EVALUATION OF THE CURRENT STATUS AND POTENTIAL WATER QUALITY IMPROVEMENT OPTIONS FOR LAKE HOLDEN

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SECTION 1

INTRODUCTION

This report provides a summary of work efforts performed by Environmental Research & Design, Inc. (ERD) for the Orange County Environmental Protection Division (OCEPD) to evaluate water quality improvement options for Lake Holden. This project has several objectives, including: (1) an evaluation of the operational characteristics of the existing Lake Holden alum treatment facility, with particular emphasis on the operational status and characteristics of the flow monitoring and alum metering equipment; (2) an evaluation of historical and current water quality trends in Lake Holden to identify potential impacts from previous water quality improvement projects; (3) collection and analysis of sediment samples within the lake to evaluate the success of recent sediment inactivation projects and the potential need for further inactivation; (4) evaluation of treatment options for Sub-basins 7 and 20, including construction and pollutant removal costs for each recommended option; and (5) evaluation of opportunities for additional stormwater treatment in Sub-basins 1, 2, and 21.

The work efforts outlined for this project were divided into two primary phases, with Phase 1 consisting of a comprehensive evaluation of the existing alum treatment system (ATS) including existing operational characteristics and functionality, potential equipment upgrades and improvements, and recommendations for expansion. The results of the Phase 1 work efforts were completed in October 2008 and summarized in a separate report titled "Evaluation of the Current Operational Status of the Lake Holden Alum Stormwater Treatment System and Recommendations for Improvements". A copy of this report is included in Appendix A for reference purposes.

Phase 2 of the project consists of a comprehensive evaluation of historical water quality trends and sediment characteristics, with the goal of identifying water quality improvements resulting from previous water quality improvement projects. Opportunities for stormwater management in Sub-basins 1, 2, 7, 20, and 21 are also summarized in this report.

This report is divided into five separate sections for presentation of the work efforts conducted by ERD. Section 1 contains an introduction to the report and a brief summary of work efforts conducted by ERD. An evaluation of runoff characteristics discharging from primary sub-basins into Lake Holden is given in Section 2, along with recommendations for improvement of operation of the existing ATS. A review of historic and current water quality trends in Lake Holden is given in Section 3. Section 4 contains an evaluation of sediment characteristics in Lake Holden, along with a discussion of the success of previous sediment inactivation projects. A discussion of additional treatment opportunities in Sub-basins 1, 2, 7, 20, and 21 is given in Section 5. Appendices are attached which contain reference documents and data collected by ERD during this project.

SECTION 2

EVALUATION OF CURRENT RUNOFF / BASEFLOW CHARACTERISTICS AND ALUM TREATMENT EFFICACY

Field and laboratory efforts were conducted by ERD from August 2008-April 2009 to evaluate the current water quality characteristics of runoff and baseflow discharging into Lake Holden from Sub-basins 1, 2, and 21. Runoff discharging from each of these sub-basins is currently treated with the existing alum stormwater treatment facility at a design dose of 7.5 mg Al/liter. The purpose of the activities conducted by ERD is to evaluate existing runoff and baseflow characteristics and to determine if the current alum addition rate is sufficient for existing conditions. Laboratory jar testing was conducted on each of the collected runoff and baseflow samples to verify the effectiveness of the current alum injection dose and to make recommendations for potential dose changes. Recommendations were generated as a result of the field and laboratory testing concerning future operation of the alum stormwater treatment system. The results of these analyses and recommendations are summarized in the following sections.

2.1 Runoff/Baseflow Characteristics

A field monitoring program was conducted by ERD from August 2008-April 2009 to evaluate the chemical characteristics of stormwater and baseflow inputs to Lake Holden from Sub-basins 1 (Division Avenue), 2 (Holden Terrace), and 21 (Paseo Street). Each of these sub-basins is currently treated with the existing alum stormwater treatment system prior to discharge into Lake Holden. A summary of sub-basins selected for collection of stormwater and baseflow samples is given in Table 2-1, and approximate monitoring locations are indicated on Figure 2-1.

TABLE 2-1

LOCATIONS FOR COLLECTION OF STORMWATER AND BASEFLOW SAMPLES IN THE LAKE HOLDEN DRAINAGE BASIN

SUB-BASIN	SUB-BASIN AREA (acres)	ANNUAL RUNOFF (ac-ft)	STORMSEWER DESCRIPTION	TREATMENT TYPE
1	98.9	260.8	54” RCP along Division Avenue	Alum Injection
2	65.7	134.5	48” x 76” RCP along Lake Holden Terrace	Alum Injection
21	19.4	35.2	42” RCP along Paseo Street	Alum Injection

Figure 2-1. Monitoring Locations of Stormwater and Baseflow Samples in Lake Holden.

Automatic sequential samplers with integral flow meters, manufactured by Sigma (Model 900MAX), were installed inside man-hole structures associated with each of the three stormsewer systems referenced in Table 2-1. In general, the automatic samplers were installed inside the first or second man-hole within each of the stormsewer systems upstream of the point of discharge into Lake Holden. Sensor cables and sample tubing were extended from each of the autosamplers into the stormsewers to the desired monitoring site. The integral flow meters were programmed to provide a continuous record of hydraulic discharges through the stormsewer systems, with measurements stored into internal memory at 10-minute intervals.

The stormsewer systems associated with Sub-basins 1 and 2 were characterized by partially full flow at each of the two monitoring sites. Flow measurements at these sites were performed using the area/velocity method. The flow probe utilized at these sites provided simultaneous measurements of water depth and flow velocity. The depth measurements are converted into a cross-sectional area based upon the geometry of the pipe, and the velocity of flow is measured directly by the probe. Discharge is then calculated by the flow meter using the Continuity Equation ($Q = A \times V$) in cubic feet per second (cfs). The stormsewer system associated with Sub-basin 21 does not exhibit surcharged conditions, and flow measurements at this site were performed using a pressure transducer sensor which transforms sensitive measurements of water depth into a flow rate using the Manning Equation and pipe geometry. This probe provided continuous measurements of water depth and converted measured water depths into an approximate flow rate.

Each of the automatic stormwater samplers contained 24 individual one-liter polyethylene bottles. The autosamplers were programmed to collect samples in a flow-weighted mode, with collected samples placed into the collection bottles in a sequential order. The automatic samplers were operated on 12 VDC gel cell batteries which were replaced on a weekly basis. After the samples were retrieved from the autosampler unit, the flow hydrographs were used to identify samples which were collected under runoff or baseflow conditions. A single composite sample was then generated for each monitored stormwater or baseflow event by combining the appropriate individual one-liter samples into a single composite sample representing the monitored stormwater or baseflow conditions. A total of five composite runoff samples was collected at each of the three monitoring sites over the period from August 2008-April 2009. A minimum separation of 30 days was maintained between the monitored events to include potential seasonal effects in runoff and baseflow characteristics.

A summary of the characteristics of stormwater runoff collected from Sub-basins 1, 2, and 21 is given in Table 2-2. In general, runoff samples collected from the sub-basins were found to be approximately neutral in pH, with the majority of measured values ranging from approximately 6.8-7.7. Measured conductivity values in each of the runoff events are similar to values commonly observed in urban runoff. Runoff collected from the Division Avenue sub-basin was found to be relatively well buffered during most runoff events, with a mean alkalinity substantially higher than values measured at the remaining sites. The elevated alkalinity values measured at this site are likely related to the industrial facilities within the sub-basin. Runoff samples collected at the Holden Terrace and Paseo Street monitoring sites were found to be moderately to poorly buffered during most events.

TABLE 2-2

CHARACTERISTICS OF STORMWATER RUNOFF COLLECTED FROM LAKE HOLDEN SUB-BASINS 1, 2, AND 21 FROM AUGUST 2008-APRIL 2009

SAMPLE DESCRIPTION	SUB-BASIN	DATE COLLECTED	pH (s.u.)	COND. (µmho/cm)	ALK. (mg/l)	NH_3 (µg/l)	NO_x (µg/l)	ORG N (µg/l)	TN (µg/l)	SRP (µg/l)	TP (µg/l)
Division Avenue	1	8/14/08	7.35	169	103	116	310	655	1081	174	477
		10/24/08	7.71	163	117	92	< 5	372	466	25	199
		11/30/08	7.31	164	89.0	213	242	1036	1491	352	789
		1/7/09	6.81	245	64.0	51	832	1192	2075	7	171
		4/14/09	7.03	162	93.8	228	441	970	1639	203	406
		Mean	**7.24**	**181**	**93.4**	**140**	**366**	**845**	**1350**	**152**	**408**
		Minimum	**6.81**	**162**	**64.0**	**51**	**< 5**	**372**	**466**	**7**	**171**
		Maximum	**7.71**	**245**	**117**	**228**	**832**	**1192**	**2075**	**352**	**789**
Holden Terrace	2	9/11/08	8.39	80	164	75	251	2071	2397	147	1266
		10/24/08	7.40	137	51.6	64	432	222	718	33	102
		11/30/08	7.05	205	61.6	46	766	1162	1974	18	415
		1/7/09	7.17	268	72.0	482	2861	856	4199	11	598
		4/14/09	6.93	105	43.2	135	283	816	1234	88	272
		Mean	**7.39**	**159**	**78.5**	**160**	**919**	**1025**	**2104**	**59**	**531**
		Minimum	**6.93**	**80**	**43.2**	**46**	**251**	**222**	**718**	**11**	**102**
		Maximum	**8.39**	**268**	**164**	**482**	**2861**	**2071**	**4199**	**147**	**1266**
Paseo Street	21	8/14/08	6.89	104	41.8	130	144	590	864	27	142
		10/24/08	7.29	80	32.0	59	69	186	314	36	78
		11/30/08	6.97	148	35.2	399	469	760	1628	34	438
		1/7/09	6.89	245	88.0	56	416	2046	2518	22	436
		4/14/09	7.03	155	69.8	228	402	1100	1730	84	346
		Mean	**7.01**	**146**	**53.4**	**174**	**300**	**936**	**1411**	**41**	**288**
		Minimum	**6.89**	**80**	**32.0**	**56**	**69**	**186**	**314**	**22**	**78**
		Maximum	**7.29**	**245**	**88.0**	**399**	**469**	**2046**	**2518**	**84**	**438**

In general, measured concentrations of ammonia in runoff samples collected at the three sub-basin sites were similar to values commonly observed in urban runoff during most events. However, somewhat elevated ammonia concentrations were observed in the Holden Terrace and Paseo Street sub-basins during one or two events. Measured NO_x concentrations were highly variable at each of the three monitoring sites, ranging from extremely low to extremely elevated. An NO_x concentration of 2861 µg/l was measured at the Holden Terrace site during January 2009 which is more than 10 times the concentration commonly observed in urban runoff. An elevated NO_x level of 832 µg/l was also measured in the Division Avenue sub-basin during the same event. Measured concentrations of organic nitrogen were also highly variable between the three monitoring sites, with measured concentrations ranging from low to elevated. However, on an average basis, organic nitrogen concentrations are similar to values commonly observed in urban runoff. Total nitrogen concentrations were also highly variable at each of the three monitoring sites, with concentrations ranging from low to elevated in value. However, on an average basis, the measured total nitrogen concentrations are similar to values commonly observed in urban areas with similar land use characteristics.

Highly variable concentrations of soluble reactive phosphorus (SRP) were measured at the Division Avenue and Holden Terrace monitoring sites, while SRP concentrations measured at the Paseo Street site were both low in value and relatively consistent between storm events. Measured total phosphorus concentrations were highly variable at each of the three monitoring sites, with measured concentrations ranging from low to extremely elevated. The mean total phosphorus concentrations measured at the Division Avenue and Holden Terrace sites are approximately two times greater than phosphorus concentrations commonly observed in urban runoff from similar land use categories. Phosphorus concentrations as high as 789 μg/l were measured at the Division Avenue site, with a value of 1266 μg/l measured at the Holden Terrace site. These values are approximately 3-6 times greater than typical phosphorus concentrations from similar land use categories.

The existing alum stormwater treatment system is designed to provide efficient removal for total phosphorus concentrations as high as 300-350 μg/l. However, exceedances of the design phosphorus level occurred during three of the five monitored events at the Division Avenue sub-basin, three of the five monitored events at the Holden Terrace sub-basin, and two of the five monitored events at the Paseo Street sub-basin. Elevated phosphorus concentrations have been observed previously by ERD at the Division Avenue, Holden Terrace, and Paseo Street stormsewers. It appears that highly variable and elevated phosphorus concentrations continue to persist within these areas.

Dry weather baseflow samples were also collected at each of the three sub-basin monitoring sites, with one baseflow sample collected at the Division Avenue site, one sample collected at the Holden Terrace site, and two samples collected at the Paseo Street site. A listing of the characteristics of baseflow samples collected from Lake Holden sub-basins 1, 2, and 21 is given in Table 2-3. In general, baseflow samples were found to be approximately neutral in pH, with conductivity measurements similar to values commonly observed in urban systems. The baseflow samples were also found to be moderately well buffered, with alkalinity values similar to those observed in stormwater runoff.

TABLE 2-3

CHARACTERISTICS OF BASEFLOW SAMPLES COLLECTED FROM LAKE HOLDEN SUB-BASINS 1, 2, AND 21

SAMPLE DESCRIPTION	SUB-BASIN	DATE COLLECTED	pH (s.u.)	COND. (μmho/cm)	ALK. (mg/l)	NH_3 (μg/l)	NO_x (μg/l)	ORG N (μg/l)	TN (μg/l)	SRP (μg/l)	TP (μg/l)
Division Avenue	1	1/29/09	6.85	207	111	447	816	2922	4185	546	1399
Holden Terrace	2	1/29/09	7.00	187	93.0	147	462	1299	1908	153	429
Paseo Street	21	1/29/09	7.20	269	82.0	60	626	1529	2215	31	264
		3/1/09	6.87	203	69.0	42	714	1863	2620	112	608
		Mean	**7.04**	**236**	**75.5**	**51**	**671**	**1696**	**2418**	**72**	**436**
		Minimum	**6.87**	**203**	**69.0**	**42**	**626**	**1529**	**2215**	**31**	**264**
		Maximum	**7.20**	**269**	**82.0**	**60**	**715**	**1863**	**2620**	**112**	**608**

Concentrations of measured nitrogen species in baseflow samples were highly variable for each of the measured nitrogen species. Elevated levels of ammonia were measured in the baseflow sample collected from the Division Avenue site, with elevated NO_x concentrations measured in baseflow samples collected at each of the three sites. Elevated levels of organic nitrogen were also observed in baseflow samples collected at the Division Avenue and Paseo Street sites. Total nitrogen concentrations measured in baseflow collected from Division Avenue and Paseo Street were higher in value than total nitrogen concentrations measured in runoff samples collected at the same site. Total nitrogen concentrations in baseflow collected from the Holden Terrace site were similar to runoff samples collected at the same site.

In general, baseflow samples collected at each of the three sites exhibited highly variable, and at times highly elevated, concentrations of both SRP and total phosphorus. Extremely elevated concentrations of both SRP and total phosphorus were measured in baseflow collected at the Division Avenue site, with measured concentrations approximately 3-4 times higher than mean values measured in stormwater runoff. The extremely elevated SRP concentration of 546 μg/l in the Division Avenue baseflow sample represents a readily available source of inorganic phosphorus capable of stimulating significant algal growth. Water column concentrations of SRP in Lake Holden are typically 200-400 times lower than the baseflow SRP concentration measured in the Division Avenue stormsewer. The SRP concentration measured in baseflow discharging through the Holden Terrace system is approximately 50-100 times greater than typical SRP concentrations measured in Lake Holden. Somewhat lower levels of SRP were observed in baseflow samples collected at the Paseo Street site, although an elevated concentration of 112 μg/l was measured during one of the two events. Overall, measured concentrations of SRP and total phosphorus in baseflow collected at the Division Avenue and Paseo Street sites are substantially higher than concentrations measured in stormwater runoff at the same sites. At the Holden Terrace site, the measured baseflow SRP concentration is substantially higher than SRP measured in runoff, while the total phosphorus concentration in baseflow is slightly lower than the mean total phosphorus in stormwater runoff.

2.2 Treatment System Efficacy

A series of standard laboratory jar tests were conducted on each of the runoff and baseflow samples collected at the three monitoring sites. Jar testing was conducted at alum doses of 5, 7.5, and 10 mg Al/liter. These alum dosage rates were selected to bracket the design injection rate for the Lake Holden alum stormwater treatment system of 7.5 mg Al/liter. The lower dose of 5 mg/l was used to evaluate if similar removal efficiencies could be achieved at a lower dose, while the higher alum application rate of 10 mg/l was selected to evaluate whether significant enhancement in removal efficiencies could be achieved using a higher alum dose. Alum doses as high as 20 mg Al/liter were tested on selected baseflow samples due to the elevated phosphorus concentrations.

Laboratory jar testing at each of the alum doses was conducted individually using a sample volume of 2 liters for each test. All laboratory jar testing was conducted using a standard Phipps and Bird jar test apparatus (Model 7790-400). A photograph of the jar test apparatus is given on Figure 2-2. To begin a test, the appropriate volume of alum is added to a 2-liter water sample and the alum and water mixture is agitated at 60 rpm for one minute using a paddle stirrer. The alum treated sample was then allowed to settle for a period of 24 hours, simulating settling processes which would occur for alum treated runoff after entering Lake Holden. At the end of the 24-hour settling period, the clear supernatant was decanted for laboratory analyses.

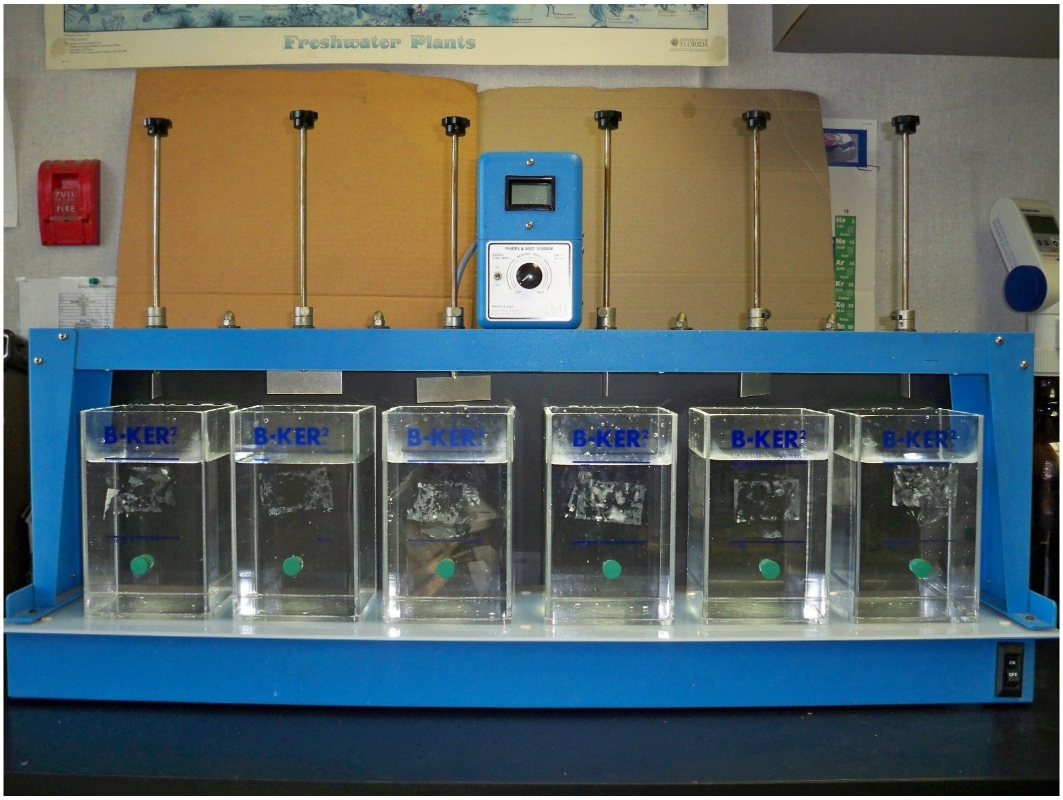


Figure 2-2. Photograph of Jar Test Apparatus.

2.2.1 <u>Division Avenue (Sub-basin 1)</u>

A summary of the results of laboratory jar tests conducted on runoff and baseflow samples collected from the Division Avenue stormsewer system is given in Table 2-4. In general, addition of alum to the runoff and baseflow samples resulted in a slight decrease in pH with increasing alum dose. Alum addition at the design treatment dose of 7.5 mg Al/liter resulted in equilibrium pH values in excess of the minimum Class III criterion of 6.0 for recreational waterbodies. A decrease in measured alkalinity was also observed in each of the treated samples, with lower equilibrium alkalinity values observed at higher alum doses. A general trend of increasing specific conductivity was observed with increasing alum dose as a result of addition of sulfate ions to the water.

In general, the addition of alum to the runoff samples had little impact on measured concentrations of ammonia or NO_x, although a slight decrease in ammonia and NO_x concentrations was observed for several of the collected samples. However, changes in ammonia and NO_x have little impact on overall concentrations of total nitrogen. The addition of alum resulted in reductions in measured concentrations of organic nitrogen in each of the tested samples. Overall, reductions ranging from approximately 60-70% were observed for organic nitrogen at the tested alum doses. Similar reductions were also observed for measured concentrations of total nitrogen, ranging from approximately 35% removal at an alum dose of 5 mg/l to 40% removal at an alum dose of 10 mg/l. A substantially lower removal efficiency was observed for the baseflow sample, with total nitrogen removals ranging from 24-28%. The lower removal efficiencies achieved with the baseflow samples are due to the relatively elevated concentrations of ammonia and NO_x which are largely unaffected by alum addition.

TABLE 2-4

RESULTS OF LABORATORY JAR TESTS CONDUCTED ON RUNOFF AND BASEFLOW SAMPLES COLLECTED FROM THE DIVISION AVENUE STORMSEWER SYSTEM

SAMPLE DESCRIPTION	ALUM DOSE	DATE COLLECTED	pH (s.u.)	COND. (μmho/cm)	ALK. (mg/l)	NH_3 (μg/l)	NO_x (μg/l)	ORG N (μg/l)	TN (μg/l)	SRP (μg/l)	TP (μg/l)
Runoff	Raw	8/14/08	7.35	169	103	116	310	655	1081	174	477
	5.0 mg/l		7.25	231	66.2	188	312	314	814	1	2
	7.5 mg/l		7.19	248	59.4	197	305	291	793	1	4
	10.0 mg/l		7.16	272	49.0	242	304	171	717	1	5
	Raw	10/24/08	7.71	163	117	92	3	372	466	25	199
	5.0 mg/l		7.57	226	77.8	45	34	288	367	6	10
	7.5 mg/l		7.44	258	73.4	30	36	287	353	2	5
	10.0 mg/l		7.55	283	69.4	28	38	282	348	< 1	1
	Raw	11/30/08	7.31	164	89.0	213	242	1036	1491	352	789
	5.0 mg/l		7.20	207	53.6	40	319	367	726	5	34
	7.5 mg/l		6.90	215	40.0	37	354	337	728	3	26
	10.0 mg/l		6.87	239	36.8	44	352	313	709	1	18
	Raw	1/7/09	6.81	245	64.0	51	832	1192	2075	7	171
	5.0 mg/l		6.72	264	40.0	96	942	691	1729	< 1	29
	7.5 mg/l		6.60	271	34.0	163	950	574	1687	< 1	11
	10.0 mg/l		6.27	275	14.0	162	954	538	1674	< 1	< 1
	Raw	4/14/09	7.03	162	93.8	228	441	970	1639	203	406
	5.0 mg/l		7.02	201	54.6	80	575	57	712	< 1	8
	7.5 mg/l		6.85	214	42.8	79	512	43	634	< 1	2
	10.0 mg/l		6.62	220	30.4	75	545	15	635	< 1	3
	Raw	**Mean**	**7.24**	**181**	**93.4**	**140**	**366**	**845**	**1350**	**152**	**408**
	5.0 mg/l		**7.15**	**226**	**58.4**	**90**	**436**	**343**	**870**	**3**	**17**
	7.5 mg/l		**7.00**	**241**	**49.9**	**101**	**431**	**306**	**839**	**2**	**10**
	10.0 mg/l		**6.89**	**258**	**39.9**	**114**	**439**	**264**	**817**	**< 1**	**6**
Baseflow	Raw	1/29/09	6.85	207	111	447	816	2922	4185	546	1399
	5.0 mg/l		6.69	216	54.2	305	898	1971	3174	117	740
	7.5 mg/l		6.68	237	46.2	314	894	1815	3023	40	715
	10.0 mg/l		6.66	238	38.8	312	924	1791	3027	3	683

Addition of alum to both the runoff and baseflow samples resulted in substantial reductions in both SRP and total phosphorus. On an average basis, a removal of approximately 98% was observed for SRP in alum treated runoff samples, with total phosphorus removals ranging from approximately 96-99%. Based upon the results summarized in Table 2-4 for the runoff samples, a treatment dose of 7.5 mg/l still appears to be adequate for this site.

In contrast, phosphorus removal was substantially lower for the baseflow sample collected from the Division Avenue site. Removal of SRP ranged from 79-99%, depending upon the applied dose. However, removal of total phosphorus in the baseflow sample was substantially lower than observed for stormwater runoff, with removals ranging from 47-51%, depending upon dose. The initial total phosphorus concentration of 1399 μg/l in the baseflow sample is substantially out of the range of phosphorus values anticipated to be removed by the alum treatment system, and a sufficient quantity of aluminum is not available to precipitate a majority of the phosphorus concentration. Even when treated at the highest alum dose of 10 mg/l, the resulting total phosphorus concentration of 683 μg/l in the baseflow sample is still approximately 67% higher than the mean raw runoff concentration measured at this site during this study. It appears that baseflow is a significant contributor of phosphorus loadings to Lake Holden, and it is extremely important that the treatment system be fine-tuned to treat the lowest possible inflow rates to ensure that at least a portion of the dry weather baseflow is treated.

2.2.2 Holden Terrace (Sub-basin 2)

A summary of the results of jar tests conducted on runoff and baseflow samples collected from the Holden Terrace stormsewer system is given in Table 2-5. In general, addition of alum to the runoff and baseflow samples resulted in decreases in pH and alkalinity with increasing alum dose. However, at the design alum addition rate of 7.5 mg Al/liter, equilibrium pH values for both runoff and baseflow samples were substantially greater than the minimum Class III criterion of 6.0 for Class III recreational waterbodies. A general trend of increasing specific conductivity was also observed with increasing alum dose as a result of the addition of sulfate ions to the water.

In general, the addition of alum to the runoff samples had relatively little impact on measured concentrations of ammonia or NO_x, although a slight decrease in ammonia concentrations was observed with increasing alum dose for most of the collected runoff samples. However, ammonia concentrations were generally low in value in runoff collected at the Holden Terrace site, and the observed reductions in ammonia concentrations had little impact on overall concentrations of total nitrogen. The addition of alum resulted in reductions in measured concentrations of organic nitrogen in each of the tested samples. These reductions were observed for both runoff and baseflow samples. Removals ranging from approximately 32-45% were observed for organic nitrogen at the tested alum doses, with removals ranging from 30-71% for organic nitrogen in the baseflow sample. Removal efficiencies for total nitrogen in the runoff samples ranged from 21-27%, with higher removal efficiencies observed at higher alum doses. Removal efficiencies ranging from 21-46% were observed for total nitrogen in the baseflow sample.

Addition of alum to both the runoff and baseflow samples resulted in substantial reductions in both SRP and total phosphorus. On an average basis, removals ranging from 98-99% were observed for SRP in the alum treated runoff samples, with total phosphorus removals ranging from 97-99%. Based upon the results summarized in Table 2-5 for the runoff samples, a treatment dose of 7.5 mg Al/liter still appears to be adequate for this site.

TABLE 2-5

RESULTS OF LABORATORY JAR TESTS CONDUCTED ON RUNOFF AND BASEFLOW SAMPLES COLLECTED FROM THE HOLDEN TERRACE STORMSEWER SYSTEM

SAMPLE DESCRIPTION	ALUM DOSE	DATE COLLECTED	pH (s.u.)	COND. (μmho/cm)	ALK. (mg/l)	NH_3 (μg/l)	NO_x (μg/l)	ORG N (μg/l)	TN (μg/l)	SRP (μg/l)	TP (μg/l)
Runoff	Raw	9/11/08	8.39	80	164	75	251	2071	2397	147	1266
	5.0 mg/l		7.55	177	58.4	20	131	2069	2220	3	11
	7.5 mg/l		7.01	221	51.6	28	124	1878	2030	< 1	10
	10.0 mg/l		6.53	250	50.8	24	99	1827	1950	< 1	1
	Raw	10/24/08	7.40	137	51.6	64	432	222	718	33	102
	5.0 mg/l		7.01	159	28.4	26	379	112	517	< 1	5
	7.5 mg/l		6.79	163	13.8	28	389	89	506	< 1	7
	10.0 mg/l		6.36	169	5.8	28	420	49	497	< 1	3
	Raw	11/30/08	7.05	205	61.6	46	766	1162	1974	18	415
	5.0 mg/l		6.67	200	31.2	56	762	558	1376	1	16
	7.5 mg/l		6.65	201	29.4	88	753	541	1382	1	8
	10.0 mg/l		6.61	235	21.2	62	773	529	1364	1	6
	Raw	1/7/09	7.17	268	72.0	482	2861	856	4199	11	598
	5.0 mg/l		7.01	272	57.8	22	2843	135	3000	2	17
	7.5 mg/l		6.92	275	45.0	12	2791	66	2869	2	15
	10.0 mg/l		6.60	277	27.4	20	2867	63	2950	1	14
	Raw	4/14/09	6.93	105	43.2	135	283	816	1234	88	272
	5.0 mg/l		6.90	164	35.2	86	474	638	1198	< 1	24
	7.5 mg/l		6.66	182	26.4	71	481	506	1058	< 1	2
	10.0 mg/l		5.58	163	6.2	70	523	365	958	< 1	3
	Raw	**Mean**	**7.39**	**159**	**78.5**	**160**	**919**	**1025**	**2104**	**59**	**531**
	5.0 mg/l		**7.03**	**194**	**42.2**	**42**	**918**	**702**	**1662**	**1**	**15**
	7.5 mg/l		**6.81**	**208**	**33.2**	**45**	**908**	**616**	**1569**	**1**	**8**
	10.0 mg/l		**6.34**	**219**	**22.3**	**41**	**936**	**567**	**1544**	**< 1**	**5**
Baseflow	Raw	1/29/09	7.00	187	93.0	147	462	1299	1908	153	429
	5.0 mg/l		7.03	189	56.8	35	566	913	1514	7	221
	7.5 mg/l		6.98	197	53.6	34	571	459	1064	< 1	41
	10.0 mg/l		6.94	203	48.0	80	574	382	1036	< 1	24

In contrast, total phosphorus removal was lower for the baseflow sample collected from the Holden Terrace site. Removal of SRP ranged from 95-99%. However, total phosphorus removal in the baseflow sample ranged from 48% at an alum dose of 5 mg/l to 94% at an alum dose of 10 mg/l. A removal efficiency of approximately 94% was also obtained at the design treatment dose of 7.5 mg/l. The total phosphorus concentration of 429 μg/l measured in baseflow collected from the Holden Terrace stormsewer system is higher than runoff phosphorus concentrations measured during three of the five collected storm events. Baseflow from the Holden Terrace stormsewer also appears to be a significant contributor of phosphorus loadings to Lake Holden, and it is extremely important that the treatment system be fine-tuned to treat the lowest possible inflow rates at this site to ensure that at least a portion of the dry weather baseflow is treated.

2.2.3 Paseo Street (Sub-basin 21)

A summary of the results of jar tests conducted on runoff and baseflow samples collected from the Paseo Street stormsewer system is given in Table 2-6. In general, addition of alum to the runoff and baseflow samples resulted in decreases in pH and alkalinity with increasing alum dose. A general trend of increasing specific conductivity was observed with increasing alum dose as a result of addition of sulfate ions to the water.

In general, the addition of alum to the Paseo Street runoff samples had little impact on measured concentrations of NO_x. However, alum addition resulted in reductions in ammonia concentrations in four of the five runoff samples. The addition of alum resulted in reductions in measured concentrations of organic nitrogen in each of the tested samples, with removals ranging from approximately 35-47% for organic nitrogen in the treated runoff samples and 35-62% in the treated baseflow samples. Removal of total nitrogen ranged from 28-36% in the runoff samples and 19-34% in the baseflow samples. In general, total nitrogen concentrations in baseflow were approximately 70% higher than concentrations measured in runoff samples.

Addition of alum to both the runoff and baseflow samples resulted in substantial reductions in both SRP and total phosphorus. On an average basis, removals ranging from 95-98% were observed for SRP in the alum treated runoff samples, with total phosphorus removals ranging from approximately 93-98%. Based upon the results summarized in Table 2-6 for the runoff samples, the design treatment dose of 7.5 mg Al/liter still appears to be adequate for this site.

In contrast, phosphorus removal was substantially lower for the baseflow samples collected from the Paseo Street site. Removal of total phosphorus in the baseflow samples ranged from approximately 50-97%, depending upon the applied dose. The mean baseflow total phosphorus concentration of 436 μg/l is approximately 51% greater than the mean total phosphorus concentration of 288 μg/l measured in stormwater runoff. The phosphorus concentrations observed in baseflow are approaching the upper range of phosphorus values anticipated to be removed by the alum treatment system. Measured concentrations of conductivity and alkalinity in the baseflow samples are substantially greater than values measured in stormwater runoff which could be used to assist in identifying the baseflow sources. Due to the elevated total phosphorus concentrations measured in baseflow collected from the Paseo Street stormsewer system, baseflow appears to be a significant contributor of phosphorus loadings to Lake Holden. Similar to the conclusions reached for the Division Avenue and Holden Terrace stormsewer systems, it is extremely important that the treatment system be fine-tuned to allow treatment of baseflow discharging through the Paseo Street stormsewer system for the lowest possible discharge rates.

TABLE 2-6

RESULTS OF LABORATORY JAR TESTS CONDUCTED ON RUNOFF AND BASEFLOW SAMPLES COLLECTED FROM THE PASEO STREET STORMSEWER SYSTEM

SAMPLE DESCRIPTION	ALUM DOSE	DATE COLLECTED	pH (s.u.)	COND. (µmho/cm)	ALK. (mg/l)	NH_3 (µg/l)	NO_x (µg/l)	ORG N (µg/l)	TN (µg/l)	SRP (µg/l)	TP (µg/l)
Runoff	Raw	8/14/08	6.89	104	41.8	130	144	590	864	27	142
	5.0 mg/l		6.85	119	19.8	330	142	237	709	< 1	6
	7.5 mg/l		6.20	123	7.2	214	135	165	514	< 1	2
	10.0 mg/l		4.79	135	1.0	196	148	137	481	< 1	1
	Raw	10/24/08	7.29	80	32.0	59	69	186	314	36	78
	5.0 mg/l		5.00	92	2.0	27	106	91	224	< 1	6
	7.5 mg/l		4.92	107	1.0	42	103	63	208	< 1	4
	10.0 mg/l		4.63	128	0.8	39	104	54	197	< 1	1
	Raw	11/30/08	6.97	148	35.2	399	469	760	1628	34	438
	5.0 mg/l		6.03	164	6.6	39	485	468	992	< 1	23
	7.5 mg/l		4.97	168	2.2	49	453	441	943	< 1	20
	10.0 mg/l		4.62	208	0.8	53	454	379	886	< 1	18
	Raw	1/7/09	6.89	245	88.0	56	416	2046	2518	22	436
	5.0 mg/l		6.85	246	50.0	40	426	1261	1727	2	58
	7.5 mg/l		6.82	274	46.0	80	439	1107	1626	1	42
	10.0 mg/l		6.59	274	34.0	109	495	1014	1618	< 1	13
	Raw	4/14/09	7.03	155	69.8	228	402	1100	1730	84	346
	5.0 mg/l		5.70	100	3.4	92	344	1001	1437	< 1	2
	7.5 mg/l		5.11	122	2.0	89	338	989	1416	< 1	3
	10.0 mg/l		4.66	138	1.0	95	341	879	1315	< 1	2
	Raw	**Mean**	**7.01**	**146**	**53.4**	**174**	**300**	**936**	**1411**	**41**	**288**
	5.0 mg/l		**6.09**	**144**	**16.4**	**106**	**301**	**612**	**1018**	**2**	**19**
	7.5 mg/l		**5.60**	**159**	**11.7**	**95**	**294**	**553**	**941**	**1**	**14**
	10.0 mg/l		**5.06**	**177**	**7.5**	**98**	**308**	**493**	**899**	**< 1**	**7**
Baseflow	Raw	1/29/09	7.20	269	82.0	60	626	1529	2215	31	264
	5.0 mg/l		7.05	263	63.8	41	870	653	1564	< 1	38
	7.5 mg/l		6.98	258	51.4	148	892	527	1567	< 1	35
	10.0 mg/l		6.94	272	53.0	139	875	402	1416	< 1	25
	15.0 mg/l		6.80	322	51.2	112	815	147	1074	< 1	26
	20.0 mg/l		6.64	360	43.0	68	820	79	967	< 1	21
	Raw	3/1/09	6.87	203	69.0	42	715	1863	2620	112	608
	5.0 mg/l		6.42	197	38.0	58	748	1544	2350	3	396
	7.5 mg/l		6.40	205	26.4	30	767	1075	1872	< 1	73
	10.0 mg/l		6.01	214	18.4	24	849	901	1774	< 1	24
	15.0 mg/l		6.13	264	14.1	35	763	933	1731	< 1	18
	20.0 mg/l		5.72	276	9.4	54	784	859	1697	< 1	16
	Raw	**Mean**	**7.04**	**236**	**75.5**	**51**	**671**	**1696**	**2418**	**72**	**436**
	5.0 mg/l		**6.74**	**230**	**50.9**	**50**	**809**	**1099**	**1957**	**2**	**217**
	7.5 mg/l		**6.69**	**232**	**38.9**	**89**	**830**	**801**	**1720**	**< 1**	**54**
	10.0 mg/l		**6.48**	**243**	**35.7**	**82**	**862**	**652**	**1595**	**< 1**	**25**
	15.0 mg/l		**6.47**	**293**	**32.7**	**74**	**789**	**540**	**1403**	**< 1**	**22**
	20.0 mg/l		**6.18**	**318**	**26.2**	**61**	**802**	**469**	**1332**	**< 1**	**19**

2.2.4 Supplemental Monitoring

When attempting to collect composite runoff samples from Sub-basins 1, 2, and 21 prior to an anticipated storm event, ERD field personnel would visit the alum pumping facility and turn off the alum injection pumps for the duration of the storm event so that untreated stormwater runoff could be collected for evaluation and jar testing. However, during a storm event which occurred on September 11, 2008, the City of Orlando maintenance crew apparently visited the pumping station after the pumps had been turned off by the ERD field personnel and unknowingly returned the system to automatic mode. As a result, the stormwater samples collected by ERD for this event received alum addition by the injection system. The collected samples contained visible alum floc, and it was later verified that the injection system was operational during the storm event.

After the samples were returned to the ERD Laboratory and the presence of floc was observed, it was decided to allow the samples to settle completely for a period of 24 hours and conduct chemical analyses on the supernatant to evaluate the characteristics of stormwater inputs into the lake following alum addition. A summary of the water quality characteristics of the alum treated runoff collected from Sub-basins 1, 2, and 21 on September 11, 2008 is given in Table 2-7. The pH of the alum treated samples ranged from 5.74-6.86. Equilibrium concentrations of total nitrogen in the treated samples were found to be extremely low in value, with the majority of nitrogen contributed by organic nitrogen. Extremely low levels of SRP were also observed in each of the treated samples. However, relatively elevated levels of total phosphorus were observed in the collected samples in spite of the alum stormwater treatment process. Unfortunately, the raw characteristics of the stormwater prior to alum treatment are not known, but the data suggest that the raw total phosphorus concentrations must have been extremely elevated for these events since relatively elevated total phosphorus concentrations were observed following treatment. The samples provide additional evidence that significantly elevated levels of total phosphorus are generated within each of the northern sub-basin areas during at least some storm events.

TABLE 2-7

WATER QUALITY CHARACTERISTICS OF ALUM TREATED RUNOFF COLLECTED FROM SUB-BASINS 1, 2, AND 21 ON SEPTEMBER 11, 2008

SITE	SAMPLE	pH (s.u.)	COND. (µmho/cm)	ALK. (mg/l)	NH_3 (µg/l)	NO_x (µg/l)	ORG N (µg/l)	TN (µg/l)	SRP (µg/l)	TP (µg/l)
Paseo St.	Runoff	5.74	108	1.2	34	117	231	382	3	82
Division Ave.	Runoff	6.05	70	11.4	28	126	350	504	8	146
Holden Terrace	Runoff	6.86	110	16.0	23	108	258	389	2	130

2.3 Recommendations

Based upon the runoff and baseflow monitoring conducted by ERD, highly variable, and sometimes elevated, phosphorus concentrations continue to discharge into Lake Holden from the Division Avenue, Holden Terrace, and Paseo Street stormsewer systems. Multiple attempts at reducing phosphorus loadings from these basins have been conducted previously by both Orlando and Orange County, and a number of potential contributors have been identified and retrofitted. However, elevated phosphorus concentrations continue to originate within these sub-basin areas. Each of these sub-basins also maintains a relatively constant dry weather baseflow which is independent of rain events within the basin. This baseflow likely reflects industrial discharges or operations occurring within the drainage basins. Baseflow samples collected from each of the three sub-basins contain extremely elevated levels of both SRP and total phosphorus and represent potentially significant phosphorus loadings to Lake Holden.

Based upon the laboratory jar testing conducted by ERD, the design alum addition rate of 7.5 mg Al/liter still appears to be adequate for treatment of stormwater runoff discharging into Lake Holden. There may be occasions where this dose is not adequate to fully treat phosphorus loadings during certain storm events, but no increases in dose appear to be warranted at this time. Given the fact that baseflow discharges contain elevated phosphorus concentrations, it is extremely important that the alum treatment system be fine-tuned to provide treatment for the lowest possible discharge rates to ensure that at least a portion of the dry weather baseflow is treated. The lower end of discharge rates which can be treated by the alum system is regulated by the limitations of the flow sensors but is typically in the range of approximately 0.5-1 cfs, with discharges less than these rates flowing into Lake Holden without treatment. However, alum addition should occur to all inflow into the lake which are in excess of the minimum measurement capabilities of the flow monitoring equipment.

SECTION 3

WATER QUALITY CHARACTERISTICS AND TRENDS

A review of available water quality data for Lake Holden was conducted by ERD to provide a compilation of historical water quality data for the lake, evaluate ambient concentrations of significant water quality parameters, and evaluate long-term and short-term water quality trends. The results of these analyses and evaluations are summarized in the following sections.

3.1 Data Sources

A review was conducted by ERD to identify available historical water quality data for Lake Holden. This evaluation included a search of water quality data in the possession of the City of Orlando, Orange County Environmental Protection Division (OCEPD), Florida Department of Environmental Protection (FDEP), and LAKEWATCH. Additional data were also obtained from the Orange County Water Atlas and the Florida STORET database. Historical water quality data obtained from each of these sources was then compiled into a single database. However, significant overlap and duplication in data occurred between the City of Orlando, OCEPD, and Water Atlas databases, since much of the data on the Water Atlas was obtained from these sources. Significant overlap in data was also observed in the FDEP STORET database. The combined data set was reviewed for duplicate data entries, and the duplicate data were removed as appropriate. When overlapping data was observed between various data sources, the data were assigned to the original data source.

A summary of available water quality data sources for Lake Holden is given in Table 3-1. Water quality monitoring has been conducted in Lake Holden on approximately a quarterly basis by the City of Orlando from March 2001 to the present, with separate samples collected at both north and south monitoring sites. Each of the collected samples evaluated for general parameters, nutrients, and chlorophyll. A limited amount of water quality monitoring was conducted by FDEP, with five samples collected from October 2003-September 2004 and an additional sample collected during June 2009. Each of these samples was collected near the center of the lake and evaluated for nutrients and chlorophyll.

Extensive water quality monitoring in Lake Holden has been conducted by the LAKEWATCH program, beginning in September 1987. From September 1987-September 1991, water quality monitoring was conducted at one location near the center of the lake on a monthly or quarterly basis, with the samples analyzed for general parameters, nutrients, and chlorophyll. Monitoring was resumed in July 1995 and continued until July 1996, with five samples collected over this period. Monthly monitoring was initiated by LAKEWATCH in June 1997 and has continued until the present, with a total of 143 samples collected (as of 5/09), with measurements conducted for general parameters, nutrients, and chlorophyll.

TABLE 3-1

SUMMARY OF AVAILBLE WATER QUALITY DATA SOURCES FOR LAKE HOLDEN

DATA SOURCE	PERIOD OF RECORD	NUMBER OF SAMPLES	FREQUENCY LOCATION	PARAMETERS MEASURED
City of Orlando	3/01-Present (8/09)	66	Quarterly at N/S sites	General parameters, nutrients, chlorophyll
FDEP	10/03-9/04	5	Quarterly at center	Nutrients, chlorophyll
	6/09	1	One event at center	
LAKEWATCH	9/87-9/91	19	Monthly/quarterly at center	General parameters, nutrients, chlorophyll
	7/95-9/96	5		
	6/97-Present (5/09)	166	Monthly at center	
Orange County EPD	10/70-3/75	12	Annual at N/S sites	General parameters, nutrients, chlorophyll, microbiology, metals, demand parameters
	3/77-11/80	31	Quarterly at N/S sites	
	1/81-12/87	182	Biweekly at N/S sites	
	3/88-11/91	23	Quarterly at N/S sites	
	2/92-12/96	20	Quarterly at S site	
	1/97-12/97	11	Monthly at S site	
	1/98-12/99	22	Monthly at S site	
	1/00-10/05	74	Quarterly at N/S sites	
	1/06-12/07	50	Monthly at N/S sites	
	1/08-Present (10/09)	40	Quarterly at N/S sites	

Extensive monitoring in Lake Holden has been conducted by OCEPD. Monitoring was initiated in October 1970 and continued on approximately an annual basis until March 1975, with samples collected at northern and southern sites. Each of the collected samples was evaluated for general parameters, nutrients, chlorophyll, microbiological parameters, metals, and demand parameters. Monitoring was resumed again during March 1977 and conducted at the north and south sites on a quarterly basis until November 1980. Beginning in January 1981 and continuing until December 1987, monitoring was conducted on a biweekly basis at the north and south monitoring sites. Each of the collected samples was evaluated for the parameters listed previously. Quarterly monitoring was initiated in March 1988 and continued until November 1991, with monitoring conducted at both north and south sites during most of these events. Quarterly monitoring was conducted from February 1992-December 1996 at the south site only. This monitoring was continued on a monthly basis during 1997. Monthly monitoring was resumed in January 1998 and continued until December 2000. Quarterly monitoring was initiated during January 2001 and continued until October 2005. Monitoring returned to a monthly frequency during January 2006 and was continued until December 2007. Beginning in January 2008 and extending to the present, monitoring has been conducted on approximately a quarterly basis, with both north and south monitoring sites included with each event.

All of the collected data were converted to common units to allow proper comparison of the historical data. For example, measurements of Secchi disk depth were provided in both feet and meters, depending upon the data source. All Secchi disk depth measurements were then converted by ERD into standard units of meters. Similarly, concentrations for nutrient species were provided in the historical data in both mg/l and µg/l units. All nutrient data were then converted to µg/l by ERD which is the most common current method for presentation of these data.

3.2 Data Summary

A partial summary of the available historical water quality data for Lake Holden is given in Appendix B. Data are provided for general parameters, nutrients, chlorophyll, demand parameters, and fecal coliform. The complete database developed by ERD also contains extensive measurements conducted for significant cations, heavy metals, additional microbiological parameters, and miscellaneous other parameters.

A graphical summary of historical total nitrogen concentrations in Lake Holden is given in Figure 3-1. Relatively close agreement appears to exist in total nitrogen measurements conducted by the various agencies and organizations. In general, the majority of measured total nitrogen concentrations in Lake Holden have ranged from approximately 500-2500 µg/l, with a small number of measurements both above and below this range. Total nitrogen concentrations in Lake Holden appear to peak during the mid-1980s, followed by relatively consistent measurements until approximately 2000. No significant differences are apparent between nitrogen concentrations measured at the north and south monitoring sites. A noticeable trend of decreasing nitrogen concentrations is apparent beginning in approximately 2000 and continuing until the present. This decrease in total nitrogen appears to be related to the water quality enhancement projects which have been constructed within the drainage basin.

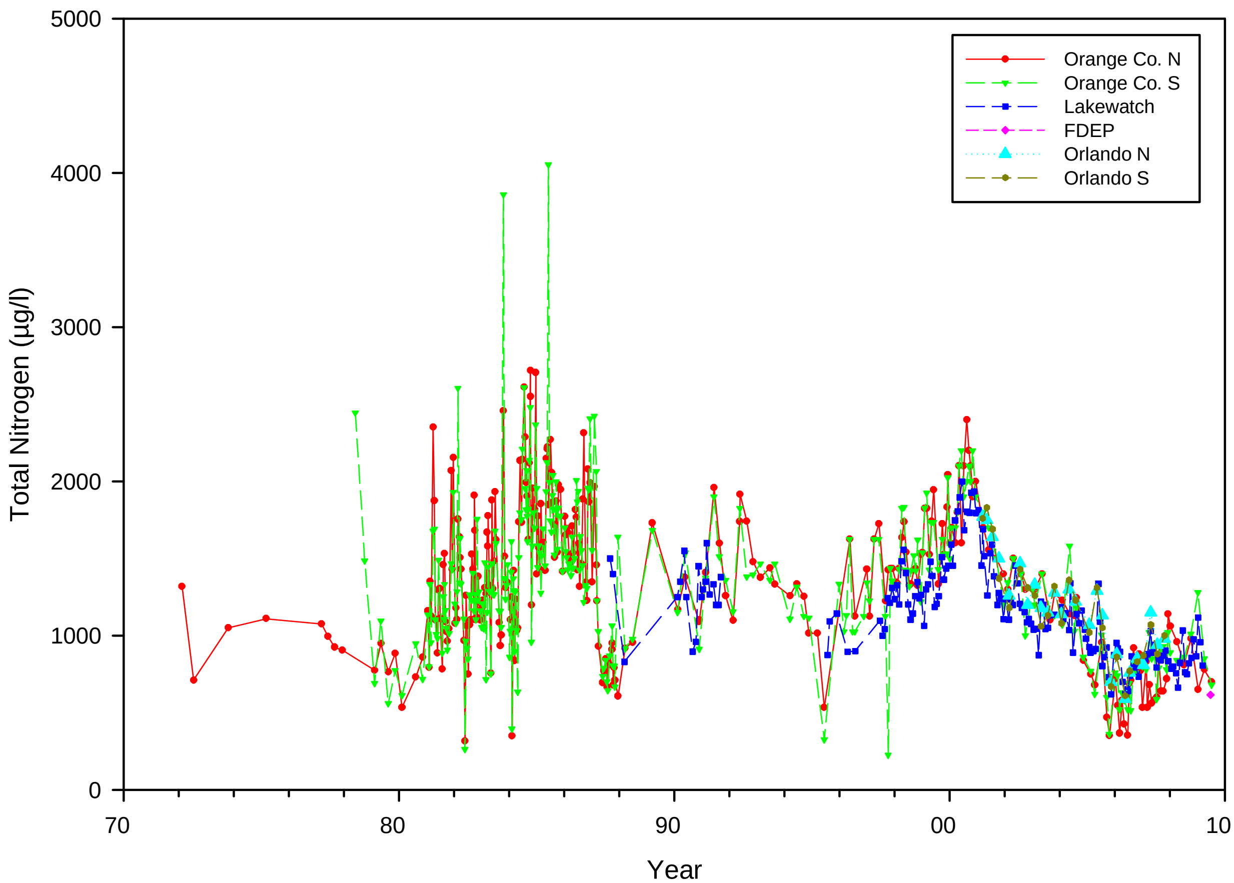


Figure 3-1. Summary of Historical Total Nitrogen Concentrations in Lake Holden.

A graphical summary of historical total phosphorus concentrations in Lake Holden is given in Figure 3-2. Total phosphorus concentrations in Lake Holden were highly variable over the period from 1980 to approximately 1995, with the majority of measured values ranging from approximately 20-80 μg/l. Spikes in phosphorus concentrations to values in excess of 100 μg/l were observed on several occasions. In general, there appears to be relatively close agreement between phosphorus concentrations reported by the data sources during this period. A trend of decreasing phosphorus concentrations in Lake Holden appears to occur in the late-1990s, with the lowest recorded phosphorus measurements occurring within the lake during the past several years. No significant differences in phosphorus concentrations are apparent between the north and south monitoring sites.

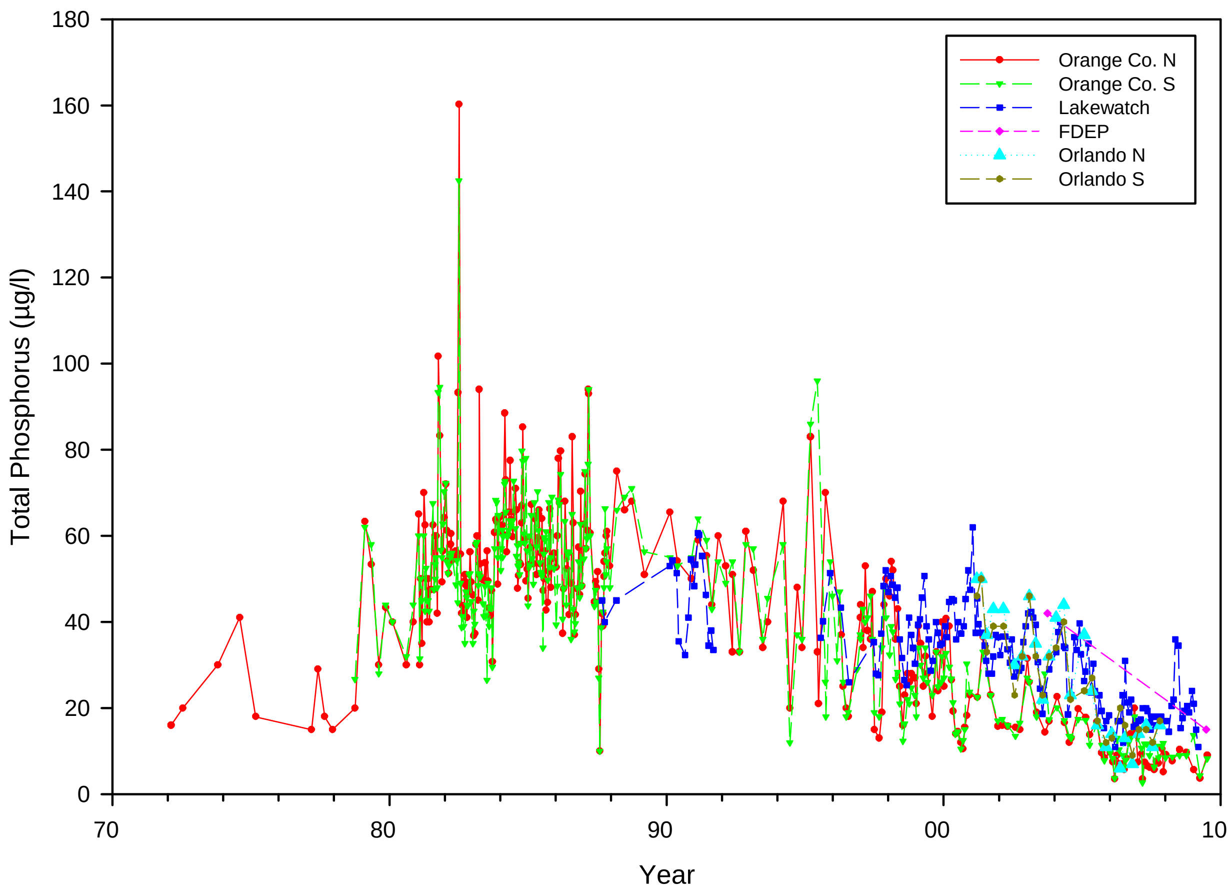


Figure 3-2. Summary of Historical Total Phosphorus Concentrations in Lake Holden.

During the period from 2000 to the present, there appears to be relatively close agreement between the phosphorus concentrations measured by LAKEWATCH, FDEP, and Orlando. However, somewhat lower total phosphorus concentrations were reported by Orange County, particularly during the period from 2000-2005. During the past several years, the Orlando and Orange County data sources appear to be more similar in value, with slightly higher total phosphorus concentrations reported by LAKEWATCH.

A graphical summary of historical chlorophyll-a concentrations in Lake Holden is given on Figure 3-3. Similar to the trends observed for total nitrogen and total phosphorus, chlorophyll-a concentrations have been highly variable in Lake Holden over the period of record, particularly prior to the year 2000. Chlorophyll-a concentrations in Lake Holden during the 1980s were highly variable, ranging from approximately 15 mg/m^3 to more than 120 mg/m^3. These rapid fluctuations in algal populations are characteristics of a highly eutrophic lake system. The highest chlorophyll-a concentrations on record in Lake Holden occurred during the mid-1980s, similar to the trends also observed for total phosphorus and total nitrogen. No significant differences in chlorophyll-a concentrations are apparent between the north and south sites.

Beginning in approximately 2000, a steady and rapid decrease in chlorophyll-a concentrations is apparent within the lake. The chlorophyll-a measurements conducted by Orange County and LAKEWATCH over this period appear to be relatively consistent. Over the past several years, chlorophyll-a concentrations in Lake Holden have ranged from approximately 5-25 mg/m^3, with some of the lowest historical chlorophyll-a concentrations measured during this time. Chlorophyll-a concentrations measured by the various monitoring agencies appear to be relatively similar.

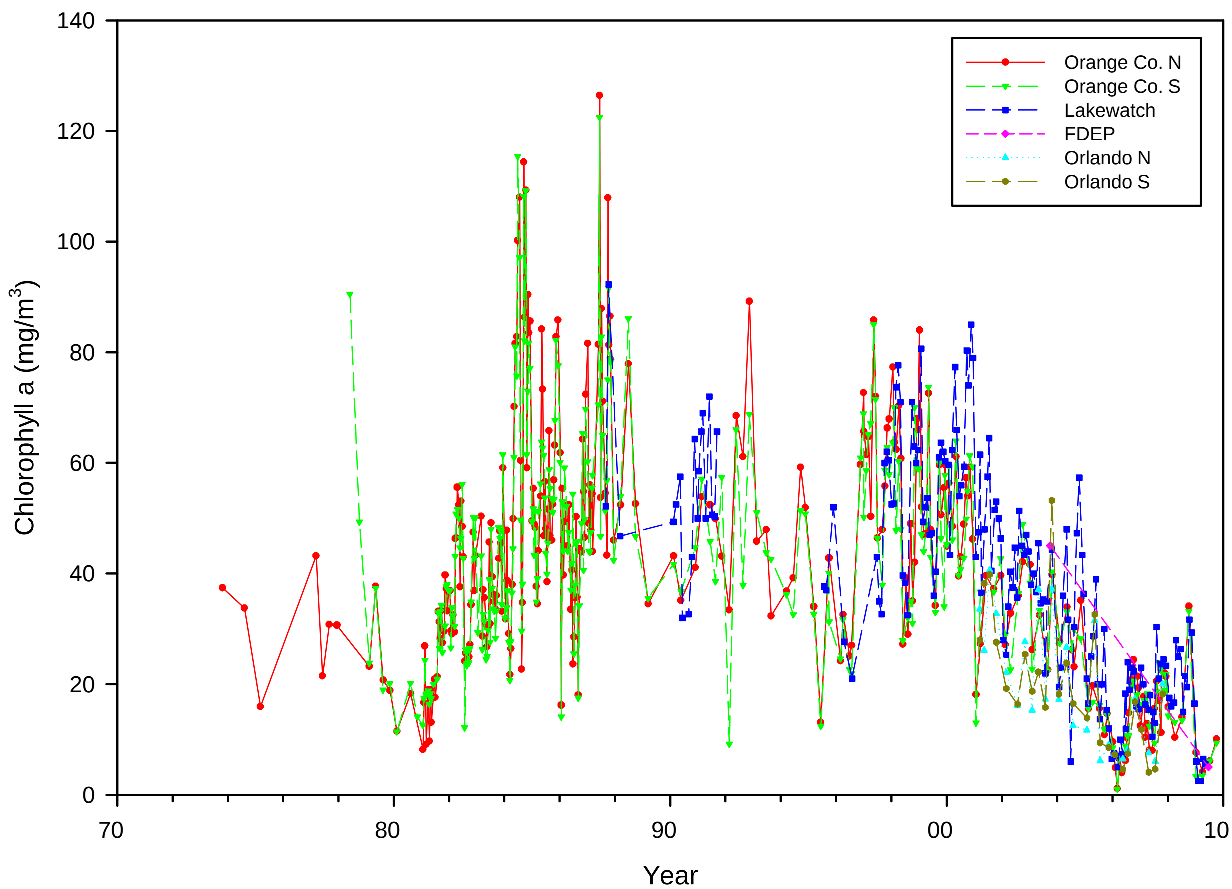


Figure 3-3. Summary of Historical Chlorophyll-a Concentrations in Lake Holden.

A graphical summary of historical Secchi disk depth measurements in Lake Holden is given in Table 3-4. Similar to the trends previously observed for total nitrogen, total phosphorus, and chlorophyll-a, Secchi disk depth has been highly variable in Lake Holden over the past 30-40 years. Secchi disk measurements substantially less than 1 m were common in Lake Holden during the period from approximately 1980-2000. However, beginning in 2000, Secchi disk depths within the lake began to increase gradually over the next 3-5 years. The sudden increases in Secchi disk depth illustrated on Figure 3-4 from 2005 to the present are likely related to the alum sediment inactivation treatments conducted to the lake during this time. In general, Secchi disk measurements appear to be relatively similar between the various sources, although slightly lower Secchi disk depths were reported by Orlando during the period from 2005-2007.

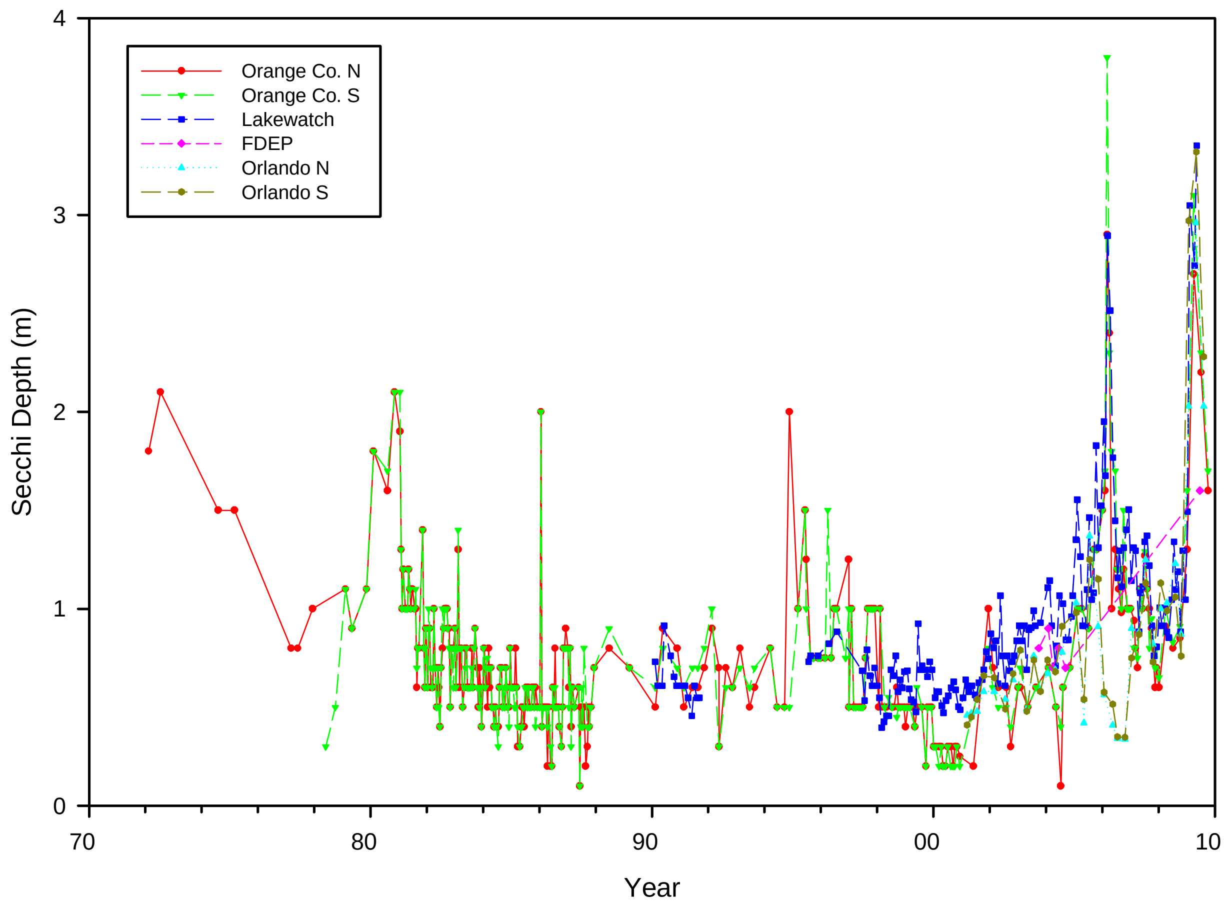


Figure 3-4. Summary of Historical Secchi Disk Depths in Lake Holden.

A graphical summary of calculated trophic state index (TSI) values in Lake Holden is given in Figure 3-5. Since TSI is a measure of primary productivity, TSI values are calculated using chlorophyll-a only. During the period from 1980-1990, Lake Holden was classified as a eutrophic or hypereutrophic lake system, with many calculated TSI values in excess of 80. A significant decrease in TSI values began to occur within the lake during 2000, with the TSI value gradually decreasing from hypereutrophic to eutrophic to mesotrophic, with highly oligotrophic conditions observed during 2007. Over the past 3-4 years, calculated TSI values in Lake Holden have indicated primarily either mesotrophic or oligotrophic conditions.

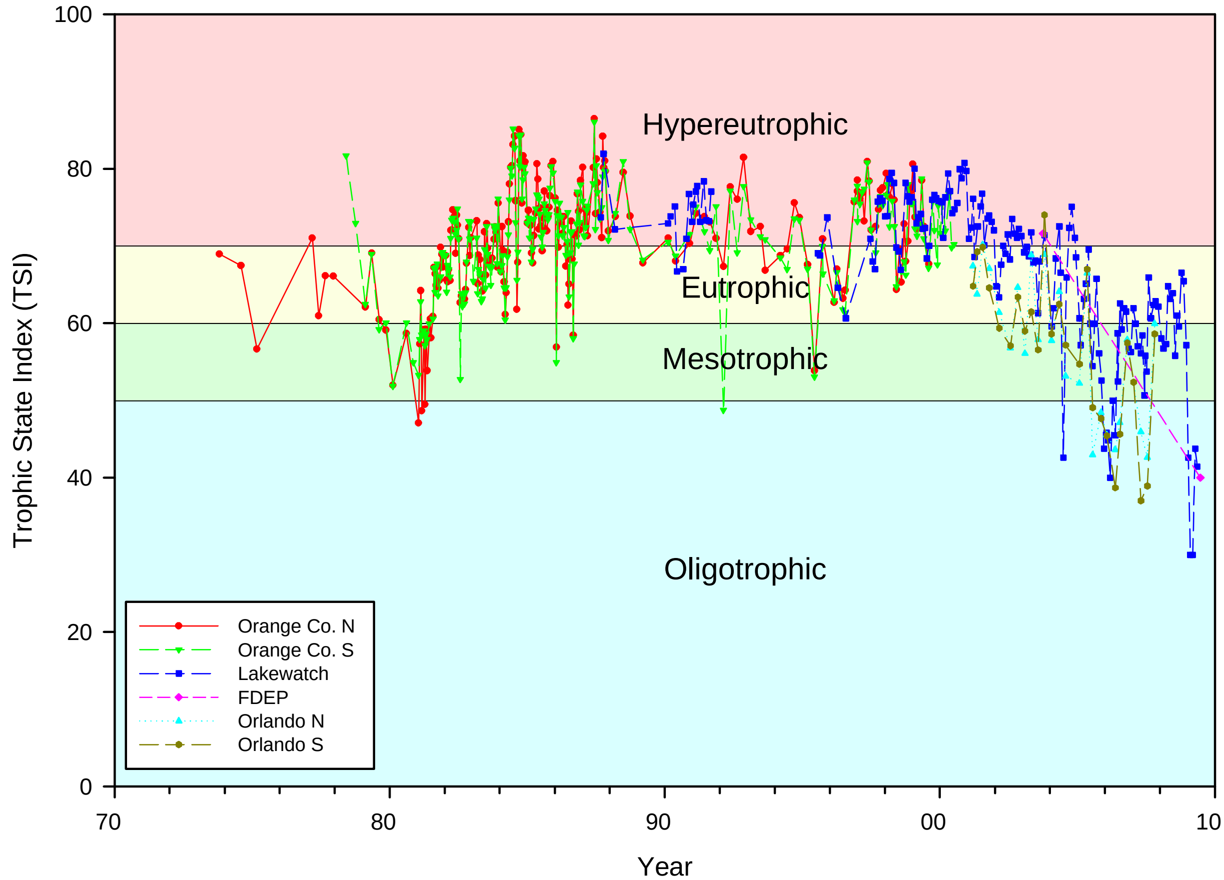


Figure 3-5. Summary of Historical Trophic State Indices (TSI) in Lake Holden.

A summary of mean water quality characteristics in Lake Holden from 1985 to the present is given in Table 3-2. Mean values for selected water quality parameters are provided for 5-year intervals over the period from 1985 to the present. The mean values for each interval reflect the mean for all data sources for a given parameter during the evaluated interval.

As seen in Table 3-2, a gradual decrease in concentrations has been observed for most parameters from 1985 to the present. Substantial reductions in mean water column concentrations are apparent for alkalinity, BOD, chlorophyll-a, chlorophyll-b, chlorophyll-c, SRP, and total phosphorus. Increases in mean water column concentrations are apparent for conductivity and sulfate due to the ongoing alum additions to the lake. Measured Secchi disk depths in Lake Holden have improved substantially, particularly over the past five years.

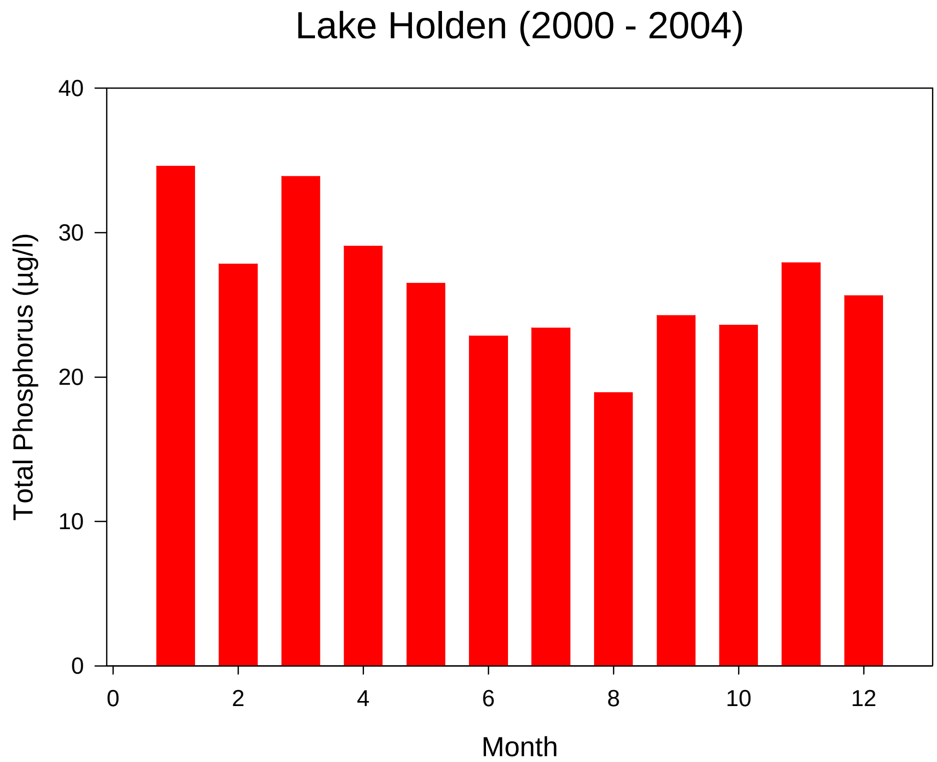
In general, improvements in water quality characteristics have been observed in Lake Holden since 1985 for virtually every parameter listed in Table 3-2, particularly since 2005. These improvements in water quality characteristics reflect the reductions in phosphorus loadings, as well as reductions in other parameters, as a result of the aggressive BMP implementation projects for the lake.

TABLE 3-2

SUMMARY OF MEAN WATER QUALITY CHARACTERISTICS IN LAKE HOLDEN FROM 1985 - PRESENT

PARAMETER	UNITS	PERIOD				
		1985-1989	1990-1994	1995-1999	2000-2004	2005-Present
pH	s.u.	8.33	8.26	8.38	8.10	7.80
Alkalinity	mg/l	70.6	70.7	60.9	66.0	30.9
Dissolved Oxygen	mg/l	8.0	8.5	8.1	8.6	8.4
Conductivity	μmho/cm	247	258	257	267	297
NH_3	μg/l	115	59	16	32	24
NO_x	μg/l	--	--	16	20	25
Organic Nitrogen	μg/l	1434	1333	1293	1369	792
Total Nitrogen	μg/l	1596	1340	1325	1421	841
SRP	μg/l	15	11	32	3	3
Total Phosphorus	μg/l	55	48	37	34	17
SO_4	mg/l	--	17.0	28.5	28.5	47.6
Turbidity	NTU	5.0	5.5	8.6	9.0	4.0
BOD_5	mg/l	4.9	4.5	3.6	3.7	1.0
Chlorophyll-a	mg/m^3	55.2	51.8	50.7	41.6	16.7
Chlorophyll-b	mg/m^3	--	--	3.1	0.6	0.7
Chlorophyll-c	mg/m^3	--	--	28.5	21.5	2.1
Color	Pt-Co	11	15	10	7	13
Fecal Coliform	cfu/100 ml	--	--	84	91	34
Secchi Disk Depth	m	0.54	0.67	0.68	0.66	1.26

A comparison of mean monthly total phosphorus concentrations in Lake Holden from 2000 to the present is given in Figure 3-6. Mean values are separated into monthly means for the period from 2000-2004 and monthly means from 2005 to the present. During the period from 2000-2004, prior to the sediment inactivation project, phosphorus concentrations in Lake Holden were lower during the wet season months and higher during dry season conditions. This trend suggests that significant internal recycling was occurring within the lake which allowed accumulated phosphorus concentrations in lower layers of the lake to circulate throughout the entire water column during fall and winter conditions when lake circulation is most common. This circulation distributes the elevated hypolimnetic phosphorus concentrations throughout the lake and results in more elevated phosphorus values during periods of circulation. The trend in mean monthly phosphorus concentrations over the period from 2000-2004 represents a classic phosphorus profile for a lake with significant internal recycling.



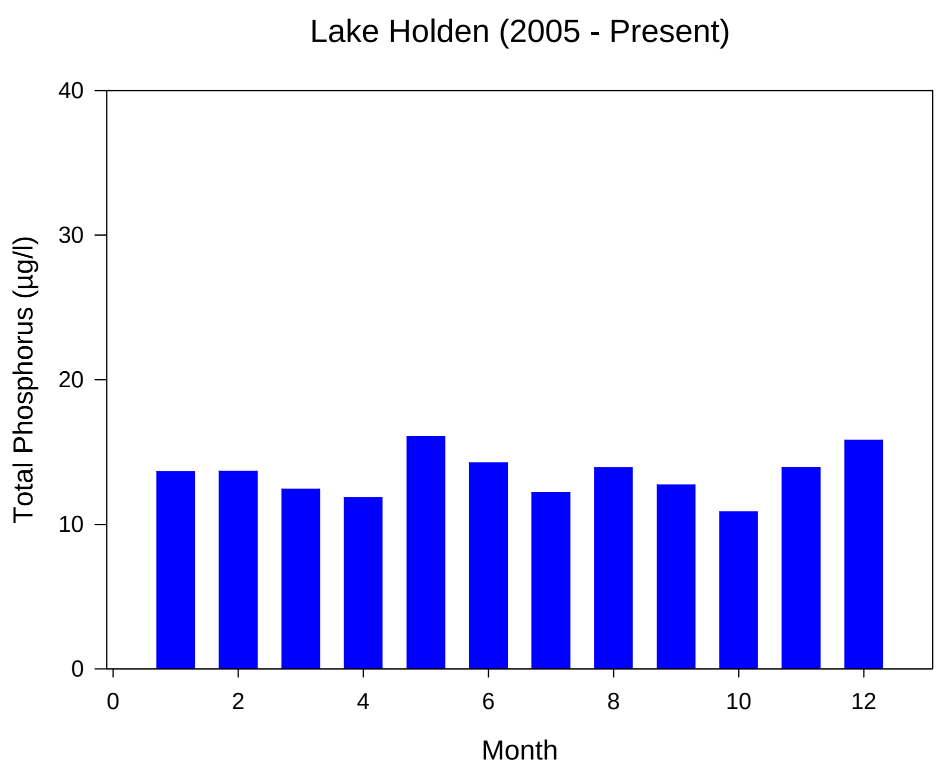


Figure 3-6. Comparison of Mean Monthly Total Phosphorus Concentrations in Lake Holden from 2000-Present.

A summary of mean monthly phosphorus concentrations in Lake Holden from 2005 to the present is given at the bottom of Figure 3-6. Two obvious patterns are apparent in phosphorus concentrations over this period. First, mean water column concentrations of total phosphorus are substantially lower throughout the year compared with phosphorus concentrations measured from 2000-2004. In addition, the elevated phosphorus concentrations observed within the lake during periods of water column circulation are now absent in the most recent monitoring data, indicating that the project to reduce internal recycling within Lake Holden has been successful.

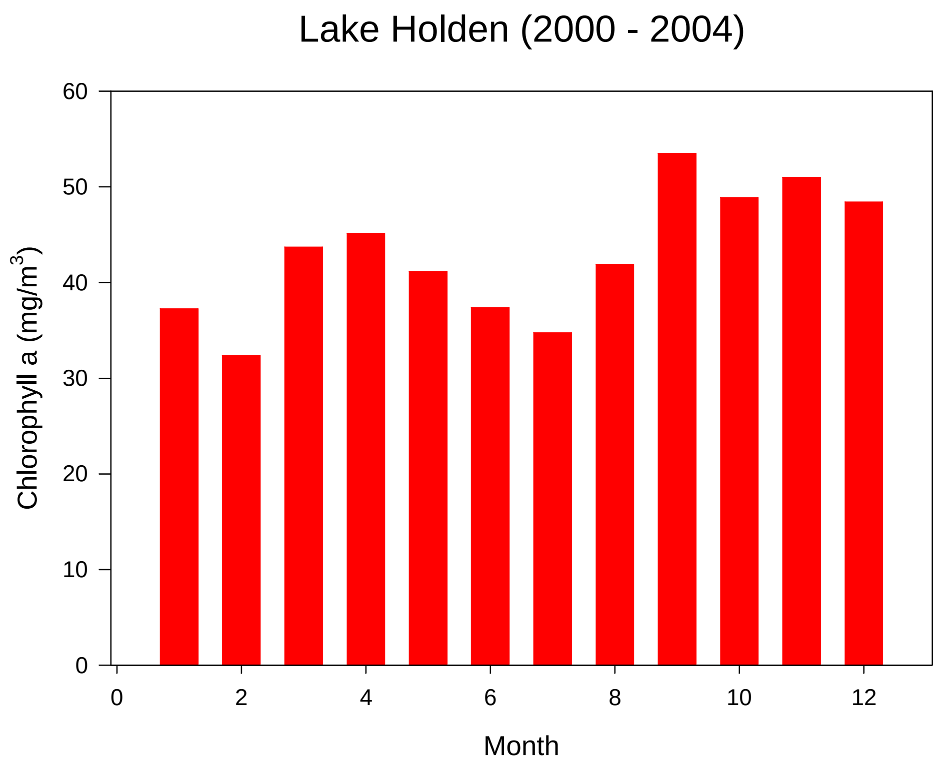
A comparison of mean monthly chlorophyll-a concentrations in Lake Holden from 2000 to the present is given in Figure 3-7. Similar to the trends observed for total phosphorus, the most elevated chlorophyll-a concentrations in Lake Holden during the period from 2000-2004 appear to occur during the fall and winter months in response to the elevated phosphorus concentrations which occur during these months.

A summary of mean monthly chlorophyll-a concentrations in Lake Holden from 2005 to the present is given at the bottom of Figure 3-7. In general, chlorophyll-a concentrations within the lake are substantially lower over the past several years than observed from 2000-2004. In addition, the elevated chlorophyll-a concentrations observed during the fall and winter months have been eliminated, with relatively consistent chlorophyll-a concentrations throughout the year.

3.3 <u>Water Quality Trends</u>

A graphical summary of calculated mean annual historical total nitrogen concentrations in Lake Holden is given in Figure 3-8. Mean annual total nitrogen concentrations were calculated for each year, with data from all sources combined, to provide a mean concentration for each year. Mean annual total nitrogen concentrations in Lake Holden have ranged from approximately 750-2000 μg/l over the historical monitoring period. Values in this range are typical of impacted lakes in an urban environment. An apparent trend of decreasing total nitrogen concentrations appears to have begun in the year 2000, with total nitrogen concentrations ranging from approximately 700-900 μg/l since 2005.

A graphical summary of calculated mean annual historical total phosphorus concentrations in Lake Holden is given in Figure 3-9. The values summarized in this figure represent the annual mean phosphorus concentration for all combined sources available in the historical data set. Total phosphorus concentrations in Lake Holden appear to have peaked in value during the late-1980s, with an annual mean of approximately 66 μg/l. However, since that time, a gradual but steady decrease in phosphorus concentrations appears to have occurred. A more significant drop in phosphorus concentrations appears to have occurred since approximately 2004, with mean annual phosphorus concentrations over the past 3-4 years ranging from approximately 10-17 μg/l. These values are extremely desirable for an urban lake system, and indicate that the extensive restoration efforts which have been conducted on Lake Holden are beginning to have measurable impacts on water quality.



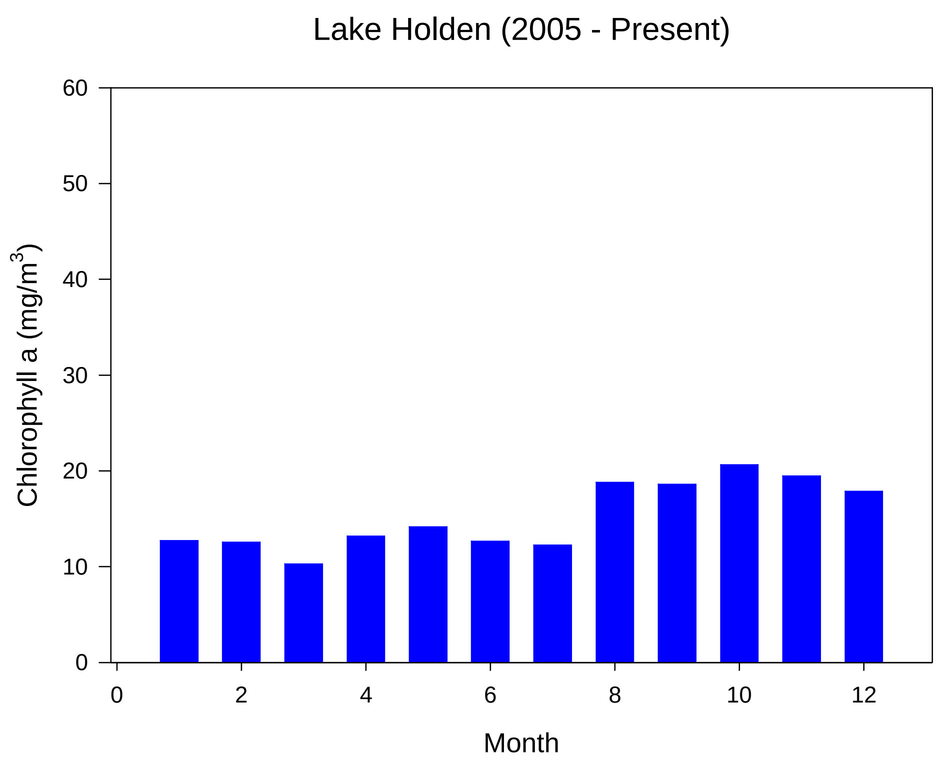


Figure 3-7. Comparison of Mean Monthly Chlorophyll-a Concentrations in Lake Holden from 2000-Present.

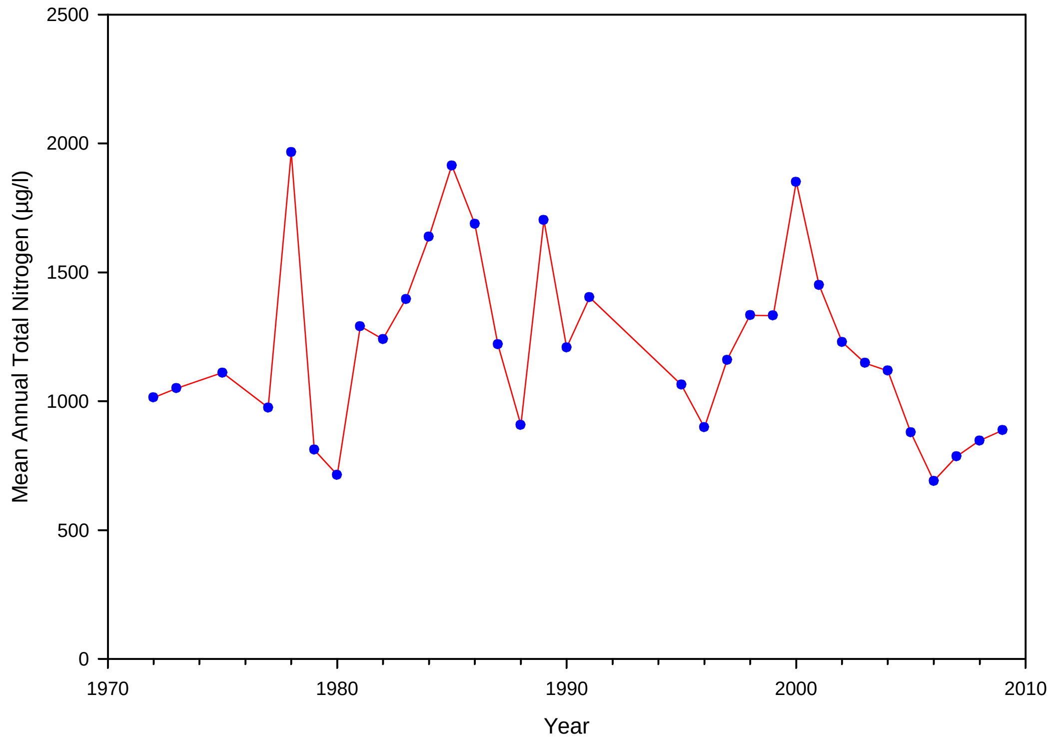


Figure 3-8. Calculated Mean Annual Historical Total Nitrogen Concentrations in Lake Holden.

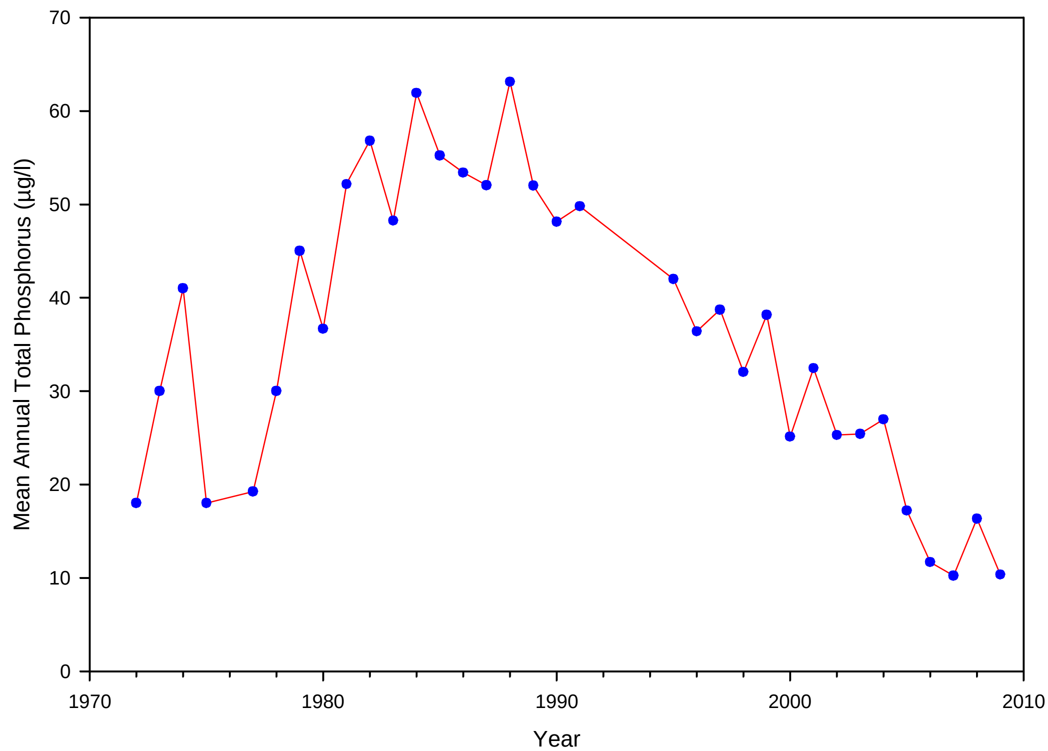


Figure 3-9. Calculated Mean Annual Historical Total Phosphorus Concentrations in Lake Holden.

A graphical summary of calculated mean annual historical chlorophyll-a concentrations in Lake Holden is given in Figure 3-10. Chlorophyll-a concentrations in Lake Holden have been highly variable, with mean annual averages ranging from approximately 5-70 mg/m^3. Some of the most consistently elevated chlorophyll-a concentrations were observed within the lake during the 1980s. Beginning in approximately 2000, a rapid decrease in annual chlorophyll-a concentrations began to occur within the lake. Over the past 3-4 years, mean annual chlorophyll-a concentrations in Lake Holden have ranged from approximately 5-21 mg/m^3, reflecting some of the lowest historic chlorophyll-a values measured within the lake.

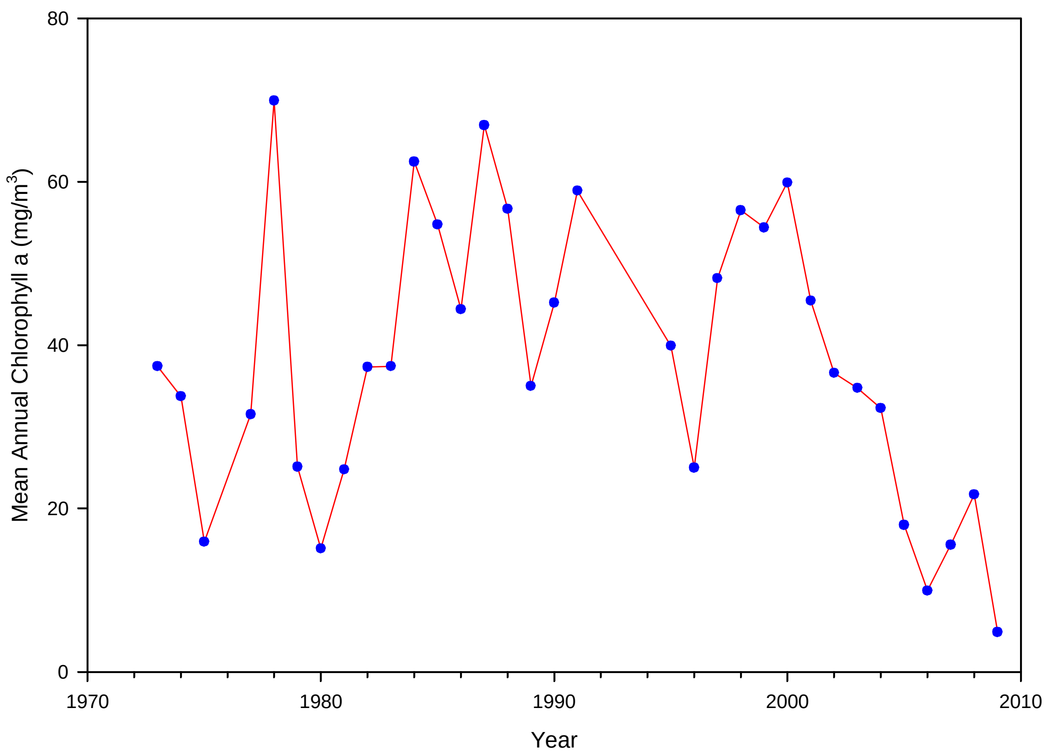


Figure 3-10. Calculated Mean Annual Historical Chlorophyll-a Concentrations in Lake Holden.

A graphical comparison of calculated mean annual Secchi disk depths in Lake Holden is given on Figure 3-11. The lowest historical Secchi disk depths within the lake were observed during the period from approximately 1980-2000, with mean annual Secchi disk depths ranging from approximately 0.4-0.8 m, reflecting extremely poor water clarity. Similar to the trends observed for total nitrogen, total phosphorus, and chlorophyll-a, improvements in Secchi disk depth began to occur in the year 2000, with an increase in mean annual Secchi disk depth from 0.4 m in 2000 to approximately 1.5 m during 2006. The mean Secchi disk depth for the first half of 2009 reflects the highest Secchi depth value ever recorded in Lake Holden.

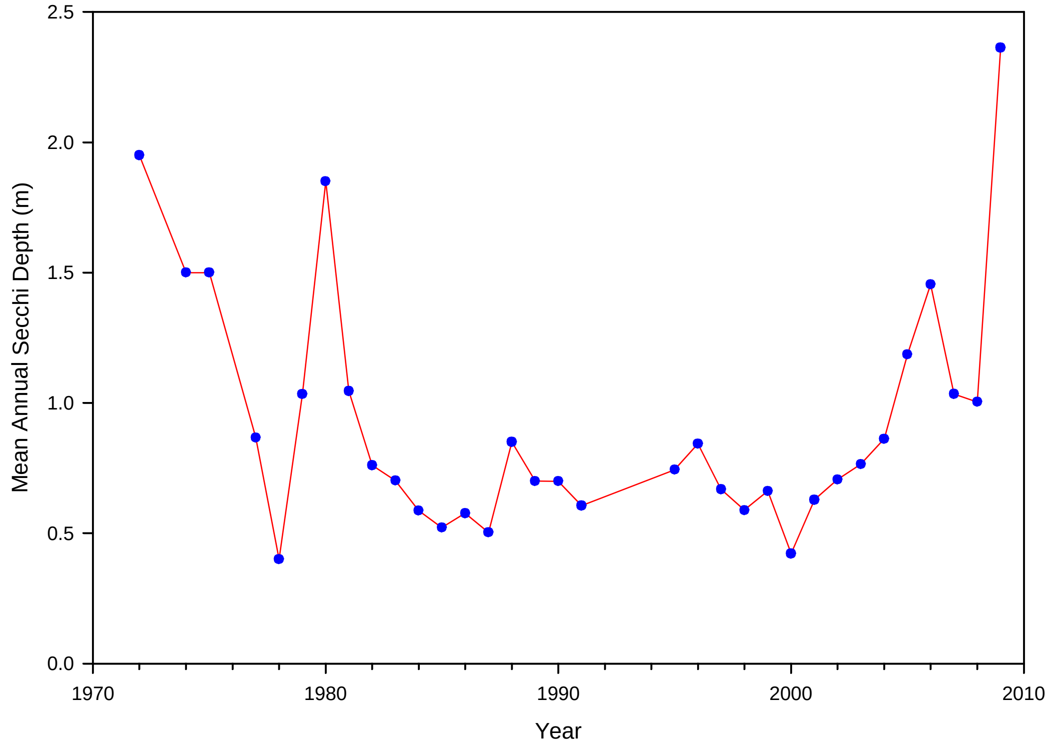


Figure 3-11. Calculated Mean Annual Historical Secchi Disk Depths in Lake Holden.

A graphical comparison of calculated mean annual TSI values for Lake Holden is given on Figure 3-12. Prior to the year 2000, mean annual TSI values in Lake Holden indicated primarily eutrophic or hypereutrophic conditions. A steady decrease in TSI value began to occur in the year 2000, with mean annual TSI values falling from hypereutrophic to eutrophic to mesotrophic from the year 2000-2006. Over the past three years, Lake Holden has exhibited primarily mesotrophic and oligotrophic conditions.

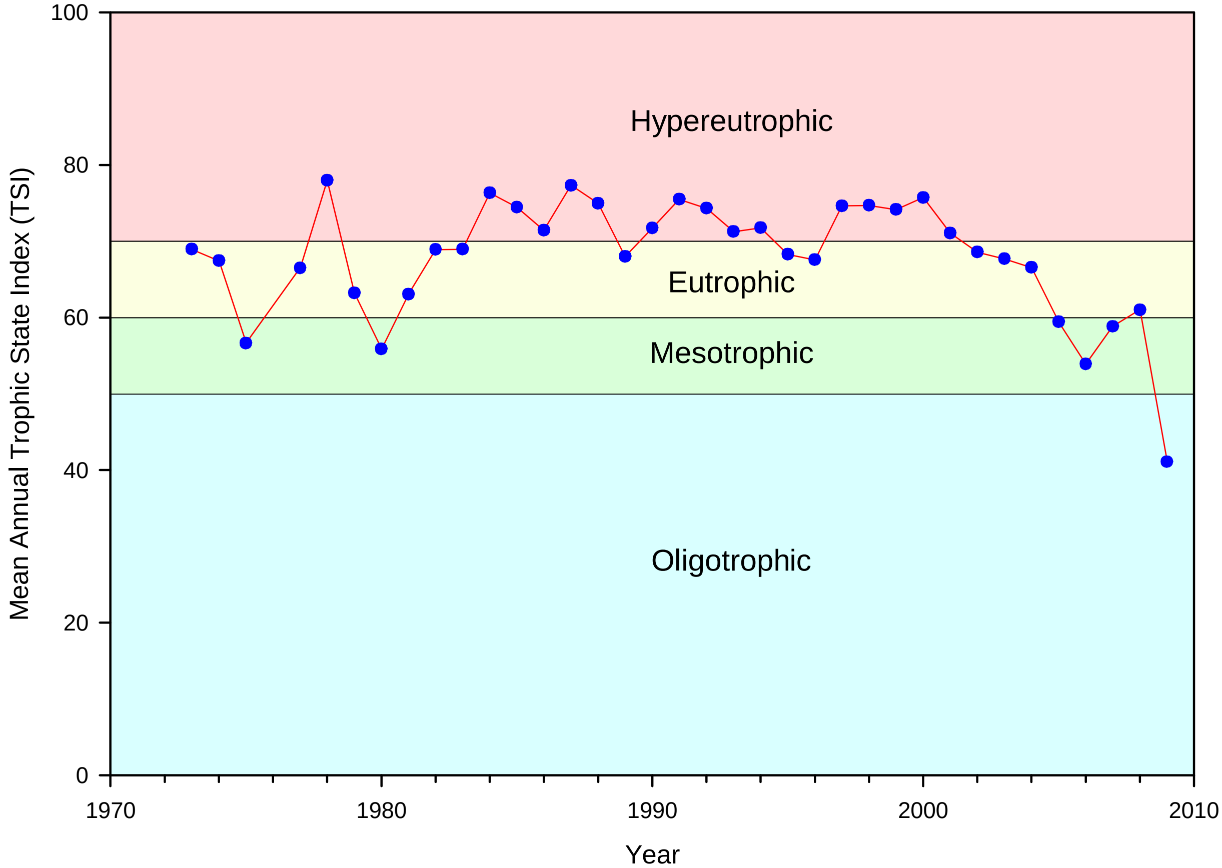


Figure 3-12. Calculated Mean Annual Historical TSI Values in Lake Holden.

SECTION 4

INTERNAL NUTRIENT RECYCLING

Sediment core samples have been collected in Lake Holden by ERD on multiple occasions to assist in evaluating the characteristics of existing sediments, potential impacts of sediment on water quality within the lake, and the success of the previous alum sediment inactivation project on the lake. A discussion of sediment characteristics, previous alum sediment inactivation project, and recommendations for future sediment inactivation work are summarized in the following sections.

4.1 <u>Sediment Characteristics</u>

Sediment core samples have been collected in Lake Holden by ERD on three separate occasions, including October 2003, May 2007, and November 2008. Sediment collection conducted during October 2003 was performed as part of a revised nutrient and hydrologic budget for Lake Holden and was used to provide estimates of available sediment phosphorus and chemical requirements for the initial sediment inactivation project conducted in Lake Holden. Sediment monitoring was conducted again in May 2007 by ERD as an independent research activity to evaluate changes in sediment characteristics and available phosphorus as a result of the initial sediment inactivation project. The final sediment monitoring event was conducted during November 2008 as part of the current project to evaluate existing sediment characteristics and to provide information and potential recommendations for additional sediment inactivation projects.

4.1.1 <u>Sampling Techniques</u>

Sediment core samples were collected by ERD at 44 separate sites within the lake. Locations of sediment sampling sites in Lake Holden are illustrated on Figure 4-1. Sediment samples were collected at the 44 monitoring sites indicated on Figure 4-1 during each of the three sediment monitoring events.

Sediment samples were collected at each of the 44 monitoring sites using a stainless steel split-spoon core device, which was penetrated into the sediments at each location to a minimum distance of approximately 0.5 m. After retrieval of the sediment sample, any overlying water was carefully decanted before the split-spoon device was opened to expose the collected sample. Visual characteristics of each sediment core sample were recorded, and the 0-10 cm layer was carefully sectioned off and placed into a polyethylene container for transport to the ERD laboratory. Duplicate core samples were collected at each site, and the 0-10 cm layers were combined together to form a single composite sample for each of the 44 monitoring sites. The polyethylene containers utilized for storage of the collected samples were filled completely so no air space was present in the storage container above the composite sediment sample. Each of the collected samples was stored on ice and returned to the ERD laboratory for physical and chemical characterization. A listing of sediment monitoring dates in Lake Holden is given in Table 4-1.

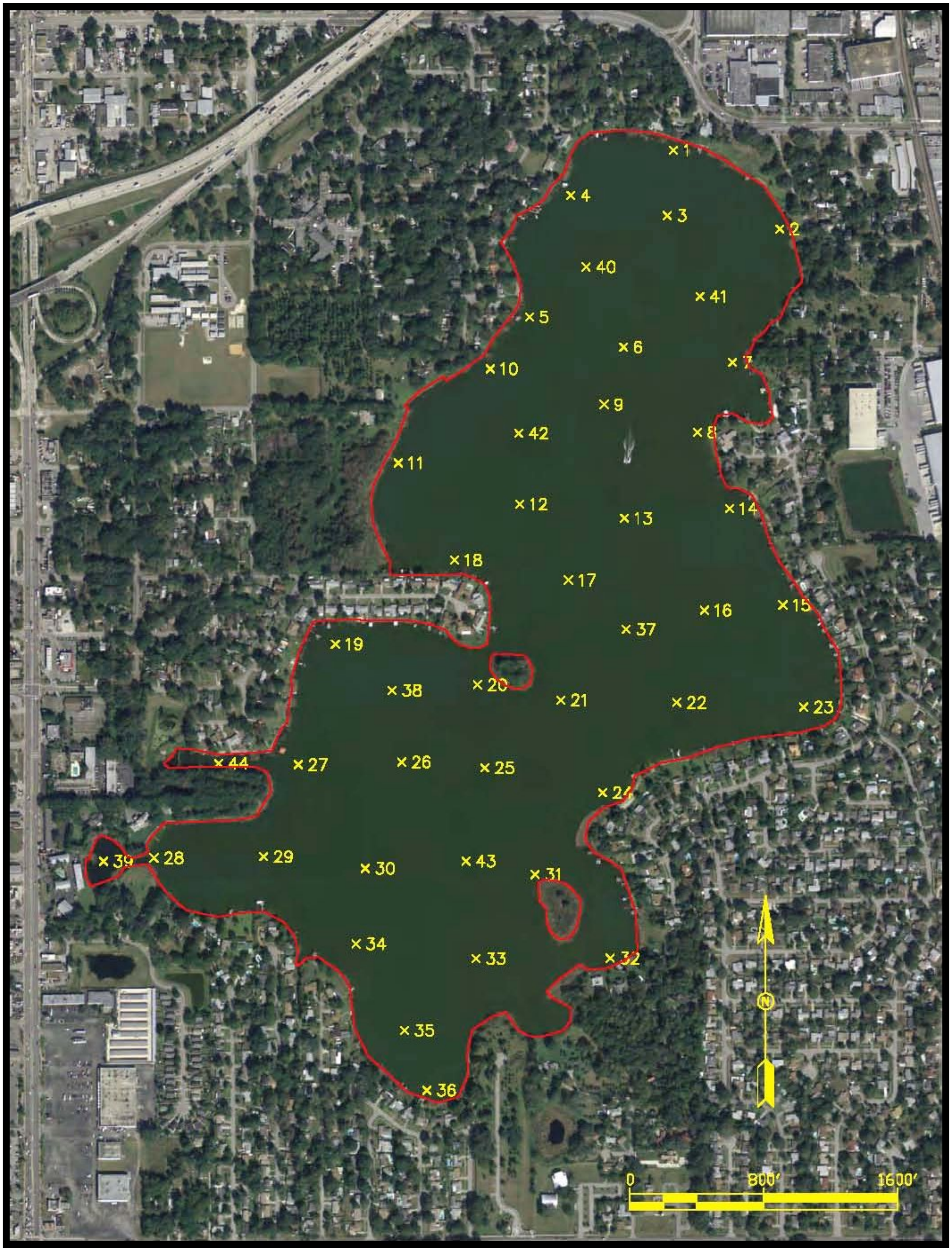


Figure 4-1. Locations of Sediment Sampling Sites in Lake Holden.

TABLE 4-1

SEDIMENT MONITORING DATES IN LAKE HOLDEN

DATE	NUMBER OF SITES	PURPOSE
10/8/03	44	Initiation evaluation of sediment characteristics used to establish alum dose for initial inactivation project
5/3/07	44	Conducted independently by ERD to evaluate success of initial alum treatment
11/13/08	44	Conducted as part of current project to evaluate treatment success and establish need and dose for potential future treatment

4.1.2 Sediment Characterization and Speciation Techniques

Each of the 44 collected sediment core samples was analyzed for a variety of general parameters, including moisture content, organic content, sediment density, total nitrogen, and total phosphorus. Methodologies utilized for preparation and analysis of the sediment samples for these parameters are outlined in Table 4-2.

TABLE 4-2

ANALYTICAL METHODS FOR SEDIMENT ANALYSES

MEASUREMENT PARAMETER	SAMPLE PREPARATION	ANALYSIS REFERENCE	REFERENCE PREP./ANAL.	METHOD DETECTION LIMITS (MDLs)
pH	EPA 9045	EPA 9045	3/3	0.01 pH units
Moisture Content	p. 3-54	p. 3-58	1/1	0.1%
Organic Content (Volatile Solids)	p. 3-52	pp. 3-52 to 3-53	1/1	0.1%
Total Phosphorus	pp. 3-227 to 3-228 (Method C)	EPA 365.4	½	0.005 mg/kg
Total Nitrogen	p. 3-201	pp. 3-201 to 3-204	1/1	0.010 mg/kg
Specific Gravity Density)	p. 3-61	pp. 3-61 to 3-62	1/1	NA

REFERENCES:

1. Procedures for Handling and Chemical Analysis of Sediments and Water Samples, EPA/Corps of Engineers, EPA/CE-81-1, 1981.

2. Methods for Chemical Analysis of Water and Wastes, EPA 600/4-79-020, Revised March 1983.

3. Test Methods for Evaluating Solid Wastes, Physical-Chemical Methods, Third Edition, EPA-SW-846, Updated November 1990.

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

Saloid-bound phosphorus is considered to be available under all conditions at all times. Iron-bound phosphorus is relatively stable under aerobic environments, generally characterized by redox potentials greater than 200 mv (E_h), while unstable under anoxic conditions, characterized by redox potential less than 200 mv. Aluminum-bound phosphorus is considered to be stable under all conditions of redox potential and natural pH conditions. A schematic of the Chang and Jackson Speciation Procedure for evaluating soil phosphorus bounding is given in Figure 4-2.

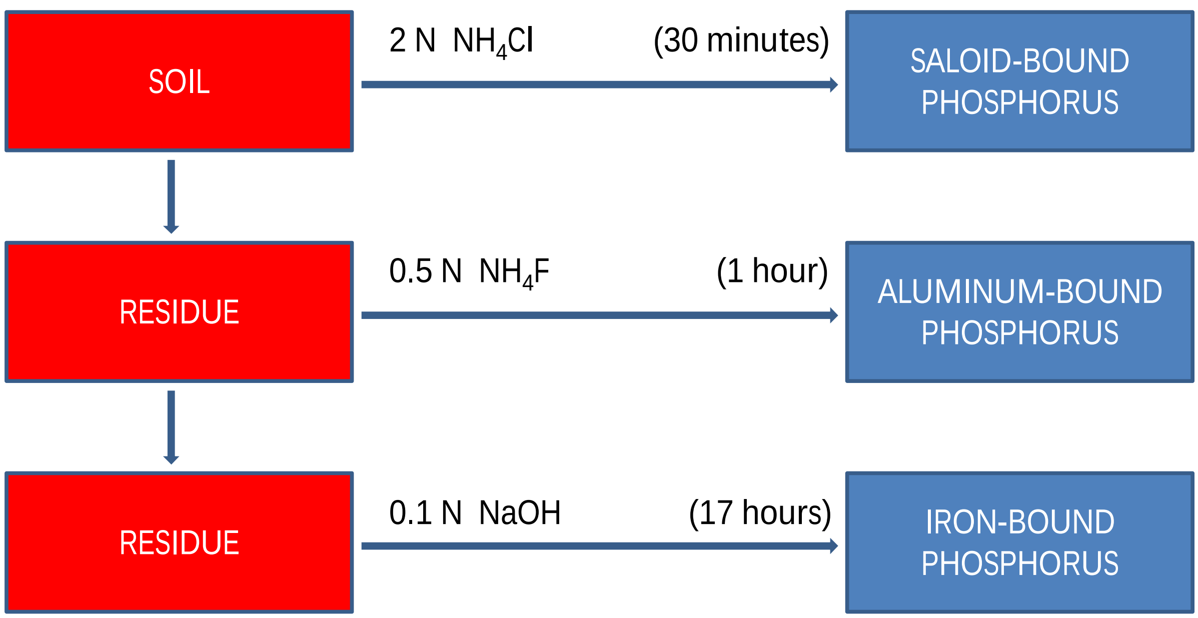


Figure 4-2. Schematic of Chang and Jackson Speciation Procedure for Evaluating Soil Phosphorus Bonding.

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

4.1.3 Visual Characteristics

Visual characteristics of sediment core samples were recorded for each of the 44 sediment samples collected in Lake Holden during October 2003, May 2007, and November 2008. A summary of visual characteristics of sediment core samples collected during each of the three monitoring events is given in Appendix C. In general, sediment characteristics appear to be relatively similar at each of the individual monitoring sites during the three events. The only significant difference appears to be the presence of visible floc in some of the high organic sediments collected during May 2007 and November 2008 compared with the original 2003 samples.

Shoreline areas of Lake Holden are characterized by sandy sediments with little or no visual accumulation of unconsolidated organic muck. The base material beneath the existing sediment accumulations consists primarily of light brown and dark brown fine sand. As water depths increase within the lake, accumulations of organic muck become more common, with thick muck accumulations in deeper portions of the lake. Areas where deep deposits of organic muck have accumulated are characterized by a surface layer of unconsolidated organic muck, approximately 1-10 cm in thickness. This unconsolidated layer is comprised primarily of fresh organic material, such as dead algal cells, which have accumulated onto the bottom of the lake. This organic material is easily disturbed by wind action or boating activities. As the sediment depth increases, the organic layer becomes more consolidated with a consistency similar to pudding. These layers typically do not resuspend into the water column except during vigorous mixing action within the lake.

4.1.4 Physical Characteristics

A complete listing of physical characteristics of sediment core samples collected in Lake Holden at each of the 44 monitoring sites during October 2003, May 2007, and November 2008 is given in Table 4-3. Data are provided for moisture content, organic content, and sediment density for each of the collected core samples.

As anticipated, the previous alum treatments have had no significant impacts on physical sediment characteristics such as moisture content, organic content, or bulk density. Measured values for moisture content, organic content, and density appear to be relatively similar in samples collected at individual sites during each of the three monitoring events. Overall, mean sediment moisture content within Lake Holden during the three monitoring events ranged from approximately 41.4-42.6%, with mean organic contents ranging from 7.7-8.9%, and bulk density values ranging from 1.86-1.86 g/cm^3. In general, a slight increase in moisture content and organic content was observed between the 2003 and 2008 sediment core samples, indicating that additional deposition of organic matter has occurred into the sediments, a normal lake process. The increases in moisture and organic content result in a slight decrease in sediment density.

TABLE 4-3

PHYSICAL CHARACTERISTICS OF SEDIMENT CORE SAMPLES COLLECTED IN LAKE HOLDEN

SITE	MOISTURE CONTENT (%)			ORGANIC CONTENT (%)			DENSITY (g/cm^3)		
	10/8/03	**5/3/07**	**11/13/08**	**10/8/03**	**5/3/07**	**11/13/08**	**10/8/03**	**5/3/07**	**11/13/08**
1	25.4	30.5	32.5	0.5	0.9	1.2	2.11	2.03	2.00
2	28.0	35.0	31.6	1.2	2.4	1.5	2.07	1.95	2.01
3	90.7	91.5	91.4	41.3	40.1	37.8	1.08	1.08	1.08
4	28.5	28.4	28.7	0.9	0.7	0.7	2.06	2.07	2.06
5	28.7	33.1	29.7	0.8	0.7	0.6	2.06	2.00	2.05
6	26.7	27.5	28.2	0.5	0.6	0.7	2.09	2.08	2.07
7	24.7	33.0	27.4	0.8	0.8	0.9	2.12	2.00	2.08
8	26.6	24.2	24.9	0.6	0.6	0.5	2.09	2.13	2.12
9	34.1	34.7	31.9	1.7	1.1	1.1	1.97	1.97	2.01
10	32.1	30.6	35.0	3.3	1.4	1.5	1.99	2.03	1.96
11	28.0	28.3	25.8	1.1	0.6	0.6	2.07	2.07	2.11
12	63.4	69.6	87.4	12.1	13.3	31.9	1.48	1.39	1.13
13	23.5	28.0	29.1	1.0	0.8	1.0	2.14	2.07	2.05
14	22.7	28.9	34.3	1.2	1.8	1.3	2.15	2.05	1.97
15	26.2	29.5	27.3	0.7	0.8	0.6	2.10	2.05	2.08
16	32.3	65.7	52.0	1.9	5.4	2.4	2.00	1.49	1.70
17	25.5	26.3	26.2	0.8	0.8	0.7	2.11	2.10	2.10
18	24.8	29.7	33.9	0.8	0.7	1.0	2.12	2.05	1.98
19	29.5	28.2	31.4	0.8	0.7	0.8	2.05	2.07	2.02
20	39.1	27.0	33.8	1.7	0.7	1.2	1.90	2.09	1.98
21	26.8	31.2	27.8	0.7	0.6	0.4	2.09	2.03	2.08
22	27.7	34.1	29.2	0.9	1.1	0.8	2.07	1.98	2.05
23	26.1	28.0	26.5	1.0	1.0	0.8	2.10	2.07	2.09
24	26.4	29.6	26.5	0.6	0.7	0.5	2.10	2.05	2.10
25	31.5	29.8	40.8	1.3	1.0	1.5	2.01	2.04	1.87
26	91.4	91.8	90.6	42.3	41.4	41.0	1.07	1.07	1.08
27	32.3	31.9	28.6	1.0	1.0	0.7	2.01	2.01	2.06
28	31.2	30.7	28.8	1.5	1.1	1.4	2.02	2.03	2.05
29	26.8	26.2	27.3	0.9	1.0	1.0	2.09	2.10	2.08
30	88.9	90.0	88.0	36.4	36.1	39.3	1.11	1.10	1.11
31	25.4	30.2	31.1	0.4	0.7	0.7	2.11	2.04	2.03
32	28.9	29.6	29.0	0.9	0.9	1.0	2.06	2.05	2.05
33	28.5	29.5	26.5	0.9	0.8	0.9	2.06	2.05	2.09
34	31.3	30.2	35.8	1.2	0.5	1.4	2.02	2.04	1.95
35	83.5	89.7	92.2	25.0	33.8	43.9	1.19	1.10	1.07
36	46.0	36.6	40.0	7.1	5.7	3.8	1.75	1.90	1.87
37	26.3	29.8	27.4	0.5	0.6	0.5	2.10	2.05	2.08
38	91.9	91.9	87.5	43.4	40.3	45.5	1.07	1.07	1.10
39	89.0	53.0	45.2	6.6	8.5	7.4	1.77	1.64	1.76
40	92.6	93.0	92.4	43.1	42.3	43.2	1.06	1.06	1.06
41	46.3	47.7	47.6	3.8	2.3	23.7	1.11	1.77	1.14
42	91.7	92.7	92.1	40.2	41.1	41.6	1.07	1.06	1.07
43	22.0	30.3	29.1	0.5	0.9	0.9	2.16	2.04	2.05
44	46.8	37.4	36.9	4.6	2.5	1.5	1.76	1.92	1.93
MEAN	**41.4**	**42.6**	**42.5**	**7.7**	**7.7**	**8.9**	**1.86**	**1.84**	**1.83**

4.1.5 Nutrient Concentrations

A complete listing of nutrient concentrations measured in sediment core samples collected in Lake Holden during the three sediment monitoring events is given in Table 4-4. Similar to the trend observed for physical characteristics, sediment concentrations of total nitrogen and total phosphorus have remained relatively constant within Lake Holden from 2003 to 2008. The apparent differences in sediment nutrient concentrations for total nitrogen and total phosphorus provided in Table 4-4 are well within the natural variability anticipated during collection and analysis of sediment samples. Mean total nitrogen concentrations in Lake Holden sediments during the three monitoring events have ranged from 851-1034 $\mu g/cm^3$, with total phosphorus concentrations ranging from 361-390 $\mu g/cm^3$.

4.1.6 Phosphorus Speciation

A complete listing of phosphorus speciation measurements conducted on sediment core samples collected in Lake Holden is given in Table 4-5. Unlike the trends observed for physical characteristics and nutrients, phosphorus speciation in Lake Holden sediments has undergone significant change as a result of the prior alum sediment inactivation project. A substantial decrease in saloid-bound phosphorus was observed between the 2003 and 2007 sediment monitoring events in Lake Holden. Saloid-bound phosphorus decreased from a mean of 10.6 $\mu g/cm^3$ during 2003 to 0.7 $\mu g/cm^3$ during 2007, a reduction of approximately 93%. A significant decrease was also observed in iron-bound phosphorus which decreased from a mean of 199 $\mu g/cm^3$ during 2003 to 54 $\mu g/cm^3$ during 2007, a reduction of approximately 73%. Overall, total available phosphorus decreased from a mean of 209 $\mu g/cm^3$ during 2003 to 55 $\mu g/cm^3$ during 2007, a decrease of 74%. In contrast, aluminum-bound phosphorus increased from 78 $\mu g/cm^3$ in 2003 to 93 $\mu g/cm^3$ in 2007, an increase of approximately 20%. Overall, available phosphorus represented 58% of the total sediment phosphorus during 2003, decreasing to only 15% of the total sediment phosphorus in 2007.

Sediment core samples collected during 2008 reflect a slight increase in saloid-bound phosphorus, iron-bound phosphorus, and total available phosphorus compared with values measured during 2007. These increases are normal phenomena and reflect inputs of additional sediment material since the completion of the initial alum application. Overall, total available phosphorus within the sediments of Lake Holden averaged 75 $\mu g/cm^3$ during November 2008, which still reflects a decrease of approximately 64% compared with the initial values measured during 2003, indicating that the previous alum treatment is still retaining a significant portion of the potentially available phosphorus mass within the sediments.

4.1.7 Summary

A summary of mean characteristics of sediment core samples collected in Lake Holden during 2003, 2007, and 2008 is given on Table 4-6. The July 2004 ERD report for Lake Holden estimated that the proposed sediment inactivation would reduce available sediment phosphorus by approximately 75% compared with the measured reduction of approximately 74%.

TABLE 4-4

NUTRIENT CONCENTRATIONS IN SEDIMENT CORE SAMPLES COLLECTED IN LAKE HOLDEN

SITE	TOTAL NITROGEN (μg/cm^3)			TOTAL PHOSPHORUS (μg/cm^3)		
	10/8/03	5/3/07	11/13/08	10/8/03	5/3/07	11/13/08
1	488	498	534	197	298	224
2	1339	1305	637	386	389	162
3	1822	1810	1669	642	454	407
4	659	624	447	191	163	165
5	516	806	324	119	161	122
6	525	584	526	214	208	205
7	982	1169	432	83	75	118
8	401	450	245	143	176	128
9	894	823	729	290	347	239
10	636	975	817	142	156	162
11	571	901	373	410	368	216
12	2162	2372	2039	507	582	659
13	244	364	422	319	147	201
14	432	704	694	280	239	180
15	472	370	336	197	184	146
16	708	420	1039	243	207	240
17	310	682	439	377	424	357
18	294	523	437	251	166	214
19	465	480	452	507	681	363
20	1481	594	581	716	577	568
21	728	463	337	156	171	113
22	900	1084	638	211	260	183
23	534	707	451	181	251	178
24	541	630	624	233	128	166
25	721	804	626	210	460	260
26	1972	1392	1635	851	209	513
27	478	759	499	805	781	572
28	410	854	1120	173	298	536
29	344	504	476	1553	1406	1821
30	2068	2309	1948	622	282	771
31	406	752	399	145	164	161
32	670	757	548	233	282	228
33	527	941	614	198	363	281
34	613	847	549	266	191	292
35	2475	2145	1942	513	492	454
36	1745	1085	1031	341	263	301
37	337	720	381	105	224	144
38	2401	2321	2372	532	620	620
39	2194	2222	1313	498	442	672
40	2004	1927	1479	404	426	369
41	1113	1310	1333	396	484	333
42	2338	2717	1633	462	632	421
43	517	643	702	192	182	194
44	1515	1171	1625	1659	1544	1244
MEAN	**976**	**1034**	**851**	**390**	**376**	**361**

TABLE 4-5

PHOSPHORUS SPECIATION IN SEDIMENT CORE SAMPLES COLLECTED IN LAKE HOLDEN

SITE	SALOID-BOUND P (µg/cm³)			Al-BOUND P (µg/cm³)			Fe-BOUND P (µg/cm³)			TOTAL AVAILABLE P (µg/cm³)			AVAILABLE P (µg/cm³)		
	10/8/03	5/3/07	11/13/08	10/8/03	5/3/07	11/13/08	10/8/03	5/3/07	11/13/08	10/8/03	5/3/07	11/13/08	10/8/03	5/3/07	11/13/08
1	5.9	0.37	0.62	22	30	51	155	18	31	161	18	32	82	6	14
2	9.3	0.20	0.57	16	20	25	117	17	35	126	17	35	33	4	22
3	13.2	2.33	1.78	143	138	115	195	36	37	208	38	39	32	8	10
4	12.7	0.38	0.64	31	26	46	111	23	47	124	23	47	65	14	29
5	10.0	0.41	0.26	12	18	32	66	23	35	76	23	35	64	14	29
6	8.6	0.34	0.74	6	9	35	63	12	35	71	12	36	33	6	18
7	3.9	0.01	0.35	3	4	13	41	10	13	45	10	13	54	13	11
8	5.7	0.43	0.59	6	62	37	88	37	39	94	37	40	66	21	31
9	13.0	0.20	1.11	19	52	41	64	29	35	77	29	36	26	8	15
10	4.4	0.10	0.45	31	21	34	72	21	28	76	22	29	54	14	18
11	11.4	0.17	0.31	115	73	85	211	37	51	223	37	51	54	10	24
12	3.9	0.92	0.75	128	212	246	214	88	85	218	89	86	43	15	13
13	9.5	0.09	0.63	67	17	32	232	24	33	242	24	33	76	16	17
14	6.2	0.00	0.57	24	77	25	201	59	70	207	59	71	74	25	39
15	8.8	0.14	0.29	48	53	66	104	40	45	113	40	45	57	22	31
16	13.8	1.39	0.31	49	68	40	178	32	54	192	34	54	79	16	23
17	13.6	0.12	0.61	124	153	189	228	163	240	242	163	141	64	38	40
18	14.2	0.36	0.65	88	21	79	129	16	62	143	16	63	57	10	29
19	17.2	0.33	0.60	160	139	187	210	74	69	227	75	70	45	11	19
20	11.3	0.35	0.61	121	210	241	199	45	35	210	45	35	29	8	6
21	13.1	0.13	0.61	8	12	14	70	12	35	83	12	35	53	7	31
22	11.8	0.08	0.46	16	20	24	112	6	43	124	6	43	59	2	24
23	11.4	0.36	0.66	28	80	32	104	49	45	115	50	45	64	20	26
24	7.5	0.72	12.79	16	21	19	107	35	43	115	35	55	49	28	33
25	9.7	0.74	0.29	55	73	66	187	29	30	197	30	30	94	6	12
26	3.5	1.92	2.59	127	132	165	667	43	148	670	45	151	79	21	29
27	10.0	0.11	0.46	173	285	272	572	136	248	582	136	248	72	17	43
28	10.5	1.05	4.05	43	80	115	169	42	226	180	43	230	104	14	43
29	4.8	0.44	0.32	211	294	533	591	210	209	596	210	209	38	15	11
30	8.0	1.13	0.78	222	228	325	351	135	188	359	136	189	58	48	24
31	7.2	0.27	1.24	32	39	28	128	21	65	135	21	66	93	13	41
32	9.8	0.48	0.85	16	14	27	118	16	30	128	16	31	55	6	14
33	13.0	0.42	0.73	41	42	135	159	51	75	172	52	76	87	14	27
34	10.0	0.46	0.63	104	90	162	176	43	72	186	43	73	70	23	25
35	15.5	3.48	3.37	190	196	161	223	97	69	239	101	73	47	20	16
36	9.3	1.42	1.94	120	132	97	130	76	26	139	77	27	41	29	9
37	6.7	0.19	0.43	9	19	22	44	13	21	51	13	21	48	6	15
38	16.2	2.74	2.41	100	134	124	524	140	84	540	143	86	102	23	14
39	6.3	0.10	3.86	66	108	102	179	51	100	185	51	104	37	12	15
40	22.0	2.65	1.57	59	97	148	199	71	62	221	74	63	55	17	17
41	14.9	0.27	2.24	59	76	118	168	30	55	182	30	58	46	6	17
42	23.5	2.46	0.65	106	110	180	181	42	78	204	45	79	44	7	19
43	6.3	0.52	1.16	85	48	60	76	22	35	83	22	36	43	12	19
44	18.2	0.19	0.81	325	341	411	623	201	288	641	201	289	39	13	23
MEAN	**10.6**	**0.7**	**1.3**	**78**	**93**	**113**	**199**	**54**	**76**	**209**	**55**	**75**	**58**	**15**	**22**

TABLE 4-6

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

PARAMETER	UNITS	SEDIMENT COLLECTION DATE		
		10/8/03	5/3/07	11/13/08
Moisture Content	%	41.4	42.6	43.4
Organic Content	%	7.7	7.7	8.9
Density	g/cm^3	1.86	1.84	1.83
Total Nitrogen	$\mu g/cm^3$	976	1034	851
Total Phosphorus	$\mu g/cm^3$	390	376	361
Available Phosphorus	$\mu g/cm^3$ % of Total Sed. P kg	209 58 21,395	55 15 5448	75 22 7627
Reduction in Available Phosphorus	%	0	74	64

Based on the 2008 monitoring event, available sediment P has increased during the 18 month period between the 2007 and 2008 events. The P reduction achieved by the initial treatment has been reduced from 75% to 64%, and the percentage of sediment P which is potentially available has increased from 15% to 23%. These changes are due to continued accumulation of organic material into the sediments which begins to cover the alum treated sediments. These changes will likely accelerate with time as the new sediment layers become thicker.

4.2 Summary of Previous Alum Sediment Inactivation

The July 2004 ERD report indicated that internal recycling of phosphorus in Lake Holden contributes approximately 265 kg/yr, equivalent to 49.2% of the estimated total annual phosphorus loadings to the lake. Previous stormwater management projects constructed within the Lake Holden watershed have reduced the significance of phosphorus loadings from stormwater runoff, elevating internal recycling to the largest single phosphorus source. A sediment phosphorus inactivation project was recommended for Lake Holden to combine with existing phosphorus within the sediments, forming insoluble inert precipitates which bind the phosphorus and make it unavailable for release into the overlying water column. The 2004 report recommended that approximately 224,050 gallons of alum be applied to Lake Holden for sediment inactivation.

The recommended sediment inactivation project was initiated during April 2005. The recommended alum quantity was divided into three separate applications to minimize pH impacts within the lake. Application of the entire recommended alum volume during one application would have resulted in an undesirable reduction in pH, requiring supplemental pH buffering compounds to be added to the lake, increasing the overall project cost.

A summary of alum applications to Lake Holden is given in Table 4-7. The initial application was conducted from April 4-8, 2005, with a total of 77,794 gallons of alum added over this period. The second alum application was conducted from September 7-22, 2005, with a total of 112,012 gallons of alum added to the lake. The final alum application was conducted from February 22-March 17, 2006, with a total of 94,510 gallons of alum added to the lake.

TABLE 4-7

SUMMARY OF PREVIOUS ALUM APPLICATIONS TO LAKE HOLDEN

APPLICATION #1			APPLICATION #2			APPLICATION #3		
Date	Alum Applied		Date	Alum Applied		Date	Alum Applied	
	Weight (lbs)	Gallons[1]		Weight (lbs)	Gallons[1]		Weight (lbs)	Gallons[1]
4/4/05	48,215	4,332	9/7/05	50,108	4,502	2/22/06	50,194	4,510
	48,099	4,322		50,090	4,500		50,111	4,502
4/5/05	48,091	4,321		50,005	4,493		50,111	4,502
	48,099	4,322	9/8/05	50,101	4,501	2/23/06	50,192	4,510
	48,096	4,321		50,084	4,500		50,098	4,501
	48,094	4,321		50,094	4,501		50,096	4,501
4/6/05	48,105	4,322		50,100	4,501	2/24/06	50,115	4,503
	48,097	4,321	9/9/05	50,107	4,502		50,198	4,510
	48,101	4,322		50,083	4,500		50,204	4,511
	48,101	4,322		50,103	4,502		50,195	4,510
4/7/05	48,092	4,321		50,103	4,502	2/27/06	50,195	4,510
	48,104	4,322	9/12/05	50,104	4,502		50,112	4,502
	48,099	4,322		50,098	4,501		50,192	4,510
	48,092	4,321		50,100	4,501		50,099	4,501
4/8/05	48,072	4,319		50,102	4,502	2/28/06	50,110	4,502
	48,095	4,321	9/13/05	50,102	4,502		50,109	4,509
	48,091	4,321		50,102	4,502		50,189	4,502
	48,099	4,322		50,093	4,501	3/16/06	50,099	4,502
				44,401	3,989		50,108	4,503
			9/21/05	50,103	4,502		50,102	4,503
				50,104	4,502	3/17/06	49,062	4,510
				50,103	4,502			
				50,100	4,501			
			9/22/05	50,099	4,501			
				50,105	4,502			
TOTALS:		**77,794**	**TOTALS:**		**112,012**	**TOTALS:**		**94,510**

1. Based on a density of 11.13 lbs/gallon

A summary of dosage and application rates for the initial sediment inactivation project in Lake Holden is given in Table 4-8. Overall, a total of 284,316 gallons of alum was added to Lake Holden during the three applications. This equates to a total water column dose of 15.9 mg Al/liter, with a mean areal dose of 58.5 g Al/m^2.

TABLE 4-8

SUMMARY OF DOSAGE AND APPLICATION RATES FOR THE INITIAL SEDIMENT INACTIVATION PROJECT

PARAMETER	VALUE			TOTAL
	APPLICATION #1	APPLICATION #2	APPLICATION #3	
Alum Applied (gallons)	77,794	112,012	94,510	284,316
Water Column Dose (mg Al/liter)	4.4	6.3	5.2	15.9
Areal Dose (g Al/m^2)	16.0	23.0	19.5	58.5

4.3 Recommendations for Additional Sediment Inactivation Treatment

Based on the results of the sediment core samples collected in Lake Holden during 2003, 2007, and 2008, an additional alum treatment to Lake Holden is recommended within the next year to sequester new sediment phosphorus accumulations since the initial treatment. Isopleths of total available phosphorus in the top 10 cm of sediments in Lake Holden, based on the November 2008 monitoring event, are illustrated on Figure 4-3. Areas of elevated total available phosphorus are apparent in the northern, central, and western portions of the lake. The isopleths presented on Figure 4-3 can be utilized directly as a guide for future sediment inactivation activities.

Estimates of the mass of total available phosphorus within the top 10 cm of the sediments in Lake Holden were generated by graphically integrating the total available phosphorus isopleths presented on Figure 4-3. Areas contained within each isopleth contour were calculated using AutoCAD Release 12.0. The top 0-10 cm layer of the sediments is considered to be the 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 substantially inactivate sediment release of phosphorus within a lake.

A summary of estimated total available phosphorus in the sediments of Lake Holden, based upon the November 2008 monitoring event, is given in Table 4-9 and estimated chemical requirements are provided for both 5:1 and 10:1 ratios. At this time, ERD recommends that the 5:1 ratio be used for the proposed future sediment inactivation event. At a 5:1 ratio, the alum requirement is approximately 149,786 gallons which is equivalent to approximately 33 tankers (rounded off). Application of this volume of alum will require at least 2 and possibly 3 treatments over a period of 6-12 months. There is increasing research evidence that multiple small applications are more effective than a single large application for sediment inactivation. As a result, it is recommended that a minimum period of approximately 3 months be used to separate the individual applications to allow each application adequate time to migrate into the lake sediments.

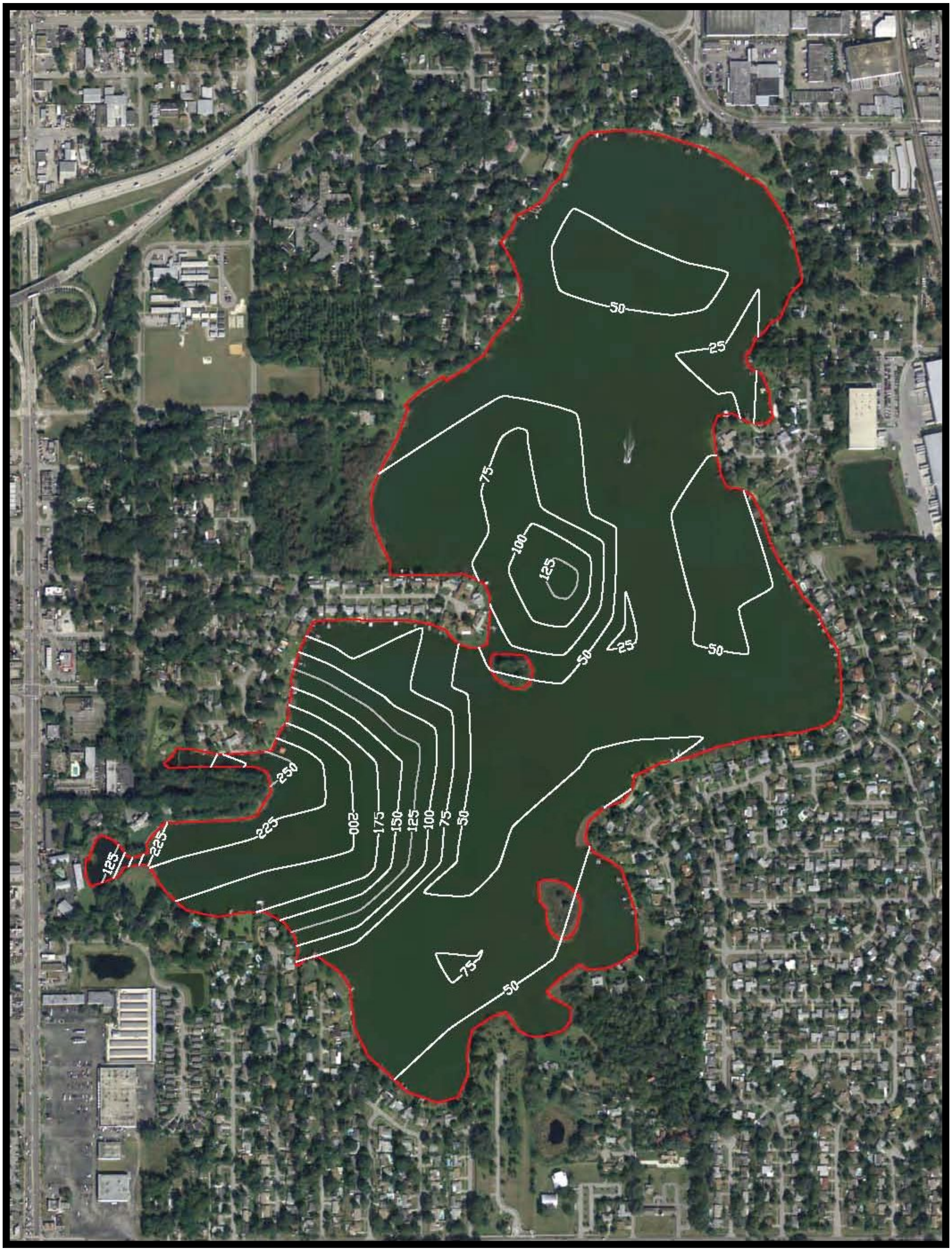


Figure 4-3. Isopleths of Total Available Phosphorus in the 0-10 cm of Sediments in Lake Holden Based on Sediment Core Samples Collected During November 2008.

TABLE 4-9

LAKE HOLDEN SEDIMENT INACTIVATION REQUIREMENTS BASED ON THE NOVEMBER 2008 SEDIMENT MONITORING EVENT

AVAILABLE P CONTOUR INTERVAL (μg/cm^3)	CONTOUR INTERVAL MID-POINT (μg/cm^3)	CONTOUR AREA (acres)	AVAILABLE P		ALUM REQUIREMENTS			
					Al:P Ratio = 5:1		Al:P Ratio = 10:1	
			kg	moles	moles Al	gal Alum	moles Al	gal Alum
<25	12.5	3.70	19	604	3,018	368	6,036	735
25-50	37.5	117.63	1,786	57,615	288,076	35,078	576,153	70,157
50-75	62.5	78.42	1,985	64,016	320,082	38,976	640,163	77,951
75-100	87.5	18.06	640	20,638	103,191	12,565	206,381	25,131
100-125	112.5	10.25	467	15,057	75,286	9,167	150,572	18,335
125-150	137.5	5.96	332	10,706	53,528	6,518	107,055	13,036
150-175	162.5	4.95	326	10,515	52,576	6,402	105,151	12,804
175-200	187.5	8.09	614	19,805	99,024	12,058	198,049	24,116
200-225	212.5	9.05	779	25,119	125,593	15,293	251,186	30,586
225-250	237.5	5.24	504	16,269	81,347	9,905	162,694	19,811
250-275	262.5	0.73	78	2,511	12,557	1,529	25,114	3,058
>275	287.5	0.84	98	3,164	15,822	1,927	31,644	3,853
Overall Totals:		**262.9**	**7,627**	**246,020**	**1,230,100**	**149,786**	**2,460,199**	**299,573**

	Al:P Ratio = 5:1	Al:P Ratio = 10:1
Estimated Chemical Cost @ $0.94/gallon ($):	**$ 140,800**	**$ 281,600**
Areal Aluminum Dose (g Al/m^2)	31.20	62.40
Number of Tankers	33	67
Water Column Aluminum Dose (mg/l)	8.4	16.8
Number of Applications	3	6
Estimated Labor Costs @ $1000/tanker ($)	**$33,000.00**	**$67,000.00**

The current cost for liquid alum under the existing City of Orlando contract is approximately $0.94/gallon. For purposes of cost estimation, it was assumed that the County can purchase the alum through the City of Orlando at this current contract price. Based upon a unit cost of $0.94/gallon, the estimated chemical cost for the proposed alum addition at an Al:P ratio of 5:1 is approximately $140,800. The estimated labor costs for application of the alum is approximately $33,000, excluding mobilization and testing.

SECTION 5

EVALUATION OF EXISTING AND PROPOSED BMPs

This section provides a summary of existing BMPs which have been constructed within the Lake Holden drainage basin as well as additional potential water quality BMPs for selected sub-basin areas. A discussion of existing and proposed BMPs is given in the following sections.

5.1 Existing BMPs

A large number of existing BMPs have been constructed throughout the Lake Holden drainage basin. A summary of existing BMPs constructed in the Lake Holden watershed is given in Table 5-1. The first water quality improvement project for Lake Holden consisted of an aeration system which was installed within the lake during 1983. This aeration project was discontinued after approximately two years due to a lack of water quality improvements.

TABLE 5-1

SUMMARY OF EXISTING BMPs IN THE LAKE HOLDEN WATERSHED

APPROXIMATE YEAR	DESCRIPTION	BMP TYPE	AREA TREATED
1983	Aeration (discontinued 2 years later)	Aeration	In-lake
1988	Westmoreland Pond	Dry Detention	Sub-basin 19 (all)
1997	In-line Alum Injection	Alum Stormwater Treatment	Sub-basins 1, 2, and 21 (all)
1997	FDOT Pond	Dry Detention	Sub-basin 13 (all)
1997	Westmoreland Pond	Wet Retention	Sub-basin 20 (partial)
1997	Weekly Street Sweeping (ongoing)*	Elgin Eagle	Various – See Table 5-2
2000	43rd Street Pond	Wet Retention	Sub-basin 12 (all)
2002	SAV Planting	Plants	In-lake
2005	Holden Terrace CDS	CDS	Sub-basin 2 (all)
2006	Surface Alum Treatment	Liquid Alum	Whole lake
2008	First installation of approximately 60 catch basin inserts	Curb/grate basket inserts	Various
2009	Second installation of approximately 60 additional catch basin inserts	Curb/grate basket inserts	Various

*In the fall of 2008, the weekly sweeping was amended to include additional sweeping twice a week from October 15-December 15 and from February 15-April 15

During 1988, a dry detention facility was constructed along Westmoreland Avenue to provide treatment for stormwater generated within a 15.2-acre portion of Sub-basin 19. The sub-basin area treated by this pond is located primarily north of I-4. This pond contains a side bank filter system which provides sand filtration for runoff prior to discharge through the outfall structure. Although this facility was designed to be a "dry" pond, portions of the pond maintain standing water throughout much of the wet season, and a continuous discharge occurs from the outfall structure virtually year-round. The performance efficiency of this facility was monitored directly by ERD for Orange County based upon field monitoring conducted from August-November 1993. The results of this evaluation are summarized in the report titled "Evaluation of the Stormwater Treatment and Management Program in Orange County" (ERD, 1995).

The first major BMP designed for treatment of stormwater for entire sub-basins was the alum stormwater treatment system which provides treatment for Sub-basins 1 (98.8 ac), 2 (65.7 ac), and 21 (19.4 ac). This system was constructed during 1996 and became operational during 1997. Also during 1997, the FDOT pond (located behind the former Ryan's Steak House) was constructed to provide stormwater treatment for Sub-basin 13 (81.5 ac). This facility consists of a dry detention facility which provides stormwater treatment for runoff along U.S. 441 prior to discharging into the canal located along the southwest side of Lake Holden.

Weekly street sweeping was initiated in various sub-basin areas during 1997 and has continued until the present. A summary of existing street sweeping operations in the Lake Holden watershed is given in Table 5-2. Overall, a total of 7.21 curb miles of roadway are swept on a weekly basis within the Lake Holden watershed. Roadway areas included in this program are indicated on Figure 5-1. Sub-basin areas where sweeping occurs include 4A, 5, 6, 7, 8, 9, 10A, 10B, 11, 17, and 18. During the fall of 2008, the weekly sweeping program was amended to provide for sweeping twice per week during periods of heavy leaf fall which are assumed to occur from October 15-December 15 and from February 15-April 15.

A second stormwater management pond was constructed on Westmoreland Avenue southeast of the intersection with I-4 during 1997. This pond provides wet retention treatment for drainage generated in the vicinity of I-4 and the nursing home facility located east of Westmoreland Avenue.

During 2000, a stormwater management facility was constructed south of 43rd Street to provide stormwater treatment for runoff generated in Sub-basin 12 (26.3 ac). This facility provides wet retention treatment for the commercial shopping area located at the northeast intersection of U.S. 441 and Holden Avenue. Excess runoff from the pond is then discharged into the southwest lobe of Lake Holden.

During 2002, an extensive planting operation was conducted in an attempt to re-establish submerged aquatic vegetation (SAV) in Lake Holden. Both submergent and emergent vegetation were planted in various locations throughout the lake.

During 2005, a CDS unit was installed along the stormsewer line which discharges from Sub-basin 2 (Lake Holden Terrace) into Lake Holden. This unit is designed to collect sediment and roadway litter to prevent direct discharge into the lake. The CDS unit was constructed downstream from the point of injection for the alum stormwater treatment system and has experienced maintenance issues related to accumulation of alum floc on the screening structure within the unit.

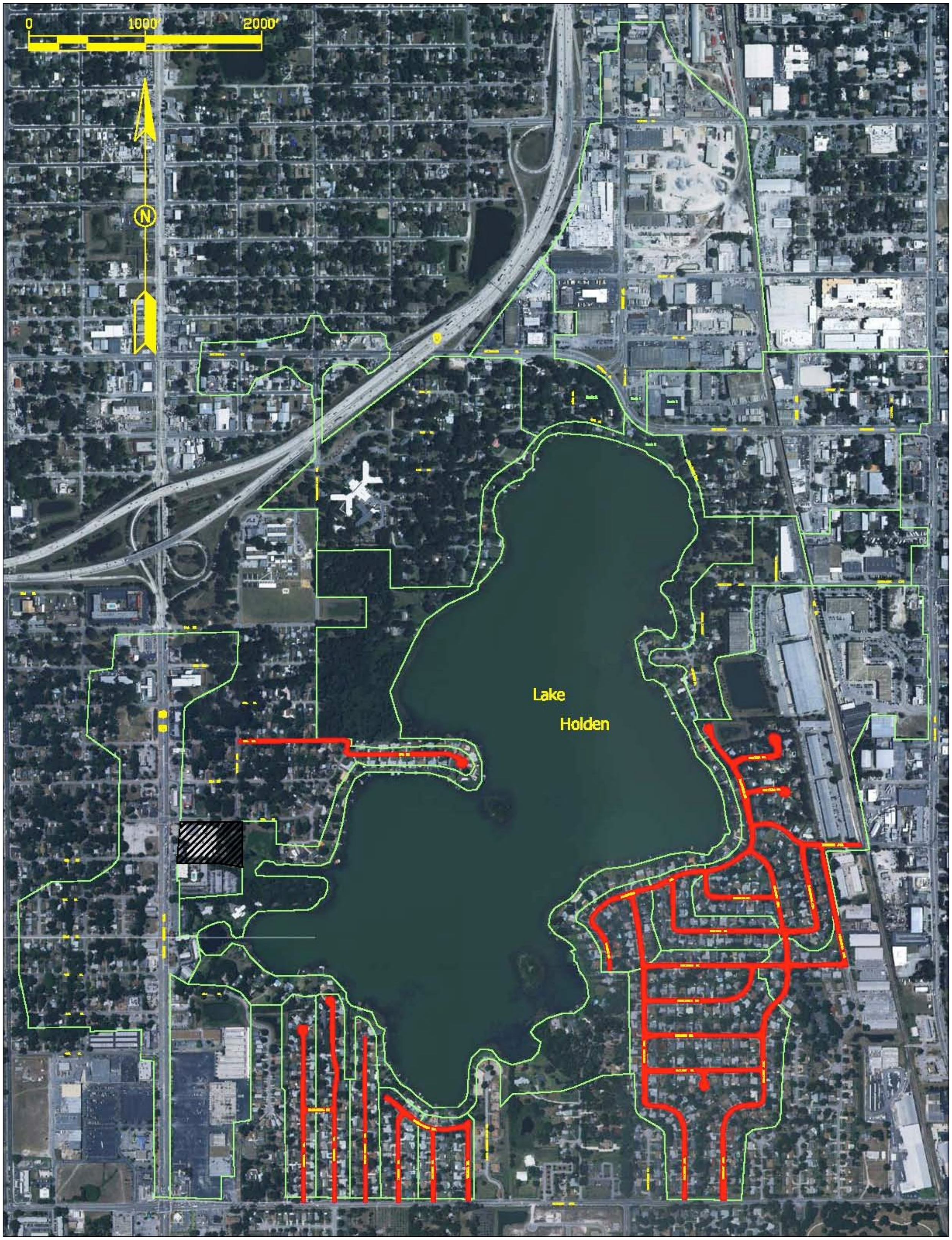


Figure 5-1. Roadway Areas with Current Street Sweeping Activities.

TABLE 5-2

SUMMARY OF EXISTING STREET SWEEPING OPERATIONS IN THE LAKE HOLDEN WATERSHED

ITEM	STREET	FROM / TO	CURB MILES	SWEPT SUB-BASIN
1	37th Street	East of Woods Ave.	0.43	17 and 18
2	Almark Drive	Total	0.57	11
3	Bainbridge Avenue	Total	0.14	4A
4	Benton Street	Total	0.23	5
5	Bradley Avenue	Total	0.64	7
6	Brandeis Avenue	Total	0.54	7
7	Cassandra Street	Total	0.09	10A and 11
8	Cattail Court	Total	0.11	4A
9	DeKalb Drive	Total	0.09	6
10	Doolittle Street	Total	0.21	7
11	Drennen Road	West of RR tracks	0.20	4A
12	Forrestal Avenue	North of Krueger	0.20	4A
13	Halsey Court	Total	0.03	7
14	Halsey Street	Total	0.19	7
15	Kingsley Avenue	Total	0.04	4A
16	Krueger Street	Total	0.33	7
17	MacArthur Drive	Total	0.51	4A, 5, 6
18	Matilda Court	Total	0.07	4A
19	Milford Avenue	Total	0.08	5
20	Raymar Drive	Total	0.68	10A
21	Redfern Drive	Total	0.21	8
22	South Shore Drive	Total	0.53	10B
23	Spencer Street	Total	0.11	4A
24	Springwood Drive	Total	0.30	8 and 9
25	Stimson Street	Total	0.19	7
26	Telfair Drive	Total	0.20	8
27	Tinsley Drive	Total	0.28	9
		TOTAL CURB MILES (ONE SIDE):	**7.21**	

During 2006, the alum surface treatments to Lake Holden were initiated by ERD. These treatments have been discussed in detail in Section 4. The objective of these treatments is to inactivate existing phosphorus accumulations within the sediments of the lake to reduce the significance of internal recycling as a nutrient source.

Installation of catch basin inserts was initiated within the Lake Holden watershed during 2008, with approximately 60 catch basin inserts installed initially. The catch basin inserts are designed to trap and collect leaves, vegetation debris, and general litter, preventing it from discharging into the lake. Previous research by ERD has shown that vegetation can release large quantities of nutrients rapidly upon entering a waterbody, and the catch basin inserts are designed to collect this vegetation before it enters the lake. An additional 60 catch basin inserts were installed within the Lake Holden watershed during 2009. Maintenance for the catch basin inserts is coordinated by Orange County, with removal of debris from the catch basins occurring on approximately a monthly basis.

The magnitude of the water quality improvement projects constructed within the Lake Holden watershed is unprecedented in the Central Florida area and perhaps within the entire State. Significant nutrient load reduction projects have been constructed in virtually every sub-basin area which discharges into Lake Holden, and there is no doubt that the implemented projects have substantially reduced pollutant loadings to the lake. As discussed in Section 3, the water quality benefits of these projects can be clearly seen both visually as well as in the chemical characteristics of the lake.

5.2 <u>Additional Potential Water Quality BMPs</u>

An evaluation was conducted by ERD to identify areas where additional BMPs or enhanced maintenance activities may be possible to further reduce nutrient loadings into Lake Holden. Detailed field evaluations were conducted under both dry and storm event conditions for five significant sub-basin areas discharging into the lake, including Sub-basins 1, 2, 7, 20, and 21. A delineation of drainage sub-basin areas discharging to Lake Holden is given in Figure 5-2 for reference purposes. A discussion of the results of these evaluations is given in the following sections.

5.2.1 <u>Sub-basin 1</u>

As indicated on Figure 5-2, Sub-basin 1 consists of the 98.8-acre commercial/industrial area located north of Lake Holden which centers along Division Avenue. Drainage generated within this basin is currently treated by the existing alum stormwater treatment facility. However, based upon the runoff and baseflow monitoring conducted by ERD as part of this project, phosphorus concentrations discharging from this sub-basin continue to be highly variable, and sometimes elevated, even following alum treatment. This sub-basin also maintains a relatively constant dry weather baseflow which is independent of rain events within the basin. As a result, a field evaluation was conducted by ERD to identify additional opportunities for reduction of pollutant loadings within this sub-basin. This evaluation was conducted under both dry and wet weather conditions to identify potential sources. A total of 10 separate areas were identified which are thought to be chronic contributors to nutrient and sediment loadings discharging into Lake Holden from Sub-basin 1. An overview of the identified areas is given on Figure 5-3, with a tabular summary provided in Table 5-3. Nine of the 10 areas are thought to be significant contributors of sediment loadings and associated nutrient concentrations, and one parcel was identified as a potential source of oil and grease.

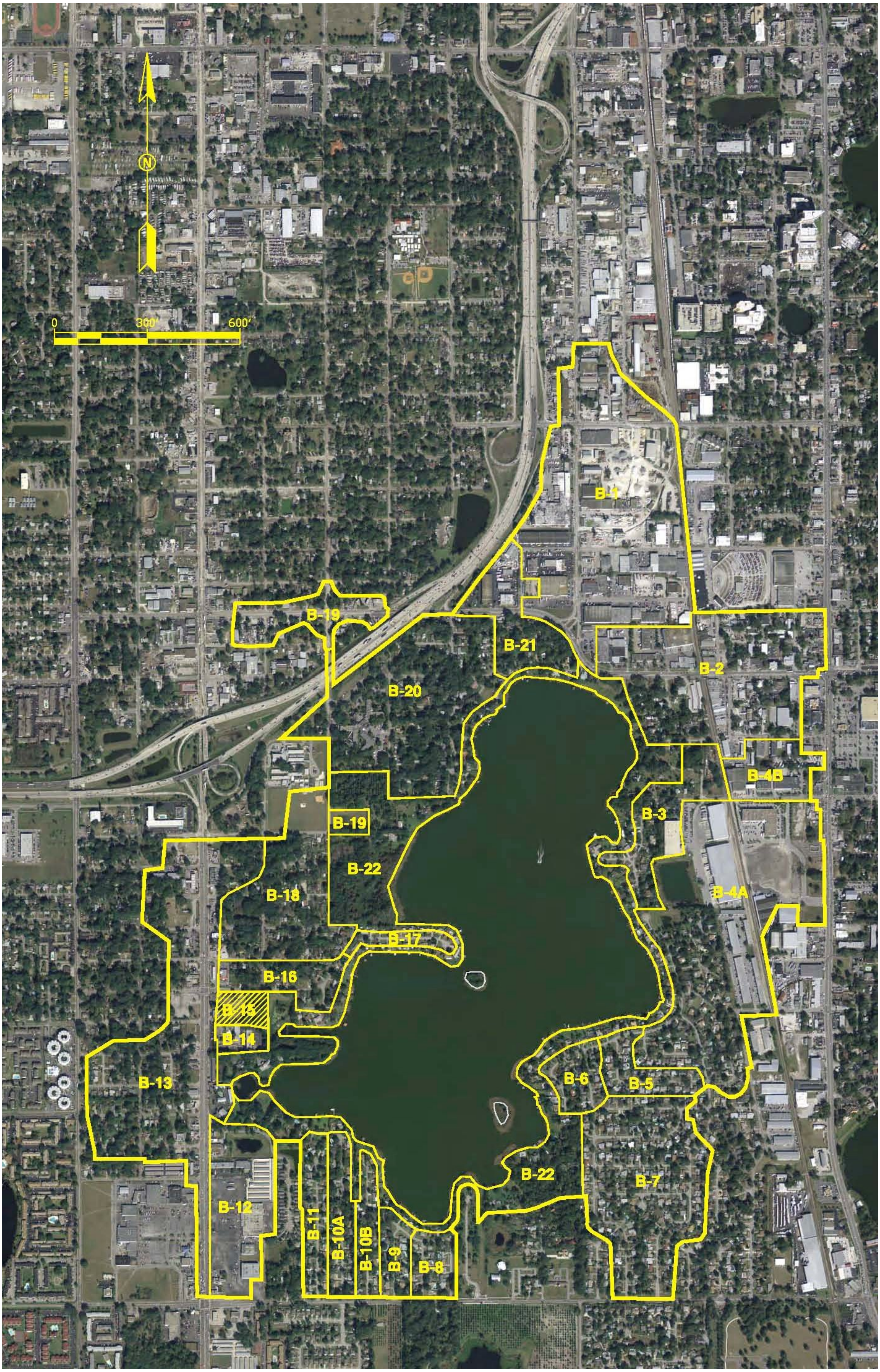


Figure 5-2. Drainage Sub-basin Areas Discharging to Lake Holden.

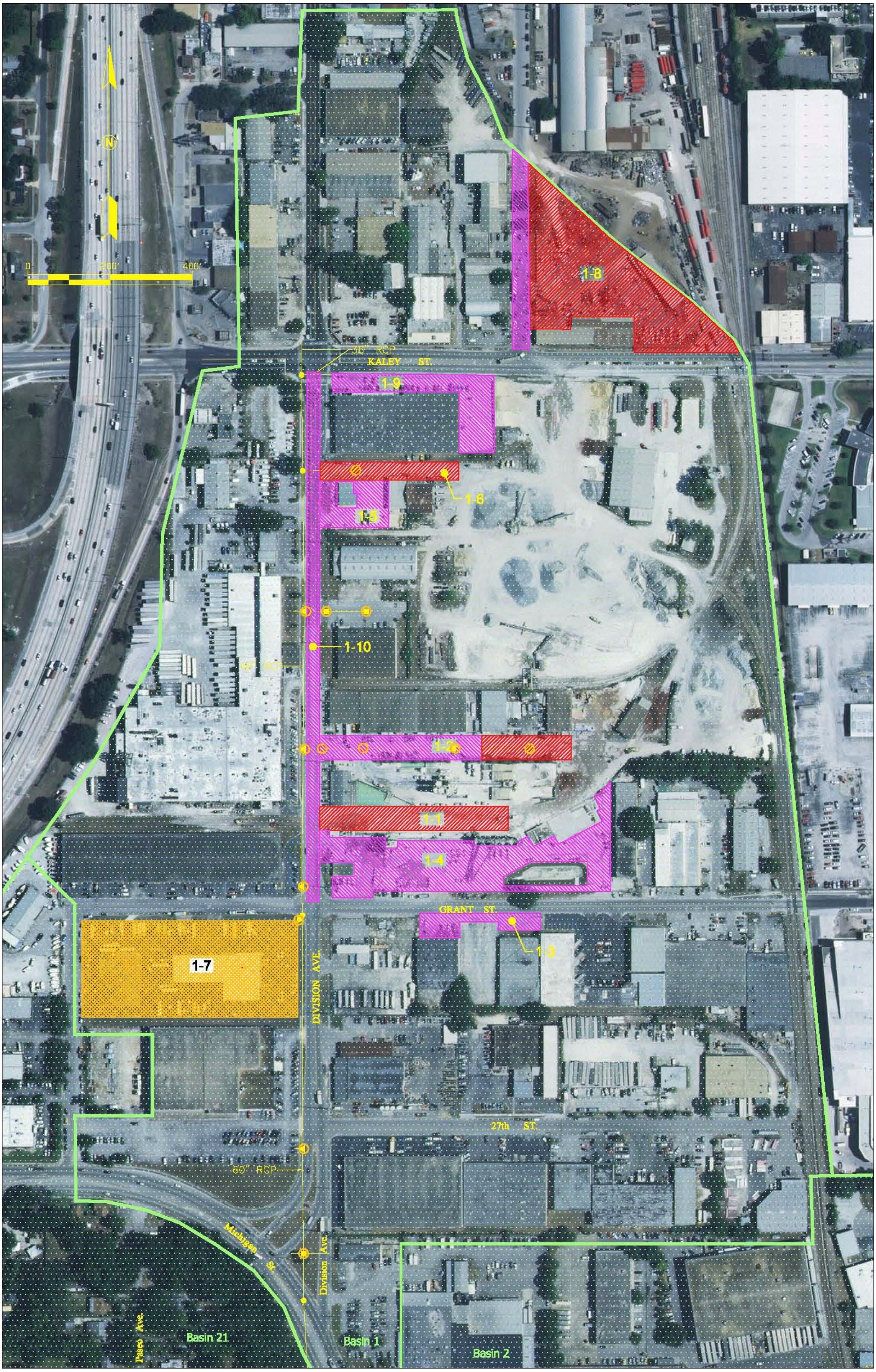


Figure 5-3. Overview of Potential Sediment/Nutrient Sources in Sub-basin 1.

TABLE 5-3

POTENTIAL NUTRIENT / POLLUTANT SOURCES IN SUB-BASIN 1

I.D. NUMBER	NAME	PROBLEM
1-1	Road between Cemex and Preferred Materials	Sediment wash-off
1-2	Warehouse Street	Sediment wash-off
1-3	Miscellaneous businesses along Grant Street	Sediment wash-off
1-4	Cemex	Sediment wash-off
1-5	Bison Supply	Sediment wash-off
1-6	Entrance road to Conrad Irrigation Dist., Inc.	Sediment wash-off
1-7	Trucks – Maudlin International	Oil and grease source
1-8	Trademark Metals Recycling, LLC	Sediment wash-off
1-9	Great Western Meats	Sediment wash-off
1-10	Division Avenue	Sediment wash-off

5.2.1.1 Area 1-1

Photographs of existing conditions and sediment wash-off during storm events in Area 1-1 are given on Figure 5-4. This area consists of a limerock stabilized service road which is part of the Cemex facility and is utilized extensively on a daily basis. During rain events, wash-off from the roadway, which is often milky in appearance with a high turbidity and suspended solids loading, discharges in an east-to-west direction, ultimately entering the Division Avenue drainage system. This roadway area should be either stabilized with asphalt, regraded to drain away from Division Avenue, or replaced with a non-calcareous gravel material.

Figure 5-4. Photographs of Existing Conditions of Sediment Wash-off During Storm Events in Area 1-1.

5.2.1.2 Area 1-2

Area 1-2 is a non-paved roadway area, located north of Area 1-1, which is used to service multiple warehouses and commercial and trucking activities. As indicated on Figure 5-3, this area contains an existing stormwater conveyance system with multiple inlets that collect and transport runoff directly into the Division Avenue system. Photographs of this area under existing conditions and during storm events are given on Figure 5-5. Transport of turbid water occurs within this area during virtually all storm events with sufficient rainfall to generate stormwater runoff, creating sediment and nutrient loadings into Lake Holden. In addition, the frequent traffic from this area onto Division Avenue also transports sediment material directly onto the Division Avenue roadway.

Elimination of the existing sediment transport could be achieved by either paving the surface to eliminate existing turbid runoff or replacement with a non-calcareous gravel material. Ideally, runoff generated within this area should be rerouted or stormwater treatment for this area should be provided within the basin. Sufficient room appears to exist in many portions of this area for construction of a roadside retention system to retain much of the generated runoff on-site.

Figure 5-5. Photographs of Existing Conditions and Sediment Wash-Off During Storm Events in Area 1-2.

5.2.1.3 <u>Area 1-3</u>

A photograph of existing conditions in Area 1-3, located on the south side of Grant Street, is given on Figure 5-6. The impervious areas on this site have accumulated a large amount of dirt, sediment, and debris which is susceptible to runoff during storm events. The land use activities within this area do not appear to have a high potential for generation of suspended solids, suggesting that the deposition of sediments within this area may originate from Grant Street, with roadway sediments transported onto the adjacent parcel by roadway activity. The current sediment problem on this parcel may be eliminated with better control of sediments along Grant Street and the Cemex property.

Figure 5-6.

Photograph of Existing Conditions in Area 1-3.

5.2.1.4 **Area 1-4**

Area 1-4 consists primarily of the Cemex concrete facility located at the northeast intersection of Division Avenue and Grant Street. Photographs of existing conditions in Area 1-4 are given on Figure 5-7. This facility has taken measures in recent years to reduce off-site sediment discharge, and a wet detention pond has been constructed to contain portions of the runoff generated within the site. However, the constant movement of vehicles into and out of the property creates a constant deposition of sediments onto the Grant Street roadway. Accumulations of suspended solids are clearly visible in the photographs given on Figure 5-7. This material becomes mobilized with rain events and is transported directly into Lake Holden. Since the solid material accumulates within the roadway areas, the best method for reducing these inputs may be simply to initiate street sweeping within this area on a routine basis.

Figure 5-7. Photographs of Existing Conditions in Area 1-4.

5.2.1.5 **Area 1-5**

Area 1-5 is located on the east side of Division Avenue, approximately one block south of Kaley Street. This area contains an industrial or commercial business with frequent truck traffic into and out of the property. Movement of the vehicles into and out of the property creates a continuous deposition of solid material onto Division Avenue. Under rain event conditions, particularly when truck traffic occurs during the storm event, turbidity and suspended solids leave the property and enter the stormsewer system for Division Avenue. There appear to be several areas within the property, as well as within the right-of-way, which could be used for storage of stormwater runoff from this site. If storage of runoff is not possible, then either paving of the impervious surfaces or replacement with a non-calcareous rock media should be considered. Photographs of existing conditions in Area 1-5 are illustrated on Figure 5-8.

Figure 5-8. Photographs of Existing Conditions and Sediment Wash-off During Storm Events in Area 1-5.

5.2.1.6 **Area 1-6**

Area 1-6 is located north of Area 1-5 and consists of an access roadway into the large industrial and rock storage area adjacent to the CSX railroad. Frequent traffic along this corridor brings suspended material onto Division Avenue which is clearly visible during dry conditions. During rain events, substantial amounts of sediment and turbidity discharge from the site into the Division Avenue stormsewer system. Several options appear to be available for this area, including construction of swales along the sides of the roadway to capture water before it discharges into Division Avenue, as well as collection and diversion of the stormwater into other areas of the property. Photographs of existing conditions and sediment wash-off during storm events are given on Figure 5-9.

Figure 5-9. Photographs of Existing Conditions and Sediment Wash-off During Storm Events in Area 1-6.

5.2.1.7 <u>Area 1-7</u>

Area 1-7 is located at the southwest corner of Division Avenue and Grant Street. This area consists primarily of a repair facility for trucks and other vehicles. Photographs of existing conditions within this area are given on Figure 5-10. Virtually all of this parcel is currently paved and does not appear to be a significant contributor of either sediments or turbidity. However, this area does contribute visible loadings of oil and grease during storm events, as evidenced by the visible oily sheen in the runoff and the substantial staining of the concrete swale which discharges from the site. Runoff which is discharged from the site enters the Division Avenue stormsewer system. Potential sources of oil and grease within the property should be evaluated and eliminated to the extent practicable. In addition, an inlet insert with oil and grease scrubbers should be inserted inside the inlet where the runoff from the site enters the Division Avenue stormsewer system.

Figure 5-10. Photographs of Existing Conditions and Oil and Grease Wash-off During Storm Events in Area 1-7.

5.2.1.8 <u>Area 1-8</u>

Area 1-8 is located within the scrap metal recycling facility on the north side of Kaley Street. This facility has frequent truck traffic which transports soil and sediments onto the adjacent roadway surfaces. Photographs of existing conditions in Area 1-8 are indicated on Figure 5-11 where accumulated sediments are clearly visible along the adjacent roadway area. Based upon aerial photographs, much of the land inside this area appears to consist of pervious areas which are responsible for the generation of soils and sediments.

Several opportunities are available to reduce sediment loadings from this area. First, exits from the property could be retrofitted with erosion control devices similar to those used for construction sites. These erosion control devices consist of either a gravel roadway or similar type device to remove soils from the vehicle tires before exiting the site. In addition, roadway areas adjacent to the site should be swept on a routine basis to remove accumulated materials.

Figure 5-11. Photographs of Existing Conditions in Area 1-8.

5.2.1.9 <u>Area 1-9</u>

Area 1-9 is located near the southeast intersection of Kaley Street and Division Avenue. This area consists primarily of parking lots associated with the adjacent commercial and industrial activities. Photographs of existing conditions in Area 1-9 are given on Figure 5-12. Accumulations of soils and sediments are clearly visible in these photographs, including soils which have migrated from the site and filled the adjacent roadway gutter. The existing parking lot areas do not appear to be significant contributors themselves of sediments and soils, suggesting that the observed conditions originate from adjacent parcels. Sources for the soils and sediments should be evaluated, and if possible, retrofit opportunities should be taken to reduce these loadings. If nothing else can be done, the situation can be corrected fairly easily with routine street sweeping operations.

Figure 5-12. Photographs of Existing Conditions in Area 1-9.

5.2.1.10 <u>Area 1-10</u>

Area 1-10 consists of Division Avenue itself. Accumulations of sediment and soils are visible in virtually all portions of the roadway and gutter systems along the entire extent of the road between Kaley Street and Grant Street. In areas where curbs do not exist, soils from the adjacent land surfaces can be seen washing into the roadway areas. It is likely that much of the sediment material along the roadway originates within the adjacent parcels, many of which have been addressed in the previous discussions. However, the easiest and least expensive method of removing sediments from the roadway appears to be initiation of frequent street sweeping operations. Areas without curbs would have to be swept using a vacuum sweeper since mechanical brush sweepers require a hard curb for proper operation. Photographs of existing conditions in Area 1-10 are given on Figure 5-13.

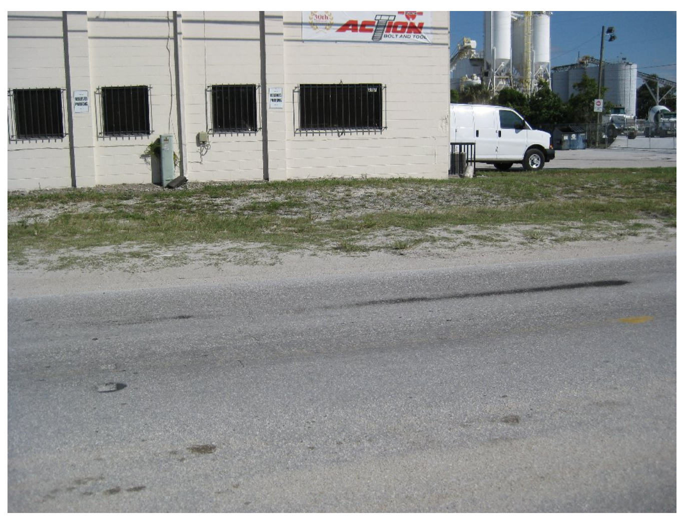


Figure 5-13.

Photographs of Existing Conditions in Area 1-10.

A number of potential sources for sediments and turbidity, along with oil and grease, have been identified within Sub-basin 1. Many of these parcels are located on private property, which complicates the ability of either the City or County to effect reductions in pollutant loadings. However, many publicly owned portions of the watershed have existing accumulations of soils and sediments which could be easily removed through a routine street sweeping operation. Therefore, it is recommended that, at a minimum, roadway areas within Sub-basin 1 be placed on a weekly sweeping schedule, with the remainder of the sub-basin areas.

5.2.1.11 General Litter/Debris

Although not identified with any particular source or location within Sub-basin 1, discharge of general debris and litter is common within the Division Avenue stormsewer system. Downstream portions of the stormsewer system are extremely deep and exhibit surcharged conditions throughout much of the year, particularly in areas south of Michigan Street. Under the surcharged conditions, the floating litter accumulates in the throat of manhole structures associated with the stormsewer system. One of these stormsewer structures is located adjacent to the alum stormwater treatment pumping facility and is used as the point of injection for the alum into the stormwater flow. The point of alum addition is located above the flow line of the stormsewer under surcharged conditions, and the alum addition is frequently intercepted by the floating debris within the manhole. Under these conditions, the alum is injected onto the top of the floating debris rather than into the stormsewer flow, creating conditions of improper dosage for stormwater treatment.

Several potential solutions exist to eliminate the interferences caused by the floating debris within the manhole riser. A relatively simple solution would be to lower the point of injection into the stormwater flow rather than dripping into the flow from above as occurs under current conditions. However, this is a very undesirable solution since the actual alum addition cannot be observed, measured, and verified if the point of discharge is submerged. The point of alum addition could also be moved upstream in the stormsewer to a location where submerged conditions would not occur. This could be achieved relatively simply by re-routing the alum feed line through the stormsewer pipe to the desired location.

A second solution for the floating debris would be to install basket inserts into each of the inlet and grate structures within Sub-basin 1. Although these inserts would do little to correct the existing issues with turbidity or suspended sediments, they would be effective in trapping floating litter, vegetation, and other large debris. Inserts and baskets are already a significant component of pollution control measures within the Lake Holden watershed, and extension of the inlet baskets and inserts into this area seems like a logical progression.

ERD identified a minimum of 14 drainage inlets within the Division Avenue stormsewer system during this project. According to OCEPD, the current cost for installation of a curb/grate inlet basket is approximately $1200 per site. If each of the 14 inlets were to be retrofitted, the installation cost would be approximately $16,800. OCEPD currently pays a subcontractor a flat rate of $18.50/ month for monthly cleaning of inlet baskets. Based upon this figure, annual maintenance fees for cleaning of the proposed inlet baskets would be approximately $3108/year.

5.2.2 Sub-basin 2

An overview of potential sediment/nutrient sources identified in Sub-basin 2 is given on Figure 5-14, with a tabular summary provided in Table 5-4. Sub-basin 2 is a 65.7-acre area located southeast of Sub-basin 1 and is centered primarily along Michigan Street. The vast majority of this sub-basin consists of industrial and commercial activities, with a small number of single-family residential units. The primary stormsewer system for this sub-basin is located beneath Michigan Street and diverts into Lake Holden along Lake Holden Terrace. This sub-basin is also commonly referred to as the Lake Holden Terrace sub-basin.

TABLE 5-4

POTENTIAL NUTRIENT / POLLUTANT SOURCES IN SUB-BASIN 2

I.D. NUMBER	NAME	PROBLEM
2-1	Industrial/commercial facility on Joseph Street	Sediment wash-off
2-2	Lake Holden Terrace Road	Sediment wash-off
2-3	Truck/auto repair shops north of Michigan Street	Oil and grease source

Three separate areas were identified in Sub-basin 2 with a significant potential for generation of soils, sediments, or oils and grease. A discussion of these areas is given in the following sections.

5.2.2.1 Area 2-1

Area 2-1 is located south of Michigan Street on the east side of Joseph Street near the intersection with West Illiana Street. This area is an industrial/commercial facility with frequent traffic from large trucks. The parking and driveway areas for this facility are constructed primarily of dirt and gravel which are subject to erosion during storm events. A photograph of potential erosion issues in this area is given on Figure 5-15. The parking and driveway area contains a stormwater inlet which receives inputs of sediment and soils during significant storm events.

Several options exist for elimination of the sediment loading issues associated with Area 2-1. One possible alternative would be to pave the existing gravel and dirt areas to eliminate the current erosion potential. A second alternative would be to cover the exposed earth areas with a non-calcareous rock material which would also reduce erosion potential. A third option for this area is to regrade the parking and driveway areas and direct the drainage into a perimeter swale system to provide retention prior to discharge from the site.

5.2.2.2 Area 2-2

Area 2-2 consists of the Lake Holden Terrace roadway. Many portions of this roadway are in disrepair, and some areas are subject to erosion during storm events. Photographs of potential erosion and sediment transport on Lake Holden Terrace are given on Figure 5-16. Most portions of this roadway slope directly toward Lake Holden, with the generated runoff discharging onto grassed areas adjacent to the roadway. As a result, only a relatively small portion of the generated runoff volume actually enters the stormsewer system associated with Sub-basin 2. For this reason, this area is a less significant contributor of sediments and nutrient loadings to Lake Holden than areas previously discussed along Division Avenue. The existing erosion problems within this basin could be solved relatively easily by paving the existing roadway and providing a shallow swale system on the downstream side of the road for collection of stormwater runoff.

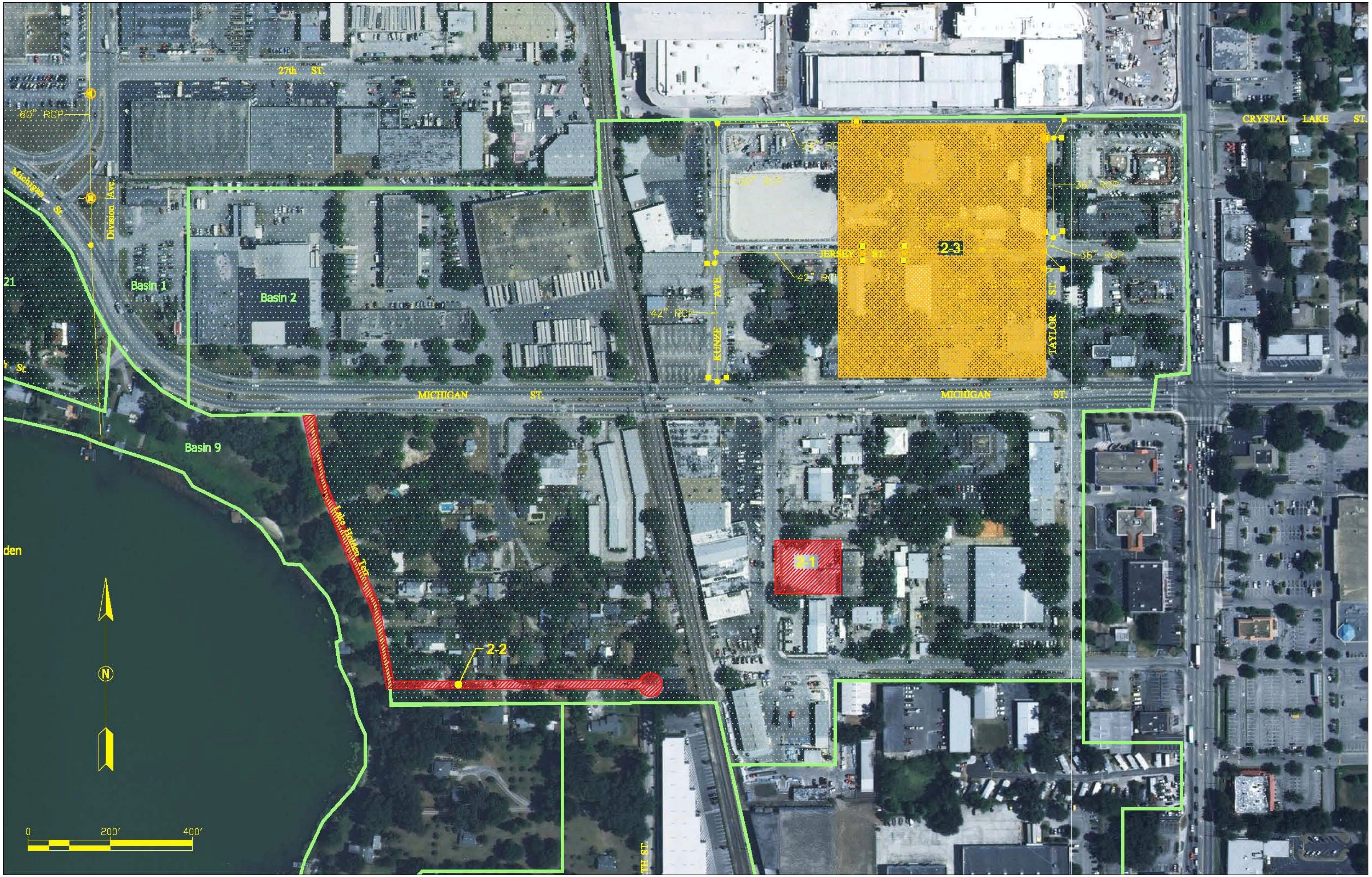


Figure 5-14. Overview of Potential Sediment/Nutrient Sources in Sub-basin 2.

Figure 5-15.

Photograph of Potential
Erosion Issues in Area 2-1.

Figure 5-16.

Photographs of Existing Conditions
and Sediment Sources in Area 2-2.

5.2.2.3 Area 2-3

Area 2-3 is located north of Michigan Street between the CSX Railroad and Orange Avenue. Activities within this basin consist primarily of industrial and commercial activities, with the largest single usage devoted to auto and truck repair. As a result, this area represents a potential source of oil and grease into the stormsewer system. A photograph of a typical business activity within this area is given on Figure 5-17. Visible oil sheen was observed discharging from this and other similar areas by ERD personnel during storm events.

There appear to be two primarily options available to address the oil and grease contributions from Area 2-3. First, a source identification and elimination program should be conducted to identify potential sources and direct remedial activities by the property owners. A second alternative would be to install curb/grate inlet structures within this area which contain oil and grease absorbent media. These devices could be installed inside each of the primary inlets and grates within the area to remove the oil and grease prior to discharge into Lake Holden.

Figure 5-17.

Photograph of Potential Oil and Grease Sources in Area 2-3.

5.2.3 Sub-basin 21

Sub-basin 21 is a 19.4-acre area located west of Sub-basin 1 and centered along Michigan Street. An overview of Sub-basin 21 is given on Figure 5-18. This sub-basin contains a mixture of industrial/commercial activities in northern portions of the sub-basin, with residential land use in southern portions of the sub-basin. The stormsewer system discharging from this sub-basin is treated by the existing alum stormwater treatment facility. However, highly variable concentrations of phosphorus, alkalinity, and suspended solids have been observed in discharges from this sub-basin which, at times, exceed the capacity of the alum treatment system for removal of runoff constituents.

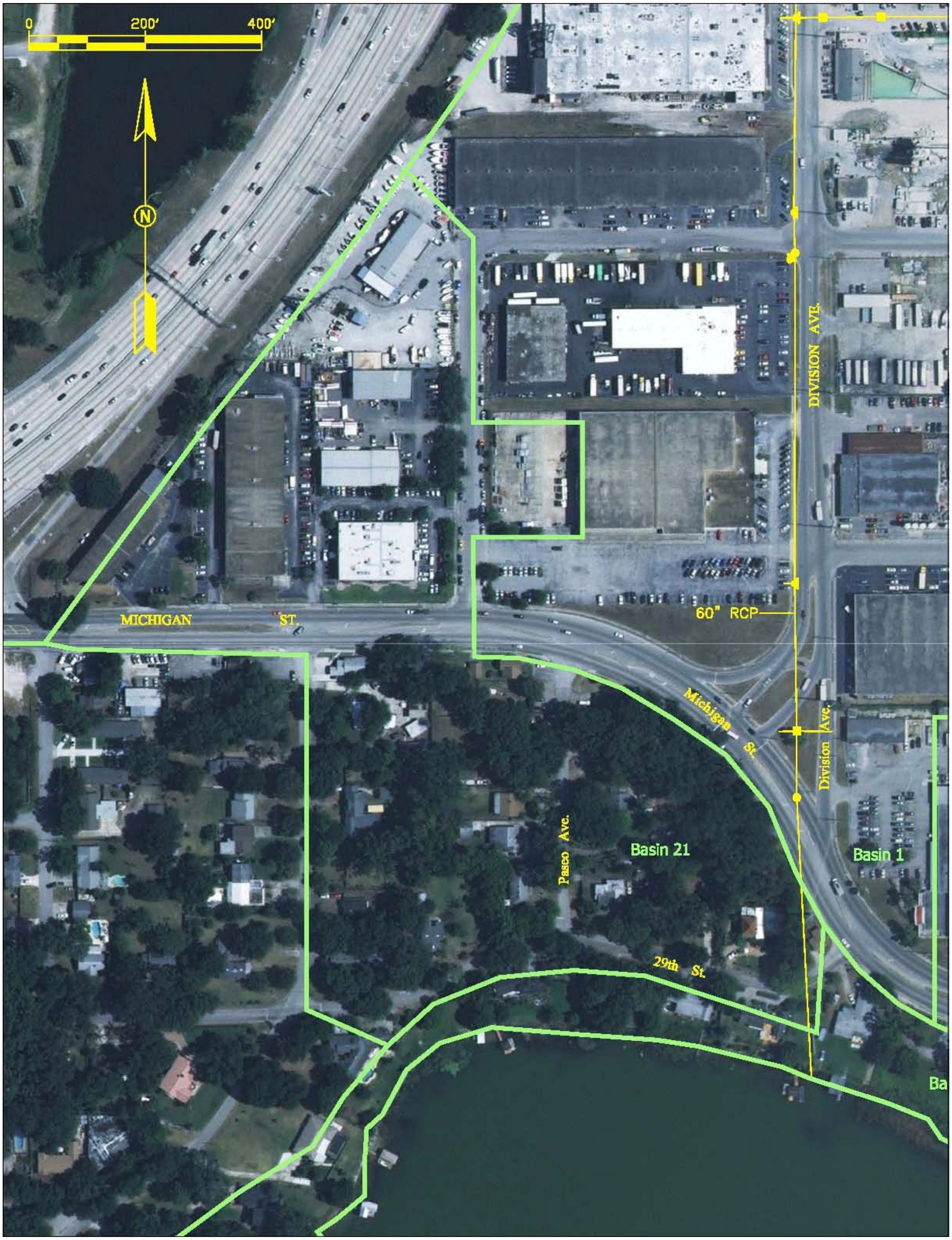


Figure 5-18. Overview of Sub-basin 21.

No obvious sources of elevated sediment or nutrient inputs were observed by ERD in Sub-basin 21 during this project. Virtually all of the existing commercial/industrial activities within this basin have existing stormwater management facilities, with the exceptions of the boat sales and repair facilities located in northern portions of the sub-basin and the parking area associated with Greybar. As a result, no recommendations are provided at this time for additional management activities within Sub-basin 21. This basin may warrant further investigation if elevated nutrient loadings continue to be observed in the Sub-basin 21 stormsewer system.

5.2.4 Sub-basin 20

An overview of Sub-basin 20 is given on Figure 5-19. Sub-basin 20 is a 60.9-acre area bordered on the west by I-4, on the north by Michigan Street, and on the east by Lake Holden. This basin consists primarily of residential homes with the exception of the extended care nursing facility located in the southwest portion of the sub-basin. This sub-basin contains a large number of mature trees which contribute significant leaf fall and litter during certain times of the year.

Over the past several years, a number of inlet/grate baskets have been installed within this sub-basin to collect leaf material before it becomes deposited in Lake Holden. Locations of inlet/grate baskets identified by ERD during this project are indicated on Figure 5-19. These baskets are cleaned on a monthly basis by a subcontractor.

Although the installed inlet/grate baskets provide significant removal for leaves and other vegetation debris, the baskets provide no treatment for soluble nutrients. The previous report prepared by ERD during October 2008 for the existing Lake Holden alum stormwater treatment system, provided in Appendix A of this document, recommends expansion of the existing alum treatment system to provide treatment for Sub-basin 20. The recommended modification includes the addition of a new alum pump in the existing pumping facility and installation of approximately 2500 ft of 1-inch diameter double-wall HDPE pipe between the alum pump building and the 24-inch RCP which traverses the south side of 33rd Street. The proposed route for the new alum discharge line is depicted on Figure 2-6 of the October 2008 document. The estimated cost for expansion of the existing alum treatment facility to the stormsewer system associated with Sub-basin 20 is approximately $77,295, as outlined in Table 2-8 of the 2008 report.

A summary of calculated present worth costs for the proposed alum treatment system expansion to Sub-basin 20 is given in Table 5-5. The construction cost for the system is assumed to be $77,295. According to the revised hydrologic/nutrient budget developed for Lake Holden by ERD during July 2004, Sub-basin 20 contributes an annual runoff volume of approximately 64.0 ac-ft to Lake Holden. Alum treatment of this inflow at the current dosing rate of 7.5 mg Al/liter will require approximately 2700 gallons of alum each year. At an assumed alum cost of $0.90/gallon, the annual chemical cost will be approximately $2400. The present worth cost for the project is calculated over a 20-year period by adding the initial construction cost to 20 years of annual chemical costs, which results in a 20-year present worth cost estimate of approximately $125,295.

Figure 5-19. Overview of Sub-basin 20.

TABLE 5-5

CALCULATED PRESENT WORTH COSTS FOR THE PROPOSED ALUM TREATMENT SYSTEM EXPANSION FOR SUB-BASIN 20

ITEM	COST ($)
Construction Cost	77,295
Annual Chemical Cost	2,400
Present Worth (20-year)	125,295

A summary of estimated pollutant removal costs for the proposed Sub-basin 20 alum system expansion is given in Table 5-6. According to the July 2004 ERD report, Sub-basin 20 contributes approximately 13.9 kg/yr of total phosphorus to Lake Holden. For purposes of this analysis, it is assumed that the proposed alum treatment system expansion will remove approximately 80% of the annual phosphorus load from this sub-basin, with an estimated removal of 11.1 kg phosphorus per year. The pollutant removal cost is calculated by dividing the 20-year present worth cost by 20 years of estimated annual phosphorus removal. This calculation results in an estimated phosphorus removal cost of approximately $564/kg over a 20-year cycle. This value is similar to phosphorus removal costs commonly observed for alum treatment systems and is substantially lower than phosphorus removal costs associated with wet or dry pond systems.

TABLE 5-6

CALCULATED POLLUTANT REMOVAL COSTS FOR THE PROPOSED SUB-BASIN 20 ALUM SYSTEM EXPANSION

PARAMETER	VALUE
Annual Phosphorus Load	13.9 kg/yr
Assumed Phosphorus Removal	80%
Annual Phosphorus Removal	11.1 kg
Phosphorous Removal Cost (20-year)	$ 564/kg

Based upon the favorable economic analysis, ERD recommends that the existing alum treatment system be expanded to include Sub-basin 20. Sufficient room is available within the existing alum pumping facility to easily accommodate this proposed expansion. ERD has discussed the permitting implications of this expansion with the St. Johns River Water Management District (SJRWMD) which permitted the original alum treatment facility, and SJRWMD indicated that the system expansion could be easily permitted through a simple permit modification.

5.2.5 Sub-basin 7

Sub-basin 7 is a 52.9-acre area located on the southeast side of Lake Holden which is often referred to as Medallion Estates. The basin area consists of a built-out residential community which was constructed prior to implementation of requirements for stormwater treatment. According to the 2004 revised hydrologic/nutrient budget report, Sub-basin 7 contributes 11.1 kg phosphorus per year to Lake Holden, approximately 6% of the total runoff generated loadings.

An overview of Sub-basin 7 is given on Figure 5-20. The sub-basin area is densely populated with residential units, and no significant land area exists for above-ground BMPs. High groundwater elevations in the general area also make underground exfiltration impractical. Over the past several years, a number of inlet/grate baskets have been installed within this sub-basin to catch leaves, vegetation, and other litter prior to discharge into Lake Holden. Locations of inlet/grate baskets observed by ERD during this project are also indicated on Figure 5-20. Roadways within this sub-basin are also part of the weekly street sweeping operation within the Lake Holden drainage basin.

In view of the densely developed characteristics of Sub-basin 7, and the lack of available land for construction of BMPs, there appears to be no cost-effective opportunities for removal of nutrient loadings from this sub-basin other than the existing grate/inlet baskets and street sweeping program. However, these two programs are likely to have a measurable impact on water quality characteristics generated from this sub-basin area. No further retrofit opportunities appear to exist within Sub-basin 7 at this time.

5.3 Recommendations

A summary of recommended water quality improvement projects in the Lake Holden drainage basin is given on Table 5-7 based upon the discussions provided in previous sections. Each of the recommended water quality improvement projects is relatively inexpensive and could be accomplished in a relatively quick time frame. However, some of the proposed recommended activities are located on private property which will require discussions and negotiations with the existing land owners. This adds a layer of uncertainty to the process and is the reason why multiple recommendations are provided for most problem areas to achieve the same goal of reducing sediment and nutrient loadings.

Figure 5-20. Overview of Sub-basin 7

TABLE 5-7

SUMMARY OF RECOMMENDED WATER QUALITY IMPROVEMENT PROJECTS IN THE LAKE HOLDEN DRAINAGE BASIN

SUB-BASIN	AREA	RECOMMENDATIONS
1	1-1	a. Stabilize existing areas with asphalt b. Regrade drainage away from Division avenue c. Replace existing limerock with non-calcareous gravel
	1-2	a. Replace existing surface with non-calcareous gravel b. Reroute runoff to on-site retention
	1-3	a. Enhance sediment control on adjacent properties
	1-4	a. Conduct routine street sweeping
	1-5	a. Stabilize existing areas with asphalt b. Replace existing surface with non-calcareous gravel
	1-6	a. Construct swales along roadway to capture runoff b. Divert runoff to on-site retention area
	1-7	a. Evaluate and eliminate oil and grease sources b. Install inlet inserts with oil and grease scrubbers in downstream inlet
	1-8	a. Install erosion control trucking devices at site exits b. Conduct routine street sweeping in roadway areas adjacent to site
	1-9	a. Install erosion control devices to prevent off-site transport of solids b. Conduct routine street sweeping in roadway areas adjacent to site
	1-10	a. Conduct routine street sweeping in roadway areas adjacent to site
2	2-1	a. Stabilize existing areas with asphalt b. Replace existing surface with non-calcareous gravel c. Regrade and redirect runoff to perimeter swale
	2-2	a. Pave existing roadway with asphalt b. Construct shallow roadside swale to collect runoff
	2-3	a. Conduct source identification and elimination b. Install curb/grate inlet structures with oil and grease absorbent media
21	--	No improvements recommended at this time
20	All	a. Expand existing alum treatment system to provide alum addition to Sub-basin 20 stormsewer
7	--	No improvements recommended at this time

APPENDICES

APPENDIX A

ERD REPORT TITLED
"EVALUATION OF THE CURRENT OPERATIONAL STATUS OF THE LAKE HOLDEN STORMWATER TREATMENT SYSTEM AND RECOMMENDATIONS FOR IMPROVEMENT"
(OCTOBER 2008)

EVALUATION OF THE CURRENT OPERATIONAL STATUS OF THE LAKE HOLDEN ALUM STORMWATER TREATMENT SYSTEM AND RECOMMENDATIONS FOR IMPROVEMENT

October 2008

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SECTION 1

INTRODUCTION

This report provides a summary of work efforts performed by Environmental Research & Design, Inc. (ERD) for the Orange County Environmental Protection Division (OCEPD, P.O. No. CO5902014) to evaluate water quality improvement options for Lake Holden. The work efforts outlined for this project have been divided into two primary phases, with Phase I consisting of a comprehensive evaluation of the existing alum treatment system (ATS), including existing operational characteristics and functionality, potential equipment upgrades and improvements, and recommendations for expansion. Phase II consists of a comprehensive evaluation of historical water quality trends and sediment characteristics, with the goal of identifying potential opportunities to improve water quality within the lake. This report only focuses on the ATS retrofit work effort and addresses the following issues: overview of ATS design, evaluation of existing ATS components, recommendations for ATS improvements, and evaluation of potential ATS expansion for treatment of new sub-basins.

SECTION 2

EVALUATION OF ALUM TREATMENT SYSTEM

The building for the existing alum stormwater treatment system for Lake Holden is located on the north side of the lake near the intersection of West Michigan Street and 29th Street. The facility was designed and permitted by ERD with construction plans finalized in April 1995. Construction began later that year and continued into 1996. The alum treatment system (ATS) has been operational since that time, providing treatment for significant runoff inputs entering the north end of Lake Holden from a total basin area of 183.9 acres, approximately 24% of the drainage area discharging to the lake. However, over time some components of the ATS have fallen into disrepair. A comprehensive evaluation of the functionality of the ATS is given in the following sections.

2.1 Overview of the Alum Treatment System Design

The ATS for Lake Holden is actually comprised of three separate systems, each treating a dedicated outfall to the lake. While specific components for the systems may vary, each system has the same major operational components which include stormwater flow measurement, alum pumping, and metering instrumentation. A detailed review of the three ATS systems is given below. All ATS injection sites are designed to inject liquid alum at a constant dose of 7.5 mg Al/liter. An overview of sub-basin delineations for areas discharging into Lake Holden is given in Appendix A.

2.1.1 Alum Treatment System No. 1

Alum Treatment System No. 1 is designed to provide alum treatment for a 48-inch RCP pipe discharging to Lake Holden from sub-basin 21, a 19.4-acre basin often referred to as the Paseo Street basin. This system collects runoff from a commercial/industrial area adjacent to and north of Michigan Street. An overview of ATS No. 1 is given on Figure 2-1. Upstream of 29th Street, the stormsewer consists of a 36-inch RCP which traverses under Paseo Avenue. The rate of stormwater flow is measured within the 36-inch RCP approximately mid-way between 29th Street and Michigan Street. Flow sensors within the 36-inch RCP detect the stormwater flow rate and transfer this information to the flow meter electronics within an adjacent instrumentation panel located on the edge of Paseo Avenue.

Within the instrumentation panel, the 4-20 mA analog signal is converted for use in a fiber-optic cable and transferred back to the alum building through a 2-inch conduit located along the eastern side of Paseo Avenue and the northern side of 29th Street. Once inside the alum building, this optic signal is converted back to a 4-20 mA signal within the alum pump control panel which controls the alum pump operations. Alum is pumped from the building through a 1-inch Sch. 80 PVC alum feed line to the 36-inch RCP at a location upstream of the point of flow measurement. The amount of alum pumped to the point of addition varies, depending on the measured flow rate through the 36-inch stormsewer, so that alum is always added at a specific dose on a flow-proportional basis relative to the measured stormwater flows.

Figure 2-1. Alum Treatment System No. 1.

2.1.2 Alum Treatment System No. 2

Alum Treatment System No. 2 is designed to treat stormwater discharging through a 60-inch RCP located directly west of the alum treatment building which discharges into the north end of Lake Holden. An overview of ATS No. 2 is given on Figure 2-2. This system provides stormwater treatment for sub-basin 1, a 98.8-acre commercial/industrial basin referred to as the Division Street basin. The original design of the this system utilized Doppler flow meters which were installed in the 60-inch RCP at the location indicated on Figure 2-2, with the flow sensor signal communicated directly to the stormwater flow meter electronics located within the alum building. Due to the close proximity of the sensor to the building, no fiber-optic cables were required.

Within the alum building, the stormwater flow rate is communicated to the alum control panel which regulates the alum dose to the point of addition. The rate of alum addition is varied on a flow proportional basis based on stormwater flows. The point of alum addition is located within the 60-inch RCP directly downstream of the point of flow measurement. To facilitate adequate mixing of alum and stormwater within the 60-inch RCP, compressed air is added to agitate the mixture. The compressed air originates from a blower within the alum building and is transferred through a 3-inch Sch. 80 PVC air line to the point of air addition downstream of the point of alum addition.

Figure 2-2. Alum Treatment System No. 2.

Over time problems developed with the stormwater flow metering of ATS No. 2. The flow sensor began to exhibit erratic behavior and sometimes indicated flow conditions when no flow was occurring. Ultimately, the flow sensor components were disconnected. ATS No. 2 remains operational by obtaining stormwater flow rate information from ATS No. 1, which is then converted to an estimated stormwater flow rate based on a proportional relationship between ATS No. 1 and ATS No. 2 derived from the sub-basin computer modeling conducted during the engineering design process.

2.1.3 Alum Treatment System No. 3

Alum Treatment System No. 3 treats stormwater from a basin located on the northeast side of the lake. This sub-basin area, approximately 65.7 acres in size and often referred to as the Lake Holden Terrace basin, ultimately discharges through a 48-inch x 76-inch ERCP pipe to the lake. The overall layout for ATS No. 3 is illustrated on Figure 2-3. In the original design, stormwater sensors were installed within the upstream portion of the 48-inch x 76-inch ERCP to monitor the rate of stormwater flow and transfer this information to the flow meter electronics housed in an above-ground stainless steel instrumentation panel located nearby. Within the instrumentation panel, the 4-20 mA analog signal is converted for use in a fiber-optic cable and transferred back to the alum building through a 1-inch PVC conduit which runs west of Lake Holden Terrace and south of West Michigan Street.

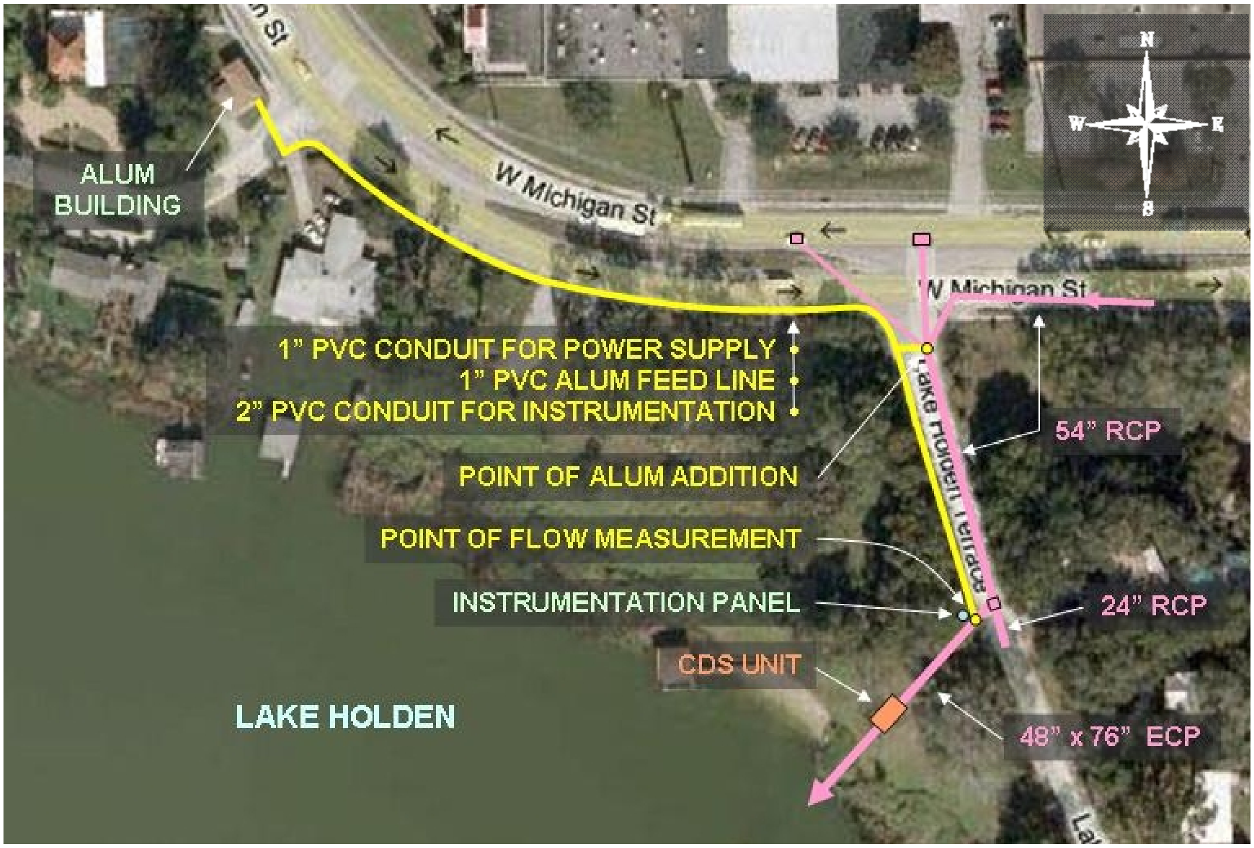


Figure 2-3. Alum Treatment System No. 3.

Once inside the alum building, the optical signal is converted back to a 4-20 mA signal within the alum pump control panel which controls the alum pump operations. The alum pump discharges alum through a 1-inch PVC line which runs south of West Michigan Street to the point of alum addition located near the intersection of Lake Holden Terrace and West Michigan Street. The amount of alum discharged into the 48-inch x 76-inch RCP at the point of addition varies so that alum is always added at a specific dose on a flow-proportional basis relative to the measured stormwater flows. Since installation of ATS No. 3, a CDS unit has been added to the 48-inch x 76-inch ERCP downstream of the alum treatment system and before discharge to Lake Holden.

Like ATS No. 2, problems developed over time with the stormwater flow metering for ATS No. 3 and ultimately, the components were disconnected. ATS No. 3 remains operational by obtaining stormwater flow rate information from ATS No. 1, based on a proportional relationship derived from the hydrologic computer modeling of the sub-basin areas conducted in the engineering design process.

2.2 Evaluation of Existing Alum Treatment System Components

ERD, in collaboration with Technical Solutions, Inc. (TSI), and with assistance of the City of Orlando, conducted a comprehensive review of the existing Lake Holden ATS. With this team approach, ERD focused on the engineering design elements and overall functionality of the system, while TSI focused on the instrumentation and electrical elements. As discussed in the previous sections, the initial design of the alum treatment system consisted of a stormwater flow meter associated with each alum pump and control panel. However, over time this design has been modified to have only one stormwater flow meter controlling all three alum pumps. The stormwater flow meter for ATS No. 1 provides input to all three systems based on a proportional relationship derived from the hydrologic computer modeling conducted in the engineering design process. These modifications were enacted due to continuing technical difficulties with the stormwater flow metering components from ATS No. 2 and ATS No. 3. The stormwater flow meter for ATS No. 1 is an Eastech 2100 model, which functions using Manning's Equation based upon pipe diameter, slope, and depth of flow.

The use of a single flow meter to control the three chemical metering pumps is a less than ideal situation for several reasons. First, the 19.4-acre Paseo Street sub-basin is substantially smaller than the 98.8-acre Division Street sub-basin and the 65.7-acre Lake Holden Terrace sub-basin. Therefore, when a rain event occurs, runoff flows will be generated for a significantly longer period of time in the Division Street and Lake Holden Terrace sub-basins compared with the much smaller Paseo Street sub-basin. Since the alum metering is regulated by flows through the Paseo Street stormsewer, alum addition will cease in all sub-basins while significant flows may still be occurring in the other two larger sub-basin areas. This may cause large portions of rain events to go untreated, resulting in additional pollutant loadings to the lake.

A second reason why the current metering methodology is inappropriate is that the hydrologic relationships between the various sub-basins may not always be the same. The rate of alum addition into the Division Street and Lake Holden Terrace stormsewer lines is based upon a modeled relationship with flows occurring through the Paseo Street line. Hydrologic modeling was used to predict flow rates through each of the three treated stormsewer lines for given storm events, and the metering pumps are designed to pump alum based upon these relationships. However, although hydrologic modeling can estimate total runoff volumes fairly accurately, large errors may be present in predicting discharge rates at any given time during a storm event. Therefore, using the current methodology, the treatment system may overdose stormwater flows under some conditions while under-dosing under other conditions. As a result, proper operation of the system requires that flow rates be monitored accurately and individually for each of the three systems.

Within the alum building itself, the alum pumps and alum pump control panels for all three systems are functional. The only significant component within the alum building which is non-functional is the air blower assembly associated with ATS No. 2. A summary of the major ATS component status is provided in Table 2-1. The major ATS components within the building are also depicted in Figures 2-4 and 2-5. The locations of the alum pumps, alum meters, and air blower for ATS No. 2 are illustrated on Figure 2-4. As seen in this figure, the alum meter for ATS No. 3 is currently disassembled and is being repaired by the City of Orlando. This repair effort is anticipated to be minor, and this component was deemed to be functional.

Figure 2-4. Alum Pumps and Meters.

Figure 2-5. Alum Pump Control Panels.

TABLE 2-1

SUMMARY OF MAJOR ALUM TREATMENT SYSTEM COMPONENT STATUS

COMPONENT DESCRIPTION	SYSTEM NO. 1	SYSTEM NO. 2	SYSTEM NO. 3
Stormwater Flow Meter Systems	Functional	Non-Functional	Non-Functional
Alum Pumps	Functional	Functional	Functional
Alum Pump Control Panels	Functional	Functional	Functional
Air Blower	N/A	Non-Functional	N/A

2.3 Recommendations for Alum Treatment System Improvements

As an extension of the existing ATS evaluation work effort, ERD and TSI developed recommendations for ATS improvements/upgrades. A recommended minimum ATS retrofit package was established along with optional upgrades. These improvements and upgrades are documented in the following sections.

2.3.1 Minimum Recommended Alum Treatment System Improvements

The major components for the minimum recommended ATS improvement package include new stormwater flow meters for all three systems and an air compressor for ATS No. 2. An analysis for each system is detailed below with an opinion of probable construction costs provided in Table 2-2.

ATS No. 1

Although the flow meter in ATS No. 1 is still functional, it is old in terms of flow meter life span. This flow meter should be updated to the Eastech 2200 to provide data logging capabilities and facilitate data input for an internet monitoring web page. These features have been requested by the City of Orlando. Since the 36-inch RCP drains dry between storm events, the use of a unit utilizing the Manning's equation is desirable. The recommended ATS No. 1 improvements include:

- Remove existing Eastech 2100 components
- Install new Eastech 2200 flow meter with data logging
- Install Wilkerson telemetry system
- Calibrate system
- Provide operational training

ATS No. 2

The existing non-operational stormwater flow meter components for ATS No. 2 will be replaced with the Teledyne Pro-20. This unit is designed to be used in surcharged conditions which exist in the 54-inch RCP along Division Street. The unit provides simultaneous measurements of flow depth and velocity and, based on the geometry of the pipe, converts the data into a flow rate using the Continuity Equation. Additionally, the existing air blower should be replaced with an Ingersol Rand rotary screw compressor model number UP67TAS-125 with the automatic restart option. Rotary screw compressors are significantly quieter than air blowers or typical reciprocating air compressors and are designed for continuous use which is necessary for extended rainfall events. A conceptual overview of the ATS No. 2 improvement tasks includes:

- Remove existing Eastech Model 4100 flow meter
- Install Teledyne Pro-20 flow meter with data logging in 54-inch RCP utilizing custom mounting bracket
- Install Wilkerson telemetry system
- Install Ingersol Rand rotary screw compressor in alum building with all associated wiring, piping, and valving
- Install new stainless steel above-ground enclosure within 100 feet of 54-inch RCP discharge point.
- Install new conduit with 120 volt power supply to enclosure
- Install new conduit from stormwater flow meter sensor to enclosure
- Calibrate system
- Provide operational training

ATS No. 3

The existing non-operational stormwater flow meter components for ATS No. 3 will be replaced with the Teledyne Pro-20 flow meter. This unit is specifically designed for submerged pipe conditions which occur in the 48-inch x 76-inch ERCP at the point of flow measurement. A conceptual overview of the ATS No. 2 improvement tasks includes:

- Remove existing Eastech Model 4100 flow meter
- Install Teledyne Pro-20 flow meter with data logging in 48-inch x 76-inch ERCP utilizing custom mounting bracket
- Install Wilkerson telemetry system
- Relocate existing stainless steel flow meter electronics enclosure within 100 feet of 48-inch x 76-inch ERCP discharge point
- Extend conduit with 120 volt power supply to relocated enclosure
- Install new conduit from stormwater flow meter sensor to enclosure
- Calibrate system
- Provide operational training

TABLE 2-2

SUMMARY OF ALUM TREATMENT SYSTEM RETROFIT COSTING

COMPONENT DESCRIPTION	ATS NO. 1 ($)	ATS NO. 2 ($)	ATS NO. 3 ($)
Stormwater Flow Meter Installation - Eastech 2200	5,500	---	---
Stormwater Flow Meter Installation - Teledyne Pro-20	---	38,500	38,500
Alum Pumps	0	0	0
Alum Pump Control Panels	0	0	0
Air Compressor - Ingersol Rand UP67TAS-125	---	11,800	---
TSI Labor & Various Materials	4,650	9,900	8,800
Sub-Totals:	**$ 10,150**	**$ 60,200**	**$ 47,300**
TOTAL:	**$ 117,650**		

2.3.2 Alum Treatment System Upgrade Option #1 – Alum Pump Replacements

The originally installed Wallace and Tiernan alum pumps for all three alum treatment systems are currently functional. These are excellent high quality pumps with a long history of trouble-free service. However, Wallace and Tiernan no longer produces or actively supports these pump models. As such, repairs parts are becoming increasingly scarce and ultimately will become unavailable. Sometime in the future, the Lake Holden ATS Wallace and Tiernan alum pumps will become non-functional due to their inability to be maintained. For this reason, an evaluation of pump replacement costs is provided. Current ERD ATS designs utilize Seepex progressive cavity alum pumps. This type of Seepex pump has proven itself reliable in a variety of newer ATS installations. The required alum pumping rates for the three Lake Holden ATS systems are summarized on Table 2-3. An opinion of probable costs for the alum pump replacements is given in Tables 2-4 and 2-5.

TABLE 2-3

SUMMARY OF ALUM PUMPING RATES (Based on an Alum Dose of 7.5 mg Al/liter)

LOCATION	TREATED STORMWATER FLOW RATES (cfs)	ALUM PUMPING RATE RANGE
ATS #1	2.1-38	0.12 to 2.20 gpm
ATS #2	7.3-148	0.42 to 8.50 gpm
ATS #3	3.5-75	0.20 to 4.30 gpm

TABLE 2-4

OPINION OF PROBABLE COSTS FOR ALUM PUMP REPLACEMENTS WITH PARTIAL CONTROL PANEL RE-BUILD

COMPONENT DESCRIPTION	AMOUNT ($)
Option #1 – Replace Existing Alum Pumps • Install three Seepex alum pumps	$ 33,500
Option #1a – Alum Pump Control Panel Modifications • Rebuild panels using as many existing components as possible	15,900
TOTAL:	**$ 49,400**

TABLE 2-5

OPINION OF PROBABLE COSTS FOR ALUM PUMP REPLACEMENTS WITH TOTAL CONTROL PANEL RE-BUILD

COMPONENT DESCRIPTION	AMOUNT ($)
Option #1 – Replace Existing Alum Pumps • Install three Seepex alum pumps	$ 33,500
Option #1b – Alum Pump Control Panel Modifications • Complete panel re-builds using all new components	28,500
TOTAL:	**$ 62,000**

As seen in Table 2-3, the alum injection pumps are currently set to treat a wide range of stormwater flow rates, ranging from 2.1-38 cfs for ATS No. 1 and 7.3-148 cfs for ATS No. 2. The upper range of treatable flow rates reflects the maximum anticipated discharges through each of the three stormsewer systems for relatively common storm events which occur in the Central Florida area. The lower end of the treatable flow rates are dictated by limitations of the original stormwater flow monitoring equipment installed at each of the three sites. The proposed stormwater flow meter enhancements will allow the treatment systems to read much smaller stormwater flows which will allow the injection system to provide treatment for a much lower range of flow rates than could be achieved by the original system. Treatable flow rates at each of the three systems could be easily reduced to less than 1 cfs which would be a substantial improvement in the amount of runoff which can be treated, particularly for small storm events.

2.3.3 Alum Treatment System Upgrade Option #2 – Enhanced Communications

A feature utilized for newer alum treatment systems is the ability to acquire system status data for various components and transmit this information to an off-site monitoring computer in real time. The data may then be integrated into an existing computer network or uploaded to the internet. This allows the owner/operator or interested parties to actively monitor the ATS functions remotely, providing increased knowledge of the sub-basin runoff and treatment characteristics.

TSI and ERD have developed a baseline enhanced communications system which provides real-time data for significant system processes. These data points include stormwater flow meter readings for all three ATS systems, alum pump "on" or "off" for all three systems, air compressor "on" or "off", and ATS shutdown alarm notification. Additional data inputs could be added to the enhanced communications system, but would require further modifications to the ATS. These additional data points include; lake elevation, alum pumping rates for all three Systems, and alum tank level. The opinion of probable cost for the enhance communications system basic package and various options is documented in Table 2-6. With input from Orange County Environmental Department, it was determined that the signals from the alum building would be sent across the lake via telemetry to a building where the receiving computer system would be located.

TABLE 2-6

OPINION OF PROBABLE COSTS FOR ENHANCED COMMUNICATIONS

COMPONENT DESCTION	AMOUNT ($)
Option #2 – Basic System Package • Telemetry system for cross-lake communications o Signal – Stormwater flow meter values for Systems #1, 2, & 3 o Signal – Alum pumps "on / off" o Signal – Air compressor "on / off" o Signal – Alum shutdown	$ 12,500
• Dedicated computer, monitor, UPS, and printer at receiving end	1,600
• Internet provider service at receiving end	---
• Basic System Package Sub-Total	**$ 14,100**
Option #2a – Added Data Input o Signal – Lake elevation	**2,300**
Option #2b – Added Data Input o Signal – Alum pumping rate for ATS #1, 2, & 3 (includes output modules for mechanical alum flow meters)	**3,750**
Option #2c – Added Data Input o Signal – Alum tank level	**2,500**
TOTAL:	**$ 22,650**

2.4 Evaluation of Potential Alum Treatment System Expansion

ERD and TSI also conducted an evaluation of a potential ATS expansion to provide treatment for sub-basin 20. This 60.9-acre drainage basin, located along the west side of the lake, is one of the largest remaining untreated basins entering the lake. Runoff from this basin is collected within the stormwater drainage system and ultimately discharges into Lake Holden through a 36-inch RCP which traverses the south side of 33rd Street. The design of the ATS expansion includes the addition of a new alum pump and the installation of approximately 2,500 feet of 1-inch inside diameter double-wall HDPE pipe between the alum building and the intersection of 33rd Street and Alamo Drive. The alum pump flow rates would be determined based on a proportional relationship derived from computer modeling with one or more of the other active stormwater flow meters. The proposed route for the new alum discharge line is depicted on Figure 2-6.

As can be noted in Figure 2-6, the proposed alum line is contained within the road easements of 29th Street and Alamo Drive. While the route is depicted as running along the centerline of the roadways, the pipeline will actually be constructed along one side of the unpaved portion of the roadway. To determine which route would impose the least impacts to existing features, an alternative analysis was conducted. The routes to the west and east of the paved roadways were compared, focusing on the extent of driveway and other hardened crossings. As documented in Table 2-7, the western route has the least number of crossed features. Since it is anticipated that these crossing will be constructed utilizing horizontal boring, actual impacts to these features will be minimized. However, this construction method is significantly more expensive than open cut trenching and will increase the overall budget for the proposed ATS expansion proportionally. A preliminary cost estimate for this work effort is provided within Table 2-8.

2.5 Summary

Although the basic components for the Lake Holden alum stormwater treatment system are currently functional, the system is operating at less than optimal efficiency. Only one of the three injection systems has an operational flow metering system under current conditions. ERD recommends, at a minimum, that Orange County and the Lake Holden Advisory Board consider implementation of the basic alum treatment system retrofit options identified in Table 2-2. Implementation of these proposed retrofit options will upgrade the system to an operational status which is superior to the status of the system when new. Implementation of the enhanced communications option is also recommended to allow real-time observation of system status under actual rain event conditions. This will allow any interested party to verify the operational status of the majority of the system components under a wide range of operational conditions.

ERD does not recommend replacement of the three chemical metering pumps at this time. As discussed previously, the existing Wallace and Tiernan metering pumps have a history of extremely reliable service and may last for many years to come, pending availability of replacement parts. However, when the metering pumps do eventually require replacement, the replacement operation is relatively easy and would be completely compatible with the proposed recommended upgrades.

Figure 2-6. Proposed Route for New Alum Discharge Line

TABLE 2-7

ALTERNATIVE ANALYSIS FOR THE PROPOSED ALUM DISCHARGE LINE ROUTES

WESTERN ROUTE ANALYSIS		
Location	**Feature**	**Length (ft)**
Alum Building	Concrete	19
Storm Inlet by Alum Building	Concrete	6
501 29th St	Gravel	16
Strom Inlet	Concrete	7
501 29th St	Gravel	20
503 w 29th St	Concrete	20
507 29th St	Dirt	15
601 Paseo Rd	Dirt	12
Paseo Rd	Asphalt	47
605 Paseo Rd	Dirt	13
605 Paseo Rd	Pavers	24
633 Paseo Rd	Concrete	16
29th St and Alamo Dr (Diagonal across road)	Asphalt	88
2900 Alamo Dr	Concrete	23
3006 Alamo Dr	Dirt / Grass	11
Alamo Dr and 30th St	Asphalt	96
Alamo Dr and 31st St	Asphalt	78
3100 Alamo Dr	Pavers	12
3100 Alamo Dr	Pavers	12
3112 Alamo Dr	Concrete	17
3112 Alamo Dr	Concrete	19
3120 Alamo Dr	Concrete	28
Alamo Dr and 32nd St	Asphalt	67
3220 Alamo Dr	Asphalt	17
Alamo Dr and 33rd St	Asphalt	34
	TOTAL:	**717**

EASTERN ROUTE ANALYSIS		
Location	**Feature**	**Length (ft)**
3221 Alamo Dr	Dirt	14
3215 Alamo Dr	Concrete	21
3211 Alamo Dr	Concrete	24
3201 Alamo Dr	Concrete	28
3201 Alamo Dr	Concrete	34
3115 Alamo Dr	Concrete	29
3109 Alamo Dr	Concrete	25
3101 Alamo Dr	Concrete	26
3005 Alamo Dr	Concrete	31
3001 Alamo Dr	Concrete	42
3001 Alamo Dr	Concrete	40
2929 Alamo Dr	Concrete	24
2915 Alamo Dr	Concrete	29
2905 Alamo Dr	Concrete	115
600 29th St and storm inlet next to driveway	Concrete	47
600 29th St	Concrete	25
532 29th St	Dirt	15
504 29th S29th St t	Asphalt and Pavers	47
504 29th St	Pavers	19
500 29th St	Pavers and Concrete	22
500 29th St	Pavers	27
320 29th St	Concrete	23
29th St across to alum building	Asphalt	33
	TOTAL:	**740**

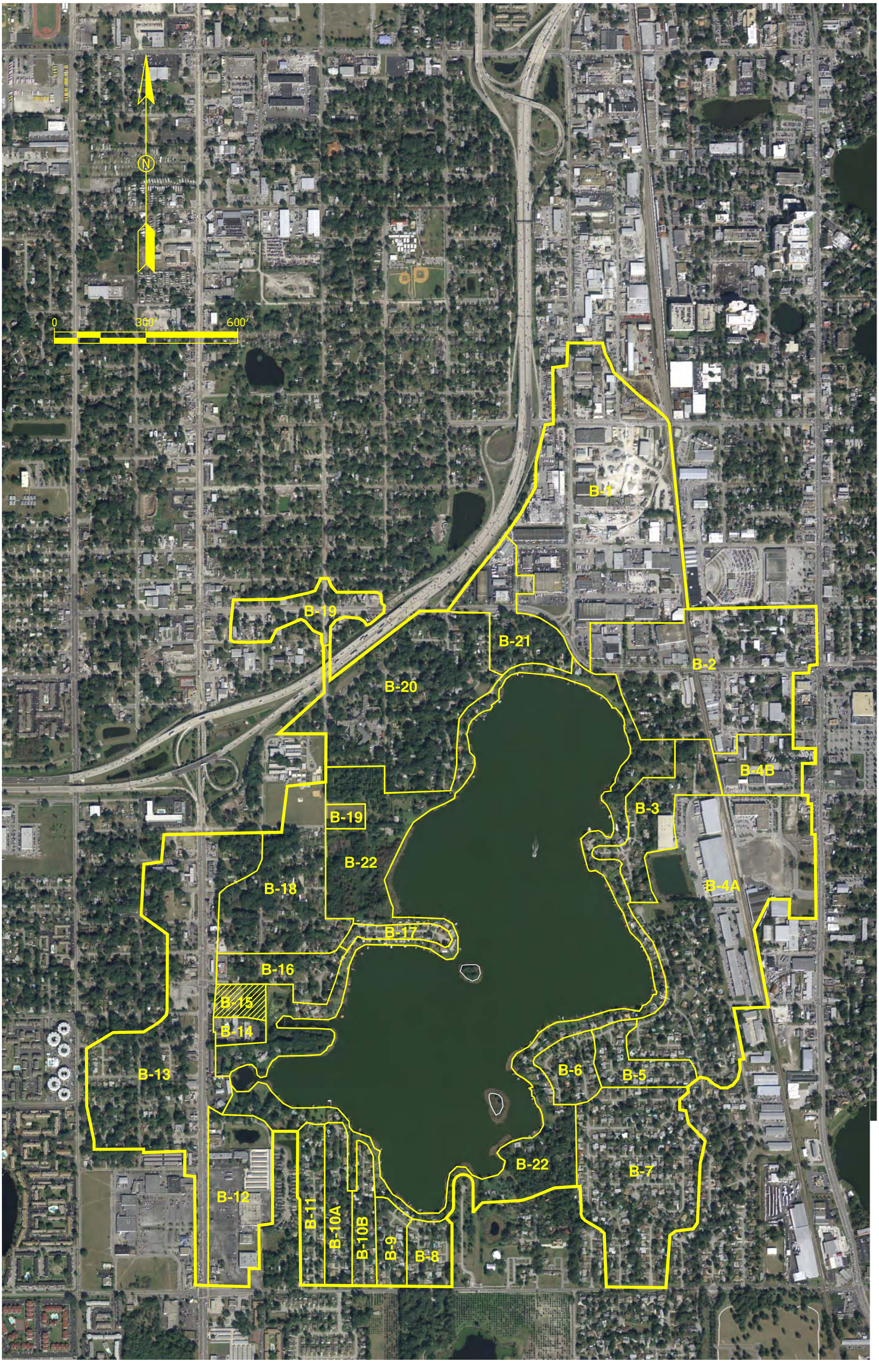
TABLE 2-8

PRELIMINARY COST ESTIMATE FOR PROPOSED ALUM TREATMENT SYSTEM EXPANSION

COMPONENT DESCRIPTION	QUANTITY	UNIT COST ($)	TOTAL COST ($)
Install Seepex alum pump	1	$ 11,200	$ 11,200
Install 1-inch I.D. double-walled HDPE piping using open trench method	1,800	20	36,000
Install 1-inch I.D. double-walled HDPE piping using horizontal boring	717	35	25,095
Miscellaneous	1	5,000	5,000
		TOTAL:	**$ 77,295**

APPENDIX A

DRAINAGE SUB-BASIN AREAS
FOR LAKE HOLDEN



Drainage Sub-Basin Areas Discharging to Lake Holden.

APPENDIX B

HISTORICAL WATER QUALITY DATA FOR LAKE HOLDEN

Source	Date	Station	Parameter																				
			pH	Cond	Secchi	Alk	BOD5	Chla	Color	DO	NH3	NO2	NO3	Nox	TKN	N Organic	Total N	SRP	Total P	Total Coliforms	Fecal Coliform	TSS	Turb
			s.u.	µmho/cm	m	mg/l	mg/l	µg/l	Co-Pt	mg/l	µg/l	µg/l	µg/l	µg/l	µg/l	µg/l	µg/l	µg/l	µg/l	cfu/100ml	cfu/100ml	mg/l	NTU
City of Orlando	3/15/01	North	8.78	303	0.46		5.0	33.6		6.0					1,770		1,770		50		250	18.0	
City of Orlando		South	8.85	303	0.41		4.5	28.0		5.5					1,760		1,760		46		60	18.0	
City of Orlando	5/10/01	North	8.62	313	0.47		4.5	26.1		8.7					1,750		1,750		50		25	13.0	
City of Orlando		South	8.56	314	0.45		4.3	38.2		8.1					1,830		1,830		50		6	12.0	
City of Orlando	7/24/01	North	8.10	235	0.48		3.5	40.6		7.6					1,640		1,640		37		230	10.0	
City of Orlando		South	8.02	236	0.54		3.2	39.8		7.0					1,690		1,690		33		56	12.0	
City of Orlando	10/18/01	North	7.86	275	0.58		3.6	32.8		7.5					1,500		1,500		43		120	12.0	
City of Orlando		South	8.23	273	0.66		4.4	27.6		8.1					1,370		1,370		39		68	12.0	
City of Orlando	2/28/02	North	7.96	282	0.58		3.0	22.1		9.6					1,260		1,260		43		44	7.5	
City of Orlando		South	8.01	280	0.65		3.4	19.2		9.6					1,180		1,180		39		16	7.0	
City of Orlando	7/25/02	North	8.69	306	0.54		3.0	16.1		8.9					1,470		1,470		30		380	6.5	
City of Orlando		South	8.66	309	0.49		2.5	16.4		8.7					1,430		1,430		23		30	6.0	
City of Orlando	11/1/02	North	7.62	251	0.64		3.4	27.7		6.3					1,200		1,200		32		80	9.5	
City of Orlando		South	7.81	250	0.67		3.7	25.4							1,310		1,310	5	32		127	8.0	
City of Orlando	2/4/03	North	8.44	228	0.79		6.8	15.3		11.0		11	53	64	1,270		1,330		46			7.5	
City of Orlando		South	8.38	229	0.79		6.0	18.7		10.9		11	101	112	1,150		1,260	3	46			8.0	
City of Orlando	4/29/03	North	8.94	242	0.49			37.1							1,180		1,180	6	35			14.5	
City of Orlando		South	8.80	243	0.48		5.1	22.2		9.2					1,060		1,060		32			10.5	
City of Orlando	7/29/03	North			0.76		3.0	17.3			10		10	10	1,140		1,150	3	22		300	7.4	
City of Orlando		South			0.74		2.6	15.8			10		10	10	1,120		1,130	6	23		24	7.6	
City of Orlando	10/21/03	North	8.12	249	0.59		4.4	37.2		8.7					1,280		1,280	3	32		18	12.7	
City of Orlando		South	8.01	250	0.58		4.6	53.2		8.2					1,320		1,320	3	32		16	12.8	
City of Orlando	1/22/04	North	8.29	258	0.67		2.1	17.2		10.0	60				1,140		1,140	2	41		46	8.6	
City of Orlando		South	8.21	258	0.74		2.2	18.2		10.2	30		10	10	1,070		1,080	2	34		8	8.4	
City of Orlando	5/4/04	North	8.09	256	0.69		3.3	26.7		7.9					1,300		1,300	3	44		104	12.4	
City of Orlando		South	8.20	257	0.68		3.5	23.8		8.3					1,360		1,360	3	40		86	12.4	
City of Orlando	7/29/04	North	8.65	249	0.78		2.4	12.5		8.6	20				1,220		1,220	3	23		90	7.6	
City of Orlando		South	8.68	252	0.91		2.6	16.5		8.8	20				1,230		1,230	3	22		28	9.6	
City of Orlando	1/27/05	North	8.00	241	1.03	66.4		11.7		10.5	120		80	80	990		1,070	3	37				
City of Orlando		South	7.93	236	0.98	64.1		13.9		10.5	60		90	90	930		1,020	2	24				
City of Orlando	5/10/05	North	7.87	263	0.42	48.8		31.5		9.4	20				1,290		1,290	3	24				
City of Orlando		South	8.30	262	0.54	48.0		32.6		10.1	20				1,310		1,310	3	27				
City of Orlando	7/21/05	North	8.19	251	1.37	49.8		6.2		8.3			50	50	1,080		1,130	2	16				
City of Orlando		South	8.19	251	1.25	48.6		9.4		8.3	10		50	50	1,000		1,050	2	17				
City of Orlando	11/10/05	North	8.28	273	0.91	28.0		9.0		9.4					700		700	3	11				
City of Orlando		South	8.00	273	1.15	28.4		8.5		8.8					670		670	3	12				
City of Orlando	1/26/06	North	8.54	283	0.56	33.4		7.4		10.4	80	0	110	110	770		880	2	14			3.6	
City of Orlando		South	7.91	283	0.58	33.2		7.3		10.4	100	0	110	110	750		860	2	13			3.4	
City of Orlando	5/18/06	North	7.93	323	0.41	14.2		6.5		8.2	30	0	5	5	590		590	1	6			4.6	
City of Orlando		South	7.62	324	0.52	14.0		4.6		8.0	30	0	5	5	610		610	1	20			4.2	
City of Orlando	7/18/06	North	7.95	330	0.34	18.8		8.2		7.5	5	0	5	5	760		760	3	13			6.8	
City of Orlando		South	7.53	329	0.35	18.2		7.4		7.6	5	0	5	5	770		770	2	16			5.8	
City of Orlando	10/24/06	North	7.74	310	0.34	25.6		17.3		7.8	10	0	5	5	850		850	3	7			6.2	
City of Orlando		South	7.67	308	0.35	25.8		16.8		7.9	10	0	5	5	830		830	3	9			6.0	
City of Orlando	1/16/07	North	8.70	300	0.90					10.8		0	5	5	810		810	2	14			6.4	7.4
City of Orlando		South	8.22	300	0.75	30.5		11.8		10.1	20	0	5	5	870		870	2	15			6.6	6.7
City of Orlando	4/24/07	North	7.98	318	0.88	35.5		7.6		9.0	5	0	5	5	1,150		1,150	1	16			6.8	6.9
City of Orlando		South	7.91	317	0.87	35.4		4.1		8.9	5	0	5	5	1,070		1,070	1	15			6.4	7.4
City of Orlando	7/19/07	North	8.23	327	1.25	36.4		6.0		7.8	20	0	20	20	920		940	1	11			6.0	4.5
City of Orlando		South	8.27	325	1.13	37.2		4.6		8.1	10	0	20	20	860		880	1	12			5.0	4.3
City of Orlando	10/23/07	North	8.02	310	0.82	39.5		20.0		8.4	10	0	5	5	980		980	3	16			9.2	6.1
City of Orlando		South	7.86	307	0.73	39.6		18.2		8.3	20	0	5	5	1,000		1,000	2	17			8.4	6.6
City of Orlando	1/31/08	North	8.18	302	1.00					9.9													

Source	Date	Station	Parameter																				
			pH	Cond	Secchi	Alk	BOD5	Chla	Color	DO	NH3	NO2	NO3	Nox	TKN	N Organic	Total N	SRP	Total P	Total Coliforms	Fecal Coliform	TSS	Turb
			s.u.	µmho/cm	m	mg/l	mg/l	µg/l	Co-Pt	mg/l	µg/l	µg/l	µg/l	µg/l	µg/l	µg/l	µg/l	µg/l	µg/l	cfu/100ml	cfu/100ml	mg/l	NTU
City of Orlando		South	8.07	301	1.13					10.0													
City of Orlando	4/22/08	North	8.49	307	1.03					10.0													
City of Orlando		South	8.51	307	0.99					9.1													
City of Orlando	8/7/08	North	8.41	298	1.23					8.2													
City of Orlando		South	8.30	298	1.06					8.3													
City of Orlando	10/21/08	North	8.25	267	0.87					8.5													
City of Orlando		South	8.06	266	0.76					8.2													
City of Orlando	1/29/09	North	8.83	282	2.03					10.5													
City of Orlando		South	8.06	282	2.97					10.2													
City of Orlando	5/7/09	North	8.71	288	2.96					9.1													
City of Orlando		South	8.69	285	3.32					9.1													
City of Orlando	8/11/09	North	7.96	252	2.03					7.5													
City of Orlando		South	7.79	251	2.28					7.5													
FDEP	10/2/03	Center	7.44		0.80			45.0		5.6					1,400				42				7.0
FDEP	2/2/04	Center	8.22		0.90					10.0													
FDEP	3/29/04	Center	8.53		0.70					10.2													
FDEP	6/14/04	Center	8.65		0.80					7.7													
FDEP	9/13/04	Center	8.34		0.70					8.4													
FDEP	6/23/09	Center	8.60	258	1.60		0.6	5.0	15.0	8.3				5	610		615		15				
Lakewatch	9/2/87		9.05	221		60.4		52.2	12.5								1,500		45				
Lakewatch	10/8/87		8.10	243		71.0		92.3	10.0								1,400		40				
Lakewatch	3/9/88		8.65	233		70.5		46.8	10.0								830		45				
Lakewatch	2/11/90				0.73			49.3									1,250		53				
Lakewatch	3/18/90				0.61			52.5									1,350		54				
Lakewatch	5/13/90				0.61			57.5									1,550		51				
Lakewatch	6/10/90				0.91			32.0									1,250		36				
Lakewatch	9/1/90				0.76			32.7									897		32				
Lakewatch	10/14/90				0.66			43.0									960		41				
Lakewatch	11/18/90				0.61			64.3									1,450		55				
Lakewatch	12/30/90				0.61			50.0									1,250		48				
Lakewatch	1/13/91				0.61			58.5									1,300		53				
Lakewatch	2/17/91				0.61			65.7									1,350		61				
Lakewatch	3/6/91		8.25	275	0.61	80.5		69.0	13.5								1,600		60				
Lakewatch	4/14/91				0.55			50.0									1,267		55				
Lakewatch	6/2/91				0.46			72.0									1,333		46				
Lakewatch	7/7/91				0.61			50.7									1,200		35				
Lakewatch	8/10/91				0.55			50.3									1,200		38				
Lakewatch	9/8/91		8.60	237	0.55	70.5		65.7	16.5								1,380		34				
Lakewatch	7/26/95				0.73			37.7									875		36				
Lakewatch	8/22/95		8.60	226	0.76	58.3		37.0	17.0								1,092		40				
Lakewatch	11/27/95				0.76			52.0									1,143		51				
Lakewatch	4/16/96				0.82			27.7									895		43				
Lakewatch	7/30/96				0.88			21.0									900		26				
Lakewatch	6/21/97				0.69			43.0									1,097		35				
Lakewatch	7/23/97				0.53			35.0									1,000		28				
Lakewatch	8/22/97				0.79			32.7									1,043		28				
Lakewatch	9/29/97				0.66			60.0									1,243		37				
Lakewatch	10/28/97				0.61			62.0									1,213		48				
Lakewatch	11/29/97				0.70			60.5									1,310		52				
Lakewatch	1/2/98				0.61			52.5									1,237		47				
Lakewatch	1/31/98				0.55			52.7									1,327		51				
Lakewatch	3/1/98				0.40			73.7									1,203		49				
Lakewatch	3/31/98				0.43			77.7									1,483		46				

Source	Date	Station	Parameter																				
			pH	Cond	Secchi	Alk	BOD5	Chla	Color	DO	NH3	NO2	NO3	Nox	TKN	N Organic	Total N	SRP	Total P	Total Coliforms	Fecal Coliform	TSS	Turb
			s.u.	µmho/cm	m	mg/l	mg/l	µg/l	Co-Pt	mg/l	µg/l	µg/l	µg/l	µg/l	µg/l	µg/l	µg/l	µg/l	µg/l	cfu/100ml	cfu/100ml	mg/l	NTU
Lakewatch	4/30/98				0.46			71.0									1,557		48				
Lakewatch	5/31/98				0.46			39.7									1,407		36				
Lakewatch	6/30/98				0.69			38.3									1,203		32				
Lakewatch	7/30/98				0.66			32.5									1,103		27				
Lakewatch	8/31/98				0.76												1,143		25				
Lakewatch	10/1/98				0.58			71.0									1,257		41				
Lakewatch	10/29/98				0.64			63.0									1,347		37				
Lakewatch	11/23/98				0.60			60.0									1,243		34				
Lakewatch	12/20/98				0.68			62.3									1,265		30				
Lakewatch	1/29/99				0.69			80.7									1,063		39				
Lakewatch	2/23/99				0.59			49.3									1,300		41				
Lakewatch	3/18/99				0.54			52.0									1,333		46				
Lakewatch	4/22/99				0.53			53.7									1,480		51				
Lakewatch	5/20/99				0.48			47.0									1,387		39				
Lakewatch	6/18/99				0.92			47.3									1,185		36				
Lakewatch	7/12/99				0.69			36.0									1,207		29				
Lakewatch	8/9/99				0.71			40.3									1,257		31				
Lakewatch	9/20/99				0.69			61.0									1,510		40				
Lakewatch	10/18/99				0.66			63.7									1,363		38				
Lakewatch	11/15/99				0.73			62.0									1,435		35				
Lakewatch	12/15/99				0.69			60.3									1,453		35				
Lakewatch	1/23/00				0.55			59.7									1,590		39				
Lakewatch	2/13/00				0.58			43.3									1,453		37				
Lakewatch	3/13/00				0.58			62.3									1,747		45				
Lakewatch	4/19/00				0.51			77.3									1,807		45				
Lakewatch	5/12/00				0.47			66.0									1,897		45				
Lakewatch	6/13/00				0.53			54.0									2,000		36				
Lakewatch	7/13/00				0.56			56.0									1,683		40				
Lakewatch	8/17/00				0.60			59.3									1,803		37				
Lakewatch	9/21/00				0.63			80.3									1,797		39				
Lakewatch	10/14/00				0.59			74.0									1,927		45				
Lakewatch	11/20/00				0.50			85.0									1,935		52				
Lakewatch	12/16/00				0.49			79.0									1,795		48				
Lakewatch	1/20/01				0.55			43.0									1,815		62				
Lakewatch	2/24/01				0.64			47.5									1,455		38				
Lakewatch	3/18/01				0.61			61.5									1,690		46				
Lakewatch	4/4/01				0.58			36.5									1,515		40				
Lakewatch	5/16/01				0.61			48.0									1,260		38				
Lakewatch	6/24/01				0.56			57.5									1,535		35				
Lakewatch	7/15/01				0.55			64.5									1,590		31				
Lakewatch	8/13/01				0.62			40.5									1,385		28				
Lakewatch	9/26/01				0.64			51.5									1,200		28				
Lakewatch	10/16/01				0.69			53.0									1,277		32				
Lakewatch	11/19/01				0.78			50.0									1,240		37				
Lakewatch	12/17/01				0.75			46.3									1,107		37				
Lakewatch	1/17/02				0.87			28.0									1,237		32				
Lakewatch	2/24/02				0.80			25.3									1,103		37				
Lakewatch	3/23/02				0.84			34.0									1,237		37				
Lakewatch	4/19/02				0.62			40.3									1,200		34				
Lakewatch	5/21/02				1.07			37.5									1,455		31				
Lakewatch	6/18/02				0.76			44.7									1,340		36				
Lakewatch	7/18/02				0.61			35.7									1,207		27				
Lakewatch	8/16/02				0.76			51.3									1,180		30				

Source	Date	Station	Parameter																				
			pH	Cond	Secchi	Alk	BOD5	Chla	Color	DO	NH3	NO2	NO3	Nox	TKN	N Organic	Total N	SRP	Total P	Total Coliforms	Fecal Coliform	TSS	Turb
			s.u.	µmho/cm	m	mg/l	mg/l	µg/l	Co-Pt	mg/l	µg/l	µg/l	µg/l	µg/l	µg/l	µg/l	µg/l	µg/l	µg/l	cfu/100ml	cfu/100ml	mg/l	NTU
Lakewatch	9/20/02				0.69			45.0									1,153		29				
Lakewatch	10/21/02				0.73			43.3									1,087		29				
Lakewatch	11/15/02				0.76			47.0									1,110		35				
Lakewatch	12/16/02				0.84			44.0									1,077		39				
Lakewatch	1/21/03				0.91			38.0									1,040		42				
Lakewatch	2/28/03				0.84			40.0									1,045		42				
Lakewatch	3/26/03				0.91			36.7									873		41				
Lakewatch	4/27/03				0.69			45.5									1,220		39				
Lakewatch	5/26/03				0.89			34.7									1,200		31				
Lakewatch	6/23/03				0.90			35.3									1,043		25				
Lakewatch	7/27/03				0.99			22.0									1,050		19				
Lakewatch	8/17/03				0.91			35.0									1,133		23				
Lakewatch	10/22/03				0.93			44.3									1,137		29				
Lakewatch	1/25/04				1.11			19.5									1,185		33				
Lakewatch	2/18/04				1.14			23.0									1,107		38				
Lakewatch	3/18/04				0.91			36.0									1,147		40				
Lakewatch	5/5/04				0.71			48.0									1,037		34				
Lakewatch	5/22/04				0.81			31.7									1,340		34				
Lakewatch	6/25/04				1.07			6.0									890		19				
Lakewatch	8/9/04				1.03			30.3									1,140		23				
Lakewatch	9/15/04				0.84			47.3									1,080		37				
Lakewatch	10/17/04				0.84			57.3									1,163		34				
Lakewatch	11/27/04				0.96			43.3									1,040		40				
Lakewatch	12/13/04				1.07			36.3									980		33				
Lakewatch	1/25/05				1.35			21.0									927		26				
Lakewatch	2/11/05				1.55			16.5									890		29				
Lakewatch	3/24/05				1.26			25.0									900		35				
Lakewatch	4/23/05				0.91			28.7									913		24				
Lakewatch	5/28/05				0.91			39.0									1,337		30				
Lakewatch	6/18/05				1.10			20.0									1,090		24				
Lakewatch	7/17/05				1.46			13.7									803		16				
Lakewatch	8/16/05				1.05			20.0									860		23				
Lakewatch	9/11/05				1.08			30.0									923		19				
Lakewatch	10/13/05				1.83			15.3									730		15				
Lakewatch	11/13/05				1.31			12.0									620		17				
Lakewatch	12/19/05				1.52			6.5									873		18				
Lakewatch	1/22/06				1.95			7.5									953		14				
Lakewatch	2/10/06				1.68			7.0									917		14				
Lakewatch	3/11/06				2.90			5.0									895		11				
Lakewatch	4/14/06				2.51			10.0									700		17				
Lakewatch	5/19/06				1.77			7.3									623		17				
Lakewatch	6/17/06				1.45			18.3									653		23				
Lakewatch	6/22/06		7.90	315		15.0		11.9	6.0								640		12				
Lakewatch	7/20/06				1.16			24.0									740		31				
Lakewatch	8/11/06				1.30			19.0									867		21				
Lakewatch	9/11/06				1.11			23.0									793		19				
Lakewatch	10/8/06				1.31			22.3									800		22				
Lakewatch	11/11/06				1.40			16.0									733		16				
Lakewatch	12/10/06				1.50			15.5									855		16				
Lakewatch	1/13/07				1.14			23.0									810		17				
Lakewatch	2/11/07				1.31			20.0									847		17				
Lakewatch	3/10/07				1.30			16.3									880		20				
Lakewatch	4/22/07				0.88			15.3									1,030		20				

Source	Date	Station	Parameter																				
			pH	Cond	Secchi	Alk	BOD5	Chla	Color	DO	NH3	NO2	NO3	Nox	TKN	N Organic	Total N	SRP	Total P	Total Coliforms	Fecal Coliform	TSS	Turb
			s.u.	µmho/cm	m	mg/l	mg/l	µg/l	Co-Pt	mg/l	µg/l	µg/l	µg/l	µg/l	µg/l	µg/l	µg/l	µg/l	µg/l	cfu/100ml	cfu/100ml	mg/l	NTU
Lakewatch	5/11/07				1.08			18.0									890		19				
Lakewatch	6/10/07				1.11			10.5									933		17				
Lakewatch	6/20/07		8.60	320		37.0		15.0	11.0								940		15				
Lakewatch	7/8/07				1.34			13.0									793		18				
Lakewatch	8/4/07				1.37			30.3									865		18				
Lakewatch	9/2/07				1.22			21.0									840		16				
Lakewatch	10/9/07				0.91			23.7									870		18				
Lakewatch	11/4/07				0.76			24.5									903		18				
Lakewatch	12/9/07				0.81			23.3									835		17				
Lakewatch	1/19/08				1.01			17.5									785		17				
Lakewatch	2/15/08				0.91			16.0									800		15				
Lakewatch	3/23/08				1.01			16.7									757		21				
Lakewatch	4/18/08				0.88			28.0									663		22				
Lakewatch	5/12/08				0.85			25.0									823		36				
Lakewatch	6/20/08				1.05			26.3									1,033		35				
Lakewatch	7/20/08				1.34			15.0									763		15				
Lakewatch	8/15/08				1.10			21.5									750		18				
Lakewatch	9/8/08				1.19			19.5									820		19				
Lakewatch	10/13/08				0.88			31.7									857		21				
Lakewatch	11/9/08				1.30			29.3									977		19				
Lakewatch	12/16/08				1.05			16.5									867		24				
Lakewatch	1/10/09				1.49			6.0									1,117		21				
Lakewatch	2/8/09				3.05			2.5									957		15				
Lakewatch	3/10/09							2.5									807		11				
Lakewatch	4/13/09				2.74			6.5															
Lakewatch	5/10/09				3.35			5.5															
Orange County	2/14/72	North		244	1.80					14.5	300		18			1,000	1,318	6	16				2.6
Orange County	7/17/72	North	8.30	274	2.10	89.0					10		90			610	710	6	20				5.4
Orange County	10/23/73	North	7.90	215		44.0	3.9	37.4		7.9			20			1,030	1,050	10	30				7.0
Orange County	8/5/74	North	8.30	190	1.50	54.0	2.0	33.7		8.3						700			41				5.0
Orange County	3/4/75	North	7.60	257	1.50	63.0	2.7	14.7		7.2	20		15			1,047	1,063	6	19				2.7
Orange County	3/8/77	North	8.30	240	0.80	60.0	3.5	42.9		9.8	25		50			1,000	1,075	5	19				5.4
Orange County	6/1/77	North	8.43	250	0.80	63.0	2.9	23.6		7.2	25		50			923	998	11	29				3.7
Orange County	8/29/77	North	7.43	240		60.0	1.6	29.2		6.1	25		50			843	918	5	18				2.8
Orange County	12/12/77	North	7.40		1.00	63.7	2.7	30.1		8.9	25		10			860	895	5	15				3.3
Orange County	2/15/78	North	7.10	240		62.0	4.1	28.5		11.6	60		10			740	810	22	54				3.2
Orange County	5/31/78	North	7.40	220	0.30	54.0	6.4	67.3		1.0	50		5			2,500	2,555	20					
Orange County		South	7.50	220	0.30	56.0	6.2	90.5		0.3	140		5			2,300	2,445	30					
Orange County	10/4/78	North	7.80	230	0.60	54.0	1.6	49.5		5.3	90		5			1,300	1,395	20	20				
Orange County		South	7.80	230	0.50	57.0	1.7	49.3		5.3	80		5			1,400	1,485	30	25				
Orange County	2/12/79	North	7.90	240	1.10	60.0	2.6	27.4		10.6	25		8			775		10	65				
Orange County		South	7.85	240	1.10	61.5	2.2	27.6		9.6	25		5			720	720	10	65				
Orange County	5/7/79	North	8.00	255	0.90	61.0	2.0	33.4		5.7	200		5			770	920	30	55				3.8
Orange County		South	8.00	260	0.90	61.5	1.9	32.6		5.7	170		5			920	1,090	20	58				3.7
Orange County	8/13/79	North	7.80	245		49.0	1.5	20.7		6.1	80		20			870	790	20	30				3.2
Orange County		South	7.65	228		49.0	1.3	19.2		5.4	85		40			565		10	28				1.6
Orange County	11/12/79	North	7.05	160	1.10	19.5	1.2	19.5		8.0	85		5			900		25	45				2.9
Orange County		South	7.35	160	1.10	20.5	1.6	21.3		8.3	85		5			680	765	25	45				3.1
Orange County	2/11/80	North	6.80	160	1.80	8.2	0.7	11.7		10.0	65		5			570		20	40				1.9
Orange County		South	6.95	160	1.80	9.8	0.7	11.0		10.5	60		8			545	595	15	40				1.7
Orange County	8/11/80	North	6.80	163	1.60	10.5	1.5	19.1		9.6	85		10			680		20	30				1.9
Orange County		South	6.65	155	1.70	11.5	2.3	23.0		6.2	190		8			745	970	20	33				2.1
Orange County	11/10/80	North	6.80	171	2.10	13.5	2.8			9.1	53		10			740		30	40				3.7

Source	Date	Station	Parameter																				
			pH	Cond	Secchi	Alk	BOD5	Chla	Color	DO	NH3	NO2	NO3	Nox	TKN	N Organic	Total N	SRP	Total P	Total Coliforms	Fecal Coliform	TSS	Turb
			s.u.	µmho/cm	m	mg/l	mg/l	µg/l	Co-Pt	mg/l	µg/l	µg/l	µg/l	µg/l	µg/l	µg/l	µg/l	µg/l	µg/l	cfu/100ml	cfu/100ml	mg/l	NTU
Orange County		South	6.80	177	2.10	13.5	1.9	13.8		7.9	70		10			685	770	40	45				3.0
Orange County	1/19/81	North	7.03	175	1.90	13.3	2.3	8.6		10.5	70		27			1,140	1,223	33	77				1.7
Orange County		South	6.90	175	2.10	15.3	2.4	11.8		10.2	73		10			967	1,122	37	63				2.2
Orange County	2/2/81	North	7.10	180	1.30	16.0	2.1	17.0		10.4	70		20			713	803	13	30				3.2
Orange County		South	6.90	182	1.30	15.3	1.8	17.4		9.6	103		12			690	803	20	32				4.0
Orange County	2/16/81	North	7.10	172	1.00	17.0	1.3	27.0		9.7	160		5			1,297	1,433	27	50				3.6
Orange County		South	7.10	178	1.00	17.7	0.6	26.4		9.5	127		7			1,157	1,340	30	50				3.7
Orange County	3/2/81	North	7.10	188	1.20	18.0	2.7	18.8		8.9	90		33			990	1,090	17	37				2.9
Orange County		South	7.00	187	1.20	18.0	2.5	24.8		7.7	347		67			580	993	23	47				3.0
Orange County	3/30/81	North	7.73	184	1.00	19.7	2.8	18.0		9.6	37		7			2,163	2,200	37	67				4.1
Orange County		South	7.57	177	1.00	20.0	2.3	18.8		9.8	67		13			1,600	1,667	40	60				4.1
Orange County	4/14/81	North	8.03	198	1.00	21.0	3.1	18.0		7.5	90		27			1,677	1,793	37	67				3.5
Orange County		South	7.77	198	1.00	20.7	3.2	19.5		7.6	83		37			1,583	1,703	43	43				3.0
Orange County	4/27/81	North	7.23		1.00	22.0	3.0	20.3			277		13			790	1,067	23	53				4.4
Orange County		South	7.33		1.00	20.7	2.4	18.6			137		10			963	1,100	27	53				3.6
Orange County	5/11/81	North	7.20	200	1.20	22.0	2.4	15.7		7.6	113		10			1,077	1,200	27	40				2.7
Orange County		South	7.37	192	1.20	22.3	2.6	19.5		8.1	87		10			937	1,033	30	47				2.9
Orange County	5/26/81	North	7.40	193	1.10	23.3	2.3			7.8	85		7			573	847	23	50				3.4
Orange County		South	7.60	185	1.10	22.7	2.0			9.1	97		32			877	1,003	20	47				3.1
Orange County	6/9/81	North	7.37		1.00	24.0	3.1	17.9			95		20			830	1,220	30	40				3.4
Orange County		South	7.37		1.00	24.0	3.0	18.8			90		20			1,103	1,413	33	43				3.5
Orange County	6/22/81	North	7.10		1.10	25.5	3.2	19.5			105		8			1,245	1,303	25	47				2.9
Orange County	6/30/81	North	6.40		1.10	26.0	3.1	18.9			38		13			1,075	1,140	30	47				2.7
Orange County	7/28/81	North	6.83		1.00	26.7	4.1	22.4		6.1	123		7			640	783	10	63				3.4
Orange County		South	6.80		1.00	25.3	7.1	22.6		3.3	350		7			520	870	10	67				3.4
Orange County	8/10/81	North	7.57	197	1.00	28.0	7.0	31.3		4.8	160		10			1,307	1,477	30	47				4.4
Orange County		South	7.17	192	1.10	27.0	8.3	33.5		4.7	47		10			1,187	1,233	33	47				4.0
Orange County	8/25/81	North	7.07	197	0.60	30.0	2.6	33.3		5.3	220		8			1,347	1,573	30	60				4.0
Orange County		South	7.17	194	0.70	28.3	2.3	27.3		5.6	740		15			1,040		37					3.6
Orange County	8/28/81	South															1,333		53				
Orange County	9/8/81	North	6.60		0.80	30.3	2.6	32.5			60		27			640	1,170	40	60				4.8
Orange County		South	6.60		0.80	30.0	2.4	31.0			103		8			1,037	1,140	33	53				4.0
Orange County	9/21/81	North	7.97		0.80	30.0	1.9	34.3			67		10			950	1,033	25	41				4.7
Orange County		South	7.90		0.80	27.7	2.0	35.3			163		20			900	1,063	27	46				4.3
Orange County	10/5/81	North	7.35	210		28.8	2.0	27.6		7.5	60		25			885	970	34	106				4.6
Orange County		South	6.95	210		30.1	2.4	27.6		7.3	135		20			780	915	35	97				4.8
Orange County	10/26/81	North	7.47	193		30.3	2.8	30.0		5.6	67		13			987	1,067	32	84				5.1
Orange County		South	7.40	183		30.5	2.9	31.4		5.0	40		10			975	1,015	45	95				5.3
Orange County	11/9/81	North	7.73	185	1.40	31.0	2.9	38.5		8.7													5.2
Orange County		South	7.93	180	1.40	31.0	2.7	34.3		8.4								19	58				5.1
Orange County	11/24/81	North	7.93	195	0.80	31.0	3.6	37.1		9.8	70		20			1,833	2,000	26	50				5.1
Orange County		South	7.87	195	0.80	30.7	3.3	38.0			57		20			1,400	1,467	20	55				5.0
Orange County	12/7/81	North	7.33	195	0.60	31.0	3.0	34.6		6.4	223		20			1,177	1,400	20	56				3.8
Orange County		South	7.13	195	0.60	31.3	2.6	37.2		6.6	200		20			1,233	1,433	37	63				4.3
Orange County	12/22/81	North			0.90			31.8		9.9	120		20			1,880	2,000	7	65				4.1
Orange County		South			0.90			31.1		9.6	127		43			1,840	2,000	9	73				4.3
Orange County	1/12/82	North	7.20		0.60	32.8	3.0	36.5		9.5	90		20			985	1,067	18	72				5.5
Orange County		South	7.13		0.60	32.0	2.7	37.8		9.2	73		20			1,093	1,167	15	71				6.2
Orange County	1/25/82	North	6.47	210	0.90	35.7	3.4	28.6		8.0	263		27			937	1,200	14	63				5.2
Orange County		South	6.33	210	1.00	32.0	3.0	26.0		8.8	313		27			787	1,100	12	54				4.8
Orange County	2/8/82	North	8.07	222	0.90	33.7	3.9	30.5		8.3	160		27			940	1,100	39	53				5.8
Orange County		South	8.13	268	0.90	33.7	6.3	30.5		6.8	103		27			1,163	1,267	18	53				5.7
Orange County	2/22/82	North	7.37		0.60	36.3	3.8	32.1		9.3	150		20			1,717	1,867	11	51				7.5

Source	Date	Station	Parameter																				
			pH	Cond	Secchi	Alk	BOD5	Chla	Color	DO	NH3	NO2	NO3	Nox	TKN	N Organic	Total N	SRP	Total P	Total Coliforms	Fecal Coliform	TSS	Turb
			s.u.	µmho/cm	m	mg/l	mg/l	µg/l	Co-Pt	mg/l	µg/l	µg/l	µg/l	µg/l	µg/l	µg/l	µg/l	µg/l	µg/l	cfu/100ml	cfu/100ml	mg/l	NTU
Orange County		South	7.33		0.70	35.3	3.5	32.0		9.3	143		27			2,290	2,433	13	53				7.0
Orange County	3/15/82	North	7.63	260	0.60	36.3	12.4	32.2		7.2	153		67			1,313	1,567	13	59				8.5
Orange County		South	7.60	260	0.60	36.7	8.0	31.7		8.4	153		57			1,147	1,400	13	55				8.2
Orange County	3/22/82	North	7.43	193	0.60	37.0	10.6	46.5		6.8	100		20			1,467	1,567	12	60				9.4
Orange County		South	7.20	193	0.70	37.0	8.0	44.1		8.1	60		20			1,473	1,533	10	56				9.8
Orange County	4/5/82	North	7.17		1.00	38.3	3.2	49.2		9.2	330		47			1,103	1,500	12	56				9.5
Orange County		South	7.33		1.00	37.0	3.1	48.1		8.3	233		47			1,067	1,333	12	55				8.5
Orange County	4/19/82	North	7.00	223	0.70	37.7	6.5	56.1		6.4													10.0
Orange County		South	7.57	227	0.70	38.0	6.8	50.3		6.7													10.0
Orange County	5/10/82	North	6.43	195	0.50	40.3	4.5	53.9		6.9	113		37			827	993						
Orange County		South	6.87	205	0.50	40.0	7.2	52.8		6.0	100		70			943	1,133	16					
Orange County	5/25/82	North	7.83	197	0.70	40.0	7.9	41.7		6.0	37		33			290	323	29	56				
Orange County		South	7.97	197	0.70	40.0	16.6	41.8		5.4	85		20			180	257	38	48				
Orange County	6/7/82	North	7.23	205	0.60	37.7	4.5	48.6		6.6	63		27			1,167	1,243	21	55				6.7
Orange County		South	7.70	210	0.50	37.7	4.1	49.5		7.3	68		20			883	960	21	54				6.5
Orange County	6/21/82	North	6.80	192	0.40	41.0	3.8	48.9		6.0	493		60			507	1,060	8	77				5.8
Orange County		South	6.70	197	0.40	40.7	3.7	51.5		5.6	243		37			627	900	4	43				5.3
Orange County	7/6/82	North	7.07	220	0.70	44.0	4.1	38.3		5.9	100		30			610	753	81	160				3.6
Orange County		South	6.80	220	0.70	43.3	3.3	38.4		5.7	80		43			760	883	76	140				3.6
Orange County	7/26/82	North	6.50	233	0.80	75.0	1.9	23.4		4.7	120		67			900	1,087	21	56				4.4
Orange County		South	6.53	223	1.00	75.3	2.2	18.9		5.7	92		43			1,117	1,237	22	49				4.1
Orange County	8/9/82	North	6.20	198	0.90	60.7	3.5	27.0		7.0	123		20			970	1,100	10	43				3.7
Orange County		South	6.33	193	0.90	44.0	3.0	26.5		7.4	42		20			1,233	1,233	10	39				3.4
Orange County	8/23/82	North	6.60	200	1.00	40.7	2.7	23.6		5.9	87		20			1,300	1,500	8	46				3.3
Orange County		South	6.73	207	1.00	43.3	2.4	22.5		6.3	157		33			1,047	1,233	12	42				3.1
Orange County	9/7/82	North	6.10	210	1.00	44.0	2.1	26.6		5.7	93		20			1,300	1,400	6	42				3.6
Orange County		South	6.30	205	1.00	44.0	2.2	27.0		6.2	117		37			1,190	1,333	4	39				3.3
Orange County	9/20/82	North	6.20		1.00	42.7	3.4	23.3		5.5	70		20			1,030	1,100	16	44				2.5
Orange County		South	6.60		1.00	44.0	3.3	22.7		5.3	82		20			1,037	1,110	4	37				2.9
Orange County	9/26/82	North															1,910		51				
Orange County	10/4/82	North	6.60	230	0.90	45.0	1.7	27.4		7.2	153		20			1,453	1,600		48				4.1
Orange County		South	7.30	230	0.90	41.7	2.3	27.9		7.7	107		20			1,167							3.9
Orange County	10/14/82	South															1,267		46				
Orange County	10/18/82	North	6.80		0.90	38.7	4.8	36.4		6.9	173		27			877	1,063	6	41				3.7
Orange County		South	6.73		0.80	38.0	2.9	37.6		7.5	103		27			993	1,100	6	44				3.5
Orange County	11/1/82	North	6.70	197	0.50	39.0	2.2			9.0	140		53			1,047	1,233	12	52				4.6
Orange County		South	6.73	193	0.50	38.3	2.7			9.3	57		20			1,710	1,767	11	43				3.8
Orange County	11/15/82	North	6.60	222	0.80	37.3	2.5	47.9		7.7	163		27			1,167	1,350	7	49				4.3
Orange County		South	6.60	270	0.80	37.0	2.6	48.0		7.7	100		20			1,153	1,267	8	51				4.2
Orange County	11/29/82	North	7.20	197	0.80	38.0	4.0	39.1		5.6	177		27			1,090	1,267	4	58				4.2
Orange County		South	7.40	200	0.80	38.0	3.4	41.3		4.4	210		50			1,090	1,333	4	54				4.2
Orange County	12/13/82	North	7.10	227	0.80	44.0	2.0	46.3			42		20			1,077	1,077	13	49				4.4
Orange County		South	6.73	212	0.60	44.0	2.0	49.7			25		20			1,167	1,167	11	46				4.6
Orange County	1/3/83	North	6.67	210	0.90	48.0	4.2			5.7	77		20			1,067	1,167	8	47				3.7
Orange County		South	6.80	210	0.90	44.0	2.8			6.5	80		20			947	1,043	10	35				3.6
Orange County	1/17/83	North	6.30		0.60	37.0	4.0	28.6		9.3	173		20			1,090	1,267	6	38				3.9
Orange County		South	6.63		0.60	37.3	3.4	27.7		9.5	100		20			1,100	1,200	8	43				3.5
Orange County	1/31/83	North	5.60		0.80	44.7	3.6			9.4	123		20			940	1,060	8	37				3.7
Orange County		South	5.60		0.80	41.7	3.3			9.6	103		20			917	1,020	11	39				4.2
Orange County	2/15/83	North	6.40	300	1.30	43.7	4.3			9.8	77		20			1,333		21					4.7
Orange County		South	6.40	300	1.40	43.7	4.4			9.8	77		20			1,400	1,500	11	58				4.3
Orange County	3/1/83	North	6.20	227	0.60	43.0	3.8	47.6		9.5	42		20			1,157		12					4.7
Orange County		South	6.47	220	0.80	43.3	3.5	45.1		9.6	62		33			637	710	9	58				4.5

Source	Date	Station	Parameter																				
			pH	Cond	Secchi	Alk	BOD5	Chla	Color	DO	NH3	NO2	NO3	Nox	TKN	N Organic	Total N	SRP	Total P	Total Coliforms	Fecal Coliform	TSS	Turb
			s.u.	µmho/cm	m	mg/l	mg/l	µg/l	Co-Pt	mg/l	µg/l	µg/l	µg/l	µg/l	µg/l	µg/l	µg/l	µg/l	µg/l	cfu/100ml	cfu/100ml	mg/l	NTU
Orange County	3/15/83	North	6.60	240	0.80	44.0	3.5	29.8		8.9	117		20			1,443		11					3.7
Orange County		South	6.60	232	0.80	44.0	3.1	27.5		9.8	63		20			1,057	1,120	13	48				3.7
Orange County	3/23/83	North	6.10	270	0.80	47.0	5.4	37.0		8.8	290		50			1,240		22					4.7
Orange County	3/28/83	North	5.80	153		45.0	4.2	40.6		8.6	275		75			1,525	1,777	16	94				6.6
Orange County		South	5.90	162	0.80	44.0	4.4	34.4		8.8	200		63			1,130	1,393	19	52				4.5
Orange County	4/12/83	North	7.47	220	0.50	46.0	3.9	34.5		6.4	110		20			1,250	1,360	25	56				4.0
Orange County		South	7.43	220	0.50	46.0	4.0	33.0		7.3	130		20			1,130	1,260	18	51				3.8
Orange County	5/3/83	North	7.60	227	0.60	49.3	3.8	27.8		6.3	100		20			660	760						4.7
Orange County		South	7.37	242	0.60	46.7	3.3	25.2		5.8	137		30			603	757						4.5
Orange County	5/17/83	North	7.63	230	0.80	48.3	4.1	29.4		6.3	83		30			1,677	1,777	13	49				4.2
Orange County		South	7.77	232	0.70	50.3	3.6	25.6		5.4	37		20			1,400	1,420	18	44				4.0
Orange County	5/31/83	North	6.30		0.80	46.0	3.8	29.9		6.6	150		20			1,120	1,270	14	51				4.3
Orange County		South	6.54		0.80	44.0	3.2	28.3		6.4	107		27			1,133	1,253	11	42				3.7
Orange County	6/14/83	North	7.25	245	0.60	49.9	3.5	43.7		6.0	63		20			1,407	1,470	11	54				4.1
Orange County		South	7.59	230	0.60	47.0	3.2	37.3		7.4	63		20			1,207	1,270	15	48				3.5
Orange County	6/28/83	North	7.73	273	0.60	51.7	3.4	30.3		4.6	97		53			1,723	1,873	13	49				3.9
Orange County		South	7.67	265	0.60	50.3	2.4	26.8		4.6	107		20			1,533	1,640	8	41				3.7
Orange County	7/11/83	North	8.50	240	0.60	51.3	2.5	51.7		7.2	103		27			1,513	1,630	36	51				4.3
Orange County		South	8.83	237	0.60	49.7	2.2	46.6		5.9	40		27			1,547	1,583		26				3.7
Orange County	7/25/83	North	8.40	228	0.60	48.3	4.2	40.0		4.9	70		20					16	48				3.7
Orange County		South	8.67	227	0.60	45.7	5.1	38.7		6.4	82		20					15	49				3.5
Orange County	8/9/83	North	7.17	240	0.80	49.0	3.8	30.3		4.9	180		97					7	43				3.8
Orange County		South	7.03	240	0.70	46.0	2.7	33.9		3.1	193		20					5	39				3.3
Orange County	8/23/83	North	7.83	240	0.60	40.3	4.7	34.4		7.3	33		20			1,073	1,090	11	42				3.0
Orange County		South	7.57	240	0.60	39.7	3.9	35.8		5.7	110		77			1,040	1,213	12	43				2.8
Orange County	9/6/83	North	7.60	230	0.80	54.7	6.6	33.2		5.2	103		20			957	1,060	10	48				3.1
Orange County		South	7.73	230	0.80	51.0	5.1	30.5		5.5	90		20			1,077	1,150	14	49				2.5
Orange County	9/20/83	North	7.73	245	0.90	52.7	2.7	34.2		5.3	77		20			953	1,030	12	31				2.7
Orange County		South	7.73	242	0.90	51.0	2.5	31.5		5.6	97		20			943	1,040	6	29				2.4
Orange County	10/18/83	North	8.00	230	0.70	54.0	3.9	47.3		7.0	67		20			2,543	2,650	16	62				3.8
Orange County		South	8.03	227	0.60	52.0	3.0	48.3		7.5	33		20			3,450	3,540	14	58				3.8
Orange County	11/1/83	North	8.27	240	0.50	53.7	4.3	48.7		8.6	63		20			1,437	1,540	17	66				3.7
Orange County		South	8.47	240	0.60	53.0	3.6	47.7		8.0	33		20			1,280	1,370	20	69				4.0
Orange County	11/15/83	North	8.37	247	0.70	79.7	4.3	47.9		8.7	48		20			1,223	1,320	14	64				4.1
Orange County		South	8.13	245	0.50	79.0	3.9	49.0		7.5	37		20			1,147	1,240	16	69				4.2
Orange County	11/29/83	North	7.73	250	0.60	56.3	4.4	34.0		6.1	120		60			1,190	1,383	24	49				4.5
Orange County		South	7.90	250	0.60	53.7	4.0	34.2		5.6	103		20			1,157	1,300	20	57				4.0
Orange County	12/12/83	North	8.40	222	0.40	54.7	2.3	60.7		6.4	68		20			1,240	1,327	14	69				4.6
Orange County		South	8.50	222	0.40	53.7	4.6	59.9		7.8	45		20			1,357	1,450	14	68				4.1
Orange County	1/8/84	South	7.87	257	0.80	49.0	3.9	30.5		9.4	133		50			847		15					3.5
Orange County	1/18/84	North	7.83	255	0.80	48.3	4.1	31.8		9.5	117		53			923	1,093	16	59				3.9
Orange County		South															1,030		57				
Orange County	1/30/84	South															1,410		61				
Orange County	1/31/84	North	7.73	265	0.60	54.0	4.7	41.6		10.5	110		27			1,110	1,260	13	63				4.2
Orange County		South	7.67	260	0.60	51.7	4.4	32.4		10.5	167		27			1,203		14					3.7
Orange County	2/8/84	North	7.67	225	0.70	52.7	3.7	37.1		8.3	117		20			213	330	9	65				4.5
Orange County		South	7.60	220	0.70	52.7	3.5	34.5		8.7	133		20			257	390	10	59				4.3
Orange County	2/28/84	North	4.83	260	0.50	53.2	3.7	29.6		8.7	120		20			1,290	1,450	10	88				4.5
Orange County		South	7.70	260	0.75	52.4	3.4	28.8		9.2	143		30			1,107		10					3.7
Orange County	2/29/84	South															1,293		73				
Orange County	3/14/84	North	8.13	273	0.80	54.0	3.5	24.5		9.7	62		20			740	850	13	74				3.5
Orange County		South	8.00	280	0.70	53.5	4.1	21.8		7.3	72		20			810	930	20	65				3.3
Orange County	3/27/84	North	8.10	313	0.60	55.4	5.3	27.9		7.9	100		20			1,160	1,260	11	56				3.2

Source	Date	Station	Parameter																				
			pH	Cond	Secchi	Alk	BOD5	Chla	Color	DO	NH3	NO2	NO3	Nox	TKN	N Organic	Total N	SRP	Total P	Total Coliforms	Fecal Coliform	TSS	Turb
			s.u.	µmho/cm	m	mg/l	mg/l	µg/l	Co-Pt	mg/l	µg/l	µg/l	µg/l	µg/l	µg/l	µg/l	µg/l	µg/l	µg/l	cfu/100ml	cfu/100ml	mg/l	NTU
Orange County		South	8.03	308	0.70	54.6	4.5	32.7		7.6	93		20			1,197	1,290	12	63				3.3
Orange County	4/11/84	North	7.70	313	0.70	58.0	4.0	36.1		6.5	160		20			850	1,010	17	60				3.8
Orange County		South	8.33	310	0.70	55.7	4.5	37.1		7.1	113		20			917	1,030	16	60				3.9
Orange County	4/24/84	North	8.20	322	0.50	53.2	4.4	41.2		6.6	93		43			897	1,033	16	66				5.1
Orange County		South	7.77	320	0.50	53.2	4.4	40.6		8.6	90		63			480	627	11	61				5.0
Orange County	5/8/84	North	8.33	248	0.50	54.3	7.2	53.5		4.5	123		20			1,637	1,760	12	77				7.8
Orange County		South	8.13	252	0.50	55.4	4.9	47.7		5.4	230		20			1,270	1,473	11	62				6.7
Orange County	5/23/84	North	8.70	255	0.40	59.4	12.1	72.9		3.9	183		20			1,947	2,130	15	63				9.1
Orange County		South	8.67	265	0.40	58.7	11.5	64.8		3.8	153		20			1,667	1,800	15	61				9.1
Orange County	6/12/84	North	8.60	263	0.50	60.9	7.2	75.4		3.2	207		20			1,360	1,567	23	57				5.1
Orange County		South	8.50	263	0.50	57.6	7.2	66.1		3.5	260		20			1,430	1,690	24	62				6.2
Orange County	6/26/84	North	9.50	272	0.40	64.7	6.4	89.9		4.4	335		20			1,823	2,150	15	65				5.9
Orange County		South	8.67	273	0.40	63.0	5.5	98.8		5.4	142		20			2,047	2,180	17	73				5.9
Orange County	7/18/84	North	8.40		0.40	62.4	7.3	93.4		4.1	443		20			2,297	2,743	21	76				4.4
Orange County		South	7.93		0.30	63.7	3.8	78.3		2.8	737		20			1,993	2,730	16	65				3.7
Orange County	7/31/84	North	7.77	230	0.60	65.7	4.9	52.8		3.7	523		20			1,793	2,317	17	66				3.7
Orange County		South	7.80	248	0.60	65.0	4.9	43.8		4.0	637		20			1,513	1,950	18	55				3.7
Orange County	8/15/84	North	8.10	245	0.70	64.7	6.8	31.5		2.2	295		27			1,803	2,103	16	49				3.6
Orange County		South	8.07	247	0.70	66.0	7.6	32.6		2.5	543		27			1,357	1,913	19	58				3.3
Orange County	8/25/84	South															2,070		53				
Orange County	8/28/84	North	7.43	238	0.70	67.3	8.1	35.9		2.8	590		20			1,310	1,900	23	52				3.6
Orange County		South	7.70	240	0.70	64.7	6.2	37.9		3.9	353		47			1,397	1,783	22	54				3.3
Orange County	9/2/84	South															1,610		54				
Orange County	9/12/84	North	8.23	240	0.50	64.3	3.7	101.2		7.5	137		30			1,443	1,597	14	54				4.2
Orange County		South	8.40	237	0.50	65.7	4.3	96.7		6.3	200		20			1,410		15					4.2
Orange County	9/25/84	North	8.20	250	0.50	64.7	4.1	87.0		6.5	163		37			1,917	2,110	21	55				3.9
Orange County		South	8.10	250	0.60	66.0	3.9	83.0		6.1	77		20			2,053	2,160	17	59				4.0
Orange County	10/10/84	North	8.30	257	0.50	66.0	4.1	112.3		7.6	70		20			2,480		14					4.8
Orange County		South	8.53	260	0.50	64.3	4.5	107.2		8.3	70		20			2,330	2,400	17	82				4.9
Orange County	10/11/84	North															2,550		67				
Orange County	10/23/84	North	8.20	273	0.70	65.0	6.2	61.5		4.7	127		20			1,053	1,180	27	82				3.9
Orange County		South	8.40	270	0.70	64.7	6.6	59.1		3.6	80		27			840	933	22	85				4.1
Orange County	11/6/84	North	8.07	278	0.60	65.0	3.9	84.6		7.5	133		20			1,717	1,850	16	58				4.3
Orange County		South	8.20	273	0.60	65.0	3.7	71.8		7.7	180		20			1,420	1,600	9	61				4.3
Orange County	11/20/84	North	8.47	265	0.50	64.3	5.4	81.9		9.7	117		20			1,539	1,850	20	60				4.3
Orange County		South	8.20	265	0.50	60.3	4.9	78.6		9.0	157		20			1,653	1,810	26	58				4.6
Orange County	12/4/84	North	7.40	253	0.50	69.0	6.2	73.5		5.6	253		30			1,537	1,807	21	49				4.5
Orange County		South	7.77	250	0.40	60.0	5.8	66.2		7.2	207		63			1,453	1,723	15	80				4.3
Orange County	12/18/84	North	7.37	260	0.80	69.3	2.2			5.1	273		20			2,493	2,767	36	52				3.7
Orange County		South	7.63	257	0.80	71.0	2.8			6.6	483		20			1,917	2,400	17	59				4.3
Orange County	1/2/85	North	8.23	270	0.60	70.3	4.3	47.9		6.7	87		20			1,253	1,340	21	47				4.8
Orange County		South	7.73	267	0.60	67.7	3.6	45.5		6.1	433		20			1,497	1,930	21	44				5.1
Orange County	1/16/85	North	8.03	245	0.60	74.7	2.8	54.3			103		447			1,297	1,847	10	55				5.1
Orange County		South	8.00	245	0.60	73.0	2.2	51.2			73		117			1,257	1,447	11	59				5.1
Orange County	1/30/85	North	7.87	258	0.60	75.0	5.0	48.3		9.0	87		43			1,493	1,617	15	57				4.6
Orange County		South	7.93	263	0.60	76.0	4.3	44.7		9.9	77		33			1,503	1,607	16	52				4.5
Orange County	2/13/85	North	7.93	233	0.60	74.6	3.9	45.8		9.2	57		20			1,403	1,460	16	68				4.8
Orange County		South	7.73	255	0.50	74.6	3.9	47.6		9.3	67		37			1,453	1,550	18	65				4.7
Orange County	2/26/85	North	8.03	255	0.80	72.5	5.1	37.5		7.4	162		67			1,447	1,660	11	53				4.1
Orange County		South	8.10	250	0.50	72.1	3.9	35.1		8.2	253		40			997	1,283	7	55				4.4
Orange County	3/13/85	North	8.30	248	0.60	75.6	4.4	38.7		8.8	103		43			1,427	1,573	14	54				4.2
Orange County		South	8.20	253	0.60	74.6	4.7	39.3		8.2	187		73			1,323	1,577	12	48				4.3
Orange County	3/27/85	North	8.33	250	0.30	77.4	3.8	47.8		9.0	37		33			1,590	1,637	15	67				4.7

Source	Date	Station	Parameter																				
			pH	Cond	Secchi	Alk	BOD5	Chla	Color	DO	NH3	NO2	NO3	Nox	TKN	N Organic	Total N	SRP	Total P	Total Coliforms	Fecal Coliform	TSS	Turb
			s.u.	µmho/cm	m	mg/l	mg/l	µg/l	Co-Pt	mg/l	µg/l	µg/l	µg/l	µg/l	µg/l	µg/l	µg/l	µg/l	µg/l	cfu/100ml	cfu/100ml	mg/l	NTU
Orange County		South	8.10	253	0.40	78.5	4.1	48.8		9.0	33		27			1,683	1,713	10	69				5.0
Orange County	4/23/85	North	8.07	247	0.30	77.0	5.4	51.6		3.9	227		20			1,183	1,410	16	51				4.5
Orange County		South	8.23	270	0.30	78.5	6.1	54.1		4.1	220		20			1,210	1,430	20	59				4.7
Orange County	5/8/85	North	8.50	250	0.40	77.7	5.1	75.3		4.6	60		20			2,077	2,120	16	61				6.8
Orange County		South	8.30	255	0.40	79.3	4.6	64.4		4.7	52		20			1,897	1,940	18	71				6.6
Orange County	5/21/85	North	8.53	262	0.50	73.2	6.6	69.0		4.5	93		53			2,077		18					7.9
Orange County		South	8.43	253	0.40	74.2	5.9	66.3		3.5	87		40			1,963	2,083	17	61				6.9
Orange County	5/26/85	North															2,223		66				
Orange County	6/5/85	North	8.37	305	0.50	72.5	5.7	53.8		5.1	25		20			1,850	1,850	15	55				4.9
Orange County		South	8.20	283	0.50	72.9	5.2	54.0		3.7	1,270		20			2,080	3,350	11	54				5.0
Orange County	6/19/85	North	8.33	220	0.40	64.4	6.9	57.2		3.4	322		20			1,727	2,040	13	55				5.6
Orange County		South	7.97	265	0.50	67.6	6.9	56.8		3.5	108		27			1,880	1,993	16	53				4.8
Orange County	7/1/85	North	8.07	265	0.50	76.7	7.5	40.5			673		93			1,647	2,400	17	64				6.8
Orange County		South	8.13	237	0.60	73.8	4.8	43.6			137		20			1,603	1,730	15	51				5.2
Orange County	7/17/85	North	7.90	250	0.60	77.4	7.1	38.6		3.3	453		20			1,713	2,000	6	47				
Orange County		South	8.03	238	0.60	72.1	5.6	40.5		3.1	217		20			1,553	1,703	8	35				4.7
Orange County	7/31/85	North	8.20	237	0.50	72.0	4.1	49.6		2.9	105		20			1,753	1,850	11	51				5.5
Orange County		South	8.10	227	0.50	76.0	4.9	47.1		3.7	510		20			1,470	1,980	6	56				6.1
Orange County	8/4/85	South															2,040		60				
Orange County	8/14/85	North	8.17	230	0.60	79.0	5.5	59.5		3.6	118		20			1,570	1,680	28	57				4.8
Orange County		South	7.97	230	0.60	79.4	5.8	55.9		3.6	637		20			1,403		12					5.2
Orange County	8/27/85	North	8.20	250	0.50	69.3	5.8	46.2		4.8	52		20			1,443	1,487	7	44				6.2
Orange County		South	8.00	247	0.50	69.0	4.9	53.0		4.5	147		113			1,243	1,497	6	61				5.3
Orange County	9/17/85	North	7.67	250	0.50	69.3	3.8	45.8		4.9	103		150			1,557	1,810	4	40				5.3
Orange County		South	7.70	257	0.50	72.0	4.2	52.3		3.9	377		103			1,450	1,947	4	49				5.1
Orange County	10/2/85	North	7.97	225	0.60	67.6	3.4	53.5		5.7	60		20			1,517	1,560	24	48				5.1
Orange County		South	8.00	223	0.60	67.4	3.3	55.0		5.9	153		14			1,417	1,570	19	69				5.1
Orange County	10/16/85	North	8.70	242	0.60	67.2	3.4	58.8		5.6	50		20			1,900	1,950	5	63				4.3
Orange County		South	8.23	237	0.60	68.3	4.0	58.5		4.3	70		20			1,770	1,840	6	53				4.4
Orange County	10/29/85	North	7.80	223	0.50	70.9	3.2	66.5		5.7	125		20			5,940	6,065	13	48				4.5
Orange County		South	7.80	200	0.50	70.4	3.7	65.5		5.6	105		20				2,085	9	55				4.5
Orange County	11/13/85	North	7.75	265	0.60	73.3	4.7	83.1		7.1	155		20			1,780	1,935	4	56				4.4
Orange County		South	8.10	248	0.40	73.0	4.8	84.2		7.5	80		20			1,720	1,800	4	70				4.9
Orange County	12/10/85	North	7.20	295	0.50	72.5	5.2	80.0		7.1	115		20			1,295	1,410	10	56				4.3
Orange County		South	7.35	290	0.50	72.5	4.7	78.1		7.8	85		20			1,295	1,380	12	53				3.9
Orange County	1/8/86	North	7.35	270	0.50	71.6	4.8	63.0			110		45			1,675	1,830	8	53				3.9
Orange County		South	7.35	270	0.50	70.5	4.7	59.4			75		40			1,560	1,675	7	33				3.7
Orange County	1/22/86	North	7.40	255	2.00	66.9	4.0	17.8		9.2	48		50			1,540	1,620	10	60				2.5
Orange County		South	7.30	260	2.00	65.9	3.6	39.3		8.7	38		50			1,475	1,550	4	50				2.2
Orange County	2/5/86	North	8.10	240	0.40	82.5	5.6	55.2		8.4	25		20			1,665	1,665	15	78				5.7
Orange County		South	7.90	240	0.40	80.0	4.2	50.7		8.4	78		20			1,420	1,485	11	72				5.7
Orange County	2/19/86	North	7.40	253	0.50	75.0	5.0	37.7		7.3	60		20			1,590	1,650	13	69				5.7
Orange County		South	7.60	260	0.50	73.9	6.6	44.2		7.1	43		20			1,395	1,425	16	67				5.3
Orange County	3/5/86	North	7.65	230	0.50	81.8	5.3	56.2		6.4	70		20			1,475	1,545	21	79				4.0
Orange County		South	7.50	250	0.50	80.1	5.0	62.3		8.6	70		20			1,370	1,440	20	75				4.5
Orange County	4/1/86	North	8.15	255	0.50	86.8	5.4	53.9			100		70			1,355	1,425	7	39				5.2
Orange County		South	8.00	270	0.50	91.0	5.2	52.2			785		90			835	1,210	4	41				4.9
Orange County	4/16/86	North	8.15	280	0.20	56.3	5.8	44.5		4.9	90		20			1,615	1,705	4	49				4.7
Orange County		South	8.20	275	0.40	56.7	4.9	43.4		7.6	43		40			1,590	1,650	4	48				4.8
Orange County	4/30/86	North	8.80	270	0.50	75.6	6.2	46.6		4.8	55		20			1,475	1,530	4	68				5.9
Orange County		South	8.65	250	0.50	80.4	6.0	49.9		6.1	150		20			1,290	1,440	7	61				5.6
Orange County	5/20/86	South															1,500		44				
Orange County	5/28/86	North	8.65	253	0.20	67.1	3.4	42.2		8.0	55		20			1,775	1,830	33	53				5.2

Source	Date	Station	Parameter																				
			pH	Cond	Secchi	Alk	BOD5	Chla	Color	DO	NH3	NO2	NO3	Nox	TKN	N Organic	Total N	SRP	Total P	Total Coliforms	Fecal Coliform	TSS	Turb
			s.u.	µmho/cm	m	mg/l	mg/l	µg/l	Co-Pt	mg/l	µg/l	µg/l	µg/l	µg/l	µg/l	µg/l	µg/l	µg/l	µg/l	cfu/100ml	cfu/100ml	mg/l	NTU
Orange County		South	8.70	238	0.30	66.6	5.5	31.5		6.8	70		20										5.0
Orange County	6/11/86	North	8.30	225	0.20	71.7	4.6	39.8		5.0	43		20			1,680	1,710	12	56				4.9
Orange County		South	8.50	228	0.20	71.2	4.6	41.9		6.2	65		20			1,900	1,965	37	56				4.6
Orange County	6/25/86	North	8.45	250	0.60	68.5	5.2	32.0		5.0	75		20			1,380	1,455	15	45				4.2
Orange County		South	8.40	263	0.60	56.5	6.3	50.8		4.5	160		20			1,820	1,980	18	59				3.9
Orange County	7/9/86	North	8.35	248	0.50	66.0	4.1	28.8		7.3	120		20			1,410	1,530						3.3
Orange County		South	7.85	248	0.50	66.5	3.6	31.1		7.0	240		180			1,455	1,865						2.8
Orange County	7/23/86	North	8.25	260	0.80	70.7	3.9	32.8		4.5	25		20			1,305	1,205	17	49				2.7
Orange County		South	7.70	255	0.60	79.8	5.5	36.5		4.6	453		20			1,390		6					3.2
Orange County	8/6/86	North	8.50	238	0.50	75.6	3.5	48.7		7.5	465		60			915	1,440	10	82				3.8
Orange County		South	8.40	243	0.50	75.6	3.2	44.1		7.2	235		40			1,385	1,560	12	64				2.5
Orange County	8/20/86	North	8.55	240		75.7	5.0	37.2		5.1	63		20			1,390	1,440	10	71				3.8
Orange County		South	7.75	245		75.5	4.2	44.0		4.6	88		20			1,440	1,530	9	43				3.2
Orange County	9/3/86	North	8.30	230	0.50	73.0	3.9	18.8		4.7	25		20			1,755	1,755	24	37				3.2
Orange County		South	8.25	223	0.50	73.7	3.4	17.8		7.4	25		20			1,470	1,470	29	38				3.3
Orange County	9/17/86	North	8.50	243	0.40	74.6	2.6	41.5		8.3	25		20			2,010	2,010	17	42				4.1
Orange County		South	8.45	228	0.40	71.2	2.5	34.4		5.4	85		20			1,130	1,215	17	41				4.1
Orange County	10/15/86	North	8.80	178	0.30	79.7	4.0	44.0		7.9	48		20			1,315	1,350	11	50				4.3
Orange County		South	8.80	240	0.30	78.8	3.9	49.1		8.4	95		20			1,225	1,320	10	49				4.2
Orange County	10/29/86	North	8.35	260	0.50	89.8	5.2	66.6		7.4	180		20			1,350	1,170	14	58				4.7
Orange County		South	8.40	260	0.50	89.6	4.3	65.6		7.2	115		20			1,160	1,275	36	55				4.4
Orange County	11/12/86	North	7.95	198	0.80	80.6	3.4	53.0		3.5	490		140			1,460	2,140	10	48				4.0
Orange County		South	8.20	140	0.80	78.7	2.4	41.2		4.4	315		65			1,635	2,015	10	47				3.8
Orange County	11/25/86	North	8.30	243	0.80	43.1	4.7	47.4		7.0	350		65			1,600	2,015	10	74				4.0
Orange County		South	8.35	235	0.80	78.0	3.5	47.4		7.1	125		45			1,750	1,920	9	62				3.7
Orange County	12/10/86	North	8.40	305	0.90	75.8	4.2	68.1		8.0	220		40			1,880	2,130	21	48				3.5
Orange County		South	8.25	305	0.80	76.0	3.8	63.3		8.0	325		20			1,925	2,250	22	50				3.9
Orange County	1/7/87	North	8.30	255	0.80	75.3	3.7	74.5			310		45			965	1,310	4	62				4.1
Orange County		South	8.35	260	0.80	74.8	3.3	63.2			875		55			625	1,555	4	57				3.9
Orange County	1/21/87	North	7.95	330	0.60	73.8	4.4	51.4		8.8	100		20					24	76				4.7
Orange County		South	8.20	315	0.50	73.0	5.5	44.1		9.8	48		20					24	74				4.6
Orange County	2/4/87	North	8.15	305	0.80	74.3	3.6	54.0		6.2	25		20			1,800	1,800	14	58				4.5
Orange County		South	8.05	305	0.80	74.0	3.0	45.9		7.7	80		35			2,170	2,275	19	57				4.3
Orange County	2/17/87	North	8.35	260	0.40	74.0	5.4	47.6		8.9	25					1,065		4	63				5.6
Orange County		South	8.30	265	0.30	73.0	5.0	46.2		9.5	43					1,215		9	62				5.1
Orange County	3/4/87	North	8.20	260	0.60	74.5	4.8	49.6		7.6	73		20			1,365	1,425	4	95				4.7
Orange County		South	8.40	255	0.60	77.8	5.1	54.4		9.1	38		20			2,000	2,025	15	76				4.5
Orange County	3/11/87	North	8.20	255		74.0	5.7	52.9		8.7	25		20			1,230	1,230	17	95				5.3
Orange County		South	8.20	258		73.5	4.9	55.8		8.8	48		20			1,180	1,215	19	93				5.0
Orange County	4/1/87	North	7.95	263	0.50	77.0				7.2	20		134			797	931	10	63				5.1
Orange County		South	7.85	260	0.50	67.0				7.0	20		56			971	1,017	10	59				4.5
Orange County	5/27/87	North		220	0.60	64.8	8.0	69.8		6.4	50		18			630	682	10	46				7.5
Orange County		South		205	0.60	58.3	5.2	72.9		7.3	20		23			710	710	10	43				7.4
Orange County	6/10/87	North	8.55	305	0.10	74.0	6.3	86.2		6.6	20		81			734	775	23	48				7.5
Orange County		South	9.35	275	0.10	52.8	7.0	88.4		8.3	20		122			651	755	23	46				7.1
Orange County	6/24/87	North	8.50	213	0.50	53.0	3.5	48.3		5.6								10	48				7.2
Orange County		South	8.25	225	0.40	55.5	2.7	40.0		7.0								10	44				6.5
Orange County	7/8/87	North	8.40	218	0.40	56.5	5.8	82.0		5.4	85		10			771	846	10	51				6.6
Orange County		South	8.45	223	0.60	59.0	5.7	71.6		5.2	272		10			578	825	10	45				6.2
Orange County	7/22/87	North	7.70	230	0.40	60.0	6.9	66.5		5.8			10				667		29				4.7
Orange County		South	7.95	210	0.40	56.5	5.2	61.2		3.5			10				701	22	27				4.6
Orange County	8/4/87	North	8.20	205	0.50	57.5	7.1			6.7	81		10			830	900	10	10				5.7
Orange County		South	8.20	215	0.80	57.5	6.3			7.8	20		10			642	642	10	10				5.4

Source	Date	Station	Parameter																				
			pH	Cond	Secchi	Alk	BOD5	Chla	Color	DO	NH3	NO2	NO3	Nox	TKN	N Organic	Total N	SRP	Total P	Total Coliforms	Fecal Coliform	TSS	Turb
			s.u.	µmho/cm	m	mg/l	mg/l	µg/l	Co-Pt	mg/l	µg/l	µg/l	µg/l	µg/l	µg/l	µg/l	µg/l	µg/l	µg/l	cfu/100ml	cfu/100ml	mg/l	NTU
Orange County	8/26/87	North	7.75	288	0.20	60.5	4.9	52.8			65		34			714	813	28	44				6.2
Orange County		South	8.40	268	0.40	62.0	4.4	50.7			20		35			804	839	29	40				6.9
Orange County	9/15/87	North																	42				
Orange County	9/16/87	North	8.60	218	0.30	62.0	8.0	52.1		5.4								43					5.9
Orange County		South	8.70	225	0.40	55.3	8.0	60.6		5.0								36	43				6.6
Orange County	9/27/87	North															910		51				
Orange County	9/29/87	North	7.65	175	0.50	60.0	7.5	88.2		3.5	84		27			800		35					7.7
Orange County		South	7.65	220	0.40	67.5	6.3	67.3		3.8			123				1,064	40	49				5.6
Orange County	10/12/87	North	7.60	200	0.40	67.3	5.5	87.0		9.8	61		23			585	668	44	58				5.3
Orange County		South	7.70	210	0.40	67.5	5.2	92.2		9.1	91		34			656	781	46	70				5.3
Orange County	10/27/87	North	8.60	280	0.50	67.0	7.0	86.5		11.5	879		31				792	32	60				5.4
Orange County		South	8.30	280	0.50	85.0	6.5	78.7		9.3	917		25				802	27	51				5.3
Orange County	11/4/87	North	7.60	280	0.50	69.0	4.3	78.7		8.8	343		10			362	705	10	61				5.5
Orange County		South	7.70	240	0.50	78.0	7.9	78.2		9.2	835		10				667	10	54				4.7
Orange County	11/9/87	South																	57				
Orange County	12/14/87	North	8.30	270	0.70	64.0	6.0	46.0		12.6	20		10			593	593	22	53				2.9
Orange County		South	8.30	300	0.70	67.0	5.5	42.4		12.2	20		1,038			592	1,630	20	48				2.9
Orange County	3/16/88	North	7.80	330		73.0	6.6	52.4		9.5	20		24			884	908	10	75				4.5
Orange County		South	7.80	340		69.0	5.5	54.0		9.3	20		21			884	905	10	66				4.5
Orange County	6/27/88	North	8.50	200	0.80	111.0	6.4	77.9		2.5	56		24			875	955	22	66				7.4
Orange County		South	8.60	220	0.90	113.0		86.1		3.5	58		75			844	977	10	69				7.3
Orange County	9/28/88	North	8.60	240		64.0	4.4	52.6		3.8	20		28					10	68				5.0
Orange County		South	8.40	235		62.0	4.5	46.7		3.6	42		36					10	71				5.3
Orange County	3/15/89	North	8.70	300	0.70	66.0	6.1	34.5		10.0	417		33			1,277	1,732	13	51				3.8
Orange County		South	8.40	300	0.70	71.0	5.9	35.5		10.3	41		22			1,615	1,688	18	58				3.8
Orange County	2/14/90	North	7.60	275	0.50	70.0	6.9	43.9		8.1	32		19			1,116	1,170	8	66				5.7
Orange County		South	7.50	274	0.60	73.0	5.1	41.7		8.8	28		20			1,099	1,157	7	55				6.1
Orange County	5/22/90	North	8.65	282	0.90	73.5	5.0	36.2		6.7	43		22			1,311	1,379	6	54				4.5
Orange County		South	8.50	281		70.0	1.9			6.0	36		20			1,472		2					4.0
Orange County	5/27/90	South			0.80	70.0		36.8									1,538		53				
Orange County	11/23/90	North			0.80												1,090		50				
Orange County	11/27/90	North	9.00	274	0.80	76.0	5.1	41.1		11.9	20		5			1,070	1,110	39	50				4.4
Orange County		South	8.90	274	0.70	76.0	5.1	44.7		11.9	110		5			790	920	23	55				4.4
Orange County	2/20/91	North	8.60	228	0.50	84.0	5.1	53.9		10.4	30		5			1,370	1,410	4	59				5.1
Orange County		South	8.50	227	0.60	84.0	3.9	57.1		10.3	30		5			1,330	1,380	10	64				5.3
Orange County	6/11/91	North	8.70	270	0.60	66.0	4.8	52.4		7.1	20		5			1,930	1,960	8	56				6.5
Orange County		South	6.70	269	0.70	67.0	4.7	45.8		7.9	5		5			1,880	1,910	10	59				6.5
Orange County	8/21/91	North	8.10	249	0.60	65.0	3.8	49.9		6.1	70		5			1,520	1,600	10	44				4.1
Orange County		South	7.80	244	0.70	65.0	5.1	38.6		4.7	80		5			1,420	1,520	7	43				3.6
Orange County	11/13/91	North	8.00	247	0.70	74.0	3.1	43.1		9.2	230		5			1,090	1,224	11	60				8.4
Orange County		South	8.10	248	0.80	73.0	3.2	57.4		9.4	90		5			1,260	1,365	9	54				7.7
Orange County	2/19/92	North			0.90			33.4									1,098		53				
Orange County		South			1.00	62.0		9.2									1,155		49				
Orange County	5/19/92	North			0.70												1,740		33				
Orange County	5/20/92	North			0.30			68.5									1,916		51				
Orange County		South			0.30	65.0		66.0									1,825		54				
Orange County	8/19/92	North			0.70			61.1									1,742		33				
Orange County		South			0.60	70.0		37.9									1,381		33				
Orange County	11/11/92	North			0.60			89.2									1,479		61				
Orange County		South			0.60	74.0		68.8									1,395		58				
Orange County	2/17/93	North			0.80			45.8									1,378		52				
Orange County		South			0.70	71.0		51.0									1,465		57				
Orange County	6/22/93	North			0.50			47.9									1,439		34				

Source	Date	Station	Parameter																				
			pH	Cond	Secchi	Alk	BOD5	Chla	Color	DO	NH3	NO2	NO3	Nox	TKN	N Organic	Total N	SRP	Total P	Total Coliforms	Fecal Coliform	TSS	Turb
			s.u.	µmho/cm	m	mg/l	mg/l	µg/l	Co-Pt	mg/l	µg/l	µg/l	µg/l	µg/l	µg/l	µg/l	µg/l	µg/l	µg/l	cfu/100ml	cfu/100ml	mg/l	NTU
Orange County		South			0.60	61.0		43.8									1,360		36				
Orange County	8/25/93	North			0.60			32.3									1,333		40				
Orange County		South			0.70	66.0		42.6									1,465		46				
Orange County	3/16/94	North			0.80			36.8									1,258		68				
Orange County		South			0.80	77.0		36.2									1,108		58				
Orange County	6/13/94	North			0.50			39.2									1,335		20				
Orange County		South			0.50	58.0		32.6									1,315		12				
Orange County	9/16/94	South			0.50	66.0		51.4									1,125		37				
Orange County	9/19/94	North			0.50			59.2									1,255		48				
Orange County		South						51.4															
Orange County	11/21/94	North			2.00			51.9									1,015		34				
Orange County		South			0.50	47.0		50.8									1,115		36				
Orange County	3/11/95	North						34.0															
Orange County		South						32.7															
Orange County	3/13/95	North			1.00			34.0									1,015		83				
Orange County		South			1.00	72.4		32.7											86				
Orange County	6/12/95	North			1.50			13.1									535		33				
Orange County		South			1.50	78.5		12.4									325		96				
Orange County	6/27/95	North			1.25														21				
Orange County		South			1.00																		
Orange County	8/23/95	North			0.75																		
Orange County		South			0.75																		
Orange County	9/26/95	North			0.75			42.8											70				
Orange County		South			0.75			40.1											26				
Orange County	10/2/95	North						42.8															
Orange County		South			0.75			31.3											18				
Orange County	11/28/95	North			0.75																		
Orange County		South			0.75														54				
Orange County	12/27/95	North			0.75																		
Orange County		South			0.75												1,335		46				
Orange County	2/28/96	North			0.75			24.2															
Orange County		South			0.75	75.0		24.6									1,025		31				
Orange County	4/3/96	North						32.6															
Orange County		South			1.50	75.0		31.7									1,131		47				
Orange County	4/22/96	North																	37				
Orange County	5/16/96	North			0.75												1,625		25				
Orange County		South			0.75	58.9											1,625		26				
Orange County	6/24/96	North			1.00			25.1											20				
Orange County		South			1.00	54.0		22.7									1,025		18				
Orange County	7/23/96	North						27.0															
Orange County		South						22.0															
Orange County	7/24/96	North			1.00			27.0									1,125		18				
Orange County		South			1.00	58.0		22.0									1,025		19				
Orange County	11/20/96	North						59.7															
Orange County		South			0.75	39.8		60.9									1,125		29				
Orange County	12/30/96	North			1.25			72.7									1,430		41				
Orange County		South			1.00	43.9		68.9									1,342		37				
Orange County	1/2/97	North			0.50			65.7											44				
Orange County		South			0.50	44.0		50.2											36				
Orange County	2/4/97	North			1.00			61.5									1,125		34				
Orange County		South			1.00	40.0		58.6									1,225		43				
Orange County	3/4/97	North			0.50			64.7											53				
Orange County		South			0.50	46.0		65.2											40				

Source	Date	Station	Parameter																				
			pH	Cond	Secchi	Alk	BOD5	Chla	Color	DO	NH3	NO2	NO3	Nox	TKN	N Organic	Total N	SRP	Total P	Total Coliforms	Fecal Coliform	TSS	Turb
			s.u.	µmho/cm	m	mg/l	mg/l	µg/l	Co-Pt	mg/l	µg/l	µg/l	µg/l	µg/l	µg/l	µg/l	µg/l	µg/l	µg/l	cfu/100ml	cfu/100ml	mg/l	NTU
Orange County	4/2/97	North			0.50			50.3									1,625		38				
Orange County		South			0.50	75.0		67.1									1,625		41				
Orange County	5/13/97	North			0.50			85.8											36				
Orange County		South			0.50	52.0		85.0											46				
Orange County	6/5/97	North			0.50			72.0									1,725		47				
Orange County		South			0.50	58.0		71.5									1,625		36				
Orange County	7/1/97	North			0.50			46.4											15				
Orange County		South			0.50	55.0		46.4											19				
Orange County	8/5/97	North			0.75																		
Orange County		South			0.75																		
Orange County	9/2/97	North			1.00			47.9									1,225		13				
Orange County		South			1.00	62.0		37.9									1,125		18				
Orange County	10/9/97	North			1.00			55.8									1,425		19				
Orange County		South			1.00	64.0		58.7									225		34				
Orange County	11/5/97	North			1.00			66.3									1,435		44				
Orange County		South			1.00	64.0		62.8									1,435		48				
Orange County	12/2/97	North			1.00			67.9									1,435		50				
Orange County		South			1.00	62.0		57.9									1,355		41				
Orange County	1/21/98	North			0.50			77.3									1,345		46				
Orange County		South	8.34	242		63.8	4.0	63.6		8.7	30	5	10	15	1,300	1,300	1,345	17	46	300	78	99.5	9.4
Orange County	2/9/98	North			1.00			63.7									1,337		54				
Orange County		South	7.57	242	1.00	59.0	4.0	70.0		9.2	20	5	10	15	1,300	1,300	1,335	17	56	106	28	100.3	9.3
Orange County	3/4/98	North			0.50			62.4									1,435		52				
Orange County		South	7.60	247		57.0	3.3	47.8		8.8	30	5	10	15	1,400	1,400	1,445	5	54	46	54	81.0	10.9
Orange County	4/8/98	North			0.50			70.3									1,635		36				
Orange County		South	8.65	255	0.50	58.8	4.7	60.3	11.0	8.2	20	5	10	15	1,800	1,800	1,835	30	25	28	14	94.3	10.4
Orange County	5/6/98	North			0.50			60.8									1,737		43				
Orange County		South	8.80	250	0.45	60.9	4.8	48.0	10.0	8.4	10	7	20	27	1,800	1,800	1,837	25	40	44	10	97.0	9.0
Orange County	6/3/98	North						27.2									1,540		25				
Orange County		South	8.92	264	0.55	57.8	4.1	27.9	10.0	7.5	20	5	10	15	1,400	1,400	1,435	19	28	6	6	92.0	7.2
Orange County	7/14/98	North			0.50			39.2									1,325		16				
Orange County		South	8.67	298	0.50	66.2	2.6		10.0	7.7	10	5	10	15	1,300	1,300	1,325	10	16	100	72	102.5	7.0
Orange County	8/6/98	North			0.50			29.0									1,335		23				
Orange County		South	7.99	274		63.0	2.5	32.0	10.0	6.1	10	5	10	15	1,400	1,400	1,425	200	22	170	600	99.8	7.0
Orange County	9/14/98	North			0.60			49.0									1,425		28				
Orange County		South	8.53	287	0.45	66.0	4.0	35.0	10.0	8.4	10	5	10	15	1,500	1,500	1,525	9	26	4	18	119.0	10.5
Orange County	10/7/98	North			0.50			35.0									1,435		26				
Orange County		South	8.78	262	0.50	57.0	3.6	31.0	5.0	9.5	10	5	10	15	1,400	1,400	1,425	21	28	46	48	99.5	7.0
Orange County	11/4/98	North			0.50			42.0									1,325		28				
Orange County		South	7.89	285	0.50	68.0	2.3	70.0	6.0	6.7	10	5	10	15	1,600	1,600	1,625	21	31	60	42	98.8	7.7
Orange County	12/2/98	North						67.9															
Orange County	12/17/98	North			0.50			66.0									1,525		27				
Orange County		South	8.12	271	0.50	65.4	3.3	59.0	7.0	8.1	10	5	10	15	1,200	1,200	1,225	12	29	310	42	91.0	7.7
Orange County	1/7/99	North			0.40			84.0									1,538		21				
Orange County		South			0.50			59.0									1,538		18				
Orange County	2/4/99	North			0.50			52.0									1,825		39				
Orange County		South			0.50	66.0		47.0									1,825		34				
Orange County	3/3/99	North			0.50			47.0									1,825		35				
Orange County		South			0.50	67.0		44.0									1,925		30				
Orange County	4/7/99	North			0.50			47.2									1,525		25				
Orange County		South				61.0		48.9									1,425		27				
Orange County	5/6/99	North			0.40			72.6									1,741		32				
Orange County		South			0.40	62.0		73.7									1,735		34				

Source	Date	Station	Parameter																				
			pH	Cond	Secchi	Alk	BOD5	Chla	Color	DO	NH3	NO2	NO3	Nox	TKN	N Organic	Total N	SRP	Total P	Total Coliforms	Fecal Coliform	TSS	Turb
			s.u.	µmho/cm	m	mg/l	mg/l	µg/l	Co-Pt	mg/l	µg/l	µg/l	µg/l	µg/l	µg/l	µg/l	µg/l	µg/l	µg/l	cfu/100ml	cfu/100ml	mg/l	NTU
Orange County	6/2/99	North			0.50			47.9									1,945		28				
Orange County		South			0.60	63.0		43.0									1,735		26				
Orange County	8/5/99	North			0.50			34.2									1,334		18				
Orange County		South			0.50	62.0		33.0									1,429		23				
Orange County	9/28/99	North			0.20			59.6									1,726		33				
Orange County		South			0.20	67.0		60.0									1,625		33				
Orange County	10/19/99	North			0.50			50.6									1,525		24				
Orange County		South			0.50	65.0		46.3									1,525		25				
Orange County	11/29/99	North			0.50			55.5									1,833		35				
Orange County		South			0.50	66.0		34.0									1,531		26				
Orange County	12/9/99	North			0.50			59.7									2,041		40				
Orange County		South			0.50	68.0		57.8									2,025		32				
Orange County	1/6/00	North	8.08	283	0.30	67.0	2.3	44.9	5.0	8.9							1,600		25	800	60	99.0	7.1
Orange County		South	8.13	283	0.30	68.0	2.7	45.2	5.0	9.9							1,500		27	500	70	98.5	8.0
Orange County	2/2/00	North	8.35	293	0.30	68.0	4.5	56.3	5.0	12.4	25	10	10	10	1,600	1,600	1,700		56	3,900	140	75.5	9.4
Orange County		South	8.39	293	0.30	69.0	4.1	59.4	5.0	10.1	20	10	10	10	1,600	1,600	1,700		47	900	52	94.0	9.2
Orange County	3/16/00	North	8.38	286	0.30	68.0	3.4	48.5	5.0	8.1	21	10	10	10	1,600	1,600	1,600		56	80	14	100.0	11.1
Orange County		South	8.57	286	0.20	68.0	3.2	46.1	5.0	7.9	23	10	10	10	1,600	1,600	1,700		37	42	18	83.0	11.5
Orange County	4/13/00	North	8.62	277	0.30	71.0	5.0		5.0	9.2	310	6	17	12	1,700	1,700	1,800		32	34	10	103.5	11.1
Orange County		South	8.64	276	0.30	71.0	4.3		5.0	8.8	25	6	104	110	1,800	1,800	1,800		30	16	18	103.0	11.4
Orange County	5/5/00	North	8.82	280	0.20	57.6	3.2	61.1	10.0	10.0	130	10	10	10	2,100	2,000	2,100		31	32	2	106.0	13.0
Orange County		South	8.89	279	0.20	57.6	3.9	64.0	5.0	10.0	32	10	10	10	2,100	2,100	2,100		35	2	8	106.5	12.5
Orange County	6/6/00	North	8.85	284	0.20	59.7	3.3	39.5	10.0	9.3	18	10	10	10	1,600	1,600	1,600		23	18	10	112.8	8.4
Orange County		South	8.78	285	0.20	60.8	2.6	39.7	10.0	9.9	25	10	10	10	2,200	2,200	2,200		23	22	8	110.8	8.5
Orange County	7/6/00	North	8.65	287	0.30	64.6	2.7	43.0	10.0	10.5	28	10	10	10	2,100	2,100	2,100		24	46	14	102.0	10.8
Orange County		South	8.67	292	0.30	65.1	3.4	40.8	10.0	9.6	27	10	10	10	1,900	1,900	1,900		24	28	22	102.5	10.2
Orange County	8/15/00	North	7.88	289	0.30	65.3	4.0	48.9	10.0	6.2	27	10	10	10	2,400	2,400	2,400		19	860	850	113.5	10.8
Orange County		South	7.81	289	0.20	65.3	3.1	42.8	10.0	6.1	29	10	10	10	2,000	2,000	2,000		16	82	78	114.5	10.4
Orange County	9/14/00	North	8.10	286	0.20	68.6	3.1	57.3	10.0	8.9	25	10	10	10	2,200	2,200	2,200		16	42	28	163.5	12.6
Orange County		South	8.42	284	0.20	67.5	2.7	49.9	10.0	10.0	26	10	10	10	2,100	2,100	2,100		20	6	4	159.0	12.3
Orange County	10/5/00	North	7.84	299	0.30	68.6	3.3	54.0	10.0	8.1	21	10	10	10	2,100	2,100	2,100		26	1,080	560	108.5	11.4
Orange County		South	8.01	299	0.20	68.1	3.0	54.9	10.0	8.0	19	10	10	10	2,000	2,000	2,000		25	264	120	105.5	12.1
Orange County	11/2/00	North	8.02	302	0.30	74.3	4.7	59.2	10.0	8.7	33	10	10	10	1,900	1,900	1,900		31	86	32	113.5	11.9
Orange County		South	7.86	302	0.30	73.2	5.1	61.3	10.0	7.4	42	10	10	10	2,200	2,200	2,200		55	1,600	1,050	114.0	13.7
Orange County	12/11/00	North	8.25	303	0.25	76.0	5.4	46.2	10.0	12.5	23	10	10	10	2,000	2,000	2,000		41	240	22	112.5	10.9
Orange County		South	8.33	303	0.20	76.0	4.9	59.3	10.0	12.3	28	10	10	10	1,900	1,900	1,900		40	60	48	113.0	11.4
Orange County	1/22/01	North						18.1															
Orange County		South						13.0															
Orange County	3/20/01	North						27.3															
Orange County	3/22/01	North										5	10	10			1,700		40				
Orange County		South						36.7				5	10	15			1,800		40				
Orange County	6/4/01	North			0.20			39.6									1,555		37				
Orange County		South															1,700		33				
Orange County	9/12/01	North						37.2									1,500		23	7,400	50		
Orange County		South						36.6									1,500		23	158	94		
Orange County	12/17/01	North	7.94	253	1.00	78.8	2.0	39.6	10.0	6.1	24	5	10	10	1,400	1,400	1,400		24	380	24	102.8	6.1
Orange County		South	7.88	252	0.80	79.8	2.0	42.7	10.0	6.5	25	5	10	10	1,200	1,200	1,200		25	200	26	110.3	5.8
Orange County	2/13/02	North	8.06	222	0.70	79.1	3.3	27.1	5.0	9.4	21	5	10	10	1,300	1,300	1,300		27	152	18	109.0	6.1
Orange County		South	8.01	223	0.60	79.6	3.0	28.6	5.0	9.0	25	5	10	10	1,300	1,300	1,367		26	130	14	112.5	5.8
Orange County	4/24/02	North	8.22	251	0.60	71.0	3.8	32.8	10.0	8.8	19	5	10	10	1,500	1,500	1,500		26	22	10	102.3	7.0
Orange County		South	8.26	252	0.50	71.0	3.1	22.6	10.0	8.8	19	5	10	10	1,500	1,500	1,500		27	14	8	98.8	6.9
Orange County	8/5/02	North	7.87	239	0.60	65.7	3.9	36.0	5.0	6.4	18	5	10	10	1,400	1,400	1,400		26	450	170	89.0	5.8
Orange County		South	7.34	238	0.50	65.2	4.5	36.4	5.0	6.0	18	5	10	10	1,400	1,400	1,400		22	500	240	86.3	5.5

Source	Date	Station	Parameter																				
			pH	Cond	Secchi	Alk	BOD5	Chla	Color	DO	NH3	NO2	NO3	Nox	TKN	N Organic	Total N	SRP	Total P	Total Coliforms	Fecal Coliform	TSS	Turb
			s.u.	µmho/cm	m	mg/l	mg/l	µg/l	Co-Pt	mg/l	µg/l	µg/l	µg/l	µg/l	µg/l	µg/l	µg/l	µg/l	µg/l	cfu/100ml	cfu/100ml	mg/l	NTU
Orange County	10/1/02	North	6.17		0.30			42.1	5.0		17	5	10	10	1,300	1,300	1,300		25	72	26		
Orange County		South	6.17		0.40			48.9	5.0		15	5	10	10	1,000	990	1,000		28	220	34		
Orange County	1/7/03	North	6.20	246	0.60	66.2	3.9	41.6	10.0	8.7	10	5	72	72	1,200	1,200	1,300		58	360	20	77.5	6.3
Orange County		South	5.80	246	0.60	70.4	3.0	38.3	10.0	8.4	110	5	110	110	1,200	1,200	1,300		49	130	12	67.5	5.9
Orange County	2/3/03	North	7.48	228	0.60	65.0	5.2	26.2	5.0	11.5	17	5	49	49	1,300	1,300	1,300		47	70	2	79.3	7.6
Orange County		South	6.87	229	0.70	68.0	5.2	22.7	5.0	10.2	18	5	110	110	1,100	1,100	1,200		47	160	12	77.8	8.4
Orange County	5/12/03	North	8.70	255	0.50	31.0	5.6	32.5	10.0	7.4	28	5	10	10	1,400	1,400	1,400		33	168	14	87.2	7.5
Orange County		South	8.60	257	0.50	59.0	5.4	33.4	10.0	7.3	23	5	10	10	1,400	1,400	1,400		31	28	8	85.3	8.2
Orange County	8/28/03	North	8.27	257	0.60	63.5	3.5	22.7	5.0	8.1	20	2	6	6	1,140	1,140	1,060		25	54	28	101.1	6.5
Orange County		South			0.60			22.4									1,140		28				
Orange County	10/23/03	North				65.2	4.4	39.8	5.0		30	2	4	4	1,270	1,240	1,270		31	84	6	81.9	7.5
Orange County		South				67.5	4.7	40.3	5.0		20	2	4	4	1,130	1,130	1,130		32	52	16	92.3	7.5
Orange County	2/5/04	North	7.43	262	0.70	68.0		27.7	5.0	10.0	26	2	4	4	1,230	1,200	1,230		43	1,934	30	81.0	
Orange County		South	7.70	263	0.70	67.0		27.4	5.0	10.2	27	2	4	4	1,070	1,040	1,070		38	109	30	84.5	
Orange County	5/11/04	North	7.81	252	0.50	2.0		33.9	5.0	9.3	20	2	4	4	1,140	1,140	1,140		29	200	40	92.5	8.0
Orange County		South	7.78	251	0.50	64.0		33.1	5.0	9.4	20	2	4	4	1,580	1,580	1,580		32	1,700	340	93.5	8.2
Orange County	7/13/04	North			0.10			26.2									1,130		12				
Orange County		South			0.40			26.3									1,030		14				
Orange County	8/9/04	North			0.60			23.1									1,245		13				
Orange County		South			0.60			29.9									1,180		13				
Orange County	11/8/04	North	7.65	227	0.70	67.0		35.1		6.9	20	20	20	20	830	830	840		25			8.0	
Orange County		South	7.50	225	0.70	66.0		28.2		7.0	20	20	20	20	850	850	860		21			12.0	
Orange County	2/16/05	North			1.00	69.0		16.1	25.0		19	302	156	160	590	590	750	3	27			75.5	4.2
Orange County		South			1.00	68.0		16.4	25.0		19	310	146	150	620	620	770	3	26			78.0	4.7
Orange County	4/11/05	North	6.10	255	1.00	48.0		19.7	25.0	7.7	19	273	20	20	660	660	680	6	21			78.5	5.1
Orange County		South	6.10	254	1.00	48.0		16.8	18.0	8.2	19	249	20	20	600	600	620	9	17			77.5	4.7
Orange County	7/11/05	North			0.90	49.0		16.3	13.8		28	381	10	20	940	910	950	3	26			88.0	5.7
Orange County		South			0.90	49.0		16.5	13.8		19	401	10	20	990	970	1,000	3	25			90.5	5.4
Orange County	9/15/05	North			1.30	31.0		11.4	11.5		19	189	10	10	460	460	470	2	14			88.5	3.1
Orange County		South			1.30	33.0		12.2	11.7		19	241	11	11	590	590	600	2	17			92.0	3.9
Orange County	10/20/05	North			1.30	27.0		14.6	3.0		19	141	2	3	350	350	350	2	12			103.0	3.9
Orange County		South			1.30	28.0		15.0	3.0		19	145	2	3	360	360	360	2	11			102.5	3.9
Orange County	1/5/06	North	7.50	279	1.50	32.0		10.5		9.0	80	2	82	83	640	560	720	2	13	22	5	92.5	2.9
Orange County		South	7.20	279	1.50	32.0		9.0		9.3	90	2	85	86	670	580	760	2	13	15	9	89.5	2.6
Orange County	2/6/06	North	7.30	271	1.60	18.0		7.8		8.6	50	4	60	62	390	350	810	4	12	85	22	45.8	1.6
Orange County		South	7.33	271	1.70	33.0		7.5		8.9	60	4	113	116	620	560	740	4	11	42	14	89.0	2.2
Orange County	3/6/06	North	5.77	295	2.90	8.0		1.3		8.8	35	4	74	75	230	205	540	4	4	5	3	50.8	0.5
Orange County		South	5.53	294	3.80	12.0		1.1		9.1	60	4	139	140	380	320	520	4	4	3	3	102.5	0.9
Orange County	4/5/06	North	7.00	309	2.40	9.0		6.8		9.0	20	4	47	49	530	530	580	11	12	11	9	111.5	1.4
Orange County		South	6.90	309	2.30	10.0		7.2		8.7	20	4	46	48	580	580	630	4	18	9	9	114.0	1.6
Orange County	5/3/06	North	6.90	320	1.00	6.5		6.3		7.9	20	4	6	6	340	340	620	4	11	11	10	58.5	1.1
Orange County		South	7.00	319	1.80	13.0		7.0		7.8	20	4	12	12	570	570	580	4	14	10	10	59.0	1.8
Orange County	6/21/06	North	7.70	323	1.30	8.5		10.1		7.7	20	4	4	4	295	295	520	4	11	14	12	61.3	1.4
Orange County		South	7.40	322	1.70	14.0		9.1		7.4	20	4	4	4	520	520	520	4	12	16	16	115.0	2.6
Orange County	7/10/06	North	7.60	324	1.20	15.0		10.5		7.3	20	4	4	4	690	690	690	4	7	11	11	116.5	3.3
Orange County		South	7.60	324	1.20	16.0		11.0		7.4	20	4	4	4	690	690	690	4	8	13	13	116.5	3.3
Orange County	8/2/06	North	7.50	327	1.10	20.0		14.9		7.4	20	3	4	4	710	710	710	4	11	166	116	115.5	4.1
Orange County		South	7.10	335	1.20	12.0		17.6		7.9	20	3	4	4	415	415	760	4	13	50	26	57.8	2.1
Orange County	9/7/06	North			0.98			20.8									920		13	340	114		
Orange County		South			1.00			19.4									820		12	590	120		
Orange County	10/4/06	North	6.70	305	1.20			24.4		7.1							760		14				
Orange County		South	7.30	301	1.50			20.6		6.9							760		13				
Orange County	11/21/06	North			1.00			21.4		9.7							880		20				

Source	Date	Station	Parameter																				
			pH	Cond	Secchi	Alk	BOD5	Chla	Color	DO	NH3	NO2	NO3	Nox	TKN	N Organic	Total N	SRP	Total P	Total Coliforms	Fecal Coliform	TSS	Turb
			s.u.	µmho/cm	m	mg/l	mg/l	µg/l	Co-Pt	mg/l	µg/l	µg/l	µg/l	µg/l	µg/l	µg/l	µg/l	µg/l	µg/l	cfu/100ml	cfu/100ml	mg/l	NTU
Orange County		South			1.00			18.1		9.6							830		18				
Orange County	12/6/06	North			1.00			19.3		7.8							770		15				
Orange County		South			1.00			16.3		7.6							820		16				
Orange County	1/4/07	North	6.80	291	1.00	16.0		15.0		9.4	10	2	1	2	420	420	800	2	16	100	112	2.8	2.5
Orange County		South	6.90	290	1.00	30.0		16.4		9.2	10	2	1	2	800	800	800	2	17	100	136	5.0	5.3
Orange County	2/21/07	North	7.60	292	0.94	33.0		18.1		9.7	20	4	4	4	830	830	830	4	12	24	22	102.5	7.1
Orange County		South	7.70	292	0.80	33.0		17.9		9.6	20	4	4	4	780	780	780	4	15	10	10	105.5	7.1
Orange County	3/7/07	North	7.60	305	0.80	18.5		16.5		9.2	20	4	5	5	435	435	800	4	5	220	30	54.3	3.6
Orange County		South	7.80	305	0.80	35.0		19.7		9.5	20	4	8	8	850	850	860	4	3	200	13	110.0	7.0
Orange County	4/4/07	North	8.20	313	0.70	20.0		17.8		8.1	10	1	1	2	530	530	1,020	2	17		13	3.8	4.3
Orange County		South	8.10	312	0.75	39.0		18.6		8.5	10	1	1	2	1,020	1,020	1,020	2	17		10	6.0	9.9
Orange County	5/3/07	North	8.30	322	1.10	19.0	1.3	13.4		8.6	10	1	1	2	440	440	840	2	15		27	3.8	0.3
Orange County		South	8.40	323	1.10	37.0	1.0	12.6		8.6	10	1	1	2	850	850	850	2	17		7	5.0	5.8
Orange County	6/6/07	North	8.20	332	1.00	20.0	0.8	13.3		8.2	10	1	1	2	455	455	870	2	14		29	3.3	2.5
Orange County		South	8.10	332	1.00	39.0	0.5	12.7		8.2	10	1	1	2	930	930	930	2	13		31	6.0	5.4
Orange County	7/9/07	North	8.40	328	1.27	20.0		16.1		7.2	10	1	1	2	470	470	900	2	14		18	2.3	2.2
Orange County		South	8.40	330	1.29	20.0		15.8		7.1	35	1	1	2	460	430	880	2	17		14	2.3	2.6
Orange County	8/7/07	North	8.50	314	1.10	38.0		20.8		7.6	10	1	8	8	840	840	850	2	8		14	6.0	6.0
Orange County		South	8.50	313	1.10	37.0		18.8		7.6	10	1	6	6	780	780	790	2	9		9	4.0	4.8
Orange County	9/6/07	North	7.40	319	1.00	20.5		28.8		6.7	10	1	1	3	498	498	960	1	17		20	2.8	2.7
Orange County		South	7.70	317	0.80	40.0		24.3		6.4	10	1	1	3	910	910	910	1	16		59	7.0	5.1
Orange County	10/3/07	North	7.80	308						7.3											58		
Orange County		South	8.00	307						7.4											31		
Orange County	10/4/07	North			0.90	21.0		22.5			10	1	3	4	493	493	960	1	16			3.3	2.8
Orange County		South			0.95	41.0		22.9			10	1	1	3	930	930	930	1	12			8.0	5.3
Orange County	11/19/07	North			0.60	42.0	2.0	22.2			10	1	1	3	720	720	720	1	15			7.0	6.7
Orange County		South			0.70	42.0	1.0	18.9			10	1	1	3	780	780	780	1	16			8.0	6.5
Orange County	12/5/07	North			0.70	44.0		22.0			10	1	1	3	1,140	1,140	1,140	1	7			8.0	7.5
Orange County		South			0.80	44.0		22.3			10	1	1	3	1,020	1,020	1,020	1	17			7.0	7.3
Orange County	1/8/08	North	7.10	311	0.60	46.0		16.3		9.9	10	1	1	3	1,060	1,060	1,060	1	13		29	7.0	7.1
Orange County		South	7.20	311	0.65	46.0		14.6		10.1	10	1	1	3	890	890	890	1	12		27	6.0	7.6
Orange County	4/3/08	North	8.20	308	0.91	48.0		10.4		8.6	10	2	6	6	950	950	960	2	10			6.0	6.2
Orange County		South	8.20	307	1.00	48.0		13.1		8.7	10	2	2	2	840	840	840	2	11			6.0	6.0
Orange County	7/8/08	North	7.90	304	0.80	47.0		14.2		2.3	30	2	2	3	810	810	810	2	15		63	5.0	4.4
Orange County		South	7.70	301	0.83	47.0		14.0		6.0	15	2	2	3	860	860	860	2	13		71	4.0	4.2
Orange County	10/7/08	North	7.60	267	0.85	49.0		35.3		7.5	15	2	2	3	980	980	980	2	14		70	5.0	6.2
Orange County		South	8.00	268	0.91	50.0		34.0		7.5	15	2	2	3	1,010	1,010	1,010	2	13		88	5.0	6.0
Orange County	1/8/09	North	7.40	278	1.30	55.0		7.9		7.5	15	1	2	3	650	650	650	2	8		17	6.0	4.8
Orange County		South	7.50	277	1.60	53.0		3.6		7.1	190	1	74	74	1,200	1,010	1,280	2	20		4	5.0	3.2
Orange County	4/2/09	North	7.90	283	2.70	54.0		4.3		8.0	15	2	122	124	660	660	780	1	5		28	2.0	0.9
Orange County		South	8.10	282	3.10	53.0		3.6		8.6	15	1	119	119	730	730	850	1	6		10	2.0	0.8
Orange County	7/7/09	North	8.00	260	2.20	52.0		6.1		6.6	10	1	3	3	700	700	700	1	9		95	5.0	1.7
Orange County		South	7.90	260	2.30	51.0		6.5		6.4	10	1	6	6	670	670	680	1	8		7	3.0	2.1
Orange County	10/6/09	North			1.60			10.1															
Orange County		South			1.70			9.4															

APPENDIX C

VISUAL CHARACTERISTICS OF SEDIMENT CORE SAMPLES COLLECTED IN LAKE HOLDEN

1. **October 2003**
2. **May 2007**
3. **November 2008**

1. <u>October 2003</u>

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

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

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

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

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

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

2. May 2007

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

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

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

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

3. <u>November 2008</u>

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

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

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

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