Bay Lake Sediment Characterization and Phosphorus Inactivation Study

Final Report

March 2006

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Environmental Protection Division

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SECTION 1
INTRODUCTION

This report provides a summary of work efforts performed by Environmental Research and Design, Inc. (ERD) for the Orange County Environmental Protection Division (OCEPD) to conduct a sediment characterization study for Bay Lake. The primary emphasis of this study is to evaluate the significance of sediment phosphorus release and the feasibility of using alum for sediment inactivation. Bay Lake is a 37.9-acre urban lake located north of Silver Star Road and west of John Young Parkway in unincorporated Orange County. A location map for Bay Lake is given in Figure 1-1.

Field monitoring and laboratory analyses were conducted by ERD during January 2006 to evaluate sediment characteristics in Bay Lake. A sediment monitoring program was performed to quantify the physical and chemical characteristics of existing sediments within the lake and to evaluate the potential for internal recycling of phosphorus from sediments into the overlying water column. Physical-chemical profiles of temperature, pH, conductivity, dissolved oxygen, and redox potential were also conducted to assist in evaluating the significance of internal recycling within the lake. Laboratory jar tests were performed to evaluate lake response to various alum doses.

This report is divided into four separate sections. Section 1 contains an introduction to the report and provides a brief summary of the work efforts performed by ERD. Section 2 contains a description of the field and laboratory activities conducted by ERD. The results of the field and laboratory activities are summarized in Section 3. The feasibility of alum inactivation of sediment phosphorus release is discussed in Section 4.

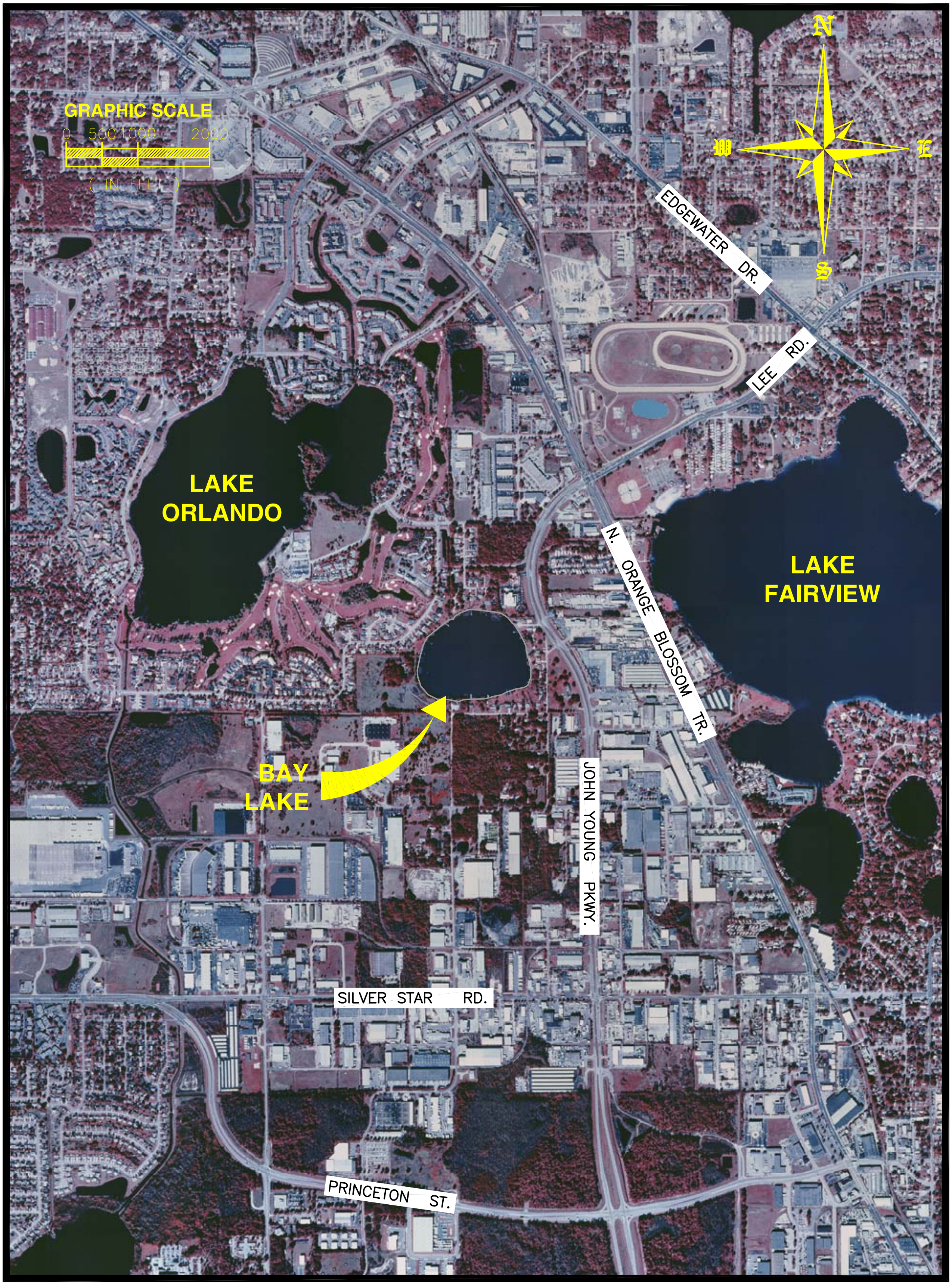

Figure 1-1. Location Map for Bay Lake.

SECTION 2

FIELD AND LABORATORY ACTIVITIES

Sediment core samples were collected and evaluated for a variety of physical and chemical characteristics to assist in evaluating the potential for internal recycling of phosphorus from the sediments into the overlying water column of the lake. Laboratory jar tests were conducted to evaluate water quality response to alum addition. Field and laboratory activities used to perform these assessments are described in the following sections.

2.1 Collection of Sediment Core Samples

Sediment core samples were collected by ERD to assist in evaluating the significance of sediments for impacting water quality in Bay Lake. Sediment core samples were collected at 36 separate locations. Locations of sediment sampling sites in Bay Lake are illustrated on Figure 2-1. Sediment samples at the 36 sites were collected on January 26, 2006.

Sediment samples were collected at each of the 36 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 36 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.

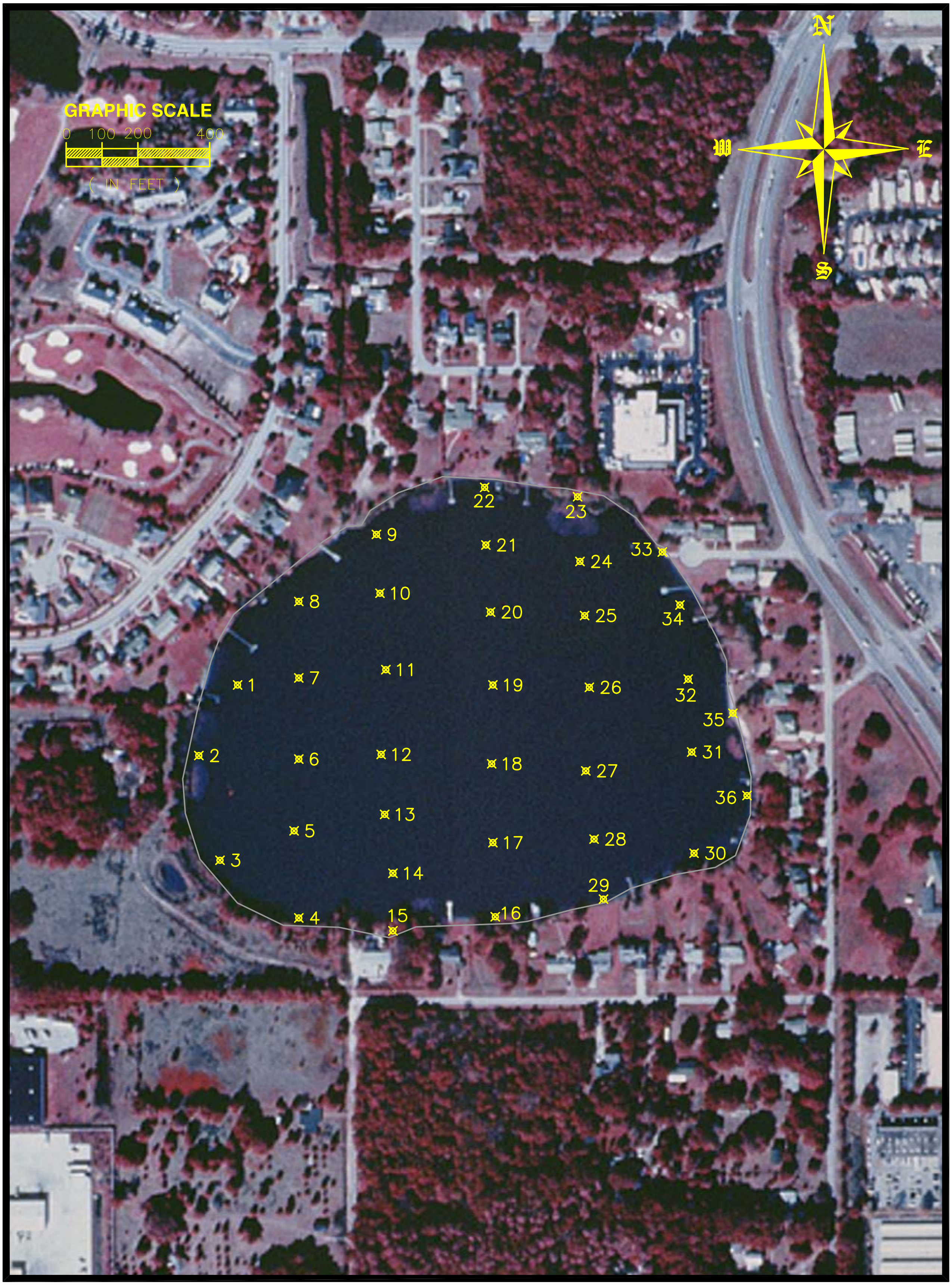

Figure 2-1. Locations of Sediment Core Collection Sites in Bay Lake.

During the sediment monitoring on January 26, 2006, field measurements of pH, specific conductivity, dissolved oxygen and oxidation-reduction potential (ORP) were recorded at water depths of 0.25 m, 0.5 m and at 0.5 m intervals to the lake bottom at the center of the lake. This information is used to evaluate stratification regimes within the lake and to assist in identifying the significance of internal recycling.

2.2 Sediment Characterization and Speciation Studies

Each of the 36 collected sediment core samples was analyzed for a variety of general parameters, including moisture content, organic content, sediment density, total nitrogen, and total phosphorus. Methodologies utilized for preparation and analysis of the sediment samples for these parameters are outlined in Table 2-1.

TABLE 2-1

ANALYTICAL METHODS FOR SEDIMENT ANALYSES

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

REFERENCES:

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

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

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

In addition to general sediment characterization, a fractionation procedure for inorganic soil phosphorus was conducted on each of the 36 collected sediment samples. The modified Chang and Jackson Procedure, as proposed by Peterson and Corey (1966), was used for phosphorus fractionation. The Chang and Jackson Procedure allows the speciation of sediment phosphorus into saloid-bound phosphorus (defined as the sum of soluble plus easily exchangeable sediment phosphorus), iron-bound phosphorus, and aluminum-bound phosphorus. Although not used in this project, subsequent extractions of the Chang and Jackson procedure also provide calcium-bound and residual fractions.

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

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 highly 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.

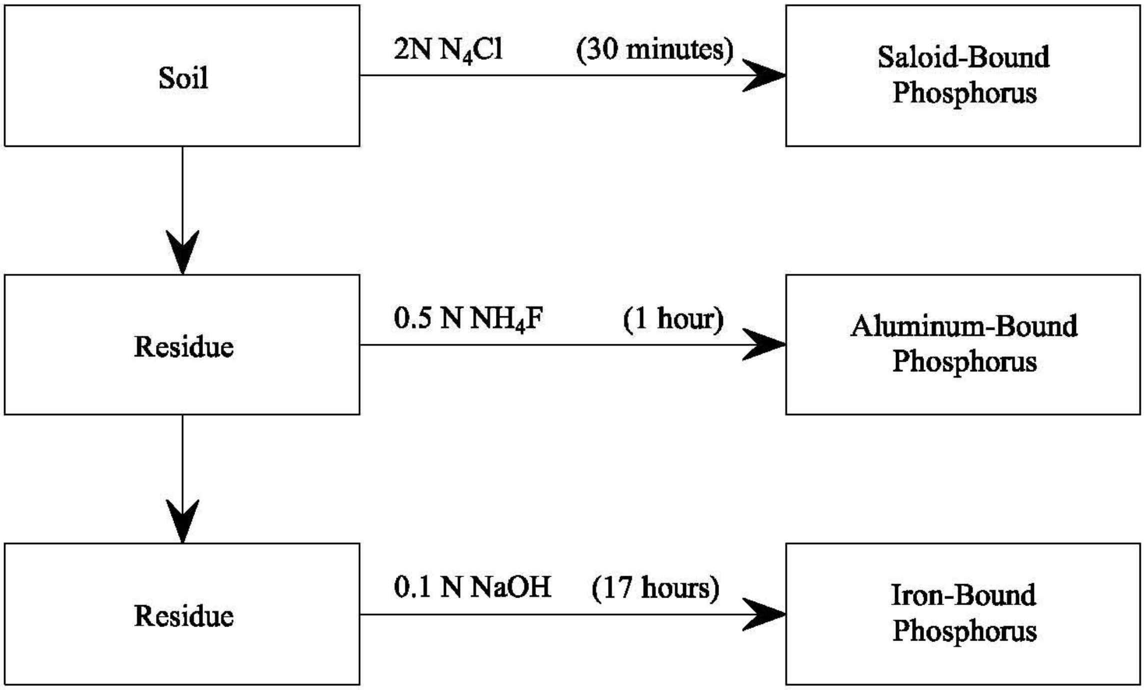

Figure 2-2. Schematic of Chang and Jackson Speciation Procedure for Evaluating Soil Phosphorus Bonding.

2.3 Jar Test Procedures

A series of laboratory jar tests were conducted using alum on composite surface water samples collected from Bay Lake to evaluate the water quality impacts of alum coagulation at various doses on surface water from the lake. A single composite surface water sample was formed by combining equal amounts of water collected at three sites in Bay Lake on January 26, 2006. Equal amounts of water were collected from the top, middle, and bottom portions of the water column at each of the individual sites used for collection of surface water samples.

Alum-based laboratory jar tests were conducted on the composite surface water sample in individual polycarbonate containers using a sample volume of two liters for each test. Jar testing was conducted at alum doses of 5.0, 7.5, and 10.0 mg Al/liter to evaluate a wide range of potential application doses.

To begin each jar test, the appropriate amount of alum was added to a 2-liter water sample contained in a polycarbonate beaker. Following addition of the alum, the mixture was agitated for approximately 60 seconds. Measurements of pH were conducted initially in the raw sample and approximately one minute after addition of the selected alum dose. Additional measurements of pH were conducted at periods of one hour and 24 hours after addition of the alum coagulant to document changes in pH which typically occur after alum addition. In general, minimum pH levels in alum treated water typically occur within one hour after addition of the coagulant. The pH value of the treated water continues to increase steadily following addition of the alum for a period of approximately 24 hours. The alum treated samples were then allowed to settle for a period of 24 hours, simulating settling processes which would occur within the water column of the lake. At the end of the 24-hour settling period, the clear supernatant was decanted from each jar test container for subsequent laboratory analyses.

Each of the samples generated during the laboratory jar test procedures was analyzed for a wide variety of chemical constituents, including general parameters, chlorophyll-a, nutrients, and dissolved aluminum. A summary of analytical methods and detection limits for laboratory analyses conducted by ERD on each of the generated jar test samples is given in Table 2-2.

TABLE 2-2

ANALYTICAL METHODS AND DETECTION LIMITS FOR LABORATORY ANALYSES CONDUCTED ON JAR TEST SAMPLES

MEASUREMENT PARAMETER	METHOD	METHOD DETECTION LIMITS (MDLs)[1]
General Parameters		
Hydrogen Ion (pH)	EPA-83[2], Sec. 150.1	NA
Specific Conductivity	EPA-83, Sec. 120.1	0.1 µmho/cm
Alkalinity	EPA-83, Sec. 310.1	0.5 mg/l
Color	EPA-83, Sec. 110.3	1 Pt-Co Unit
Turbidity	EPA-83, Sec. 180.1	0.1 NTU
T.S.S.	EPA-83, Sec. 160.2	0.7 mg/l
Sulfate	SM-19[3] Sec. 4500-SO_4^{-2} E.	0.7 mg/l
Biological Parameters		
Chlorophyll-a	SM-19, Sec. 10200 H.3	0.08 mg/m^3
Nutrients		
Ammonia-N (NH_3-N)	EPA-83, Sec. 350.1	0.005 mg/l
Nitrate + Nitrite (NO_x-N)	EPA-83, Sec. 353.2	0.005 mg/l
Organic Nitrogen	Alkaline Persulfate Digestion[4]	0.01 mg/l
Orthophosphorus	EPA-83, Sec. 365.1	0.001 mg/l
Total Phosphorus	Alkaline Persulfate Digestion[4]	0.001 mg/l
Metals		
Diss. Aluminum	SM-19, Sec. 3500-Al E.	0.001 mg/l

1. MDLs are calculated based on the EPA method of determining detection limits.
2. Methods for Chemical Analysis of Water and Wastes, EPA 600/4-79-020, Revised March 1983.
3. Standard Methods for the Examination of Water and Wastewater, 19th Edition, 1992.
4. FDEP-approved method.

SECTION 3

RESULTS

3.1 Bathymetric Characteristics

Water depth contours for Bay Lake were obtained by ERD from the City of Orlando 2003 Lake Water Quality Report. These water depth contours were digitized, using AutoDesk Land Desktop Version 2006, and superimposed on an aerial photograph of Bay Lake. The resulting water depth contour map for Bay Lake is given in Figure 3-1.

Based upon the contour data contained within the City of Orlando 2003 Lake Water Quality Report, Bay Lake is a relatively shallow lake with a maximum depth of approximately 14 ft. The sides of the lake appear to be relatively steep, sloping rapidly to a flat bottom area.

Stage-storage relationships for Bay Lake are summarized in Table 3-1. At the water surface elevation represented by the City of Orlando contour map, the lake surface area is approximately 37.86 acres. The lake volume at this surface area is 288.1 ac-ft which corresponds to a mean water depth of 7.6 ft. This value is relatively shallow for a Central Florida lake.

TABLE 3-1

STAGE-STORAGE RELATIONSHIPS FOR BAY LAKE

DEPTH (ft)	AREA (ac)	VOLUME (ac-ft)	DEPTH (ft)	AREA (ac)	VOLUME (ac-ft)
0.0	37.86	288.1	8.0	20.32	59.68
1.0	35.38	251.5	9.0	18.26	40.40
2.0	32.90	217.3	10.0	15.70	23.42
3.0	30.55	185.6	11.0	9.76	10.69
4.0	28.11	156.3	12.0	4.25	3.69
5.0	26.04	129.2	13.0	1.46	0.83
6.0	24.07	104.1	14.0	0.21	0.00
7.0	22.26	80.97			

Figure 3-1. Water Depth Contours in Bay Lake (from City of Orlando 2003 Lake Water Quality Report).

3.2 Sediment Characteristics

3.2.1 Visual Characteristics

Visual characteristics of sediment core samples were recorded for each of the 36 sediment samples collected in Bay Lake during January 2006. A summary of visual characteristics of sediment core samples is given in Table 3-2. In general, shoreline areas of Bay Lake are characterized by sandy sediments with little or no visual accumulations of unconsolidated organic muck. The base material beneath the lake bottom consists primarily of light brown fine sand.

As water depths increase within the lake, the accumulations of organic muck become deeper. Areas where deep deposits of organic muck have accumulated are characterized by a surface layer of unconsolidated organic muck, approximately 1-4 inches 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 resuspended by wind action or boating activities which disturb the bottom. As the sediment depth increases, the organic layer becomes more consolidated with a consistency similar to pudding. These deeper layers typically do not resuspend into the water column except during vigorous mixing action within the lake.

3.2.2 General Sediment Characteristics

After return to the ERD laboratory, the collected sediment core samples were evaluated for a variety of general characteristics including pH, moisture content, organic content, sediment density, total nitrogen, and total phosphorus. A summary of general characteristics measured in each of the 36 collected sediment core samples is given in Table 3-3. In general, sediments in Bay Lake were found to be approximately neutral in pH, with measured sediment pH values ranging from 6.03-6.92 and an overall mean of 6.47. These values are typical of pH measurements commonly observed in hypereutrophic urban lakes.

TABLE 3-2

VISUAL CHARACTERISTICS OF SEDIMENT CORE SAMPLES COLLECTED IN BAY LAKE ON JANUARY 26, 2006

SITE NO.	LAYER (cm)	VISUAL APPEARANCE
1	0 - 4	Light brown fine sand with green algae
	4 - 10	Light brown fine sand
	10 - >16	Brown fine sand with organics
2	0 - 4	Brown fine sand with organics
	4 - 13	Dark brown consolidated organic muck
	13 - >21	Brown fine sand with organics
3	0 - 3	Light brown fine sand
	3 - 11	Brown fine sand with organics
	11 - >15	Light brown fine sand with roots
4	0 - 1	Dark brown unconsolidated organic muck
	1 ->11	Brown fine sand with organics
5	0 - 5	Dark brown unconsolidated organic muck
	5 - >74	Dark brown consolidated organic muck
6	0 - 6	Dark brown unconsolidated organic muck
	6 - >76	Dark brown consolidated organic muck
7	0 - 6	Medium brown fine sand
	6 - >19	Light brown fine sand
8	0 - 9	Medium brown fine sand
	9 - >14	Brown fine sand with organics
9	0 - 1	Light brown fine sand with algae
	1 - 7	Light brown fine sand
	7 - >16	Brown fine sand with organics
10	0 - 2	Dark brown unconsolidated organic muck
	2 - 8	Dark brown consolidated organic muck
	8 - >30	Brown fine sand with organics
11	0 - 4	Dark brown unconsolidated organic muck
	4 - 35	Dark brown consolidated organic muck
	35 - >49	Brown fine sand with organics
12	0 - 3	Dark brown unconsolidated organic muck
	3 - >61	Dark brown consolidated organic muck
13	0 - 7	Dark brown unconsolidated organic muck
	7 - >49	Dark brown consolidated organic muck
14	0 - 1	Dark brown unconsolidated organic muck
	1 - >19	Brown fine sand with organics
15	0 - 3	Light brown fine sand with green algae
	3 - >12	Brown fine sand with organics
16	0 - >16	Brown fine sand with organics
17	0 – 1	Dark brown unconsolidated organic muck
	1 - 6	Brown fine sand with organics
	6 - >17	Light gray clay
18	0 - 10	Dark brown unconsolidated organic muck
	10 - >52	Dark brown consolidated organic muck
19	0 - 6	Dark brown unconsolidated organic muck
	6 - >54	Dark brown consolidated organic muck

TABLE 3-2 -- CONTINUED

VISUAL CHARACTERISTICS OF SEDIMENT CORE SAMPLES COLLECTED IN BAY LAKE ON JANUARY 26, 2006

SITE NO.	LAYER (cm)	VISUAL APPEARANCE
20	0 - 1 1 - >40	Dark brown unconsolidated organic muck Dark brown consolidated organic muck
21	0 - >17	Brown fine sand with organics
22	0 - 3 3 - 14 14 - >19	Light brown fine sand with green algae Light brown fine sand Brown fine sand with organics
23	0 - >17	Brown fine sand with organics
24	0 - 3 3 - 8 8 - >17	Dark brown unconsolidated organic muck Dark brown consolidated organic muck Brown fine sand with organics
25	0 - 1 1 - 24 24 - >30	Dark brown unconsolidated organic muck Brown fine sand with organics Light brown fine sand
26	0 - 3 3 - 31 31 - >42	Dark brown unconsolidated organic muck Dark brown consolidated organic muck Light brown fine sand
27	0 - 3 3 - 12 12 - 16 16 - >19	Dark brown unconsolidated organic muck Dark brown consolidated organic muck Brown fine sand with organics Light brown fine sand
28	0 - 6 6 - 22 22 - >30	Dark brown unconsolidated organic muck Brown fine sand with organics Light brown fine sand
29	0 - 3 3 - 7 7 - >13	Light brown fine sand with green algae Light brown fine sand Brown fine sand with organics
30	0 - 5 5 - >16	Light brown fine sand with green algae Light brown fine sand
31	0 - >15	Brown fine sand with organics
32	0 - 1 1 - >19	Light brown fine sand with green algae Brown fine sand with organics
33	0 - 2 2 - 9 9 - >15	Light brown fine sand with green algae Light brown fine sand Brown fine sand with organics
34	0 - 2 2 - >14	Light brown fine sand with green algae Light brown fine sand
35	0 - 1 1 - 14 14 - >19	Light brown fine sand with green algae Light brown fine sand Brown fine sand with organics
36	0 - 6 6 - >27	Brown fine sand with organics and green algae Brown fine sand with organics

TABLE 3-3

GENERAL CHARACTERISTICS OF SEDIMENT CORE SAMPLES COLLECTED IN BAY LAKE DURING JANUARY 2006

SITE	pH	MOISTURE CONTENT (%)	ORGANIC CONTENT (%)	DENSITY (g/cm^2)	TOTAL NITROGEN ($\mu g/cm^3$)	TOTAL PHOSPHORUS ($\mu g/cm^3$)
1	6.92	26.9	0.6	2.09	5038	406
2	6.32	49.3	4.3	1.73	14947	1005
3	6.64	33.3	1.8	1.98	6103	841
4	6.38	33.3	2.1	1.98	10127	1354
5	6.06	85.9	36.0	1.13	15567	2077
6	6.07	87.5	48.5	1.10	18029	2263
7	6.66	29.0	0.6	2.06	5930	874
8	6.79	31.6	0.9	2.02	5720	527
9	6.67	35.1	12.9	1.85	5814	1209
10	6.27	42.3	5.5	1.82	12761	1216
11	6.33	89.1	37.6	1.10	15214	1659
12	6.24	89.4	51.1	1.08	18770	1906
13	6.20	89.1	43.1	1.09	15061	1691
14	6.61	44.4	2.5	1.81	9687	1028
15	6.85	29.0	0.9	2.05	5188	664
16	6.42	79.8	19.2	1.24	17565	1256
17	6.17	50.3	3.9	1.72	10369	2195
18	6.24	88.0	39.9	1.11	16075	1999
19	6.26	88.7	48.0	1.09	18328	1984
20	6.33	89.1	56.1	1.07	20079	1642
21	6.51	39.7	2.1	1.89	11249	947
22	6.60	31.4	1.1	2.02	7408	613
23	6.36	88.3	24.8	1.13	11029	627
24	6.57	57.7	4.0	1.61	16312	1109
25	6.44	52.8	3.9	1.68	11100	925
26	6.20	88.7	34.3	1.11	15028	1837
27	6.61	49.9	3.4	1.73	10837	1007
28	6.59	61.3	2.7	1.56	8662	939
29	6.54	31.7	0.2	2.02	5844	460
31	6.49	30.8	0.9	2.03	5170	389
30	6.81	32.4	1.8	2.00	6611	534
32	6.89	30.3	1.0	2.03	4965	483
33	6.83	32.1	1.2	2.01	7533	575
34	6.71	29.8	0.7	2.05	7186	511
35	6.03	49.4	2.8	1.74	5076	401
36	6.39	49.3	3.6	1.73	4976	836
Mean	**6.47**	**54.1**	**14.0**	**1.65**	**10704**	**1111**
Minimum	**6.03**	**26.9**	**0.2**	**1.07**	**4965**	**389**
Maximum	**6.92**	**89.4**	**56.1**	**2.09**	**20079**	**2263**

Isopleths of pH measurements in the top 10 cm of sediment collected in Bay Lake are illustrated on Figure 3-2. The lowest sediment pH values were observed in central portions of Bay Lake, where organic muck accumulations were greatest. The highest sediment pH values were observed in perimeter areas of the lake in areas where sediment accumulations were least.

Measurements of sediment moisture content and organic content in Bay Lake were found to be highly variable throughout the lake. Sediment samples with relatively low moisture contents are often comprised largely of fine sand and are also characterized by a relatively low organic content. In contrast, sediments which exhibit a high moisture content are often comprised primarily of organic muck and are also associated with a high organic content.

Isopleths of sediment moisture content in Bay Lake are summarized in Figure 3-3 based upon the information provided in Table 3-3. Areas of elevated moisture content are present in central portions of the lake. Sediment moisture contents in access of 50-70% are often indicative of highly organic sediments, with moisture contents less than 50% reflecting either sand or mixtures of sand and muck.

Isopleths of sediment organic content in Bay Lake are illustrated on Figure 3-4 based upon the information provided in Table 3-3. In general, sediment organic contents in excess of 30% are often indicative of organic muck-type sediments, with values less than 30% representing mixtures of muck and sand. Based upon this criterion, areas of concentrated organic muck are apparent in central portions of Bay Lake. Measured organic sediment content within the lake ranges from 0.2-56.1%, with an overall mean of 14.0%.

Values of sediment density are also useful in evaluating the general characteristics of sediments within a lake. Sediments with calculated densities between 1.0-1.5 are often indicative of highly organic muck-type sediments, while sediment densities of approximately 2.0 or greater are often indicative of sandy sediment conditions. Measured sediment densities in Bay Lake range from 1.07-2.09 g/cm^3, with an overall mean of 1.65 g/cm^3. Isopleths of sediment density are illustrated on Figure 3-5.

Figure 3-2. Isopleths of pH (s.u.) in the Top 10 cm of Sediments in Bay Lake.

Figure 3-3. Isopleths of Moisture Content (% dry wt.) in the Top 10 cm of Sediments in Bay Lake.

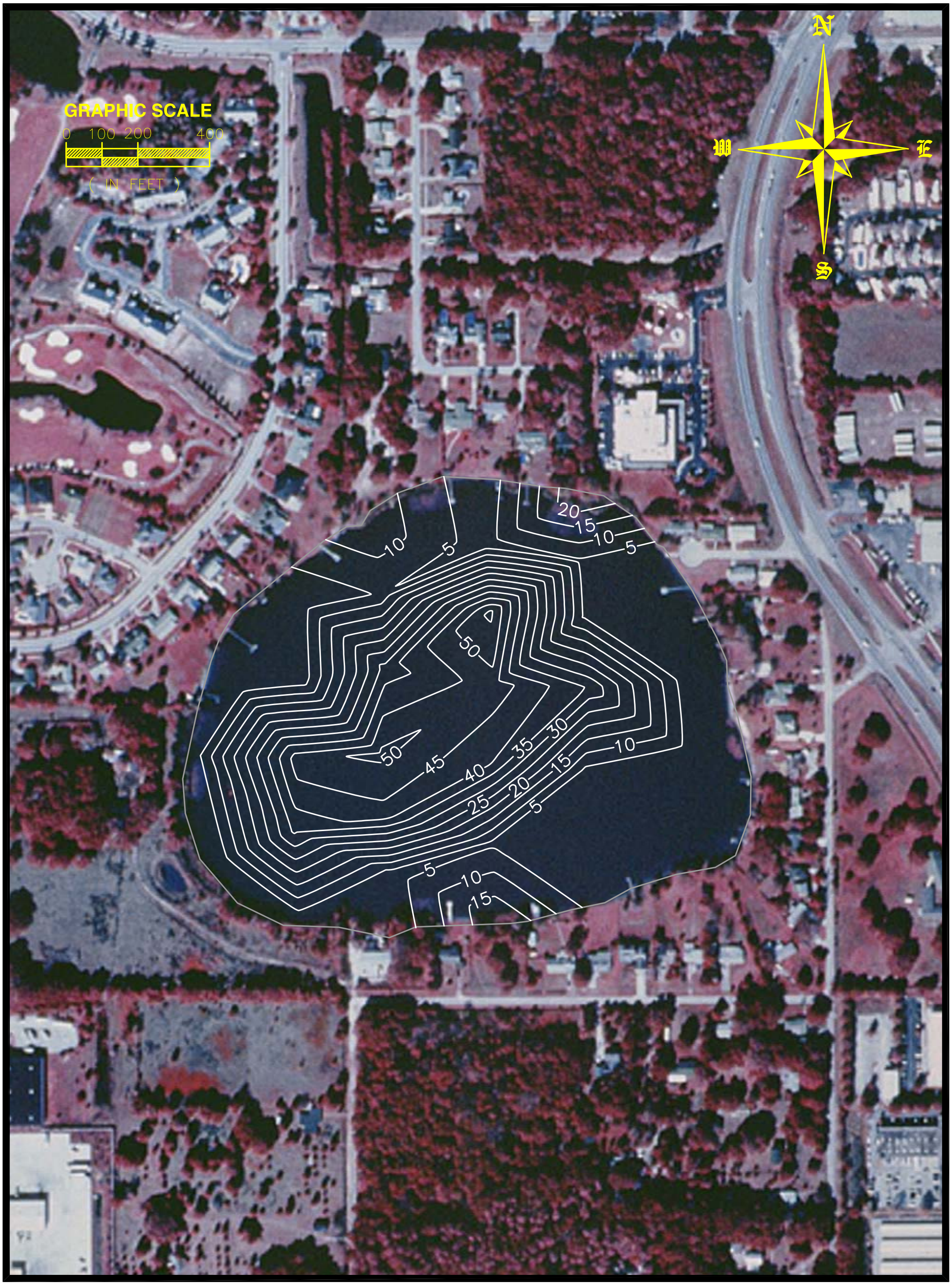

Figure 3-4. Isopleths of Organic Content (% dry wt.) in the Top 10 cm of Sediments in Bay Lake.

Figure 3-5. Isopleths of Sediment Density (g/cm^3 wet wt.) in Bay Lake.

Measured concentrations of total phosphorus in Bay Lake sediments were found to highly variable throughout the lake. Sediment total phosphorus concentrations range from 389-2263 μg/cm^3, with an overall mean of 1111 μg/cm^3. In general, sandy sediments are often characterized by low total phosphorus concentrations, while highly organic muck-type sediments are characterized by elevated total phosphorus concentrations.

Isopleths of sediment phosphorus concentrations in Bay Lake are presented on Figure 3-6 based on information contained in Table 3-3. Areas of elevated sediment phosphorus concentrations are primarily present in the central portions of the lake. The areas of elevated total phosphorus concentrations within the lake are similar to the areas of elevated moisture content and organic content summarized in Figures 3-3 and 3-4, respectively. In general, the overall total phosphorus concentrations observed in Bay Lake appear to be elevated compared with phosphorus sediment concentrations normally observed by ERD in urban lakes.

Similar to the trends observed for sediment phosphorus concentrations, sediment nitrogen concentrations are also highly variable in Bay Lake. Sediment nitrogen concentrations range from 4965-20,079 μg/cm^3, with an overall mean of 10,704 μg/cm^3. Similar to the trends observed for total phosphorus, the nitrogen concentrations measured in Bay Lake sediments appear to be significantly elevated compared with values normally observed in urban lakes.

Isopleths of sediment nitrogen concentrations in Bay Lake are illustrated on Figure 3-7. Areas of elevated nitrogen concentrations are apparent in the central portions of the lake similar to the area of elevated moisture content indicated in Figure 3-3.

3.2.3 <u>Phosphorus Speciation</u>

As discussed in Section 2, each of the collected sediment core samples was evaluated for phosphorus speciation based upon the Chang and Jackson Speciation Procedure. This procedure allows phosphorus to be speciated with respect to bonding mechanisms within the sediments. This information is useful in evaluating the potential for release of phosphorus from the sediments under anoxic or other conditions.

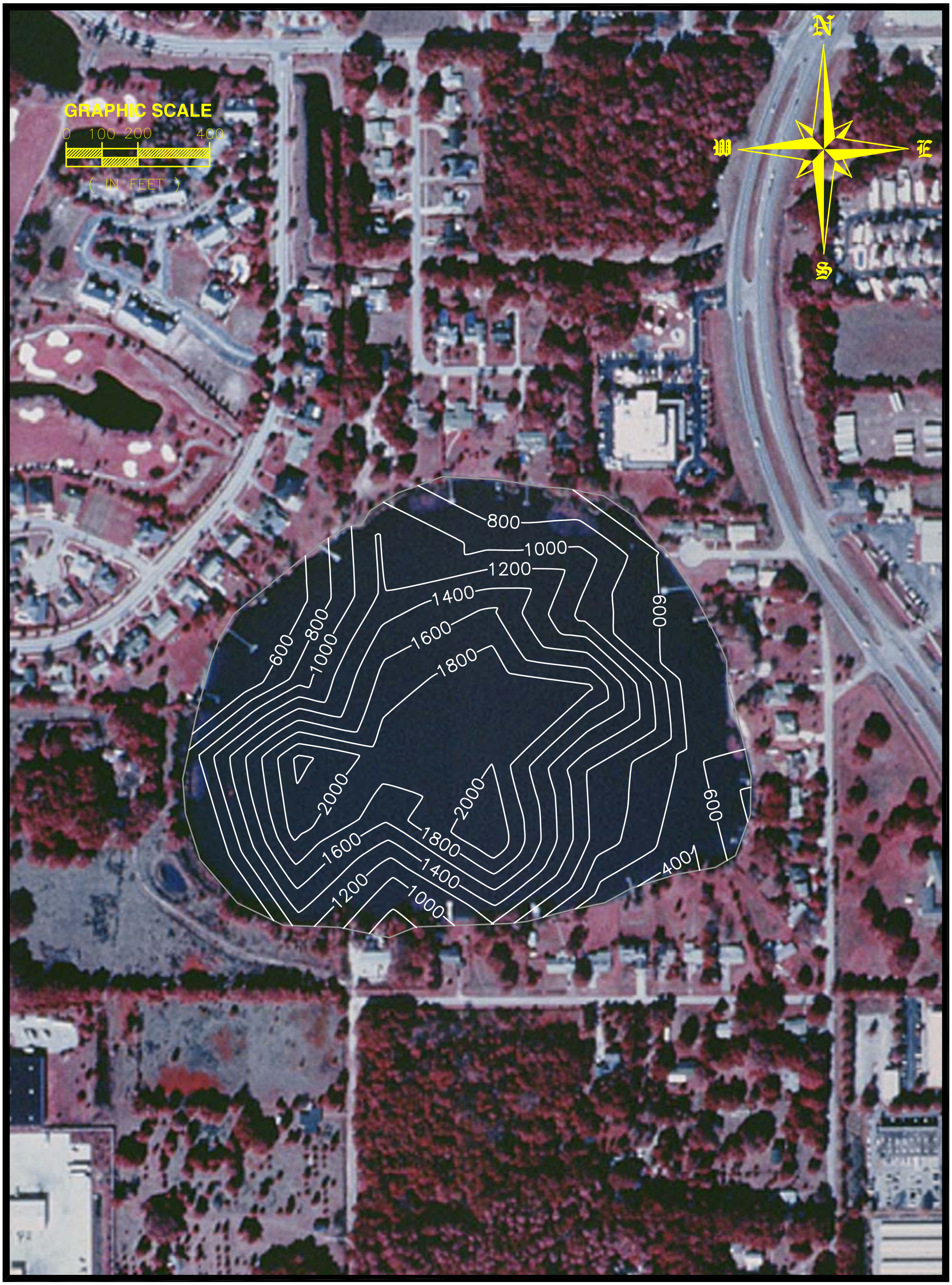

Figure 3-6. Isopleths of Total Phosphorus ($\mu g/cm^3$ wet wt.) in the Top 10 cm of Sediments in Bay Lake.

Figure 3-7. Isopleths of Total Nitrogen ($\mu g/cm^3$ wet wt.) in the Top 10 cm of Sediments in Bay Lake.

A summary of phosphorus speciation in sediment core samples collected in Bay Lake during January 2006 is given in Table 3-4. Saloid-bound phosphorus represents sediment phosphorus which is either soluble or easily exchangeable and is typically considered to be readily available for release from the sediments into the overlying water column. As seen in Table 3-4, a moderate degree of variability is apparent in saloid-bound phosphorus within the sediments of Bay Lake. Measured values for saloid-bound phosphorus range from 0.02-9.76 $\mu g/cm^3$, with an overall mean value of 0.95 $\mu g/cm^3$. In general, low levels of saloid-bound phosphorus are associated with sandy sediments within the lake, while elevated levels of saloid-bound phosphorus are associated with highly organic sediments.

Isopleths of saloid-bound phosphorus in Bay Lake sediments are illustrated on Figure 3-8. Areas of elevated saloid-bound phosphorus are apparent along the western end of the lake. The saloid-bound phosphorus concentrations summarized in Figure 3-8 are typical of values commonly observed in urban lake systems.

In general, iron-bound phosphorus sediment associations appear to follow a pattern similar to that exhibited by saloid-bound phosphorus. Areas of the lake with relatively sandy sediments are characterized by low levels of iron-bound phosphorus, while highly organic sediment areas appear to have higher values of iron-bound phosphorus. Iron-bound phosphorus is relatively stable under oxidized conditions, but becomes unstable under a reduced environment, causing the iron-phosphorus bounds to separate, releasing the oxygen bound phosphorus directly into the water column. When anoxic conditions occur near the water-sediment interface in Bay Lake, large portions of the lake appear to have conditions favorable for release of iron-bound sediment phosphorus into the overlying water column. The iron-bound phosphorus concentrations summarized in Table 3-4 appear to be similar to values commonly observed in urban lake systems.

Isopleths of iron-bound phosphorus in Bay Lake sediments are illustrated in Figure 3-9. Areas of elevated iron-bound phosphorus associations are apparent in the south central portion of the lake.

TABLE 3-4

PHOSPHORUS SPECIATION IN SEDIMENT CORE SAMPLES COLLECTED IN BAY LAKE DURING JANUARY 2006

SITE	SALOID-BOUND P ($\mu g/cm^3$)	Fe-BOUND P ($\mu g/cm^3$)	TOTAL AVAILABLE P ($\mu g/cm^3$)	PERCENT AVAILABLE P (%)
1	9.76	9.0	18.8	4.63
2	0.29	12.3	12.6	1.25
3	1.13	16.9	18.0	2.14
4	0.07	23.0	23.1	1.71
5	0.31	21.0	21.3	1.03
6	0.25	23.9	24.2	1.07
7	0.69	17.0	17.7	2.02
8	0.97	11.5	12.5	2.37
9	0.22	23.6	23.8	1.97
10	0.24	19.1	19.3	1.59
11	0.37	21.3	21.7	1.31
12	0.23	44.5	44.8	2.35
13	0.05	41.5	41.6	2.46
14	0.19	43.9	44.1	4.29
15	0.92	21.2	22.1	3.33
16	0.06	4.5	4.6	0.36
17	0.05	65.2	65.2	2.97
18	0.28	22.6	22.9	1.14
19	0.02	19.9	19.9	1.00
20	0.34	21.0	21.3	1.30
21	0.92	14.1	15.0	1.59
22	2.23	11.0	13.2	2.16
23	0.33	3.0	3.3	0.53
24	0.72	13.8	14.5	1.31
25	0.74	14.9	15.7	1.70
26	0.45	28.5	28.9	1.57
27	0.63	12.7	13.3	1.32
28	1.05	21.9	23.0	2.45
29	1.26	13.6	14.8	3.22
31	1.58	11.8	13.4	3.43
30	1.01	8.7	9.7	1.82
32	0.31	10.8	11.1	2.30
33	1.86	13.1	15.0	2.60
34	3.84	14.6	18.4	3.60
35	0.64	11.2	11.8	2.95
36	0.08	14.7	14.8	1.77
Mean	**0.95**	**19.5**	**20.4**	**2.07**
Minimum	**0.02**	**3.0**	**3.3**	**0.36**
Maximum	**9.76**	**65.2**	**65.2**	**4.63**

Figure 3-8. Isopleths of Saloid-Bound Phosphorus ($\mu g/cm^3$ wet wt.) in the Top 10 cm of Sediments in Bay Lake.

Figure 3-9. Isopleths of Iron-Bound Phosphorus ($\mu g/cm^3$ wet wt.) in the Top 10 cm of Sediments in Bay Lake.

Total available phosphorus represents the sum of the saloid-bound phosphorus and iron-bound phosphorus associations in each sediment core sample. Since the saloid-bound phosphorus is immediately available, and the iron-bound phosphorus is available under reduced conditions, the sum of these speciations represents the total phosphorus which is potentially available within the sediments. This information can be utilized as a guide for future sediment inactivation procedures.

A summary of total available phosphorus in each of the 36 collected sediment core samples is given in Table 3-4. Total available sediment phosphorus concentrations range from 3.3-65.2 $\mu g/cm^3$, with an overall mean of 20.4 $\mu g/cm^3$. The mean total available phosphorus in Bay Lake appears to be moderate in value compared with typical urban lake systems.

Isopleths of total available phosphorus in Bay Lake sediments are illustrated on Figure 3-10. Similar to the trends observed with previous sediment parameters, areas of elevated total available phosphorus are apparent in the central and southern portions of the lake. The isopleths presented in Figure 3-10 can be utilized as an application guide for future sediment inactivation activities.

Estimates of the percentage of available phosphorus within the sediments in Bay Lake are also provided in Table 3-4. These values represent the percentage of the total sediment phosphorus concentration, summarized in Table 3-3, which is potentially available for sediment release, based upon the total available phosphorus values summarized in Table 3-4. Based upon this comparison, the percentage of available sediment phosphorus within the lake ranges from 0.4-4.6%, with an overall mean of 2.1%. Therefore, on an average basis, approximately 2% of the total sediment phosphorus within the lake is potentially available for release into the overlying water column.

Figure 3-10. Isopleths of Total Available P ($\mu g/cm^3$ wet wt.) in the Top 10 cm of Sediments in Bay Lake.

3.4 Physical-Chemical Profiles

Physical-chemical profiles of temperature, pH, specific conductivity, dissolved oxygen, and redox potential were performed in the northern, central, and southern portions of Bay Lake by ERD field personnel on January 26, 2006. Measurements of Secchi disk depth were also performed at each site, with values ranging from 0.55-0.61 m, reflecting extremely poor water column clarity. A complete listing of physical-chemical profiles collected during January 2006 is given in Appendix A.

A graphical comparison of vertical profiles for temperature, pH, dissolved oxygen, and specific conductivity in Bay Lake on January 26, 2006 is given in Figure 3-11. Significant thermal stratification was observed in Bay Lake at a depth of 2.5-3.0 m at each of the three sites, with a temperature decrease of about 2^{o}C over a depth of 1.0-1.5 m. Significant thermal stratification is rare in Central Florida lakes during winter conditions, and is a reflection of the extremely poor water quality characteristics within the lake.

Relatively isograde pH profiles were observed in the top 2 m of Bay Lake on January 26, 2006, with surface pH values ranging from 8.3-8.5. However, below a depth of 2 m, measured pH values were observed to decrease steadily, reaching values ranging from 6.9-7.0 near the water-sediment interface.

Supersaturated dissolved oxygen conditions were observed in Bay Lake within the top 1.5-2.0 m of the lake at each of the three monitoring sites. These supersaturated dissolved oxygen conditions are a result of the visible algal bloom which was occurring within the lake during the monitoring event. However, after a depth of 2 m, dissolved oxygen concentrations were observed to decrease rapidly, reaching 0.4-0.5 mg/l at the water-sediment interface. In addition, highly reduced conditions, as indicated by redox potential values less than 200 mv, were observed near the sediment-water interface at each site. These reduced conditions create an environment which maximizes the potential for release of phosphorus into the overlying water column.

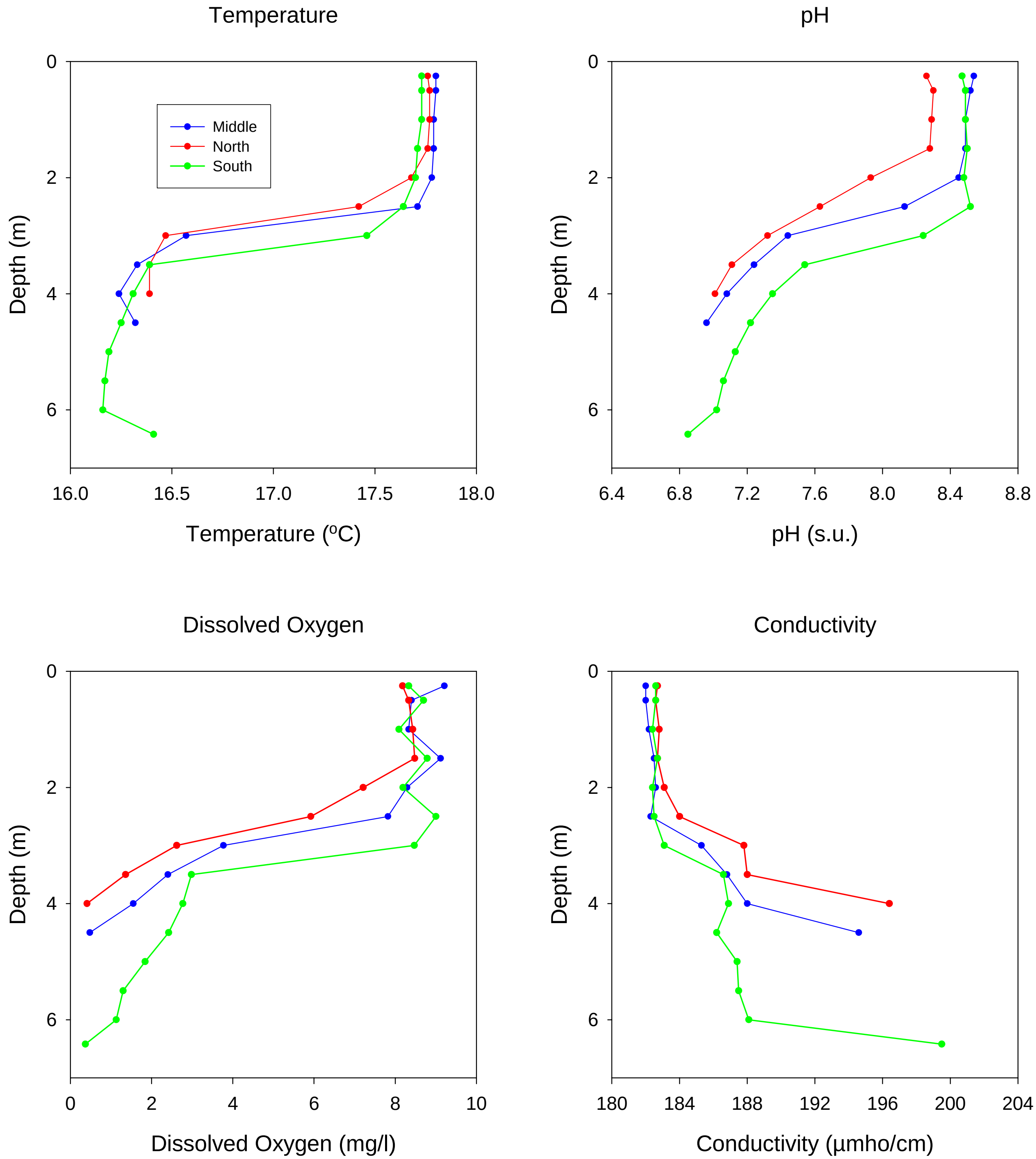

Figure 3-11. Vertical Profiles of Temperature, pH, Dissolved Oxygen, and Conductivity in Bay Lake on January 26, 2006.

Specific conductivity values in Bay Lake were relatively uniform within the top 2.0-2.5 m of the lake at each of the three sites. However, increases in specific conductivity were observed at depths greater than 2 m and particularly near the water-sediment interface. These observed increases in conductivity are a reflection of sediment release of ions, including phosphorus, near the water-sediment interface.

In summary, the vertical profiles presented in Figure 3-11 provide evidence that conditions of low dissolved oxygen are present near the sediment-water interface in Bay Lake even during winter conditions when dissolved oxygen is typically abundant in most lakes. Reduced conditions were also observed in this zone during January 2006, with rapid decreases in dissolved oxygen and pH and an increase in specific conductivity. This information suggests that internal recycling of ions is an ongoing occurrence in Bay Lake under existing conditions.

SECTION 4

EVALUATION OF ALUM INACTIVATION REQUIREMENTS

4.1 Significance of Internal Recycling

Based upon the sediment characterization and field monitoring performed by ERD, it appears that internal recycling of ions, including phosphorus, from anoxic bottom sediments is an ongoing occurrence within Bay Lake. Vertical profiles collected within the lake suggest that portions of the lake sediments exhibit anoxic conditions during much of the year. In addition, increases in specific conductivity are observed in lower layers of the lake, suggesting release of ions from the sediments into the overlying water column. As a result, internal recycling appears to be a significant occurrence in Bay Lake, which could be reduced by a properly designed application of aluminum sulfate to the lake sediments.

4.2 Sediment Inactivation Requirements

Estimates of the mass of total available phosphorus within the top 0-10 cm layer of the sediments in Bay Lake were generated by graphically integrating the total available phosphorus isopleths presented on Figure 3-10. Areas contained within each isopleth contour were calculated using AutoCAD Release 12.0. The top 0-10 cm layer of the sediments in the lake is considered to be an active layer with respect to exchange of phosphorus between the sediments and the overlying water column. Inactivation of phosphorus within the 0-10 cm layer is typically sufficient to inactivate sediment release of phosphorus within a lake.

A summary of estimated total available phosphorus in the sediments of Bay Lake is given in Table 4-1. On a mass basis, the sediments of Bay Lake contain approximately 338 kg of available phosphorus in the top 10 cm. On a molar basis, this equates to approximately 10,911 moles of available phosphorus to be inactivated during the sediment inactivation process.

TABLE 4-1

ESTIMATES OF AVAILABLE SEDIMENT PHOSPHORUS AND INACTIVATION REQUIREMENTS FOR BAY LAKE

AVAILABLE P CONTOUR INTERVAL ($\mu g/cm^3$)	INTERVAL MID-POINT ($\mu g/cm^3$)	AREA (ac)	AVAILABLE P (kg)		INACTIVANT REQUIREMENT	
			kg	moles	moles Al[1]	gallons of alum
< 5	2.5	0.18	0.2	6	60	7
5-10	7.5	0.87	2.6	85	847	103
10-15	12.5	7.06	35.7	1,152	11,520	1,403
15-20	17.5	12.10	85.7	2,765	27,652	3,367
20-25	22.5	8.07	73.5	2,371	23,713	2,887
25-30	27.5	2.93	32.7	1,053	10,533	1,283
30-35	32.5	2.11	27.7	894	8,938	1,088
35-40	37.5	1.80	27.3	880	8,797	1,071
40-45	42.5	1.27	21.8	704	7,035	857
45-50	47.5	0.64	12.3	397	3,973	484
50-55	52.5	0.46	9.8	315	3,151	384
55-60	57.5	0.28	6.5	209	2,092	255
60-65	62.5	0.10	2.5	80	798	97
> 65	67.5	0.00	0.0	0	1	0
Total:		**37.86**	**338**	**10,911**	**109,112**	**13,286**

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

Estimated inactivation requirements were calculated for Bay Lake based upon a molar Al:P ratio of 10:1, as utilized by ERD in previous inactivation evaluations. Prior research involving sediment inactivation has indicated that an excess of aluminum is required within the sediments to cause phosphorus to preferentially bind with aluminum rather than other available complexing agents. A 10:1 molar ratio of Al:P has been shown to be adequate to create this driving force. Based upon this ratio, inactivation of phosphorus release from sediments in Bay Lake will require approximately 109,112 moles of aluminum which equates to approximately 13,286 gallons of alum. Based on an average tanker volume of 4500 gallons, the required alum addition is equivalent to approximately 2.95 tanker loads. For convenience, this value is rounded up to 3 tankers (13,500 gallons).

An average water column dose of alum resulting from the sediment inactivation was calculated by dividing the alum requirement of 13,500 gallons by the overall volume of the lake (288 ac-ft). Since the alum application would occur at the surface, the overall whole-lake alum dose must be considered to evaluate potential water column impacts during the application. Application of approximately 13,500 gallons of alum to Bay Lake into a water column volume of approximately 288 ac-ft would result in an applied alum dose of 8.4 mg Al/liter.

4.3 Results of Laboratory Jar Tests

The results of laboratory jar tests performed on a Bay Lake composite sample collected on January 26, 2006 are summarized in Table 4-2. The laboratory results are provided for the raw composite sample and samples treated at alum doses of 5, 7.5, and 10 mg Al/liter.

TABLE 4-2

RESULTS OF LABORATORY JAR TESTS PERFORMED ON A BAY LAKE COMPOSITE WATER SAMPLE COLLECTED ON JANUARY 26, 2006

PARAMETER	UNITS	RAW	ALUM DOSE (mg Al/liter)		
			5.0	7.5	10.0
pH (raw)	s.u.	7.23	7.23	7.23	7.23
pH (1 minute)	s.u.	7.23	6.63	6.47	6.26
pH (1 hour)	s.u.	7.23	6.70	6.59	6.39
Conductivity	μmho/cm	155	158	159	158
Alkalinity	mg/l	48.8	38.2	30.8	23.8
Ammonia	μg/l	172	85	46	31
NO_x	μg/l	95	9	8	15
Organic N	μg/l	1479	1185	948	781
Total N	μg/l	1746	1279	1002	827
SRP (Ortho-P)	μg/l	3	< 1	< 1	< 1
Organic P	μg/l	72	26	16	11
Total P	μg/l	75	27	17	12
Turbidity	NTU	5.3	2	1.2	0.8
TSS	mg/l	6.5	5.9	2.0	0.7
Chlorophyll-a	mg/m^3	27.3	10.2	6.1	4.1
Diss. Al	μg/l	47	61	58	40
Sulfate	mg/l	12	29	29	37

The raw composite sample collected from Bay Lake was approximately neutral in pH, with a measured value of 7.23. The composite sample was moderately buffered, with a measured alkalinity of 48.8 mg/l. The measured total nitrogen concentration in the composite sample was somewhat elevated, with a measured value of 1746 μg/l. The total nitrogen observed within the sample was primarily organic in nature, with a relatively small contribution from ammonia and NO_x. The sample also contained a relatively elevated total phosphorus concentration of 75 μg/l which was primarily organic in nature. The initial chlorophyll-a concentration in the composite sample was 27.3 mg/m^3.

The addition of alum to the Bay Lake composite sample resulted in an initial decrease in pH with a minimum pH value of 6.26 observed after one minute at an alum dose of 10 mg Al/liter. The measured pH of the treated samples increased slightly after a settling period of approximately one hour. The addition of alum also resulted in a reduction in measured alkalinity within the water, with alkalinity decreasing to approximately 23.8 mg/l at a dose of 10 mg Al/liter. At the anticipated applied alum dose of 8.4 mg Al/liter, the equilibrium pH value within the lake should be approximately 6.5, with a final alkalinity of approximately 25-30 mg/l.

The addition of alum resulted in significant reductions in measured total nitrogen concentrations within the Bay Lake sample, primarily resulting from reductions in organic nitrogen and ammonia. At the proposed alum dose of 8.4 mg Al/liter, the equilibrium total nitrogen concentration within the lake should be approximately 900-1000 μg/l, a reduction of approximately 40-50% over existing concentrations.

The addition of alum resulted in substantial reductions in measured total phosphorus concentrations within the Bay Lake samples. At the anticipated applied alum dose, the equilibrium total phosphorus concentration within the lake should be approximately 15 μg/l, a reduction of approximately 80% compared with existing concentrations. The equilibrium chlorophyll-a concentration should be approximately 5 mg/m^3, a decrease of approximately 82% over existing conditions. Based on the laboratory jar test results summarized in Table 4-2, the addition of alum to Bay Lake will not result in significant increases in dissolved aluminum concentrations within the water column.

4.4 Application Strategy

Previous alum surface applications performed for inactivation of sediment phosphorus release by ERD have indicated that the greatest degree of improvement in surface water characteristics and the highest degree of inactivation of sediment phosphorus release are achieved through multiple applications of alum to the waterbody. Each subsequent application results in additional improvements in water column quality and additional alum floc added to the sediments for long-term inactivation of sediment phosphorus release. The additional aluminum provided to the sediments also creates an active absorption mechanism for other phosphorus inputs into the water column as a result of groundwater seepage. Inputs of phosphorus from groundwater seepage into a lake can easily exceed inputs from internal recycling in only a few annual cycles. Multiple applications of alum provide an abundance of aluminum which can intercept groundwater inputs of phosphorus over a period of many years. As a result, multiple inputs can eliminate phosphorus from the combined inputs resulting from internal recycling as well as groundwater seepage. Therefore, it is recommended that the required aluminum addition for Bay Lake, summarized in Table 4-1, be divided into a minimum of two separate surface treatments, with two tankers added during the initial treatment and one tanker added during the second treatment.

4.5 Application Costs

A summary of estimated application costs for sediment inactivation in Bay Lake is given in Table 4-3. This estimate assumes an alum volume of 13,500 gallons will be applied in two separate applications. Planning and mobilization costs are estimated to be approximately $500 per application, which includes initial planning, mobilization of equipment to the site, demobilization at the completion of the application process, and clean-up. Estimates of man-hour requirements for the application are provided based upon experience with similar previous applications by ERD. A labor rate of $100/hour is assumed which includes labor costs, water quality monitoring, expenses, equipment rental, insurance, mileage, and application equipment fees. The estimated cost for sediment inactivation in Bay Lake is $14,775.

TABLE 4-3

ESTIMATED APPLICATION COSTS FOR SEDIMENT INACTIVATION IN BAY LAKE

PARAMETER	AMOUNT REQUIRED	UNIT COST	TOTAL COST
1. Chemicals			
A. Alum	13,500 gallons	$0.65/gallon	$ 8,775
2. Labor			
A. Planning and Mobilization	2 applications	$750/application	$ 1,500
B. Chemical Application	40 man-hours	$100/hour[1]	$ 4,000
3. Lab Testing	Pre-/Post-samples x 2 events	$250/event	$ 500
		TOTAL:	**$ 14,775**

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

4.6 Longevity of Treatment

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

Based on previous experiences by ERD, as well as research by others, it appears that a properly applied chemical treatment will be successful in inactivation of the available phosphorus in the sediments of Bay Lake. However, several factors can serve to reduce the effectiveness and longevity of this treatment process. First, wind action may cause the floc to become prematurely mixed into deeper sediments, reducing the opportunity for maximum phosphorus adsorption. Significant wind resuspension has been implicated in several alum applications in shallow lakes which exhibited reduced longevity. However, in the absence of wind resuspension, alum inactivation in lake sediments has resulted in long-term benefits ranging from 3 to more than 10 years. However, due to the depth and small surface area of Bay Lake, it is not anticipated that wind-induced resuspension will be a problem.

Another factor which can affect the perceived longevity and success of the application process is recycling of nutrients by macrophytes from the sediments into the water column. This recycling will bypass the inactivated sediments since phosphorus will cross the sediment-water interface using vegetation rather than through the floc layer. Although this process will not affect the inactivation of phosphorus within the sediments, it may result in increases in dissolved phosphorus concentrations which are unrelated to sediment-water column processes. However, the degree of macrophyte growth in Bay Lake appears to be limited, and recycling of phosphorus by macrophytes does not appear to be a significant concern.

A final factor affecting the longevity of an alum treatment is significant upward migration of groundwater seepage through the bottom sediments. This seepage would almost certainly contain elevated phosphorus levels which would be adsorbed onto the aluminum floc, reducing the floc which is available for interception of sediment phosphorus release. At the recommended application dose, an additional available pool of aluminum may be present within the sediments which can be used to adsorb phosphorus migrating upward as a result of groundwater seepage. The recommended repeat alum application will further reduce the impacts of groundwater seepage on phosphorus loadings to the lake. Therefore, groundwater inflow through the sediments is not anticipated to substantially reduce the longevity of a sediment inactivation process in Bay Lake.

4.7 <u>Summary and Recommendations</u>

Based upon the results presented in the previous sections, it appears that sediment recycling of phosphorus is significant in Bay Lake. Since Bay Lake appears to be predominantly a phosphorus-limited ecosystem, reduction of phosphorus released from internal recycling will result in improved water quality characteristics within the lake. Therefore, a surface alum application for inactivation of sediment phosphorus in Bay Lake is recommended. The application should be performed using a water column dose of 8.4 mg Al/liter which equates to approximately 13,500 gallons of alum. Application of this dose could be safely achieved while maintaining an equilibrium pH value in excess of 6.0. Dividing the required dose into two separate applications will further improve water column clarity and provide additional aluminum to the sediments to inactivate sediment phosphorus release and absorb phosphorus loadings from groundwater seepage.

APPENDIX A

PHYSICAL-CHEMICAL PROFILES COLLECTED IN BAY LAKE DURING JANUARY 2006

		Date	Time	Dep25 (m)	Temp (°C)	pH (s.u.)	SpCond (µmho/cm)	DO (mg/l)	DO% (Sat)	ORP (mV)	Turb (NTU)	Secchi (m)
Bay Lk	Middle	1/26/06	8:10	0.25	17.80	8.54	182	9.2	115	411	17.4	0.61
Bay Lk	Middle	1/26/06	8:11	0.50	17.80	8.52	182	8.4	105	411	15.6	0.61
Bay Lk	Middle	1/26/06	8:12	1.00	17.79	8.49	182	8.3	104	411	13.7	0.61
Bay Lk	Middle	1/26/06	8:13	1.50	17.79	8.49	183	9.1	114	411	13.4	0.61
Bay Lk	Middle	1/26/06	8:14	2.00	17.78	8.45	183	8.3	104	412	13.4	0.61
Bay Lk	Middle	1/26/06	8:15	2.50	17.71	8.13	182	7.8	98	397	12.4	0.61
Bay Lk	Middle	1/26/06	8:17	3.00	16.57	7.44	185	3.8	46	367	8.2	0.61
Bay Lk	Middle	1/26/06	8:18	3.50	16.33	7.24	187	2.4	29	358	8.8	0.61
Bay Lk	Middle	1/26/06	8:19	4.00	16.24	7.08	188	1.6	19	341	10.0	0.61
Bay Lk	Middle	1/26/06	8:22	4.38	16.32	6.96	195	0.5	6	172	>1000	0.61
Bay Lk	North	1/26/06	8:27	0.25	17.76	8.26	183	8.2	102	335	16.7	0.55
Bay Lk	North	1/26/06	8:28	0.50	17.77	8.30	183	8.3	104	338	15.8	0.55
Bay Lk	North	1/26/06	8:29	1.00	17.77	8.29	183	8.4	105	337	13.7	0.55
Bay Lk	North	1/26/06	8:30	1.50	17.76	8.28	183	8.5	106	336	13.0	0.55
Bay Lk	North	1/26/06	8:31	2.00	17.68	7.93	183	7.2	90	316	12.5	0.55
Bay Lk	North	1/26/06	8:32	2.50	17.42	7.63	184	5.9	73	298	10.7	0.55
Bay Lk	North	1/26/06	8:33	3.00	16.47	7.32	188	2.6	32	280	9.0	0.55
Bay Lk	North	1/26/06	8:34	3.50	16.39	7.11	188	1.4	17	267	11.5	0.55
Bay Lk	North	1/26/06	8:36	3.95	16.39	7.01	196	0.4	5	181	>1000	0.55
Bay Lk	South	1/26/06	8:41	0.25	17.73	8.47	183	8.3	104	344	16.3	0.59
Bay Lk	South	1/26/06	8:41	0.50	17.73	8.49	183	8.7	109	346	15.7	0.59
Bay Lk	South	1/26/06	8:42	1.00	17.73	8.49	182	8.1	101	347	14.6	0.59
Bay Lk	South	1/26/06	8:43	1.50	17.71	8.50	183	8.8	110	348	14.0	0.59
Bay Lk	South	1/26/06	8:44	2.00	17.70	8.48	182	8.2	102	348	13.1	0.59
Bay Lk	South	1/26/06	8:46	2.50	17.64	8.52	183	9.0	112	351	13.1	0.59
Bay Lk	South	1/26/06	8:47	3.00	17.46	8.24	183	8.5	105	334	12.5	0.59
Bay Lk	South	1/26/06	8:48	3.50	16.39	7.54	187	3.0	36	292	9.0	0.59
Bay Lk	South	1/26/06	8:49	4.00	16.31	7.35	187	2.8	34	282	8.5	0.59
Bay Lk	South	1/26/06	8:50	4.50	16.25	7.22	186	2.4	29	274	8.2	0.59
Bay Lk	South	1/26/06	8:51	5.00	16.19	7.13	187	1.8	22	270	7.6	0.59
Bay Lk	South	1/26/06	8:52	5.50	16.17	7.06	188	1.3	16	265	8.2	0.59
Bay Lk	South	1/26/06	8:52	6.00	16.16	7.02	188	1.1	14	193	>1000	0.59
Bay Lk	South	1/26/06	8:53	6.42	16.41	6.85	200	0.4	4	115	>1000	0.59