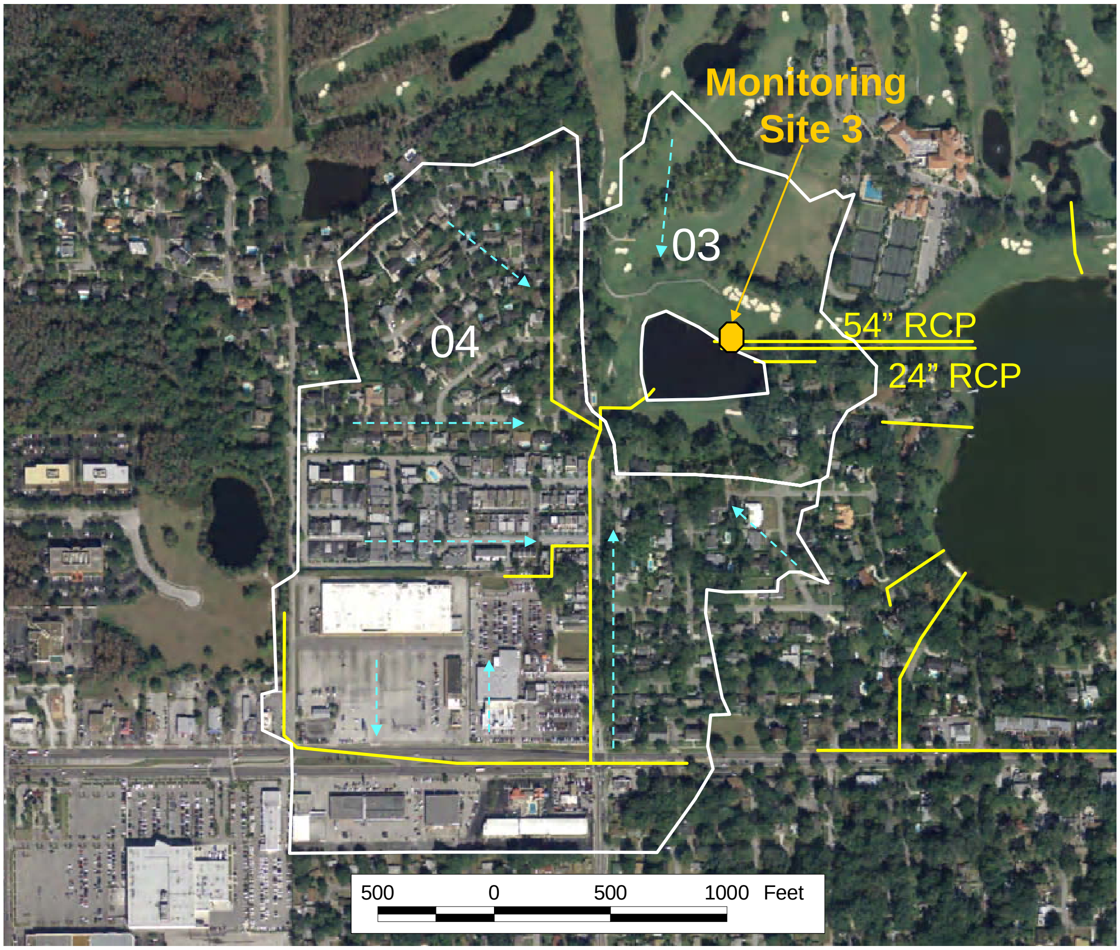


Figure 5-6. Overview of the Sub-basin 3 Monitoring Site (Site 3).

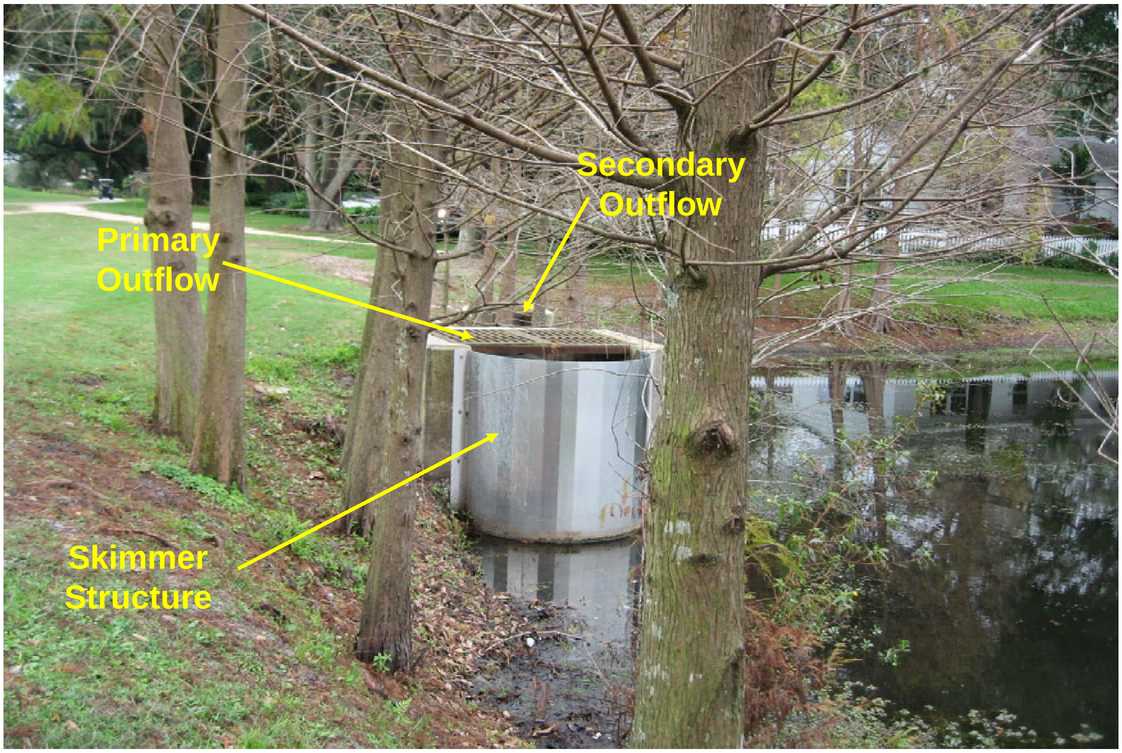


Figure 5-7. Photograph of the Two Outfall Structures at Site 3.

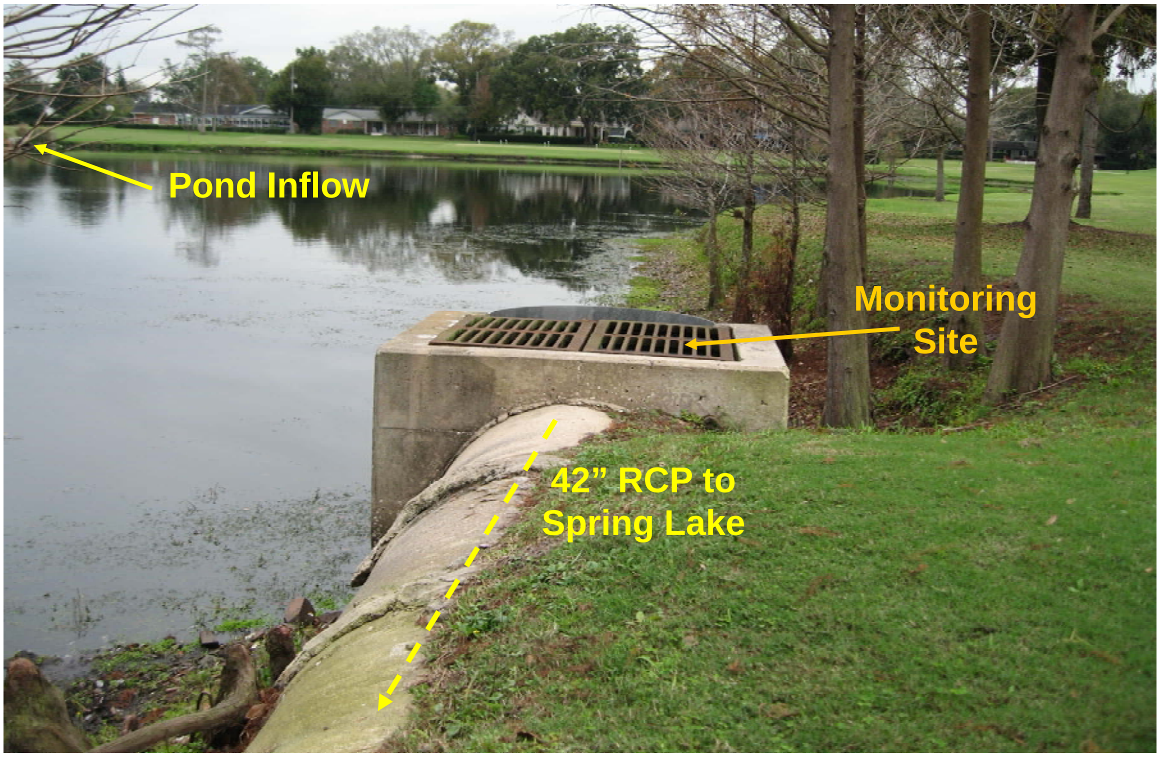


Figure 5-8. Location of Monitoring Site 3.

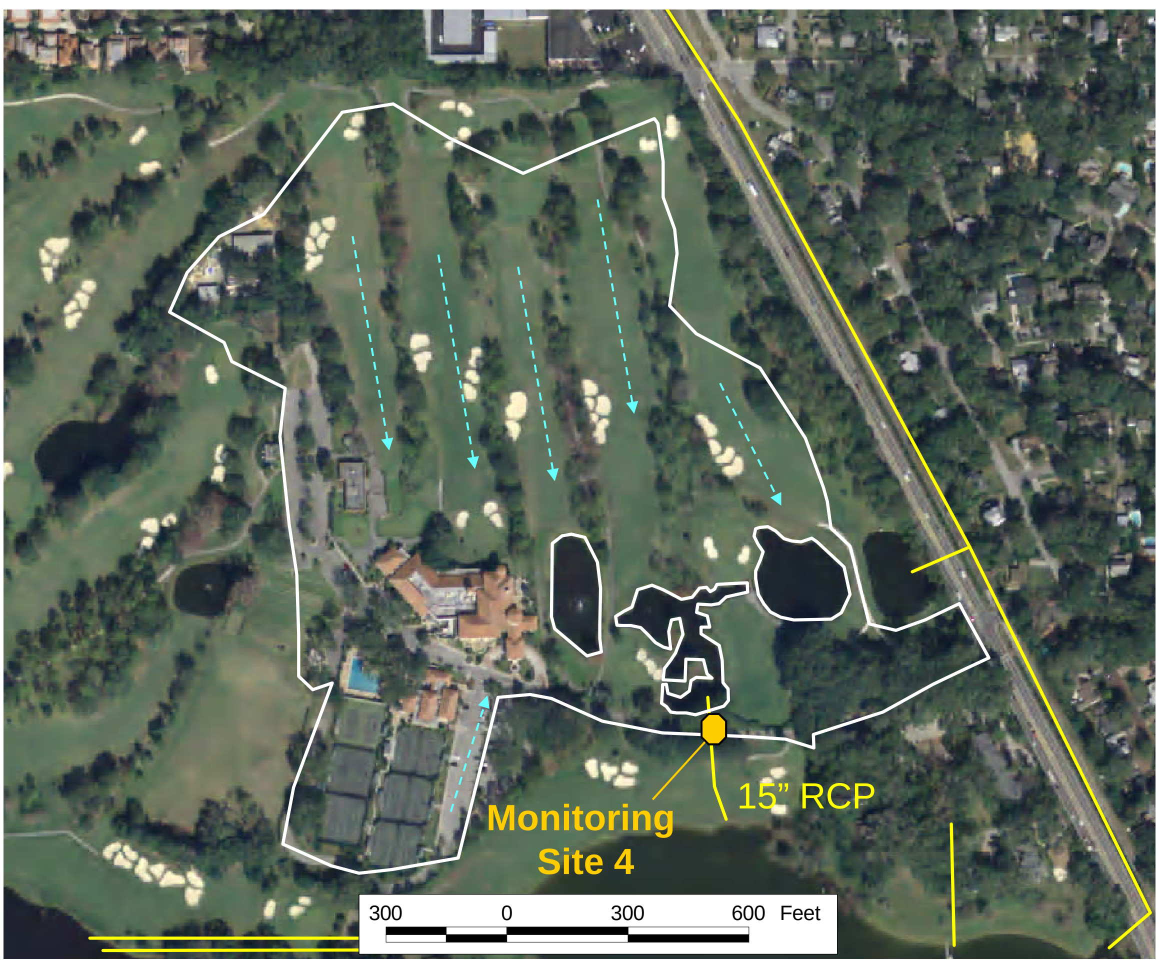


Figure 5-9. Overview of Land Use and Drainage Features in the Vicinity of Monitoring Site 4.

Discharges from the final golf course pond migrate through a shallow earthen ditch. A photograph of the final golf course pond and connecting ditch is given in Figure 5-10a. The earthen ditch terminates into a 15-inch RCP (Figure 5-10b) which travels beneath the entrance roadway to the club house and the golf course area south of the monitoring site prior to discharging into Spring Lake. A photograph of the stormwater monitoring equipment is given on Figure 5-11. The autosampler was housed inside an aluminum equipment shelter adjacent to the earthen channel. Sample tubing and flow meter probes were extended from the equipment shelter onto the bottom of the earthen channel for collection of stormwater samples and measurement of flow rates.

Stormwater monitoring at each of the four sites was conducted using Sigma Model 900 MAX-AV stormwater autosamplers which were installed at the identified manhole and stormsewer locations indicated previously. An ultrasonic flow probe was mounted on the bottom of the stormsewer channel at each site to provide a continuous record of discharges through the stormsewer system under both storm event and dry weather baseflow conditions. At monitoring Sites 1, 2, and 4, the autosamplers were programmed to collect samples in a flow-weighted mode, with each discrete sample placed into one of 24 one-liter bottles within the autosampler. The flow hydrographs were retrieved from each unit and used to segregate the collected samples into either baseflow or storm event conditions. The autosampler installed at monitoring Site 3 contained a single composite bottle which was used to collect flow-weighted samples of discharges from the wet detention pond. Eight flow-weighted composite stormwater samples were collected from Site 1 (Sub-basin 1), with 6 storm events collected at Site 2 (Sub-basin 8), 17 composite outfall samples at Site 3 (Sub-basins 3 and 4), and 5 storm events at Site 4 (Sub-basin 8).

Figure 5-10a. Photograph of the Final Golf Course Pond and Connecting Ditch.

Figure 5-10b. Photograph of Earthen Ditch Terminating into a 15-inch RCP.

Figure 5-11. Photograph of the Stormwater Monitoring Equipment.

5.1.2.2 Chemical Characteristics

Each of the collected composite stormwater samples was returned to the ERD Laboratory and analyzed for the general parameters, nutrients, fecal coliform bacteria, and BOD. A complete listing of laboratory measurements performed on the collected samples is given in Table 5-4, along with a summary of analytical methods and detection limits. A complete listing of individual laboratory analyses performed on the collected stormwater samples is given in Appendix E.

TABLE 5-4

ANALYTICAL METHODS AND DETECTION LIMITS FOR LABORATORY ANALYSES CONDUCTED BY ENVIRONMENTAL RESEARCH AND DESIGN, INC.

MEASUREMENT PARAMETER		METHOD	METHOD DETECTION LIMITS (MDLs)[1]
General Parameters	Hydrogen Ion (pH)	EPA-83[2], Sec. 150.1/Manf. Spec.[3]	N/A
	Alkalinity	EPA-83, Sec. 310.1	0.6 mg/l
	TSS	EPA-83, Sec. 160.2	0.7 mg/l
	Color	EPA-83, Sec. 110.3	1 Pt-Co Unit
	Specific Conductivity	EPA-83, Sec. 120.1/Manf. Spec.	0.3 μmho/cm
	Turbidity	EPA-83, Sec. 180.1	0.1 NTU
Nutrients	Ammonia-N (NH_3-N)	EPA-83, Sec. 350.1	0.005 mg/l
	Nitrate + Nitrite (NO_x-N)	EPA-83, Sec. 353.2	0.005 mg/l
	Organic Nitrogen	Alkaline Persulfate Digestion[4]	0.025 mg/l
	Orthophosphorus	EPA-83, Sec. 365.1	0.001 mg/l
	Total Phosphorus	Alkaline Persulfate Digestion[4]	0.001 mg/l
Biological Parameters	Fecal Coliform	SM-19, Sec. 9222 D.	1 cfu/ml
Demand Parameters	BOD	SM-19, Sec. 5210 B.	2 mg/l

1. MDLs are calculated based on the EPA method of determining detection limits.
2. Methods for Chemical Analysis of Water and Wastes, EPA 600/4-79-020, Revised March 1983.
3. Subject to manufacturer's specifications for test equipment used.
4. FDEP-approved method.

A summary of the characteristics of stormwater runoff samples collected at Site 1 (Sub-basin 1) and Site 2 (Sub-basin 8) from December 2006-June 2007 is given in Table 5-5. In general, stormwater runoff collected at the two monitoring sites was approximately neutral in pH and moderately to poorly buffered, with mean alkalinities ranging from 46.7-76.6 mg/l. Mean conductivity values at the two sites range from 138-189 μmho/cm, slightly lower than conductivity measurements commonly observed in urban runoff.

TABLE 5-5

CHARACTERISTICS OF STORMWATER SAMPLES COLLECTED AT MONITORING SITE 1 (SUB-BASIN 1) AND SITE 2 (SUB-BASIN 8) FROM DECEMBER 2006-JUNE 2007

PARAMETER	UNITS	SITE 1 (SUB-BASIN 1)[1]			SITE 2 (SUB-BASIN 8)[2]		
		Mean	Min	Max	Mean	Min	Max
pH	s.u.	7.13	6.94	7.28	7.22	6.58	7.80
Conductivity	μmho/cm	138	74	213	189	73	333
Alkalinity	mg/l	46.7	24.2	66.0	76.6	31.6	161
NH_3	μg/l	64	< 5	109	387	24	1265
NO_x	μg/l	287	100	621	549	132	1125
Diss. Org N	μg/l	133	< 30	574	468	116	1020
Particulate N	μg/l	196	25	714	1879	615	4884
Total N	μg/l	677	236	1089	3162	998	6549
SRP	μg/l	18	< 1	48	175	32	327
Diss. Org P	μg/l	12	1	56	62	5	101
Particulate P	μg/l	114	34	227	620	136	1314
Total P	μg/l	144	61	236	857	173	1538
Turbidity	NTU	22.9	6.3	40.3	70.2	2.8	290
TSS	mg/l	60.9	16.8	129	189	9.6	453
BOD	mg/l	5.7	< 2	22.3	12.2	6.5	19.2
Fecal Coliform	cfu/100 ml	2426	115	8700	20,644	320	58,667
Color	Pt-Co units	16	11	25	34	16	67

1. n = 8 samples
2. n = 6 samples

Measured total nitrogen concentrations at Site 1, which primarily reflects runoff collected along U.S. 441, were found to be low in value, with a mean total nitrogen concentration of only 677 μg/l. This value is substantially lower than the mean of 3162 μg/l measured at Site 2 which reflects runoff generated from a residential area. The dominant nitrogen species in runoff collected along U.S. 441 is NO_x which comprised approximately 42% of the total nitrogen measured at the site. An additional 29% was contributed by particulate nitrogen, with 20% contributed by dissolved organic nitrogen and 10% contributed by ammonia. In the residential runoff, the dominant nitrogen species is particulate nitrogen which comprised approximately 59% of the total nitrogen measured at this site. Dissolved organic nitrogen contributed approximately 15% of the total nitrogen, with 17% contributed by NO_x and the remainder by ammonia. Nitrogen concentrations measured at the residential site are somewhat higher than nitrogen concentrations commonly observed from this land use type.

The measured total phosphorus concentration at the U.S. 441 monitoring site was relatively low in value, with a mean total phosphorus concentration of only 144 μg/l. The dominant phosphorus species measured at this site is particulate phosphorus which comprised approximately 79% of the phosphorus observed at this site. In contrast, substantially elevated total phosphorus concentrations were observed at the residential site, with a mean concentration of 857 μg/l. This value is approximately three times greater than the typical total phosphorus concentrations observed in residential runoff. The dominant phosphorus species at this site is particulate phosphorus which comprised approximately 72% of the measured phosphorus. Total phosphorus concentrations as high as 1538 μg/l were measured at this site, which is approximately five times greater than phosphorus concentrations commonly observed in residential runoff. Sub-basin 8 appears to contribute elevated phosphorus loadings from runoff generated within this area.

Measured concentrations of turbidity, TSS, BOD, and fecal coliform bacteria at the U.S. 441 monitoring site are typical of concentrations commonly observed in highway runoff. In general, measured values for these parameters were found to be relatively low in value. In contrast, substantially elevated concentrations of turbidity, TSS, BOD, and fecal coliform bacteria were measured at the residential monitoring site. In addition to contributing elevated phosphorus loadings, this sub-basin also appears to be a significant source of suspended solids and fecal coliform bacteria into Spring Lake.

Characteristics of stormwater samples collected at monitoring Site 3 (Sub-basins 3 and 4) and Site 4 (Sub-basin 2) from December 2006-June 2007 are summarized in Table 5-6. In general, stormwater collected at the two monitoring sites was found to be approximately neutral in pH and moderately buffered, with mean alkalinity values ranging from 55.3-75.2 mg/l. The mean conductivity value of 247 μmho/cm measured at Site 3 is typical of conductivity measurements commonly observed in urban runoff. The mean conductivity value of 466 μmho/cm measured at Site 4, which reflects outflow from the golf course ponds, appears to be somewhat elevated.

In general, low to moderate concentrations of total nitrogen were observed at each of the two monitoring sites. The dominant nitrogen species at each of the two monitoring sites is dissolved organic nitrogen, followed by particulate nitrogen and inorganic nitrogen species.

In contrast, elevated levels of total phosphorus were observed at each of the two monitoring sites. A mean total phosphorus concentration of 294 μg/l was observed at Site 3 which reflects the outflow from a wet detention treatment system. Since wet detention systems typically achieve approximately 60% removal for phosphorus, the mean input concentration of total phosphorus into this system would be approximately 735 μg/l to result in an outflow concentration of 294 μg/l. This site receives runoff from portions of adjacent golf course areas which may be responsible for the elevated phosphorus levels observed at this site. Elevated phosphorus concentrations were also observed at Site 4 which reflect discharges from the on-site golf course ponds. Substantially elevated levels of SRP were observed at this site, with concentrations approximately 10 times higher than normally observed in urban runoff.

Measured concentrations of turbidity, TSS, BOD, and fecal coliform bacteria measured at Sites 3 and 4 are typical of values commonly observed in urban runoff. A relatively low level of fecal coliform bacteria was observed at the outfall from the wet detention pond for Sub-basins 3 and 4 (Site 3), with a somewhat higher fecal coliform level observed in the outflow from the golf course ponds. Exceedances of the Class III criterion for fecal coliform of 200 cfu/100 ml were observed in 6 of the 17 samples collected at the outflow from Site 3, with exceedances occurring during 3 of the 5 monitoring events in discharges from the golf course ponds.

TABLE 5-6

CHARACTERISTICS OF STORMWATER SAMPLES COLLECTED AT MONITORING SITE 3 (SUB-BASINS 3 AND 4) AND SITE 4 (SUB-BASIN 2) FROM DECEMBER 2006 - JUNE 2007

PARAMETER	UNITS	SITE 3 (SUB-BASINS 3 & 4)[1]			SITE 4 (SUB-BASIN 2)[2]		
		Mean	Min	Max	Mean	Min	Max
pH	s.u.	7.40	7.01	7.94	7.07	6.85	7.32
Conductivity	μmho/cm	247	163	328	466	387	525
Alkalinity	mg/l	75.2	52.2	103	55.3	41.2	64.0
NH_3	μg/l	166	< 5	632	254	86	570
NO_x	μg/l	273	52	604	187	52	476
Diss. Org N	μg/l	556	133	1502	885	133	1502
Particulate N	μg/l	424	115	1335	767	115	1335
Total N	μg/l	1410	1017	2380	2009	1017	3170
SRP	μg/l	115	7	284	214	7	463
Diss. Org P	μg/l	32	3	123	49	3	123
Particulate P	μg/l	148	39	479	204	39	479
Total P	μg/l	294	72	784	505	215	692
Turbidity	NTU	13.1	2.8	42.4	16.1	5.0	39.3
TSS	mg/l	33.2	1.2	116	50.4	7.7	148
BOD	mg/l	6.0	< 2	11.0	5.0	3.1	6.1
Fecal Coliform	cfu/100 ml	327	4	2100	3855	112	14,100
Color	Pt-Co units	40	31	54	72	48	101

1. n = 17 samples
2. n = 5 samples

A statistical summary of measured values for nitrogen species in stormwater collected at the four monitoring sites is given in Figure 5-12. A graphical summary of laboratory data is presented in the form of Tukey box plots, also often called "box and whisker plots". The bottom of the box portion of each plot represents the lower quartile, with 25% of the data points lying below this value. The upper line of the box represents the 75% upper quartile, with 25% of the data lying above this value. The **blue horizontal line** within the box represents the median value, with 50% of the data falling both above and below this value, while the **red horizontal line** represents the mean value. The vertical lines, also known as "whiskers", represent the 5 and 95 percentiles for the data sets. Individual values which lie outside of the 5-95 percentile range are indicated as **red dots**.

As seen in Figure 5-12, a relatively high degree of variability was observed in measured concentrations of ammonia at the four monitoring sites, with the largest degree of variability observed at the residential site (Site 2). A high degree of variability was also observed in measured concentrations for NO_x, particulate nitrogen, and total nitrogen at the residential monitoring site. A much lower degree of variability is apparent at the remaining sites, particularly for particulate nitrogen and total nitrogen. The most elevated total nitrogen concentrations were observed at the residential site, followed by outflow from the golf course ponds, outflow from the wet detention pond, and runoff from U.S. 441.

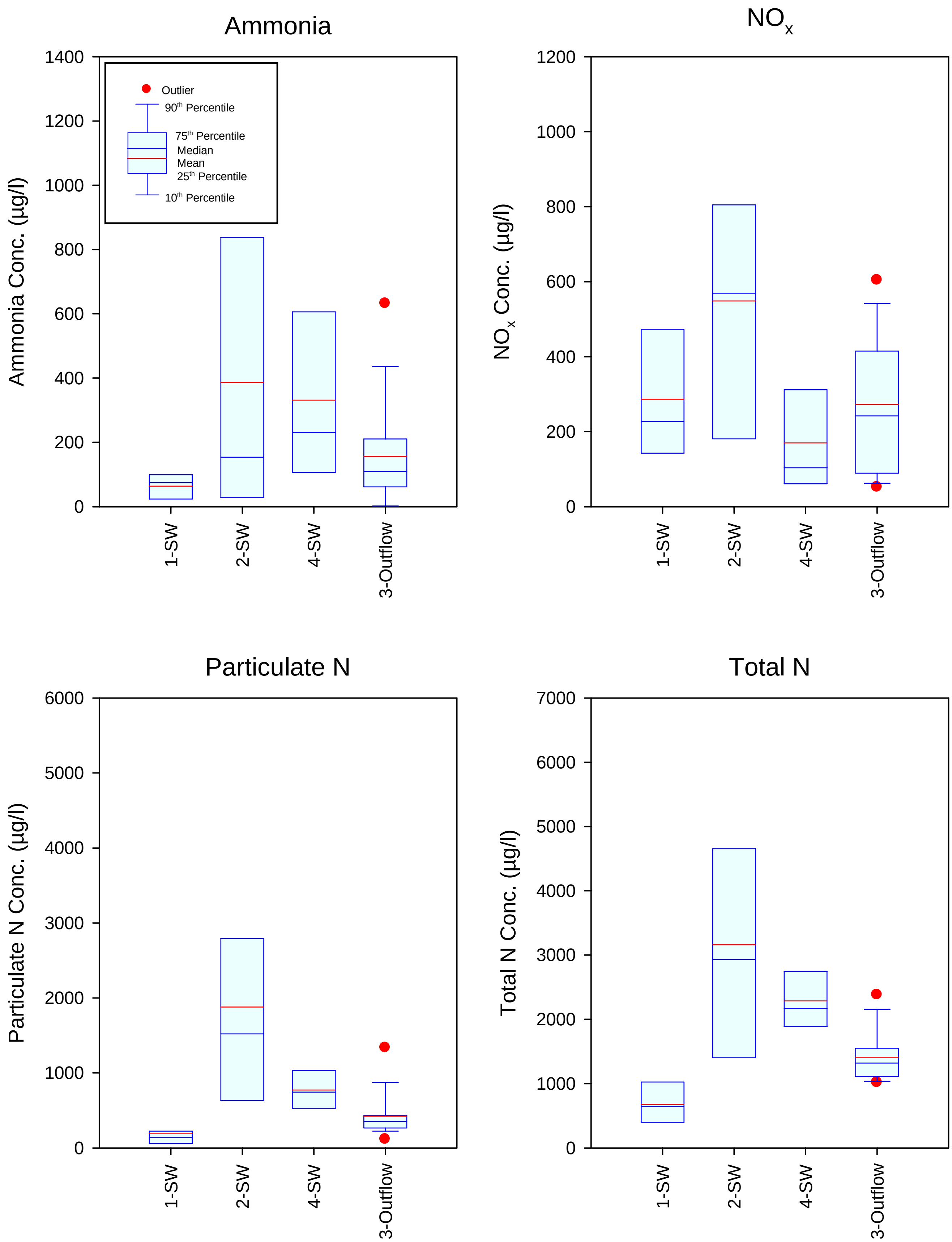


Figure 5-12. Statistical Summary of Measured Values for Nitrogen Species in Runoff Samples Collected in the Spring Lake Drainage Basin from December 2006-June 2007.

A statistical summary of measured concentrations for phosphorus species in stormwater runoff at the four monitoring sites is given in Figure 5-13. A relatively high degree of variability was observed at the residential monitoring site for dissolved organic phosphorus, particulate phosphorus, and total phosphorus. The most elevated phosphorus concentrations were observed at the residential monitoring site, followed by discharges from the golf course ponds, discharges from the wet detention pond, and runoff from U.S. 441. Discharges from the golf course ponds were also found to have substantially elevated levels of SRP which are approximately 2-3 times higher than observed at the remaining monitoring sites.

5.1.2.3 Selection of Characterization Data

A comparison of mean runoff characteristics measured at the four monitoring sites is given in Table 5-7. The most elevated concentrations of total nitrogen, total phosphorus, TSS, BOD, and fecal coliform bacteria were observed in runoff collected from the residential sub-basin. The measured runoff characteristics in this sub-basin are substantially higher than common observed in residential areas, particularly for total phosphorus and TSS. The second highest concentrations for runoff constituents were observed in the golf course area at Site 4. Runoff characteristics monitored at this site are similar to characteristics commonly observed from golf course areas. The lowest concentrations for the measured parameters were observed in the highway and commercial areas along U.S. 441.

TABLE 5-7

COMPARISON OF MEAN RUNOFF CHARACTERISTICS MEASURED AT THE FOUR MONITORING SITES

PARAMETER	UNITS	SITE 1	SITE 2	SITE 3	SITE 4
pH	s.u.	7.13	7.22	7.40	7.07
Conductivity	μmho/cm	138	189	247	466
Alkalinity	mg/l	46.7	76.6	75.2	55.3
NH_3	μg/l	64	387	166	254
NO_x	μg/l	287	549	273	187
Diss. Org N	μg/l	133	468	556	885
Particulate N	μg/l	196	1879	424	767
Total N	μg/l	677	3162	1410	2009
SRP	μg/l	18	175	115	214
Diss. Org P	μg/l	12	62	32	49
Particulate P	μg/l	114	620	148	204
Total P	μg/l	144	857	294	505
Turbidity	NTU	22.9	70.2	13.1	16.1
TSS	mg/l	60.9	189	33.2	50.4
BOD	mg/l	5.7	12.2	6.0	5.0
Fecal Coliform	cfu/100 ml	2426	20,644	327	3855
Color	Pt-Co units	16	34	40	72
Primary Land Use Types		Highway/ Commercial	Residential	Pond Outflow for Commercial/ Residential/ Golf Course	Golf Course

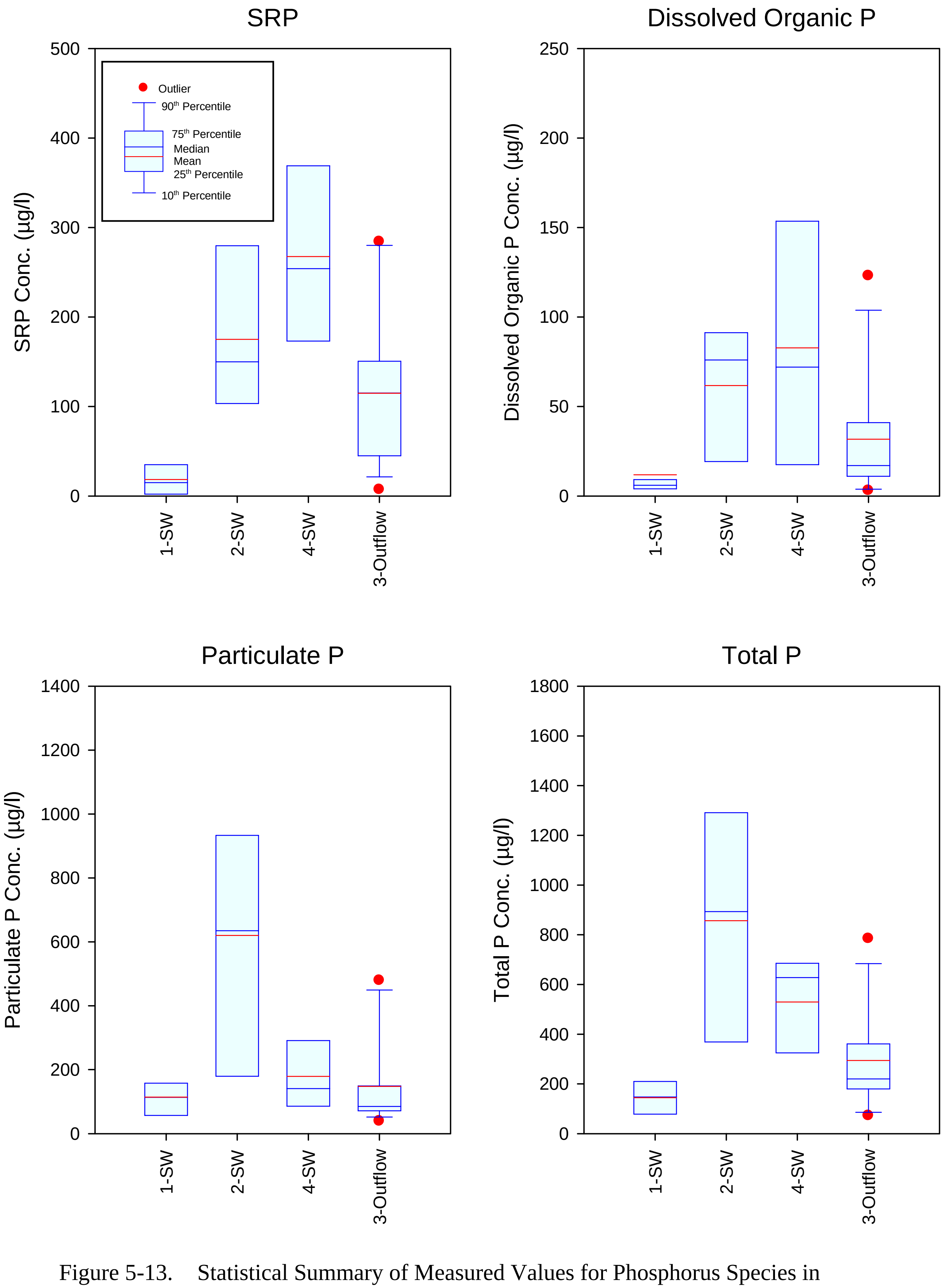


Figure 5-13. Statistical Summary of Measured Values for Phosphorus Species in Runoff Samples Collected in the Spring Lake Drainage Basin from December 2006-May 2007.

Unfortunately, it was not feasible to conduct runoff characterization studies in each of the 10 sub-basin areas which discharge to Spring Lake. Therefore, sub-basin areas which were not directly monitored are assigned runoff characteristics based upon similarities between land use characteristics in the unmonitored sub-basins and in the five monitored sub-basins. A summary of assumed runoff characteristics for sub-basin areas discharging to Spring Lake is given in Table 5-8. Sub-basins 1, 2, 3, 4, and 8 were monitored directly as part of this project. Sub-basin areas 6 and 7 (which reflect primarily residential land use characteristics immediately adjacent to Spring Lake) are assumed to have runoff characteristics similar to those measured in Sub-basin 8.

TABLE 5-8

SUMMARY OF ASSUMED RUNOFF CHARACTERISTICS FOR SUB-BASIN AREAS DISCHARGING TO SPRING LAKE

SUB-BASIN NO.	SUB-BASIN DESCRIPTION	ASSUMED RUNOFF CHARACTERISTICS			EXPLANATION
		Total N (µg/l)	Total P (µg/l)	TSS (mg/l)	
1	U.S. 441	677	144	60.9	Direct measurement
2	Golf course area	2009	505	50.4	Direct measurement
3	Golf course area	1410	294	33.2	Direct measurement
4	Commercial/ residential	1410	294	33.2	Direct measurement
5	Commercial/ Residential	1920	501	125	Assumed to be mean of Sub-basins 1 and 8
6	Residential	3162	857	189	Assumed to be similar to Sub-basin 8
7	Residential	3162	857	189	Assumed to be similar to Sub-basin 8
8	Residential	3162	857	189	Direct measurement
9	U.S. 441	677	144	60.9	Assumed to be similar to Sub-basin 1
10	Residential[1]	1581	429	945	Assumed to be 50% of Sub-basin 8
11	Direct runoff	2589	681	120	Assumed to be mean of Sub-basins 2 and 8

1. Assumed to be equal to 50% of the sub-basin characteristics

Sub-basin 5 contains a mixture of highway and commercial activities along Colonial Drive as well as a continuation of the residential community monitored in Sub-basin 8. Residential areas are also located within this basin south of Colonial Drive. Therefore, for purposes of estimating runoff characteristics, this basin is assumed to be a blend of highway and commercial areas monitored as part of Sub-basin 1 and residential areas monitored in Sub-basin 8. Runoff characteristics for Sub-basin 5 are assumed to be the mean of runoff characteristics measured in Sub-basins 1 and 8.

Runoff characteristics for Sub-basin 9 (which reflects primarily U.S. 441 and adjacent areas) are assumed to be similar to direct measurements conducted in Sub-basin 1. Sub-basin 11 reflects areas which have direct runoff into Spring Lake. These areas reflect a combination of golf course areas and residential lawns. Therefore, runoff characteristics for these areas are assumed to be reflected by the mean of runoff characteristics measured in Sub-basin 2 and Sub-basin 8. Sub-basin 10 is a residential area which is entirely treated with a dry stormwater treatment area. In addition to the runoff volume reduction achieved in a dry system, a reduction in concentration of runoff can also be expected. Therefore, for purposes of this analysis, concentrations of total nitrogen, total phosphorus, and TSS in Sub-basin 10 are assumed to be 50% of the values measured in Sub-basin 8. The information summarized in Table 5-7 is used as input into the pollutant loading model to provide estimates of runoff generated pollutant loadings from each of the identified sub-basin areas into Spring Lake.

5.1.2.4 Mass Loadings

Estimates of mass loadings of total nitrogen, total phosphorus, and TSS discharging into Spring Lake from stormwater runoff were calculated for average annual conditions. The runoff characterization data summarized in Table 5-8 is used as input to provide estimates of the mass loadings of total nitrogen, total phosphorus, and TSS. The runoff characteristics listed in Table 5-8 are multiplied by the observed runoff volumes summarized in Table 4-4 to obtain estimates of mass loadings for these parameters entering Spring Lake. The hydrologic impacts of existing stormwater management systems within the basin are included in the runoff estimates summarized in Table 4-4. Impacts of existing stormwater management systems on runoff characteristics within the drainage basins are included in the runoff characterization studies conducted by ERD since monitoring sites were located downstream from existing stormwater facilities.

A summary of estimated annual loadings of total nitrogen, total phosphorus, and TSS discharging into Spring Lake is given in Table 5-9. During average hydrologic conditions, stormwater runoff contributes approximately 864 kg of total nitrogen, 199.3 kg of total phosphorus, and 37,552 kg of TSS to Spring Lake. Based upon this analysis, the largest contributors of nitrogen, phosphorus, and TSS to Spring Lake appear to be Sub-basins 1, 2, 4, and 5. Combined together, these sub-basins contribute approximately 80.6% of the total nitrogen loading, 78.2% of the total phosphorus loading, and 75.7% of the TSS loading to Spring Lake. The remaining sub-basin areas contribute approximately 6% or less of the loadings to the lake.

Calculated areal loading rates for each sub-basin area are also provided in Table 5-9. These values are obtained by dividing the mass loading for total nitrogen, total phosphorus, and TSS for each sub-basin by the sub-basin area. This type of analysis allows an evaluation of pollutant loadings which is independent of the size of the drainage basin. Average areal loading rates for the 10 sub-basin areas are provided at the bottom of Table 5-9. Higher than average pollutant loading rates were observed in Sub-basins 4, 5, 6, 7, 8, and 9. The information summarized in Table 5-9 is used for development of overall nutrient budgets for the lake and to assist in evaluating opportunities for water quality improvement projects.

TABLE 5-9

RUNOFF GENERATED ANNUAL MEAN LOADINGS OF TOTAL NITROGEN, TOTAL PHOSPHORUS, AND TSS TO SPRING LAKE

SUB-BASIN NO.	AREA (ac)	RUNOFF VOLUME (ac-ft)	MASS LOADING (kg)			PERCENT OF TOTAL (%)			AREAL LOADING (kg/ac)		
			Total N	Total P	TSS	Total N	Total P	TSS	Total N	Total P	TSS
1	72.59	135.40	113.1	24.01	10169	13.1	12.1	27.1	1.56	0.33	140.1
2	46.42	43.17	107.0	26.89	2683	12.4	13.5	7.1	2.30	0.58	57.8
3	34.07	10.93	19.0	3.96	448	2.2	2.0	1.2	0.56	0.12	13.1
4	104.76	213.57	371.4	77.4	8744	43.0	38.9	23.3	3.55	0.74	83.5
5	38.99	44.26	104.8	27.35	6823	12.1	13.7	18.2	2.69	0.70	175.0
6	10.79	9.46	36.9	10.0	2205	4.3	5.0	5.9	3.42	0.93	204.4
7	5.76	4.52	17.6	4.8	1054	2.0	2.4	2.8	3.06	0.83	182.9
8	13.46	11.39	44.4	12.0	2655	5.1	6.0	7.1	3.30	0.89	197.2
9	3.67	11.29	9.4	2.0	848	1.1	1.0	2.3	2.57	0.55	231.0
10	6.83	1.17	2.3	0.6	136	0.3	0.3	0.4	0.33	0.09	20.0
11	26.31	12.07	38.5	10.1	1786	5.1	5.1	4.8	1.46	0.39	67.9
Totals:	**363.65**	**497.23**	**864.4**	**199.3**	**37552**	**100.0**	**100.0**	**100.0**	**2.25**	**0.56**	**124.8**

In general, the mean areal loading rates for total nitrogen, total phosphorus, and TSS in stormwater runoff discharging to Spring Lake appear to be substantially elevated compared with values observed in other Central Florida lakes. A hydrologic and nutrient budget was recently completed by ERD for Lake Pineloch. The mean areal loading rates from stormwater runoff to Spring Lake are approximately 2.2 times greater for total nitrogen, 4.0 times greater for total phosphorus, and 2.5 times greater for TSS than observed in stormwater runoff discharging to Lake Pineloch. Based on the summary of runoff generated loadings summarized in Table 5-8, existing residential areas appear to be largely responsible for the observed elevated areal loadings.

5.1.3 Dry Weather Baseflow

During the field monitoring program conducted by ERD, measurable baseflow was observed only at the U.S. 441 (Site 1) monitoring site. Baseflow monitored at this site represents a combination of drawdown from the wet detention stormwater pond located west of U.S. 441 along with groundwater infiltration into the stormsewer system. Baseflow is anticipated at this site whenever discharges occur from the wet pond as a result of inputs of stormwater runoff or under high groundwater elevation conditions. Therefore, a discussion of baseflow characteristics and estimated annual loadings at this site is provided in this section. A complete listing of laboratory analyses performed on the collected dry weather baseflow samples is included in Appendix E.

5.1.3.1 Chemical Characteristics

A summary of the characteristics of dry weather baseflow collected at the U.S. 441 monitoring site from December 2006-June 2007 is given in Table 5-10. Dry weather baseflow was found to be approximately neutral in pH and moderately to poorly buffered. Measured conductivity values are similar to values commonly observed in urban runoff. Baseflow samples collected at this site were found to have low levels of total nitrogen, with approximately 44% of the total nitrogen composed of NO_x. Dissolved organic nitrogen comprises approximately 22% of the total nitrogen, with the remaining nitrogen comprised of ammonia and particulate nitrogen.

TABLE 5-10

CHARACTERISTICS OF DRY WEATHER BASEFLOW SAMPLES COLLECTED FROM SUB-BASIN 1 FROM DECEMBER 2006-JUNE 2007

PARAMETER	UNITS	SUB-BASIN 1[1]		
		Mean	Min	Max
pH	s.u.	7.21	7.06	7.36
Conductivity	µmho/cm	215	207	223
Alkalinity	mg/l	58.1	46.4	73.8
NH_3	µg/l	111	50	170
NO_x	µg/l	305	18	511
Diss. Org N	µg/l	151	95	209
Particulate N	µg/l	129	68	257
Total N	µg/l	695	634	763
SRP	µg/l	3	1	5
Diss. Org P	µg/l	5	2	6
Particulate P	µg/l	51	32	91
Total P	µg/l	58	35	100
Turbidity	NTU	9.3	4.2	21.8
TSS	mg/l	20.8	9.2	49.8
BOD	mg/l	2.2	< 2.0	4.6
Fecal Coliform	cfu/100 ml	272	92	480
Color	Pt-Co units	16	12	20

1. n = 4 samples

Dry weather baseflow at the U.S. 441 monitoring site was found to have relatively low levels of total phosphorus. The dominant phosphorus species at this site is particulate phosphorus which comprised approximately 88% of the total phosphorus measured. Relatively low levels of turbidity, TSS, and BOD were observed in baseflow which would be expected in discharges from a stormwater treatment facility or groundwater infiltration. Relatively low levels of fecal coliform bacteria were observed in the dry weather baseflow samples, with exceedances of the Class III criterion for fecal coliform bacteria observed in two of the four collected baseflow samples.

5.1.3.2 Mass Loadings

Estimates of mass loadings of nitrogen, phosphorus, and TSS discharging from the U.S. 441 sub-basin into Spring Lake as a result of dry weather baseflow were generated by multiplying the mean baseflow characteristics summarized in Table 5-8 times the estimated annual dry weather baseflow volume of 14.28 ac-ft. A summary of the results of this analysis is given in Table 5-11. During an average year, baseflow from the U.S. 441 sub-basin contributes approximately 12.2 kg of total nitrogen, 1.0 kg of total phosphorus, and 366 kg of TSS to Spring Lake. This information is utilized in a subsequent section for development of pollutant inputs into the lake.

TABLE 5-11

ANNUAL MASS LOADINGS OF DRY WEATHER BASEFLOW ENTERING SPRING LAKE FROM THE U.S. 441 SUB-BASIN

VOLUME (ac-ft)	MASS LOADING (kg)		
	TOTAL N	TOTAL P	TSS
14.28	12.2	1.0	366

5.1.4 Groundwater Seepage

5.1.4.1 Chemical Characteristics

Nutrient influx from groundwater seepage was quantified using a total of 11 underwater seepage meters installed at locations throughout the lake. A discussion of the hydrologic inputs resulting from groundwater seepage is given in Section 4.1.4. Each of the collected groundwater seepage samples was analyzed in the ERD Laboratory for pH, alkalinity, conductivity, total nitrogen, and total phosphorus. A complete listing of laboratory measurements conducted on seepage samples collected at each of the 11 sites is given in Appendix F.1.

A summary of mean chemical characteristics of seepage samples collected in Spring Lake from October 2006-May 2007 is given in Table 5-12. Groundwater seepage collected from Spring Lake was found to be approximately neutral in pH, with measured conductivity values slightly higher than most commonly observed in urban runoff. A wide range of nitrogen concentrations was observed in seepage samples, with mean values ranging from 3441-14,543 µg/l. A similar degree of variability was observed for mean total phosphorus concentrations which ranged from approximately 302-1063 µg/l. The overall mean total phosphorus concentration of 692 µg/l in groundwater seepage appears to be similar to values commonly observed in groundwater seepage entering urban lakes, while the mean total nitrogen concentration appears to be substantially elevated.

Mean isopleths of conductivity in groundwater samples entering Spring Lake from October 2006-May 2007 are illustrated on Figure 5-14. In general, relatively elevated conductivity values were observed in groundwater seepage along the northwestern and western portions of the lake adjacent to golf course areas. Substantially lower levels for specific conductivity were observed along the southeastern and southern portions of the lake.

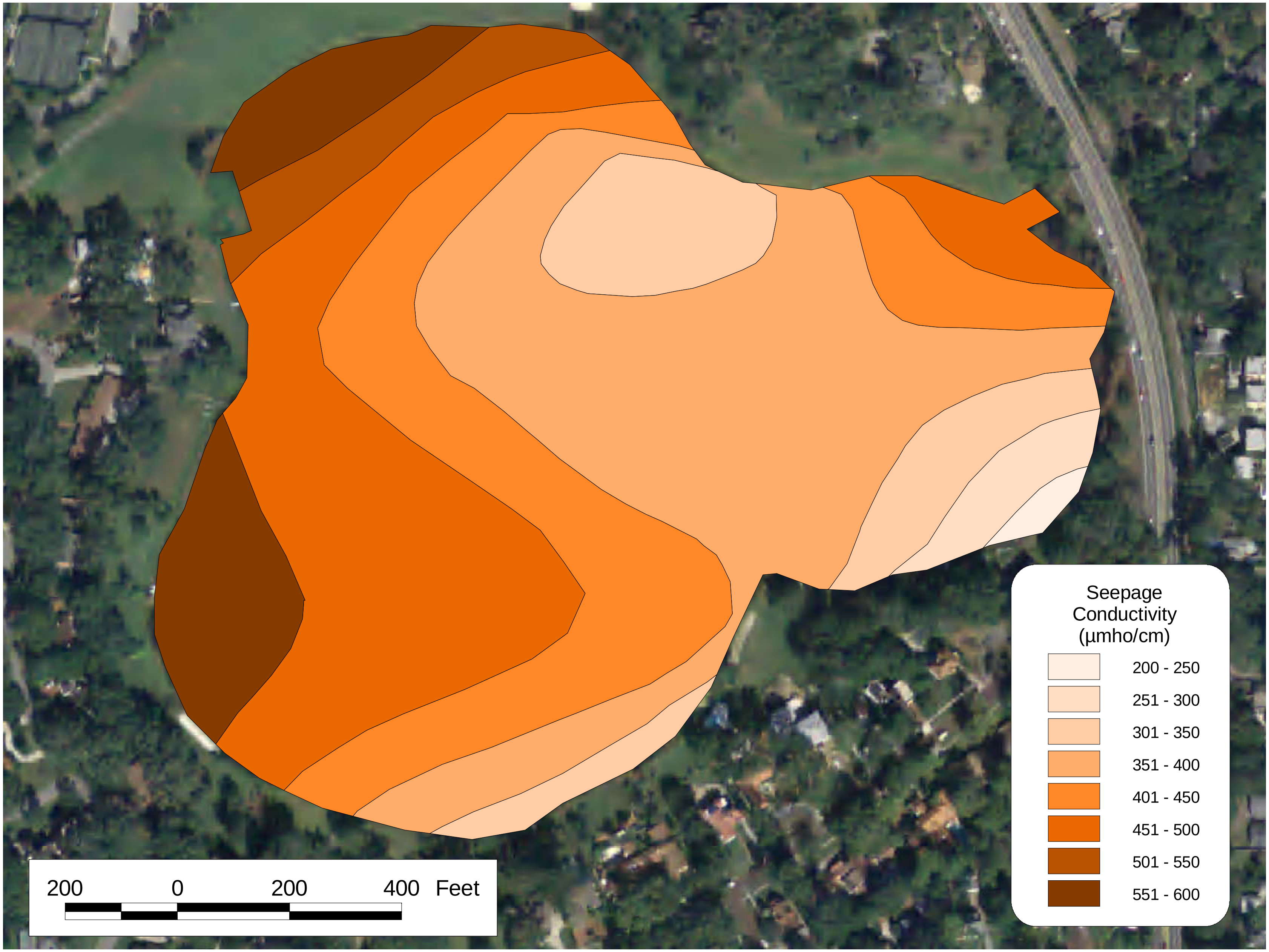


Figure 5-14. Mean Isopleths of Conductivity in Groundwater Seepage Entering Spring Lake from October 2006-May 2007.

TABLE 5-12

MEAN CHARACTERISTICS OF SEEPAGE SAMPLES COLLECTED FROM SPRING LAKE FROM OCTOBER 2006-MAY 2007

SITE	NO. OF SAMPLES	pH (s.u.)	ALKALINITY (mg/l)	CONDUCTIVITY (μmho/cm)	TOTAL N (μg/l)	TOTAL P (μg/l)
1	6	7.56	204	564	14,747	2,200
2	6	7.53	101	324	5,060	246
3	6	7.59	120	485	6,497	238
4	6	7.37	65.7	248	1,479	79
5	6	7.20	80.5	378	13,313	843
6	6	7.73	125	402	12,752	497
7	6	7.71	129	340	3,441	302
8	6	7.83	242	511	7,226	772
9	6	7.68	238	480	6,995	1,063
10	6	7.32	154	476	14,543	845
11	6	7.21	94.6	376	7,837	532
Mean:		**7.52**	**141**	**417**	**8,535**	**692**

Mean isopleths of total nitrogen concentrations in groundwater seepage entering Spring Lake from October 2006-May 2007 are illustrated on Figure 5-15. Areas of substantially elevated seepage concentrations of total nitrogen are apparent adjacent to the golf course areas, and in deep pockets, with lower seepage nitrogen concentrations observed along the eastern and southern sides of the lake.

Mean isopleths of total phosphorus concentrations in groundwater seepage entering Spring Lake from October 2006-May 2007 are illustrated on Figure 5-16. Areas of elevated total phosphorus concentrations, exceeding 2000 μg/l, are apparent in northwestern portions of the lake adjacent to the golf course areas. Phosphorus concentrations approaching 1000 μg/l were measured in deep pockets of the lake. Areas of lower total phosphorus concentrations are apparent along the eastern and southern sides of the lake. In general, the seepage isopleths for total phosphorus appear similar to the isopleths for total nitrogen.

5.1.4.2 <u>Mass Loadings</u>

Mean seepage isopleths for nitrogen influx, in term of $\mu g/m^2$-day, were generated by combining the concentration isopleths for total nitrogen (provided in Figure 5-15) with the hydrologic isopleths for groundwater seepage (summarized on Figure 4-6). This procedure results in estimates of nitrogen influx in terms of mass of nitrogen per square meter of lake surface per day. For purposes of this analysis, the term "influx" or "flux" is defined as the areal mass input or loading per unit of time.

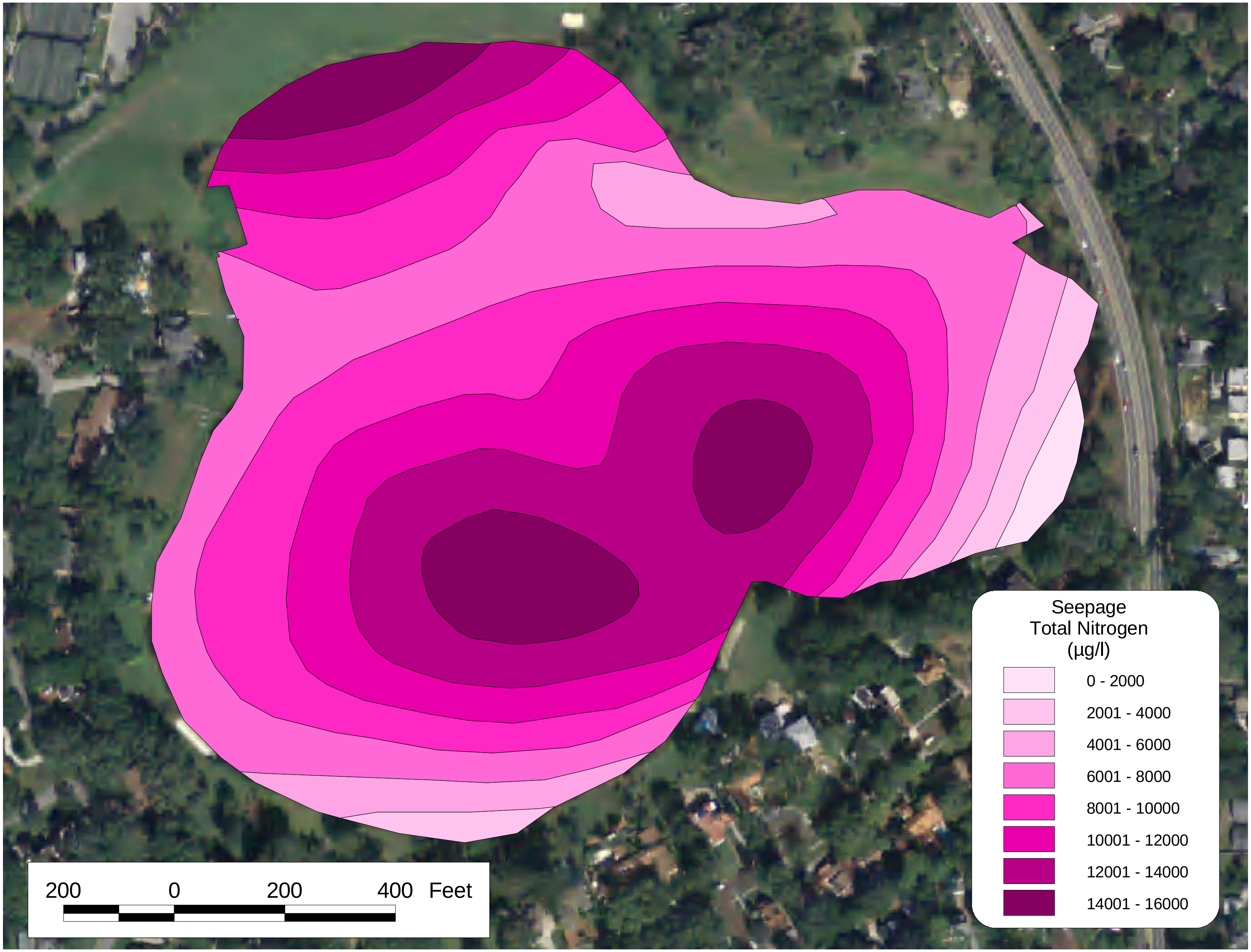


Figure 5-15. Mean Isopleths of Total Nitrogen Concentrations in Groundwater Seepage Entering Spring Lake from October 2006-May 2007.

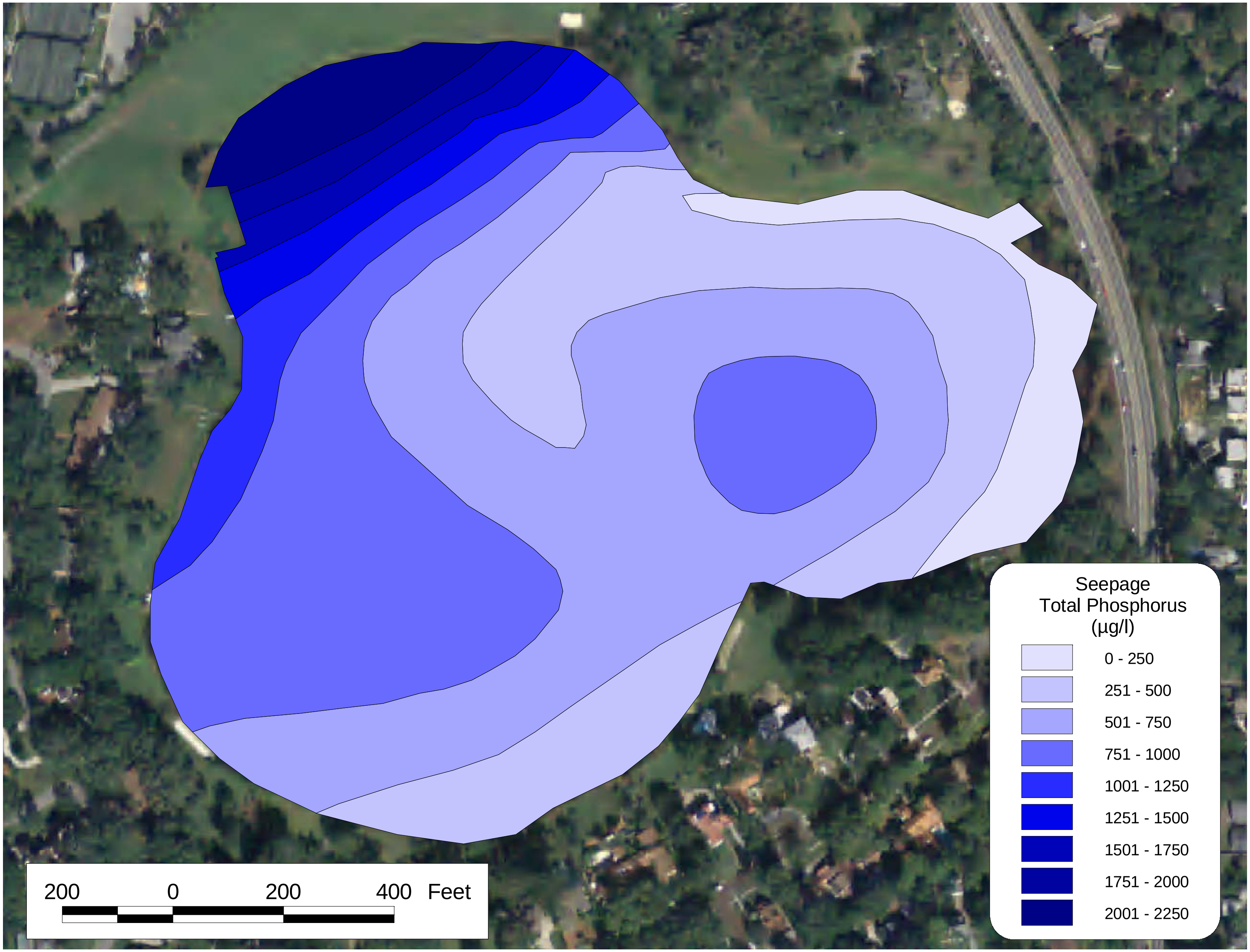


Figure 5-16. Mean Isopleths of Total Phosphorus Concentrations in Groundwater Seepage Entering Spring Lake from October 2006-May 2007.

Isopleths of mean seepage influx of total nitrogen into Spring Lake are illustrated on Figure 5-17. In general, nitrogen influx from groundwater seepage ranges from approximately 2,000-20,000 μg/m^2-day within the lake. Substantially elevated levels of nitrogen influx were observed along the southern side of the lake, with substantially lower nitrogen influx along the east shoreline of the lake. The elevated nitrogen flux along the southern lake shoreline is due primarily to the impacts of the elevated flow rates measured in this area.

Mean seepage phosphorus influx isopleths are summarized on Figure 5-18. These isopleths were generated by combining the phosphorus concentration isopleths (summarized on Figure 5-16) with the seepage inflow isopleths (summarized on Figure 4-3). In general, phosphorus influx into Spring Lake ranges from approximately 250-2000 μg/m^2-day. These values appear to be similar to phosphorus influx commonly observed in urban lakes. Areas of elevated phosphorus influx are apparent along the northwestern, western, and southern shorelines of the lake, with lower levels of phosphorus influx along the eastern portions of the lake.

The isopleths summarized in Figures 5-17 and 5-18 were integrated to develop estimates of daily influx of nitrogen and phosphorus from groundwater seepage into Spring Lake over an annual period. The estimated daily mass influx values for nitrogen and phosphorus were multiplied by 365 days/year to provide an estimate of annual loadings of nitrogen and phosphorus to Spring Lake from groundwater seepage. Calculations used for estimation of seepage influx are included in Appendix F.2.

A summary of estimated annual mass loadings of total nitrogen and total phosphorus from groundwater seepage is given in Table 5-13. Overall, groundwater seepage contributes approximately 456.6 kg of total nitrogen and 35.8 kg of total phosphorus to Spring Lake each year. Calculated areal loadings of groundwater seepage are provided in the final columns of Table 5-13. These values reflect the mass influx divided by the lake surface area of 38.24 ac. The mean annual total nitrogen influx into the lake is approximately 11.9 kg/ac, with a mean phosphorus areal loading of approximately 0.94 kg/ac. The estimated annual areal loading of 11.9 kg/ac-yr for total nitrogen is approximately 2.1 times greater than the areal loading for total nitrogen from groundwater seepage entering Lake Pineloch. Areal phosphorus loadings for Spring Lake and Lake Pineloch are approximately equal.

TABLE 5-13

ESTIMATED ANNUAL MASS LOADINGS TO SPRING LAKE FROM GROUNDWATER SEEPAGE

INFLOW VOLUME (ac-ft/yr)	MASS INFLOW (kg/yr)		AREAL LOADING (kg/ac-yr)	
	Total N	Total P	Total N	Total P
213.8	456.6	35.8	11.9	0.94

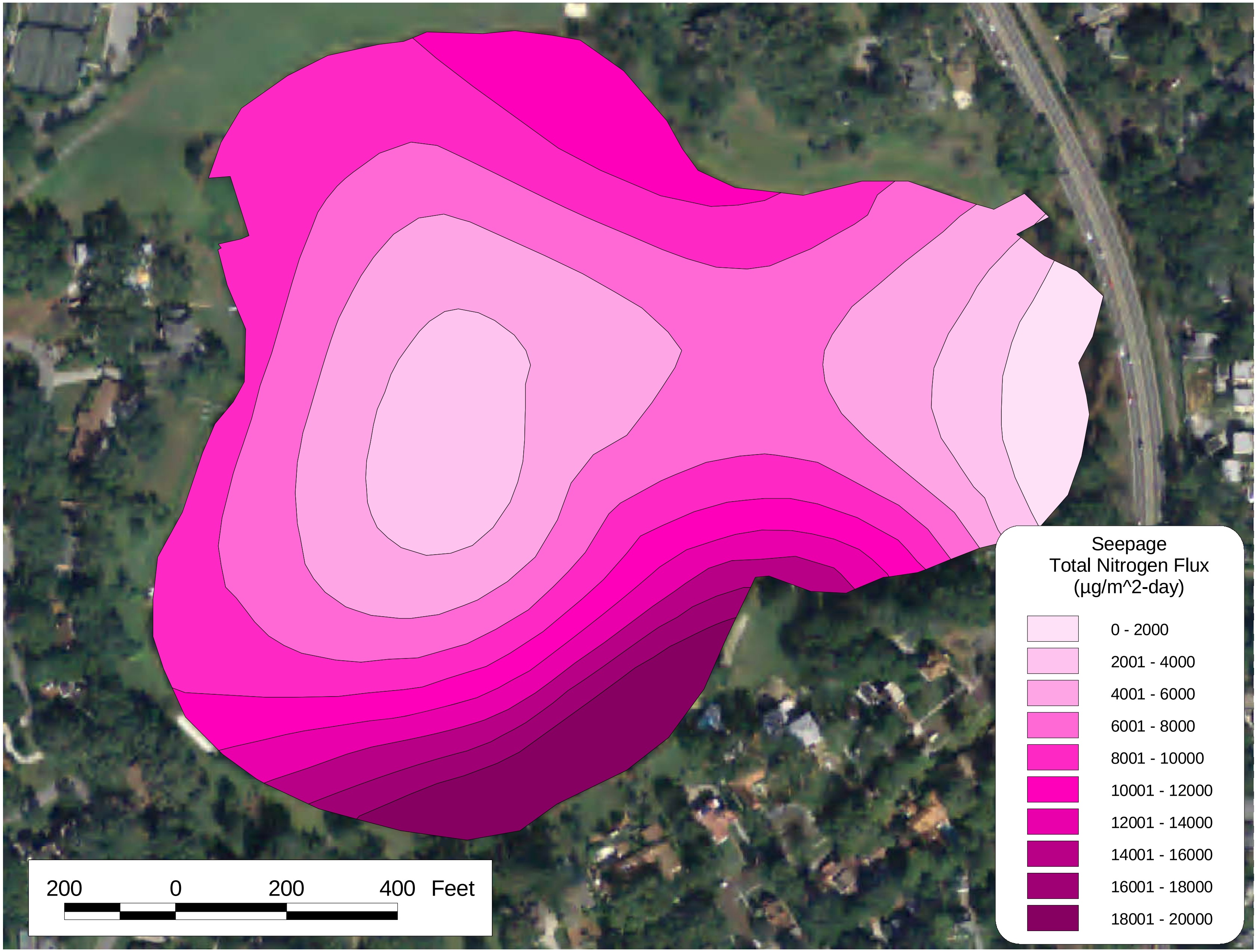


Figure 5-17. Isopleths of Total Nitrogen Influx from Groundwater Seepage Into Spring Lake.

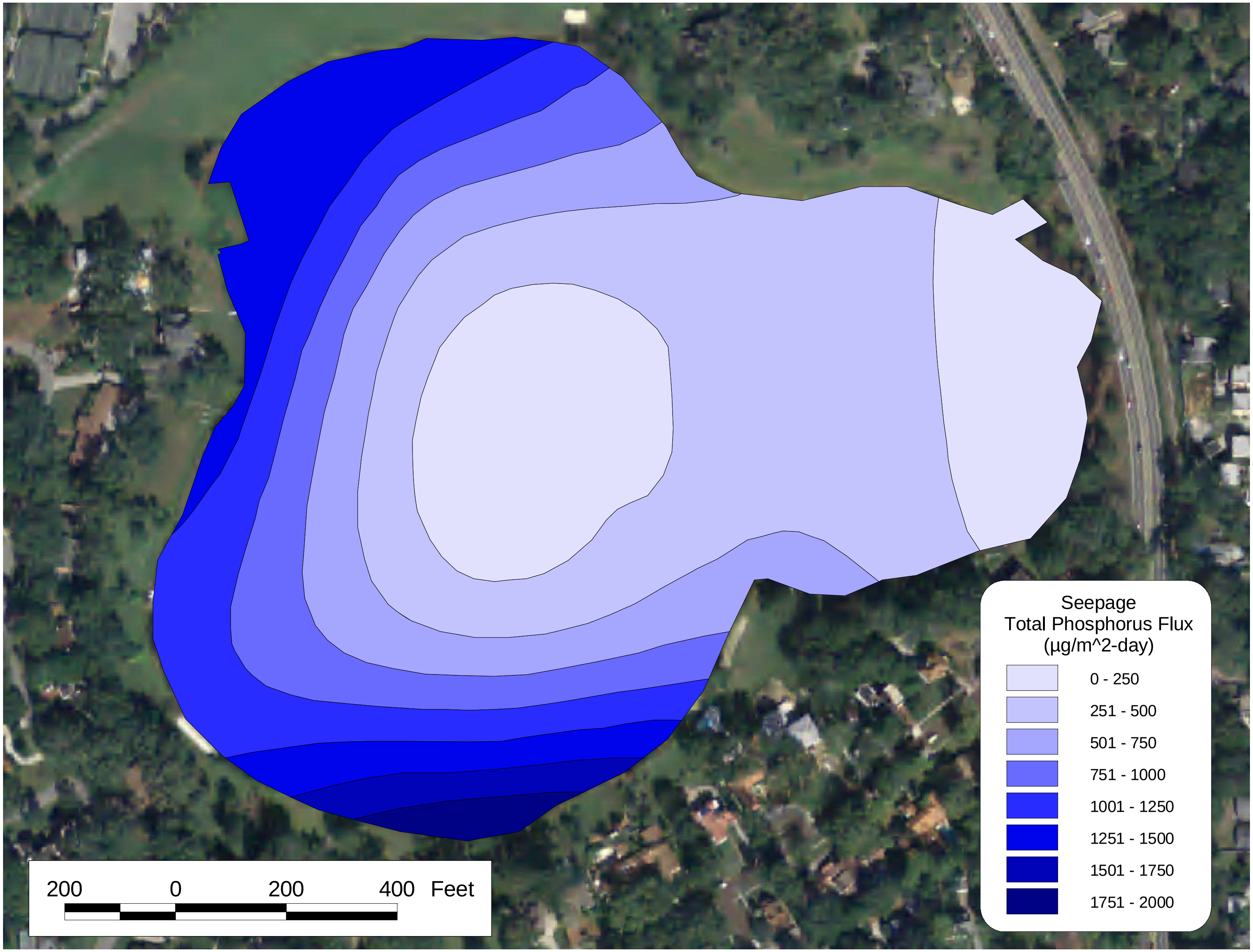


Figure 5-18. Isopleths of Total Phosphorus Influx from Groundwater Seepage Into Spring Lake.

5.1.5 Internal Recycling

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

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

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

The final method used for quantification of internal loadings is to perform sediment release experiments. In this method, large diameter sediment cores are collected from various locations within the lake and incubated in the laboratory under a variety of conditions to simulate variability in the lake throughout the year. Changes in phosphorus concentrations are measured in the overlying sediments, and this information is extrapolated to an areal release rate within the lake. This is the only method of estimating internal loadings which provides a direct measurement of phosphorus release. This method has been used by ERD on multiple occasions in previous work efforts, including Lake Holden and Lake Pineloch in the Central Florida area.

Direct quantification of internal recycling in Spring Lake was not part of the work efforts performed by ERD as part of this evaluation. However, it appears that sediments and water column characteristics in Spring Lake are similar to sediment and water column characteristics in Lake Holden and Lake Pineloch where direct phosphorus release measurements have been performed by ERD. A comparison of measured sediment phosphorus release rates in Lake Pineloch and Lake Holden is given in Table 5-14. Fairly close agreement was observed between these measured values. Due to the similarities between Spring Lake, Lake Holden, and Lake Pineloch, the mean sediment phosphorus release of 582 $\mu g/m^2$-day is used to estimate sediment phosphorus release into Spring Lake.

A summary of calculated sediment phosphorus release in Spring Lake is given in Table 5-15. The surface area of Spring Lake is approximately 38.24 ac which is equivalent to 154,831 m^2. Based upon an assumed phosphorus release rate of 582 $\mu g/m^2$-day, the sediments in Spring Lake are estimated to contribute approximately 90.11 g of phosphorus to the water column each day. Over an annual cycle, this input is equivalent to approximately 32.89 kg/yr.

TABLE 5-14

MEASURED SEDIMENT PHOSPHORUS RELEASE RATES IN SPRING LAKE AND LAKE HOLDEN

LAKE	SEDIMENT PHOSPHORUS RELEASE (μg/m^2-day)
Holden	684
Pineloch	481
MEAN	**582**

TABLE 5-15

CALCULATED SEDIMENT PHOSPHORUS RELEASE IN SPRING LAKE

PARAMETER	VALUE
Lake Area	38.24 acres 154,831 m^2
Sediment Phosphorus Release	582 μg/m^2-day 90.11 g/day 32.89 kg/yr

5.2 Nutrient Losses

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

5.2.1 Outfall and Drainage Well Discharges

Chemical characteristics of discharges through the outfall structure and into the drainage well are assumed to be similar to water quality characteristics in Spring Lake. Water column concentrations of total nitrogen, total phosphorus, and TSS in Spring Lake are assumed to be similar to the historical water quality characteristics summarized in Table 2-7. These mean water quality characteristics are multiplied by the combined annual hydrologic losses through the drainwell and outfall structure, as summarized in Table 4-14, to obtain an estimate of the corresponding annual mass loss through lake outflow. On an annual basis, mass losses as a result of lake outflow remove approximately 1012 kg of total nitrogen, 57.3 kg of total phosphorus, and 7247 kg of TSS from Spring Lake each year. A summary of calculated annual mass losses from Spring Lake from combined outflow is given in Table 5-16.

TABLE 5-16

CALCULATED ANNUAL OUTFLOW MASS LOSSES FROM SPRING LAKE

DISCHARGE VOLUME (ac-ft)	MASS LOSS (kg)		
	Total N	Total P	TSS
725.5	1012	57.3	7247

5.3 Estimated Mass Budgets

An estimated annual mass budget was developed for total nitrogen, total phosphorus, and TSS in Spring Lake based upon the analyses presented in the previous sections. A discussion of estimated mass inputs and losses to Spring Lake is given in the following sections.

5.3.1 Mass Inputs

A summary of estimated annual mass loadings of total nitrogen, total phosphorus, and TSS entering Spring Lake from the evaluated sources is given in Table 5-17. Estimated mass loadings summarized in this table are based upon the discussions and analyses presented in previous sections. Stormwater runoff appears to be the largest source of nitrogen to Spring Lake, contributing approximately 58% of the mass loading. Approximately 31% of the total nitrogen is contributed by groundwater seepage, with 10% by bulk precipitation. Nitrogen loadings from baseflow are relatively minimal.

TABLE 5-17

ESTIMATED ANNUAL MASS LOADINGS OF TOTAL NITROGEN, TOTAL PHOSPHORUS, AND TSS ENTERING SPRING LAKE

SOURCE	TOTAL N		TOTAL P		TSS	
	kg	Percent of Total	kg	Percent of Total	kg	Percent of Total
Stormwater Runoff	864	58	199	71	37,552	91
Baseflow	12.2	< 1	1.0	< 1	366	1
Groundwater Seepage	457	31	35.8	13	Negligible	0
Bulk Precipitation	151	10	12.0	4	3,401	8
Internal Recycling	--	0	32.9	12	--	0
TOTALS:	**1,484**	**100**	**280.7**	**100**	**41,319**	**100**

The largest contributor of phosphorus loadings to Spring Lake appears to be stormwater runoff which contributes approximately 71% of the annual loadings. Approximately 12% of the loading is contributed by internal recycling, with 4% from bulk precipitation. Phosphorus inputs from baseflow appear to be minimal.

Stormwater runoff appears to be the primary input for TSS into Spring Lake, contributing 91% of the measured loadings. Approximately 1% of the TSS loadings originate from baseflow, with 8% from bulk precipitation.

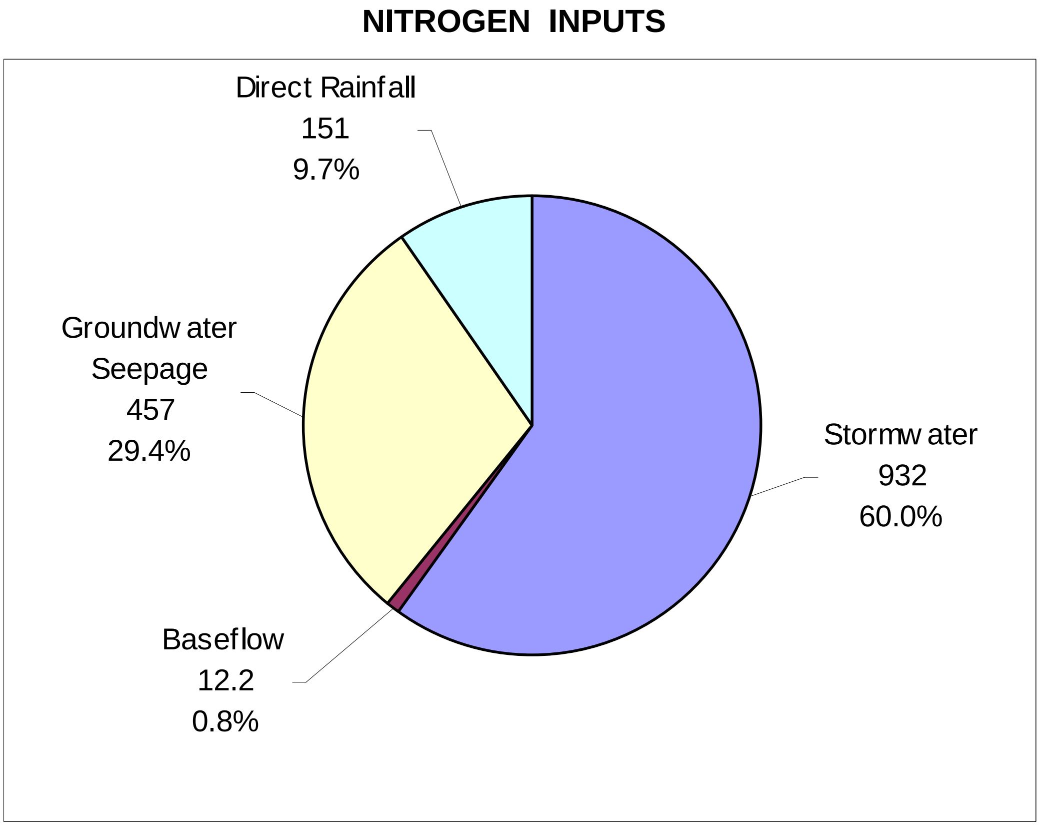
5.3.2 Mass Losses

A summary of estimated annual mass losses of total nitrogen, total phosphorus, and TSS from Spring Lake is given in Table 5-18. Approximately 68% of the nitrogen inputs into Spring Lake are discharged to the drainage well and the outfall structure, and 32% retained in the sediments of the lake. In contrast, approximately 80% of the phosphorus inputs are retained within the sediments of the lake, with 20% of the phosphorus loadings lost to the drainage well and through the outfall structure. A similar pattern is also apparent for TSS, with 82% of the TSS inputs retained within the sediments and 18% discharging to the drainage well and the outfall structure. Graphical comparisons of annual inputs and losses of total nitrogen, total phosphorus, and TSS to Spring Lake are given in Figures 5-19, 5-20, and 5-21, respectively.

TABLE 5-18

ESTIMATED MASS LOSSES OF TOTAL NITROGEN, TOTAL PHOSPHORUS, AND TSS FROM SPRING LAKE

SOURCE	TOTAL N		TOTAL P		TSS	
	kg	Percent of Total	kg	Percent of Total	kg	Percent of Total
Lake Outflow	1,012	68	57.3	20	7,247	18
Retained in Sediments	472	32	223.4	80	34,072	82
TOTALS:	**1,484**	**100**	**280.7**	**100**	**41,319**	**100**



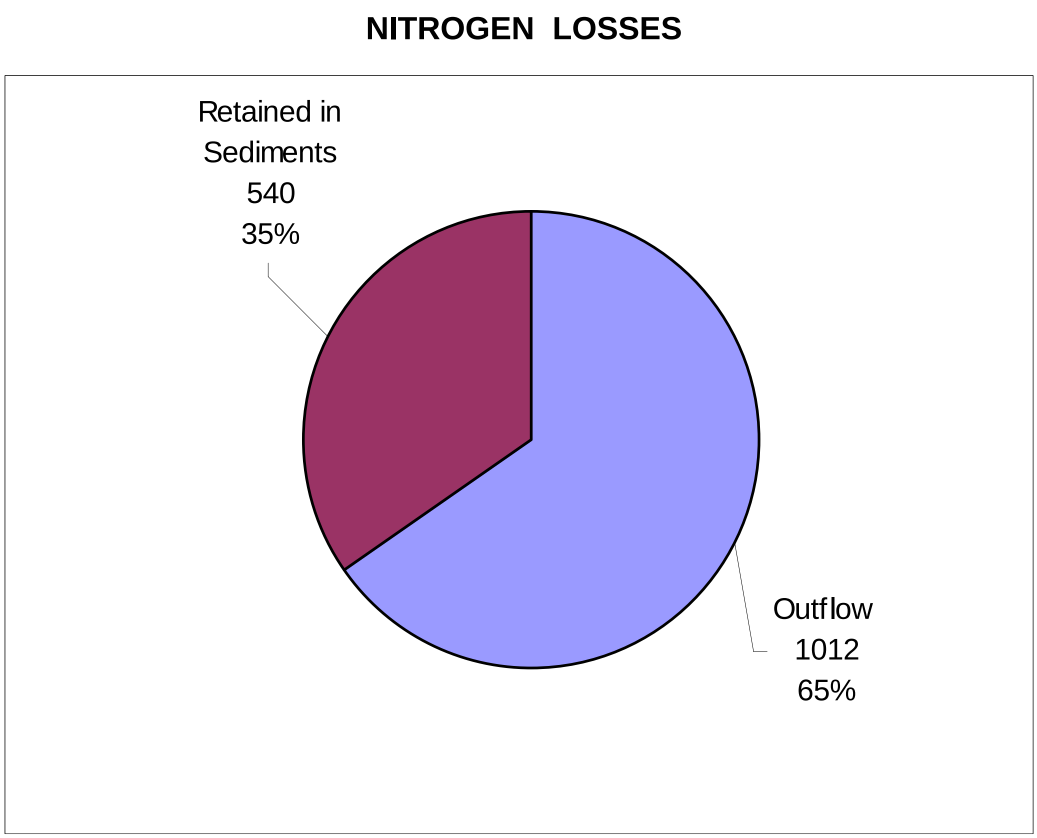
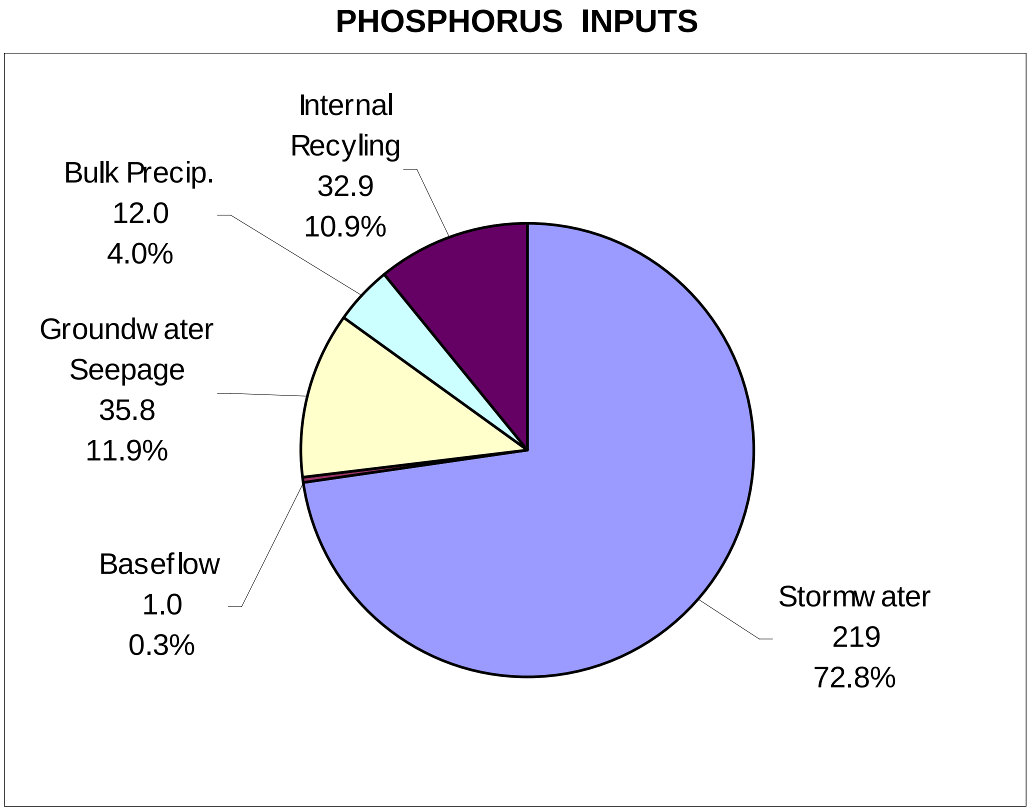


Figure 5-19. Comparison of Mass Inputs and Losses of Total Nitrogen for Spring Lake.



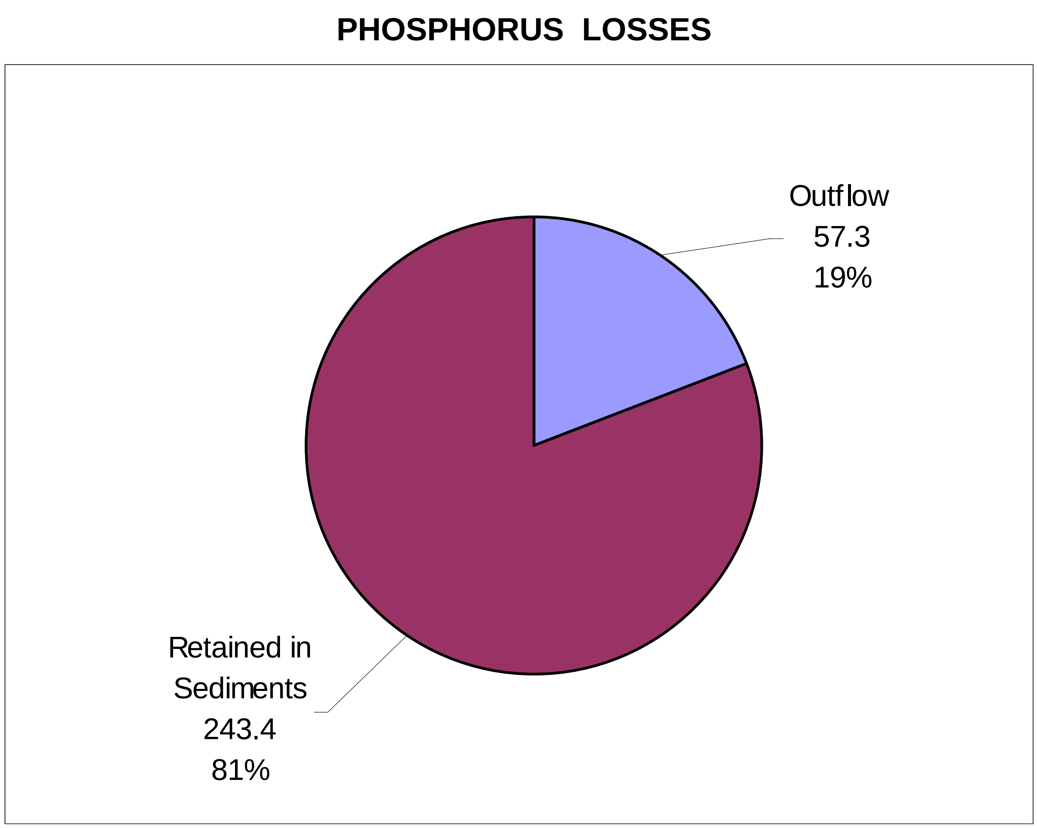
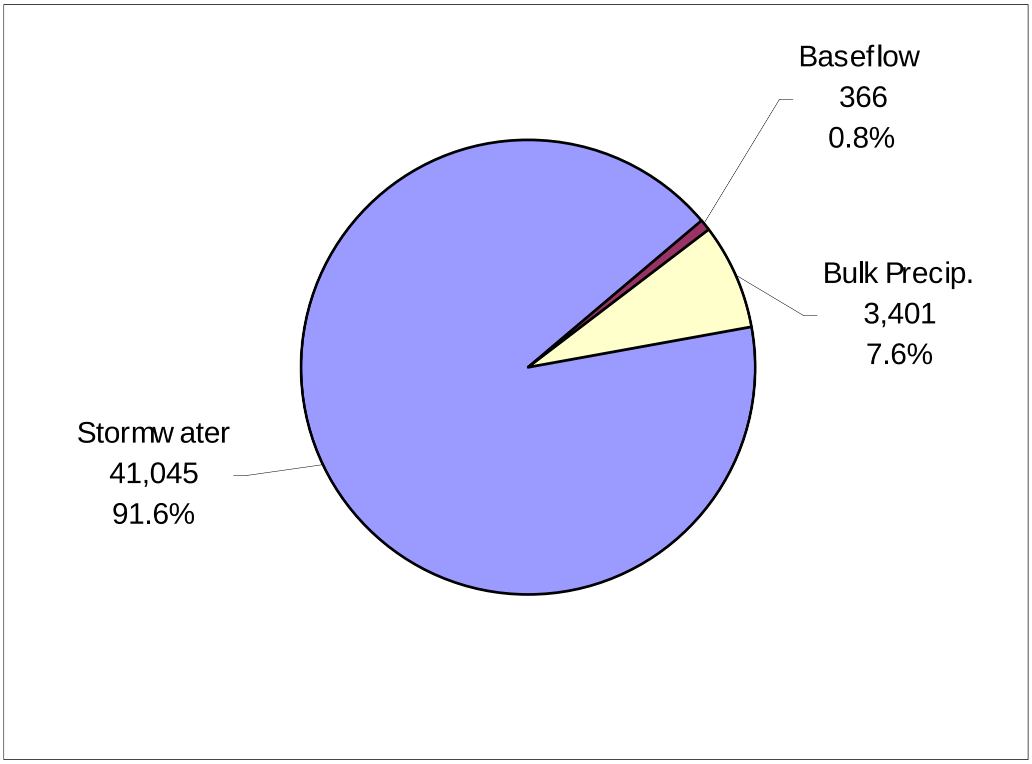


Figure 5-20. Comparison of Mass Inputs and Losses of Total Phosphorus for Spring Lake.

TSS INPUTS



TSS LOSSES

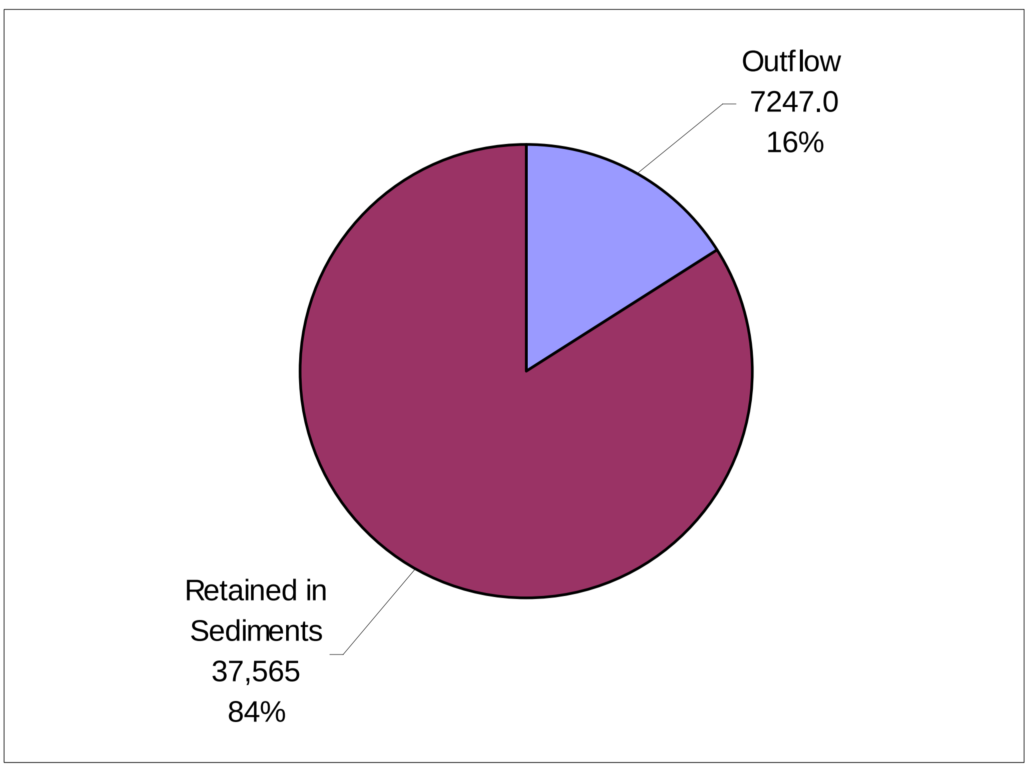


Figure 5-21. Comparison of Mass Inputs and Losses of TSS for Spring Lake.

SECTION 6

WATER QUALITY MODEL

As discussed in previous sections, Spring Lake is primarily a nutrient-balanced or phosphorus-limited ecosystem. This implies that all elements necessary for stimulation of algal productivity, such as carbon, magnesium, calcium, silica, sodium, potassium, and sulfur, are abundant within the water column of the lake with the exception of phosphorus, and on occasion, nitrogen as well. The growth of algae within the lake is directly correlated to the amount of phosphorus added since all other elements necessary for growth are already present in abundance of the needs of the algae. Nitrogen may also be co-limiting at times but is difficult to remove using traditional BMPs. Therefore, control of phosphorus is most likely to result in improvements in water quality in Spring Lake. As a result, the primary objective of the water quality management options discussed in this section is to control and limit the introduction of phosphorus into Spring Lake.

6.1 Model Components

A water quality model was developed for Spring Lake for use in evaluating anticipated water quality improvements resulting from evaluated phosphorus management options. The water quality model is developed for the average annual conditions based upon the hydrologic budget summarized in Section 4 and the nutrients budgets summarized in Section 5. Phosphorus inputs summarized in Table 5-16 are assumed to represent mean annual phosphorus loadings into the lake. The model is calibrated under existing conditions using the historical water quality data summarized in Table 2-7. The model is then used to predict improvements in water quality characteristics resulting from evaluated phosphorus management options.

The water quality model was developed using a modified Vollenweider phosphorus limitation model as proposed by Vollenweider (1976), Vollenweider and Dillon (1974), and Dillon and Rigler (1974). Prediction of in-lake phosphorus concentrations are based upon four parameters, including the estimated annual phosphorus inputs to the lake, a phosphorus retention coefficient which is based upon phosphorus sedimentation dynamics, the mean depth of the lake, and the flushing rate for the lake system.

The first step in modeling involves estimation of the phosphorus retention coefficient, R_{TP}, which is an estimate of the fraction of phosphorus inputs which are retained within the lake. The phosphorus retention coefficient for any lake can be estimated based upon the lake flushing time and mean depth as proposed by Vollenweider (1976):

$$R_{TP} = \frac{\sigma}{\rho\bar{z} + \sigma}$$

where:

R_{TP} = phosphorus retention coefficient (dimensionless)

ρ = lake flushing rate, Q/V = (inflow/time)/(lake volume)

$\bar{z}$ = lake mean depth = lake volume/surface area (m)
σ = sedimentation rate coefficient (1/time)

The sedimentation rate coefficient (σ) is often considered to be analogous to an apparent settling velocity for total phosphorus. This coefficient is different for each lake and is impacted by parameters such as flushing lake, mean depth, sediment composition degree, impacts of boating activities, and hydraulic factors. Both empirical and theoretical formulations for the phosphorus retention coefficient suggest that this coefficient decreases as the flushing rate of the lake increases. This inverse relationship appears appropriate since, as flushing rate increases, there is less time for phosphorus to settle, resulting in a decrease in the retention coefficient.

Estimates of equilibrium total phosphorus concentrations within the lake are developed based upon the relationship proposed by Vollenweider and Dillon (1974):

$$TP = \frac{L_p \, (1 - R_{TP})}{\bar{z} * \rho}$$

where:

L_p = areal total phosphorus loading (mg/m^2-time)

R_{TP} = phosphorus retention coefficient (dimensionless)

ρ = lake flushing rate (1/time)

$\bar{z}$ = mean depth (m)

Estimates of in-lake equilibrium chlorophyll-concentrations can also be calculated based on the empirical relationship between chlorophyll-a and total phosphorus developed by Harper and Baker (2007) specifically for Florida lakes:

$$\ln(chyl\text{-}a) = 1.058 \ \ln \ TP - 0.934$$

$$R^2 = 0.815$$

where:

TP = mean total phosphorus concentration (µg/l)

The model also estimates mean Secchi disk depth based upon the empirical relationship proposed by Harper and Baker (2007), also developed specifically for Florida lakes, which results in an estimated Secchi disk depth in meters, based upon chlorophyll-a input in units of mg/m^3:

$$SD = \frac{[24.2386 + 0.3041 \; x \; chyl - a]}{(6.0632 + chyl - a)}$$

$$R^2 = 0.807$$

where:

SD = Secchi disk depth (m)

chyl-a = chlorophyll-a concentration (mg/m^3)

Trophic State Index (TSI) values are calculated based upon the Florida Trophic State Index proposed by Brezonik (1984) which was developed specifically for Florida lakes. The empirical equations for calculating the Florida Trophic State Index are as follows for phosphorus-limited lakes:

TSI (Chyl-a)	=	16.8 + 14.4 ln (Chyl-a)	(Chyl-a in mg/m^3)
TSI (SD)	=	60.0 - 30.0 ln (SD)	(SD in m)
TSI (TP)	=	23.6 ln (TP) - 23.8	(TP in µg/l)
TSI (Avg)	=	1/3 [TSI (Chyl-a) + TSI (SD) + TSI (TP)]	

Average trophic state values less than 50 indicate oligotrophic conditions, values between 50 and 60 indicate mesotrophic conditions, and values from 61 to 70 indicate eutrophic conditions. Values over 70 represent hypereutrophic conditions.

6.2 Model Calibration

A modified Vollenweider mass balance model was developed for Spring Lake based on mean annual hydrologic inputs and nutrient loadings. The model includes hydrologic inputs to the lake from direct precipitation, stormwater runoff, dry weather baseflow, and groundwater seepage. Nutrient inputs to the lake include estimated loadings from bulk precipitation, stormwater runoff, dry weather baseflow, groundwater seepage, and internal recycling.

Hydrologic and mass losses from Spring Lake are assumed to occur as a result of evaporation and discharges to the outfall structure and drainage well. The net hydrologic inputs into the lake are used to provide an estimate of mean detention time as well as the flushing rate, which is utilized in calculation of the phosphorus retention coefficient. Phosphorus inputs to the lake are used to generate estimates of the areal phosphorus loading rate and the final in-lake phosphorus concentration. Estimates of equilibrium chlorophyll-a concentrations and Secchi disk depth in the lake are calculated based upon the predicted in-lake phosphorus concentration.

The Vollenweider Model assumes that the lake behaves like a continuously stirred tank reactor (CSTR), and the modeled in-lake phosphorus concentration reflects the weighted phosphorus concentration within the water column of the lake. In lakes which are well mixed, the phosphorus concentration is typically uniform throughout the water column, and the equilibrium total phosphorus concentration can be estimated by samples collected near the water surface.

After developing the trophic state model, initial model runs were performed to examine predicted water quality characteristics in Spring Lake based upon the estimated loadings of total phosphorus to the lake from the identified sources. Model calibration was performed using the sedimentation rate coefficient, (σ), which is present as a variable in both a numerator and denominator in the equation used for estimation of the phosphorus retention coefficient. The assumed sedimentation rate coefficient was varied for the lake until the model predicted total phosphorus concentration approached the measured mean total phosphorus concentration of 64 μg/l based upon the field monitoring program from 1998-2006. A summary of the results of this calibration procedure is given in Table 6-1. The required sedimentation rate coefficient to calibrate the model for Spring Lake is 7.02. The calculated sedimentation rate coefficient reflects the site-specific phosphorus sedimentation dynamics for Spring Lake based on the physical characteristics of the lake and the mean annual hydrologic budget. A summary of the results of the calibrated water quality model for Spring Lake under existing conditions is given in Appendix G.1.

A comparison of measured and model predicted trophic state variables in Spring Lake is given in Table 6-2. Using the calibrated sedimentation rate coefficient of 7.02, the measured and model predicted values for total phosphorus are identical. The model predicted chlorophyll-a concentration in Spring Lake is 32.2 mg/m^3 compared with a mean measured concentration of 33.7 mg/m^3 from 1998-2006, a difference of only 4.5%. Similarly, a relatively close agreement was also obtained for estimates of Secchi disk depth, with a difference of only 6.0% between the model predicted and measured Secchi disk depths for the lake.

TABLE 6-1

RESULTS OF MODEL CALIBRATION PROCEDURES AND ASSUMED SEDIMENTATION RATE COEFFICIENT

MEAN TOTAL PHOSPHORUS CONCENTRATION FROM 1998-2006 (mg/l)	MODEL PREDICTED TOTAL PHOSPHORUS CONCENTRATION. (mg/l)	SEDIMENTATION RATE COEFFICIENT (σ)	MODEL PHOSPHORUS RETENTION COEFFICIENT
0.064	0.064	7.02	0.500

TABLE 6-2

COMPARISON OF MEASURED AND MODEL PREDICTED TROPHIC STATE VARIABLES IN SPRING LAKE

PARAMETER	UNITS	MEASURED VALUE (1998-2006)	MODEL PREDICTED VALUE	PERCENT DIFFERENCE (%)
Total Phosphorus	µg/l	0.064	0.064	0
Chlorophyll-a	mg/m^3	33.7	32.2	- 4.5
Secchi Disk	m	0.84	0.89	+ 6.0

Based upon the comparison summarized in Table 6-2, it appears that the calibrated water quality model for Spring Lake provides close agreement with historical trophic state variables within the lake. The calibrated water quality model is used to evaluate anticipated water quality responses to evaluated phosphorus reduction strategies discussed in Section 7.

SECTION 7

EVALUATION OF WATER QUALITY IMPROVEMENT OPTIONS

A discussion of water quality improvement options for Spring Lake is presented in this section. The evaluated water quality improvement options are designed to target sources which have been identified as significant contributors of total phosphorus loadings to the lake which can be accomplished within the limited areas available within the Spring Lake watershed. The evaluated options include both structural and non-structural approaches to controlling and reducing pollutant inputs into Spring Lake. A discussion of general management philosophy and recommended water quality improvement projects is given in the following sections.

7.1 Management Philosophy

Phosphorus inputs into Spring Lake occur from a wide variety of sources, including stormwater runoff, baseflow, groundwater seepage, bulk precipitation, and internal recycling. On an average annual basis, the most significant phosphorus input to Spring Lake is stormwater runoff which contributes approximately 71% of the annual phosphorus loadings to the lake. An additional 12% of the phosphorus loadings is contributed by internal recycling, with 13% contributed by groundwater seepage. The remaining phosphorus inputs of bulk precipitation and baseflow contribute approximately 4% of the annual phosphorus loading. Therefore, it appears that improvements in water quality characteristics in Spring Lake can best be achieved by providing treatment of stormwater runoff and internal recycling, which together contribute 83% of the total annual phosphorus loadings to the lake.

As discussed in Section 5.1.2.4, approximately 66% of the total phosphorus loadings from stormwater runoff originate from Sub-basins 4 (38.9%), 5 (13.7%), and 2 (13.5%). As a result, opportunities for management of stormwater runoff should concentrate on these three significant sub-basins.

Approximately 25% of the total phosphorus loadings to Spring Lake originate from the combined sources of groundwater seepage and internal recycling. Achieving a reduction in phosphorus concentrations in groundwater seepage would be difficult for many reasons. First, the specific sources of elevated phosphorus concentrations in groundwater seepage have not been determined, and the activities contributing to these loadings have not been identified. Second, groundwater seepage is a diffuse input which occurs around the entire perimeter of the lake, further complicating efforts to reduce this input. However, although groundwater seepage cannot be eliminated, it can be treated as part of a sediment inactivation project within the lake. If alum is applied to the lake sediments to reduce internal recycling, additional alum can also be added to adsorb phosphorus seeping into the lake from groundwater seepage. The desired number of years of treatment can be used to estimate the additional alum required for treatment of groundwater seepage. The feasibility of a combined alum treatment for internal recycling and groundwater seepage is discussed in a subsequent section.

7.2 Stormwater Treatment Options

A discussion of potential stormwater treatment projects is provided for Sub-basins 2, 4, and 5 which generate the largest stormwater-related phosphorus loadings to Spring Lake. As discussed in Section 5.1.2.4, approximately 38.9% of the runoff-related phosphorus loadings to Spring Lake are generated in Sub-basin 4, with 13.7% generated in Sub-basin 5, and 13.5% in Sub-basin 2. A discussion of potential retrofit opportunities for these sub-basin areas is given in the following sections.

7.2.1 Sub-basin 4

As discussed in Section 5.1.2.1, stormwater runoff within Sub-basin 4 is collected in a series of 15- to 48-inch stormsewers which run in an east/west direction along Colonial Drive and in a north/south direction along Texas Avenue and Tampa Avenue. These stormsewers converge into a 60-inch RCP which discharges into the southwest side of the large golf course pond located in Sub-basin 3. Portions of Sub-basin 3 also discharge into this pond by both stormsewer and overland flow, although the vast majority of runoff inputs originate in Sub-basin 4. A schematic of portions of Sub-basins 3 and 4, including the golf course pond, is given on Figure 7-1. A summary of modeled annual runoff inputs into the wet detention pond from Sub-basins 3 and 4 is given in Table 7-1. On an annual basis, approximately 95% of the annual inflow into the wet detention pond originates within Sub-basin 4.

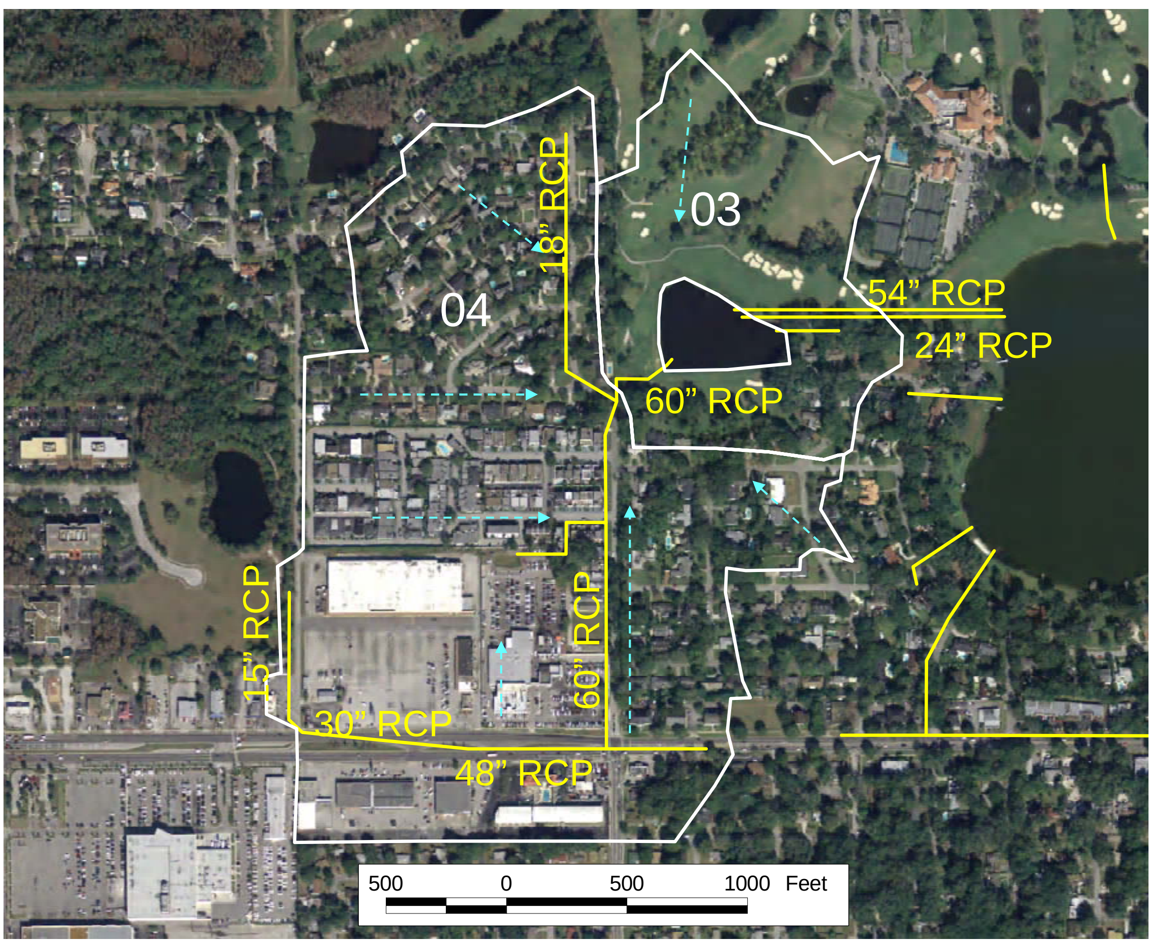


Figure 7-1. Overview of the Sub-basins 3 and 4 Stormsewer System.

TABLE 7-1

COMPARISON OF ANNUAL RUNOFF INPUTS TO THE SUB-BASIN 3 WET DETENTION POND

SOURCE	ANNUAL RUNOFF (ac-ft/yr)	PERCENT OF TOTAL (%)
Sub-basin 3	10.43	4.9
Sub-basin 4	213.57	95.1
TOTAL:	**224.0**	**100.0**

A depth contour map for the Sub-basin 3 wet detention pond was generated by ERD to provide estimates of the pond volume and estimated detention time for runoff inputs. Depth soundings were conducted within the wet detention pond by ERD field personnel on November 29, 2007. Water depth within the pond was determined by lowering a 10-cm diameter Secchi disk attached to a graduated fiberglass tape. Approximately 25 depth soundings were conducted within the pond. Water level within the pond was approximately 1 inch above the weir control elevation for the pond on the date of field measurements.

An approximate depth contour map for the Sub-basin 3 wet detention pond is given on Figure 7-2. The majority of the lake appears to have current water depths ranging from approximately 1-2 ft. A slightly deeper area, with water depths extending to approximately 5 ft, is located in the southwestern portion of the pond, near the point of inflow for the 60-inch RCP. The existing bottom of the pond is covered with a deep accumulation of loose organic muck. Based on a limited number of deeper soundings conducted by ERD, this layer extends deeper than 5 ft in most areas of the pond.

Stage-volume relationships for the Sub-basin 3 wet detention pond are summarized in Table 7-2. At the control water elevation for the pond, the surface area is approximately 3.35 ac, with a water volume of 5.63 ac-ft and a mean depth of 1.68 ft. Calculated mean annual detention time in the Sub-basin 3 wet pond is summarized in Table 7-3. Based upon estimated annual runoff inputs of 224.0 ac-ft/yr from Sub-basins 3 and 4, and a pond volume of 5.63 ac-ft, the mean annual detention time within the Sub-basin 3 wet detention pond is approximately 0.025 years or 9.2 days. This detention time is substantially shorter than detention times normally associated with wet detention ponds used for stormwater treatment, which typically range from approximately 20-50 days on an annual average basis.

Wet detention systems are currently a very popular stormwater management technique throughout the State of Florida, particularly in areas with high groundwater tables. A wet detention pond is simply a modified detention facility which is designed to include a permanent pool of water. These permanently wet ponds are designed to slowly release collected runoff through an outlet structure. A schematic diagram of a wet detention system is given in Figure 7-3.

Figure 7-2. Approximate Depth Contour Map for the Sub-basin 3 Wet Detention Pond. (data collected on 11/29/07)

TABLE 7-2

STAGE-VOLUME RELATIONSHIPS FOR THE SUB-BASIN 3 WET DETENTION POND

WATER DEPTH (ft)	AREA (acres)	VOLUME (ac-ft)
0	3.35	5.63
1	2.69	2.61
2	0.81	0.86
3	0.31	0.29
4	0.12	0.08
5	0.02	0.01

TABLE 7-3

CALCULATED MEAN ANNUAL DETENTION TIME IN THE SUB-BASIN 3 WET DETENTION POND

RUNOFF INPUTS (ac-ft/yr)	POND VOLUME (ac-ft)	MEAN DETENTION TIME	
		YEARS	DAYS
224.0	5.63	0.025	9.2

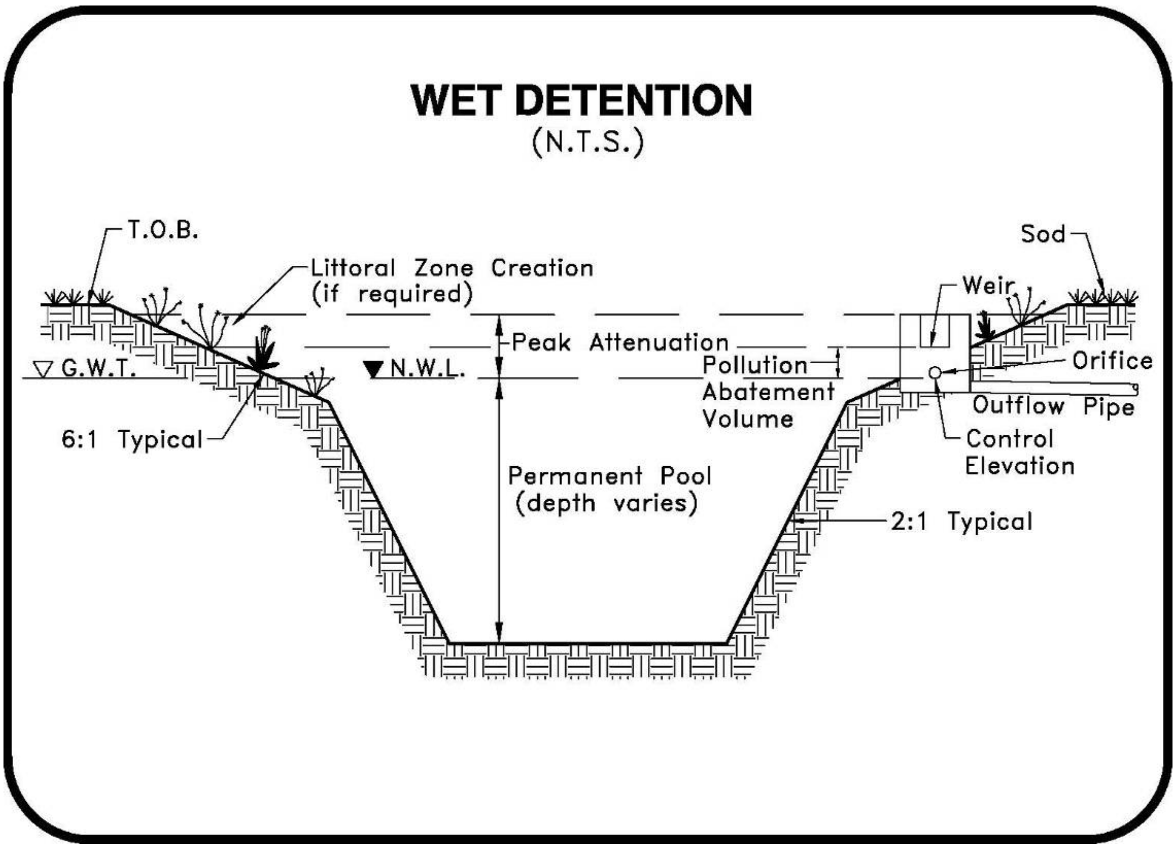


Figure 7-3. Schematic of a Wet Detention System.

Pollutant removal processes in wet detention systems occur through a variety of mechanisms, including physical processes such as sedimentation, chemical processes such as precipitation and adsorption, and biological uptake from algae, bacteria, and rooted vegetation. In essence, these systems operate similar to a natural lake system. The water level in a wet detention system is controlled by an orifice located in the outfall structure from the pond. A littoral zone may be planted around the perimeter of a wet detention facility to provide additional biological uptake and enhanced biological communities.

Upon entering a wet detention facility, stormwater inputs mix with existing water contained in the permanent pool. Physical, chemical, and biological processes begin to rapidly remove pollutant inputs from the water column. Water which leaves through the orifice in the outfall structure is a mixture of stormwater and the water contained within the permanent pool. In general, the concentration of constituents in the permanent pool are typically much less than input concentrations in stormwater runoff, resulting in discharges from the facility which are substantially lower in concentration than found in raw stormwater. As a result, good removal efficiencies are achieved within a wet detention facility for most stormwater constituents. Although the littoral zone provides a small amount of enhanced biological uptake, previous research has indicated that a vast majority of removal processes occurring in wet detention facilities occur within the permanent pool volume rather than in the littoral zone vegetation for the treatment volume (Harper, 1985; Harper 1987; Harper and Herr, 1993).

Wet detention systems offer several advantages over some other stormwater management systems. First, wet detention systems provide relatively good removal of stormwater constituents since physical, chemical, and biological mechanisms are all available for pollutant attenuation. Other stormwater management facilities provide only one or two of these basic removal methods for stormwater. A second advantage of wet detention systems is that the systems are not complex and can be relatively easily maintained.

The removal of stormwater constituents in wet detention ponds is primarily a function of residence time within the pond (Harper and Baker, 2007). A mathematical relationship between removal efficiencies for total phosphorus and residence time in wet detention ponds is given in Figure 7-4. In general, a removal efficiency of approximately 60% can be achieved within a wet detention pond with a mean residence time of approximately 15 days. Removal efficiencies as high as 90% can be achieved, although residence times approaching two years may be necessary to achieve this level of removal. Based upon the mathematical relationship summarized in Figure 7-4 for removal efficiency as a function of detention time, the Sub-basin 3 wet detention pond is expected to have an annual removal efficiency of approximately 58% based upon the mean annual residence time of 9.2 days.

Although the relationship summarized in Figure 7-4 suggests a removal efficiency of approximately 60% for the Sub-basin 3 wet detention pond, it is extremely unlikely that the pond achieves this level of removal under current conditions. As seen in Table 5-6, approximately 50% of the total phosphorus discharging from the pond outfall is comprised of particulate phosphorus. This is extremely unusual for a wet detention pond since wet detention ponds provide an excellent opportunity for removal of particulate phosphorus. The pond also appears to be discharging elevated concentrations of SRP, particularly in comparison with values normally observed in discharges from a wet detention facility. Based upon these elevated values, it appears likely that portions of the particulate matter which has accumulated on the bottom of the pond may be mobilizing and discharging through the outfall structure, particularly during larger storm events. Disturbance of the existing sediments by incoming stormwater runoff would account for the elevated levels of both particulate phosphorus and SRP observed in the discharge from this site. As a result, it appears that the Sub-basin 3 wet detention pond is having a relatively minimal net impact on total phosphorus loadings generated in Sub-basins 3 and 4.

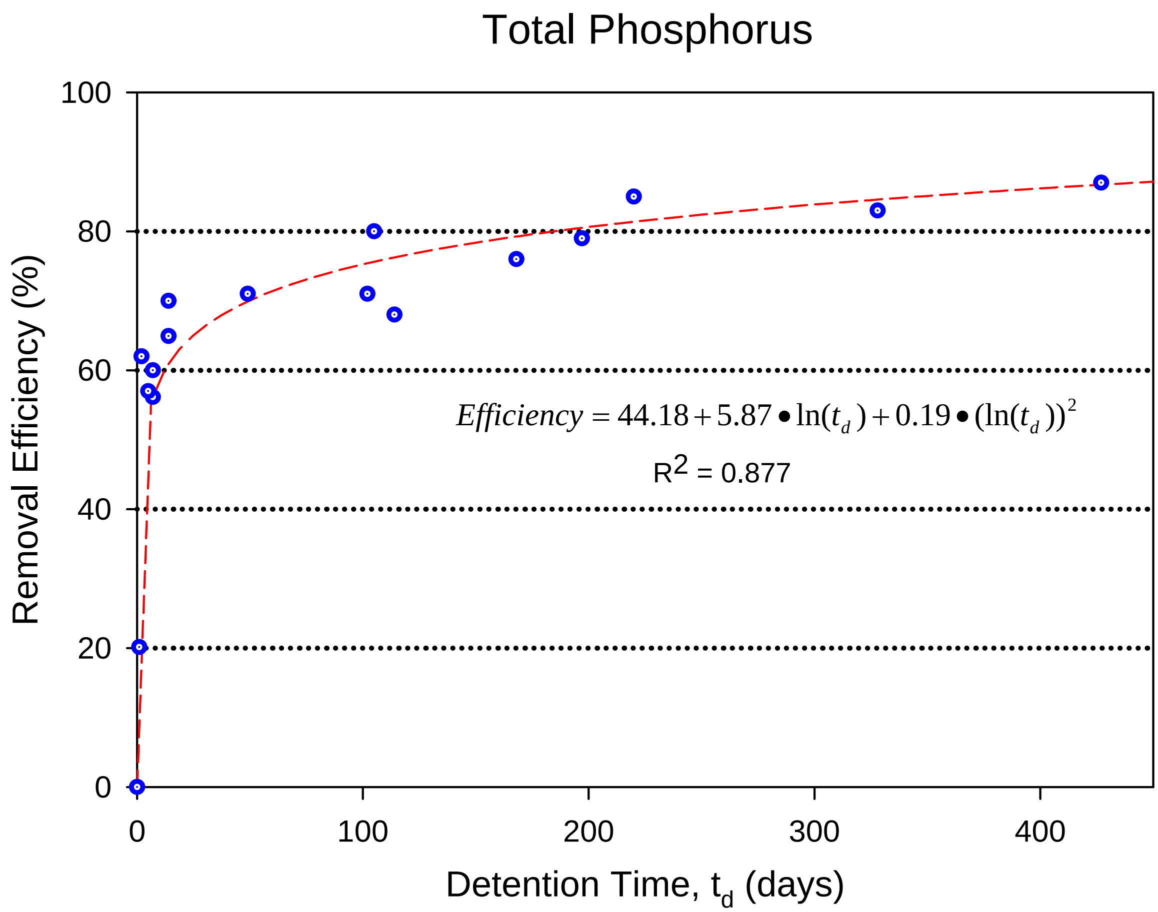


Figure 7-4. Removal Efficiency of Total Phosphorus in Wet Detention Ponds as a Function of Residence Time.

One potential option for reducing phosphorus loadings discharging from Sub-basins 3 and 4 is to dredge the existing muck accumulations from the wet detention pond and reconfigure the pond to meet current wet detention design criteria. Removal of existing sediments will increase the pond volume, resulting in a corresponding increase in detention time. In addition, excavation of the existing accumulated sediments will minimize potential resuspension of particulate phosphorus and SRP resulting from sediment disturbance during larger rain events.

An overview of proposed water depth contours in the wet detention pond following reconfiguration is given on Figure 7-5. This figure assumes that the pond would be constructed to a maximum depth of 12 ft, with 4:1 side slopes from the control elevation to a water depth of approximately 3 ft, followed by a 2:1 side slope to the pond bottom at a depth of 12 ft. Stage-area-volume relationships for the excavated pond are given on Table 7-4. The dredged pond will have a surface area of 3.35 ac, with a permanent pool volume of 19.5 ac-ft and a mean depth of 5.8 ft.

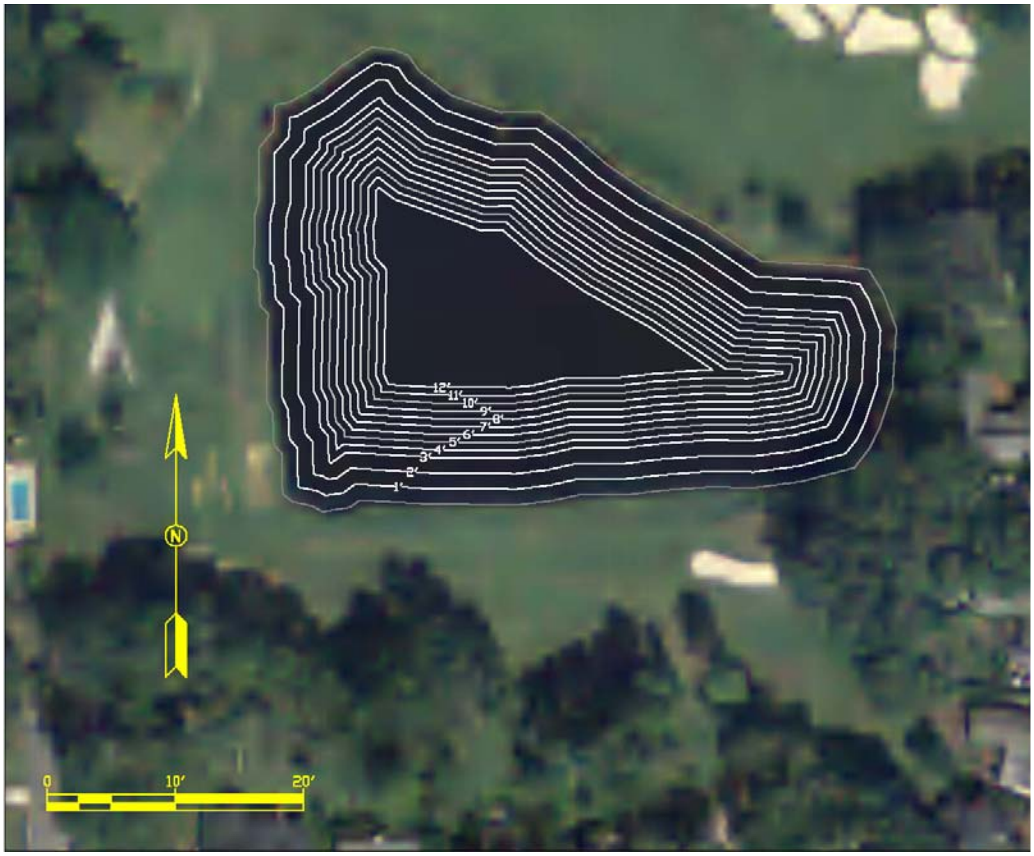


Figure 7-5. Overview of Proposed Water Depth Contours in the Wet Detention Pond Following Reconfiguration.

TABLE 7-4

STAGE-AREA-VOLUME RELATIONSHIPS FOR THE RECONFIGURED SUB-BASIN 3 WET DETENTION POND

DEPTH (ft)	AREA (acres)	POND VOLUME (ac-ft)
NWL	3.36	19.50
-1	2.90	18.84
-2	2.46	18.05
-3	2.05	17.12
-4	1.86	16.04
-5	1.68	14.79
-6	1.50	13.38
-7	1.33	11.79
-8	1.16	10.02
-9	1.01	8.07
-10	0.86	5.81
-11	0.72	3.13
-12	0.59	0.00

Calculated detention time within the reconfigured wet detention pond is given in Table 7-5. Based upon the anticipated pond volume of 19.50 ac-ft and the estimated annual runoff inflow of 224.0 ac-ft/yr, the modified wet detention pond will have a mean annual detention time of 0.09 years or 31.7 days. Based upon the relationship summarized in Figure 7-4, the modified wet detention pond will have a mean annual removal efficiency of approximately 67%.

TABLE 7-5

CALCULATED DETENTION TIME WITHIN THE MODIFIED WET DETENTION POND

RUNOFF INFLOW (ac-ft/yr)	POND VOLUME (ac-ft)	DETENTION TIME	
		YEARS	DAYS
224.0	19.50	0.09	31.7

Calculations of estimated removal of total phosphorus by the modified Sub-basin 3 wet detention pond are given in Table 7-6. The existing total phosphorus input to Spring Lake from Sub-basins 3 and 4 is approximately 81.4 kg/yr based upon the field monitoring program conducted by ERD at the discharge from the wet detention pond and includes phosphorus removal which occurred within the pond. However, for reasons discussed previously, it is believed that the pond under existing conditions provides relatively poor removal for phosphorus inputs. For purposes of this analysis, it is assumed that the current phosphorus removal efficiency is approximately 20%. As a result, the input phosphorus loading into the pond is estimated to be approximately 101.8 kg/yr.

TABLE 7-6

ESTIMATED REMOVAL OF TOTAL PHOSPHORUS BY THE MODIFIED SUB-BASIN 3 WET DETENTION POND

EXISTING TOTAL PHOSPHORUS INPUT TO SPRING LAKE (kg/yr)	ESTIMATED CURRENT TOTAL PHOSPHORUS EFFICIENCY (%)	TOTAL PHOSPHORUS LOAD ENTERING POND (kg/yr)	EFFICIENCY OF MODIFIED POND (%)	PHOSPHORUS REMOVED (kg/yr)	TOTAL PHOSPHORUS LOAD TO LAKE (kg/yr)
81.4	20	101.8	67	47.8	33.6

As indicated previously, the modified pond is expected to have a removal efficiency of approximately 67% for total phosphorus. If the estimated incoming total phosphorus load of 101.8 kg/yr is reduced by 67%, the estimated total phosphorus load discharged to Spring Lake will be approximately 33.6 kg/yr, a reduction of approximately 47.8 kg/yr compared with existing conditions.

An evaluation of anticipated construction costs for reconfiguration of the Sub-basin 3 wet detention pond is given in Table 7-7. The estimated construction cost for reconfiguration of the pond is approximately $248,530. These estimated costs include dewatering, excavation, and removal of the dredged material, as well as repair of sod and landscaping damage which occurs during the process. The construction cost appears to be relatively inexpensive since no land costs are involved with this project.

TABLE 7-7

ESTIMATED MODIFICATION COSTS FOR THE SUB-BASIN 3 WET DETENTION POND

ITEM	QUANTITY	UNIT COST ($)	TOTAL COST ($)
Mobilization	LS	41,400	41,400
Excavation / Dewatering / Removal	16,330 yd^3	10.00	163,300
Landscape / Sod Repair	LS	50,000	25,000
Contingency	LS	37,660	18,830
		TOTAL:	**$ 248,530**

The calculated present worth costs for the wet detention pond reconfiguration is summarized in Table 7-8. This value is obtained by dividing the estimated construction cost by the total phosphorus mass which would be removed over the anticipated 20-year life span for the pond. Based upon the analysis summarized in Table 7-6, the modified wet detention pond is expected to remove approximately 68.2 kg total phosphorus per year (101.8 kg/yr – 33.6 kg/yr) which discharges from Sub-basins 3 and 4. Over the anticipated 20-year life span of the pond, the total phosphorus mass removed will be approximately 1364 kg (68.2 kg/yr x 20 years). If the estimated construction cost of $248,530 is divided by the anticipated phosphorus mass removal of 1364 kg, the present worth cost per kg of phosphorus removed will be approximately $182/kg. This present worth cost is extremely attractive and substantially lower than phosphorus removal costs normally associated with wet detention treatment systems since land purchase is not required for this project.

TABLE 7-8

PHOSPHORUS MASS REMOVAL COSTS FOR THE SUB-BASIN 3 WET DETENTION POND

PARAMETER	VALUE
Present Worth Cost ($20-year)	$ 248,530
Annual Total Phosphorus Mass Removed	68.2 kg/yr
Total Phosphorus Mass Removed (20 years)	1364 kg
Present Worth Cost ($/kg TP removed)	$ 182

1. Based on an expected pond life span of 20 years

7.2.2 Sub-basin 2

An overview of Sub-basin 2 is given on Figure 7-6. As discussed previously, Sub-basin 2 includes primarily golf course areas along with multi-family residential and recreational areas in southwest portions of the sub-basin. Runoff generated on the golf course and impervious areas travels by combination of overland flow and stormsewer systems into a series of interconnected wet detention ponds located in the southern portion of the sub-basin. Discharges from these ponds occur through a 15-inch RCP into Spring Lake. This sub-basin contributes approximately 13.5% of the runoff generated phosphorus loadings to Spring Lake.

Figure 7-6. Overview of Sub-basin 2.

Development of stormwater strategies for Sub-basin 2 is complicated since the majority of runoff generated within this sub-basin originates as overland flow and migrates slowly into the on-site wet ponds. This lack of a concentrated stormwater flow makes it difficult to collect and treat the runoff prior to discharge into the wet pond system. As a result, stormwater treatment opportunities within this sub-basin must occur within the stormwater ponds themselves. This can be achieved by either reducing the concentration of phosphorus in discharges from the ponds or by reusing water from the ponds, reducing the quantity of off-site discharges.

According to golf course personnel, irrigation water for the golf course is obtained primarily from deep groundwater sources. Irrigation water is initially withdrawn from an on-site pond and the water level within the pond is maintained by the groundwater source. This method is used to irrigate virtually all areas of the existing golf course.

The use of stormwater ponds as a source of water for irrigation purposes is receiving increased attention within the State of Florida as a technique which both conserves water and reduces pollutant discharges to downstream waterbodies. Enhanced use of on-site water for irrigation purposes has the potential to reduce or potentially eliminate surficial discharges from Sub-basin 2 into Spring Lake, while also conserving dwindling groundwater resources and reduce energy requirements for golf course maintenance. This process would initially involve interconnecting all of the golf course ponds to create a substantially larger reservoir of available water. Irrigation water would be initially withdrawn from the ponds until a predetermined minimum acceptable water level is reached. The water level within the pond will gradually recover between irrigation events as a result of groundwater inflow and stormwater runoff. If these inputs are insufficient to maintain the desired minimum water level, the lakes can then be supplemented with the existing groundwater source. This operation can be actively managed to minimize discharges from the system into Spring Lake by using most of the generated runoff for in-site purposes. These types of systems will become increasingly popular within the State of Florida as competition increases for finite groundwater resources.

7.2.3 Sub-basin 5

An overview of Sub-basin 5 is given on Figure 7-7. This sub-basin area contributes approximately 13.7% of the total runoff generated phosphorus loadings to Spring Lake. As seen on Figure 7-7, Sub-basin 5 is highly developed, with virtually no vacant land remaining within the sub-basin. This sub-basin includes a dense commercial corridor along Colonial Drive, with single-family residential homes both north and south of this area. Drainage from this sub-basin includes portions of Colonial Drive as well as the adjoining residential areas.

Virtually no opportunities exist within Sub-basin 5 for construction of traditional stormwater management systems such as dry retention or wet detention systems. The only significant structural opportunity appears to be construction of a baffle box structure near the intersection of the 24-inch RCP and Spring Lake Drive. This baffle box structure would provide removal of both litter and vegetation, such as leaves, discharging from this area. Accumulation of litter along Colonial Drive is a common occurrence, and this litter is discharged directly into Spring Lake with rain events. In addition, the adjacent residential areas also generate substantial organic material, particularly during periods of leaf fall.

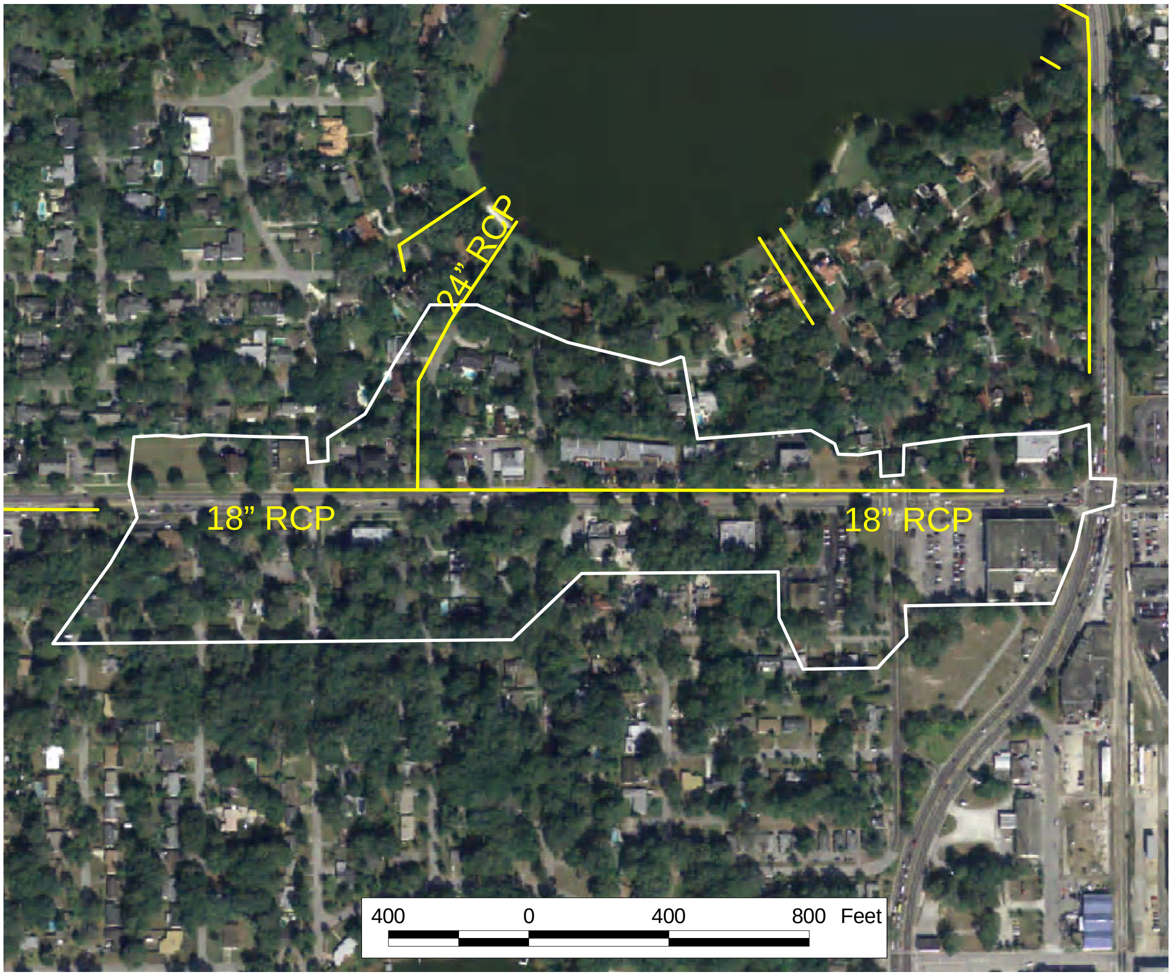


Figure 7-7. Overview of Sub-basin 5.

A review of records maintained by the Orange County Property Appraiser's Office was conducted by ERD to evaluate potential existing right-of-way parcels along the path of the 24-inch RCP. Other than areas immediately adjacent to the roadway, no significant right-of-way parcels exist in this area. Therefore, installation of a baffle box for Sub-basin 5 would require construction to occur within the roadway or private property would have to be purchased for the project. Construction of the baffle box system within the roadway right-of-way would be substantially complicated due to potential conflicts with existing utilities within the right-of-way which could include the sanitary sewer system, potable water lines, and communication conduits. These potential conflicts would likely impact the design and potential effectiveness of a proposed baffle box system.

A cost estimate was generated for construction of a baffle box structure beneath Spring Lake Drive to provide partial stormwater treatment for Sub-basin 5 based upon the assumption that a suitable effective design could be achieved within the existing limitations of the right-of-way area. This cost estimate is based upon discussions with City of Orlando personnel regarding installation costs for similar systems. A summary of estimated construction costs for the Sub-basin 5 baffle box is given in Table 7-9. Construction costs are included for purchase of the baffle box structure, installation, removal and replacement of the roadway, and utility conflict resolution. The estimated construction cost for the project is approximately $128,000. If no significant utility conflicts are encountered, the estimated construction cost will be approximately $100,000.

TABLE 7-9

ESTIMATED CONSTRUCTION COSTS FOR INSTALLATION OF A BAFFLE BOX STRUCTURE FOR SUB-BASIN 5

ITEM	TOTAL COST ($)
Baffle Box Structure	18,000
Installation	70,000
R/R Roadway	15,000
Utility Conflict Resolution	25,000
TOTAL:	**128,000**

7.3 Sediment Inactivation

7.3.1 General Considerations

Sediment phosphorus inactivation is a lake restoration technique which is designed to substantially reduce sediment phosphorus release by combining available phosphorus in the sediments with a metal salt to form an insoluble inert precipitate, rendering the sediment phosphorus unavailable for release into the overlying water column. Although salts of aluminum calcium and iron have been used for sediment inactivation in previous projects, aluminum salts are the clear compounds of choice for this application. Inactivation of sediment phosphorus using aluminum is often a substantially less expensive option for reducing sediment phosphorus release since removal of the existing sediments is not required.

Sediment phosphorus inactivation is most often performed using aluminum sulfate, commonly called alum, which is applied at the surface in a liquid form. Upon entering the water column, the alum forms an insoluble precipitate of aluminum hydroxide which attracts phosphorus, bacteria, algae, and suspended solids within the water column, settling these constituents into the bottom sediments. Upon reaching the bottom sediments, the residual aluminum binds tightly with phosphorus within the sediments, forming an inert precipitate which will not be re-released under any conceivable condition of pH or redox potential which could occur in a natural lake system. These sediment treatments have been shown to be effective from 2-20 years, depending upon the sediment accumulation rate within the lake from the remaining phosphorus sources.

Based on the nutrient budget for Spring Lake, summarized in Table 5-17, internal recycling contributes approximately 11% of the phosphorus loading to the lake, with an additional 12% is contributed by groundwater seepage. It is possible to control both internal recycling and groundwater seepage through a carefully planned alum treatment application. Therefore, the goal of the proposed sediment inactivation alum treatment for Spring Lake is to provide simultaneous control for both internal recycling and groundwater seepage. Together, these sources contribute approximately 23% of the total phosphorus loading to the lake. Control of these inputs has the potential to result in improvements in water quality within Spring Lake.

7.3.2 Chemical Requirements and Costs

Sediment inactivation in Spring Lake would involve addition of liquid aluminum sulfate at the water surface. Upon entering the water, the alum would form insoluble precipitates which would settle onto the bottom while also clarifying the existing water column within the lake. Upon entering the sediments, the alum will combine with existing phosphorus within the sediments, primarily saloid- and iron-bound associations, forming insoluble inert precipitates which will bind the phosphorus, making it unavailable for release into the overlying water column. It is generally recognized that the top 10 cm layer of the sediments is the most active in terms of release of phosphorus under anoxic conditions. Therefore, the objective of a sediment inactivation project is to provide sufficient alum to bind the saloid- and iron-bound phosphorus associations in the top 10 cm of the sediments.

Estimates of the mass of total available phosphorus within the top 0-10 cm layer of the sediments in Spring Lake were generated by graphically integrating the total available phosphorus isopleths presented on Figure 2-10. The top 0-10 cm layer of the sediments is considered to be an active layer with respect to exchange of phosphorus between the sediments and the overlying water column. Inactivation of phosphorus within the 0-10 cm layer is typically sufficient to inactivate sediment release of phosphorus within a lake. Prior research involving sediment inactivation has indicated that an excess of aluminum is required within the sediments to cause phosphorus to preferentially bind with aluminum rather than other available competing agents. Previous sediment inactivation projects performed by ERD have been conducted at molar Al:P ratios of 2, 3, 5, and 10, with most recent sediment inactivation projects performed using a 10:1 ratio.

A summary of estimated total available phosphorus in the sediments of Spring Lake is given in Table 7-10. On a mass basis, the sediments of Spring Lake contain approximately 387 kg of available phosphorus in the top 10 cm. On a molar basis, this equates to approximately 12,469 moles of available phosphorus to be inactivated as part of the sediment inactivation process. A summary of alum requirements for sediment inactivation is also provided in Table 7-10. Using an Al:P ratio of 10:1, sediment inactivation in Spring Lake would require approximately 15,183 gallons of alum, equivalent to approximately 3.4 tankers of alum. Assuming a chemical cost of $0.75 cents per gallon, the chemical cost for sediment inactivation in Spring Lake would be $11,387. The equivalent aerial aluminum dose for this application would be 21.7 g Al/m^2.

TABLE 7-10

SPRING LAKE SEDIMENT INACTIVATION REQUIREMENTS

AVAILABLE P CONTOUR INTERVAL (μg/cm^3)	CONTOUR INTERVAL MID-POINT (μg/cm^3)	CONTOUR AREA (acres)	AVAILABLE PHOSPHORUS		ALUM REQUIREMENTS (Al:P Ratio = 10:1)	
			kg	moles	moles Al	gal alum
< 20	10	13.58	55	1,773	17,729	2,159
20-40	30	21.03	255	8,238	82,376	10,031
40-60	50	3.27	66	2,135	21,350	2,600
60-80	70	0.35	10	323	3,235	394
Overall Totals:		**38.24**	**387**	**12,469**	**124,690**	**15,183**

Estimated Chemical Cost:	$ 11,387
Areal Aluminum Dose:	21.74 g Al/m^2
Number of Tankers:	3.4

Previous alum surface applications performed for inactivation of sediment phosphorus release by ERD have indicated that the greatest degree of improvement in surface water characteristics and the highest degree of inactivation of sediment phosphorus release are achieved through multiple applications of aluminum to the waterbody over a period of approximately 6-12 months. Each subsequent application results in additional improvements in water column quality and additional aluminum floc added to the sediments for long-term inactivation of sediment phosphorus release.

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

A summary of calculations of alum requirements for control of phosphorus loading from groundwater seepage is given in Table 7-11. As indicated in Table 5-17, phosphorus inflow from groundwater seepage is estimated to be approximately 35.8 kg/yr. This analysis assumes that control of groundwater seepage is desired for a period of approximately 10 years. Therefore, the total mass of phosphorus from groundwater seepage which must be inactivated is approximately 358 kg over the 10-year period. This mass of phosphorus equates to approximately 11,548 moles of total phosphorus. Assuming an Al:P ratio of 10:1 for adequate inactivation, control of 11,548 moles of total phosphorus will require approximately 115,480 moles of aluminum, equivalent to an alum volume of 14,062 gallons.

TABLE 7-11

CALCULATION OF ALUM REQUIREMENTS FOR CONTROL OF PHOSPHORUS LOADING FROM GROUNDWATER SEEPAGE

PARAMETER	UNITS	VALUE
Annualized Mass Total Phosphorus Inflow[1]	kg/yr	35.8
Desired Length of Control	years	10
Total Phosphorus Mass to be Controlled	kg	358
Moles of Total Phosphorus to be Controlled	moles	11,548
Moles of Aluminum for Control[1]	moles	115,480
Equivalent Quantity of Alum	gallons	14,062

1. Based on an Al:P ratio of 10:1

The proposed alum treatment to Spring Lake would add sufficient alum to control both internal recycling and intercept phosphorus loadings from groundwater seepage. Assuming that approximately 15,183 gallons of alum are needed for sediment inactivation and 14,062 gallons of alum are needed for interception of groundwater seepage, the total amount of alum to be added to Spring Lake would be 29,245 gallons. This equates to a whole-lake alum dose of approximately 13.6 mg Al/liter. This dose exceeds the available buffering capacity in the lake to withstand potential reductions in water column pH. As a result, the proposed application would need to be divided into a series of multiple applications or a buffering compound would be needed to neutralize the pH impacts from the alum addition.

The most attractive option for Spring Lake is to use a buffering compound in addition to the alum to neutralize the anticipated undesirable pH impacts, reducing the number of required repeat applications. However, a minimum of two repeat applications is still recommended, to ensure a uniform coating over the lake bottom. Sodium aluminate, an alkaline form of alum, is commonly used in these applications as the buffering agent. Sodium aluminate provides a high level of buffering, as well as supplemental aluminum ions, which reduces the total amount of alum required during the application process. If alum and sodium aluminate are used in combination, changes in pH within the lake during the application process can be minimized.

The specific ratio of alum and sodium aluminate required to control water column pH varies based on the characteristics of each lake. This ratio is often determined in a series of laboratory jar test experiments. However, the simultaneous addition of 1 gallon of sodium aluminate for every 4.0 gallons of alum is often sufficient to create neutral pH conditions during the application process. One gallon of alum provides approximately 8.21 moles of available aluminum for sediment inactivation, while one gallon of sodium aluminate provides 21.46 moles of aluminum. Therefore, the use of sodium aluminate not only provides pH buffering, but it can also reduce the amount of alum required for the inactivation project.

The total estimated alum volume for inactivation of internal recycling and control of seepage inputs in Spring Lake, without the use of supplemental buffering agents, is approximately 29,245 gallons. If sodium aluminate is used as a buffering agent, the total chemical requirements necessary to generate an equivalent total mass of available aluminum are 17,692 gallons of alum combined with 4423 gallons of sodium aluminate. As recommended previously, this application should be divided into two separate applications, with approximately one-half of the required chemical volume for alum and sodium aluminate applied during each application.

A summary of estimated application costs for sediment inactivation and control of groundwater seepage in Spring Lake is given in Table 7-12. This estimate assumes an alum volume of 8846 gallons and a sodium aluminate volume of 2212 gallons will be applied during each of two separate applications. It is assumed that the alum and sodium aluminate are purchased at current market price. Planning and mobilization costs are estimated to be approximately $2500 per application, which includes initial planning, mobilization of equipment to the site, demobilization at the completion of the application process, and clean-up. Estimates of man-hour requirements for the application are provided based upon experience with similar previous applications by ERD. A labor rate of $110/hour is assumed which includes labor costs, water quality monitoring, expenses, equipment rental, insurance, mileage, and application equipment fees. The estimated cost for sediment inactivation and control of groundwater seepage in Spring Lake is $47,954 or approximately $23,977 per application.

TABLE 7-12

ESTIMATED APPLICATION COSTS FOR SEDIMENT INACTIVATION AND CONTROL OF GROUNDWATER SEEPAGE IN SPRING LAKE
(Based on 2 separate treatments)

PARAMETER	AMOUNT REQUIRED/ TREATMENT	UNIT COST/ TREATMENT	COST/ TREATMENT	TOTAL COST
Chemicals				
A. Alum	8846 gallons	$0.75/gallon[1]	$ 6,635	$ 13,270
B. Sodium Aluminate	2212 gallons	$3.50/gallon	$ 7,742	$ 15,484
Labor				
A. Planning and Mobilization	2 applications	$2500/application	$ 2,500	$ 5,000
B. Chemical Application	60 man-hours	$110/hour[2]	$ 6,600	$ 13,200
Lab Testing	Pre-/Post-samples x 2 events	$500/event	$ 500	$ 1,000
		TOTAL:	**$ 23,977**	**$ 47,954**

1. Assumed market cost
2. Includes raw labor, water quality monitoring, insurance, expenses, application equipment, mileage, and rentals

Estimates of phosphorus mass removal costs were also calculated for the proposed alum treatment. A summary of this analysis is given in Table 7-13. As indicated in Section 5.1.5, internal recycling contributes approximately 32.9 kg of total phosphorus to Spring Lake each year. This analysis assumes that the sediment inactivation will be effective in reducing internal recycling for a period of 10 years. Therefore, over the 10-year period of effectiveness, the alum treatment has the potential to impact approximately 329 kg (32.9 kg/yr x 10 years) entering Spring Lake. As indicated in Table 7-13, inputs of total phosphorus from groundwater seepage have the potential to contribute 358 kg over the same 10-year period of control. Over the anticipated 10-year period of control, the combined inputs of internal recycling and groundwater seepage have the potential to contribute approximately 687 kg of total phosphorus to Spring Lake.

TABLE 7-13

CALCULATED PHOSPHORUS REMOVAL COSTS FOR ALUM TREATMENT

TOTAL PHOSPHORUS LOAD (kg)			TOTAL PHOSPHORUS LOAD REMOVED[2] (kg)	TREATMENT COST ($)	COST/kg TOTAL PHOSPHORUS REMOVED ($)
INTERNAL RECYCLING[1]	SEEPAGE[1]	TOTAL			
329	358	687	550	47,954	87

1. Assumes a 10-year period of effective control
2. Assumes that 80% of the internal recycling and seepage load is removed

Based on previous research performed by ERD, phosphorus inactivation is approximately 80% effective in retaining available phosphorus within sediments. Therefore, it is assumed that approximately 80% of the potential 687 kg of total phosphorus is attenuated by the proposed alum treatment. As a result, the proposed alum treatment has the potential to remove approximately 550 kg (687 x 0.8) of total phosphorus from Spring Lake over the 10-year anticipated life or approximately 55.0 kg/yr. Based upon the estimated treatment cost of $47,954, the cost per kg of phosphorus removed for the proposed alum treatment is $87/kg. This is an extremely attractive phosphorus removal cost, particularly when compared with structural stormwater retrofit options. For example, the estimated cost of $87/kg of phosphorus removed for alum treatment is 48% of the estimated cost per kg of phosphorus removed for the proposed Sub-basin 3 pond enhancement.

7.3.3 Longevity of Treatment

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

Based on previous experiences by ERD, as well as research by others, it appears that a properly applied chemical treatment will be successful in inactivation of the available phosphorus in the sediments of Spring Lake as well as phosphorus inputs from groundwater seepage. The most significant of these factors is disturbance and agitation of the sediments by boating activities or strong winds. However, several factors can serve to reduce the effectiveness and longevity of this treatment process. Sediment agitation can mobilize the newly deposited alum floc and cause the floc to migrate away from the target area and become prematurely mixed into deeper sediments, reducing the opportunity for maximum phosphorus adsorption in more shallow areas. Significant re-suspension has been implicated in several alum applications in shallow lakes which exhibited reduced longevity. However, in the absence of re-suspension, alum inactivation in lake sediments has resulted in long-term benefits ranging from 3 to more than 20 years. Due to the depth of Spring Lake, relatively small surface area and lack of significant boating activities, it is not anticipated that re-suspension will be a significant problem.

Another factor which can affect the perceived longevity and success of the application process is recycling of nutrients by macrophytes from the sediments into the water column. This recycling will bypass the inactivated sediments since phosphorus will cross the sediment-water interface using vegetation rather than through the floc layer. This process is commonly associated with shoreline emergent macrophytes such as cattails but can also occur in a limited number of submergent macrophytes. Although this process will not affect the inactivation of phosphorus within the sediments, it may result in increases in dissolved phosphorus concentrations which are unrelated to sediment-water column processes. Macrophyte growth in Spring Lake is expanding rapidly and nutrient recycling by macrophytes may be a concern. A plan for macrophyte control should be implemented prior to performing the proposed alum treatment. This plan would be limited to control of nuisance exotic vegetation only, since State law prohibits control of native vegetation in most cases.

7.4 Non-Structural Techniques

A number of non-structural techniques are also available which have the potential to reduce phosphorus loadings entering waterbodies. Examples of non-structural techniques include enhanced regulations for erosion and sediment control, as well as stormwater management. However, virtually all of the Spring Lake drainage basin is currently developed, and opportunities for improving water quality by enhancing sediment and erosion control and stormwater management regulations are severely limited within the basin. Another popular non-structural technique is revegetation of shoreline areas. The majority of shoreline areas within Spring Lake are sparsely vegetated, and substantial additional opportunities exist for enhancement of shoreline vegetation. Street sweeping is also a non-structural technique with a potential for reducing runoff loadings. Another non-structural technique is a source reduction program which attempts to reduce pollutant accumulation within the watershed. Source reduction programs have the potential to provide effective reductions in stormwater concentrations, particularly for nutrients and suspended solids. These programs have a valid potential for improving the characteristics of stormwater runoff in the Spring Lake drainage basin.

7.4.1 Street Sweeping

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

Street sweeping involves the use of machines which basically pick-up contaminants from the street surface and deposit them in a self-contained bin or hopper. Mechanical sweepers are the most commonly used sweeping devices and consist of a series of brooms which rotate at high speeds, forcing debris from the street and gutter into a collection hopper. Water is often sprayed on the surface for dust control during the sweeping process. The effectiveness of mechanical sweepers is a function of a number of factors, including: (1) particle size distribution of accumulated surface contaminants; (2) sweeping frequency; (3) number of passes during each sweeping event; (4) equipment speed; and (5) pavement conditions. Unfortunately, mechanical sweepers perform relatively poorly for collection of particle sizes which are commonly associated with total phosphorus loadings in stormwater runoff. During the 1980s, the U.S. EPA concluded that street sweeping using mechanical sweepers had no significant impact on runoff characteristics.

Over the past decade, improvements have been made to street sweeping devices which substantially enhance the performance efficiency. Vacuum-type sweepers, which literally vacuum the roadway surface, have become increasingly more popular, particularly for parking lots and residential roadways. The overall efficiency of vacuum-type sweepers is generally higher than that of mechanical cleaners, especially for particles larger than 3 mm. Estimated efficiencies of mechanical and vacuum-assisted sweepers are summarized in Table 7-14 based upon information provided by the Federal Highway Administration. Mechanical sweepers can provide approximately 40% removal of phosphorus in roadway dust and debris, while vacuum-assisted sweepers can provide removals up to 74%. Recent studies in Hamilton County, Ohio indicated a significant reduction in runoff concentrations of nutrients after implementation of a vacuum sweeper program in residential areas.

TABLE 7-14

EFFICIENCIES OF MECHANICAL (BROOM) AND VACUUM-ASSISTED SWEEPERS

CONSTITUENT	MECHANICAL SWEEPER EFFICIENCY (%)	VACUUM-ASSISTED SWEEPER EFFICIENCY (%)
Total Solids	55	93
Total Phosphorus	40	74
Total Nitrogen	42	77
COD	31	63
BOD	43	77
Lead	35	76

SOURCE: Federal Highway Administration (FHWA)

The efficiency of street sweepers is highly dependent upon the sweeping interval. To achieve a 30% annual removal of street dirt, the sweeping interval should be less than two times the average interval between storms. Since the average interval between storms in the Central Florida area is approximately three days, a sweeping frequency of once every six days is necessary to achieve a 30% removal of street dirt. To achieve a 50% annual removal, sweeping must occur at least once between storm events. In the Central Florida area, a 50% removal would require street sweeping to occur approximately once every three days.

Street sweeping activities can be particularly effective during periods of high leaf fall by removing solid leaf material and the associated nutrient loadings from roadside areas where they can easily become transported by stormwater flow. Previous research has indicated that leaves release large quantities of both nitrogen and phosphorus into surface water within 24-48 hours after becoming saturated in an aquatic environment. Loadings to waterbodies from leaf fall are often the most significant loadings to receiving waters during the fall and winter months. Street sweeping operations are typically performed on a monthly basis, with increased frequency during periods of high leaf fall.

An analysis was conducted to evaluate potential phosphorus load reductions within the Spring Lake watershed which could be achieved using high efficiency street sweeping techniques. This analysis assumes that a high efficiency vacuum-assisted sweeper will be used and that street sweeping will be conducted at a frequency of once per week for impervious surfaces within the Spring Lake watershed. It is also assumed that the street sweeping operation will remove approximately 60% of the particulate phosphorus present on impervious surfaces within the basin, and that this will result in a reduction of approximately 40% in particulate phosphorus concentrations in runoff which reaches Spring Lake.

Based on the runoff characterization data summarized in Tables 5-5 and 5-6, approximately 60% of the total phosphorus discharging into Spring Lake as a result of stormwater runoff is comprised of particulate matter. For this analysis, it is assumed that weekly street sweeping is performed using a vacuum-assisted sweeper which will reduce the concentration of particulate phosphorus in stormwater runoff by approximately 70%. This will generate a reduction in total phosphorus of approximately 42% (0.6 times 70%). However, street sweeping activities are not practical in Sub-basin 2 (which includes primarily golf course areas) and in Sub-basin 11 (which represents direct overland flow into the lake). Phosphorus loadings from the remaining sub-basin areas contribute approximately 162.3 kg/yr. If this phosphorus loading is reduced by approximately 42%, this equates to an annual load reduction of approximately 68.2 kg/yr of total phosphorus from the Spring Lake phosphorus budget. A summary of anticipated load reductions from weekly street sweeping in the Spring Lake basin is given in Table 7-15.

TABLE 7-15

ANTICIPATED PHOSPHORUS LOAD REDUCTION FROM WEEKLY STREET SWEEPING IN THE SPRING LAKE BASIN

ASSUMPTION	VALUE
Particulate Phosphorus / Total Phosphorus Ratio	0.60
Reduction in Particulate Phosphorus Concentration by Street Sweeping[1]	70%
Reduction in Total Phosphorus Concentration/Load by Street Sweeping	42%
Current Total Phosphorus Runoff Loading	199.3 kg/yr
Phosphorus Loading (excluding Sub-basins 2 and 11)	162.3 kg/yr
Total Phosphorus Removed by Sweeping	68.2 kg/yr

1. Assumes weekly sweeping using a vacuum-assisted sweeper

Capital costs for street sweepers range from approximately $75,000-200,000, with the lower end of the range associated with mechanical street sweepers and the higher end of the range associated with vacuum-type sweepers. The useful life span is typically 4-8 years, with an operating cost of approximately $70/hour.

A summary of phosphorus mass removal costs for street sweeping operation in the Spring Lake drainage basin is given in Table 7-16. This analysis is based upon a unit cost of approximately $175,000/unit for a vacuum-assisted sweeper. A lifespan of approximately seven years is assumed, with units purchased initially and after years 7 and 14, for a total of three units over the 20-year lifespan. Operating costs are also estimated based upon weekly street sweeping and the assumption that street sweeping within the basin area could be accomplished during a single 8-hour work day. An operating cost of $70/hour is assumed. Based upon these assumptions, the net 20-year present worth cost for the street sweeping option is approximately $1,107,400. Over the 20-year cycle, the sweeper would remove approximately 68.2 kg/yr of total phosphorus or 1364 kg over 20 years. This equates to a present worth cost of approximately $812/kg of total phosphorus removed. Although this value is substantially higher than the cost associated with restoration of the FDOT pond or alum treatment, the listed cost of $812/kg is on the lower end of phosphorus removal costs commonly associated with structural BMPs. Since opportunities for BMPs are limited within the Spring Lake basin, the street sweeping option becomes more attractive.

TABLE 7-16

PHOSPHORUS MASS REMOVAL COSTS FOR THE STREET SWEEPING OPTION

PARAMETER	VALUE	20-YEAR VALUE
Capital Cost[1] (20 years)	$ 175,000/unit	$ 525,000
Annual Operating Cost[2]	$ 29,120/yr	$ 582,400
Total Present Worth Cost (20-years)	--	$ 1,107,400
Annual Total Phosphorus Mass Removed	68.2 kg	1,364 kg
Present Worth Cost ($/kg TP removed)	--	$ 812

1. Assumes vacuum-assisted sweeper at $175,000/unit with unit purchased initially and at years 7 and 14 (3 units total)

2. Assumes weekly sweeping at 8 hours/week at $70/hour

7.4.2 Public Education

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

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

1. Relationship between land use, stormwater runoff, and pollutants

2. Functions of stormwater treatment systems

3. How to reduce stormwater runoff volume

4. Impacts of water fowl and pets on runoff characteristics and surface water quality

5. County stormwater program goals and regulations

6. Responsible use of fertilizer, pesticides and herbicides

7. Elimination of illicit connections to the stormwater system

8. Controlling erosion and turbidity

9. Proper operation and maintenance of stormwater systems

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

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

7.4.3 Shoreline Revegetation

Under current conditions, very little quality shoreline vegetation exists around the perimeter of Spring Lake. A diagram of areas with significant existing shoreline vegetation is given on Figure 7-8. Based upon this analysis, approximately 816 ft of the shoreline of Spring Lake is currently vegetated. As indicated in Table 2-2, the shoreline of Spring Lake is estimated to be approximately 5461 ft, indicating that less than 15% of the shoreline currently contains significant emergent vegetation.

Shoreline vegetation has the opportunity to provide measurable improvements in water quality within a lake. Although the nutrient uptake capacity of the vegetation itself is relatively limited, and most shoreline vegetation receives nutrients directly from the soil, extensive shoreline vegetation does provide valuable habitat for other species which have the potential to enhance water quality. Previous research conducted by ERD has also indicated that areas without shoreline vegetation are subject to enhanced erosion and introduction of particulate phosphorus into the water column of the lake during wind and boating activities. Therefore, revegetation of shoreline areas in Spring Lake is recommended. Both public and private grants are available for revegetation of shoreline areas which will assist in offsetting the cost for this management alternative.

Figure 7-8. Diagram of Areas Around Spring Lake with Significant Existing Shoreline Vegetation.

7.4.4 Rear Yard Swales and Berms

Runoff originating from lawn, landscaped, and golf course areas has the potential to contribute significant loadings of both nutrients and pesticides into Spring Lake. Untreated stormwater runoff from lawns and landscaped areas contains total phosphorus concentrations which are 10-25 times greater than concentrations commonly observed in the water column of Spring Lake. As a result, a relatively small volume of untreated rear yard runoff can impact a large quantity of adjacent water.

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

The volume of water retained by a rear yard swale or berm system is directly proportional to the efficiency for reducing loadings discharging into the waterbodies. The minimum design criteria for retention systems constructed in the St. Johns River Water Management District is storage of the first 0.5-inch of runoff. This standard should also be applied in the design of swales and berm systems for areas which discharge into Spring Lake. This volume is calculated by multiplying the area of each parcel which discharges to the rear of the lot (rather than the front) times 0.50 inches over this area. The resulting volume represents the amount of water which should be retained in the rear yard and dictates the design of the swale and berm. A schematic of the recommended berm and swale design for Spring Lake is given in Figure 7-9.

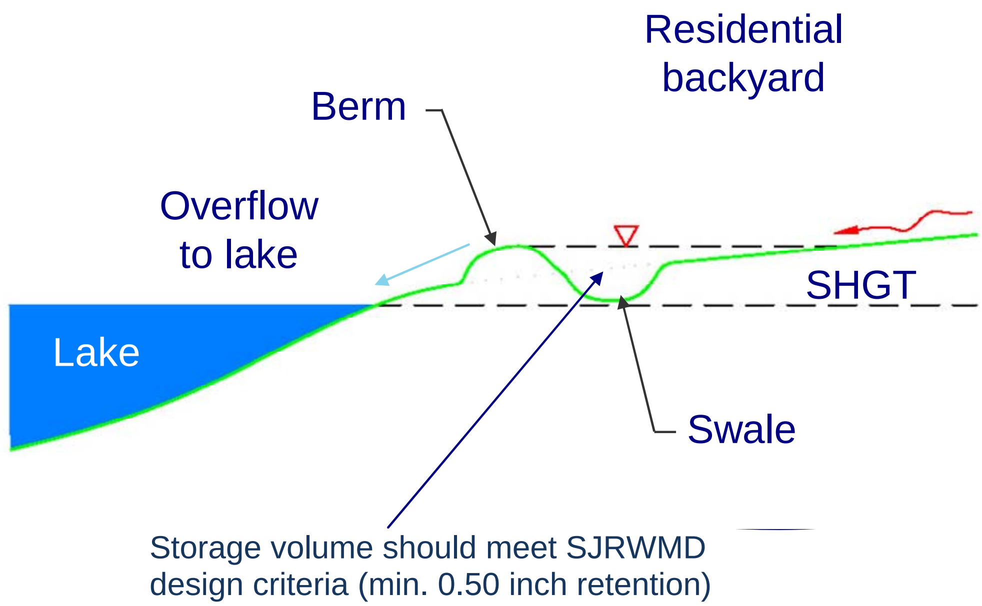


Figure 7-9. Schematic of Recommended Rear Yard Swale and Berm Design.

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

The overall objective of retaining direct runoff from rear yard areas can also be achieved using decorative walls or landscaped areas, as long as the areas provide retention for the specified treatment volume. A schematic of a typical wall section which would also provide retention for rear yard runoff is given in Figure 7-10.

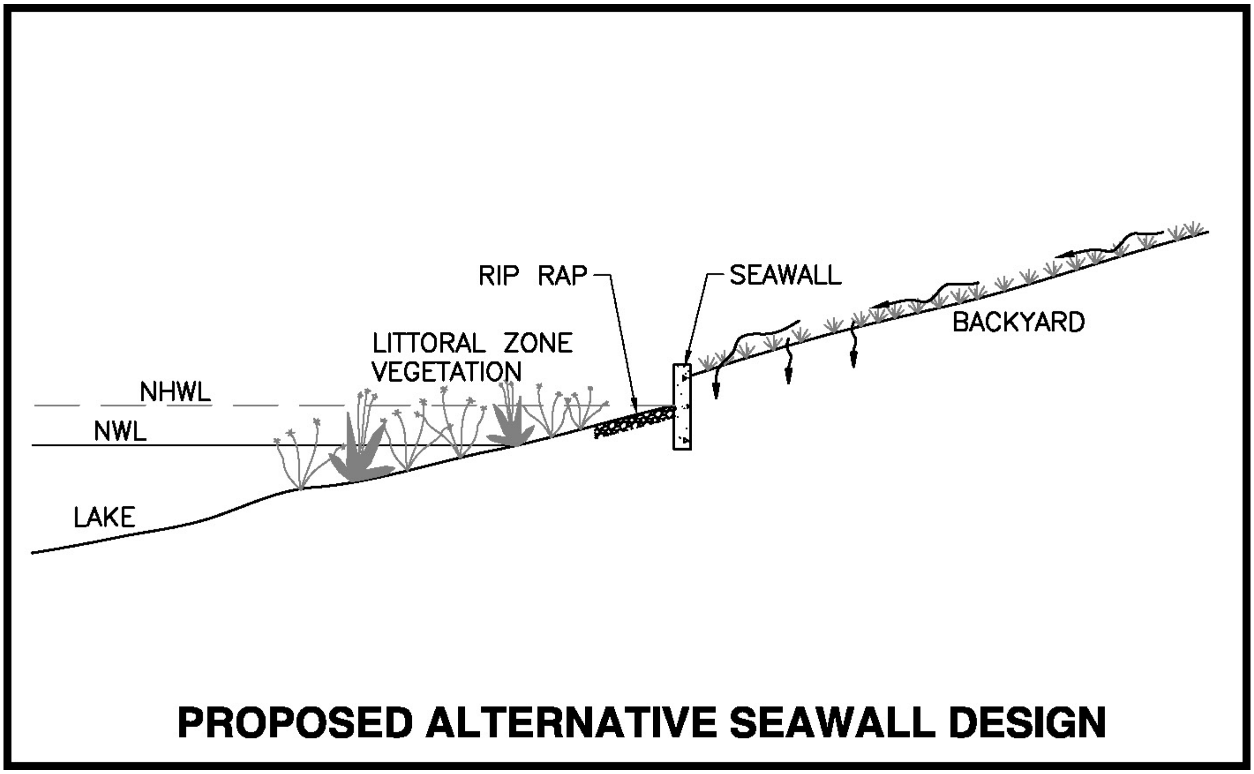


Figure 7-10. Alternative Seawall Design Used as Rear Yard Berm.

Berm and swale systems are an inexpensive method of reducing discharges of direct runoff from rear yards and landscaped areas into Spring Lake. It is strongly recommended that a program be established to encourage construction of berms and swales along all shoreline areas of Spring Lake, including both residential and golf course areas. Such a program has the potential to provide nutrient load reductions equivalent to a large structural retrofit project costing millions of dollars. It is difficult to envision how the construction or presence of a swale or berm would create a hardship for any lake front property owner. The swales and berms should be designed according to existing SJRWMD design criteria which would require retention of 0.50 inches of runoff from all parcel areas which discharge to the waterbody. Standard design criteria and standards should be developed for construction of new systems. Existing development should be granted a period of approximately five years to come into compliance with this new ordinance. Funding for construction of the berm and swale systems could be provided by the land owner, or in hardship cases, by grants from the City. A number of funding grants may be available for this program from both FDEP and SJRWMD.

7.5 Water Quality Benefits from Evaluated Management Options

The anticipated water quality benefits of the proposed stormwater management and alum treatment projects for Spring Lake were evaluated using the calibrated water quality model discussed in Section 6. This analysis is based upon the anticipated total phosphorus reductions for the proposed Sub-basins 3 and 4 pond reconfiguration, alum treatment, street sweeping, and combinations of these projects. A comparison of modeled load reductions for the evaluated stormwater retrofit and alum treatment projects is given in Table 7-17.

TABLE 7-17

SUMMARY OF MODELED LOAD REDUCTIONS FOR EVALUATED WATER QUALITY IMPROVEMENTS PROJECTS

TREATMENT OPTION	CURRENT TOTAL PHOSPHORUS LOAD (kg/yr)	TOTAL PHOSPHORUS REMOVAL (kg/yr)	MODIFIED TOTAL PHOSPHORUS LOAD (kg/yr)
1. Enlargement of Sub-basin 3 Pond	101.8[1]	68.2	33.6[1]
2. Alum Surface Treatment			
a. Internal Recycling	32.9	26.3	6.6
b. Groundwater Seepage	35.8	28.6	7.2
3. Street Sweeping	199.3[2]	68.2	131.1[2]

1. Annual total phosphorus load from Sub-basins 3 and 4
2. Annual total phosphorus load from all sub-basins

A complete listing of the results of the water quality models used to simulate anticipated benefits from the evaluated treatment options is given in Appendix G.2. A summary of these results is given in Table 7-18. Enlargement of the Sub-basin 3 pond would reduce phosphorus concentrations in Spring Lake from 64 μg/l to approximately 49 μg/l, with a corresponding decrease in chlorophyll-a. Water column clarity would increase by approximately 18%, with a reduction in TSI value from 76 to 71. Implementation of stormwater reuse in Sub-basin 2 would result in only a slight improvement in water quality within the lake when considered individually.

TABLE 7-18

MODELED WATER QUALITY BENEFITS FROM THE EVALUATED TREATMENT OPTIONS

OPTION	MEAN TOTAL PHOSPHORUS CONCENTRATION (mg/l)	MEAN CHLOROPHYLL-A CONCENTRATION (mg/m3)	MEAN SECCHI DISK DEPTH (m)	TSI VALUE
1. Existing Conditions	0.064	32.2	0.89	76
2. Enlargement of Sub-basin 3 pond	0.049	24.0	1.05	71
3. Stormwater reuse in Sub-basin 2	0.061	30.3	0.92	75
4. Alum Treatment	0.052	25.6	1.01	72
5. Sub-basin 3 pond enhancement and alum treatment	0.036	17.5	1.26	65
6. Street sweeping	0.049	24.0	1.05	71
7. Implementation of Options 2, 4, and 6	0.020	9.6	1.74	55

Alum treatment in Spring Lake, which would provide phosphorus removal for both internal recycling and groundwater seepage, is expected to produce water quality benefits similar to those achieved by enlargement of the Sub-basin 3 pond. Implementation of alum treatment combined with enlargement of the Sub-basin 3 pond would result in significant improvements in water quality in Spring Lake, with a 44% reduction in total phosphorus, 46% reduction in chlorophyll-a, 42% improvement in water clarity, and a reduction in TSI from hypereutrophic to eutrophic conditions.

Implementation of street sweeping is expected to generate water quality benefits similar to those achieved by alum treatment and enlargement of the Sub-basin 3 pond. However, if street sweeping is combined with alum treatment and enlargement of the Sub-basin 3 pond, substantial improvements in water quality can be achieved in Spring Lake. The combination of these three options will reduce total phosphorus concentrations within the lake by approximately 65%, with a 70% reduction in chlorophyll-a, and a 96% improvement in water clarity, while reducing the lake TSI value from hypereutrophic to mesotrophic conditions. The improvement in water clarity would be highly visible, and nuisance growth of algae in shoreline areas would be substantially reduced.

7.6 Recommendations

Based on the evaluations conducted by ERD, the following specific recommendations are proposed:

1. Based on the evaluations presented in the previous sections, it is apparent that the highest degree of water quality improvement in Spring Lake can be achieved through enhancement of the Sub-basin 3 pond, alum treatment, and street sweeping options. Both the Sub-basin 3 pond enhancement and the alum treatment options have extremely attractive phosphorus mass removal costs which are substantially lower than removal costs commonly associated with urban retrofit projects. The alum treatment will provide phosphorus removal at a cost of approximately $87/kg and is expected to provide control of both internal recycling and phosphorus inputs from groundwater seepage for a period of approximately 10 years. The proposed enhancement to the Sub-basin 3 pond has a phosphorus removal cost of approximately $334/kg which is also extremely attractive compared with phosphorus removal costs normally associated with wet detention treatment systems. It is recommended that these two management options be adopted and implemented as soon as possible.

2. An additional attractive alternative for improvement of water quality in Spring Lake is the street sweeping option. This option provides water quality benefits similar to the Sub-basin 3 pond enhancement and alum treatment, while removing substantial amounts of common litter and vegetation from the watershed prior to discharging to Spring Lake. Street sweeping operations should be conducted with a vacuum-type unit to maximize the benefits of this option. Implementation of all three options will result in significant improvements in water quality in Spring Lake and will restore the lake from the existing hypereutrophic condition to borderline eutrophic/mesotrophic conditions. Street sweeping should be conducted on a weekly interval, with more frequent sweeping during periods of heavy leaf fall, if needed.

3. A public education campaign should also be conducted to educate residents about the direct link between watershed activities and water quality in Spring Lake. Many instances of poor landscaping practices, such as blowing grass clippings and leaves onto paved surfaces, were observed by ERD during this project. Based upon these observations, it is apparent that many residents within the watershed are unaware of the potential impacts from their poor maintenance activities. It is obvious from the collected runoff samples that watershed activities, particularly in the residential areas, are having a significant impact on phosphorus concentrations in stormwater runoff originating from these areas. Although the specific sources of these loadings were not evaluated as part of this study, the most likely sources include misuse of fertilizer and improper landscaping activities. Residents in the Spring Lake drainage basin should be fully advised of the potential water quality impacts from these activities.

4. It is recommended that an aggressive program be implemented to establish berm and swale systems along all shoreline areas adjacent to Spring Lake. This is an extremely inexpensive alternative for managing direct runoff inputs into the lake which often carry elevated levels of nutrients and pesticides directly into the lake. Implementation of this option will achieve water quality benefits similar to a more expensive structural management option.

5. Finally, it is strongly recommended that a shoreline revegetation program be implemented in Spring Lake. This program would consist of revegetating the existing bare shoreline areas with native vegetation. This program should also include ongoing maintenance to remove exotic species which attempt to colonize the shoreline areas before the planted vegetation becomes fully established. These shoreline areas will enhance water quality by providing habitat for organisms and processes which enhance water quality.

SECTION 8

CITED REFERENCES

Brezonik, P.L. (1984). “Trophic State Indices: Rationale for Multivariate Approaches.” In *Lake and Reservoir Management – Proceedings of the Third Annual Conference of the North American Lake Management Society*, pp. 441-445, October 18-20, 1983; Knoxville, TN, EPA 440/5/84-001.

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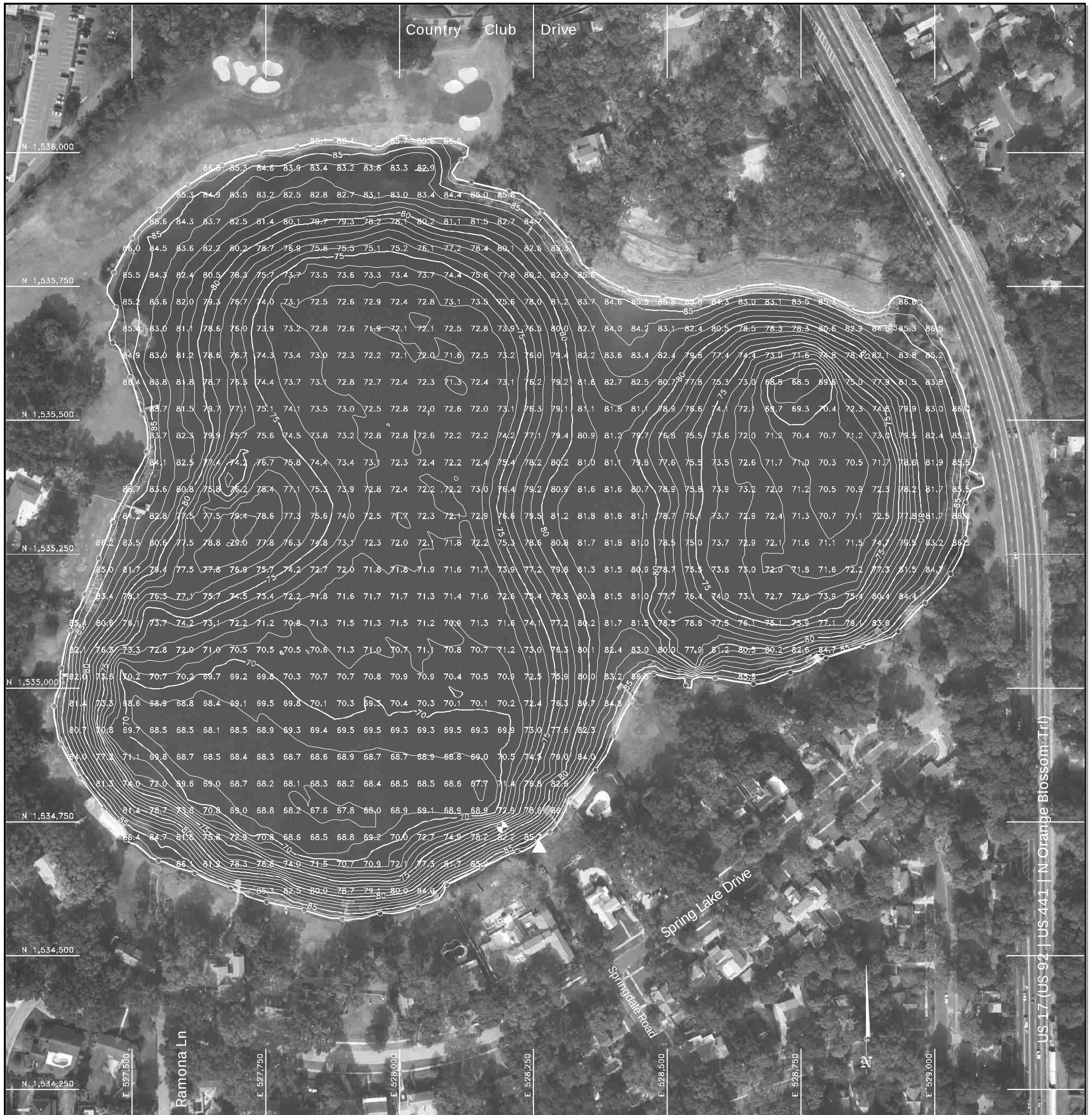
APPENDICES

APPENDIX A

HYDROGRAPHIC SURVEY OF SPRIN G LAKE

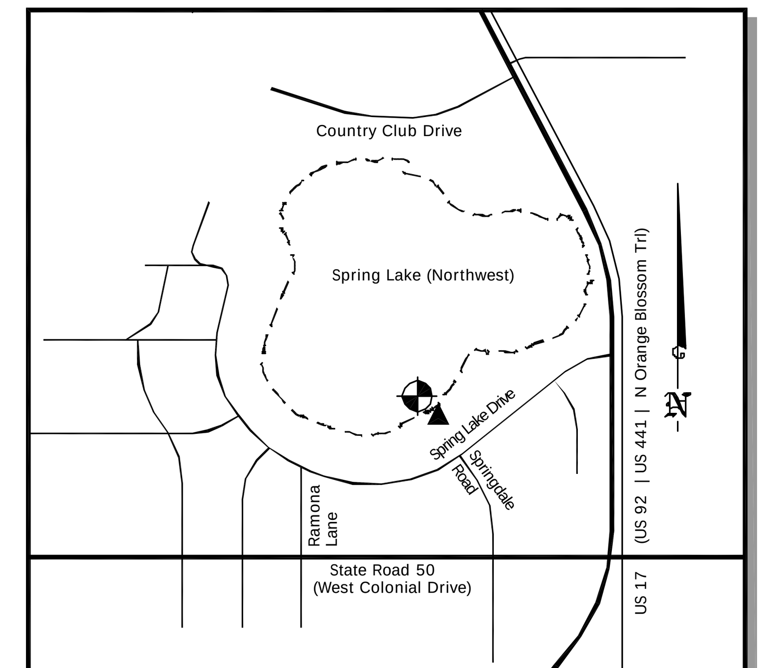
(Source: City of Orlando)



A MAP SHOWING A HYDROGRAPHIC SURVEY OF Spring Lake (Northwest)

Location: Section 22, Township 22 South, Range 29 East, Orange County, Florida.
West of Orange Blossom Trail (US 441) between Country Club Road and Spring Lake Drive

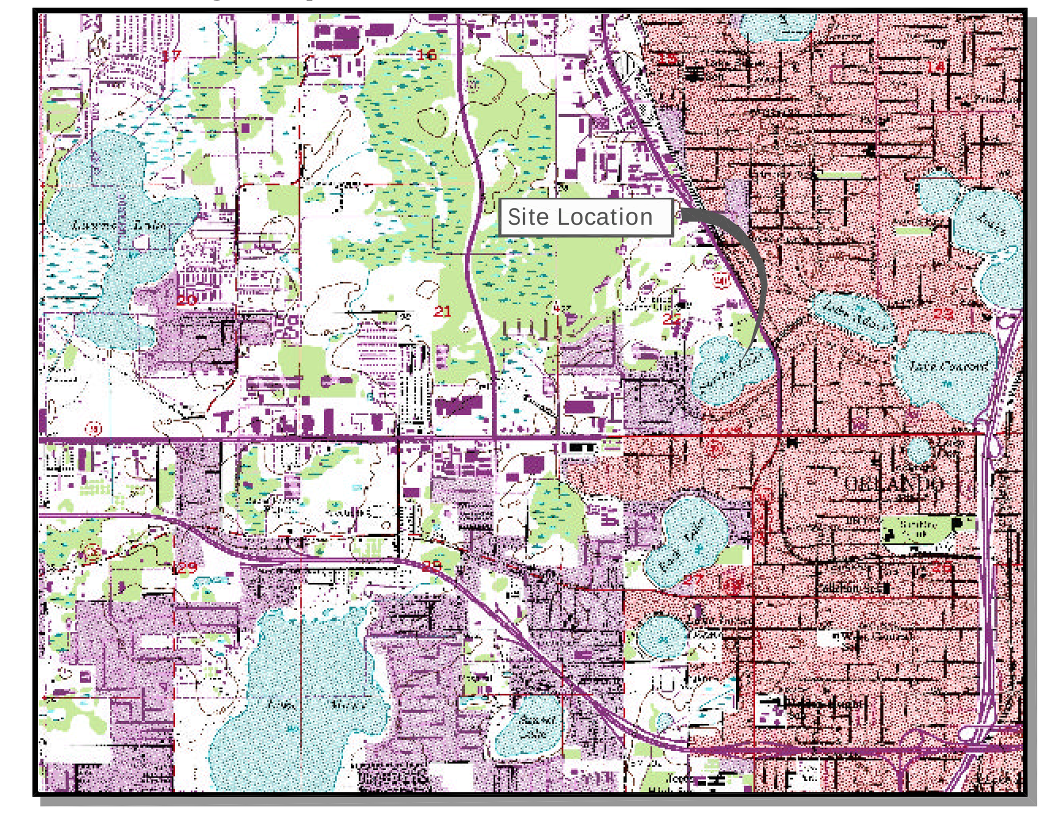
Benchmark Location



Description:
Top of 36" corrugated metal Pipe between house #1271 and #1307 at the intersection of Springlake Drive and Springdale Road.
(Elev. 87.38')

Not to Scale

Vicinity Map



Not to Scale

Legend

- ▲ Bench Mark provided by City of Orlando
- Approximate Lake Gauge Location
- Approximate Ordinary high Water Line (Field Located) 87.08' 3/27/03
- Approximate Ordinary high Water Line (Areial Digitized)

Lake Data

3/27/03

Edge of Water Elevation 86.6'	(0 Depth)
Min.Elevation 67.0' Max.Depth	(19.6' Depth)
Lake Surface Area	38.24 Acres
Lake Volume	16,905,557 Cubic Feet
Shoreline Perimeter	5,461 Feet
Lake Origin:	Natural

Stage / Volume / Area Table

Elev. in Feet	Cubic Feet	Surface Area Acres
67	0	0.000
68	2231	0.221
69	56051	2.431
70	201499	4.166
71	428249	6.458
72	773402	9.588
73	1288744	13.845
74	1950919	16.407
75	2706247	18.191
76	3534047	19.819
77	4431760	21.398
78	5400731	23.112
79	6445416	24.850
80	7562391	26.413
81	8749192	28.186
82	10030717	30.578
83	11399606	32.333
84	12852335	34.293
85	14384259	35.953
86	15982669	37.429
86.6	16905557	38.236

Survey Notes:

1.) REFER TO L.D. BRADLEY SURVEY No. 02-126.

2.) NORTH AND AZIMUTHS REFER TO THE TRANSVERSE MERCATOR GRID LINES FOR THE EAST ZONE OF FLORIDA, NORTH AMERICAN DATUM OF 1983 (NAD83).

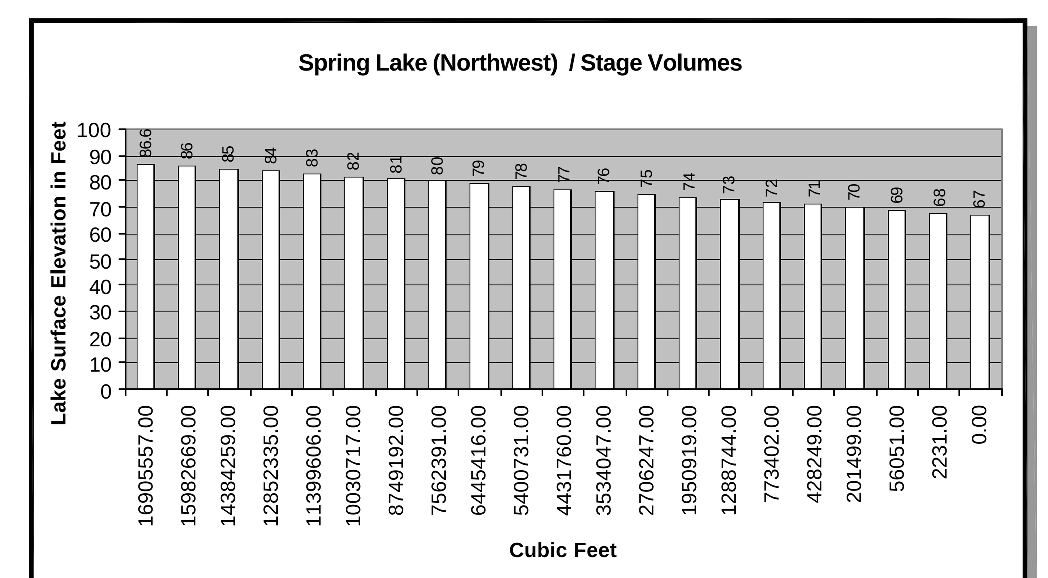
3.) ELEVATIONS AND CONTOURS REFER TO THE NORTH AMERICAN VERTICAL DATUM OF 1988 (NAVD88).

4.) LAKE SURFACE ELEVATIONS WERE MONITORED FROM A LAKE SURFACE GAUGE ESTABLISHED FROM A LOCAL BENCH MARK FOR EACH LAKE AND PROVIDED BY THE CITY OF ORLANDO.

5.) THE APPROXIMATE ORDINARY HIGH WATER LINE WAS LOCATED BY VISUAL INSPECTION AND TIED VERTICALLY BY DIFFERENTIAL LEVELING TECHNIQUES. THE HORIZONTAL POSITION OF THE APPROXIMATE ORDINARY HIGH WATER LINE WAS LOCATED BY DIFFERENTIAL GPS SURVEYING PROCEDURES ONLY WHERE THE SHORELINE ALLOWED FOR ACCESS AND SATELLITE COVERAGE.

6.) THE HYDROGRAPHIC PORTION OF THIS SURVEY WAS PERFORMED UTILIZING DIFFERENTIAL GPS SURVEYING PROCEDURES FOR VESSEL POSITIONING. DIFFERENTIAL CORRECTIONS WERE OBTAINED FROM THE U.S. COAST GUARD NAVBEACON SYSTEM AND OR THE WASS POSITIONING SYSTEM. DEPTH SOUNDINGS WERE MEASURED WITH A KNUDSEN MODEL 320M DUAL FREQUENCY SURVEY FATHOMETER CONFIGURED WITH A 200 kHz (HIGH FREQUENCY) TRANSDUCER.

7.) THE INFORMATION DEPICTED ON THESE MAPS REPRESENT THE RESULTS OF THE SURVEY ON THE DATE INDICATED AND CAN ONLY BE CONSIDERED AS INDICATING THE GENERAL CONDITIONS EXISTING AT THAT TIME.



100 50 0 100 200
SCALE IN FEET
1" = 100'

RICHARD J. SAWYER
FLORIDA PROFESSIONAL SURVEYOR AN MAPPER NO. 6131
NOT VALID WITHOUT THE SIGNATURE AND THE ORIGINAL RAISED SEAL OF A FLORIDA LICENSED SURVEYOR AND MAPPER

4SHEET 43 OF 50

L.D. BRADLEY LAND SURVEYORS
5773 NORMANDY BOULEVARD, JACKSONVILLE, FLORIDA 32205
PHONE (904) 786-6400 FAX (904) 786-1479
LICENSED BUSINESS No. 6888

W.O. NO.: 02-126	HYDRO DATE: 2/24/03	DRAFTED BY: WF
CHECKED BY: RS	CAD FILE: Spring-nw.dwg	

W.O. NO.: D-02-126

APPENDIX B

HISTORICAL WATER QUALITY DATA FOR SPRING LAKE COLLECTED BY THE CITY OF ORLANDO

a. Vertical Field Profiles
b. Lab Analyses

a. Vertical Field Profiles

b. Lab Analyses

Spring Lk Historic Profiles

Date MMDDYY	Time HHMMSS	Depth meters	Temp degC	pH units	SpCond uS/cm	TDS mg/l	DO mg/l	DO % Sat	Turb NTU	Redox mV	Secchi m
8/9/94	11:33	0.5	29.56	8.52	210	134	8.4		13.9	163	0.57
8/9/94	11:35	1.0	29.17	7.53	211	135	5.7		13.5	192	0.57
8/9/94	11:35	2.0	29.09	8.27	211	135	7.6		13.9	175	0.57
8/9/94	11:37	3.0	28.95	7.43	217	139	5.7		14.2	200	0.57
8/9/94	11:39	4.0	27.58	6.47	265	170	0.1		18.9	-16	0.57
8/9/94	11:39	4.3	27.08	6.25	581	372	0.1		13.5	-13	0.57
11/28/94	8:53	0.6	22.07	8.31	188	120	10.3		9.5	227	0.80
11/28/94	8:55	1.0	22.06	8.21	189	121	10.0		7.1	237	0.80
11/28/94	8:57	2.0	22.03	7.98	191	122	9.6		7.2	250	0.80
11/28/94	8:58	3.0	21.77	7.53	191	122	6.8		8.3	264	0.80
11/28/94	8:59	4.0	21.39	7.20	188	120	4.6		29.6	221	0.80
11/28/94	9:01	4.3	21.65	6.69	201	129	0.1		0.0	60	0.80
3/7/95	10:50	0.5	21.09	8.57	227	145	9.1		8.3	192	0.94
3/7/95	10:51	1.0	21.09	8.59	227	145	9.0		10.1	194	0.94
3/7/95	10:52	2.0	21.03	8.58	227	145	8.7		9.8	195	0.94
3/7/95	10:53	3.0	20.71	8.32	228	146	5.5		11.8	202	0.94
3/7/95	10:54	4.0	18.73	6.98	236	151	0.2		99999.0	72	0.94
3/7/95	10:55	4.1	18.55	6.51	251	161	0.2		99999.0	31	0.94
6/6/95	9:53	0.5	28.56	8.16	230	147	7.2		13.2	193	0.70
6/6/95	9:54	1.0	28.48	8.16	230	147	7.3		12.8	194	0.70
6/6/95	9:56	2.0	28.17	7.76	231	148	6.7		13.2	205	0.70
6/6/95	9:57	3.0	28.04	7.61	231	148	6.4		13.0	210	0.70
6/6/95	9:59	4.0	27.82	7.01	241	154	0.1		0.0	73	0.70
6/6/95	10:00	4.3	27.30	6.06	416	266	0.1		0.0	28	0.70
9/7/95	7:57	0.5	28.68	7.35	162	104	5.4		21.7	236	0.66
9/7/95	7:57	1.0	28.61	7.30	162	104	4.8		21.8	240	0.66
9/7/95	7:59	1.9	28.21	7.15	159	102	3.6		20.8	247	0.66
12/12/95	10:49	0.5	18.05	7.34	201	129	8.7		14.2	254	0.75
12/12/95	10:50	1.0	18.02	7.34	201	129	8.6		14.3	254	0.75
12/12/95	10:51	1.3	18.01	7.34	201	129	8.4		17.3	255	0.75
2/28/96	10:45	0.5	22.60	8.80	214	137	11.4		9.3	238	1.01
2/28/96	10:46	1.0	22.59	8.85	214	137	11.4		8.3	239	1.01
2/28/96	10:47	2.0	20.32	8.70	214	137	9.7		11.5	247	1.01
2/28/96	10:48	3.0	16.74	7.91	212	136	2.7		22.0	282	1.01
2/28/96	10:50	4.0	15.66	7.58	210	134	0.3		36.2	288	1.01
6/3/96	12:08	0.5	28.34	8.91	202	129	8.3		38.9	211	0.59
6/3/96	12:08	1.0	27.92	8.86	203	130	7.9		29.5	214	0.59
6/3/96	12:09	1.4	27.04	8.46	204	131	5.6		29.8	229	0.59
8/27/96	11:07	0.5	30.14	8.88	201	129	8.8		34.1	185	0.66
8/27/96	11:08	1.0	29.88	8.76	201	129	8.0		32.4	192	0.66
8/27/96	11:08	2.0	29.63	8.60	201	129	6.9		32.2	200	0.66
8/27/96	11:09	3.0	29.49	8.33	200	128	5.4		31.7	215	0.66
8/27/96	11:10	4.0	29.10	7.81	217	139	0.7		36.2	82	0.66
8/27/96	11:11	4.5	28.60	6.41	566	362	0.1		0.0	10	0.66
3/6/97	12:13	0.5	25.55	8.69	238	152	10.1	124		220	0.92
3/6/97	12:14	1.0	25.43	8.79	238	152	10.1	123		222	0.92
3/6/97	12:15	2.0	23.98	8.55	236	151	8.4	99		239	0.92
3/6/97	12:16	3.0	22.09	8.11	233	149	1.4	16		278	0.92
3/6/97	12:17	4.0	20.38	7.13	262	168	0.1	1		99	0.92

Spring Lk Historic Profiles

Date MMDDYY	Time HHMMSS	Depth meters	Temp degC	pH units	SpCond uS/cm	TDS mg/l	DO mg/l	DO % Sat	Turb NTU	Redox mV	Secchi m
6/3/97	11:44	0.5	28.60	8.69	223	143	10.1	130		274	1.25
6/3/97	11:45	1.0	27.56	8.71	224	143	9.0	114		274	1.25
6/3/97	11:46	2.0	27.10	8.41	222	142	7.9	100		288	1.25
6/3/97	11:47	3.0	26.77	8.08	225	144	3.1	38		312	1.25
6/3/97	11:48	4.0	25.53	7.57	296	189	0.1	1		133	1.25
6/3/97	11:50	4.1	25.42	6.89	328	210	0.1	1		77	1.25
8/5/97	10:39	0.5	30.29	7.24	148	94	7.7	102		294	0.76
8/5/97	10:40	1.0	30.23	7.31	147	94	7.5	100		295	0.76
8/5/97	10:41	2.0	30.01	7.31	147	94	6.8	90		299	0.76
8/5/97	10:42	3.0	29.83	7.27	147	94	6.0	79		306	0.76
8/5/97	10:43	3.9	29.43	6.59	324	207	2.9	38		158	0.76
11/20/97	12:33	0.5	20.50	7.80	176	113	9.2	102		328	0.75
11/20/97	12:34	1.0	20.38	7.79	176	113	8.7	97		331	0.75
11/20/97	12:35	2.0	19.96	7.75	176	113	8.0	88		337	0.75
11/20/97	12:36	3.0	19.80	7.69	177	113	7.3	80		343	0.75
11/20/97	12:37	4.0	19.76	7.63	176	113	7.1	78		346	0.75
11/20/97	12:47	4.5	19.90	7.16	180	115	0.4	4		332	0.75
3/10/98	8:44	0.5	19.48	6.91	165	106	7.7	84		372	0.61
3/10/98	8:45	1.0	19.45	6.97	165	106	7.7	84		370	0.61
3/10/98	8:45	1.7	19.41	7.03	165	106	7.7	84		369	0.61
6/4/98	9:55	0.5	30.21	8.46	181	116	9.3	123		321	0.78
6/4/98	9:56	1.0	30.20	8.70	181	116	9.3	123		317	0.78
6/4/98	9:56	2.0	30.18	8.73	180	115	9.2	122		316	0.78
6/4/98	9:58	3.0	27.86	7.30	182	116	0.2	2		355	0.78
11/17/98	11:33	0.5	24.67	8.88	169	108	12.0	145		323	0.70
11/17/98	11:34	1.0	24.18	8.72	169	108	10.8	129		328	0.70
11/17/98	11:36	2.0	23.65	7.63	169	108	6.5	77		374	0.70
11/17/98	11:38	3.0	23.01	7.03	169	108	0.8	10		390	0.70
11/17/98	11:39	4.0	22.71	6.88	173	111	0.1	1		68	0.70
2/11/99	11:59	0.5	23.33	8.83	203	130	11.0	130		281	0.92
2/11/99	11:59	1.0	22.53	8.87	203	130	11.2	129		280	0.92
2/11/99	12:00	1.9	21.79	8.60	202	129	9.3	106		288	0.92
2/11/99	12:01	2.5	21.11	7.78	202	129	5.2	58		316	0.92
6/1/99	12:05	0.5	28.01	7.72	174	111	7.1	91		280	1.30
6/1/99	12:05	1.0	27.97	7.64	174	111	7.1	91		280	1.30
6/1/99	12:06	2.0	27.86	7.55	173	111	6.9	88		280	1.30
6/1/99	12:08	3.0	27.49	7.38	173	111	5.3	67		287	1.30
6/1/99	12:09	3.9	26.69	6.60	217	139	0.9	11		48	1.30
8/10/99	12:25	0.5	31.59	7.17	137	88	7.4	100		271	1.37
8/10/99	12:26	1.0	31.47	7.12	137	88	7.4	100		272	1.37
8/10/99	12:27	1.6	31.20	7.06	137	88	6.9	93		275	1.37
11/11/99	12:28	0.6	22.55	8.85	134	86	11.6	135		227	0.88
11/11/99	12:30	1.0	22.08	8.68	134	86	11.1	127		235	0.88
11/11/99	12:31	1.8	21.75	8.29	134	86	10.1	115		252	0.88
5/4/00	12:02	0.5	26.19	8.46	194	124	9.6	119		270	1.45
5/4/00	12:03	1.0	26.20	8.46	194	124	9.6	119		269	1.45
5/4/00	12:04	2.0	26.14	8.46	193	124	9.5	118		268	1.45
5/4/00	12:05	3.0	25.03	7.76	194	124	7.2	87		301	1.45
5/4/00	12:06	4.0	24.52	7.24	192	123	0.5	6		321	1.45
5/4/00	12:07	4.9	23.12	6.54	209	134	0.2	2		-19	1.45
8/10/00	12:41	0.5	31.51	8.86	166	106	8.6	117		48	0.99
8/10/00	12:42	1.0	30.86	8.70	165	106	8.2	111		54	0.99

Spring Lk Historic Profiles

Date MMDDYY	Time HHMMSS	Depth meters	Temp degC	pH units	SpCond uS/cm	TDS mg/l	DO mg/l	DO % Sat	Turb NTU	Redox mV	Secchi m
8/10/00	12:43	2.0	30.56	7.89	165	106	6.2	82		76	0.99
8/10/00	12:44	3.0	30.21	7.27	167	107	2.6	34		93	0.99
8/10/00	12:45	4.0	29.54	6.81	177	113	0.4	5		-88	0.99
8/10/00	12:46	4.5	29.19	6.40	238	152	0.2	3		-141	0.99
11/28/00	12:43	0.5	18.99	7.87	183	117	11.9	129		140	0.70
11/28/00	12:44	1.0	18.44	7.74	184	118	11.7	125		148	0.70
2/1/00	12:58	0.5	15.75	8.05	156	100	10.8	109	0.9	332	1.05
2/1/00	12:58	1.0	14.94	8.29	155	99	11.2	111	1.0	322	1.05
2/1/00	12:59	1.6	14.83	8.25	155	99	11.1	109	1.3	322	1.05
5/25/01	11:14	0.5	28.86	8.80	254	163	8.6	111		10	1.14
5/25/01	11:15	1.0	28.60	8.84	254	163	8.6	111		15	1.14
5/25/01	11:15	1.5	28.48	8.87	253	162	8.6	111		16	1.14
8/16/01	13:10	0.5	32.09	8.92	229	147	10.3	142		-14	0.50
8/16/01	13:10	1.0	31.34	8.88	229	147	9.8	133		-10	0.50
8/16/01	13:11	2.0	30.85	8.80	228	146	9.3	125		-3	0.50
8/16/01	13:12	3.0	29.92	8.15	227	145	4.0	53		10	0.50
8/16/01	13:12	4.0	28.15	7.54	246	157	0.7	9		-158	0.50
8/16/01	13:13	4.7	27.75	7.02	335	214	0.4	5		-176	0.50
11/6/01	13:36	0.5	22.39	7.96	195	125	8.7	100		-2	0.59
11/6/01	13:38	1.0	22.34	7.99	195	125	8.8	101		4	0.59
11/6/01	13:39	1.9	22.16	7.96	195	125	8.3	95		6	0.59
3/12/02	13:14	0.5	22.80	8.40	239	153	11.2	130		35	0.98
3/12/02	13:15	1.0	22.46	8.45	238	152	11.2	129		44	0.98
3/12/02	13:17	2.0	21.22	8.50	237	152	11.9	134		50	0.98
3/12/02	13:18	3.0	18.42	8.51	235	150	12.4	132		52	0.98
3/12/02	13:19	4.0	17.32	7.83	237	152	2.2	23		72	0.98
3/12/02	13:20	4.5	17.30	7.66	234	150	1.5	15		38	0.98
6/4/02	11:31	0.5	31.42	8.25	208	133	9.8	132		5	0.87
6/4/02	11:31	1.0	31.20	8.35	208	133	10.1	137		8	0.87
6/4/02	11:33	2.0	29.05	8.00	210	134	8.0	105		32	0.87
6/4/02	11:33	3.0	28.02	7.92	210	134	5.3	68		35	0.87
6/4/02	11:34	4.0	26.72	7.28	224	143	0.8	10		-177	0.87
6/4/02	11:36	4.1	26.78	7.05	222	142	0.7	9		-217	0.87
8/22/02	12:18	0.5	30.63	8.84	204	131	10.6	142		167	0.81
8/22/02	12:19	1.0	30.58	8.85	203	130	10.6	141		178	0.81
8/22/02	12:20	2.0	29.47	7.97	203	130	7.6	100		221	0.81
8/22/02	12:20	3.0	29.27	7.75	202	129	6.6	86		230	0.81
8/22/02	12:20	4.0	29.18	7.62	207	132	5.6	73		188	0.81
8/22/02	12:21	4.9	28.16	6.59	241	154	1.3	17		-54	0.81
11/19/02	13:52	0.5	20.65	7.67	173	111	8.8	98		178	0.79
11/19/02	13:53	1.0	20.49	7.68	173	111	8.8	98		181	0.79
11/19/02	13:53	2.0	20.25	7.67	173	111	8.9	98		183	0.79
11/19/02	13:53	3.0	20.01	7.63	173	111	8.6	95		190	0.79
11/19/02	13:54	4.0	19.76	7.61	173	111	8.2	90		194	0.79
11/19/02	13:55	5.0	20.96	6.59	285	182	2.0	23		49	0.79
11/19/02	13:56	5.0	20.96	6.51	290	186	0.7	7		16	0.79

Spring Lk Historic Profiles

Date MMDDYY	Time HHMMSS	Depth meters	Temp degC	pH units	SpCond uS/cm	TDS mg/l	DO mg/l	DO % Sat	Turb NTU	Redox mV	Secchi m
5/27/03	13:20	0.5	30.96	8.87	207	132	11.1	150			0.93
5/27/03	13:21	1.0	30.69	8.91	208	133	11.4	153			0.93
5/27/03	13:22	2.0	28.60	8.60	199	127	10.6	137			0.93
5/27/03	13:23	3.0	27.80	7.74	199	127	4.4	56			0.93
5/27/03	13:23	4.0	26.32	7.15	215	138	1.1	13			0.93
5/27/03	13:24	4.8	24.70	6.74	248	159	0.4	5			0.93
11/4/03	14:22	0.5	26.56	8.66	211	135	11.6	145			0.76
11/4/03	14:23	1.0	26.32	8.75	211	135	11.5	143			0.76
11/4/03	14:24	2.0	25.34	8.55	214	137	10.9	133			0.76
11/4/03	14:25	3.0	25.28	8.34	213	136	8.8	107			0.76
11/4/03	14:25	4.0	24.84	8.09	214	137	6.6	80			0.76
11/4/03	14:25	4.8	24.82	7.47	282	180	3.6	43			0.76
3/11/03		0.5	25.00	9.06	194	124	12.0	145			0.83
3/11/03		1.0	24.28	9.06	193	124	12.2	146			0.83
3/11/03		2.0	23.15	8.38	198	127	10.1	118			0.83
3/11/03		3.0	20.59	7.87	193	124	5.6	63			0.83
3/11/03		4.0	18.27	7.43	196	125	1.9	21			0.83
3/11/03		5.0	17.11	6.83	257	164	0.3	3			0.83
3/11/03		5.2	17.10	6.73	302	193	0.2	2			0.83
8/21/03	10:16	0.5	29.58	7.75	192	123	7.2	94			0.77
8/21/03	10:16	1.0	29.58	7.76	191	122	7.1	93			0.77
8/21/03	10:18	2.0	29.58	7.73	192	123	6.9	90			0.77
8/21/03	10:19	3.0	29.47	7.45	191	122	3.9	51			0.77
8/21/03	10:19	4.0	28.79	7.08	222	142	0.8	10			0.77
8/21/03	10:20	4.8	27.71	6.59	335	214	0.3	4			0.77
2/12/04	13:27	0.5	20.80	8.52	230	147	11.1	124			0.86
2/12/04	13:28	1.0	19.50	8.66	228	146	11.8	128			0.86
2/12/04	13:29	2.0	18.19	8.63	227	145	11.8	126			0.86
2/12/04	13:30	3.0	17.28	8.09	228	146	8.1	84			0.86
2/12/04	13:31	4.0	17.10	7.80	228	146	3.4	35			0.86
2/12/04	13:32	4.6	17.04	7.36	247	158	0.8	8			0.86
5/13/04	12:43	0.5	27.19	8.37	240	154	8.6	108			1.21
5/13/04	12:45	1.0	27.17	8.39	240	154	8.7	109			1.21
5/13/04	12:45	2.0	27.09	8.40	240	154	8.7	110			1.21
5/13/04	12:45	3.0	26.30	8.00	240	154	8.0	100			1.21
5/13/04	12:46	4.0	24.05	7.26	251	161	5.2	62			1.21
5/13/04	12:48	4.4	23.24	6.53	288	184	0.2	2			1.21
9/2/04	13:11	0.3	30.81	7.48	182	116	8.9	119			0.85
9/2/04	13:13	1.0	30.70	7.72	182	116	8.9	120			0.85
9/2/04	13:14	2.0	30.45	7.65	182	116	8.9	118			0.85
9/2/04	13:14	3.0	28.57	6.78	216	138	2.1	27			0.85
9/2/04	13:16	4.0	27.78	6.31	217	139	0.2	2			0.85
9/2/04	13:16	4.7	27.39	6.01	307	196	0.1	2			0.85
11/15/04	13:32	0.3	22.71	7.85	215	138	8.3	97			0.58
~~11/15/04~~	~~13:33~~	~~0.5~~	~~22.69~~	~~7.81~~	~~215~~	138	~~8.2~~	~~95~~			0.58
11/15/04	13:36	1.0	22.71	7.82	215	138	8.1	94			0.58
11/15/04	13:38	2.0	22.71	7.80	215	138	8.0	93			0.58
11/15/04	13:39	3.0	22.68	7.79	215	138	8.1	93			0.58
11/15/04	13:39	4.0	22.65	7.77	215	138	8.0	92			0.58
11/15/04	13:40	4.7	22.68	7.60	218	140	5.1	59			0.58

Spring Lk Historic Profiles

Date MMDDYY	Time HHMMSS	Depth meters	Temp degC	pH units	SpCond uS/cm	TDS mg/l	DO mg/l	DO % Sat	Turb NTU	Redox mV	Secchi m
2/8/05	13:04	0.3	18.05	8.87	236	151	13.1	139			0.51
~~2/8/05~~	~~13:05~~	~~0.5~~	~~18.06~~	~~8.99~~	~~237~~	152	~~13.6~~	~~144~~			0.51
2/8/05	13:07	1.0	16.83	8.87	236	151	12.9	134			0.51
2/8/05	13:08	2.0	16.36	8.43	238	152	10.8	110			0.51
2/8/05	13:09	3.0	15.85	7.98	238	152	7.5	76			0.51
2/8/05	13:10	4.0	15.72	7.87	238	152	7.0	70			0.51
2/8/05	13:10	4.3	15.84	7.55	243	156	2.9	29			0.51
5/19/05	13:27	0.3	28.24	9.05	250	160	9.9	128			0.92
~~5/19/05~~	~~13:29~~	~~0.5~~	~~28.26~~	~~9.20~~	~~250~~	160	~~10.2~~	~~130~~			0.92
5/19/05	13:30	1.0	28.21	9.25	250	160	10.1	130			0.92
5/19/05	13:30	2.0	26.45	9.18	247	158	10.4	129			0.92
5/19/05	13:31	3.0	23.47	8.48	248	159	2.2	26			0.92
5/19/05	13:32	4.0	21.17	7.69	262	168	0.6	6			0.92
5/19/05	13:33	4.4	20.57	7.03	300	192	0.2	2			0.92
8/18/05	13:43	0.3	34.08	9.29	216	138	12.3	174			0.68
~~8/18/05~~	~~13:43~~	~~0.5~~	~~33.19~~	~~9.35~~	~~216~~	138	~~12.6~~	~~176~~			0.68
8/18/05	13:44	1.0	32.20	9.28	216	138	12.3	169			0.68
8/18/05	13:45	2.0	31.29	8.39	214	137	7.5	101			0.68
8/18/05	13:45	3.0	29.97	7.87	225	144	2.6	34			0.68
8/18/05	13:46	4.0	26.34	6.63	291	186	0.5	7			0.68
8/18/05	13:46	4.5	25.07	6.36	332	212	0.3	4			0.68
12/1/05	9:32	0.3	19.62	9.48	228	146	8.3	91			0.71
~~12/1/05~~	~~9:34~~	~~0.5~~	~~19.64~~	~~8.75~~	~~228~~	146	~~6.9~~	~~75~~			0.71
12/1/05	9:36	1.0	19.64	8.23	228	146	6.7	73			0.71
12/1/05	9:37	2.0	19.64	8.12	228	146	6.7	74			0.71
12/1/05	9:38	3.0	19.64	8.05	228	146	6.5	71			0.71
12/1/05	9:39	4.0	19.64	7.98	228	146	5.8	64			0.71
12/1/05	9:40	4.6	19.74	7.52	244	156	3.3	36			0.71

APPENDIX C

HYDROLOGIC MODELING OF ANNUAL RUNOFF INPUTS TO SPRING LAKE

Parameter	01					
	Commercial	Golf Course	Highway	Industrial	Railroad	Single Family
Total Area (ac)	**3.21**	**0.35**	**10.50**	**15.62**	**2.01**	**27.62**
DCIA (%)	**40.0**	**0.0**	**90.0**	**59.3**	**0.0**	**19.9**
non DCIA CN	**82.0**	**75.2**	**84.2**	**85.5**	**65.0**	**75.5**
S (in)	2.20	3.30	1.88	1.70	5.38	3.25

Rainfall Event Range (in)	Mean Rainfall Depth (in)	Number of Annual Events in Range	01					
			Commercial	Golf Course	Highway	Industrial	Railroad	Single Family
0.00-0.10	0.041	54.85	0.24	0.00	1.75	1.72	0.00	1.02
0.11-0.20	0.152	18.52	0.30	0.00	2.22	2.17	0.00	1.29
0.21-0.30	0.252	10.37	0.28	0.00	2.06	2.01	0.00	1.20
0.31-0.40	0.353	6.79	0.26	0.00	1.89	1.85	0.00	1.10
0.41-0.50	0.456	5.79	0.28	0.00	2.08	2.06	0.00	1.21
0.51-1.00	0.716	16.39	1.34	0.00	9.32	9.65	0.00	5.42
1.01-1.50	1.225	7.03	1.16	0.02	6.95	7.77	0.00	5.07
1.51-2.00	1.725	3.24	0.85	0.02	4.56	5.38	0.04	4.16
2.01-2.50	2.228	1.65	0.60	0.02	3.02	3.69	0.06	3.25
2.51-3.00	2.702	0.82	0.39	0.02	1.84	2.31	0.05	2.22
3.01-3.50	3.271	0.39	0.23	0.01	1.06	1.36	0.04	1.42
3.51-4.00	3.721	0.31	0.22	0.01	0.96	1.24	0.04	1.37
4.01-4.50	4.218	0.18	0.15	0.01	0.63	0.83	0.03	0.95
4.51-5.00	4.703	0.06	0.06	0.00	0.26	0.34	0.02	0.41
5.01-5.50	5.203	0.10	0.10	0.01	0.43	0.57	0.03	0.71
5.51-6.00	5.767	0.10	0.12	0.01	0.47	0.64	0.04	0.81
6.01-6.50	6.255	0.03	0.04	0.00	0.17	0.23	0.01	0.30
6.51-7.00	—	—						
7.01-7.50	7.280	0.02	0.03	0.00	0.10	0.14	0.01	0.19
7.51-8.00	7.900	0.02	0.03	0.00	0.11	0.15	0.01	0.21
8.01-8.50	8.190	0.02	0.03	0.00	0.11	0.16	0.01	0.22
8.51-9.00	—	—						
>9.00	12.310	0.03	0.09	0.01	0.34	0.49	0.04	0.72
Generated Volume (ac-ft/yr)			**6.80**	**0.16**	**40.33**	**44.78**	**0.43**	**33.25**
Weighted Basin "C" Value			**0.508**	**0.110**	**0.921**	**0.688**	**0.052**	**0.289**

Dry						
Percent Removal	0.8	0.8	0.8	0.8	0.8	0.8
Weighted Percent Removal	0.0	0.0	0.0	0.0	0.0	0.0
Volume Removed	**0.00**	**0.00**	**0.00**	**0.00**	**0.00**	**0.00**
Wet						
Percent Removal	0.2	0.2	0.2	0.2	0.2	0.2
Weighted Percent Removal	0.0	0.0	0.0	0.0	0.0	0.0
Volume Removed	**0.00**	**0.00**	**0.00**	**0.00**	**0.00**	**0.00**

6.80	**0.16**	**40.33**	**44.78**	**0.43**	**33.25**

Parameter	01				02		
	Commercial (Dry Pond)	Golf Course (Wet Pond)	Single Family (Wet Pond)	Woods (Wet Pond)	Commercial (Wet Pond)	Golf Course (Wet Pond)	Woods (Wet Pond)
Total Area (ac)	**2.76**	**2.84**	**4.63**	**2.39**	**11.68**	**30.33**	**1.79**
DCIA (%)	**40.0**	**0.0**	**31.7**	**0.0**	**82.4**	**0.0**	**0.0**
non DCIA CN	**82.0**	**74.6**	**81.3**	**74.0**	**75.9**	**74.0**	**47.7**
S (in)	2.20	3.40	2.30	3.51	3.18	3.51	10.96

Rainfall Event Range (in)	Mean Rainfall Depth (in)	Number of Annual Events in Range	01				02		
			Commercial (Dry Pond)	Golf Course (Wet Pond)	Single Family (Wet Pond)	Woods (Wet Pond)	Commercial (Wet Pond)	Golf Course (Wet Pond)	Woods (Wet Pond)
0.00-0.10	0.041	54.85	0.20	0.00	0.27	0.00	1.79	0.00	0.00
0.11-0.20	0.152	18.52	0.26	0.00	0.34	0.00	2.26	0.00	0.00
0.21-0.30	0.252	10.37	0.24	0.00	0.32	0.00	2.09	0.00	0.00
0.31-0.40	0.353	6.79	0.22	0.00	0.29	0.00	1.92	0.00	0.00
0.41-0.50	0.456	5.79	0.24	0.00	0.32	0.00	2.12	0.00	0.00
0.51-1.00	0.716	16.39	1.15	0.00	1.55	0.00	9.42	0.00	0.00
1.01-1.50	1.225	7.03	0.99	0.13	1.41	0.09	7.02	1.21	0.00
1.51-2.00	1.725	3.24	0.73	0.19	1.07	0.15	4.64	1.89	0.00
2.01-2.50	2.228	1.65	0.52	0.19	0.78	0.15	3.09	1.93	0.00
2.51-3.00	2.702	0.82	0.33	0.15	0.51	0.12	1.90	1.51	0.00
3.01-3.50	3.271	0.39	0.20	0.10	0.31	0.08	1.09	1.06	0.01
3.51-4.00	3.721	0.31	0.19	0.10	0.29	0.09	0.99	1.08	0.01
4.01-4.50	4.218	0.18	0.13	0.08	0.20	0.06	0.66	0.79	0.01
4.51-5.00	4.703	0.06	0.05	0.03	0.08	0.03	0.27	0.35	0.00
5.01-5.50	5.203	0.10	0.09	0.06	0.14	0.05	0.45	0.62	0.01
5.51-6.00	5.767	0.10	0.10	0.07	0.16	0.06	0.50	0.73	0.01
6.01-6.50	6.255	0.03	0.04	0.03	0.06	0.02	0.18	0.28	0.01
6.51-7.00	—	—							
7.01-7.50	7.280	0.02	0.02	0.02	0.04	0.01	0.11	0.17	0.00
7.51-8.00	7.900	0.02	0.02	0.02	0.04	0.02	0.12	0.20	0.00
8.01-8.50	8.190	0.02	0.03	0.02	0.04	0.02	0.12	0.21	0.01
8.51-9.00	---	---							
>9.00	12.310	0.03	0.08	0.07	0.13	0.06	0.37	0.73	0.02
Generated Volume (ac-ft/yr)			**5.84**	**1.24**	**8.37**	**1.00**	**41.10**	**12.77**	**0.09**
Weighted Basin "C" Value			**0.508**	**0.105**	**0.434**	**0.101**	**0.844**	**0.101**	**0.013**

Dry	**2.76**						
Percent Removal	0.8	0.8	0.8	0.8	0.8	0.8	0.8
Weighted Percent Removal	0.8	0.0	0.0	0.0	0.0	0.0	0.0
Volume Removed	**4.68**	**0.00**	**0.00**	**0.00**	**0.00**	**0.00**	**0.00**
Wet		**2.84**	**4.63**	**2.39**	**11.68**	**30.33**	**1.79**
Percent Removal	0.2	0.2	0.2	0.2	0.2	0.2	0.2
Weighted Percent Removal	0.0	0.2	0.2	0.2	0.2	0.2	0.2
Volume Removed	**0.00**	**0.25**	**1.67**	**0.20**	**8.22**	**2.55**	**0.02**

1.17	**1.00**	**6.70**	**0.80**	**32.88**	**10.21**	**0.08**

135.41 **43.17**

Parameter	03			04						
	Commercial	Golf Course	Single Family	Commercial	Golf Course	Multi Family	Single Family	Woods	Commercial (Dry Pond)	Commercial (Wet Pond)
Total Area (ac)	**0.18**	**22.84**	**7.72**	**32.41**	**0.09**	**15.70**	**47.45**	**0.56**	**1.35**	**7.20**
DCIA (%)	**90.0**	**0.0**	**18.2**	**83.7**	**0.0**	**75.0**	**20.0**	**0.0**	**40.0**	**90.0**
non DCIA CN	**39.0**	**60.0**	**61.3**	**62.9**	**80.9**	**68.2**	**67.9**	**61.0**	**58.7**	**68.5**
S (in)	15.64	6.66	6.32	5.89	2.36	4.66	4.74	6.39	7.05	4.60

Rainfall Event Range (in)	Mean Rainfall Depth (in)	Number of Annual Events in Range	03			04						
			Commercial	Golf Course	Single Family	Commercial	Golf Course	Multi Family	Single Family	Woods	Commercial (Dry Pond)	Commercial (Wet Pond)
0.00-0.10	0.041	54.85	0.03	0.00	0.26	5.03	0.00	2.19	1.76	0.00	0.10	1.20
0.11-0.20	0.152	18.52	0.04	0.00	0.33	6.37	0.00	2.77	2.23	0.00	0.13	1.52
0.21-0.30	0.252	10.37	0.03	0.00	0.31	5.90	0.00	2.56	2.06	0.00	0.12	1.41
0.31-0.40	0.353	6.79	0.03	0.00	0.28	5.42	0.00	2.35	1.90	0.00	0.11	1.30
0.41-0.50	0.456	5.79	0.03	0.00	0.31	5.97	0.00	2.59	2.09	0.00	0.12	1.43
0.51-1.00	0.716	16.39	0.15	0.00	1.38	26.53	0.00	11.52	9.28	0.00	0.53	6.34
1.01-1.50	1.225	7.03	0.11	0.00	1.01	19.47	0.01	8.50	7.15	0.00	0.39	4.66
1.51-2.00	1.725	3.24	0.07	0.13	0.71	12.70	0.01	5.61	5.54	0.00	0.25	3.04
2.01-2.50	2.228	1.65	0.05	0.33	0.54	8.40	0.01	3.75	4.31	0.01	0.17	2.01
2.51-3.00	2.702	0.82	0.03	0.37	0.38	5.14	0.01	2.31	2.99	0.01	0.11	1.23
3.01-3.50	3.271	0.39	0.02	0.32	0.25	2.96	0.00	1.34	1.94	0.01	0.07	0.70
3.51-4.00	3.721	0.31	0.01	0.37	0.24	2.68	0.00	1.22	1.89	0.01	0.06	0.64
4.01-4.50	4.218	0.18	0.01	0.29	0.18	1.77	0.00	0.81	1.34	0.01	0.04	0.42
4.51-5.00	4.703	0.06	0.00	0.14	0.08	0.72	0.00	0.33	0.58	0.00	0.02	0.17
5.01-5.50	5.203	0.10	0.01	0.26	0.14	1.21	0.00	0.56	1.01	0.01	0.03	0.28
5.51-6.00	5.767	0.10	0.01	0.33	0.16	1.35	0.00	0.63	1.19	0.01	0.04	0.32
6.01-6.50	6.255	0.03	0.00	0.13	0.06	0.49	0.00	0.23	0.45	0.00	0.01	0.11
6.51-7.00	—	—										
7.01-7.50	7.280	0.02	0.00	0.09	0.04	0.29	0.00	0.13	0.28	0.00	0.01	0.07
7.51-8.00	7.900	0.02	0.00	0.10	0.04	0.31	0.00	0.15	0.31	0.00	0.01	0.07
8.01-8.50	8.190	0.02	0.00	0.11	0.05	0.33	0.00	0.15	0.33	0.00	0.01	0.08
8.51-9.00	—	—										
>9.00	12.310	0.03	0.01	0.42	0.17	1.00	0.00	0.47	1.13	0.01	0.03	0.23
Generated Volume (ac-ft/yr)			**0.66**	**3.38**	**6.89**	**114.02**	**0.06**	**50.18**	**49.77**	**0.09**	**2.36**	**27.23**
Weighted Basin "C" Value			**0.900**	**0.036**	**0.214**	**0.844**	**0.166**	**0.767**	**0.252**	**0.038**	**0.419**	**0.907**

Dry									**1.35**	
Percent Removal	0.8	0.8	0.8	0.8	0.8	0.8	0.8	0.8	0.8	0.8
Weighted Percent Removal	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.8	0.0
Volume Removed	**0.00**	**0.00**	**0.00**	**0.00**	**0.00**	**0.00**	**0.00**	**0.00**	**1.88**	**0.00**
Wet				**32.41**						**7.20**
Percent Removal	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2
Weighted Percent Removal	0.0	0.0	0.0	0.2	0.0	0.0	0.0	0.0	0.0	0.2
Volume Removed	**0.00**	**0.00**	**0.00**	**22.80**	**0.00**	**0.00**	**0.00**	**0.00**	**0.00**	**5.45**

0.66	**3.38**	**6.89**	**91.22**	**0.06**	**50.18**	**49.77**	**0.09**	**0.47**	**21.78**

10.93 **213.57**

Parameter	05				06	07	08
	Commercial	Highway	Single Family	Commercial (Dry Pond)	Single Family	Single Family	Single Family
Total Area (ac)	18.02	0.23	11.77	8.97	10.79	5.76	13.46
DCIA (%)	38.1	90.0	19.7	38.0	19.4	17.4	18.7
non DCIA CN	57.1	68.5	53.5	57.1	53.2	51.3	52.6
S (in)	7.50	4.60	8.70	7.51	8.80	9.48	9.01

Rainfall Event Range (in)	Mean Rainfall Depth (in)	Number of Annual Events in Range	05				06	07	08
			Commercial	Highway	Single Family	Commercial (Dry Pond)	Single Family	Single Family	Single Family
0.00-0.10	0.041	54.85	1.27	0.04	0.43	0.63	0.39	0.19	0.47
0.11-0.20	0.152	18.52	1.61	0.05	0.54	0.80	0.49	0.24	0.59
0.21-0.30	0.252	10.37	1.49	0.05	0.50	0.74	0.46	0.22	0.55
0.31-0.40	0.353	6.79	1.37	0.04	0.46	0.68	0.42	0.20	0.50
0.41-0.50	0.456	5.79	1.51	0.05	0.51	0.75	0.46	0.22	0.55
0.51-1.00	0.716	16.39	6.71	0.21	2.27	3.34	2.05	0.98	2.47
1.01-1.50	1.225	7.03	4.93	0.15	1.66	2.45	1.50	0.72	1.81
1.51-2.00	1.725	3.24	3.22	0.10	1.08	1.60	0.98	0.47	1.17
2.01-2.50	2.228	1.65	2.19	0.06	0.74	1.09	0.67	0.31	0.80
2.51-3.00	2.702	0.82	1.40	0.04	0.49	0.69	0.44	0.21	0.53
3.01-3.50	3.271	0.39	0.85	0.02	0.31	0.42	0.28	0.13	0.34
3.51-4.00	3.721	0.31	0.80	0.02	0.31	0.40	0.28	0.13	0.33
4.01-4.50	4.218	0.18	0.55	0.01	0.22	0.27	0.20	0.09	0.24
4.51-5.00	4.703	0.06	0.23	0.01	0.10	0.11	0.09	0.04	0.11
5.01-5.50	5.203	0.10	0.40	0.01	0.17	0.20	0.16	0.07	0.19
5.51-6.00	5.767	0.10	0.46	0.01	0.20	0.23	0.19	0.09	0.22
6.01-6.50	6.255	0.03	0.17	0.00	0.08	0.08	0.07	0.03	0.09
6.51-7.00	---	---							
7.01-7.50	7.280	0.02	0.10	0.00	0.05	0.05	0.05	0.02	0.06
7.51-8.00	7.900	0.02	0.12	0.00	0.06	0.06	0.05	0.03	0.06
8.01-8.50	8.190	0.02	0.12	0.00	0.06	0.06	0.05	0.03	0.07
8.51-9.00	---	---							
>9.00	12.310	0.03	0.42	0.01	0.22	0.21	0.20	0.10	0.25
Generated Volume (ac-ft/yr)			**29.92**	**0.88**	**10.49**	**14.87**	**9.46**	**4.52**	**11.39**
Weighted Basin "C" Value			**0.398**	**0.907**	**0.214**	**0.398**	**0.210**	**0.188**	**0.203**

Dry				**8.97**			
Percent Removal	0.8	0.8	0.8	0.8	0.8	0.8	0.8
Weighted Percent Removal	0.0	0.0	0.0	0.8	0.0	0.0	0.0
Volume Removed	**0.00**	**0.00**	**0.00**	**11.90**	**0.00**	**0.00**	**0.00**
Wet							
Percent Removal	0.2	0.2	0.2	0.2	0.2	0.2	0.2
Weighted Percent Removal	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Volume Removed	**0.00**	**0.00**	**0.00**	**0.00**	**0.00**	**0.00**	**0.00**

29.92	**0.88**	**10.49**	**2.97**	**9.46**	**4.52**	**11.39**
			44.26	**9.46**	**4.52**	**11.39**

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Parameter	09		10		11			
	Highway	Single Family	Multi Family (Dry Pond)	Single Family (Dry Pond)	Commercial	Golf Course	Single Family	Woods
Total Area (ac)	**2.77**	**0.90**	**1.84**	**4.99**	**0.70**	**8.28**	**15.58**	**1.76**
DCIA (%)	**90.0**	**20.0**	**40.0**	**11.7**	**90.0**	**0.0**	**9.3**	**0.0**
non DCIA CN	**68.5**	**53.8**	**58.7**	**46.8**	**71.3**	**70.7**	**45.0**	**40.4**
S (in)	4.60	8.60	7.05	11.35	4.02	4.14	12.21	14.73

Rainfall Event Range (in)	Mean Rainfall Depth (in)	Number of Annual Events in Range	09		10		11			
			Highway	Single Family	Multi Family (Dry Pond)	Single Family (Dry Pond)	Commercial	Golf Course	Single Family	Woods
0.00-0.10	0.041	54.85	0.46	0.03	0.14	0.11	0.12	0.00	0.27	0.00
0.11-0.20	0.152	18.52	0.59	0.04	0.17	0.14	0.15	0.00	0.34	0.00
0.21-0.30	0.252	10.37	0.54	0.04	0.16	0.13	0.14	0.00	0.32	0.00
0.31-0.40	0.353	6.79	0.50	0.04	0.15	0.12	0.13	0.00	0.29	0.00
0.41-0.50	0.456	5.79	0.55	0.04	0.16	0.13	0.14	0.00	0.32	0.00
0.51-1.00	0.716	16.39	2.44	0.18	0.72	0.57	0.61	0.00	1.42	0.00
1.01-1.50	1.225	7.03	1.79	0.13	0.53	0.42	0.45	0.17	1.04	0.00
1.51-2.00	1.725	3.24	1.17	0.08	0.35	0.27	0.30	0.36	0.68	0.00
2.01-2.50	2.228	1.65	0.77	0.06	0.24	0.18	0.20	0.40	0.44	0.00
2.51-3.00	2.702	0.82	0.47	0.04	0.15	0.11	0.12	0.33	0.27	0.00
3.01-3.50	3.271	0.39	0.27	0.02	0.09	0.07	0.07	0.24	0.18	0.00
3.51-4.00	3.721	0.31	0.24	0.02	0.09	0.07	0.06	0.25	0.18	0.00
4.01-4.50	4.218	0.18	0.16	0.02	0.06	0.06	0.04	0.19	0.14	0.00
4.51-5.00	4.703	0.06	0.07	0.01	0.02	0.02	0.02	0.08	0.06	0.00
5.01-5.50	5.203	0.10	0.11	0.01	0.04	0.05	0.03	0.15	0.12	0.00
5.51-6.00	5.767	0.10	0.12	0.02	0.05	0.06	0.03	0.18	0.15	0.01
6.01-6.50	6.255	0.03	0.04	0.01	0.02	0.02	0.01	0.07	0.06	0.00
6.51-7.00	---	---								
7.01-7.50	7.280	0.02	0.03	0.00	0.01	0.01	0.01	0.04	0.04	0.00
7.51-8.00	7.900	0.02	0.03	0.00	0.01	0.02	0.01	0.05	0.05	0.00
8.01-8.50	8.190	0.02	0.03	0.00	0.01	0.02	0.01	0.05	0.05	0.00
8.51-9.00	---	---								
>9.00	12.310	0.03	0.09	0.02	0.04	0.08	0.02	0.19	0.22	0.02
Generated Volume (ac-ft/yr)			**10.47**	**0.82**	**3.21**	**2.65**	**2.64**	**2.75**	**6.63**	**0.05**
Weighted Basin "C" Value			**0.907**	**0.217**	**0.419**	**0.127**	**0.908**	**0.080**	**0.102**	**0.006**

Dry			**1.84**	**4.99**				
Percent Removal	0.8	0.8	0.8	0.8	0.8	0.8	0.8	0.8
Weighted Percent Removal	0.0	0.0	0.8	0.8	0.0	0.0	0.0	0.0
Volume Removed	**0.00**	**0.00**	**2.57**	**2.12**	**0.00**	**0.00**	**0.00**	**0.00**
Wet								
Percent Removal	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2
Weighted Percent Removal	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Volume Removed	**0.00**	**0.00**	**0.00**	**0.00**	**0.00**	**0.00**	**0.00**	**0.00**
	10.47	**0.82**	**0.64**	**0.53**	**2.64**	**2.75**	**6.63**	**0.05**
		11.29		**1.17**				**12.07**

APPENDIX D

ESTIMATES OF GROUNDWATER SEEPAGE INFLOW INTO SPRING LAKE FROM OCTOBER 2006-MAY 2007

1. Field Measurements
2. Calculations for Seepage Influx

1. Field Measurements

Seepage Meter Field Measurements

Location: Spring Lake   Site: 1

Date Installed: 8/14/06   Chamber Diameter: 0.58 m   Sediment Area Covered: 0.27 m2

Date	Time Collected	Volume Collected (liters)	Previous Collection Event		Seepage Time (days)	Seepage (liters/m2-day)	Comments / Observations
			Date	Time			
8/14/06	11:30	-----	-----	-----	-----	-----	Bags Installed
9/19/06	11:30	12.5	8/14/2006	11:30	36.0	1.29	Measured volume, no sample collected
10/16/06	8:40	6.25	9/19/2006	11:30	26.9	0.86	Sample collected, bag in good condition
11/28/06	11:45	4.75	10/16/2006	8:40	43.1	0.41	Sample collected, bag in good condition
1/2/07	10:12	4.25	11/28/2006	11:45	34.9	0.45	Sample collected, bag in good condition
2/28/07	10:00	6.5	1/2/2007	10:12	57.0	0.42	Sample collected, bag in good condition
4/12/07	9:45	7.5	2/28/2007	10:00	43.0	0.65	Sample collected, bag in good condition
5/11/07	9:24	3.5	4/12/2007	9:45	29.0	0.45	Sample collected, bag in good condition

Seepage Meter Field Measurements

Location: Spring Lake   Site: 2

Date Installed: 8/14/06   Chamber Diameter: 0.58 m   Sediment Area Covered: 0.27 m2

Date	Time Collected	Volume Collected (liters)	Previous Collection Event		Seepage Time (days)	Seepage (liters/m2-day)	Comments / Observations
			Date	Time			
8/14/06	11:45	-----	-----	-----	-----	-----	Bags Installed
9/19/06	11:35	7.5	8/14/2006	11:45	36.0	0.77	Measured volume, no sample collected
10/16/06	8:47	13.5	9/19/2006	11:35	26.9	1.86	Sample collected, bag in good condition
11/28/06	11:55	21.25	10/16/2006	8:47	43.1	1.82	Sample collected, bag in good condition
1/2/07	10:17	30.25	11/28/2006	11:55	34.9	3.21	Sample collected, bag replaced
2/28/07	10:07	15.25	1/2/2007	10:17	57.0	0.99	Sample collected, bag in good condition
4/12/07	9:50	27.5	2/28/2007	10:07	43.0	2.37	Sample collected, bag replaced
5/11/07	9:35	23.25	4/12/2007	9:50	29.0	2.97	Sample collected, bag in good condition

Seepage Meter Field Measurements

Location: Spring Lake Site: 3

Date Installed: 8/14/06 Chamber Diameter: 0.58 m Sediment Area Covered: 0.27 m2

Date	Time Collected	Volume Collected (liters)	Previous Collection Event		Seepage Time (days)	Seepage (liters/m2-day)	Comments / Observations
			Date	Time			
8/14/06	11:50	-----	-----	-----	-----	-----	Bags Installed
9/19/06	11:39	9.25	8/14/2006	11:50	36.0	0.95	Measured volume, no sample collected
10/16/06	8:52	7.5	9/19/2006	11:39	26.9	1.03	Sample collected, bag in good condition
11/28/06	12:00	12.25	10/16/2006	8:52	43.1	1.05	Sample collected, bag in good condition
1/2/07	10:22	9.5	11/28/2006	12:00	34.9	1.01	Sample collected, bag in good condition
2/28/07	10:12	12.5	1/2/2007	10:22	57.0	0.81	Sample collected, bag in good condition
4/12/07	9:55	13.25	2/28/2007	10:12	43.0	1.14	Sample collected, bag in good condition
5/11/07	9:45	6.25	4/12/2007	9:55	29.0	0.80	Sample collected, bag in good condition

Seepage Meter Field Measurements

Location: Spring Lake Site: 4

Date Installed: 8/14/06 Chamber Diameter: 0.58 m Sediment Area Covered: 0.27 m2

Date	Time Collected	Volume Collected (liters)	Previous Collection Event		Seepage Time (days)	Seepage (liters/m2-day)	Comments / Observations
			Date	Time			
8/14/06	12:00	-----	-----	-----	-----	-----	Bags Installed
9/19/06	11:42	8	8/14/2006	12:00	36.0	0.82	Measured volume, no sample collected
10/16/06	8:58	13.5	9/19/2006	11:42	26.9	1.86	Sample collected, bag in good condition
11/28/06	12:05	21	10/16/2006	8:58	43.1	1.80	Sample collected, bag replaced
1/2/07	10:29	3.5	11/28/2006	12:05	34.9	0.37	Sample collected, bag in good condition
2/28/07	10:17	2.5	1/2/2007	10:29	57.0	0.16	Sample collected, bag in good condition
4/12/07	10:00	2.5	2/28/2007	10:17	43.0	0.22	Sample collected, bag in good condition
5/11/07	9:55	16.25	4/12/2007	10:00	29.0	2.08	Sample collected, bag in good condition

Seepage Meter Field Measurements

Location: Spring Lake | Site: 5

Date Installed: 8/17/06 | Chamber Diameter: 0.58 m | Sediment Area Covered: 0.27 m2

Date	Time Collected	Volume Collected (liters)	Previous Collection Event		Seepage Time (days)	Seepage (liters/m2-day)	Comments / Observations
			Date	Time			
8/17/06	13:05	-----	-----	-----	-----	-----	Bags Installed
9/19/06	12:20	4.5	8/17/2006	13:05	33.0	0.51	Measured volume, no sample collected
10/16/06	9:36	7.5	9/19/2006	12:20	26.9	1.03	Sample collected, bag replaced
11/28/06	12:45	2.25	10/16/2006	9:36	43.1	0.19	Sample collected, bag replaced
1/2/07	11:09	4.25	11/28/2006	12:45	34.9	0.45	Sample collected, bag replaced
2/28/07	10:59	2.25	1/2/2007	11:09	57.0	0.15	Sample collected, bag replaced
4/12/07	10:40	6.5	2/28/2007	10:59	43.0	0.56	Sample collected, bag replaced
5/11/07	11:10	2.25	4/12/2007	10:40	29.0	0.29	Sample collected, bag replaced

Seepage Meter Field Measurements

Location: Spring Lake | Site: 6

Date Installed: 8/14/06 | Chamber Diameter: 0.58 m | Sediment Area Covered: 0.27 m2

Date	Time Collected	Volume Collected (liters)	Previous Collection Event		Seepage Time (days)	Seepage (liters/m2-day)	Comments / Observations
			Date	Time			
8/14/06	12:10	-----	-----	-----	-----	-----	Bags Installed
9/19/06	11:45	15	8/14/2006	12:10	36.0	1.54	Measured volume, no sample collected
10/16/06	9:03	13.5	9/19/2006	11:45	26.9	1.86	Sample collected, bag in good condition
11/28/06	12:09	15.25	10/16/2006	9:03	43.1	1.31	Sample collected, bag in good condition
1/2/07	10:34	12.5	11/28/2006	12:09	34.9	1.33	Sample collected, bag in good condition
2/28/07	10:23	11.25	1/2/2007	10:34	57.0	0.73	Sample collected, bag in good condition
4/12/07	10:05	15.5	2/28/2007	10:23	43.0	1.34	Sample collected, bag in good condition
5/11/07	10:05	10.25	4/12/2007	10:05	29.0	1.31	Sample collected, bag in good condition

Seepage Meter Field Measurements

Location: Spring Lake   Site: 7

Date Installed: 8/14/06   Chamber Diameter: 0.58 m   Sediment Area Covered: 0.27 m2

Date	Time Collected	Volume Collected (liters)	Previous Collection Event		Seepage Time (days)	Seepage (liters/m2-day)	Comments / Observations
			Date	Time			
8/14/06	12:20	-----	-----	-----	-----	-----	Bags Installed
9/19/06	11:50	0	8/14/2006	12:20	36.0	0.00	Measured volume, no sample collected
10/16/06	9:06	79.5	9/19/2006	11:50	26.9	10.95	Sample collected, bag replaced
11/28/06	12:12	80.5	10/16/2006	9:06	43.1	6.91	Sample collected, bag replaced
1/2/07	10:39	70.25	11/28/2006	12:12	34.9	7.45	Sample collected, bag replaced
2/28/07	10:27	75	1/2/2007	10:39	57.0	4.87	Sample collected, bag replaced
4/12/07	10:10	70.25	2/28/2007	10:27	43.0	6.05	Sample collected, bag in good condition
5/11/07	10:14	65.5	4/12/2007	10:10	29.0	8.36	Sample collected, bag in good condition

Seepage Meter Field Measurements

Location: Spring Lake   Site: 8

Date Installed: 8/14/06   Chamber Diameter: 0.58 m   Sediment Area Covered: 0.27 m2

Date	Time Collected	Volume Collected (liters)	Previous Collection Event		Seepage Time (days)	Seepage (liters/m2-day)	Comments / Observations
			Date	Time			
8/14/06	12:25	-----	-----	-----	-----	-----	Bags Installed
9/19/06	11:55	0	8/14/2006	12:25	36.0	0.00	Measured volume, no sample collected
10/16/06	9:11	17.5	9/19/2006	11:55	26.9	2.41	Sample collected, bag in good condition
11/28/06	12:19	49.25	10/16/2006	9:11	43.1	4.23	Sample collected, bag in good condition
1/2/07	10:43	9.5	11/28/2006	12:19	34.9	1.01	Sample collected, bag in good condition
2/28/07	10:31	7.5	1/2/2007	10:43	57.0	0.49	Sample collected, bag in good condition
4/12/07	10:15	7.5	2/28/2007	10:31	43.0	0.65	Sample collected, bag in good condition
5/11/07	10:20	10.5	4/12/2007	10:15	29.0	1.34	Sample collected, bag in good condition

Seepage Meter Field Measurements

Location: Spring Lake   Site: 9

Date Installed: 8/14/06   Chamber Diameter: 0.58 m   Sediment Area Covered: 0.27 m2

Date	Time Collected	Volume Collected (liters)	Previous Collection Event		Seepage Time (days)	Seepage (liters/m2-day)	Comments / Observations
			Date	Time			
8/14/06	12:35	-----	-----	-----	-----	-----	Bags Installed
9/19/06	12:00	16.25	8/14/2006	12:35	36.0	1.67	Measured volume, no sample collected
10/16/06	9:15	12.5	9/19/2006	12:00	26.9	1.72	Sample collected, bag in good condition
11/28/06	12:23	11.5	10/16/2006	9:15	43.1	0.99	Sample collected, bag in good condition
1/2/07	10:46	12.25	11/28/2006	12:23	34.9	1.30	Sample collected, bag in good condition
2/28/07	10:36	7.75	1/2/2007	10:46	57.0	0.50	Sample collected, bag in good condition
4/12/07	10:25	11.5	2/28/2007	10:36	43.0	0.99	Sample collected, bag in good condition
5/11/07	10:30	8.5	4/12/2007	10:25	29.0	1.09	Sample collected, bag in good condition

Seepage Meter Field Measurements

Location: Spring Lake   Site: 10

Date Installed: 8/17/06   Chamber Diameter: 0.58 m   Sediment Area Covered: 0.27 m2

Date	Time Collected	Volume Collected (liters)	Previous Collection Event		Seepage Time (days)	Seepage (liters/m2-day)	Comments / Observations
			Date	Time			
8/17/06	13:15	-----	-----	-----	-----	-----	Bags Installed
9/19/06	12:05	12.25	8/17/2006	13:15	33.0	1.38	Measured volume, no sample collected
10/16/06	9:31	2.5	9/19/2006	12:05	26.9	0.34	Sample collected, bag replaced
11/28/06	12:30	1.5	10/16/2006	9:31	43.1	0.13	Sample collected, bag replaced
1/2/07	10:55	2.25	11/28/2006	12:30	34.9	0.24	Sample collected, bag replaced
2/28/07	10:50	5.25	1/2/2007	10:55	57.0	0.34	Sample collected, bag replaced
4/12/07	10:30	2.5	2/28/2007	10:50	43.0	0.22	Sample collected, bag replaced
5/11/07	11:00	4.25	4/12/2007	10:30	29.0	0.54	Sample collected, bag replaced

Seepage Meter Field Measurements

Location: Spring Lake　　　　Site: 11

Date Installed: 8/17/06　　　　Chamber Diameter: 0.58 m　　　　Sediment Area Covered: 0.27 m2

Date	Time Collected	Volume Collected (liters)	Previous Collection Event		Seepage Time (days)	Seepage (liters/m2-day)	Comments / Observations
			Date	Time			
8/17/06	13:25	-----	-----	-----	-----	-----	Bags Installed
9/19/06	12:15	2.25	8/17/2006	13:25	33.0	0.25	Measured volume, no sample collected
10/16/06	9:23	2.5	9/19/2006	12:15	26.9	0.34	Sample collected, bag replaced
11/28/06	12:35	3.25	10/16/2006	9:23	43.1	0.28	Sample collected, bag replaced
1/2/07	11:00	4.25	11/28/2006	12:35	34.9	0.45	Sample collected, bag replaced
2/28/07	10:44	2.25	1/2/2007	11:00	57.0	0.15	Sample collected, bag replaced
4/12/07	10:35	10.5	2/28/2007	10:44	43.0	0.90	Sample collected, bag replaced
5/11/07	10:53	10.5	4/12/2007	10:35	29.0	1.34	Sample collected, bag replaced

2. Calculations for Seepage Influx

Spring Lake Seepage

Seepage Interval (l/m^2-day)	Mid Point (l/m^2-day)	Contour Area (m^2)	Seepage (l/day)	Seepage (ac-ft/day)
0-1	0.5	323,917	161,959	0.131
1-2	1.5	121,456	182,184	0.148
2-3	2.5	86,444	216,111	0.175
3-4	3.5	14,153	49,537	0.040
4-5	4.5	10,931	49,188	0.040
5-6	5.5	7,403	40,716	0.033
6-7	6.5	3,513	22,836	0.019
			Total	**0.586**

Annual Seepage (ac-ft) **213.8**

APPENDIX E

CHEMICAL CHARACTERISTICS OF STORMWATER AND BASEFLOW SAMPLES COLLECTED FROM THE SPRING LAKE DRAINAGE BASIN FROM DECEMBER 2006-JUNE 2007

Spring Lake Stormwater / Baseflow Monitoring Results

	Sample Location	Date Collected	pH	Alkalinity	Conductivity	NH3	NOX	Diss. Org N	Part. N	TN	OP	Diss. Org. P	Part. P	TP	TSS	Turbidity	Color	Fecal	BOD
Stormwater	Site 1	12/14/06	7.24	24.2	74	32	100	<30	104	236	48	8	161	217	87.6	25.9	16	8700	5.8
Stormwater	Site 1	12/22/06	7.17	42.8	110	94	289	25	162	570	39	1	148	188	68.6	18.0	17	400	2
Stormwater	Site 1	12/23/06	7.16	35.8	92	87	222	55	25	389	23	4	34	61	16.8	6.3	18	115	<2.0
Stormwater	Site 1	12/25/06	7.28	40.6	122	109	139	62	113	423	16	4	62	82	26.2	8.6	15	470	<2.0
Stormwater	Site 1	1/2/07	7.00	66.0	213	62	534	78	42	716	<1	10	99	109	48.4	36.3	14	520	3.8
Stormwater	Site 1	1/3/07	6.94	62.4	192	101	621	53	165	940	14	8	55	77	28.4	9.7	12	1200	2.8
Stormwater	Site 1	1/24/07	7.17	57.8	193	<5	233	574	245	1054	1	56	128	185	82.4	40.3	25	3400	22.3
Stormwater	Site 1	2/2/07	7.07	43.6	105	21	154	200	714	1089	5	4	227	236	129.0	38.2	11	4600	6.8
		average	**7.13**	**46.7**	**138**	**64**	**287**	**133**	**196**	**677**	**18**	**12**	**114**	**144**	**60.9**	**22.9**	**16**	**2426**	**5.7**
		min	**6.94**	**24.2**	**74**	**<5**	**100**	**<30**	**25**	**236**	**<1**	**1**	**34**	**61**	**16.8**	**6.3**	**11**	**115**	**<2.0**
		max	**7.28**	**66.0**	**213**	**109**	**621**	**574**	**714**	**1089**	**48**	**56**	**227**	**236**	**129.0**	**40.3**	**25**	**8700**	**22.3**
Baseflow	Site 1	12/4/06	7.36	57.4	223	50	511	134	68	763	1	2	32	35	14.3	5.1	14	480	4.6
Baseflow	Site 1	12/8/06	7.19	54.8	212	57	463	95	117	732	3	6	91	100	49.8	21.8	19	200	2.3
Baseflow	Site 1	12/24/06	7.22	73.8	219	167	18	209	257	651	1	4	49	54	9.2	4.2	20	92	<2.0
Baseflow	Site 1	3/16/07	7.06	46.4	207	170	228	164	72	634	5	6	33	44	9.8	6.1	12	317	<2.0
		average	**7.21**	**58.1**	**215**	**111**	**305**	**151**	**129**	**695**	**3**	**5**	**51**	**58**	**20.8**	**9.3**	**16**	**272**	**2.2**
		min	**7.06**	**46.4**	**207**	**50**	**18**	**95**	**68**	**634**	**1**	**2**	**32**	**35**	**9.2**	**4.2**	**12**	**92**	**<2.0**
		max	**7.36**	**73.8**	**223**	**170**	**511**	**209**	**257**	**763**	**5**	**6**	**91**	**100**	**49.8**	**21.8**	**20**	**480**	**4.6**
Stormwater	Site 2	2/2/07	6.99	44.2	73	24	132	205	637	998	32	5	136	173	93.4	18.8	17	6800	7.4
Stormwater	Site 2	4/15/07	7.25	107.0	286	1265	1125	1020	615	4025	152	88	194	434	293.0	46.3	36	760	19.2
Stormwater	Site 2	5/6/07	6.58	31.6	159	225	591	849	4884	6549	148	76	1314	1538	211.0	39.2	67	58667	15
Stormwater	Site 2	6/2/07	7.80	161.0	333	83	197	116	1142	1538	127	24	709	860	453.0	290.0	16	320	6.5
Stormwater	Site 2	6/10/07	7.27	66.6	160	695	698	283	2096	3079	327	76	806	1209	71.8	24.1	28	55967	13.7
Stormwater	Site 2	6/14/07	7.40	49.2	121	29	548	337	1897	2784	264	101	561	926	9.6	2.8	42	1347	11.1
		average	**7.22**	**76.6**	**189**	**387**	**549**	**468**	**1879**	**3162**	**175**	**62**	**620**	**857**	**169**	**70.2**	**34**	**20644**	**12.2**
		min	**6.58**	**31.6**	**73**	**24**	**132**	**116**	**615**	**998**	**32**	**5**	**136**	**173**	**9.6**	**2.8**	**16**	**320**	**6.5**
		max	**7.80**	**161**	**333**	**1265**	**1125**	**1020**	**4884**	**6549**	**327**	**101**	**1314**	**1538**	**453**	**290**	**67**	**58687**	**19.2**
Outflow	Site 3	1/24/07	7.41	93.8	294	23	517	211	442	1193	7	3	79	89	1.2	3.5	41	9	<2.0
Outflow	Site 3	2/1/07	7.55	83.6	263	<5	604	1502	272	2380	25	8	39	72	2.8	2.8	42	4	<2.0
Outflow	Site 3	2/2/07	7.21	63.4	182	<5	356	541	759	1658	30	14	55	99	10.8	7.8	31	200	2.4
Outflow	Site 3	3/16/07	7.39	94.8	307	248	308	643	291	1490	60	39	72	171	7.7	6.5	51	540	3
Outflow	Site 3	4/10/07	7.94	103.0	328	60	90	699	251	1100	120	17	70	207	7.0	3.9	50	10	4.6
Outflow	Site 3	4/11/07	7.74	92.2	315	63	88	728	420	1299	139	18	146	303	30.6	19.8	54	28	8.5
Outflow	Site 3	4/12/07-4/14/07	7.34	64.6	212	81	242	579	115	1017	97	16	75	188	26.3	11.8	36	125	5.3
Outflow	Site 3	4/14/07	7.16	52.2	163	110	260	414	259	1043	106	10	82	198	31.8	13.5	32	347	5.6
Outflow	Site 3	4/15/07	7.45	77.8	273	79	235	649	605	1568	116	14	251	381	84.6	26.4	41	88	9.8
Outflow	Site 3	4/25/07	7.55	70.0	227	115	181	434	352	1082	77	123	141	341	29.4	15.6	46	14	8.8
Outflow	Site 3	4/30/07	7.40	76.8	265	95	52	617	1335	2099	168	12	479	659	110.0	27.4	44	17	7.9
Outflow	Site 3	4/30/07-5/06/07	7.13	63.4	193	198	192	630	375	1395	284	99	65	448	10.3	5.8	32	2100	5.3
Outflow	Site 3	5/6/07	7.36	98.2	311	223	88	507	341	1159	279	63	442	784	116.0	42.4	38	280	11.1
Outflow	Site 3	5/16/07	7.70	74.2	251	157	470	489	418	1534	115	4	85	204	17.6	6.7	32	25	3.2
Outflow	Site 3	5/17/07-5/18/07	7.13	55.2	206	388	526	151	256	1321	138	24	152	314	26.0	7.5	34	1504	7.5
Outflow	Site 3	5/18/07	7.01	54.8	189	632	360	133	378	1503	162	32	128	322	14.4	5.6	39	248	8.1
Outflow	Site 3	6/2/07	7.30	61.2	214	182	65	529	347	1123	30	43	147	220	37.3	15.4	44	26	6.1
		average	**7.40**	**75.2**	**247**	**166**	**273**	**556**	**424**	**1410**	**115**	**32**	**148**	**294**	**33.2**	**13.1**	**40**	**327**	**6**
		min	**7.01**	**52.2**	**163**	**<5**	**52**	**133**	**115**	**1017**	**7**	**3**	**39**	**72**	**1.2**	**2.8**	**31**	**4**	**<2.0**
		max	**7.94**	**103.0**	**328**	**632**	**604**	**1502**	**1335**	**2380**	**284**	**123**	**479**	**784**	**116.0**	**42.4**	**54**	**2100**	**11**
Stormwater	Site 4	2/2/07	7.32	63.8	387	86	148	679	857	1770	126	3	86	215	7.7	5.0	48	246	3.1
Stormwater	Site 4	4/15/07	7.09	64.0	525	570	476	1379	745	3170	463	32	183	678	24.0	9.2	101	14100	6.1
Stormwater	Site 4	5/6/07	6.85	52.2	484	127	70	1109	700	2006	275	74	86	435	21.7	10.7	66	960	3.8
Stormwater	Site 4	6/2/07	7.01	41.2	469	231	52	834	1210	2327	220	72	400	692	148.0	39.3	71	112	6.2
Stormwater	Site 4	7/1/07	7.64	72.4	536	643	104	1718	346	2170	254	233	141	628	6.8	6.3	87	530	4.8
		average	**7.18**	**58.7**	**480**	**331**	**170**	**1144**	**772**	**2289**	**268**	**83**	**179**	**530**	**41.6**	**14.1**	**75**	**3190**	**4.8**
		min	**6.85**	**41.2**	**387**	**86**	**52**	**679**	**346**	**1770**	**126**	**3**	**86**	**215**	**6.8**	**5.0**	**48**	**112**	**3.1**
		max	**7.64**	**72.4**	**536**	**643**	**476**	**1718**	**1210**	**3170**	**463**	**233**	**400**	**692**	**148**	**39.3**	**101**	**14100**	**6.2**

APPENDIX F

CHEMICAL CHARACTERISTICS OF GROUNDWATER SEEPAGE SAMPLES COLLECTED FROM SPRING LAKE FROM OCTOBER 2006-MAY 2007

1. Laboratory Analyses
2. Calculations of Mass Influx

1. Laboratory Analyses

Sample Description		Sample Location	Date Collected	pH	Alkalinity	Conductivity	TN	TP
Spring Lake	Seepage	Site 1	10/16/06	7.79	559	1123	21434	3343
Spring Lake	Seepage	Site 1	11/28/06	7.62	274	935	43055	4628
Spring Lake	Seepage	Site 1	1/2/07	7.33	107	391	8076	3076
Spring Lake	Seepage	Site 1	2/28/07	7.48	96.2	328	7341	1189
Spring Lake	Seepage	Site 1	4/12/07	7.58	81.4	272	2698	394
Spring Lake	Seepage	Site 1	5/11/07	7.56	106	334	5877	570
			average	**7.56**	**204**	**564**	**14747**	**2200**
			min	**7.33**	**81.4**	**272**	**2698**	**394**
			max	**7.79**	**559**	**1123**	**43055**	**4628**
Spring Lake	Seepage	Site 2	10/16/06	7.26	151.0	449	9001	332
Spring Lake	Seepage	Site 2	11/28/06	7.24	100	359	12472	616
Spring Lake	Seepage	Site 2	1/2/07	7.75	97.0	286	1929	290
Spring Lake	Seepage	Site 2	2/28/07	7.82	121	347	4539	55
Spring Lake	Seepage	Site 2	4/12/07	7.47	70.2	247	927	82
Spring Lake	Seepage	Site 2	5/11/07	7.66	66.4	253	1490	101
			average	**7.53**	**101**	**324**	**5060**	**246**
			min	**7.24**	**66.4**	**247**	**927**	**55**
			max	**7.82**	**151**	**449**	**12472**	**616**
Spring Lake	Seepage	Site 3	10/16/06	7.17	139	503	8548	519
Spring Lake	Seepage	Site 3	11/28/06	7.46	107	404	10804	288
Spring Lake	Seepage	Site 3	1/2/07	7.74	165	647	7139	335
Spring Lake	Seepage	Site 3	2/28/07	7.67	108	464	4674	159
Spring Lake	Seepage	Site 3	4/12/07	7.62	74.0	292	1335	43
Spring Lake	Seepage	Site 3	5/11/07	7.87	124	599	6480	82
			average	**7.59**	**120**	**485**	**6497**	**238**
			min	**7.17**	**74.0**	**292**	**1335**	**43**
			max	**7.87**	**165**	**647**	**10804**	**519**
Spring Lake	Seepage	Site 4	10/16/06	6.76	63.0	234	1634	148
Spring Lake	Seepage	Site 4	11/28/06	7.25	68.4	235	2106	113
Spring Lake	Seepage	Site 4	1/2/07	7.54	64.2	252	1390	80
Spring Lake	Seepage	Site 4	2/28/07	7.57	64.0	260	1607	68
Spring Lake	Seepage	Site 4	4/12/07	7.60	70.4	251	768	30
Spring Lake	Seepage	Site 4	5/11/07	7.51	64.4	253	1368	32
			average	**7.37**	**65.7**	**248**	**1479**	**79**
			min	**6.76**	**63.0**	**234**	**768**	**30**
			max	**7.60**	**70.4**	**260**	**2106**	**148**
Spring Lake	Seepage	Site 5	10/16/06	6.74	59.0	310	10789	647
Spring Lake	Seepage	Site 5	11/28/06	7.21	131	517	28780	1710
Spring Lake	Seepage	Site 5	1/2/07	7.42	60.2	270	3093	336
Spring Lake	Seepage	Site 5	2/28/07	7.24	87.8	464	9847	642
Spring Lake	Seepage	Site 5	4/12/07	7.26	61.8	253	8774	377
Spring Lake	Seepage	Site 5	5/11/07	7.33	83.4	451	18595	1344
			average	**7.20**	**80.5**	**378**	**13313**	**843**
			min	**6.74**	**59.0**	**253**	**3093**	**336**
			max	**7.42**	**131**	**517**	**28780**	**1710**
Spring Lake	Seepage	Site 6	10/16/06	7.25	113	383	9297	464
Spring Lake	Seepage	Site 6	11/28/06	7.65	117	402	18671	583
Spring Lake	Seepage	Site 6	1/2/07	7.83	133	423	12416	635
Spring Lake	Seepage	Site 6	2/28/07	7.82	121	356	9522	420
Spring Lake	Seepage	Site 6	4/12/07	7.87	112	376	8570	337
Spring Lake	Seepage	Site 6	5/11/07	7.96	152	473	18034	543
			average	**7.73**	**125**	**402**	**12752**	**497**
			min	**7.25**	**112**	**356**	**8570**	**337**
			max	**7.96**	**152**	**473**	**18671**	**635**

Sample Description		Sample Location	Date Collected	pH	Alkalinity	Conductivity	TN	TP
Spring Lake	Seepage	Site 7	10/16/06	7.31	138	375	3983	674
Spring Lake	Seepage	Site 7	11/28/06	7.83	148	372	5870	424
Spring Lake	Seepage	Site 7	1/2/07	7.72	120	323	1161	168
Spring Lake	Seepage	Site 7	2/28/07	7.75	119	317	4037	232
Spring Lake	Seepage	Site 7	4/12/07	7.87	124	329	2215	133
Spring Lake	Seepage	Site 7	5/11/07	7.75	124	325	3381	178
			average	**7.71**	**129**	**340**	**3441**	**302**
			min	**7.31**	**119**	**317**	**1161**	**133**
			max	**7.87**	**148**	**375**	**5870**	**674**
Spring Lake	Seepage	Site 8	10/16/06	7.81	288	614	15219	2213
Spring Lake	Seepage	Site 8	11/28/06	7.73	256	526	15764	1122
Spring Lake	Seepage	Site 8	1/2/07	7.69	230	456	2548	468
Spring Lake	Seepage	Site 8	2/28/07	7.76	234	476	1864	298
Spring Lake	Seepage	Site 8	4/12/07	8.05	232	505	2566	299
Spring Lake	Seepage	Site 8	5/11/07	7.95	210	489	5397	232
			average	**7.83**	**242**	**511**	**7226**	**772**
			min	**7.69**	**210**	**456**	**1864**	**232**
			max	**8.05**	**288**	**614**	**15764**	**2213**
Spring Lake	Seepage	Site 9	10/16/06	7.85	538	696	17378	3152
Spring Lake	Seepage	Site 9	11/28/06	7.57	305	679	12515	1748
Spring Lake	Seepage	Site 9	1/2/07	7.46	104	296	1216	283
Spring Lake	Seepage	Site 9	2/28/07	7.64	158	392	2962	373
Spring Lake	Seepage	Site 9	4/12/07	7.76	144	384	3165	339
Spring Lake	Seepage	Site 9	5/11/07	7.78	179	433	4736	482
			average	**7.68**	**238**	**480**	**6995**	**1063**
			min	**7.46**	**104**	**296**	**1216**	**283**
			max	**7.85**	**538**	**696**	**17378**	**3152**
Spring Lake	Seepage	Site 10	10/16/06	7.41	85.2	475	19508	852
Spring Lake	Seepage	Site 10	11/28/06	7.22	166	680	21675	1532
Spring Lake	Seepage	Site 10	1/2/07	7.54	272	579	20874	1314
Spring Lake	Seepage	Site 10	2/28/07	7.17	79.4	253	7580	482
Spring Lake	Seepage	Site 10	4/12/07	7.60	227	593	13508	785
Spring Lake	Seepage	Site 10	5/11/07	6.98	92.4	275	4113	103
			average	**7.32**	**154**	**476**	**14543**	**845**
			min	**6.98**	**79.4**	**253**	**4113**	**103**
			max	**7.60**	**272**	**680**	**21675**	**1532**
Spring Lake	Seepage	Site 11	10/16/06	7.14	115	421	16576	1098
Spring Lake	Seepage	Site 11	11/28/06	6.87	73.8	509	10070	595
Spring Lake	Seepage	Site 11	1/2/07	7.13	124	330	8570	689
Spring Lake	Seepage	Site 11	2/28/07	7.26	102	480	8974	598
Spring Lake	Seepage	Site 11	4/12/07	7.51	78.8	262	1431	77
Spring Lake	Seepage	Site 11	5/11/07	7.35	74.2	252	1399	134
			average	**7.21**	**94.6**	**376**	**7837**	**532**
			min	**6.87**	**73.8**	**252**	**1399**	**77**
			max	**7.51**	**124**	**509**	**16576**	**1098**

2. Calculations of Mass Influx

Spring Lake Total Nitrogen Flux

Total Nitrogen Flux Interval (µg/m²-day)	Mid Point (µg/m²-day)	Contour Area (m²)	Total Nitrogen Flux (kg/day)
0-2000	1000	5,209	0.005
2001-4000	3000	14,672	0.044
4001-6000	5000	30,633	0.153
6001-8000	7000	35,825	0.251
8001-10000	9000	32,357	0.291
10001-12000	11000	14,804	0.163
12001-14000	13000	5,814	0.076
14001-16000	15000	4,670	0.070
16001-18000	17000	3,333	0.057
18001-20000	19000	7,439	0.141
		Total	**1.251**

Annual TN Flux (kg/yr) **456.6**

Spring Lake Total Phosphorus Flux

Total Phosphorus Flux Interval (µg/m²-day)	Mid Point (µg/m²-day)	Contour Area (m²)	Total Phosphorus Flux (kg/day)
0-250	125	31,356	0.004
251-500	375	47,026	0.018
501-750	625	18,616	0.012
751-1000	875	16,370	0.014
1001-1250	1125	18,284	0.021
1251-1500	1375	15,888	0.022
1501-1750	1625	2,881	0.005
1751-2000	1875	1,789	0.003
		Total	**0.098**

Annual TP Flux (kg/yr) **35.8**

APPENDIX G

WATER QUALITY MODELS

1. Calibrated Current Conditions Model
2. Evaluation of Water Quality Impacts from Evaluated Treatment Options

1. Calibrated Current Conditions Model

Modified Vollenweider Mass Balance Phosphorus Limitation Model for Spring Lake - Base Model

Initial P Conc. (mg/l)	Hydrologic and Mass Inputs														
	Direct Precipitation			Stormwater		G.W. Seepage		Baseflow		Additional Inflow		Internal Recycling	Total Inputs		
	(in)	(ac-ft)	(kg)	(ac-ft)	(kg)	(ac-ft)	(kg)	(ac-ft)	(kg)	(ac-ft)	(kg)	(kg)	(ac-ft)	(kg)	(mg/l)
0.064	50.02	159.4	11.10	497	199.25	213.8	35.80	14.3	1.02	0.0	0.0	32.9	885	280.1	0.256

Hydrologic and Mass Losses								Detention Time (days)	P Ret. Coeff.	Areal P Loading (g/m2)	Final P Conc. (mg/l)	Chyl-a Conc. (mg/m3)	Secchi Disk Depth (m)	Florida TSI Value
Evaporation		Outfall Losses		Deep Recharge		Total Losses								
(in)	(ac-ft)	(ac-ft)	(kg)	(ac-ft)	(kg)	(ac-ft)	(kg)							
49.98	159	725	57.6	0.0	0.0	885	57.6	160	0.499	0.907	0.064	32.2	0.89	76

Calibration Numerator Coefficient: 7.02

Calibration Denominator Coefficient: 7.02

2. Evaluation of Water Quality Impacts from Evaluated Treatment Options

Phosphorus Limitation Model for Spring Lake - Enhancement of Sub-basin 3/4 Pond

Initial P Conc. (mg/l)	Hydrologic and Mass Inputs														
	Direct Precipitation			Stormwater		G.W. Seepage		Baseflow		Additional Inflow		Internal Recycling	Total Inputs		
	(in)	(ac-ft)	(kg)	(ac-ft)	(kg)	(ac-ft)	(kg)	(ac-ft)	(kg)	(ac-ft)	(kg)	(kg)	(ac-ft)	(kg)	(mg/l)
0.049	50.02	159.4	11.10	497	131.05	213.8	35.80	14.3	1.02	0.0	0.0	32.9	885	211.9	0.194

Hydrologic and Mass Losses								Detention Time (days)	P Ret. Coeff.	Areal P Loading (g/m2)	Final P Conc. (mg/l)	Chyl-a Conc. (mg/m3)	Secchi Disk Depth (m)	Florida TSI Value
Evaporation		Outfall Losses		Deep Recharge		Total Losses								
(in)	(ac-ft)	(ac-ft)	(kg)	(ac-ft)	(kg)	(ac-ft)	(kg)							
49.98	159	725	43.6	0.0	0.0	885	43.6	160	0.499	0.686	0.049	24.0	1.05	71

Calibration Numerator Coefficient: 7.02

Calibration Denominator Coefficient: 7.02

Phosphorus Limitation Model for Spring Lake - Reuse in Sub-basin 2

Initial P Conc. (mg/l)	Hydrologic and Mass Inputs														
	Direct Precipitation			Stormwater		G.W. Seepage		Baseflow		Additional Inflow		Internal Recycling	Total Inputs		
	(in)	(ac-ft)	(kg)	(ac-ft)	(kg)	(ac-ft)	(kg)	(ac-ft)	(kg)	(ac-ft)	(kg)	(kg)	(ac-ft)	(kg)	(mg/l)
0.061	50.02	159.4	11.10	497	183.12	213.8	35.80	14.3	1.02	0.0	0.0	32.9	885	263.9	0.242

Hydrologic and Mass Losses								Detention Time (days)	P Ret. Coeff.	Areal P Loading (g/m2)	Final P Conc. (mg/l)	Chyl-a Conc. (mg/m3)	Secchi Disk Depth (m)	Florida TSI Value
Evaporation		Outfall Losses		Deep Recharge		Total Losses								
(in)	(ac-ft)	(ac-ft)	(kg)	(ac-ft)	(kg)	(ac-ft)	(kg)							
49.98	159	725	54.3	0.0	0.0	885	54.3	160	0.499	0.854	0.061	30.3	0.92	75

Calibration Numerator Coefficient: 7.02

Calibration Denominator Coefficient: 7.02

Phosphorus Limitation Model for Spring Lake - Alum Treatment

Initial P Conc. (mg/l)	Hydrologic and Mass Inputs														
	Direct Precipitation			Stormwater		G.W. Seepage		Baseflow		Additional Inflow		Internal Recycling	Total Inputs		
	(in)	(ac-ft)	(kg)	(ac-ft)	(kg)	(ac-ft)	(kg)	(ac-ft)	(kg)	(ac-ft)	(kg)	(kg)	(ac-ft)	(kg)	(mg/l)
0.052	50.02	159.4	11.10	497	199.25	213.8	7.16	14.3	1.02	0.0	0.0	6.6	885	225.1	0.206

Hydrologic and Mass Losses								Detention Time (days)	P Ret. Coeff.	Areal P Loading (g/m2)	Final P Conc. (mg/l)	Chyl-a Conc. (mg/m3)	Secchi Disk Depth (m)	Florida TSI Value
Evaporation		Outfall Losses		Deep Recharge		Total Losses								
(in)	(ac-ft)	(ac-ft)	(kg)	(ac-ft)	(kg)	(ac-ft)	(kg)							
49.98	159	725	46.3	0.0	0.0	885	46.3	160	0.499	0.729	0.052	25.6	1.01	72

Calibration Numerator Coefficient: 7.02

Calibration Denominator Coefficient: 7.02

Phosphorus Limitation Model for Spring Lake - Enhancement of Sub-basin 3/4 Pond + Alum Treatment

Initial P Conc. (mg/l)	Hydrologic and Mass Inputs														
	Direct Precipitation			Stormwater		G.W. Seepage		Baseflow		Additional Inflow		Internal Recycling	Total Inputs		
	(in)	(ac-ft)	(kg)	(ac-ft)	(kg)	(ac-ft)	(kg)	(ac-ft)	(kg)	(ac-ft)	(kg)	(kg)	(ac-ft)	(kg)	(mg/l)
0.036	50.02	159.4	11.10	497	131.05	213.8	7.16	14.3	1.02	0.0	0.0	6.6	885	156.9	0.144

Hydrologic and Mass Losses								Detention Time (days)	P Ret. Coeff.	Areal P Loading (g/m2)	Final P Conc. (mg/l)	Chyl-a Conc. (mg/m3)	Secchi Disk Depth (m)	Florida TSI Value
Evaporation		Outfall Losses		Deep Recharge		Total Losses								
(in)	(ac-ft)	(ac-ft)	(kg)	(ac-ft)	(kg)	(ac-ft)	(kg)							
49.98	159	725	32.3	0.0	0.0	885	32.3	160	0.499	0.508	0.036	17.5	1.26	65

Calibration Numerator Coefficient: 7.02

Calibration Denominator Coefficient: 7.02

Phosphorus Limitation Model for Spring Lake - Street Sweeping

Initial P Conc. (mg/l)	Hydrologic and Mass Inputs														
	Direct Precipitation			Stormwater		G.W. Seepage		Baseflow		Additional Inflow		Internal Recycling	Total Inputs		
	(in)	(ac-ft)	(kg)	(ac-ft)	(kg)	(ac-ft)	(kg)	(ac-ft)	(kg)	(ac-ft)	(kg)	(kg)	(ac-ft)	(kg)	(mg/l)
0.049	50.02	159.4	11.10	497	131.05	213.8	35.80	14.3	1.02	0.0	0.0	32.9	885	211.9	0.194

Hydrologic and Mass Losses								Detention Time (days)	P Ret. Coeff.	Areal P Loading (g/m2)	Final P Conc. (mg/l)	Chyl-a Conc. (mg/m3)	Secchi Disk Depth (m)	Florida TSI Value
Evaporation		Outfall Losses		Deep Recharge		Total Losses								
(in)	(ac-ft)	(ac-ft)	(kg)	(ac-ft)	(kg)	(ac-ft)	(kg)							
49.98	159	725	43.6	0.0	0.0	885	43.6	160	0.499	0.686	0.049	24.0	1.05	71

Calibration Numerator Coefficient: 7.02

Calibration Denominator Coefficient: 7.02

Model for Spring Lake - Enhancement of Sub-basin 3/4 Pond + Alum Treatment + Street Sweeping

Initial P Conc. (mg/l)	Hydrologic and Mass Inputs														
	Direct Precipitation			Stormwater		G.W. Seepage		Baseflow		Additional Inflow		Internal Recycling	Total Inputs		
	(in)	(ac-ft)	(kg)	(ac-ft)	(kg)	(ac-ft)	(kg)	(ac-ft)	(kg)	(ac-ft)	(kg)	(kg)	(ac-ft)	(kg)	(mg/l)
0.020	50.02	159.4	11.10	497	62.85	213.8	7.16	14.3	1.02	0.0	0.0	6.6	885	88.7	0.081

Hydrologic and Mass Losses								Detention Time (days)	P Ret. Coeff.	Areal P Loading (g/m2)	Final P Conc. (mg/l)	Chyl-a Conc. (mg/m3)	Secchi Disk Depth (m)	Florida TSI Value
Evaporation		Outfall Losses		Deep Recharge		Total Losses								
(in)	(ac-ft)	(ac-ft)	(kg)	(ac-ft)	(kg)	(ac-ft)	(kg)							
49.98	159	725	18.3	0.0	0.0	885	18.3	160	0.499	0.287	0.020	9.6	1.74	55

Calibration Numerator Coefficient: 7.02

Calibration Denominator Coefficient: 7.02