**US Army Corps of Engineers**
Los Angeles District

# LOS ANGELES REGIONAL DREDGED MATERIAL MANAGEMENT PLAN PILOT STUDIES

## LOS ANGELES COUNTY, CALIFORNIA

## LONG-TERM EVALUATION OF AQUATIC CAPPING DISPOSAL ALTERNATIVE

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**September 2005**

## ABSTRACT

In early 2001, the Los Angeles District of the U.S. Army Corps of Engineers initiated the Los Angeles County Regional Dredge Material Management Plan Pilot Studies to evaluate the feasibility of four alternatives for treating and/or disposing of contaminated dredged sediments originating from within Los Angeles County. The four alternatives evaluated were cement stabilization, sediment washing, sediment blending, and aquatic capping.

For the aquatic capping study (the subject of this report), 105,000 $m^3$ of contaminated sediment were mechanically dredged from the Los Angeles River Estuary in the City of Long Beach and placed into an existing pit located in the inner harbor off the coast of Long Beach. The contaminated sediment, which contained elevated concentrations of metals and PAHs, was subsequently capped with a 1-m layer of clean sand. Water quality monitoring was conducted during all phases of construction to evaluate potential environmental impacts.

Following construction, the capped site was monitored annually for three years to evaluate long-term cap stability, containment/isolation of the contaminated sediments, and biological re-colonization of the cap surface. Three years of intensive monitoring has shown that the cap has maintained its structural integrity. There has been no measurable erosion of cap material or fissures visible in the cap surface; rather an accumulation of newly deposited material is now present suggesting a rapid depositional process is at work. Chemical containment has also been maintained. Elevated concentrations of contaminants have not been detected in overlying cap material or in the cap pore water at concentrations suggesting that contaminant migration is occurring. Biological re-colonization of the cap was rapid during the first two years of monitoring and maintained in Year 3.

The results of the three-year long-term monitoring study confirm the conclusions of the aquatic capping evaluation presented immediately following construction (USACE 2002). The use of aquatic capping within the Los Angeles Region appears to be a feasible alternative for cost-effective and environmentally protective long-term management of contaminated sediments.

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| | |
|---|---|
| BHNIP | Boston Harbor Navigation Improvement Project |
| BRI | Benthic Response Index |
| CAC | contained aquatic capping |
| CDF | confined disposal facilities |
| CERCLA | Comprehensive Environmental Response, Compensation, and Liability Act |
| CLDS | Central Long Island Sound Disposal Site |
| cm | centimeter(s) |
| $cm^3$ | cubic centimeter(s) |
| COP | California Ocean Plan |
| CSTF | Contaminated Sediments Task Force |
| CTD | conductivity depth meter |
| DDE | Dichlorodiphenyldichloroethylene |
| DDT | Dichlorodiphenyltrichloroethane |
| DGPS | Differential Global Positioning System |
| DMMP | Dredged Material Management Plan |
| DRET | Dredging Elutriate Test |
| ECB | USACE Environmental Chemistry Branch |
| EPA | U.S. Environmental Protection Agency |
| ER-L | Effects Range-Low |
| ER-M | Effects Range-Median |
| ETS | Environmental Tracing Systems |
| FFCPT | free-fall cone penetrometer test |
| GPS | Global Position System |
| ISC | In-situ Capping |
| km | kilometer(s) |
| $km^2$ | square kilometer(s) |
| LARE | Los Angeles River Estuary |
| LTMP | Long-term Monitoring Program |
| m | meter(s) |
| $m^2$ | square meter(s) |
| $m^3$ | cubic meter(s) |
| MLLW | Mean Lower Low Water |
| NEIBP | North Energy Island Borrow Pit |
| NEPA | National Environmental Policy Act |

| | |
|---|---|
| ppb | parts per billion = micro gram per liter (μg/L) = micro gram per kilogram (μg/Kg) |
| ppm | parts per million = milligram per liter (mg/L) = milligram per kilogram (mg/Kg) |
| ppt | parts per trillion = nanogram per liter (ng/L) = nanogram per kilogram (ng/Kg) |
| PAHs | polycyclic aromatic hydrocarbons |
| PCBs | polychlorinated biphenyls |
| PSEP | Puget Sound Estuary Program |
| PSU | Practical Salinity Unit |
| QAPP | Quality Assurance Project Plan |
| RPDs | redox potential depths |
| RWQCB | Regional Water Quality Control Board |
| SBLT | Sequential Batch Leaching Test |
| SEIBP | South Energy Island Borrow Pit |
| SET | Standard Elutriate Test |
| SPI | Sediment Profile Imaging |
| TOC | total organic carbon |
| TS | total solids |
| TSS | total suspended solids |
| USACE | U.S. Army Corps of Engineers |
| VST | Vane Shear Tests |
| $yd^3$ | cubic yard(s) |

# EXECUTIVE SUMMARY

In early 2001, the Los Angeles District of the U.S. Army Corps of Engineers (USACE) initiated the Los Angeles County Regional Dredged Material Management Plan Pilot Studies (DMMP Pilot Studies) to evaluate the feasibility for treating and/or disposing of contaminated dredge sediments within the Los Angeles County Region. The four alternatives evaluated in this series of laboratory bench-scale and field pilot studies were identified in the Los Angeles County Regional DMMP 905(b) Reconnaissance Report (USACE 2000) and included cement stabilization, sediment washing, sediment blending, and aquatic capping.

For the aquatic capping study (the subject of this report), 105,000 cubic meters ($m^3$) of contaminated sediment were mechanically dredged from the mouth of the Los Angeles River Estuary (LARE) in the City of Long Beach. The dredge material was transported via split hull barge to a large, pre-existing, borrow pit located in Long Beach Harbor where it was deposited into a demonstration cell termed the North Energy Island Borrow Pit (NEIBP). After allowing the approximately 2.5-meter (m) layer of LARE material to consolidate in the disposal pit for three months, clean cap material was dredged from a second borrow pit, the South Energy Island Borrow Pit (SEIBP), and used to cover the LARE material with a 1.0- to 1.5-m layer cap.

USACE (2002) evaluated the results of the four pilot studies (including aquatic capping) against a series of evaluation criteria that included implementability, short and long-term effectiveness, environmental impacts and costs. The evaluation of long-term effectiveness continued after the completion of the original evaluation report by conducting three years of field monitoring. This report reviews the results of that monitoring effort, referred to as the Aquatic Capping Site Long-Term Monitoring Project, which began 10 months following the completion of capping operations in the NEIBP aquatic capping site.

Surveys were conducted in October 2002 (Year 1), August of 2003 (Year 2), and July 2004 (Year 3) and included video and bathymetric surveys of the cap surface, physical and chemical analysis of sediment cores taken through the cap to the underlying LARE material, and the evaluation of the benthic infaunal community in and around the NEIBP capping site. The key elements addressed by the monitoring program included:

- Determining if the NEIBP cap site had maintained its physical integrity, ensuring that fractures, erosion or deposition had not compromised the cap's ability to sequester underlying contaminants.
- Determining if burrowing organisms (bioturbators) were having a measurable impact on the integrity of the cap.
- Determining if, during the three years following capping operations, contaminants were migrating through the cap at an unacceptable rate.
- Evaluating the rate of re-colonization of the cap site by benthic infauna and comparing this community to the surrounding harbor habitats.

Bathymetry results from all three surveys of the NEIBP cap site indicated that both the aquatic capping engineering goals of the project had been met and that the integrity of the cap has been maintained. The surface of the cap site was found to range from -14 to -15 m Mean Lower Low Water (MLLW) with a cap thickness ranging from 1.0 to 2.5 m. Comparison of surface isopachs between post-construction and the end of the three-year monitoring effort showed that the surface of the cap has not significantly eroded, fractured or subsided. Video transects across the surface of the cap, however, do show some small areas of minor (less than 6 inches) subsidence.

No evidence of chemical migration through the cap from the LARE dredge material was measured during the three years of monitoring. Visually, the core samples revealed a clear boundary layer between the LARE and cap materials. The LARE material was fine-grained, black in color, and smelled of petroleum, and the cap material was dark grey, odorless and sandy. Of the 15 metals and total polycyclic aromatic hydrocarbons (PAHs) analyzed for in the bulk sediment samples from the cap layer, none were detected at concentrations approaching those observed in the LARE material. Total PAH concentrations were considered to be the best marker for the LARE material as they were orders of magnitude lower in the cap material. Further, in Year 2, core layer samples taken from 3 centimeters (cm) above the LARE material showed no evidence of either metals or PAH migration into the cap. Sediment pore water analyzed from the cap layer confirmed the bulk sediment chemistry results because elevated chemical concentrations were not detected in the pore water.

Re-colonization of the NEIBP cap surface by benthic infauna proceeded at a rapid pace during the ten-month period between Year 1 and Year 2. Although total abundances of infauna at the cap site decreased slightly during this time, the numbers of species, diversity, and dominance (number of species comprising 75% of the abundance) had each increased dramatically. During this period, almost twice as many species were collected, diversity was 30 percent greater and the dominance had tripled. This contrasted with areas in the non-capped portions of the borrow pit and harbor where numbers of species declined slightly, while diversity and dominance remained relatively unchanged between Years 1 and 2. At all cap site locations, Benthic Response Index (BRI) values (a measure of benthic community health) indicated that the infauna community on the cap site was similar or approaching the values measured in communities found at other, uncontaminated, harbor sites in southern California.

Between Years 1 and 2, the infauna population on the cap site began shifting toward a taxa composition that was similar to that found on the surrounding harbor sediments. Infaunal dominance on the cap site increased from 5 in Year 1 to 20 in Year 2, which included 8 species common to the harbor sites. In Year 1 at the cap site, 64 percent of the most abundant species found there have been classified as "characteristically" found in sediments with low to moderate organic enrichment. This can sometimes be an indication of the transitional nature of a benthic community after disturbance of the substrate. By Year 2 there was a 50 percent reduction in this type of species indicating the community was moving away from conditions more characteristic of disturbed substrates.

Immediately following capping, re-colonization occurred at a rapid pace on the cap surface. Two mechanisms could have been involved. First, the composition of the infauna populations at the cap site and SEIBP were very similar in terms of abundance, numbers of species, dominance, BRI and shared species. Therefore, inoculation of species from the SEIBP to the cap site during the capping process may have been a source of potential re-colonization. Second, in light of the numbers of dominant species shared by the cap site, SEIBP and harbor sites, recruitment of infauna from the nearby harbor sediments to the cap site was probably occurring.

Of the eight organisms collected in the survey that were potential bioturbators, only the ghost shrimp (*Neotrypaea* sp.) has been reported to burrow to depths that could potentially penetrate the LARE material. Members of this group have been reported to create burrows up to 90 cm in depth. During Years 1 and 2, a total of 46 individuals were collected from the survey area, with the majority found at cap site stations. The impact of these burrowers is difficult to assess. The individuals collected during both Year 1 and 2 were small (< 3 cm) and were most likely incapable of burrowing to great depths. However, the depth of penetration of the van Veen grab used to collect the infauna samples did not exceed 15 cm. Thus, it is possible that the larger, adult ghost shrimp could have been present at depths below 15 cm, avoiding capture altogether. To evaluate the potential for adult ghost shrimp residing on the cap surface, a very large macro grab sample was taken from an area adjacent to the pit (to prevent disruption of the cap) and from the SEIBP and screened for invertebrates. This exercise confirmed that adult ghost shrimp may occur on the cap surface.

Bioturbators were not observed in the sediment core samples during the long-term monitoring, but during video surveys across the cap surface, burrow mounds were clearly evident. Sediment samples from these mounds in Year 1 revealed elevated concentrations of several target metals, and, in several cases, above those measured in the LARE material. Further investigations in Year 2 included the collection of both burrow mound and surface samples from the cap site and surrounding harbor sediments. These samples showed that while, in some cases, metals concentrations were elevated in the burrow mounds, they were likewise elevated in surface sediment samples without burrows. It appeared that the elevated metals concentrations in the burrow and surface sediment samples were the result of deposition from the surrounding harbor. Similarly, PAH concentrations were over an order of magnitude higher in the LARE than in the burrow mounds, suggesting that sediments from burrow mounds did not originate from the LARE material.

The results of the three-year long-term monitoring study appears to confirm the conclusions presented in the previous evaluation report (USACE 2002). Short-term effectiveness, implementability, and environmental impact objectives were all met during construction, and long-term effectiveness appears successful as the predicted long-term modeling results for chemical migration, bioturbation, and cap erosion have been verified. Although not previously included in the cost estimates for the aquatic capping evaluation, estimated construction-related and long-term monitoring resulted in approximately \$0.70/$m^3$ in additional per unit costs for this alternative (from \$26.90/$m^3$ to \$27.60/$m^3$).

# 1 INTRODUCTION

The U.S. Army Corps of Engineers (USACE), Los Angeles District is currently preparing a Regional Dredged Material Management Plan (DMMP) to evaluate several alternatives for disposal and reuse of clean and contaminated dredged sediments within the Los Angeles Region. Some of the alternatives (cement stabilization, sediment washing, sediment blending and aquatic capping) were selected for field and laboratory pilot studies to gather additional information to aid in the evaluation.

The DMMP Aquatic Capping Pilot Study was completed in 2001, at which time a long-term monitoring program (LTMP) was immediately initiated to monitor the long-term effectiveness of the procedure for isolating contaminated sediments. This document presents the results of this three year, post-construction, monitoring project for the cap site and re-visits the feasibility evaluation previously conducted when the cap was first completed (USACE 2002).

Specifically, the objectives of this document include the following:

- Provide a review of the Aquatic Capping Pilot Study construction process and monitoring data;
- Describe the pre-, during- and post-construction monitoring activities for the cap site;
- Review the objectives and results of the LTMP;
- Review the evaluation criteria previously used for the aquatic capping alternative;
- Evaluate the results of the LTMP relative to the goals, objectives, and costs originally developed for the aquatic capping alternative;
- Review costs associated with aquatic capping field monitoring; and
- Compare the results of the Los Angeles Aquatic Capping Pilot Study to other capping programs.

## 1.1 Aquatic Capping Pilot Study History

The coastline of Los Angeles County (Figure 1-1) includes two of the nation's largest commercial ports and several major marina complexes and small-vessel harbors.


**Figure 1-1**
Los Angeles County Region

Maintenance of authorized depths in existing channels and berthing areas and expansion and modernization of ports, harbors, and marinas, requires periodic dredging in virtually all of these facilities. Some of the sediments dredged from these harbors contain elevated levels of heavy metals, pesticides, and other contaminants. In most cases, the concentrations of these contaminants do not approach hazardous levels, but are sufficiently high to be designated unsuitable for unconfined ocean disposal per U.S. Environmental Protection Agency (EPA) guidelines. Current options for disposal of contaminated sediments include placement in a confined disposal facility, capping, or disposal in an upland landfill site. Additionally, some ports and harbors have considered other management techniques, such as treatment and beneficial re-use.

In 1998, to resolve re-occurring regulatory issues inhibiting necessary dredging by the ports and the USACE, and to address public health concerns about dredging, placing, and capping contaminated sediments, the regulatory and resource agencies, ports, environmental groups, and other interested parties in the region agreed to establish the Contaminated Sediments Task Force (CSTF). The CSTF was chartered with developing a long-term management strategy for managing contaminated sediments. Concurrently, the USACE initiated a Regional Dredged Material Management Plan to provide the regulatory framework for managing both clean and contaminated sediment originating from federal projects within the Los Angeles Basin. In 2001, the USACE initiated the Los Angeles County Regional Dredged Material Management Plan Pilot Studies (DMMP Pilot Studies) to evaluate the feasibility of managing contaminated sediments in the Los Angeles County Region through various disposal or treatment options. The purpose of these studies was to provide technical information to support both the DMMP and CSTF Strategy documents.

As part of the DMMP Pilot Studies, the USACE completed four pilot/bench scale studies for the treatment and/or disposal of contaminated sediments, and the alternatives selected for these studies were identified in the Los Angeles County Regional Dredged Material Management Plan 905(b) Reconnaissance Report (USACE 2000). The four alternatives the USACE selected to be evaluated in the pilot studies include the following management technologies:

- Aquatic Capping – dredging and placing contaminated sediments into a pre-existing inner harbor borrow pit and capping with clean sediments (field pilot study).

- Cement-Based Stabilization – dredging and re-handling contaminated sediments to an upland staging area where the dredged sediments were mixed with cement-based products to produce structurally stable soil material (bench scale and field pilot studies).
- Sediment Washing – dredging and re-handling contaminated sediments to an upland staging area where the dredged sediments were washed to remove chlorides to allow disposal of the material at an upland landfill (bench scale pilot study).
- Sediment Blending – evaluating the feasibility of dredging and re-handling contaminated sediments to an upland staging area where the contaminated dredged sediments were blended with other materials to enhance the structural stability of the material for use as near shore fill (literature review only).

## 1.2 Aquatic Capping Technology

Aquatic capping technology refers to placing a covering or cap over contaminated sediments to isolate the material from the marine environment. The cap may be constructed of clean sediments, sand, gravel, or may involve a more complex design with geotextiles, liners, and multiple layers. Two methods of capping dredged sediment are: (1) *in-situ* capping, in which a mound of dredged sediment is capped, and (2) contained aquatic capping (CAC), in which dredged sediment is placed in a depression or where other provisions for lateral confinement are made prior to placing the cap (Figure 1-2). CAC sites have been used extensively for management of dredged material in New York, Boston, Portland, Holland, Belgium, Hong Kong, New Bedford, MA, and Puget Sound for over 20 years. For example, the Boston Harbor Navigation Improvement Project (BHNIP) involved deepening of the main ship channel and three tributary channels to the Inner Harbor, and associated berthing areas. Lack of an upland disposal site and resource agency denial of permission to place and cap the contaminated sediments at an open water site resulted in the decision to use in-channel CAC cells for placement of contaminated material.

CAC sites differ from confined disposal facilities (CDFs) in that they are sub-aqueous in nature. CDFs are diked structures that have been built for the disposal of dredged material and may be an upland or in-water structure. The USACE has constructed 44 CDFs around the Great Lakes since the late 1960s for the disposal of contaminated dredged materials from navigation projects. Although, CDFs have been successfully constructed regionally throughout the Ports of Los Angeles and Long Beach harbor complex (e.g., Pier 400), but are becoming a less visible alternative as port development has significantly slowed in recent years.

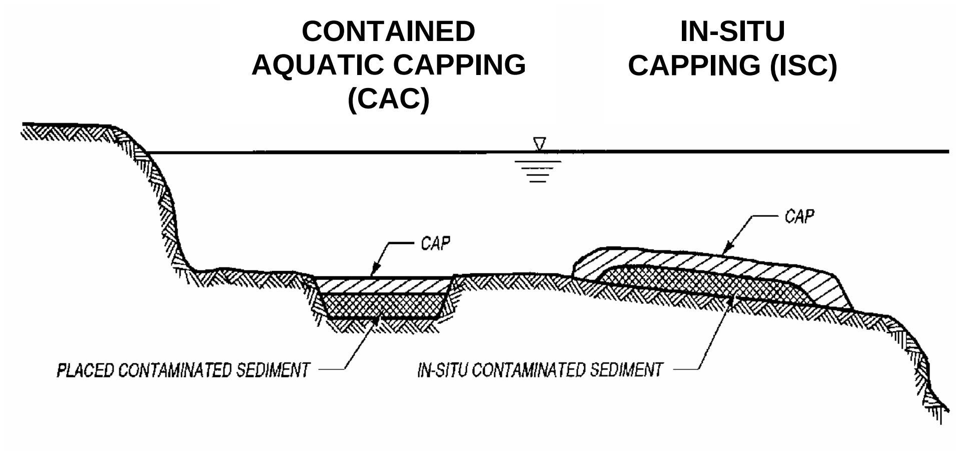


**Figure 1-2**
**Aquatic Capping Schematic**

The Aquatic Capping Pilot Project was a dredged sediment capping project constructed in a depression that essentially created a CAC facility. For CAC of contaminated dredged sediments, sediments are removed from their *in-situ* location, and site evaluation issues are framed around the selection of an acceptable site for placement of the contaminated sediment and capping with clean sediment.

Many processes influence the fate of contaminants in bottom sediments. For example:

- Contaminants can be transported into the overlying water column by advective and diffusive mechanisms.
- Mixing and reworking of the upper layer of contaminated sediment by benthic organisms continually exposes contaminated sediment to the sediment-water interface where it can be released to the water column (Reible et al. 1993).
- Bioaccumulation of contaminants by benthic organisms in direct contact with contaminated sediments may result in movement of contaminants into the food chain.
- Sediment resuspension, caused by natural and man-made erosive forces, can greatly increase the exposure of contaminants to the water column and result in the transportation of large quantities of sediment contaminants downstream (Brannon et al. 1985).

The basic criterion for a successful aquatic capping project is simply that the cap be successfully designed, placed, and maintained in order to minimize contaminant migration pathways and eliminate scenarios where ecological or human health risks may occur.

## 2 OVERVIEW OF AQUATIC CAPPING PILOT STUDY

The aquatic capping alternative was identified in the 905(b) Reconnaissance Study (USACE 2000) as a dredge disposal option that required further study for use in the Los Angeles Region. Therefore, sediment to be dredged and placed in the cap site was to be similar in nature to the sediments found in this region. This material is characterized as unsuitable for open ocean disposal because it contains elevated chemical concentrations above commonly-used sediment quality guidelines (EPA/USACE Ocean Disposal Regulations), but is not hazardous.

The aquatic capping option required several initial steps to be taken in advance of furthering the study:

- Identifying a suitable location for the cap site and suitable source for capping material;
- Modeling and predicting implementability, short- and long-term effectiveness, and potential environmental impacts;
- Completing the dredging and placement design, cap site design, and capping design;
- Pre-construction sampling of the dredged material, cap material, and cap site;
- Completing an Environmental Assessment to comply with the National Environmental Policy Act (NEPA);
- Obtaining California Coastal Commission Consistency Determination; and
- Obtaining Los Angeles Regional Water Quality Control Board (RWQCB) Water Quality Certification.

After the environmental reviews were completed and the background data collected, the cap site was constructed and the LTMP was implemented. The duration of the LTMP was determined by the CSTF to be annually for the first three years, and is expected to be repeated (in some form) at subsequent intervals thereafter (e.g., 5, 10, 15). The Los Angeles RWQCB provided funding for the first two years of monitoring, and the USACE provided funding for the third year of monitoring.

The LTMP was developed to gather sufficient information to determine the overall long-term effectiveness of the technology using a regional case study. The information gathered will be used to evaluate CAC as a sediment management alternative for contaminated sediments in the Los Angeles Region.

## 2.1 Goals and Objectives of Aquatic Capping

The aquatic capping pilot field study was undertaken with the following overall objectives in mind:

- Demonstrate that cap sites can be an economically feasible alternative for managing contaminated sediments in the Los Angeles Region.
- Collect evidence to determine if the cap can:
  - Be effectively constructed without causing significant environmental impacts, and
  - Maintain its physical integrity and be effective in containing the contaminants.
- Demonstrate that aquatic capping is technically feasible (constructable) alternative for managing contaminated sediments in the Los Angeles Region.

While some of these objectives can be evaluated during the construction process, ultimate success or failure of the cap site will be determined by monitoring the cap site to determine whether the cap is working as designed to minimize contaminant exposure to the marine environment. Success or failure of the cap site would be determined if chemicals migrated through the cap at a rate that resulted in significant contamination of the surface sediment or overlying water. The remainder of this document first reviews the results of the cap site construction process and then discusses the results of the LTMP to assess the cap's effectiveness.

## 2.2 Construction Overview

Prior to construction, a location for the cap site and suitable fill and capping materials were identified. The cap site is an "L" shaped depression, one of a group of depressions created in the 1960s by excavating material in the Long Beach Harbor for constructing a series of islands to house oil and gas production facilities. The test cell was termed the North Energy Island Borrow Pit (NEIBP). Contaminated sediments proposed for fill were located at the mouth of the Los Angeles River Estuary (LARE) in the City of Long Beach. Clean capping material was located in a second borrow pit, termed the South Energy Island Borrow Pit (SEIBP). Figure 2-1 shows the location of the NEIBP, LARE, and SEIBP, and the features surrounding the estuary. The estuary connects the Los Angeles River channel with Los Angeles/Long Beach Harbor. Section 2.2.2 more fully describes the construction activities.

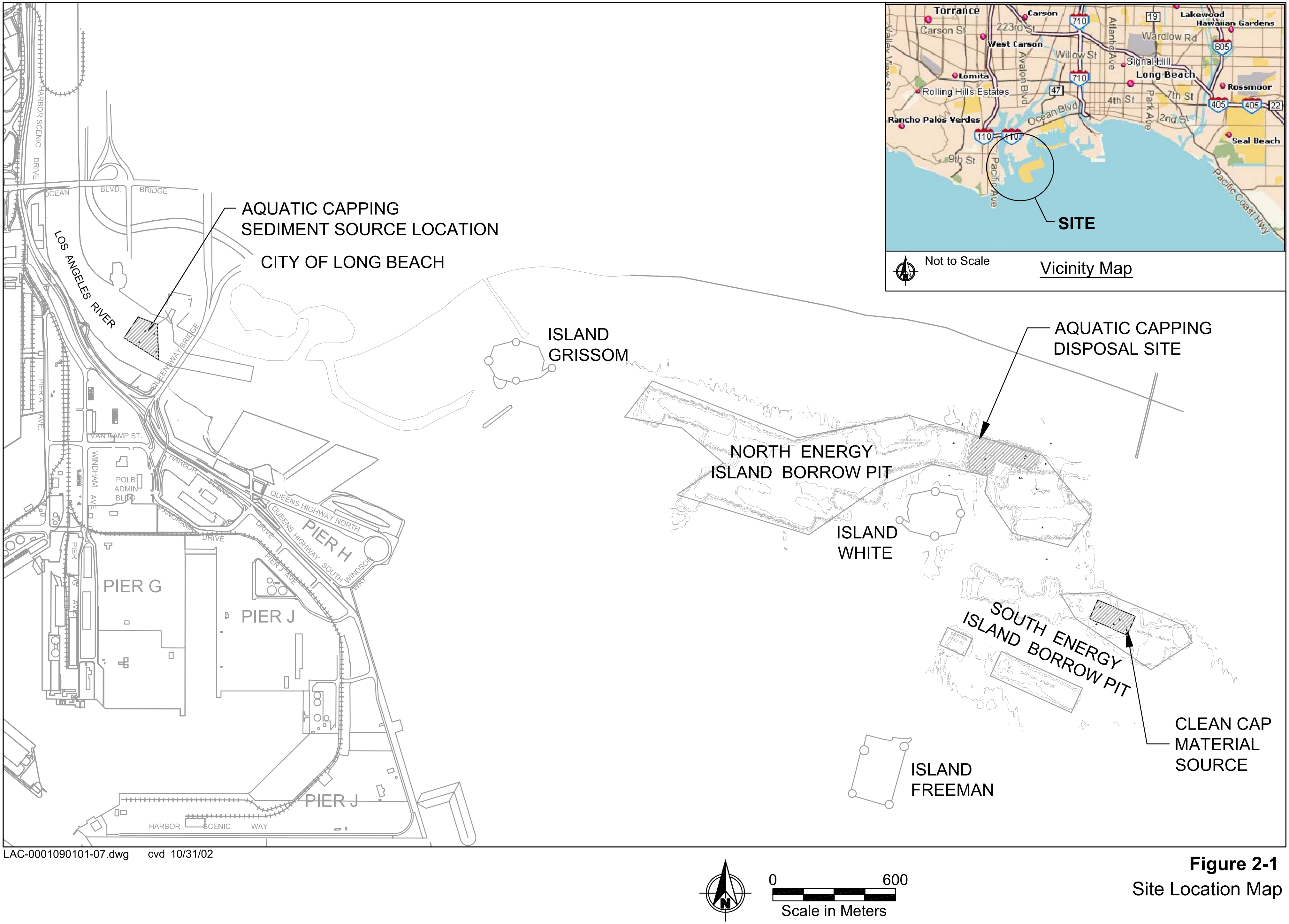


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**Figure 2-1**
Site Location Map

Approximately 105,000 cubic meters ($m^3$) of contaminated sediment was mechanically dredged from the LARE. The dredge plan was fairly simple with a dredge elevation of -6.0 meters (m) Mean Lower Low Water (MLLW) with 4 horizontal to 1 vertical (4H:1V) cut slopes. This represents a dredge cut thickness of 0 to 6.5 m across the site. The contaminated sediment was transported by barge approximately 3.2 kilometers (km) to the cap site location within the NEIBP and placed into the NEIBP by split hull barges. The cap site within the NEIBP represented a small portion of the entire NEIBP area (Figure 2-1). The NEIBP is a relatively steep walled depression. The top of the pit wall is approximately -8 m MLLW, and the deepest point in the pit is approximately -20 m MLLW. The total capacity of the NEIBP is approximately 5.5 million $m^3$.

### 2.2.1 Pre-Construction Site Characterization

Sediment samples were collected at the LARE dredge site, the NEIBP location, and the SEIBP location to characterize the material for each phase of the study. Sediment core samples were collected through the LARE dredge prism to measure chemical concentrations, determine leaching potential, and to measure physical properties to assist in the required dredge procedures and cap design. Sediment core samples were collected at the NEIBP to measure pre-existing chemical concentrations and physical characteristics of the sediment to be used in the cap design. Sediment core samples were also taken at the SEIBP site to measure chemical concentrations in the target cap material to ensure that it was non-contaminated. Physical tests were also conducted to assist in cap design.

#### 2.2.1.1 Los Angles River Estuary

Sediment cores samples revealed that sediments in the LARE area consisted of a top layer of sand about 1 to 3 m thick. Underlying that were finer sediments ranging from silty sands to clay down to about 4 to 5 m below mud line. In some locations, another layer of sand existed below this level and its ultimate lower extent was unknown. Some metals, pesticides, and polycyclic aromatic hydrocarbons (PAHs) were found at concentrations above Effects Range-Low (ER-L) toxicity guidelines (Long et al. 1995) in both the coarser surface sediments and finer subsurface sediments. Some chemicals in the subsurface sediments also exceeded the Effects

Range-Median (ER-M) for several pesticides and zinc. Figure 2-2 shows the locations of the chemical and physical cores taken at the LARE dredge site.

Contaminant mobility through the LARE material was tested using a Sequential Batch Leaching Test (SBLT), a Dredging Elutriate Test (DRET), and a Standard Elutriate Test (SET). The tests detected only metals and organotins in the leachate samples, which indicated that the chemicals present in the LARE sediments would not be highly mobile during dredging operations, contaminated sediment placement, or in the long term at the disposal site.

#### 2.2.1.2 North Energy Island Borrow Pit

Sediment cores collected in the NEIBP foundation sediment were analyzed for bulk chemistry and physical properties. Several metals detected in the sediments exceeded ER-L levels which suggests the material may be toxic to some benthic organisms. Organotins were detected in every NEIBP sample, with dibutyltin detected the most frequently and tributyltin detected in two samples.

Physical characteristics of the foundation sediment were characterized using gravity cores, free-fall cone penetrometer tests (FFCPTs), and vane shear tests (VSTs). The tests indicated that there was a minimum of 3 m of very soft to soft organic silty clay with occasional layers of silty clay at the surface. Figure 2-3 shows the location of the cores (NEIBP3 through NEIBP6) where chemistry analyses were completed.

#### 2.2.1.3 South Energy Island Borrow Pit

The SEIBP was the source of capping sediment for the cap site in the NEIBP. The SEIBP was previously the source of borrow sediments for the building of the various energy islands in the area. After the pit was created, a portion of it was filled with clean sediments from the Port of Long Beach Main Channel Deepening project conducted in December 1998 through April 1999.

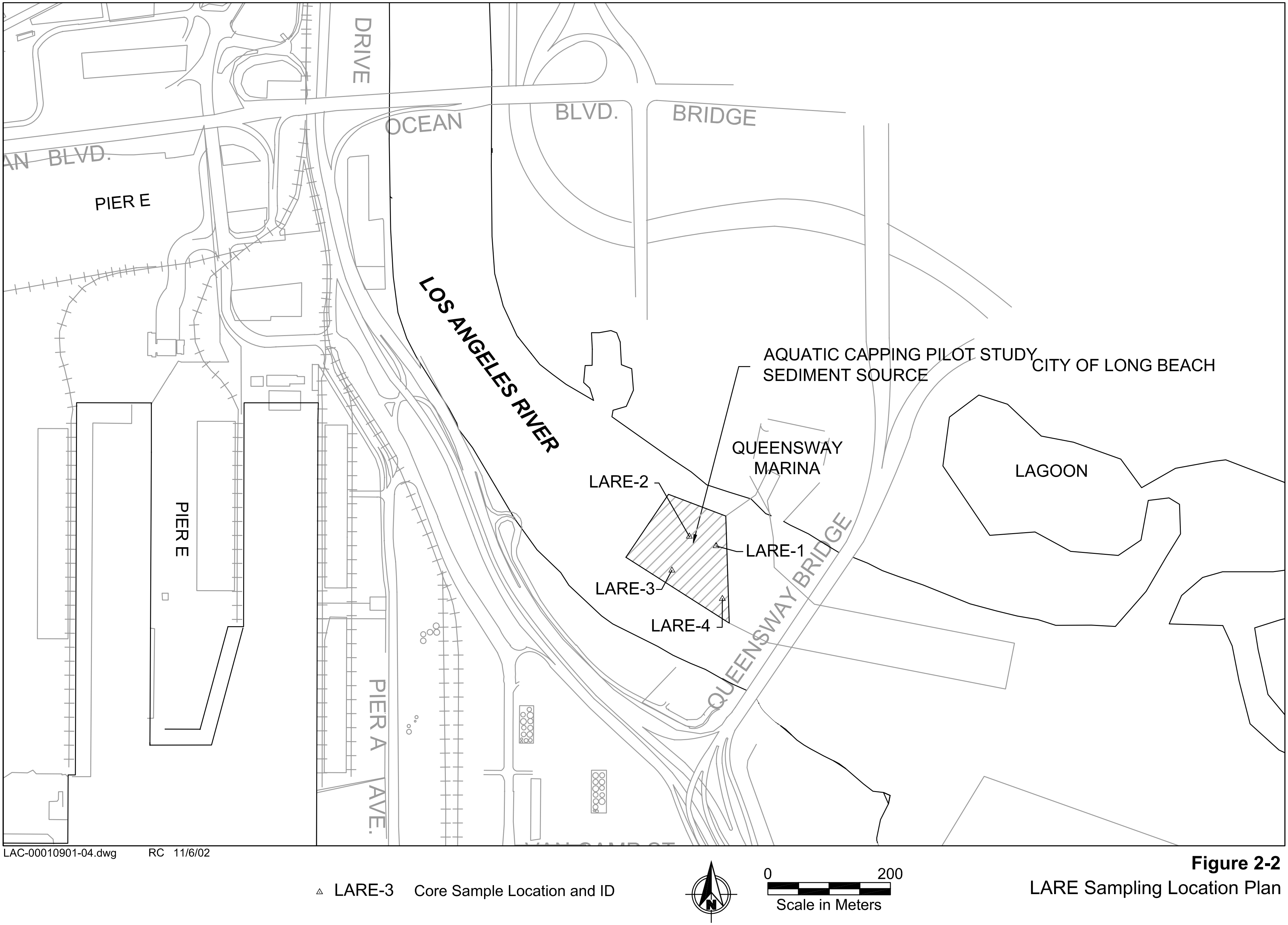
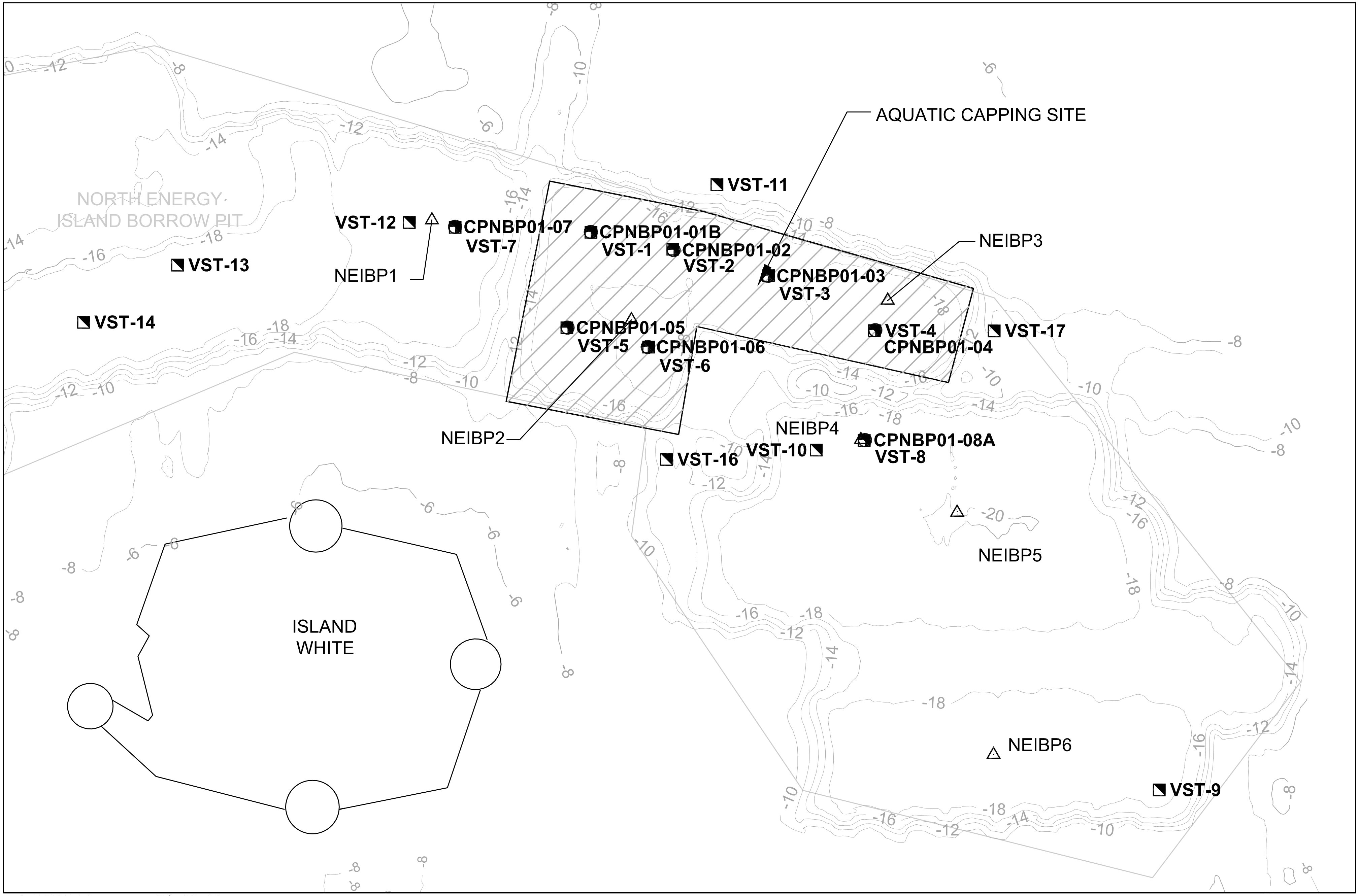



**Figure 2-2**
LARE Sampling Location Plan

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| | |
|---|---|
| △ NEIBP4 | Core Sample Location and ID |
| **CPNBP01-08A** | Cone Penetrometer Test Location and ID |
| **VST-8** | Vane Shear Test Location and ID |

0 100
Scale in Meters

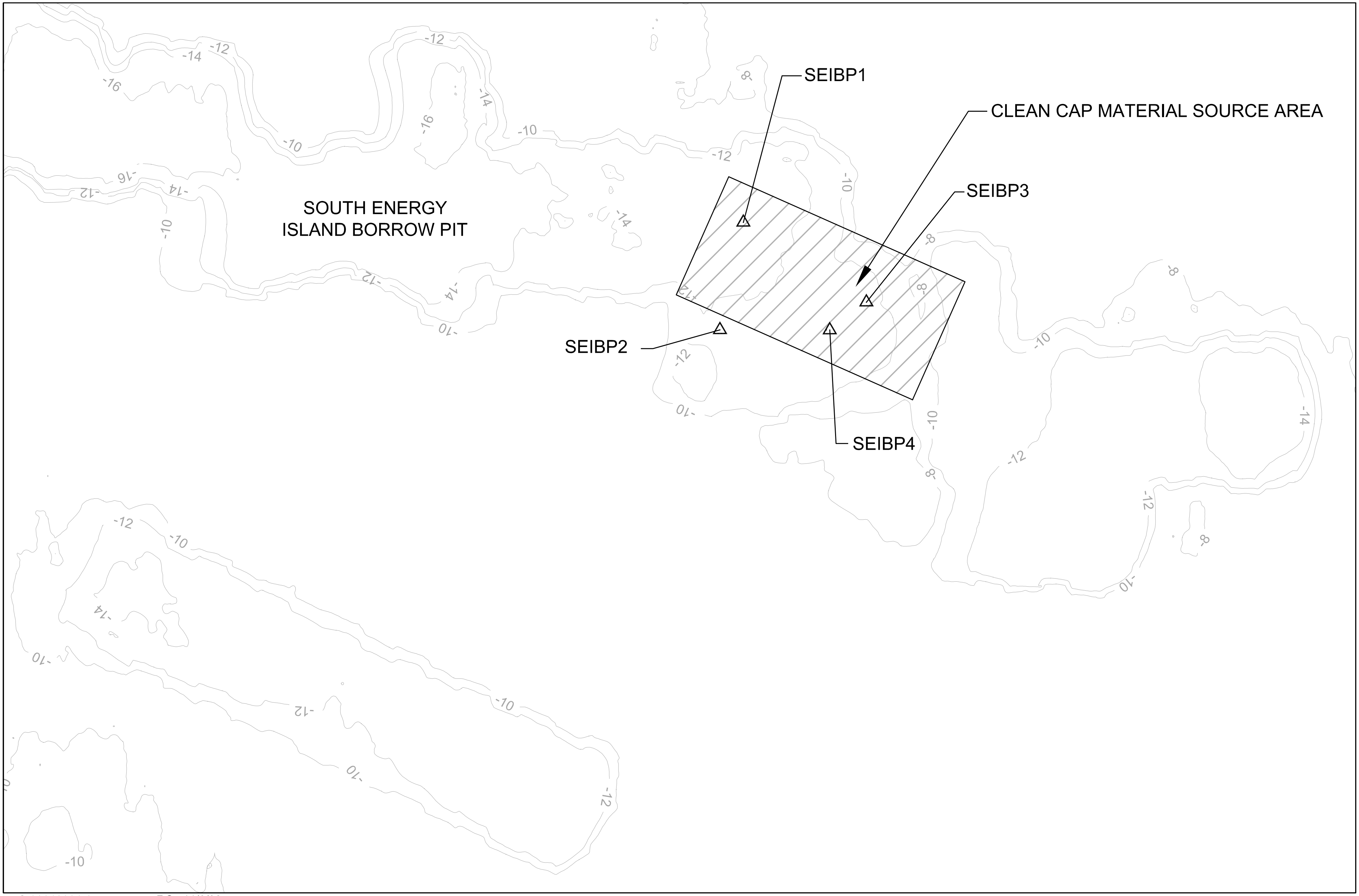
**Figure 2-3**
NEIBP Sampling Location Plan

Four cores from the SEIBP were taken to determine sediment chemistry, absorption characteristics, and physical properties of the cap sediment. All metals in the SEIBP cores were below the ER-L levels. Organotins were detected in every SEIBP sample, with tetrabutyltin detected the most frequently and tributyltin detected in one sample. The general stratigraphy observed in the four cores was silty sand with areas of slightly silty and very silty gradations.

Absorption characteristics of the SEIBP material were modeled to estimate the retardation factor of SEIBP cap material on the movement of three major categories of chemicals present in the LARE sediments: PAHs, pesticides, and metals. These chemicals provided examples of the range of retardation factors likely found chemicals of high concern in the LARE sediments. These factors indicate that the cap sediment would provide an acceptable level of absorptive capacity. These retardation factors were also used to calculate the rate of diffusive flux through the cap to further quantify the acceptability of the cap sediment. That evaluation predicted that 1 m of SEIBP sand would provide sufficient absorptive capacity to chemically isolate LARE sediments. Figure 2-4 shows the location of the cores advanced for chemical and physical testing at the SEIBP site. The sampling revealed that the SEIBP sediments used as cap sediment are mostly clean sand (e.g., 75 to 92% sand).

### 2.2.2 Construction Activities

A derrick barge equipped with a 12 $m^3$ rehandling bucket was used for dredging roughly 5,500 $m^3$ per day. Typical dredge cycle times ranged from 50 to 70 seconds with net production rates of 220 $m^3$ per hour (predictive modeling conducted prior to construction assumed a 3 to 6 $m^3$ bucket and cycle times ranging from 45 to 90 seconds). Approximately 1,000 $m^3$ of dredged sediment was loaded into 1,200 $m^3$ split hull barges for placement, and a total of 103 placement events were completed. Initially placement events were conducted by holding the barge stationary during placement. Post-placement bathymetry indicated that this placement method was possibly causing bearing failures of the soft NEIBP foundation sediment, and subsequently the barges were pulled at a rate of 0 to 5 knots during placement. The final surface ultimately did not vary more than 1 m between the high and low spots on the cap, and the final surface elevation at the NEIBP site after disposal was relatively even.

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△ SEIBP4 Core Sample Location and ID

0 100
Scale in Meters

**Figure 2-4**
SEIBP Sampling Location Plan

The LARE sediment consolidated 113 days between the last placement event and the first cap placement. The cap construction consisted of mechanically dredging cap sediment from the SEIBP and controlled placement at the NEIBP. The contractor used the DB Vulcan equipped with an 11 $m^3$ re-handling bucket to dredge approximately 68,850 $m^3$ of sediment at roughly 3,820 $m^3$ per day. A total of 69 placement events were completed over a total of 18 days. Typical dredge cycle times ranged from 50 to 70 seconds.

To compare potential differences in controlling the amount of cap mixing by various placement methods, a second cap placement method was used over a small portion of the NEIBP test cell. For this test, the cap material was re-handled from the transport barge using a clamshell bucket and placed in a controlled manner by releasing the material just under the water surface using a sweeping motion. Approximately 8,500 $m^3$ were placed using this method.

Split hull barges were loaded with approximately 1,000 $m^3$ and sediments were directly discharged over the NEIBP. Once at the NEIBP, the split hull barges were only partially opened, and the tug would push the barge over the entire length of the NEIBP, spreading a thin layer of cap material with each pass. Approximately 110 $m^3$ was released from the barge with each pass, and the tug would make 8 to 9 passes with each barge to discharge the 1,000 $m^3$ load. During disposal, tugs traveled at speeds between 0 to 5 knots. Net production rates for barge placement were approximately 1,240 $m^3$/hr.

### 2.2.3 Construction Monitoring

Monitoring was conducted prior to, during, and immediately after dredging, disposal, and capping of the LARE sediments. Water column samples were taken to provide data to evaluate the technical ability to control the loss of contaminated sediments during dredging, placement, and capping operations, and to result in isolated sediments immediately after construction. Four basic types of monitoring were conducted including:

- Field monitoring of continuous depth profiles (temperature, salinity, dissolved oxygen, light transmission, and pH)
- Total suspended solids (TSS) sampling
- Metals
- Organic compound sampling

#### *2.2.3.1 Los Angles River Estuary Dredging*

Monitoring was conducted during the dredging of the LARE material for research purposes which consisted of water column samples for chemical contamination and suspended solids. Samples were collected at stations fixed on transects extending up-current and down-current from dredging and placement operations. Figure 2-5 shows the location of the water quality monitoring stations during construction.

Continuous Depth Profiles

In general, temperature, salinity (reported in Practical Salinity Units [PSUs]), dissolved oxygen, and pH measurements did not vary greatly between stations downstream of the dredging operation and background sites (see Table 2-1, Figure 2-6). Temperature and salinity were generally comparable between downstream and background stations. Dissolved oxygen was measurably lower on average at downstream stations. Overall light transmissivity was similar at background stations and downstream of the dredge operations. There were some measurable differences between downstream and background pH values on some occasions.

**Table 2-1**
**Average Profile Results – Comparison to Background Conditions**

| | Temperature (°C) | Salinity (PSU) | DO (mg/L) | Transmissivity (%) | pH |
|---|---|---|---|---|---|
| Average All Downstream | 19.11 | 32.63 | 6.44 | 25.43 | 8.18 |
| Average 25 m from Dredge | 19.14 | 32.63 | 5.78 | 23.74 | 8.23 |
| Average Background | 18.95 | 31.98 | 8.13 | 20.84 | 8.34 |

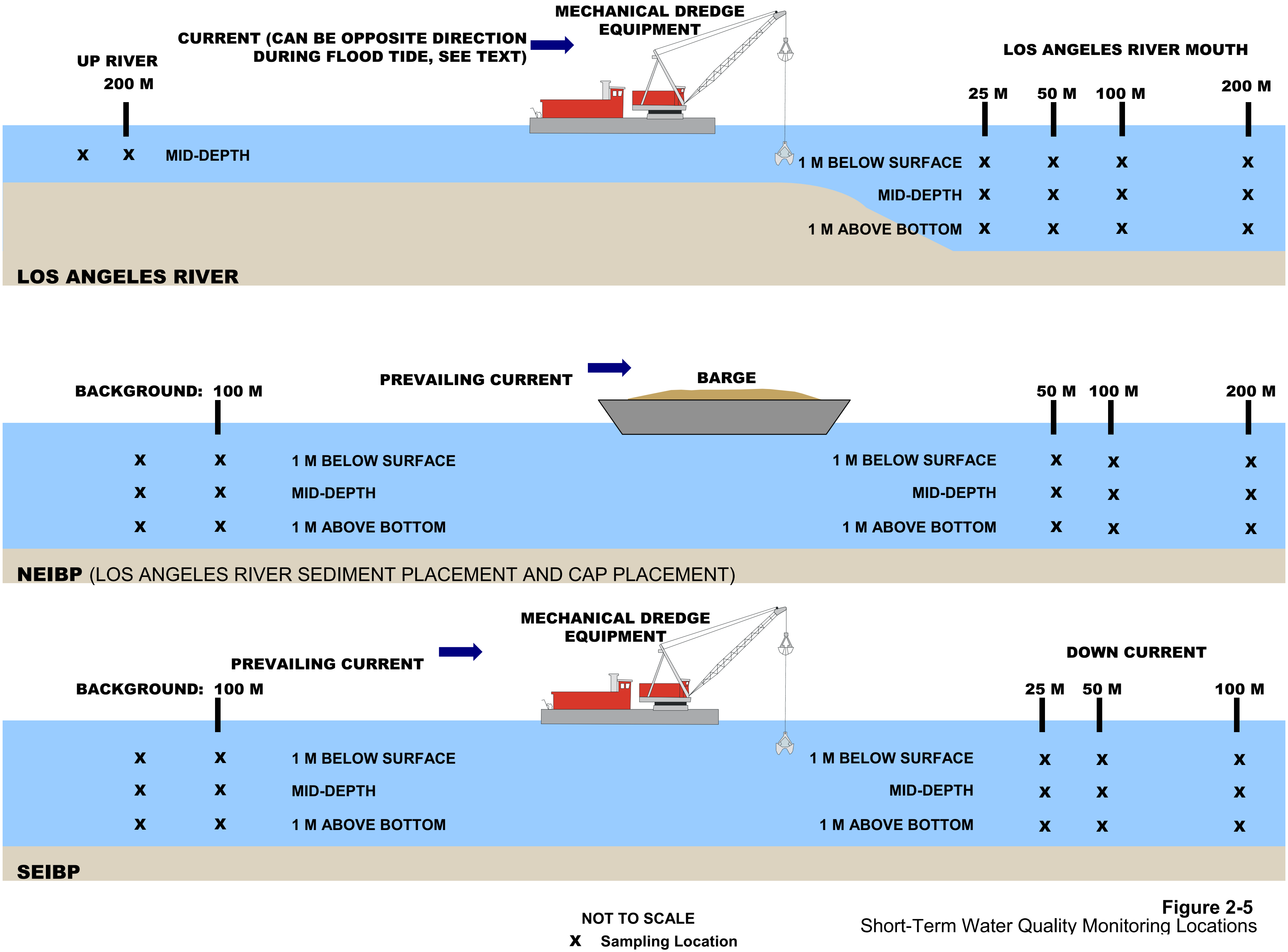



**Figure 2-5**
Short-Term Water Quality Monitoring Locations

Total Suspended Solids

TSS samples were collected from 1 m below the surface, mid-depth, and 1 m above the bottom for the downstream locations and only mid-depth for the upstream (background) locations. The average TSS concentrations observed were approximately 8 mg/L at background stations and ranged between 10 and 14 milligrams per liter (mg/L) at downstream stations (see Table 2-2). Overall, many downstream measurements were within the range typically observed for background conditions, however, in several cases downstream TSS concentrations were higher than the typical background range observed.

**Table 2-2**
**Total Suspended Sediment Concentrations (mg/L) Observed Near NEIBP Operations**
**(Downstream by Distance and Background)**

| | 25 m | 50 m | 100 m | 200 m | Background |
|---|---|---|---|---|---|
| Minimum | 3.0 | 1.0 | 3.0 | 2.0 | 2.0 |
| Average | 14.4 | 10.4 | 9.7 | 10.3 | 7.9 |
| Maximum | 48.0 | 20.0 | 22.0 | 28.0 | 14.0 |

It appears likely that the riverine conditions at the LARE site create relatively high TSS levels (for this area) and low water clarity that make it difficult to observe any related effects from the dredge operation. Consequently, it would be expected that changes in TSS (and transmissivity as an indicator of the level of TSS) observed downstream of the dredging operation do not represent substantial environmental impacts when considered in the context of the normal variability in river conditions.

Trace metals

Metals results are summarized in Table 2-3. Total and dissolved arsenic, cadmium, copper, lead, selenium, silver, and zinc were all either undetected or detected at concentrations below either background conditions and/or COP daily maximum water quality objectives. Chromium, mercury, and nickel were detected in a few cases at concentrations above background conditions and COP daily maximum objectives.

**Table 2-3**
**Comparison of Dissolved and Total Metals Data (μg/L) from All Downstream LARE Samples to Rinsate, Background, and California Ocean Plan Objectives**

| | Arsenic | Cadmium | Chromium | Copper | Lead | Mercury | Nickel | Selenium | Silver | Zinc |
|---|---|---|---|---|---|---|---|---|---|---|
| **Downstream LARE Data** | | | | | | | | | | |
| Minimum | 0.5 | 0.5 | 0.5 | 0.3 | 0.3 | 0.10 | 2 | 0.5 | 0.3 | 6 |
| Average | 0.8 | 0.5 | 18 | 5 | 0.4 | 0.23 | 26 | 0.5 | 0.3 | 11 |
| Maximum | 1.3 | 0.5 | 28 | 20 | 1.8 | 1.70 | 84 | 0.5 | 1.5 | 17 |
| Percent of Samples Exceeding[1] | 0% | 0% | 29% | 0% | 0% | 8% | 13% | 0% | 0% | 0% |
| **Rinsate and Background Data** | | | | | | | | | | |
| Rinsate Maximum | 0.5 | 0.5 | 3 | 2 | 0.3 | 0.54 | 1 | 0.5 | 0.3 | 10 |
| Background Maximum | 1.4 | 0.5 | 23 | 45 | 3.1 | 0.38 | 75 | 0.5 | 2.0 | 22 |
| **California Ocean Plan Objectives** | | | | | | | | | | |
| 6-Month Median Objective | 8 | 1 | 2 | 3 | 2.0 | 0.04 | 5 | 15 | 0.7 | 20 |
| Daily Maximum | 32 | 4 | 8 | 12 | 8.0 | 0.16 | 20 | 60 | 2.8 | 80 |
| Instantaneous Maximum | 80 | 10 | 20 | 30 | 20.0 | 0.40 | 50 | 150 | 7.0 | 200 |

1. Percent of samples with concentrations exceeding both the lowest California Ocean Plan Objective, Rinsate Maximum, and Background Maximum.

Downstream values in bold exceed the lowest California Ocean Plan Objective, Rinsate Maximum, and Background Maximum; and Rinsate and Background values in bold exceed at least one California Ocean Plan Objective.

Organic compounds

Water samples were collected within one of three depth strata (1 m below the surface, mid-depth, or 1 m above the bottom), whichever had the lowest light transmissivity (the exception being upstream sites at LARE where only the mid-depth stratum was sampled). Samples were analyzed for selected PAHs, pesticides, and polychlorinated biphenyls (PCBs). No sample had concentrations above the detection limits of the analysis method. Detection limits achieved were generally at or below those normally achievable by commercial laboratories using standard methods.

#### *2.2.3.2 Disposal of LARE Material at NEIBP*

Sampling events were dependent upon the disposal of the dredged LARE sediment. Sampling occurred at 10 and 30 minutes following complete release of the dredged sediments from the split hull barge. Five locations were sampled during each sampling event: three stations were located at 50, 100, and 200 m downstream from the point of disposal and two stations were located upstream from the disposal point at 100 m and 300 m (background). Current direction was measured using doppler sonar just prior to the disposal to establish the most likely direction of the turbidity plume, which was then used to determine sampling locations following dredged sediment disposal. Figure 2-5 shows the location of the water quality monitoring stations during construction.

Continuous Depth Profiles

In general, temperature, salinity, and pH did not vary greatly between downstream and background stations, particularly when average results are compared (see Table 2-4). Because there appeared to be measurable differences between background conditions and downstream conditions for dissolved oxygen, light transmissivity, and pH, the results for these parameters at downstream stations were compared to background stations for each monitoring event. Comparisons were made across the same water depths only (i.e., 1 m deep results at background were compared to 1 m deep results at downstream stations). The results of these comparisons are summarized in Table 2-5.

**Table 2-4**
**Average Downstream Profile Results – Dredge Sediment Placement at NEIBP, Comparison to Background**

| Location/Event | Temperature (°C) | Salinity (PSU) | DO (mg/L) | Transmissivity (%) | pH |
|---|---|---|---|---|---|
| Average 50 m 10 min | 17.59 | 33.40 | 6.73 | 32.04 | 8.27 |
| Average 100 m 10 min | 17.55 | 33.42 | 6.89 | 36.65 | 8.24 |
| Average 200 m 10 min | 17.57 | 33.41 | 6.68 | 44.26 | 8.37 |
| Average 50 m 30 min | 17.63 | 33.39 | 6.85 | 32.61 | 8.23 |
| Average 100 m 30 min | 17.55 | 33.39 | 7.08 | 36.57 | 8.24 |
| Average 200 m 30 min | 17.72 | 33.38 | 6.46 | 41.73 | 8.31 |
| Average Background | 17.62 | 33.25 | 9.02 | 46.94 | 8.14 |

**Table 2-5**
**Differences between Downstream and Background Conditions Observed at NEIBP Water Quality Monitoring Stations for Dissolved Oxygen, Light Transmissivity, and pH**

| | DO (mg/L) | Transmissivity (%) | pH |
|---|---|---|---|
| Minimum | -10.41 | -72.86 | -1.57 |
| Average | -1.64 | -3.52 | -0.03 |
| Maximum | 4.01 | 69.17 | 3.67 |

The average difference in light transmission between background and downstream conditions was about -3.5 percent (i.e., the downstream condition was about 3.5% absolute less light transmission). Light transmission at downstream stations exceeded the criteria of 30 percent less than background about 19 percent of the time at 50 m from the operation but only 2 percent of the time 200 m from the operation. For pH, downstream pH exceeded the COP criteria of not more than 0.2 pH unit change from background most of the time. Exceedances were less likely at greater distances from the dredge.

<u>Total Suspended Solids</u>

Table 2-6 summarizes TSS results by distance from the NEIBP placement operation. Notably, the highest TSS concentration of 117 mg/L was observed at a background station. Based on average TSS concentrations, there was a reduction in TSS concentrations with increasing distance from the placement operation. At 200 m, the average concentration was not distinguishable from the average background concentration.

**Table 2-6**
**Total Suspended Sediment Concentrations (mg/L) Observed Near NEIBP Operations (Downstream by Distance and Background)**

| | 50 m | 100 m | 200 m | Background |
|---|---|---|---|---|
| Minimum | 0.5 | 0.5 | 0.5 | 0.5 |
| Average | 20.3 | 15.8 | 5.5 | 9.6 |
| Maximum | 83.0 | 99.0 | 26.0 | 117.0 |

<u>Trace metals</u>

Dissolved metals were measured from samples collected at the NEIBP site during each of the six discrete sampling events to produce a total of 45 samples. During three of the six sampling events, 15 total metals samples were also collected. Total and dissolved metal concentrations were determined for ten selected metals (see Table 2-7). Water samples were collected within one of three depth strata (1 m below the surface, mid depth, or 1 m above the bottom), whichever had the lowest light transmissivity. Table 2-7 summarizes metals results. No metal was detected at concentrations above both background and COP criteria concentrations. In several cases, including for cadmium, chromium, copper, lead, mercury, nickel, silver, and zinc, background concentrations were observed that were well in excess of California Ocean Plan (COP) instantaneous maximum criteria. This would indicate that background variations in metals concentrations in this part of the Los Angeles/Long Beach Harbor are well in excess of any total or dissolved metals that might be liberated during the disposal process.

**Table 2-7**
**Comparison of Dissolved and Total Metals Data (μg/L) from All Downstream NEIBP Samples to Rinsate, Background, and California Ocean Plan Objectives**

| | Arsenic | Cadmium | Chromium | Copper | Lead | Mercury | Nickel | Selenium | Silver | Zinc |
|---|---|---|---|---|---|---|---|---|---|---|
| **Downstream NEIBP Data** | | | | | | | | | | |
| Minimum | 0.5 | 0.5 | 9.3 | 2.3 | 0.3 | 0.1 | 3.3 | 0.5 | 0.3 | 2.5 |
| Average | 1.0 | 0.5 | 18.5 | 5.5 | 0.6 | 0.3 | 27.3 | 0.5 | 0.3 | 9.4 |
| Maximum | 1.6 | 0.5 | 56.0 | 18.0 | 7.7 | 1.9 | 85.0 | 0.5 | 0.3 | 42.0 |
| Percent of Samples Exceeding[1] | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 0% |
| **Rinsate and Background Data** | | | | | | | | | | |
| Rinsate Maximum | 0.5 | 0.5 | 3.0 | 2.1 | 0.3 | 0.54 | 0.5 | 0.5 | 0.3 | 10.0 |
| Background Maximum | 2.0 | 370 | 660 | 540 | 440 | 1.9 | 810 | 0.5 | 370 | 380 |
| **California Ocean Plan Objectives** | | | | | | | | | | |
| 6-Month Median Objective | 8 | 1 | 2 | 3 | 2.0 | 0.04 | 5 | 15 | 0.7 | 20 |
| Daily Maximum | 32 | 4 | 8 | 12 | 8.0 | 0.16 | 20 | 60 | 2.8 | 80 |
| Instantaneous Maximum | 80 | 10 | 20 | 30 | 20.0 | 0.40 | 50 | 150 | 7.0 | 200 |

1. Percent of samples with concentrations exceeding both the lowest California Ocean Plan Objective, Rinsate Maximum, and Background Maximum.

Downstream values in bold exceed the lowest California Ocean Plan Objective, Rinsate Maximum, and Background Maximum; and Rinsate and Background values in bold exceed at least one California Ocean Plan Objective.

<u>Organic compounds</u>

Water samples were collected within one of three depth strata (1 m below the surface, mid-depth, or 1 m above the bottom), whichever had the lowest light transmissivity. Samples were analyzed for selected PAHs, pesticides, and PCBs. All concentrations were below the detection limits of the analysis method. Detection limits achieved were generally at or below those normally achievable by commercial laboratories using standard methods. Some COP criteria for organic chemicals in water are well below levels normally achievable by most laboratories. The project detection limits for organic compounds were compared to minimum levels recommended by the COP, and generally, these minimum levels were met with the exception of some pesticides.

After placement of the LARE material within the NEIBP, surface sediment samples and sediment profile imaging (SPI) camera shots were collected around the edges of the pit to monitor for sediment losses during disposal. Surface sediment grab samples were also collected from the surface of the LARE material to monitor for re-settlement of fine-grained material on the surface.

#### *2.2.3.3 SEIBP Dredging*

Three downstream water quality monitoring stations were located at 25, 50, and 100 m from the point of dredging. An upstream station was located at 200 m and a background station that was at 300 m from the point of dredging. Figure 2-5 shows the location of the water quality monitoring stations during dredging of the SEIBP and placement on the NEIBP.

<u>Continuous Depth Profiles</u>

Profile results during dredging were similar to those found during disposal of LARE sediment at the NEIBP with little downstream variation observed in temperature or salinity (see Table 2-8, Figure 2-6). On average, dissolved oxygen was slightly depressed downstream on SEIBP cap dredging operations, but the magnitude of these changes was very small in comparison to those seen at LARE dredging and NEIBP sediment disposal operations.

**Table 2-8**
**Average Downstream Profile Results – Cap Sediment Dredging at SEIBP, Comparison to Background**

| Distance | Temperature (°C) | Salinity (PSU) | DO (mg/L) | Transmissivity (%) | pH |
|---|---|---|---|---|---|
| 25 m | 14.06 | 33.23 | 8.71 | 27.50 | 7.91 |
| 50 m | 14.06 | 33.24 | 8.80 | 28.46 | 7.91 |
| 100 m | 14.08 | 33.24 | 8.93 | 33.57 | 7.91 |
| Background | 13.88 | 33.10 | 9.21 | 35.34 | 8.88 |

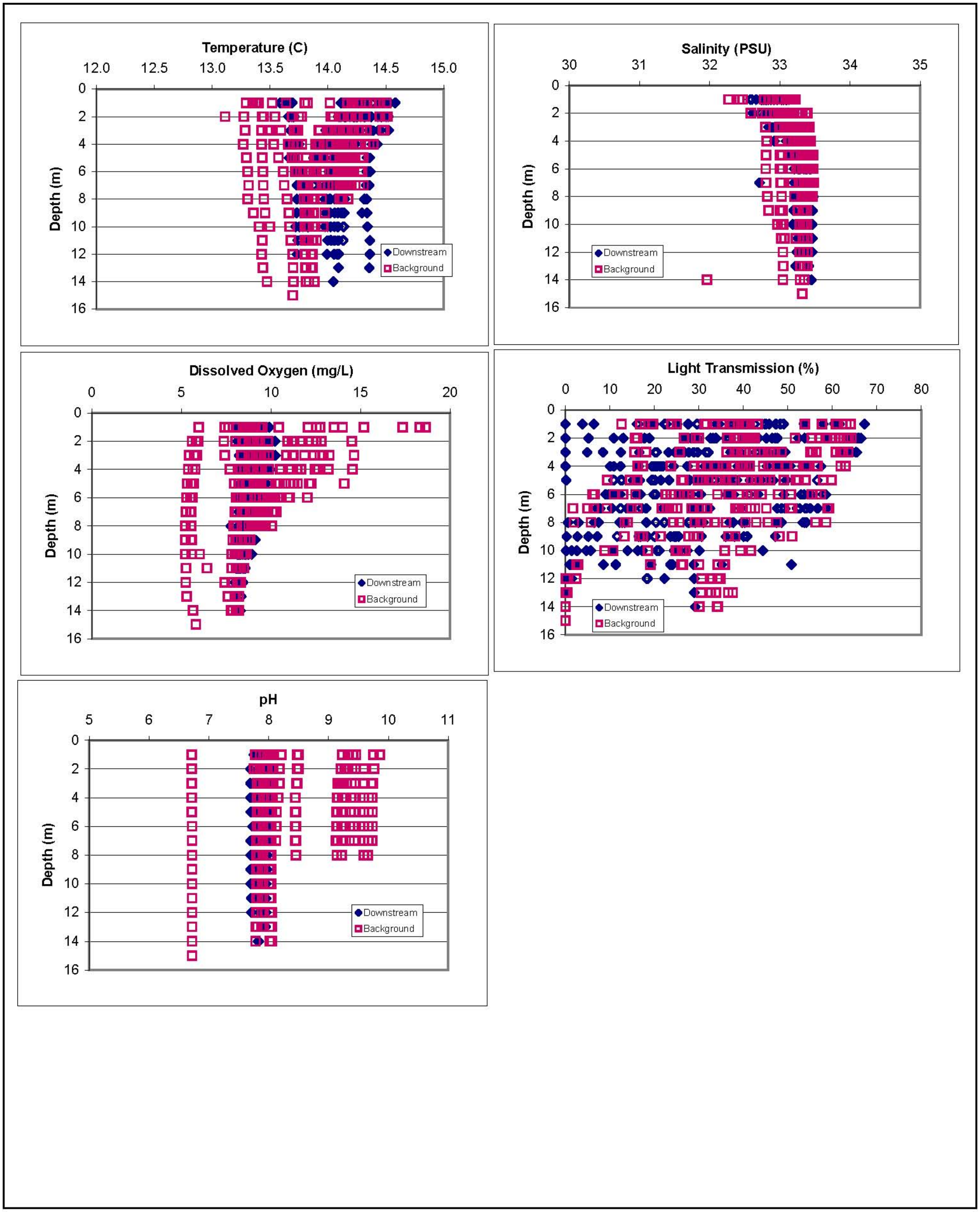



**Figure 2-6**
CTD Profile Data Near Cap Material Dredging Operations at the SEIBP

Downstream results for dissolved oxygen, light transmission, and pH were compared to background results for each monitoring event. The average difference in dissolved oxygen levels between downstream and background stations was about 0.1 mg/L. Samples exceeded the COP standard for dissolved oxygen between 26 percent and 19 percent of the time depending on distance from the dredge. On average, light transmission was also slightly lower than background at stations downstream of the cap dredging operations, and exceeded COP standards five times at distances very close to the dredge (25 m). Average pH results were also slightly lower than background at downstream stations. These pH changes exceeded the COP criteria of less than 0.2 pH unit change about 70 to 80 percent of the time.

Total Suspended Solids

Table 2-9 summarizes the ranges of TSS concentrations observed downstream of the cap sediment dredging and at background stations. Generally, there was a decrease in observed TSS concentrations with increasing distance from the dredging. The average background concentration was higher than the average observed concentration at 100 m from the dredge.

**Table 2-9**
**Total Suspended Sediment Concentrations (mg/L) Observed Near SEIBP Cap Dredging Operations (Downstream by Distance and Background)**

| | Distance from Dredge | | | |
|---|---|---|---|---|
| | 25 m | 50 m | 100 m | Background |
| Minimum | 8.0 | 6.0 | 0.5 | 0.5 |
| Average | 26.1 | 22.8 | 8.1 | 9.6 |
| Maximum | 88.0 | 69.0 | 30.0 | 70.0 |

#### *2.2.3.4 SEIBP Placement*

Sampling events were dependent upon the disposal of the dredged cap sediment. Two types of disposal were used during the capping phase. The first was the split hull barge disposal. The second was re-handling of cap sediment from the transport barge and placement over the contaminated sediments in the NEIBP borrow pit.

Continuous Depth Profiles

Table 2-10 summarizes the average results from the conductivity depth meter (CTD) profiles for both clamshell and split hull barge operations. Overall, these differences appeared to be somewhat less for clamshell placement than for split hull placement. Event- and depth-specific comparisons between downstream and background stations were made for dissolved oxygen, light transmission, and pH and are summarized in Table 2-11. The average difference between downstream and background dissolved oxygen concentrations was very close to zero. On average light transmission was slightly better downstream than at background, and pH differences averaged about -0.25 pH units. These differences resulted in occasional downstream exceedances of relevant dissolved oxygen and light transmission criteria and more extensive pH exceedances. However, as noted in the previous sections, most of the pH exceedances were likely due to measurement variability.

**Table 2-10**
**Average CTD Downstream Profile Results – Cap Sediment Placement at NEIBP, Comparison to Background**

| Distance/Event | Temperature (°C) | Salinity (PSU) | DO (mg/L) | Transmissivity (%) | pH |
|---|---|---|---|---|---|
| **Clamshell Placement** | | | | | |
| Average 50 m | 13.84 | 33.21 | 8.13 | 29.02 | 7.91 |
| Average 100 m | 13.84 | 33.22 | 8.08 | 30.53 | 7.89 |
| Average 200 m | 13.84 | 33.21 | 8.14 | 42.16 | 7.87 |
| Average Background | 13.82 | 33.09 | 8.40 | 38.16 | 8.11 |
| **Split-hull Barge Placement** | | | | | |
| Average 50 m 10 min | 14.10 | 33.21 | 8.29 | 13.06 | 7.90 |
| Average 100 m 10 min | 14.07 | 33.20 | 8.30 | 16.27 | 7.84 |
| Average 200 m 10 min | 14.10 | 33.22 | 8.42 | 25.75 | 7.82 |
| Average 50 m 30 min | 14.06 | 33.20 | 8.09 | 17.26 | 7.85 |
| Average 100 m 30 min | 14.09 | 33.23 | 8.24 | 14.11 | 7.85 |
| Average 200 m 30 min | 14.09 | 33.25 | 8.44 | 26.61 | 7.81 |
| Average Background | 14.02 | 33.08 | 9.29 | 19.36 | 9.22 |

**Table 2-11**
**Differences between Downstream and Background Conditions Observed During Cap Sediment Placement at NEIBP for CTD Profile Parameters**

| | DO (mg/L) | Transmissivity (%) | pH |
|---|---|---|---|
| Minimum | -4.67 | -44.19 | -2.00 |
| Average | -0.02 | 4.74 | -0.25 |
| Maximum | 3.24 | 48.18 | 1.44 |

Exceedances of water quality criteria were also compared between the two placement techniques (see Table 2-12). There were many more exceedances of the dissolved oxygen criteria using the split hull technique. Similarly, there were somewhat more pH exceedances using the split hull technique, but as described above, pH changes in this range may be due to measurement variability alone. Conversely, there were fewer exceedances of the RWQCB light transmission criteria (>30-40% reduction) using the split hull placement technique. This result is somewhat counter intuitive and may be due to the majority of TSS being present near the bottom during split placement. With clamshell placement, there may have been more suspension of sediment at mid and shallow depths.

**Table 2-12**
**Comparison of Downstream Results to Water Quality Criteria by Cap Sediment Placement Technique at NEIBP**

| | Clamshell | Split Hull |
|---|---|---|
| **Dissolved Oxygen** | | |
| No. Exceeding | 4 | 69 |
| No. of Comparisons | 407 | 285 |
| % Exceeding | 1% | 24% |
| **Transmissivity** | | |
| No. Exceeding | 25 | 0 |
| No. of Comparisons | 458 | 338 |
| % Exceeding | 5% | 0% |
| **pH** | | |
| No. Exceeding | 208 | 257 |
| No. of Comparisons | 458 | 338 |
| % Exceeding | 45% | 76% |

Criteria are:

DO - not more than 10% below background (as measured in mg/L)
Transmissivity - not more than 30% below background (as measured in percent light transmission)
pH - no change from background greater than 0.2 pH

Total Suspended Solids

Samples were taken from 1 m below the surface, mid-depth, and 1 m above the bottom at each station. Table 2-13 summarizes the TSS concentrations observed at downstream and background stations. Generally, for both the clamshell and split hull placement methods, the downstream TSS concentrations were within the range of typical background levels within 200 m of both placement operations. The overall spread of TSS results for clamshell versus split hull operations are shown in Figure 2-7, which shows that clamshell operations were generally within one standard deviation of the average background station. Split hull barge placement occasionally had TSS concentrations greater than this range and resulted in the nine highest observed downstream TSS concentrations.

**Table 2-13**
**Total Suspended Sediment Concentrations (mg/L) Observed near Cap Placement Operations at NEIBP (Downstream by Distance and Background)**

| | Distance from Placement | | | |
|---|---|---|---|---|
| | **50 m** | **100 m** | **200 m** | **Background** |
| **Clamshell Placement** | | | | |
| Minimum | 6 | 3 | 1 | 0.5 |
| Average | 17.8 | 16.2 | 3.9 | 3.2 |
| Maximum | 38 | 48 | 6 | 11 |
| **Split Hull Placement** | | | | |
| Minimum | 3 | 5 | 3 | 1 |
| Average | 30.8 | 25.8 | 10.1 | 24.6 |
| Maximum | 94 | 123 | 63 | 204 |

Trace metals

The validity of the trace metals data analyzed by ToxScan, Inc. was questioned during the dredging process. After a technical review by the USACE Environmental Chemistry Branch (ECB) (Vicksburg, Mississippi); it was determined that data from ToxScan, Inc. had numerous analytical problems and that the majority of the reported results should be treated as estimated values. The reported values therefore were used qualitatively to look at trends in concentrations up- and downstream from the disposal site.

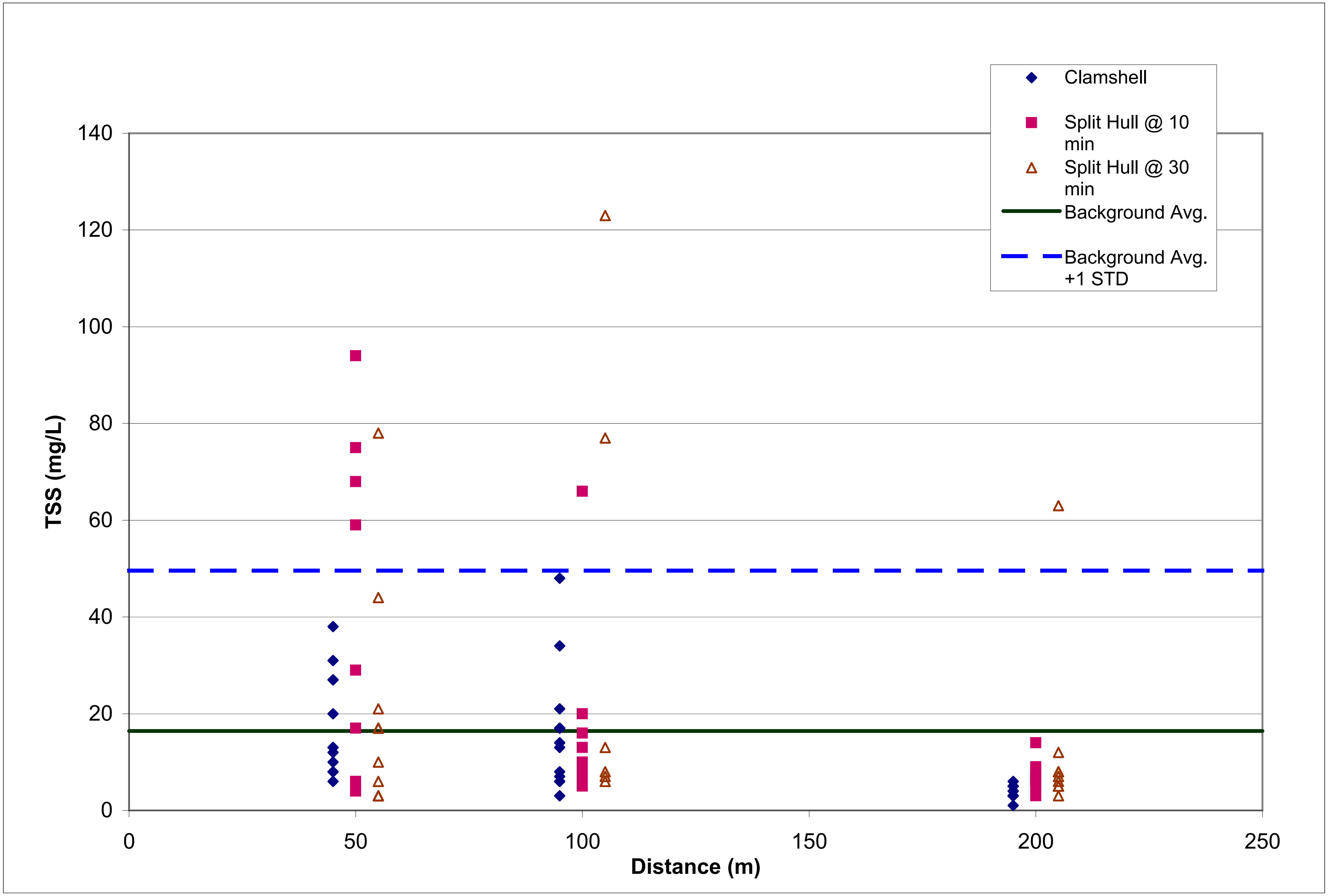



**Figure 2-7**

TSS Data Compared to Background - Cap Placement at NEIBP

Only one metal (chromium) exceeded both the COP criteria and the background maximum observed concentration during clamshell placement of the cap. However, it should be noted that background concentrations of chromium were also sometimes well in excess of COP criteria for this metal. For the split hull placement operations, chromium, lead, and zinc were occasionally found at concentrations greater than both the COP criteria and background concentrations. Generally, the exceedances were infrequent, with only one sample exceeding chromium and zinc criteria and background concentrations and only three lead samples exceeding these levels.

Organic compounds

Dissolved and total organic compounds were measured at the NEIBP site. Water samples were collected within one of three depth strata (i.e., 1 m below the surface, mid-depth, or 1 m above the bottom); whichever had the lowest light transmissivity. Samples were analyzed for selected PAHs, pesticides, and PCBs. All concentrations were below the detection limits of the analysis method. Detection limits achieved were generally at or below those normally achievable by commercial laboratories using standard methods.

### 2.2.4 Post-Construction Monitoring

Monitoring conducted immediately after construction activities were completed was used to ensure that the engineering and construction objectives for the project were met. This included evaluating potential mixing of the cap with the LARE material, measuring the thickness and consistency of the cap material across the NEIBP test cell, and monitoring for sediment loss during disposal and capping.

Monitoring post-placement of the cap included collecting sediment core samples at nine locations through the cap and LARE material to evaluate mixed layer depths (via grain size and visual observations), cap thickness, and sediment chemistry. Surface sediment samples were collected at eight locations around the edges of the pit to monitor for material losses during construction.

#### 2.2.4.1 Post-Construction Bathymetry

A post-cap construction bathymetry survey was conducted to determine the final configuration and elevations of the capped site. This information was to help determine whether design criteria were met and provide a baseline for comparison to long-term bathymetry surveys.

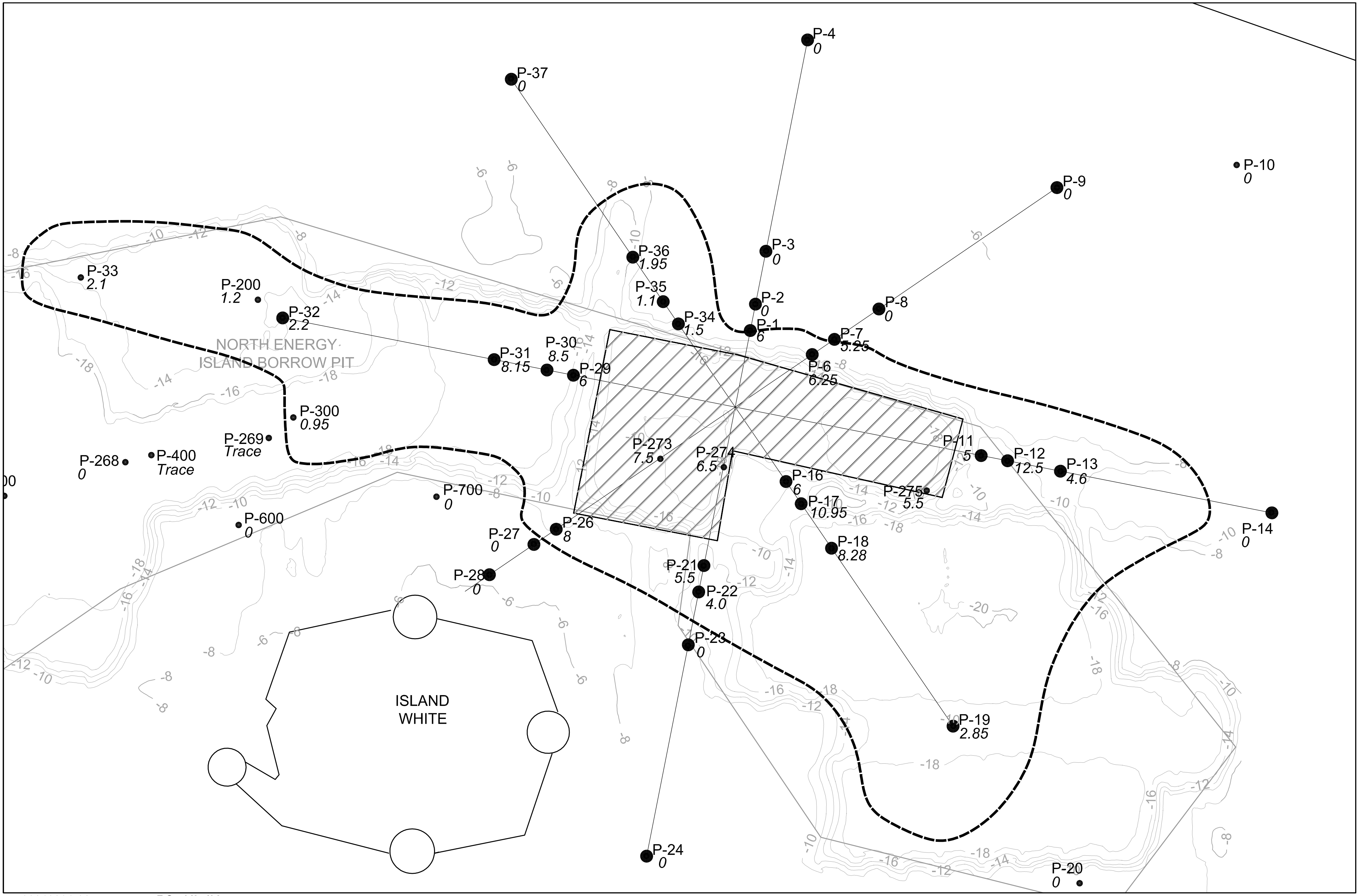
The surface of the cap was between -12 and -14 m MLLW throughout the cap site surrounded by harbor sediment elevations of -4 to -8 m MLLW. Areas of unevenness were most notable on the west side of the pit and were probably caused due to various disposal techniques. The walls of the borrow pit are between -8 and -10 m deep, with areas on the west side that are shallower and considerably eroded on the southeast side.

#### 2.2.4.2 Sediment Profile Imaging

SPI was proposed for within three weeks after construction to provide information on any LARE and cap sediment that may have dispersed outside the immediate NEIBP area.

A third (post-capping) SPI survey was completed by Germano & Associates, Inc. and MEC Analytical Systems in the area surrounding the NEIBP on February 5 and 6, 2001. Two replicate SPI images were collected from 69 survey stations as shown in Figure 2-8. The images were analyzed and compared to images taken during the baseline and post disposal surveys. A complete depiction of all SPI images is contained in Attachment B (at the end of the Phase II report).

Figure 2-9 shows the cap sediment depths observed near the NEIBP after cap placement. At least small amounts of cap sediment were found several hundred meters from the site. At some sites the cap sediment thickness was greater than the penetration of the SPI. In these cases, the penetration depth is separated and it is only known that the cap sediment was at least the penetration thickness of the camera and could have been greater. The minimum cap sediment thicknesses in areas outside disposal site ranged from 12.5 centimeters (cm) thick to trace amounts.

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P-300 STATION LOCATION AND ID
16.9 MATERIAL DEPTH IN CM

**Figure 2-8**
Post-Cap Sediment Placement
SPI Locations and Material Depths (February 2002)

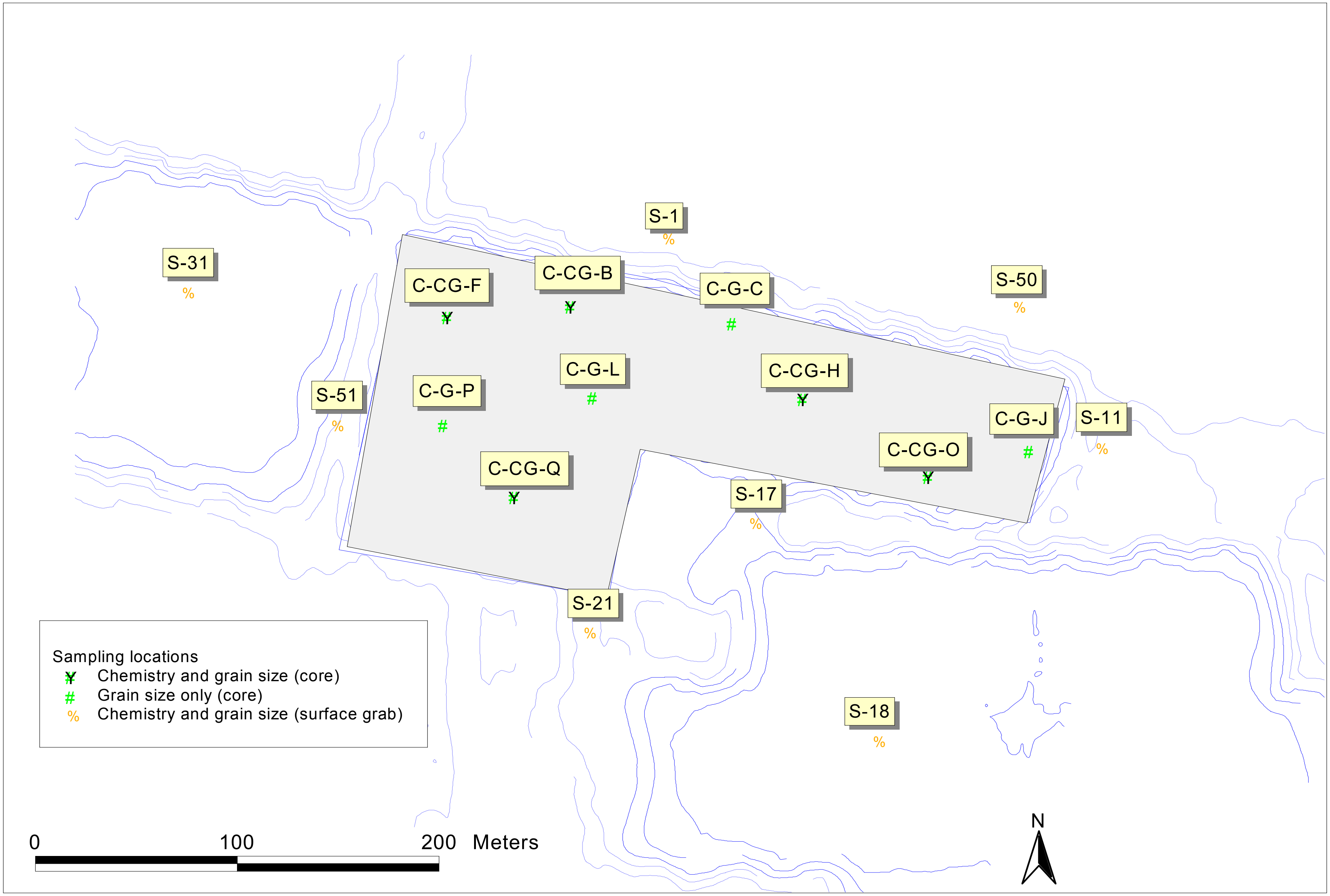


**Figure 2-9**
Core and Surface Sediment Samples
(January and February 2002)

#### *2.2.4.3 Post Construction Cap Coring*

Sediment cores were collected in February 2002 during the post-construction phase to obtain baseline information on cap thickness, mixing between cap and underlying sediment, and contaminant distribution in various layers of the cap and underlying LARE sediment. Sediment cores were collected using a Rossfelder P-5 electric vibracore. The vibracore method mixed the cap layer sediment and the LARE sediment distorting the information on cap thickness and contaminant distribution.

Therefore, a second set of cores was taken in March 2002 using a diver-operated piston core to determine cap thickness and contaminant distribution. Because the failed coring attempt carried considerable cost, the core re-sampling with divers was limited in scope to the available budget. This meant that fewer chemistry samples were taken within the cores and only metals and PAHs were analyzed in chemistry samples. The resulting coring information is sufficient to determine the following:

- Cap thickness via visual observations;
- Approximate location of cap/LARE sediment interface; and
- Mixing of the interface in excess of 10 to 30 cm (depending on the core in question).

A total of 19 core samples from nine stations within the NEIBP disposal site were collected and analyzed on March 14, 2002 (Figure 2-9). Analysis included sediment grain size distribution, total organic carbon (TOC), and chemical analysis for metals, pesticides, and PAHs.

Visual observations reported by the cap thickness ranged between approximately 90 cm to more than 120 cm. The interface between cap and underlying sediment was reported as being visually distinct. Chemical analyses confirmed the visual observations. The average concentrations of metals, total PAHs, and TOC in the LARE were above those measured in the cap material and were consistent with those measured in the LARE before construction. This indicated that little mixing of the cap and LARE sediment had occurred.

Chemical results for all chemicals in all subsurface sediment core samples were compared to ER-L values. No sediment sample in the top 10 cm of the cap sediment had any exceedance of any of the ER-L levels. In two instances cap sediment samples just above the cap/LARE interface had slight exceedances of the ER-Ls, one for lead and one for zinc. Because these sediments are well below the biologically active zone and these exceedances are still well below the ER-Ms (0.71 mg/Kg for mercury and 218 mg/Kg for lead), these metals results do not indicate any likely environmental impact.

#### *2.2.4.4 Surface Grab Sediment Sampling*

Intact surficial sediment samples (i.e., top 10 cm) were collected using a 0.1 square meters ($m^2$) box corer at eight stations surrounding the NEIBP (Figure 2-9) after cap construction was completed in February 2002.

In general, metals in sediments were detected at relatively low levels. All metals concentrations in all samples were below ER-L values. PAHs were undetected in five of the eight surface sediment samples. In the other three samples all detections were well below the ER-Ls. PCBs were undetected in all samples. All pesticides were undetected in all sediment samples, with the exception of 4, 4-DDE, which was detected at levels very close to the detection limit in seven of the eight samples. These DDE concentrations are above the ER-L values. However, it is important to note that DDE and related DDT-like compounds were found in all NEIBP cores taken prior to construction.

These results indicate that any contaminants lost during the LARE disposal and capping process had no measurable effect on the surface sediments surrounding the disposal area. That is, any increases in chemical concentrations in surrounding sediments were minor in comparison to sediment effects guidelines often used to screen for sediment toxicity (i.e., Long et al. 1995).

These results also indicate that LARE sediments found just outside the designated disposal area prior to cap construction, were either removed and/or successfully capped along with all the LARE sediments present in the designated disposal area.

Specifically, sample S-17 was located in the area where some PAHs were detected prior to cap construction. All PAHs were undetected in samples from S-17 indicating successful removal and/or isolation of any chemicals there.

#### 2.2.4.5 Sediment Tracer Study Results

In August 2002, a tracer sediment manufactured by Environmental Tracing Systems (ETS) was deployed into barge load #60 of LARE sediment during the dredging process (after approximately 20,000 $m^3$ had been dredged from the LARE). This barge load was subsequently released over the NEIBP. Sediment samples taken around the NEIBP shortly after disposal of this barge load, 11 weeks later (in November 2001 before capping commenced), and after cap construction (February 2002) were examined in a laboratory for the presence of the tracer sediment. Water column samples were also taken immediately after release of the barge load and analyzed for the tracer.

The tracer manufactured by ETS for this study was fluorescent yellow silt and was intended to mimic the finer portion of the fine-grained fraction of the LARE sediments in the 4 to 20 micron range, based on LARE grain size analyses conducted prior to construction. Originally, ETS planned to use a series of different colored tracers to mimic different grain size fractions but budgetary constraints limited the final test to a single color. Approximately 150 Kg of tracer were deployed in the barge load. The tracer manufactured had the following properties:

- D50 of 7.5 microns
- D10 of 1.5 microns
- D90 of 17.8 microns
- Density 2.65 $g/m^3$

These finer fractions represent the most mobile portion of the LARE sediment. Any dispersion of these tracers during operations would theoretically mimic the movement of finer sediments but not any coarser fractions such as sand, etc. Given the average fine silt-size fraction content for the LARE sediment was 12.5 percent, for sediment size 2 to 16 microns and 24 percent for sediment size < 2 to 31 microns, ETS estimated that the tracer represented approximately 15 percent, by weight, of the sediment released by the barge to the NEIBP.

Results – Immediately After Release of Tracer

The tracer concentrations measured in sediment grab samples collected immediately after the barge load (August 15 and 16, 2001) was released indicated deposition of tracer up to 50 m and 75 m from the edge of the pit. Tracer was also found at high concentrations within the disposal site. Water column samples collected near the NEIBP immediately after dumping had measurable amounts of tracer.

Results – 11 Weeks After Release of Tracer

At 11 weeks after the tracer release (November 2 and December 11, 2001), tracer in sediment surrounding the NEIBP was spread over a wider area with tracer detected out to 400 m from the edge of the pit. Generally, the highest concentrations outside the pit were measured within 100 to 150 m from the edge of the pit, with the highest concentrations toward the northwest and southeast in line with tidal currents. As would be expected, substantial amounts of tracer were observed within the disposal site.

Results – After Cap Construction

ETS found no tracer in sediment grab samples collected within NEIBP after construction of the cap (February 12, 2002). This indicates that the tracer present in the pit prior to capping was completely isolated by capping. It further indicates that the tracer observed surrounding the disposal area had not been transported back onto the cap surface. Tracer concentrations outside NEIBP decreased between pre- and post-cap surveys.

Tracer Study Conclusions

Because this was an initial effort to study the usefulness of the tracer technology, the study was limited to silt-sized tracer deployed in just one barge load. The study results indicate that tracer can be effectively deployed in this type of scenario and can be used to understand movement of similarly sized sediment particles in and around such operations. It would be reasonable to evaluate the technology further in other full-scale deployments, along with other types of monitoring techniques (such as current monitoring), to help better understand sediment movement during dredging operations.

Clearly, for this project, the tracer results confirm water quality monitoring results and predictive TSS dispersion models that show some amount of disposed sediment is likely dispersed outside the immediate disposal site. All of this information is consistent with typical observations at other confined and open-water disposal sites.

The tracer study was limited to a single barge load and consisted of only fine particulates; therefore, it is difficult to estimate how much LARE sediment might have been dispersed outside the NEIBP during the course of the disposal operations. For example, wind, wave, and current conditions during the one tracer barge drop may be different from conditions during other barge drops. Similarly, there could be variations in barge drop locations, speeds, directions, and characteristics of the sediments contained within loads. In addition, the tracer consisted of fine particulates, and only about 15 percent of the LARE sediment was estimated to be in this size range. The tracer study provides no direct information on the dispersion of other grain size fractions.

With these caveats in mind, ETS estimated that between 1 percent and 22 percent of the tracer present in the one barge load was found outside the NEIBP disposal site. Given that fines in this range represent about 15 percent of the LARE sediments, this equates to between 0.15 percent and 3.3 percent of the total mass of the barge load. It should also be noted that the wide range of these estimates gives some indication of the difficulties of making quantitative estimates given the limited scope of this tracer study.

# 3 LONG-TERM MONITORING PLAN

## 3.1 Goals and Objectives of the LTMP

Following completion of the construction portion of the capping project, the USACE and the CSTF members met on several occasions to discuss the objectives and format for the cap site LTMP. As a result of those discussions, the following study objectives for the monitoring plan were developed:

- The monitoring plan should include intensive (or extensive) monitoring during the first three years to provide substantial evidence for predicting long-term cap effectiveness by monitoring cap integrity, chemical containment, and biological re-colonization.
- Monitoring should be sensitive enough to detect "fatal-flaws" in design or site condition factors that are likely to be evident within the first three years after cap placement so that the technology may be considered during development.

To meet these specific study objectives, a series of questions and corresponding data collection methods were developed:

1. *Is the surface of the cap eroding or are depositional forces at work?*
   a. Conduct bathymetric surveys
   b. Conduct diver video surveys
   c. Collect sediment core samples to evaluate visual evidence of erosion

2. *What is the impact of bioturbation on cap integrity?*
   a. Conduct diver video surveys
   b. Evaluate cap core chemistry results for evidence of vertical migration
   c. Use cap core visual observations for evidence of mixing
   d. Evaluate benthic community surface samples for the presence of juvenile bioturbators such as Ghost Shrimp.

3. *Are chemicals migrating through the cap at an unacceptable rate?*
   a. Evaluate cap core chemistry results for evidence of vertical migration
   b. Evaluate cap core sediment grain size samples for evidence of mixing
   c. Use cap core visual observations for evidence of mixing

4. *How quickly are biological organisms re-colonizing the surface of the cap?*
    a. Collect surface sediment grab samples on the cap and surrounding areas for benthic organism identification and enumeration

5. *How do the populations of benthic organisms on the surface of the cap compare to surrounding areas?*
    a. Compare surface sediment grab samples (benthic organism identification and enumeration) for the cap to surrounding areas

Ultimately, it was decided, that measurement of success or failure of the cap site would be determined if chemicals migrated through the cap at a rate that resulted in significant contamination of the surface sediment or overlying water. According to the equilibrium partitioning and flux models conducted during cap design, chemical migration through nearly 4 feet of cap material would not be expected to cover, and certainly would not be detected within the first three years of monitoring. The questions and corresponding data collection methods developed by the CSTF monitored the near-term success of the cap site, which enabled likely predictions of what might occur many years in the future.

To meet the objectives outlined by the USACE and CSTF, the LTMP was divided into three monitoring categories: cap integrity, chemical containment, and biological re-colonization. Monitoring for cap integrity and chemical containment are the two primary objectives of the monitoring plan. Biological re-colonization was included to provide information on long-term biological impacts associated with aquatic capping for possible use in future projects such as when a final cap layer is placed on a completed CAC site, thus bringing the surface elevation back to the surrounding areas.

## 3.2 Cap Integrity

The aquatic cap for the NEIBP site was designed to be effective in containing chemical contaminants despite potential physical (e.g., wave action, propeller wash) and biological (e.g., bioturbation) disturbances. A key component of the LTMP was to monitor the long-term integrity of the cap surface and thickness of the mixed layer (the interface between the cap and LARE material that formed during the initial disposals of the cap material). To determine changes in the thickness and integrity of the cap layer annual visual observations and bathymetric surveys were employed.

#### 3.2.1 Visual Observations

Core samples collected through the cap layer for sediment chemical analysis were subjected to visual observations to record the thickness of the cap, the depth of bioturbation (if visible), and the depth of the mixed layer between the cap and the LARE material. Sediment core samples were collected via SCUBA diver by hand using clear tubes so that visual observations could be made both before and after the tubes were extruded.

#### 3.2.2 Bathymetric Surveys

Bathymetric surveys were conducted of the entire NEIBP disposal cell and surrounding area (to a minimum of 50 m in all directions) during each annual monitoring event using a multi-beam sonar device such that a maximum 0.1 m vertical resolution was obtained.

### 3.3 Chemical Containment

In addition to ensuring that the cap remained physically intact over the LARE material, a key aspect of the LTMP was to ensure that chemicals were not migrating through the cap at concentrations that exceeded potential aquatic risk levels. Chemical advection and diffusion potential was estimated and accounted for during cap design. Monitoring for chemical diffusion was determined annually using sediment cores to sample the LARE material, SEIBP material and the interface of samples in between the two layers. In Year 3, cap material pore water analyses were also conducted.

#### 3.3.1 Sediment Core Sampling

Sediment coring provided physical and chemical information on the cap profile. The information was used to determine whether contaminated sediments remain in place underneath the cap. Analysis of core samples determined whether chemicals might be moving into or through the cap to the water column either through physical/biological movement of contaminated sediment particles or through dissolved chemical migration.

#### *3.3.1.1 Station Locations*

Each monitoring year, sediment core samples were collected at the same nine stations (2 – 10) within the NEIBP disposal cell as were sampled for the post-cap placement monitoring event and are depicted in Table 3-1 and Figure 3-1. These cores were used for chemical/physical analysis and visual observations.

**Table 3-1**
**Station Location Coordinates**

| Station Identification | Latitude | Longitude |
|---|---|---|
| Station-2 | 33 45.3518 | 118 09.4291 |
| Station-3 | 33 45.3205 | 118 09.4304 |
| Station-4 | 33 45.2994 | 118 09.4077 |
| Station-5 | 33 45.3286 | 118 09.3825 |
| Station-6 | 33 45.3551 | 118 09.3896 |
| Station-7 | 33 45.3503 | 118 09.3378 |
| Station-8 | 33 45.3282 | 118 09.3151 |
| Station-9 | 33 45.3055 | 118 09.2749 |
| Station-10 | 33 45.3131 | 118 09.2426 |

#### *3.3.1.2 Core Sampling Procedures*

Sediment core samples were collected by hand using SCUBA diving equipment. At each location, a new, clear, butyrate 3.048 m core liner (1.5-inch diameter) was used to take a 2 m core by a team of two Navy Divers. These core lengths were sufficient to pass through the cap layer and penetrate at least 15 cm into the LARE material. Core samples were processed the same day as collected by splitting the core tube onto a protective lined table for logging and sub-sampling.

#### *3.3.1.3 Sample Depths*

The focus of the sediment coring was to monitor for potential chemical migration from the LARE material through the cap. A total of three sample intervals were collected for each core sample. The exact width of the sample interval was determined after completing a project specific Quality Assurance Project Plan (QAPP) and calculating the minimum sample size required to meet the target detection limits. For this project, a 10-cm sample interval was selected. Thus, the three sample intervals were the top 10-cm layer of the cap, the top 10-cm layer of the LARE material, and the 10-cm interval at the mid-point in between the two previous depths.

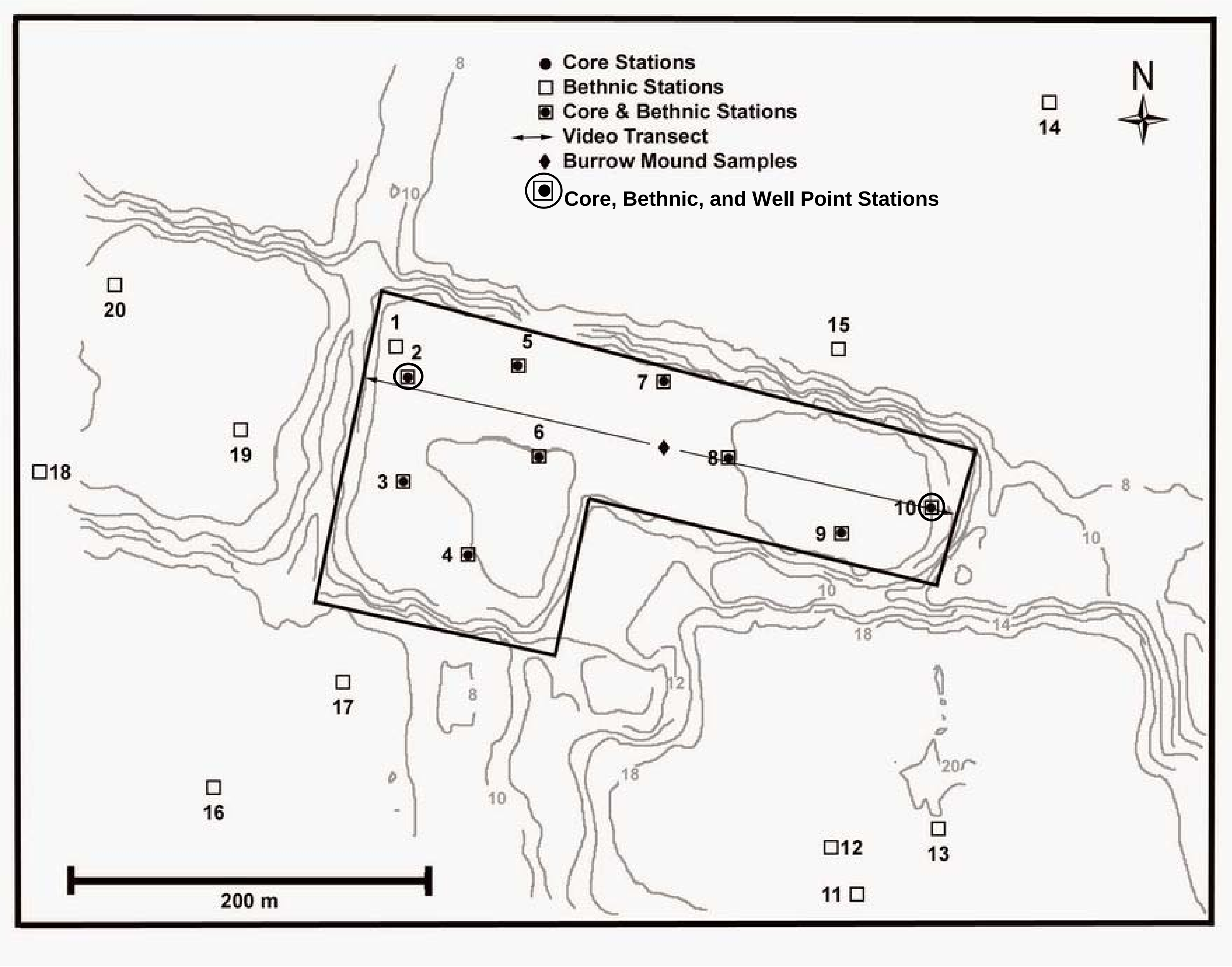


**Figure 3-1**
Long-Term Monitoring Locations for Video Transect, Cores, Benthic Infauna, Burrow Mounds, and Well Points
Source: ABC 2004

Because the purpose of the sediment core monitoring was to detect potential chemical migration, the CSTF group decided to alter the sample depths after the first year of monitoring to move the midpoint sample interval closer to the LARE/cap interface. The concern was that the three years selected for initial monitoring may not be sufficient to detect chemical migration halfway through the cap layer. However, if chemical migration were occurring, it should be detectable in the interval just above the interface.

Also, if significant amounts of newly settled material was observed on the cap surface (e.g., > 5 cm) during sampling, this upper layer was removed from the 0 to 10 cm core interval to create a sample of the original cap surface and a separate grab sample of the newly settled material for separate chemical analysis. This allowed the issue of chemical migration to be analyzed individually without concerns from potential recontamination due to deposition on the cap surface.

#### *3.3.1.4 Chemical Analyses*

Because of limited sample volume from the core intervals, the use of indicator chemicals was required to meet the project's objectives. As such, each sample was analyzed only for metals and PAHs. Metals and PAHs were selected because they represent contaminants of concern in the LARE material and include analytes that are most susceptible for migration. All chemical analyses were conducted using laboratory methods capable of obtaining detection limits similar to those developed for the Bight 1998 data collection program.

In addition to the chemical analyses, sediment moisture, grain size, bulk density, and organic carbon content were measured for each sample interval. Chemical analyses, analytical methods, and detection limits are depicted in Table 3-2.

#### *3.3.1.5 Sediment Core Sample Schedule*

Sediment core samples were collected once per year for the three years of monitoring, beginning with June-September 2002 and occurring during the same time period in 2003 and 2004.

**Table 3-2**
**Indicator Chemicals Analyzed in Sediment Core Samples**

| Analyte | Method | Project Detection Limit | Ocean Plan Minimum Levels |
|---|---|---|---|
| **Conventionals** | | | |
| **Metals (µg/L)** | | | |
| Arsenic | EPA 6020 | 1 | 2 |
| Cadmium | EPA 6020 | 0.3 | 0.2 |
| Chromium | EPA 6020 | 0.5 | 0.5 |
| Copper | EPA 6020 | 0.5 | 0.5 |
| Lead | EPA 6020 | 0.5 | 0.5 |
| Mercury | EPA 7471 | 0.2 | 0.2 |
| Nickel | EPA 6020 | 1 | 1 |
| Selenium | EPA 270.3 | 0.5 | 1 |
| Silver | EPA 6020 | 0.2 | 0.2 |
| Zinc | EPA 6020 | 5 | 1 |
| **Polycyclic Aromatic Hydrocarbons (µg/L)** | | | |
| 2-methylnaphthalene | EPA 8270 | 2 | N/AV |
| Acenaphthene | EPA 8270 | 2 | N/AV |
| Acenaphthylene | EPA 8270 | 2 | 10 |
| Anthracene | EPA 8270 | 2 | 10 |
| Benzo(a)anthracene | EPA 8270 | 2 | 10 |
| Benzo(a)pyrene | EPA 8270 | 2 | 10 |
| Benzo(b)fluoranthene | EPA 8270 | 2 | 10 |
| Benzo(g,h,I)perylene | EPA 8270 | 2 | 5 |
| Benzo(k)fluoranthene | EPA 8270 | 2 | 10 |
| Chrysene | EPA 8270 | 2 | 10 |
| Dibenzo(a,h)anthracene | EPA 8270 | 2 | 10 |
| Dibenzofuran | EPA 8270 | 2 | N/AV |
| Fluoranthene | EPA 8270 | 2 | 1 |
| Fluorene | EPA 8270 | 2 | 10 |
| Indeno(1,2,3-cd)pyrene | EPA 8270 | 2 | 10 |
| Naphthalene | EPA 8270 | 2 | N/AV |
| Phenanthrene | EPA 8270 | 2 | 5 |
| Pyrene | EPA 8270 | 2 | 10 |

N/AV = Not available

## 3.4 Biological Re-Colonization

Data collected from monitoring benthic re-colonization of the cap surface was not used to determine effectiveness of the cap for containing the contaminants in the LARE dredge material, but instead was used to track overall long-term biological recovery rates for aquatic capping in southern California. The benthic monitoring program did provide useful data for the current objectives by monitoring for the presence of juvenile bioturbators that were located in the surface sediments. The presence of bioturbators can be used as indicators for potential biological mixing within the cap.

### 3.4.1 Benthic Sampling

Benthic community sampling included collection, identification, and enumeration of benthic infauna (organisms living in the top 10 cm of bottom sediments) larger than 1,000 microns (often called macrofauna). Typically, the vast majority of benthic macrofauna reside in the top 10 cm of sediment. Thus, surface grabs were taken of the top 10 cm of the most biologically active zone.

Benthic community data provided information on both the abundance (number of individual organisms) and richness (numbers of species or taxa). A species diversity comparison of a nearby natural reference stations was used to track re-colonization of the cap. The comparison also provided evidence of potential bioturbators, particularly juvenile burrowers and infauna larva likely to be in surface sediments.

#### 3.4.1.1 Sample Station Locations

A total of 20 locations were sampled for the benthos: 10 stations from within the NEIBP disposal cell and 10 stations from the surrounding areas as shown in Figure 3-1. Sample stations were randomly located along a 10-m grid laid over the study area. One sample was collected from each of the stations and attempts were made to return to the same sample stations each year using a differentially corrected Global Positioning System (DGPS).

#### 3.4.1.2 Sample Procedures

Sampling was conducted using a 0.1-$m^2$ modified van Veen grab, which was capable of retrieving 6 to 10 cm of sediment depth. The grab was operated following procedures described in the EPA's *Methods for Collection, Storage, and Manipulation of Sediments for Chemical and Toxicological Analyses: Technical Manual* (EPA 2001). Each sample was evaluated for acceptability criteria defined in EPA (2001) including adequate depth of penetration. If the sample did not meet all of these criteria, it was rejected.

#### 3.4.1.3 Sample Processing

Sample processing followed those detailed in EPA (2001). In summary, each complete replicate sample, including overlying water, was sieved through a 1000-micron (1 mm) screen. Organisms and debris on the screen were transferred to sample containers with a label placed on the inside of the container. Benthic organisms were subjected to a suitable relaxant for a period of 30 minutes and then fixed with 10 to 15 percent borax-buffered formalin. After an appropriate fixing period (minimum 24 hours, maximum seven days), the samples were rewashed with tap water through a 500-micron or smaller screen. The samples were rinsed in 70 percent ethanol/water solution and then stored in sample containers in 70 percent ethanol/water solution with internal and external labels.

Samples were sorted from sediment/debris into major taxonomic groups, which were then stored in separate vials for each sample. Wet-weight biomass determination was made for each major taxonomic group following Puget Sound Estuary Program (PSEP 1987) guidelines. Qualified taxonomists identified and enumerated organisms to the lowest practical taxonomic level.

To ensure that juvenile bioturbators potentially present in the samples did not pass through the 1-mm screen, five of the 20 sample stations were randomly selected and re-sampled using a 500-micron screen instead of the 1,000-micron screen. All other procedures remained the same.

#### 3.4.1.4 Benthic Sampling Schedule

Benthic sampling occurred annually for a three-year period, which coincided with the other monitoring activities. The sampling represents a time when peak infaunal abundance was expected.

### 3.4.2 Video Surveying

Underwater video photography was taken of the cap surface to evaluate for the presence of ghost shrimp burrows or other evidence of bioturbation. The surveys also provided general observations on the status of the cap (e.g., evidence of erosion or subsidence).

#### *3.4.2.1 Video Surveying Locations*

Video surveys were conducted over transects of the cap specified before each monitoring event (Figure 3-1).

#### *3.4.2.2 Video Surveying Methods*

A hand held Sony TRV900 digital camcorder encased in an Underseas underwater housing with an attached bank of fluorescent underwater lights was used to survey the cap site during Years 1 and 2. The video camera captured 30 digitized frames per second along each transect, which allowed for detailed analysis of the bottom.

Organism burrows were identified from the mounding or other disturbances of sediments on the surface of the cap. Organism abundance was estimated from the number of burrows observed in the surveys. These data were evaluated to determine whether more quantitative evaluations of bioturbation were needed. If numerous large burrows were present on the surface of the cap, samples of the mounded material were collected for chemical analysis to determine if the LARE material had been penetrated.

#### *3.4.2.3 Video Surveying Schedule*

Video surveys occurred at the same frequency as sediment coring and benthic community analyses during Years 1 and 2. No video surveying was conducted during Year 3.

# 4 LONG-TERM MONITORING RESULTS

The following sections present the results of the three-year long-term monitoring program implemented at the cap site. Long-term monitoring was first conducted in October 2002 (Year 1), then again in August 2003 (Year 2) and most recently in July 2004 (Year 3). Study results for Years 1 and 2 were initially reported in *Confined Aquatic Disposal Site Long-Term Monitoring Program 2002 – 2003* (ABC 2004) and are summarized below along with the recent Year 3 results. Study modifications and refinements in the sampling plan implemented between years are also presented. For consistency, monitoring results are presented by category (cap integrity, chemical containment, and biological re-colonization), as described in Section 3.

## 4.1 Cap Integrity

The CAC site was designed to maintain a barrier between the contaminants associated with the LARE material and the surface sediments. The cap barrier of clean sediments could potentially be breached by forces such as currents, earthquakes, and settling of the surface sediments. Additionally, the potential for organisms (bioturbators) to transport contaminants to the surface through their burrows and/or provide vertical pathways for chemical migration if the cap was penetrated was also evaluated. While the presence of a small number of deep burrowers would likely not have an impact on cap integrity, a large number of bioturbators penetrating the cap could provide a significant mechanism for the transport of contaminants upward to the cap surface. As mentioned in Section 3, cap integrity was investigated using visual observations of the sediment cores (evident by lack of mixing between cap and LARE material), visual observations for bioturbators, and bathymetric surveys (evaluating contours to determine settling or erosion of cap surface). Each is described in further detail below.

### *4.1.1 Visual Observations*

#### *4.1.1.1 Year 1*

In Year 1, nine sediment cores were taken from Stations 2 – 10 within the cap site and visually inspected (Figure 3-1). No new depositional material or evidence of bioturbation was observed in any of the core samples. All surface and middle core sediments were dark grey, composed of sand, contained large amounts of shell hash, and were odorless. In contrast, the LARE material was black, composed of coarse silt, and had an odor of petroleum, which made it easily discernable from the cap material (Figure 4-1).

#### 4.1.1.2 Year 2

The same nine sediment core locations were sampled in Year 2 (Figure 3-1) and appeared visually similar to those collected in Year 1. No new depositional material or evidence of bioturbation was observed in any of the core samples; however, divers collecting the samples reported the presence of a flocculent-like material on the surface of the cap. All surface and middle core sediments were dark grey, composed of sand and contained large amounts of shell hash. Each of these was odorless except at Stations 7 and 8 where sulfur was detected in both the surface and middle layers and Station 10 in the middle layer. The LARE material was again easy discernable from the cap material because it was black in color and composed of fine silt with the presence of a petroleum odor.

#### 4.1.1.3 Year 3

In July 2004, nine sediment core samples were again taken at Stations 2-10 (Figure 3-1). The average total penetration of the nine core samples was 195 cm (Table 4-1). As in previous years, core penetration met the minimum requirement of 15 cm into the LARE material at all locations. The depth of the LARE material exceeded the 1-m cap design depth with an average of 136 cm and ranged from 100 to 171 cm deep.

Cap layer material and LARE material remained visually unique as observed in Years 1 and 2. The SEIBP cap material is comprised of grey to dark grey sand, interspersed with large amounts of shell hash, and has no odor. The LARE material is black, soft silt interspersed occasionally with organic matter and contains an identifiable petroleum odor. During collection, the Navy divers noted that the layer of flocculent material on the surface of the cap had increased in depth to between 5 and 10 cm. The flocculent layer blanketed the entire cap area and numerous burrow mounds were present throughout the site. As with previous sampling events, the cores collected in Year 3 did not reflect the diver's visual observations of a fluffy flocculent material or the evidence of biological activity in the cap material. Digital photos are shown in Figure 4-1 and are representative of all cap site core samples.

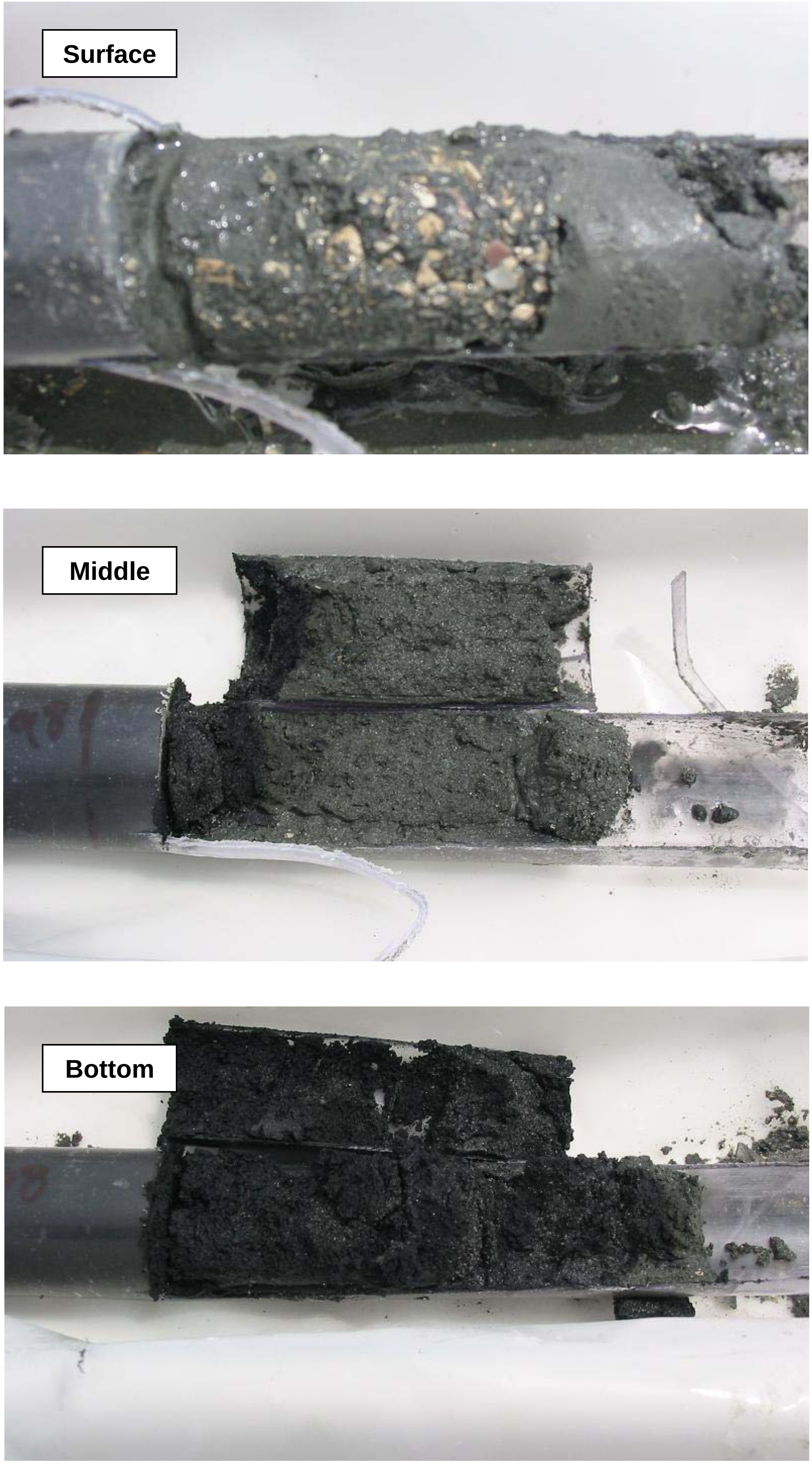


**Figure 4-1**
Example Sediment Core Photos
Source: ABC 2004

**Table 4-1**
**Year 3 Summary of Visual Observations of Sediment Core**

| NEIBP Core Stations | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| | **2** | **3** | **4** | **5** | **6** | **7** | **8** | **9** | **10** |
| Total Penetration Depth (cm) | 180 | 239 | 204 | 200 | 215 | 174 | 185 | 190 | 200 |
| LARE Penetration Depth (cm) | 140 | 105 | 130 | 153 | 148 | 125 | 141 | 130 | 160 |
| Mid Sample Depth (cm) | 100-120 | 60-80 | 80-100 | 140-153 | 120-140 | 100-120 | 120-135 | 100-120 | 140-160 |
| Bottom Sample Depth (cm) | NA | 80-94 | 140-160 & 160-180 | NA | NA | NA | NA | NA | NA |
| New Surface Deposition | N | N | N | N | N | N | N | N | N |
| Bioturbation Present | N | N | N | N | N | N | N | N | N |
| **Sediment Composition** | | | | | | | | | |
| Surface | Sand/Shell Hash | Sand/Shell Hash | Fine Sand | Fine Sand | Sand/Shell Hash | Sand/Shell Hash | Sand/Shell Hash | Fine Sand | Sand/Shell Hash |
| Mid | Coarse Sand/Shell Hash | Coarse Sand/Shell Hash | Coarse Sand/Shell Hash | Coarse Sand/Shell Hash | Coarse Sand/Shell Hash | Coarse Sand/Shell Hash | Coarse Sand/Shell Hash | Coarse Sand/Shell Hash | Coarse Sand/Shell Hash |
| Bottom | Fine Silt | Fine Silt | Sandy Silt | Fine Silt | Fine Silt | Fine Silt | Fine Silt | Fine Silt | Fine Silt |
| **Sediment Color** | | | | | | | | | |
| Surface | Dark Grey | Grey | Dark Grey | Grey | Dark Grey | Dark Grey | Grey | Grey | Grey |
| Mid | Dark Grey | Dark Grey | Dark Grey | Dark Grey | Dark Grey | Dark Grey | Grey | Grey | Grey |
| Bottom | Black | Black | Black | Black | Black | Black | Black | Black | Black |
| **Sediment Odor** | | | | | | | | | |
| Surface | None | None | None | None | None | None | None | None | None |
| Mid | None | None | None | None | None | None | None | None | None |
| Bottom | Petroleum | Petroleum | Petroleum | None | Petroleum | Petroleum | Petroleum | Petroleum | Petroleum |

#### 4.1.1.4 Discussion on Visual Observations

Visual observations of core samples collected for three years post-construction revealed a clear boundary layer between the LARE material, which was fine-grained, black in color, and smelled of petroleum. The capping material was dark grey in color, odorless, and sandy. This suggests physical cap integrity has been maintained. In addition, the depth of the overlying cap material met the 1-m depth design criteria for the study based on visual measurements of the cores collected during all three surveys.

### 4.1.2 Bathymetric Surveys

#### 4.1.2.1 Year 1

A bathymetry survey of the cap site and surrounding area was conducted using a multi-beam echo sounder. Two and three-dimensional images were analyzed, showing the surface of the cap at -12 to -14 m MLLW surrounded by harbor sediment elevations of -4 to -8 m MLLW. Areas of unevenness were most notable on the west side of the pit and were probably caused due to various disposal techniques. The walls of the borrow pit are between -8 and -10 m below MLLW, with areas on the west side that are shallower and considerably eroded on the southeast side. This condition existed before cap placement and does not appear in any way related to disposal or capping activities.

Measured thickness of the LARE layer, cap layer and a combination of the two was determined by comparing bathymetric surveys taken prior to construction, after LARE placement and after cap placement. The average depth of both the LARE and cap material was 1 m deep with a combined average depth of approximately 2 m deep. These results confirmed those observed immediately following construction.

#### 4.1.2.2 Year 2

A bathymetry survey of the cap site and surrounding area was conducted in Year 2 using the same multi-beam echo sounder as with Year 1. Depth contours revealed similar results in Year 2 compared to those in Year 1. Cap layer thickness was again determined, as was thickness of LARE material and the combined depth of the cap and LARE material. The cap and LARE layers did not significantly change between

Years 1 and 2 indicating no significant erosion or consolidation. The elevation of the cap surface was nearly identical between years. The largest difference between years was a small -0.35 m depression in the northwestern corner of the cap site indicating a small area of settling.

#### *4.1.2.3 Year 3*

A third bathymetry survey of the cap site and surrounding area was conducted in Year 3 using the same multi-beam echo sounder as in Years 1 and 2. Two and three-dimensional images were analyzed and are depicted in Figures 4-2 and 4-3. Figures 4-4 through 4-6 show a plan view and cross sections of the cap from post construction to Year 3. Analysis of the images determined the surface of the cap was at -12 to -14 m MLLW surrounded by harbor sediment depths of -4 to -8 m MLLW. The cap and LARE layers did not significantly change between throughout the three-year monitoring program indicating no significant erosion or consolidation. Unevenness on the cap surface was observed during Year 3 as it was in Years 1 and 2. This has been attributed to various disposal techniques during cap placement. The walls of the borrow pit were again calculated to be between -8 and -10 m below MLLW as was seen in Years 1 and 2. Areas on the west side are shallower and considerably eroded on the southeast side. This condition existed before cap placement and does not appear in any way related to disposal or capping activities.

#### *4.1.2.4 Discussion on Bathymetric Survey Results*

Bathymetry survey results further indicate that the engineering design criteria of the project have been met and that the integrity of the cap has been maintained. The surface elevation of the cap site ranged from -12 to -14 m MLLW. Isopach thickness, comparing pre and post-placement of LARE dredge and SEIBP cap materials, showed that the thickness of the LARE material ranged from 1 to 2.5 m, and that the cap ranged from just under 1 to 2 m. Comparison of surface isopachs between Year 1 and Year 3 suggests that the surface of the cap is unchanged indicating that no significant erosion, consolidation, or sloughing had occurred. There was also no evidence of any fractures or large depressions that would impact cap integrity.

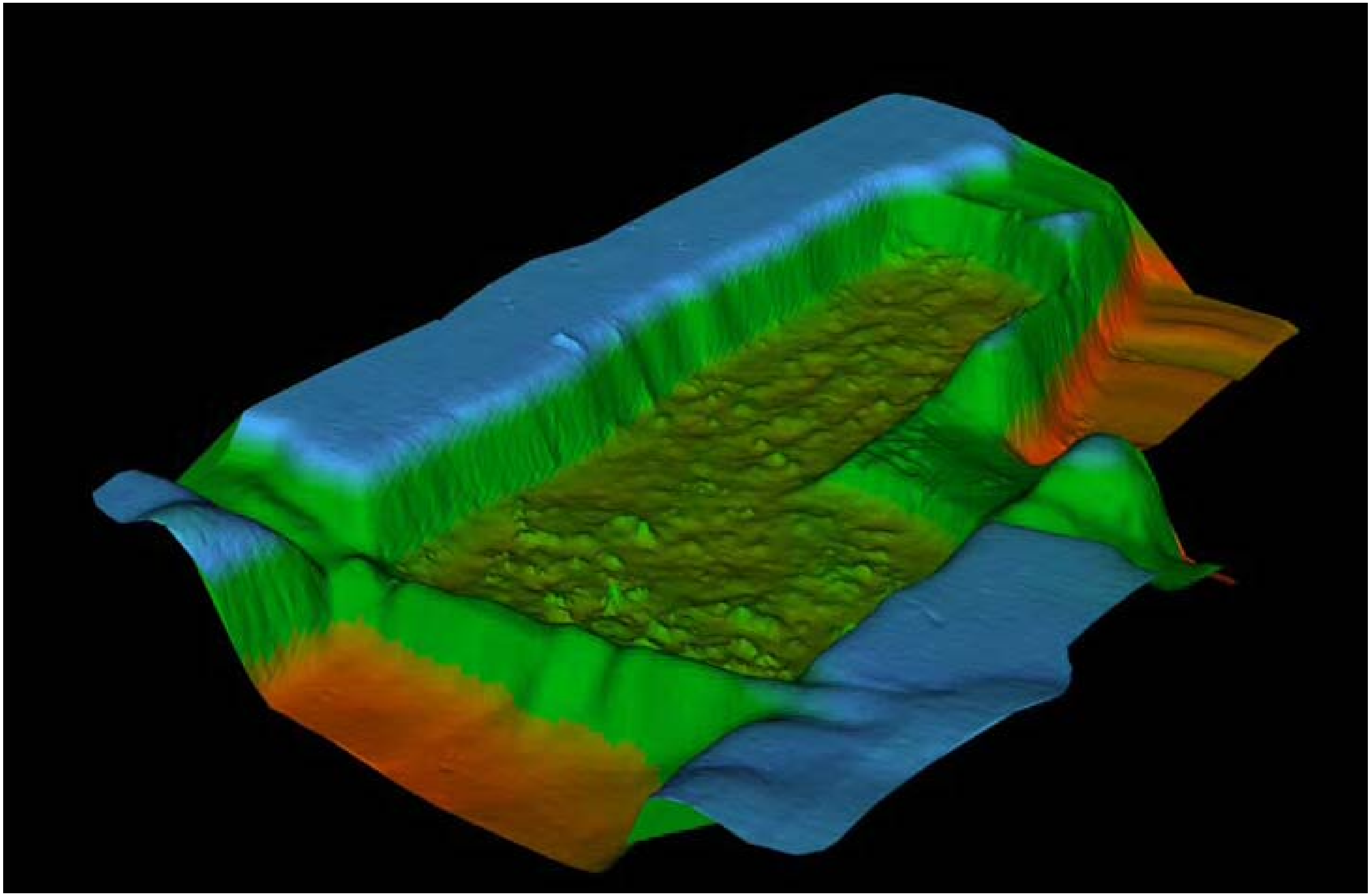

**Figure 4-2**
Year 3 Bathymetry Figure

6/9/05 cvd K:\Jobs\04007601-NEI LA Dist Pilot Studies\04007601\FIG 4-3.cdr

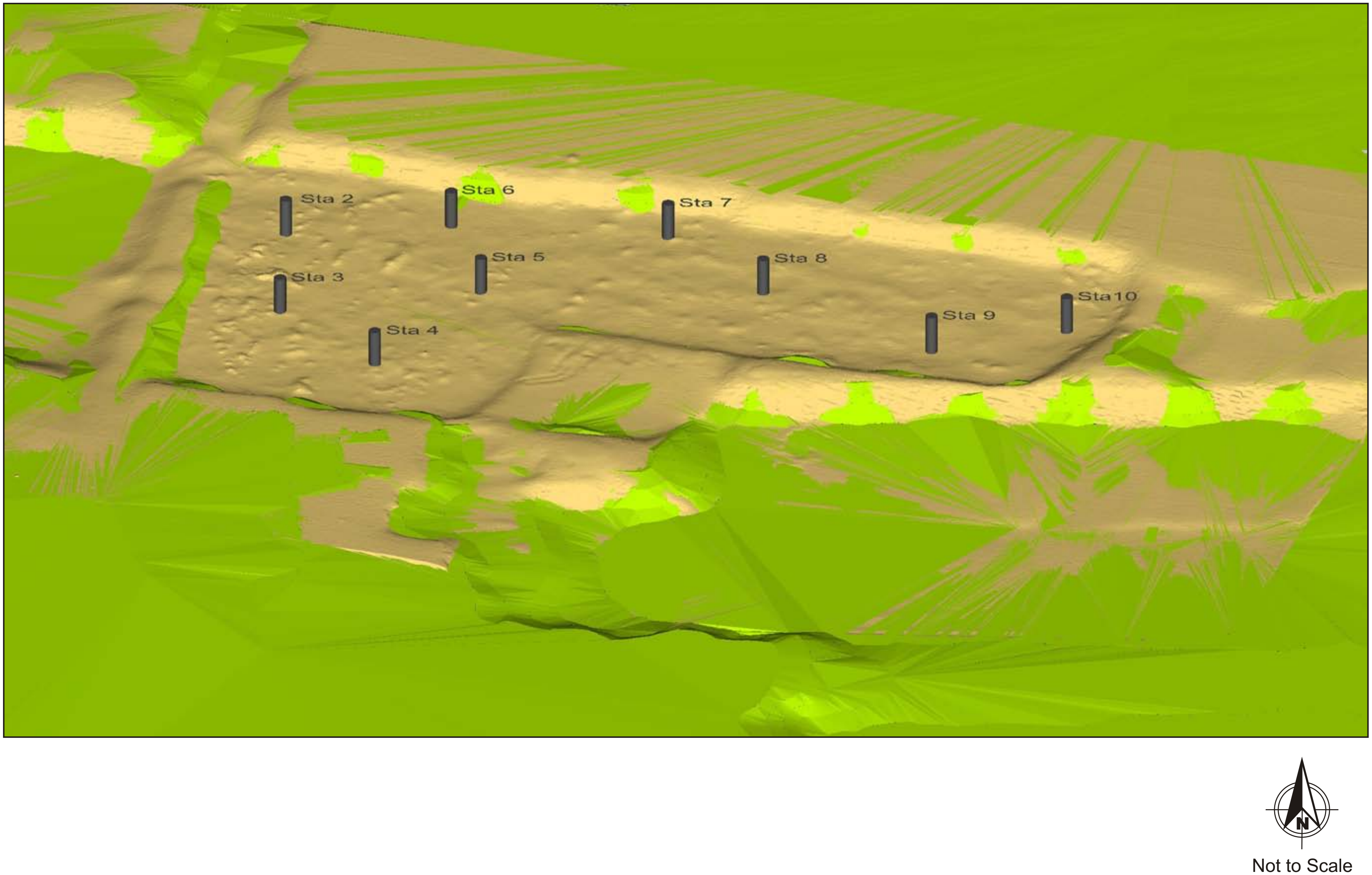


**Figure 4-3**
Post Construction to Year 3 Isopach Figure - Plan View


Jun 09, 2005 12:50pm cdavidson K:\Jobs\040076-NEI LA Dist Pilot Studies\04007601\04007601-03.dwg Anc-B-Land

**Figure 4-4**

Year 3 Topographic Plan View of NEIBP Cap Site

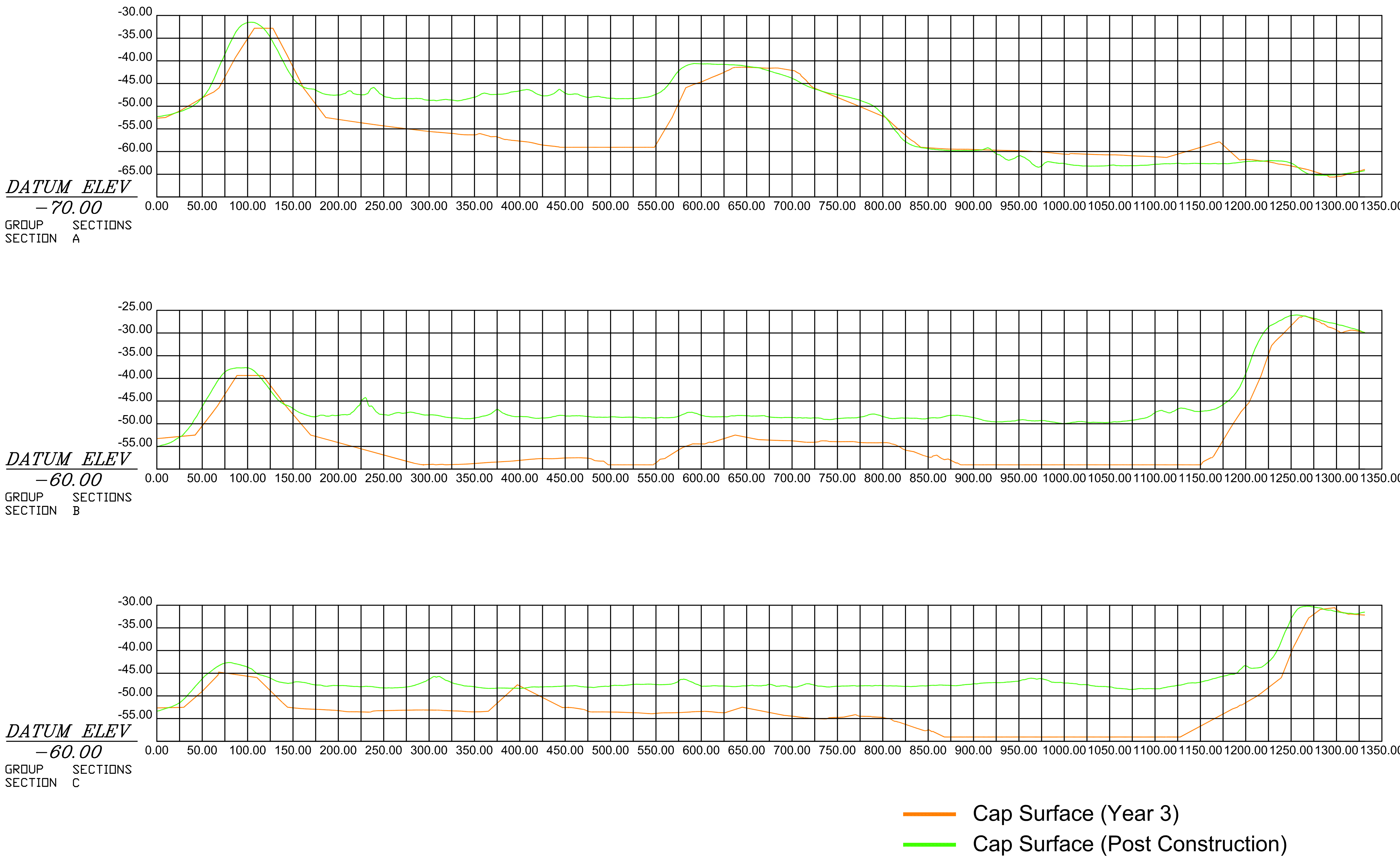


**Figure 4-5**

Post Construction to Year 3 Cross Sections a, b, c

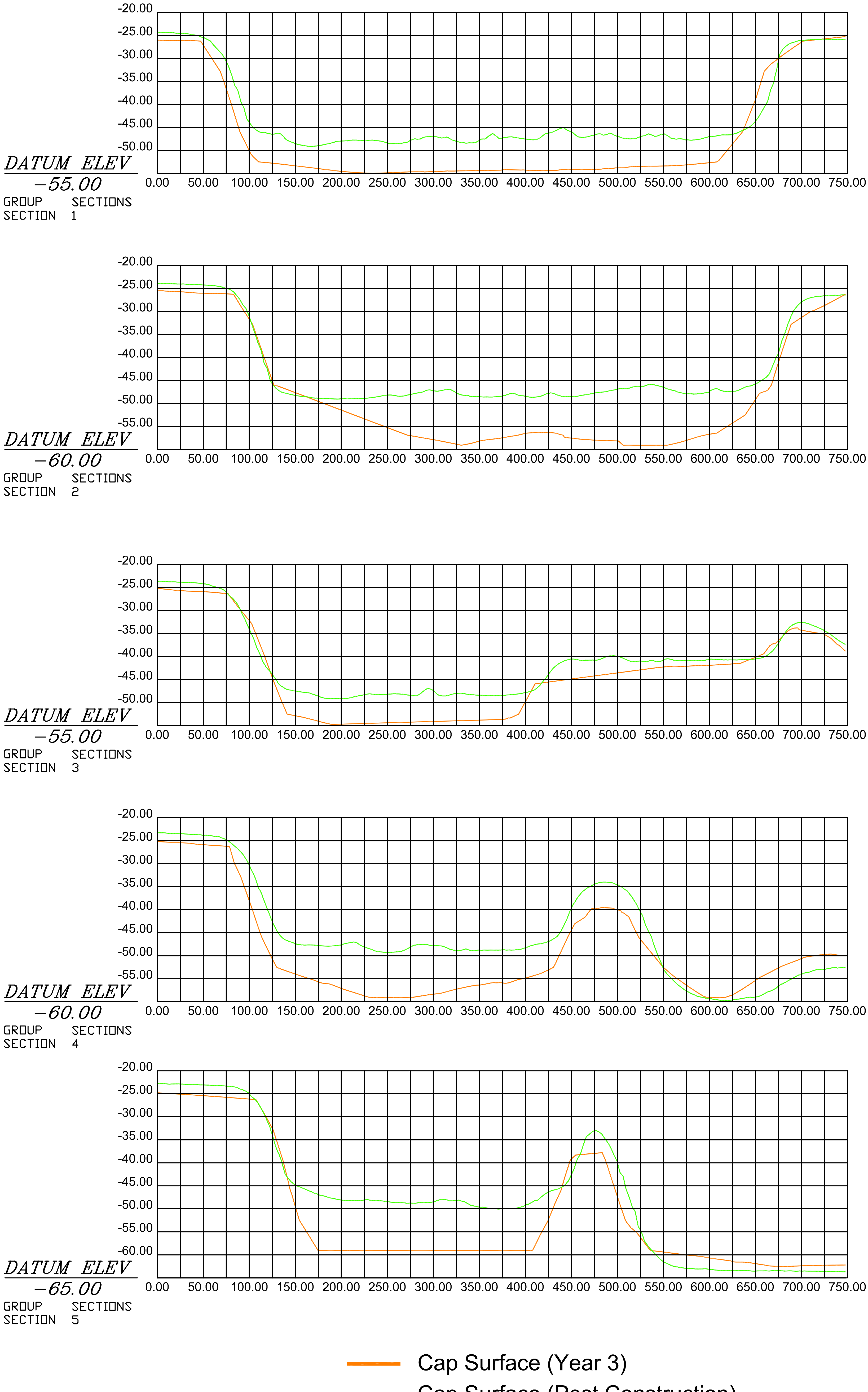


**Figure 4-6**

Post Construction to Year 3 Cross Sections 1,2,3,4,5

Multi-beam echo sounder images revealed surface mounding on the west end of the cap site in all three years. These mounds ranged in height from 0.5 to 0.75 m above the surrounding sediment and were likely created early in the construction process when the split hull barges were held stationary while placing the LARE material into the borrow pit. The engineering team noted this during operations and immediately changed procedures for the remainder of the project by moving the split hull barges by tug as the dredge material was being discharged to reduce the impact on the borrow pit bottom. As a result, the surface on the east end of the cap site is much smoother. Another factor that may have caused the mounding could be a result of a re-handling experiment conducted early in the pilot study to evaluate the feasibility of placing the cap using the clam shell bucket.

## 4.2 Chemical Containment

### *4.2.1 Physical and Chemical Characteristics of Sediment Cores*

#### *4.2.1.1 Year 1*

In Year 1, samples were collected from the nine sediment cores collected for visual observations (see Section 4.1.1) and analyzed for particle size, density, TOC, total solids (TS), metals, and PAHs. Three sample intervals were collected from each core (the upper 0 - 10 cm; the upper 10 cm of the LARE material at the interface with the cap; and a 10-cm interval from the mid-point between the other two samples) (Figure 4-7).

<u>Year 1 Observations and Deviations from the LTMP</u>

During the video survey of the NEIBP, several "large" burrow mounds were observed on the cap surface prompting speculation that adult ghost shrimp may be present and burrowing through the cap sediments and into the LARE material. To test this hypothesis, six additional sediment samples were collected from randomly selected burrow mounds that were greater than 2 cm in diameter to determine if the burrow mound material matched the chemical constituents and concentration of the LARE. Divers collected samples of the burrow mound material using an 8 ounce EPA certified glass container until the container was ¾ full and then capped the container underwater. These samples were then analyzed for the same constituents described above for the cap cores. Study results are presented in subsequent sections, by analyses.

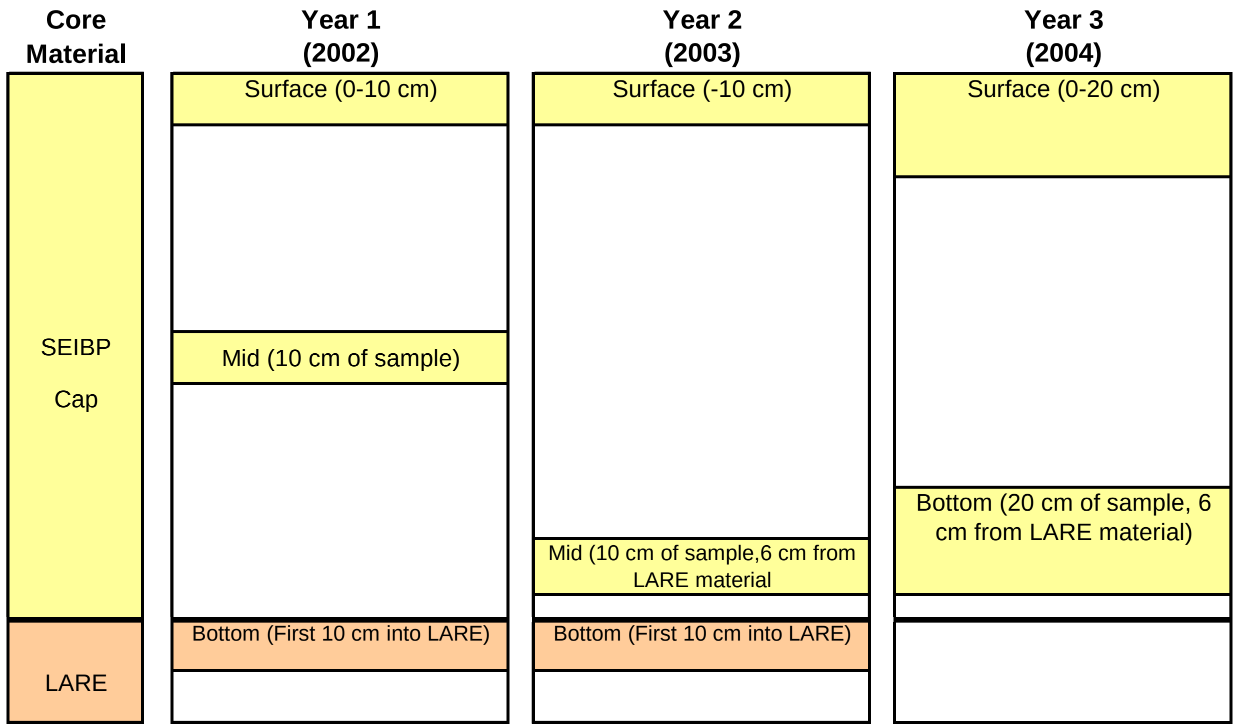


**Figure 4-7**
**Schematic of Core Samples Taken Years 1 through 3**

Particle Size

The cap site surface and middle core layers were composed of sand (91 and 85%, respectively) and the bottom LARE material, while still high in sand, contained a much higher percentage of fines (45%) (Table 4-2). Burrow mound sediments were similar in composition to the core bottom samples, contained 45 percent fines and 55 percent sand, and were characterized as very fine sand. The dispersion of particle sizes for all of the core layers and burrow mounds were relatively heterogeneous, being either poorly or very poorly sorted. However, the difference between the cap, the burrow, and LARE material was evident as index values in both the burrow mound and bottom samples were greater (1.80 and 2.10, respectively) than the surface and middle core layers (1.08 and 1.25, respectively).

Percent fine sediments were greatest in the bottom LARE material (45.26%) and burrow mound sediments (44.86%) and lowest in the surface and middle core layers (average = 8.46 and 14.34%, respectively). Percent fine grain size for all samples ranged from 2.20 to 68.13 percent.

**Table 4-2**
**Year 1 Chemistry Results**

| Constituent | NEIBP Year 1 – Cap Material | | | NEIBP Year 1 – Bottom LARE Material | | |
|---|---|---|---|---|---|---|
| | Avg[1] | 95% CI | Min - Max | Avg | 95% CI | Min - Max |
| Fines (<63 μm) – (%) dry wt. | 10.15 | 0.00 | 2.20 - 40.67 | 45.3 | 11.9 | 15.8 – 68.1 |
| TOC – (%) dry wt. | 0.54 | 0.00 | 0.29 - 0.81 | 1.38 | 0.38 | 0.64 – 2.50 |
| TS – (%) dry wt. | 77.66 | 0.00 | 63.60 - 81.80 | 67.81 | 4.52 | 55.30 – 69.70 |
| **Metals – mg/Kg (ppm) dry wt.** | | | | | | |
| Antimony | 0.00 | 0.00 | 0.00 - 0.00 | 0.08 | 0.11 | 0.00 - 0.49 |
| Arsenic | 4.14 | 0.00 | 3.11 - 6.63 | 4.95 | 0.79 | 2.96 - 7.09 |
| Cadmium | 0.15 | 0.00 | 0.12 - 0.22 | **1.77** | 0.74 | 0.38 - **3.78** |
| Chromium | 15.84 | 0.00 | 11.40 - 23.40 | 41.88 | 24.06 | 18.40 - **136.00** |
| Copper | 3.97 | 0.00 | 1.97 - 6.12 | **44.81** | 16.22 | 11.10 - **92.70** |
| Lead | 4.17 | 0.00 | 3.31 - 5.37 | **78.32** | 35.10 | 16.10 - 179.00 |
| Mercury | 0.000 | 0.000 | 0.000 - 0.000 | 0.006 | 0.007 | 0.000 - 0.030 |
| Nickel | 5.91 | 0.00 | 3.58 - 9.59 | **24.97** | 18.02 | 8.34 - **96.20** |
| Silver | 0.02 | 0.00 | 0.00 - 0.18 | 0.44 | 0.24 | 0.02 - **1.18** |
| Zinc | 32.36 | 0.00 | 24.10 - 47.60 | **228.21** | 81.92 | 61.90 - **477.00** |
| **Organics – μg/Kg (ppb) dry wt.** | | | | | | |
| Total PAH | 99.73 | 0.00 | 6.00 - 897.00 | 2278.51 | 696.04 | 946.70 - **4140.80** |

1. Includes surface and mid core layer samples from each of 9 CAD sites.
Bold Value = exceeds ER-L from Long et al. 1995.
Bold Value = exceeds ER-M from Long et al. 1995.

Density

Average sediment density for all stations combined was highest in the surface and mid-depth cap samples (average = 2.64 and 2.62 g/cm$^3$) and was lowest in the LARE material (average = 1.83 g/cm$^3$). Density ranged from 1.32 to 2.74 g/ cm$^3$ for all samples. Burrow mound sediment density was similar to the surface and mid-depth core layers (2.47 ±0.13 g/cm$^3$).

Total Organic Carbon

TOC concentrations were highest in the LARE material (average = 1.38%) compared to the surface (average = 0.62%) and mid-depth core samples (average = 0.47%). TOC ranged from 0.29% to 2.50 percent. Average burrow mound TOC concentrations was slightly higher than the surface and middle core samples (0.73%).

Total Solids

TS were similar among all core depths and were only slightly lower, on average, in the LARE material (average = 67.8%) compared to the surface (average = 75.0%) and mid-depth core samples (average = 80.3%). Burrow mound TS were much lower than in the core layers (average = 29.8%). TS for all samples ranged from 23.0 to 81.8 percent.

Metals and PAHs

Of the 15 metals measured in each core layer, the average concentrations of 12 (Al, Sb, Be, Cd, Cr, Cu, Fe, Pb, Hg, Ni, Ag, and Zn) were higher in the bottom LARE material than in either the surface or mid-depth core layers. Antimony (Sb) and mercury (Hg) were below detection limits in the surface and mid-depth core layers, while selenium (Se) was the only metal that was below detection in the LARE material. Total PAH concentrations were an order of magnitude higher in the bottom core material (average = 2,278 μg/Kg) than in either the surface or mid-depth core layer samples (56 and 142 μg/Kg, respectively).

Burrow Mound Chemistry Results

The burrow mound and bottom core sediments were more widely distributed or heterogeneous, while the surface and mid-depth core samples were more narrowly distributed or homogeneous. Three of the six burrow mound samples contained a greater proportion of larger sand particles indicating that the cap material probably mixed with these predominantly finer particles.

The average concentrations of six of the 15 metals (Al, Sb, As, Be, Fe, and Se) measured in the six burrow mound samples exceeded concentrations in the surface, mid-depth, and bottom core material. The concentrations of seven metals (Cd, Cr, Cu, Pb, Ni, Ag, and Zn) were greater in the burrow mound sediments than in either the surface or middle core layers, but were less than the concentrations found in the bottom material. The concentration of barium measured in the burrow mound sediments was similar to both the middle layer and bottom material, and was greater than the surface core layer. Total PAH concentrations in the burrow mound sediments (176 μg/Kg) were similar to those measured in the surface and mid-depth core layers, and far below those measured in the LARE material.

To determine if the elevated metals concentrations in the burrow mounds were from bioturbation or settling of new material on the cap, both surface sediment and burrow mound data were normalized to % fine sediments. Normalized results indicated that the burrow mounds and surface sediment concentrations were similar and not related to the LARE material. This suggests that contaminant concentrations in the burrow mounds were most likely due to deposition of new material on the surface of the cap instead of chemical migration from the LARE either by chemical flux or through bioturbation.

#### *4.2.1.2 Year 2*

Year 2 samples were collected from the same nine stations as in Year 1. Three sub-samples were again taken from each core. The first two samples were collected from the same intervals of the core as were described in Year 1: a surface sample and a bottom sample at the boundary of the LARE and cap material. The third sample, however, was moved from the mid-point between the first two samples to 3 cm above the bottom sample. A 10-cm composite sample was taken from each of these depth intervals and analyzed for particle size, density, TOC, TS, metals, and PAHs.

This modification was made to the sediment core sampling design to determine if chemical migration could be detected immediately above the boundary layer of the LARE and cap material. If a complete failure of the cap had occurred, chemical migration would have been observed at the mid-point of the sediment core which was sampled in Year 1. The results from Year 1 indicated that a complete failure had not occurred. However, to ensure that no chemical migration was occurring, the mid-depth sample was moved to the point just above the interface between the LARE and the cap.

<u>Year 2 Observations and Deviations from the LTMP</u>

Other modifications to the sediment core sampling design also occurred in Year 2. The core taken at Station 2 was sampled every 10 cm to evaluate potential mixing between the cap and LARE material and to provide a better understanding of potential chemical flux from the LARE material. To investigate the possibility that organisms were transporting contaminants from the LARE to the surface sediments through bioturbation, additional sediment from burrow mound samples was also collected using a more accurate sampling technique. The revised burrow mound sampling program included six burrow mound and six non-burrow mound surface samples from the NEIBP cap site, plus three burrow mound and three non-burrow mound surface samples from adjacent harbor sediments outside the borrow pit. Sampling occurred via SCUBA diver using a slurp gun and all the additional sediment samples were analyzed for the same constituents described above.

Particle Size

The surface and mid-depth core layers were composed of sand (76 and 75%, respectively) compared to the bottom LARE material (54% sand) (Table 4-3). Conversely, the bottom layers contained a higher percentage of fines (41%) than either the surface (20%) or middle layers (21%). Each layer was characterized as fine sand and, as in Year 1, were slightly more heterogeneous in the bottom LARE material compared to the surface and mid-depth layers.

The particle size distribution of burrow mound and surface sediments from the cap site were similar as were the samples taken from outside the pit from the surrounding harbor surface sediments, but differed between the two locations (Table 4-3). The composition of cap site burrows and surface sediments were more balanced between fines (61 and 55%, respectively) and sand (39 and 45%, respectively), while the harbor burrows and surface sediments were characterized by much greater percentages of sand (77 and 76%, respectively) than fines (23 and 23%, respectively). Both cap site burrows and surface sediments were characterized as medium to coarse silt, while the harbor burrows and surface sediments were characterized as fine sand.

Percent fine sediments were greatest in the bottom LARE material (41.5%) and burrow mound sediments (61.0%) and smallest in the surface and middle core layers (average = 19.9 and 21.2%, respectively). Percent fines for all samples ranged from 2.20 to 68.13 percent.

**Table 4-3**
**Year 2 Chemistry Results**

| Constituent | NEIBP Year 2 – Cap Material | | | NEIBP Year 2 – Bottom LARE Material | | |
|---|---|---|---|---|---|---|
| | Avg[1] | 95% CI | Min - Max | Avg | 95% CI | Min - Max |
| Fines (<63 µm) – (%) dry wt. | 20.28 | 4.83 | 4.20 - 44.59 | 43.9 | 13.4 | 21.6 – 71.1 |
| TOC – (%) dry wt. | 0.43 | 0.11 | 0.00 - 0.92 | 2.37 | 0.78 | 0.00 – 3.74 |
| TS – (%) dry wt. | 75.69 | 1.50 | 71.60 - 82.30 | 65.09 | 2.73 | 58.80 - #VALUE! |
| **Metals – mg/Kg (ppm) dry wt.** | | | | | | |
| Antimony | 0.28 | 0.11 | 0.14 - 1.25 | 0.88 | 0.20 | 0.47 - 1.41 |
| Arsenic | 4.19 | 0.24 | 3.50 - 5.35 | 5.11 | 1.25 | 2.04 - 7.92 |
| Cadmium | 0.17 | 0.05 | 0.08 - 0.44 | 2.26 | 0.88 | 0.74 - **4.49** |
| Chromium | 20.14 | 1.84 | 14.40 - 30.90 | 38.82 | 10.30 | 14.50 - **62.20** |
| Copper | 10.56 | 1.84 | 6.18 - 20.80 | **58.69** | 18.89 | 23.50 - **108.00** |
| Lead | 8.88 | 3.91 | 1.98 - 34.00 | **98.07** | 33.00 | 37.40 - 170.00 |
| Mercury | 0.034 | 0.015 | 0.000 - 0.130 | **0.198** | 0.088 | 0.010 - **0.380** |
| Nickel | 10.49 | 0.85 | 7.73 - 15.30 | **23.29** | 5.54 | 10.70 - **36.20** |
| Silver | 0.03 | 0.01 | 0.00 - 0.07 | 0.05 | 0.02 | 0.00 - 0.08 |
| Zinc | 48.80 | 7.34 | 31.30 - 91.00 | **301.00** | 87.54 | 126.00 - **537.00** |
| **Organics – µg/Kg (ppb) dry wt.** | | | | | | |
| Total PAH | 94.41 | 67.06 | 0.00 - 431.60 | 3161.01 | 687.44 | 1759.30 - **5117.70** |

1. Includes surface and mid core layer samples from each of 9 CAD sites.
Bold Value = exceeds ER-L from Long et al. 1995.
Bold Value = exceeds ER-M from Long et al. 1995.

Density

Average sediment density was similar in the surface, middle and bottom samples (average = 1.72, 1.58 and 1.43 g/cm$^3$, respectively) and lowest in the cap site burrow mound samples (0.78 g/cm$^3$). Density ranged from 0.78 to 1.97 g/cm$^3$ for all samples (ABC 2004).

Total Organic Carbon

TOC concentrations were greatest in the bottom LARE material (2.37%) and less than 1 percent in the surface, middle and burrow mound samples (average = 0.36, 0.49 and 0.82%, respectively). TOC ranged from 0.01 to 3.74 percent.

Total Solids

TS were similar among core depths and were only slightly lower, on average, in the LARE material (65.1%) compared to the surface (73.79%) and middle core samples

(77.4%). Burrow mound TS were lower than in the core layers (36.48%). TS for all samples ranged from 36.48 to 82.3 percent.

Metals and PAHs

The average of most metal concentrations was higher in the bottom LARE material than either the surface or middle core layers. Aluminum and silver concentrations were not much higher in the LARE material compared to the cap layers. None of the metals measured were below detection limits in any core layer. Total PAH concentrations were an order of magnitude higher in the bottom core material (average = 3161 μg/Kg) than in either the surface or middle core layer samples (23 and 166 μg/Kg, respectively).

High Resolution Core Study

Density for all Station 2 core layers was greatest at the surface and just above the LARE/cap interface, and lower at all other depths. TOC was above 2 percent in the bottom LARE material and below 1 percent in each of the cap layers. TS were similar at all depths (80%) though slightly lower in the bottom LARE material (<70%). Percent fine sediments were greatest in the bottom LARE material (63%), followed by the 60- to 70-cm cap layer (42%). Percent fines at all other core layers were below 20 percent.

Except for silver, the concentrations of each of the 15 metals measured were lower in the cap material than in the bottom LARE layers. Of particular note are the metals concentrations measured in the layer just above (3 cm) the LARE/cap interface where no elevated concentrations were observed. This confirmed that vertical migration of the LARE contaminants was not occurring and the cap has not been compromised. Silver concentrations were slightly elevated in the middle layers of the cap, but were undetected in the lower layers of the cap and bottom LARE material. This suggests and outside source of silver, perhaps from the SEIBP when the cap material was harvested. Regardless, all detected concentrations were very low and just above the method detection limit of 0.01 mg/Kg.

Burrow Mound Study

The average concentration of five (Al, As, Be, Fe, and Ag) of the 15 metals measured in the six burrow mound samples exceeded concentrations in the surface, middle and bottom core material. The concentrations of five other metals (Sb, Cd, Cu, Pb, and Zn) were greater in the burrow mound sediments than in either the surface or middle core layers, but were less than the concentrations found in the bottom material. The concentrations of four metals (Ba, Cr, Ni, and Se) were similar in the burrow mound samples and the bottom LARE material. Total PAH concentrations in the burrow mound sediments (564 μg/Kg) were slightly higher than those measured in the surface and middle core layers, but far below those measured in the LARE material (3,161 μg/Kg).

The concentrations of metals and PAHs collected in sediments from cap site burrow mounds and the associated surface sediments were not significantly different from one another, but were, on average, slightly higher in the burrow mound samples. Metals concentrations from harbor burrow mounds and the associated surface sediments were also nearly the same. In every case, metals concentrations from either the cap site burrows or surface sediments were the same or slightly greater than those measured from the harbor burrows or surface sediments. A clear cut pattern was not evident when surface and burrow mound metal results were compared to core measurements. Several metal results (Al, As, Be, and Fe) were higher in burrow mound and surface sediments, than in either the surface and bottom core samples. For the rest, concentrations were higher in the burrow mound and surface sediments than in the surface core samples, but equal to or below the concentrations measured in the LARE.

To determine if physical sediment characteristics were a major factor contributing to elevated contaminant concentrations in the burrow mounds, Year 2 chemistry results were normalized to sediment percent fines. Normalized data results showed a decrease in eight of the 15 metals concentrations from the burrow mound and LARE samples, but not samples taken from the surface or the middle of the cap. This indicated elevated concentrations of metals were dependent upon particle size rather than upon input from the LARE layer. Cadmium, copper, lead, and zinc, and, in particular, total PAH concentrations were low in the burrow mound sediments, but remained elevated in the LARE material, indicating that the sources of these compounds are different between the burrow mounds and LARE material.

#### *4.2.1.3 Year 3*

In July 2004, the original nine sampling stations, 2 – 10, were re-sampled by the Navy divers using push core sampling equipment. Samples collected from the cores focused primarily on the cap material. Surface samples were collected to determine the characteristics of newly settled material on the cap. As in Year 2, samples were collected just above the LARE/cap interface to determine if chemical migration from the LARE material was occurring. If a distinct layer was visually identified between the surface and interface layers, additional sub-samples were collected at each layer. As in previous years, all samples were analyzed for particle size, density, TOC, TS, metals, and PAHs (Table 4-4).

<u>Observations and Deviations from the LTMP</u>

Two additional stations were added to the original nine locations in Year 3 for pore water analyses to determine if dissolved metals could be detected moving through the cap from the LARE material. Sediment pore water was collected using a well point assembly which consisted of a 1-inch-diameter by 1-foot-long pre-cleaned stainless steel, screened tube (well point) covered by a stainless steel driving sheath, and a 4-foot extension rod. The well points were installed adjacent to Station 2 and Station 10 in the cap site by the Navy divers using SCUBA equipment. After descending to the bottom along a fixed rope, the divers drove the well point assembly approximately 1.5 feet into the cap material so that the screened portion of the well would be positioned approximately half way through the cap layer. After purging the line and allowing to equilibrate for 24 hours, pore water was pumped to the surface using a peristaltic pump and filtered through a 0.45 mm cartridge filter directly into the sample bottles for metals analyses.

**Table 4-4**
**Year 3 Chemistry Results**

| Analyte | ER-L | ER-M | LAC-2 0-20 | LAC-2 100-120 | LAC-3 0-20 | LAC-3 60-80 | LAC-3 80-94 | LAC-4 0-20 | LAC-4 140-148 | LAC-4 148-160 | LAC-4 160-180 | LAC-5 0-20 | LAC-5 140-153 | LAC-6 0-20 | LAC-6 120-140 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Bulk Density | --- | --- | 1.64 | 1.68 | 1.58 | 1.67 | 1.54 | 1.64 | 1.71 | 1.79 | 1.42 | 1.76 | 1.68 | 1.54 | 1.63 |
| Total Organic Carbon (dry) | --- | --- | 0.14 | 0.16 | 0.24 | 0.25 | 0.23 | 0.11 | 0.24 | 0.19 | 0.31 | 0.32 | 0.6 | 0.08 | 0.38 |
| Total Organic Carbon (wet) | --- | --- | 0.11 | 0.13 | 0.2 | 0.2 | 0.19 | 0.09 | 0.2 | 0.16 | 0.25 | 0.24 | 0.49 | 0.06 | 0.3 |
| Total Solids | | | 79.7 | 80.2 | 82.4 | 81.4 | 82.1 | 79.2 | 82.4 | 82.2 | 81.9 | 75.8 | 82.2 | 79.8 | 79.3 |
| | | | | | | | | | | | | | | | |
| **Metals (mg/Kg dry wt)** | | | | | | | | | | | | | | | |
| Antimony | --- | --- | 0.1 | ND | ND | ND | ND | ND | 0.2 | ND | 0.4 | 0.2 | ND | 0.1 | ND |
| Arsenic | 8.2 | 70 | 2.4 | 2.8 | 3 | 2.9 | 2.7 | 2.5 | 3.2 | 3.4 | 2.8 | 4.8 | 2.6 | 2.8 | 2.9 |
| Barium | --- | --- | 69.6 | 66.1 | 64.9 | 68.6 | 66.1 | 72 | 57.7 | 92.5 | 80.6 | 117 | 68.8 | 78.4 | 57.7 |
| Beryillium | --- | --- | 0.19 | 0.29 | 0.23 | 0.17 | 0.17 | 0.19 | 0.24 | 0.25 | 0.27 | 0.54 | 0.2 | 0.23 | 0.18 |
| Cadmium | 1.2 | 9.6 | ND | 0.1 | 0.1 | ND | ND | ND | ND | 0.1 | 0.2 | 0.4 | 0.1 | ND | ND |
| Chromium | 81 | 370 | 12.1 | 13.9 | 12.1 | 13.8 | 11.3 | 11.9 | 10.4 | 14.1 | 14.2 | 27.4 | 11.9 | 12.8 | 9.5 |
| Copper | 34 | 270 | 6 | 8.7 | 7.4 | 5.5 | 5.9 | 5.9 | 6.9 | 7.6 | 9 | 23 | 6.3 | 5.8 | 4.9 |
| Lead | 46.7 | 218 | 4.6 | 5 | 3.5 | 2.6 | 3.4 | 2.8 | 3 | 3.5 | 7.1 | 29.1 | 4.1 | 3 | 2.4 |
| Mercury | 0.15 | 0.71 | ND | ND | ND | 0.05 | ND | 0.02 | ND | ND | 0.04 | 0.06 | ND | ND | ND |
| Nickel | 20.9 | 51.6 | 7 | 8.3 | 7.4 | 7.7 | 6.1 | 6.9 | 6.5 | 8.7 | 8.5 | 16.3 | 6.9 | 7.5 | 5.9 |
| Selenium | --- | --- | ND | ND | ND | ND | ND | ND | ND | ND | ND | ND | ND | ND | ND |
| Silver | 1 | 3.7 | ND | ND | ND | ND | ND | ND | ND | ND | ND | 0.2 | ND | ND | ND |
| Zinc | 150 | 410 | 29 | 32 | 32 | 27 | 26 | 25 | 23 | 28 | 42 | 81 | 30 | 30 | 27 |
| | | | | | | | | | | | | | | | |
| **Organics (ug/Kg dry wt)** | | | | | | | | | | | | | | | |
| Naphthalene | 160 | 2100 | 1.3 | 1.3 | 0.93 | 0.68 | 1.2 | 1.1 | 1 | 0.84 | 1.3 | 0.8 | 1.5 | 1 | 0.62 |
| 2-Methylnaphthalene | 70 | 670 | 0.56 | 0.6 | 0.44 | ND | 0.62 | ND | 0.47 | 0.46 | 0.6 | ND | 0.93 | ND | ND |
| Acenaphthylene | 44 | 640 | ND | ND | ND | ND | ND | ND | ND | ND | 0.68 | ND | 0.39 | ND | ND |
| Acenaphthene | 16 | 500 | ND | 0.24 | ND | ND | 0.34 | ND | ND | ND | 0.39 | ND | 0.8 | ND | ND |
| Fluorene | 19 | 540 | 0.35 | 0.54 | 0.66 | ND | 0.38 | ND | ND | 0.27 | 0.55 | ND | 1.1 | ND | ND |
| Dibenzofluran | --- | --- | 0.25 | 0.31 | 0.21 | ND | 0.32 | ND | ND | 0.22 | 0.35 | ND | 0.67 | ND | ND |
| Phenanthrene | 240 | 1500 | 1.5 | 2.1 | 4.1 | ND | 3.2 | 0.47 | 0.42 | 1.7 | 5.1 | 0.44 | 3.9 | ND | ND |
| Anthracene | 85.3 | 1100 | 0.45 | 0.45 | 5 | ND | 0.82 | ND | ND | 0.48 | 1.3 | ND | 1.1 | ND | ND |
| Fluoranthene | 600 | 5100 | 3.2 | 3.8 | 2.5 | 0.64 | 8.1 | 0.7 | 0.75 | 7.2 | 11 | 0.84 | 9.2 | 0.65 | ND |
| Pyrene | 665 | 2600 | 3.3 | 4 | 1.8 | 1.2 | 9.6 | 0.85 | 0.93 | 7.6 | 13 | 1.2 | 9.5 | 0.85 | 0.49 |
| Benzo(b)fluoranthene | --- | --- | 1.7 | 1.6 | ND | ND | 3.8 | ND | ND | 1.8 | 5.5 | ND | 3.9 | ND | ND |
| Benzo(k)fluoranthene | --- | --- | 1.5 | 1.2 | 0.57 | ND | 3.7 | ND | ND | 1.6 | 5.5 | ND | 3.4 | ND | ND |
| Benz(a)anthracene | 261 | 1600 | 1.3 | 1.2 | 2 | 0.26 | 3.7 | 0.23 | 0.34 | 1.9 | 5.4 | 0.35 | 3.1 | ND | ND |
| Chrysene | 384 | 2800 | 2.3 | 2.2 | 6.6 | ND | 5.6 | ND | 0.54 | 2.7 | 8.3 | ND | 5.6 | ND | ND |
| Benz(a)pyrene | 430 | 1600 | 1.4 | 1.3 | 0.47 | 0.35 | 3.5 | 0.31 | 0.4 | 1.5 | 5.7 | 0.37 | 4 | 0.42 | ND |
| Indeno(1,2,3-cd)pyrene | --- | --- | 1.4 | 1.2 | 0.37 | 0.41 | 2.7 | ND | 0.41 | 1.4 | 4.4 | 0.38 | 3.2 | 0.38 | ND |
| Dibenz(a,h)anthracene | 63.4 | 260 | 0.37 | 0.34 | ND | ND | 0.57 | ND | ND | ND | 0.94 | ND | 0.85 | ND | ND |
| Benzo(g,h,i)perylene | --- | --- | 2.1 | 1.8 | 0.48 | 0.56 | 3.4 | 0.41 | 0.5 | 1.9 | 5.6 | 0.49 | 5.4 | 0.46 | ND |
| | | | | | | | | | | | | | | | |
| **Total PAHs** | 4022 | 44792 | 22.98 | 24.18 | 26.13 | 4.1 | 51.55[1] | 4.07 | 5.76 | 31.57 | 75.61 | 4.87 | 58.54[1] | 3.76 | 1.11 |

**Table 4-4**
**Year 3 Chemistry Results (continued)**

| Analyte | ER-L | ER-M | LAC-7 | LAC-7 | LAC-8 | LAC-8 | LAC-8 | LAC-9 | LAC-9 | LAC-10 | LAC-10 | LAC-10 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | 0-20 | 100-120 | 0-20 | 100-120 | 120-135 | 0-20 | 100-120 | 0-20 | 120-140 | 140-160 |
| Bulk Density | --- | --- | 1.77 | 1.85 | 1.66 | 1.78 | 1.76 | 1.68 | 1.52 | 1.94 | 1.67 | |
| Total Organic Carbon (dry) | --- | --- | 0.19 | 0.21 | 0.12 | 0.25 | 0.76 | 0.13 | 0.42 | 0.23 | 1.3 | |
| Total Organic Carbon (wet) | --- | --- | 0.15 | 0.17 | 0.1 | 0.2 | 0.62 | 0.1 | 0.32 | 0.19 | 0.97 | |
| Total Solids | | | | | 79.5 | 80.4 | 81.2 | 77.4 | 75.7 | 80.6 | 74.9 | |
| | | | | | | | | | | | | |
| **Metals (mg/Kg dry wt)** | | | | | | | | | | | | |
| Antimony | --- | --- | ND | ND | 0.1 | 0.2 | 0.1 | ND | 0.2 | 0.1 | ND | 0.2 |
| Arsenic | 8.2 | 70 | 3.7 | 2.9 | 3 | 3.3 | 4.3 | 2.5 | 3 | 2.7 | 2.4 | 3.7 |
| Barium | --- | --- | 106 | 61.2 | 60.5 | 56.1 | 116 | 60.1 | 56.6 | 51.9 | 80.8 | 80 |
| Beryillium | --- | --- | 0.37 | 0.22 | 0.23 | 0.18 | 0.68 | 0.16 | 0.22 | 0.17 | 0.22 | 0.3 |
| Cadmium | 1.2 | 9.6 | 0.2 | ND | ND | ND | 1.4 | ND | 0.3 | ND | ND | 0.6 |
| Chromium | 81 | 370 | 19.5 | 11.7 | 12.6 | 10.1 | 24.6 | 11 | 11.8 | 11.4 | 12.4 | 17.4 |
| Copper | 34 | 270 | 12.6 | 6.3 | 6.3 | 5 | 32.8 | 5.1 | 9.2 | 16.3 | 6.1 | 23.1 |
| Lead | 46.7 | 218 | 6.8 | 3 | 3 | 2.9 | 10.8 | 2.7 | 8.4 | 4.3 | 3.6 | 72.9 |
| Mercury | 0.15 | 0.71 | ND | ND | 0.06 | 0.04 | 0.05 | ND | 0.04 | ND | ND | ND |
| Nickel | 20.9 | 51.6 | 12.1 | 6.9 | 7.6 | 6.1 | 24.2 | 6.6 | 7.4 | 6.3 | 7.4 | 12.5 |
| Selenium | --- | --- | ND | ND | ND | ND | ND | ND | ND | ND | ND | ND |
| Silver | 1 | 3.7 | ND | ND | ND | ND | 0.2 | ND | ND | ND | ND | 0.2 |
| Zinc | 150 | 410 | 51 | 25 | 46 | 23 | 56 | 25 | 51 | 25 | 28 | 96 |
| | | | | | | | | | | | | |
| **Organics (ug/Kg dry wt)** | | | | | | | | | | | | |
| Naphthalene | 160 | 2100 | 1 | 1 | 0.8 | 1.1 | 5.1 | 0.97 | 1.5 | 0.91 | 0.92 | 3.3 |
| 2-Methylnaphthalene | 70 | 670 | 0.56 | 0.61 | ND | 0.5 | 5.2 | 0.54 | 1.5 | ND | ND | 2.4 |
| Acenaphthylene | 44 | 640 | ND | ND | ND | ND | 6.2 | ND | 0.36 | ND | ND | 1.3 |
| Acenaphthene | 16 | 500 | ND | ND | ND | ND | 3.2 | ND | 0.29 | ND | ND | 1.1 |
| Fluorene | 19 | 540 | ND | ND | ND | ND | 7.2 | ND | 0.8 | ND | ND | 1.7 |
| Dibenzofluran | --- | --- | 0.24 | 0.22 | ND | ND | 3.1 | 0.27 | 0.52 | ND | ND | 0.97 |
| Phenanthrene | 240 | 1500 | 1 | 0.93 | 0.44 | 0.79 | 32 | 1.1 | 5 | 1.2 | 0.95 | 15 |
| Anthracene | 85.3 | 1100 | 0.34 | 0.29 | ND | 0.29 | 18 | ND | 1.3 | 0.39 | 0.45 | 3.6 |
| Fluoranthene | 600 | 5100 | 2.2 | 2.2 | 0.84 | 2.5 | 110 | 1.7 | 15 | 2.7 | 1.3 | 40 |
| Pyrene | 665 | 2600 | 2.6 | 2.8 | 1.2 | 2.7 | 150 | 2.1 | 16 | 3.1 | 2 | 44 |
| Benzo(b)fluoranthene | --- | --- | 1.3 | 1.4 | ND | 1.5 | 74 | 0.94 | 7.1 | 3.1 | 0.81 | 17 |
| Benzo(k)fluoranthene | --- | --- | 1.1 | 1 | ND | 1.2 | 56 | 0.79 | 5.3 | 3.2 | 0.75 | 16 |
| Benz(a)anthracene | 261 | 1600 | 1.2 | 1.2 | 0.35 | 1.3 | 42 | 0.91 | 5.1 | 2.7 | 0.89 | 13 |
| Chrysene | 384 | 2800 | 1.5 | 1.6 | ND | 1.9 | 79 | 1.1 | 10 | 3.1 | 0.82 | 24 |
| Benz(a)pyrene | 430 | 1600 | 1.2 | 1.3 | 0.37 | 1.3 | 59 | 1 | 5.7 | 3.1 | 0.98 | 17 |
| Indeno(1,2,3-cd)pyrene | --- | --- | 1 | 1.1 | 0.38 | 1.1 | 44 | 0.86 | 4.9 | 2.5 | 0.67 | 15 |
| Dibenz(a,h)anthracene | 63.4 | 260 | ND | ND | Nd | ND | 10 | ND | 1.1 | 0.75 | 3.2 | 3.1 |
| Benzo(g,h,i)perylene | --- | --- | 1.3 | 1.4 | 0.49 | 1.4 | 56 | 1.2 | 8.5 | 2.5 | 0.85 | 21 |
| | | | | | | | | | | | | |
| **Total PAHs** | 4022 | 44792 | 16.54 | 17.05 | 4.87 | 17.58 | 760[1] | 13.48 | 89.97 | 29.25 | 14.59 | 239.47 |

1. May be mixed LARE/Cap material

Particle Size

The surface cap material was composed primarily of fine to very fine sand (averaging 38% and 26%, respectively). The interface material was also composed of mostly sand which indicated to mixing of the LARE and cap material.

Density

Average sediment density was similar in the surface, middle and interface samples (average = 1.69, 1.72, and 1.63 g/cm$^3$, respectively). The average density measured in all samples was 1.67 g/ cm$^3$ and ranged from 1.42 g/cm$^3$ at Station 4 in the interface sample and 1.94 g/cm$^3$ in the surface sediments at Station 10 (Table 4-4).

Total Organic Carbon

TOC concentrations within the cap material were generally low (average = 0.30%) with coincided with concentrations measured in Years 1 and 2. The range of TOC from all samples ranged from 0.08 percent to 1.3 percent.

Total Solids

TS were highest in the surface layers of the cap material (average = 75.4%) relative to middle (74.5%) and interface samples (58.61%).

Metals and PAHs

Average metal concentrations were similar to previous years and not significantly different between the cap surface and the layer just above the LARE material (Table 4-4). However, at Station 8 elevated concentrations of cadmium (1.4 mg/Kg) and nickel (24.2 mg/Kg) were detected in the interface layer of the core. Also at Station 10, an elevated concentration of lead (72.9 mg/Kg) was detected in the interface layer. Because elevated levels of these metals were not detected in any of the other interface layers, these samples may have resulted from small amounts of LARE material mixed into the cap material sample. Total PAH concentrations further suggest that this may have been the case with these two samples. Total PAH concentrations in the interface layers at these two locations were 760 μg/Kg (Station 8) and 239 μg/Kg (Station 10), which is much higher than the average concentration of 26 μg/Kg found in all other core samples.

Comparison to Biological Screening Thresholds

Ten metals and total PAHs were compared against the ER-L/ER-M threshold limits (Long et al. 1995) in Years 1 and 2 and nine metals and total PAHs were compared in Year 3 (Tables 4-2, 4-3, and 4-4). For the bottom LARE material collected in Year 1, the average concentration of five metals exceeded the ER-L threshold limit (cadmium, copper, lead, nickel and zinc). Additionally, the maximum concentrations of five constituents exceeded the ER-L (cadmium, chromium, copper, silver, and PAHs) and two exceeded the ER-M (nickel and zinc). In Year 2, the same five metals exceeded the ER-L for the bottom LARE material (cadmium, copper, lead, nickel, and zinc) in addition to mercury. The maximum concentrations of six constituents exceeded the ER-L (cadmium, chromium, copper, mercury, nickel, and PAHs). Only zinc exceeded the ER-M threshold value in Year 2. In Year 3, cadmium and nickel exceeded the ER-L in the interface layer at Station 8 and lead exceeded the ER-L at Station 10. These exceedances were likely due to sampling error where some of the LARE material may have been inadvertently included in the interface layer while sectioning the cores. Total PAHs did not exceed the ER-L or ER-M in Year 3.

Pore Water Chemistry

At Station 2, the pore water concentration of nickel 5.34 µg/L was slightly above the COP water quality objective of 5.0 µg/L (Table 4-5), but well below the average harbor background concentration (29.5 µg/L) observed during the eight-week construction monitoring program. All other metals concentrations measured in the pore water were below COP water quality objectives. These results further confirm that the cap has been effective in isolating the LARE contaminants.

An exceedance of surface water quality criteria deep within a cap is a conservative measure of cap success. If exceedances of surface water criteria did occur in deep pore water this still has very little to do with the success or failure of a cap as it does not represent the actual concentrations of constituents seeping into the surface waters from the cap.

**Table 4-5**
**Well Point Pore Water Chemistry Results**

| Analyte | California Ocean Plan (6 Mo. Median) | California Toxics Rule (CCC) | EPA (CCC) | Mean Harbor Background | Dissolved Pore Water Result (ug/L) | |
|---|---|---|---|---|---|---|
| | | | | | Station 2 | Station 10 |
| Aluminum | --- | --- | --- | --- | 8.02 | 7.06 |
| Antimony | --- | --- | --- | --- | 0.16 | 0.29 |
| Arsenic | 8 | 36 | 36 | 1.3 | 0.18 | 1.11 |
| Beryllium | --- | --- | --- | --- | ND | ND |
| Cadmium | 1 | 9.3 | 9.3 | --- | 0.024 | 0.13 |
| Chromium | 2 | 50 | 50 | 17.9 | 0.6 | 0.36 |
| Cobalt | --- | --- | --- | --- | 0.32 | 0.09 |
| Copper | 3 | 3.1 | 3.1 | 11.5 | 0.037 | 0.056 |
| Iron | --- | --- | --- | --- | 1930 | 615 |
| Lead | 2 | 8.1 | 8.1 | 1.5 | 0.042 | 0.11 |
| Manganese | --- | --- | --- | --- | 103 | 127 |
| Mercury | 0.04 | --- | 0.94 | 0.43 | 0.006 | 0.007 |
| Molybdenum | --- | --- | --- | --- | 12.8 | 24.2 |
| Nickel | 5 | 8.2 | 8.2 | 29.5 | **5.34** | 0.48 |
| Selenium | 15 | 71 | 71 | --- | ND | ND |
| Silver | 0.7 | --- | --- | --- | ND | ND |
| Thallium | --- | --- | --- | --- | ND | ND |
| Tin | --- | --- | --- | --- | 0.046 | 0.06 |
| Titanium | --- | --- | --- | --- | 1.98 | 0.44 |
| Venadium | --- | --- | --- | --- | 1.17 | 1.09 |
| Zinc | 20 | 81 | 81 | 10.8 | 2.77 | 3.52 |

Bold Value = exceeds ER-L from Long et al. 1995.

#### *4.2.1.4 Discussion on Physical and Chemical Characteristics Results*

After three years of monitoring the NEIBP cap site, no evidence of contaminant migration into or through the cap from the LARE dredge material has been observed. Visual observations of the core samples reveal a clear boundary layer between the LARE material, which was fine-grained, black in color, and smelled of petroleum; and the capping material which was dark grey in color, odorless, and sandy. The depth of the overlying cap material met the 1-m depth design criteria for the study based on visual measurements of the core samples collected during all three surveys. Burrows created by bioturbators or surface depositional material from outside the cap site were not observed in any of the cores, but were observed during the video surveys.

Burrow mounds were clearly evident during the diver surveys and sediment samples collected from these mounds in Year 1 revealed elevated concentrations of several target metals above those measured in the LARE material. Further investigation in Year 2 led to the collection of both burrow mound and surface samples from the cap site and surrounding harbor sediments. These samples showed that, while in some cases metals concentrations were elevated in the burrow mounds, they were likewise elevated in surface sediment samples without burrows. Thus, the CSTF concluded that the elevated metals concentrations in the burrow and surface sediment samples were the result of deposition from the surrounding harbor and not material from LARE layer in the cap. This was confirmed with PAH measurements of burrow mound material which showed nearly an order of magnitude lower concentration of PAHs (a LARE indicator chemical) than typically observed in the LARE material, supporting the conclusion that the burrow mounds are not composed of LARE material.

Of the 15 metals and total PAHs measured, none were elevated in the cap material compared to concentrations found in the LARE during each survey. Total PAH concentrations, considered to be the best marker for the LARE material, were orders of magnitude lower in the cap material than in the LARE. Sampling procedural changes occurred during all three years to refine the program and make it more sensitive to potential contaminant migration from the LARE material. The sampling changes did not reveal any evidence that contaminants were migrating into the cap material. Pore water analysis, which is a direct measure of any potential dissolved chemical migration, rather than an indirect measure like bulk chemistry, confirmed that chemical seepage into the cap layers was not occurring.

The ER-L threshold levels were exceeded for several metals and PAHs in the LARE material during Years 1 and 2. In addition the maximum concentrations of several metals exceeded the ER-M levels. None of the constituents measured from either the NEIBP cap or SEIBP sediments exceeded the ER-L limits. In Year 3, cadmium, nickel, and lead exceeded ER-L levels in the interface sediments, but it was likely due to a sampling error rather than chemical migration since it was not detected in any of the other samples or in the pore water.

## 4.3 Biological Re-Colonization of the Cap

### *4.3.1 Benthic Sampling*

The re-colonization of the NEIBP cap site by benthic infauna was investigated during the Year 1 and Year 2 surveys. This investigation included the rate of infauna re-colonization of the cap site, their population composition and a comparison of this community with other areas of the harbor. In Years 1 and 2, samples were collected from the cap site, the harbor sediments and the southern and western portion of the un-capped NEIBP site (Figure 3-1). In Year 2, two additional samples were taken from the SEIBP to determine if the infauna community there could have inoculated the cap site during dredging operations. The sampling results of Years 1 and 2 are presented by ABC (2004) and are summarized below.

Observations and Deviations from the LTMP

A small van Veen grab sampler was used to collect benthic samples during Years 1 and 2. The grab was only able to penetrate 15 cm into the sediment, which may not have been deep enough to collect the bioturbators creating the large burrow mounds. Therefore, in Year 3, two macro benthic grabs (11 cubic yards [$yd^3$]each) were taken in an attempt to collect some of the macro-benthos suspected of creating the large burrow mounds observed by the Navy divers. One grab was collected from the harbor sediments just outside the cap site[1] and the other from the SEIBP (Table 4-6). Both grabs were sieved[2] using a 0.25-inch screen (or wash using hoses), sorted and identified to the lowest practicable taxon. Results from the Year 3 grab sampling are discussed below.

**Table 4-6**
**Benthic Macro Grab Station Locations**

| Station Identification | Latitude | Longitude |
|---|---|---|
| Harbor Macro Grab Station | 33 45.3518 | 118 09.4291 |
| SEIBP Macro Grab Station | 33 45.3205 | 118 09.4304 |

[1] Macro-benthos samples were not collected from within the NEIBP to prevent disturbance of the cap.

[2] Samples were initially sieved using metal screens, but later simply washed off the deck surface while organisms were collected to expedite the process.

#### *4.3.1.1 Year 1*

The total number of organisms (abundance) collected from the survey area during Year 1 was 11,742. Average abundances for each area during Year 1 were greatest in samples collected from uncapped areas of the NEIBP site, but also had the lowest diversity index. The lowest abundance was counted at the cap site as well the lowest average number of species relative to the other areas. The harbor area had the highest average number of species collected.

Polychaetes numerically dominated the infauna community on the cap site in Year 1. Four polychaetes (*Paraprionospio pinnata, Mediomastus* sp.*, Monticellina siblina, Cossura candida*) and a phoronid (*Phoronis* sp.), accounted for 75 percent of the abundance. In contrast, a total of 24 species, including 18 polychaetes and six crustaceans, accounted for 75 percent of the abundance at the harbor during the same survey. Both areas of the uncapped NEIBP were numerically dominated by the polychaete *Cossura candida*, which accounted for 87 percent of the abundance in these areas. Additionally, far fewer taxa were collected in the uncapped NEIBP areas compared to the cap and harbor areas.

Benthic Response Index (BRI) was evaluated each year to determine the condition of the benthic assemblage relative to levels of environmental disturbance such as pollution. In Year 1, the BRI index at the southern part of the uncapped NEIBP fell just above the reference threshold, indicating that some contamination may have affected the composition of this community. The other areas sampled did not appear to have been affected.

Bioturbators were identified each year to determine which infauna species were creating the burrow mounds observed in all three years. Eight infauna species recognized as bioturbators were collected on the 1.0- and 0.5-mm screens during the Year 1 and 2 surveys. Of these, most confine their burrowing activities to less than 18 inches beneath the sediment surface. The burrows of the nemertean, Cerebratulus californiensis, can reach 36 inches, but their burrows travel laterally under the sediment surface. Only *Neotrypaea* sp., the ghost shrimp, has been observed to burrow vertically to depths (> 50 - 90 cm) that could reach the bottom LARE material.

In Year 1, a total of 46 ghost shrimp, mostly juveniles, were collected at 14 of the 20 survey stations in the 1mm screen. Eight of the 14 stations where the ghost shrimp occurred were on the cap site with the greatest abundances of ghost shrimp found at Stations 9 and 10. Ghost shrimp were over twice as abundant on the 0.5-mm screen.

#### *4.3.1.2 Year 2*

The total number of organisms collected from the survey during Year 2, was 11,106 and nearly identical to Year 1. Average abundances were again highest on the uncapped areas of the NEIBP and lowest at the SEIBP site. Harbor sediments again had the highest average of species found. However the number of species doubled at the cap site from the Year 1 survey and the diversity index increased dramatically indicating a rapid recovery of the cap sediments.

The most abundant organisms collected included the polychaetes *Monticellina siblina, Chaetozone corona,* and *Mediomastus* sp., and the crustacean *Amphideutopus oculatus,* which was also the most abundant species collected from the harbor sediments. The infauna population at the harbor sites was similar between Years 1 and 2 in terms of numbers of species and abundance. The uncapped portions of the NEIBP were again dominated by the polychaete *Cossura candida*. Ten species accounted for 75 percent of the abundance at the SEIBP including eight polychaetes, a mollusk, and a phoronid. Like the cap site, the most abundant species collected were the polychaetes *Monticellina siblina* and *Paraprionospio pinnata, and* a phoronid, *Phoronis* sp.

The lowest average BRI values measured in Year 2 were from the harbor station sediments, the cap site and the SEIBP sites indicating the community composition of these areas was not detrimentally affected by contamination. Both areas of the uncapped NEIBP site did have BRI values that were above the reference threshold suggesting that the communities in these areas are affected by contamination.

In Year 2, at total of 46 ghost shrimp were captured in the study area, 32 juveniles and 14 adults. Twenty-nine of these occurred on the cap site, with the greatest abundances occurring at Station 10. No ghost shrimp were collected at the SEIBP.

#### *4.3.1.3 Year 3*

Ghost shrimp were the most abundant species (N=11) found in the harbor macro grab sample (Table 4-7), seven of which were adults. A large maldanid polychaete was also found in the harbor sample. These species are indicative of a climax community; however the lack of other organisms that are found in the surrounding areas indicates that this is an impaired area. In the grab sample taken at the SEIBP, ghost shrimp were also abundant (Table 4-7) suggesting that it is a dominant species in the area. The results of the macro grab samples suggest that ghost shrimp may be the organisms creating the large burrow mounds on the surface of the cap, but the chemical results do not suggest that they are actually burrowing through the cap layer and into the LARE.

#### *4.3.1.4 Discussion of Benthic Sampling Results*

Re-colonization of the NEIBP cap site by benthic infauna proceeded at a rapid pace during the 10-month period between Years 1 and 2. Although total abundances of infauna at the cap site decreased slightly during this time, the numbers of species, diversity, and dominance (number of species comprising 75% of the abundance) had each increased dramatically. Almost twice the numbers of species were collected, diversity was 30 percent greater and the number of taxa comprising 75 percent of the abundance had tripled. This was in contrast to locations in the non-capped portions of the borrow pit and harbor where numbers of species declined slightly, and diversity and dominance remained relatively unchanged between the Year 1 and 2 surveys.

The BRI is another measure of infaunal community "health." BRI scores below 31 characterize communities which are comparable to reference communities from other southern California bays and harbors (Smith et al. 2003). BRI scores exceeding 31 indicate that pollution effects have caused a net loss of species. However, other effects not strictly related to pollution may also result in scores above 31. At all cap site locations, BRI values were below 31 during both the Year 1 and 2 surveys, and, on average, actually declined somewhat from Year 1 to Year 2. This indicates that by Year 2, the infauna community on the cap site had begun to approach the ecological health of communities found at other harbor reference sites as measured through the BRI.

**Table 4-7**
**Macro Benthic Grab**

| Sample/Phylum | Species | Count | Length/Size (cm) | Comments |
|---|---|---|---|---|
| Harbor Sediments | | | | |
| Polychaeta | Maldanidae sp. *(Axiothella rubrocincta)* | 1 | 13 | |
| Arthropoda | *Pyromaia tuberculata tuberculata* | 1 | 0.5 | |
| | *Neotrypaea californiensis* | 11 | 4 to 5 | 7 berried |
| Nemertea | *Amphiporus bimaculatus* | 1 | 11 | Incomplete thorax (decapitated) |
| | *Micrura pardalis* | 1 | 6.5 | |
| | *Malacobdella grossa?* | 1 | 2.5 | |
| | *Nemertopsis gracilis* | 1 | 2.5 | |
| SEIBP | | | | |
| Sub-Sample 1 | | | | |
| Polychaeta | Nereidae *(Neanthes?)* | 2 | 22,8 | |
| | Phyllodocida | 1 | 27 | Body fragments |
| | *Glycera nana* | 1 | 15 | |
| Arthropoda | *Neotrypaea californiensis* | 8 | 6 to 7 | |
| Mollusca | *Macoma nasuta* | 1 | 5 | |
| Sub-Sample 2 | | | | |
| Polychaeta | *Glycera nana* | 1 | 19 | |
| | Nereididae *(Nereis?)* | 1 | 21 | |
| | Ampharetidae | 1 | 5.5 | Mud tube 12 cm long |
| Arthropoda | *Neotrypaea californiensis* | 9 | 4 to 7 | |
| | *Pinnixa franciscana* | 1 | 1.2 | |
| Sub-Sample 3 | | | | |
| Polychaeta | Oenonidae *(Arabella iricolor)* | 2 | 14, 8 | |
| | *Cirriformia luxuriosa* | 1 | 9 | |
| | *Pherusa capulata* | 1 | 9 | |
| | Nereididae *(Neanthes?)* | 4 | 9,7,6,4 | |
| Arthropoda | *Neotrypaea californiensis* | 8 | 4 to 7 | |
| Nemertea | *Tubulanus frenatus* | 1 | 3 | |
| Mollusca | *Macoma nasuta* | 3 | 4.5, 2, 1.5 | |
| Sub-Sample 4 | | | | |
| Polychaeta | *Pherusa sp.* | 5 | 3 to 8 cm | |
| Arthropoda | *Pinnixa franciscana* | 1 | 1.1 | carapace |
| | *Neotrypaea californiensis* | 11 | 4 to 9 | |

The highest BRI index scores were measured at the southern part of the uncapped NEIBP site where they exceeded threshold levels during both surveys. The scores here were just above 31, indicating that there was a net reduction in species, possibly due to some anthropogenic disturbance. Other community metrics from the area concurred with these findings. Decreased numbers of species and dominance by a single species indicate that these sites were impacted, possibly to a greater degree than the BRI index indicated. Sediment chemistry from the area in Year 2 revealed that sediment metals and total PAHs were similar to concentrations found in other outer harbor locations. Additionally, these same sediments were not toxic to *Eohaustorius estuaries*. These findings combined indicate that impacts to the community structure appear to be more subtle than could be detected by chemistry and toxicity alone.

The polychaete worm, *Cossura candida,* was the most dominant benthic organism found in the survey area, and comprised 40 percent of the entire population. Found in relatively high abundances at each of the strata during both years, it comprised over 80 percent of the NcapS and NcapW site populations. *Cossura candida* was reported by Reish (1959) as an indicator of relatively undisturbed reference conditions. During the Year 2000 baseline survey (MEC 2002), *Cossura candida* was abundant at locations similar in depth and sediment grain size, and was the 13th most abundant species found in both Long Beach and Los Angeles Harbors. Additionally, between 1954 and 2000, *Cossura* was a member of the top three most dominate species collected in six out of seven surveys conducted in the harbors (Reish 1959, HEP 1976, HEP 1980, MBC 1984, MEC 1988, and SAIC and MEC 1997). It is not known why this species numerically dominates the infauna community at these non-capped borrow site locations.

Of eight organisms collected in the survey that are potential bioturbators, only the ghost shrimp (*Neotrypaea* sp.) is reportedly capable of burrowing to depths that could potentially penetrate the LARE material. Members of this group have been reported to create burrows ranging from much less than 50 to 90 cm in depth (Atkinson and Nash 1990 and Suchanek 1985). During Years 1 and 2, a total of 46 individuals were collected from the survey area with the majority found at cap site stations. The impact of these burrowers is difficult to assess. The individuals collected during both Year 1 and Year 2 were small (< 3 cm in length) and most likely incapable of burrowing to great depths. However, in Year 3 the macro grab samples which penetrated at least 1 m into the sediments revealed adult ghost shrimp (4 to 5 cm in length) at both the site next to the cap area and in the SEIBP sediments. This indicated that the van Veen grab used to collect the infauna samples in Year 1 and 2 and only penetrates the top 15 cm of sediment is not capable of sampling deeper burrowing adult ghost shrimp at these two sites. However, both the burrow mound chemistry results indicate that any deeper burrowing shrimp do not appear to be penetrating the cap to the underlying sediments.

It appears that the disturbance caused by capping the site and dredging of the SEIBP site, played a significant role in determining the composition of the infauna community at these stations. This is consistent with the impacts often expected and seen as benthic communities recover during physical disturbances such as dredging or capping. The middle to outer harbor stations (Year 2000 survey) were similar in sediment composition and recent dredging activity and shared many of the same species with the cap site and SEIBP. Also, immediately following capping, re-colonization occurred at a rapid pace on the cap site. Two mechanisms were likely involved. First, inoculation of species from the SEIBP to the cap site during the capping process is likely, since the composition of the infauna populations at the cap site and SEIBP were very similar in terms of abundance, numbers of species, dominance, BRI, and shared species. Secondly, larval recruitment by infauna from the general harbor water column likely also occurred, considering the numbers of dominant species (those comprising 75% of the population) shared by the cap site, SEIBP, and harbor sites.

#### 4.3.2 Video Surveying

Video surveys were conducted across the NEIBP cap site in Year 1 and 2. Since numerous burrow mounds were counted on the cap site during the Year 1 survey, an additional video survey was conducted for comparison purposes across the SEIBP in Year 2. Each video was reviewed looking for cap site erosion, fracture and burrow mounds created by bioturbators. Burrow mounds were quantified, and estimates of the total numbers and sizes of burrow mounds were calculated for each survey.

#### 4.3.2.1 Year 1

Underwater visibility during the NEIBP video transect was less than a foot (30 cm). Burrows, recorded by hand-held video, were still readily visible by divers. Surface color was gray-brown and surface sediments were composed of an extremely fine, flocculent material that was dispersed with the slightest disturbance. This flocculent ranged from between 1 and 3 cm in thickness. Beneath the flocculent, sediments were considerably more dense, indicating that the flocculent material may have been the product of new deposition onto the cap. This fine surface layer was not observed in either the core or grab samples and may have been dispersed by the sampling device and divers as they neared the sediment surface.

The video transect covered an area equivalent to 84 $m^2$ and yielded a total of 190 burrows. This was converted to an average of 2.3 burrows per $m^2$. Thus, for the 40,000 $m^2$ cap site, the total number of burrows could be estimated at 92,000 ± 18,400.[1] The smallest burrow diameter (by definition) observed was 2 cm and the largest was 7 cm. The average diameter of all burrows was 3.6 cm (standard deviation = 1.1 cm). Most burrows ranged from 3 - 3.9 cm (35%), followed by 4 - 4.9 cm (28%), and 2 - 2.9 percent (22%). The least number of burrows was in the largest group, greater than 5 cm (15%).

Upon review and discussion of the Year 1 visual observations, the CSTF members were unsure if all of the depressions were truly a result of benthic activity. It is possible that some of the depressions may have been formed by the release of methane gas bubbles from the decomposing detritus in the LARE material. The group decided that the counting procedure would be modified for future events by only counting burrows where material was rounded up adjacent to the hole vs. simple depressions in the surface.

#### 4.3.2.2 Year 2

Visibility on the NEIBP was again poor (10 cm) during Year 2. Burrows were readily observed by divers and recorded by hand held video. The surface of the cap

[1] Since interpretation of what was a burrow and what was not a burrow could be questioned, it was estimated that a + 20 percent error was probably not unreasonable

appeared the same as in Year 1 and no fractures or erosion were observed. The surface color of the cap sediment was grey-brown and the light flocculent material observed in Year 1 covered the surface. The video transect covered an area equivalent to 81 $m^2$ and yielded a total of 88 burrows (using the modified approach). This was converted to an average of 1 burrow per $m^2$. Thus, for the 40,000-$m^2$ cap site, the total number of burrows was estimated at 40,000 ± 8,000, almost half as many as estimated during the previous survey. Burrow sizes were similar to the 2002 survey.

The video survey on the SEIBP was conducted during extremely poor visibility (5 cm) and strong tidal current. Burrows were visible to divers during portions of the dive and were recorded on the hand held video. The surface of the SEIBP was similar to NEIBP cap site, but the light flocculent found on the cap site was not as prevalent; probably due to the strong current. The surface was grey-brown and was composed of dense sand. The 24 $m^2$ SEIBP quadrat yielded 32 burrows or 1.3 burrows per $m^2$. Thus, for the 19,000 $m^2$ SEIBP site, the total number of burrows was estimated to be 24,700 + 4,940. Burrow sizes were similar to the NEIBP.

#### 4.3.2.3 Year 3

Due to the rapid recolonization of the cap site, a video survey was not conducted during Year 3.

#### 4.3.2.4 Discussion of Video Surveying Results

The video transects across the NEIBP during both the Year 1 and 2 surveys indicated that there were no visible fractures or large depressions in the cap surface and that there were more burrow mounds present than were expected. As a result, in Year 2, an additional transect was added in the SEIBP to provide a comparison with the NEIBP. During both years, surface sediments were grey-brown and were composed of a very fine layer of flocculent material on the surface. This fine material was 1 to 3 cm thick, very light, dispersed with little disturbance, and was probably deposited from the surrounding harbor sediments. The estimated average number of burrow mounds observed ranged from 2.3 $m^2$ in Year 1 to 1 $m^2$ in Year 2 on the NEIBP. The average diameter of the burrow mounds for both years was 3.6 cm and ranged from

2 to 7 cm. The greatest concentration of burrows was in the 3 to 3.9 cm (35%) diameter range.

The video survey of the SEIBP in 2003 yielded an estimated 1.3 burrows $m^2$ or 24,700 + 4,940 for the entire site. The sizes of burrows were similar to the NEIBP. The visibility during the video transect across the SEIBP was extremely poor making the estimated numbers of burrows found there probably less accurate. The surface of this site appeared very similar to the NEIBP except that there was less surface flocculent material present. This is probably due to strong currents that were evident during the dive operation.

### 4.4 Summary of Long-Term Monitoring Results

After three years of monitoring the NEIBP cap site, no evidence of contaminant migration into or through the cap from the LARE dredge material has been observed. Visual observations of the core samples reveal a clear boundary layer between the LARE material, which was fine-grained, black in color, and smelled of petroleum and the capping material which was dark grey, odorless, and sandy. The depth of the overlying cap material met the 1-m depth design criteria for the study based on penetration depths of the cores collected during all three surveys. Burrows created by bioturbators or surface depositional material from outside the cap site were not observed in any of the cores, but were observed during the video surveys.

Of the 15 metals and total PAHs measured, none were elevated in the cap material compared to concentrations found in the LARE during each survey. Total PAH concentrations, considered to be the best marker for the LARE material, were orders of magnitude lower in the cap material than in the LARE. Sampling procedural changes occurred during all three years in an attempt to make the monitoring program more sensitive to potential cap failure (moving sampling intervals closer to the cap layer interface and sampling for pore water); however no evidence was observed that contaminants were migrating into the cap material.

Burrow mounds were clearly evident during the surveys and sediment samples collected from these mounds in Year 1 revealed elevated concentrations of several of target metals above those measured in the LARE material. Further investigation in Year 2 led to the collection of both burrow mound and surface samples from the cap site and surrounding harbor sediments. These samples showed that while in some cases metals concentrations were elevated in the burrow mounds, they were likewise elevated in surface sediment samples without burrows. Thus, it appears that the elevated metals concentrations in the burrow and surface sediment samples were the result of deposition from the surrounding harbor and not material from LARE layer in the cap. This was confirmed with subsequent PAH analyses of the burrow mounds which were nearly an order of magnitude lower than typically observed in the LARE material, supporting the conclusion that the burrow mounds are not composed of LARE material.

Bathymetry survey results show that the engineering goals of the project have been met and that the integrity of the cap has been maintained. Comparison of surface isopachs between Year 1 and Year 3 showed that the surface of the cap was unchanged indicating that no significant erosion, settling, or sloughing had occurred. There was also no evidence of any fractures or large depressions that would impact cap integrity.

The video transects across the NEIBP during both the Year 1 and 2 surveys also indicated that there were no visible fractures or large depressions in the cap surface and that there were more burrow mounds present than were expected. As a result, in Year 2 an additional transect was added in the SEIBP to provide a comparison with the NEIBP. During both years, surface sediments were grey-brown and were composed of a very fine layer of flocculent material on the surface. This fine material was 1 to 3 cm thick, very light, dispersed with little disturbance, and was probably deposited from the surrounding harbor sediments. The surface of this site appeared very similar to the NEIBP except that there was less surface flocculent material present. This is probably due to strong currents that were evident during the dive operation.

It appears that the disturbance caused by dredging or, in the case of the cap site, capping played a key role in determining the composition of the infauna community. The middle to outer harbor stations (Year 2000 survey) were similar in sediment composition and recent dredging activity and shared many of the same species with the cap site and SEIBP. Also, immediately following capping, re-colonization occurred at a rapid pace on the cap site.

Two mechanisms could have been involved.  First, inoculation of species from the SEIBP to the cap site during the capping process is likely since the composition of the infauna populations at the cap site and SEIBP were very similar in terms of abundance, numbers of species, dominance, BRI and shared species.  Secondly, recruitment by infauna from the nearby harbor sediments may have also occurred, considering the numbers of dominant species (those comprising 75% of the population) shared by the cap site, SEIBP and harbor sites.

# 5 UPDATED AQUATIC CAPPING ALTERNATIVE EVALUATION

The completion of the Aquatic Capping Pilot Study Long-Term Monitoring Program provides an opportunity to re-evaluate the aquatic capping disposal alternative using this new data according to the original criteria developed for the Evaluation Report completed by the USACE in 2002. This section first revisits the success criteria developed by the USACE for the original Evaluation Report completed immediately following construction, and then re-evaluates each item with respect to the long-term monitoring results presented in Section 4.

## 5.1 Aquatic Capping Evaluation Criteria

Evaluation criteria were established early in the planning process for the DMMP Pilot Studies to help focus field sampling and testing efforts during the design and construction of both bench-scale and pilot-scale (field-scale) projects. The evaluation criteria were generally based on the balancing criteria found in the Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA), which include: Short-term effectiveness; long-term effectiveness and permanence; reduction of mobility, toxicity, and volume through treatment; implementability; and cost. The CERCLA evaluation criteria were slightly modified to better match the objectives for the DMMP Pilot Studies. The selected evaluation criteria, which were discussed and approved by both the USACE and CSTF, are defined in more detail below. These evaluation criteria are:

- Short-term effectiveness
- Long-term effectiveness
- Implementability
- Environmental impacts
- Costs

### *5.1.1 Short-Term Effectiveness*

This evaluation criterion addresses the effectiveness of the Aquatic Capping alternative during the construction and implementation phases until the sediment management objectives are met. The Aquatic Capping short-term effectiveness refers to the ability to control the loss of contaminated sediments during dredging, placement, and capping operations and to result in isolated sediments immediately after construction. The main questions related to short-term effectiveness are:

- Were the contaminated sediments effectively placed in the area designated for disposal?
- Were the contaminated sediments effectively isolated in that disposal area?

### 5.1.2 Long-Term Effectiveness

This evaluation criterion addresses the effectiveness of the Aquatic Capping alternative at maintaining sediment management objectives over the long-term following the construction and implementation phases. The Aquatic Capping long-term effectiveness refers to the ability of the constructed facility to continually isolate contaminants from the marine environment.

### 5.1.3 Implementability

The implementability criterion addresses the technical feasibility of implementing the Aquatic Capping alternative and the availability of various services and materials required during implementation. This criterion focuses on technical issues related to the construction of an alternative (e.g., the availability of equipment, experienced personnel, and sites) and does not include evaluation of the administrative issues (e.g., regulatory approval and permitting).

### 5.1.4 Environmental Impacts

This evaluation criterion addresses whether the Aquatic Capping alternative poses unacceptable short-term impacts (i.e., during or shortly after construction), to water and sediment quality.

### 5.1.5 Cost

This evaluation criterion addresses the associated construction costs (both direct and indirect) and annual operations and maintenance costs for the Aquatic Capping alternative. Although not included in the original evaluation report (USACE 2002), construction and long-term monitoring costs have been added to this evaluation criterion.

##### *5.1.5.1 Short-Term Costs*

Short-term costs are associated with the construction of the cap site and the construction monitoring.

##### *5.1.5.2 Long-Term Costs*

Long-term costs are those associated with completion of the LTMP, including monitoring and reporting.

## 5.2 Updated Aquatic Capping Site Evaluation

Measurement of success or failure of the cap Site is determined by whether chemicals migrate through the cap at a rate that results in the significant contamination of the surface sediment or overlying water. According to the equilibrium partitioning and flux models conducted during cap design, chemical migration through 1.5 m of cap sediment would not be expected within the first three years of monitoring.

### *5.2.1 Short-Term Effectiveness*

This criterion refers to the ability of the contractor to control the loss of contaminated sediments during dredging, placement, and capping. A comparison of actual contaminant loss — as represented by TSS concentrations, water quality contaminant concentrations, and post-placement surface sampling results — to the predicted results indicates that the contractor successfully controlled sediment loss during dredging, placement, and capping. Additionally, the cap material was found to be clean and there was no mixing of the cap with the LARE material. These results have been re-confirmed through visual observations during each round of monitoring. As a result, the short-term effectiveness for this pilot study is essentially identical to the original Evaluation Report and has not changed as a result of the long-term monitoring program.

### *5.2.2 Long-Term Effectiveness*

The long-term effectiveness criterion addresses the effectiveness of the alternative at maintaining sediment management objectives following the construction and implementation phases; for instance, maintaining isolation of contaminants after capping has been completed. Based on long-term monitoring of aquatic caps for other projects (Sumeri 1995), as well as on successful placement of the cap to the required thickness and horizontal coverage without excessive mixing, the NEIBP site was expected to be effective at isolating contaminants in the long-term.

The three main components of a successful cap are physical isolation, erosion protection, and chemical containment. The primary mechanisms that could impact the long-term effectiveness of the cap by impacting those components are:

- Bioturbation (i.e., sediment mixing by organisms living in sediments)
- Erosive forces, including waves, currents, and propeller wash
- Contaminant mobility, including advective and diffusive transport

**Physical Isolation**. The cap thickness required to address all the design components was determined to be 95 cm. For construction, a targeted average cap thickness of 1.5 m was specified, with a minimum cap thickness of 1 m. This target thickness was confirmed with post-construction monitoring, as well as annual monitoring.

Design criteria were developed to account for bioturbation and were incorporated into cap design. Long-term monitoring of the cap has demonstrated that bioturbation does not exceed the design criteria established for the pilot project and has not resulted in unacceptable mixing of underlying sediment with the cap material.

**Erosion Protection.** Predictive modeling was used to assess long-term effectiveness of the cap against erosive forces. The LTFATE model predicted potential erosion at the NEIBP site under the January 1988 storm event, which was considered a major storm event. Using conservative assumptions, the model predicted average erosion depths of less than 6 cm for both cohesive and non-cohesive sediments. The maximum erosion depths (representing the deepest points predicted) were 33.5 cm for non-cohesive sediments and 8.2 cm for cohesive sediments. Because the cap Site is located within a depression, erosion, if it occurred, would likely represent surficial mixing rather than loss of cap material. In addition, the NEIBP has been shown to be a depositional area, so that effective cap thickness would likely be increasing over time. Long-term monitoring of the cap has demonstrated that the site is depositional. Due to this, long-term erosion is not expected to occur even in the event of a significant storm event which would produce mixing rather than loss of cap material.

**Chemical Containment.** Contaminant mobility modeling for this alternative included the RECOVERY model and empirical equations to estimate the time it would take for the cap to reach chemical saturation. Results of the RECOVERY modeling indicated that the cap would be highly effective at isolating contaminants from the water column and aquatic organisms. Continuous burial of the cap by new deposition of suspended solids was predicted to occur at a faster rate than diffusion of contaminants up into the cap. The NEIBP experiences increased sedimentation compared to surrounding areas because the bottom of the NEIBP is at a much lower elevation, which causes the NEIBP to act as a sediment trap. The sources of sedimentation are the Los Angeles River and Long Beach Harbor. The ongoing process of off-site sedimentation means that potential contaminant mobility through the cap is further mitigated by the addition of new cap material.

Simple diffusive flux calculations also indicate that any migration of contaminants through the cap would occur at an extremely slow pace (hundreds to thousands of years). Even if it is assumed that equilibrium conditions are not eventually reached (which is evaluated by more complex models such as RECOVERY), simple flux calculations indicated that the rate of flux would be outpaced by the sedimentation rate observed in the NEIBP.

Actual long-term results depend on how well the cap was placed to avoid excessive mixing or insufficient cap thickness. The post-construction monitoring data, which included post-capping bathymetric surveys, core logs, and sediment chemical concentrations through the cap, indicate that the contractor was able to place a discrete cap that had limited mixing and was able to meet the design criteria for cap thickness and horizontal coverage. Sediment chemistry results both immediately post construction and for all three monitoring events, show a distinct difference between chemical concentrations in contaminated sediments versus the clean cap material. Low chemical concentrations were also detected in analysis of the cap pore water, which confirms chemical containment.

### 5.2.3 Implementability

The implementability criterion addresses the technical feasibility of implementing an alternative and the availability of various services and materials required during its implementation, such as the contractor's ability to construct the project to the specified design criteria. Aquatic Capping is generally considered readily implementable. Mechanical dredging and accessory equipment are available locally, and the process uses reliable, proven technologies. Results from the monitoring performed during dredging and placement operations, as well as review of the post-placement and post-capping bathymetry, demonstrate that the contractor was able to meet the required design criteria. The implementability of this pilot study remains unchanged from that presented in the original Evaluation Report (USACE 2002).

#### 5.2.3.1 Dredging of LARE Contaminated Sediment

Implementability issues at the LARE dredge site would be the same for all alternatives considered by the USACE and the CSTF, because the contaminated sediments must be removed for all alternatives. Therefore, no criteria for implementability of dredging the LARE sediments were developed.

#### 5.2.3.2 Placement of LARE Contaminated Sediments in NEIBP

The design criteria specified that all contaminated sediments placed into the NEIBP were to be placed within the pit boundaries to an elevation of –15 m MLLW, with an allowance for equipment tolerance of ±0.5 m vertically. MDFATE modeling predicted that material could be placed within the specified 1 m total vertical tolerance using bottom-dump barges. During construction, the contractor did use bottom-dump barges to place the contaminated sediments, and post-placement bathymetric surveys indicated that the contractor met the specified elevation range.

The contractor employed a real-time positioning system using the Differential Global Positioning System (DGPS) to ensure that bottom-dump barge loads were not discharged outside of the specified NEIBP boundaries. All placement events were recorded by the contractor, and the records showed that the contractor was within the specified boundaries during all discharge, except one that was placed just outside the designated area. That material was immediately retrieved and placed inside the pit.

#### 5.2.3.3 Dredging of SEIBP Clean Cap

The contractor had no difficulties during dredging of the SEIBP clean cap material and was able to meet the specified grades and elevations. The cap material from SEIBP is clean navigational dredged sediment. The ideal grain size for cap material is slightly fine to medium sand.

#### 5.2.3.4 Placement of SEIBP Clean Cap in NEIBP

The design criteria for the cap specified placing clean cap sediment within the pit boundaries to elevation –13.5 m MLLW with an allowance for equipment tolerance of ±0.5 m vertically. MDFATE modeling predicted that material could be placed within the specified 1 m total vertical tolerance using bottom-dump barges. The design required the contractor to place the clean cap material using two techniques: via bottom-dump barge and through re-handling cap sediment from the haul barge using mechanical equipment. Both cap placement techniques produced a discrete cap layer without excessive mixing as indicated from diver cores and chemical testing. The post-capping bathymetric survey indicated that the contractor was able to meet the specified elevation range using either placement technique.

Because the NEIBP is relatively deep and somewhat protected from wind, wave, and propeller wash action, the sandy cap material used for this project is sufficient to resist what are predicted to be minimal erosive forces, and no site restrictions are needed for the NEIBP disposal area or any future similar projects.

Production rates for cap placement were much higher for the bottom-dump barge technique than for the re-handling bucket placement. Because there was no measurable difference between the techniques in terms of meeting cap design criteria and minimizing the mixing of contaminated sediments with cap material, the bottom-dump barge technique, with its higher production rate, appears preferable.

### 5.2.4 Environmental Impacts

The environmental impacts criterion refers to whether significant short-term adverse water quality impacts occurred during construction operations. Potential water quality impacts include changes in physical parameters (e.g., changes in dissolved oxygen or pH or reduced light transmission), elevated dissolved or particulate chemical concentrations in the water column, contaminated sediment loss, and/or significant changes to other standard water quality parameters (e.g., TSS, temperature, salinity).

#### 5.2.4.1 Dredging of LARE Contaminated Sediment

Dissolved oxygen concentrations were generally depressed downstream of LARE dredging. However, a similar (although less frequent) trend was observed during the dredging of clean cap material. Light transmission was also depressed to some extent downstream of both operations, regardless of whether LARE or cap sediments were being dredged. This indicates that some of the observed water quality effects are not caused by sediment contaminants alone and would be applicable in any dredging operation.

TSS concentrations downstream of dredging were generally greater than background levels and light transmission was generally lower than background, as were predicted. Observed TSS concentrations were within the overall range predicted by pre-project modeling with concentrations often being lower than was predicted close to the dredge and sometimes higher than was predicted at 200 m from the dredge. However, the observed TSS concentrations fell within the normal range of standard dredging operations in the Los Angeles County Region (see review in Anchor 2002).

Occasionally, some metals, including chromium, mercury, and nickel, were detected at concentrations greater than the COP (COP 2001) objectives and above background concentrations. In typical dredging projects, a mixing zone distance of 100 m is allowed for dredging dilution. Metals were periodically and sporadically detected above background concentrations and COP objectives at distances greater than 100 m from the dredging. However, these exceedances were not chronic.

Chemistry results for samples collected from the water column downstream of dredging showed no detected organic compounds.

#### *5.2.4.2 Placement of LARE Contaminated Sediment in NEIBP*

As observed during dredging operations, dissolved oxygen and light transmission were commonly depressed near the disposal operations. However, a similar trend (although to a lesser degree) was observed for cap material disposal as well. Therefore, contaminated sediments may not strictly cause these effects.

The results of water quality monitoring during placement of the contaminated sediments into the NEIBP indicated slightly higher average TSS concentrations than were found during dredging operations, particularly at distances of about 50 m from the respective operations. The higher TSS concentrations were more frequent in deeper water samples from near the disposal barge, which indicates that the elevated TSS may at least be partially caused by bottom sediments that are re-suspended as the contaminated sediment load impacts the bottom.

In addition, all surface sediment chemistry results for samples collected in areas around the NEIBP after placement of the LARE sediments and after all operations were complete were below the ER-L (a commonly used sediment quality guidance), indicating that no significant chemical impacts occurred to the surrounding sediment as a result of disposal operations.

Also, as with the dredging operations, no organic compounds were detected in any water samples taken near the disposal operation. In addition, there were no metals exceedances of background concentrations or COP objectives downstream of disposal operations.

#### *5.2.4.3 Dredging of SEIBP Clean Cap*

As noted in USACE 2002, dissolved oxygen and light transmission were fairly commonly depressed during dredging of the cap material. The range of TSS concentrations was generally comparable to the concentrations predicted by computer modeling, and TSS concentrations were in the range of background by 200 m from the operation.

#### 5.2.4.4 *Placement of SEIBP Clean Cap in NEIBP*

Dissolved oxygen and light transmission were again observed to be depressed downstream of cap placement operations. TSS concentrations were generally within the range predicted by computer modeling, with slightly higher concentrations observed at 100 m from the placement operation. However, TSS concentrations were within the range of background at 200 m from the operation. With the exception of chromium in 17 percent of the samples, no metals were detected at concentrations above background and COP objectives. No organic compounds were detected in any samples.

#### 5.2.4.5 *Long-Term Isolation of Contaminants*

Sediment chemistry results consistently showed a distinct difference (visually and chemically) between contaminated LARE sediments and clean cap material indicating the lack of chemical migration. Pore water analyses conducted during year 3 monitoring also confirmed this conclusion.

### 5.2.5 Costs

#### 5.2.5.1 *Short-Term Construction Costs*

The cost criterion addresses the associated capital costs (both direct and indirect) and annual operations and maintenance costs. There are annual costs associated with monitoring the site, but because the NEIBP is a depositional area, there are no anticipated costs included for maintaining the cap over time. Monitoring costs (construction related or long-term), which were not included in the original cost evaluation because the level of monitoring conducted was much greater than typically occurs due to the research nature of the pilot study, have been added to this revised evaluation.

The actual Aquatic Capping Pilot Study unit cost for contaminated sediment was approximately \$27.50/$m^3$, as detailed in Table 5-1. To allow comparison between different alternatives in the original Evaluation Report, each cost estimate was adjusted to a Baseline Case scenario which was developed using the same cost estimate format but adjusted to account for the reduced volume that would be dredged and isolated (in this case 100,000 $m^3$ is assumed). The Baseline Case unit cost was approximately \$27/ $m^3$, as detailed in Table 5-2.

**Table 5-1**
**Actual Aquatic Capping Pilot Study Costs**

| Description | Quantity | Unit | Unit Price | Amount |
|---|---|---|---|---|
| **Dredging** | | | | |
| Mobilization/Demobilization | 1 | LS | $ 290,716 | $ 290,716 |
| Dredging and Hauling | 105,000 | $m^3$ | $ 8.24 | $ 865,200 |
| **Placement of Contaminated Sediment** | | | | |
| Placement | 105,000 | $m^3$ | $ 2.00 | $ 210,000 |
| Hydrographic Surveys | 1 | LS | $ 46,631 | $ 46,631 |
| **Capping** | | | | |
| Mobilization/Demobilization | 1 | LS | $ 141,749 | $ 141,749 |
| Dredging and Capping | 66,000 | $m^3$ | $ 11.90 | $ 785,400 |
| Hydrographic Surveys | 5 | each | $ 4,513 | $ 22,565 |
| **Cost Subtotal** | | | | $ 2,362,261 |
| OVERHEAD @ 8.0% | | | | $ 188,981 |
| PROFIT @ 6.5% | | | | $ 165,831 |
| BOND @ 1.23% | | | | $ 33,420 |
| **TOTAL** | | | | $ 2,750,493 |

**Table 5-2**
**Aquatic Capping Baseline Case Costs**

| Description | Quantity | Unit | Unit Price | Amount |
|---|---|---|---|---|
| **Dredging** | | | | |
| Mobilization/Demobilization | 1 | LS | $ 290,716 | $ 290,716 |
| Dredging and Hauling | 100,000 | $m^3$ | $ 8.24 | $ 824,000 |
| **Placement of Contaminated Sediment** | | | | |
| Placement | 100,000 | $m^3$ | $ 2.00 | $ 200,000 |
| Hydrographic Surveys | 1 | LS | $ 46,631 | $ 46,631 |
| **Capping** | | | | |
| Mobilization/Demobilization | 1 | LS | $ 141,749 | $ 141,749 |
| Dredging and Capping | 66,000 | $m^3$ | $ 11.90 | $ 785,400 |
| Hydrographic Surveys | 5 | each | $ 4,513 | $ 22,565 |
| **Cost Subtotal** | | | | $ 2,311,061 |
| OVERHEAD @ 8.0% | | | | $ 184,885 |
| PROFIT @ 6.5% | | | | $ 162,236 |
| BOND @ 1.23% | | | | $ 32,696 |
| TOTAL | | | | $ 2,690,878 |

#### *5.2.5.2 Long-Term Monitoring Costs*

As mentioned above, long-term monitoring costs were not included in the original evaluation of study costs because the LTMP was designed not to meet minimum standards, but rather to collect an over abundance of information for research purposes. Actual monitoring costs for completing the LTMP were approximately $30K per annum. These costs include the following:

- Administrative and Reporting - $10,000
- Bathymetric Survey - $5,000
- Field Sampling - $5,000
- Analytical - $10,000

It is reasonable to assume that long-term monitoring could occur at a level that is approximately half of what was conducted during the original pilot study (e.g., $15K/year). It is also reasonable to assume that long-term monitoring could be required for a period of up to three years following construction, assuming additional dredge materials were not added to the pit within this time frame. Therefore, total long-term monitoring costs for each dredge cycle are estimated at $45K.

Similar to the post-construction monitoring, the level of effort expended monitoring during construction activities for the pilot studies was much greater than would typically be required. It is reasonable, however, to assume that some level of water quality monitoring would be required and that it would be similar to what is typically required for regional maintenance dredging projects. For this cost estimate, that level of effort is assumed to be equal to one year of post construction monitoring (e.g., $15K).

Table 5-3 presents an adjusted Baseline Case cost that includes estimates for construction and long-term monitoring. Construction monitoring costs are estimated at $15K and long-term monitoring costs are estimated at $45K (three years at $15K/year). The additional cost of water quality monitoring during construction and three years of long-term monitoring to the Baseline Case unit cost is approximately \$0.70/ $m^3$ (Table 5-3).

**Table 5-3**
**Aquatic Capping Adjusted Baseline Case Costs**

| Description | Quantity | Unit | Unit Price | Amount |
|---|---|---|---|---|
| **Dredging** | | | | |
| Mobilization/Demobilization | 1 | LS | \$ 290,716 | \$ 290,716 |
| Dredging and Hauling | 100,000 | $m^3$ | \$ 8.24 | \$ 824,000 |
| **Placement of Contaminated Sediment** | | | | |
| Placement | 100,000 | $m^3$ | \$ 2.00 | \$ 200,000 |
| Hydrographic Surveys | 1 | LS | \$ 46,631 | \$ 46,631 |
| **Capping** | | | | |
| Mobilization/Demobilization | 1 | LS | \$ 141,749 | \$ 141,749 |
| Dredging and Capping | 66,000 | $m^3$ | \$ 11.90 | \$ 785,400 |
| Hydrographic Surveys | 5 | each | \$ 4,513 | \$ 22,565 |
| **Water Quality Monitoring** | | | | |
| Construction | 1 | LS | \$ 15,000 | \$ 15,000 |
| Long-term | 3 | each | \$ 15,000 | \$ 45,000 |
| Cost Subtotal | | | | \$ 2,371,061 |
| OVERHEAD @ 8.0% | | | | \$ 189,685 |
| PROFIT @ 6.5% | | | | \$ 166,136 |
| BOND @ 1.23% | | | | \$ 33,482 |
| TOTAL | | | | \$ 2,760,364 |

# 6 COMPARISON TO OTHER CAPPING PROGRAMS

This section presents several case studies where level bottom capping and CAC were used to manage contaminated sediments sub-aqueously. These case studies were chosen for their similarities and lessons learned for direct comparison to the Los Angeles DMMP aquatic capping pilot study. Case studies are reviewed to consider the evaluation criteria and objectives used in the Los Angeles DMMP Pilot Studies. These evaluation criteria are:

- Short-term effectiveness
- Long-term effectiveness (including cap integrity, chemical containment)
- Implementability
- Environmental impacts (direct impacts and biological re-colonization)
- Costs

Overall, these projects showed similar results as experienced with the Los Angeles DMMP Pilot Study: cap integrity and chemical isolation have been maintained, even with the earliest projects on record (17+ years); and biological recolonization has occurred rapidly at each site. The remainder of this section provides a brief summary of each project considered.

## 6.1 Boston Harbor – Boston, MA

In-channel CAC cells were used for placement of dredged material in Boston Harbor during the BHNIP. CAC was chosen as the method for dredged material disposal, and was intended to minimize environmental impacts and to maximize cost-efficiency and environmental benefits.

Monitoring for cap integrity, performed during the period of June 1999 through March 2001, was composed of (1) monitoring contaminated dredged material consolidation and strength prior to and after placement of the sand cap, and (2) monitoring cap erosion predictions from tidal currents and ship propeller wash to characterize the likely amount of cap damage to be expected from either source. It was determined that bottom sediments may be temporarily re-suspended during the passage of large vessels, however, the volumes of sediment re-suspended from both capped and uncapped CAC cells was very small and does not constitute a long-term flux of material (Bottin 2000). There were no signs of chemical migration through the cap.

In order to assess biological recolonization, a random stratified sampling plan was used to sample bottom sediments from the Phase I pilot cell, a Phase II cell, and from undisturbed sediments. Sediment profile images, water quality data, grain size distribution, invertebrate species composition and abundance, trace metals concentrations, and organic carbon concentrations were analyzed for 10 stations in the Inner Harbor.

Preliminary results indicate that sediments sampled from the cells are qualitatively similar to sediments adjacent to the cells or in an undisturbed area. Fine sediment fractions (72-98%) were consistently larger than sand fractions (2-32%). Sediment profile images revealed shallow (< 3 cm) redox potential depths (RPDs). Concentrations of trace metals appear to be similar among the ten stations. Invertebrate abundance was low at all locations, and only seven polychaete genera were found in total. While further data analysis is required, these preliminary results indicate that no major changes to the benthic habitat and community have resulted thus far from the construction of CAC cells in the Inner Harbor and tributaries (Bourque et al. 2001).

## 6.2 Long Island Sound

The Central Long Island Sound Disposal Site (CLDS) is one of four regional dredged material disposal sites located in the waters of Long Island Sound. CLDS covers a 6.86 square kilometers ($km^2$) (2 $nmi^2$) area, and is located approximately 10.89 km (5.6 miles) south of East Haven, Connecticut. Historically, CLDS has been one of the most active disposal sites in the New England Region. Since 1980, 6,301,000 $yd^3$ of dredged material have been disposed of at the site.

Since 1977, the management strategy at CLDS has entailed the controlled placement of small to moderate volumes of sediment to form individual disposal mounds on the seafloor. Field efforts continue to consist of bathymetric and SPI surveys designed to document changes in seafloor topography, evaluate the physical distribution of dredged material, and assess the recovery of the benthic community relative to ambient sediment conditions and previous monitoring surveys (USACE 2004).

In 1984 this management strategy was modified to include the selection of dredged material placement locations in a manner that would promote the development of rings of disposal mounds on the CLDS seafloor. The network of mounds would form containment cells on the seafloor that would facilitate subsequent large-scale CAC operations. The most recent mound, created from five previously placed projects, was used to make a depression in which to place 500,000 $yd^3$ of New Haven sediments. Surveys showed that the planned depression was successful in reducing the spread of the contaminated sediments and thereby significantly reduced the volumes of capping sediments required.

Cores were taken from capped disposal mounds created approximately three and 11 years prior to sampling. Visual observations of the transition from cap to contaminated sediment closely correlated with the sharp changes in the sediment chemistry profiles. The lack of diminishing concentration gradients away from the contaminated sediments strongly suggests that there has been minimal long-term transport of contaminants up into the cap (USACE 2004).

The results of the bathymetric survey conducted in September 2003, indicated a 0.5 m decrease in the height of the CLIS 00 Mound. This scale of volume decrease is typical of the self-weight consolidation of recently disposed dredged materials in Long Island Sound (USACE 2004). The SPI survey was performed at historic, older, and newer mounds, and results indicated that benthic recovery of the mounds has proceeded at least as well as expected or has exceeded initial expectations, and conditions at all mounds were indicative of a slightly disturbed or undisturbed benthic environment. The RPD layer was generally deeper than 2 cm, indicative of well-oxygenated sediments and active benthic fauna (USACE 2004).

The Mound Complex from 1995/1996 was in an advanced state of recolonization, with benthic habitat conditions that were improved relative to the 2001 monitoring survey and comparable to the ambient conditions observed at the reference areas. This mound complex exhibited a stable and fully recovered benthic habitat (USACE 2004).

In the 1993 mounds, methane bubbles were observed, the presence of which was likely due to the high organic content of the dredged material at depth. Despite the continued presence of organic-rich surface sediments and the sub-surface production of methane at these mounds, both showed advance benthic recolonization and fully recovered benthic habitat (USACE 2004).

### 6.3 Puget Sound Naval Shipyard, Bremerton, WA

In 2001, approximately 400,000 $yd^3$ of contaminated sediment was disposed of in a borrow pit located 10 m deep, near the Bremerton Naval Shipyard. This was followed by a 5-foot layer of capping material. During early monitoring activities, sediment grab samples indicated elevated levels of PCBs and mercury up to 300 feet outside the CAC pit boundary (Germano 2002). These results have been found in other borrow pit sites immediately after disposal, yet it has been shown in this and other projects that a lateral spread of contaminated sediment during disposal can be controlled by careful disposal operations.

This project was unique due to the large amount of dredged material, tight schedule; significant daily tidal exchange, water depth, and CAC pit volume constraint which required precision dredging. Long-term monitoring will reveal more information about this project.

There was evidence of mature, infaunal deposit-feeding activity at all the stations where dredged material was detected. The local fauna had re-colonized the stations and reestablished themselves near the sediment-water interface. Six months after disposal, it was impossible to distinguish the optical characteristics of the dredged material layer from the ambient sediment using SPI technology (Germano 2002).

### 6.4 Duwamish River Demonstration – Seattle, WA

The first aquatic capping project in Puget Sound was conducted on the Duwamish Waterway in 1984 and was lead by the USACE with assistance from the EPA. The Seattle District initiated a demonstration project to dispose of 840 $m^3$ of contaminated material in an existing sub-aqueous depression in the West Waterway and to cap it with 3,220 $m^3$ of clean sand. The cap design included a 3-foot target, while the actual cap size was approximately 2 feet after consolidation.

Functionally there was no erosion on the cap surface. A small amount of the cap eroded from one side to the other, but then was covered by natural sedimentation. Vibracore sediment samples taken up to five years following capping showed a sharp and relatively unmixed interface between the contaminated and cap sediments, and no chemical migration was observed. Measured contaminant concentrations were either absent or present in low concentrations in the cap material (USACE 1998). In addition, the 18-month and five-year sediment chemistry sand-cap concentrations were essentially unchanged.

### 6.5 One Tree Island – Olympia, WA

One Tree Island was the first permitted CAC project in 1987, and was essentially a maintenance dredging project within a marina. The upper 2 to 3 feet of PAH and heavy metal contaminated sediments were dredged and placed in a deep CAC cell within the marina. Four feet of clean sand was placed over the cell to provide a 3-foot consolidated cap. The last monitoring event for this site occurred in 1989 and confirmed that sediment contaminants were not significantly migrating into the cap. Divers confirmed that the cap appears to be intact and that little prop scour or other evidence of erosion exists.

### 6.6 Simpson Tacoma Craft/St. Paul Waterway

Constructed in 1988, this was the first designed and permitted capping project under the Superfund regulatory process. The site area is 17 acres in size, with 11 acres of capped marine sediments and six acres of new intertidal habitat built along the shoreline. The cap is comprised of 3- to 20-foot layers of coarse sand dredged from the nearby Puyallup River.

Intensive monitoring was conducted annually for 10 consecutive years, and has been scaled back to minimal monitoring. No chemical migration has been detected and the cap is still within design specifications. Bioturbation (including ghost shrimp burrows) has been detected in the surface sediments, but has not affected cap performance. More than 10 years of chemical and biological monitoring has shown that contaminated sediments have remained confined and isolated beneath the cap and the cap is providing good habitat for estuarine biota.

### 6.7 Pier 51 Ferry Terminal – Seattle, WA

This project was primarily an experiment to see if marine traffic would compromise the integrity of the cap. Four acres of a coarse sand cap was constructed over contaminated sediments near the ferry docks. In the first year of the project, part of the cap was re-contaminated with creosote when a pile was pulled up during Ferry Terminal reconstruction. This portion of the cap was repaired after the contamination was found. Additionally, the top 2 cm of the overall cap material were re-contaminated with metals probably due to sediment deposition. Fate and transport models demonstrated that the ferry terminal was at the nexus of two gyres (from north and south), and required additional source control cleanup efforts.

Once the initial problems were considered, no additional problems with the cap were found. The cap remains within specifications, no chemical migration has been documented, and recolonization of benthic infauna has been observed. There is no indication of cap breach due to benthic organisms as they have not been found deeper than 1 m.

### 6.8 East Eagle Harbor – Bainbridge Island, WA

In Phase I of this project contaminated subtidal harbor sediments were capped to reduce immediate risk. The Phase I project area is 54.4 acres and was covered with 3 feet of clean river sediment. Significant localized cap erosion has taken place at this site caused by vessel prop wash. However, the EPA has determined that the erosion was not significant to the sediment remediation. A recent National Oceanic and Atmospheric Administration study has documented a rapid and substantial increase in the quality of benthic habitat. Source control remains an issue for this site as oncoming releases from the ferry parking lot and other upland sources continue to contribute to surface contamination of the cap.

### 6.9 Everett Homeport

Approximately 928,000 $yd^3$ of sediment from the East Waterway of Port Gardner Bay in Puget Sound was treated as contaminated. The Navy proceeded with in-water disposal using CAC. Contaminated sediment was deposited at depths of 400 feet and capped with 1.7 m (Palermo et al. 1989) of clean sediment to isolate contaminants from the aquatic environment of Puget Sound (Lukjanowicz et al. 1989).

The cap appears to be intact with little erosion or sloughing. Annual monitoring reveals that chemical migration through the cap is not occurring, and bioturbation on the surface (1 to 2 feet) indicates a recovering benthic habitat (Palermo et al. 1989).

# 7 CONCLUSIONS

The long-term monitoring results for the aquatic capping/cap pilot study presented in this report indicate that this is a feasible, cost-effective, and environmentally protective alternative for managing contaminated sediments within the Los Angeles Region. Visual observations, bathymetric surveys and chemical analysis of the cap material sediments and pore water provide conclusive evidence that the physical integrity of the cap has not been compromised and that chemical containment has been effectively maintained.

Furthermore, these results suggest that the use of the NEIBP (or other similar sites) provides a suitable location for implementing this management approach within the region. The NEIBP provides an existing depression with significant storage capacity that is located in very close proximity to the source of future dredge materials. Significant natural sedimentation within the NEIBP, combined with the lack of chemical migration also suggests that the 1-m thick cap used in the DMMP Pilot Study may be more material than would be required to ensure adequate environmental protection. Future disposal events might consider a thinner cap layer or no cap at all if multiple disposal activities are planned over a short time period.

Regionally, the use of aquatic capping/cap as a long-term management tool should still be evaluated under the context of a comprehensive environmental impact assessment (e.g., an Environmental Impact Statement (EIS) prepared under the NEPA or California Environmental Quality Act [CEQA]) to ensure non-aquatic impacts are considered. Those activities are planned tasks under the Los Angeles Regional DMMP program, currently underway within the USACE.

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# APPENDIX A

# YEAR 3 SEDIMENT DATA

# NEIBP CAD Site - Sediment Metals Results (mg/kg dry wt.)

| Analyte | ERL | ERM | LAC-2 (0-20) | LAC-2 (100-120) | LAC-3 (0-20) | LAC-3 (60-80) | LAC-3 (80-94) | LAC-4 (0-20) | LAC-4 (80-100) | LAC-4 (140-160) | LAC-4 (160-180) | LAC-5 (0-20) | LAC-5 (140-153) | LAC-6 (0-20) | LAC-6 (120-140) |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Antimony | --- | --- | 0.1 | ND | ND | ND | ND | ND | 0.2 | ND | 0.4 | 0.2 | ND | 0.1 | ND |
| Arsenic | 8.2 | 70 | 2.4 | 2.8 | 3 | 2.9 | 2.7 | 2.5 | 3.2 | 3.4 | 2.8 | 4.8 | 2.6 | 2.8 | 2.9 |
| Barium | --- | --- | 69.6 | 66.1 | 64.9 | 68.6 | 66.1 | 72 | 57.7 | 92.5 | 80.6 | 117 | 68.8 | 78.4 | 57.7 |
| Beryillium | --- | --- | 0.19 | 0.29 | 0.23 | 0.17 | 0.17 | 0.19 | 0.24 | 0.25 | 0.27 | 0.54 | 0.2 | 0.23 | 0.18 |
| Cadmium | 1.2 | 9.6 | ND | 0.1 | 0.1 | ND | ND | ND | ND | 0.1 | 0.2 | 0.4 | 0.1 | ND | ND |
| Chromium | 81 | 370 | 12.1 | 13.9 | 12.1 | 13.8 | 11.3 | 11.9 | 10.4 | 14.1 | 14.2 | 27.4 | 11.9 | 12.8 | 9.5 |
| Copper | 34 | 270 | 6 | 8.7 | 7.4 | 5.5 | 5.9 | 5.9 | 6.9 | 7.6 | 9 | 23 | 6.3 | 5.8 | 4.9 |
| Lead | 46.7 | 218 | 4.6 | 5 | 3.5 | 2.6 | 3.4 | 2.8 | 3 | 3.5 | 7.1 | 29.1 | 4.1 | 3 | 2.4 |
| Mercury | 0.15 | 0.71 | ND | ND | ND | 0.05 | ND | 0.02 | ND | ND | 0.04 | 0.06 | ND | ND | ND |
| Nickel | 20.9 | 51.6 | 7 | 8.3 | 7.4 | 7.7 | 6.1 | 6.9 | 6.5 | 8.7 | 8.5 | 16.3 | 6.9 | 7.5 | 5.9 |
| Selenium | --- | --- | ND | ND | ND | ND | ND | ND | ND | ND | ND | ND | ND | ND | ND |
| Silver | 1 | 3.7 | ND | ND | ND | ND | ND | ND | ND | ND | ND | 0.2 | ND | ND | ND |
| Zinc | 150 | 410 | 29 | 32 | 32 | 27 | 26 | 25 | 23 | 28 | 42 | 81 | 30 | 30 | 27 |

| Analyte | ERL | ERM | LAC-7 (0-20) | LAC-7 (100-120) | LAC-8 (0-20) | LAC-8 (100-120) | LAC-8 (120-135) | LAC-9 (0-20) | LAC-9 (100-120) | LAC-10 (0-20) | LAC-10A (0-16) | LAC-10 (120-140) | LAC-10 (140-160) |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Antimony | --- | --- | ND | ND | 0.1 | 0.2 | 0.1 | ND | 0.2 | 0.1 | 0.2 | ND | 0.2 |
| Arsenic | 8.2 | 70 | 3.7 | 2.9 | 3 | 3.3 | 4.3 | 2.5 | 3 | 2.7 | 6.3 | 2.4 | 3.7 |
| Barium | --- | --- | 106 | 61.2 | 60.5 | 56.1 | 116 | 60.1 | 56.6 | 51.9 | 138 | 80.8 | 80 |
| Beryillium | --- | --- | 0.37 | 0.22 | 0.23 | 0.18 | 0.68 | 0.16 | 0.22 | 0.17 | 0.69 | 0.22 | 0.3 |
| Cadmium | 1.2 | 9.6 | 0.2 | ND | ND | ND | **1.4** | ND | 0.3 | ND | 0.5 | ND | 0.6 |
| Chromium | 81 | 370 | 19.5 | 11.7 | 12.6 | 10.1 | 24.6 | 11 | 11.8 | 11.4 | 37.7 | 12.4 | 17.4 |
| Copper | 34 | 270 | 12.6 | 6.3 | 6.3 | 5 | 32.8 | 5.1 | 9.2 | 16.3 | **34** | 6.1 | 23.1 |
| Lead | 46.7 | 218 | 6.8 | 3 | 3 | 2.9 | 10.8 | 2.7 | 8.4 | 4.3 | 42.8 | 3.6 | **72.9** |
| Mercury | 0.15 | 0.71 | ND | ND | 0.06 | 0.04 | 0.05 | ND | 0.04 | ND | 0.08 | ND | ND |
| Nickel | 20.9 | 51.6 | 12.1 | 6.9 | 7.6 | 6.1 | **24.2** | 6.6 | 7.4 | 6.3 | **21.6** | 7.4 | 12.5 |
| Selenium | --- | --- | ND | ND | ND | ND | ND | ND | ND | ND | ND | ND | ND |
| Silver | 1 | 3.7 | ND | ND | ND | ND | 0.2 | ND | ND | ND | 0.3 | ND | 0.2 |
| Zinc | 150 | 410 | 51 | 25 | 46 | 23 | 56 | 25 | 51 | 25 | 112 | 28 | 96 |

Notes on Cores:

**Bold** = Exceeds ER-L value

# NEIBP CAD Site - Sediment PAHs Results (ug/kg dry wt.)

| Station | | | LAC-2 | LAC-2 | LAC-3 | LAC-3 | LAC-3 | LAC-4 | LAC-4 | LAC-4 | LAC-4 | LAC-5 | LAC-5 | LAC-6 | LAC-6 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Depth | ERL | ERM | 0-20 | 100-120 | 0-20 | 60-80 | 80-94 | 0-20 | 140-148 | 148-160 | 160-180 | 0-20 | 140-153 | 0-20 | 120-140 |
| Bulk Density | --- | --- | 1.64 | 1.68 | 1.58 | 1.67 | 1.54 | 1.64 | 1.71 | 1.79 | 1.42 | 1.76 | 1.68 | 1.54 | 1.63 |
| Total Organic Carbon (dry) | --- | --- | 0.14 | 0.16 | 0.24 | 0.25 | 0.23 | 0.11 | 0.24 | 0.19 | 0.31 | 0.32 | 0.6 | 0.08 | 0.38 |
| Total Organic Carbon (wet) | --- | --- | 0.11 | 0.13 | 0.2 | 0.2 | 0.19 | 0.09 | 0.2 | 0.16 | 0.25 | 0.24 | 0.49 | 0.06 | 0.3 |
| Total Solids | | | 79.7 | 80.2 | 82.4 | 81.4 | 82.1 | 79.2 | 82.4 | 82.2 | 81.9 | 75.8 | 82.2 | 79.8 | 79.3 |
| Naphthalene | 160 | 2100 | 1.3 | 1.3 | 0.93 | 0.68 | 1.2 | 1.1 | 1 | 0.84 | 1.3 | 0.8 | 1.5 | 1 | 0.62 |
| 2-Methylnaphthalene | 70 | 670 | 0.56 | 0.6 | 0.44 | ND | 0.62 | ND | 0.47 | 0.46 | 0.6 | ND | 0.93 | ND | ND |
| Acenaphthylene | 44 | 640 | ND | ND | ND | ND | ND | ND | ND | ND | 0.68 | ND | 0.39 | ND | ND |
| Acenaphthene | 16 | 500 | ND | 0.24 | ND | ND | 0.34 | ND | ND | ND | 0.39 | ND | 0.8 | ND | ND |
| Fluorene | 19 | 540 | 0.35 | 0.54 | 0.66 | ND | 0.38 | ND | ND | 0.27 | 0.55 | ND | 1.1 | ND | ND |
| Dibenzofluran | --- | --- | 0.25 | 0.31 | 0.21 | ND | 0.32 | ND | ND | 0.22 | 0.35 | ND | 0.67 | ND | ND |
| Phenanthrene | 240 | 1500 | 1.5 | 2.1 | 4.1 | ND | 3.2 | 0.47 | 0.42 | 1.7 | 5.1 | 0.44 | 3.9 | ND | ND |
| Anthracene | 85.3 | 1100 | 0.45 | 0.45 | 5 | ND | 0.82 | ND | ND | 0.48 | 1.3 | ND | 1.1 | ND | ND |
| Fluoranthene | 600 | 5100 | 3.2 | 3.8 | 2.5 | 0.64 | 8.1 | 0.7 | 0.75 | 7.2 | 11 | 0.84 | 9.2 | 0.65 | ND |
| Pyrene | 665 | 2600 | 3.3 | 4 | 1.8 | 1.2 | 9.6 | 0.85 | 0.93 | 7.6 | 13 | 1.2 | 9.5 | 0.85 | 0.49 |
| Benzo(b)fluoranthene | --- | --- | 1.7 | 1.6 | ND | ND | 3.8 | ND | ND | 1.8 | 5.5 | ND | 3.9 | ND | ND |
| Benzo(k)fluoranthene | --- | --- | 1.5 | 1.2 | 0.57 | ND | 3.7 | ND | ND | 1.6 | 5.5 | ND | 3.4 | ND | ND |
| Benz(a)anthracene | 261 | 1600 | 1.3 | 1.2 | 2 | 0.26 | 3.7 | 0.23 | 0.34 | 1.9 | 5.4 | 0.35 | 3.1 | ND | ND |
| Chrysene | 384 | 2800 | 2.3 | 2.2 | 6.6 | ND | 5.6 | ND | 0.54 | 2.7 | 8.3 | ND | 5.6 | ND | ND |
| Benz(a)pyrene | 430 | 1600 | 1.4 | 1.3 | 0.47 | 0.35 | 3.5 | 0.31 | 0.4 | 1.5 | 5.7 | 0.37 | 4 | 0.42 | ND |
| Indeno(1,2,3-cd)pyrene | --- | --- | 1.4 | 1.2 | 0.37 | 0.41 | 2.7 | ND | 0.41 | 1.4 | 4.4 | 0.38 | 3.2 | 0.38 | ND |
| Dibenz(a,h)anthracene | 63.4 | 260 | 0.37 | 0.34 | ND | ND | 0.57 | ND | ND | ND | 0.94 | ND | 0.85 | ND | ND |
| Benzo(g,h,i)perylene | --- | --- | 2.1 | 1.8 | 0.48 | 0.56 | 3.4 | 0.41 | 0.5 | 1.9 | 5.6 | 0.49 | 5.4 | 0.46 | ND |
| Total PAHs | 4022 | 44792 | 22.98 | 24.18 | 26.13 | 4.1 | 51.55* | 4.07 | 5.76 | 31.57 | 75.61 | 4.87 | 58.54* | 3.76 | 1.11 |

| Station | | | LAC-7 | LAC-7 | LAC-8 | LAC-8 | LAC-8 | LAC-9 | LAC-9 | LAC-10 | LAC-10 | LAC-10 | LAC-10A |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Depth | ERL | ERM | 0-20 | 100-120 | 0-20 | 100-120 | 120-135 | 0-20 | 100-120 | 0-20 | 120-140 | 140-160 | 0-16 |
| Bulk Density | --- | --- | 1.77 | 1.85 | 1.66 | 1.78 | 1.76 | 1.68 | 1.52 | 1.94 | 1.71 | 1.67 | 1.28 |
| Total Organic Carbon (dry) | --- | --- | 0.19 | 0.21 | 0.12 | 0.25 | 0.76 | 0.13 | 0.42 | 0.23 | 0.12 | 1.3 | 1.46 |
| Total Organic Carbon (wet) | --- | --- | 0.15 | 0.17 | 0.1 | 0.2 | 0.62 | 0.1 | 0.32 | 0.19 | 0.1 | 0.97 | 0.72 |
| Total Solids | | | | | 79.5 | 80.4 | 81.2 | 77.4 | 75.7 | 80.6 | 80 | 74.9 | 49 |
| Naphthalene | 160 | 2100 | 1 | 1 | 0.8 | 1.1 | 5.1 | 0.97 | 1.5 | 0.91 | 0.92 | 3.3 | 1.1 |
| 2-Methylnaphthalene | 70 | 670 | 0.56 | 0.61 | ND | 0.5 | 5.2 | 0.54 | 1.5 | ND | ND | 2.4 | ND |
| Acenaphthylene | 44 | 640 | ND | ND | ND | ND | 6.2 | ND | 0.36 | ND | ND | 1.3 | 0.61 |
| Acenaphthene | 16 | 500 | ND | ND | ND | ND | 3.2 | ND | 0.29 | ND | ND | 1.1 | ND |
| Fluorene | 19 | 540 | ND | ND | ND | ND | 7.2 | ND | 0.8 | ND | ND | 1.7 | ND |
| Dibenzofluran | --- | --- | 0.24 | 0.22 | ND | ND | 3.1 | 0.27 | 0.52 | ND | ND | 0.97 | ND |
| Phenanthrene | 240 | 1500 | 1 | 0.93 | 0.44 | 0.79 | 32 | 1.1 | 5 | 1.2 | 0.95 | 15 | 3.4 |
| Anthracene | 85.3 | 1100 | 0.34 | 0.29 | ND | 0.29 | 18 | ND | 1.3 | 0.39 | 0.45 | 3.6 | 1.2 |
| Fluoranthene | 600 | 5100 | 2.2 | 2.2 | 0.84 | 2.5 | 110 | 1.7 | 15 | 2.7 | 1.3 | 40 | 11 |
| Pyrene | 665 | 2600 | 2.6 | 2.8 | 1.2 | 2.7 | 150 | 2.1 | 16 | 3.1 | 2 | 44 | 11 |
| Benzo(b)fluoranthene | --- | --- | 1.3 | 1.4 | ND | 1.5 | 74 | 0.94 | 7.1 | 3.1 | 0.81 | 17 | 4.3 |
| Benzo(k)fluoranthene | --- | --- | 1.1 | 1 | ND | 1.2 | 56 | 0.79 | 5.3 | 3.2 | 0.75 | 16 | 4.9 |
| Benz(a)anthracene | 261 | 1600 | 1.2 | 1.2 | 0.35 | 1.3 | 42 | 0.91 | 5.1 | 2.7 | 0.89 | 13 | 7.6 |
| Chrysene | 384 | 2800 | 1.5 | 1.6 | ND | 1.9 | 79 | 1.1 | 10 | 3.1 | 0.82 | 24 | 6.8 |
| Benz(a)pyrene | 430 | 1600 | 1.2 | 1.3 | 0.37 | 1.3 | 59 | 1 | 5.7 | 3.1 | 0.98 | 17 | 5.4 |
| Indeno(1,2,3-cd)pyrene | --- | --- | 1 | 1.1 | 0.38 | 1.1 | 44 | 0.86 | 4.9 | 2.5 | 0.67 | 15 | 2.6 |
| Dibenz(a,h)anthracene | 63.4 | 260 | ND | ND | Nd | ND | 10 | ND | 1.1 | 0.75 | 3.2 | 3.1 | 0.6 |
| Benzo(g,h,i)perylene | --- | --- | 1.3 | 1.4 | 0.49 | 1.4 | 56 | 1.2 | 8.5 | 2.5 | 0.85 | 21 | 2.6 |
| Total PAHs | 4022 | 44792 | 16.54 | 17.05 | 4.87 | 17.58 | 760* | 13.48 | 89.97 | 29.25 | 14.59 | 239.47 | 63.11 |

Notes on Cores:
Concentrations in ppb
*May be mixed LARE/Cap material

# APPENDIX B

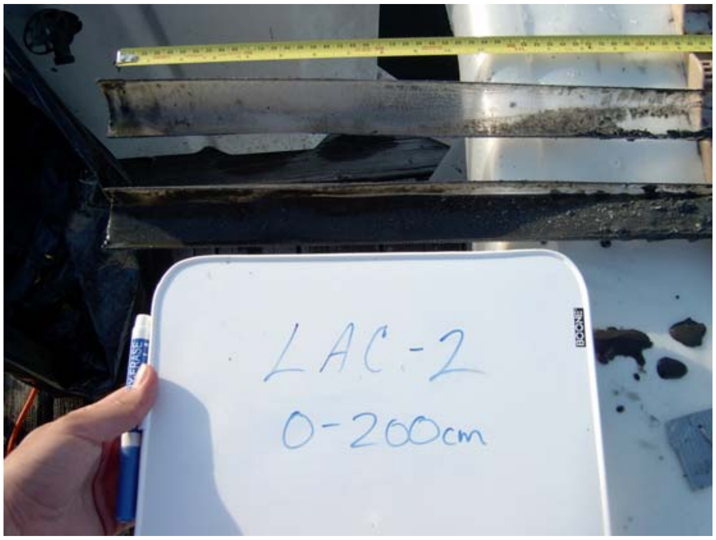
# YEAR 3 PORE WATER DATA

# NEIBP CAD Site - Pore Water Analysis (ug/L)

| Analyte | Cal Ocean Plan (6 Mo. Median) | Cal Toxics Rule (CCC) | EPA AWQC (CCC) | Mean Harbor Bkgrd | Dissolved Pore Water Result (ug/L) | | | PW MDL | PW RL | PWS Blank | PWS Blank -D | Blank MDL | Blank RL |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | PWN | PWS | PWS-Dup | | | | | | |
| Aluminum | --- | --- | --- | --- | 8.02 | 7.06 | 3.87 | 0.01 | 0.0125 | ND | ND | 1 | 5 |
| Antimony | --- | --- | --- | --- | 0.16 | 0.29 | 0.13 | 0.01 | 0.015 | ND | ND | 0.1 | 0.5 |
| Arsenic | 8 | 36 | 36 | 1.3 | 0.18 | 1.11 | 0.94 | 0.01 | 0.015 | 0.03 | 0.04 | 0.1 | 0.5 |
| Beryllium | --- | --- | --- | --- | ND | ND | ND | 0.005 | 0.01 | ND | ND | 0.1 | 0.5 |
| Cadmium | 1 | 9.3 | 9.3 | --- | 0.024 | 0.13 | 0.025 | 0.005 | 0.01 | ND | ND | 0.1 | 0.2 |
| Chromium | 2 | 50 | 50 | 17.9 | 0.6 | 0.36 | 0.5 | 0.005 | 0.01 | 0.16 | 0.16 | 0.1 | 0.5 |
| Cobalt | --- | --- | --- | --- | 0.32 | 0.09 | 0.066 | 0.005 | 0.01 | 0.13 | 0.18 | 0.1 | 0.5 |
| Copper | 3 | 3.1 | 3.1 | 11.5 | 0.037 | 0.056 | 0.02 | 0.005 | 0.01 | 0.07 | 0.07 | 0.1 | 0.5 |
| Iron | --- | --- | --- | --- | 1930 | 615 | 1150 | 0.01 | 0.025 | 0.7 | 1.48 | 1 | 5 |
| Lead | 2 | 8.1 | 8.1 | 1.5 | 0.042 | 0.11 | 0.027 | 0.005 | 0.01 | ND | ND | 0.1 | 0.5 |
| Manganese | --- | --- | --- | --- | 103 | 127 | 185 | 0.005 | 0.01 | 0.28 | 0.26 | 0.1 | 0.5 |
| Mercury | 0.04 | --- | 0.94 | 0.43 | 0.006 | 0.007 | 0.006 | 0.005 | 0.01 | ND | ND | 0.05 | 0.1 |
| Molybdenum | --- | --- | --- | --- | 12.8 | 24.2 | 10.7 | 0.005 | 0.01 | ND | ND | 0.1 | 0.5 |
| Nickel | 5 | 8.2 | 8.2 | 29.5 | **5.34** | 0.48 | 0.4 | 0.005 | 0.01 | 0.06 | 0.05 | 0.1 | 0.5 |
| Selenium | 15 | 71 | 71 | --- | ND | ND | ND | 0.01 | 0.015 | ND | 0.01 | 0.1 | 0.5 |
| Silver | 0.7 | --- | --- | --- | ND | ND | ND | 0.005 | 0.01 | ND | ND | 0.1 | 0.2 |
| Thallium | --- | --- | --- | --- | ND | ND | ND | 0.005 | 0.01 | ND | ND | 0.1 | 0.5 |
| Tin | --- | --- | --- | --- | 0.046 | 0.06 | 0.029 | 0.005 | 0.01 | ND | ND | 0.1 | 0.5 |
| Titanium | --- | --- | --- | --- | 1.98 | 0.44 | 0.57 | 0.005 | 0.01 | 0.14 | 0.14 | 0.1 | 0.5 |
| Venadium | --- | --- | --- | --- | 1.17 | 1.09 | 0.99 | 0.005 | 0.01 | 0.14 | 0.14 | 0.1 | 0.5 |
| Zinc | 20 | 81 | 81 | 10.8 | 2.77 | 3.52 | 3.45 | 0.005 | 0.01 | 2.35 | 1.47 | 0.1 | 0.5 |

# APPENDIX C

# YEAR 3 SEDIMENT CORE PHOTOS



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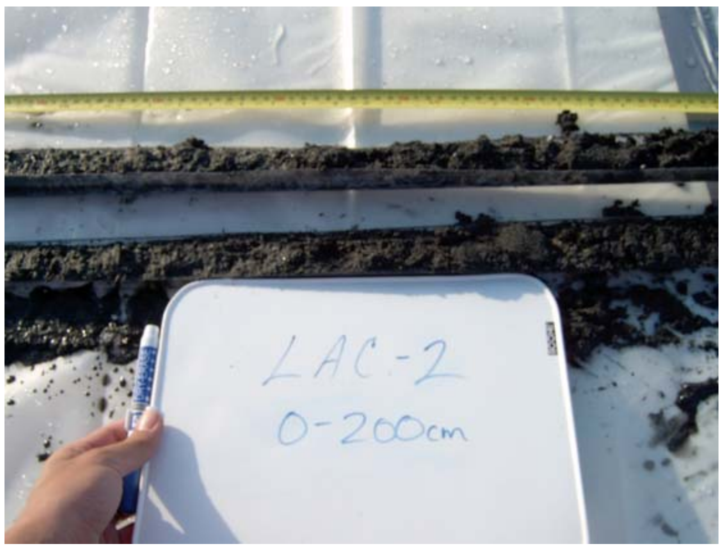


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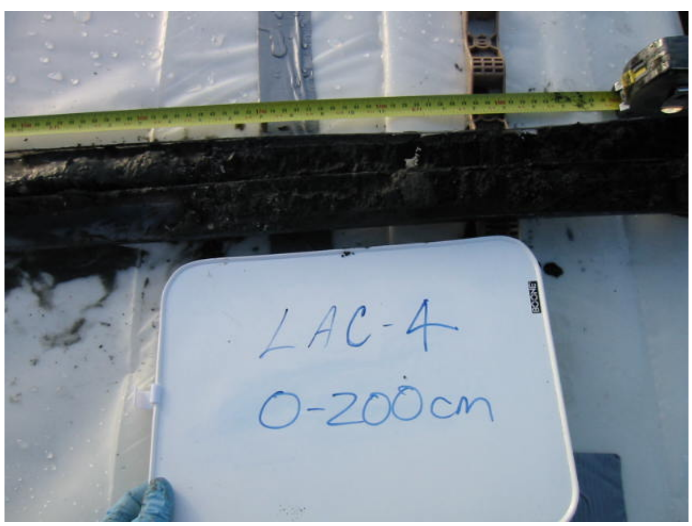

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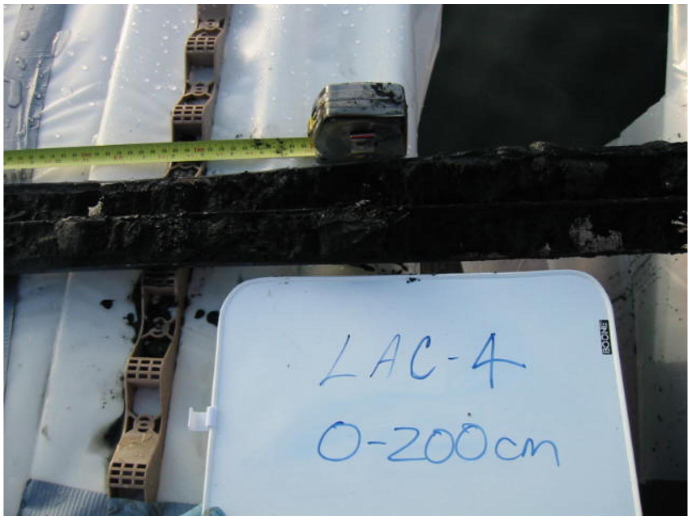
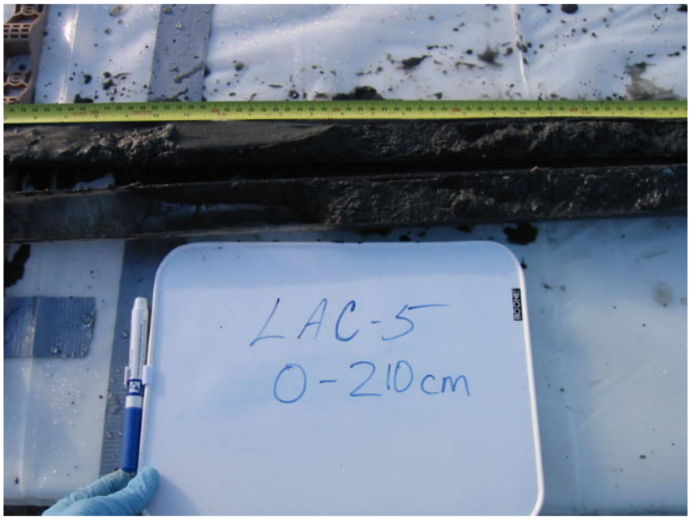



Station 4


Station 5

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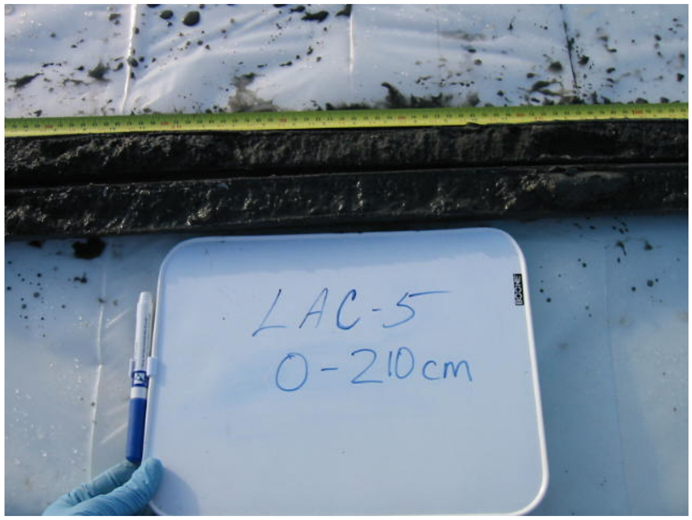


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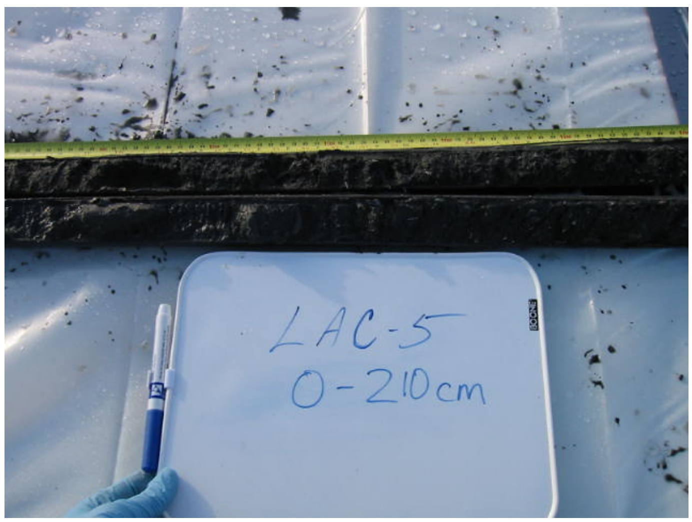


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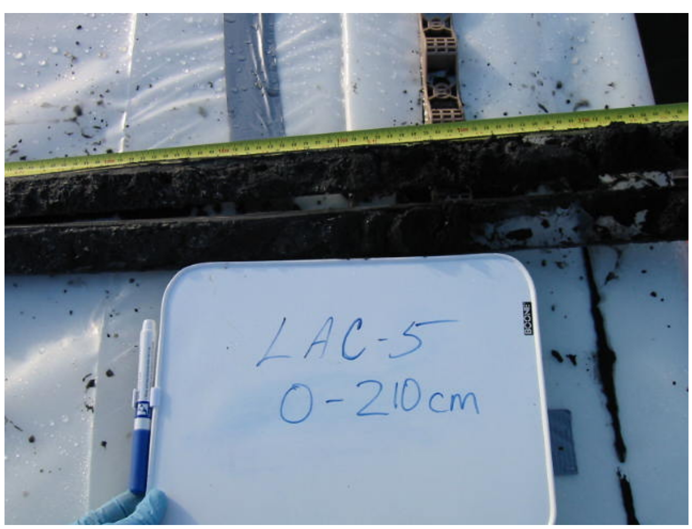


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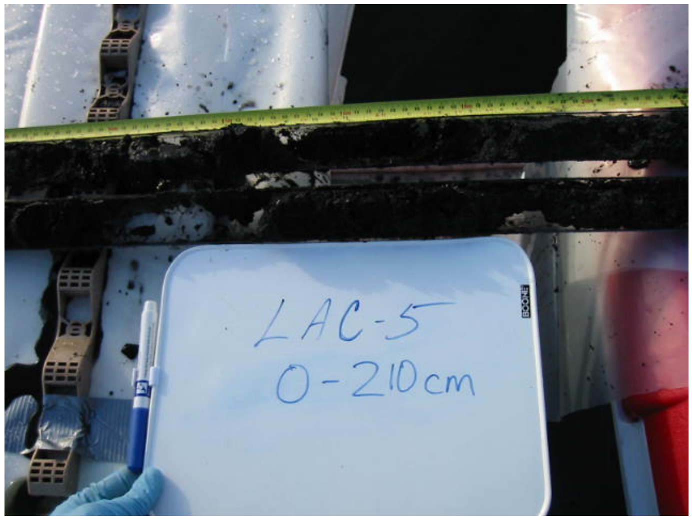

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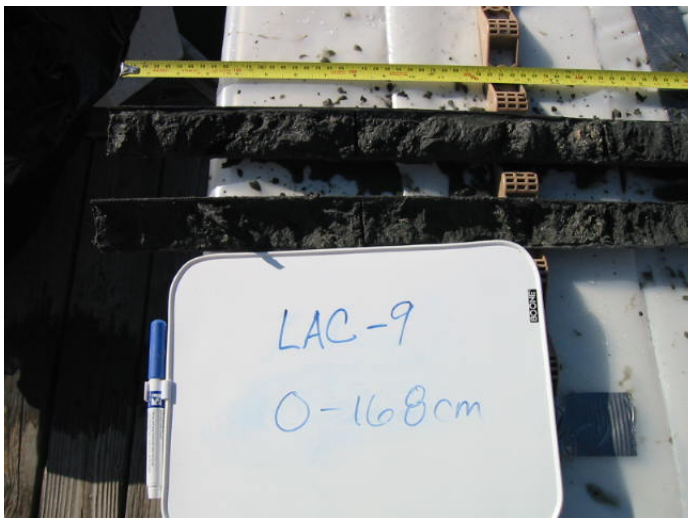


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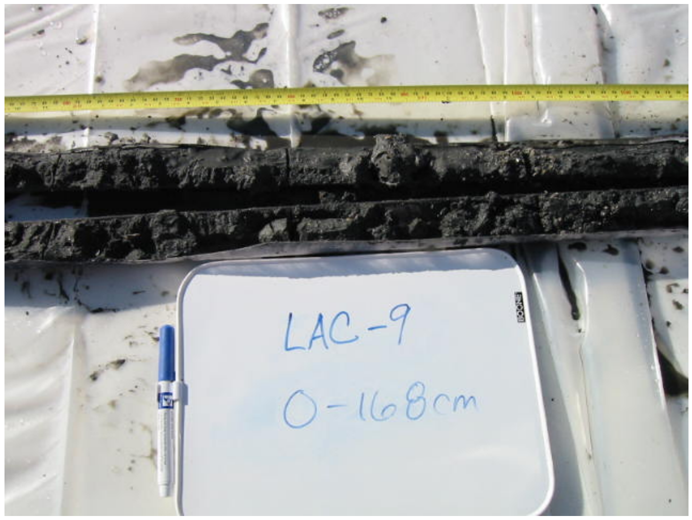

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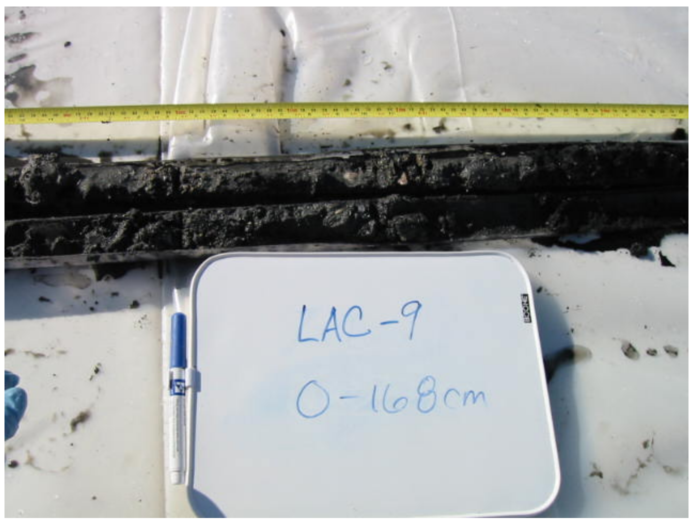

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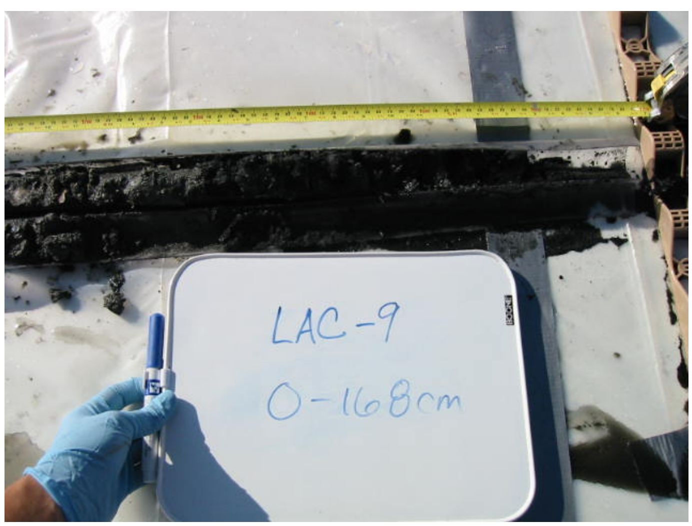

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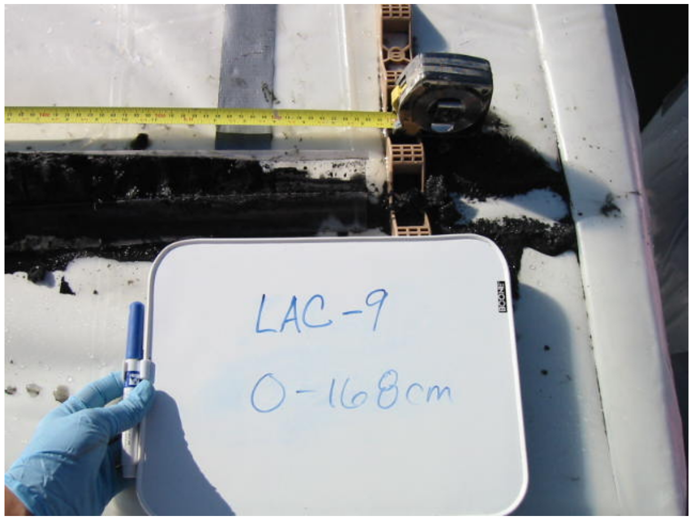


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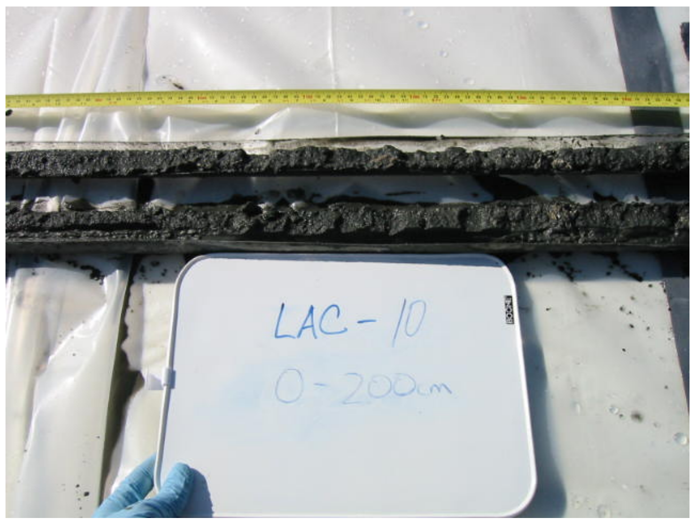

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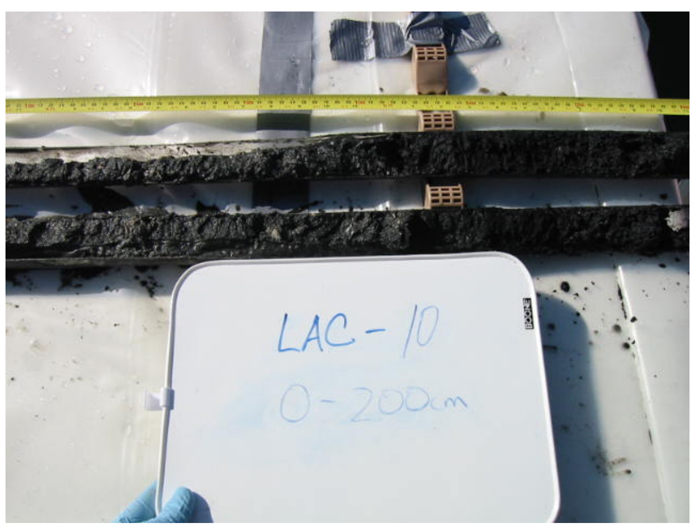

Station 10

Station 10