LAKE WORTH LAGOON MONITORING PROJECT

FINAL REPORT
DEP AGREEMENT NO. WAP028
PBC NO. R2001-0401

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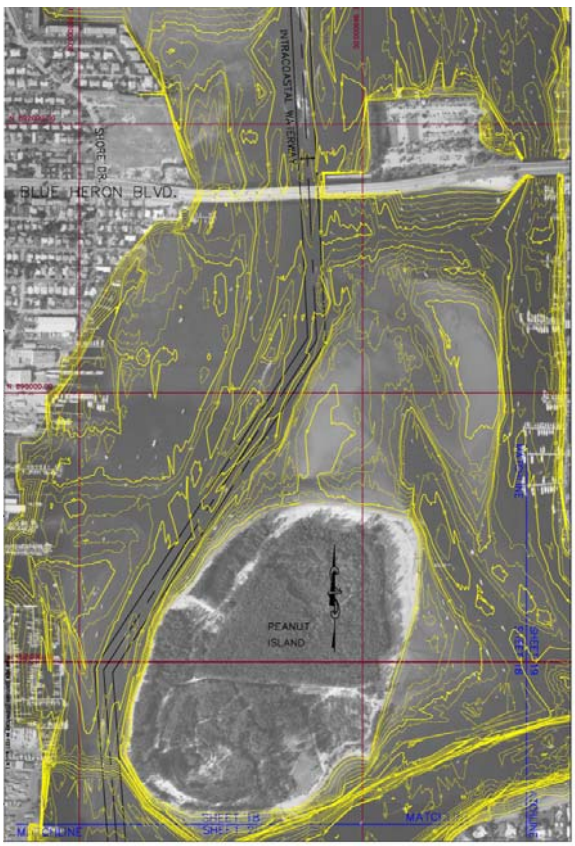

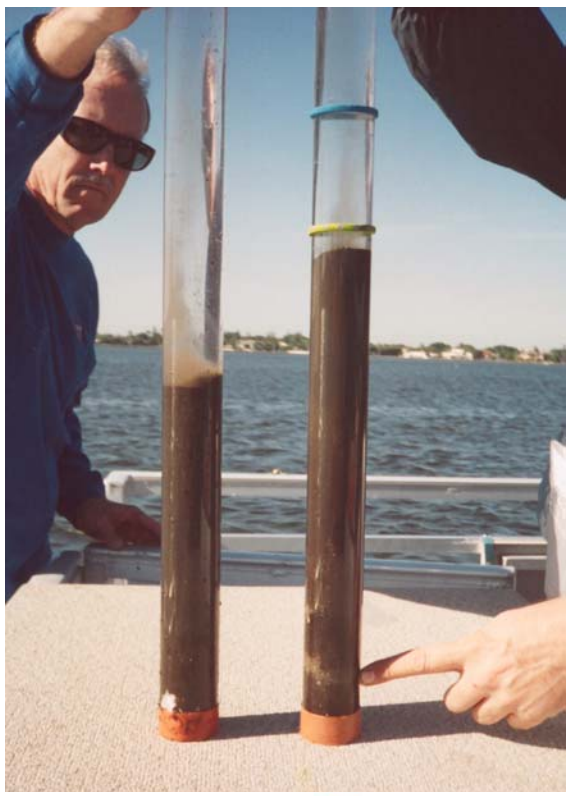

LAKE WORTH LAGOON
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DEPARTMENT OF ENVIRONMENTAL PROTECTION
FLORIDA

PALM BEACH COUNTY
FLORIDA

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INTRODUCTION

Since 1998, the Florida Legislature has supported a partnership developed between the Florida Department of Environmental Protection (DEP) and Palm Beach County (PBC) Board of County Commissioners by appropriating $9.4 million for the Lake Worth Lagoon Partnership Grant Program (LWLPG). This pass-through grant program, from the DEP to PBC and from PBC to local sponsors, provides funding for the reimbursement of locally sponsored construction projects designed to benefit the water quality and habitat in Lake Worth Lagoon. The PBC Department of Environmental Resources Management Department (ERM) acts as the grant administrator for the program and facilitates a "Request for Proposals" process to solicit projects from local sponsors. A selection committee reviews the project proposals and qualifies projects to receive funding. A qualified project is a construction project designed to have measurable improvement to the Lake Worth Lagoon. Types of projects which have been funded include:

- stormwater improvements such as wet detention, baffle boxes and other pollution control devices;
- upgrading septic systems to centralized sewage collection and treatment;
- marina sewage pumpout system;
- artificial reef construction;
- mangrove planters; and
- comprehensive habitat restoration including exotic removal, scrape down, and wetland planting.

Twenty-nine construction projects have been funded, fourteen are complete and the remaining projects are in various stages of planning, permitting and construction. Local project sponsors have committed more than $23 million in matching dollars for the funded projects for a total estimated project cost of nearly $34 million (Attachment 1).

Construction projects are located throughout the lagoon and surrounding watershed (Attachment 2). Until recently, there was no effective way to fund any comprehensive monitoring in order to determine if these projects are making any difference in the overall environmental health of the lagoon. In addition, better baseline data was needed for a comparison of pre- and post-project conditions in the lagoon. Generally, such funding is difficult to secure through grants or other traditional funding opportunities. As a result, DEP agreed to allow a limited portion of the grant funds to be used for monitoring the lagoon's environmental health.

In SFY 2000-2001, the State Legislature appropriated $3,000,000 for the LWLPG program. Of this amount, 5% or $150,000 was directed to the LWL monitoring project. DEP and PBC entered into DEP Agreement No. WAP028, for the implementation of three monitoring sub-projects in Lake Worth Lagoon. This report summarizes those efforts.

Sub-project 1.0: Water Quality & Sediment Monitoring Program

Water quality monitoring of surface waters within Palm Beach County has been conducted for 26 years. Initially, the monitoring was conducted by the Palm Beach County Health Department. In 1988, the monitoring program was transferred to PBC ERM. In 1998, to comply with the National Pollutant Discharge Elimination System (NPDES) permit monitoring requirements, 27 "core" water quality monitoring sites were selected (in Palm Beach County) based on location. The NPDES program was implemented in 1998. Of the 27 sites, 22 are monitored by ERM and five are

monitored by the Loxahatchee River District. Five of the 22 sites monitored by ERM are in the Lake Worth Lagoon.

The purposes of the water quality monitoring program are the identification of trends in water quality and existing water quality status, and the assessment of the effectiveness of the NPDES Stormwater Management Programs implemented by the co-permitees. The monitoring protocol requires that samples be collected and analyzed quarterly. However, a more aggressive sampling program in terms of frequency is considered necessary to provide statistically valid water quality results. As a result, PBC ERM proposed Sub-Project 1.0 to expand the existing quarterly sampling program within Lake Worth Lagoon to every other month and to add additional sampling stations. Subsequent to the agreement's execution, however, DEP expanded its current water quality monitoring program to add six Lake Worth Lagoon sites and to sample all stations on a monthly basis in conformance with State and Federal requirements and initiatives, including the Comprehensive Everglades Restoration Plan (CERP), and the need to determine Total Maximum Daily Loads (TMDLs) for surface waters. As such, DEP and PBC ERM discussed and agreed that it was in the best interest of both parties for the DEP to assume responsibility for the expanded water quality monitoring responsibilities under the agreement. As a result, Amendment No. 1 to the agreement was executed on June 17, 2003, and the monies originally designated for this sub-project were allocated to Subprojects 2.0 and 3.0.

Sub-project 2.0: Muck Sediment Monitoring

Natural sediments in the Lake Worth Lagoon are composed primarily of sand or shell fragments. A common occurrence during the last 50 or more years is the deposition of fine-grained silt and clay - enriched organic sediments known as "muck" - in areas downstream from freshwater discharge points which convey stormwater (non-point source pollution) from upstream agriculture and urban sources into the lagoon. Muck has been observed in localized areas throughout the lagoon system and has appeared to be largely confined in areas near major stormwater discharge locations, within deep dredge holes (greater than 10' deep) and in the vicinity of the C-51 canal. Muck contributes to turbidity and reduced light penetration in the water column. Preliminary investigations have revealed that a large area of the lagoon, from the confluence of the C-51 canal and the lagoon, north to the Southern Boulevard Bridge and south to the Lake Avenue Bridge, appear to be partially covered with a layer of muck, and, for the most part devoid of submerged aquatic vegetation.

One of the major objectives of the ***Lake Worth Lagoon Management Plan*** is to decrease the input of suspended materials from point and non-point sources. A number of projects either under construction or to be constructed within the next decade include projects funded under the Lake Worth Lagoon Partnership Grant Program, the West Palm Beach Master Stormwater Plan, Stormwater Treatment Area 1 East, and components of the North Palm Beach County CERP. It is expected that these projects will reduce the sediments and pollutants carried by those waters into the lagoon, and that the benthic habitat and submerged aquatic vegetation downstream of the receiving area will improve as a result. In addition, the NPBC CERP project has a component which recommends that muck sediments be addressed by either dredging and/or capping. Sub-project 2.0 was designed to provide data to help assess the feasibility of these management options.

Prior to the implementation of LWLPGP and CERP construction activities, which are expected to reduce sediment loading to the lagoon, PBC proposed, under Sub-Project 2.0, to investigate both the quantity and quality of muck sediments with a five-mile stretch of the lagoon at the confluence of the C-51 canal and the lagoon, from approximately the Southern Boulevard Bridge to the Lake

Avenue Bridge, known as the Lake Worth Lagoon study area. The results from implementation of Sub-Project 2.0 will help identify the pre-construction conditions within the study area and provide the baseline data necessary to evaluate the lagoon's environmental health.

Under Phase I of Sub-Project 2.0, a comprehensive bathymetric (lagoon-wide) and muck survey was produced using single and dual frequency fathometers. Maps depicting the lagoon's bathymetry relative to NGVD and MLLW and approximate muck location maps were produced and provided under separate cover as part of the deliverables under Sub-Project 2.0.

The dual frequency portion of the survey indicated the approximate location of muck greater than one foot deep. Unfortunately, the dual frequency fathometer was unable to reliably define the extent of the muck layer beyond one foot. A planned rod probe survey to define the vertical extent of the muck was also found to be potentially unreliable in that it appeared the rod probe could penetrate sand well as muck, resulting in an overestimation of the depth of the muck. The problems were discussed with DEP and it was agreed that monies designated for the rod probe survey would instead be used to expand the dual frequency survey south from the study area so that a larger muck map, indicating the areal extent of muck and the approximate minimum volume of muck, was generated. The expanded study area for the purpose of muck delineation was expanded southward to the Woolbright Road Bridge. The approximate minimum volume of muck calculated for the expanded study area is 681,000 cubic yards.

The muck survey and maps produced under Phase I assisted PBC staff with the implementation of Phase II of Sub-Project 2.0. Staff was able to target areas of known muck accumulation to implement a study of the muck quality, sediment age and sediment accumulation rates within the original study area. ERM staff implemented a preliminary study resulting in the collection of two core samples for comprehensive analysis. In an expanded study, staff collected six cores each from three additional sites within the study area to further define and more thoroughly investigate any pollutants of concern contained in the muck. The results of the Phase II investigation are provided with this report as part of the deliverables under this sub-project.

Sub-project 3.0: Comprehensive Seagrass Monitoring

One of the most important resources in the estuarine environment is seagrass. Seagrasses are flowering plants that live underwater, produce oxygen as a metabolic byproduct, have a limited depth range because of their need for light and provide many desirable functions including:

- Maintaining water clarity by trapping fine sediments and particles with their leaves;
- Stabilizing bottom sediments with their roots and rhizomes;
- Providing habitat and nursery areas for the majority of Florida's recreationally and commercially important marine fishes, crustaceans, and shellfish; and
- Providing substrate for epiphytes which, along with seagrasses, furnish food for marine animals including manatees.

Seagrasses within the Lake Worth Lagoon historically have existed primarily near the inlets and were never very abundant. In general, seagrasses are most abundant and dense in the shallow areas and in areas which contain good water quality. The largest seagrass beds found in the lagoon are north of the Palm Beach Inlet.

Seagrasses are also an important indicator of the environmental health of a water body. Seagrass surveys are an important tool for assessing the health of the Lake Worth Lagoon. In surveys done in 1940 (Harris et al 1983), there were 4271 acres of seagrass found in the lagoon. In 1975 a resource inventory found only 61 acres of seagrass. In 1990 a comprehensive survey by ERM staff found an estimated total of 2010 acres (Dames and Moore, 1990). This increase can probably be attributed to passage of the Federal Clean Water Act in 1973 and the subsequent elimination of sewage disposal outfalls that had discharged directly into the lagoon. For the most part, wastewater discharges, known as point source discharges, are now under control. However, untreated stormwater and other non-point source discharges are now considered one of the greatest threats to the health of surface waters and, thus, to seagrasses. Stormwater enters the lagoon through three major drainage canals and hundreds of stormwater outfalls which discharge directly to the lagoon. The sediments contained in stormwater damage seagrass by the formation of a muck layer which, in some areas, may be thick enough to physically prevent the establishment of seagrasses. In addition, wind, wave action and boat wakes re-suspend the top of the muck layer, clouding the water column which reduces light penetration, reduces the depth of the photic zone, and hence, affects the health and distribution of seagrasses.

A major objective of the ***Lake Worth Lagoon Management Plan*** is to restore, preserve and create seagrass beds, oyster bars and other submerged benthic habitat. Protection and preservation of existing beds is the top priority, followed by restoration and creation. In order to preserve existing seagrass beds, it is necessary to first determine where seagrasses are located. Sub-Project 3.0 was implemented in order to map existing seagrasses in the lagoon and to monitor seagrasses in an effort to determine if selected seagrass beds are stable, expanding or receding in response to current efforts underway to improve the lagoon's water quality and habitat under the LWLPGP. First, true color aerial photographs of the Lake Worth Lagoon were acquired in order to prepare a Geographic Information System (GIS) coverage of lagoon seagrasses. This updated seagrass map will be an important management tool for obtaining a current inventory of this resource, identifying healthy areas that deserve special protection efforts and other potential problem areas requiring further attention.

Another objective of Sub-Project 3.0 was to conduct selected area monitoring via fixed transects to determine whether seagrass beds in the lagoon are stable, improving or declining and by how much. It is expected that as water clarity improves due to the implementation of projects funded under the Lake Worth Lagoon Partnership Grant Program and other construction projects which will benefit the lagoon, seagrass beds will expand to deeper waters because of increased light penetration in the water column.

This report also includes a summary of the in-kind projects used as match, recommendations for future monitoring and management, and a summary of all financial activity under the referenced agreement.

SUB-PROJECT 2.0: MUCK SEDIMENT MONITORING AND MANAGEMENT
Phase I - Bathymetric and Muck Survey

Phase I of this sub-project consolidated existing bathymetric data with new field measurements into one comprehensive bathymetric map for Lake Worth Lagoon. An additional component of the Phase I sub-project was to locate, to the greatest extent possible, significant muck deposits within the central portion of the lagoon.

Objectives

Morgan & Eklund, Inc. was contracted by the Palm Beach County Board of County Commissioners (PBC BCC) to provide professional hydrographic surveying services to the PBC ERM. These services were provided under Task Order No. 0178-17, and Task Change Order Nos. 0178-17A and 0178-17B of Contract Number R2000-0178. The objectives of the task order were as follows:

1. Conduct a bathymetric survey of the Lake Worth Lagoon from Indiantown Road Bridge (S.R. 706) to the Woolbright Road Bridge (S.W.15th St.) including Little Lake Worth.
2. Conduct a dual frequency bathymetric survey from Everglades Island to the Woolbright Road Bridge in specific locations to determine locations where the depth of muck was greater than one foot.
3. Conduct a bathymetric survey to more accurately define dredged or naturally occurring deep holes in specific locations.
4. Combine the results of all surveys with data from other professional surveyors that were previously under contract to survey various areas of the Lake Worth Lagoon. The results of these combined field surveys will be presented in the form of: (1) plan view data point plots, and; (2) contours plotted on aerial photos to Palm Beach County and NOAA. The X, Y, Z files from Morgan & Eklund's surveys will be provided with the corresponding metadata files.

Methodology

Record Research and Survey Setup

Morgan & Eklund acquired National Geodetic Survey (NGS) data sheets for benchmarks in the vicinity of Lake Worth Lagoon to use as primary benchmarks for establishing elevations at the tide staff locations. Palm Beach County Department of Environmental Resources Management provided aerial photography of the area and coordinated with Sea Systems, Inc. to provide previously surveyed data. Single frequency survey lines were created between the existing 400-meter survey lines to densify the bathymetry. In areas where there was no existing data, new survey lines were spaced 200-meters apart. Based on the results of the single frequency survey, dual frequency survey lines (to delineate areas of muck) and deep-hole survey lines (to detail and quantify areas that are substantially deeper than surrounding areas) were created. Palm Beach County Department of Environmental Resources Management personnel reviewed the location of all survey lines prior to the field survey being conducted. The survey lines were created in AutoCAD Land Development Desktop Version 2i and converted into HYPACK Survey Software line file format for use in navigation onboard the survey vessel.

Bathymetric and Muck Survey

The surveys were conducted in the following sequence:

1) Temporary benchmarks were established at the edge of the Lake Worth Lagoon survey area

at approximately two-mile intervals to be utilized as water surface elevation monitoring sites during the collection of sounding data. Tide staffs were more closely spaced around inlets.

2) The elevations for the tide staff locations (TBM's) were determined by closed loop differential leveling from published NGS benchmarks.
3) The northing, easting and elevation of each of the TBM's were observed with RTK/GPS. The leveled values were compared to the GPS derived values to provide a "second independent check" on the accuracy of the elevations of the tide staffs that were used to determine the bottom elevations.
4) The single frequency survey was completed throughout the project area.
5) The dual frequency survey was conducted from Everglades Island to Lake Worth (Lake Ave.) Bridge to determine areas where the depth of muck was greater than one foot.
6) The results of the single and dual frequency surveys were plotted and then reviewed by PBC ERM staff. It was determined that the rod probe survey originally planned to further define the vertical definition of the muck layer would be of limited value. It was agreed that additional investigation with the dual frequency fathometer was needed to further define the location of the muck layer know to exist in the area from Everglades Island to Lake Worth Bridge. In addition, dual frequency survey lines were extended south to the Woolbright Road (S.W. 15th St.) Bridge (Task Change Order No. 0178-17B).
7) Preliminary Data Point Plots and Contour Maps were provided to the Palm Beach County Department of Environmental Resources Management project manager in order to select deeper areas for further investigation.
8) Three additional days of bathymetry were conducted to further delineate a limited number of deep holes identified on the preliminary contour maps.
9) The survey data collected was combined with data from four existing professional surveys:

✓ Peanut Island/Lake Worth Inlet	September 2000	Morgan & Eklund
✓ Lake Worth Golf Course	February 2002	Morgan & Eklund
✓ FDOT Bridge Survey	1999-2000	Sea Systems, Inc.
✓ South Lake Worth Inlet	2001-2002	Sea Systems, Inc.

The bathymetric surveys were conducted using three of Morgan & Eklund's survey vessels: a 25' Parker, a 22' Privateer, and a 16' Lowe. All vessels were outfitted with Panasonic Toughbook Laptop Computers with HYPACK Survey Software that were used for collecting the horizontal positioning and sounding data, together with providing navigation during the survey. Trimble 4000 SE or Trimble DSM 212-L Differential Global Positioning System Receivers using Real-Time Coast Guard Radio Beacon corrections provided the horizontal positioning data. Soundings were obtained with an Odom Hydrotrac Fathometer for the single frequency bathymetric surveys, an Odom Mark II Echo Sounder for the first phase of the dual frequency survey and an Odom Mark III Echo Sounder for the remainder of the dual frequency survey. A fiberglass survey rod was used to sound in areas too shallow for the transducer, and to determine if the depth of muck was greater than one foot in some areas.

At the beginning and end of each survey day, the echo sounder was calibrated for depth accuracy, adjusting for the speed of sound in water using a "bar check". In addition, "check-lines" were run each survey day that could be compared to either the previous day's data and or data previously surveyed by others. Lake Worth Lagoon is a tidal estuary and the tide staffs were located throughout the Lagoon to correct for the change of water surface elevation due to tides and wind induced set-up

during the survey day. As previously discussed, tide staff elevations were referenced to NGS vertical control. Two tide staffs bounding the area where the survey was conducted were observed simultaneously to ensure that accurate water surface elevations were applied to the sounding data. On most occasions, the difference between the two tide staffs being read simultaneously was ± 0.1'.

Results

Preparation of Project Deliverables. The bathymetric survey data was downloaded from the laptop computers to a Dell Precision 410 Desktop Computer equipped with HYPACK Survey Software in the office. The data was processed using HYPACK's single beam editor sorting the data to 25' intervals and correcting the soundings to elevations using the tide staff elevation data. The digital data was compared to the analog depth charts to eliminate any false returns or spikes. The dual frequency sounding data was edited in the same manner and the two sounding frequencies were compared to determine where the muck depth was greater than one foot. The edited high frequency (lagoon bottom) data was then converted to X, Y, Z format.

The X, Y, Z data was brought into AutoCAD Land Development Desktop Version 2i. Terrain break-lines were created and used to create a Triangulated Irregular Network (TIN) and a Digital Terrain Model (DTM). Contours are plotted on 1 foot intervals from 0' to -6' NGVD, and 2-foot intervals from -8' to -58' NGVD from the DTM.

The survey data is displayed as NGVD29 elevations plotted on digital aerial images of the project area. The elevations were color-coded to delineate between the data collected by Morgan & Eklund, Inc. and Sea Systems, Inc. Color was also used to show the areas where the muck depth was greater than 1-foot. Contours were labeled and displayed on the digital aerial images. The plan view drawings are plotted at 1"=200' scale.

Quality control procedures employed to ensure the accuracy of all data sets included:

1) Closed loop level runs from published benchmarks to tide staffs;
2) RTK/GPS observations of tide staff TBM's;
3) Calibration of boat for draft, squat and settlement;
4) Calibration of fathometer for speed of sound in water (bar check);
5) Overlap of survey lines between survey days, plot comparative profiles;
6) Comparative profiles of newly acquired data versus historical data; and
7) Simultaneous reading of tide staffs bracketing each survey reach.

Final Deliverables. The deliverables for this sub-project were previously submitted under separate cover and include the following:

1. Bathymetric survey of elevation data and muck probe survey (track lines) as an overlay with digital aerial photo as base on 24" x 36" paper sheets – 1 set of drawings;
2. Bathymetric survey with one foot contours (for areas < or = 5') and two-foot contours (for areas >5' depth) relative to NGVD as an overlay with digital aerial photo as base on 24" x 36" paper sheets 1 set of drawings;
3. Bathymetric survey with one foot contours (for areas < or = 5') and two foot contours (for areas >5' depth) relative to MLLW as an overlay with digital aerial photo as base on 24" x 36" paper sheets – 1 set of drawings;
4. An electronic copy of each bathymetric survey, relative to NGVD and MLLW;

5. An "Approximate Area" muck map as an overlay with digital aerial photo as base on 24" x 36" paper sheets – 1 set of drawings (Note: An estimate of minimum muck volume as determined by this survey is equal to 680,959 cubic yards. The estimated volume is considered to be conservative in that there are known locations where the muck depth exceeds six feet.)

Also please note that the bathymetric data relative to MLLW will soon be available by logging on PBC ERM's website, via the following link:

www.co.palm-beach.fl.us/erm/divisions/enhancement/habitat/lake_worth_lagoon/lwl.htm

Discussion/Recommendations

This project provides a comprehensive bathymetric map of Lake Worth Lagoon which will assist in future management decisions. Specifically, the information provided will be useful for:

1. documentation of navigable waters as an aid for recreational boaters with a focus on protecting existing seagrass beds and other resources;
2. identification of deep dredge holes which may be targeted for restoration;
3. documentation of areas which may support seagrasses in the future and other restoration efforts;
4. documentation of the location of muck sediments for further study and/or restoration (see Phase II –Sediment Sampling and Evaluation); and
5. assessing the success of improved management of muck sediments within both Lake Worth Lagoon and the sources contributing to the muck deposition.

SUB-PROJECT 2.0: MUCK SEDIMENT MONITORING AND MANAGEMENT
Phase II - Sediment Sampling and Evaluation
Preliminary Study -1a

Objective

This preliminary evaluation of muck deposits was designed to identify any contaminants associated with sediment deposition in the Lake Worth Lagoon occurring at elevated levels. In addition, distribution of these elements in the sediment column was determined by analyzing each distinct sediment layer individually. This information will be used to decide whether cores collected as part of a more comprehensive sampling will be divided into layers prior to analysis, or composited. This preliminary evaluation was also planned to provide information on sediment composition and accumulation rates. Various sediment sampling procedures were evaluated in order to determine the best method for use in further studies.

Sample Collection and Processing

On August 26, 2002, ERM staff went by boat to a site near the northwest corner of Ibis Isle (Attachment 3) to collect sediment cores. This site was selected due to its proximity to the mouth of the C-51 canal, and had been identified in earlier surveys as having a deep accumulation of muck sediments. The coring device used was based upon a design engineered by South Florida Water Management District (SFWMD) staff for use in Lake Okeechobee (Davis and Steinman, 1998). A PVC check valve had female fittings (PVC, schedule 40, 2" i.d.) attached to each end. To the downstream end, varying lengths of PVC pipe, with a female fitting at one end and a male fitting at the other, were connected, allowing samples to be collected at water depths from 0 to 25 feet. At the upstream end of the check valve, an eight foot length of Lexan tubing, (with a male fitting at one end), was attached to be used as the coring tube.

Upon reaching the sample site, the water depth was recorded using both the depth gauge mounted on the boat (recorded 42" of water), and using a measuring tape (recorded 46" of water). The coring tube was inserted into the sediment until refusal, and then pounded a further ~6" into the substrate. The depth to which the coring tube was inserted was measured in order to compare to the thickness of the collected sample. Compression of the sediment core was expected as a result of the sampling process, and the degree of this compression was documented. Following the collection of these measurements, staff attempted to remove the coring tube from the sediment. This proved to be impossible. Retrieval of the coring tube was delayed until the following day, August 27, 2002, when additional staff could be pressed into service to assist. A second core sample (Field Duplicate) was also collected on this day, approximately 12 feet from the site of the first sample. Although there was good correlation between these two samples in the top two layers (predominantly muck), the field duplicate contained an obvious layer of white sand at a depth of 21 to 25 inches, which was absent from the first core sample. A more detailed characterization of these core samples can be found in Attachment 4. On September 16, 2002, ERM staff returned to this site to collect an additional core for analysis of Cs-137 and Pb-210. Concentrations of these stable isotopes would be used to calculate accumulation rates of sediment at this site. This core was collected using the same procedures described above.

On September 28, 2002, ERM staff accessed the C-51 canal from the Lake Clark Shores boat ramp in an attempt to collect a sediment core from the canal, upstream of control structure S155. Attempts were made to collect sediment cores at the bend in the C-51 canal from which point it begins its easterly flow into the Lake Worth Lagoon. This site was chosen on the basis of previous surveys that showed it to be an area of deep muck deposits. Depth of sediment deposits prevented the collection of sediment cores as it was impossible to penetrate the muck sediments to the underlying sand in order to create a sand plug in the bottom of the coring tube. A petite ponar dredge sampler was instead used to collect a surficial sediment sample in this location.

Cores were photographed, and depth of the layers measured immediately following extraction. Sub-samples were collected by cutting through the Lexan tubing with a circular saw to a depth sufficient to penetrate the wall of the tubing. The cores were then split using a stainless steel knife. Cores were again photographed alongside a tape measure. Samples for metals/nutrient/toxins analysis were spooned from the interior of the core to avoid possible contamination in the outer surfaces. Samples for grain size, percent organics, etc., analysis were collected from the remaining sample.

Results/Discussion

A total of ten samples, for metals, nutrient, and toxins analysis, were sent to Severn Trent Laboratories (STL). Five sub-samples were taken from core number Ibis-1, and four sub-samples from core number Ibis-FD. One sub-sample was taken from the grab sample (C51) collected in the C-51 Canal. A spreadsheet and graphical representation of the results can be seen in Attachments 5 and 6, respectively. A brief summary of these results and a comparison to the results of the Indian River Lagoon study conducted by Trefry*, et. al.*, (1994), follows.

- The following parameters were analyzed by STL:

Percent solids	Chromium
TKN	Copper
TP	Iron
NO_2	Lead
NO_3	Mercury
Aluminum	Nickel
Arsenic	Silver
Cadmium	PCBs
	PAHs

- Of these parameters, all of the following were below MDL in all sub-samples:

  Cadmium
  Mercury
  Nickel
  Silver
  PAHs
  NO_2
  NO_3
  PCBs

- There were several instances of an analyte exceededing the Threshold Effects Level (TEL). These analytes were: Arsenic, chromium, copper, and lead. The concentration of arsenic in sample FD4 was 19.50 mg/kg, while the TEL for arsenic is 7.24 mg/kg. Chromium concentrations in samples 1-1, FD1, FD2, and FD4 were 63.73, 55.30, 59.15, and 59.17 mg/kg respectively, while the TEL for chromium is 52.3 mg/kg. Copper concentrations in samples 1-1, FD1, FD2, and C51 were 42.71, 48.11, 32.93, and 101.86 mg/kg – the TEL for copper is 18.7 mg/kg. Lead concentrations in samples 1-1, FD1, FD2, and C51 were 87.80, 59.47, 76.22, and 67.70 mg/kg – the TEL for lead is 30.2 mg/kg.

- No analytes exceeded the Probable Effects Level (PEL) in any sub-sample.

A cursory review of nutrient/metals concentrations in the collected sediment samples revealed an apparent division between those elements that showed up at higher concentrations in more recent (i.e., upper level) deposits, and those in which higher concentrations were found in older (i.e., lower level deposits). The groupings were as follows:

- Higher concentrations in upper layers:
  Copper
  Lead
  Total Phosphorus
  Total Kjeldahl Nitrogen

- Higher concentrations in lower levels:
  Aluminum
  Arsenic
  Chromium
  Iron

These trends can be seen graphically in Attachment 6.

Metal concentrations were normalized in relation to aluminum concentrations by plotting aluminum vs. metal concentrations on charts delineating normal ratios (see Attachment 7). Metals concentrations exceeding those ratios are considered indicative of an anthropogenic source. These charts were developed by FDEP and are included in the document, *A Guide to the Interpretation of Metal Concentrations in Estuarine Sediments* (web site location: http://www.dep.state.fl.us/water/monitoring/docs/seds/estuarine.pdf). Similar charts have been developed for freshwater sediments and were used to plot the results of the C-51 samples. Both aluminum and iron concentrations were used to normalize concentrations of other metals in freshwater sediments.

A summary of metal concentrations, in relation to aluminum concentrations, follows:

- Arsenic: All concentrations (above MDL) were within the 95% confidence interval for natural concentrations.
- Cadmium: All concentrations were below MDL.
- Chromium: Six subsamples, 1-1, 1-2, 1-4, FD1, FD2, and FD4 were outside the limits for natural concentrations, implying an anthropogenic source. All other subsamples were within limits.
- Copper: Five subsamples were found to have concentrations outside expected limits: 1-1, 1-2, FD1, FD2, and C51. The C51 sample showed copper to be high in comparison to both aluminum and iron.
- Nickel: all BDL
- Lead: Almost all subsamples – with the exceptions of 1-3b and 1-4 – had concentrations of lead outside of the naturally occurring limits.

These results appear to show significant anthropogenic contribution of lead, copper, and chromium. . As far as the lead is concerned, both the absolute concentrations and the concentrations in comparison to aluminum seem to show more recent deposition. Higher concentrations of copper are found in the upper layers, but in comparison to aluminum, the ratio is higher in deeper layers. Chromium did not appear to reveal any temporal trends in regard to its concentration in comparison to aluminum.

The findings of the preliminary sediment survey were compared to the findings by Trefry, et. al (1990) in the Indian River Lagoon (IRL).

METAL	MDL for LWL Samples (mg/kg)	LWL Highest Concentration (Phase II-1a)	MDL for IRL Samples (mg/kg)	IRL Highest Concentration
Cadmium	1.0	<MDL (1.0mg/kg)	1.0	0.6 mg/kg
Mercury	0.1	<MDL (0.1mg/kg)	0.001	0.5 mg/kg
Copper	1.0	101.86 mg/kg	1.0	~150 mg/kg
Lead	1.0	87.80 mg/kg	1.0	~85 mg/kg
Chromium	1.0	63.73 mg/kg	N/A	N/A
Nickel	1.0	< MDL (1.0mg/kg)	N/A	N/A
Arsenic	0.75	19.50 mg/kg	N/A	N/A
Zinc		N/A		~205mg/kg

MDLs for Indian River Lagoon samples are estimated, based on charts found in the report, *Design and Operation of a Muck Sediment Survey* (Trefry, et al., 1990).

- Cadmium: Levels of cadmium in LWL samples appear to be comparable to IRL samples (i.e., below 1.0 mg/kg).
- Mercury: Mercury concentrations in LWL samples are comparable to IRL samples in that they are below 0.5 mg/kg.
- Copper: Copper levels in LWL samples are comparable to those in IRL.
- Lead: Lead levels in LWL samples are comparable to those in IRL.

- Chromium, Nickel, and Arsenic levels do not appear to have been analyzed in the Indian River samples. Zinc concentrations were not analyzed in our samples as this element was not listed by DEP as a parameter expected to be tested and analyzed (FDEP 2001), also, the TEL and PEL for zinc are extremely high, as is the level at which disposal restrictions take effect (23,000 mg/kg). Samples collected as part of the upcoming, more extensive sediment core sampling project will also be analyzed for zinc.

A comparison of analytes surveyed by both studies shows concentrations to be similar in both the Indian River Lagoon and the Lake Worth Lagoon. This is somewhat surprising given the urban characteristics of LWL compared to IRL. Higher concentrations had been expected in the LWL samples.

Results of the grain size, percent organics, and percent carbonate analyses performed by Scientific Environmental Applications, Inc. follow:

Sample	Mean Grain Size (Phi Units)	Mean Grain Size (mm)	Median Grain Size (Phi Units)	Median Grain Size (mm)	% Gravel	% Coarse Sand	% Medium Sand	% Fine Sand	% Silt and Clay	% Organics	% $CaCO^3$
1-1	4.75	0.04	5.24	0.03	0	0	1	6	93	21.45	85.81
1-2	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
1-3	1.24	0.42	1.22	0.43	0	0	52	46	2	1.49	4.11
1-4	1.32	0.40	1.29	0.41	0	0	47	49	4	1.71	6.94
FD1	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
FD2	5.36	0.02	6.89	0.01	0	0	0	1	98	20.44	86.71
FD3	2.11	0.23	2.18	0.22	0	1	15	82	3	1.11	17.12
FD4	4.31	0.05	1.59	0.33	0	0	34	45	21	7.08	20.21
C51	5.34	0.02	5.51	0.02	0	0	1	6	93	28.17	87.83

Grain size analysis was not performed on cores 1-2 or FD1, as sample size was not adequate for both metals/nutrients analysis and grain size analysis. The top two layers of the cores were simply a subdivision of the organic-rich, fine grained sediments. This layer was divided into an upper, unconsolidated layer, and a lower more compacted layer to achieve a greater resolution of the distribution of nutrients, metals, and toxins. Visual assessment of sediment core layers determined that sample 1-2 was similar to sample FD2 (compacted sediments), while sample FD1 was similar to 1-1(fluffy, unconsolidated sediment).

These samples were classified by the analytical lab as follows:

1-1 Organic rich, carbonate rich, silty moderate plasticity (OH)
1-3 Medium to fine sand (SP)
1-4 Medium to fine sand (SP)
FD2 Organic rich, carbonate rich silt moderate plasticity (OL)
FD3 Fine quartz sand grading to medium carbonate sand (SP)
FD4 Silty fine quartz sand and medium carbonate sand (SM)
C51 Organic rich, carbonate rich silt moderate plasticity (OL)

Based on grain size analysis, the visual characterization of sediment layers into distinct horizons proved accurate. The top layer (~1" to 20"), was composed primarily of silt and clay. This layer was also very high in organic content, generally between 20 and 30%. One of the defining characteristics of muck is an organic content greater than 10%. Based on these criteria, these sediments can be accurately described as "muck".

Accumulation rates, based on analysis of concentrations of Cesium-137 and Lead-210, were calculated by Battelle Marine Sciences Laboratory in Sequim, Washington. Only the Ibis Island sample could have accumulation rates calculated, as a core could not be collected from the C-51 Canal site. The core was analyzed in 2-cm increments. Mixing was obvious in many of the increments analyzed, making precise accumulation rate determination difficult for several sections of the core. While mixed layers at the top of the core could be eliminated from the accumulation rate calculations, layers which appeared to be mixed in deeper areas of the core could not be eliminated and were averaged. This provided a range of years of deposition and an average accumulation rate over that period of time. The data is summarized in Attachment 6, Accumulation Rates.

Analysis of the 40-cm core collected from the lagoon on the east side of Ibis Island showed a high degree of mixing in the upper 16cm, which made precise aging difficult. This mixing is probably due to the shallow water in this area as well as its physical characteristics – it is a small bay, with a very shallow center and deeper channels along the sides. There was also a high degree of mixing between 22 and 34 cm. Accumulation rates calculated for these layers (22 to 34 cm depth) indicate that they were laid down between 1944 and 1963. The mixing probably occurred as a result of disturbance caused by construction of this island from dredged material during this time period, and by construction of the seawall in the 1960's. The three deepest layers could only be assessed as "pre-1944", and had accumulation rates of 0.452 to 0.482 cm/yr. Accumulation rates varied only slightly, dropping from 0.463 cm/yr in 1967 to 0.444 cm/yr around 1984. After 1984, sediment accumulation rates varied from 0.436 to 0.430 cm/yr. These data show a slight, although probably insignificant, decrease in sediment accumulation rates in this area. Accumulation rates were also determined by averaging the mixed sections, as accurately assessing the date of deposition of these sediments is hampered by the apparent mixing. The results derived by averaging are comparable to those derived by analyzing each 2 cm section separately.

Recommendations

A more extensive sampling event will be implemented as follows:

1.) Three additional sites will be sampled and the cores analyzed for the full range of parameters covered in the preliminary survey.
2.) At each site, three cores will be collected and composited rather than separated into distinct layers, and all parameters analyzed in the preliminary study will again be analyzed, with the addition of zinc. In addition, one core from each site will be collected and separated into distinct layers, analyzed and compared against composited cores.
3.) One core at each site will be collected for analysis of grain size and percent organics
4.) One core at each site will be collected for ^{137}Cs and ^{210}Pb analysis for the determination of accumulation rates.

5.) Recommended locations for the collection of these samples are:
    a.) Near the Lake Worth Bridge, as sediments in this area may have a longer residence time due to its position between inlets.
    b.) South of the Southern Boulevard Bridge, as it is closer to the Lake Worth Inlet and may have a shortened residence time, and, in combination with the previously collected cores, brackets the study area.
    c.) Near the mouth of the C-51 Canal on the west bank of the Lagoon where deep muck deposits have been identified.

These sites are noted in Attachment 9 – Lake Worth Lagoon Muck Sediment Monitoring, Phase II-1b Site Map.

In addition to the sampling event described above, cores will be collected from six additional sites as part of the "Ship for Kids" project. Data collected as part of this project will be used to augment data on Lake Worth Lagoon sediments. The "Ship for Kids" project, while designed by ERM based on experience gained through this sampling event, will be conducted under the auspices of the Marine Industries Education Foundation. The collection and analysis of cores collected as part of the "Ship for Kids" project will be in accordance with the SOW written for that project. Accumulation rate determination and grain size analysis will not be performed on samples from these six sites.

SUB-PROJECT 2.0: MUCK SEDIMENT MONITORING AND MANAGEMENT
Phase II - Sediment Sampling and Evaluation
Expanded Study-1b

Objective

The objective of Phase II-1b of the referenced study was to determine the quality of the muck sediments which will provide the basis for a feasibility study to determine management options, including whether the muck can be removed and disposed of, or beneficially reused, or left in place and capped. This study built upon the procedures tested and developed in the earlier preliminary study (see Phase II-1a). While one objective of the preliminary study had been to potentially reduce the set of parameters being analyzed to only those that were found at concentrations above the Method Detection Limit (MDL), it was decided that the full suite of analyses should be performed on these samples.

An additional aspect of this expanded study was to determine the viability of compositing sediment core samples rather than analyzing discrete layers. The reasoning is that, while any management option will deal with the entire muck sediment deposit, compositing may effectively dilute contaminant concentrations, masking contaminants sequestered in a specific layer. Another reason for experimenting with compositing is that, at some sites, the distinct layers are often so thin that they provide an inadequate sample volume for analysis. Analysis of earlier samples showed no obvious partitioning of contaminants.

In addition, muck age and sedimentation rates were calculated in order to determine the likelihood of success and relative benefits of the management alternatives, such as the construction of a sediment trap and the implementation of upstream Best Management Practices (BMPs) for the prevention of sediment accumulation in the future. The data collected during Phase II-1b was also used to help define the procedures used in Phase II-2 of this study, the Ship-for-Kids project.

Sample Collection and Processing

On November 23, 2002, the following personnel boarded the Research Vessel Trident, owned by the Marine Industries Education Foundation, for a sediment core sample collection trip on the Lake Worth Lagoon:

- Ken Todd, P.E., Palm Beach County Water Resources Manager
- Kevin Aubry. P.E., Engineer, Dunkelberger Engineering & Testing
- Allen Dupont, P.E., Engineer, Case O'Bourke
- Andre Rayman, P.L.S., Surveyor, Shalloway, Foy, Rayman, and Newell, Inc.
- Ben Harkanson, Biologist, Palm Beach County ERM
- Ginny Powell, Biologist, Palm Beach County ERM
- Rob Beretta, Chemist
- Gidget Greco, PB Lakes HS Marine Academy Teacher, Boat Captain
- Steve Oenbrink, P.E., Engineer, Kimley-Horn

Three sites were sampled, selected by their locations relative to the mouth of the C-51 Canal which is believed to be the major contributor of muck sediments to the Lake Worth Lagoon. These sites had been shown by the previously conducted dual-frequency bathymetry to have muck deposits of one foot or greater.

The sites chosen were:

- Sed01, on the east side of the Lagoon near the foot of the Lake Worth Bridge, at the extreme southern end of the study area.
- Sed19, on the west side of the Lagoon, just south of the mouth of the C-51 Canal, at the epicenter of the study area.
- Sed31, on the east side of the Lagoon, near the south end of the Bingham Islands, at the north end of the study area.

See Attachment 9, Phase II-1b - Site Map.

The PVC coring device used in the preliminary study was found to lack the strength necessary to collect core samples in a strong current. A gravity-driven ball-check corer purchased by the Marine Industries Education Foundation for the purpose of collecting sediment core samples was tested and found deficient. The pressure wave produced by the corer as it fell to the bottom displaced large amounts of the light, unconsolidated sediments generally found in the upper portion of the sediment column. In addition, the corer drove into the sediment with such velocity that it caused severe compression of sediments that were collected in the core tube. On the other hand, slowly lowering the ball-check corer to the substrate didn't provide the force necessary to penetrate the sediment, with the result that the corer simply fell on its side. Slowly lowering the corer and then pounding it into the sediment by hand was a potential intermediate solution, but much more problematic and time-consuming than simply putting a diver into the water to push a cellulose-acetate-butyrate (CAB) core tube into the sediment by hand. A hand driven corer was used as a standard by which to test the applicability of the ball-check corer, and in the end, was the method used to collect the samples.

Upon reaching the sample site, the water depth was recorded using the fathometer installed on the boat. The diver entered the water with a length of CAB tubing and inserted it slowly, by hand, using even pressure, into the substrate until refusal. Prior to retrieving the sample, an elastic band was placed around the tube to mark the depth to which the corer penetrated the sediment. A plastic cap was placed on the top of the tube to create vacuum pressure, and then the tube was pulled slowly from the substrate. As soon as the tube was removed, a second plastic cap was fitted to the bottom of the tube to prevent sample loss. A second elastic band was placed around the tube to mark the top of the sediment core. The difference between the two bands was used to assess the apparent compression of the sample.

Six cores were collected at each site. Care was taken to collect samples from within a small area at each site in order to reduce potential variability in sample composition due to location. Because sample collection involved disturbance of an area around the core, subsequent cores were collected from locations that had not been disturbed by previous coring. Following collection, a hole was drilled in the core tube to drain excess water; the tube was then cut just above the waterline to facilitate transportation and storage. The samples were stored upright in a cooler of ice and transported to the ERM lab for processing.

At ERM, the cores were split using a circular saw with the blade set to just barely penetrate the thickness of the CAB core tube on opposite sides of the tube. A stainless steel knife was then run through the center of the core to divide it in half. For each core, distinct layers were delineated and their depths measured and recorded. Samples to be analyzed for nutrients, metals, and toxins were scooped from the center of each core with a plastic spoon, with care being exercised to avoid collection of any sediment in direct contact with the tube in order to avoid potential contamination caused by the saw blade, and any compromise of sample integrity due to smearing of the outside of the core sample. All collected material was placed in a stainless steel bowl and thoroughly mixed with a

plastic spoon prior to placing in labeled sample jars. The bowl was thoroughly rinsed with DI water between each homogenization. Plastic spoons were discarded following the collection and processing of each sample. The first core (labeled with the suffix "a") collected in each set was divided into layers according to sediment characteristics, (i.e., one upper, unconsolidated layer; and one lower, consolidated layer). These sub-samples were collected, processed, and bottled separately. The next three cores (labeled "b – d") collected at each site had the sediment layers composited for analysis. The fifth core collected at each site (labeled "e") was separated into layers and the sub-samples placed in plastic Ziploc© bags to be analyzed for grain size. The sixth core was kept intact and frozen to be shipped off for stable isotope analysis and accumulation rate determination. Of the three sites from which cores were collected, one site – Sed19 – did not provide cores with more than one distinct layer. Sediment deposits at this site were so deep that the six-foot core tubes were unable to penetrate beyond the fluffy, unconsolidated layer. Detailed information for each core can be found in Attachment 10, Phase II-1b - Core Summary.

Results/Discussion

Samples for metals/nutrient/toxins analysis were sent to Severn Trent Laboratories (STL). Analysis was conducted in December 2002, and the results received by ERM staff on January 7, 2003. A summary of the analytical data can be found in the following attachments: Attachment 11, Phase II-1b - Chemical Analysis, Tables; Attachment 12, Phase II-1b - Chemical Analysis, Charts; and Attachment 13, Chemical Analysis, Averages and Standard Deviations.

The following parameters were analyzed by STL:

Analyte:	Method:	MDL:
Percent Solids	160.3	0.01%
TOC	9060 (N&S)	1.00 mg/kg
TKN:	351.2	20.00 mg/kg
TP:	365.4	20.00 mg/kg
Al:	7020	1.00 mg/kg
As:	3050/6010B	1.00 mg/kg
Cd:	3050/6010B	1.00 mg/kg
Ca:	7140	1.00 mg/kg
Cr:	3050/6010B	1.00 mg/kg
Cu:	3050/6010B	1.00 mg/kg
Fe:	3050/7380	1.00 mg/kg
Pb:	3050/6010B	1.00 mg/kg
Mg:	3050/7450	1.00 mg/kg
Mn:	30507460	1.00 mg/kg
Hg:	7471A	0.10 mg/kg
Mo:	3050/6010B	10.00 mg/kg
Ni:	3050/6010B	1.00 mg/kg
Ag:	3050/6010B	1.00 mg/kg
Zn:	3050/6010B	1.00 mg/kg
Pesticides/PCBs:	8081	Varies with compound, but generally 10 μg/kg
Herbicides:	615	Varies with compound
PAHs:	8100	0.33 mg/kg

1) Of these parameters, all of the following were below MDL in all sub-samples: cadmium, mercury, molybdenum, PCBs, herbicides, and PAHs. These results were consistent with the results of Phase II-1a, with the exception of molybdenum and herbicides, which weren't analyzed in that phase.

2) All of the samples with concentrations of silver exceeding the MDL of 1.0 mg/kg (6 of 14 samples) also exceeded both the Threshold Effects Limit (TEL) of 0.733 mg/kg, and the Probable Effects Limit of 1.77 mg/kg. Because the MDL in this case is higher than the TEL, it is impossible to tell whether or not all samples exceeded the TEL, although, based on the averages and standard deviations for those samples that did exceed the MDL, it seems probable that silver concentrations in all samples exceeded the TEL. In Phase II-1a, the silver concentration was below the detection limit in all samples.

3) Five of the fourteen samples had arsenic concentrations above the TEL. Three samples had copper levels above the TEL. Six samples had lead concentrations above the TEL. All of these samples were from sites sed01, (near the east end of the Lake Worth Bridge), and sed19, (just south of the mouth of the C-15 Canal). No other analytes exceeded the TEL in any samples, and no analytes other than silver exceeded the Probable Effects Level (PEL) in any sample. It could not be determined whether any samples exceeded the TEL for cadmium, as the TEL for this element (0.676 mg/kg) is lower than the MDL (1.00 mg/kg).

4) Within-site comparisons between composite samples and samples in which discrete layers were analyzed separately showed no obvious loss of resolution due to compositing. Standard deviations calculated for samples in which discrete layers were analyzed separately were comparable to standard deviations calculated for composite samples. Variation in the concentrations of nutrients and metals was quite pronounced for most analytes at most sites. In most cases, the standard deviation was lowest at site Sed19, the only exceptions being arsenic, copper, and total organic carbon. A probable explanation for the narrower range of standard deviation among the analyte concentrations at this site is that sediment deposition appearsto occur at a much higher rate at this site. Sed19 is at the mouth of the C-51 Canal, most likely the main contributor of muck sediments to the lagoon. As flow from the canal hits the waters of the lagoon, sediment would be expected to fall out of suspension. This supposition is reflected in the deep deposits of light, unconsolidated sediments found at this site. In fact, a six-foot core tube was unable to penetrate to deeper, more consolidated sediment layers. A high rate of sedimentation would imply that contaminant concentrations would show less temporal variation within a given length of core.

5) Among the data received there were some seemingly anomalous results:

   - Cores sed19c and sed19d both had TP and TKN concentrations far below any of the other samples (sed19c: TP = 9.49mg/kg and TKN = 10.82mg/kg; sed19d: TP = 5.92mg/kg and TKN = BDL). These values are low not only in comparison to all other samples in this set, but for sediment samples in general. Average concentrations of these nutrients generally ranged between 150mg/kg and 1000mg/kg for all other sites. The analytical laboratory was contacted about these aberrant data. They reported that their records showed no problems encountered during the analysis, but offered to do several more analyses at no cost. Accordingly, a large volume of sediment was collected from this site, thoroughly homogenized, and ten samples sent to the lab for analysis in generically labeled sample jars, with no indication of the origin of any of the samples. These data returned values within the normal range, indicating that abnormally low values were apparently not characteristic of sediment at this site. Due to the uncharacteristically low concentrations reported for the original samples, these data were not used in any assessment of nutrient concentrations.

- Other anomalous data were reported from sample sed31a2. This sample was a consolidated sediment layer from a sample in which the layers were analyzed separately. The TP value reported was 16.3 mg/kg, while the average concentration for samples from this site (excluding this core) was 282 mg/kg with a standard deviation of 122 mg/kg. The calcium concentration reported for this sample was also anomalously low at 2,187 mg/kg, while the average for this site (excluding this core) was 78,969 mg/kg, with a standard deviation of 32,201 mg/kg. While the lab reported no analytical problems with either of these results, the anomalously low values resulted in the exclusion of these data from any assessment of nutrient or metals concentrations. In fact, concentrations of all metals analyzed were low in this sample, many being below detectable limits, but only the TP and calcium data were excluded from an assessment of the analysis.

Metal concentrations were normalized in relation to aluminum concentrations by plotting aluminum vs. metal concentrations on charts delineating normal ratios, (see Attachment 6, "Metal concentrations in relation to aluminum"). These charts were developed by FDEP and are included in the document, *A Guide to the Interpretation of Metal Concentrations in Estuarine Sediments*, (http://www.dep.state.fl.us/water/monitoring/docs/seds/estuarine.pdf).

A summary of metal concentrations, in relation to aluminum concentrations, follows:

- Arsenic: All concentrations (above MDL) were within the 95% confidence interval for natural concentrations.
- Cadmium: All concentrations below MDL.
- Chromium: All concentrations (above MDL) were within the 95% confidence interval for natural concentrations. Only one sample, sed01a1, had chromium at concentrations above the MDL.
- Copper: Four samples were found to have concentrations outside natural limits: Sed01d,, sed01a1, sed19a, and sed19d.
- Lead: All samples except one (Sed31a2, the concentration of which was below the MDL) were above the 95% confidence interval for natural concentrations.
- Nickel: All concentrations (above MDL) were within the 95% confidence interval for natural concentrations.
- Zinc: All samples except one (Sed31a2, the concentration of which was below the MDL) were above the 95% confidence interval for natural concentrations.

These results appear to show significant anthropogenic contribution of copper, lead and zinc.

The findings of this sediment survey were compared to the findings by Trefry, et al., (1990) in the Indian River Lagoon.

METAL	MDL (mg/Kg)	LWL Highest Concentration (mg/kg) (Phase II-1b)	MDL (mg/Kg)	IRL Highest Concentration (mg/kg)
Cadmium	1.0	<MDL (1.0mg/kg)	1.0	0.6 mg/kg
Mercury	0.1	<MDL (0.1mg/kg)	0.001	0.5 mg/kg
Copper	1.0	26.85 mg/kg	1.0	~150 mg/kg

Lead	1.0	85.13mg/kg	1.0	~85 mg/kg
Chromium	1.0	23.98mg/kg	N/A	N/A
Nickel	1.0	7.645 mg/kg	N/A	N/A
Arsenic	0.75	11.31 mg/kg	N/A	N/A
Zinc	1.0	289.81mg/kg		~205mg/kg

MDLs for Indian River Lagoon samples are estimated, based on charts found in the report, *Design and Operation of a Muck Sediment Survey*, (Trefry, et al., 1990).

- Cadmium: Levels of cadmium in LWL samples appear to be comparable to IRL samples (i.e., below 1.0 mg/kg).
- Mercury: Mercury concentrations in LWL samples are comparable to IRL samples in that they are below 0.5 mg/kg.
- Copper: Copper levels in LWL samples are well below those in IRL.
- Lead: Lead levels in LWL samples are comparable to those in IRL.
- Chromium, Nickel, and Arsenic levels appear not to have been analyzed in the Indian River samples.
- Zinc: Zinc levels in LWL samples appear to be slightly above those in IRL.

In summary, Cadmium and Mercury levels were about the same as IRL; Copper levels are lower than those in IRL, Lead levels were comparable to IRL levels, and Zinc levels were slightly higher than IRL.

The results of the grain size analysis are summarized below:

Sample	**Mean Grain Size (Phi Units)**	**Mean Grain Size (mm)**	**Median Grain Size (Phi Units)**	**Median Grain Size (mm)**	**% Gravel**	**% Coarse Sand**	**% Medium Sand**	**% Fine Sand**	**% Silt and Clay**	**Depth (cm)**
Sed01e1	4.13	0.06	3.56	0.08	0	0	4	48	48	0 – 9
Sed01e2	4.83	0.04	4.63	0.04	0	0	3	47	51	9 – 15
Sed19e	5.02	0.03	5.36	0.02	0	0	1	41	58	0 – 35
Sed31e1	3.83	0.07	3.69	0.08	0	0	14	38	48	0 – 13
Sed31e2	2.95	0.13	1.97	0.26	0	1	27	52	20	13 - 21

These samples were classified by the analytical lab as follows:

Sed01e1	SM	Silty Sand
Sed01e2	ML	Sandy Silt
Sed19	ML	Sandy Silt
Sed31e1	ML	Sandy Silt
Sed31e2	SM	Silty Sand

The one somewhat anomalous finding was at site Sed01 in which the upper layer had a lower percentage of silt and clay in relation to sand than the lower, more consolidated layer. This is the opposite of what is generally found. In addition, the classification of soil type appears to be inverted,

that is, silty sand seems to have been found above sandy silt, again, the opposite of what would be expected. These findings imply that these sub-samples were switched and that the sub-sample labeled Sed01e1 should actually be labeled Sed01e2, and vice versa. This apparent switch will not have an effect on any of the other analyses because this sample was analyzed for grain size only.

Determination of accumulation rates (see Attachment 15 – Accumulation Rates) through the analysis of concentrations of the stable isotopes ^{137}Cs and ^{210}Pb helped to illuminate patterns of sediment deposition in the lagoon. Samples were analyzed in two-centimeter sections.

- Site Sed01:
  A 28 cm sample from site Sed01 yielded sediment accumulation rates varying between 0.385 cm/year and 0.440 cm/year. Mixing in the top three layers (0-6cm) inhibited accurate dating of these sections; all three sections are estimated to have been deposited between 1963 and the present. The fifth section from the bottom, at a depth of 20 to 22 cm, yielded a deposition date of 1936. The six centimeters below that could only be estimated as "pre-1936" due to apparent mixing, which prevented accurate aging.

- Site Sed31:
  Sedimentation rates were much lower, ranging from 0.0803 cm/year to 0.114 cm/yr. The bottom four two-centimeter layers of the 29 cm core were dated to "pre-1801". Apparent mixing in these sections inhibited accurate dating. Between 1801 and 1882 sediment accumulation rates decreased slightly from 0.104 cm/yr to 0.0919cm/yr – a difference of 0.0085cm. From 1882 to the present, accumulation rates steadily increased from 0.0919cm/yr to 0.114 cm/yr – a difference of about one-fifth of a millimeter.

- Site Sed19:
  The core collected from site Sed19 displayed a very high rate of accumulation, ranging from 0.738 cm/yr in the bottom three layers to 0.945 cm/yr in one of the most recent layers. The top six layers, from 0 to 12 cm, showed evidence of mixing, and were all calculated to have been deposited since 1988. Concentrations of ^{137}Cs never reached background in this core, indicating deposition since the advent of atmospheric nuclear testing following the end of World War Two. In fact, the entire 46 cm core is estimated to have been deposited since 1960, making impossible any comparison to historic conditions (i.e., pre-canal or pre-inlet).

These data imply that sedimentation rates are higher at site Sed01 at the south end of the study area than they are at site Sed31 at the northern end. While it could be extrapolated that this implies a higher flow of sediment to the south from the C-51 Canal, the difference in accumulation rates may be due to other factors. For example, site Sed01 is near a corner formed by the east bank of the lagoon and the eastern foot of the Lake Avenue Bridge. It is possible that eddies form in this area, entraining sediments and allowing them to fall out of suspension at a higher rate. Site Sed31, on the other hand, is near the south end of a small group of islands (Bingham Islands). It may be that these islands and the Southern Boulevard Bridge, which crosses their northern end, constrict flow, causing an increase in the velocity of the flow which prevents or reduces the precipitation of suspended sediments in that area. This site, due to its proximity to the Lake Worth Inlet, is also subject to greater tidally driven flow than the more southern site, which may also prevent settling of suspended sediments. Site Sed 19, at the mouth of the C-51 Canal would be expected to have a higher rate of sediment accumulation as sediments carried by the flow of the canal would tend to settle out quickly upon entering the slower moving waters of the lagoon. Attachment 16 graphically compares sedimentation rates at all four sites which were analyzed for sedimentation rates.

Conclusions

Based on the findings of this study, muck sediment deposits appear to be very patchily distributed within the lagoon. Even in areas identified by the dual-frequency survey as having significant muck deposits, (i.e., greater than one foot in depth), the actual depth of these deposits has been found to vary greatly within an area of only a few square meters. While concentrations of potential contaminants do not appear to pose an obstacle to dredging, the patchy distribution of muck deposits would make this option difficult in most areas. Dredging of muck sediment deposits, on both the freshwater and saltwater sides of the S-155 control structure, as well as the possibility of creating a sediment trap, has been proposed as a potential management measure by the North Palm Beach County Comprehensive Everglades Restoration Project (NPBC CERP) to address the problem of sediment accumulation in the Lake Worth Lagoon study area. A feasibility study should be conducted to assess the costs and benefits of dredging, and the possibility of creating a sediment trap, in those areas where muck deposits are sufficiently concentrated (i.e., near the mouth of the C-51 Canal).

Capping of muck deposits has also been proposed as a potential management measure by NPBC CERP. Such a project is, in fact, already underway for a stretch of the lagoon along the edge of the Lake Worth Golf Course. Spoil material from a restoration project on Peanut Island will be used to fill an extensive, sediment-filled dredge hole west of the ICW channel. Fill will be added to bring the substrate to levels at which mangroves can be planted, and seagrass is expected to recruit. An assessment of fisheries and benthic invertebrate populations in this project area will be conducted by the Florida Fish and Wildlife Conservation Commission (FWC) in cooperation with ERM pre- and post-construction in an attempt to compare the results of capping muck deposits accumulating in these holes to the potential management option of doing nothing. The project, when completed, will provide valuable information on the efficacy of capping, as well as the potential for the success of habitat enhancement projects in highly impacted areas of the lagoon.

Once suspended sediments enter the lagoon they are distributed over a wide area. Sediments have accumulated at a variable rate depending on location, varying from roughly 0.1 to 0.9 cm/year over the last 20 years. The success of the many restoration projects taking place within the lagoon may depend on shutting off, or at least minimizing, the inflow of these sediments. Due to the logistical difficulties of attempting to manage these sediments once they have been so widely distributed, this inflow is best addressed at its source rather than at its ultimate destination. Therefore, the most significant recommendation resulting from this study is that a study of sediment transport via the C-51 Canal be undertaken in an attempt to determine the actual volume of sediment entering the lagoon from the canal. This study should be undertaken prior to the diversion of the western basin of the C-51 watershed into STA1E, in order to assess the effects of that project on sediment input to the lagoon. An estimate of the current volume of sediment inflow to the lagoon from the C-51 Canal is needed by NPBC CERP in order to set targets for the future reduction of sediment inflow. NPBC CERP has set reduction of sediment inflow as a performance measure for the Lake Worth Lagoon Study Area, but has not yet set a target for the amount of reduction nor does it have a means of measuring progress toward a target. Once a target is developed, assessment of the volume of sediment inflow to the lagoon following the diversion of the western C-51 basin will allow measurement of progress toward the target. In addition, an estimate of sediment inflow (and an estimate of eventual reduction following large-scale projects such as the C-51 West Basin redirection) should allow for an estimation of the scope of upstream management practices that would need to be implemented in order to further stem the flow of muck sediments into the lagoon. Among the potential management measures proposed by NPBC CERP are dredging and/or the construction of sediment traps upstream of the S-155 control structure, which regulates the flow of freshwater from the C-51 Canal into the Lake Worth Lagoon. The structure itself, with its bottom-dump design, enhances the flow of sediments from the

canal. Redesign of this structure is another potential management measure proposed by NPBC CERP. All of the alternatives should be thoroughly evaluated.

Analysis of the concentrations of nutrients, metals, and toxins reveals no hazardous levels of contamination within these sediments. Instead, the most damaging aspect of these deposits appears to be the sediments themselves. By blanketing the substrate, the sediments inhibit colonization by the natural flora and fauna of the lagoon. The small particle size allows these sediments to be easily disturbed, thus attenuating light penetration in large areas of the lagoon, further inhibiting the growth of seagrasses and other natural vegetation. Management of this problem would be best addressed by prevention and control on the freshwater side of the lagoon rather than attempting a remedy after sediments have settled in the lagoon.

Recommendations for Further Study

Ship-for-Kids Sediment Coring

Further sediment core collection has been conducted as part of the Ship-for-Kids project, a cooperative educational venture between the Marine Industries Education Foundation (MIEF), the Forest Hill High School Environmental Academy, and the Marine Technologies Academy. The project work plan has been developed by ERM with oversight and sample analysis provided by DEP. Sediment cores were collected from six locations within the Lake Worth Lagoon. Collection sites were:

Site:	**Latitude:**	**Longitude:**
SedSIS	26°37’02.01”	80°02’40.77”
Sed07	26 37' 27.76"	80 02' 40.55"
Sed11	26°37’53.91”	80°02’43.32”
Sed15	26 38' 13.32"	80 02' 42.38"
Sed16	26°38’24.29”	80°02’43.82”
SedC51	26°38’55.90”	80°02’40.92”

See Attachment Eight – SFK Site Map.

The sediment cores were composited, and sent to the DEP central lab to be analyzed for the following parameters: TKN, TP, VOC, Al, Mg, Ca, Zn, Cu, Mn, Fe, Cd, Pb, Ni, Mo, As, Cr, Hg, Ag, Chlorinated Pesticides/PCBs (EPA Method 8081), Herbicides (EPA 615), and PAHs (EPA 8100). Analysis should be completed and data submitted to MIEF and ERM by August 2003.

Samples were also collected for grain size analysis by Dunkelberger Engineering. These data should also be received by August 2003.

Cores were collected for stable isotope analysis and accumulation rate determination, although funds are not available for this at present. These cores have been archived pending availability of funding.

Fisheries and Benthic Invertebrate Monitoring

As mentioned earlier, ERM and FWC will undertake a study of the fish and benthic invertebrate populations in the muck-filled dredge hole along the edge of the Lake Worth Golf Course. Fish populations will be assessed using a variety of methods such as hook-and-line and trawling. Benthic invertebrates will be collected using a dredge or corer, and the samples will then be preserved, sorted, and classified. This study will compare the abundance and diversity of fish and benthic invertebrate populations at this site before restoration to the populations at this site following the restoration project. The results will allow us to measure the success of this project in enhancing the fisheries value by the creation of additional habitat through the filling of deep dredge holes. A nearby dredge hole, which will not be filled during the course of this study, will be used as a control and, as such, will allow an assessment of the option of taking no action. Such a study is necessary not only to determine the efficacy of capping as a management option to control muck sediments, but also to assess the success of such restoration projects in this area of the lagoon.

Sediment Transport Study

NPBC CERP has listed reduction of muck sediment inflow to the lagoon from the C-51 Canal as one of the management measures for the Lake Worth Lagoon Restoration project. At this time, there is no data on sediment loads from the C-51 and, therefore, no way to measure progress toward any targets for reduction that may be set. While no money appears to be available through CERP to undertake a sediment transport study, ERM believes that such a study is necessary; otherwise, this very important aspect of NPBC CERP may be neglected. Therefore, ERM is working with the United States Geological Survey (USGS) to develop and conduct a sediment transport study for the C-51 Canal and Lake Worth Lagoon. This project will involve the collection of water quality samples a short distance upstream of the S-155 control structure along with concurrent collection of suspended sediment data using an optical backscatter sensor. This data collection will take place at different flow rates in an attempt to correlate measured sediment concentration (as determined by suspended sediment concentration of the water samples) with data collected using the sensor, and relate these data to flow rate. Once an adequate correlation has been made, data will be collected continuously by the deployed sensor in lieu of water sample collection. In addition, sediment samples will be collected for analysis of shear stress and fall velocity and this data incorporated into a model developed by the South Florida Water Management District.

Dredging and Sediment Traps

While the patchy distribution of sediment deposits throughout most of the lagoon limits the feasibility of dredging as a management option, the deep deposits at the mouth of the C-51 Canal may lend themselves to dredging. Dredging of sediment deposits and the creation of sediment traps within the lagoon are proposed as potential management options by NPBC CERP. While elimination of sediment inflow to the lagoon is the ideal objective, this may not be possible. Construction of a sediment trap near the mouth of the C-51 may be a viable method for evaluating the efficacy of capturing and controlling these sediments before they can be transported further into the lagoon.

Dredging and trapping upstream of the S-155 control structure are also potential management measures proposed by NPBC CERP. As stated earlier, preventing the flow of these sediments into the lagoon should be a more effective method of controlling them than trying to dredge or cap sediments once they have entered the lagoon and been dispersed. Sediments dredged from the freshwater side of S-155 are also more likely to be beneficially reused than those on the saltwater side that have been contaminated by salt. Very serious consideration should be given by SFWMD, DEP, or other local partners to the acquisition of land along the eastern portion of the C-51 Canal for dredged spoil material management. Among the potential management measures proposed for the freshwater side is the creation of a de-watering plant beside the canal which would remove sediments from a trap upstream of S-155, filter out the sediments, and return the water directly to the canal. Such a project would make the sediments easier to transport to their ultimate destination – whether for disposal or use as a soil amendment – and avoid the cost of acquiring the limited amount of land available along the canal for disposal.

This study has verified the extent of deep muck deposits as revealed by dual-frequency bathymetry. The evaluation of these sediments has shown them to be a clearly delineated layer covering the natural sand bottom of the lagoon, detrimental simply by their presence rather than by associated contaminants. Further studies, such as those described above, need to address not only the appropriate management actions to clean up the existing problem, but also the steps necessary to shut this problem off at its source.

SUB-PROJECT 3.0: COMPREHENSIVE SEAGRASS MAPPING AND MONITORING – EXECUTIVE SUMMARY

A major objective of the Lake Worth Lagoon Management Plan is to restore, preserve and create seagrass beds, oyster bars and other submerged benthic habitat. The top priority of the seagrass project is to protect and preserve the existing seagrass beds in the lagoon. Restoration and creation efforts will follow as deemed appropriate. In order to preserve existing seagrass beds, it was necessary first to determine where seagrasses are located. Using funds from the State of Florida Department of Environmental Protection, a 2001 seagrass mapping and monitoring project was initiated to acquire aerial photographs of Lake Worth Lagoon seagrasses, map the extent of seagrass beds within the lagoon, and monitor nine (9) fixed transects throughout the lagoon to enable Palm Beach County Department of Environmental Resources Management (ERM) to determine if selected seagrass beds are stable, expanding or receding.

The first objective was to acquire true color aerial photographs of the Lake Worth Lagoon system for use in mapping and classifying seagrass and other submerged aquatic vegetation (SAV). The imagery is of the highest quality, and allows for the accurate photointerpretation of SAV utilizing photogrammetric mapping equipment. The aerial photography resulted in 96 - 9 inch x 9 inch color prints, 54 frames for the Lake Worth Lagoon and 42 frames for the ICW. The photos will be converted to digital orthophotography in 2003. The same flight lines from 2001 will be photographed again in the spring of 2006.

The second objective was to prepare a 2001 Geographic Information System (GIS) coverage of Lake Worth Lagoon seagrasses. This coverage was produced using a combination of the 2001 aerial photography, field checking and photo-interpretation using an analytical stereoplotter.

Lagoon-wide seagrass coverage was mapped by ERM in 1990, and is presented in the Lake Worth Lagoon Natural Resources Inventory and Resource Enhancement Study. The 1990 survey estimated that there were a total of 2,010 acres of seagrass within the lagoon. These lagoon-wide maps, based on field surveys, provide an overall picture of the seagrass resources in the lagoon. Comparisons between the 1990 and 2001 surveys should be limited to general overall summaries, as opposed to detailed quantitative analyses, because the mapping methodologies of each survey were so dissimilar.

The 2001 project produced a new map and associated GIS data for seagrasses within the lagoon. The new seagrass map serves as an important management tool for obtaining a current inventory of this resource, identifying “healthy” areas that may deserve special protection efforts, and identifying potential “problem” areas that require further investigation. The map will serve as a baseline inventory for future studies, and will be updated every three to five years to document large-scale trends in the status of this resource. This report summarizes the mapping portion of the project.

Results of the mapping project show that seagrass beds cover at least 1,630.61 acres or 22% of the lagoon (Table 1). This is considered an underestimate, as aerial interpretation does not have sufficient resolution to detect all seagrasses and the mapping project incorporated only seagrass beds 0.25 acres or greater in size. Seagrass coverage varies throughout the lagoon, with more seagrass found in the north end than in the south end of the lagoon. Specifically, 70% of the seagrasses in Lake Worth Lagoon are in the northern segment of the lagoon (Little Lake Worth just north of PGA Blvd. to Royal Palm Beach bridge), 20% of the seagrasses are in the central segment of the lagoon (Royal Palm Beach bridge to Ocean Ave. bridge in Lantana), and 10% of the seagrasses are in the southern segment of the lagoon (Ocean Ave. bridge in Lantana to Ocean Ave. bridge in Boynton Beach). This pattern is not surprising since the northern segment is the largest in area (3,746 acres), followed by the central

segment (2,708 acres) and the southern segment (1,004 acres). To get a better idea of differences between segments, the proportion of seagrasses within each segment was evaluated. The overall seagrass coverage within each of the segments is 30% in the northern, 12% in the central and 15% in the southern segments of the lagoon. This coverage pattern is directly attributable to the extent of flushing by ocean water in the north and south segments and the location of the primary freshwater input in the central segment.

The third objective was to conduct monitoring via fixed transects to determine whether seagrass beds in the lagoon are stable, improving or declining and by how much. Five (5) fixed transects were established in 2000 and four (4) additional fixed transects were established in 2001. The nine (9) transects are located throughout the lagoon and were monitored for species presence/absence, depth distribution, abundance and shoot density. ERM is currently under contract to have the transects monitored again in 2003, and plans to have the transects monitored annually to detect small-scale changes over time as the Lake Worth Lagoon Management Plan is implemented and the water quality in the lagoon improves. The fixed-transect report was produced under separate cover. Currently, no trends have been observed for the fixed transects, as these are considered baseline surveys for monitoring future improvements to water clarity. It is expected that as water clarity improves due to the completion of projects funded through the LWLPGP, seagrass beds will expand to deeper waters because of increased light penetration of the water column; in addition, seagrass density and diversity are expected to increase.

The deliverables for this sub-project were submitted under separate cover and included the following reports in hard copy and on CD:

1) Full Analytical Aerial Triangulation Report for 2001- Lake Worth Lagoon Seagrass Mapping Project, dated November 29, 2001;
2) Final Project Report for 2001 - Lake Worth Lagoon Seagrass Mapping Project, dated July 24, 2002; and
3) Seagrass Monitoring in Lake Worth Lagoon - Report for 2000 and 2001, dated February 2002.

In addition to the above deliverables for DEP Agreement No. WAP028, fixed transect monitoring was conducted in August 2002. The final report, which is still in process, will be part of the deliverables under DEP Agreement No. WAP062.

Future seagrass-related projects include:

1) annual monitoring of the nine fixed transects;
2) seagrass mapping for all PBC water that were not included in the previous mapping project using 2001 aerial photography (Loxahatchee River and non-lagoon Atlantic Intracoastal Waterway);
3) mapping of mangroves for PBC, including trend analysis from mid-1980's map; and,
4) conversion of photographs to digital orthophotography.

See ERM's website for all reports, maps and GIS files associated with this project:

http://www.co.palm-beach.fl.us/erm/divisions/enhancement/habitat/lake_worth_lagoon/lwl.htm

IN-KIND PROJECT SUMMARIES

In order to determine match credit for staff time attributed to the in-kind match credit for the Lake Worth Lagoon Monitoring project, an internal accounting system was used. Specific tasks associated with each project or sub-project, are noted below.

Sub-Project 2.0, Phase I – Bathymetric and Muck Survey:

- Project design and development of task list
- Contractor oversight (Morgan & Eklund, Inc.)
- Muck field survey and ground-truthing
- Deliverable review and comment

Sub-Project 2.0, Phase II – Sediment Sampling and Evaluation:

- Project design and development of task list
- Coring device design and construction
- Extensive field sampling
- Sample preparation and packaging
- Contractor oversight (STL-Miami, SEA, and Batelle)
- Deliverable review and comment
- Interpretation of results
- Report preparation

Sub-Project 3.0, Comprehensive Seagrass Monitoring Project:

- Project design and development of task list
- Daily water quality observations to determine optimum flight conditions for aerial photography
- Contractor oversight (ATM, Agra-Baymont)
- Deliverable review and comment
- Technical presentation coordinated
- Project overview and results presented at Lake Worth Lagoon Symposium

Palm Beach Islands:
This project included monitoring and management of exotic vegetation on Fisherman's, Hunter's and Government Lot 6 Islands in the central part of the lagoon. ERM staff spent time on the following specific tasks:

- Project design and development of task list
- Development of funding source
- Development and implementation of interlocal agreements
- Contractor oversight (All-Green, Aquatic Vegetation Control)
- Site visits
- Field trip for Florida Audubon

Salinity Distribution and Flow Management Study for Lake Worth Lagoon :
The South Florida Water Management District (SFWMD) contracted with Environmental Consulting and Technology, Inc. (ECT), to develop a Salinity Distribution and Flow Management Study for Lake Worth Lagoon. ERM staff spent time on the following specific tasks:

- Consultation and meetings with WMD regarding project set-up
- Discussion with County staff to secure appropriate sampling stations (Ocean Inlet Park)
- Boating assistance for data downloading and station cleaning
- Report review and comment

Ship-For-Kids Project:

- Project design and development of task list
- Project oversight (bathymetry and muck survey)
- Extensive field sampling (sediment)
- Sample preparation and packaging

ERM Water Quality Monitoring Project:

- Quarterly water quality sampling and sample packaging
- Contractor oversight (STL-Miami)
- Deliverable review and comment
- Interpretation of results
- NPDES liaison at monthly steering committee meetings
- Report preparation

A total of 1,426 hours of ERM staff time, in the amount of $69,186.26, was used for the required match on the Lake Worth Lagoon Monitoring Project. In addition, $80,813.74 attributed to the SFWMD consultant's cost for the Flow Management Study was used towards the in-kind match requirement.

RECOMMENDATIONS FOR FUTURE MONITORING AND MANAGEMENT

The water quality and habitat in Lake Worth Lagoon is unlikely to be dramatically affected by improvements implemented under the Lake Worth Lagoon Partnership Grant Program, or any other program, in the near term. However, we believe that the baseline data collected as a result of this monitoring project and follow-up studies will provide the necessary inventory for future studies. Over time, as more studies are conducted, and more improvement projects are implemented, comparisons can be made with earlier studies to determine any trends that are taking place and whether the lagoon's environmental health is improving, declining or maintaining the status quo.

Recently, G. Tracy Mehan III, the Assistant Administrator for Water at the USEPA, called on partners at the federal, state and local level to join with him in "energizing the nation's water quality monitoring programs." From "EPA Waternews," for June 24, 2003, ….

> Mehan noted that the United States has made real progress in reducing pollution in our streams, rivers, lakes, wetlands, estuaries, and coasts. However, when asked to characterize the condition of waters and watersheds in the United States, Mehan cited the just-released Draft Report on the Environment 2003, which found that "At this time, there is not sufficient information to provide a national answer to this question with confidence and scientific credibility." Said Mehan, we risk flying blind if we aren't able to get dramatic improvements in water quality monitoring and data to support wise management decisions."
>
> The Draft Report on the Environment 2003 follows in the footsteps of several recent reports by the General Accounting Office, the National Research Council, the National Academy of Public Administration, and the H. John Heinz III Center for Science, Economics and the Environment. Together, these reports point to the need to use a combination of tools (such as probability-based assessments, predictive models, targeted monitoring and remote sensing) to better characterize the quality of the nation's waters at multiple scales. Said Mehan, "These tools would help states target their actions to make the most of each dollar they spend on clean water. And for the first time, we would also be able to produce a scientifically-defensible overall picture of the quality of the nation's waters."
>
> Addressing the challenge of improving water monitoring nationwide is a task far greater than EPA can undertake alone. "Success will require a sustained and coordinated commitment from many partners," said Mehan, "and our work together is just beginning." Investment in improved monitoring, he noted, will yield significant social cost savings by pointing to the most cost-effective steps to improve water quality at the national, state and local levels.

We believe it is critical to continue on-going and future monitoring efforts to the greatest extent possible. The table below recognizes ongoing efforts and recommends future monitoring projects as well as data collection and compilation projects. The information collected from implementation of these projects will produce a "scientifically-defensible" picture of the lagoon's environmental health, leading to appropriate management decisions.

ONGOING AND FUTURE LAKE WORTH LAGOON MONITORING PROJECTS

Project	Sponsor	Initiative	Status
WQ Trend Analysis	DEP	NPBC Pollutant Abatement and Analyses Study	Underway
Seagrass – Fixed Transect Monitoring (annually)	PBC, DEP	LWLPG/DEP Grant No. WAP028, WAP062, S0089	2001 is complete 2002 and 2003 are underway, 2004 is planned
Seagrass Mapping	PBC, DEP	LWLPG/DEP Grant No. WAP028, future LWLPGP funding	2001 map is complete New maps planned in 2006
Shoreline Mapping	PBC, DEP	LWLPG/DEP Grant No. WAP062	Underway
Sediment Transport Study	PBC, DEP, USGS	LWLPG/DEP Grant No. S0089	Underway
Sediment Management	SFWMD/ACOE	NPBC CERP	Planning
Expanded WQ Monitoring	DEP	CERP, TMDL	Underway
Engineering Analysis	PBC, DEP	LWLPG/DEP Grant No. WAP062	Planning
Fish and Benthic Analyses	PBC, DEP, & FWCC	LWLPG/DEP Grant Nos. WAP062 and S0089	Planning
Deep Hole Assessment	PBC, ERM, & FWCC	Future LWLPG funding	Planning
Management Plan update	?	?	Pending
Bird Surveys	?	?	Pending
Stormwater Outfall Mapping	?	?	Pending
Submerged Land Acquisition	?	?	Pending
Public Outreach	?	?	Pending
Updated Resource Inventory	?	?	Pending
GIS database for all lagoon layers	?	?	Pending

FINANCIAL STATUS REPORT FOR EXPENDITURES AND MATCH

The grant is fully reimbursed, in the amount of $150,000, and there are no outstanding invoices. In addition, the required match credit, in the amount of $150,000, has been met. Attachment 18 details all expenditures under the referenced grant agreement.

We would like to thank the Florida Legislature and the Florida Department of Environmental Protection for making these funds available to the Lake Worth Lagoon effort.

LIST OF ATTACHMENTS

REFERENCES

Davis, W. P., and A. D. Steinman, 1998. A lightweight, inexpensive benthic core sampler for use in shallow water. Journal of Freshwater Ecology. 13(4): 475-479.

Florida Department of Environmental Protection, 1988. *A Guide to the Interpretation of Metal Concentrations in Estuarine Sediments*, (http://www.dep.state.fl.us/water/monitoring/docs/seds/estuarine.pdf).

Florida Department of Environmental Protection, 2001. Comments on "*Draft Scope of Work for Sediment Identification and Evaluation in the C-51 Canal and Lake Worth Lagoon*". (Interoffice Memorandum).

Palm Beach County Department of Environmental Resources Management, 2001. Preliminary muck survey in Lake Worth Lagoon, Lake Clarke and C-51 Canal. T:\coastal\grants\lwl\muck\muck report.wpd.

Palm Beach County Department of Environmental Resources Management and State of Florida Department of Environmental Protection, Southeast District. 1998. Lake Worth Lagoon Management Plan. August 1998. 257 pages.

Scientific Environmental Applications, Inc., and Environmental Consulting and Technology, Inc. 2002. Salinity Distribution and Flow Management Studies for Lake Worth Lagoon, Final Project Report, Contract No. C-11818. Prepared for South Florida Water Management District, West Palm Beach, FL 33406..

Trefry, J.H., S. Metz, R. P. Trocine, N. Iricanin, D. Burnside, N-C. Chen, and B. Webb, 1990. Design and operation of a muck sediment survey, Final report to the St. Johns River Water Management District. Special Publication SJ 90-SP3. Florida Institute of Technology, Melbourne, FL 32901.

Trefry, J.H., R. P. Trocine, S. Metz, N. Iricanin, and N-C. Chen, 1989. Particulate nutrient and metal investigations in the Turkey Creek watershed, Final report to the St. Johns River Water Management District. Special Publication SJ 90-SP2. Florida Institute of Technology, Melbourne, FL 32901.

LAKE WORTH LAGOON PARTNERSHIP GRANT PROGRAM - PROJECT AWARDS

STATE FISCAL YEARS 1998-1999 through 2002-2003

						FY98-99		FY99-00		FY00-01		FY01-02		FY02-03	
			Applicant	Project	DEP Contract No.	Total Project Cost	Grant Award	Total Project Cost	Grant Award	Total Project Cost	Grant Award	Total Project Cost	Grant Award	Total Project Cost	Grant Award
1	**	98-1	School District	Artificial Reef Habitats	**SP505**	$102,000	$51,000								
2	**	98-2	Boynton Beach	Regional SW Facility-Phase 1		$1,500,000	$300,000								
3		98-3	Lake Park	Marina Pump Out		$125,000	$42,500								
4		98-4	Lake Park	SW Management System		$160,000	$80,000								
5	**	98-5	Port of Palm Beach	Master Drainage Plan		$294,816	$147,408								
6	**	98-6	West Palm Beach	Renaissance-Phase 1		$555,556	$100,000								
7		98-7	PBC ERM	Peanut Island Env. Restoration		$1,693,765	$250,000								
		98-8	PBC ERM	Administration		$58,184	$29,092								
8	**	99-9	Boynton Beach	Regional SW Facility-Phase 2	**SP505**			$750,000	$250,000						
9	**	99-10	Hypoluxo	Installation of Sewers				$900,000	$450,000						
10		99-11	Lake Park	SW Outfall/Treatment Retrofit				$146,000	$73,000						
11	**	99-12	Palm Beach	Par 3 Habitat Restoration				$439,560	$200,000						
12	**	99-14	West Palm Beach	Renaissance-Phase 1				$1,626,016	$200,000						
13		99-15	PBC ERM	John's Island Restoration				$809,900	$202,475						
		99-17	PBC ERM	Administration				$49,050	$24,525						
14		00-1	Boynton Beach	ICW Stormwater Outfall	**WAP029**					$725,000	$325,000				
15	**	00-2	Lantana	Lantana Cove Enhancement						$24,000	$12,000				
16	**	00-3	Palm Beach	D-12 Pump Station						$4,585,000	$200,000				
17		00-4	PBC ERM	Snook Islands						$2,460,000	$1,082,201				
18		00-5	PBC ERM	Peanut Island Env. Restoration						$2,943,611	$244,274				
19		00-6	School District	Artificial Reef Habitats						$124,000	$62,000				
20	**	00-7	West Palm Beach	54th, Cordova, Arkona - PCD						$1,026,000	$500,000				
21	**	00-8	West Palm Beach	Renaissance Phase 2 - Year 1						$2,187,096	$400,000				
			PBC ERM	Monitoring	**WAP028**					$300,000	$150,000				
		00-9	PBC ERM	Administration	**WAP029**					$49,050	$24,525				
22		01-1	Ocean Ridge	Stormwater Improvements	**WAP062**							$1,393,475	$493,475		
23	**	01-2	West Palm Beach	Renaissance - Phase 2 - Year 2								$500,000	$250,000		
24		01-3	PBC ERM	Ocean Ridge Restoration								$1,215,000	$607,000		
		01-4	PBC ERM	Monitoring								$250,000	$125,000		
		01-5	PBC ERM	Administration								$49,050	$24,525		
25		02-1	Boynton Beach	NE 7th Street SW Improvements	**WAP0089**									$1,400,000	$500,000
26		02-2	Ocean Ridge	Stormwater Improvements										$1,505,000	$400,000
27		02-3	PBC ERM	Snook Islands										$1,769,071	$546,863
28		02-4	Westgate CRA	Westgate Infrastructure Improve										$840,267	$400,000
29		02-5	West Palm Beach	Garden Ave. Drainage										$1,130,000	$500,000
		02-6	PBC ERM	Monitoring										$220,000	$110,000
		02-7	PBC ERM	Administration										$56,274	$28,137
			TOTALS			**$4,489,321**	**$1,000,000**	**$4,720,526**	**$1,400,000**	**$14,423,757**	**$3,000,000**	**$3,407,525**	**$1,500,000**	**$6,920,612**	**$2,485,000**
			Total Number Construction Projects				**29**								
			Total Cost for all Projects (Construction, Monitoring and Administration)				**$33,961,741**								
			Total Grant Dollars				**$9,385,000**								

** Construction complete

ATTACHMENT 1

Lake Worth Lagoon Partnership Grant Program

•**Since 1998, the Florida legislature has appropriated $9,385,000 for the Lake Worth Lagoon Partnership Grant Program.**
•**This appropriation supports a pass-through grant program - from the Florida Department of Environmental Protection to Palm Beach County to local sponsors – for the construction of projects to benefit the lagoon's water quality and habitat.** •**Local sponsors have committed more than $24,000,00 in matching funds to complete the approved projects for a total project cost of nearly $34,000,000.**
•**Twenty-nine construction projects have been funded.**
•**Fourteen projects are complete or nearly complete.**
•**Remaining projects are in various stages of implementation.**
•**The grant program has also funded a limited amount of monitoring in the lagoon including seagrass mapping and monitoring, and the evaluation of muck sediments.**

Total Grant Award = $494,274


School District Artificial Reef at Peanut Island
Total Grant Award = $113,000

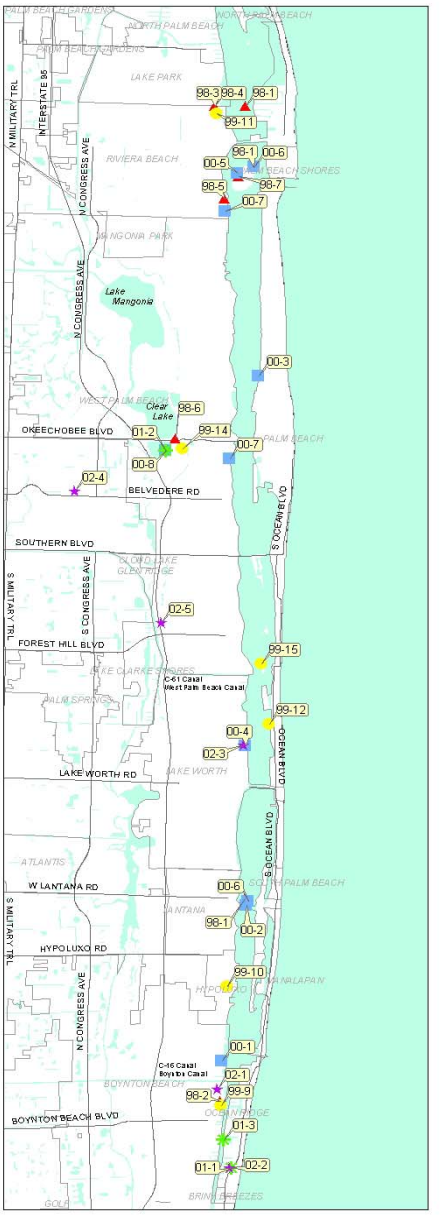

Lantana Cove Mangrove Planter
Total Grant Award = $12,000


Town of Palm Beach Stormwater/D12 Pump Station
Total Grant Award = $200,000


Town of Palm Beach Stormwater/D12 Wet Well
Total Grant Award = $200,000


Hypoluxo Installation of Sewers (Septic Replacement)
Total Grant Award = $450,000


Mangrove Mapping
Total Grant Award = $50,000

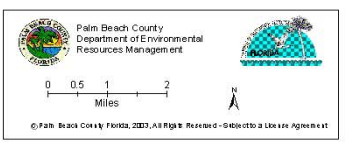


FUNDED PROJECTS

ID	STATUS	PROJECT	SPONSOR
98-1	1	Artificial Reef Habitat	School District of PB
98-1	1	Artificial Reef Habitat	School District of PB
98-1	1	Artificial Reef Habitat	School District of PB
98-2	1	Downtown SW Facility - Phase 1	Boynton Beach
98-3	3	Marina Pump Out	Town of Lake Park
98-4	2	Stormwater Management	Town of Lake Park
98-5	1	Stormwater, Trench Gate	Port of Palm Beach
98-6	1	Renaissance, Phase 1 - Year 1	West Palm Beach
98-7	2	Peanut Island Restoration	PBC ERM
99-9	1	Downtown Stormwater Facility	Boynton Beach
99-10	1	Hypoluxo Sewers	Town of Hypoluxo
99-11	3	Stormwater Retrofit	Town of Lake Park
99-12	1	Par 3 Wetland Restoration	Town of Palm Beach
99-14	1	Renaissance, Phase 1 - Year 2	West Palm Beach
99-15	3	John's Island	PBC ERM
00-1	3	ICW Stormwater Outfalls	Boynton Beach
00-2	1	Lantana Cove Mangroves	Town of Lantana
00-3	1	D-12 Stormwater	Town of Palm Beach
00-4	2	Snook Islands Natural Area	PBC ERM
00-5	2	Peanut Island Restoration	PBC ERM
00-6	1	Artificial Reef Habitat	School District of PB
00-6	1	Artificial Reef Habitat	School District of PB
00-7	1	Pollution Control Devices	West Palm Beach
00-7	1	Pollution Control Devices	West Palm Beach
00-8	1	Renaissance, Phase 2 - Year 1	West Palm Beach
01-1	3	Stormwater Improvements	Ocean Ridge
01-2	1	Renaissance, Phase 2 - Year 2	West Palm Beach
01-3	3	Ocean Ridge Natural Area	PBC ERM
02-1	3	NE 7th Street	Boynton Beach
02-2	3	Stormwater Improvements	Ocean Ridge
02-3	2	Snook Islands Natural Area	PBC ERM
02-4	2	Infrastructure Improvements	Westgate CRA
02-5	3	Garden Ave. Drainage	West Palm Beach

PROJECT YEAR
- 98-99
- 99-00
- 00-01
- 01-02
- 02-03

STATUS KEY
1 - Construction Complete
2 - Construction Underway
3 - Planning & Design




Boynton Beach Regional Stormwater Facility
Total Grant Award = $550,000

West Palm Beach Renaissance Stormwater Retrofit
Total Grant Award = $950,000


PBC ERM Snook Islands Natural Area
Total Grant Award = $1,629,064


PBC ERM Ocean Ridge Natural Area
Total Grant Award = $607,000


PBC ERM John's Island Mangrove Restoration
Total Grant Award = $202,475


Town of Palm Beach Par 3 Wetland Restoration
Total Grant Award = $198,023


Port of Palm Beach Drainage Improvements
Total Grant Award = $114,784

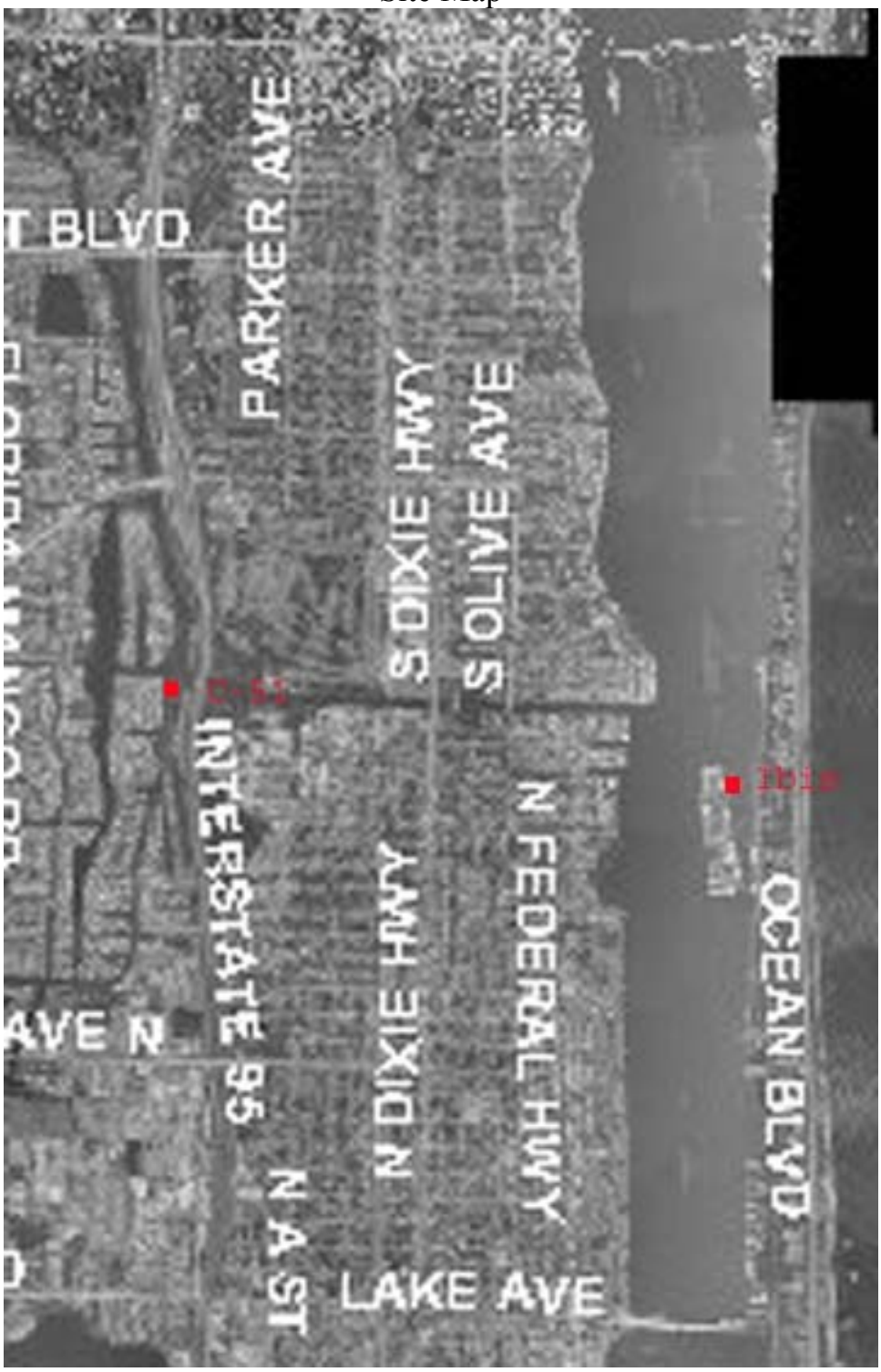

Westgate CRA Infrastructure Improvements
Total Grant Award = $400,000


PBC ERM Seagrass Monitoring and Mapping
Total Grant Award = $121,062


PBC ERM Muck Sampling and Mapping
Total Grant Award = $119,991

ATTACHMENT 2

Attachment 3 – Central Lake Worth Lagoon Muck Sediment Monitoring,
Phase II-1a – Preliminary Study,
Site Map



Three cores were collected from site Ibis, they were: Ibis-1, Ibis-FD (Field Duplicate), and Sed-Ibis (Accumulation rate analysis). Collection of a core was not possible at site C-51, therefore a ponar grab sample was collected.

Attachment 4 - Central Lake Worth Lagoon Muck Sediment Monitoring,
Phase II-1a - Preliminary Study,
Core Summary

Sediment Core Samples for Nutrient, Metals, Pesticide/PCB Analysis

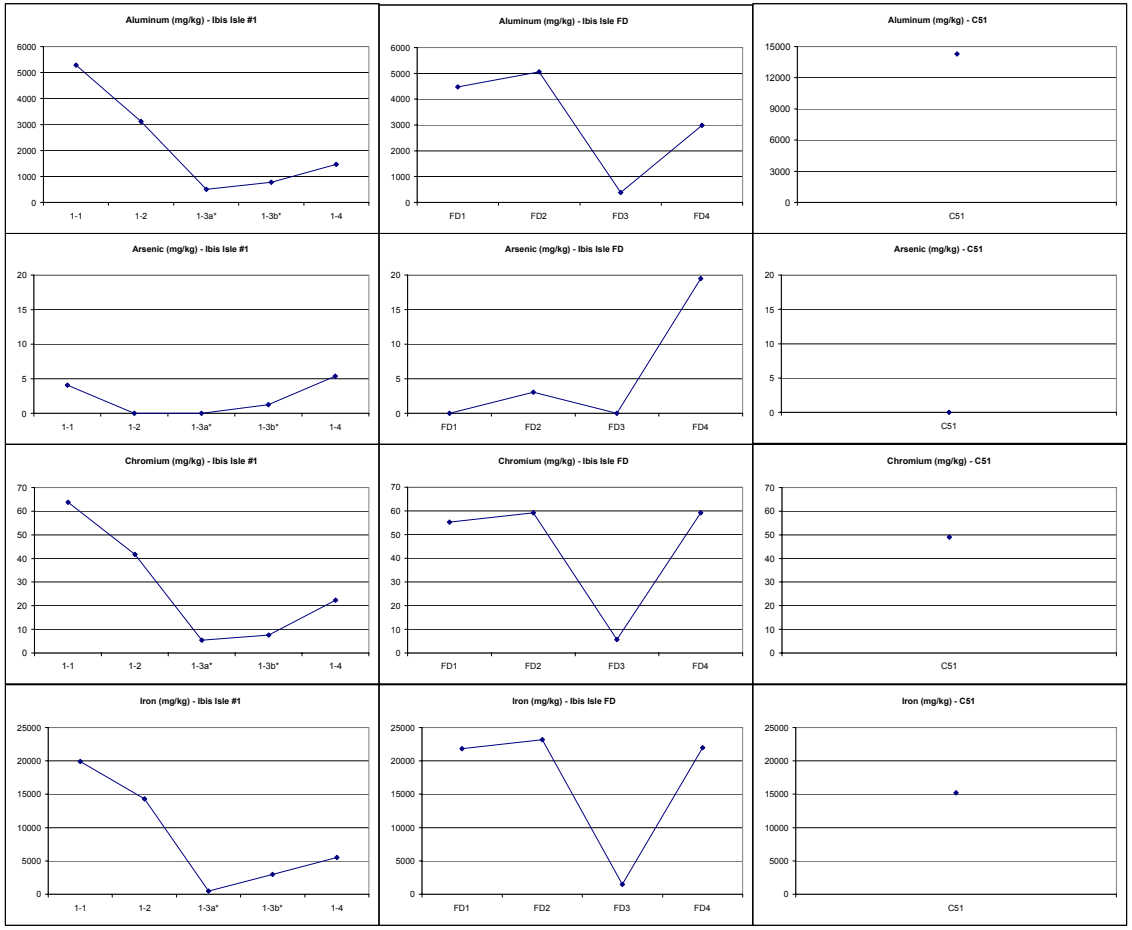
Date	Site	Core Number	Sample Number	Layer # (from top)	Depth of subsample (from top)	Characterization
8/27/2002	Ibis Isle	Ibis-1	1-1	1	0 - 10.5"	Black, soft ooze
8/27/2002	Ibis Isle	Ibis-1	1-2	2	10.5 - 20	Black, peat-like
8/27/2002	Ibis Isle	Ibis-1	1-3a	3	20 - 31"	Sandy, coarse, relatively light in color
8/27/2002	Ibis Isle	Ibis-1	1-3b	3	31 - 42"	Sandy, coarse, relatively light in color
8/27/2002	Ibis Isle	Ibis-1	1-4	4	42 - 55"	Sandy, finer-grained, darker in color
8/27/2002	Ibis Isle	Ibis-FD	FD1	1	0 - 9"	Thick, dark, sticky, soft, muck
8/27/2002	Ibis Isle	Ibis-FD	FD2	2	9 - 19.25"	Thicker, dark muck
8/27/2002	Ibis Isle	Ibis-FD	FD3	3	19.25 - 28.5"	White sand
8/27/2002	Ibis Isle	Ibis-FD	FD4	4	28.5 - 43"	Thick, consolidated sediment
8/28/2002	C51 Canal	NA	C51	NA	NA	Very black mud, soft. (Ponar grab sample)

Attachment 5 - Central Lake Worth Lagoon Muck Sediment Monitoring,
Phase II-1a - Preliminary Study,
Chemical Analysis

Analyte	Method	MDL (mg/Kg)	TEL	PEL	1-1	1-2	1-3a*	1-3b*	1-4	FD1	FD2	FD3	FD4	C51
Al	7020	1.0			5288.136	3112.745	501.5576	780.4569	1460.674	4469.697	5060.976	384	2991.736	14285.71
As	3050/6010B	0.075	7.24	41.6	4.067797	BDL	BDL	1.243655	5.36829	BDL	3.04878	BDL	**19.50413**	BDL
Cd	3050/6010B	1.0	0.676	4.21	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL
Cr	3050/6010B	1.0	52.3	160	**63.72881**	41.66667	5.451713	7.614213	22.34707	**55.30303**	**59.14634**	5.733333	**59.17355**	49.06832
Cu	3050/6010B	1.0	18.7	108	**42.71186**	15.44118	BDL	BDL	BDL	**48.10606**	**32.92683**	2.226667	BDL	**101.8634**
Fe	3050/7380	1.0	NA	NA	19932.2	14313.73	462.6168	2994.924	5505.618	21818.18	23170.73	1493.333	21983.47	15217.39
Pb	3050/6010B	1.0	30.2	112	**87.79661**	28.92157	BDL	2.030457	1.747815	**59.4697**	**76.21951**	1.733333	6.61157	**67.70186**
Hg	7471A	0.100	0.13	0.696	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL
Ni	3050/6010B	1.0	15.9	42.8	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL
Ag	3050/6010B	1.0	0.733	1.77	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL
TP	365.4	1.0	NA	NA	813.5593	357.8431	21.33956	33.50254	86.39201	916.6667	987.8049	220	319.0083	2385.093
TKN	351.2	1.0	NA	NA	3450.847	7490.196	1476.636	246.1929	365.7928	3946.97	4182.927	261.3333	578.5124	7577.64
NO2	9056	10.0	NA	NA	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL
NO3	9056	1.0	NA	NA	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL
PCBs	3550/8082	20.000	NA	NA	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL
PAHs	3550/8270C	0.333	NA	NA	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL
Percent Solids	160.3				29.5	20.4	64.2	78.8	80.1	26.4	32.8	75	60.5	16.1

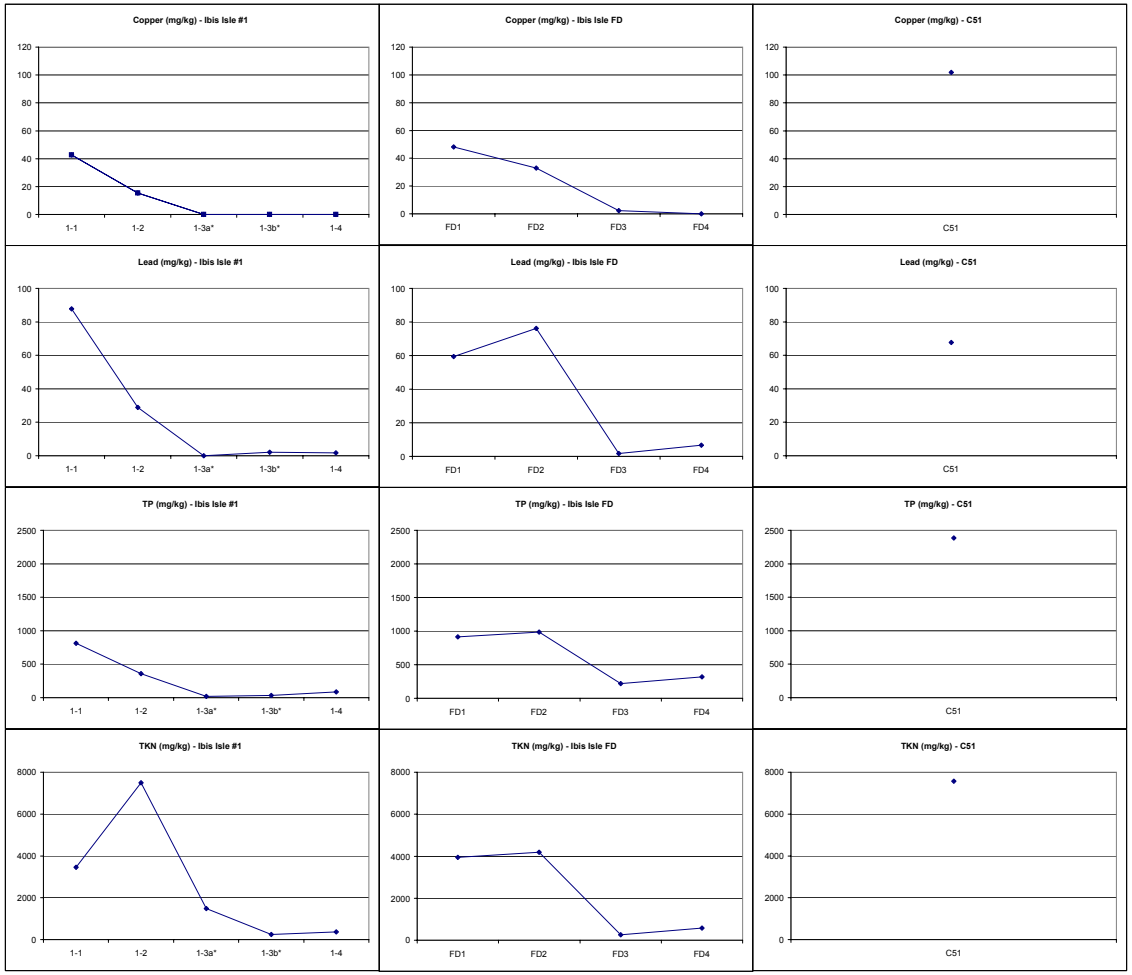
* Because layer 3 was so thick (from 20 to 55 inches below sediment surface), the sample was divided in half for analysis.
Sample 3a was 20 to 31 inches below sediment surface, sample 3b was 31 to 55 inches below sediment surface.

Attachment 6 - Central Lake Worth Lagoon Muck Sediment Monitoring,
Phase II-1a, Preliminary Study,
Chemical Analysis



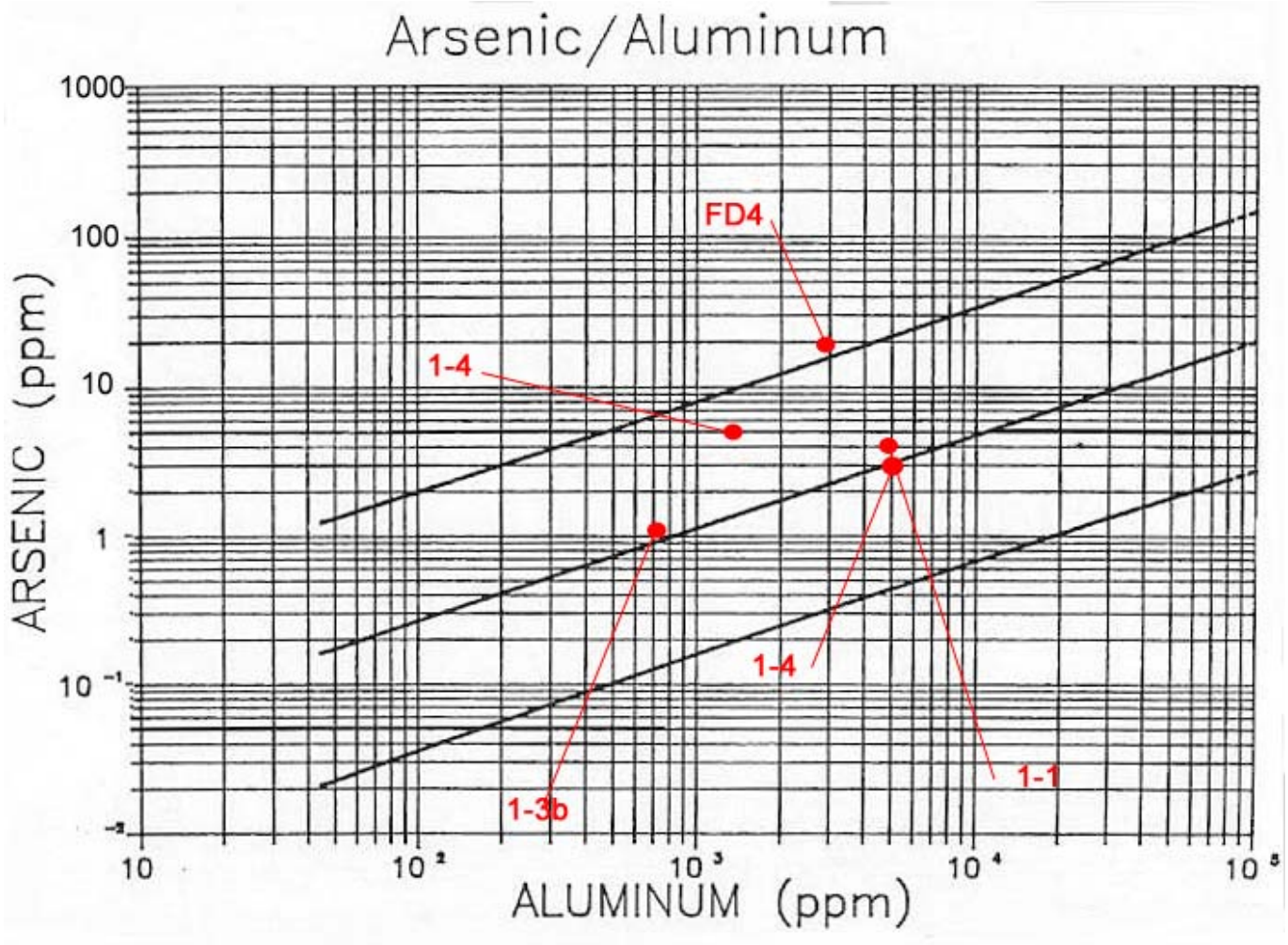
Sample 1-1: Top layer of core Ibis-1, 0-10.5" from top of core; field characterization: black, soft ooze.
Sample 1-2: Second layer from top of core Ibis-1, 10.5-20" from top of core; field characterization: black, peat-like
* Because layer 3 was so thick (from 20 to 55 inches below sediment surface), the sample was divided in half for analysis.
Sample 1-3a: Top half of third layer of core Ibis-1, 20-31" from top of core; field characterization: sandy, coarse, relatively light in color
Sample 1-3b: Bottom half of third layer of core Ibis-1, 31-42" from top of core; field characterization: soft, black ooze.
Sample 1-4: Fourth layer from top of core Ibis-1, 42-55" from top of core; field characterization: sandy, finer-grained, darker in color
Sample FD1: Top layer of core Ibis-FD, 0-9" from top of core; field characterization thick, dark, sticky, soft muck
Sample FD2: Second layer from top of core Ibis-FD, 9-19.25" from top of core; thicker, dark muck
Sample FD3: Third layer from top of core Ibis-FD, 19.25-28.5" from top of core; field characterization white sand
Sample FD4: Fourth layer from top of core Ibis-FD, 28.5-43" from top of core; field characterization thick, consolidated sediment
C51: Ponar grab Sample from C-51 Canal; field characterization: very black mud, soft

Attachment 6 - Central Lake Worth Lagoon Muck Sediment Monitoring,
Phase II-1a, Preliminary Study,
Chemical Analysis



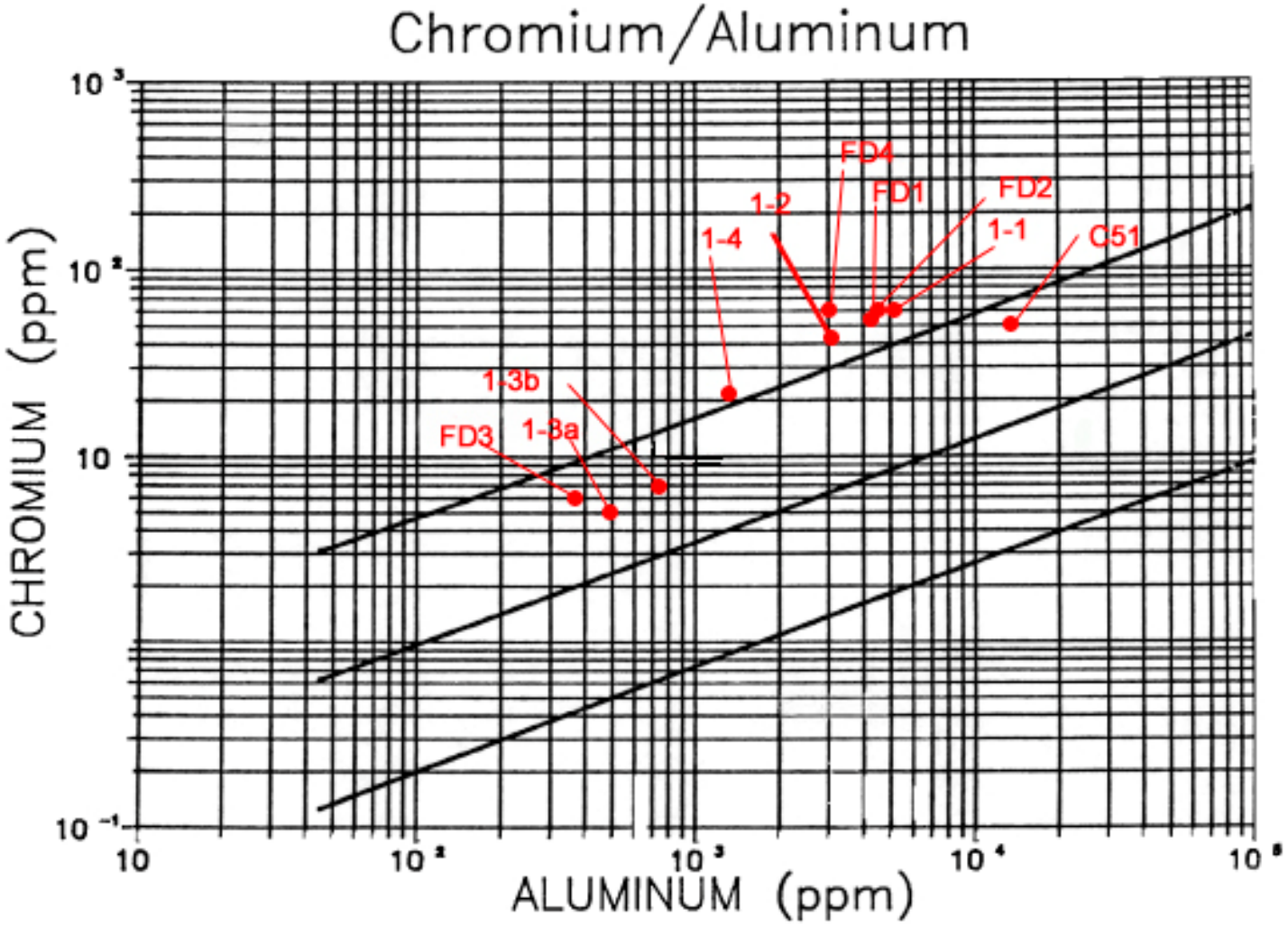
Sample 1-1: Top layer of core Ibis-1, 0-10.5" from top of core; field characterization: black, soft ooze.
Sample 1-2: Second layer from top of core Ibis-1, 10.5-20" from top of core; field characterization: black, peat-like
* Because layer 3 was so thick (from 20 to 55 inches below sediment surface), the sample was divided in half for analysis.
Sample 1-3a: Top half of third layer of core Ibis-1, 20-31" from top of core; field characterization: sandy, coarse, relatively light in color
Sample 1-3b: Bottom half of third layer of core Ibis-1, 31-42" from top of core; field characterization: soft, black ooze.
Sample 1-4: Fourth layer from top of core Ibis-1, 42-55" from top of core; field characterization: sandy, finer-grained, darker in color
Sample FD1: Top layer of core Ibis-FD, 0-9" from top of core; field characterization thick, dark, sticky, soft muck
Sample FD2: Second layer from top of core Ibis-FD, 9-19.25" from top of core; thicker, dark muck
Sample FD3: Third layer from top of core Ibis-FD, 19.25-28.5" from top of core; field characterization white sand
Sample FD4: Fourth layer from top of core Ibis-FD, 28.5-43" from top of core; field characterization thick, consolidated sediment
C51: Ponar grab Sample from C-51 Canal; field characterization: very black mud, soft

Attachment 7 – Central Lake Worth Lagoon Muck Sediment Monitoring,
Phase II-1a – Preliminary Study,
Metals concentrations in relation to Aluminum



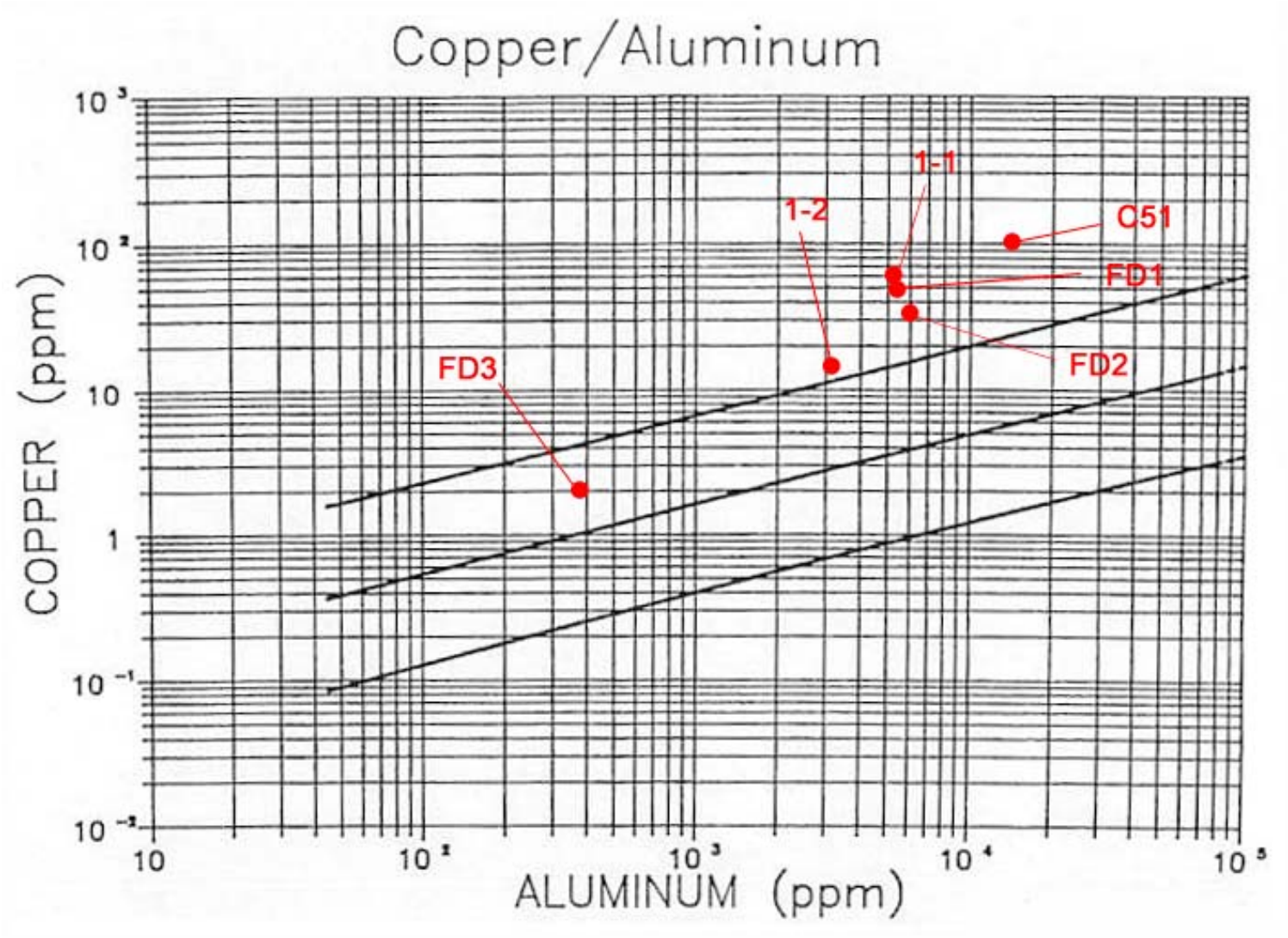
Arsenic concentrations were below the detection limit (0.75mg/Kg) in samples Ibis1-2, Ibis1-3a, IbisFD1, IbisFD3, and C-51.

Attachment 7 – Central Lake Worth Lagoon Muck Sediment Monitoring,
Phase II-1a – Preliminary Study,
Metals concentrations in relation to Aluminum



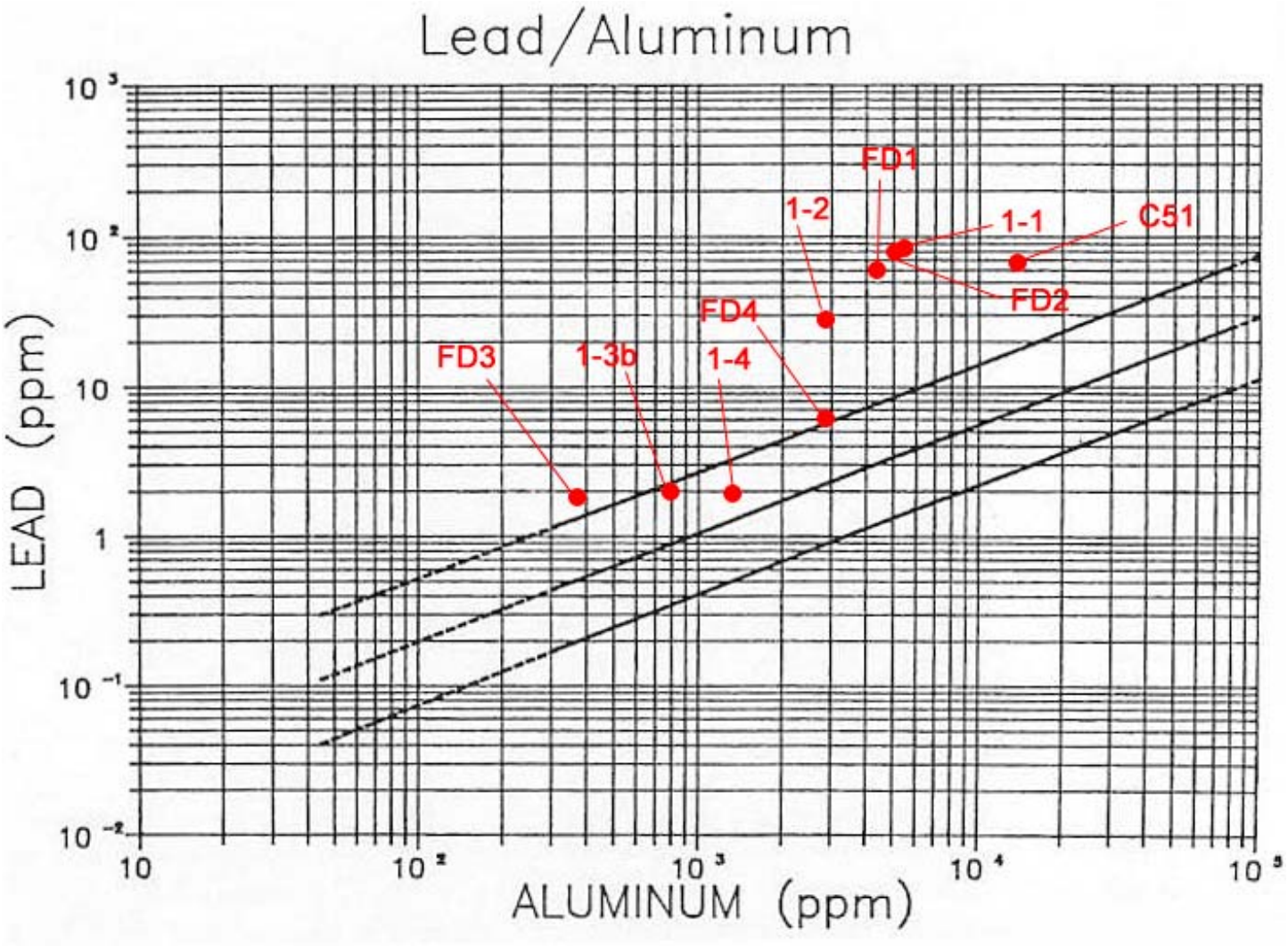
No samples were below the method detection limit of 1.0 mg/Kg.

Attachment 7 – Central Lake Worth Lagoon Muck Sediment Monitoring,
Phase II-1a – Preliminary Study,
Metals concentrations in relation to Aluminum



Copper concentrations were below the detection limit (1.0 mg/Kg) in samples Ibis1-3a, Ibis1-3b, Ibis1-4, and IbisFD4.

Attachment 7 – Central Lake Worth Lagoon Muck Sediment Monitoring,
Phase II-1a – Preliminary Study,
Metals concentrations in relation to Aluminum

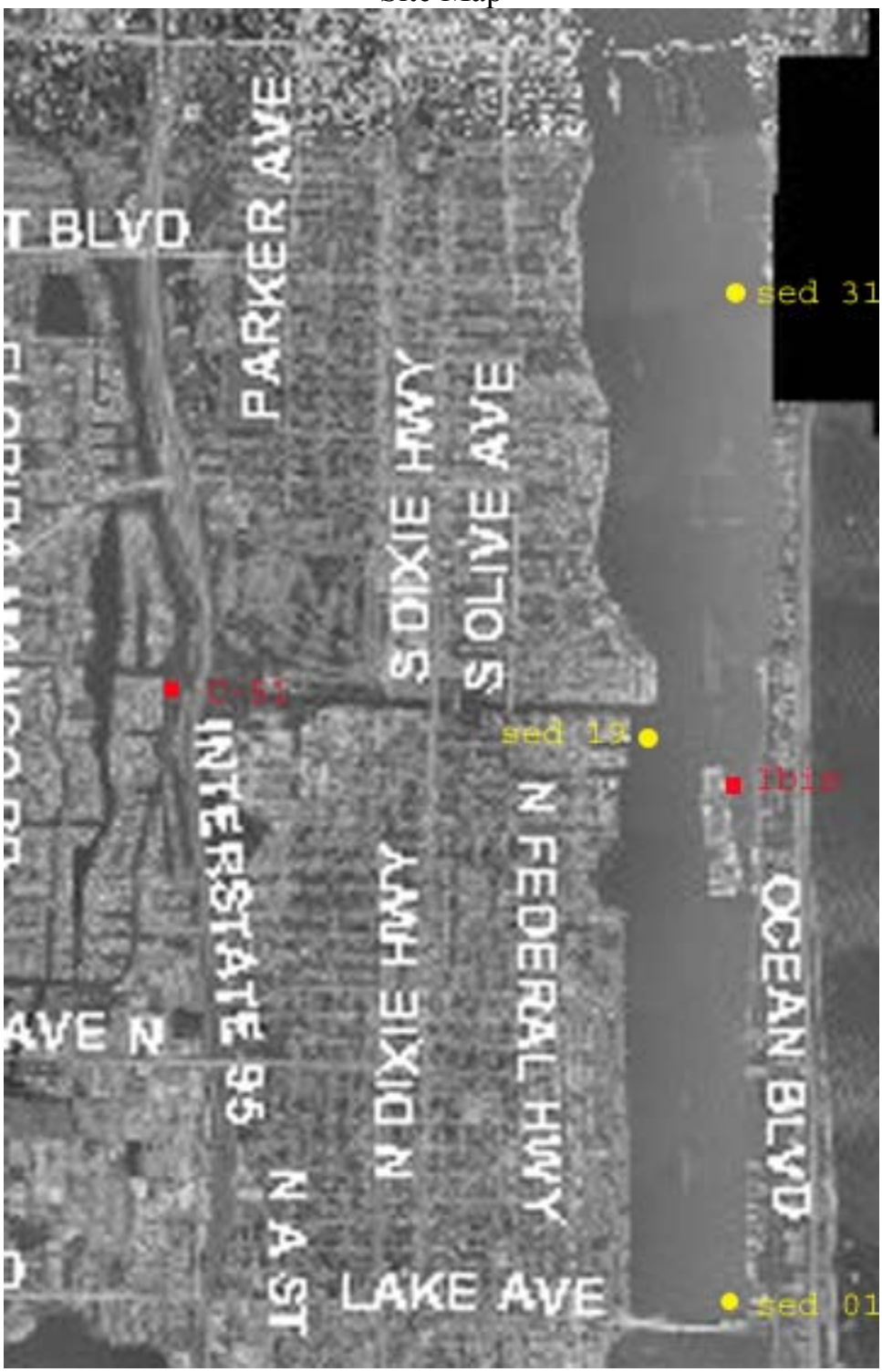


Lead concentration was below the detection limit (1.0 mg/Kg) in sample Ibis1-3a.

Attachment 8 - Central Lake Worth Lagoon Muck Sediment Monitoring,
Phase II-1a - Preliminary Study,
Accumulation Rates

Site	Sediment Depth (cm)	% Dry Wt. (g)	Dry wt. Density (g/cm3)	YEAR	Sediment Accumulation Rate (cm/yr)	Site	Sediment Depth (cm)	% Dry Wt. (g)	Dry wt. Density (g/cm3)	YEAR	Sediment Accumulation Rate (cm/yr)
									Averaged Sections*		
Ibis	0-2	43.7	0.580	1984-present	0.431						
Ibis	2-4	43.8	0.583	1984-present	0.430						
Ibis	4-6	43.3	0.574	1984-present	0.431						
Ibis	6-8	41.4	0.537	1984-present	0.436	Ibis	0-8	43.1	0.568	1984	0.445
Ibis	8-10	40.5	0.519	1976-1984	0.444						
Ibis	10-12	40.7	0.523	1976-1984	0.450						
Ibis	12-14	41.2	0.533	1976-1984	0.454						
Ibis	14-16	41.0	0.529	1976-1984	0.456	Ibis	8-16	40.9	0.527	1976	0.456
Ibis	16-18	40.4	0.518	1975	0.458	Ibis	16-18	40.4	0.518	1965	0.463
Ibis	18-20	40.3	0.516	1971	0.461	Ibis	18-20	40.3	0.516	1961	0.466
Ibis	20-22	39.6	0.504	1967	0.463	Ibis	20-22	39.6	0.504	1957	0.469
Ibis	22-24	39.1	0.493	1944-1963	0.466						
Ibis	24-26	38.4	0.482	1944-1963	0.470						
Ibis	26-28	38.5	0.482	1944-1963	0.473						
Ibis	28-30	38.3	0.479	1944-1963	0.476						
Ibis	30-32	37.3	0.461	1944-1963	0.479						
Ibis	32-34	37.0	0.456	1944-1963	0.483	Ibis	22-34	38.1	0.476	1944	0.482
Ibis	34-36	46.0	0.628	pre-1944	0.482	Ibis	34-36	46.0	0.628	1930	0.487
Ibis	36-38	56.0	0.850	pre-1944	0.471	Ibis	36-38	56.0	0.850	1924	0.476
Ibis	38-40	64.9	1.08	pre-1944	0.452	Ibis	38-40	64.9	1.08	1917	0.457

Attachment 9 – Central Lake Worth Lagoon Muck Sediment Monitoring,
Phase II-1b – Expanded Study,
Site Map



Sites Ibis (3 core samples) and C-51 (single ponar grab sample) were sampled during Phase II-1a of this study.
Sites sed01, sed19, and sed31 were sampled during Phase II-1b of this study.

Attachment 10 - Central Lake Worth Lagoon Muck Sediment Monitoring,
Phase II-1b – Expanded Study, Core Summary

			Layer 1		Layer 2		Layer 3		Layer 4	
Time	Site	Sample Number	Depth (in.)	Characterization	Depth (in)	Characterization	Depth	Characterization	Depth	Characterization
12:30	1	sed01a	0 - 4.2	Unconsolidated Muck	4.2 - 6.9	Consolidated Muck	6.9 - 9.84	White Sand		
12:35		sed01b	0 - 4.2	Unconsolidated Muck	4.2 - 6.72	Consolidated Muck	6.72 - 11.04	White Sand		
12:36		sed01c	0 - 4.44	Unconsolidated Muck	4.44 - 7.44	Consolidated Muck	7.44 - 7.68	White Sand		
12:37		sed01d	0 - 5.04	Consolidated Muck	5.04 - 8.04	White Sand				
12:40		sed01e	0 - 3.6	Unconsolidated Muck	3.6 - 6.0	Consolidated Muck		White Sand		
12:46		sed01f	0 - 6.12	Unconsolidated Muck	6.12 - 10.2	Consolidated Muck		White Sand		
11:33	19	sed19a	0 - 14.4	Unconsolidated Muck						
11:41		sed19b	0 - 16.2	Unconsolidated Muck						
11:44		sed19c	0 - 15	Unconsolidated Muck						
11:46		sed19d	0 - 17.04	Unconsolidated Muck						
11:49		sed19e	0 - 13.92	Unconsolidated Muck						
11:52		sed19f	0 - 20.28	Unconsolidated Muck						
9:37	31	sed31a	0 - 6.9	Unconsolidated Muck[1]	6.9 - 16.8	Consolidated Muck[2] (peaty)				
9:50		sed31b	0 - 7.92	Unconsolidated Muck[3]	7.92 - 15.24	Consolidated Muck[4] (peaty)				
10:06		sed31c	0 - 3.6	Unconsolidated Muck[5]	3.6 - 9.12	Consolidated Muck	9.12 - 13.44	Consolidated Muck (peaty)	13.44 - 14.4	Sand and Shell
10:19		sed31d	0 - 8.16	Unconsolidated Muck	8.16 - 13.2	Consolidated Muck (peaty)	13.2 - 13.56	Sand with Some Shell		
10:25		sed31e	0 - 5.04	Unconsolidated Muck	5.04 - 8.4	Consolidated Muck[6] (peaty)		Sand with Some Shell		
10:30		sed31f	0 - 5.16	Unconsolidated Muck	5.16 - 10.08	Consolidated Muck (peaty)		Sand with Some Shell		

a: samples for which each individual layer of muck to be analyzed for chemical concentration (samples labeled a-1, a-2)
b: samples for which all muck layers will be composited for analysis of chemical concentrations
c: samples for which all muck layers will be composited for analysis of chemical concentrations
d: samples for which all muck layers will be composited for analysis of chemical concentrations
e: samples for which each individual layer of muck to be analyzed for characterization (samples labeled e-1, e-2)
f: samples to be shipped whole to lab for stable isotope analysis

1: muck mixed with sand at 1.8 - 2.4 inches depth and 4.2 - 4.8 inches depth
2: muck mixed with sand throughout layer
3: layer of sand from 1.68 - 2.16 inches depth
4: layers of sand at 9.84 - 10.32 inches depth and 12.48 - 13.2 inches depth
5: mixed with sand and shell at 5.16 - 5.64 inches depth
6: sand and shell throughout layer

Attachment 11 - Central Lake Worth Lagoon Muck Sediment Monitoring,
Phase II-1b - Expanded Study, Chemical Analysis

Analyte	TEL	PEL	sed01a1	sed01a2	sed01b	sed01c	sed01d	sed19a	sed19b	sed19c	sed19d	sed31a1	sed31a2	sed31b	sed31c	sed31d
Al			2741.12	5132.53	4915.46	7010.87	6621.92	8726.11	6484.15	6677.22	5443.79	3002.31	668.48	1416.53	1577.10	3609.34
As	7.24	41.6	3.86	**10.36**	6.11	5.84	**10.22**	**11.31**	2.97	**8.83**	**8.20**	5.13	BDL	3.63	4.88	6.48
Cd	0.676	4.21	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL
Ca			79949.24	154939.76	200483.09	173369.57	176286.35	121019.11	113832.85	100316.46	109763.31	72517.32	2187.50	42327.15	91822.43	102760.08
Cr	52.3	160	23.98	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL
Cu	18.7	108	13.35	BDL	BDL	13.56	**26.85**	**23.92**	5.76	**26.23**	13.40	8.71	BDL	BDL	BDL	11.51
Fe			12106.60	16578.31	13357.49	18750.00	17337.81	20382.17	15590.78	20664.56	15532.54	10923.79	3070.65	5227.66	8294.39	13736.73
Pb	30.2	112	22.51	17.57	19.40	**31.25**	**39.37**	**81.85**	**58.50**	**85.13**	**62.43**	26.79	BDL	6.75	14.14	26.96
Mg			5913.71	7831.33	5966.18	8016.30	7606.26	8375.80	7925.07	9303.80	8372.78	5173.21	4211.96	2462.06	5280.37	5201.70
Mn			43.40	69.88	54.35	67.39	65.10	102.55	83.29	104.43	92.60	40.88	18.21	20.91	39.49	50.32
Hg	0.13	0.696	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL
Mo			BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL
Ni	15.9	42.8	4.57	4.34	3.62	5.16	5.59	7.64	6.34	7.59	5.92	3.23	BDL	BDL	2.34	3.82
Ag	0.733	1.77	BDL	**4.10**	**2.66**	**2.99**	**3.36**	BDL	**3.46**	BDL	**2.96**	BDL	BDL	BDL	BDL	BDL
Zn			150.76	46.27	80.19	157.61	208.28	244.90	138.04	259.81	181.07	121.71	BDL	15.43	52.80	117.62
TP			451.78	491.57	579.71	750.00	657.72	847.13	662.82	9.49	5.92	369.52	16.30	168.63	266.36	411.89
TKN			1010.15	1330.12	223.19	312.50	259.51	331.21	291.07	10.82	BDL	230.95	304.35	140.30	192.06	282.38
TOC			48020.30	33132.53	41304.35	60434.78	48859.06	76082.80	74265.13	119493.67	66538.46	23533.49	82771.74	18836.42	42406.54	64373.67
Pest/PCB (8081)			BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL
Herbi (615)			BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL
PAH (8100)			BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL
Percent Solids			39.40	41.50	41.40	36.80	44.70	31.40	34.70	31.60	33.80	43.30	36.80	59.30	42.80	47.10

Cores suffixed "a" had sediment layers divided into subsamples of "unconsolidated muck" and "consolidated muck" in order to determine whether compositing of subsequent samples (suffixed b, c, and d) provided data comparable to analyzing the layer as two subsamples.

Sed01a1 - Collected from site Sed01, top half of the muck layer (0-4.2" in depth), field characterization: unconsolidated muck

Sed01a2 - Collected from site Sed01, lower half of the muck layer (4.2-6.9" in depth), field characterization: consolidated muck

Sed01b - Collected from site Sed01, entire muck layer (0-6.72" in depth), field characterization: muck

Sed01c - Collected from site Sed01, entire muck layer (0-7.44" in depth), field characterization: muck

Sed01d - Collected from site Sed01, entire muck layer (0-5.04" in depth), field characterization: consolidated muck (This sample lacked the usual upper layer of light, unconsolidated muck sediments - possibly as a result of previous disturbance).

Sed19a - Collected from site Sed19, top portion of the muck layer (0-14.4" in depth, bottom of muck layer never reached at this site), field characterization: unconsolidated muck

Sed19b - Collected from site Sed19, top portion of the muck layer (0-16.2" in depth, bottom of muck layer never reached at this site), field characterization: unconsolidated muck

Sed19c - Collected from site Sed19, top portion of the muck layer (0-15" in depth, bottom of muck layer never reached at this site), field characterization: unconsolidated muck

Sed19d - Collected from site Sed19, top portion of the muck layer (0-17.04" in depth, bottom of muck layer never reached at this site), field characterization: unconsolidated muck

Sed31a1 - Collected from site Sed31, top half of the muck layer (0-6.9" in depth), field characterization: unconsolidated muck

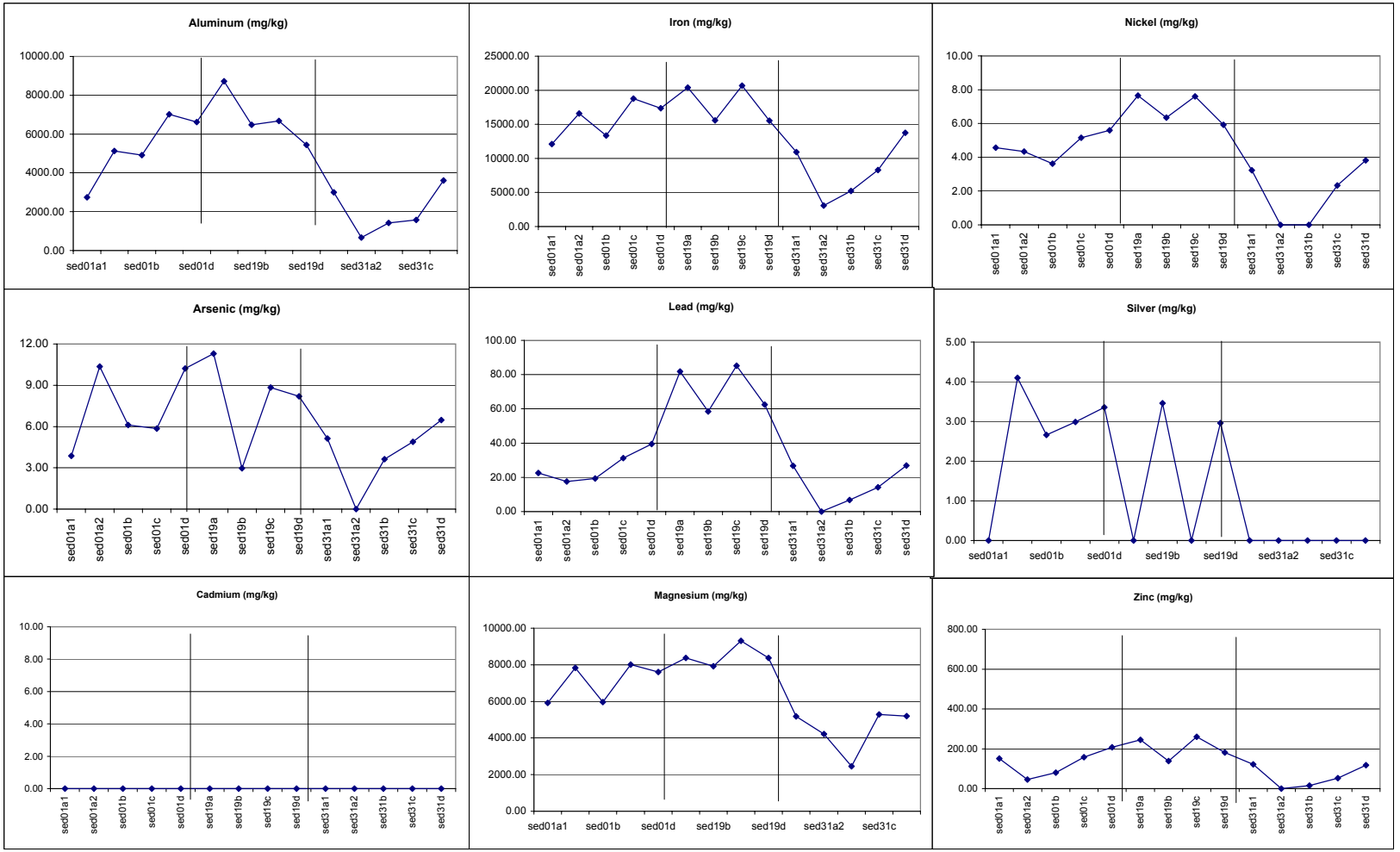
Sed31a2 - Collected from site Sed31, lower half of the muck layer (6.9-16.8" in depth), field characterization: consolidated muck (peaty)

Sed31b - Collected from site Sed31, entire muck layer (0-15.24" in depth), field characterization: muck (peaty at bottom of sample)

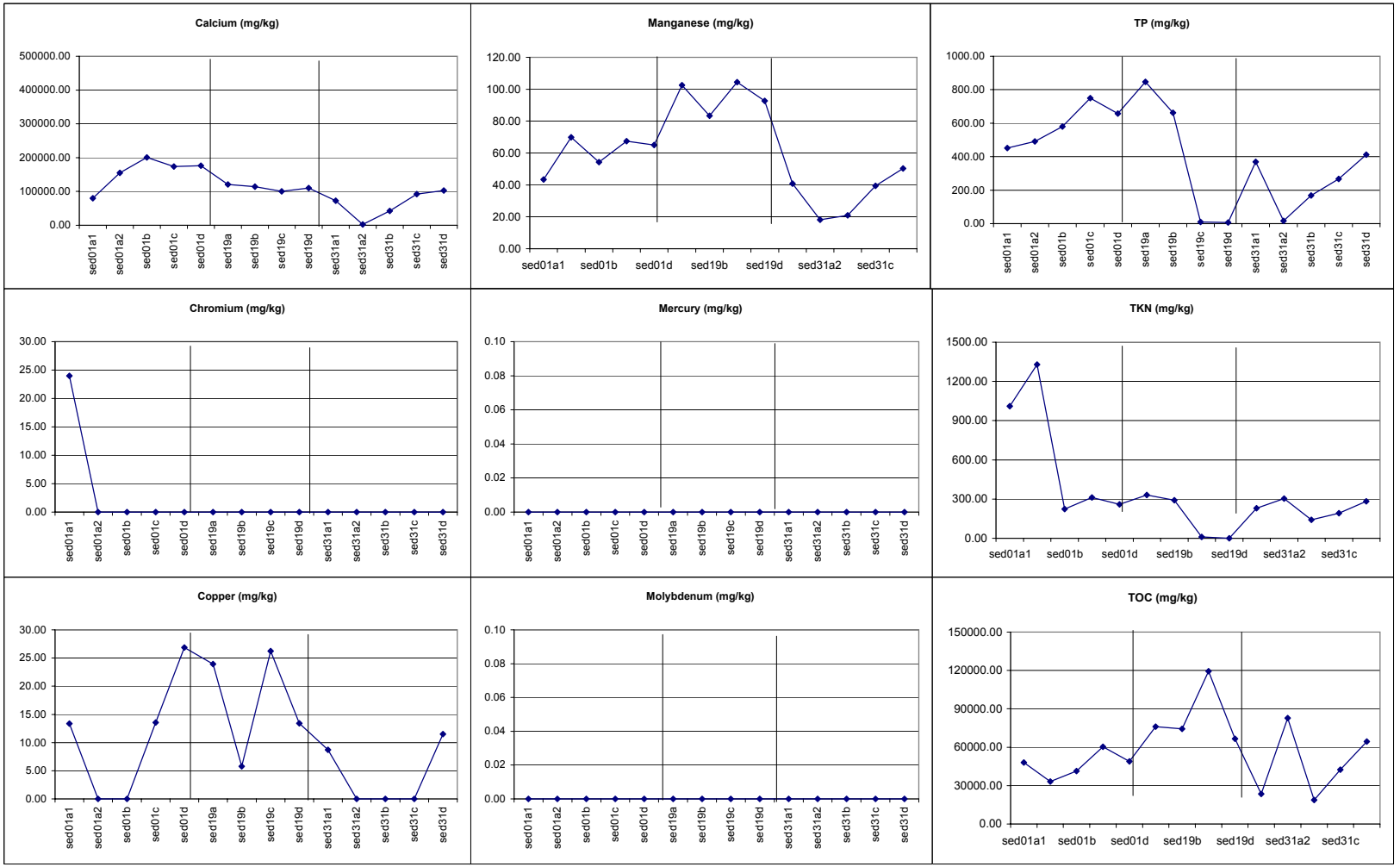
Sed31c - Collected from site Sed31, entire muck layer (0-9.12" in depth), field characterization: muck

Sed31d - Collected from site Sed31, entire muck layer (0-13.2" in depth), field characterization: muck (peaty at bottom of sample)

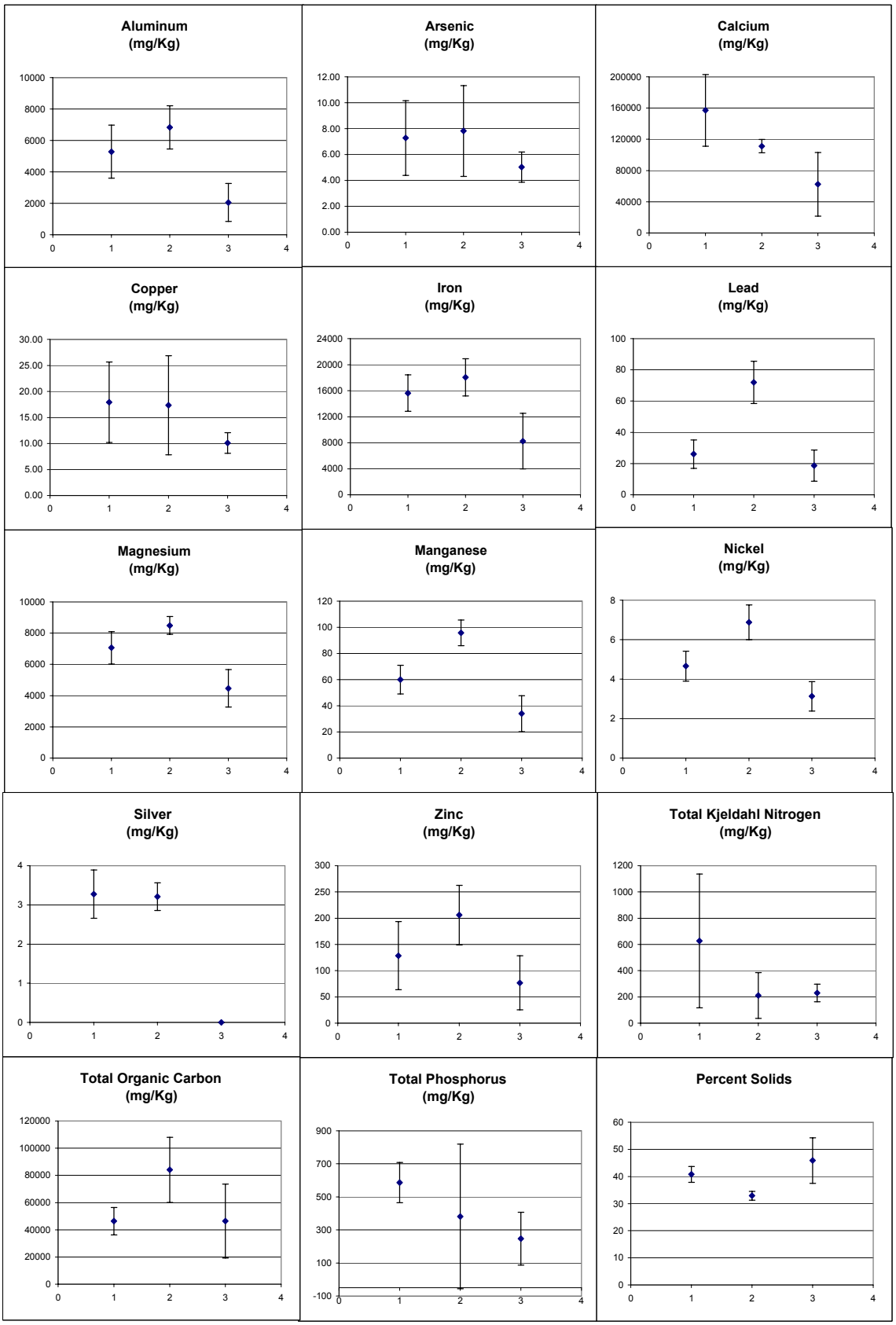
Attachment 12 - Central Lake Worth Lagoon Muck Sediment Monitoring,
Phase II-1b - Expanded Study, Chemical Analysis



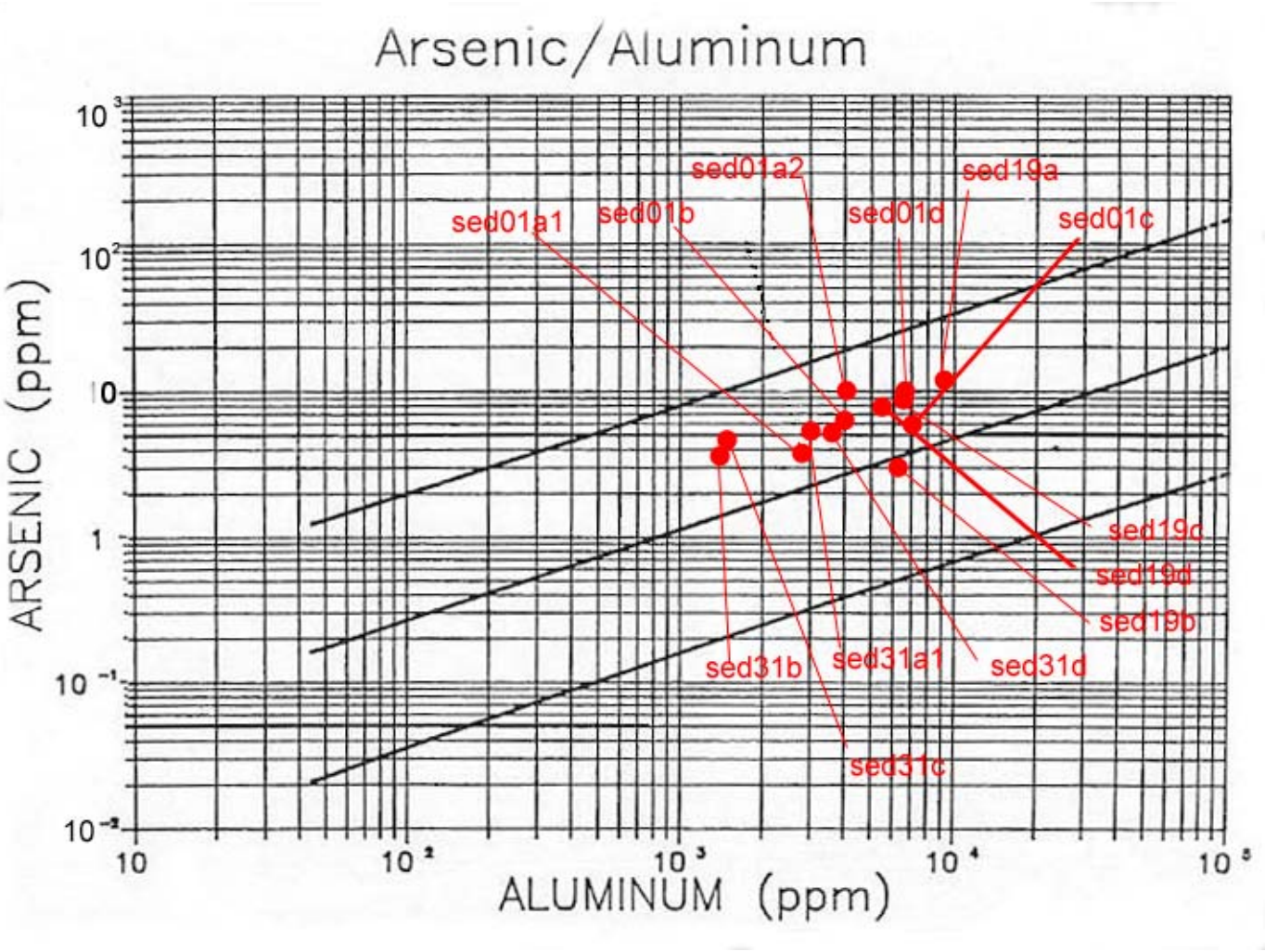
Attachment 12 - Central Lake Worth Lagoon Muck Sediment Monitoring,
Phase II-1b - Expanded Study, Chemical Analysis



Attachment 13 - Central Lake Worth Lagoon Muck Sediment Monitoring,
Phase II-1b - Expanded Study, Chemical Analysis

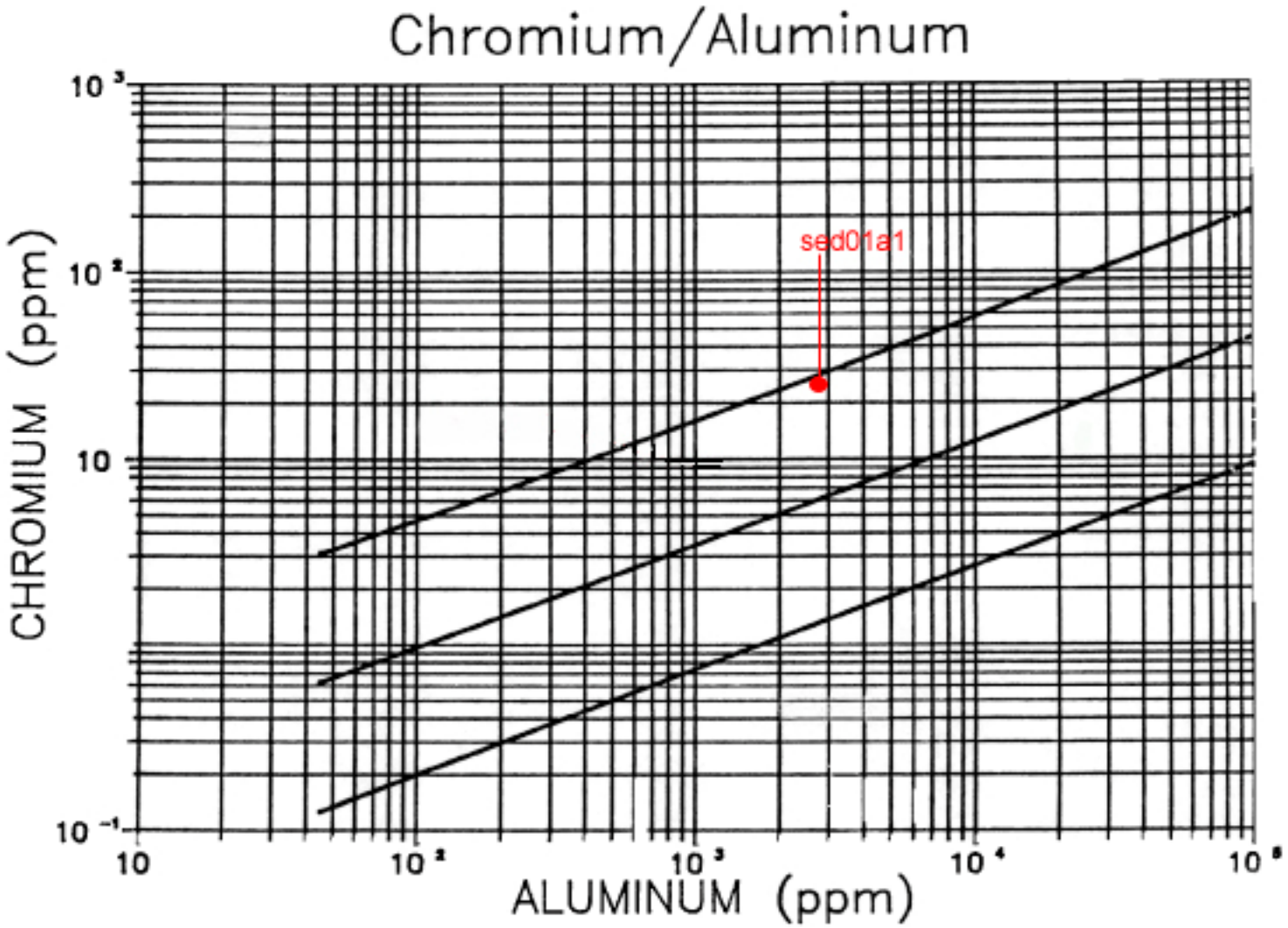


Attachment 14 – Central Lake Worth Lagoon Muck Sediment Monitoring,
Phase II-1b – Expanded Study,
Metals concentrations in relation to Aluminum



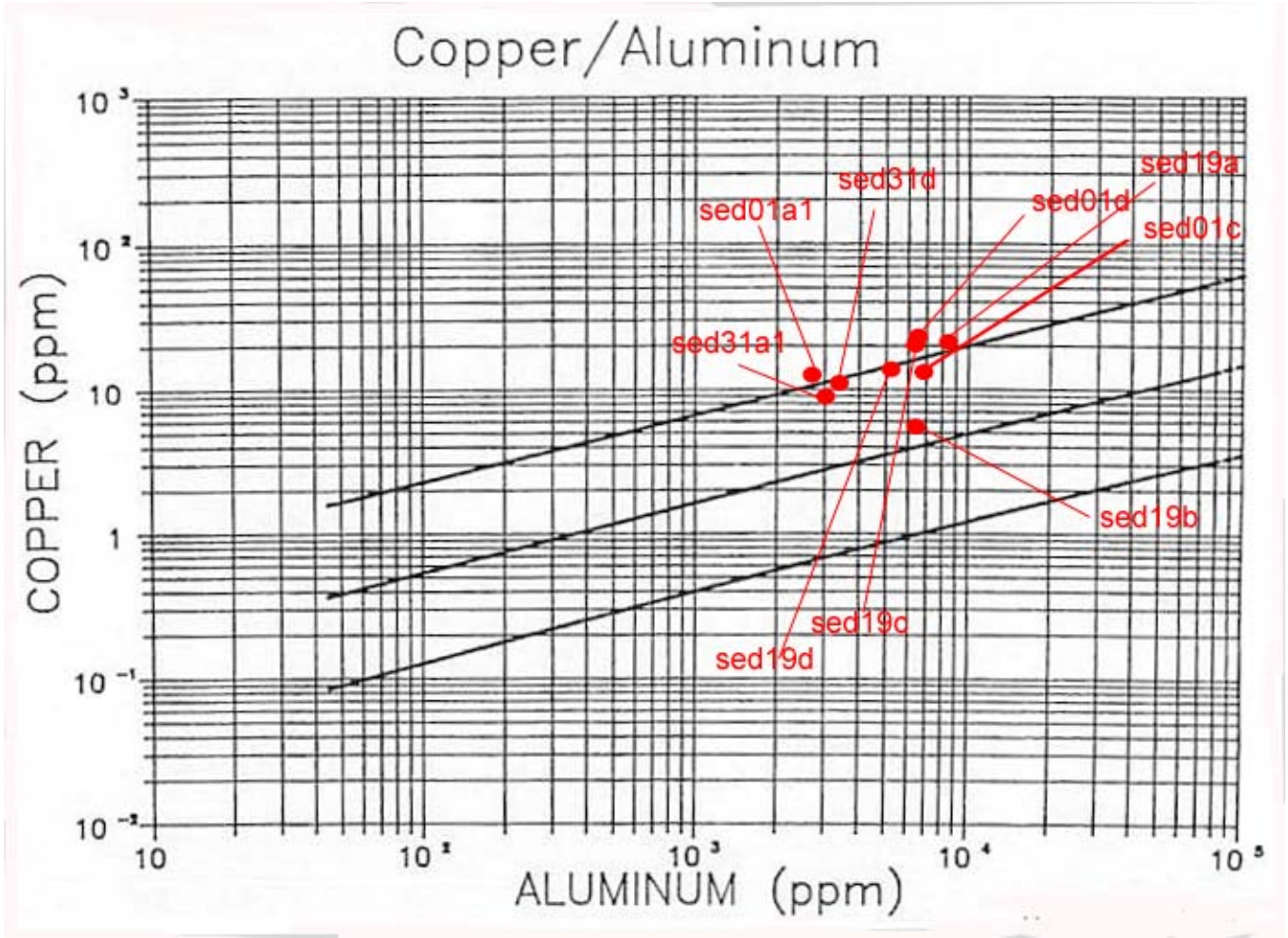
Arsenic concentration was below the method detection limit (MDL) in sample sed31a2.

Attachment 14 – Central Lake Worth Lagoon Muck Sediment Monitoring,
Phase II-1b – Expanded Study,
Metals concentrations in relation to Aluminum



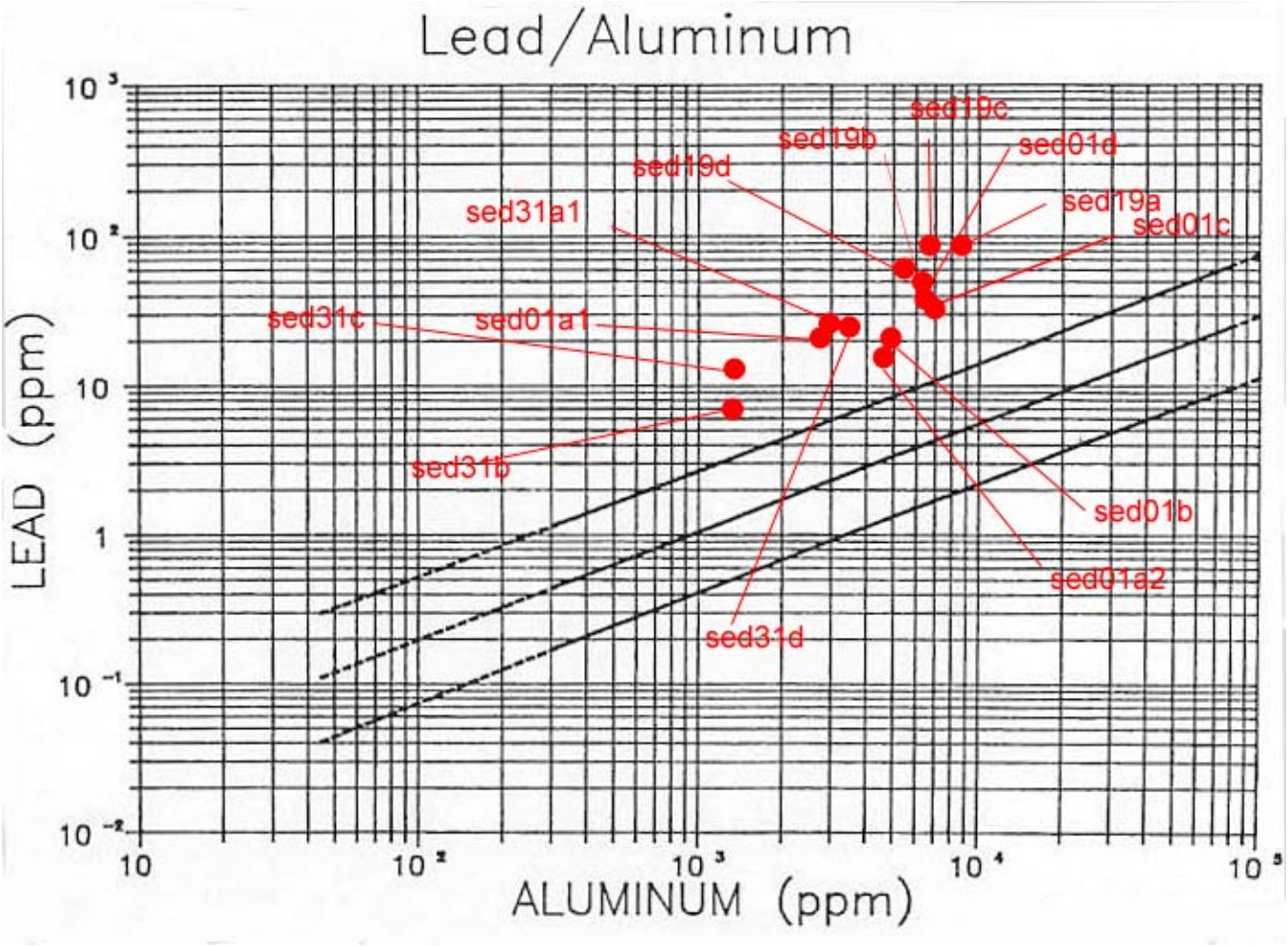
Chromium concentrations were below the detection limit of 1.0 mg/Kg in all other samples.

Attachment 14 – Central Lake Worth Lagoon Muck Sediment Monitoring,
Phase II-1b – Expanded Study,
Metals concentrations in relation to Aluminum



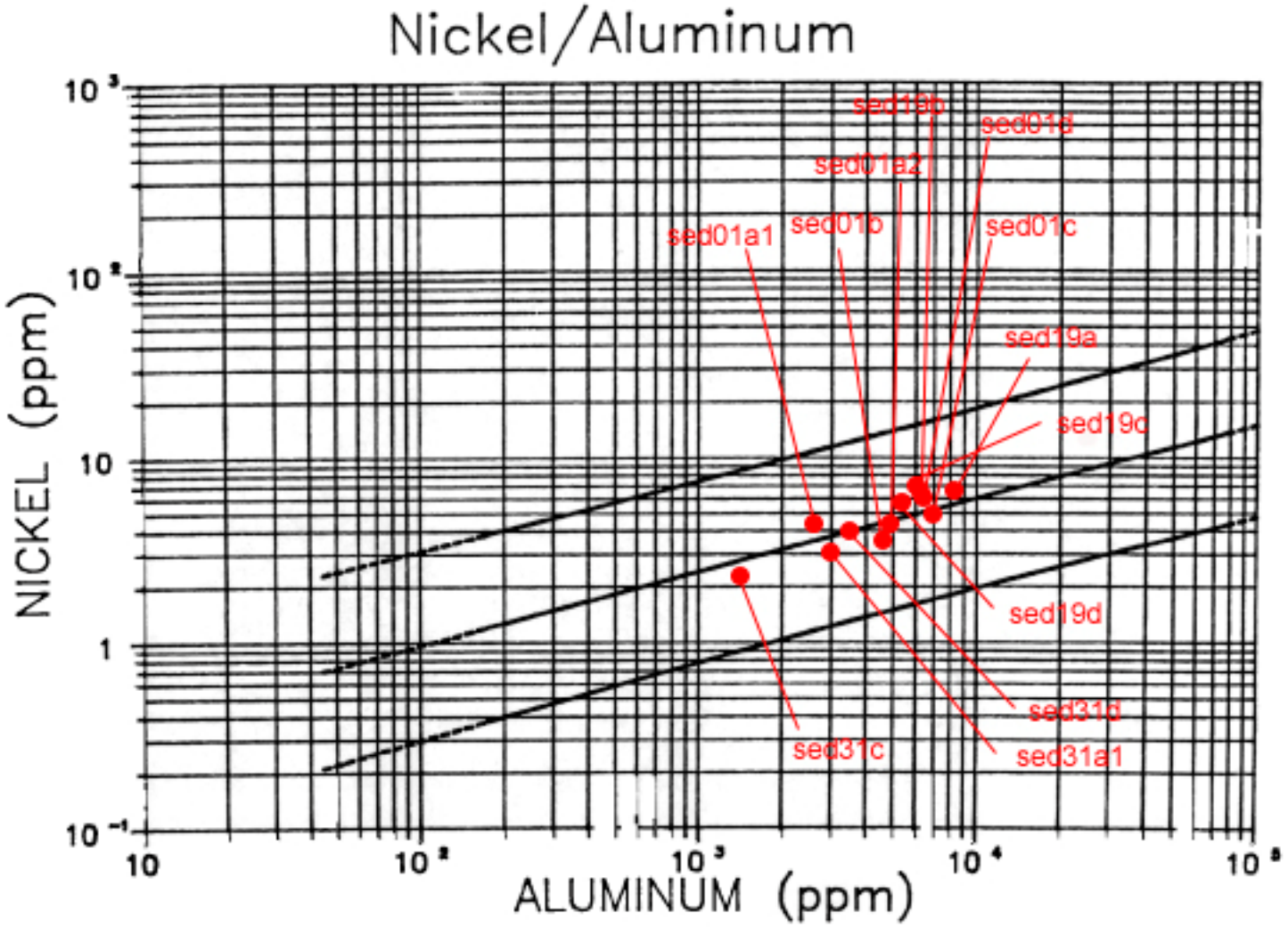
Copper concentrations were below the method detection limit (MDL) in samples sed01a2, sed01b, sed31a2, sed31b, and sed31c.

Attachment 14 – Central Lake Worth Lagoon Muck Sediment Monitoring,
Phase II-1b – Expanded Study,
Metals concentrations in relation to Aluminum



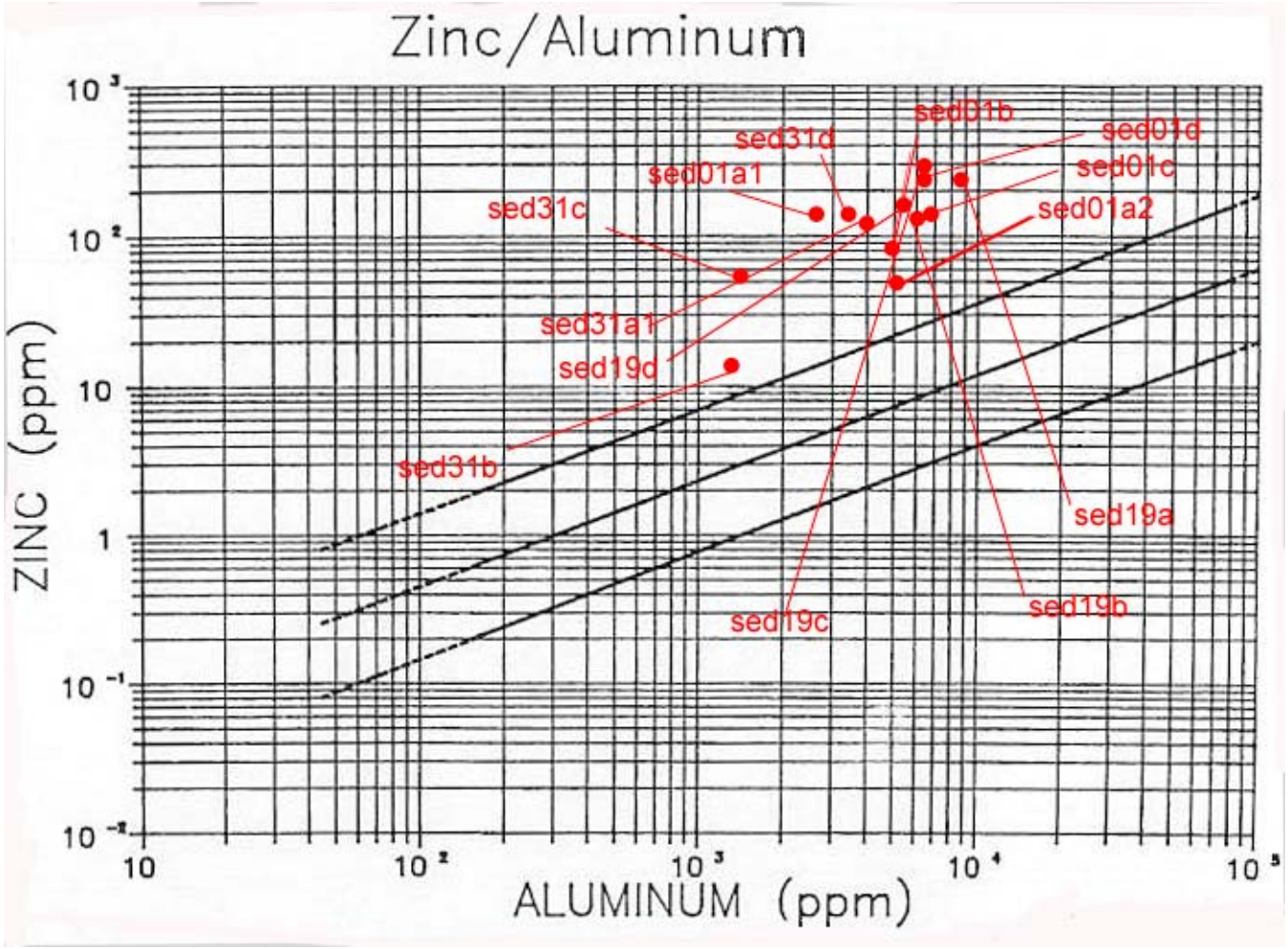
Lead concentration was below the method detection limit in sample sed31a2.

Attachment 14 – Central Lake Worth Lagoon Muck Sediment Monitoring,
Phase II-1b – Expanded Study,
Metals concentrations in relation to Aluminum



Nickel concentrations were below the detection limit of 1.0 mg/Kg in samples Sed01a2, and Sed01b.

Attachment 14 – Central Lake Worth Lagoon Muck Sediment Monitoring,
Phase II-1b – Expanded Study,
Metals concentrations in relation to Aluminum



Zinc concentration was below the method detection limit (MDL) in sample sed31a2.

Attachment 15 - Central Lake Worth Lagoon Muck Sediment Monitoring,
Phase II-1b - Expanded Study,
Accumulation Rates

Sample Site
Sed 01f

S=0.26

Site	Sediment Depth (cm)	% Dry Wt. (g)	Dry wt. Density (g/cm3)	YEAR	Sediment Accumulation Rate (cm/yr)	
1950*1	0-2	44.2	0.591	1963-2003	0.440	x
1950*2	2-4	44.9	0.606	1963-2003	0.436	x
1950*3	4-6	46.4	0.634	1963-2003	0.429	x
1950*4	6-8	48.3	0.676	1963-2003	0.420	
1950*5	8-10	54.9	0.823	1963	0.401	
1950*6	10-12	48.8	0.686	1957	0.389	
1950*7	12-14	43.2	0.572	1952	0.393	
1950*8	14-16	40.4	0.518	1948	0.402	
1950*9	16-18	41.2	0.533	1944	0.411	
1950*10	18-20	38.2	0.477	1940	0.420	
1950*11	20-22	43.3	0.574	1936	0.426	
1950*12	22-23	51.3	0.741	pre-1936	0.414	x
1950*13	23-25	63.0	1.03	pre-1936	0.406	x
1950*14	25-27	64.7	1.08	pre-1936	0.398	x
1950*15	27-28	64.6	1.07	pre-1936	0.385	x

x indicates samples considered to have background Pb210 levels or to be a mixed layer
S = average sedimentation rate in g/cm2/yr for entire core

Attachment 15 - Central Lake Worth Lagoon Muck Sediment Monitoring,
Phase II-1b - Expanded Study,
Accumulation Rates

Sample Site
Sed 31f

S=0.07

Site	Sediment Depth (cm)	% Dry Wt. (g)	Dry wt. Density (g/cm3)	YEAR	Sediment Accumulation Rate (cm/yr)	
1950*16	0-2	44.2	0.591	1984	0.114	
1950*17	2-4	47.0	0.648	1975	0.110	
1950*18	4-6	48.9	0.688	1955	0.106	
1950*19	6-8	56.6	0.864	1932	0.0995	
1950*20	8-10	55.6	0.839	1906	0.0940	
1950*21	10-12	52.5	0.768	1882	0.0919	
1950*22	12-14	45.4	0.615	1862	0.0926	
1950*23	14-16	40.9	0.528	1845	0.0953	
1950*24	16-18	36.2	0.442	1830	0.0990	
1950*25	18-20	38.1	0.476	1816	0.102	
1950*26	20-22	42.9	0.564	1801	0.104	
1950*27	22-24	74.2	1.36	pre-1801	0.100	x
1950*28	24-26	77.2	1.47	pre-1801	0.0919	x
1950*29	26-28	73.0	1.33	pre-1801	0.0861	x
1950*30	28-29	76.3	1.43	pre-1801	0.0803	x

x indicates samples considered to have background Pb210 levels or to be a mixed layer
S = average sedimentation rate in g/cm2/yr for entire core

Attachment 15 - Central Lake Worth Lagoon Muck Sediment Monitoring,
Phase II-1b - Expanded Study,
Accumulation Rates

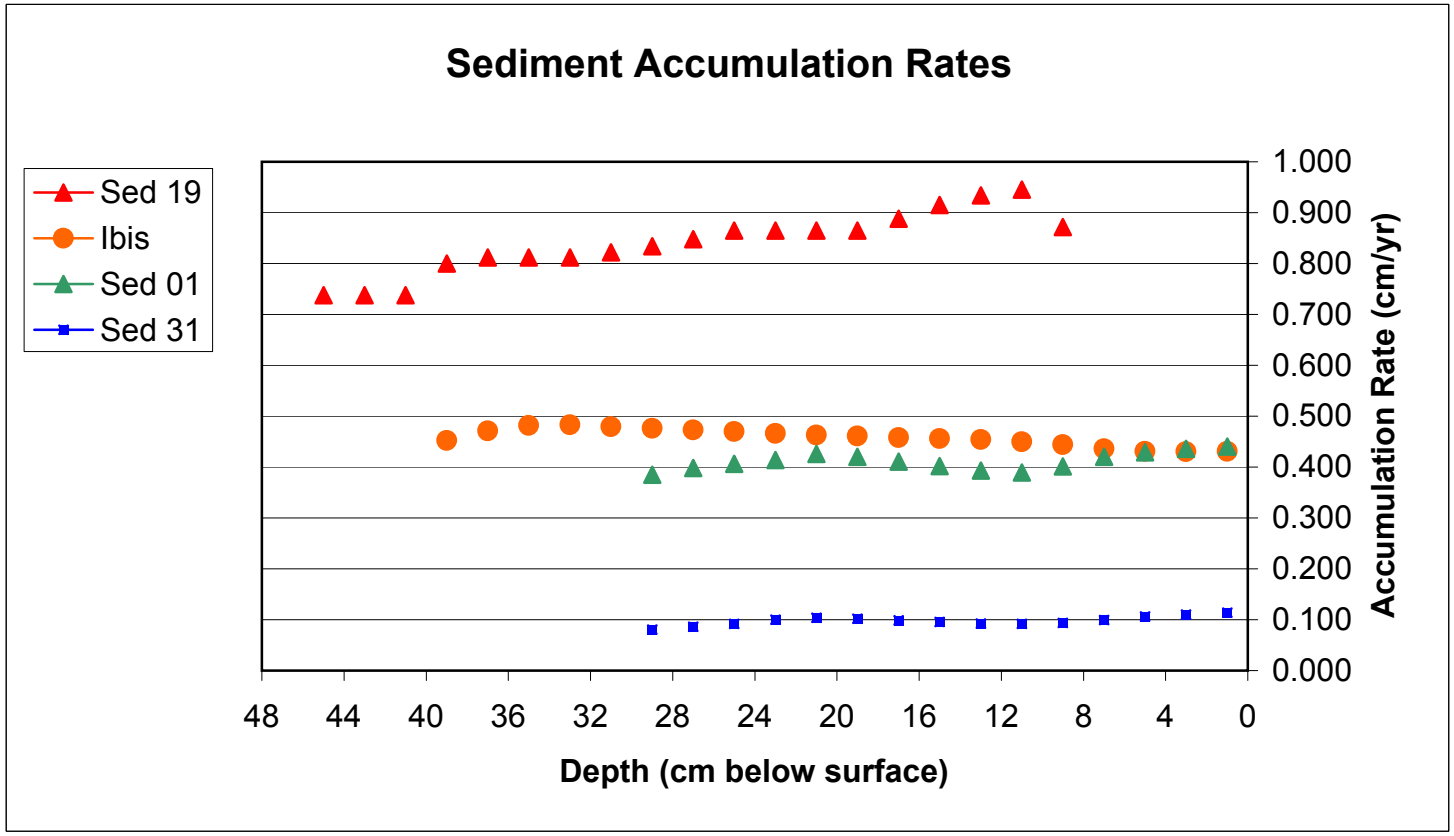
Sample Site
Sed 19f

S=0.23

Site	Sediment Depth (cm)	% Dry Wt. (g)	Dry wt. Density (g/cm3)	YEAR	Sediment Accumulation Rate (cm/yr)	
1950*51	0-2	28.0	0.310	1988-present	NA	x
1950*52	2-4	30.8	0.353	1988-present	NA	x
1950*53	4-6	31.1	0.358	1988-present	NA	x
1950*54	6-8	29.0	0.324	1988-present	NA	x
1950*55	8-10	27.3	0.299	1988-present	0.872	x
1950*56	10-12	27.7	0.305	1988-present	0.945	x
1950*57	12-14	29.3	0.330	1986	0.934	
1950*58	14-16	29.9	0.339	1983	0.915	
1950*59	16-18	33.3	0.394	1981	0.888	
1950*60	18-20	34.9	0.420	1978	0.865	
1950*61	20-22	34.9	0.420	1978	0.865	
1950*62	22-24	33.6	0.399	1978	0.865	
1950*63	24-26	35.7	0.433	1978	0.865	
1950*64	26-28	33.3	0.393	1975	0.848	
1950*65	28-30	36.5	0.447	1972	0.834	
1950*66	30-32	35.7	0.433	1969	0.822	
1950*67	32-34	40.3	0.516	1966	0.812	
1950*68	34-36	42.1	0.551	1966	0.812	
1950*69	36-38	40.5	0.520	1966	0.812	
1950*70	38-40	38.1	0.476	1963	0.8	
1950*71	40-42	30.6	0.350	Pre-1960	0.738	
1950*72	42-44	32.7	0.384	Pre-1960	0.738	
1950*73	44-46	35.7	0.434	Pre-1960	0.738	

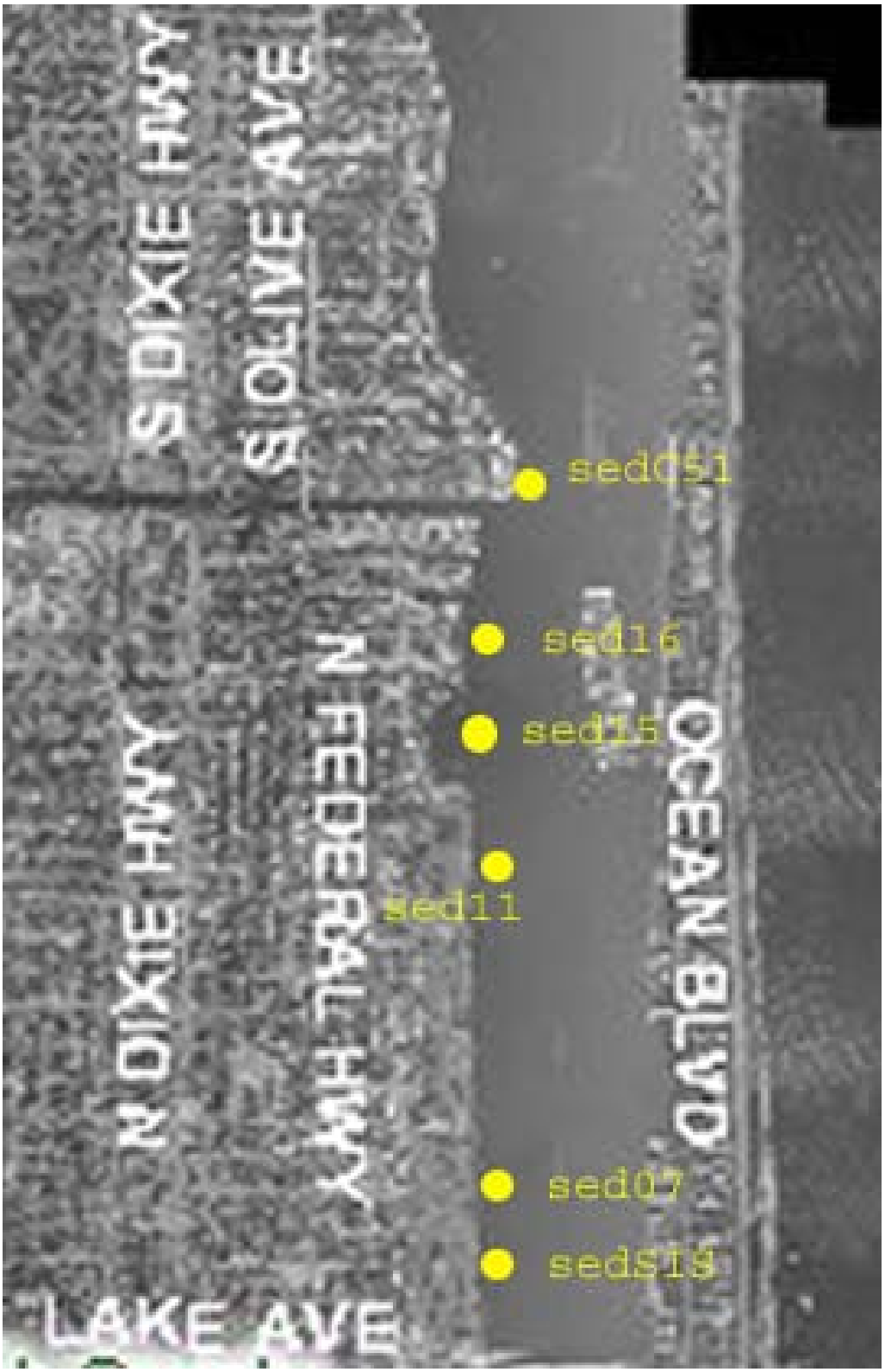
x indicates samples considered to have background Pb210 levels or to be a mixed layer
S = average sedimentation rate in g/cm2/yr for entire core

Attachment 16 - Central Lake Worth Lagoon Muck Sediment Monitoring,
Phase II-1a - Preliminary and Expanded Study,
Comparitive Sediment Accumulation Rates



Sediment cores were analyzed in 2 cm sections.
Core Sed19 had a high degree of mixing in the top 4 layers (top 8 cm) making accurate accumulation rate assessment impossible.

Attachment 17 – SFK Site Map



Samples collected by the Ship-for-Kids project, April and May 2003.

SUMMARY BY SUB-PROJECT TASK

TASK		WAP028	
		150,000.00	
Sub-Project 2.0			
Phase I - Muck Bathymetry			
M&E		5,110.00	
M&E		11,975.00	
Subtotal			17,085.00
Phase II - Sediment Evaluation			
Supplies		302.21	
STL		2,270.00	
STL		75.00	
SEA		568.00	
Batelle		5,425.52	
STL		4,630.50	
Subtotal			13,271.23
Sub-Project 3.0			
Seagrass 00/01			
ATM	#1	9,561.19	
	#2	25,335.16	
	#3	16,519.23	
	#4	1,707.38	
	#5	26,555.30	
	#6	3,900.84	
	Retainage	4,398.90	
Seagrass 02/03			
ATM	#1	24,252.00	
	#2	5,136.14	
	#3	2,277.63	
Subtotal			119,643.77
TOTAL		**150,000.00**	**150,000.00**
Balance		**0.00**	